SCP nontechnical experiment plan

7 June 2012

1 Motivation

Extensive advances have been made toward understanding cold pool formation in well-defined deep basins and depressions. However, little is known about the more common shallow or marginal cold pools. With weak largescale flow and clear nocturnal skies, all but the flattest terrain leads to shallow cold pool formation that may be embedded within deeper large-scale cold pools, such as basin scale. Shallow cold pool formation may lead to high concentrations of contaminants, cold surface temperatures and occasional dense fog formation. Based on existing data from eastern Colorado, even shallow cold pools can persist for several hours after sunrise.

Ubiquitous shallow cold pools form in small valleys (and gullies) when the downvalley slope is weak or the downvalley flow is restricted at locations where the valley narrows. Our casual mapping of the horizontal distribution of the nocturnal surface temperature using hand held or vehicle mounted thermistors suggests that the weak-wind nocturnal boundary layer can often be viewed as numerous shallow cold pools on various scales that interact with always-present submeso motions. Submeso motions include gravity waves, microfronts and more complex structures on time scales of minutes or tens of minutes. The entire weak-wind system can be viewed as interaction between the weak mean flow, nonstationary drainage flows from higher terrain outside of the cold pool, submeso motions, nonstationary downvalley flow within the cold pool and thin side slope drainage. Quantification of this nonstationary system probably requires stochastic considerations.

We anticipate four scenarios:

1) Clear skies with very weak flow. The drainage flows dominate the local
circulations and include drainage flows in the upper shallow gullies, drainage down side slopes, and weaker colder flow within the main “valley” cold pool characterized by a very weak down valley slope. The behavior of the merging flows from the upper gullies is also an important part of this system. This flow system may or may not be interrupted by submeso motions.

2) With more significant large-scale flow, thin clouds or partial cloud cover, the drainage flows and valley cold pool may be maintained only intermittently and disrupted by shear instability.

3) With still stronger large-scale flow or more cloud cover, weak variations of temperature near the surface may develop, but they are not sufficiently strong to significantly alter the wind field.

4) With strong winds or cloudy skies, the wind and air temperature are horizontally uniform.

This speculation is supported only by casual observations and thus the need for a rigorous field program. The instrument configuration was designed with the recognition that no configuration will be optimal for this variety of potential flow situations.
2 Configuration of the network

The network spans a small shallow valley about 500 m across and about deep.** The three types of towers are sketched in Figure 3. The approximate locations of the towers are recorded in Figure 4. The main tower is designed to provide relatively dense resolution in the lowest 5 m that might include resolution of the wind maximum associated with slow drainage down the main valley. The courser resolution from 5-20 m provides some information on waves and other nonstationary submeso motions over a deeper layer.

The 19 A stations span the main valley, the side slopes and the two shallow upper gullies where they feed into the main valley. The main tower and the C tower are located in the center of the valley. The booms for the sonic anemometers on the towers will be pointed westward in anticipation of drainage flows and generally north-south large-scale flows. Final staking will be done on approximately 10 September.

The surface energy budget at the main tower is primarily for generality of the dataset for other users and will be used only qualitatively for the current
Figure 2: Upper gullies looking SW and one of the onsite houses available for rent.
project. The C tower provides information on the down valley drainage flow as it exists the experimental region.
Figure 3: Tower configurations for the A towers, the main tower and the C tower.
Figure 4: Plan view of the entire domain. The yellow pins identify the numbered A stations. The main tower (red M) is located in the middle of the easterly transect (green line) and tower C (red) at the east end of the network. S refers to the sodar at the same approximate position. The red line identifies the OSU network. The westerly green line shows the Picarro CO2 line. P refers to stations with pressure sensors. Booms for the sonics will be pointed westward. For reference, 100 m horizontal distance is indicated in the lower left of the plan view. See the Table for more information on the A stations.
TABLE 1: A-station number, extra sensors (P=pressure, H - hander), comments. Should Handars fail, the lowest priority would be H5, followed by H4 and H3 and then undetermined Handars on the main tower.

