Center for Severe Weather Research

SNOWIE FEASIBILITY ANALYSIS

DOPPLER ON WHEELS DOW

PROJECT NAME	SNOWIE: Seeded and Natural Orographic Wintertime clouds - the Idaho Experiment
PROJECT LOCATION	Payette Basin, NE of Boise, ID, USA
PROJECT PERIOD	05 January – 15 March, 2017 (10 weeks operational)
FACILITIES REQUESTED	2 dual-polarization DOWs, ISFS, UWKA
OTHER, NON-NSF FACILITY PARTICIPATION	Yes
LEAD INVESTIGATORS	Katja Friedrich CU (DOWs), Bart Geerts UWY (ISFS), Jeffrey French UWY (UWKA)
CO-INVESTIGATOR	Robert Rauber, U. of Illinois (UI)
NSF PROGRAM OFFICER	
THIS DOCUMENT VERSION	27 September 2015 a

PROJECT SUMMARY

Scientific Justification and Merit

The two dual-polarization DOW radars (DOW6, DOW7) are essential for addressing the research objectives in SNOWIE, i.e., monitoring the cloud depth, mesoscale structure, and organization of the cloud systems in order to determine appropriate times to seed clouds and to interpret the subsequent analyses in the context of natural cloud structure present at the time of the experiments. One dual-polarization DOW radar will be used as a surveillance radar providing 360° volume scans (PPI – Plane Position Indicator) to monitor the reflectivity, wind (using Velocity-Azimuth-Display processing), and microphysical information (using dual-

polarization) within the storms. The second dual-polarization DOW radar will scan over the target area in high-resolution Range Height Indicator (RHI) mode (15°/s) with scans parallel to the wind (±5°) providing updates every 30 s to monitor fast-evolving processes (e.g., generating cells, mountain waves). Potential radar sites are at *Snowbank* (PPI volume scans) and *Packer John* (RHI scans).

PLATFORMS AND INSTRUMENTATION

Two DOWs will be deployed near the Payette Basin in Idaho. Sites have been identified and surveyed by CSWR and one of the PIs. Permissions to deploy at the sites will need to be finalized by CSWR and the PIs.

The sites are described in detail in the facility request:

a. The ***Snowbank*** site is on a hillside immediately (5-10 m) adjacent to a road leading to an FAA radar. The road is plowed during the winter, but possibly not in a timely fashion. Supplemental plowing likely will be necessary. A key will have to be obtained to access to the gated access road. The road is 15-20 km from base (permanently and reliably plowed) to the DOW site. Road conditions will be evaluated by a collaborator at Idaho Power during the 2015-2016 winter to inform the refinement of these plans. Transport to this site will be by 4WD truck and/or snowmobile. The DOW will be deployed either in October, prior to snow, or in early January, then removed immediately after the project. Snow removal likely will be required during either/both deployment and extraction. A crew trailer will be deployed near the DOW to allow for operators to remain at the site for 1-3 days, in the event of severe weather and during the likely frequent event that the beginning or end of an IOP precludes daylight snowmobile travel to/from the site. Emergency food and other supplies will be stored at the trailer. A vestibule will be constructed and attached to the DOW in order to buffer the radar cabin from severe winds and windblown snow, and to allow the crew to change in and out of snowmobile gear and the storage of that gear (as was done during ASCII). A solar panel attached to the vestibule will provide trickle charging of generator batteries. If deployed before January, a CSWR team will visit and test the radar approximately every few weeks, prior to the project, depending on driving and/or snowmobile accessibility. There may be a period during which the road is too snowy for driving, but not covered by snow sufficiently for snowmobile access. A tow trailer, equipment shed, and portable toilet will be installed at the site to accommodate crew overnighting.

