REQUEST FOR LAOF FACILITY SUPPORT
OWLES
NCAR/EOL - NOVEMBER 2012 OFAP MEETING

Submitted on 2 July 2012

UWKA with WCR & WCL
Two Dual-Pol DOWs, one Rapid-Scan DOW
Field Catalog & Data Archive support

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PART I: GENERAL INFORMATION

A. Corresponding Principal Investigators

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Neil Laird	Hobart and William Smith Colleges (HWS)
Kevin Knupp	University of Alabama in Huntsville (UAH)
Karen Kosiba	Center for Severe Weather Research (CSWR)
Nicholas Metz	Hobart and William Smith Colleges
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James Steenburgh	University of Utah
Scott Steiger	State University of New York – Oswego (SUNY-O)
George Young	Pennsylvania State University (PSU)

B. Project Description

Project Title	**OWLeS (Ontario Winter Lake-effect Systems)**
Location of Project	southeastern and eastern shores of Lake Ontario, and vicinity
Start and End Dates of Field Deployment Phase	1-21 December 2013 and 3-24 January 2014, with a flexibility of 2-3 weeks
NSF Facilities requested	UWKA with WCR and WCL 2 dual-pol DOWs and 1 rapid-scan DOW
Funding Agency and Program Officer Name(s)	NSF-AGS, Bradley Smull and Chungu Lu
Proposal(s) affiliated with this request	**three proposals to NSF AGS:** OWLeS – SAIL (Surface and Atmospheric Influences on Lake-effect convection, when the winds are at large angles to the long axis of the lake) (Lead PI: Kristovich, UIUC; collaborative with MU, HWS, and PSU) OWLeS – BIC (Bands of Intense Convection, when winds are aligned with the lake) (Lead PI: Geerts, UW; collaborative with SUNY-O, UIUC, CSWR, and UAH)

	OWLeS – Lake-effect snow bands interactions with downstream orography (PI: Steenburgh, UU)
Proposal Status	in preparation (all three)
Do you expect other, non-NSF support? If yes, from whom?	no
Is this a resubmission of a previous request?	A campaign with the same acronym was evaluated by OFAP in 2009. That campaign was broadly motivated by the OWLeS-SAIL proposal (see below). The objectives of the current OWLeS campaign are broader. This campaign also considers intense lake-effect snow bands under along-lake steering flow, the subject of a 2010 pilot project with 2 DOWs supported by an EAGER grant to Steiger/Frame.
Is this a multi-year deployment or a request for a follow-on field campaign?	No, all operations would be in a single winter.

C. Abstract

The OWLeS project examines the formation mechanisms, cloud microphysics, boundary layer processes and dynamics of lake-effect systems (LeS) using new observational tools capable of detailing LeS characteristics not observed in previous LeS field experiments. Lake-effect systems form through surface-air interactions as a cold air mass is advected over relatively warm (at least partially) ice-free mesoscale bodies of water. The OWLeS project focuses on Lake Ontario because of its geometry and size, influence of upstream lakes, frequency of LeS, nearby modest orography, and proximity to several participating universities with a strong record of undergraduate research. We distinguish between short-fetch LeS (those oriented at large angles to the long axis of the lake) and long-fetch LeS (those more aligned with the lake's long axis).

The overarching **objectives** of the OWLeS project are to:

a. understand the development of, and interactions between, internal planetary boundary layers (PBL) and residual layers resulting from advection over multiple mesoscale water bodies and intervening land surfaces;
b. understand the processes involved in the development of lake-effect snows over the New York Finger Lakes and how these processes differ from the larger Great Lakes;
c. examine how organized, initially convective LeS structures in short-fetch conditions persist far downstream over land, long after leaving the buoyancy source (i.e., the ice-free water);
d. examine how surface fluxes, lake-scale circulations, cloud microphysics and radiative processes affect the formation and structure of long-fetch LeS;
e. understand dynamical and microphysical processes controlling the fine-scale kinematic structures and electrification processes of intense long-fetch LeS;
f. provide *in situ* validation of operational (S-band) and research (X-band) dual-polarization hydrometeor type classification and lake-effect snowfall QPE; and

g. understand the influence of downwind topography on LeS generated over Lake Ontario.

Facilities requested from the NSF Lower Atmosphere Observing Facility (LAOF) pool are:

- the University of Wyoming King Air (UWKA), with the Wyoming Cloud Radar (WCR) and Lidar (WCL) systems; and
- three Center for Severe Weather Research (CSWR) Doppler on Wheels (DOW) radar systems.

In addition, several PI-supported mobile and stationary flux, surface, and sounding systems will be deployed. These non-LAOF systems will enhance the ability to observe mesoscale surface and PBL conditions and will facilitate student learning opportunities.

Intellectual merit: Building on previous LeS field campaigns, OWLeS provides a unique opportunity to broaden the understanding of LeS by deploying new remote sensing instruments and a network of profiling systems, by documenting the growth and evolution of LeS at unprecedented resolution, and by focusing more on overland evolution. Fundamental understanding of internal PBL evolution in response to spatially-variable surface conditions will be gained.

Broader impacts. Lake-effect snow remains a major weather hazard, especially downwind of the eastern Great Lakes. While current operational numerical weather prediction (NWP) models sufficiently capture LeS locations and timing, the predictability of snowfall intensity and inland extent of convection remains poor. Likely causes of poor QPF include unresolved variations in upwind and over-lake PBL structure, downwind circulations within residual layers, and inadequate coupling between buoyantly-driven PBL turbulence and cloud microphysics. Thus, the mesoscale NWP community will benefit from the results of OWLeS. The main benefit of the national WSR-88D dual-pol radar upgrade is believed to be improved QPE, yet this outcome is largely untested in lake-effect snowfall. OWLeS would fill in this information void. An improved understanding of processes driving LeS becomes more urgent in a warming global climate. Climatological trends and recent trend changes in LeS snowfall and related atmospheric and lake properties are not well understood, and improved understanding of LeS will allow for investigations of possible impacts on regional ecology and communities. In addition, boreal lakes and the Arctic coastal waters are expected to remain ice-free for longer periods in the cold season, resulting in complex internal PBL interactions and substantial increases in PBL moisture and snowfall.

D. Experiment Design

An “OWLeS” facility request was considered at the Fall 2009 OFAP meeting. The OWLeS_2009 request was different, asking for three Integrated Sounding Systems and the UWKA, but no DOWs. The proposed science was more limited, essentially covering the OWLeS-SAIL proposal only, not the OWLeS-BIC proposal (see Table 1 below). In early 2010 NSF declined the OWLeS request, but the cognizant program manager (Smull) encouraged resubmission of the request some time later, in part because one component of the project (dual-pol particle ID and dual-pol QPE validation) was being jeopardized by a delay in the WSR-88D dual-pol upgrade schedule. Dr. Smull recommended that this resubmission occur in combination with a follow-up to the LLAP campaign, funded by an NSF EAGER grant (P/Is Steiger and

Frame) and considered a pilot study. The LLAP (Long-Lake-Axis Parallel) campaign, conducted between Oct 2010 and Jan 2011, focused on the more intense lake-parallel snow bands that may form under westerly flow. These bands are the main topic of the OWLeS-BIC proposal. The two relevant proposals for OWLeS_2009 were not peer-reviewed, but both the EOL and UWKA teams produced a feasibility analysis in response to the facility request.

Now, three years later, the present OWLeS request combines the original OWLeS objectives with objectives that have emerged from the LLAP pilot study, plus some new initiatives. Aside from its intellectual merit and broader impact potential, the OWLeS project has two important and rather unique strengths: (a) the pooling of Lower Atmosphere Observing Facility (LAOF) and other facilities for a range of objectives in a common environment implies a cost-effective facility use; and (b) this coordination of research interests effectively combines the EOL experience of scientists at a variety of academic institutions with research opportunities for large numbers of undergraduate students.

D.1 RESPONSE TO THE 2009 OWLES FEASIBILITY ANALYSIS

Integrated Sounding Systems: There were no concerns raised regarding instrumentation or deployment of the equipment, other than obtaining needed permissions for operating in Canada. No ISS is requested for OWLeS. Permissions will be obtained by individual universities involved in rawinsonde operations in Ontario.

UWKA, WCR, WCL: Concerns were raised regarding:

- flying at low altitudes due to flight and weather restrictions: addressed in Section D.4 below
- restricted airspace involving multiple ATC units including a Canadian one: not insurmountable, yet to be addressed with the UWKA management well in advance of the field phase, possibly leading to changes in flight levels or track sequences
- Rochester below minimums on return-to-base: several alternate airports should be examined. Note that LeS snowfall and limited visibility usually rapidly improve inland.
- VFR flight in marginal weather conditions: addressed in Section 4 Experimental Design
- inability to deploy both the Heimann KT and down-pointing WCL: this restriction still applies, and our preference has been given. In general there may be other issues regarding space and power limitations. This request indicates a desired instrument configuration on the UWKA and lists priorities such that the P/Is can discuss options with the UWKA team.

D.2 COLLABORATIVE EFFORTS AND PROPOSAL ORGANIZATION

The OWLeS project is a collaborative effort between several institutions. The Principal Investigators (P/Is) intend to maintain this cooperation for both the field project operations and subsequent research activities. Many of the project objectives connect in a natural manner. Therefore, the P/Is will submit three research proposals that focus on connected areas of research (Table 1):

i. (collaborative proposal) surface and atmospheric influences on lake-effect convection when the winds are at large angles to the long axis of the lake (“short-fetch”, related to objectives a, b, and c from Summary)

ii. (collaborative proposal) convective snow bands oriented parallel to the long axis of Lake Ontario (“long-fetch”, related to objectives d, e, and f).
iii. (PI: Steenburgh) coastal and orographic effects on LeS snow bands (objective g).

The third proposal will not be submitted as a collaborative proposal (NSF definition), but in effect much of the work will be collaborative, based on a common experimental design. A single, coordinated field campaign such as OWLeS is much preferred over single-P/I efforts given the synergy of instruments and superior data density.

Table 1*: Research proposals and PIs linked to the OWLeS project. Objectives are listed in Section C above.*

OWLeS – SAIL **(Surface and Atmospheric Influences on Lake-effect convection)** **Short-Fetch LeS** **Mainly objectives a, b, c**	**OWLeS – BIC** **(Bands of Intense Convection)** **Long-Fetch LeS** **Mainly objectives d, e, f**	**Independent proposals** **Mainly objective g** **and other** **collaborators and participants**
Richard Clark, MU	Jeffrey Frame, UIUC	* James Steenburgh, UU
* David Kristovich, UIUC	* Bart Geerts, UW	
Neil Laird, HWS	Kevin Knupp, UAH	Michael Evans, NWS-BGM
Nicholas Metz, HWS	Karen Kosiba, CSWR	David Zaff, NWS-BUF
Todd Sikora, MU	Scott Steiger, SUNY-O	
George Young, PSU	Joshua Wurman, CSWR	

* Lead PI; CSWR-Center for Severe Weather Research; HWS-Hobart and William Smith Colleges; MU-Millersville University; NWS-BUF-National Weather Service Forecast Office (NWSFO) – Buffalo, NY; NWS-BGM-NWSFO-Binghamton, NY; PSU-Pennsylvania State University; SUNY-O-State University of New York – Oswego; UAH-University of Alabama in Huntsville; UIUC-University of Illinois in Urbana-Champaign; UU-University of Utah; UW-University of Wyoming. Proposed objectives are identified by the letters used in the Summary.

