Atmospheric Boundary Layer Activities in ESRL

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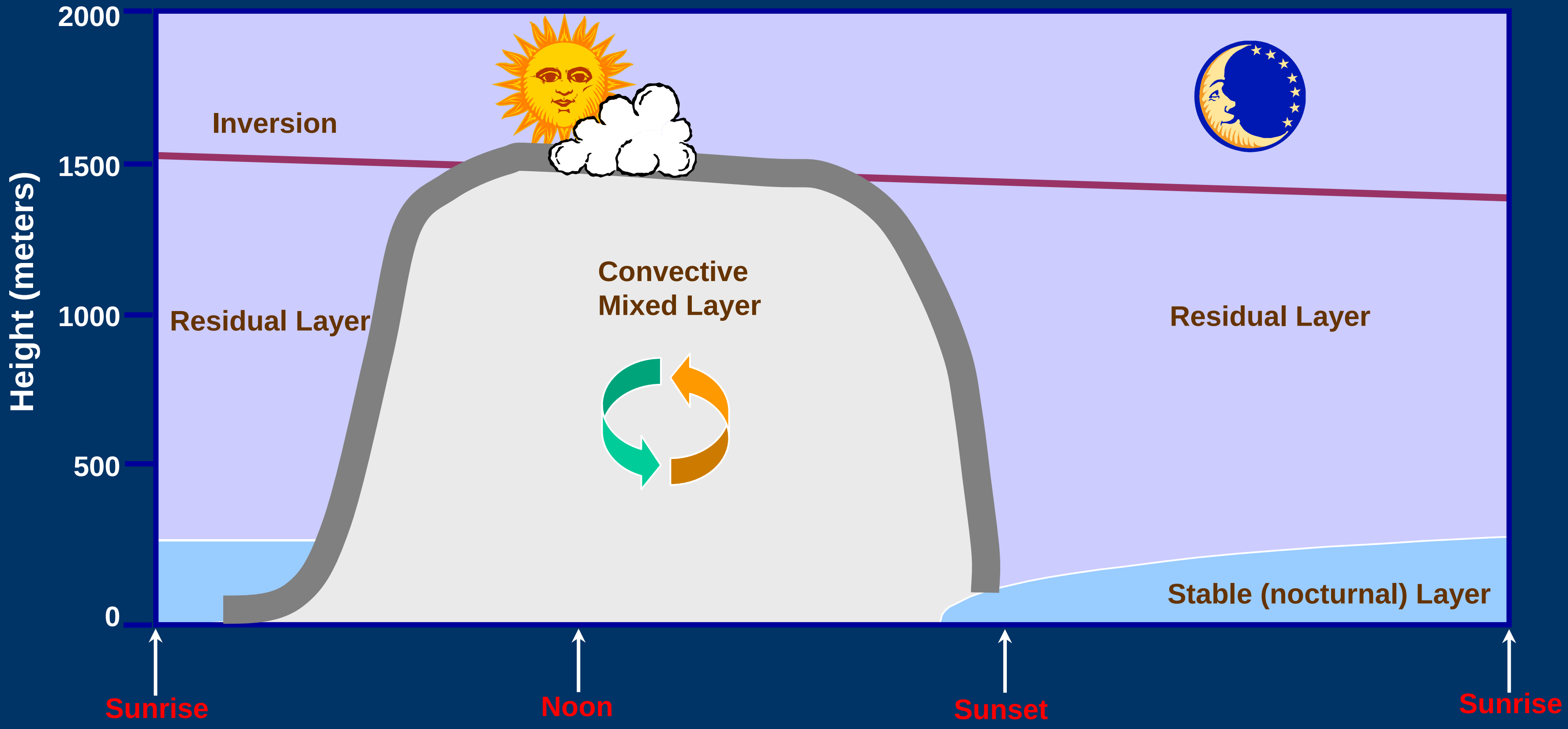
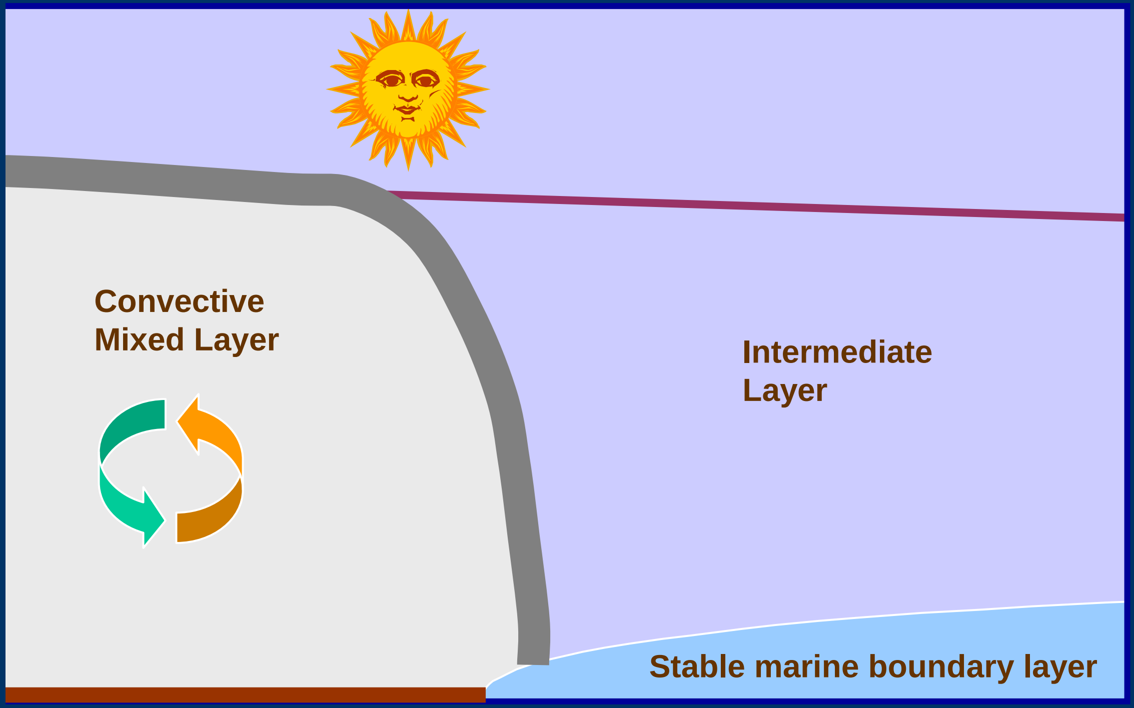
Atmospheric Boundary Layer Diurnal Variation (a severe simplification)



