Fast radiative transfer including scattering by clouds and precipitation: The Successive Order of Interaction (SOI) radiative transfer model

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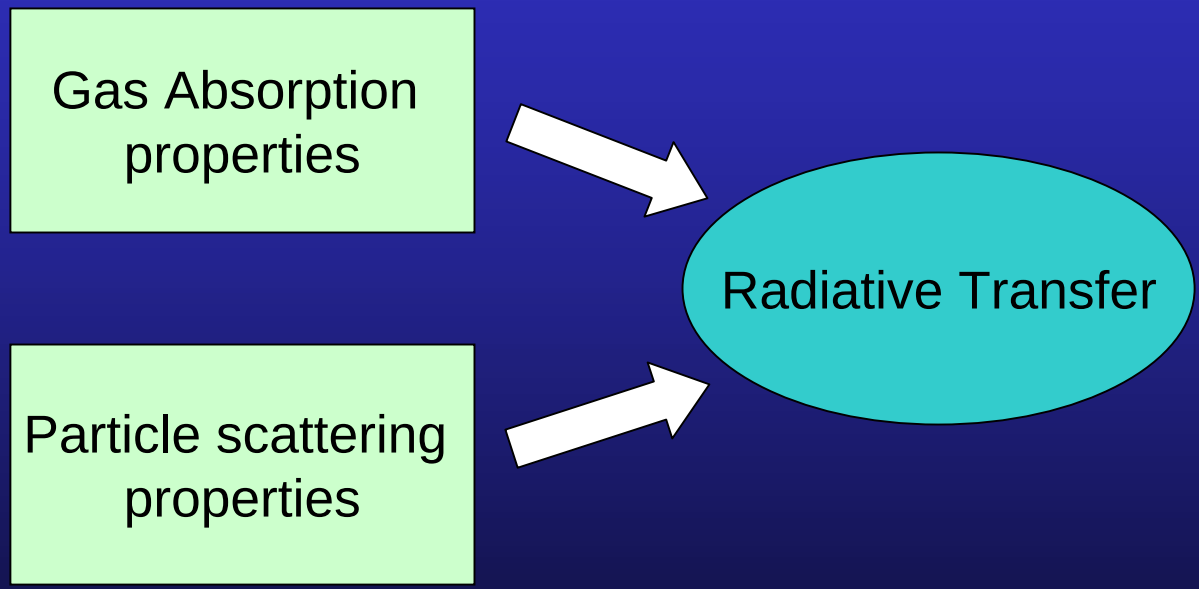
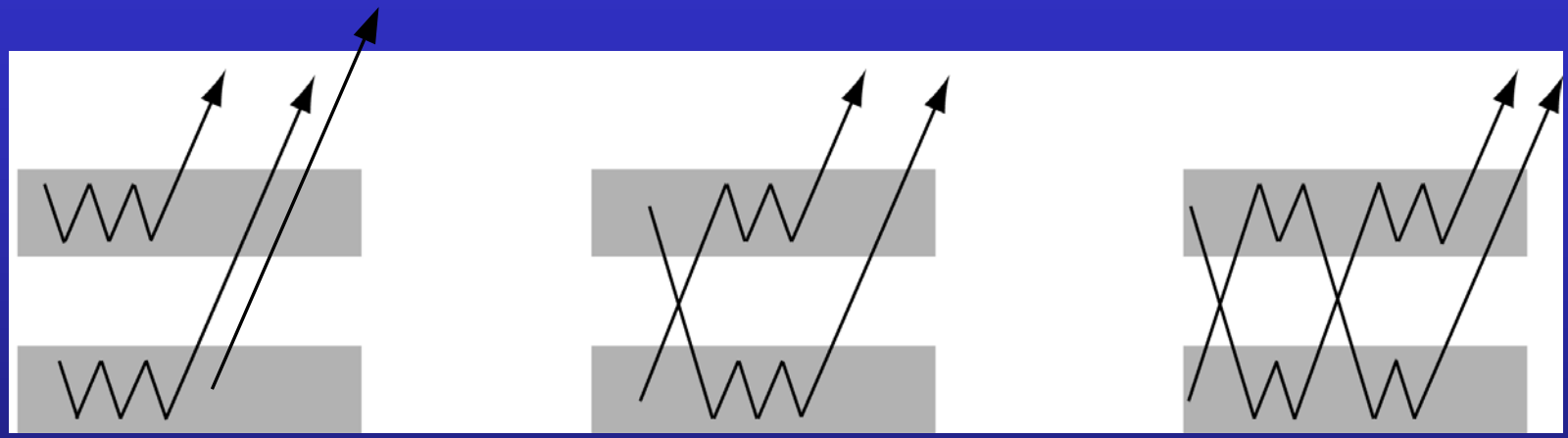
Outline

- Introduction
- The SOI forward TL and adjoint RT model
  - Accuracy
  - Speed
- Microwave applications
  - Cloud-free biases GFS/AMSR, surface emissivity
  - Biases under cloudy conditions
- Infrared comparisons (cloud-free/cloudy): First results
  - MSG SEVIRI
  - AVHRR
- Conclusions and outlook