b. The ***Packer John*** site is on a hilltop on a mountain ridge accessible only by an unimproved road, which is not plowed in the winter. Access during operations will be by snowmobile. Most of the trail is groomed for snowmobiles, but possibly not in a timely fashion. Trail conditions will be evaluated by a collaborator at Idaho Power during the 2015-2016 winter to inform the refinement of these plans. A living trailer will be deployed near the DOW to allow for operators to remain at the site for 1-3 days, in the event of severe weather, and during the likely frequent event that the beginning or end of

an IOP precludes daylight snowmobile travel to/from the site. Emergency food and other supplies will be stored at the trailer. A vestibule will be constructed and attached to the DOW in order to buffer the radar cabin from severe winds and windblown snow, and to allow the crew to change in and out of snowmobile gear and the storage of that gear. A solar panel attached to the vestibule will provide trickle charging of generator batteries. If deployed before January, a CSWR team will visit and test the radar approximately every few weeks, prior to the project, depending on driving and/or snowmobile accessibility. There may be a period during which the road is too snowy for driving, but not covered by snow sufficiently for snowmobile access. A tow trailer, equipment shed, and portable toilet will be installed at the site to accommodate crew overnighting. A spare diesel generator will be deployed at the site to allow operations or the remainder of the project in the event of a catastrophic primary generator failure.

The Snowbank and Packer John sites are challenging deployments. CSWR crews have experience with a qualitatively similar, and higher altitude, site, Battle Pass, during ASCII. Site requirements such as the vestibule, crew trailer, solar panel, etc. and safety requirements are informed by experiences during ASCII. Special care must be taken for crew safety. Specific procedures, informed by the DOW ASCII deployment, including buddy system snowmobile travel, travel during daylight, satellite emergency beacons and satellite communications systems, emergency cold weather kits, check in/out procedures, etc. will be developed prior to the project. Personal Delorme InReach satellite-based tracking systems will be carried by all crew. These permit SOS messages, and web-based real-time tracking of the crew. Snowshoes and skies will be required at the sites to facilitate emergency extraction and near-site travel. It is expected that VHF communication will be possible between the sites due to their high visibility.

The PIs expect 15-20 operational periods lasting up to 9 hours, for a maximum of 180 hours of operations, and CSWR anticipates ~3 additional testing days, resulting in up to 22 operational and test days. Most data collection periods will last less than 5 hours. Two people per DOW, minimum, are required for safety. IOPs will occur mostly during the day, but long travel times and inclement weather will likely require overnighting at the Snowbank and Packer John sites before and/or after operations. Restrictions on snowmobile activities during inclement weather and at night are likely to require overnighting at the sites frequently. DOWs will require up to 2 hours warm up time, particularly if ambient conditions are very cold, and up to one hour shut down time. Site preparation before operations may involve considerable shoveling of snow and related site maintenance tasks, and snow blowers will be stored at the sites. Prospective crew will be informed of these and other physical requirements for participation. Altitude (~< 2,500 m) is not expected to cause health issues for operators. Winter conditions will be common, but extreme cold (below -30 C) is not expected. Extreme winds, possibly 40 m/s, are likely at the Packer John and Snowbank sites. Skis and snowshoes will be required at the Packer John and Snowbank sites. Operators will be provided training in their use. Operators will be trained in snowmobile use and safety.

The PIs will provide 2 operators for every IOP. PI supplied crew must be physically and mentally capable of rigorous outdoor activity at moderate altitude, including snowmobiling, shoveling snow, carrying supplies and equipment, assisting with maintenance and repairs, and