Adapted from **Introduction to Boundary Layer Meteorology** -R.B. Stull, 1988

Coastal Boundary Layer
- warm to cold

- One of many “other” types of boundary layers
- Polar BLs are stable for long periods
- Some oceanic BLs are continuously weakly convective



Why do we care about the boundary layer?

- Controls transport of pollutants and climate-forcing constituents
- Source of heat, water, and turbulence
- Vital for weather and climate prediction
- Location of aerosols, clouds, and pollutants
- Context for other measurements

Almost any measurement or prediction involves the boundary layer

~~Critical scientific gaps~~
Grand challenges

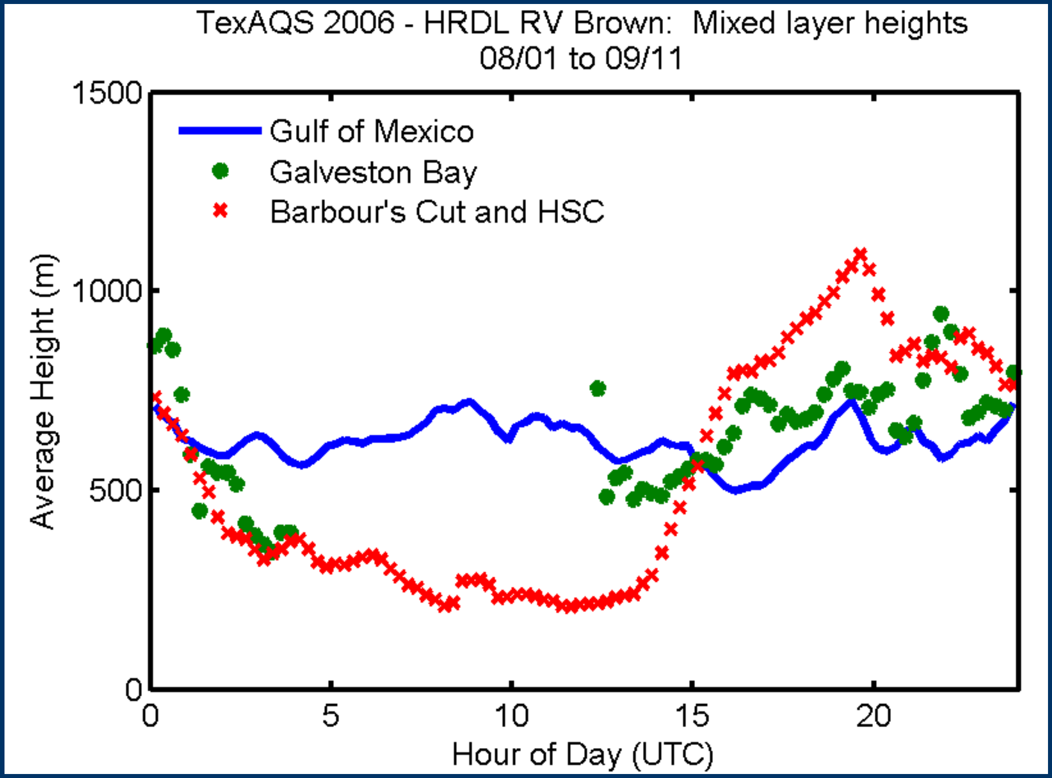
- Cloud formation and transitions within the boundary layer
- Concentration and transport of pollutants in realistically variable boundary layer structures
- Factors affecting the vertical transport of heat and matter during the boundary layer daily cycle
- Partitioning of various causes of climate changes in the polar regions
- Interaction between the boundary layer and atmosphere above (free troposphere)

