SESSION 1: BOUNDARY-LAYER FLOW AND TURBULENCE

Plenary: Goals and Expectations

Dr. Petra Klein

Professor and Edith Kinney Gaylord Presidential Professor,
Associate Director for Graduate Programs

School of Meteorology, University of Oklahoma, Norman, OK, USA

Agenda

Session I: Boundary Layer Flow and Turbulence

8:30- 8:40: Plenary - Goals and expectations of Boundary Layer Flow and Turbulence (Petra Klein)

8:40-9:40: Overview Presentations (three 20 min presentations)

1. Stable Boundary Layers
2. Convective Boundary Layers and Entrainment Processes
3. Influence of Topography and Land Use

Main goal: Identify Science Frontiers
We all stay together!

9:40-10:00: Discussion **Introduction of Breakout Moderators**

10:00-10:15: *Break* (move to breakout rooms) set up posters (new and emerging technologies), posters will remain

10:15-11:30: Session I Breakout Groups

1. Stable Boundary Layers
2. Convective Boundary Layers and Entrainment Processes
3. Influence of Topography and Land Use

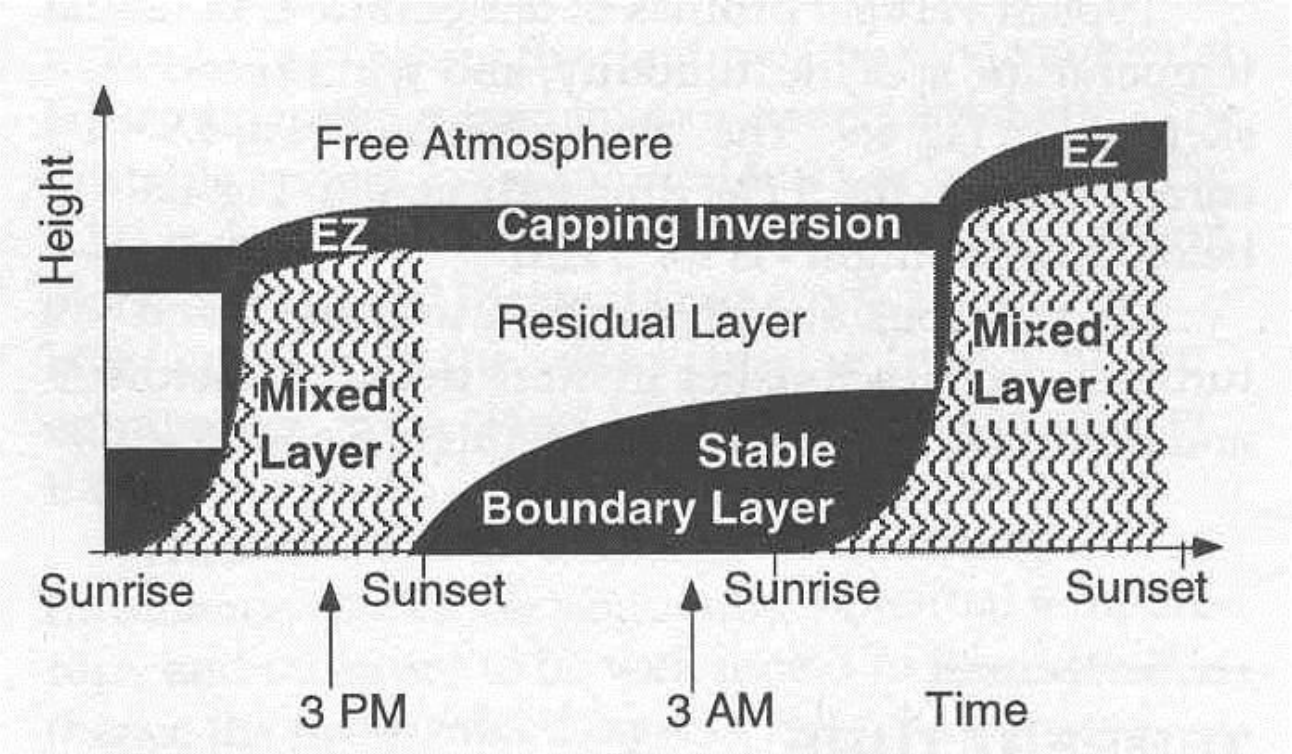
Main goal: Match Science Frontiers with Instrumentation
We break up in 3 groups!

