# NOMADSS-Operations Plan

**Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks**
**Operations Plan**
**NOMADSS is a component of the Southeast Atmosphere Study (SAS)**
**http://www.eol.ucar.edu/projects/sas/**

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# I. Project Overview

## a. Scientific Objectives

The Nitrogen, Oxidants, Mercury and Aerosol Distributions, Sources and Sinks (NOMADSS) project integrates the objectives from three NSF funded projects; SOAS (Southern Oxidant and Aerosol Study), NAAMEX (North American Airborne Mercury Experiment) and TROPHONO

(Photolysis of Particulate Nitrate: a Daytime HONO Source and a Re-NOx-ification Pathway in the Troposphere). These three projects were not proposed together in advance, but were merged onto the C-130 platform as a means to complete all three projects in the same year and to maximize the scientific value of the combined experiment. Thus the primary objective from each separate project now becomes the primary objective for NOMADSS. These are:

1) Quantify biogenic emissions and their interactions with anthropogenic pollutants and to understand the implications for atmospheric chemistry, air quality and climate (primary SOAS goal);

2) Constrain emissions of mercury from major source regions in the Eastern United States and quantify the distribution and chemical transformations of speciated mercury in the troposphere (primary NAAMEX goal);

3) Investigate the role of particulate nitrate photolysis in the cycling of reactive nitrogen species in the troposphere, focusing on HONO as an intermediate product (primary TROPHONO goal).

Further details, hypotheses and scientific for each objective above described in the original proposals and White Papers at the URLs given below:

SOAS: http://climate.envsci.rutgers.edu/SOAS/SOAS_White_Paper_final.pdf

NAAMEX: http://www.atmos.washington.edu/jaffegroup/modules/NAAMEX/

TROPHONO:
http://www.eol.ucar.edu/projects/nomadss/meetings/2012Nov/presentations/TROPHONO.pdf

## b. Study Regions

NOMADSS will take place over the Southeastern U.S. from 1 June -15 July 2013. The NCAR C-130 aircraft will be based out of Smyrna/Rutherford County Airport in Tennessee (36.00o N, 86.52 o W- KMQY), which is located approximately 20 km southeast of Nashville, TN. Because of the range of scientific objectives, NOMADSS will involve 10 different flight patterns. Flight tracks for NOMADSS will cover much of the eastern U.S. This includes a north-south stretch from Michigan to Florida, and an east-west extent from the North Atlantic to western Oklahoma. Detailed flight tracks are given in section 6 of this document. A ground-based component will use existing sites from the SEARCH network (South Eastern Aerosol Research and Characterization; http://www.atmospheric-research.com/studies/SEARCH/). A large ground based experiment will take place at the Centerville, AL SEARCH site (32.90 o N, 87.25 o W), focused on the SOAS objectives.

c. Climatology of the Southeastern U.S.

The climate of the southeastern U.S. is sub-tropical and generally warm and humid during summer. For Nashville, average high temperatures in June and July are 30$^{o}$C and 32$^{o}$C, respectively. Rainfall averages about 105 and 92 mm per month for June and July, respectively. The Birmingham area is somewhat warmer, with average high temperatures of 32$^{o}$C and 33$^{o}$C for June and July, respectively. Average rainfall for June and July in Birmingham is 60 mm and 44 mm, respectively. The warm summer temperatures, combined with natural emissions of organic compounds (e.g., isoprene and monoterpenes), anthropogenic precursors, high humidity and photochemistry results in substantial production of oxidants and aerosol. Thus this region is ideal for the NOMADSS objectives.

d. Key personnel

The table below provides contact information on key project personnel.

Table 1. NOMADSS Key Personnel.

| Name | Affiliation | Role | Cell phone | Email |
|---|---|---|---|---|
| Dan Jaffe | UW | PI (NAAMEX) | 206-225-8264 | djaffe@uw.edu |
| Alex Guenther | NCAR | PI (SOAS) | 720-505-0137 | guenther@ucar.edu |
| Xianliang Zhou | SUNY Albany | PI (TROPHONO) | 518-339-7850 | zhoux@wadsworth.org |
| Allen Schanot | NCAR | Aircraft Mgr. | 303-319-1052 | schanot@ucar.edu |
| Vidal Salazar | NCAR | Project Mgr. | 720-771-5018 | vidal@ucar.edu |
| Steve Williams | NCAR | Data Mgr. | | sfw@ucar.edu |
| Anne Marie Carlton | Rutgers | Ground Site Coordinator | | carlton@envsci.rutgers.edu |

## Schedule

The NCAR's C-130 will be deployed for the NOMADSS field campaign over the period of June 1 – July 15, 2013, using the Smyrna/Rutherford County Airport (SRCA-KMQY) as the operation base. Test flights will take place between May 20 and 28, from the Rocky Mountain Metropolitan Airport (RMMA- KBJC). The aircraft will be ferried from RMMA to SRCA on May 30 and back to RMMA on July 17. Instruments are uploaded between April 8 and May 17 and offloaded during July 18-26. The calendar for C-130 activities is shown as follows.

Table 2. NOMADSS key project dates:

| | |
|---|---|
| May 8-10 | C-130 Access all day - no flights |
| May 11 - May 12 | Weekend - no access |
| May 13-15 | C-130 Access all day - no flights/Payload Upload Complete |
| May 16 | EMI Test - instrument operators required |
| May 17 | C-130 Weigh-in; Maintenance Flight; Pilot Proficiency Flight |
| May 18 - May 19 | Weekend - no access |
| May 20 | Safety Briefing / Potential Test Flight |
| May 21 | Potential Test Flight |
| May 22 | Potential Test Flight |
| May 23 | C-130 Access all day - no flights |
| May 24 | C-130 Access all day - no flights / Ground Shipment departs from RMMA |
| May 25 - May 27 | Holiday Weekend - no access |
| May 28 | Potential Test Flight |
| May 29 | C-130 Prep for departure |
| May 30 | C-130 Ferry to Smyrna |
| June 1 – July 15 | Research flights out of Smyrna |
| July 17 | C130 Ferry back to Colorado |

a. Daily Schedule

Most of the scheduled flights are designed to study daytime processes in the troposphere. To maximize the flight time around solar noon during the day and to allow for sufficient instrument preparation time in the morning, a complete cycle of daily activities is planned starting with a Daily Weather Briefing and a Daily Planning Meeting as follow:

1000 (LT/CDT): Daily Forecast/Modeling discussion.

The lead forecaster will organize this meeting. All forecasting groups should be present at the meeting. The current PI will be present also to ask questions. Others can listen in but are not required to be present. The meeting will focus on the next primary flight pattern and on one alternative flight pattern. This meeting will be held at the operations center and will be routinely broadcasted on ReadyTalk.

Duration of the meeting: between 40-90 minutes

1300 (LT/CDT): Daily Planning Meeting.

This meeting will present a summary of the weather and chemical forecasts for the next possible flights (20 minutes). Discuss any instrument and aircraft maintenance issues (10 minutes), coordination with the NOAA aircraft and the ground sites (10 minutes) and announce a decision about the next day’s flight, if one will occur (10 minutes). This meeting should not last more than one hour. This meeting occurs on both flight and non-flight days. On non-flight days, the meeting is led by the project PI and representatives from each instrument on the C130 must be present. If a flight is planned for the next day, access and take off time will be confirmed at the meeting. On flight days, when the PI is flying, the meeting will be lead by the lead forecaster and it is not expected that every instrument group will be represented. Nonetheless, even on flight days, this meeting will allow the forecasters to discuss and plan for future flight scenarios.

The outcomes of the meeting will be summarized in the NOMADSS Field Catalog.
The Daily Planning meetings are broadcast visually and audibly using ReadyTalk (see the communications section for connection information), allowing those who not present at the Operations Base to participate. Because of the important information disseminated during the meeting that is needed for decision-making, details (e.g. weather, flight plans) presented at the meeting are necessarily kept to a minimum. Science Team meetings are scheduled for presentation and discussion of preliminary scientific results. Suggestions and questions about the process are addressed outside of the meeting.

Table 3. Schedule for daily Planning meeting (1300 (LT/CDT)

| **Start** | **Length** | **Item** |
|---|---|---|
| 13:00 | 0:15 | Weather summary (from Daily Weather Briefing) |
| 13:15 | 0:10 | Facilities status updates |
| 13:25 | 0:05 | Flight plans |
| 13:30 | 0:20 | Discussion of deployment options |
| 13:50 | 0:10 | PI discussion |
| 14:00 | End | Decision for next day; tentative decisions for next few days |

There are five types of daily schedules during flight days, corresponding to seven flight patterns taking into account the proposed flight times in the day and the durations. The instrument warm-up and preflight calibration will start at least 2-3 hours before the scheduled take off. Weather forecast will be updated, and pilots, mission scientist and coordinators will be briefed with the updated forecast. After each mission, enough time will be provided for post-flight instrument maintenance and calibration, and instrument status should be reported immediately at the data catalog status report form or to the mission scientist. <u>ANY INSTRUMENT OR AIRCRAFT ISSUES SHOULD BE REPORTED TO THE PI AS SOON AS THEY ARE IDENTIFIED.</u>

NOMADSS Flight Patterns

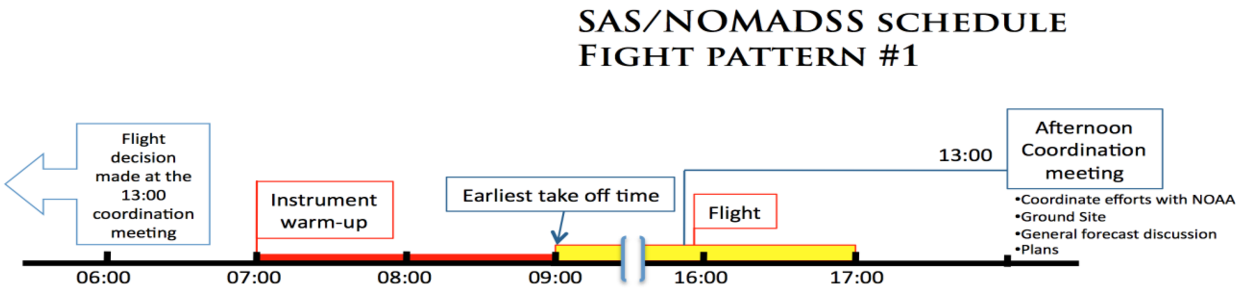


Figure 1: SAS/NOMADSS Schedule for flight pattern #1. On a day with flight pattern #1, the scheduled take off time is 9:00 CDT, and mission is completed at 17:00 CDT. There are eight flights scheduled to follow this schedule.

