Data Assimilation in the Whole Atmosphere Community Climate Model

Nick Pedatella[1]

Collaborators: Hanli Liu[1], Kevin Raeder[2], and Jeffrey Anderson[2]

[1]High Altitude Observatory, National Center for Atmospheric Research
[2]Institute for Mathematics Applied to Geosciences, National Center for Atmospheric Research
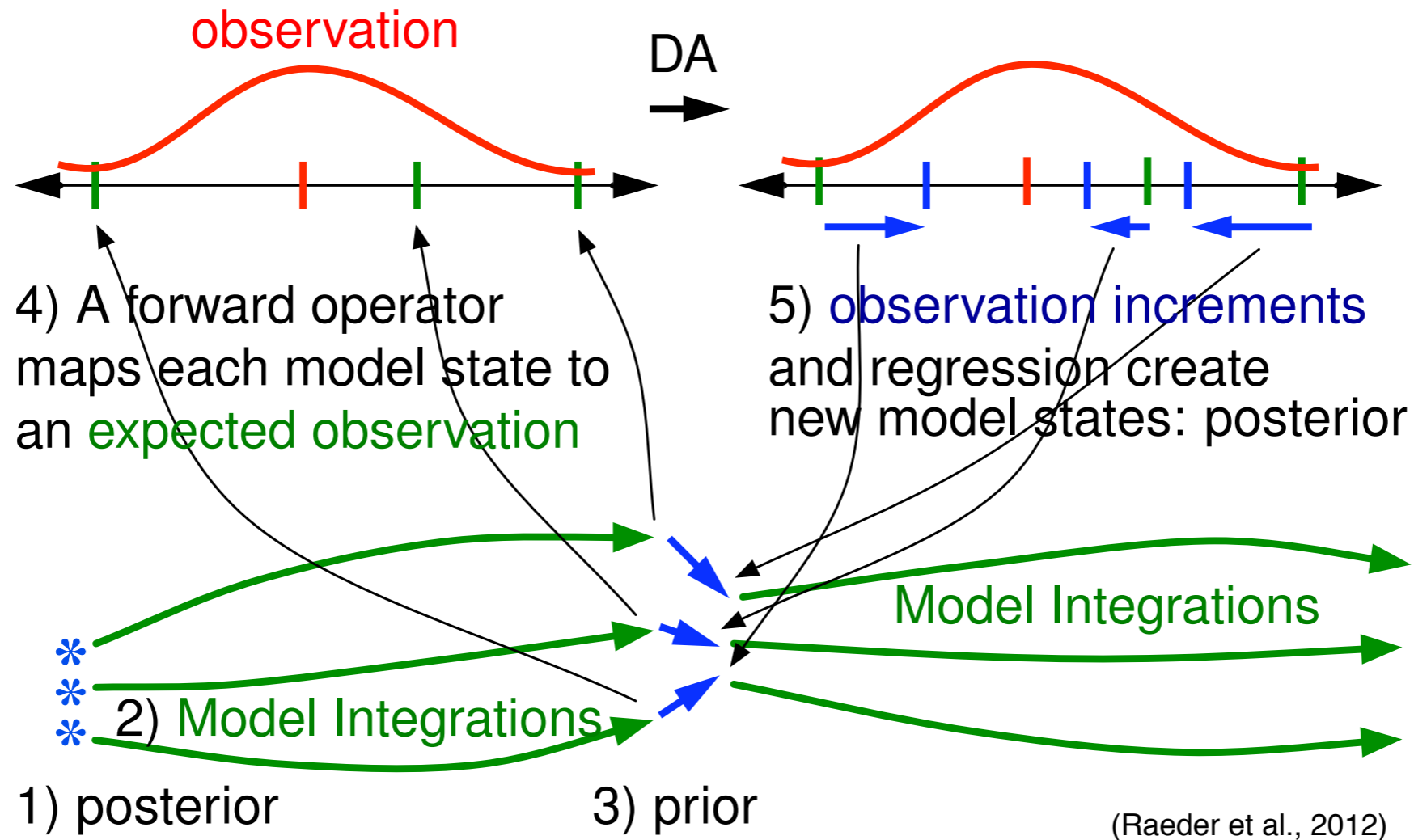
HA●

Outline

- Motivation

- Data Assimilation and Research Testbed (DART)

- Results:

  - Synthetic Observation Case

  - Real Observation Case

- Summary and Conclusions

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 the WACCM should provide a better representation of the real atmospheric state
- In addition to dynamics, many other potential uses of DA:
  - Assimilation of chemical species
  - Parameter estimation
  - Ionosphere and upper atmosphere applications

<u>D</u>ata <u>A</u>ssimilation and <u>R</u>esearch <u>T</u>estbed (DART)

observation

DA

4) A forward operator maps each model state to an expected observation

5) observation increments and regression create new model states: posterior

Model Integrations

2) Model Integrations

1) posterior

3) prior

(Raeder et al., 2012)

- Ensemble Kalman filter developed and distributed by NCAR/IMAGe

- Used for numerous applications (CAM, TIE-GCM, WRF)

- 'Easily' adapted to different models

Observations

DART

Ocn Obs

DART

Atm Obs

Implementation of DART with WACCM

- Almost entirely based on the framework developed for CAM/DART
- Uses the CESM multi-instance capability to run N-members of WACCM simultaneously
- Standard lower atmosphere observations and TIMED/SABER observations of the middle/upper atmosphere are assimilated
- Assimilation performed every six hours
- Preliminary experiments run from 1 Nov. 0UT to 10 Nov. 0UT:
  - Synthetic observations obtained by sampling a known model state
  - Real observations
- For a 40 member ensemble, one simulated day requires ~400 core hours on Yellowstone
  - Computational expense likely limits studies that are on the order of weeks

Outline

- Motivation

- Data Assimilation and Research Testbed (DART)

- Results:

