Feasibility studies of global-scale airglow radiance data assimilation with GOLD observations

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Far ultraviolet observations of Earth's dayglow from the NASA Global-scale Observations of the Limb and Disk (GOLD) mission present an unparalleled opportunity for upper atmosphere data assimilation. Assimilation of the Lyman-Birge-Hopfield (LBH) band emissions can be formulated in a similar fashion to lower atmosphere radiance data assimilation approaches. To provide a proof-of-concept for such an approach, **we present assimilation experiments with simulated LBH emission data using an ensemble square root filter (EnSRF) measurement update step** implemented with NOAA's Whole Atmosphere Model and simulation of Earth's airglow by NCAR's Global Airglow model (Solomon, 2017). The observing system simulation experiments (OSSEs), wherein "truth" atmospheric conditions are simulated by NCAR's Thermosphere Ionosphere Electrodynamic General Circulation Model (TIEGCM), **assess the feasibility of estimating 3-dimensional structure of thermospheric temperature through assimilation of GOLD Level 1C LBH data.**

Data assimilation system design

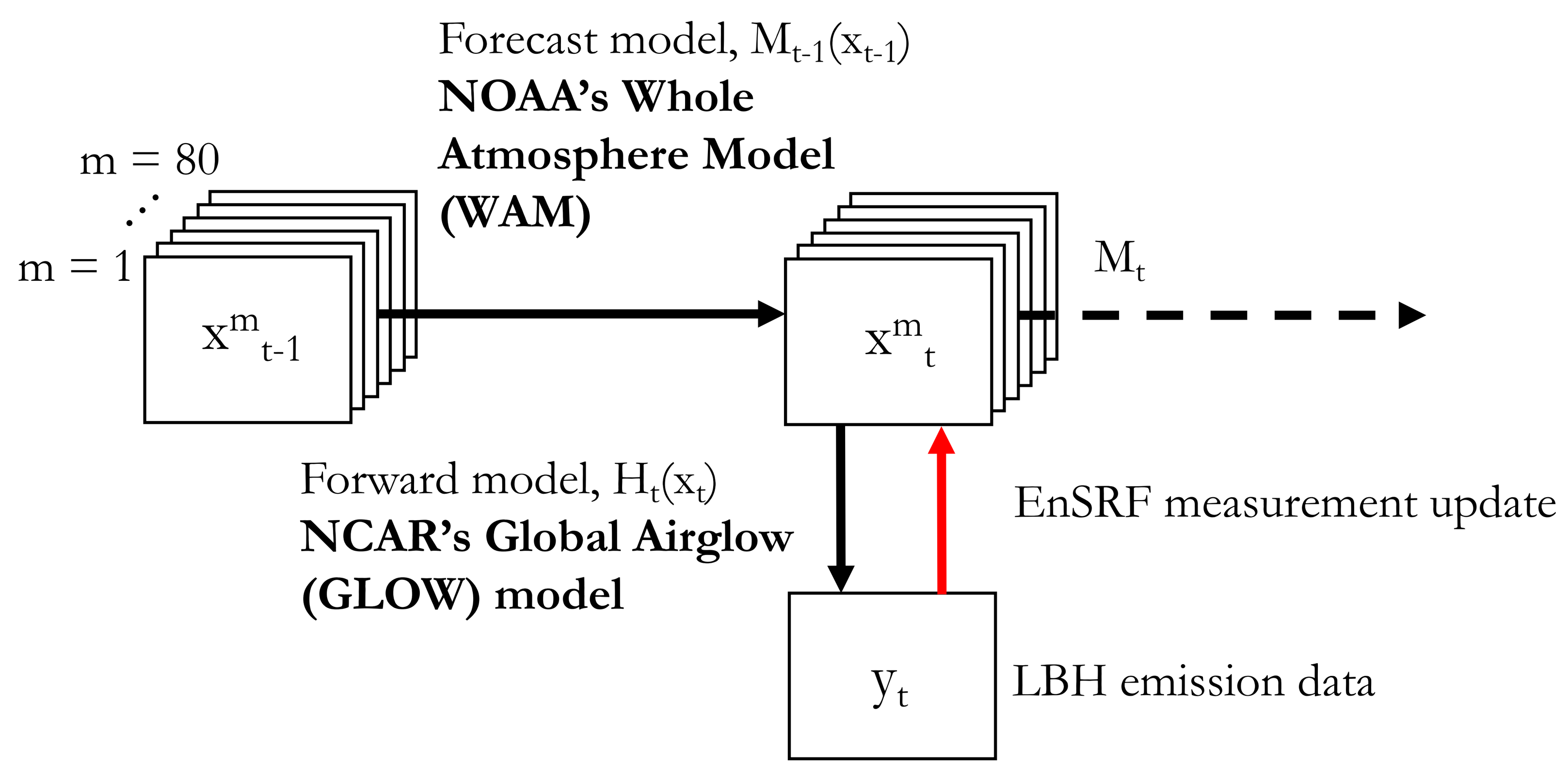


Figure 1 - Data assimilation is an iterative process of a state forecasting step and a measurement update. A forecast model M_t defines the prior knowledge of the state x at time *t*. If an observation y is available at time *t*, the forecasted state is mapped to observation space via a forward model H_t. This forward model is effectively inversed as part of the EnSRF process to update the state at time *t*. After this measurement update step, a new forecast is launched from the updated model states. This process is summarized for an EnSRF with *m* ensemble members. Our results focus only on the measurement update step (red arrow) where y is LBH emissions and x is 3-dimensional thermospheric temperature.

