Data Assimilation in the Whole Atmosphere Community Climate Model

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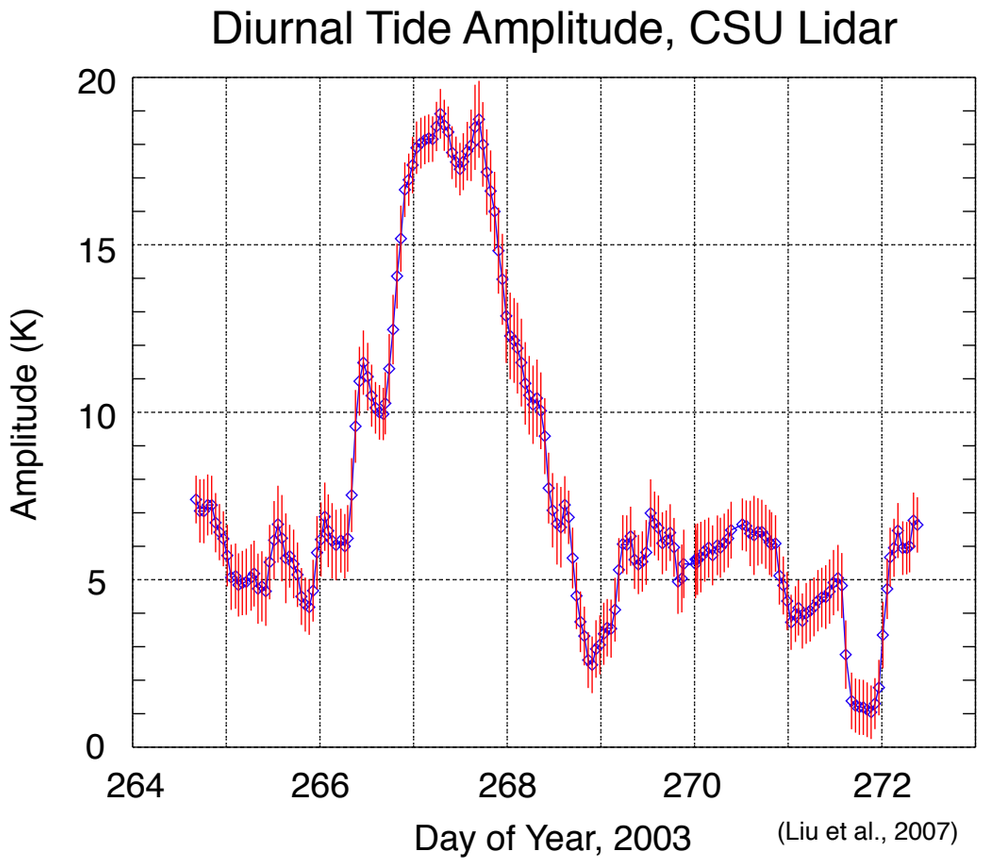
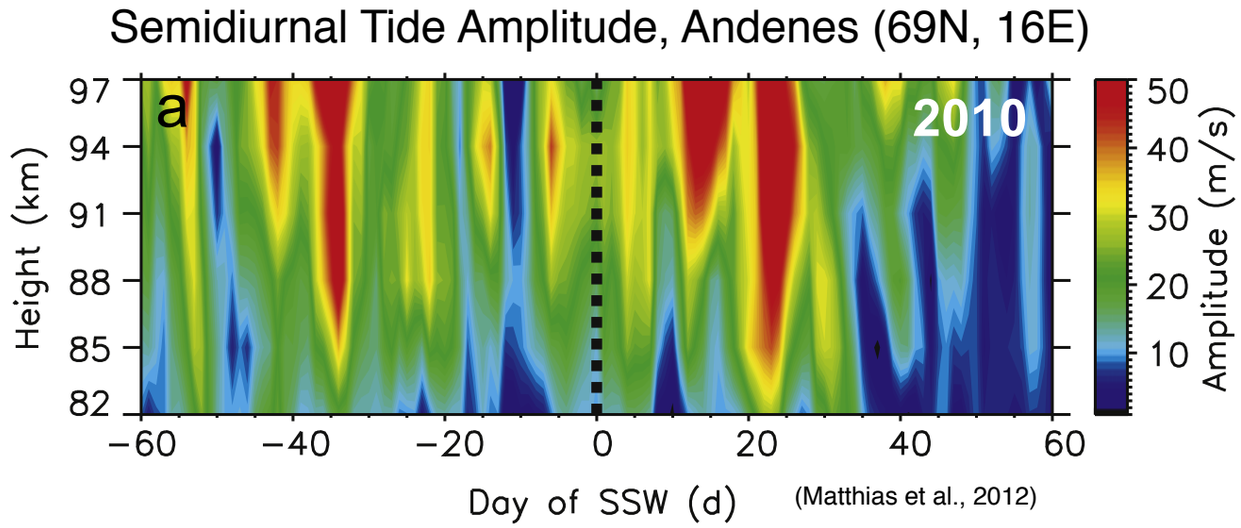
Outline

- Background and motivation
- WACCM+DART Data Assimilation System
- Results:
  - Synthetic observations
  - Real observations
- Summary and Conclusions

Radar observations reveal large day-to-day tidal variability in the mesosphere and lower thermosphere





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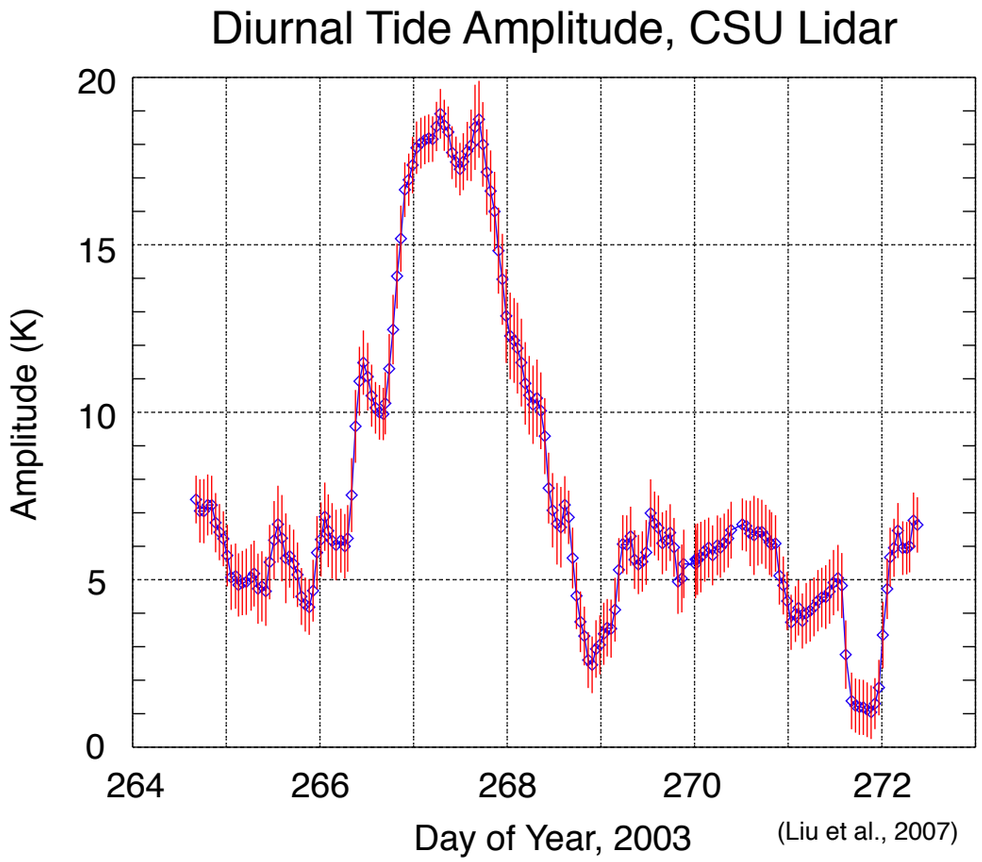

