DEPT of ATMOSPHERIC SCIENCE
P.O. BOX 3038
LARAMIE, WY 82071-3038
(307) 766-4947/Phone
(307) 766-2635/Fax

REQUEST FOR WYOMING KING AIR SUPPORT

Rec'd:

Date submitted:

IHOP 2002

Proj. No.: **WYO-0201**

A. IDENTIFICATION (2 contacts)

1. Name: **Peggy LeMone**	2. Title: Senior Scientist	3. Dept./Institution: NCAR MMM	
4. Address: P.O. Box 3000 Boulder, CO 80307-3000		5. Phone: (303) 497-8962 Fax (303) 497 8181	6. Signature:
1. Name: **Bart Geerts**	2. Title: Dr.	3. Dept./Institution: Atmospheric Sciences/ University of Wyoming	
4. Address: Dept. of Atmospheric Sciences, Univ. of Wyoming, Laramie, WY 82071		5. Phone: 307 766 2261 Fax: 307 766 3681	6. Signature:

8. Other Persons and Their Responsibilities in Proposed Airborne Research:
CI group: Drs. David Kingsmill (DRI), Dr. Conrad Ziegler (NSSL)
ABL group: Drs. Kenneth Davis (PSU), Dr. Robert Grossman (CU)
QPF group: Dr. Steven Koch (NOAA FSL), Dr. Fei Chen (NCAR)

9. Project Title (about three words for identification purposes): **IHOP 2002**

10. Abstract (suitable for publication) of Proposed Program:

The primary goal of the International H_2O Project (IHOP), to be conducted in Oklahoma, Kansas, and the Texas Panhandle between 13 May and 30 June 2002, is improved characterization of the 4-D distribution of water vapor and its application to improving the understanding and prediction of the initiation and organization of deep convection. The region of the Southern Great Plains of the U.S. is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and continued low skill in the short-term prediction of convective initiation. The IHOP investigators will focus on four coordinated and overlapping research themes:

i) the contribution of Atmospheric Boundary Layer (BL) processes to atmospheric moisture variability;
ii) mechanisms of Convection Initiation (CI);
iii) Quantitative Precipitation Forecasting (QPF); and
iv) remote and in situ measurements of water vapor: Instrumentation Research and Validation.

The Wyoming King Air (UWKA) will be used in primary support of themes i (BL processes), ii (convective initiation), and iii (QPF); instrument intercomparisons are designed into several aircraft missions.

11. Importance of the Proposed Airborne Measurements to the overall Research Project:

The UWKA is one of several aircraft to participate in IHOP. The Scientific Overview Document for IHOP2002 (Parsons et al. 2001, http://www.atd.ucar.edu/dir_off/projects/2002/IHOP.html) should be consulted for more detailed information on airborne and ground-based instrument platforms. The key contributions of the UWKA are:

First, the UWKA is equipped with state-of-the-art atmospheric research probes, to measure winds, temperature, pressure, humidity, cloud properties, and radiative fluxes. Of particular importance are high frequency probes, allowing flux estimation, mainly of latent and sensible heat. These flux measurements, plus profiles of moisture and other thermodynamic quantities, are essential components for determining the link between land surface properties, surface fluxes, organized large eddies in the boundary layer, lines of convergence, BL clouds, and ultimately deep precipitating convection.
King-Air fluxes at 100 ft agl (above ground level) will be used in ‘regionalizing’ surface fluxes, contributing to validation and improvement of land-surface models and, with addition of satellite data and information on soil properties, generation of surface-flux maps for numerical simulations; both efforts are aimed at improving QPF. King-Air in-situ measurements are essential to validate and complement remotely-sensed winds and moisture fields, in particular from the ELDORA and LEANDRE-II aboard the NRL P3, and the DLR DIAL and HRDL aboard the DLR Falcon, and from ground-based sensors such as water vapor, temperature, and wind profilers, and fixed and mobile precipitation radars. In order to optimize comparisons of water vapor and water-vapor fluxes to those from other platforms, a second high-frequency water vapor probe is being requested. Particle probes will be used to validate S-POL polarimetric hydrometeor classification schemes in stratiform precipitating convection, which will be used to verify FSL Water-In-All-Phases Analyses, and in CI missions.

Secondly, the UWKA is proposed to carry the Wyoming Cloud Radar (WCR) operating in dual beam (nadir-fore) mode. Transects of nadir reflectivity visualize thermals and other large organized eddies in the BL. The vertical echo and airflow structure of BL convergence zones (radar 'fine-lines') can be used to understand how these fine lines modulate low-level moisture and initiate deep convection. Nadir reflectivity profiles in precipitation can also be used to assess the effect of S-POL vertical smoothing in hydrometeor classification.

The data from previous convection initiation experiments such as CINDE and CaPE have been used quite effectively to improve understanding of the kinematic structure of boundaries. 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 detailed kinematic and moisture datasets and thus to make significant progress in understanding convection initiation. Similarly, previous boundary-layer experiments such as CASES '97 and SGP-97 allowed detailed analysis of the moisture transfer between the surface and the free atmosphere, but the ability describe and explain horizontal moisture advection and 4-D mesoscale variations was limited. IHOP's multi-platform design allows a bridging of scales, ranging from microscale surface and flux processes to sub-synoptic forcing.

12. Previous Airborne Research Experience of Requesting Scientist (list all previous NCAR/RAF, Wyoming and other aircraft-supported research):

LeMone: STORM-FEST, TOGA COARE, CASES97; CASES99
Grossman: GALE, FIFE, STORM-FEST, TOGA COARE, CASESE97;
Davis: BOREAS, LASE validation, SGP97, COBRA
Kingsmill: ERICA, CaPE,, MCTEX, CALJET, IPEX, KWAJEX, PACJET
Ziegler: COPS (89,91), VORTEX (94,95), MEaPRS-98
Geerts: GALE, TOGA-COARE, TEFLUN, TRMM-LBA
Koch: STORM-FEST, COPS-91, CCOPE, NSSL field projects 1977-8.
Chen: CASES-97 UWKA and NOAA Twin Otter data analysis

13. List of Publications Resulting from Past Flight Support:

LeMone:

LeMone, M.A., 1995: The cumulus-topped boundary layer over the ocean. *The Boundary Layer and its Parameterization*. C.-H. Moeng, Ed., NCAR 109-136.

Miller, L.J., M.A. LeMone, W. Blumen, R.L. Grossman, N. Gamage, and R.J. Zamora, 1996: The low-level structure and evolution of a dry cold front over the central United States. Part I: Mesoscale observations. *Mon. Wea. Rev*., **124**, 1648-1675.

Blumen, W., N. Gamage, R.G. Grossman, M.A. LeMone, and L.J. Miller, 1996: The structure and evolution of a dry cold front over the central United States. Part II: Comparison with theory. *Mon. Wea. Rev*., **124**, 1676-1692.

Lucas, C., E.J. Zipser and M.A. LeMone, 1996: Reply to 'Comment on convective available potential energy in the environment of oceanic and continental clouds.' *J. Atmos. Sci*., **53**, 1212-1214.

Sun, J., L. Mahrt, S.K. Esbensen, J. Howell, C.M. Greb, R.L. Grossman, and M.A. LeMone, 1996: Scale dependence of air-sea fluxes over the western equatorial Pacific. *J. Atmos. Sci*., **53**, 2997-3012.

LeMone, M.A., E.J. Zipser and S.B. Trier, 1998: The role of environmental shear and thermodynamic conditions in determining the structure and evolution of mesoscale convective systems during TOGA COARE. *J. Atmos. Sci*., **55**, 3493-3518.

LeMone, M.A., M. Zhou, C.-H. Moeng, D.H. Lenschow, L.J. Miller and R.L. Grossman, 1999: An observational study of wind profiles in the baroclinic convective planetary boundary layer. *Bound.-Layer Meteor*., **90**, 47-82.

Igau, R.C., M.A. LeMone and D. Wei, 1999: Updraft and downdraft cores in TOGA COARE: Why so many buoyant downdraft cores. *J. Atmos. Sci*., **56**, 2232-2245.

LeMone, M.A., R.L. Grossman, R.T. McMillen, K.-N.Liou, S.C. Ou, S. McKeen, W. Angevine, K. Ikeda, and F. Chen, 2001: CASES-97: Late-morning warming and moistening of the convective mixed layer over the Walnut River watershed. *Bound.-Layer Meteor.*, submitted.

Davis:

Yi, C., K.J. Davis, P.S. Bakwin, and B.W. Berger, Long-term observations of the evolution of the planetary boundary layer. In press, *J. A Sci.*

Davis, K.J., N. Gamage, C. Hagelberg, D.H. Lenschow, C. Kiemle and P.P. Sullivan, 2000. An objective method for determining atmosp structure from airborne lidar observations. *J. Atmos. Oceanic Tech.*, **17**, 1455-1468.

Giez, A., G. Ehret, R. L. Schwiesow, K. J. Davis and D. H. Lenschow, 1999. Water vapor flux measurements from ground-based vertically-pointed water vapor differential absorption and Doppler lidars, *J. Oceanic Atmos. Tech.,* **16**, 237-250.

Davis, K. J., D. H. Lenschow, S. P. Oncley, C. Kiemle, G. Ehret and A. Giez, 1997: The role of entrainment in surface-atmosphere interactions over the boreal forest. *J. Geophys. Res*., **102**, 29219-29230.

Kiemle, C., G. Ehret, A. Giez, K. J. Davis, D. H. Lenschow and S. P. Oncley, 1997: Estimation of boundary-layer humidity fluxes and statistics from airborne DIAL. *J. Geophys. Res*., **102**, 29189-29204.

Oncley, S.P., D.H. Lenschow, K.J. Davis, T.L. Campos and J. Mann, 1997: Regional-scale surface flux observations across the boreal forest during BOREAS. *J. Geophys. Res*., **102**, 29147-29154.

Sun, J., D. H. Lenschow, L. Mahrt, T. L. Crawford, K. J. Davis, S. P. Oncley, J. I. MacPherson, Q. Wang, R. J. Dobosy, and R. L. Desjardins, Lake-induced atmospheric circulations during BOREAS, 1997*: J. Geophys. Res*., **102**, 29155-29166.

Ehret, G., A. Giez, C. Kiemle, K. J. Davis, D. H. Lenschow, S. P. Oncley and R. D. Kelly, 1996: Airborne water vapor DIAL and in situ observations of a sea-land interface. *Contrib. Atmos. Physics*, **69**, 215-228.

Grossman:

Grossman, R.L., and N. Gamage, 1995: Moisture flux and mixing processes in the daytime, continental convective boundary layer. *J. Geophys. Res.*, **100**, 25, 665—25,678.

Blumen, W., N. Gamage, R.G. Grossman, M.A. LeMone, and L.J. Miller, 1996: The structure and evolution of a dry cold front over the central United States. Part II: Comparison with theory. *Mon. Wea. Rev*., **124**, 1676-1692.

Sun, J., L. Mahrt, S.K. Esbensen, J. Howell, C.M. Greb, R.L. Grossman, and M.A. LeMone, 1996: Scale dependence of air-sea fluxes over the western equatorial Pacific. *J. Atmos. Sci*., **53**, 2997-3012

LeMone, M.A., R. Grossman, R. Coulter, M. Wesely, G. Klazura, G. Poulos, W. Blumen, J. Lundquist, R. Cuenca, S. Kelly, E. Brandes, S. Oncley, R. Mcmillen, and B. Hicks, 2000: Land-atmosphere interaction research and opportunities in the Walnut River Watershed in Southeast Kansas: CASES and ABLE. *Bull. Amer. Meteor. Soc*., **81**, 757-780.

