Boundary Layer Characterization

Tilden P. Meyers

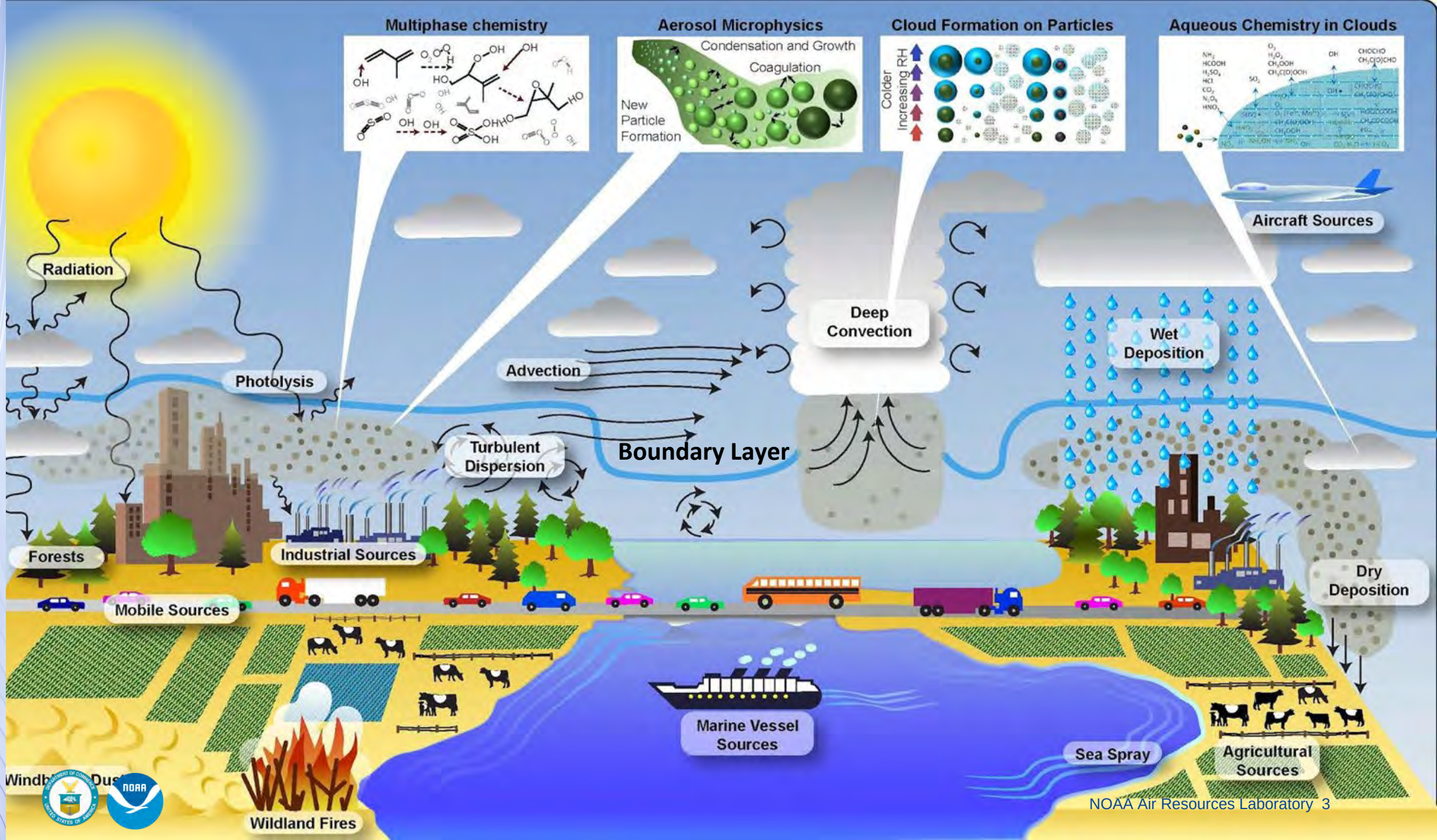
Improving the understanding and representation of the earth surface and boundary layer interactions in both weather and climate models, and dispersion models especially as it relates to water, air chemistry, greenhouse gas processes and predictions. This research plays a major role in helping communities to adapt and be more resilient to a changing climate and associated extreme events.