Definitions



Successive Order of Interaction



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No interaction

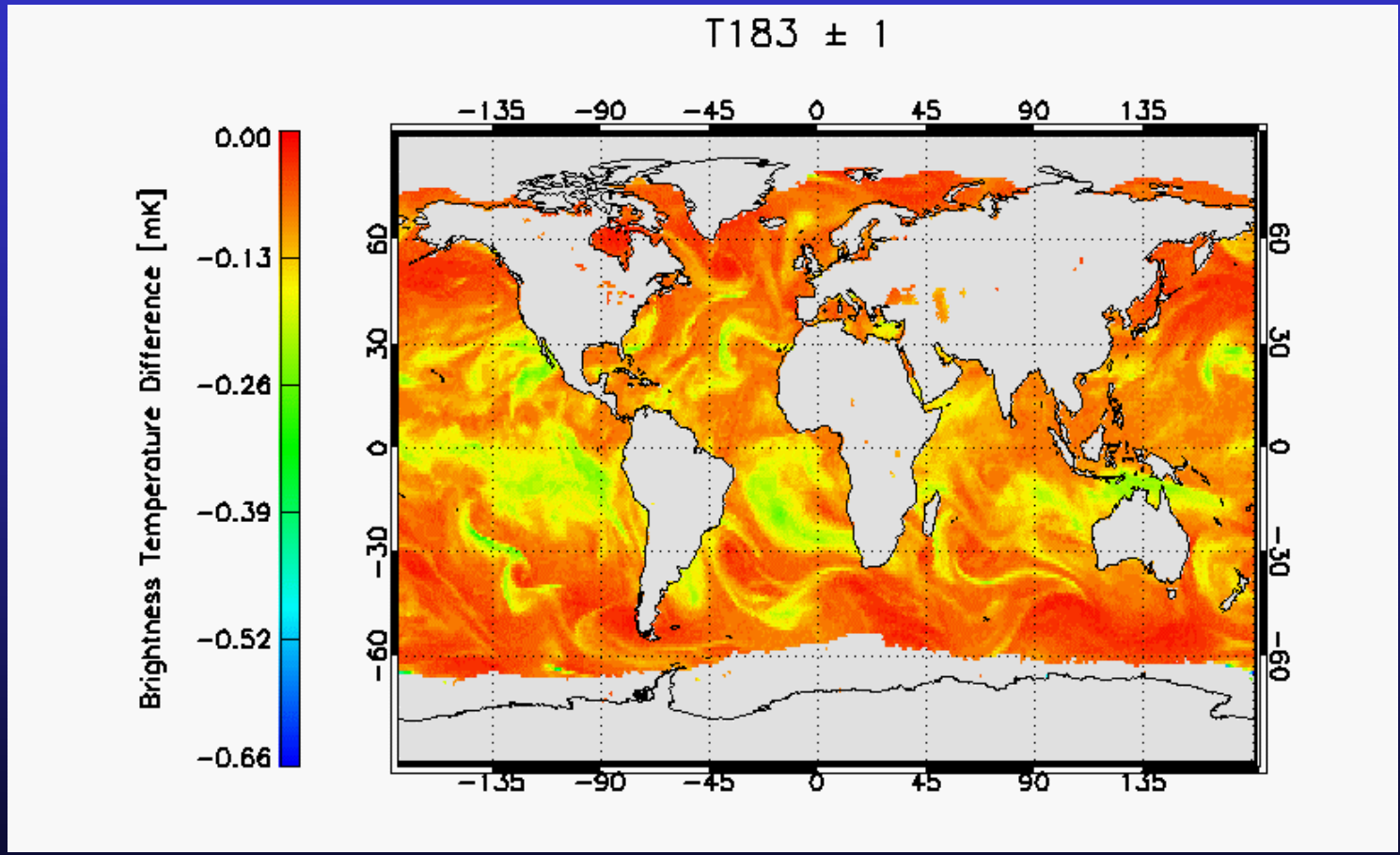
1st order interaction

2nd order interaction

Uses (truncated) doubling within layers

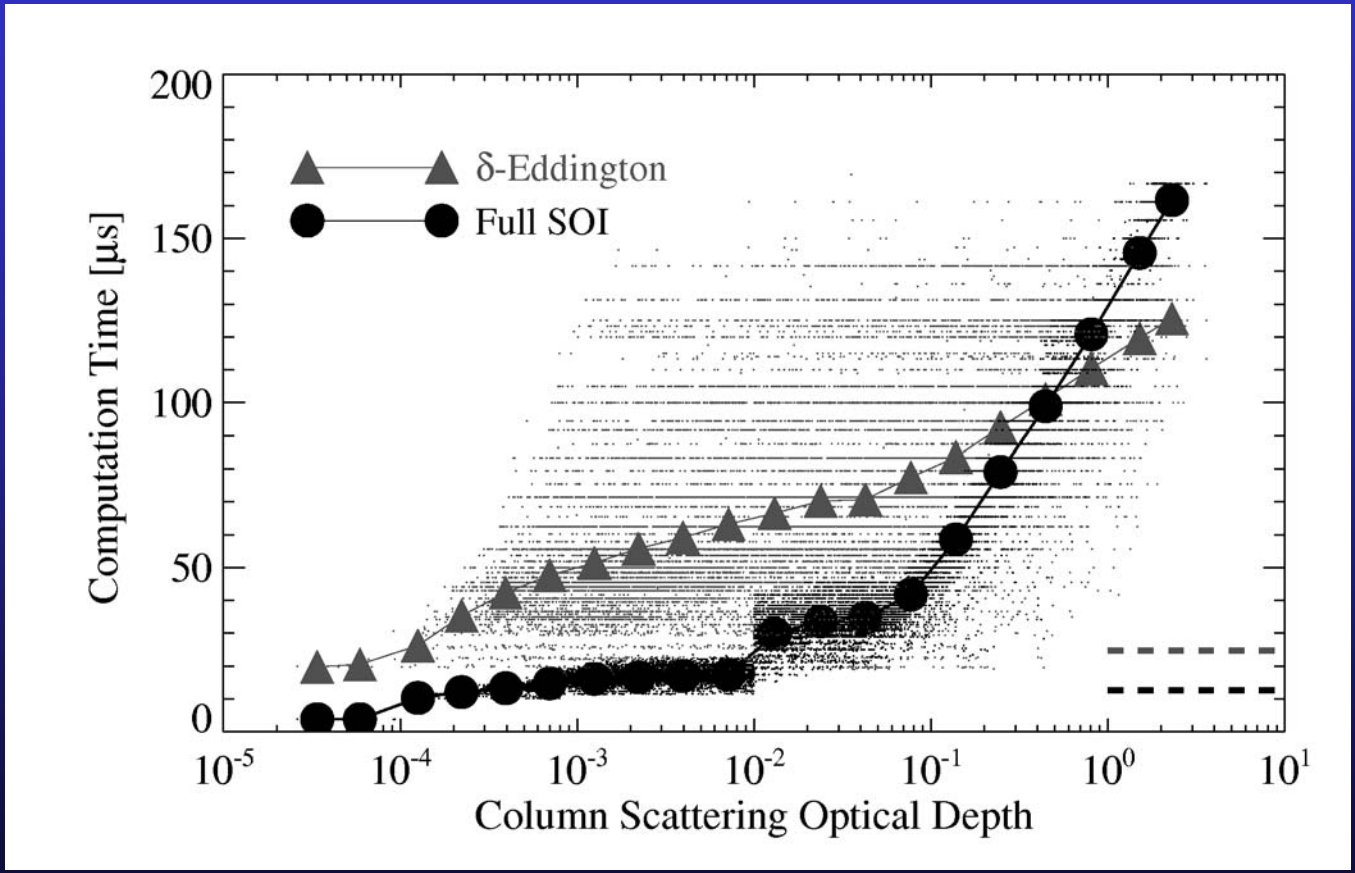
Uses accelerated successive order of scattering between layers

SOI - OPTRAN (gas absorption only)
Difference 89 GHz

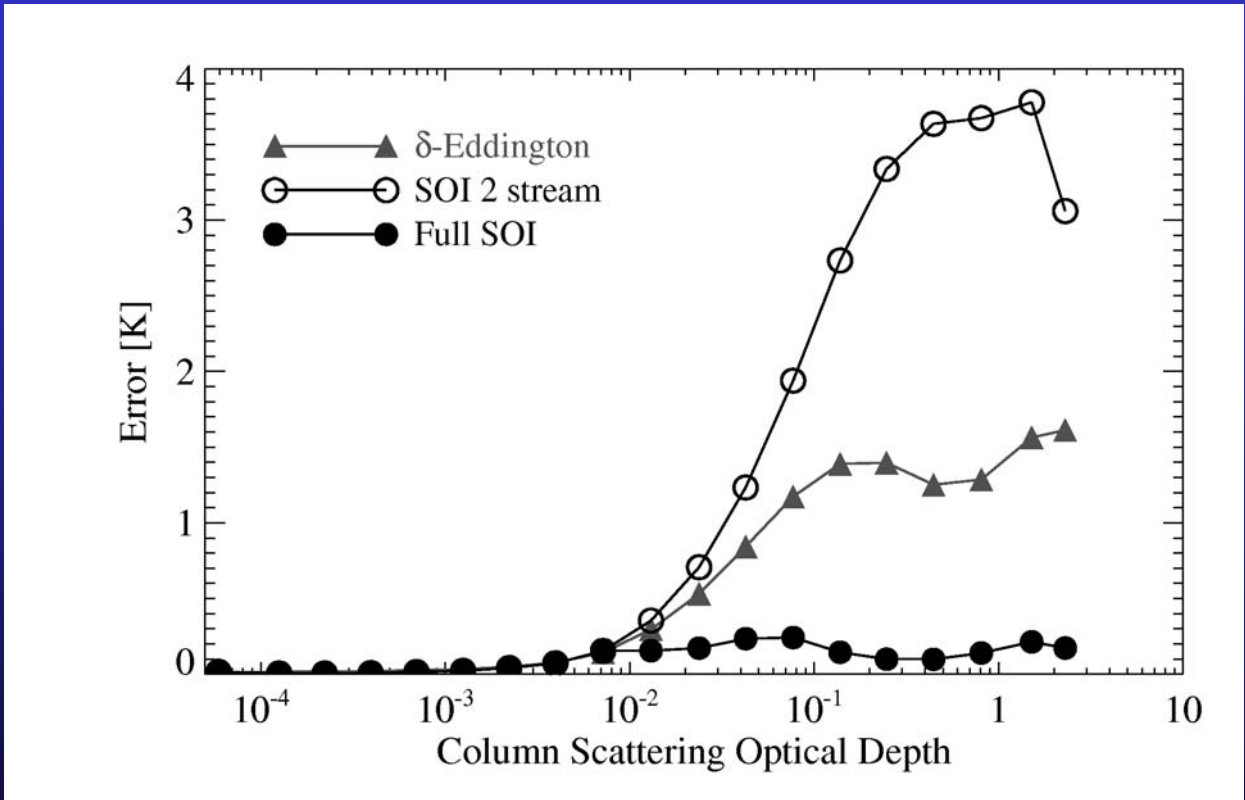


(Note: Units here are milli-Kelvin)

