



Boundary layer data assimilation and interaction with parameterizations in the NASA GEOS model

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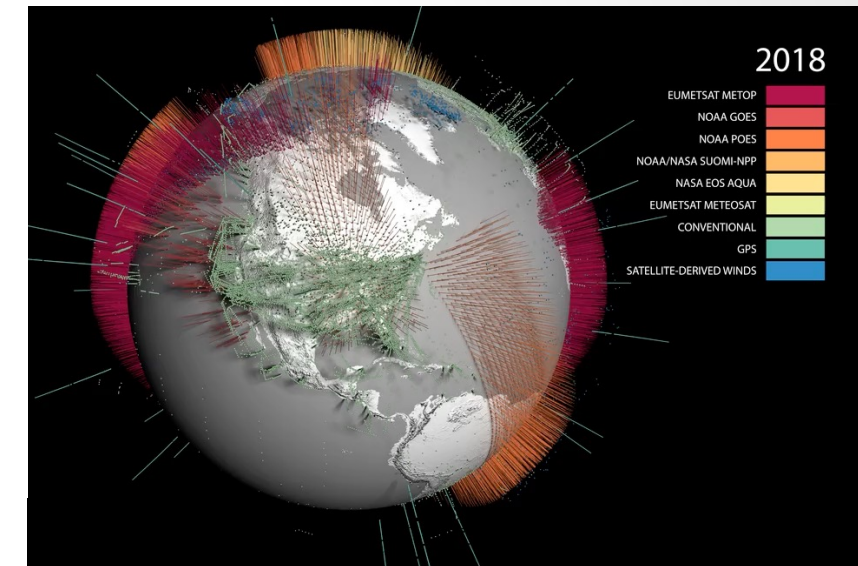
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⁶ Hunter College, CUNY

⁷ Hydrological Sciences Laboratory, NASA/GSFC

Data assimilation in the GMAO

- NASA Global Modeling and Assimilation Office produces a variety of research products, from reanalyses to composition forecasts.
- Use data assimilation to enhance the value of space-based observations: combining **observations from multiple platforms** with a **physics-based model** of the Earth system.
- Data assimilation **may be particularly well-suited for PBL** where no single platform/instrument is ideal.
- GMAO and partners recently funded to **improve use of existing data in the PBL**, and explore **assimilation of PBL height** observations from multiple sources.



GMAO approach to PBL height assimilation

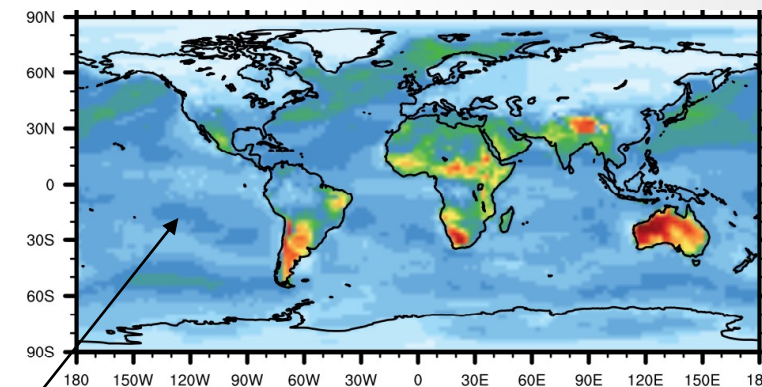
Add model PBLH control variables in 4D EnVar, instead of construction of complicated observation operators

- T and Q tendencies from background covariance

Assimilate PBLH from multiple observing systems, **using appropriate model PBLH variables for each obs type:**

- Radiosonde – Bulk Richardson number
- GNSS RO - Refractivity gradient
- Space-based lidars (CALIPSO, CATS and ICESat-2) – Maximum ATB gradient
- Ground-based lidar MPLNET and Radar Wind Profilers – maximum gradient

