NOAA/PSL PERiLS Boundary Layer Studies

Bianca Adler, Laura Bianco, Tim Myers, Dave Turner, **Jim Wilczak**

Outline:

- Thermodynamic profile retrievals
  - What we’ve done to improve them for PERiLS
- PWV characteristics during PERiLS 2022 and 2023
  - How IOPs are different from non-IOP days
- Evaluation of HRRR forecasts at Courtland, AL
  - Interaction between surface and clouds

Columbia, LA NOAA/PSL PERiLS site

Infrared Spectrometer (IRS)

Optimal estimation physical retrieval TROPoe

- Based on AERIoe (Turner and Löhnert, 2014, Turner and Blumberg, 2019, Turner and Löhnert, 2021)

- Three ingredients:
  - Observations: (IRS and/or MWR irradiances) + (Optional T&q from RASS, aircraft, UAS, radiosondes, surface met, models)
  - Prior $\boldsymbol{X_a}$ (nearby radiosonde climatology)
  - Radiative transfer model *F* (LBLRTM or MONORTM).

  -> optimal state vector ***X:*** T(z), q(z), LWP

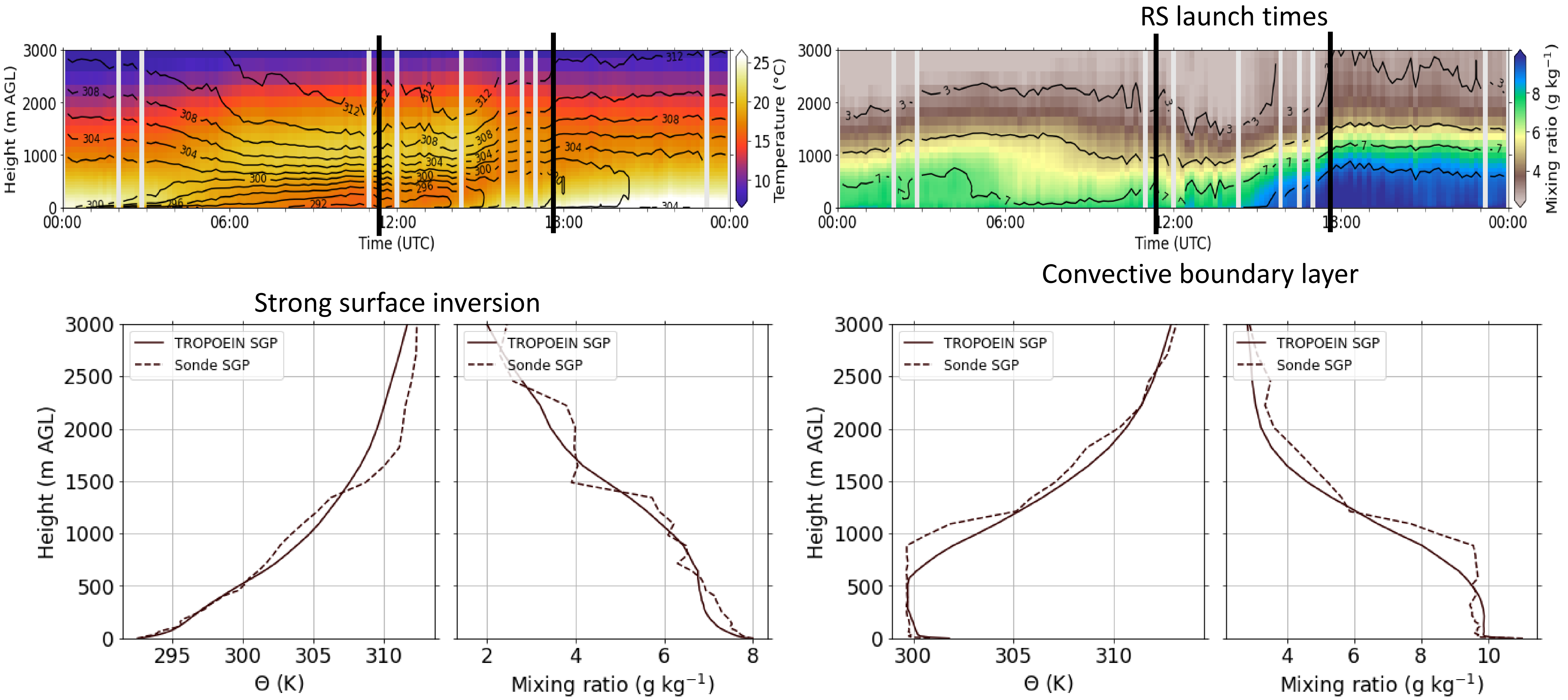
- The state vector at the *n+1* iteration is computed as:

$$\boldsymbol{X}_{n+1} = X_a + (\gamma \boldsymbol{S}_a^{-1} + \boldsymbol{K}_n^T \boldsymbol{S}_\epsilon^{-1} \boldsymbol{K}_n)^{-1} \boldsymbol{K}_n^T \boldsymbol{S}_\epsilon^{-1} (\boldsymbol{Y} - F(\boldsymbol{X}_n) + \boldsymbol{K}_n(\boldsymbol{X}_n - \boldsymbol{X}_a))$$

where *K* is the Jacobian of *F*, $\boldsymbol{S_a}$ is the covariance matrix of the prior, ***Y*** is the observation vector, and $\boldsymbol{S_\epsilon}$ denotes the observation error covariance matrix.

- Monthly priors are computed for each site recentered using daily average of near-surface water vapor mixing ratio.

Example of IRS retrieved thermodynamic profiles



IRS time resolution: 5 min

Issues with past TROPoe configurations

1. Overfitting of profiles for IRS-based retrievals

- TROPoe may not converge because it is overly constrained.
- Constraint comes because uncertainty of forward model is currently not included due to computational limitations. Instead radiance uncertainty is inflated to compensate for this (Turner and Blumberg 2019).
- **But even inflation of uncertainties** may not be sufficient to prevent overfitting and lack of convergence

→ **Implement default minimum noise level for radiance uncertainty**

2. Saturation of IRS water vapor bands in very moist environments

- TROPoe may not converge because traditional spectral bands used for water vapor can be saturated and contain little information content

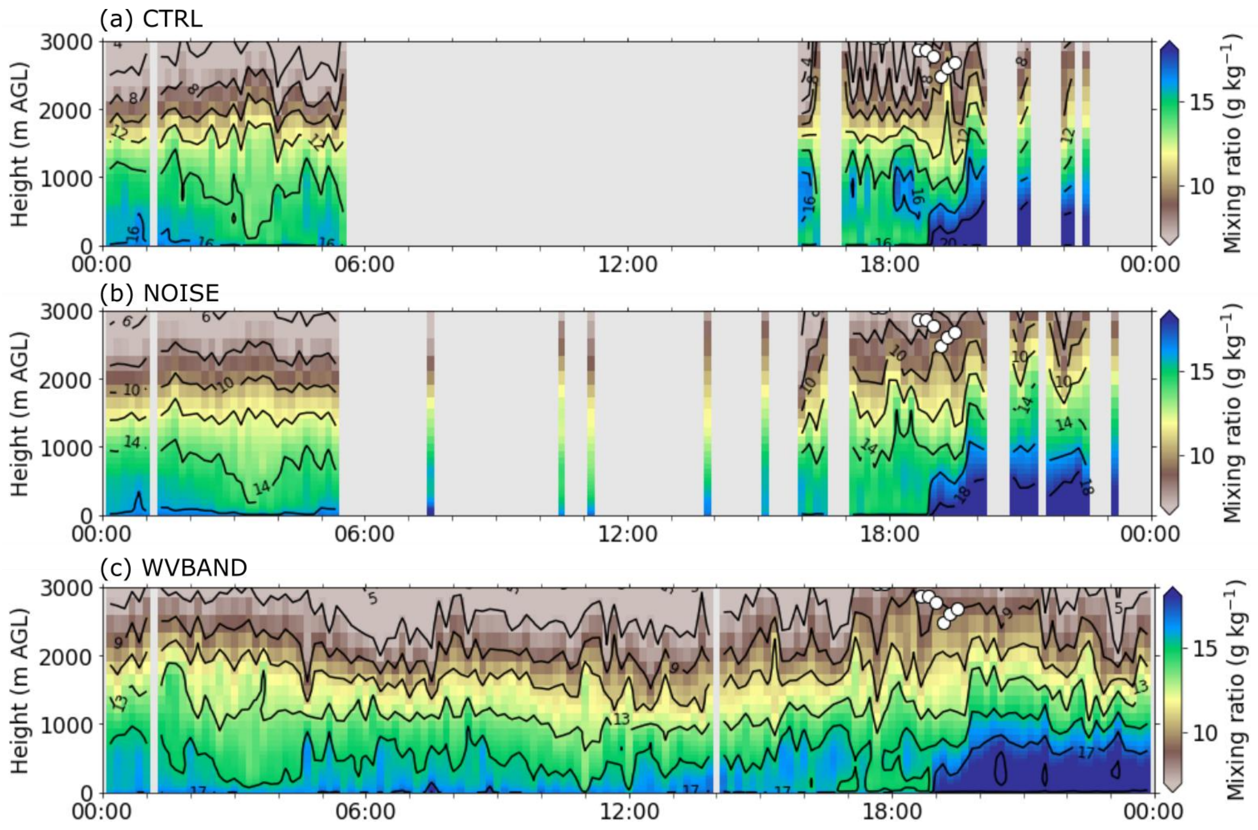
→ **Add additional spectral band for water vapor**