Observations and temperature sensitivity

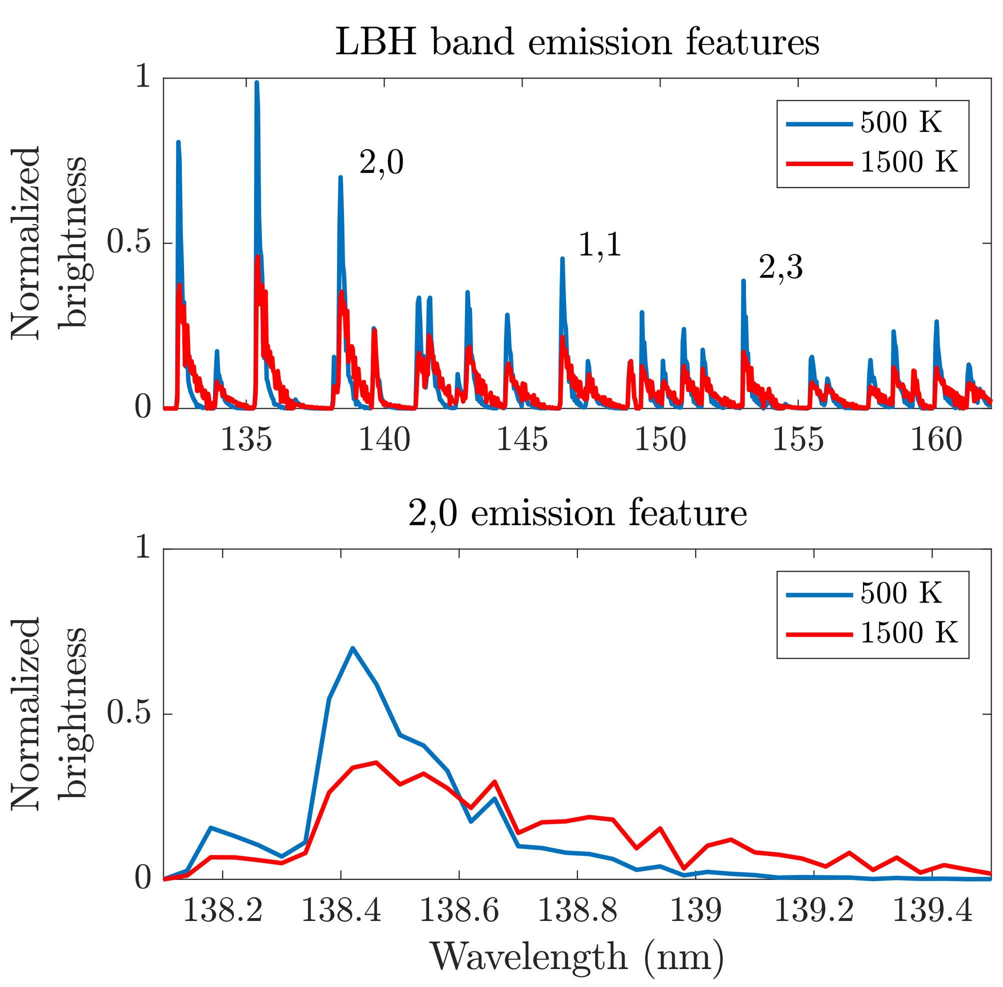


Figure 2 - (a) Simulated N_2 LBH emissions between the GOLD bandwidth of 132 and 162 nm at two temperatures. The (2,0), (1,1), and (2,3) vibrational transitions are assimilated. (b) The temperature dependence is observed by the effective skewing of the (2,0) feature with increased temperature due to increased occupancy of N_2 rotational energy levels (Aksnes et al., 2006). Notice the emissions at wavelengths above and below 138.6 nm have a positive and negative correlation with temperature, respectively.

Synthetic LBH emissions are produced for the experiments by applying the forward model on a TIEGCM "truth" atmosphere. Counting statistics, the dominant noise source, are modeled with a Poisson distribution.