  - Synthetic Observation Case

  - Real Observation Case

- Summary and Conclusions

Temperature Root Mea500 hPa
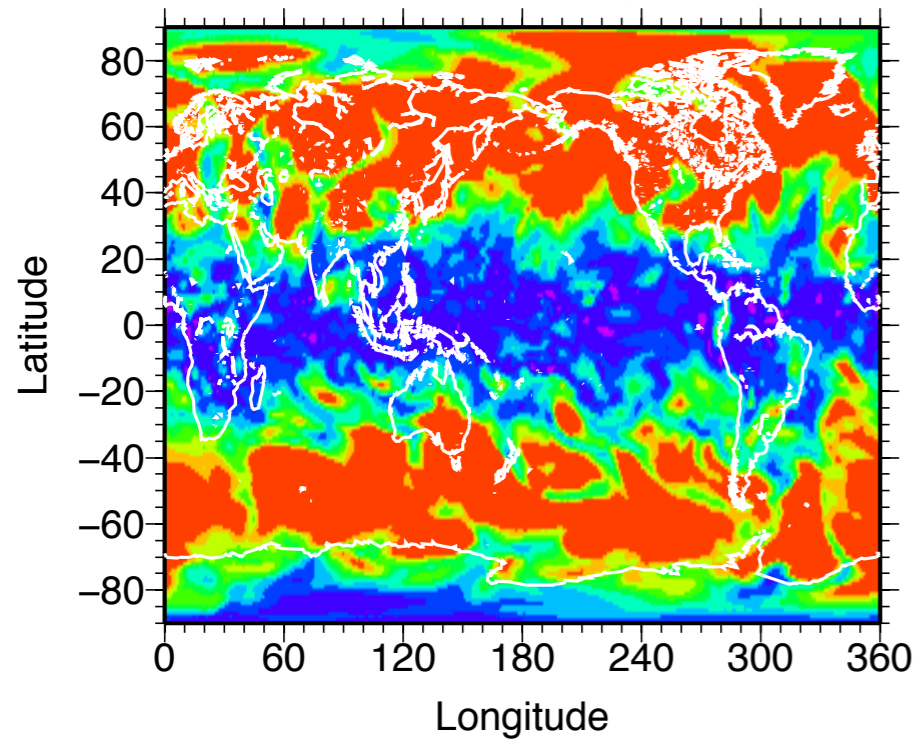
1 November, 0UT
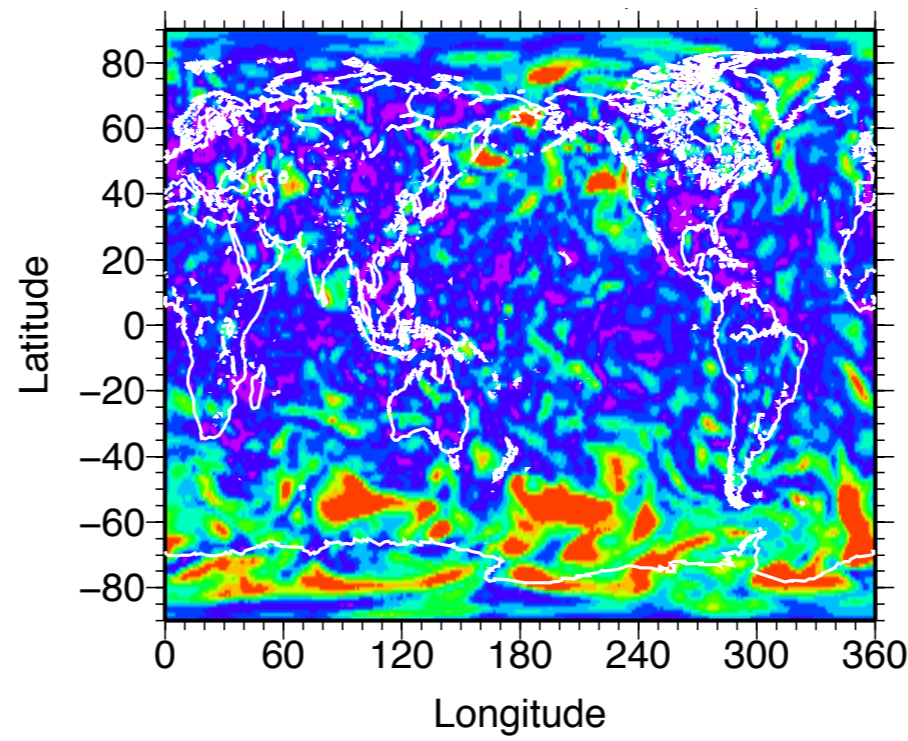
2 November, 0UT
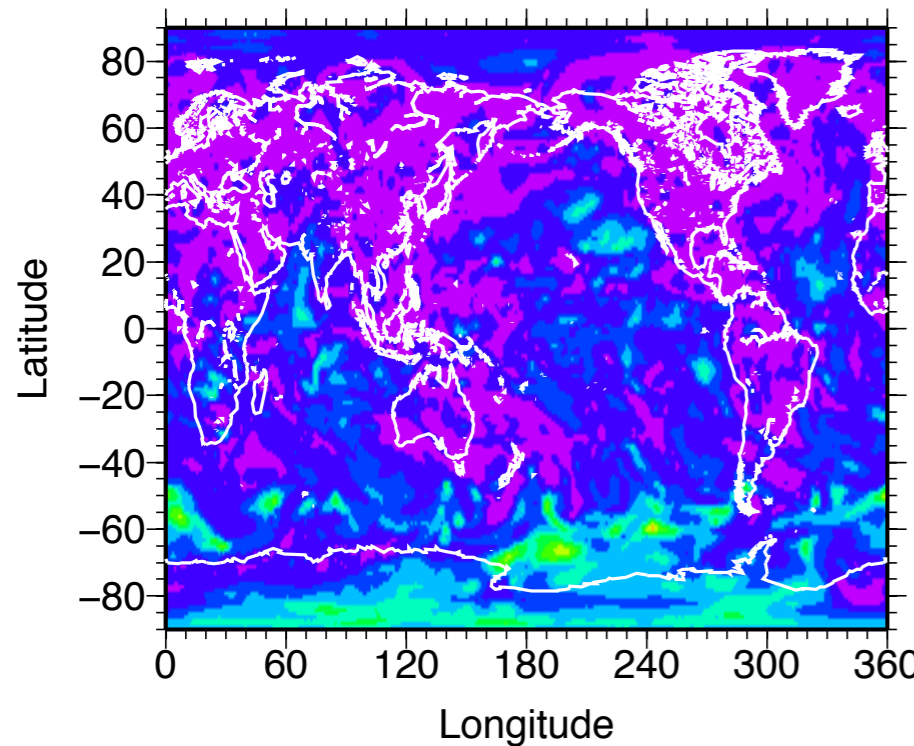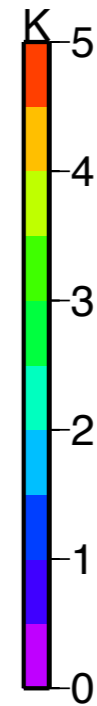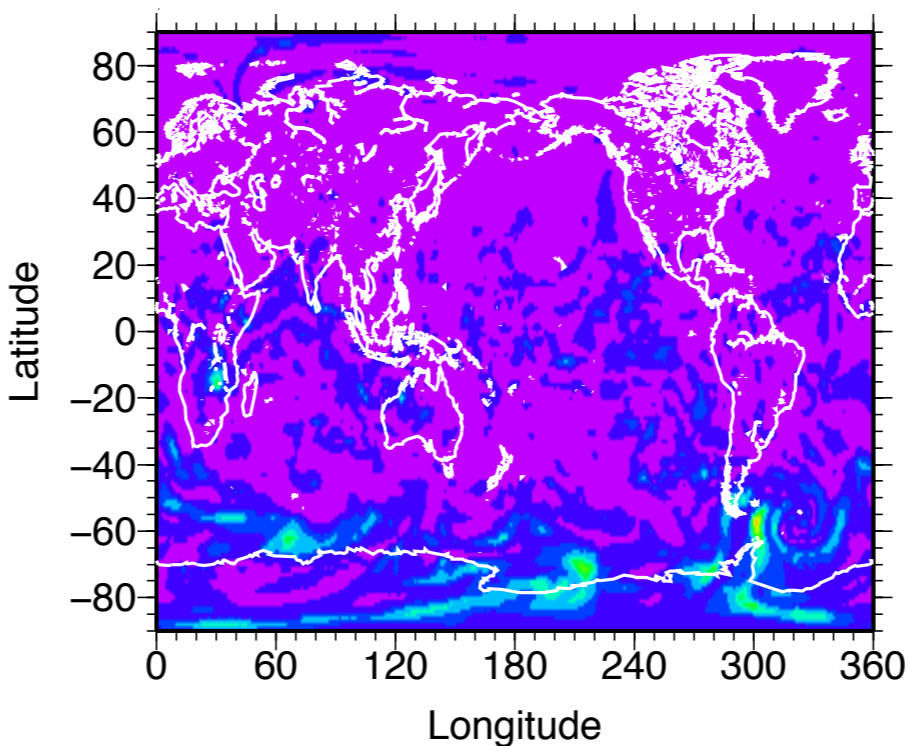
6 November, 0UT

