REQUEST FOR EOL FACILITY SUPPORT
SONDE – 08
(Simultaneous Observation of the Near-Dryline Environment)
NCAR/EOL -NOVEMBER 2007 OFAP MEETING
Submitted on 15 December 2006

PART I: GENERAL INFORMATION

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Project Description

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<th>Project Title</th>
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Fei Chen – NCAR  
Chris Weiss - Texas Tech University  
Bart Geerts – University of Wyoming  
Kevin Knupp – University of Alabama/Huntsville |
| Location of Project | Texas Panhandle (Lubbock) |
| Start and End Dates of Field Deployment Phase | 1 May – 9 June 2008 |
SONDE 08 PROPOSAL SUMMARY

1. OVERVIEW

a. 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-08) 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-08 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 20-30 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 the fluxes of sensible and latent heat (H and LE) 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 spatial variability.

Numerical modeling will be a significant component of both the field campaign and subsequent data analysis. 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 dryline evolution.

b. Background

Drylines are roughly north-south oriented boundaries within the 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. A line of cumuli sometimes occurs along the
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 morerapidly 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
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.

**c. Uniqueness**

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). In particular, several recent IHOP-based studies have revealed substantial fine-scale horizontal structure along drylines, especially misovortices and associated vertical motion. We believe SONDE-08 is unique in the following ways:

*(a) Focus on physics of dryline 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 foci the mechanisms responsible for fine-scale convergence along the dryline, namely: (a) the differential vertical transfer of westerly momentum from above the convective boundary layer (CBL) due to larger surface buoyancy fluxes 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 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 horizontal convective rolls (HCRs). Under sufficient horizontal
wind shear, misocyclones may form along these boundaries. These ancillary fine-lines will be examined as well as the primary dryline.

(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. 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. From the foregoing, several numerical experiments have been conducted to understand 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. 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. Research simulations will be performed at 1-km resolution.

The HRLDAS/WRF system has been tested using IHOP datasets under fair-weather conditions with relatively small regional land use or terrain variations (Chen et al. 2006). 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.

d. 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, Trier et al. 2004, Holt et al. 2006). 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 the SONDE-08 missions, affording them 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.

References


3. Scientific Objectives

SONDE-08 data will be used to address the following specific objectives:

Primary Objectives (focus on dryline structure/evolution)

(a) To run HRLDAS in real time to guide field operations, to examine how it simulates regional soil moisture and surface sensible and latent heat fluxes, and how it can be used in the WRF modeling system to forecast the timing, location, and strength of dryline and resulting 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, if present, the associated cumulus cloud line; and

(f) To examine the fine-scale horizontal structure of drylines, including the kinematic and thermodynamic properties of “misovortices”.

Secondary Objectives (focus on surface exchange, boundary layer)

(a) Examine the horizontal variability of H and LE as a function of number of days after rainfall using observations and HRLDAS fluxes (offline and coupled to WRF);

(b) Assess the surface energy balance, and response of stressed savannah grassland vegetation to diverse environmental forcings; evaluate the ability of HRLDAS (offline and coupled to WRF) to simulate diffuse and direct short-wave radiation components.

(c) Assess the effect of HCRs on the fluxes at the surface

4. Testable hypotheses

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 θ, 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 θ, gradient to much finer scales. [Key resources: ISFF transect; UWKA stepped traverses; West Texas Mesonet; 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 resource: MIPS, King Air, ISFF]
A3. The 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, West Texas Mesonet]

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

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), TTU Ka band radar, WSR-88D, 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 \( \theta_v \) difference, and is evident in the vertical slope of the dryline echo. This circulation assumes the characteristics of a density current if the local \( \theta_v \) difference exceeds a threshold. The sharp humidity contrast at the dryline is sustained by the convergence associated with this circulation. [Key resources: UWKA and WCR, TTU Ka band radar, 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 cumulonimbi 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 at finer scales will provide new insight into their kinematic and thermodynamic structure, and their origin.** [Key resources: UWKA/WCR, TTU Ka band radar]

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

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

IHOP_2002 (drylines, horizontal variability in fluxes)
CASES-97 (horizontal variability in fluxes, development of mesoscale circulations)
COPS (drylines and severe thunderstorm development)
VORTEX-94, VORTEX-95 (drylines and development of severe thunderstorms and tornadoes)

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

The use of ISFF surface observation observations relates primarily to objectives (a) through (d); and secondary objectives (a) –(c).

**Part 1. Primary objectives (focus on dryline evolution)**

(a) **To run HRLDAS in real time to guide field operations, to examine how it simulates regional soil moisture and surface sensible and latent heat fluxes, and how it can be used in the WRF modeling system to forecast the timing, location, and strength of dryline and resulting convective initiation.**

SONDE-08 would represent the first time, to our knowledge, that high-resolution soil moisture would be used as guidance in a dryline experiment. If they are available in spring 2008, we could also to have access to high-resolution (innermost domain 4 km or possibly less) MMM runs of the WRF/HRLDAS system (Morris Weisman, personal communication), enabling us to try using the coupled system in operational forecasting. In either case, we will examine the ability of the high-resolution (innermost grid 1 km) WRF/HRLDAS to forecast drylines in post-field campaign “hindcast” case studies.

SONDE-08 enables the convergence of two efforts Fei Chen and colleagues have been involved in. The first effort is looking at 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. The second effort is the development of the High Resolution Land Data Assimilation System (HRLDAS, Chen et al. 2006) 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. HRLDAS uses the Noah LSM, which has several similarities to the OSU LSM.

Note that the ability of the coupled WRF-land-surface-model to accurately simulate the variable PBL depth and the position of the dryline depends not only on the accuracy of the surface fluxes, but also on the WRF PBL parameterization. Various PBL parameterization options can be tested with the SONDE-08 dataset.

LeMone, along with Chen and Mukul Tewari, have been using IHOP_2002 data collected in southeastern Kansas to do more extensive comparisons of surface fluxes with those produced by both offline HRLDAS and HRLDAS coupled to WRF, and comparisons of BL depth and thermodynamic predictions, and the presence/absence of mesoscale circulations/inland sea breezes will soon follow. They found reasonable agreement in the surface fluxes, and soil moisture, allowing for the differences between precipitation from rain gauges at the surface flux sites and that from the NCEP Stage IV data used in HRLDAS (LeMone et al. 2007). SONDE-08 will afford the opportunity to do similar comparisons but in a region with tight east-west gradients forced locally, and with the likelihood of better-defined mesoscale circulations.

Niyogi is currently comparing AMSR (Advanced Microwave Scanning Radiometer –EOS) 0-5 cm depth soil moisture to in-situ measurements from a watershed in northern Indiana. The West Texas Mesonet and ISFF soil moisture products and HRLDAS soil moisture from SONDE-08 provide an excellent opportunity for comparison with AMSR in a different environment.


