SNOwD UNDER Operations Manual

Draft Version – October 5, 2010
Revised Draft – November 1, 2010
Final Version - November 15, 2010

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1. Introduction

SNOwD UNDER (The Student Nowcasting and Observations with the DOW at UND: Education through Research) is a UND student-led field project taking place in the vicinity of the University of North Dakota (UND) in collaboration with K-12 schools during the early winter of 2010 (Fig. 1). The project will use surface, *in situ*, and remote sensing instruments to collect coordinated observations of precipitation events in the Red River Valley (Table 1).

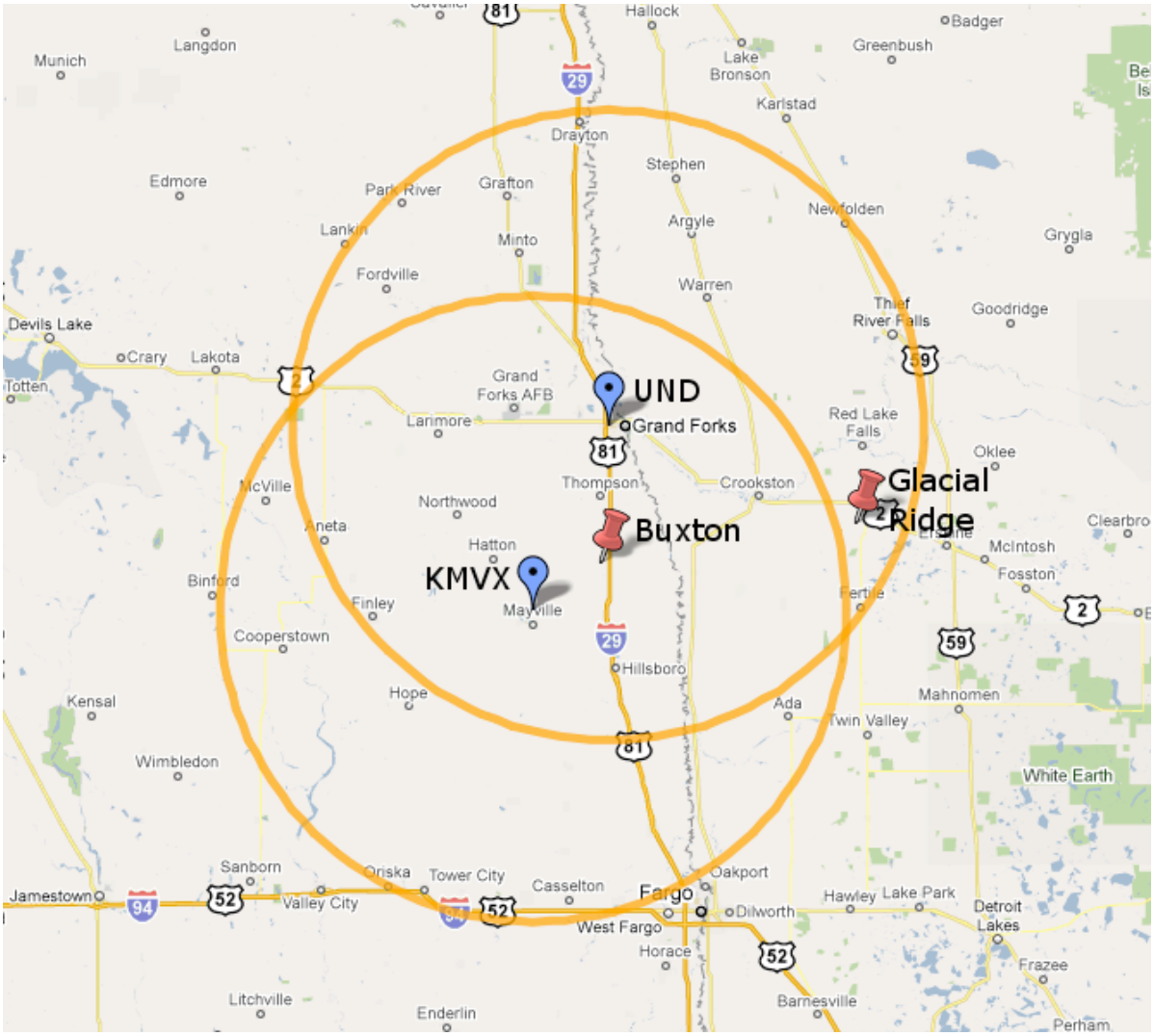

Fig. 1. Map of the SNOwD UNDER field campaign domain. Radars (surface sites) are denoted by blue (red) markers. The orange circles represent the 75-km range-rings from the UND and KMVX radars and serve as the domain for operations.

This operations manual is organized as follows. In section 2, the project goals and scientific objectives will be summarized. The procedure for forecasting will be provided in section 3. Radar, aircraft, surface, and satellite operations will be discussed in sections 4, 5, 6, and 7, respectively.

Table 1. List of vehicles and instruments used within the SNOwD UNDER field campaign. The relevant group and section in this operations manual is given in the rightmost column for each instrument/vehicle.

Vehicle/Instrument Name	Measurements Collected	Group and Section
Doppler on Wheels (DOW)	dual-pol radar fields	Radar (4)
UND NorthPol Radar	dual-pol radar fields	Radar (4)
UND Citation II Aircraft	*in situ* microphysics	Aircraft (5)
Snowboards/rulers	Snowfall accumulation & liquid equivalent	Surface Obs (6)
Satellites products (see Table 5)	Cloud physical and optical properties	Satellite (7)
Snow Box	Snowflake properties	Surface Obs (6)

2. Summary of the field campaign

2.1 Scientific Objectives

SNOwD UNDER has the following scientific objectives listed in order of operational priority.

Goal 1: Investigation of snow systems in the Red River Valley.

The primary scientific goal of the field campaign is to use the combined assets of radars, surface observations, and the UND Citation aircraft to study numerous properties of snow events in the region. Dual-polarimetric radars will be used to investigate signatures associated with snow crystal types measured *in situ*, correlate radar-derived snow amounts with K-12 student-measured snowfall at the ground, and to retrieve the mesoscale windfield. These coordinated measurements will enable a greater understanding of the dynamic, kinematic, and microphysical structure of these snow events. The measurements will also help to verify snow forecast models and to improve future forecasts of snow systems in the region. Additionally, high school students will measure snow density by relating the snow depth to the liquid equivalent depth. Snow density will be related to the polarimetric radar observables. The snow depth and snow cover products from satellites will be validated using ground measurements from schools and the National Weather Service (NWS).

Goal 2: Investigation of cool-season precipitation events

Besides ice phase precipitation events, the project will also study mixed or liquid only precipitation events in the Red River Valley. The objectives for these systems generally follows

that of science goal #1 except aircraft assets will not be deployed, and surface observations may occur in limited quantity.

Goal 3: Observation of cirrus clouds with radar

Cirrus clouds have unique optical and physical properties that are poorly understood. Radar observations of cirrus clouds will be compared to satellite products that estimate the microphysical properties of these clouds.

2.2 Educational Objectives

Besides the scientific objectives, one of the main purposes of this field campaign is to educate the community, get or keep them interested in atmospheric science, and provide chances for K-12 students to know and get involved in science.

2.3 Day-to-Day Operations

A timeline of a typical event is given in Appendix A. Student leaders will be in charge of disseminating information to group participants during the field project. This will be done via the SNOwD UNDER blog (http://snowdunder.blogspot.com/) and personal communications. All students that wish to participate during deployments are urged to frequently check the blog and attend daily forecast briefings. Sign-up sheets for deployments within the next 24 hours of a mission briefing will be available. If a student is unable to attend a briefing, they may contact their group's student leader to be placed onto the deployment list. On-call lists will also be maintained by individual groups in case a participant is unable to attend at the last moment.