Speed Test (SOI versus RTTOV-8 Eddington)



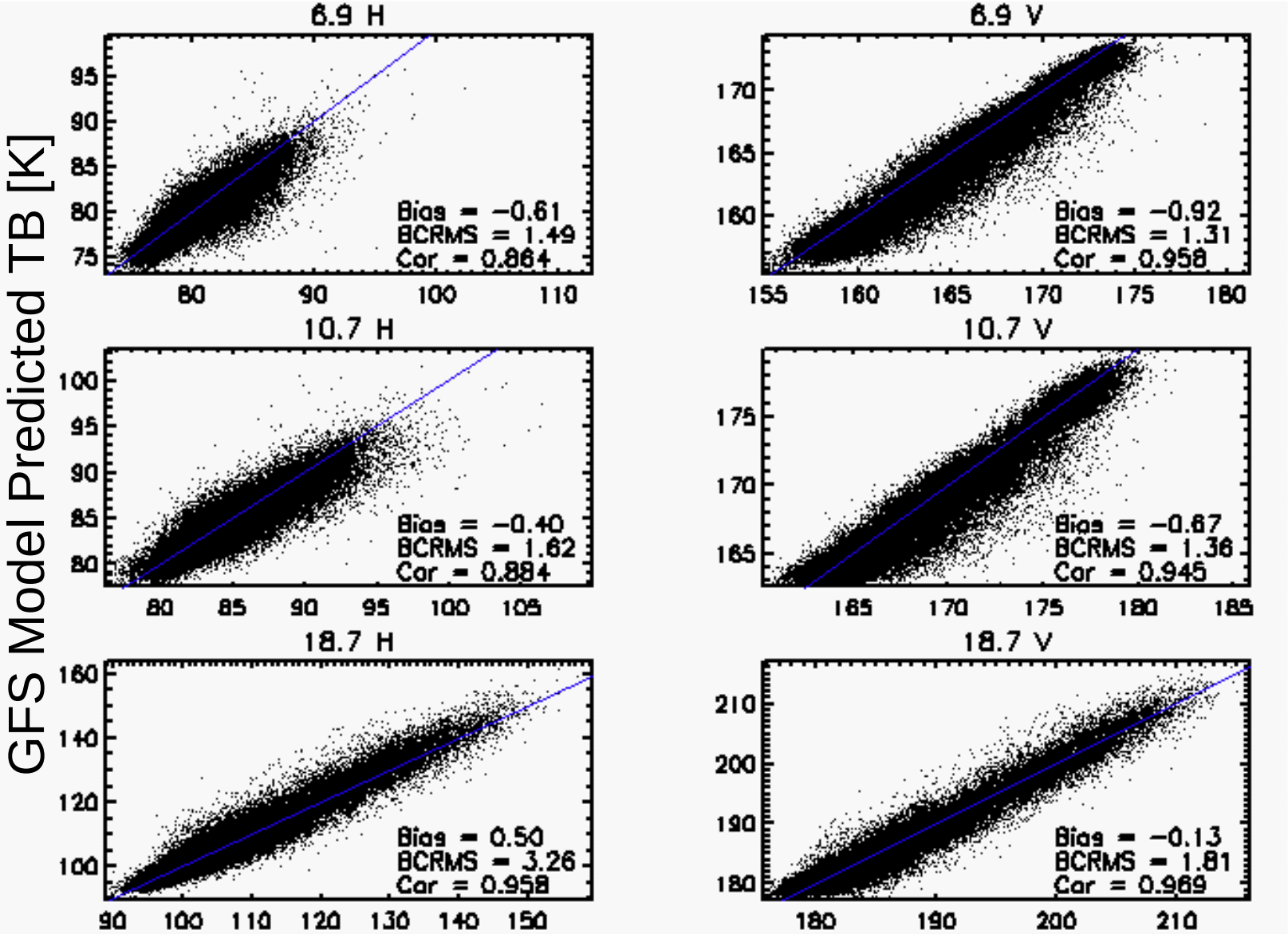
Accuracy of Results (Eddington and SOI versus Monte-Carlo model)



Setup for satellite versus GFS comparisons

- SOI radiative transfer
- Gas absorption:
  - RTTOV-8 for SEVIRI
  - CRTM/OPTRAN for AVHRR
  - Rosenkranz 98 (monochromatic) for MW
- Cloud/precip scattering & absorption:
  - Ice IR: B. Baum
  - Clouds, precip: Mie scattering
- FASTEM-2 surface emissivity

Clear-sky Biases microwave (6, 10, 19 GHz AMSR)