11:30-12:15: Plenary - Summary from each breakout session and brief discussion/clarifications

Reports from Breakout Moderators and Joint Discussion of Science Frontiers and Related Observational Needs

Atmospheric Boundary Layer

- Diurnal cycle of the ABL under fair weather conditions



R.B. Stull, 2000: Meteorology for Scientists and Engineers. Brooks/Cole. .

Boundary-Layer Flow and Turbulence – Stability Effects

Convective BL

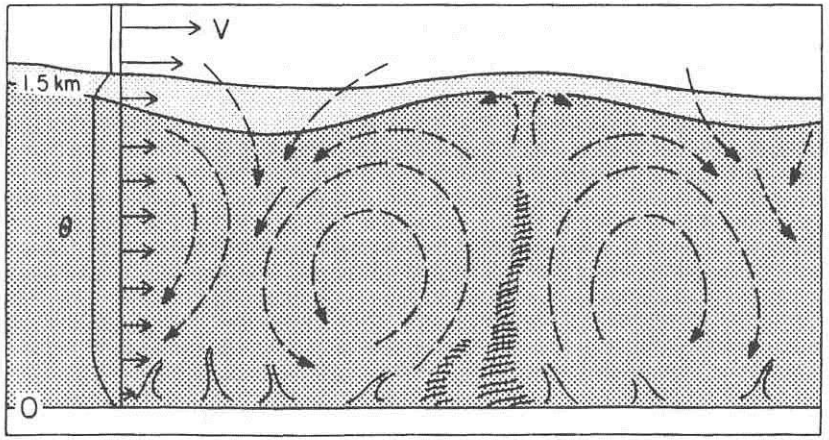


FIG. 1.4. Schematic of convective boundary layer circulation and entrainment of air through the capping inversion (from Wyngaard, 1990).

Stable BL

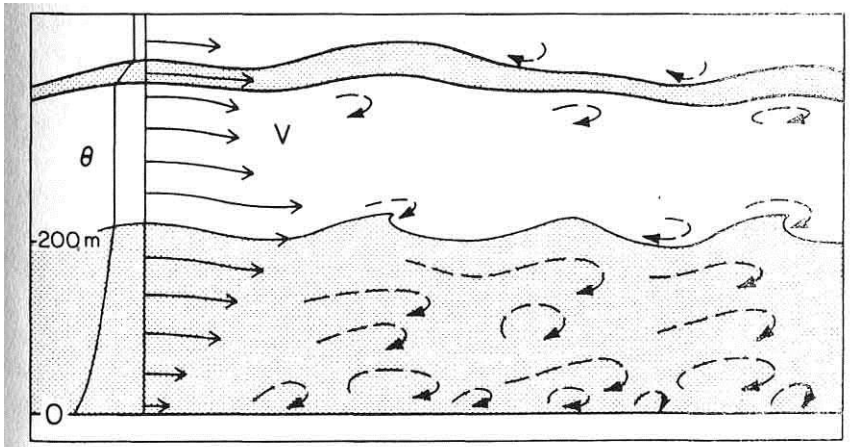


FIG. 1.5. Schematic of stable boundary layer flow showing eddy structure, waves, and elevated inversion layer (from Wyngaard, 1990).

J. C. Kaimal, J.J. Finnigan, 1994: Atmospheric Boundary Layer Flows. Oxford Univ. Press .

Boundary-Layer Flow and Turbulence – Influence of Topography and Landuse

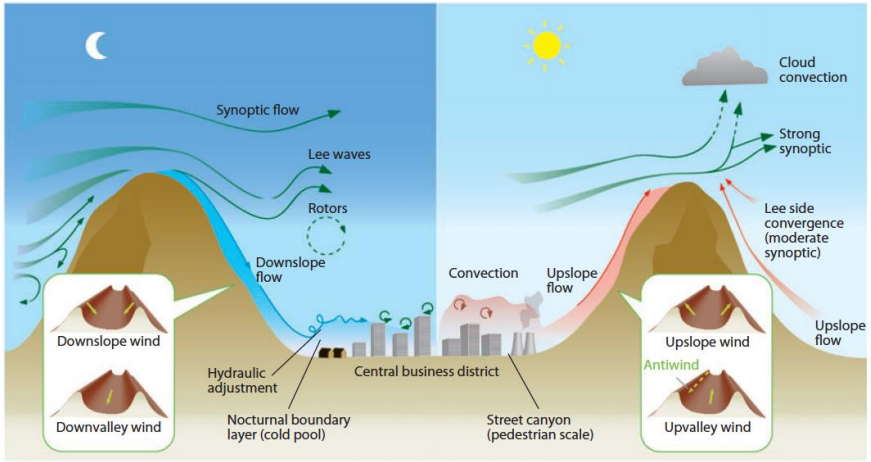


Figure 1

Some basic flow types of an urban atmosphere in complex terrain. The left panel shows nocturnal conditions, and daytime conditions are on the right.

