U.S. NAVAL RESEARCH LABORATORY

# Assimilation of Boundary Layer Height Estimates from High Vertical-Resolution Radiosonde Data

**Clark Amerault, Brian Blaylock, Pat Pauley, & Dan Tyndall**
**In collaboration with PEMDAS Technologies and Innovations**

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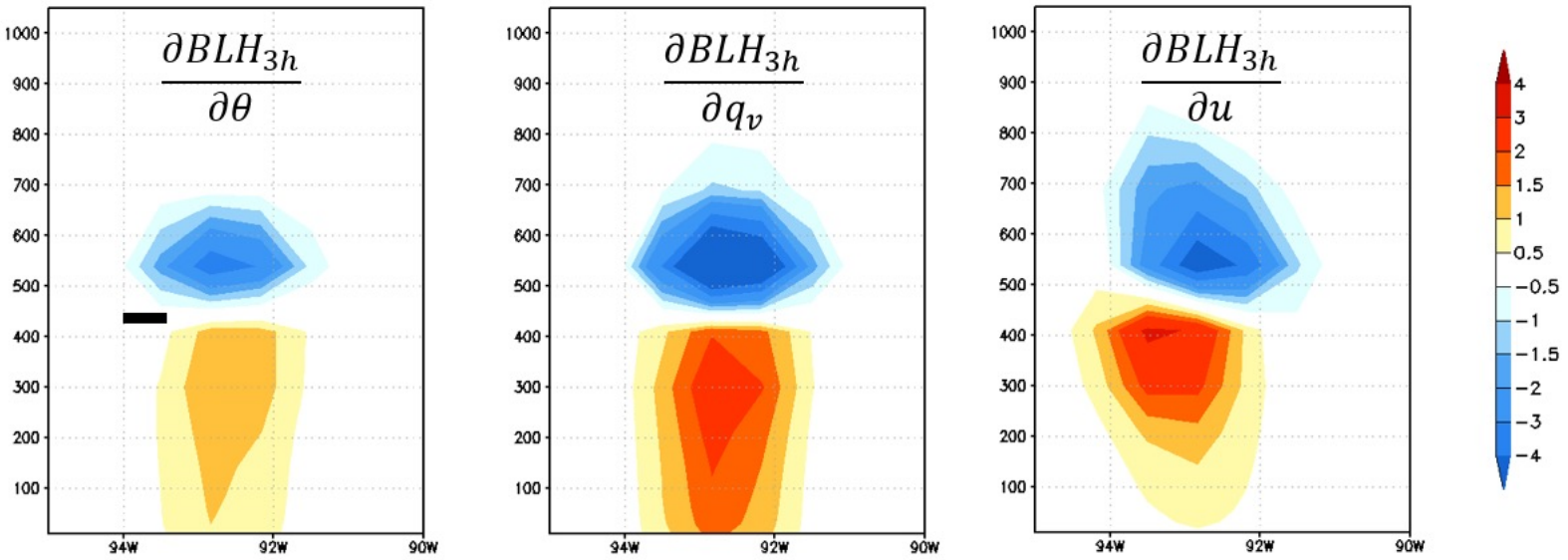
# Assimilation of BLH Estimates from HVRRD

Amerault, Blaylock, Pauley, & Tyndall

- Boundary layer height (BLH) assimilation capability developed for the Coupled Ocean Atmosphere Mesoscale Prediction (COAMPS) atmospheric model.
- BL characterization important in electromagnetic (communication) and electro-optical (lasers) applications.
- Why assimilate BLH from in situ profile data?




Adjoint sensitivity of COAMPS 3 h forecast of BLH at one point indicated by the horizontal line in the left panel (the diagnostic BLH value was 430 m) with respect to initial potential temperature (left), water vapor mixing ratio (middle), and zonal wind component (right). The vertical cross section was taken over the Gulf of Mexico on 0000 UTC July 30, 2020.