Student leaders will serve as a committee to determine when to operate. The primary DOW and NORTHPOL radar operators (Aaron Kennedy and Jason Naylor) as well as the aircraft leader (Andrea Neumann) will serve as field coordinators. They are in charge of operations while in deployment including when to call off operations. In case one of these individuals is unable to participate for a deployment, a member of the relevant group will be chosen to serve as a field coordinator.

2.4 General Deployment Strategies

Depending on the forecasted precipitation event, SNOwD UNDER will have the option of operating in full, partial, or radar-only deployment modes. These scenarios are summarized below.

2.41 FULL DEPLOYMENT (SCENARIO A)

Full deployments will occur in support of science objective #1 when it appears likely that significant snowfall or banding will occur over the Buxton Field site (Fig 2a) or over the city of Grand Forks/East Grand Forks. In this scenario, all assets will be deployed.

2.42 PARTIAL DEPLOYMENT (SCENARIOS B & C)

In the case of snow events that will not directly pass over the Buxton field site (Fig. 2b) or Grand Forks, scattered and or weak in nature, or events that are mixed phase (Fig. 2c), SNOwD UNDER will operate in a partial deployment mode. For these scenarios, the Citation aircraft will not be used due to the limited number of flight hours allocated for the project. Although the DOW will remain deployed, surface observations may be collected in a limited quantity.

2.43 RADAR-ONLY DEPLOYMENT FOR RAIN (SCENARIO D)

Radar-only deployments will occur in support of science objective #2 when only liquid precipitation is expected (Fig. 2d). These deployments may occur anywhere within the operational domain in effort to obtain high-quality dual-Doppler datasets.

2.44 RADAR-ONLY DEPLOYMENT FOR CIRRUS (SCENARIO E)

When no significant precipitation is expected, but cirrus are forecast, the radars will scan at high elevation angles in an attempt to detect cirrus clouds in support of the science objectives of the satellite team. For this deployment, the DOW will remain within Grand Forks, deployed near the UND radar.

2.5 Communications

Cellular communications will be used for general communication between groups during the SNOwD UNDER project. A general contact list for the project is provided in Appendix B. The radar and aircraft student operators will serve as field coordinators and are in charge of making operational decisions and relaying communications to all other participants. For coordination between the Citation II aircraft and the UND radar, VHF radio will be used on a frequency of 122.825 MHz. Student leaders are in charge of communications within individual groups and they will provide contact information on an individual group basis. Prior to an event starting, a contact list will be provided for all participants. This sheet will be available online and from Room 452 in Clifford Hall.

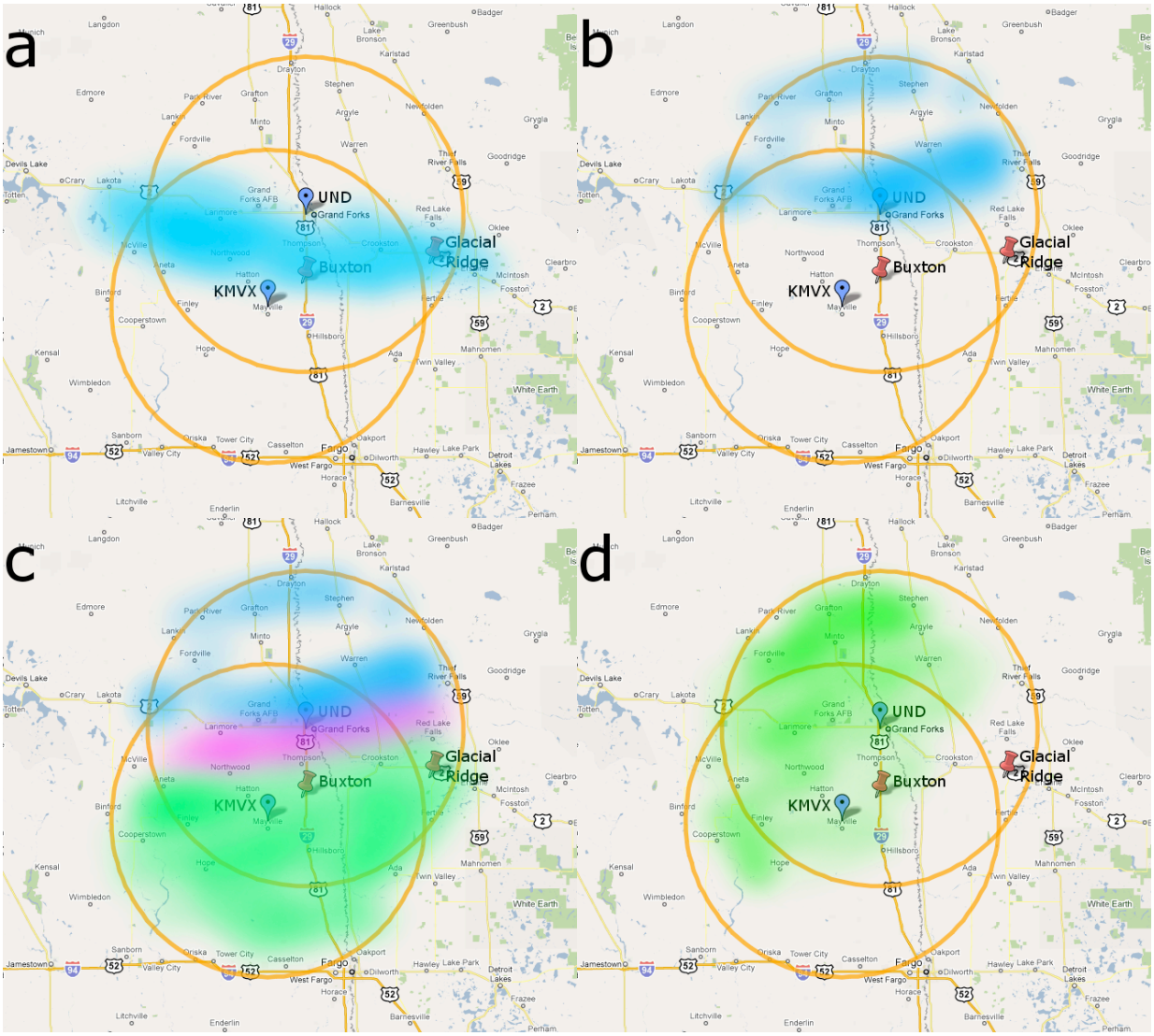

Fig. 2. Precipitation scenarios for the SNOwD UNDER field campaign. a) Heavy snow band present over the Buxton field site. b) Snow bands elsewhere within the operational domain. c) Mixed precipitation event throughout the region. d) Liquid only event

2.6 Suspension Criteria

The safety of all SNOwD UNDER participants is of the utmost importance. In an effort to avoid dangerous weather conditions, ground operations will be called off by the student field coordinator (Aaron Kennedy or Andrea Neumann) if a blizzard warning is issued at the DOW or UND student surface observation deployment locations and is expected to persist for more than 12 hours. This will primarily affect UND students who are driving to Buxton to take surface measurements on the weekend and students working the DOW. Additional safety and suspension criteria are used for aircraft observations (see section 5.5). The field coordinators will relay the information to the respective team leaders, or the designated contact person for that group, who will relay it to the participants via a text message/call tree.

3. Forecasting

Daily forecasting operations will be conducted using senior students from the synoptic meteorology course as well as other graduate and undergraduate students. Forecasting operations will commence no later than 6 A.M. Central Standard Time in the Regional Weather Information Center (RWIC). Two students per shift will conduct forecast operations. Forecasting duties will be broken into two sections, (1) nowcasting and (2) synoptics.