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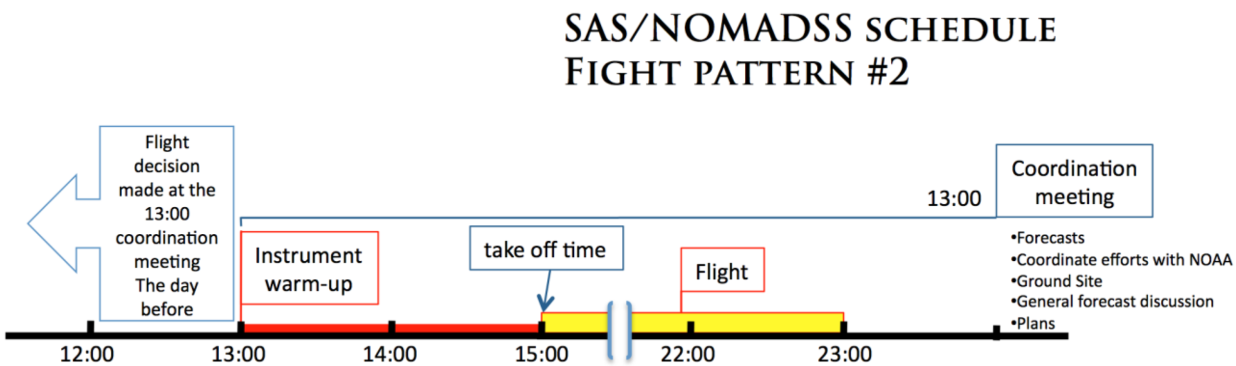


Figure 2 SAS/NOMADSS Schedule for flight pattern #2. Flight pattern #2 is an afternoon/nighttime mission; the scheduled take off time is 15:00 CDT, and mission is completed at 23:00 CDT. There is no flight scheduled the next day. Only one such flight is scheduled.

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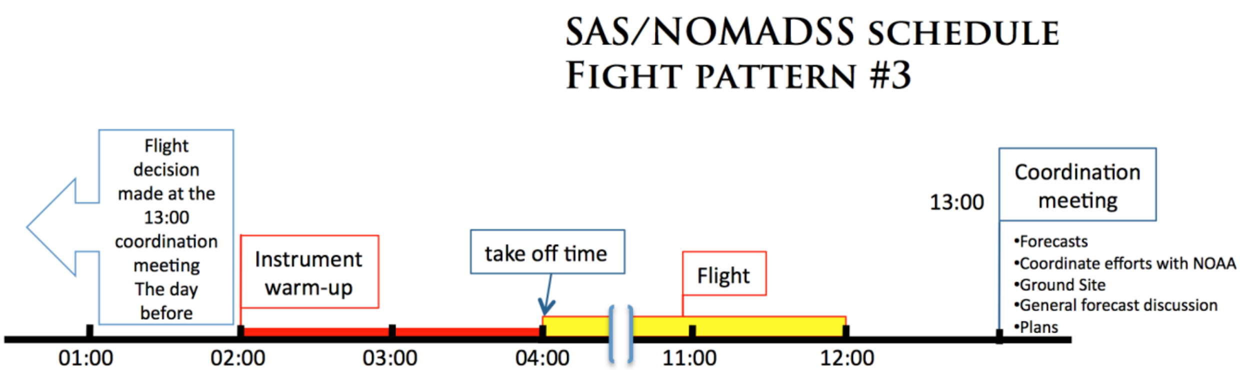


Figure 3 SAS/NOMADSS Schedule for flight pattern #3. Flight pattern #3 contains an early morning component; the scheduled take off time is 4:00 CDT, and mission is completed at 12:00 CDT. Only one such flight is scheduled.

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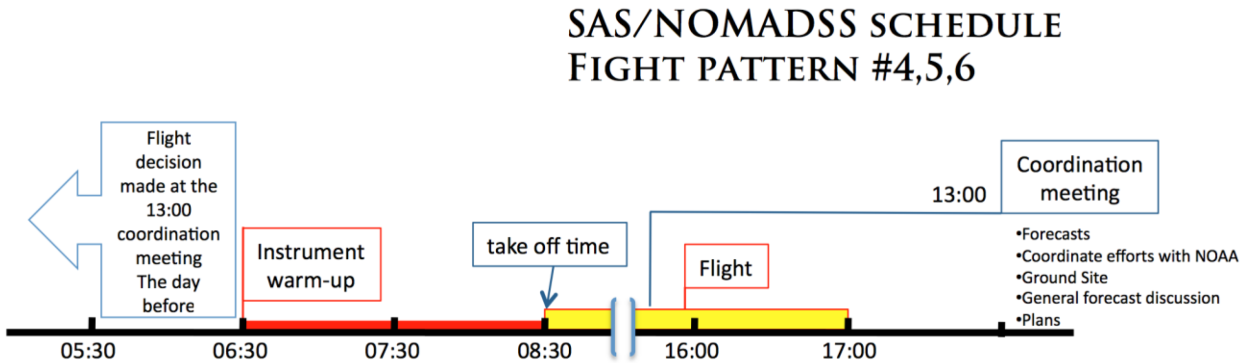


Figure 4 SAS/NOMADSS Schedule for flight pattern #4, 5 and 6. On a day with flight patterns #4, 5 or 6, the scheduled take off time is 8:30 CDT, and mission is completed at 17:00 CDT. There are six flights in total to follow this schedule. Note that flight pattern #6 offers the best possibility for comparisons with the CARIBIC flights. These could occur on June 17, 28th, July 3rd, or July 10th, depending on the CARIBIC and NOMADSS schedules.

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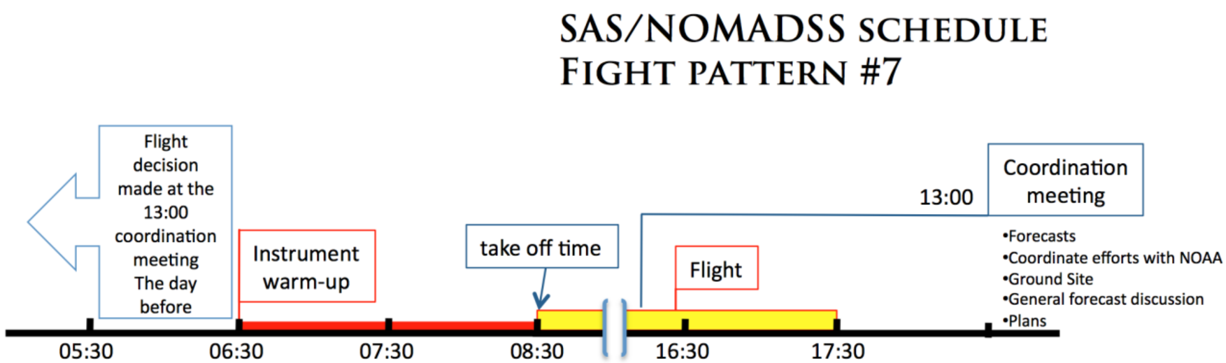


Figure 5. SAS/NOMADSS Schedule for flight pattern #7. Flight pattern #7 is for offshore outflow flights with long flight duration of 9 hours; the scheduled take off time is 8:30 CDT, and mission is completed at 17:30 CDT. There is no flight scheduled the next day. Two such flights are scheduled.

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Occasionally, a science meeting will be held on non-flight days for discussion of interesting scientific findings from the campaign. No major decisions will be made at this meeting, all project personnel should be confident that decisions on daily activities will be made and announced at the 1300 daily planning meeting.

Approximately every seven days, a hard down day is declared. On those days, no aircraft access is allowed and the aircraft operation teams will not be available. The Daily Forecast and Planning meetings are held on hard down days.

Confirmation or changing of announced decisions are posted on NOMADSS data catalog web site and broadcast via email and Twitter. Please see the communications section of this document for additional details.

**Decision Making**

In the field, after general and planning meetings, it must be decided on a daily basis the decision of go, no go and which flight pattern will be the target of the flight.
These decisions are based on evaluation of:

- Weather forecasts
- Readiness of the aircraft in consultation with the facility managers
- Readiness of aircraft instrumentation
- Readiness of ground-based facilities
- Balance between the various types and locations of studies needed to address the goals and hypotheses of the experiment
- Aircraft flight hours and study days remaining.