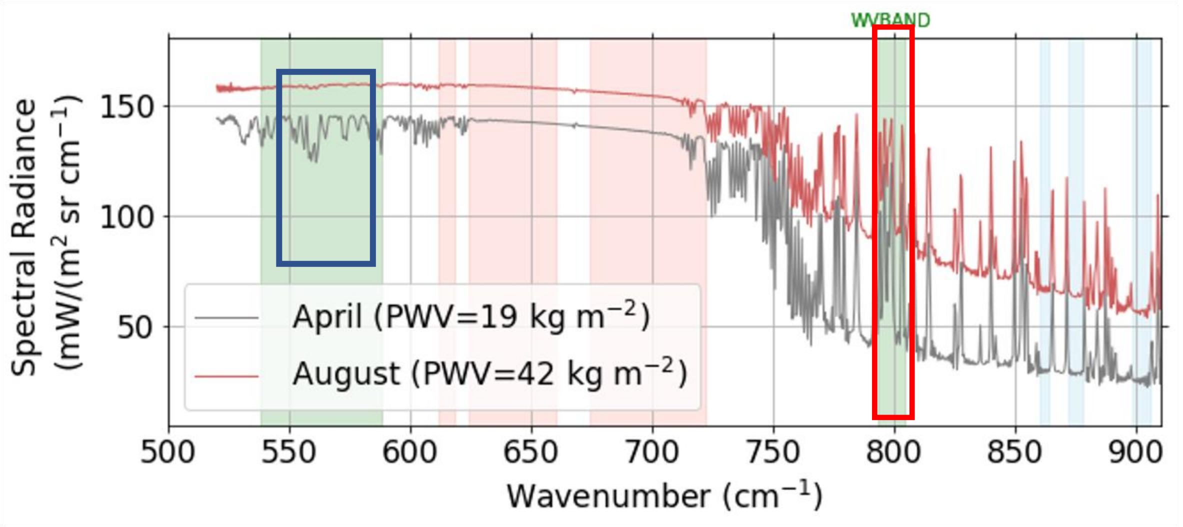
3. Temporal consistency of profiles

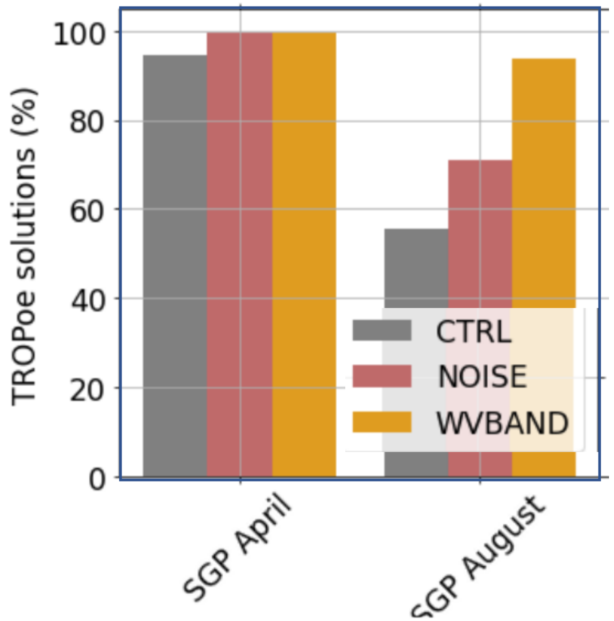
- Every time stamp is processed separately without using any information from previous state of the atmosphere
- 'Noisy' time series hindering analysis of physical processes and diurnal cycles

→ **Include information from previous retrieved thermodynamic profile with inflated uncertainty as input to the retrieval**

1 & 2. Noise and Saturation of water vapor bands



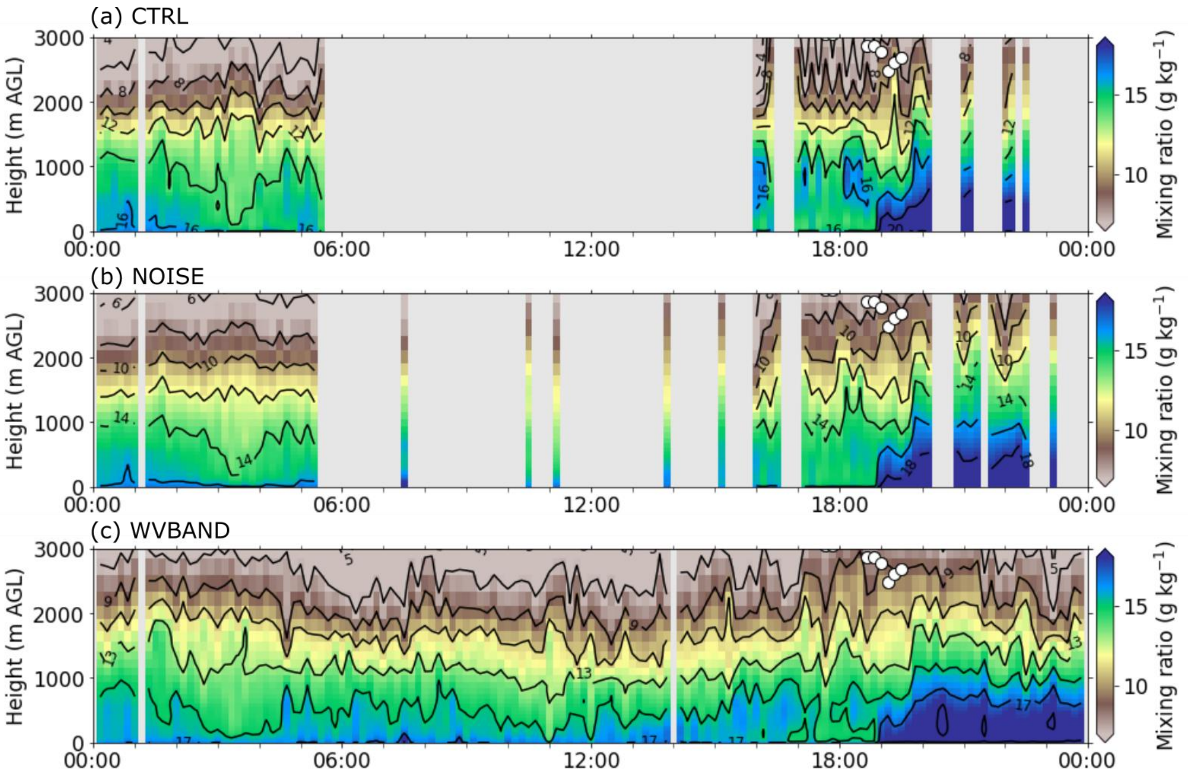


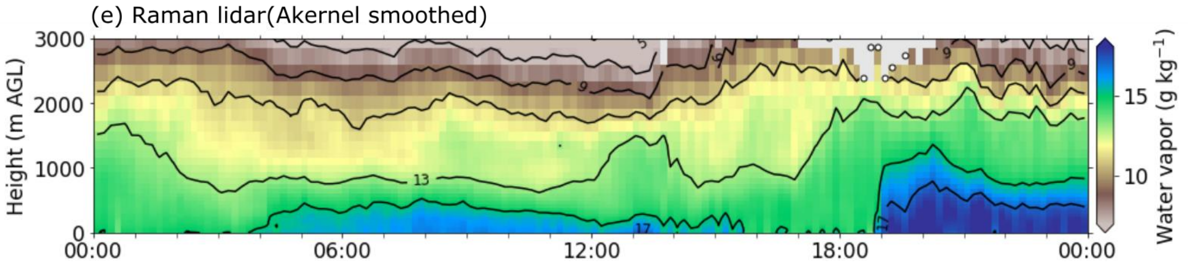


3. Temporal consistency of profiles

- Every time stamp is processed separately without using any information from previous state of the atmosphere
- ‘Noisy’ time series make analysis of physical processes and diurnal cycles challenging

→ **Include information from previous retrieved thermodynamic profile with inflated uncertainty as input to the retrieval**