3.1 Nowcasting

Duties of the nowcasting forecaster will be as follows: (1) create a detailed, 24 hour forecast (8am-8am) with the first 12 hours of said forecast using nowcasting techniques taught in the "Synoptic Meteorology" class; (2) This forecaster will be responsible for forecasting probability of precipitation, start/stop time, precipitation type, total accumulation, wind speed and direction, temperature, precipitation rate, probability and location of mesoscale banding, and forecasting the presence of cirrus clouds. This forecaster will be responsible for briefing the participants of the daily forecast during the designated briefing time (see below).

3.2 Synoptics

Duties of the synoptics forecaster will be to create a forecast encompassing hours 25-72. This forecaster will be responsible for forecasting probability of precipitation, start/stop time, temperatures and wind speed and direction. This 25-72 hour forecast will be more general than the first 24 hour forecast, as this forecast is simply to give the other groups a general idea of possible upcoming operations 3 days out.

3.3 Briefings

Forecasters will conduct daily briefings at 8 A.M. in RWIC located on the 2nd floor of Odegard Hall.

4. Radar operations

SNOwD UNDER will utilize several different ground-based weather radars for the field campaign. These include:

- National Weather Service WSR-88D (S-band) Doppler radar located in Mayville, ND
- University of North Dakota (C-band) polarimetric Doppler radar (NORTHPOL) located in Grand Forks, ND
- Center for Severe Weather Research (CSWR) Doppler on Wheels (DOW) mobile polarimetric X-band radar

A number of considerations need to be made for radar operations during SNOwD UNDER. These include personal issues, deployment chronology, and safety measures. Finally, a variety of operation modes and scanning strategies will be implemented depending on the goals and scenarios listed in Section 1.

4.1 Personnel

A minimum of two individuals will be required to operate the DOW. This will include a driver/communicator and a radar-operator/navigator. Both individuals must have attended DOW training. If personnel allow, a third individual may be included who will assist with the navigation and communications. It is anticipated that the third individual will typically be an underclassman and will be taught how to operate the DOW.

One individual will be required to operate and monitor the UND radar during a deployment. This individual must be a graduate student with prior experience operating the radar. If personnel allow, it will be preferable to have one or two others to assist the primary radar operator with communications, operating the radar, and performing other miscellaneous tasks. The primary operator must update the radar log every time the radar is operated. Information that should be included in each log entry includes date, time, name of primary radar operator, scanning strategy used and a brief description of weather phenomenon observed.

4.2 Chronology of an event

4.21 FORECASTED EVENT

- Days prior the event

In the days prior to a forecasted event, the radar team leaders will work on scheduling for the anticipated deployment. This will include determining shifts if it appears that the event may last for a prolonged period. Scheduling will be finalized after the daily 8am briefing, and members involved will be alerted to the possible deployment time +/-3 hours. At the same time, the scanning strategy for the combined radars along with a preferred DOW position will be determined.

- Day of the event

On the day of the event, three hours of forecast lead time will be required to have deployment occur on time. This is a conservative estimate to cover a worst-case scenario, which may involve travel of crew from off campus and a deployment location that is distant. Once radar crews arrive on campus, a nowcast will be made to determine whether the prior positioning and scanning strategies are still appropriate. If it appears that the forecasted event is delayed, at this time, the DOW's leave time will be postponed to prevent waiting in the field.

- Deployment

Immediately prior to the deployment, the DOW will be fully gassed and taken out of the garage. Gas-up will occur either at a local filling station which has enough clearance to accommodate the 14' tall DOW. The DOW will then be driven to the predetermined location and setup. In communication with the NorthPol radar operators, it will be determined whether the DOW radar will be instantly turned on or will sit until echoes enter the DOW's domain. Deployment will last during the entirety of the event. Depending on the temperature and where the DOW is stored, extended warm-up time may be required. Details of the deployment will be logged to the DOW mission summary sheet (Appendix C).

- End of Deployment

Deployment end will be determined in conjunction with the NorthPol radar operators.
No crew will remain deployed for more than 12 hours at one time barring extenuating circumstances. If the event reaches this time frame, then the crew will have the option of calling operations or switching out with a replacement shift. After deployment is ended, the UND and DOW radars will be turned off. Data will be immediately backed up before crews return home. On return to the bus garage, the crew will clean out the DOW thoroughly. The DOW leader will be responsible for transferring data from the DOW to the pre-determined storage at UND. The mission summary will be completed and will be transcribed and posted to the SNOwD UNDER blog within 24 hours of the deployment end.

4.22 SCRAMBLE MODE

In the event of an unforecasted precipitation event, the DOW may be operated in scramble mode. Prior to the scramble occurring, team leaders will keep track of personnel that are available on any given day. If snow is noted on the Mayville radar, team leaders will call personnel and attempt to form a crew for the UND and DOW radars. A scanning strategy and position will be determined as the DOW is being prepared for deployment. After the scramble is made, the rest of the deployment will operate as specified previously.

4.3 Safety Considerations

The safety of participants operating the DOW radar is of the utmost importance during SNOwD UNDER. For this reason, numerous considerations have and will be made during the project. As mentioned previously, no crew shall operate the radar for a duration exceeding 12 hours unless weather conditions prevent safe return. As mentioned in section 2, operations will be called off if a blizzard warning is issued for the deployment location and is expected to persist for more than 12 hours.

Deployment locations have been determined using several safety guidelines. These positions will have adequate room to pull the radar completely off the roadway or are on county roads, which should have no traffic and adequate shoulders. They have also been chosen based on their proximity or location to roads that are frequently plowed such as US and state highways. Locations along county roads will not be used for heavy snow events. If roads appear to be impassable to a chosen deployment position, a backup will be determined in the field.

The DOW has a **height clearance of 14ft.** Drivers will need to use extreme caution when driving the vehicle to avoid low bridges, trees, power lines, and gas station awnings. Although care was taken to choose locations, which do not have these obstacles, **DO NOT ASSUME** they are not present. Further, ice or strong winds could create these obstacles. For this reason, drivers should proceed cautiously through small towns. If a driver and a crewmember outside are unsure whether the DOW is able to clear an obstacle, a different route must be chosen.

Due to the nature of the field campaign, which will operate during snow events, there remains a small possibility that a crew may become stranded during low-visibility conditions. For this reason, the DOW will be stocked with fresh water and snacks in case of emergencies. Non-messy food may be brought if deployments are expected to span over meal times. Crewmembers are required to carry their fully charged cellular phones for emergency communications. A list of emergency contact numbers is provided in Appendix B.

4.4 Radar scanning strategies

4.41 WSR-88D S-BAND RADAR

The WSR-88D will operate in several predetermined volume coverage patterns (VCPs), which are normally determined automatically by the radar system. These VCPs are summarized in Table 1. In summary, VCP 21 (precipitation mode) will most likely be used for scenarios c and d (Fig 2.) when mixed or liquid phase precipitation is occurring. Depending on the intensity of the snowbands or snow showers, VCP 21 or VCP 32 (clear-air mode) may be used. VCP 21 is triggered once reflectivity values approach ~35 dBZ. Operations for dual-Doppler with this radar and the DOW (i.e. locations south of Mayville, ND) will only occur when the WSR-88D is running in VCP 21 which has ample vertical resolution with the increased number of tilts. In the event that the WSR-88D is operating in clear-air mode, and it appears that precipitation mode is also feasible, the SNOwD UNDER radar operators may request the NWS to manually change the

VCP. This will be done by calling the NWS FGF forecast desk. Because this is a private line, this phone number will only be provided on a need-to-know basis.

