

Dynamic Adjustment of Model Parameters Using Assimilated Boundary Layer Height

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Background

The NASA Global Modeling and Assimilation Office is exploring the assimilation of boundary layer height (PBLH) derived from a variety of observations, including radiosondes, GNSS-RO, space- and ground-based lidar, and radar wind profilers. Previous work using the Goddard Earth Observing System (GEOS) has shown that in the lower troposphere, the representation of thermodynamic structure is strongly affected by model parameterizations. In assimilation experiments, the forecast model can compensate for analysis thermodynamic increments and reduce the observation information carried forward in time (Fig. 1). This study presents a parameter adjustment approach to mitigate model compensation.

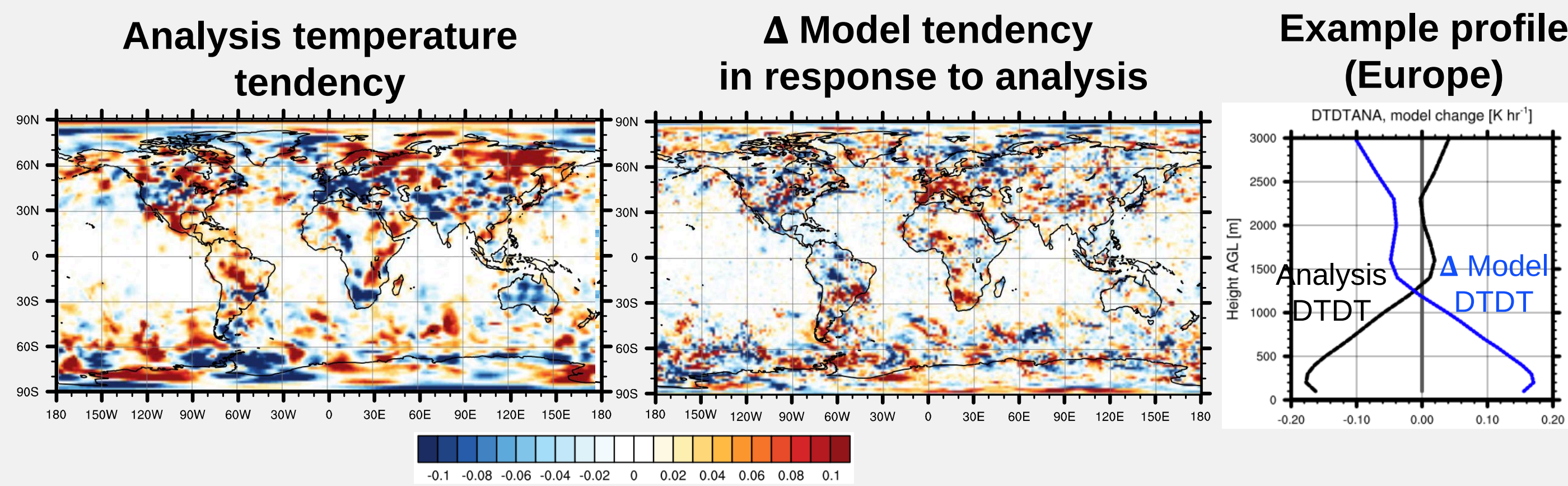
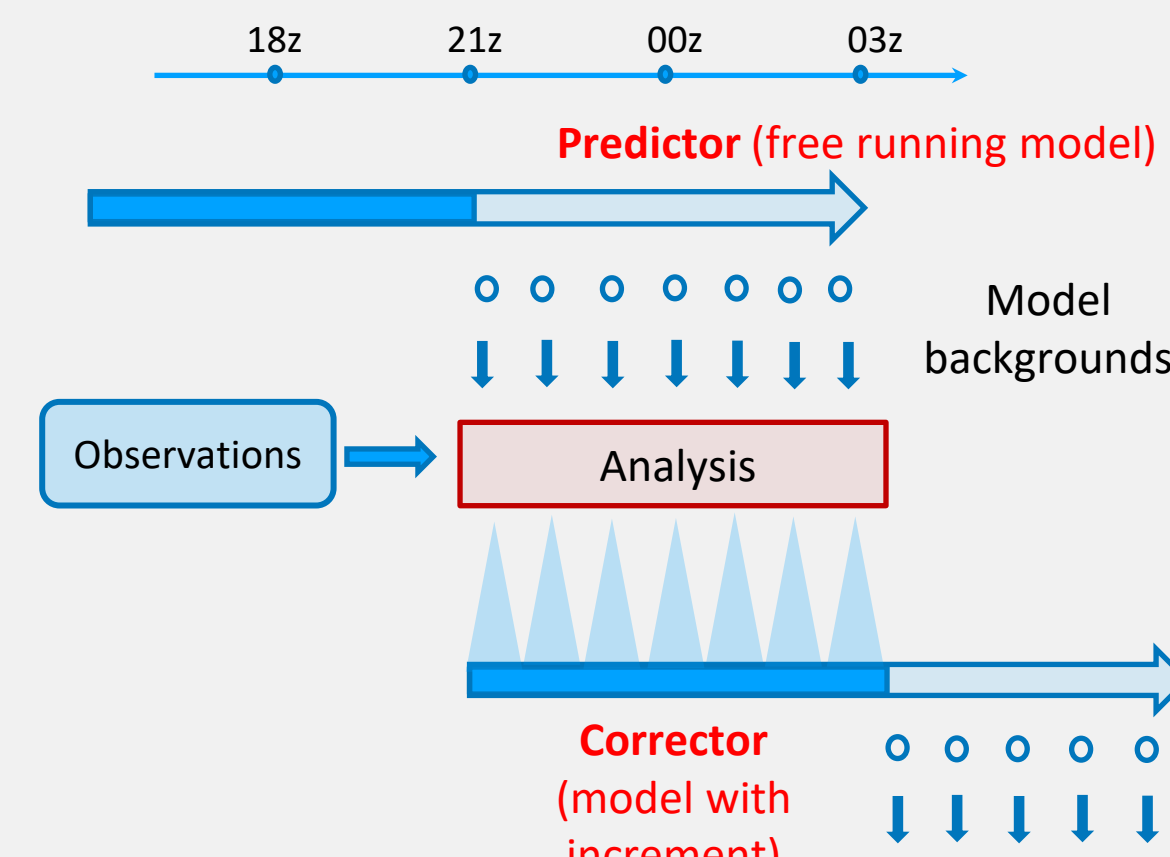


Figure 1. Temperature tendencies from the GEOS-FP system, Sept. 8 2015 12z, at 400m AGL.

The GEOS analysis cycle includes a 6 hr “predictor” step, in which a free-running forecast provides the background state. This is combined with observations to produce an analysis, which is used to correct the model in a 6 hr “corrector” segment.



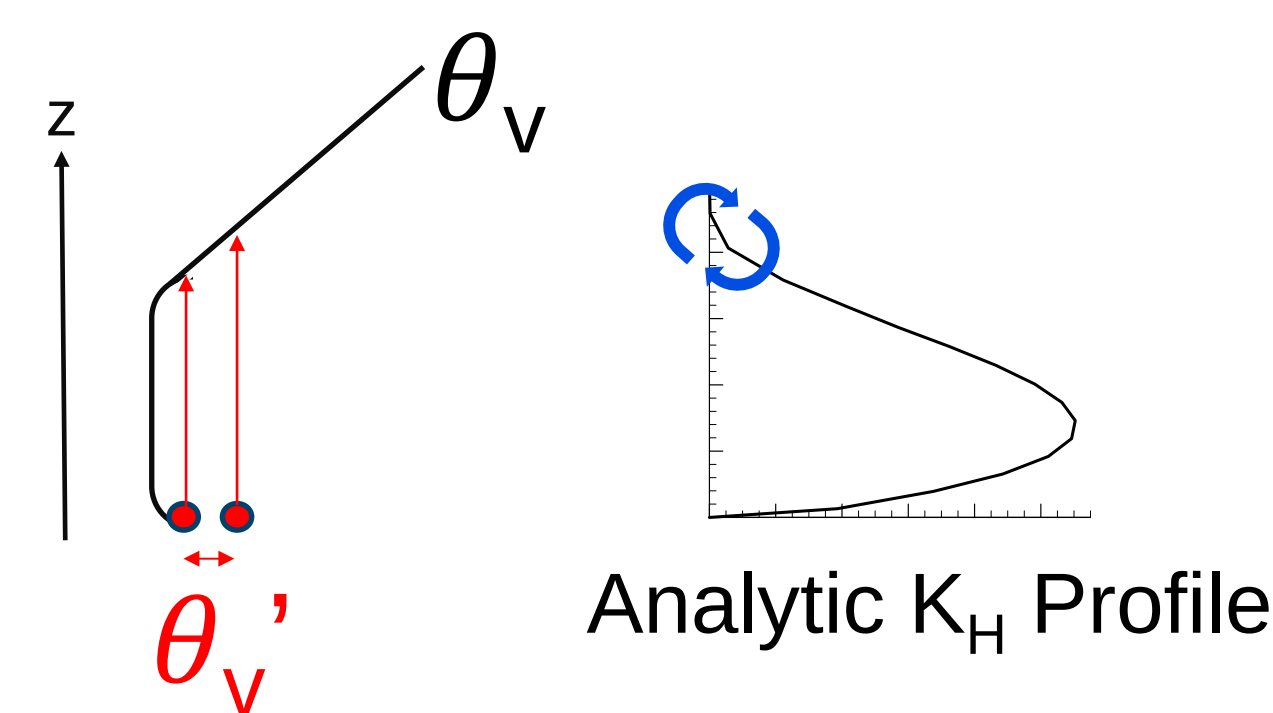
Model Parameter Adjustment

GEOS uses the Lock et al. (2000) PBL scheme, which specifies an analytic profile of diffusivity over a depth determined by a parcel released from the surface.

We adjust two parameters related to the 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 parameter is adjusted proportional to the analysis PBLH increment (ΔPBLH) up to +/-50% of its default value.

Parameter Adjustment Reduces Model PBLH Error ...and Compensation of Analysis Increments

Dynamic parameter adjustment was tested by replaying the model to an independent precomputed analysis (ERA5). Parameters β and θ_v' were adjusted in corrector segment based on the increment, ΔPBLH . Adjustment results in model diagnostic PBLH **closer to analysis**.

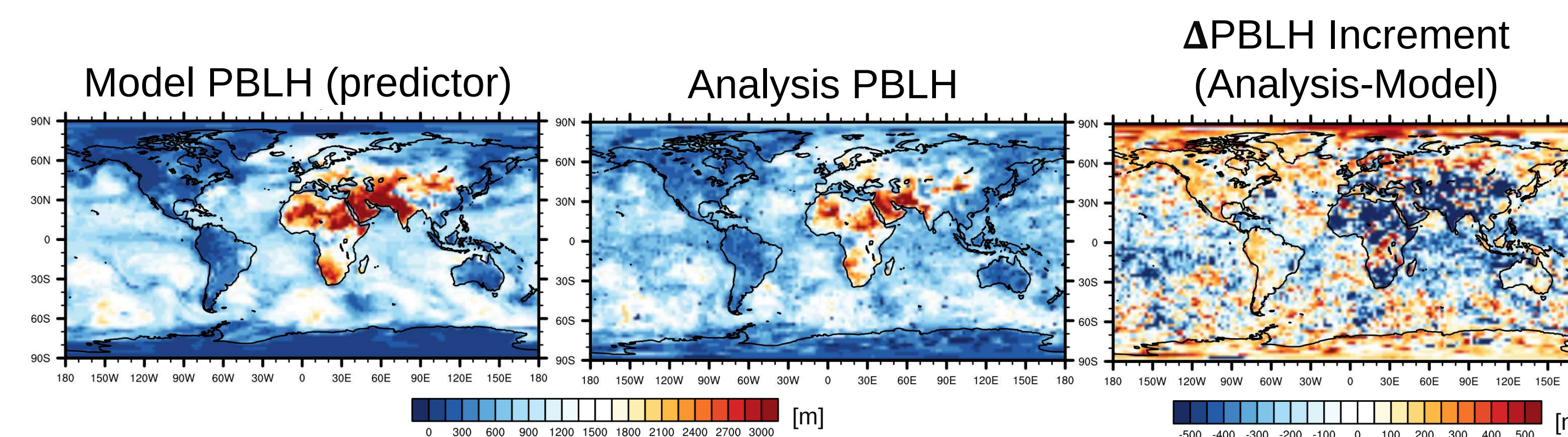


Figure 2: PBLH from model predictor (left), and analysis (mid). PBLH increment (right).

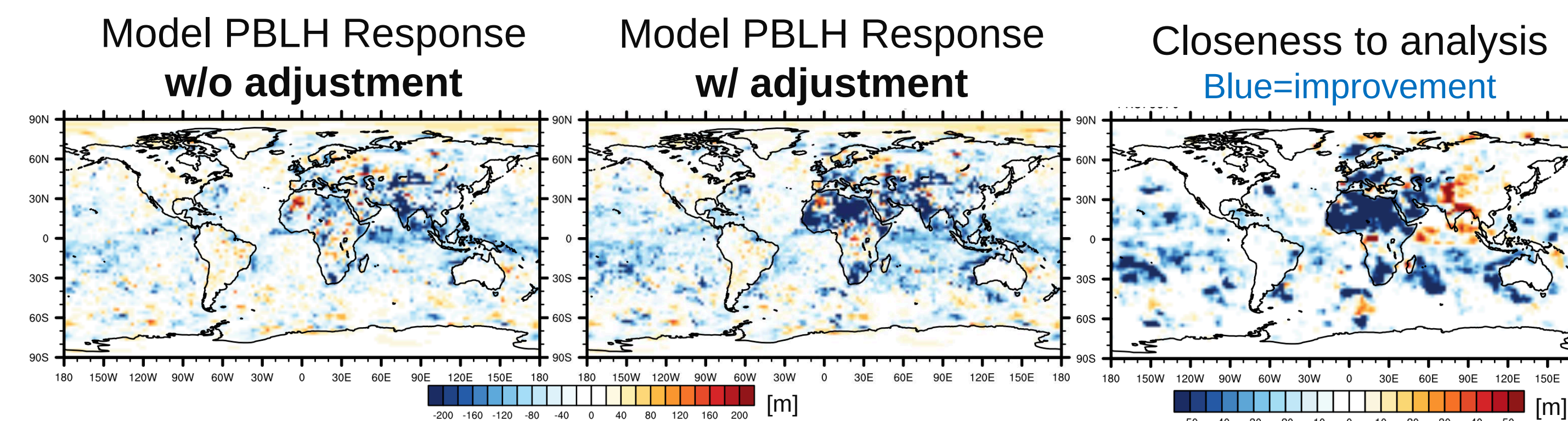


Figure 3: Response (corrector-predictor) of model PBLH due to IAU only (left), and including parameter adjustment (mid). Change in error (model-analysis) due to parameter adjustment (right).

The Role of the Surface

The surface flux response to the IAU (Fig. 5) is **small**, accounting for only a fraction of the PBL-integrated compensation (Fig. 6). This implies a larger part of the compensation due to changes in PBL top entrainment.

Ratio: $\Delta \text{SHF} / \Delta \int^{PBL} c_p \frac{\partial T}{\partial t} dm$

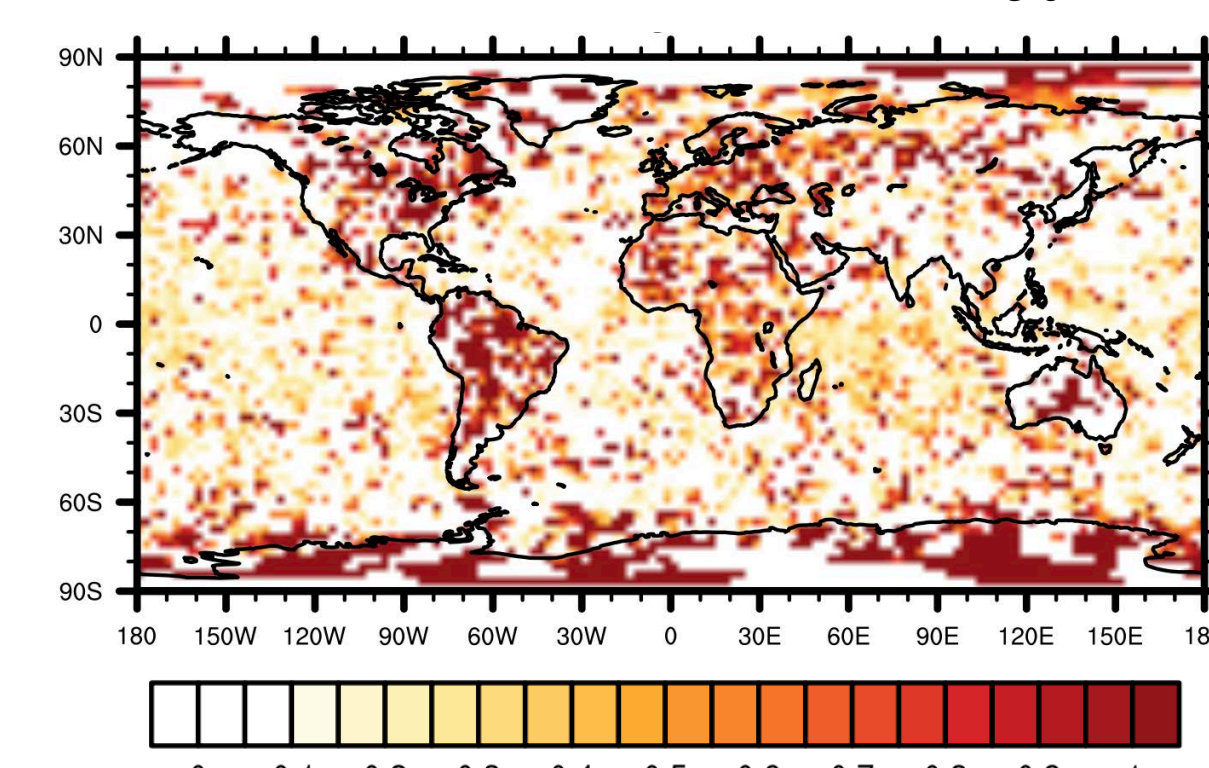


Figure 6: Fraction of PBL-integrated heat change due to change in surface heat flux.

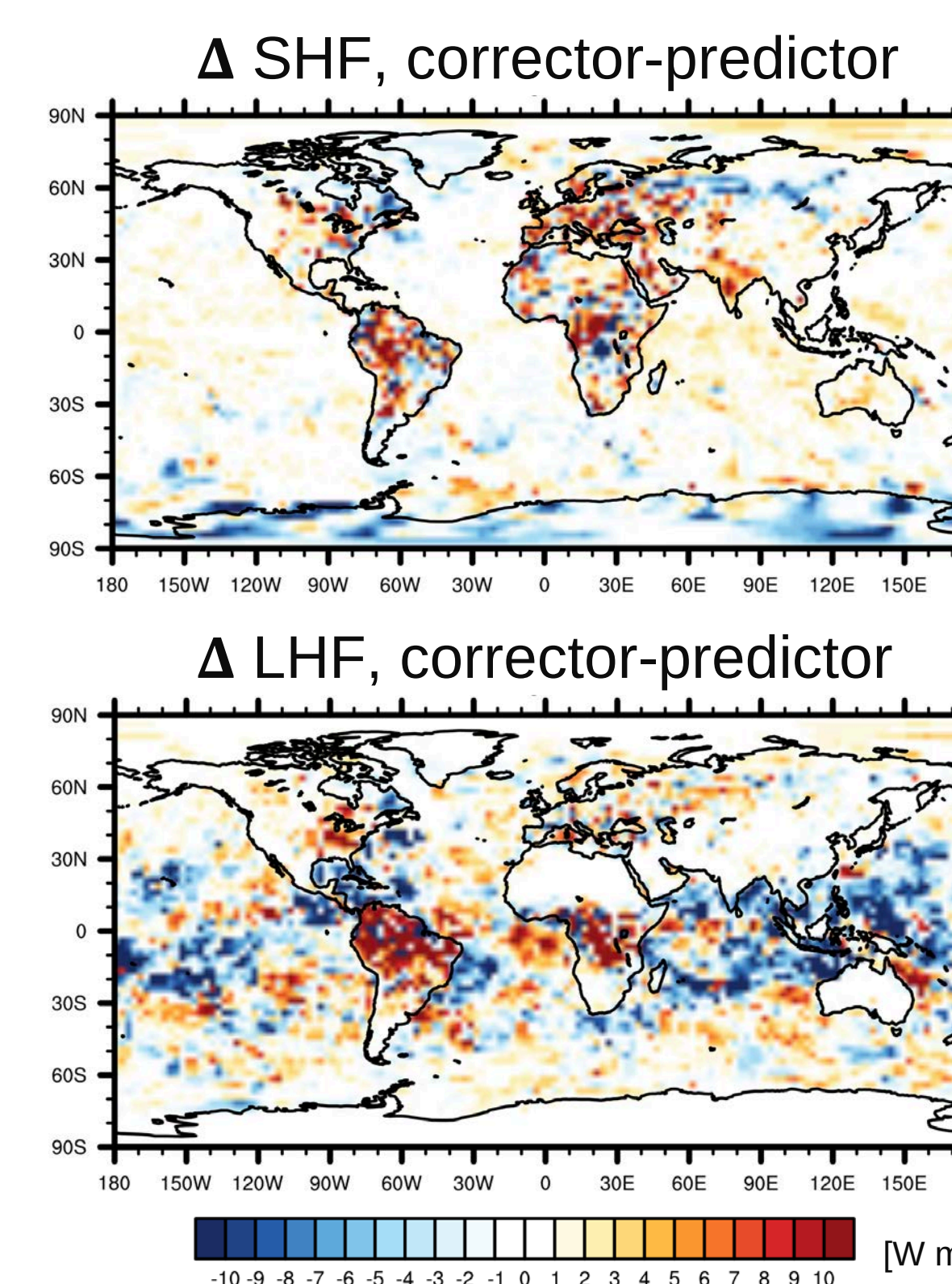


Figure 5: Change in surface sensible (top) and latent (bot) heat flux in response to IAU increments.

Without parameter adjustment, model T/Q tendencies change in the corrector segment to compensate for analysis tendencies, reducing impact of analysis correction. With parameter adjustment, model compensation is significantly reduced, allowing model to absorb analysis correction and propagate information forward in time.

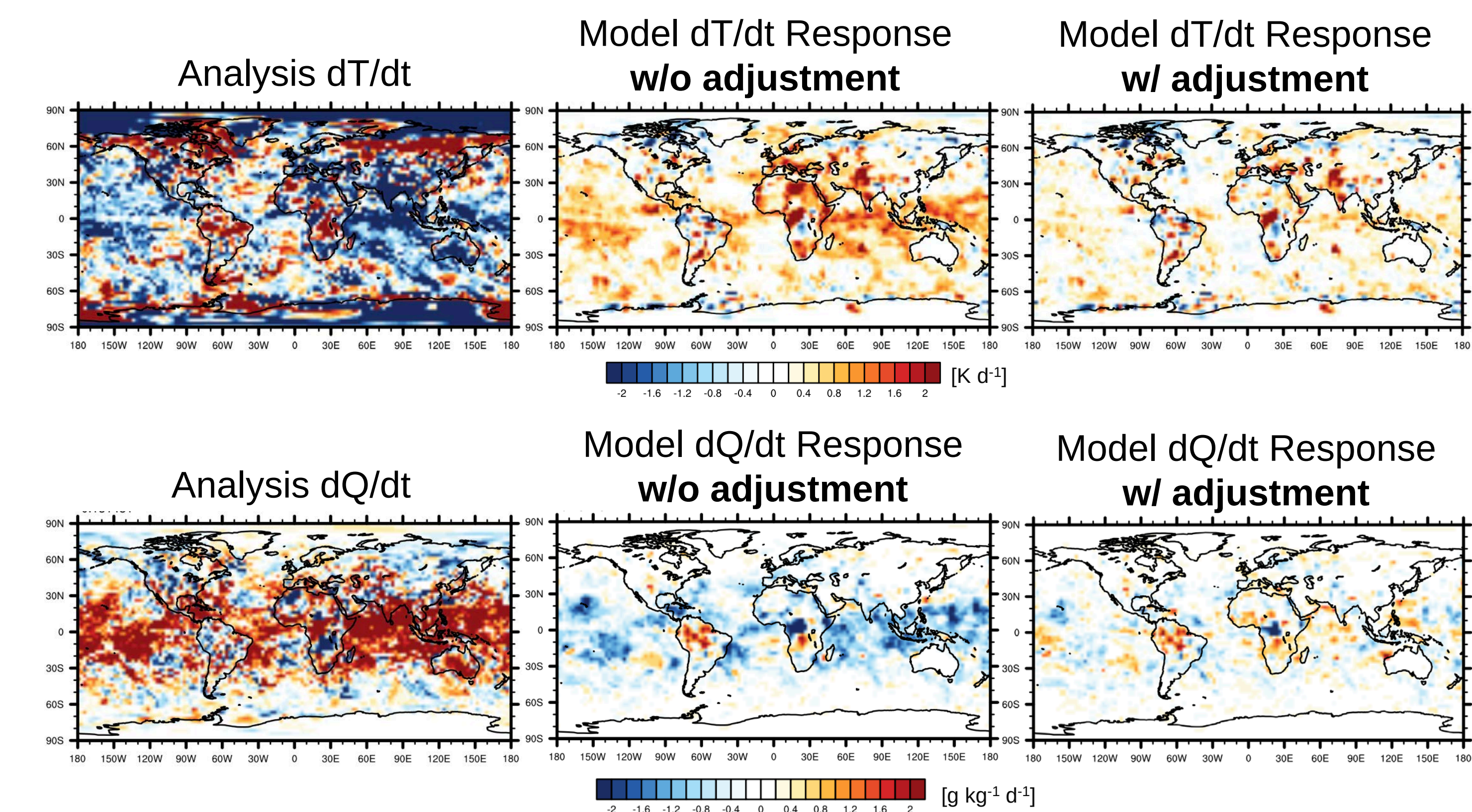


Figure 4: Temperature and humidity tendencies at 400 m height: Analysis tendencies (left); Change in model tendencies w/o parameter adjustment (mid); Change w/adjustment (right).

Conclusions and Future Work

- PBL parameterizations can rapidly compensate for analysis tendencies, reducing impact of PBL observations in subsequent forecasts.
- Changes in surface fluxes account for only a fraction of the model tendency response.
- Using analyzed PBLH increments to increase/decrease the model's parameterized mixing depth was found to:
 - Nudge model PBLH closer to analysis and;
 - Reduce model compensation of analysis tendencies.
- This study targeted the unstable/convective mixed layer regime only, as this accounts for most model T/Q compensation.
- Future work will: test parameter adaptation in a cycled analysis with PBLH assimilation; extend to new SHOC+MF PBL scheme; and potentially carry adjusted parameters into forecasts.