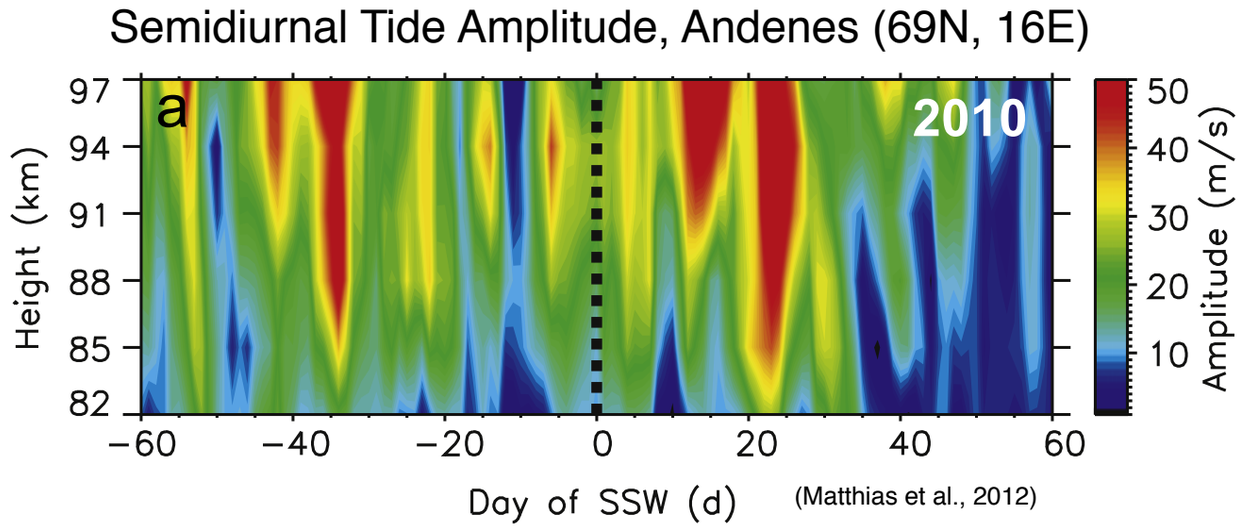

Can WACCM reproduce the observed short-term tidal variability?

Motivation: Why Data Assimilation?

- Current approach to simulate real events in WACCM is by nudging WACCM to external reanalysis (MERRA, NOGAPS-ALPHA, etc.)
  - Some control is lost due to using an external model as the 'truth'
  - Typically nudge only up to ~60-70 km, potentially resulting in missing information above this altitude
  - Not entirely clear how well tides are reproduced given the potentially coarse temporal resolution of the analysis
- Including a data assimilation scheme directly in WACCM should provide a better representation of the real atmospheric state
- In addition to dynamics, many other potential uses of data assimilation in WACCM:
  - Assimilation of chemical species (e.g., ozone)
  - Parameter estimation
  - Ionosphere and upper atmosphere applications

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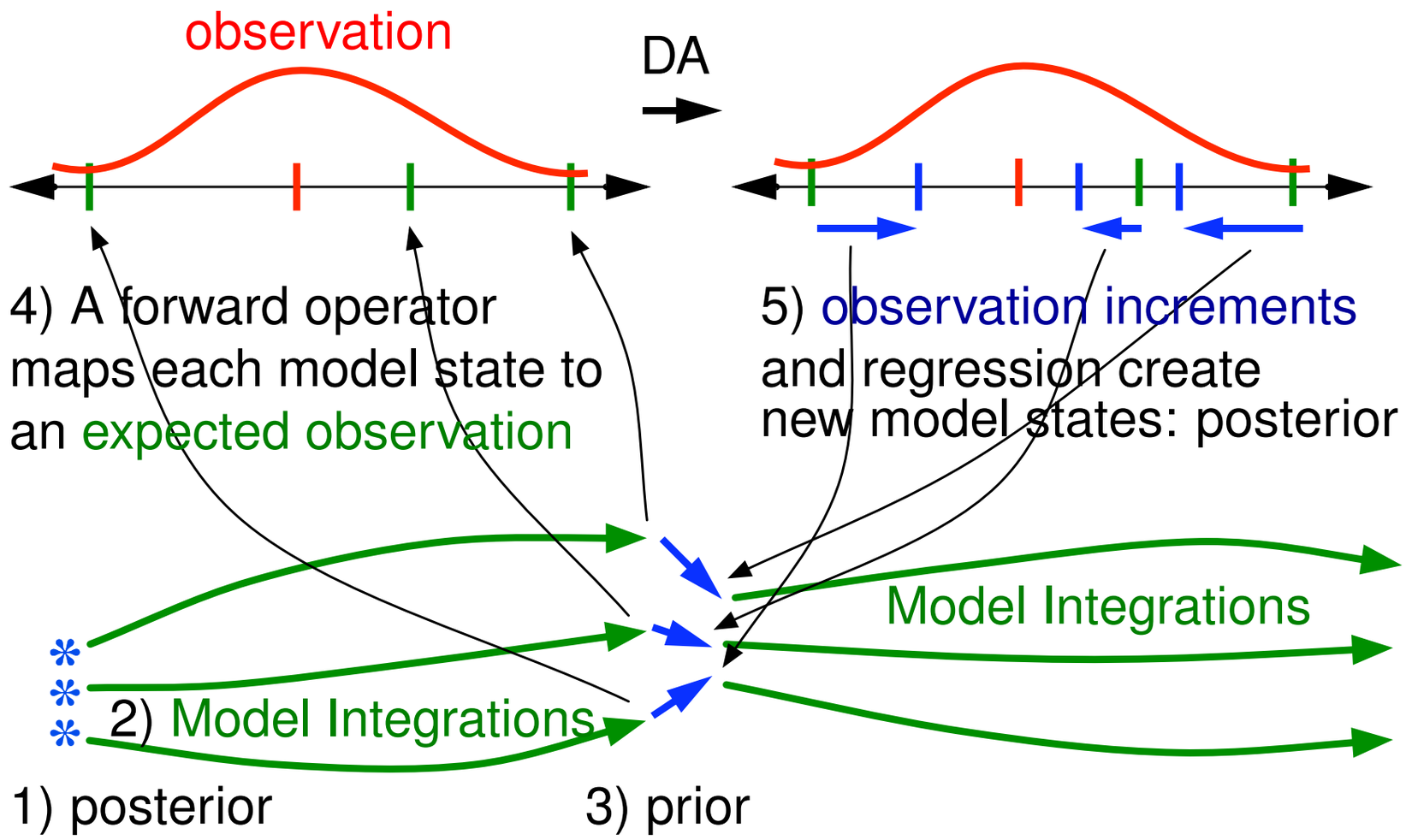
Data Assimilation capability added to WACCM using **D**ata **A**ssimilation and **R**esearch **T**estbed (DART)



