A One-Year Experimental Arctic Reanalysis and Comparisons with ERA-40 and NCEP/NCAR Reanalyses

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7th International Conference on Global Change: Connection to the Arctic (GCCA-7)
February 19-20, 2007, Fairbanks, Alaska, USA

Outline

- Introduction – Arctic Reanalysis Project
- The EARS system
- Verification method
- Results: Comparison with ERA-40 and NCEP/NCAR reanalyses
- Summary & Discussion

Introduction – Arctic Reanalysis Project

- This work was supported by the Arctic System Reanalysis (ASR) project that was funded by NOAA and led by Dr. John Walsh.

- The aim of the ASR project was to establish a prototype (proof of concept) based on Polar MM5, and finally on the WRF model.
- The ASR was planned to encompass a region north of 45˚N and to be driven at the lateral boundaries by a global reanalysis.
- The foci of our work were Data assimilation approach and data utilization.

Experimental Arctic Reanalysis System

The EARS system was set up based on a series of intensive experiments and tests.

- Model & Domain
- Resolution
- Approach
- Data
- Cycling scheme design

– Model & Domain

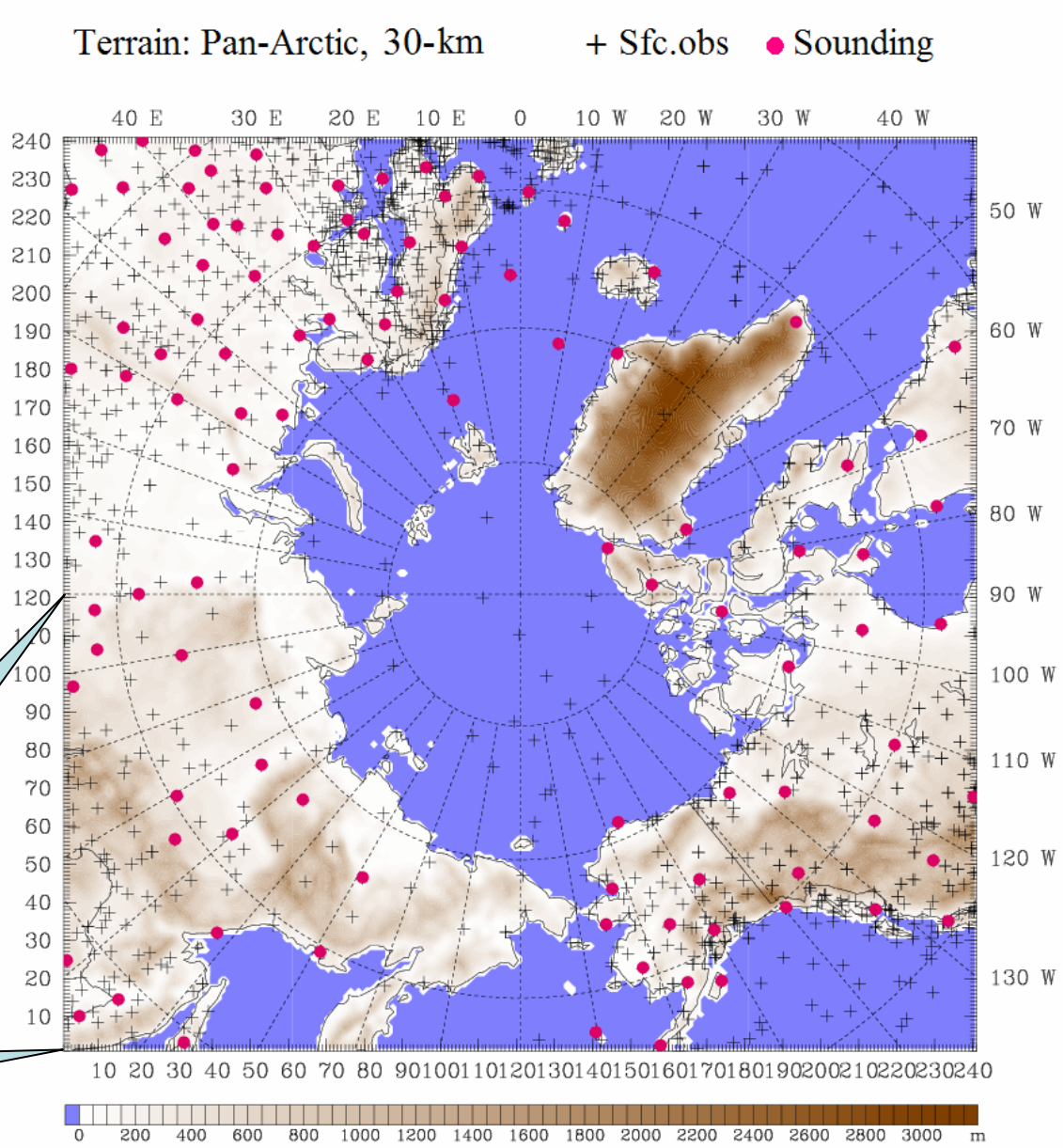
Arctic MM5 real-time system at UAF

(Tilley et al., 2002: The Arctic MM5 System: Characteristics and a Preliminary Evaluation of Performance)

Pan-Arctic domain centered at north pole

56 ˚N

44 ˚N



– Resolution

Tested (together with 3DVAR approach):