possible skiing or snowshoeing in the case of vehicle breakdown or other contingency, and be prepared for extended periods at the sites if weather or other factors prevent safe extraction. Primary DOW crews will consist of 1 CSWR staff member and one or more PI-supplied crewmember(s) per DOW. CSWR will provide two snow mobiles per DOW. First priority for snowmobiles will be the primary crew at each site (1 CSWR and one PI supplied). The PIs state that an additional person will be present at the Packer John site, operating other instrumentation. CSWR anticipates that this 3rd person will likely be able to ride on one of the 2 snowmobiles for many IOPs. But, if substantial supplies need to be towed in sleds (and we note that food/liquids for 2 days per mission may need to be hauled on a regular basis, in addition to disks, fuel, and other supplies), or if additional CSWR scientists, engineers, or others need to be transported, at CSWR's discretion, these will take first priority. Fuel will be stored at the Packer John and Snowbank sites to minimize fuel hauling. Any required fuel and supply hauling will be accomplished with snowmobile trailer sleds. CSWR will likely store extensive spares including a spare generator and other difficult-to-haul-by-snowmobile equipment and supplies. Consecutive-day operations will be possible depending on the history of recent IOPs, crew fatigue, and other safety-related conditions. Consecutive or closely-spaced IOPs will be possible, but will be limited by the available of rested 2-person crews. It is anticipated that the resident CSWR data manager, CSWR-scientists who can fly in, the PIs, and possibly others can assist during occasional closely-spaced IOPs. Care must be taken to avoid overly long crew duty days, particularly since travel to/from the Packer John site to lodging may require two hours or more (each way). PIs will give CSWR > 24 hour, preferably 48 hour, notice of the consecutive-day operations so that Boulder-based staff may travel to the study area. CSWR operator crew will be relieved and/or return home to Colorado during prolonged periods of no operations. It is anticipated that there will be forecastable few-to-several day down periods during the project, as there were during ASCII.

The CSWR crew and set up team will arrive a several days before the start of the project. A CSWR scientist will remain at the project during the first week or so of operations, through 2 or so deployments, to supervise/evaluate data quality, site suitability, crew shifting logistics, reliable DOW operations, interface with the PIs, and other conduct other tasks. During the bulk of the project, three CSWR staff will be at the project. CSWR scientific and engineering staff will sometimes attend especially long IOPs or IOPs in close succession, and as needed during the project, but will not be permanently resident.

Ferrying of the DOWs to the project will require 2 days. Crews will be housed in the Payette Basin, likely in or near Garden Valley, which is the most centrally located town with sufficient lodging, but the exact location has yet to be determined. A data management office will also be rented near lodging.

The PIs state that cellular service is reliable at the sites. This is not our recollection, but it may be true. Our recollection is that Verizon service was poor in Garden Valley. This feasibility does not assume reliable cellular service. Crew safety will be enhanced by Delorme InReach satellite-based tracking and emergency beacons. These were recently used during PECAN. Delorme-maintained web-sites permit real-time tracking of crew-carried InReach units.

The sites are at moderate altitude, at 2,500 m or below AMSL, which is not anticipated to result in operational difficulties. Compressor-based pressurization systems for waveguides will be

tested at comparable altitudes prior to the project, so that, ideally, the DOW truck engines do not have to run during IOPs. DOWs have operated at altitudes approaching 13,000 feet AMSL and the ASCII DOW site was at 10,000 AMSL.

The PIs request that data be sent in real time to the internet. Raw time series (IQ) data cannot be sent in real time since approximately 120 GB/hour are recorded. Using a BGAN or cellular internet connection, selected radar sweeps will be uploaded to the internet for access at the University of Wyoming. Raw data and translated data will be recorded on external disk packs. It is anticipated that up to ~2 TB/IOP will be collected, but precise data collection modes have not been finalized. About 60 TB of raw primary copy data will be collected, not including backup copies. One back up copy of the disk packs will be shipped to CSWR approximately once per week, and archived on the main Boulder-based CSWR archive. 180 hours of DOW operations will result in ~20 TB of primary copy data per DOW, with additional storage required for backups, resulting in 180 TB total. Several large, 48TB RAIDED disk arrays will be required. A resident CSWR data manager, not normally participating in on-mountain operations, will manage backup and archiving operations from the 3 DOWs.

Requested radar observations in winter precipitation are feasible. Normal radar products, including dual-polarization products are requested. In intense snowy precipitation, X-band signals will be slightly attenuated, but velocities will be preserved and attenuation corrections can be applied. Blockage and ground clutter are both significant issues in the mountainous terrain, and these have been considered during siting. In intense snow or icing conditions, operations may need to pause for antenna and radome cleaning.