How do we define the **boundary layer?**

"The boundary layer is defined by the presence of mixing that couples the air to the underlying surface on a time scale of less than a few hours"

Don Lenschow, 2003, NCAR Boundary Layer Scientist

BUT, We also have to understand how the surface and atmosphere processes change over longer periods of time in order to advance our medium and seasonal predictive capabilities.


Multiphase chemistry
Aerosol Microphysics
Condensation and Growth
Coagulation
New Particle Formation
Cloud Formation on Particles
Colder
Increasing RH
Aqueous Chemistry in Clouds
Aircraft Sources
Radiation
Photolysis
Advection
Deep Convection
Wet Deposition
Turbulent Dispersion
Boundary Layer
Forests
Industrial Sources
Mobile Sources
Dry Deposition
Marine Vessel Sources
Sea Spray
Agricultural Sources
Wildland Fires

From Discussions with Forecasters

Modeling: Engaging Forecast Community in Developing UFS Modeling Priorities

Three recent workshops to identify top priority forecast requirements/gaps in UFS development

- November 16, 2020: NWS Forecaster "top 20" forecast issues that require model improvements
- January 29, 2021: Forecasters & UFS modelers: Medium Range/S2S specific issues
- February 11, 2021: Forecasters & UFS modelers: Short Range Weather model specific issues
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Land Model Relevance

1. PBL and surface layer parameterizations
2. Impact of land surface properties and emission on convection initiation and development
3. Boundary layer interaction with clouds
4. Impacts of complex terrain
   - Upslope/downslope stability, wind, precipitation;
   - Impact of terrain on convection;
   - Inadequate resolution
5. Land model development, coupling and Land, data assimilation.

Top Forecast Concerns

1. Boundary layer profile, stability, surface temperature; feedbacks across coupled systems
2. Convection details, initiation, structure, cold pools
3. Severe storm characteristics and short-range evolution
4. Probabilistic storm information (ensemble)
5. Wind, temperature, QPF near terrain and land-water boundaries
6. Precipitation type
7. Precipitation rate
8. Flooding events
9. Land hydrology
10. Tropical cyclone intensity changes
11. Tropical cyclone genesis, pre-genesis
12. Visibility, ceilings, clouds, fog
13. Cloud structure
14. Turbulence, including clear sky
15. Inundation, extratropical
16. Extratropical storm intensity
17. Extreme heat, urban island, apparent temperature
18. Air quality - volcanic, gases, particulates, smoke

Relevance to OAR goals

This theme/component is linked to:

OAR Strategic Goal 2.2 (Identify and address gaps in observation requirements needed to understand causes of variability and change)

OAR Strategic Goal 3.1 (Develop interdisciplinary Earth system models)

OAR Strategic Goal 3.2 (Design tools and processes to forecast high-impact weather, water, climate, ocean, and ecosystem events)

"ARL's endeavor to develop and improve BL parameterizations for weather and climate predictions. Short and long-term measurements are part of a suite of carefully designed networks and planned observation campaigns". [Strategic Plan 2021-2016]

Background & Motivation (Relevance to ARL)