(b) To examine how observed and simulated regional heat flux variations at the surface and near the CBL top contribute to dryline formation;

Several modeling studies, with varying degrees of idealization, have confirmed the importance of surface properties to dryline formation and evolution (e.g., Ogura and Chen 1977; Benjamin 1986; Ziegler et al. 1995; Pielke et al. 1997; Grasso 2000). The current study will combine a continental-scale outer domain with higher-resolution inner domains (innermost domain: 1 km)
with detailed observations, enabling examination of this mechanism in context with other factors. Furthermore, the contribution of along-line variability in surface properties can be examined. We note that the IHOP_2002 surface sites in the vicinity of expected dryline development (Homestead area) were oriented north-south, rather than east-west, which would have been better for studying development of mostly north-south drylines.


(c) To examine how observed and simulated east-west differences in vertical transport of westerly momentum into the CBL contribute to dryline formation;

Downward mixing of westerly momentum has been thought to contribute to dryline formation and evolution as well as eastward motion for several decades (e.g., Schaefer 1974; Danielson 1974; Ogura and Chen 1977; McCarthy and Koch 1982). Momentum transport and density-gradient-induced solenoidal circulations both contribute to the concentration of thermodynamic gradients at the dryline. Winds increasing with height through the mixed layer (as opposed to constant winds) have been associated by LeMone et al. (1999) with rapid entrainment of higher-momentum air. Atkins et al. (1998, Figure 4) shows such profiles just west of the dryline for times just prior to its intensification; they attribute the dryline intensification to entrainment of westerly momentum.

Estimates of the vertical wind profile and vertical flux of horizontal momentum, based on aircraft, ISFF data, and MIPS, will enable examination of the momentum-flux divergence effect, which can be put into context with other frontogenetic effects using analyses of observations and WRF/HRLDAS simulations.


(d) To document the properties and evolution of ancillary boundaries, and to relate their formation to surface terrain and fluxes

A preliminary dryline climatology, using the West Texas Mesonet and the LBB and AMA WSR-88D data for the spring months of 2004 and 2005, suggests that some ancillary boundaries (seen as radar fine-lines) are locked to either local ridges in the terrain, or to horizontal differences in land use and soil moisture such as 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). SONDE-08 will provide the opportunity to study the dynamics of these ancillary boundaries; ISFF will enable more detail and, with HRLDAS, the association of the primary and ancillary boundaries with flux and soil-moisture gradients.


(e) To dynamically interpret the vertical echo and flow structure of the dryline convergence zone and, if present, the associated cumulus cloud line

Several studies using ground-based and airborne radar have resolved a 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), and associated tilted dryline updraft (Miao and Geerts 2007). The “classic” dryline circulation is positive, i.e., the horizontal vorticity points to the north for a N-S dryline, because the moist air is denser (lower $\theta_v$) than the dry air, although exceptions may exist (Sipprell and Geerts 2007). The ISFF array can supply further detail on surface kinematics and thermodynamics.


(f) To examine the fine-scale horizontal structure of drylines, including the kinematic and thermodynamic properties of “misovortices”
The last paragraph of the Background Section in the SONDE 08 Overview (Section 1b) describes IHOP-based work on misconvales and related updrafts. These studies have focused on the evolution of the kinematic fields. The vertical structure and buoyancy/moisture properties of misconvales and associated updraft will be a focus in SONDE-08. The addition of the ISFF stations to the surface network raises the probability of obtaining needed surface detail.

Secondary Objectives (Focus on surface exchange, boundary layer)

(a) Examine the horizontal variability of the sensible and latent heat fluxes as a function of number of days after rainfall.

Using IHOP_2002 and CASES-97 data from the mostly grass- and winter-wheat covered Walnut River Watershed in SE Kansas, and idealized simulations with the Noah LSM to represent the same region/periods, LeMone et al. (2007) found for days of sparse cloudiness, that H and LE averaged for the 6 h centered on local solar noon followed a repeatable pattern after a rain event, namely:

1. As found by many previous authors (e.g., Yates et al. 2001, Alfieri et al. 2006), LE and H over lush vegetation remained about the same over ~5 days, with large LE and low H; while over sparse or dormant vegetation, LE was high and H low right after rainfall, but LE rapidly decreased and H rapidly increased from day to day.

2. This resulted in an increase in horizontal variability in H and LE (and hence variability in buoyancy flux and the possibility of generation of mesoscale circulations) with time for several days.

3. If one plots LE(x,y) averaged over 6h centered around local noon as a function H(x,y) averaged over the same time period, for an array of stations or locations along a flight track,
   a. The points cluster around a common point right after rainfall (high LE, low H)
   b. Once a slope $\Delta LE/\Delta H$ can be defined, its value is something like -1.5 (from the surface energy budget, $H+LE = R_{net} - G_{sfc}$, where $R_{net}$ is the net radiation, and $G_{sfc}$ is the flux into the soil. If $R_{net} - G_{sfc}$ = constant (sometimes closely approximated with clear skies), we would expect $H+LE = constant$ and the slope $\Delta LE/\Delta H = -1$)
   c. The slope becomes shallower from day to day reaching values between -1 and -0.5 after ~5 days.

The behavior in (b) and (c) is due to less available energy (more flux into soil) at the sparse-vegetation sites compared to beneath the green lush sites shortly after rainfall. The soil heat flux at all sites decreases with time (dry soil a poor conductor), but it decreases faster at the sparsely-vegetated sites.

We expect a negative $\Delta LE/\Delta H$ slope in the Texas Panhandle. However, since the vegetation is sparse, we expect soil moisture contrast will be relatively more important than in SE Kansas. Indeed, horizontal contrast could be largest right after rainfall, and the $\Delta LE/\Delta H$ slope could remain close to -1. Furthermore, the effects of net radiation should be detectable and the effects of irrigation should be important.


(b) *Assess the surface energy balance, and response of stressed savannah grassland vegetation to diverse environmental forcings, and evaluate the ability of HRLDAS offline and HRLDAS coupled to WRF to simulate the diffuse and direct short-wave radiative components.*

Niyogi used the IHOP_2002 data in testing the surface data assimilation schemes for sequential assimilation of surface temperature and humidity (Childs et al. 2006; Alapaty et al. 2006) and to test the ability of satellite-driven ET models for their ability to simulate regional fluxes (Alfieri et al. 2006a,b). These satellite-based models use photosynthesis and water usage efficiencies, which are a function of diffuse and direct short-wave radiation, vegetation type, and water availability. The datasets were also used in testing the impact of introducing detailed vegetation transpiration schemes within the Noah land surface model for coupled and uncoupled mesoscale operations (Holt et al. 2006; Niyogi et al. 2006; Kumar et al. 2006).

Previously, the work was based on winter wheat and grasslands; SONDE-08 offers a chance to look at new vegetation types and to sample diffuse radiation at two or more sites.