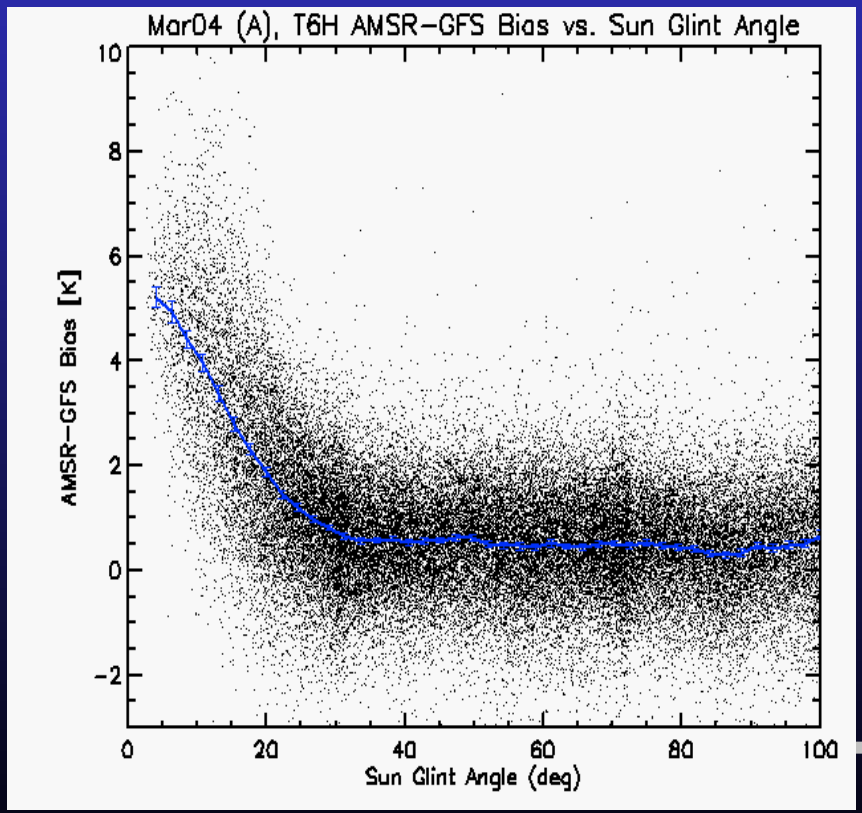


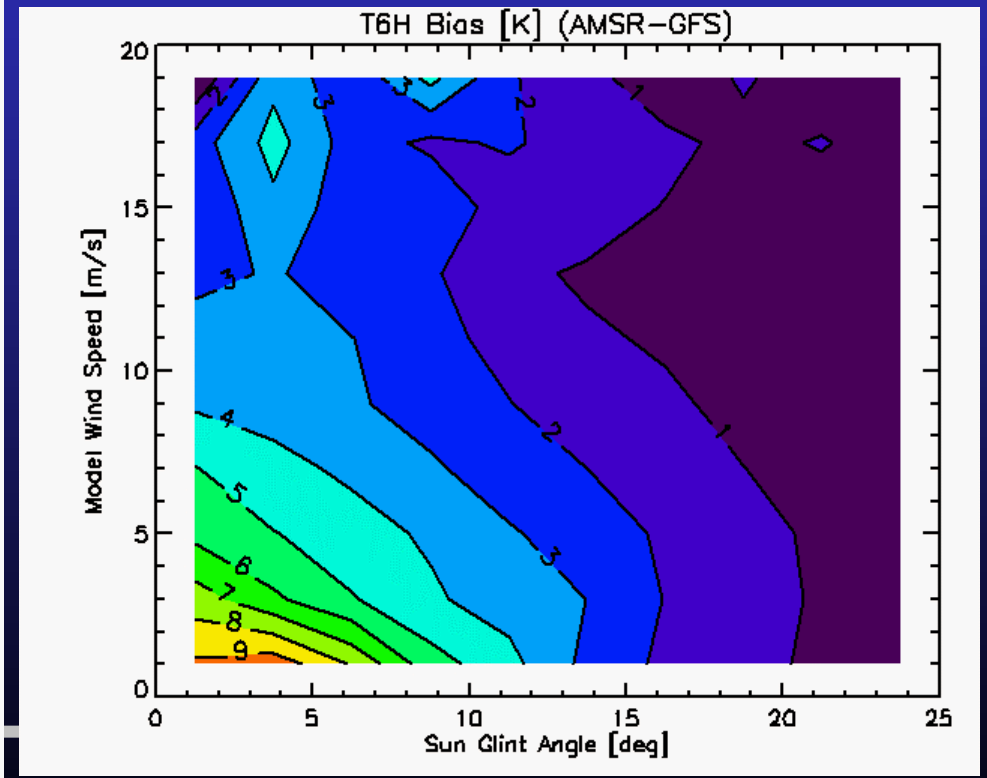
Clear-sky Biases microwave (6, 10, 19 GHz AMSR)

- TB variations driven by surface emissivity
- Needed to exclude Bragg scattering term in FASTEM 2 (was not designed for such low frequencies)
- Needed to exclude sun-glint contaminated areas

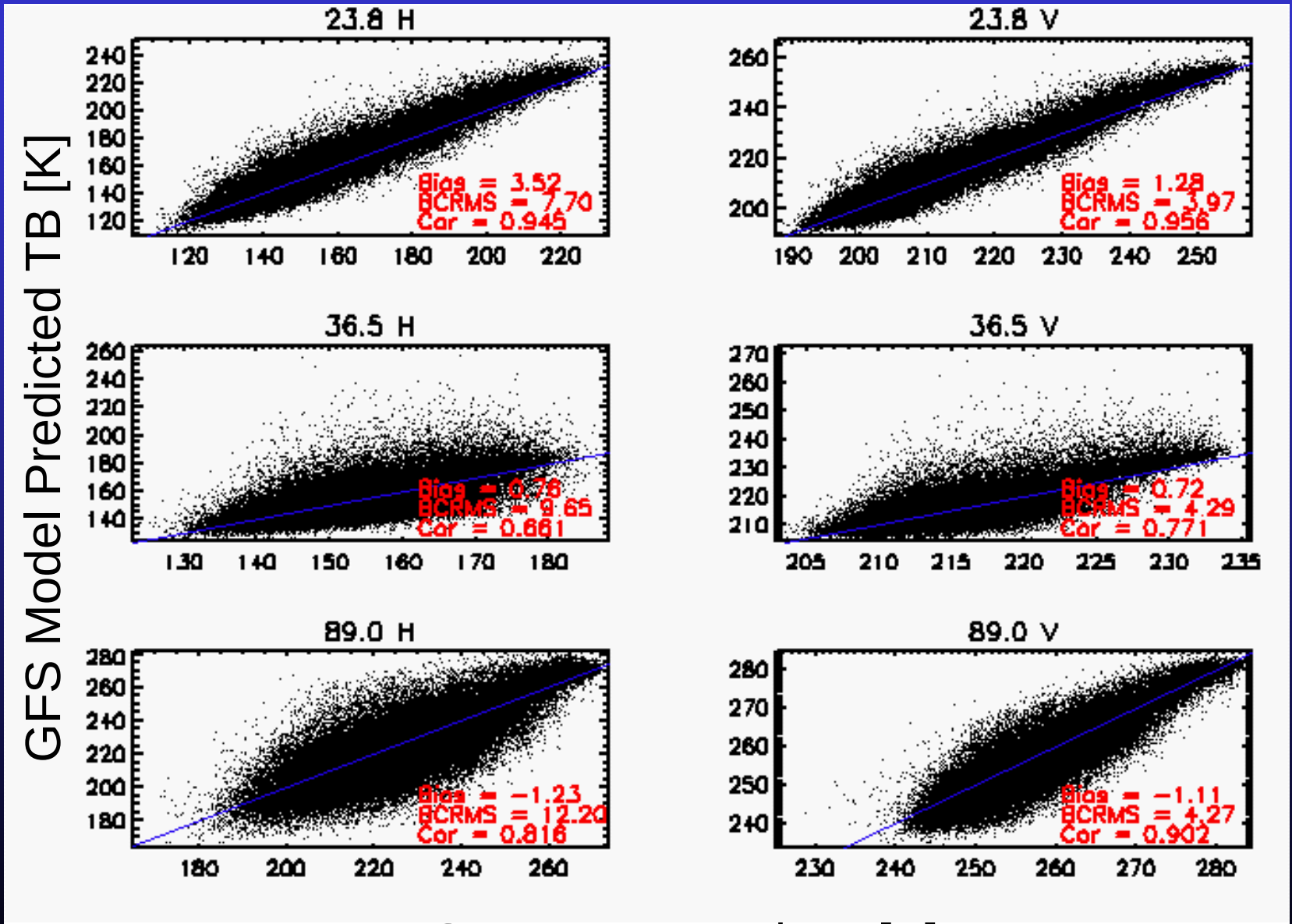
Sun Glint Clearly Observed

- Most pronounced at low frequencies due both to higher reflectivity and wider sensor beam width.
- Can be greater than 10 K effect at 6 GHz (about 4 K at 19 GHz -> SSM/I). Effect mitigated with higher wind speeds.





