Connecting ATMS to AMSU Time Series for Long-Term Monitoring of Climate Change

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Outline

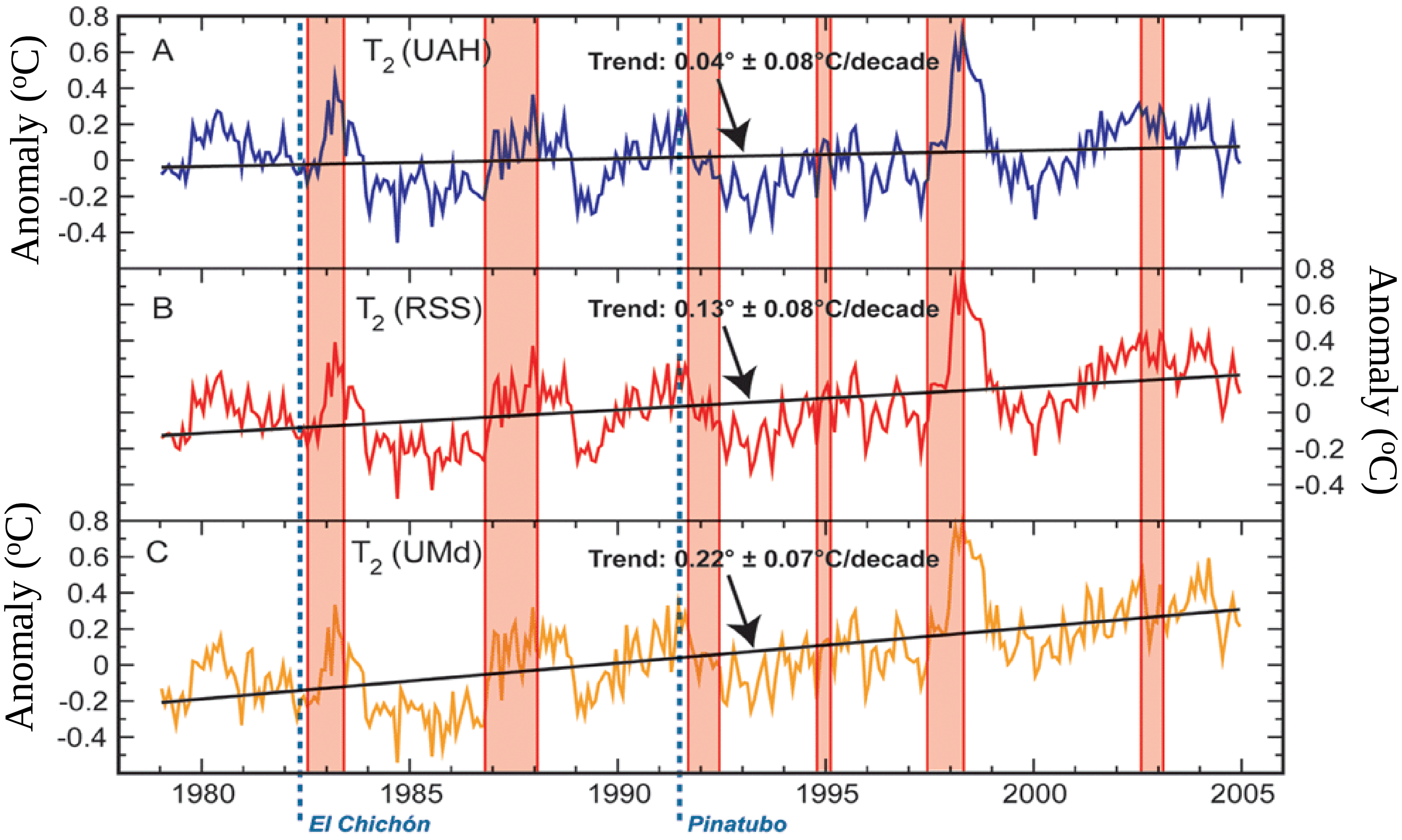
- **Satellite Microwave Sounding Data for Climate Study**
  - ✓ MSU/AMSU climate data record (CDR)
  - ✓ Cloud impact on MSU/AMSU trend
  - ✓ 1D-Var derived temperature trend
- **Converting ATMS into AMSU-like Observations**
  - ✓ The need for a spatial homogenization
  - ✓ ATMS remapping algorithm
  - ✓ Differences resulted from remap within TCs
  - ✓ SNO data sample & quality control
- **Numerical Results**
- **Summary and Future Plan**

T2 Trends Obtained from Three MSU CDR Datasets

UAH Trend: 0.04^{o}C/Decade

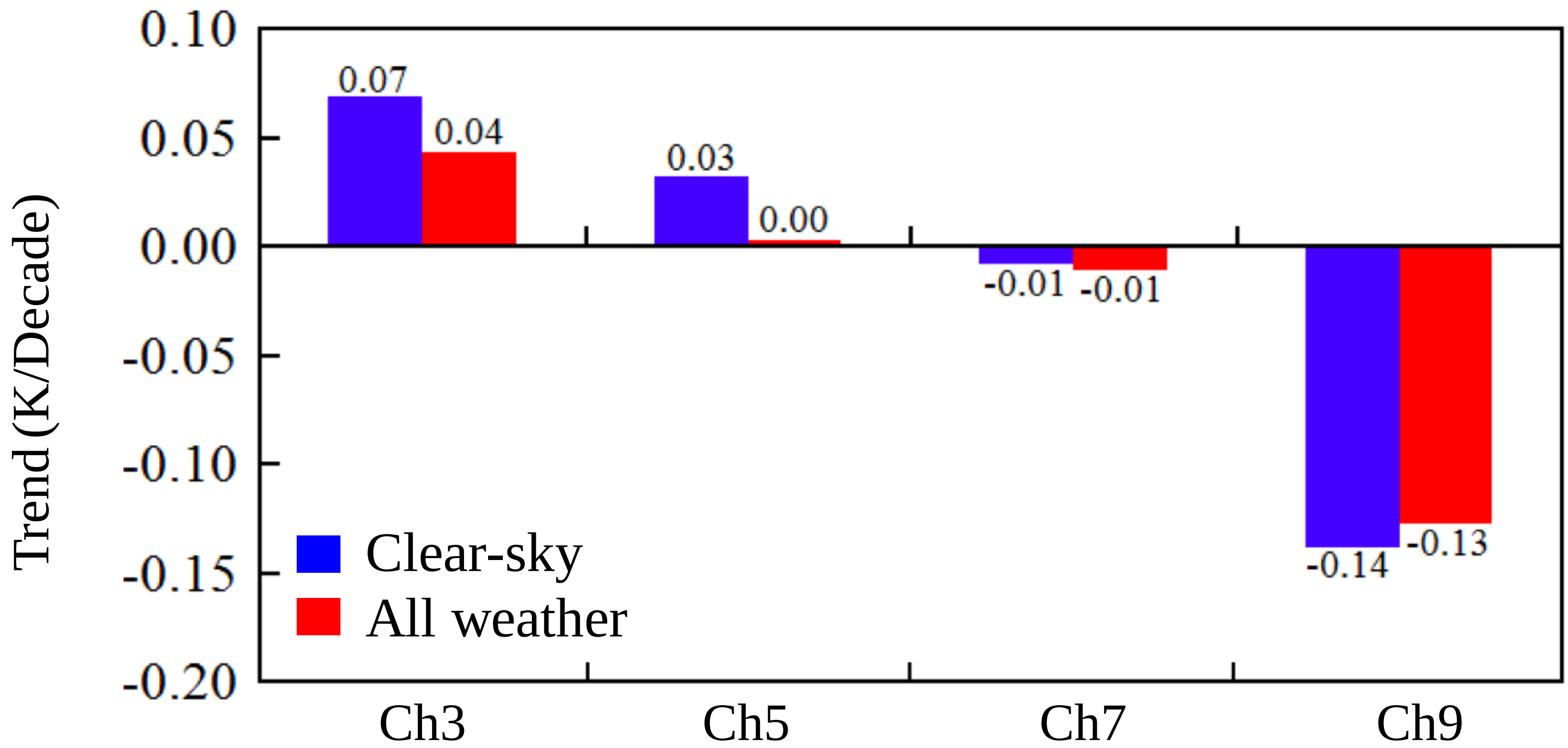
RSS Trend 0.13^{o}C/Decade

UMD Trend: 0.22^{o}C/Decade



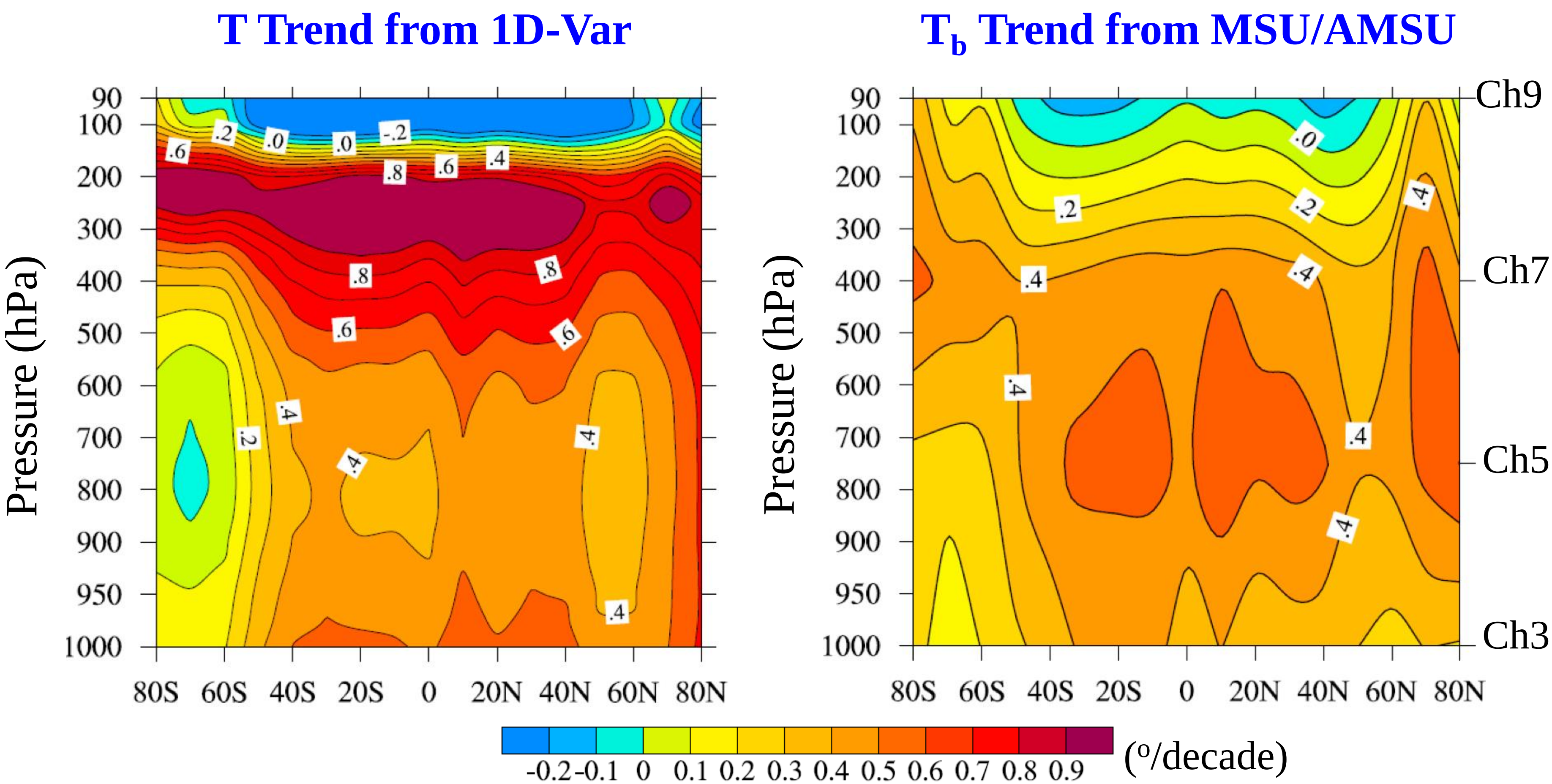
Large differences of the T2 trend may be partially related to different ways of calculating biases from one instrument to the next and other calibration details in three different CDR datasets, which are obtained from the same SDR observations.