Miller, L.J., M.A. LeMone, W. Blumen, R.L. Grossman, N. Gamage, and R.J. Zamora, 1996: The low-level structure and evolution of a dry cold front over the central United States. Part I: Mesoscale observations. *Mon. Wea. Rev*., **124**, 1648-1675.

Song, J., M.L. Wesely, M. A. LeMone, and R. L. Grossman, 2001: Estimating watershed evapotranspiration with PASS. Part II: Moisture budgets during drydown periods. *J. Hydrometeorology*, **1**, 462-473.

.

Yates, D.N., F. Chen, M. LeMone, R. Qualls, S. Oncley, and R. Grossman, 2000: A CASES dataset for analyzing and parameterizing the effects of land-surface heterogeneity on area-averaged surface heat fluxes. *J. Appl. Meteor*., in press.

LeMone, M.A., R.L. Grossman, R.T. McMillen, K.-N.Liou, S.C. Ou, S. McKeen, W. Angevine, K. Ikeda, and F. Chen, 2001: CASES-97: Late-morning warming and moistening of the convective mixed layer over the Walnut River watershed. *Bound.-Layer Meteor.,* submitted

Kingsmill:

Houze, R. A., Jr., S. S. Chen, D. E. Kingsmill, Y. Serra, and S. E. Yuter, 2000: Convection over the Pacific warm pool in relation to the atmospheric Kelvin-Rossby wave. *J. Atmos. Sci.*, **57**, 3058-3089

Kingsmill, D. E., and R. A. Houze, Jr., 1999: Kinematic characteristics of air flowing into and out of precipitating convection over the west Pacific warm pool: An airborne Doppler radar survey.. *Quart. J. Roy. Meteor. Soc.*, **125**, 1165-1207.

Kingsmill, D. E., and R. A. Houze, Jr., 1999: Thermodynamic characteristics of air flowing into and out of precipitating convection over the west Pacific warm pool. *Quart. J. Roy. Meteor. Soc*, **125**, 1209-1229.

Kingsmill, D. E., 1995: Convection initiation associated with a sea-breeze front, a gust front and their collision. *Mon. Wea. Rev.*, **123**, 2913-2933.

Wakimoto, R. M. and D. E. Kingsmill, 1995: Structure of an atmospheric undular bore generated from colliding boundaries during CaPE. *Mon. Wea. Rev.*, **123**, 1374-1393.

Wakimoto, R. M., C. J. Kessinger and D. E. Kingsmill, 1994: Kinematic, thermodynamic and visual structure of low-reflectivity microbursts. Mon. Wea. Rev., 122, 72-92.

Kingsmill, D. E. and R. M. Wakimoto, 1991: Kinematic, dynamic and thermodynamic analysis of a weakly sheared, severe thunderstorm over Northern Alabama. Mon. Wea. Rev., 119, 262-297

Ziegler:

Ziegler, C.L., and C.E. Hane, 1993: An observational study of the dryline. *Mon. Wea. Rev.* **121**, 1134—1151.

Hane, C., C. Ziegler, and H.B. Bluestein, 1993: Investigation of the dryline and convective storms initiated along the dryline: Field experiments during COPS-91. *Bull. Amer. Meteor. Soc*., 74, 2133-2145.

Zrnic, D.S., N. Balakrishnan, C.L. Ziegler, V.N. Bringi, K. Aydin, and T. Matejka, 1993: Polarimetric signatures in the stratiform region of a mesoscale convective system. *J. Appl. Meteor.*, **32**, 678—693.

Shaw, B., R. Pielke and C. Ziegler, 1997: A three dimensional numerical simulation of a Great Plains dryline. *Mon. Wea. Rev*., 125, 1489-1506.

Ziegler, C., T. Lee, and R. Pielke, 1997: Convective initiation at the dryline: A modeling study. *Mon. Wea. Rev*., 125, 1001-1026.

Atkins, N., R. Wakimoto, and C. Ziegler, 1998: Observations of the fine-scale structure of a dryline during VORTEX95. *Mon. Wea. Rev.*, 126, 525-550.

Ziegler, C. and E. Rasmussen, 1998: The initiation of moist convection at the dryline: Forecasting issues from a case study perspective. *Wea. Forecasting*, 13, 1106-1131.

Ziegler, C.L., E.N. Rasmussen, T.R. Shepherd, A.I. Watson, and J.M. Straka, 2001: The evolution of low-level rotation in the 29 May 1994 Newcastle-Graham, Texas, storm complex during VORTEX, *Mon. Weath. Rev.*, **129**, 1339—1368.

Geerts:

Knupp K.R., B. Geerts and S. Goodman, 1998: Analysis of a small, vigorous mesoscale convective system in a low-shear environment. Part I: Formation, radar echo structure, and lightning behavior. *Mon. Wea. Rev.*, **126**,1812-1836.

Knupp K.R., B. Geerts and J.D. Tuttle, 1998: Analysis of a small, vigorous mesoscale convective system in a low-shear environment. Part II: Evolution of the stratiform precipitation and mesoscale flows. *Mon. Wea. Rev.*, **126**,1837-1858.

Geerts, B., G.M. Heymsfield, L. Tian, J.B. Halverson, A. Guillory, and M.I. Mejia, 2000: Hurricane Georges' landfall in the Dominican Republic: detailed airborne Doppler radar imagery. *Bull. Amer. Meteor. Soc*., **81**, 999-1018.

Koch:

Trexler, C. M., and S. E. Koch, 2000: The life cycle of a mesoscale gravity wave as observed by a network of Doppler wind profilers. *Mon. Wea. Rev*., **128**, 24232446.

Koch, S. E., and L. M. Siedlarz, 1999: Mesoscale gravity waves and their environment in the central U. S. during STORM-FEST. *Mon. Wea. Rev*., **127**, 2854-2879.

Koch, S. E., and W. L. Clark, 1999: A nonclassical cold front observed during COPS-91: Frontal structure and the process of severe storm initiation. *J. Atmos. Sci*., **56**, 2862-2890.

Koch, S. E., F. Einaudi, P. B. Dorian, S. Lang, and G. H. Heymsfield, 1993: A mesoscale gravity wave event observed during CCOPE. Part IV: Stability analysis and Doppler-derived wave vertical structure. *Mon. Wea. Rev*., **121**, 2483-2510.

Koch, S. E., and R. E. Golus, 1988: A mesoscale gravity wave event observed during CCOPE. Part I: Multi-scale statistical analysis of wave characteristics. *Mon. Wea. Rev*., **116**, 2527-2544.

Koch, S. E., R. E. Golus, and P. B. Dorian, 1988: A mesoscale gravity wave event observed during CCOPE. Part II: Interactions between mesoscale convective systems and the antecedent waves. *Mon. Wea. Rev*., **116**, 2545-2569.

Koch, S. E., and P. B. Dorian, 1988: A mesoscale gravity wave event observed during CCOPE. Part III: Wave environment and probable source mechanisms. *Mon. Wea. Rev*., **116**, 2570-2592.

Koch, S. E., and J. McCarthy, 1982: The evolution of an Oklahoma dryline. Part II: Boundary-layer forcing of meso-convective systems. *J. Atmos. Sci.,* **39**, 237-257.

Chen:

Yates, D.N., F. Chen, M. LeMone, R. Qualls, S. P.Oncley, R.L. Grossman, and E. A. Brandes. 2001: A CASES dataset for assessing and parameterizing land-surface heterogeneity on area-averaged surface heat fluxes. *J. Appl. Meteor.*, **40**, 921-937.

LeMone, M., R. Grossman, R.T. McMillen, K.N. Liou, S. Ou, S. McKeen, W. Angevine, K. Ikeda, and F. Chen, 2001: CASES-97: Late morning warming and moistening of the convective mixed layer over the Walnut River watershed. Submitted to *Bound. Layer Meteor.*

Chen, F., D. Yates, H. Nagai, M. LeMone, R. Grossman, K. Ikeda, 2000: Modeling Land Surface Heterogeneity and Comparison with CASES-97 Field Observations. In preparation

14. After flight operations are complete, how long do you anticipate will be required for data analysis? Explain.

JOSS will be in charge of the collection of core and ancillary IHOP data, including UWKA data. The IHOP community will be able to access IHOP quality-controlled data through CODIAC. An estimated 2-3 years or more will be required for the analysis of these data leading to publications.

15. Where and when do you expect the results of the airborne observations to be published?

Starting within 3 years in Monthly Weather Review, Boundary-Layer Meteorology, Journal of Atmospheric Sciences, Journal of Atmospheric and Oceanic Technology, Journal of Hydrometeorology, or Journal of Geophysical Research

16. Educational Activities: Anticipated Student Involvement:

About 70 scientists have expressed an interest in IHOP participation. Many of these are employed at or affiliated with a university. Therefore numerous graduate students, and possibly undergraduate students, will participate in the field and/or the consequent data analysis. Participating universities include the University of Oklahoma, University of Colorado, Penn State University, University of Alabama in Huntsville, University of Wisconsin, University of Wyoming, McGill University, Desert Research Institute, University of Massachusetts, University of California at Los Angeles, Florida State University, University of Maryland Baltimore County, Ecole Polytechnique, and Universität Höhenheim.

As of 15 June 2001:
Grossman and LeMone: one student requested on NSF grant supplement for BL work
Geerts: One PhD student and one MSc candidate from UWyo for work related to convective initiation
Davis: One PhD or MS student from PSU working on BL topics,
Kingsmill: one graduate student to work in the field and on data analysis on convective initiation
Ziegler: 1-2 graduate students in field and post-field data analysis (mainly CI), 10 undergraduate students to help operate the mobile armada.

B. RESEARCH SPONSOR

1. Name of Primary Sponsor: *National Science Foundation*	2. Contract Officer: *Dr. Stephan Nelson*
3. Address: *Mesoscale Dynamic Meteorology , NATIONAL SCIENCE FOUNDATION, 4201 Wilson Blvd., Arlington, VA 22230*	4. Contract Identification: N/A

5. Funding:
[Several proposals to be submitted by June 2001]

a. Chen, LeMone, and others: “Land-Surface Atmosphere interaction and its relationship to improving QPF of deep convection in the Southern Great Plains.” (NCAR Internal USWRP Grant, Funded Sept 2001-2002, with intention to fund through Sept 2003.)
b. Grossman and LeMone: supplement to NSF Grant 9981811, “Atmosphere Land-Surface interaction over a Midwest watershed: CASES-97” being requested (pending).
c. Davis, D. Sauffer, and N. Seaman (PSU), J. Mecicalski and G. Diak (U WI): “Mesoscale structure of boundary layer water vapor budgets and depth during IHOP: Observations, modeling, and convective initiation.” (NSF, pending.)
d. Geerts and D. Leon: “Fine-scale description of shallow atmospheric boundaries during IHOP.” NSF 0129296, (pending)
e. Kingsmill: supplement to NSF Grant 9901688 “Studies of convective initiation and evolution” (pending)
f. Ziegler and E. Rasmussen: “Measurement and Analysis of the preconvective boundary layer and convection initiation during IHOP.” (NSF, pending)
g. Koch : “Interpretation and Verification of S-Pol polarimetric data for use in validating the LAPS Water-In-All Phases Analysis,” part of a broader proposal to be submitted by FSL to John Gaynor at NOAA.

