RiCO

Rain In Cumulus over the Ocean

OPERATION PLAN

November 18, 2004

Rain in Cumulus over the Ocean (RICO) Operations Plan
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Rain in Cumulus over the Ocean (RICO) Operations Plan
Chapter 1: Overview of RICO

1. Overview of RICO

1.1 Scientific Objectives

RICO focuses on shallow, maritime, cumulus convection is one of the most prevalent cloud types on the planet. Trade wind cumuli typically extend to no greater than 4 km altitude, the height of the tropical trade wind inversion, and are dominated by warm rain processes. They are ubiquitous over much of the tropical oceans, and characterizing their properties is important to understanding the global energy balance and climate. Because of the disparity in the range of scales from the microphysical/cloud scale (microns to a kilometer), to the cloud-interaction scale (kilometers to tens of kilometers), to the ensemble cloud field scale (tens of kilometers or more), past work has tended to focus on processes occurring on only one of these three scales – often neglecting the important interactions that occur across scales. The objective of RICO in the broadest sense is to characterize and understand the properties of trade wind cumulus at all scales, with particular emphasis on determining the importance of precipitation. At the smallest scale, the most fundamental problem – recognized for over a half century – is explaining the rapid onset of precipitation in shallow tropical clouds. At the intermediate scale, processes controlling the mesoscale structure and coverage of shallow tropical cloud systems are not well understood. At the largest scale, our inability to describe the statistical behavior of trade wind cloud fields confounds our attempts to properly represent the exchange of radiant energy, moist enthalpy, momentum and trace constituents between the atmosphere and ocean over vast expanses of the planet. These scales are inextricably linked and the nature of these linkages is an important aspect of RICO.

RICO will focus on the following interrelated scientific issues:

1.1.1 The Microphysical/Cloud Scale

Research on spectral broadening and the initiation of precipitation in trade wind cumulus: The microphysical mechanisms directly responsible for spectral broadening and the rapid onset of precipitation remain mired in controversy. A goal of RICO is to obtain the critical observations that, when analyzed in conjunction with numerical modeling experiments, will provide the key evidence required to confirm or refute hypotheses related to precipitation initiation. The RICO scientific objectives in this area focus on 1) the ultragiant nuclei hypothesis; 2) the effects of turbulence on spectral broadening and precipitation initiation; 3) the effects of entrainment on spectral broadening; 4) the effects of pre-existing clouds and cloud processing on precipitation initiation. The measurement of aerosol, particularly CCN, is essential to the evaluation of all hypotheses explaining the onset of precipitation.

Research on the microphysics of the transition to a mature rainshaft: It is unknown whether the processes responsible for the onset of precipitation are also important for the continued production of precipitation in trade wind cumulus. An objective of RICO is to understand the microphysical processes that are important as clouds undergo and complete the transition to a mature rainshaft.

1.1.2 The cloud-interaction scale

Research on the mesoscale organization of trade wind clouds: The mechanisms by which convection organizes in the trade wind environment are poorly understood. An objective of RICO is to understand the cloud and boundary layer processes that lead to the development and organization of convective structures in the trades. In particular, it is important to understand how dynamic and thermodynamic processes within and near precipitation-generated cold pools influence the organization and evolution of tropical cumulus.

1.1.3 The ensemble cloud field scale

Research on the water budget of trade wind cumulus: Although shallow cumulus cover vast expanses of the world's oceans, very little is known about how much they precipitate and how precipitation affects their statistical properties. One objective of RICO will be to estimate the water budget of trade wind cumulus using modern radar and satellite remote sensing, calibrated with in situ data. These estimates will be compared to inferences from thermodynamic budgets.

Research on the large-scale trade wind cloud environment: An objective of RICO will be to augment precipitation estimates with detailed characterizations of the large-scale environment, clouds, and their microphysical and aerosol properties. These data will be used to test hypotheses regarding scaling laws (e.g., for cloudiness, cloud base mass flux, entrainment and detrainment rates, cloud-environment differences, and momentum transport) for trade wind cumulus derived from recent large-eddy simulations (LES). They will also provide a basis for the next generation of LES studies that will strive to understand the dependence of trade-cumulus on microphysical and radiative processes, both affected by the properties of the environmental aerosol. The coupling of simulation/theoretical studies with field data across a range of scales will provide a basis for representing shallow convection in large-scale climate and weather forecast models.

1.1.4 Related research studies

RICO will involve a number of additional studies. These include research on 1) the age of cloud parcels, 2) the chemistry and origin of aerosols, 3) radar remote-sensing, 4) developing a satellite cloud climatology, and 5) studies of the effects of clouds on radiation.

1.2 Field schedule and activities

General Schedule of Operations for RICO facilities

	11 Nov 04 - 06 Dec 04	07 Dec 04 – 20 Dec 04	21 Dec 04 – 03 Jan 05	04 Jan 05 – 24 Jan 05
Spol Radar	×	×	×	×
NCAR C-130		×		×
Wyoming King Air		×		×
BAE 146				×
Seward Johnson				×
GLASS soundings		×	×	×
PAM-3		×	×	×

The RICO Graduate Student Seminar Series: 5-22 January 2005

Date	Speaker	Title
05 January 05	Stevens	Structure of the trade wind layer
06 January 05	Lasher-Trapp	Cloud thermodynamics and the warm rain process
08 January 05	Geerts	Fundamentals of radar
09 January 05	Knight	ZDR and the early formation of precipitation in cumulus
11 January 05	Jensen	Giant Aerosols and Warm Rain, from measurements to GCM implementation
12 January 05	Gerber	Liquid water content in cumulus
14 January 05	Thornton	Sulfur gas chemistry, CCN and clouds
15 January 05	Anderson	Imaging and chemically analyzing aerosol particles
17 January 05	Brenguier	Entrainment and mixing processes
18 January 05	Albrecht	Aerosol, cloud and drizzle interactions
19 January 05	Baker	Small scale heterogeneities in clouds
Alternates	Rogers	Cloud and aerosol measurements on the C-130
	Twohy	Marine aerosols, clouds and climate
	Stith	Opportunities in airborne research
	Moore	Organizing field campaigns

Graduate Research Flight: within period of January 19-21, 2005

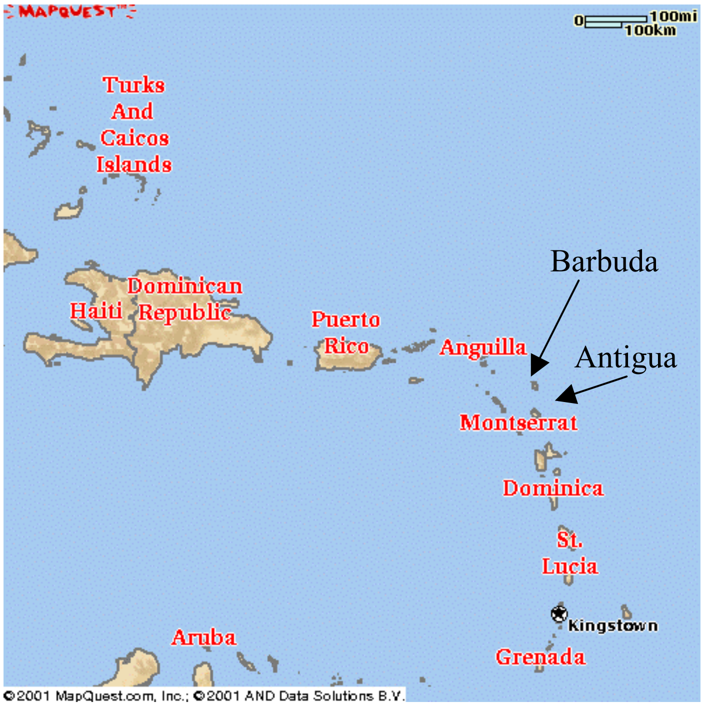
Tentative schedule of RICO Science Meetings during Field Campaign

December 6, 2004
December 10, 2004
December 15, 2004
December 20, 2004
January 3, 2004
January 10, 2004
January 15, 2004
January 20, 2004

RICO Operations Plan
Chapter 2: Maps of RICO region

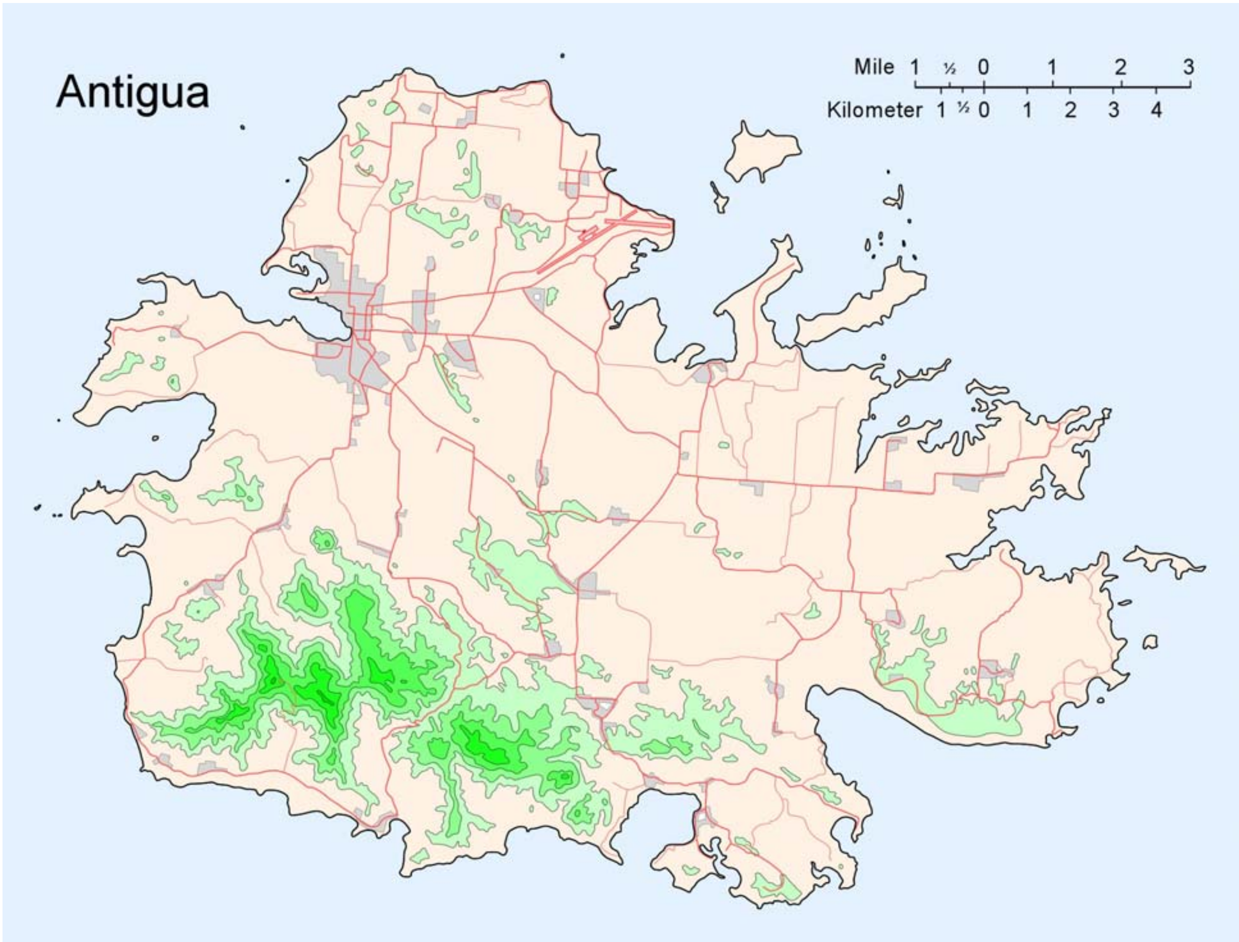
2. Maps

Map of the Caribbean



Map of Antigua and Barbuda

Map of Antigua



Map of Barbuda

Map of Puerto Rico

3. RICO Missions

In the long term average, the trade winds in the vicinity of Antigua and Barbuda blow from the east-northeast (Figure 3.1) at about 10 m/s, and the tropical trade wind inversion is typically between 2-4 km altitude. However, during any particular period, there can be significant variations in these average conditions. The controlling features appear to be the location and intensity of the Bermuda High over the North Atlantic, large synoptic features over North America, such as anticyclones over the continental U.S. or strong cyclones along the East Coast, frontal boundaries that extend into tropical latitudes, and easterly waves in the trade wind flow. As a result the wind direction near Antigua and Barbuda can vary from 0 through 180°, based on a four-year examination of satellite animations for the November through January period. Individual soundings from Guadeloupe for the same period (e.g. Fig. 3.2) show variability in the trade wind inversion height and strength. Typically the inversion is at or below 3 km, although on some days there is no inversion.

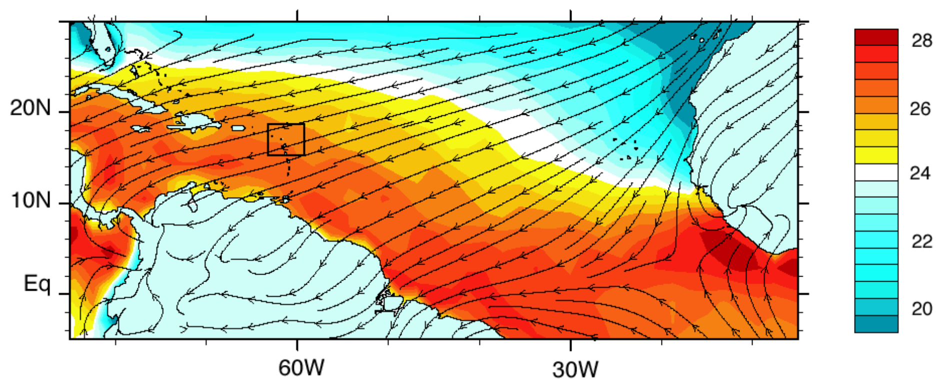


Figure 3.1: Mean streamlines for 10 m winds from NCEP climatology for January superimposed on sea surface temperatures. RICO experimental area is in the box.

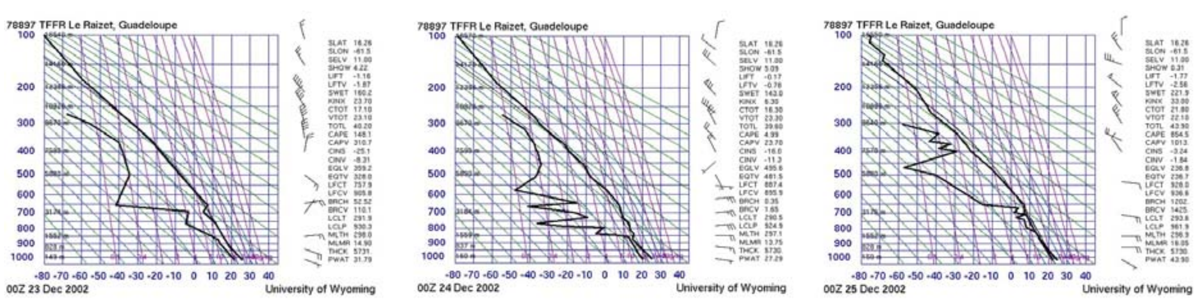


Figure 3.2: Three 00 UTC soundings from December 23, 24, and 25, 2002 from Le Raizet, Guadeloupe, about 175 km south of Barbuda.

Satellite images, photographs, and video of Atlantic trade wind cumulus show three preferred modes of organization: single clouds, clouds organized along lines, and long-lived cloud clusters. The lines have varied length from 10's of km to 100's of km or more. Clouds clusters are relatively long lived, with turrets frequently emerging from the clusters and rising 1 to 2 km above the top of the cluster. Cloud lines also frequently extend downwind of individual islands.

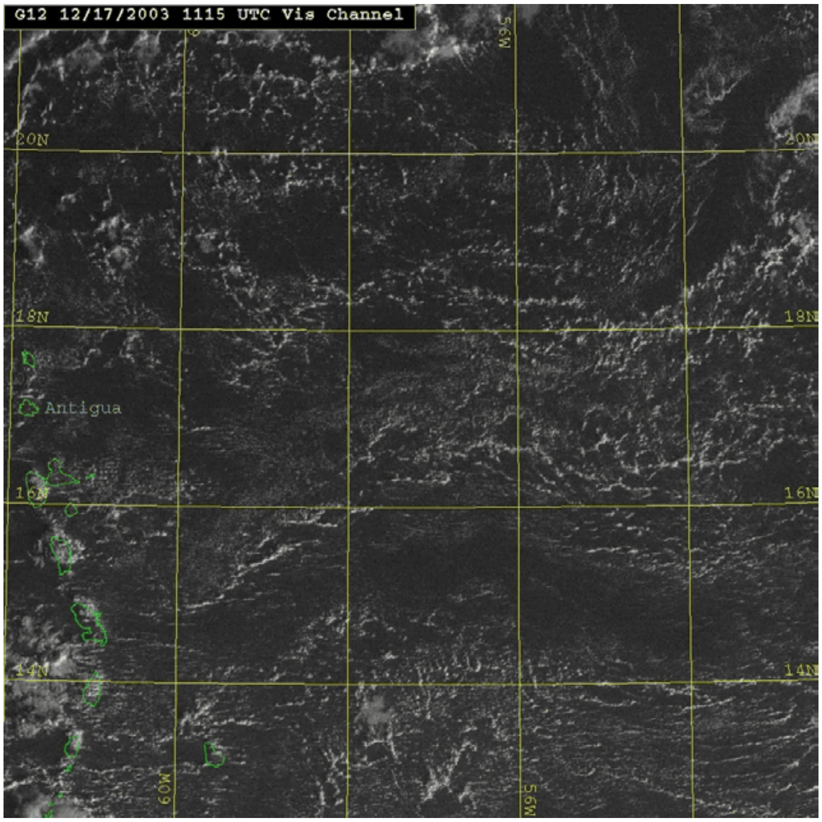


Figure 3.3 Visible 1 km resolution GOES satellite image of the Atlantic Ocean east of Antigua and Barbuda on 17 December 2003 at 1115 UTC showing typical organizations of trade wind cumulus.

3.1 The radar only period (November 24 to December 06, 2004)

The initial period, from November 24 through December 6, will be devoted to an SPol radar-only study. The purpose of this period will be to fine-tune flight strategies based on the observed spatial and temporal distribution and evolution of the trade wind cloud and precipitation fields, and fine-tune the radar scanning strategies to optimize observations of cloud lifetimes. During the radar only period, the relationship between the satellite-observed cloud field and the precipitation that these clouds produce will be established. The diurnal cycle of cloudiness and precipitation will be determined so that flights can be timed to study precipitation processes and the diurnal cycle itself. We will determine cloud lifetime, times to precipitation formation and fallout, and better determine preferred modes of cloud organization. We will also examine clouds forming over and downwind of the island.

There are a number of technical questions related to radar operations. These include:

- What is the best PRF to use?
- Should we oversample?
- How should a volume sector be defined to maximize opportunities to observe entire cloud lifecycles with sufficient temporal and spatial resolution?
- What is the best scanning strategy to define cloud heights with sufficient accuracy?
- How can the K-Band be used most effectively?
- Where is sea clutter a problem and what are there wind/wave conditions where sea clutter is particularly bad?
- What is the utility of using PPI vs RHI scans?
- What standard levels should the aircraft fly based on cloud depths and lifetimes?

3.2 General principles for Missions

The following represent science-driven principles which we hope to guide mission choice and design:

1. Flights will be scheduled to maximize opportunities to sample Saharan dust events and to coordinate with overpasses of polar orbiting satellites.
2. Every C-130 flight will have segments designed to characterize aerosol near the sea surface and just below cloud base, and to determine area-averaged fluxes of heat, moisture, and momentum. These baseline measurements will be flown in 30 km radius circles made at three levels: 1) a dropsonde segment, flown at (I + 1000 m), where I is the inversion height; 2) a near-surface segment; and 3) a cloud base segment flown at (LCL-100), where LCL is the lifting condensation level.
3. Flight operation areas will be defined with reference to the region scanned by the S-Pol radar. Changes in flight operation areas will be coordinated with the radar. Ship placement will be coordinated with S-Pol. The baseline measurements in (2) above will be made with reference to the ship and radar.
4. Three types of studies will be conducted: 1) Statistical Studies (Eulerian, environmental sampling and unorganized convection), 2) Process studies (Lagrangian – sustained organized cloud systems, targets of opportunity), and 3) Coordinated studies (e.g. special coordination with ship remote sensing scans, intercomparison flights).

5. During periods of cloud penetrations for statistical sampling of cloud properties, each aircraft will sample at a single flight level for at least 30 minutes, and preferably longer, before changing levels. During flights, clouds will be sampled at a variety of levels by each aircraft.

6. Flight levels for statistical sampling will be at fixed increments with respect to the lowest in-cloud level (LCL+ 100 m) or the ocean surface (S). Rainshaft sampling will be S + 300 m. In cloud sampling will be at incremental levels, for example LCL+100 m, LCL + 600 m, LCL + 1100 m, LCL +1600 m, LCL+ 2100 m, etc. The exact levels will be chosen based on our experience with the clouds during the radar only period. One flight level (H) will be chosen to sample the tops. An attempt to systematically determine the cloud top flight level will be made prior to statistical cloud sampling using radar, DMS, lidar, soundings and visual cues during the dropsonde circle.

7. A high priority will be to take advantage of targets of opportunity when they move into the radar domain. Targets of opportunity include 1) long steady cloud lines; and 2) long lived cloud clusters with emergent convective towers.

8. The S-Pol scan strategies must meet two objectives: 1) gather adequate statistics on rainfall in trade wind cumulus and 2) obtained detailed measurements to support cloud microphysical studies.

3.3 S-Pol Radar Scanning Strategy

3.3.1 Beam geometry

The isolated tradewind clouds to be studied in RICO with the S-Pol radar have bases near 0.5 km, and tops ranging from 2 to 4 km. Single clouds have maximum widths of 2-3 km. Clusters and lines can be much larger, although individual clouds within these clusters and lines have dimensions similar to isolated tradewind clouds. The lifetimes of individual clouds that produce rain are expected to be of the order of 30 - 40 minutes. The dimensions and lifetimes of tradewind clouds are the controlling parameters governing the radar scanning strategy.

Table 3.1 shows the altitude above the ocean surface of the center of the 1° S-Pol radar beam as a function of range and elevation angle for top (0.75 km starting elevation and 1° steps) and botton ((0.5 km starting elevation and 1° steps). For each elevation and range, the altitude of the center of the beam is shown. The table also shows the diameter of the beam at each range.

Table 3.1 shows that beyond 40 km the number of levels in a 2 km deep cloud is three or less, and the beamwidth exceeds 0.7 km. For deeper tradewind clouds, which top out near the 4 km level, there are six levels at 40 km. This assumes no beam overlap. The table also shows that to cover a 4 km cloud at 20 km range with no overlapping beams requires 12 elevations.

Table 3.1: Beam geometry for the S-Pol radar.

Angle	Distance 15	20	25	30	35	40	45	50	55	60	65	70	75	80
0.75	0.23	0.31	0.39	0.47	0.56	0.64	0.73	0.83	0.92	1.02	1.12	1.23	1.34	1.45
1.75	0.50	0.66	0.83	0.99	1.17	1.34	1.52	1.70	1.88	2.07	2.26	2.45	2.65	2.84
2.75	0.76	1.01	1.26	1.52	1.78	2.04	2.30	2.57	2.84	3.11	3.39	3.67	3.95	4.24
3.75	1.02	1.36	1.70	2.04	2.39	2.73	3.09	3.44	3.80	4.16	4.52	4.89	5.26	5.63
4.75	1.28	1.70	2.13	2.56	2.99	3.43	3.87	4.31	4.76	5.20				
5.75	1.54	2.05	2.57	3.08	3.60	4.13	4.65							
6.75	1.80	2.40	3.00	3.60	4.21									
7.75	2.06	2.75	3.43	4.12										
8.75	2.32	3.09	3.86											
9.75	2.58	3.43	4.29											
10.75	2.84	3.78												
11.75	3.09	4.12												
12.75	3.35													
13.75	3.60													
14.75	3.86													
15.75	4.11													
Beam Width (km)	0.26	0.35	0.44	0.52	0.61	0.70	0.79	0.87	0.96	1.05	1.13	1.22	1.31	1.40

Angle	Distance 85	90	95	100	105	110	115	120	125	130	135	140	145	150
0.75	1.56	1.68	1.80	1.92	2.05	2.18	2.31	2.44	2.58	2.72	2.86	3.01	3.16	3.31
1.75	3.05	3.25	3.46	3.67	3.88	4.10	4.31	4.54	4.76	4.99	5.22	5.45	5.69	5.93
2.75	4.53	4.82	5.11	5.41	5.71	6.01	6.32	6.63	6.94	7.25				
Beam Width (km)	1.48	1.57	1.66	1.75	1.83	1.92	2.01	2.09	2.18	2.27	2.36	2.44	2.53	2.62

Angle	Distance 15	20	25	30	35	40	45	50	55	60	65	70	75	80
0.5	0.17	0.22	0.28	0.34	0.40	0.47	0.54	0.61	0.68	0.76	0.84	0.92	1.01	1.10
1.5	0.43	0.57	0.72	0.86	1.01	1.17	1.32	1.48	1.64	1.81	1.97	2.15	2.32	2.50
2.5	0.69	0.92	1.15	1.39	1.62	1.86	2.11	2.35	2.60	2.85	3.11	3.37	3.63	3.89
3.5	0.95	1.27	1.59	1.91	2.23	2.56	2.89	3.22	3.56	3.90	4.24	4.59	4.93	5.28
4.5	1.22	1.62	2.02	2.43	2.84	3.26	3.67	4.09	4.52	4.94				
5.5	1.48	1.97	2.46	2.95	3.45	3.95	4.46							
6.5	1.74	2.31	2.89	3.47	4.06									
7.5	2.00	2.66	3.32	3.99										
8.5	2.26	3.00	3.76											
9.5	2.51	3.35	4.19											
10.5	2.77	3.69												
11.5	3.03	4.03												
12.5	3.28													
13.5	3.54													
14.5	3.79													
15.5	4.05													
16.5	4.30													
Width (km)	0.26	0.35	0.44	0.52	0.61	0.70	0.79	0.87	0.96	1.05	1.13	1.22	1.31	1.40

Angle	Distance 85	90	95	100	105	110	115	120	125	130	135	140	145	150
0.5	1.19	1.29	1.38	1.49	1.59	1.70	1.81	1.92	2.03	2.15	2.27	2.40	2.53	2.66
1.5	2.67	2.86	3.04	3.23	3.42	3.62	3.81	4.01	4.22	4.42	4.63	4.84	5.06	5.27
2.5	4.16	4.43	4.70	4.97	5.25	5.53	5.82	6.10	6.39	6.69				
Width (km)	1.48	1.57	1.66	1.75	1.83	1.92	2.01	2.09	2.18	2.27	2.36	2.44	2.53	2.62

3.3.2 Modes of operation

The radar scanning strategies discussed below are initial attempts to meet the objectives stated in Section 2.2, particularly Objective 8. These strategies will be tested during the radar only period and modified as necessary to meet the core objectives of RICO. There are three basic modes of operation: 1) unattended; 2) operation with a radar controller, but without coordination with other platforms; and 3) operation with a radar controller, and with coordination with other platforms. These are considered separately below:

3.3.2.1 Unattended mode of operation

3.3.2.1.1 Beam angles

The triple objective of the following unattended mode scan strategy is to keep a certain minimum spatial resolution in the vertical when sampling clouds, to observe clouds from their base to over their tops as close as 15 km to the radar, and minimize the turn-around time for volume scans. With these purposes in mind, During the radar only period, we will investigate the utility of volume scans with 10 levels at elevation angles of 0.5, 1.5, 2.5, 3.5, 4,5, 5.8, 7.5, 9.8, 12.5, and 16.5 degrees. This procedure would give better altitude resolution low than high in the nearby clouds, but it would cover ranges from 15 to 80 km, and provide one scan completely above cloud top if the top is no higher than 4 km. The traditional "first echo" (meaning detectable Z_e from hydrometeors) in clouds observed in Florida is visible at S-band at 3 km or below. The first significant, positive Z_{DR}, in all cases where this has been recorded so far (none of them truly maritime), has been in the vicinity of cloud base, and constitutes one of the problems with real interest to the understanding-precipitation objective of RICO. We don't know yet if RICO will follow this pattern; but the best assumption is that it might, so it then is most important to get detailed data down low, and especially on nearby clouds where the resolution within the scans is best. The high maximum scan angle also gives some information about cloud top for the closer clouds, which are the clouds that have the best radar resolution within the scans.

3.3.2.1.2 PPI sectors scans and wind direction

The proposed PPI volume scans are designed to collect a large quantity of data for statistical analysis of rainfall from tradewind cumulus and observe the full life cycle of a large number of tradewind clouds. When used in coordination with other platforms (see below) these scans should also provide the context in which large numbers of aircraft cloud penetrations can evaluated. Two goals are to document the time of initiation of clouds (as measured by the first detectable echo on either the K or S band radar) and to document the full life cycle of as many clouds as possible. The typical lifetime of a cloud is expected to be 30-40 minutes. Our goal is to obtain about ten complete volume scans that cover the evolution of individual clouds and to obtain a very large sample of clouds for statistical analysis.

The proposed standard scans will use a PRF = 1000 s^{-1}, 64 pulses/average for Z_H and Z_V (128 total), Scan rate 8 degrees/sec, averaging volume 1.02 degrees. With this scanning option, a 120° sector allows a volume to be collected every 3 to 4 minutes with 11 elevations. The optimal placement of a 120° scan relative to the wind direction is one in which an individual cloud remains in the view of the radar for as long as possible and within optimal range from the radar.

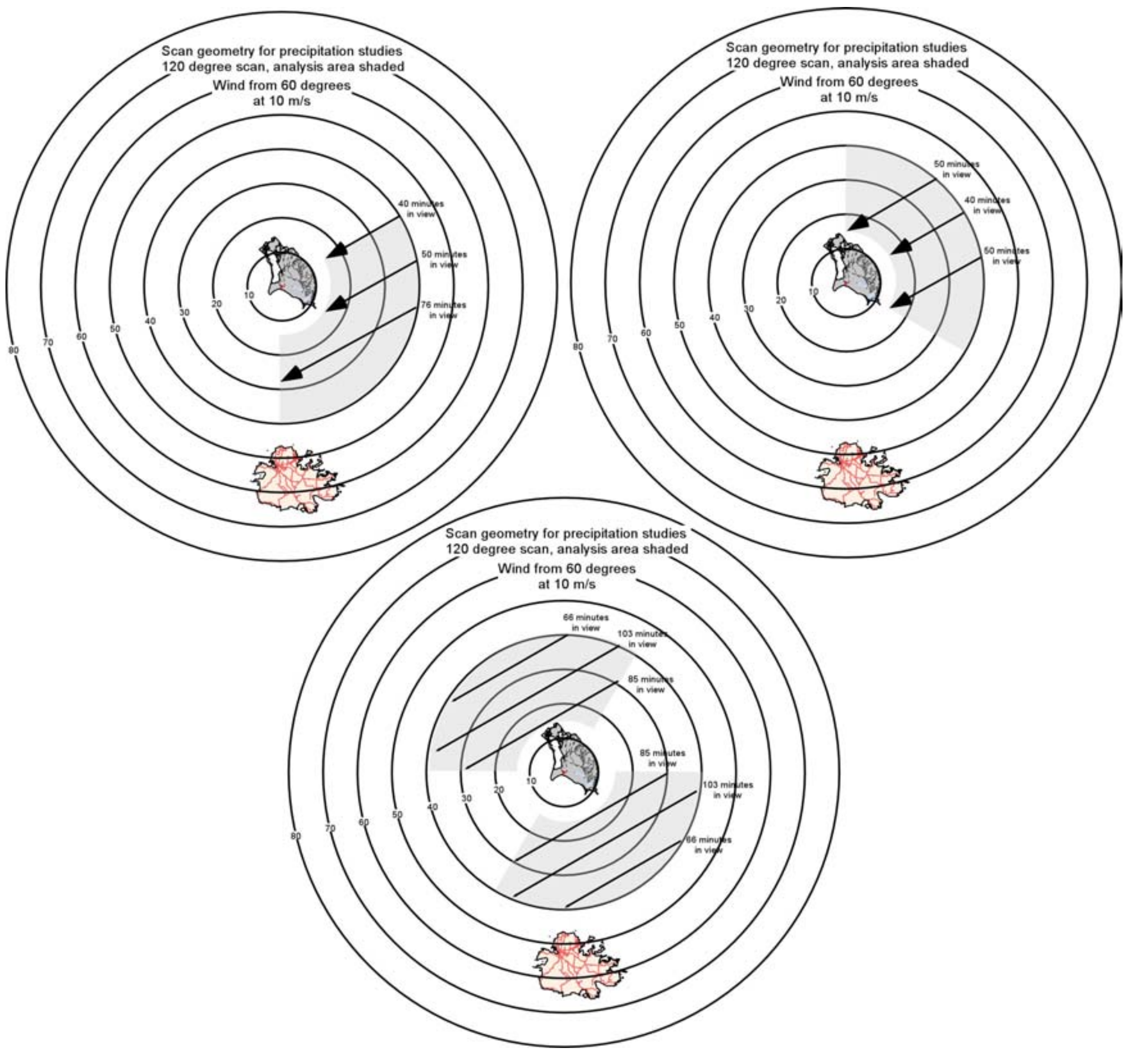


Figure 3.4: Three options for a 120 degree sector scan placement with a wind from 60° at 10 m/s.

Figure 3.4 shows three potential 120° sectors. The primary analysis area between 15 and 40 km range is shaded. The top left sector has one side along the upwind direction, the top right has the center of the sector along the upwind direction and the bottom figure has the sector centered along a line perpendicular to the wind direction. On each figure, the time a cloud would be in view within the sector is labeled for clouds passing along three paths. The figures clearly show that the optimal orientation for the sector to view an individual cloud the longest is one where the sector center is aligned perpendicular to the wind direction. The bottom figure shows two possible options. Two factors determine which of the two sectors will be optimal. The first is distribution of ground and sea clutter. The second is the frequency of commercial and private air traffic within the sector, and our ability to operate aircraft in the sector. The optimal sector will be determined during the radar-only period for each wind direction, but can be changed during operations if the cloud field warrants. The figures below show one or two of the two possible sectors for other wind directions varying between 0 and 180°.

