REQUEST FOR LAOF SUPPORT
PASE
NCAR/EOL APRIL 2006 OFAP MEETING

PART I: GENERAL INFORMATION

Corresponding Principal Investigator

Name	**Alan Bandy**
Institution	Drexel University
Address	3142 Chestnut Street
Phone	215-895-2640
FAX	215-895-1980
Email	bandyar@drexel.edu

Project Description

Project Title	**Pacific Atmospheric Sulfur Experiment (PASE)**
Co-Investigator(s) and Affiliation(s)	Don Lenschow and Lee Mauldin (NCAR), Rodney Weber and Yuhang Wang (Georgia Tech), Barry Huebert, Steve Howell, and Anthony Clarke (University of Hawaii), Brian Heikes and John Merrill (University of Rhode Island), Ian Faloona (University of California, Davis), Jim Hudson (Desert Research Institute).
Location of Project	**Christmas Island**
Start and End Dates of Field Deployment Phase	**July 26 to Sept 7, 2007**

Abstract of Proposed Project

Pacific Atmospheric Sulfur Experiment (PASE) is a comprehensive study of the chemistry of sulfur in the remote marine troposphere. A major part of PASE (Phase I) will be devoted to the chemistry and physics (primarily of sulfur) in a cloud free convective boundary layer (CBL). Our strategy is to first understand the chemistry and physics of gases and aerosols (including CCN) in a cloud free environment before trying to understand systems containing cloud. Studies of systems containing cloud can be logically built on an understanding of cloud free systems. Phase II of PASE is dedicated to developing a better understanding of the buffer layer and formation of new particles in the cloud outflow of marine cumulus.

PASE will provide information on aerosol chemistry and physics in the remote marine atmosphere essential for developing an understanding for the Aerosol Indirect Effect (AIE) in

this region. However, as alluded to above, PASE is just a first step in this process. PASE will also explore key elements of the CLAW (Charlson, Lovelock, Andreae, Watson) hypothesis that describes how dimethyl sulfide oxidation can have important impacts on AIE. At the core of PASE is the chemistry of sulfur because much of the chemistry of AIE in the marine atmosphere involves the products of dimethyl sulfide (DMS) oxidation and their interactions with sea salt aerosols. The detailed information on sulfur chemistry of both aerosols and gases obtained in PASE will make a major contribution to understanding the link between sulfur chemistry in the marine atmosphere and resultant aerosol properties and their evolution. We expect that our measurements will allow us to test the viability of the atmospheric sulfur portions of the CLAW hypothesis even if they cannot fully resolve the issue.

Phase I of PASE will be conducted in the CBL of the marine atmosphere east of Christmas Island (Kiritimati) during a cloud free period in August 2007. This CBL is exceptionally well mixed. Its turbulence and wind fields have very small vertical and temporal variability and the very high solar intensity is ideal for driving photochemistry. The high and spatially uniform DMS flux is another important characteristic. The region for Phase II which will revisit new particle formation in cloud outflow must be selected in the field. Sufficient cloud should be present especially during unstable periods which occur every few days. If not then flights toward the intertropical convergence zone should intercept sufficient cloud for the experiment. A mission meteorologist will be onsite with phone, internet and fax communications to help plan these flights throughout PASE.

State of the art instruments will be used to make accurate and high speed airborne determinations of sulfur dioxide (SO_2), dimethyl sulfide, dimethyl sulfoxide (DMSO, dimethyl sulfone ($DMSO_2$), methane sulfonic acid (MSA), hydroxyl radical (OH), ammonia (NH_3), water vapor (H_2O), ozone (O_3), hydrogen peroxide (H_2O_2), methyl hydrogen peroxide (CH_3OOH), liquid water, temperature, pressure, wind velocity. DMS, SO_2, H_2O and O_3 will be determined at 25 samples per second allowing vertical fluxes of these species to be determined by eddy correlation. Chemical budgets for these species can be calculated from the concentrations and fluxes of these species. These budgets will contain valuable information on chemistry in general but specifically on their chemical formation and destruction rates.

The entire suite of aerosol probes available for C-130 will be flown. In addition, PI's will measure size and volatility (0.15-10.0 um), size and volatility (0.01-0.3 um), size resolved mixing state, refractory and volatile number, ultrafine number concentration, absorption coefficient (Black Carbon), whitecap/bubble coverage, size integrated ambient total ions around a circle, leg average size resolved ions, coarse particle size distribution, fast submicron aerosol ion composition, CCN concentration and supersaturation spectrum. Aerosol non-sea salt sulfate (NSS), methane sulfonate (MS), sodium, ammonium, calcium, magnesium, nitrate, oxalate, chloride, bromide and organic carbon will be determined using filter and impactor methods, integrated over 30 minute constant-altitude legs.

As stressed above, Phase I of PASE is a study of the chemistry and physics of a cloud free marine CBL. From time series obtained in 9 hour nighttime and daytime flights in a well mixed cloud free convective boundary layer (CBL), the time evolution of gases, aerosols (including composition as a function of size), and CCN in a system free of liquid water will be obtained perhaps for the first time. PASE data will provide restraints for models of aerosols, gases and CCN in dry systems that are necessary for understanding and modeling systems containing liquid water.

PHASE I of PASE will be conducted in a Lagrangian framework similar to that used in the Dynamics and Chemistry of Marine Stratocumulus Study (DYCOMS) I and II programs. The Lagrangian framework allows the budgets of dynamical properties, H_2O, O_3, DMS, and SO_2 to be determined experimentally.

Using entrainment models for transport across the CBL top, similar budgets will be derived for aerosols and gases which are not determined fast enough for the fluxes at the CBL top to be obtained by the eddy correlation technique. Faloona et al. (2005) showed that in DYCOMS II, fluxes of DMS, O_3, and H_2O at the CBL top and concentration jumps across the CBL top could be used to compute entrainment velocities with which the fluxes of species measured at slower rates could be determined. This is more easily done at Christmas Island than for the stratocumulus case in DYCOMS due to the lack of cloud that would interfere with the H_2O measurements. Examples of gases in this category of more slowly measured species are DMSO, $DMSO_2$, H_2O_2, NH_3, MSA, H_2SO_4 and CH_3OOH.

The use of entrainment velocities and measured jumps across the CBL top also can be used to compute the fluxes of CCN and aerosol at the CBL top. Using some assumptions, fluxes of CCN and aerosol at the ocean surfaces can be estimated. Another intriguing hypothesis that can also be tested is that small particles are formed by wave breaking that grow by accreting H_2O and H_2SO_4 and that these particles with a sea salt core are also CCN.

The fluxes of CCN and aerosol at the CBL top allow several models of the source of aerosol and CCN to be tested. Since the formation of new particles in the CBL is rarely observed there must be other sources. One hypothesis advanced by Raes and Clark is that the new particles are formed in the free troposphere, particularly in cloud outflow (Hobbs et al., Clarke et al.), and are later brought into the trade wind system and then to the CBL where they grow into larger particles by accreting H_2O and H_2SO_4. The underlying hypothesis is that these particles are or will become CCN.

The origin of small particles and their growth to larger particles and CCN are core issues in developing an understanding of AIE and in testing CLAW. Note, however, as mentioned above PASE is a first step in developing an understanding of AIE and in testing CLAW since it is done in a simplifying cloud free CBL,

Detailed modeling of the chemistry and dynamics of the marine trade wind regime is an integral part of PASE. In phase II issues such as the photochemical formation of small particles of sulfuric acid in the outflow of cumulus cloud will be investigated and evaluated for their potential to grow to CCN by accreting gases such as water vapor, sulfur dioxide, sulfuric acid, and ammonia. The formation of nanometer size sea salt preCCN will be studied including their potential growth to CCN. Loss of SO_2 and H_2SO_4 acid to aerosol surface area, including sea salt near the ocean surface, will be intensively studied.

Finally the research described can be perceived as part of a longer term effort of atmospheric scientists to understand the chemistry and physics of the marine atmosphere. A representative specific goal of this perceived long term effort is to develop accurate mathematical representations of the aerosol indirect effect (AIE) in marine cloud which is a major cooling term in Earth's radiation budget. Another specific goal is to test the viability of the CLAW hypothesis.

The marine atmosphere, however, is an exceedingly complex place. So much so in fact, reliable models of AIE and quantitative tests of CLAW have so far eluded atmospheric scientists. Although exceeding difficult, these issues are sufficiently important to justify the long term goals of understanding and quantifying AIE and testing CLAW.

PROPOSAL SUMMARY

What are the scientific objectives of the proposed project?

PASE is a comprehensive study of the chemistry and physics (primarily of sulfur) in the remote marine troposphere. Phase I of PASE is devoted to the study of a cloud free convective boundary layer (CBL). The strategy is to first understand the chemistry and physics of gases and aerosols (including CCN) in a cloud free environment. Studies of systems containing cloud can be logically built on an understanding of cloud free systems. Phase II of PASE is dedicated to developing a better understanding of the formation of new particles in the cloud outflow of marine cumulus.

What are the hypotheses and ideas to be tested?

We have placed much of this material in the abstract. Included here is similar material presented in a slightly different form.

Existing models of sulfur chemistry have never been challenged with comprehensive sulfur observations that include measured fluxes of DMS and SO_2 at the top and bottom of the CBL. Our observational capabilities have advanced so significantly that we can now constrain budgets of many species with few if any assumptions, making it possible to answer a variety of climate-relevant questions: What fraction of DMS becomes SO_2? How significant is the entrainment of SO_2 and particle number from the FT? Do the diurnal variations of the various species agree with existing sulfur photochemical kinetic models? What fractions of SO_2 go to dry deposition, cloud processing, sea salt oxidation, and sulfuric acid vapor formation? How important is ammonia for particle nucleation and growth? Do new particles form in the trade wind boundary layer, and if so what is the relevant chemistry? (H_2SO_4 is certainly a key player in the tropics.) How significant are preCCN from wave and bubble breaking over the open ocean vs formation in the outflow of cumulus clouds? How important is preCCN entrainment into the boundary layer? Is gas phase halogen chemistry important in the remote trade wind regime? (Our halogen measurements will be limited by the C-130 payload.) How much SO_2 is lost to aerosol vs the sea surface? What is the exchange coefficient for sulfur dioxide at the sea surface?

The answers to these questions will make models of the atmospheric portions of the CLAW hypothesis more accurate. *Since chemical transport models and climate models will be the users of our results, we propose to invite (indeed, encourage) all interested modelers to participate in our second (12 month) data workshop, to get them started using this unique data set.*

What previous experiments of similar type have been performed by you or other investigators?

RICO, DYCOMS I and II, ACE-1, PEM Tropics-A, ACE ASIA, PELTI

Give references of results published and explain how the proposed experiment and the use of the requested facilities go beyond what has already been done.

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Lenschow, D. H., et al., Use of a mixed-layer model to estimate dimethylsulfide flux and application to other trace gas fluxes, Journal of Geophysical Research, 104, 16275-16295, 1999.

Mitchell, G. M., Determination of vertical fluxes of sulfur dioxide and dimethyl sulfide in the remote marine atmosphere by eddy correlation and an airborne isotopic dilution atmospheric pressure ionization mass Spectrometer, Ph.D. Dissertation, Drexel University, 2001.

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Thornton, Donald C., Alan R. Bandy, Fang H. Tu, Byron W. Blomquist, Glenn M. Mitchell, Wolfgang Nadler, Donald H. Lenschow, Fast Airborne Sulfur Dioxide Measurements by Atmospheric Pressure Ionization Mass Spectrometry(APIMS), Journal of Geophysical Research, 107 (D22), 4632 doi:10.1029/2002JD002289, 2002

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The papers listed above were developed from the following field programs: Drexel Christmas Island Campaign, ASTEX, PEM Tropics A and B, ACE 1, ACE Asia, TRACE P, DYCOMS I and II. The PI was a member of the science team of all of these programs. Although important these experiments provided windows of limited size and clarity into the chemical and physical processes in the marine environment. The reasons varied from experiment to experiment but there were three main reasons: 1. The experiment had many objectives other than studies of the marine atmosphere so there was a lack of focus, 2. The study region was a poor choice because of meteorology, presence of cloud, pollution or because the DMS source was too weak and/or spatially or temporally too variable, 3. The instrument payload was not adequate.

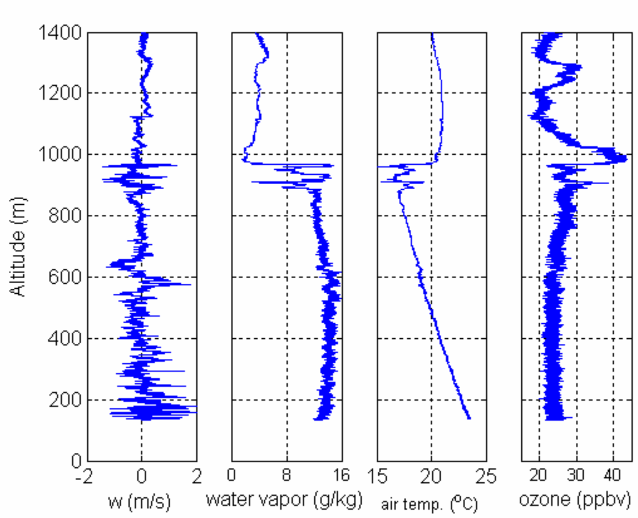

Figure 1 Soundings for vertical velocity, water vapor, air temperature and ozone in the Christmas Island trade wind system. The convective boundary layer (CBL) extends from the surface to about 630 m. The buffer layer (BuL)

PASE is different is several ways. ≈70% of the program is focused on the chemistry of a small region: the marine CBL, 2. The region has excellent meteorology for budget work and pollution is insignificant for the chemical processes studied, 3. The DMS source is large and uniform, 4. The PI's are highly experienced and the payload is comprehensive and contains the best instruments available. Finally the NCAR C130 has good payload characteristics and an excellent set of standard instruments and can fly legs altitudes as low as 30 m. Also the C130 pilots are experienced in flying the advected circles used in Phase I of PASE.

