REQUEST FOR S-POL, NRL P-3, ELDORA, WCR, DROPSONDES, ISS, MGLASS, AND ISFF SUPPORT

IHOP_2002

NCAR/ATD - OCTOBER 2001 OFAP MEETING

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PART I: GENERAL INFORMATION

1.1 Corresponding Principal Investigator

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1.2 Project Description

Project Title	International H_2O Project (IHOP)_2002
Co-Investigator(s) and Affiliation(s)	Roger Wakimoto (UCLA) – NRL P-3, ELDORA and Dropsondes Howie Bluestein (OU) – NRL P-3 and ELDORA Cyrille Flamant (CNRS, France) – NRL P-3 Conrad Ziegler (NSSL) – NRL P-3, ELDORA, MGLASS and Dropsondes Jim Wilson (NCAR/ATD/RAP) – NRL P-3, ELDORA and S-Pol Steve Koch (NOAA/FSL) – S-Pol, UWKA and Dropsondes Cindy Mueller (NCAR/RAP) – NRL P-3 and ELDORA Wen-Chau Lee (NCAR/ATD) – NRL P-3 and ELDORA David Kingsmill (DRI) – NRL P-3, ELDORA, S-Pol, MGLASS and UWKA Margaret A. LeMone (NCAR/MMM) – ISFF, UWKA, S-Pol and WCR Bob Grossman (CU) - ISFF, ISS and UWKA Ken Davis (PSU) - ISFF, ISS and UWKA

	Belay Demoz (U. of Maryland at B.C.) - ISS Bart Geerts (U. of WY) – WCR and UWKA David Leon (U. of WY) - WCR Frederic Fabry (McGill U.) - S-Pol Rita Roberts (NCAR/RAP) - S-Pol Steve Cohn (NCAR/ATD) - ISS Fei Chen (NCAR/RAP) – UWKA and ISFF Jeff Basara (OU) – ISFF Dev Niyogi (NCSU) – ISFF Sethu Raman (NCSU) – ISFF Ed Brandes (NCAR/RAP) – S-Pol
Location of Project	Kansas & Oklahoma
Start and End Dates of Project	13 May – 30 June 2002

1.3 Abstract of Proposed Project

The primary objective of IHOP is to ascertain whether or not improved characterization of the 4-dimensional water vapor field will result in significant, detectable improvements in warm season quantitative precipitation forecasting (QPF). Accurate prediction of precipitation amounts has remained an elusive goal for the atmospheric sciences. Although improvements in QPF skill have occurred in recent years, QPF skill has not advanced as rapidly as the prediction of other variables. QPF skill also varies seasonally with the summer marked by significantly lower forecast skill. The extremely low skill scores and the relative lack of progress for warm season rainfall are particularly worrisome as significant weather hazards result from warm season rainfall. To achieve a better understanding of QPF, IHOP is also studying the related issues of convection initiation (CI) and atmospheric boundary layer (ABL) processes and determining the future optimal mix of water vapor instrumentation/assimilation systems.

1.4 Proposal Summary

A more complete summary of the experiment can be found in the Scientific Overview Document for the Project. The document and further information concerning the experiment is available at http://www.atd.ucar.edu/dir_off/projects/2002/IHOP.html

- *What are the scientific objectives of the proposed project?*

The overarching hypothesis is that the improved characterization of the 4-D distribution of water vapor will result in significant, detectable improvements in warm-season QPF skill. The *QPF* component will use data assimilation to explore how to best improve the characterization of the water vapor field and simulations based on IHOP_2002 data to test for improvement in forecast skill for several different types of models and nowcasting systems. Exploration using these data sets will also attempt to establish the improvement relative to limits of predictability. The primary hypothesis of the *CI* group is that improved water vapor measurements will advance our understanding of processes that initiate deep, moist convection over the Southern Great Plains (SGP). Specific studies will test the role of boundary-layer convergence zones, undular bores, solitary waves, internal gravity waves, boundary inflections and vortices and elevated frontal interfaces and the related moisture distribution along these features upon thunderstorm initiation.

The *ABL* processes hypothesis is that improved understanding of the relationship between water vapor and surface and boundary layer processes will improve QPF ability. Specific questions to be addressed include examining the processes governing the water vapor distribution within and just above the ABL and determining how well these processes are simulated in mesoscale forecast models. Assimilation of detailed ABL observations will be done to determine improvements to model performance. The *instrumentation* component will allow for comparison between various water vapor measuring sensors and techniques. Furthermore this component will provide insight into the future optimal mix for water vapor measurement strategies for operational forecasts and the relative importance of water vapor measurements to other variables.

IHOP_2002 has strong links to the operational communities including the Atmospheric Research and Applications of the Division of the Office of Research and Applications of National Environmental Satellite Data Information Service (NOAA/NESDIS), and relevant components of the National Weather Service (NOAA/NWS) ranging from local forecast offices, to Hydrometeorological Prediction Center (HPC) of the National Centers for Environmental Prediction (NCEP), the Mesoscale Modeling Branch of the Environmental Modeling Center of NCEP (NCEP/EMC), and the Storm Prediction Center (NCEP/SPC). Generally the efforts of these operational groups typically include both real-time forecasting support and subsequent research efforts.

- *What are the hypotheses and ideas to be tested?*
- *Give references of results published and explain how the proposed experiment and the use of the requested facilities goes beyond what has already been done.*

We believe that our general strategy of measuring the 4-D distribution of water vapor over a large mesoscale area for improved prediction and understanding of convective and boundary layer processes is truly unique. The need and justification for such an experiment is clearly laid out in the reports of several distinguished panels, such as the reports of the Prospective Development Teams 1 and 2 of the USWRP (Emanuel et al. 1995, BAMS, 1194-1208; Dabberdt and Schlatter 1996, BAMS, 305-324) and the National Research Council's Board of the Atmospheric Sciences and Climate (BASC) (1998, National Academy Press) as described in sections 2 and 3 of the IHOP_2002 overview document. These reports also state that progress in these areas has been hindered by a lack of reliable 4-D measurements of water vapor as the BASC report states (1) "high priority must be given to new water vapor measurement systems and to research that delineate the water vapor observations necessary to address specific research and forecast issues“, (2) ”…prediction of convective precipitation is limited by uncertainties in the distribution of water vapor in the atmosphere and the amount of water in the soil," and (3) "..existing means of characterizing the distribution of water vapor are greatly inadequate if not totally absent."

The benefits of improved water vapor measurements also have strong implications for understanding and predicting climate change. For example, the Committee on Global Change Research in their National Research Council (NRC) report entitled <u>Overview Global Environmental Change: Research Pathways for the Next Decade</u> (NRC 1998) discusses the need for better water vapor measurements and concludes "Any assessment of climate change, its causes and impacts, must be based on significantly better observations of water vapor." Thus, while IHOP_2002 is linked to the USWRP and aims to improve QPF skill in weather forecasts, the experiment also addresses probably the most fundamental issue facing climate studies. After these general comments we offer more specific points regarding for the four components of IHOP_2002.

QPF: The latter two comments above directly address a possible link between water vapor and QPF skill. To our knowledge a field project aimed at systematically testing and quantifying this link has not been attempted despite numerous studies in the literature that show how improved characterization of the water vapor field often leads to improved forecasts of precipitation typically in case studies (e.g., Perkey 1976, MWR, 1513-1526; Mills 1983 Aust. Meteor. Mag., 111-119; Mills and Davidson 1987, Aust. Meteor. Mag., 109-118; Mailhot et al. 1989, Atmos-Ocean, 24-58; Bell and Hammon 1989, Meteor. Mag., 152-158; Emanuel et al. 1995, BAMS, 1194-1208; Dabberdt and Schlatter 1996, BAMS, 305-324; Crook 1996, MWR, 1767-1785; Koch et al. 1997, MWR, 384-409).

A specific effort will be directed at evaluating water vapor measurement techniques, which have promise for near-term operational utility to improve quantitative precipitation nowcasts using expert systems. It is felt that expert systems are the most promising method, in the foreseeable future, to provide sufficiently accurate short-term time and place specific forecasts so that effective precautionary steps can be taken to mitigate loss from heavy rain and other severe convective events. Numerical forecasting output will be integrated into the expert systems along with forecast parameters derived from high-resolution observations. The NCAR expert nowcasting system called the Auto- nowcaster and the Interactive Flash Flood Analyzer and Rainfall Autonowcaster of NOAA/NESDIS will be utilized for these studies. In addition to the special IHOP water vapor measurement facilities, existing satellite water vapor retrieval systems will be included in this evaluation.

These nowcasting systems have demonstrated significant skill at forecasts for timescale of ~3-h and shorter. A goal for IHOP_2002 is the extension of accurate forecasts by these expert systems to time scales of ~6 h. An additional goal of IHOP_2002 is to establish the degree of improvement possible in QPF skill in numerical simulations and to provide a catalyst for lasting improvements in how water vapor is treated in numerical models and assimilation systems. These QPF goals will be addressed in both real-time and post-analysis. Modeling efforts will likely including but not limited to LAPS, MM5, WRF, high-resolution ETA, ARPS, RAMS, CRAS and RUC with most of these groups providing real-time simulations. The post analysis phase will include simulations conducted with and without the special water vapor data sets. These efforts will utilize a quality controlled data set provided to the modeling and nowcasting teams. The general strategy will be to use IHOP_2002 to develop forward models for assimilation systems for a variety of water vapor measurement and to also use the knowledge of how water vapor varies in space to better treat high resolution spatial measurements of water vapor. This problem is particularly relevant for developing improved assimilation systems for data sets, such as GPS and satellite sounding systems that will continue to be available after the IHOP_2002 experimental period thus likely providing a lasting socio-economic benefit of the experiments.

Convective Initiation: Discussions between IHOP_2002 investigators and forecasters at the NOAA/NCEP/SPC, NOAA/NCEP/HPC and several NWS Southern Region forecast offices have identified the problem of where and when deep, moist convection will initially form as a key concern for operational predictions, specifically of severe weather, heavy rainfall QPFs. For the convective initiation component, the data from previous field projects have been used quite effectively to improve understanding of the kinematic structure of boundaries (e.g., Mueller and Carbone 1987, JAS, 1879-1898; Parsons et al. 1991, MWR, 1242-1258; Weckwerth and Wakimoto 1992, MWR, 2169-2187; Ziegler and Hane 1993, MWR, 1134-1151; Hane et al. 1993, BAMS, 2133-2145; Wilson et al. 1994, JAOT, 1184-1206; Atkins et al. 1995, MWR, 944-969; Fankhauser et al. 1995, MWR, 291-313; Kingsmill 1995, MWR, 2913-2933; Atkins et al. 1998, MWR, 525-550; Ziegler and Rasmussen 1998, WF, 1106-1131).). Unfortunately, the moisture datasets from those projects were far inferior to the kinematic datasets, which has hindered our progress in convection initiation research. IHOP provides a unique opportunity to merge both detailed kinematic and moisture datasets and make a giant leap in understanding convection initiation.

These detailed IHOP boundary layer measurements will additionally provide the context i) to compare model- and observationally-based hypotheses of boundary formation and convective initiation processes, ii) to evaluate how skillfully cloud resolving, mesoscale and operational models predict the initiation of convection and iii) to work to improve this prediction and iv) to explore the accuracy, spatial scales, and temporal resolution of water vapor measurements necessary for successful operational prediction of convection onset using the high-resolution measurements of water vapor taken during IHOP_2002. Finally the special observations taken during IHOP_2002 will allow the CI group to assess the locations of elevated phenomenon, such as frontal boundaries and waves, and their influence on the moisture distribution and CI.validate numerical simulations and compare model- and observationally-based hypotheses of boundary formation and convective initiation processes.

ABL studies: The characteristics of the ABL are central to both the QPF and CI components discussed thus far. For example, most of the boundaries discussed in the convective initiation section are essentially examples of heterogeneity in the ABL. Also, it is the relatively warm, humid air in the ABL that provides a majority of the thermodynamic energy responsible for convective storms and it is well established that small changes in ABL moisture can translate into significant changes in surface rainfall. Understanding the dynamics of the ABL requires knowledge of the statistical properties of turbulence, the advection of water vapor, the latent heat flux divergence, and the storage term and how these processes interact to drive water vapor heterogeneity. IHOP_2002 will allow for the first time, direct and simultaneous measurement of the spatial variation of these quantities within the context of a convective experiment. We are able to accomplish this goal by a network of surface sensing systems and by extending recent advancements in ground-based remote sensing techniques (e.g., Senff et al. 1994, JAOT, 85-93; Davis et al. 1997, J. Geophys. Res., 29219-29230; Giez et al. 1999, JAOT, 237-250; Wulfmeyer 1999a, JAS, 1055-1076; Wulfmeyer 1999b, JAS, 1077-1087; Lenschow 2000, JAOT, 1110-1126) to airborne platforms.

Some of the specific major questions that can be addressed with the IHOP_2002 data sets include determining what processes govern the water vapor distribution within and just above the ABL and how well these processes are simulated in mesoscale forecast models? The researchers under this component also seek to determine to what extent the assimilation of detailed observations of ABL characteristics improve model performance and whether remote sensing instrumentation can provide detailed ABL water vapor budget observations, particularly vertical flux divergence? Finally investigators seek to determine the mechanisms that control water vapor heterogeneity within and above the ABL and how this heterogeneity influences convection initiation and convective processes. Possible sources of heterogeneity include spatial variations in mixing depth and water vapor flux divergence, driven in part by land-surface processes, the convergence of air masses in the study region, and localized intense mesoscale flows.

Instrumentation: For the instrumentation component, IHOP_2002 will go beyond the goals of the ARM water vapor IOPs (e.g. AMS news article, BAMS, 284-286; Guo et al. 2000, MWR, 619-643; Richardson et al. 2000, JAOT, 312-322) which concentrated on accurate water vapor profiles in clear air for a single vertical column. In contrast, IHOP_2002 will attempt to accurately determine the 4-D distribution of water vapor in pre-convective and convective environments. These differences allow us to address the performance limitations of these instruments in the context of determining the optimal mix of future operational water vapor measurement techniques for forecasting warm season convection. The investigators within the instrumentation community will work closely with the investigators working on assimilation studies to provide relevant information for observing experiments including potential number and cost of future observing systems, error characteristics and performance limitations. Of course, we will, however, rely heavily on the knowledge gained during the ARM water vapor IOPs as these same instruments will be utilized for IHOP_2002 research.

The improved sampling of the water vapor field will allow evaluation of the accuracy of several instruments and techniques that have been difficult to evaluate with current measurement technology. For example, the three-dimensional fields of water vapor measured during IHOP_2002 by the aircraft with downward looking DIAL lidar and the time variation found at the ground-based lidar sites will have several uses in this regard including the evaluation of slant range GPS, GPS occultation and the ability of satellite sounder information to detect those time and spatial variations of the water vapor field important to the initiation and evolution of convection. For example, we will test the techniques put forth by Menzel and Purdom (1994, BAMS, 757-781) who cite the combined use of current GOES imager channels 4 and 5 (~10.5 and 12.0 micron wavelengths) as a means for providing improved low-level moisture measurements under clear sky conditions. The current GOES sounder retrieves vertical profiles of specific humidity from sounder radiance measurements. The radiance measurements respond to the total integrated moisture above a particular pressure level, so the specific humidity is a differentiated quantity rather than an absolute retrieval. Stability indices such as CAPE, CIN and Lifted Index are products generated from these vertical profiles, in addition to precipitable water and cloud products. The value of these products for nowcasting will be assessed, particularly with respect to documenting the changing stability and evolution of the capping inversion. The following IHOP measurements will be used in these studies: enhanced radiosonde launches from the NWS, the ARM facilities and MGLASS along with the evolution of cumulus clouds obtained from S-Pol.

The instrumentation goals of IHOP_2002 also include the development of new techniques for water vapor measurement and for improved prediction of convection. For example, the water vapor fields derived from IHOP_2002 will provide a benchmark for studies of future satellite systems such as Aqua, GIFTS, and GOES-R. The measurements by the NAST system from the Proteus together with the three dimensional mapping of water vapor by other sensors from IHOP_2002 will prove crucial in this regard. NOAA/NESDIS also has the goal of utilizing low-level wind fields derived from satellite cloud and water vapor tracks to detect regions of convergence and possible initiation of deep convective systems.