(c) *Assess the effect of HCRs on the fluxes at the surface*
Since at least the 1970s, many have speculated on the effects of rolls (HCRs) on surface flux sampling and whether the “standard” 30-minute averaging time used for computing surface fluxes is optimum (e.g., LeMone 1976; Mahrt 1998). These authors focused mostly on the effects of the roll circulations themselves; pointing either to a concentration of flux-transporting plumes in the roll upwelling regions (LeMone 1976), or to strong horizontal variability in surface winds associated with the roll circulation (e.g., Morrison et al. 2005 and references therein). More recently, coupled HRLDAS/WRF runs by Chen and Mukul Tewari (underway) suggest an additional mechanism, shading by clouds. While long-recognized as a factor in the surface energy budget, the effects of cloud shading are difficult to assess in half-hour averages. Hence, we need five-minute ISFF fluxes so that longer-term averages can be computed relative to phase in the roll circulation, which is easily seen as slowly-varying wind direction in the record (LeMone 1974), particularly if satellite or radar images are available to predict the expected roll advection time (which gets longer as rolls become more closely aligned with the mean PBL wind direction).


Comment [BG1]: I think the dryline-environment is generally cloud-free even on the moist side (22 May in HOP was an exception?) . Better HCR control over the cloud field is found further east where the LCL is below zi.
How will the instruments/platforms requested be used to test the hypotheses and address each of the objectives?

**ISFF Placement Philosophy (Schematic locations in Figure 1)**

Based on experience in previous field campaigns and subsequent analysis and model comparisons, we will place the 12 requested ISFF flux stations in two east-west bands north of Lubbock, Texas, according to the following criteria:

- Land use (and possibly elevation).
- Nested within the West Texas Mesonet (see Appendix for further detail).
- In two 150-200-km east-west bands.
  - 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 would be of the order of 30 km to the north, to help assess variability in the north-south direction (e.g., Texas Caprock Escarpment, Fig. 2).
  - The bands should be centered roughly at 100.6°W (climatological dryline location [Hoch and Markowski 2005], which corresponds roughly with location of Texas Caprock Escarpment). The layout would have six stations to the east of the Caprock and six to the west, as illustrated schematically by the layout in Figure 3.
- Possibly, one or more ISFF sites collocated with a West Texas Mesonet site for intercomparison. (West Texas Mesonet is interested in doing this). Of course such sites must have sufficient fetch (at least 100 m in all directions) for eddy-correlation fluxes.
- We request momentum fluxes in addition to H and LE, to help assess the influence of vertical transport of horizontal momentum on dryline development (Objective (c), King Air request, Fig. 1, Figure 4).
- If possible it is desirable to place a station immediately downstream from (north of) an irrigated area to assess the effects of irrigation on the fluxes.

**How goals are achieved**

Such a placement would enable a good sample of:

- The horizontal variability of H and LE across drylines for conceptual analyses; HRLDAS/WRF would “fill in” the missing data.
- Supplement West Texas Mesonet and mobile “Stick-Net” (Appendix) surface data, to improve sample of surface kinematics and thermodynamics needed for analysis of near-dryline fields.
- ISFF Momentum fluxes will be combined with those from aircraft to assess the effects of the vertical flux of horizontal momentum on dryline development. (Figure 4). We believe the best chances to get surface momentum fluxes that represent a larger region are to the west of the Texas Caprock Escarpment, where the terrain is flat. Momentum fluxes will also be estimated using MIPS (Appendix), for comparison with data from the other sources.
- ISFF surface data will be combined with data from other surface instruments, King Air, and MIPS to document the wind profiles and their evolution from the King Air and MIPS in the momentum-flux study.
Figure 1. Idealized SONDE-08 instrument layout. For philosophy regarding placement of ISFF, see text. NOTE: MIPS, Ka band radar, and Stick-Net placement varies from day to day. King Air track would be straight; ideally near one of the ISFF bands. The West Texas Mesonet, the Stick-Net, MIPS, and the TTU Ka Band radars are described in the Appendix.
Figure 2: Texas Caprock Escarpment from space, Nov. 1985. Top is toward the Northeast. Note the sharp differences in land use between across the escarpment. NASA photo.

Figure 3. Schematic of the dryline with expected flux variation and a “direct” solenoidal circulation. “South” is into the page.
Vertical Momentum Transfer

Figure 4. Schematic of the contribution of momentum transfer on the development of the dryline. Mixing down of westerly momentum will accelerate wind on the west side, contributing to convergence and the concentration of thermodynamic gradients.

**KING AIR**

King-Air flight patterns are described in detail in the King Air facility request. The ISFF array should be placed beneath where we know that the King Air can fly (given FAA restrictions) to enable tying the two datasets together. For example, the ISFF sites will be spread out so that probability is high that some ISFF stations would be upstream of the aircraft patterns that cross the dryline circulation and the two types of land surfaces in Figure 3.

In addition to kinematics and thermodynamics, observations of momentum flux will be important to achieve SONDE-08 primary objective (c) (to examine the role of momentum flux in dryline evolution, Figure 4), because HRLDAS/WRF is not equipped to produce horizontal fields of surface momentum flux. Based on IHOP data and Mann and Lenschow (1994, JGR), a roughly 300-km sample is required to get momentum flux at a given level within about 10%; flights near the top and bottom of the boundary layer could reduce the sampling length needed. Flux-uncertainty evaluations during the experiment could reduce the flight time needed to get momentum fluxes. Fortunately, the ISFF surface momentum fluxes should be more representative of the “real” surface effect over the relatively level terrain west of the Caprock Escarpment, where the expected deeper CBL should result in larger eddies and hence longer aircraft sampling times needed.
What results do you expect and what are the limitations? (related to ISFF role)

For ISFF-related primary objectives:
(a) Continuous records of the terms of the surface energy balance (sensible and latent heat flux, soil heat flux, net radiation), for comparison with HRLDAS and evaluation of the flux contrast across the dryline.
(b) Continuous records of radiometric surface temperature, for comparison with HRLDAS. This parameter has recently received (justifiably) a lot more attention than previously, and the offline version doesn’t do as good a job as it should around sunset.

We would rely heavily on the model, calibrated by the surface-flux measurements, to examine the role of the horizontal surface flux gradient in dryline evolution.

Limitations
(a) More often than not, the surface energy budget doesn’t balance. We recognize that as a limitation using observed fluxes to test HRLDAS. However, recent improvements in accounting for the distance between the humidity sensor and the sonic anemometer on the ISFF tower (Horst, personal communication, 2006) led to better-than-expected balance during IHOP_2002 (LeMone et al., to appear in BAMS in 2007).
(b) The momentum flux from the surface may not be representative of the true surface flux (form drag plus skin drag); so such measurements are probably going to be the most useful to the west of the dry line. Fortunately, where terrain is hillier and form drag probably an issue, the shallower CBL will enable sampling the momentum flux in a shorter time.
(c) The model treatment of the BL is less certain; in fact understanding the model successes and limitations in replicating the thermodynamic and wind profiles will be a goal.