Table 2. Commonly used VCPs for winter season precipitation events.

VCP	21	32
Type	PPI-Precipitation	PPI-Clear-Air
Elevation Angles (degrees)	0.5,1.5,2.4,3.4,4.3,6.0,9.9,14.6,19.5	0.5,1.5,2.5,3.5,4.5
Scan Time	~6 minutes	~10 minutes
Nyquist Velocity	32 m/s	8 m/s

4.42 NORTHPOL C-BAND POLARIMETRIC RADAR

The primary goal of the NorthPol radar is to collect high-resolution, dual-Doppler, dual-wavelength data in conjunction with the DOW. Under most of the precipitation scenarios, NorthPol will perform 180 degree PPI and RHI scans in tandem with the DOW. However, in the event of precipitation occurring directly above the NorthPol radar, the radar will perform PPI scans with large elevation angles with the goal of sampling the fall speed of hydrometeors. NorthPol may also be run as surveillance radar prior to deployment.

Table 3. Scanning Strategies for the NorthPol radar

Scan Type	PPI (Precipitation)	RHI (Precipitation)	PPI (Cirrus)
Scan angles	360 degrees	0.1 degree resolution	360 degrees
Elevation angles (degrees)	0.5, 1.25, 2.0, 2.75, 3.5, 4.25, 5.0, 6, 7, 8, 9, 10, 11	0.5 - 80	60-85
Scan rate	12 degrees / second	12 degrees/second	5 degrees/sec
PRF	1000 Hz	1000 Hz	300 Hz
Number of samples	64	64	128
Pulse length	0.6 μs	0.6 μs	2.0 μs
Nyquist velocity	13.4 m/s	13.4 m/s	4 m/s
Gate spacing	125 m	125 m	125 m
Duration	6.5 min	5 min	16 min

In the event of a non-precipitating cirrus cloud scenario, NorthPol will perform RHI scans and/or PPI scans with large elevation angles ranging from 45 to 80 degrees, depending on the location of the cirrus clouds.

4.43 DOW X-BAND MOBILE POLARIMETRIC RADAR

4.431 PPIs

Scanning strategies for the DOW will vary by the scenario and location for deployment. In the majority of situations, the DOW will operate in a traditional sense by performing PPIs at various tilts (Table 3). Although sites have been chosen for the lack of trees, power lines, etc. that may cause beam blockage, these objects still exist. Once DOW training is completed, the DOW will perform ground clutter scans as proactive deployments each location to determine whether beam blockage is acceptable and what the minimum elevation angle is for each location. Depending on these practice deployments, some low elevation tilts may be modified.

Table 4. Scanning strategies for the DOW

Scan Type	PPI (weak echo)	PPI (strong echo)	RHI (strong echo)	RHI (weak echo)
Elevation angles	0.5,1,1.5,2,2.5,3,3.5,4.5, 5,5.5,6.5,7.5,8.5,9.5,10.5,11.5	0.5,1,1.5,2,2.5,3,3.5,4.5,5,5. 5,6.5,7.5,8.5,9.5,10.5,11.5	TBD	TBD
Scan rate (deg/sec)	20/**15**/10	**30**,20	5	5
PRF (Hz)	1000	2500	2500	1000
Number of samples	25/**~33**/50	**~41**,50,~62	250	100
Nyquist velocity (m/s)	7.5	11.25	11.25	7.5
Pulse Width	1μs	0.4μs	0.4μs	1μs
Gate spacing	150m	60m	60m	150m
Duration (min)	4.8,**6.4**,9.6	**3.2**, 6.4	TBD	TBD
Max Range (km)	150	60	60	150

The DOW will use 360-degree scans for events. Sector scans may be used for isolated cases where snow events that are focused over small regions.

There are multiple purposes for scanning similar locations at nearly the same time with two radars. One is to perform a dual-Doppler analysis. Another is to compare dual-Pol signatures from radars with two different wavelengths. Thus, simultaneous PPI scans are still important even if radar operators do not notice mesoscale circulations or banding.

4.432 Vertically oriented modes

As with the NorthPol radar, the possibility exists to obtain RHIs and/or high angle PPIs with the DOW or to determine hydrometeor fall speeds or detect of cirrus. This scanning strategy will only occur when the following conditions are met:

- The Mayville WSR-88D is operating in VCP 21
- A snow band sets up within the 40 degree dual-Doppler lobes of the 88D and NorthPol radars
- The snow band is not occurring over the Buxton field site.
- If no precipitation is present, but cirrus are viewable with the naked eye or visible satellite imagery

For cirrus cases, the pulse width will be increased to assist the sensitivity of the radar. The DOW will be positioned near Clifford Hall so that data can be inter-compared with NorthPol. For precipitation cases, the DOW will be moved to a location underneath the most intense portion of the snow band. Because beam blockage is not an issue with RHIs, the DOW may be placed at nearly any location within the operational domain.

4.5 DOW positioning

4.51 SCENARIO A: SNOW BAND OVER BUXTON FIELD SITE

For this scenario, the focus of the radars is to collect high-quality Triple Doppler datasets over the Buxton, ND field site. The DOW will be positioned at sites either south of Larimore, ND or south of Crookston, MN. Both of these regions provide a suitable geometry necessary for these observations.

4.52 SCENARIO B: SNOW BANDS ELSEWHERE WITHIN THE DOMAIN

For other banding or heavy snow events in the region, the DOW may be placed in dual-Doppler baselines either with the UND or WSR-88D radars. If a snow band sets up over Grand Forks, ND, the DOW will be placed in a baseline with the WSR-88D so that NorthPol may be operated in a vertical fashion.

4.52 SCENARIO C AND D: MIXED AND LIQUID PHASE EVENTS

Under the assumption that the WSR-88D is operating in VCP-21, the DOW may be positioned at any location within the operational domain such that the Dual and/or Triple Doppler lobes contain the precipitation event.

4.53 SCENARIO E

When no significant precipitation is expected, but cirrus are forecast, the DOW will remain within Grand Forks, deployed near the UND radar, and will scan high elevation angles to attempt cirrus detection.

5. Aircraft Operations

5.1 Instrumentation installed on Citation for SNOwD UNDER operations:

The Citation aircraft is equipped with standard temperature and pressure sensors along with a five-port gust probe on the nose of the Citation to measure three-dimensional winds. The citation also has two hygrometers: a tunable diode laser hygrometer and an EdgeTech Chilled Mirror hygrometer. There are also two ice detectors installed: a Goodrich Optical Ice detector and a Rosemount Ice Detector. A TSI 3771 Condensation Particle Counter measures total aerosol content and a Cloud Droplet probe measures cloud particle distributions and liquid water content for particles between 2 – 50 μm. A Cloud Particle Images records high-resolution, 2.3 micron pixel size, digital images of particles that pass through the sample volume at speeds up to 200 m/s. The Citation also has two optical imaging array probes installed: a High Volume Precipitation Spectrometer (HVPS) and a 2-Dimensional Optical Array Spectrometer (2DC).

5.2 Aircraft Personnel

The primary duty of all aircraft personnel is to ensure proper maintenance of the aircraft and instrumentation. Additional duties specific to each person are summarized below.

5.21 FLIGHT SCIENTIST

The flight scientist is responsible for maintaining contact with the DOW and NorthPol radar operators and with them, deciding whether the conditions warrant either a full or partial deployment. Upon full deployment, the flight scientist will coordinate with the radar operators to determine the location of the main flight observations. The flight scientist will also be responsible for the archiving of the flight data upon the completion of the flight.