CONCLUSIONS: FEASIBLE

Support of requested SNOWIE DOW operations is feasible as requested.

Schedule conflict with LOBSTAS.

COST SUMMARY

CSWR/DOW	$584,862 estimated (some cost items remain approximate)

Summary:

The University of Wyoming King Air (UWKA) with the Wyoming Cloud Radar (WCR) and the nadir and upward looking Wyoming Cloud Lidars (WCL) are requested to study wintertime orographic precipitation and the effectiveness of both ground and airborne seeding over Idaho's Payette Basin region. Two Doppler on Wheels (DOW) XBand dual-polarization radars, and other ground-based remote sensing and in-situ instrumentation from Universities of Colorado, Illinois, and Wyoming, and NCAR, are also requested. This project will be conducted in coordination with the Idaho Power Company (IPC), who has an operational seeding program in this region.

Flight Hours Requested:

The PIs request **80 research hours** to support 15-20 IOPs (flight days) which may include 1-2 flights per day. An additional **10 hours** of test flights will be needed for instrument tests (8 hours) and pilot proficiency (2 hours), and **6 hours** for ferry to the operations base. A total of **96 flight hours are requested** to support SNOWIE-17.

Project Dates/Scheduling:

The period 5 January – 15 March 2017 is requested, but PIs have agreed to delay the start 5 days to 10 January – 20 March 2017 to accommodate facility conflicts. The LOBSTAS-17 flight request directly conflicts with SNOWIE and both project PIs were asked if their respective projects could be shifted one year to alleviate the conflict. SNOWIE PIs note that their agreement with Idaho Power Company adds a level of complexity in delaying the schedule by a year, and since IPC has already graciously accepted a 1-year delay from their original plan, another year's delay could be problematic.

Operations:

The preferred base of operation is Boise, ID (KBOI). UW conducted a few pre-investigation flights out of Boise in spring 2014. Since this airport is close to the winter storms we wish to fly, there may be occasions that the flight is cancelled due to the accumulation of snow on the aircraft. We don't anticipate any other issues with using this airport.

The flight plans can be divided into three groups. When airborne seeding operations are taking place, the King Air will fly either a race track, with the legs perpendicular to the seeding curtain, or a ladder pattern with the legs parallel to the seeding flight track. On days with ground seeding or no seeding the flight track will be along the wind and oriented such that it passes over one of two ground sites. A third type of mission involves looking for direct evidence of the effectiveness of seeding by targeting super-cooled stratus that is decoupled from the ground. The seeding aircraft would fly above the stratus and lay down a line of flares and the King Air would fly either a racetrack perpendicular to the line or a ladder with legs parallel to the line.

The request indicates that most IOPs will likely only last long enough for 1 flight. However, in cases where the system persists for 8 hours, they would like to consider multiple flights, up to a maximum of 7 hours total flight time during a crew duty period. Also, in order to maximize opportunity, they request that operations are available from a 6 AM earliest takeoff to 12 AM (midnight) latest landing, within the constraints of the maximum crew duty day. Since conditions favorable to the experiment are likely to occur for one to three days, the PI would like to be able to fly multiple missions each day. Flying multiple missions on consecutive days may not be possible due to crew fatigue.

Crewing:

For a ten week project, two crew swaps will be required with each crew being in the field about 3.5 weeks. The crew will consist of a pilot, technician, remote sensing scientist, and a project manager/system scientist. An engineer will be deployed at the beginning of the project for two weeks. Because of the length of this project, we are budgeting for a mechanic to be in the field for two weeks.

Hazards and other Operation Considerations:

Crew Duty Guidelines:

For planning purposes, a duty period begins approximately two hours prior to takeoff, and ends approximately one hour after the last flight. On a "standby" day, crew duty ends when the flight is called down for the day.