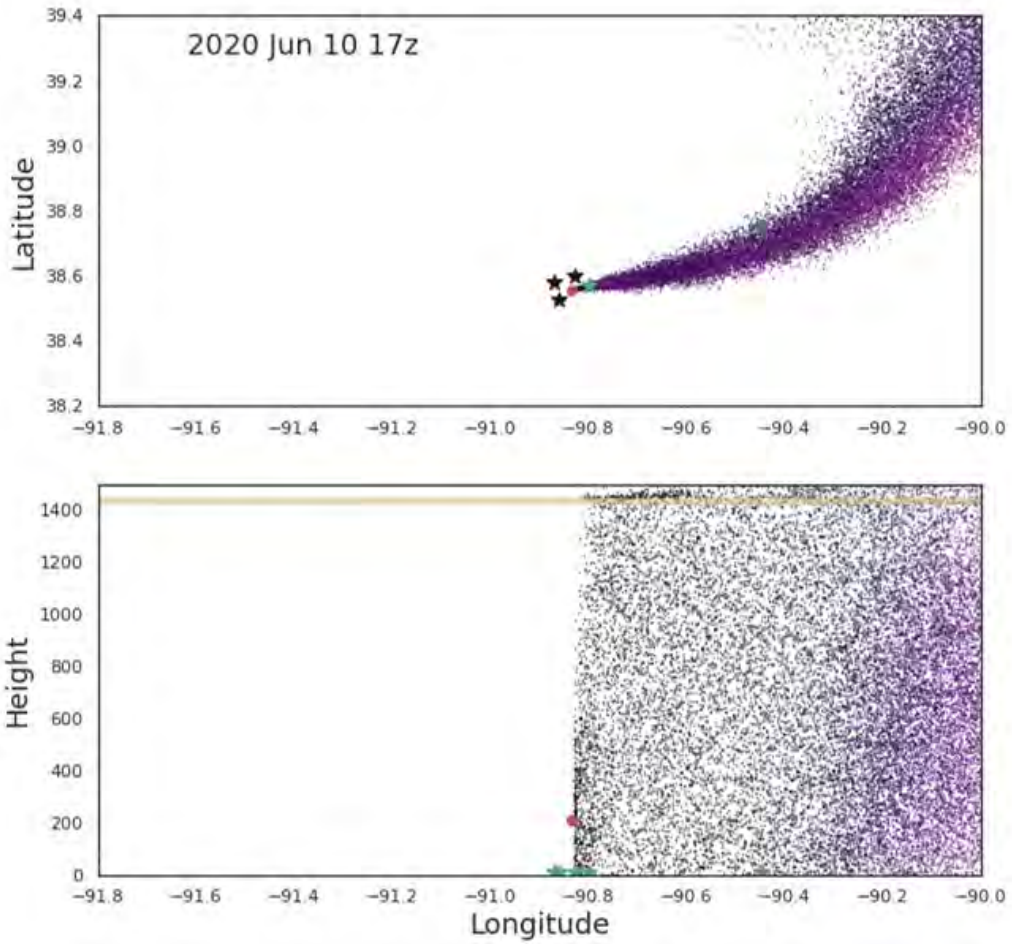
Modeling and Observation Perspective

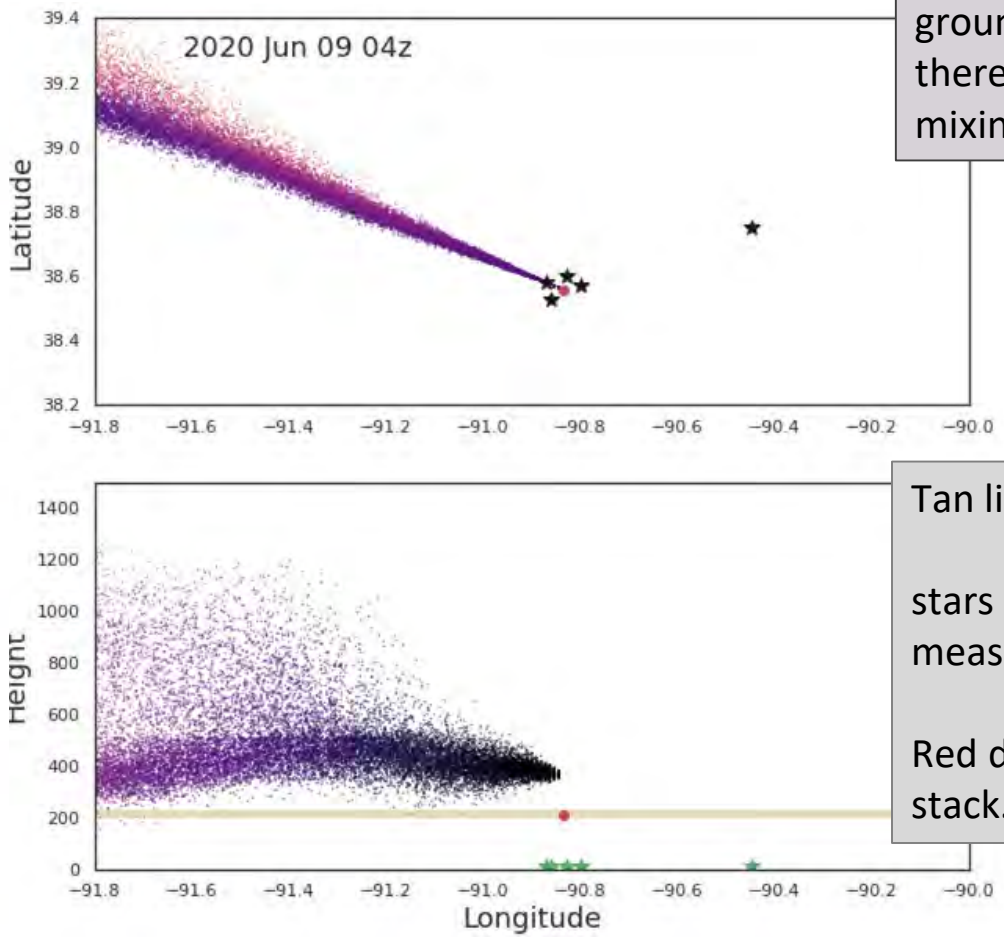
- Air quality predictions -alerts
- plume dispersion forecasts -smoke, fire weather, dusts, volcanic eruptions, emergency response