The NCAR Auto-nowcaster uses satellite observations of cumulus clouds to indicate possible regions of instability. To obtain a better understanding of the utility of this technique the satellite cumulus cloud field will be compared with IHOP high-resolution water vapor fields. The Auto-nowcaster also uses satellite IR cloud-top temperatures to indicate when a cumulus cloud reaches a height where freezing may occur. Evidence of ice near the tops of growing cumulus is used as a forecast parameter that rapid cloud growth will likely follow. The S-Pol polarimetric fields, combined with in situ aircraft particle probe measurements, will be used to document the onset of ice formation in cloud and how this compares with satellite-sensed temperatures. GOES rapid-scan data collection would be ideal during this period of cloud evolution. In a related study the satellite reflectance product will also be examined as a means for detecting the onset of ice formation in cumulus cloud tops. Turk et al. 1998 (JAM, 819-831) have developed a satellite application that removes the infrared emissions from the near-infrared GOES imager channel 2 (3.9 micron wavelength) using IR information from channel 4, and produces an image field with only the shortwave reflectance contributions remaining. This satellite reflectance product has been demonstrated, primarily with winter storms, to be useful for discriminating between cloud top water and ice, as ice is less reflective than water drops. This promising technique will be evaluated further as a robust forecast parameter for the Auto-nowcaster. The S-Pol hydrometeor typing capability will be used to help verify the reliability of the radiance product to identify initial ice formation in cumulus clouds. The hydrometeor mapping will also be used in model initializations that include hydrometeors such as the work ongoing at NOAA/FSL with LAPS and experimentation at NCEP. FSL scientists will also be making extensive use of observations from satellite to enhance specific humidity analysis for LAPS. If funded, NESDIS will provide numerous data sets and products. The LAPS specific humidity analysis includes satellite cloud information, GOES sounder and imager radiances, GOES derived products of layer precipitable water and GPS derived water vapor estimates. As important as these research efforts, the NCEP/HPC, SPC, and local NWS will attempt to gage the impact of improved mapping of the water vapor fields on their forecasts.

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

The project has some similarities to other experiments such as JAWS (Joint Airport Weather Studies), TEXEX (Texas Frontal Experiment), MIST (Microburst and Severe Thunderstorms

Experiment), CINDE (Convection INitiation and Downburst Experiment), CaPE (Convection and Precipitation/Electrification Experiment), TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment), VORTEX (Verification of Rotation in Tornadoes Experiment), FASTEX (Fronts and Atlantic Storm Track Experiment), and MCTEX (Maritime Continent Thunderstorm Experiment) in that they're related to convective processes and include a wide array of sensors. In particular, VORTEX and FASTEX are similar to IHOP_2002 since there will be a CI focus on deploying mobile platforms. FASTEX, TEXEX, TOGA COARE, LIFT (Lidars in Flat Terrain) and several of the other experiments also made similar use of ground-based supporting remote and in-situ sensors to provide continuous measurements over the domain of interest. The focus of IHOP_2002 on water vapor measurements also has some similarities to ARM Water Vapor IOPs. CASES-97 and SGP-97 have goals related to understanding the sources of horizontal variability in the water-vapor field, and they took place in this part of the country.

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

Specifically, ***S-Pol's*** unique contributions to the project are i) the refractivity mapping capability which will be used to estimate the low-level water vapor field, ii) the early cumulus cloud detection capability which will allow monitoring the entire cloud evolution, iii) the hydrometeor typing capability which will provide details of ice formation in growing cumulus, iv) the capability to retrieve wind fields from S-pol alone which will allow continuous monitoring of the boundary layer wind field even in the absence of a second nearby Doppler radar, v) the polarimetric quantitative precipitation estimate capability which will be useful in evaluating model QPF performance. S-Pol will also be used to monitor boundary layer convergence lines when paired with mobile radars to obtain high-resolution wind fields. Less high-resolution wind fields will result from dual Doppler analysis with the nearest (44 km) WSR-88D. More information on the uses of S-Pol in IHOP can be obtained from the attached S-Pol/IHOP proposal.

The ***NRL P-3*** is requested to house ELDORA, the French CNRS Leandre II water vapor DIAL and the high-resolution, high-accuracy tunable diode laser (TDL). With the P-3 flying at low levels, ELDORA would be used to sample the winds in the clear-air ABL. For this convection initiation application, it is desired that Leandre II be mounted in a horizontal pointing mode to map out the horizontal water vapor field. For the QPF flights above the boundary layer, ELDORA would be used to sample convective precipitation. For these QPF flights we would like to have Leandre II in a nadir mode. The P-3 is one of several aircraft utilized in this regard in order to map the 4-d distribution of water vapor over a large mesoscale area for input into nowcasting and QPF studies, which is central to goals of the experiment.

ELDORA will be an invaluable tool for obtaining the kinematics in the context of the water vapor field. One key to this project is that ELDORA and the LEANDRE II water vapor DIAL will be operated on the same platform and will be sampling the same regions. Such a combination of 3-D winds and 2-D water vapor fields is unprecedented. For convection initiation studies, the aircraft would be flown at low levels to maximize the quality of clear-air return from

ELDORA. The LEANDRE II would be pointed horizontally. For larger-area QPF studies, ELDORA would sample the precipitation features while LEANDRE II pointed downward.

The flux measurements on the ***UWKA***, plus time-variant profiles of moisture and other thermodynamic quantities, are essential components for determining the link between land surface properties, surface fluxes, mesoscale variability in the boundary layer, convective clouds, and ultimately deep precipitating convection. In addition, they are needed to validate remotely-sensed fluxes and fields from airborne and ground-based sensors. Specifically, the UWKA in situ measurements will be used to validate the first use of a downward pointing combined water vapor DIAL and Doppler lidar on the DLR Falcon which will be used to derive vertical profiles of water vapor flux and flux divergence.

Some of the uses of the ***WCR*** include:

i) To assess under what conditions or in what regions the BL contains enough scatterers to be seen by the airborne WCR, and how well their vertical motion represents air motion (*instrument objective*);

ii) To describe, in detail, the structure and evolution of radar-detected fine-lines in the BL, using both in situ aircraft data, and the 2D airflow in transects below the UWKA derived from the WCR, using the vertical plane dual-Doppler (VPDD) technique, with a focus on thunderstorm initiation along or near such lines; flying at low levels along boundaries, with the WCR looking horizontally, document the detailed airflow in the same field of view as the LEANDRE-II water vapor DIAL on the NRL P-3 (*CI objective*);

iii) To characterize the depth of the BL, and the topography of the BL top, either while flying at lower levels (WCR looking up) or while flying above the BL (VPDD mode); as well as organized large BL eddies (OLEs), possibly producing cloud streets, in terms of air flow and vertical echo structure, both within and below the clouds (*ABL objective*);

iv) To obtain high-resolution profiles of radar reflectivity in stratiform precipitation regions, especially near and above the bright band (*QPF objective*);

v) Ultimately, to contribute to a better understanding of the BL structure and its vertical circulation, especially near boundaries, thereby increasing the lead time for warm-season precipitation/storm events and improving quantitative precipitation nowcasting (*IHOP objective*)

The ***dropsondes*** will have multiple purposes and it is therefore requested that a dedicted dropsonde aircraft be obtained for IHOP. The *QPF objective* requires two dropsonde aircraft (the DLR Falcon and a dedicated dropsonde aircraft) to map out the moisture flux in the ARM/CART domain. Sondes would be dropped every 50 km along the boundaries of this domain to assess NWP applications. The *CI objective* requires that dropsondes be launched as rapidly as possible from flight legs perpendicular to boundary layer convergence zones, such as the dryline and gust fronts. Thus they will be used to assess the rapid change in stability across boundaries and how this compares with thermodynamic profiles tens of kilometers away from the boundaries. This CI effort would be an intensive dropsonde-specific flight pattern and data collection from other instruments on the DLR Falcon would not be optimized in this scenario.

The *ISS* would be within range of S-Pol and co-located with the NASA/Goddard scanning Raman lidar. The ISS will be useful for a variety of purposes including providing continuous information useful to ABL and CI processes to complement the intermittent aircraft measurements. The site also serves as one of six sounding sites utilized to characterize the large-scale environments for QPF, CI and ABL studies. These sites will be launching every 3-h during at least five weeks of the experiment and the site is the only fixed rawinsonde system supported by NSF making the network extremely cost effective for the deployment pool. The time continuous nature of the ISS and Raman measurements make these instruments a useful complement to the intermittent aircraft observations and have proven useful to the study of convective initiation at fronts and drylines. We will request the MAPR ISS in order to increase the temporal resolution and to attempt some vertical profiles of water vapor fluxes from the two instruments. Also, NASA may likely bring other lidars to the site to complement the measurement capability, including a scanning high resolution backscatter lidar to observe spatial variations in ABL height.

The *MGLASS* will be used to assess the environmental stability and moisture. The mobility of the platform is ideal so that we can target boundary-layer convergence zones. This information is necessary for model initialization as well as for observational analyses. It will also be used in studies to determine the representativeness of the 12 Z sounding that is used so extensively by models and forecasters to anticipate convective storm potential.

The *ISFF* data will be used to evaluate Land Surface Models (LSMs) and to estimate the surface fluxes across the IHOP domain and hence the role of surface fluxes in the evolution of humidity and temperature in the boundary layer. At least one LSM, improved using IHOP surface-flux data, will be coupled to MM5 and run for selected cases and the resulting fields validated against boundary-layer and precipitation data. To generalize from fluxes sampled over only a small fraction of the domain to surface fluxes across the IHOP domain, two complementary methods will be used. First, LSMs evaluated using the flux data will be combined with satellite, radar precipitation, and in-situ weather data, land-use and soil properties to produce surface flux fields for selected cases. Second, spatial samples from the aircraft and temporal samples from the flux towers will be combined to infer the fluxes in areas not sampled. ISFF data will be compared with aircraft data to assess the relative role of land use, soil properties, and terrain in distribution of boundary-layer fluxes. Insofar as surface processes affect storm initiation and evolution, these will address IHOP goals corresponding CI and QPF as well as ABL processes.

- *What results do you expect and what are the limitations?*

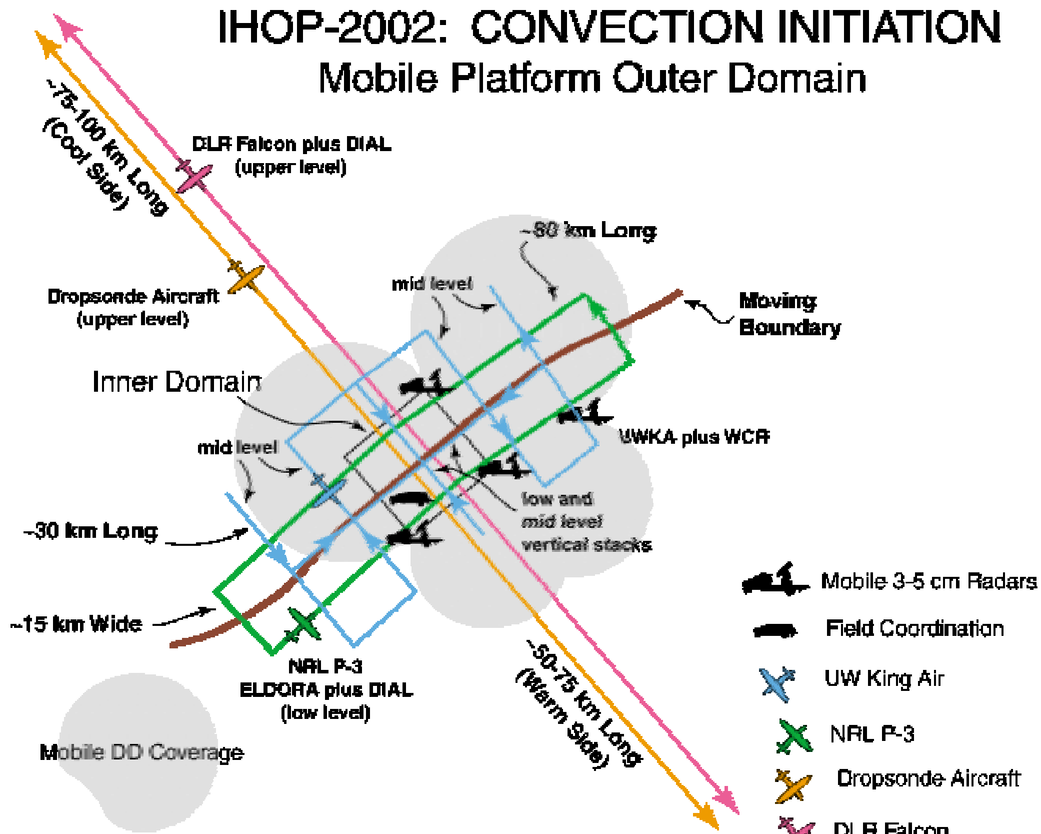
Water vapor is an atmospheric variable that we're not currently measuring very well. We expect to determine if that is a crucial component in improving our understanding convective initiation and evolution, the link between boundary and surface characteristics and convective rainfall and finally improved quantitative prediction of precipitation amounts in nowcasting systems and numerical models. The potential of this experiment in these regards has led to the project being part of the USWRP Implementation Plan approved by the USWRP Interagency Working Group. The potential to impact future operational activities is evident by the participation of operational forecast groups including NOAA/NESDIS, and the National Weather Service including local offices and NCEP/HPC, NCEP/SPC, and NCEP/EMC.

Limitations include the difficulties in combining these varied datasets into one overall picture of the water vapor field and associated dynamics. Inter-calibrations will be an important issue.

- *Provide details about the experiment design.*

One example of an experimental design showing the need for the multitude of requested instruments is shown for the CI objectives. The dedicated dropsonde aircraft would frequently release sondes along a long leg (yellow track) normal to the boundary. The NRL P-3 would fly a low level box pattern keeping the boundary within 10 km of its right side to obtain the moisture data from the sideways pointing Leandre II water vapor DIAL. ELDORA would concurrently be collecting data along this same region of the boundary. The UWKA with the WCR would be flying both within the CBL to obtain in situ measurements, as well as atop the CBL to obtain radar measurements of the bug plumes and CBL depth from the downward pointing WCR. These OFAP instruments are just a subset of the necessary instrumentation required to measure the water vapor and kinematics along the boundary prior to convective development.

Another example of an experiment design is shown for examining the evolution of the water vapor field. This design will utilize nearly all of the proposed IHOP facilities. Soundings will be obtained at frequent intervals from the central facility and nearby MGLASS to assess whether there is a significant difference in the stability profiles during the development of the CBL. Surface moisture measurements will be obtained from the S-pol refractivity technique and mobile mesonet. The mobile mesonet vehicles will continuously drive around the grid of roads surrounding the central facility to map out the surface water vapor, temperature, wind and pressure fields. These measurements will be centered in an area about 50 km on a side of water vapor measurements obtained from the airborne DIALs. The NRL P-3 will fly as low as possible with the Leandre II water vapor DIAL staring horizontally out the right side of the aircraft. In this configuration, Leandre II will map out the horizontal distribution of the water vapor field within ~7 km of the P-3. The UW King Air will fly at the same altitude as the NRL P-3 and thus provide in situ verification within the air volume sampled by Leandre II. The DLR Falcon with a downward-pointing water vapor DIAL will fly at 5 km directly above the UW King Air.


IHOP-2002: CONVECTION INITIATION
Mobile Platform Outer Domain
~75-100 km Long
(Cool Side)
DLR Falcon plus DIAL
(upper level)
~80 km Long
mid level
Moving
Boundary
Dropsonde Aircraft
(upper level)
Inner Domain
mid level
UWKA plus WCR
low and
mid level
vertical stacks
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~15 km Wide
NRL P-3
ELDORA plus DIAL
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UW King Air
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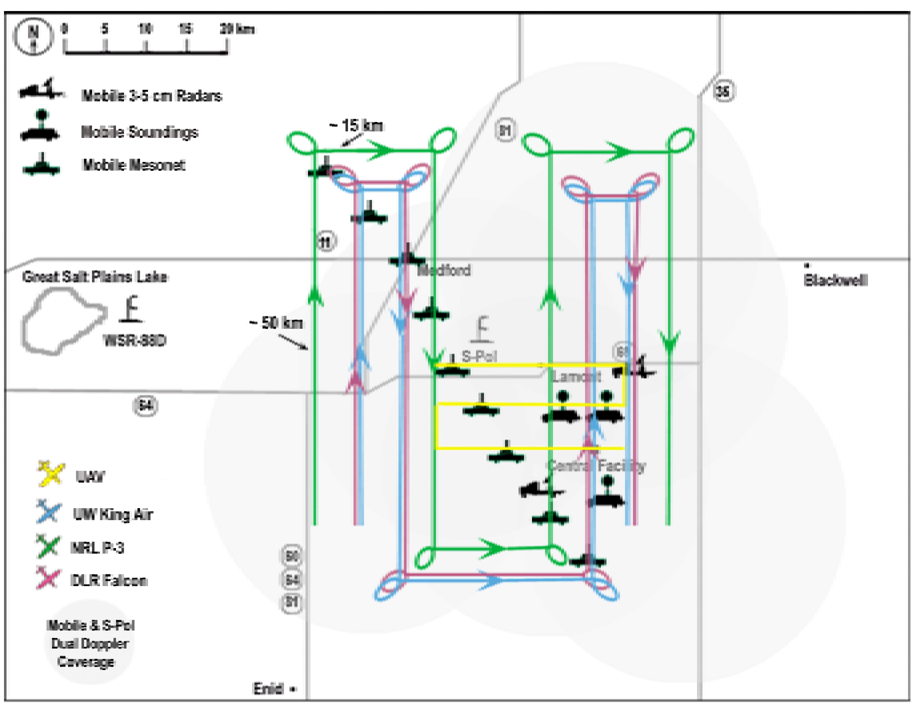
Dropsonde Aircraft
DLR Falcon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Lamont
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UAV
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DLR Falcon
Mobile & S-Pol
Dual Doppler
Coverage
Enid

This instrument will obtain vertical profiles of water vapor from the surface all the way up to the flight level. Thus the UW King Air will also provide in situ verification for the DLR DIAL. The UAVs (unattended aerial vehicles) will be flown as a vertical tower, obtaining measurements at numerous heights within the CBL. These six un-manned aircraft may also be flown in a horizontal configuration that would provide high-resolution measurements of the horizontal distribution of water vapor. The high-resolution GPS tomography array will estimate the horizontal distribution of water vapor over an area of about 6 km on a side centered on the central facility. Also at the central facility time-height profiles of water vapor will be obtained from AERI, microwave radiometer, profiling radiometer, Raman lidar, and tethersonde. The mobile radiometer will also be driven around the study area to investigate horizontal variations of integrated precipitable water. So as to obtain a more complete picture of factors affecting the distribution and evolution of the water vapor field a high-resolution depiction of the boundary layer winds will be obtained from ELDORA, S-Pol and at least 2 mobile radars. If the evolution of the CBL is rapid, as it will be early in the morning, an alternative is to do repeat passes over the same area to evaluate the evolution in a small area rather than the horizontal variability over a larger area.

The third experimental design example is for the ABL objectives. The following map superimposes the proposed experimental design on the IHOP array. It is uncertain which of the dozen of so ARM/CART Bowen-ratio or eddy-flux stations are represented, so these are not plotted, but it is assumed they are widely distributed across the ARM/CART domain. Similarly, the location of the second eddy-correlation site in the ABLE area during the time of IHOP is unknown, but a location somewhere in the northwest part of the watershed is likely, since an intensive hydrologic experiment will take place at that location during IHOP.

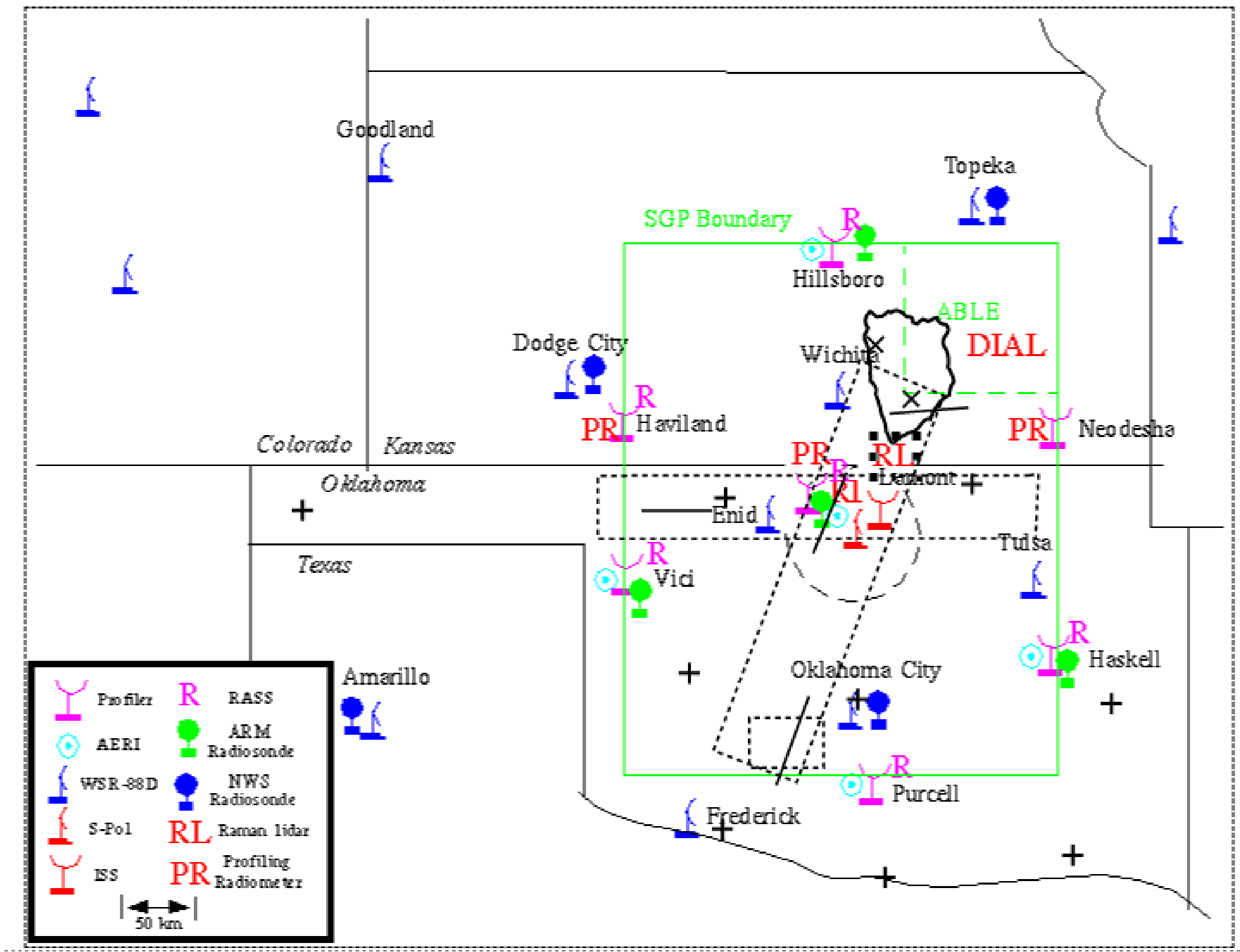
The long rectangles on the map mark the general locations of the repeated flight tracks for the DLR Falcon and the NRL P3, designed to map the horizontal variability, particularly of water vapor, in the boundary layer and to provide data that will be used to explain the variability. The shorter (~50 km) flight tracks are *schematic* locations of four proposed King-Air flight tracks, located to maximize impact of terrain and land-use variability and collocation with other instruments; three will be selected. Assuming that we have access to the existing flux data (OASIS, ABLE, ARM, AmeriFlux), current thinking is that the surface stations will be evenly divided among the three locations and lie along the flight tracks, located thus:

- Little Washita: Located in the southern rectangle (Little Washita River basin) is along-wind, would be underneath the IHOP-scale flight track, would take advantage of long-term soil-moisture measurements in the southern part of the domain. A concern is that there may be too much terrain variability for good surface-flux aircraft intercomparisons.
- Lamont: The track at Lamont is along-wind, would be underneath the IHOP scale flight track if the flight track curved to go over Lamont, and is normal to the local river (Salt Fork of the Arkansas). It would be within range of much of the equipment to be located at Lamont.
- ABLE: The track in the ABLE area is roughly cross-wind, and normal to the Walnut River, basin-scale elevation contours, and land-use boundaries; would be underneath the

northern extent of the IHOP scale aircraft track, and close to currently proposed DIAL location. The track (and thus surface stations) might be moved northward for synergism with DOE intensive hydrologic field campaign which occurs at the same time.

- West of Lamont: The track would parallel the east-west P-3 or Falcon track, and would be used at times for joint ABL-CI studies. It represents the far western, highest elevation, low precipitation portion of the study area.

The maximum separation of the stations along each flight track would be around 40 km, since the flight tracks are 50 km long, and it is unlikely that we would site stations at the ends of the flight tracks. Where possible, we will take advantage of flux or soil-moisture measurements already in place.



Map: IHOP experimental design, with selected surface-flux towers and ABL aircraft component superimposed. Crosses: 9 OASIS (Oklahoma Mesonet) eddy-correlation flux sites. Walnut River watershed (ABLE location) is outlined. The southern X in the watershed is the Smileyberg eddy-correlation site (grassland); the other X is Whitewater (Bowen ratio flux and Cuenca soil array site). A second eddy-correlation site will probably be located north of the Whitewater site for a DOE field campaign. Small rectangle: Little Washita area. Long rectangles: general area of *proposed repeated ABLE flight tracks. Solid lines. Possible King Air flight tracks, to be decided during site survey. NCAR surface flux stations will be sited along the selected King-Air tracks.*

The *ISS* will be placed in the central portion of the domain where there is a strong water vapor gradient. The site will be within the expected range of S-Pol refractivity measurements. The plan is to have the ISS co-located with the NASA/Goddard scanning Raman lidar and perhaps another lidar (backscatter and Doppler) provided by NASA.

1.5 Educational Benefits of the Project

List anticipated number of graduate and undergraduate students who will be involved directly and in a meaningful way in fieldwork and/or data analysis related to this project:
Bluestein: 1
Davis: 1 graduate students at PSU.
Possibly one with LeMone and Grossman.
Demoz: 1
Fabry: 1
Geerts: 2 graduate
Grossman and LeMone: 1 undergraduate or graduate
Kingsmill: 1 graduate
Koch: 1 PHASE graduate
Niyogi: 1
Raman: 1
Wakimoto: 2 graduate
Ziegler: 1-2 graduate, 10 undergraduate

Dave Leon (PhD candidate) is an essential participant, as he has extensive experience with the operation of the WCR and the analysis of its data, including dual-Doppler synthesis (Leon and Vali, 1998, J. Atmos. and Oceanic Tech., 15, 860-870; Leon, et al, 1999, 29th Internat. Conf. on Radar Meteor., Montreal, 472-475; Vali et al, 1998,J. Atmos. Sci., 55, 3540-3564). WCR data collected during IHOP will be the centerpiece of a MSc thesis for a candidate, yet to be determined.

Do you plan to enhance undergraduate and/or graduate classes with hands-on activities and observations related to this project?
Not at this time.

Will you develop new curricula that will be related to the project?
All new research results eventually make it into the curriculum but this will not come until years after the project.

Do you plan any outreach activities to elementary and/or secondary school students and/or the public related to the project?

Yes, NOAA/NSSL is planning K-12 outreach activities involving near-real-time access to ground-based mobile field observations via the Internet for Norman and Oklahoma City area public school students.

Additionally we will seek opportunities to give talks in local schools and expose students to the data, and to plug into local outreach programs. Specifically, the Oklahoma Climate Survey (OCS) and the OK Mesonet team operate several award-winning programs [at the national and international level] in educational outreach. These include:

1. K-12: Entering its 10th year of existence, EarthStorm has ~225 K-12 teachers who regularly use Mesonet data in their classrooms. Some great material is on-line. We have had 8 consecutive science fairs with attendance by students from all corners of OK. We also reach into KS and have 5 teachers in south central KS who are Mesonet/ARM data users.

2. Public Safety: Entering its 6th year of existence, OK-FIRST and ON-ALERT have ~160 public safety officials who are trained to use all forms of NWS, NEXRAD and Mesonet data in their public safety capacities. These officials represent police, fire and civil emergency management.

3. Public Utilities: In its 3rd year of existence, our educational outreach into the operations centers at the Rural Electric Cooperatives mirror our success via OK-FIRST.

With these programs serving as our platform for educational outreach, the OCS and Mesonet team desire to assist IHOP with its educational outreach.

Do you plan to have any interactions with primary and secondary school educators to involve them in the project?
Yes, NOAA/NSSL is planning interactions with secondary school educators in the Norman and Oklahoma City area public schools during the experiment.

Are you cooperating with an agency outreach program during this project?
Yes, both NCAR and NOAA/NSSL are planning media coverage of IHOP activities.

Will information about the project's activities, results, data, and publications be made available via the internet?
Yes, JOSS will maintain a catalog of project activities and data in real time during and after the project. ATD will also maintain the IHOP web page with key activities, results and publications.

NOAA/NSSL is planning to provide near-real-time access to ground-based mobile field observations via the Internet using 900 MHz hopping and satellite uplink technologies.

1.6 Previous Research Project Experience

Past ATD support:
Bluestein:COPS91, VORTEX

Brandes: PRECIP 96, CASES- 97, PRECIP-98
Chen: FIFE, HAPEX-MOBILHY, CASES-97
Cohn: Including both research and project management, participation includes LANTEX, Reno Basin Inversion project, LABEX, SCMS, ACE-1, BLX-96, FLATLAND-LIFT, LakeICE, FABLE, CASES-99, Juneau airport PROPHET, VTMX
Davis: FABLE, BOREAS
Demoz: None, his expertise is Raman lidars
Geerts: GALE, TOGA COARE
Grossman: FIFE, TOGA COARE, STORM-FEST, CASES-97
Kingsmill: CaPE, ERICA
Koch: STORM-FEST, COPS91, UW Queen Air deployments in 1977-78
LeMone: STORM-FEST, TOGA COARE, CASES-97
Leon: SCMS (other experiments: CS95, CARE98, CS99, WYICE00)
Niyogi: INDOEX, FIFE
Parsons: CYCLES, PRE-Storm, TAMEX, TOGA COARE, in house developments of ARMs-GPS Water Vapor, TOCS, Nauru-99 and VTMX
Mueller**:** JAWS, CINDE, MIST, CaPE
Raman: INDOEX, GALE, FIFE
Roberts: JAWS, CINDE, MIST, CaPE
Wakimoto: JAWS, CINDE, MIST, CaPE, ERICA, VORTEX, FASTEX
Weckwerth: CaPE, SCMS
Wilson**:** JAWS, CINDE, MIST, CaPE, SCMS, CASES 97, PRECIP 98

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Expected publication date and journal:

Within 3 years in Monthly Weather Review, Boundary-Layer Meteorology, Journal of Atmospheric Sciences, Journal of Atmospheric and Oceanic Technology, Journal of Geophysical Research, Journal of Hydrometeorology, and Weather and Forecasting.

1.7 Funding Agency Information

A scientific overview document was reviewed by NSF in November, 2000. Modifications are currently underway and will be completed shortly. The experiment has been approved by the USWRP interagency working group to be part of the USWRP implementation plan. Under this umbrella several proposals have already been funded. For example, Parsons and Weckwerth currently receive funds from NSF under a special allotment to NCAR for USWRP research. A portion of these research funds is utilized for planning, participation in and analysis after the IHOP_2002 experiment. This funding extends through September, 2003.

Wilson, Roberts and Mueller will receive funds from the FAA Aviation Weather Research Program and the U.S. Weather Research Program. Portions of these funds are available for participating in the IHOP field project and analyzing the data.

Chen, LeMone, Parsons and others receive funds from USWRP through September, 2003 for land surface studies and improving QPF through the use of IHOP data.

Koch will be submitting a proposal to NOAA/USWRP to fund the efforts of FSL in modeling, data assimilation and analysis of IHOP data.

Funding Agency	NSF, NASA, USWRP, FAA and DOE
Contract Officer	R. Rodgers (NSF/ATM) S. Nelson (NSF/ATM) J. Gaynor (NOAA)
Contract Identification	Basura: tbd Davis: tbd Geerts: NSF 0129296 Kingsmill: ATM-9901688 Koch: tbd Grossman and LeMone: ATM-09981811 Niyogi and Raman: tbd Wakimoto: tbd Ziegler and Rasmussen: tbd
Proposal Status	Basura: Submitted to NSF Chen and LeMone: USWRP funded Davis: Submitted to NSF Geerts: Submitted to NSF Kingsmill: funded, supplement request submitted to NSF Koch: To be submitted to NOAA/USWRP Grossman and LeMone: funded, supplement request submitted to NSF Niyogi and Raman: To be submitted to NSF Wakimoto: Submitted to NSF Wilson, Roberts, Mueller: FAA funded and USWRP funded Weckwerth, Parsons, LeMone, Wilson: USWRP funded Ziegler and Rasmussen: Submitted to NSF Chen and LeMone: $150K/yr for 2 yrs Davis: $150K/yr for 3 years

	Geerts: $110K/year for 3 years Kingsmill: $335K over 3 yrs + $70K supplemental request Grossman and LeMone: $150K/yr for 3 yrs Parsons: $150K/yr for 3 yrs Wakimoto: $200K/yr for 3 yrs Wilson, Roberts, Mueller: 150K/yr for 2 yrs Weckwerth, Parsons, LeMone, Wilson: $200K/yr for 2 yrs

PART II: FACILITY-SPECIFIC REQUESTS

2. AIRCRAFT: NRL P-3

2.1 Aircraft Operations

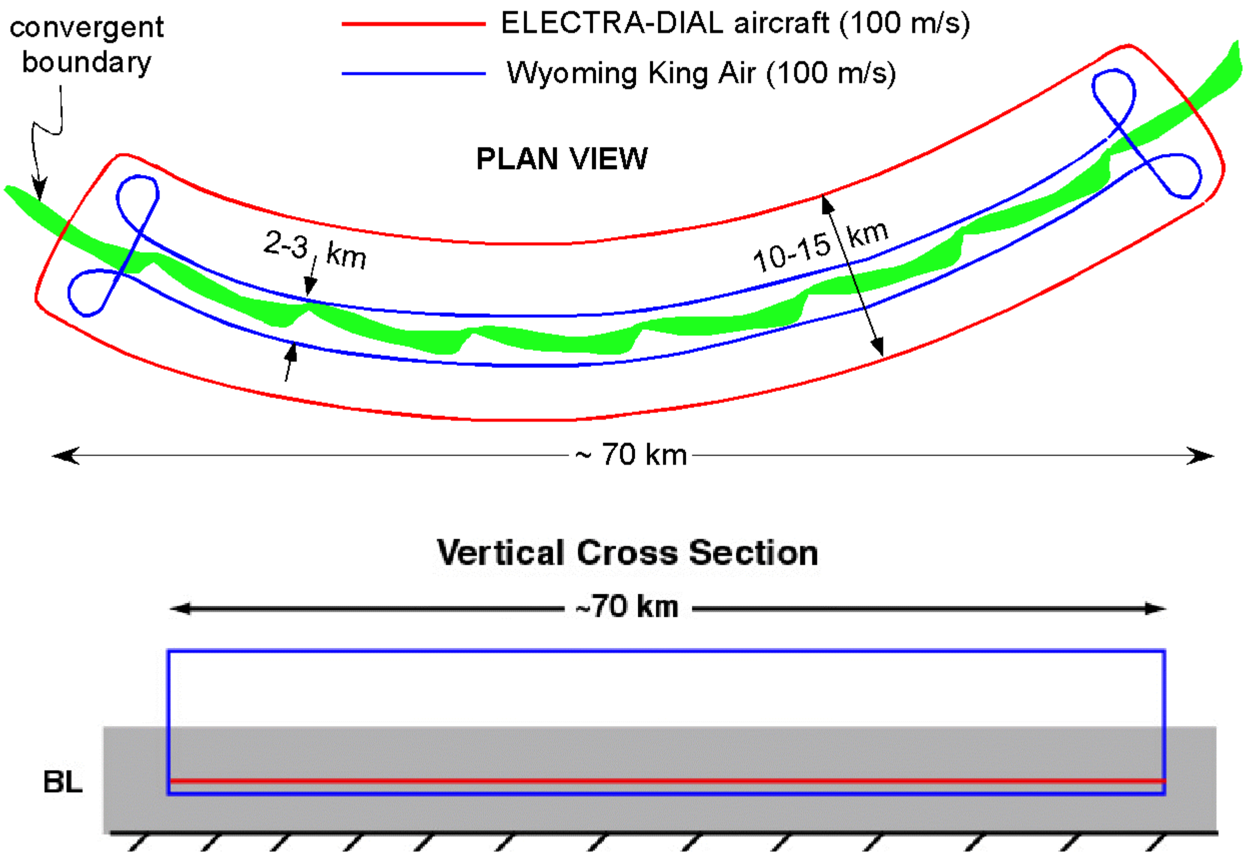
Preferred flight period	13 May – 30 June 2002
Number of flights required	20
Estimated duration of each flight	8 hrs
Number of flights per day	1
Preferred base of operation	Oklahoma City
Alternate base	
Is Patuxent River Naval Air Station in Lexington Park, Maryland (base for the NRL P-3) acceptable as your operations base?	Yes
Average flight radius from base	200 km
Desired flight altitudes(s)	100 m (or as low as possible) up to 5 km
Particular part(s) of day for flights	5 am – 5 pm LT for low-level water vapor evolution and convection initiation flights; some nighttime flights for QPF studies
Statistically, how many days during specified period should be acceptable for flight operations?	~75%
Number of scientific observers on each flight *	6

Scientific rationale for the use of this aircraft in the proposed project:
An aircraft which can house ELDORA, Leandre II water vapor DIAL and TDL is essential for the success of IHOP. The combination of 3-D winds in the clear-air and in the precipitation regions (ELDORA) and the 2-D water vapor field (Leandre II) and in situ high-resolution water vapor measurements (TDL) from the same platform is unprecendented and invaluable in addressing water vapor evolution, CI and QPF issues.

Description of desired flight pattern(s), priorities, and estimate number of flights:
Following are some examples of the types of flights we would like to do.

1) The first one shows the NRL P-3 (red lines) and UWKA (blue lines) flying near a boundary layer convergence zone, such as dryline, gust front or cold front. This would be in support of the CI objectives. We need to fly at 100 m or as low as possible in order for ELDORA to obtain strong clear-air echoes. We will also need to fly within 7 km of the convergence zone so that Leandre II, in its side-pointing mode, can sample the water vapor field.

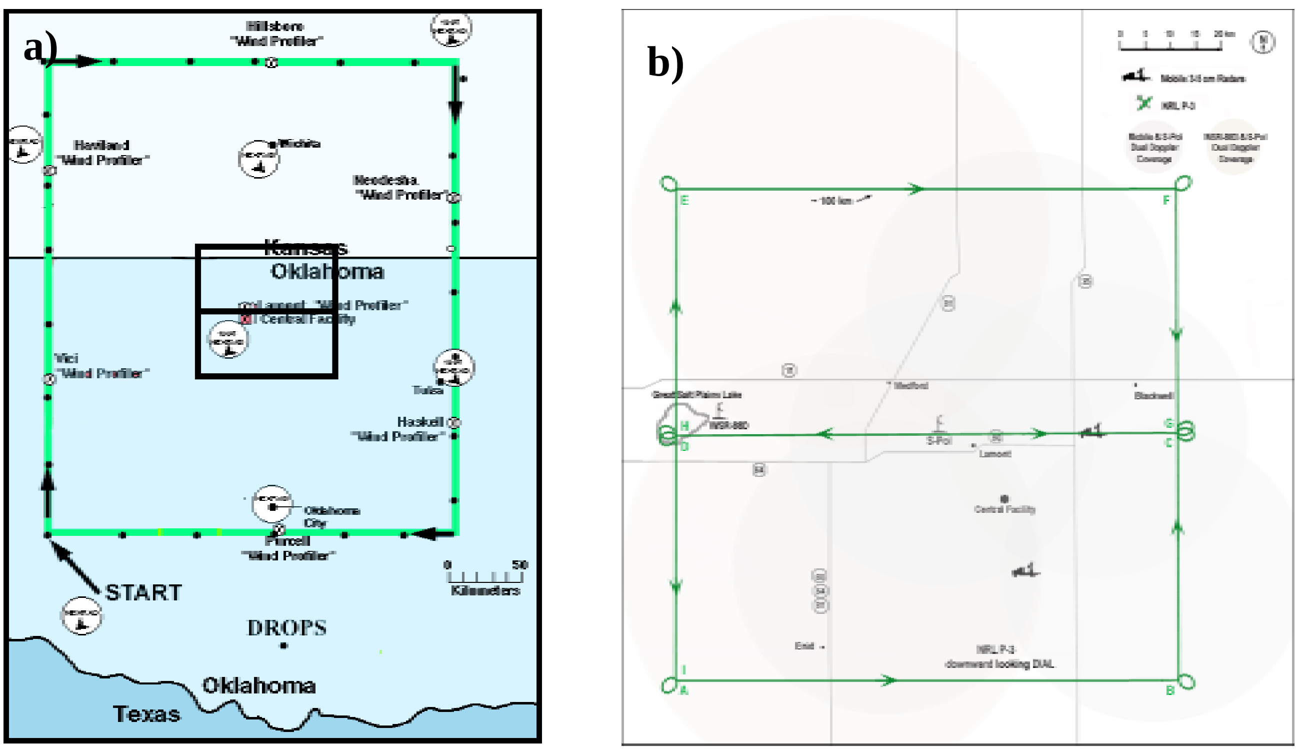
NRL P-3

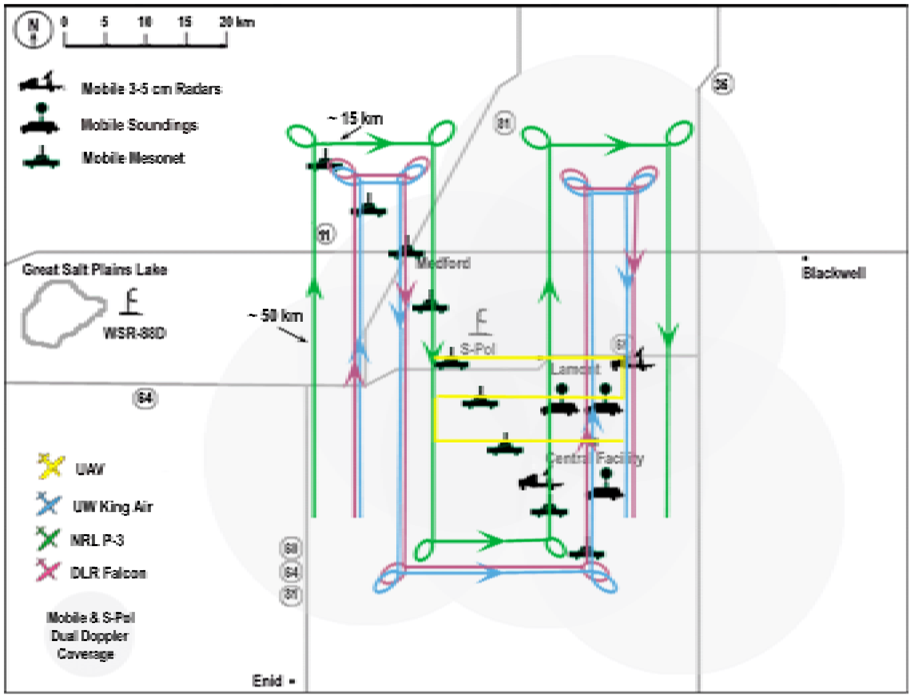


2) The second flight track example would be used to assess the water vapor budget over the 275 km X 350 km IHOP (i.e., ARM/CART) domain and examine the low-level jet. This would be in support of the QPF objectives. Two aircraft (DLR Falcon and a dedicated dropsonde aircraft) would be flown in a staggered arrangement releasing GPS dropsondes every 4 min (~50 km at the location of the black dots along the green track in a) in a circuit defined by the perimeter of the ARM/CART domain. The downward-pointing water vapor DIAL data from the Falcon would also be valuable to this experiment. The black box showing the inner domain around S-Pol and the Central Facility are enlarged in b). The green track in b shows the NRL P-3 flight track which would utilize the downward pointing Leandre II water vapor DIAL data obtained on a smaller scale than the outer domain mapping data.

3) A third possible flight track is shown in the following figure. This design will utilize nearly all of the proposed IHOP facilities. Soundings will be obtained at frequent intervals from the central facility and nearby MGLASS to assess whether there is a significant difference in the stability profiles during the development of the CBL. Surface moisture measurements will be obtained from the S-pol refractivity technique and mobile mesonet. The mobile mesonet vehicles will continuously drive around the grid of roads surrounding the central facility to map out the surface water vapor, temperature, wind and pressure fields. These measurements will be centered in an area about 50 km on a side of water vapor measurements obtained from the airborne DIAL's. The *NRL P-3* will fly as low as possible with the Leandre II water vapor DIAL staring horizontally out the right side of the aircraft. In this configuration, Leandre II will map out the horizontal

distribution of the water vapor field within ~7 km of the P-3. The UW King Air will fly at the same altitude as the NRL P-3 and thus provide in situ verification within the air volume sampled by Leandre II. The DLR Falcon with a downward-pointing water vapor DIAL will fly at 5 km directly above the UW King Air. This instrument will obtain vertical profiles of water vapor from the surface all the way up to the flight level. Thus the UW King Air will also provide in situ verification for the DLR DIAL. The UAVs (unattended aerial vehicles) will be flown as a vertical tower, obtaining measurements at numerous heights within the CBL. These six un-manned aircraft may also be flown in a horizontal configuration that would provide high-resolution measurements of the horizontal distribution of water vapor. The high-resolution GPS tomography array will estimate the horizontal distribution of water vapor over an area of about 6 km on a side centered on the central facility. Also at the central facility time-height profiles of water vapor will be obtained from AERI, microwave radiometer, profiling radiometer, Raman lidar, and tethersonde. The mobile radiometer will also be driven around the study area to investigate horizontal variations of integrated precipitable water. So as to obtain a more complete picture of factors affecting the distribution and evolution of the water vapor field a high-resolution depiction of the boundary layer winds will be obtained from ELDORA, S-pol and at least 2 mobile radars. A possible alternative to this plan will be to repeat one to two legs of the NRL P-3 track to obtain better temporal resolution early in the morning when the CBL is evolving rapidly.





2.2 ATD/RAF Airborne Scientific Instrumentation

It is probable that only a very limited set of RAF's standard measurements will be available. (See list above in Appendix 1.) At present, we expect to provide barometric (static) pressure, ambient temperature, dew point, 3-dimensional winds and aircraft position. For details about instrument type and performance, consult the RAF Bulletins on the RAF web site at http://raf.atd.ucar.edu/Bulletins.

This is sufficient for IHOP needs.

2.3 User-supplied Scientific Payload

Please provide the following information for each user-supplied scientific instrument:

Instrument Name:	**Leandre II**
Weight of all components:	340 lbs rack mount; 250 lbs transmitter/telescope/receiver
Complete size dimensions of all components:	Transmitter/telescope: 69 X 24 X 40"; Receiver: 18 X 40 X 30"
Rack-mountable 19" panel space required:	36 U (63 ")
Supplying your own 19" rack (yes/no): (Note: racks must survive 20G crash load.)	No
Hazardous material required:	None
Radioactive sources or materials:	4 kW; 115 V/ 400 Hz; 28 V DC
Power required (watts, volts, amps):	
Type of power (DC, 60 Hz, 400 Hz):	Needs to look out window and should be able to be pointed sideways for some flights and up or down for other flights
External Sensor Location (if any):	None
Are Signal(s) to be recorded on RAF's Aircraft Data System (yes/no):	No
If yes: Signal format (digital, analog, serial)	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 50, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	
Need IRIG time-code feed?	
Special sensor calibration service required?	
Need full-time operator during flight?	
Number of lap-top computers for on-board use:	
Extra information not covered above:	

2.4 Data Recording and Processing Requirements

What additional recording capability is needed? Please give us details on the number of signals, their characteristics, format, synchronous, fire-wire, ethernet, etc. (We may not be

able to accommodate *any and all* signals.)
Standard in situ data and frequency are sufficient.

If nonstandard output formats and/or data rates are required, how often are the measurements needed? Note: The standard format for processed, RAF output data is netCDF. The standard output media are magnetic tape and ftp transfer. *(Nonstandard rates and/or formats will be considered as special processing requests.)*
N/a

Will you be using your own recording system?
Yes.

2.5 Supporting Services

Will you require air-ground communication? *(If so, specify location of base station and operating frequencies.)*
Yes, we require air-to-ground voice communications between the NRL P-3 and the operations center in Norman, OK. Due to the high level of coordination requested between aircraft, voice communications with the UWKA, DLR Falcon and NASA DC-8 are also required. Furthermore it is desired to have air-to-ground communications with the NSSL field control (FC) vehicle and S-Pol, as well. Operating frequencies are unknown.

We also require real time overlays of aircraft positions on some combination of S-Pol, WSR-88D and visible satellite imagery in the Norman operations center.

Will NCAR support be required in preparing this instrument for use on the aircraft (other than inspection, installation and power hookup). ATD/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time.)*
Yes, RTF, RAF and DFS support is needed to mount Leandre II.

2.6 Ground Support Needs for User-supplied Instrumentation

Preflight needs (prior to take-off) on flight days:

Access	1 hrs
Power	1 hrs

Post flight needs (after landing) on flight days:

Access	0.5 hrs
Power	0.5 hrs

Special support needs on flight days (and comments):
N/a

Routine Maintenance on non-flight days:

None.

Access	0 hrs
Power	0 hrs

Special support needs on non-flight days (and comments):
N/a

On-site data access requirement:
The standard RAF data support is sufficient.

