Summary of ABL group discussions: IHOP Planning meeting

National Center for Atmospheric Research
Boulder, CO
24-25 April, 2001

Scientific objectives:

Summary list:
It was agreed that the majority of the ABL scientific objectives could be subsumed under three broad questions. (A detailed list with all suggested topics is at the end of this document.)

1. How does land-surface heterogeneity drive ABL development?
   - what are the spatial scales involved (heterogeneity and expression in the ABL)
   - focus on convective conditions, expect mean wind speed to be important
   - heterogeneity encompasses terrain, vegetation and soils
   - ABL development that will be monitored and is of interest includes:
     - Water vapor (x,y,z,t)
     - ABL depth (x,y,z,t)
     - Vertical fluxes (x,y,z,t), especially surface and entrainment fluxes
     - Temperature (x,y,z,t)
     - Winds (x,y,z,t)

     Note that IHOP will sample water vapor, ABL depth, and vertical fluxes with high resolution over large spatial scales (a few hundred km) using airborne DIAL and Doppler lidar. Winds and temperature field sampling is not as well sampled. Microscale sampling may be achieved via cooperation with the convective initiation group and ground-based remote sensing.

2. How well is the ABL simulated at the mesoscale?
   - Test mesoscale model simulation of the ABL including land surface heterogeneity and assess its importance for convective initiation.
   - Assimilate ABL data (see above list of variables) to see if convective initiation and quantitative precipitation forecasting is improved.

3. How well can we observe mesoscale ABL water vapor budgets?
   - Focus is on the use of airborne lidar, especially Doppler-DIAL flux divergence studies, and validation with surface sensors and the U. Wyoming King-Air

Where : Instrument locations, flight plans, spatial scales

Aircraft: Primary aircraft requirements for the ABL objectives are

- repeated flights over the same flight tracks (both airborne lidar and flux aircraft),
- focus on midday boundary layer development,
- flight tracks that are long enough to encompass mesoscale variability in ABL structure (lidar aircraft), and
- flight patterns that capture the time rate of change and advective components of the boundary layer water vapor field.

These requirements should be complementary to the Quantitative Precipitation Forecasting group, which requires mapping of the inflowing water vapor field, and observations of the water vapor budgets within the study region. The ABL focus on fair weather also suggests segregation of ABL vs. Convective Initiation flight days.

Current ABL flight plan (see figure on the following page):
Optimizes instrument intercomparison possibilities with surface-based sensors and among aircraft, especially airborne lidar and the Wyoming King Air. Provides observations of the evolution of the air that is being advected into the ARM-CART region – that is, these flight tracks combine characterization of the upwind air masses with observations of the space-time distribution of water vapor within the ARM-CART region. Optimizes observation of the vertical turbulent transport of water vapor within the ARM-CART region via the DLR DIAL-Doppler lidar pair and the Wyoming King Air.

Surface-based observations:

Surface flux towers are needed to encompass the land-surface types in the study region. NCAR ISFF towers will complement existing towers in the region (ABLE, ARM-CART, OK Mesonet, AmeriFlux).

An NCAR Integrated Sounding System near the western end of the E-W lidar flight track (panhandle of OK) would be beneficial. ARM-CART, ABLE, and other IHOP-specific profiling equipment will also be utilized.

Surface based remote sensing instruments and unattended aircraft may provide valuable microscale ABL data, and opportunities exist to coordinate with the convective initiation group. Discussion at the meeting was not focused in this area.

Other land-surface data that is of interest:

- AVHRR or MODIS or GOES surface IR temperatures – used for mapping surface fluxes
- Thematic Mapper or ASTER surface IR temperatures – used for land-use/vegetation mapping
- AQUA microwave radiometer data – useful for soil moisture mapping if available.
- Radar precipitation field – needed to generate the space-time distribution of soil moisture using land-surface hydrology models.
- Surface meteorological data – needed for land-surface models. OK Mesonet, flux towers.
- In situ soil moisture data – needed to compare with hydrology models. OK Mesonet.