The approximate timeline for decision-making is shown as follow

| Time relative to take off | Activity |
|---|---|
| 2 to 3 days | Tentative decisions on primary and alternate flight patterns for next flight and the location. |
| - 18 hrs | Decision on next day's flight. Meet with the pilots to finalize candidate flight patterns, and finalize takeoff times; review recommendations and assess deployment probability for next several days. |
| - 3 hrs | Final decision on that day's flight. |

**Afternoon Weather Forecast Update**
Once a decision has been made for a flight the next day, the lead forecaster should continuously monitor weather conditions. Significant changes to the forecast should be reported immediately to the PI. If the changes are substantial, the PI may need to make late changes to the flight plans.

**Pre-flight Aircraft Sortie Briefing**
On flight days 2-3 hours before takeoff , the pilots, mission scientists, and mission coordinators are briefed by the NOMADSS PIs/designees and the Lead Forecaster on the weather forecast and the flight plans, including any changes to plans since the "go" decision made the previous afternoon.

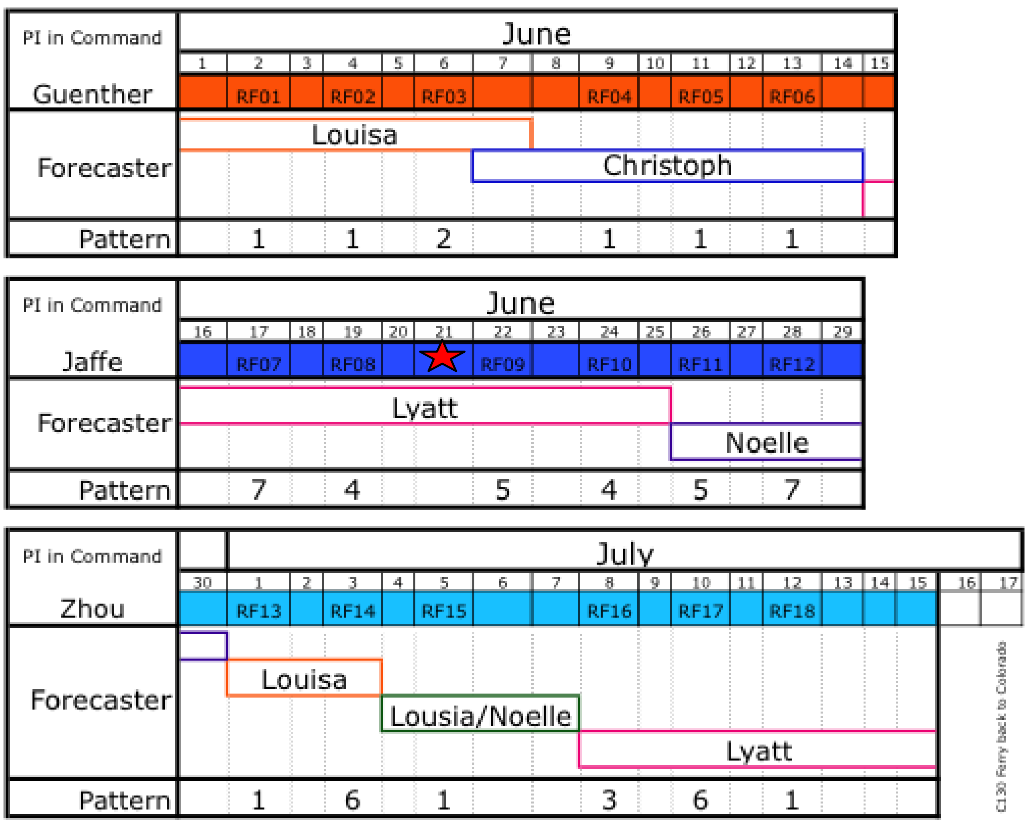
**Post-flight Aircraft Sortie Debriefing**
During ferry back to the Operations Base, the aircraft instrument teams are surveyed by the platform Mission Scientist on the success of their measurements during the flight and the status of their instruments. The status of the aircraft and the instruments will be further updated during the 1-hr post-flight instrument maintenance/calibration period. These are summarized in the Field Catalog and at a short Post-Flight Status meeting after the aircraft return to base by the

facility manager or the platform Mission Scientist. This information will feed into decisions for upcoming airborne deployments.

**PI Schedule**

The NOMADSS field study integrates three individual projects, the NAMEX, SOAS, and TROPHONO. Close coordination and cooperation among the scientists of the three projects is the key to the success of this integrated study. The three PIs (and their designates) will work closely, together with pilots, project coordinators and forecasters, in making daily decisions regarding flight operations. To facilitate the decision making, one PI (or the designate) is assigned to be the primary PI, who will be present at the site and be responsible for coordinating the overall NOMADSS activities. The schedule for the primary PI is as shown in Table 4:

Table 4. Principal Investigators lead forecaster and tentative flight plan schedule. Schedule notes: Open house/media day is on June 21. No flight that day. All groups should have someone present at the Smyrna airport. A comparison with CARIBIC is possible on June 17, 28th, July 3rd, or July 10th. For NOMADSS this would require we fly flight pattern #6 on that day.




In the first week, all three PIs plan to be at the site to oversee their individual projects and to help setting up daily NOMADSS operation routine during the campaign.

## Operations Base

The airport in Smyrna, Tennessee (Smyrna/Rutherford County Airport, SRCA, or Smyrna Airport, http://www.smyrnaairport.com/) was selected as the Operations Base for the NOMADSS campaign. A number of factors influenced this decision including the length and weight capacity characteristics of the runway, availability and suitability of hangars, laboratory and meeting space, availability of vendors for the science team needs, and other factors. Smyrna is a town in Rutherford County, Tennessee (http://townofsmyrna.org/.aspx). It is located, 35°58′46″N 86°31′16″W, about 20 miles southeast of Nashville, off interstate highway I-24. Smyrna's population was about 40,200 in 2011. In 2007 U.S. News & World Report listed Smyrna as one of the best places in the United States to retire. There are 14 hotels/motels and 59 restaurants within 10 miles from the airport.

### Layout of Smyrna Airport Facilities

Smyrna Airport is designated a General Aviation/Reliever Airport, certificated by the FAA as a Part 139 Class IV airport. A Public Safety Department staffed round the clock provides police, fire and emergency medical services. The primary runway is 8,037 feet long and is equipped with an Instrument Landing System, and the second runway is 5,546 feet long. The airfield is equipped with a complete lighting system with intensity sensitive runway lighting. The Air Traffic Control Tower operates 7 a.m. - 7 p.m., seven days per week. Smyrna Airport currently operates as a joint use facility with the Tennessee Army National Guard. The airport also serves as a military flight training facility as well as a hurricane evacuation point for military bases along the Gulf and East Coasts. Airport and Business Park amenities include:

- High-speed internet access/free Wi-Fi in airport terminal
- Outdoor airfield observation areas
- Conference and business meeting facilities in airport
- Airport business center
- Shuttle service

During the project deployment period, the C-130 will use **Hangar 621 located at 621 Fitzhugh St. Smyrna TN.** The hangar area reserved for instrument maintenance totals 1000 square feet. We will also use the office space on the 2nd floor of the West side of the hangar. The facility has wired (in the office space) and Wifi internet service (throughout the hangar and office space). NOAA’s P3 will use the same hangar area during the same period of time.

Information on the Smyrna Airport facilities and other issues related to the Operations Base can be found in the site visit report at: http://www.eol.ucar.edu/projects/sas

### Uses, Regulations, and Security

The NOMADSS Science Team members are required to take a safety briefing prior to using the Smyrna airport facilities. There will be two security briefings before the departure of the C130 and at the beginning of the field campaign. Please make sure that you are aware of security protocols and if you were not part on one of the briefings, please contact the project manager.

Everyone participating on the deployment of NOMADSS will be issued a security badge to be able to work in and around the hangar area. This badge must be worn at all times. An example of the badge is shown in figure 9.

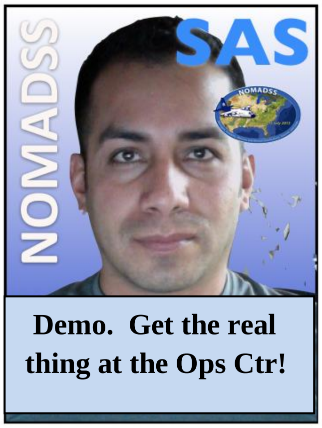



Figure 9 SAS/NOMADSS security badge.

## Project Communications

Communications between participants, facilities, and team members are critical to the NOMADSS operations. These communications range from in-person and virtual attendance at planning meetings to ground-to-aircraft communication and communication with the ground-based facility teams. The Operations Base at Smyrna Airport is configured with high bandwidth Internet connectivity that includes wired and Wi-Fi access.

Daily briefings will take place at the Data analysis and SAS/NOMADSS operations center located at the **hotel Hampton INN, 2573 Highwood Blvd. Smyrna, TN 37167**. Every member of the SAS/NOMADSS working team will have direct access to the data center 24/7 to work and to interact with the PI team. The Data center is equipped with high speed internet access, two large screen monitors (to display weather and aircraft position) and teleconferencing services.

All meetings will be operated with **ReadyTalk** teleconferencing services, allowing virtual attendance of the overall SAS team. Audio will be transmitted via telephone, and video/presentations via the web. The following is the access information for ReadyTalk valid throughout the campaign.

Audio Dial-In Information:
U.S. & Canada: 866.740.1260
U.S. Toll: 303.248.0285

Access Code: 4978380

For Web access (presentations, etc) please point your browsers to: http://www.readytalk.com/

on "Join a meeting" enter the same access code 4978380

During flight operations, Xchat (available trough the Field Catalog website) will be used to communicate in real-time between the airborne platforms, the ground facilities, and the Operations Base. Various chat rooms will be set up for specific communication purposes. Twitter will be setup for project specific communications as well.