OSSE result: Quiet geomagnetic conditions

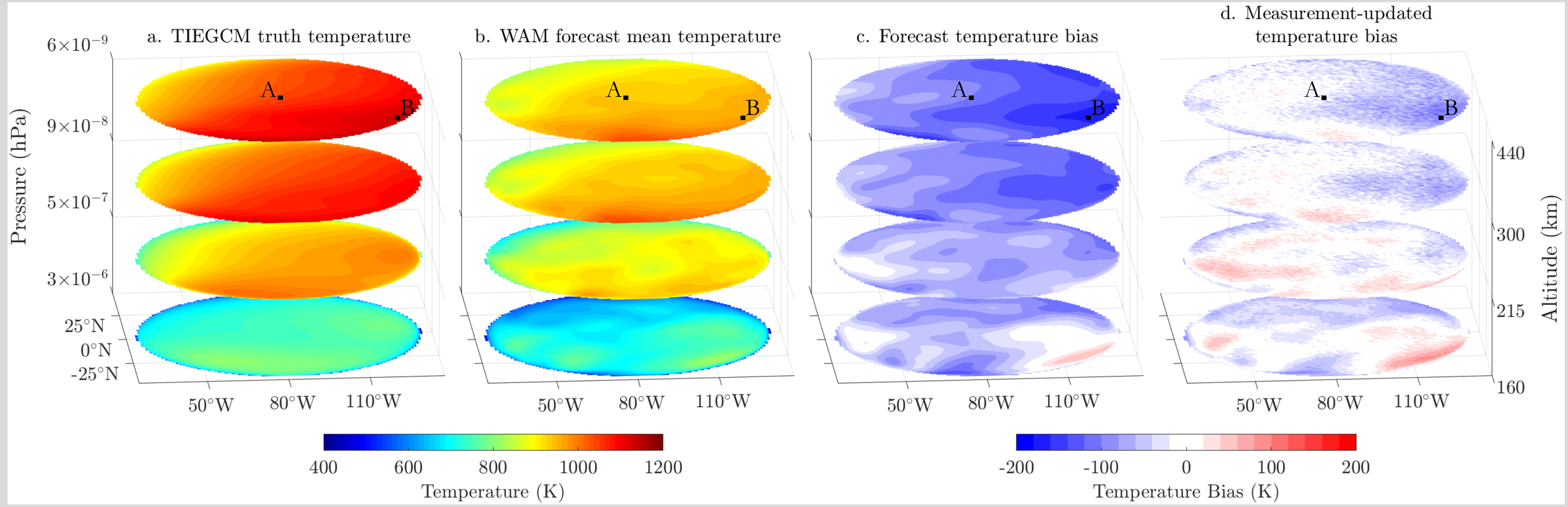


Figure 3 – Results for January 20th 6 UT on the dayside hemisphere with low magnetospheric forcing. The bias is the difference between the WAM ensemble mean (best estimate of temperature) and the TIEGCM truth temperature. There is a significant reduction in model