Characterizing the Turbulent Structure of the Convective Boundary Layer over the SGP Using ARM/ASR Observations and LES Model Output

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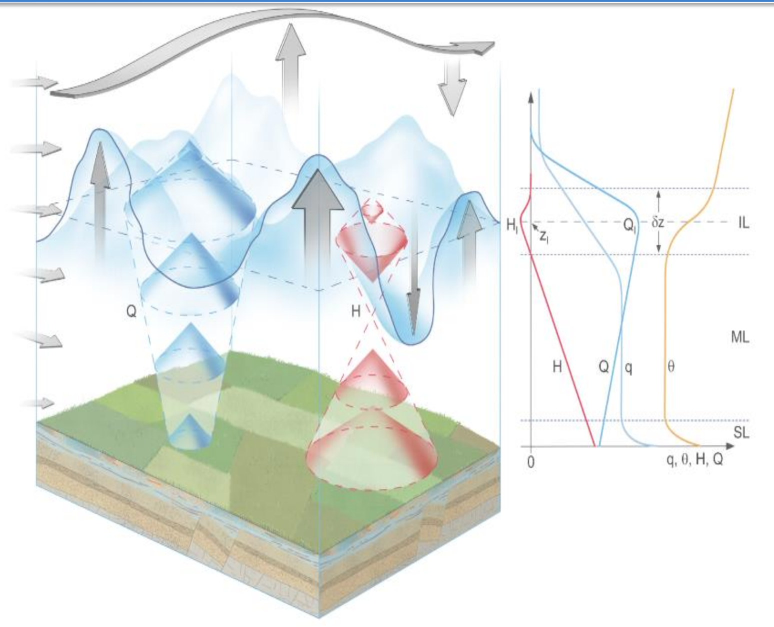
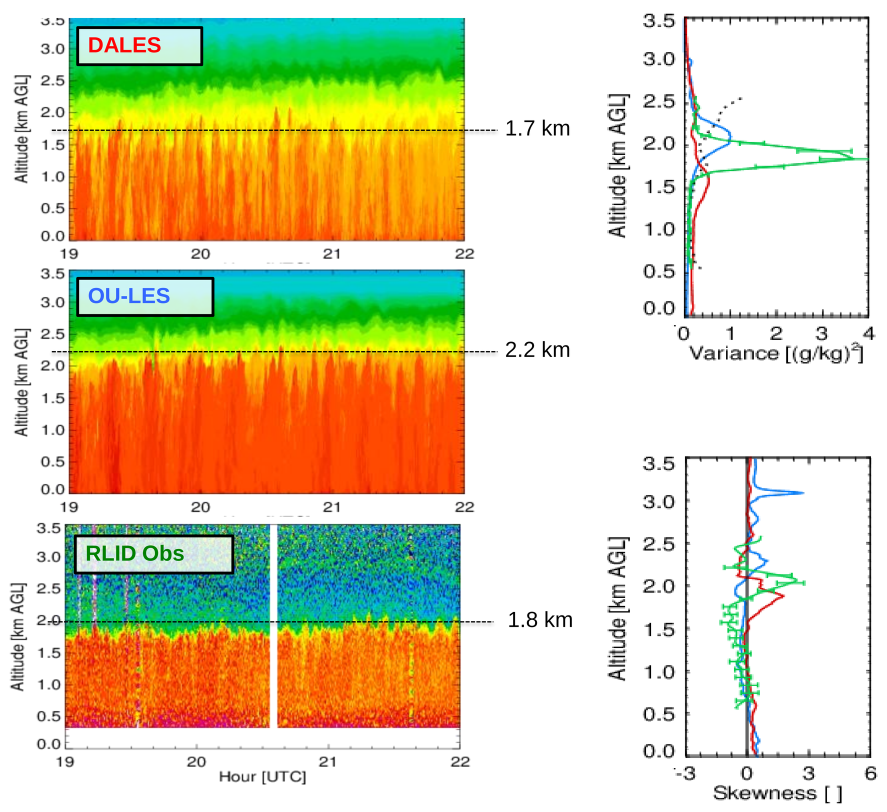
Background

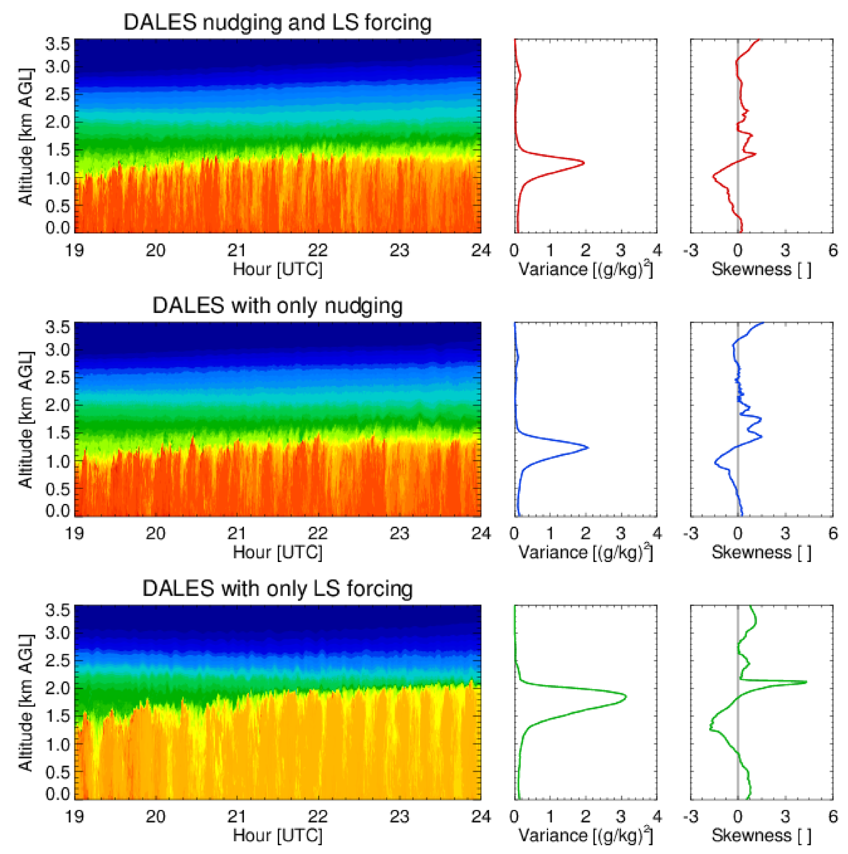
- Turbulence redistributes heat, momentum, and moisture in the boundary layer
- Subgrid scale in most models and needs to be parameterized in CRMs/GCMs
- Accurate representation of the fluxes of heat and moisture at the top of convective boundary layer (also called interfacial layer – IL) is critical
- Turner et al (2014) suggested strong correlation between the variance at the inversion and the higher order moments
- Do LES models accurately capture structure of turbulence in CBL and fluxes at IL?



Generating Variance in LES



Left: Water vapor mixing ratio from 2 different LES models (DALES and OULES) and from Raman Lidar observations. LES models are driven by a larger scale WRF simulation. Right: Variance and of the WV mixing ratio.



Left: Water vapor mixing ratio from DALES, driven by the ARM variational analysis. Right: Variance and of the WV mixing ratio.

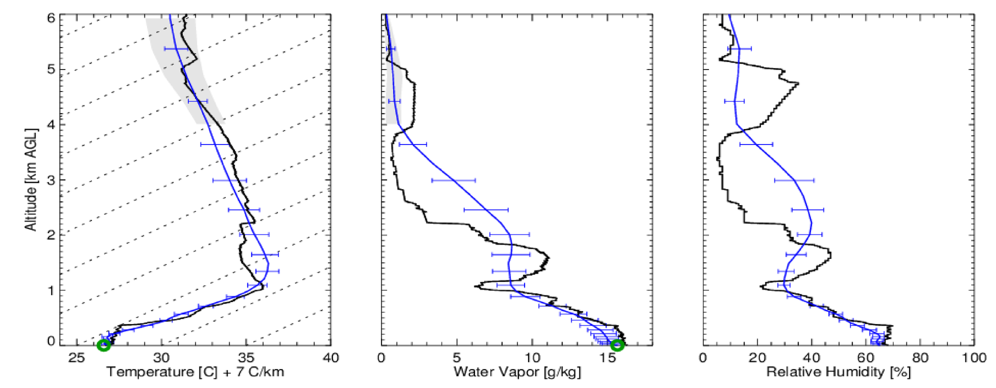
- Initial simulations of a single day were run driven by a WRF, and run in two different models
- Produced low variance, both in the Dutch Atmospheric LES (DALES) and in OULES
- One reason for the low variance production in the LES is the lack of dry air that is brought down from the free troposphere by WRF.
- New simulations driven by the ARM variational analysis (Wulfmeyer et al, 2016) behave better in that sense
- Still too low BL-height in DALES; the model is likely not perfectly constrained yet. This is also evident from the run with no nudging at all.
- Adding the sub-filter scale variance to the LES results helps, but not enough.
- We expect that running with interactive soil models and radiation will further increase the variability.

Outlook

- Driven by the variational analysis we are currently simulating multiple days of clear convection to study the correlations that were find by Turner et al (2014)
- After improvement of the method of driving the LES the system can easily be extended to different models and different weather conditions
- Using this large and internally consistent dataset, we will further study the interfacial layer, both for dry convection and for the initiation of boundary layer clouds
- The LES will remain a testbed for AERI algorithm development, for instance in assessing the quality of different boundary layer height definitions.

AERIoe Algorithm Improvements

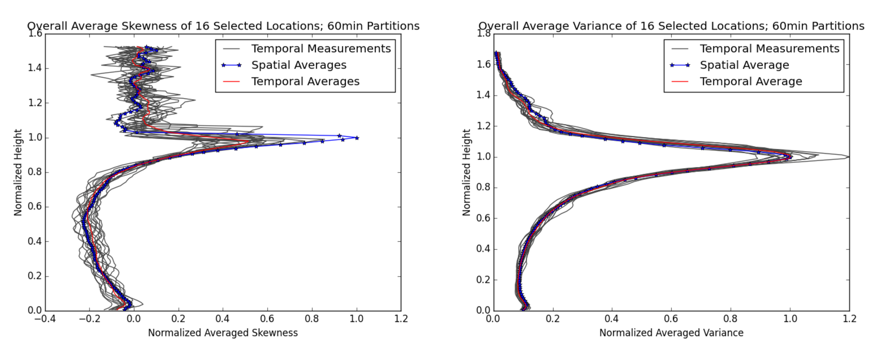
- High-temporal resolution thermodynamic profiles can be retrieved from AERI infrared radiance obs
- AERIoe is an optimal estimation based physical-iterative retrieval algorithm; provides error bars
- Able to retrieve temperature and humidity profiles and overhead cloud properties simultaneously; converges >95% of the time
- Additional datastreams used as input to help constrain the ill-posed retrieval problem: CBH from ceilometer, NWP output for upper troposphere, surface met obs



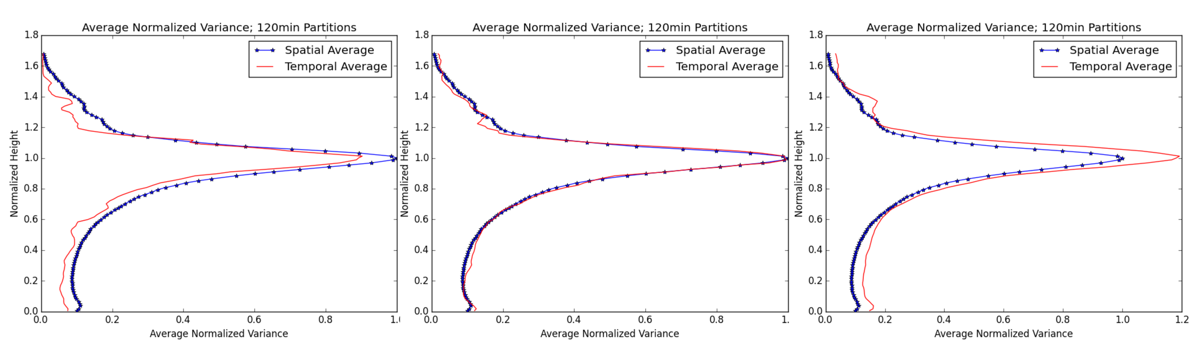
Example Retrieved Temperature (left), WV mixing ratio (center), and derived RH profile (right) relative to radiosonde

Spatial vs temporal averaging

- The LES data is used to study the convergence between spatial and temporal averages and skewness
- For temporal averages longer than a few hours, the boundary layer growth biases the variance and skewness
- For temporal averages shorter than 15-30 minutes, variance of the largest eddies is missed
- Even with multiple "measuring stations" and sufficiently long time intervals, the skewness remains fluctuating strongly



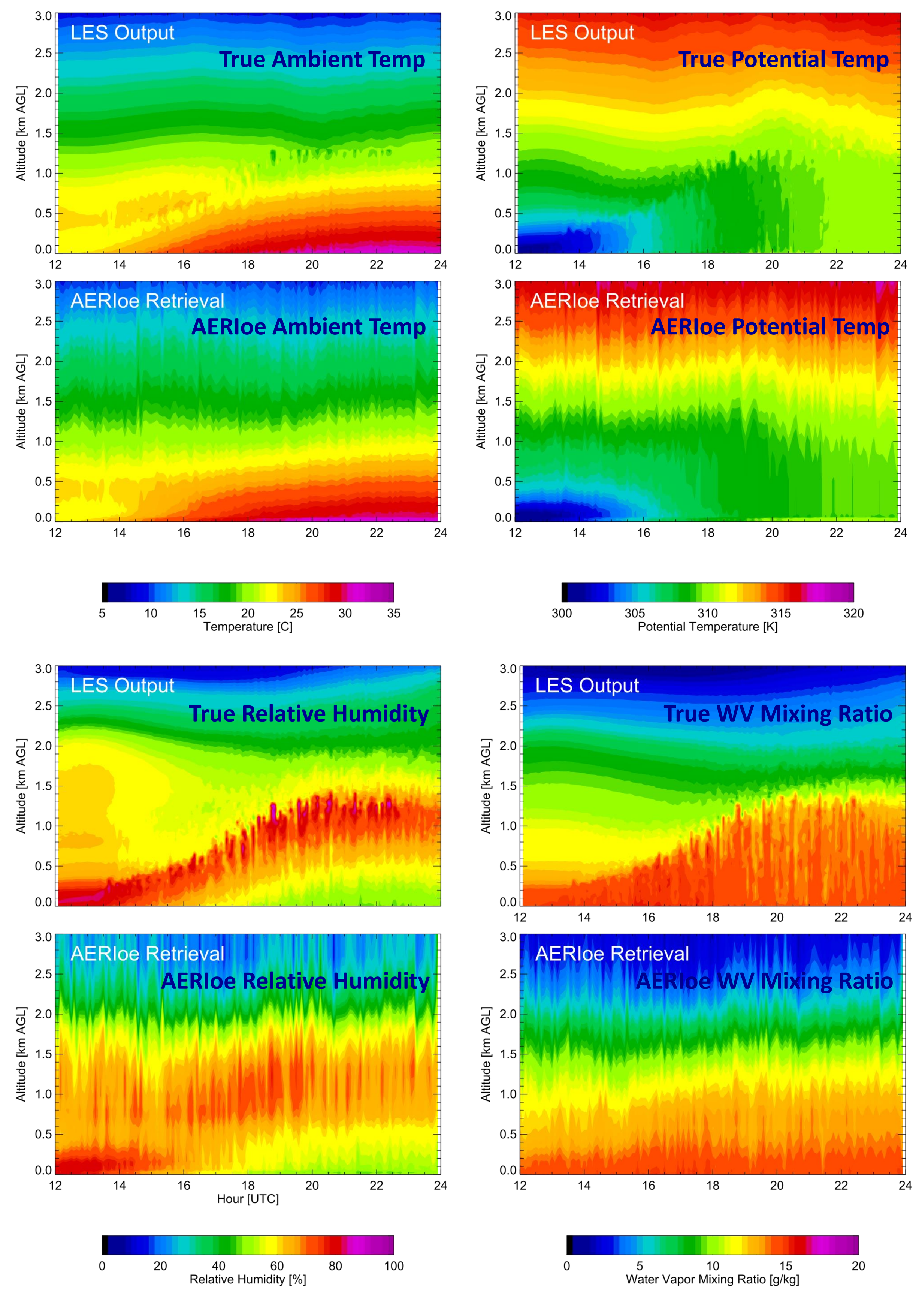
Average variance and skewness taken from 16 "stations" distributed about the time series LES data compared to the spatial series LES.



Average variance vs normalized height for both time and spatial series LES data Left: 15 minute temporal partitions. Middle: 60 minute partitions. Right: 120 minute partitions.

Evaluating AERIoe Retrievals using LES

- We simulated AERI radiance observations from LES model output
- The temperature and virtual potential temperature retrieval work well during the convective phase
- The algorithm has more difficulties with periods with less variability (morning and evening transitions). Especially for the morning transition, this may also point to a lack of turbulence in the LES simulation
- The humidity retrieval show larger biases. Gradients are not as well captured by the algorithm. Mean PWV difference is 0.02 cm
- Given that climatological *observations* are used to constrain the retrieval algorithm, this also validates the LES data as a realistic data set



LES data and AERIoe retrievals based on those LES fields.

References

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