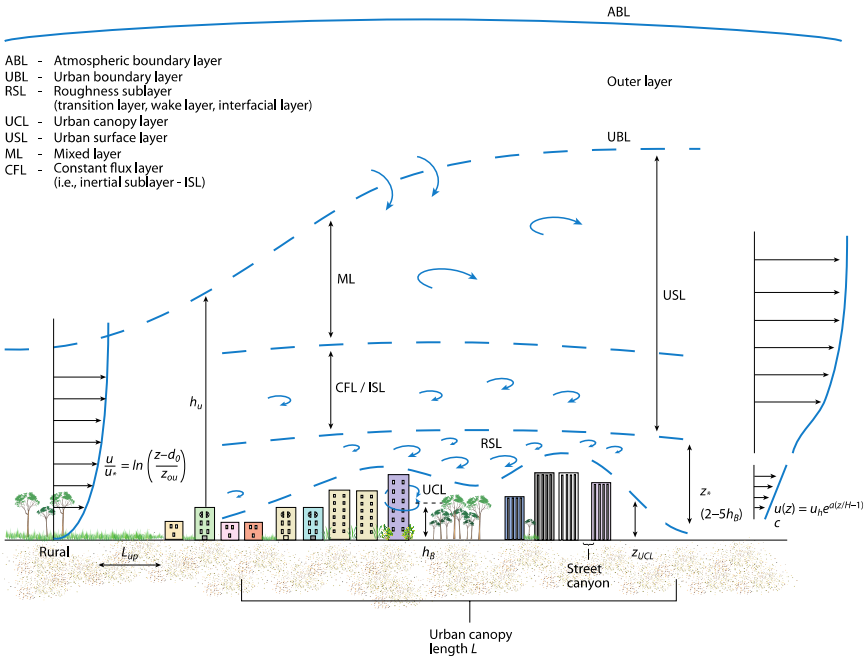


Figure 9

Various zones of the urban boundary layer (e.g., Oke 1988). The typical logarithmic form of approach velocity (d_o and z_o are the displacement and roughness heights, respectively) and exponential form of in-canopy average velocity proposed by Cionco (1965) are shown. Here a is an attenuation coefficient, and u_h is the approach velocity at the average canopy height h_B. The velocity profile in the constant flux layer is also logarithmic, having similarities to a rough wall boundary layer.

Fernando, H.J.S., 2010: Fluid Dynamics of Urban Atmospheres in Complex Terrain. *Annual Review of Fluid Mechanics*, 42:1, 365-389

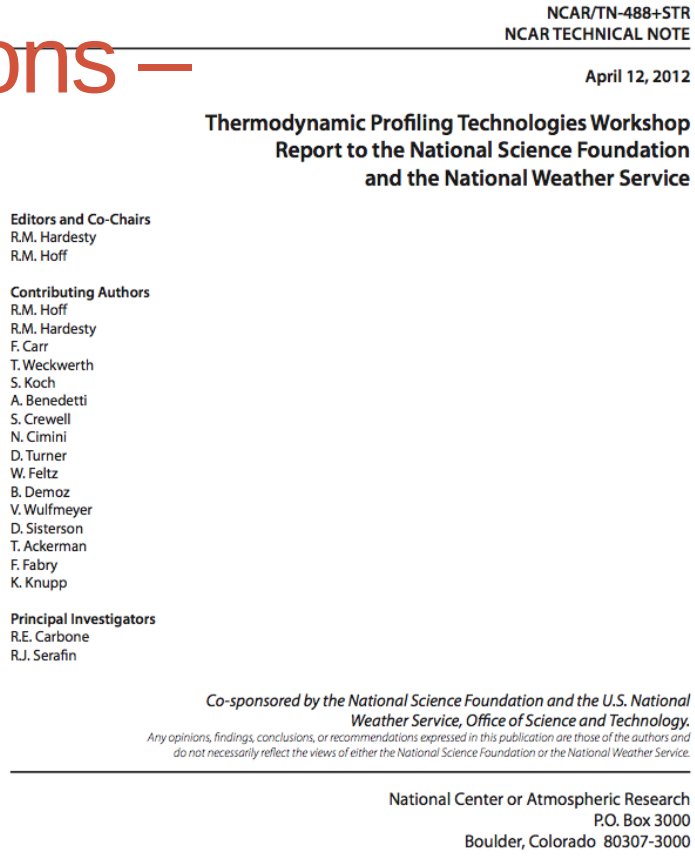
Boundary-Layer Observations – Applications and Needs