For Secondary Objective (a) – Horizontal variability of fluxes
We expect to be able to assess the evolution of horizontal variability on sparsely-clouded days with horizontal variation in H and LE greater than 100 Wm\(^{-2}\) (given a flux error of 50 Wm\(^{-2}\), Yates et al. 2001, J. Appl. Meteor. in above references). The presence of clouds complicates the pattern.

For Secondary Objective (b) – Surface energy balance, vegetation, diffuse radiation
As above, with similar limitation, we expect surface energy balance terms, supplemented with data on diffuse and direct solar radiation, that are useful for testing of surface-data assimilation schemes.

For Secondary Objective (c) – HCR effect on fluxes at surface
We expect to see a measurable effect of HCR-produced cloud streets on surface fluxes by forming a running average of fluxes based on the five-minute values. Clear-air HCRs (rolls) could also modulate fluxes; and this could be tested by using wind direction as a reference to roll phase, as in LeMone (1973, JAS). Comparisons of instantaneous (1-sec) downwelling radiation to that produced by the model will reveal how realistic the modeled values are.

Limitations: For this objective to be met, the rolls have to advect by the surface towers: they cannot be exactly parallel to the wind. The rolls studied by LeMone (1973 and 1976, JAS) were
sampled from a 444-m TV tower near Oklahoma City, indicating that they were advected by the tower. Since the focus is on surface fluxes rather than roll dynamics, it is not necessary to assume the rolls are steady-state. Relative scarcity of cumulus near the dryline and clouds induced by the dryline probably limit us to using ISFF sites farthest from the dryline for this purpose on dryline days.

**Provide details about the experiment design:**
Array layout described above and in King-Air request; individual arrays and instruments described in Appendix.

If this is a re-submittal of a request, please address all concerns and questions raised in the “Confidential Comments and Feedback to PI” portion that was provided with the notification letter.
N/A for ISFF

If this is a second year request for continuation of a program, please provide a summary or highlights describing the results of the first field phase.

N/A

**PREVIOUS RESEARCH EXPERIENCE**

**Past EOL support:**
LeMone: Since 1990: IHOP_2002, CASES-97, TOGA COARE, STORM-FEST
Chen: IHOP_2002
Geerts: IHOP_2002, NASA ROLLS, RICO, CuPIDO
Weiss: VORTEX (ELDORA), IHOP_2002 (tornado radar, WCR)
Knupp: IHOP_2002, BAMEX
Niyogi: pre-INDOEX (onsite meteorologist, flux station, CLASS launches), INDOEX (on-site flux and BL data analysis, modeling), IHOP_2002 (onsite measurements, BL data analysis modeling)

**Publications resulting from past EOL support (since 2000):**


Geerts:


Knupp


Niyogi


**Weiss:**


---, ---, ---, and B. Geerts, 2006: Fine-scale radar observations of a dryline during the International H2O Project (IHOP 2002). *Sanders Symposium Monograph (accepted)*

**Expected publication date and journal(s):** It will take roughly three years to complete data analysis; likely journal articles would be in *MWR, JGR* or *Journal of Hydrometeorology*.

**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.

**Niyogi/Chen/LeMone:** Proposal will be for two graduate students to participate in the field measurements and data analysis. At least 2 undergraduate students will participate for data analysis and as feasible for field measurements.

**Geerts/LeMone:** Requesting funding for 2 PhD students

**Weiss:** 2 Proposals in for 2 M.S., 2 Ph. D. Students will assist in data collection, instrument maintenance, forecasting, and nowcasting. Some undergraduate student participation is also anticipated.

**Knupp:** About 4 graduate students will be involved in the field phase: 1 graduate student will be dedicated to data analysis.

**Do you plan to enhance undergraduate and/or graduate classes with hands-on activities and observations related to this project? Will you develop new curricula that will be related to the project? If yes, please describe.**

**Weiss, Geerts and Knupp** will use SONDE-08 material to illustrate the dryline in their
introductory meteorology class. Geerts' graduate level Mesoscale Meteorology class, offered annually will use SONDE-08 data as laboratory material.

Weiss instructs Radar Meteorology (graduate level) 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.

Niyogi teaches two courses at Purdue: (i) Instrumentation Meteorology (senior undergraduate and graduate level) and (ii) Land Surface Modeling. Both will benefit directly from the proposed project. In particular, his Land Surface Modeling course will be modified to include a dryline case study with observations and case studies from the proposed experiment. He will add course component on irrigated landscapes in graduate level land surface model course.

Knupp teaches two graduate-level course on alternative years, both of which will use SONDE-08 data. These include Boundary-Layer Meteorology and Ground-Based Remote Sensing.

Do you plan any outreach activities to elementary and/or secondary school students and/or the public related to the project? If yes, please describe. For example, do you plan to have any interactions with primary and secondary school educators to involve them in the project? Are you cooperating with an agency outreach program during this project?

LeMone is Chief Scientist of GLOBE, a world-wide (~110 countries) 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 will include some of her experiences in SONDE-08 in her science blog (enter website, click on “Chief Scientist’s Blog”). 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 GLOBE Coordinator in late December.

Niyogi is a State Climatologist and has ongoing interactions with extension community, as well as middle and high school teachers and student interns. He will utilize SONDE-08 to provide theme topics on land surface heterogeneity and severe weather as part of Environmental Science internships and training opportunities.

Weiss 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. His pending CAREER proposal includes internships for high school students for participation in the field.

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

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 Data Archive.
2. The project planning, field activities, preliminary results, and publications, will be available through the websites of the PIs, namely: http://www.rap.ucar.edu/projects/land (Chen/LeMone; mainly surface-flux, aircraft flux, modeling results) http://www-das.uwyo.edu/~geerts/sonde/. (Geerts) http://www.atmo.ttu.edu/sonde/ (Weiss) http://vortex.nsstc.uah.edu/mips (current web site for Knupp)

Each site will provide a link to the others.

**FUNDING AGENCY INFORMATION**

<table>
<thead>
<tr>
<th>Funding Agency</th>
<th>National Science Foundation</th>
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<tbody>
<tr>
<td>Program Officer Name</td>
<td>Dr. Stephan Nelson</td>
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<tr>
<td>Proposal ID</td>
<td>Geerts UWyo ATM proposal ~400K/3 yrs (LeMone unfunded Co-I*)</td>
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<td>Weiss TTU ATM proposal (~$450K/3 yrs)</td>
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<td>TTU CAREER Proposal ($800K/5 yrs, submitted)</td>
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<td></td>
<td>Niyogi Purdue ATM proposal (~400K/3 yrs, Chen, LeMone unfunded Co-Is*)</td>
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<td>Knupp UAH ATM Proposal ($300K/3 yrs)</td>
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<td>Proposal Status</td>
<td>See above.</td>
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*LeMone and Chen, as NCAR scientists, cannot write proposals to NSF/ATM. If experiment 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.

**Do you expect other (non-NSF) agency support?**

No.
PART II – OPERATIONAL CONSIDERATIONS & LOGISTICS

How many people will be involved in the field campaign? Please specify number of participants and location(s)
10-15 on site, not counting ISFF and University of Wyoming Flight Crews. All will be based at the Operations Center at Reese Technology Center, just west of Lubbock. Some 10 undergraduates will participate as well.

LeMone: Will attend part of the field program.
Geerts: PI and 2 grad students, will be 2 on site at any given time.
Weiss: PI + ~5 (2 grad students + 3 undergrad students)
Niyogi: One graduate student, funded by NSF proposal, 2, and 2-3 undergraduates, to get field experience, leading to about 2 in the field at a time. Niyogi will be out for part of program as well.
Chen: His group will train one PhD student to run HRLDAS during the field phase, starting a few weeks in advance. This student is listed as funded by Niyogi’s proposal, but this student could be from Geerts proposal. Student preferred on site at the Reese Operations Center but could be at NCAR.
Knupp: MIPS team leader (PI or Research Associate) + 3 graduate students

What other facilities/platforms outside the EOL suite and UWKA/WCR will be deployed? Are any of them non-US facilities?
Weiss: (Texas Tech University): West Texas Mesonet (~50 sites, see Fig 1), 2 Ka Band mobile radars, 5 mobile mesonet vehicles, a fleet of ~20-30 Stick-Net probes, 1 mobile sounding unit.
Knupp (University of Alabama-Huntsville): Mobile Integrated Profiling System (MIPS) + one mobile mesonet vehicle.

Are complex inter-facility or inter-agency permissions required for flight operations and/or other facility operations that would benefit from EOL leadership and experience?
See King Air request. Minimum sustained flight level will be 500 ft AGL.

Is there a need for integrated diplomatic arrangements? (e.g., customs, immigration, focal point with local hosts/governments)
N/A

If there are multiple instrumentation/operations sites, is there a need for operational coordination?
Yes.
1. King Air crew will probably base at Lubbock Airport.
2. If all are funded, there will be five crews to coordinate: the Stick-Net crew, the Ka radar crew, a mobile sounding crew, a MIPS crew, and the UWKA/WCR crew. We believe that we can manage operational coordination at the Reese Operations Center without support from EOL FPS (Field Program Support).

What kind of real-time data display and project coordination needs do you anticipate?
(These are preliminary assessments, we would work with JOSS to determine exact products if approved)

For weather forecasting/nowcasting

- Weather maps and forecast products.
- Visible and Infrared satellite images
- NEXRAD Surveillance Scans (lowest elevation angle)
- A subset of King Air data will be transmitted by satellite phone (or a 900 MHz Freewave connection) for real-time use in IDV, e.g. on overlays over WSR-88D or GOES VIS imagery.
- 5 min-ISFF data transmitted to a server at EOL, for similar use in IDV. The IDV-based imagery will be placed on the SONDE 08 FPS Field Catalog, for use by all participants. The images will also be queried by the King Air, using the same low-bandwidth connection. Some support from Unidata for this effort would be useful.
- HRLDAS soil-moisture fields (either produced at NCAR or on-site)
- If available, high-resolution (4-km at present) WRF coupled to HRLDAS forecasts, from the MMM web site (recently run by MMM during the warm season; it is not known whether this product can be available without additional support in spring 2008).

For assessing data quality: All ISFF data, near-real time fluxes and variables

Is forecasting support required for project operations?
No. Texas Tech crew has experience forecasting and nowcasting for dryline missions; Geerts will also participate. Local WFO has experience in dryline prediction, and has been called on for help in the past (secondary source of help, not primary).

What kind of communications capabilities do you expect on site? (e.g., bandwidth)

Data communication
- Capability to ingest needed data (High-Speed Internet, ftp)
- THREDDS server with data on a format legible to IDV
- Aircraft data communication needs in King Air Request

Voice Communicating to the field
- Cell phone communication from Ops center to field radio coordinator at a Ka band site
- Radio coordinator communicate with King Air and surface crews
(We hope to secure a good radio frequency for verbal communication between the various crews in the field, including the King Air and ISFF people).

Will additional Operations Center and Real-time Display and Coordination Center (RDCC) services (http://www.atd.ucar.edu/rdp/services/RDCC_whitepaper.htm) be required?
A basic data/analysis center with LAN connections to the EOL computers and access to the Internet will be provided in the field by EOL. Support will include real-time communications links to the facility via “chat” and real-time display of selected variables via web site links. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service. RDCC services are presently not supported by the NSF Deployment Pool. Funds to support its deployment currently must be obtained from separate sources, such as NSF Special Funds. For more information, please contact the CDS Facility Manager.
No additional Ops Center and RDCC services will be required. But the basic support mentioned above is important. Specifically,
1. An x-chat server will be needed. X-chat will serve as an additional communications system; oral radio-communication is the preferred primary medium, because several groups in the field will not have internet access.
2. A Field Catalog is essential (including experimental and operational data; see below).
3. We also request a FPS Data Archive for SONDE 08,

We are not asking FPS for assistance with forecast discussions or presentations.

Will you require work space? (e.g., office, lab and storage space)
Yes, the plan is to request the Reese Technology Center, a few miles west of Lubbock. Chris Weiss will coordinate this. This is 25-30 minute drive to the Lubbock Airport, where the King Air will be, and about 10 minute drive to the nearest hotels.

Will you require system administration support on site?
Based on previous experience (Geerts, in CuPIDO), we request an FPS person to be available in Boulder for questions/help during the field phase. This will be particularly important during the week prior to operations, and in the first part of the experiment, so we can interact about the products and displays.

We do not need anyone on site in Texas, since TTU personnel will be available. King Air systems person will be accessible to a limited extent.

Is there a need for coordinated shipping, lodging or transportation (especially if this is an international project)?
No.

Will you be shipping hazardous/radioactive material?
No.

Will you be shipping expendables? (e.g., radiosondes to local NWS offices)
No

Do you require assistance with various activities/services? (e.g., organizing of workshops and meetings, site surveys, leases, permits etc.)
If SONDE-08 is approved, we request that EOL organize one planning workshop in summer 2007, at the Reese Tech Center, and one science meeting in late summer 2008 in Boulder. Dr. Weiss at TTU is the contact person for the facilities at the Reese Tech Center.

Regarding ISFF: ISFF siting: LeMone, Niyogi, and Weiss have expressed their willingness to take part in the site survey. We hope that the ISFF personnel can manage leases/permits for selected sites. West Texas Mesonet personnel might also be willing to help us find sites.
PART III: DATA MANAGEMENT

What operational data do you need? (e.g., satellite, upper air, radar, surface, oceanographic, hydrological, land characterization, model products)

We’d like the following operational data in the Field Catalog and Data Archive
- Satellite data (1-km GOES VIS, and 4-km GOES IR 12 μm, in a 1000 km sector centered on LBB, NDVI if available
- West Texas Mesonet data (other regional surface data?)
- NWS rawinsonde data at MAF and AMA.
- NEXRAD Level II data from AMA, LBB, MAF, FDR, DYX
- NCEP HiRes ARW WRF model output, Central model domain
- If NCAR/MMM runs WRF/HRLDAS, we would access that from the MMM web site.