- Ensemble Kalman filter freely distributed through NCAR/IMAGe
- Provides framework for data assimilation, and is used with several atmosphere models (CAM, WRF, TIE-GCM)
- ‘Easily’ adapted to different models

WACCM+DART Data Assimilation System

- Observations assimilated:
  - Radiosonde temperature and winds
  - Aircraft temperature and winds
  - Satellite drift winds
  - COSMIC Refractivity
  - TIMED/SABER Temperature (100 - $5x10^{-4}$ hPa)
  - Aura MLS Temperature (260 - $1x10^{-3}$ hPa)
- State variables: cloud ice/water content, humidity, surface pressure, temperature, and horizontal wind
- Use standard NWP six-hourly data assimilation
- All results are based on an ensemble size of 40 members
- Two experiments performed:
  1. Synthetic observations sampled from a known model truth for 5-25 November 2008
  2. Real observations for 9-24 September 2011

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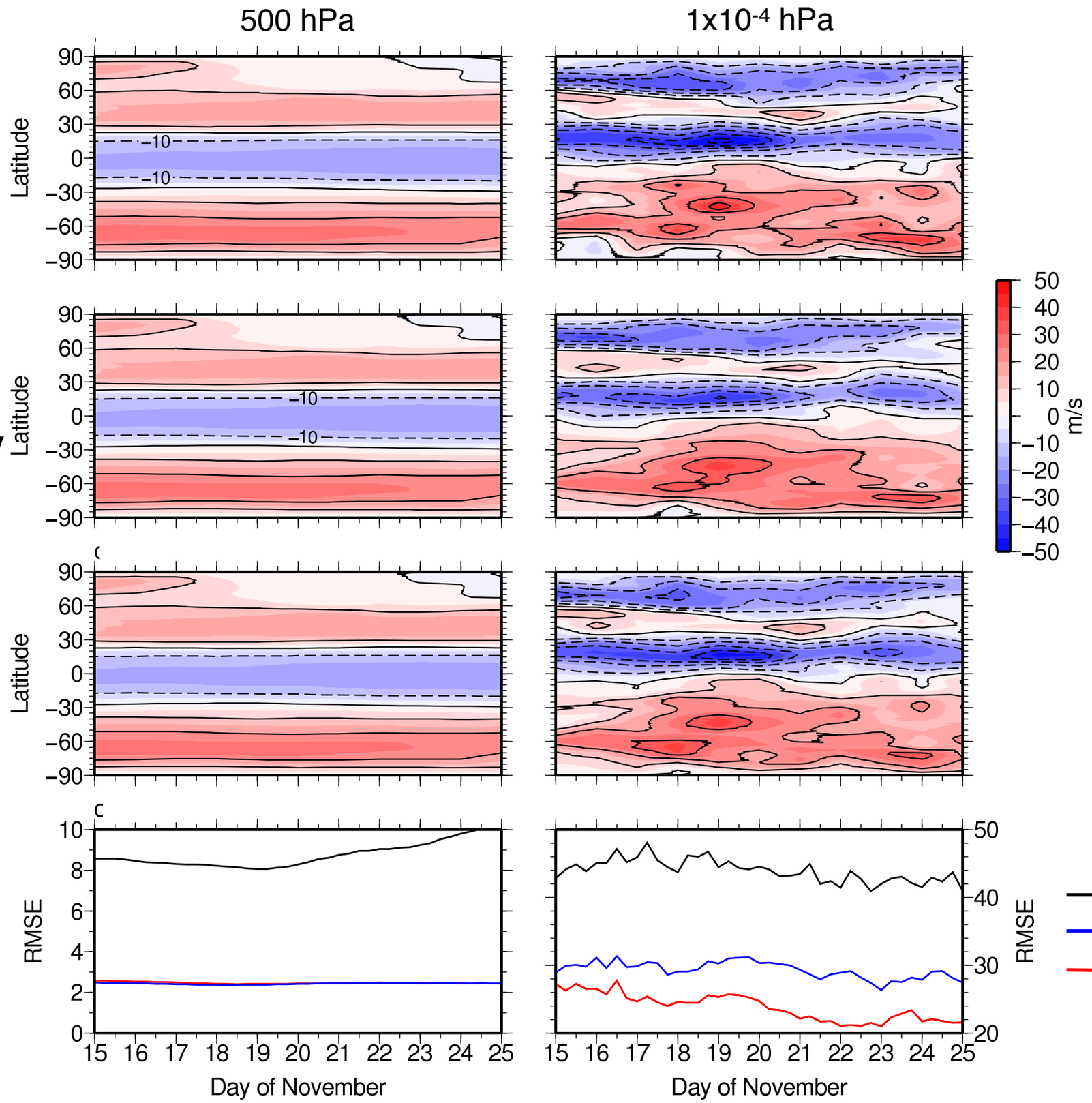
Structure and variability of the zonal mean zonal wind is captured by WACCM+DART

Model Truth

WACCM+DART lower atm. obs. only

WACCM+DART lower atm. & SABER obs.



