REQUEST FOR UNIVERSITY OF WYOMING
KING AIR SUPPORT

SONDE 08
15 December 2006

GENERAL INFORMATION

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Project Description

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<th>Project Title</th>
<th>SONDE-08 (Simultaneous Observation of the Near-Dryline Environment 2008)</th>
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| Co-Investigator(s) and Affiliation(s) | Christopher Weiss, Texas Tech University
                                            Peggy LeMone, NCAR
                                            Kevin Knupp, University of Alabama in Huntsville |
| Additional Co-Investigators | Fei Chen, NCAR
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| Location of Project | Lubbock, TX |
| Start and End Dates of Field Deployment Phase | 1 May – 9 June 2008 |
SONDE-08

Abstract

The dryline is a well-known boundary that forms during the warm season at around 100-101°W over the Southern Great Plains, between hot dry air flowing northeastward from Mexico, and warm, moist air flowing northward from the Gulf of Mexico. The Simultaneous Observation of the Near-Dryline Environment (SONDE-2008) project is being proposed to examine the evolution of the dryline, and the processes that cause this boundary to tighten, develop three-dimensional structure, and initiate convection; as well as examining how more than one dryline can form. Thus, SONDE-2008 will focus on scales from 200 km to 200 m.

We are requesting the University of Wyoming King Air (UWKA) and Wyoming Cloud Radar (WCR), and an array of ISFF stations, to complement the University of Alabama in Huntsville Mobile Instrumented Profiling System (MIPS), and several Texas Tech University (TTU) instruments, in a campaign in an area where, and at a time - 1 May - 9 June - when convectively-active drylines are most common. The TTU instruments are two Ka band mobile radars, a mobile mesonet, a fleet of ~ 20 rapidly-deployable "Stick-Net" instruments, a mobile sounding unit, and the West Texas Mesonet, which has grown into a dense network of ~ 50 Texas Panhandle stations providing comprehensive meteorological and soil measurements.

Major applications of ISFF measurements will be (a) providing context for aircraft measurements, (b) examining the influence of sensible and latent heat fluxes on dryline evolution, and (c) examining the influence of momentum transport on dryline evolution. Secondary objectives for ISFF include their use in improving HRLDAS, and looking at the influence of surface properties and horizontal convective rolls on surface-flux variability.

Numerical modeling will be a significant component of both the field campaign and subsequent data analysis. The dryline environment of west Texas is an ideal environment to test the importance of land use and soil moisture variations on mesoscale circulations and convective initiation. The Noah model based High-Resolution Land Data Assimilation System (HRLDAS) at 4-km resolution will be used for operational guidance. HRLDAS fluxes will be evaluated and refined using ISFF fluxes; and coupled WRF-HRLDAS runs will be designed to simulate the interplay between the mechanisms involved in dry-line evolution.

Broader impacts. The main thrust of SONDE-08 is to examine whether the formation and details of a dryline can be accurately predicted, to improve our understanding of how a dryline is affected by land surface differences at various scales, and to gain further insight into how thunderstorms are triggered along shallow convergence zones. The weather research community has established the objective to improve the specificity, accuracy, and reliability of weather forecasts for disruptive, high impact weather (Fritsch et al. 1998). A significant percentage of dryline storms become severe; this appears to be related to the regional soil moisture gradient and terrain (Ogura and Chen 1977; Benjamin and Carlson 1986; Benjamin 1986; Lanicci et al. 1987). Thus studies such as SONDE-08 are critical in improving these forecasts. Numerous graduate and undergraduate students will participate in the planning and execution of data collection. Moreover, students will gain hands-on experience with a wide variety of instruments. Some of these students have backgrounds in fields other than meteorology (e.g., many students participating from Texas Tech will have background in wind engineering) and therefore will have the opportunity to expand their knowledge base.
SONDE-08 PROPOSAL SUMMARY

1. Background: dryline formation in the context of boundary-layer evolution

Drylines are roughly north-south oriented boundaries within the convective boundary-layer (CBL). They mark a sharp decrease in mixing ratio to the west. The length of a dryline can be hundreds of kilometers, while its width can be O(1 km). The dryline tends to form on about 50% of the days in May at an average longitude of 100.6°W in West Texas (Hoch and Markowski 2005), although there is considerable day-to-day variability as the synoptic flow evolves. There is some interannual variability in the mean dryline position (Hoch and Markowski 2005). Yet on fair-weather days the dryline position remains close to its climatological mean position, presumably because it is locked to the terrain and land surface conditions. Thunderstorms sometimes break out along the dryline, or at some distance east of the dryline (e.g., Ziegler and Rasmussen 1998). Radars generally see the dryline as a convergent ‘fine-line’; only in some cases is the dryline marked by a cloud line or cloud edge.

The formation and evolution of the dryline involves multiple spatial scales. On the large scale, the dryline marks the boundary between hot, dry air coming north and east from Mexico, and the warm, moist air coming north from the Gulf of Mexico (e.g., Schaefer 1974a). The warm, dry air typically overrides the cooler, moist air. The moist airmass originating from under the trade wind inversion over the Gulf of Mexico becomes shallower to the west in response to the slope of the Great Plains.

It has long been speculated that the regional east-west gradient in soil moisture and vegetation properties (moister soil and more lush vegetation to the east, and the resulting differences in daytime surface sensible heat fluxes), result in a mesoscale $\theta_v$ (virtual potential temperature) gradient (e.g., Hane et al. 1997) that generally coincides with the synoptically-induced gradient. Several modeling studies confirm this hypothesis (Ziegler et al. 1995; Grasso 2000). The formation and evolution of the dryline, and associated convective initiation and precipitation distribution, may have been altered by agricultural activity and irrigation in West Texas (Pielke et al. 1997; Moore and Rojstaczer 2002).

Observations and numerical studies have shown that the dryline becomes more defined during the course of the day, and moves eastward by vertical mixing of the shallow moist airmass (e.g. Schaefer 1974a, b); when the zonal wind increases with height, this eastward movement can be intensified through downward mixing of westerly momentum. As the day progresses, the surface heating is stronger on the west side of the dryline, resulting in a more-rapidly growing boundary layer and more entrainment of warm air. The resulting buoyancy gradient can lead to a solenoidal circulation which tightens the gradient. Several studies using ground-based and airborne radar have resolved the solenoidal circulation in the vertical plane across the dryline (e.g., Atkins et al. 1998; Weiss et al. 2002; Demoz et al. 2006; Weiss et al. 2006; Miao and Geerts 2007). The “classic” dryline circulation is positive (i.e., the horizontal vorticity points to the north for a N-S dryline), thus the dry air rides over the usually denser moist airmass (exceptions may exist; see Sipprell and Geerts 2007). This circulation may explain why the dryline cumulus cloud line, if present, tends to occur on the east side of the dryline (e.g., Ziegler and Rasmussen 1998). Larger-scale convergence associated with troughing in the lee of the Rockies may be important as well (Parsons et al. 1991; Ziegler et al. 1993, 1995; Sipprell and Geerts 2007), but it cannot explain the formation of a narrow convergence zone visible on the radar as a fine-line.

The primary dryline is often accompanied by several ancillary lines. A preliminary dryline climatology by Chris Weiss’ group, using the West Texas Mesonet and WSR-88D (LBB and AMA) data for the spring months of 2004 and 2005, suggests that some ancillary radar fine-lines, with specific humidity gradients comparable to the primary dryline in some cases (Weiss et al. 2006), form either near local ridges in the terrain, or near horizontal gradients in land use and soil moisture (e.g., variations in agricultural practices and native vegetation). Satellite observations of fine-line cumulus convection have also supported this association (e.g.,
Hane et al. 2002). Such finelines have also been documented by Weiss et al. (2006) and Miao and Geerts (2007).

A substantial amount of along-dryline variability can likely be related to the development of these ancillary boundaries. The intersection points of ancillary boundaries with the dryline have been shown to be favored regions for cumulus development (Atkins et al. 1998; Hane et al. 1997). However, little is known about the dynamics of these ancillary boundaries.

Small-scale cyclonic circulations ("misocyclones", <4 km in diameter) have recently been described along some drylines. They have been attributed to horizontal shear instability in a weakly capped CBL. Their spacing is not very regular; their location may be affected by intersections with horizontal convective rolls (HCRs), and a history of vortex mergers and decay. It is well-known that superposition of updraft and vertical-vorticity maxima can generate significant vortex stretching, as in tornadoes. Yet several studies found that updrafts and vertical vorticity maxima are displaced from each other along drylines and other radar fine-lines (Murphey et al. 2006; Arnott et al. 2006; Markowski and Hannon 2006; Xue and Martin 2006; and Kingsmill 1995). These studies suggest that misocyclones are not rotating thermals (i.e., plumes of buoyant, rising air that populate the CBL). While much effort has been devoted to the horizontal structure and evolution of misocyclones, their vertical structure and buoyancy/moisture properties remain undocumented.

2. Scientific objectives of SONDE 08

SONDE-08 data (including UWKA/WCR data) will be used to address the following specific objectives:

Primary Objectives (focus on dryline structure and evolution)
(a) to run the HRLDAS in real time to guide field operations, and to examine how it simulates regional soil moisture and surface sensible & latent heat fluxes, and how it can be used in a WRF system to forecast the timing, location, and strength of drylines and associated convective initiation;
(b) to examine how observed and simulated regional heat flux variations at the surface and near the CBL top contribute to dryline formation;
(c) to examine how observed and simulated east-west differences in vertical transport of westerly momentum into the CBL contribute to dryline formation;
(d) to document the properties and evolution of ancillary boundaries, and to relate their formation to surface terrain and fluxes;
(e) to dynamically interpret the vertical echo and flow structure of the dryline convergence zone, and variations in thermodynamic properties (including convective inhibition) of the ambient CBL including cumulus cloud lines, if present;
(f) to examine the fine-scale horizontal structure of drylines, including the kinematic and thermodynamic properties of "misovortices".

Secondary Objectives (focus on surface exchange and boundary layer impact)
(a) to examine the horizontal variability of the sensible and latent heat fluxes as a function of number of days after rainfall using observations and HRLDAS fluxes (offline and coupled to WRF);
(b) to assess the surface energy balance, and response of stressed savannah grassland vegetation to diverse environmental forcings; to evaluate the ability of HRLDAS (offline and coupled to WRF) to simulate diffuse and direct short-wave radiation components;
(c) to assess the effect of HCRs on the fluxes at the surface.
3. SONDE 08 hypotheses

The following hypotheses will be tested using SONDE-08 data. The main instrument platforms are mentioned following each hypothesis.

A. Surface heat fluxes, differential vertical transport of heat and momentum, and dryline formation

A1. The formation of boundaries (primary or ancillary drylines) can be explained by a meso-β $\vartheta_v$ gradient, caused by differences in surface sensible heat flux and/or downward heat transfer. The secondary solenoidal circulations associated with these boundaries concentrate this background virtual potential temperature ($\vartheta_v$) gradient to much finer scales. [Key resources: ISFF transect; UWKA/WCR stepped traverses; WTM and Stick-net; MIPS and radiosondes; WRF output]

A2. Enhanced downward transport of the westerly component of horizontal momentum to the west of the dry line will enhance mesoscale CBL convergence across the dryline. [Key resources: MIPS, UWKA, ISFF, Stick-Net]

A3. A high-resolution WRF model coupled with a state-of-the-art land-surface model is capable of replicating the location and propagation of drylines in both synoptically-active and synoptically-quiescent scenarios, which are controlled in large part by terrain and land surface conditions. [Key resources: HRLDAS, WRF, ISFF, WTM]

A4. The higher-resolution (1-km) WRF model coupled with a state-of-the-art land-surface model will produce crude, correctly-oriented HCRs (horizontal convective rolls) and identifiable ancillary drylines in the vicinity of the primary dryline [key resources: HRLDAS, WRF, UWKA, Ka band radars, WSR-88D radars].

A5. HCRs will have a measurable effect on surface fluxes if clouds are present. This will primarily result from the presence of clouds in their upwelling region. [Key resources: ISFF (net radiation, radiometric surface temperature, and running-averages on 5-min fluxes), Ka band radars, WSR-88D radars, GOES visible]

A6. (Secondary objective, related to horizontal variability) The surface sensible and latent heat flux ($H$ and $LE$), averaged over a given time interval, will vary horizontally in such a way that the slope $\Delta LE/\Delta H$ is negative. They will have maximum horizontal contrast right after a rain event, and the contrast will decrease with time. This is in contrast to regions with a mix of unstressed (amply-watered) lush vegetation with dormant vegetation (harvested or mature crops), for which the horizontal contrast increases with time (LeMone et al. 2007). [Key resources: ISFF, HRLDAS, WRF/HRLDAS]

B. Variations in the dryline vertical structure and cumulus development

B1. Drylines are marked by a secondary solenoidal circulation whose width scales with the CBL depth. This thermally direct circulation is consistent with the local (~10 km) horizontal $\vartheta_v$ difference, and is evident in the vertical slope of the dryline echo. This circulation assumes the characteristics of a density current if the local $\vartheta_v$ difference exceeds a threshold. The sharp humidity contrast at the dryline is sustained by the convergence associated with this circulation. [Key resources: UWKA/WCR, TTU Ka band radars, MIPS]

B2. Deeper, more upright ascent along the dryline occurs if the solenoidal vorticity is roughly equal to the ambient dryline-normal shear vorticity, but of opposite sign (RKW theory). [Key resources: MIPS, soundings]
B3. The sometimes-observed failure of towering dryline Cu to grow into cumulonimbus, notwithstanding substantial CAPE (convective available potential energy), may be attributed to the erosion of their buoyant cores by entrainment of constantly renewed supply fresh, dry air advected from the west, rather than air moistened by previous towering Cu. [Key resources: UWKA/WCR, soundings, possibly MIPS]

C. Vertical velocity, moisture, and buoyancy properties of dryline misovortices

C1. Observations of misovortices and associated updrafts will provide new insights into their thermodynamic structure and relation to cumulus formation. [Key resources: UWKA/WCR, TTU Ka band radars, Stick-Net]

C2. The northern side of misocyclones is a preferred location for updrafts and convection initiation. [Key resources: UWKA/WCR, TTU Ka band radars]

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

Much insight about the structure and evolution of drylines and convective initiation along drylines has been gained from previous experiments, notably COPS_1991 (Central Oklahoma Profiler Studies), VORTEX (Verification of the Origins of Rotation in Tornadoes Experiment) in 1994-95, and IHOP_2002 (the International H2O Project). None of these campaigns had as objective to study the formation of the dryline in the context of heterogeneous boundary-layer evolution. Instead, the dryline was studied mainly as potential locus of convective initiation. SONDE-08 primarily builds on IHOP-02, in which all SONDE-08 investigators were involved. Other relevant experiments in which we participated include CASES-97 (LeMone) and CuPIDO-06 (Geerts).

5. SONDE-08 uniqueness

To explain how SONDE-08 goes beyond what has already been done, we first refer to the Background section (see p3 above). We believe SONDE-08 is unique in the following ways:

(a) Focus on physics of dryline formation and evolution. While several studies have speculated that a solenoidal circulation is present across the dryline, with denser air on the moist side, and recent observations document such circulation in some cases, SONDE-08 has as primary focus the mechanisms responsible for fine-scale convergence along the dry-line, namely: (a) the differential vertical transfer of westerly momentum from above the CBL due to larger surface buoyancy fluxes over the higher terrain to the west, and (b) the development of a solenoidal circulation driven by meso-β scale (20-200 km) baroclinicity, which is strongly diurnally modulated by horizontal differences in surface buoyancy fluxes. This circulation may affect both the movement of drylines, especially later in the afternoon, and the likelihood and location of convection initiation relative to the dryline.

(b) Focus on ancillary boundaries. Several studies based on IHOP and previous field campaigns have shown that the synoptic-scale dryline can be composed of, or co-exist with, several ancillary convergent boundaries or radar ‘fine-lines’. It is not known whether these ancillary lines are dynamically the same as the primary line. Both primary and ancillary boundaries may intersect with HCRs. Under sufficient horizontal wind shear, misocyclones may form along these boundaries. These ancillary fine-lines, and their influence on the primary dryline, will be examined.

(c) Focus on moisture and buoyancy characteristics of misocyclones. Previous studies focused on the kinematics rather than the thermodynamics of the fine-scale dryline structure. In SONDE-08, the close proximity of fixed and mobile surface observations, MIPS, and aircraft enables the assessment of the thermodynamic characteristics of boundaries and misovortices at high resolution. Since the moisture and
buoyancy characteristics of misocyclones and ancillary boundaries are largely unsampled, it is not known how important these vortices are for cumulus formation and storm initiation.

(d) High-resolution modeling with emphasis on land-surface processes. Several numerical experiments have been conducted to understand the impact of the land surface on dryline formation and convection initiation along the dryline. From these studies it has become clear that the heat and moisture exchange with the land surface is important for the formation and diurnal evolution of drylines. But most dryline modeling studies have been sensitivity experiments with various degrees of idealization. Few have used realistic land surface and soil moisture conditions. If a model can accurately capture surface fluxes and the CBL depth as well as the larger scale, it should also accurately simulate dryline formation. More generally, the dryline environment of west Texas is an ideal environment to test the importance of land use and soil moisture variations on mesoscale circulations and convection initiation.

To supplement other forecast products, HRLDAS will be run on a 4 km grid for real-time SONDE operational guidance. As far as we know, this is the first time a land-atmosphere model will be used in real time to predict where and when drylines will form. ALEXI (Atmosphere-Land Exchange Inverse, Anderson et al. 1997) was available for IHOP_2002, but boundary-layer flights were geographically fixed, and dryline missions focused on convective initiation. Given the preliminary results of the Weiss survey, HRLDAS should provide useful guidance for the SONDE-08 mobile facilities in the field. The substantial multi-scale heterogeneities in terrain elevation, land-use, and synoptic conditions in the Texas Panhandle will allow the sampling and study of a variety of dryline genesis pathways, dryline fine-scale structures, and convection initiation mechanisms.

The HRLDAS modeling effort will be coordinated by Fei Chen’s group. That group has extensively studied the impact of land-surface models (LSM) on the simulation of convective precipitation. Chen et al. (2001) demonstrated that replacing the older “bucket” model with the Oregon State LSM (Pan and Mahrt 1987; Chen et al. 1996) improved 24-28 h Eta model precipitation forecasts as much as doubling the horizontal resolution. Trier et al. (2004) illustrated two manifestations of the effect of surface processes in modulating convective precipitation, (a) through PBL growth that resulted in destabilization, and (b) through the enhancement of mesoscale circulations that favored the growth of convection in their upwelling regions. Fei Chen’s group also developed the High Resolution Land Data Assimilation System (HRLDAS, Chen et al. 2007) to enable the running of high-resolution coupled WRF-land-surface-model runs to forecast the onset and evolution of convective precipitation. Much of the testing was done using ISFF and OK Mesonet data collected during IHOP_2002. Since soil moisture observations are sparse, the soil moisture in HRLDAS is initialized by running it offline for several months model time, with meteorological data as input, to allow the soil moisture profile to equilibrate.

In addition, it is possible that fully-coupled HRLDAS/WRF simulations at resolutions down to 4 km or less will be conducted during SONDE-08 by NCAR MMM as part of a continuing effort of WRF PBL and convective initiation testing during the spring/summer season (Morris Weisman, personal communication). Such coupled system has been tested using IHOP datasets under fair-weather conditions with relatively small regional land use or terrain variations (Chen et al. 2007). The ability of the system to accurately predict observed surface flux variations, boundary-layer depth variations, and the formation of a mesoscale convergence line in a region encompassing a strong gradient in land surface properties, remains untested. Finally, we plan to run a stand-alone WRF (uncoupled with a LSM, but using the full NCEP initialization datastream including the WTM) in nested form over west Texas at an inner grid resolution of about 1 km. Such simulations will be run in real-time, to aid with the decision making, and will prove particularly useful as dynamically-consistent ‘hindcasts’ as part of the data analysis.
6. **Additional facilities to be used in SONDE 08**

NSF LAOF: Integrated Surface Flux Facilities ISFF (12 units)
NSF proposals from Texas Tech University (one pending, one to be submitted): 2 Ka band mobile radars, a mobile mesonet (5 vehicles), a fleet of 20-30 rapidly-deployable "Stick-Net" instruments, and a mobile sounding unit
NSF proposals from University of Alabama in Huntsville: Mobile Integrated Profiling System (MIPS)

We also rely on the operational West Texas Mesonet (WMT), the instrumented 200 m tall tower at the Reese Operations Center just west of Lubbock, and on the WSR-88D radar at Lubbock (LBB) and, secondarily, at Amarillo (AMA). Proximity to the LBB radar is important primarily to enable us to make the fine-scale radar operations. In many cases the dryline is expected to be too far east of the LBB (or AMA) radar. Even in close proximity to a WSR-88D radar, a spectral gap will exist in radar coverage, from the broad scale provided by the WSR-88D, to the very fine scale provided by Ka-band radar. We are aware of this limitation, and have made contact with two groups that are expected to have a mobile X-band radar available by 2008, i.e. the National Severe Storms Lab (Conrad Ziegler) and the University of Alabama in Huntsville (Kevin Knupp). In the meantime, we are confident that we can successfully target a slowly moving dryline within view (~<80 km) of a WSR-88D radar.

More info on the SONDE 08 Experimental Design can be found below. Further information on the West Texas Mesonet, TTU Stick-Net and Ka Band Radars, and MIPS can be found in the EOL (ISFF) request appendix.

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

**UWKA/WCR:** see below

**ISFF:** will be sited according to land use, and in two lines across the expected dryline position (see below). Its measurements of vertical fluxes of heat and moisture will be used to assess the impact of surface fluxes on dryline evolution (Hypothesis A1), and to calibrate or validate HRLDAS simulations (Hypothesis A3). Its measurements of momentum flux will provide the near-surface component of the momentum-flux profile (Hypothesis A2). Its measurements of 5 minute winds, temperature, humidity, pressure, and soil moisture will supplement the WMT and Stick-net networks (Hypothesis A1).

**MIPS:** will monitor wind, temperature, and humidity profiles mainly west of the dryline and in the dryline convergence zone. The MIPS microwave profiling radiometer will have 20 s temporal resolution, as opposed to 14 min for IHOP. Such high resolution resolves temperature and water vapor variations very well within the CBL, which is important for hypothesis A1. The MIPS 915 MHz wind profiler will provide wind profiles at high temporal resolution, and may even be used to estimate momentum fluxes (Hypothesis A2). The wind profiler will also be used in combination with the microwave profiling radiometer to estimate sensible and latent heat flux profiles (relevant to Hypotheses A5, A6). A new MIPS instrument (under construction) is a vertically-pointing x-band (9.5 GHz) radar with 1.3 deg beamwidth and 1-2 s temporal resolution. The vertical velocity statistics from this vertically-pointing x-band radar, or the 915 MHz wind profiler, can be compared to those of WRF simulations (relevant to Hypothesis A4). Finally, the MIPS 915 MHz and 9.5 GHz radar reflectivity and vertical velocity profiles can be compared to those of the WCR (95 GHz) for UWKA overflights. Reflectivity profiles can be used to estimate CBL depth, and vertical velocity measurements in both the Bragg and Rayleigh (or Mie) regimes can be used to resolve the downward velocity bias documented in the CBL (e.g., Geerts and Miao 2005).
Ka-band mobile radars: will describe the detailed echo and velocity structure within the primary or ancillary drylines in up to three dimensions. The two radars are expected to operate in dual-Doppler mode, with a baseline of ~10 km. This baseline will typically be normal to drylines. However, for a nearly stationary late-afternoon dryline, a dryline-parallel baseline may be used. These radars are currently under construction, so their sensitivity is unknown, but it is expected that they are at least as sensitive as the WCR at corresponding ranges, thus they should be able to map CBL structures and towering cumuli, out to a range of at least 15 km.

Stick-Net: 20-30 units will be deployed on an IOP basis to supplement the WMT with kinematic and thermodynamic measurements near the dryline. Wind is measured either with sonic anemometer or propeller anemometer. Measurements are stored on site on a data logger.

Mobile sounding unit: measure stability and wind profile mainly west of the dryline. In addition, a mobile mesonet of 5 vehicles will continuously measure thermodynamic and wind properties across the dryline.

8. What results do you expect and what are the limitations?

(For ISFF-related primary objectives, see ISFF request)

WCR measurements and limitations. Based on IHOP experience, the WCR is expected to see the dryline and other fine-lines, thermals within the CBL, and (at least on the moist side) most of the CBL between thermals (Geerts and Miao 2005; Miao et al. 2006; Miao and Geerts 2007). There was significant day-to-day variability in the echo strength in IHOP; on some days the inter-plume regions were devoid of echoes. The echo strength (insect density) should peak in the 2nd half of May in West Texas, although this strongly depends on the rainfall history. Chris Weiss is examining the climatology of dryline fine-lines near the AMA and LBB WSR-88D radar, and he finds relatively high dryline reflectivity values. In general the reflectivity (insect density) is higher east of the dryline. In any event, WCR sensitivity is important, which is why we will operate a minimal set of antennas. This is discussed further in the WCR request below.

UWKA measurements and limitations. In situ data will be collected during stepped dryline traverses, along-dryline legs, and long flight legs across the dryline. The latter pattern is intended to estimate fluxes near the surface and in the upper CBL. It is difficult to measure momentum fluxes using aircraft data, thus relatively long legs and repetitive sampling are required (see below), making it difficult to estimate temporal changes of momentum fluxes in relation to dryline development. However, momentum flux measured at the surface (at ISFF sites) can be an underestimate because it doesn’t account for trees and terrain. Fortunately vegetation is sparse and the terrain is flat, so these problems are minimized.

9. Expected publication date and journal(s):

Within 3 years, manuscripts will be submitted to Monthly Weather Review, Journal of Atmospheric Sciences, and Boundary-Layer Meteorology. Results will also be published in multiple conference proceedings.
SONDE 08 Experiment Design

A schematic layout of facilities near a dryline is shown in Fig. A. Location parameters are discussed below.

Fig. A: Sonde-08 facility layout superimposed on a highway map. The Caprock Escarpment and a typical dryline location are shown. The Operations Center is below a 200 m instrumented tower at Reese, west of Lubbock.
ISFF
Based on experience in previous field campaigns and subsequent analysis and model comparisons, the 12 requested ISFF stations will be located according to the following criteria:

- Land use (and possibly elevation)
- Nested within the West Texas Mesonet
- In two 150-km east-west bands to the north of Lubbock separated by ~30 km.
  - The southern band will be as close as possible to the Lubbock WSR-88D radar to enable combining Doppler, aircraft, and surface data.
  - The northern band will help assess variability in the north-south direction.
  - The bands should be centered roughly at the -100.6°W Longitude line (climatological dryline location, which corresponds roughly with location of the Texas Caprock Escarpment).

The reader is referred to the EOL (ISFF) request for further details.

MIPS
Located either ~25 km west of the dryline, to follow the evolution of BL depth, wind profiles, and momentum fluxes; or closer to the dryline convergence zone (and initially ahead of it), in order to capture changes in vertical structure of the CBL across the dryline, and possibly the dryline solenoidal circulation. In both cases, MIPS is preferably located within 30 km of a Ka band radar, and under the UWKA track.

Ka-Band radars
Located within 10 km of the dryline, in dual-Doppler mode (base line ~10 km across or along the dryline). If the dryline is further than 60 km from the LBB WSR-88D radar, then the radars may be positioned within the dryline convergence zone, separated from each other by 40-50 km.

Stick-Net, mobile mesonet, mobile sounding
At various locations within ~50 km from the dryline.
EDUCATIONAL BENEFITS OF THE PROJECT

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

Active student involvement is planned in the SONDE-08 field phase and subsequent analysis. Some 5-10 undergraduate students and 10 graduate students will participate in the collection of SONDE-2008 data. This involves participation in the daily planning meetings, forecast and nowcast support, instrument maintenance, and data collection. The students will man the mobile mesonet with Stick-Net units, the mobile sounding unit, the Ka-band radars, and MIPS. Data collection will not be possible without their involvement. The undergraduate students will be supported in part through Weiss’ CAREER proposal (pending), in part through a supplemental REU request to NSF. The graduate student origin is as follows: four from TTU (Weiss), two from UWyo (Geerts), four from UAH (Knupp), and two from Purdue (Niyogi).

Research and education merge in the proposed field work, especially through mechanisms itemized in Weiss’ CAREER proposal (e.g., high school and undergraduate student internships). Select Ph.D. students are expected to work directly with Fei Chen (modeling) and Margaret LeMone (analysis); this work will include considerable time spent at NCAR.

These are the number of graduate assistantships requested:
Geerts/LeMone, NSF proposal: two Ph.D. students, one to work directly with LeMone;
Weiss’ NSF proposal: one M.S., one Ph.D. student;
Weiss’ CAREER proposal: one M.S., one Ph.D. student;
Knupp’s NSF proposal: one Ph.D. student;
Niyogi/Chen, NSF proposal: two Ph.D. students, one to work directly with Fei Chen.

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

Yes. At undergraduate level, Weiss, Knupp, and Geerts will use SONDE-08 material to illustrate the dryline in an introductory meteorology class.

At graduate level, SONDE-08 data will be used as laboratory material in Geerts’ graduate-level Mesoscale Meteorology class, offered annually. Weiss instructs Radar Meteorology at Texas Tech University, and will use the proposed SONDE project as an extension of the course, which will next be taught in Spring 2008. Knupp teaches two graduate level courses on alternate years, both of which will utilize SONDE-08 data. These include Boundary Layer Meteorology and Ground-Based Remote Sensing. Finally, Niyogi teaches Land Surface Modeling course at Purdue and has previously taught Instrumentation Meteorology. He has used IHOP_2002 datasets and would use SONDE-08 datasets as well.

Are any outreach activities to elementary and/or secondary school students and/or to the public planned? If yes, please describe.

Weiss has a CAREER proposal pending that includes internships for high school students for participation in the field. Furthermore, he is involved with Project EXPLORE (Engaging Extraordinary Professional Learning Opportunities in the Research Environment), which will include weekend and after-school visits to/by a number of rural elementary and secondary schools in the region surrounding Lubbock, TX.

LeMone is Chief Scientist of GLOBE (Global Learning through Observations to Benefit the Environment), a
world wide (~110 countries, over 100 Partners in the U.S. who implement GLOBE in their regions) K-12 science education outreach effort sponsored mainly by NASA (www.globe.gov). GLOBE emphasizes learning through hands-on observation, inquiry-based learning, and environmental awareness. LeMone has contacted the GLOBE Partners in the Texas Panhandle area (one is at Texas Tech) as well as the lead Texas GLOBE coordinator; she will meet with the lead Texas Partner in late December 06. LeMone will include SONDE-08 in her “Chief Scientist’s Blog” (www.globe.gov, click on “Chief Scientist’s Blog”).

Niyogi is a State Climatologist and has ongoing interactions with extension community, as well as middle and high school teachers and students interns. He would utilize experiment to provide theme topics on land surface heterogeneity and severe weather as part of Environmental Science internships and training opportunities.

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

1. Upon approval of SONDE 08 a request will be made to NSF for NCAR EOL FPS (Field Program Support, formerly JOSS). This support includes a Field Catalog and a Data Archive.

2. The project planning, field activities, data, preliminary results, and publications will be available through the websites of the PIs, including
   - http://www-das.uwyo.edu/~geerts/sonde/ (Geerts)
   - http://www.atmo.ttu.edu/sonde/ (Weiss)
   - http://www.rap.ucar.edu/projects/land (Chen and LeMone)
   - http://vortex.nsstc.uah.edu/mips/ (Knupp)
Each site will provide a link to the others.

PREVIOUS RESEARCH EXPERIENCE

Past airborne research support (include all NCAR/EOL, Wyoming and other aircraft-supported projects):

Geerts: IHOP_2002, NASA-ROLLS, RICO, CuPIDO (all UWKA)
Weiss: VORTEX (ELDORA) and IHOP_2002 (tornado radar, WCR)
LeMone: IHOP_2002 (UWKA), CASES-97 (UWKA), TOGA COARE (Electra), STORM-FEST (Electra)
Chen: IHOP_2002 (UWKA)

Publications resulting from past airborne research:

Geerts:


Weiss:


LeMone:


**Knupp:**


FUNDING AGENCY INFORMATION

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>National Science Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract Officer</td>
<td>Dr. Stephan Nelson</td>
</tr>
<tr>
<td>Contract Identification</td>
<td></td>
</tr>
<tr>
<td>Proposal Status</td>
<td>4 proposals to be submitted to NSF/ATM</td>
</tr>
<tr>
<td>Approximate Amount Budgeted (total research):</td>
<td>Geerts/LeMone*: ATM proposal ~ $400 K/ 3 years, Weiss: ATM proposal ~ $450 K/ 3 years, Weiss: CAREER prop $800 K/ 5 yrs, pending, Knupp: UAH ATM proposal ~ $300 K/ 3 years, Niyogi/Chen*/LeMone*: ATM proposal ~ $400 K/ 3 years</td>
</tr>
<tr>
<td>Is support for deployment expected through NSF-LAOF deployment pool (see note below)?</td>
<td>yes, for ISFF and UWKA/WCR</td>
</tr>
<tr>
<td>If answer to above is no, provide amount budgeted for deployment costs:</td>
<td></td>
</tr>
</tbody>
</table>

* LeMone and Chen, as NCAR scientists, cannot write their own NSF proposal but they plan to act as co-investigators on the proposals of Geerts and Niyogi. If SONDE-08 goes forward, Chen and LeMone could get some support from NCAR Water Cycle Initiative for data analysis and modeling. LeMone can also use some of her base funding (0.55 FTE) to work on SONDE-08.

NOTE: NOT ALL NSF-FUNDED PROJECTS ARE ELIGIBLE FOR SUPPORT THROUGH THE LAOF DEPLOYMENT POOL

DATA ACCESS POLICY

UWYO King Air policy will make all King Air data publicly available once the data are quality controlled. If a PI wants to have exclusive access to these data for the first year, s/he has to officially request such a restriction via email from the flight facility manager (rodi@uwyo.edu) eight weeks prior to the start of an experiment.

Do you intend to request restricted access? no
AIRCRAFT OPERATIONS

<table>
<thead>
<tr>
<th>Preferred flight period</th>
<th>5/1/2008-6/9/2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flights required</td>
<td>72 research flight hours</td>
</tr>
<tr>
<td>Estimated duration of each flight</td>
<td>4 hrs</td>
</tr>
<tr>
<td>Number of flights per day</td>
<td>one (occasionally two)</td>
</tr>
<tr>
<td>Preferred base of operation</td>
<td>Lubbock, TX (LBB)</td>
</tr>
<tr>
<td>Alternate base</td>
<td>Amarillo, TX (AMA)</td>
</tr>
<tr>
<td>Is Laramie Airport acceptable as your operations base?</td>
<td>no</td>
</tr>
<tr>
<td>Average flight radius from base</td>
<td>75 km</td>
</tr>
<tr>
<td>Desired flight altitudes(s)</td>
<td>500 ft AGL - 17,000 ft MSL</td>
</tr>
<tr>
<td>Particular part(s) of day for flights</td>
<td>Late morning through early evening (10 am -7 pm CDT). Generally only 1 flight per day, although a 2nd flight cannot be ruled out (see under ‘flight patterns’ below).</td>
</tr>
<tr>
<td>Statistically, how many days during specified period should be acceptable for flight operations?</td>
<td>Conditions should be favorable for dryline development on 30-60% of days in the period. We will select those drylines that are rather stationary and in the vicinity of the LBB or AMS radars. Thus maybe only one in four days will present a ‘good’ dryline.</td>
</tr>
<tr>
<td>Number of scientific observers for required each flight</td>
<td>None required (other than the flight scientist). Depending on communication method (see below), we may be able to operate without 4th seat manned.</td>
</tr>
</tbody>
</table>

Scientific rationale for the use of this aircraft in the proposed project:
The UWKA is ideally suited for the relatively short low-level flight legs proposed for SONDE 08 (see below). Many flight legs will be at 500 ft AGL. High maneuverability is needed in particular for flight legs along the dryline. All five WCR viewing angles are needed, and this is only possible on the UWKA. Finally, there are several measurements (from the gust probe, flux probes, GPS, and others) that the King Air can reliably and accurately provide.

Description of desired flight pattern(s), priorities, and estimate number of flights for each:
(Please include graphics and flight pattern images as needed.)

Four flight patterns are listed. Some flights may be dedicated exclusively to a single pattern (esp. #1), others may consist of a blend of patterns, depending on the definition and shape of the dryline and the development of cumuli.

(1) Flux legs (Fig. 1)
- Objectives: to estimate sensible and latent heat fluxes, and momentum fluxes, at the bottom and top of the CBL (see Hypotheses A1 and A2), and secondarily, to depict the meso-β scale environment of the dryline.
- The low-level leg is ~500 ft AGL, upper-level leg is ~500 ft below CBL on the respective sides of the dryline. The upper-level legs are flown at constant pressure altitude, unless they can be flown at constant height AGL.
- Prefer a single, relatively stationary dryline in an environment without much active Cu (dryline Cu o.k.).
- These flight legs should preferably be over, or slightly downwind (north) of an ISFF transect. The upper legs can be displaced northward from the lower legs when southerly winds prevail.

**Fig. 1:** Flux legs. Plan view on the right, cross-section below. The preference for this flight pattern is to work with a single dryline separating two homogenous airmasses. In reality it is likely that one (possibly more) more secondary humidity gradients (ancillary drylines) will be encountered over the ~100 km distance. Since it is unlikely that we will have full radar coverage of the boundary layer along this track, we will not know until flying the pattern.

- The legs are necessarily long in order to compute momentum fluxes (Lenschow et al. 1994). IHOP statistics (done by LeMone) indicate that a roughly 300-km sample is required to get momentum flux at a given level within about 10% uncertainty; flights just near the top and bottom of the boundary layer could reduce that size. Fortunately, the surface momentum fluxes should be more representative to the west of the Caprock, where larger eddies (deeper CBL) are equivalent to longer aircraft sampling times. The dryline crossings at upper levels are not needed for flux estimates, but they provide some additional WCR vertical transects and in situ data of the dryline.
- One entire loop (‘start’ to ‘end’) takes just over 2 hours to complete. To economize, one can reduce the depth of the pop-up sounding on the eastern side, especially if MIPS is in that area. Thus two loops may be completed in one flight. In-the-field calculations may lead to a change in leg lengths.
- Clear air is preferred. Momentum-fluxes measurements are degraded when “active” cumuli are present. Some scattered shallow clouds are OK, esp. if they are quite organized and small as in some roll cases.
UWYO King Air Facility Request

- WCR should be in up mode on the lower legs and in dual-down or profiling modes along the upper legs.
- # flight hours: 12-16
- This pattern is to be flown mainly during the dryline development phase when surface fluxes tend to peak (between ~11 am – 3 pm CDT), possibly at most 2 hours later. It is possible that this flight is followed by a second flight in which patterns #2, 3, or 4 (below) are flown.

(2) **multiple-level stepped traverse** (Fig. 2)

- Objectives: to examine dryline vertical structure, formation of main and ancillary drylines, and vertical transport (Hypotheses B1 and B2).
- Flight legs are stacked and the end points are geographically fixed. The end points move with the dryline only if the dryline propagates at 4 m/s or more.
- The traverse is ~ 30 km long: longer if multiple ill-defined fine-line drylines are present. The flight legs should be centered near the dryline.
- The stepped traverse is to be repeated in opposite direction to assess differences relative to a central time.
- The vertical separation between legs is 400-600 m; the lowest flight leg is as low as possible and is flown at constant height AGL; the highest flight leg is just above the highest WCR plume or thermodynamically defined BL depth.
- WCR in profiling mode, plus vertical-plane dual-Doppler (VPDD) mode in the upper flight legs.
- # flight hours: 20-24, to be flown between ~2-6 pm CDT.

(3) **dryline-cumulus interaction** (Fig. 3)

- Objectives: to examine the origin of (preferably towering) cumulus formation along or near drylines, and cumulus evolution in the context of the ambient stability and humidity (Hypothesis B3).
- Flight plan is the same as (2), but legs should be extended to include cumuli (usually towards the moist side), and shrunk on opposite side (usually the dry side); also, the vertical separation should be larger to confine the duration of the stepped traverse; flight levels should include mid- and upper-CBL, cloud base (lifting condensation level, LCL), and mid- to upper-levels of Cu.
- To be attempted only when a line of cumulus is found parallel to, and over or near the dryline.
- To be terminated if/when deep convection develops.
- WCR in profiling mode, plus VPDD in the upper flight legs. CuPIDO-06 experience (Arizona, in summer) testifies that the WCR can see young Cu at close range when the Cu is at least ~500 m deep (Damiani et al. 2007). The cloud base is hard to determine, esp. in updraft regions.
- # flight hours: 12-16, to be flown between ~2-6 pm CDT.

![Fig. 2: Stepped traverse normal to a developing or mature dryline.](image)

![Fig. 3: Stepped traverse normal to a dryline with line of cumuli.](image)
(4) dryline-parallel plus cross-dryline legs (Fig. 4)

- Objectives: to examine the finescale kinematic and thermodynamic structure of misocyclones and HCR intersections (Hypotheses C1, C2)
- To be attempted only when the dryline is well-defined, relatively straight, and within reach of a scanning ground-based radar (WSR-88D, Ka-band radars, or other).
- The along-dryline legs are 30-50 km long, the cross-dryline legs ~30 km long.
- Flight levels mainly at ~0.5 z, where ground clutter is small and the echoes rather strong. The CBL depth z; ranges between 1000-2500 m AGL, e.g. Sipprell and Geerts (2007).
- The along-dryline legs should be level yet also keep the dryline within WCR range (3-4 km) to the right of the aircraft. Their separation should match the WCR range. If a cumulus line is present near the dryline, an upper leg (near the moist-side CBL depth) can be aimed below the cumuli (see green line in Fig. 4).
- If HCRs are well-defined, the length of the along-leg can be adjusted such that the diagonal legs are approximately normal to the HCRs (relevant to Hypothesis A5)
- The WCR operates in HPDD (horizontal-plane dual-Doppler) mode on the 0.5 z; along-dryline leg and in VPDD + sideview mode on all other legs.
- # flight hours: 20-24, to be flown between ~2-6 pm CDT.
STANDARD AND OPTIONAL STANDARD UWYO KING AIR AIRBORNE SCIENTIFIC INSTRUMENTATION AND MEASUREMENTS

Standard Measurements
The list in Appendix 1 shows the UWYO King Air’s standard measurements that are provided automatically when the King Air is allocated for a project.

Additional instruments available upon request (Optional Standard)
Before requesting optional standard instruments in this section, please consider some require additional resources and may need special data handling. The number and/or combination of instruments may exceed UWYO’s personnel and/or hardware resource limits. Mark these extra, Needed instruments with “yes.”

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurements Available</th>
<th>Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cloud Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosemount 871FA</td>
<td>• Icing Rate</td>
<td>n</td>
</tr>
<tr>
<td>DMT LWC-100</td>
<td>• Cloud Liquid Water</td>
<td>y</td>
</tr>
<tr>
<td>Gerber PVM-100</td>
<td>• Cloud Liquid Water,</td>
<td>y</td>
</tr>
<tr>
<td></td>
<td>• Droplet Surface Area,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Droplet Effective Radius</td>
<td></td>
</tr>
<tr>
<td>PMS FSSP-100</td>
<td>• Cloud Particle Size Distribution (0.5 – 47(\mu)m; selectable)</td>
<td>y</td>
</tr>
<tr>
<td></td>
<td>• Total Concentration,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Derived Liquid Water Content</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Derived Droplet Effective Radius</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Derived Droplet Surface Area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Derived Mean Volume Radius</td>
<td></td>
</tr>
<tr>
<td>PMS OAP-200X (1DC)</td>
<td>• Cloud Particle Size Distribution (12.5 – 185.5 (\mu)m)</td>
<td>n</td>
</tr>
<tr>
<td>PMS OAP-2DC</td>
<td>• Cloud Particle Images (&gt;25 (\mu)m)</td>
<td>n</td>
</tr>
<tr>
<td></td>
<td>• Cloud Particle Size Distribution</td>
<td></td>
</tr>
<tr>
<td>PMS OAP-2DP</td>
<td>• Precipitation Particle Images (&gt;200 (\mu)m)</td>
<td>n</td>
</tr>
<tr>
<td></td>
<td>• Precipitation Particle Size Distribution</td>
<td></td>
</tr>
</tbody>
</table>
(optional standard instruments continued)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurements Available</th>
<th>Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiative Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eppley PSP (Pyranometer)</td>
<td>• Up-welling and Down-welling Radiation (0.285 – 2.800 μm)</td>
<td>y</td>
</tr>
<tr>
<td>Eppley PIR (Pyrgeometer)</td>
<td>• Up-welling and Down-welling Radiation (3.50 - 50 μm)</td>
<td>y</td>
</tr>
<tr>
<td>Heimann KT-19.85 (Radiative Thermometer)</td>
<td>• IR Radiometric Surface Temperature</td>
<td>y</td>
</tr>
<tr>
<td>Exotech 100BXT 4-channel Spectrometer</td>
<td>• Upwelling Radiation (456 – 521 nm) • Upwelling Radiation (456 – 521 nm) • Upwelling Radiation (456 – 521 nm) • Upwelling Radiation (456 – 521 nm) viewing angle may be set for 1 or 15 degrees by changing lenses</td>
<td>y</td>
</tr>
<tr>
<td><strong>Miscellaneous Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VHS Video recording</td>
<td>• Down-looking with date/time stamp (toggle between standard forward-looking video, see Appendix 1)</td>
<td>forward</td>
</tr>
</tbody>
</table>

**NON-STANDARD INSTRUMENTATION GROUPINGS**

The following instrument groupings are considered non-standard and may require additional resources for preparation, maintenance, and data processing. If any of the additional measurements available in a given group are needed mark with “yes.” For each grouping that is marked yes, please fill in instrument group specific information found later in this request.

<table>
<thead>
<tr>
<th>Instrument Grouping</th>
<th>Measurements Available in Grouping</th>
<th>Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Response Instrumentation Suitable for Flux Measurements</td>
<td>• Fast Response Temperature, Carbon Dioxide, and Water Vapor</td>
<td>y</td>
</tr>
<tr>
<td>Trace Gas Chemistry</td>
<td>• Nitrogen Oxides, Sulfur Dioxide, Ozone, Sulfur Hexafluoride, Hydrogen Peroxide</td>
<td>n</td>
</tr>
<tr>
<td>Aerosol Properties</td>
<td>• Aerosol Size Distribution (0.02 to 3 μm), Total CN and CCN Concentration, Light Scattering Coefficient, Elemental Black Carbon</td>
<td>n</td>
</tr>
</tbody>
</table>
WYOMING CLOUD RADAR (WCR)
The Wyoming Cloud Radar is available for deployment on the UWYO King Air or other platforms with support through the LAOF Deployment Pool. Deployment of the WCR on the UWYO KA requires considerably more resources than the UWYO King Air alone. Requests for the WCR require additional information pertaining to both operational considerations and scientific justification.

Specific Technical Questions may be addressed to:
Dr. Samuel Haimov
Email: haimov@uwyo.edu; Phone: (307) 766-2726
http://www-das.uwyo.edu/wcr/

requested? yes

RADAR OPERATIONS

Scientific rationale for the use of WCR in the proposed project:
WCR data will describe (a) the vertical structure and (b) the horizontal structure of the dryline or ancillary radar fine-lines.

Vertical single- and dual-Doppler transects will reveal the variations in depth of the CBL, updraft strength, echo and updraft slope, the presence of a solenoidal circulation, and on occasion vertical circulations in cumulus clouds. Vertical-plane data from 3 antennas (side/up, down, and down-fore) will be collected on flight legs across the radar fine-lines. Such flight legs will dominate in SONDE-08.

Horizontal-plane single and dual-Doppler displays will reveal the horizontal variability of the dryline, and variations of vertical vorticity and divergence along the dryline. Horizontal transects are to be collected on flight legs along a radar fine-line, and real-time side-antenna data will fine-tune the aircraft’s track along the line. Again 3 antennas would be used, side/up, side-fore, and down. If misocyclones are present at close range then their thermodynamic and vertical velocity characteristics can be determined. The WCR would be more effective for this purpose if there were an antenna viewing to the left of the aircraft. Based on IHOP experience, we expect to be able to fly along fine-lines, yet conditions are more stringent (see pattern #4), so ‘along-dryline’ flight legs will be a minority.

Weather events during which collection is desired:
Clear air. Cumulus humilis to congestus are possible.

Estimated number of flights for which the radar will be used:
The WCR will be operated on all flights.

Desired radar configuration and parameters (if known):
Antenna configuration (pick one):
Single antenna (single or dual-polarization): ____ side/up (use mirror to re-direct the beam)
Two antennas (single linear polarization): ____ down (near nadir) and down-fore
Two antennas (single or dual polarization*): ____ side/up and side-fore
Three antennas (single/dual-polarization*): _x_ side/up, down, and down-fore
Four antennas (single polarization): _x_ side/up, side-fore, down, down-fore
* dual linear polarization available for side/up antenna only

Note: a distinction is made between h(orizontally) and v(ertically) viewing antennas
Maximum range (3-4 km typical): 2.5v, 7.5h [km]
Number of Gates (100 to 200 typical): 170
Sampling along the beam (15 to 75 m typical): 15v, 45h [m]
Sampling along the flight track (3-5 m typical): 5-10m
Minimum Sensitivity Needs (dBZ at 1 km): as can be achieved with WCR-II

Scientific rationale for desired radar parameters:
These parameters are based on experience in IHOP, NASA-ROLLS, and CuPIDO. Some tuning will probably be needed in the field, depending on echo strength and echo depth.
SUPPORTING AND DATA SERVICES

Multiple radar coordination requirements:

If WCR will coordinate with other radars (airborne or surface), please provide brief details

Unless one or more mobile cm-wave radars participate in SONDE-08, the UWKA will preferably operate when the dryline is within 60 km of the LBB WSR-88D (see Fig. A). Proximity to a scanning ground radar is needed to guide the UWKA, primarily for flight pattern 4. In essence WSR-88D (or other scanning ground-based radar) data provide a spatial and temporal context within which fine-scale data can be collected. Of course the larger-scale coverage is useful also in the analysis phase. Flight patterns 1-3 can be conducted without ground radar coverage, although some flight time will have to be used to locate the dryline.

The UWKA flight patterns will take the aircraft over MIPS, over (or just downstream of) the string of ISFF sites, and often within 30 km range of the TTU Ka-band mobile radars. The purposes of this are:

(with MIPS) CBL depth comparison, triple wavelength profiling radar comparison, and wind/temperature/moisture profiles along the flight track;
(with ISFF) flux comparison;
(with Ka-band radars) to place the UWKA data in volumes of single and dual-Doppler synthesized wind fields derived from the Ka band radars, for instance to describe thermodynamic properties of misocyclones.

A standard WCR power calibration is expected, but further efforts to improve the accuracy of reflectivity are not needed, since the WCR reflectivity will not be compared with that of other radars in order to characterize the scatterers.

Summary of on-site radar data access and analysis requirements:

Real-time on-board display of last few minutes of WCR side/up and down antenna data is essential in aircraft operations, especially for pattern #4. Post-flight same-day data processing is expected, to see how well we did and to possibly adjust future flight patterns or WCR settings.

Processed data made available after quality control include ‘typical’ radar parameters such as reflectivity, Doppler velocity (corrected for aircraft motion), polarization parameters (ZDR, LDR, if appropriate), and three dimensional spatial reference (location and beam pointing directions). Additional products that require more extensive analyses may be available through special arrangement with UWYO but require additional funding from the project. Please contact the facility manager or the WCR radar technical contact for consultation.

Do you intend to request WCR special products? no

Note: Consultation with the facility manager or WCR scientist is encouraged before submitting a request that includes the WCR.
User-supplied scientific payload: none

Special data recording and processing requirements: none

Payload ground support needs for user-supplied instrumentation: none

Trace gas chemistry: not requested

Aerosol properties: not requested
SUPPORTING SERVICES

Will you require air-ground communication? (If so, specify location of base station and operating frequencies, some limited communications may also be available through sat phone connections on the UWYO King Air.)

Yes, for the following purposes:

1. two-way data transfer for real-time guidance of UWKA flight legs through imagery of combined operational and UWKA data

Undersampled UWKA data need to be communicated to the ground, for use in IDV, as was done in CuPIDO. The dataset can be quite low-volume, e.g. 10 sec (0.1 Hz) measurements of aircraft location, wind fields, temperature, water vapor, and LWC. We need to go further than in CuPIDO, to make this data available for real-time flight guidance, since our target (the dryline) usually is invisible, unlike in CuPIDO. We will work with Larry Oolman to build IDV bundles and to have IDV (script-based?) generate imagery containing a blend of operational data (WSR-88D, GOES VIS, WTM) and SONDE-08 data (UWKA, ISFF, possibly also TTU sounding data). These images can be viewed on-board thru a low-bandwidth accessible website (e.g. a text version of the Field Catalog), using the on-board sat-phone modem. A drawback of this "operator-requested" imagery upload is that the sat phone is intermittent and the band-width low. Would it be possible to run a script on the 4th seat computer that queries a server for the latest imagery whenever the sat phone connection is up? That way near-real-time animations or snapshots of this imagery are instantly available on-board at the time that the flight scientist needs it.

2. radio communication

Oral radio-communication is preferred over sat-phone based x-chat, because it is faster, and because the various crews on the ground will not have internet access. The desired range capacity is 200 km. In IHOP we used a 900 MHz Freewave antenna. The TTU folks only have limited experience with radio-communication. The UWKA flight scientist needs to be able to contact the Reese Ops Center (just west of Lubbock) and the Ka radar mobile station. The possibility exists that NSSL (Conrad Ziegler) will participate. In that case, they will bring a Field Coordination Vehicle, as in IHOP, and they are quite experienced, e.g. they can set up a 10 m Freewave antenna and have internet access. If radio-comm proves too difficult, we can manage with x-chat.

What real-time display and data services are required?

A basic data/analysis center with LAN connections to the UWYO computers and access to the internet will be provided in the field by UWYO. Support, if requested, may include real-time communications links to the aircraft via “chat” and real-time display of selected variables through UDP data forwarding, currently supported through NCAR JOSS. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service.

See above, for real-time display and x-chat. We are not asking JOSS (now called FPS) for assistance with forecast discussions or presentations, but the Field Catalog is essential.

On-site data access requirement: yes, shortly after the flight
FAST-RESPONSE INSTRUMENTATION SUITABLE FOR FLUX MEASUREMENTS

Specific Technical Questions may be addressed to:
Dr. Robert Kelly
Email: rkelley@uwyo.edu; Phone: (307) 766-4955
http://flights.uwyo.edu/bulletin1.html

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurements Available</th>
<th>Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Friehe-type Air Temperature Probe w/ UWYO modifications (Developmental)</td>
<td>• Fast Response Temperature</td>
<td>Y</td>
</tr>
<tr>
<td>Licor 6262</td>
<td>• Water Vapor</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>• Carbon Dioxide</td>
<td></td>
</tr>
</tbody>
</table>

Please note that UWYO does not provide computation of fluxes, but rather measurements suitable for the computation of fluxes.

*Developmental instruments may require additional support

Scientific rationale for the use of special fast response instruments in the proposed project:

Heat, water vapor, and momentum fluxes will be measured on either side of the dryline, both near the surface and in the upper CBL, at times that the prevailing wind blows at a small angle to the dryline (see flight pattern #1, Fig. 1). The 500 ft AGL estimates will be extrapolated to the surface and compared with ISFF and HRLDAS fluxes on respective sides of the dryline. Pattern #1 is designed to be sufficient to measure momentum fluxes; sensible and latent heat fluxes should be well sampled through this pattern, since they typically require less averaging distance than momentum fluxes (e.g., LeMone et al. 2003). This work will be conducted by one of the two UWyo graduate students, in close cooperation with Peggy LeMone.

The CO₂ data from the Licor 6262 will be used to estimate photosynthetic activity. The correlation between CO₂ fluxes and nadir NDVI measurements is an indication of the footprint (geographic origin) of flight-level fluxes.

The Licor 6262 data will also be used pinpoint the location of the dryline, marked by a sharp humidity change. The Cambridge chilled mirror dewpoint sensor has a lagged response and displays a hysteresis in the presence of a step function change (Ziegler and Hane 1993).

Summary of any special requirements that pertain to fast response measurements, include frequency resolution (or spatial resolution) required:

They need to be adequate to measure fluxes.

Note: Consultation with the facility manager or technical contact is often useful and therefore encouraged before submitting a request that includes measurements utilizing the special fast-response instrumentation.
References


UWYO King Air Facility Request


### Appendix I: Standard Airborne Scientific Measurements

Instrument list with range, accuracy, and resolution can be found at: [http://flights.uwyo.edu/base/InstList.pdf](http://flights.uwyo.edu/base/InstList.pdf)

#### I. TIME

<table>
<thead>
<tr>
<th>Name</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOUR</td>
<td>hr</td>
<td>Slaved to GPS time (GMT)</td>
</tr>
<tr>
<td>MINUTE</td>
<td>min</td>
<td>Slaved to GPS time (GMT)</td>
</tr>
<tr>
<td>SECOND</td>
<td>sec</td>
<td>Slaved to GPS time (GMT)</td>
</tr>
<tr>
<td>TIME</td>
<td>hhmmss</td>
<td>Slaved to GPS time (GMT)</td>
</tr>
<tr>
<td>DATE</td>
<td>yymmdd</td>
<td>Slaved to GPS time (GMT)</td>
</tr>
<tr>
<td>base_time</td>
<td>s</td>
<td>Reference Start Time (UNIX time format)</td>
</tr>
<tr>
<td>time_offset</td>
<td>s</td>
<td>Offset from Reference Start Time</td>
</tr>
</tbody>
</table>

#### II. INERTIAL REFERENCE SYSTEM (Honeywell Laseref SM IRS)

<table>
<thead>
<tr>
<th>Name</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hlat, LAT</td>
<td>degree_N</td>
<td>Inertial Latitude</td>
</tr>
<tr>
<td>hlon, LON</td>
<td>degree_E</td>
<td>Inertial Longitude</td>
</tr>
<tr>
<td>hthead</td>
<td>degree_T</td>
<td>Aircraft True Heading Angle</td>
</tr>
<tr>
<td>hpitch</td>
<td>degree</td>
<td>Aircraft Pitch Angle</td>
</tr>
<tr>
<td>hroll</td>
<td>degree</td>
<td>Aircraft Roll Angle</td>
</tr>
<tr>
<td>hyawr</td>
<td>radian s⁻¹</td>
<td>Aircraft Yaw Angle Rate</td>
</tr>
<tr>
<td>hpitchr</td>
<td>radian s⁻¹</td>
<td>Aircraft Pitch Angle Rate</td>
</tr>
<tr>
<td>hrollr</td>
<td>radian s⁻¹</td>
<td>Aircraft Roll Angle Rate</td>
</tr>
<tr>
<td>hlata</td>
<td>g</td>
<td>Aircraft Lateral Acceleration (body axis)</td>
</tr>
<tr>
<td>hlonga</td>
<td>g</td>
<td>Aircraft Longitudinal Acceleration (body axis)</td>
</tr>
<tr>
<td>hnorma</td>
<td>g</td>
<td>Aircraft Normal Acceleration (body axis)</td>
</tr>
<tr>
<td>hivs</td>
<td>m s⁻¹</td>
<td>IRS-Computed Aircraft Vertical Velocity</td>
</tr>
<tr>
<td>hgs</td>
<td>m s⁻¹</td>
<td>Inertial Ground Speed</td>
</tr>
<tr>
<td>htrk</td>
<td>degree_T</td>
<td>Inertial Ground Track Angle</td>
</tr>
<tr>
<td>hewvel</td>
<td>m s⁻¹</td>
<td>Inertial Ground Speed Vector, East Component</td>
</tr>
<tr>
<td>hnsvel</td>
<td>m s⁻¹</td>
<td>Inertial Ground Speed Vector, North Component</td>
</tr>
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</table>

#### III. GLOBAL POSITIONING SYSTEM (GPS, Ashtech Z-Sensor)

<table>
<thead>
<tr>
<th>Name</th>
<th>Units</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>GLAT</td>
<td>degree_N</td>
<td>GPS Latitude</td>
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<tr>
<td>GLON</td>
<td>degree_E</td>
<td>GPS Longitude</td>
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<tr>
<td>GALT</td>
<td>m</td>
<td>GPS Altitude</td>
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## IV. Altitude and Position

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<th>Description</th>
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<tbody>
<tr>
<td>ralt1</td>
<td>m</td>
<td>Geometric (Radar) Altitude (King) (0-610 m)</td>
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<tr>
<td>ralt3</td>
<td>m</td>
<td>Geometric (Radar) Altitude (APN232)</td>
</tr>
<tr>
<td>z, PALT</td>
<td>m</td>
<td>Pressure Altitude (Std Atm)</td>
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<tr>
<td>ztrue</td>
<td>m</td>
<td>Altitude (Hypsometric)</td>
</tr>
<tr>
<td>hi3</td>
<td>m</td>
<td>IRS Altitude, (Baro-loop corrected)</td>
</tr>
<tr>
<td>LATC</td>
<td>degree N</td>
<td>IRS Latitude, GPS-Corrected</td>
</tr>
<tr>
<td>LONC</td>
<td>degree E</td>
<td>IRS Longitude, GPS-Corrected</td>
</tr>
<tr>
<td>xdist</td>
<td>km</td>
<td>Distance East from ‘Center Coordinate’</td>
</tr>
<tr>
<td>ydist</td>
<td>km</td>
<td>Distance North from ‘Center Coordinate’</td>
</tr>
<tr>
<td>xerr</td>
<td>km</td>
<td>Position Error (east component); IRS-GPS difference</td>
</tr>
<tr>
<td>yerr</td>
<td>km</td>
<td>Position Error (north component); IRS-GPS difference</td>
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## V. Velocity and Acceleration

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<tbody>
<tr>
<td>hacz3</td>
<td>m s⁻²</td>
<td>Vertical Acceleration (Baro-loop corrected)</td>
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<tr>
<td>hwp3</td>
<td>m s⁻¹</td>
<td>Vertical Speed (Baro-loop corrected)</td>
</tr>
<tr>
<td>uerr</td>
<td>m s⁻¹</td>
<td>Velocity Error (east component; subtract from ‘hewvel’)</td>
</tr>
<tr>
<td>verr</td>
<td>m s⁻¹</td>
<td>Velocity Error (north component; subtract from ‘hnsvl’)</td>
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## VI. Aircraft and Meteorological State Parameters

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<thead>
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<th>Name</th>
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<td>Attack Angle</td>
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<tr>
<td>beta</td>
<td>degree</td>
<td>Sideslip Angle</td>
</tr>
<tr>
<td>pmb</td>
<td>mb</td>
<td>Static Pressure (Rosemount 1201)</td>
</tr>
<tr>
<td>ps_hads_a</td>
<td>mb</td>
<td>Static Pressure (Rosemount HADS)</td>
</tr>
<tr>
<td>ps_had_b</td>
<td>mb</td>
<td>Static Pressure (Rosemount HADS)</td>
</tr>
<tr>
<td>dpa</td>
<td>mb</td>
<td>Differential Pressure Normal (body axis)</td>
</tr>
<tr>
<td>dpb</td>
<td>mb</td>
<td>Differential Pressure Lateral (body axis)</td>
</tr>
<tr>
<td>dpr</td>
<td>mb</td>
<td>Differential Pressure (approximately Q for zero sideslip and attack)</td>
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<tr>
<td>aias</td>
<td>knots</td>
<td>Indicated Airspeed, pilot pitot</td>
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<tr>
<td>bias</td>
<td>knots</td>
<td>Indicated Airspeed, co-pilot pitot</td>
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<td>tas, TASX</td>
<td>m/s</td>
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<tr>
<td>torque</td>
<td>ft lbs</td>
<td>Left Engine Torque</td>
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<td>turb</td>
<td>MKS</td>
<td>Turbulence</td>
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VII. THERMODYNAMIC MEASUREMENTS

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<tr>
<td>trf</td>
<td>C</td>
<td>Ambient Temperature (Reverse-Flow)</td>
</tr>
<tr>
<td>trose</td>
<td>C</td>
<td>Ambient Temperature (Rosemount 102)</td>
</tr>
<tr>
<td>tdp</td>
<td>C</td>
<td>Dew Point Temperature (Cambridge model 137C3 chilled mirror)</td>
</tr>
<tr>
<td>thetad</td>
<td>K</td>
<td>Potential Temperature (dry)</td>
</tr>
<tr>
<td>thetad</td>
<td>K</td>
<td>Equivalent Potential Temperature</td>
</tr>
<tr>
<td>rh</td>
<td>%</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>mr</td>
<td>g kg⁻¹</td>
<td>Mixing Ratio</td>
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VIII. WINDS

<table>
<thead>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hu</td>
<td>m s</td>
<td>Wind Vector, East Component</td>
</tr>
<tr>
<td>hv</td>
<td>m s</td>
<td>Wind Vector, North Component</td>
</tr>
<tr>
<td>hw</td>
<td>m s</td>
<td>Wind Vector, Vertical Component</td>
</tr>
<tr>
<td>hwf</td>
<td>m s</td>
<td>Wind Vector, Vertical Component (high-pass filtered)</td>
</tr>
<tr>
<td>hwmag</td>
<td>m s</td>
<td>Horizontal Wind Speed</td>
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<tr>
<td>hwdir</td>
<td>degree T</td>
<td>Horizontal Wind Direction</td>
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<tr>
<td>ux</td>
<td>m/s</td>
<td>Wind Vector, Longitudinal Component</td>
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<tr>
<td>vy</td>
<td>m/s</td>
<td>Wind Vector, Lateral Component</td>
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</table>

In addition to the above listed standard measurements, also provided are the following as part of the standard flight log:

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHS Video recording Forward-looking with date/time stamp (may be replaced with down-looking video; see optional standard measurements section)</td>
</tr>
<tr>
<td>Audio recording Full flight record of King Air intercom and radios</td>
</tr>
<tr>
<td>Event markers Multiple event markers set by flight crew</td>
</tr>
</tbody>
</table>