REQUEST FOR ISFF SUPPORT

FLOSS

NCAR/ATD- April 2001OFAP Meeting

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Project Description

Project Title	**Fluxes over snow surfaces (FLOSS)**
Co-Investigator(s) and Affiliation(s)	Dean Vickers Jielun Sun (NCAR)
Location of Project	**North Park, Colorado**
Start and End Dates of Project	**18-28 February and 1-10 April 2002**

Abstract of Proposed Project

Research has been proposed to NSF, Atmospheric Sciences Division, to study turbulent transport in thin drainage flows and very stable boundary layers. Very stable boundary layers occur due to weak ambient flow and strong nocturnal radiative cooling over snow surfaces and stable stratification due to advection of warm air over cooler surfaces such as snow. The surface-based turbulent stable boundary layer may be only 5-10 m deep, creating large vertical divergence of the flux. This strong vertical divergence renders traditional eddy correlation measurements inapplicable to surface layer similarity and estimates of surface fluxes, as discussed below.

The relative contribution of the downward heat flux to snow melt is poorly understood. Recent model comparisons have shown that the parameterization of the downward heat flux to the snow surface leads to large differences between models and significant discrepancies with observations of snow pack melt. The time-dependence of the roughness length of the snow surface is also poorly understood.

Proposal Summary

We propose to address two separate problems with the same instrumentation: 1) transport in thin nocturnal drainage flows and very stable boundary layers, and 2) the influence of downward heat transport on snow melt.

Drainage flows, pooling of cold air and thin very stable boundary layers are often too shallow to estimate surface fluxes from standard observational levels and standard instrumentation. Over grasslands and short crops, we have commonly observed drainage flows of only a few meters deep and stable boundary layers less than 20 m deep. For these common cases, flux measurements are required at 1 m or below. We think the normal practice of making flux measurements at several meters and higher partly explains severe closure problems for the surface energy budget with very stable conditions. We also anticipate shallow boundary layers in warm air advection over snow surfaces due to a combination of strong stratification and very small surface roughness.

Physical understanding and reliable modeling of snow pack are crucial to understanding climate change since snow cover completely alters the exchange of heat and moisture between the surface and atmosphere. We contend that substantial improvements in certain snow pack model components are required before regional and global models can more successfully simulate snow pack evolution and its impact on water supplies and role in climate change. Recent comparisons of snow pack models with observations (Boone and Etchevers, 2001) suggest that model differences and errors are due mostly to differences in formulation of turbulent fluxes between the atmosphere and the snow surface and model simulations are particularly poor in advection of warm air over snow surfaces. However, more definite statements are not possible because of general lack of eddy correlation data and expected serious underestimation of fluxes in very stable conditions. Deploying sonic anemometers sufficiently close to the ground surface in thin drainage flows and thin stable boundary layers may lead to significant flux loss due to pathlength averaging, as can be predicted from universal cospectra and arguments in Kristensen and Fitzjarrald (1984).

Our recent comparisons between sonic anemometers and hot film anemometers at a flat grassland site near Oregon State University suggest that pathlength averaging by sonic anemometers eliminates more than 50% of momentum flux at a measurement level of 0.5 m. The flux loss increases with increasing stability or decreasing wind speed but decreases with height and appears to be small above 2 m. Of course in very stable boundary layers and thin drainage flows, 2 m is too high to estimate the surface flux. This momentum flux loss further implies that the sensible and latent heat fluxes are also significantly underestimated.

Except for intrinsic limitations of instrument response time and preprocess filtering, the sampling rate should not be a serious limitation since the flux at higher frequencies is folded back onto resolved frequencies by aliasing (Stoughton and Miller, 2000), provided that the record length is sufficiently long. The framework for assessing high frequency flux loss due to pathlength averaging and other difficulties is presented in Massman (2000), who concludes that more work is needed for stable cases.