Large-scale day-to-day tidal variability is reproduced by WACCM+DART

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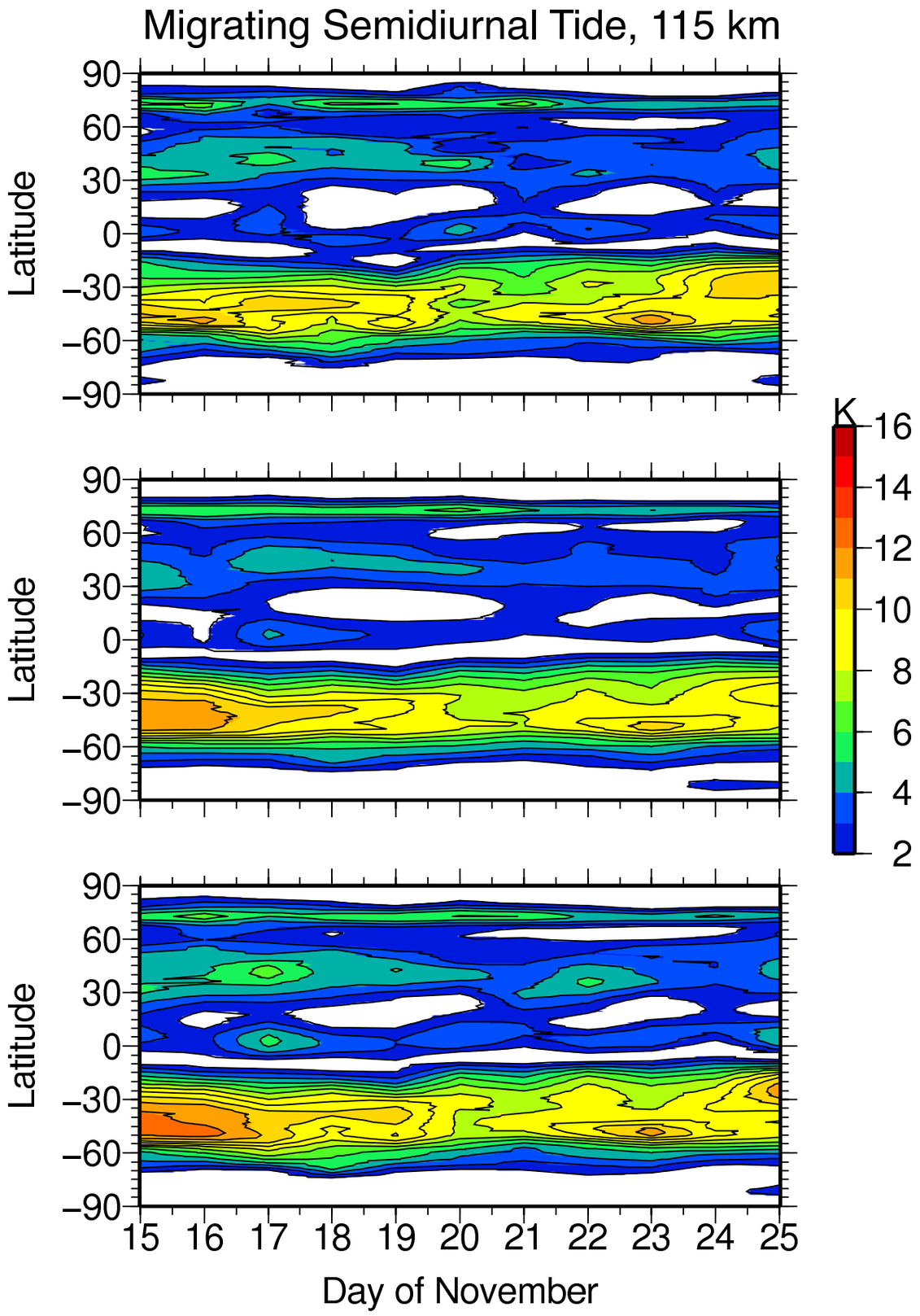

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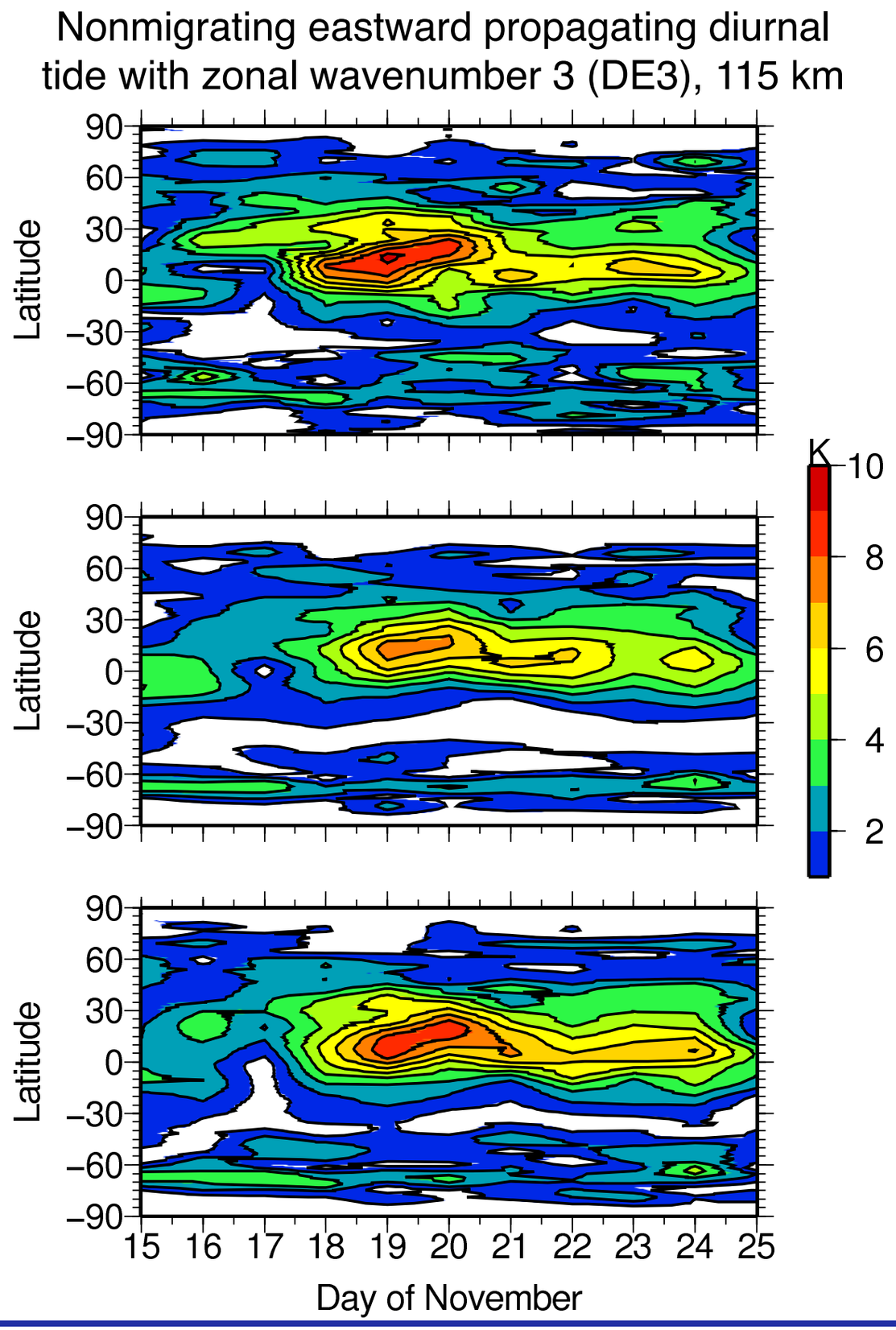

WACCM+DART captures the variability that would be observed at a single location

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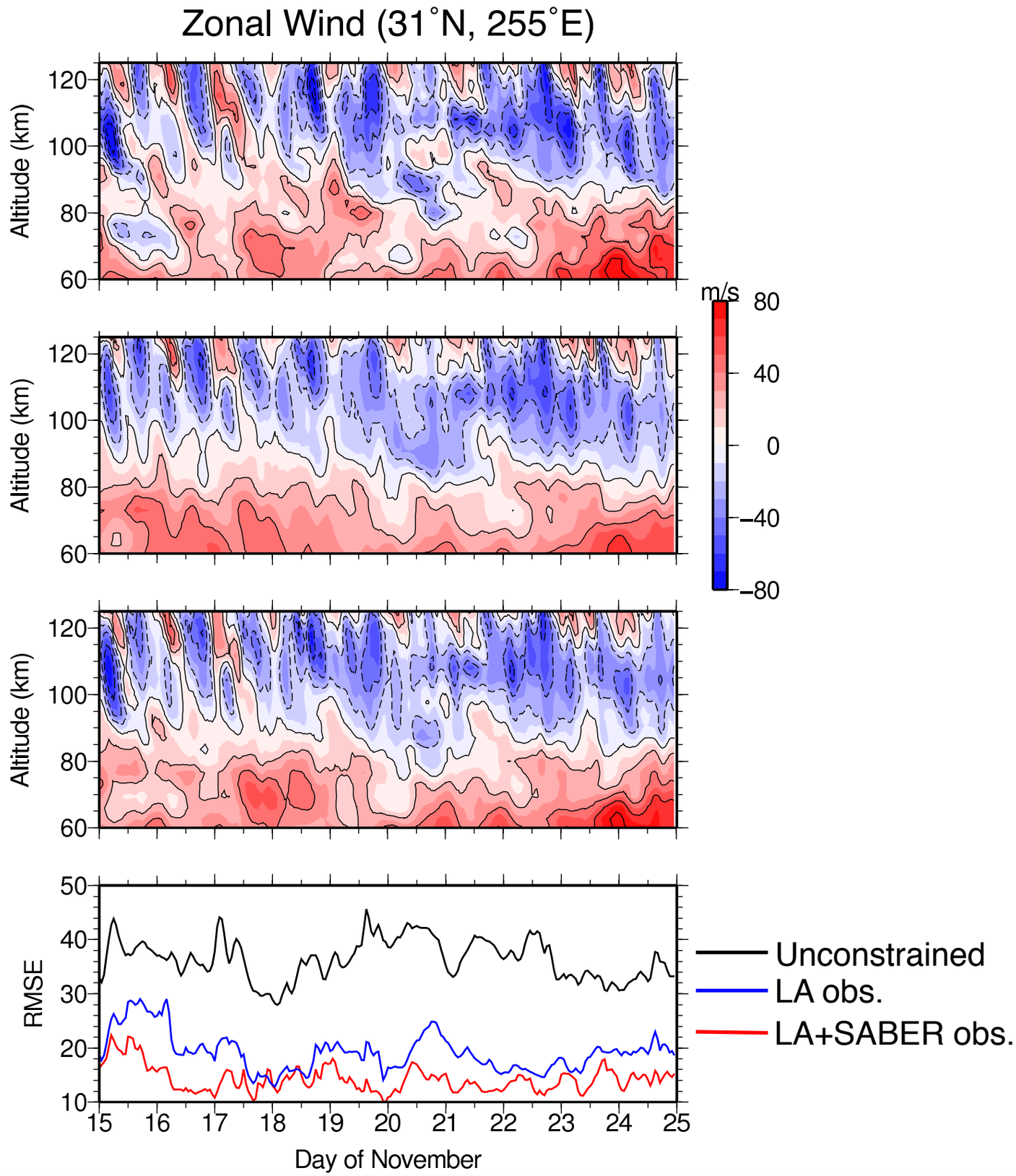

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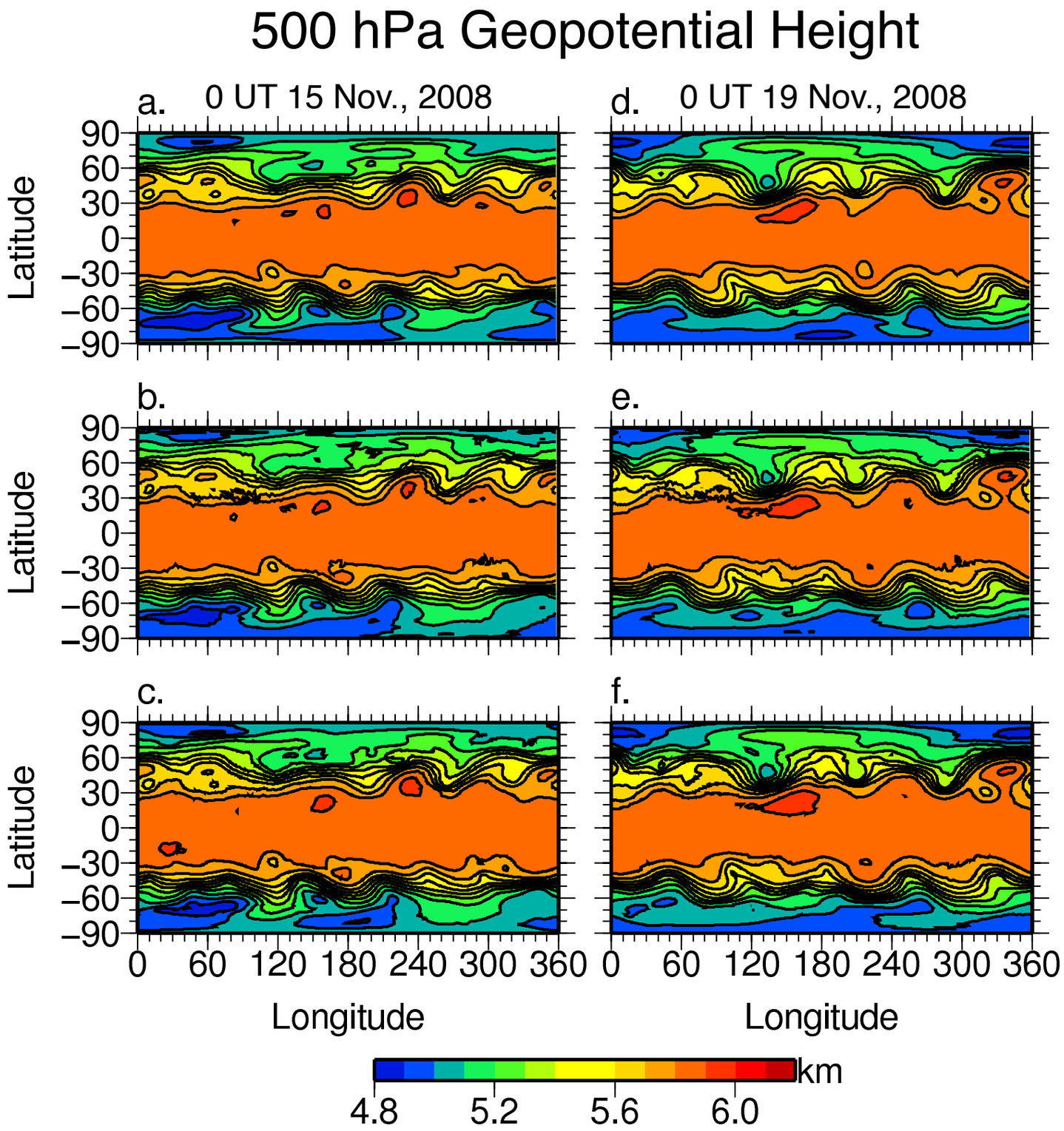
WACCM+DART results in the troposphere reproduce large-scale features of NCEP reanalysis and CAM+DART