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# Ensemble BLH Height Assimilation Approaches:

Tangborn et al. 2021: Assimilation of lidar planetary boundary layer height observations. DOI: https://doi.org/10.5194/amt-14-1099-2021

- Lidar data assimilated (EnKF) for 1-day in Kansas (PECAN) using WRF
- Larger error in afternoon forecasts of BLH, assimilation had larger impact

Dang et al. 2022: Observation system simulation experiments (OSSEs) for assimilation of the planetary boundary-layer height (PBLH) using the EnSRF technique. DOI: 10.1002/qj.4254

- Simulated BLH observations assimilated (EnKF) for 1 day over China using WRF
- Larger assimilation impact in afternoon
- Temperature & moisture (afternoon); winds (night)
- Impact smaller above BL

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# Assimilation of BLH Estimates from HVRRD

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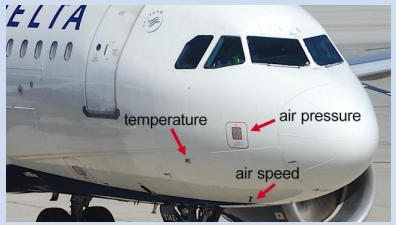
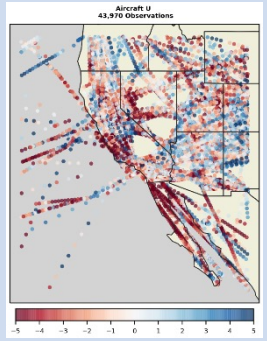
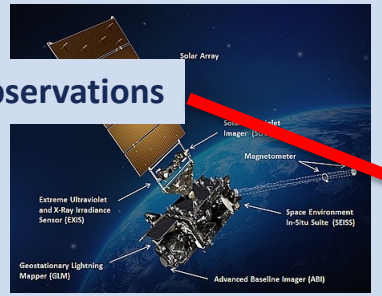
## DATA