Activity	**Hours**
Flight in any 24 hour period	7 hours
Flight in any 7 day period	35 hours
Flight in any 30 day period	110 hours
Crew duty period	14 hours (10 hours for 100% encroachment on WOCL, see below)
Crew rest period	12 hours
Consecutive work days	6 days
Operations during Circadian Low	Any duty within the time period from 0200 to 0600 is considered within the Window of Circadian Low (WOCL). For any operations within the WOCL, the maximum crew duty period will be reduced by 100% of the amount of encroachment—*e.g.* if operations begin at 0400, 2 hours before the end of the WOCL, maximum duty period is reduced by 2 hours.

Safety Considerations:

1. **Icing:**

Wintertime orographic clouds may contain significant super-cooled water. The flight may be cancelled if severe icing is encountered. Mitigation may include:

a) Climbing to initial research altitude to west of mountains to allow for escape maneuver in case of severe icing.
b) Remaining clear of clouds while over research area for ~1 hour to map moisture content of clouds via remote sensing instruments, allows for reduction of gross weight while obtaining data.
c) Adjusting research altitude within clouds as to avoid highest concentration of liquid water.
d) Utilizing profiles that work toward descending terrain.
e) Being extremely cautious during warmer than -10C.

At this point, we don't think that we fully have a complete grasp on what to expect for icing. Obviously it could be very significant. We think that our mitigations may change as we work further in the planning.

2. Low ceilings and visibility for approach: The pilot will maintain awareness of weather at base and alternates and return to base when appropriate.

3. Snow on aircraft prior to take off: Snow and ice on the wings and tail during takeoff can be very dangerous. External research installations do not allow for chemical deicing. For this reason, we seek to operate from smaller airports where there are few delays in taxing and taking off. Further mitigation includes:

a) Checking wings prior to start to determine if snow is melting / freezing to wings
b) Coordinating with Lead Operations Director to check wings prior to taxi or anytime necessary prior to takeoff
c) Monitoring outside air temperature.

4. **Seeding aircraft in same airspace:** Mitigation includes:

a) Flying b*elow* the flight level of the seeding aircraft to ensure adequate separation
b) Maintaining a separate radio frequency for communication between the pilots of the two aircraft.

Instrumentation:

The following sensors have been requested for this project:

Optional Standard:
Rosemount 871FA, DMT LWC100, Gerber PVM100, DMT CDP, PMS FSSP100, PMS OAP-2DP, MRI Turbulence, DMT CIP, LICOR 6262 (should be replaced by the LICOR 7000 by the time of this project)
Non-standard:
WCL_Nadir, WCR, WCL_Zenith (see electrical power discussion)
User Supplied:
Nevzorov Total Condensed Water, SPEC 2DS, Ka-band profiling radar

User-supplied equipment: The UW KPR (Ka-band Profiling Radar), which is under development with ProSensing, was requested if available. It is not likely that the KPR will be available by Q4 2016, because of required extensive ground and flight testing, software development for data processing, and validation. Furthermore, KPR will impact pylon canister allocation as well as the overall power budget which already may limit zenith WCL deployment.

Electrical Power analysis: Our analysis indicates that there is insufficient electrical power to accommodate the zenith WCL. As noted above, this discussion does not take into account the possibility of the KPR deployment.

Space, weight/balance analysis: Feasible as requested

Sensor installation considerations: Feasible as requested with the caveats noted in the pylon canister allocations above.

Investigator deadlines and/or special requirements: The 2DS, the Nevzorov and the KPR are user supplied instruments. Investigator(s) must have the instruments deployment ready 4 months prior to the project start date.

Summary:

SNOWIE is feasible from an ops perspective, although depending on the intensity of the icing, we may not be able to remain in the heaviest conditions to the maximum duration requested by the PI. Also,

considering probable icing conditions, we may not be able to descend to the lowest altitudes desired in all cases.

The instrumentation package is feasible, with the exception that the zenith WCL cannot be accommodated (insufficient electrical power), and the likelihood that KPR will not be available in addition to the problem KPR would present with adding electrical power loading and competition for available probe canister locations.