Scales of interest

- Thermals and blending heights – a few 100m to a few km
- Landscape variability – a few meters to the precip/vegetation/terrain gradient across the Great Plains
- advection and air-mass modification – 10 m/s * 8 hours = 288km

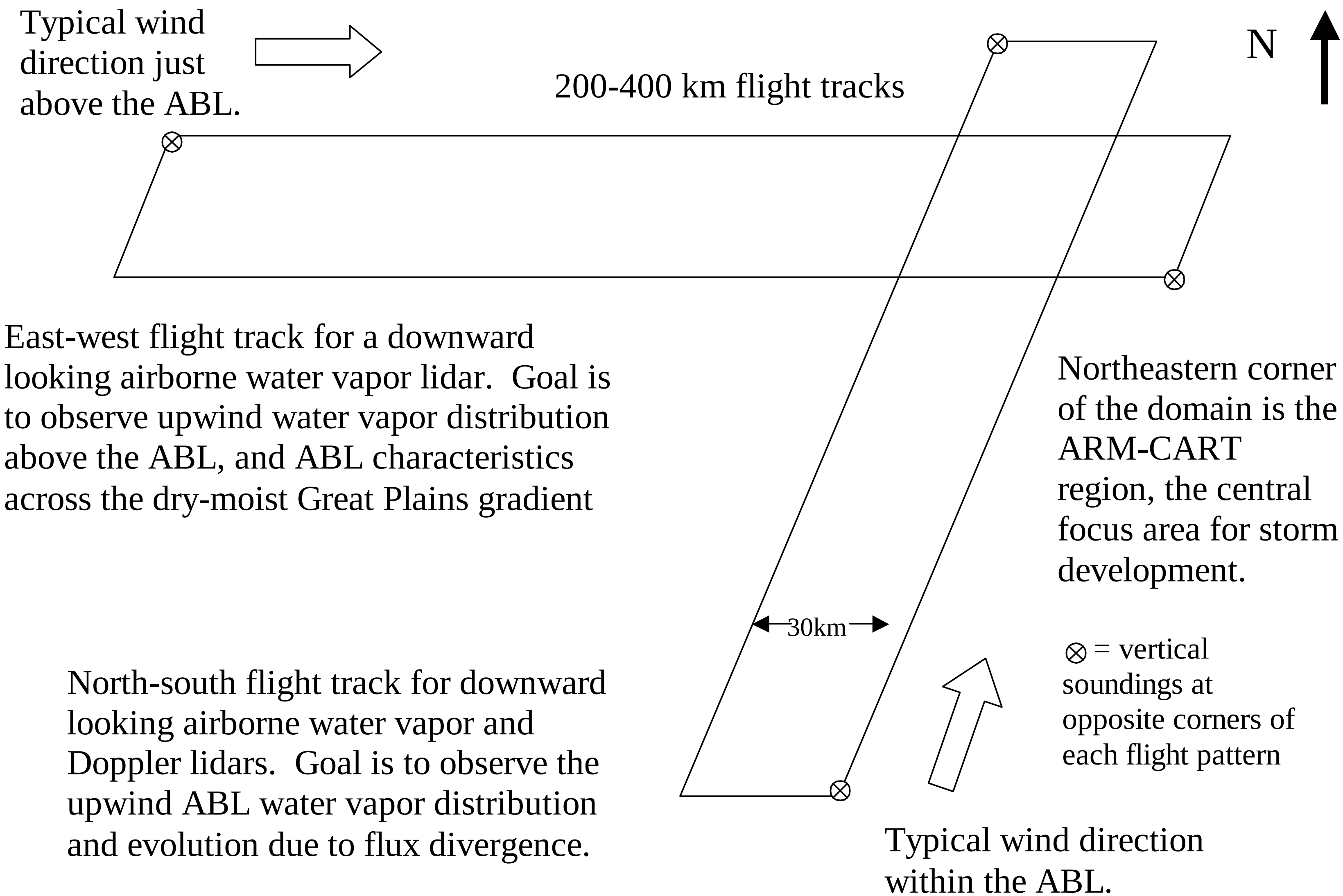

Figure 1: Proposed airborne lidar flight tracks for ABL studies. Suggested flight altitudes are approximately 5km above ground, with vertical soundings from this altitude down to the lower ABL (~100m if possible). Dropsondes could be used in place of direct aircraft soundings. The north-south leg DIAL-Doppler lidar airborne leg would encompass the Little Washita to the south, the ARM-CART CF near the cross in the patterns, and the ABLE/CASES area in the north.