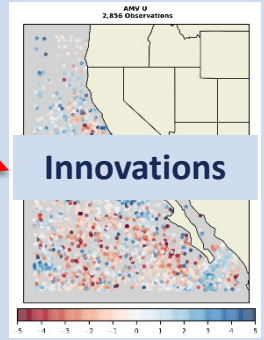


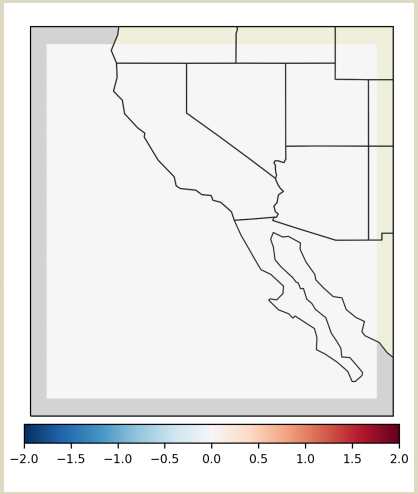
Observations



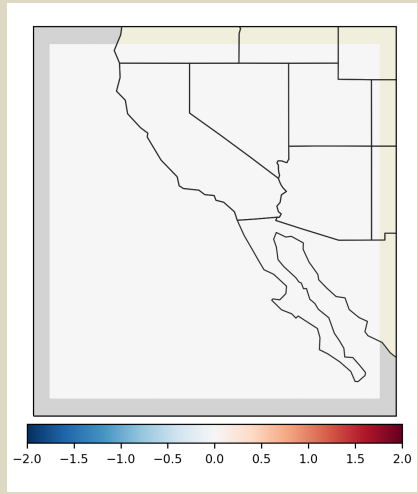

Innovations



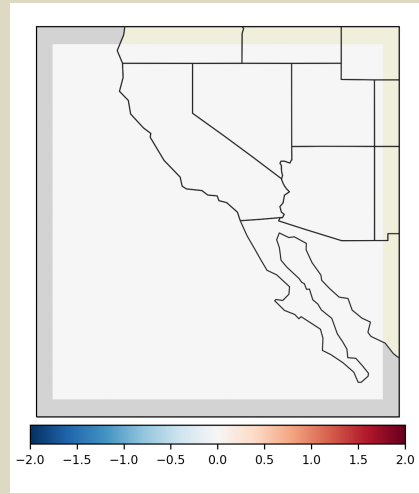
## ASSIMILATION



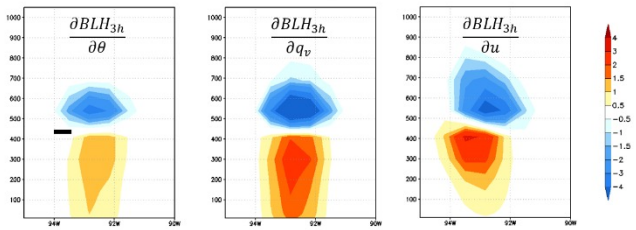

Adjoint




Background Error Covariance




Tangent Linear




Sensitivity of BLH to COAMPS state variables

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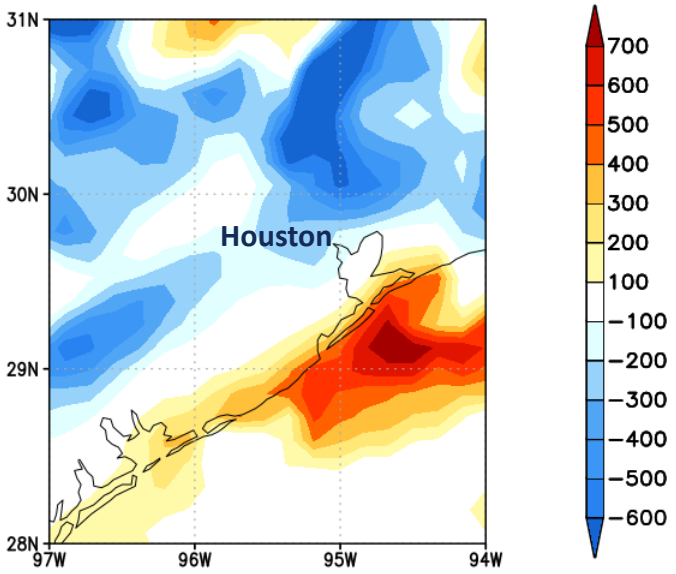
# Boundary Layer Height Variability




COAMPS BLH increment 1800 UTC 6 Sep 2022

State variable analysis increments result in BLH increments ~ 100s m

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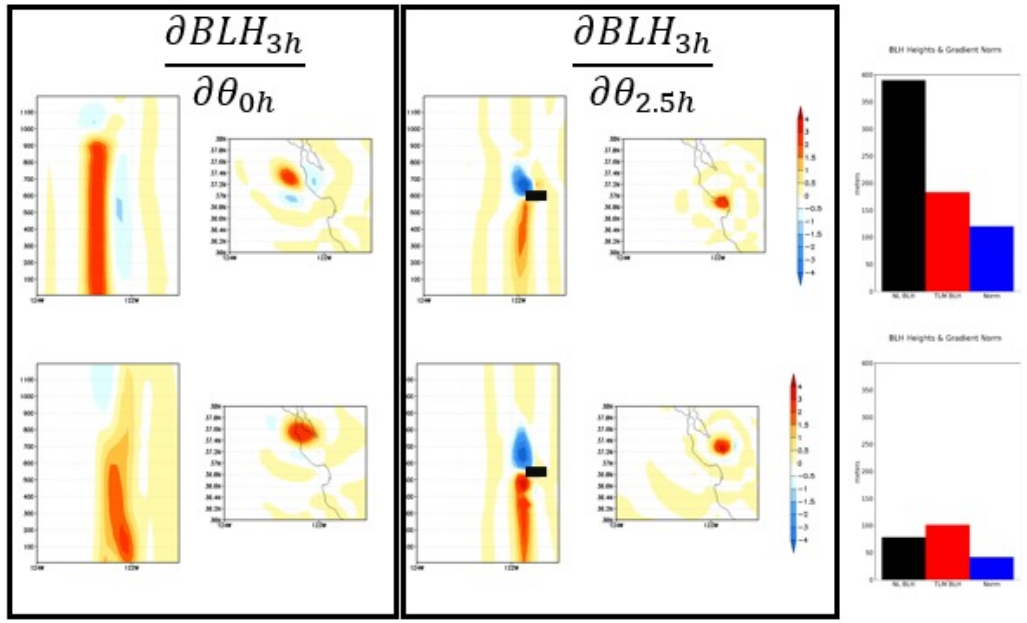
# Boundary Layer Height Variability




1800 UTC 22 February 2022

- 1 K perturbations → 100s m BLH perturbations.
- Response is more linear as sensitivity decreases.