To keep team members informed of the day-to-day decisions and changes to those decisions, brief broadcast messages will be sent via email, Twitter and posted on the project data catalog website (http://catalog.eol.ucar.edu/sas). The web interface of the data catalog will be used to access information needed by the decision-making team, such as research model output, operational model output, data from aircraft instruments and ground-based facilities, and other types of information. Thus, the main repository for such information is the C-130 Field Catalog: http://catalog.eol.ucar.edu/sas.

Table 5. Communications protocols to be used during NOMADSS.

| Forum | Purpose | Details |
|---|---|---|
| Data Catalog | Operational announcements<br>• Daily ops plan<br>• Facility status<br>• Weather and chemical forecasts<br>• Also suitable for mobile devices | http://catalog.eol.ucar.edu/sas |
| Xchat | • Real-time communications: Ground to aircraft<br>• Smyrna to Centerville | Available through the data catalog website Communications with the ground can happen at any time. Ground to aircraft communications can happen only when the aircraft is in the air. |
| Twitter | Direct announcements to subscribers of daily decisions and other short messages. | #SAS_Operations on any twitter capable device. |
| Emails | Emails to the general community to announce status updates and daily planning schedules and decisions. | Email to nomadss@eol.ucar.edu<br>To subscribe, please go to:<br>http://www.eol.ucar.edu/mailman/listinfo/nomadss |
| Phone | Direct line communications between project participants. | A full list of phone numbers will be collected from project participants upon arrival in Smyrna |
| Bulletin board | Bulletin board at the operations center and hangar work space | Bulletin board can be used for short messages at the project locations. |

## Aircraft Operations

The NSF/NCAR C130 aircraft will be the primary platform for the NOMADSS airborne component. Three other research aircraft will be operated within the NOMADSS domain during the study period. This includes the NOAA P3 flown for SENEX, a regional study conducted across the eastern U.S., and the Purdue Duchess and Stonybrook Long EZ aircraft operated for SOAS, around the SOAS ground site near Centerville Alabama. The four aircraft will conduct complementary measurements and the coordination and intercomparison of these measurements is described in section XXX .

Capabilities, Payloads, Constraints, Safety

The C130 is configured primarily to quantify fluxes, transformations and distributions of VOC, Ozone, NOx, mercury and HONO. Real-time communication between PIs on the ground and operators on the aircraft will facilitate the ability to examine instrument performance and data during flights. Typical C130 aircraft performance parameters include

- Cruise speed: 200-220 kt IAS
- Slow flight: 150 kt IAS
- Maximum speed: 250 kt IAS
- Runway length requirements (155,000 lb gross weight): 6300 ft (sea level), 8500 ft (5000 ft elevation)
- Maximum altitude

More details can be found in the C130 investigators handbook. See http http://www.eol.ucar.edu/instrumentation/aircraft/C-130/documentation/c-130-investigator-handbook

Onboard crew must undergo an aircraft safety briefing prior to participation in C130 flights.

Constraints for operation of C130: NCAR missions will be flown in accordance with FAA Regulations Subpart B, appropriate FLIP publications, ICAO procedures applicable to the host country, and NCAR directives.

*Operations under Adverse Conditions*
Adverse conditions include, but are not limited to, ceiling or visibility at or near minimums, marginal runway conditions, marginal approach aids, aircraft emergencies, severe turbulence, near maximum crosswind, unusual icing, terrain features that present an unusual hazard, and aircraft system malfunctions. NCAR aircraft will not be operated into known or forecasted weather conditions (icing included) that will exceed aircraft limitations as described in the handbook. The NCAR aircraft will not be operated into areas of known or forecasted thunderstorms unless radar is installed and operational or the weather forecast indicates that the flight can be conducted through the areas visually. Final responsibility for the safe conduct of the mission rests with the Aircraft Commander. If in his/her judgment an unsafe condition exists, the mission will be delayed, canceled, or re-routed.

*Altitude Restrictions for NCAR Aircraft*
Minimum stated altitudes apply unless a waiver has been obtained. Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

a. Anywhere. An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

b. Over congested areas. Over any congested area of a city, town, or settlement, or over any open-air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

c. Over other than congested areas. An altitude of 1,000 feet above the surface, except over Ocean water. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

d. Over Ocean water - VFR Conditions - An altitude of 100 feet above the surface for straight and level flight, and a minimum altitude of 300 feet for turning maneuvers exceeding bank angle of 5 degrees.

e. Auto pilot engaged – Minimum altitude of 300 feet above the surface.

Added constraints for hours of Darkness or During Restrictive Visibility

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

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

Note: These minimums do not apply to coupled approaches.

*Weather Forecasts*

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

*Normal Procedures for Formation Flight*

Close formation is only to calibrate and collect data from scientific instruments with other aircraft participating in scientific exercises. Close formation is defined as when an aircraft is flying in close proximity to another aircraft in such a manner as to require the following aircraft to take all external visual references from the lead aircraft. Close formation leading is defined as being totally responsible for all aspects of the safety, terrain clearance, positioning and handling for aircraft that are formatting in close proximity to the lead aircraft. Close formation is only allowed with one other aircraft at any one time.

The more restrictive regulations of the aircraft's state of registration, and airspace used, will always apply. Aircraft shall not fly formation unless the aircraft commanders of the aircraft have agreed to do so.

Crew duty limitations for the C130:

Adequate rest for crewmembers is essential for the safe and efficient operations of NSF/NCAR aircraft in support of research programs. The restrictions in this section are the minima and maxima allowable. The 14-hour duty limit is intended for short, intensive operational periods and is not to be considered as a normal workday for NCAR flight crews. Investigators must be aware of other factors that flight crews must contend with, such as the fatiguing effects of continued IFR operation, extremes of temperature, complexity of mission requirements, and other variables that the pilot-in command must consider in determining actual crew limits for any operation. During extensive research periods, proper rest becomes increasingly important, and when deemed necessary, the project pilot may elect to declare additional crew rest periods other than those listed below. Specific project flight schedules may necessitate additional staffing in order to meet the crew duty limitation requirements specified. Single C-130Q crew duty limits, assuming ideal working conditions include:

- Any 24-hour period 10 flight hrs
- Any consecutive 7 days 35 flight hrs
- Any 30-day period 110 flight hrs
- Consecutive working days 6 days
- Crew duty period 14 hrs
- Minimum crew rest period 12 hrs

Flight hours are calculated from block to block times, i.e., from the time the aircraft first moves under its own power for the purpose of flight to the moment it comes to a rest at the next point of landing. Crew duty periods start at the briefing time or when the crew is considered on alert and ends when the aircraft is shut down and secured. Days off will be scheduled at least 12 hours in advance, with the crew being relieved of all duties.

More details can be found at http://www.eol.ucar.edu/about/our-organization/raf/policies

Aircraft Instrumentation

Table 6, below summarizes the C-130 payload for NOMDASS:

Table 6. Measurements on the C-130 for NOMADSS.

| Instrument | Lead | Location |
|---|---|---|
| RAF Mission Scientist Display | Webster | flight deck |
| RAF State Parameters | Schanot | fuselage |
| RAF Fast Hygrometer | Beaton | fuselage |
| RAF Fast Temperature | Schanot | fuselage |
| RAF CDP Cloud Probe | Rogers | wing pod |
| RAF PCASP Aerosol Probe | Rogers | wing pod |
| RAF SPP-300 Aerosol Probe | Jensen | wing pod |
| RAF UHSAS Aerosol Probe | Rogers | wing pod |
| RAF King Probe Liquid Water | Schanot | wing |
| RAF OPHIR-III In Cloud Temperature | Beaton | wing pod |
| RAF Cloud Base Temperature | Schanot | fuselage |
| RAF Radiometric Surface Temperature | Schanot | fuselage |
| RAF Up/Down IR Irradiance | Haggerty | fuselage |
| CARI NO-NO2 | Weinheimer | cabin / HIMIL (1) inlet |
| CARI Fast Ozone | Campos | cabin / HIMIL (1) inlet |
| CARI Carbon Monoxide | Campos | cabin / HIMIL (1) inlet |
| CARI Picarro Carbon Dioxide | Flocke | cabin / HIMIL (1) inlet |
| EOL / HAIS TOGA | Apel | cabin / HIMIL (3) inlet |
| NCAR/ACD PTRMS | Kaser | cabin / inlet |
| UW Gaseous Elemental Mercury (GEM) | Jaffe | cabin /Special inlet (A) |
| UW Total Gaseous Mercury (TGM) | Jaffe | cabin /Special inlet (A) |
| CU HOx / H2SO4 | Cantrell | cabin / Special inlet (B) |

| | | |
|---|---|---|
| SUNY HONO / HNO3 | Zhou | cabin / HIMIL (4) inlet |
| SUNY pNO3 / pOrganics | Zhou | cabin / SDI inlet |
| SUNY Bulk Aerosol | Zhou | cabin / SDI inlet |
| UCLA Mini - DOAS | Stutz | cabin / window |
| Up/Down Vis & UV Irradiance | Haggerty | fuselage |
| $SO_2$ | Mauldin | ?? |

All of the measurements aboard the C130 will make important contributions to the NOMADSS science goals and may enable unexpected findings. All instruments occasionally have some downtime or periods of degraded data quality and so it will be necessary in the decision-making process to consider instrument readiness as one of the factors in choosing flight patterns and considering deployment decisions. The critical instruments for each of three general flight types are listed below:

Vertical Profiling Flight Type: HONO, DOAS, NOx
Transect Flight –Type: Hg, HONO, DOAS
Flux Flight Type: PTRMS, TOGA, $O_3$, NOx