How will the instruments/platforms requested be used to test the hypotheses and address each of the objectives?

The C130 has a large suite of instruments that provide essential information for interpreting data obtained by PI instruments. Some examples of these data are aircraft location and altitude, winds, temperature, O_3, H_2O (liquid and vapor), upwelling and downwelling solar radiation and aerosol size distribution.

What results do you expect and what are the limitations?

Again much of the material appropriate in this section was included in the abstract and a previous section. Some additional details, however, are included here.

During the daytime the driving force will be the photooxidation of DMS. Reaction of DMS with OH is the major initiator. This oxidation has two paths. The first involves extraction by OH:

$$(CH_3)_2S + OH \rightarrow CH_3SCH_2\bullet + H_2O \tag{0.1}$$

Current wisdom is that this channel leads to SO_2 with relatively high efficiency. The other channel occurs through OH addition

$$(CH_3)_2S + OH \rightarrow (CH_3)_2SOH \tag{0.2}$$

Oxygen then extracts the active hydrogen producing dimethyl sulfoxide (DMSO)

$$(CH_3)_2SOH + O_2 \rightarrow (CH_3)_2SO + HO_2 \tag{0.3}$$

OH also adds quickly to DMSO

$$(CH_3)_2SO + OH \rightarrow (CH_3)_2S(O)OH \tag{0.4}$$

Oxygen again extracts the active hydrogen producing dimethyl sulfone ($DMSO_2$)

$$(CH_3)_2S(O)OH\ + HO_2 \rightarrow (CH_3)_2SO_2 \tag{0.5}$$

The valence of $DMSO_2$ is saturated and thus does not react by addition of OH. However, it can react by OH extraction but this is thought to be quite slow. Current wisdom suggests that $DMSO_2$ is lost to aerosol and the sea surface.

The addition channel is thought to be the main channel for producing MSA with a minor amount of SO_2, however to a large extent this is intuition with little field data supporting it. Except for the clear anticorrelation of DMS and SO_2 during daytime the available field data do not at all follow that predicted by models. Phase I of PASE should provide very important data for understanding the serious disagreement between models and observations for the addition channel.

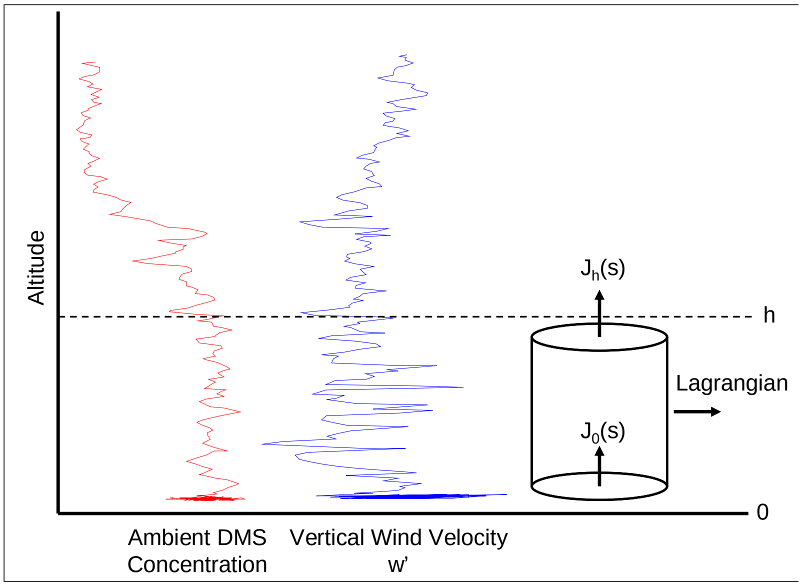

Figure 2 Soundings DMS and vertical velocity (1 Hz) for the trade wind regime east of St. Croix. The CBL depth is h and is about 800m.

The formation and destruction of will also he observed during nighttime and daytime. Because the field data is limited and from systems that were complicated meteorologically the picture of H_2SO_4 chemistry remains uncertain. PASE is designed to dramatically improve our knowledge of the chemistry of this substance.

Some of the most important chemistry is summarized here. SO_2 is converted to H_2SO_4 by the following gas phase processes

$$\begin{aligned} &SO_2 + OH \rightarrow SO_2\,OH \\ &SO_2\,OH \rightarrow SO_3 + HO_2 \\ &SO_3 + H_2O \rightarrow H_2SO_4 \end{aligned} \tag{0.6}$$

In most environments the primary sink of H_2SO_4 is adsorption on aerosol. Many of the fluctuations of H_2SO_4 are caused by changes in the aerosol surface area on which the concentration of H_2SO_4 strongly depends.

Finally both SO_2 and H_2SO_4 can absorb into aerosol creating NSS. SO_2 tends to adsorb and be oxidized in the larger aerosols which are more basic than smaller aerosol although this picture is far from being complete. H_2SO_4 can react with H_2O to produce ‘new’ nm size particles and adsorb onto these and other particles to grow into aerosol having sizes in the 0.1 to 1 nm size range.

In the marine environment intuition and some evidence indicate some of the particles in the 0.01 to 1 nm size range are either CCN or precursors of CCN. Unfortunately this important picture is incomplete. Completing this picture for the cloud free environment is a major goal of PASE. The very long nighttime and daytime time series for all the species and parameters measured in PASE should go a long way in filling in this picture for the cloud free environment. Again it is emphasized that the cloud free picture will be a logical foundation on which future programs containing cloud can be logically built.

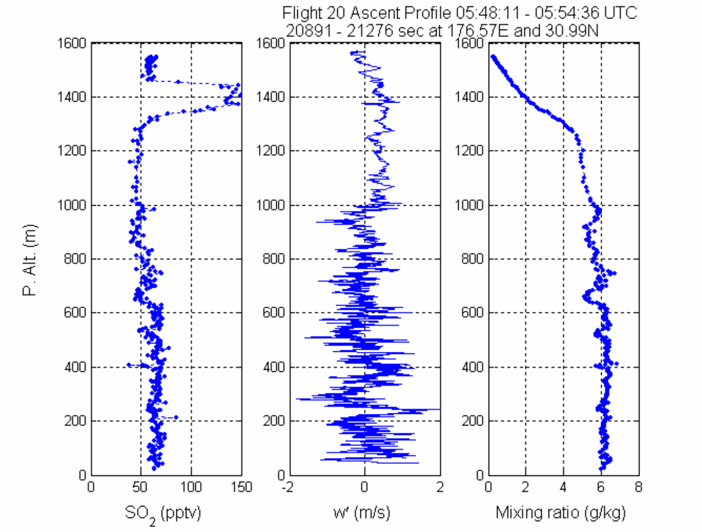

Figure 3 Vertical profiles for SO_2, vertical wind velocity and moisture mixing ratio for the Midway Island region. In this system the CBL extended to about 1 km with the buffer layer between 1 and 1.3 km. The SO_2 layer at about 1.4 km is in the free troposphere.

Provide details about the experiment design:

The study region

PASE will be conducted east of Christmas Island (Kiritimati, 2 N, 157 W). This region was chosen because its chemistry and meteorology are well characterized and it is an ideal outdoor laboratory to study the chemistry of DMS. The chemical and aerosol characteristics have been reported by Bandy et al. [1996], Huebert et al., [1996], Clarke et al. [1996], Davis et al. [1999], and Chen et al. [2000]. The meteorological characteristics were reported by [Lenschow et al., 1999]. These investigations contain considerable detail so only the most relevant characteristics will be discussed here.

Christmas Island is in the southeast trade wind regime, far from anthropogenic sources of sulfur. Soundings of the 25 Hz vertical velocity, water vapor mixing ratio, air temperature and ozone are shown in Figure 1. The CBL is characterized by a region of high and uniform fluctuations in vertical velocity that imply effective and rapid vertical mixing. Typical of turbulent layers, the sounding of water vapor is almost constant up to the CBL top where it rapidly decreases. The BuL is less well mixed because turbulence is weaker and intermittent. The top of the BuL is characterized by a further large drop in turbulence, water vapor, DMS, etc. at the trade wind inversion. Above the BuL is the free troposphere.

An important property of the Christmas Island trade wind regime in August and eptember is that there are long periods during which few clouds exist, especially in the CBL [Bandy et al., 1996]. The budget studies of PASE will be carried in one of these common, very stable, nearly cloud-free periods in August. However, aging, growth, and uptake onto aerosol will be enhanced in the small non-precipitating clouds that are often present in the BuL [Bandy et al., 1996].

Studies of cloud processing is an important component of PASE. Focus will be on both the nonprecipitating clouds that are often present in the BuL layer and above during the stable periods and the outflow of convective cumulus clouds that penetrate the trade wind inversion and often appear at the end of stable periods.

The characteristics of the CBL appear to be a general property of the marine trade wind regime. The soundings for DMS and vertical velocity in Figure 2 were obtained in the northeast trade wind regime in the Atlantic east of St. Croix, VI. Soundings for SO_2, vertical velocity and water vapor mixing ratio for Midway Island in the Pacific are shown in Figure 3. Each of these trade wind regimes has a turbulent, well mixed CBL and a less well mixed BuL.

Because fluxes and time derivatives of concentrations are the variables to be measured in this study, requirements of homogeneity are greatly reduced (Lenschow, private communication) compared to previous studies of the Christmas Island trade wind regime [Bandy et al., 1996; Chen et al., 2000; Davis et al., 1999]. However, homogeneity makes data analysis easier and to some extent more precise.

East of Christmas Island for a few hundred kilometers, the ocean appears to have a reasonably homogeneous flux of DMS. Evidence of this homogeneity was obtained in Mission 7 of PEM Tropics A that was flown over a track 100 km in length just east of Christmas Island. In this mission level legs were flown as circles 60 km in diameter (30 minutes in length) that were advected with the mean wind. The variability of the concentrations along the track was small and very repeatable [Lenschow et al., 1999] and fit on a smooth curve determined by the photochemistry of the system [Davis et al., 1999]. To draw this inference of homogeneity it is useful to recognize that the CBL mixes vertically within the CBL in less than 0.5 hours (I. Faloona and Don Lenschow, private communication). Horizontal mixing is slower, so any change in surface flux quickly appears as a change in DMS around the circle. Systematic changes of this type were not observed at Christmas Island [Lenschow et al., 1999]. Finally, Bandy et al. [1996] reported a repeatable diel variations of DMS and SO_2 and Huebert et al. [1996] reported repeatable diel variation of NSS and MSA over 4 days that could not have been achieved unless the upstream DMS flux was reasonably uniform and constant.

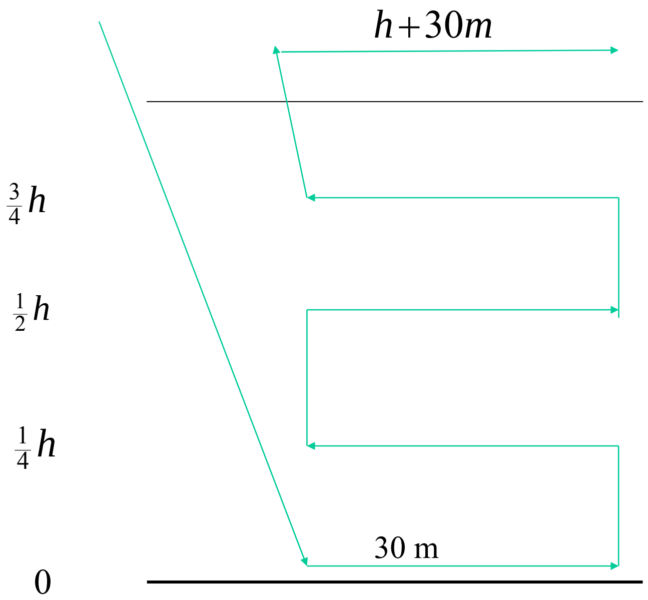

Figure 4 Flight profile for budget studies.