Summary of any special requirements which pertain to NRL and RAF support:
We request RAF, RTF and DFS support in mounting Leandre II and in designing and mounting a fairing which will allow Leandre II to point sideways or up/down.

Has an ATD scientist/engineer/project manager been consulted to help complete this request?
Yes.

AIRBORNE INSTRUMENTATION:
ELECTRA DOPPLER RADAR (ELDORA)

3.1 Radar Operations

Scientific rationale for the use of ELDORA in the proposed project:
We desire the use of ELDORA to help map out the 3-D flow field for water vapor evolution studies and prior to thunderstorm initiation and during its evolution. This, in combination with the LEANDRE II water vapor, will assist in studying water vapor evolution and convection initiation issues.

Additionally, ELDORA's ability to map out the flow field within precipitation features will be utilized by flying above the boundary layer while LEANDRE II points downward. This combination of sensors would be invaluable for our QPF studies.

Weather events during which collection is desired:
Early morning, pre-convective, clear-air conditions to storm development to storm dissipation

Typical operations schedule:
9 am – 5 pm LT for convection initiation studies; nighttime operations may be required for QPF studies. There will be occasional starts as early as 5AM to study full water vapor evolution.

Estimated number of radar hours:
160 hrs.

Typical radar parameters:
Number of PRFs: 2
Number of Frequencies: 4
Antenna Rotation Rate: 100 deg/s
Gate Spacing along Beam (m): 150 m
Number of Gates: 250
Minimum Sensitivity Needs (dBZ at 50 km): 10 dBZe

Scientific rationale for desired radar parameters:
Maximum sensitivity is desired to obtain clear-air measurements before precipitation occurs. We would also like to be able to modify the radar parameters in-flight to switch to sampling early storm development.

3.2 Radar Display and Communications Needs

Summary of radar display and communication needs:
We require CAPPI displays in real-time. We must have air-to-ground communications between the NRL P-3 and the operations center in Norman to aid in guiding the aircraft flights. We also require air-to-air communications between the NRL P-3, Wyoming King Air, DLR Falcon and

NASA DC-8. Furthermore it is desired to have air-to-ground communications with the NSSL field control (FC) vehicle and S-Pol, as well.

We also require real time overlays of aircraft positions on some combination of S-Pol, WSR-88D and visible satellite imagery in the Norman operations center.

Summary of on-site radar data access and analysis requirements:
The standard data content and format (exabyte tape) are sufficient.

3.3 User-supplied Scientific Payload

Summary of auxiliary equipment located on airplane:
LEANDRE II water vapor DIAL is a necessary tool for this project. It should be mounted in a sideways-pointing mode in order to obtain water vapor measurements in the same airspace as the ELDORA clear-air measurements. We would also like the capability to point LEANDRE II downward for QPF flights.

3.4 Supporting Services

Multiple radar coordination requirements:
We will not coordinate scans with other radars but require the capability of using ground radars to help guide the aircraft. Thus, air to ground communications are essential. We would also need to communicate with the Wyoming King Air, DLR Falcon and NASA DC-8 so that all of our flight tracks can be coordinated.

Summary of any special requirements that pertain to ATD or NRL support:
The combination of sensors is key to this request. ELDORA with LEANDRE II and the TDL (tunable diode laser) in situ water vapor sensor would be an exciting, unique combination of sensors. This combination would provide an unprecedented dataset with measurements of aerosols, water vapor, precipitation and the 3-D wind field.

We must have real-time CAPPI’s based on the fore antenna’s reflectivity and single Doppler velocity at flight level to assist in aircraft navigation.

Is an ATD Scientific Project Manager needed for the project?
Yes.

Has an ATD scientist/engineer/project manager been consulted to help complete this request?
Yes.

AIRBORNE INSTRUMENTATION:
WYOMING CLOUD RADAR (WCR) REQUEST

4.1 Radar Operations

Scientific rationale for the use of WCR in the proposed project:

The WCR will operate in dual-beam down-looking/slant-forward mode on the University of Wyoming King Air (UWKA), which is equipped with in situ probes to measure humidity, temperature, cloud characteristics, and air motion (Fig 1). This configuration is currently being developed. The design objectives will allow a switching, during the flight, from VPDD mode to single-beam side-looking or single-beam up-looking modes. (The latter modes are the existing ones, and switching between the two is based on the position of a mirror.) The VPDD mode will be the primary one during IHOP. The UWKA is equipped also with a gust probe, and at least one high-rate moisture and temperature sensor, so fluxes can be derived.

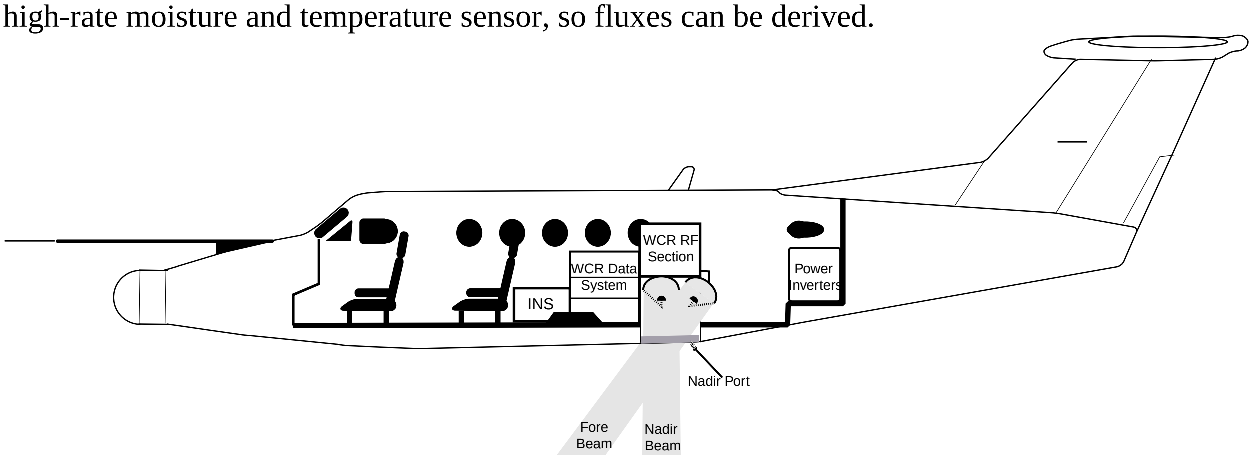


Fig 1. Vertical plane dual-Doppler configuration of the WCR in the UWKA.

We propose to use the WCR to directly measure the vertical air motion and along-track horizontal flow below the UWKA, at a resolution of about 30 m and an accuracy around 1 ms^{-1}. The 95 GHz radar is sufficiently sensitive to see insects in the boundary layer, especially in convergence zones. The WCR will be used both for convection initiation (CI) and boundary layer (ABL) flights. If a third type of flight, for QPF purposes is to be conducted during IHOP [this is uncertain at this time], then the WCR will be operational there as well.

The kinematic information, combined with in situ humidity measurements collected during CI flights, allow a detailed and unprecedented description of the vertical structure of winds, moisture convergence, and depth of the moist layer across a radar fine line, thereby fostering our understanding of thunderstorm initiation processes. The flight pattern of the UWKA, shown in Fig 2, is intended to describe the vertical kinematic and moisture structure across radar fine lines, and to document along-line variability, in coordination mainly with the NRL P-3, which will document the horizontal velocity and moisture structure (by means of the ELDORA and LEANDRE-II DIAL).

(1) ABL flights will assume various flight levels within the boundary layer (BL), possibly

starting with a surveillance track above the BL. WCR reflectivity will depict the structure of thermals and other organized eddies in the BL, provide an estimate of the BL depth, and depict the topography of the BL top along the flight track. The latter can be obtained while flying within the BL, if the WCR is configured in a single-beam up-looking mode. WCR nadir-beam velocities will describe the vertical motion in these plumes. At lower flight levels in situ measurements are important, but except for the lowest flight level, WCR data will still be useful to depict, at high resolution, the eddy structure and along-track circulations below the UWKA.

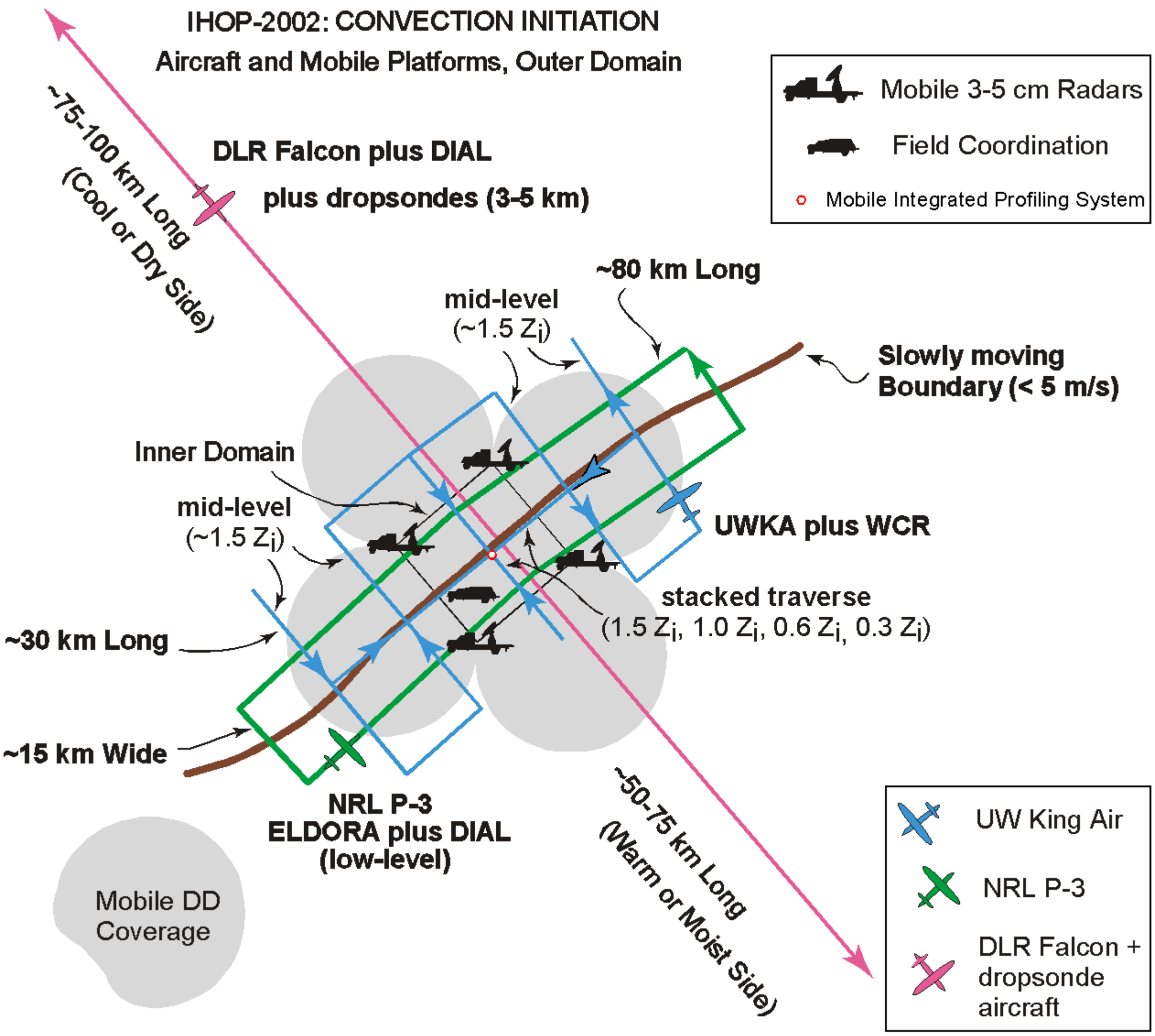


Fig 2. *Coordination between the UWKA, other aircraft, and mobile ground facilities in the event of a well-defined, slow-moving boundary. Z_i is the depth of the shallow BL (moist layer in case of a dryline).*

(2) QPF flights will spiral, porpoise, and transect the stratiform portions of MCSs. WCR signal will become too attenuated after 1-4 km, depending on the rainrate. The combination of attenuation and rainrate can be used to more accurately estimate water

content.

Weather events during which collection is desired:

ABL: fair-weather conditions; CI: pre-convective through early storm development. Boundaries and cloud streets may be examined also on days on which deep convection fails to develop. It is possible that the UWKA will also fly near the freezing level and between 3-8 km in the stratiform portions of MCSs, or overriding stratiform precipitating systems. Vigorous and/or electrically active storms will not be targetted.

Typical operations schedule:

The WCR operations schedule is built upon the UWKA operations schedule: ABL flights generally are to be conducted around 9 am – 1 pm, while CI flights are more likely between 1 pm-7 pm. Some flexibility in flight schedules is needed, for example some flights at 5 am will be requested for CBL evolution studies. One or two flights should be performed after the development of a nocturnal ground inversion, sometimes between 10 pm – 7 am, in order to study the effect of undular bores on convective initiation. QPF flights are more likely at night (8 pm-midnight), however, depending on the presence of suitable targets, they can be conducted any time of the day.

To operate the WCR we will need AC power and access to the UWKA for 1 hour before each flight. We may or may not need access to the aircraft after each flight, if so for 1.5 hrs max. And barring serious radar problems, we need access to the UWKA with AC power, at a specific location outside the hangar, up to 3 times during IHOP, 2 hours each, for corner reflector calibrations.

Estimated number of radar hours:

135 hrs (slightly less than the UWKA requested flight hours, because the WCR will not be operational during ferry, and close to take-off/landing times)

Desired radar parameters:

<u>Primary mode: two beams, one pointing nadir, one pointing ~40º forward:</u>

PRFs (4 or 6-pulse packets): 20,000 Hz; 275 ns pulse
Gate Spacing along Beam (m): 30 m
First Gate Location (min 75 m): 75 m
Number of Gates: 100
Minimum Sensitivity Needs (dBZ at 1 km): -31 dBZ
Antenna Configuration (pick one)
Dual antennas (single linear polarization): __X_ down-looking (NADIR PORT), ____ side-looking
Single antenna (dual lin. pol.): ____ down-looking, ____ up-looking ____ side-looking

Other modes:
The <u>up-looking single-beam mode</u> should use the same as above.
The <u>side-looking single-beam mode</u> is as follows:
mode PRFs (4 or 6-pulse packets): 10,000 Hz; 1000 ns pulse
Gate Spacing along Beam (m): 140 m

First Gate Location (min 75 m): 130 m
Number of Gates: 100
Minimum Sensitivity Needs (dBZ at 3 km): -24 dBZ
Antenna Configuration (pick one)
Dual antennas (single linear polarization) : ___ down-looking (NADIR PORT), __X__ side-looking
Single antenna (dual lin. pol.): ____ down-looking, ____ up-looking ____ side-looking

Scientific rationale for desired radar parameters:

We desire to describe the fine-scale echo and kinematic structures of organized large eddies in the BL, as well as boundaries (such as drylines), gravity currents, and cloud street roll vortices in the boundary layer. Since the flight level will not exceed 3 km AGL and some air motions may be quite turbulent, a high resolution and large Nyquist interval (+/- 16 m/s) is preferred. In the horizontal mode, we aim for large coverage, maximum sensitivity at range, and a resolution more comparable to that of the LEANDRE-II.

Multiple radar coordination requirements: (If WCR will coordinate with other radars (airborne or surface), please provide brief details.)

We will not coordinate scans with other radars, other than, on occasion, with the U. Mass. 3 mm mobile radar. The capability of using ground radar information to guide the aircraft is desired. The aircraft carrying the WCR will fly close to ground-based mobile or fixed Doppler radars where possible, in part such that WCR velocity estimates can be used to obtain a more complete and higher-resolution depiction of the phenomenon in question. Both air-to-air and air-to-ground communications are needed (see below).

4.2 Radar Display and Communications Needs

Summary of radar display and communication needs:

Time cross-sections of real-time radar displays are available on board, and they are essential: nadir reflectivities determine the existence and strength of a boundary. We require air-to-ground voice communications to aid in guiding the aircraft. Ground station can be the NSSL Field Coordination Vehicle (FC), Norman Operations Center, and/or S-POL. We also require air-to-air voice communications with the NRL-P3, and, less essentially, with the DLR Falcon. We are interested also in direct data feed to the FC, of select WCR and in situ WCR data, using a 900 MHz Freewave system. Finally, the capability to display the UWKA's real-time position on ground radar PPIs (S-POL, WSR-88D) and satellite imagery would be very useful. Various techniques are being considered (transponder, GPS location transmission).

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

It is preferable that data be in a format readable by NCAR software packages (e.g., SOLO, REORDER, CEDRIC) . Support from the WCR staff will be needed if the current WCR data analysis software cannot be imported into the NCAR software packages.