NOMADSS flight track scenarios

The NOMADSS C-130 aircraft measurements will be accomplished using 13 flight scenarios grouped into three general flight types. While all of these flight types will include some flux, vertical profiling, and transect components, the 13 flight scenarios can be broadly categorized into three groups as follows:

Vertical Profiling Flights: Flight scenarios 2 and 3Transect Flights: Flight  scenarios 4, 5, 6, and 7
Flux Flights: Flight scenarios 1, 8, 9, 10 , 11, 12 and 13

Table 7.  Flight scenarios for NOMADSS-

| **Flight scenarios** | **Objectives** |
|---|---|
| **1. Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, daytime.** | |
| • Morning ~450-km horizontal transect at 300 m, to the target location for vertical profiling (~1.5  hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with “top-down” emission estimates; better understanding of |

| | |
|---|---|
| • 6-level vertical profiling in a 70-km long racetrack pattern starting in the FT (6000 m, 4000 m, and 2000 m, 20 min at each level) and then in the PBL (just below the PBL top, middle of the PBL, and 300 m, 30 min at each level) (~3 hr)<br>• Noontime ~275-km horizontal transect at 300 m (~1 hr)<br>• 6-level vertical profiling in a 50-km long racetrack pattern starting in the PBL (300 m, middle of the PBL, and just below the PBL top, 30 min at each level) and then in the FT (2000 m, 4000 m, and 6000 m, 20 min at each level) (~2 hr)<br>• Afternoon ~275-km horizontal transect at 300 m, back to the airport (~1 hr) | $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **2. Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, early afternoon/night, one flight.** | |
| • Afternoon 150-km horizontal transect at 300 m, to the target location for vertical profiling (~0.5 hr)<br>• 6-level vertical profiling in a 70-km long racetrack pattern starting in the PBL (300 m, , middle of the PBL, and just below the PBL top 30 min at each level) and then in the FT (2000 m, 4000 m, and 6000 m, 20 min at each level) (~3 hr)<br>• Time series, alternating at two altitudes: 500 m and 3000 m, ~20 min each, in 30-km diameter circles, starting ~1 hr before sunset. (~3.5 hr)<br>• nighttime 150-km horizontal transect at 300 m, back to the airport (~0.5 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory; (3) examination of nighttime HONO formation and accumulation in the PBL and FT. |
| **3. Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, early-late morning, one flight.** | |
| • Early morning 150-km horizontal transect at 300 m, to the target location for vertical profiling (~0.5 hr)<br>• Time series, alternating at two altitudes: 500 m and 3000 m, ~20 min each, in 30-km diameter | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks. |

| | |
|---|---|
| circles, starting ~1 hr before sunrise. (~3.5 hr)<br>• 6-level vertical profiling in a 70-km long racetrack pattern starting in the FT (6000 m, 4000 m, and 2000 m, 20 min at each level) and then in the PBL (just below the PBL top, middle of the PBL, and 300 m, 30 min at each level) (~3 hr)<br>• Late morning 150-km horizontal transect at 300 m, back to the airport (~0.5 hr) | **NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in the laboratory; examination of maximal HONO nighttime accumulation and its morning photolytic decay in the PBL and in the FT. |
| **4. Ohio Valley transect and profiling , daytime, two flights.** | |
| • Morning transect from Tennessee to Ohio Valley at 3500 m, with some descents in BL enroute (~2 hr)<br>• 6-level vertical profiling in Ohio Valley in a 70-km long racetrack pattern from lower PBL to 8000 m. (~3hr)<br>• PBL profiling over Lake Michigan (~1.5 hr)<br>• Afternoon transect from Ohio Valley to Tennessee at 3500 m (~2 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of most concentrated Hg source region in North America, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in the laboratory; evaluation of relative HONO source strengths from photo-enhanced $NO_x$ reaction on aerosol surface *vs* p-$NO_3$ photolysis in urban and industrial plumes. |
| **5. High elevation transect to west and profiling, daytime, two flights.** | |
| • Depart Smyrna to west and ascend to 20,000 feet. Continue west to a point near 36.8 N, 103.0 W (~780 nautical miles)<br>• Head south and descend slowly to 2.5 km for a vertical profile.<br>• Continue south and re-ascend/sample back to 20,000 feet.<br>• Turn east and return to Tenn via a northward arc at approx 20,000 feet.<br>• Descend to Smyrna and land. | **SOAS objectives**: Direct quantification of VOC, ozone and NOx surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HOx/NOx/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Examination of vertical profile of $Hg^0$ and $Hg^{+2}$ in region where models predict high $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental and oceanic air masses; |

<table>
<tr><td></td><td>collection of bulk aerosol samples for photochemical experiments in the laboratory.</td></tr>
<tr><td colspan="2">6. Florida/North Atlantic transect and profiling , daytime, two flights.</td></tr>
<tr><td>
• Morning transect from Tennessee to North Atlantic 300-400 km off north Florida/south Georgia coast at 3500 m (~2 hr)<br>
• Five -level vertical profiling over the North Atlantic (300-400 km off North FL and GA coast) in a 70-km long racetrack pattern from lower MBL to 6000 m (three in MBL and two in FT). (~2 hr)<br>
• Off-coast transect from North FL to North Carolina at 3500 m (~2 hr)<br>
• Return to TN from North Carolina coast at 3500 m (~2.5 hr)
</td><td>
SOAS objectives: Direct quantification of VOC, ozone and NOx surface fluxes and reconcile differences with “top-down” emission estimates; better understanding of HOx/NOx/ozone/organics/aerosol distributions, sources and sinks.<br>
NAAMEX objectives: Characterization of outflow from major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$, verification of model predicted gradients in Hg.<br>
TROPHONO objectives: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental and oceanic air masses; collection of bulk aerosol samples for photochemical experiments in the laboratory.
</td></tr>
<tr><td colspan="2">7. Offshore outflow flight: daytime, two 9-hr flights requested, early to late July</td></tr>
<tr><td>
• Morning transect due east from Tennessee for 1100 km at 3000 meters over land, dropping to 1000 meters over the ocean (~3 hrs).<br>
• Proceed due north for 600 km, remaining at 1000 meters (~1.5 hrs)<br>
• Ascend to 3000 meters and trace route back to Tennessee. (~4.5 hrs)
</td><td>
SOAS objectives: N.A.<br>
NAAMEX objectives: Characterization of outflow from major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$, verification of model predicted gradients in Hg.<br>
TROPHONO objectives: Examination of distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental and oceanic air masses; Collection of bulk aerosol samples for photochemical experiments in the laboratory.
</td></tr>
<tr><td colspan="2">8. Flight over Alabama with racetracks over SOAS forest sites: daytime, three 8 hour flights.</td></tr>
<tr><td>
• Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (~1.5 hr)<br>
• Four 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000’ AGL to ~1000’ above the BL, 12 min at each level) (~5 hrs)<br>
• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (~1.5 hr)
</td><td>
SOAS objectives: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with “top-down” emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>
NAAMEX objectives: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>
TROPHONO objectives: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and
</td></tr>
</table>

| | |
|---|---|
| | $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **9. Flight over Alabama with racetracks over Noxubee forest: daytime, one 8 hour flight.** | |
| • Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (~1.5 hr)<br>• Four 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000' AGL to ~1000' above the BL, 12 min at each level) (~5 hrs)<br>• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (~1.5 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **10. Flight over Alabama with racetracks over SOS-ROSE forest sites: daytime, one 8 hour flight.** | |
| • Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (~1.5 hr)<br>• Four 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000' AGL to ~1000' above the BL, 12 min at each level) (~5 hrs)<br>• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (~1.5 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **11. Flight over Carolinas with racetracks over forest sites: daytime, one 8 hour flights.** | |
| • Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (~1.5 hr)<br>• Four 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000' AGL to ~1000' above the BL, 12 min | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of |

| | |
|---|---|
| at each level) (~5 hrs)<br>• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (~1.5 hr) | $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **12. Flight over Indiana and Missouri with racetracks over forest sites: daytime, one 8 hour flights.** | |
| • Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (~1.5 hr)<br>• Four 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000' AGL to ~1000' above the BL, 12 min at each level) (~5 hrs)<br>• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (~1.5 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |
| **13. Flight over Tennessee with racetracks over forest site: daytime, one 7 hour flights.** | |
| • Morning ~500-km horizontal transect to the target location. In BL about half to two-thirds of the time (<0. 5 hr)<br>• Six 5-level vertical profile with ~30-km long vertical stacked racetrack pattern starting at ~1000' AGL to ~1000' above the BL, 12 min at each level) (~7 hrs)<br>• ~500-km horizontal transect return to the airport. In BL about half to two-thirds of the time (<0.5 hr) | **SOAS objectives**: direct quantification of VOC, ozone and $NO_x$ surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of $HO_x$/$NO_x$/ozone/organics/aerosol distributions, sources and sinks.<br>**NAAMEX objectives**: Characterization of major Hg source region, examination of vertical profile of $Hg^0$ and $Hg^{+2}$.<br>**TROPHONO objectives**: Examination of horizontal and vertical distributions of HONO, $HNO_3$, $pNO_3$ and $NO_x$ in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory. |

***Flux flights***

The flux flights are designed to characterize surface-atmosphere exchange of VOC and other constituents from a range of landscapes including various forest, agricultural, and built types.

