1 MATERHORN-X Operations Overview

1.1 Summary of MATERHORN Science Objectives

MATERHORN is a three-year meteorological research program to identify and study the limitations of current state-of-the-science mesoscale models for mountain terrain weather prediction and to develop scientific tools to help gain advances in predictability. It consists of four synergistic components --, a modeling component (MATERHORN-M), a technology component (MATERHORN-T), a parameterization component (MATERHORN-P) and a field experimental component (MATERHORN-X)

The core scientific objective of MATERHORN-X is to gain a fundamental understanding of the interaction of small and large-scale motions in the complex terrain of the Granite Mountain Atmospheric Science Testbed (GMAST) facility at Dugway Proving Ground (DPG), and to improve the predictability of complex terrain weather by gaining an improved understanding of model errors, error growth and predictability limits. The data collected in MATERHORN-X will facilitate model validation, data assimilation and development of physics-based parameterizations.

To meet the MATERHORN-X objectives, observations are designed to: (i) resolve the variations of surface boundary conditions (e.g., radiation and surface energy budgets, moisture availability, surface and subsurface processes) that drive diurnal mountain winds; (ii) study fundamental near-surface exchange processes (e.g., radiative and sensible heat fluxes, advection); (iii) investigate the spatial and temporal variations of the PBL in complex terrain; (iv) understand the interactions of flows of different scales (e.g., synoptic, meso and sub-meso scale flows); and (iv) provide data for model evaluation and improvement. The GMAST terrain ranges between ~1300 m ASL over the flat playas and 2159 m ASL over rugged Granite Peak. The area is characterized by slopes, valleys and playas (Figure 1) that host a full suite of complex-terrain physical processes, allowing studies of broad relevance. The measurements will span from meso-β to Kolmogorov (~1mm dissipation) scales.

Further information on the science objectives of the broader MATERHORN research program can be found at http://www.nd.edu/~dynamics/materhorn/

1.2 MATERHORN-X field schedule

MATERHORN-X will have two one-month-long field campaigns, covering both spring and fall conditions. Based on climatology, the spring is expected to have moist soils and occasional passing synoptic disturbances, while the fall is expected to have dry soils and weaker synoptic-scale influences. Each field campaign will consist of 10 Intensive Observational Periods (IOPs). The field campaigns will start in the fall of 2012 with a Dry Run and an initial shakedown IOP (IOP0). This will be followed by the major fall and spring campaigns:

27-30 August 2012:	**Dry Run MATERHORN-X-FALL**
24 Sept 2012	**Fall IOP 0**
28 Sept. – 25 Oct. 2012:	**MATERHORN-X-FALL**
1 May – 31 May 2013:	**MATERHORN-X-SPRING**

The 10 IOPs may be conducted on any day of the week during the Fall and Spring experimental periods, as determined by the MATERHORN science team. The protocol for choosing IOP days will be covered below.

A Daily Planning Meeting will be held at the Operations Center at the DPG Meteorology Division office at Ditto. DPG forecasters will present forecasts at 0900 LT to help with the IOP operational decisions. Remote participation will be available via a teleconference phone number that will be provided weekly by the DPG Test Officer.

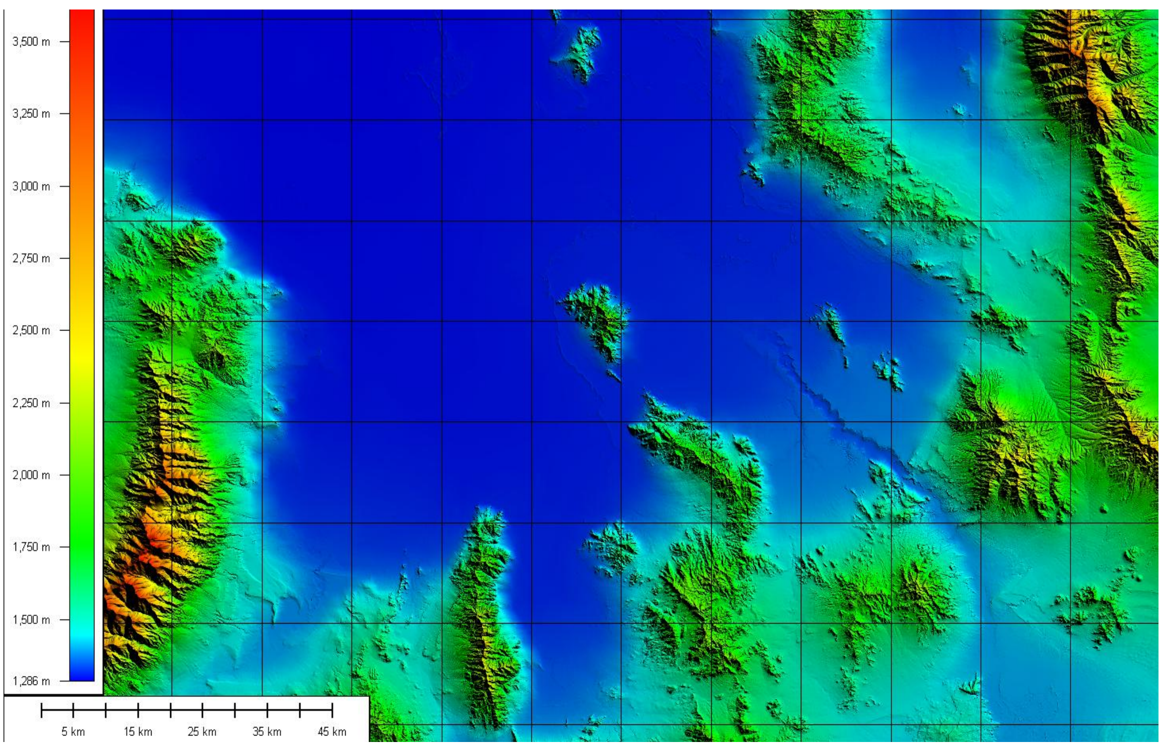

Figure 1 Topographic map of the region centered on Granite Peak [ADD LANDMARKS].

At each daily planning meeting, a decision will be made whether the following day will be designated as a “likely IOP” or a “non-IOP”. On the day following a "likely IOP" decision, a “Go/No-Go” decision will be made. The meeting will be short if a “Go” decision is made, so researchers can rapidly deploy to the field. If a 'No-Go” decision is made, the meeting will focus on whether an IOP is “likely” the following day. More details on the daily planning meeting and the decision making process can be found in Section 3.2. Once a "Go" decision is made, the following day will automatically be a "No-Go" day to allow rest for the field crews and replenishment of supplies.

The Science Team will try to cover a range of weather conditions during the IOPs, consistent with proposed research. IOPs will include a number of days with “Quiescent” conditions where thermal circulations dominate, “Moderate” conditions where synoptic effects have increased importance, and “Transition” conditions where large scale events such as frontal passages are present during the IOP. Table 1 summarizes this approach.

IOPs will be of two types -- Daytime Starts and Nighttime Starts (see Table 1). This will allow the 24-hour IOP window to cover a full night or a full day, respectively. For example during Fall 2012 there will be three Daytime Starts and three Nighttime Starts IOPs Quiescent IOP conditions.

IOP Type	Definition 700mb wind speed	Number Fall 2012	Number Spring 2013	Start – End
Quiescent	< 5 m/s	3	2	1400LT -1400LT
		3	2	0200 LT -0200LT
Moderate	5 m/s – 10 m/s	2	2	1400LT -1400LT
		1	2	0200 LT -0200LT
Transition	Variable, could be >10m/s, front passage	1	2	Flexible (timed around the event)

Table 1 Ideal distribution of MATERHORN IOP types and classifications.

During the Fall IOPs the sunrise/sunset times are ~ 7:21am/7:24pm (local time, MDT) respectively on September 25.

During the Spring IOPs the sunrise/sunset times are ~ 6:26am/8:24pm (local time, MDT) respectively on May 1.

1.3 MATERHORN-X Instrumentation

The MATERHORN-X comprehensive observing program, which has both substantial ground-based and airborne components, reflects the need to document processes that involve spatial and temporal scales ranging from micro-scale to the scale of the Basin-and-Range topography, and extend from below the ground up to the upper troposphere. A combination of airborne and ground-based measurements is important for documenting the coupling between boundary layer and synoptic scale motions and the dynamical linkages between thermally driven flows and flows aloft.

Airborne Operations: MATERHORN will use several Unmanned Aerial Systems (UAS) and perhaps one research aircraft for documentating flow interactions. The research aircraft is equipped with doppler wind LiDAR capability. The UASs will be used for dense sampling of thermodynamic and velocity data for documentation of airflow on both sides of Granite Peak. One UAS will sample turbulence data along its flight path. Table 2 gives the list of MATERHORN aircraft, their deployment periods, research flight hours, and bases of operation.

Research Aircraft	Deployment Period	Research Flight Hours	Base of Operation
Flamingo (UAS)	IOP	NA	DPG Stark Road between Papa and Romeo
DATAHAWK – University of Colorado (UAS)*	IOP	NA	Anywhere at DPG
Twin Otter (w/airborn doppler lidar)	IOP	29	DPG Airport (or possible airports nearby)

Table 2 Fall Campaign - List of MATERHORN research aircraft and unmanned aerial systems (UAS) with their deployment periods, number of research flight hours, and bases of operation.

The Navy Twin Otter will be based at U42, the South Valley regional Airport in Salt Lake City. Approximate ferry time from U42 to Granite Mountain is about 30 minutes. The maximum flight time of a complete mission is around 4 hours. While exact numbers still have to be worked out, we anticipate having 6 to 7 missions in the time period between 5 and 17 October. On the ferry flight to and from CIRPAS in Monterey, CA, (4 and 18 October, respectively) the Twin Otter will fly over Granite Mountain if possible.

The DATAHAWK will run from 7 October to 13 October for ~7-8 days. Unmanned DATAHAWK operations can begin and end at any location within DPG within the experimental area.

Details of the Flight Plans are given in Appendix A.

Tethered Balloon (Tethersonde, TS)

Two Tethered Balloon Systems will be deployed to collect thermodynamic profiles of the lower atmospheric boundary layer (up to ~ 500m). Their operation needs a **shelter for balloons**. UND will operate the tethersonde at the Sage Brush EFS Site, and UU will operate the tethersonde at the Playa EFS site. Vertical profiling flights will be made every 30 minutes. Data will be collected on the slow upward ascent of the balloon. When the maximum height is reached (depending on meteorological conditions) the balloon will be brought down quickly – the descent data will be discarded. ***Operations of the tethered balloons will be limited to IOPs with quiescent to moderate wind conditions.***

Upper Air Soundings (Radiosondes, RS)

Radiosondes will be flown every 3 hours during IOPs from the EFS Playa (SLTEST) site. Three mobile GRAW GS-H sounding systems (2 from UU, 1 from UV) are available to be used in a flexible operation. During selected IOPs, additional flights will be launched from Fish Springs National Wildlife Refuge or a location along I-80 northwest of DPG. A decision on these flights will be made on an IOP by IOP basis. These locations are indicated in Figure 2a with red dots. Coordinates for these sites are given in Table 3 below. Expendables: 8 sondes are available for each 24-hour IOP.

Ten GPS-sondes will be launched from the North Playa I-80 site (LATITUDE: 40.72728, LONGITUDE: -113.4691, ELEVATION: 4125 ft), one in the morning and one in the afternoon in five select IOPs. The launches will coincide with the Playa 0515, 0815, 1115 LST. These special soundings will be launched around the time of minimum temperature and around the time of maximum temperature. The latter is ~1700 LST and corresponds roughly to the standard upper-air observing time. The former falls in a bit of a grey area.

Given that we will pick five IOPs, here are the priorities:

1. A quiescent, "dry" IOP
2. A quiescent, "moist" IOP (i.e., following precipitation with higher soil moisture)
3. A moderately disturbed event, preferably with background NW flow where obs from the playa site will be most useful
4. A transitional event, assuming it is accompanied by NW flow or a transition to NW.
5. Pot luck.

<u>Ground-based Operations:</u> MATERHORN ground-based instrument systems will include a wide range of instruments including: lidars (wind Doppler and aerosol), ceilometers, SoDAR/RASS, wind profilers, sounding systems, dense networks of automatic weather stations, flux towers, and a Combo-probe system. A brief description of these instruments and their deployments follow.

Platform/Instrument/Institution	Deploy-ment Period	Location	Lat/Long location	Elevation (m)
DPG Network				
SAMS	CM	See Appendix		
mini-SAMS	CM	See Appendix		
PWIDs	CM	See Appendix		
Extended Flux Sites (EFS)				
EFS-P (UoU)	CM	Playa / former SLTEST	40.13498 -113.45158	1298 ?
EFS-SB (UoU)	CM	Vegetated /"Sagebrush"	40.12136 -113.12907	1317 ?
EFS-ESL2 / ES5 (UoU)	CM	Granite Peak East Slope	40.09652 -113.25861	1378 ?
EFS-ESL1 / ES3 (UND)	CM	Granite Peak East Slope	40.09567 -113.24405	1417 ?
WS2 / EFS-WSL (UND)	CM	Granite Peak West Slope	40.11179 -113.30230	???
East Slope Towers				
ES1 / DPG32mEast Tower (DPG)	CM	Granite Peak East Slope	40.0938 -113.2032	1314
ES2 / Combo Probe (UND)	CM	Granite Peak East Slope	40.09588 -113.237544	1339
ES3 / EFS-SL1 (UND)	CM	Granite Peak East Slope	40.09567 -113.24405	1363
ES4 / DPG32mSlope (DPG)	CM	Granite Peak East Slope	40.09585 113.25258	1396
ES5 / EFS-SL2 (UoU)	CM	Granite Peak East Slope	40.09652 -113.25861	1437
IR Camera (UND)		Granite Peak East Slope – looking upslope from SL2 tower	40.096365 -113.249540	1378
West Slope Towers				
WS1 / DPG32mWest Tower (DPG)		Granite Peak West Slope	40.102550 113.319990	1315
WS2/ EFS-WSL (UND)	CM	Granite Peak West Slope	40.11179 -113.30230	
Other Towers				
GAP/ DPG32mGAP Tower (DPG)	CM	Gap: Sapphire Mtn. - Dugway Range	40.0448 -113.23737	1315
SGT1 (Small Gap Tow. 1, UND)	CM	Gap: Sapphire Mtn. - Granite Pk.	40.06664 -113.26827	
SGT2 (Small Gap Tow. 2, UND)	CM	Gap: Sapphire Mtn. - Granite Pk.	40.06001 -113.24789	
Radiosonde Launch Sites				
RS Playa	IOP	Playa site (former SLTEST)	40.134909 -113.45097	1298
RS Fish Springs	IOP		39.84617 -113.57443	1326
RS I-80	IOP		40.74007 -113.85222	1287
Tethered Balloon Operations				
TS-P Tether Balloon-Playa (UoU)	IOP	Playa (former SLTEST)	40.134909 -113.45097	1298
TB-SB Tether Balloon-Sagebrush (UND)	IOP	Sagebrush EFS Site	40.12136 -113.12907	
SoDAR Operations				
SoDAR Gap (UoU-ATM))	CM	Gap between Sapphire Mtn. and Dugway Range	40.04503 -113.23729	
SoDAR North (UoU-ME)	CM	North of Granite Peak	40.159720 ..-113.241060	
SoDAR West (UND)	CM	West of Granite Pk. "Upwind"	40.10138 -113.33759	1347
LiDAR Operations				
LiDAR–Halo (UND)	IOP / CM	Slope Experiment	40.09587 +±/-x -113.23733 +/-±x	1338
LIDAR–Halo-Slope (UoU)	IOP / CM	Slope Experiment	40.09587±x -113.23733±x	1338
UVA ALS300 Aerosol LIDAR	CM	East of Granite Peak	40.1350 -113.4417	1298
ARL Leosphere Windcube 100S		Pointing toward Gap	40.070680 -113.191370	1315
Wind Profilers				
DPG FM/CW		Horizontal Grid	40.196902 -113.167763	1313
DPG Profiler (449 & 924 Mhz)		Horizontal Grid	40.196902 -113.167763	1313

Ceilometers				
DPG Ceilometer-D	CM	Ditto	40.182440 -112.926140	1324
DPG Ceilometer-TG	CM	Tower Grid	40.10345 -112.98039	1325
DPG Ceilometer-BSP	CM	Baker Strong Point, West gate	40.092380 -113.69934	1316
UND Ceilometer-WS	CM	West Slope of Granite	40.10138 -113.33759	
PWIDS - as requested for MATERHORN				
PWID PE West	CM	Pony Express road	39.921320 -112.96932	1382
PWID PE Central	CM	Pony Express road - in Old River Bed	39.967120 -112.90195	1344
PWID PE East	CM	Pony Express road	39.999350 -112.84744	1385
LEM Stations				
LEMS A				
LEMS B				
DTS East Slope				

Table 2 List of MATERHORN ground-based instruments with their deployment periods and locations. *indicates need to verify location. CM – continuous monitoring, IOP – monitoring only during IOPs.