SNOWIE (Fall 2015 OFAP)
EOL Feasibilities

A: Field Catalog

Scope:
Field Catalog support with Catalog Maps tool

Assumptions:
- Small campaign with few mobile instrument platforms and the potential for few people to centrally gather will require considerably less on-site field catalog support than a typical aircraft campaign.
- Field Catalog is needed to handle the variety of products PIs want to collect/consult during the campaign and to document project operations.
- PIs will upload preliminary data into the field catalog via the internet. These data will be limited access to project participants only and available during and after the field campaign.
- High-speed internet access will be available on-site at the project operations center

Deliverables:
Staffing:
- 1 Field Catalog administrator on-site for up to 1 week to work with and train users

Field Catalog & Catalog Maps Display:
Field Catalog services including the Catalog Maps tool have been requested for this project. While there will likely be new products to collect that we haven't worked with before, this should not present any problems. The most important products for real-time decision-making will be included in the Catalog Maps tool where they can be overlaid by current aircraft positions and tracks and replayed for case review. Since the PECAN field campaign this past summer, we've also worked with these PIs to track a number of mobile facilities in real-time via Catalog Maps and the use of the DeLorme inReach GPS device. If the PIs are willing to operate their inReach devices for this field campaign, the Maps tool could track the movement of teams on snowmobile in real-time to provide an extra measure of safety for the project participants. Since the inReach device communicates via satellite and can provide updates as often as once per minute, this shouldn't be a problem to accomplish.

Supplemental funding will be required by EOL/CDS to provide this requested support.

Communications:
It sounds like cell phone communications will be the main communications strategy employed here to communicate with researchers at various remote sites. IRC Chat

could be useful for ground-air communications but it is not mentioned in this request. The PIs should clarify if ground to air communications are needed in this campaign and if so, what methodology they plan to use.

Risks:
None.

Feasibility:
Feasible

B: Data Management

Scope:
Long-term Data Archive Support

Assumptions:
- Long-term data storage of all data collected in SNOWIE to be maintained at NCAR/EOL. EOL will be responsible for the stewardship, maintenance, and open access of the data archive.
- Data Providers may also archive their data at home institutions, but copies will be provided to EOL.
- PIs may upload preliminary data to the EOL Field Catalog and Data Archive via the internet. These data will be limited access to project participants only and available during and after the field campaign.
- EOL will assist the SNOWIE PIs with the generation and implementation of a Project Data Policy in accordance with the EOL Data Policy.

Deliverables:
Staffing:
2 weeks - Data Manager
2 weeks – Associate Scientist
1.5 weeks – Software Engineer III
2.5 weeks – Webmaster/Software Engineer II
2 weeks – Student [0.5 FTE]

A special funds request will need to be submitted by EOL to the NSF to provide all these requested data services. The staffing estimate above includes the pre-field planning and field phase of SNOWIE. Any additional data management support would be requested through a supplemental funds request (post-field Phase III funding).

Archive Details:
The SNOWIE field phase period is 5 January to 15 March 2017. A complete project archive was requested to be provided by EOL. This will include special research

facility data as well as routine supporting operational meteorological data collected in the region such as surface and sounding network data, satellite, radar, model output (as determined by the SNOWIE PIs).

EOL will provide normal collection and processing of these data and metadata as well as providing dissemination to the project participants through the EOL Data Management System (EMDAC). It is requested that EOL provide project data in a variety of native formats including standard radar data formats (e.g. DORADE), ASCII, and NetCDF. All other metadata and dataset documentation will comply with EOL standard procedures and data policy. EOL should begin communication and coordination with the PIs soon after SNOWIE project approval to establish a data policy, data management plan, project web site, establishment of a preliminary data exchange site, and other special requirements during the planning process.

NOTE – The PIs have requested 6-month restriction for the data after conclusion of the field phase.

Risks:
None.

Feasibility:
Feasible. No conflicts to support data management from multiple projects at this time (should they be approved) are expected. No data (or requested supporting datasets) have been requested that will cause any problems or issues for EOL support.