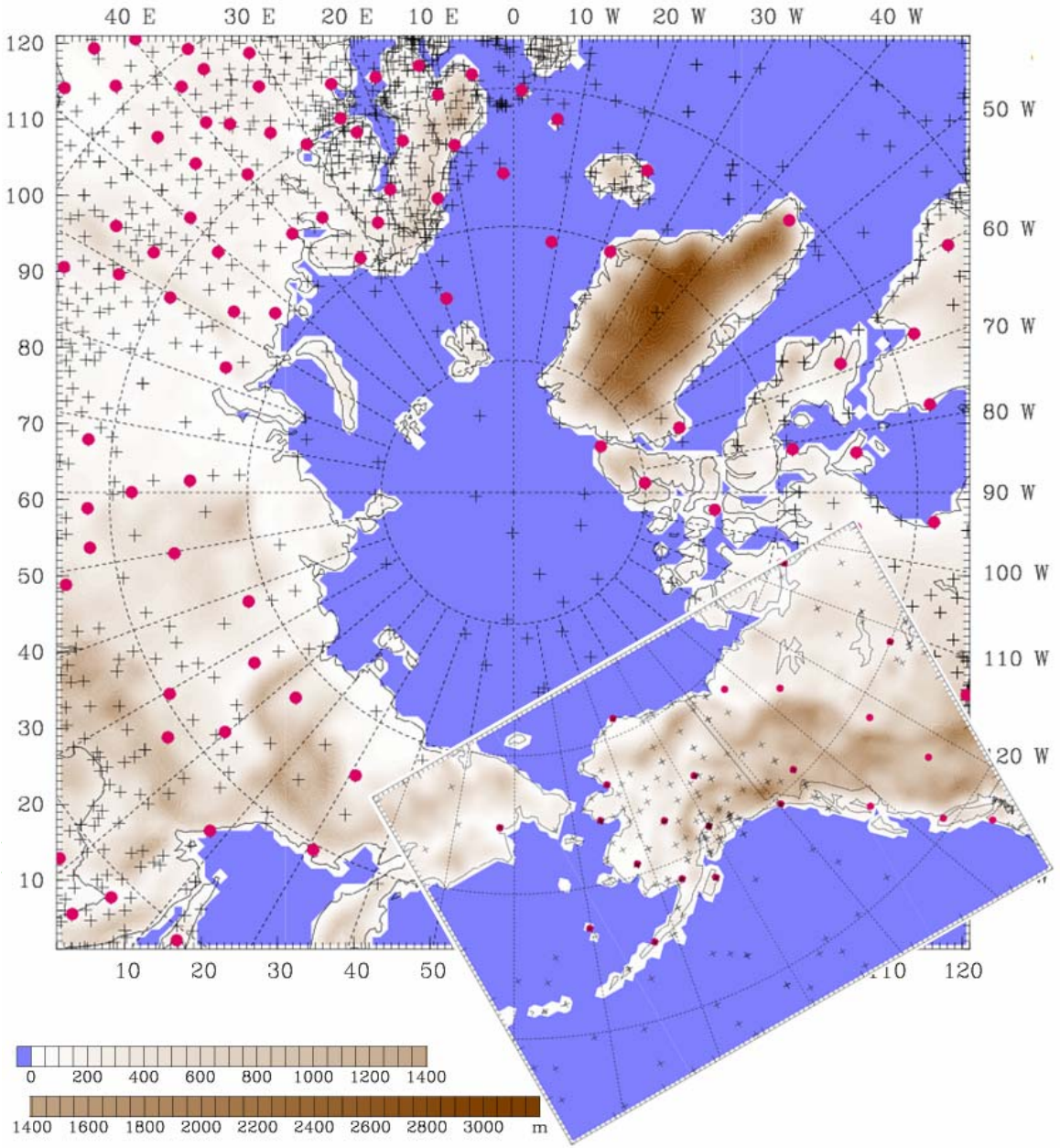
Pan-Arctic domain:

60 km vs. 30 km

Alaska domain:

45 km vs. 15 km

Concluded that higher resolution always produces bette results in a domain-averaged sense.



– Assimilation Approaches

Variational – 3DVAR system developed at NCAR is applied to the Arctic domain:

- Customized background error for the Arctic region from a one-year MM5 forecast dataset, using the so-called NMC method.
- Adjusted and tested length scale factors and error variance factors.
- Added sub-packages to assimilate MODIS and TOVS retrieval data as new data types, including obs error est.
- Tuned and tested the factor of satellite data thinning.

Newtonian Nudging:

- Intermittent nudging to a global reanalysis helps to constrain the MM5 to large scale states.

– Data Assimilated

Surface observations of T, Td (RH), U, V, Psfc

Upper-air soundings of T, Td (RH), U, V

TOVS retrieved 3D T, Thickness, TPW (total precipitable water)