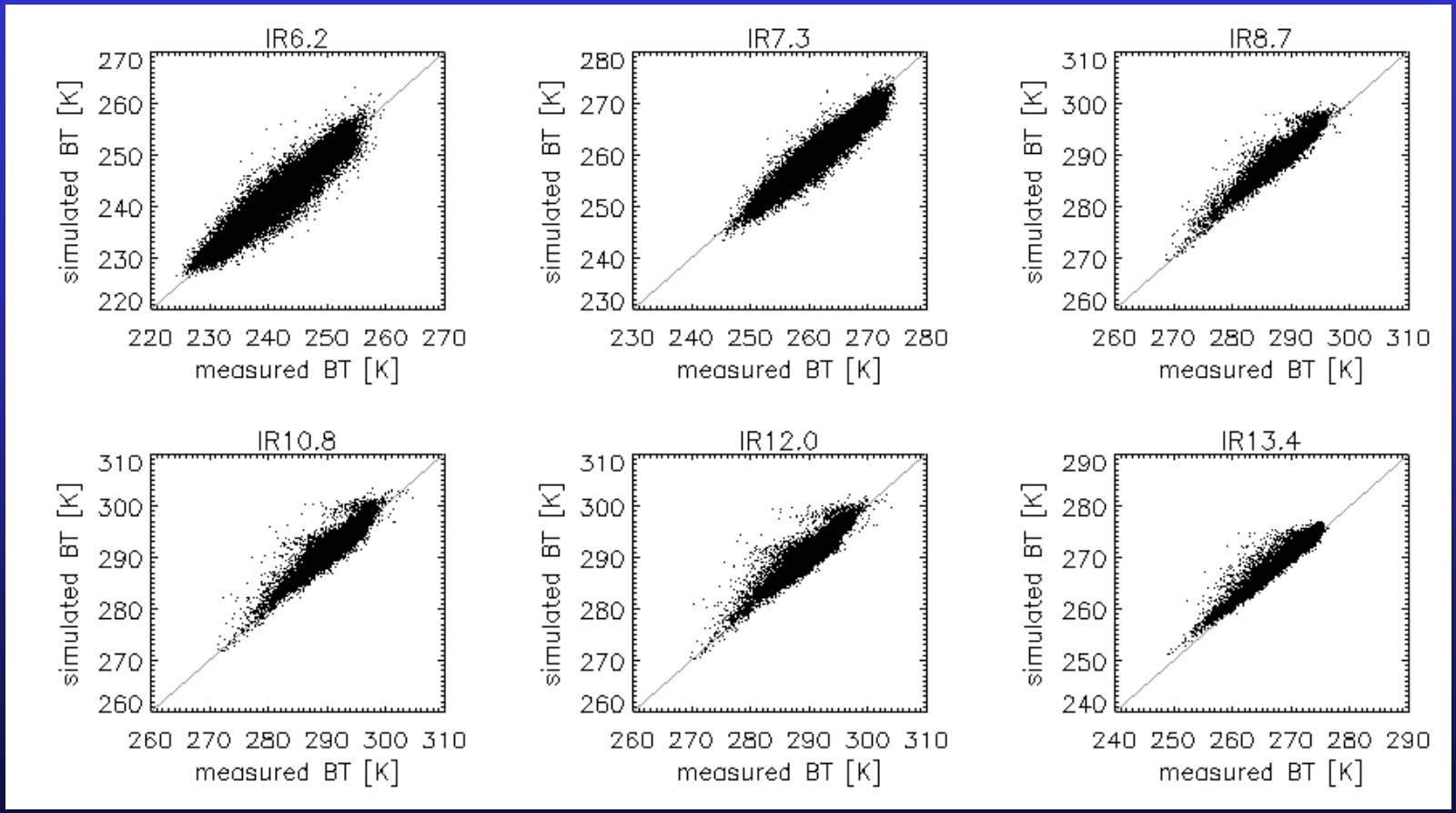
Cloudy-sky Biases (high frequencies)



Infrared:

Comparisons to MSG SEVIRI and AVHRR

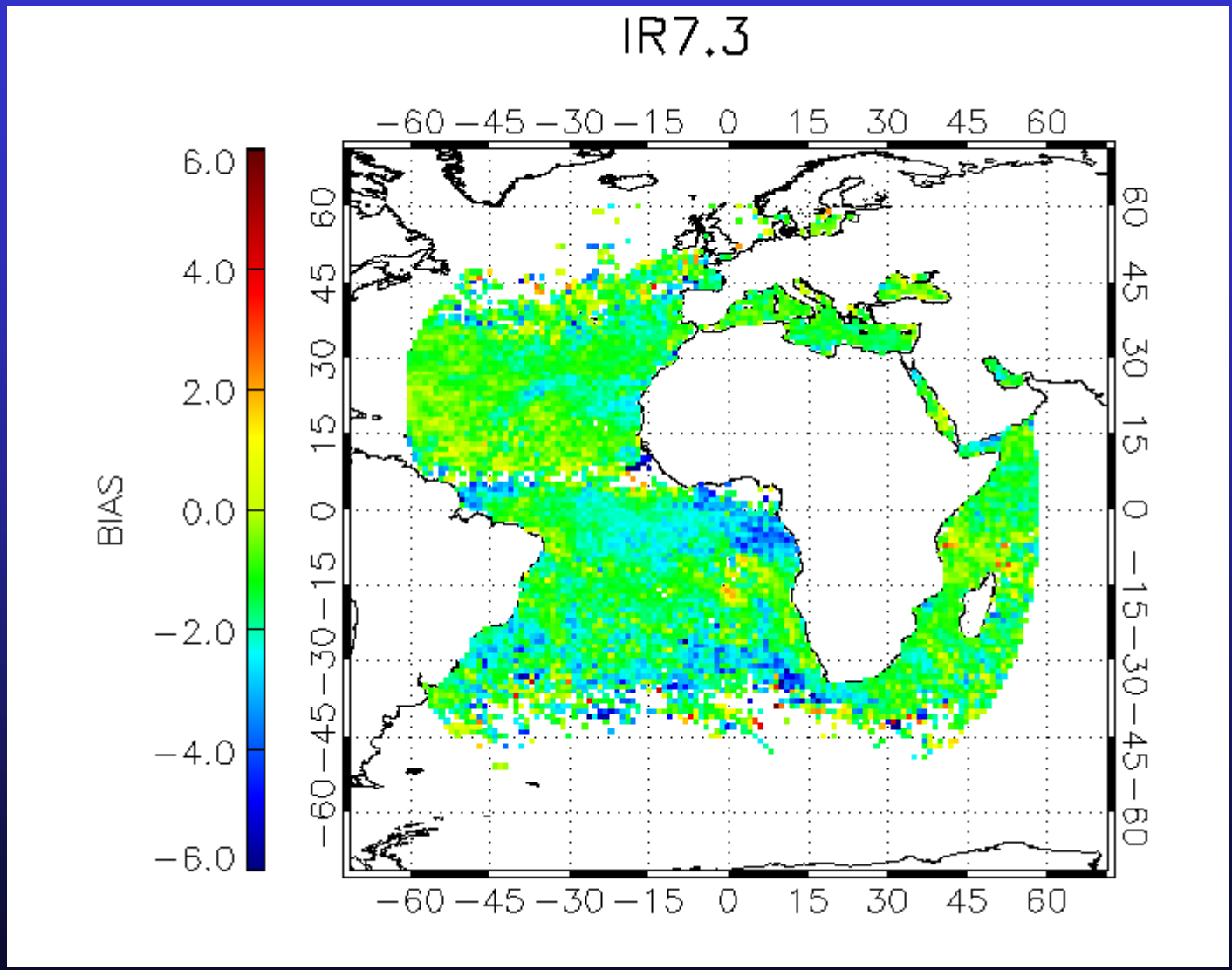
Infrared: MSG SEVIRI (June 2004)