- **Highest priorities identified in NRC report:**
  - height of the planetary boundary layer
  - soil moisture and temperature profiles
  - high-resolution vertical profiles of humidity
  - measurements of air quality and related chemical composition above the surface layer
- **High priorities identified in NRC report:**
  - direct and diffuse solar radiation
  - vertical profiles of wind
  - subsurface temperature profiles (e.g., under pavement)
  - icing near the surface
  - vertical profiles of temperature
  - surface turbulence parameters
- **No systematic national capability exists for these quantities, which are critical to the dynamical prediction of high impact weather and/or chemical weather.**

National Research Council. *Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks*. Washington, DC: The National Academies Press, 2009.

Boundary-Layer Observations – Applications and Needs

- "Requirements for thermodynamic profiles are highly dependent on the specific applications.
- ….to improve forecasts of convective initiation and storm strength:
  - **profile measurements are needed to better than 1°C accuracy,**
  - **moisture profiles should be better than 1 g kg-1.**
  - **desired vertical resolution was 50-100 m.**
- Adding wind profiles alongside thermodynamic profiles has been shown to improve forecasts of convective activity**, suggesting co-location of thermodynamic and wind profiling capabilities.**
- Knowledge of the fine scale structure of boundaries improved knowledge of moisture convergence, which then can be derived from timeseries analysis of continuous vertical profiles.
- Such analyses would also benefit substantially from horizontal gradient information provided by horizontal scanning."



NCAR/TN-488+STR
NCAR TECHNICAL NOTE

April 12, 2012

Thermodynamic Profiling Technologies Workshop
Report to the National Science Foundation
and the National Weather Service

Editors and Co-Chairs
R.M. Hardesty
R.M. Hoff

Contributing Authors
R.M. Hoff
R.M. Hardesty
F. Carr
T. Weckwerth
S. Koch
A. Benedetti
S. Crewell
N. Cimini
D. Turner
W. Feltz
B. Demoz
V. Wulfmeyer
D. Sisterson
T. Ackerman
F. Fabry
K. Knupp

Principal Investigators
R.E. Carbone
R.J. Serafin

Co-sponsored by the National Science Foundation and the U.S. National Weather Service, Office of Science and Technology.

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of either the National Science Foundation or the National Weather Service.

National Center or Atmospheric Research
P.O. Box 3000
Boulder, Colorado 80307-3000

Challenges and Open Questions

BAMS NOVEMBER 2010

WHITHER THE STABLE BOUNDARY LAYER?

A Shift in the Research Agenda

Conclusions: "The SBL remains the least understood element of the atmospheric boundary layer, and its study is fraught with the complex dynamics of stably stratified turbulent flow. Although substantial progress has been made in understanding the SBL, many critical problems and new problems have been identified"