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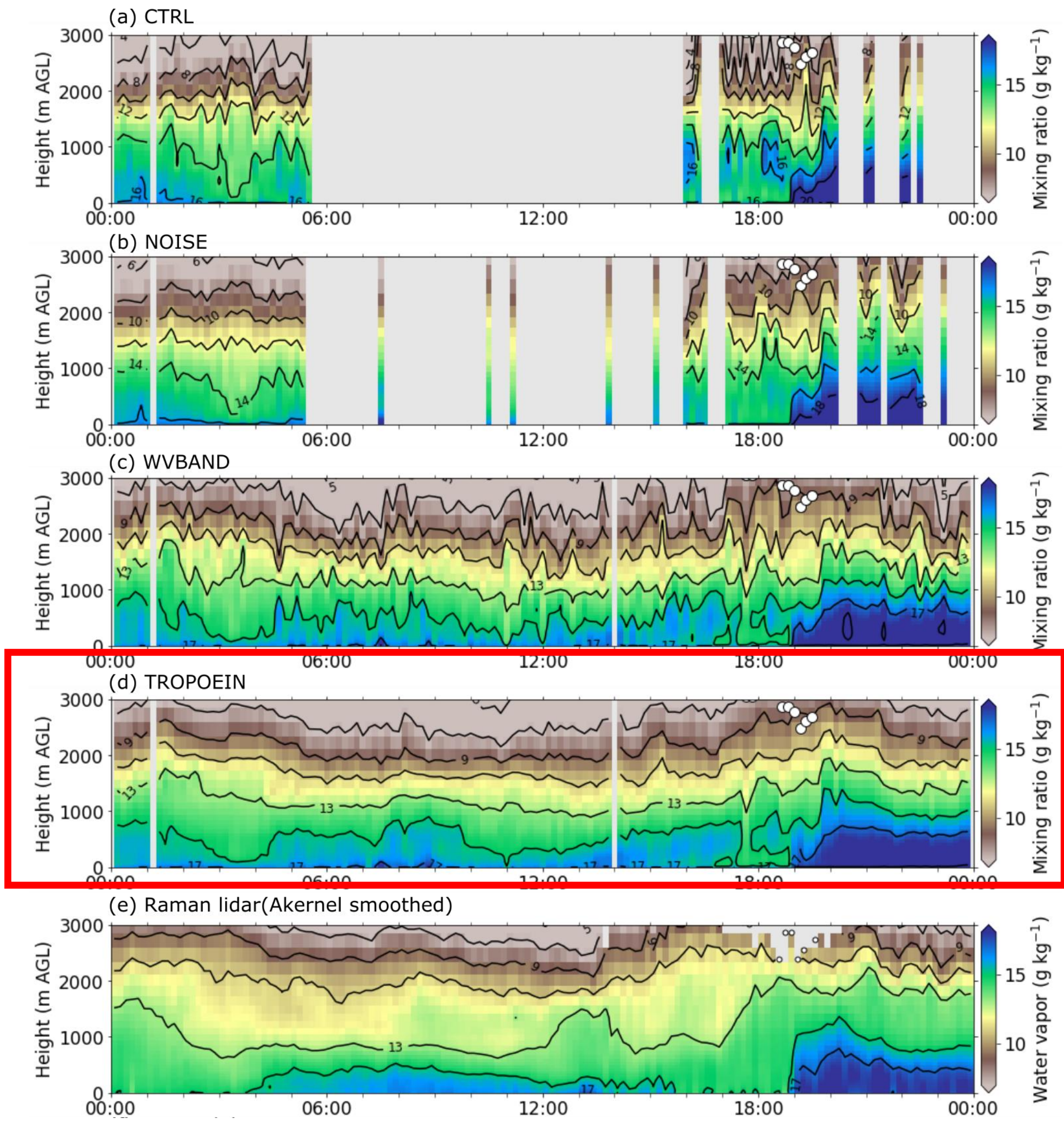
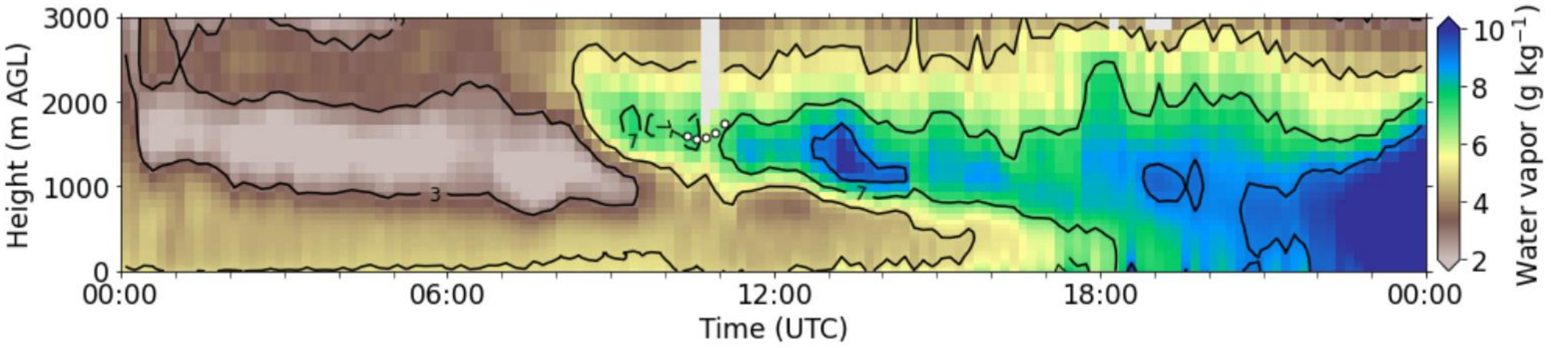
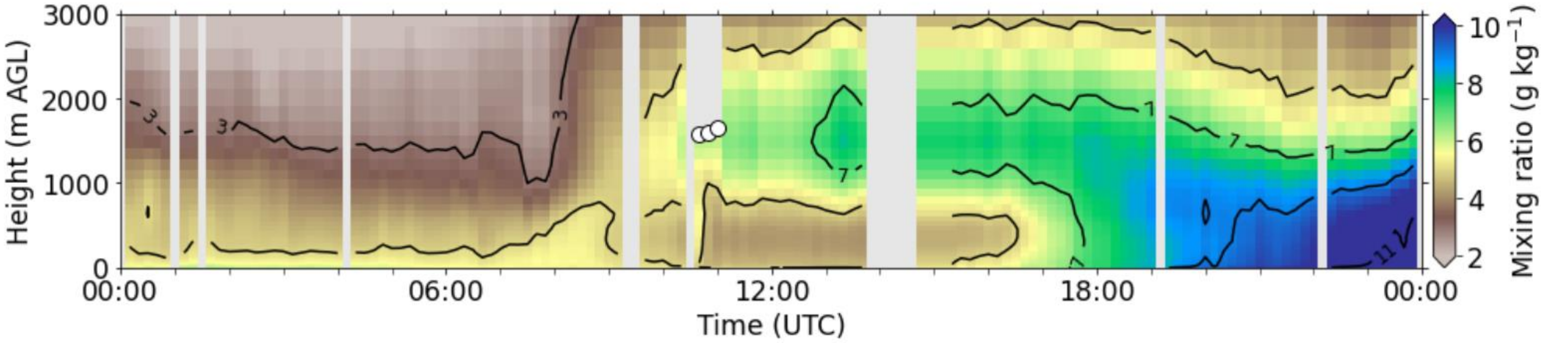


Example of advection of elevated moist air layer

Raman lidar



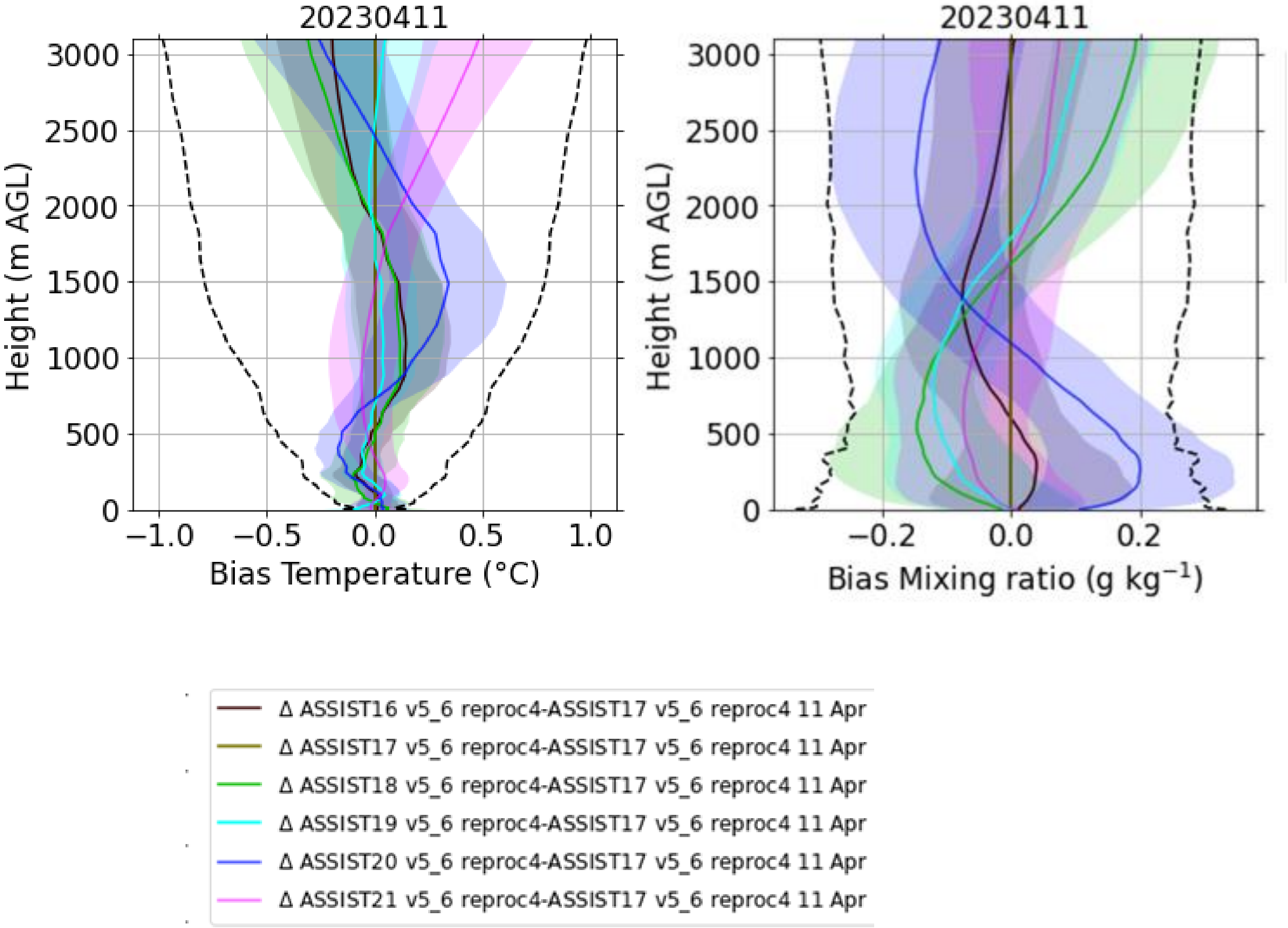
TROPOEIN



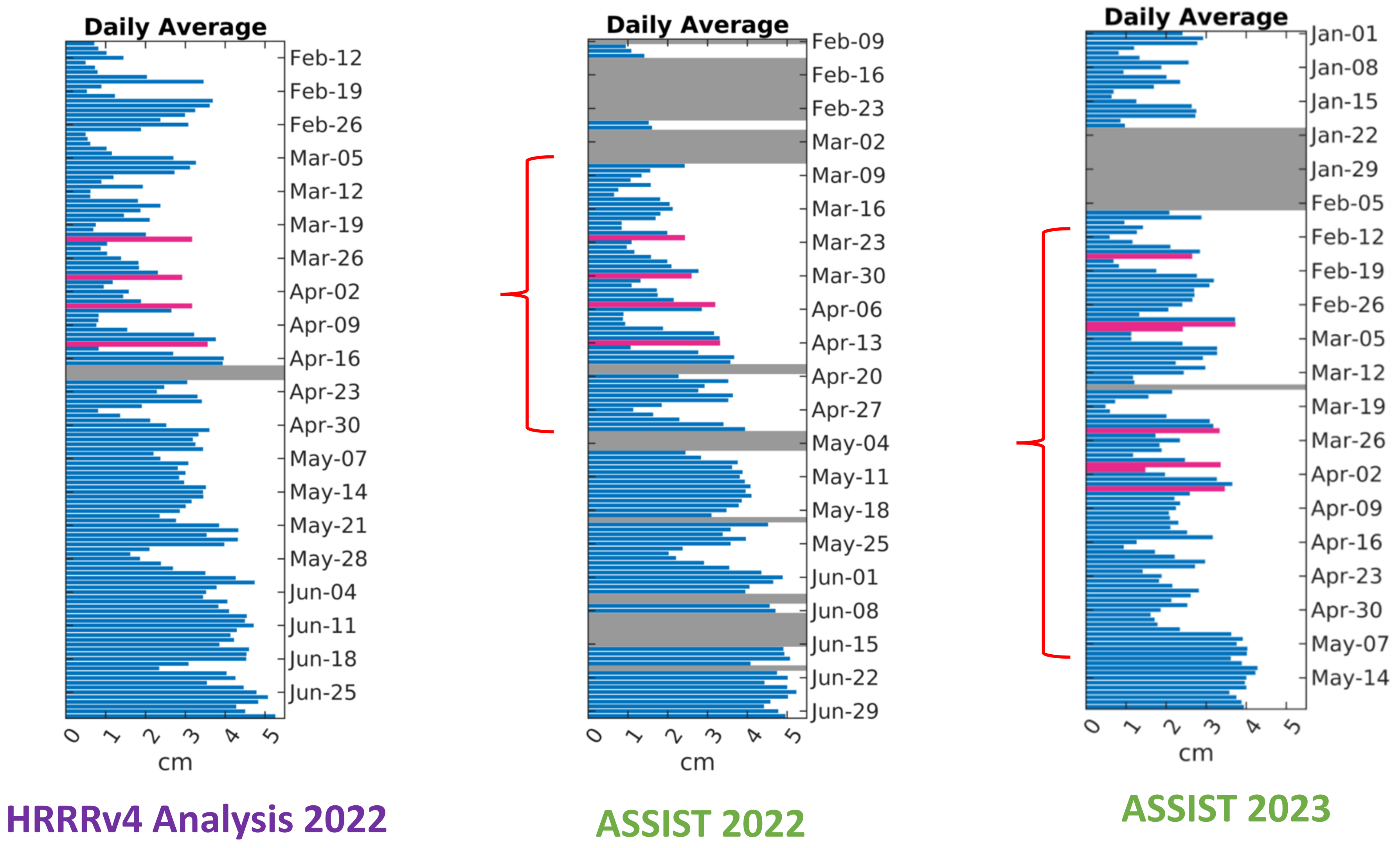
While noise is reduced in TROPOEIN, mesoscale changes are still well represented

We are currently reprocessing all PERiLS data for our IRS and MWR using these improved techniques

Inter-instrument differences reprocess 4 - 20230411

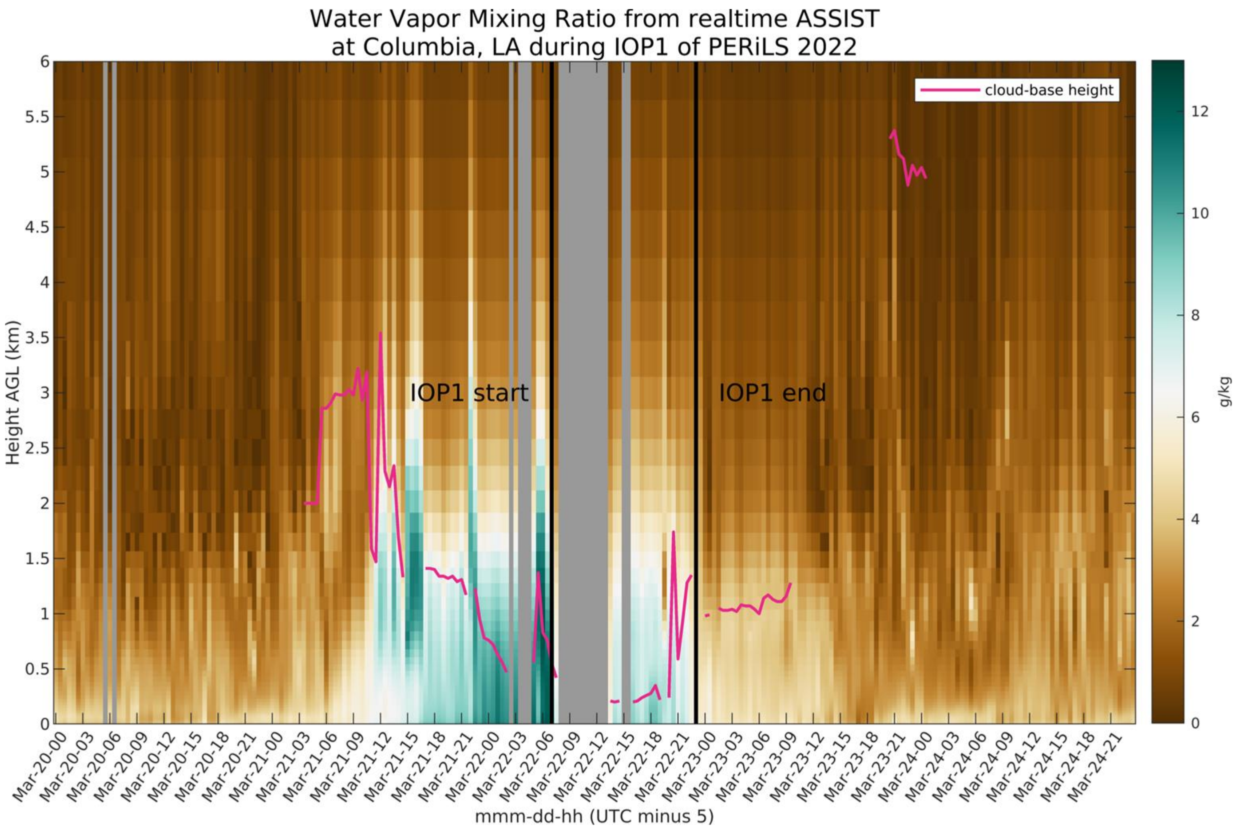


PWV Daily Averages from Columbia, LA During PERiLS 2022 and 2023

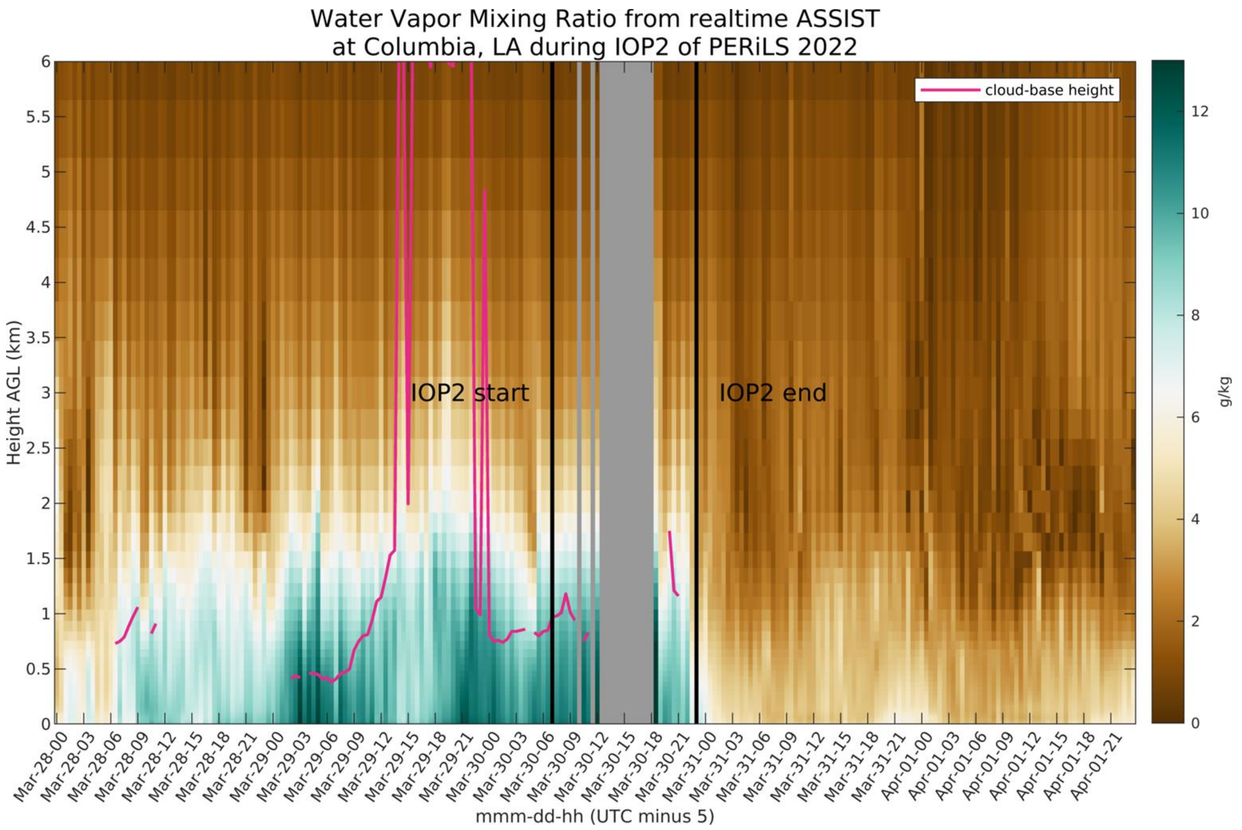


QLCSs, as identified by the IOPs, feature seasonally high PWV, followed by drier conditions

A water vapor view of a QLCS during IOP1 and IOP2 of PERiLS 2022

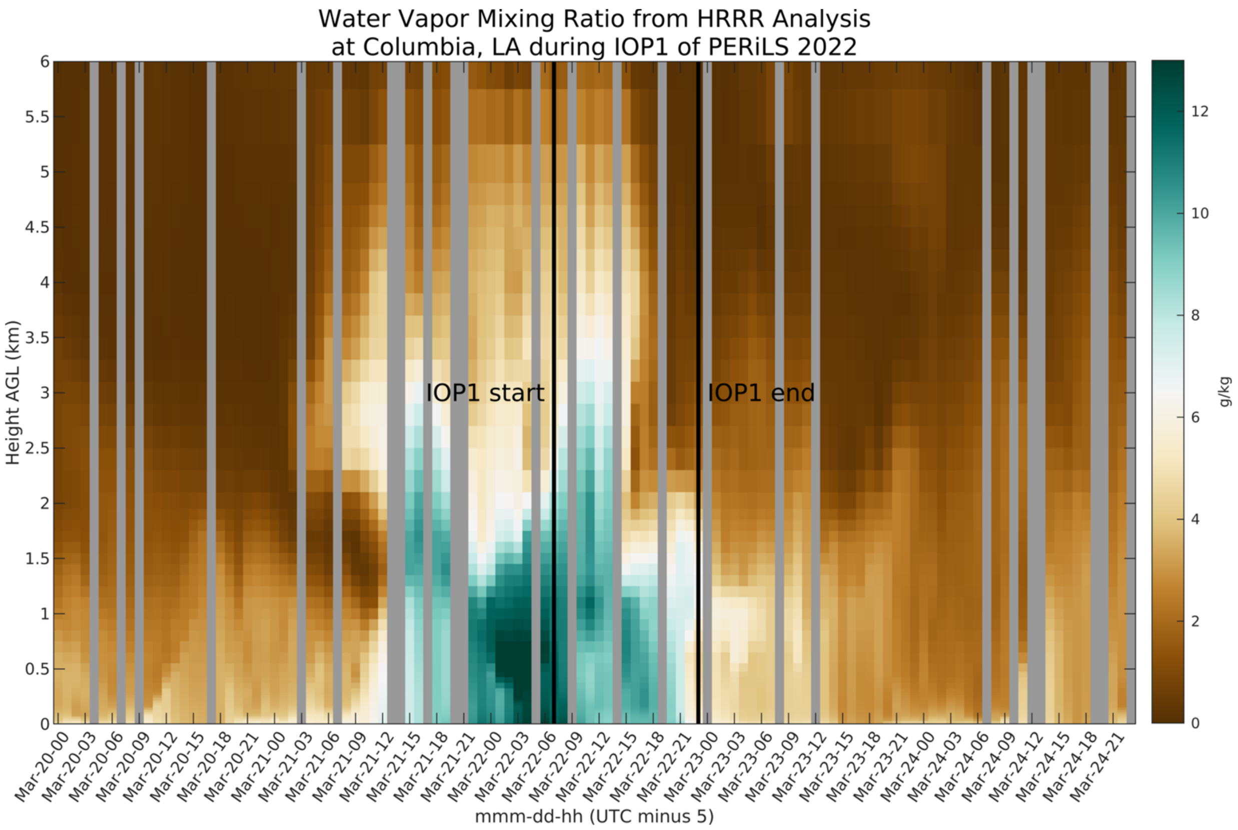


IOP1

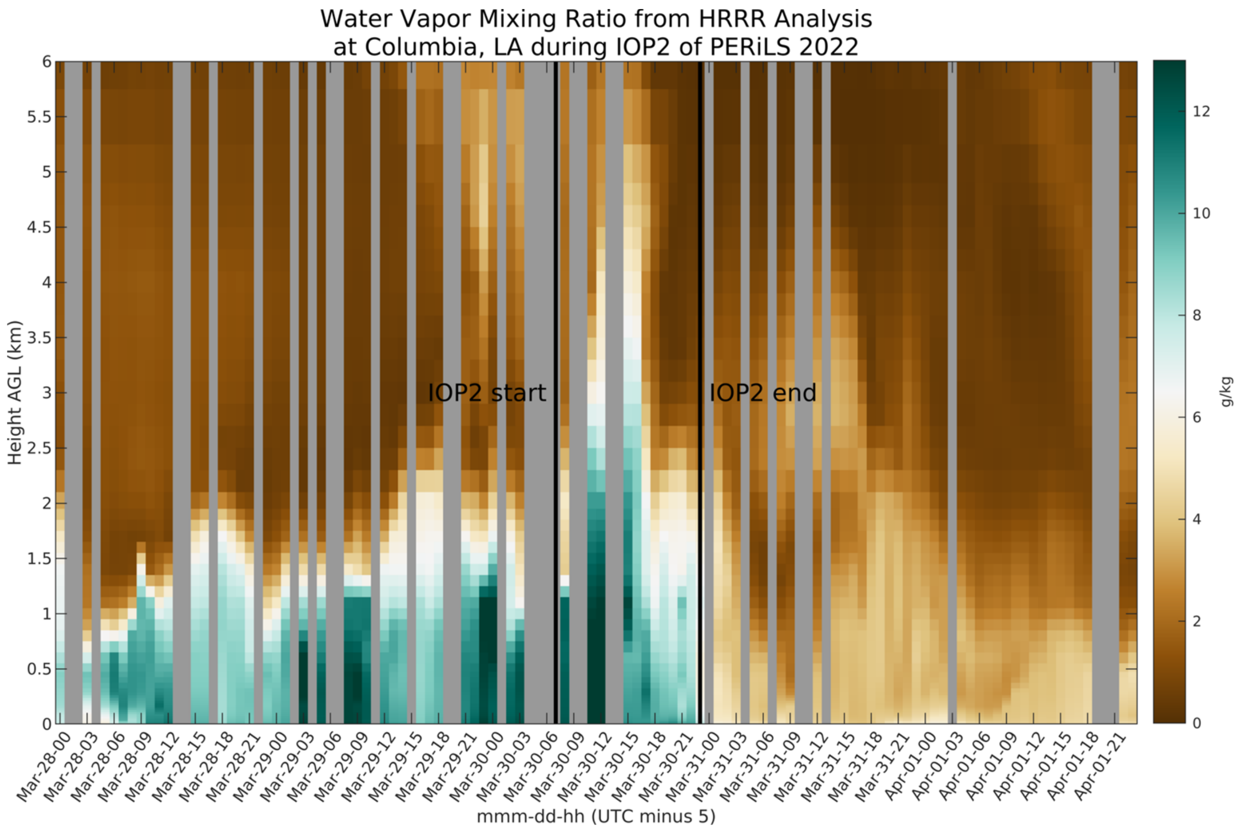


IOP2

IRS only



IOP1



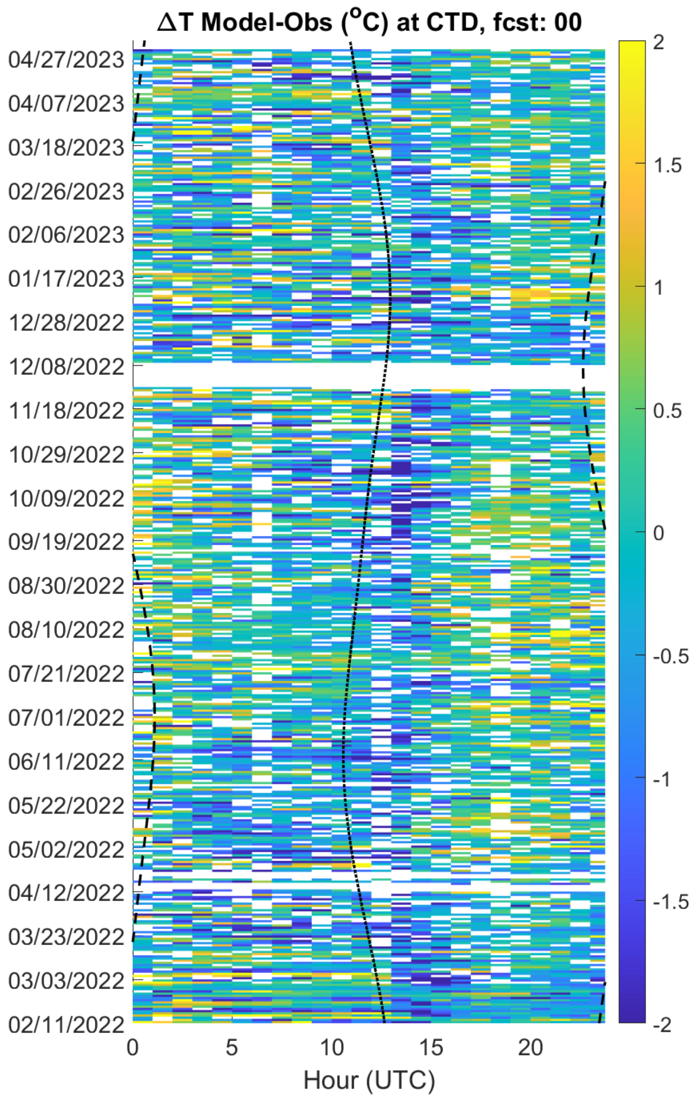
IOP2

HRRRv4 Analysis

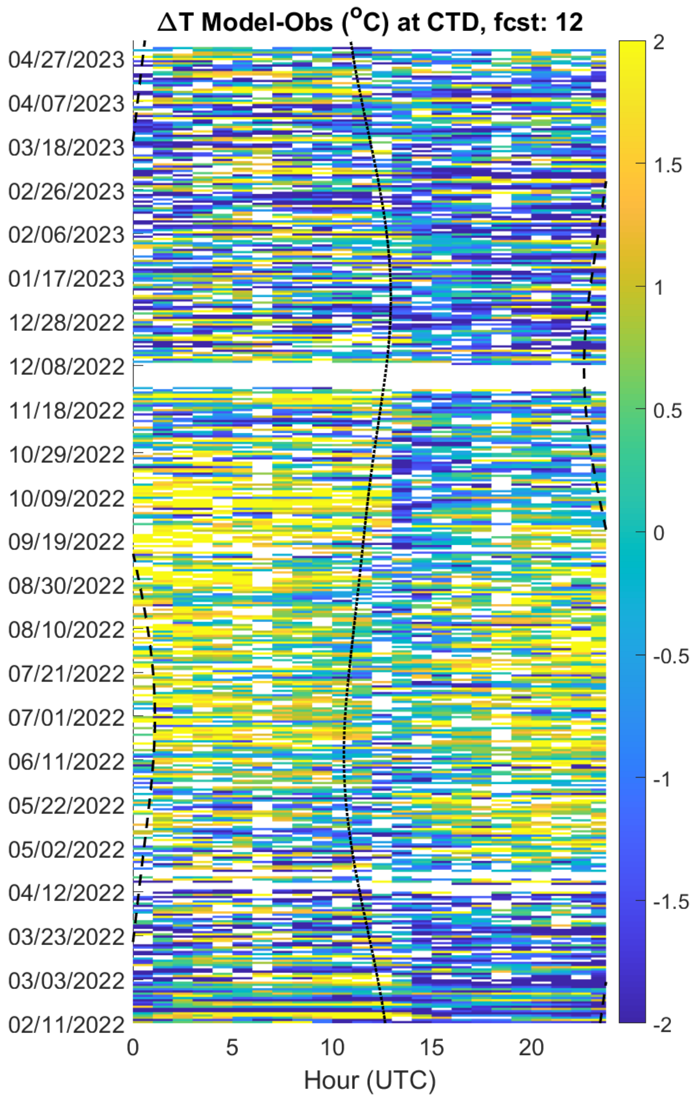
Evaluation of HRRR forecasts at Courtland, AL

HRRR 2-m Temperature Biases, Feb 2022 – May 2023, Courtland, AL

ΔT, Initialization time

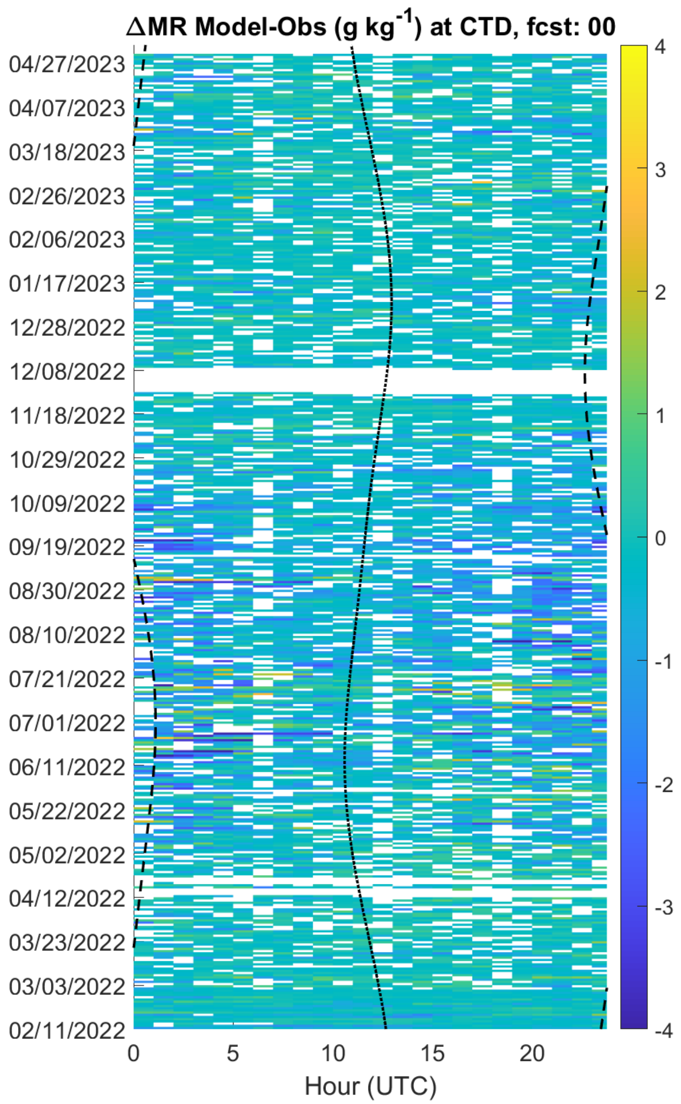


ΔT, Forecast horizon 12

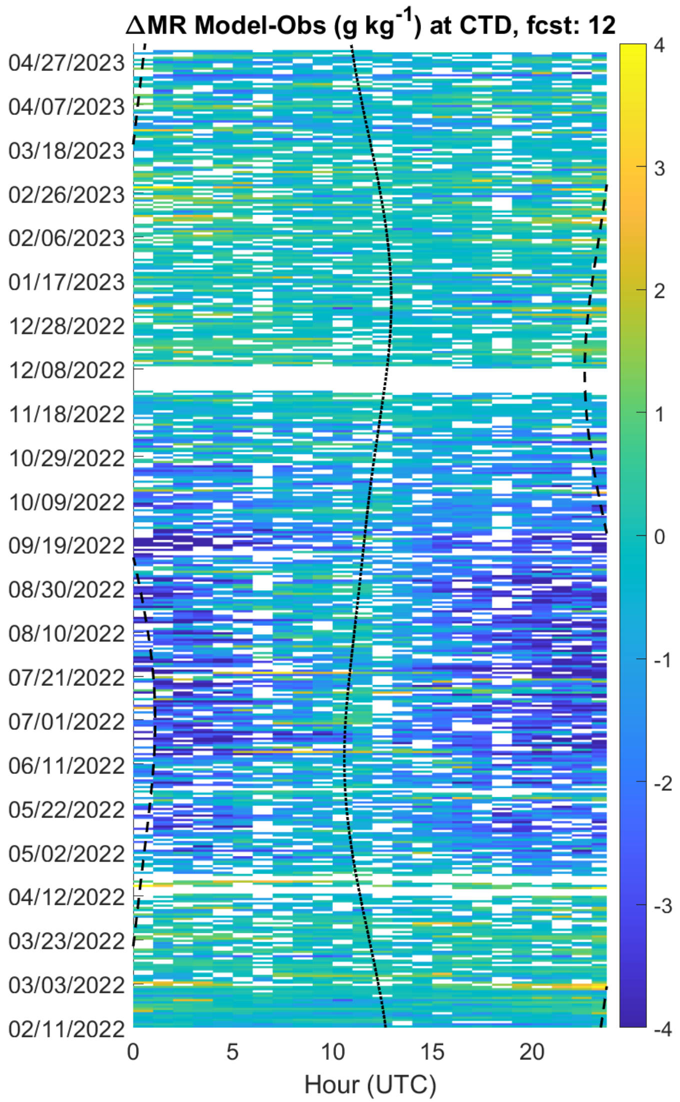


HRRR 2-m Mixing Ratio Biases, Feb 2022 – May 2023, Courtland, AL

ΔMR, Initialization time



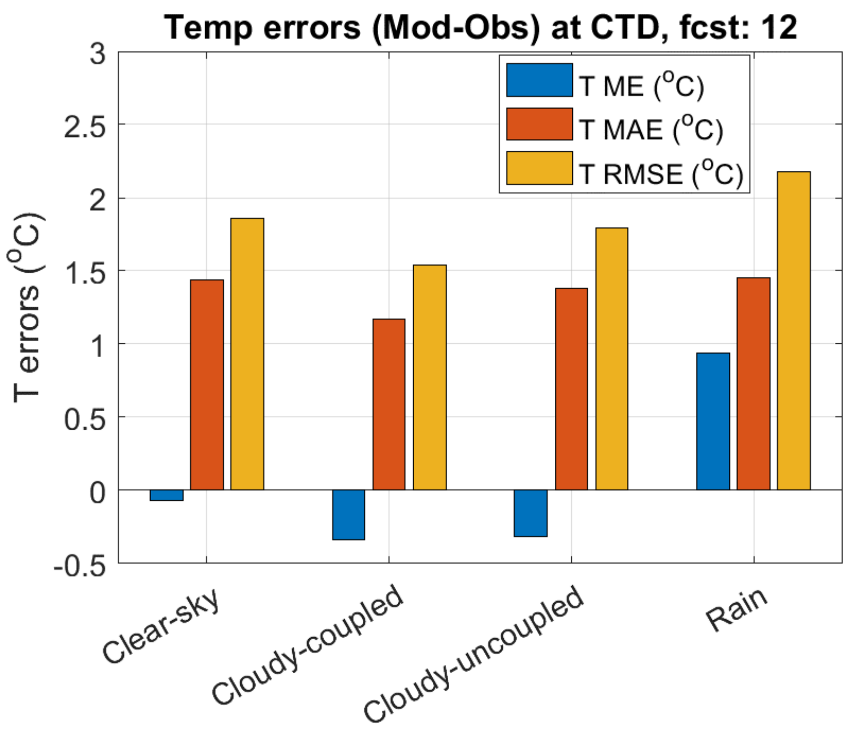
ΔMR, Forecast horizon 12

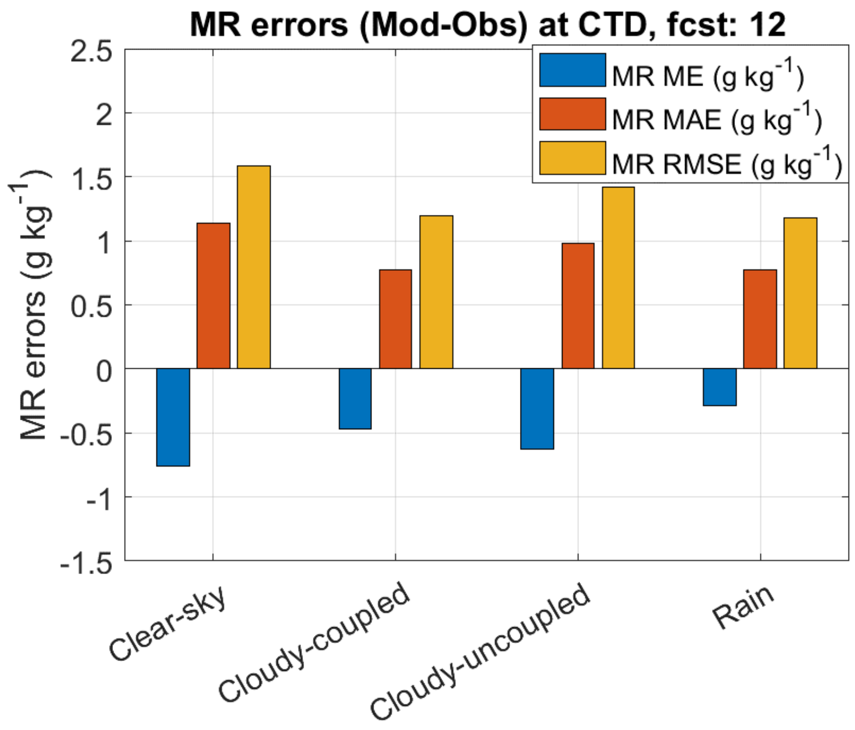


1) Do the HRRR 2m T & MR errors translate to cloud base height errors?

HRHR Cloud Base Height Bias (HRRR-Ceilometer)
Initialization time: -219 m
12 h forecast: -53 m

2) Does the presence of clouds impact model 2m T and MR errors?