Flight Plans

CBL budgets for DMS, SO_2, O_3, H_2O and possibly DMSO and $DMSO_2$ will be determined using the flight plan shown in Figure 4. Each set of legs will begin and end with a sounding to identify the top (h) of the CBL by locating the large decrease in variance of vertical velocity at the top of the CBL. Thirty-minute circles will then be flown at 30 m, h/4 , h/2, 3/4h and h+30m. This will be repeated 4 times. For nighttime missions the 30 m level can be flown only in daylight or twilight (for safety reasons). It is noteworthy that the soundings will be performed at 800 ft min^{-1} so the total expected duration for the sounding is about 3 min. The column concentrations of DMS, SO_2, DMSO, $DMSO_2$, and many other species will be obtained from these soundings, while the column concentrations of the aerosol species will be derived by averaging the four 30 minute samples for each stack. Since there will be 4 soundings per flight there will be 4 determinations of the column concentrations of these 4 species, separated by about 2.5 hours. We will compute 3 time derivatives of concentrations of DMS, SO_2, DMSO, $DMSO_2$, and many other gases from these data. For the aerosols we will derive two time derivatives from the three stacked sets of circular legs.

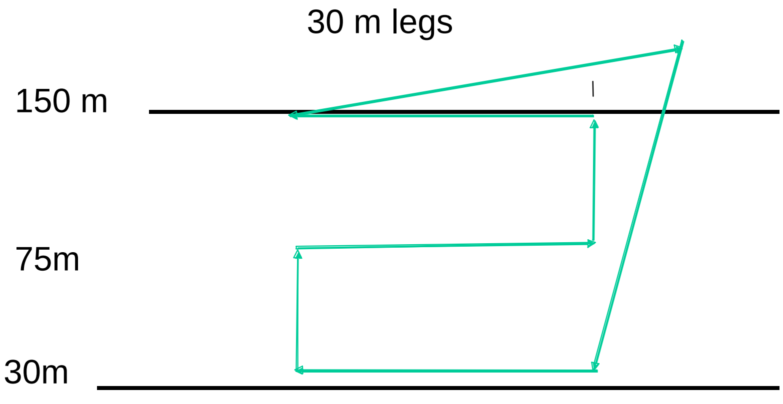

Figure 5 Profiles for studying the CBL near the sea surface.

Near-surface budgets of gases, aerosols and CCNwill be determined using the flight profiles shown in Figure 5. To minimize the impact of any variation in surface flux these studies will be flown over the same circle geographically to the extent possible, without entering the aircraft plume. These profiles will be flown 5 times per mission. Most of this flight will be flown under low light conditions to minimize photochemistry.

Note that recently RAF was given permission to perform unrestricted night operations from Kiritimati so many of the experiments designed for low light conditions can be flown in the dark. The lowest levels must be flown with some daylight as determined by the pilots. This has the advantage of studying chemistry during the transition from dark to twilight which may be important for detecting the presence of halogen chemistry although this is not one of the major goals of PASE.

METEOROLOGICAL FRAMEWORK

As described in 3.1.1 the experiment will be carried out in the well mixed CBL east of Christmas Island. For this CBL the following budget approach provides the basis for interpreting data to be obtained in this study.

The budget for scalar s is given by the relationship

$$\frac{\partial \bar{s}}{\partial t} + \bar{u}\frac{\partial \bar{s}}{\partial x} + \frac{\partial \overline{s'w'}}{\partial z} = f(s) - d(s) \qquad (1.1.1)$$

The rate of change of each species is controlled by horizontal advection, vertical fluxes, formation, and destruction. Here s is the concentration of scalar s, $\bar{u}$ is the mean wind speed along the mean wind direction, x is the direction of the mean wind, w is the vertical velocity, z is the altitude, and $\overline{s'w'}$ is the eddy flux at the altitude z. Also f(s) is the chemical formation rate and d(s) is the chemical destruction rate of s.

Integrating (1.1.1) from the surface through the top of the CBL yields

$$\frac{\partial \overline{<s>}}{\partial t} + \bar{u}\,\frac{\partial \overline{<s>}}{\partial x} - \bar{u}\,\Delta s\frac{\partial h}{\partial x} - J_0(s) + J_h(s) = F(s) - D(s) \qquad (1.1.2)$$

where angle brackets denote a column concentration for the boundary layer defined by

(1.1.3)

Here h is the depth of the CBL, $J_o(s)$ is the flux at z=0, $J_h(s)$ is the flux at z=*h*, F(s) is the column chemical formation rate of s, and D(s) is the column chemical destruction rate of s. All missions will be flown in the Lagrangian framework (drifting patterns with the wind) so that $\bar{u}=0$. Equation (1.1.2) then simplifies to:

$$\frac{\partial <s>}{\partial t} - J_o(s) + J_h(s) = F(s) - D(s) \qquad (1.1.4)$$

All the terms on the left can be measured for DMS, H_2O, O_3 and SO_2. Budget analyses described below are based on (1.1.4).

How will (1.1.4) be used in this study?

The variable s represents the concentrations of O_3, SO_2, DMS, H_2O, or any other scalar quantity. Each of the terms has the units of flux, e.g., pptv m s^{-1} or molecules $m^{-2}s^{-1}$. As illustrated in Figure 2, (1.1.4) represents the conservation of mass of s in a cylinder that is moving at the mean wind speed along the direction of the mean wind. The chemical formation and destruction terms contain gas phase processes as well as gas-to-particle and particle-to-gas conversions. These issues are discussed in further detail in 3.5.

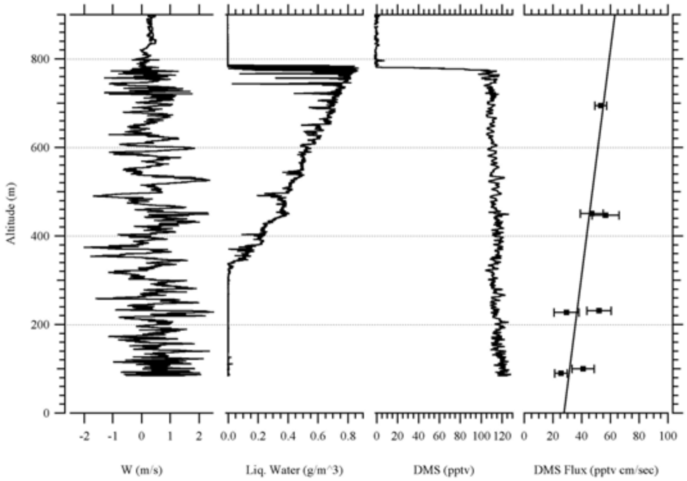

Figure 6 Soundings for vertical velocity, liquid water, DMS and DMS vertical flux. The slope of the DMS vertical flux curve is the vertical flux divergence of DMS.

DMS data obtained during DYCOMS II illustrate the budget process. This program was a study of the dynamics of the stratocumulus regime west of San Diego that was conducted in the summer of 2001. The legs in the CBL were flown as 30 min circles, just as planned in PASE. Soundings for vertical wind velocity, liquid water, DMS and DMS flux are shown in Figure 6. (The stratocumulus region near San Diego is a one-layer system, so there is no BuL.). The CBLs of the stratocumulus and trade wind regimes are dynamically similar. Note the high uniform turbulence in the CBL as illustrated by the fluctuations in vertical velocity in the CBL and the transition to very low fluctuations at the top of the CBL. The almost constant DMS levels in the CBL reflect good vertical mixing. The flux of DMS increases with altitude in this case because dry, DMS-free air is being entrained at the CBL top and the DMS must be brought from lower altitudes to keep the DMS concentration constant with altitude. Note that the slope of the DMS flux vertical profile is the flux divergence of DMS.

Extrapolation of the DMS flux profile to the surface yields 27.5 pptv cm $s^{-1}$for the surface flux of DMS, J_0(DMS), and extrapolation to the CBL top yields 62 pptv cm s^{-1} for the flux for DMS at the CBL top, J_h(DMS). This is a general strategy for obtaining these two important quantities in the chemical budgets of the CBL. Computation of the time derivative of the column concentration of a scalar is straightforward and is described in 3.2.1.

Strategy for computing real world chemical budgets

Because all terms on the left side of **(1.1.4)** will be experimentally determined, it is convenient to rewrite it in the form:

$$C(s)=F(s)-D(s) \tag{1.1.5}$$

where C(s) represents the difference between chemical formation and destruction, and can be experimentally determined:

$$C(s)=\frac{\partial <s>}{\partial t}-J_o(s)+J_h(s) \tag{1.1.6}$$

The program to determine complete CBL budgets will be designed so that one set of legs is flown at night. C(s) can be conveniently divided into nighttime processes that occur all the time and daytime processes that occur only during the daytime.

$$C(s)=F_n(s)-D_n(s)+F_g(s)-D_g(s) \tag{1.1.7}$$

$$C^{'}(s)=F_g(s)-D_g(s) \tag{1.1.8}$$

$$C_n(s)=F_n(s)-D_n(s) \tag{1.1.9}$$

$$C^{'}(s)=C(s)-C_n(s) \tag{1.1.10}$$

$F_g(s)$ and $D_g(s)$ are photochemical terms and are assumed to be gas phase processes as indicated by a g subscript. By flying one leg set at nighttime, $C_n(s)$ is obtained. Using standard propagation of errors techniques, the error in C(s) is obtained from the equation:

$$\delta C(s)=\sqrt{\left(\delta\frac{\partial<s>}{\partial t}\right)^2+[\delta J_o(s)]^2+[\delta J_h(s)]^2} \tag{1.1.11}$$

$$\delta C'(s)=\sqrt{[\delta C(s)]^2+[\delta C_n(s)]^2} \tag{1.1.12}$$

To estimate errors, $C_n(s)$ is assumed to be 10% of C(s). Therefore

$$\delta C'(s)=\sqrt{[\delta C(s)]^2+[0.1\delta C(s)]^2}\approx\delta C(s) \tag{1.1.13}$$

Although not as precise or complete there is another approach that requires only vertical profile data and does not require flux measurements. The full budget equation can be rearranged to yield

$$\frac{\partial <s>}{\partial t}=[J_o(s)-J_h(s)+F_n(s)-D_n(s)]+F_g(s)-D_g(s) \tag{1.1.14}$$

$$C'(s)=\frac{\partial <s>}{\partial t}-\left[\frac{\partial <s>}{\partial t}\right]_n=F_g(s)-D_g(s) \tag{1.1.15}$$

This approach assumes that the terms in square brackets in (1.1.14) do not change rapidly with time and is the preferred approach for a species that cannot be determined at 25 sps but can be determined at 1 sps or faster.

Propagation of errors in C(SO_2)

In this section the propagated errors in C(s) are computed for SO_2. The same strategy can be used to compute the propagated error in C(s) for DMS, DMSO and $DMSO_2$. Propagated errors for these species are summarized in Table 1.

From the soundings $<SO_2>$ can be computed at two different times, t_1 and t_2. From these data the time derivative of the SO_2 column concentration at each leg can be computed:

$$\frac{\partial \overline{< SO_2 >}}{\partial t} = \frac{< SO_2 >_2 - < SO_2 >_1}{t_2 - t_1} \tag{1.1.16}$$

The contribution of errors from instrumental noise is now computed for each sounding. At a data rate of 25 sps, 4500 measurements of SO_2 are obtained in each 180 s sounding. At a typical sensitivity of 60 counts per second per pptv and 60 pptv of ambient SO_2, a total of 648,000 counts are obtained in the 180 s interval. The standard deviation of this signal is the square root of the counts, which is 805. Here the error is estimated using the average of the SO_2 in the soundings. Note that this approximation is used only in making error estimates and not in the actual data processing.

The confidence interval for errors arising from detector noise is computed from the equation

$$Confidence\ Interval(95\%) = \frac{t\sigma}{\sqrt{N}} = \frac{1.96 * 805}{\sqrt{4500}} = 24\,counts \tag{1.1.17}$$

Here t is the two tailed t value (1.96), σ is the standard deviation of the signal in counts (805 counts) and N is the number of measurements (4500). In pptv the confidence interval is

$$Confidence\ Interval\ in\ pptv\,(95\%) = \frac{24\,counts}{60\,counts\ pptv^{-1}} = 0.4\ pptv \tag{1.1.18}$$

Therefore

$$\delta \frac{\partial < SO_2 >}{\partial t} = h\left(\delta \frac{d[SO_2]}{dt}\right) = \frac{1000m * \sqrt{(0.4^2 + 0.4^2)\ pptv^2}}{7200\,s} = 0.08\,pptv\,ms^{-1} \tag{1.1.19}$$

Here the height of the boundary layer was assumed to be 1000 m and the error in the boundary layer height was negligible compared to other errors. Also the time between soundings is about 7200 s.

The error in the surface flux, $\delta J_o(SO_2)$, is computed using the fact that the eddy flux measurement technique can determine SO_2 fluxes to about 10% [Mitchell, 2001]. The surface flux of SO_2 on Christmas Island is estimated using the deposition velocity parameterization for J_0:

$$|J_o(SO_2)| = \upsilon_d[SO]_0 = 0.01\,ms^{-1} * 60\,pptv = 0.6\,pptv\,ms^{-1} \tag{1.1.20}$$

where v_d is the deposition velocity and $[SO_2]_0$ is the SO_2 concentration just above the ocean surface. The estimated error in the deposition velocity is 10% so the absolute error in $J_o(SO_2)$ is 0.06 pptv m s^{-1}.