D.3 BACKGROUND

Over the last three decades, several field experiments have focused on understanding processes involved in the development of lake-effect snow storms. For example, the Lake-Induced Convection Experiment was conducted over Lake Michigan in the winter of 1997/98 (Kristovich et al. 2000) and the Lake Ontario Winter Storms project occurred in early 1990 (Reinking et al. 1993). Most recently, a small NSF EAGER-supported project, conducted downwind of Lake Ontario in late 2010 and early 2011, documented some remarkable shear-driven convective structures in intense snow bands, including multiple vortices less than 1 km in diameter, vertical wave patterns, and bounded weak echo regions (Cermak et al. 2012). This observation motivates the need for high-resolution three-dimensional wind data to better characterize and understand the development of these structures. Observational and associated numerical modeling studies have revealed much about the complex evolution of LeS and examined the broader issues of atmospheric convective PBL responses, mesoscale circulations, and cloud-microphysical processes which are associated with variations in surface properties (e.g., Agee and Hart 1990, Braham 1990, Hjelmfelt 1990, Chang and Braham 1991, Rao and Agee 1996, Braham and Kristovich 1996, Grim et al. 2004, Kristovich and Braham 1998, Kristovich and Laird 1998, Kristovich et al. 1999, Young et al. 2000, Laird et al. 2001, Young et al. 2002, Kristovich et al. 2003, Laird et al. 2003, Miles and Verlinde 2005, Schroeder et al. 2006, Yang and Geerts 2006, Cordeira and Laird 2008, Steiger et al. 2009, Laird et al. 2009, Alcott et al. 2012). This extensive work has raised a number of important scientific questions. These include:

- How do multiple internal boundary layers develop and interact as an air mass progresses over mesoscale stretches of open water and intervening land?
- What role does the variation in these multiple internal boundary layers have on the circulation patterns, longevity, and intensity of LeS?
- How does the interplay between dynamics and mixed-phase cloud processes produce long-lived LeS persisting far downwind of open water?
- How do lake-scale circulations and surface and convective processes control the formation of intense long-fetch LeS snowbands?
- What is the fine-scale kinematic, dynamic and microphysical structure of intense LeS bands, which may contain cells with all characteristics of thunderstorms except for their depth in a highly-sheared low-CAPE environment?
- What processes lead to lightning production in intense LeS?
- What processes control snow production over and downwind of a lake?
- How are PBL circulations and lake-effect intensity affected by coastal transitions and downwind orographic effects?

To develop a better understanding of such LeS processes, the proposed OWLeS (Ontario Winter Lake-effect Systems) project will collect measurements during the peak months of lake-effect snows (December and January) in the vicinity of Lake Ontario.

On a broader scientific scale, improved understanding of processes in LeS is expected to become more important in a changing global climate. In particular, a recent study identified a reversal in the long-term increasing trend in lake-effect snow over the last century over a portion of the Great Lakes (Bard and Kristovich 2012). In addition, boreal lakes and the Arctic coastal waters are expected to remain ice-free for longer periods in the cold season (Stroeve et al. 2012), likely resulting in substantial increases in atmospheric modification and precipitation (especially snowfall) potential (Brown and Duguay 2010), resulting from interactions of multiple internal PBL generated by such lakes.

D.4 SCIENTIFIC HYPOTHESES

The following hypotheses will be tested using measurements collected during OWLeS.

I. <u>Effect of Upwind Land/Lake Variations</u>: Spatial variations in PBL structure over Lake Ontario and, in turn, short-fetch LeS, critically depend on *upwind* PBL characteristics developed over alternating mesoscale land/water surfaces, modified by the combined influences of above-PBL stability and internal PBL circulations. (mainly objective a)

II. Small Lakes: Mesoscale circulations, PBL evolution, and snowfall distribution are altered and enhanced through downstream interactions of residual boundary layers with internal layers generated by smaller water bodies (such as individual Finger Lakes in New York). Additional enhancement comes from changes in downstream orography through channeling convergence and topographic lift. (mainly objective b)

III. Downwind Persistence: LeS bands are sustained over downwind land by one of three mechanisms: solenoidal circulations driven by weak moist convection in a decoupled mixed layer, ducted gravity waves, or continued coupling of lake-initiated convection to the surface due to overland instability created by differential temperature advection and solar heating. (mainly objective c)

IV. Dynamics of long-fetch LeS: Depending on wind, upwind temperature and stability, lake-parallel LeS may become sufficiently strong to produce lightning, vortical band structures (such as line-echo wave patterns), and heavy snowfall downwind, through a combination of lake-scale solenoidal flow, enhanced surface heat fluxes, and convective dynamics. (mainly objective d)

V. Electrification of LeS: Long-fetch lake-effect system electrification is supported by microphysical and kinematic characteristics that include relatively deep convection (up to about 4 km, cloud top temperature down to about -30°C) with moderate updrafts (≈3-5 m s^{-1}). (mainly objective e)

VI. Hydrometeor Particle Types and QPE: LeS contain a variety of particles (dry snow, rimed snow, graupel, wet snow …), which can be revealed by means of DOW and WSR-88D dual-pol fields (especially differential reflectivity ZDR and differential propagation phase K_{DP}) and can be identified using the WSR-88D dual-pol algorithms. The WSR-88D dual-pol snow rate estimation is superior to reflectivity-based snow rate estimation. (mainly objective f)

VII. Orographic enhancement: Enhanced snowfall occurs as lake-modified air ascends over downwind elevated terrain, such as the Tug Hill Plateau east of Lake Ontario. Orographic convection and boundary layer turbulence contribute to this enhancement, with hydrometeor advection and fall speed also affecting the intensity and distribution of snowfall upwind and over the Plateau. Variations in PBL structure, height and strength of the capping inversion, and storm morphology (e.g., shoreline bands, widespread coverage) produce intra- and inter-storm variations in these orographic effects and snowfall rates from the Lake Ontario coast across the Tug Hill Plateau. (mainly objective g)

Thus, these 7 hypotheses broadly correspond with the 7 objectives listed in the Abstract.

D.5 OBSERVATIONAL FACILITIES

Facilities requested from the NSF LAOF pool are:

- the University of Wyoming King Air (UWKA), with the WCR and WCL systems; and
- three CSWR Doppler on Wheels (DOW) radar systems, i.e. two dual-polarization DOWs and one Rapid-Scan DOW.

The following instruments and platforms are PI-supported:

- A total of five mobile sounding systems will be deployed, from UIUC, MU, SUNY-O, HWS, and one from UU (see Table 1 for abbreviations).
- The *Millersville University Profiling System* (MUPS) includes a surface flux tower, GPS rawinsonde system, a sodar & RASS, micropulse LiDAR, and a high wind aerostat with probes measuring standard meteorological variables, turbulence structure function (CT^2) and energy dissipation rate, up to a height that depends on conditions (~500 m AGL).
- The *Mobile Integrated Profiling System* (MIPS) includes a 915 MHz wind profiler, a CL51 ceilometer, a microwave profiling radiometer, a vertically pointing X-band Doppler radar, Parsivel disdrometer, a hot plate precipitation gage, and an electric field mill.
- *Deployable weather pods*. The DOW team plans to deploy up to ~20 “tornado” pods in each IOP, as detailed in the deployment plans. These pods are rapidly deployable weather stations measuring T, RH, and wind direction & speed at 1 Hz frequency. The data storage currently limits these pods to 17 hours of data collection. These pods will be deployed by means of 2 DOW support vehicles, which themselves measure all basic meteorological variables, but are otherwise not used to collect transect data along roads.
- Additional observations:
    - snow photography and surface snow board measurements at 4 sites along a transect from the coast to Tug Hill Plateau.
    - a Yankee hot plate (precipitation rate) plus WXT520 weather station (UW)
    - a GPS receiver station (UWKA) for improved aircraft position. The three above-mentioned instruments will be mounted during the duration of OWLeS at a site (such as the home of a CoCoRaHS volunteer) near Sandy Point on the east end of Lake Ontario.

A summary of the relative importance of the facilities (LAOF and non-LAOF) for the seven OWLeS hypotheses is given in Table 2. Nearly all requested facilities will be at least useful for each of the hypotheses.

Table 2. *Relative importance of the facilities for OWLeS hypotheses, rated as follows: 1=essential, 2=important, 3=useful, 4=not needed.*

Hypotheses	I effect of upwind	II small lakes downwind	III downwind persistence	IV dynamcs intense LeS	V electrification	VI hydro-meteors and QPE	VII oro-graphy
NSF LAOF							
UWKA in situ probes	1	2	1	1	2	1	1
UWKA WCR	2	2	1	1	2	1	1
UWKA WCL	1	2	2	3	2	2	2
single DOW (Z, V, dual-pol variables)	2	2	2	1	1	1	1
DOW dual-Doppler winds	2	4	3	1	2	1	1
DOW weather pods	4	2	2	1	3	3	1
PI- instruments							
mobile rawinsondes	1	1	2	1	1	1	2
MUPS	1	1	2	4	4	4	4
MIPS profiling sensors	2	1	3	1	1	1	1
MIPS in situ microphysics & field mill	4	2	3	2	1	1	1

D.6 OWLeS FIELD OPERATIONS

The lake-effect systems to be examined during OWLeS are either generated or augmented by Lake Ontario. It is convenient to organize our conceptualization of Lake Ontario convective systems as those generated when the winds are at large angles to the long axis of the lake (short-fetch, such as northerly or northwesterly winds) and those generated with winds nearly parallel to the long axis of the lake (long-fetch, usually westerly to southwesterly winds, but occasionally winds from opposite direction, ENE). Two of the OWLeS proposals (see Table 1) generally follow the same partitioning (i.e., OWLeS-SAIL focuses mainly on short-fetch LeS, OWLeS-BIC focuses on long-fetch LeS). Thus, the operations of OWLeS will vary with the predicted organization of the LeS convective structures, as illustrated below. The third proposal (focusing on orographic influences on LeS) is included in the long-fetch experiment plan.

a. **Experiment Plan 1** (map in **Fig. 1** and cross section in **Fig. 2**) is designed for conditions giving rise to short-fetch LeS. The internal lake-effect PBL structure develops in response to heat, moisture, and momentum fluxes from the lake surface. The atmospheric response to these fluxes may be controlled by such factors as the stability of the atmosphere, spatial variations in land cover, shoreline shape, upwind lakes, and internal PBL circulations. The most common convective structure in these conditions is multiple wind-parallel bands originating over Lake Ontario. Such bands occasionally extend far downwind of the lake. With this wind regime, convective bands also frequently develop within the PBL over the Finger Lakes within air modified by Lake Ontario.

   Plan 1 primarily serves hypotheses I through III (objectives a through c). In this experiment, observational platforms focus on obtaining information on either the spatial evolution of the PBL north of and over Lake Ontario or the spatial evolution of convective bands over and south of Lake Ontario, depending on the objective chosen for that day. Observational platforms can be deployed to determine:

   1) PBL and environmental conditions near the upwind shore of Lake Ontario (objective a)
   2) Surface fluxes, PBL evolution, and LeS development over Lake Ontario (objectives a, b)
   3) PBL structure and convective precipitation structures near the downwind shore of the lake (objectives a, b, c)
   4) PBL and convective structures between Lake Ontario and the Finger Lakes (objectives b, c)
   5) PBL and convective structure over the Finger Lakes (objectives b, c)
   6) Convective and microphysical structure within convective bands extending long distances downwind from their convective source regions. (objective c)