4.3 Supporting Services

Is a WCR Scientific Project Manager needed for the project?
Yes

Has a WCR scientist been consulted to help complete this request?
Yes

AIRBORNE INSTRUMENTATION:
GPS DROPSONDE SYSTEM

5.1 System Operations

Number of Systems requested:
1 system on dedicated dropsonde aircraft

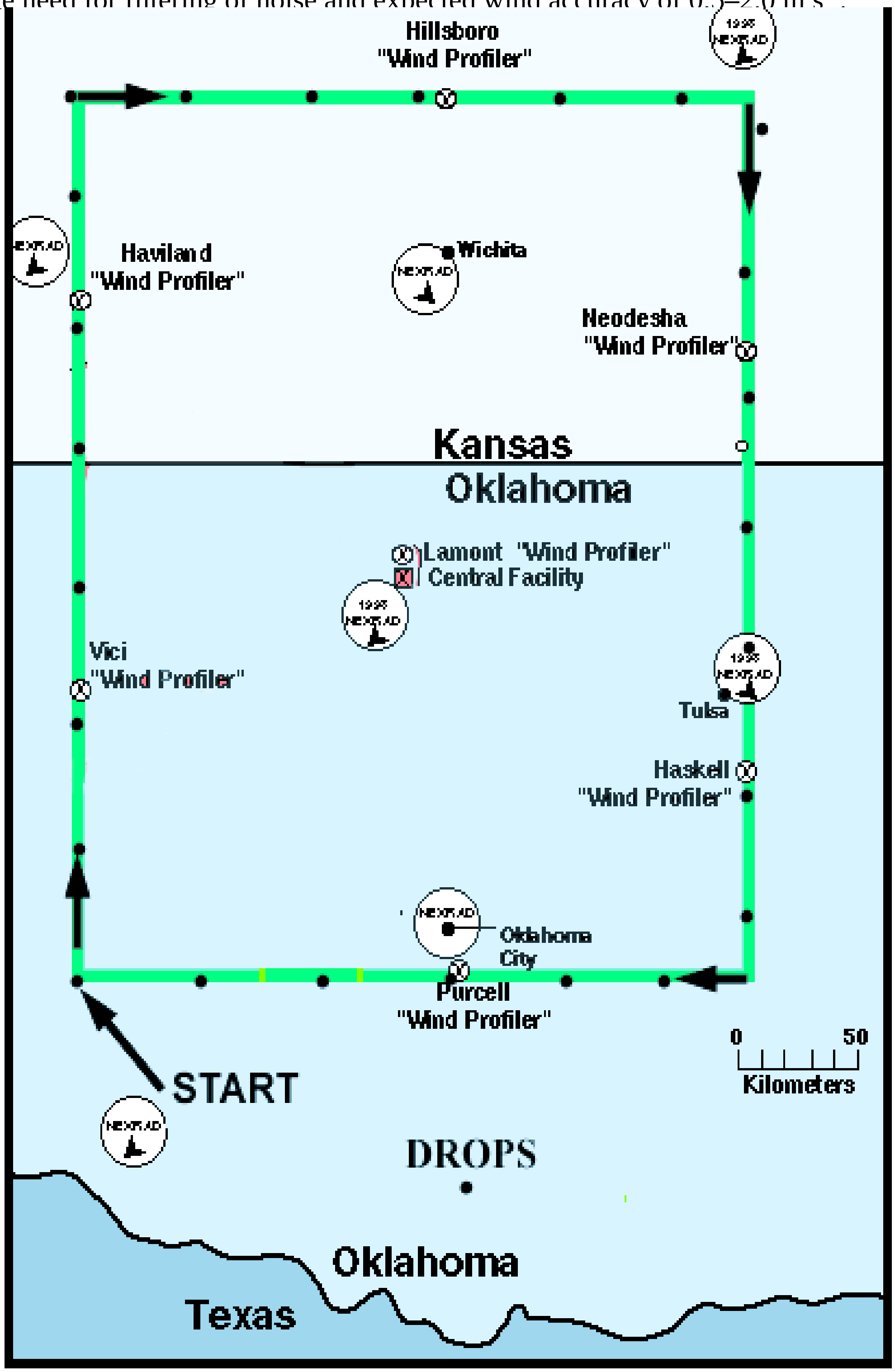
Number of Sondes requested:
400 (200 from dedicated dropsonde aircraft and 200 from DLR Falcon to be used with their dropsonde system)

Scientific rationale for the use of the system in the proposed project:
The dropsondes are essential to the CI and QPF research components. The dropsondes will be used to measure the dynamics and thermodynamics (especially useful are the temperature measurements) in the regions of the remote sensing data obtained on the aircraft. Ideally, they will obtain high horizontal-resolution profiles of the thermodynamics on both sides of boundaries and beyond.

A variety of closure and feedback issues create both complexity and uncertainty in convective QPF as there are a number of empirical assumptions underlying all cumulus parameterization (CP) schemes. For example, assumptions in the Kain-Fritsch scheme include those that determine the fraction of updraft condensate that is evaporated in moist downdrafts, the rate at which stabilization occurs, and the nature of the mesoscale "trigger function". Given the great variety of closure assumptions and convective feedback assumptions used in the various CP schemes, it is not surprising that researchers have recently started to explore the use of CP closure ensembles in mesoscale modeling. The relative merits of the various assumptions and hypotheses need to be examined with observational data sets that are sufficiently complete. The opportunity exists in IHOP to determine the horizontal and vertical flux convergence of moisture, and indirectly the vertical profiles of apparent moisture sources and sinks, with much higher resolution than has been possible in previous investigations. Past observational studies that have attempted to address the water vapor (moisture) budget question in the extratropics have been limited to a few studies from AVE-SESAME 1979 and composite large-scale studies of mesoscale convective systems (as reviewed by Cotton and Anthes (1989, Storm and Cloud Dynamics)). IHOP offers a composite set of observing systems for measuring three-dimensional moisture, winds, as well as precipitation and surface fluxes, at unprecedented spatial and temporal scales.

Water vapor budgets will be determined from syntheses of a combination of airborne and ground-based sensing systems over the 275 km x 350 km IHOP region (this being the size of the CART/ARM domain). These measurements also offer the advantage of being able to determine the changes in the environment surrounding regions of convection initiation within the domain, including changes in stability and the capping inversion strength. In particular, two aircraft (the DLR Falcon and a dedicated dropsonde aircraft) would be flown in a staggered arrangement releasing GPS dropsondes every 4 min (~50 km) in a circuit defined by the perimeter of the

IHOP domain. The GPS dropsondes can be deployed at even higher rates than this because as many as four sondes per aircraft using multiple frequencies can be accommodated (Hock and Franklin 1999, BAMS, 407-420). This new dropsonde is far superior to the Omega-based dropwindsonde (ODW), including nearly an order of magnitude better vertical sampling (~5 m) without the need for filtering of noise and expected wind accuracy of 0.5–2.0 m s^{-1}.



The first aircraft would depart from the southwestern corner of the IHOP domain (START in the following figure) and fly northward at a level altitude of 10 km to the northeastern corner in approximately 45 min, whereupon the second aircraft would be deployed from the same original location and follow the first one around the rectangular IHOP domain. See the figure below. Both aircraft would repeat the above pattern one more time and then stop to refuel and repeat the double circuit another time — thus, providing information about the evolution of moisture flux transport with a temporal sampling of ~45 min and spatial resolution of 50 km over a period of 6 h. This will enable accurate budget calculations to be performed over a sufficiently long period of time prior to the outbreak of deep convection to examine the assumptions underlying the CP schemes. Missions will be conducted during morning pre-convective situations in which both a strong low-level jet is present to transport moisture into the domain and, ideally, a dryline is present somewhere within the domain. The mission ends once strong convection has developed to avoid serious ATC problems. The number of such missions will be severely restricted by the resources available, since each box sampling will require 25 dropsondes per aircraft (100 dropsondes for two rectangular traverses over a 6 h window) at a cost of $500 per drop ($50K for one complete 6-h mission).

Approximately how many dropsondes will be released on each mission flight?

10-25

At which frequency (i.e., time between drops) will the dropsondes be released?

One after the other as quickly as possible for the CI missions; Every 4 min (~50 km) for the QPF missions.

What is the general location in which the dropsondes will be dropped?

Southern Great Plains

5.2 Supporting Services

Will you provide an operator for the dropsonde system?

No

Is a ATD Scientific Project Manager needed for the project?

Yes

Summary of any special requirements that pertain to ATD support:

None at this time.

Has an ATD scientist/engineer/project manager been consulted to help complete this request?

Yes

GROUND-BASED SYSTEMS:

S-BAND DUAL POLARIZATION DOPPLER RADAR (SPOL)

6.1 Radar Operations

Scientific rationale for the use of SPOL in the proposed project:
S-Pol will be a critical instrument in conducting the following scientific studies, a) detailed distribution and evolution of the boundary layer water vapor, b) convective storm initiation, c) nowcasting of convective storms and quantitative precipitation, d) moisture return in the low-level jet, and e) numerical quantitative precipitation forecasting. S-pol's unique capabilities for these studies are: i) the refractivity mapping capability which will be used to estimate the low-level water vapor field, ii) the early cumulus cloud detection capability which will allow monitoring the entire cloud evolution, iii) the hydrometeor typing capability which will provide details of ice formation in growing cumulus and help evaluate the utility of satellite for detecting the onset of ice in cumulus for input into nowcasting systems, iv) the hydrometeor typing capability which will provide validation for the Local Analysis and Prediction System Water-In-All-Phases (LAPS WIAP) fields used in initializing mesoscale models, v) the capability to retrieve wind fields from just S-pol will allow continuous monitoring of the boundary layer wind field even in the absence of a second nearby Doppler radar, vi) a new polarimetric quantitative precipitation estimation technique will be tested for the first time.

S-Pol will also be used to monitor boundary layer convergence lines and to obtain high-resolution wind fields when paired with mobile radars. Less high-resolution wind fields will result from dual Doppler analysis with the nearest (44 km) WSR-88D.

When convergence lines and convection initiation are anticipated near S-pol the mobile facilities will operate in the near vicinity allowing for the maximum use to be made of all IHOP facilities. Even when the mobile facilities are not in the vicinity of S-pol, the cost-effective continuous monitoring of boundaries, water vapor and storm initiation will nicely complement the intermittent mobile measurements.

Please see the attached S-Pol/IHOP scientific proposal for further information regarding the necessity of S-Pol during IHOP.

Weather events during which collection is desired:
From clear-air conditions near sunrise through the development of convection during the afternoon and evening to the end of the precipitation event. Night time operations will also be desired for nocturnal low-level jet episodes.

Typical operations schedule: (daily operation hours)
We will often require 24 hour operations. During nighttime periods, it is likely that unattended operations will be sufficient but we will often need attended daytime operations from 8 am – 9 pm LT. A few boundary layer evolution data collection periods will commence at 5 am LT.

Estimated number of radar observation hours:

500 hours

Typical radar parameters:

PRF: 1000
Gate Spacing: 150 m
Type of Scans: SUR, PPI, RHI
Scan Rate: 5 deg/sec
Minimum Sensitivity Needs (dBZ at 50 km): -10 dBZe

Scientific rationale for desired radar parameters:
Standard radar parameters are sufficient for this project. In addition to the typical standard radar parameters listed above, we also require S-Pol's new refractivity mapping capability for IHOP. The high sensitivity requirements are critical for early cumulus cloud detections.

Would you like to request the Bistatic Network (BINET) system as well to obtain three-dimensional winds in real-time?
Yes, the 3-D winds around S-Pol would be an excellent additional observation that would allow for high-resolution 3-D wind fields even in the absence of the mobile radars.

Summary of auxiliary equipment located at radar site:
None at this time.

6.2 Radar Display and Communications Needs

Summary of radar display and recording, radar control and data communication needs:
We require real-time data display, with all of the capabilities of Zebra. Standard data recording and radar control are sufficient. Real-time data links to the operations center would be invaluable. Display of project aircraft tracks (NRL P-3, UWKA, DLR Falcon and NASA DC-8) on Zebra is necessary.

We will require voice communications with the low-flying aircraft (NRL P-3 and UWKA) in the event that they do not have satellite communications and thus are unable to communicate with the IHOP operations center in Norman. If S-Pol is providing input to the aircraft, then we will also require realtime aircraft tracks of those aircraft overlaid on S-Pol data.

6.3 Supporting Services

Summary of any special requirements that pertain to RTF support:
Real-time data and voice communications with the operations center in Norman and the NSSL Field Control vehicle would be invaluable.

Refractivity mapping is an essential component of this request. Thus we would like to see real-time displays of the refractivity and estimated water vapor fields, in addition to the real-time displays of standard S-pol parameters at the operations center in Norman.

Is an ATD Scientific Project Manager needed for the project?
Yes.

Has an ATD scientist been consulted to help complete this request?
Yes.

GROUND-BASED SYSTEMS:

GPS/LORAN ATMOSPHERIC SOUNDING SYSTEM (GLASS) AND MOBILE GLASS

7.1 System Operations

Number of Systems requested:
2

Number of Sondes requested:
400

Scientific rationale for the use of the system:
Scientific rationale for the use of the system in the proposed project IHOP_2002 is aimed at improved characterization of the 4-D distribution of water vapor. This improved characterization will be utilized (1) to test the impact of improved water vapor measurements on quantitative precipitation forecast (QPF), (2) as additional information in a convective initiation study to improve our understanding of and ability to predict processes that initiate convection, (3) to improve our understanding and prediction of how boundary layer and surface processes produce spatial heterogeneities of water vapor in the boundary layer and in turn how these heterogeneities impact the initiation and evolution of convection, and (4) how to optimally measure water vapor in pre-convective and convective environments for research and prediction purposes.

Within this larger context, two *MGLASS* are essential to the convective initiation research component. MGLASS will be used to launch soundings on each side of boundaries that may or may not trigger convection, as well as to give an overall assessment of the environmental stability. These systems can be used to provide regular soundings when the aircraft are not flying and are not dropping sondes. Furthermore, MGLASS will be used in studies to examine the boundary layer moisture evolution and determine the representativeness of the NWS 12Z radiosondes to estimate the daily potential for convective storms. These studies will take place in the general S-pol/central facility vicinity. Additionally the systems could be used west of the ARM/CART domain to enhance boundary condition measurements for QPF purposes.

7.2 Supporting Services

Is a RTF Scientific Project Manager needed for the project?
Yes

Summary of any special requirements that pertain to ATD support:
It would be valuable to have the sounding data transmitted back to the IHOP operations center in Norman as soon as possible after the launch to be used for planning our daily operations.

Has an ATD scientist/engineer/project manager been consulted to help complete this request? Yes

GROUND-BASED SYSTEMS:
INTEGRATED SOUNDING SYSTEM (ISS)

8.1 System Operations

Scientific rationale for the use of the system in the proposed project:
The scientific applications of the ***ISS*** include:

Supplementing the ground-based measurements utilized for QPF studies and for determining the larger-scale context to interpret the convective initiation and boundary layer measurements. The sounding site to the west of those voluntarily supported by ARM places measurements near where strong moisture gradients and convective initiation events are more likely to occur.

ii) The combined profiling instrumentation will also be utilized to study the dynamics of boundaries relevant to convective initiation studies as has been demonstrated by several studies (e.g., Parsons et al. 1991, MWR, 1242-1258; Hutchinson and Bluestein 1998, MWR, 141-166; May 1999, MWR, 1796-1807; Parsons et al. 2000, 3824-3838; Brown et al. 2001, in preparation). The high spatial and temporal capabilities of MAPR and the continuous measurements of vertical motion are particularly well suited to the task and integration with the Raman system (see Figs. 11 and 12 in the overview document). The continuous ground-based measurements of fronts, outflows, bores, drylines and other boundaries will be a cost-effective complement to the intermittent airborne measurements. Spatial variations will be addressed by examination of other sites with combined sensing systems (ARM Central Facility and the DIAL in the ABLE array) and the AERI sites.

iii) The location of the ISS-Raman lidar site within the S-Pol refractivity region will provide further data to verify that concept, to determine the heights represented by the measurements and to investigate the utility of refractivity measurements to representing the water vapor within the deeper boundary layer and to predicting convective behavior.

iv) The combination of the MAPR wind profiler and RASS of the ISS with the Raman lidar will be utilized to attempt to derive the vertical profile of sensible and latent heat fluxes. To our knowledge, this technique has not yet been attempted with Raman lidar and is possible only due to recent modifications made to the lidar system. Past studies using wind profiler data has been proven useful in also providing information about several key boundary variables including boundary layer depth (White et al. 1991, JAOT, 639-658), turbulent eddy dissipation rate (Jacoby-Koaly et al. 2000, MST-COST 76), vertical profiles of sensible heat flux (e.g., Angevine et al. 1993, JAM, 1901-1907) and information about the entrainment zone (e.g., Angevine et al. 1998; JAOT, 818-825). Soundings will be used to evaluate and understand these measurements. This information will and can be compared with airborne remote and in-situ sensing estimates and with numerical simulations as described in the goals of the ABL component.

v) ATD is embarking on a scanning water vapor DIAL development. Our experience with this technology and combining these measurements with other instrumentation will benefit this

NSF development**.**

Number of Systems requested:
1

Will you require balloon launches. If yes, how many sondes are needed? At what frequency over which time period will the sondes be launched?
Yes, 280, regularly about 5 times a day.