10 November, 0UT

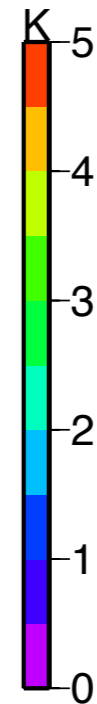# Temperature Root Mea‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍‍500 hPa
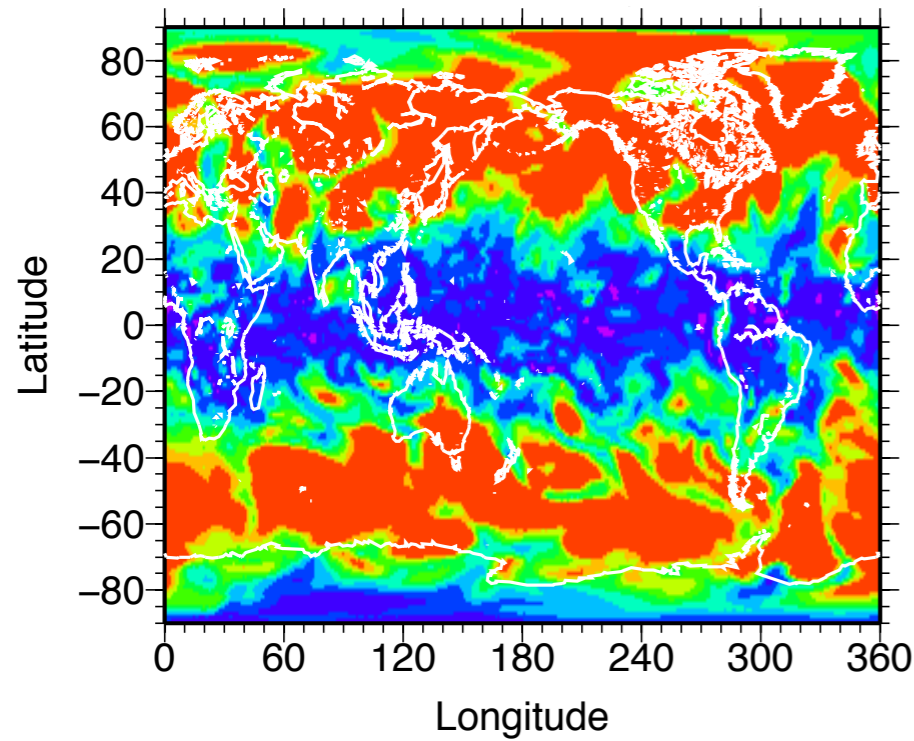
1 November, 0UT
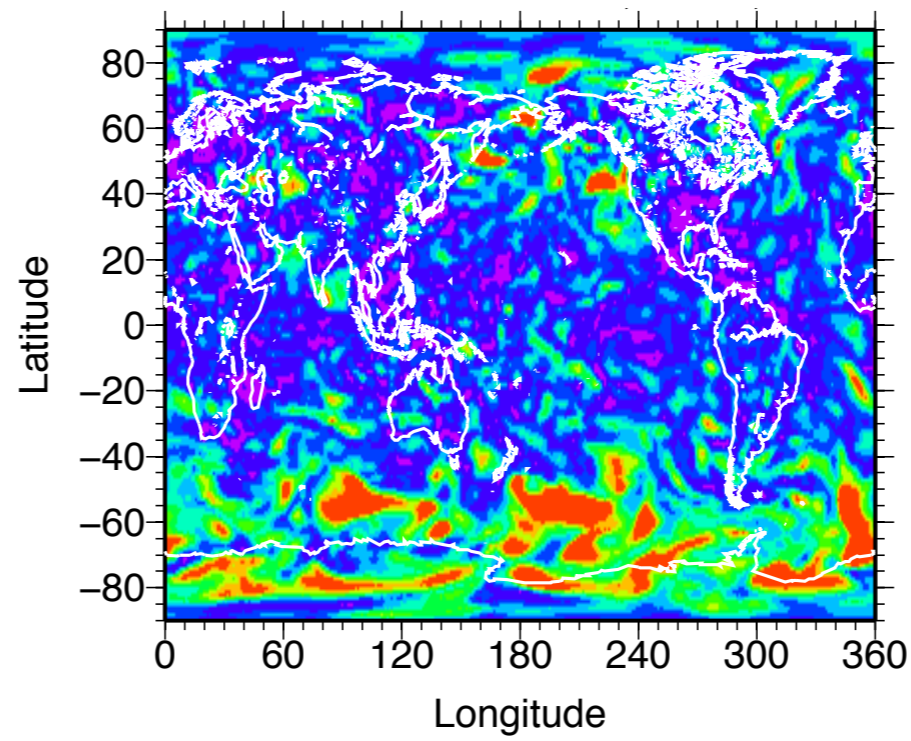
2 November, 0UT
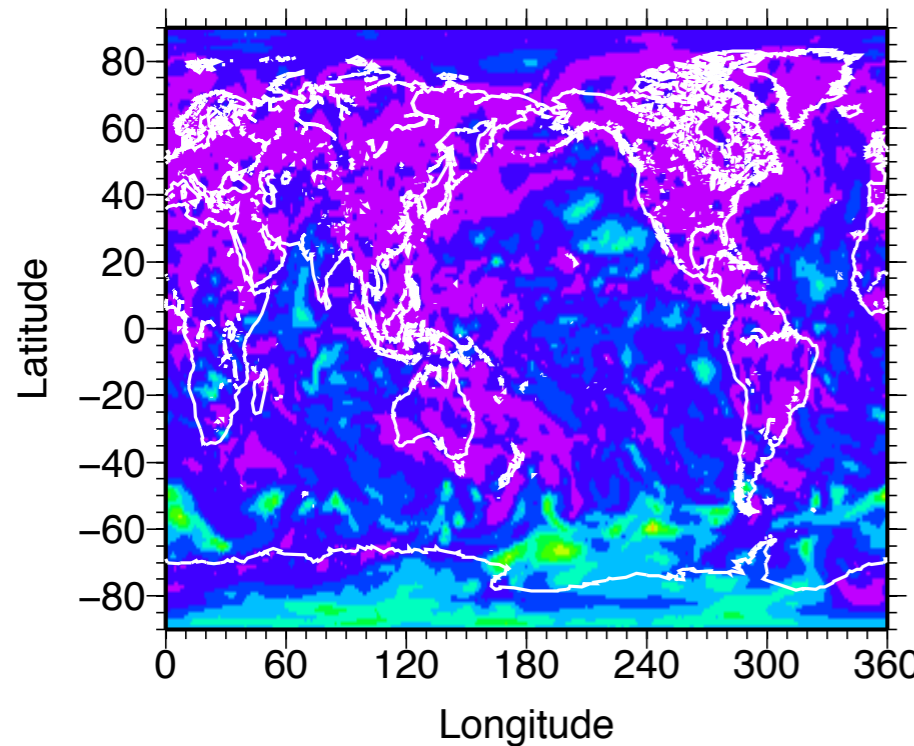
6 November, 0UT
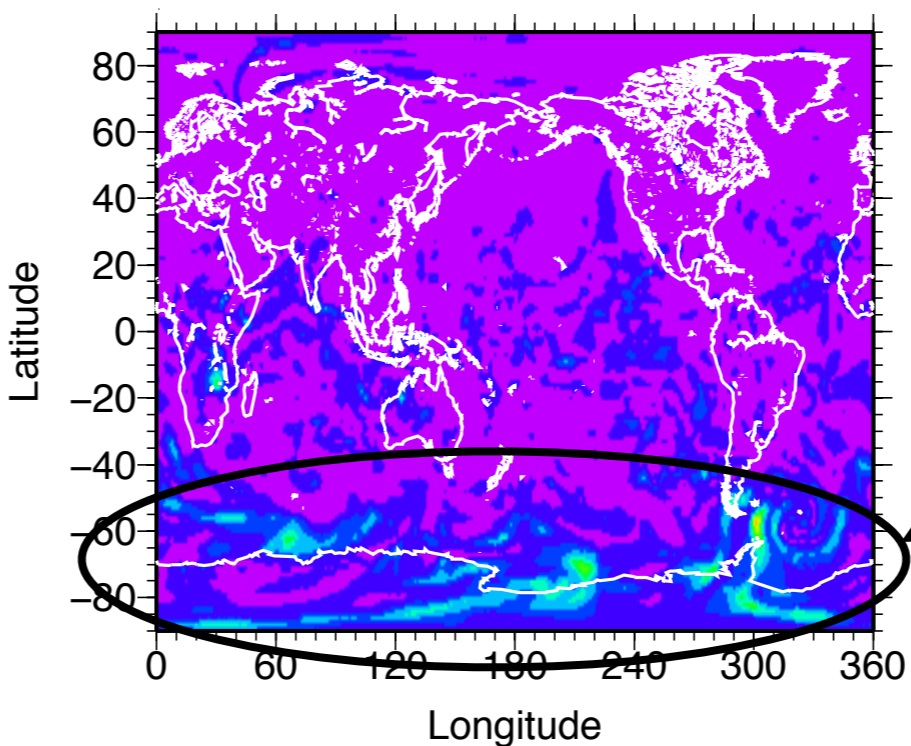
10 November, 0UT