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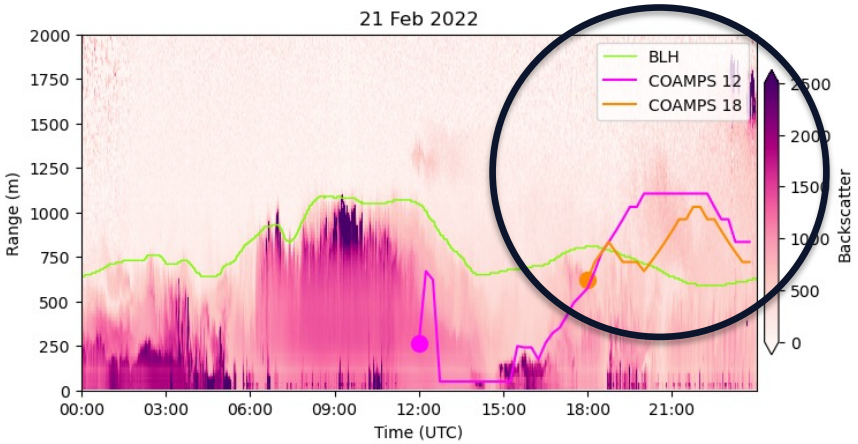
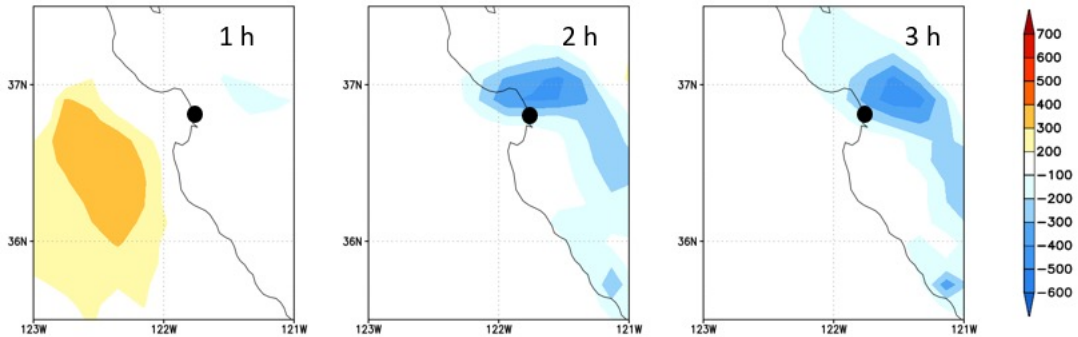
# Ceilometer Assimilation

Ceilometer

Backscatter and BLH




BLH Differences




- Assimilation of BLH observations for 1800 UTC draw analysis and forecast toward observation.
- Feature extends inland and along eastern Salinas Valley.

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# ASAPS BLH Estimate

- Atmospheric Sensing and Prediction System (ASAPS) sensor developed by PEMDAS Technologies and Innovations.
- Measures temperature and humidity on UAS.
- BLH estimated using ensemble of temperature and humidity techniques.


| BLH Estimate Technique | Input Variables |
|---|---|
| Max vertical gradient of potential temp | $\theta$ |
| Max vertical gradient of virtual potential temp | $\theta_v$ |
| Level where $\theta$ is 1.5K warmer than min $\theta$ | $\theta$ |
| Min vertical gradient of specific humidity | q |
| Level of min vertical gradient of relative humidity | RH |
| Level of min vertical gradient of refractivity | P, T, $P_{H2Ov}$ |
| Level of min vertical gradient of water vapor partial pressure | P, r |
| Level of min vertical gradient of mixing ratio | r |