Each of the eight flights will include horizontal surveys and multiple stacked racetrack vertical profiles and will be about 8 hours duration. All flights will be daytime (between 900 and 1600 hours) and in clear skies. The flights will focus on 4 different regions. Three of the flights (scenario 8) will target the SOAS ground sites near Centerville Alabama. An additional two flights (scenarios 9 and 10) will target nearby forest sites at Noxubee MS and SOS-ROSE site in AL. The other three flights will target flux tower and SOAS ground sites in North Carolina (Flight scenario 11), flux tower sites in Indiana and Missouri (flight scenario 12) and sites near the aircraft base in Smyrna TN (flight scenario 13).

The horizontal surveys will be flown at the minimum allowed air speed (typically 150 kt) and altitude (typically 1000 ft AGL) for about half to two-thirds of the flight with occasional climbing to higher altitude to facilitate complex terrain or improve cabin conditions (i.e. too hot or turbulent).

The stacked racetrack vertical profiles will begin above the planetary boundary layer and descend into the boundary layer to determine the PBL height. This will be followed by a racetrack (~30 km length; 2 km width) at the minimum allowed altitude (typically ~1000’ AGL) and then 3 more stacked racetracks equally spaced at altitudes between the minimum altitude and the PBL height. A fifth racetrack will be above the PBL and then a level in the PBL will be repeated. For example, if the minimum altitude is 1000’ AGL and the PBL height is 7000’ AGL then the racetracks will be at 1000’, 2500’, 4000’, 5500’, 8500’ and then again at 4000’. This will result in a total of 6 racetracks within a little over an hour.

*Flight scenario 8 (three flights)***:**

This flight pattern will consist of ~ 5 hours of stacked racetracks and ~ 3 hours of horizontal surveys and will cover ~700 nautical miles.

From Smyrna, TN, the first survey leg will go to GHM (Centerville, TN) then LDK (near Tuscaloosa, AL). Along the way, a stacked racetrack can be conducted in the Sipsey wilderness area : 34°20’N, 87°31'W). The flight will then continue to the SOAS Centerville sites (within Birmingham/ Birmingham 2 MOA) for stacked racetracks that include 32°57’N, 87°15'W to 32°37'N, 87°15'W and

The horizontal surveys on the return leg will go through BENTO, JEFER, KOMER, BEEZE, LAYIN, KT30O, UXM, KMQY

*Flight scenario 9 (one flight)***:**

This flight pattern will consist of ~ 5 hours of stacked racetracks and ~ 3 hours of horizontal surveys and will cover ~700 nautical miles.

From Smyrna, TN, the first survey leg will go to GHM (Centerville, TN) then LDK (near Tuscaloosa, AL). Along the way, a stacked racetrack can be conducted in the Sipsey wilderness area : 34°20’N, 87°31'W). The flight will then continue to Noxubee NWR (within Meridian 1 West MOA) for stacked racetracks that include 33°18’ N, 88°56’ W to 33° 18’N, 88° 34’ W

The horizontal surveys on the return leg will go through BENTO, JEFER, KOMER, BEEZE, LAYIN, KT30O, UXM, KMQY

*Flight scenario 10 (one flight)***:**

This flight pattern will consist of ~ 5 hours of stacked racetracks and ~ 3 hours of horizontal surveys and will cover ~700 nautical miles.

From Smyrna, TN, the first survey leg will go to GHM (Centerville, TN) then LDK (near Tuscaloosa, AL). Along the way, a stacked racetrack can be conducted in the Sipsey wilderness area : 34°20’N, 87°31'W). The flight will then continue to the SOS-ROSE site for stacked racetracks that include 32°19’ N, 88°16’ W to 32°19’N, 87° 51’ W

The horizontal surveys on the return leg will go through BENTO, JEFER, KOMER, BEEZE, LAYIN, KT30O, UXM, KMQY

*Flight scenario 11 (one flight)***:**

This flight pattern will consist of ~ 4 hours of stacked racetracks and ~ 4 hours of horizontal surveys and will cover ~850 nautical miles.

From Smyrna, TN, the first survey leg will go towards TYS (Knoxville, TN) then to RDU (Raleigh, NC). Stacked racetracks will be conducted at 35°56’N, 79°17'W to 35°44'N, 79°6'W. The survey will then continue to GSP (Greenville, South Carolina) and then a stacked racetrack at 34°37’N, 83°15'W to 34°54'N, 83°7'W. The survey will then continue on the return to Smyrna.

*Flight scenario 12 (one flight)***:**

This flight pattern will consist of ~ 4 hours of stacked racetracks and ~ 4 hours of horizontal surveys and will cover ~800 nautical miles.

From Smyrna, TN, the first survey leg will go towards BFR (Bedford, Indiana) then a stacked racetrack at Morgan Monroe Forest (39°8’N, 86°26'W to 39°22'N, 86°26'W). The survey will then continue to COU (Columbia, MO), UUV (Sullivan MO) and then a stacked racetrack from 38°20’N, 90°58'W to 38°6'N, 91°W. The survey will then continue on the return to Smyrna.

*Flight scenario 13 (one flight)***:**

This flight pattern will consist of ~ 7 hours of stacked racetracks and ~ 1 hour of horizontal surveys and will cover ~150 nautical miles.

Stacked racetracks will be flown at the following sites near Smyrna, TN:

Lawrence: 35°35’N, 87°25'W to 34°54'N, 87°28'W

Perry: 35°42’N, 87°53'W to 35°25'N, 87°53'W

Dresden: 36°29’N, 88°43'W to 36°12'N, 88°43'W

Land between lakes: 37°2’N, 88°6'W to 36°45'N, 88°6'W

***Vertical Profiling flights***

The objective of these flights is to characterize the vertical profile of constituents in the atmosphere up to a height of 6000m and examine morning, dusk and nighttime formation and accumulation of compounds in the PBL and FT

*Flight scenario 2 (one flight)*

This 7.5 hour afternoon/evening flight will be conducted from 1630 to 2400 hours. A horizontal transect at the minimum allowed altitude to one of the profiling locations selected for flight pattern 1d (37°2’N, 88°6'W to 36°45'N, 88°6'W). A 6-level stacked racetrack (70 km length, 30 minutes at each level) will start at 305 m and continue upwards at 700m, 1200m, 2000m, 4000 m and 6000 m. This will be followed by a time series, alternating at two altitudes (500 m and 3000 m), ~20 minute each, in 30-km circles, starting ~1 hr before sunset. A horizontal transect at near the minimum allowed altitude will then be conducted on the return to Smyrna.

*Flight scenario 3 (one flight)*

This 7.5 hour early/late morning flight will be conducted from 230 to 1000 hours. A horizontal transect at the minimum allowed altitude will be taken from Smyrna to the profiling locations selected for flight pattern 2. A time series will be conducted, alternating at two altitudes (500 m and 3000 m), ~20 minute each, in 30-km circles, starting ~1 hr before sunrise. Following this, a 6-level stacked racetrack (70 km length, 30 minutes at each level) will start in the FT and move downwards (6000m, 4000m, 2000m, 1200m, 700m, 305 m. A horizontal transect at near the minimum allowed altitude will then be conducted on the return to Smyrna.

***Transect flights***

*Flight scenario 4 (two flights)*

This 8.5 hour flight is focused on the Ohio Valley which is the most concentrated Hg source region in North America.

*Flight scenario 5 (two flights)*

This 8.5 hour flight is a western transect to the Oklahoma panhandle that will investigate high altitude oxidized Hg pools.

*Flight scenario 6 (two flights)*

This 8.5 hour flight is focused on horizontal and vertical gradients over the North Atlantic

*Flight scenario 7 (two flights)*

This 9 hour flight is focused on the outflow to the Atlantic and will examine gradients from continental to marine regions.

Coordination and intercomparison with other aircraft

Comparison of C130 measurements with those of the SENEX (NOAA P3) and SOAS (Purdue Duchess and Stonybrook Long EZ) aircraft is an important objective. In addition we will attempt to coordinate with the CARIBIC aircraft. The CARIBIC Airbus A340-600 will make several scheduled flights in/out of Orlando airport during NOMADSS and in addition to the other compounds, is the only other aircraft that measures Hg. Other possible comparisons include $CO_2$, $H_2O$, VOC and Ozone vertical concentration profiles and fluxes measured by the LongEZ; VOC vertical profiles on the Duchess; and VOC, $O_3$ and NOx on the P3. This will NOT require these aircraft to fly in close proximity to the C130 but will be accomplished through coordinated flight plans that will allow the C130 and these other aircraft to sample a location under similar conditions.

Test flights and shake-down flights

Test flights are scheduled to begin on May 21, 2013 out of Rocky Mountain Metropolitan Airport. The C-130 will then ferry to Smyrna, TN on May 30. A short shake-down flight will be conducted on June 1 or 2 to test communications and the decision making process.