Cloud Impact on MSU/AMSU Derived Trends



Weng, F. X. Zou and Z. Qin, 2013: Uncertainty of AMSU-A derived temperature trends in relationship with clouds and precipitation. *Clim. Dyn.*, DOI 10.1007/ s00382-013-1958-7.

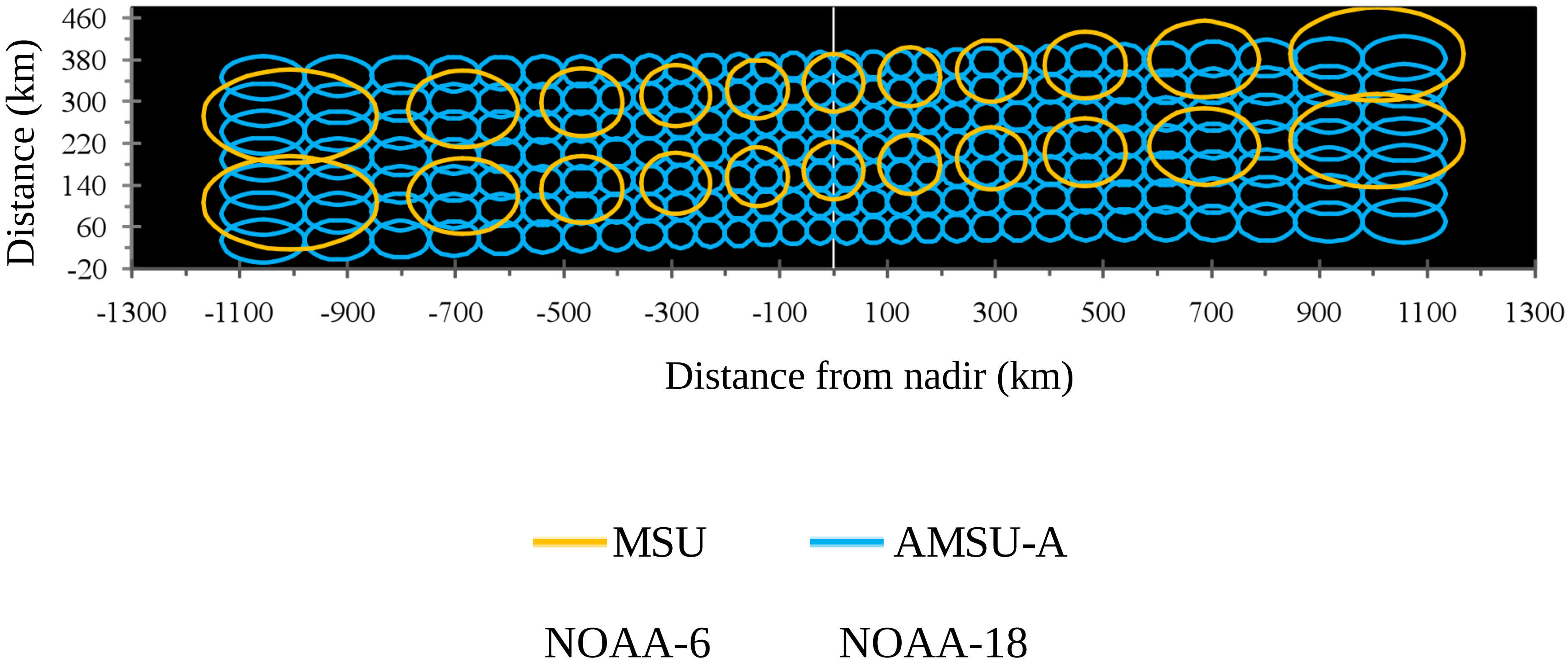
1D-Var Derived Temperature Trend



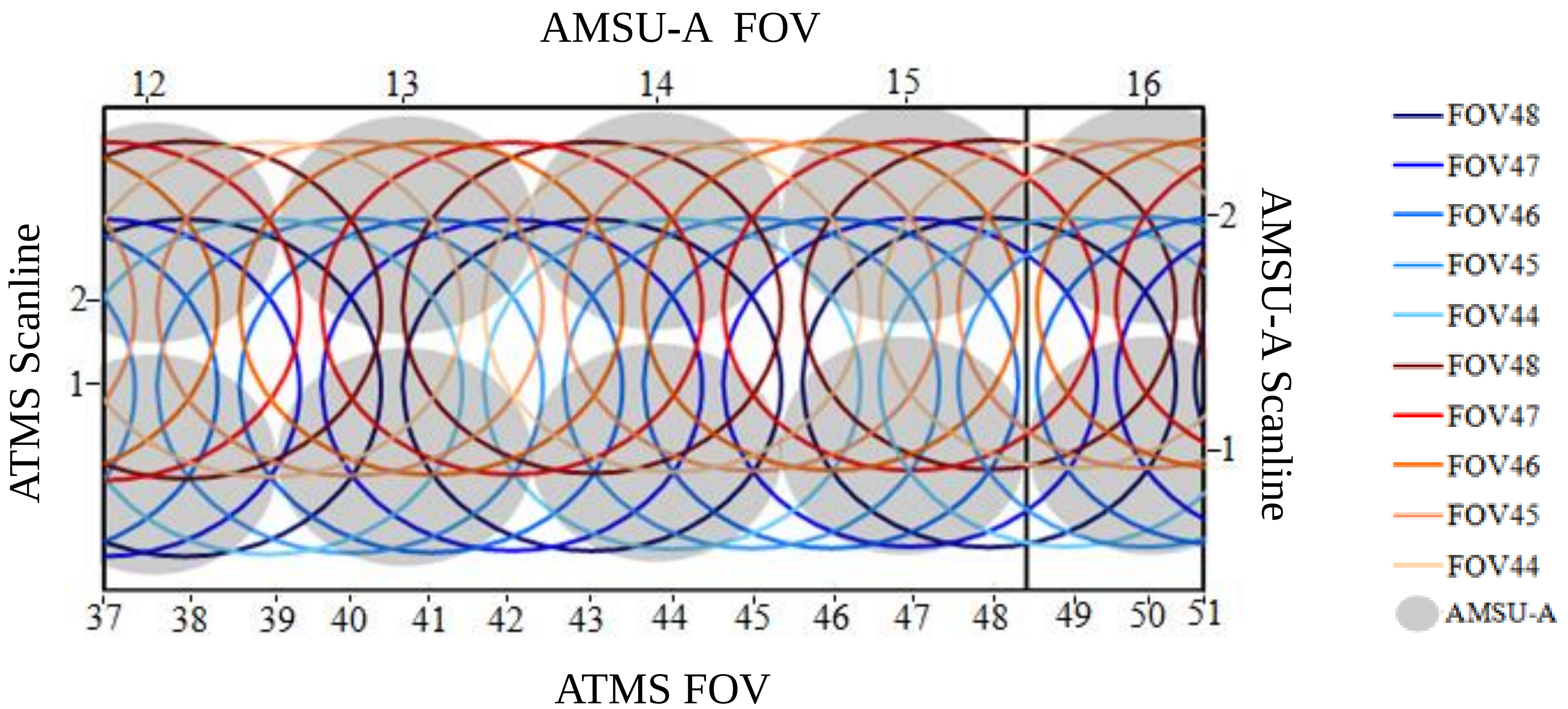
Weng, F. and X. Zou, 2013: 30-year atmospheric temperature trend derived by one-dimensional variational data assimilation of MSU/AMSU-A observations. *Clim. Dyn.*, DOI: 10.1007/s00382-013-2012-5.