Proposed PWIDS Deployment

We propose the siting of 24 DPG PWIDS (Portable Weather Information Display System) stations to augment the existing network of DPG weather stations. PWIDS are described in section 5 below. The proposed locations are:

1) 9 PWIDS on Slope Experiment: two across-slope lines.
2) 4 PWIDS between Sapphire Mountain summit and Granite Peak ridge.
3) 3 PWIDS along Pony Express trail, including the "Old Riverbed".
4) 4 PWIDS along the west slope of Granite Peak [PROPOSED BY JULIAN HUNT - CHECK WITH HIM IF SITING OK]
5) 3 PWIDS - deployed with each of three planned SoDARs
6) PWIDS at Playa Site (also called the SLTEST site)ww

Add GPS Coordinates here

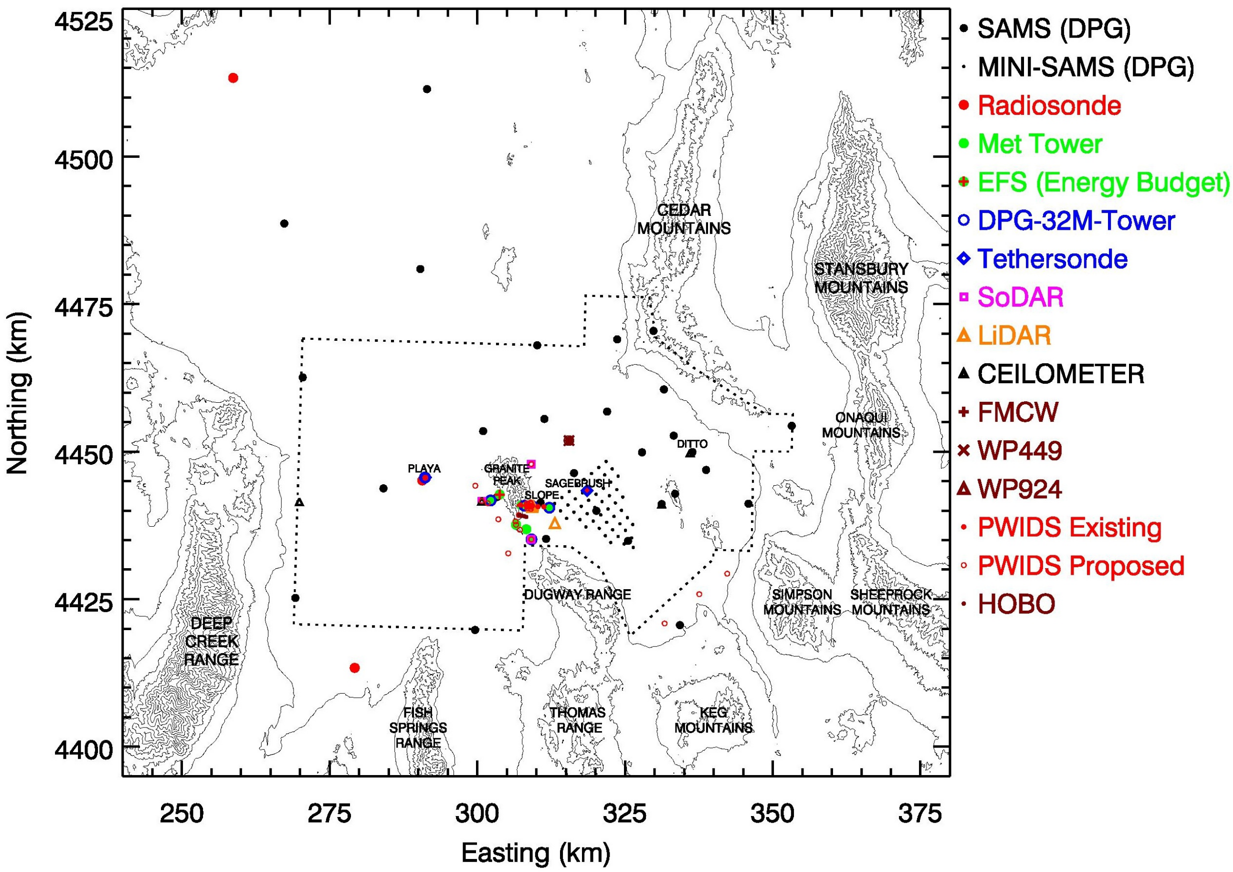

Figure 2a MATERHORN ground-based instrumentation systems and their locations. "Radiosonde" denotes potential radiosonde launch locations for upwind soundings during different large scale flow regimes. Dotted line indicates approximate boundaries of DPG. UTM projection, 200 m elevation contours.

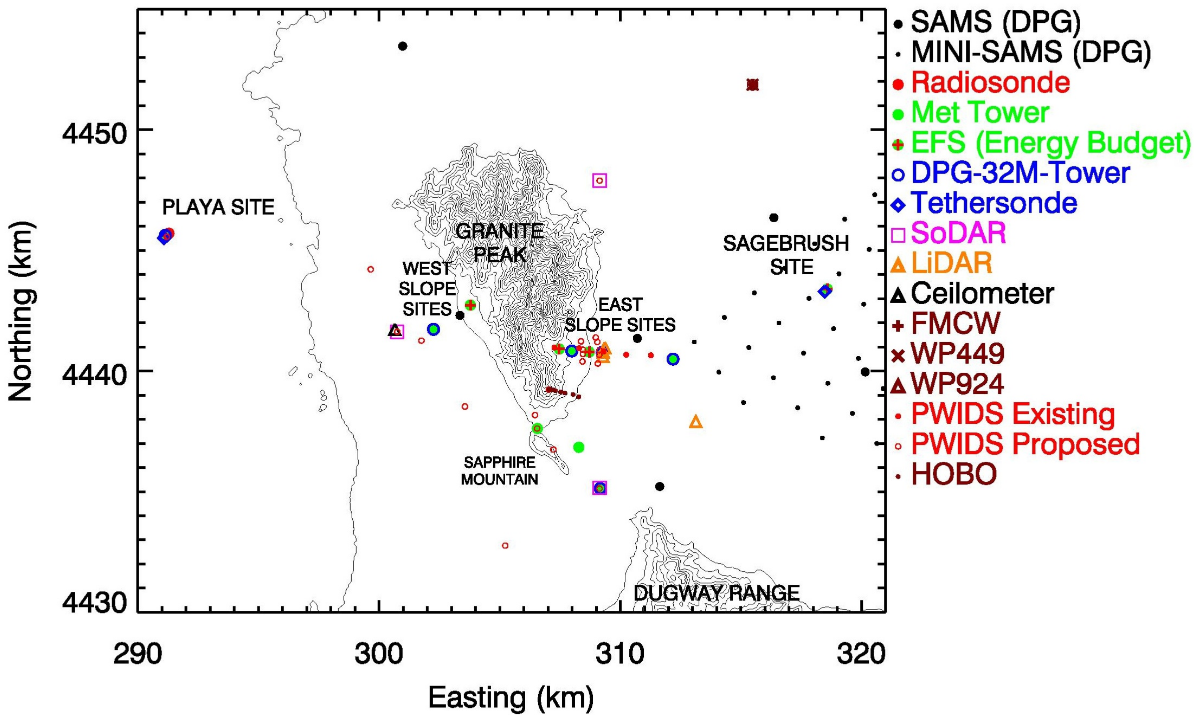

Figure 2b MATERHORN ground-based instrumentation systems and their locations near Granite Peak. UTM projection, 50 m elevation contours.

LiDAR Siting

The two Halo Photonics Streamline Doppler LiDARs (UU and UND) and the Aerosol LiDAR (UVA) will be deployed at the East Slope Experiment site (ES2). The Army Research Laboratory (ARL) scanning wind lidar is a Leosphere Windcube 100S that will be placed ~ 5 km northeast of the main gap between the Dugway Range and Granite Peak.

SoDAR Siting

The three mini-SoDARS (2 UU and 1 UND) will be deployed 1) in the main gap between the Dugway Range and Granite Peak; 2) on the west side of Granite Peak; and 3) on the north-east side of Granite Peak.

Ceilometer Siting

Five ceilometers will be deployed during the campaign. Four of the ceilometers are DPG instruments that are standard instruments already in-place and one is owned and operated by UND and will be deployed specifically for the experiment. One DPG Ceilometer will be at Ditto, one at Tower grid, one at Baker Strong Point, and one at the West gate. The UND ceilometer will be deployed at the Playa (SLTEST) site.

East Slope Experiment - Towers ES1-ES5

[THIS PARA ENUMERATING THE TOWERS IS NOT UNDERSTANDABLE]The eastern slope of Granite Peak will be heavily instrumented to observe flow interactions between local up-and downslope flows and larger-scale valley and synoptic-scale winds. Four towers will be erected west of the 2-track road. ES1 is DPG's existing 32 m tower. ES4 is UND's "Combo Probe" tower, two towers (1 UU/ES5, 1 UND/ES3) will observe flows at 5 levels and the entire energy budget. The 4th tower (sonics on 6 levels) will be instrumented by DPG (ES4). Figures 2c and 3a show the present stage (1 May 2012) of planning of the slope experiment (Siting and instrumentation, respectively).

An existing west to east PWIDS line descends the slope and will be left in place for the experiments. Two cross-slope lines (9 PWIDS total) will be added to determine the effect of local inhomogeneities on the slope flows and to provide a better understanding of the flow as it exits the laterally confined portion of the slope.

Distributed Temperature Sensing (DTS) - 20 km of fiber-optic cable will be deployed by Chad Higgins to observe near surface temperatures at 2 m resolution along the east slope of Granite Peak [....]

West Slope Experiment - Towers WS1 & WS2

To better understand the interactions of synoptic and slope flows, and the contrasting development of thermal circulations on the east and west slopes of Granite Peak during transition periods, the western slope of Granite Peak will be instrumented with two towers. These towers will supplement an existing SAMS station (#32) on the West Slope. The West Slope plan is shown in Figure 2d. This plan will include one DPG 32m tower (WS1) equipped with sonic anemometers. In addition, a second tower supplied by UND (WS2) and instrumented by both UND and UU will be located 20 m in elevation farther up the slope. This tower is an EFS tower that will have full energy budget measurement capabilities.

In addition to the tower-based measurements, a remote sensing platform will be deployed on a berm (rise) that essentially separates the Playa from the sage brush on the west side of Granite Peak. The site will host a SODAR/RASS system operated by UND and a supplemental PWIDS station.

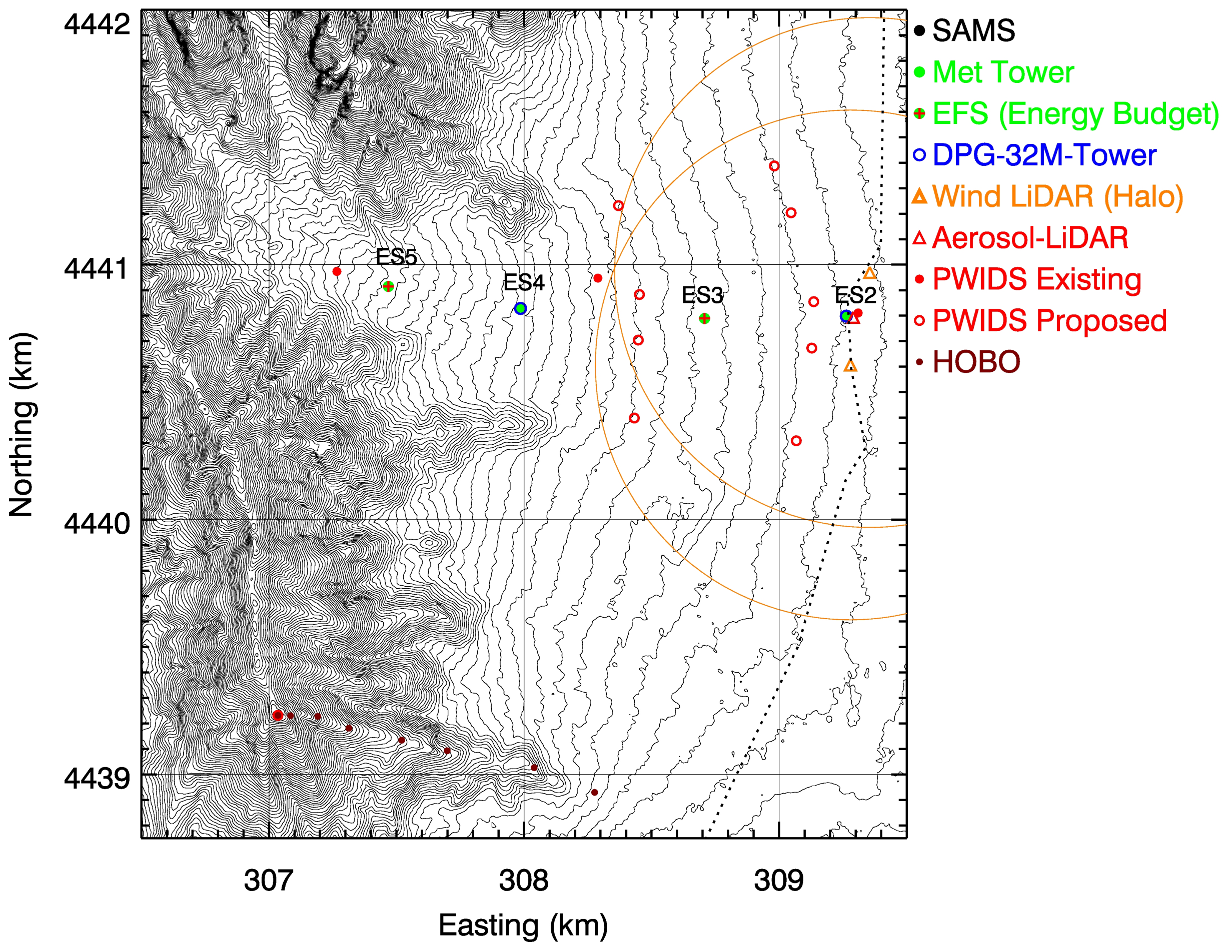

Figure 2c MATERHORN ground-based instrumentation systems and their locations near the east slope of Granite Peak. UTM projection, 5 m elevation contours [MATERHORN-X-SLOPE-EAST]

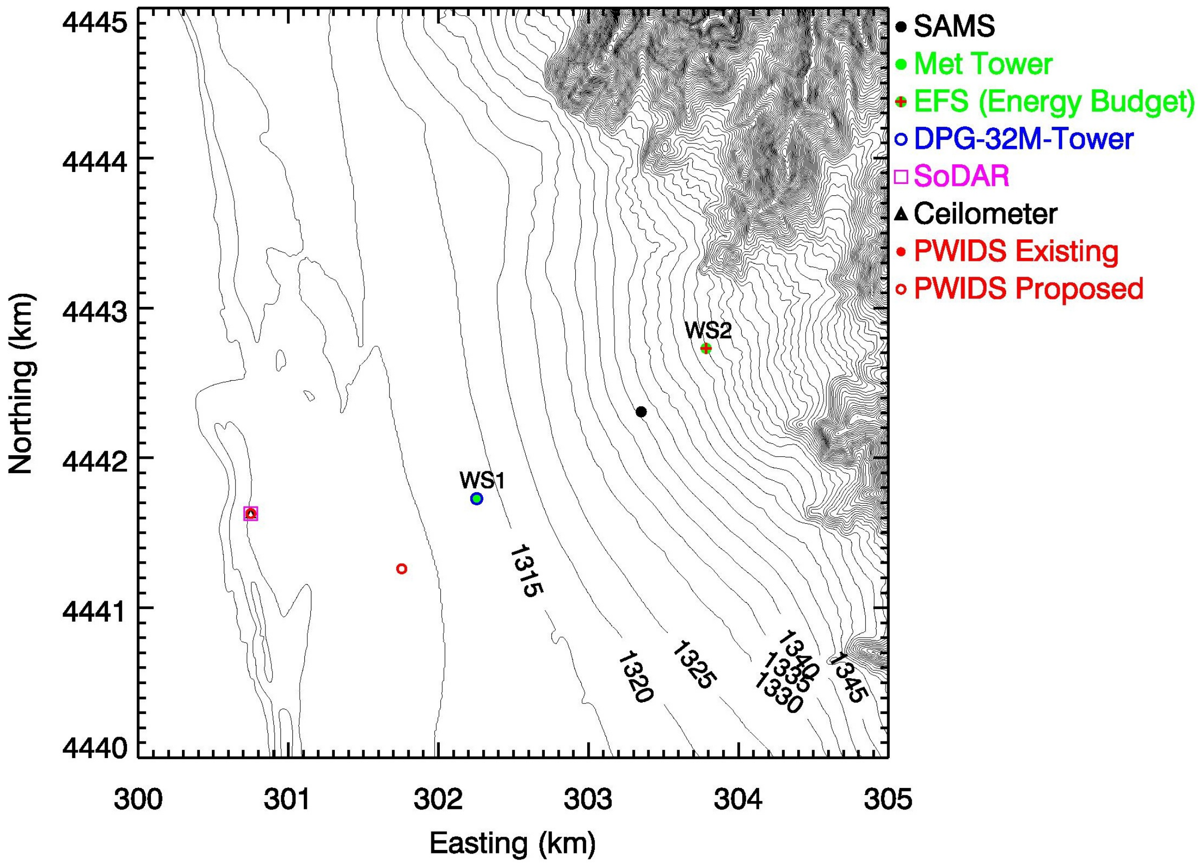

Figure 2d MATERHORN ground-based instrumentation systems and their locations near the west slope of Granite Peak. **UTM projection, 5 m elevation contours** [MATERHORN-X-SLOPE-WEST]

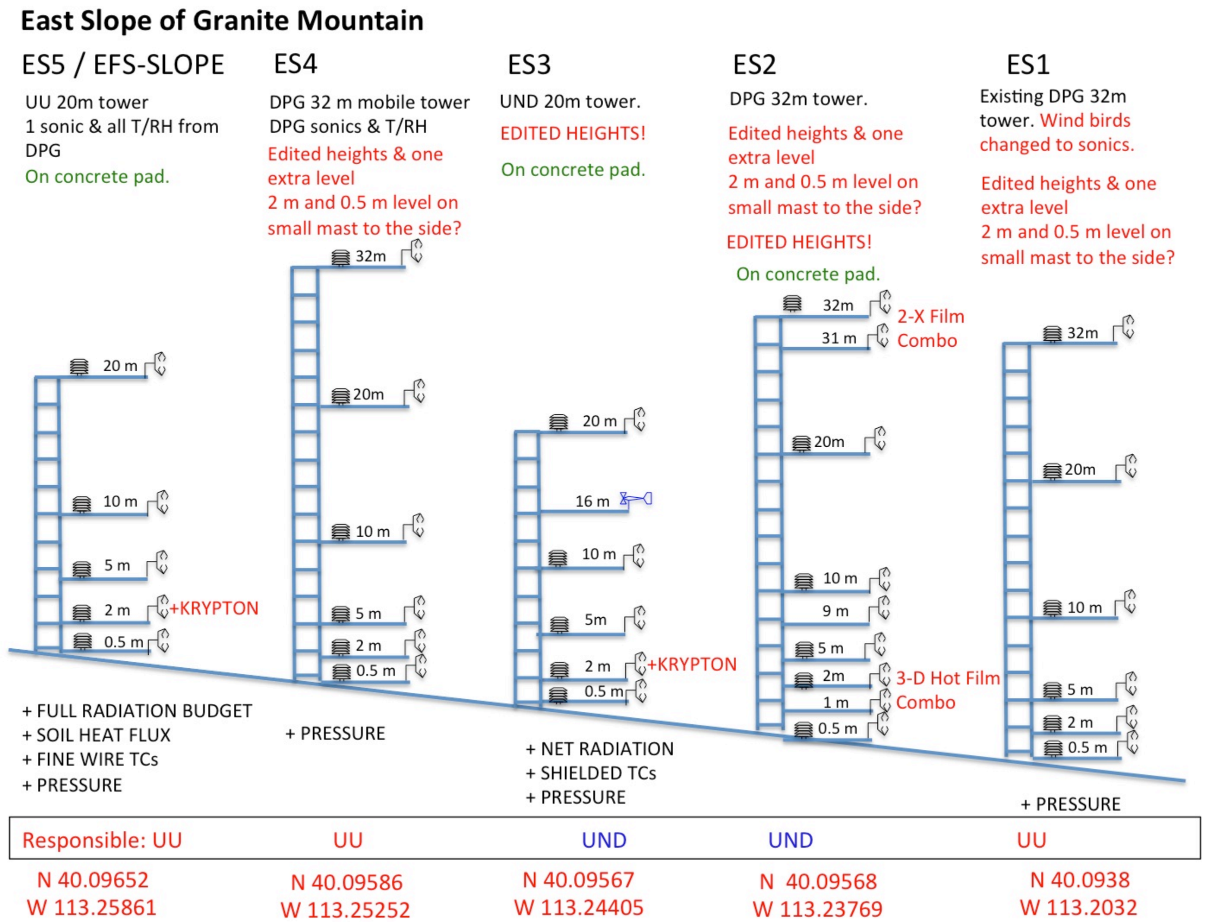

Figure 3a MATERHORN schematic of the instrumentation on the east slope of Granite Peak. Note that the towers span approximately 6 kilometers from the top UU tower to the bottom DPG tower[??, THE UPPER AND LOWER TOWERS ARE BOTH LABELED UU]. The spacing between the towers is nominally 1.5 km.