Do you have any specific real-time data needs to aid in your data collection activities?
1. ISFF met data at 5-min rate
2. Data to run HRLDAS if run from Reese Center
   (a) Satellite data from University of Maryland
   (b) NCEP analyses and precip data

Is there a requirement for a local satellite receiver to acquire local or real time polar orbiter or high resolution geostationary satellite data?
No. We believe we can get what we need over the Internet.
Dev Niyogi is planning to use AMSR soil-moisture estimates in his simulations. He already has capability to obtain the data.

Beyond the EOL dataset, will you or your Co-PIs provide additional research data to the project?
Yes, from instruments in the Appendix. See list of web sites. Also, quicklooks of these data will be useful in the Field Catalog and Data Archive (especially skew-T diagrams of the TTU mobile soundings and MIPs profiles.)

In addition, Niyogi and students will be collecting some surface phenology data on site (as in IHOP_2002).

What data analysis products will you provide during the deployment?
None.

What other research data and products do you need?
None

Is an EOL Field Catalog needed to provide real-time information management, reporting, decision dissemination, data exchange and resource monitoring?
Yes, including all aspects mentioned. Will be important for forecasting.
Experimental data to be included in the Field Catalog (the proposed data communication methods are discussed above):

- ISFF station time series
- Quicklooks of thermodynamic (possibly in Skew T format) and wind (zonal and meridional) profiles from MIPS, radiosonde, and King Air
- IDV imagery of blended operational and field data, including WSR-88D reflectivity, GOES VIS, King Air track and $\theta$, $T_d$, and wind along the track, West Texas Mesonet data, and possibly ISFF data.

Do you plan on moving a large amount of data back to your home institution during the project?

- 25 Hz King Air data will be transmitted to Laramie, usually overnight. (probably from Lubbock Airport rather than Reese)
- Details on HRLDAS runs have not yet been worked out, and could involve moving data from site to NCAR.

What arrangements have been made for a comprehensive data archive, including the management and distribution of data from non-EOL platforms?

None yet. In addition to what we have requested for the field catalog, and what is routinely put on the EOL web site (e.g., ISFF data), we will include links to PI web sites where other data will reside.

For instance, the WCR and UWKA data are usually stored at the University of Wyoming. Fei Chen’s web site (www.rap.ucar.edu/projects/land/) will post abbreviated ISFF data set and will provide a link to the ISFF web site. PI-supplied land-characterization data will also be posted on this site, in addition to some data-analysis products, and, if applicable, flight leg times. Weiss will also store Stick-Net and Ka-Band data on his web site at: www.atmo.ttu.edu.

Do you intend to request restricted data access?

No.
Part IV: Facility Specific Request

Integrated Surface Flux System (ISFF)

Contact: Steve Oncley (oncley@ucar.edu, 303 497 8757) or Tom Horst (horst@ucar.edu, 303 497 8838)
http://www.atd.ucar.edu/ssf/facilities/isff/

For the period 1 May – 9 June 2008, in support of SONDE-08, we are requesting 12 surface flux towers, equipped to measure the surface energy balance (and supporting PAR, radiometric surface temperature, and downwelling solar radiation, with four-component and diffuse radiation at some stations), momentum flux, and meteorological variables. The flux towers would be located along two east-west lines displaced by about 30 km, in a 200-km band centered around 101.6°W degrees longitude, north of Lubbock, Texas (Figure 1). Drylines are most likely in this region during the proposed deployment period, according to 30-year climatology (Hoch and Markowski 2005, being updated by Weiss). Other factors affecting the general location of SONDE-2008 are the dense network of surface stations (the West Texas mesonet) and the proximity to the LBB WSR-88D radar (close is better) and the Lubbock airport (King Air would want to fly over sites, so away from FAA restricted areas important). Clear-air surveillance reflectivity imagery from this radar will reveal the location of nearby drylines to within 50 km for most drylines, and to within 100 km for strong drylines. The flux sites would be located to cover the range of important land cover classes. The King Air will fly across drylines in the vicinity of the arrays to document the evolution of dryline(s) and its(Their) environment.

RATIONALE

Scientific objectives to be addressed using the ISFF:

The flux towers will primarily document the east-west gradient in surface heat, moisture, and momentum fluxes. They will also supplement the West Texas Mesonet in documenting the evolving water vapor, temperature and surface wind along and around the dryline, resulting in a dense surface observation network. Together with the other SONDE-08 measurement platforms, this will allow the measurement of gradients at scales from meters to ~150-200 km, and capture the thermodynamic and kinematic contrast across the primary and ancillary boundaries during their lifetime.

The observations will be used in combination with coupled HRLDAS-WRF simulations to analyze the evolution of selected drylines with time, with a focus on two interacting dryline formation mechanisms, namely:

- development of solenoidal frontogenetic circulations arising from horizontal contrasts in surface buoyancy fluxes and buoyancy fluxes arising from entrainment, and
• generation of low-level convergence through vertical divergence of the vertical transport of horizontal momentum normal to the dryline.

Both mechanisms have been shown in idealized model studies and observational case studies to have a role in the evolution of the dryline during the day. Surface processes promote both rapid CBL growth and downward mixing of westerly momentum to the west of the dryline (e.g., Danielson 1974; Schaeffer 1974 a, b; Ogura and Chen 1977), and the development of solenoidal circulations that tighten the dryline gradient (e.g., Ogura and Chen 1977; Ziegler et al. 1995; Grasso 2000; Trier et al. 2004). Combining SONDE measurements from ISFF surface sites and other platforms with detailed simulations using WRF coupled with HRLDAS (initialized to equilibrate the soil moisture and temperature profiles) will provide a unique opportunity to analyze these processes in more detail.

In addition, Chen, Niyogi, and LeMone will use the surface energy flux data in a continuing effort (references supplied in overview)

(a) To evaluate and improve the Noah land surface model in HRLDAS (Chen et al. 2006 and references therein).
(b) To analyze the evolution of horizontal flux variability as a function of days after rainfall, following LeMone et al. (2007, J Hydromet).
(c) To examine the role of diffuse vs direct short-wave radiation with observations and satellite-driven ET models.
(d) Because of the probability of HCRs in the region (e.g., Atkins et al. 1998, MWR), the effect of rolls (HCRs) on surface fluxes will also be examined. Mahrt (1998, JTech) and others have suggested modulation of surface fluxes by HCRs can account for the observed imbalances in the surface energy budget.