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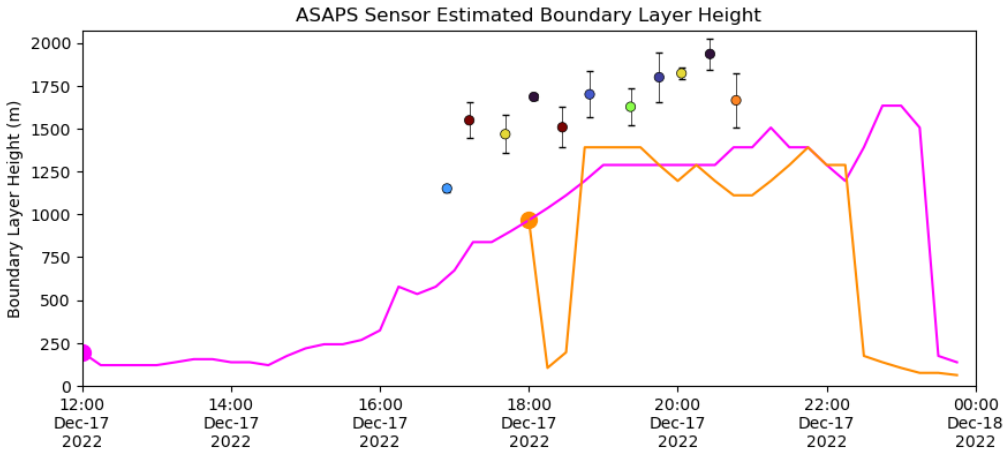
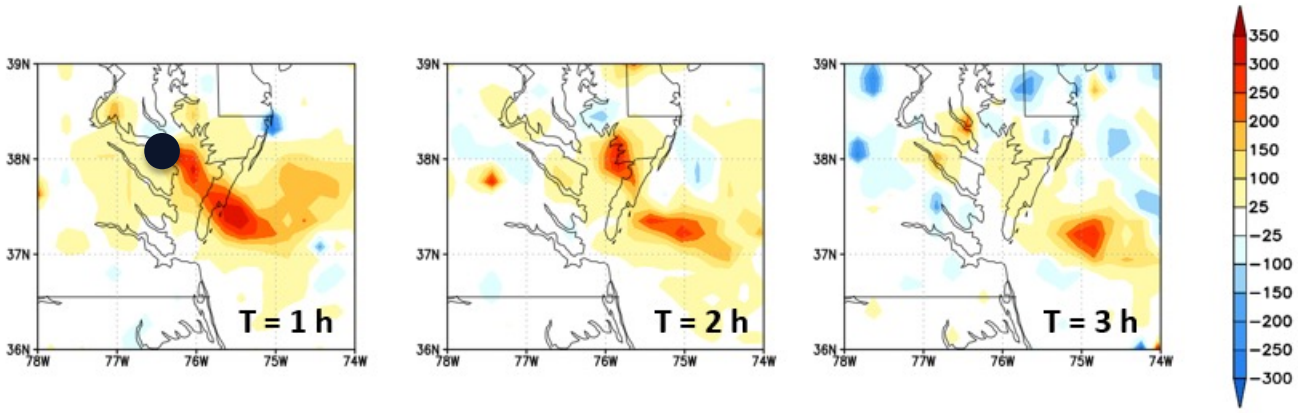
# ASAPS Assimilation

ASAPS and COAMPS




BLH Differences




- ASAPS mounted on Vanilla long endurance UAS, flew multiple ascents/descents.
- Data assimilation diagnostics indicated that the BLH should draw closer to the observations, but there was an early adjustment that collapsed the BL.
- BLH was increased to the SE of the assimilation area.