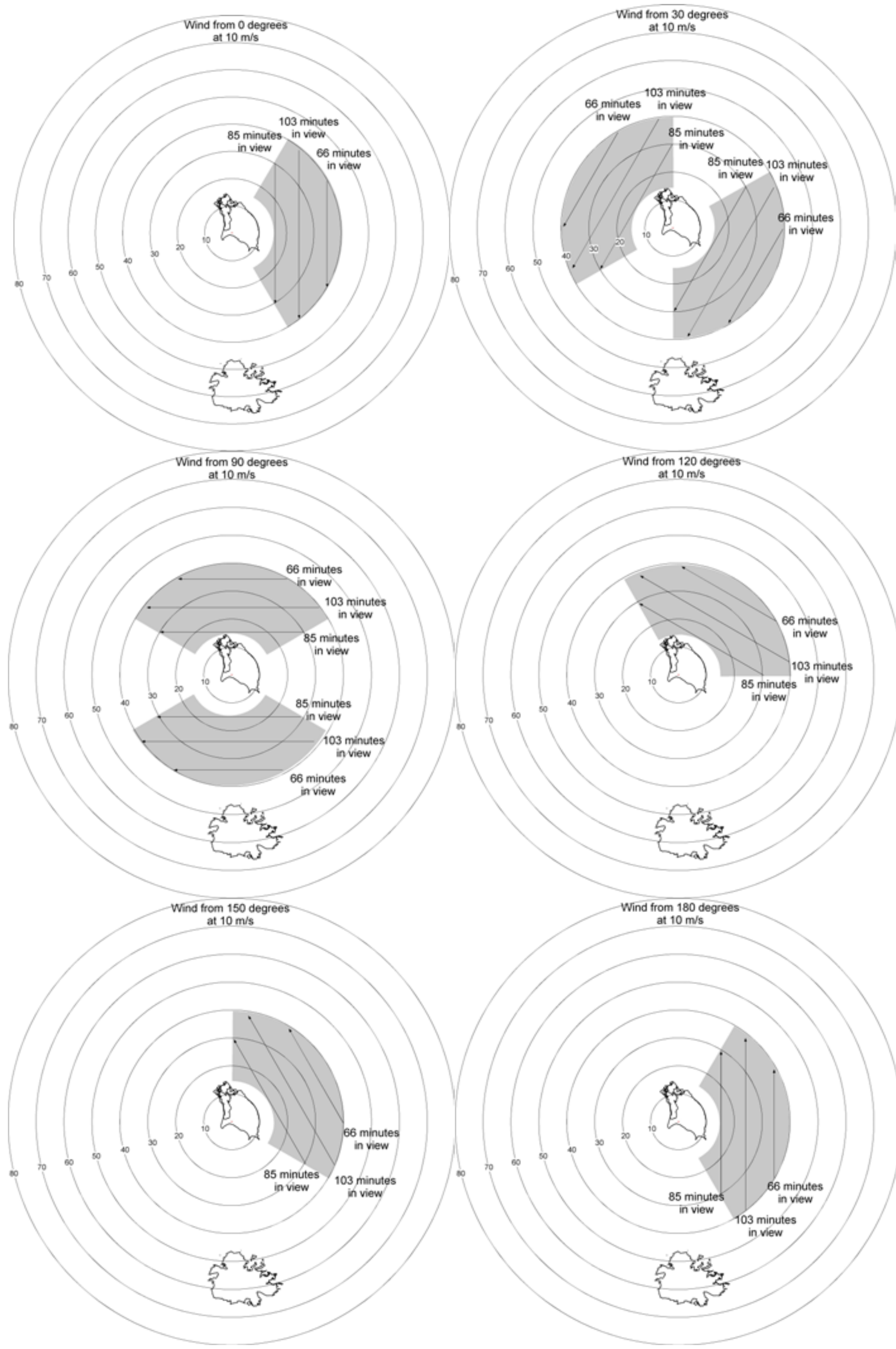


Figure 3.5: Options for optimal scanning of a 120 degree sector with winds from 0°, 30°, 90°, 120°, 150°, and 180°,at 10 m/s.

3.3.2.1.3 Surveillance scans

In unattended mode, surveillance scans at the lowest elevation will be performed once per hour, corresponding to the nominal time of the GOES satellite image time. The low-level surveillance scan will commence at the edge of the 120° sector and rotate 360° so that the next volume scan can start immediately after the surveillance. Surveillance scans at 10°/s should interrupt the volume scans for no more than 40 seconds.

3.3.2.1.4 RHI scan

In unattended mode, a single routine RHI will be added to the scan sequence 30 minutes after the surveillance scan. The RHI will begin at the lowest elevation used for the sector scan and go to 90° and back down. The purpose is to examine the trade wind inversion. This scan will be at the edge of the sector scan so that upon return to the lowest elevation, a sector scan can begin immediately. The RHI is expected to interrupt the sector scanning no more than 30 seconds.

3.3.2.2 Attended mode of operation, no coordination with other platforms

When a radar coordinator is attending the radar, decisions can be made about the best mode of operations based on the surveillance scans of the cloud field. It is likely that there will be many times in operations with a radar controller when the scan mode prescribed for unattended operation will be the best choice. However, other scenarios may evolve in which modifying the scan sequence will lead to better data collection. We describe two such possibilities here as examples.

1. Suppose no clouds at all within interesting radar range (say, within 60 km) but some kind of interesting cloudiness is approaching from the East. In this case, it would make better sense to concentrate scanning on this cloudiness as it comes into range, and then adapt the scanning to it as it comes close and passes by. If it's a linear system, the operator might adjust the scan one way; if a coherent cloud cluster that continually regenerates itself, another way. START HERE Both of those circumstances might be quite common.

2. RHI Scans: Based on experience in the Small Cumulus Microphysics Study with the CP2 radar, the need for sufficient (128) samples for polarization studies, and estimating that we scan vertically at least through 12 degrees at a rate to obtain adjacent 1° beams in azimuth, we have estimated that scanning using RHIs will be limited to about a 30° sector if a return rate of 3 to 4 minutes on an individual cloud is to be achieved. Given that the winds are likely to be 10 m/s or greater, tracking individual clouds within a small sector, particularly when the sector is across the wind direction, will be exceedingly difficult. For this reason, we believe that the optimal direction for RHIs will either be nearly into the direction of cloud movement, or opposite the direction of cloud movement (~ upwind or downwind). It may be possible to enhance the chances of tracking clouds through their lifetime if one edge of the RHI sector is aligned near the direction of cloud motion. Also, a line of clouds often extends downwind of each of the islands of the Lesser Antilles, often as far as a hundred kilometers (Figure 3.6). One advantage of the downwind direction is that these clouds nearly align along an RHI, form in a predicable location, often in the early afternoon, and develop vertically as they advect downstream. These clouds may provide an exceptional target for studying microphysical processes, and could be a focus during periods where no coordination is required with other facilities and an operator is present.

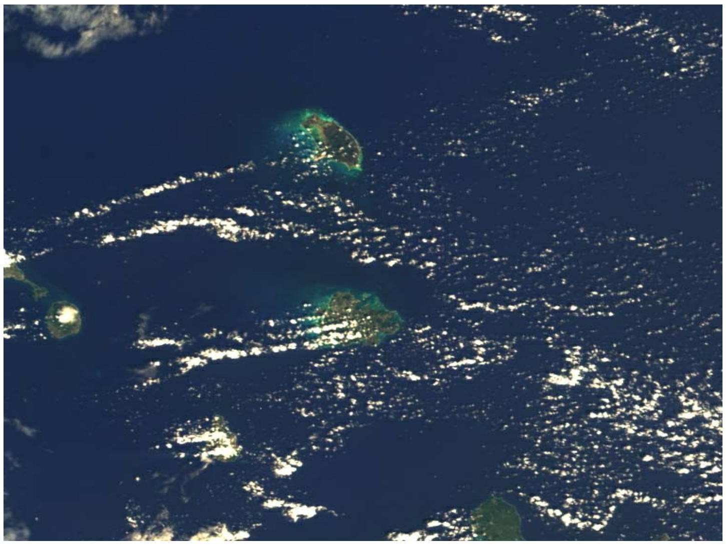


Figure 3.6 MISR image showing cloud line downwind of the radar site on Barbuda.

3.3.2.3 Attended mode of operation, coordination with other platforms

When aircraft operations are underway, decisions about the best mode of operations will be based on the state of the cloud field and the mission of the aircraft. Again, it is likely that most times, the scan mode prescribed for unattended operation will be the best choice. However, scenarios may evolve in which modifying the scan sequence will lead to better coordination with the aircraft. The most common scenario will be during the passage of cloud lines or clusters. If aircraft operations focus on an organized feature such as a cloud line, it will be imperative to keep that feature within the active radar sector. This may necessitate a shift in the radar sector to track the feature during the operation.

In general, the radar surveillance scans, in conjunction with satellite, wind and other information available at the operation center, will be used to determine the best location for the radar sector scans during flight operations. These will be modified as required to accommodate targets of opportunity as they approach the operations area. However, the general philosophy will be to operate the radar so that high quality statistics concerning precipitation development within the cloud field are obtained.

3.3.2.4 Satellite overpasses

Certain extremely high resolution satellites (e.g. ASTER) have very narrow swaths and will only image the radar domain several times during RICO. During these short overpasses, the radar will be operated in low level full surveillance scans.

3.3.2.5 Other scanning options

These have yet to be determined, but will be added once we investigate what options are available during the radar only period.

3.4 Aircraft Missions

Aircraft missions will be planned around three sampling strategies 1) Statistical Studies (Eulerian, environmental sampling and unorganized convection), 2) Process Studies (Lagrangian – sustained organized cloud systems – targets of opportunity), and 3) Coordinated Studies (special coordination with ship remote sensing scans, intercomparison flights). Flight operation areas will be defined with reference to the region scanned by the S-Pol radar and changes in flight operation areas will be coordinated with the radar. The ship placement will also be coordinated with S-Pol.

3.4.1 Statistical studies

3.4.1.1: Characterization of the trade wind environment

The purpose of this flight pattern is to quantify the characteristics of the trade wind layer on scales of about 60 km. During this pattern, the aircraft will obtain data to determine surface fluxes of heat, moisture and momentum, aerosol characteristics including giant CCN, thermodynamic profiles, the structure of the trade wind inversion, and the cloud distribution and structure. Figure 3.7 shows an example of the pattern with all observing platforms for a 60° wind. Figure 3.8 shows the pattern for a 120° wind. In this pattern, the C-130 will complete a

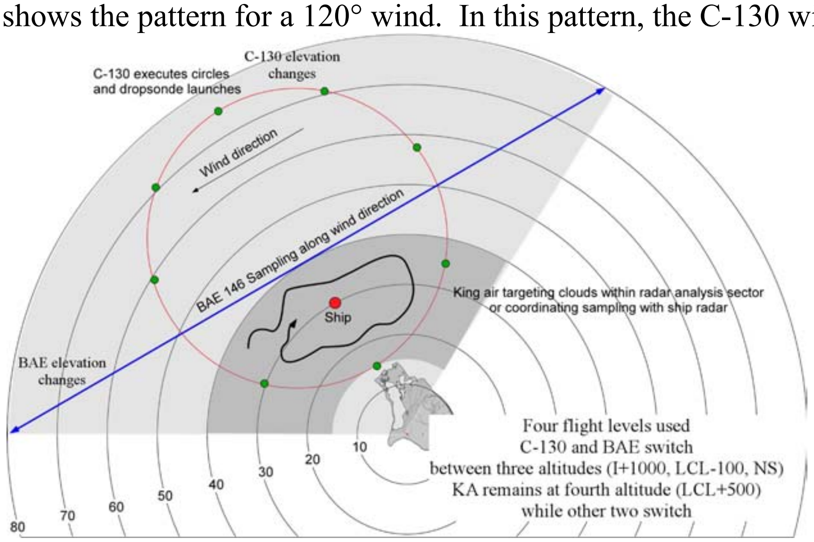


Figure 3.7: Flight patterns for trade wind environment characterization. Wind is from 60°. The three aircraft will either all fly circles, or use other patterns as illustrated on the figure.

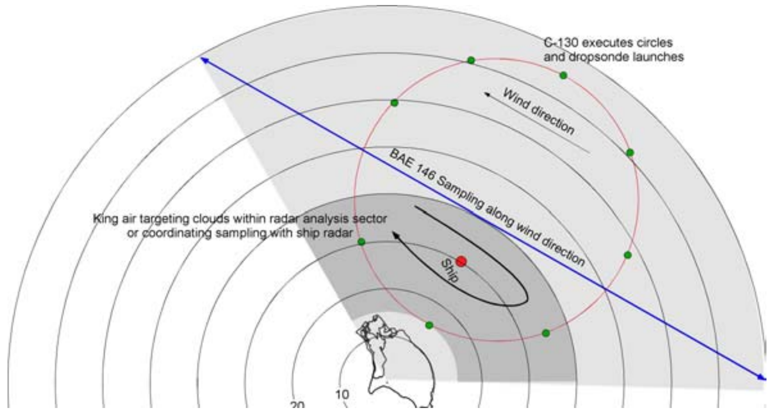


Figure 3.8: Flight patterns for trade wind environment characterization. Wind is from 120°. The three aircraft will either all fly circles, or use other patterns as illustrated on the figure.

series of 3 circles 60 km in diameter, in the center of the 120° volume scan sector of the S-Pol radar. The first circle will be 1 to 1.5 km above the trade wind inversion. Six dropsondes will be dropped equally spaced around the circle. The second circle will be in the middle of the trade wind layer and the final circle in the boundary layer. The ship (in January) will be located within the circle. During the January period, while the C-130 is flying the circles, the BAE-146 will either fly long legs along the wind direction across the sector, or also fly circles, provided that the C-130 is not dropping dropsondes. The Wyoming King Air during this period will either fly circles with the C-130, sample clouds within the circle, or coordinate with the ship, which will be scanning across the wind direction approximately along the central radial of the S-Pol radar.

3.4.1.2: Individual cloud sampling

The strategy, shown in Figure 3.9, is to statistically sample microphysical properties. Flights will consist of a series of constant altitude legs that intersect as many clouds and rainshafts as possible, within a wide sector. Flight levels for statistical sampling will be at fixed increments with respect to the lowest in-cloud level (LCL+ 100 m) or the ocean surface (S). Rainshaft sampling will be S + 300 m. In cloud sampling will be at incremental levels, for example LCL+100 m, LCL + 600 m, LCL + 1100 m, LCL +1600 m, LCL+ 2100 m, etc. The exact levels will be chosen based on our experience with the clouds during the radar only period. One flight level (H) will be chosen to sample the tops. An attempt to systematically determine the cloud top flight level will be made prior to statistical cloud sampling using radar, DMS, lidar, soundings and visual cues during the dropsonde circle. Individual aircraft will remain at one level at least 30 minutes, but may fly several levels during the course of a flight. The radar will scan in sector mode, covering 120°, rapidly enough to provide adequate cloud histories in the whole sector. The aircraft legs will be at different levels (e.g. below cloud base, just above, mid-cloud, near cloud top), but during the statistical studies, there will be no attempt for a single aircraft to fly multiple levels in a single cloud, or coordinate aircraft at different levels to target the same cloud. Rather, the S and K band radar data will be used in post-analysis to determine the stage of the lifecycle of individual clouds at the time of aircraft penetration. Aircraft penetrations of clouds will be guided in real time by visual cues or by the aircraft's forward-looking hazard avoidance radar. This approach is designed to obtain a large data set that can be applied to the scientific objectives related to microphysical studies. The purpose of this pattern is to sample the structure of as many clouds as possible. Aircraft may make multiple passes through the same cloud at the same level. If a cloud rises to the level of the upper aircraft, the aircraft should always make as many passes as possible through the cloud since there will be fewer opportunities to sample tall clouds near their summits.

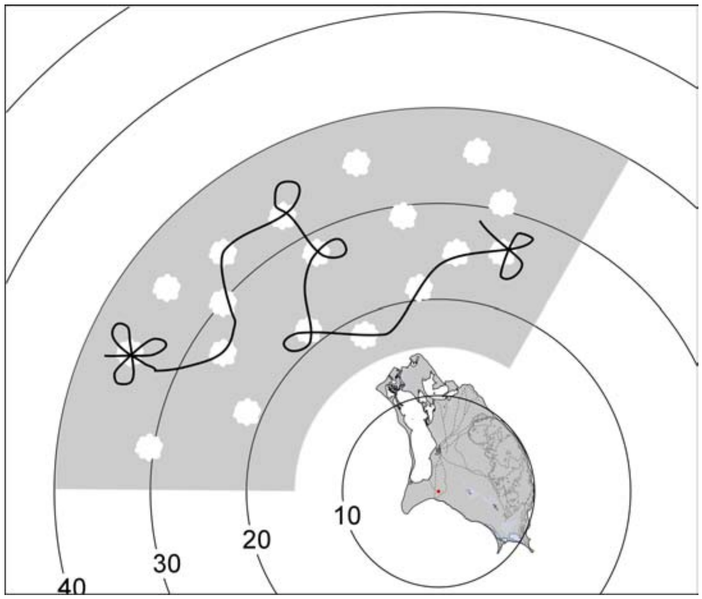


Figure 3.9: Flight patterns for statistical sampling of trade clouds. Wind is from 60°.

During the statistical sampling pattern, while doing the just above cloud base level, when a particularly solid base is seen and penetrated, on some occasions the aircraft can ascend to the next highest level that we are sampling, and make 3 quick penetrations of the same cloud at that level, then return to the previous cloud base level, make one more penetration of the same cloud, and continue on with statistical sampling of many clouds.

The purpose of this maneuver is to answer the question regarding whether the statistical sampling method is as good as the traditional single cloud case study for process studies such as droplet growth. This question will be answerable with this additional data by comparing the variances of cloud physical parameters (LWC, characteristic droplet size parameters, spectrum width) for the statistical data from different clouds with the same variances from repeat penetrations of the same clouds. Also in case the answer is no, we will have the data necessary for process studies of droplet growth and spectral broadening.

3.4.2 Process studies

A high priority will be to take advantage of targets of opportunity when they move into the radar domain. Targets of opportunity include 1) long steady cloud lines; and 2) long lived cloud clusters with emergent convective towers. The strategy for sampling each of these is described below. In either case, the cloud line or cluster will be targeted as it moves through the primary radar analysis domain. Once a study begins, it will continue until the flight patterns are complete, during which time, the S-Pol radar will attempt to keep the line or cluster within radar coverage.

3.4.2.1: Targets of opportunity: Cloud lines

Satellite observations of trade wind cumuli in the western Atlantic subtropical regions often show persistent lines of cumulus bands. The bands may have lifetimes of many hours, but the individual cells are likely to be much shorter, possibly about 30 minutes. The long duration of the bands make them good candidates for airborne experiments that have time spans longer than that of individual cells.

The band organization does not follow a distinct direction, e.g. across or along the shear vector. The many bands with differing orientations would suggest that they are formed in convergence driven by precipitation generated cold pools that spread over the ocean.

The wind direction below the trade inversion is usually easterly and above the trade inversion it is typically westerly. This will lead to the expectation that anvils are most likely to form on the eastern side of the convective bands. Thus most of the recently detrained air is also likely to be on the eastern side of the bands, in particular towards the upper part of the cloud layer where cumulus generated entrainment leads to downwards mixing of air with an easterly wind component into the cloud layer.

Two potential flight plans involve both the C-130 and the King Air.

3.4.2.1.1 Across-band flight pattern

C-130 flight plan

The flight plan for the C130 is shown in Fig. 3.10. This figure shows a cross section of such a band with east in the right part and west in the left part of the figure; this is only a schematic as the actual band may have different orientation. The important aspect is that the flight track is oriented perpendicular to the band orientation.

The flight plan is formulated as a series of stacked horizontal legs.

Most of these are expected to extend about 3 minutes on each side of the main band to allow sampling of both cloudy, recently detrained air, and older environmental air. Each flight leg may take 10 minutes when turns and altitude change are included, and they may cover a distance of

40 km across the band system. The band thickness may be substantially narrower than the 10 km shown in Fig. 3.10.

C-130 flight leg #1 - surface leg: The first leg (labeled "1" in figure 1) is a near surface leg from west to east. This leg should be done no more than 100 m above sea level in order to give highly accurate measurements of radar altitude, such that the location of cloud-scale highs and lows can be determined using pressure perturbation analysis. The persistent bands are likely to precipitate to some degree, in particular in the older parts of the cloud located on the eastern side. New convection is likely to be triggered on the western side of the band. Measurements of the wind speed perpendicular to the band may also show the likely source of the air which is about to enter the cumulus through cloud base. This is useful for determining the aerosol spectrum in air that is about to form new cloud elements. This surface leg is also intended as a means to map the cloud base topography with the SABL lidar pointed upwards.

C-130 flight leg# 2 - above cloud base leg: This leg should be done 200 m above cloud base, such that the immediate effects of activation can be examined in the absence of entrainment processes.

C-130 flight leg# 3 - lower mid-cloud leg: This flight leg, to be done somewhat below the mid point of cloud base and cloud top, is a primary means of determining the development of the cloud droplet and raindrop spectrum. Measurements of conserved tracers and reactive tracers will be used to determine the sources and amounts of entrained air, as well as aiding in the determination of the "age" of the cloudy air, that is the amount of time since the air moved through cloud base. Outside the cloud, the detrained air may be examined to determine the processing of aerosols.

C-130 flight leg #4 - upper mid-cloud leg: Same as leg #3, but to be done somewhat above the mid point of the cloud base and cloud top.

C-130 flight leg #5 - cloud top leg: The largest drops and most vigorous rain development may be expected for this flight leg. The leg should be done about 200 m below the trade inversion to ensure that the cross-band development of precipitation can be examined. For this flight level there may be some or even considerable amounts of anvil cloud.

C-130 flight leg #6 - long-duration detrained air flight leg: Examination of the chemical composition of "rare" giant aerosol particles require 10-15 minute sampling time (needed for EDX and CVI sampling) in order to achieve adequate sampling statistics. It may be necessary or desirable to do these sampling using a flight path close to the cloud, but always in clear air. This may require that the aircraft makes several turns in order to stay near to the cloud and thus sample recently detrained air. This flight leg does not have to be done perpendicular to the band; in fact, flight legs along the bands may be more desirable. This flight leg can potentially be done a few hundred meters lower than the cloud top flight leg.

C-130 flight leg #7 - above cloud top leg: This is a final flight leg aimed at remote sensing of the cloud top topography using SABL in the down-looking mode. This flight leg should be done 1000 m above the trade inversion.

C-130 flight leg #8 - upstream descent sounding: This flight leg should be done on the western side of the band, and great care should be taken to ensure that no cloud is penetrated on the way down. The beginning of the descent should be done well past the band, such that a full altitude sounding is accomplished in air that was likely not to be recently detrained. Peroxide measurements should be taken during this flight descent sounding, and the discrete grab sampling technique requires that the descent be done slowly, typically at 1000 ft/min. This may necessitate occasional turns or a slow spiral descent, depending on the cloud conditions. The final sounding should go as low as possible.

Trace gas measurements will be used for all level legs (below, inside, outside and above cloud) and for the descent sounding. Hence, it is desirable to sample trace gases continuously during these periods, and to do the necessary calibrations during the shorter turns and ascents.

SABL should be viewing upwards for flight legs #1-#4, and downwards for flight legs #5-#8.

Turns should in general be done as a combination of climb and 90/270 degree turns. The total duration of the flight plan is about 90 minutes. If conditions are right, perhaps the end of leg #8 could lead into the start of leg #1 for another sequence. This flight plan may also be done in reverse order to examine if aircraft exhaust impacts the data

King Air flight plan

The flight plan for the King Air is shown in Figure 3.11. The King Air will primarily do flight legs at three altitudes with the legs being perpendicular to the bands. One focus is to investigate the formation and development of the precipitation generated cold pool and the resulting organization of the cloud system. Another is to observe the near-cloud base structure of the clouds, and document changes in that structure from the beginning of the study through the time the C-130 is making measurements in the upper regions of the clouds. C-130 flight leg #2 and King Air flight leg #1 will be arranged to provide near-simultaneous radar coverage of the C-130 flight path. The flight legs will be somewhat shorter than those of the C-130, but the actual extent will be determined by measurements showing the extent and influence of the cold pool in real-time during the flights.

The King Air Doppler radar is a major remote sensing instrument for providing detailed cloud structure, microphysics and wind measurements in the cloud band.

Coordination between the King Air and C-130 will be necessary while both aircraft are in the cloud base environment.

King Air flight leg #1 - above cloud base leg: The purpose of this leg, 200 m above cloud base, is to do in-situ measurements in newly-formed cloud and in more mature cloud, as well as to measure the cloud structure locally and with remote sensing. Before commencing this leg the King Air will be at the eastern end of the flight track, 500 m above cloud base, while it waits for the C-130 climbing up to C-130 flight leg-2 at 200 m above cloud base. After the aircraft have made contact (visual or via TCAS), the King Air will descend to 200 above cloud base, and the C-130 will lead the King Air into the cloud band at the same altitude. The King Air should be flying parallel to the C-130, but about 2 km to the south and lagging the C-130. During this flight leg the King Air radar should be in the horizontal scanning mode.

King Air flight leg #2 - surface leg: The surface leg, 100 m altitude, is intended to map the band-perpendicular component of convergence and divergence, the extent of the cold pool, as well as the cloud-scale pressure perturbations that affect new convection formation. Aerosol distributions and precipitation fluxes will be measured using in-situ probes, and the spatial structure of cloud and precipitation will be measured using the Doppler radar in the vertical mode.

King Air flight leg #3 - below cloud base leg: The cold pool organization of convection should be apparent in this flight leg 100 m below cloud base with in-situ measurement of vertical wind speed. This flight leg will also be used to identify which part of the boundary-layer air west of the cold pool will form the new cloud. The radar will be operated in the vertical scan mode during this leg.

In some flights it is possible that the King Air will make penetrations of the cloud band at other altitudes while the C-130 is either below or above it; alternatively the King Air can perform flight legs #1-#3 again.

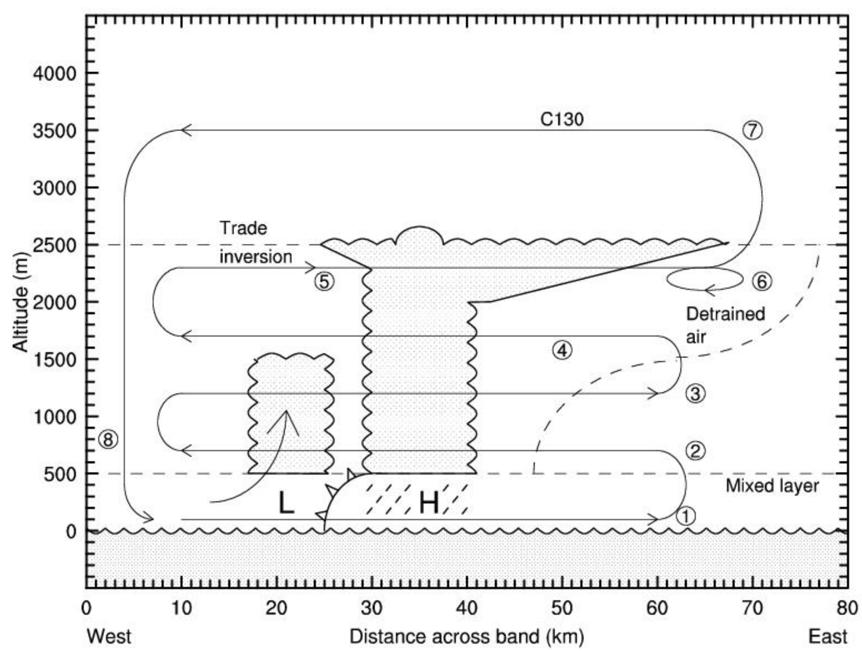


Figure 3.10: C-130 Flight pattern for sampling a line of trade wind clouds.

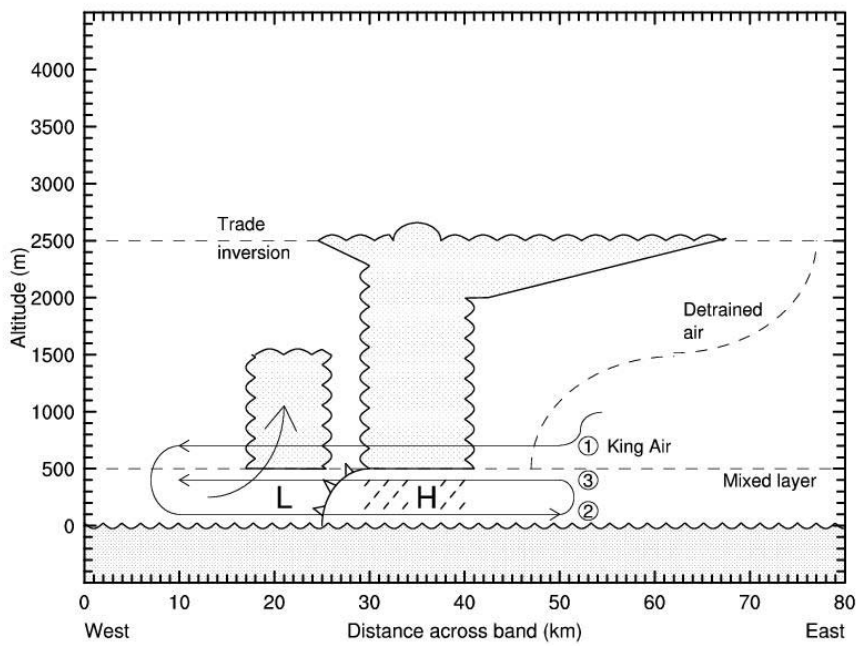


Figure 3.11: C-130 Flight pattern for sampling across a line of trade wind clouds.

3.4.2.1.2 Along Band flight pattern

The along-band flight plan for the C130 is shown in Fig. 3.12. This figure shows a top view of a band with east (detraining region) to the right; this is only a schematic as the actual band may have different orientation. The flight track is oriented lengthwise along the band for maximum time for CVI in-cloud and clear-air single-particle analysis.

The flight plan is formulated as a series of horizontal racetrack patterns, starting above the cloud and working down to avoid possible exhaust contamination as much as possible. Flight legs are numbered at the bottom of the figure. Each flight leg should take about 15 minutes when turns and altitude change are included, for a total flight time of about two hours.

C-130 flight leg #1 – Above cloud-top lidar leg: Remote sensing of the cloud topography using SABL in the down-looking mode. Altitude about 1000 m above the trade inversion.

C-130 flight leg #2 – Cloud-top detraining air leg: In detraining cloud region near cloud band but completely in clear air. Altitude about 200 m below the trade inversion or slightly lower.

C-130 flight leg #3– Cloud top leg: In-cloud leg about 200 m below the trade inversion. There may be some rain and/or anvil cloud.

C-130 flight leg #4 – Mid-cloud detraining air leg: Same as leg #2, in clear air approximately mid-way between cloud base and cloud top.

C-130 flight leg #5 – Mid-cloud leg: In-cloud leg approximately mid-way between cloud base and cloud top.

C-130 flight leg #6 – Cloud base leg: This leg should be done about 200 m above cloud base, such that the immediate effects of activation can be examined.

C-130 flight leg #7 – Cloud in-flow leg: A near surface leg to measure input conditions. Altitude about 100 m above sea level, on the west side of the band where convection is likely to be triggered. Track should be offset from the cloud band to completely avoid precipitation. Cloud mapping with SABL lidar pointed upwards.

C-130 flight leg #8 - upstream ascent sounding: As in cross-band flight plan, above, except ascending rather than descending. This flight leg should be done on the western side of the band, with no cloud penetrations. The beginning of the ascent should be done well past the band, such that a full altitude sounding is accomplished in air that was likely not to be recently detrained. The final sounding should go as low as possible. SABL should be viewing downwards for flight legs #1-#4, and upwards for flight legs #5-#8.

King Air: Along band radar and microphysics at levels suitable for the radar and whenever it can be coordinated with the C-130.

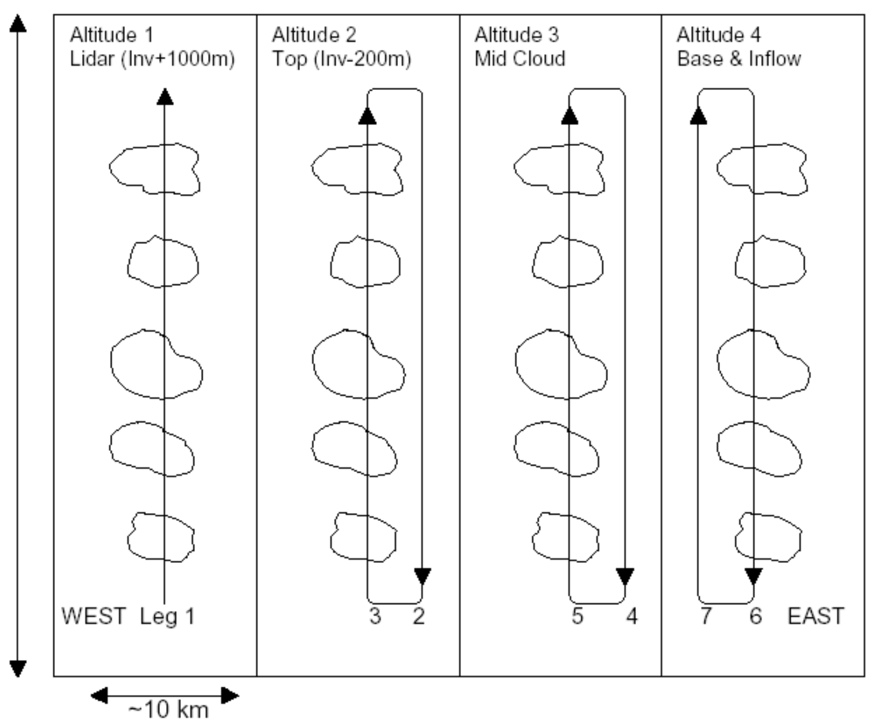


Figure 3.12: C-130 Flight pattern for sampling along a line of trade wind clouds.

3.4.4.2: Targets of opportunity: Cloud clusters

Long lived cloud clusters, with emergent cloud towers, often occur in the trade winds. When these clusters move into the radar viewing area, they represent a target of opportunity. Sampling of cumulus towers emerging from cloud patches, and the patches themselves are a high priority. The top panels show example strategies for one aircraft. The bottom shows a cross section with two aircraft (left) or one aircraft (right). The lowest level track would be at the lowest safe altitude above the ocean surface. A pass below cloud base and within the low level cloud deck would occur, followed by continuous passes trough the turrets. With two aircraft, the C-130 would do the low level passes up to the lower turret level, while the King Air would sample the turrets continually at a higher altitude.

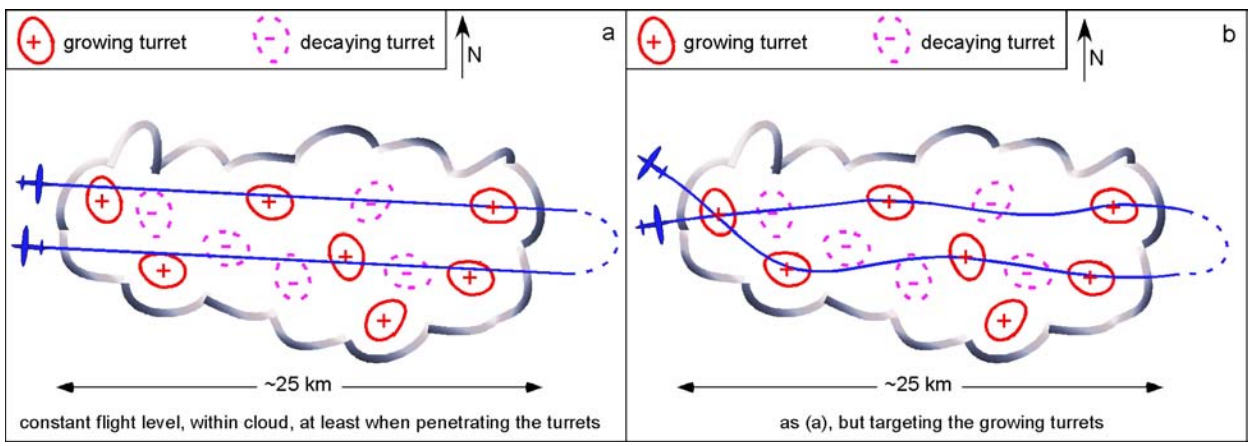


Figure 3.13: Sampling strategy for cloud turrets emerging from cloud patches (Left: aircraft flying within patch, and Right: aircraft sampling turrets emerging from patches.)

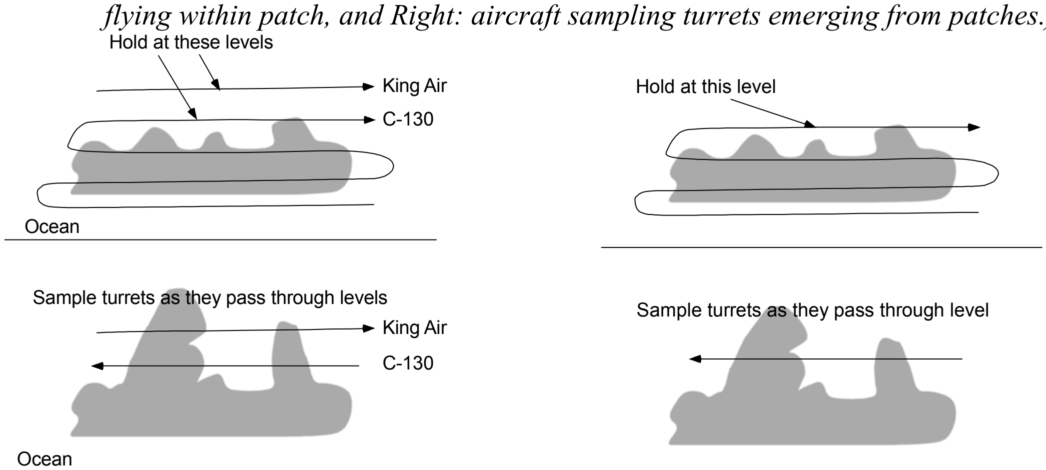


Figure 3.14: Sampling strategy for cloud turrets emerging from cloud patches (Left: two aircraft, and right: one aircraft.