6. Approximate Amount Budgeted for Research Pertaining to this Proposed Airborne Measurement Program: exact amount unknown

C. OTHER AVIATION FACILITIES

1. Aircraft Identification: *UWyo King Air - as per this request; NRL P3; DLR Falcon; dropsonde aircraft (unidentified; possibly DLR Falcon); Proteus; a set of unmanned aerial vehicles (UAVs) operated by NSSL. More details can be found in the Scientific Overview Document.*

2. Will above aircraft be used in proposed flight program (if not, why not?); **Yes** List Hourly Operating Cost: ??

3. What other sources of research aviation support have been contacted ? *NASA DC-8*

D. FLIGHT OPERATIONS

1. IHOP Flight Period

From: 13 May 2002 To: 30 June 2002

2. Type of Aircraft Required: UWKA

3. Number of Research Flights Required

Designation	Flights	Flight hours	Comments
Boundary Layer	12	56	4 5.5-hr flights ABLE*+ 4 4.5.hr-flights at Lamont+ 4 4-hr flights Little Washita
BL early-morning development and instrument comparison	4	14	2 3.5-h back-to-back missions coordinated with NRL P3, DLR Falcon and CI armada.
Convective Initiation	15	60	Focused on boundaries, mostly in conjunction with mobile armada. Possible scenario, 10 sorties flown on 5 days x 3.5 h/sortie = 35 h; 6 sorties x 4 h/sortie = 24
Joint ABL – CI	5	17.5	Assumes 3.5 h/mission; possible two-sortie days. Some patterns possible on Lamont or Little Washita tracks.
QPF microphysics	5	20	Patterns in range of S-Pol
Ferry to/from Laramie	2	6	
Test	2	8	Part: comparison with C130? before IHOP.
Total	45	181.5	

*time allows ~4 hours on site; additional is ferry. Duration of mission based on CASES-97.

Potential flexibilities that could reduce flight hours:

1. Flights focused on surface fluxes could be shorter than 4 hours. Impact: possible reduction of hours at all three 'fixed sites'. Possible savings: 3-4 hours.
2. Joint ABL/CI flights could overlap with BL flights at Lamont dedicated to sampling through the BL. Savings: 3.5-4 hours per 'overlap' mission.
3. Could try to schedule two ABLE flights on two consecutive days with fair weather. Savings: one ferry round trip or 1.5 hours.
4. Intercomparison with other aircraft could involve fewer hours.
5. BL early-morning flights combined with Lamont flights. Possible if fly on BL fixed flight track. Savings: 8 h.

Using savings of flight hours: could save around 18 hours. Assuming 5 h for intercomparison before IHOP, this would leave 158.5 hours during IHOP.

4. Estimated Duration of Each Flight: *3-4 hours*		5. Number of Flights Per Day: *1, maximum 2*
6. Preferred Base of Operation: *Oklahoma City (OKC) or nearby*	7. Alternate Bases: *Ponca City, OK; Wichita, KS (Jabara), Augusta, KS, Amarillo, TX; others*	8. Is Laramie acceptable? *No*
9. Average Flight Radius from Base: 150-200 km		10. Desired Flight Altitude: *100 – 30,000 ft AGL*
11. Particular Part(s) of Day for Flights: Flights during daytime. **ABL**: fair-weather flights typically in middle-late morning to early afternoon (9 am –2pm LT) and over a limited number of tracks. **CI:** mostly afternoon (noon – 7pm); fair-weather conditions, except for turbulence near boundaries **ABL Early morning:** 5 a.m. – 3:00 p.m. LST, 2 sorties, refueling locally **ABL-CI:** 9:00 a.m. -- 7 p.m LST. possible two sorties on a day if boundary persistent and promising. **QPF:** daytime		12. Statistically, how many days during specified period should be acceptable for flight operations? *Climatologically, most days should be acceptable for IHOP missions. In terms of climatological probability of suitable conditions, ABL missions probably fair best (>50%), followed by CI missions (30-60%), followed by QPF missions (<30%).* *Number of research flight days requested: 35-45*

13.Sketch or Describe Desired Flight Pattern(s). State **Priorities** and Estimate Number of Flights for Each (flight plans attached).

The flight patterns are divided into types outlined below. This is followed by a set of guidelines used in setting up the flight patterns, and the patterns themselves. They are based on the assumption that the UWKA has the WCR, primarily in downward vertical-plane dual-Doppler mode. The references to remote-sensing platforms are general rather than specific, with refinements to patterns expected once aircraft and ground-based systems and scans are determined.

Outline of Flight Pattern Descriptions

1.
Atmospheric Boundary Layer (ABL) processes (fair weather)

2.1. Principles

2.2. Flight Patterns

2.
Convective Initiation (CI): Flights relative to identified lines of convergence

2.1. Principles

2.2. Coordinated flight plan: examine across-line structure and along-line variability

3.
Joint ABL-CI missions

3.1. Principles

3.2. Patterns

4.
QPF: Hydrometeor microphysics with S-Pol

4.1 Principles

4.2 Patterns

5.
Validation of remote measurements

5.1 Principles

5.2. Patterns

6.
Issues

DEFINITIONS:

- **Leg:** flown level along straight track (unless otherwise specified) at constant pressure or radar altitude.
- **Sounding:** sustained climb or descent at 500 to 1000 feet per minute.
  - at a constant banking angle ('spiral soundings'); or
  - at discretely changing headings ('box soundings', 90º turns with straight de/ascending legs); or
  - no change in heading ('ramp soundings').
- **Porpoise**: up and down across reference level (e.g. freezing level)

1. ABL PROCESSES: FAIR-WEATHER FLIGHTS

Flights are designed for fair weather: i.e., there are no precipitating systems, fronts, drylines, or outflow boundaries in the area. Studies are designed to study the evolution of the daytime BL with a focus on the development of heterogeneities, due to differences in soil moisture, natural or man-made land surface conditions, and topography. Questions to be answered include the depth over which these inhomogeneities are felt, whether a mesoscale circulation can be detected, how mixing ratio varies in 4D in a convective BL, and how moisture variability and organized BL eddies may contribute to the outbreak of thunderstorms. Mean conditions and fluxes are measured at various levels in the BL. WCR data are used to pinpoint the height of the BL top and to depict the vertical structure of buoyant bubbles/plumes. These are the only flight patterns for which flight legs as low as 100 feet are required. Flight patterns typically will be conducted between 9 am and 2 pm LST. (For combined boundary-layer convective initiation flights, see Section 3).

1.1 Principles:

1.Geographically fix a small number of flight **tracks** mainly before field program starts. Three reasons :
   (a) FAA guidance and approval is needed for 100 ft flight level legs
   (b) In fair weather conditions, heterogeneity in land use, soil moisture, and terrain control BL heterogeneity
   (c) It allows the best-possible statistics relating fluxes measured at 100 ft AGL to surface fluxes.
2.Fix flight **tracks** to surface installations (or vice versa, fix surface installations – especially surface flux towers) to desirable flight tracks. The surface stations will be sited to be along the flight tracks.

This leads to a concentration of UWKA patterns in three locations with enhanced instrumentation: ABLE, Lamont, and the Little Washita watershed.

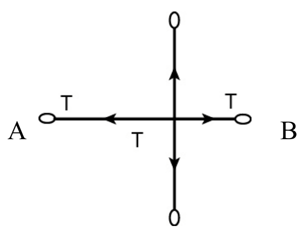
3. Relate fixed **tracks** to prevailing wind direction (along or cross wind); length of legs is about 50 km (about 10 min flight time).

4. Each location will have one **primary flight track**. Flux towers will be sited along this track.
    (a) Flux regionalization flights (below) should be along the primary track
    (b) Flights through the boundary layer should be mainly along the primary track
    (c) If the primary track is east-west, allowance should be made for comparison with remote-sensing aircraft. See modules in Section 5.2.
5. Perform **Soundings** to estimate top of mixed layer z_i or for comparison with WCR mixed-layer top: a mandatory part of all single aircraft missions, and desirable for many coordinated missions.
6. **Altitudes** determined according to primary objective, measured relative to surface and top of mixed layer zi, defined as the top of the ground-based layer with nearly constant potential temperature
    (a) Comparison to surface fluxes: as low as possible (pre-selected tracks with FAA approval)
    (b) Vertical flux divergence: alternate near top and near bottom of mixed layer (100 ft, 0.8 z_i).
    (c) Mesoscale eddies or horizontal advection: through the boundary layer (100 ft, 0.20, 0.50, 0.80 z_i)
    (d) BL top (z_i) and topography of the BL top, using WCR data (1.2 z_i)
    (e) Verification of remote sensing: A-D, or according to criteria set by remote sensing validation group.
7. **Comparison** is important, including
    (a) Aircraft moisture flux (e.g. using TDL vs. LICOR 6262)
    (b) Aircraft flux to remotely sensed fluxes (e.g., DLR Falcon HRDL -DIAL) and fields (e.g. WCR, ground-based DIAL)
    (c) Aircraft flux to tower eddy covariance
    (d) Aircraft flux to aircraft flux (prior to experiment)
8. **Unexpected changes:** Preliminary decisions for fair-weather flights should be made the night before, but alternate missions should be planned in case of unexpected weather changes. The decision to fly the primary mission would be made the morning of the mission.
9. **Calibration**: Calibration maneuvers should be performed to minimize angle of attack, angle of slide slip, true airspeed, etc. errors.

1.2 ABL Flight Patterns are to be flown along pre-determined tracks in ABLE, near Lamont, and over the Little Washita research area. Location of tracks will be coordinated with existing and requested flux towers and other facilities, and beneath the long, repeated remote-sensing aircraft flight tracks proposed by the ABL group.

1.2a. Evolution of large eddies fixed to surface terrain/land-use features

Tracks are as in Fig 1.2a. Start with sounding from 100 ft through zi. Fly track straight-and level starting at 1.2 zi to characterize mixed-layer top using WCR, and step down though the mixed layer. Follow with sounding through zi. Repeat cycle. Time for one cycle of four legs plus sounding: about 1 h.



Variant 1: L or X pattern to get convergence and structure through mixed layer.
Variant 2: Alternate 1.2a with 1.2b.

Notes: For example, after sounding, fly at 1.2 zi to determine height and topography of mixed layer top. Next, fly AB at 0.8 zi, BA at 0.6zi, AB at 0.25zi, and BA at 100 feet. Repeat. Time for one module: ~1 h; total mission = 4 h.

Fig 1.2a. Plan view of ABL flight pattern to sample large eddies and mesoscale circulations in the mixed layer. In this figure, the primary track is east-west, but north-south primary tracks are also likely. Alternate leg depicted for X pattern.

1.2b. Validation and regionalization of tower surface fluxes (low-level pattern, primary track only) "Regionalization" refers to determining how representative a tower is of patches of similar surface, and from that understanding, extrapolating the spatial coverage from the aircraft and the temporal coverage from the tower fluxes to a larger region where direct flux measurements are lacking.

Fly main track in Fig. 1.2a at 1.2zi to characterize ABL with WCR, reverse heading and fly track at 0.8 zi to get flux at top of ABL. Then fly 3-4 repeated straight-and level legs at 100 ft along primary track. Follow with box or spiral sounding. Repeat cycle. May want to eliminate one upper leg on some cycles to maximize sampling. Leg length: 32 mi (50 km).