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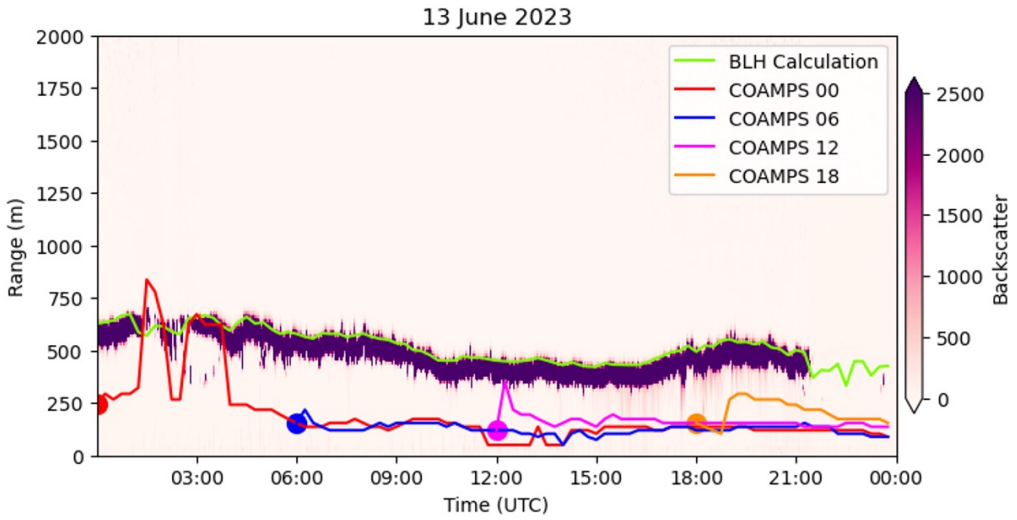
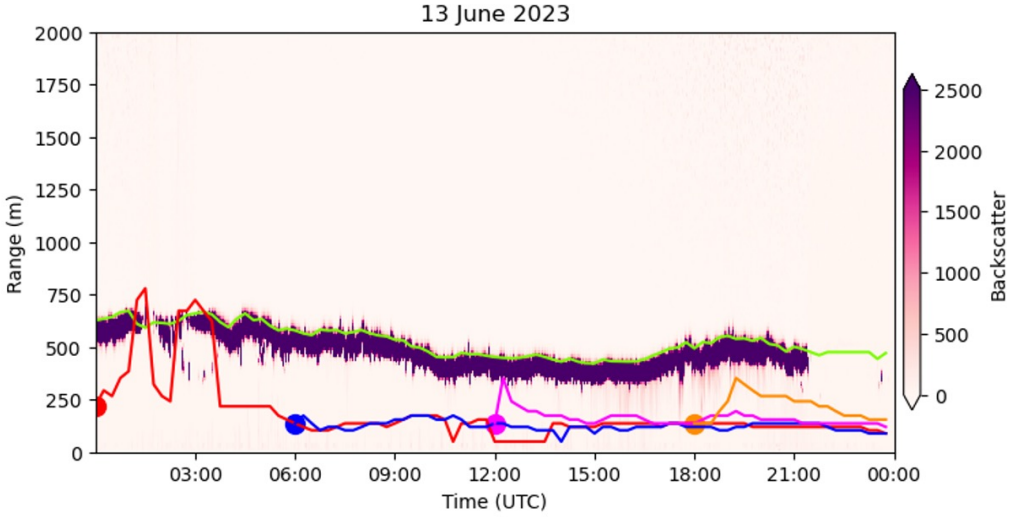
# Less Impactful BLH Assimilation

No BLH Assimilation




BLH Assimilation




- Adjoint sensitivity of BLH to state variables relatively small….smaller increments.
- Investigating the environmental conditions for small sensitivities.