Schedule for installation and preparation:

| | |
|---|---|
| Instrument installation | 8 April- 6 May, 2013 |
| Flight Readiness Review (FRR), C-130 Weigh in and Mandatory Project Safety Briefing | 20 May |
| Start of local flight testing | 21 May |
| Seatainers depart RMMA with ground support equipment and spare gases | 26 May |
| C-130 Ferry to Smyrna | 30 May |

Tentative research flight schedules.

| | |
|---|---|
| RF 1, (Flight scenario 1 ) | June 2 |
| RF 2, (Flight scenario 1 ) | June 4 |
| RF 3, (Flight scenario 2 ) | June 6 |

| | |
|---|---|
| RF 4, (Flight scenario 1 ) | June 9 |
| RF 5, (Flight scenario 1 ) | June 11 |
| RF 6, (Flight scenario 1 ) | June 13 |
| RF 7, (Flight scenario 7 ) | June 17 |
| RF 8, (Flight scenario 4 ) | June 19 |
| RF 9, (Flight scenario 5 ) | June 22 |
| RF 10, (Flight scenario 4) | June 24 |
| RF 11, (Flight scenario 5) | June 26 |
| RF 12, (Flight scenario 7) | June 28 |
| RF 13, (Flight scenario 1) | July 1 |
| RF 14, (Flight scenario 6) | July 3 |
| RF 15, (Flight scenario 1) | June 5 |
| RF 16, (Flight scenario 3) | June 8 |
| RF 17, (Flight scenario 6) | June 10 |
| RF 18, (Flight scenario 1) | June 12 |

## I. Forecasting, modeling and satellite Data

a. Satellite Products

In order to optimize flight planning during NOMADSS, we will use satellite observations from several platforms: GOES-13 visible, infrared and water vapor imagery, MODIS aerosol optical depth and fire count observations. These products will be archived on the Field Catalog.

b. Weather and chemical forecasts

*Daily weather briefing*

The daily weather forecasting discussions will take place during the daily planning meeting. The weather discussions will start with a large-scale overview of the current and projected weather of the Eastern U.S. (from Texas in the SW to Pennsylvania in the NE). Specific weather conditions over the next few days will be discussed for the Southeast (Alabama/Tennessee region), Texas, Ohio River Valley, Gulf of Mexico, and coastal N. Atlantic. Forecasting will address issues such as surface temperature forecasts, stagnation conditions, cloudiness, regions with likely convective rain in the domain, etc.

*Daily tracer forecasts*

Daily tracer forecasts will be available from two global models (NASA GEOS-5 Chemical and aerosol constituent forecasts; MOZART-4 chemistry forecasts), two regional models (WRF-Chem chemistry forecasts; GEOS-Chem Hg forecasts) and a particle dispersion model (FLEXPART).

The daily briefing will start with a 10-minute large-scale overview of the current and projected weather over the Eastern U.S. This discussion will be led by the lead weather forecaster. Following this, the lead tracer forecaster will provide a 10-minute overview of the tracer forecasts. Tracer forecasts will include information on transport of pollution tracers (CO), aerosols, vegetation emissions, and, if relevant, fire emissions. The goal of these discussions will be to help guide decision making for choosing the best flight pattern and flight track.

**Table 6-1. Forecast and Near-Real-Time models used during NOMADSS**

| **Name** | **Resolution** | **Run time** | **Update time** | **Products available** |
|---|---|---|---|---|
| NASA GEOS-5 chemical forecasts | Global; 1/2° | 5-day global forecasts | 0Z; 12Z | Global CO and $CO_2$; 9 tagged CO tracers; CFC-12 (trop and strat origin); aerosols ($SO_2$, DMS, sulfate, BC, OC, sea salt, dust); assimilated AOD from MODIS; O3 assimilation; real time fire emissions from MODIS. |
| GEOS-Chem Hg forecasts | Global (4°×5°) and regional (0.5°×0.667°) | 5-day forecasts | 0Z | Mercury tracers ($Hg^0$, $Hg^{II}$ and $Hg^P$) |
| GEOS-Chem Hg Near Real Time | Global (4°×5°) and regional (0.5°×0.667°) | | 0Z | Mercury tracers ($Hg^0$, $Hg^{II}$ and $Hg^P$) |
| MOZART-4 driven by GEOS-5 forecasts | Global; full chem (2°), tracers (0.5°) | 5-day global forecasts | 0Z | Tracers: CO from fires & regions, isoprene, anthropogenic NO |
| FLEXPART particle dispersion model (GFS forecasts) | 10000 particles per hour released, GFS: 0.5° | 3 days | 0Z | Air mass origin, sensitivity to emissions during aging |
| WRF-Chem | 4-10 km | 2-day forecast | 0Z | Full chemistry with SOA |

c. Available models

**NASA GEOS-5 chemical forecasts**

We will use chemical forecasts from the NASA Global Modeling and Assimilation Office (GMAO), based on the GEOS-5 meteorological real-time analysis and forecasts. The meteorological fields will be at a horizontal resolution of 0.5x0.667° 5-day forecasts, initialized at 0Z and 12 Z. Tracers include nine CO tracers originating from different sources, $O_3$, aerosol species, and CFC-12 (tropospheric and stratospheric origin). Output from these chemical forecasts will be available via an interactive web interface at UW. The CO tracers will help target specific plumes during flights (N. America vs. Asian, anthropogenic vs. biomass burning, stratospheric vs tropospheric). The aerosol tracers and precipitation fields will allow us to identify air masses recently exposed to wet scavenging.

**GEOS-Chem Hg forecasts**
The GEOS-Chem Hg simulation will be run at a global 4x5° horizontal resolution (and potentially higher resolution over a nested-grid domain over the U.S.) using the GEOS-5 5-day meteorological forecasts. The Hg simulation will include forecasts of elemental and reactive Hg tracers.

**GEOS-Chem Near Real Time**
In addition, we will run the GEOS-Chem Hg high-resolution nested-grid simulation in near-real time (NRT) mode using GEOS-5 real-time analysis. The NRT model results will be available 2-3 days after the flights. They will be used to rapidly compare model results with observations in order to monitor how the flights are meeting mission goals for the Hg component of NOMADSS. This will allow to quickly re-evaluate strategies for flight planning.

**MOZART-4 Chemical tracer forecasts**
MOZART-4 will be run in forecast mode with a number of artificial tracers. The driving meteorology will be from GEOS-5, and the horizontal resolution will be 0.5x0.67° 5-day forecasts, initialized at 0Z, will be available each day by 14Z. CO-like tracers will be initialized from emissions of anthropogenic pollution and wildfires in local, western US, Asia, and other regions. A biogenic isoprene-like tracer will be included as well as an anthropogenic NOx tracer. Forecasts of full chemistry from MOZART-4 are also available at 2° resolution. Results will be available on both static and interactive websites: http://www.acd.ucar.edu/acresp/forecast/.

**WRF-Chem**

WRF-Chem will be run in forecast mode with full chemistry and some tracers. WRF-Chem will be run at 4-10 km horizontal resolution over the study domain (AL-TN) for 48 hours starting at 0Z, driven by GFS meteorology and nudged to forecast above the boundary layer. Half-hourly output of tracer concentrations and derived quantities will be available on a website. Products will be available each day at 14Z.

**FLEXPART dispersion modeling**

FLEXPART will be driven by global GFS meteorology (0.5°), with particles initialized from anthropogenic and biogenic sources. 3-day back trajectories from the ground sites will also be calculated each day.

# VII. Decision Making

Table 4 lays out the schedule for each PI and the initial sequence for research flights. In general, each PI is responsible for the flights that tie most closely to their original project goals (SOAS, NAAMEX and TROPHONO). In the event that weather or chemical forecasts are not favorable for a particular flight, then the PI should always have in mind an alternate flight pattern. Each forecasting meeting should always consider the primary and one alternate flight pattern. If a mission critical instrument is not operating, then the PI should consider whether an alternate flight pattern may meet other NOMADSS objectives that can be achieved without this particular observation. If an instrument fails in flight the PI should consider whether the remaining measurements will still allow for completion of some NOMADSS goals and, if so and it can be done safely, the flight should continue through the entire flight plan.

# VIII. Coordination with Ground-Based Facilities

a. Centerville, AL

Centerville will be the location of a major ground based experiment focused on the SOAS objectives. This site includes measurements of gas and aerosol chemistry from approximately xx different research groups. Aircraft flights during flight pattern 1a, will fly over the Centerville site. Coordination of these flights will take place at the daily coordination meeting (1300)

b. Other sites in the SEARCH network

A smaller effort will occur at other SEARCH sites (http://www.atmospheric-research.com/studies/SEARCH/). Routine measurements of gases, aerosols are made at 8 SEARCH sites in the SE US. Routine measurements of Hg using the standard method are made at YRK, JST, BHM and OLF (Yorkville GA, Jefferson Street, GA, Birmingham AL, Outlying Landing Field, FL). At Birmingham, the UW group will add a research instrument to measure total Hg and use a gaseous calibration system for $Hg^{+2}$ compound.

# IX. Data Management Plan

The development and maintenance of a comprehensive and accurate data archive is a critical step to meet the scientific objectives of NOMADSS. This Data Management Plan (DMP) covers all measurements made on the C-130 as part of NOMADSS. The overall guiding philosophy for the NOMADSS data management is to make the completed data set available to the scientific community as soon as possible following the NOMADSS Field Phase, while providing ample time for the NOMADSS Investigators and Participants to process, quality control, and analyze their data before providing open access.

The NOMADSS data will be available to the scientific community through one or more designated NOMADSS Data Archive Centers (NDACs) coordinated by NCAR/EOL. This includes the main archive at EOL but could also include archives at other sites (e.g. the archive for the SOAS ground component).

The EOL coordination activities fall into three major areas, which are described below.

(1) Determine the data requirements of the NOMADSS scientific community and develop them into a comprehensive NOMADSS Data Management Plan through input received from the NOMADSS Scientific Steering Committee (SSC), project participants, and other tools such as data questionnaires;
(2) Develop and implement the on-line Field Catalog to provide in-field support and project summaries/updates for the Principal Investigators (PIs) and project participants to insure optimum data collection and access; and
(3) Establish a coordinated distributed archive system and provide data access/support of both research and operational data sets for the NOMADSS PIs and the scientific community.