Error remains in poorly observed regions

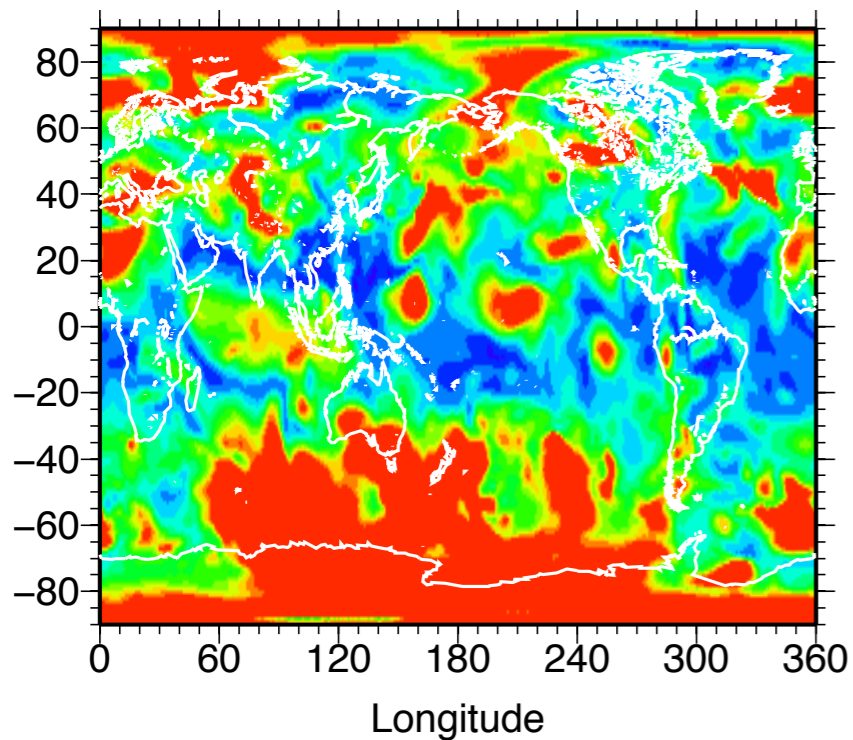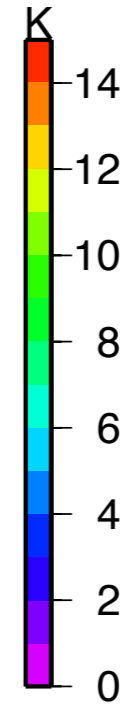# Temperature Root Mean Square Error at 0.01 hPa without SABER observations