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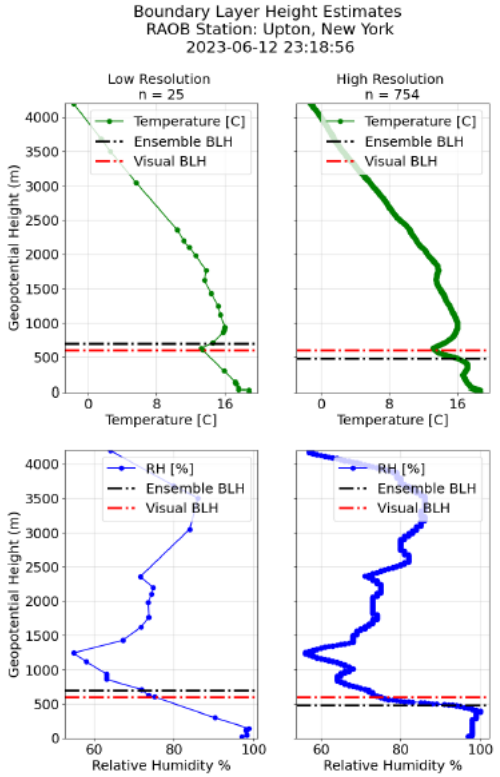
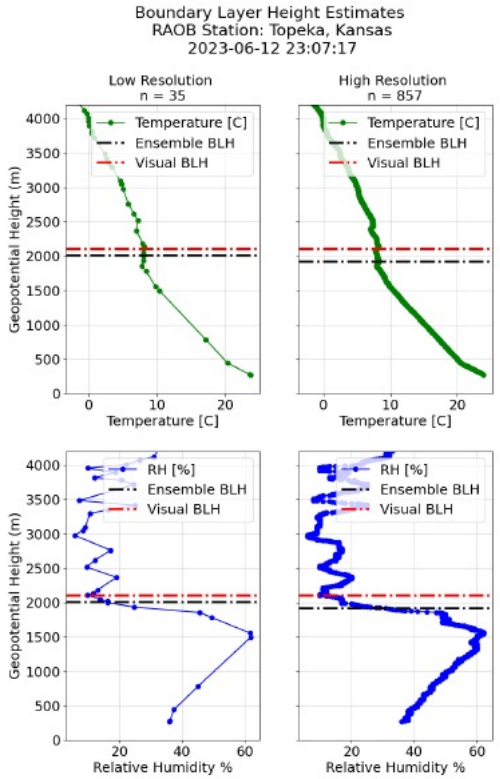
# BLH from High and Low Resolution Radiosonde

## Upton, NY (Long Island)




## Topeka, KS




- PEMDAS calculates BLH from ensemble of temperature and moisture techniques (same as ASAPS sensor).
- Difference in high and low resolution BLH estimate ~ 200 m for Upton.

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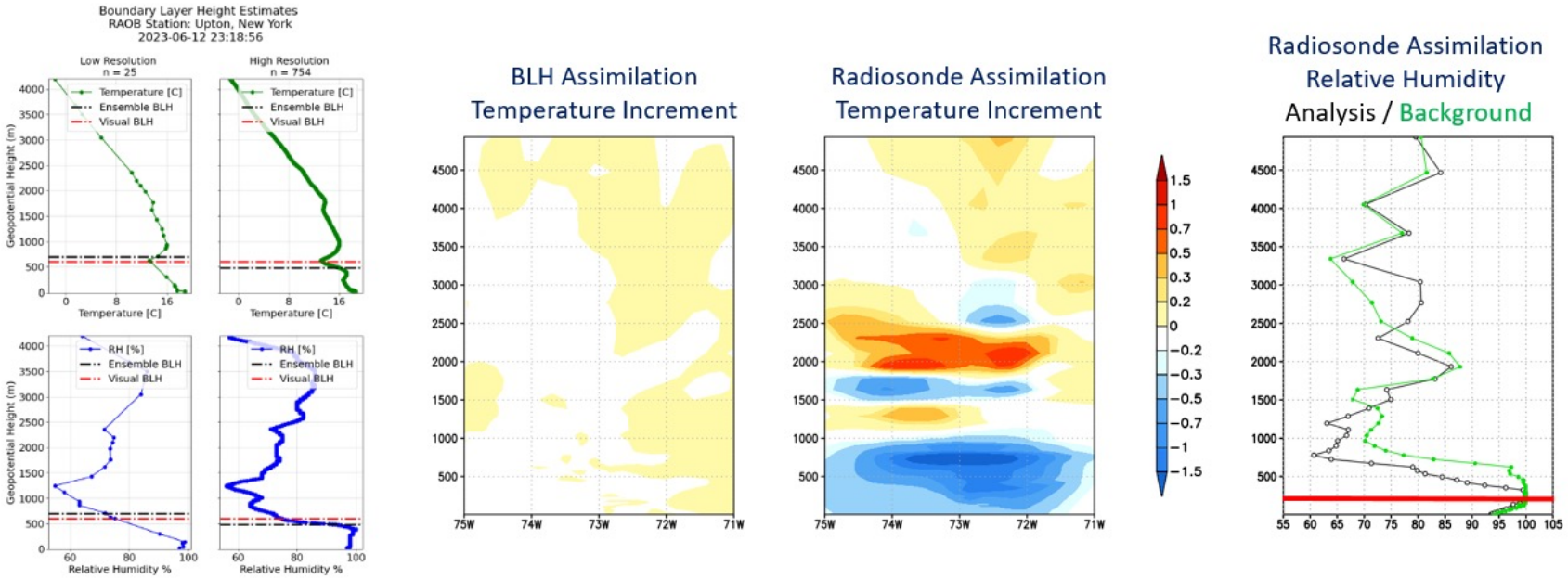
# Radiosonde BLH Assimilation – Upton, NY