Notes: flight legs on primary track only. Each mission must have at least 8 legs at 100 ft on same track. Time on site: 4 h.

1.2c. Evolution of the water-vapor field in the developing convective boundary layer and comparison/integration measurements from several platforms (coordinated mission)

The objective is to study ABL horizontal variability and its causes, particularly for mixing ratio, from sunrise through early afternoon. Since the representativeness of the 12Z soundings, taken at 0530 LST in the central U.S, impacts numerical weather prediction models and estimates of convective potential for the day, this pattern addresses CI and QPF objectives as well. The opportunities for comparing instrumentation benefits the instrumentation group.

Soundings will be obtained at frequent intervals from the central facility and nearby mobile sounding systems 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 (30 nm) on a side of water vapor measurements obtained from the airborne DIALs.

The NRL P3 will fly as low as possible (e.g., 1000 ft) 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 (4 nm) of the NRL P3.

The UWKA will fly at the same altitude as the NRL P3 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 (16,000 ft) directly above the UWKA. This instrument will obtain vertical profiles of water vapor from the surface all the way up to the flight level. Thus the UW UWKA will also provide in situ verification for the DLR DIAL.

The UAVs 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, which 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 (3.2 mi) on a side centered on the central facility.

Also at the **central facility time-height profiles of water vapor** will be obtained from the Atmospheric Emitted Radiance Interferometer (AERI), microwave radiometer, profiling radiometer, Raman lidar, and tethersonde. 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**.

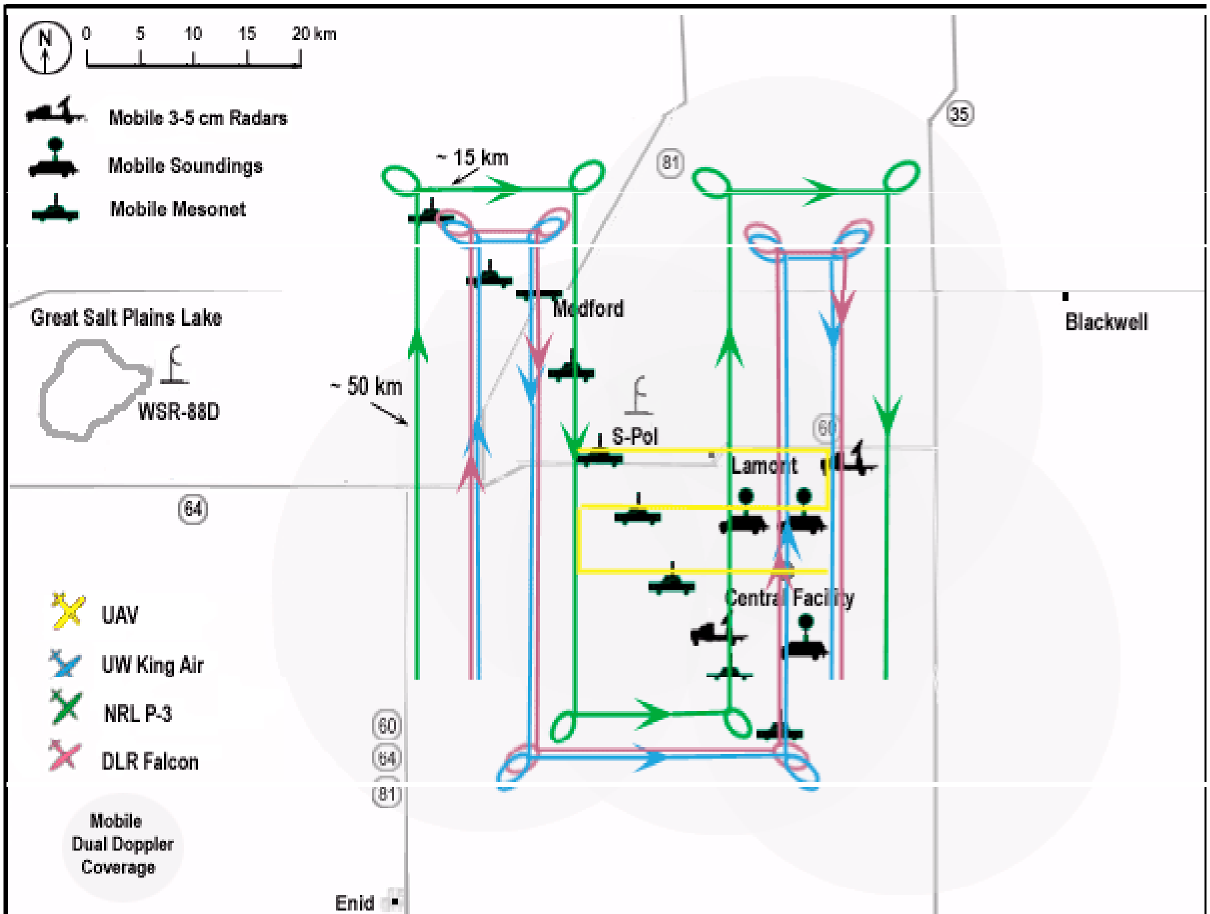


Figure 3.2b. Above: Plan view of Pattern 3.2b; Below: aircraft altitudes. Note: Tracks for faster aircraft should be longer so that aircraft coincide roughly at the center of each track. English units: 50 km = 27 nm; 15 km = 8 nm; 300 m = 1000 ft.

Variant 1: Using similar relative altitudes to those in Fig. 3.2b, the DLR Falcon and UWKA fly repeated legs over the same track, with the NRL P3 flying a box around the UWKA track, so that the two remote-sensing aircraft sample the same volume as the King Air on the inner part of their flight tracks. The legs for the DLR Falcon and the NRL P3 would be lengthened so that the 3 aircraft sample same volume roughly at track center. The UWKA could fly at same height, or a in stack at 2-5 heights ranging from lowest safe altitude to 1.2 zi. The variant (with UWKA at 1-2 levels) could be flown in early morning to maximize sampling of a rapidly-growing boundary layer, or as the second sortie with more UWKA and NRL P3 flight levels to more thoroughly sample the deeper mixed layer. The UAVs fly parallel to the aircraft tracks, in horizontal or vertical stack (or "tower") or two vertical stacks. A less severe modification of variant is to fly two rather than 4 parallel legs.
Variant 2: The pattern is flown in reverse second time.
Variant 3: The aircraft fly the original pattern or Variant 1, but in range of fixed ground facilities without the mobile armada or with a subset of the mobile armada.

2. CI FLIGHTS RELATIVE TO IDENTIFIED LINES OF CONVERGENCE

2.1 Principles:

1. **Tracks usually with respect to feature** rather than fixed point. Target is a linear boundary, i.e. a line of convergence, usually detected first as a fine line by ground radar. Visible evidence of the convergence line from the UWKA is desirable. Examples of such evidence are a line of clouds, the western limit of shallow clouds (in case of a dryline), or a line of dust.
2. **Existence, strength and depth of convergence line is assessed in real time during the first transect** over the boundary at ~1.2zi, by means of WCR reflectivity and velocity data.
3. **Tracks should be concentrated primarily in the vicinity of the mobile ground-based armada** (radars, soundings, surface obsservations, profiling probes), and secondarily where fixed ground-based observations are available, e.g. near the ARM CART site or S-POL.
4. Boundaries targeted by the mobile ground-based armada should be **slow-moving (< 5 m/s).** This is necessary because of the limited mobility of the ground-based armada, and the desire for a significant set of dual-Doppler volumes.
5. **Validation of remotely-sensed water vapor should always be a priority**, esp. by the side-looking NRL P3 DIAL and the nadir-looking DLR Falcon DIAL.
6. **Flight patterns should be close enough to base to be practical**. One-way ferry time from OKC to Amarillo TX is 1 hour. Therefore missions in the TX Panhandle may require two flights with a refueling stop.
7. **Flights will start once a suitable boundary is identified**; thus planning time will be short. Given the short lifespan of some boundaries, it may be necessary to take off before clear boundary target has been singled out, under the expectation that a boundary can be identified in the target region in the next hour.
   a. We start from a generic plan, involving multiple aircraft, the mobile armada, and a well-defined, slow-moving boundary.
   b. We will fine-tune generic plan based on experience during experiment.
   c. Fine-turning will occur also during flight pattern, through visual observation and/or communication with NRL P3 or FC (field coordination vehicle).
8. When a boundary persists, a second sortie may be flown to take advantage of already-coordinated resources.
9. Opportunities for in-situ as well as remotely-sensed data should be built into pattern or ferry.

2.2 Primary Coordinated flight plan: examine across-line structure and along-line variability

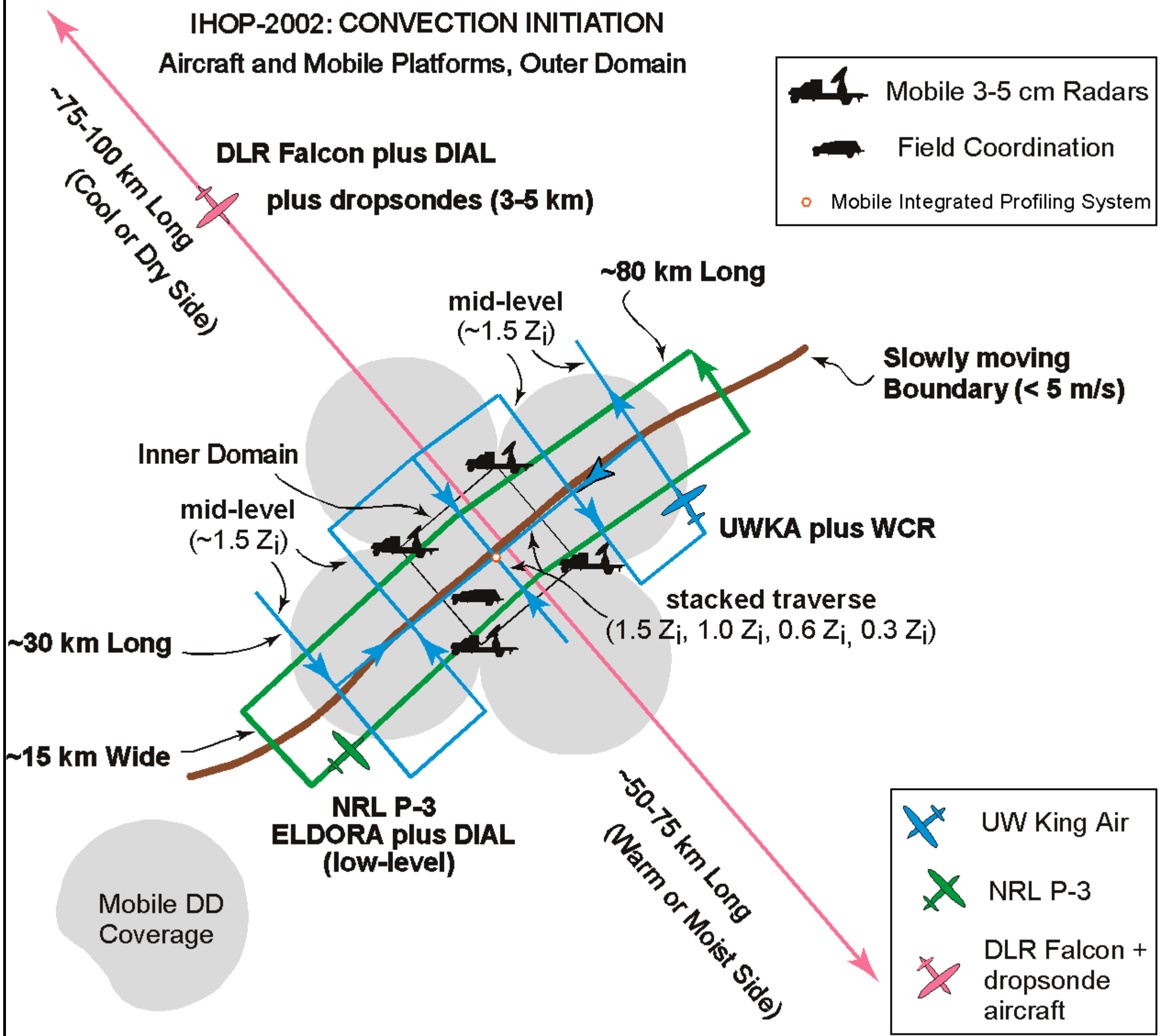


Fig 2.2. *Coordination between UWKA, other aircraft, and mobile ground facilities in the event of a well-defined, slow-moving boundary. More mobile ground-based platforms are concentrated in the Inner Domain. In case of a dryline, Z_i is the depth of the shallow BL on the moist side. Note: if conditions permit, 0.3zi leg should be at 150 m (500 ft) to ensure capture of discontinuity and easier comparison with surface armada data.*