The error in the flux at the CBL top would also be about 10% [Mitchell, 2001]. The entrainment velocity at the CBL top is about -0.005 m s^{-1}. The jump in SO_2 is assumed to be 60 pptv. The estimated flux at the boundary top is

$$|J_h(SO_2)| = w_e\Delta[SO]_h = 0.005\,ms^{-1} * 60\,pptv = 0.3\,pptv\,ms^{-1} \tag{1.1.21}$$

Since this flux also can be determined to 10%, the error is $\delta J_h(SO_2) = 0.03$ pptv m s^{-1}. Assuming that $C_n(s)$ is 10% of C(s) the total error in C'(s) is 0.1 pptv m s^{-1}.

To put these errors into perspective, the formation rate of SO_2 is about 2 pptv m s^{-1} [Bandy et al. 1996; Mitchell 2001] so a 0.1 pptv m s^{-1} error in C'(SO_2) yields a relative propagated error of ≈5%.

Table 1. Estimates for uncertainty calculations

Molecule	ν[1]	w[2]	h[3]	s[4]	J_0[5]	J_h[6]	δJ_0[7]	δJ_h[8]	<s>[9]	δ(d<s>/dt)[10]	δC'(s)[11]
SO_2	0.01	0.01	1000.00	60.00	0.60	0.30	0.06	0.03	60000.00	0.08	0.10
DMS	NA	0.01	1000.00	150.00	2.00	0.75	0.20	0.08	150000.00	0.12	0.25
DMSO	0.01	0.01	1000.00	20.00	0.20	0.10	0.02	0.01	20000.00	0.04	0.05
$DMSO_2$	0.01	0.01	1000.00	20.00	0.20	0.10	0.02	0.01	20000.00	0.04	0.05

[1] Deposition velocity (ms^{-1})
[2] Entrainment velocity (ms^{-1})
[3] CBL depth (m)
[4] Concentration (pptv)
[5] Surface flux (pptv m s^{-1})
[6] flux at CBL top (pptv m s^{-1})
[7] Error surface flux (pptv m s^{-1})
[8] Error in flux at CBL top (pptv m s^{-1})
[9] Column concentration (pptv m^{-2})
[10] Error in time derivative of s (pptv m s^{-1})
[11] Error in C'(s) (pptv m s^{-1})

Daytime Studies

The daytime studies must consider the fact that some species such as SO_2, DMSO and $DMSO_2$ can be destroyed by reaction with aerosol as well as photochemical processes. Loss to aerosol and photochemistry will be separately evaluated by flying a series of legs shown in Figure 4.

During daytime

$$C'(SO_2) = F_g(SO_2) - D_g(SO_2) \qquad (1.1.22)$$

$$C'(DMS) = -D_g(DMS) \qquad (1.1.23)$$

$$C'(DMSO) = F_g(DMSO) - D_g(DMSO) \qquad (1.1.24)$$

$$C'(DMSO_2) = F_g(DMSO_2) - D_g(DMSO_2) \qquad (1.1.25)$$

The gas phase formation rate of DMS is assumed to be negligible. The photochemical loss rate of SO_2 due to reaction with OH is slow and can be computed with small relative error. For example the reaction of OH and SO_2 has a rate constant of 3.88 x 10^{-13} cm^{3}molecule^{-1}s^{-1}. The concentration of SO_2 is about 60 pptv or 1.47 x 10^9 molecules cm^{-3}, the daytime averaged OH is about 10^6 molecules cm^{-3} and the depth of the CBL is about 1000 m. Using these estimates D(SO_2) from photochemistry is estimated to be 0.023 pptv m s^{-1}. Taking a conservative estimate of error of 30%, the contribution of this term to the overall error is 0.015 pptv m s^{-1} which is acceptable. For convenience this correction is included in C'(SO_2). Therefore,

$$C'(SO_2) = F_g(SO_2) \qquad (1.1.26)$$

The efficiency of conversion of DMS to SO_2 can be computed:

$$\%Eff = 100\frac{|F_g(SO_2)|}{|D_g(DMS)|} \qquad (1.1.27)$$

Here %Eff is the efficiency of conversion of DMS to SO_2 and ranges from 0 to 100%. To estimate an error in %Eff, the formation rate of SO_2 is assumed to be 1 pptv m s^{-1} and the destruction rate of DMS is assumed to be -2 pptv m s^{-1}. Using the data in Table 1 leads to a propagated error in %Eff of 15%. If the experiment is repeated 5 times the propagated error would be reduced to 7%.

The rate of reaction of OH and $DMSO_2$ is probably negligible compared to other processes such as the loss to aerosol [Davis et al., 1998], so the gas phase chemical column destruction rate of $DMSO_2$, $D_g(DMSO_2)$, is negligible. Consequently, $F_g(DMSO_2)$ is uniquely determined:

$$C'(DMSO_2)=F_g(DMSO_2) \tag{1.1.28}$$

The fraction of DMS leading to DMSO can be approximated by that which is not converted to SO_2:

$$F_g(DMSO)=\left|D_g(DMS)\right|\left(1-\frac{\%Eff(SO_2)}{100}\right) \tag{1.1.29}$$

In this way the destruction rate of DMSO can be determined as a function of time. Also the efficiency of the formation of $DMSO_2$ from DMSO can be estimated

$$\%Eff=100\frac{\left|F_g(DMSO_2)\right|}{\left|D_g(DMSO)\right|} \tag{1.1.30}$$

Nighttime circles are flown in the same way as the daytime circles except that the 30 m leg must be flown in twilight for safety reasons.

Full Nighttime Budgets.

At night we assume (for now) that the chemical formation rates of most s are negligible. Hence

$$C(s)=-D(s) \tag{1.1.31}$$

D(s) is probably negligible for DMS but not necessarily for the other species where it contains a contribution from loss to aerosol..

Studies of s just above the ocean surface

Just above the ocean surface a layer of basic sea salt particles having large surface area is thought to remove s. Several missions will be flown to provide quantitative determination of the removal of s by aerosol. This study will be focused on the region below 150 m where a large fraction of the loss of s to aerosol is expected [Suhre et al., 1995]. In this study 3 circles will be flown at 30, 75, and 150 m. Three flight levels were chosen because the reactivity of s in this region may change with height producing nonlinear changes in J (s) with height within this layer. The choice of three levels was a compromise between available time on station and the need to account for this nonlinear behavior. The 30 and 150 m circles will be flown during twilight for safety reasons.

The relative contribution of loss of s to the sea surface and loss of s to aerosol can be estimated. The budget equation for s in integral form for this region from the surface to 150m is

$$C(s)=-D(s) \tag{1.1.32}$$

$J_0(s)$ is the true surface flux that will be obtained by fitting the fluxes at 30, 75 and 150 m to a quadratic and then extrapolating J(s) to the surface to obtain $J_0(s)$. The percentage loss of s to aerosol below 150 m compared to the total loss in the region being studied including that lost at the ocean surface is given by the expression:

$$\% \, Lost\ Aerosol < 200m = \frac{|D(s)|}{|D(s)| + |J_0(s)|} \times 100 \qquad (1.1.33)$$

This can be done only for any species that can be determined at 25 sps and will include both DMS and SO_2.

To compute an estimated error in the loss of s to aerosol we assume that the rate of loss of s to aerosol is equal to the rate of loss of s to ocean surface. For SO_2 the propagated error in the *% lost to aerosol* is 16%. **.** This error can be decreased by repeating this experiment 5 times under conditions of similar wind speeds in which case the error would be reduced to 7%.

The many additional measurements in PASE allow a more detailed study of the boundary layer budget of sulfur to be performed near the ocean surface. For instance, the aerosol surface area will be measured, allowing an estimate of the loss rate of SO_2 to aerosol to be compared with the result from the gas phase analysis described in this section. The observed deficit of Cl and Br in various sizes of aerosol can be combined with an estimate of the flux of sea salt aerosol to estimate the source of gas phase halogens from the sea salt aerosol. This will be compared to the rate at which SO_2 is lost to aerosol.

Dependence of $J_0(s)$ on wind speed

In the summer of 1994 the Christmas Island meteorology occurred in regimes in which the atmosphere was near steady state for 3-4 days in which the wind speed gradually increased from 5 to 10 m s^{-1}. During days 6 and 7 the wind speed increased gradually to about 12 m s^{-1}. This kind of variability provides an opportunity to investigate the surface fluxes of s and the losses of s to aerosol during a more than doubling of the wind speed. Models indicate a significant change in SO_2 surface flux and loss to aerosol as the wind speed increases. Some models suggest the magnitude of exchange velocities for gas emission increase with the cube of the wind speed [Wanninkhof and McGillis, 1999]. Computation of exchange velocity requires the surface ocean concentration measurements. However, the concentration of SO_2 in the surface ocean is negligible, thus the exchange velocity of SO_2 can be determined by flux divergence of surface flux and concentration. The flux of SO_2 at the ocean surface can be obtained by extrapolating vertical fluxes made at higher altitude to the ocean surface.

Nighttime budget of DMS

At nighttime both the chemical formation and destruction rates of DMS should be negligible. Therefore

$$F(DMS) = D(DMS) = 0 \qquad (1.1.34)$$

As described above C(DMS) can be determined to about 0.25 pptv m s^{-1}. Since the chemical formation of DMS in the atmosphere is assumed to be negligible the magnitude of the chemical destruction rate of DMS and the formation rate of SO_2 during nighttime can be shown to be $\leq$0.25 pptv m s^{-1}. Although the destruction rate of DMS and the formation rate of SO_2 should be zero at night, this experiment allows us to test the assumption that halogen and nitrate radical reactions are unimportant at night in this region.

Determination and use of entrainment velocities

Although not used in the budget calculations, several determinations of the entrainment velocity will be obtained in this study. This parameter is very important in developing dynamical models of the CBL that is of interest to meteorologists and modelers. The entrainment velocity is defined by the relationship

$$\left[\overline{s'w'}\right]_h = -w_e \Delta s \tag{1.1.35}$$

Here $\left[\overline{s'w'}\right]_h$ is the eddy flux at the CBL top obtained by extrapolating eddy fluxes obtained at various altitudes in the CBL to the CBL top. Also w_e is the entrainment velocity and Δs is the jump in s at the CBL top. In the DYCOMS II program DMS flux data were used to obtain good estimates of the entrainment velocity [Faloona et al., 2003; Stevens, 2003]. Estimates of the entrainment velocities will be obtained from DMS, H_2O, SO_2, O_3, momentum and heat during PASE.

We stress that the entrainment velocities are not used to obtain the budgets of DMS, SO_2, O_3 and H_2O since fluxes at the top and bottom are obtained by extrapolation of measured fluxes. However, fluxes across the CBL top for species and parameters which cannot be determined by measured fluxes can be obtained by computing the flux from the entrainment velocity and their measured jump across the CBL top. For aerosols this can be done by dividing the aerosol distribution into bins of narrow range of particle sizes and computing the flux for each bin using the entrainment velocity and the jump across the CBL top for each bin. These fluxes can be used to interpret their importance to the evolution of the aerosol size distribution and chemical composition during the 9 hour flights. This is equivalent to computing the budget for each bin and observing how the budget for each bin changes with time. This approach can be used for CCN also. We expect that the time evolution of aerosol and CCN budgets will contain valuable information on which aerosol bins are also good CNN.

Measurements

During PASE we will determine most of the chemical species required to characterize the photochemical environment of the study region. On the aircraft, these measurements include OH (Mauldin), H_2O_2, CH3OOH (Heikes), O_3 and CO. NO will not be determined because its concentration is known to be <5 pptv in the study area [Davis et al., 1999] and thus will play a secondary role in the photochemistry of this regime. Because sulfur plays a huge role in the chemistry of AIE a large suite of gas phase species will be determined. These include DMS, DMSO, $DMSO_2$, and SO_2 (Bandy) and H_2SO_4, NH_3 and MSA (Mauldin). Because the products of those gas-phase reactions are often aerosols, a large suite of complimentary aerosol physical and chemical measurements also will be made. Continuous fast size-resolved measurements of ambient aerosol surface area will be determined to estimate rates of loss of gaseous sulfur species to aerosol (Clarke). These measurements will include ambient size-distributions, dry size distributions and both wet and dry scattering coefficients that can be used to confirm both size distribution measurements. Continuous measurements of thermally resolved dry aerosol size distributions will be used to estimate the 3-D changes in aerosol size due to both nucleation and uptake of volatile components (Clarke). These size-resolved measurements will address issues related to the contributions of entrainment and DMS derived sulfates to aerosol variability. It will also provide evaluation of the role of refractory sea-salt aerosol, its flux, and its contributions to aerosol volume, surface area and number.

The aerosol chemical measurements include a Particle-Into-Liquid Sampler (PILS) coupled to a dual channel ion chromatograph (IC) that will be used to measure the bulk chemical composition of ionic constituents (Weber). This will include cations sodium, ammonium, potassium, magnesium, calcium, and anions chloride, nitrate, sulfate, and methane sulfonate

(MS) in small particles [up to 1 micro meter]. This instrument will provide 1 Hz (or possibly even faster) measurements of bulk sulfate and methane sulfonate with high sensitivity (LOD ng m^{-3}). Aerosol chemistry will also be collected using the Total Aerosol Sampler, TAS, which collects even the largest sea salt particles without inlet bias (Huebert) and analyzed for cations and anions (Howell). The other methods may miss the coarse fraction of NSS, which results from the ozone oxidation of SO_2 in sea salt. A MSP Flying MOUDI (MOI) on the aircraft will be used to get size-resolved chemistry from the aircraft (Howell). Because many of the mission legs will be flown as 30 minute level legs, integrated samples taken over a complete leg will provide high precision concentration data for these aerosol substances.