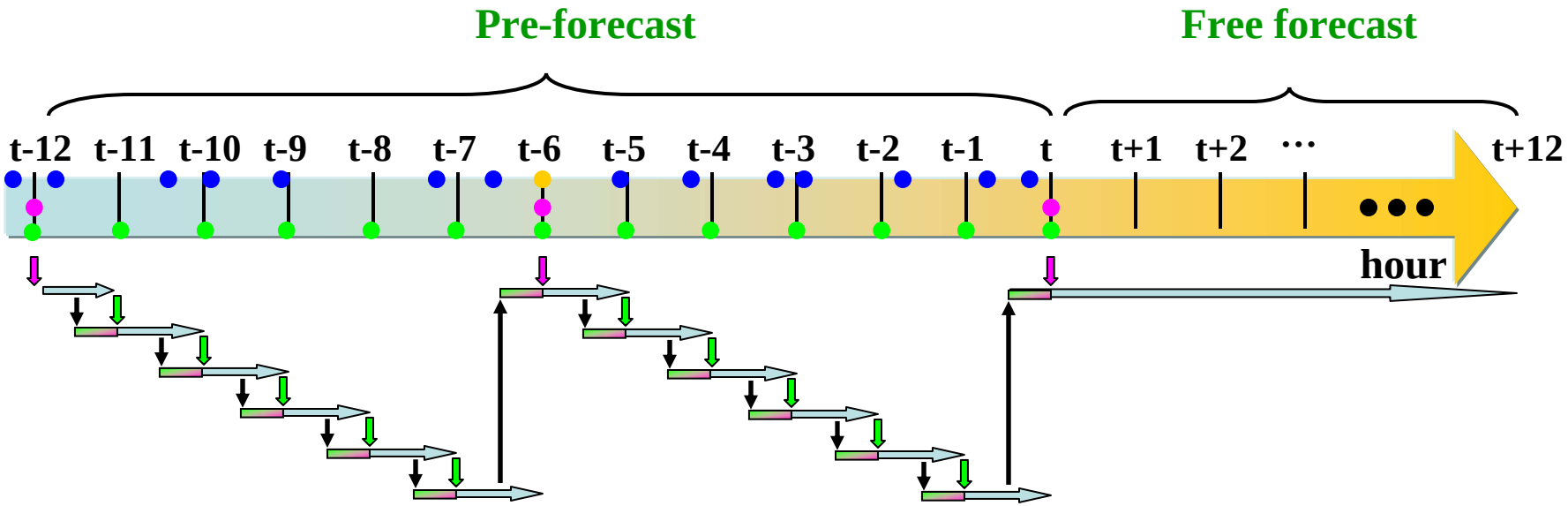
~~MODIS retrieved 3D T, Td (RH), TPW~~

Tests indicated that assimilation of MODIS dataset is not improving the forecasts. A brief check of data found that Td has extreme biases at different levels. Thus MODIS data was not assimilated in the EARS experiments.

Initial and Boundary Conditions:

The System is driven by ERA-40 reanalysis, which was found to produce superior results than using NNRP.

– Cycling Scheme Design



3DVAR analysis: uses ERA-40 reanalysis ( ) or model forecast ( ) as background, and assimilates all available data, including surface, sounding, and satellite data.

Forecast: save at 30 min interval for restart and analysis in pre-forecast period and save at 6-hour interval in free forecast period.

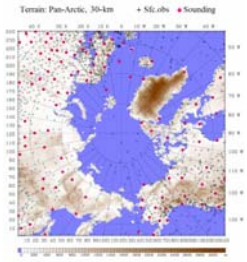
Restart: Uses half hour forecast to restart next forecast.

Nudging: from the restart time point, nudge to 3DVAR analysis during the first 30 min.

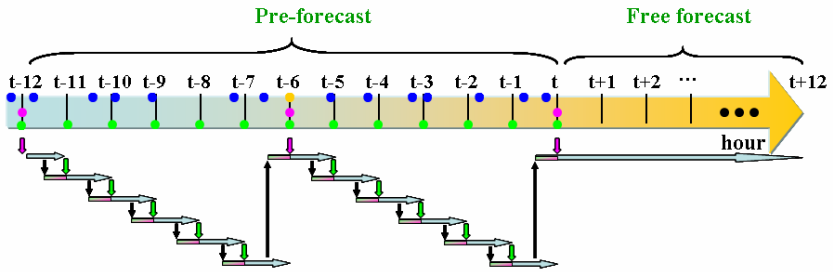
Observations:

- **Satellite observation**
- **Sounding observation**
- **ERA-40 reanalysis**
- **Surface observation**

EARS Setup – Summary:



- Model & Domain Arctic MM5
- Resolution 30 km, 41 levels
- Approach 3DVAR + Nudging
- Data SFC, Sounding, TOVS retrievals, ERA-40
- Cycling scheme



Verification & Comparison:

At each 6-hour time point:

~1050 surface observations of T, Td, RH, U, V, SLP, rain

At each 12-hour time point (00Z & 12Z):

~100 soundings of T, Td, RH, U, V, Z

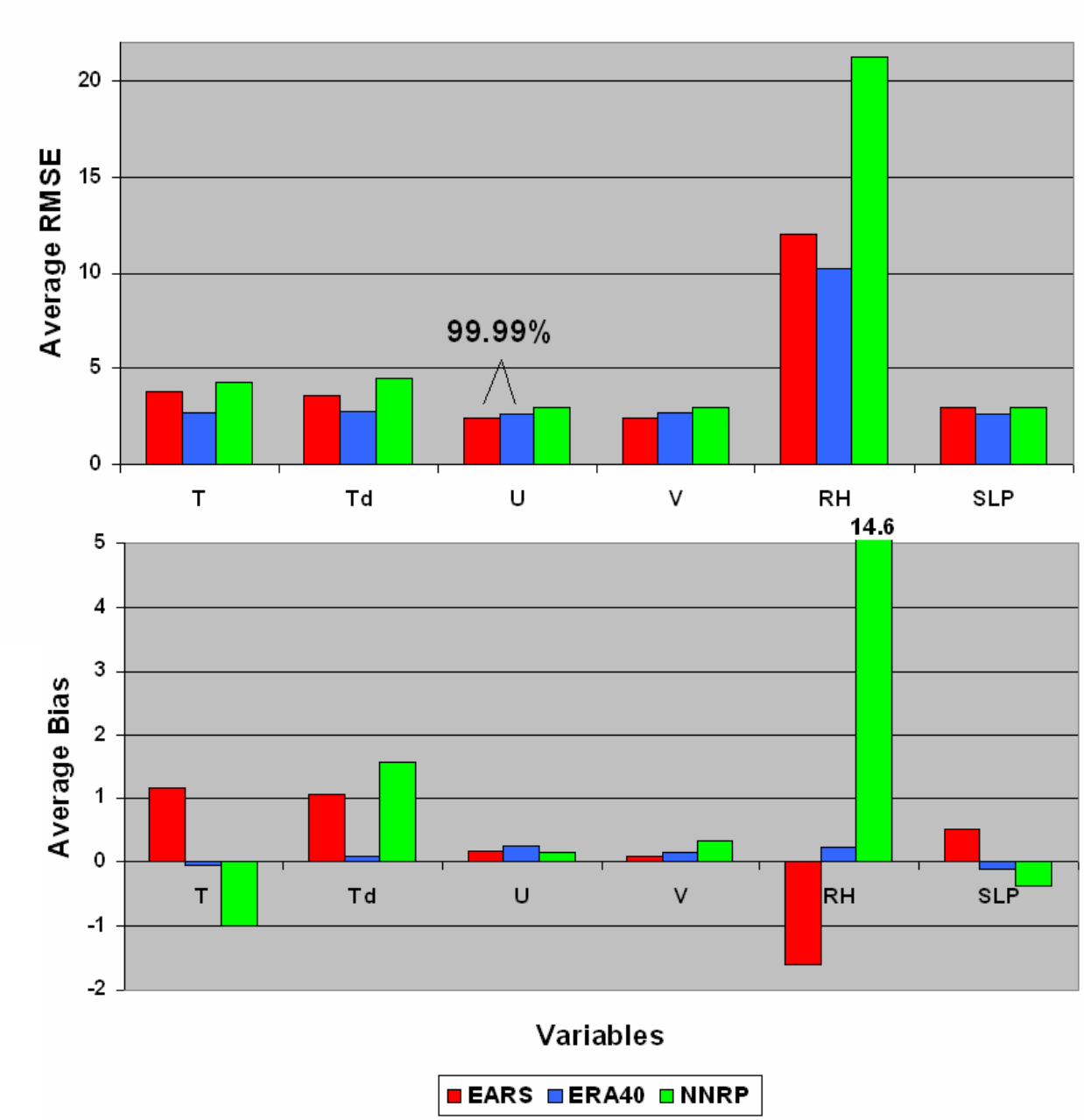
Metrics – Domain-averaged:

- ETS, BIAS (Categorical): 6-hr accumulated rainfall
- RMSE, bias: T, Td, RH, U, V, SLP, Z

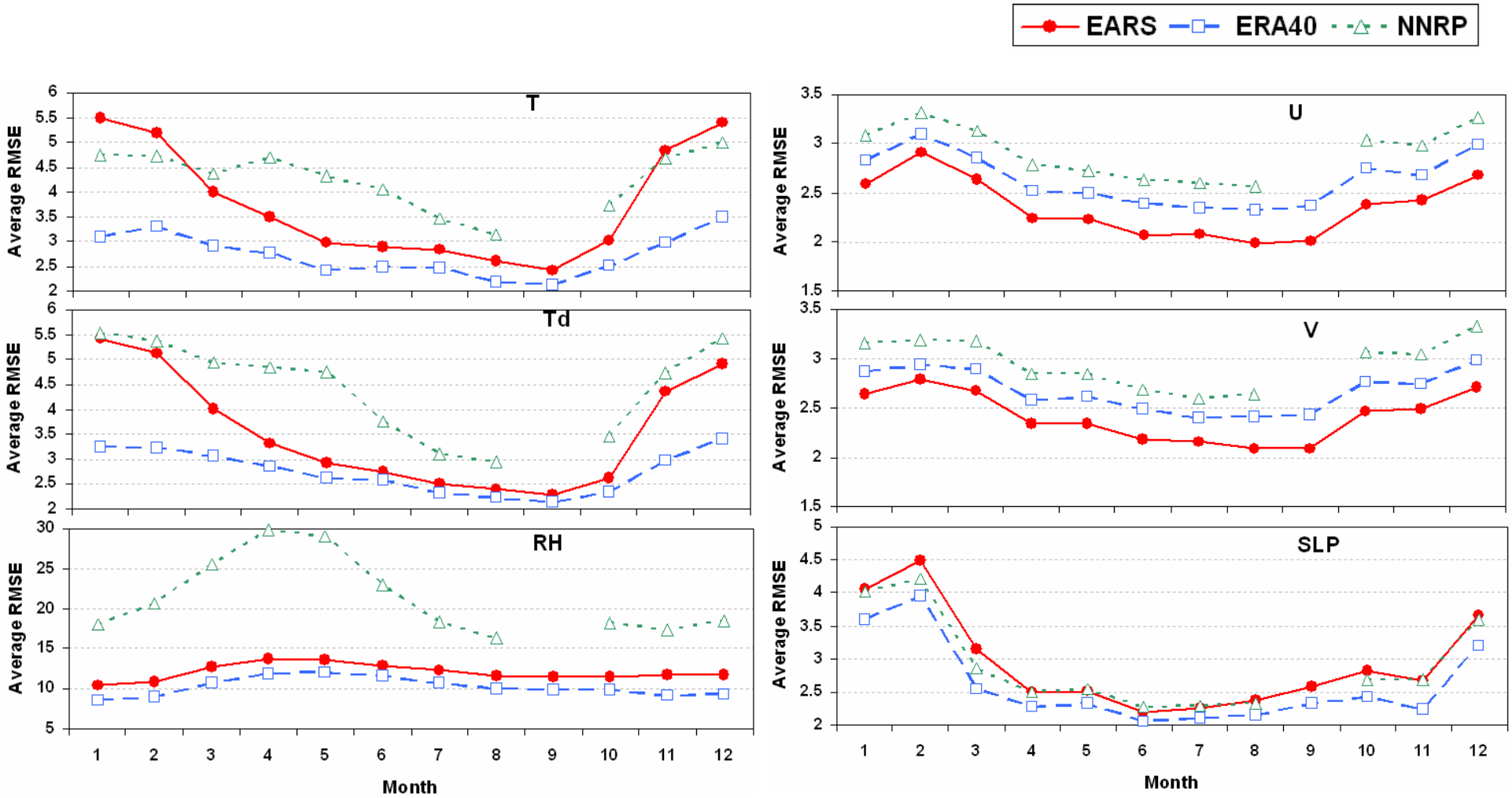
Compares to :

- ERA-40 and NNRP (NCEP/NCAR Reanalysis)

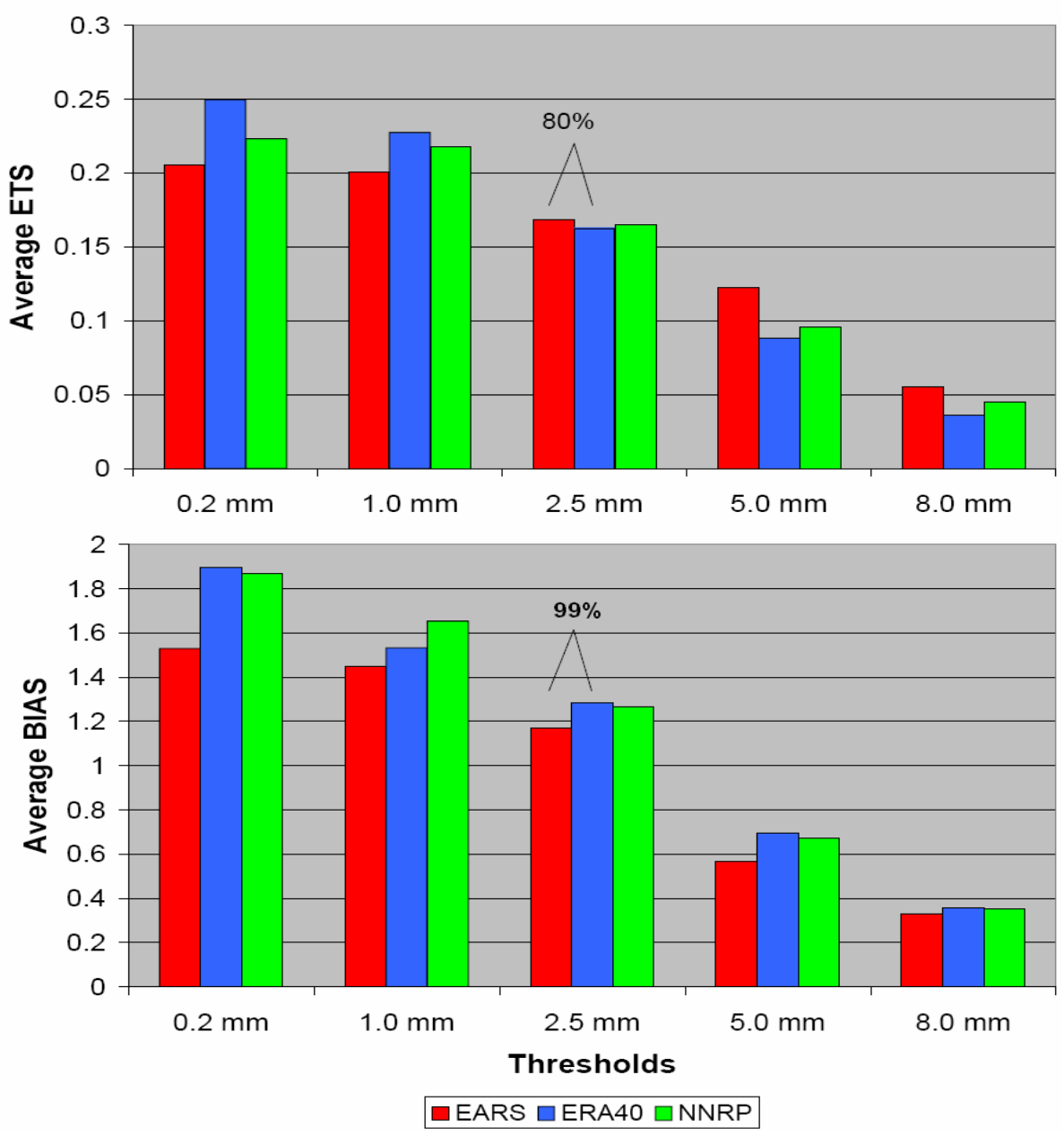
Surface:


Average RMSE
20
15
10
5
0
99.99%
T
Td
U
V
RH
SLP
Average Bias
14.6
5
4
3
2
1
0
-1
-2
T
Td
U
V
RH
SLP
Variables
EARS
ERA40
NNRP

Surface:



Precipitation:



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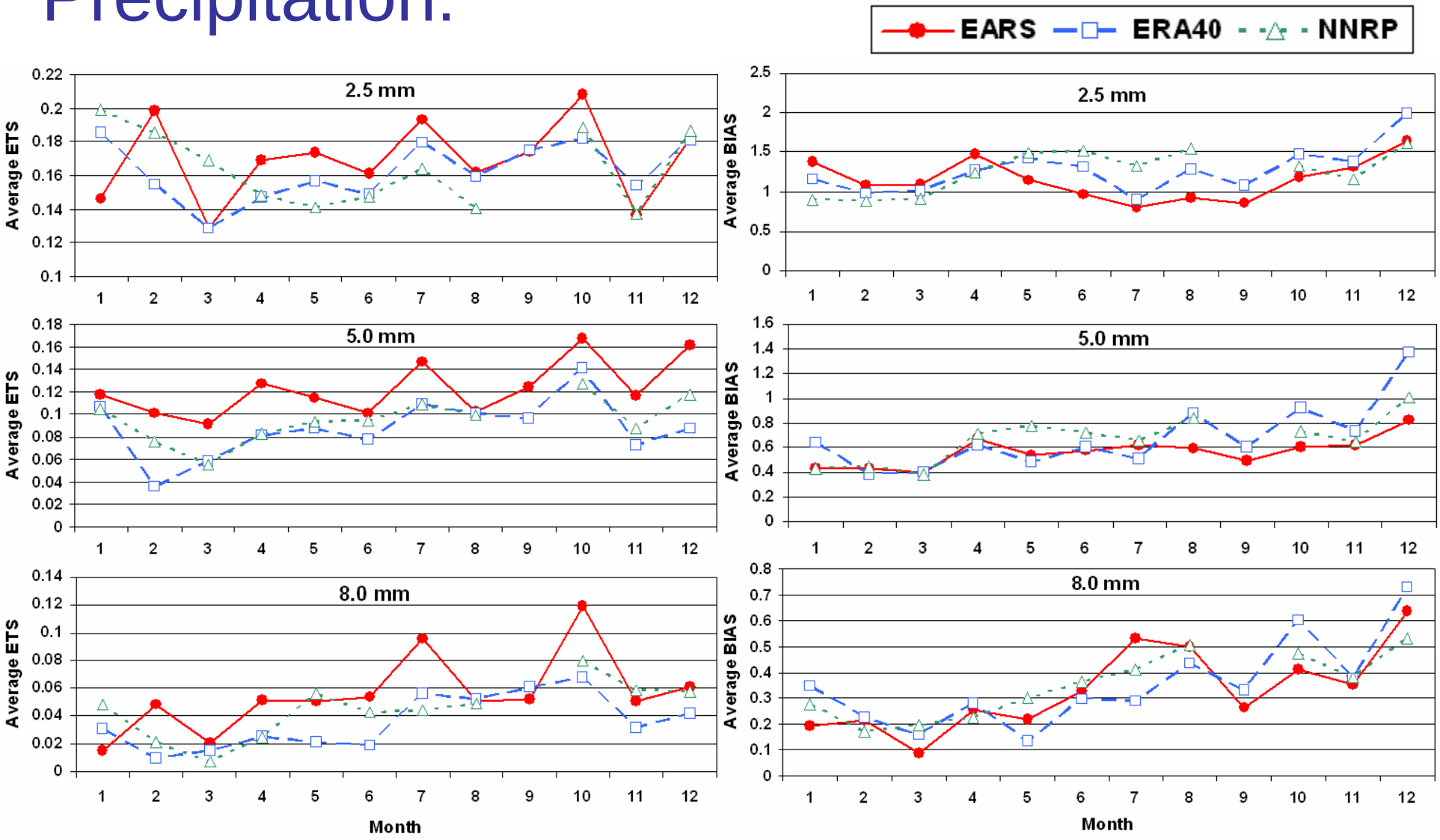
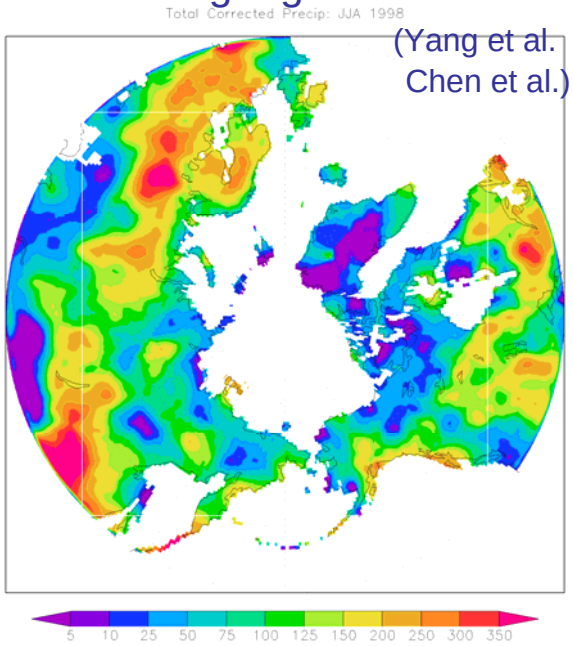