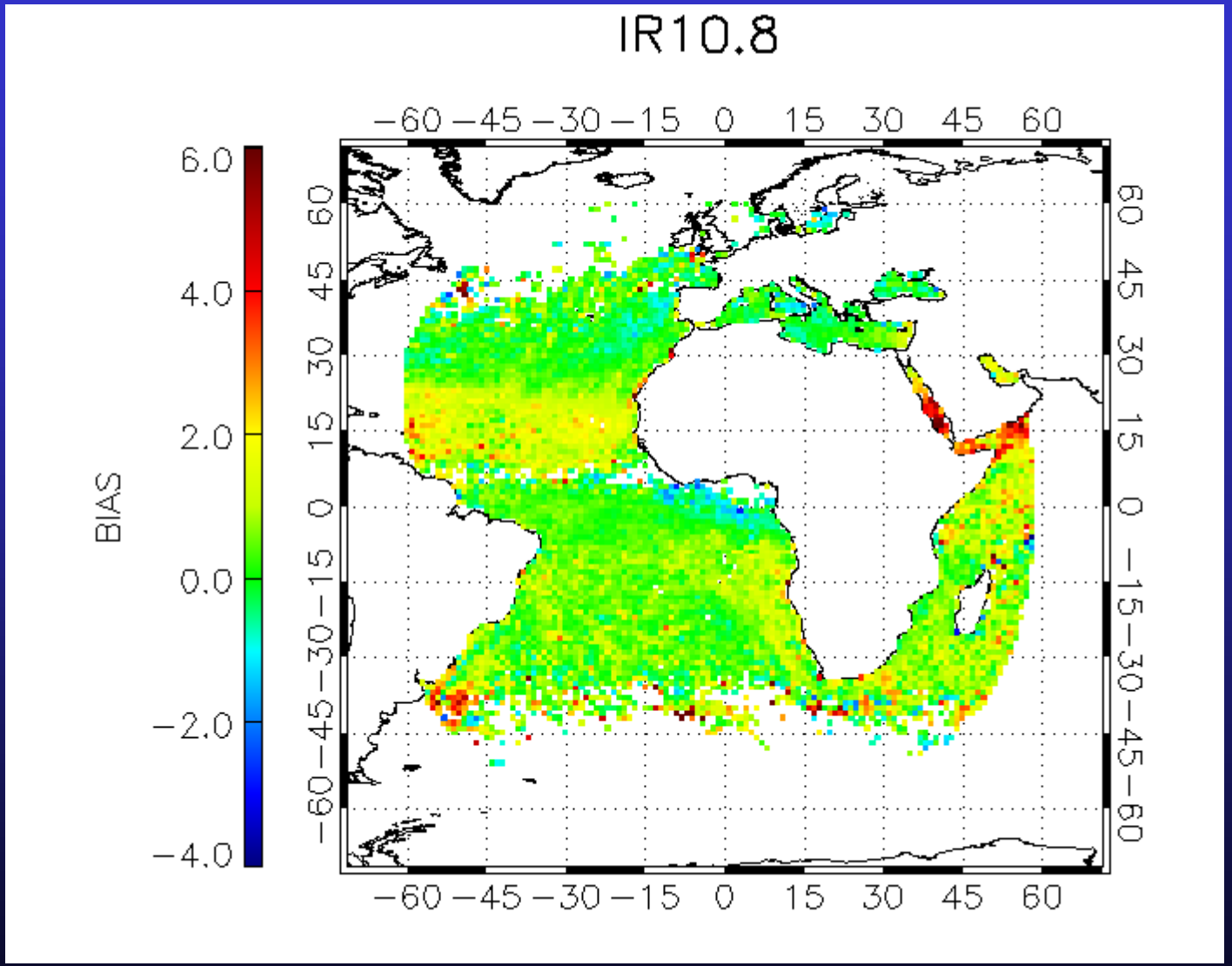
Infrared: MSG SEVIRI

Channel	RMSE [K]	Bias [K]
6.2	1.93	0.22
7.3	1.91	-1.25
8.7	1.54	1.17
10.8	1.38	0.73
12.0	1.37	0.64
13.4	1.37	1.06