3.4.3 Other flight patterns

3.4.3.1: Short flight patterns for instrument evaluation and intercomparison

Short flight patterns will be performed on occasion for specific instrument evaluations. These include, but are not limited to:

1) Cloud base ascent

Meteorological selection:	Cumulus base, preferably as hard and flat as possible, none or minimal precipitation, substantial clouds are best
Frequency:	Four times during each deployment period, for a total of eight times
Duration:	10 minutes (estimated) to allow for positioning of the aircraft
Goal:	(i) Detect gain errors in liquid water probes, (ii) examine difference in width of cloud droplet spectra between FSSP and Phased Doppler sensors during conditions of well-defined expectation

Gain errors in liquid water sensors can lead to erroneous conclusions about the degree of entrainment or rainout of cloud water in cumulus, and rapid ascents through adiabatic or near-adiabatic updrafts from cloud base can be used to check for such errors. Measurement of droplet spectra using FSSP sensors are known to artificially broaden the drop-size distribution. The Phased Doppler sensor works with a completely different measurement principle from that of the forward scattering FSSP. It is not clear if or to what extent the Phased Doppler sensor artificially broadens the droplet size distribution.

For sub-cloud measurements of aerosol particles, it is possible to calculate the droplet spectrum in an adiabatically ascending parcel. During RICO there should be an unprecedented opportunity to compare the calculated droplet spectrum width to that measured by three droplet sensors: the normal FSSP, the Fast-FSSP and the Phased Doppler sensor. The flight plan calls for a rapid ascent up into a hard and flat cumulus base, preferably with none or minimal visible precipitation. Large cumulus are preferred, and it may be desirable to fly a max speed just below cloud base, and then to follow this with a very rapid ascent for 3-400 m up into the cloud. The cloud base ascent can be done at any convenient time during a flight. It should not be done as part of one of the extensive soundings from sea-surface to well above the trade inversion.

2) Lenschow maneuvers

Meteorological selection:	Clear air conditions, away from clouds and cold-pools, altitudes above trade inversion

Frequency: Once during each deployment period, for a total of two times.

Duration: 15 minutes (estimated) to allow for positioning of the aircraft

Goal: Characterization of wind measurement system

The so-called Lenschow maneuvers are commonly used as in-flight calibration maneuvers. These maneuvers will be done extensively in the test-flight period leading up to the field phase. There remains a desire to do a scaled-back version of the maneuvers in the field, essentially to check that no changes have occurred with time. The proposed maneuvers cover a single reverse heading leg, consisting of two 3-minute legs separated by a 90-270 turn. The legs should preferably be done along the mean wind direction, but this is not an absolute requirement. The pitch maneuver can be done on the C-130, but on this aircraft the sideslip maneuver should not be conducted during RICO due to the installation of the SABL pod and the CPI. The flights should be done as straight and level legs several thousands of feet above the trade inversion in as homogenous conditions as possible, preferably far from overshooting convection.

3) Aircraft speed runs

Meteorological selection: Clear air conditions, away from clouds and cold-pools, altitudes from below cloud base level to above the trade inversion

Frequency: Four times during each deployment period, for a total of eight times

Duration: 10 minutes (estimated) to allow for positioning of the aircraft

Goal: (i) Improved characterization of static pressure defects that impact on pressure, wind and temperature measurements, (ii) determination of wet-bulb temperature sensor recovery factor

Any aircraft will cause a disturbance of the ambient pressure field as the aircraft moves through the air. Measurement of static pressure is done on the skin of the aircraft in an area which is affected by pressure errors. The usual method is to fly trailing cones. This should preferable be done for the entire altitude range covered by the aircraft. Recent installation of differential L1/L2 GPS systems on both the UWY King Air and the NCAR C-130 can, in conjunction with ground-based stations on Antigua and Barbuda, give high accuracy measurements of aircraft altitude (0.5 m or better). A speed run, for which the aircraft pitches up at slow speeds and is more level at high speeds, will give different pressure error which can be determined using the aircraft GPS altitude and the hydrostatic equation. An additional error caused by aircraft engine torque may also be characterized. The wet-bulb temperature sensor has not been flown on the C-130 previously. It is intended to give temperature measurements in cloud; where normal immersion sensors give errors when wetted in cloud, the wet-bulb temperature sensor is continuously kept wetted, both in clear and cloud air. The wet-bulb sensor should thus have negligible effect of the liquid water in the clouds. The dynamic heating of the wet-bulb sensor needs to be characterized. Speed runs will be used to determine this effect, and measurements at in the trade environment, with the sensor both dry and wet, will be used to determine the recovery factor assuming that the ambient temperature is constant during the speed run. The flight plan calls for flight straight and level away from clouds. The aircraft should be steady at normal research speed at the beginning of the leg for one minute, then the speed is slowed down and subsequently accelerated to cover a wide range, followed by another minute of straight flight at normal research speed.

4)Temperature and dewpoint offset

Meteorological selection: Cumulus base, preferably as hard and flat as possible, none or minimal precipitation

Frequency: Once every two flights minimum, once per flight is ideal.

Duration: 10 minutes (estimated) to allow for positioning of the aircraft

Goal: Accurate offset between temperature and dewpoint

The trade wind regime will be characterized by small buoyancy differences between the temperature inside and outside cumulus clouds. This will necessitate accurate measurements of temperature and dewpoint temperature to calculate the LCL cloud base from sub-cloud legs and for estimating buoyancy and entrainment. The marine environment with strong winds will lead to considerable accumulation of salt sprays. Routine maintenance will in part keep this in check, but additional in-flight maneuvers can add in the determination of the offsets. Offsets may also result from large raindrops impacting on the temperature sensor wires. Normal penetrations of cloud should show approximately identical temperature and dewpoint, but the short duration of cumulus penetrations may show considerable lag of the cooled mirror sensors. The flight plan calls for a slow ascent up into a hard and flat cumulus base, preferably with none or minimal visible precipitation. The slow ascent is intended to avoid rapid changes in the dewpoint temperature. The offset between temperature and dewpoint can be done, e.g., for the first second that shows consistent counts in the high-rate FSSP drop measurements. The cloud base ascent can be done at any convenient time during a flight. It should not be done as part of one of the extensive soundings from sea-surface to well above the trade inversion.

5) Boundary-layer right angle legs

Meteorological selection: Clear air conditions, away from clouds and cold-pools, altitudes below cloud base

Frequency: Two times during each deployment period, for a total of four times

Duration: 12 minutes (estimated) to allow for positioning of the aircraft

Goal: (i) Testing of the mean-wind measurement dependence on heading, and (ii) measurement of heading dependence on turbulence spectral shape

The C-130 wind measurement system has in some past experiments given results that vary with the aircraft heading. This may have multiple reasons. For RICO it is desirable to characterize the heading effect both early and later in each flight period, such that any changes can be noted. The flight plan calls for flight straight and level flight away from clouds and cold pools. The aircraft should be steady at normal research speed at the start of the maneuvre, then do a five-minute flight leg along the wind, followed by a five-minute leg perpendicular to the mean wind. Alternatively the cross-wind leg could be done first, followed by the along wind leg. The flight leg should be done below the cloud base level in the mixed layer.

6) Wing-tip intercomparison

Meteorological selection: Clear air conditions, away from clouds and cold-pools, altitudes below cloud base

Frequency: Once during each deployment period, for a total of two times. Each intercomparison should be done with two of the three aircraft.

Duration: 12 minutes (estimated) to allow for positioning of the aircraft

Goal: Comparison between temperature, humidity, winds and particles measurements from multiple aircraft.

Measurement systems on each of the aircraft are calibrated individually. The intercomparisons are intended to determine the differences between aircraft. The measurements to be compared cover many sensors including thermodynamics, mean winds and fluxes, particle concentrations and size spectra, and common trace gases. The flights should be done as straight and level legs in the mixed layer in as homogenous conditions as possible. Cloud penetrations should not be done due to safety considerations, and precipitation areas and cold pools in the mixed layer should also be avoided.

3.4.3.2: King-Air/Ship coordination

During certain flights the King Air will perform coordinated studies with the ship. The ship's radar will sample clouds as they pass across the scan plane normal to the wind direction, and the King Air will perform dual Doppler scanning to determine the cloud's kinematic structure during or near the time clouds are scanned by the ship-borne radar (e.g., see Figure 3.8)

3.5 Ship Operations

3.5.1 Observing strategies

During RICO the remote sensing and in situ measurements from the ship will be made continuously. Observations from the ship will be coordinated with the radar observations form the NCAR S-POL/Ka Band radar that will be operated on Barbuda.

3.5.2 Ship Position and Observing plan

The ship will generally be operated from a near stationary position centered within a sector that will be sampled by the NCAR S-POL/Ka radar operating from the island of Barbuda during RICO. The sector scan will be perpendicular to the wind and the optimal location for the ship will be about 25 km from the radar (see Fig. 3.7). As winds change, the ship will be relocated to stay within the S-Pol sampling volume as its position is changed. Since only slow variability in the mean winds is expected, updated positions will be obtained from the radar operations center every 4-6 hours. Any plans for moving the ship in response to changing wind conditions should assume a nominal speed of 10 knots for the ship during repositioning. Turbulent flux sampling requires the ship to be bow into the wind as much as possible. This may require the ship to go slow ahead for best heading control. To maintain a geographical operations circle, the ship may periodically turn down wind and run at 10 kts to reposition.

3.5.3 Observations on station

Instruments on the RICO mission typically will be acquiring data continuously, both while the ship is underway and when it is holding station. The upward-facing and scanning remote systems will, with some exceptions, be operated continuously while the ship is on station with the ship heading into the wind or underway. In the interest of preserving transmitter and laser lifetime, the Ka-band radar, the W-band radar, and the lidar may stand down in widespread cloud free conditions. For the ship, intensive operations will be defined as periods with coincident aircraft operations or when the land-based radar advises us of significant probability of encountering precipitating clouds.

The Ka band radar will make RHI scans (horizon-to-45°) perpendicular to the wind; these scans will be oriented towards the land based radar. These may be modified (e.g. horizon to horizon) if this strategy increases opportunities for cloud sampling. During intensive periods, the lidar will operate by sequencing through 3 or 4 scan modes:

1. Forward-facing azimuthal sector scans (nominally -90° to +10°) at two elevations angles. The lower elevation angle (2°) to resolve fields of horizontal wind fluctuations and the higher

elevation angle (12°) to locate clouds in the wind field. The return period for this mode will be about 40 s.

2. Cross-wind RHI scans (horizon to 45°) to mimic the Ka-band scans.
3. Vertical stares to provide data matching the other vertical remote sensors.
4. VAD's at three different elevation angles to determine high resolution mean wind profiles.

The scan modes will be sequenced with a 30-min or 60-min return period. For example, one sequence will be 1-4-2-4-3-4 where 1, 2, and 3 are 15 minutes and 4 is 5 minutes. In conditions with no aircraft operations or significant precipitating systems, the lidar may operate in a continuous vertically staring mode if there are interesting clouds.

Continuous observations of turbulent and solar/IR radiative fluxes will be made along with standard meteorological observations and sea surface temperature. Rawinsonde launches will be made 4-8 times daily. Vaisala GPS RS-92 sondes (weather balloons) will be launched nominally every 4 hours from the ship's main deck aft. Additional or fewer launches may be decided on location. A sounding procedure will be agreed upon by UM/CU/ETL. All sounding launches should follow a set procedure to ensure consistency. The sounding procedure will include surface humidity and temperature measurements from a handheld psychrometer on deck in proximity to the launch area. Members of the scientific crew will be trained in launch procedures on the transit to the on station area. The 00Z and 12Z launches will be sent to the Global Transmission System (GTS), as usual. The data from the soundings will be made available to the work station in the main lab via ftp from the ship's computer network and on writeable CD (to be supplied by UM). In addition digital cloud photos will be taken at designated areas around the ship at the time of launch. The ship's IMET system data will be provided to the science work stations via the ship computer network; a realtime RS-232 or wireless link is requested. Recording rate of these data will be the same as for all other ship instruments and on same time base.

A small number of aerosol measurements will be made. A PMS Lasair II instrument will record surface aerosol size distributions in six size bins: 0.1-0.2, 0.2-0.3, 0.3-0.5, 0.5-1, 1-5, and greater than 5.0 μm diameter.at a temporal resolution of 1 min. A Microtops hand-held sunphotometer will be used to measure aerosol optical depth (spectral) during daylight hours. The frequency of these measurements will be determined by the variability in aerosol loading and will be increased if there is indication of significant transport of aerosol into the region.

3.5.4 Ship Communications

UNOLS ships normally provide standard email transmissions twice daily. Voice communications are available through INMARSAT. ETL will also be providing an IRIDIUM phone. This will be available for voice or data transmissions, but the data rates are very slow and cumbersome. Marine radios are unlikely to have sufficient range for reliable comms with the SPOLKa; VHF radios are a possibility but may interfere with some measurements. ETL will bring an aircraft radio for local communications with research aircraft.

3.5.5 Ship Data Transmissions

Selected data products will be produced for transmission to the operations center or the SPOLKa. Assuming limited bandwidth, these will generally take the form of zipped ascii files or image files. Sonde profiles will be sent as soon as they are available. Processed near-surface mean meteorological parameters, remote sensor image files, and other products of interest will be sent daily or every 12 hours. Other information (e.g., as required by aircraft operational briefings) can be transmitted as per request.

3.6 GLASS/PAM operations

Trade-wind cumuli have a pronounced diurnal cycle, with cloudiness and the height of the trade inversion increasing during the night. During ATEX cloud fraction varied from 20% coverage during the day to near 80% coverage at night. Similarly, the trade inversion varied by as much as 400 m through the course of the diurnal cycle, tending to be deepest at night. Evidence of subsidence-like modulations of maritime cloudiness was also evident during the recent EPIC 2001 stratocumulus measurements in the heart of the Peruvian stratocumulus regime at 20°S. Evidence of a diurnal cycle in maritime convection has a long history – for instance, in 1963, Kraus referred to the early morning maximum in maritime precipitation.

To relate cloudiness and precipitation to large-scale conditions, it is important to resolve the diurnal cycle during RICO. Although the radar will provide excellent temporal sampling of the cloud field, temporally dense soundings are required to information about the diurnal cycle in larger-scale meteorological conditions. During 5 days in December and 9 days in January, 8 soundings per day (3 hour resolution) will be launched to resolve the diurnal cycle. These days will all coincide with aircraft missions. The emphasis on the January period is because more facilities (e.g. Ship, UK BAE 146 aircraft) will be present. The GLASS system sondes have 0.5 m/s winds with 2 m resolution, which is ideal for the trade wind environment, where winds are expected to be ~10 m/s. The PAM system will provide continuous data with which to identify/confirm the passage of large-scale features that regulate cloudiness and precipitation. Both the PAM and GLASS sites will be located on the windward side of Barbuda on the southeast part of the island.

Outside of the intensive operation periods, GLASS soundings will be launched routinely twice per day. These launches will be timed to coincide with the diurnal maximum and minimum in cloudiness and precipitation, as determined during the radar-only period. Launches will commence on December 6 and continue, through the holiday break, to the end of the project on January 24.

3.7 Ground based aerosol sampling

Ground based aerosol sampling will take place simultaneously at three different sampling platforms, two of which are in Puerto Rico (PR, 18' 15 N, 66' 30 W), and the other in Antigua (17.03 N, 61.48 W). The predominance of easterly wind currents (trade winds) minimizes the effects of anthropogenic sources in northeastern PR and Antigua because of their location relative to the Atlantic Ocean and the absence of significant land masses with anthropogenic activity upwind that could interfere with the proposed study (see maps in Chapter 2). Additionally, these marine sites have the common occurrence of trade wind cumulus and the weak tropical inversion that limits the depth of many clouds. In PR, two stations will serve as platforms, Cape San Juan (CSJ) and East Peak. CSJ is located in a natural reserve at the most northeastern part of PR and is ideal for the study of marine background aerosol. East Peak, at the Caribbean National Forest (CNF), is located downwind of CSJ (ca. 15 km southwest) and provides the opportunity to study aerosols emitted from the ocean and from urban areas between CSJ and CNF and transported to this region. The elevation of this site at ca. 1050 m allows the collection of cloud/fog water samples almost year round. The third sampling platform will be in the northeastern part of Antigua (Figure 2b).

The PR locations have the major advantage being within an hour's drive of a large university research center, University of Puerto Rico-Río Piedras (UPR-RP). University staff, faculty, and facilities will facilitate the proposed sampling, minimize concerns about sample handling and preservation, and provide highly reliable data. The close proximity of UPR-RP to the sampling site will also permit a continuous sampling program that is essential to monitoring the variations in aerosol composition and properties that occur due to seasonal changes.

Sampling Strategy

Aerosol filter sampling, cloud/fog water collection, and real-time measurements will be conducted on a daily basis. Fog/cloud water sampling will be only at the East Peak. Sample collection will integrate diurnal and nocturnal periods or be done separately for these periods. Meteorological data will be collected continuously at each ground station. Filter samples will be taken only when the wind direction is from the northeast in order to minimize contamination from island sources. To determine the origin of the air masses, back trajectories will be calculated for every sample using the hybrid single-particle Langragian integrated trajectories model, HYSPLIT-4 [*Draxler and Hess*, 1997] and the "final model run" (FNL) meteorological data set produced by the U.S. National Center for Environmental Prediction.

The sampling schedule is as follows:

- Period 1: November 21 – December 21 – sampling stations operating will be CSJ, East Peak and Antigua.

- Period 2: January 4 – January 26 – sampling stations operating will be CSJ and Antigua. East Peak station will not be fully operating.

Coordination is planned between the NCAR C-130 and the three sampling stations for up wind flights during the ferry flights to Antigua (December 4 and January 3) and on the way back to Colorado (December 21 and January 26). Flights will consist of soundings with duration of about 20 minutes at a distance approximately 10 km to the northeast of the island, or in a direction determined by the average winds at the time of the flights. This will be for intercomparison purposes with real-time measurements such as particle number concentrations, scattering and absorption coefficients, and BC concentrations.

4. RICO Mission Planning and Execution

This chapter describes the mission planning and implementation process. The planning of a mission involves several steps. These include facility status, weather forecasting, daily planning meetings, staffing for missions, and the execution of mission.

4.1 Key staff for each mission

<u>Mission Scientific Staff</u>

Science Director

- ROC Director for scientific mission decisions
- Co-chairs RICO Daily Planning Meeting
- Leads daily Mission Planning discussion
- Decides (with consultation) the final deployment of all facilities
- Provides Science Progress Reports to Daily Planning Meeting
- Works with OD and mission scientists to produce flight plans
- Assumes Mission Scientist Role for Mission Planned (next day)

Mission Scientist

- Makes go/no go decision for day's mission
- Flight Scientist on C-130
- Leads in-flight coordination during operations
- Prepares Daily Mission Summary Report

Flight Scientist

- Scientific director onboard aircraft (one on each aircraft)
- Point of contact for all flight planning and execution
- Prepares daily aircraft operations report
- Participates in mission debriefing

Ship Chief Scientist

- Scientific director aboard ship
- Point of contact for all ship coordination

SPOL Chief Scientist

- Point of contact for all SPOL coordination

<u>Operations Center Functions and Operations Coordination Team (OCT) Staff</u>

Operations Director

- Convenes and co-chairs the RICO Daily Planning Meeting
- Implements the daily RICO Operations Plan
- Provides Status Report summary to Daily Planning Meeting
- Coordinates required support activities
- Assigns duties to Operations Coordination Team personnel
- Responsible for form and content of Daily Operations Summary
- Updates RICO recorded status message
- Conducts aircraft flight debriefings
- Monitors progress and integration of all facility operations

Aircraft Coordinator

- Single Point of Contact for all RICO Aircraft Facility Project Managers
- Coordinates ATC requirements—alerts, advanced notifications, etc.
- Coordinates all communications between Operations Center and research aircraft—flight track changes, data products transmitted to/from aircraft
- Works with SD, OD and mission scientists to update flight tracks as needed

Surface Observing Systems Coordinator

- Point of contact for all surface based observing systems
- Coordinates all communications between ROC and surface observing systems
- Monitors status of all surface observing systems and expendables
- Works with SD and OD to coordinate aircraft overflights of surface observing systems (particularly ship)

Antigua Site Coordinator

- Primary point of contact/project liaison with all operations space, local airport and government authorities on Antigua
- Coordinates public relations for RICO activities on Antigua

Barbuda Site Coordinator

- Acts as point of contact/project liaison with all operations sites, local arrangements, and local government authorities on Barbuda
- Coordinates public relations for RICO activities on Barbuda

Communications/Networking Coordinator

- Manages LAN and related computer support
- Assists participants with set-up of computer systems on the RICO LAN
- Responsible for computer and networking security
- Primary point of contact with local Internet Provider

In-Field Data Management Coordinator

- Responsible for implementation and updating of the RICO Field Data Catalog
- Assists participants with submitting preliminary data products to the catalog
- Monitors supplementary operational real time data collection for RICO
- Assures ingest and display of RICO specific satellite data and products

Weather Forecaster/Nowcaster Coordinator

- Schedules daily operations support for forecasting and nowcasting, including Pre-Flight Briefings
- Trains forecasters and nowcasters on RICO requirements and procedures
- Coordinates RICO forecast data support requirements with JOSS
- Establishes standard forecast content and products for RICO Field Catalog

Staffing Table (as of 10/15/04)

FUNCTION	PARTICIPANT
Science Director (SD)	Rauber, Ochs, Stevens
Mission Scientist (MS)	Rauber, Ochs, Stevens
Operations Director (OD)	Dirks, Moore, Stossmeister, Williams
Aircraft Coordinator (AC)	Moore, Dirks, Stossmeister, Williams
Sfc Obs Systems Coord	
Antigua Site Coordinator	Dirks, Moore
Barbuda Site Coordinator	Bauerle, Gates…
Comms/Network Coord.	Daniels, Bradford, Russ,..
Field DM Coord.	Stossmeister, Roberts, Williams
Forecast/Nowcast Coord	Rauber, Stevens, Cotton

4.2 Daily Planning meeting

There will be a general meeting each day of the RICO field program to discuss relevant issues, remaining resources and status, science objective status, current weather and synoptic situations and PI proposals. The RICO Daily Planning Meeting will be held at 1500 Local Time (LT, 1900 UTC) at the RICO Operations Center, seven days per week throughout the field season beginning 5 December 2004 thru 20 December 2004 and 2 January 2005 thru 24 January 2005.

The Daily Planning Meeting will be co-chaired by the RICO Science Director and Operations Director. The agenda for the meeting will be consistent each day and include the following items:

- Status of aircraft, mobile facilities and remote observing systems
- Data management and communications status report
- Forecast discussion from 24-36 hours, special products; outlook to 72 hours
- Report on the status of scientific objectives and results of the last mission and/or update on the status of an on-going mission
- Mission Selection, staff assignment, and schedule of operations
- Logistics or administrative matters
- Other announcements

<u>Mission Selection Process</u>

- Science proposals
- Discussion of proposals
- Primary and secondary mission selection
- Staff assignments
- Schedule of operations

<u>Mission Plan Preparation</u>

When there is a plan for a mission beginning the next day, the Science Director and Operations Director will meet immediately following the Daily Planning Meeting (MST Meeting) to finalize the Mission Plan for the next 12-36 hours. This meeting may include other PIs or staff crucial to formulate the details of the Mission Plan. The following items will be decided during this meeting and reported in the Daily Operations Summary:

- Description of mission (primary and alternate), including a brief discussion of objectives and strategy and criteria for proceeding to the alternate mission

- Assignment of staffing for mission support for the next 24-36 hours

- Preliminary Aircraft Operations Domain
    - Aircraft pre-flight briefing times
    - Proposed aircraft flight plans
    - Aircraft take-off times
    - Ship movements and schedules
    - Weather forecast/nowcast support
    - Special observation schedules
- Debriefing schedule

4.3 Operations Implementation

Facility Notification Procedure

Once the facility operating schedules for missions are decided at the Daily Planning Meeting the responsibility for the conduct of operations shifts to the Operations Coordination Team (OCT) under the leadership of the Operations Director. Official notifications to Facility Managers are made by OCT staff. Notification of planned aircraft take-off times will be given by the Operations Director (or Aircraft Coordinator) to the Aircraft Facility Managers and flight scientists at least 12 hours in advance. The Aircraft Coordinator will provide advanced notification to the appropriate government aviation authorities, Air Traffic Control (ATC) Centers (Antigua, Piarco, San Juan) and Military Operations Centers. Notification of operations schedules for the ship, radar and soundings will be made by the Operations Director (or Ground-based Facility Coordinator). The Operations Director prepares the Daily Operations Summary. This summary will be distributed to all participants via the RICO Field Catalog. A brief version of the Daily Operations Summary will be prepared for the recorded phone message.

Aircraft Operations Coordination

Determination of aircraft flight schedules will follow aircraft operational guidelines (See Appendix B). The Mission Scientist and Aircraft Coordinator will work with the aircraft pilots in the preparation of detailed flight plans. Aircraft pilots will submit flight plans following normal ATC procedures. Individual pre-flight briefings will be given 2 hours prior to the scheduled take-off and will be prepared to meet individual aircraft facility requirements. During flight operations coordinated observations will be conducted via continuous satellite chatroom communications between the Aircraft Coordinator or Science Director (at the ROC) and the Mission Scientists onboard the aircraft. The Science Director will make flight operations decisions with input from the Operations Director, Nowcaster, SPOL Scientist and Aircraft Mission Scientists.

Debriefing and Reporting

At the completion of a day's mission, post-flight debriefings will be held for each aircraft mission. The debriefings will be conducted by the Operations Director (or Aircraft Coordinator) at the ROC as soon as possible after landing so that all onboard scientists and selected crewmembers can participate. Key issues are the perceived success of the mission, and the status of the facility (and crew) for the next day's operations. The Operations Director (or Aircraft Coordinator) may also announce the alert and schedule for the next day's operations. Each Flight Scientist or Ground System Manager is expected to provide a Facility Operations Report (or Flight Report) of their operations, within 24 hours to the RICO Field Catalog.

Surface System Operations Coordination

Ship Operations Coordination (Jan. only)

- Ship location, movement schedule
- Scheduled measurement operations, continuous measurement operations
- Overflight & intercomparison plans

Sounding Operations Coordination

- Scheduled measurement operations
- Expendable and Helium supply, staff schedule restrictions

Satellite Operations Coordination

- Rapid –scan guidelines, schedules, notification procedure
- Satellite overpass schedules and locations, interception plans

4.4 Daily Operations Timeline

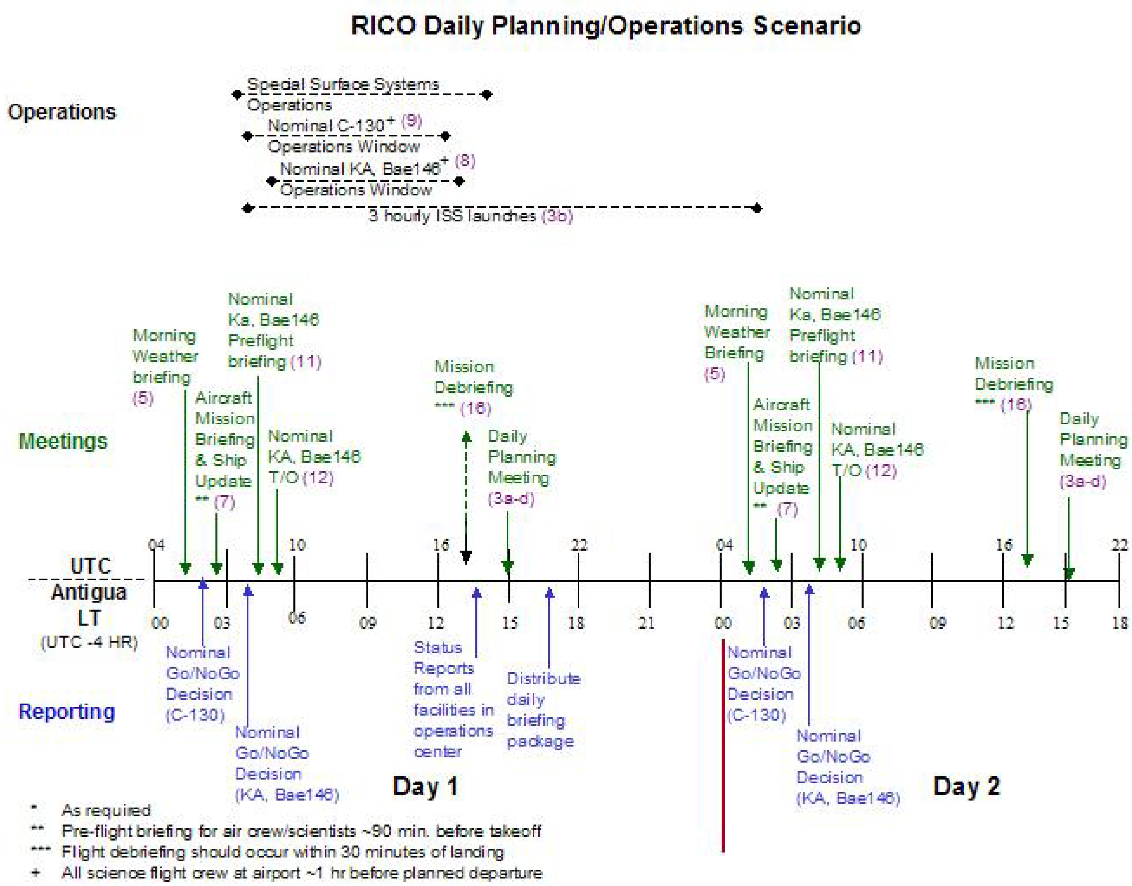


Figure 4.1 Example RICO daily operations timeline for early morning operation

The following is an explanation of Figure 4.1:

Day-1= day of operations, today
Day-2=tomorrow, day of plan
Example time for aircraft operations 0400-1230 LT, T/O 0400.

Day-1:

0145	Short-term forecast
0200	Operations update
0330	Pre-flight briefing
1300	Day-1 debriefing, Day-2 alert
1400	Day-2 forecast
1500	Daily Planning Meeting

Mission Preparation and Support Steps

The timing of these steps are referenced to the time of takeoff of the C-130 for the mission under consideration, which will be referred to in this chapter as "T+0 hr". The number of each step is referenced in Fig. 4.1, as appropriate. Flight patterns involving cloud sampling require daylight. This, and the expected nocturnal peak in the diurnal cycle of clouds and precipitation, suggests that most operations targeted at cloud physics studies will be scheduled near dawn. Flights, or parts of flights conducted in darkness will be limited to characterization of the trade wind environment, and involve only the C-130. With these considerations, the most likely takeoff time of the C-130 will be at 4 a.m. The other aircraft will depart near dawn. Although the schedule of events below is timed to the launch of the C-130, the local times in parentheses are the expected times of these events for this typical early morning operation.

1) T-61 hr (3 p.m. daily mission planning meeting) If the flight times are planned to shift in time sufficiently to change the rest cycle for the pilots (e.g. a switch from an early morning to a late evening flight), a decision must be made 60 hours in advance that the change will occur so that pilots have adequate time to modify their rest cycle. In the case of a change, no flights will occur in the period T -36 to T+0 hr.

2) T-37 hr (3 p.m. daily mission planning meeting) An initial go/no-go decision on flight operations will be made. A no-go decision ends planning for the mission for the day of C+0, i.e. flights will not occur on that day. Scheduled down days, for example, will be decided at T-36.

3) T-13 hr (3 p.m. daily mission planning meeting) Decisions will be made at this time:

   a) An alert for a mission scheduled at T+0 will be made or a stand down decision will be made.

   b) A decision to use a 24 hour launch schedule for the GLASS soundings will be made. If a "go" decision is made, the 3 hourly soundings will commence launch at the time of the nearest twice daily sounding to T - 6 hr.

   c) A decision on the number of King Air flights and BAE-146 flights will be made, and any special coordinated activities between the platforms

   d) A forecast for the direction of the prevailing trade wind direction (the expected direction of the motion of the cloud field) in the vicinity of Barbuda is required. In the January period, this forecast will be used to position the ship into the center of the radar sector for the next day's mission. The ship will either immediately proceed to this location, or proceed there as soon as current operations terminate.

4) T-12 through T+2 (4 pm – 2 am) Rest time for pilots and scientists involved in mission.

5) T-3.0 (1:00 am) Forecasters prepare pre-flight briefing for pilots and scientists. Briefing should include 1) a review of the operational sector and prevailing wind; 2) a discussion

of expected cloud features based on the latest radar and satellite guidance; 3) a discussion of the latest Barbuda sounding; 4) Any other meteorological information of interest.

6) T-2.0 (2:00 am) Go/No go decision made. If go, C-130 powered up and fueled.

7) T-1.5 (2:30 am) Pre-flight briefing at operation center.

8) T-1.0 (3:00 am) All scientists, students etc. on the flight should be at the airport and ready to board aircraft. Scientists should be on station at radar in Barbuda. Sounding launches will have already commenced. Ship operations should have commenced already at location in operational sector. Operations director and Mission Scientist for next mission should be on site at the operations center at the pre-flight briefing.

9) T+0 (4 am) C-130 takeoff. King air crew and BAE crew arrive at airport. Go/No go decision for King Air and BAE-146. If go, Power up and fuel aircraft at appropriate times.

10) T+0 through T+1.5 (4 am through 5:30 am): C-130 begins characterization of the trade wind environment, commences dropsonde circle launches.

11) T+0.5 (4:30 am) Pre-flight briefing for KA and BAE pilots at operations center. All BAE and KA staff to fly should proceed to airport after briefing or already be at airport.

12) T+1.5 (5:30 am) Takeoff of KA and BAE.

13) T+4.5 (8:30 am) Approximate landing time for first flights of KA and BAE

14) T+5.5 (9:30 am) Takeoff times for 2nd flights of KA and BAE if a second flight is warranted.

15) T+8.5 (12:30 pm) Landing time of all aircraft

16) T+9.0 (1:00 pm) Mission debriefing at operation center

17) T+11 (3:00 pm: Mission planning meeting) Brief review of mission by mission scientist.

4.5 Forecasting

Forecasting and nowcasting support for RICO is required for the planning and conduct of aircraft flight operations in and around precipitating cumulus clouds. Emphasis will be given to conducting flight operations in the high-resolution (<50 km) domain of the S-Pol radar located on Barbuda (Fig. 3.5). Measurements of the statistical properties of cloud fields may extend to 100 km from Barbuda. Developing 12-48 hr forecasts for this domain will require monitoring cloud fields and weather systems up to 1000 km distance from Barbuda.

RICO PIs and students will provide forecasting and nowcasting support for RICO. The RICO forecasts and nowcasts will be provided from 5-20 December 2004 and 2-24 January 2005.

We define "short-term forecasting" as the generation of 1-12 hr guidance based on observations, model output and forecaster intuition. In contrast, "nowcasting" is defined as the assessment and very short-range (0-1 hour) extrapolation of mesoscale weather conditions, primarily based on real-time observations and possibly experimental forecast model output. Longer term forecast products include forecasts beyond 12 hours, as well as outlooks for general planning purposes that could extend out to perhaps several days.

4.5.1. Location of Support Services

The RICO Operations Center (ROC) will be located in the ACT Communications Building, Old Parham Road, east of St. John's. Forecasting will take place in the Science Support Area and nowcasting and short-term forecasting will occur in the Command and Coordination Center. Preflight briefings and Daily Planning Meetings will take place in the ROC Meeting Area.