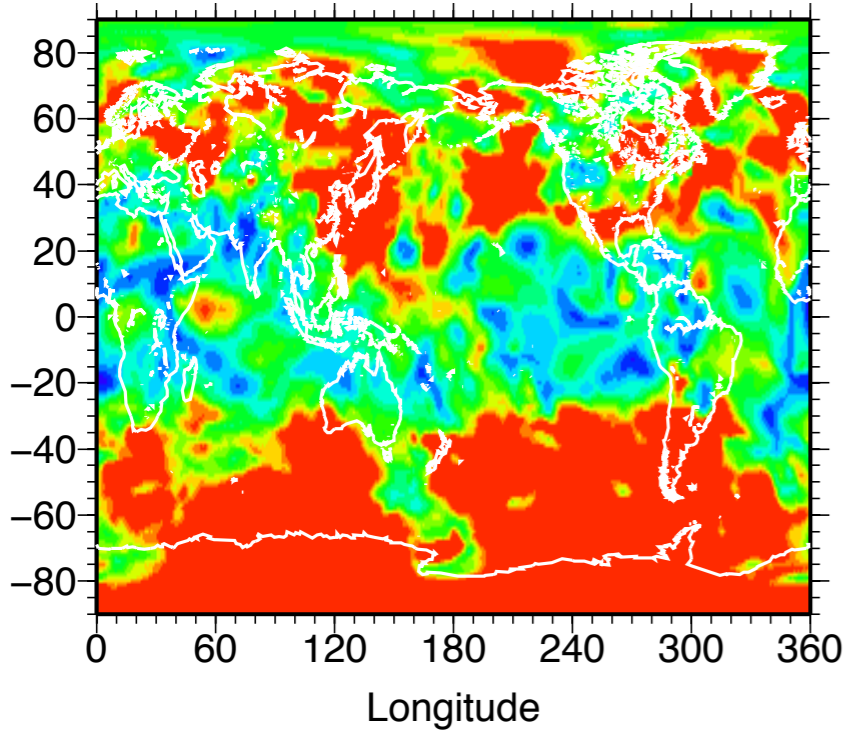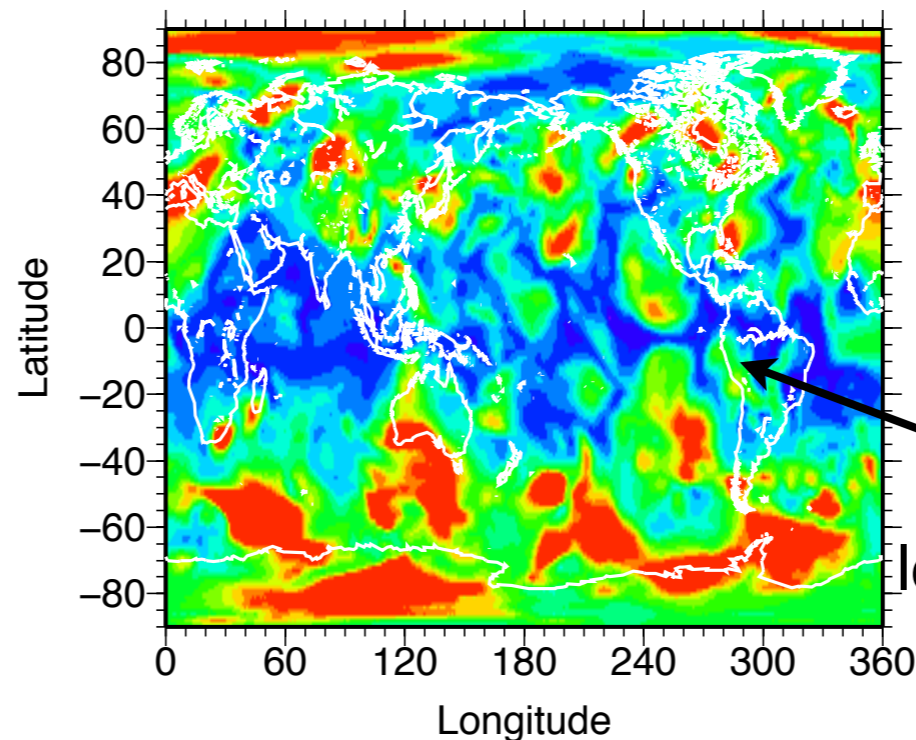
1 November, 0UT
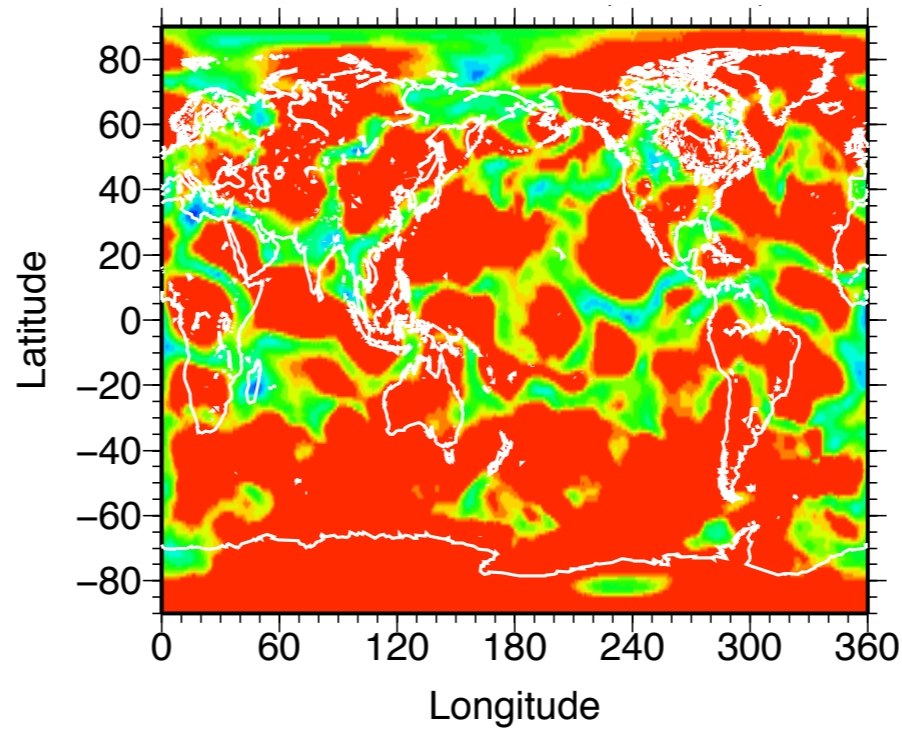
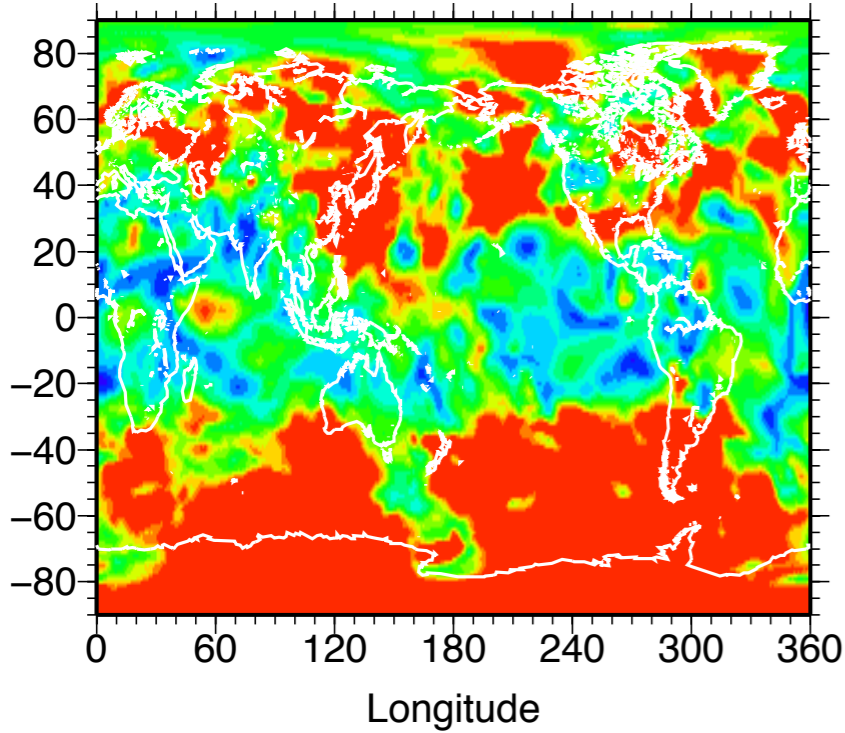## 2 November, 0UT