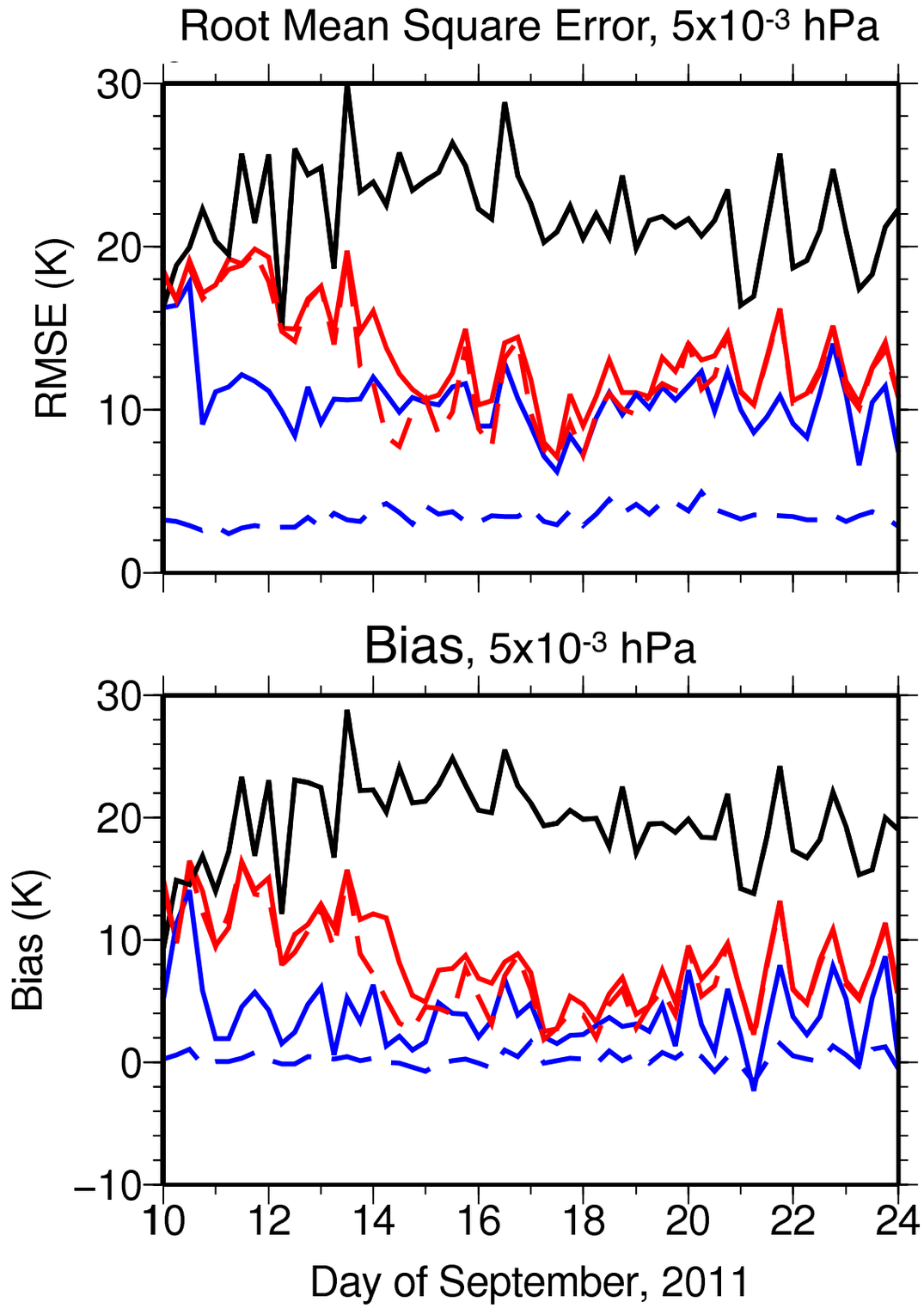
NCEP

WACCM+DART

CAM+DART



Assimilation of SABER temperatures reduces the RMSE and bias relative to Aura MLS observations