1. **The UWKA flies above the BL in several transects displaced along the boundary** (square wave pattern 180 km or 100 nm long in figure), allowing the WCR to document the across-boundary structure and along-boundary variability. WCR echoes are likely to be strong enough here to see undulations in the BL top at and on the moist side of a dryline, or on the cool side of an outflow boundary. In-situ UWKA data at ~ 1.5 z_i should assess the influence of the boundary on the air aloft, which is typically well-mixed in the case of a dryline but may contain convection waves in some cases. (~0.6h at 175 kt)
2. **UWKA flies a stacked traverse containing 3-4 levels below the track of the DLR Falcon**. Several ground facilities will operate along this main cross-axis, including the MIPS (Mobile Integrated Profiling System), which allows comparisons of WCR vertical velocity profiles. At lower levels in situ measurements become more important, and will be used to validate the DLR Falcon nadir DIAL measurements. (0.5 h for 4 levels, allowing 10 min for turning and changing altitude between levels)
3. **UWKA flies along the boundary** to provide in situ validation for the LEANDRE-II on the NRL P3. Probably only two levels will be flown in this case, above the BL and at the level of the NRL P3 (~0.3Z_i). On most flight legs the UWKA will fly a little slower than the NRL P3, at about 90 ms^{-1} (175 kt), but the along-boundary flights will be coordinated with the NRL P3, such that the UWKA is in sync with NRL P3, remaining a few km behind the side-looking LEANDRE beam, for eye-safety. As an alternative to the ~0.3Z_i along-line flight leg in Fig 2.2, the UWKA can fly a km or two away from the boundary, on the same side as the NRL P3. This may be possible for a well-defined, quasi-stationary boundary visible from the aircrafts, esp. as a line of clouds. Straddling the boundary at low levels allows better comparison with LEANDRE-II, which cannot sample

high gradients, and allows sampling of temperature, moisture and wind on both sides of the line. (0.5 h assuming 2 60-km passes at 175 kt plus 5 min for maneuvering and changing levels.)

These flights typically are conducted in the afternoon, when slow-moving boundaries are best-defined near the ground and CI is most likely. The lowest UWKA flight level depends on the flight rules, local conditions, and the presence of UAVs. It is 100-200 m AGL under VFR. Safety considerations will mandate a higher minimum flight level for the more intense radar fine-lines, or possibly prohibit low-level penetration of some boundaries. The entire UWKA flight pattern in Fig 2.2 is of the order of 1.6 h at 175 kt.

3. JOINT ABL-CI MISSIONS

3.1 Principles

(a) Flight pattern is a hybrid of BL mission 1.2b and CI Primary Coordinated Flight Plan
(b) The patterns should be flown with respect to fixed surface features (soil-moisture boundary, ridge, land-use boundary) within close range of the mobile armada base. Flights along pre-determined flight tracks desirable but not mandatory. (e.g.,. we cannot pre-determine location of soil-moisture boundaries).
(c) Contiguity to locations of surface-based instrumentation desirable but not mandatory.
(d) Two back-to-back 3.5-h sorties may be flown if boundary persists.
(e) Minimum vertical and horizontal separations between the UWKA and UAVs must be established.

3.2. Pattern: Coordinated Mission with ground-based mobile armada to study surface-generated mesoscale circulation

The objective is to document the development of the CBL in the vicinity of a terrain ridge or major gradient in land surface characteristics (soil moisture, land use), on a fair-weather day with light winds yet with the potential for the outbreak of airmass-type thunderstorms, to test the hypothesis that terrain or a surface-characteristics boundary triggers a mesoscale circulation which may trigger deep convection. The mobile ground-based armada is ideally suited to study CI in the vicinity of a quasi-stationary boundary. As part of the site survey, we will look for potential flight tracks with respect to land-use and terrain boundaries, especially near ground facilities (e.g., Lamont, S-Pol) within 1-2 hours drive of the Mobile Armada base (Norman?).

The smaller-scale CI measurements (mobile ground armada in the Inner CI Domain) are blended with ABL flight pattern 1.2a. The pattern includes long nadir DIAL traverses (~100-200 km or 60-120 nm) and pre-selected UWKA flight tracks (order 50 km or 30 nm long). The UWKA repeats a stacked traverse, between 1.2 Z_i (allowing WCR dual-Doppler synthesis in the vertical plane below the UWKA) and as close as possible to the ground (100-330 ft). In this hybrid mission the NRL-P3 documents along-line variability of airflow (ELDORA) and water vapor (LEANDRE-II DIAL). Repeated horizontal and vertical DIAL and UWKA flights along the same tracks give us understanding of the persistence of these features over time, plus a larger-scale spatial context for the UAVs, surface mesonet data, and other instruments in the Inner Domain. When the UAVs are airborne, the UWKA flies at heights to avoid the UAVs. Two UAV configurations have been considered, a vertical stack about 20 km (11 nm) long and between 30 m and 700 m agl (100 – 2300 feet), and spaced horizontally at one or two levels in this altitude interval.

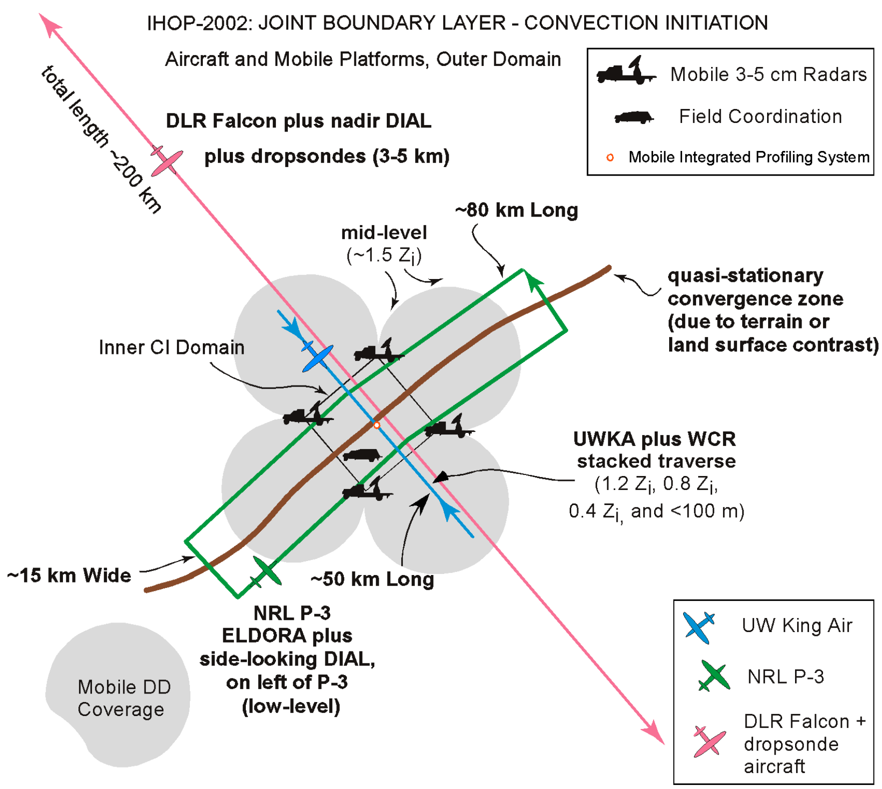


Fig. 3.2a. Joint BL-CI mission in the western region, with support of the mobile ground armada. DLR Falcon track 100-200 km (54-108 nm); 60 km = 32 nm; 15 km = 8.1 nm); 100 m = 330 ft.

4. **QPF: Hydrometeor/Microphysics Studies with S-Pol**

4.1 Principles

1. All UWKA QPF flights will be within the effective range of and coordinated with S-Pol scans so measurements can be used to validate hydrometeor types estimated in real-time from S-Pol, and hence enhance the value of S-Pol for validating the LAPS Water-In-All Phases mesoscale analyses.
   (a) Spiral soundings should be within 20-40 km of S-Pol
   (b) Horizontal legs should stay within approximately 80 km of S-Pol
2. The UWKA will be flown in primarily stratiform precipitation or convection with reflectivity less than 40 dBZ and away from hazards (lightning, hail)**.**
3. Flight-patterns will be of sufficiently large horizontal dimensions to enable meaningful "upscaling" of the 3-D distribution of cloud ice, snow, cloud water, rainwater, and graupel, for use in initializing mesoscale models with grid resolutions of 5-10 km.
4. Sampling should extend vertically primarily from about +3 (10,000 ft) to –25 C (30,000 feet). This extends from the bottom of the melting layer to the ceiling for King Air operations. Below 10,000 feet, the precipitation is liquid or hail, which is well handled by S-Pol. Such altitude ranges are practical for spiral soundings only. However, flights at 6,000 – 10,000 ft will be useful to sample clouds.
5. Sample a variety of situations.
6. King Air location must appear on radar screen to facilitate comparisons.

4.2 Flight Pattern Modules

4.2a: Spiral Soundings: to document particle habits, water contents, aggregation, and hydrometeor size distributions as a function of temperature.

Spiral ascents and descents will be made in regions of stratiform precipitation or decaying convection between 3 and 9 km (10,000-30,000 ft agl, roughly +3 C to –25 C). Spirals will be flown in the vicinity of S-Pol to obtain required verification data for the hydrometeor classification algorithm. The measurements should be made within 20-40 km of the radar to minimize beam-smoothing effects and permit detailed comparison between the radar and aircraft measurements. Spiral duration: 20-40 minutes, depending on ascent/descent rate.

4.2b Porpoising: to document cloud microphysical characteristics of aggregation and melting layers

The flight patterns will have up to 160 km horizontal legs (within 80 of the radar for meaningful comparison) and concentrated in the temperature layer between 3 and -8C (roughly 6000 ft thick); at 175 kt and 1000 fpm, ascent will be accomplished in 17.5 nm or 32 km). It is desired to have some legs over the radar.