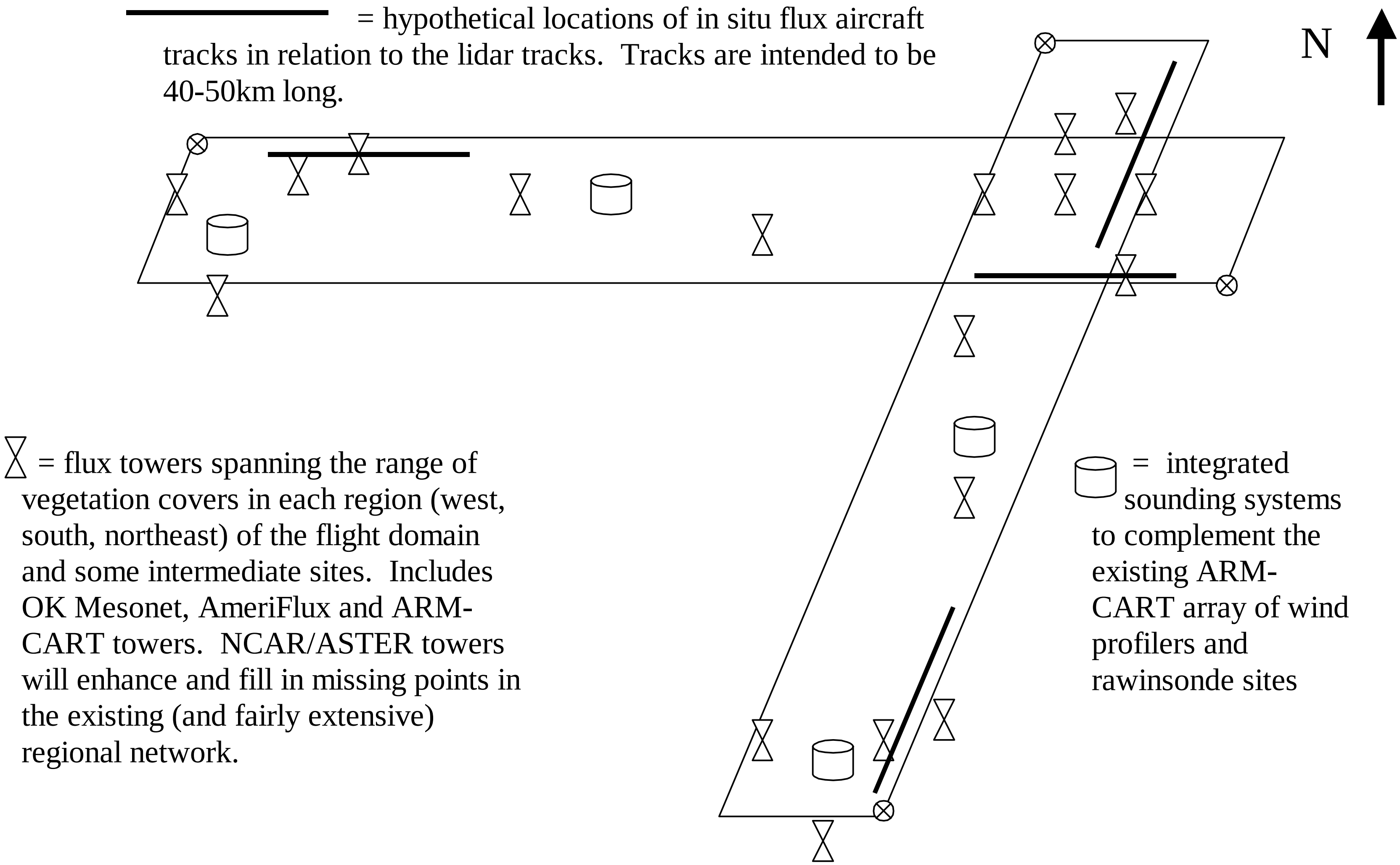

Figure 2. Rough schematic of surface array and flux aircraft flight locations in relation to the lidar tracks. Flux aircraft would focus on repeated low level flux runs over fixed tracks with upper-ABL flights (about 0.7 zi) to characterize flux divergences and entrainment. Flux aircraft flights would occur at similar times as the lidar flights and would cover each track approximately every other day, with roughly 8 passes at low level over each track and 2-3 upper level legs, with 2-4 vertical soundings. A full pattern over each flight track would therefore take about 1.5 to 2 hours for the Wyoming King Air. Flux aircraft flight tracks (one each) would be located in the ABLE and ARM-CART regions.

When: Preferred study times/days/weather.

The ABL group likes fair weather, daytime convective conditions, and flight tracks that are fixed with respect to the landscape. (There are also secondary interests in nighttime noctural jet studies that may be satisfied via the primary data collection approaches of other groups.)

Preferred flight time is mid-morning to mid-afternoon to capture the development of the convective boundary layer and lead into (cloud) convective initiation.