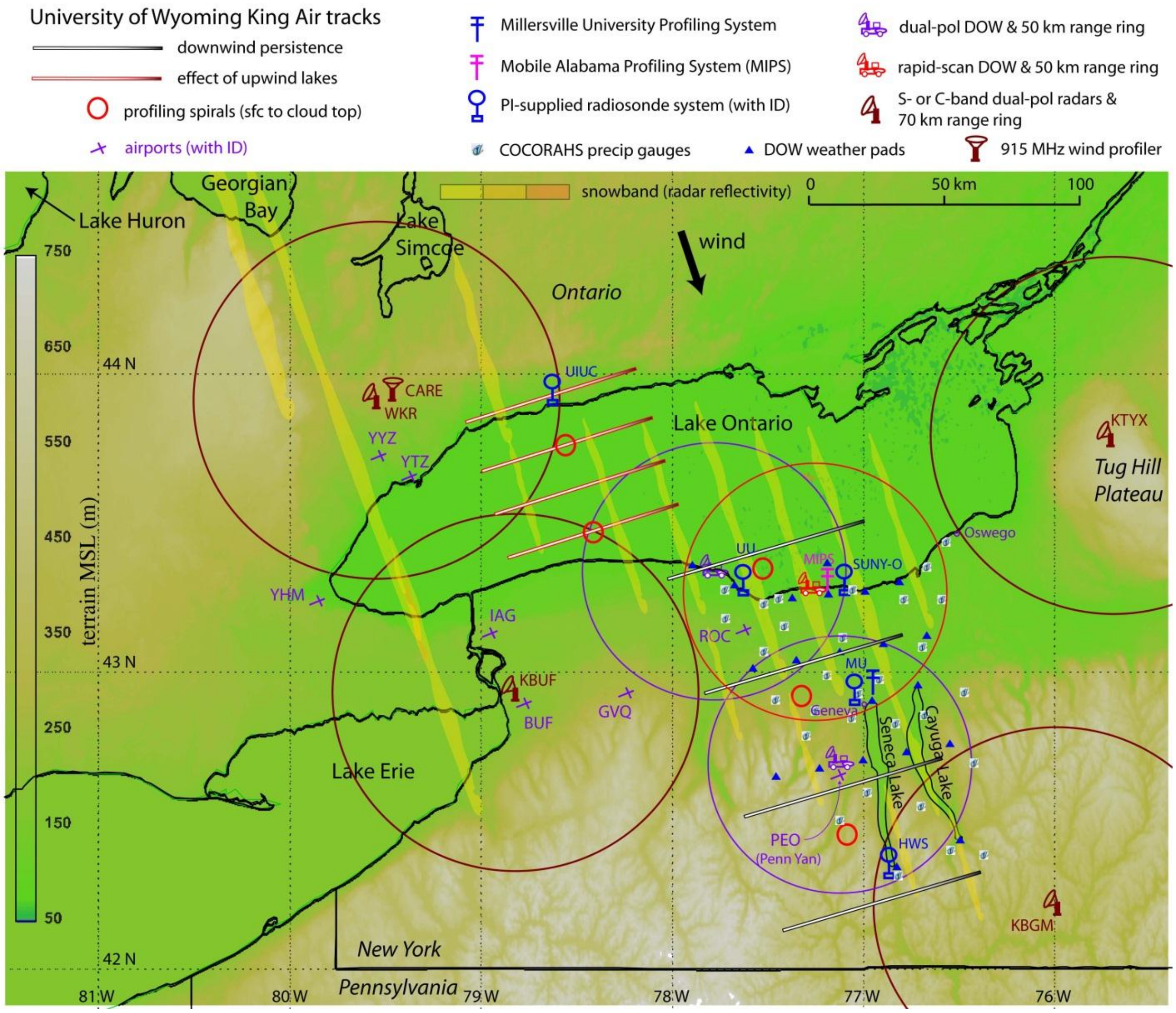

Fig. 1*: Terrain map showing schematic location of UWKA flight patterns, the OWLeS facilities, and relevant operational facilities in Experimental Plan 1 during conditions with short-fetch LeS bands. Light-colored regions oriented NW-SE illustrate the types of multiple convective bands frequently seen in these conditions. The colored UWKA flight tracks serve hypotheses I and III. All OWLeS facilities are mobile but are designed to remain stationary during the duration of short-fetch IOPs. The two largest Finger Lakes in New York, Cayuga and Seneca, are highlighted.*

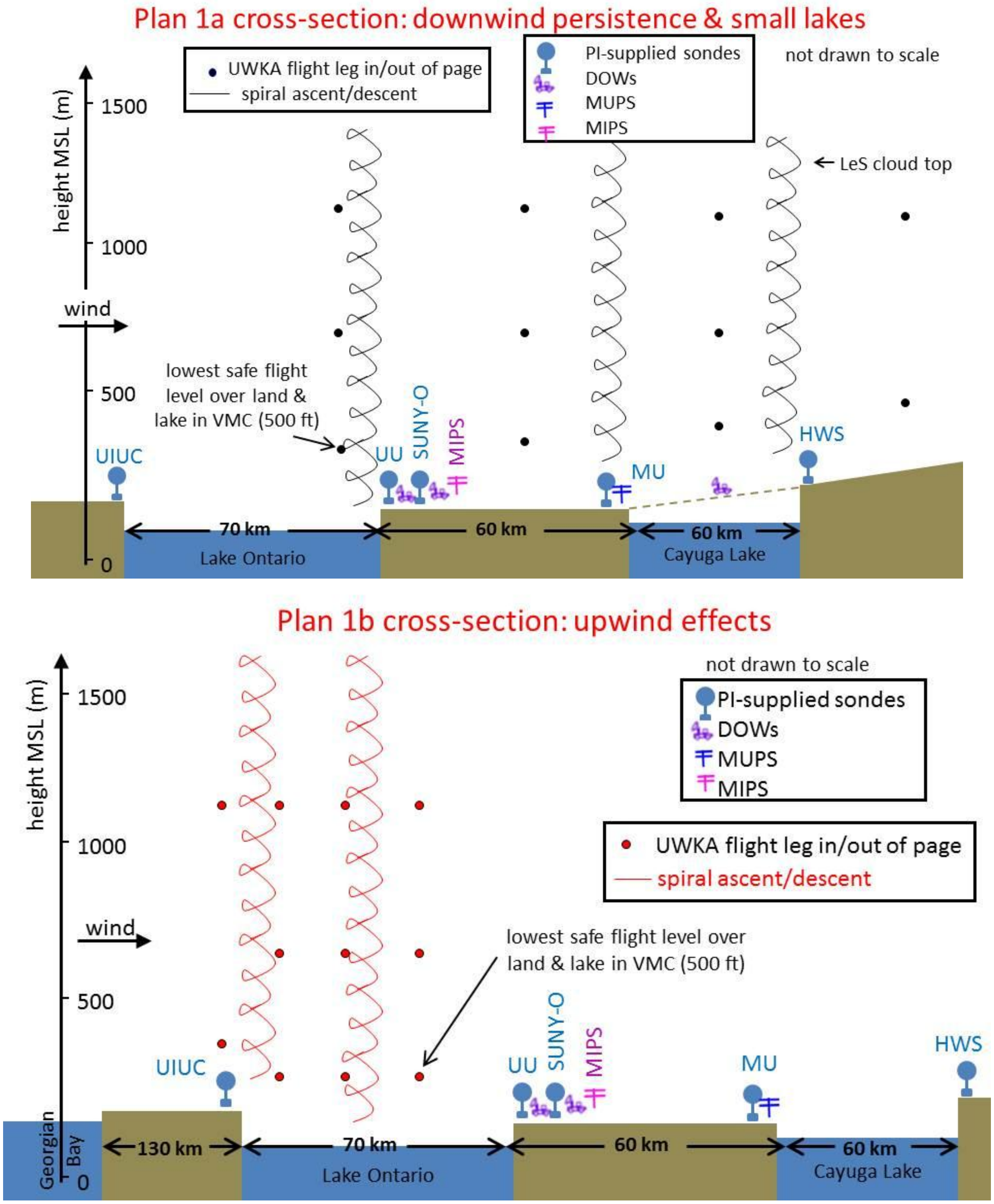

Fig. 2*: Schematic vertical cross-section showing schematic location of UWKA flight patterns, the five sites with OWLeS facilities, and mobile sites in Experimental Plan 1.(a) upwind effects (objective a); (b) downwind persistence and small lakes (objectives b and c).*

b. **Experiment Plan 2** (map in Figs. 3 and 4, cross section in Fig. 5) is designed for conditions giving rise to long-fetch LeS. The most common LeS structures in these conditions are single or multiple bands, generated over Lake Ontario and extending over higher terrain east of the lake. Plan 2 primarily serves hypotheses IV through VII (objectives d through g). In this experiment, observational platforms focus on obtaining information on the spatial evolution of the LeS over and east of Lake Ontario.

On occasion intense lake-parallel bands form under low-level ENE winds associated with an arctic high to the north, with heavy snowfall along the shore between Rochester and Buffalo. In that case the OWLeS facilities will be deployed between Rochester and Buffalo, and the relevant WSR-88D radar will be KBUF.

More details about the OWLeS Experimental Design and other planning documents can be found at http://www.atmos.uwyo.edu/~geerts/owles/

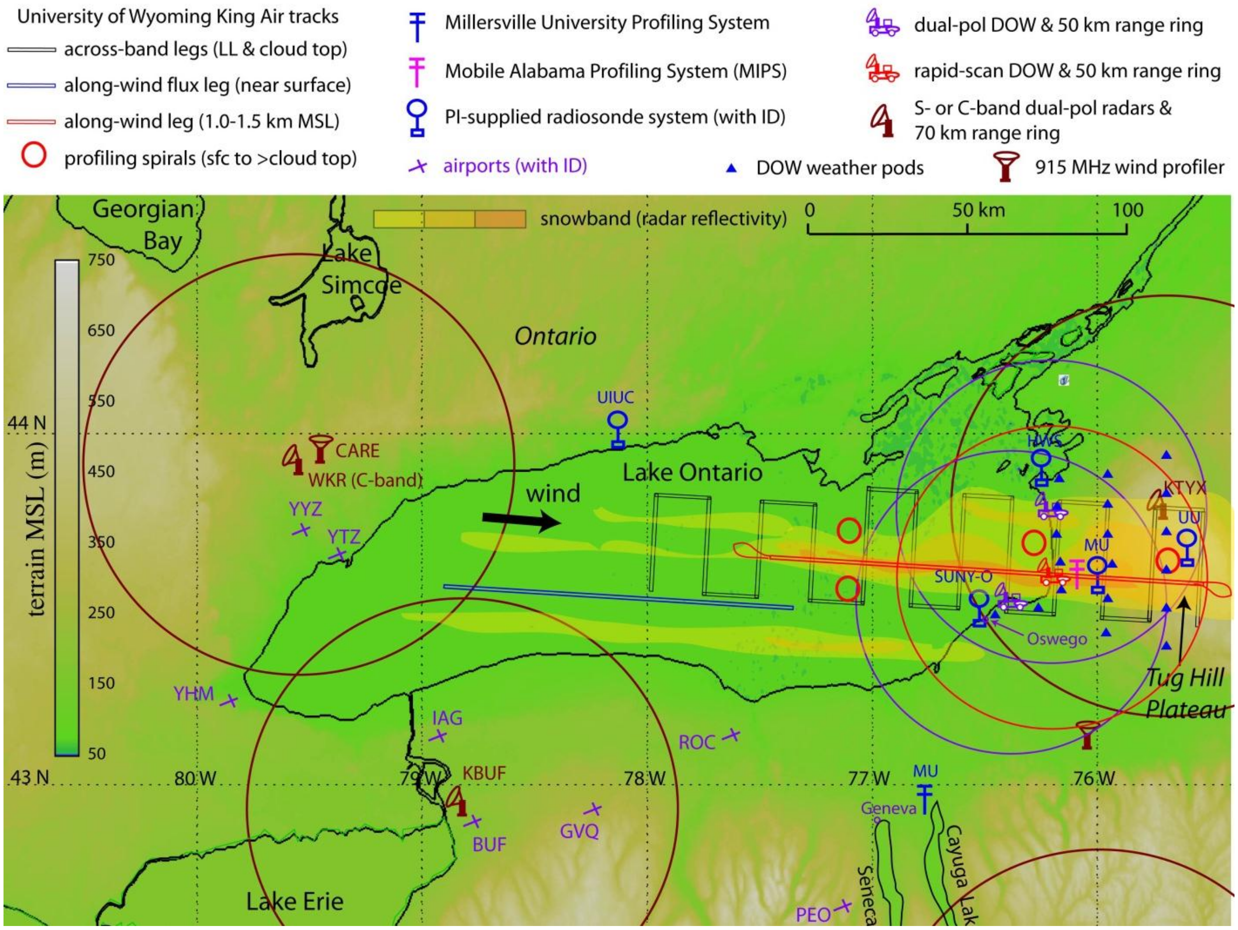

***Fig. 3**: Terrain map showing schematic location of UWKA flight patterns, OWLeS facilities, mobile sites and relevant operational facilities in Experimental Plan 2 during conditions with LeS oriented approximately parallel to the long axis of Lake Ontario. Sounding sites, MIPS and MUPS are designed to remain stationary during the duration of the long-fetch IOPs, but one or more DOWs may be moved between pre-selected sites during an IOP, if road conditions allow.*