4.2c Straight and Level Legs: to compare WCR and S-Pol reflectivity profiles above the freezing level

The flight level can be selected anywhere between 4-7 km (13,000-23,000 ft); leg length is at least 30 km (20 nm), to determine the vertical reflectivity structure, including the details of the bright band, as obtained from WCR nadir beam or a combination of nadir and fore beams (using the technique by Guyot and Testud 1999).

4.2d. Ramp Sounding: to sample microphysics in a volume larger horizontally than typical sounding, and larger vertically than practical for porpoising

The aircraft climbs (or descends) at a prescribed rate (typically 500-1000 fpm) for the entire leg (e.g., 100 km or 54 nm).

4.3 Sample patterns for two Meteorological Scenarios

The degree to which the aircraft measurements may offer representative samples for the radar validation is dependent upon the type of precipitation system in which the aircraft is flying. Two types of situations are of particular interest for validation purposes, each of which requires a different flight pattern.

4.3a Overrunning associated with a stationary or warm front: to sample hydrometeors through and above the melting layer

This situation may contain a large variety of hydrometeor types within mixed stratiform-convective precipitation. It is important to map a sufficiently large region of the system to capture this distribution. Mesoscale precipitation systems in overrunning situations typical display important variations on scales of 10-200 km, which are related to the relative importance of convective and mesoscale lifting. Patterns should be flown **normal to the low level jet and at two distances (75 and 125 km or 40 and 70 nm) from the surface warm front** (Fig.4.3a). This pattern is a porpoise (up then down) through the melting level from 10,000 feet to 22,000 feet. Assuming an ascent rate of 1000 feet per minute and ground speed of 175 kt, it will take the aircraft 12 min or 65 km (35 nm) to make the ascent, implying one porpoise (up + down) per 130 km (70 nm) leg. Maximum leg length: 160 km (86 nm).

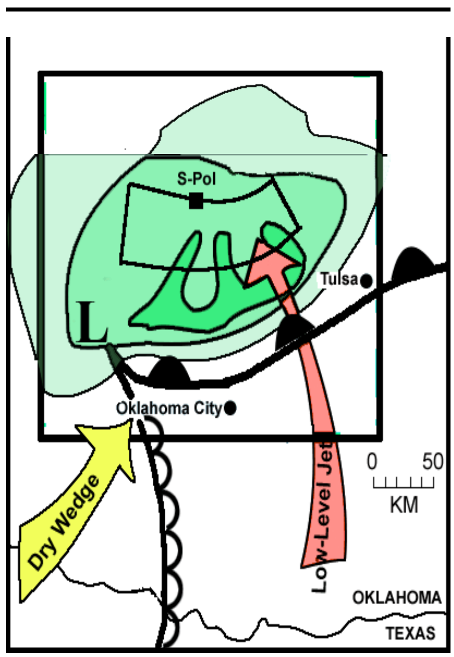


Fig. 4.3a. Flight track of UWKA through a region of overrunning precipitation of varying intensity (shades of green) containing mesoscale features forced by the "elevator-type" of lifting associated with the moist, southerly low-level jet in the IHOP domain (large rectangle). Precipitation is primarily stratiform and does not exceed 40 dBZ. Aircraft must remain < 80 km from S-Pol during pattern.

4.3b Precipitation and Cloud Debris from mesoscale convective system the previous night: to verify LAPS Water-In-

All Phases Analysis

Cloud fields are likely to be a mixture of cirrostratus, altostratus, altocumulus, and stratocumulus types, and to contain a wide variety of essentially non-precipitating hydrometeors. High spatial variability and multiple cloud layers make it difficult to determine the cloud field for initializing numerical models with existing satellite, surface, and aircraft data.

The pattern is a rectangle within a region of variable cloudiness as determined from satellite imagery. In Figure 4.3b, leg lengths are 100 km x 160 km (54 nm x 86 nm). The UWKA ascends or descends at 500 ft/min on the 160-km legs, between 6,000 and 22,000 ft. The shorter legs are flown straight and level. Time for one circuit: 280 nm /175 kt = 1.6 h.

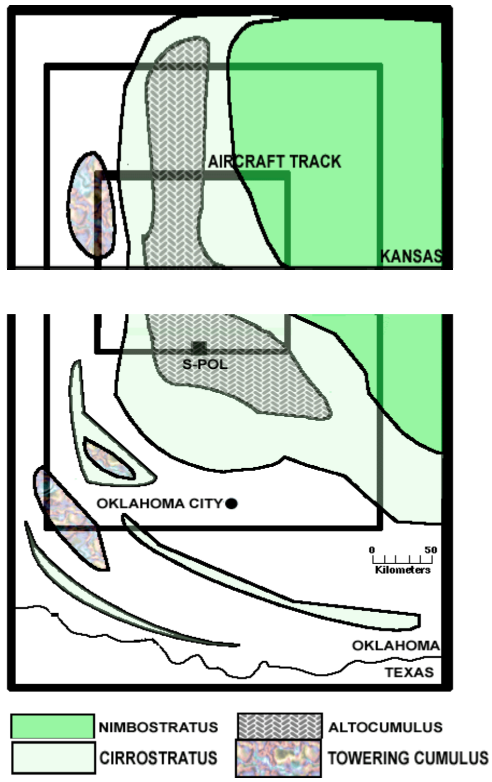


Fig. 4.3b. UWKA box flight track (ramp soundings) through a region of mixed cloud types and fractions left behind as complex "cloud debris" by a mesoscale convective system that is passing away from Oklahoma. Aircraft would ascend or descend at a rate of 500 feet per minute over the 160-km east-west flight legs to encompass the full range of cloud altitudes extending from ~6 Kft to ~22Kft (8C to -20C temperature range).

5. VALIDATION OF REMOTE MEASUREMENTS

5.1. Principles

(a) All flight plans should maximize intercomparison opportunities consistent with achieving the scientific objectives.
(b) A running tally of intercomparisons including instruments/platforms compared and weather conditions should be kept.
(c) With the exception of 5.2d, all the patterns listed would be flown in combination with other missions.
(d) The slower aircraft begins the run, and the faster aircraft overtakes it.
(e) The option "WCR scan sideways" should be considered when UWKA flying parallel to NRL P3 track when this is not in conflict with mission objectives, if this option is available.

5.2 Coordinated flight plan to verify remotely-sensed moisture field/flux in fair weather

5.2a Parallel tracks for validation of airborne remote sensor: with the UWKA directly measuring moisture and moisture fluxes in the area covered by the NRL P3 or DLR Falcon. Patterns located so that this could be done as part of ferry or in combination with 1.2d pattern when remote-sensing aircraft in area.
Orientation: to be flown along the remote-sensing aircraft heading at ~0.3 zi.
Altitude: determined by (a) remote sensing scientist, and (b) secondary objectives (e.g., stage in BL pattern 1.2b).
Location: away from boundaries; one of the 3 locations mentioned in (1a).

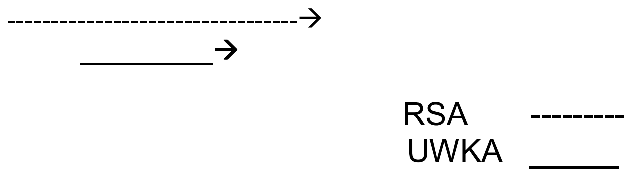


Fig 5.1a. Plan view of line pattern for stacked or side-by-side remote-sensing validation flights. Headings along NRL P3 or DLR remote sensing aircraft track headings. Vertical and horizontal separation to be determined.

5.2b. L patterns for validation of airborne remote sensing: with UWKA directly measuring fluxes covered by remote-sensing aircraft. Faster aircraft have longer L. Outside turns. Altitudes determined according to remote-sensing or fair-weather pre-storm boundary-layer objective. This pattern would be flown near north or south end of long remote-sensing flight legs proposed by the ABL group. The remote-sensing aircraft legs extend from the Little Washita watershed in the south to the Walnut River watershed in the north.

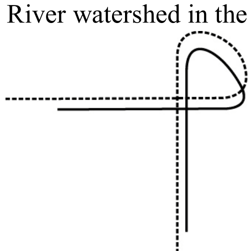
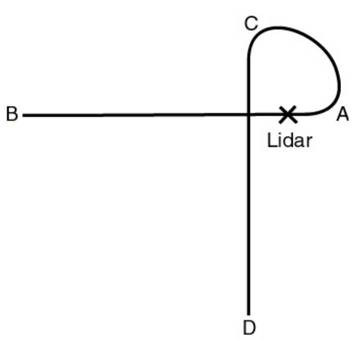


Fig *1b.2. Plan view of L-pattern. RSA and UWKA tracks defined, elevations and tracks determined as in 1.b.1.*

5.2c. Fair-weather validation with respect to surface remote sensors

Fix tracks so that straight-and-level flights along them will be useful to validate scanning lidar or radar, or profiling probes such as S-Pol, DIAL, FM-CW radar (fixed), etc. Should retain long tracks, but could add shorter segments if needed. Could be combined with 5.2b.



Note: Location of pattern depends on scan. If the lidar is scanning 360 degrees, the legs might cross over it.

Sample pattern: assumes BL is sampled remotely through its depth, attempts to sample BL at same time along previously-fixed track.

a. sounding to get zi
b. AB at 0.8 zi
c. BA at 0.6 zi
d. CD at 0.6 zi
e. DC at 0.8 zi
f. AB at 0.2 zi
g. BA at 100 feet
h. CD at 0.2 zi
i DC at 100 feet
Repeat

Fig 5a. Plan view of pattern for validation of ground-based remote sensors. Details to be determined in coordination with lidar or radar scientists. Figure assumes lidar scans in the SW quadrant. Alternative: fly pattern at one heading.

5.2d Intercomparison (to be flown before IHOP); could be in Colorado if C-130 available.
The objective is to check fluxes of sensible and latent heat against another gust-probe aircraft. This is particularly critical since (1) the UWKA will be used as a validation aircraft for remotely sensed moisture fluxes, (2) The UWKA may be flying a relatively new humidity sensor (the TDL), and (3) When compared with the NOAA Twin Otter during CASES-97, there were some differences in sensible heat flux estimates from the two aircraft that are not understood. UWKA flies 40-50 km (25-30 nm) legs in convective BL at as low as deemed safe, mid-ABL, and upper ABL, in formation with or along parallel tracks with another gust-probe aircraft (e.g., C-130). Should have at least 4 passes at each height, could be on separate days. Perform calibration maneuvers.

6. Issues

This section highlights unusual aspects of this deployment that need special attention by the Facility or the PIs

(a) Flights at 30 m (100 ft) are essential for ABL flights. PIs propose to survey potential tracks in advance of the experiment and visit relevant FAA offices to discuss tracks and brief them on what to expect. (This was highly successful in CASES-97). This would be coordinated with Facility and IHOP leadership
(b) Coordination procedure for multi-aircraft missions and multi-aircraft plus ground armada missions should be defined and possibly 'rehearsed' prior to first 'real' mission.
(c) Safety restrictions with UAVs nearby need to worked out.
(d) Crew/scientist may want option to stay at remote location overnight for deployment the next day in the same region.
(e) Calibration maneuvers important, especially for flux measurements.
(f) Naming convention for variables from different aircraft is desirable.
(g) There must be a means of obtaining realtime UWKA location information into the IHOP operations center in Norman and putting aircraft tracks on some combination of WSR-88D, S-Pol and visible satellite imagery display.

14. How many staff will you require on each flight?

Two, the flight scientist and the instrument engineer

- *flight scientist communicates with other aircraft, the ground (CI armada field control vehicle, S-POL, etc.), to guide the pilot*
- *instrument engineer will operate WCR and other probes*

E. SCIENTIFIC PAYLOAD				
1. LIST OF STANDARD SENSORS (These items are usually on the aircraft and part of the archive data set)				
VARIABLE	**INSTRUMENT**	**RANGE[1]**	**ACCURACY[2]**	**RESOLUTION[1]**
Air temperature	Rosemount 102	-50 to +50 °C	0.5 °C	0.006 °C
Air temperature	Reverse flow (Minco element)	-50 to +50 °C	0.5 °C	0.006 °C
Dewpoint temp.	Cambridge Model 137C3	-50 to +50 °C	1.0 C if > 0 °C 2.0 C if < 0 °C	0.006 °C
Static pressure	Rosemount 1501	0-1080 mb	0.5 mb	0.003 mb
Static pressure	Rosemount 1201FA1B1A	0-1034 mb	0.5 mb	0.06 mb
Static pressure	Rosemount HADS (under dev)			
Static pressure	Weston (under dev)			
Geometric alt.	Stewart Warner APN159 radar altimeter	60000 ft (18288 m)	1%	0.24 ft (0.07 m)
Geometric alt.	King KRA 405	2000 ft (610 m)	3% if < 500 ft 5% if > 500 ft (152 m)	0.48 ft (0.15 m)
Total pressure	Rosemount 831CPX	0-85 mb	0.2 mb	0.005 mb
Lat./long.	Trimble 2000 GPS	±90° lat. ±180° long.	100 m (3)	0.000172°
Lat./long.	Honeywell Laseref SM Inertial Reference System (IRS)	±90° lat. ±180° long.	0.8 mm/h (50% CEP) 1.66 mm/h (95% CEP)	0.000172°
Ground velocity	Honeywell Laseref SM	0-4095 kts	13.5 ft/s (4)	0.0039 kts
Vertical velocity	Honeywell Laseref SM	±32768 ft/min	0.5 ft/s (4)	0.03125 ft/min
Pitch/roll angle	Honeywell Laseref SM	±90° pitch ±180° roll	0.05° (4)	0.000172°
True heading	Honeywell Laseref SM	±180°	0.2° (4)	0.000172°
Flow angle	Rosemount 858AJ/831CPX	±15°	0.2°	0.00015°
Engine torque	Engine gauge	2230 ft-lbf	---	0.2 ft-lbf
Video record (forward-looking)	if feasible substitute by high-resolution digital camera (see below)	---	---	---
Audio record	Intercomm/Radios	---	---	---
Event markers		---	---	---

Notes:
(1) In units native to the instrument.
(2) In units of customary usage.
(3) Limited by reception.
(4) 6-hour accuracy
(5) Selectable.

E. SCIENTIFIC PAYLOAD (continued)				
2. OPTIONAL STANDARD SENSORS (These items are not automatically included but are available on request)				
VARIABLE	**INSTRUMENT**	**RANGE**[1]	**ACCURACY**[2]	**RESOLUTION**[1]
Cloud Properties (Check those requested)				
☒ Cloud droplet spectra	Particle Measuring Systems, FSSP scattering probe	0.5-45 μm ([5])	---	0.5-3 μm ([5])
☒ Cloud particle spectra	Particle Measuring Systems 200X (1D-C) optical array	12.5-185.5 μm	---	12.5 μm
☒ Cloud particle spectra	Particle Measuring Systems, 2D-C optical array	---	---	25 μm
☒ Precipitation particle spectra	Particle Measuring System, 2D-P optical array	---	---	200 μm
☒ Liquid water content	DMT LWC-100	0-3 g/m^3	0.2 g/m^3	0.00015 g/m^3
☒ Liquid water content	Gerber PVM-100	0.002-10g/m^3	5%	.000015 g/m^3
☒ Droplet surface area	Gerber PVM-100	5-20,000 cm^2/m^3	5%	.03 cm2/m^3
☒ Droplet effective radius	Gerber PVM-100	2-70um	10%	.00015 g/m^3
☒ Icing rate	Rosemount 871FA	0.5 mm/trip	n/a	0.0004 cm
Other				
☐ Video record	Down looking	---	---	---

E. SCIENTIFIC PAYLOAD (continued)				
3. NON-STANDARD INSTRUMENT GROUPINGS – Available only by request. See http://flights.uwyo.edu/bulletin1.html				
VARIABLE	**INSTRUMENT**	**RANGE**[1]	**ACCURACY**[2]	**RESOLUTION**[1]
BL eddy fluxes: (Check those requested)				
☒ Air temperature	Friehe type, with UWyo modifications.			
☒ Water vapor	LICOR 6262	0-75 mb	1%	0.1 mb
☒ Carbon dioxide	LICOR 6262	0-3000 ppm	±1 ppm at 350 ppm	1 ppm
Radiation sensors: (Check those requested)				
☒ Pyranometer	Eppley PSP (0.285-2.8 mm)	0-1400 W/m^2	5 W/m^2	0.0-8 W/m^2
☒ Pyrgeometer	Eppley PIR (3.5-50 mm)	0-700 W/m^2	15 W/m^2	0.04 W/m^2
☒ Radiative Thermometer	Heimann KT-19.85 (9.6-11.5 mm)	-50 to 400°C	0.5°C	0.1°C for 10 s response
☒ Exotech 4-channel Spectrometer[3,4,5]	Exotech Model 100BXT			
Channel A:	456-521 nm	0-100 W/m^2	+/-5%	1.5 mW/m^2
Channel B:	523-595 nm	0-50 W/m^2	+/-5%	0.76 W/m^2
Channel C:	629-687 nm	0-50 W/m^2	+/-5%	0.76 W/m^2
Channel D:	762-898 nm	0-250 W/m^2	+/-5%	3.8 mW/m^2
E. SCIENTIFIC PAYLOAD (continued)				
3. NON-STANDARD INSTRUMENT GROUPINGS (continued)				
☒ **Wyoming Cloud Radar** http://www-das.uwyo.edu/wcr (<- follow link)				

[X] H_2O vapor fluxes	TDL preferred, otherwise IRGA	source: NCAR ATD (??)		
[X] hi-res digital video imagery	e.g. SR-CMOS Phantom v5.0	source TBD		
<u>Trace gas chemistry:</u> (Check those requested)				
[ ] Hydrogen peroxide	Enzyme-fluorometric	0-20 ppbv	0.05 ppbv	0.001 ppbv
[ ] Ozone	TEI model 49	0-1000 ppbv	2 ppbv	0.1 ppbv
[ ] Nitrogen oxides	TEI model 42s	0.1-100 ppbv	0.5 ppbv (as NO)	0.1 ppbv
[ ] Sulfur dioxide	TEI model 43bs	1-100 ppbv	0.5 ppbv	0.1 ppbv
[ ] Sulfur hexafluoride	Scientech model LBF3	0-20 ppbv	0.01 ppbv	0.001 ppbv
<u>Aerosol properties:</u> (Check those requested)				
[ ] Scattering extinction	Radiance Rsch. M903	0-10^3 Mm^{-1}	2 Mm^{-1}	0.1 Mm^{-1}
[ ] CCN concentrations	UWyo CCNC-100A	0-1,000 cm^{-3}	+/-30%	+/- 1 cm^{-3}
[ ] CN Concentration	TSI 3010	0-10,000 cm^{-3}	+-10%	30 cm^{-3}

Notes to Table E3:

(1) In units native to the instrument.

(2) In units of customary usage.

(3) As mounted in the nose ring, the field of view could be set to 1 degree or 15 degrees by changing lenses. For the 1998-2000 flights we had selected 15 degrees.

(4) Several sensitivities, ranges, and resolutions are available for each channel.

(5) The manufacturer's accuracy (+/-5%) applies to the instrument gain, i.e, to the conversion factor from volts to W/m^2. Thus, the accuracy is +/-5% whatever value the instrument is detecting, regardless of range.

4.a **Justification for STANDARD INSTRUMENTS**

- *The cloud particle spectrometers (esp 2DC and 2DP) will document the microphysical characteristics of hydrometeors (QPF flights); LWC estimates are needed for BL water vapor budgets, in case of shallow cumulus (CI flights).*
- *Turbulent flux measurements are essential in BL flights for comparison with and regionalization of surface fluxes, and for estimates of vertical flux divergence.*
- *Radiation sensors will be used on BL flights to detect surface inhomogeneities.*
- *NDVI sensor aids in linking aircraft fluxes to vegetation beneath.*

4.b **Justification for NON-STANDARD INSTRUMENTS**

- *A separate request is submitted for the use of the WCR on the UWKA, in dual-beam nadir-looking configuration. The WCR provides transects of BL echo structure, vertical air motion, and along-track circulation (u,w), especially for buoyant thermals and in convergence zones.*
- *A second high-frequency water vapor sensor, preferably a Tunable Diode Laser, is desirable for instrument comparison and redundancy since UWKA will be used as 'ground truth' for remote water-vapor field and flux measurements.*
- *A forward-looking digital video camera with high spatial resolution (e.g. 1024x1024) is needed for photogrammetry, i.e. to locate and size cloud, surface features (lakes, terrain, surface cover, etc.), and to estimate visibility. Such a camera, in combination with NDVI data and catalogued land-surface information (soil properties, crop descriptions, etc.), will allow us to relate surface conditions to fluxes, mesoscale circulations and the first clouds in the CBL to the land surface conditions.*

F. USER-SUPPLIED SCIENTIFIC PAYLOAD					
1. List Requirements of User-Supplied Scientific Payload.					
Instrument	**Weight**	**Size** (19" panel or other)	**Power Required** (watts, amps)	**Type of Power** (AC, DC, Hz)	**External Sensor Location** (if any)
HVPS (details available from Spec, Inc.	?	Fits in PMS canister	?	wingtip	

Justification for User-Supplied Payload

High-volume particle sampler allows more accurate characterization of drop size distribution and ice size/habit over short sampling distances. This would allow the UWKA to descend at 1000 ft/min and still obtain accurate particle size spectra.

G. DATA RECORDING AND PROCESSING REQUIREMENTS

1. Summarize the scientific prerequisites (Hypotheses) leading to the UWKA Instrument Specifications stated in Part E

The overarching hypothesis of IHOP is that the improved characterization of the water vapor field will result in significant, detectable improvements in warm-season QPF skill.