Photochemical Models

A photochemical model will be developed based on that of Davis et al. [1999] that was used to study the chemistry of sulfur in the tropical marine atmosphere including the Christmas Island trade wind regime. These studies will be performed by Dr. Yuhang Wang as the principal investigator and Dr. Doug Davis as a co-investigator. It will be modified to reflect knowledge gained about the chemistry, sources and sinks of species such as DMSO and $DMSO_2$. Since we recognize that the entire modeling community needs access to this data set, we will encourage all interested modelers to attend our second data workshop. We believe this is the most cost-effective way to ensure rapid use of the data by the modeling community.

Project Flight Plans

In July or August 2007 the C130 will be ferried from RAF to Christmas Island. Some portions of this ferry can be used for research. However, this is not the primary goal of the mission.

The field phase of the program will be conducted about 250 km east of Christmas Island (Kiritimati). Approximately 5 weeks onsite will be devoted to this study so that the best available meteorological conditions can be chosen for study. As mentioned above the stable meteorological phases tend to be 3-4 days in length with the overall length of a stable-unstable period being approximately 7 days. In 5 weeks approximately 4 stable periods are expected which provides ample opportunities to complete this research. The plan presented below assumes that the flights will be flown on every opportunity that does not exceed crew rest requirements. There also may be some adjustments if critical measurement systems are not operational.

Stable meteorological phases are easily recognized. The beginning of such a phase is characterized by very steady winds at speeds of 4-6 m $s^{-1}$and a direction of almost 100^o. Also the skies are almost cloud free (cloud free in CBL) with very bright sunshine. Decision to fly can be made the previous evening with good prospects for the flight program the next day.

A detailed discussion of using satellite and other meteorological information to guide aircraft deployment is included in Merrill proposal (University of Rhode Island). Relevant portions are included in this proposal. We will also get both data and analyses from the University of Hawaii Department of Meteorology.

Precipitation in the vicinity of Christmas Island and the central and eastern equatorial Pacific in general is a product of cumulus clouds associated with easterly waves propagating through the region. The classical description of these waves gives a length of 3000-4000 km, phase speed of 8-10 m/s and period of 4-5 days (Holton, An Introduction to Dynamic Meteorology 4th Ed., Elsevier Academic Press, 2004). Mean surface winds in this region for July and August are on the order of 4-5 m/s (8-10 knots; US Navy Climatic Atlas for the South Pacific, 1979). Hence, the waves may be thought to move through an air mass. These characteristics correspond to the phenomenological observations of cloud, rain and fair-weather conditions noted by Bandy during the 1994 experiment at Christmas Island. The 2001-2004 TOGA-COARE TAO daily data (viewable at www.pmel.noaa.gov/tao/data_deliv <http://www.pmel.noaa.gov/tao/data_deliv>) suggest clouds (diagnosed from shortwave radiation) and precipitation are more episodic than cyclic in July and August, with on-order of 10 events within a July-August interval.

The easterly waves tend to be asymmetrical. The smaller trough portion is associated with cloud and precipitation processes resulting in scavenging of soluble gases and aerosols. Petersen et al., [2004] describe convection and precipitation structure associated with 3 easterly waves in the eastern Pacific during September 2001. Briefly, three of their findings are relevant: rain is predominantly ahead of or west of the surface trough, approximately 85% of the precipitation was contributed by “convection” and 15 % by “stratiform”, and “heavy convection” precedes the trough by 0-2 days and “light convection” and “stratiform” comes 1-3 days after the trough passage. Daily average and 10 minute average data from TAO buoys bracketing Christmas Island indicate precipitation periods are typically a few 10's of minutes in duration with isolated occurrences of rain episodes on 2 or more consecutive days. Cloudy periods, significant enough to affect short-wave radiation and MBL chemistry, exhibit similar time intervals. The broader ridge portion of the easterly waves corresponds with suppressed convection and relatively cloud-free conditions. The buoy data show these periods to persist for 4-6 days. The ridge is identified as the best meteorology for studying marine sulfur fluxes and photochemistry. The trough portion would be best for examining cloud outflow events testing new-particle production mechanisms, since, the gas-to-particle path for new particle production (i.e., $SO_{2(g)}$ -> $H_2SO_{4(g)}$ -> $SO_4{}^{-2}{}_{(p)}$), is thought to principally occur in air recently scrubbed by cloud and precipitation processes of accumulation mode and larger aerosols. The resulting reduction in aerosol surface area minimizes the competition for gaseous H_2SO_4 by existing aerosol, thereby allowing it to condense on the embryonic particles, growing them to stable sizes and making new particles.

The easterly waves and their associated cloud and clear regions are readily observable in near real-time imagery from orbiting and geostationary satellites. Merrill will monitor these products, the TAO network, other tropical meteorological analyses on Christmas Island, Kiribati. His input will facilitate selection of a photochemistry/flux or cloud outflow flight plan for each mission day. In addition, he will capture data and products from satellite VIS, IR and microwave sensors for cloud and precipitation properties (e.g., TRMM and SSM/I & II systems) for later analysis of H_2O_2 and other constituent flight data sets.

In addition to these flights, three 9 hours missions will be flown to investigate the formation of nuclei in the outflow of cloud and BuL processes described in previous sections. These flights will be flown when conditions are favorable. Satellite and meteorological support is described briefly in a previous section and in detail in the Heikes and Merrill proposal.

Data Processing and Dissemination

It is the responsibility of the mission scientist to archive all the data produced by this experiment. Al PI’s will be required to submit their data for archiving before the end of the second year. Workshops to discuss the data and plan publications will be held 6 and 12 months after the completion of the experiment. The PI’s have been asked to include travel funds for themselves and participating students to attend this meeting. The data archive will enter the public domain through a web site at NCAR 2 years after completion of the experiment. It is the intent to publish a special volume in an appropriate journal.

PREVIOUS OFAP INFORMATION REQUEST

If this is a re-submittal of a request or a second year request for continuation of a program, please address all concerns and questions raised in the "Confidential Comments and Feedback to PI" portion that was provided with the notification letter.

SUMMARY ASSESSMENT

Project Name: Pacific Atmospheric Sulfur Experiment (PASE)
Investigator: Alan Bandy (Drexel University)
Facilities requested: NSF/NCAR C-130

Summary of Project:
The Pacific Atmospheric Sulfur Experiment (PASE) is an airborne study of the gas- and aerosol-phase chemistry of sulfur species in the lower marine troposphere, to be conducted from Christmas Island. Numerous questions about atmospheric sulfur chemistry will be addressed and investigations of the formation and subsequent evolution of cloud condensation nuclei (CCN) in the marine atmosphere will be carried out.
The project requests use of the NSF/NCAR C-130 for about thirteen flights in the lower troposphere within the convective boundary layer
(CBL) and buffer layer (BuL), from altitudes of 30 m to about 2 km. The aircraft would carry instruments to measure numerous gas-phase sulfur-containing species plus species known to interact chemically with the sulfur family (hydroxyl, ozone, peroxides). In addition, several types of aerosol samplers would be used to characterize the number, size, and chemical properties of atmospheric particulates. Finally, fast response (25 Hz) sensors for SO_2, DMS, H_2 O, and O_3 would be combined with observations of vertical winds from the aircraft gust probe to determine the fluxes of these species to/from the ocean surface using eddy correlation flux techniques.

Summary of OFAP comments and suggestions:
Importance/Uniqueness of Project: /The formation of CCN from sulfur gases, the overall chemistry and budget of sulfur-containing species in remote regions, and the effects of sulfur chemistry and CCN on clouds are key issues in atmospheric chemistry. These processes have linkages to important climate problems, including the so-called aerosol indirect effect and the CLAW hypothesis, which links production of dimethyl sulfide by oceanic phytoplankton to regulation of cloud cover in a negative feedback loop. While these were acknowledged by the committee as significant motivations for this research, the proposers did not explore them in any detail in the request, and we were thus uncertain about how the science team planned to link their observations to addressing these questions.

The request was revised in an effort to show these linkages and will be reviewed here. The linkages among the sulfur gas determinations and the aerosol was explored in a previous section and there are reasonable expectations for many of them. Some exceptions are NH_3, DMSO and DMSO. Although we believe that NH_3, DMSO and DMSO are linked to photochemistry the existing measurements do not agree with models. PASE data should improve the understanding of these linkages but we cannot be certain this will be complete. The evolution of the gas and aerosol species during the 9 hour nighttime and daytime flights will produce some very exciting data. One thing for sure is that for the first time long time series during nighttime and daytime will be obtained for all the species and parameters obtained. These data will contain the time evolution of both gases and aerosol including CCN and should place very tight restraints on the predictions of models.

The committee is familiar with the extensive work that this group of investigators has done on sulfur-species chemistry, especially from airborne platforms. There have clearly been some advances in instrumentation since previous similar measurements were made, however it was difficult to quantify the expected increases in understanding that would result from this experiment on the basis of the information provided in the request.

Existing models of sulfur chemistry have never been challenged with comprehensive sulfur observations that include measured fluxes of DMS and SO_2 at the top and bottom of the MBL. Our observational capabilities have advanced so significantly that we can now constrain budgets of many species in the MBL with few if any assumptions, making it possible to answer a variety of climate-relevant questions: What fraction of DMS becomes SO_2? How significant is the entrainment of SO_2 and particle number from the FT? Do the diurnal variations of the various species agree with existing sulfur photochemical kinetic models? What fractions of SO_2 go to dry deposition, cloud processing, sea salt oxidation, and sulfuric acid vapor formation? Is ammonia important for particle nucleation and growth? Do new particles form in the trade wind boundary layer, and if so what is the relevant chemistry? (Sulfuric acid is certainly a key player in the tropics.) How significant are preCCN from wave and bubble breaking over the open ocean vs formation in the outflow of cumulus clouds? How variable is preCCN entrainment into the boundary layer? Is gas phase halogen chemistry important in the remote trade wind regime? (Our halogen measurements will be limited by the C-130 payload.) How much sulfur dioxide is lost to aerosol vs the sea surface? What is the exchange coefficient for sulfur dioxide at the sea surface?

The answers to these questions will make models of the atmospheric portions of the CLAW hypothesis more accurate. Since chemical transport models and climate models will be the users of our results, we propose to invite (indeed, encourage) all interested modelers to participate in our second (12 month) data workshop, to get them started using this unique data set.

Finally phase I of PASE will yield 9 hour time series for all the PASE instruments. Except for DMSO and $DMSO_2$ we have some idea of what to expect. For DMSO and $DMSO_2$ observations and models are at such variance it is difficult to speculate. The evolution of the gases and aerosols including CCN during nighttime and daytime should provide important information of about the aerosol system. A lot will be learned about the relationship of aerosol and CCN specifically but due the lack of data this too would be speculation.

Several members of the committee commented on the balance of material presented in the facility request and attached proposal. While the project goals and hypotheses were numerous, the text seemed to focus primarily on the high-rate measurements and associated flux studies. The lack of chemical equations and specifics related to the photochemistry and aerosol process portions of the project were shortcomings of this proposal.

Partially this problem was caused because of the attempt to give each of the PI's a chance to advance their own ideas in the proposal. The time frame to get the proposals out always worked against us in this effort. The new PASE proposal being prepared will try very hard to identify and explain these linkages and there are many as there should be.

Adequacy of plan for hypothesis testing or problem definition: The proposed flight plans were judged to be adequate for addressing objectives. One of the most significant concerns of the OFAP was the uncertainty related to nighttime flying. As of the time of review, EOL staff have been unable to verify whether airfield infrastructure exists to permit takeoffs and/or landings in the dark. This issue is critical because the availability of nighttime data seem essential to the goals related to photochemistry. In the initial proposal, the PIs plan for 6 of 10 of the flights devoted to sulfur budget studies to be conducted during night; if this capability is not available, the science would seem to be severely compromised. The committee found it difficult to assess, however, as the specific goals related to photochemistry were not clearly spelled out in the proposal or request. In addition, there were questions about whether twilight is dark enough and of long enough duration to serve the purpose of zeroing out photochemistry. Further, should nighttime flying be permitted, this would almost certainly take the form of takeoff in the pre-dawn hours and flying through sunrise, as landing after dark is unlikely to be supported. This type of flight pattern would preclude assessment of any sunrise/sunset asymmetry in the photochemistry.

The RAF now has permission for unrestricted nighttime operations and we plan to have several nighttime flights as described. However, 30 m flights still must be flown at least in twilight at the discretion of the pilots.

The EOL feasibility assessment noted that the low-turbulence inlet (LTI) will not be available for this project. The committee is concerned that lack of the LTI will compromise scientific objectives, because it will affect large particle sampling, which seems especially important for sea-spray measurements and addressing the halogen activation question.

PASE as described does not require the large particle sizes the LTI makes available. However, many of the PI's and other scientists want them and if made available the LTI will be flown.