We propose to deploy three-component hot film anemometers, similar to Miller et al. (1989), with a 3 mm pathlength. The pathlength is 30 times shorter than that for conventional sonic anemometers. While hot film anemometers greatly reduce the path averaging problem compared to sonic anemometers, they are more labor intensive. Hot film anemometers require frequent calibration and are characterized by small wind direction acceptance angle. The latter is a serious problem with light and variable winds. Our system, developed by David Miller, calibrates once per hour with an automated sleeve, which creates zero flow conditions for a 40 s period. We propose to deploy two hot film systems at the same level in two different horizontal directions. Before deployment, we must replace the present bridge with a linear version for more accurate wind tunnel calibration.

Can the hot film anemometer data be used to construct a general correction procedure for the sonic anemometer? Can existing similarity models for cospectra be extrapolated to higher frequencies or is a new approach required? Can information on high frequency momentum flux loss be used to guide correction for heat and moisture flux loss?

HYPOTHESES

The usual conceptual view of a stable internal boundary layer forming at the upstream edge of warm air advection over a cooler surface, such as snow, is questionable. Advection of stronger turbulence from the upstream warmer surface over the cooler air adjacent to the new surface leads to vertical structure where the turbulence increases with height and the vertical transport of the turbulence is downward toward the surface. Our attempts to model this transition with state-of-the-art models has failed and more observational information is needed to improve parameterizations.

Complex vertical structure also occurs with formation of local slope flows. Air above the drainage flow, being decoupled from the surface stress, accelerates and often forms a low-level jet. Eventually shear-generated turbulence bursts downward toward the surface, leading to elimination of the drainage flow and warming. We hypothesize that surface layer similarity theory does not apply to these non-traditional boundary layers, without further modification. The new instrumentation will provide an excellent opportunity to evaluate and possibly modify surface similarity theory for very stable conditions.

PREVIOUS EXPERIMENTS OF THIS TYPE

We conducted cold air drainage observations in a gully as a sub-program in CASES99. Our analysis of this data indicated formation of thin drainage flows down local slopes on most nights, particularly before midnight (Mahrt et al., 2000). After midnight, turbulence generated by shear associated with the low-level jet, extended downward to the surface and often eliminated the local slope flows. Since the depth of the local drainage flows generally ranged between 1 and 4 m, sonic anemometers at standard heights (5, 10 m) were unable to estimate surface fluxes. We need to make eddy correlation measurements closer to the surface, which in turn may require new instrumentation such as hot film anemometry.

We are currently conducting observations of surface fluxes over snow-covered and bare surfaces in Central Oregon. The site is in complex terrain with sparse Ponderosa Pine and the spatial variability of the flow is complex. We look forward to the simpler North Park site.

EXPERIMENTAL DESIGN

Two 10-m towers are requested to measure momentum, heat, moisture and carbon dioxide fluxes and radiative components of the surface energy balance for the last ten days of February and first ten days of April, 2002. These are the two intensive observing periods of EX-7, a NASA/NOAA snow pack field program, which concentrates on remote sensing and ground measurements of snow pack. We would also like to operate between the two intensive periods if the site is found to be sufficiently secure.

We propose to deploy sonic anemometers and fast response thermistors at 3 and 10 m height to study the vertical flux divergence in those stable boundary layers where flux loss is not found. We also propose to deploy two hot film anemometers with different boom directions at 0.5 m to estimate surface fluxes and a third system at 3 m for comparison with the sonic anemometer. The second tower will be implemented with one sonic anemometer only and a fast response moisture sensor, which would double as a backup should the one on the first tower fail.

Jielun Sun and Sean Burns of NCAR will implement thermocouple measurements on the tower at 1-m intervals. We will also deploy a downward looking sonic to measure changes of snow depth. The 2-D Handar sonic anemometers and slow response thermistors are also the responsibility of Oregon State University. Measurement of heat flux in the snow pack is currently under investigation.