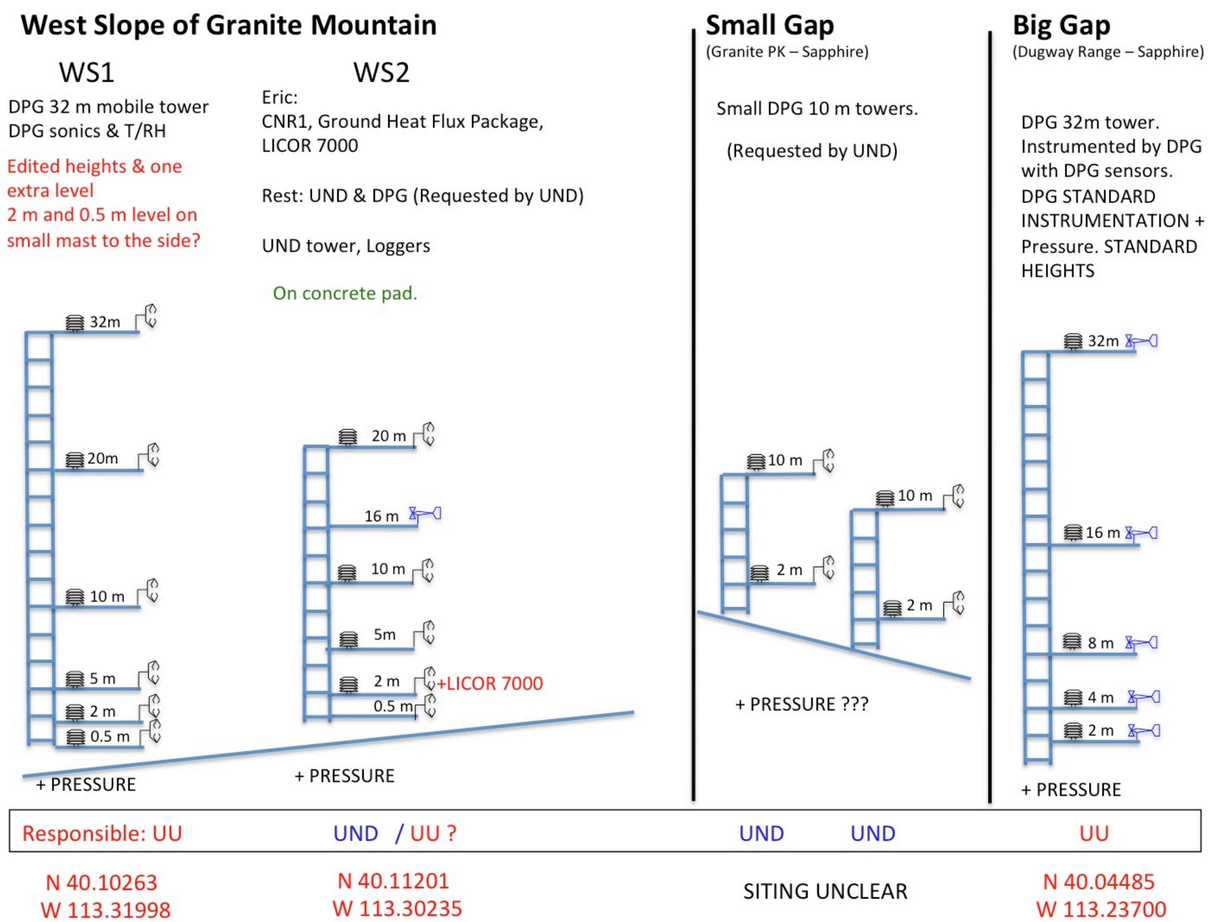

Figure 3b MATERHORN schematic of the instrumentation on the west slope of Granite Peak, as well as the instrumentation planned for the gaps between Sapphire Mountain and Granite Peak and Sapphire Mountain and the Dugway Range.

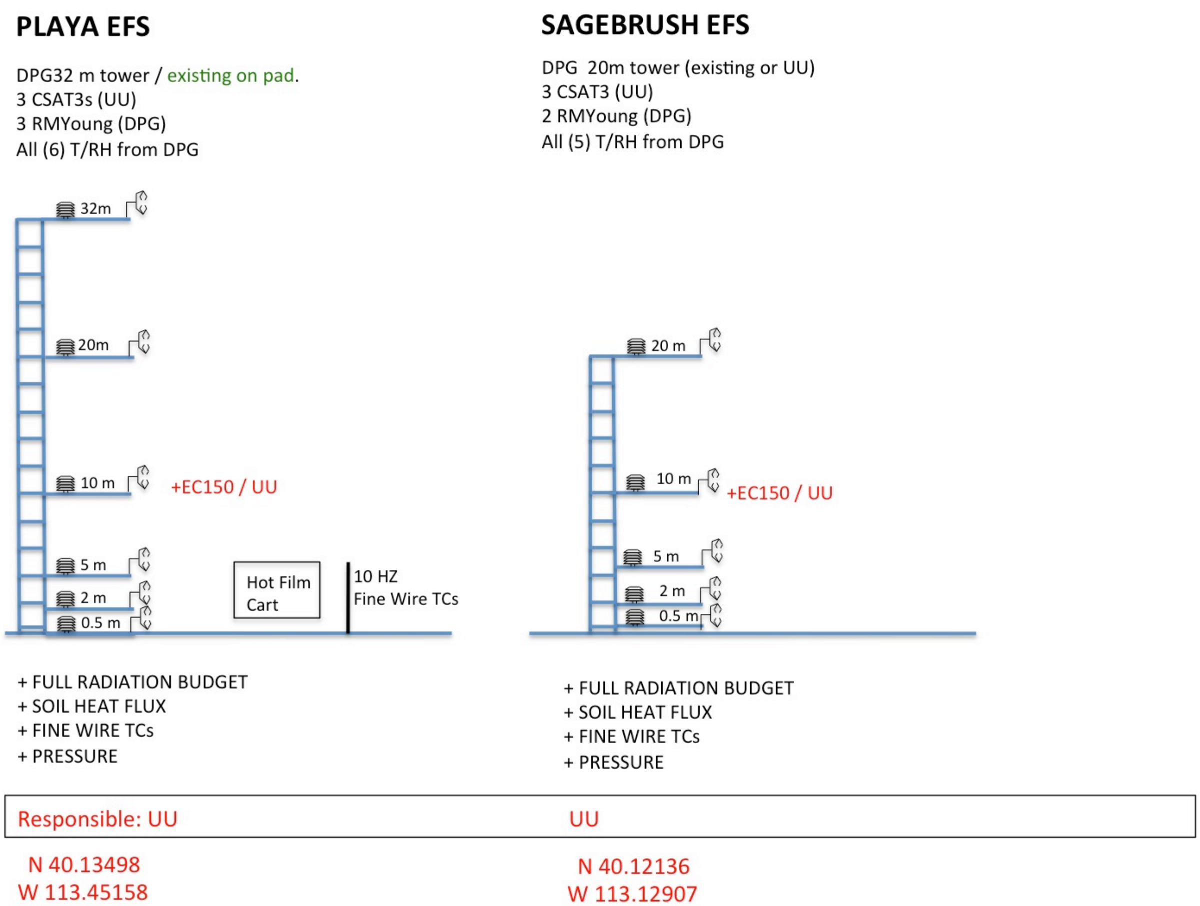

Figure 3c MATERHORN non-slope EFS sites.

Extended Flux Measurement Sites (EFS)

Five extended flux site experiments will be deployed at the following locations: Playa (SLTEST) Site, Sage Brush Site, East Slope 3 Site, East Slope 5 Site and West Slope 2 Site. The purpose of these sites will be to monitor the complete surface energy balance and the fluxes of momentum, sensible and latent heat and carbon dioxide (3 sites) using the Eddy Covariance technique. The five sites represent very different surface conditions (e.g. albedo, roughness) and will potentially be influenced very differently by local thermal circulations.

Fine Scale Turbulence and Mixing Experiments

Hot-wire/cold wire anemometry experiments will be conducted at the Playa (SLTEST) Site. Experiments there will include fast response thermocouples at high vertical resolution very close to the surface to calculate temperature tendencies, and to model clear air radiative heating and cooling rates due to radiative flux divergence in the surface layer. Sensible heat flux profiles from a “flux Richardson number probe” will allow us to determine the role of sensible heat flux divergence. Horizontally spaced thermocouples downwind of the flux probes and the vertically spaced thermocouples will further allow us to quantify the roles of the various terms at different heights including horizontal and vertical advection terms, and thermal diffusion.

Distributed LEM stations

To better understand the spatial distribution of near-surface meteorological variables, twenty small local energy monitoring (LEM) stations will measure surface radiating temperature, solar radiation, air temperature, humidity, soil moisture and soil temperature. Locations are still to be determined, but stations will likely be deployed around each of the EFS sites.

Preliminary Deployment

The University of Utah will begin preliminary deployment as early as Spring 2012 beginning with Surface Stations and basic Extended Flux Site (EFS) infrastructures. Tower infrastructures will be deployed during the summer of 2012. And UU will test a? hot-wire system Richardson number probe at the SLTEST site.

Dry Run

MATERHORN-X-FALL: Dry-Run Tests, 25-27 August 2012

The first experimental campaign scheduled in the 25 September - 25 October 2012 period is fast approaching. This is part of the MATERHORN-X component coordinated by Prof. Pardyjak from UU.

At this stage, all teams involved (from UU, UND) in primis??) are engaged in making final instrumentation and technological development checks. The technological aspects involve among others instrumental development for UAV and high-resolution turbulence measurements i.e. “combo probes and RF systems for soil moisture measurements. This is part of the MATERHORN-T component coordinated by UND.

Currently, teams coordinators are working with Mr. John Pace and Dr. D. Zajic at DPG to ensure that all instruments and technical aspects have been fully evaluated and logistic arrangements are set in place.

Dry-Run tests are scheduled for August 25-27 as part of the preparatory phase for the fall 2012 campaign. The tests have been designed to evaluate the Operational Plan to ensure success of the fall campaign. During the three day prep phase, the full campaign will be simulated starting with the *Daily Briefing* at the Operations Center at DPG's Meteorology Division at Ditto. Here, DPG forecasters will present simulated meteorological forecasts to aid in making an IOP “Go/No-Go decision”. A detailed log of the time required to deploy personnel to the key sites will be maintained, including reporting of possible problems and difficulties. An end-of-day report and assessment by the participating teams will be presented to participants. The primary on-site participating teams are: UU, UND, and UVA. Additional participants include Prof. Chad Higgins (Oregon State University), Prof. Marcus Hultmark (Princeton University) and Dr.

Yansen Wang from the Army Research Laboratory. Some team members will participate in the planning remotely via Skype.

The Dry Run will evaluate both equipment operations and team coordination. The coordination strategic plan takes into account the management required:

a) to coordinate several sites located in an area of about 25 km x 50 km with all instruments working simultaneously in synchronized mode;
b) to coordinate ground-based and aerial operations;
c) to test communication links among the different field and operations center crews.

The Dry Run will attempt to simulate actual field experiment conditions with as many ground-based instruments as possible deployed in the field, and with the main personnel in position at the key sites.

The main objectives of the Dry Run are:

a) to check the operation of data-recording systems for ground-based instruments deployed by UU, UND and DPG as specified in the Operational Plan. This will be done for both continuous measurement (CM) as well as for special IOP measurements;
b) to test the synchronization of the various systems and data transmittal for systems using radiofrequency links;
c) to evaluate the timing of all major activities associated with IOPs;
d) to verify personnel coordination and communication strategies during IOPs;
e) to test data collection strategies and the daily data verification and reporting schemes;
f) to consider all other problems that may arise and make adjustments where necessary.

Ground-based Operations:

The key sites for Ground-based operations during the Dry Run include: standard DPG instrument sites (SAMs, PWIDS, FM/CW, Profilers, and Ceilometers), the extended flux sites (EFS), and lidar, ceilometer and sodar measurement sites. Although most of the instrumentation required during IOPs with the exception of tethered balloon is not included in the Dry Run tests, the time phasing of field activities for running IOPs will also be evaluated. Instruments will be deployed per the Operational Plan. The Dry Run will also include a test radiosonde release from the Playa site.

Aerial Operations:

Unmanned Flamingo operations and manned CIRPAS Twin Otter operations will begin and end at SLC airfield #2. Unmanned DATAHAWK operations can begin and end at any location within DPG within the experimental area. During the Dry Run, potential flight plans for each of the aircraft will be proposed and discussed with the respective PIs and DGP personnel. Several potential flight plans will be drafted prior to the Dry Run and a selection of a particular flight plan will be made depending on meteorological conditions and the science objectives of the IOP. The flight plan will include the flight paths and the starting and ending times of the flights. Prior to the Dry Run, DPG personnel will be contacted to inquire about external tests and circumstances that preclude the operation of any MATERHORN aircraft during an IOP.

1. Flamingo
2. DATAHAWK
3. Twin Otter

IOP Timing and Duration:

Two types of IOPs are planned that each last 24 hours.
Type 1 IOP: Starts at 1400
Type 2 IOP: Starts at 0200

A report generated at the end of the Dry Run will be available to all participants.

1.4 MATERHORN-X Operations Domain

The MATERHORN field campaign will take place at the DPG in Utah's West Desert (Figure 1). This area has been selected because it has several key features that make it suitable and interesting for study of complex terrain flows including: mountainous topography (isolated peaks, slopes, gaps, etc.), adjacent plains, and variable surface cover (Malek and Bingham 1997).

<u>Aircraft Operation</u>
One major aircraft operations base exists on DPG at the Ditto site.
Flamingo – Deploy from Stark Road
DATAHAWK – Deploy from the East Slope area near the East Slope towers. Vertical profiles and transects.

<u>Playa Site (SLTEST)</u>
MATERHORN operations will be conducted on the silty-clay playa of the SLTEST (Surface Layer Turbulence and Environmental Science Test) site, which has been operating since the mid-1990s. This site is extremely flat, with the elevation varying less than a 1 m over an area of ~65 km in the east-west direction and 130 km in the north-south direction surrounding the site (Malek 2003). According to Malek the site can become a shallow lake. Many fundamental studies associated with high Reynolds number boundary layers and dispersion have been conducted there (e.g. (Metzger, Klewicki et al. 2001; Priyadarshana and Klewicki 2004; Metzger, McKeon et al. 2007; Morris, Stolpa et al. 2007)). (Malek and Bingham 1997) describe the microclimate of at this site, and the soil properties are described by (Malek 2003). The soil has very high electrical conductivity.

<u>Slope Site</u>

The lower slope site is covered by sparse high desert vegetation (e.g. Greasewood, grasses) that is mostly less than 50 cm tall. The upper slopes also have juniper trees that can be several meters tall.

1.5 MATERHORN Funding, Support, and Participation

MATERHORN is a multi-agency, multi-national research project. Major funding for MATERHORN is provided by the Office of Naval Research's MURI program. THE FUNDING FOR PARTNERS COMES FROM ……(ADD LATER). Participants in MATERHORN include investigators from a large number of US universities and agencies, the National Center for Atmospheric Research, and several European universities and research institutes (www.nd.edu/~dynamics/materhorn).

Additional collaborators are considered after consideration of the merits or added value of their proposed participation, on a case-by-case basis. A brief proposal from prospective collaborators is required stating their contribution to the scientific and technological development of MATERHORN and a description of how they will complement existing resources. The funding mechanism for additional activities must be identified. A committee comprised of Stephan De Wekker, Joshua Hacker and David Whiteman will review the proposals and make recommendations to the project director, Joe Fernando.

The MATERHORN data will be available to approved collaborators during the embargo period, provided that the resulting research papers are jointly authored with a MATERHORN PI.

2 MATERHORN Modes of Operation and Missions

MATERHORN observational activities will be conducted within two operational modes:

- Intensive Observing Periods (IOPs),
- Continuous Monitoring (CM)

2.1 Intensive Observing Periods

An Intensive Observing Period (IOP) is a period of comprehensive ground-based and/or airborne observations in the project target area organized and launched to document …[OUTLINE THESE PROCESSES AND REFER TO SPECIFIC HYPOTHESES HERE] IOP measurements include special data from

- Most airborne operations
- Tethered balloon operations
- Hot-film/Hot-wire based measurements including the UND Combo-probe to be deployed at the East Slope (ES2) and the UofU's hot-wire/cold-wire flux measurements to be deployed at the Playa Site (SLTEST).