6 November, 0UT
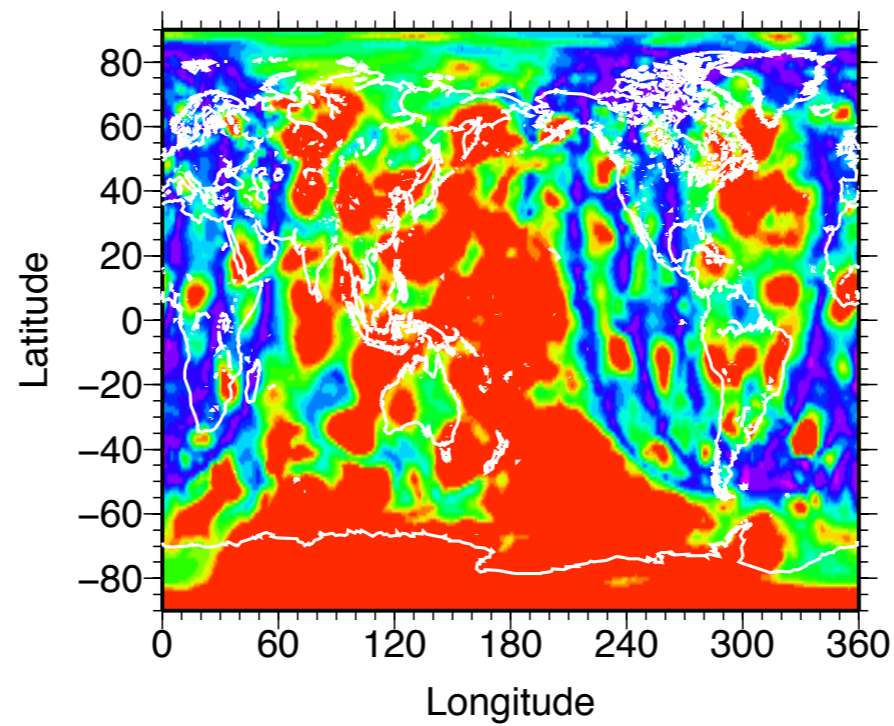
10 November, 0UT

Error reduction due to lower atmosphere observations

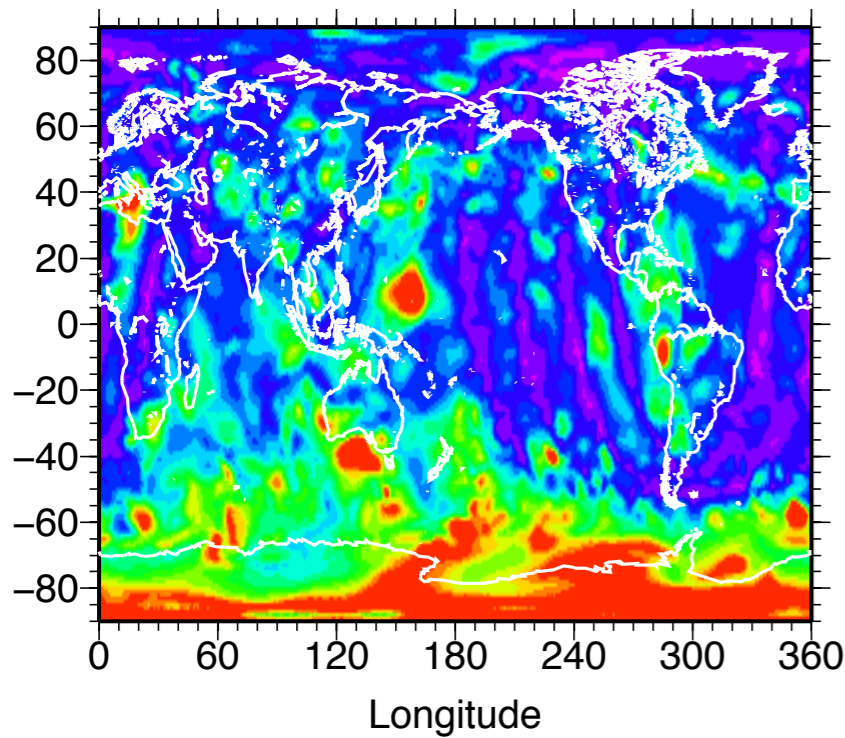# Temperature Root Mean Square Error at 0.01 hPa with SABER observations
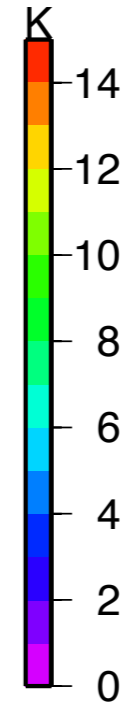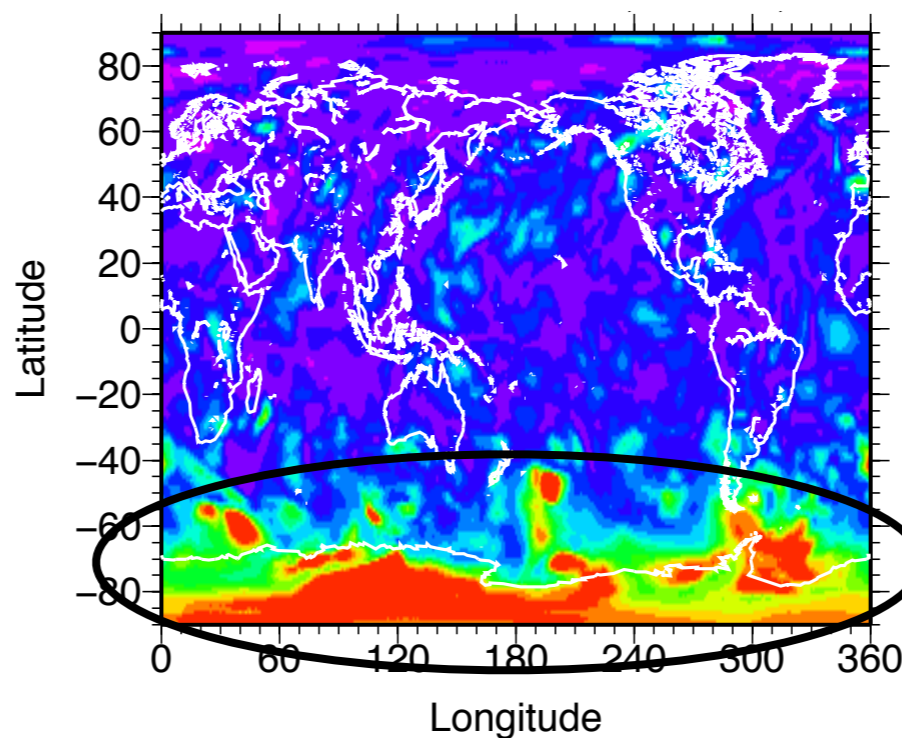
1 November, 0UT