5.22 FLIGHT ENGINEERS/OBSERVERS

The flight engineers are responsible for observing the status of the instrumentation during flight and noting any irregularities that occur. Observer(s) will be responsible for photo and video documentation of the flight. The flight engineers and observers are also responsible for the completion of the instrumentation pre- and post-flight checklists.

5.23 INSTRUMENT TECHNICIAN

The instrument technician is responsible for proper maintenance and installation of the aircraft instrumentation listed above.

5.24 PILOTS

The pilots are responsible for all operational procedures of the aircraft. They are also responsible for suspending the flight if weather conditions deteriorate to the point where it is unsafe to fly the aircraft.

5.3 Flight Criteria

In order for Citation group to launch the plan, several conditions have to be met. These include:

1. The plane must be in an operable state
2. Enough advanced notice has been given to the pilots. These include:
    a. A week for standby notice
    b. Three (3) hours notice for final launch
3. Conditions at the time of takeoff and forecasted conditions for landing must be above the suspension criteria given below.
4. There must be a snow band that is forecasted to drop a significant amount of snow into the Grand Forks (Scenario B) or Buxton (Scenario A) area
5. The NorthPol and DOW radars should be actively sampling the same storm

5.4 Suspension Criteria

All aircraft operations will be suspended if conditions deteriorate to the point where all project activities are suspended (section 2.5). Additional suspension criteria for a Citation flight include ceilings below 200 ft overcast, less than one half-mile visibility, and over a 23-knot crosswind across the 35L runway at the Grand Forks airport (KGFK). The pilots get final decision whether conditions meet suspension criteria or not.

5.5 Flight Plans

5.51 PRIMARY FLIGHT GOALS

The first and primary flight for the Citation will focus on providing data for vertical cross-sections of the snow event. This will be done through ascending and descending legs through the cloud.

There are two main types of snow events that Citation will fly through: a banded snow event and a widespread snow event. The banded snow event comprises of mesoscale bands of heavier snow that are embedded in the larger system. This type also includes frontal snow bands. The widespread snow event is defined as an event where there is no clearly defined mesoscale banding and no large reflectivity gradients shown on the radar data. All flights will target areas of dual-Doppler coverage.

5.52 BANDING SNOW EVENT

In the case of a banded snow event, the Citation Aircraft will fly within the band, parallel with the long dimension of the band. Flight level will be as follows: ascend from takeoff to a flight level near the top of the snow band. Once there, the flight will intersect the snow band diagonally decreasing with height until the aircraft is at a flight level at or near cloud base, or as low as the aircraft can safely go in the current conditions. The aircraft will turn 180 degrees, maintaining constant altitude, and then ascend back through the snow band with a flight path parallel to the descending flight path. When the aircraft reaches cloud top, the pattern will be repeated for as long as time allows, then the aircraft will return back to KGFK and land. This pattern is shown in Fig. 3, where there an ideal snow band has set up over the Buxton field site. With each repetition, the pattern will get translated in the direction of the snow band movement.

5.53 WIDESPREAD SNOW EVENT

In the case of a widespread snow event, the Citation Aircraft will fly a “figure 8” pattern through the snow event. As with the banded snow event, the flight levels will start at the top of the clouds and intersect down to cloud base. The aircraft will then turn around and intersect the storm again ascending to cloud top. This pattern will be repeated for as long as time allows and then the aircraft will land at KGFK.

5.54 SECONDARY FLIGHT GOALS AND FLIGHT PLAN

There is a possibility of a second aircraft flight during the SNOwD UNDER project. For this flight, the objective will to sample horizontal cross-sections of the snow event over the Grand Forks and Buxton areas. This flight will focus on horizontal flight through the cloud at several levels. The aircraft will sample near cloud top, two altitudes in cloud, and near cloud base. If time permits and conditions allow, sample below cloud base while returning to KGFK to land.

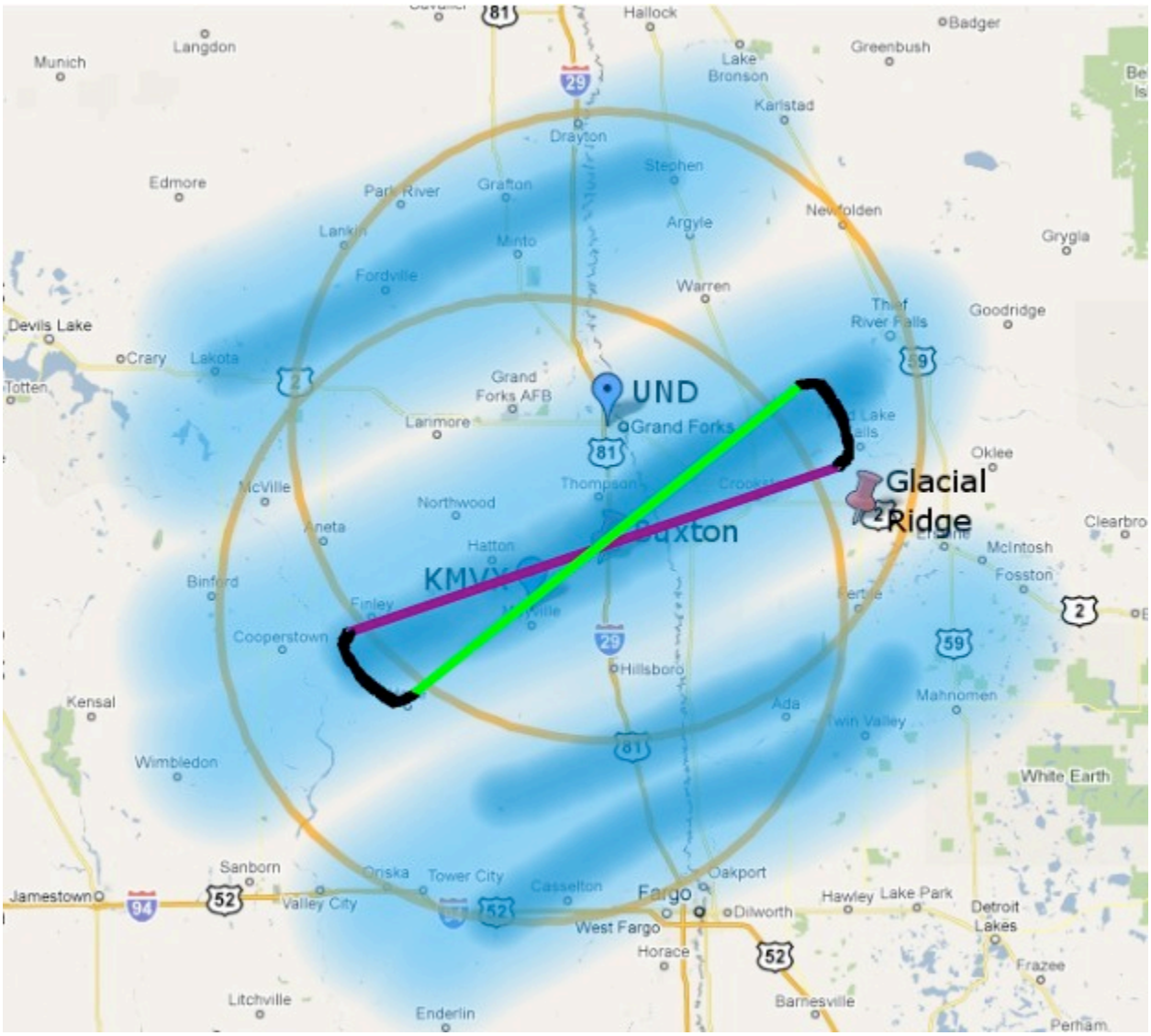

Fig. 3. Idealized flight plan for a sampling a mesoscale banding event over the Buxton field site with a ascending leg shown in purple, a descending leg shown in green, and level turns shown in black. Light blue shading indicated regions of light snowfall and dark blue shading indicates regions of heavy snowfall.