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2.1 Pressure sensors

Because the cold air in the gullies at SCP is likely to “slosh” around in association with fluctuating horizontal pressure gradients, possibly connected with wave-like motions, it would be useful to measure the pressure contribution to the total energy of the waves and other submeso motions (e.g. intermittent drainage fronts). In order to do so, we need to have pressure sensors co-located with sonic anemometers if possible, so we can calculate \( \frac{\partial \bar{u}' p'}{\partial x} \), \( \frac{\partial \bar{v}' p'}{\partial y} \), and \( \frac{\partial \bar{w}' p'}{\partial z} \), which should be dominated by the wave related pressure perturbations.

SCP will install the EOL Vaisalla pressure sensors. Three pressure sensors \((P_1, P_2, \text{ and } P_3)\) can be installed on the main tower. Using these measurements with the co-located sonic anemometers, we can estimate \( \frac{\partial \bar{w}' p'}{\partial z} \). The A towers associated with \( P_4, P_6, P_7 \) are approximately on the same el-
evation above sea level, and the A towers associated with $P_8$, $P_9$, and $P_{10}$ are on the same elevation. With the two triangle setups, we should be able to study propagation of waves and other nonturbulent disturbances. $P_4$ together with the 3-D sonic anemometer at the A tower up gully from the main tower should be aligned with one of the pressure sensors with a 3-D sonic anemometer on the main tower (possibly the one at 3 m depending on the gully slope). By doing so, we can calculate the horizontal pressure gradient along the gully axis. For the same reason, $P_5$ on the A tower downslope from the main tower should be aligned with one of the pressure sensors with a 3-D sonic anemometer on the main tower (possibly at 1 m depending on the exact gully slope).

2.2 Undecided

1. Effective height of the air sampled by the TRH sensors deployed at 0.5 m?

2. There was also discussion of a digital camera at the top of the tower. Motivations include snow distribution, early evening and morning shadow distributions, an overview of any fog releases and any undesired activity by 2 and 4-legged creatures. I assume with a 20 m tower, the domain of the digital camera will be rather small.

3 Additional Instrumentation

3.1 Fogger

The fogger (Rosco Alpha 900, 120 volts, 10 amps) is approved for indoor use (e.g., stage fog). Examples of releases can be found at http://www.youtube.com/watch?v=8fu1bvGI. The released fog will be videoed to examined the flow of different layers of drainage flow and stagnant air at the surface. Preliminary work has been completed on inference of 2D velocity vectors from the video data.

3.2 Fibre-optic system

The fiber optic system provides a cross valley fast response measurement of the structure of the disturbances, as inferred from the fluctuating temperature field.
The fiber optic cross section is sketched in Figure 5. The distributed fiber-optic temperature sensing (DTS) will be deployed with three strands at different heights to construct a time dependent temperature cross section (Figure 5). The DTS uses a short laser pulse sent down an optical fiber to sense its temperature, which is a direct function of the temperature of the air that surrounds it. DTS temperature measurements employ the amplitude ratio of the amplitudes of the back-scattered Stokes to the anti-Stokes signals. The Stokes and anti-Stokes signals are the result of the Raman effect, in which incident light interacts inelastically with the electrons in the molecular bond. The ratio of these signals provides a quantity independent of light intensity that depends only on the temperature of the fiber at the location identified by the two-way travel time of light since the time of injection. Since only a small fraction of the incident light is scattered in an optical fiber, signal strengths are very low, which is the primary limitation on the precision of DTS measurement. Temperature resolution approaching 0.01 K is possible when averaging over periods of several minutes. We will deploy a very recent high-resolution DTS instrument with a high temperature (\( \leq 0.1 \) K) and spatial resolution (0.125 cm) achieved at a much faster sampling rate of 1 Hz.

The Fiber-Optic Sodar systems have web capabilities / links and Christoph downloads / checks / verify datas at least on a daily basis remotely. This has proven very successful over the years requiring little being-on-site time. Steve and Christoph talked in Feb about Christoph using your web /cell phone link. Alternatively, Christoph can bring his cell phone modems if linking the tow ersystems proves too difficult.

EOL has been requested to: 1) swap a card every 11 days, 2) refill the ice bath every 3 to 4 days in one of the containers (the cool bath, the hot bath has an aquarium heater) and 3) possibly restart a PC for the fiber optic system (historically, this has been required at most once per month).