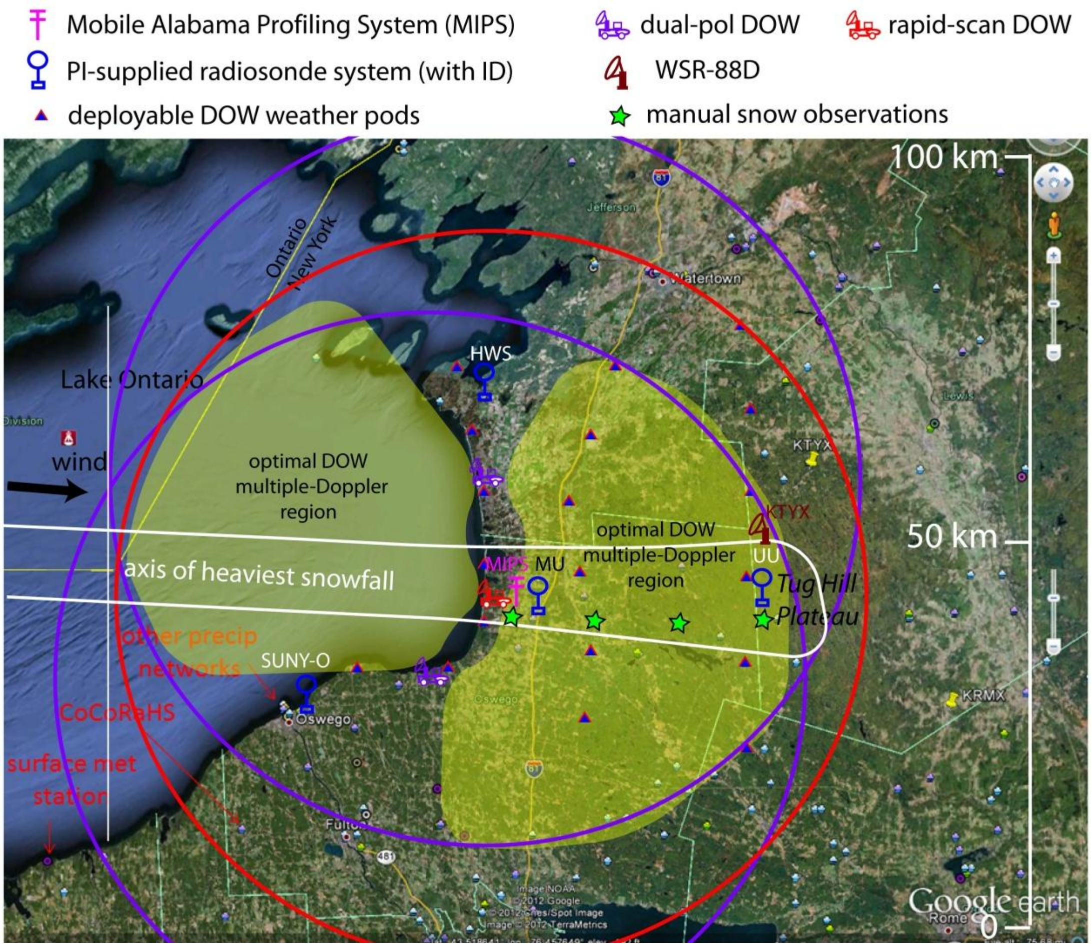

***Fig. 4**: Zoom-in map from eastern Lake Ontario to the Tug Hill Plateau, showing the same platforms as in Fig. 3 (except the UWKA), plus the DOW dual- to triple-Doppler regions, the transect of manual snow observations (photograph & snow board), and all operational weather stations including hourly to daily precipitation networks.*

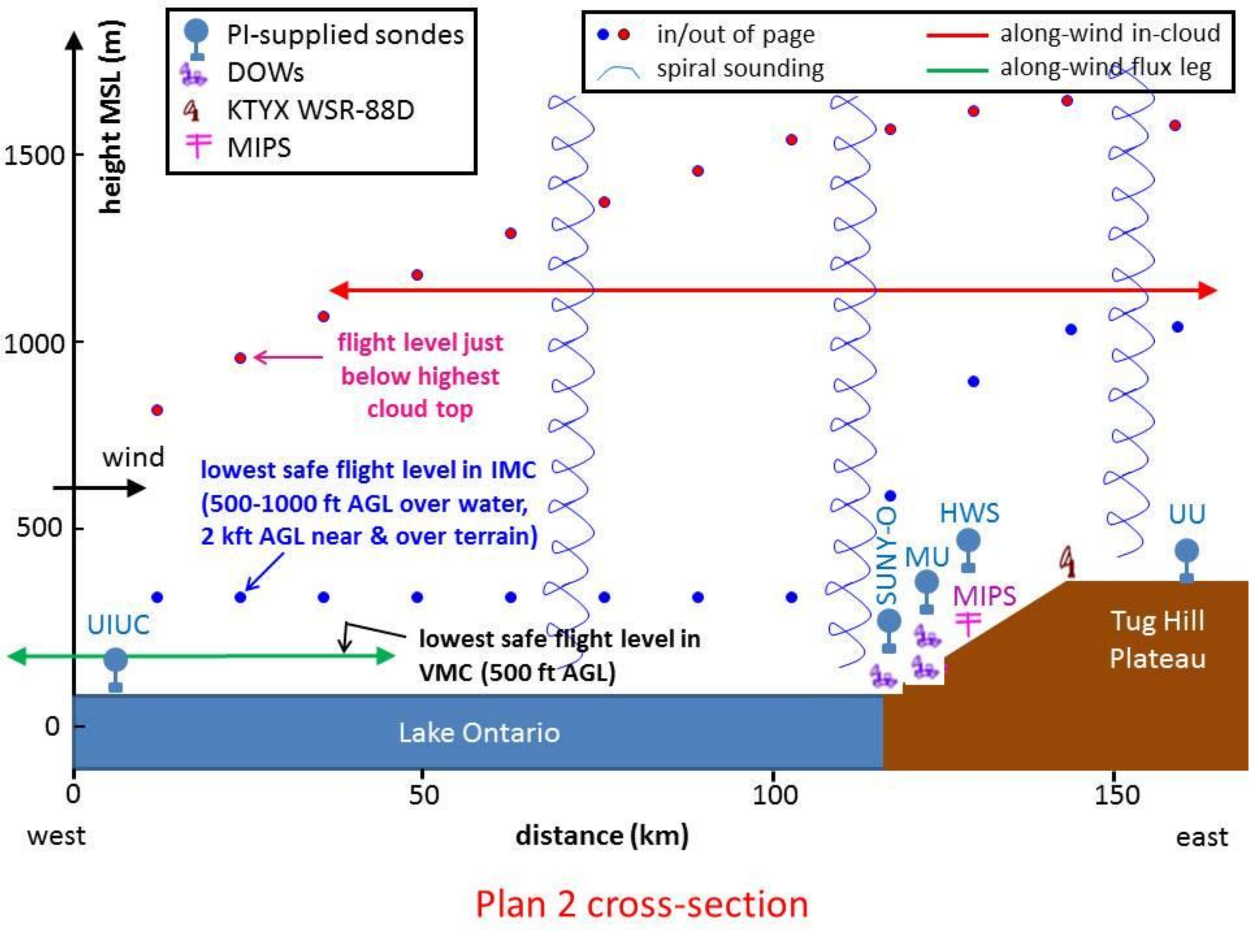

***Fig. 5**: Schematic vertical cross-section showing schematic location of UWKA flight patterns and OWLeS facilities, in Experimental Plan 2.*

D.7 OWLeS TIMING AND DURATION

The field phase is planned to coincide with the peak frequency of LeS near Lake Ontario. Specifically, the field operations are planned for 1-21 December 2013 and 3-24 January 2014, a 43-day period.

The duration of the field campaign is planned to be sufficient to capture approximately eight LeS events. Climatological analyses have shown that a six-week period spanning late November through early January typically yields about 10 LeS events (**Table 3**). Note that techniques available to Rodriguez et al. (2008) enabled them to identify weaker events than Kristovich and Steve (1995), and thus may be more representative of appropriate conditions for OWLeS. Of these events, typically about 5 are short-fetch LeS under northwesterly flow (Experimental Plan 1) some of which may extend between upwind lakes and Lake Ontario, and extend far downwind from Lake Ontario. Long-fetch LeS events (Experimental Plan 2) are less common (typically 1-3 during the time period), although they tend to last longer (**Table 4**). Note that since Kristovich and Steve (1995) and Rodriguez et al. (2008) based their LeS classification on visible satellite imagery, roughly half of the lake-effect cases could not be clearly categorized into one of these two types. In addition, weaker cases of PBL modification that do not produce significant clouds/snow over Lake Ontario but are useful for studying the influence of upwind lake and land variations, are thought to occur more frequently than reported by these previous studies. During the LLAP project, 7 long-fetch lake-effect wind cases were observed by Cermak et al. (2012). At least a third of the cases during a typical year last longer than a day (Table 4), allowing for multiple missions and possible different Experimental Plans during a single intensive operations period.

***Table 3**. Climatic frequency (in # days) over Lake Ontario in a 43 day period in late November-early January, based on visible satellite imagery.*

Number of days with …	Kristovich & Steve (JAM, 1995)	Rodriguez et al. (MWR, 2008)
Lake-effect snow	5-12	10-12
Widespread snow or multiple bands (rolls, usually oriented NW-SE)	2-6	5-6
Long lake axis parallel bands (W-E)	< 2	2-3

***Table 4**. Duration (in # days) of lake-effect snows over Lake Ontario.*

Percentage of	Based on data compiled by Kristovich and Steve 1995 and Rodriguez et al. 2008)	Based on LeS events listed by NWS Forecast Office, Buffalo, NY, 2009 (http://www.erh.noaa.gov/buf/)
1-day events	66%	18%
2-day events	23%	46%
Both 1- and 2-day events	89%	64%

E. Educational and Outreach Activities

Here we list training and learning opportunities for participating students, and further outreach activities. We are not requesting any EOL assistance for this.

E.1 TRAINING OPPORTUNITIES FOR OWLES PARTICIPANTS

The NSF LAOF Users Workshop held at NCAR in September 2007 highlighted the importance of the training of future observational scientists through participation in field work (Serafin et al. 2008), not just in data analysis, but also in campaign planning, instrument preparation, and data collection. We intend to bring several graduate students and a larger number of undergraduates into the field (**Table 5**). The positions to be assigned to these students are listed in **Table 6**. The student participation in the DOW operations is important as it will reduce the facility deployment cost. The preparation and release of rawinsonde balloons requires two people. For safety, at least two people will be at any one site, and IOP-related travel requires two people per vehicle (the buddy system).

***Table 5**: Student participation in OWLeS. Rotations are anticipated.*

University	# undergraduate students	# graduate students
Hobart and William Smith Colleges	~5	-
Millersville University	~12	-
Pennsylvania State University	-	1-2
State University of New York – Oswego	~10 or more	-
University of Alabama in Huntsville	-	1-2
University of Illinois Urbana-Champaign	4	2-3
University of Utah	-	1-2
University of Wyoming	-	1-2
Total	31 or more	6-11

***Table 6**: Student assignments in OWLeS. These positions must be filled during the entire field phase; rotations are anticipated.*

Instrument	# positions
DOWs (3 positions per DOW)	9
mobile sounding systems – 6 total (1 from HWS, 1 from MU, 1 from UIUC, 1 from SUNY-O, and 2 from UU)	12
Millersville University Profiling System (MUPS)	4
Mobile Integrated Profiling System (MIPS)	2
Snow photography	8
Forecasting, IOP nowcasting	2
total	37

Students will be involved in all aspects of the project. This includes logistics, deployment and data collection, real-time running of WRF, with an inner domain centered over Lake Ontario, daily weather briefings, interaction with the NWS WFOs at Buffalo and Binghamton, and nowcasting during IOPs in support of the operations director who coordinates the crews in the field. A smaller number of students will conduct OWLeS research as part of their degree program (BSc to PhD).

In addition, we plan to take advantage of non-IOP days between cold-air outbreaks. A for-credit *OWLeS seminar series* will be organized, on both the science of lake-effect snowfall and on field instrumentation, which will include visits to the facilities (radar polarimetry and Doppler synthesis; passive microwave atmospheric profiling; airborne and ground-based flux measurements …). Students register at their home institutions. The seminar sequence will be determined in advance; the exact timing depends on the IOP sequence. Most seminars will be open to anyone. One seminar will be dedicated to the planning of an IOP, whereby the students decide on the UWKA flight plan, the schedule of rawinsonde releases, and the deployment of participants in the field. This seminar, aimed at participating graduate and undergraduate students, will be modeled after the seminar held as part of RICO (Rauber et al. 2007). The richness and breadth of instrumentation deployed in OWLeS will ensure that students participating in the seminar will be exposed to in-situ ground-based and airborne platforms and remote observing facilities, with sensors operating at several different frequencies, capturing multiple spatial scales, with each sensor dedicated to a specific measurement while serving as a component of a coordinated project-scale observing system.