6. Surface Observations

Surface observations are a critical part of the experiment for both teaching K-12 students on how to take scientific measurements and for obtaining snow ground truth (for comparison against radar-derived snowfall rates, satellite observations of snowcover, and for judging the skill of NWP forecasts). The measurements are straightforward and a video has been developed to guide K-12 teachers. Instruments used during the project include a snowboard, ruler, and a metal can for taking “snow cores”.

6.1 Personnel

While many personnel are comprised of the teachers and students in the ten K-12 classrooms and two home schools (see map of schools, Fig. 4), there is also a team of recruited students who will assist with answering K-12 questions, surface snowfall measurements (primarily on weekends), more detailed automotive radar measurements, and snowbox measurements. A sign-up sheet detailing student availability will be used during the event.

6.2 Outreach to K-12

The team will provide educational training packages, a video, and instruments to the K-12 schools at the beginning of the experiment. The video will be available on YouTube throughout the experiment and the team will be available to answer teacher's questions. (See http://www.youtube.com/watch?v=jrQKo6dJ_l0)

6.3 Operations Scenarios

Each day, a communication will be sent out via Email, Facebook and Twitter to participants that will collect data in the Buxton area (Scenario A) or Grand Forks (Scenario B) to inform them whether observations will be collected during the expected periods.

6.3.1 WEEKDAY EVENT (Fig. 2a, 2b)

Both the UND students and the local K-12 schools will participate. Observations will only be taken at 9 am and 2 pm, which is in conjunction when schools are in session.

6.3.2 WEEKEND EVENT

If the event occurs on a weekend, a group from UND will drive to the Buxton STRWIC site to take snow measurements around the site or to selected locations in Grand Forks. The snow measurements will be taken at the same interval as the schools (9 am and 2 pm). During the break the students are free to drive back to Grand Forks. These weekend groups will be contacted via email and phone call when they are to go down to the STRWIC site.

The field coordinators will be in charge of suspending operations if safety conditions warrant (see section 2.5). K-12 schools will make their own decisions on school cancellation due to weather.

6.4 Surface Data Archiving

The schools will either return observations via a Google document or email. The data will be saved in a master spreadsheet on one of the main servers.

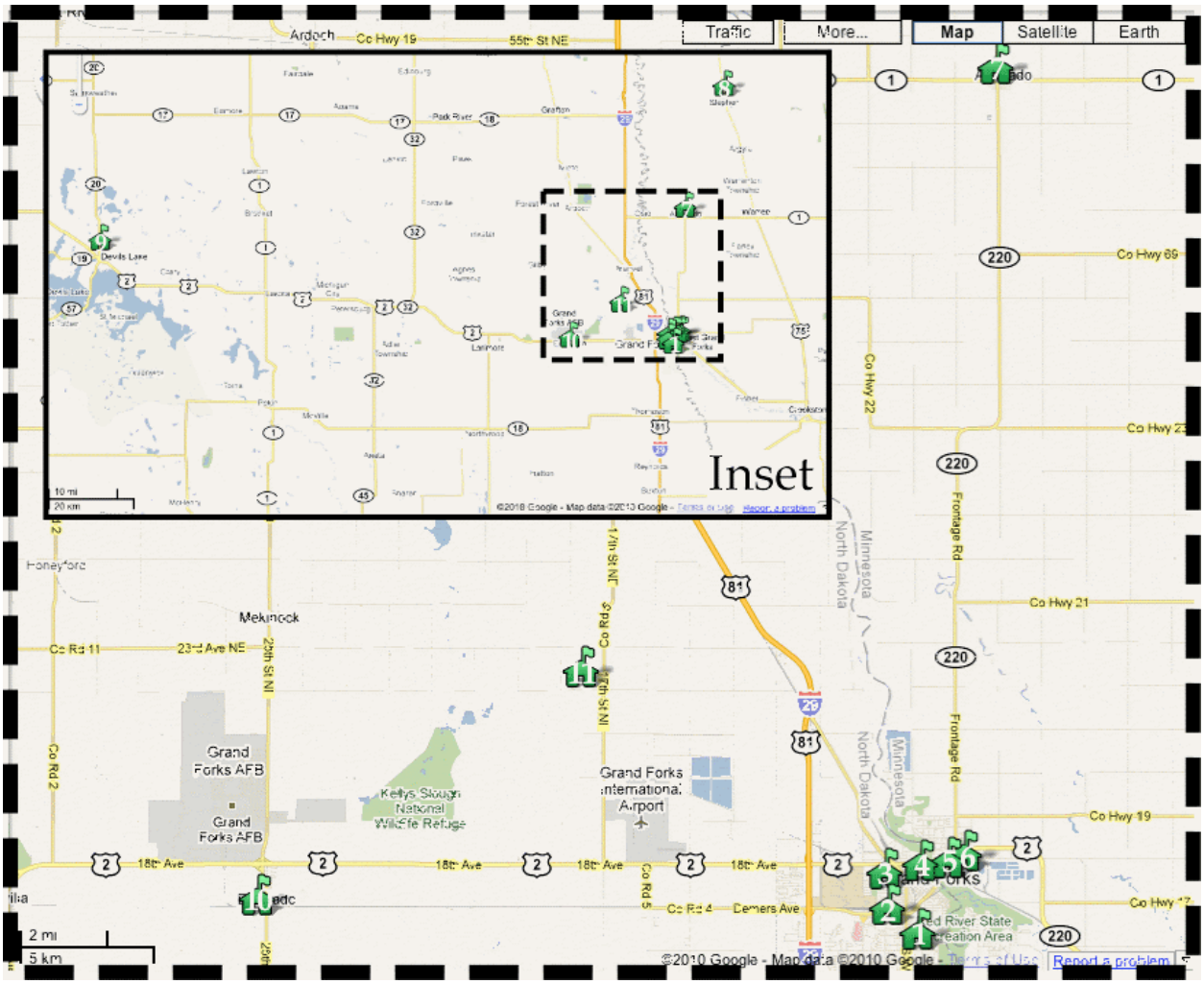

Fig. 4. Locations of the eleven K-12 schools and home schools: 1) Holy Family Elementary, 2) Ben Franklin Elementary, 3) Valley Middle School, 4) St. Mike's Elementary, 5) Sacred Heart High School, 6) Riverside Christian School, 7) Home School "A", 8) Stephen-Argyle Central, 9) Central Middle School in Devils Lake, 10) Emerado High School, and 11) Home School "B".

7. Satellite

The satellite team will try to answer the satellite involved research questions in Goal 1 and Goal 3 (see section 2). The relative operation procedures are discussed in section 7.1 and 7.2, respectively. To achieve the educational objective (section 2.2), the satellite team will post amazing patterns of nature captured by the satellite as they are powerful products to keep the community interested in atmospheric science. The science behind the weather phenomena also serves as good material for K-12 teachers. The procedures of the daily operations are in section 7.3.

Table 5. Satellite and products' acronyms, full names and their corresponding parameters .