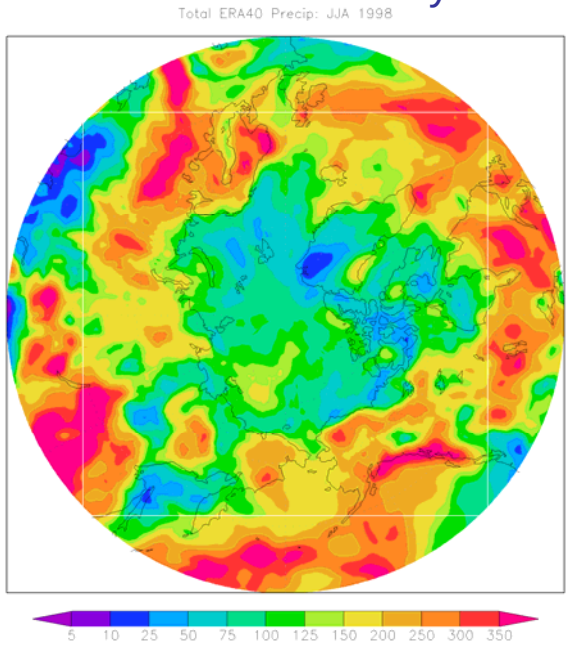
Corrected gauge observation (Yang et al. Chen et al.)

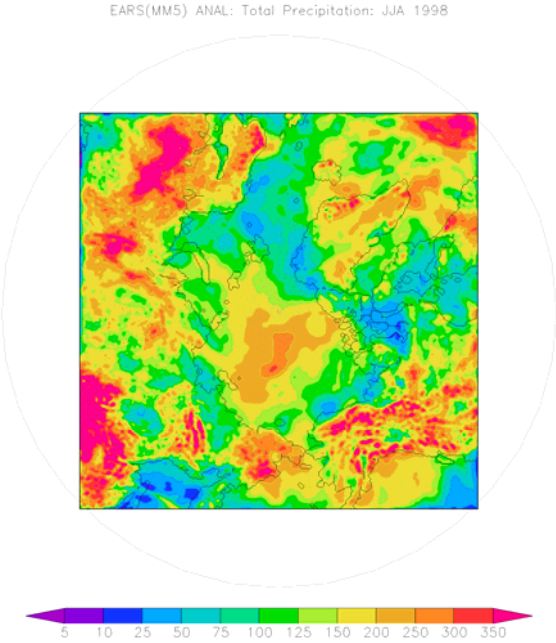
ERA-40 Reanalysis

EARS

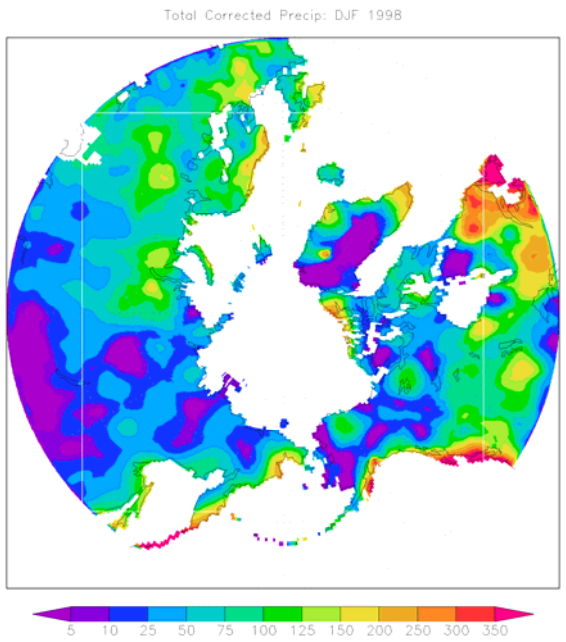
JJA 1998

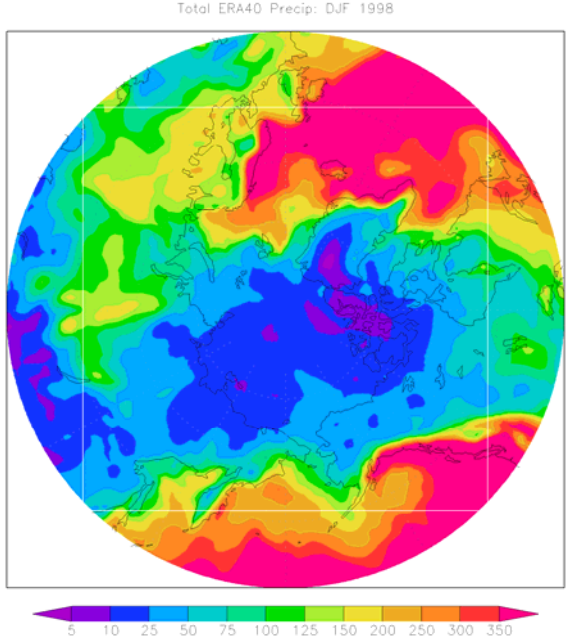


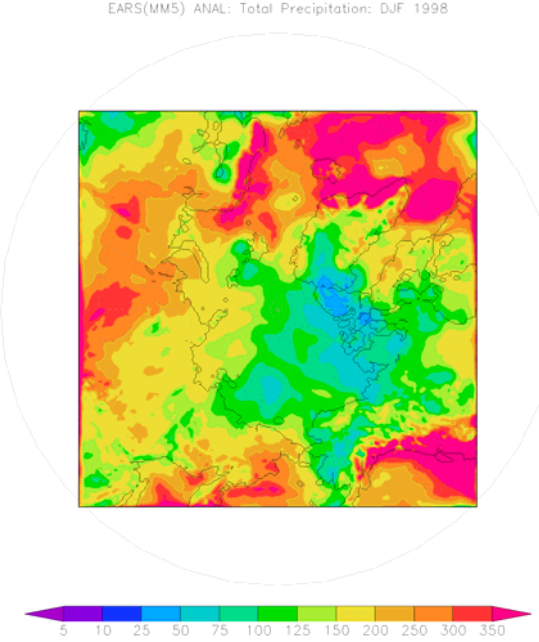




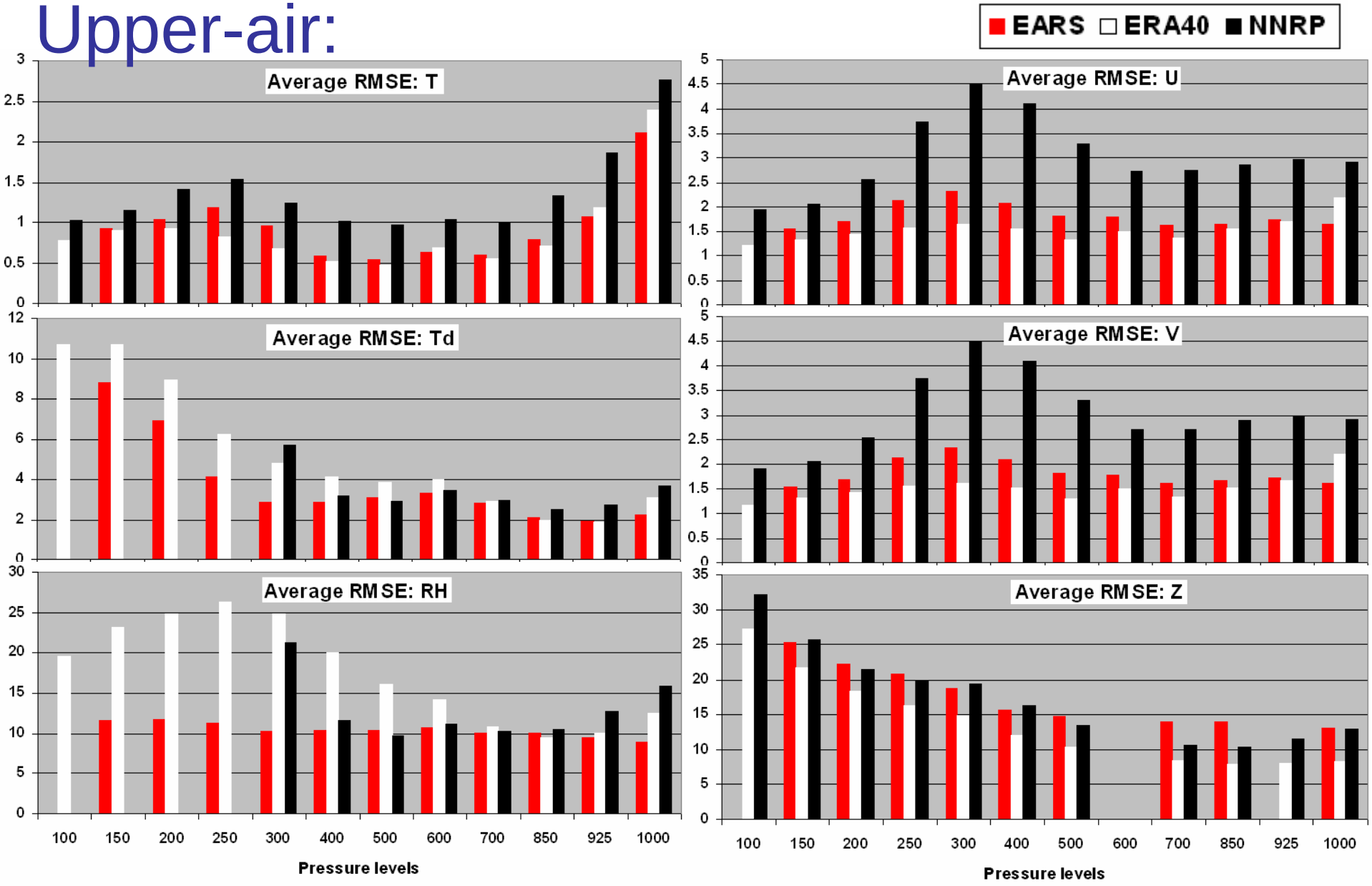
JFD 1998



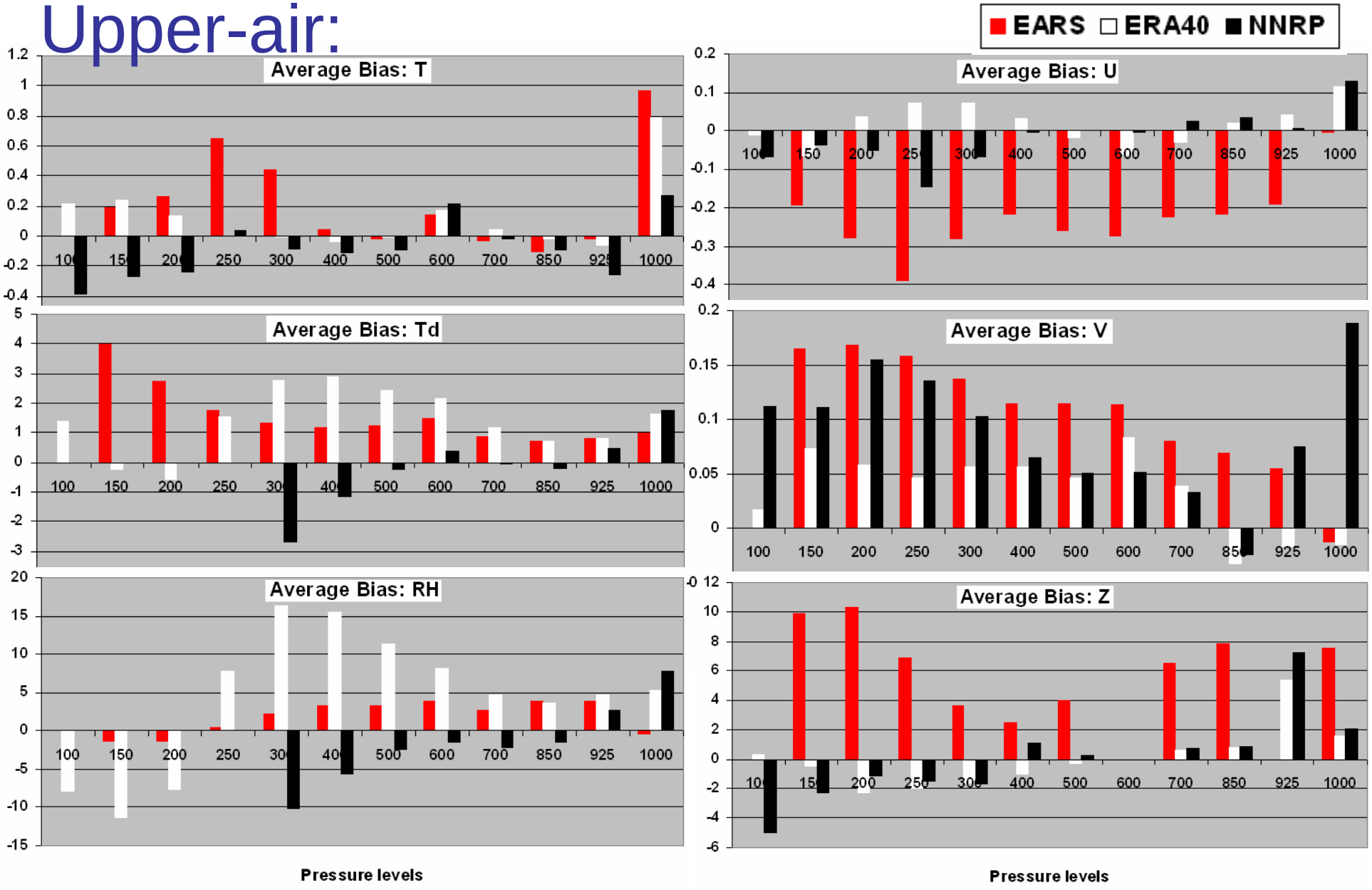




Upper-air:


EARS
ERA40
NNRP
Average RMSE: T
Average RMSE: U
Average RMSE: Td
Average RMSE: V
Average RMSE: RH
Average RMSE: Z
100 150 200 250 300 400 500 600 700 850 925 1000
Pressure levels
100 150 200 250 300 400 500 600 700 850 925 1000
Pressure levels

Upper-air:


EARS
ERA40
NNRP
Average Bias: T
Average Bias: U
Average Bias: Td
Average Bias: V
Average Bias: RH
Average Bias: Z
Pressure levels
Pressure levels

Summary:

- Higher horizontal resolution is better – for the tested resolutions;
- Needs good large scale initial and boundary conditions;
- Assimilation of TOVS retrievals has benefits, but not MODIS retrievals at this stage (as a whole dataset);
- EARS is better than NNRP;
- EARS is better than ERA-40 for such variables as: large precipitation events, low-level winds and temperature, RH at all levels;
- Verification results show seasonal differences in all three analyses. Analysis in winter has larger error than in summer for, especially, low-level temperature and geopotential height. This reminds us that Arctic modeling needs further attention.
- Problems: consistent positive bias in SLP and geopotential heights, and excessive winter precipitation.

Discussion & Future Work:

- Areas of future work include: coupled air-sea-ice model, or at least assimilation of snow and ice data;
- Identify impacts of each individual variable of each observation data type. MODIS data (Td bias)? Surface 2-m temperature (as lesson from NARR)? Bias corrections?
- Opportunity of independent verification using such as SHEBA data. We have chosen the year 1998 for this purpose, but work is not finished yet.