Assimilate LA Obs

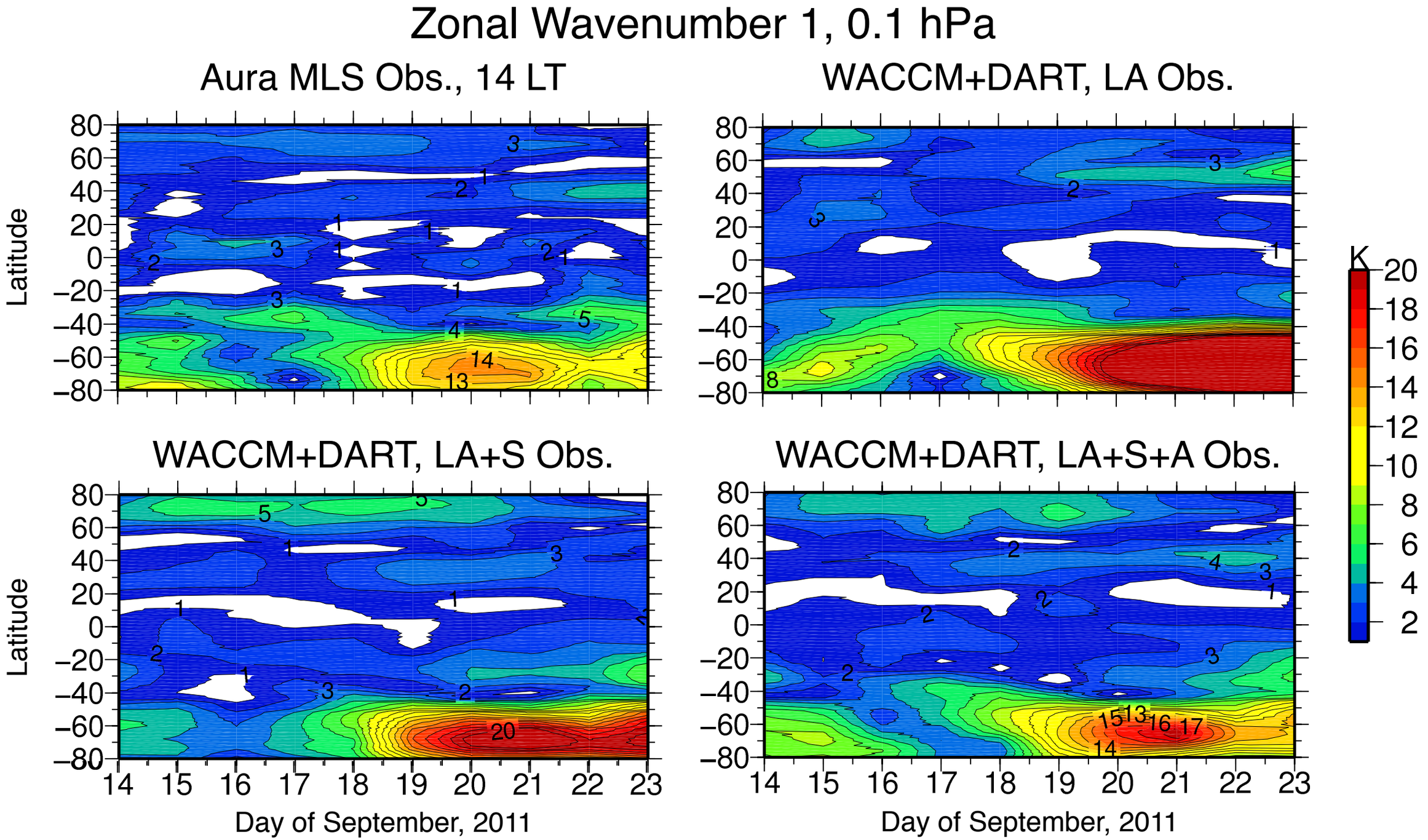
Assimilate LA & SABER Obs

Assimilate LA, SABER & Aura Obs

Solid: six-hour forecast

Dashed: analysis

Similar variability is present in observations and WACCM+DART for large scale waves



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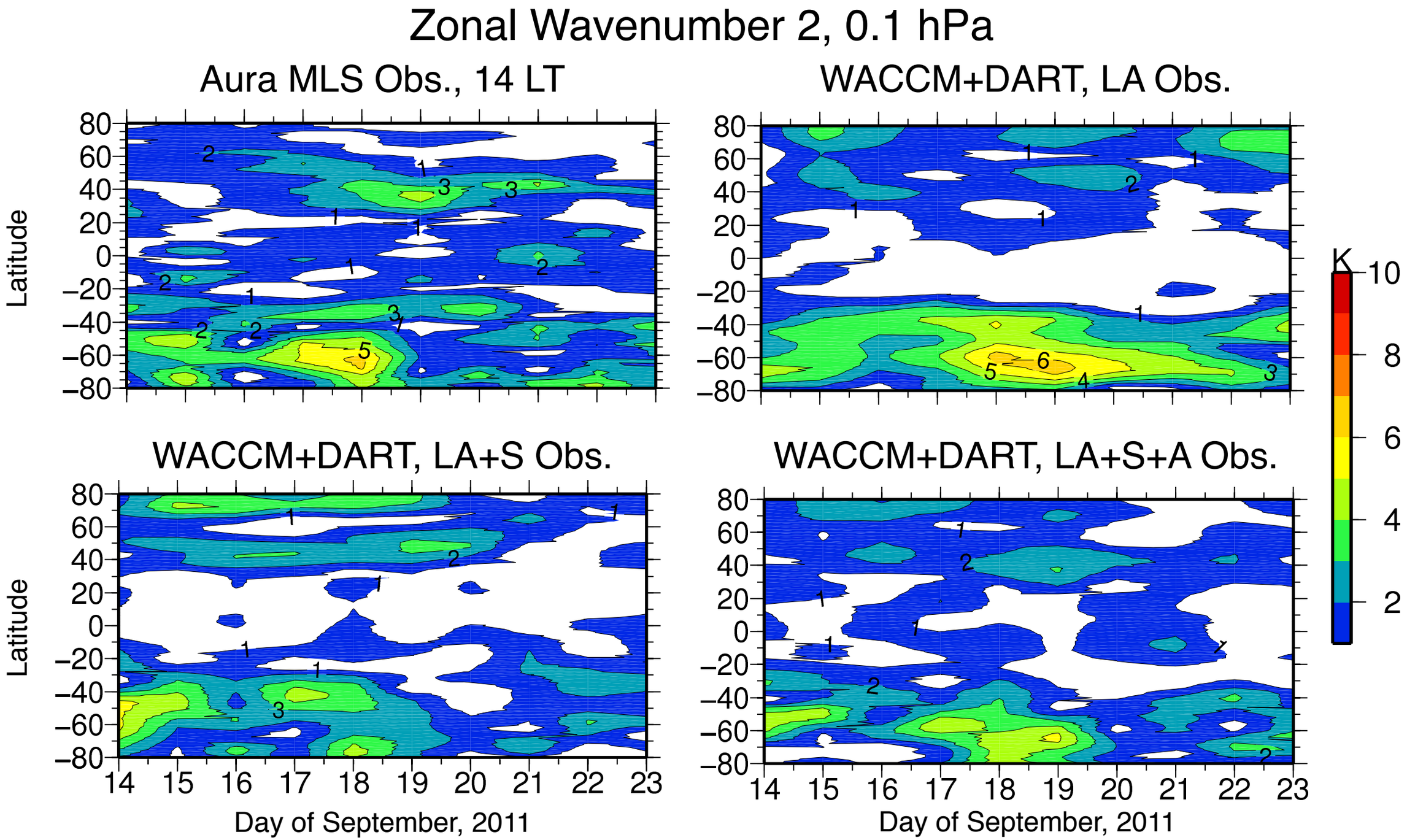
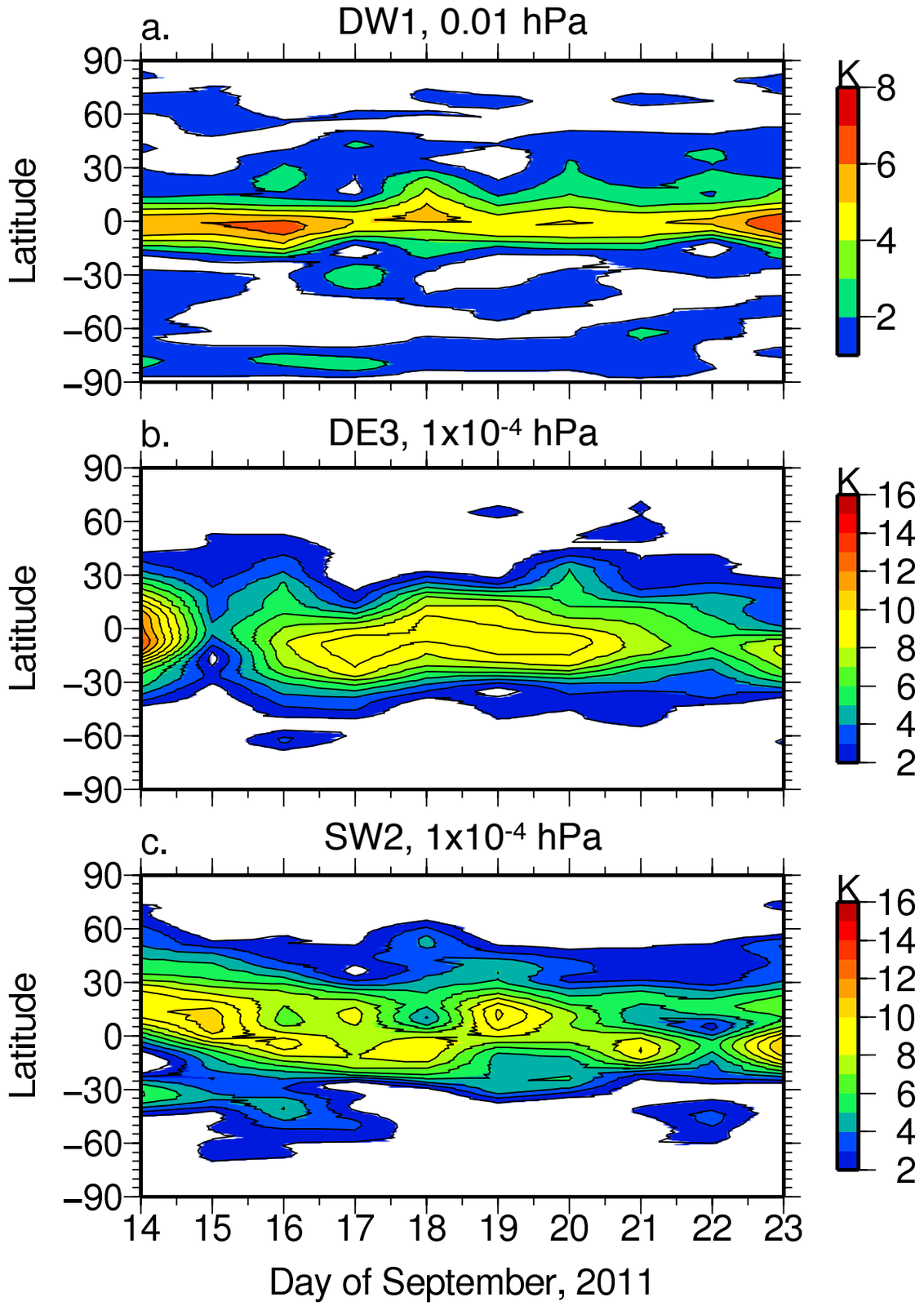