Approximate flight hours anticipated:

- ~ 50 DLR Falcon
- ~ 50 NRL P-3 with LEANDRE downlooking
- ~ 70 U. Wyoming King-Air

How? Instrument priorities

critical
DLR Falcon with the DLR DIAL and NOAA Doppler lidar, and dropsondes (~ 40)
U. Wyoming King Air with radar and flux capabilities
Surface flux towers (9 NCAR towers + existing towers are anticipated. Precise number is somewhat negotiable.)
Infrared surface remote sensing data (e.g. AVHRR, GOES)
Land-use/vegetation cover data
Radar precipitation fields

very desirable
NRL P-3 with LEANDRE DIAL downlooking

Also potentially very desirable, but not considered in depth due to uncertain availability
NASA LASE DIAL
NOAA Long-EZ
Conical-scanning doppler lidar (airborne) to provide horizontal winds (CNRS/DLR or NOAA)

Helpful
The following will help describe regional temperature and wind profiles, in support of ABL depth and water vapor profiles from airborne DIAL. Continuous profiling systems will also provide a picture of ABL development throughout the diurnal cycle at particular points, to complement airborne spatially extensive but temporally limited data. Finally, dense microscale data in the ARM-CART CF region should support microscale studies of ABL development, but discussion at the meeting was limited.

ISS on the western edge of our domain with ~50 rawinsondes.
Raman scanning lidar near the ARM-CART CF
Profiling radiometers (including AERI)
ARM-CART Raman lidar
915 MHz radars in the region
Unattended NOAA DIAL in the ABLE region
ARM-CART rawinsondes
GPS profiling, including dense network at the ARM-CART CF

Pending Issues:

Flight tracks (Falcon, P-3, King Air) need to be chosen. NCAR flux tower locations must also be chosen. King Air flight patterns during ferry should be discussed.

Locations of existing flux towers, and collaboration with PIs of these towers should be formalized.

Discussion of coordinating ABL goals with convective initiation (CI) goals is underway.

CO_2 sensor on the Wyoming King Air should be calibrated to high precision if possible.

Flight hour estimates:

Falcon/P-3 (DIAL aircraft).

12 ABL flights * 4 hours/flight = 48 flight hours (Falcon endurance is 4 hours. P-3 is longer. Keep P-3 ABL flights at the same time to match the Falcon data?)

300km legs / 120m/s flight speed = 42 minutes/leg, implies 4 – 300km flight legs per 4 hour flight is possible.

4 passes over terrain / flight * 12 flights = 48 passes over the same terrain over the course of 12 days from which to construct ensemble average ABL structure vs. terrain.

Intercomparison flights: 3 x 1 common 300km flight leg including the P-3, Falcon, and King Air, flown once early in IHOP, one mid-experiment, and once late in IHOP. The flux aircraft would try to time-center since the aircraft speeds do not match up. Overflight of ARM-CART CF is required.

Flux Aircraft (King Air):

4 hours/flight (endurance) x 4 flights / flight track * 4 flight tracks = 64 flight hours. This would provide a minimum coverage of the 4 proposed flux aircraft tracks.

Intercomparison opportunities:

Fluxes:
King Air and Falcon (Doppler DIAL) – vertical flux divergences
Tower, King Air and Falcon – surface fluxes

H_2O:
Airborne DIAL (2), Raman lidar, King-Air, rawinsonde, GPS, Profiling radiometers including AERI, SPOL, dropsondes.

Detailed list of scientific objectives:

The following is the detailed list of scientific objectives offered at the meeting. The summary was derived from this detailed list. Most notable is the inclusion of a couple of more purely microscale ABL objectives that are likely to be able to be addressed in part through IHOP, the issue of nocturnal jets, and the issue of regional roughness lengths. Also included is a list of participants, affiliations, and a few instrumental issues, reflecting the discussion at the meeting.

Davis – Penn State

To what degree is land-surface forcing important in the mesoscale development of the ABL? / Surface flux heterogeneity at scales less than 10-20km does not substantially influence the depth of convection in the midday ABL, except under extremely light-wind conditions, when compared to turbulent variations in ABL depth.
Grossman – add variability with atmospheric stability and wind speed
Lemone/Grossman – add sensitivity to terrain

What processes govern the water vapor distribution within and just above the ABL? / Substantial spatial variability in the ABL water vapor budget will be evident at spatial scales of 50 km and greater, and will be caused by spatial heterogeneity in surface fluxes, entrainment velocity, and the thermodynamic environment above the ABL.
LeMone – also investigate advection of water vapor. Is terrain relatively unimportant for driving variations in water vapor fields?