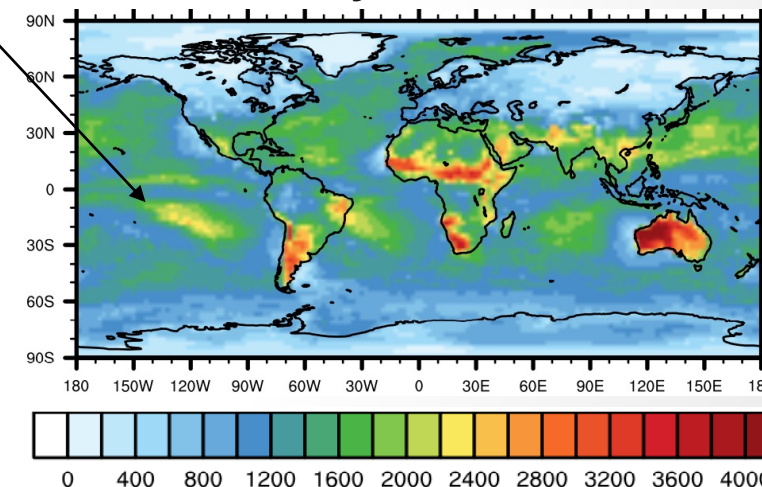
Bulk Richardson # PBLH



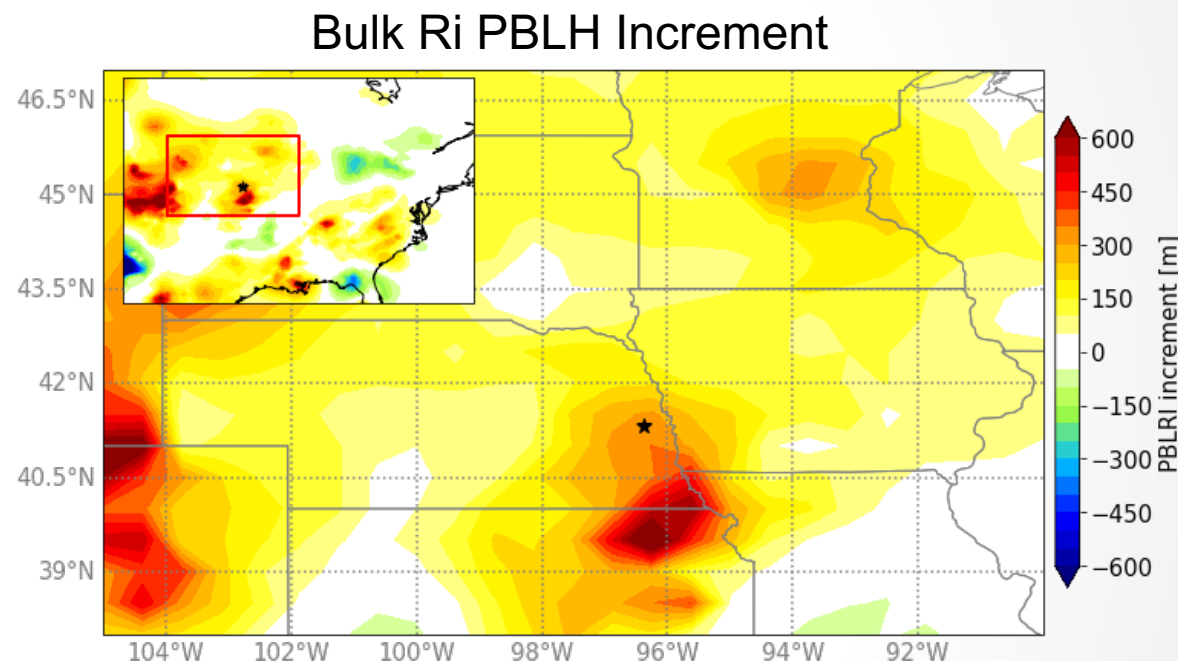
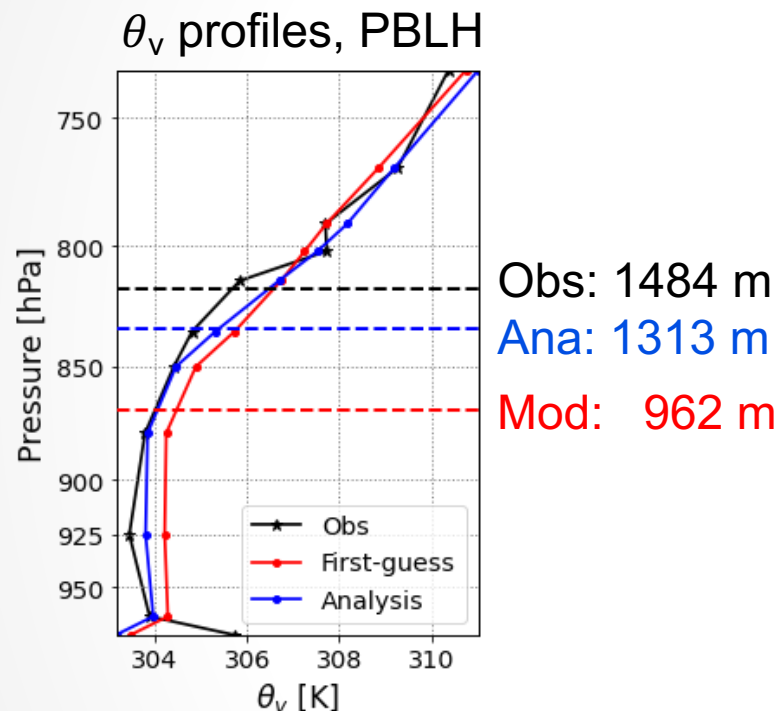
Mixed layer depth