Recent findings

- Cloud formation and transitions within the boundary layer
  - Cloud effects on pollutant concentration and transport
  - Aerosol effects on clouds
- Concentration and transport of pollutants in realistically variable boundary layer structures
  - Stable boundary layer characterization
  - Mixing depths over water
- Factors affecting the vertical transport of heat and matter during the boundary layer daily cycle
  - Coastal pollutant transport
  - Parameterizations for mesoscale models – validation and development
  - Automated BL height detection
- Partitioning of various causes of climate changes in the polar regions
  - Arctic boundary layer characterization
- Interaction between the boundary layer and atmosphere above (free troposphere)
  - Transitional boundary layers
  - BL-top entrainment
  - Links to larger scales

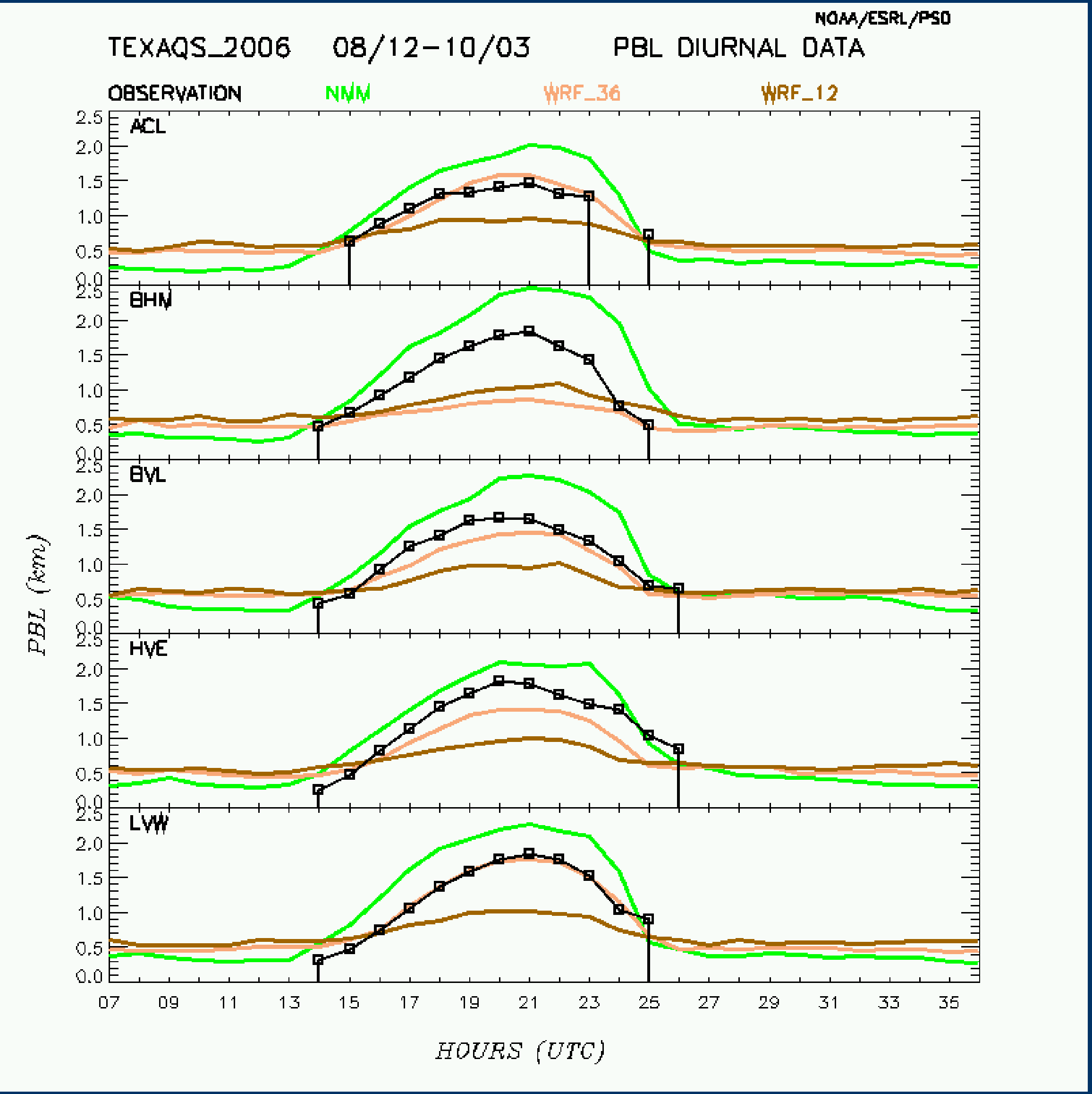
Mixing depths over the Gulf of Mexico and Galveston Bay