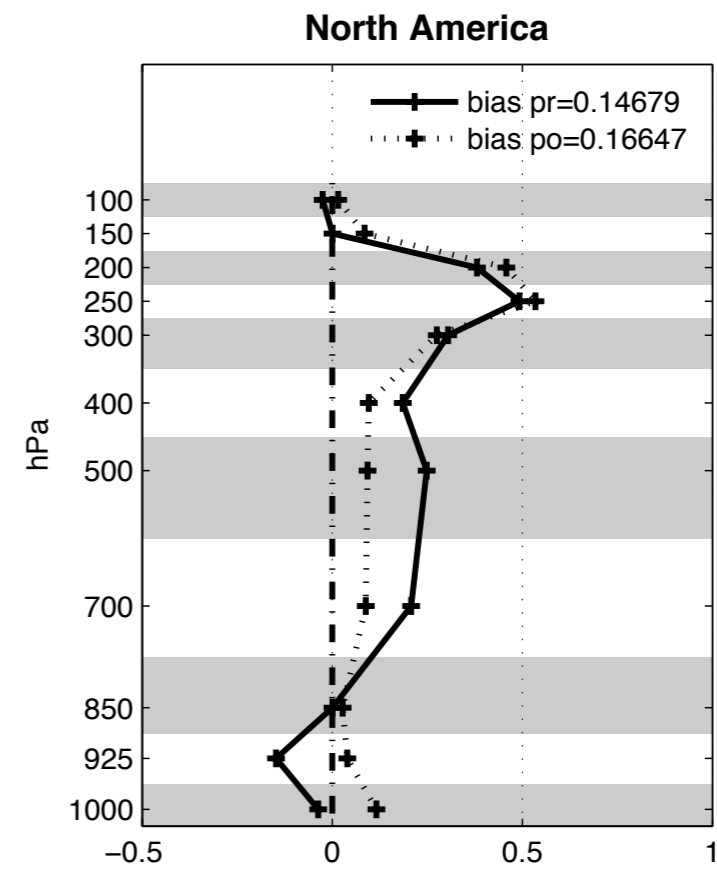### 2 November, 0UT

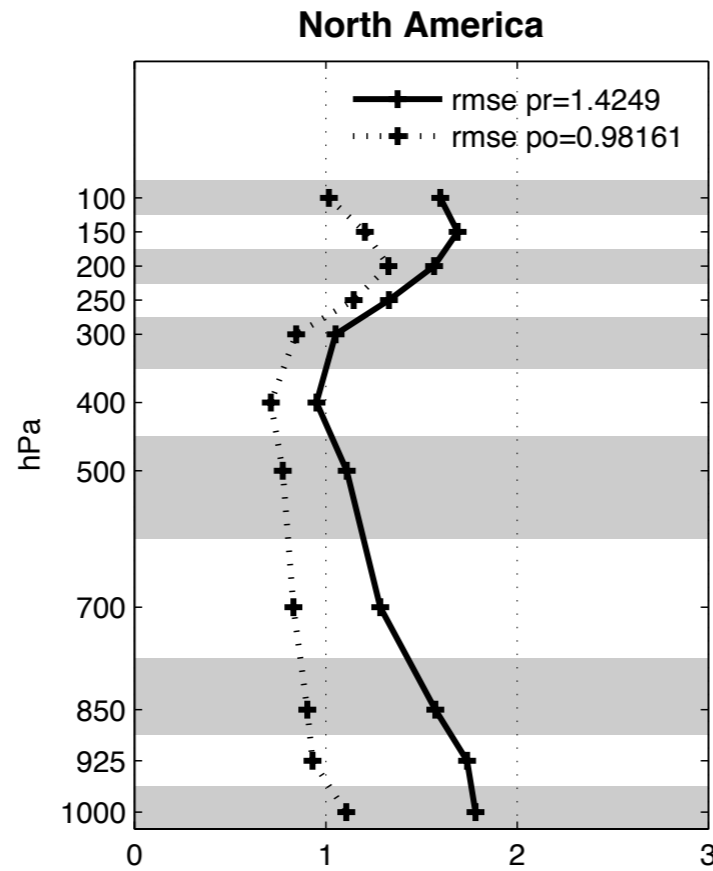### 6 November, 0UT

10 November, 0UT

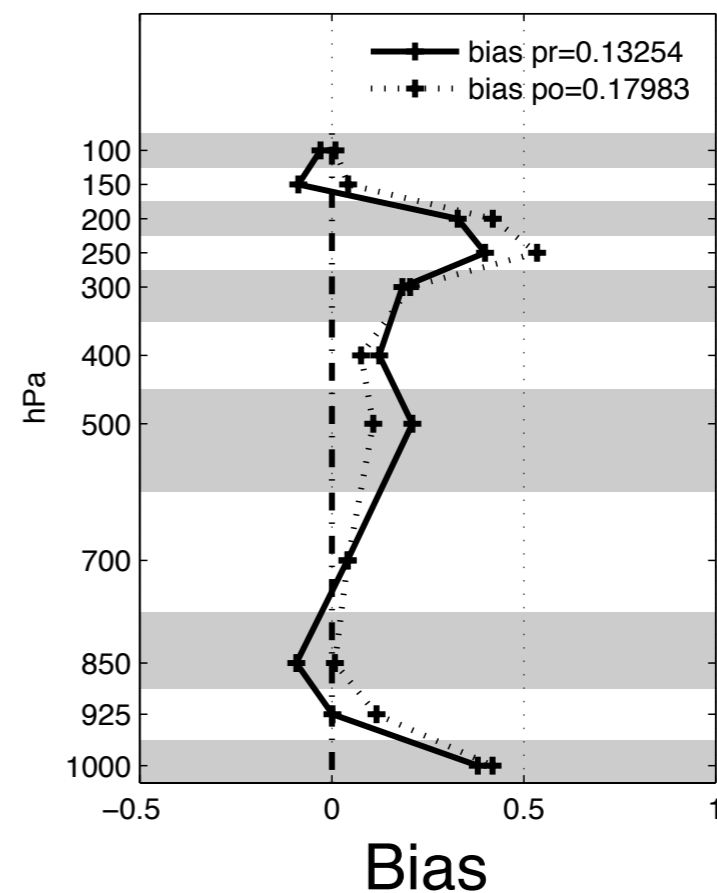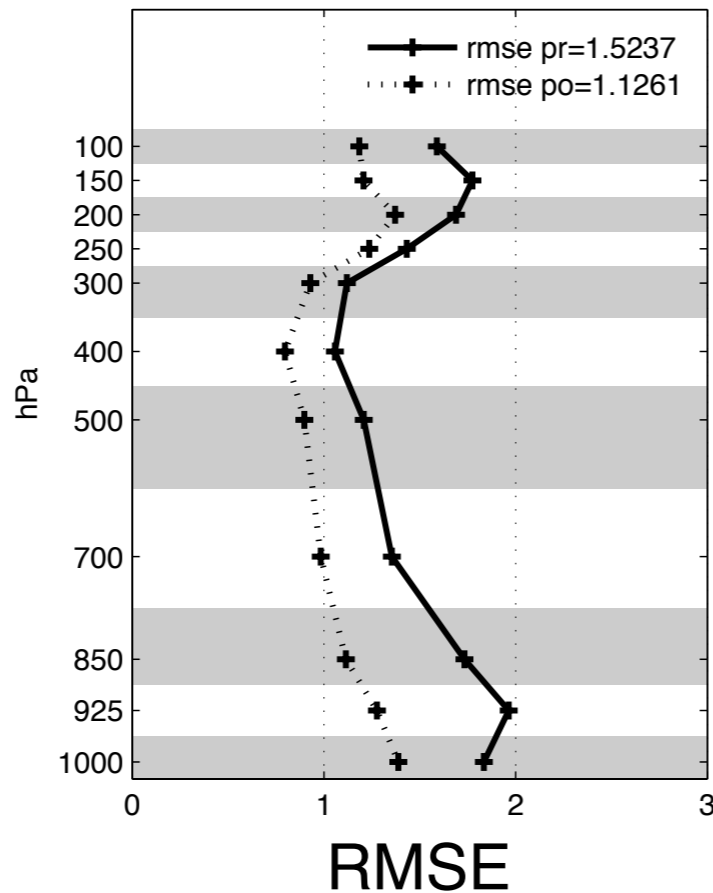Region with no SABER observations

Outline

- Motivation

- Data Assimilation and Research Testbed (DART)

- **Results:**

  - Synthetic Observation Case

  - **Real Observation Case**

- Summary and Conclusions

HA●

RMSE and bias relative to radiosonde observations
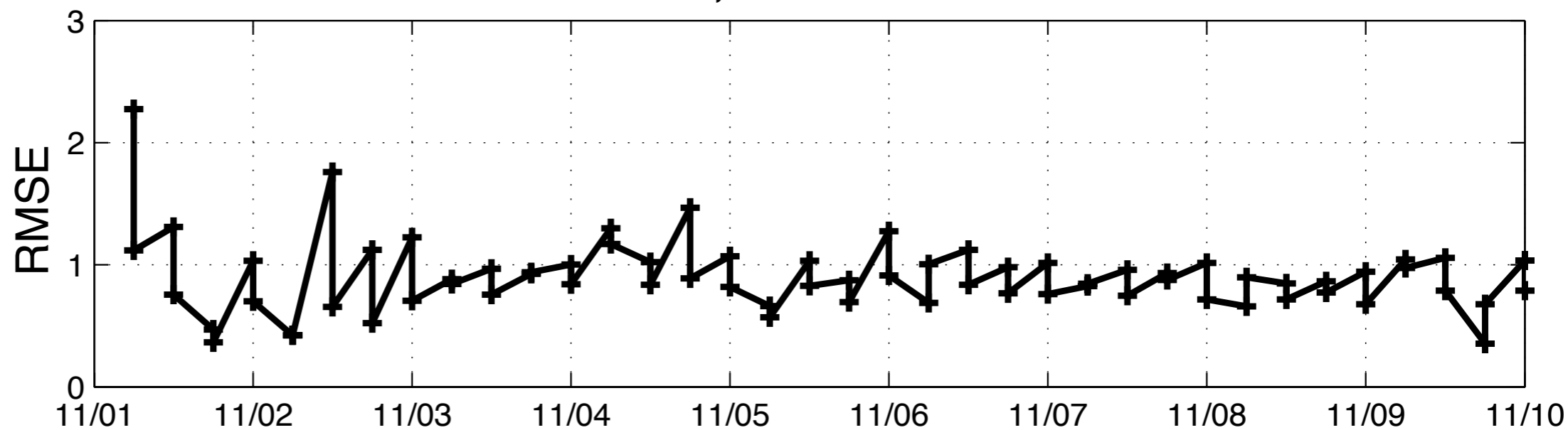

CAM
80 member ens.
Results from K. Raeder

WACCM
40 member ens.