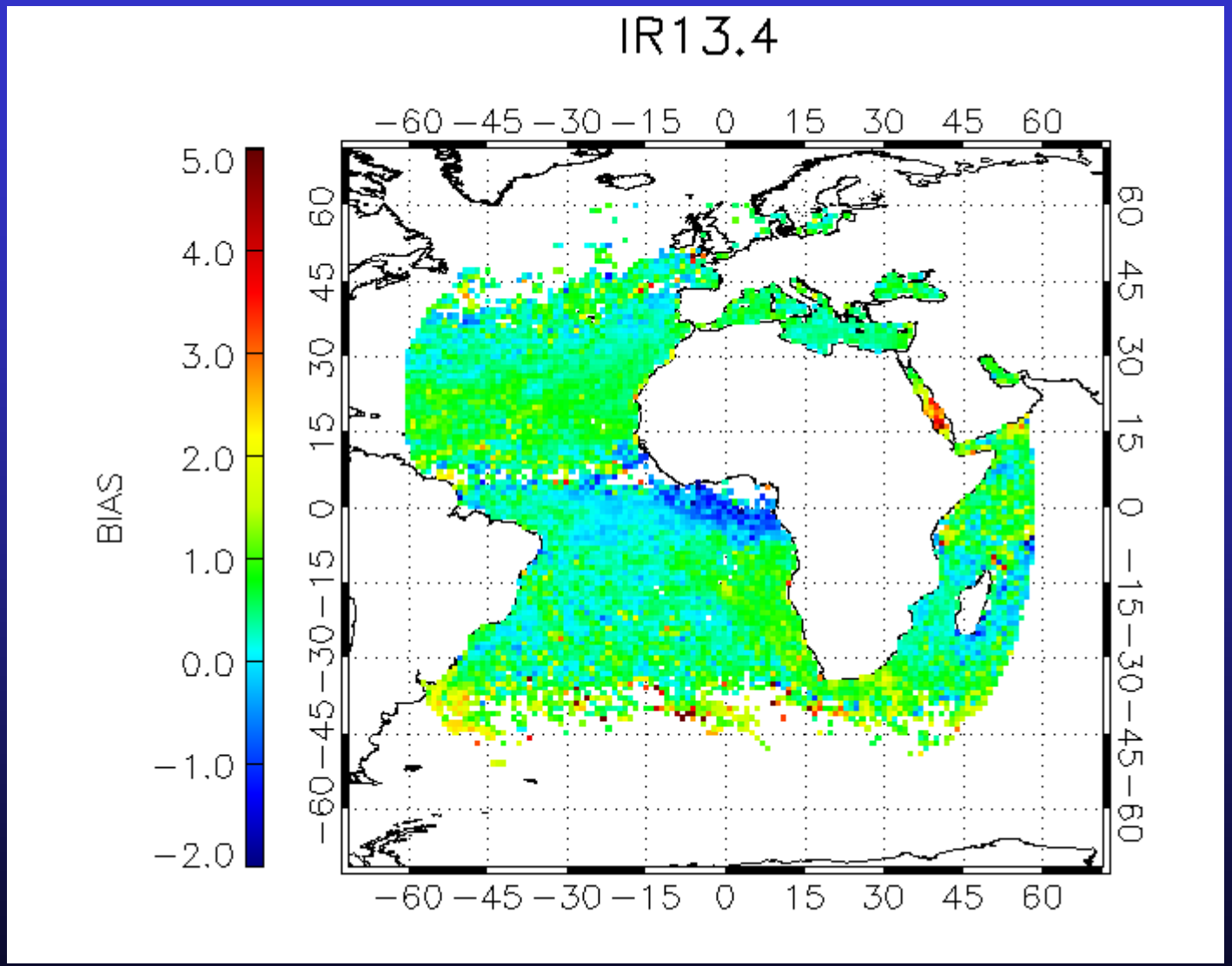
Infrared: MSG SEVIRI BIAS mid-trop WV



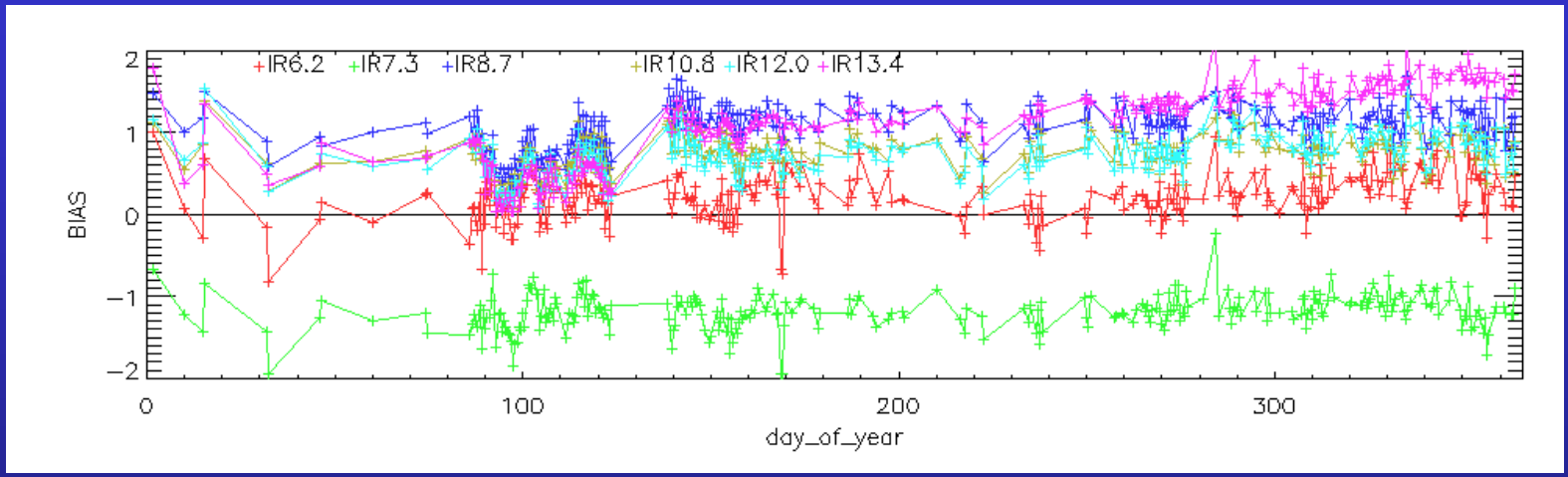
Infrared: MSG SEVIRI BIAS window

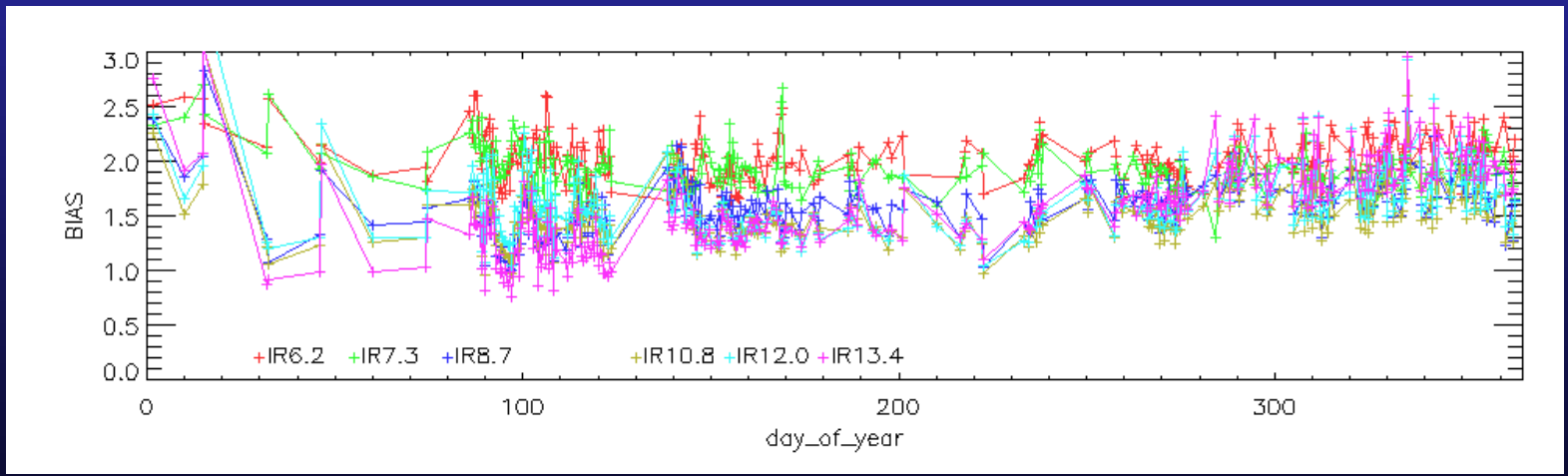


Infrared: MSG SEVIRI BIAS CO2



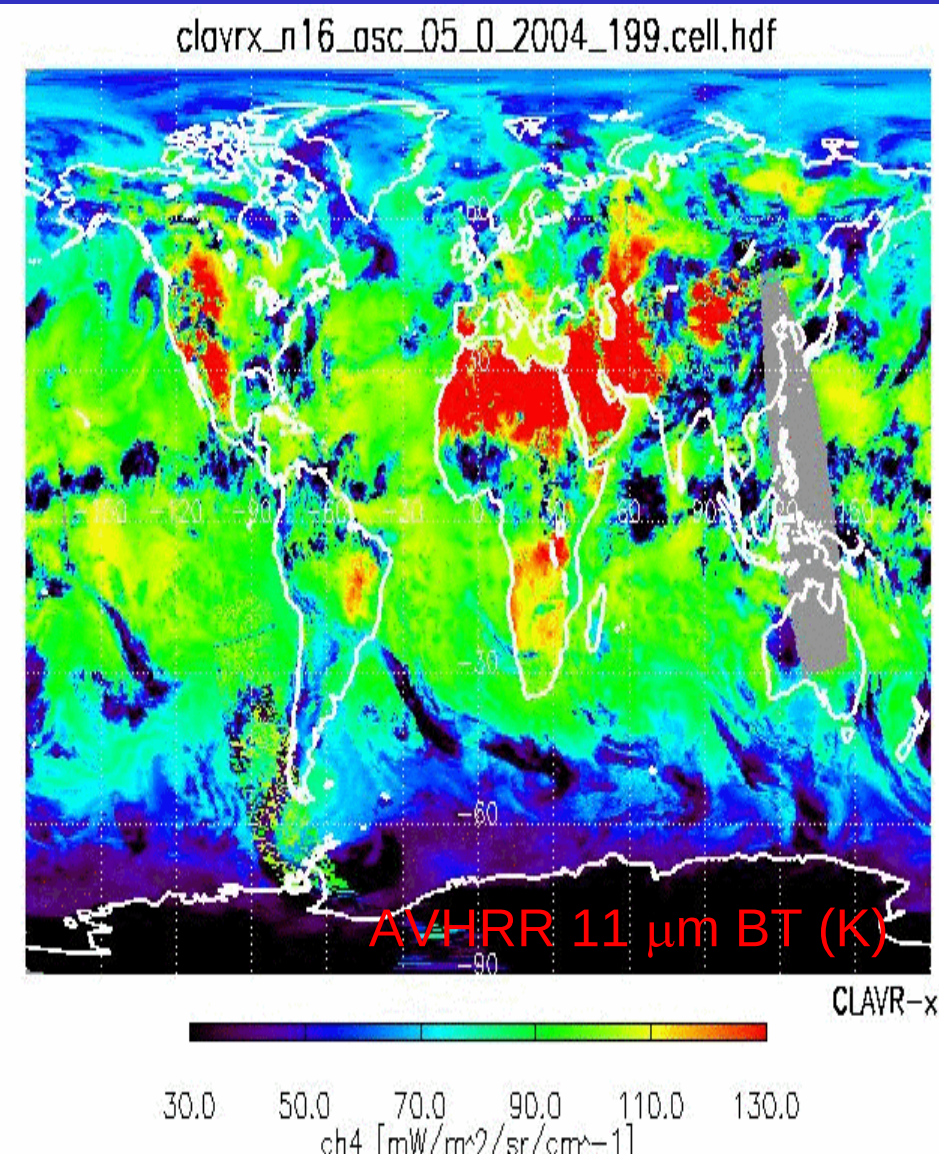
Time series bias/rmse 2004

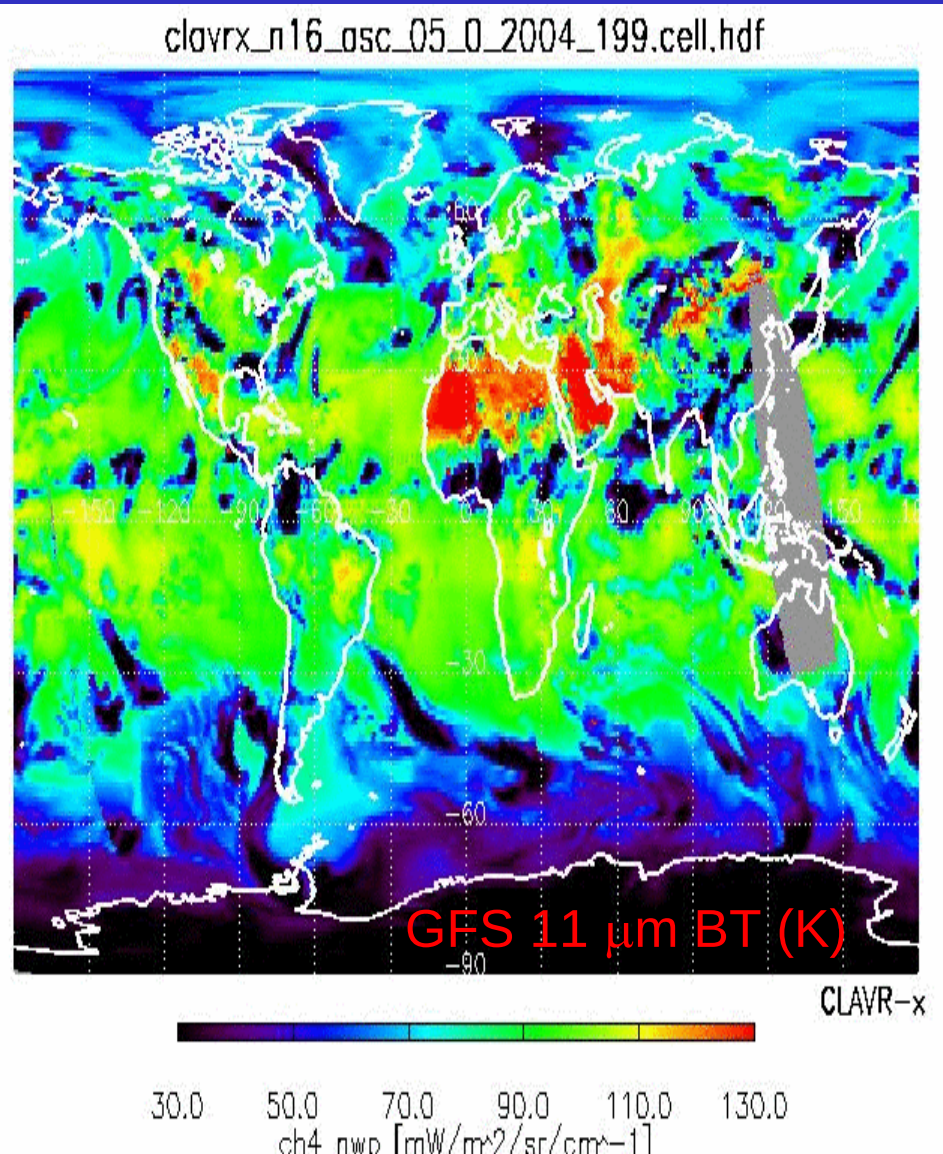




Comparison of ascending data from AVHRR Ch 4 on NOAA-16 for July 2004

We have started with analyzing 11 μm radiances because of their sensitivity to cloud height / opacity and due to their abundance (all imagers/sounders)



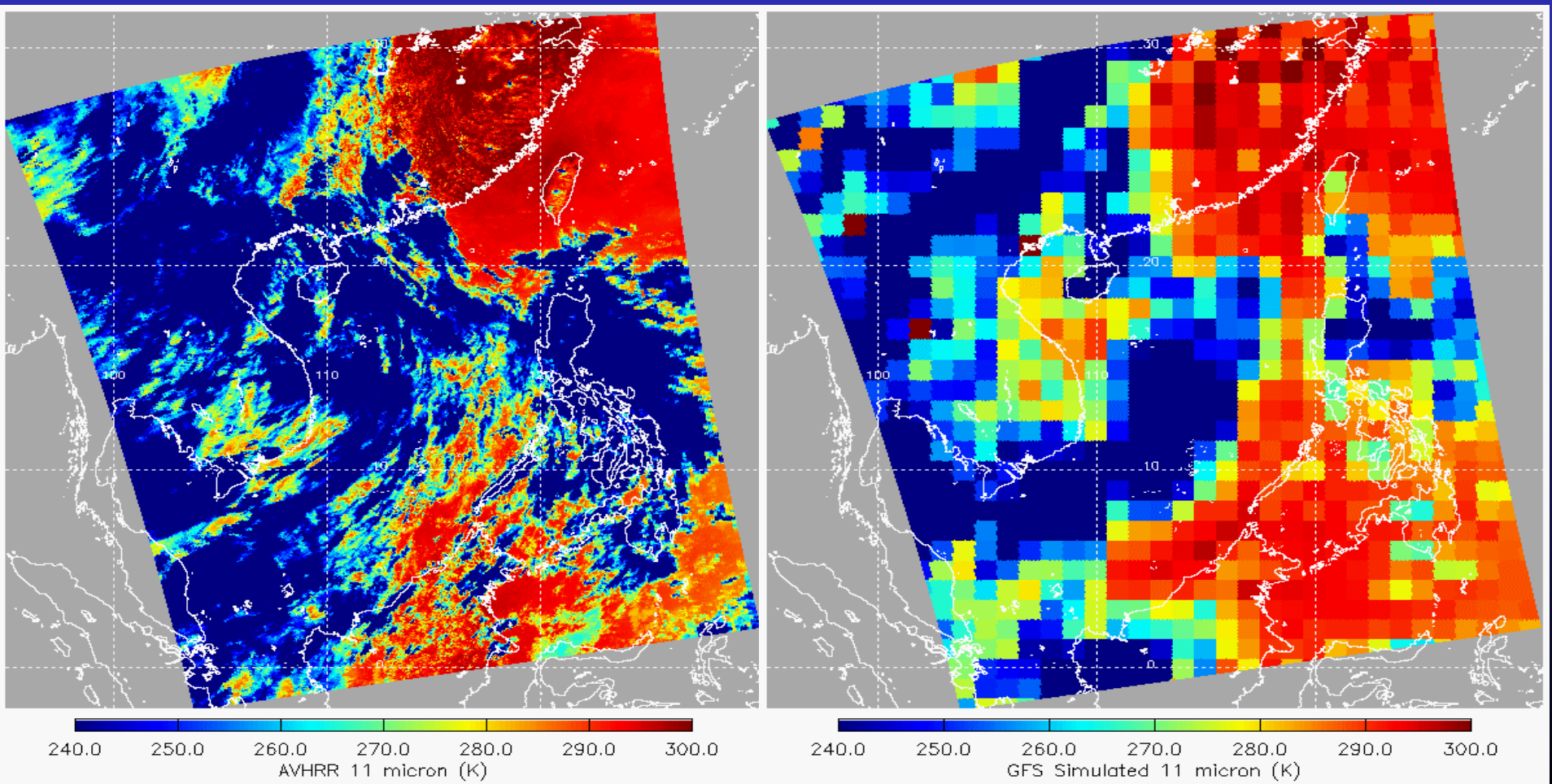


Regional Scale Comparisons of Satellite and GFS 11 μm Brightness Temps.

While the global comparison indicate agreement on the synoptic scales, there are difference revealed in smaller scales.

AVHRR 11 μm BT at 6Z

GFS Simulated 11 μm BT at 6Z



Conclusions and outlook

- SOI provides a fast and accurate radiative transfer model including full treatment of scattering. Included in CRTM.
- We plan to extend the GFS comparisons (IR+MW) to longer time series and evaluate model cloud/precip against observations. Extend to AIRS
- Motivated by NCEP interest, we are currently developing a capability to simulate infrared radiances (6.7, 11 and 12 mm) from imagers from the GFS forecasts.
- SOI model (FWD/TL/AD) including documentation and related publications is available at:

naftali.aos.wisc.du/soi