The Need for a Spatial Homogenization

FOV Comparison between MSU and AMSU-A

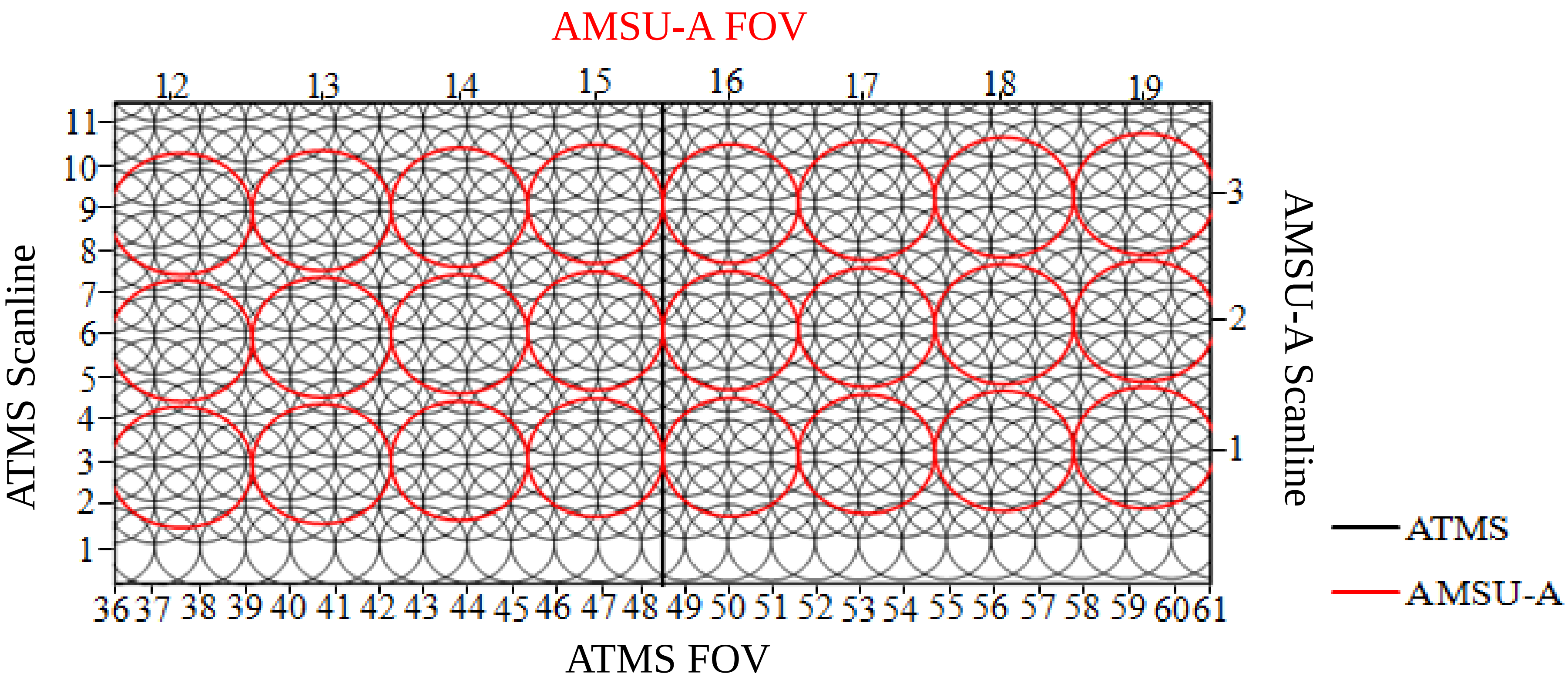


FOV Comparison between ATMS and AMSU-A for Window Channels 1-2



ATMS channels 1-2 beam width 5.2°
AMSU-A channels 1-2 beam width 3.3°

FOV Size Comparison between ATMS (channels 3-16) and AMSU-A (channels 3-15)



ATMS beam width 2.2°, AMSU-A beam width 3.3°

ATMS Remapping Algorithm

$$T_{b,k,l}^{ATMS\ remap} = \sum_{i,j=-N_{ch}}^{N_{ch}} w_{i,j} T_{b,k+i,l+j}^{ATMS}$$

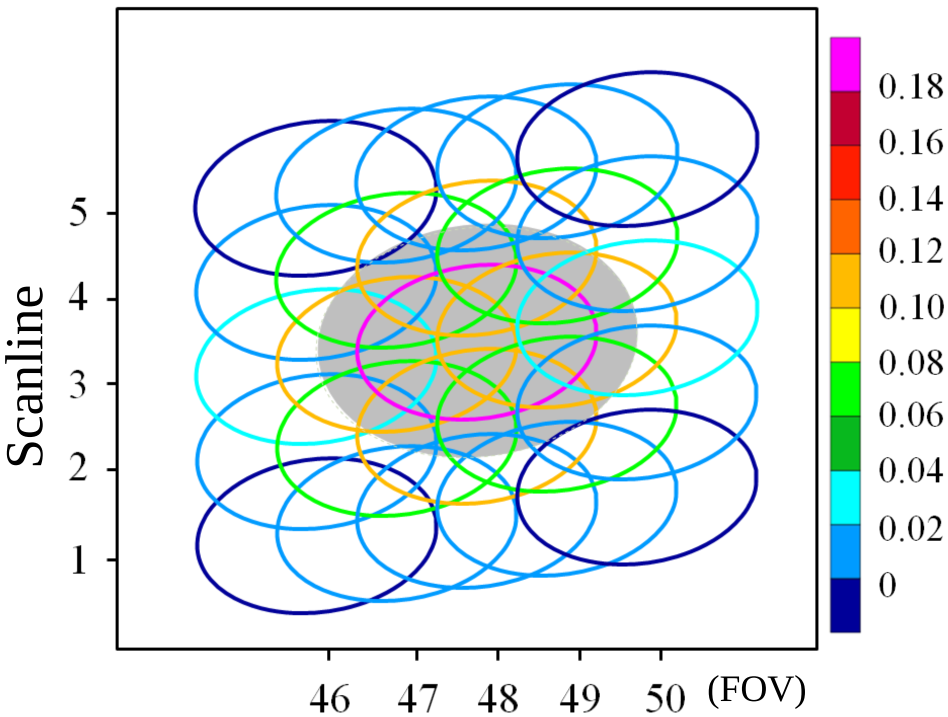
$w_{i,j}$ – B-G coefficients

$$N_{ch} = \begin{cases} 1 & \text{channels 1-2} \\ 2 & \text{channels 3-16} \end{cases}$$

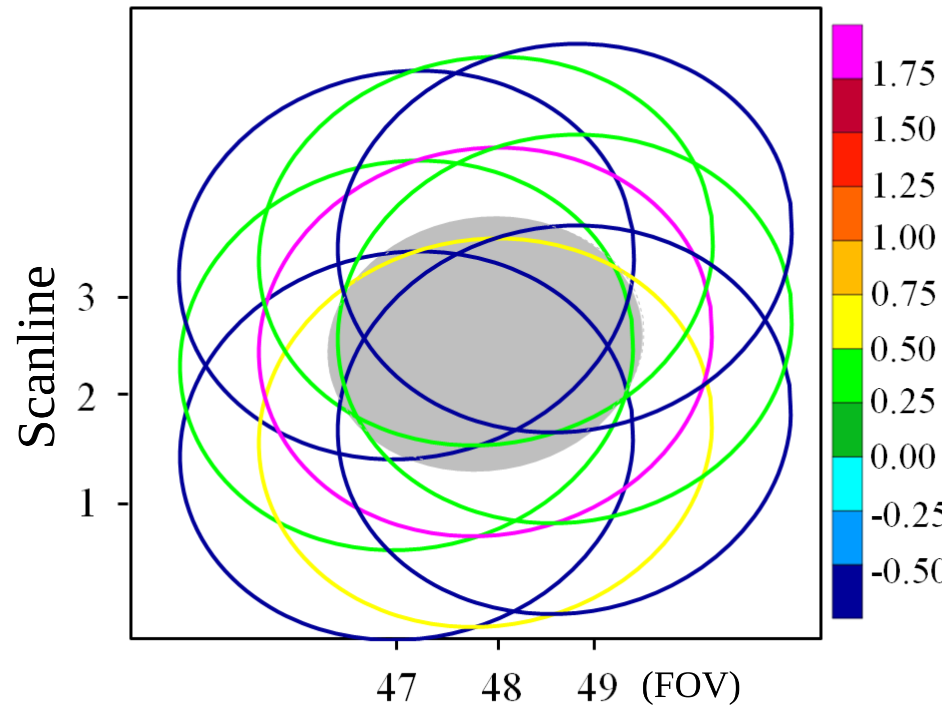
Stogryn, A., 1978: Estimates of brightness temperatures from scanning radiometer data. *IEEE Transaction on antennas and Propagation*, Vol. AP-26, No.5, 720-726.

B-G Coefficients for ATMS Remap near Nadir

ATMS Channels 3-16



ATMS Channels 1-2

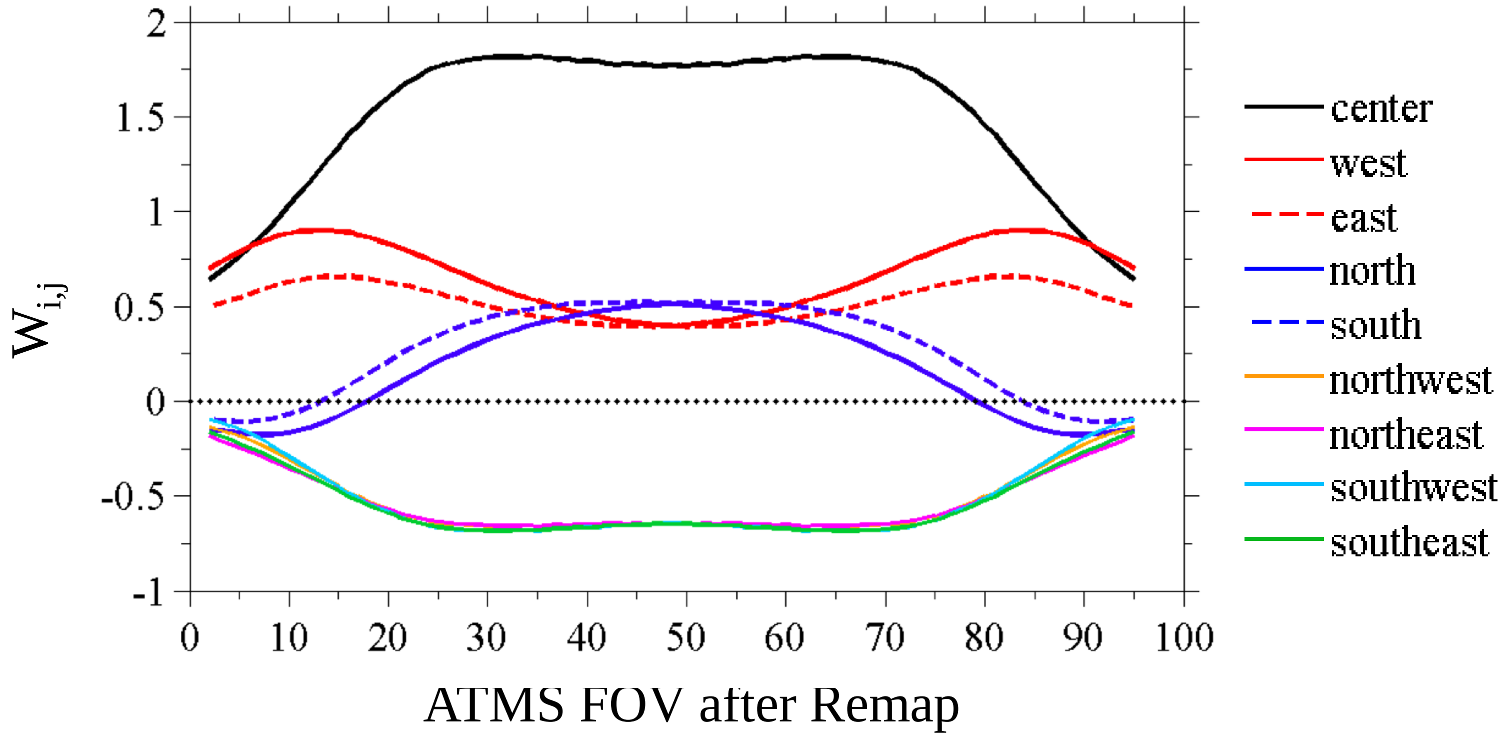


An effective AMSU-A target FOV: output of BG remap (shaded in gray)

ATMS effective FOVs: Circles with colors indicating the magnitude of BG coefficients

B-G Coefficients for ATMS Remap at All FOVs

Channels 1-2

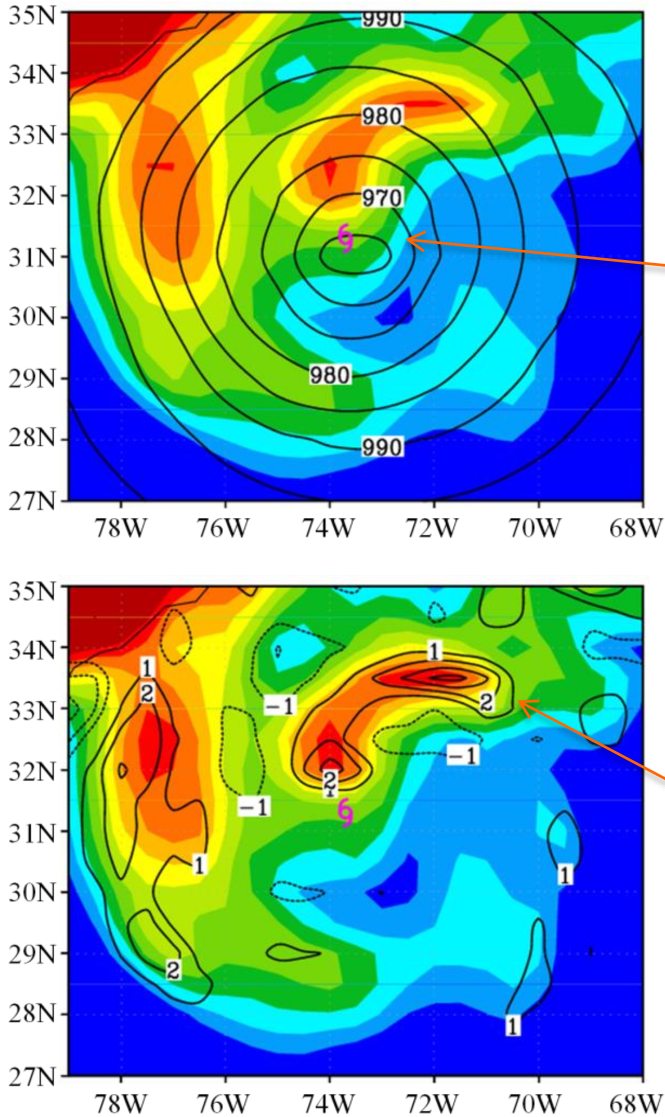


T_b at Channel 1 within Sandy before and after Remap

(0600 UTC October 28, 2012)

T_b

(before remap)



NCEP GFS SLP

(contour interval: 10hPa)

T_b^{remap}

(after remap)

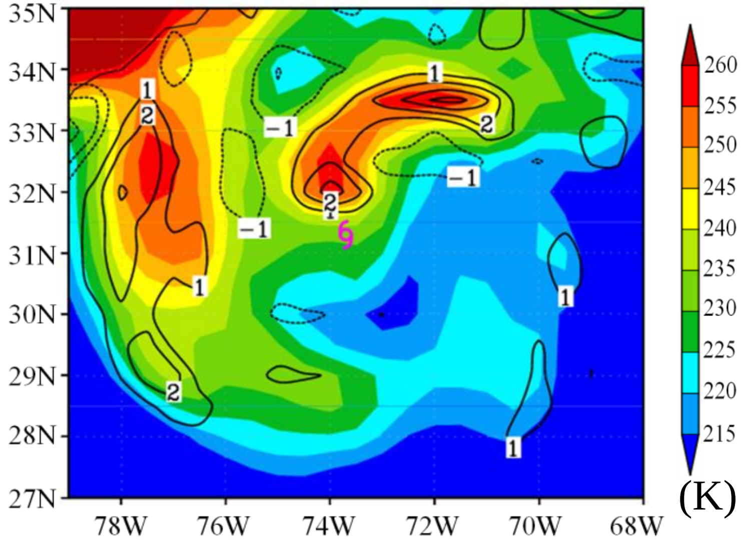
$$\Delta T_b = T_b^{remap} - T_b$$

(contour interval: 1K)

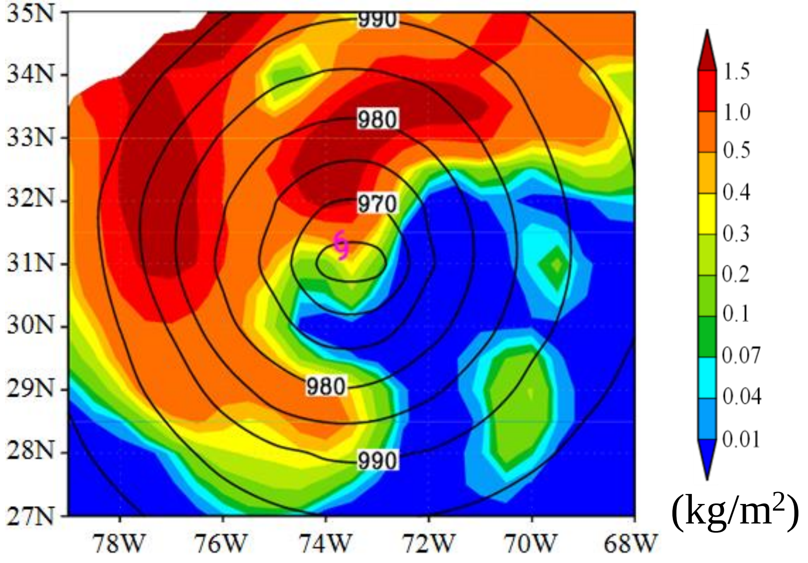
T_b at Channel 1 within Sandy before and after Remap

(0600 UTC October 28, 2012)

T_b^{remap} and ΔT_b



LWP

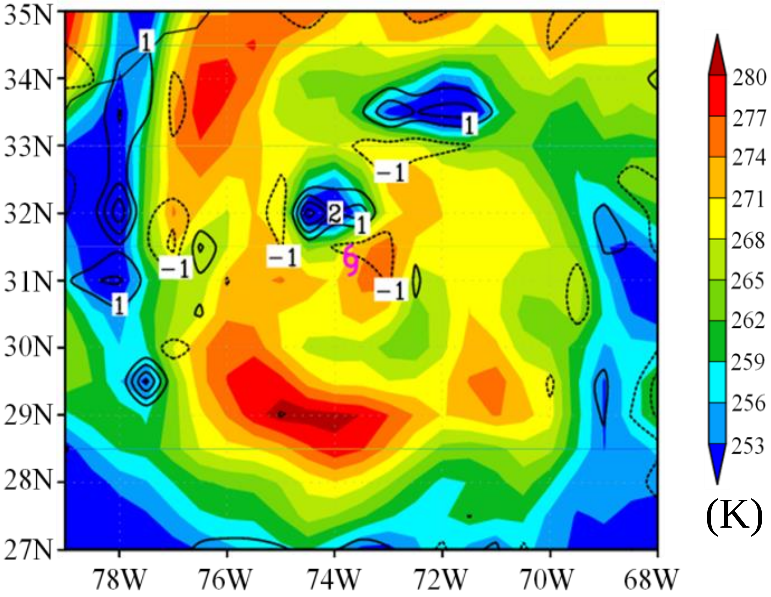


- The measured brightness temperatures at 23.8 GHz are higher over hurricane rainbands due to the contributions from cloud and water vapor emission
- The maximum brightness temperatures over cloud areas after remap are more than 2-3K lower than those before the remap
- The gradients of brightness temperatures near cloud edges become sharper

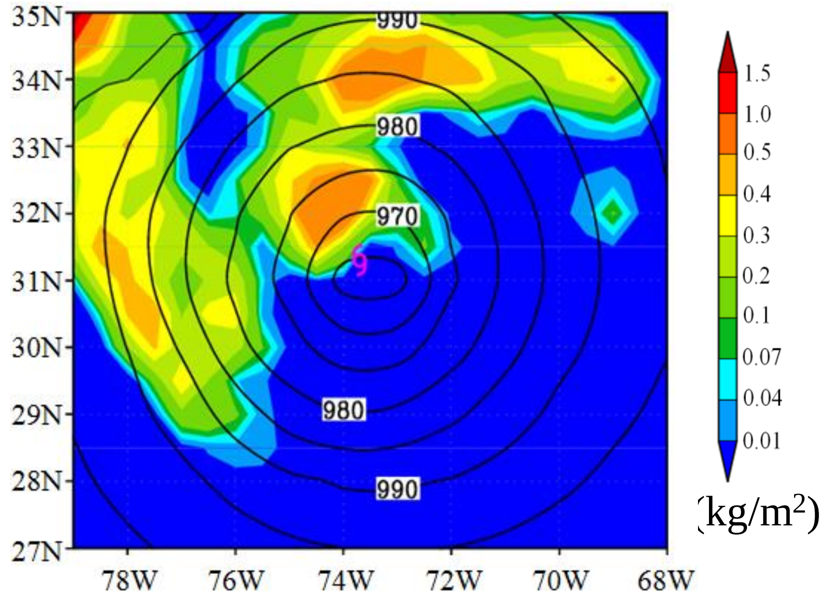
T_b at Channel 16 within Sandy before and after Remap

(0600 UTC October 28, 2012)

T_b^{remap} and ΔT_b

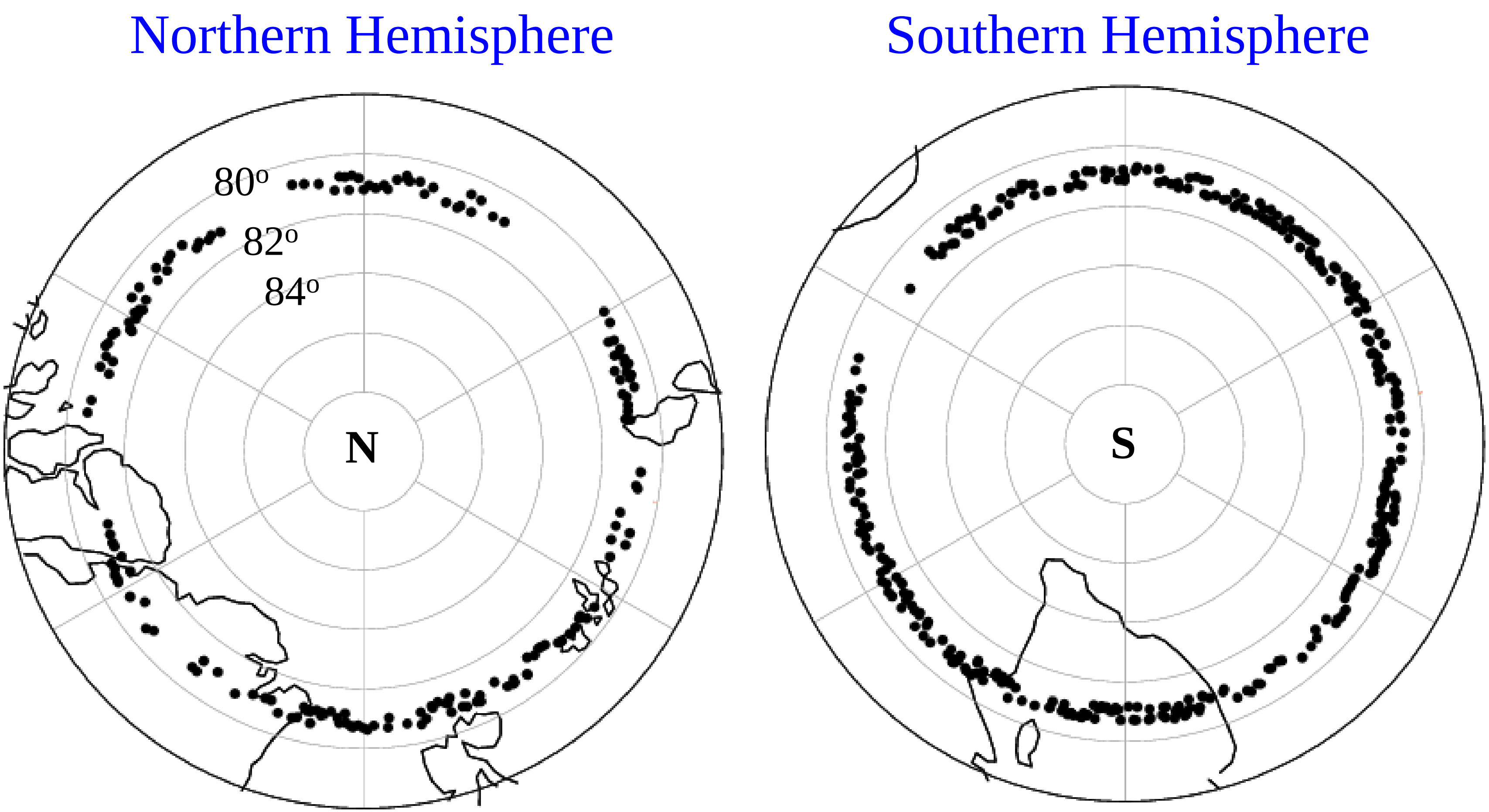


IWP



- The measured brightness temperatures at 88.2 GHz are lower over areas with ice cloud within hurricane rainbands due to ice scattering effect on radiation
- The minimum brightness temperatures over ice cloud areas after remap are more than 2-3K lower than those before the remap

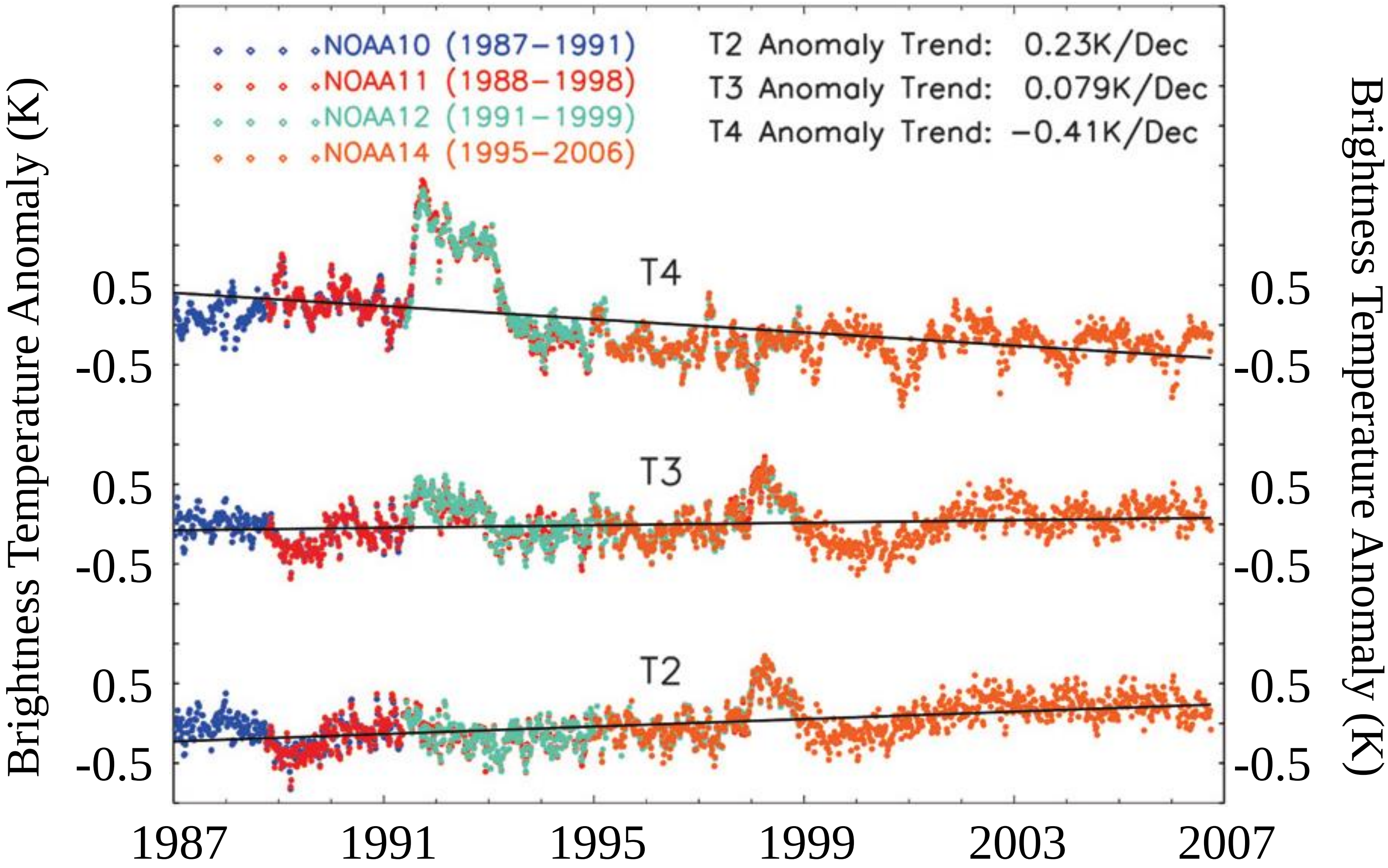
SNO Distribution



Time Period: January 1, 2012 - March 31, 2013

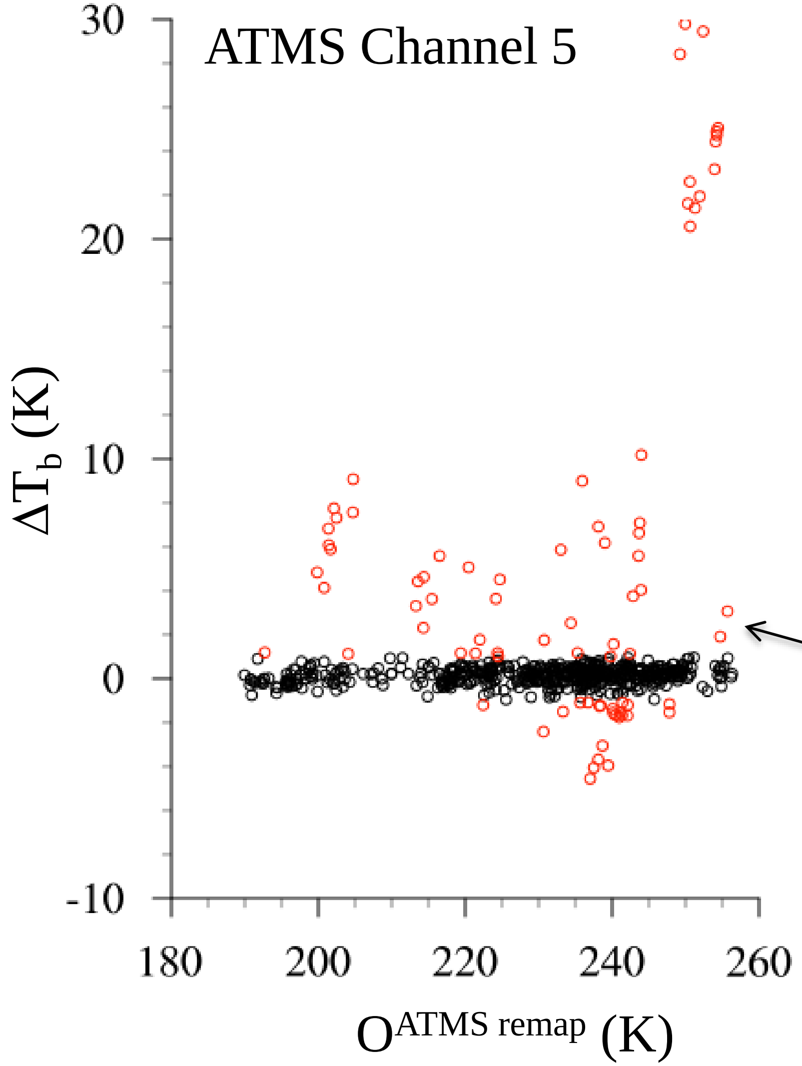
Collocation Criteria: 15 km and 60 seconds

Global Trends of SNO-Calibrated MSU Channels 2-4



C. Zou et al., 2009: Error structure and atmospheric temperature trends in observations from the microwave sounding unit. *J. Climate*, **22**, 1661-1681.

Quality Control



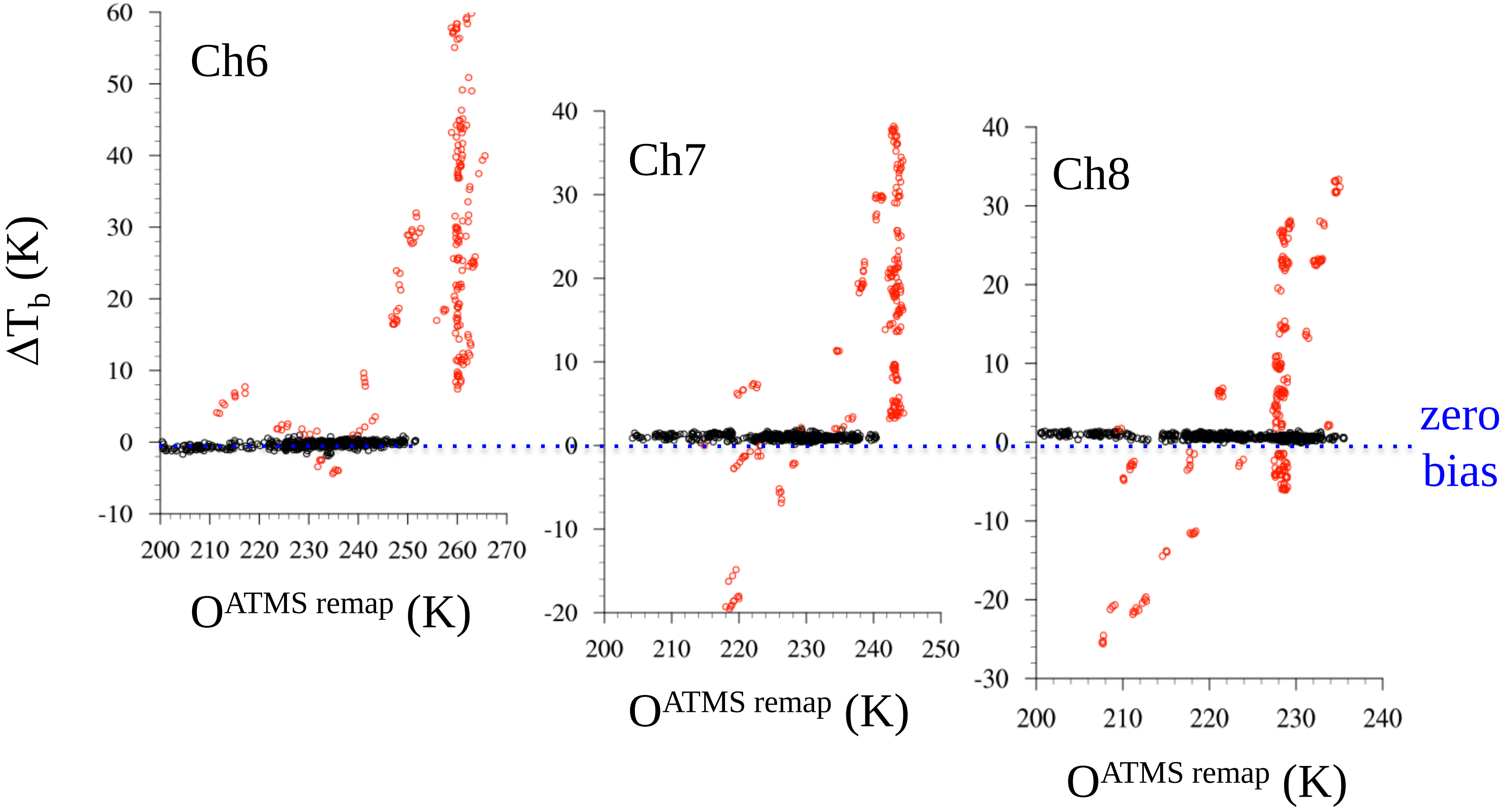
SNO differences between remap ATMS and AMSU-A data:

$$\Delta T_b = O^{ATMS\ remap} - O^{NOAA\text{-}18}$$

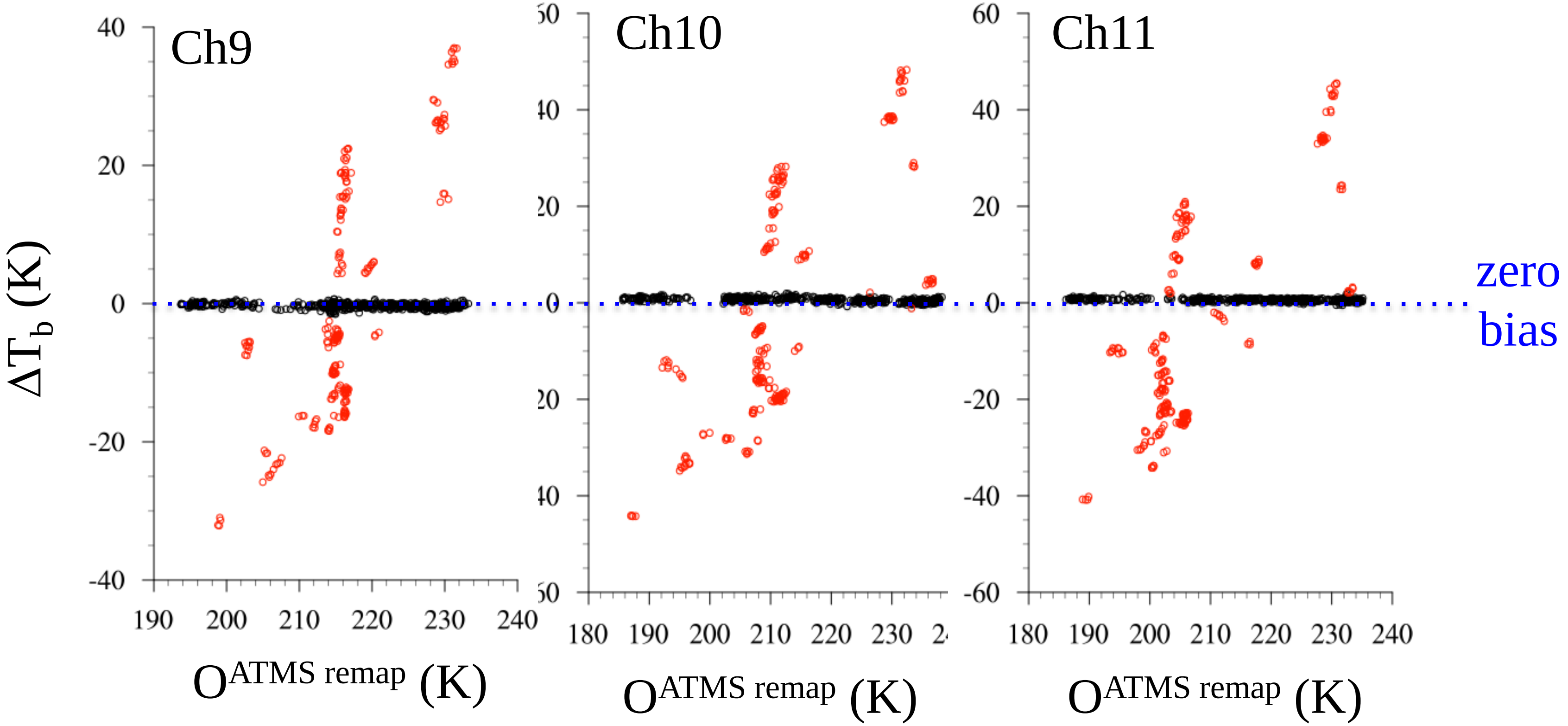
Outliers:

ΔT_b of ATMS channel 5 is outside the range [-2K, 1 K].

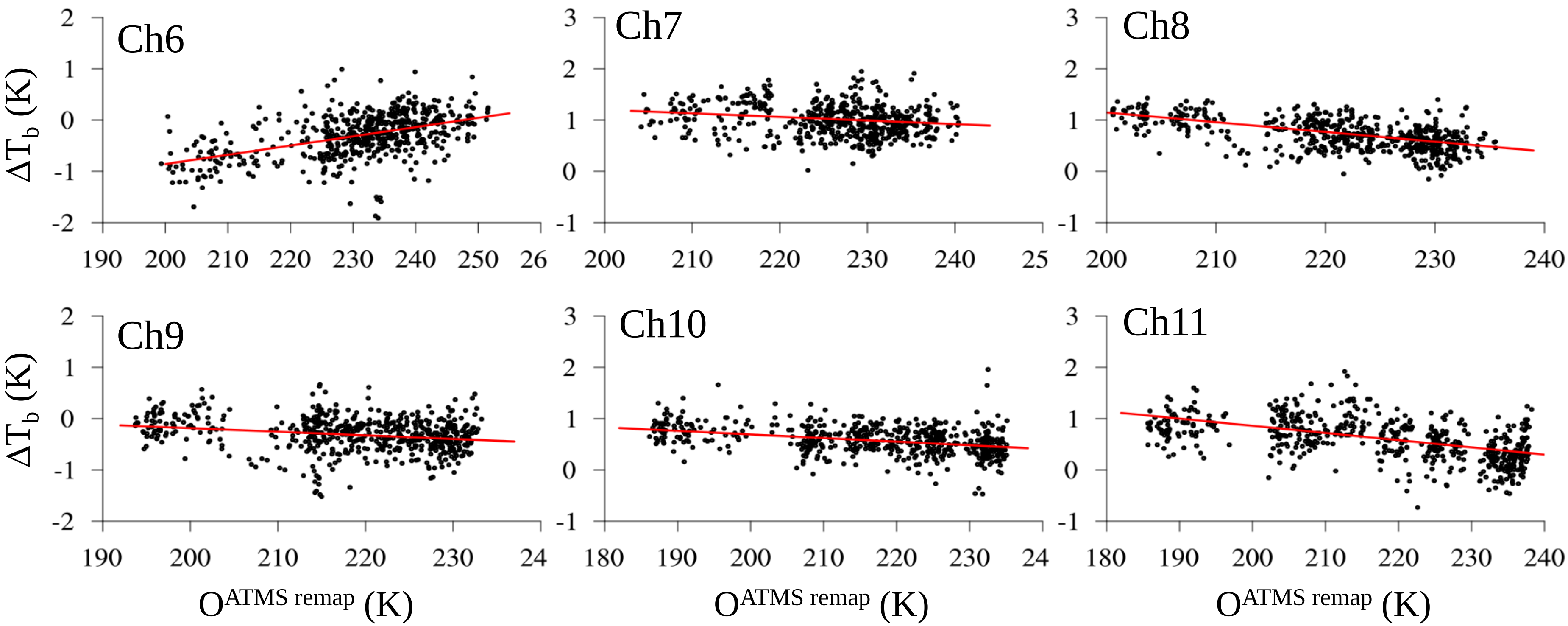
Scatter Plots of ΔT_b for ATMS Channels 6-8

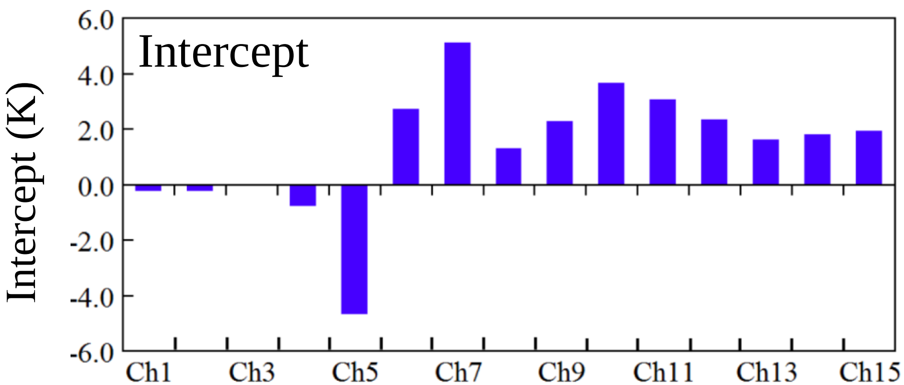


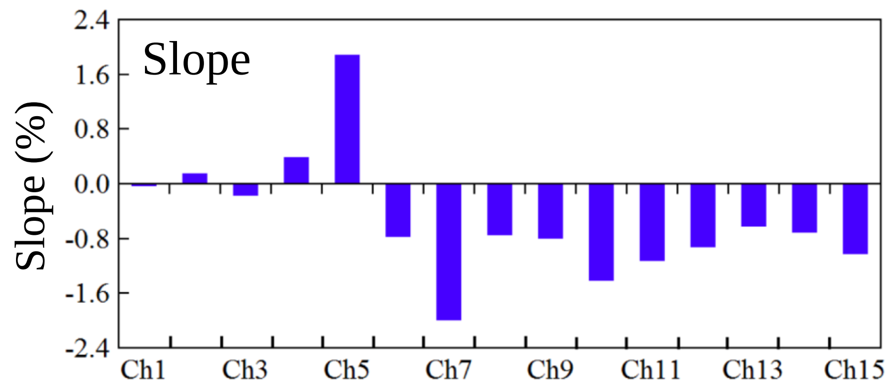
Scatter Plots of ΔT_b for ATMS Channels 9-11



Scatter Plots of $\Delta T_b (= O^{ATMS\ remap} - O^{NOAA\text{-}18})$ after Quality Control



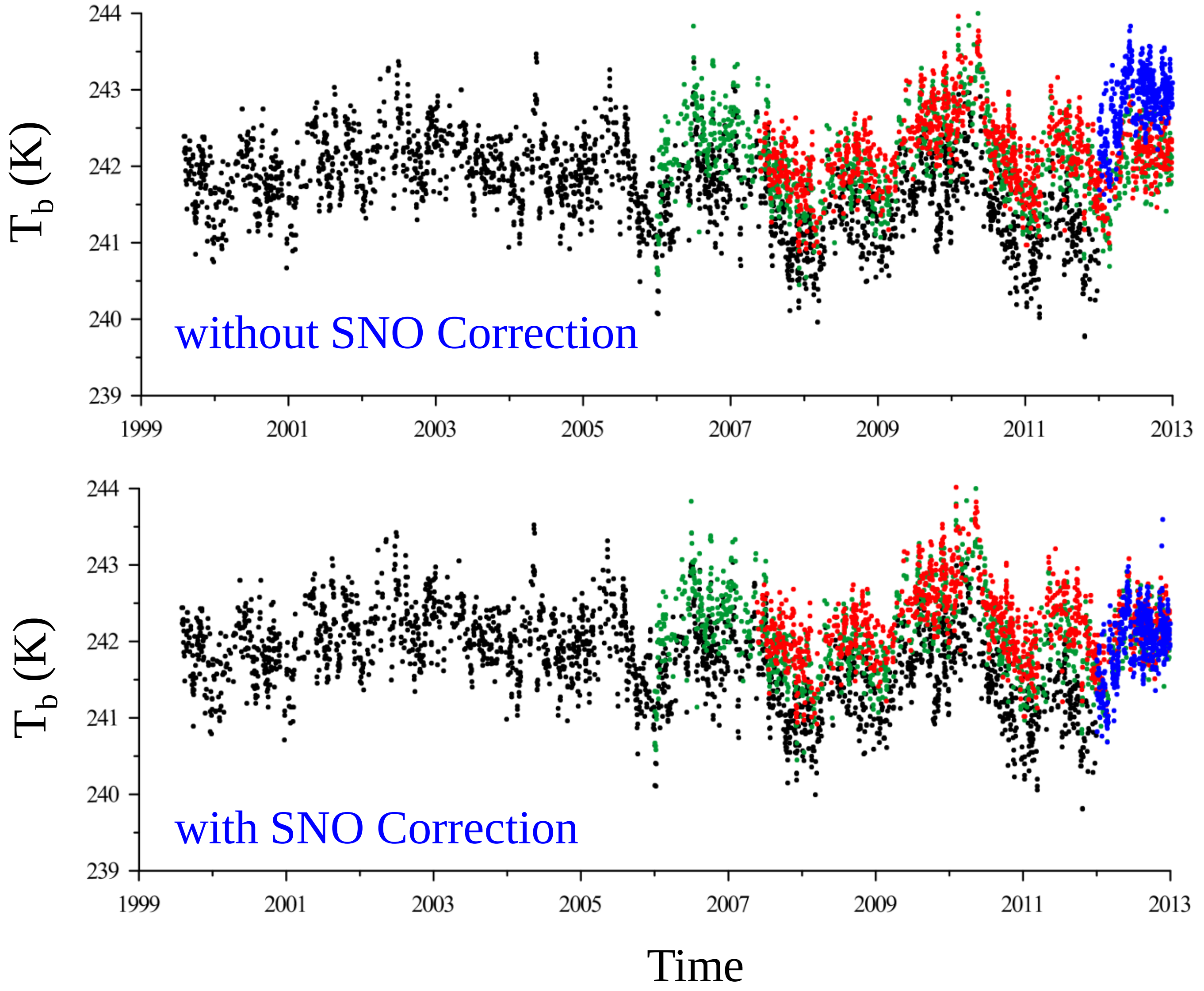




Biases of $\Delta T_b = O^{ATMS\ remap} - O^{NOAA\text{-}18}$

Channel	ATMS remap minus NOAA-18 AMSU-A		
	mean	intercept	slope
1	-0.25	-0.22	-0.0002
2	0.08	-0.20	0.0015
3	-0.35	-0.01	-0.0016
5	0.15	-0.74	0.0039
6	-0.29	-4.66	0.0189
7	0.99	2.73	-0.0077
8	0.70	5.12	-0.0199
9	-0.30	1.31	-0.0074
10	0.58	2.29	-0.0079
11	0.59	3.66	-0.0141
12	0.60	3.06	-0.0112
13	0.26	2.35	-0.0092
14	0.18	1.61	-0.0061
15	0.08	1.82	-0.0070
16	-0.05	1.95	-0.0102

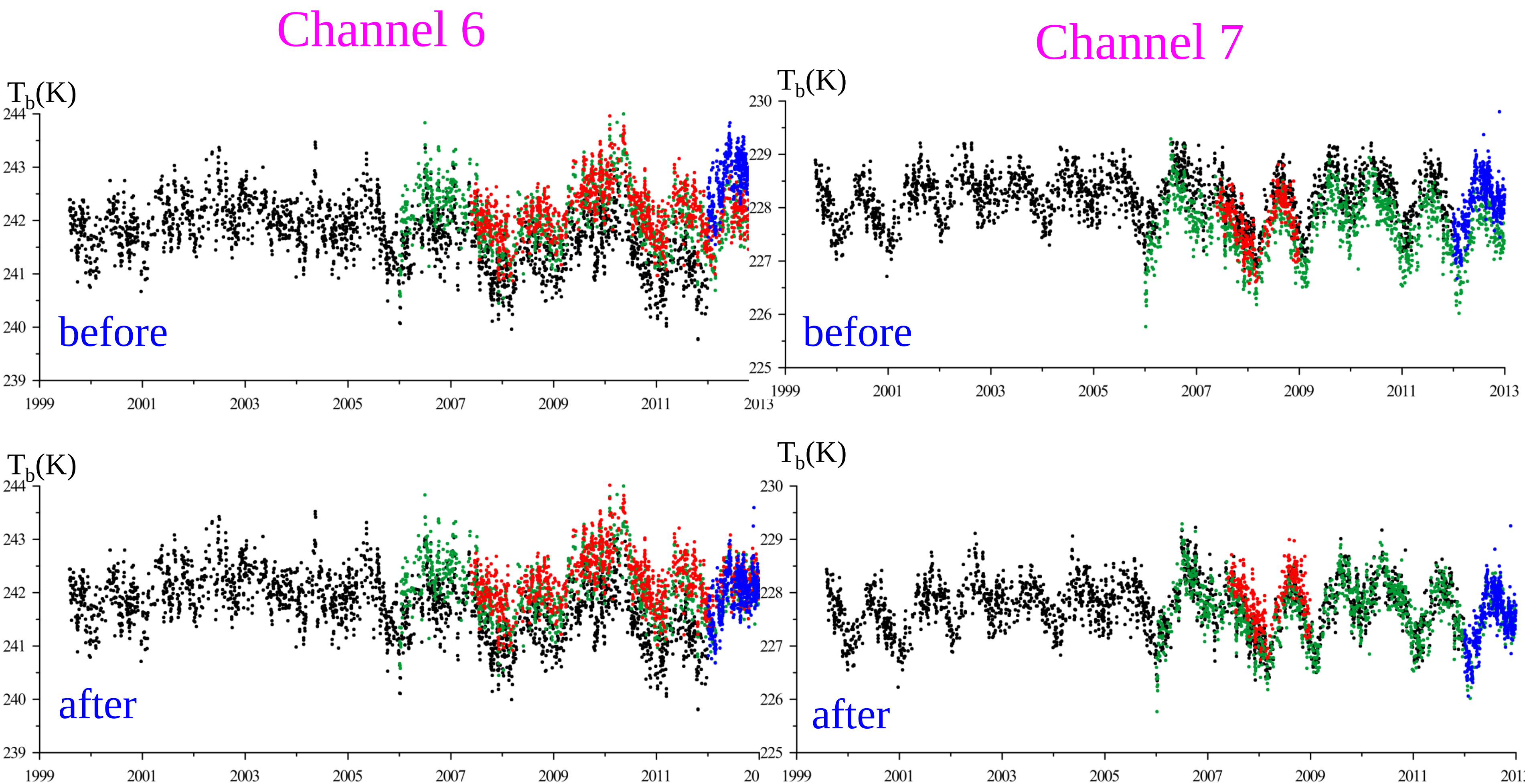
Temporal Evolution of Channel 6 Observation