North America

rmse pr=1.4249

North America

bias pr=0.14679

rmse pr=1.5237
rmse po=1.1261

bias pr=0.13254
bias po=0.17983
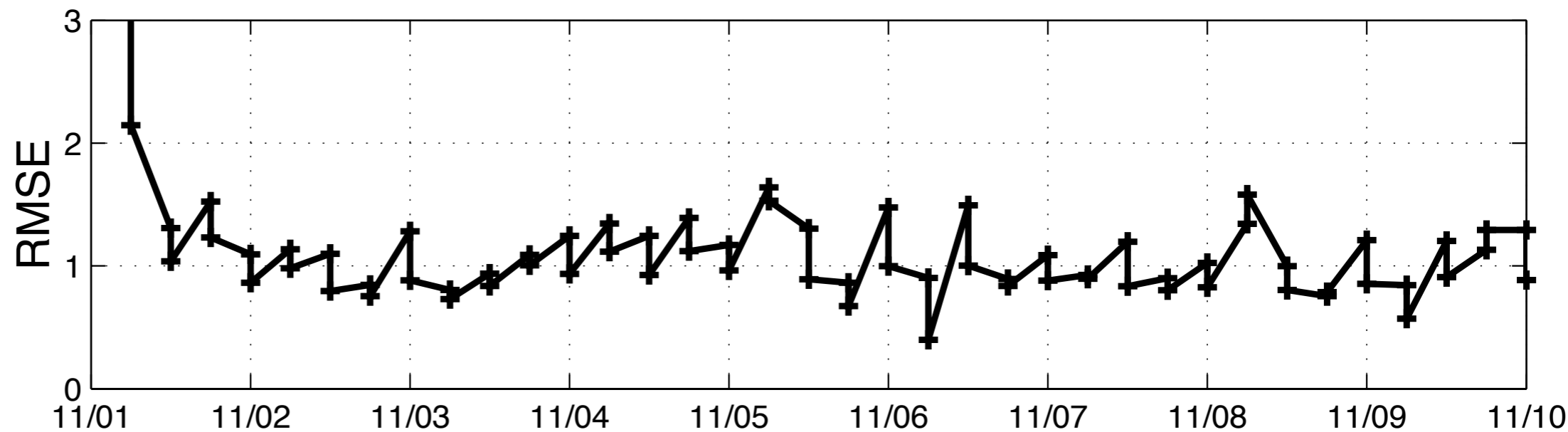
RMSE

Bias

HAO

RMSE relative to radiosonde observations

500hPa, North America

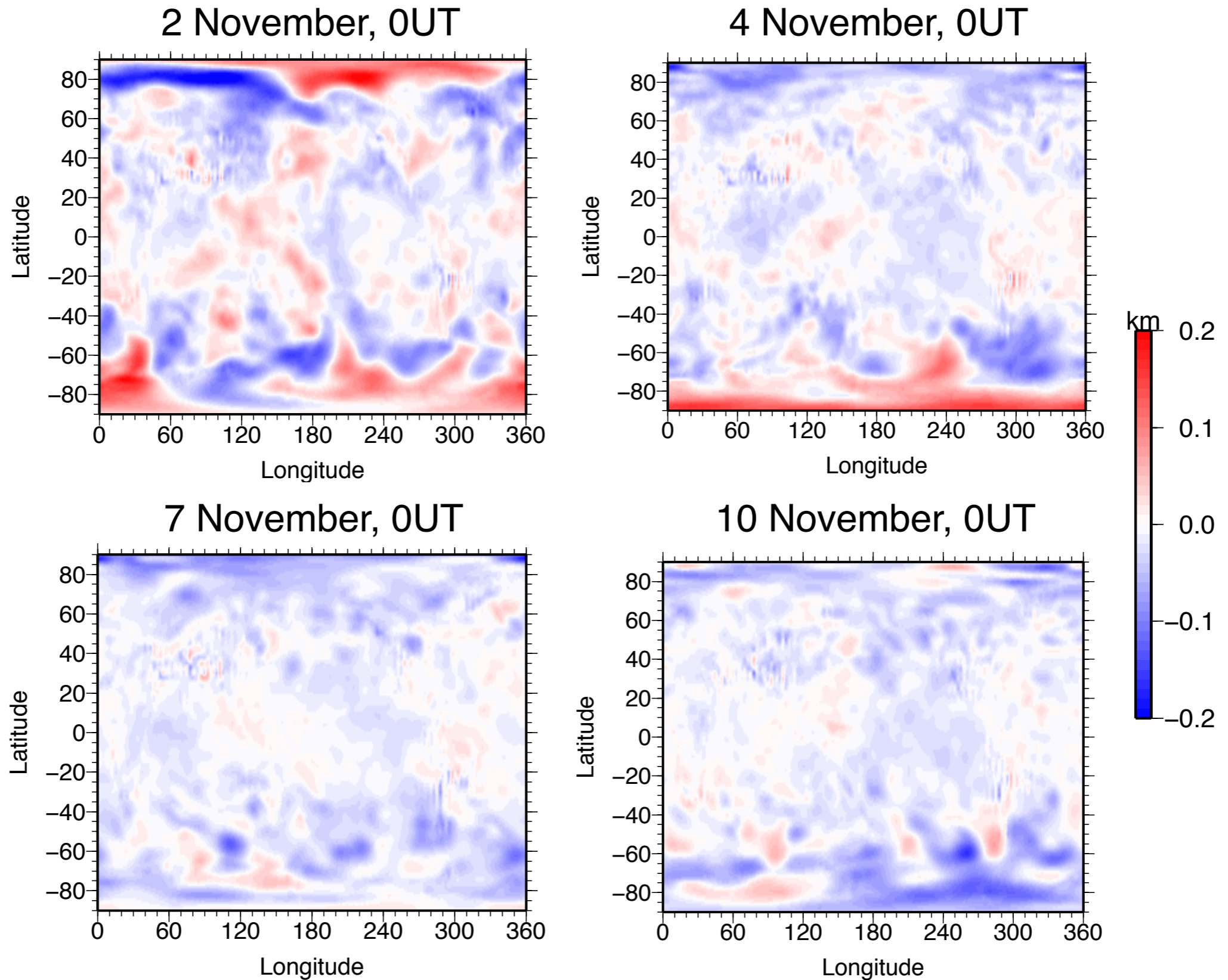CAM
80 member ens.
Results from K. Raeder

WACCM
40 member ens.

Error relative to NCEP 500hPa geopotential height

2 November, 0UT

4 November, 0UT

7 November, 0UT

10 November, 0UT

Summary and Conclusions

- The DART has been used to add the capability of data assimilation to the WACCM.

- Currently can assimilate a full set of lower atmosphere observations and middle/upper atmosphere temperature from SABER.

- Preliminary results demonstrate the potential of the data assimilation in the WACCM, and future studies are planned.

- WACCM will hopefully become part of the DART standard release, providing anyone interested the option to perform data assimilation.