2.2 Continuous Monitoring

Continuous Monitoring (CM) involves continuously operating fixed networks of remote and in situ sensors to be operated throughout the entire one-month period of each MATERHORN campaign …

- PWIDs
- SAMS
- EFS towers

2.3 Special Observation Periods

Radiosoundings from different locations.

3 MATERHORN Mission Planning and Implementation

The planning of a mission requires access to facility status reports, weather forecasts, and an assessment of proposals for new missions by MATERHORN investigators. These inputs will feed the daily planning meeting, during which a mission plan is formulated and mission staffing decisions are made. To implement the mission personnel will need to be alerted to the upcoming mission and the mission itself must be initiated and executed.

3.1 Key Mission Staff

3.1.1 Mission Scientific Team (MST)

1. Science Director (SD, director for scientific mission decisions)
    - Co-chairs MATERHORN Daily Planning Meeting
    - Leads daily mission planning discussion
    - Decides (in consultation with Mission Planning Panel) the final deployment of all facilities
    - Provides Science Progress Reports to the Daily Planning Meeting
    - Works with the Operations Director (OD) and flight scientists to produce flight plans
    - Makes the go/no go decision for the day’s mission
    - Leads in-flight coordination during operations
    - Prepares Daily Mission Summary Report
    - Co-chairs special science meetings

2. Flight Scientist(s) - Aircraft onboard science director

- Is point of contact for all flight planning and execution (for a given aircraft or balloon)
- Prepares in daily aircraft operations support
- Participates in mission debriefings

3. Mission Planning Panel

- Is composed of one or two MATERHORN PIs at BOC with a broad overview of MATERHORN objectives
- Advises SD as part of the mission planning process to facilitate achievement of MATERHORN science objectives as described in the Science Overview Document
- The membership will be rotated during the field campaign
- BOC members must be present in person at BOC and other [??]two members at their respective OCs and attend all Daily Planning Meetings during their rotation

FUNCTION	PARTICIPANT
Science Director (SD)/Materhorn-X	Eric Pardyjak
Flight Scientist	Stephan DeWekker
Mission Planning Panel	Joe Fernando (Silvana DiSabatino); Dragan Zajic (John Pace); Dave Whiteman (Sebastian Hoch)

Table 3 Staffing table of Mission Scientific Team members. As of 14 January 2012.

3.1.2 Operations Coordination Team (OCT)

1. Operations Director (OD)

- Convenes and co-chairs the MATERHORN Daily Planning Meeting
- Implements the daily MATERHORN Operations Plan
- Provides a Status Report Summary to the Daily Planning Meeting
- Assigns duties to OCT personnel
- Is responsible for the form and content of the Daily Operations Summary
- Coordinates aircraft flight debriefings

2. Aircraft Coordinator (AC)

- Is the single Point of Contact (POC) for all MATERHORN Aircraft Facility Project Managers
- Coordinates ATC requirements–alerts, advanced notifications, etc.
- Coordinates all communications between the Operations Center and research aircraft–flight track changes, data products transmitted to/from aircraft
- Works with SD, OD and flight scientists to update flight tracks as needed

3. Surface Observing System Coordinator

   - Point of contact for all surface-based observing
   - Coordinates all communications between BOC and the surface observing systems
   - Monitors the status of all surface observing systems and expendables
   - Works with SD and OD to coordinate aircraft overflights of surface observing systems

4. DPG Site Coordinator

   - Acts as the point of contact/project liaison with all operation sites, local arrangements
   - Coordinates public relations for MATERHORN activities at DPG and Salt Lake City

5. DPG Communications/Networking Coordinator

   - Manages communications at DPG

6. In-Field Data Management/Catalog Coordinator

   - Is responsible for the implementation and updating of the MATERHORN Field Data Catalog
   - Assists participants with submitting preliminary data products to the catalog
   - Works with DPG
   - Monitors supplementary operational real-time data collection for MATERHORN
   - Assures ingest and display of MATERHORN-specific satellite data and products

7. Weather Forecaster Coordinator

   - Schedules daily operations support for forecasting and nowcasting including Pre-Flight Briefings
   - Trains forecasters and nowcasters on MATERHORN requirements and procedures
   - Establishes standard forecast content and products for MATERHORN Field Catalog

FUNCTION	PARTICIPANT
Operations Director (OD)	Eric Pardyjak

Aircraft Coordinator (AC)	Charles Retallack, Stephan DeWekker
Sfc Obs System Coordinator	Sebastian Hoch
Playa Site Coordinator	Sebastian Hoch
Slope Site Coordinator	Matt Jeglum, Derek Jensen, UND pers.
DPG Site Coordinator	Dragan Zajic
DPG Communications Coordinator	Dragan Zajic
Field DM Coordinator	Silvana Di Sabatino
Forecaster	DPG Personnel
UU Synoptic Meteorologist	Jim Steenburgh, Jeff Massey, Matt Jeglum

Table 4 Staffing table of Operation Coordination Team members. Need to make decisions here.

3.2 MATERHORN Daily Planning Process

3.2.1 Daily Planning Meeting

A daily general meeting and weather briefing will be held at the Operations Center at DPG's Meteorology Division at Ditto. DPG forecasters will present forecasts at 0900 to help with the IOP decision-making process. The meeting will be held seven days per week throughout the field campaigns. There will be no back-to-back IOPs. At the meeting, it will be decided whether an IOP on the following day is "likely" or if there won't be an IOP ("no-IOP"). At the meeting on a day following a "likely" decision, a "Go/No-Go" decision is made. The meeting will be short if a "Go" decision is made, so researchers can rapidly deploy to the field. If a 'No-Go" decision is made, a decision will be made if an IOP is "likely" the following day.

The Daily Planning Meeting will be co-chaired by the MATERHORN Science Director and the Operations Director. The meeting agenda will be consistent from day to day and will include the following items:

- Status of aircraft, mobile facilities and remote observing systems
- Data management and communications status report
- Forecast discussion from 2-36 hours, special products; outlook
- Report on the status of scientific objectives and results of the last mission and/or update on the status of an on-going mission
- Mission Selection, staff assignment, and schedule of operations
- Report on potentially conflicting DPG tests and limitations to MATERHORN operations
- Logistics or administrative matters
- Other announcements

3.2.2 Mission Plan Preparation

When there is a plan for a mission beginning the next day, the Science Director and Operations Director will meet immediately following the Daily Planning Meeting (MPP Meeting) to finalize the Mission Plan for the next 12-36 hours. This meeting may include other PIs or staff crucial to formulate the details of the Mission Plan. The following items will be decided during this meeting and reported in the Daily Operations Summary:

- Description of mission (primary and alternate), including a brief discussion of objectives and strategy and criteria for proceeding to an alternate mission
- Assignment of staffing for mission support for the next 24-36 hours
- Preliminary Aircraft Operations Domain
    - Aircraft pre-flight briefing times
    - Proposed aircraft flight plans
    - Aircraft takeoff times
    - Weather forecast support
    - Special observation schedules
- Debriefing schedule

3.2.3 Daily Operations Timeline

Figure 6 illustrates the planning–implementation sequence of IOP activities, emphasizing the scheduling of aircraft operations. Times are given relative to Local Time (Mountain Daylight Time).

Every Day:[INDICATE WHO WILL BE RESPONSIBLE FOR EACH OF THESE TASKS]

0700–0800 Forecasters will evaluate various current weather models

0800–0900 Forecasters will prepare and submit their forecast to the MATERHORN Field Catalog.

0800–0900 [WHO?]Update the status of all MATERHORN facilities to the MATERHORN Field Catalog.

[WHO?]Initialize remote communications links (e.g. Skype)

0900–1000 [WHO?]Conduct the MATERHORN Daily Planning Meeting (see previous details).

1000–1100 [WHO?]Select the mission and IOP-type (Daytime Start / Nighttime Start IOP) and prepare the Mission Plan (flight plans, scanning strategies, TB operations).

1100–1600 {WHO?[Notifify facilities, Air Traffic Control Centers, Field Catalog
Prepare Operations Report.

Operational (IOP) Day: (Approximate times for daylight operations)

0900 Operational update—weather and facility status.
0930 Go/No Go/ decision
1000 Notify all field personnel and DPG personnel of decision and mission plan

a) Daytime Start IOP

1200–1200+24h IOP operations for soundings and other enhanced ground-based operations.
1000–1100 Pre-flight briefings (1.5 hr before takeoff).
0700–2000 Flight operations–vary by aircraft but limited [DAYTIME RESTRICTIONS?].
1600–2100 Debriefings (1 hr after landing).

b) Nighttime Start IOP

2400–2400+24h IOP operations for soundings and other enhanced ground-based operations.
2000–2200 Pre-flight briefings (1.5 hr before takeoff).
0700–2000 Flight operations–vary by aircraft but limited [DAYTIME RESTRICTIONS?].
0200–0400 Debriefings (1 hr after landing). [REALLY???]

Daytime Start IOP

Time MDT	1400 - 1500	1500 - 1600	1600 - 1700	1700 - 1800	1800 - 1900	1900 - 2000	2000 - 2100	2100 - 2200	2200 - 2300	2300 - 2400	0000 - 0100	0100 - 0200	0200 - 0300	0300 - 0400	0400 - 0500	0500 - 0600	0600 - 0700	0700 - 0800	0800 - 0900	0900 - 1000	1000 - 1100	1100 - 1200	1200 - 1300	1300 - 1400
RS	1415			1715 00 Z			2015			2315			0215			0515 12 Z			0815			1115		
TS	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x
Misc.																				Plan ning Meeti ng				

Nighttime Start IOP

Time MDT	0200 - 0300	0300 - 0400	0400 - 0500	0500 - 0600	0600 - 0700	0700 - 0800	0800 - 0900	0900 - 1000	1000 - 1100	1100 - 1200	1200 - 1300	1300 - 1400	1400 - 1500	1500 - 1600	1600 - 1700	1700 - 1800	1800 - 1900	1900 - 2000	2000 - 2100	2100 - 2200	2200 - 2300	2300 - 2400	0000 - 0100	0100 - 0200
RS	0215			0515 12 Z			0815			1115			1415			1715 00 Z			2015			2315		
TS	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x	x x
Misc.								Plan ning Meeti ng																

Figure 6 MATERHORN Daily timeline of operations..

3.3 Operations Implementation

3.3.1 Facility Notification Procedure

Once the facility operating schedules for missions are decided at the Daily Planning Meeting the responsibility for the conduct of operations shifts to the Operations Coordination Team (OCT) under the leadership of the Operations Director. Official notifications to Facility Managers are made by OCT staff. Notification of planned aircraft takeoff times will be given by the Operations Director (or Aircraft Coordinator) to the Aircraft Facility Managers and Mission Scientists at least 6 hours in advance. The Aircraft Coordinator will provide advanced notification to the appropriate Federal Aviation Administration (FAA) Air Traffic Control (ATC) Centers (Salt Lake City) and Military Operations Centers. Notification of operations schedules for the lidars and soundings will be made by the Operations Director (or Ground-based Facility Coordinator). The Operations Director prepares the Daily Operations Summary. This summary will be distributed to all participants via the MATERHORN Field Catalog.

3.3.2 Aircraft Operations Coordination

Aircraft flight schedules will be determined following aircraft operational guidelines. The Aircraft Flight Scientists and Aircraft Coordinator will work with the aircraft pilots in the preparation of detailed flight plans. Aircraft pilots will submit flight plans following normal ATC procedures. Individual pre-flight briefings will be given 2 hours prior to the scheduled takeoff and will be prepared to meet individual aircraft facility requirements. Pre-flight briefings will be attended by the Science Director or Operations Director, aircraft coordinator, flight scientists, and pilots.

3.3.3 Debriefing and Reporting

At the completion of a day's mission, post-flight debriefings will be held for each aircraft mission. The debriefings will be conducted by the Operations Director (or Aircraft Coordinator, or Flight Scientist) at the aircraft operations base as soon as possible after landing so that all onboard scientists and selected crew members can participate. Key issues are the perceived success of the mission, and the status of the facility (and crew) for the next day's operations. Each Aircraft Flight Scientist or Ground System Manager is expected to provide a Facility Operations Report (or Flight Report) for their operations to the MATERHORN Field Catalog within 24 hours.

3.3.4 Surface System Operations Coordination

Lidar Operations Coordination [THIS SECTION NEEDS INFO ON WHO DOES WHAT]
 Scheduled scan coordination operations, continuous operations
 Overflight and intercomparison plans
Sounding Operations Coordination
 Scheduled measurement operations
 Expendables and helium supplies, staff schedule restrictions
Tethered Balloon Operations Coordination
 Scheduled measurement operations
 Expendables and helium supplies, staff schedule restrictions

3.4 Forecasting for MATERHORN

The MATERHORN forecasting support will be provided by DPG's Meteorology Division in conjunction with MATERHORN PIs. They will use forecasting products based on an ensemble of mesoscale models. This forecast information will be used to help plan daily IOPs. Products that will be emailed to MATERHORN participants will include:

1. Forecast meteograms from the DPG ensemble for Horizontal Grid (DPG08) and Target S (DPG04).
2. Screen shot from the wind profiler.
3. Screen shots of the ceilometers.
4. Ensemble Max Rain Rate plots, 10 km domain, every 2 or three hours (great for forecasting convection).

4 Ground-Based Operations

This chapter provides additional information on the MATERHORN ground-based instrument systems listed in Table 2 including deployment locations, system characteristics, and scanning strategies. EACH GROUP NEEDS TO SUBMIT THEIR INFORMATION HERE.

UND

1. Flux Tower Measurement Systems (East Slope Granite Peak) -Updated
2. Combo probe system (East Slope Granite Peak) -Updated
3. UAVs (should be coordinated with Stephan de Wekker) –first draft-TO BE COMPLETED
4. Ceilometers (West Slope Granite Peak) -Updated
5. Lidars-Updated
6. SODAR/RASS-Updated
7. Soil moisture system (Tom Pratt) – Received.
8. Tethered balloon operations-Updated

9. Flow Visualization-Updated

Utah –
1. Tethered Balloon Operations – Playa (Pardyjak)
2. Flux Tower Operations (Sebastian)
    a. Playa
    b. Slope
    c. Sage Brush
3. LEMS - Local Energy Measurement Stations – (Pardyjak/Derek/Nipun)
4. HOBOs (Whiteman)
5. Hot-wire anemometry Experiments – Playa (Pardyjak)
6. SODAR operations (Hoch/Whiteman)
7. Radiosonde operations (Hoch/Whiteman)
8. Lidar operations (Hoch/Whiteman)

Dugway -
1. SAMS
2. PWIDS
3. Lidar
4. Ceilometer

4.1 Flux Tower Measurement Systems

4.1.1 UND Flux Tower Measurement Systems

Overview
The University of Notre Dame will be responsible of 5 Flux Tower (FT) Measurement Systems:

- 20-m East Middle Slope Tower (EMS Tower)
- 32-m East Lower Slope Tower (ELS Tower)
- 20-m West Middle Slope Tower (WMS Tower)
- two 10-m Small Gap Towers (SG1 and SG2 Towers)

Details of each Tower are given at the end of this section (Figures 7 - 11).

The EMS, ELS towers will be deployed on the eastern slope of Granite Peak (slope experiment) while the WMS tower will be on the western slope of Granite Peak (west slope experiment). The SG1 and SG2 towers will be deployed at the small gap between Granite Peak and Sapphire Mountain.

All the towers are 24/7 operation. All data on the towers will be collected using CSI CR5000 and CR3000 dataloggers.

UND staff will be onsite, mainly at the ES Site, monitoring and maintaining the FT systems. At least two members of ND FT staff will be available during the entire operations period, possibly in 2-week shifts with some overlap. Additional personnel may be deployed, as necessary.
Working hours generally will be daylight, seven days a week. Staff will be based at the ND trailer at the base of Granite Mountain, but may be temporarily offsite for other experiment-related activities.

Contact information

Silvana Di Sabatino…………..… cell: 574-440-4650, silvana.disabatino@unisalento.it
Laura S Leo……………..……… cell: 574-339-5762, lleo1@nd.edu

Lodging

UND staff will stay at the Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Personnel

Silvana Di Sabatino (University of Salento): Field Deployment and Data QA
Laura S Leo (University of Notre Dame): Field Deployment and assistant of the Data QA
Gennaro Rispoli (University of Salento): Technician
Orsen Hyde: Technician Assistant
Dan Liberzon: Post doctoral fellow (combo tower), two weeks
Eliezer Kit: Post doctoral fellw (combo tower), two weeks

Junior personnel

Chris Hocut (University of Notre Dame): Graduate student (combo tower)
Zachariah Silver (University of Notre Dame): graduate student, one week

Alerting Procedures

Staff will send a daily message to the ops center (probably via walkie-talkie or e-mail) advising of the status of each flux tower measurement system under ND responsibility. Timing of this message and other details are to be determined.

Safety

All UND staff will rely on DPG staff if tower maintenance is needed. First aid kits are available at the ND trailer. Staff will consult onsite medic if any first aid is required.

Coordination with other Participants

The set-up operations will be coordinated with DPG and, eventually, the UoU staff.
For sake of safety, tower maintenance will be always coordinated and relied on DPG staff. Regular maintenance will be performed on non-IOP days.

Data Access

Not real-time; raw data will be downloaded daily and given to Data QA (Silvana Di Sabatino). There will be no direct transmittal of data.

Procedures

Set-up The UND instrumentation and the two UND 20-m masts (EMS, WMS) will be shipped to the field on Aug 12, 2012 from South Bend, IN.

The 32-m ELS mast is already on site. The two UND masts (EMS, WMS) and the other two DPG 10m-masts (SG1, SG2) will be installed/raised by DPG staff. Tower bases, guys, anchors, etc. are needed for these 4 masts.

UND staff will equip all the five tower and will rely on DPG staff when a ladder or tower-climbing is required (in particular for the not telescopic towers WMS, SG1(?) and SG2 (?) towers if they will be raised before they are equipped).

The experimental set-up will begin on Aug 20, 2012 and final tests will be completed around Aug 31.

Based on the advice of DPG staff and our own experience during set up, a part or all the equipment will be dismounted and stored at DPG till the time of IOP-0 (around Sept 21, 2012).

Tear-down The system will be dismantled immediately at the end of the field campaign (Oct 25, 2012). A part or all the instrumentation will be placed in storage at Dugway between the fall and spring campaigns.

Specification

20-m East Middle Slope Tower

The 20-m EMS Tower is a T-160 telescoping tower with T-base (drawing AT-1335).

The 20-m EMS Tower will have an eddy correlation system (Campbell Scientific, Inc. CSAT3 three-dimensional sonic anemometer and Campbell Scientific, Inc. KH20 infrared hygrometer) and a 4-component radiation balance measurement (Kipp&Zonen CR1). Soil temperature, soil heat flux, and soil water content will be measured at one location near the base of the tower or in the surrounding area, depending on soil consistency and available depth. The 20-m EMS Tower will also be equipped with a total of 4 R.M. Young 81000 3-D sonic anemometers, 13 fast thermocouples (homemade, type K), 1 barometer Vaisala PTB110, 4 shielded relative humidity and temperature probes Vaisala hmp45, 1 wind vane anemometer. Details are given in Figure7 and Table 5.

All the instruments will be provided by UND, except the wind vane anemometer and three of the Vaisala hmp45 probes, which will be provided by DPG staff. UND will also provide the 20-m mast.

32-m East Lower Slope Tower

The 32-m ELS Tower will be equipped with the University of Notre Dame Combo probe system (NDCPS) described in next section. Furthermore, the tower will have 7 levels, each one equipped with one R.M. Young 81000 3-D sonic anemometer, one fast thermocouple (homemade, type K), one shielded relative humidity and temperature probes Vaisala hmp45; the lower level will be also equipped with one barometer. Details are given in Figure8 and Table 66. Except NDCPS, all the instruments will be provided by DPG staff. DPG will also provide the 32-m mast.

20-m West Middle Slope Tower

The 20-m WMS Tower will be instrumented with 5 R.M. Young 81000 3-D sonic anemometers, 13 fast thermocouples (homemade, type K), 1 barometer Vaisala PTB110, 5 shielded relative humidity and temperature probes Vaisala hmp45, 1 wind vane anemometer. Potentially, the WMS Tower will also monitor the entire energy budget, if equipment is available from UoU.
Details are given in Figure 9 and Table . Both UND and DPG (and perhaps UoU) will contribute to equip the WMS Tower, as specified in Table 7. UND will also provide the 20-m mast.
At present, the west tower is about 15 m but we are checking if it is feasible to add an extra 5 m piece

10-m Small Gap Towers

These two 10-m towers, SG1 and SG2, will be have three levels, 2 m, 5m and 10 m. Specifically, the SG1 tower (10) will have three level, each one equipped with one fast thermocouples (homemade, type K) and one shielded relative humidity and temperature probes Vaisala hmp45. Lower level (2m) and the highest level (10 m) will also have one R.M. Young 81000 3-D sonic anemometer.
The SG2 tower (Figure 11e 11) will have a similar configuration. The SG2 tower will also have a barometer.
Details are given in Table8 and Table 99. All the equipment, including the two 10-m masts, will be provided by DPG staff, except the thermocouples which will be provided by UND.

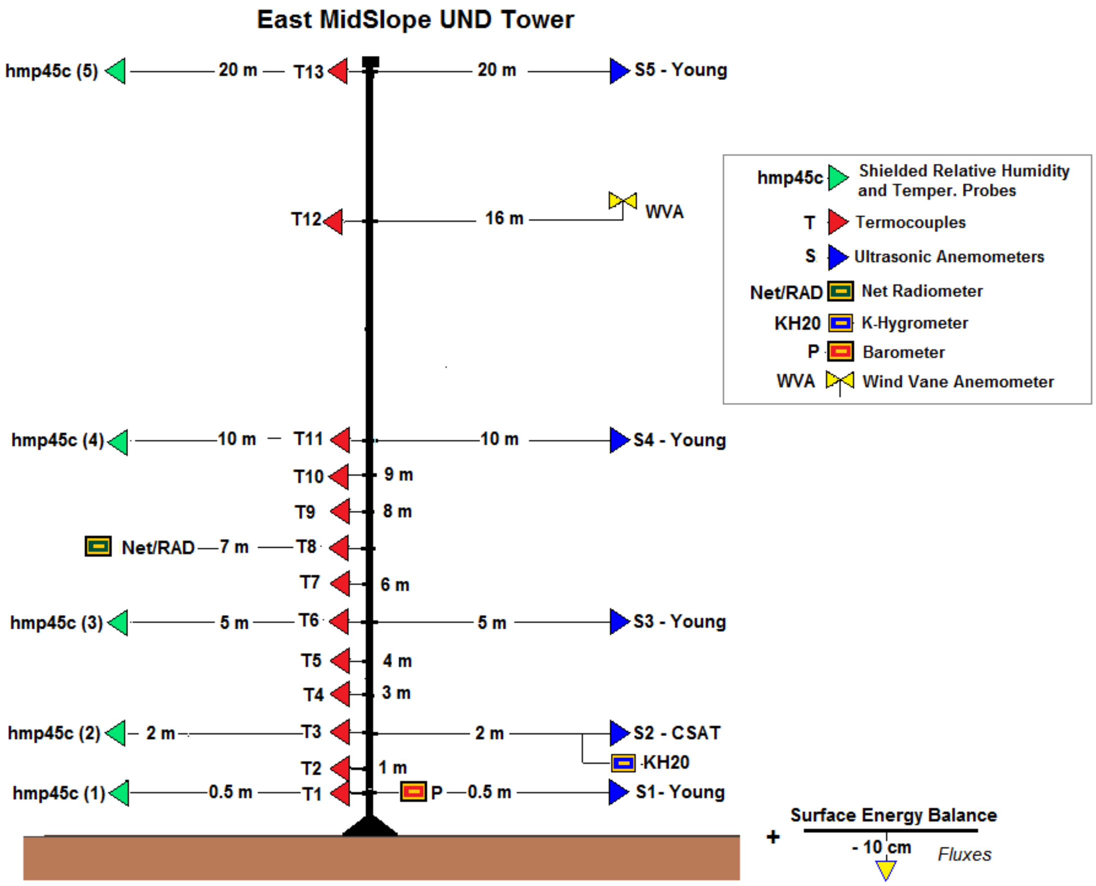

Figure 7: Set-up of the East Middle Slope UND Tower.

Table 5: List of Equipment for the East Middle Slope UND Tower

Instruments	Quantity	Level	Provided by
R.M. Young 81000 3-D sonic anemometers	4	0.5 m	ND
		5 m	
		10 m	
		20 m	
Campbell Scientific, Inc. CSAT3 3-D sonic anemometer	1	2 m	ND
Campbell Scientific, Inc. KH20 infrared hygrometer	1	2 m	ND
Kipp&Zonen CNR1 net radiometer	1	7 m	ND
Thermocouples	13	0.5 m	ND
		1-10 m (each meter)	
		16 m	
		20 m	
barometer Vaisala PTB110	1	0.5 m	ND
Wind Vane Anemometer	1	16 m	**DPG**
shielded relative humidity and temperature probes Vaisala hmp45	5	0.5 m	ND
		2m	**DPG** (shield by ND)
		5 m	
		10 m	
		20 m	
Hukseflux HFP01SC soil heat flux plates	2	About 8 cm under the ground	ND
Campbell Scientific, Inc. CS616 Water Content Reflectometer	1	under the ground	ND
Campbell Scientific, Inc. 107 Soil Temperature Probe	4	About 2 and 6 cm under the ground	ND
5TM	**3**	**Under ground**	**ND**
OTHER EQUIPMENT			
Campbell Scientific, Inc. CR5000 datalogger	3		ND
12V MARINE Deep Cycle Battery **110Ah**	3		**DPG** *(NOT confirmed yet)*
20-m Mast (telescopic)	1		ND

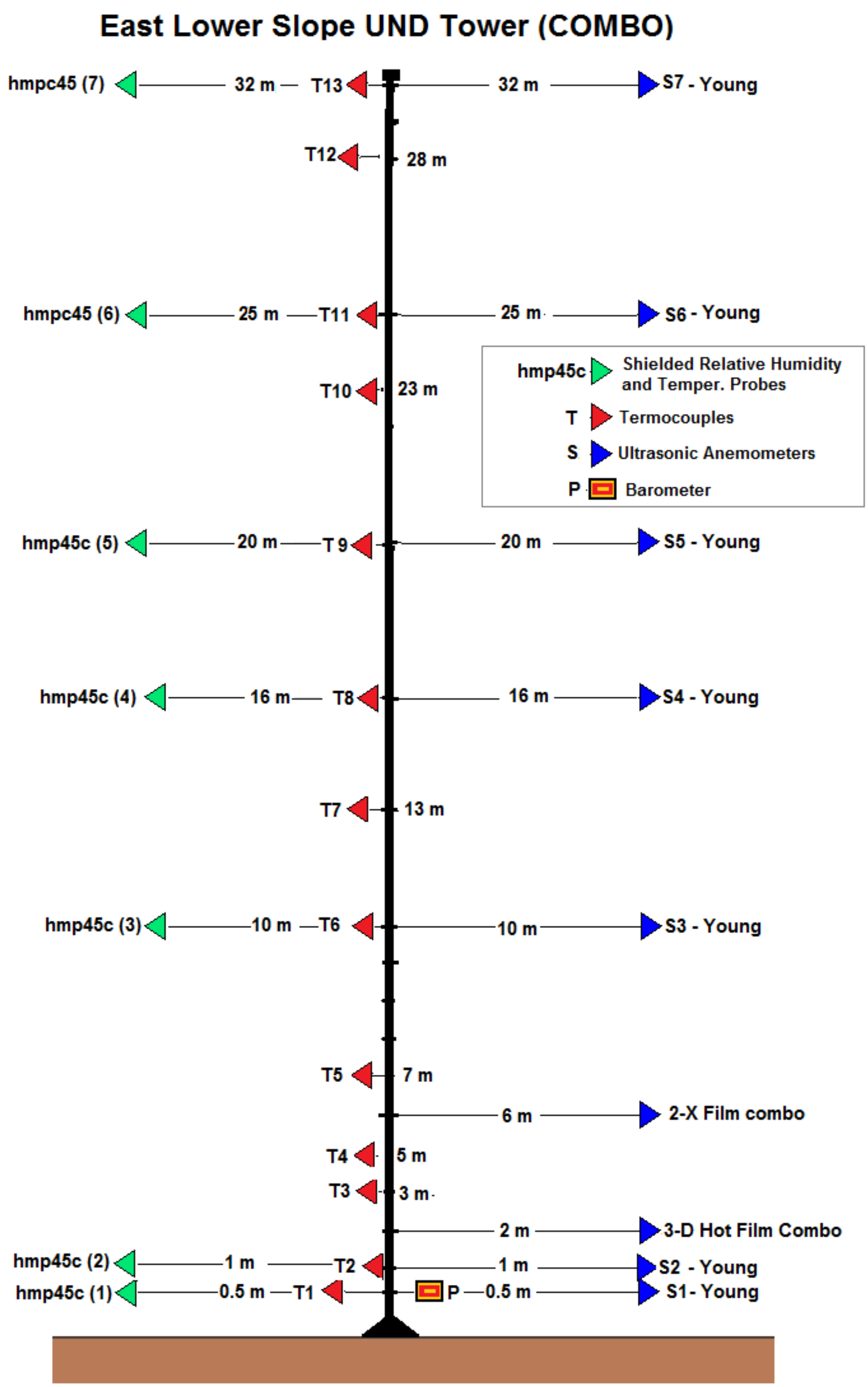

Figure 8: Set-up of the East Lower Slope UND Tower.

Table 6: List of Equipment for the East Lower Slope UND Tower.

Instruments	Quantity	Level	Provided by
R.M. Young 81000 3-D sonic anemometers	7	0.5 m (serial)	**DPG**
		1 m (serial)	
		10 m (serial)	
		16 m (diff)	**ND**
		20 m (diff)	
		25 m (diff)	
		32 m (diff)	
3-D Hot Film Combo System	1	2 m	ND
2-X Hot Film Combo System	1	6 m	ND
Thermocouples	12	0.5 m	ND
		1 m	
		3 m	
		5 m	
		7 m	
		10 m	
		13 m	
		16 m	
		20 m	
		23 m	
		28 m	
		32 m	
barometer	1	0.5 m	**DPG**
shielded relative humidity and temperature probes Vaisala hmp45	7	0.5 m	**DPG** (shielded by ND)
		1 m	
		10 m	
		16 m	
		20 m	
		25 m	
		32 m	
OTHER EQUIPMENT			
Campbell Scientific, Inc. CR5000 datalogger	2		**DPG**
Campbell Scientific, Inc. CR3000 datalogger	1		**DPG**
12V MARINE Deep Cycle Battery **110Ah**	2		**DPG** *(NOT confirmed yet)*
32-m Mast	1		**DPG**

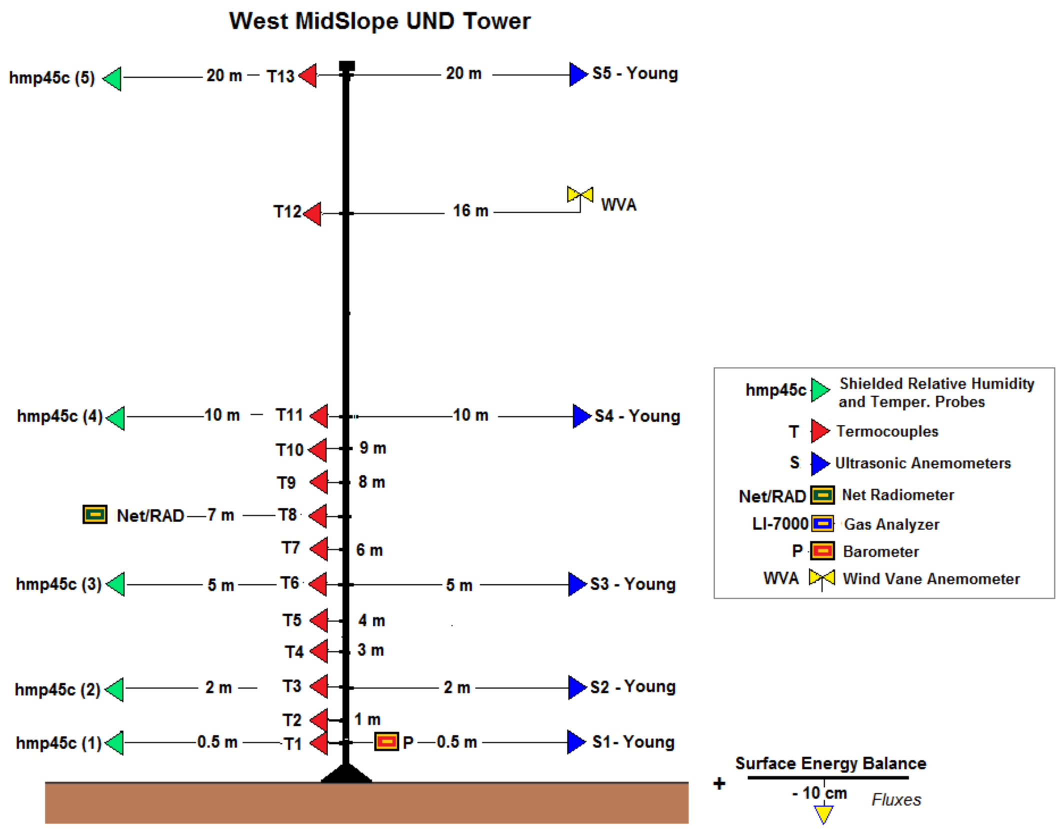

Figure 9: Set-up of the West Middle Slope UND Tower.

Table 7: List of Equipment for the West Middle Slope UND Tower

Instruments	Quantity	Level	Provided by
R.M. Young 81000 3-D sonic anemometers	5	0.5 m (serial)	**DPG**
		2 m (diff)	
		5 m (serial)	
		10 m (serial)	
		20 m (diff)	
Kipp&Zonen CNR1 net radiometer	1	7 m	**UoU**
Thermocouples	13	0.5 m	ND
		1-10 m (each meter)	
		16 m	
		20 m	
barometer	1	0.5 m	**DPG**
Wind Vane Anemometer	1	16 m	**DPG**
shielded relative humidity and temperature probes Vaisala hmp45	5	0.5 m	**DPG** (shield by ND)
		2 m	
		5 m	
		10 m	
		20 m	
Hukseflux HFP01SC soil heat flux plates	2	About 8 cm under the ground	**UoU**
Water Content Reflectometer	1	under the ground	**UoU**
Soil Temperature Probe	4	About 2 and 6 cm under the ground	**UoU**
OTHER EQUIPMENT			
Campbell Scientific, Inc. CR5000 datalogger	2		**DPG**
Campbell Scientific, Inc. CR3000 datalogger	1		**DPG**
12V MARINE Deep Cycle Battery **110Ah**	3		**DPG** *(NOT confirmed yet)*
20-m Mast	1		ND

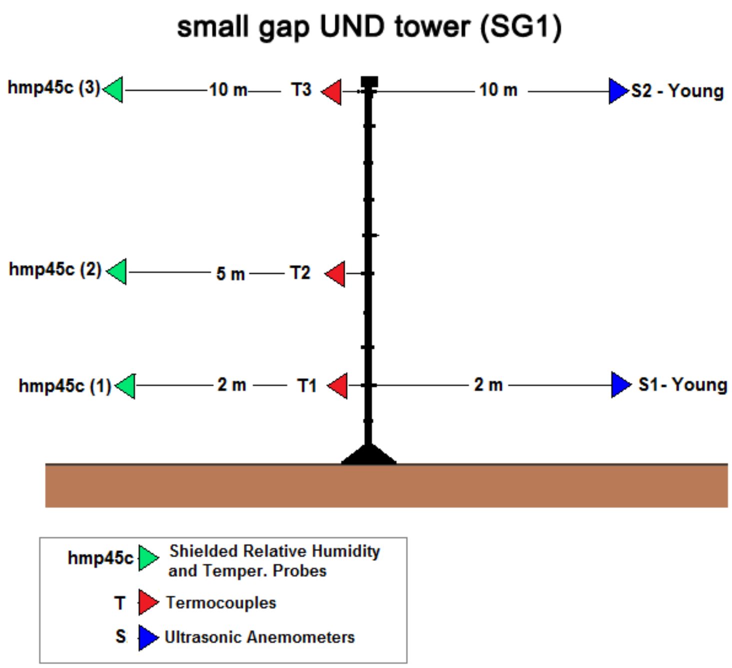

Figure 10: Set-up of the small gap UND tower (SG1).

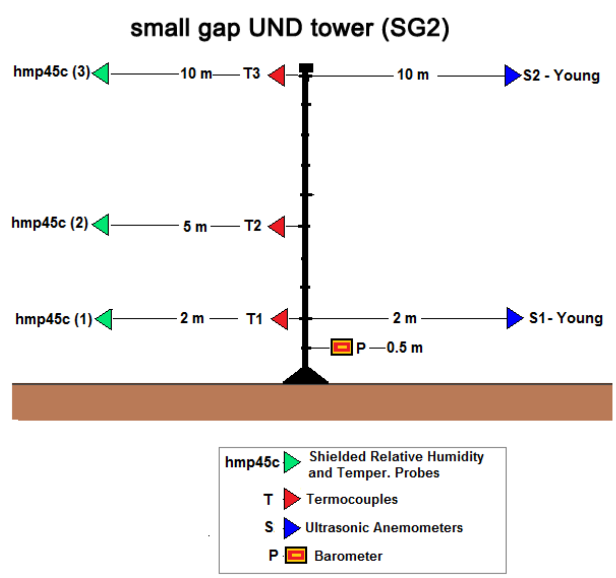

Figure 11: Set-up of the small gap UND tower (SG2).

Table 8: List of Equipment for the small gap UND tower SG1.

Instruments	Quantity	Level	Provided by
R.M. Young 81000 3-D sonic anemometers	2	2 m (serial)	**DPG**
		10 m (serial)	
Thermocouples	3	2 m	ND
		5 m	
		10 m	
shielded relative humidity and temperature probes Vaisala hmp45	3	2 m	**DPG**
		5 m	
		10 m	
OTHER EQUIPMENT			
Campbell Scientific, Inc. CR3000 datalogger	1		**DPG**
12V MARINE Deep Cycle Battery **55Ah**	2		**DPG** *(NOT confirmed yet)*
10-m Mast	1		**DPG**

Table 9: List of Equipment for the small gap UND tower SG2.

Instruments	Quantity	Level	Provided by
R.M. Young 81000 3-D sonic anemometers	2	2 m (serial)	**DPG**
		10 m (serial)	
Thermocouples	3	2 m	ND
		5 m	
		10 m	
shielded relative humidity and temperature probes Vaisala hmp45	3	2 m	**DPG**
		5 m	
		10 m	
barometer	1	0.5 m	**DPG**
OTHER EQUIPMENT			
Campbell Scientific, Inc. CR3000 datalogger	2		**DPG**
12V MARINE Deep Cycle Battery **55Ah**	3		**DPG** *(NOT confirmed yet)*
10-m Mast	1		**DPG**

4.2 Combo probe system

4.2.1 UND Combo probe system

The University of Notre Dame Combo probe system (NDCPS) is a 24/7 operation. Staff is onsite to ensure the maximum data recovery is obtained by monitoring, maintaining, and servicing sensors and data systems. At least two NDCPS staff (one senior personnel and one junior personnel) will be available during the entire operations period, in 2-week shifts with some overlap.
Working hours generally will be during IOPS. Staff will be based at the ND trailer at the base of Granite Mountain, but may be offsite for UAV activities.

Contact information

Eliezer Kit ……………………………… cell: TBD, elikit@gmail.com
Dan Liberzon ……………………………cell: 269-861-2274, dan.liberzon.1@nd.edu
Chris Hocut …………………………… cell: 208-310-1315, chocut@nd.edu

Lodging

Staff will stay at the Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Alerting Procedures

Staff will send a daily message to the ops center (probably via walkie-talkie or e-mail) advising of NDCPS sensor status, noting any down systems and their impact. Timing of this message TBD.

Safety

All staff will rely on DPG staff if tower maintenance is needed. First aid kits are available at the ND trailer. Staff will consult onsite medic if any first aid is required.

Coordination with other Participants

None needed. Regular maintenance will be performed on non-IOP days.

Data Access

All data will be given to Data QA (Silvana Di Sabatino) at the end of each IOP.

Hot-Film Anemometers

There will be five hot-film combos (embedded within two R.M. Young 81000 and three Campbell CSAT3 3-D sonic anemometers). The R.M. Young combos will be mounted on one 32 m DPG telescoping triangular tower (ELS Tower) oriented to measure katabatic flows, at 2 m (2 x-films) and 32 m (3D film) above the slope. The Campbell CSAT3 combos will mounted on one 10 m triangular tower (NCAR Tower) oriented to measure anabatic flows 2 m (3D film), 5 m (3D film) and 10 m (3D film) above the slope. Both towers will be located on the eastern slope of Granite Mountain XX m from the base. A crane or tower-climbing will be required to service the tower.

The system will operate September 25, 2012 – October 25, 2012 during favorable meteorological conditions, and will generate 2000 Hz u, v and w (including dissipation estimates), provided that our experimental calibration procedure and system set-up are adequate.

Procedures

Set-up The hot-film system will be shipped to the field on Aug 12, 2012 from South Bend, IN. It will be unpacked and inventoried before set-up begins on Aug 26. Final tests will be completed on Aug 31 with a heavily monitored mock-operational day on Sep 1.

Operations The hot-films are more fragile than most atmospheric instruments and will only be operated when mean winds are less than 10 m/s and non-precipitating. If the conditions appear to be adverse:

a) the hot-film system will be shut down and data will be downloaded as appropriate, and,
b) the hot-film anemometers will be removed from their probe supports and placed in protective cover.

When suitable atmospheric conditions are restored:

a) the hot-film anemometers will be returned to their individual probe supports,
b) the hot-film system will be turned on, and,
c) data recording will be verified.

Data downloads will occur at the end of each IOP. These procedures will be repeated throughout the experimental period.

Tear-down The system will be dismantled immediately following the experiment and completion is anticipated by Oct 31, 2012.

Staffing and Schedule

Set-up: C. Hocut, Aug 26 - Aug 31.
Operations: C. Hocut, Sept 25 - Oct 25, E. Kit, Sept 25 – Oct 9, D. Liberzon Oct 9 - Oct 25.
Tear-down: C. Hocut, Oct 26 – Oct 31.

4.3 Unmanned Ariel Vehicles (UAVs)

4.3.1 UND UAV

Overview

The University of Notre Dame Unmanned Ariel Vehicle (UAV) is an assembled Flamingo F-18 from Silvertone UAV in Australia with Piccolo SL autopilot components from Cloud Cap Technology, Zotac Ion Computer and National Instruments Data Acquisition System. It is a self-contained measurement platform taking in-situ measurements of turbulence, wind velocity, temperature, atmospheric pressure and humidity along automated flight paths. Data acquisition and storage are accomplished on board the aircraft.

NOTE: We will likely need to add more to the UAV part once we get it working and figure out the details. There is also a possibility we will be building our own runway located closer to Granite Mountain

Contact information

Charles Retallack …………………. cell: xxx-xxx-xxxx ,Charles.Retallack.1@nd.edu
(UAV coordinator for UND)
Chris Hocut ………………………. cell: 208-310-1315, chocut@nd.edu
(UAV coordinator for UND)

Scott Coppersmith: ……………..……cell: xxx-xxx-xxxx, RScott.Coppersmith.1@nd.edu
(UAV coordinator for UND)

Generator service: xxxxxxxxxxxxxxxx………….....…………….. cell: xxx-xxx-xxxx
Generator refueling: xxxxxxxxxxx…………………………. cell: xxx-xxx-xxxx

Location

The UND UAV will be located at the DPG runway flying data collection paths near Granite Mountain.

Setup

Initial assembly and systems checks of the UAV will take place one week prior to the first operational day of the fall MATERHORN campaign. Initial setup will require two program members and will take approximately 8 hours. The UAV will require 2 hours setup before each IOP.

Schedule

The ND UAV will operate during IOP days only. Only a limited number of flights are planned because of the operational intricacies of the flights.

Teardown

The UND UAV will be operational for the duration of the fall campaign but placed in storage at Dugway between the fall and spring campaigns. During non-IOP days, the UAV will be stored near the DPG runway. Two staff members will be required for teardown and will require approximately 1 – 2 hours.

Staffing

The UND UAV requires two staff members to operate the base station as well as take-off and landing operations. Additional staff members will also be employed as spotters while the plane is out of visual range of the DPG runway.

Charles Retallack:
Chris Hocut:
Orsen Hyde:
Scott Coppersmith: First week only

It is planned to employ an experienced pilot during the first few weeks of the experiment.

Lodging
UND staff will stay at the Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Safety
The UAV is powered by a small gasoline engine with an attached high RPM propeller. The propeller can cause severe injury and needs to be avoided while the engine is running. The UAV weighs over 10 kilograms and flies at speeds up to 78 knots. Great care must be taken to all staff to avoid runway areas where the UAV will be operating at low altitudes.

System Maintenance
1. The engine will need general maintenance including fueling.

2. Control systems will need to be checked before every flight.

3. Onboard measurement systems and data acquisition systems will require regular calibration checks.

Data
Data is saved onboard and downloaded at the end of each flight operation. Data will consist of signals from hotwire probes, sonic anemometer, thermocouples, pressure transducer, and avionics.

Data Communications
A minimal amount of data is transmitted to the base station during flights for diagnostic purposes. Most of the data will be stored in an onboard computer.

Experimental Strategies
The UAV will be launched during IOP's from the DPG runway. Flight paths will be prescribed and executed by the autopilot to collect data at desired locations and elevations near Granite Mountain. These flight paths will include staked traverses both parallel and perpendicular to the mountain range. No more than 2 flights will take place during a given IOP.

4.4 Ceilometers

4.4.1 UND Vaisala CL31

Overview
The University of Notre Dame Vaisala Ceilometer CL31 utilizes pulsed diode laser LIDAR technology, where laser pulses are sent out in near-vertical direction to obtain backscatter

profiles. The diode laser emits at 910 nm and has energy per pulse of 1.2 μJ with a maximum measurement range of 7.5 km.

Vaisala Ceilometer CL31 is classified as a Class 1M laser. This means that when CL31 is installed in a field environment with instrument covers on and pointed vertically or near-vertically, it poses no established biological hazard to humans.

Contact information

Silvana Di Sabatino…………..… cell: 574-440-4650, silvana.disabatino@unisalento.it
Laura S Leo……………..……… cell: 574-339-5762, lleo1@nd.edu

Generator service: xxxxxxxxxxxxxxxx…………...…………….. cell: xxx-xxx-xxxx
Generator refueling: xxxxxxxxxxx…………………………. cell: xxx-xxx-xxxx

Location

The UND Vaisala Ceilometer CL31 will be located about 2 km away from the base of the western slope of Granite Mountain. Approximate coordinates of this location are: N40.10138, W 113.33759. (We need to check if this site can be accessible frequently enough).

Setup

Installation of the UND Ceilometer will take place about one-two week prior to the first dry–run day of the fall MATERHORN campaign. Setup will require three program members and will take approximately 4 hours. One PC with a serial interface, a terminal emulation program and with the ceilometer embedded software will be provided by UND for operation and maintenance of Ceilometer as well as for daily data storage.
Additionally, the power generation unit will need to be on site and operational to complete the setup. The ceilometer has a built-in 12 V battery, which enables operation without external power supply for ONLY about an hour in normal room temperature. Note that CL31 ground installation requires a (concrete) foundation with minimum dimensions as in Figure12. If such a foundation is not available at the measurement site, a new one has to be constructed prior to the deployment of the ceilometer.

Teardown

The UND Vaisala Ceilometer CL31 will be operational for the entire duration of the fall campaign and will be placed in storage at Dugway between the fall and spring campaigns.

Staffing

As the UND ceilometer operates autonomously, staff requirements are minimal.
Two program members from UND will visit the Ceilometer location only for scheduled maintenance operations described below.

Schedule

Program members from UND will check daily the Ceilometer to make sure data are being collected and the instrument is functioning properly.

Lodging
The UND ceilometer staff will stay at Desert Lodge Hotel, English Village.

Safety
To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. Operating personnel must not remove instrument covers because dangerous voltages may exist even with the power cable removed.

Laser eye-safety: the Vaisala Ceilometer CL31 emits infrared laser beams that are invisible to the human eye. The laser is classified as class 1M, hence it is safe for all conditions of use except when passed through magnifying optics. Care should be taken by anyone using spotting scopes or binoculars in the area.

System Maintenance
1. Generator refueling: The generator will require periodic refueling.

2. Data downloading: Data will be downloaded daily to a USB driver by UND ceilometer staff and given to Data QA (Silvana Di Sabatino) according to the data management procedure.

Data
The UND Vaisala Ceilometer CL31 will record raw data at a rate of approximately 900 kB per hour. Data are saved in 7-bit USASCII format files of type *.DAT.

Raw data will be processed using the CL31 MLH PC software. The software produces MATLAB figures containing text and density graphs, text files containing surface layer and cloud base heights, and PNG-graphic files. Averaging times will be adjusted according to the data management procedure.

Data Access
All data will be given to Data QA (Silvana Di Sabatino) daily.

Experimental Strategies
Retrievals and post-processing will be planned and executed to fulfill the data collection requirements of IOP's.

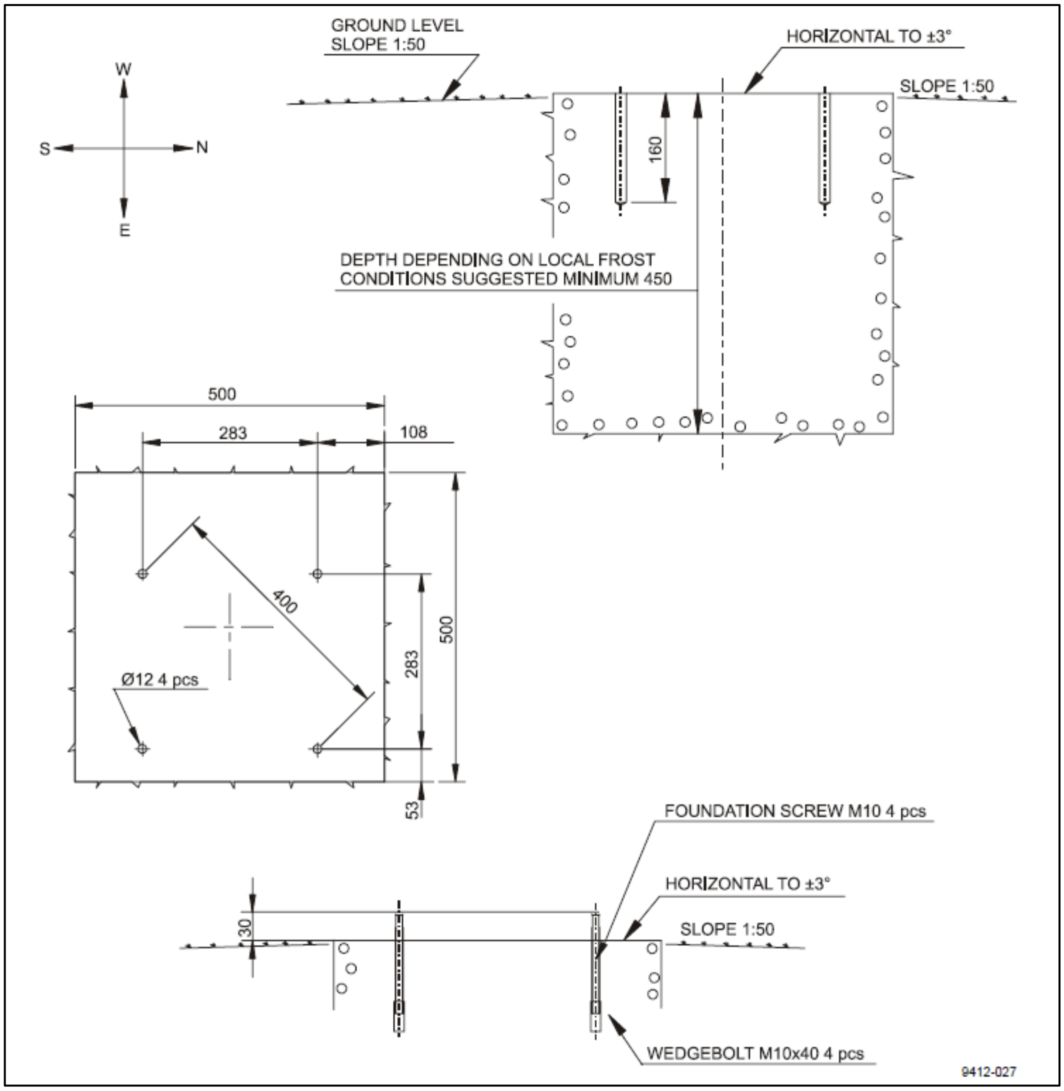

Figure12: Foundation construction for the Vaisala Ceilometer CL31.

4.5 Doppler Lidars

4.5.1 UND Halo Photonics Doppler lidar

Overview

The University of Notre Dame Halo Photonics Doppler lidar utilizes a 1.5 μm pulsed infrared laser beam to obtain radial velocities and backscatter magnitude. The laser has a pulse energy of 100 μJ with a maximum range of 10 km. The laser beam is aimed via a two axis scanning head that transmits outgoing and receives returned signal pulses. The laser is Class 1M and eye safe.

Contact information

Charles Retallack: Lidar coordinator for UND……………….…… cell: xxx-xxx-xxxx

Generator service: xxxxxxxxxxxxxxxx…………..…………….. cell: xxx-xxx-xxxx
Generator refueling: xxxxxxxxxxx…………………………. cell: xxx-xxx-xxxx

Location
The UND Halo Photonics lidar will be located near the base of the eastern slope of Granite Mountain.