- Measurements from High Resolution Doppler Lidar on the *Ronald H. Brown*
- Reliability enhanced by multiple parameters
  - aerosol backscatter
  - turbulence intensity
  - wind shear
- Key finding: BL over water is weakly convective
  - shallow but not *very* shallow
  - no diurnal cycle
- Backed up by sea surface flux and temperature measurements
- Key to interpretation of in-situ chemistry and aerosol measurements

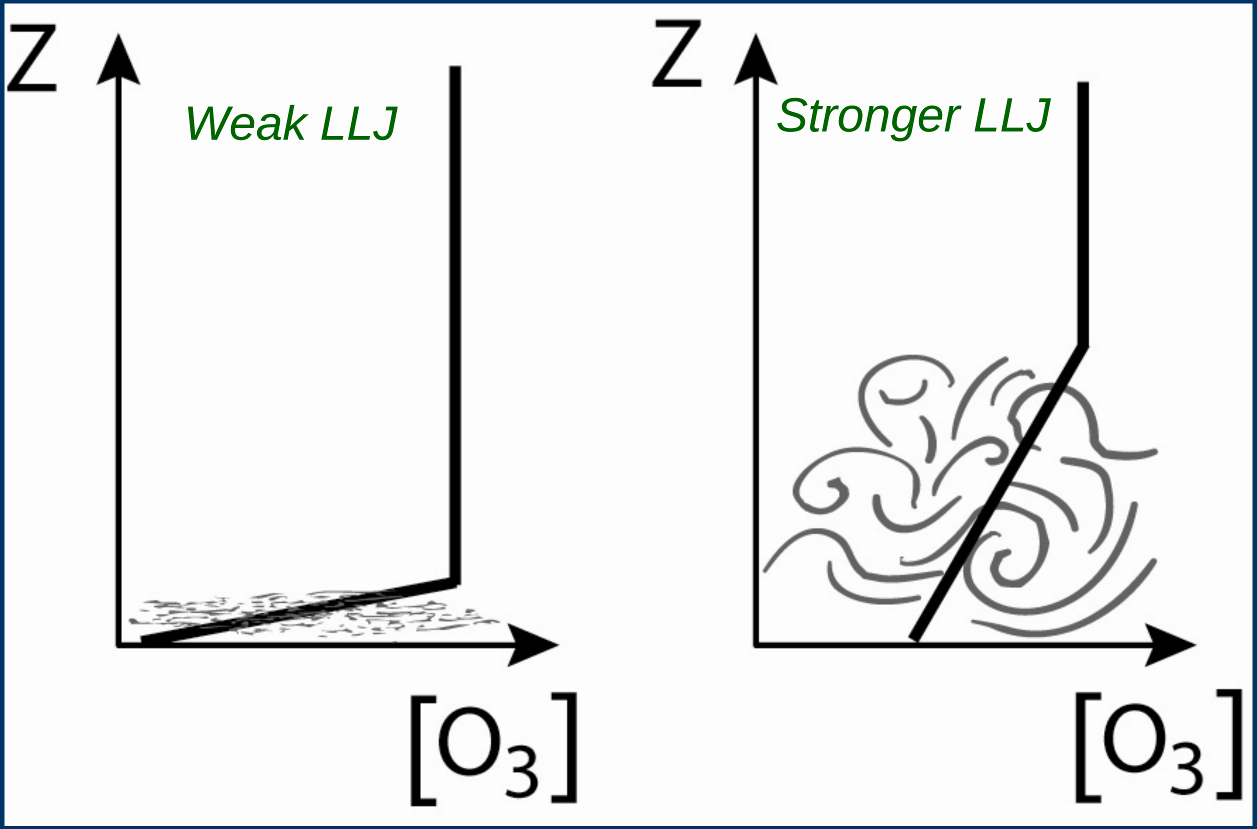


Validation of diurnal cycle in forecast models

- Using BL heights derived by an automated algorithm for 5 radar wind profilers in Texas
- Average over 52 days



Stable boundary layer structure



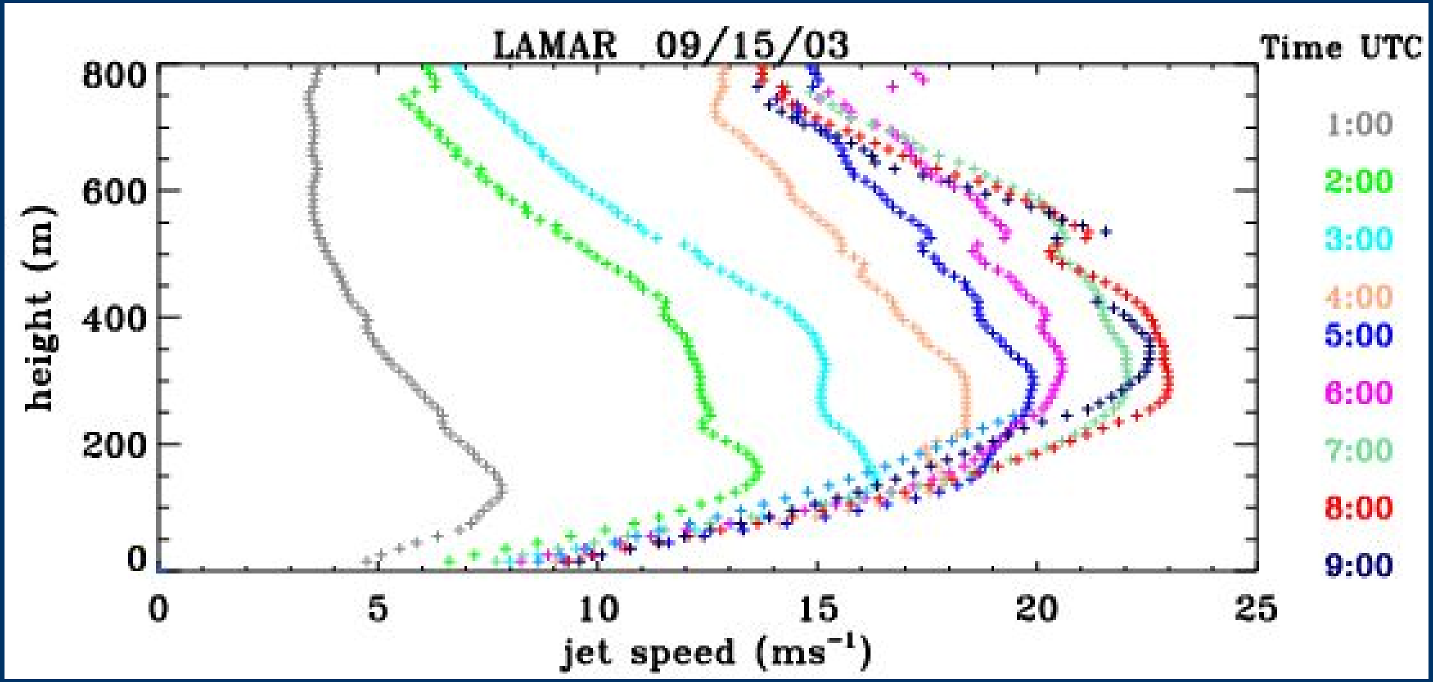
- Two types lead to different chemical and physical behavior
- Closely tied to strength of low-level jet:
  Weak LLJ (< 3 m s^{-1})
  - $O_3 \rightarrow 0$

  6-7 m s^{-1} or more
  - $[O_3]$ stays > 20 ppb

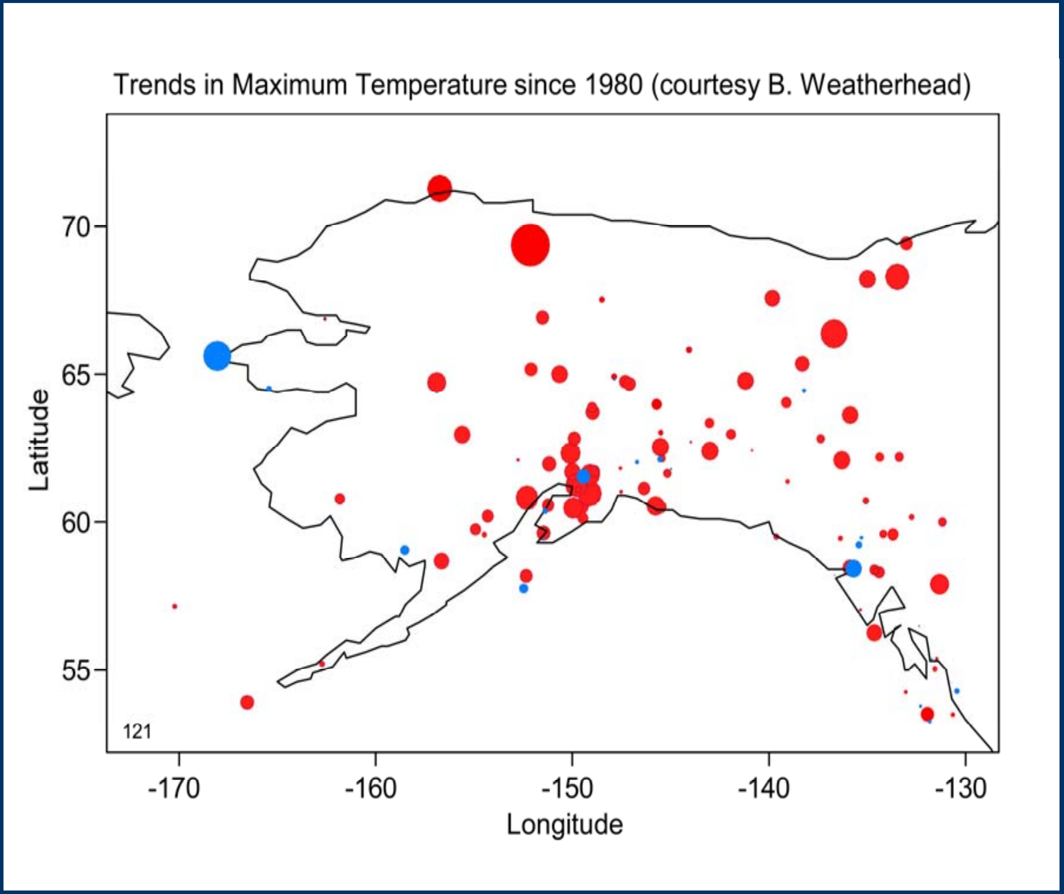
- Similar effects on temperature and water vapor profiles

Stable boundary layer structure

- Decoupling of flow aloft from surface friction → acceleration after sunset
- Happens every night to some degree
- Doppler lidar provides highly resolved wind and turbulence information
- A challenge to model parameterizations, and a framework for improving them



Arctic climate trends driven by boundary layer processes



- Magnitude and sign of temperature trends can vary significantly over small spatial distances
  - Red = positive
  - Blue = negative
  - size of dot proportional to trend magnitude
- Spatial variability of near-surface trends is caused by boundary-layer phenomena linked to complex terrain and the presence of coastlines

Arctic climate trends driven by boundary layer processes

➢Boundary layer structure during downslope wind events at Alert (from rawinsonde data)

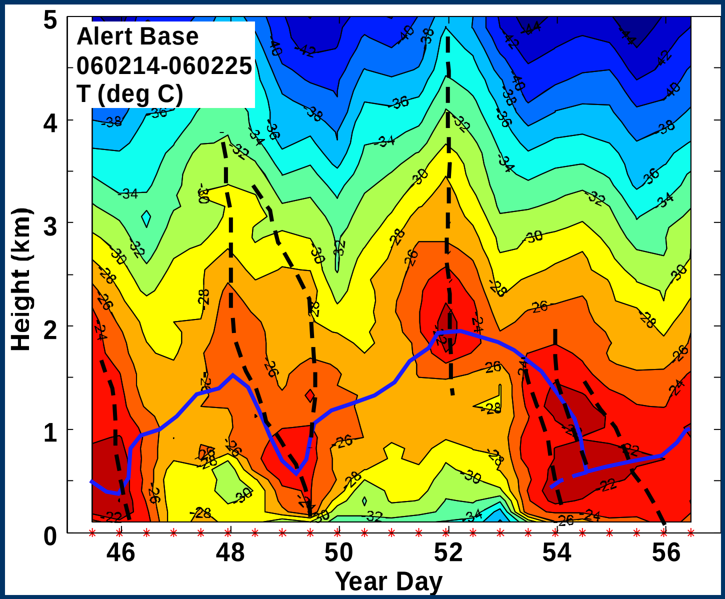
➢Drastically different from mid-latitude continental BL structure

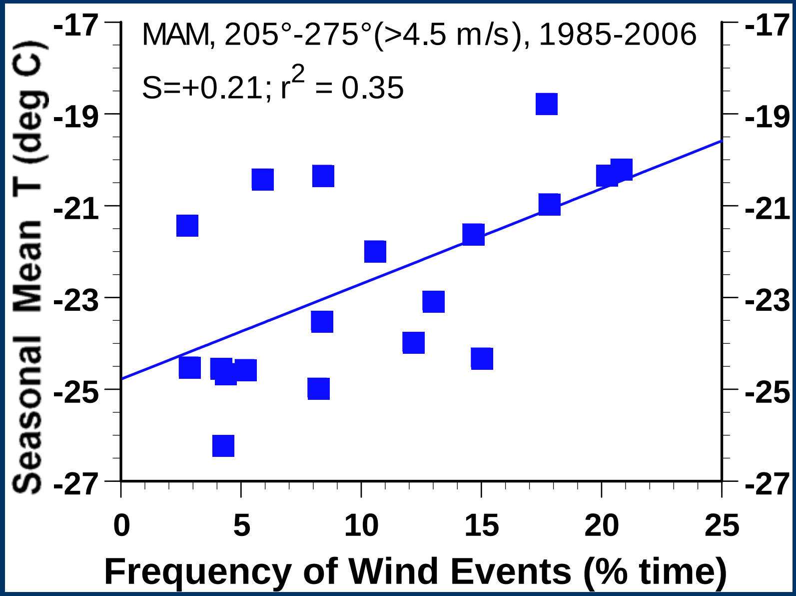
➢Descent of temperature and mixing ratio inversion top causes low-level warming and moistening

➢Events descend from 2-4 km heights

➢Relatively few events have a big impact on annual averages

➢Will climate change affect the number of these events?