temperature bias from (c) to (d) when the observation is assimilated. The disk-mean temperature bias reduction from forecast to measurement update is -55 K to -31 K at 160 km, -71 K to -23 K at 215 km, -96 K to -27 K at 300 km, and -105 K to -33 K at 440 km.

A

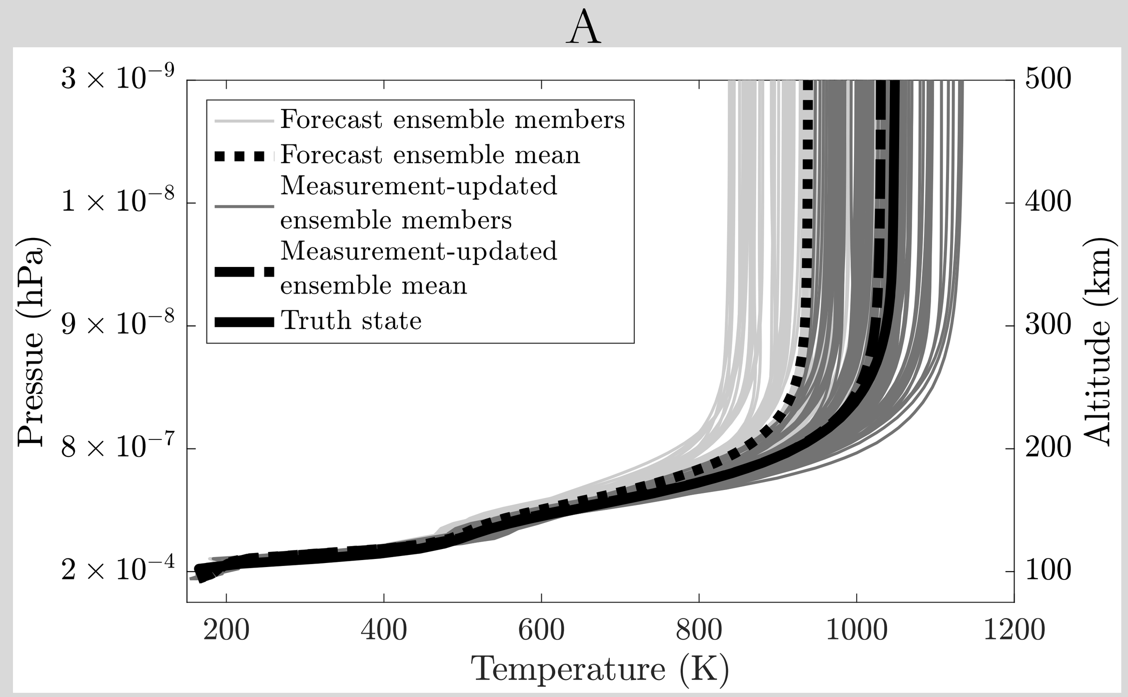
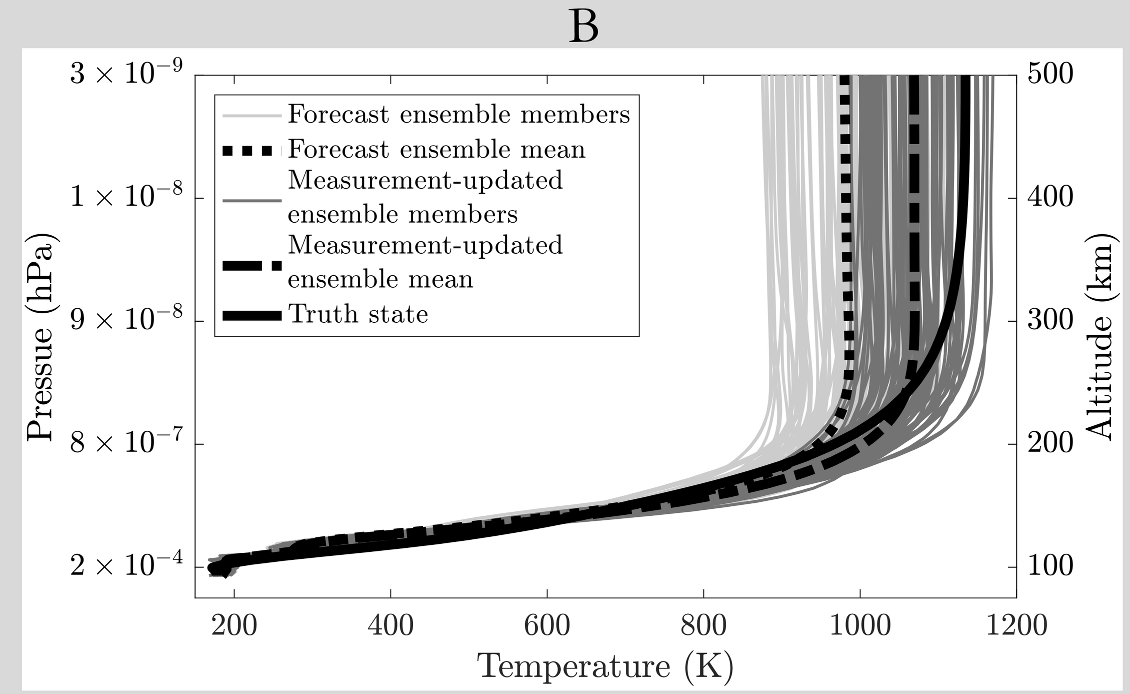


Figure 4 – The measurement update step at two pixels from Figure 3. The measurement update reduced model temperature bias in both cases but notice in (B) that the true temperature gradient between 150-300 km was not captured.

B



OSSE result: Moderate magnetospheric forcing

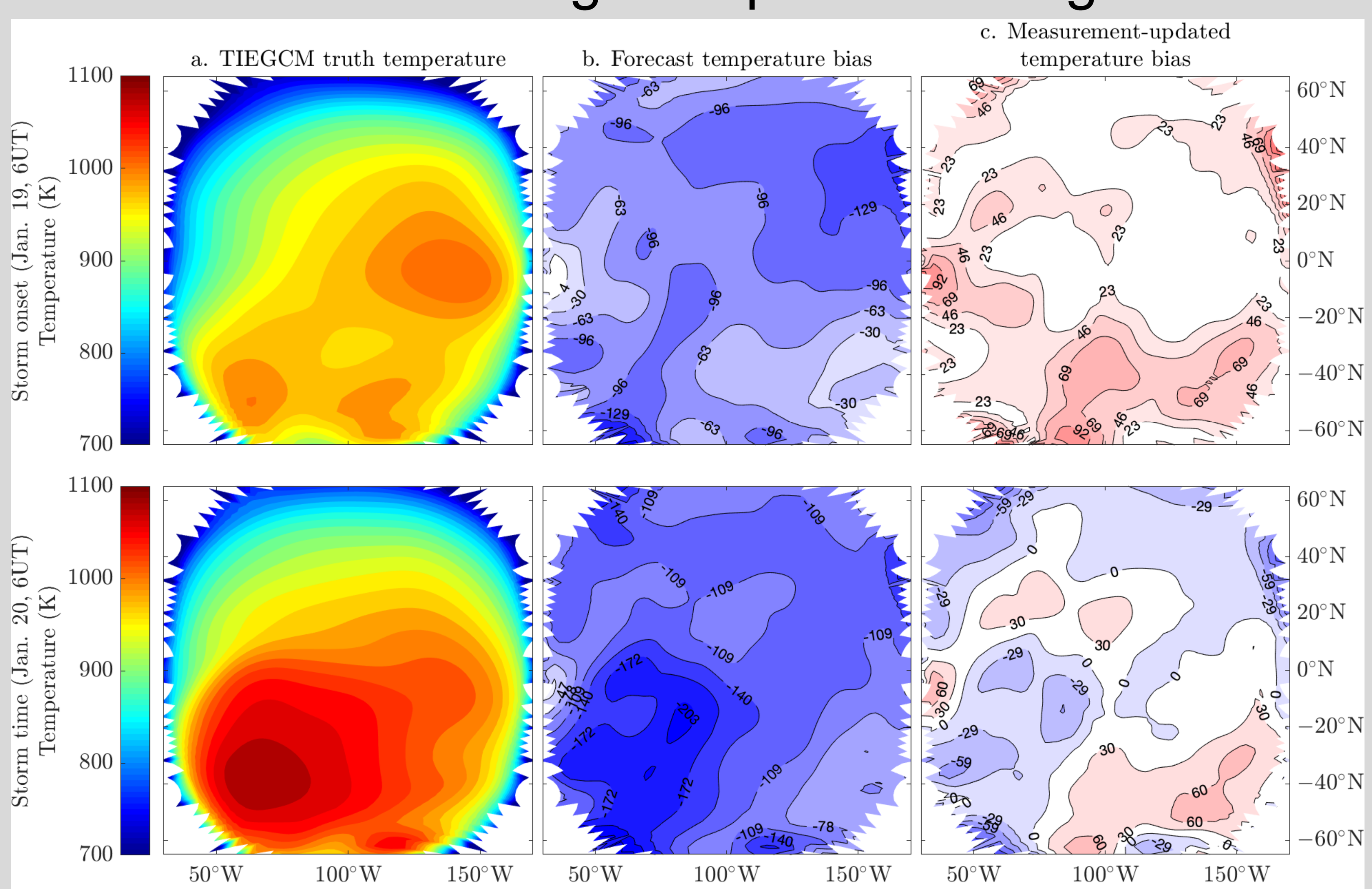


Figure 5 – Results for January 20th 6 UT at 390 km altitude on the dayside hemisphere with moderate magnetospheric forcing. We focus on 390 km to be in conjunction with CHAMP mas density measurements that have revealed post-storm rapid recovery of thermospheric density not captured in current models (Lei et al., 2011). The disturbed conditions were generated by introducing a sudden injection of energy into high latitudes (cross-tail potential = 120 kV and hemispheric power = 90 GW) within the TIEGCM model on January 19th. The bias is reduced from a absolute maximum of 210 K (b) to a maximum of 70 K (c) when the observation is assimilated.

The OSSE results demonstrate the potential of a radiance data assimilation approach to estimate 3-dimensional structure of thermospheric temperature from GOLD Level 1C disk data and to track medium-large scale transient features during times of elevated forcing. However, the methods' reliance on prior information (forecast model), means the measurement updated temperature will not significantly deviate from the forecast ensemble (Figure 4B) and unknown physical processes will likely not be reproduced by this approach. This work is under review with JGR – Space Physics.

References: Solomon, S. Journal of Geophysical Research - Space Physics, 122, 2017. Lei, J. et al. Journal of Geophysical Research, 116, 2011. Aksnes, A. et al. Geophysical Research Letters, 33, 2006.
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