The EOL feasibility assessment further states that not all of the proposed instrumentation can be accommodated on the aircraft for this project. Without a complete list of what can and cannot be installed, and details about the proposed instrumentation (lacking in the proposal itself), the OFAP was unable to fully assess the likelihood that the payload would adequately address the goals and hypotheses of the project (see below).

This request describes the actual payload. We have worked these issues and we believe this package can be loaded and flown.

The OFAP noted that flight planning operations should be on-site, and should not only rely on obtaining information from the University of Rhode Island via potentially unreliable phone, fax and e-mail from the US. Perhaps there is more local weather information available, such as US Navy operations sources or the University of Hawaii.

John Merrill has agreed to be the mission meteorologist and will be on site throughout the program. He will communicate with colleagues at Hawaii, University of Rhode Island and elsewhere to obtain need information. Merrill will submit his own proposal this time and will be a PI.

Readiness: There were no concerns about the readiness of any of the instrumentation proposed for this project. It seems that too little information is currently available about airfield logistics (e.g., night-time operations) to assess the overall readiness for operations.

At the present time the situation on Kiritimati is much better politically and logistically than for any of the previous programs. However, there is always uncertainty.

Structure of program:
Major gaps or flaws/ (if any): In addition to those elements described above, the OFAP wanted to know what will happen should there be an ENSO in summer 2007 (predictive models suggest a 30% likelihood)? The ideal meteorological conditions typical of Christmas Island will no longer be expected in ENSO periods. Could the experiment still proceed as planned?

An intense El Nino could definitely create problems but not necessarily ruin the experiment. Our investigations suggest that even in very strong El Nino conditions the rainfall can be quite low in August as found for 1998. We investigated the situation for the previous four studies and found to our amazement that El Nino was weak to nonexistent in each case - we got lucky. Our conclusion is that we cannot totally eliminate the risk although 30% is acceptable to us.
Essential components: The apparent need to trim the payload to fit on the plane requires prioritization by the PIs to enable them to meet scientific objectives. How this measurement reduction would be done is not clear. Which objectives are the most important? What is the de-scoping strategy? The emphasis in the request was largely on gas-phase chemistry despite the proposers saying that the payload was meant to equally address gas-phase and aerosol chemistry; this imbalance should be addressed in prioritizing the science and the payload.

We believe this was done.

Qualifications of the proposers: The proposers are extremely well-qualified to engage in this proposed project. They have a well-established publication record in the areas of sulfur chemistry and aerosol composition measurements and extensive experience in carrying out similar airborne studies.

Other comments or suggestions: The lack of planned outreach activities or a coordinated educational effort was disappointing to the committee.

We have tried to handle this problem by introducing plans to give lectures to the general public and to include the material in our graduate and undergraduate programs. This can be described only for Drexel since that is the institution submitting this request.

The PI is discussing this issue with the 'Science in Motion' program of the State of Pennsylvania and administered by Drexel University for the Philadelphia area. Just how this will happen is still being discussed.

In addition one reporter at the Philadelphia Inquirer is also interested in the program but again these discussions are in the preliminary stages.

The details concerning undergraduate and graduate student involvement were unclear, as were the affiliations of the students who might be involved.

Because of his age the Drexel PI will focus on undergraduates. Our REU program involves 2 students every summer and has been very successful. Drexel students are not employed during the summer following their freshman year. The honors program at Drexel has helped us recruit highly qualified students who have done a great job. We expect some of these students to accept coop positions and participate in PASE. Another set of REU's will be employed in PASE during the summer throughout the program. These will be recruited through the Honors Program at Drexel.

What is the methodology for calculating fluxes when the gust probe and instrument inlets are not collocated? How will the known problems with the gust probe wind data affect the proposed flux measurements?

The PI has had extensive discussions with Don Lenschow on this subject. The problems affect the dynamical information that occurs at reasonably high frequency. The gust probe problems should not affect the fluxes much since they do not require the high frequency data. The important frequencies are between 0.5 and 5 hertz. For further information Don Lenschow should be contacted.

Many instruments require cryogens, which will be difficult to procure in a remote location. One committee member noted that dry ice can be made from compressed CO_2 with an adiabatic nozzle. Cylinders of compressed
CO_2 could be shipped by sea along with the rest of the cargo.

We believe this problem can be solved in more than one way. It is also too early to determine exactly just how serious the problem will be. Presently, there is a freight flight on a 737 once per week which is frequent enough to main supplies of cryogens. An easy solution is to ship the liquid nitrogen in stainless steel unpressurized dewars and not in the pressurized cylinders in which the LN2 is normally supplied. The boil off rate in unpressurized stainless steel dewars is very small so that the lifetime will be extended from days to several weeks. The PI shipped enough liquid nitrogen to the South Pole to last throughout a several week program.

EDUCATIONAL BENEFITS OF THE PROJECT

List anticipated number of graduate and undergraduate students who will be involved directly and in a meaningful way in field work and/or data analysis related to this project.

The Drexel proposal will involve 5 undergraduate students. Three students will be REU students and two will be COOP students .The Coop have major roles in the execution of the experiment. The REU students will work on data interpretation. These REU students will be chosen from the Honors Program at Drexel university which identifies students who have finished their first year at Drexel and have a 4.0 grade point average their first year at Drexel. We have been very successful in recruiting through this program in the past. Availability of students and student interest is high.

After the first year all undergraduates must become Coop students and are not eligible to be REU investigators. The Drexel program will include 3 coop students who will perform most of the field activities. Again these will be selected through the Honors program but will not be first year students. Age considerations limit the ability of the principal investigator to accept new graduate students so the emphasis is on undergraduates which have shorter term obligations.

Faculty from other universities will also involve their students in PASE. At UH, Barry Huebert frequently uses the data from field programs for student exercises in classes, directly connecting more students with experimental situations.

Do you plan to enhance undergraduate and/or graduate classes with hands-on activities and observations related to this project? If yes, describe.

Because the PI teaches chemistry courses whose content are controlled by the chemistry faculty as a whole, there is a limited opportunity to include such information in the PI's courses. However, there have been brief periods when such materials could be included directly in lectures although most of the effective communications were with students outside of the formal process.

The coPI's involved in this program come from more environmentally oriented academic and government organizations. The PI has observed the dedication of these coPI's to the education process which includes incorporation of new information produced in their research in the formal education process.

Each PI has been asked to include both undergraduate and graduate students in their budgets and for students to be involved in the research on Christmas Island. A series of seminars by PI's will be presented to students on Christmas Island and students will participate in two data workshops. To further encourage student participation in the field phase one seat on each mission will be reserved for students who do not otherwise get to deploy on the C130. The undergraduate students deployed with the Bandy group will be enrolled in the undergraduate research courses at Drexel University, which are required of all Drexel Chemistry majors (Chemistry 493 and 497).

Will you develop new curricula that will be related to the project? If yes, please describe.

The PI teaches in the core curriculum of the Chemistry Department in the course content is highly controlled. However, inclusion of this information in courses in atmospheric science taught by others will be encouraged.

Do you plan any outreach activities to elementary and/or secondary school students and/or the public related to the project? If yes, please describe.

Yes. Drexel has several outreach to elementary and secondary school students and the PI will volunteer to participate in these programs

Do you plan to have any interactions with primary and secondary school educators to involve them in the project? If yes, please describe.

Yes. Presently the Drexel PI is advising one student in the Cherry Hill, NJ system in his special projects in atmospheric chemistry.

Are you cooperating with an agency outreach program during this project? If yes, which one?

Drexel has such an office and the PI will request to participate in this program.

Will information about the project's activities, results, data, and publications be made available via the Internet? If yes, where?

Each PASE investigator will be required to have submitted his/her data to the official PASE data set by the end of the second year. These data will be available from NCAR or from a Drexel web page to be developed.

PREVIOUS RESEARCH EXPERIENCE

Past EOL support:

RICO, DYCOMS I and II, ACE 1, ACE ASIA, PELTI

Publications resulting from past EOL support:

Bandy, A., D. Thornton, F. Tu, B. Blomquist, W. Nadler, G. Mitchell, and D. Lenschow, Determination of the vertical flux of dimethyl sulfide by eddy correlation and atmospheric pressure ionization mass spectrometry (APIMS), Journal of Geophysical Research, 107 (D24), 4743 doi:10.1029/2002JD002472, 2002.

Clarke, A.D., Z. Li and M. Litchy, Aerosol Dynamics in the Pacific Marine Boundary Layer: Microphysics, Diurnal Cycles and Entrainment: Geophys. Res. Lett., 23, pg 733-736, 1996.

Clarke, A.D., J. L. Varner, F. Eisele, R. Tanner, L. Mauldin and M. Litchy, Particle production in the remote marine atmosphere: Cloud outflow and subsidence during ACE-1, Jour. Geophys,

Res., 103, 16,397-16,409, 1998.

Clarke, A.D., D. Davis, F. Eisele, G. Chen, K. Moore, L. Mauldin, R. Tanner and M. Litchy, Particle nucleation in the marine boundary layer and its coupling to marine sulfur sources, SCIENCE, Oct 2., 1998.

Clarke, A.D., F. Eisele, V.N. Kapustin, K. Moore, R. Tanner, L. Mauldin, M. Litchy, B. Lienert, M.A. Carroll, G. Albercook, Nucleation in the Equatorial Free Troposphere: Favorable Environments during PEM-Tropics, Jour. Geophys. Res, 104, 5735-5744, 1999.

Clarke, A.D., V.N. Kapustin, F. L. Eisele, R. J. Weber, P. H. McMurry, Particle Production near Marine Clouds: Sulfuric Acid and Predictions from Classical Binary Nucleation , Geophys. Res. Lett., 26, 2425-2428, 1999.

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Huebert, B.J., S. Howell, P. Laj, J.E. Johnson, T.S. Bates, P.K. Quinn, V. Yegorov, A.D. Clarke, and J.N. Porter, Observations of the atmospheric sulfur cycle on SAGA-3, Journal of Geophysical Research, 98, 16985-16995, 1993.

Huebert, B.J., S.G. Howell, L. Zhuang, J.A. Heath, M.R. Litchy, D.J. Wylie, J.L. Kreidler-Moss, S. Coeppicus, and J.E. Pfeiffer, Filter and impactor measurements of anions and cations during the First Aerosol Characterization Experiment (ACE 1), J. Geophys. Res., 103 (d13), 16,493-16,510, 1998.

Lenschow, D. H., et al., Use of a mixed-layer model to estimate dimethylsulfide flux and application to other trace gas fluxes, Journal of Geophysical Research, 104, 16275-16295, 1999.

Mitchell, G. M., Determination of vertical fluxes of sulfur dioxide and dimethyl sulfide in the remote marine atmosphere by eddy correlation and an airborne isotopic dilution atmospheric pressure ionization mass Spectrometer, Ph.D. Dissertation, Drexel University, 2001.

Nowak, J. B., Davis, D. D., Chen, G., Eisele, F. L., Mauldin, R. L., Tanner, D. J., Cantrell, C., Kosciuch, E., Bandy, A., Thornton, D. and Clarke, A., Airborne observations of DMSO, DMS, and OH at marine tropical latitudes, Geophys Res. Lett., 28, 2201-2204, 2001.

Russell, L.M., D.H. Lenschow, K.K. Laursen, P.B. Krummel, S.T. Siems, A.B. Bandy, D.C.

Thornton, and T.S. Bates, Bidirectional mixing in an ACE 1 marine boundary layer overlain by a second turbulent layer, J. Geophys. Res., 102 (16), 16411-16432, 1998.

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Thornton, Donald C., Alan R. Bandy, Fang H. Tu, Byron W. Blomquist, Glenn M. Mitchell, Wolfgang Nadler, Donald H. Lenschow, Fast Airborne Sulfur Dioxide Measurements by Atmospheric Pressure Ionization Mass Spectrometry(APIMS), Journal of Geophysical Research, 107 (D22), 4632 doi:10.1029/2002JD002289, 2002

Tu Fang Huang, Donald C. Thornton, Alan R. Bandy, Mi-Sug Kim, Gregory Carmichael, Youhua Tang, Lee Thornhill and Glenn Sachse, Dynamics and Transport of Sulfur Dioxide over the Yellow Sea during TRACE-P, J. Geophys. Res., 108, 8790, doi:10.1029/2002jd003227, 2003

Zhuang, L., and B.J. Huebert, A Langrangian Analysis of the Total Ammonia Budget during ASTEX/MAGE, J. Geophys. Res., 101 (D2), 4341-4350, 1996.

Expected publication date and journal:

JGR Special Issue Fall 2008.

FUNDING AGENCY INFORMATION

Funding Agency	NSF
Contract Officer	Anne Marie Schmoltner
Contract Identification	
Proposal Status	In review
Approximate Amount budgeted	$660,000

DATA ACCESS POLICY

EOL policy will make all LAOF data publicly available once the data are quality controlled. If a PI wants to have exclusive access to these data for the first year, s/he has to officially request such a restriction via email from the EOL Division Director (wakimoto@ucar.edu <mailto:wakimoto@ucar.edu>) eight weeks prior to the start of an experiment.

Do you intend to request restricted access?

No restrictions of RAF data.