- Develop new innovative technologies for observing boundary layer characteristics and processes to improve our understanding and advance model parameterizations

Plume Dispersion Research and Development

Hysplit predictions are sensitive to boundary layer parameters such as the vertical profiles turbulence as well as the local atmospheric stability.





Peaks seen at ground level when there is strong mixing.

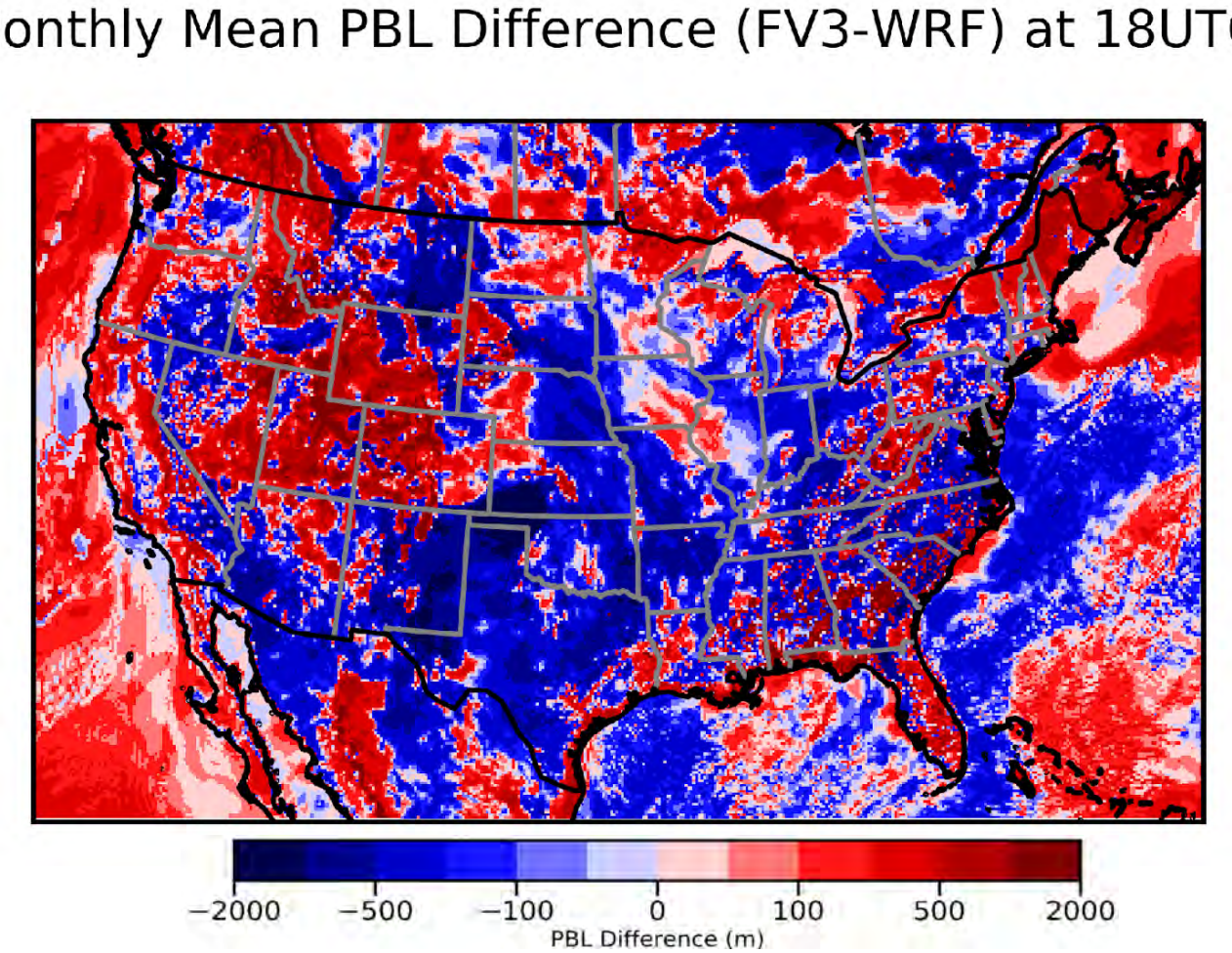
Tan line is PBLH

stars are measurement stations

Red dot is the top of stack.