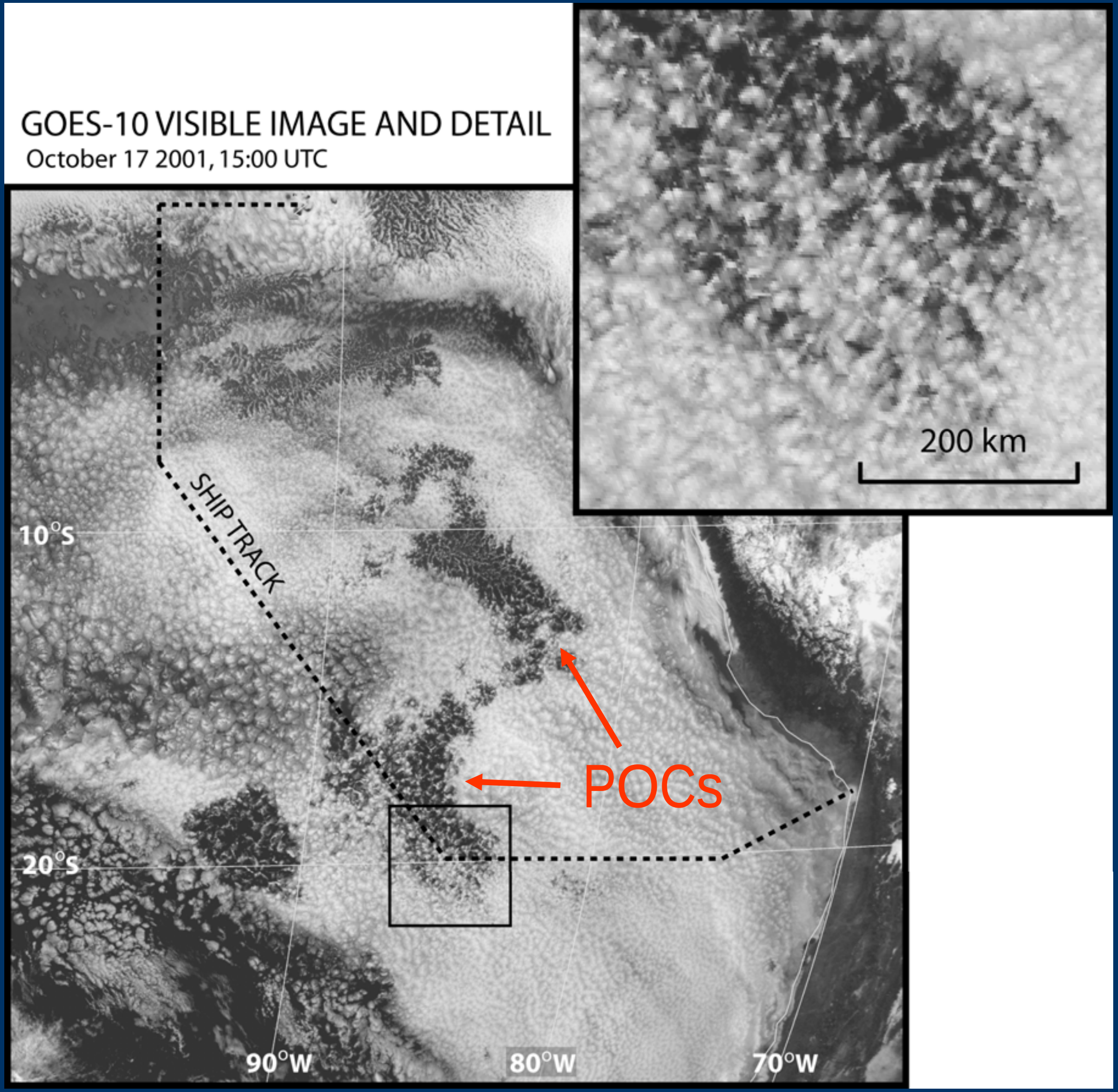


Cloud-aerosol feedbacks: Stratocumulus cloud form variability off Chile

- Most climate models do not make reasonable marine stratus clouds
- Present PBL models do not capture solid-broken transition
- *Major effect on radiative input to sea surface and BL structure*
- One Hypothesis: Aerosol – drizzle coupling

Cloud-aerosol feedbacks

Manifest in POCs (pockets of open cells)?