Challenges and Open Questions

NOVEMBER 2013 BAMS |

STABLE ATMOSPHERIC BOUNDARY LAYERS AND DIURNAL CYCLES

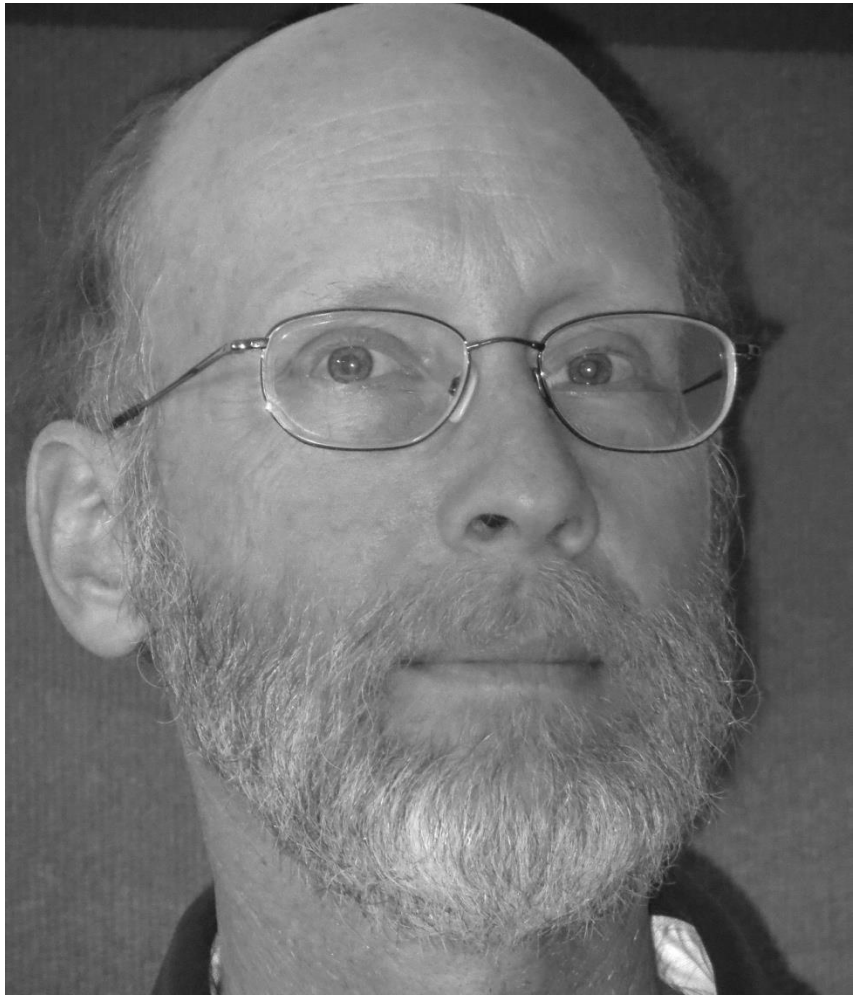
- Weather forecast and climate models generally have too much vertical mixing in stable conditions, resulting in too deep boundary layers, too less turning of wind with height, too large downward sensible heat fluxes, and too weak low-level jets.
- Operational weather forecast models still need enhanced mixing for good forecast scores but have difficulty in representing the diurnal cycles over land.
- Coupling between the atmosphere and the land surface is key for a good representation of the diurnal cycles of temperature, wind, and other variables.

Introduction of Speakers - Stable Boundary Layer

- Dr. Gunilla Svensson
  - A Professor in Dynamic Meteorology at the University of Stockholm, Sweden.
  - Her research focuses on developing and applying numerical models for small-scale atmospheric processes and studying their effects using the models in combination with observations.

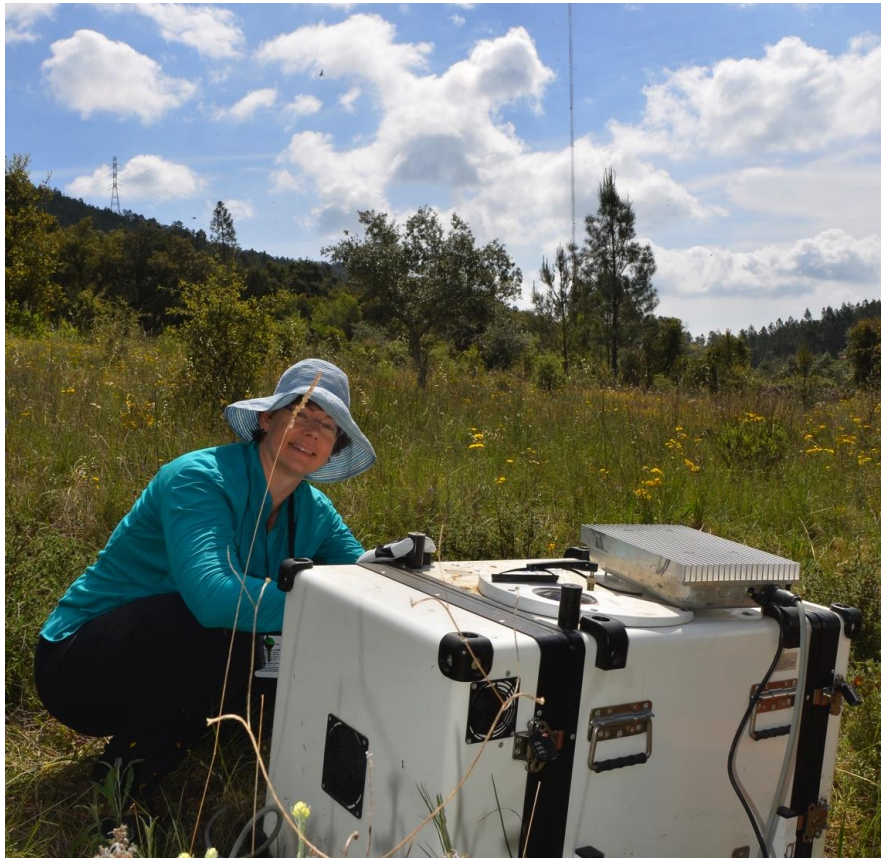
Introduction of Speakers – Convective Boundary Layer and Entrainment Processes