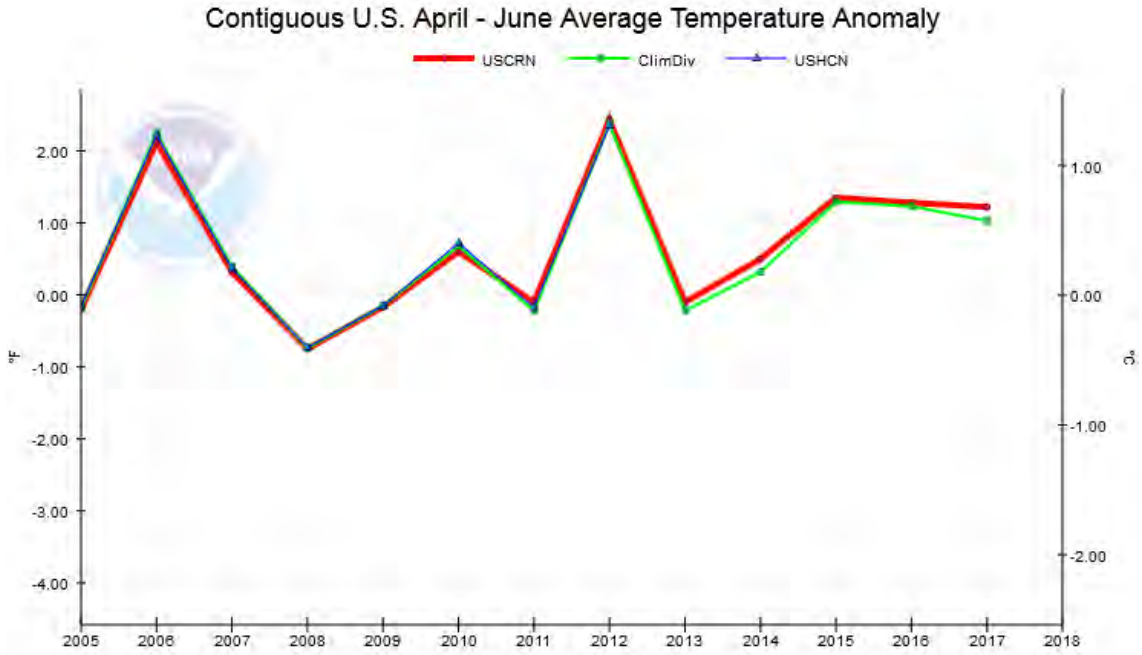
Air Quality Forecasts, especially urban areas

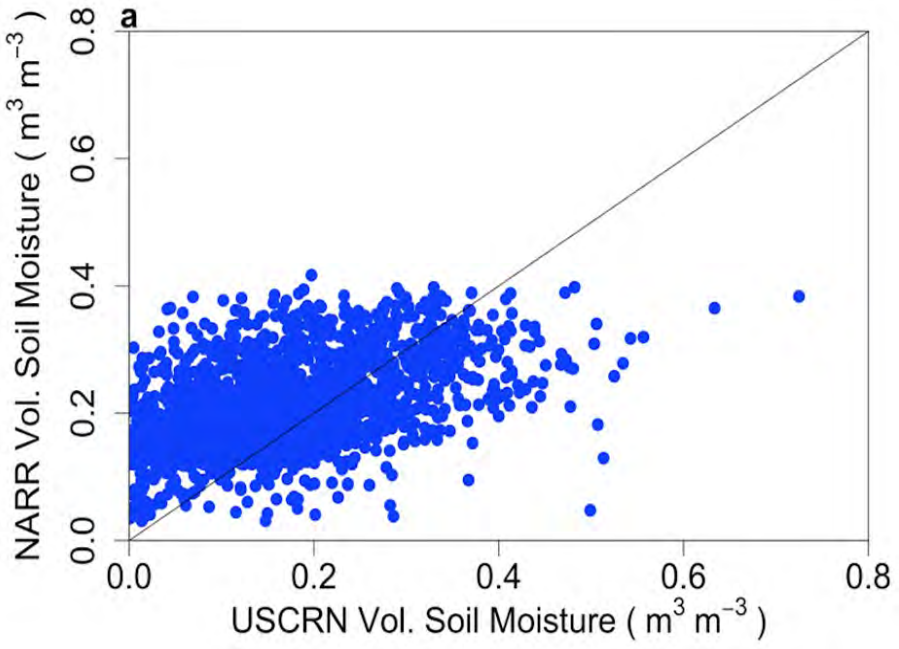
Air quality predictions are not only sensitive to boundary layer parameters such as the vertical profiles turbulence but to profiles of humidity, temperature and radiation levels