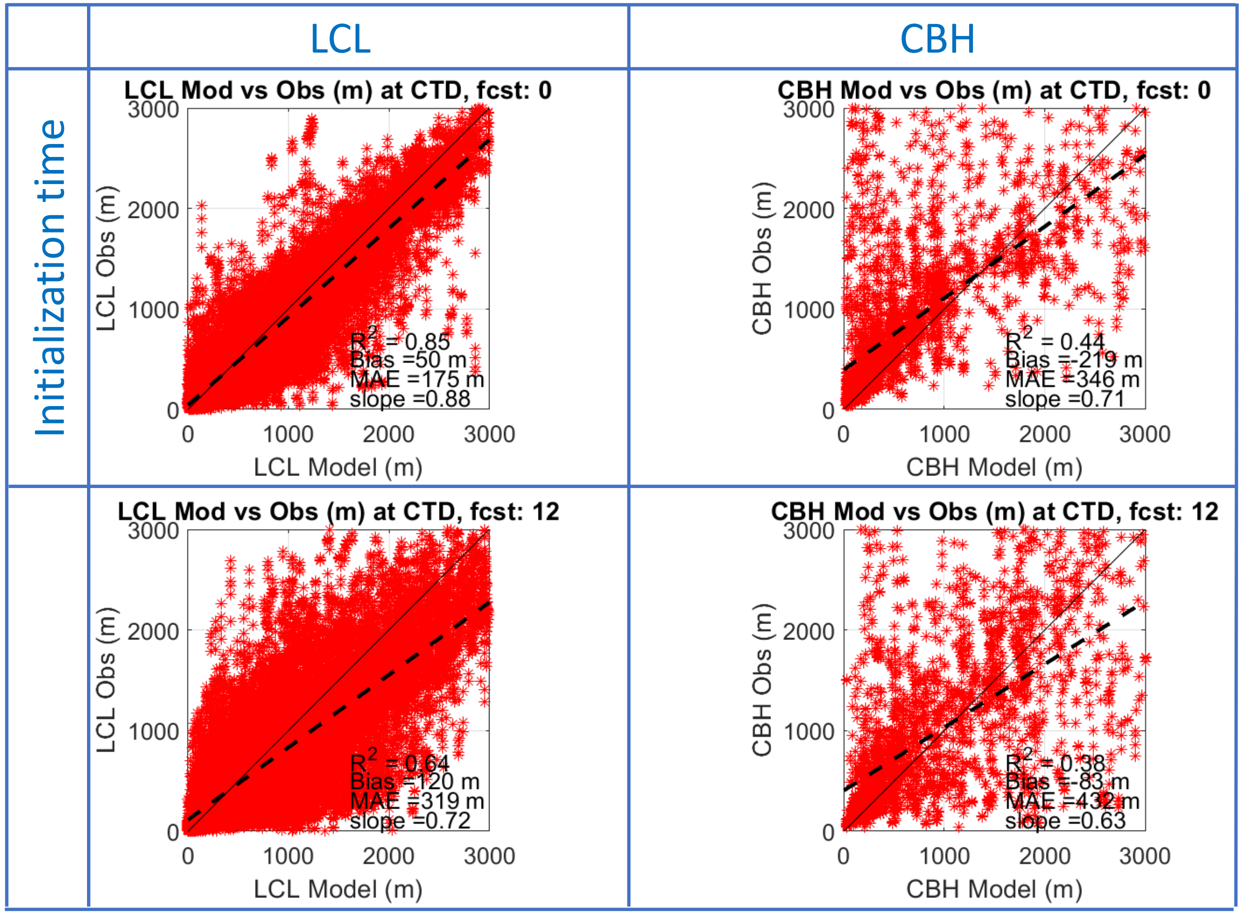




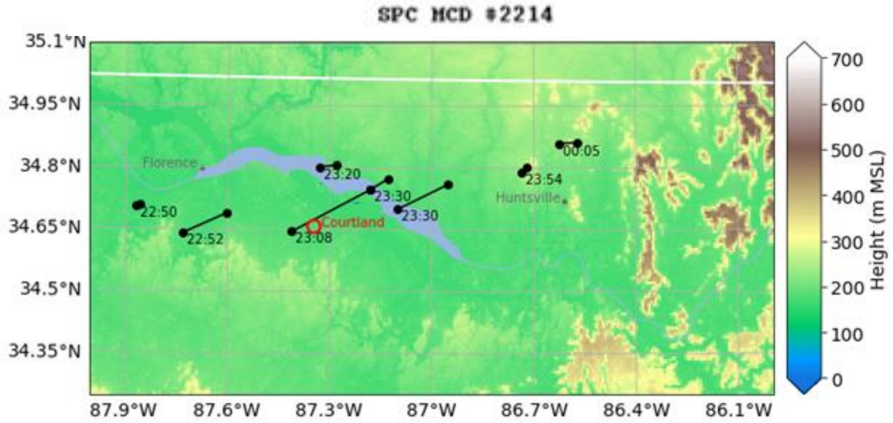
Thanks!

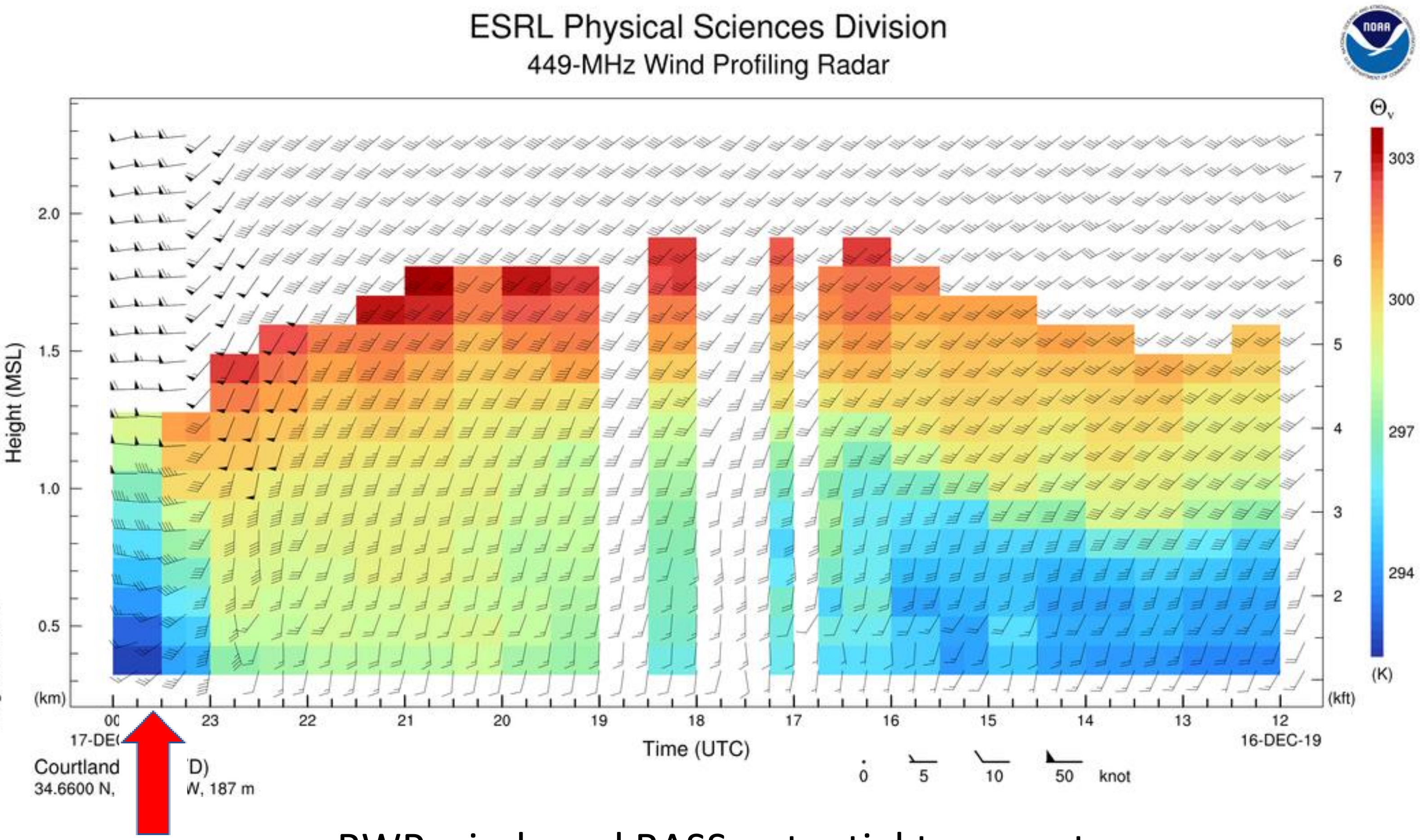
Questions?

February 2022 – May 2023, OBS vs HRRR, LCL and CBH at Courtland, AL



PERiLS QLCS Tornado Case Study 16 Dec 2019





RWP winds and RASS potential temperature

1. Overfitting of profiles

- Uncertainty of forward model is currently not included due to computational limitations. Instead radiance uncertainty is inflated to compensate for this (Turner and Blumberg 2019).
- **But** radiance uncertainty is instrument dependent and even inflated uncertainty my not be sufficient to prevent overfitting and result in unrealistic profiles

→ Implement default minimum noise level for radiance uncertainty

Indicators for suspicious profiles

- γ (from state vector equation) is used to change relative weight between prior and observations. $\gamma > 1$: More information from the prior than from the observations
- Large RMSR indicate a large discrepancy between the solution and the observations (here RMSR > 5)

$$RMSR = \sqrt{\frac{1}{M}\sum_{i=1}^{M}\left(\frac{\mathbf{Y}_i - F(\mathbf{X}_n)_i}{\sigma_{\mathbf{Y}_i}}\right)^2}$$