How well are ABL processes simulated in mesoscale forecast models? / Spatially resolved land surface models will enable a mesoscale model to simulate spatial variability in ABL depth and water vapor content at scales of tens of km and greater. Precipitation data, a soil hydrology model, satellite-based vegetation cover maps and simple plant physiological parameters will provide sufficient detail for simulating spatial patterns in surface fluxes.

How much does assimilation of detailed observations of ABL characteristics improve model performance? / Assimilation of ABL data will improve the ability of mesoscale models to forecast convective initiation in the study region.
Oncley - How can we best use ABL data to improve mesoscale models. Assimilation may not be the best choice – improving parameterizations might be better.
LeMone – add terrain to mesoscale modeling

Can remote instrumentation provide detailed ABL water vapor budget observations, particularly vertical flux divergence? / Doppler-DIAL, and DIAL-only data can be used to derive many of the terms of the ABL water vapor budget.

What are the microscale structures of entrainment at the ABL top? / The mechanisms of entrainment into the ABL will be directly observed using an airborne DIAL-Doppler lidar pair supported at times with in situ airborne turbulence data.

Drobinski – CNRS

Do low-level jets lead to convective initiation and mesoscale structures?

Does surface variability lead to CI?

How does wave activity organize the PBL?

Participation of a DLR – CNRS doppler lidar. Flew in MAP. Not possible here? Conical scan can provide 3-d winds.

Oncley – NCAR/ATD

Instrumentation – surface flux facilities

Lenschow – NCAR/MMM

Ehret – DLR

Vertical flux divergence measurements

Falcon - $3K/hour – 15 May – 20 June time slot tentatively reserved.

DLR DIAL measurements. 3-4km range/optical line. Order 200-300m vertical resolution, 200m horizontal resolution. 100 Hz DIAL first flown in MAP, 1999.

Brown – NCAR/ATD – wind profiler and surface systems

Senff – NOAA/ETL

Work with the DLR DIAL and NOAA Doppler lidars. Flux divergence measurements.

2.5 km range, 30 min time averaging, 100m vertical resolution unattended continuously operating DIAL. NOAA ETL project. Can be tilted for low level horizontal data. 200m dead zone. Validation needed. First deployment fall 2001 with limited validation.

Richardson – OU/Mesonet

Representing the OK Mesonet. 100+ towers. 10 eddy correlation systems with net radiation and ground heat flux measurements. 90 sites with net radiation and ground heat flux. Soil moisture at about 100 sites. Gradients of winds, temperature over 0-10m.

Wesely – Argonne National Labs

Can 0.1 zi flux and vertical profile measurements (above the "blending height") be used to compute mesoscale roughness lengths. Work of Brutsaert et al, early 1990s. Are these useful for modeling or computing regional fluxes?

Grossman – U. Colorado

How is the mixed layer height related to the underlying terrain, and what scales of heterogeneity are relevant?

Small scale plumes have been observed to be tied to terrain features in CASES. Are terrain-located plumes found in consistent locations across the landscape. 10km scale.

Surface flux averaging. Select slope, soil, vegetation sites categories and place surface flux stations to sample these categories, then aggregate up. Test – choose two locations identified as similar to see if similar fluxes are indeed obtained. Smileyburg and another site like it?

LeMone – NCAR/MMM

Add terrain as an important factor in governing surface fluxes and boundary layer development. E.g. radiation on slopes in MM5 is lacking. Plumes found in the CASES domain are found on a single latitude line. ABL temperatures seem to follow the terrain in CASES, but not water vapor. Water vapor is more governed by vegetation.

Horizontal advection is important in boundary layer water vapor budgets.

Porte-Agel – U. Minnesota

Boundary layer development using LES with new subgrid models. Evaluate performance of LES on scales of 10km using high-resolution small-scale observations in fair weather daytime and nocturnal conditions.

Larar – NASA/LaRC

Proteus, ER-2 borne profiling instrument testbed, NAST.
NAST = NPOESS Airborne Sounder Testbed. Microwave and infrared radiometers. Scanning, downlooking. 1-2km vertical resolution. Proteus, 0-56K feet, 2 pilots. 50x50km domain covered in 45 minutes, 700, 500 and 200 mb water vapor slices. 2.5km horizontal resolution below 700mb and finer resolution as data is nearer to the aircraft. Temperature and water vapor profiles.
Proteus – 150 m/s, 7-8 hours typical. Flight endurance is 20+ hours.

Map temperature and water vapor profiles over the domain

Vertical profiling

Measurements over clouds and precipitation.

Braun – GPS network at ARM-CART, plus Suomi-net – 15 more GPS receivers.