To accomplish these goals, EOL will be responsible for the establishment and maintenance of the NOMADSS Data Management Portal. These web pages provide "one-stop" access to all distributed NOMADSS data sets, documentation, on-line Field Catalog products, collaborating project data archives, and other relevant data links. EOL will also ensure that "orphan" data sets (i.e. smaller regional and local networks) will be archived and made available through the archive. EOL may also quality control and reformat selected operational data sets (e.g. atmospheric soundings or surface data) prior to access by the community as well as prepare special products or “composited” data sets (see Section 9.4.1). Oversight of the NOMADSS data management tasks comes from the NOMADSS Principal Investigators and other participating agencies and groups.

**NOMADSS data Policy**
In general, all scientific users will have free and open access to all the NOMADSS data, subject to procedures to be put into place at the NDAC. NOMADSS PIs will coordinate closely and be as consistent as possible with the Data Policy and protocol enacted for SOAS since these projects are closely related, collaborative, and sequential. The following is a summary of the NOMADSS Data Management Policy by which all NOMADSS participants, data providers, and data users are requested to abide by.

1. All investigators participating in NOMADSS agree to promptly submit their quality-controlled data to the appropriate NDAC to facilitate intercomparison of results, quality control checks and inter-calibrations, as well as integrated interpretation of the combined data set.
    a. Standard operational meteorological data such as synoptic observations, special rawinsonde observations, and satellite imagery shall be submitted to the appropriate NDAC within six months following the end of the field campaign.
    b. Preliminary research data shall be submitted by **1 January 2014.**
    c. Final research datasets such as PI instrument data and other special observations requiring additional post-processing shall be submitted to the appropriate NDAC no later than **1 July 2014**. Exemptions may be granted on an individual case-by-case basis by Program Managers and Project Management.
2. The data analysis period is defined as 12 months following the end of the field phase of NOMADSS. During this 12-month period, the NOMADSS investigators shall have exclusive access to the data. This data analysis period is defined to accommodate the amount of processing required for all data products, to provide an opportunity to quality control the combined data set, and to provide the investigators time to perform analysis in

preparation of publication of their results. Data providers have the option to restrict (or password protect) their datasets for part or all of the data analysis period.

3. During the data analysis period, the investigator(s) who collected the special data sets must be notified first of any intent to use the data. In particular, this applies if data are to be provided to other parties via journal articles, presentations, and research proposals. It is expected that for any use of the NOMADSS data, investigators responsible for acquisition of data will be invited to become collaborators and/or co-authors on any projects, publications and presentations. If the contribution of the data product is significant to the publication, the NOMADSS investigator responsible for generating the measurement or data product should be offered co-authorship or collaboration at the discretion of the investigator who collected the data. Any use of the data should include an acknowledgment (e.g. citation). In all circumstances, the NOMADSS investigator or data source responsible for acquisition of data must be acknowledged appropriately.
4. All data shall be promptly provided to other NOMADSS investigators upon request. All NOMADSS investigators will have equal access to all data. A list of NOMADSS investigators will be maintained by the NOMADSS Project Office and will include the investigators directly participating in the field experiment as well as collaborating scientists who have provided guidance in the planning of the campaign and in the analysis of the data. During the data analysis period, no data may be provided to a third party via journal articles, presentations, or research proposals without the consent of the investigator who collected or is responsible for the data. Individual investigators may use their own data in any way they feel is appropriate (e.g. presentations and publications, distribution to third parties).
5. Following the end of the initial data analysis period, all data shall be considered in the public domain (**1 July 2014**). A data set within the NOMADSS archive can be opened to the public domain earlier at the discretion of the data provider for this particular data set.
6. All acknowledgments of NOMADSS data and resources should identify: (1) the NOMADSS project; (2) the providers who collected the particular datasets being used in the study; (3) the relevant funding agencies associated with the collection of the data being studied; and (4) the role of EOL or relevant data archive center.

It is anticipated that three types of data and/or modeling output will be submitted and archived by most NOMADSS PIs:

1) Near real time data– quick turnaround data (<48 hours) with preliminary calibration factors;

2) Preliminary data submitted to the archive within six months after the campaign completion (1 January 2014 or earlier);

3) Final data submitted within 12 months of the end of the campaign (1 July 2014)

## 9.3 Near Real-Time Data

### *9.3.1 NOMADSS Field Catalog*

NCAR/EOL will implement and maintain a web-based NOMADSS on-line Field Catalog that will be operational during the field phase to support the field operations, planning, product display, and documentation (e.g. facility status, daily operations summaries, weather forecasts, and mission reports) as well as provide a project summary and “browse” tool for use by researchers in the post-field analysis phase. Data collection products (both operational and research) will be ingested into the catalog in near real time beginning **the week of 20 May 2013**. The Field Catalog will permit data entry (data collection details, field summary notes, certain operational data etc.), data browsing (listings, plots) and limited catalog information distribution. A Daily Operations Summary will be prepared and contain information regarding operations (aircraft flight times, major instrument systems sampling times, weather forecasts and synopses, etc.). These summaries will be entered into the Field Catalog either electronically (via a web interface and/or e-mail) or manually. It is highly desirable that each group contribute graphics and/or preliminary data to the Field Catalog whenever possible. Although the Field Catalog will be publically available, access to field and preliminary data will be restricted to project participants only. Updates of the status of data collection and instrumentation (on a daily basis or more often depending on the platforms and other operational requirements) will be available. Public access to the on-line Field Catalog is located at: http://catalog.eol.ucar.edu/nomadss/ . EOL will monitor and maintain the field catalog through the duration of the field deployment and also provide in-field support and training to NOMADSS project participants. Following the field phase, this Field Catalog will continue to be available on-line (as part of the long-term archive) to assist researchers with access to project products, summaries, information, and documentation. Field data will not be retained as part of the Field Catalog, but final data will be submitted and available through the NOMADSS data archive.

#### *9.3.2 Field Catalog Components, Services and Related Displays*

The Field Catalog will be the central web site for all activities related to the field campaign. As such it will contain products and reports related to project operations as well as forms for entering/editing reports, uploading new products, data files, photos or reports. The field catalog will also provide a preliminary data sharing area, a missions table to highlight major project operations, links to related project information and help pages to familiarize users with the various features of the catalog interface. For users who may be accessing the catalog through limited bandwidth connections such as a cellular network, there will be a low-bandwidth catalog interface to provide quick and easy access to the latest reports and products. The Field Catalog front page will be customized to provide pertinent project information and rapid access to the most popular catalog features and will include access to the GIS display tools like Catalog Maps and the Mission Coordinator displays. Access to project chatrooms will be provided through the Field Catalog with a link on the front page as well.

The Mission Coordinator and Catalog Earth displays are the main GIS display tools that will be provided by EOL for the NOMADSS campaign. The Mission Coordinator display is a real-time tool for situational awareness and decision-making aboard the C-130 aircraft. This display will contain a small subset of products pertinent to aircraft operations from the Field Catalog that can be displayed along with C-130 and other aircraft tracks. The Mission Coordinator display is also accessible to forecasters and aircraft coordinators on the ground. The Catalog Earth display is a GIS tool that is integrated into the Field Catalog and provides access to a larger number of real-time products as well as an ability to replay products from any previous day during the campaign. A mobile version of the Catalog Earth tool is also being fielded that will provide access to real-time products and instrument locations for those operating mobile facilities on the ground.

IRC Chat
EOL will provide IRC chat services as the primary communications tool between the various regional centers and the mobile and airborne facilities. A number of logged chatrooms will be provided for DC-3 including:
#NOMADSS – for chat related to mission coordination and real-time decision for all NOMADSS facilities
#GV – for chat related to instrument issues aboard the GV
#SOAS – for chat related to mission coordination and real-time operational decisions with the

SOAS ground sites
After the NOMADSS campaign is completed, the logs from these chatrooms will be sanitized to remove sensitive information and will become part of the long-term data archive for the project. As many project participants will be connecting to chat via different networks including satcom and cellular, dropouts may occur when the user loses their internet connection or in a no-coverage area. In each of the logged chatrooms a replay capability is provided so that when connectivity is re-established the user can query the system to replay all messages in a given chatroom sent during the last user selectable number of minutes. The chat service also provides the capability for users to have private conversations that are not logged should they wish to move their discussion to a separate chatroom or desire to exchange sensitive information. Help documentation is available in the Field Catalog that describes all of these features along with a description of the chat interface and common chat commands.

## 9.4 Data Archive and Access

NOMADSS will take advantage of the capabilities at existing DACs to implement a distributed data management system. This system will provide "one-stop" single point access (Project Portal) at EOL using the web for search and order of data from DACs operated by different agencies/groups with the capability to transfer data sets electronically from the respective DAC to the user. Access to the data will be provided through a Data Management link from the NOMADSS Project page (http://www.eol.ucar.edu/nomadss/). This Data Management link will contain general information on the data archive and activities on-going in the project (i.e. documents, reports), data submission instructions and guidelines, links to related programs and projects, and direct data access via the various NDACs. Parts of the website will be password protected and access restricted, as appropriate.

EOL will be responsible for the long-term data stewardship of NOMADSS data and metadata. This includes ensuring that "orphan" datasets are properly collected and archived, verifying that data at the various NDACs will be archived and available in the long-term, and that all supporting information (e.g. Field Catalog) are included in the archive.

### *9.4.1 Data Merges*

Data from the airborne platforms will be submitted in ICARTT format. The submitted data will be evaluated by EOL to confirm that it complies with the ICARTT protocols. Merges of the submitted data on various time bases will be generated to allow direct comparisons of data collected at slightly different times and to provide input to constrained numerical models.

“Composite” datasets will be created that will bring together data from different observing networks. The data will be converted to a common format and will undergo uniform quality control. Various “composites” will be made for all three stages of data (field, preliminary, and final).