### 3.3 SODAR

The SODAR measures winds over a deeper layer that provides estimates of the depth of the submeso motions.

The proposed SODAR is a commercially available system of a monostatic, phased-array design that uses a sequence of short (0.5 seconds) audible sound pulses to sample the three-dimensional wind field in the air volume above the instrument by comparative analysis of the backscatter. The acoustic array of transceivers is shielded by a 2.5 m (8 feet) tall sound shield lined
Figure 5: The fiber optic transect operated by Christoph Thomas. The number of sonic anemometers will likely be reduced pending budget/manpower considerations.
with sound-absorbing foam on the inside to minimize the potential impact of the sound pulses on the surrounding environment and to protect the array from environmental noise to enhance data quality. When standing next to the operating sodar, a normal conversation can be conducted. Testing the SODAR with heart rate-monitored rabbits showed no increase in stress or heart rate due to the SODAR chirps. However, stress was observed with isolated, non-repetitive event noises.

3.4 Picarro

Jielun Sun will supervise a $CO_2$ measurement system. The Picarro analyzer will provide information on the $CO_2$ and water vapor budgets and, more importantly, provides a tracer for tracking different air masses (drainage flows from different sources). The Picarro analyzer measures $CO_2$, water vapor, and $CH_4$ simultaneously at 1 Hz from 16 inlets. The current proposal includes 2 inlets on the main tower for the profile measurement. The 2 inlets can be co-located with the 2 LICORs, providing calibration and comparison for the LICOR measurements. 6 inlets will be deployed across the main gully transect next to the fiber-optical cross section (red line, Figure 4) nominally at a height of 0.5 m. 4 additional inlets will be placed across the main cross gully transect (eastern green line, Figure 4). The remaining two inlets on the One of the A stations will be used for installation of inlets at 0.5 and 2.0 m. The Picarro analyzer itself will be located close to the main tower. All the inlets can be moved easily should initial analyses suggest a better configuration.

3.5 Snow measurements

A grid will be traversed with a Mattew Sturm Magnaprobe that measures the depth and GPS coordinates. At as many points as possible over the study area. The snow surveys can include patchy snow of just a few cm thick. Then, we would core the snow with a federal sampler at a few points and dig shallow snow pits within the snow (no dirt removal) at a few points should the snow be deep enough. These measurements provide snow water content. This work will be carried out by a student of Jessica Lundquist (Nic Wayand who will be at NCAR) and Martyn Clark (NCAR). This all assumes that there is a snow event.
4 Some details

4.1 Participants

Larry Mahrt, mahrt@nwra.com  541 754 7501  
Christoph Thomas, chthomas@coas.oregonstate.edu, fiber optic system and  
attendant sonics/thermocouple profile  
Tom Horst, horst@ucar.edu  
Steve Oncley, oncley@ucar.edu, ISFS representative  
Steve Semmer, semmer@ucar.edu, Field operations  
Jielun Sun, jsun@ucar.edu, Picarro CO2 system, pressure  
Jessica Lundquist, U. Wash. jdlund@u.washington.edu, snow surveys for any  
snow events. Her team includes Nic Wayand nicway@gmail.com, and Mar-  
tyn Clark mclark@ucar.edu.

5 Dates

Staking and setup begins 10 Sept.

    Field Program 1 Oct - 1 Dec

5.1 preliminary on site schedules for non-NCAR personnel

Larry Mahrt 10-24 Sept, 17 Oct - 10 Nov. and possibly more.

Christoph Thomas 20-30 Sept, 17-24 Oct, 1-5 Dec

OSU student with Christoph, 20-30 Sept

Jessica Lundquist, 5-9 November.
5.2 Lodging

According to Lindsey Hoffner, getting a refund is a hassle and one might wait until dates are known for sure.

See

http://sgsric.colostate.edu/facilities.aspx

or contact lindsey.hoffner@colostate.edu

5.3 In the field

Larry will work with EOL personnel to obtain NetCDF files in the field for immediate analysis.

Nic Wayand, who is a student of Jessica Lundquist and will be working at NCAR, might be available for a day or two should assistance be required during setup or during the field program.