Figure 1 outlines one project scenario. The tower locations will take advantage of preferred locations of snow fields in the North Park area. If one or both towers are located in snow during the intensive period, then the main goals of the project can be realized. If the towers straddle the snow line during the observational program, then flow adjustment and possible local circulations can also be studied.

REFERENCES

Boone, A. and P. Etchevers, 2001: An intercomparison of three snow schemes of varying complexity coupled to the same land-surface and macroscale hydrologic models. Part I: Local scale evaluation at an Alpine site. Submitted to *J. Hydro.*

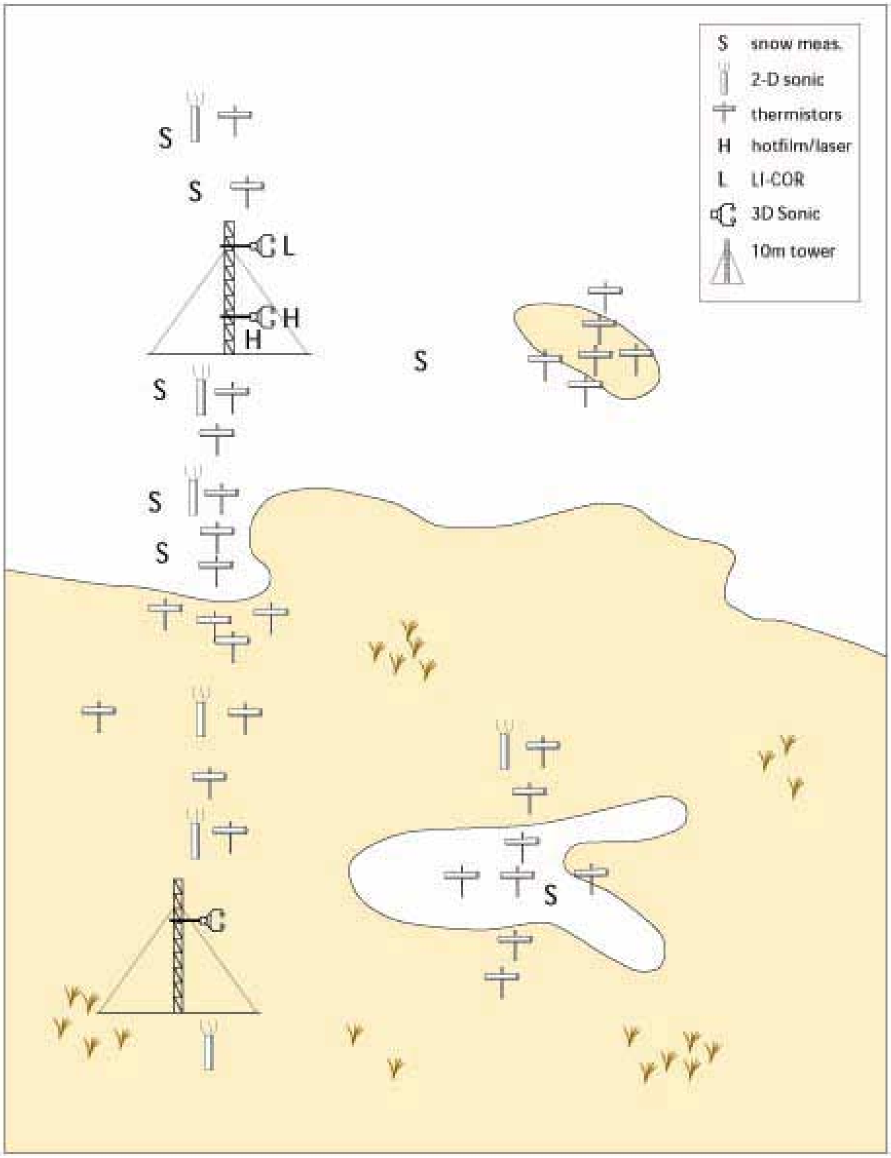
Mahrt, L., D. Vickers, R. Nakamura, J. Sun, S. Burns and M. Soler, 2000: Shallow drainage and gully flows. submitted to Bound.-Layer Meteorol.