Long Term Climate Observations- H. Diamond

Long-term and sustained climate observations such as surface air temperature and precipitation are key signatures of atmospheric process and interactions in the boundary layer, including max/min air temperature, precipitation rates, and soil moisture/temperature.





Western Regional Mesonets and Applications-W. Schalk

Brings together both the observational and modeling components of the boundary layer in support of public safety via emergency response.

What? An operational WRF modeling system to provide forecasts for daily operations, special experimental support, and emergency response components of the ARL Western Division missions.

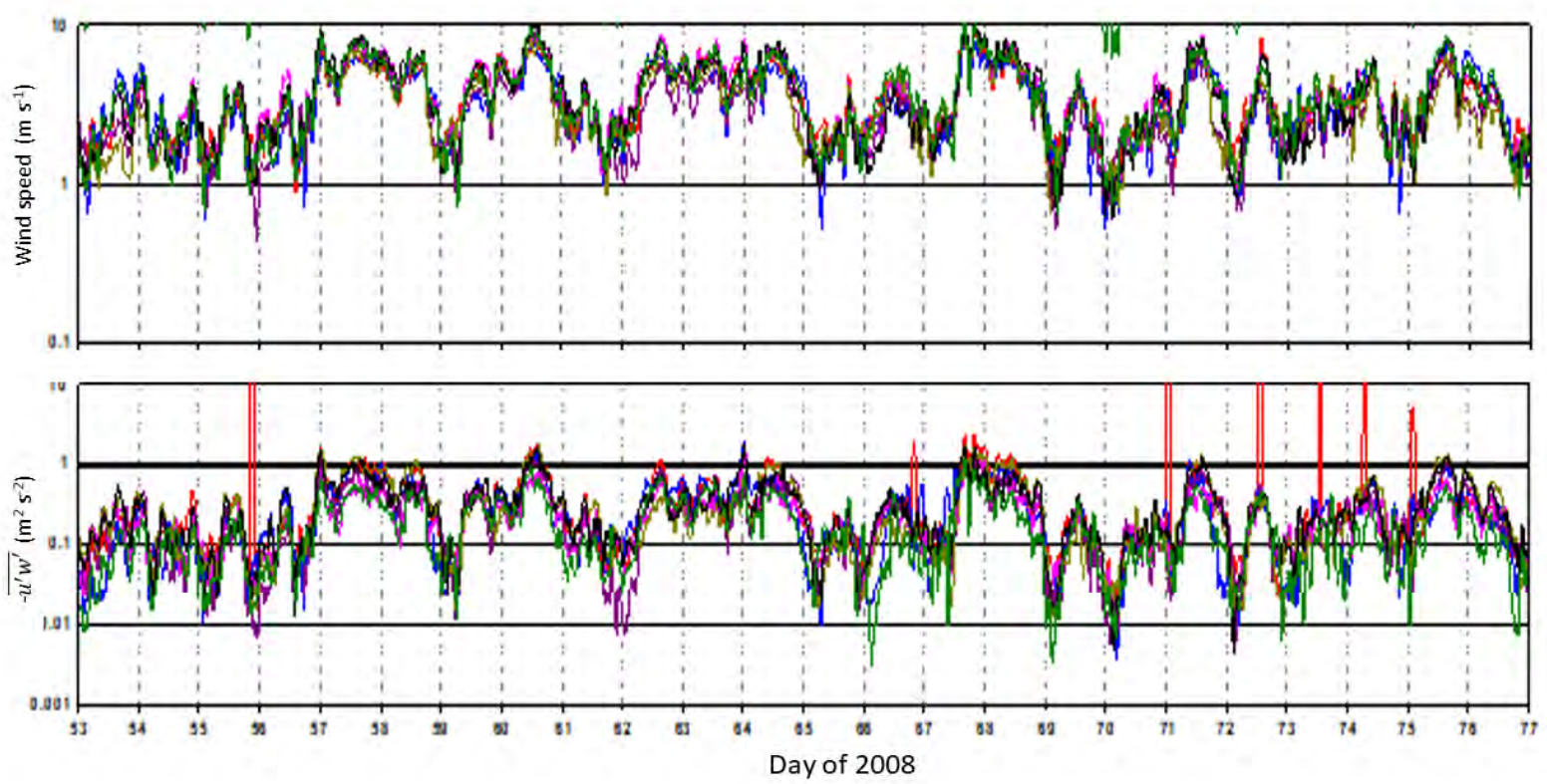
Why? A coupling of modeling and measurements provide a platform to increase understanding of PBL dynamics, with attention to particular aspects of atmospheric fluid flow that impact the transport and dispersion of pollutants.