Acronym	Satellite/Products Full Name	Parameters
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations	cloud depth, height, particle shape
GOES	Geostationary Operational Environmental Satellites	images, used as input for VISST/SIST
VISST	Visible Infrared Solar-Infrared Split Window Technique	cloud optical depth, cloud height, particle size
SIST	Solar-Infrared Infrared Split Window Technique	cloud optical depth, cloud height, particle size
MODIS	Moderate Resolution Imaging Spectroradiometer	true color images, snow cover
AMSR-E	Advanced Microwave Scanning Radiometer for EOS	snow-water equivalent (snow depth)

7.1 An Evaluation of the Satellite Snow Depth and Snow Map

7.11 Summary

AMSR-E is a space-borne microwave radiometer that has lower frequencies of 6 and 10 GHz. Among the level 3 daily products it provides, the snow water equivalent (SWE), which is the estimation of global snow volume is the product that will be examined using the snow depth measurements from the ground observations. The daily tile snow cover map and the 8-day composite snow-cover map from the MODIS satellite will be evaluated with the ground measurements and reported snow spatial distribution.

7.12 Operations
7.121 Pre-coding plan

The Satellite products AMSR-E and MODIS need to be archived in a local cluster a month before the field campaign for pre-coding purposes. Several types of codes need to be made in order to analyze the data. The first is to restrain the satellite retrievals within 20 km of Grand Forks within a certain period of time. The second is to modify the spatial resolutions of products in order to minimize the sampling bias when compared towards the ground based measurements. Compared to the 25 km spatial resolution of AMSR-E, the ground measurements of snow depth at the SNOWD UNDER operations region (refer to section 4) need to be averaged.

7.122 Event day operations

The briefing team will give a forecast every morning at 8:00 AM during the field campaign period. If snowfall occurrences are forecasted, that day is set to be an event day. After the snow event day is determined, the overpass of the daily orbit of AMSR-E and MODIS will be reviewed. The time of the overpass above the field campaign region needs to be archived for ground observation reference.

The MODIS snow cove product has 500 m spatial resolutions and is fine enough to distinguish the difference between the country and the urban areas. The reported snow depth will be mapped around the SNOWD UNDER operations region areas and compared to the daily and 8-day accumulated snow coverage map. The daily snow coverage map will be influenced more by the surface albedo because of the short time span that exists between the snow events and the observations. In contrast, the 8-day snow cover map will be influenced more by the human induced uncertainties, such as road plow, especially for urban areas. It is expected that the retrieval will be more consistent around the rural areas because of the darker surface albedo and fewer anthropogenic impacts after the snowfall.

The AMSR-E level 3 products can be downloaded approximately 4 days after the snow event. The accuracy of the increments of SWE will be evaluated towards daily measurements, if a continuous snow event occurs during the field campaign period.
For details of the ground measurements operations, refer to the section 6.

7.123 Data processing plan

All data will be reviewed and pre-processed after the operation. The quality of the data, including the content and the range of the data, needs to be checked and further evaluations will be made.

7.13 Potential Problems

Having no overpass above the field campaign regions after the snow even can influence plans for both satellites, if the snow event approaches later in the field campaign period or does not even occur. Full-sky cloud coverage can also block the satellite retrievals and leads to less data or no data for comparisons.

One of the main concerns regarding the AMSR-E SWE evaluation is the representativeness of the ground observations. The ground observations include measurements from grades K-12 at local schools, and the National Weather Service (NWS) observations. The NWS observations will be accurate, however, they are short of spatial coverage. Moreover, the K-12 measurements will be concentrated around urban areas and the quality of the measurements might be lower. Thus, the comparison results may not be optimal regarding the quality of the ground measurements.

For the evaluation towards the MODIS snow coverage map, the biggest uncertainty is the human modification of the snow coverage. Thus, it is important for the surface observation to have the exact time of measurements in order to explain the inconsistency between the observation and retrievals.

7.2 An Evaluation of the Satellite Cirrus Cloud Products
7.21 Summary

Combined observations CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations), DOW (Doppler on Wheels), and the UND radar will be used to evaluate VISST/SIST (the Visible Infrared Solar-Infrared Split Window Technique) cirrus cloud retrievals during the field campaign. CALIPSO provides the cloud vertical distributions to evaluate the cloud depth and cloud top height. DOW and the UND radar will be used to evaluate the cirrus particle shapes and possibly size distribution. There is the possibility that if no snow event occurs within the field campaign period, the citation aircraft will use flying time to observe cirrus clouds and provide more accurate data of cloud phase, particle shape, and size.

7.22 Operation
7.221 Pre-coding plan

The Satellite products of CALIPSO, and VISST/SIST (utilizing GOES observations) data need to be archived in a local cluster a month before the field campaign for pre-coding purposes. Several types of codes need to be made in order to analyze the data. The first is to restrain the satellite retrievals within 20 km of Grand Forks within a certain period of time. The second is to modify the spatial resolutions of products in order to minimize the sampling bias. There are two popular methods to use for changing the spatial resolution: using the representative data or averaging. It depends on the characteristics and the performances of the products to determine the method to use. The third is to compare the products and analyze the causes of the

differences. The comparisons will be made both at pixel level and gridded level in order to fully evaluate the products.

7.222 Event day operations

The briefing team will give a forecast every morning at 8:00 AM during the field campaign period. If cirrus clouds occurrences are forecasted with no snowfall events, that day is set to be an event day. Any possible satellite overpass of CALIPSO was checked before the operation period, and the GOES will have data over Grand Forks region every half hour. During the event day, all the available team members will separate into two groups and need to be at the DOW radar and at the UND site ten minutes before the operation. For both groups, the exact time of cirrus cloud occurrence, as well as the start and end of the operation time need to be documented. The conditions and the appearances of the cloud should also be recorded using a camera.

The operation will end at 4:30 pm or whenever the daylight ends, unless the CALIPSO will pass above Grand Forks within 50 km that day. The late operation is manned on a volunteer basis only. The operation will be ended if one of the following conditions is met: a) more than half of the members (including the radar team, if applicable) intend on leaving, b) weather conditions are not suitable for further observation, and c) Equipment is under danger if the operation continues.

7.223 Data processing plan

All data should be reviewed and pre-processed right after the operation, if possible, or within the next day. The quality of the data, including the content and the range of the data, needs to be checked. Any problems in the data need to be handed to the student leaders immediately. Emergency meetings should be held to solve the problems and prepare the next operation. The radar team will review the raw radar data (under negotiation). However, the feedbacks are required after every operation for documentation purposes.

After the field campaign, the data will be gathered and further evaluations will be made. The procedures will follow the pre-code process.

7.23 Potential Problems

This section lists the foreseen potential problems that this operation will face. They are divided into the data, theory, and operation conditions, which can cause partial or total failure of this plan. The data and theory parts have influences on the satellite and radar sections, respectively, and will not influence the operations of other sections. The operation conditions, in the worst-case scenario, can lead to a situation where no cirrus clouds can be observed. If none of the satellite and the radar operations can be completed or the operation conditions are in the worst scenario with no observations made, then Plan B will be activated.

7.231 Data that may not be obtained

One of the most unpredictable factors is whether the satellite will have an overpass over Grand Forks during the field campaign period. The calculated results shown there are two possible CALIPSO overpass during the field campaign period within 50 km around Grand Forks. Whether cirrus cloud will be good enough to observe at that time is one of the most important problems that this plan is facing.

7.3 Plan C: Daily Operations

7.31 Summary

One of the main purposes of this field campaign is to educate the community and provide chances for K-12 children to know and get involved in science. The amazing patterns of nature captured by the satellite are powerful products to keep the community interested in atmospheric science. The science behind the weather phenomena is also good material for K-12 teachers.

7.32 Procedures

7.321 K-12

In order to educate the K-12 students and illustrate the satellite products, interesting satellite images around Grand Forks will be selected everyday through MODIS and GOES satellites, since these are the only two satellites that have observations over Grand Forks at least once a day. Moreover, the multi-wavelength MODIS sensor, whose bandwidths cover the most of the visible channel, can provide the true color image that no other satellite can. Since MODIS images are provided every five minutes and GOES images are provided every thirty minutes, the selecting procedure should be operated at least twice a day at noon and in the evening to guarantee the near-real time service is provided. A short description of each image is required, which includes the contents of the image, the highlight of the patterns, and the cause of the symptoms. The images will be provided on the Facebook SNOWD UNDER group, which is accessible to the community. This operation will start as soon as the Facebook SNOWD_UNDER group is available and remain through the entire field campaign period.