Massman, W., 2000: A simple method for estimating frequency response corrections for eddy covariance systems. Ag. and Forest Meteorol., 104, 185-198.

Miller, D, J. Lin, Y. Wang and H. Thistle, 1989: A triple hot-film and wind octant combination probe for turbulent air flow measurements in and near plant canopies. Ag. and Forest Meteorol., 44, 353-368.

Kristensen, L. and D. Fitzjarrald, 1984: Effects of line averaging on scalar flux measurements with a sonic anemometer near the surface. J. Atm and Oc. Tech., 1, 138-146.

Stoughton, T. and D. Miller, 2000: Turbulence sampling in the nocturnal stable surface layer above a forest canopy. Submitted to Ag. and Forest Meteorol.



Educational Benefits of the Project

List anticipated number of graduate students involved in observation and analysis:

One Ph.D. student, Reina Nakamura, will participate in the project and will focus on cold air drainage and spatial variability. We may also employ one undergraduate student.

List other students who might help in the field phase:

Not answered

Previous Research Project Experience

Past ATD support:

I have recently participated in the ATD Microfronts and CASES99 projects, which led to the following publications:

Publications resulting from past ATD support:

Mahrt, L., 1998: Flux sampling strategy for aircraft and tower observations. J. Atm. and Oc. Tech., 15, 416-429.

Mahrt, L., 1998: Stratified atmospheric boundary layers and breakdown of models. J. of Theor. and Comp. Fluid Dyn., 11, 263-280.

Mahrt, L., 1999: Stratified atmospheric boundary layers. Bound.-Layer Meteorol., 90, 375-396.

Mahrt, L., Sun, J., Blumen, W., Delaney, A., McClean, G. and Oncley, S.: 1998, 'Nocturnal Boundary-Layer Regimes', Bound.-Layer Meteorol., 88, 255-278.

Mahrt, L., D. Vickers, J. Sun, N. O. Jensen and H. Jorgensen, 1999: Determination of the surface drag coefficient. To appear in Bound.-Layer Meteorol.

Mahrt, L., D. Vickers, R. Nakamura, J. Sun, S. Burns and M. Soler, 2000: Shallow drainage and gully flows. submitted to Bound.-Layer Meteorol.

Mahrt, L., E. Moore, D. Vickers and N.O. Jensen, 2000: Dependence of turbulent velocity variances on scale and stability. To appear in J. Appl. Meteorol.

Ha, K.-J. and L. Mahrt, 2000: Simple inclusion of z-less turbulence within and above the modelled nocturnal boundary layer. To appear in Month. Wea. Rev.

Expected publication date and journal:

We expect to publish our new results in Boundary-Layer Meteorology and Advances in Water Resources in 2003.

Funding Agency Information

Funding Agency	National Science Foundation, Physical Meteorology
Contract Officer	Roddy Rogers
Contract Identification	Transport in Stable Boundary-Layers and Thin Drainage Flows: A New Direction.
Proposal Status	Under review
Approximate Amount budgeted	120 K.

ISFF Request

System requested	Number of Systems	Number of Sondes
ISFF	2	N/A

Scientific rationale for the use of the system in the proposed project:

The two systems would be used to measure the flux divergence and components of the surface energy budget over a snow covered surface.

Is a SSSF Scientific Project Manager needed for the project?

A Scientific Project Manager is needed.

Summary of any special requirements that pertain to SSSF support:

If possible, we would also like to log our three hot film anemometer systems into the NCAR data system at 100 HZ.

Has a SSSF scientist been consulted to help complete this request?

I have consulted with Steve Oncley to help complete this request

Data reporting and averaging intervals required for ISFF:

We do not require any averaging and would prefer to record the sonic anemometers at a minimum of 20 Hz. We would also prefer to avoid pre-process filtering.