Refractivity Gradient PBLH

Trade inversion



Preliminary results of PBLH assimilation: radiosondes

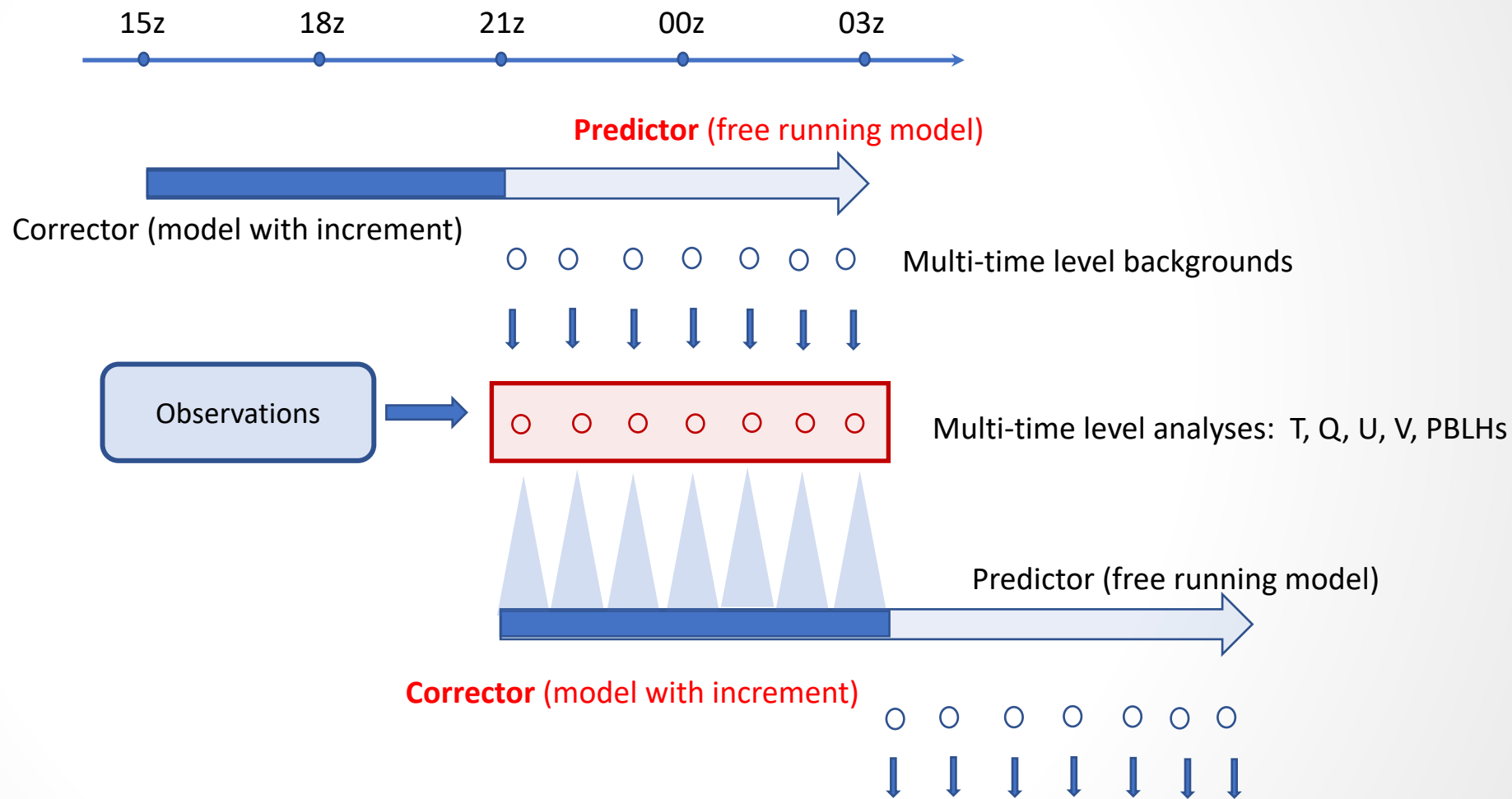


Through ensemble covariance, observations influence PBLH analysis in surrounding area

*See more at Manisha Ganeshan's poster
Wednesday, A31M-2570: "Utilizing Multi-Source PBL..."*

The role of the model

Analysis Cycle with Incremental Analysis Update (IAU)



The role of the model

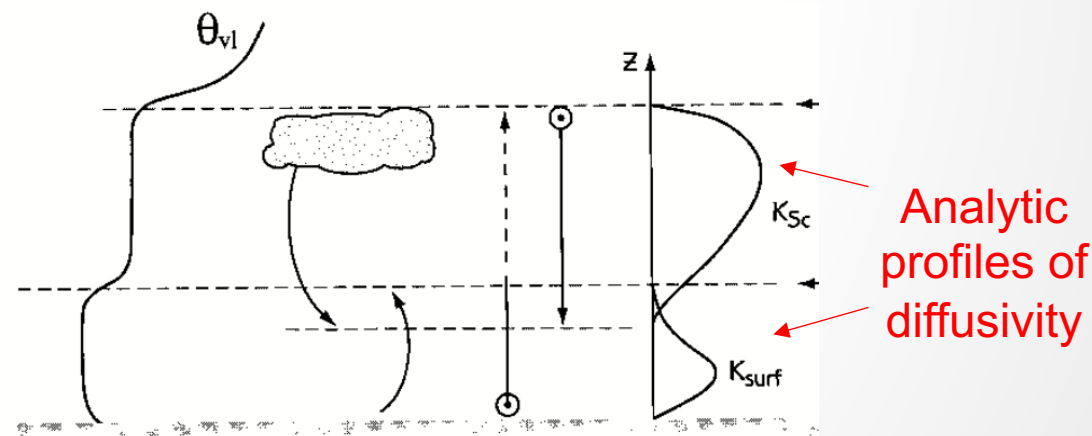
Ideally, the model:

- Carries information forward in time, fills gaps;
- Allows interaction between Earth system components (and related observations can indirectly constrain PBL, e.g. surface state or large-scale flow);
- Constrains other processes or diagnostics of interest: constituent transport, TKE budgets, convective storms...

GEOS currently uses Lock et al (2000):

But! Limitations:

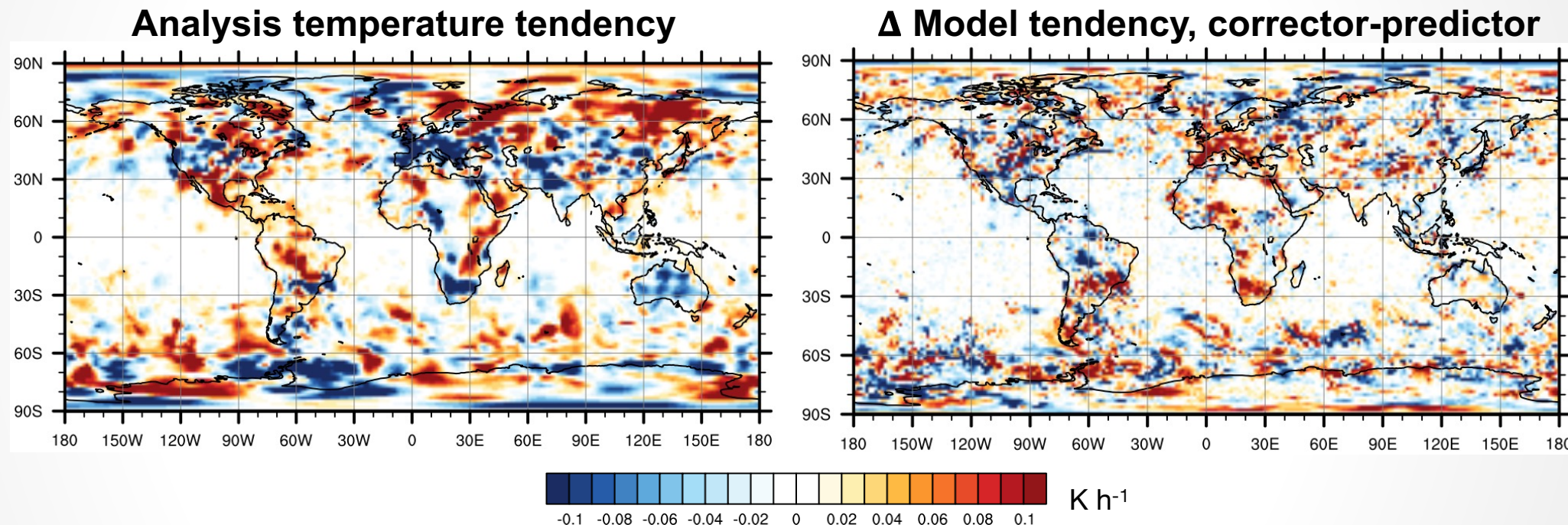
- Model PBL depends on parameterizations based on simple conceptual models
 - Can artificially limit PBL structure
 - Or simply mix to the wrong depth
- PBLH is diagnostic: cannot directly adjust w/incr



Model tendency can change to compensate for analysis

GEOS-FP, 20150908 12z:

@ $z=400\text{m}$

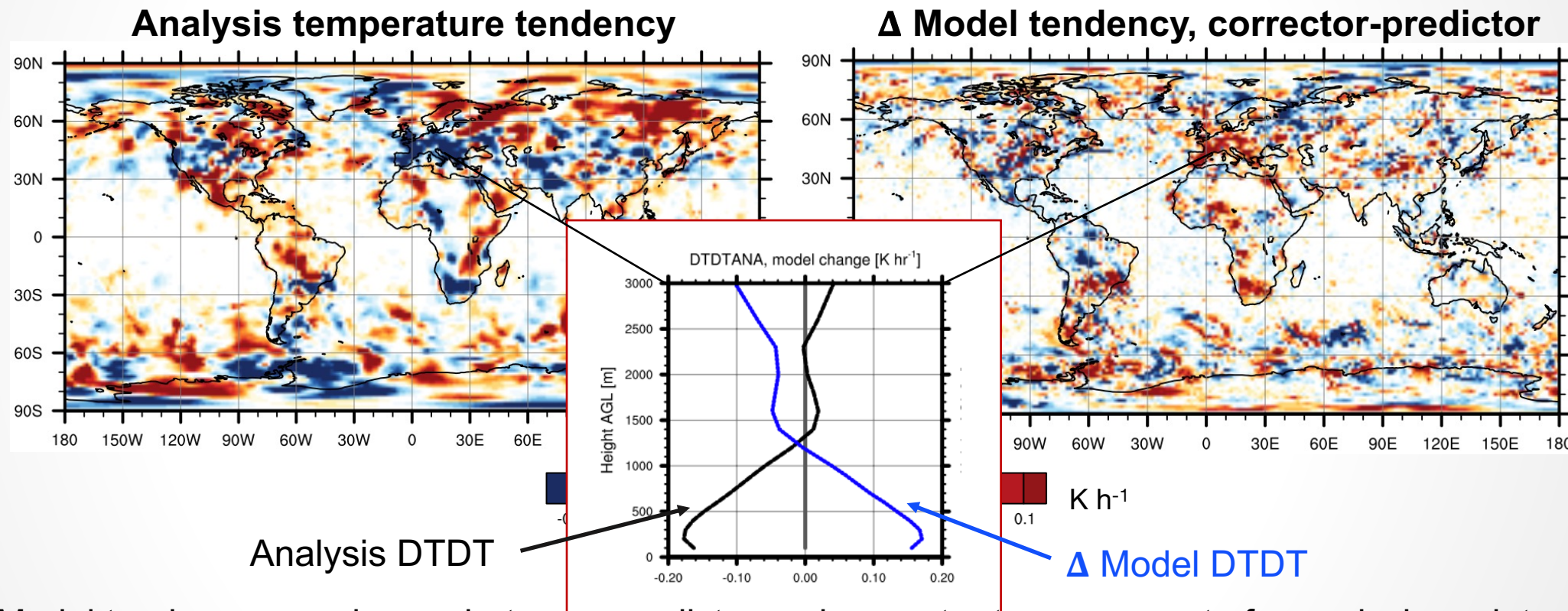


Model tendency can change between predictor and corrector to compensate for analysis update.
(Global correlation: -0.34)

Model tendency can change to compensate for analysis

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Model tendency can change between predictor and corrector to compensate for analysis update.
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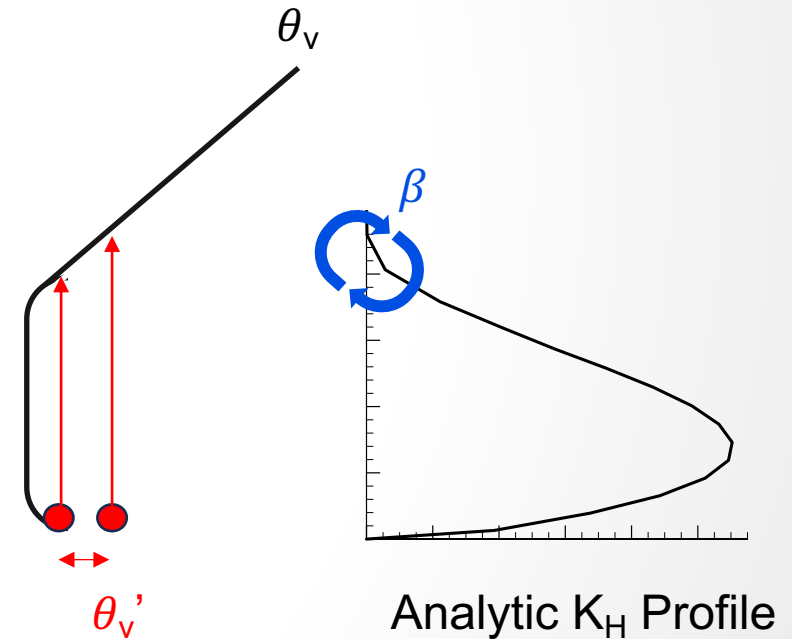
Reducing model PBL error with adaptive parameter adjustment

- Goals:**
1. Nudge model PBL depth into agreement with analysis
 2. Reduce model compensation of analysis tendencies

We adjust two parameters related to Lock surface plume:

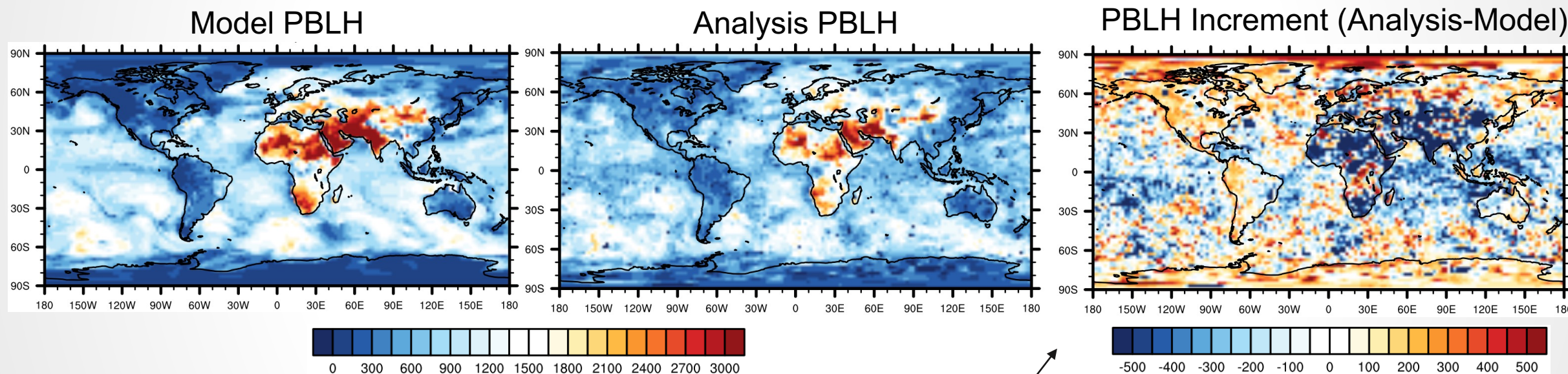
1. Test parcel θ_v perturbation: $\theta_v' = \theta_v'(1 + \alpha_\theta \Delta\text{PBLH})$
2. PBL-top entrainment rate: $\beta = \beta (1 + \alpha_\beta \Delta\text{PBLH})$

Each adjusted proportional to PBLH increment (based on Bulk Richardson #) up to +/-50% of default value.



Testing adaptive parameter adjustment in a replay experiment

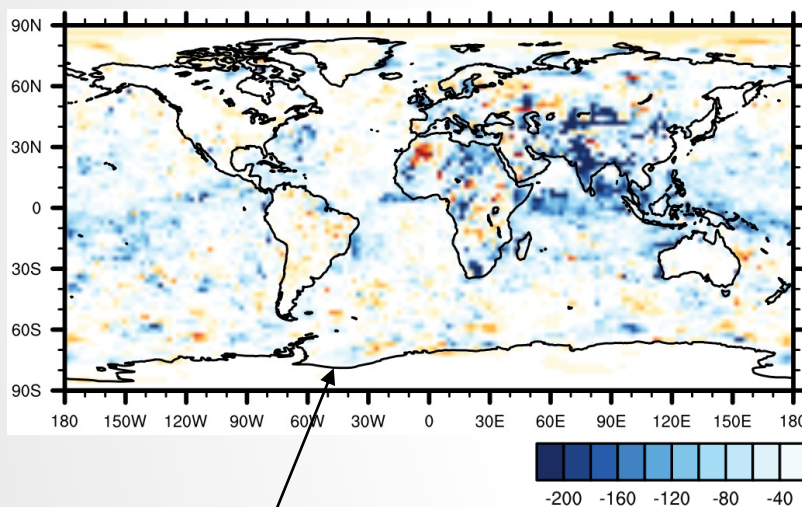
- In replay, analysis cycle uses **pre-computed** analysis, independent of model.
- PBLH increment uses Ri-based PBLH derived from analysis profiles.



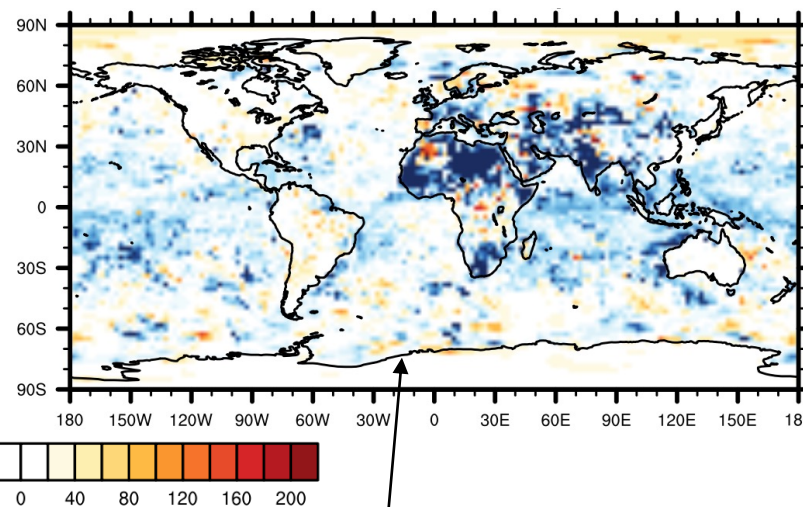
Analysis PBLH typically shallower than model in tropics, deeper at high latitudes.

Adaptive parameter adjustment reduces model PBLH error

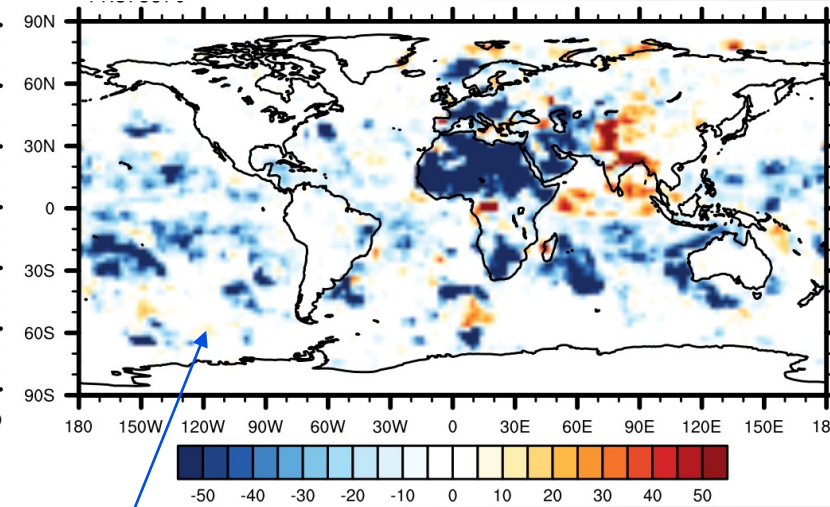
Δ Model PBLH
w/o parameter adjustment



Δ Model PBLH
w/ parameter adjustment



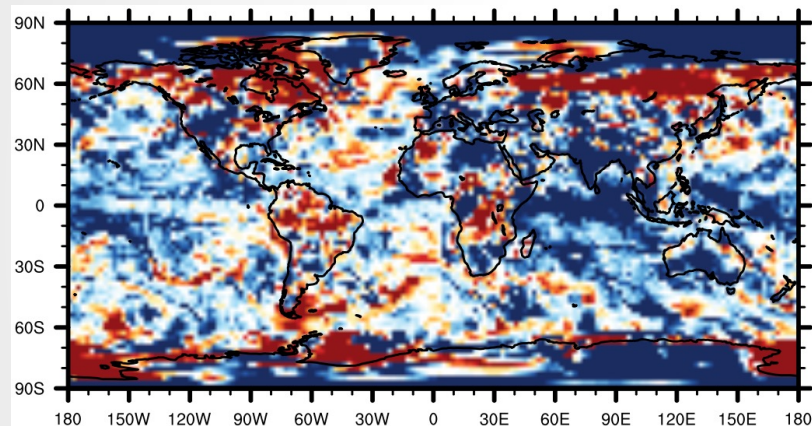
Closeness: Δ PBLH error
from parameter adjustment



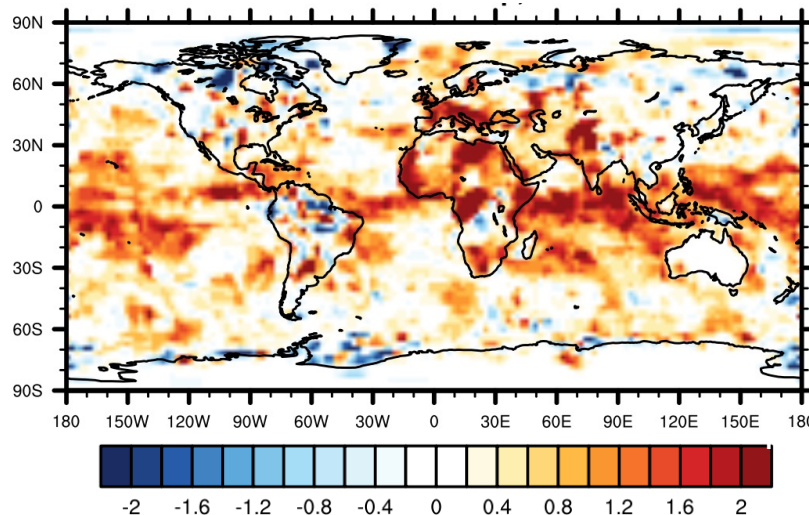
Adaptive parameter adjustment reduces model tendency change

Tendencies @ z=400 m:

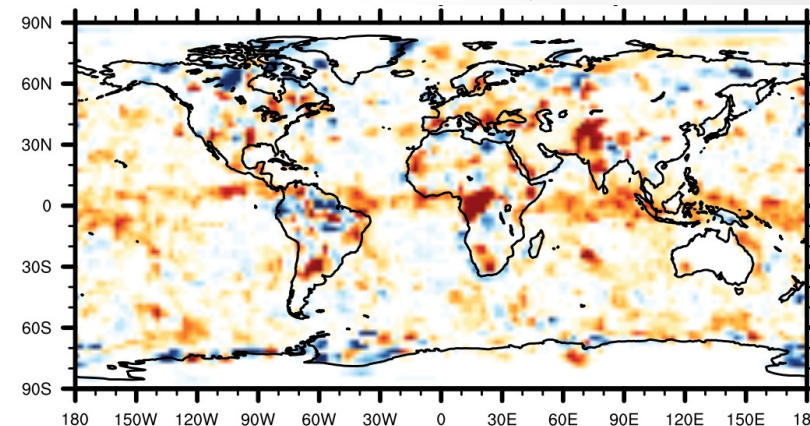
Analysis temperature tendency



Δ Model tendency
w/o parameter adjustment



Δ Model tendency
w/ parameter adjustment



Parameter adjustment reduces model compensation of analysis tendency by ~50%



Conclusions

- GMAO is working to **assimilate PBL heights** from radiosondes, GNSS-RO, space/ground-based lidars and wind profilers, using appropriate model-based PBLH definitions for each.
- The physical model can **add constraints** and realistic features to PBL representation, and **allow interactions** with other parts of Earth system, but is also subject to **parametric and structural errors**.
- Model PBL parameterizations can respond to, and compensate for, analysis tendencies, reducing impact of observations in the PBL.
- Model errors in parameterized mixing depth can be corrected with **adaptive parameter adjustment** using the analyzed PBLH. This can **improve model PBLH** and reduce compensation of analysis tendencies.
- Parameter adaptation in a cycled analysis with PBLH assimilation, and potentially carrying adjusted parameters into subsequent forecasts.