- Dr. Wayne Angevine
  - A CIRES Research Scientist at the NOAA Earth System Research Laboratory, Chemical Sciences Division.
  - He has contributed to instrument and technique development, data analysis, and model development for boundary layer physics and chemistry.



Introduction of Speakers – Influence of Topography and Landuse

- Dr. Julie Lundquist
  - An Associate professor in the Department of Atmospheric and Oceanic Sciences at the University of Colorado Boulder, and Fellow in the joint Renewable and Sustainable Energy Institute between CU Boulder and the National Renewable Energy Lab.
  - She uses field observations, mesoscale simulations, and large-eddy simulations to understand the atmospheric boundary layer with special attention to atmosphere-wind energy interactions and flow in complex terrain.



Agenda

Session I: Boundary Layer Flow and Turbulence

8:30- 8:40: Plenary - Goals and expectations of Boundary Layer Flow and Turbulence (Petra Klein)

8:40-9:40: Overview Presentations (three 20 min presentations)

1. Stable Boundary Layers
2. Convective Boundary Layers and Entrainment Processes
3. Influence of Topography and Land Use

Main goal: Identify Science Frontiers
We all stay together!

9:40-10:00: Discussion **Introduction of Breakout Moderators**

10:00-10:15: *Break* (move to breakout rooms) set up posters (new and emerging technologies), posters will remain

10:15-11:30: Session I Breakout Groups

1. Stable Boundary Layers
2. Convective Boundary Layers and Entrainment Processes
3. Influence of Topography and Land Use

Main goal: Match Science Frontiers with Instrumentation
We break up in 3 groups!

11:30-12:15: Plenary - Summary from each breakout session and brief discussion/clarifications

Reports from Breakout Moderators and Joint Discussion of Science Frontiers and Related Observational Needs

Introduction of Breakout Moderators - Stable Boundary Layer

- Dr. Jielun Sun
  - A scientist in the Mesoscale and Microscale Meteorology Laboratory, NCAR.
  - Her current research areas are in fundamental understanding of turbulent physical processes in the planetary boundary layer by conducting field experiments and analyzing observations.
  - **Rapporteur: Dr. Andrey Grachev**
  - **Room: 3131**

Introduction of Breakout Moderators – Convective Boundary Layer and Entrainment Processes

- Dr. Jordi Vila
  - A professor of Meteorology and Air Quality at the University of Wageningen in The Netherlands.
  - His research interests focus on clear and cloudy boundary layers and their interactions with mesoscale flow, plant/soil processes, and chemistry by using large-eddy simulations, conceptual models and observations.
- **Rapporteur: Dr. Tim Wagner**
- **Room: Center Auditorium**

Introduction of Breakout Moderators – Influence of Topography and Landuse

- Dr. Petra Klein
  - A Professor and Associate Director for Graduate Programs in the School of Meteorology at the University of Oklahoma in Norman, OK and current Member of the UCAR Board of Trustees.
  - She uses in-situ and remote sensing observations, supplemented by numerical model output, to investigate the structure of the atmospheric boundary layer and turbulence properties in rural and urban areas, and most recently also in complex terrain.
- **Rapporteur: Dr. Dan Li**
- **Room: South Auditorium**

Organizational Remarks

- Please choose the breakout session topic wisely!
- Initial interest expressed by participants at time of registration is very uneven in terms of numbers:
  - Topic 1: SBL: 11 Participants
  - Topic 2: CBL: **74** Participants
  - Topic 3: Topo/Landuse: 14 Participants
- Discussions will likely be much more productive if people consider switching from topic 2 to one of the other topics!
- Goals of Breakout Sessions:
  - Update Instrumentation Inventory
    - Make sure you provide information about available instruments (including development activities) to note takers (speakers and rapporteurs)
  - Development of Traceability Matrices

Organizational Remarks

C-RITE Workshop Science Traceability Matrix

(Insert your science theme here)

Science Frontier	Key measurement requirement(s) (e.g. physical parameter)	Instrument requirement(s)	Challenges (technological, cost, resolution, coverage	Other Comments