Is the RASS system needed? If so, will noise be an issue for the RASS operation (i.e., near residential areas)?
Yes. We would locate the system sufficiently far away from residential areas.

Do you have any special scanning requirements for the profilers?
No

Do you have experience in the analysis of profiler data? Are software tools available?
Yes

Is the MAPR system required? If so, why?
Yes, we'd like to obtain high resolution vertical velocity profiles to be combined with Raman lidar data. The combination of these instruments will provide us with vertical profiles of latent heat fluxes.

Do you plan to conduct Intensive Observing Period (IOPs)? Under which circumstances?
We plan to operate every day, in addition to some 24-hr intensive observing periods.

8.2 Supporting Services

Is an ATD Scientific Project Manager needed for the project?
Yes

How many of your staff will be available full time to help operate the system?
None.

Summary of any special requirements that pertain to ATD support:
None.

Has an ATD scientist/engineer/project manager been consulted to help complete this request?
Yes.

GROUND-BASED SYSTEMS:
INTEGRATED SURFACE FLUX SYSTEM (ISFF)

9.1 System Operations

Number of Systems requested:
9

Scientific rationale for the use of the system in the proposed project:
The overarching IHOP hypothesis is that the improved characterization of the water vapor field will result in significant, detectable improvements in warm-season QPF skill.

The ABL hypothesis is that improved understanding of the relationship between water vapor and surface and boundary layer processes will improve QPF ability. Specifically to be addressed by the flux towers are the following hypotheses, ordered according to the impact of the surface-flux data:

(a) Inclusion of improved LSMs will improve QPF. The towers will be used to test and improve the LSMs to be used. This effort will help to improve land-surface and ABL simulation in mesoscale models.

(b) Surface-flux measurements can improve characterization of the water-vapor field in time and space. This overlaps with (a). However, we seek to understand the relative role of vertical flux divergence and horizontal advection. This effort will help us understand what determines the water vapor distribution in the ABL.

(c) Heterogeneous surface properties (terrain, land-use, soil properties) produces mesoscale heterogeneities in the ABL. The requested towers will thus be placed along pre-determined flight tracks designed to isolate mesoscale heterogeneities in ABL structure and fluxes that result from surface heterogeneity. This effort will help us determine how land-surface heterogeneity (land-use, soil moisture and terrain) drive ABL development, including development of mesoscale (50-200 km) heterogeneities that could lead to storm initiation.

In addition, we will support the other components of IHOP:

QPF: Providing surface fluxes to test and improve LSMs and for generating flux maps, providing fluxes/flux maps for numerical weather forecast model testing, coupling improved LSMs to MM5 and performing simulations for selected IHOP cases and validating runs with IHOP data; to test the hypothesis that accounting for surface processes will improve QPF.

Instrumentation: Collocating a significant fraction of the requested flux towers near water-vapor sensing instruments and along flight tracks to enable an integrated comparison/synthesis that includes aircraft data (which provides spatial coverage) and surface-flux data (which provides temporal coverage), lidar and radar water-vapor estimates, etc.

Convective Initiation: We will combine surface and ABL sensing across boundaries in land-use and terrain to assess their potential in generating mesoscale variability that can contribute to storm initiation, in support of the hypothesis that improved water-vapor measurements will advance our understanding of processes that initiate deep, moist convection in the Southern Great Plains. The flux towers will provide surface measurements at strategic points across a few pre-selected terrain or land-use features.

Specifically, the ISFF will be needed to assess these scientific issues:

a. *Effect of Land-Surface on QPF:* Chen et al. (1998, *Proc. Spec. Sum. Hydrology*, AMS, Phoenix) have already shown that use of a version of the OSU LSM in the ETA model improves QPF on the synoptic scale. As noted in the overview document, IHOP will provide the first opportunity to use detailed and validated surface-flux data to directly examine its impact on convective initiation and QPF. It will also be the first study to test the coherence between land surface properties and fluxes at the mesoscale and convective boundary layer development. Methodology now exists for mapping surface fluxes from scattered surface stations, satellite, meteorological, and soil data (e.g., Song et al. 2000, J. Hydromet., 462-473; Anderson et al. 1997, Remote Sens. Environ., 195-216, Chen et al. AGU Dec. 2000). This affords the opportunity to study the impact of surface fluxes on the mesoscale evolution of the boundary layer and its role in storm initiation and intensification and QPF. Finally, data from the requested surface-flux installations would facilitate LSM improvements, such as incorporation of a dynamic vegetation/crop model (Chen et al. USWRP proposal, see Section 5), improved characterization of bulk canopy stomatal conductance (Uebelherr et al. AGU, Dec. 2000), and improved characterization of soil properties (Ek and Cuenca 1997, *JGR*, 7269-7277).

b. Characterization of the Water-Vapor Field and the roles of vertical flux divergence and horizontal advection: Water Vapor Budgets

ABL water vapor budget studies have typically been conducted either via flux aircraft (e.g. FIFE, BOREAS, CASES-97, SGP97) or repeated rawinsonde launches. In both cases the observational sampling is limited and uncertainties are large. Horizontal advection is particularly difficult to assess. The spatial gradients in water vapor are difficult to measure within and above the ABL (above is relevant for the entrainment portion of the budget) with in-situ airborne sampling. Also sources of validation, that is, independent estimates of the terms of ABL budget studies, have been limited. Measurements of the spatial variability of the ABL water vapor budget over heterogeneous terrain are almost completely lacking. The combination of large-area airborne water vapor DIAL data, flux aircraft, rawinsondes, and flux-tower validated surface flux mapping proposed for IHOP will provide a data set suitable to assess the ABL water vapor budget with a degree of confidence that has only been approached in recent campaigns for 1-2 case studies. The proposed combination of airborne Doppler lidar and DIAL has never been done before and would represent a major instrumental advance. Observational evaluation of the spatial variability of daily ABL H_2O budgets would be entirely new. The surface flux measurements are critical to providing a proven lower boundary for this work.

c. We have the opportunity to assess the roles of terrain and land-surface properties (vegetative cover, soil properties, soil moisture) in setting up mesoscale circulations, concentrating fluxes, and initiating convection. The surface towers have a particularly significant role in verifying and assessing the mechanisms of flux concentration.

Mesoscale Circulations.

There is ample numerical modeling evidence that land-surface properties (vegetative cover, soil properties, soil moisture) affect local heating and evapotranspiration, and hence the distribution and intensity of convective storms in idealized situations (e.g., Pielke et al. 1997, *Ecological Applications*, 3-21). However, observations of such circulations are rare. Mahrt et al. (1994, *JAS*, 2484) found weak "inland breezes" during light-wind conditions over flat terrain, but only at 33 m, and there are reports of "forest breezes" in HAPEX (e.g., Andre et al., 1988, *Ann. Geophys*, **6**, 477; Mahrt and Ek, 1993, *BLM*, **65**, 381). Finally, Tapper (1997, *J. Paleogeography, Paleoclimatology, Paleoecology*, **84**, 259) reports a mesoscale thermal circulation over a dry salt flat in Australia.
Similarly, numerical simulations of convective PBLs over varying terrain by Walko et al. (1991. BLM, 133-150), Krettenauer and Schuman (1992, *JFM*, **237**, 261-299), and Gopalakrishnan et al. (*JAS*, 2000, 334-351) produce circulations with upwelling air over hills, and downwelling air over valleys, for terrain similar to the IHOP domain (of the order of 10-15% ABL depth). But observations are again limited. Analysis of ARM data by Shaw and Doran (2001, *J. Climate*, **14**, 1753-1764) indicate that surface air temperature and convergence patterns are more closely linked to terrain than to land use in the ARM-CART (IHOP) domain, with convergence-divergence patterns consistent with the modeling studies. Analysis of CASES-97 data in the Walnut River Watershed in the NE part of the IHOP domain (map, p. 10) provides an example of a mesoscale circulation that extended through the boundary layer, with upwelling air over the edges of the watershed and downwelling air over the lowlands (LeMone et al. 2001, BLM, submitted, AGU presentations by LeMone and Grossman, Dec. 2000; LeMone et al., June 2001).

We hypothesize that the lack of success in observing such circulations is for the following reasons:

(a) the significant mesoscale circulations or variability result from both land-surface and terrain variability. Segal et al. (1989, *MWR*, **117**, 109), for example, found both factors to contribute to mesoscale variability. LeMone et al. (2001) point out that land use could reinforce the observed circulations.

(b) The observations are often on too small a scale to capture the significant circulations. Simulations by Avissar and Chen (1993, *JAS*, **50,** 3751) and Chen and Avissar (1994, *JAM*, **50**, 3751) and a theoretical study by Dalu et al. (1991, *Ann. Geophys.*, **9**, 641) suggest that the wavelength (upwelling + downwelling portions) is of the order of the Rossby radius, of the order of 100+ km).

(c) The observations are often limited to one dimension, e.g. in situ instrumentation on a single aircraft. It is challenging to document evolving two- and three-dimensional flows that may exist at the mesoscale with these observations.

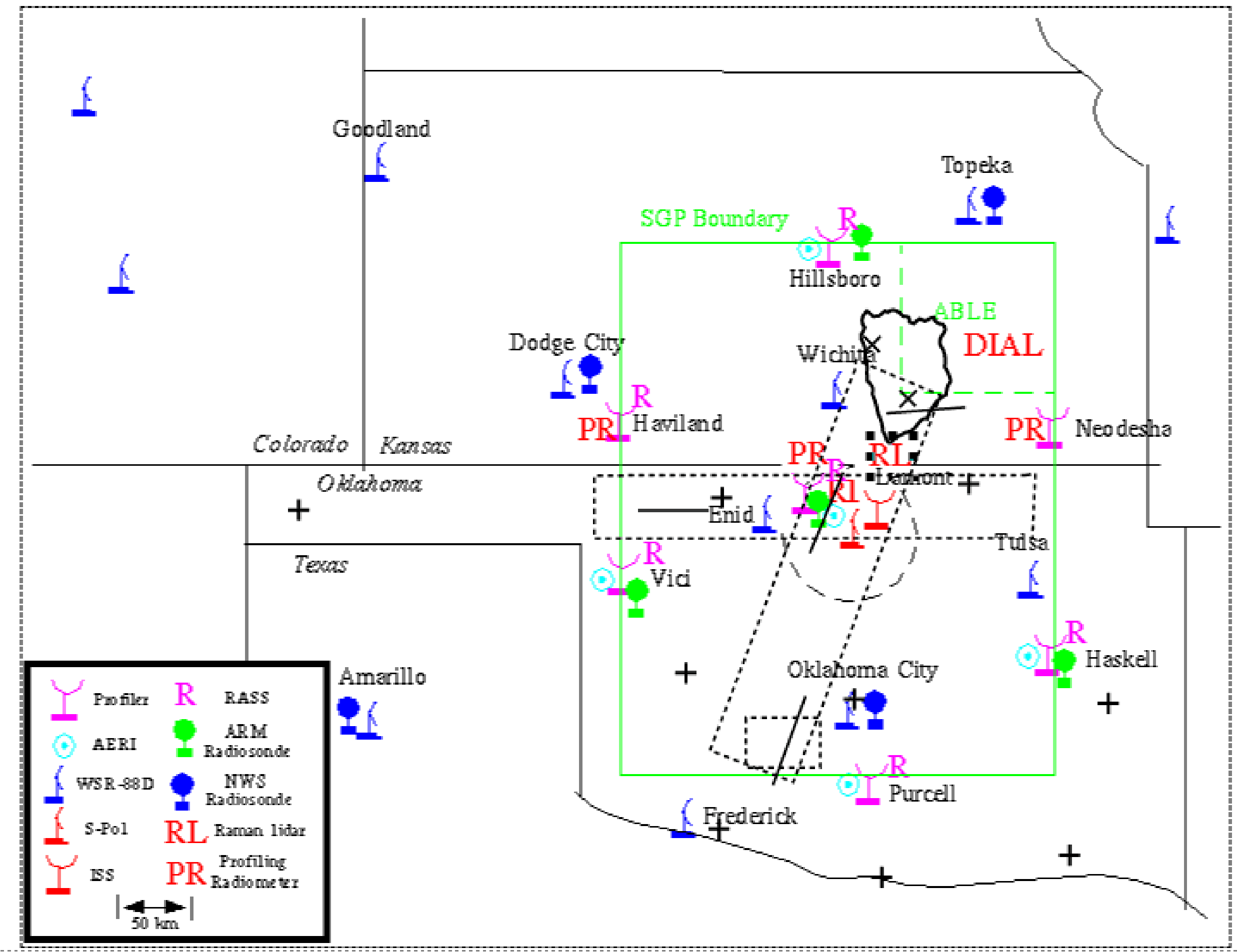
These issues will be addressed in IHOP through a nested approach. Repeated 300-km flight tracks oriented roughly along and across the prevailing ABL wind will be flown by the NRL P3 and DLR Falcon, which will use lidar to create two-dimensional “curtain” views of the atmosphere encompassing a wide range of surface heterogeneity across the IHOP domain. King-Air patterns will sample fluxes and BL structure up to the 50-km scale on fixed tracks close to the DLR Falcon and NRL P3 tracks, using both in-situ measurements and the Wyoming Cloud Radar. The surface-flux stations will be concentrated along the King-Air fixed tracks, which will be sited across terrain features and land-use boundaries. Both the King-Air tracks and the 300-km tracks will cross the major ground-based instruments (radar, lidar, etc.) deployed in the IHOP array. Some of the King-Air patterns will be in coordination with the Convective Initiation Group’s mobile armada, which has Doppler radars, surface meteorological measurements, radiosonde launches, and wind-profiling systems.

Concentration of Fluxes

Recent results by Grossman et al. (Dec 2000, AGU presentation) suggest that one of the reasons that they were not able to match LSM-predicted fluxes to those based on data from low-lying aircraft may relate to terrain or land-surface processes not being properly accounted for in the LSMs On more than one day in CASES-97, there appeared to be a persistent maximum in sensible heat flux over a quasi-level shelf of land just west of the eastern edge of the Walnut River watershed. The maximum coincides with a 10-km scale maximum in infrared brightness (“surface”) temperature, which is associated with locally flat terrain (through some combination of soil properties, slope, aspect), vegetative cover, and soil moisture patterns. However, the three LSMs used (OSU LSM, NCAR LSM, and SOLVEG, an LSM recently developed by Nagai of the Japanese Atomic Energy Agency) do not replicate this maximum. It is hoped that surface tower measurements over this area, complemented by careful measurements and documentation of soil characteristics, will clarify whether the models failed to reproduce the flux maximum because of poorly-documented soil properties or inadequacies in the models.

Aircraft data from both the large-scale and 50-km tracks will be examined for evidence of similar persistent flux extrema. One flux tower will be sited within the terrain feature associated with the persistent sensible-heat flux maximum in CASES-97.

How will the ISFF be used to test the hypotheses and address each of the objectives?
The following map superimposes the proposed experimental design on the IHOP array. It is uncertain which of the dozen of so ARM/CART Bowen-ratio or eddy-flux stations are represented in Table 1, so these are not plotted, but it is assumed they are widely distributed across the ARM/CART domain. Similarly, the location of the second eddy-correlation site in the ABLE area during the time of IHOP is unknown, but a location somewhere in the northwest part of the watershed is likely, since an intensive hydrologic experiment will take place at that location during IHOP.



Map: IHOP experimental design, with selected surface-flux towers and ABL aircraft component superimposed. Crosses: 9 OASIS (Oklahoma Mesonet) eddy-correlation flux sites. Walnut River watershed (ABLE location) is outlined. The southern X in the watershed is the Smileyberg eddy-correlation site (grassland); the other X is Whitewater (Bowen ratio flux and Cuenca soil array site). A second eddy-correlation site will probably be located north of the Whitewater site for a DOE field campaign. Small rectangle: Little Washita area. Long rectangles: general area of proposed repeated ABLE flight tracks. Solid lines. Possible King Air flight tracks, to be decided during site survey. NCAR surface flux stations will be sited along the selected King-Air tracks.