4.5.2 Daily Operations Schedule

RICO scientists and students are expected to fill out the weekly duty rotation to insure that forecasting and nowcasting services are provided continuously through the RICO operations schedule. The weather forecaster/nowcaster coordinator will assure the completeness of the staffing schedule and staff training.

A 2 person forecast team is envisioned. Forecaster #1 will begin 3 h before the scheduled take-off (T/O) of the first aircraft by preparing a short-term forecast for Day-1 (today). Forecaster #1 will brief the Science Director and Operations Director about 45 min later. Decisions about cancellation, delay or flight modifications will be made and these will be included in the pre-flight briefing presented about 90 min before T/O. Forecaster #1 will then assume the role of Nowcaster for this day's flight operations. Forecaster #2 will begin in the late morning to prepare a forecast for Day-2 (tomorrow's) operations, with an outlook for Day-3. Forecaster #2 will prepare the forecast discussion for the Daily Planning Meeting at 3:00 p.m. and prepare the Forecast report for the RICO Field Catalog. Forecaster #2 will become the "Forecaster #1" the next morning and the previous Forecaster #1 becomes "Forecaster #2". Figure 4.2 illustrates the forecaster schedule and availability of data and products.

Nominal staffing daily schedule (Local Time) is as follows (shown for a 4:00 am T/O schedule):

~1:00 am – 12:00 pm (**Forecaster #1**): Forecasting/Nowcasting support for operations on Day-1 (Starting time variable with aircraft T/O time, i.e. T/O minus 3h).

1:00 am - 1:45 am: Prepare Day-1 Short-term Forecast (mesoscale discussion and convection outlook) for small, early operations weather briefing

1:45 am -2:15 am: Lead small operations weather briefing, and participate in mission planning discussion.

2:30 am-4:00 am: Pre-flight briefings (Nominally 90 min before T/O)

4:00 am-12:00 pm: Prepare operations weather summary report for RICO Field Catalog. Provide Nowcasting support for flight operations.

11:30 am – 4:30 pm (**Forecaster #2**): Forecasting for Day-2 operations and Day-n outlook

3:00 – 4:30 pm: Present forecast and outlook discussion at Daily Planning Meeting and prepare report for RICO Field Catalog.

On the next day **Forecaster #2** becomes **Forecaster #1** and vice-versa.

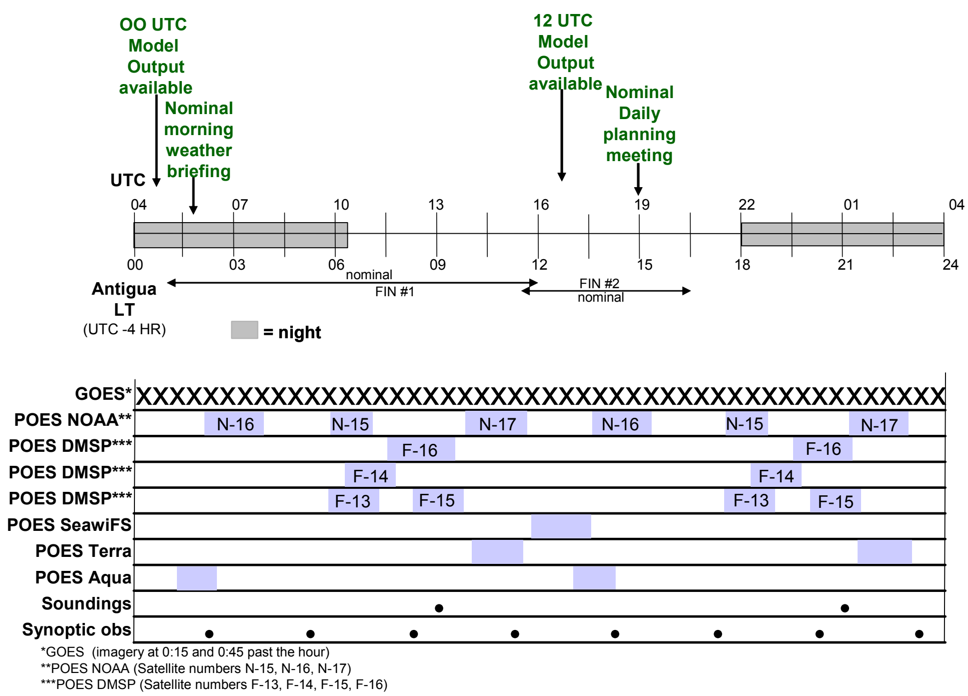


Figure 4.2 RICO real-time data and products schedule for operations

4.5.3 Forecast Products

The common forecast needs of RICO objectives require an extrapolation of mesoscale weather conditions over the full RICO regional domain (~1000 km radius of Barbuda) through 48 hours. These forecasts would include general flow and stability regimes, airmass and mesoscale boundaries, and general convective weather conditions.

Primary forecasting tools and model products include soundings, satellite loops, radar loops, RAMS, ECMWF & NCEP Model products, and 3 hourly ship reports.

The Science Director, Operations Director, flight scientists, and pilots will attend pre-flight briefings. The pre-flight briefing package, prepared by the forecaster, will include hard-copy of latest satellite and radar imagery, surface weather observations, project sounding plots, and mesoscale model products. RICO real-time data and products schedule for operations use is shown in Figure 4.2.

Forecasting will be done primarily using products on the JOSS RICO Operational products website http://www.ofps.ucar.edu/cgi-bin/catalog/rico/ops/index

and the CSU RICO RAMS model website (TBA).

4.5.4 Nowcasting

Nowcasting the regions and strengths of cloud fields and the development of precipitation will be an important component of RICO flight operations support.

Primary products used for nowcasting will include real-time SPOL and satellite imagery loops, project soundings, synthesis of real-time field observations received from aircraft mission scientists, and possibly short-range experimental mesoscale model forecast products.

The Nowcaster will keep the Operations Director and Aircraft Coordinator informed of evolving weather conditions that might impact aircraft operations and will prepare weather updates and products for transmission to the aircraft mission scientists. The RICO nowcasters will also communicate routinely with SPOL scientists, passing on and receiving mesoscale weather information.

Experience in other field programs has made it clear that comprehensive notes and summaries of the evolving weather during operations can be of great value for research efforts following the period of the experiment. The nowcasters will be expected to electronically enter notes during the period of flight operations, as well as provide a cohesive daily summary. These descriptions become part of the overall project documentation in the RICO Field Catalog. The catalog provides forms that are easily used by the nowcaster for compiling notes and including graphics (e.g. model snapshots, data, images, etc.) that are helpful in describing the weather situation.

4.5.5 Evaluation of Forecasting and Nowcasting Tools and Products

A test and evaluation of forecasting and nowcasting techniques and model products will be made during the period of 1-5 December 2004 of the radar-only operations. The best radar products for use in short-term forecasting and nowcasting will be determined as well as those radar products best suited to select cloud systems for life cycle studies.

4.6 Operational Guidelines

Refer to Appendix B Aircraft crew duty limitations.

5.1 Overview of RICO Operations Center at Antigua and Barbuda

5.1.1 Operations Center Space

RICO operations will be coordinated and directed from the RICO Operations Center (ROC) located on the 2nd floor of the ACT Communications Building, Old Parham Road, east of St. John's (Figure 5.1). Operations support will occur in the RICO Operations Command and Coordination Center (Fig. 5.2). An analysis area will be available for participants to review in-field data and discuss preliminary results. A weather forecast/nowcast area will be used to prepare weather forecasts for operations planning and update the situation in real time. A meeting area will be available for the Daily Planning Meeting, pre-flight briefings and science review. Internet connectivity will be provided in the ROC through both a local area network and a wireless server. All power in the ACT Building is 120V/60Hz with U.S. plug configuration.

Antigua

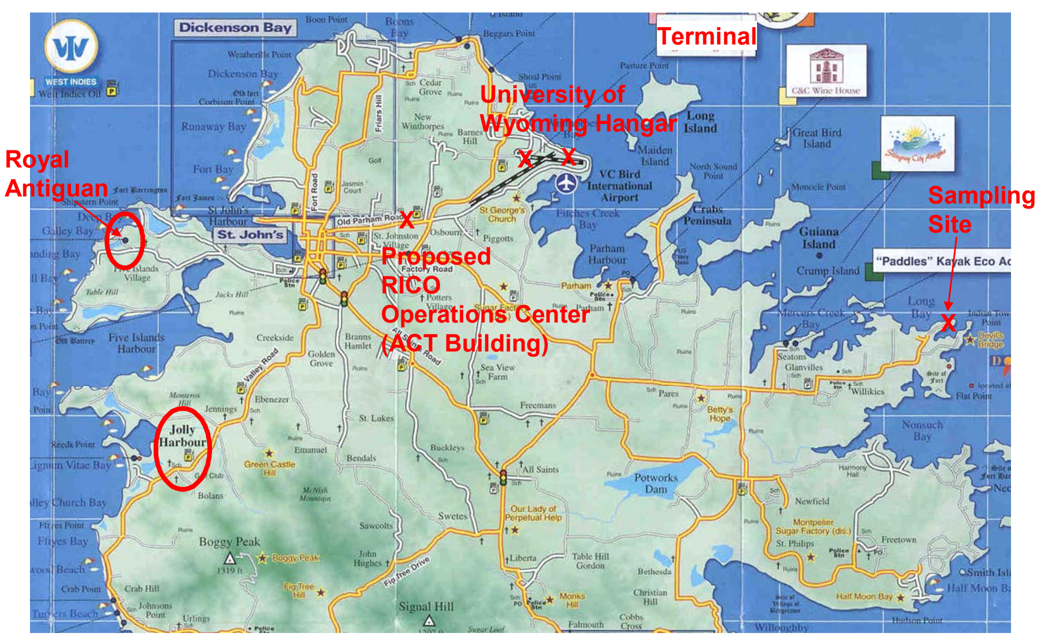


Figure 5.1: RICO Facilities and Main Lodging on Northern Antigua

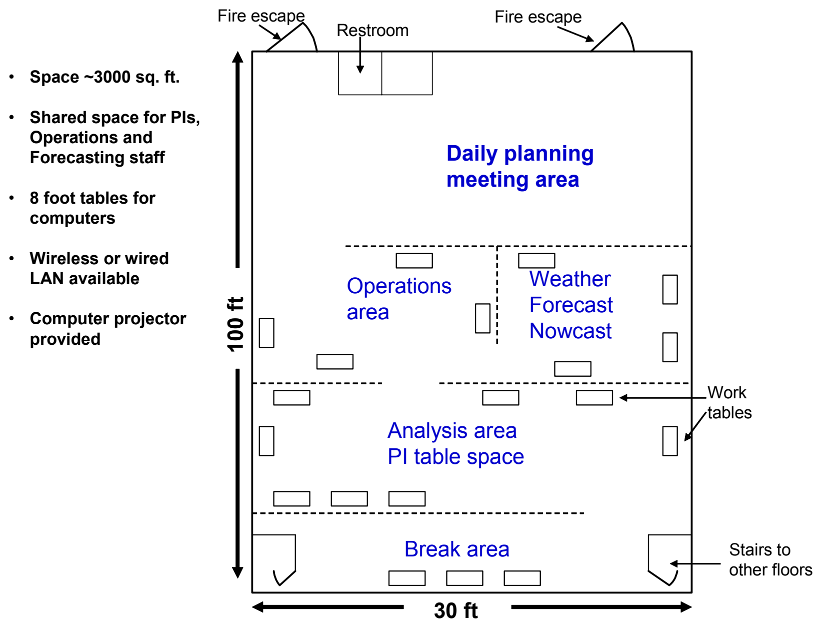


Figure 5.2 RICO Operations Center Layout (Tentative)

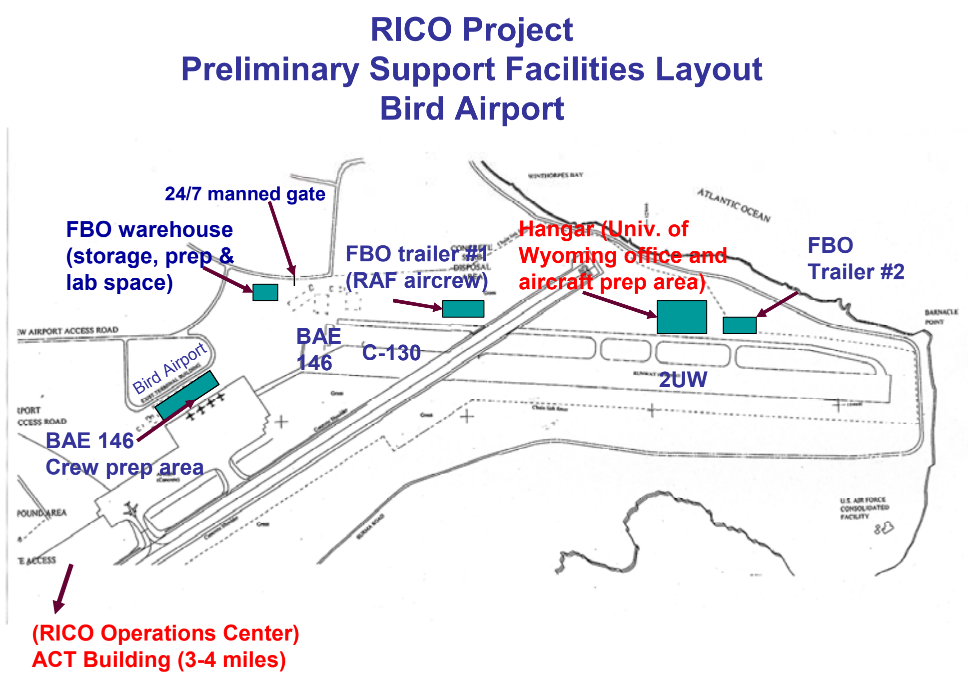


Figure 5.3: RICO Project Facilities at VC Bird International Airport

5.2 V.C. Bird International Airport Facilities

VCBI Airport has a 9000 ft runway at an elevation of 62 ft. The approaches are non-precision VOR with minimums from 600-1000 ft and 3600-4800 m. (Weather is normally not a problem, except for short duration rain showers.) The airport is open 24 hr, however, normal fuel service is closed from 12:00 am-6:00 am; fueling during this time will incur additional costs.

The location of RICO operations and aircraft support services is shown in Figure 5.3. Aircraft ramp services and fueling will be provided by FBO 2000 Antigua Ltd (psltapa@candw.ag). The FBO warehouse is located about 2 blocks from the terminal and contains approximately 4500 sq ft of space. About 1000 sq ft of space is set up for offices and will be used for instrument maintenance and repair and laboratory space for C130 and BAE-146 facilities. Phone and Internet service via phone modem will be provided to this site. The laboratory and office space can be accessed outside of the airport security boundary. A section of the warehouse will be set aside for hazardous material storage with appropriate safety procedures implemented.

The C-130 and BAE-146 will be parked on the ramp a short distance from the warehouse (~300 m). (The VCBI Airport Authority has waived ramp fees.) C-130 flight crews will stage operations from FBO trailer #1 located on the ramp, and the BAE-146 flight crews will stage operations from an office area located in the VCBI Airport Terminal. Seatainers can be parked near the FBO trailers or near the aircraft.

The Wyoming King Air operations will be located at the Carib Aviation Hangar (Figure 5.3). The Hangar will also include office and equipment/laboratory space for King Air instruments and crew. A dedicated 256 kbps Internet link has been established between the Hangar and the ROC.

5. 3 Dums Point Sampling Site (Under development)

A requirement exists to make some surface based observations of air chemistry and aerosols on the upwind side of Antigua to further document the air stream coming from the open ocean. A site has been selected at Dum's Point on the far eastern side of Antigua (see 'sampling site' in Fig, 5.1). At the present time negotiations are underway to obtain a secure site with access to power. Jim Hudson and Olga Mayol will be installing sampling equipment to be operational for the duration of the experiment.

5. 4 Barbuda Facilities (S-Pol, GLASS, PAM, etc.)

Barbuda

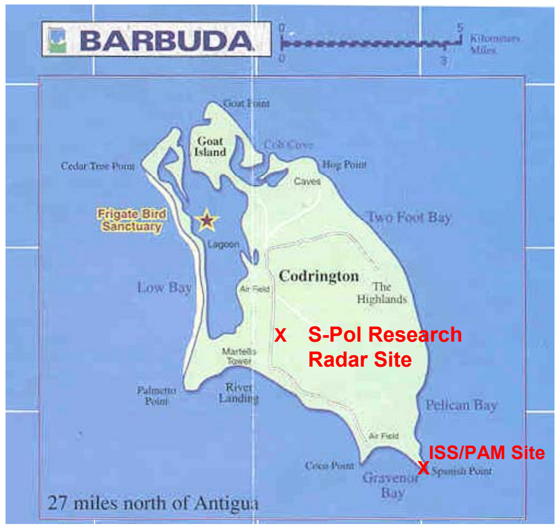


Figure 5.4: RICO Facilities on Barbuda

S-Pol Site and Directions

RICO was given permission to locate the radar about two miles south of Codrington, referred to as “New Town” or “New Village. The GPS coordinates for SPOL are **17 deg 36.448 N; 61 deg 49.456 W**. Coming from the Palm Tree Guesthouse turn-off, drive exactly 2 miles south before turning left onto a single-lane dirt road. The site is 0.3 miles up the road on the right.

GLASS/PAM Site and Directions

The GLASS and PAM sites are located at Spanish Point on the southeastern corner of the island. The site is quite windy and there is no shade. The ground surface is limestone and coral covered by a thin layer of sand and vegetation. Cell phone coverage is good. The GPS coordinates for the ISFF are **17 deg 33.047 min N, 61 deg 44.259 min W.** The site is about 40 minutes from Codrington and requires driving on 10 miles of fairly bad roads. Just head south on the main road and keep on following the signs to the K-Club and Coco Beach. Once you reach the K-Club, keep to the left on a secondary road that is in pretty bad shape. Continue until you reach the ocean and then STOP!

The NCAR/ATD site manager will coordinate Barbuda facilities and services.

5.4 RICO Communications

RICO Communications Overview

The communications network for RICO will involve several systems to assure reliable transfer of data, relay of information for facility coordination and updating of all project participants on project activities. Figure 5.5 provides a schematic overview of the variety of communications networks and systems that will be used in support of RICO operations. All aircraft and the ship are equipped with satellite communications that will permit the close coordination needed to execute RICO observational strategies. These links will allow limited transmission of chat room text messaging, imagery and periodic relay of aircraft position and data. VHF-FM and Marine (line-of-sight) radio tuned to RICO frequencies will be available at S-POL, aboard ship and on the aircraft to permit direct voice communication as needed.

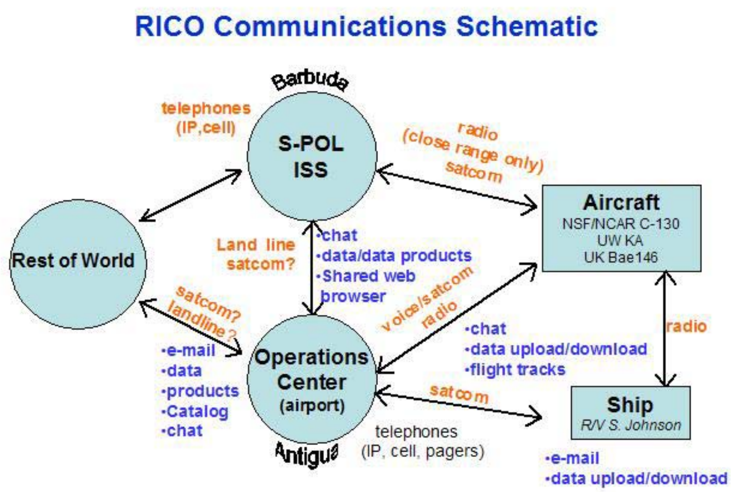


Figure 5.5 RICO Communications

ROC Computer Network Configuration and Capabilities

Description

The RICO Operations Center on Antigua will contain a two-segment Local Area Network (LAN) for data communications. Each segment will consist of both wired (100baseT Ethernet) and wireless (802.11g wireless Ethernet) components. There will be an unsecured segment, to which any computer may connect at any time, and a secured segment, to which computers may only connect with prior approval from RICO systems administrators.

Available Bandwidth

The network connection to the operations center will support one megabit (1024kB/s) incoming and one half megabit (512kB/s) outgoing data rates. Initially, no restrictions will be placed on the use of this bandwidth. If it is determined that acquisition of necessary data products is being impaired, RICO systems administrators will apply limits to the bandwidth available for general purpose use.

Terms of Service

The RICO Operations Center network connection is subject to the Terms of Service agreement negotiated with the Internet provider. Provisions of this agreement include, but are not limited to:

- This service may not be used to originate or terminate voice services, including, but not limited to, VOIP (Voice Over IP) services, in keeping with Antiguan law.
- The Customer shall not user the Services to circulate, publish, transmit, distribute any unsolicited advertising or promotional information or any content that is seditious, obscene, defamatory, indecent, threatening, offensive, liable to incite racial hatred, discriminatory, menacing, or in breach of confidence; or which infringes the privacy of an individual or may cause the Company to be in breach of any applicable law or regulation.
- The Company may suspend or terminate provision of the services without notice if the Customer is in breach of any terms of the agreement.

Connection Requirements

Any computer with a standard 10baseT or 100baseT Ethernet port will be able to connect to the network using a cable. The RICO Ops Center will provide appropriate cabling. Participants needing to connect more than one computer using cable should provide prior notice to ensure that enough ports are provided. Any computer capable of 802.11b or 802.11g wireless Ethernet will be able to connect to the network without the use of a cable. No wireless Ethernet cards will be available for participant use; participants desiring wireless access are responsible for providing their own.

The network will be configured so that systems set for automatic configuration, also known as "DHCP" (Dynamic Host Configuration Protocol), will be able to connect without needing specific settings. If a participant's system is incapable of automatic configuration, a static address will be assigned by a RICO systems administrator; the participant is responsible for properly configuring the system, although RICO systems administrators will assist on a time-available basis.

Security

The Internet, at the present time, harbors numerous worms, viruses, and other malicious programs that actively seek to propagate themselves. In order to protect RICO participants against such programs, *no connections from the Internet to inside the RICO LAN will be permitted.* However, it is possible for participants to unknowingly bring compromised systems with them to the Ops Center. Therefore, we recommend that all participants follow certain recommendations for systems safety:

- Ensure that your operating systems are fully patched according to vendor recommendations
- If antivirus software is available for your system, have an up-to-date version installed and active
- If your system supports a firewall, have it active and set to reject connections
- Do not run any unnecessary services on your system

Owners of systems on the unsecured segment are responsible for their own computer security.

Before a system is permitted to connect to the secured network segment, a RICO systems administrator must inspect the system and verify that it is:

- Fully patched
- Running antivirus software (if available)
- Configured appropriately in terms of firewall and/or services

If the system's owner does not have administrative access to the system (for example, a Windows system for which the user does not know the Administrator password), it will be restricted to the unsecured segment, unless it is already configured properly.

The final judgment call on secured network access will rest with the senior RICO systems administrator present.

If a participant's system is determined to be infected by malicious software or otherwise a threat to RICO network security, it will be removed from the network until the problem can be repaired to the satisfaction of the senior RICO systems administrator.

Services

The following services will be provided to all participants in the RICO Operations Center, possibly hosted on a UCAR system at a remote location:

- File sharing via FTP
- RICO Field Catalog
- Web caching
- Internet real-time chat
- Web-based forum
- DNS (Domain Name Service)
- DHCP (Dynamic Host Configuration Protocol)
- NTP (Network Time Protocol)

- Color and monochrome laser printers
- Symantec Anti-Virus server

Outbound connections to the Internet are permitted. Inbound connections from the Internet are not.

Antigua/Barbuda Communications/Technology: Public Telephone and Cell Pones

Pay phones in Antigua are card operated.

International direct dialing is available. To place an international call (except to the U.S., Canada and some Caribbean countries), dial 011 + country code + area code + number. To place a call to U.S., Canada and some Caribbean countries, dial 1 + area code + number. International calls are discounted 15% Monday-Friday 1800-2000 and all day Saturday and Sunday. There are no area codes. To place a local or domestic call, simply dial the seven-digit number.

Caribbean phone cards are sold by many vendors and Cable and Wireless (C&W) offices in denominations of ECD 10, 20, 40, 54, 60 and 100. To place a call with the card, lift the handle, insert the card, and dial. Upon completion of the call, hang up and remove card. These cards can be used to place local and international calls, not only in Antigua, but also in other Caribbean countries with C&W companies (with the exception of Jamaica and Trinidad & Tobago). Card operated pay phones are found throughout the island.

Country code is 268.

Calling from Antigua and Barbuda to the US is expensive. The hotel charges $2 US/min, even if using 1-800 numbers. GSM phones have to be activated at the main PCS Office, which is located on Long Street right next to the Church. The SIM costs EC $ 100. An ID and a contact address/phone number are needed to get the phone activated. There is also a small store right across the street that charges EC $ 50 for unlocking GSM phones. Pre-paid phone cards can be purchased for 20, 30, 60 and EC $100 at the PCS office or in various banks (incl. Barbuda). If not used, phone cards and sim cards will expire after 3 months.

Phone charges: **($1 USD = $2.67 EC)**

Local call	90 EC/min	
Incoming international	Free	
Outgoing international	3.86 $EC	Weekday
Outgoing international	3.40 $EC	Weeknights (6 pm - 6 am)
Outgoing international	3.86 $EC	Weekends

For local calls: dial the last seven digits

For calls to the US: dial 1 – area code – phone #

For intl. calls: dial 011 - country code - phone #

5.5 Security

ROC Security

The ACT Inc. building that houses the ROC has 24 hour, seven day security surveillance. RICO participants will have unrestricted access to the building using key card or keys provided for entrance. The building has guards on station at all times due to the critical nature of communications support to Antigua provided by ACT. There will be no need for individual badges when on site at the ROC. Details of building security procedures will be provided upon arrival to the project in November-December 2004 and January 2005

Airport Security

Access to aircraft ramp, hangar, and laboratory facilities at V.C. Bird International (VCBI) Airport requires background security checks and identification badges for RICO personnel. The RICO Project Office will compile a list of participants requiring access to the secured Airport areas, obtain information from participants and will coordinate access application documentation. Temporary security badges will be prepared by the RICO Project Office and issued, after approval by the VCBI Airport Security Office. ID badges must be visible at all times in secured areas.

Limited vehicle access to the VCBI Airport ramp areas will be possible through advanced arrangements. The Airport Security Office will issue gate access cards and/or key lock codes to key RICO personnel upon arrival in Antigua.

5.6 Antigua Shipping

All participants are responsible for shipping equipment and materials to Antigua/Barbuda and retuning them to their homes after the project is completed. Everyone is encouraged to contact the freight forwarder listed below to get details about documentation and other requirements to bring equipment into Antigua. We have secured a full waiver of all customs duties on equipment used for RICO. A complete and detailed list of all equipment is to be provided to the Antigua Customs Department and the Ministry of International Transportation prior to arrival in Antigua.

It is also important to remember that shipping times to Antigua will be approximately 6 weeks if more economical surface shipment routes are taken. Again contact the freight forwarder or institutional shipping sources to confirm details, timing and cost.

Shipping destination address for RICO (sent to "self" in care of FBO):

Your name
Your facility
In care of FBO 2000 Antigua, Limited
V. C. Byrd International Airport
St. John's, Antigua

There is also a freight forwarder that was recommended. The name is:

Caribbean Forwarders, Limited
Attn. Foster George
Phone 268-480-1106

Customs Contact Information

Controller of Customs

Mr. Raphael Brown

Cell: 268 462 3902; Phone: 268 462 0829

FAX: 268 462 2767

Email: custom@antigua.gov.ag

Custom Office hours: 8:30 am to 4 pm

Medical facilities available in Antigua.

The standard of medical care in Antigua is fair. There are many qualified doctors, but medical facilities are limited to public hospitals and private clinics. In some cases, the quality of medical care and resources are not up to U.S. expectations. Travelers are advised to obtain personal medical insurance and emergency evacuation insurance that is valid in Antigua.

Medical facilities are available at the following locations in Antigua:

Gambles Medical Centre Friars Hill Road and Gambles Road St. John's, Antigua Phone: 268-462-3050	**Woods Centre** Friar's Hill Road, Box W748 St. John's, Antigua Phone: 268-462-1932
Ramco Building Independence Avenue St. Johns, Antigua Phone: 268-462-6241	**The Women's Clinic** Deanery Place, Box 1374 St. John's, Antigua Phone: 268-462-4133

The U.S. Embassy in Bridgetown Barbados can also provide a list of local doctors in Antigua. Contact the U.S. Embassy at:

U.S. Embassy
P.O. Box 302
Bridgetown, Barbados, W.I.
Phone: 246-436-4950
Web: http://bridgetown.usembassy.gov/

If calling any of the phone numbers list above from outside Antigua or Barbados, dial the country code 1 before the number.

Medical Facilities Available on Barbuda

The Hanna Thomas Hospital is on the southern side of town (460 0076 and 460 0585). The local doctor's name is Dr. Ready. A doctor's visit is EC$35 plus the cost of the medicine. The hospital has five beds and a doctor's office as well as a waiting room. Major emergencies are treated in Antigua. There is a second doctor on the island, who is from the US, but s/he changes every month

Banking on Antigua

There are two ATMs at the airport that take the CU Credit Union debit cards. ATMs are also widely available in downtown St. John's and there is one at the Scotiabank next to the Supermarket on the way out of town towards the Royal Antiguan.

Banking on Barbuda

BANK AND ATM

AZB Antigua Commercial bank has a branch close to the airport. The outside ATM is supposed to accept US Visa and ATM cards but it didn't work during the site surveys. However, cash can be withdrawn inside with a debit card for no charge (up to US$1000/day with an ID).

Banking hours:

Mon through Fri – 9 am to 3 pm; Tue, Wed, Thu – 8 am to 4 pm.

Lunch break is from 12:00 to 1:00 pm every day.

Contact: Lois Tague Teague Phone: 268 481 4215, FAX: 268 481

RICO Operations Plan
Chapter 6: Satellite data acquisition

6.1 Satellite Operations

Satellite data collection for the RICO project will begin with the commencement of Radar only operations on 24 Nov 2004 and will continue uninterrupted until 1 week after the project ends (31 Jan 2005). Data will be routinely collected from the GOES-East satellite during this period by JOSS. In addition some limited imagery from MODIS will be collected by JOSS in near real-time during the project and will be made available via the JOSS Field Catalog for RICO. Other satellite data is unlikely to be available during the field operations period but may be available afterward for post-analysis. Please see the discussion below regarding Polar-orbiter data.

6.2 GOES

6.2.1 Data Collection

High temporal resolution satellite data for RICO is limited to the GOES-East satellite (Currently GOES-12). The North American and Full Disk sectors are the only ones that contain imagery of the RICO area of interest. These sectors provide half-hourly coverage at 15 and 45 minutes after the hour regardless of rapid scan operations. Table 6.1 lists the attributes of data collected from GOES.

Table 6.1 GOES-12 Imager Channels

Band	Central Wavelength (□m)	Resolution (km)	Spectral Range
1	0.65	1	Visible
2	3.9	4	Shortwave
3	6.5	4	Water Vapor
4	10.7	4	Longwave Window
6	13.3	4	CO_2

Images covering the RICO area of interest will be produced from the above channels as the data are received and made available through the JOSS Field Catalog. The delay between when the images are produced and when they are available in Antigua or Barbuda for viewing will depend on Internet bandwidth.

Data from GOES for all imager channels will be routinely collected for all GOES sectors and stored on the NCAR Mass Store System in TDF (Terascan Data Format). These data are available immediately to users with Mass Store Access although this format requires the user to have Terascan satellite processing software in order to work with the data.

6.2.2 GOES SRSO (Super-Rapid Scan Operations)

While routine operations of the GOES-East Imager provide only half-hourly coverage of the RICO area, higher temporal resolution is possible through a request for SRSO on behalf of RICO. Through contacts at NESDIS, JOSS has arranged for RICO to be able to request SRSO during the field campaign. SRSO is not run on a routine basis but must be requested through NESDIS. There are limitations to this service which include:

- SRSO can be requested for a period of no longer than 6 hours per day

- NWS requests take precedence, so RICO request could be denied

- NESDIS requires at least 2 hrs notice before SRSO can commence

- SRSO sector is limited to 1000 x 1000 km

A RICO SRSO sector has been defined and is shown below in Fig. 6.1. SRSO will provide data at 1 minute resolution for the RICO sector with the exception that these scans are not continuous through any given hour. SRSO for the GOES satellites follow a prescribed schedule. At any one time, a maximum of eight 1-minute scans will be collected before the satellite performs scans of other sectors. A 3 hour block of the SRSO schedule for GOES-East is shown in Table 6.2. These blocks repeat every 3 hours throughout a 24 hour period. The SRSO schedule at a later time of day can be determined from this table by adding a multiple of 3 hours to the time shown. SRSO can be run for a maximum of 6 hours in any 24 hour period.

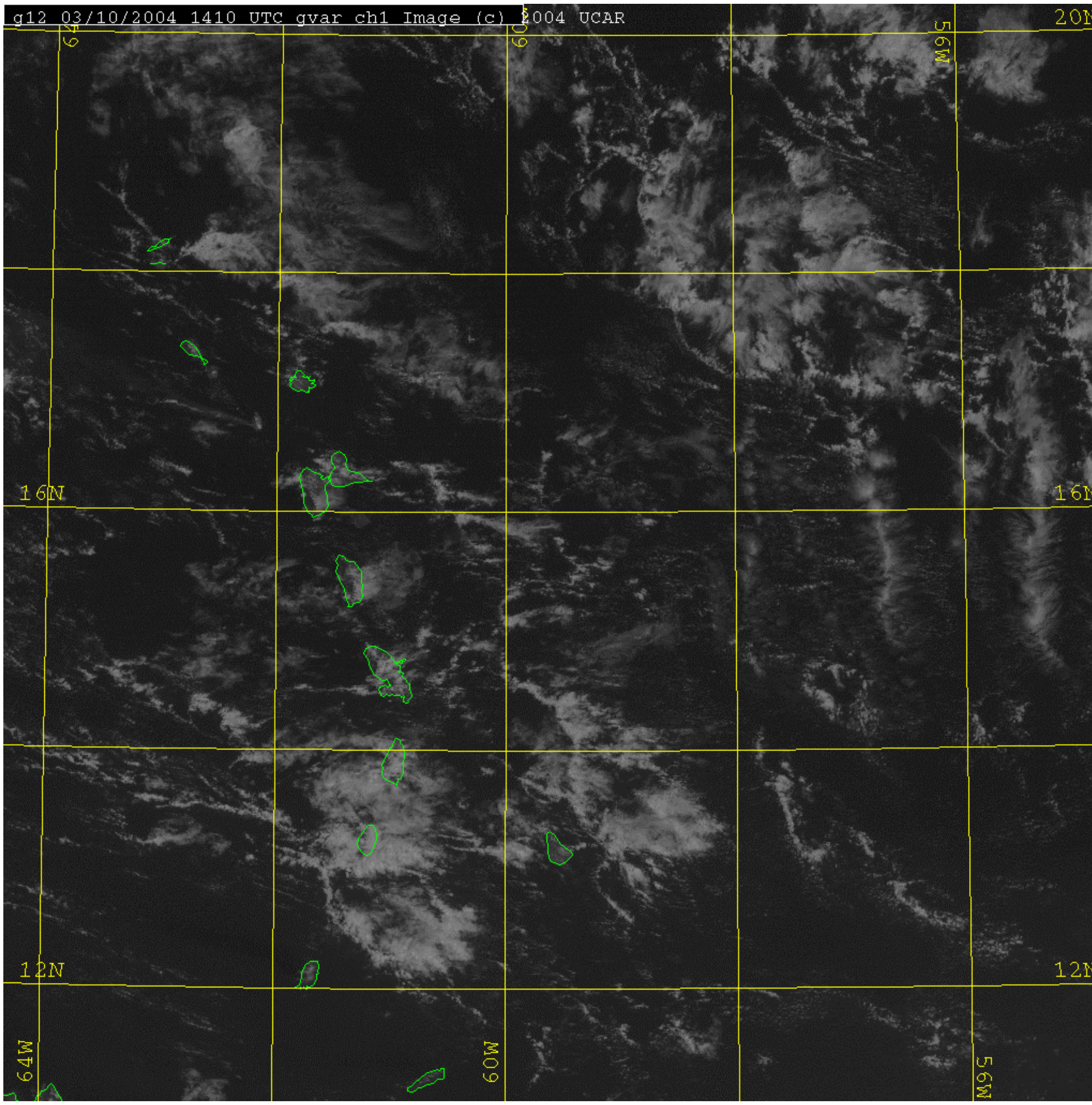


Fig *6.1. The RICO SRSO sector. Image is 1024 x 1024 pixels centered on 15^{o} 40' N, 59^{o} 36' W.*

Table 6.2 GOES-East SRSO 3-Hour Block
TIME (UTC) SCAN SECTOR DURATION (MM:SS)
00:45:00 NORTHERN HEMISPHERE 9:44
00:55:00 SRSO SECTOR 1:00
00:59:05 CONTINENTAL US (CONUS) 4:43
01:04:00 SRSO SECTOR 8:00
01:15:00 NORTHERN HEMISPHERE 9:44
01:25:00 SRSO SECTOR 1:00
01:30:00 CONTINENTAL US (CONUS) 4:43
01:35:00 SRSO SECTOR 8:00
01:45:00 NORTHERN HEMISPHERE 9:44
01:55:00 SRSO SECTOR 1:00
01:59:05 CONTINENTAL US (CONUS) 4:43
02:04:00 SRSO SECTOR 8:00
02:15:00 NORTHERN HEMISPHERE 9:44
02:25:00 SRSO SECTOR 1:00
02:30:00 CONTINENTAL US (CONUS) 4:43
02:35:00 SRSO SECTOR 8:00
02:45:00 FULL DISK 26:06
03:15:00 NORTHERN HEMISPHERE 9:44
03:25:00 SRSO SECTOR 1:00
03:30:00 CONTINENTAL US (CONUS) 4:43

6.2.3 GOES Archival Procedures

As stated above, GOES data is routinely archived in TDF format on the NCAR Mass Store as it is received. Users wishing to view GOES inventory should visit http://www.joss.ucar.edu/~stoss/satellite and click on GOES Data Inventory on the green bar near the top of the page. The inventory tool will allow users to find available passes and will provide directory locations. At this time, the inventory tool does not provide download capability.

JOSS recognizes that TDF is a proprietary format and many RICO investigators may not have access to Terascan software. By recommendation of the Satellite Working Group, JOSS will also provide GOES-East data in HDF format after the field campaign is concluded.

6.3 Polar Orbiter Data Collection

Polar Orbiter data provides an opportunity to obtain very high spatial resolution data in the RICO area of interest but at the cost of rather low temporal resolution. Depending on the instrument, polar orbiter coverage of a specific location varies from several views per day by multiple satellites, morning and evening, to one pass every several days. The Satellite Working Group has specified a number of satellite instruments that are of interest for RICO. Details of data collection for these instruments are described below.

6.3.1 AVHRR

These instruments are carried aboard the NOAA polar orbiting environmental satellites (POES). The Advanced Very High Resolution Radiometer (AVHRR) is a broad-band, six channel scanner, sensing in the visible, near-infrared, and thermal infrared portions of the electromagnetic spectrum. Table 6.3 lists the wavelengths observed by the AVHRR instrument.

Table 6.3. AVHRR Characteristics

Channel Number	Resolution at Nadir	Wavelength (μm)	Typical Use
1	1.09 km	0.58-0.68	Daytime cloud and surface mapping
2	1.09 km	0.725-1.0	Land-Water Boundaries
3A	1.09 km	1.58-1.64	Snow and Ice Detection
3B	1.09 km	3.55-3.93	Night Cloud Mapping, Sea-Surface Temperature
4	1.09 km	10.30-11.30	Night Cloud Mapping, Sea-Surface Temperature
5	1.09 km	11.50-12.50	Sea-Surface Temperature

Currently, there are three POES satellites in orbit providing calibrated data from AVHRR. These satellites and their approximate overpass times of Antigua and Barbuda are listed below in Table 6.4 along with sunrise/sunset times for comparison.

Table 6.4. NOAA POES Satellites – Approximate RICO Crossing Times (UTC)		
Instrument	**Daytime Pass**	**Nighttime Pass**
NOAA-15	2130-2255 (SS)	0945-1115 (SR)
NOAA-16	1740-1915	0600-0735
NOAA-17	1400-1530	0135-0300
Sunrise/Sunset	Nov 24: 1016/2131	Jan 25:1039/2159

AVHRR data are acquired in three formats:

- High Resolution Picture Transmission (HRPT)
- Local Area Coverage (LAC)
- Global Area Coverage (GAC)

HRPT data are full resolution image data transmitted to a ground station as they are collected. The average instantaneous field-of-view of 1.4 milliradians yields a HRPT ground resolution of approximately 1.1 km at the satellite nadir from the nominal orbit altitude of 833 km (517 mi).

LAC are full resolution data that are recorded on an on board tape for subsequent transmission during a station overpass. The average instantaneous field-of-view of 1.4 milliradians yields a LAC ground resolution of approximately 1.1 km at the satellite nadir from the nominal orbit altitude of 833 km (517 mi).

GAC data are derived from a sample averaging of the full resolution AVHRR data. Four out of every five samples along the scan line are used to compute one average value and the data from only every third scan line are processed, yielding 4 km resolution at the subpoint.

These data are archived at the NOAA Comprehensive Large Array-data Stewardship System (CLASS) formerly known as the Satellite Active Archive. JOSS has determined that limited HRPT data is available via the CLASS from a ground station in Wallops Island, VA. There is also some limited LAC data occasionally recorded in the tropics, which may cover the RICO area of interest from time to time. JOSS will collect available HRPT and LAC data from the CLASS and make it available via the RICO Data Archive after the field phase has concluded.

For more information on AVHRR, please see: http://www.oso.noaa.gov/poes/index.htm .

6.3.2 MODIS

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. Table 7.5 lists band characteristics for the MODIS instrument.

Table 6.5. MODIS Channel Characteristics

Band	Spatial Resolution	Bandwidth (μm)	Primary Use
1	250 m	.620-.670	Land/Cloud/Aerosols Boundaries
2	250 m	.841-.876	
3	500 m	.459-.479	Land/Cloud/Aerosols Properties
4	500 m	.545-.565	
5	500 m	1.230-1.250	
6	500 m	1.628-1.652	
7	500 m	2.105-2.155	
8	1 km	.405-.420	Ocean Color/ Phytoplankton/ Biogeochemistry
9	1 km	.438-.448	
10	1 km	.483-.493	
11	1 km	.526-.536	
12	1 km	.546-.556	
13	1 km	.662-.672	
14	1 km	.673-.683	

15	1 km	.743-.753	
16	1 km	.862-.877	
17	1 km	.890-.920	Atmospheric Water Vapor
18	1 km	.931-.941	
19	1 km	.915-.965	
20	1 km	3.660-3.840	Surface/ Cloud Temperature
21	1 km	3.929-3.989	
22	1 km	3.929-3.989	
23	1 km	4.020-4.080	
24	1 km	4.433-4.498	Atmospheric Temperature
25	1 km	4.482-4.549	
26	1 km	1.360-1.390	Cirrus Clouds/ Water Vapor
27	1 km	6.535-6.895	
28	1 km	7.175-7.475	
29	1 km	8.400-8.700	Cloud Properties
30	1 km	9.580-9.880	Ozone
31	1 km	10.780-11.280	Surface/ Cloud Temperature
32	1 km	11.770-12.270	
33	1 km	13.185-13.485	Cloud Top Altitude
34	1 km	13.485-13.785	
35	1 km	13.785-14.085	
36	1 km	14.085-14.385	

As mentioned above, the morning satellite (Terra) has a descending node crossing time of 10:30 am (local) and the afternoon satellite (Aqua) has an ascending node crossing time of 1:30 pm (local). These orbits produce RICO crossing times listed in Table 6.6.

Table 6.6. NASA EOS Satellites – Approximate RICO Crossing Times		
Satellite	Daytime Pass	Nighttime Pass
Terra	1408-1525	0145-0301
Aqua	1654-1811	0512-0630
Sunrise/Sunset	Nov 24: 1016/2131	Jan 25:1039/2159

JOSS has access to near real-time 5-minute MODIS granules and will provide selected imagery through the RICO field catalog during the field phase of the project. JOSS will not archive these data in the RICO archive but will provide a link to the NASA DAAC where the data may be obtained by interested investigators.

For more information on MODIS, please see: http://modis-atmos.gsfc.nasa.gov/ .

6.3.3 MISR

The Multi-angle Imaging SpectroRadiometer (MISR) is flown aboard the NASA Terra spacecraft and routinely provides multiple-angle, continuous sunlight coverage of the Earth with high spatial resolution. The instrument obtains multidirectional observations of each scene within a time scale of minutes, thereby under virtually the same atmospheric conditions. MISR uses nine individual charge-coupled device (CCD)-based pushbroom cameras to observe the Earth at nine discrete view angles: One at nadir, plus eight other symmetrical views at 26.1, 45.6, 60.0, and 70.5° forward and afterward of nadir. Images at each angle will be obtained in four spectral bands centered at 446, 558, 672, and 866 nm. Each of the 36 instrument data channels (4 spectral bands x 9 cameras) is individually commandable to provide ground sampling of 275 m, 550 m, or 1.1 km. The swath width of the MISR imaging data is 360 km, providing global multi-angle coverage of the entire Earth in 9 days at the equator, and 2 days at the poles.

Dates and times of MISR overpasses of the RICO area of interest along with sample swaths are shown in Figs. 6.2 and 6.3.

At the moment it is unclear whether JOSS will be able to obtain imagery from MISR in near real-time during the field phase of RICO. Access to MISR data will be available through the NASA DAACs to investigators. At this time, JOSS does not intend to collect this data for additional archival in the RICO Data archive, but will provide a link to the DAAC.

For more information on MISR, see: http://www-misr.jpl.nasa.gov/ .

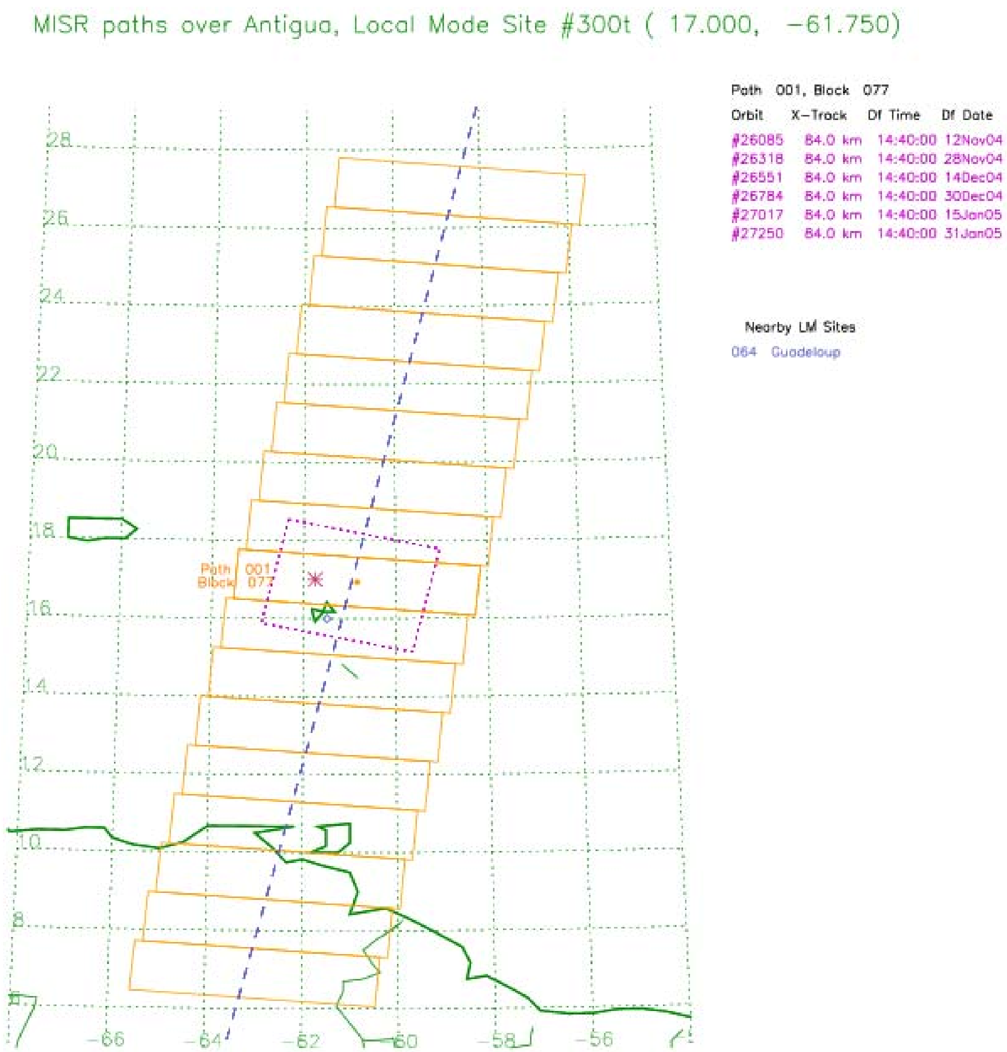


Fig 6.2. MISR Overpasses East of Antigua and Barbuda during RICO.

Fig 7.3. MISR Overpasses West of Antigua and Barbuda during RICO.

6.3.4 ASTER

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is an advanced multispectral imager that was launched on board NASA's Terra spacecraft. ASTER covers a wide spectral region with 14 bands from the visible to the thermal infrared with high spatial, spectral and radiometric resolution. An additional backward-looking near-infrared band provides stereo coverage. The spatial resolution varies with wavelength: 15 m in the visible and near-infrared (VNIR), 30 m in the short wave infrared (SWIR), and 90 m in the thermal infrared (TIR). Each ASTER scene covers an area of 60 x 60 km.

ASTER can acquire data over the entire globe with an average duty cycle of 8% per orbit. This translates to acquisition of about 650 scenes per day, that are processed to Level-1A; of these, about 150 are processed to Level-1B. All 1A and 1B scenes are transferred to the EOSDIS archive at the EROS Data Center's (EDC) Land Processes Distributed Active Archive Center (LP-DAAC), for storage, distribution, and processing to higher-level data products. All ASTER data products are stored in a specific implementation of Hierarchical Data Format called HDF-EOS.

ASTER Data for the RICO region of interest will have to be requested. At this time JOSS does not expect to have access to these data in near real-time. Again, a link will be provided from the RICO Data Archive to the appropriate DAAC.

For more information on ASTER, please see: http://asterweb.jpl.nasa.gov/ .

6.3.5 SeaWiFS

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) is currently flying on the Orbview-2 (SeaStar) spacecraft. The instrument has scanning mechanisms to drive an off-axis folded telescope and a rotating half-angle mirror that is phase-synchronized with, and rotating at half the speed of, the folded telescope. The rotating scanning telescope, coupled with the half-angle scan mirror arrangement, provides a design configuration that permits a minimum level of polarization to be achieved, without field-of-view rotation, over the maximum scan angle requirement of 58.3 degrees. A scanner tilt mechanism enables the instrument to be oriented in the along-track direction to +20, 0 -20 degrees to avoid sun glint from the sea surface. Table 6.7. Lists the properties of the SeaWiFS instrument.

SeaWiFS 1 km data may be available for the RICO area of interest if there are stations nearby collecting it in real-time. HRPT data is only available in the NASA DAAC where ground stations have captured it from direct broadcast and then lodged their data with the DAAC. At this time, there do not seem to be any active SeaWiFS ground stations in the Caribbean. Attempts have been made to contact several possible stations but have not yet met with any success. Several US stations however may provide limited coverage for Antigua and Barbuda vicinities. LAC data recorded on-board the satellite and downlinked several times per day may be available for the RICO area. Attempts are underway also to determine if there is a possibility of requesting LAC coverage for the RICO area.

Table 6.7. SeaWiFS Instrument Bands	
Channel	**Wavelength (nm)**
1	402-422
2	433-453
3	480-500
4	500-520
5	545-565
6	660-680
7	745-785
8	845-885
Mission Characteristics	
Orbit Type	Sun Synchronous at 705 km
Equator Crossing	Noon +20 min, descending
Orbital Period	99 minutes
Swath Width	2801 km LAC/HRPT (58.3 degrees)
Swath Width	1502 km GAC (45 degrees)
Spatial Resolution	1.1 km LAC, 4.5 km GAC
Revisit Time	1 day

Regarding archival of SeaWiFS data. Again JOSS will not acquire these data for the RICO Data Archive but will provide a link to the appropriate DAAC. It should be noted that access to SeaWiFS data requires the user to register with NASA and provide some information on the research being done. This registration will authorize the user to obtain SeaWiFS data.

For more information on SeaWiFS, please see: http://seawifs.gsfc.nasa.gov/SEAWIFS.html .

6.3.6 DMSP

There are currently 4 operational DMSP satellites, named f-13 – f-16. Each satellite has a 101 minute, sun-synchronous near-polar orbit at an altitude of 830km above the surface of the earth. The visible and infrared sensors (OLS) collect images across a 3000km swath, providing global coverage twice per day. The combination of day/night and dawn/dusk satellites allows monitoring of global information such as clouds every 6 hours. The microwave imager (MI) and sounders (T1, T2) cover one half the width of the visible and infrared swath. These instruments cover polar regions at least twice and the equatorial region once per day.

Of the different instruments, only the OLS is operational on all 4 satellites. Three of the 4 satellites have working microwave imagers, while only one has both sounders functional. In the OLS instrument, the visible telescope is sensitive to radiation from 0.40 - 1.10 um (0.58 - 0.91 um FWHM) and 10-3 - 10-5 Watts per cm^2 per sterradian. The infrared telescope is sensitive to radiation from 10.0 - 13.4 um (10.3 - 12.9 um FWHM) and 190 to 310 Kelvins. The PMT is sensitive to radiation from 0.47 - 0.95 um (0.51 - 0.86 um FWHM) at 10-5 - 10-9 Watts per cm2 per sterradian. The detectors sweep back and forth in a "whisk broom" or pendulum-type motion. The continuous analog signal is sampled at a constant rate so the Earth-located centers of each pixel are roughly equidistant, i.e., 0.5 km apart. 7,325 pixels are digitized across the 1080 swath from limb to limb.

An OLS archive file contains an orbit header, and data records organized by scan line. A "smooth" resolution scan line consists of 1,465 visible pixels, 1,465 IR pixels, satellite ephemeris, a quality assessment and other satellite and astronomical parameters. A high resolution scan line contains 7,325 pixels and the same supporting information.

DMSP data will not be available in real-time during the field campaign. Data are normally available from the NGDC archive, although there appear to be substantial costs involved with ordering. At this point JOSS is attempting to obtain these data on behalf of the RICO PIs. If successful, JOSS will add these data to the RICO Data Archive and they will be available to RICO scientists at no cost.

For more information on DMSP please see: http://dmsp.ngdc.noaa.gov/dmsp.html .

6.3.7 QuikSCAT

The SeaWinds instrument on the QuikSCAT satellite is a specialized radar that measures near-surface wind speed and direction at 25 km resolution. SeaWinds uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 gigahertz across broad regions on Earth's surface. The instrument will collect data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band, making approximately 400,000 measurements and covering 90% of Earth's surface in one day.

JOSS will collect imagery from QuikSCAT and make it available during the project via the field catalog. An example of this imagery is shown in Fig. 6.4. JOSS will not collect any of this data for additional archival but will provide links to the appropriate archive.

For more information on QuikSCAT, please see:

http://winds.jpl.nasa.gov/missions/quikscat/index.cfm .

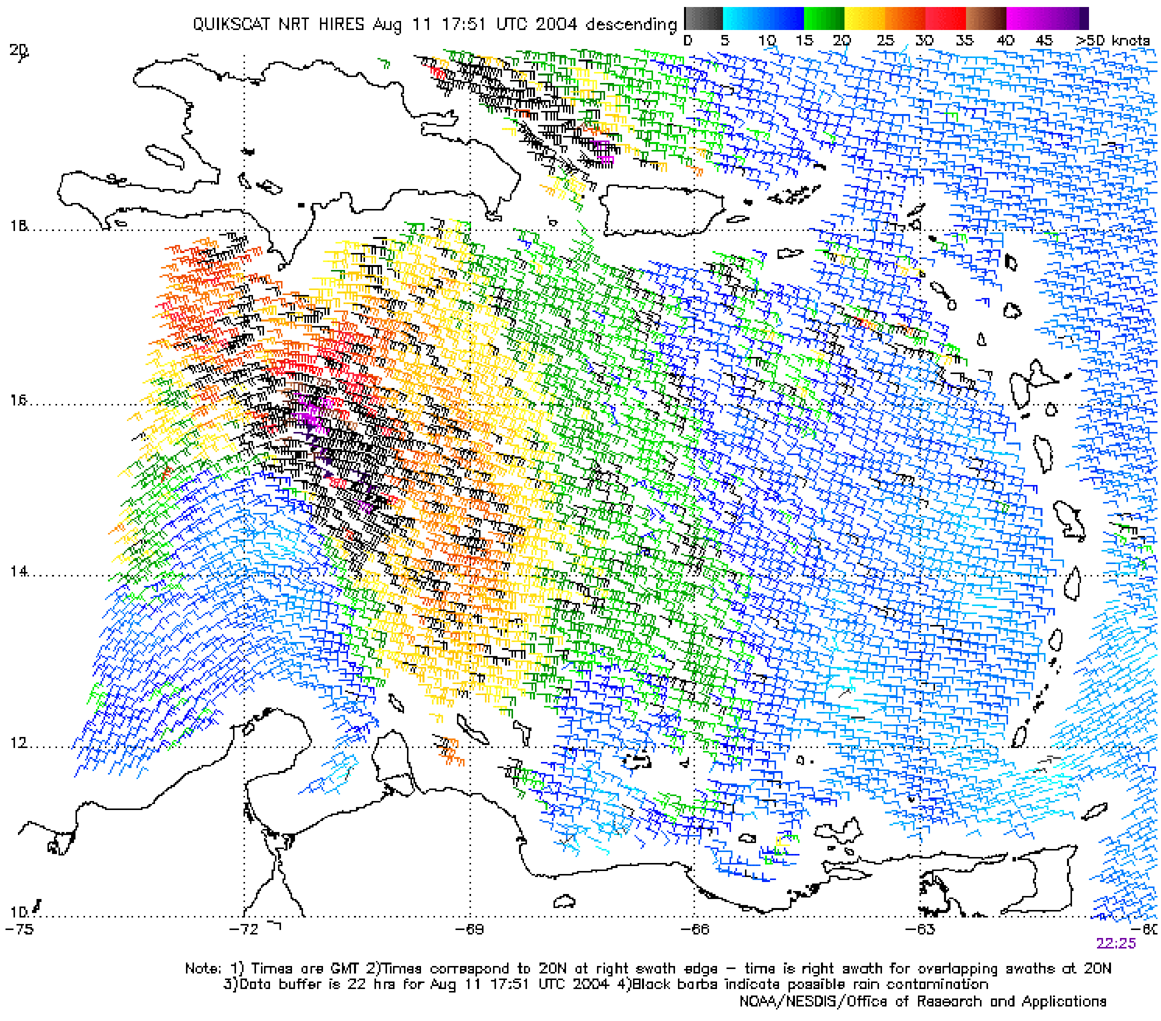


Fig 6.4. Example of QuikSCAT Imagery provided via the field catalog during RICO.

6.4. Overpass schedules for selected satellites

During the field campaign, JOSS will provide overpass times and satellite coverage maps each day for passes of interest from NOAA AVHRR, Terra, Aqua, SeaWiFS and DMSP via the field catalog. This information will also be provided on the RICO web page at JOSS prior to the field campaign. An example of these coverage maps is shown below in Fig. 6.5.

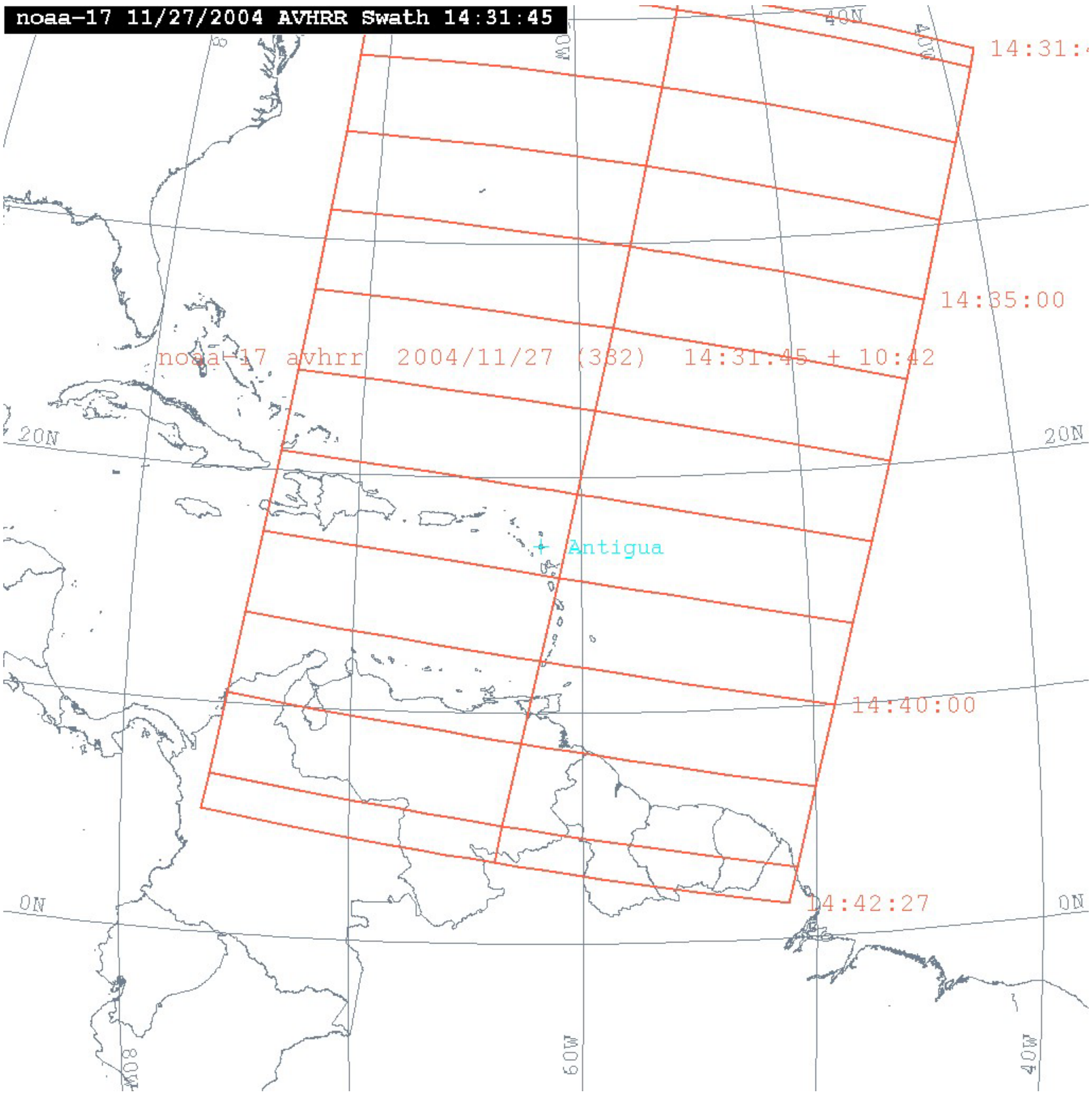


Fig. 6.5. Example swath coverage of AVHRR instrument aboard NOAA-17.

6.5 Satellite Data Archival at JOSS

The RICO Data Archive will be described in detail in the RICO Data Management Plan. Satellite data of interest to RICO PIs will be available in that archive in one of two ways.

First, satellite data held at JOSS will be directly orderable by PIs through the JOSS Archive. Table 6.8 lists items likely to be in this category. Second, for satellite data held elsewhere, the JOSS archive will contain active links that direct the user to the appropriate DAAC or other archive center.

Table 6.8 Satellite Data Archived by JOSS

Instrument	Channel/ Product	Archived Resolution	Units	File Format	Comments
GOES-12	1	1, 4 km	Albedo	HDF	Raw data is not saved from GOES, only calibrated units.
	2	4 km	Temp (C)	HDF	
	3	4 km	Temp (C)	HDF	
	4	4 km	Temp (C)	HDF	
	6	4 km	Temp (C)	HDF	
AVHRR	1-5	1 km	Raw	L1b	Data of Opportunity that are received at CLASS
DMSP-OLS ?	VIS, IR	550 m	Raw	HDF	Possible arrangement for collection from NGDC

6.6 Browse products for field campaign

JOSS will provide browse products for selected satellites and instruments based on near real-time availability. The products will be in image formats such as gif, png, etc. as appropriate and will be provided to RICO participants through the field catalog. Due to bandwidth limitations, numerical satellite data will be unavailable at the Operations Center in Antigua. A list of satellite browse products JOSS expects to provide are listed in Table 6.9

Table 6.9 Satellite Browse Products provided in the JOSS Field Catalog (Near real-time)				
Instrument	**Channel/ Product**	**Spatial Resolution**	**Temporal Resolution**	**File Format**
GOES-12	1	1 km	15 min	gif
	3,4	4 km	15 min	gif
	Ch2-Ch4	4 km	30 min	gif
MODIS	1,2	250 m	As available	gif
	Color Composite	500 m	As available	gif
QuikSCAT	Winds	25 km	Daily	png
AVHRR-GOES	SST Composite	6 km	3 hourly	gif
GOES	Cloud Drift Winds	Low-level Upper-level	6 hourly	gif
Polar Orbiting satellites	Daily Overpass Times	-	-	Table
	Overpass swaths	-	-	gif

RICO Operations Plan
Chapter 7: Required Observations For Modeling Studies

7.1 Group activities

RICO investigators are interested in modeling studies that span the range of observed scales. The University of Utah, Purdue University, University of Illinois and NOAA groups are particularly interested in studying microphysical processes occurring within and on the cloud scale. Specific interests are on the influence of the ambient aerosol, particularly giant aerosol, and entrainment and mixing processes on the evolution of the droplet spectrum and the development of precipitation. The UCLA group is interested in the statistics of cloud ensembles and the ability of the observations to constrain large-eddy simulations of cloud fields. On the regional scale, the CSU group plans to use RICO observations directly to constrain parameterizations of shallow clouds and their interaction with the ambient aerosol.

7.2 RICO Observations in support of modeling studies

In support of these studies, the following RICO data are required:

a. Data for characterizing the environment for model initialization or constraints:

- daily (or more frequent) atmospheric soundings
- rawinsonde data incorporated into GTS for inclusion in standard NWP analyses and forecasts
- daily horizontal and vertical mapping of aerosol, CCN and giant/ultragiant particles. These are critical for the aerosol and chemistry modeling, and for studying entrainment effects on precipitation formation.
- temporal evolution of surface fluxes and state variables at surface and beneath cloud base
- fluxes and state variables at cloud levels (outside of cloud) and directly above cloud (needed at lower frequencies than the sub-cloud layer)
- profiles of aerosol and trace gases up- and down-shear of clouds. [Priority days will be those when background aerosol concentrations (and perhaps trace gases) are higher than normal.]
- integrated total water vapor from ship microwave radiometer
- detailed measurements of aerosol and wind motion beneath cloud bases from ship Doppler lidar data
- Within ship-centered control volumes:

1) estimates of surface fluxes and temperature

2) radiative fluxes at the top and bottom of the control volume, i.e., at the surface and at some level some hundreds of meters above the highest clouds

3) profiles of the thermodynamic quantities and horizontal winds through the depth of the boundary layer, extending perhaps to 1km above the highest clouds for the purposes of radiative calculations.

4) turbulent fluxes of heat, moisture and momentum in the sub-cloud layer

5) cloud and environmental statistics at several levels within the cloud layer

6) interface statistics indicating the height and variability of the trade inversion and the transition layer often observed at cloud base.

b. Data for characterizing the clouds for model initialization or validation:

- accumulation mode aerosol, CCN, giant/ultragiant aerosol particles beneath cloud bases. These are necessary to initialize any detailed microphysical calculations correctly.

- aircraft documentation of cloud base heights and thermodynamic properties. These are also required to initialize/constrain cloud microphysical and dynamical models. The ship's ceilometer can also be used to document cloud base height and changes throughout the operations period.

- radar coverage of cloud properties: cloud top heights and widths, radar echo evolution from initial stages through precipitation development. These macroscopic cloud properties place necessary temporal and spatial constraints on microphysical calculations.

- *multilevel*, in-situ characterization of the following cloud properties by the aircraft, at the highest sampling rate possible:

    1) cloud liquid water content

    2) drop size distributions from standard and Phase-Doppler instrumentation

    3) temperature

    4) water vapor

    5) winds

    6) dissipation rate of turbulent kinetic energy

- for clouds at different stages of development being scanned by the land and/or ship-based radars. Some studies require penetrations immediately above cloud bases after documentation of the conditions immediately below the bases. At a minimum, 3 in-cloud levels should be sampled during the ops period: cloud base passes, mid-level passes, and passes near the maximum cloud top heights. Some modeling studies would benefit from the NCAR C130 aircraft making all of these passes on given days, because of the presence of the new Phased-Doppler instrument on the C130 for measuring droplet size distributions.

- raindrop size distributions and rainrate estimates. Estimates of these variables can be derived from the radar data and the ship-based precipitation spectrometer and rain gauges

- liquid water paths from ship-based microwave radiometer

- High-resolution spatial mapping of in-cloud velocities and circulations at different levels in the cloud (especially near cloud top) with the Wyoming Cloud Radar

7.3. Notes on data collection strategy in support of modeling studies

- It is critical to the RICO modeling studies to have coordination between the radar(s) and the aircraft sampling the clouds. Aircraft sampling of the environment (including the below cloud and above-cloud layers), and multiple levels within clouds being scanned by the radar(s), are necessary for interpreting the radar data and completing the observational data set necessary for the RICO modeling studies. Several of the studies are heavily dependent upon data gathered by instrumentation on the ship, and thus coordination between the aircraft and ship operations is critical for those studies. Other studies will make more use of the ground-based radar and aircraft data, which must also be coordinated.

- The modeling studies planned by these RICO investigators will benefit the most from "*statistical studies*", i.e., gathering data through many clouds at different stages in their lifetimes, rather than "case studies", i.e., attempting to acquire high-resolution data through a single cloud. Collecting data each day on the largest number of clouds possible aids in defining "average" cloud properties and evolution, and thus makes comparison between the observed and modeled clouds more robust.

RICO Operations Plan
Chapter 8: Working Groups

RICO has established five working groups to facilitate data analysis and quality control in the field. Each working group was to submit a report following the September 2004 meeting outlining a plan for action in the field. The following are the members of the groups and the reports received.

8.1 Working Group 1 - Particle Spectra Measurements

Members:

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WG1 REPORT:

Purpose:

RICO P.I.s collaborate by scrutinizing cloud-probe calibration techniques and data, and cloud data collected during the experiment, leading to an assessment of the accuracy of measured particle size spectra and higher moments.

Work Plan:

1) Documentation of cloud microphysical probe calibration from the three participating aircraft is placed prior to the RICO field phase in a wiki (NCAR/JOSS web site). Sought are detailed descriptions of the calibration (or a link where the details can be accessed) and the resulting critical parameters that define probe operation. A description of the perceived strengths and weaknesses of each probe is also desired.

2) A detailed log of probe performance (repair, cleaning, removal, re-installation, re-calibration, etc.) during the RICO experiment is kept and submitted to the wiki. Post-RICO calibrations are included.