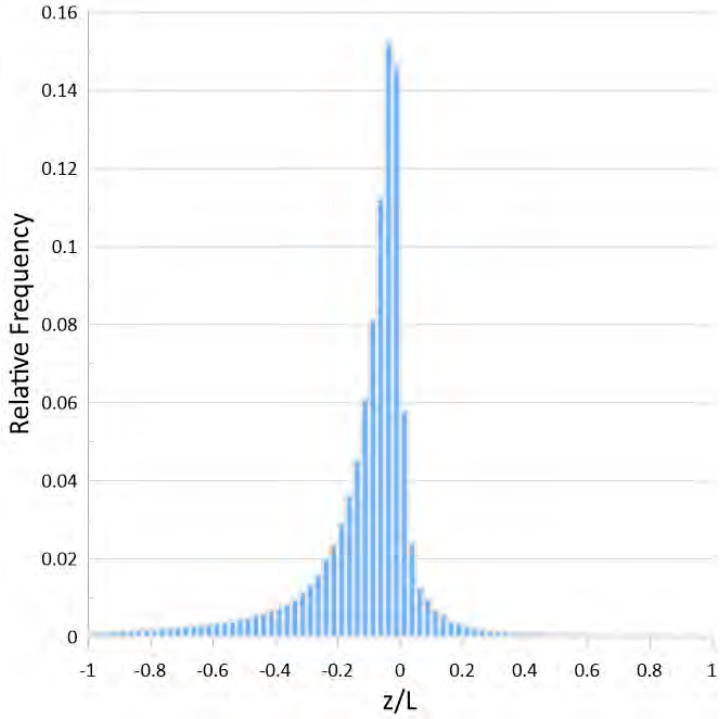
How? The system will be a testbed for ARL research projects such as general PBL parameterizations, direct mesonet data inclusion, and desert climate studies.

- Platform: 112 vCPU, 48TB storage Dell Servers + backup
- WRF running since May 2021 with
  - 3 Domains:
    - one Common 16 km resolution grid
    - two 6 km resolution grid one each for ID and NV
    - two 2 km resolution grid one each for ID and NV
  - 34 vertical layers
  - Producing forecasts out to 102 hours (4+ days)
  - Four cycles per day (00z, 06z, 12z, and 18z)
  - Output can be linked to HYSPLIT for a dispersion product

Urban Mesonet (DCNet) - W. Pendergrass

*The **urban boundary layer** is the part of the atmosphere in which most people live, and yet is one of the most complex and least understood microclimates, especially when it comes to modeling.*



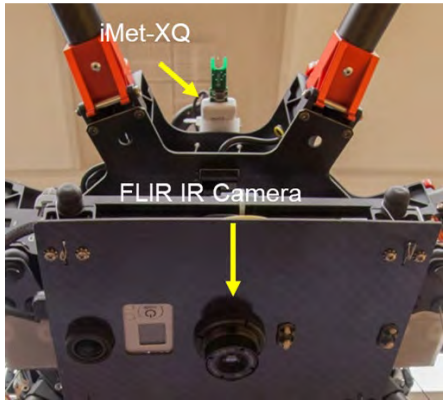


Land/Atmosphere Interactions, Campaigns- T. Meyers

Coordinated and collaborative boundary layer field campaigns allow us to address specific questions about surface and boundary layer processes and interactions.