8. Media and Outreach

The Media and Outreach group is responsible for communicating with public about SNOwD UNDER through press releases and online forms of media. The group will also document the project with their cameras.

8.1 Press Releases

The Media and Outreach group have already written one short and one longer "backgrounder" press release prior to the field phase of the project. A follow-up piece was released on 12 November to advertise Josh Wurman's visit. During and after the field phase, additional press releases will be prepared to report on the progress and success of the project and will be released based upon the advice and guidance of the UND University Relations Office. The group will also assist with formal publications after the project.

8.2 Photography

It will be the responsibility of the group to document the project with photographs; this includes taking, captioning, and properly archiving those photographs. The group will be taking "in-action" (candid) shots of groups during fieldwork as well as staged/posed shots. These pictures will be uploaded to SNOwD UNDER's online sources of public communication and archived at full resolution. Photographs will have 10-megapixel resolution minimum.

8.3 Online Forms of Media

Online forms of communication include SNOwD UNDER's blog page (updated daily), the wiki page (as necessary), and Facebook. Other groups will also be uploading their communications and photos.

Appendix A - A typical timeline for a full deployment

This appendix details what will occur for a possible full deployment (Scenario A) event. For this event, heavy, banded snow is expected to occur within the Red River Valley during the late afternoon (start 3pm) and end that evening.

1-3 Days out:

- Forecasters
    - Provide input on possibility of upcoming event at 8am briefings
    - Post relevant discussion to blog to keep all participants aware
- Student Leaders
    - Discuss possible deployment strategies (which scenario, etc.)
    - Notify group participants of possibility of upcoming operations
- Radar Group
    - Identify preferred DOW deployment locations
    - Determine scanning strategies for event
- Aircraft Group
    - Notify Citation pilots of potential flight
- Surface Group
    - Deploy Snowboards over location of forecast snow day prior to event. Leave UND around 2pm to deploy boards for overnight events.

Day of the event

6am:

- Forecasters arrive at RWIC to commence forecast operations

8am:

- Student leaders discuss any operations the day prior at the briefing
- Forecasters provide briefing at RWIC.
- Student leaders discuss deployment possibilities and determine a Scenario A event is likely to occur that afternoon.

9am: (immediately post briefing)

- Signup sheet (Appendix D) is provided to meeting participants. This list may contain individuals who have already contacted their group's student leaders.
- Aircraft Group
    - Contact Citation pilots to update flight status from potential to likely and give an estimated time of flight based off the briefing.
- Surface Group
    - If there was a overnight event Students would travel to site and take depth measurements and clear snowboards

9-11am (1 hour post briefing)

- Student leaders access sign-up sheet and their on-call lists to determine any holes within the current participant list for the day's deployment
- Participant list is finalized.

12pm (3 hours prior to event)

- Forecast Group
    - On-call and lead forecaster reassess conditions and alert the field coordinators to any change(s) in the forecast.
- Radar Group
    - DOW crew convenes and prepares truck for deployment
    - DOW location finalized after any last-minute nowcasting
    - DOW and UND radar operators coordinate to plan scanning strategy
    - In case of cirrus event, satellite team will deploy with DOW and UND radar
- Surface Group
    - Deploy Snow boards over target location

2pm (1 hour prior to event)

- Radar Group
    - DOW is deployed
    - UND radar crew is at the penthouse to assist with deployment communications
- Aircraft Group
    - Aircraft crew members head to the airport to prepare for flight.
- Surface Group
    - Goes down to see if boards are clean or measures what was collected.

3pm (weather echoes are occurring within study domain - band is expected to pass over Buxton site at 4:30pm)

- Radar Group
    - DOW is deployed and operational
    - NORTHPOL is deployed and operational
    - All crews have updated their deployment time, location, scanning strategies, etc. in their mission notebooks.
    - Cirrus event
        - Coordinate with satellite team
- Aircraft Group
    - Determine initial flight plan, including which in direction the Citation should fly and how snow bands will be sampled
- Satellite Group
    - Download the near real time GOES image for future references.

4pm (during event)

- Aircraft Group
    - Initial flight plan is finalized and filed with Grand Forks Air Traffic Control
    - Citation takes off to sample snowbands over Buxton area

5pm

- Aircraft Group
    - Citation lands
    - Data is saved to disk and then transferred to UND data servers
    - Mission summary is written

10pm (weather echoes subsiding and moving out of region)

- Radar Group
    - DOW and NORTHPOL cease operations
    - DOW and UND back-up and archives data
    - NORTHPOL crew writes up mission summary

11pm (+1 hour after event has ended)

- Radar group
    - DOW is returned to bus garage and cleaned
    - Mission summary is written by DOW crew if this has not been done already

Next day (+1-24 hours)

- Mission summaries are posted to the blog for each group
- Student leaders discuss a summary of the event at the following day's briefing.
- Surface Group
    - At 9am travel to site of snowboards take measurements and collect snowboards for next event.

After event (1 week after or later)

- CALIPSO satellite data for cirrus events will be collected after the data is put online which is typically at least a week after the event

Appendix B- CONTACT INFORMATION and EMERGENCY PROCEDURES

Description	Name/Place	Number
Emergency		911
Towing for DOW	Interstate Towing	701-772-6592
National Weather Service	Grand Forks, ND	701-772-0720
NorthPol radar operations	Clifford Hall, 6th floor	701-777-4599
Faculty Mentor	Matt Gilmore	
DOW leader	Aaron Kennedy	
UND radar leader	Jason Naylor	
SFC observation leader	Dan Koller	
Aviation leader	Andrea Neumann	
Satellite leader	Yingxi Shi	
Forecast leader	Matt Clegg	
Media co-leader	Corey Amiot	
Media co-leader	Krista Cooley	
Instrumentation Lab	Aaron Ness	
Computer Room	Clifford Hall 422	701-777-2392
Pilot	Wayne Schindler	
NWS Forecast Desk	NWS FGF	Contact Aaron Kennedy

In the event of a serious emergency such as a fire, disturbance, or medical problems, 911 should be contacted first. When possible, the field coordinators should then be notified of the problem. The field coordinators will then determine whether all operations will stand-down.

For less-serious issues such as instrument problems, questions about operation procedures, etc., the respective student leader should be contacted.

Appendix C - DOW Mission Log/Summary Template

Date: **Mission:**	**Crew:**
Site: **Heading:**	**Lat:** **Lon:**
Deployment Start: **Deployment End:**	

Notes and Mission Summary:

Appendix D - Surface Mission Log/Summary Template

Date: **Mission:**	**Crew:**
Site of Snowboards: **Board 1** **Lat:** **Lon:** **Board 2** **Lat:** **Lon:**	**Board 3** **Lat:** **Lon:** **Board 4** **Lat:** **Lon:** **Board 5** **Lat:** **Lon:**
Depth of Snow: **Board 1:** **9am:** **2pm:** **Board 2:** **9am:** **2pm:**	**Board 3:** **9am:** **2pm:** **Board 4:** **9am:** **2pm:** **Board 5:** **9am:** **2pm:**
Deployment Start: **Deployment End:**	

Notes and Mission Summary:

Appendix E - NORTHPOL Mission Log/Summary Template

Date: **Mission:**	**Crew:**
Deployment Start: **Deployment End:**	

Notes and Mission Summary: