

# Applying the Local Ensemble Transform Kalman Filter to the non-hydrostatic atmospheric model NICAM

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RIKEN, Advanced Institute for Computational Science

Data assimilation seminar on 25th June, 2015.

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# Outlines

1. Developing two NICAM－LETKF systems (with Sawada-san)
   - Use the original LETKF code (**LL-LETKF**)
     (with interpolation between icosahedral and lat-lon grids)
   - Direct I/O of icosahedral grid (**ICO-LETKF**)
   - 3D-LETKF
   - Observation search algorithm
   - Observation operator for assimilating conventional observations

2. Extending initial version to 4D-LETKF

3. Assimilating satellite observations (AMSU-A)
   - Observation operator using RTTOV
   - Bias correction



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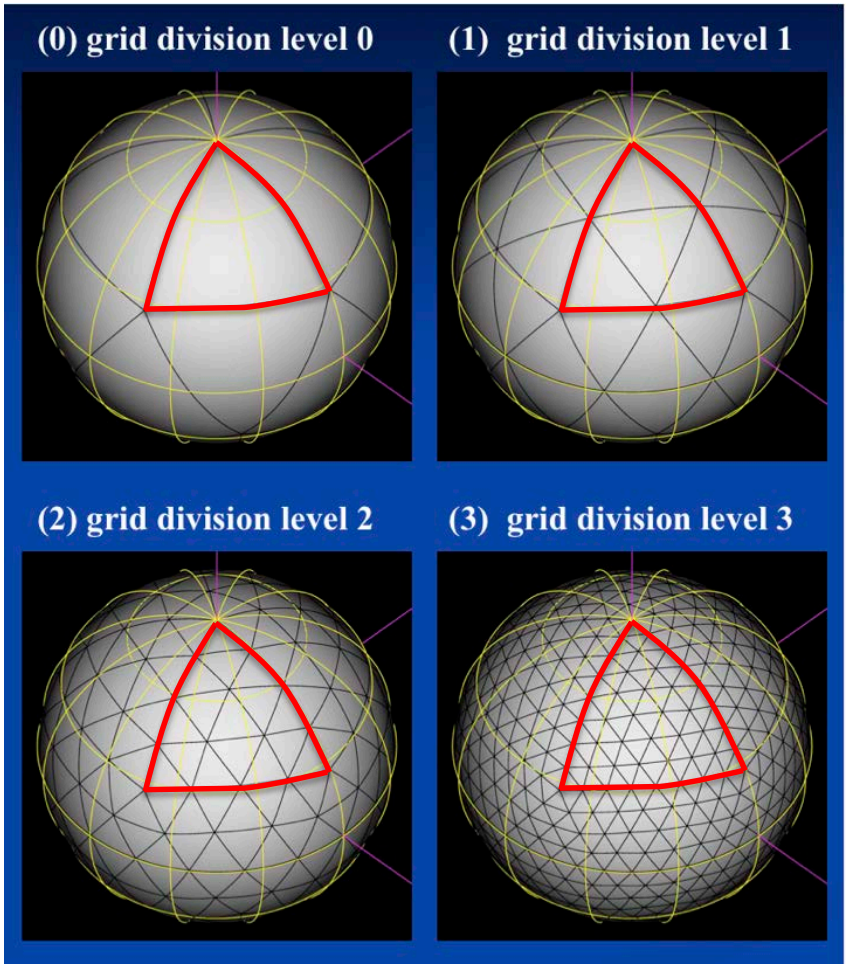
# NICAM: Icosahedral grid arrangements

Grid division level 0 is the original Icosahedron.

The horizontal resolution can be increased by splitting one triangle into four triangles.

| Grid division level | Horizontal resolution |
|---|---|
| 6 | 112 km |
| 7 | 56 km |
| 8 | 28 km |
| 9 | 14 km |
| 10 | 7 km |
| 11 | 3.5 km |
| 12 | 1.7 km |
| 13 | 0.87 km |



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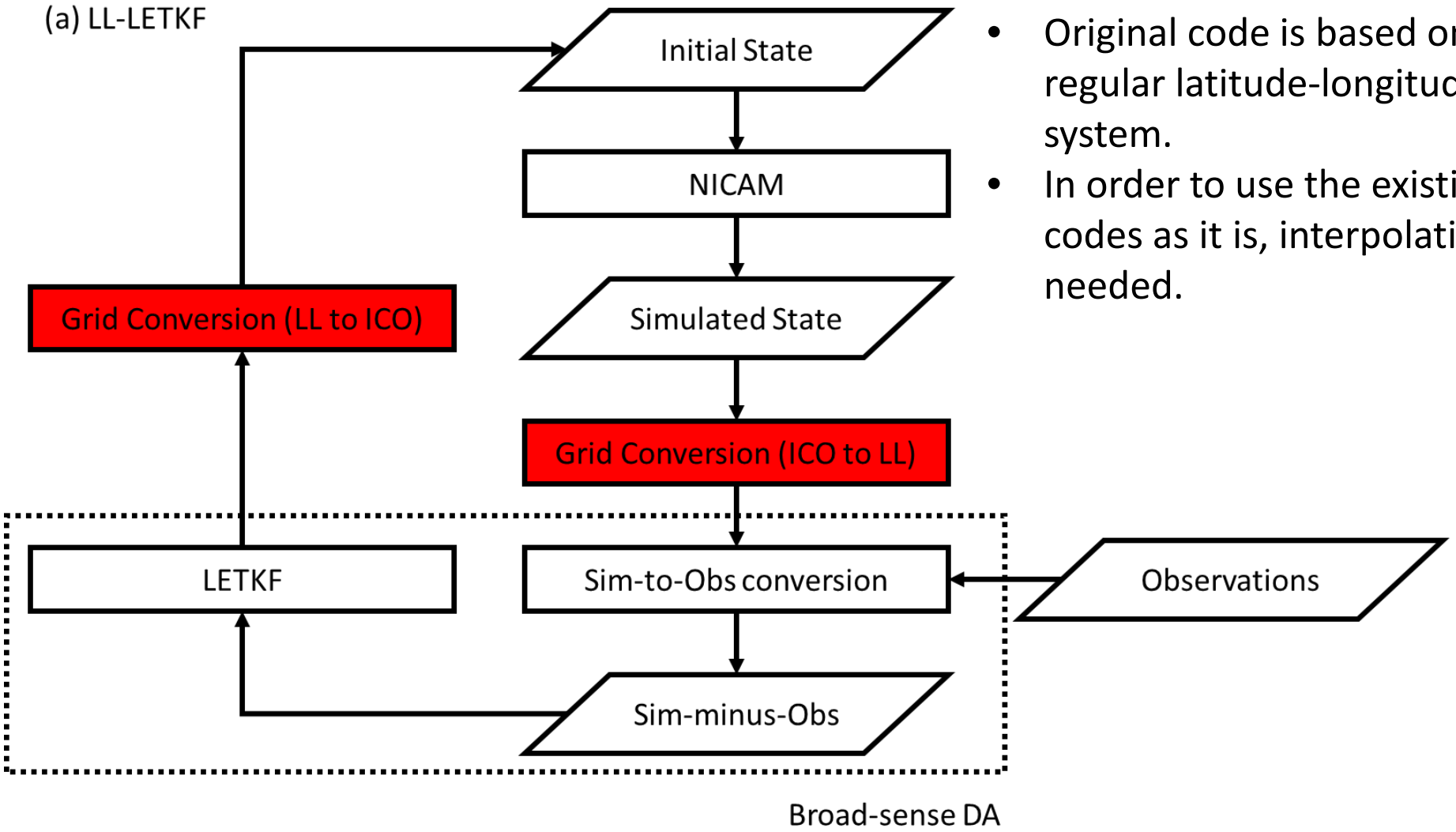
# Flow chart (LL-LETKF)




- Original code is based on the regular latitude-longitude grid system.
- In order to use the existing codes as it is, interpolation is needed.



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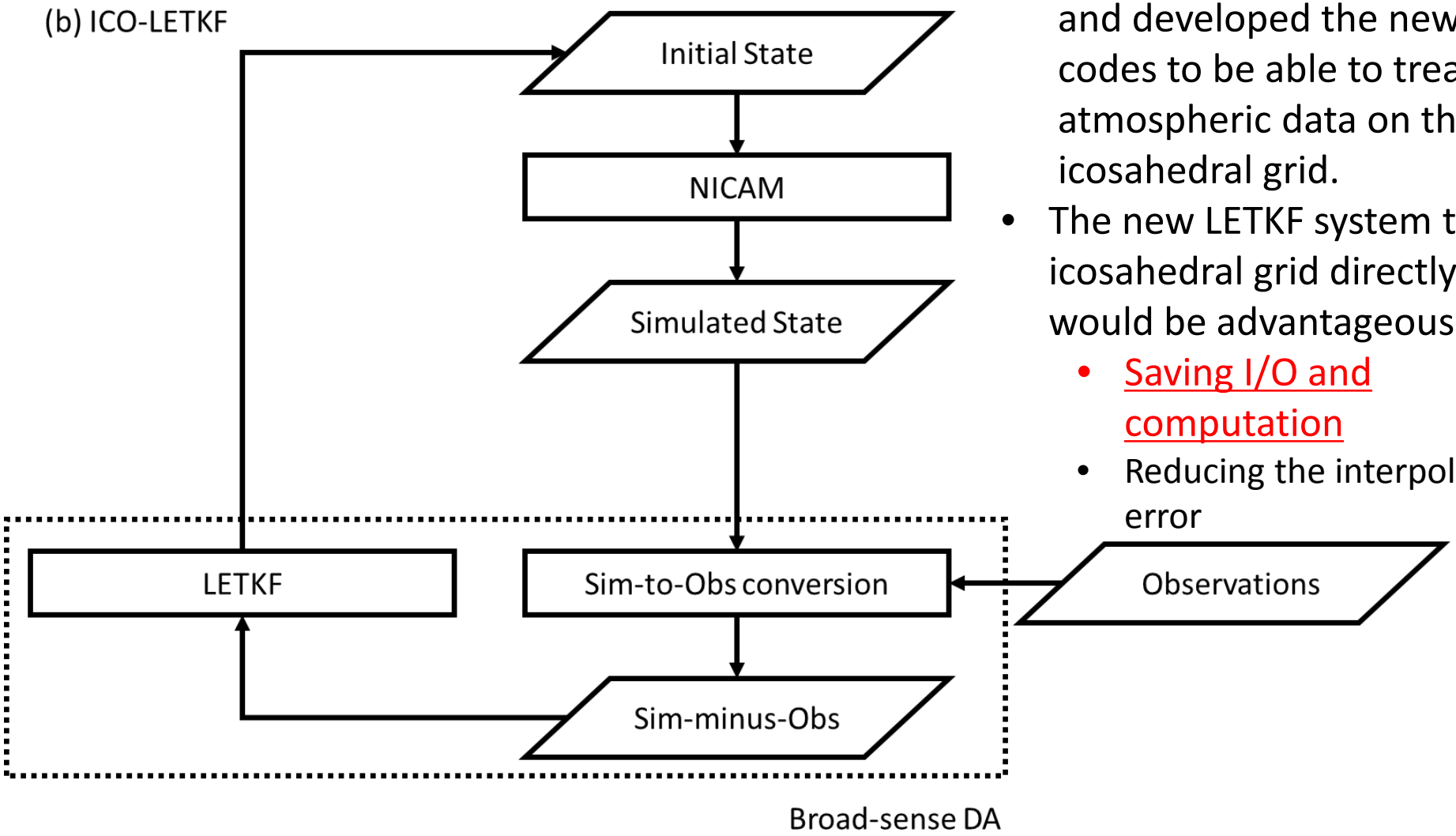
# Flow chart (ICO-LETKF)




- In new system, we modified and developed the new LETKF codes to be able to treat the atmospheric data on the icosahedral grid.
- The new LETKF system treats icosahedral grid directly and would be advantageous in
  - Saving I/O and computation
  - Reducing the interpolation error



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# Observation search algorithm

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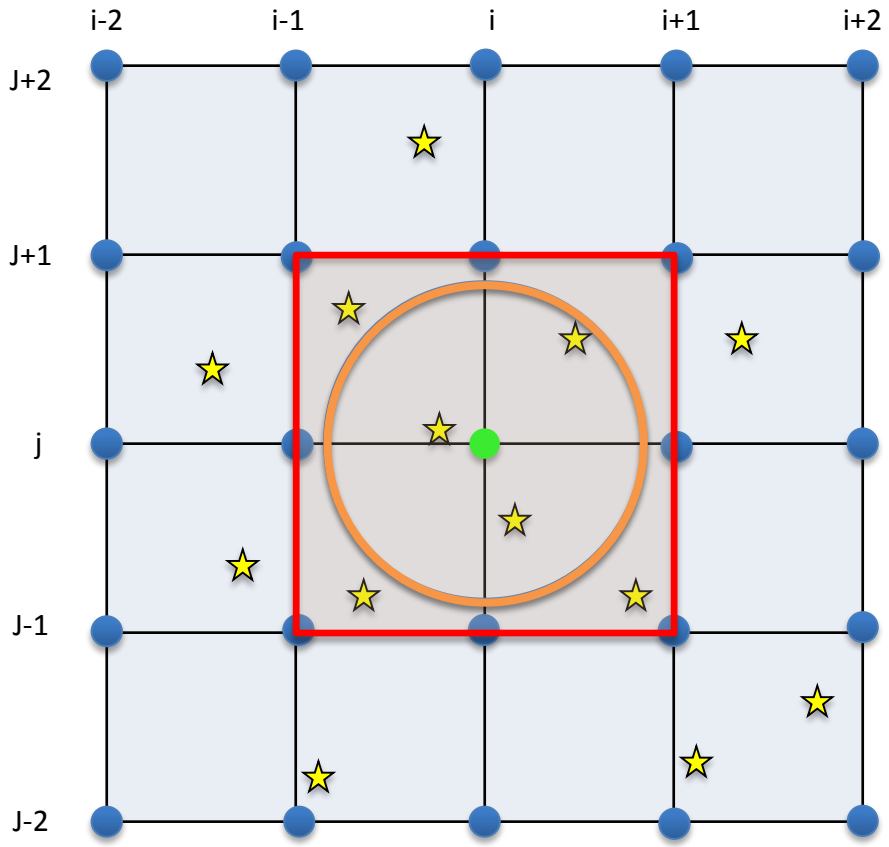
# Observation search algorithm

1. The original LETKF code has the nearest neighbor search based on the longitude-latitude grid.

2. Find the observations in the red box.

3. Calculate the distances between all observations in the red box and the model grid point.



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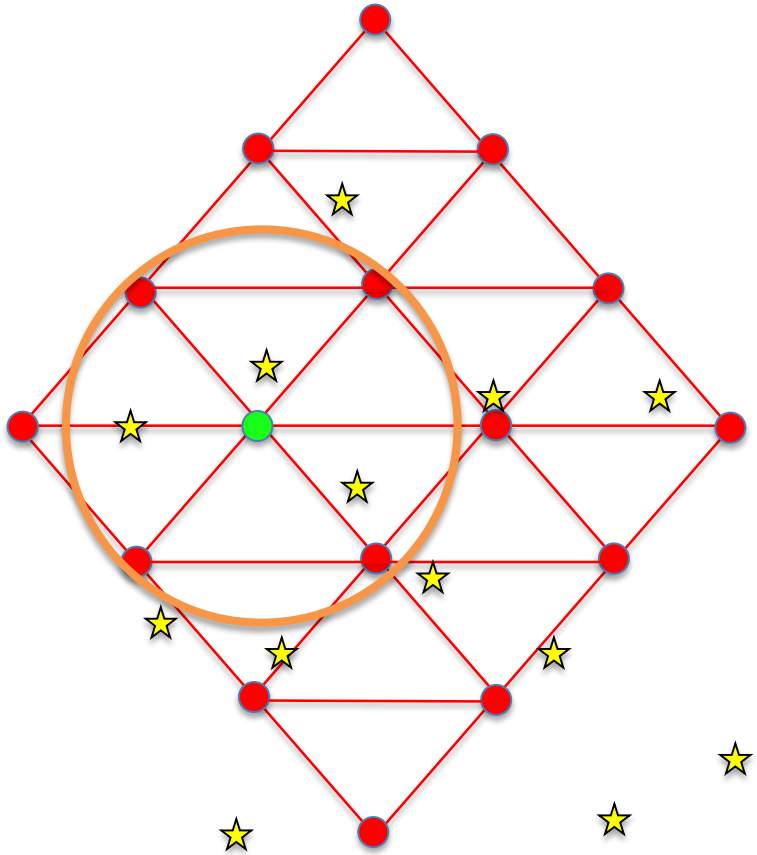
# Observation search in Icosahedral grid

We would like to take advantage of the existing search algorithm in the icosahedral grid.



● : model grid of NICAM

★ : observation

○ : localization scale



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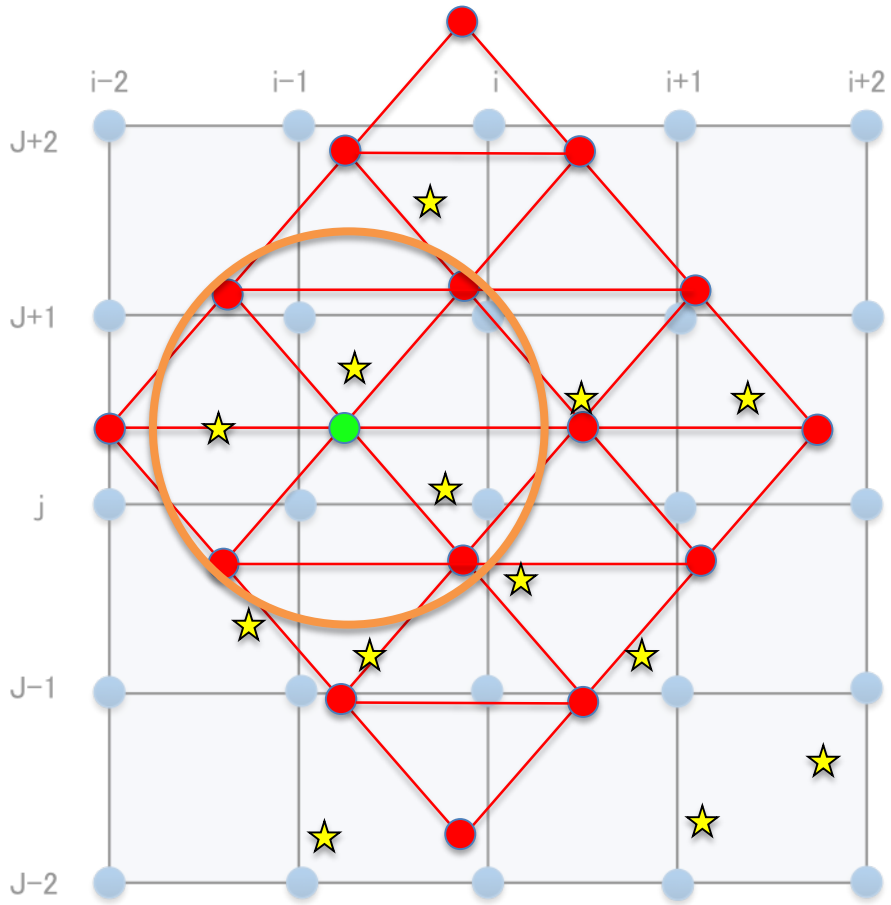
# Observation search in Icosahedral grid

We would like to take advantage of the existing search algorithm in the icosahedral grid.

Use the latitude-longitude grid for the observation search



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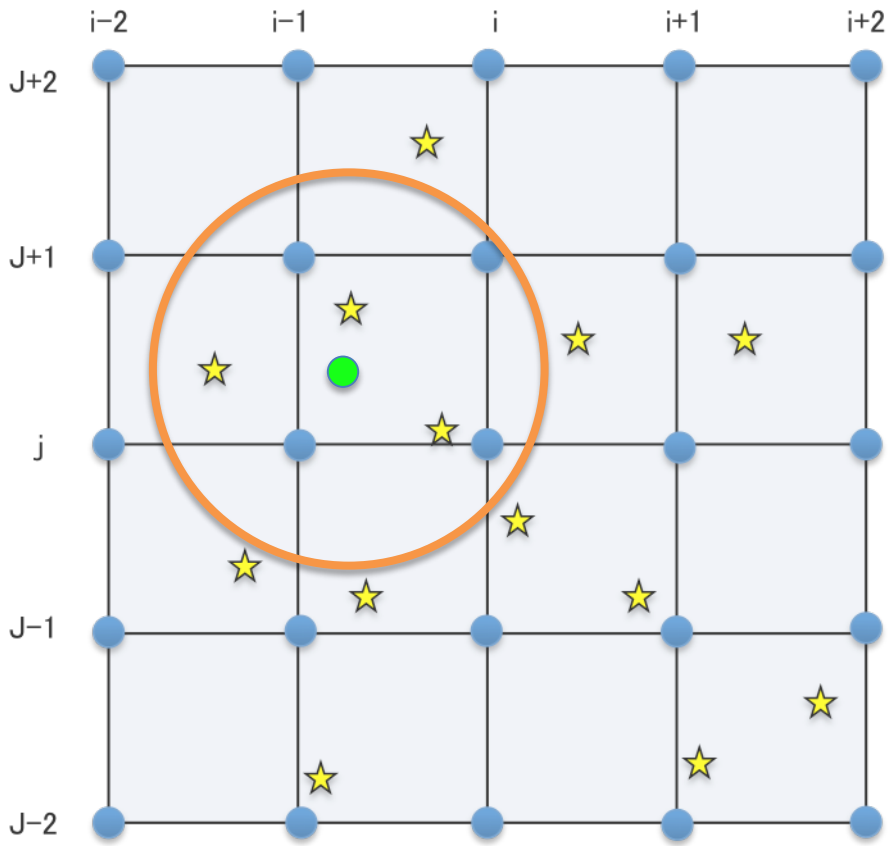




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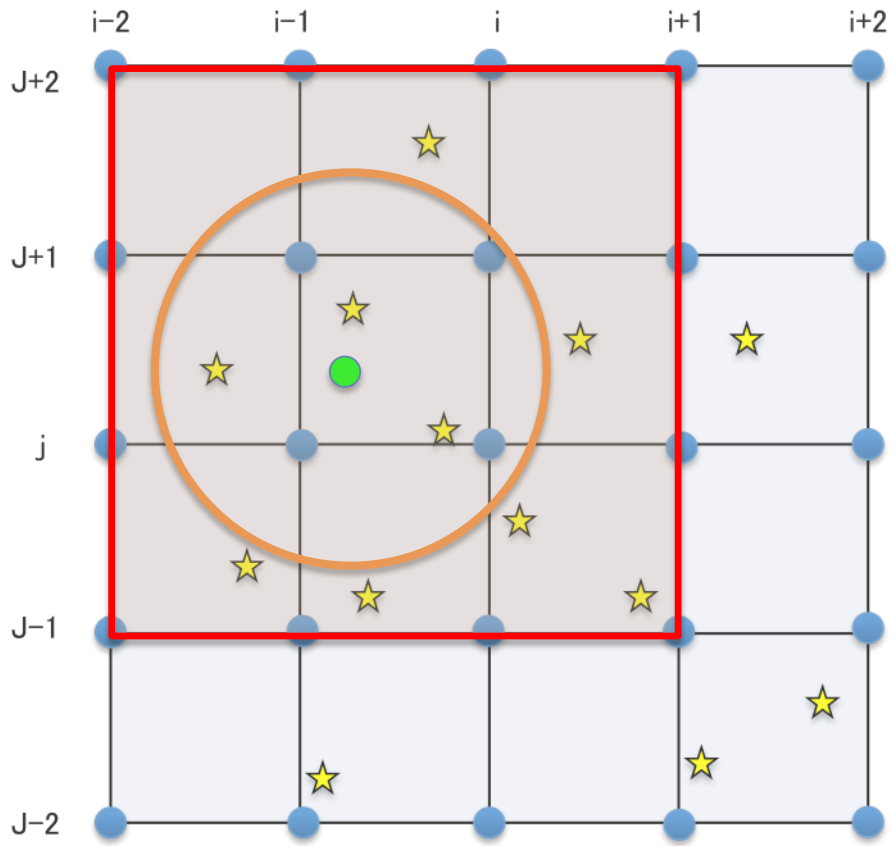
# Observation search in Icosahedral grid

We would like to take advantage of the existing search algorithm in the icosahedral grid.

Use the latitude-longitude grid for the observation search

Calculate the distances between all observations and the model grid point



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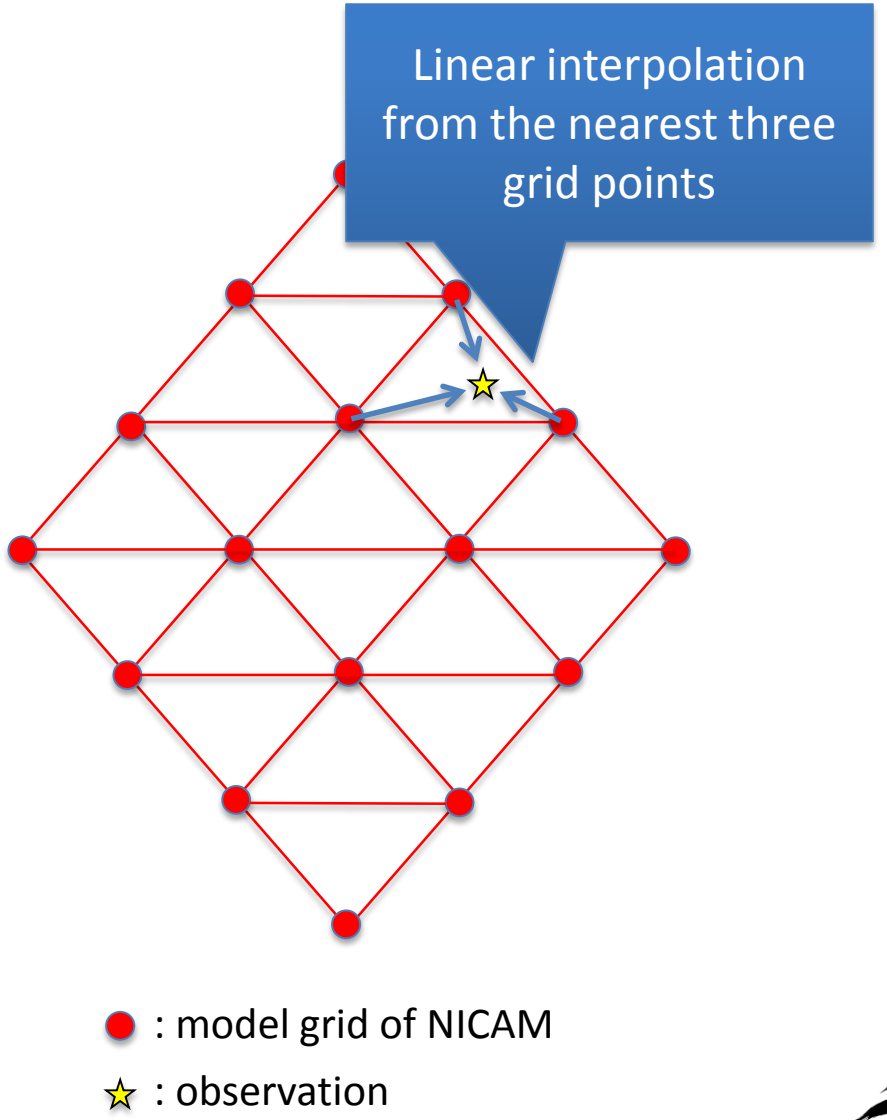
   - Observation operator for assimilating conventional observations
2. Extending initial version to 4D-LETKF
3. Assimilating satellite observations (AMSU-A)
   - Observation operator using RTTOV
   - Bias correction

# Observation operator

1. Spatial interpolation
   - Observation is not located at the same place of the model
   - NICAM has a tool to interpolate from a model grid point to an arbitrary grid point
2. Variable conversion
   - Observed variable is not always same with model variable

$$\mathbf{y} - \mathbf{H}\mathbf{x}_f$$

$\mathbf{y}$: Observation
$\mathbf{H}$: Observation operator
$\mathbf{x}_f$: forecast



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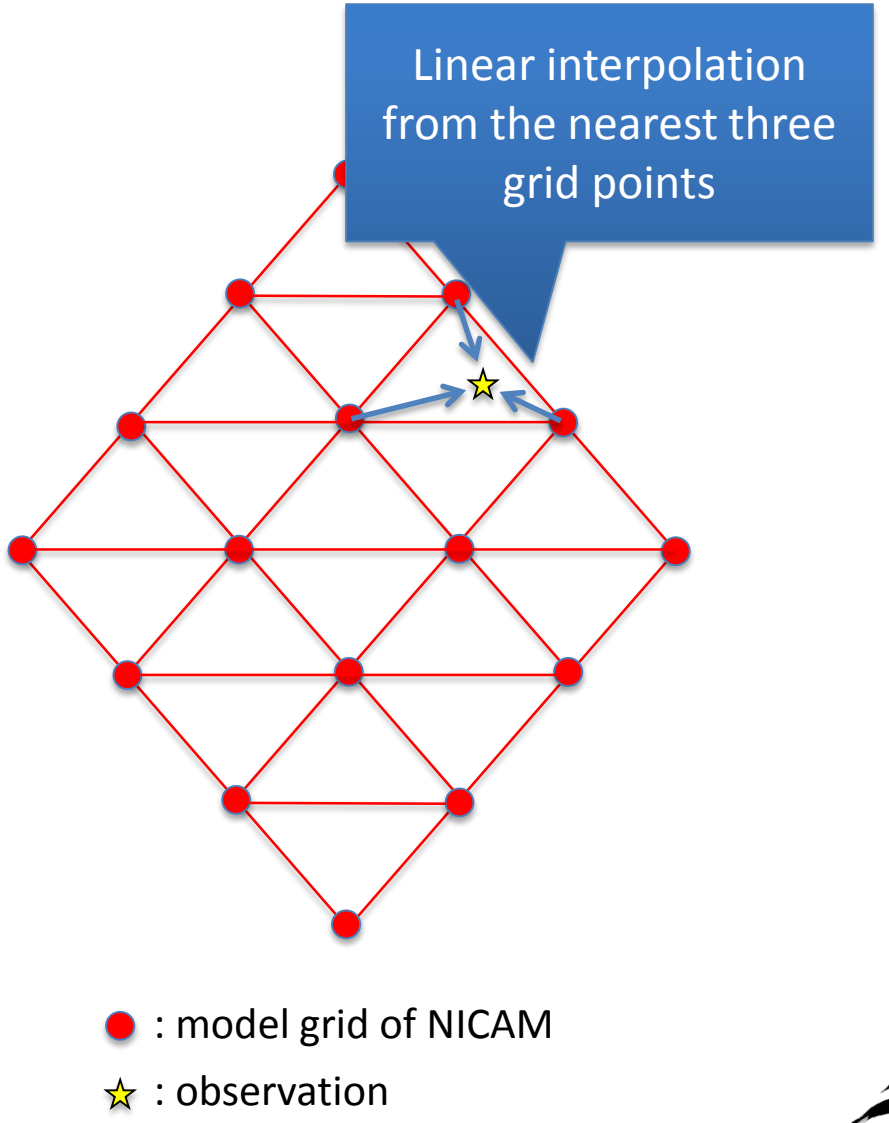
# Observation operator

- NICAM has a tool to compute coefficients to interpolate from icosahedral grid to an arbitrary location (an observation in this case).



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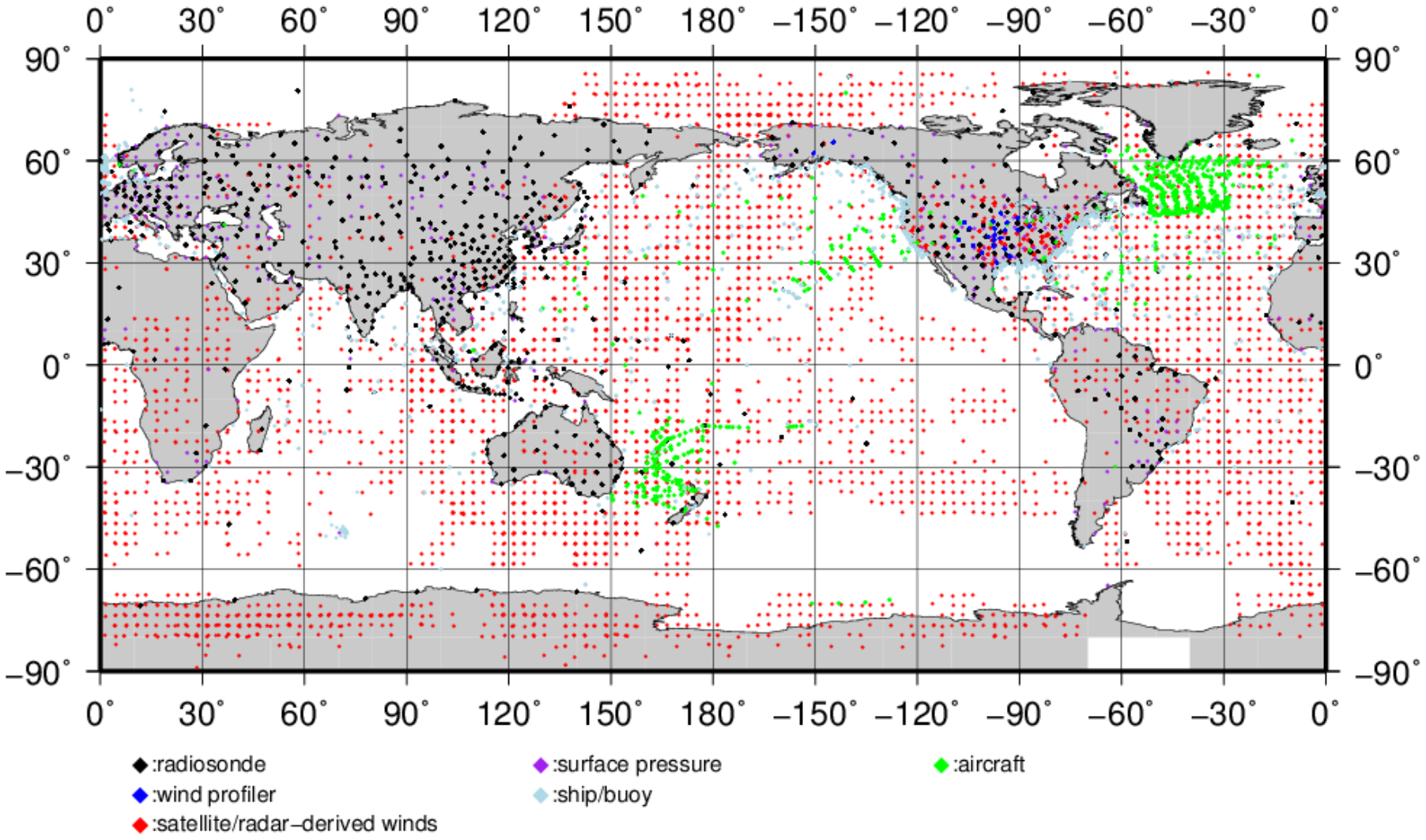
# Conventional observations

6 hourly observation



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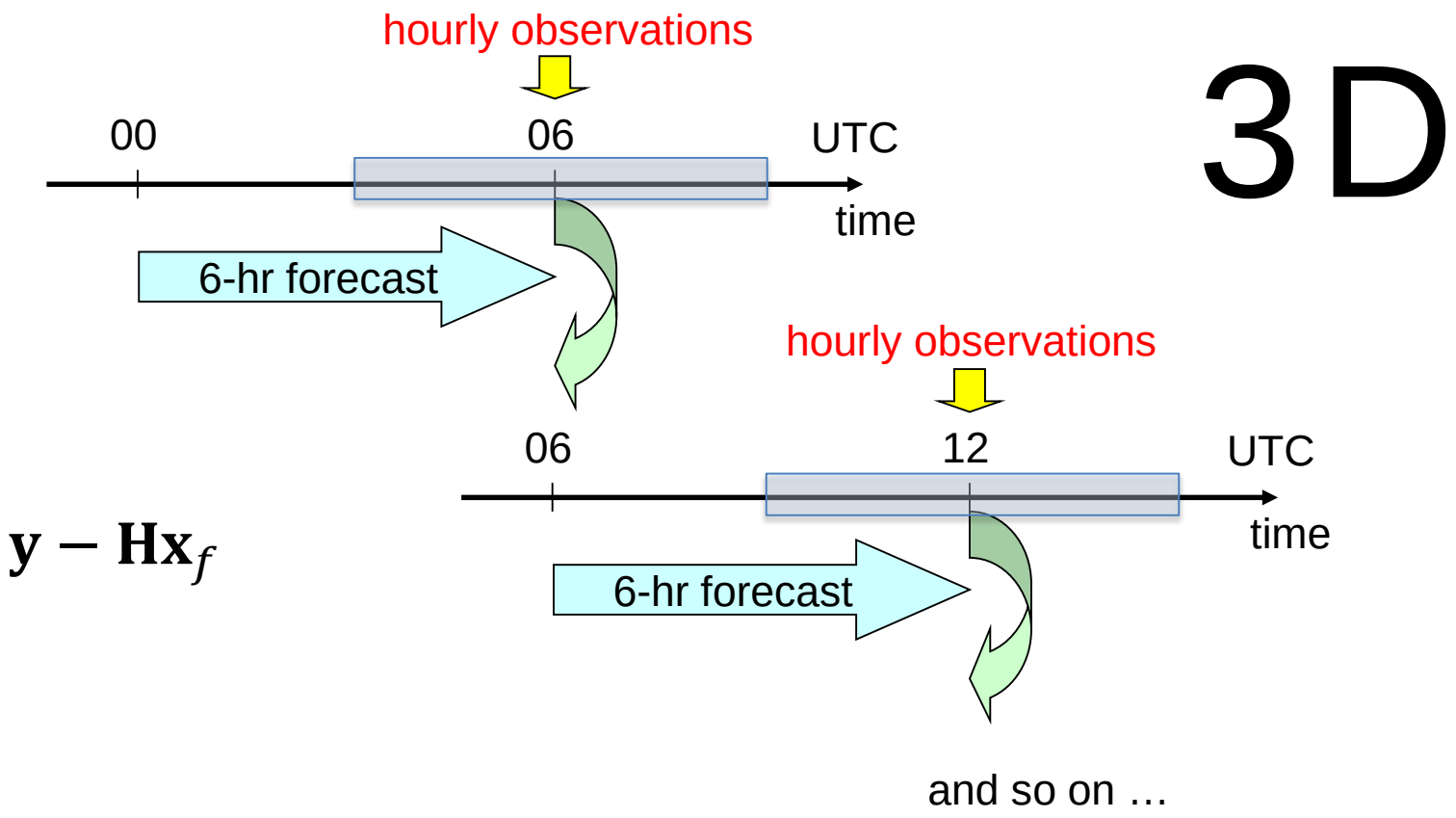
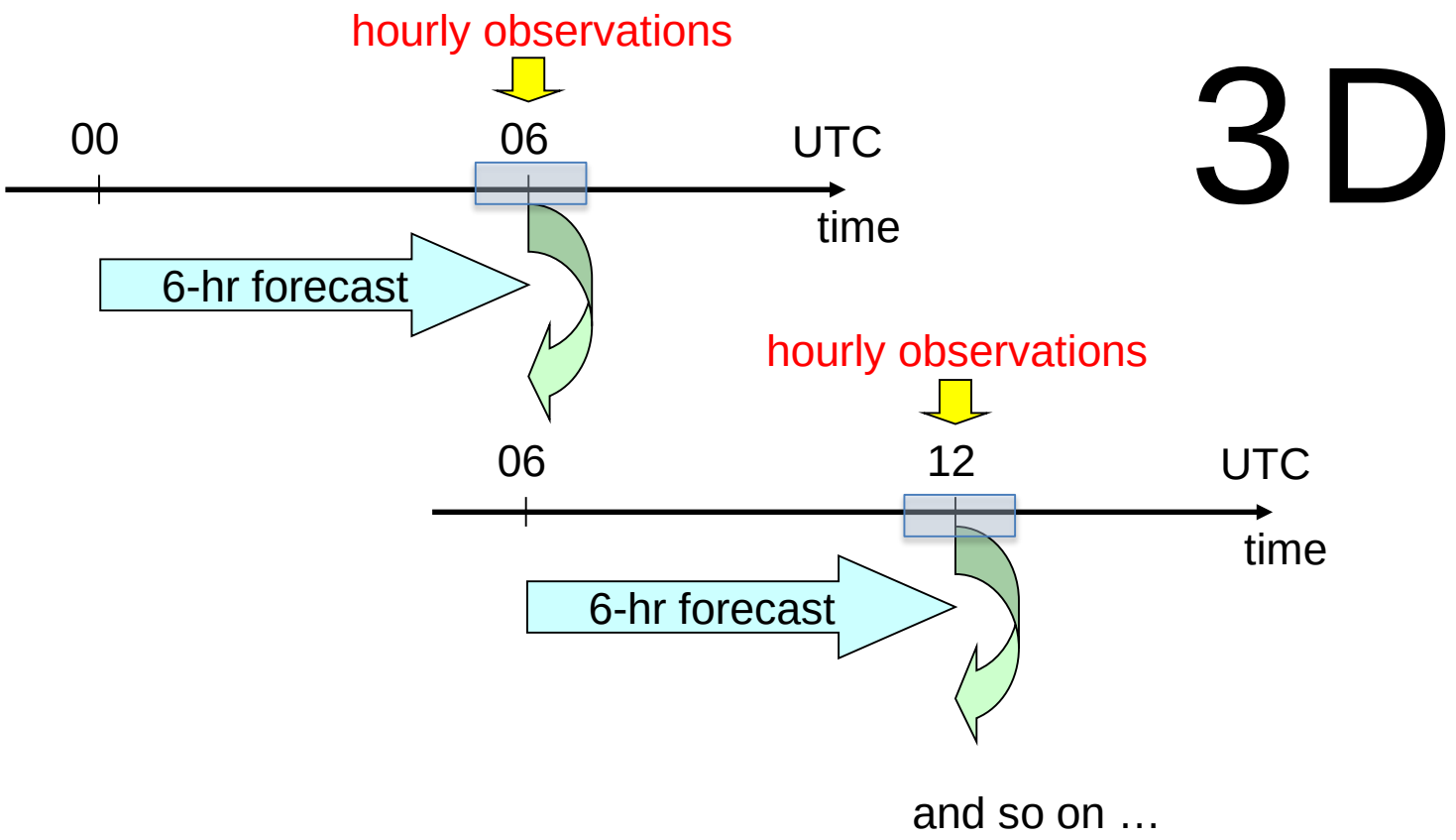
# 3D LETKF




$\mathbf{y} - \mathbf{H}\mathbf{x}_f$

Usually observation data within a 6-hour window from 3 hours before to 3 hours after the analysis time are assimilated.

# 3D LETKF

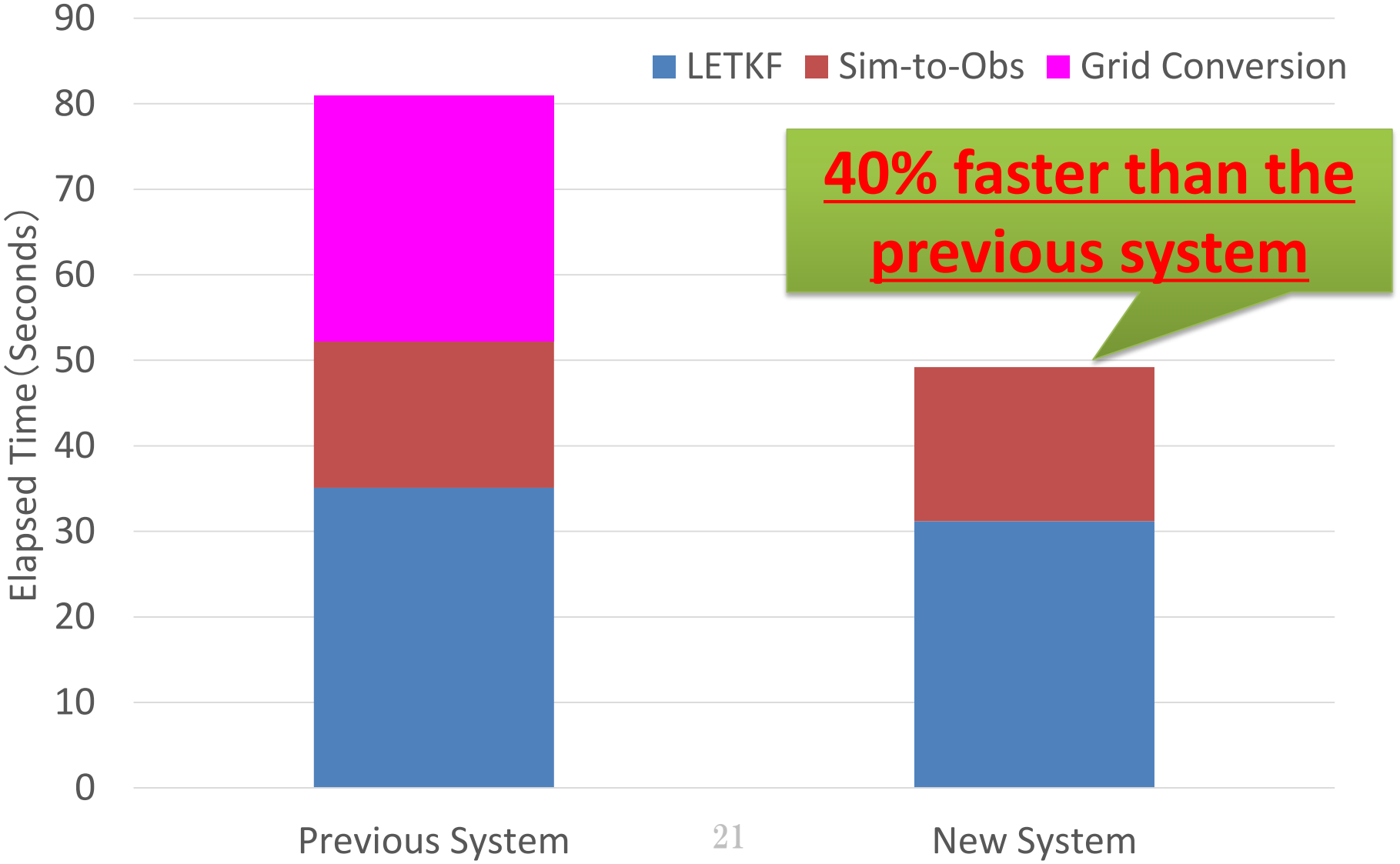



In this study, Observation data within a 1-hour window from 30 minutes before to 30 minutes after the analysis time are assimilated.

# Computation Time

200 nodes of K computer (1600 CPU cores)
Ensemble size is **20**

Assimilating NCEP PREPBUFR



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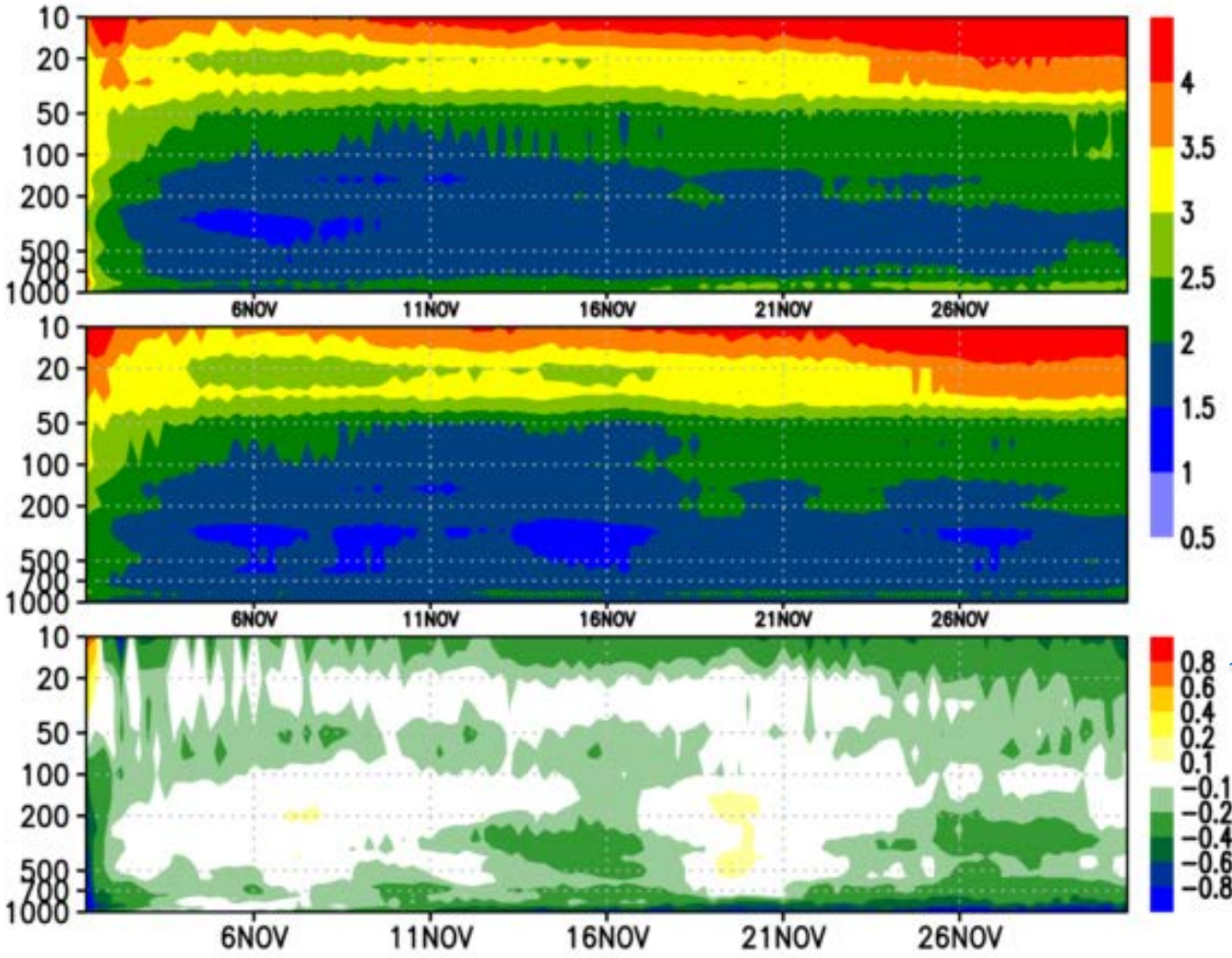
# RMSD in Air temperature vs. ERA-Interim

06 UTC 1 NOV → Assimilating NCEP PREPBUFR → 00 UTC 30 NOV

LL-LETKF

ICO-LETKF

Difference




New system is worse

New system is better



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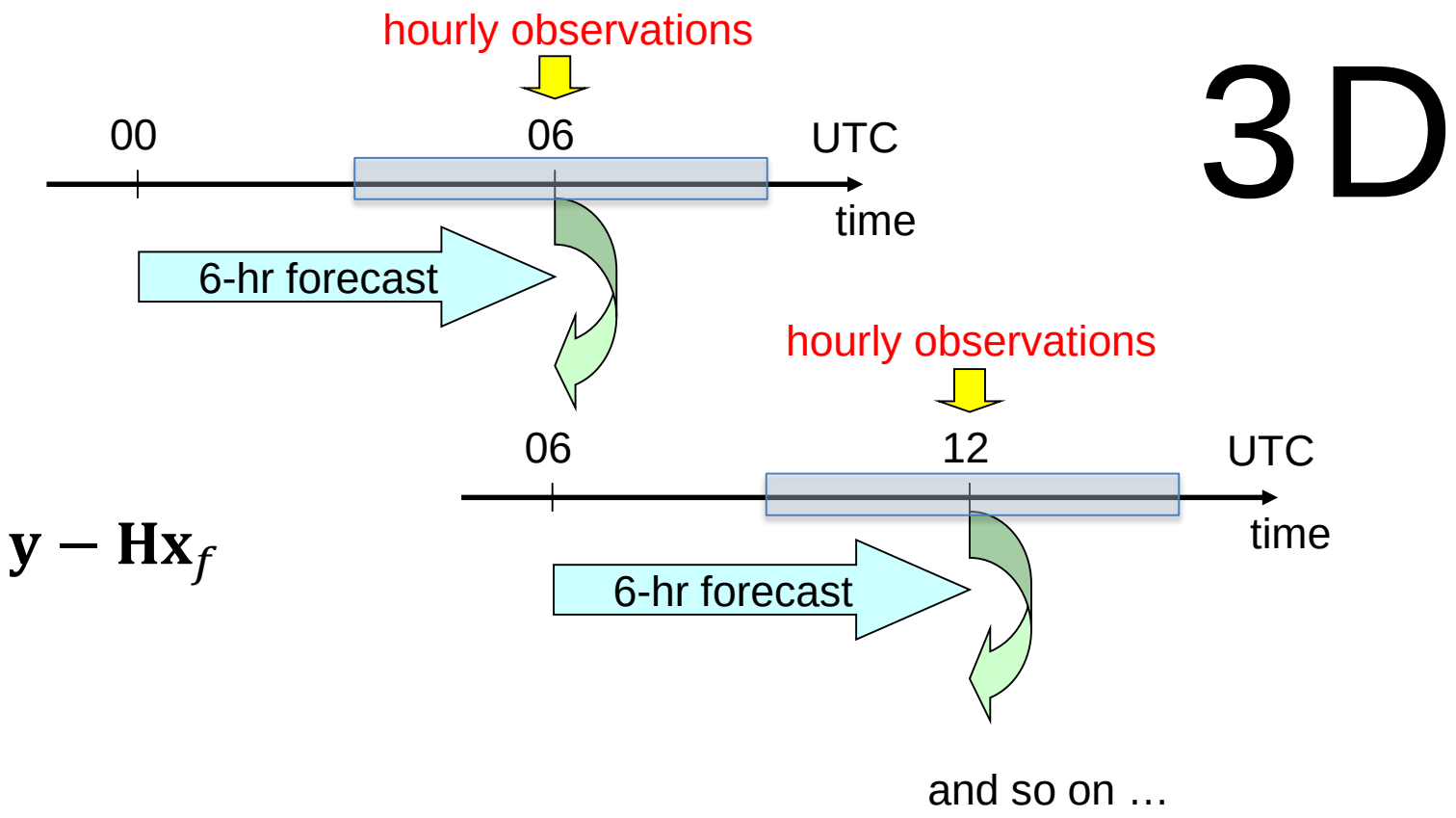
# 3D and 4D LETKF

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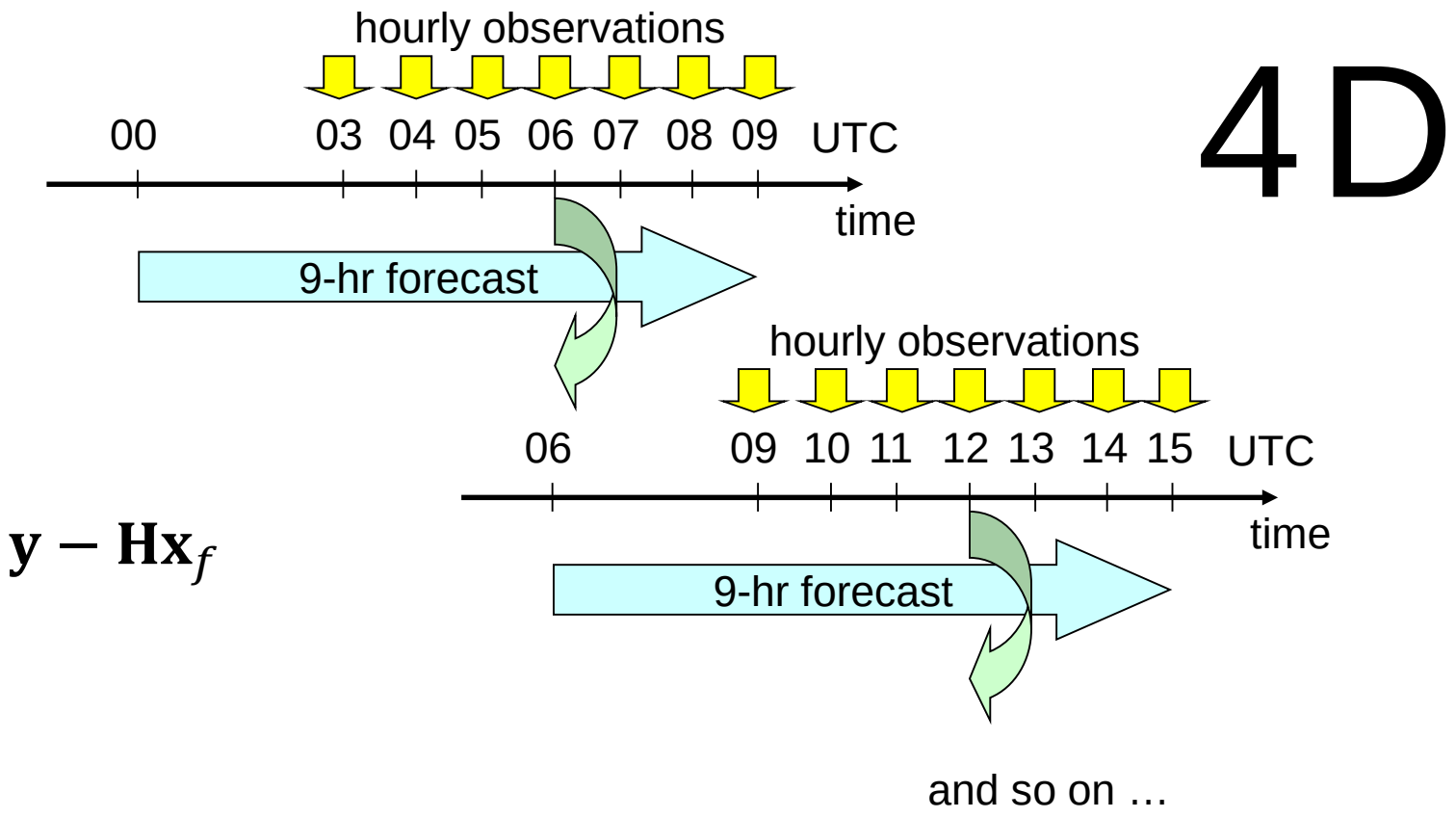
# 3D and 4D LETKF




4D

$\mathbf{y} - \mathbf{H}\mathbf{x}_f$

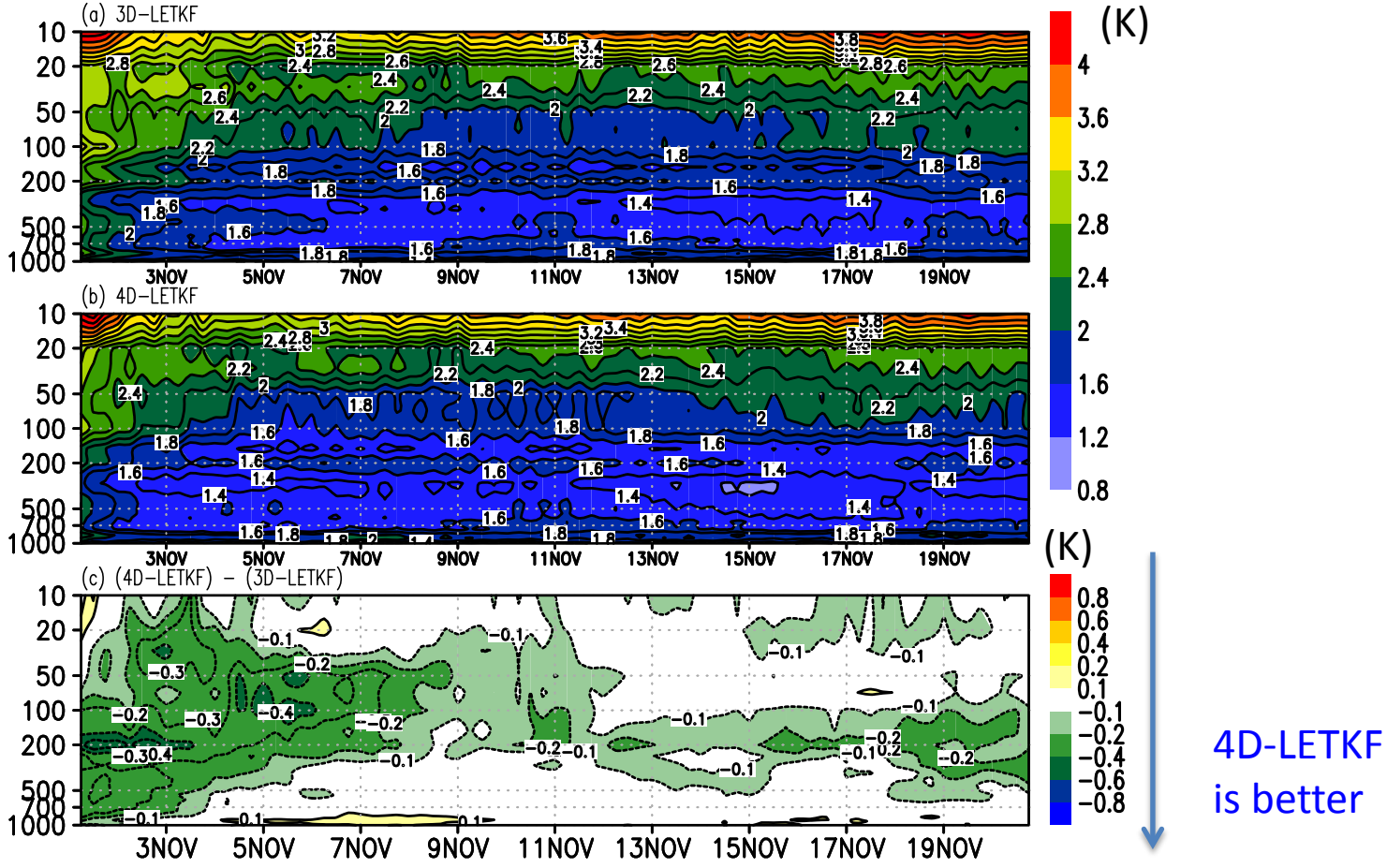
This is essential in treating asynchronous data (e.g., satellites)

# Global RMSD for temperature (vs. ERA-interim)

3D-LETKF

4D-LETKF

Difference




4D-LETKF is better

- 4D-LETKF shows faster convergence than 3D-LETKF.
- Assimilating asynoptic observations improve the analysis fields especially around the tropopause.



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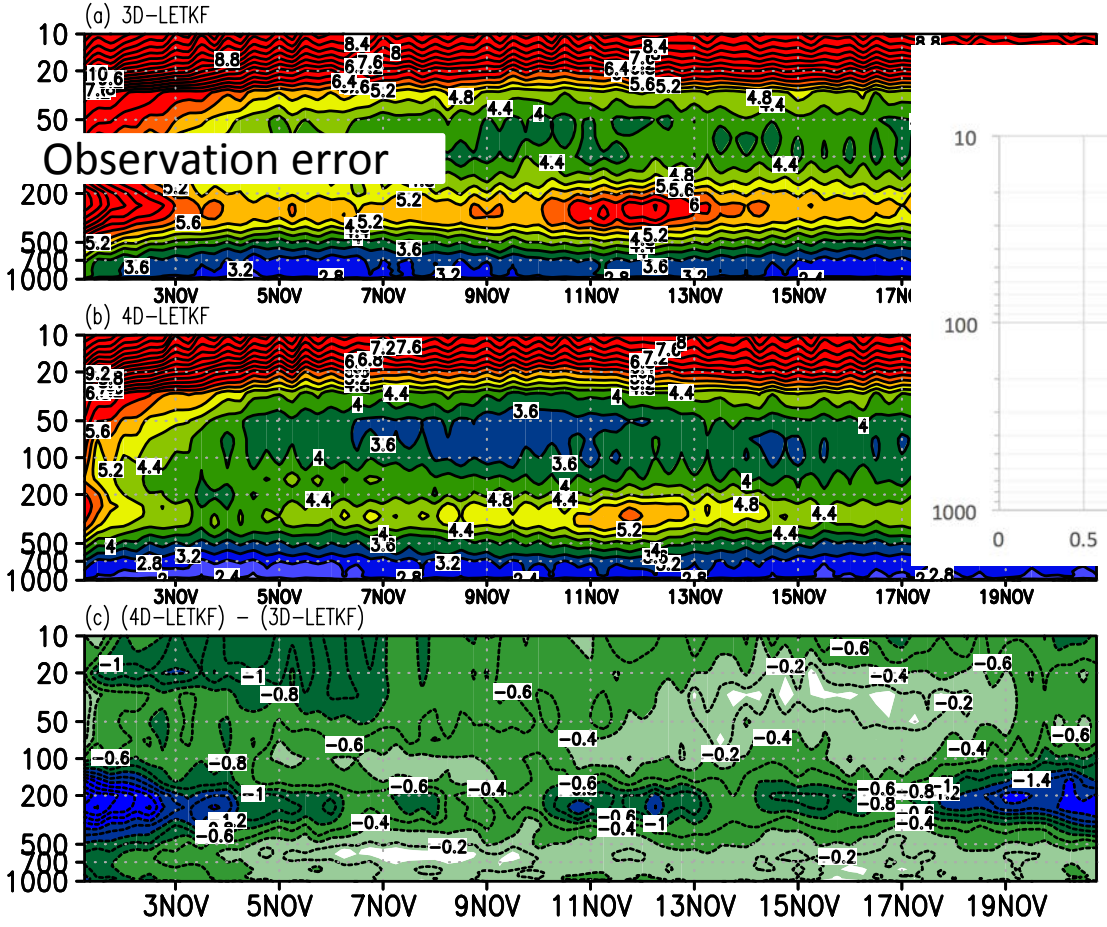
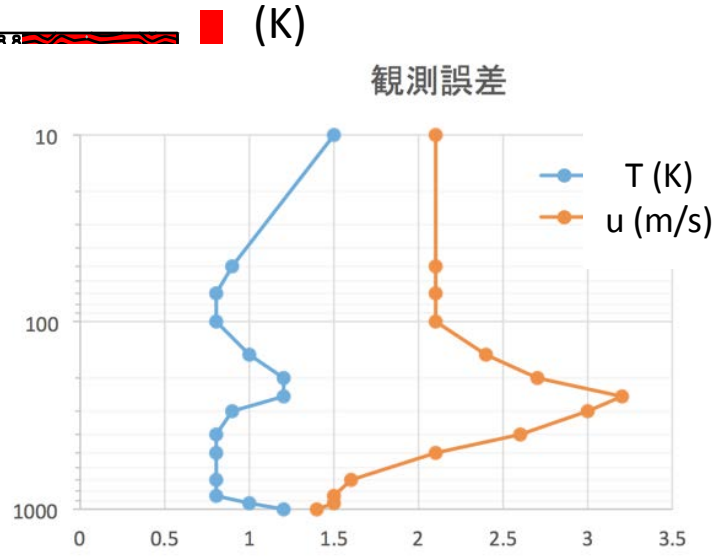
# Global RMSD for zonal wind (vs. ERA-interim)

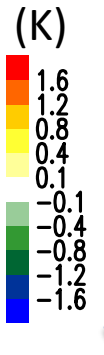
3D-LETKF

4D-LETKF

Difference




4D-LETKF is better

- 4D-LETKF outperformed 3D-LETKF at all vertical levels, especially around the tropopause.
- Analysis is inaccurate around the tropopause.



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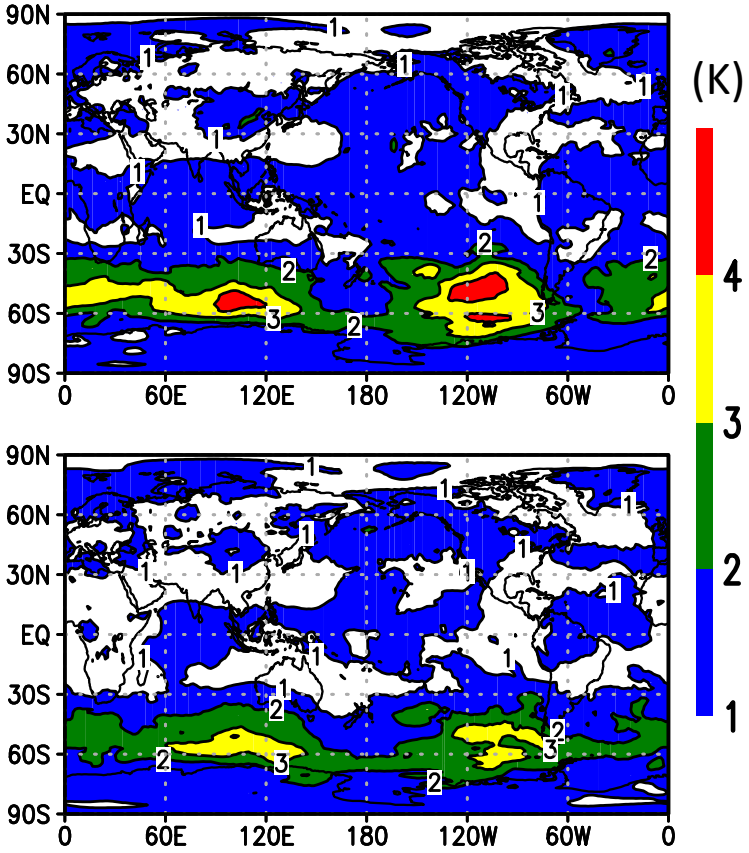
# Analysis Error of 200 hPa T (K)

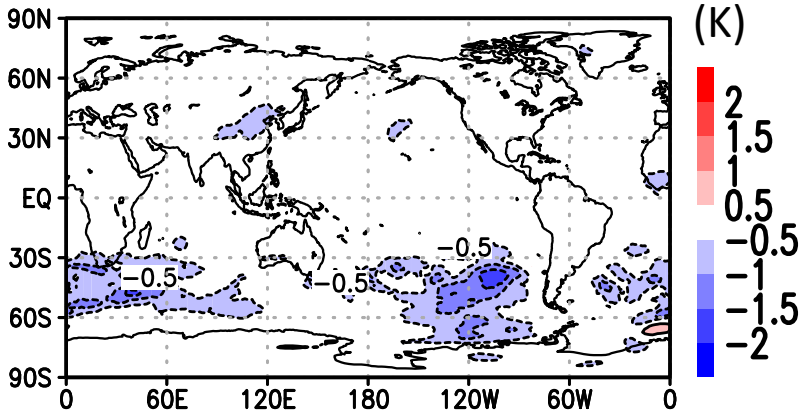
Mean absolute difference from ERA-interim
20 days average

3D-LETKF

4D-LETKF




Difference




- Analysis field is greatly improved in the Southern Hemisphere over the ocean.



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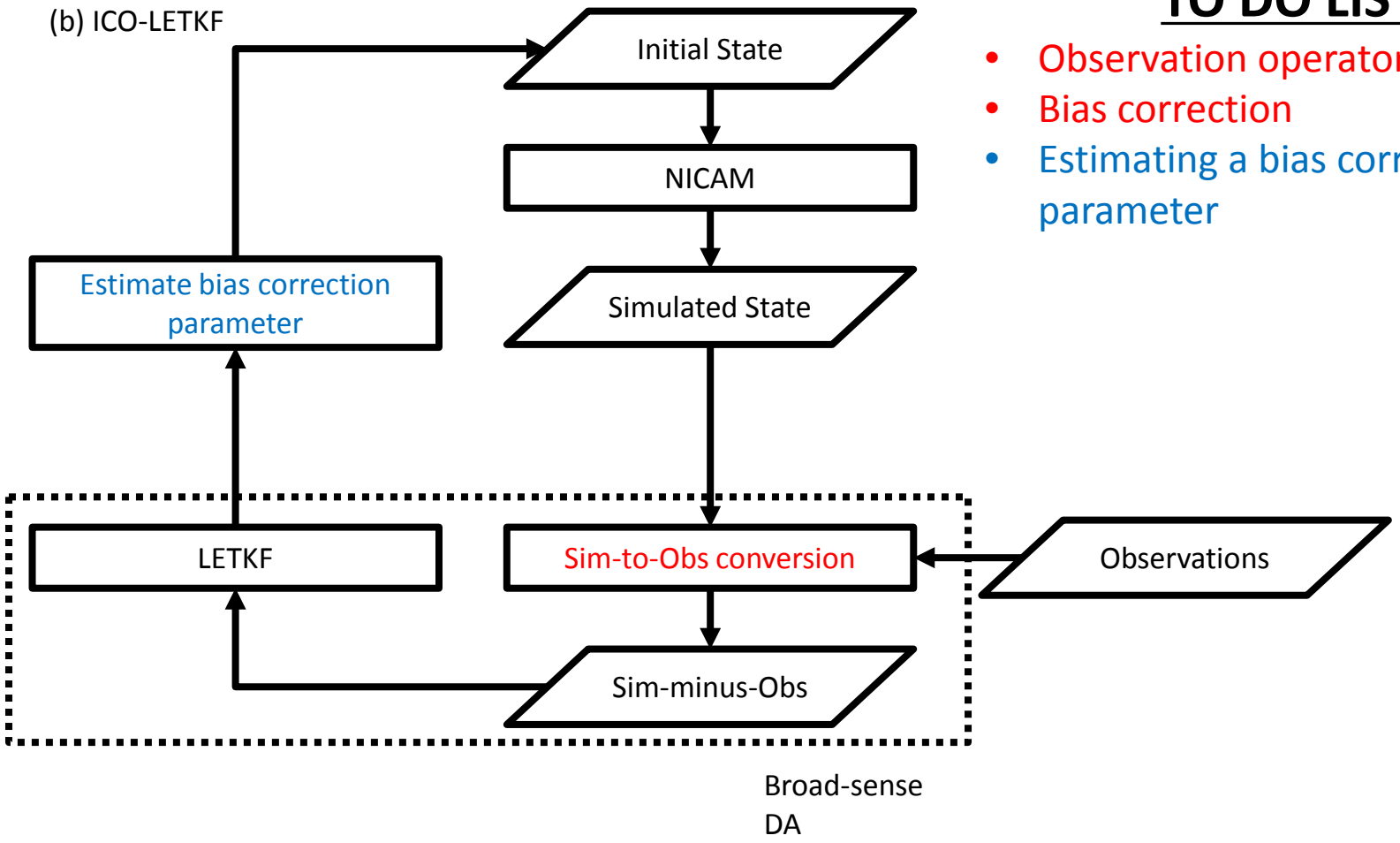
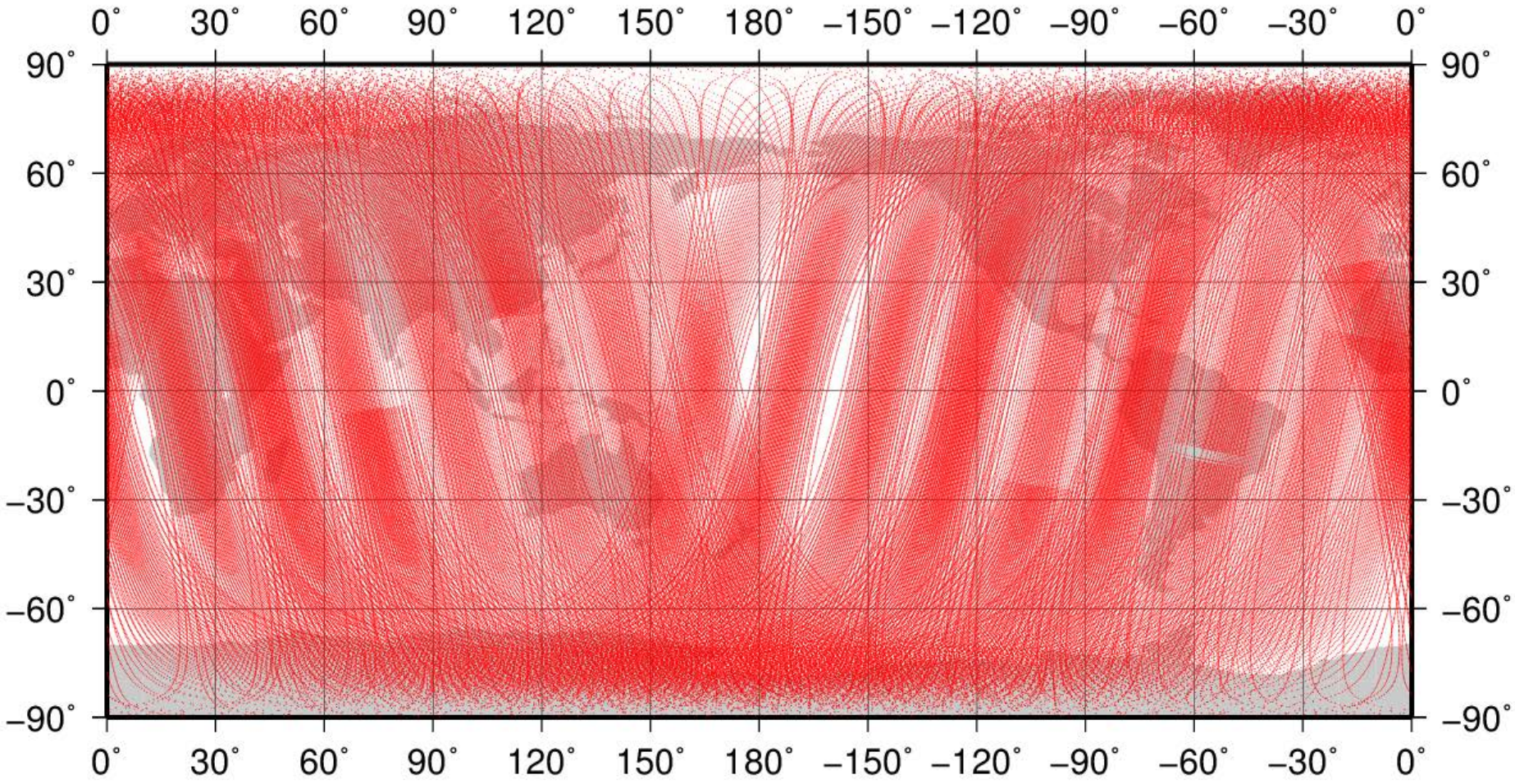



## TO DO LIST

- Observation operator（RTTOV）
- Bias correction
- Estimating a bias correction parameter

# AMSU-A (before thinning)

NOAA-15, 16, 18, 19
6 hourly observation



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NOAA-15, 16, 18, 19
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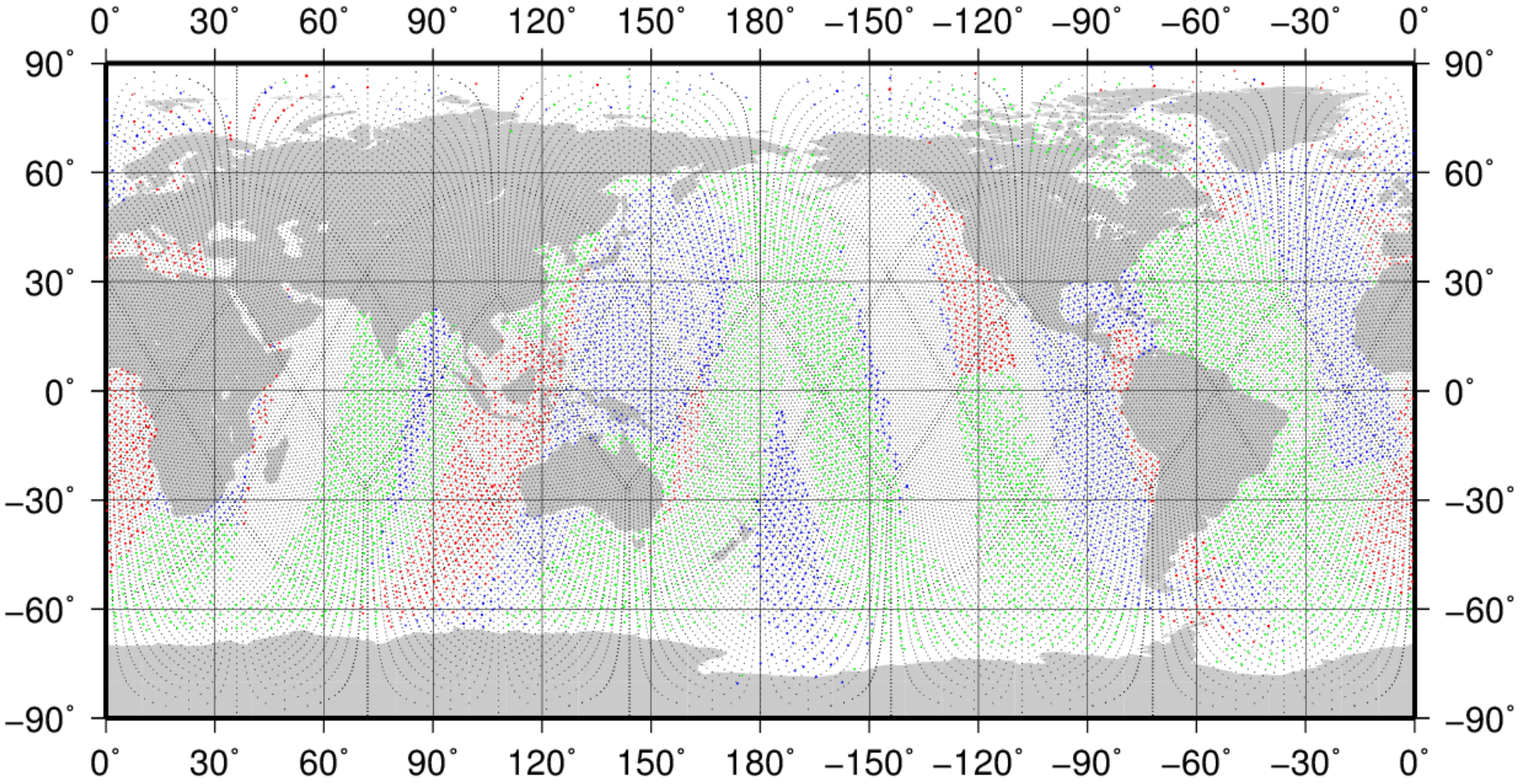




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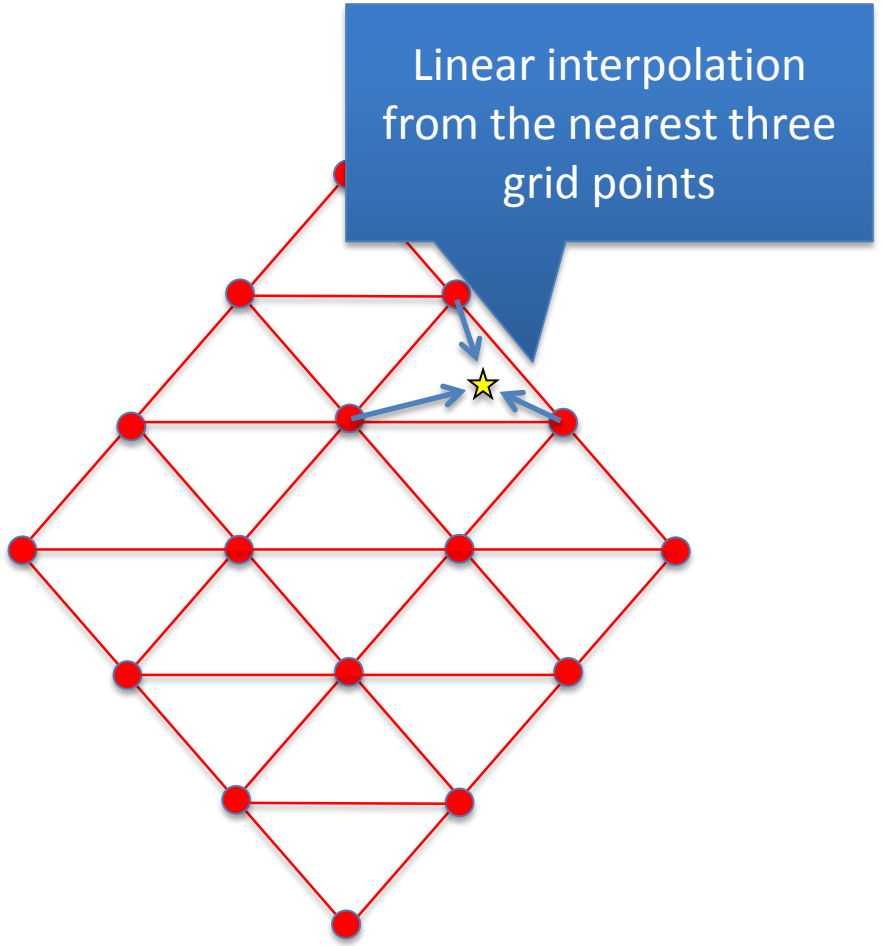
# Observation operator

1. Spatial interpolation
   - Observation is not located at the same place of the model
   - NICAM has a tool to interpolate from a model grid point to an arbitrary grid point
2. Variable conversion
   - Observed variable is not always same with model variable

$$\mathbf{y} - \mathbf{H}\mathbf{x}_f$$

$\mathbf{y}$: Observation (brightness temperature)
$\mathbf{H}$: Observation operator (Radiative transfer model: RTTOV)
$\mathbf{x}_f$: forecast (air temperature, pressure, humidity・・・)

AMSU-A observes the brightness temperature, but the model does not have it.




● : model grid of NICAM
☆ : observation



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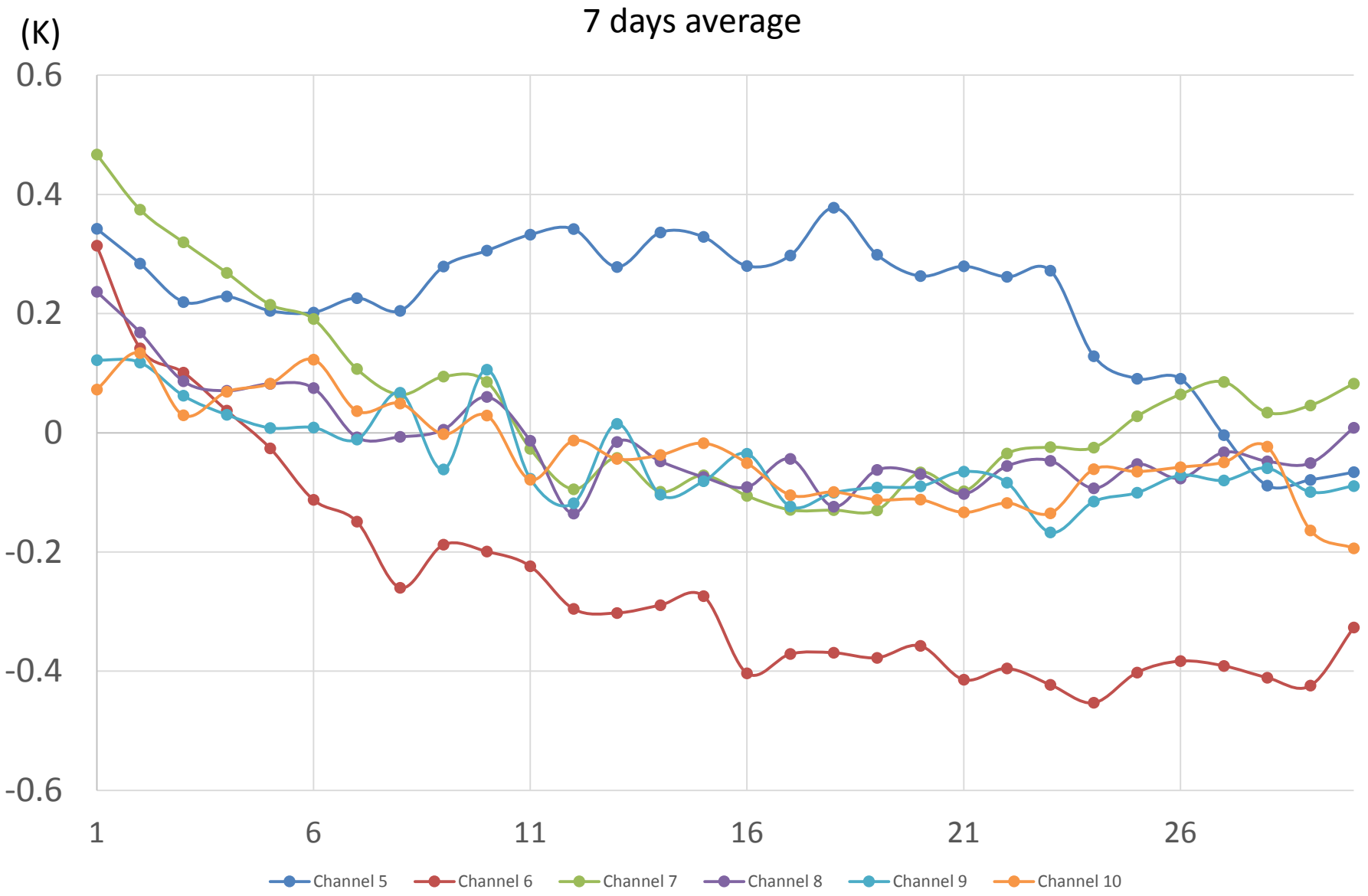
# Scan bias (AMSU-A NOAA-15)



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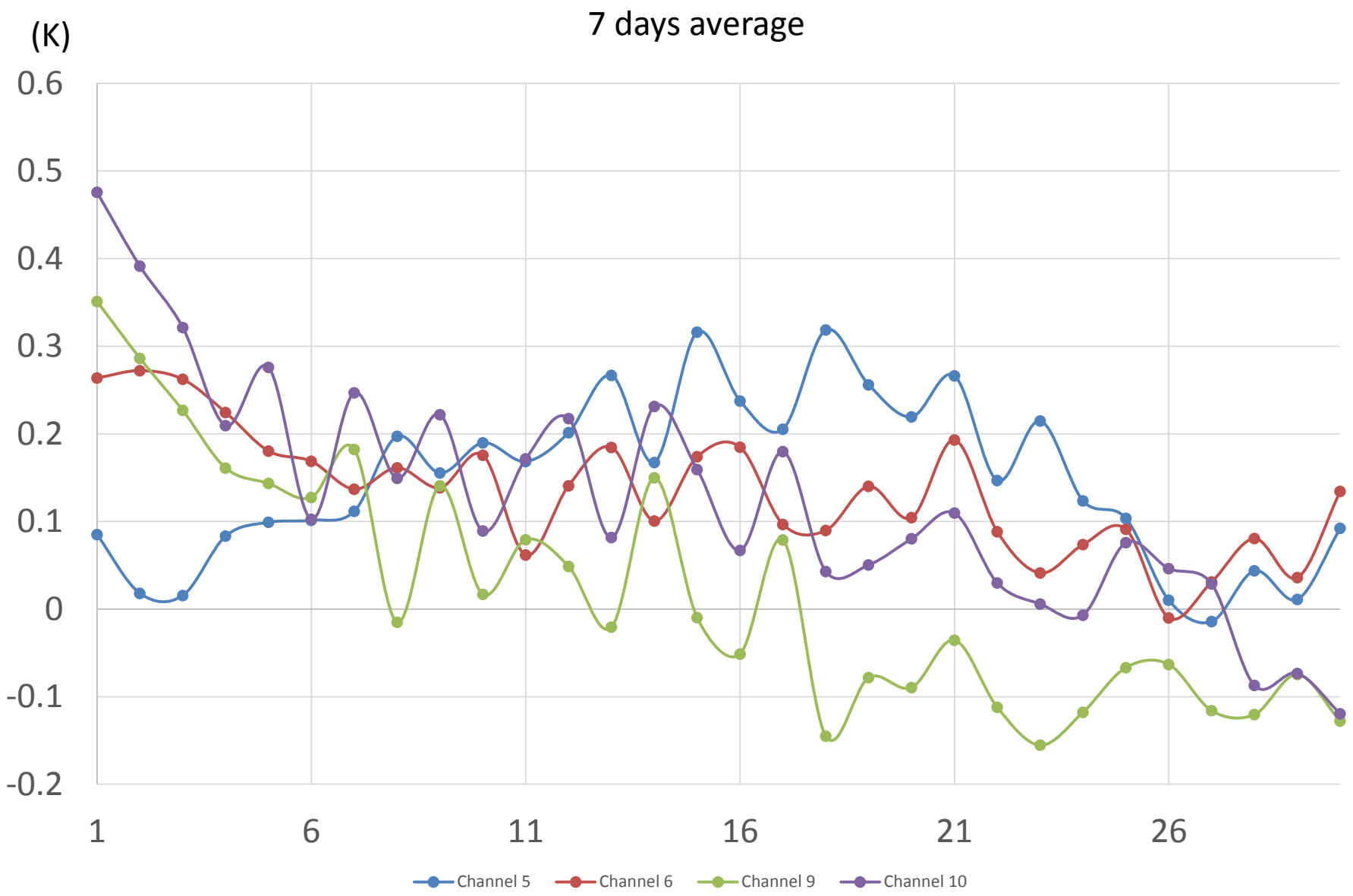
# Scan bias (AMSU-A NOAA-16)



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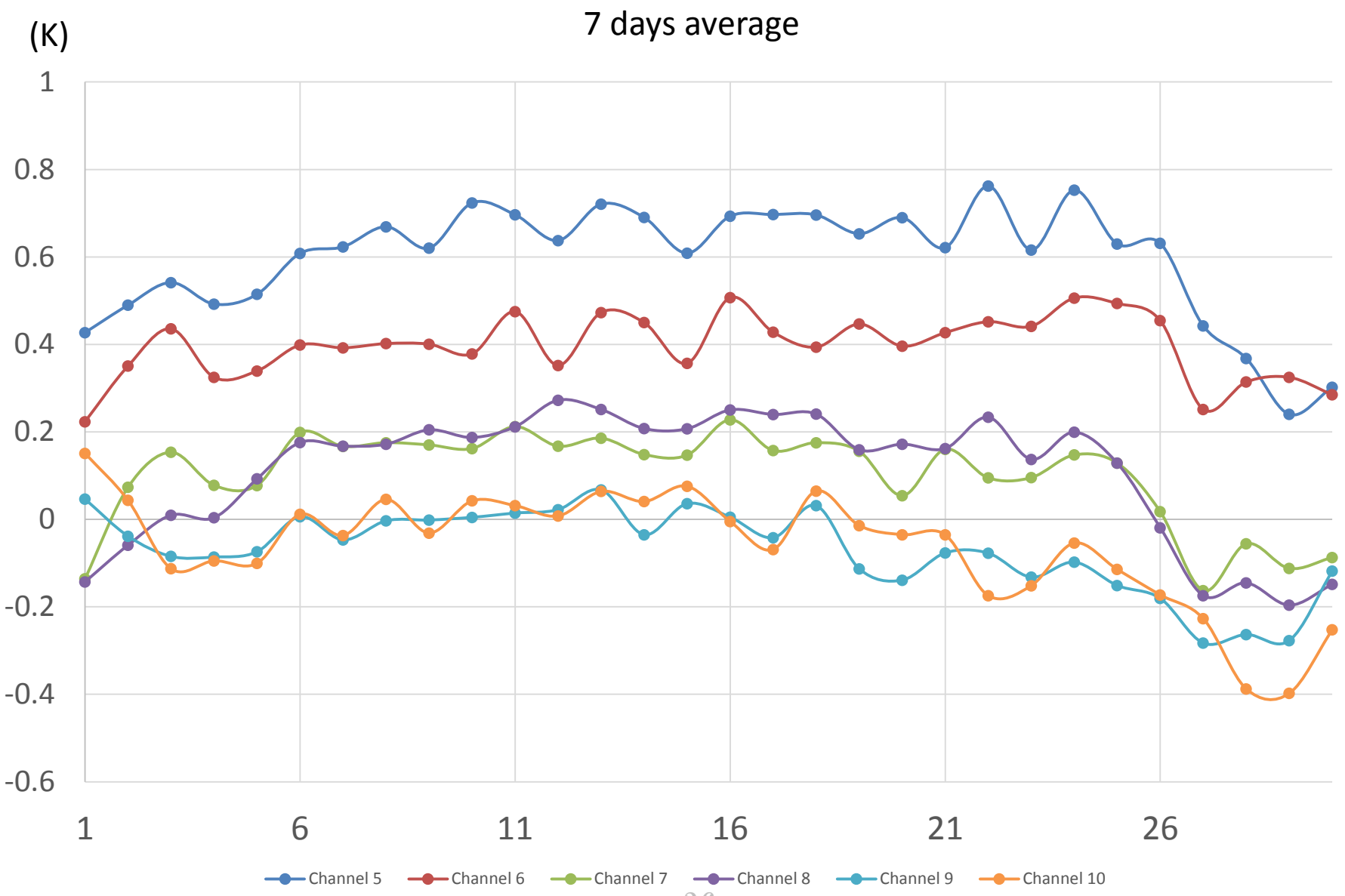
# Scan bias (AMSU-A NOAA-18)



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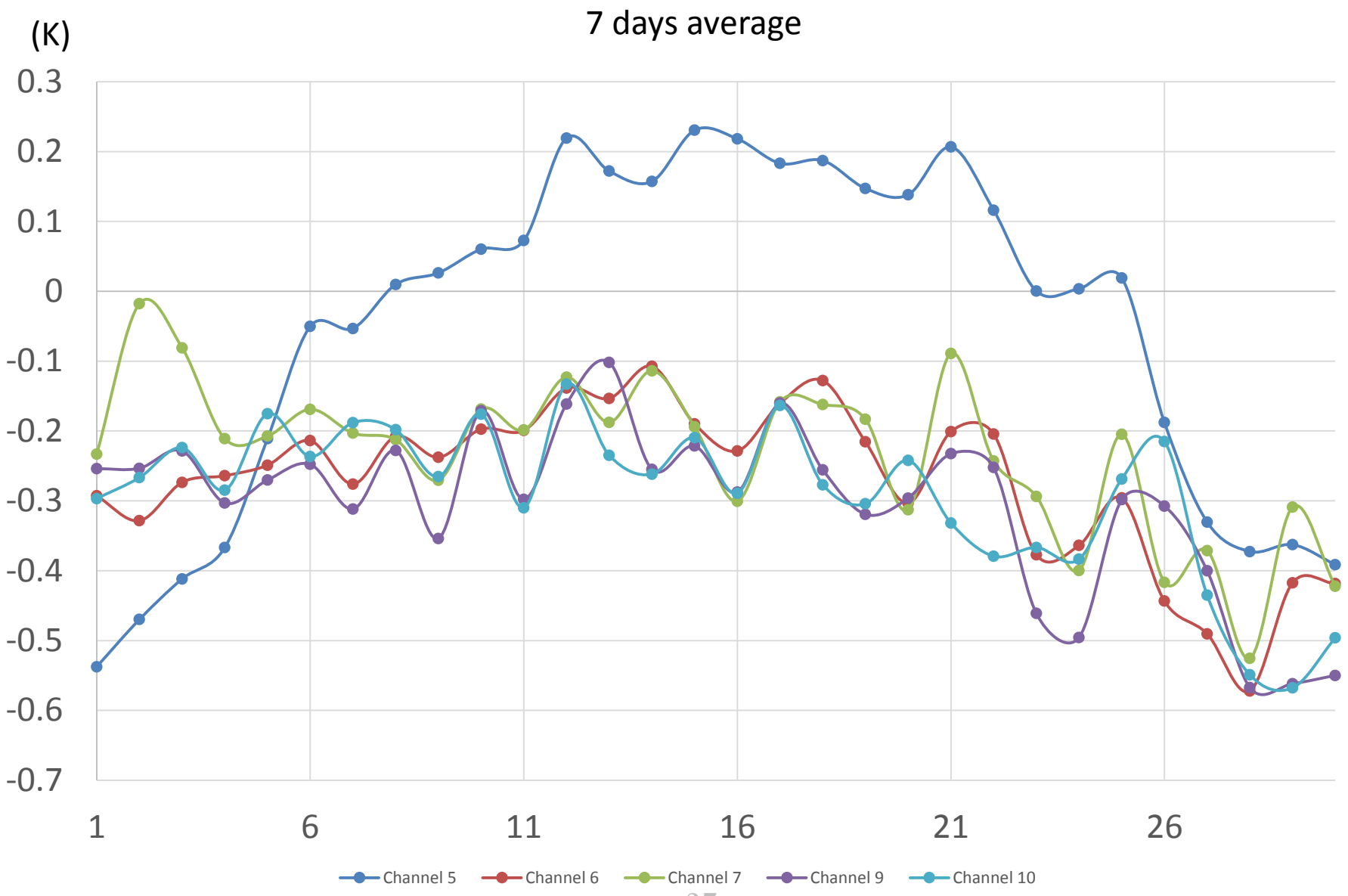
# Scan bias (AMSU-A NOAA-19)



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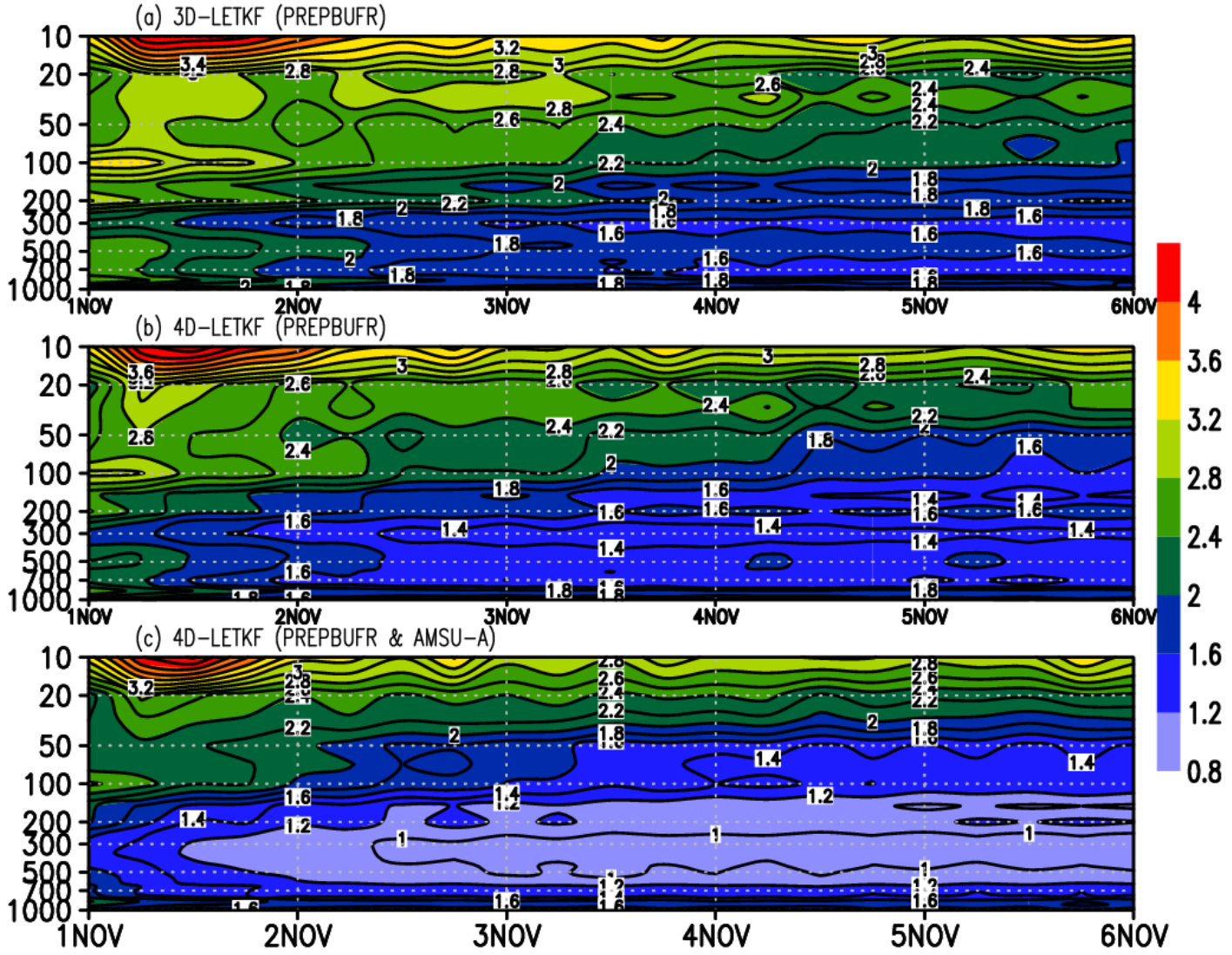
# RMSD in temperature (vs ERA-interim)



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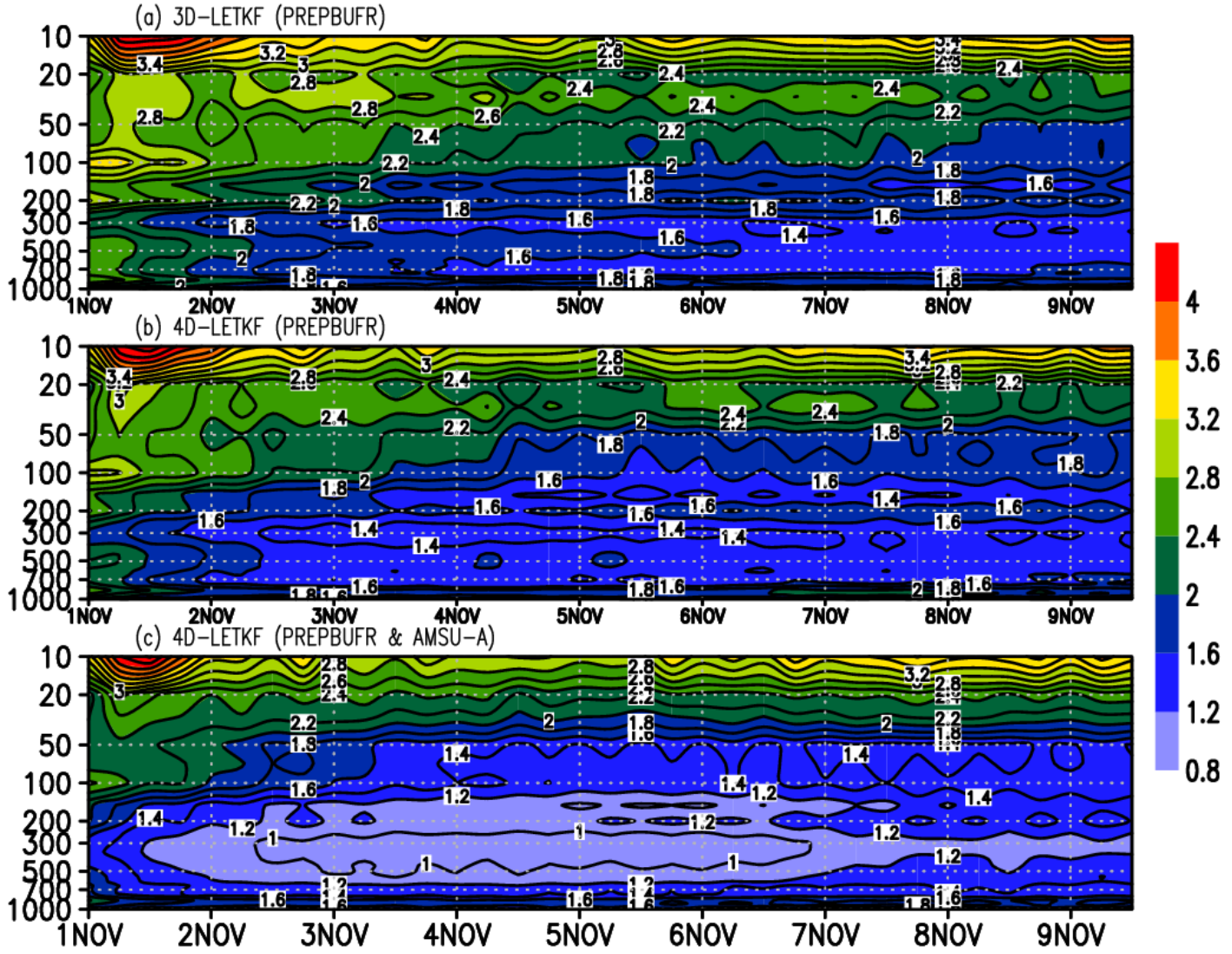




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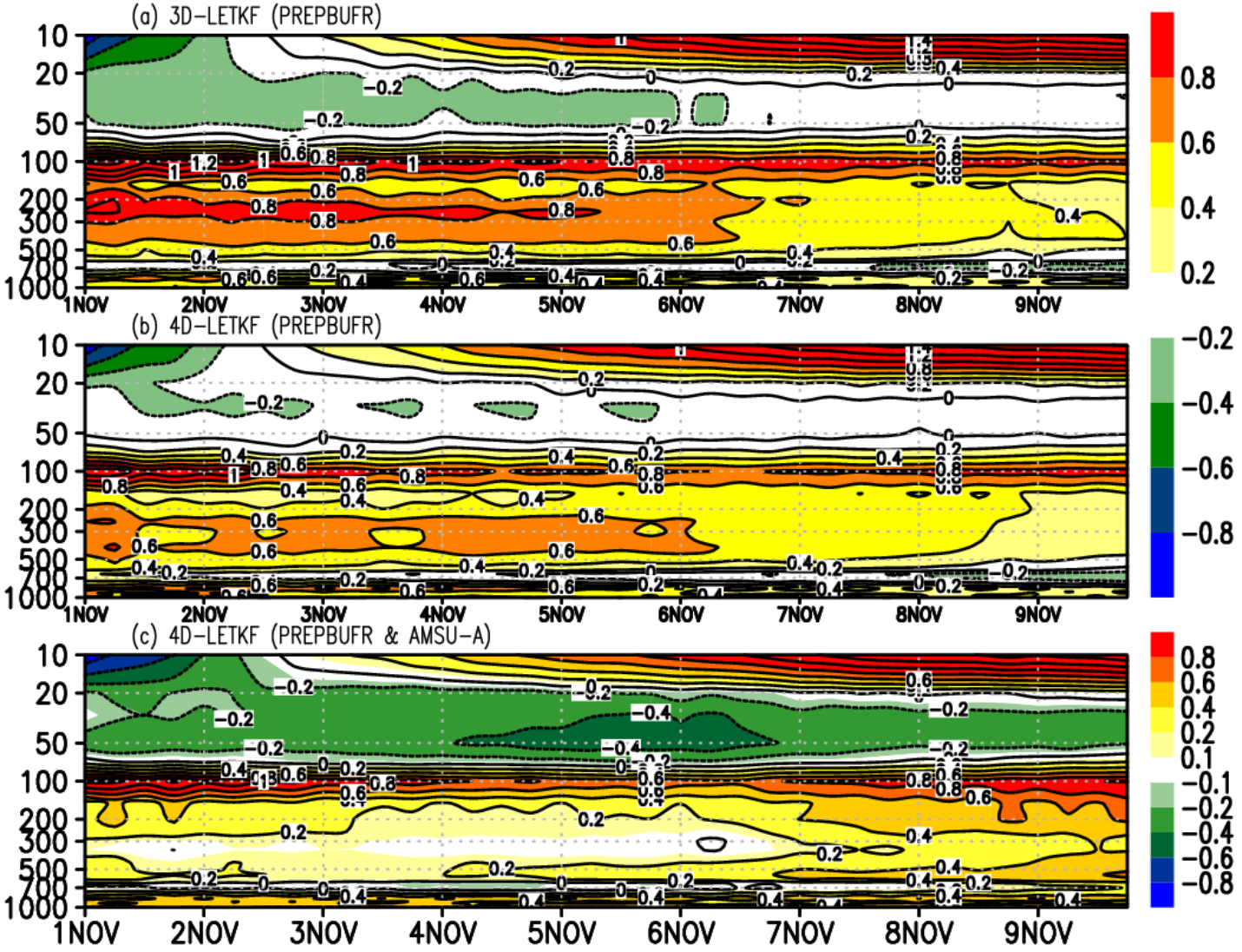
# Temperature bias



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# Summary and Future work

- We developed two NICAM-LETKF systems
  - Use the original LETKF code

    (with interpolation between icosahedral and lat-lon grids)
  - Direct I/O of icosahedral grid (ICO-LETKF)
- The new system (ICO-LETKF) reduces computation time and makes the analysis accurate (interpolation error)

- Extending initial version to 4D-LETKF
  - Analysis became more accurate than 3D-LETKF
- Assimilating satellite observations (AMSU-A)
  - Analysis error decreases remarkably

# Summary and Future work

- Find bugs in bias correction

- Dr. Yashiro has been developing a new NICAM-LETKF system as a work in the post K project.
  - It can reduce the computation time

- Dr. Kotsuki has been trying to assimilate surface precipitation.

➢ High resolution experiment (glevel-8, # of ensembles=64)