PBLH Data Assimilation in the GMAO

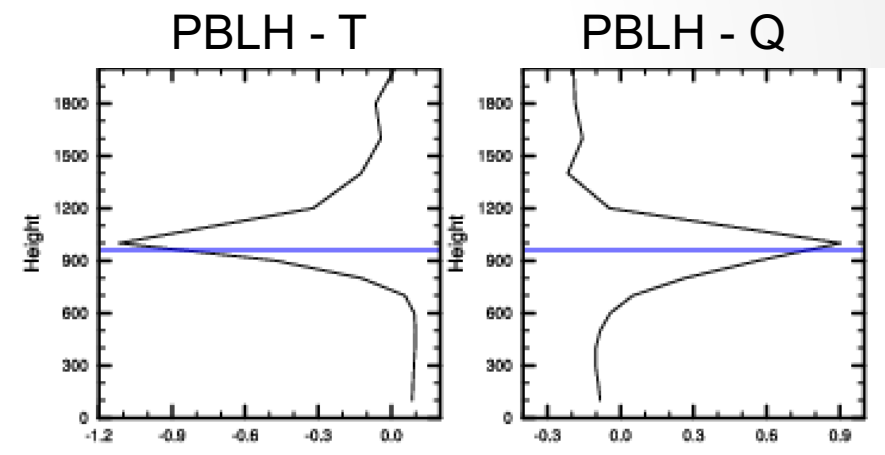
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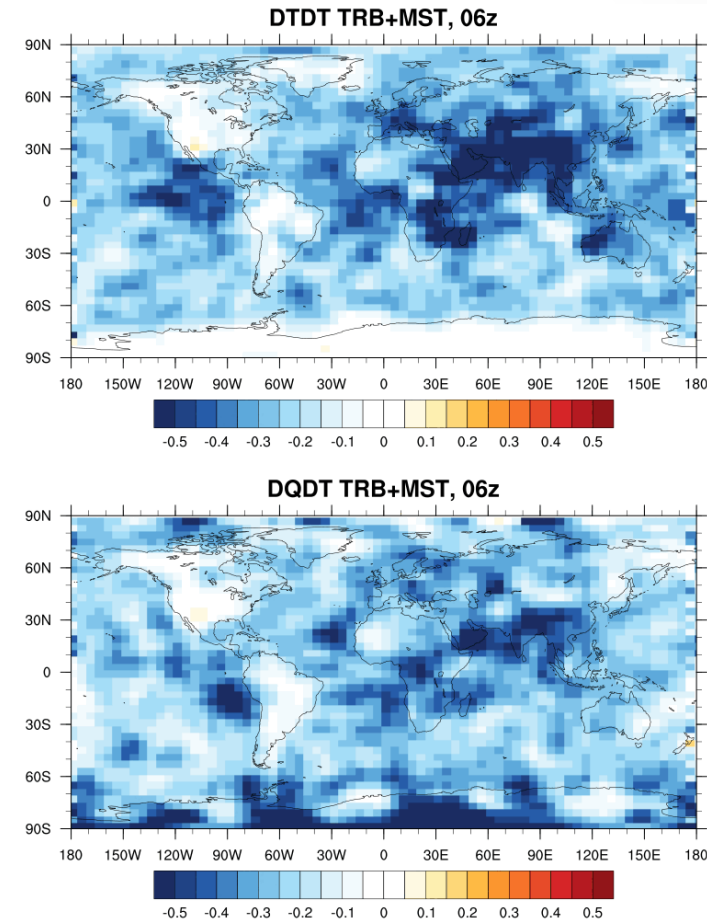
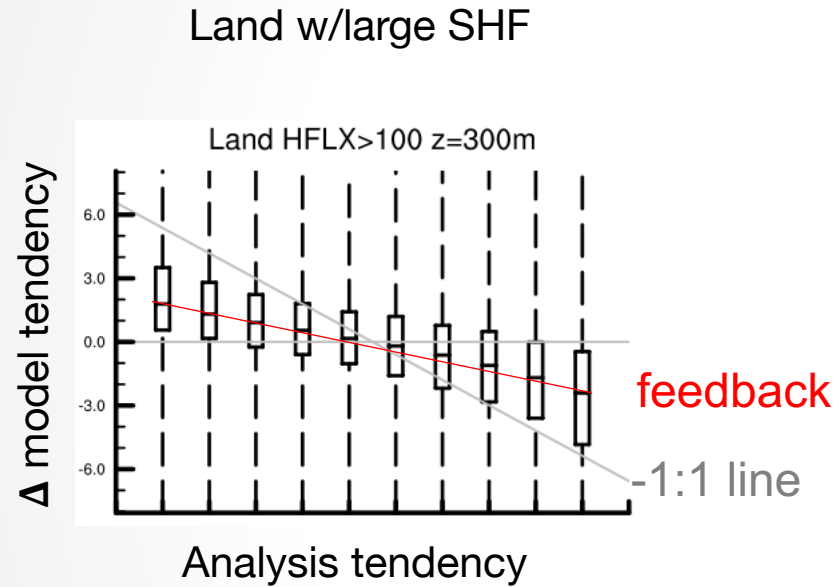
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Ensemble covariance can relate PBLH to thermodynamic profiles:



Model compensation in global DAS



Regression
coefficient,
 Δ model vs IAU,
@z=300 m

Typically 10-20%, but can be 50%+ in strongly unstable boundary layers