The long rectangles on the map mark the general locations of the repeated flight tracks for the DLR Falcon and the NRL P3, designed to map the horizontal variability, particularly of water vapor, in the boundary layer and to provide data that will be used to explain the variability. The shorter (~50 km) flight tracks are *schematic* locations of four proposed King-Air flight tracks, located to maximize impact of terrain and land-use variability and collocation with other instruments; three will be selected. Assuming that we have access to the flux data listed in Table 1, current thinking is that the surface stations will be evenly divided among the three locations and lie along the flight tracks, located thus:

- Little Washita: Located in the southern rectangle (Little Washita River basin) is along-wind, would be underneath the IHOP-scale flight track, would take advantage of long-term soil-moisture measurements in the southern part of the domain. A concern is that there may be too much terrain variability for good surface-flux aircraft intercomparisons.
- Lamont: The track at Lamont is along-wind, would be underneath the IHOP scale flight track if the flight track curved to go over Lamont, and is normal to the local river (Salt Fork of the Arkansas). It would be within range of much of the equipment to be located at Lamont.
- ABLE: The track in the ABLE area is roughly cross-wind, and normal to the Walnut River, basin-scale elevation contours, and land-use boundaries; would be underneath the northern extent of the IHOP scale aircraft track, and close to currently proposed DIAL location. The track (and thus surface stations) might be moved northward for synergism with DOE intensive hydrologic field campaign which occurs at the same time.
- West of Lamont: The track would parallel the east-west P-3 or Falcon track, and would be used at times for joint ABL-CI studies. It represents the far western, highest elevation, low precipitation portion of the study area.

The maximum separation of the stations along each flight track would be around 40 km, since the flight tracks are 50 km long, and it is unlikely that we would site stations at the ends of the flight tracks. Where possible, we will take advantage of flux or soil-moisture measurements already in place.

Siting issues: We have considerable experience with siting in the ABLE area, and would expect to pay a modest fee for leasing (this has been true for previous experiments). Tom Jackson (letter, Appendix) anticipates that leases would not be required in the Little Washita if NCAR works through the ARS (process outlined in letter). He notes that the procedure at Lamont might be more difficult if siting is arranged through ARM. We anticipate sites with grassland, crops, or shrubland.

a. *Effect of Land-Surface on QPF*

Flux maps for the IHOP domain will be developed for selected cases by using spatially distributed flux tower and flux aircraft data to calibrate LSMs (e.g., the OSU LSM) that are run using gridded meteorological, radar precipitation, satellite, soil-characteristics and land-cover data such as EROS and STATSGO (which will be checked, see Table 4) as inputs. Flux towers will provide diurnal cycles of surface fluxes spanning the range of land cover typical of the study area. The King Air (see aircraft facility request) will sample fluxes along tracks collocated with surface towers to “regionalize” the results of the flux towers. This requires concentrating towers along a few flight tracks (for the “regionalization”) and distributing the flight tracks horizontally to capture a range of surface conditions (e.g., winter wheat is harvested in central Oklahoma a few weeks before harvest in Kansas; climate becomes drier east to west). The tracks will be selected to cover a range of surface types (according to ground cover, elevation/terrain), with surface flux stations representing the surface types. For this purpose, we will use all the available flux towers in the IHOP domain (Table 1, Map), and supplement these fluxes with the NCAR flux towers.

An improved version of the OSU LSM, including a dynamic vegetation/crop model and tested using IHOP data, will be coupled with MM5 to predict the impact of surface heterogeneity (both local and remote) on the development of mesoscale patterns in the boundary layer, convective initiation, and precipitation. The predicted mesoscale patterns will be compared to observations of boundary layer depth and water vapor content collected via airborne lidar, radar, etc.

Table 1: Surface-flux stations in IHOP.

Network	No.	Type	Locations	Reference
OASIS	10	Eddy Correlation (EC)	Oklahoma (map)	Brotzge (2000) Dissertation. OU.
ABLE	3	2EC, 1Bowen Ratio (BR)	SE Kansas (map)	LeMone et al. 2001 (BAMS, 757)
ARM*	5	BR	KA, OK.	ARM CART web site, Wesely.
ARM *	5	EC (currently not functional)	KA, OK	“
AmeriFlux	1	EC	OK	ARM CART site, M. Fischer, LBNL
NCAR	9	EC	KA, OK	

*M.L. Wesely, personal communication.

b. Water-Vapor Distribution and Budgets

We have hypothesized that the water-vapor distribution in the Southern Great Plains results from a mixture of local (vertical flux divergence) effects and regional (horizontal transport) effects. The long aircraft transect for the DLR Falcon (see map) will provide remotely-sensed estimates of flux divergence along those flight lines; the surface towers will provide point surface flux data that can be used to produce surface-flux fields using the King Air fluxes and the LSMs.

c. Mesoscale Variability

We will select surface locations in the vicinity of the concentrated measurements in IHOP to document mesoscale variability of ABL structure and fluxes and their relationship to surface characteristics (vegetative cover, soil properties, soil moisture) and terrain. The ABL group will use aircraft sampling at two scales: The scale of the IHOP domain (about 300 km), and the 50-km scale. The IHOP-scale flight tracks (map) will be fixed, one track running NNE from the Little Washita River Basin to the ABLE area and a second track running east-west through Lamont. The tracks thus cross all four locations the ABL group is considering for intensive study: (a) the ABLE region, (b) the Lamont area, and (c) the Little Washita area, and (d) an area 50-100 km west of Lamont. These sites were selected because of concentration of ground-based measurements, their location along the IHOP-scale flight patterns, and because they represent a range of land-surface and climate .

9.2 Radar Display and Communications Needs

Data reporting and averaging intervals required for ISFF:
5 min averaging of fluxes, 1 min averaging of standard meteorological variables

Special sensors on ISFF:

Table 2: Descriptions of measurements at NCAR flux sites for IHOP

Measurement	Sensor	Frequency	Comments
REQUIRED			
Radiation			
Downward Solar	PIR	Continuous	Available
Downward longwave	PSP	Continuous	Available
Net Radiation	Q7	Continuous	Available
IR “surface” temp	Everest?	Continuous	
PAR	Licor Quantum	Continuous	Standard, have 6, $315 each
Soil			
Soil Heat Flux	HFT	Continuous	Standard
Soil Moisture	CS615	Continuous	5 cm, standard
Soil Temperature	REBS	Continuous	5 cm, standard
Fluxes			
Sensible Heat	Sonic	Continuous	Standard
Latent Heat	Sonic/krypton	Continuous	Standard
Carbon Dioxide		Continuous	Min: 2 sites w/different veg cover
Weather Data			
Temperature	T/RH	Continuous	Standard
Humidity	T/RH	Continuous	Standard
Wind	Prop-vane	Continuous	Standard
Pressure	Vaisala barometer	Continuous	Standard
Rainfall	Tipping Bucket	Continuous	Standard
DESIRED			
Soil			
Soil moisture (strong first choice)	Many CS615 is first choice	Continuous	3 levels adequate (5, 30, 100 cm) Other option: Vitel sensor profile? Gypsum for 1 m and greater?
(alternative)	Trime Tube + augur	2 times a week	NSF deployment; PIs and students take measurements
Soil temperature profile	NCAR thermocouples?	Continuous	NCAR Build?
Soil thermal conductivity	Lab sample		See Table 3
Soil hydraulic Conductivity	Lab sample		See Table 3

Of the ‘desired’ measurements, we (the PIs, NCAR) have the least experience with soil properties (thermal and hydraulic conductivity). Not surprisingly, poor representation of these properties is a significant limitation in LSMs. (Ek and Cuenca, 1996, *JGR*, 7269-7277). Thus we contacted Richard Cuenca of Oregon State University (collaborator on CASES and Chen et al. USWRP grant, see section 5), who designed a complementary suite of measurements that would provide the ‘desired’ data. (see the following table). Similar instrumentation is currently operational over a 175 x-200 m array at the ABLE Whitewater site. Cuenca will seek funding (from NSF Hydrology or GAPP) to make such measurements at one or more NCAR sites in the IHOP domain. .

Table 3: IHOP Soil Moisture / Soil Hydraulic Property Instrumentation (Richard Cuenca, Hydrology Science Team (HST), Oregon State University)

Objectives: Continuous monitoring of soil moisture content, soil water tension (potential), soil temperature profiles, from surface to depth of 135 cm in six soil horizons (i.e., measurements centered at 0.075, 0.225, 0.375, 0.600, 0.900, and 1.200 m depth for three depth layers of 15 cm thickness each from surface followed by three depth layers of 30 cm each). Data collected to support parameterization of the following soil properties: soil bulk density, saturated hydraulic conductivity, unsaturated hydraulic conductivity function, thermal conductivity, soil-water retention function.

Assumptions: HST can provide soil bulk density and tension infiltrometers to run infiltration tests for determination of hydraulic conductivity function. Thermal IR for surface temperature will be measured as part of site instrumentation. Price list is for one profile. Three profiles per site is optimum.

Instrument/Parameter	Number Per site	Unit Cost	Cost per Site
Decagon ECH_2O Dielectric Aquameter – TDR soil moisture	6	75	450
Campbell Heat dissipation Matric Water Potential – soil water tension	6	95	570
Campbell Soil Temperature probe – soil temperature	6	68	408
Campbell CR10X Micrologger	1	1190	1190
Campbell keyboard/display, thermocouple reference, 12 V power supply with charging regulator and sealed rechargeable battery for CR10X	1	555	555
Campbell 12 x 14 in fiberglass enclosure and mounting bracket	1	250	250
Campbell 10 W solar panel with mounts	1	220	220
Miscellaneous wiring, hardware and software (@ 15 per cent of sum of unit costs)	1	368	368
TOTAL			4011

NB: Price list reflects cost of an autonomous installation in terms of power and micrologger. Prices of tripod for mounting CR10X enclosure and micrologger communications have not been accounted for. Total cost of soil sensors to incorporate with existing micrologger and communication-ready installation is $1,428 per profile. Using this figure, total cost for two instrumented profiles at the same site is $5,439 and total cost for three profiles is $6,867.

Supplemental Measurements:

Simply documenting the vegetation photographically and characterizing height and fraction of vegetation types qualitatively proved to be useful in evaluating LSM inputs and performance with CASES-97 data. In particular, it was found that the greenness fraction estimated by NDVI was an overestimate; adjusting greenness downward based on photographic evidence improved LSM behavior. Uebelherr et al. (AGU 2000) showed a strong relationship between satellite-derived NDVI and bulk canopy stomatal conductance during the month-long grassland greenup in CASES-97. Adding local estimates of NDVI and LAI to photographs and plant characterization and to the satellite and other data used as input into LSMs would put such work on firmer ground. In addition, the supplemental measurements described below will provide valuable data for comparison to modeled plant life cycle, which Chen plans to insert into the OSU LSM. As in CASES-97, the PIs and students will collect these supplemental data in coordination with NCAR staff and in ways consistent with agreements with landowners.

Table 4. Supplemental Measurements

Measurement	Method	Frequency	Who?
Vegetation			
Photographs of sites to N,S,E,W	Student/PI site visit with digital camera	Weekly	PIs
Vegetation description	Different types of land cover with heights, estimate of fractional cover. Cross reference with photos and LAI.	Weekly	PIs
LAI	Student/PI use Licor LAI2000 applied to characteristic vegetation in footprint.	Weekly	PIs
NDVI	Student/PI manual observations with reflectometer	Weekly	PIs
Evapotranspiration	ET (sensor type?)	Continuous	NCSU
Soil			
Sand, silt, clay content	Soil samples surface to 1 m. (at least depths sampled)	Begin and end IHOP	NCAR or PIs
Soil cores for comparison to automated measurements	Student/PI visit. OASIS only?	Weekly?	OU?
Land use in vicinity	Student Survey	Beginning and end?	PIs

Discussions among the listed investigators (LeMone, Davis, Grossman, Chen) and Sethu Raman and Dev Niyogi of North Carolina State University and Jeff Basara at University of Oklahoma suggest that several students would be available to help collect the data specified in Table 4. A candidate scenario being discussed is having teams of students assigned to the three NCAR sites, and a fourth team working on OASIS sites. Funding would be sought for needed instrumentation and student costs not covered by current grants.

9.3 Supporting Services

Is an ATD Scientific Project Manager needed for the project?
Yes

Summary of any special requirements that pertain to ATD support:
In the field, time-series plots of variables by station are desirable in real time for quality control and check on conditions in the three areas, at the IHOP operations center in Norman. Real-time fluxes only for checking instrument performance, so need only be at ATD operations center.

For analysis, preferred formats are Ascii and netcdf. Archive fluxes and means at 5 min frequency. Record one-minute averages of meteorological data (for boundary tracking in support of convective-initiation part of experiment). Distribution on the web is acceptable. It is assumed that standard corrections (tilt angle, etc.) will be applied to the data before release to the PIs.

For display on the Web: Time-series plots of variables by station, both during the field program and afterward. It should be freely accessible, so that the landowners and students can see it as well as IHOP participants.

Data distribution according to UCAR policy.

Has an ATD scientist/engineer/project manager been consulted to help complete this request?
Yes

Appendix: Exchange of letters regarding Little Washita, one of the four sites currently being considered for concentrating surface towers

From lemone@mmm.mmm.ucar.EDU Mon Jun 18 23:01:32 2001
Hi Tom,
At the AGU, you suggested that we might consider siting some NCAR flux stations that we wanted to put in the Little Washita area at sites where soil moisture and temperature were already being measured.

I have been looking at the web site (http://hydrolab.arsusda.gov/sgp97/ and note several sites (numbered LW 1-23).

(a) Are these sites still active? If not, where are the active sites?
(b) What soil data are available from these sites? Fei Chen is interested not only in soil moisture and temperature profiles but also soil hydraulic conductivity and soil thermal conductivity, as well as soil composition.
(c) If NCAR allows us to deploy some surface towers for IHOP, what procedure should the PIs and NCAR go through the secure permission, etc.?

Will there be a lease cost?

(The current thinking is locating three flux towers in the Little Washita area).

(d) Have you decided whether or not to go ahead with SGP-2002?

Re IHOP:

The current thinking is that we would want to site the towers along a roughly north-south (along-wind) direction, and fly the University of Wyoming King Air several times along the track, to relate tower fluxes to aircraft fluxes and hopefully use this for 'regionalization' or 'scaling up.' A second aircraft (probably the DLR Falcon with downward looking Doppler lidar and water-vapor lidar) would fly along roughly the same track, at a higher level, on several days.

This would be one of three areas of concentration -- the north area being Argonne's Atmospheric Boundary Layer Experiments (ABLE, site of CASES-97), and near Lamont, where some additional instrumentation will supplement what's already there.

(e) I note several soil sites near Lamont (CF 01-10). Are these still active, and if so, would it be feasible to collocate with one or these locations? (if so, other questions regarding permission/leasing etc. apply).

Good seeing you at AGU -- one of the many things that made staying until Saturday worthwhile!

Best regards,

Peggy

Response:
From tjackson@hydrolab.arsusda.gov Wed Jun 20 10:46:47 2001
To: "Peggy Lemone" <lemone@ncar.ucar.edu>
Subject: RE: IHOP

Peggy,

As a reminder, I'm still waiting to see what happens w/ the schedule for the NASA Aqua launch before I fully commit to Oklahoma in 2002. It could be 2003.

The sites we'll use will be a subset of the ones you identified. Of these sites, we have a continuing interest in LW03 (with 04 and 05), LW11 (with 12), LW02, and LW21. These sites have been fully characterized in previous studies.
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/SGP97/soil_prop.html

Most of our "sites" are small enclosures near a road for a met station and soil moisture. At the sites noted above we have had pretty good relationships with the owners and have had towers placed there temporarily w/o problems. I don't anticipate that there would be any lease required if
things are done through ARS. Our local support has good relationships and if the visitors observe the usual good neighbor procedures things work fine.

The process would be:

- Come up with a tentative request (number of sites, square feet needed, known constraints, land cover, access required (foot or vehicle), enclosure, time line, power.....
- I send a note to ARS OK requesting coop
- They say OK in principle and assign a POC
- Here or previously, you make site visit to look at options (fetch, cover, ...and resolve with the POC
- Final request
- POC will secure access
- ARS would not incur any out of pocket costs

With regard to Lamont, I'm still thinking. This will depend on several things. But I can answer some of your questions:

- Site arrangements are made through the ARM folks. They are much more formal than we are and they charge for most everything!
- We characterized most of the sites (soils, etc) in 97

Finally, note that there are ARM towers at LW03, LW08 (bad site for soils), and at the CF.

Hope this gives you a starting point.

Tom