3) After each flight a quick look and comparison is made of the microphysical probe data for perhaps half a dozen short time intervals chosen by WG members. The data consists of drop spectra, and calculated or measured 2^{nd} (total surface area, extinction coefficient) and 3d (liquid water content) moments of the spectra. Patrick has kindly offered the services of a grad student to plot up the comparisons. It was thought that this first look was important to give an indication of probe consistency, and identify probe failure. The probes identified for the quick look are FFSSP, FSSP, PDPA, CPI, 2DS, 2DC, 2DP, King (x2), PVM, CVI, CIN. The quick looks are placed in the wiki for all P.I.s to see.

4) Three options were stated for units to be used for microphysical properties: all units are mks, units are from the metric system, and units are the same as used by RAF in other NCAR cloud studies. Clarification is still needed.

5) The original microphysics data collected during the RICO field experiment will be saved along with subsequent versions of the data if those become necessary, and all data will be available to RICO P.I.s (as per RICO protocol). Any post-experiment data changes are justified and described in the wiki.

6) Incloud comparisons of the microphysics probes on the three aircraft are proposed for the Operations Plan of RICO. The suggested flight plans are sequential flight of the aircraft through the same Cu at a given level. A first level is ~200m above cloud base, and a second level is 500m or more higher. It was thought that the lowest level could assist the evaluation of probe performance by utilizing identified adiabatic parcels in non-precipitating Cu.

7) The WG will explore during the experiment potential synergisms between the various types of microphysical probes. For example, looks will be taken at the possibility of constraining spectral probes with integral probes that measure higher moments. Given that both spectral and integral probes can have measurement issues that depend on the variability of RICO conditions, only changes to the original data will be proposed.

8) Based on the submitted wiki material, the WG generates post-RICO a final report summarizing the performance of the microphysical probes, including error bars of the measurements to the extent these are quantifiable. This report can include majority as well as individual WG member opinions. Suggestions are made for improving the accuracy of the original data.

8.2 Working Group 2 – Aerosol and Chemistry measurements

Members:

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WG2 REPORT

- Emphasis on getting preliminary field data in as quickly as possible; at a minimum instrument status will be reported to the C-130 Flight Mission Scientist during the in-flight flight debrief (~ last 30 min of flight) as to whether each instrument worked during the flight, special issues, and time required on ground before the next flight.

- Instrument readiness will be reported to the science team at the "4:00 PM" meeting on the day prior to a scheduled flight. Are there mission critical instruments that if not working would delay/cancel a flight?

- Discussion dominated by C-130 and ground station community and there is a need to have representation from King Air and BAE-146 groups.

- A Chemical-Aerosol Mission Flight Straw Plan is to be developed by Bandy, Thornton, Jensen, Hudson, and others for inclusion in the *RICO Operation Plan* for the DMS-SO_2-H_2O_2-CCN and aerosol spectral evolution portion of the experiment. This could be a refinement of that presented by Jensen or in addition to that plan.

- Need to include a procedure to refine the flight plan once airborne in response to the data acquired in near real-time from SABL, dropsondes and *in situ* instruments – ability to cherry pick interesting aerosol or chemical layers.

- Request flights start with a "circle" at highest altitude (4-5 km) for 1) dropsonde release, 2) alleviate possible over-heating on cabin, 3) SABL aerosol survey, 4) instrument warm up (~15 min for selected instruments like peroxides, sulfur gases)

- Design flight segments for Targets of Opportunity, e.g., Montserrat, identified Saharan dust, …

- Request Tampa-Antigua ferry flights pass by University of Puerto Rico ground stations.

- Request short flight segments at lowest altitude possible for comparison of aircraft measurements with ground site observations (perhaps 5 min after takeoff and 5 min prior to landing). Also, request ground site trailer to be collocated near C-130 for instrument comparison on a non-fly day. Is this feasible and what permissions are required.

- Request the CN and CCN instruments available for the Wyoming King Air be flown on that aircraft. These did not appear on the list of instruments to be flown on that platform.

- The C-130 science group recognized the need to compare instruments-in-common between the King Air and BAE-146, however, representatives from those platforms were not present. This is an action item for the RICO Science Team and especially the flight operations people from each respective aircraft to workout.

8.3 Working Group 3 – Sounding, Surface based timeseries, and aircraft/shipdeck turbulence data

Members:

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WG3 REPORT

Goals

To evaluate the quality of sounding, surface based timeseries, and aircraft/shipdeck turbulence data during RICO.

To provide baseline data in real time.

To develop methods and templates for synthesizing similar data from diverse platforms.

To coordinate intercomparison of probes from diverse platforms.

Summary of September 2, 2004 Meeting

Recommended intermingling of Seward Johnson and Barbuda Sounding Batches to faciliate comparison. Preliminary plan will be for ATD to provide the ETL group with 20 soundings from their batch, these soundings will be replaced once the ETL group receives their soundings.

Recommended that all sounding data be place in a common NetCDF file with data interpolated to a 2m grid, the template for which is being developed by Bjorn Stevens

Recommended that both the Ship and the ground site in Barbuda will provide 5 minute averaged data in near real time to the operations center. This data will be put in a NetCDF file following a template to be decided upon and will contain 10m winds, 2m Temperature, 2m Humidity, Pressure, Sea Surface Temperature (if applicable), and Liquid Water Path (if applicable).

Rcommended that at three periods during the experiment, once during the first phase and twice during the second phase, intercomparision flights will be conducted. The preliminary plan is for these to consist of coordinated set of maneouvers as well as four thirty minute circles of all aircraft flown in formation, with a pair of alternating direction circles flown at the lowest safe flight level and another pair flown at a higher altitude within the subcloud layer. The circles will be 60km in diameter and will be flown near the ship (during the second phase). These measurements are consistent with the baseline measurements to be flown by the C130 on every mission, and thus primarily place additional constraints on the BAE146 and the Wyoming King Air.

8.4 Working Group 4 – Radar and surface based remote sensors

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WG4 Report:

None Received.

8.5 Working Group 5 – Satellite remote sensing

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WG5 Report: None Received.

8.6 Working Group 6 – Forecasting

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WG6: Report:

It is critical that forecasting information be limited to as few websites as possible, with the preferable route having links to all key products from a single site. We prefer that the JOSS RICO Operational Data site contain these products.

Key forecasting parameters include 1) low level cloud motion, 2) Winds through the trade wind layer depth 3) Trade wind layer depth and inversion strength 4) Cloud organizational modes 5) Any synoptic scale influences (fronts, ITCZ, easterly waves, Jetstream cirrus etc) that may impact operations, 5) percent cloud cover associated with trade wind clouds,

Key operational decisions related to forecasting: 1) operational sectors for the radar, 2) ship placement based on wind, 3) aircraft departure times; 4) satellite overpass times.

Key nowcasting decisions: 1) short time nowcast on the approach of targets of opportunity, such as cloud lines and clusters; 2) anything that will impact the sector of operations for the aircraft.

WG6 will work to insure that all the products required for forecasting will be available by the time that the aircraft phase of the project begins.

8.7 WIKI Webpages

Wiki webpages have been established to facilitate communication in the working groups. These pages can be found at
https://www.joss.ucar.edu/twiki/bin/view/RICO/WorkingGroupN

where N is the working group number. Mark Bradford (UCAR JOSS, mark@ucar.edu, 303-497-8169) maintains these pages. All Working group members should take advantage of these wikis and place into them agreed upon material (see attached Work Plan of WG1 for an example) before as well as during the RICO field study. All other RICO P.I.s are invited to read the contents of the WG1 wiki at any time.

RICO Operations Plan
Chapter 9: Education and Outreach

9.1 Educational Benefits of the Project

9.1.1 RICO Graduate Seminar Series

RICO will provide unique field research experiences to graduate students from several institutions. RICO will integrate research and education more completely through the creation of the "RICO Graduate Seminar Series" (RGSS), which will be offered during the last three weeks of the field campaign (i.e., in early January). This time period will allow the greatest student participation because it coordinates well with the academic calendar. The RGSS, a unique idea for in-the-field pedagogy, is motivated by two facts: (i) the realization that modern field programs have such a degree of automation that students are often left with little to do beyond routine monitoring tasks; (ii) the assemblage of scientific instrumentation and expertise provides unique educational opportunities for students. The goals of the RGSS will be to educate students about theoretical issues underlying the field campaign, the techniques and instrumentation used to address these issues, and the process of designing and executing a field campaign such as RICO. We anticipate that students from numerous U.S. universities and foreign countries will participate. The RGSS will include a series of nine to fifteen lectures by RICO science team members. No more than one lecture will be given per day, with each lecture lasting from 50 to 75 minutes. The RGSS will include hands-on practical experience with instrumentation and data analysis.

9.1.2 RICO Student Flight

A special aspect of RGSS will be a dedicated flight of six hours that will be designed by participating students. The students will coordinate this flight with radar operations, and design the flight to be consistent with the goals of RICO. The flight will take place at the end of the project, which will give students the opportunity to meaningfully apply what they learn during the RGSS. After the field program, RICO scientists will help students coordinate and analyze data from this flight and will encourage them to publish their results in the Bulletin of American Meteorological Society.

9.2 Media and Outreach day

A second thrust of the RICO plan for education and outreach will be to hold a media and outreach day. This will be coordinated with local schools and media to provide access to the instruments and scientists participating in RICO. In this manner, the scientific objectives of RICO will be communicated to the public during the experiment.

RICO Operations Plan
Chapter 10: Data Management

10.1 RICO Data Management

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the scientific objectives of RICO. The overall guiding philosophy for the RICO data management is to make the completed data set available to the scientific community as soon as possible following the field project in order to better accomplish the scientific objectives of RICO as well as incorporate these results into improved operational forecast and precipitation prediction models.

The RICO data management archive activities are being coordinated by the UCAR/Joint Office for Science Support (JOSS). These activities fall into three major areas:

X Determine the needs of the RICO scientific community and develop them into a comprehensive RICO Data Management Plan.

X Develop and implement a real-time web-based field data catalog to provide in-field support products for operations planning, project summaries and field phase documentation, facility and product status for the PIs, and

X Establish a RICO Data Archive Center (RDAC) which provides data distribution/support for the PIs and the general scientific community. This includes comprehensive seamless access to all operational and research data sets through a distributed data archive.

Full details of the RICO Data Management strategy and activities will be included in the RICO Data Management Plan document. The Data Management Plan outline will be available at:

http://www.joss.ucar.edu/rico/dm/Data_Plan_Outline.html

10.2 RICO Data Management Policy

RICO Data management is bound by the policy of ATD regarding their data sets, and other organizations who provide specific data sets. Outside these groups, the Data Management Policy that all participants of RICO are requested to abide by.

1. All investigators participating in RICO must agree to promptly submit their data to the RDAC to facilitate intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined data set.

2. All data shall be promptly provided to other RICO investigators upon request. A list of RICO investigators will be maintained by the RICO Project Office and will include the Principle Investigators (PIs) directly participating in the field experiment as well as

collaborating scientists who have provided guidance in the planning and analysis of RICO data.

3. During the initial data analysis period (one year following the end of the field phase; February 2006), no data may be provided to a third party (journal articles, presentations, research proposals, other investigators) without the consent of the investigator who collected the data. This initial analysis period is designed to provide an opportunity to quality control the combined data set as well as to provide the investigators ample time to publish their results.

4. All data will be considered public domain after one year following the end of the RICO field experiment phase.

5. Any use of the data will include either acknowledgment (i.e., citation) or co-authorship at the discretion of the investigator who collected the data.

Further details of the data management strategy are provided in the following sub-sections.

10.2.1 Data Processing/Quality Control

All data released in the field will be considered preliminary data to be used for planning and operational purposes *ONLY.* Preliminary data are defined as data that have not been thoroughly analyzed or quality assured (i.e., final instrument calibrations applied, etc.) by the PI to become Afinal@ processed data. No distribution of preliminary data outside the RICO Operations Center will be permitted without the consent of the PI who collected that data. At the end of the RICO field phase, no preliminary data will be archived or distributed at the RDAC unless agreed to by the PI. Individual PIs will be responsible for the final processing, quality control and submission of their own data sets to the RDAC since they are the best qualified to do so. The RDAC will perform any necessary processing for the operational data sets only (e.g., satellite, upper air soundings, surface observations, model output, etc.).

10.2.2 Data Availability

All PIs participating in RICO must agree to promptly (within 12 months following the conclusion of the field phase) submit their processed, quality controlled Afinal@ data to the RDAC. The requirement for PIs to submit their final data following 12 months after the field phase will facilitate intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined RICO data set. The PIs will greatly benefit by further collaborative analysis of his/her data sets within the RICO community. Complete metadata (including data set descriptions, documentation, calibrations, quality assurance results, etc.) must accompany the submitted data. Upon submission, unless otherwise specified by the PI, these data will be available to the general scientific community. The PI does reserve the right to request that the RDAC password protect these data or send notifications when a request for his data is received during the initial one year data analysis period.

Most operational data sets collected in real time (e.g., satellite, upper air soundings, surface observations, model output) will initially be available through the RICO on-line Field Data Catalog for project operations purposes. These data will be archived and available through the RDAC no later than six months following the field phase. All field documentation (e.g., daily operations summaries, mission summaries, status reports, mission scientist reports, etc.) will also be available through the RICO on-line Field Data Catalog and the RDAC in an electronic format.

10.2.3 Data Attribution

All data shall be promptly provided to other RICO PIs upon request with the approval of the PI that collected the data. RICO PIs are defined as those designated by the RICO Scientific Steering Committee/RICO Project Office and/or those directly participating in the field experiment. Distribution can be done either directly by the PI or through the RDAC with the permission of the PI.

During the initial data analysis period (up to one year after the data have been collected) no data may be provided to a third party (journal articles, presentations, research proposals, other investigators) without the consent of the PI that collected the data. This initial analysis period is designed to provide an opportunity to quality control and analyze the combined data set to release a better quality product. Also, any use of the data will include either acknowledgment (i.e., citation) or co-authorship at the discretion of the investigator who collected the data.

10.2.4 Community Access to Data

It is the intent of the RICO Scientific Steering Committee that all data will be considered public domain no later than one year after the end of the field experiment (i.e., February 2006) and that any use of the data will include either acknowledgment or co-authorship of the PI who collected the data. General community access to the data will be available through the RDAC who will be responsible for making arrangements on data distribution (e.g., cost, if any, method of distribution, etc.) and coordinate data orders with the requestor(s).

10.3 RICO Field Data Catalog

UCAR/JOSS will implement and maintain the web-based RICO Field Data Catalog that will be operational during the RICO field phase to support the field operational planning, product display, and documentation (e.g. facility status, daily operations summary, and mission reports). The catalog will be operational at the RICO Operations Center with a Amirror@ site in Boulder, CO. Data collection information about both operational and research products (including documentation) will be entered into the system in near real time beginning on or about 1 December 2004. The catalog will permit data entry (data collection details, field summary notes, certain operational data etc.), data browsing (listings, plots) and limited catalog information distribution. A Daily Operations Summary will be prepared and contain information regarding operations (aircraft flight times, major instrument systems sampling times, weather forecasts and synopses, etc.). These summaries will be entered into the Field Data Catalog either electronically (via web interface and/or e-mail) or manually. It is important and desirable for the PIs to contribute graphics (e.g., plots in gif, jpg, png, or postScript format) and/or data for retention on the catalog whenever possible. Updates of the status of data collection and instrumentation (on a daily basis or more often depending on the platforms and other operational requirements) will be available. Public access to status information, mission summaries and selected data sets outside of the RICO Operations Center will be available from the "mirrored" catalog in Boulder.

10.4 Distributed Data Archive Center

The RDAC will be located at UCAR/JOSS in Boulder, CO, and data will be available through the existing JOSS Data Management System (CODIAC). CODIAC offers scientists access to research and operational data. It provides the means to identify data sets of interest, facilities to view data and associated metadata and the ability to automatically obtain data via Internet file transfer or magnetic media. The user may *browse data* to preview selected data sets prior to retrieval. Data displays include time series plots for surface parameters, skew-T/log-P diagrams for soundings and gif images for model analysis and satellite imagery. CODIAC users can *directly retrieve data.* Users can download data via the Internet directly to their workstation or personal computer or request delivery of data on magnetic media. Data may be selected by time or location and can be converted to one of several formats before delivery. CODIAC automatically includes associated documentation concerning the data itself, processing steps and quality control procedures.

Contact Information:

Contact:	CODIAC (codiac@joss.ucar.edu).
Mailing Address:	P.O. Box 3000, Boulder, CO, USA, 80307
Shipping Address:	3300 Mitchell Lane (Suite 175), Boulder, CO 80307, USA
Telephone:	(303) 497-8987, FAX (303) 497-8158
Internet Access:	http://www.joss.ucar.edu/rico/dm/

10.5 RICO Data Questionnaire

UCAR/JOSS and the RICO Project Office developed and distributed an on-line data questionnaire to gather information from RICO Investigators regarding their needs for specific data sets. The information provided will help JOSS determine what data and products are necessary in real-time during the project (for inclusion into the field catalog) and what data need to be archived for analysis efforts by RICO PI's (both operational and research data sets). The questionnaire is available at: http://www.joss.ucar.edu/cgi-bin/rico/q_dataneeds. Information will be compiled from all responses into a summary report and incorporated into the RICO Data Management Plan. Individual responses are available at: http://www.joss.ucar.edu/rico/dm/webresponse/ .

10.6 RICO Data Management WWW Pages

To organize RICO data management activities and access to data sets, JOSS has created and maintains RICO Data Management web pages located directly at: http://www.joss.ucar.edu/rico/dm/ . These pages (also linked from the RICO AHome@ Page) will provide access to RICO data sources and information (in-situ, satellite, and model output), project documentation, on-line field catalog, data submission/guidelines, collaborating project data archives, and other relevant data related links. The future AData Access@ link from this page (or to be located directly at: http://www.joss.ucar.edu/rico/dm/archive/) will consist of a master searchable table of all RICO data sets with links to distributed data sources (including documentation, data set status, and date of availability). As data sets become available, this table will be updated providing an easy one-stop access to all RICO data sets.

RICO Operations Plan
Appendix A: RICO Instrumentation

A1. RICO Instrumentation

A1.1 NCAR C-130

<u>RAF-Supplied Instrumentation</u>:

I. Airborne Data System.

A. *Acquisition.* C-130 ADS2 (Motorola 68040 based). NCAR Distributed Sampling Modules (4 units), one in each wing pod and two in cabin.

B. *Operator Station*. Intel L440GX+ Motherboard with 2 Pentium III-500 CPU's, 512 MB Memory, Redhat Linux 6.2 OS. 9GB Disk Storage with RAID-1. General Digital 17 inch 1280x1024 TFT Flat Panel Color Monitor. IBM-DRHS36D 36GB Removable Disk Drives In Kingston Carriers (2 units). Exabyte Model EXB-8505 Tape Drive. UPS.

C. *Aft User Displays* (4):

1. Dell Latitude Pentium III-850 Laptop (1), Linux OS, 15" Display – Clyde
2. Dell Latitude Pentium II-300 Laptop (1), Linux OS, 13" Display – Grendel
3. Dell Latitude Pentium MMX-266 Laptop (1), Linux OS, 13" Display – Agave
4. Dell Latitude Pentium MMX-233 Laptop (1), Linux OS, 13" Display – Nuvola
5. Lexmark Optra Color 45 Inkjet Printer

D. *Flight Deck Display*

1. Dell Latitude Pentium III-850 Laptop, Linux OS, 15" Display – Bonnie
2. Lexmark Optra Color 45 Inkjet Printer

II. Aircraft Position, Velocity and Attitude

A. Honeywell Model HG1095-AC03 Laseref SM Inertial Reference System . (Research).

B. Garmin GPS16 Global Positioning System. (GPS).

III. Static Pressures

A. Rosemount Model 1501 Digital Pressure Transducer – Fuselage Port (PSFD).

B. Ruska Model 7885 Digital Pressure Transducer – Fuselage Port (PSFRD, PSFC).

C. Rosemount Model 1201F1 Pressure Transducer – Cabin (PCAB).

IV. Dynamic Pressures

A. Rosemount Model 1221F1VL – Radome (QCR).

B. Rosemount Model 1221F1VL – Left Fuselage Pitot (QCF).

C. Rosemount Model 1221F1VL – Right Fuselage Pitot (QCFR).

V. Temperatures

A. Rosemount Type 102 Non-deiced Sensor – Rosemount Model 510BF Amplifier - Starboard Radome Mount (TTRR).

B. Rosemount Type 102 Non-deiced Sensor – Rosemount Model 510BF Amplifier - Port Radome Mount (TTRL).

C. Rosemount Type 102E Deiced Sensor – Rosemount Model 510BF Amplifier - Left Inboard Wing Access Plate (TTWH).

D. OPHIR-III Radiometric Near-field Temperature Sensor – Starboard Wing Pod Mount (OAT).

VI. Flow Angle Sensors, Radome

A. Attack - Rosemount Model 1221F1VL Differential Pressure Transducer (ADIFR).

B. Sideslip - Rosemount Model 1221F1VL Differential Pressure Transducer (BDIFR).

VII. Dew Point and Humidity

A. General Eastern, Model 1011B Dew Point Hygrometer - Starboard Radome Mount (DPT).

B. General Eastern, Model 1011B Dew Point Hygrometer - Starboard Radome Mount (DPB).

C. SpectraSensors Open Path TDL Hygrometer – Starboard Wing Pod Mount (MRLH).

D. NCAR Model LA-3 Crossflow Lyman-alpha Hygrometer – Port Radome Mount (VLA).

E. NCAR Model LA-3 Crossflow Lyman-alpha Hygrometer – Port Radome Mount (VLA1).

VIII. Radiation Fluxes.

A. Visible Radiation. RAF Modified Eppley Model PSP Pyranometers - 2 units: Upward looking (SWT), Downward looking (SWB). Multipurpose Radiometer Housings.

B. Ultraviolet Radiation. RAF Modified Eppley Model TUV Pyranometers - 2 units: Upward looking (UVT), Downward looking (UVB). Multipurpose Radiometer Housings.

C. Infrared Radiation. RAF Modified Eppley Model PIR Pyrgeometers - 2 units: Upward looking (IRT), Downward looking (IRB). Multipurpose Radiometer Housings.

D. Remote Surface Temperature. Heiman Model KT19.85 Radiometer - 2 units: Down looking (RSTB,RSTB1).

E. Remote Sky Temperature. Heiman Model KT19.85 Radiometer. Up looking (RSTT).

IX. Basic Cloud Physics

A. Rosemount Model 871FA Icing Rate Detector – Right Inboard Wing Access Plate (RICE).

B. PMS Liquid Water Sensor (King Probe) - Left Outboard Wing Access Plate (PLWC).

C. PMS Liquid Water Sensor (King Probe) - Right Outboard Wing Access Plate (PLWC1).

D. TSI Model 3760 CN Counter - Belly Inlet (CONCN). Size Distribution, 0.01 to 3 um.

X. Wing Stores

A. RAF – Particle Measuring Systems Model SPP-200 Size Distribution, 0.12 to 3.12 um.

B. RAF – Particle Measuring Systems Model SSP-100 Size Distribution, 3 - 45 um.

C. RAF – Particle Measuring Systems Model 2D-C Size Distribution, 25 to 800 um.

D. RAF – Particle Measuring Systems Model 2D-P Size Distribution, 100 to 3200 um.

E. RAF – Particle Measuring Systems Model 260X Size Distribution, 50 to 640 um.

F. RAF – PVM-100 Liquid Water Probe - Left wing Pod mount (XGLWC).

G. SPEC – Model 2D-S Dual Particle Imager Size Distribution, 25 to 800 um.

H. SPEC – Cloud Particle Imager (CPI) Size Distribution,

I. Brenguier – X Probe / or Fast FSSP Size Distribution, 3 to 50 um.

J. CIRPAS – Phase Doppler Cloud Droplet Analyzer Size Distribution

K. Gerber – Cloud Integrating Nephelometer (CIN)

XI. Geometric Altitude

A. Steward-Warner Model APN-232(v) – Fuselage Mount, 0 to 1,500 m AGL (HGM); 0 to 15,000 m AGL (HGM232).

XII. Photography

A. Sony XC-999 SVHS Color Camera with JVC Model HR-S4700U Super VHS Recorder (2 pairs), Horita GPS Video Titler, Forward facing Cockpit Mount, Side Looking.

XIII. RAF Chemistry (T.Campos).

A. TECO Slow Response Ozone Analyzer (TEO3C).

B. Aero-Laser Fast Response Carbon Monoxide Analyzer (UV resonance fluorescence - CO).

C. RAF Fast Response Ozone Analyzer (O3FSC).

XIV. NCAR Special Request Instruments

A. ATD SABL Up/Down looking Lidar - 2 wavelength backscatter system. Left Wing Pod Mount. ½ Std C-130 rack.

B. ATD GPS Dropsonde System. Cabin Mount. Aft ramp chute. ½ Std C-130 rack.

C. RAF Aerosol Rack w RDMA Radial Differential Mobility Analyzer and wet/dry nephelometers. 1 Std C-130 rack.

D. ATD WARDS Weather Avoidance Radar Data System. ½ Std C-130 rack.

E. RAF Counter-flow Virtual Impactor. 1 Std C-130 rack/Specialty inlet takes entire aperture plate.

F. CSIRO/RAF Giant Aerosol Impactor. Space on Std aperture plate.

XV. User Supplied Cabin Mounted Instrumentation

A. Hudson CCN – 2 User supplied specialty racks / 1 inlet to share part of Std Aperture plate + CVI feed.

B. Bandy SO2 – 1 Std C-130 User supplied rack / 1 inlet.

C. Bandy DMS - 1 Std C-130 User supplied rack / 1 inlet.

D. Heikes In-Situ Peroxides – ½ Std C-130 rack / Specialty inlet takes entire aperture plate + CVI feed.

E. Anderson Filter pack – space in CVI rack / 1 inlet to share part of Std Aperture plate + CVI feed.

F. Univ. of Hawaii Total Air Sampler – ¼ Std C-130 rack for Pump / Specialty inlet takes entire aperture plate.

G. SPEC Data Systems for 2D-S and CPI wing probes – ½ Std C-130 rack.

H. CIRPAS Data System for Phase Doppler Analyzer – ¼ Std C-130 rack.

I. Brenguier Laptop Computer for X Probe – 1/8 Std C-130 rack.

XVI. Provisional User Equipment.

A. Mayol Bracero - Stacked Filter Packs – ¼ Std C-130 rack.

B. Gerber – Cloud Integrating Nephelometer / Wing Store

C. PH Meter / share part of Std Aperture plate

D. CSIRO – Wet and Dry Bulb Temperature / share part of Std Aperture plate

A1.2 Wyoming King Air

Table 2.1 SCIENTIFIC PAYLOAD				
1. LIST OF STANDARD SENSORS (These items are usually on the aircraft and part of the archive data set)				
VARIABLE	**INSTRUMENT**	**RANGE**[1]	**ACCURACY**[2]	**RESOLUTION**[1]
Air temperature	Rosemount 102	-50 to +50 °C	0.5 °C	0.006 °C
Air temperature	Reverse flow (Minco element)	-50 to +50 °C	0.5 °C	0.006 °C
Dewpoint temp.	Cambridge Model 137C3	-50 to +50 °C	1.0 C if > 0 °C 2.0 C if < 0 °C	0.006 °C
Static pressure	Rosemount 1501	0-1080 mb	0.5 mb	0.003 mb
Static pressure	Rosemount 1201FA1B1A	0-1034 mb	0.5 mb	0.06 mb
Static pressure	Rosemount HADS	0-1034 mb	0.5 mb	0.006 mb
Static pressure	Weston (under dev)			
Geometric alt.	Stewart Warner APN159 radar altimeter	60000 ft (18288 m)	1%	0.24 ft (0.07 m)
Geometric alt.	King KRA 405	2000 ft (610 m)	3% if < 500 ft 5% if > 500 ft (152 m)	0.48 ft (0.15 m)
Total pressure	Rosemount 831CPX	0-85 mb	0.2 mb	0.005 mb
Lat./long.	Trimble 2000 GPS	±90° lat. ±180° long.	100 m ([3])	0.000172°
Lat./long.	Honeywell Laseref SM Inertial Reference System (IRS)	±90° lat. ±180° long.	0.8 mm/h (50% CEP) 1.66 mm/h (95% CEP)	0.000172°
Ground velocity	Honeywell Laseref SM	0-4095 kts	13.5 ft/s ([4])	0.0039 kts
Vertical velocity	Honeywell Laseref SM	±32768 ft/min	0.5 ft/s ([4])	0.03125 ft/min
Pitch/roll angle	Honeywell Laseref SM	±90° pitch ±180° roll	0.05° ([4])	0.000172°
True heading	Honeywell Laseref SM	±180°	0.2° ([4])	0.000172°
Flow angle	Rosemount 858AJ/831CPX	±15°	0.2°	0.00015°
Engine torque	Engine gauge	2230 ft-lbf	---	0.2 ft-lbf
Video record	Forward-looking	---	---	---
Audio record	Intercomm/Radios	---	---	---
Event markers		---	---	---

Notes:
([1]) In units native to the instrument.
([2]) In units of customary usage.
([3]) Limited by reception.
([4]) 6-hour accuracy
([5]) Selectable.

Table 2.1 KING AIR SCIENTIFIC PAYLOAD (continued)				
2. OTHER STANDARD SENSORS				
VARIABLE	**INSTRUMENT**	**RANGE**[1]	**ACCURACY**[2]	**RESOLUTION**[1]
Cloud Properties				
Cloud droplet spectra	Particle Measuring Systems, FSSP scattering probe	0.5-45 μm ([5])	---	0.5-3 μm ([5])
Cloud particle spectra	Particle Measuring Systems 200X (1D-C) optical array	12.5-185.5 μm	---	12.5 μm
Cloud particle spectra	Particle Measuring Systems, 2D-C optical array	---	---	25 μm
Precipitation particle spectra	Particle Measuring System, 2D-P optical array	---	---	200 μm
Liquid water content	DMT LWC-100	0-3 g/m^3	0.2 g/m^3	0.00015 g/m^3
Liquid water content	Gerber PVM-100	0.002-10g/m^3	5%	.000015 g/m^3
Droplet surface area	Gerber PVM-100	5-20,000 cm^2/m^3	5%	.03 cm2/m^3
Droplet effective radius	Gerber PVM-100	2-70um	10%	.00015 g/m^3
Icing rate	Rosemount 871FA	0.5 mm/trip	n/a	0.0004 cm
Other				
Video record	forward looking	---	---	---

Table 2.1 KING AIR SCIENTIFIC PAYLOAD (continued)				
3. NON-STANDARD INSTRUMENT GROUPINGS – See http://flights.uwyo.edu/bulletin1.html				
VARIABLE	**INSTRUMENT**	**RANGE**[1]	**ACCURACY**[2]	**RESOLUTION**[1]
BL eddy fluxes:				
Air temperature	Friehe type, with UWyo modifications.			
Water vapor	LICOR 6262	0-75 mb	1%	0.1 mb
Carbon dioxide	LICOR 6262	0-3000 ppm	±1 ppm at 350 ppm	1 ppm
Radiation sensors:				
Pyranometer	Eppley PSP (0.285-2.8 mm)	0-1400 W/m^2	5 W/m^2	0.0-8 W/m^2
Pyrgeometer	Eppley PIR (3.5-50 mm)	0-700 W/m^2	15 W/m^2	0.04 W/m^2
Radiative Thermometer	Heimann KT-19.85 (9.6-11.5 mm)	-50 to 400°C	0.5°C	0.1°C for 10 s response
SCIENTIFIC PAYLOAD (continued)				
3. NON-STANDARD INSTRUMENT GROUPINGS (continued)				
Wyoming Cloud Radar http://www-das.uwyo.edu/wcr (more below)				
Trace gas chemistry:				
Ozone	TEI model 49	0-1000 ppbv	2 ppbv	0.1 ppbv
Aerosol properties:				
CCN concentrations	UWyo CCNC-100A	0-1,000 cm^{-3}	+/-30%	+/- 1 cm^{3}
CN Concentration	TSI 3010	0-10,000 cm^{3}	+-10%	30 cm^{-3}
Aerosol black carbon	Magee AE16	>50 ngm^{-3}	±2%	Function of avg. time
Size distribution	PCASP-100X	0.12-3.0μm		20 or 30 Bins
Size distribution	TSI 3936L10	0.02-0.5μm	±5%	64 Bins

Notes to Table 2.1:
(1) In units native to the instrument.
(2) In units of customary usage.

(3) As mounted in the nose ring, the field of view could be set to 1 degree or 15 degrees by changing lenses. For the 1998-2000 flights we had selected 15 degrees.

(4) Several sensitivities, ranges, and resolutions are available for each channel.

(5) The manufacturer's accuracy (+/-5%) applies to the instrument gain, i.e, to the conversion factor from volts to W/m^2. Thus, the accuracy is +/-5% whatever value the instrument is detecting, regardless of range.

Wyoming Cloud Radar

The WCR is a 95 GHz, multiple-beam Doppler radar. There are four fixed WCR antennas on the King Air:

- one oriented towards nadir,
- one looking ~30º forward of nadir in the vertical plane,
- one looking sideways or upward [depending on the position of a mirror in a faring on the aircraft frame], and
- one looking ~35º forward from the lateral beam in the horizontal plane.

The first (last) two antennas allow dual-Doppler synthesis of the air motion in the vertical (horizontal) plane, a configuration referred to as vertical (horizontal) plane dual-Doppler, or VPDD (HPDD). Along straight & level flight tracks, the two beams will view approximately the same sample volume from different directions, with time differences of the order of seconds, allowing dual-Doppler synthesis of the radial velocities in a plane below or to the right of the aircraft.

The usual WCR range resolution is about 30 m, depending on the pulse width. The beamwidth is very narrow (about 0.7º for the various antennae), thus the across-beam resolution is even better than 30 m, at least at range less than ~2.6 km. For purposes of dual-Doppler synthesis the useful radar range interval is about 100 m to 3000 m. The minimum detectible signal is about -25 dBZ at a range of 1 km and -16 dBZ at 3 km, varying somewhat depending on the selected operating mode and antenna. A range resolution of 75 m may be used, resulting in increased sensitivity and larger maximum range. More detailed radar specifications can be found at http://www-das.uwyo.edu/wcr/.

Several antenna pairs can be operated at one time, with each operated in a pulse-by-pulse interleaved fashion, resulting in a quasi-simultaneous data stream from the selected antennas. The key pairs are: VPDD (down/foreward-down); HPDD (side/foreward-side); single Doppler profiling (up/down); and single Doppler side/down. The VPDD mode is more sensitive than the HPDD mode, mainly because the down-pointing antennas are larger.

We expect that at the time of RICO, a new fast switching network and control system will be in operation, allowing simultaneous operation of all four antennas listed above, at the cost of some loss in sensitivity. This system will be capable of: quasi-simultaneous interleaved HPDD/VPDD (denoted DPDD, Dual-Plane Dual-Doppler); side-forward/down/up profiling mode, by which a vertical plane above and below, and a horizontal one starboard of the aircraft will be scanned in single Doppler mode. In addition to all the configurations, the side/up-pointing antenna can be used for polarimetric studies.

A1.3 United Kingdom BAE-146

Duration:	5h 15 min
Max altitude:	35,000 ft
Duration at max alt:	2.5 h
Ascent rate: between	800 - 1500 ft/min (depending on weight) at 2000 ft
Science payload:	4000 kg
Science crew:	19

Cloud/Aerosol Instruments

AMS	Aerosol Mass Spectrometer
ADA	Airborne Droplet Analyzer
CCN	Cloud Condensation Nuclei (Met Office)
CVI	Counter flow Virtual Impactor
FFSSP	Fast Forward Scattering Spectrometer Probe
HVPS	High Volume Precipitation Spectrometer
Johnson Williams	Liquid Water Content Probe
Nevzorov	Liquid and Total Water Content Probe
PCASP	Aerosol Size Spectrum optical probe
TWC	Total Water Content (Lyman-alpha absorption - MO)
VACC	Volatile Aerosol Concentration and Composition
2D-C	Two Dimension Cloud particle imaging probe
2D-P	Two Dimension Precipitation particle imaging probe

Airborne Research Interferometer Evaluation System

Airborne Vertical Atmospheric Profiler System (Dropsonde)

Broad Band (pyranometers and pyrgeometers) Radiometers

Dual-frequency Extension to In-flight Microwave Observing System

RDR4B Navigation Weather Radar

Fluorescence Water Vapour Sensor Met Office

General Eastern Hygrometer

Inertial Navigation Unit

Integrating Nephelometer

Particle Soot Absorption Photometer

Radar Altimeter.

Rosemount Temperature Sensors.

SATCOM Honeywell/RACAL MCS-7000

TECO - O3, SO2 and NOx measurement

Turbulence Probe

Upward, Downward, Forward and Rear view cameras

Small Ice Detector (SDI-1_

DRI Cloudscope

A1.4 Seward-Johnson NSF Ship

A suite of remote sensing and in situ measurements will be made from the Research Vessel Seward Johnson in the RICO study area for studies of trade-wind cumuli and the onset of precipitation. These studies will focus on the following:

- Clouds – precipitation microphysics
- Clouds – dynamics
- PBL structure and transports
- Surface fluxes (turbulent, radiative)
- Aerosols

The observations from the ship will be coordinated with research aircraft flights and the island-based radar observations.

A1.4.1 Instrumentation

The University of Miami, the University of Colorado and ETL will deploy a unique sea going suite of instruments (see Table 1). This suite includes remote sensing systems--radars, lidars, and microwave radiometers--, a surface flux measurement system, and surface met instruments for mean near-surface atmospheric and ocean conditions. Rawindsondes will be launched to provide tropospheric thermodynamics and wind structures. Some engineering work will be required to prepare, deploy and operate this state of the art facility on board the research vessel. For the cloud radars, engineering efforts for platform stabilization and linkage to the ship navigation data are required. Furthermore, this unique deployment and radar synergy (0.9, 3, 35 and 94 GHz) provides additional opportunities for radar remote sensing studies. The collocation of three vertically pointing radars with different wavelength and sampling characteristics will provide a multi frequency radar product for the development of radar based retrieval techniques of cloud microphysics, turbulence and precipitation. The radars on board the research vessel cover three different atmospheric scattering regimes, Bragg scattering (915-MHz profiler), Rayleigh scattering (X, K and W-band) and Mie scattering (W-band) that offer the opportunity for the application of various radar-based retrieval techniques for turbulence, cloud and precipitation microphysics and a means for improving our interpretation of the Bragg scattering effects at longer radar wavelength—a key issue for other radar studies proposed for RICO. The Doppler lidar has seen prior shipboard deployments and already has a stabilized platform. A three channel microwave radiometer (21 and 31 GHz), ceilometer, air-sea radiative and turbulence flux measurements, drizzle droplet spectral measurements (DMT/CIP) and rain-gauges, will provide important information about the PBL structure.

Table 2.2. Instruments and measurements for the ship-based cloud microphysics and PBL properties in precipitating trade cumulus clouds during RICO		
Item	**System**	**Measurement**
1	Motion/navigation package	Motion correction for turbulence
2	Sonic anemometer/thermometer	Direct covariance turbulent fluxes
3	IR fast H_2O/CO_2 sensor	Direct covariance moisture/CO2 fluxes
4	Mean SST, air temperature/RH	Bulk turbulent fluxes
5	Pyranometer/Pyrgeometer	Downward solar and IR radiative flux
6	Ceilometer	Cloud-base height
7	Doppler lidar (NOAA ETL)	High resolution Doppler spectra around and below clouds
8	94-GHz W-Band) Doppler radar (UM)	High resolution Doppler spectra, cloud and precipitation microphysics and dynamics
9	35 GHz Doppler cloud radar (NOAA/ETL)	Cloud microphysical properties
10	9.4 GHz (X-Band) Doppler Radar (UM)	Cloud dynamics and precipitation physics
11	915-MHz wind profiler (NOAA/ETL)	PBL 3-D winds, inversion height, clouds
12	23 and 31 GHz microwave radiometer. ARM type (Mailbox)	Integrated cloud liquid water Integrated total water vapor
13	Riegl Laser wave sensor	Ocean surface wave height/period
14	Precipitation spectrometer	Drizzle droplet size spectra
15	BNL rotating shadowband radiometer	Direct/diffuse solar

A1.4.1.1 University of Miami 94-GHz (W-Band) Doppler Cloud Radar

The UMDCR (Albrecht et al., 1999) is a single antenna 94-GHz Doppler radar. The UMDCR is lightweight (200 pounds, 4x4x4 ft radar container and 3-foot Cassegrain antenna) and with a scanning reflector will provide small angle (10^o-20^o) off zenith scans to map the 3-D structure of trade-wind cumuli entities. Due to its short wavelength (λ=3.2mm), it is highly sensitive to small cloud droplets and it is suitable for the study of weak non-precipitating boundary layer clouds (estimated sensitivity -52 dBZ at 1 km). Typical radar spatial and temporal resolution for the detection of boundary layer clouds is 30 m vertical and 1 s. The antenna beamwidth is 0.24°, so that the radar horizontal sample size is about 8 m at 2 km. Real time signal processing provides

Doppler spectra at all range gates sampled by the processor. The high point FFT gives excellent Doppler spectra resolution (e.g., 3.2 cm s^{-1} for 10 kHz PRF).

A1.4.1.2 NOAA/ETL 35 GHz (K-Band) Cloud Radar

NOAA/K was the first cloud radar to combine scanning, Doppler and polarimetric capabilities (Martner et al., 2002) for research. Operating at 35-GHz (λ=8.6mm), with a high power transmitter (80 kW peak power) and a large antenna (1.8 m with 0.3 deg. beamwidth) the NOAA/K is highly sensitive to clouds and precipitation (sensitivity -50 dBZ at 1 km). The radar can perform fast (up to 30deg/s) PPI and RHI scans. The data system comprises a real time data processing and display system known as the Radar Acquisition and Display System (RADS) that controls the radar's scan and signal characteristics and processes, displays and records the data (Campbell and Gibson, 1997). The radar is suitable for scanning large volumes of the atmosphere and its excellent sensitivity allows the 3-D mapping of non-precipitating clouds. Pulse-pair (reflectivity and mean Doppler velocity) estimates are recorded.

A1.4.1.3 University of Miami 9.4 GHz (X-Band) Radar

The University of Miami X-Band radar has full Doppler capability with a sensitivity of -48 dBZ at 1 km. It has a 4 ft. antenna with a beam width of 1o and will be used in an upward-facing mode to explore cloud and precipitation vertical structure and vertical velocities from the Doppler velocity spectrum. It will provide reflectivity and vertical velocity measurements in the same volume sampled by the other upward facing instruments. It provides reflectivities that are relatively unattenuated relative to the W and Ka Band radars during heavier precipitation events.

A1.4.1.4 NOAA ETL 915 MHz Doppler Wind Profiler

The 915 MHz wind profiler planned for the Seward Johnson is mechanically compensated for ship motion. This is one of the original systems used for the TOGA COARE field programs in the 1990's. It uses a standard 3-beam method with one vertical and two 15 degree tilted beams. Typical averaging time is 30 s, which allows conditional averaging of wind within the boundary layer and cloud pattern. Data extend from the minimum range of about 160 m to the top of the trade wind PBL (about 2 km). Range resolution of either 60-m or 100-m is typically used to measure at lower and higher heights, respectively. For cases of weak signals, range resolutions of 240 m and 470 m are also available.

A1.4.1.5 NOAA/ETL Doppler Lidar

The lidar transmits a pulsed beam of light with an extremely low divergence. The typical measurement volume is 30 meters in length and less than 60 cm in diameter out to a range of 5 km. The instrument provides range resolved radial wind speed and intensity measurement once a second. The precision of these one-second velocity estimates is SNR dependent, but typically exceeds 20 cm/s over the measurement range. The lidar has a motion compensated hemispheric scanner that allows for full sky coverage. A differential GPS navigation unit provides information for real time removal of ship's motion from the velocity data stream. It provides detailed measurement of both aerosol and wind motion.

A1.4.1.6 Near-surface bulk and flux data

The University of Colorado and NOAA ETL Air-Sea Interaction Group has developed techniques for accurate direct covariance ship-based measurements of the turbulent heat, mass, and momentum fluxes (Fairall et al., 1996a; 1997). High resolution wind components and temperature are measured with an ultrasonicanemometer/thermometer (sonic) with full motion corrections (Edson et al., 1998). This information is used to compute the sensible heat flux and wind stress over the water. In addition, information from a fast response infrared H2O/CO2 sensor is combined with the corrected sonic signal to compute estimates of the fluxes of latent heat and carbon dioxide. The direct covariance and inertial-dissipation fluxes are computed at 10-min and 1-hr time intervals. Flow distortion by the ship's structure is also applied and is based on computational fluid dynamics (CFD) calculations with empirical tuning. Downwelling radiative flux components are also measured. The flux system mean temperature and humidity measurements are accurate to better than 0.2 C and 0.3 g/kg, and the near surface ocean temperature is measured with a floating temperature sensor ('seasnake') which samples at a depth of about 5 cm. This sensor fully resolves all diurnal warm layers, and the true interface temperature is obtained by subtracting a cool-skin correction (Fairall et al., 1996b). The flux system is also complemented by the addition of an eye-safe laser ceilometer, which provides measurements of cloud base height. The capability for measurement of direct covariance carbon dioxide fluxes is a recent addition (Fairall et al., 2000; McGillis et al., 2001)

A1.4.2 Research Vessel Seward Johnson

Remote and in situ measurements in support of RICO will be made with the R/V Seward Johnson. This is a 204-foot Oceanographic and Submersible-Support Research Vessel that was built in 1984, commissioned in 1985 and extensively rebuilt and stretched in 1994. With a 6000 nautical mile range and a speed of 13 knots, the vessel is capable of traveling and working in any of the world's oceans, while accommodating up to 40 people (including the 11 crew members). The R/V Seward Johnson part of the University-National Oceanographic Laboratory System (UNOLS) fleet and is operated by the Harbor Brach Oceanographic Institution (HOBI).

A1.4.2.1 General Specifications

The general specifications for the *R/V Seward Johnson* are:

- Length Overall - 204 feet.
- Length between Perpendiculars - 183 feet.
- Beam Overall - 36 feet.
- Fuel Capacity - 60,000 Gal.
- Fuel Consumption - 70 gal./hr., normal cruise.
- Potable Water - 15,000 gal. with RO Unit (120 gal. hr.).

- Accommodations - 40 (including crew).
- Speed - 13 knots.
- Year Built/Converted - 1984/1994.

A1.4.2.2 Detailed Specifications and Cruise Planning Documents

Detailed specifications for the ship and operation parameters can be found in Appendix A. The "HBOI Cruise Planning Manual" and additional details on this ship can be found at http://www.hboi.edu/marineops/sj.html.

Communications, including INMARSAT link for data and written messages, and e-mail will be required. In the vicinity of Barbuda Islands, ship-to-shore and ship-to-ship voice communications via HF and/or VHF radio may also be needed. There will be a need to communicate with the research aircraft via a small handheld VHF aircraft or marine radio.

A1.4.3 Instrument Locations on the Ship

The instruments will be located on the ship following the plan provided in Appendix B. Power and space requirements for each of the instruments are included in this appendix. Only the following power outputs are available from the ship, all at 60 Hz: 1) 450 VAC, 3 phase, 2) 220 VAC, 1 or 3 phase, and 3) 120 VAC, 1 or 3 phase. Three-phase power is configured as "delta" (no ground), not as "Y" (with central ground). Transformers or motor-generators for other power requirements will not be provided by the ship and must be provided by the participants. Only U.S. standard power plugs and jacks will be provided by the ship.

A1.4.4 Dates for Operations/Itinerary

Table 2.3 Schedule for Seward/Johnson

Activity	Location	Dates
Staging	Ft. Pierce, FL	Dec. 13-21
Transit	Atlantic/Caribbean	Dec. 29-Jan. 3
On Station (Leg 1)	Upwind of Barbuda—20-100 km	Jan. 4-14
Port Call	Antigua	Jan. 15
On Station (Leg 2)	Upwind of Barbuda	Jan. 16-26
Transit	Atlantic/Caribbean	Jan. 27-Feb 2

A1.4.5 Personnel on Cruises

Leg 1

Bruce Albrecht		Chief Scientist
Bruce Bartram	(+ one?)	NOAA K
Scott Abbott		Flux/profiler Engineer
3 persons		ETL lidar
Pavlos Kollias (+ 2 grad & 2 ug students)		UM radars
2 persons		Sondes

Leg 2

MJ Post		Chief Scientist
Bruce Bartram	(+ one?)	NOAA K
Sergio Pezoa		Flux/profiler Engineer
Pasquita Zuidema		Cloud/precip Scientist
3 persons		ETL lidar
Pavlos Kollias (+ 2 graduate students)		UM radars
2 persons		Sondes

A1.4.6 Staging Plan

Loading and setup of scientific equipment for this cruise will take place in Ft. Pierce from December 13-23, 2004. Disposition of containers and mooring components on the decks is given in APPENDIX B along with laboratory work space assignments

A1.5 NCAR SPOL Radar

S-Band Polarization Radar (S-Polka) Characteristics

Radar Characteristics	
Meteorological radar const (│K2│=0.93)	68.5
Minimum detectable reflectivity at 30 km	-12 dBZ
Predicted Blue Sky Noise Power in 1 MHz bandwidth	-115.0
Transmitter	
Frequency	2.7 -- 2.9 GHz
Pulse width	.3 -- 1.4 µsec-tapered
PRF	0 -- 1300 Hz
Peak power	>1Mw
Staggered pulse	Yes
Random phase jitter for 2nd trip supression	Yes
Receivers (2)	
Polarization	H & V simultaneously
Noise power	-115.5 dBm
Radar Noise figure	2.9 dB
Dynamic range	90 dB
Bandwidth	.738 MHz
Digital IF	Linear floating point processing
I-Q image rejection	50 dB
Minimum detectable dBZ at 50km/1km	-15 dBZ/-52 dBZ at -6 dB SNR
Polarization switching	**H-V alternating or H only**
Mechanical switch isolation	47 dB measured
Ferrite switch isolation	28 dB
Antenna	
Shape	Parabolic, center feed
Gain	44.5 dB including wave guide loss
Diameter	8.5 m (28 ft.)
Beamwidth	0.87 degrees
First sidelobe	better than -30 dB
Isolation (ICPR)	better than -35 dB
Scan rate	Up to 18°/s each axis, 30°/s with pulley change
Wind limit for operation	30 m/s / 60 m/s (no radome)
Data system	NCAR designed VME system (VITAQ)
Number of range gates	4000
Gate spacing	37.5 -- 1000m
Number of samples	16 -- 1000
Clutter filter	Single polarization only, 50 dB
Times series (I/Q) capability	Yes
Real time scientific display	NCAR Zebra
Recorded variables	P_{HH}, P_{VV}, V, W, $R(1)_{HV}$, $R(1)_{VH}$|, |R(2)|, Phi_{DP}, Pho_{HV}, NCP, Z_H, Z_{DR}, LDR, K_{dp}
Recording medium	Exabyte, Dorade format

S-Polka Ka and S Band Radar Parameters

	Ka-band	S-band
Predicted Blue Sky Noise Power in 1MHz Bandwidth dBm-	112.1	-115.0
Carrier Frequency GHz	34.9	2.8
Pulse Width microseconds	0.8	1.0
Peak Power KWatts	11.98	560.0
Antenna Gain dB	45.2	45.0
Half-Power Beamwidth degrees	0.93	0.87
Meteorological Radar Constant (|K2|=0.93)	66.0	68.5
Minimum detectable reflectivity at 30 km dBZ	-16.6	-12.0

A1.6 GLASS Rawinsonde system

The GLASS rawinsonde system includes equipment to conduct atmospheric soundings and make supporting surface meteorological observations. GLASS can employ either GPS or LORAN-C navigation data for windfinding. In GPS-based windfinding, a Vaisala RS 80-15GH radiosonde is used, with a MWG201 GPS Processor Card processing the navigational signals from the sonde. Sounding thermodynamic data measured by the radiosonde are processed by an NCAR RS-80 Met processor. Surface data are collected from surface instruments connected to a Campbell CR-10 datalogger.

The Vaisala radiosonde used in RICO contains a GPS receiver, a 403 MHz band transmitter, and pressure, temperature, and relative humidity sensors multiplexed to an oscillator which generates a tone that is transmitted to the surface receiver. The thermodynamic data are transmitted from the sonde roughly every 1.5 seconds. GPS navigation signals are received by the sonde and re-transmitted to the surface station. Both signals, the thermodynamic data and the radionavigation signals, are transmitted to the surface on separate subcarriers of the 403 MHz band transmitter. Upon reception, the two signals are separated and directed to their respective processors. The thermodynamic data are transferred to the NCAR RS-80 Met processor while the radionavigation signals are sent to the appropriate navigator.

The standard GLASS data system consists of a power supply, an RS-232 Multiplexer, a rack controller, a 403 Mhz receiver, a navigation data processor, a meteorological data processor, and a personal computer. Information is transferred to and from the GLASS personal computer through RS-232 connections using the MUX mentioned above. The MUX switches between the navigator, the Met processor and the Campbell datalogger to gather the data required to process and display the atmospheric soundings.

When GPS sondes are deployed, the operating software used consists of four main programs—Surface Logging, Sounding, Utilities, and Analysis—written in LabVIEW, a graphical programming language that allows multitasking and provides graphical user interfaces. The software configuration can provide sounding data displays in real time. The displays are both graphical and text-based. The data are stored to the hard disk in ASCII and binary files which contain the information required to "recreate" the flight. These data files are saved and used in subsequent post-processing.

Before a sonde is launched, it is run through a pre-flight procedure in which the telemetry is verified and radionavigation signals are acquired. Thermodynamic data - pressure, temperature, and humidity - are checked and as soon as a sufficient number of GPS satellites are acquired, the sonde can be launched. There are several launch configurations possible at any GLASS site. The balloon can be launched (1) from the trailer itself through an aperture in the roof; (2) from a "bag" launcher, a heavy vinyl tarp that contains and protects the balloon prior to launch (used in shipboard deployments); or (3) by hand when wind and other conditions allow.

Balloons of varying weight can be used with the radiosondes. Typically, a 200-gram balloon is filled with roughly 40 cubic feet of helium, which will take a Vaisala sonde to 50 or 60 mb before the balloon bursts. The ascent rate obtained with this amount of helium and a Vaisala sonde is about 4 m/s.

The sonde specifications are tabulated below.

Radiosonde Specifications

Manufacturer - type	Vaisala RS 80-15 GH or Navaid Sonde
Mass	525 grams (GH); 325 grams (LH) (both with activated wet battery)
Dimensions	6cm X 14cm X 20cm (GH); 6cm X 9cm X 15cm (LH)
Ascent Rate	4 m/s avg
Transmitter Frequency	403.5 MHz
Transmitter Power	300 mW
Pressure Sensor	BAROCAP Capacitive aneroid
Temperature Sensor	THERMOCAP Capacitive bead
Humidity Sensor	HUMICAP thin film capacitor

Pressure Measurement

The pressure sensor is an encapsulated steel aneroid sensor. It utilizes a capacitive transducer with a vacuum inside the capsule. The entire unit is precision welded requiring no mechanical adjustment. The unit is friction free and continuously variable.

Radiosonde Pressure Sensor Specifications

Manufacturer	Vaisala
Sensor	Capacitive aneroid
Range	3 to 1060 mb
Accuracy	0.5 mb
Data System Resolution	0.1 mb
Sensor Resolution	0.1 mb

Temperature Measurement

The temperature sensor is a capacitive bead in glass encapsulation. The temperature sensors are calibrated at the factory.

Radiosonde Temperature Sensor Specifications

Manufacturer	Vaisala
Sensor	Capacitive bead
Range	-90 C to 60 C
Accuracy	0.2 C
Data System Resolution	0.1 C
Sensor Resolution	0.1 C

The manufacturer's specification for the time constant is 2.5 seconds. The time constant of the thermistor, combined with the ascent rate of the sonde produce a slight lag in temperature measurement through the sounding. However, with typical atmospheric lapse rates the resultant smoothing of the temperature profile is less than the accuracy of the thermistor. The smoothing resulting from the lag time becomes more significant when the sonde crosses frontal boundaries or goes through strong inversions.

Experience has shown that if the sonde sensor arm is not protected or properly ventilated prior to launch, it can be adversely affected by solar heating. This results in a temperature reading that is too high, producing a false near-surface super-adiabatic lapse rate. Due to the small thermal mass of the temperature sensor and its supporting structure this effect is not long-lived. The thermal time constant of the sensor arm is 13 seconds and thus the problem goes away soon after launch, once the sensor is adequately ventilated.

Relative Humidity Measurement

The humidity sensor is a thin-film capacitive type sensor. The Vaisala type H radiosonde utilizes the type H sensor, which uses a humidity algorithm incorporating temperature compensation. This new sensor has improved humidity measurements over previous sensors, particularly in the high end of the humidity range (95% to 100%). Table 10 summarizes the humidity sensor specifications.

Radiosonde Humidity Sensor Specifications

Manufacturer	Vaisala
Sensor	HUMICAP thin film capacitor
Range	0 to 100% Relative Humidity
Accuracy	2.0% Relative Humidity
Data System Resolution	0.1% Relative Humidity
Time Constant	1.0 second @ 6m/s flow, 1000mb, 20 C

Solar heating of the sonde temperature/humidity sensor arm prior to launch can produce an error in the low level humidity measurement (and hence dew point). The humidity sensor gives a reading of the humidity relative to the temperature of the sensor surface itself. In a situation where the sensor surface is warmer than the surroundings, the humidity reading will be lower than ambient (vapor pressure remains unchanged, "sensed" saturation vapor pressure value goes up). Due to the thermal time constant of the sensor arm (13 seconds), the initial heating of the sensor arm affects the humidity data for roughly the first 40 seconds of the flight. (In a shaded, well ventilated situation, in which the sensor surface is in thermal equilibrium with its surroundings, an accurate ambient humidity measurement at the surface can be obtained.)

The effect of the heated sensor arm persists for a longer time in the humidity measurement than it does in the temperature measurement. The portion of the sensor arm where the temperature sensor is mounted is an isolated small cylinder which quickly comes to a thermal equilibrium with its surroundings whereas that portion of the sensor arm on which the humicap is mounted is much larger and thus takes more time to come to a thermal equilibrium with its environment.

Wind and Position Measurement

The wind accuracy obtained from the LORAN navigation system is dependent on a number of factors which in general relate to the quality of coverage for a given area. The number of stations received (three is minimum), the strength of signal, and the geometry of the receiver with respect to the stations are all important factors. Winds derived from GPS have a constant accuracy once the minimum number of satellites (typically four) are received. Specifications for LORAN and GPS wind and position measurements are presented in Table 11.

Wind and Position Measurement Specifications

Manufacturer / Model #	Advanced Navigation Inc. Model #7000 (ANI 7000)	Vaisala MWG201
Wind Accuracy	1.0 m/s	0.5 m/s
Averaging Time	60 seconds	0.5 seconds
Data System Resolution	0.1 meter; 0.1 m/s	0.1 meter; 0.1 m/s

In GPS windfinding (Vaisala RS 80-15GH radiosonde), the MWG201 GPS Processor Card processes the 1200 baud FSK signal from the telemetry receiver to compute winds from the Doppler frequencies measured by the dropsonde. The MWG201 contains a high-quality 12-channel commercial GPS full-up (code-correlating) receiver that measures the local satellite RF carrier Doppler frequencies. The 12-channel receiver also generates GPS time and time satellite ephemerides, and identifies the satellites and their Doppler frequencies. The local Doppler frequencies are then compared with the telemetered dropsonde Doppler frequencies; this allows the frequencies sent back from the sonde to be identified as originating from a particular satellite. The MWG201 then removes the satellite component of motion.

A1.7 GPS dropsonde system

The dropsonde incorporates a new pressure, temperature, humidity sensor module (RSS903) and a new GPS receiver module (GPS111), both designed by Vaisala, Inc., for their RS90 radiosonde. The sensor specifications are shown in the following table.

Dropsonde Sensor Specifications

	Range	Accuracy	Resolution
Pressure	1080-100 hPa	± 1.0 hPa	0.1 hPa
Temperature	-90 to +60 C	± 0.2 C	0.1 C
Humidity	0-100%	± 5%	1.0%
Horiz Wind	0-200 m/s	± 0.5 m/s	0.1 m/s

The winds are derived using a low-cost codeless 8-channel GPS receiver in the dropsonde that tracks the relative Doppler frequency from the RF carrier of the GPS satellite signals containing the satellite and the dropsonde motion. These Doppler frequencies (8 maximum) are digitized and sent back to the aircraft data system as a 1200 baud Frequency Shift Key modulation on the 400 MHz sonde telemetry transmitter. The aircraft data system has a Vaisala winds processing card (MWG201) which contains a high-quality 12-channel GPS commercial full-up receiver (GPS engine) that measures the local carrier phase Doppler frequencies, which are then compared to the telemetered sonde Doppler frequencies. The GPS engine also generates GPS time and the satellite ephemeredes data, and identifies the satellites and their Doppler frequencies so that the Doppler frequencies sent back from the sonde can be identified as coming from a particular satellite to make the wind calculations. The MWG201 card uses this data to compute independent velocity measurements every 0.5 seconds.

In addition to the RSS903 sensor module and the GPS111 receiver module, the dropsonde electronics board includes a microprocessor for measuring and controlling the sensor module and sending the measured data to the 100 milliwatt 400 MHz telemetry transmitter, and an 18-volt lithium battery pack for power. Surface mount technology is used on the electronics board to reduce size and increase the ease of manufacture. In addition, the electronics board contains a connector that serves as an RS-232 link with the aircraft data system for test and checkout and for setting the telemetry transmitter frequency prior to deployment. The transmitter can be set anywhere in the 400-406 MHz meteorological band in 20 kHz steps, creating about 300 separate channels.

A unique square-cone parachute is used to reduce the initial shock load and slow and stabilize the sonde. The parachute is immediately deployed on exit from the launch chute and streamers for about five seconds until filled by ram-air. The stability of the square cone parachute is very good during the sonde's descent and reduces or eliminates any pendulum motion of the sonde.

A1.8 Portable Automated Mesonet III

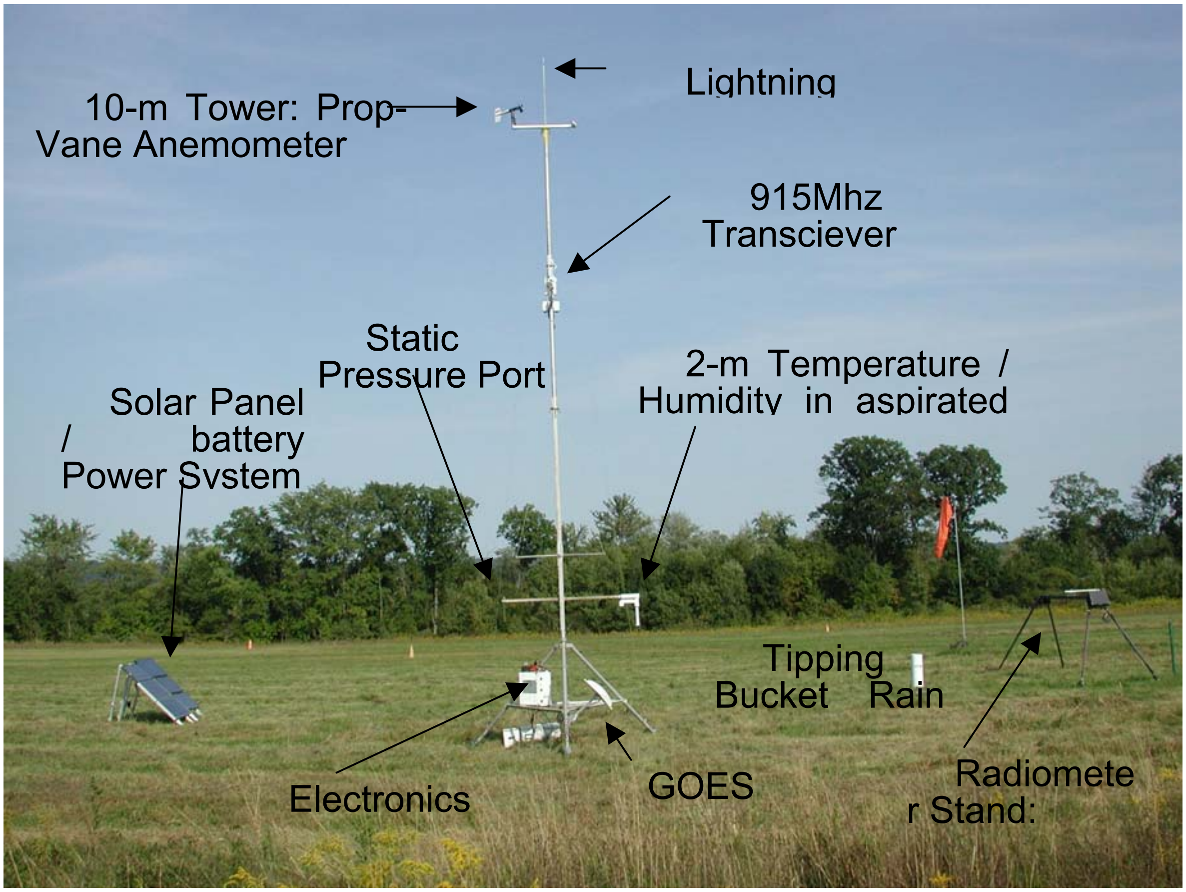

Fig. A1 PAM station to be used in RICO

Instruments:

- •Wind speed / Direction 10m
- •Temperature / Humidity 10m
- •Pressure 2m
- •Rain
- •Longwave / shortwave radiation incoming

Communication:

–Line of site, RF 915 Mhz
–GOES satellite
•
Siting

Anchoring 10 meter tower
Sand bag or anchor into stone

A1.9 Ground-based aerosol studies

A1.9.1 Aerosol Particle Collection

Aerosol collections will be made with four different samplers: a Dekati low-pressure impactor (DLPI, Dekati Ltd.), a micro-orifice uniform deposit impactor (MOUDI, MSP Corp.), stacked-filter units (SFUs, NILU), and a high-volume dichotomous sampler (HiVol, *Solomon et al.,* 1983) as presented in Table 1. Samples will be collected during day, and night intervals and integrated across these periods, only when the prevailing wind is from the northeast and with a velocity greater than 2 ms^{1}. This conditional sampling will be made using a controller built by UNAM and interfaced to their anemometer system. The type of substrates/filters used (aluminum/quartz) will depend on the analytical techniques to be employed. The estimated sampling times presented below are based on the limit of detection of each analytical technique and on previous results in PR [*Novakov et al.,* 1997], where OC concentrations were in the range of 200-800 ng m^{-3}.

Table 1. Instruments for Aerosol Sampling

Name	Description and Provider
Dekati low-pressure impactor (DLPI, Dekati Ltd.)	Size-resolved aerosol samples collected on 13 stages (7 nm to 10 μm), pressure 100 mbar, flow 30 L min^{-1}, UPR-RP.
Micro-orifice uniform deposit impactor (MOUDI, MSP Corp.)	Size-resolved aerosol samples collected on 8 stages (0.18 μm to 10 μm), flow 30 L min^{-1}, UPR-RP, Lawrence Berkeley National Laboratory and UNAM.
Stacked-filter units (SFUs, NILU)	Fine (D_p < ca. 1.2 □m) and coarse (D_p > ca. 1.2 μm) aerosol samples, flow 50 L min^{-1}, UPR-RP.
High-volume dichotomous impactor (HVDS, *Solomon et al.,* 1983)	Fine (D_p < ca 2.5 μm) and coarse (D_p > ca. 2.5 μm) aerosol samples, total flow ca. 330 L min^{-1}, available through Max Planck Institute for Chemistry, MPIC.

A1.9.2 Cloud/Fog Water Sampling

Cloud/fog water samples will be collected using an active string collector made of stainless steel to avoid problems of artifact formation and/or adsorption of organic compounds on the surfaces. Samples will be filtered on 47-mm quartz filters within a few hours of collection, frozen, and stored in glass bottles until analysis. These samples will be collected only at the East Peak station.

A1.9.3 Chemical Characterization

Several analyses will be performed to obtain chemical mass apportionment of the marine background aerosol (inorganic and organic fractions). The analytical techniques to be used, the species they determine, and collaborating institutions for some of the analyses are presented in Table 2.

Table 2. Analytical Techniques for Chemical Characterization of the Aerosol

Technique	Species Determined	Institution that will Perform Analysis
Evolved Gas Analysis, EGA	Total carbon, organic carbon, elemental carbon (TC, OC, EC)	National University of México, UNAM
Thermal/optical analysis	TC, OC, EC	UPR-RP
Total Organic Carbon, TOC,	Water-soluble organic carbon (WSOC)	UPR-RP and Institute of Atmospheric Sciences and Climate, ISAC, Bologna, Italy
^{1}H-Nuclear Magnetic Resonance, ^{1}H-NMR	Chemical functional groups	ISAC, Bologna, Italy
High-Performance Liquid Chromatography, HPLC	Neutral compounds, mono- and dicarboxylic acids, polycarboxylic acids	ISAC, Bologna, Italy
Ion Chromatography, IC	Water-soluble ions	Vienna University of Technology, Austria

In addition, two Aerodyne aerosol mass spectrometers (AMS) will be operating at the East Peak station. One instrument will be measuring behind a heated inlet to measure total particles, i.e. interstitial and droplet nuclei, the other will be operating behind a counter-flow impactor (CVI) to measure only the chemistry of the cloud nuclei. These instruments will provide information on the chemical composition of individual particles with respect to the amount removed by cloud processing.

A1.9.4 Measurements of Surface Tension

Surface tension of aerosol water extracts, cloud/fog samples, and the three classes of compounds obtained after the HPLC fractionation process will be measured by an oscillating bubble tensiometer. These analyses will be performed in collaboration with ISAC, Bologna, Italy.

A1.9.5 Measurements of Physical and Optical Properties

Table 3 includes the physical and optical measurements to be performed, the instruments that will be used, and the provider. The mass of the aerosol collected on substrates and filters, except for quartz filters, will be determined by gravimetric methods (not presented in Table 2) to be performed in Dr. H. Puxbaum's laboratory in the Vienna University of Technology.

Table 3. Instrumentation for Measuring Physical and Optical Properties of Aerosols, Cloud and Rainwater

Measurement	Instrument	Description and Provider
Total aerosol particle number concentration	CPC (Model 3022A, TSI)	Condensation particle counter for particles from 7 nm to 3 μm, UPR-RP.
Total aerosol particle number concentration	CPC (Model 3010, TSI)	Condensation particle counter for particles > 50 nm, UNAM.
Size distribution	SMPS (GRIMM)	Scanning mobility particle sizer for measuring high-resolution size distributions of particles from 10 nm to 900 nm, MPIC.
Size distribution	PMS LasAir II	Optical particle counter, 0.3 – 25 μm diameter, UNAM
Cloud condensation nucleus concentration	3-D CCN counter (MPIC and DMT)	Cloud condensation nuclei counter for measuring the concentration of CCN as a function of aerosol particle diameter (~25-150 nm) and supersaturation (~0.15-2.5%).
Cloud	CCN counter	Cloud condensation nuclei counter for

condensation nucleus concentration	(University of Wyoming)	measuring the concentration of CCN at constant supersaturation (0.2 to 1%), UNAM
Absorption coefficient	Particle Soot Absorbing Photometer (Radiance Research)	Aerosol light absorption at 550 nm, UNAM
Black Carbon and aerosol light absorption	Aethalometer (AE-31 Magee Scientific), with URG PM 2.5 cyclone.	Aerosol light absorption at 7 different wavelengths (350 to 950 nm), UPR-RP.
Aerosol light scattering coefficient	Nephelometer (Model 3563, TSI), with URG PM 2.5 inlet. *	Aerosol light scattering at 3 different wavelengths (450, 550, and 700 nm), requested in previous proposal.
Aerosol light scattering coefficient	Nephelometer (Radiance Research)	Aerosol light scattering at 550 nm, UNAM
Aerosol column burden and properties	Sunphotometer (CE318-1, CIMEL)	Aerosol column burden and properties (e.g., aerosol optical thickness, size distributions), available at UPR-RP through AERONET (http://aeronet.gsfc.nasa.gov).
Droplet size distribution (2-47 μm)	PMS FSSP-100	Cloud particle properties, UNAM
Drop size distribution (25-800 μm)	PMS 2D-C	Drizzle properties, UNAM
Drop size distribution (200-6400 μm)	PMS 2D-P	Rain properties, UNAM

A1.9.6 Quality Control and Quality Assurance

To control the quality of the data acquired, the following precautions will be taken. Sampling will be performed only when the wind direction is appropriate since samplers will be wind-direction driven. The procedures to be used for the preparation of the samplers, filters, substrates, and containers that store filters and substrates are described by *Salmon et al.* [1998]. Two types of blanks (filters/substrates not exposed to the air stream and filters/substrates treated in the same way as the real samples, but exposed to the air stream for only 10 seconds) will be collected and analyzed on a regular basis. Aluminum foils and quartz filters will be conditioned at 450 °C for 24 h to reduce carbon content associated with new filters. Quartz filters will be stored in precleaned glass vials (prebaked for 12 h at 650 °C). The aluminum substrates will be stored in Petri Slides (Millipore) for environmental analysis. Blanks for the cloud water sampler will also be collected. In this case, blanks and samples will be stored in precleaned glass vials. Samples in vials and slides will be stored in a freezer at −18 °C until analysis. To assure optimal operation of analytical systems, internal and external standard samples will be used for calibration. When the mass of the collected sample is sufficient (high loadings) duplicate analyses will be performed. The analytical techniques to be employed have been widely used for the analyses of air samples and the methods to be used are established and known for producing high quality data.

A1.9.7 Preliminary Analysis and Results during the Experiment

During the field project (period 1), preliminary analyses of aerosol filter samples will be performed with the EGA, the thermal/optical and the TOC analyzers. Additionally, the real-time measurements mentioned in Table 3 will be processed and quality assured every evening and made available on a web site for RICO investigators.

A1.9.8 Instrumentation to be Deployed at the Different Ground-Based Stations

The following tables present the instruments that will be deployed at the three sampling locations: CSJ, East Peak and Antigua.

CAPE SAN JUAN (MARINE SITE), PUERTO RICO

INSTRUMENT	INSTITUTION
Low-Pressure Impactor (DLPI, Dekati)	UPR-RP
Low-Pressure Impactor (MOUDI, MSP)	UPR-RP
Stacked-Filter Units (SFUs, NILU)	UPR-RP
Hi-Volume Filter Sampler (Solomon et al., 1983)	UPR-RP MPIC Germany
CPC (Model 3022A, TSI)	UPR-RP
3-D CCN Counter (MPIC + DMT)	MPIC Germany
Scanning mobility particle sizer SMPS (Grimm)	MPIC Germany
Aethalometer (AE-31 Magee Scientific) with URG PM 2.5 cyclone	UPR-RP
Nephelometer (Model 3563, TSI) with URG PM 2.5 inlet	UPR-RP
Sunphotometer (CE318-1, CIMEL)	UPR-RP
OPC PMS LasAir II	UNAM, Mexico
CPC (Model 3010, TSI)	UNAM, Mexico
CCN Counter (University of Wyoming)	UNAM, Mexico

EAST PEAK (MOUNTAIN SITE), PUERTO RICO	
INSTRUMENT	**INSTITUTION**
Stacked-Filter Units (SFUs, NILU)	UPR-RP
Cloud Water Collector	UPR-RP
CCN Counter (MPIC)	MPIC Germany
SPMS	MPIC Germany
Aerosol Mass Spectrometer	MPIC Germany
Aerosol Mass Spectrometer	UMIST, UK
Low-Pressure Impactors (MOUDI, MSP)	UNAM, Mexico
CPC (Model 3010, TSI)	UNAM, Mexico
OPC PMS LasAir II	UNAM, Mexico
Particle Soot Absorbing Photometer, PSAP (Radiance Research)	UNAM, Mexico
Nephelometer (Radiance Research)	UNAM, Mexico
PM-1 or heater	UNAM, Mexico
Rain Water Collector	UNAM, Mexico
PMS FSSP-100	UNAM, Mexico
PMS 2D-C	UNAM, Mexico
PMS 2D-P	UNAM, Mexico

ANTIGUA (MARINE SITE), PUERTO RICO	
INSTRUMENT	**INSTITUTION**
Low-Pressure Impactor (MOUDI)	UPR-RP
Stacked-Filter Units (SFUs)	UPR-RP
CPC (Model 3025A, TSI)	Meteo-France
CCN Counter (University of Wyoming)	Meteo-France
Ground-based volatility system	University of Leeds, UK

UPR-RP – University of Puerto Rico – Río Piedras Campus

UNAM – Universidad Nacional Autónoma de México

MPIC – Max Planck Institute for Chemistry, Mainz, Germany

UMIST – University of Manchester Institute of Science and Technology, United Kingdom.

RICO Operations Plan
Appendix B: Aircraft Operational Guidelines

B.1 NCAR Research Aviation Facility Crew Compliment, Safety and Scheduling Procedures

Definitions: The personnel aboard NCAR/RAF aircraft are all designated aircrew and their presence is necessary for the completion of the flight mission. The Flight Crew consists of the Aircraft Commander, Pilot(s), and the Flight Engineer(s) (as required).

A. Equitable Distribution of Flight Time

Flight crewmembers are scheduled so that flight time is distributed among those in the same crew positions to insure training and proficiency requirements are met.

B. Guidelines (assuming normal working conditions)

The following crew duty guidelines are provided to assist in insuring that flying safety is maximized and consistent with operational efficiency. These duty limitations are consistent with professional standards and are neither maximums nor minimums. It is the individual responsibility of each crewmember to ascertain and affirm that his/her state of health and rest is appropriate for the safe completion of the planned mission.

Flight hours are determined as the time the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the point of landing ("block-to-block").

The crew duty period starts at the briefing time or when the crew starts being "on alert" and ends when the aircraft is shutdown and secured. Days off must be scheduled at least 12 hours in advance. When the crew is scheduled to switch from day to night or night to day operations at least 24 hours notice will be required. The crew is relieved of all duties during off days.

1. Crew Rest and Flight Duty Limitations:

- Any 24-hour period……………………………..10 flight hours
- Any consecutive 7 days…………………………35 flight hours
- Any 30-day period………………………………110 flight hours
- Consecutive working days………………………6 days
- Crew Duty Period……………………………….14 hours
- Minimum crew rest period………………………12 consecutive hours

Note: Above limits may be exceeded for ferry purposes at project pilots discretion.

The project pilot will always have the option of calling a no flight day when consecutive flights are scheduled and crew fatigue is a factor.

B.1-2 Scheduling Restrictions

Crewmembers will not be scheduled to fly, nor will they perform crew duties under the following conditions (unless required by the mission as a special exemption).

A. Maximum Flying Time

A flight crewmember will not fly when his/her flying time exceeds the stated limits described in Section B-1 (B) of this chapter.

B. Alcohol, Drugs, Narcotics (8 Hours)

Aircrew members shall not consume alcoholic beverages during the 8-hour period to scheduled departure time, nor shall they be assigned duties when under the influence of such substance.

Note: Any flight crew member or scientific crewmember under the influence of alcohol, drugs, or narcotics will not be permitted aboard the aircraft.

C. Immunization (24-Hours)

A flight crewmember will not fly within 24 hours after receiving immunization (other than smallpox/oral poliomyelitis vaccines) or after being administered anesthetics for dental or surgical procedures.

D. Blood Loss (72Hours)

A flight crewmember will not fly within 72 hours after a blood loss or donation of 200cc or more. Flight crews normally should not donate blood.

E. Oral or Injected Medications

A flight crewmember will not fly when taking oral or injected medication, unless individual medical waiver has been granted by the FAA Medical Examiner. Mild analgesics may be used if prescribed by a FAA Medical Examiner when the underlying disease is not cause for grounding. Dexedrine or similar stimulant "pep pills will not be used.

F. Scuba Diving (24Hours)

Any aircrew member who has engaged in recreational diving where an underwater breathing apparatus is used will not be scheduled for flight for 24 hours after a dive that has not required controlled ascent.

G. Medical

A flight crewmember will not be scheduled for, or fly on an NCAR/NSF aircraft as a crewmember unless he/she holds a current medical certificate for the position he/she crews.

H. Flight Check

A designated flight crewmember will not be scheduled for, or fly on an NCAR/NSF aircraft as a flight crewmember unless he/she has successfully passed an annual flight check for the position he/she holds within the preceding year.

I. Physiological Training

Prior to flying to cabin pressure above 14,000 feet, all aircrew carried aboard NCAR/NSF aircraft must complete a physiological training course, including a low-pressure chamber flight.

B-1.3 Other Aircrew Considerations

While it is the primary task of this manual to focus on the flight crew, safety issues also apply to the rest of the aircrew in varying degrees. As a matter of routine, the project Manager and the Aircraft Commander will advise all aircrew that these activity guidelines constitute prudent behavior normally expected of all aircrew. Both the Project Manager and Aircraft Commander are granted broad authority to delay or cancel a mission or deny boarding to an aircrew member whose failure to follow this guideline poses a safety risk to either the individual or the mission.

B-1.4 Departure, In-flight, and Landing Procedures

SECTION B—MISSION ACCOMPLISHMENT

B-1.4.1 General

The policies in this chapter cover operations of aircraft from takeoff through landing. Procedures will follow the rules prescribed in appropriate FLIP publications, FAR's USAF Foreign Clearance Guide, this manual, and appropriate flight manuals.

A. Command

The individual group chief will designate pilots (co-captains) for each flight or group of flights. The pilot in the left seat (see note below), Aircraft Commander, has command responsibility over all crewmembers in flight and is responsible for the safe conduct of the mission.

Note: To be designated as Aircraft Commander, the pilot must be fully qualified in the aircraft being flown and approved by the RAF Chief Pilot to serve as Aircraft Commander.

B. Control

A designated pilot will be in control of the aircraft at all times during flight. The Aircraft Commander and all other crewmembers will be in his/her seats during takeoffs, climbs to initial cruising altitudes and during descents and landings. At the discretion of the Aircraft Commander, a flight engineer in training may occupy the flight engineers position on all NCAR/RAF missions from takeoff through landing. Flight engineers in training will be directly supervised by a qualified flight engineer when occupying the flight engineer position.

B-1.4.2 Operating Policies

NCAR missions will be flown in accordance with FAA Regulations Subpart B, appropriate FLIP publications, ICAO procedures applicable to the host country, and NCAR directives.

A. Aircraft Checklists

The pilot flying the aircraft normally calls for the appropriate checklist. These checklists will be rigidly adhered to by flight crewmembers on all flights. The co-pilot and/or flight engineer is normally responsible for reading the checklist. Designated crewmembers will provide the response.

B. Takeoffs and Landings

The Aircraft Commander will occupy either the left or right seat during all takeoffs and landings.

C. Radio transmissions

In order to preclude the inadvertent blocking out or interruption of any radio communications to and from the cockpit, there will be only essential radio transmissions or ICS conversations permitted from the cabin beginning with the before start engine checklist and continuing to completion of the climb checklist. (Sterile cockpit below 10,000 feet)

D. Operations under Adverse Conditions

Adverse conditions include, but are not limited to, ceiling or visibility at or near minimums, marginal runway conditions, marginal approach aids, aircraft emergencies, severe turbulence, near maximum crosswind, unusual icing, terrain features that present an unusual hazard, and aircraft system malfunctions.

1. NCAR aircraft will not be operated into known or forecast weather conditions (icing included) that will exceed aircraft limitations. Aircraft limitations will be determined by the applicable flight manual.

2. NCAR aircraft will not be operated into areas of known or forecast thunderstorms unless radar is installed and operational or the weather forecast indicates that the flight can be conducted through the areas visually.

3. Final responsibility for the safe conduct of the mission rests with the Aircraft Commander. If in his/her judgment an unsafe condition exists, the mission will be delayed, canceled, or re-routed.

E. Maximum Cloud Reflectivity During NCAR Operations

Radar reflectivities of clouds have traditionally been utilized to establish rainfall rates that in turn are associated with turbulence and possible hail formations. Areas of high reflectivity gradients indicate steep rainfall gradients and are associated with turbulence. In order to maximize safety criteria for NCAR aircraft operations and still accomplish research objectives, maximum cloud reflectivity levels are hereby established. While this will not guarantee that NCAR research aircraft will not sustain damage the risk will be minimized.

1. Criteria – NCAR aircraft may penetrate, operate under, and operate within two nautical miles of a radar reflectivity echo of up to 40 dbz providing:

A properly calibrated ground radar is operated by a skilled technician within the quantitative observing range of the radar.

An RAF-approved, radar-trained scientist has access to the real- time display and is assigned to monitor and direct the aircraft operations. The radar scientist will maintain surveillance of the storm radar structure and voice contact with the plane at all times the aircraft is in the near-vicinity of storms, keeping cognizant of growth rates within storms, the fall rates of hail, and the limits of radar scan processes. The Aircraft Commander retains overall responsibility for safety of the aircraft and will remain in contact with radar scientist for all storm penetrations.

In the absence of ground radar data, when only airborne radar is utilized, NCAR aircraft will not penetrate, operate under, or operate within three nautical miles of any storm cell having a radar echo that shows contouring reflectivity judged to be 39 dbz or greater.

F. Safety Belts

Aircraft Commanders will insure that all crewmembers have safety belts securely fastened prior to all takeoffs and landings, when turbulence is encountered or anticipated, when flying through areas of forecast clear air turbulence, and when commencing low altitude runs. Crew movement within the aircraft is allowed when it is essential to operate equipment.

1. Cockpit Crew/Crew Members

All crewmembers occupying seats will have safety belts and shoulder straps fastened at all times.

2. Exceptions

When performing assigned flight examiner/instructor duties, a pilot or flight engineer need not use safety belts during takeoffs and landings, except when occupying a crew station. However, the individual will have a designated position equipped with a safety belt available in the compartment.

Note: Pilots will be in assigned seats with seat belts fastened. One pilot, designated by the Aircraft Commander will have at least one hand on the yoke and in close proximity to the autopilot disengage button. This will exert his full undivided attention to activities both outside and ahead of the aircraft.

G. Oxygen and Smoke Masks

Each mask should be given a pre-flight inspection. This inspection is the responsibility of the crewmember using the mask.

H. Altimeters

The field barometric setting will be obtained from the tower or appropriate area control center and will be set in the index window of the aircraft altimeters. The altimeter reading will be compared with known field elevation. The maximum allowable difference (error) between these two figures is 75 feet. If the difference exceeds this figure, the altimeter is unsatisfactory for instrument flight. During the course of flight, altimeter error is not considered and no correction is applied. Altimeter settings should be compared with the useable flight levels.

I. Altitude Restrictions for NCAR Aircraft

1. Minimum altitudes apply unless a waiver has been obtained.

Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

(a) Anywhere. An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.
(b) Over congested areas. Over any congested area of a city, town, or settlement, or over any open-air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.
(c) Over other than congested areas. An altitude of 1,000 feet above the surface, except over Ocean water. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.
(d) Over Ocean water - VFR Conditions - An altitude of 100 feet above the surface for straight and level flight, and a minimum altitude of 300 feet for turning maneuvers exceeding bank angle of 5 degrees.
(e) Auto pilot engaged – Minimum altitude of 300 feet above the surface.

Note: These minimums do not apply to coupled approaches.

2. Hours of Darkness or During Restrictive Visibility

When operating under these conditions, over a flat surface such as the ocean or polar ice cap, a minimum altitude of 500 feet above the surface will be observed providing the radar altimeter is operational. Flight path excursions of short duration to a radar altitude of 300 feet are permissible.

The above minimums have been established with near ideal conditions in mind. The Aircraft Commander must evaluate other factors such as turbulence, surface conditions, fatigue, and duration of flight at low altitudes, etc. It may be necessary to raise these levels to what in his/her judgment, is appropriate for the existing conditions.

A-1.4.3 Departure and Climb

A. Takeoff and Landing Data Completed

Takeoff and landing data will be completed immediately prior to takeoff.

B. Takeoff

Takeoff will normally be initiated from the beginning of the approved usable portion of the runway.

C. Obstacle Clearance

Aircraft must be capable of vertically clearing (considering one engine failure after V1) all obstacles along the climbout flight path.

D. After Takeoff

1. Turns are not to be made after takeoff below 500 feet unless specifically directed by departure control or ATC.

2. The after takeoff checklist should not be initiated or called for until an altitude of 500 feet AGL is reached, permitting flight crewmembers to maintain a more thorough outside watch.

3. The seat belt sign can be turned off at pilot's discretion providing all systems are operating normally.

E. Flight Station Entry

With the Aircraft Commander's approval, additional crewmembers will be permitted in the flight station during takeoff, climb, descent and landing only if seats not required by primary crewmembers or flight examiner/instructors are available, and seat belts are utilized.

F. Use of Oxygen

Crewmembers will use oxygen as specified in the appropriate aircraft flight manual, FAR 91.32, or as follows:

1. During daylight when the cabin pressure altitude is above 8,000 feet in excess of four hours, pilots and flight engineers 100% should use oxygen for 10 minutes of the last 45 minutes of the flight.

2. Unpressurized flights from 18,000 feet to 25,000 feet MSL require pre-flight denitrogenation breathing for 10 minutes. All crewmembers will breath 100% oxygen from start of prebreathing until the mission above 18,000 feet MSL has been completed and the aircraft has descended below 18,000 feet.

3. Unpressurized flights above 25,000 feet MSL will not be conducted.

A-1.4.4 In Flight

A. Navigational Aids

All available navigational aids will be utilized from departure to landing to readily provide the aircraft's geographical position.

B. Flight Progress

When the aircraft id flown at an altitude where terrain avoidance becomes a factor, all available aids will be used to maintain positive fixing of the aircraft position relative to the intended line of flight.

C. Inertial/GPS Navigation

Inertial or GPS navigation will be the primary aid during all scientific missions.

D. Weather Forecasts

The Aircraft Commander will insure that the destination and alternate weather forecasts are obtained before reaching ETP on overwater missions. Weather forecasts will provide the Aircraft Commander with sufficient terminal weather information for diverting or continuing to destination.

E. Cancellation of IFR Flight Plans, Airborne

1. Flight plans should not be canceled during daylight hours whenever weather in unknown, reported as marginal, or when scud, haze, or other restrictions to visibility are known to exist. In these cases, maximum use of all available navigation facilities should be utilized to effect an instrument approach to the point of intended landing.

2. IFR flight plans should not be canceled during night operations until an instrument approach is initiated and then only if the terminal airfield is in sight and VFR weather conditions are reported and verified by the pilot.

3. The above policy is no way intended to restrict the authority of the Aircraft Commander during inflight emergencies or under any other condition wherein the cancellation of an IFR flight is fully justified.

Note: For safety reasons the aircraft should have flight following untillanding.

F. Use of Oxygen

Crewmembers shall use oxygen as specified in the appropriate aircraft flight manual, FAR 91.32, or as follows:

1. During daylight when the cabin pressure altitude is above 8,000 feet in excess of four hours, pilots and flight engineers should use 100% oxygen for 10 minutes of the last 45 minutes of flight.

2. Unpressurized flights from 18,000 feet to 25,000 feet MSL require preflight denitrogenation breathing for 10 minutes. All crewmembers will breathe 100% oxygen from start of prebreathing until the mission above 18,000 feet MSL has been completed and the aircraft has descended below 18,000 feet.

3. Unpressurized flights above 25,000 feet MSL will not be conducted.

A-1.4.5 In-Flight Emergency Procedures

A. General

When the Aircraft Commander experiences an in-flight difficulty or emergency, or believes a situation exists that would create an emergency, he/she may take any action deemed appropriate to assure safety of flight. The Aircraft Commander is encouraged to use all personnel on the aircraft in a judicious manner incident to assisting in the emergency. As for proper procedures, the Aircraft Commander is guided by current NCAR/RAF and aircraft flight manual directives. Deviations from directives by any crewmembers that may occur as a result of an emergency will be reported to the Aircraft Commander.

B. Notification of Controlling Agencies

After completing the aircraft emergency action checklist, the Aircraft Commander will furnish the controlling agency a description and extent of the difficulty, assistance required, intentions, and any information on other causes which may endanger the mission.

1. Alert Phase - If the Aircraft Commander of an overwater flight experiences an inflight difficulty, but not a distress, he/she will transmit to the ground station PAN-PAN-PAN.

2. Distress Phase – If the Aircraft Commander encounters an inflight condition that poses serious and imminent danger to the aircraft, or if a forced landing or ditching appears probable, he/she will transmit to the ground station, MAYDAY-MAYDAY-MAYDAY.

Controlling agencies and SAR forces are required to provide every assistance possible, including intercept and escort, during this phase.

3. Turnaround Procedures – When a turnaround is necessary, the Aircraft Commander will maintain VFR, reverse course, and request ATC clearance. If unable to maintain VFR and reversing course without a clearance, descend 500 feet or select an altitude plus 500 feet. This will add some margin of safety to aircraft separation until a clearance can be obtained.

4. Termination of Emergency Phase – Upon termination of the emergency or when the condition of the aircraft improves so no further special assistance is required, the Aircraft Commander will notify appropriate agencies.

C. Engine Inoperative (4-Engine Aircraft)

In the event of a single power failure or when no more than one engine is stopped on a four engine aircraft, the Aircraft Commander may proceed to a destination that he selects if, after considering the following, he decides that proceeding to that destination is as safe as landing at the nearest suitable airport.

1. The nature of the malfunction and the possible mechanical difficulties that may occur if flight is continued.

2. The altitude, weight, and usable fuel at the time of engine stoppage.

3. The terrain and weather conditions enroute and suitable landing points.

4. Possible air traffic congestion at suitable landing point.

5. Pilot familiarity with the airport to be used.

D. Engine Inoperative, Twin-engine Aircraft

The Aircraft Commander lands at an airfield other than the nearest suitable airfield in point of time, he/she will report to the NCAR/RAF Chief pilot, stating his/her reason(s) for determining that the selection of an airfield, other than the nearest one, is as safe a course of action as landing at the nearest suitable airfield.

E. Ditching

1. Ditching Precautions – When an aircraft must crash land on either land or water, the sudden shifting of cargo, equipment, and other heavy items may cause injury or loss of life. All personnel will arrange and secure this equipment in the aircraft to guard against such dangers. Emergency gear such as life rafts should be quickly accessible. The responsibility for proper securing of cargo and equipment lies with the Aircraft Commander of each aircraft.

2. Ditching procedures – Ditching procedures are prominently displayed in all appropriate NCAR/RAF aircraft.

3. Ditching Checklist – Ditching checklists are used and the appropriate aircraft flight manual emergency procedures followed.

A-1.4.6 Descent and Approach

Only authorized published approaches as delineated in the appropriate aeronautical publications are executed under actual instrument conditions. The criteria set forth in the approach procedures is judiciously adhered to. Additionally, pilots will not accept enroute descents below MEA approaching terminal airfields unless they are within the area covered by and are above the emergency safe altitude, the minimum vectoring altitude, or the minimum sector altitude.

A. Canceling IFR

1. IFR flight plans should not be canceled during daylight when weather is unknown, reported as marginal, or when scud, haze, or other visibility restrictions are known. In these cases, all available facilities will be used to make an instrument approach, up to the point of intended landing, under IFR.

2. IFR flight plans should not be canceled during night operations until an instrument approach is initiated and then only if the terminal airfield is in sight and VFR weather conditions are reported and verified by the pilot.

3. These procedures do not prevent the Aircraft Commander from canceling IFR during an emergency or other condition when justified.

B. Approach Briefing

Before beginning every instrument approach, the Aircraft Commander will brief his crew on procedures he/she intends to follow during approach, landing and missed approach intentions. Briefing items for considerations may be, but are not limited to, the following:

1. Type of approach and landing.

2. Navigational aids to be used during an approach verified by both pilots.

3. Inbound course from FAF.

4. Weather conditions at the airfield of intended landing.

5. Pressure altimeter setting.

6. Radar altimeter setting.

7. Altimeter Call Outs to Preclude Misreading Altimeters – The pilot not flying the aircraft will call out 1,000 feet above/below ATC assigned altitude, transition level and initial approach or holding altitude. The pilot flying will check his radar or radio altimeter with the pressure altimeter during descent/approach to insure proper operation. During the approach, the pilot not flying will announce 1000 feet above minimums, 500 feet above, and 100 feet above, and when reaching precision approach Decision Height (DH) or nonprecision approach Minimum Descent Altitude (MDA). The altitude will be cross checked at the FAF for published altitude and airspeed will be called out +/- 10 kts from briefing, or deviation +/- one dot gs/loc.

8. Runway conditions and braking expected.

9. Crosswind component and specific assistance required during the landing and rollout phase.

10. Approach lighting expected.

11. Minimums and Decision Height.

12. Response of Pilot and Co-pilot – Response of pilot and copilot when the runway environment becomes visible (for example, copilot advises pilot that he has visual contact with strobes, approach lights, runway lights or runway, or pilot makes transition from complete instrument flight to that which includes the runway environment.)

13. Duty and Response – Duty and response of pilot and copilot if the runway environment is not visible at DH or MDA. (For example, copilot advises the pilot of no visual contact at decision height and both pilot and copilot go on the gages while executing the wave-off. When clear of obstructions and in stable climbing configuration, the copilot is then authorized to use radio and navigation aids as directed by the pilot.)

14 Use of reversing.

15. Use of landing lights.

16. Use of windshield wipers.

17. Alternate airport and route of flight.

18. Specific briefing on any emergency which the aircraft may be experiencing.

19. Any other pertinent information which the pilot may consider appropriate.

C. Cockpit Coordination (As Appropriate)

There is no substitute for the harmonious rapport between flight deck crews in the execution of aircraft operations. Each crewmember must know what is expected of the other during all phases of flight. A misunderstanding or an erroneous assumption on the part of either can result in a gross and unnecessary tragedy when operating near the ground in low visibility conditions where the margin of error is narrow. As the result of pairing in the cockpit of crews with various experience and proficiency levels, it is an absolute necessity that each flight deck crewmember respond to the other in the interest of safety and for the successful accomplishment of the mission.

D. Use of Approach Aids

To maintain the required degree of proficiency in instrument flying procedures, pilots are encouraged to make instrument approaches under VFR conditions.

A-1.4.7 Landing

A. Instrument Approach Minimums

Instrument approach minimums will be as published. However, in the event that RVR or other components or visual aids associated with an instrument approach are inoperative, consult the inoperative component or visual aid table for increased DH, MDA, or visibility minimums.

Note: Instrument approach minimums for NCAR/RAF may be the lowest minimums (excluding CAT II) as set forth in one of the appropriate and approved publications listed below:

1. Jeppesen Approach Manuals or Charts.
2. DOD or NOS Instrument Approach procedures.
3. DOD Flight planning Documents.
4. Host Government approach Charts.

B. After Landing Checklist

Flight deck crewmembers will not accomplish or start the after landing checklist until clear of the active runway.

SECTION B—IN FLIGHT COMMUNICATIONS

B-1 General Policy

A. Voice Communications

Voice communication is primary means of air/ground communications. Air ground communications will conform to FLIP (Flight Information Publications), ICAO (International Civil Aviation Organization) regulations where applicable, and to current briefing data for the area involved.

B. Unauthorized Transmissions

Message traffic handled by aeronautical stations and aircraft will be confined to essential operational matters. Other information is not authorized to be transmitted to ground aeronautical stations on a routine basis.

C. Use of Aircraft Interphone

Use of aircraft interphone will be in accordance with the procedures and phraseology contained in the appropriate flight manual. During ground operations, takeoff, approach and landing, or during any critical phase of flight, crewmembers will limit transmissions to those essential for crew coordination.

B-2 HF Communications

A. Initial Airborne Contact

As soon as practical after takeoff, the aeronautical station will be contacted on the recommended/assigned HF frequency.

B. Loss of HF Communications

When HF communications are lost on overwater flights, an attempt will be made to contact other aircraft to relay position reports. The SATCOM can also be used tom contact ATC Facilities. If unable to establish air/air or air/ground communications, the Aircraft Commander will proceed in accordance with ICAO or appropriate FLIP procedures.

C. Mission Within CONUS and Canada

Schedule HF communications are not required when operating within CONUS or Canada; however, on extended flights, Aircraft Commanders may use HF communications as necessary to assure positive command control of the mission. The Aircraft Commander is encouraged to use phone patch facilities when unusual reports or direct coordination is required to insure mission completion.

B-3 VHF/UHF Communications

A. Primary Uses

Normally, VHF/UHF communications will be used for air traffic control purposes when operating over the North American landmass, Europe, and other areas as specified in the appropriate FLIP.

B-4 Position Reports

A. General

Aircraft Commanders will provide the aircraft position to Air Route Traffic Control Centers (ARTCC) or controlling agency. Position reports will be given as prescribed by the appropriate FLIP.

B. Within CONUS and Canada

Normally within the Continental United States and Canada, except when otherwise specified, position reports will be transmitted in accordance with FLIP or as advised by the control agency.

C. Oceanic Areas

Primary communications selection will be at the discretion of the Aircraft Commander and will largely depend on the geographical areas of operations and the reliability of the HF frequency involved. Some of the pilots options are listed below in no particular order:

1. The Aircraft Commander may elect to transmit their position report or traffic to the ICAO station serving the ATC agency responsible for the area in which they are operating.

2. Aeronautical Radio, Inc. (ARINC) frequency is a reliable means of transmitting position reports and traffic.

D. Other ICAO Areas

Position reports will be given as prescribed by the appropriate FLIP or ICAO documents.

B-5 SELCAL

On aircraft so equipped, the Selective Calling System known as SELCAL, is available on many HF networks and provides a more desirable listening watch or guard on the working frequencies.

The Aircraft Commander and/or the Project Manager are encouraged to use the SATCOM when direct coordination is required to insure mission completion. Phone patch capabilities are also available on both VHF and HF, depending on location of the aircraft. Phone patch facilities can be used when the SATCOM is not available.

B-6 Emergency and Urgent Messages

Upon direction of the Aircraft Commander, emergency and urgent messages will be prepared and transmitted by the pilot.

B-7 ARINC

NCAR/RAF ARINC agreement # 1666 – See Attachment VII.

B-8 SATCOM/FAXCOM

SATCOM will be one of the primary means for communication when contacting facilities or project related parties when direct coordination is required to insure mission completion. (See Attachment IX for procedures).

A-1.5 Aircraft Access Before and after Missions and on Days-off

The general plan for the C-130 operations will be to have two flight days, then a maintenance day, two more flight days, a maintenance day, and finally a hard down day. This is the optimum schedule based on maintenance of instruments over a 7-day period. The schedule is preferable, but not mandatory. However, the maximum of 4 flight days of 9 hour duration in any 7-day period is fixed.

On a flight day, the aircraft will be powered on at 2 AM. The aircraft will be fueled and ready for a take-off at 4 AM. Scheduled landing will be 9 hours later at 1 PM. The aircraft will be powered on for the next hour until 2 PM.

On a maintenance day, the aircraft will be powered on during the period 6 AM - 12 Noon. The reason for these hours is that the aircrew will be on a 'night schedule'. In exceptional cases, and if the science crew has started work at 6 AM, the RAF will consider extending the maintenance day to 2 PM. Given HIAPER requirements, the RAF will have a limited crew only on Antigua. This is the main cause for specifying the limited maintenance periods upfront.

There will be no access to the C-130 on hard down days. As the experiment progresses there is a possibility that the flight schedule will change, and this may lead to a movement of the C-130 hours as well.

C-130 Crew Rest and Flight Duty Limitations:

- Any 24-hour period……………………………..10 flight hours
- Any consecutive 7 days…………………………35 flight hours
- Any 30-day period………………………………110 flight hours
- Consecutive working days………………………6 days
- Crew Duty Period………………………………14 hours
- Minimum crew rest period………………………12 consecutive hours

The above limits may be exceeded for ferry purposes at the discretion of the project pilots. The project pilot will always have the option of calling a no flight day when consecutive flights are scheduled and crew fatigue is a factor.

B-2.1 University of Wyoming Crew Duty Procedures

The University of Wyoming will have two pilots in the field in RICO so pilot crew-duty limitations should not be an issue.

Our guidelines for each pilot is stated below.

Activity	Hours
Flight in any 24 hour period	7
Flight in any 7 day period	35
Flight in any 30 day period	110
Crew duty period	14
Crew rest period	12
Consecutive work days	6 days

In theory we could fly 14 hours per day. We will need to plan for night time operations so that the pilot can get his 12 hours rest. Due to fuel considerations, our maximum duration for any one flight is 4 hours.

We have no guidelines for the rest of the crew. Since our support staff is small, we ask that consideration be given to addition crew rest be given when switching between day and night operations.

While we will be able to operate 24/7, we are requesting that at least one day per week be designated as a hard down day for the entire crew.

A-3.1 UK BAE-146

The main constraints that we have for the BAe146 are:
- aircrew require 1 rest day in every 7 and two consecutive rest days in 14.
- aircrew can be on duty for maximum 7 days
- aircrew can perform only 4 early starts in a row (where an early start is prior to 6am local time).
- crew duty starts at flight briefing 2 hours prior to scheduled takeoff
- there are restrictions on the total length of a single crew duty which would limit our ability to do a double flight on a single day if the first involves an early start.
- NOTAMs are mandatory under our operating conditions for any flight below 1000ft or where sonde-dropping is involved - this probably means every flight.

Given the requirement for at least one period of two consecutive down days during the BAE-146 detachment, The aircraft won't depart too much from this sort of schedule other than to achieve better coordination with the C-130 and King-Air. The total of 47 hours flying from Antigua is the upper limit. With our outbound transit schedule, Sunday 9 Jan is the first likely operational day.

If work starts between 0600 and 0800 local time, crew can work 13 hours total including pre and post-flight duties. If work starts between 2200 and 0600 local time, total duty would be 11 hours.

For 2 flights in the day:

Reduce 13 -> 12hr 15 min and 11 -> 10hr 15 min

The total number of duty hours per week is 55.

Crew report 2 hours before TO and are off duty 1 hour after landing. So for a 5 hr 30 min flight, the total duty would be 8 hrs 30 minutes.

Crews require 12 hrs off between duty periods. So if crew finish at 1700, they cannot report for duty until 0500 the following day.

RICO Operations Plan
Appendix C: Participant and interested scientists email adresses

Last name	Complete name	Email Address
Ackerman	Andy Ackerman	ack@fog.arc.nasa.gov
Ackerman	Tom Ackerman	Thomas.Ackerman@pnl.gov
Albrecht	Bruce Albrecht	albrecht@mail.rsmas.miami.edu
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Austin	Phillip Austin	paustin@eos.ubc.ca
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Bandy	Alan Bandy	bandyar@drexel.edu
Barth	Mary Barth	barthm@ucar.edu
Bartram	Bruce Bartram	bruce.bartram@noaa.gov
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RICO Operations Plan
Appendix D: Key Contact numbers in Antigua and Barbuda
(This list will be updated – it is current as of 11/18/2004)

Antigua:

Royal Antiguan	(268)462-3733
Jolly Harbor Villas	(268)462-6166 (Annie - Office)
Dickenson Bay Cottages	(268)462-4940
Beachcomber	(268) 462-3100
	(268) 462-2756
Carter Rental Car	(268) 463 0675 (airport)
Carib Air	(268) 562 2742
	(268) 481 2403
Barbuda Express (Boat)	(268) 773 9766
	(268) 461 9766
RICO Operation Center	(268) 480-2370 (main number)
	(268) 480 2371
	(268) 480 2372
	(268) 480 2373
	(268) 480 2374
	(268) 480 2375

Barbuda:

Palm Tree Guest House	(268)562-5058
Island Chalet	(268)773-0066 (Myra's cellphone)
Byron Askie	(268) 773 6082 (Byron’s cell)

People (on the islands)

Harry Ochs	(268) 775-4942 (cell)