OPERATIONS IN FOREIGN COUNTRIES

Is the PI aware of any factors that could impact operations from this location? Health and safety issues in particular should be noted.

Christmas Island has limited channels for logistical support, so we may only be able to get weekly shipments of supplies and spare parts from Hawaii. There are also limited health care options, so a serious illness would require transport to Honolulu for medical care.

NSF/NCAR C-130

Contact: Dr. Jorgen Jensen
Email: jbj@ucar.edu <mailto:jbj@ucar.edu>, Phone: (303) 497-1028
http://raf.atd.ucar.edu/Aircraft/c130.html

AIRCRAFT OPERATIONS

Preferred flight period	August 1 -Sept 5, 2007
Number of flights required	13
Estimated duration of each flight	9.3
Number of flights per day	<0.4
Preferred base of operation	Christmas Island
Alternate base	
Is JeffCo Airport (near Boulder) acceptable as your operations base?	No
Average flight radius from base	500 km
Desired flight altitudes(s)	30 to 6000 m
Particular part(s) of day for flights	Day and night flights
Statistically, how many days during specified period should be acceptable for flight operations?	25

Number of scientific observers for each flight (max is 15)	15

Scientific rationale for the use of this aircraft in the proposed project:
The Lagrangian experimental design requires an aircraft platform to be successful. Also, the C-130 is the only platform capable of carrying the large payload this project requires. Its ability to operate in the MBL for extended periods of time is also a significant factor in the choice of the C-130.

Description of desired flight pattern(s), priorities, and estimate number of flights:
Described in detail in the attached project description

EOL/RAF AIRBORNE SCIENTIFIC INSTRUMENTATION

Description	**Special Considerations**	**Data Rate(s)**	**Name**	**Needed**
Radiometric Ambient Air Temperature (Ophir III) (in cloud)		Low	OAT	Yes
Radiometric Sky Temperature		Low	RSTT	yes
TDL Laser Hygrometer	B,C,D	Low	TDL	No
Gerber Probe (Liquid Water Content)		High	PVM-100	Yes
Cloud Particle Size Distribution (0.5 - 47 m)		Low, High	FSPP/SPP-100	Yes
Cloud Particle Size Distribution (40 - 640 m)		Low, High	OAP 260X	Yes
Aerosol Particle Size Distribution (0.1 - 3.0 m)		Low, High	PCAS/SPP-200	Yes
Aerosol Particle Size Distribution (0.3 - 20 m)		Low, High	FSSP/SPP-300	Yes
PMS Cloud Particle Images (2-dimensional)	B	Auto	OAP 2D-C	No
PMS Hydrometeor Images (2-dimensional)	B	Auto	OAP 2D-P	No
Fast-Response Chemiluminescence Ozone Concentration	A, D	High	O3FSM	Yes
Carbon Dioxide Concentration	C, D	Low, High	CO2C	No
Carbon Monoxide Concentration	D, D	Low	COCAL	No
TECO Ozone Concentration		Low	TEO3	Yes
Radial Differential Mobility Analyzer (8 - 130 nm)	B, D	Low	RDMA	Yes
Number of RAF Air Sample Inlet(s) (standard or solid diffuser)				*See below*
VHS Video recording (fwd) with date/time				Yes
VHS Video recording (side) with date/time				Yes
VHS Video recording (down) with date/time				Yes
Digital video recording (fwd or down) with date/time stamp	C, D			Yes
GPS Dropsonde System	A, B, C, D, E		GDS	No
Multi-channel Cloud Radiometer	B, D	High	MCR	

Counter-flow Virtual Impactor	A, B, D	Low, High	CVI	
Airborne Imaging Microwave Radiometer	A, B, C, D	High	AIMR	
Cloud Particle Imager	A, B, C, D	High	CPI	
Wyoming Cloud Radar	A, B, C, D, E	High	WCR	
Scanning Aerosol Backscatter Lidar*	A, B, C, D, E	High	SABL	

The two CN counters detecting particles > 4 nm and > 15nm are also requested.

A - Instrument requires a dedicated operator on board the aircraft.
B - Special software tools are required for routine processing, display and analysis of the data acquired by this instrument.
C - Data recorded on a separate data acquisition system, not on RAF's ADS.
D - Data acquired by this instrument requires unique post-processing.
E - This instrument requires filling out a separate request form (available in this document).

USER-SUPPLIED SCIENTIFIC PAYLOAD

First Priority

INSTRUMENT	MEASUREMENT	ORGANIZATION
GAS PHASE		
APIMS 1	Fast SO_2	Drexel University
APIMS 2	Fast DMS	Drexel University
APIMS 3	DMSO and $DMSO_2$	Drexel University
SICIMS	OH, H_2SO_4, MSA and NH_3	NCAR
HPLC	H_2O_2 and CH_3OOH	URI and Naval Academy
AEROSOL		
ThermalOPC	Fast Size, Volatility (0.15-10.0 um)	UH (Clarke)
ThermalDMA	Fast Size, Volatility (0.01-0.3 um)	UH (Clarke)
ThermalTDMA	Size resolved mixing state	UH (Clarke)
CNhot, CNcold	Refractory and volatile number	UH (Clarke)
Ultrafine CN	Ultrafine number concentration	UH (Clarke)
PSAP (3wave)	Absorption Coeff. (Black Carbon)	UH (Clarke)
Nephelometer(3wave)	Scattering Coeff.	UH (Clarke)
CCD imagery	Whitecap/Bubble Coverage	UH (Clarke)
TAS	Size Integrated Ambient Total Ions	UH (Huebert)
MOUDI	Leg Average Size Resolved Ions	UH (Huebert)
APS	Coarse partice size distribution	UH (Howell)
PILS	Fast Submicron Aerosol Ions	Georgia Tech
CCN	CCN Spectrum	DRI

Secondary Priority t

These instruments may be added to the instrument list if the instrument and space are available.

AMS	Size-resolved Mass Spectra Aerosol	UH Clarke or Georgia Tech.
LTI	Isokinetic aerosol sampling	UH (Huebert) and RAF

Dr. Alan Bandy

Instrument Name:	**APIMS 2**
Individual weight of all components:	930 lbs including rack
Complete size dimensions of all components:	1 C-130 rack; inlet as for RICO
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	1 C-130 rack
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	Yes
Hazardous material required:	Compressed air & N2 w/SO2 (150 ppbv) in aluminum cylinders
Radioactive sources or materials:	Ni-63 source (10 mCi) for mass spectrometer
Power required (watts, volts, amps):	2 ea 15 A
Type of power (DC, 60 Hz, 400 Hz):	115V 60 Hz
External sensor location (if any):	Inlet port on belly at about FS 500; venturi on aft window
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	Yes
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes
Number of lap-top computers for on-board use:	0

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

Need inlet mounting used on RICO and venturi on right side aft window used on RICO. Need to mount 2 ea. 54" H x 8" o.d. aluminum cylinders in cylinder rack forward of paratroop door.

Instrument Name:	**APIMS 3**
Individual weight of all components:	930 lbs
Complete size dimensions of all components:	

Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	One C-130 (2-bay) rack with calibration cylinder attached to forward side
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	One C-130 (2-bay) rack made by NCAR and owned by Drexel University will be used.
Hazardous material required:	Compressed Air and DMS in N2 cylinders
Radioactive sources or materials:	Ni-63 sealed source (10 mCi)
Power required (watts, volts, amps):	Two 15 A, 115 V circuits are needed.
Type of power (DC, 60 Hz, 400 Hz):	60 Hz

Instrument Name:	**APIMS 4**
Individual weight of all components:	900 lbs
Complete size dimensions of all components:	
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	One C-130 (2-bay) rack
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	One C-130 (2-bay) rack is needed to be supplied by NCAR.
Hazardous material required:	Compressed Air cylinder. (1)
Radioactive sources or materials:	Ni-63 sealed source (10 mCi)
Power required (watts, volts, amps):	Two 15 A, 115 V circuits are needed.
Type of power (DC, 60 Hz, 400 Hz):	60 Hz
External sensor location (if any):	Inlet port on belly at about FS 680; venturi on aft window
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	Yes
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes (1)
Number of lap-top computers for on-board use:	None

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

Need inlet tube similar to APIMS 3. We will also use the same venturi on left side aft window which will be used APIMS 3. Need to mount one 54” H x 8” o.d. aluminum cylinders in cylinder rack forward of paratroop door.

Dr. Brian Heikes

Instrument Name:	PEROXIDES
Individual weight of all components:	400 lbs (estimated)
Complete size dimensions of all components:	1 full bay of RAF double bay high rack and bottom ½ bay of second bay.
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	No, using RAF supplied double high rack
Hazardous material required:	Yes, (1) compressed air (alu cylinder 144 cuft, 2000 psi), (2) 2 L water, (3) 120 ml of 30% ammonium hydroxide (liquid), (4) 250 ml of 1-normal hydrochloric acid (liquid), (5) 250 ml of 1-normal sodium hydroxide (liquid)
Radioactive sources or materials:	No
Power required (watts, volts, amps):	12 amps, 110VAC 60 Hz
Type of power (DC, 60 Hz, 400 Hz):	12 amps, 110VAC 60 Hz
External sensor location (if any):	Inlet for gas sample collection – close to rack
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes
Number of lap-top computers for on-board use:	2

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. No.

External sensor location (if any):	Inlet port on belly at about FS 500; venturi on aft window
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	Yes
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes (1)
Number of lap-top computers for on-board use:	None

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

Need inlet mounting used on RICO and venturi on left side aft window used on RICO. Need to mount 2 ea. 54" H x 8" o.d. aluminum cylinders in cylinder rack forward of paratroop door.

SUPPORTING SERVICES

Will you require air-ground communication? *(If so, specify location of base station and operating frequencies.)*

Will additional Operations Center and Real-time Display and Coordination Center (RDCC) services be required?
A basic data/analysis center with LAN connections to the EOL computers and access to the Internet will be provided in the field by EOL. Support will include real-time communications links to the aircraft via "chat" and real-time display of selected variables via web site links. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service.

On-site data access requirement:

Has an EOL scientist/engineer/project manager been consulted to help complete this request? *Consultation with EOL staff is strongly encouraged before submitting this request.*

Yes

Dr. Lee Mauldin

Instrument Name:	NCAR SICIMS
Individual weight of all components:	1150 lbs for rack and inlet plus 200 lbs of cylinders
Complete size dimensions of all components:	26" x 44" plus 2 full and 2 small cylinders
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	Yes, custom rack used on TOPSE. 26" x 44" footprint
Hazardous material required:	Propane
Radioactive sources or materials:	^{241}Am – 5µCi (Total for 4 sources)
Power required (watts, volts, amps):	25A - 60 Hz, 25A - 400 Hz
Type of power (DC, 60 Hz, 400 Hz):	
External Sensor Location (if any):	Front Port Window Opening
Are Signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	Yes
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes, 2 Operators
Number of lap-top computers for on-board use:	

Dr. Anthony Clarke

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)?

Yes. The bulk of this instrumentation was previously deployed aboard the NCAR/RAF C-130 during both INDOEX and ACE-Asia. The installation of the external probes (CDP, AISS, Gerber Probe), the 3-λ nephelometer, and the venturi exhaust ports will require some fabrication of appropriate mounting hardware. The UH solid diffuser inlet and window mounting plate have already been fabricated but will require installation. Estimated integration time for rack-mounting instrumentation as well as plumbing/electrical integration with NCAR/RAF C-130 is 2-3 weeks.