Setup
Installation of the UND lidar will take place one week prior to the first operational day of the fall MATERHORN campaign. Setup will require two program members and will take approximately 4 hours. Calibration will require the use of a nearby tower for sighting. Additionally, the power generation unit will need to be on site and operation to complete setup. The data will be stored on site computer – check.

Teardown
The UND lidar will be operational for the duration of the fall campaign but placed in storage at Dugway between the fall and spring campaigns.

Staffing
As the UND lidar operates autonomously, staff requirements are minimal. Once daily data downloading will be required (via laptop). Scanning strategy changes will also require a project member to upload scan files. The power generator will need to be fueled at regular intervals.

Lodging
UND staff will stay at Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Safety
Laser eye-safety: The Halo Photonics lidar emits infrared laser beams that are invisible to the human eye. The laser is considered eye safe and is classified as class 1m. The beam is divergent and remains eye safe if it is not viewed through magnification. Care should be taken by anyone using spotting scopes or binoculars in the area.

System Maintenance
1. Generator refueling: The generator will require periodic refueling.

2. Data downloading: Data will need to be downloaded periodically to avoid data being overwritten due to the hard disk being full.

Data
Data is saved in ASCII format files of type *.hpl with pertinent parameters saved in the header portion of the file.

Data Communications
Due to the lack of internet connection in the remote location where the lidar will be located, real time data link will not be likely.

Scan Strategies
Scanning will be planned and executed to fulfill the data collection requirements of IOP's. The scanning patterns will be coordinated along with other lidars located in the vicinity.

4.6 SODAR/RASS

4.6.1 UND Scintec Sodar/RASS

Overview
The University of Notre Dame Scintec Sodar/RASS measures 3-D wind velocity and temperature using a combination of audible pulsed acoustic sequences and emitted radio waves. The system is composed of an acoustic transmission/receiving unit and two radio dish antennae.

Contact information
Silvana Di Sabatino…………..… cell: 574-440-4650, silvana.disabatino@unisalento.it
Laura S Leo…………….……… cell: 574-339-5762, lleo1@nd.edu

Generator service: xxxxxxxxxxxxxxxx…………...…………….. cell: xxx-xxx-xxxx
Generator refueling: xxxxxxxxxxx…………………………. cell: xxx-xxx-xxxx

Location
The UND Scintec Sodar/RASS will be will be located about 2 km away from the base of the western slope of Granite Mountain. Approximate coordinates of this location are: N40.10138, W 113.33759. (We need to check if this site can be accessible frequently enough).

Setup
Installation of the UND Sodar/RASS will take place one-two week prior to the first dry–run day of the fall MATERHORN campaign. If necessary or considered more convenient, all the equipment will be dismounted and stored at DPG till the time of IOP-0 (around Sept 21, 2012). Setup will require three program members and will take approximately 3-4 hours. A base for the unit of either a concrete pad or paving stone will be required. Additionally, the power generation unit will need to be on site and operational to complete setup.

Teardown
The UND sodar/RASS will be operational during the entire fall campaign and placed in storage at Dugway between the fall and spring campaigns. Three staff members will be required for teardown and will require approximately 1 – 2 hours.

Staffing
As the UND sodar/RASS operates autonomously, staff requirements are minimal.

Two program members from UND will drive to the sodar/RASS location only for the schedule and maintenance operations described below.

Schedule
Program members from UND will check the Ceilometer daily to make sure that data are being collected and the instrument is functioning properly.

Lodging
UND staff will stay at Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Safety
The Scintec Sodar/RASS emits audible tones during measurements. Care should be taken to avoid standing near the sodar unit during operation without ear protection.

System Maintenance
1. Generator refueling: The generator will require periodic refueling.

2. The transmission and receiving components should be checked periodically for leveling to insure that their positions have not shifted due to the soft ground.

3. System self-checks should be performed before each IOP to verify the health of the sodar.

4. Data downloading: Data will be downloaded daily to an USB driver by the UND staff and given to Data QA (Silvana Di Sabatino) according to the data management procedure (under discussion).

Data
There will be no real time transition. Data is saved in ASCII format files of type *.mnd and *.mnt with pertinent parameters saved in the header portion of the file.

Experimental Strategies
Retrievals will be planned and executed to fulfill the data collection requirements of IOP's. The retrieval patterns will consist of combined wind velocity and temperature retrievals with averaging times adjusted based on experimental conditions.

4.7 RF Remote Soil moisture system

4.7.1 UND RF CROSSHAIR

Test Overview
RF CROSSHAIR is a remote soil moisture sensing system that operates in three frequency bands: 470 MHz, 915 Mhz, and 2.437 GHz. The system consists of a transmitter station (which

will be deployed on the slope of the mountain) and a receiver station that will be mounted on a 20m mast near the base of the mountain. The system transmits signals in each of these frequency bands from directional antennas that are directed toward the intended target area on the ground between the transmit and receive stations. The forward scatter energy from the ground reflections are sensed by a receiver that collects the signal at programmable intervals (e.g., every 10 minutes). The measured responses are used to interpret changes in moisture content

Contact information

Tom Pratt: Lead-PI for using RF CROSSHAIR…………………. cell: 770-853-5277
Neil Dodson: RF Crosshair engineer

Location

At present, we intend to install the receiver on a dedicated 20m mast near the Granite slope. The transmitting unit will be deployed on a shorter mast on the mountain slope at a height approximately equal to that of the receiver.

Setup

The RF CROSSHAIR system will be arriving by cargo van. The transmitter will be manually installed on a tripod/mast system on the mountain slope. The receiver will be installed on a dedicated 20m mast to be installed by DPG. Somebody trained in climbing will be needed to install the receiver system on the 20m mast.

Teardown

RF CROSSHAIR is scheduled to remain in the field for the full duration of the experiment. At the conclusion of the experiment, the equipment will be removed from the mountain slope and from the dedicated 20m mast and packed into the cargo van for transport back to University of Notre Dame. Help will be required for unmounting the receiver from the 20m mast.

Staffing

Plans are to have Tom Pratt and Neil Dodson on-site during the first week to ensure proper installation and operation of the equipment. Laura Leo and Silvana Di Sabatino will provide oversight of equipment operation in subsequent weeks. The equipment operates in a relatively autonomous manner, but periodic checking of the system's operation is recommended to ensure the quality of collected data.

Safety Issues

1. RF Transmissions: Avoid standing in front of the transmit antennas at close range.
2. Mounting of receiver system on 20m mast will likely require assistance from somebody who is qualified for this task.

System Maintenance

4. Generator refueling: The generators at the transmitting and receiver sites will have to be refueled on a periodic basis.

5. <u>External Hard Disk:</u> The RF CROSSHAIR system records raw data at a rate of approximately 500 Mbyte per hour. For MATERHORN, we have chosen to store raw data on a 2 TB Maxtor hard disks. The disk will fill after about 6 months of continuous operation. Hence the external drive should not need to be replaced during the tests, however, three additional 2 TB disks have been purchased for the experiment just in case we decide to collect data more frequently or to store raw time-domain signals as well.

Unattended Operation

RF CROSSHAIR is designed for automated operation. However, it lacks self-health diagnostics and the ability to report problems if they occur. Therefore, an operator should be present in order to keep an eye on things. Examples of items that should be monitored:

a. Presence of received signals in all three frequency bands
b. Data quality, as indicated by near real-time outputs on host laptop
c. Presence of of data files on the external drive
d. Ensure that the Matlab scripts are still running

Data

RF CROSSHAIR produces the following data products in the field:

1. *Raw data files are in ".mat" format*: This is a binary format native to Matlab.
2. *Quick-look images*: Near real-time figures of the measurements are plotted on the host laptop.
3. *Video files from a fixed webcamera*
4. *Files from a pressure/humity/temperature sensor*

Programs

1. *Raw data files are generated by custom data acquisition software created for RF CROSSHAIR,* which runs under MATLAB on the data acquisition computer. This custom code was written by the engineers at University of Notre Dame.
2. *Quick-look images are created in near real-time on the host computer using Matlab scripts that process the raw data*.
3. *A MATLAB program is also being developed to display raw data in post-analysis.*
4. *Vendor software is used to control video/audio collections from the webcam*
5. *Vendor software is used to control data collection from the temperature probe*

Data Communications

No data communications are anticipated. All collected data will be stored locally on an external hard disk.

4.7.2 System Description

The purpose of this section is to provide an overview of the system used for RF-based moisture monitoring and to describe the anticipated deployment topology, the operation of the instrumentation, data collection, and data storage methods.

The RF-based moisture sensing system consists of components for RF transmission and components for signal reception. The system is configured in a manner to enable bistatic collection of clutter returns from the target area to be monitored, as shown in Figure 13 for a single transmitter-to-receiver link.

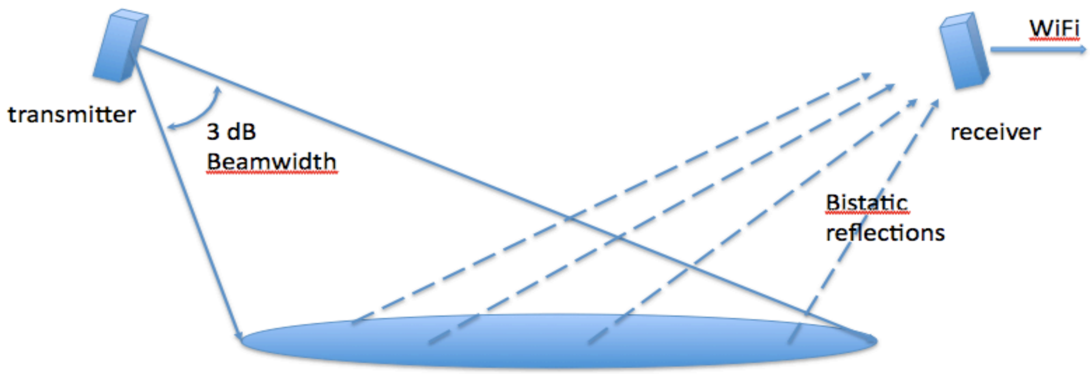

Figure 13: Bistatic Collection Geometry.

As indicated in the figure, the clutter returns can be monitored to characterize polarimetric features of the received signal that are modulated by changes in the moisture and temperature of the target area. These changes are monitored using transmitted signals from multiple transmitter sites and multiple frequency bands to help detect and characterize soil moisture changes. In the presence of precipitation, the sensor outputs may enable characterization of hydrometeors.

The specific frequency bands that are being employed are shown in **Error! Reference source not found.**.

Table 10: Frequency Band Descriptions.

Band Designation	Frequency Range
Band 1	2.4 GHz to 2.5 GHz
Band 2	902 MHz to 928 MHz
Band 3	450 MHz to 500 MHz

A block diagram of the sensing system is shown in Figure. It indicates three operational frequencies, where transmission is achieved using COTS access points, and where a multi-band system is employed at the receiver. In addition to processing RF signals to generate data products, the system will also employ a pressure/temperature/humidity gauge to track ambient values with time.

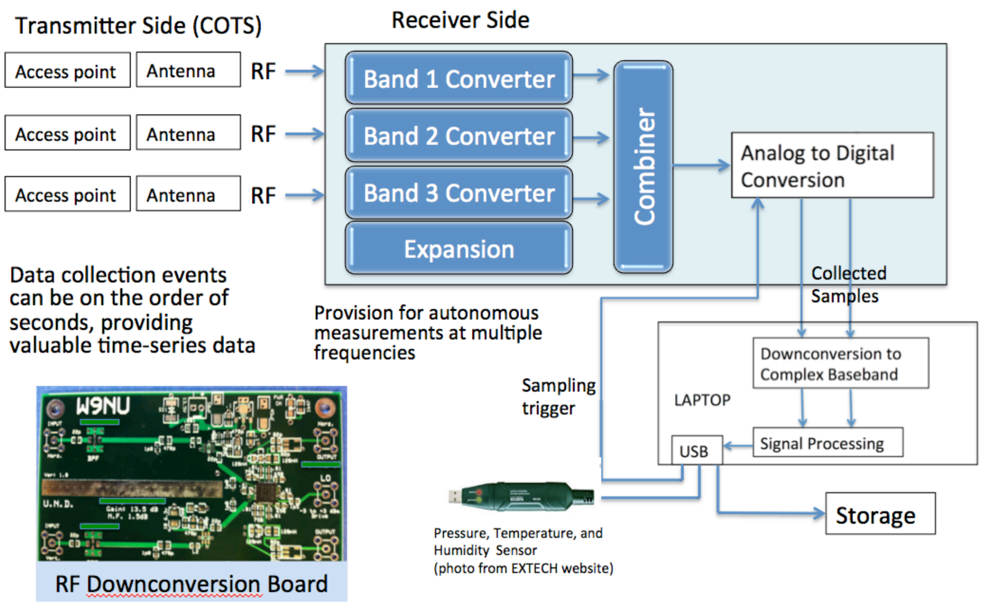

Figure 14: Sensor System Block Diagram.

An example of a transmitter system for one of the frequency bands is shown in Figure 15. It consists of an encased weather-protected transmit unit that requires DC power, an Ethernet cable to initialize the transmitter, and cabling to drive an external antenna. In the case of the 2.4 GHz system, a power amplifier may be employed to increase the system range since propagation losses are more severe at 2.4 GHz than at the other transmit frequencies used by the system. These will be mounted on masts that are deployed near the maintain base, roughly 20m above the base. Since three frequencies are to be used, three such systems will be deployed on the mast at each transmit locations.

The receiver system consists of an antenna and RF front-end combination for each frequency subband, a combining circuit, an analog to digital converter subsystem, and digital signal processing of the digitized signals to extract the polarization features from the received signals. Snapshots derived from the receiver are collected periodically, e.g., every 15 minutes and data products are calculated from the received snapshot. A "record" consisting of a time stamp and extracted signal features is then stored on a 2 TByte external drive for post-test processing. Temperature/pressure/humidity (TPH) are also simultaneously collected at periodic intervals using an EXTECH probe, and these data are also stored on the 2 TByte external hard disk. Webcam video images and audio samples will also be collected and stored.

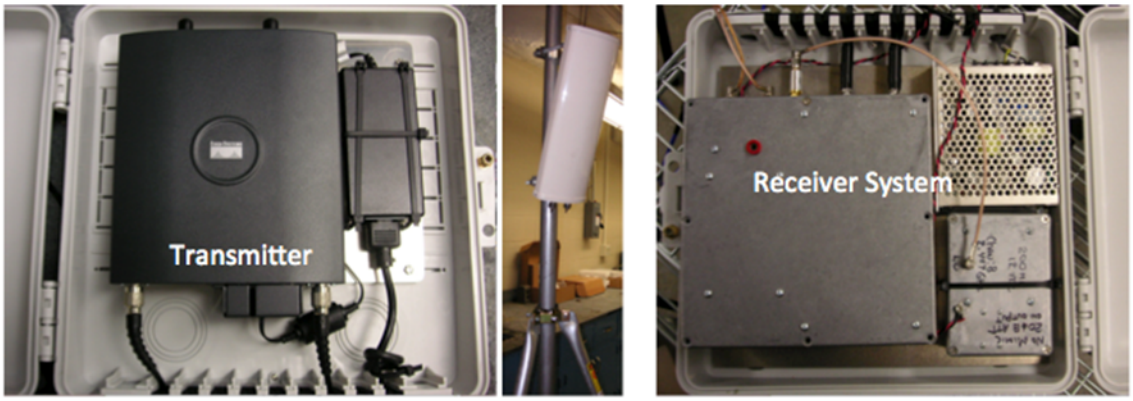

Figure 15: Transmitter and Receiver Subsystems.

4.7.3 Anticipated Deployment Topology

The CROSSHAIR system is to be deployed at Dugway Proving Grounds near the Target R Command Post to monitor soil moisture changes and to potentially detect hydrometeors and fog formation. The deployment will include up to three transmitter sites. The sites will each employ an 8' tripod for mounting transmitter equipment and antennas for three subbands, 2.4 GHz, 900 MHz, and 400 MHz. The tripods will be cemented into the ground and anchored bracing may also be applied to limit vibration due to the wind. We anticipate that a generator (and inverters) will be required at each transmit site due to the power demands of the transmitters and amplifiers.

A single receiver site will be used, where the receiver equipment will be placed on a 20m mast. Near the top of the mast, antenna/RF front-ends for each frequency subband will be installed. Near the base of the tower, a weather-protected console unit will be deployed. This unit contains a laptop, an external drive, a TPH sensor, and I/O and power cabling to the units on the mast. The 20m mast must be secure to the ground in a manner that minimizes motion/vibration that would otherwise degrade the quality of measurements of the sensor system. A generator, or possibly 12V batteries will be needed to power the receiver system.

Figure depicts the anticipated topology. The transmitters will be mounted on the lower slope of the mountain at widely separated angles (as viewed by the receiver) and the receiver will be mounted on a 20m mast. The figure depicts an illustrative topology at a site near Granite Mountain that was originally considered for the tests. However, a new test site location has been selected, one that is farther south on the eastern side of Granite Mountain (e.g., where the other major test equipment is being deployed).

Note that we are requesting that in-situ sensors be deployed by DPG to measure soil moisture at different depths in the target area footprint between each transmitter and the receiver. These will provide data that can be correlated with the RF sensor measurements.