E.2 OUTREACH

Several universities in the vicinity offer undergraduate degree programs in meteorology or related fields (SUNY Brockport, SUNY Oswego, HWS Colleges, Cornell …). We plan to arrange events for students to see the UWKA, the DOWs, MIPS and MUPS at the UWKA's base airport. We may be able to release and track a weather balloon with the visitors. We may also develop a web-based OWLeS Outreach Program similar to the program at Millersville University where teachers from local high schools, community colleges, and universities can request an on-site visit to the facilities.

"*Most scientists today began their careers as children, chasing bugs, collecting spiders,* [observing weather], *and feeling awe in the presence of nature. Since such untidy activities are fast disappearing, how, then, will our future scientists learn about nature?* (Richard Louv, *Last Child in the Woods: Saving our children from nature deficit disorder.* Algonquin Books of Chapel Hill, 2008 p.144.) OWLeS activities are replete with opportunities for students to learn about winter weather, meet the scientists that endeavor to understand the atmosphere, and visit exciting facilities such as the DOWs and the UWKA.

F. Publications resulting from EOL support within the last five years

Note that the OWLeS campaign pairs more senior scientists with extensive EOL experience, with relatively new scientists and college faculty with high teaching responsibilities. This is a unique strength of OWLeS, combining EOL experience with research opportunities for large numbers of undergraduate students and their mentors.

Project Name and Year	Facilities used	Publication Citation (2008-2012 only)
Lake-ICE 1997-1998	ISS (3), NCAR Electra, NCAR ELDORA, UWKA	Barthold, F. E., and D. A. R. Kristovich, 2011: Observations of the cross-lake cloud and snow evolution in a lake-effect snow event. *Mon. Wea. Rev*. **139**, 2386-2398.
TEXAQS 2000	NCAR Electra	Nielsen-Gammon, J.W., C.L. Powell, M.J. Mahoney, W.M. Angevine, C. Senff, A. White, C. Berkowitz, C. Doran, and K. Knupp, 2008: Multisensor Estimation of Mixing Heights over a Coastal City. *J. Appl. Meteor. Climatol*., **47**, 27–43.
IHOP 2002	NRL P-3, UWKA, MGAUS, ISFS	LeMone, M.A., F. Chen, M. Tewari, J. Dudhia, B. Geerts, Q. Miao, R. Coulter, and R. Grossman, 2010: Simulating the IHOP_2002 fair-weather convective boundary layer with the WRF-ARW-Noah Modeling System, Part 1: Surface fluxes and CBL structure and evolution along the eastern track. *Mon. Wea. Rev.* , **138**, 722–744. LeMone, M.A., F. Chen, M. Tewari, J. Dudhia, B. Geerts, Q. Miao, R. Coulter, and R. Grossman, 2010: Simulating the IHOP_2002 fair-weather convective boundary layer with the WRF-ARW-Noah Modeling System, Part 2:

		Structures from a few km to 100 km across. *Mon. Wea. Rev.* , **138**, 745-764. Bennett, L.J., T.M. Weckwerth, A.M. Blyth, B. Geerts, Q. Miao, Y.P. Richardson, 2010: Observations of the evolution of the nocturnal and convective boundary layers and the structure of open-celled convection on 14 June 2002. *Mon. Wea. Rev.*, **138**, 2589-2607. Frame, J, P. Markowski, Y. Richardson, J. Straka, and J. Wurman, 2009: Polarimetric and dual-Doppler radar observations of the Lipscomb County, Texas, supercell thunderstorm on 23 May 2002. *Mon. Wea. Rev*., **137**, 544-561. Marquis, J.N., Y.P. Richardson, and J. M. Wurman, 2008: Kinematic observations of misocyclones along boundaries during IHOP. Monthly Weather Review , 135, 1749-1768. Knupp, K.R., D. Phillips, and B. Geerts, 2012: Observations of a microbursts and microscale vortices associated with a heatburst event. *Mon Wea. Rev*., in revision. Weiss, C.C., H.B. Bluestein, A.L. Pazmany, and B. Geerts, 2008: Fine-scale radar observations of a dryline during the International H_2O Project (IHOP). In: *Synoptic–Dynamic Meteorology and Weather Analysis and Forecasting*: A Tribute to Fred Sanders. Bosart and Bluestein, Eds., AMS Meteorological Monograph, **33**, No. 55, 440 pp.
BAMEX 2003	MGAUS, NRL P3 with ELDORA	Karan, H., and K. Knupp, 2009: Radar and Profiler Analysis of Colliding Boundaries: A Case Study. *Mon. Wea. Rev*., **137**, 2203–2222.
GLICAF 2004	UWKA	Gerbush, M. R., D. A. R. Kristovich, and N. F. Laird, 2008: Mesoscale Boundary Layer and Heat Flux Variations over Pack Ice-Covered Lake Erie. *J. Appl. Meteor. and Climatol*., **47**, 668-682.
CuPIDO 2006	UWKA, MGAUS, ISFS	Damiani, R., J. Zehnder, B. Geerts, J. Demko, S. Haimov, J. Petti, G.S. Poulos, A. Razdan, J. Hu, M. Leuthold, and J. French, 2008: Cumulus Photogrammetric, In-situ and Doppler Observations: The CuPIDO 2006 Experiment. *Bull. Amer. Meteor. Soc.*, **89**, 57–73. Geerts, B., 2008: Dryline characteristics near Lubbock, Texas, based on radar and West Texas Mesonet data for May 2005 and May 2006. *Wea. Forecasting*, **23**, 392–406. Koch, S.E., W. Feltz, F. Fabry, M. Pagowski, B. **Geerts**, D. O. Miller, and J. W. Wilson, 2008: Turbulent mixing processes in atmospheric bores and solitary waves deduced from profiling systems and numerical simulation. *Mon. Wea. Rev.*, **136**, 1373-1400. Geerts , B., Q. Miao, and J.C. Demko, 2008: Pressure perturbations and upslope flow over a heated, isolated mountain. *Mon. Wea. Rev.*, **136**, 4272–4288 Wang, Y., and B. Geerts, 2009: Estimating the evaporative cooling bias of an airborne reverse flow thermometer. *J. Atmos. Ocean. Tech.* , **26**, 3-21. Demko, J. C., B. Geerts, J. Zehnder, and Q. Miao, 2009: Boundary-layer energy transport and cumulus development over a heated mountain: an observational study. *Mon. Wea. Rev.* , **137**, 447–468. Wang, Y., B. Geerts, and J. French, 2009: Dynamics of the cumulus cloud margin: an observational study. *J. Atmos. Sci*., **66**, 3660–3677. Demko, J.C., and B. Geerts, 2010: A numerical study of the evolving convective boundary layer and orographic circulation around the Santa Catalina Mountains in

		Arizona. Part I: Circulation without deep convection. *Mon. Wea. Rev.*, **138**, 1902–1922. Demko, J.C., and B. Geerts, 2010: A numerical study of the evolution of the convective boundary layer and orographic circulations around the Santa Catalina Mountains in Arizona. Part II: Interaction with deep convection. *Mon. Wea. Rev.*, **138**, 3603–3622. Wang, Y., and B. Geerts, 2010: Humidity variations across the edge of trade wind cumuli: observations and dynamical implications. *Atmos. Res.,* **97**, 144-156. doi:10.1016/j.atmosres.2010.03.017. Wang, Y., and B. Geerts, 2011: Observations of detrainment patterns from non-precipitating orographic cumulus clouds. *Atmos. Res.*, **99**, 302-324. Wang, Y. and B. Geerts, 2012: Composite vertical structure of vertical velocity in shallow cumulus clouds. *Mon. Wea. Rev.*. accepted.
COPS 2007	DOW	Wulfmeyer, V. and Coauthors, 2011: The Convective and Orographically-induced Precipitation Study (COPS): The scientific strategy, the field phase and first highlights. *Q. J. Roy. Met. Soc*., **137**, 3-30. Wulfmeyer, V., and co-authors, 2008: The Convective and Orographically-induced Precipitation Study: A Research and Development Project of the World Weather Research Program for improving quantitative precipitation forecasting in low-mountain regions. *Bull. Amer. Meteor. Soc*., **89**(10), 1477-1486. Weckwerth, T. M., J. W. Wilson, M. Hagen, T. J. Emerson, J. O. Pinto, D. L. Rife and L. Grebe, 2011: Radar climatology of the COPS region. *Q. J. Roy. Met. Soc*., **137**, 31-41. Bennett, L. J., A. M. Blyth, R. R. Foster, A. Gadian, T. M. Weckwerth, A. Behrendt, P. Di Girolamo, M. Dorninger, S.-J. Lock, V. Smith and S. D. Mobbs, 2011: Initiation of convection over the Black Forest mountains during COPS IOP 15a. *Q. J. Roy. Met. Soc*., **137**, 176-189.
VORTEX-II 2009-10	DOWs	Wakimoto, R. M., Atkins N. T., and J. Wurman, 2011: The LaGrange tornado during VORTEX2. Part I: Photogrammetric Analysis of the Tornado Combined with Single-Doppler Radar Data. *Mon. Wea. Rev*., **139**, 2233–2258. Atkins, N. T., A. McGee, R. Ducharme, R. M. Wakimoto, and J. Wurman, 2012: The LaGrange Tornado during VORTEX2. Part II: Photogrammetric Analysis of the Tornado Combined with Dual-Doppler Radar Data. *Mon. Wea. Rev.*, in press. Markowski, P., Y. Richardson, J. Marquis, J. Wurman, K. Kosiba, P. Robinson, D. Dowell, E. Rasmussen, and R. Davies-Jones, 2012: The pretornadic phase of the Goshen County, Wyoming, supercell of 5 June 2009 intercepted by VORTEX2. Part I: Evolution of kinematic and surface thermodynamic fields. *Mon. Wea. Rev.*, in press. Markowski, P., Y. Richardson, J. Marquis, R. Davies-Jones, J. Wurman, K. Kosiba, P. Robinson and E. Rasmussen, 2012: The pretornadic phase of the Goshen County, Wyoming, supercell of 5 June 2009 intercepted by VORTEX2. Part II: Lagrangian circulation analysis. *Mon. Wea. Rev*., in press. Wakimoto, R.M, P. Stauffer, W.-C. Lee, N. Atkins, J. Wurman, 2012: Finescale Structure of the LaGrange,

		Wyoming Tornado during VORTEX2: GBVTD and Photogrammetric Analyses, Mon. Wea. Rev., In Press. Kosiba, K. A., J. Wurman, Y. Richardson, P. Markowski, P. Robinson, J. Marquis, 2012: Genesis of the Goshen County, Wyoming Tornado on 05 June 2009 during VORTEX2. Accepted to *Mon. Wea. Rev*. Pending revisions. Wurman, J., K A. Kosiba, P. Robinson, 2012: In-Situ, Doppler Radar and Video Observations of the Interior Structure of a Tornado and Wind-Damage Relationship. Submitted to *Bull. Amer. Meteor. Soc*. Toth, M., R. J. Trapp, J. Wurman, K. A. Kosiba, 2012: Improving tornado intensity estimates with Doppler radar. Submitted to Wea. Forecasting. Toth, M., E, Jones, D. Pittman, D. Solomon, 2011: DOW Radar Observations of Wind Farms. *Bull. Amer. Meteor. Soc*., **92**, 987–995.
PLOWS 2009-10	NCAR C-130 with Wyoming Cloud Radar and Lidar, MISS, MGAUS	Robert M. Rauber, R.M., G.M. McFarquhar, B.F. Jewett, K.R. Knupp, D. Leon, P.S. Market, D.M. Plummer, J.M. Keeler, A. Rosenow, J. Wegman, M. Peterson, R. Wade, and K. Crandall, 2012: Generating Cells and Convection in Winter Storms. *Bull. Amer. Meteor. Soc*., in revision. Wade, R., and K. Knupp 2012: A kinematic and microphysical analysis of a thundersnow event during PLOWS. *Mon. Wea. Rev*., in preparation
LLAP 2010-11	DOWs	Cermak, T, E. Ahasic, J. Frame, S. Steiger, J. Wurman, and K. Kosiba, 2012: Dual-Polarization radar observations of long-lake-axis parallel lake-effect snow bands over Lake Ontario. To be submitted to *Mon. Wea. Rev.* Steiger et al. 2012: Circulations, bounded weak echo regions, and horizontal vortices observed by the Doppler on Wheels during long lake-axis-parallel lake-effect storms over Lake Ontario during the winter of 2010-11. In preparation for *Mon. Wea. Rev.*
ASCII 2012	UWKA, DOW	Miao, Q. and B. Geerts, 2012: Airborne measurements of the impact of ground-based glaciogenic cloud seeding on orographic precipitation. *Advances in Atmospheric Sciences*, accepted.

PART II : OPERATIONAL CONSIDERATIONS & LOGISTICS

Approx. how many people will be involved in the field campaign? *Please specify number of participants and location(s).*	~55 people at any one time (35 undergraduate and graduate students, ~10 scientists, ~10 crew) The Operations Center will be either on the HWS campus in Geneva (1st choice) or the SUNY-O campus in Oswego (2nd choice). Both campuses have adequate hotels and some spare dorm rooms, restaurants/cafeteria, parking, as well as meeting, office space, and teleconferencing facilities. The UWKA will be based at Penn Yan (PEO, 1st choice) or at Rochester International (ROC, 2nd choice). It is possible that the DOW trucks and MIPS will be collocated with the UWKA in a hangar at PEO.
What other facilities/platforms outside the EOL suite will be deployed? Are any of them non-US facilities?	See Experimental Design. All instruments & platforms are US-owned. One P/I-supported sounding unit will operate from outside the US (Ontario).
Are complex inter-facility or inter-agency permissions required for flight operations and/or other facility operations that would benefit from EOL leadership and experience?	FAA waivers are required for the UWKA and for the Millersville tethered balloon system. The UWKA project scientist will submit request for permissions and Rich Clark will seek waivers from the FAA for tether balloon operations. No EOL involvement is necessary.
Is there a need for integrated diplomatic arrangements? *(e.g., customs, immigration, focal point with local hosts/governments)*	**Unlikely**. Note that on occasion the UWKA flight track will extend into Canadian airspace. The experimental design does not call for any landing at a Canadian airport.
If there are multiple instrumentation/operations sites, is there a need for operational coordination?	**No EOL support is needed**, i.e. no EOL staff in the field. One or more P/Is will serve as Operations Director. Daily meetings will be held at the Operations Center. Some people will be remote and will be able to connect using GoToMeeting™ or other conferencing software. Communications between crews during IOPs will use email and x-chat (or other chatroom). The UWKA is expected to have internet access, and/or radio-communication with the Ops Director.
What kind of real-time data display and project coordination needs do you anticipate?	**EOL participation may be needed here, as part of the Field Catalog development**. We plan to collect and display select undersampled real-time data to assist in the IOP decisions, including UWKA flight track and DOW ops. Data include DOW low-level surveillance scans (Z, Vr), UWKA 5 sec average select data, WCR vertical-plane reflectivity (Z), all rawinsonde data (skew T plots with wind), MUPS tethersonde soundings, as well as operational real-time data. The images will be generated in IDV, Gempak, or NCL, and the scripts will be prepared well in advance using a similar array of data collected in a previous campaign. The near-real-time images should be accessible

	on the Field Catalog, some with animation option.
Is forecasting support required for project operations?	**Not from EOL**. We have received statements of support from the two relevant NWS WFOs (Michael Evans, NWS-BGM, and David Zaff, NWS-BUF). We will rely on forecasting and nowcasting by dedicated students. We will develop specific forecast products, such as time-height plots of relevant parameters. Todd Sikora will serve as the liaison for the project in interacting with NWS WFOs.
What kind of communications capabilities do you expect on site? *(e.g., bandwidth)*	Facilities in the field (DOWs, UWKA, MIPS …) should have sufficient bandwidth for the download of select images, and to run x-chat or other chatroom. **EOL to provide an x-chat channel**.
Will operations center and real-time display and coordination services be required? [1]	We will establish an Operations Center and use online conferencing tools (such as GoToMeeting®, x-chat) to communicate between the Ops Center and remote sites such as the UWKA crew, for the daily briefings and for the IOP coordination.
Will you require work space? *(e.g., office, lab and storage space)*	The Ops Center will have access to an auditorium that can seat at least 50 people, for the OWLeS seminars and daily weather briefings. The Ops Center will also have one or more rooms that can serve as office space with tables, power, and fast internet connection.
Will you require system administration support on site?	No
Is there a need for coordinated shipping, lodging or transportation?	No
Will you be shipping hazardous/radioactive material?	No
Will you be shipping expendables? (e.g., radiosondes to local NWS offices)	No EOL assistance needed – PI coordinated (rawinsondes, helium bottles)
Do you require assistance with various planning and support activities/services? *(e.g., help with Air Traffic Control, organizing of workshops, meetings, site surveys, leases, permits)*	The UWKA project scientist is expected to start early with ATC arrangements. The DOW crew will conduct a site survey, and obtain the necessary leases and permits. Clark (MU) will seek a waiver from the FAA for tethered balloon operations. Kristovich (UIUC) will seek needed permissions for rawinsonde launches in Ontario

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[1] *A basic data/analysis center with LAN connections to the EOL computers and access to the Internet will be provided in the field by EOL. Support will include real-time communications links to the facility via "chat" and real-time display of selected variables via web site links. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service. These services are presently not supported by the NSF Deployment Pool. Funds to support its deployment currently must be obtained from separate sources, such as NSF Special Funds. For more information, please contact the CDS Facility Manager.*

PART III: DATA MANAGEMENT

What operational data do you need? *(e.g., satellite, upper air, radar, surface, oceanographic, hydrological, land characterization, model products)*	Given the large number of participants, **we ask EOL to build a Data Archive** (mostly data files, to be used for OWLeS-related research) and **a Field Catalog** (real-time ops from OWLeS and operational data to help in IOP decisions, mission reports, quicklooks, …) The Data Archive should host all data collected in OWLeS, and, in addition, the following *operational* data (details to be discussed in due time): GOES visible and IR, select products from polar orbiting satellites (MODIS, NASA A-train) within 200 km from Lake Ontario during IOPs, sounding data (all in NE US & E Canada), WSR-88D (KBUF, KBGM, and KTYX, level II and level III data, including polarization variables), WKR (King City, Ontario) radar data, CARE and Syracuse 915 MHz wind profiler data, METAR and other surface data in New York and Ontario CoCoRahs in New York state, GFS and NAM initial fields at 6 hour intervals and hourly RAP (Rapid Refresh) data
Do you have any specific real-time data needs to aid in your data collection activities?	Not beyond what is listed above, re the Field Catalog.
Is there a requirement for a local satellite receiver to acquire local or real time polar orbiter or high resolution geostationary satellite data?	No
Beyond the EOL dataset, will you or your Co-PIs provide additional research data to the project?	In addition to the DOW and UWKA/ WCR/WCL data, the Data Archive should include the data (or links to the data) from PI-supported instruments (rawinsondes, MIPS, MUPS, …)
What data analysis products will you provide during the deployment?	Standard
What other research data and products do you need?	None
Is an EOL Field Catalog needed to provide real-time information management, reporting, decision dissemination, data exchange and resource monitoring?	**Yes** please
Do you plan on moving a large amount of data back to your home institution during the project?	We hope all data can be centrally archived for broad access. Data not centrally archived should be and remain readily accessible.
What arrangements have been made for a	We are asking that EOL provides the primary

comprehensive data archive, including the management and distribution of data from non-EOL platforms?	comprehensive Data Archive.
Do you intend to restrict data access? [2]	No. OWLeS will adhere to the EOL Data Policy.

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[2] *Please note that EOL policy will make all EOL data publicly available once the data are quality controlled.*

DOW Request

Two dual-polarization DOWs and the Rapid-Scan DOW

A. General Information

13. *Number of Personnel You Will Bring to the Field, can they assist with radar operations Bringing your own students/staff to assist with radar operations will reduce costs and add educational value. Basic DOW operation can be accomplished by personnel with little or no radar or meteorology experience. (CSWR will provide training for operators, drivers, etc.):* We can provide as many students as needed for DOW operations in OWLeS. **We are planning to have 9 students available at any one time, 3 per DOW.** Some participating students already have, or will have, experience with the DOWs, for instance Laird (HWS) has requested a DOW for an educational initiative in winter 2013, and this will give HWS students (and possibly Oswego students) a training opportunity. **We are asking the NSF deployment pool to cover travel expenses and a stipend of those students**. We have discussed this with Brigitte Baeuerle, EOL Field Project Services Manager. For budget purposes 6 students can be assumed to be local students, based in Oswego or Geneva NY (SUNY Oswego and HWS Colleges resp.). They do not need to be reimbursed for accommodation. The remaining 3 students can be assumed to be flying in, e.g. from UIUC, (assume 6 round-trip flights to allow a single crew rotation) and will need accommodation.

14. *Typical operations (daily ops hrs, number of days per week).* Suitable synoptic conditions for OWLeS are intermittent, and fairly predictable. Such conditions may last 48 hours (see Experimental Design, above). <u>An IOP is defined as a single cold-air outbreak with conditions suitable for OWLeS missions</u>. Thus an IOP typically lasts less than 24 hours, but it may last 36 and even 48 hours (see Table 4). A total of 8 IOPs will be targeted, for DOW budget purposes. Within a suitable cold-air outbreak we plan at least one UWKA flight. Multiple flights with different core objectives are likely. During “northerly” missions (see Experimental Design) DOW radars should be stationary for the entire IOP at pre-selected sites with excellent low-level coverage. During “westerly” missions DOWs may have to be moved upon short notice during the operations as lake-aligned bands may move. Both “westerly” and “northerly” missions may be conducted in a single cold-air outbreak (IOP), as the prevailing wind direction may shift. Crew duty limitations will determine the duration of a DOW observation period. Maximum UWKA flight duration per day is 7 hours (2 flights). DOW operations probably will be longer. For budgeting purposes, a single crew per DOW should suffice, i.e. there is no need to budget for crew rotation during IOPs. The DOW crew has the experience from LLAP 2010-11, when some of the crew rotated out and slept in or close to the DOW truck. IOPs can cover any time of the day or night. Note: On occasion along-lake snow bands with winds from the ENE, resulting in snowfall on the SW side of the lake. Such “easterly” snow bands should be targeted if possible, not just with the UWKA but also with the DOWs. The KBUF radar serves the same purpose as KTYX for westerly events.

15. *CSWR provides a Scientific Project Manager for all field programs to assist in experiment*

design, site selection, field coordination and general liaison with Principal Investigators. Does the proposed project require a CSWR scientist resident at the field site for the duration of the experiment? Yes. Karen Kosiba can wear two hats, as P/I and as DOW scientist.

16. *Describe the other observational facilities involved in your program. (e.g. aircraft, surface sensors)* see Section D. Experimental Design

17. *What assistance will you require in locating deployment sites for the radar(s)? (Note that some logistics details will depend on how far these sites are from the personnel, whether sites are secure for DOW storage between operations, how far DOWs must be driven to sites for operations, etc.* Given the focus on relatively shallow, weak echoes, the heavily forested environment and the lack of public land in upstate New York, site pre-selection is important and probably will require a visit in advance. Several sites had identified for LLAP 2010-11, but that campaign focused on westerly lake-aligned LeS only.