ARL brings decades of experience in observing land-atmosphere interactions and is also using UxS technology to gather additional data to bridge in situ observations and model grid scales.

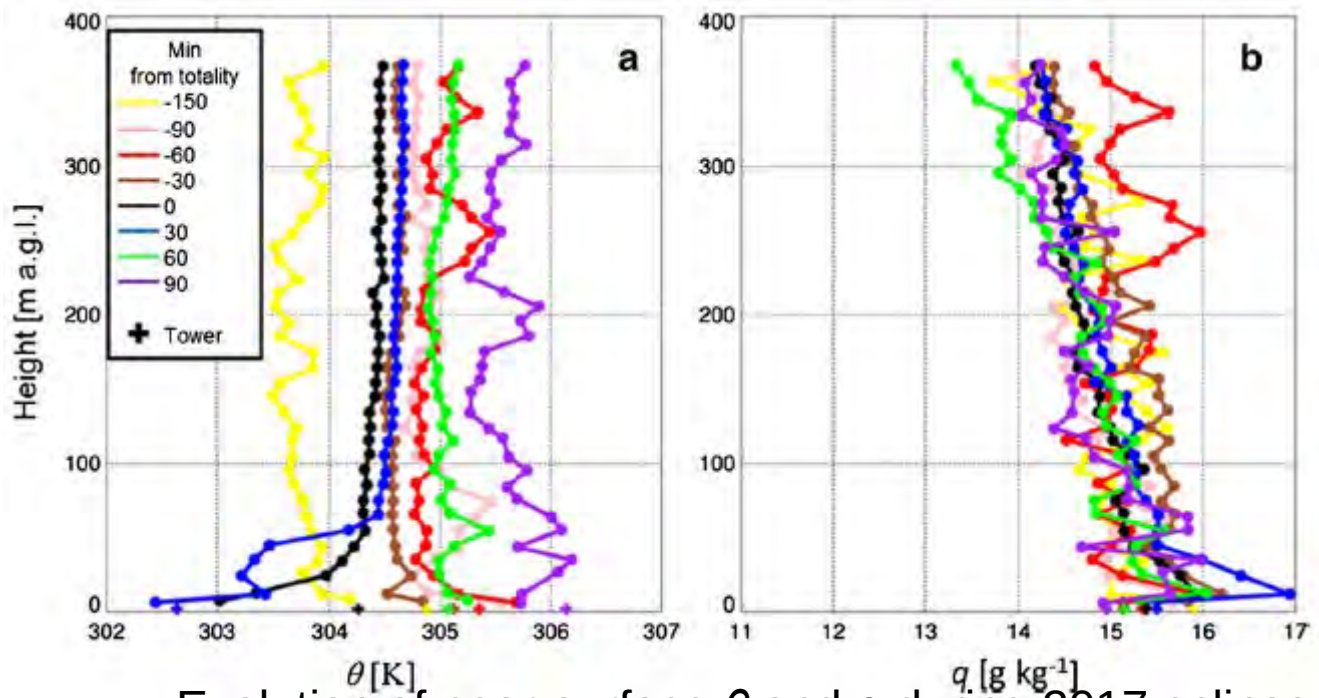
MD4-1000



Underside of APH-28

New Boundary Layer Measurement Technologies
T. Lee and E. Dumas

UsX's are developing into a key observational tool for observing and characterizing the lower boundary layer (up to 1 km) on a spatial and temporal scale relevant to enhance model development via additional data assimilation



Evolution of near-surface θ and q during 2017 eclipse

Meteodrone

Transitions/Future plans (Boundary Layer Activities)

- Fire Weather Initiatives (infrastructure bill) - supports research and the development of products for both air quality forecasts, smoke dispersion, and BL supersites
- Urban boundary layer processes-research efforts will continue with some expansion to better characterize represent boundary layer interactions in urban/metro regions.
- OAR BL experiments and campaigns-SPLASH effort now expected to continue until August 2023 (almost 2 -years of data)
- UxS technology - developments and applications continue to rapidly advance with new imaging and sensor technology including small trace gas sensors, IR camera systems, better 3-d wind probes (turbulence statistics, fluxes)
- GRUAN, USCRN will continue to provide *reference* surface and atmospheric observations of temperature, humidity, and precipitation, with a completion nearly 30 sites in Alaska by 2025.