- In situ profile assimilation produces larger increments…little effect on BLH.

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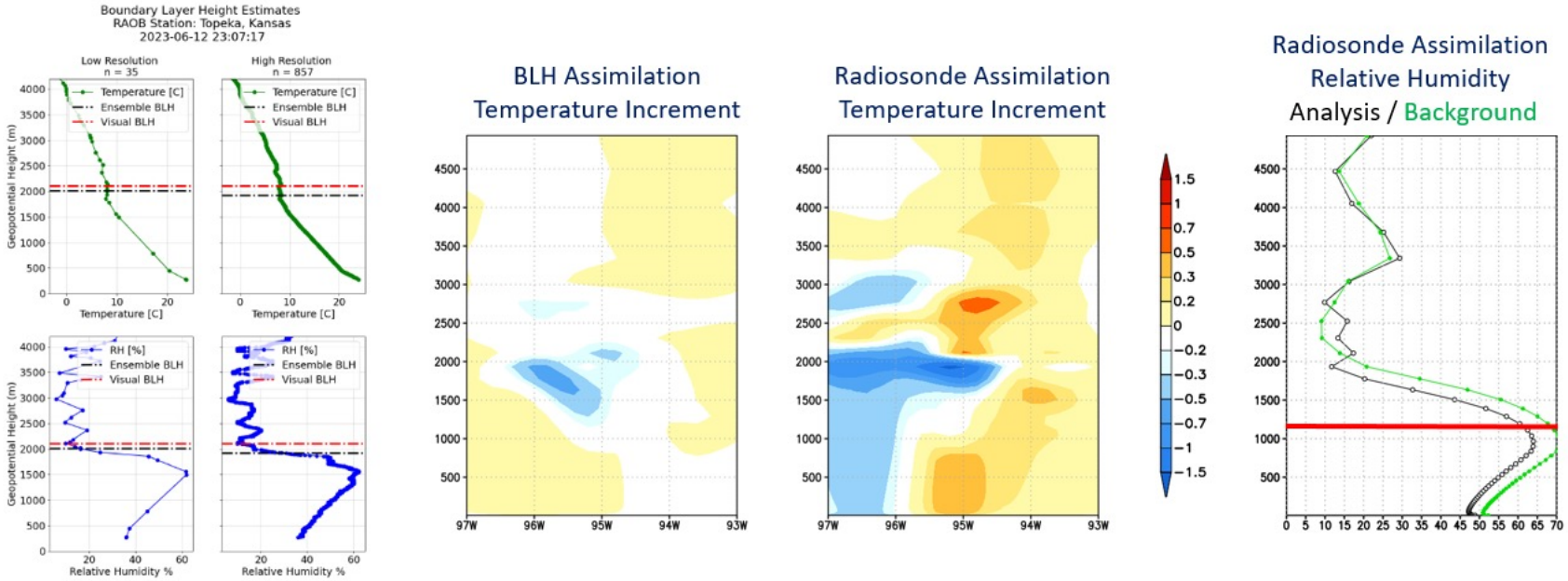
# Radiosonde BLH Assimilation – Topeka, KS

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# Assimilation of BLH Estimates from HVRRD

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- BLH assimilation still in developmental stage.
- Adjoint sensitivities of BLH to state variables are not always large enough to produce impactful increments.
- Need for consistent BLH estimate technique across observations, model, and data assimilation operators.
- Differences in BLH estimates from high and low resolution radiosondes smaller than differences in model and observations.
- In situ profiles (HVRRD) important for testing capability.

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