B. Requirements

18. Radar Parameters (be as specific as possible)

PRF: standard

Gate Spacing: 30-50 m [50 m for Plan 1 (northerly deployment), 30 m for Plan 2 (westerly deployment)]

Types of Variable Recorded Scans:

2 dual-pol radars: ZH, VR, ZDR, RHV, LDR, KDP

1 rapid-scan radar: ZH, VR

Number of Pulses Per Integration Cycle: standard

Update rates for volumetric scans: standard (1-3 minute per volume)

Number of tilts per volume: Scan strategies should be decided case-by-case in order to optimize both the dual-Doppler and the dual-polarization missions, and depending on the depth and strength of the LeS. Additionally, maximizing both sensitivity and volumetric coverage is important for the “northerly” missions. We should consider a hybrid scanning strategy will be implemented to maximize the collection of a diverse data. Scan strategy will be discussed in detail with the DOW P/Is before and during each mission

- 1-minute volumes, with a scan rate of 50 degrees/second, comprise approximately 7 elevations with the dual-polarization, dual-frequency DOWs, maximizing the temporal coverage in the low-levels, which is ideal for studies of the dynamics and structure of the bands.
- 2-3 minute volumes (~20-30 elevation tilts, including a ZDR calibration tilt) will optimize coverage through the depth of the bands, which is necessary for dual-polarization studies.
- Rapid-Scan DOW, which is capable of scanning 6 elevations in ~7 seconds, will be used both as a dual-Doppler radar (increasing the coverage) and to provide high temporal resolution data of misovortices and other rapidly evolving phenomena.

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Volumetric resolution: 30-50m x 30-50m x 100m within a 45 km range

Do you require dual-Doppler? 10-20 km baseline, 4 dual-Doppler lobes with some triple-Doppler regions

19. *List of auxiliary equipment you will bring (please include description, volume, power, and voltage):* None. Other OWLeS platforms may be collocated with a DOW, but they will have their own power. We request a number (~20) of **DOW weather pods** (aka tornado pods), to document the surface wind, temperature and relative humidity at strategic locations within the mission domain, which will aid in characterizing the horizontal distribution of meteorological conditions over a broad region. CSWR will provide specially-equipped vehicles to transport these pods for each IOP. These vehicles are not needed to conduct transects following the road network. The pods will be deployed by some of the 9 students assigned to work with the DOWs.

20. *Communication Requirements (including the need for sending radar data to a remote site).* Low-bandwidth internet access is desired for each of the DOWs. This will allow select quicklook images or undersampled data files to be sent to a server at regular intervals, e.g. ZH, VR at the lowest elevation angle in each radar volume. This data will help in the decision making at the Ops Center.

21. *Data:*

Estimated number of radar observations hours: 8 IOPs, 10 hours per IOP → 80 hours in total
What level of product would you desire for a final data set (raw files or translated sweeps)? Raw time series files and translated sweeps.

C. Previous Experience

22. Previous Research Radar Experience of Requesting Scientist(s):

Frame: DOW: Radar Observations of Thunderstorms and Tornadoes Experiment (ROTATE): 2004, 2005, 2012; Verification of the Origins of the Rotation in Tornadoes Experiment-2 (VORTEX2): 2009-2010; Long-Lake-Axis Parallel (LLAP) Project: 2010-2011.
Geerts: DOW: ASCII 2012; WCR: 5 campaigns since 2000; EDOP: 3 campaigns (1997-99); NCAR CP radar series: GALE 1986.
Knupp: NCAR CP radars, Mobile Alabama X-band dual pol radar in multiple experiments (landfalling hurricanes, local severe storms, PLOWS) since 2008
Kosiba: extensive DOW experience (e.g., ROTATE, COPS, VORTEX2, LLAP, ASCII, HAL (Hurricanes at Landfall) and various education projects).
Kristovich: NCAR CP radars: Univ. Chicago lake-effect snows 1984, ELDORA: Lake-ICE 1997/1998.
Laird: NCAR CP radars: CaPE 1991, SCMS 1995, ELDORA: Lake-ICE 1997/1998.
Steenburgh: IPEX 2000, SCHUSS 2011 (Educational deployment to University of Utah)
Steiger: LLAP 2010-11 (dual-pol DOW)
Young: TEP 1999, JTFEX 2000, both with shipborne radars

23. List of Publications Resulting from Past Radar Programs (attach list if necessary):

*This list is similar to the list "**Publications resulting from EOL support in the last 5 years**" (see p. 14), but focuses on papers that use DOW data*

Atkins, N. T., A. McGee, R. Ducharme, R. M. Wakimoto, and J. Wurman, 2012: The LaGrange Tornado during VORTEX2. Part II: Photogrammetric Analysis of the Tornado Combined with Dual-Doppler Radar Data. *Mon. Wea. Rev*., in press.

Cermak, T, E. Ahasic, J. Frame, S. Steiger, J. Wurman, and K. Kosiba, 2012: Dual-Polarization radar observations of long-lake-axis parallel lake-effect snow bands over Lake Ontario. To be submitted to *Mon. Wea. Rev.*

Cox, A. W., W. J. Steenburgh, D. E. Kingsmill, J. C. Shafer, B. A. Colle, O. Bousquet, B. F. Smull, and H. Cai, 2005: The kinematic structure of a Wasatch Mountain winter storm during IPEX IOP3. *Mon. Wea. Rev*., **133**, 521-542.

Colle, B. A., J. B. Wolfe, W. J. Steenburgh, D. E. Kingsmill, J. A. W. Cox, and J. C. Shafer, 2005: High resolution simulations and microphysical validation of an orographic precipitation event over the Wasatch Mountains during IPEX IOP3. *Mon. Wea. Rev*., **133**, 2947-2971.

Frame, J, P. Markowski, Y. Richardson, J. Straka, and J. Wurman, 2009: Polarimetric and dual-Doppler radar observations of the Lipscomb County, Texas, supercell thunderstorm on 23 May 2002. *Mon. Wea. Rev*., **137**, 544-561.

Geerts, B., B. Pokharel, K. Friedrich, T. Deshler, J. Wurman, B. Boe, and B. Lawrence, 2013: The AgI Seeding Cloud Impact Investigation 2012 campaign: overview and preliminary findings. In preparation for *J. Appl. Meteor. Clim*.

Kosiba, K. A., J. Wurman, Y. Richardson, P. Markowski, P. Robinson, J. Marquis, 2012: Genesis of the Goshen County, Wyoming Tornado on 05 June 2009 during VORTEX2. Accepted to Mon. Wea. Rev. Pending revisions.

Markowski, P., Y. Richardson, J. Marquis, J. Wurman, K. Kosiba, P. Robinson, D. Dowell, E. Rasmussen, and R. Davies-Jones, 2012: The pretornadic phase of the Goshen County, Wyoming, supercell of 5 June 2009 intercepted by VORTEX2. Part I: Evolution of kinematic and surface thermodynamic fields. *Mon. Wea. Rev*., in press.

Markowski, P., Y. Richardson, J. Marquis, R. Davies-Jones, J. Wurman, K. Kosiba, P. Robinson and E. Rasmussen, 2012: The pretornadic phase of the Goshen County, Wyoming, supercell of 5 June 2009 intercepted by VORTEX2. Part II: Lagrangian circulation analysis. *Mon. Wea. Rev.*, in press.

Schultz, D. M., W. J. Steenburgh, R. J. Trapp, J. Horel, D. E. Kingsmill, L. B. Dunn, W. D. Rust, L. Cheng, A. Bansemer, J. Cox, J. Daugherty, D. P. Jorgensen, J. Meitin, L. Showell, B. F. Smull, K. Tarp, and M. Trainor, 2002: Understanding Utah Winter Storms: The Intermountain Precipitation Experiment. *Bull. Amer. Meteor. Soc*., **83**, 189-210.

Steiger et al. 2012: Circulations, bounded weak echo regions, and horizontal vortices observed by the Doppler on Wheels during long lake-axis-parallel lake-effect storms over Lake Ontario during the winter of 2010-11. In preparation for *Mon. Wea. Rev.*

Toth, M., R. J. Trapp, J. Wurman, K. A. Kosiba, 2012: Improving tornado intensity estimates with Doppler radar. Submitted to *Wea. Forecasting*.

Toth, M., E, Jones, D. Pittman, D. Solomon, 2011: DOW Radar Observations of Wind Farms. *Bull. Amer. Meteor. Soc.*, **92**, 987–995.

Wakimoto, R. M., Atkins N. T., and J. Wurman, 2011: The LaGrange tornado during VORTEX2. Part I: Photogrammetric Analysis of the Tornado Combined with Single-Doppler Radar Data. *Mon. Wea. Rev.*, **139**, 2233–2258.

Wakimoto, R.M, P. Stauffer, W.-C. Lee, N. Atkins, J. Wurman, 2012: Finescale Structure of the LaGrange, Wyoming Tornado during VORTEX2: GBVTD and Photogrammetric Analyses, *Mon. Wea. Rev.*, In Press.

Wurman, J., K A. Kosiba, P. Robinson, 2012: In-Situ, Doppler Radar and Video Observations of the Interior Structure of a Tornado and Wind-Damage Relationship. Submitted to *Bull. Amer. Meteor. Soc.*

University of Wyoming King Air Request

Preferred flight period	1-21 December 2013 and 3-24 January 2014, with a flexibility of 2-3 weeks
Number of flights required	75 research flight hours
Estimated duration of each flight	3-4 hours
Number of flights per day	up to 2 (i.e., a single crew is requested, and are aware of the limitation of 7 hours of flight per day)
Preferred base of operation	1st choice: Penn Yan (PEO). Located about 19 miles drive south of the preferred Ops Center (HWS Colleges, Geneva), hangar available, little air traffic, relatively little LeS snow (almost none for the northerly deployment; LeS snow from Lake Erie possible during westerly deployments) 2nd choice: Rochester (ROC). Located 1 hour drive from HWS Colleges in Geneva, hangars available, more air traffic, slightly more LeS snow, but snow may be cleared faster at a larger airport.
Alternate base	TBD
Is Laramie Airport acceptable as your operations base?	Unlikely. While cold-air conditions can be predicted several days in advance, we are budgeting for 8 IOPs, each up to 2 days long. The roundtrip ferry to KLAR probably is more costly.
Average flight radius from base	100-200 km
Desired flight altitudes(s)	lowest safe flight level, up to 10,000 ft MSL (see Experimental Design for discussion) minimum <u>sounding</u> flight level: ~200 ft AGL in VMC minimum <u>sustained</u> flight level: • VMC: 500 ft AGL (land & lake) • IMC: we are asking that an FAA waiver for the minimum vectoring altitude to allow sustained flight over Lake Ontario, away from shore, between 500 and 1000 ft AGL be requested. It is possible that Transport Canada Aviation needs to be involved since part of Lake Ontario is in Canadian Airspace. The standard minimum altitude in IMC over the lake (2700 ft MSL) still allows most OWLeS objectives, but not all, or only partially.
Particular part(s) of day for flights	any time of the day/night subject to crew duty limitations
Statistically, how many days during specified period should be acceptable for flight operations?	~12 on average during the 43 day field phase (8 lake-effect events, 4 of which last 2 days). See Experimental Design (II.D.7) for discussion.
Number of scientific observers for	We would like to have a 4th seat available; 4th seat

required each flight	duties may include radar/lidar operations and x-chat. Both the 2nd and the 4th seats will be occupied by OWLeS personnel (P/Is and their students).

Scientific rationale for the use of this aircraft in the proposed project:
The UWKA is ideally suited for the relatively short low-level flight legs proposed for OWLeS. High maneuverability is needed for these legs, and for the soundings. All five WCR viewing angles are needed, and this is only possible on the UWKA. Finally, there are several measurements (from the gust probe, flux probes, GPS, and others) that the UWKA can reliably and accurately provide.

Description of desired flight pattern(s), priorities, and estimate number of flights for each:
See Part I Section D Experimental Design.

More detailed flight plans (flight levels, leg sequences …) will be discussed with the UWKA team in the context of any opportunities and limitations that may arise when contacting relevant ATC centers. For instance, from a science perspective we prefer to fly all 3 levels and then move to the next track in a northerly wind deployment (see Fig. 1 and 2). Yet ATC communication requirements may make this time-consuming, and it may be advantageous to fly the 3-4 tracks one level at the time.

Other flight track variations are possible depending on experience in the field. If the aircraft experiences significant icing within the more intense LeS bands, or if lightning has been reported in such bands, we should reduce our time within the bands, and instead fly above (along & across) and on the side (along). Experience in Lake-Ice (97-98) and in NASA ROLLs (2004) suggests that high LWC values and large droplets are quite rare, but these experiments targeted rather short-fetch LeS bands.