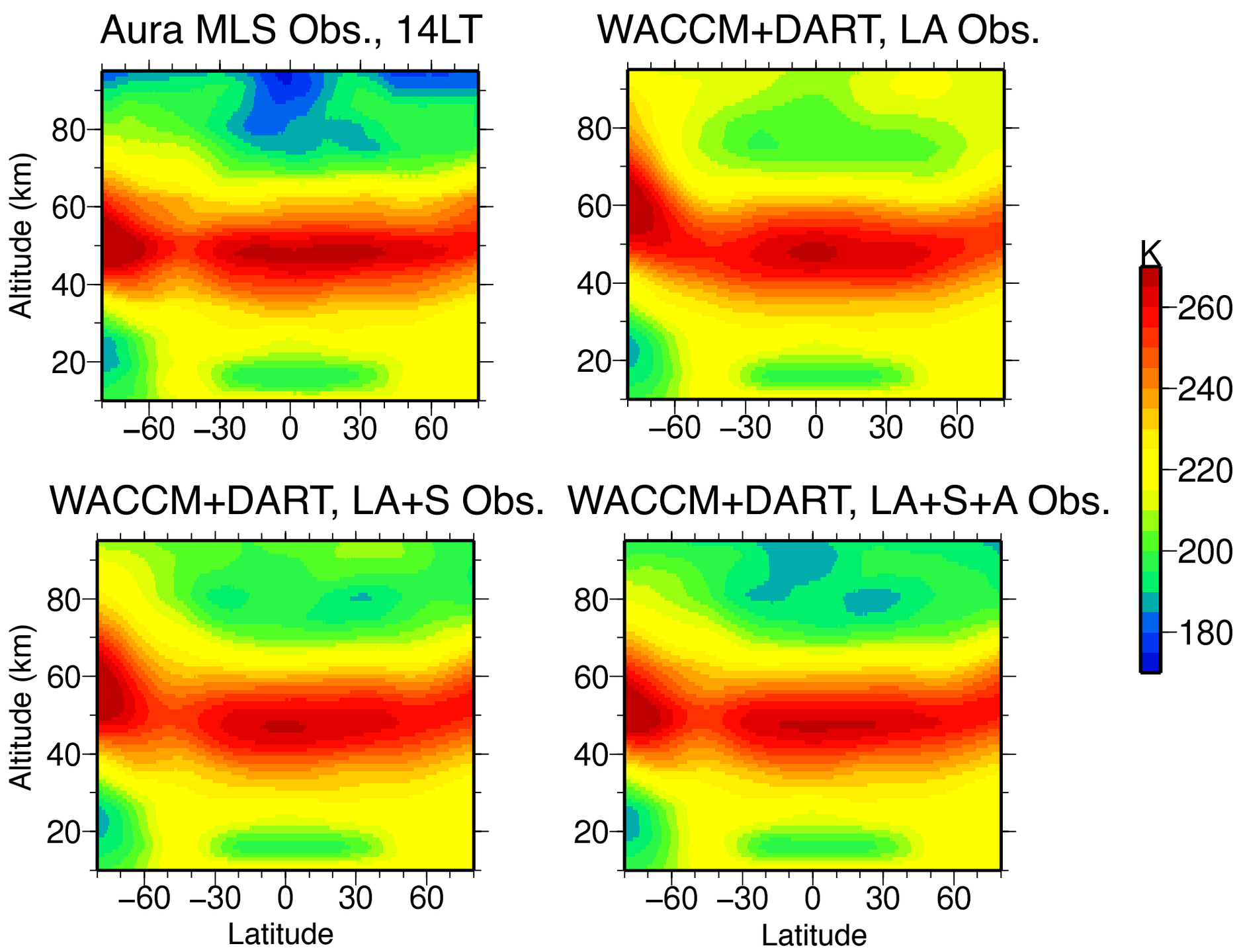
WACCM+DART reveals significant day-to-day variability in migrating and nonmigrating tides



Summary and Conclusions

- The data assimilation capability has been added to WACCM using an ensemble Kalman filter.
- The WACCM+DART data assimilation system can reproduce the large-scale dynamical variability in the mesosphere and lower thermosphere that is present in independent observations.
- Although the assimilation of lower atmosphere observations can constrain the MLT, observations in the middle/upper atmosphere significantly improve the data assimilation result.
- WACCM+DART can be used in the future for specific case studies, such as studies of tidal variability during SSWs.
- WACCM will soon be included as a supported model in the DART release.

Assimilation of SABER temperatures reduces the temperature bias in the MLT



Note that SABER and Aura MLS temperature observations are known to be biased by 3-4K