1. **ABL group**: fair weather atmospheric boundary layer goals and hypotheses:

We aim to better understand the evolution of the water vapor field and its sources of heterogeneity, as it relates to surface processes and horizontal transport (p. 12, IHOP Scientific Overview). This requires accurate water vapor and water vapor flux estimates. The ABL group has agreed on three overarching and overlapping goals:

a. To understand what determines the water vapor distribution in the ABL,
b. To determine how land-surface heterogeneity (land-use, soil moisture, terrain) affect ABL development, including development of mesoscale (50-200 km) heterogeneities that could lead to storm initiation.
c. Improve ABL simulation at the mesoscale by accounting for surface and ABL effects

Each goal has corresponding hypotheses:

a1. *In the southern Great Plains, under fair-weather conditions ,horizontal transport and vertical flux divergence are both major factors determining humidity evolution.* This has been suggested by the CASES 97 dataset (LeMone et al. 2001, submitted), and will be examined in multiple-aircraft missions. Mesoscale advection will be assessed remotely by means of DIAL and HRDL water vapor and wind measurements. The UWKA will provide smaller-scale advection (humidity gradient, wind) estimates and fluxes of latent heat within the ABL.

a2. *The small-scale (1-20 km) horizontal variation of precipitable water in the BL is significant magnitude and can be largely explained by organized large eddies in the BL.* Weckwerth et al. (1996, MWR, 769-784) document such variability induced by boundary-layer roll vortices. Large-eddy airflow and vertical structure can be inferred combining WCR and in-situ humidity and wind data on vertically stacked flight legs in BL and CI missions.

a3. *Heterogeneity in the ABL is significant in the early morning, compromising the representativeness of the 12Z (0530 LST) sounding*. UWKA measurements in south central Kansas show terrain and surface cover can exert strong controls on mixing ratio and temperature near the surface just after sunrise (LeMone et al. 2001, BAMS). Moisture measurements from surface stations are often used to interpolate stability changes horizontally and between sounding times. However, since the moisture content decreases rapidly with height in the lowest 100 m in the convective boundary layer, surface measurements can grossly overestimate the amount of water vapor available (e.g., Mueller et al.1993, Weckwerth 2000). The UWKA will provide in-situ samples of water vapor and temperature to be integrated with data from other sources to document the evolution of the water-vapor field and its causes in coordinated pattern 1.3c.

b. horizontal variability in temperature and fair-weather convergence and divergence are related to terrain features, land use, or soil moisture, at least up to a certain depth in the boundary layer. Terrain role: Shaw and Doran (J. Climate, 2001, p. 1753-1764), LeMone et al. (BLM, 2001, submitted). Land use/soil moisture (Tapper 1991, Paleogeog., Paleoclim, Paleoecol., p. 259-69, Mahrt and Ek 1993, Chen and Avissar, 1994, JAM, 3751-3774, etc., BOREAS, SGP97 studies). In the southern Great Plains, these features are of the order of 50-200 km in scale. To assess this, we need accurate location, radar and pressure altitudes, potential temperature, mixing ratio, winds, flux estimates, and terrain and land surface conditions, NDVI vegetation indicator. Also need coordinated flights with NRL-P3 and/or DLR Falcon. These aircraft will supplement the UWKA measurements at larger scales. Differential BL processes alter the distribution of the first low-level convective clouds and the horizontal distribution of CAPE, proving a linkage to CI. Also Pielke et al. (1997, Ecol. Appl, 3-21) demonstrate that land-use heterogeneity leads to stronger thunderstorms than similar terrain with uniform land use.

c. *Improved land-surface characterization can improve QPF*. Chen et al. (1997, BLM, 391-421) show that improving the land-surface scheme in the Eta model improved the precipitation forecasting as much as doubling the horizontal resolution. It follows that improved representation of surface processes in numerical weather forecast models should improve QPF further. And there is need for improvement. CASES-97 studies show features in the surface temperatures and aircraft fluxes that are not consistent with model predictions; we suspect either inadequate documentation of soil type or weakness in the models (Grossman and David Yates manuscript in preparation). Needed: King-Air sensible and latent heat fluxes, position (height, lat, long), thermodynamics, kinematics, radiation (upwelling, downwelling, Heimann surface temp, NDVI), and videos from repeated legs at 100 ft over a small number of fixed tracks (ABLE, Little Washita, Lamont regions). Carbon dioxode flux helpful here, too.

2. **Convection initiation** hypotheses and objectives

The primary hypothesis of the convection initiation group is that improved water vapor measurements will advance our understanding of processes that initiate deep, moist convective over the southern Great Plains. Specific studies will test the role of boundary-layer convergence zones, undular bores, solitary waves, internal gravity waves, boundary inflections and vortices and the related moisture distribution along these features upon thunderstorm initiation. It is hypothesized that convection in the SGP in May-June is commonly initiated along shallow convergence zones, detectable as fine-lines by ground-based radar. The initial organization of deep convection may be affected by along-boundary variability (resulting from shear instabilities, interactions with roll vortices, etc.) and by the structure of BL roll vortices in the antecedent moist/warm BL. Planned measurements will provide a data set that includes water-vapor information in unprecedented detail. The role of the UWKA will be in sampling in-situ thermodynamic and kinematic fields for studies of boundary evolution and water vapor and kinematic fields to validate and aid in interpretation of remotely sensed fields. WCR data will provide information on ABL structure and cloud structure and distribution along and across boundaries, and microphysics instruments will provide information on the clouds along the boundary. All measurements are dependent on good position information and good communication.

3. **QPF** hypothesis and objectives (also see ABL goal 1c)

The key hypothesis is that improved description of the 4D distribution of water in all phases, and improved understanding of processes controlling this distribution, will improve QPF ability. Specific questions to be addressed include 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 observations will be done to determine improvements to model performance.

It is now possible for weather forecast offices (WFOs) to run sophisticated, high-resolution models with full microphysics and have the output available within 3 h of the initialization time. Such a real-time forecast system, the Local Analysis and Prediction System (LAPS) using diabatic initialization, has been running routinely at FSL since fall 2000 and at the WFO in Boulder for operational evaluation (Shaw et al, 2001: 14th AMS Conf NWP preprints). LAPS integrates data from mesonetworks, Doppler radars, satellites, wind profilers, and aircraft every hour using a variational procedure to dynamically adjust the wind and mass fields to produce a high-resolution gridded analysis. The LAPS cloud analysis produces 3-D distributions of “Water In All Phases” (WIAP), i..e., cloud ice, cloud water, rain, snow, and graupel (Albers et al. 1996, *Wea. Fcstg*, 273-287), which are used to initialize models such as RAMS, MM5, and Eta, which have microphysical schemes. When combined with properly balanced vertical motions, cloud and precipitation forecasts up to 5-6 hours are substantially improved (Shaw et al. 2001). Despite this success using this "hot start" diabatic initialization, it remains to be determined whether short-range QPF can be significantly improved with a good initialization of hydrometeors. Assimilation of radar-retrieved cloud microphysics improves storm prediction in cloud-resolving models (Sun and Crook 1997), but this has not yet been demonstrated for mesoscale models initialized with observed hydrometeor fields over many cases. Furthermore, the LAPS cloud analysis necessarily involves a number of assumptions and empirical relationships about cloud depth, fraction and content (liquid/ice partition) as the various measurement systems are integrated to produced the final fields. Thus, there is a need to validate these analyses with in-situ observations of cloud matter and hydrometeors.

The IHOP project presents an excellent opportunity to compare parallel forecasts made using conventional datasets against the candidate next-generation datasets to determine the potential value of these data in the advancement of these key aspects of numerical predictions. It is hypothesized that an analysis of water in all its phases with proper dynamical balancing (the LAPS "hot start" procedure) will lead to important improvements in short-range prediction of precipitation amounts, type, and distributions. It will be determined whether any such improvement is due primarily to the direct effects of hydrometeor insertion into the model initial state, or because of the indirect influence of the cloud analysis on the model radiation fields, and resultant temperature, wind, and humidity fields.

The UWKA will be used to determine hydrometeor species, in order to validate the S-POL polarimetric hydrometeor classification and rain rate. The S-Pol data, so validated, will be used to validate Water-In-All-Phases (WIAP) analyses that form the basis of the "hot-start" LAPS/MM5 model forecasting.

4. **Instrument research and validation** objectives

(a). To provide 'ground truth' for remote sensing instruments, including airborne (p. 27, IHOP Scientific Overview), and surface (p. 15). Need UWKA water-vapor, wind, and position data in a variety of environments.
(b). To provide insight into the optimal mix for water vapor measurement instruments and the relative importance of water vapor measurements to other variables. Needs same as (a).
(c) To assess the effects of high gradients, rapid evolution, and the presence of contaminating factors on the remote measurement of water vapor concentration. Needs are same as (a), esp. for CI missions.

Opportunities for comparison with instruments have played a role in both location and design of the flight patterns.

2. If nonstandard formats and/or data rates are required, how often are the measurements required? (Attach statement justifying the need for nonstandard rates as processing procedures. Nonstandard rates and formats will be considered as a special processing request.)

The standard formats and data rates should be fine. Data files should be compatible with NCAR netcdf software. Should consider making data available via ftp.

**Note: The standard media for data transfer is Exabyte magnetic tape.

3. If additional processing is required, will it be done at NCAR? **No** At UWYO? **Yes**

4. Has request for computing services been sent to NCAR Computing Facility? **No**

H. OTHER SUPPORTING SERVICES

1. Will you require Air-Ground Communication? **YES** If so, what range? Specify location of base station and operating frequencies.

verbal communication (flight scientist): *UWKA should be able to communicate with other aircraft (NRL P3 and DLR Falcon) and with a ground station, preferably the IHOP operations center in Norman. Additionally it would be useful to communicate with the NSSL mobile Field Coordination Vehicle (FC), S-Pol, the ABLE Project Office and/or the ARM-CART Project Office.*

data transfer: (a) GPS location of UWKA should be transferred to the IHOP operations center in Norman and possibly to S-POL, so that real-time UWKA location can be plotted on radar PPI and visible satellite imagery; if this is impossible, use transponder, or 'skin paint'. (b) select data transfer from the UWKA to mobile Field Control Vehicle is desired to allow Field Control to make more

educated decisions re guidance of mobile-ground facilities and aircraft. In situ atmospheric variables can be used to pinpoint location/strength of boundary/ radar fine-line.
proposed data transfer system: 900MHz Freewave telemetry/data transfer system.

2. Any special sensor calibration services required?
Dedicated flux intercomparison, prior to experiment, is necessary, especially for water vapor fluxes. (see Pattern 5.2d)

3. What additional recording capability is requested? Explain below.

Voice Record	Yes
Video Recording	Yes – see above about high-resolution digital video recording

4. Will WYO Support be required in preparing special instruments for use on aircraft? (If so, specify type and lead time.)
No, except for the additional water vapor sensor (TDL or IRGA), and the hghi-resolution camera (see notes at end of facilities request).

Use the remaining space to provide any additional information which WYO may need to support this program:

Flux intercomparisons should be done prior to the experiment, since we have proposed that the UWKA be used for ground truth for remotely-sensed water vapor and water-vapor fluxes, the UWKA may be carrying a relatively new humidity instrument, the TDL, and a new comparison is overdue. This could be done as soon as the second water vapor instrument is mounted, in the Colorado-Wyoming area in early 2002.

Two new instruments are proposed for the UWKA: the TDL or other water vapor flux instrument, and a high-resolution digital camera. These have not been tested on the UWKA. Their status (UWYO or user-supplied) and sponsorship have not yet been determined.

In order to determine the height of the BL top (zi), its definition, and its undulations, at the same time and place as lower-level UWKA measurements, it would be useful if the WCR were pointing upward during at least some of the BL missions. The ability to readily switch from nadir dual-beam to zenith single-beam is highly desirable. An additional advantage of this ability is that it automatically will also allow side-ways WCR observations, because of the WCR mirror configuration. This could reduce the length of the ABL patterns by eliminating the need for repeated flights above the ABL.

An independent request is being submitted simultaneously for the WCR.