STANDARD AND OPTIONAL-STANDARD UWYO KING AIR AIRBORNE SCIENTIFIC INSTRUMENTATION AND MEASUREMENTS

Standard Measurements

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

Additional instruments available upon request (Optional Standard)

Before requesting optional standard instruments in this section, please consider some require additional resources and may need special data handling. The number and/or combination of instruments may exceed UWYO's personnel and/or hardware resource limits. Mark these extra, **Needed** *instruments with "yes."*

Instrument	Measurements Available	Needed
Cloud Properties		
Rosemount 871FA	Icing Rate	yes
DMT LWC-100	Cloud Liquid Water	maybe
Gerber PVM-100	• Cloud Liquid Water, • Droplet Surface Area, • Droplet Effective Radius	yes
PMS FSSP-100	• Cloud Particle Size Distribution (0.5 – 47µm; selectable) • Total Concentration, • Derived Liquid Water Content, • Derived Droplet Effective Radius, • Derived Droplet Surface Area, • Derived Mean Volume Radius	
PMS OAP-200X (1DC)	• Cloud Particle Size Distribution (12.5 – 185.5 µm)	
PMS OAP-2DC	• Cloud Particle Images (>25 µm) • Cloud Particle Size Distribution	
PMS OAP-2DP	• Precipitation Particle Images (>200 µm) • Precipitation Particle Size Distribution	yes
Fast Response Measurements suitable for fluxes and/or turbulence		
Friehe-type thermistor bead (in-house developmental) or Reverse Flow wire	• Air Temperature	yes
Licor 6262	• Water Vapor • Carbon Dioxide	yes
Special High Frequency Data Processing	• 1 Hz data is standard, high-rate processing available, specify frequency needed	25 Hz

(optional-standard instruments continued)

Instrument	**Measurements Available**	**Needed**
Radiative Properties		
Eppley PSP (Pyranometer)	• Up-welling and Down-welling Radiation (0.285 – 2.800 µm)	yes
Eppley PIR (Pyrgeometer)	• Up-welling and Down-welling Radiation (3.50 - 50 µm)	yes
Heimann KT-19.85 (Radiative Thermometer)	• IR Radiometric Surface Temperature	see below
Aerosol Properties		
PMS PCASP-100X w/ DMT Signal Processing Package	• Aerosol Size Distribution (0.12-3.0 µm; 30 size bins)	yes
TSI 3010 CPC	• CN Concentration (> 15 nm)	
Trace Gas Properties		
Licor 6262	• Water Vapor • Carbon Dioxide	yes
Miscellaneous Properties		
Digital Video recording	• Down-looking with date/time stamp (in addition to the standard forward-looking video, *see Appendix 1*)	yes

NON-STANDARD INSTRUMENTATION

Instrument Grouping	Measurements Available in Grouping	Needed
Cloud Properties (technical contact: Dr. Jeff French, jfrench@uwyo.edu, 307-766-4143)		
DMT Cloud Droplet Probe	• Cloud Particle Distribution (2-50 μm)	yes
DMT Cloud Imaging Probe	• Cloud Particle Distribution and Images • Diameter > 25 μm	yes
Trace Gas Chemistry (technical contact: Dr. Jeff Snider, jsnider@uwyo.edu, 307-766-2637)		
TEI model 49	• Ozone (0-1000 ppbv)	
TEI model 42S	• Nitrogen Oxides (0.1-100 ppbv)	
TEI model 43bs	• Sulfur Dioxide (1-100 ppbv)	
Aerosol Properties (technical contact: Dr. Jeff Snider, jsnider@uwyo.edu, 307-766-2637)		
TSI 3025 CPC	• UFN Concentration (> 5 nm)	
UWYO CCNC-100A	• CCN Concentration (0.2% - 1.6% S)	
Radiance Research M903 Nephelometer	• Light Scattering Extinction Coefficient @ 530 nm	
*******Experimental/Developmental Instruments******		
TSI 3936L10 SMPS Spectrometer	• Aerosol Size Distribution (0.02-0.5 μm; 64 size bins)	
Magee Scientific AE16 Aetholometer	• Elemental Black Carbon	
Scientech model LBF3	• Sulfur Hexaflouride (0-20 ppbv)	
UWYO Enzyme-fluorometric	• Hydrogen Peroxide (0-20 ppbv)	

****Experimental instruments require additional support*

Overall instrument priority discussion

(rationale: power and other limitations)

- **WCR – highest priority**
- in situ cloud probes: the selected probes are essential. Our interest in the CDP with ice shattering avoidance tip is based on recent experience in CAMP and ASCII. In part to save power, we propose to operate without the FSSP, as the CDP has been shown to be superior, even though the FSSP is a legacy instrument. CAMP and ASCII data show that the CIP is superior to the 2D-C (2D-C appears to significantly underestimate the small particle count), so there is no need for the 2D-C (or 1D-C).
- PCASP: essential: this is the only aerosol probe, and its data can serve as a first surrogate for both CCN and IN concentrations.
- WCL: both nadir and zenith probes are essential/important (see below). **The nadir lidar is more important than the Heimann**. We very much like to have vertical-plane WCR and WCL data, above and below the aircraft. We may not be able to run both lidars, because power limitations, so we state the next-best choices. We could alternate between up and down lidars during flight, depending mainly on the flight level relative to the feature of interest, with only one lidar on. This would imply short operation periods for the WCL (see Experimental Design – many flight level changes), although we can maximize that by flying all tracks in sequence, and only then change flight level (see Fig.

2). If only one lidar can operate during OWLeS, then we choose the zenith WCL, and request the Heimann IR temperature probe in lieu of the nadir WCL.

- Licor 6262 (or 7500): essential (fluxes)
- high frequency data processing (25 Hz): essential (fluxes, synergy with radar and lidar data)
- Eppley Pyranometer & Pyrgeometer: important, not essential
- Downward Video recording: essential if we do not have the Heimann KT, to detect lake ice below cloud base. So we definitively want it if we have WCL up & down. Otherwise it is important, not essential.
- DMT LWC-100 gives us another LWC sensor, not affected by icing. It is useful (lowest priority).

Wyoming Cloud Radar (WCR)

We are requesting deployment of the WCR on the UWKA.

RADAR OPERATIONS

Scientific rationale for the use of WCR in the proposed project: The WCR is essential to depict the horizontal and vertical structure of LeS. See Experimental Design.

Weather events during which collection is desired:
Some flight legs are in the turbulent convective BL, others are above this turbulence. The turbulence probably tends to become weaker over land further from the lake, except maybe over high terrain and in some long-lived convective cells.
Estimated number of flights for which the radar will be used: All flights require the WCR to be on during most of the flight. None of the proposed flight patterns are WCR-off.

Desired radar configuration and parameters:

Antenna configuration [#](*select all desired*):

Up/side-pointing[*] antenna (linear dual-polarization):	yes
Down-pointing antenna (linear single polarization):	yes
Side-slant-pointing antenna (linear single polarization):	yes
Down-slant-pointing antenna (linear single polarization):	yes

[#] up to 4 fixed-direction antennas are switched electronically on a pulse-by-pulse basis
[*] mechanical switching from side-pointing to up-pointing using a reflector

Maximum range (6 km typical):	3 km down, 3.5 km down-fore, 4 km side/up
Number of Gates (100 to 500 typical):	~200 (can be computed from sampling rate & max range)
Sampling along the beam (15 m typical):	15-20 m
Sampling along the flight track (4 m typical):	4-8 m
Minimum Sensitivity Needs (dBZ at 1 km):	weak echoes are of interest

Scientific rationale for desired radar parameters:
Most flight legs will use side/up and dual-down antennas (profiling + VPDD). The maximum range listed above is determined by the flight level range and the maximum depth of lake effect systems.
Along a few level/straight flight legs, in the clear air between and along snow bands, will attempt dual-side (HPDD). For these legs, the max range is ~10 km, the pulse width fairly large (~300 ns, sampling rate 45 m), yielding ~225 gates.
No side/up antenna dual-polarization variables are needed, since only ZDR & LDR have been evaluated (Wolde and Vali 2001) and these polarimetric variables are quite different than those for cm-wave radars.

Wolde, M., and G. Vali, 2001: Polarimetric Signatures from Ice Crystals Observed at 95 GHz in Winter Clouds. Part I: Dependence on Crystal Form. *J. Atmos. Sci.*, **58**, 828–841.

Level II WCR/WCL dataset request

We request that the WCR and WCL scientists develop a WCR/WCL profile dataset redistributed on a common grid at a 2D resolution that is the coarser one of the two instruments (approximately, dx=10 m, dz=20 m), i.e. a resolution sufficient to retain the finest common features. All variables should be included from the two profiling antennas (zenith and nadir). This "level II" combined WCR/WCL dataset will be useful as for many OWLeS participants, including many students, such dataset will suffice.

WCR SUPPORTING AND DATA SERVICES

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

> There are no plans for direct coordination, to enable multiple-Doppler synthesis for instance. The ground-based scanning radars used in OWLeS (DOWs, WSR-88D) will operate independently.

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

> Post-flight access to WCR quicklooks and to processed data. Post-experiment (within 6 months): final data including level II data.

Do you intend to request WCR special products? No

Wyoming Cloud Lidar (WCL)

We are requesting deployment of the WCR on the UWKA.

LIDAR OPERATIONS

Scientific rationale for the use of WCL in the proposed project:
The up/down lidar data will be used to

- when flying in clear air:
    - detect cloud top/base
    - detect and describe aerosol layers (upwind stratification)
    - detect first boundary-layer clouds over the lake, in relation to the aerosol layers and possible blowing snow plumes (which would be WCR-detected)
- when flying in clear air or cloud:
    - determine liquid water presence (rapid attenuation)
    - determine ice presence (high depolarization)
    - combine with in situ cloud and ice measurements for quantitative analysis (LWC, ice concentration)

Weather events during which collection is desired: aerosol layers & shallow mixed-phase clouds (some water only & some ice-only clouds possible)

Estimated number of flights for which the lidar will be used: All flights require the WCL to be on during most of the flight. None of the proposed flight patterns do not need the WCL. As discussed above, the zenith WCL can be off during the highest flight levels, and the nadir WCL may be redundant during some near-surface flight legs.

Desired radar configuration and parameters:
The WCL system consists of an up-pointing lidar and a down pointing lidar, they can be deployed together or individually. Both operate at 355 nm and provide similar range sampling/resolution (3-5 m, typical). Along track resolution is typically 20 m, but may be decreased if necessary to increase sensitivity. Both Lidars are capable of providing measurements of co-polar and cross-polar returned power.

Lidar Configuration [#](*select all desired*):

Up Pointing WCL:	co-pol & cross-pol
Down Pointing WCL:	co-pol & cross-pol

Maximum range:	3 km (2 km for some flights)
Range sampling (in meters):	10 m
Sampling along the flight track (in meters):	10 m
Minimum Sensitivity Needs (dBZ at 1 km):	____

Level II WCR/WCL dataset request

We request that the WCR and WCL scientists develop a WCR/WCL profile dataset redistributed on a common grid at a 2D resolution that is the coarser one of the two instruments (approximately, dx=10 m, dz=20 m), i.e. a resolution sufficient to retain the finest common features. All variables should be included from the two profiling antennas (zenith and nadir). This "level II" combined WCR/WCL dataset will be useful as for many OWLeS participants, including many students, such dataset will suffice.

Scientific rationale for desired configuration:
Very fine range resolution is not needed.

Summary of on-site lidar data access and analysis requirements:
Post-flight access to WCR quicklooks and to processed data.

UWKA SUPPORTING SERVICES

Will you require air-ground communication? *(If so, specify location of base station and operating frequencies, some limited communications may also be available through sat phone connections on the UWYO King Air.)*
Internet access with sufficient bandwidth for chat and for small-file transfer (~5 sec select data download through UDP data forwarding, and either scheduled or manual (web-based) image upload). This may not be needed on all missions, but it would much help coordinate flight tracks and DOW operations during the “westerly” deployments (Fig. 3-4. During all missions this imagery (e.g. IDV maps with DOW reflectivity, satellite imagery, and past UWKA track colored by T & with wind barbs) will improve “environmental awareness” and can be useful in flight choices, e.g. in case of still-manageable ice accumulations. It is also beneficial from an education perspective (4th seat will usually have a student).

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

See above.

On-site data access requirement: shortly after each flight, as usual.

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