Bretherton et al (2004)

What are we doing?

- Research to understand BL structure and its interactions with clouds, aerosols, chemistry, and larger-scale processes
  - in maritime, mid-latitude continental, coastal, and polar environments
  - to address climate, air quality, and weather prediction

~~Problems Issues~~ Opportunities

- Faster progress through better coordination in parameterization development
  - Model users may get ahead of us in some areas
- Making best use of past and future field projects and data
- Extending BL expertise to others within ESRL

ESRL's capabilities

Observations

↕

Analysis

↕

Models

Chemistry and Physics

How?

- ➢ Collect data during small and large field projects that last for a few weeks to many years
- ➢ Frequently utilize internally-developed, unique instrumentation
- ➢ Develop and test model capabilities
- ➢ Use observations and models
  - to understand processes and interactions
  - to plan future observations, instruments, and models

Validation of WRF BL and land surface schemes

Noah RUC

Y
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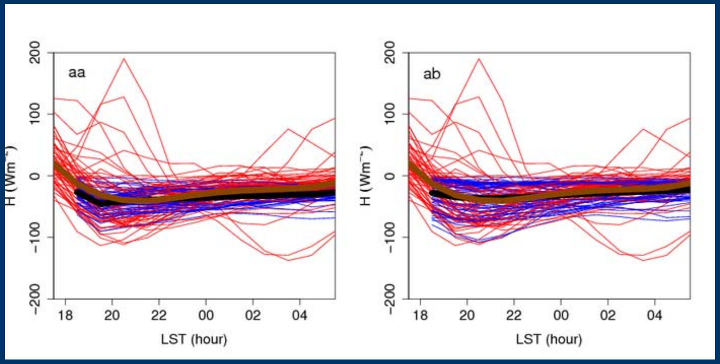

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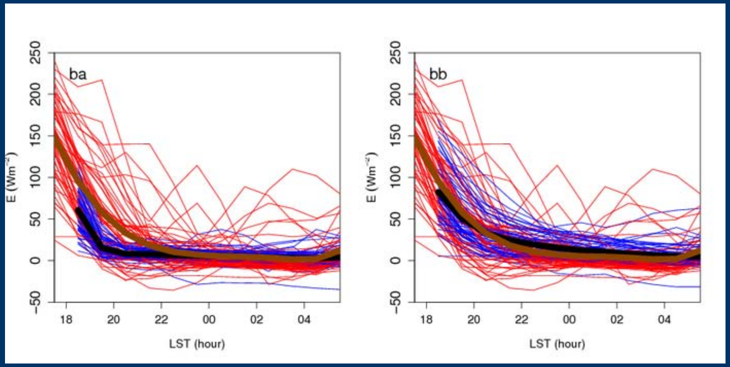


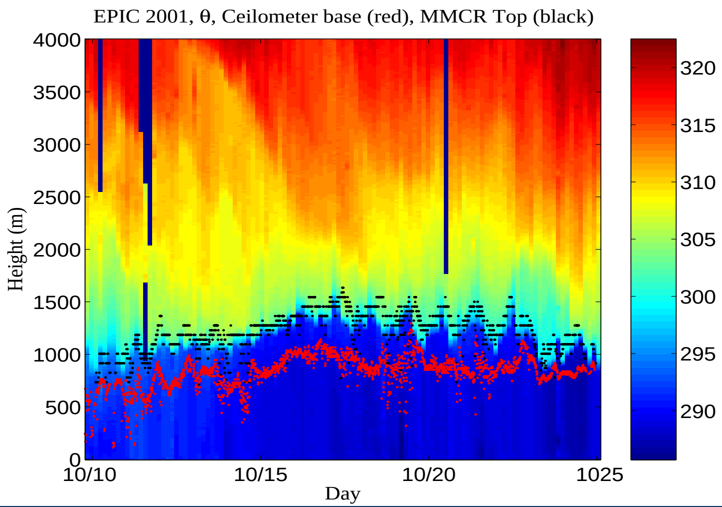
- ➢Looking at two BL schemes with two land surface schemes
- ➢Nighttime
- ➢Approx. 2 months in Oklahoma
- ➢Mean sensible heat flux agrees with observations
- ➢Lots of variation not captured by the model
- ➢Both sensible and latent heat fluxes overestimated in daytime (not shown)

red thin – obs, brown bold – mean obs,

blue thin – models, black bold – mean models

Stratocumulus cloud observations

- Much more variable than they look!



Time height mapping of potential temperature θ, ceilometer cloud base (red) and MMCR cloud top (black). The temporal resolution of the cloud boundaries is 10 min

Stratocumulus cloud form variability off Chile