Instrument Name:	Fast Mobility Particle Sizer Spectrometer – TSI

	Model 3091
Instrument weight:	70 lbs
Instrument dimensions:	28”x14”x18”
Rack space required: **“**	
Supplying own 19” rack:	No
Hazardous material required:	None
Radioactive sources or materials:	None
Power:	120 VAC, 60 Hz, 250 W
External sensor location (if any):	UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	Yes
Number of computers:	1

Instrument Name:	DMT Cloud Droplet Probe (CDP)
Instrument weight:	5 lbs
Instrument dimensions:	9”x6”x5” (external) 7”x4”x2” (internal)
Rack space required:	7”x4”x2”
Supplying own 19” rack:	No
Hazardous material required:	None
Radioactive sources or materials:	None
Power:	+28VDC, 3A (system), +28VDC, 10A (de-icing)
External sensor location (if any):	External wing or window-plate mounting (fabrication required)
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	No
Number of computers:	1

Instrument Name:	tandem Differential Mobility Analyzer (tDMA) and lagged aerosol grab sampler
Instrument weight:	80 lbs & 45 lbs
Instrument dimensions:	19”x19”x12” + 6”x8”x60”
Rack space required:	“
Supplying own 19” rack:	No
Hazardous material required:	10 mL, Butanol (n-butyl alcohol)
Radioactive sources or materials:	Polonium 210 < 500μC, $T_{1/2}$ = 140d
Power:	120 VAC, 60 Hz, 1500 W (peak)
External sensor location (if any):	UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No

Special sensor calibration?	No
Full-time operator during flight?	Yes
Number of computers:	1

Instrument Name:	Optical Particle Counter (OPC) & Thermo-Optical Aerosol Discriminator (TOAD)
Instrument weight:	35 lbs & 25 lbs
Instrument dimensions:	22”x14”x8” + 27”x17”x5”
Rack space required: **“**	
Supplying own 19” rack:	No
Hazardous material required:	TOAD includes isolated, fully insulated 150°C, 360°C and 420°C heaters
Radioactive sources or materials:	None
Power:	120 VAC, 60 Hz, 1200 W (peak)
External sensor location (if any):	UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	Yes
Number of computers:	1

Instrument Name:	Aerial Image Sensing System (AISS)
Instrument weight:	10lbs
Instrument dimensions:	10”x6”x5” (external) 7”x4”x2” (internal)
Rack space required:	7”x4”x2”
Supplying own 19” rack:	No
Hazardous material required:	None
Radioactive sources or materials:	None
Power:	20 VAC, 60 Hz, 20 W (peak)
External sensor location (if any):	External wing or window-plate mounting (fabrication required)
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	Yes
Special sensor calibration?	No
Full-time operator during flight?	No
Number of computers:	1

Instrument Name:	Condensation nuclei counters (1xTSI model 3025, 2xTSI model 3010
Instrument weight:	25 lbs + 2x12 lbs
Instrument dimensions:	14”x10”x8” + 2x(9”x9”x8”)
Rack space required:	“

Supplying own 19" rack:	No
Hazardous material required:	3x10mL Butanol (n-butyl alcohol) Isolated, fully insulated 360°C heater
Radioactive sources or materials:	None
Power:	120 VAC, 60 Hz, 180 W, 1.2 A (peak) 2x(120 VAC, 60 Hz, 20 W (peak))
External sensor location (if any):	UH Solid Diffuser Inlet
Signal to RAF's Aircraft Data System:	Yes, RS232 or TCP/IP
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	No
Number of computers:	1

Dr. Rodney Weber

Note: We are proposing 2 instruments. The specifications for each instrument is given below.

Part 1

Instrument Name: PILS-IC

Individual weight of all components:

Right Side Bay	
Instrument Component	WT (lbs)
Electronics	10
Laptop	20
2 ICs	130
PILS + liquid pumps	50
Vac. Pump	50

Complete size dimensions of all components:

Rack-mountable 19" panel space required
(Note: depth beyond 25" will overhang in back):
All components fit within rack

Supplying your own 19" rack (yes/no):
(Note: racks must survive 9G crash load.)
No

Hazardous material required:
CATION: 8.5 mM L-Tartaric Acid, 4.1 mM Dipicolinic Acid
ANION:11 mM Na_2CO_3, 6mM $NaHCO_3$
H_2SO_4 was 0.4N

Radioactive sources or materials:
No

Power required (watts, volts, amps):
120VAC, 8 amps continuous

Type of power (DC, 60 Hz, 400 Hz):
60Hz

External sensor location (if any):
None, external inlets, possibly the LTI

Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?
No

Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?
RS-232, RAF aircraft data.
Need IRIG time-code feed?
Yes

Special sensor calibration service required?
No

Need full-time operator during flight?
Yes (1 person)

Number of lap-top computers for on-board use:
1

Part 2
Instrument Name: Aerosol-Chemical Ionization Mass Spectroscopy (Aerosol-CMIS)

Individual weight of all components:

Right Side Bay	
Instrument Component	*WT (lbs)*
Inlet flow controllers	10
Adapter plate (1/2)	20
Alcatel controller	5
Temperture controller box	17
HV box	13
Computer	24
Monitor	20

Left Side Bay	
Instrument Component	*WT (lbs)*
Flow Controllers	12
Adapter plate (1/2)	20
RF Unit	13
MFC box	11
Pump controller	18

Complete size dimensions of all components:

Right Side Bay	
Instrument Component	*Moment Arm (in)”*
Inlet flow controllers	24
Adapter plate (1/2)	22
Alcatel controller	17
Temperature controller box	13
HV box	11
Computer	8
Monitor	30

Left Side Bay	
Instrument Component	*Moment Arm (in)”*
Flow Controllers	12
Adapter plate (1/2)	20
RF Unit	13
MFC box	11
Pump controller	18

Rack-mountable 19" panel space required
(Note: depth beyond 25" will overhang in back):

No

Supplying your own 19" rack (yes/no):
(Note: racks must survive 9G crash load.)

No

Hazardous material required:
Compressed gases (Nitrogen, SF_6 diluted in Nitrogen, CF_3Br), Nitric Acid

Radioactive sources or materials:
Radioactive Polonium

Power required (watts, volts, amps):
Average: 10 Amps, 110 Volts
Peak: 20 Amps, 110 Volts

Type of power (DC, 60 Hz, 400 Hz):
400 Hz

External sensor location (if any):
Will need an inlet probe

Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?
Can be setup if requested

Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?
RS-232

Need IRIG time-code feed? Yes

Special sensor calibration service required?
No

Need full-time operator during flight?
Yes

Number of lap-top computers for on-board use:
One

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. (If so, specify type and lead time).

Probably, minor sheet metal work for rack

Instrument Name: Aerodynamic Particle Sizer (TSI model 3321 APS)
Instrument weight: 22 lbs
Instrument dimensions: 15”x14”x9”
Rack space required: “
Supplying own 19” rack: No
Hazardous material required: None
Radioactive sources or materials: None
Power: 120 VAC, 60 Hz, 100 W
External sensor location (if any): UH Solid Diffuser Inlet

Signal to RAF’s Aircraft Data System: No
Real-time serial data feed: No
Need IRIG time-code feed? No
Special sensor calibration? No
Full-time operator during flight? Yes
Number of computers: 1

Instrument Name: 3-wavelength integrating nephelometer (TSI model 3563)
Instrument weight: 55 lbs
Instrument dimensions: 12”x9”x42”[*]
Rack space required: None
Supplying own 19” rack: No
Hazardous material required: None
Radioactive sources or materials: None
Power: 120 VAC, 60 Hz, 125 W (peak)
External sensor location (if any): UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System: Yes, RS232 or TCP/IP
Real-time serial data feed: No
Need IRIG time-code feed? No
Special sensor calibration? No
Full-time operator during flight? Yes
Number of computers: 1

[*] This instrumentation is too large to be mounted inside a standard rack. In the past this unit has been mounted to the floor directly using an aluminum plate. A location and fabrication of the plate will need to be coordinated with RAF staff.

Instrument Name: 3-wavelength particle soot absorption photometer (PSAP)
Instrument weight: 15 lbs
Instrument dimensions: 18”x10”6”
Rack space required: “
Supplying own 19” rack: No
Hazardous material required: None
Radioactive sources or materials: None
Power: 120 VAC, 60 Hz, 60 W, 0.5A
External sensor location (if any): UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System: Yes, RS232 or TCP/IP
Real-time serial data feed: No
Need IRIG time-code feed? No
Special sensor calibration? No
Full-time operator during flight? No
Number of computers: 1

Instrument Name: Extinction vs. humidity using a custom [f(RH)]

	system
Instrument weight:	20 lbs
Instrument dimensions:	24”x24”x10”
Rack space required:	None*
Supplying own 19” rack:	No
Hazardous material required:	1L H_2O reservoir
Radioactive sources or materials:	None
Power:	120 VAC, 60 Hz, 200 W (peak)
External sensor location (if any):	UH Solid Diffuser Inlet
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	Yes
Number of computers:	1

*During ACE-Asia this instrumentation was mounted on top of the rack

Instrument Name:	Cloud droplet (Gerber) Probe + Control Box
Instrument weight:	10 lbs + 10 lbs
Instrument dimensions:	8”x8”x20” + 17”x10”x4”
Rack space required:	17”x10”x4”
Supplying own 19” rack:	No
Hazardous material required:	None
Radioactive sources or materials:	None
Power:	120 VAC, 60 Hz, 200 W
External sensor location (if any):	External wing or window-plate mounting (fabrication required)
Signal to RAF’s Aircraft Data System:	No
Real-time serial data feed:	No
Need IRIG time-code feed?	No
Special sensor calibration?	No
Full-time operator during flight?	No
Number of computers:	1

Dr. Howell

Instrument Name:	TAS – Total Aerosol Sampler
Individual weight of all components:	125 lb
Complete size dimensions of all components:	12” x 16” x 6” external
Rack-mountable 19” panel space required (Note: depth beyond 25” will overhang in back):	Half a rack for flowmeters, datalogger, power supplies, and pump
Supplying your own 19” rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	1500 watts
Type of power (DC, 60 Hz, 400 Hz):	400 Hz
External sensor location (if any):	A Forward lasagna pan
Are signal(s) to be recorded on RAF’s Aircraft Data System (yes/no)?	yes
If yes: Signal format (digital, analog, serial):	Analog
Full-scale Voltage:	5 vdc
Range:	0 - 5
Resolution:	1 mv

Sample Rate (1, 5, 250 sps):	1 sps
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	yes
Number of lap-top computers for on-board use:	0

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)?
No.

EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*
TAS just flew on RICO, so unless some major changes are needed, it should be ready to mount and fly again.

Instrument Name:	TSI 3320 Aerodynamic Particle Sizer
Individual weight of all components:	15 lb
Complete size dimensions of all components:	12” x 15” x 10”
Rack-mountable 19” panel space required (Note: depth beyond 25” will overhang in back):	15”
Supplying your own 19” rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	50 watts
Type of power (DC, 60 Hz, 400 Hz):	60 hz
External sensor location (if any):	No – Air from an LTI
Are signal(s) to be recorded on RAF’s Aircraft Data System (yes/no)?	No – on our own PC
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	

Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	Yes
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes
Number of lap-top computers for on-board use:	1

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*
The APS will be mounted as near the LTI inlet as possible, to monitor the aerosol size distribution coming out of the LTI and entering the MOI.

Instrument Name:	MSP "Flying MOUDI" Impactor, MOI
Individual weight of all components:	120 lb
Complete size dimensions of all components:	11" x 11" x 17" pump/control unit 6" x 6" x 12" stacks and valve on lasagna pan
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	12"
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	800 watts
Type of power (DC, 60 Hz, 400 Hz):	400 Hz
External sensor location (if any):	Stacks hang inside of LTI
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No – It uses its own PC for flow control and Recording.
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	

Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes
Number of lap-top computers for on-board use:	1

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)?

Yes. I have spoken with Jack Fox about building a new mount for the MOI. We are removing the impactor stacks from the MSP structure they came in and mounting them one at a time on the LTI outlet. The order will be: LTI, to a short "Y" (5 lpm to the APS), to a stainless ball-valve, to the impactor stack. Jack is building the Y and a support system for the stacks. We will use the same pump and flow control system that came with the MOI and was used in ACE-Asia.

Instrument Name:	PC-BOSS Organic Carbon sampler
Individual weight of all components:	120 lb
Complete size dimensions of all components:	3” x 3” x 36” denuder & filter stack 9” x 9” x 4” particle concentrator 12” x 8” x 8” pump
Rack-mountable 19” panel space required (Note: depth beyond 25” will overhang in back):	One side of a rack for flowmeters, pump, control valves, etc.
Supplying your own 19” rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	800 watts
Type of power (DC, 60 Hz, 400 Hz):	60 Hz
External sensor location (if any):	Needs a solid diffuser inlet
Are signal(s) to be recorded on RAF’s Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes
Number of lap-top computers for on-board use:	1

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

No, although we will no doubt need to make mounts and interface pieces.

Instrument Name:	LTI, Low-turbulence inlet (property of RAF)
Individual weight of all components:	N/A
Complete size dimensions of all components:	N/A
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	No
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	N/A
Type of power (DC, 60 Hz, 400 Hz):	N/A
External sensor location (if any):	Forward lasagna pan
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	Yes
If yes: Signal format (digital, analog, serial):	No
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No – but need post-processing help
Need full-time operator during flight?	No
Number of lap-top computers for on-board use:	0

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

This RAF-owned inlet will need to be installed for our use. I am unaware of many of the details of its power and weight, but presume that RAF has those numbers. We plan to use 105 lpm of LTI flow, so a small additional amount might be available for other users.

Dr. Jim Hudson

Instrument Name:	**CNN**
Individual weight of all components:	540 lbs
Complete size dimensions of all components:	
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	1.5 C-130 (2-bay) rack with calibration cylinder attached to forward side
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	Yes
Hazardous material required:	None
Radioactive sources or materials:	None
Power required (watts, volts, amps):	Two 15 A, 115 V circuits are needed.
Type of power (DC, 60 Hz, 400 Hz):	60 Hz
External sensor location (if any):	Inlet On side window
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	No
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	No
Need IRIG time-code feed?	No
Special sensor calibration service required?	No
Need full-time operator during flight?	Yes (1)
Number of lap-top computers for on-board use:	Two

Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*

SUPPORTING SERVICES

Will you require air-ground communication? *(If so, specify location of base station and operating frequencies.)*

Will additional Operations Center and Real-time Display and Coordination Center (RDCC) services be required?

A basic data/analysis center with LAN connections to the EOL computers and access to the

Internet will be provided in the field by EOL. Support will include real-time communications links to the aircraft via "chat" and real-time display of selected variables via web site links. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service.

On-site data access requirement:

Has an EOL scientist/engineer/project manager been consulted to help complete this request? *Consultation with EOL staff is strongly encouraged before submitting this request.*

Yes