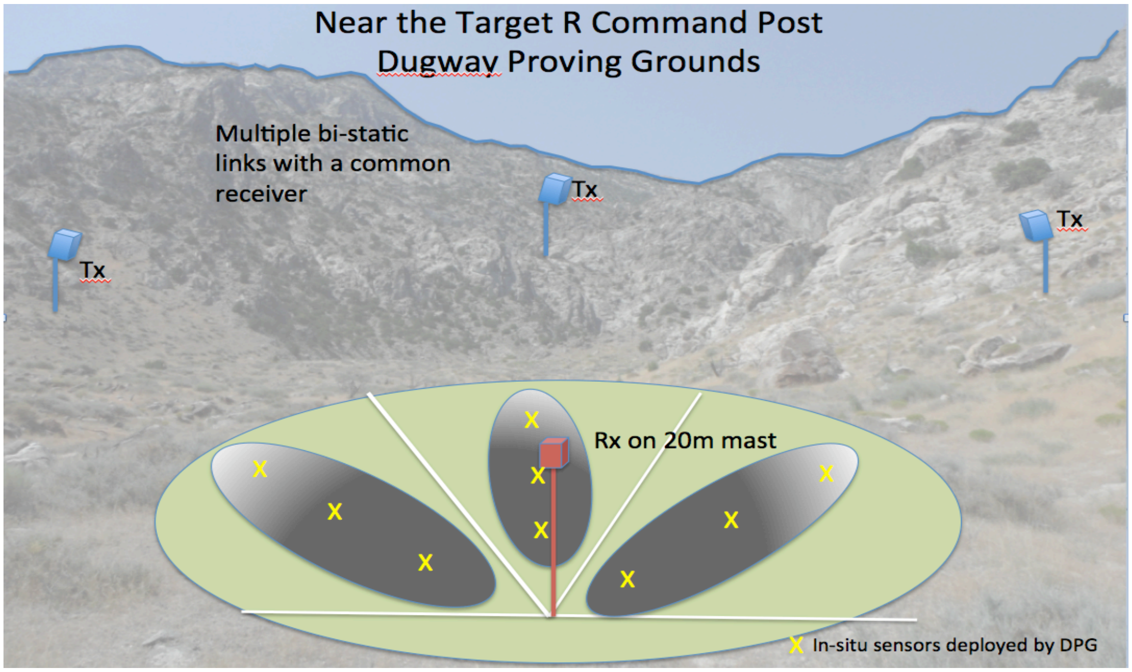

Figure 16: Example of Anticipated Deployment Geometry.

4.7.4 Operation of the Instrumentation

Operation of the instrumentation is as follows.

- After deployment and power-up of the transmitter units, the laptop from the receiver console unit is used to program and initiate transmission by each transmit unit. Once the transmitters are initiated, they will transmit continuously throughout the experiments and will function autonomously.

- The laptop is then placed in the console and all I/O lines are connected, including to the external drive, the TPH sensor, and to the RF sensor units.

- Software on the laptop is then used to initiate collection by the TPH sensor. We intend to configure the system to collect data every 15 minutes, although collections at other rates are possible. Once initiated, collections should be autonomous, and no intervention should be required.

- Other software on the laptop is used to initiate collection by the RF sensor. The RF sensor system software will be configured to collect snapshots every 15 minutes, and data products associated with each transmit location and each transmit frequency will be stored to the external hard disk. The software should be able to run autonomously, although periodic checking is recommended to ensure that the system is operational.

- The laptop will display outputs on the screen to provide indications of its status.

The specific outputs that will be stored by the sensor system are listed in

Table 1. Additional parameters may be added if deemed useful. A snippet of the time-domain received signal may be periodically stored (e.g., once per hour) to assist with signal association in post-test processing.

Table 1: Collected Parameters to be Stored on External Hard Disk.

Parameter Number	Description
1	Date/Time (based on computer clock)
2	Temperature (from probe deployed near base of tower)
3	Pressure (from probe deployed near base of tower)
4	Humidity (from probe deployed near base of tower)
5	Signal Power Level (for Tx signal 1 through Tx signal 9)
6	SNR (for Tx signal 1 through Tx signal 9)
7	Polarization parameters (for Tx signal 1 through Tx signal 9)
8	Signal Frequency (for Tx signal 1 through Tx signal 9)
9	Signal Quality Measurements (Tx 1 through Tx 9)
10	Noise Power Level (Tx 1 through Tx 9)

4.8 Tethered Balloon Operations

4.8.1 ND Tethered Balloon

Overview

The University of Notre Dame Vaisala DigiCORA Tethersonde Balloon system measures profiles of the atmospheric boundary layer through in-situ measurements utilizing tethered sondes. Profiles are obtained by varying the height of the sondes by way of the balloon and winch system. Data is transmitted to the SPS220T base station.

Contact information

Silvana Di Sabatino……………..… cell: 574-440-4650, silvana.disabatino@unisalento.it
Laura S Leo……………..……… cell: 574-339-5762, lleo1@nd.edu

Generator service: xxxxxxxxxxxxxxxx…………...…………….. cell: xxx-xxx-xxxx
Generator refueling: xxxxxxxxxxx…………………………. cell: xxx-xxx-xxxx

Location

The UND Tethered Balloon system will be located at the Sagebrush Site east of Granite Mountain.

Setup

Installation of the UND Tethered Balloon system will take place one week prior to the first operational day of the fall MATERHORN campaign. Setup will require three program members and will take approximately 2 hours. Helium tanks will be used fill the balloon. A temporary storage unit will also be installed to house the balloon while not in use. Additionally, the power generation unit will need to be on site and operational to complete setup.

Schedule
Operations of the UND Tethered Balloon system will be limited to IOPs with quiescent to moderate wind conditions.

Teardown
The UND Tethered Balloon system will be operational for the duration of the fall campaign but placed in storage at Dugway between the fall and spring campaigns. During non-IOP days, the balloon will be stored in an onsite storage shelter. Two staff members will be required for teardown and will require approximately 1 – 2 hours.

Staffing
The UND Tethered Balloon system requires two staff members to operate the winch, as well as attach the sondes to the tether line. Also, two staff members are recommended for taking the balloon in and out of storage.

Lodging
UND staff will stay at Desert Lodge Hotel, English Village, and may take occasional days off on non-IOP days.

Safety
The Tethered Balloon system should not be operated when surface level winds exceed 5 m/s.

System Maintenance

1. Generator refueling: The generator will require periodic refueling.

2. The tethered balloon will need to be filled with helium periodically as needed to insure full inflation. (Helium provide by Dugway)

3. The balloon shall be stored (maintaining inflation) in the onsite structure for protection when not in use.

Data
Data is saved in ASCII format. Data is transmitted from tethersondes to the base station and recorded locally. Data is taken in real time and stored by staff. Data will be checked for overall quality.

Data Access
All data will be given to Data QA (Silvana Di Sabatino) at the end of each IOP

Experimental Strategies
The Tethered Balloon system can be operated in a combination of two modes. The first "tower" mode is used to retrieve time-trace data at fixed balloon heights, utilizing up to six tethersondes. The second "traversing" mode sweeps the tethersondes vertically across the boundary layer to obtain profiles of measured quantities with height.
For Materhorn-X, the following strategy will be adopted: the profiles will be sampled every 30-60 minutes. Data will be collected on the slow ascent of the balloon. When the maximum height is reached (depending on meteorological conditions) the balloon will be brought down quickly – the descent data will be discarded.
Details about the maximum height reachable need to be discussed with Eric Pardjack.
The UND Tethered Balloon system utilizes two tethersondes. However, the number will be increased up to six if additional tethersondes can be provided by DPG staff and/or UoU.

4.9 Visualization

4.9.1 ND Thermal Infra-red (IR) Camera

Overview
The University of Notre Dame FLIR Systems ThermoCAM SC4000 IR camera (sensitivity <0.02 ºK) will be used to visualize surface temperature along the East slope of Granite Peak.

Contact information
Silvana Di Sabatino…………..… cell: 574-440-4650, silvana.disabatino@unisalento.it
Laura S Leo…………..……… cell: 574-339-5762, lleo1@nd.edu

Lodging
The UND staff will stay at Desert Lodge Hotel, English Village.

Location
The UND IR camera will be located at the base of the East slope of Granite Peak, about 1 m above the ground level, looking upward at the slope (fixed position).

Setup
Setup will require at least one program member and will take approximately 2 hours. One (desk) PC with serial interface, IR camera software and monitor will be provided by UND for operation of IR camera as well as for data storage.
Additionally, the power generation unit will need to be on site and operational to complete setup.
Final tests will be completed one week prior to the first operational day of the fall MATERHORN campaign. Depending on time availability, initial tests might be also done at the time of the dry run.

Schedule
The ND IR camera will operate during IOP days only.

Teardown
At the end of the fall campaign, UND staff will make sure that DGP staff has completed the inspection of the IR images/videos and approve them; after that, the UND IR camera will be shipped back to University of Notre Dame.

Staffing
As the UND IR camera operates autonomously, staff requirements are minimal.
A program member from UND will check the camera drive periodically to make sure that the instrument is functioning properly.

System Maintenance
Generator refueling: The generator will require periodic refueling.

Data Access
All data will be given to Data QA (Silvana Di Sabatino) at the end of each IOP.

4.9.2 ND Smoke Visualization

Overview
The UND will provide the following smoke visualization system:

1) ZV40,000 smoke release machine releases zero visibility oil to provide rapid sustained visual obscuration at a rate of 18 m^3/s.
2) A high Wattage 1W laser will illuminate a strip of the mountain so that smoke releases can be visualized.
3) Video Camera for recording.

Contact information
Scott Coppersmith: …………..……cell: 574-904-3694, RScott.Coppersmith.1@nd.edu

Location
The UND smoke visualization system will be located at the East middle slope of Granite Peak (fixed position), looking downward at the slope during the nighttime period.

Setup
Setup will require at least one program member and will take approximately 2 hours. Final tests will be completed one week prior to the first operational day of the fall MATERHORN campaign. Depending on time availability, initial tests might be also done at the time of the Dry Run.

Schedule
The UND smoke visualization system will operate during selected IOP days (two or three IOP only).

Teardown
At the end of the fall campaign, UND staff will make sure that DGP staff has completed the inspection of the images/videos; after that, the UND smoke visualization system (at least the video camera) will be shipped back to University of Notre Dame.

Staffing
The smoke visualization will be performed by Scott Coppersmith (UND staff) with the help of junior personnel.

Lodging
The UND staff will stay at Desert Lodge Hotel, English Village.

Safety
Smoke: Smoke is produced with petroleum hydrocarbon oil and contains no hazardous ingredients and causes no significant health hazards. If irritation occurs wash the affected area with soap and water. The oil is slightly flammable however requires preheating before ignition will occur.

Laser eye-safety: As with all use of lasers, proper laser safety goggles are required for all personnel in the vicinity of the smoke release.

System Maintenance
The smoke machine runs on gasoline and will require periodic refueling.

Data Access
The smoke visualization pictures taken must be scrutinized by the DPG staff and approved for release for research and publication purpose. The tapes will also be provided to DPG for future use and selected image sequences will be stored in the Materhorn database.

4.10 Doppler Lidars

4.10.1 UU Doppler Lidar

Summary of Goals

A. Development and structure of up- and downslope flows, especially transient behavior
B. Flow interactions between valley and slope flows
C. Support boundary-layer studies
D. Acquire data for data assimilation into 4DVAR, dual Doppler (?)

Site Selection

1. Site visit by Hoch Nov 2011. Investigated sites for UU.
2. Location of UU lidar –primary site ....

Equipment Performance and Programming
1. Doppler lidar -- assembled and tested ...

Power
1. Lidar - Tests necessary! Test with mobile generator.

Personnel

Contact Information

Safety

4.10.2 DPG Doppler Lidar

Instrument
WindTracer rented from Coherent Technologies Inc. (CTI)

Measured Parameter
Line-of-sight velocity, backscatter intensity

Deployment
??? - ???

Location
??? ºN, ???ºW

Data Availability
???

Staff

Proposed Lidar Scanning Strategies

4.11 Aersosol Lidars

…
…

4.12 PWIDS (Portable Weather Information Display System)

a. The WDTC-developed PWIDS consists of mobile meteorological measurement stations capable of collecting and displaying weather information at a predetermined rate. Each station consists of a tripod-mounted propeller-vane wind monitor, a temperature/humidity sensor mounted in a naturally aspirated radiation shield, a data logger, an optically isolated RS-232 interface, and a spread-spectrum radio/modem. Power is supplied by a solar panel and battery combination.
b. Typically, the measurement height is 2 m AGL, although many other configurations have been fielded that were anything but typical. In most uses, the PWIDS data acquisition rate is 1 Hz, and the data collected are averaged to 10-sec intervals. Accuracies of the R.M. Young 05103 wind monitor are ±0.2 m s^{-1} and ±3°. The Vaisala HMP-45 temperature/humidity probes are accurate to ±0.4°C for temperatures ranging from -20 to 55 °C and to ±2 percent for relative humidity (RH) ranging from 0 to 90 percent.
c. Pressure is measured with the Vaisala PTB-101B, which has an accuracy rating of ±2 hectopascal (hPa) over the temperature range of -20 to 45°C. PWIDS data are processed by the Campbell Scientific (Logan, Utah) CR1000 datalogger and forwarded via a FreeWave 902-928 MHz spread spectrum transceiver to the DPG Weather Station via a radio link and then routed to the test site through the DPG computer intranet or through a second radio network. Forty PWIDS will be deployed for FFT-07 [??]with lateral spacing of 150 m and a separation of 150 m between rows.

Note that this description is verbatim from the FFT-07 Test Plan (Storwald, 2007) https://www.fft07-slc.org/documents/TestPlan.pdf.

4.13 Wind Profiling Radar

The 924 MHz radar wind profiler is a ground-based, phased array pulsed radar designed to provide wind profiles in 100-m range gates from 100 m through several kilometers AGL. The radar emits radio energy along radial beams (vertical and tilted towards north or south and east or west) and then listens for returned signals, which are Doppler shifted in frequency by along-radial wind velocity components and reflected back to the radar antenna by density discontinuities in the atmosphere. The time-tagged radial velocity data are then resolved into along-wind, crosswind, and vertical velocity components at each range gate. These velocity components are used to produce vertical profiles of wind speed and direction. The wind profiling radar will be stationed near the CP and will be operated continuously with 15-min averaging during FFT-07.
Note that this description is verbatim from the FFT-07 Test Plan (Storwald, 2007) https://www.fft07-slc.org/documents/TestPlan.pdf.

4.14 FM-CW Radar

The FM-CW radar uses Bragg scatter from atmospheric refractive index inhomogeneities to observe, in fine detail, the turbulence and wave structure within the planetary boundary layer (PBL). When pointing vertically and operated in a range-only mode, the FM-CW radar produces time-height refractive index profiles that can be used to identify boundary layer growth and collapse, daytime convection, and wave structure in the nocturnal residual layer. The FM-CW radar uses a linear, continuous, sinusoidal, waveform in the 3-GHz range (10-cm wavelength) swept over a 200-MHz band. The frequency emitted at one part of this band propagates vertically, with a portion of the energy backscattered to the receiving antenna where it is differenced against the original transmitted frequency. The resulting beat frequency is proportional to the range at which the backscatter occurred, and the signal magnitude is proportional to the strength of the index of refraction variation. FM-CW radar resolution is on the order of 1 m in range and a few seconds in time, providing detailed boundary layer time-height sections. The FM/CW radar is located at Horizontal Grid at DPG, which is approximately 7 miles northwest of the FFT-07 test grid. Note that this description is verbatim from the FFT-07 Test Plan (Storwald, 2007) https://www.fft07-slc.org/documents/TestPlan.pdf.

5 Aircraft Operations

Stephan please fill this in.

A. Appendix: FLIGHT PLANS

A.1 Draft plan for Twin Otter Doppler Wind Lidar Flights

The Navy Twin Otter will be based at U42, the South Valley regional Airport in Salt Lake City. Approximate ferry time from U42 to Granite Mountain is about 30 minutes. The maximum flight time of a complete mission is around 4 hours. While exact numbers still have to be worked out, we anticipate having 6 to 7 missions in the time period between 5 and 17 October. On the ferry flight to and from CIRPAS in Monterey, CA, (4 and 18 October, respectively) the Twin Otter will fly over Granite Mountain if possible.

All missions will have a specific flight pattern in common. The flight pattern is centered aound Granite Peak and consists of along-wind and across-wind legs where the along wind direction is determined by the average wind direction between 700 and 850 mbar shortly before arrival of the Twin Otter at DPG. Along wind flight legs will be about 30 km, across wind legs will be around 20 km. These distances are based on the anticipated predominant westerly wind direction and the larger scale of Granite Mountain in the north-south direction relative to the scale of Granite Mountain in the east-west direction. The along- and across wind legs will take place at an altitude of 12,000 ft MSL with the wind lidar looking down and scanning in a step-stare pattern. The goal of these legs is to obtain wind-profiles from 11,000 FT MSL to 1,000 ft AGL of the horizontal and the vertical wind components every 1.5 to 2 km. If the boundary layer is deeper than 11,000 feet at the time of arrival at DPG, the Twin Otter can fly 1,000 ft above the top of the boundary layer but with supply of oxygen to pilots and instrument operator(s). After completion of the along-and across wind legs, horizontal flight legs along the mean wind direction will be flown at 2 to 4 levels in the boundary layer, depending on the available time and interest. The goals of these legs will be the collection of in-situ flux data in a plane across Granite Mountain. In addition, the Twin Otter may occasionally fly to within several hundred feet above the surface for comparison with in-situ flux measurements at the various towers. In the latter situation of near-surface flight legs, we must ensure that no tethered balloon, radiosonde balloon, and UAV operations take place to ensure maximum safety of the mission. Slides 1 and 2 in the attached powerpoint shows a draft of the flight pattern for situations with a synoptic (700-850mb) wind direction from the west and from the northwest, respectively.

The flight missions can take place at any time of the day. Below are the 'standard' flight time scenarios. It is assumed that local time of sunrise and sunset is at 0730 and 1900 LT, respectively. It is assumed that every mission takes four hours with a minimum time between landing and take-off for next flight at U42 of two hours.

1. Early morning mission. 0600-1000; at DPG between 0630 and 0930
2. Mid-morning mission. 0900-1300; at DPG between 0930 and 1230
3. Noon-mission 1200-1600; at DPG between 1230 and 1530
4. Afternoon-mission 1500-1900; at DPG between 1530 and 1830
5. Evening-mission 1800-2200; at DPG between 1830 and 2130

On one given day, we can do, for example, a mid-morning and afternoon session or an early morning and a noon session. We cannot do a combination of an early morning mission and an evening mission the same day or a combination of an evening mission and an early morning session the next day because of the 12-hour limit for pilots.

Coordination with UAV operators, tethered and radiosonde balloon operators, and wind lidar operators is required prior to the mission.

A.2 Draft plan for Flamingo
Transects east of Granite Peak

A.3 Draft plan for DATAHAWK
Profiles over Playa or Sage Brush
Gap dual basin Missions – fly in the Gap to the south of Granite Peak between Saphire and Dugway Mountains. Profiles will be done over the playa basin and then again over the Sage Brush basin region to the south east of granite

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