The ISFF analyses will be combined with numerical simulations using the WRF with soil moisture initialized using HRLDAS. In the model runs, we will focus on:

(a) The contribution of surface fluxes to the evolution in the dryline, in particular vertical mixing of heat and momentum, and the development of the solenoidal “inland sea breeze” that has been shown to intensify dryline convergence and affect dryline movement.
(b) The relationship of north-south differences in the horizontal flux gradient to north-south differences in the evolution of the dryline on the meso-beta scale (20-200 km).
(c) The ability of the WRF HRLDAS/Noah and PBL schemes to replicate the east-west contrast in boundary layer growth documented by radiosondes, King-Air soundings and Wyoming Cloud Radar profiles, and MIPS.
(d) The effects of HCRs on the development of 5-km scale variability along the dryline.
(e) Comparison of horizontal variability in HRLDAS H and LE as a function of time after rainfall events in this sparsely-vegetated environment to its evolution for the more densely-vegetated areas in southeastern Kansas, studied in IHOP-02 and CASES-97 (parallel to (b) above).
(f) A combination of HRLDAS/WRF and ISFF measurements will be used to study the impact of regional irrigation on dryline location, dryline intensity, and convective initiation and precipitation near the dryline in a far more realistic way than accomplished in previous work (Douglas et al. 2006; Moore and Rojstaczer 2002, Hane et al. 1997).
**Data analysis methods to be used for ISFF:**

(a) Compare diurnal cycle of fluxes and other variables at the ISFF sites to Noah/HRLDAS diurnal cycle to calibrate and check Noah model. (Chen)

(b) Assess horizontal variability of H and LE during times of clear skies or sparse cloudiness using methods outlined in LeMone et al. (2007, J. Hydromet). This involves plotting LE(x,y) and a function of H(x,y), averaged over a given time interval (usually 6 h, centered on solar noon) for sequences of sparsely-clouded days and looking at how the slope of the resulting best-fit straight line varies with time after rainfall. (LeMone)

(c) Associate fluxes with phase of HCR circulation. Roll orientation and horizontal wavelength (determined from satellite cloud or radar images) can be combined with PBL wind to estimate surface-relative roll period. This period (expected to be 30-60 min) would be used to low-pass filter the surface wind data. Phase in the roll circulation is then determined from a combination of wind direction variation and downwelling radiation (cloud) records. In the absence of clouds, the WSR-88D radar or WCR could be used. Running-average surface fluxes would be based 5-min flux and mean data. (LeMone)

(d) Use momentum flux from ISFF, the King Air, and (possibly) MIPS, and wind profiles based on ISFF, the King Air, MIPS, and radiosonde soundings, to assess the impact of the vertical divergence of vertical momentum transport in determining the convergence of winds in dryline confluence zones (Weiss, LeMone, Geerts, Knupp).

(e) The dense network of ISFF, West Texas Mesonet, and Stick-Net stations will be used to map the wind, humidity, and \( \theta \), fields around the dryline. This is useful both to understand the dynamics of primary and ancillary drylines, and to validate WRF model runs. (Geerts, Weiss, Knupp)

For this work, it would be helpful to have the fluxes available in five-minute averages as well as the half-hour averages.

**MEASUREMENTS (Figure 1)**

The flux towers (heat, surface, momentum flux, plus supporting radiation and meteorological measurements) would be located roughly along two east-west lines north of Lubbock, TX, separated by ~30 km, in a 150-200 km band. The lines would be centered around 100.6°W (where drylines are expected during the proposed deployment period based on Hoch and Markowski’s 30-year climatology), and within the West Texas Mesonet. Between 20 and 30 Texas Tech Stick-Net instruments will also be available for short-fuse deployment. The ISFF flux sites would be located to cover the range of important land cover classes. Ideally, a subset of the sites will be within 50 km of the Lubbock WSR-88D radar. The King Air will fly across drylines in the vicinity of the arrays and as close as reasonable to the radar to document the evolution of the dryline and its environment, but yet far enough so that the desired flight patterns can be flown with minimal air-traffic control problems (the flight patterns would be north of the Lubbock airport, which is located north of the radar). We have discussed the possibility of some flux observations and other measurements coinciding with one or more of the West Texas Mesonet sites, to allow some comparisons.
Number of measurement sites:
12

Minimum/maximum separation of these sites:
Order 20-30 km; maximum separation 200 km.

Number and type of measurement at each site (e.g., 2 moisture flux, 5-level temperature profile):

Standard Sites (see following for description of “special” measurements):
As in IHOP_2002:
- Fluxes at 2-3 m above the surface (displacement height).
- Meteorological data
- Everest Radiometric Surface Temperature
- Downwelling solar radiation
- PAR

New:
- Momentum flux at all sites (NCAR)
- Diffuse radiation (NCAR at 2 sites, see below; user-supplied (Niyogi) at additional sites)

Number and description of NCAR-supplied nonstandard sensors (see www.atd.ucar.edu/sssf/facilities/isff/sensors/):
2 “shadow-band” Li-Cor 200SA Pyranometers to measure diffuse radiation (as many as possible, PI Niyogi may purchase more)

At “supersites” (2) 4-component radiation

Number and description of user-supplied sensors
Give power requirements, data output (e.g. RS232 ASCII or 0-1V analog), and data handling (e.g., sampling rate, sorting by valve position). Providing user-supplied sensors to EOL for pre-experiment testing is highly desirable.
- Li-Cor 200SA diffuse radiation sensor(s): (Niyogi may request additional sensors to supplement the two available at NCAR/EOL.)
- Vitel Potential-evapotranspiration sensors (Niyogi) Can be used in manual mode or with data logger.

Logistics requirements for each location
(e.g., power, phone, vehicle access, owner permission):
Owner permission needed at all 12 sites, unless covered by the West Texas Mesonet leases. Vehicle access will be needed for periodic surface characterization, calibration, and maintenance visits. Following IHOP_2002 procedure, student and PIs will perform site characterization ea 7-10 days, including:

Student/PI visits ea 7-10 day (List still under development)
- For readjustment of Li-Cor 200SA diffuse radiation sensor(s) for changing sun angle:
(Niyogi may request additional sensors to supplement the two available at NCAR/EOL.)

- For reading Vitel Potential-evapotranspiration sensors if in manual mode (Niyogi group)
- For characterizing vegetation biophysical/transpiration response using steady state porometer or photosynthesis system (Niyogi group)
- To photograph and characterize vegetation (similar to but less ambitious than IHOP_2002)
- Evaluate surface temperature readings with hand-held radiometer (for bias, horizontal variability)

**OPERATIONS BASE**

**Will an operations base be available or should EOL supply one?**

Weiss will obtain permission to use the Reese Technology Center west of Lubbock, so it might be feasible to locate the ISFF base there as well. If ISFF chooses to do this, the requirements listed in the main proposal would have to be adjusted to include needs of ISFF staff.

**Location of the base relative to measurement sites:**

About 25 min from the airport, which is south of the measurement sites.

**Logistics requirements at the base site:**

*(e.g., power, phone, network, vehicle access, owner permission)*

The following are needed at the Reese Operations Center:

- Phone
- High-speed Internet to allow
  - x-chat and email capability
  - web access (Field Catalog, see above)
  - data download from servers at NCAR, UWyo, TTU
  - up to 15 users
- HRLDAS computer (if runs at operations center)
- IDV/weather computer
- Cell phone for coordination with field coordinator
- Places for 10-15 people to “plug in” their computers

**DATA NEEDS**

**Is archiving of high-rate (each sample) data needed or are time-averaged statistics sufficient?**

Time averaged statistics are sufficient, except we would like to have high-rate (1-s) radiation components and radiometric surface temperature for comparison with model results for at least two sites. (at least one near LBB radar)

**Averaging needed for statistics (ISFF default is 5 min.)?**

5 minutes and 30 minutes.
What data products are needed in real time? How should these be made available (e.g. WWW, display in base)?

As in IHOP_2002.

- Meteorological variables, including net radiation, rainfall – for operations
- Surface energy balance – for QC and operations
- Would like to input from all instruments for QC.

Post-project: EOL typically distributes statistics via the WWW. What additional data products (plots, high-rate data, derived products) are desired? Is WWW distribution acceptable?

Yes.

Special data requirements:
As in the case of IHOP_2002, we would like to have at least one “super site”. At this (these) site(s), we are interested in direct and diffuse solar radiation, 4 component solar radiation. These could also be sites for “fast” radiation data.

OPERATIONS
Will there be intensive observation periods requiring 24-hour staffing?
(ISFF data are collected continuously in any case.)

No

Availability of investigator-supplied staff:
We encourage investigators and their students to participate in ISFF deployments, including reviewing data on-site.
The PIs and students will routinely review ISFF data.

OTHER
Has EOL/RTF staff been consulted to help complete this request?
Consultation with EOL staff is strongly encouraged before submitting this request.

Yes

Other requirements:
None
APPENDIX:
Description of Instrumentation Systems

1. WEST TEXAS MESONET (www.mesonet.ttu.edu).
The approximately 50 West Texas Mesonet stations appear, along with identifiers, in Fig. A1. Quantities measured appear in the Table.

![Map of West Texas Mesonet stations](image)

Figure A1. The West Texas Mesonet. Basic data appear in Table 1.

<table>
<thead>
<tr>
<th>Measurement/depth</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed/direction</td>
<td>R.M. Young Wind Monitor</td>
</tr>
<tr>
<td>9 meter self aspirated air temperature</td>
<td>Campbell Scientific 107-L probe with 6-plate radiation shield</td>
</tr>
<tr>
<td>2 meter self aspirated air temperature</td>
<td>Campbell Scientific 107-L probe with 6-plate radiation shield</td>
</tr>
<tr>
<td>2 meter wind speed</td>
<td>R.M. Young Wind Sentry</td>
</tr>
<tr>
<td>1.5 meter temperature/relative humidity probe</td>
<td>Vaisala HMP45C temp/RH probe with 12-plate radiation</td>
</tr>
<tr>
<td>Air Pressure</td>
<td>Vaisala PTB220 Digital Barometer</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Hydrological Services TB3 gauge tipping bucket siphon rain gauge.</td>
</tr>
<tr>
<td>Incoming Solar Radiation</td>
<td>Kipp and Zonen SP-Lite and CM3 Pyranometers</td>
</tr>
<tr>
<td>Soil temperature (5 measurements)</td>
<td>Campbell Scientific 107-L probes: under natural Sod: at 5, 10, and 20 cm depth</td>
</tr>
<tr>
<td>Soil water content reflectometers (4 measurements)</td>
<td>Campbell Scientific 615L at 5, 20, 60, and 75 cm</td>
</tr>
<tr>
<td>Leaf Wetness</td>
<td>Campbell Scientific Wetness Sensing Grid</td>
</tr>
</tbody>
</table>

Table A1. Data at Basic Site, West Texas Mesonet (from www.mesonet.ttu.edu)
2. Texas Tech University Stick-Net

Figure A2. Photographs of two “Stick-Net” probes, developed by Texas Tech University. These instruments are designed for 90-second deployments. They sense air temperature, dewpoint temperature, air pressure, wind direction, and wind speed. On the left is a model that senses wind with a prop-vane anemometer (sample rate 1 or 10 Hz, selectable); on the right is a model with a sonic anemometer (sample rate 1 Hz). Campbell Scientific data loggers are used to store measurements on-site.
3. Mobile Instrumented Profiling System

For SONDE-08, the MIPS will include a 915 MHz Doppler wind profiler (915), a vertically-pointing X-band profiling radar (XPR), a 12-channel microwave profiling radiometer (MPR), a lidar ceilometer, and standard surface (3.7 m AGL) meteorological measurements. Collectively, the MIPS is capable of measuring horizontal wind profiles (several minute resolution); vertical motion (60 s resolution with the 915, 1 s resolution with the XPR); temperature profiles, water vapor profiles and total integrated water vapor from the MPR; and aerosol backscatter and cloud base height from the ceilometer. The dual-frequency (0.915 and 9.5 GHz) capability will provide a clear distinction between Bragg scatter (refractive index) and Rayleigh scatter (insects) within the CBL. The MIPS is fully mobile and requires a set-up time of 5-10 minutes. Additional details and examples of measurements are available at the web site http://vortex.nsstc.uah.edu/mips.

4. Texas Tech Ka Radars

Selected specifications for the TTU Ka platforms are presented in Table A2. The radars will be completely mobile, permitting measurements of targeted dryline sections at close range. Hydraulic leveling on both platforms will ensure that scan planes are horizontal and that recorded elevation angles are horizon-relative. We place emphasis on precision, in order that two-dimensional winds can be synthesized with minimal error, at a spatial resolution close to that of the native radial velocity data from each radar.

Table A2: Selected specifications for the Texas Tech University Ka radars

<table>
<thead>
<tr>
<th>Frequency</th>
<th>35 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflector</td>
<td>Parabolic dish within radome, 4 ft. diameter</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear horizontal</td>
</tr>
<tr>
<td>Minimum along-range resolution</td>
<td>&lt;=20 m</td>
</tr>
<tr>
<td>Azimuthal angular half-power beamwidth</td>
<td>&lt;=0.5 deg</td>
</tr>
<tr>
<td>Operation modes</td>
<td>Pointing, full PPI, RHI, sector scans</td>
</tr>
<tr>
<td>Moments</td>
<td>Reflectivity, radial velocity, spectrum width, returned power</td>
</tr>
<tr>
<td>Calibration / steering / visual record</td>
<td>Bore-sighted video camera mounted to dish</td>
</tr>
<tr>
<td>Range</td>
<td>15 km</td>
</tr>
</tbody>
</table>