NOAA-15
NOAA-18
MetOp-A
SNPP

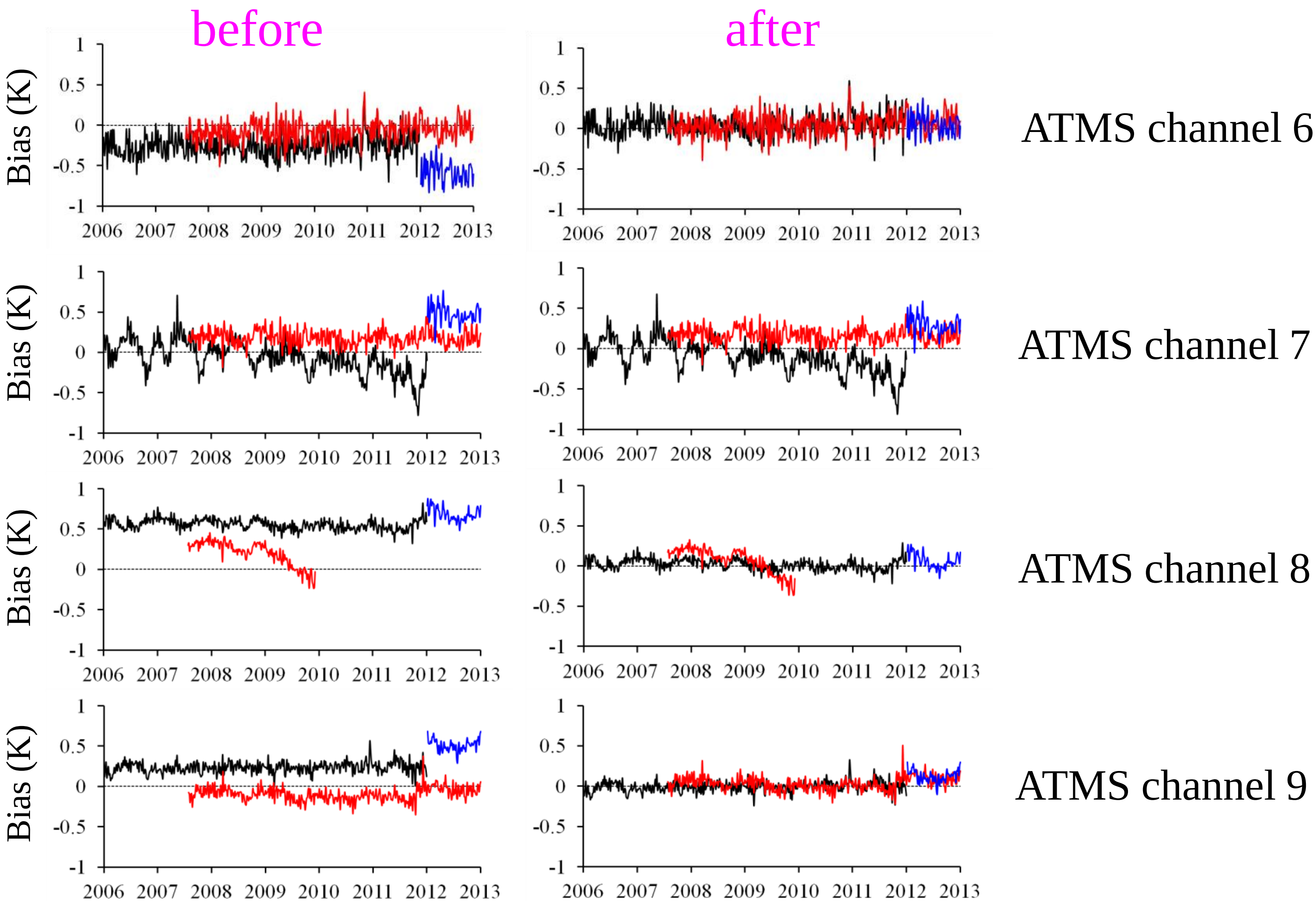
nadir
clear-sky
(2S-2N)
(80W-100W)

Data from NOAA-15, NOAA-18, MetOp-A, SNPP



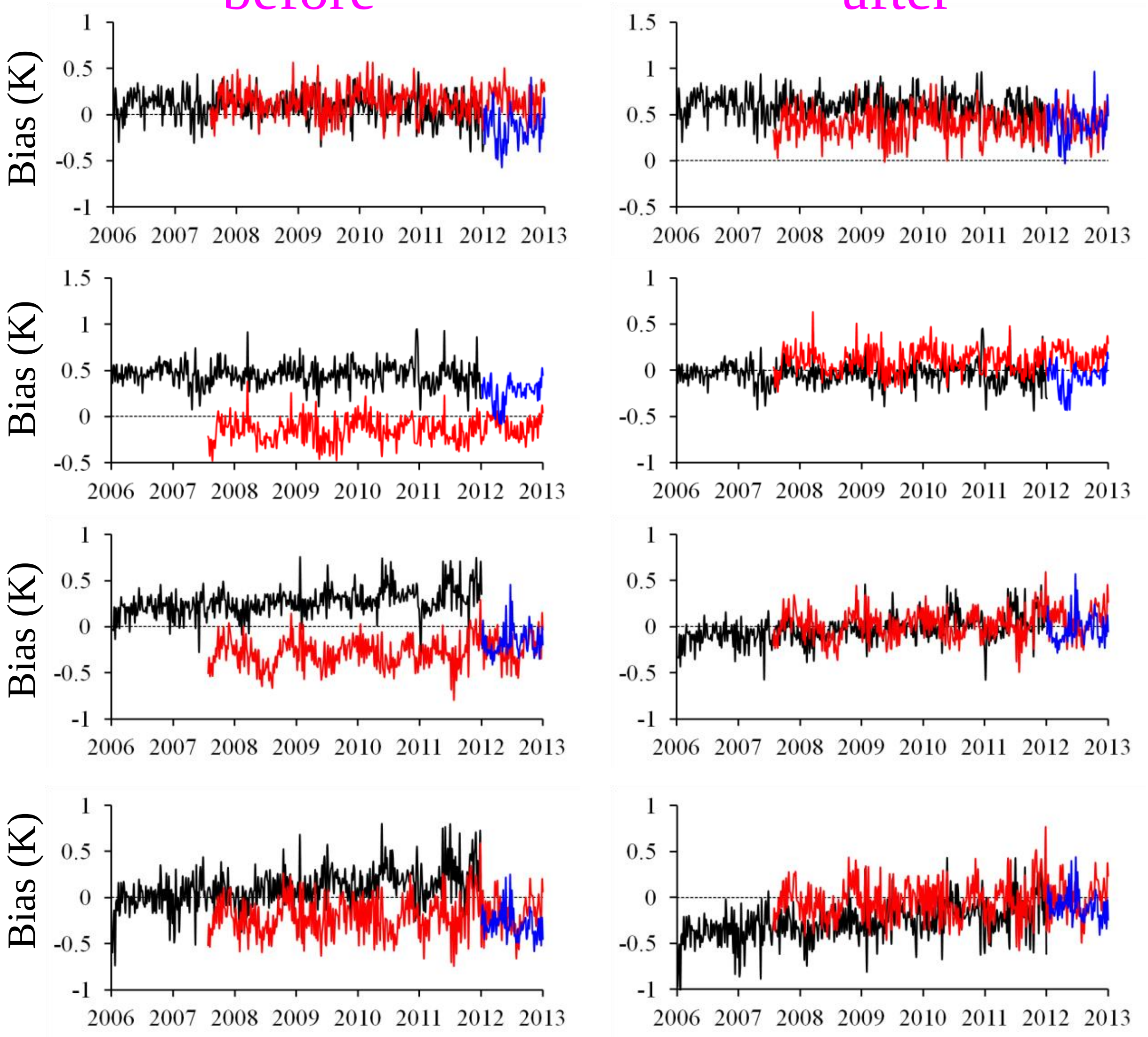
Nadir only, clear-sky, (2S-2N), (80W-180W)

Biases in the Tropics (NOAA-15, NOAA-18, MetOp-A, SNPP)



NOAA-18 is subtracted. The pentad data set within ±30º latitudinal band.

Biases in the Tropics (NOAA-15, MetOp-A, SNPP)



NOAA-18 is subtracted. The pentad data set within ±30° latitudinal band.

Summary & Conclusions

- ATMS data after remap compare much more favorably to NOAA-18 AMSU-A than before

- Channels 1 and 2 remap (i.e., a resolution enhancement) increases noise and bias increase; while remap of other channels (i.e., a downscaling) will reduce noise and bias

- After remap and SNO correction, data among NOAA-15, NOAA-18, MetOp-A and SNPP are more consistent within the same regions

gThe ATMS pentad dataset within $\pm 30^o$ latitudinal band after remap are more consistent with AMSU-A data from NOAA-15, NOAA-18, MetOp-A and

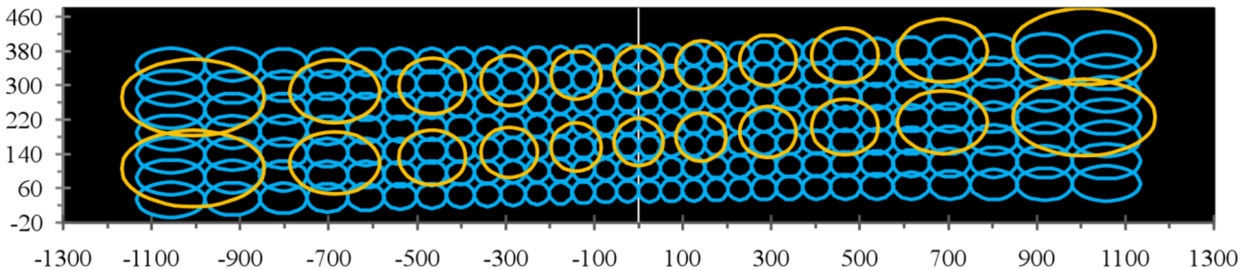
Future Work

- **Comparison between double difference (DD) method and SNO method**
- **Find the root causes of SNO and DD biases with respect to**
  - ✓ Differences of nonlinearity correction
  - ✓ Full radiance versus brightness temperature in radiometric calibration
  - ✓ Noise change related to instrument degradation
  - ✓ Calibration target stability related to orbital drift
  - ✓ Uncertainty of TDR to SDR conversion

Future Work

- **Comparison between double difference (DD) method and SNO method**

- **Find the root causes of SNO and DD biases with res**



  ✓

  ✓ Full radiance versus brightness temperature in radiometric calibration

  ✓ Noise change related to instrument degradation

  ✓ Calibration target stability related to orbital drift

More details can be found in

Zou, X. and H. Yang, 2013: Connecting the time series of microwave sounding observations from AMSU to ATMS for long-term monitoring of climate change. *J. Ocean Atmos. Tech.*, (submitted)

Yang, H. and X. Zou, 2013: Optimal ATMS remapping algorithm for climate research. *IEEE Trans. Geo. Remote Sensing*, (revised)

Weng, F. X. Zou and Z. Qin, 2013: Uncertainty of AMSU-A derived temperature trends in relationship with clouds and precipitation. *Clim. Dyn.*, DOI 10.1007/ s00382-013-1958-7.

Weng, F. and X. Zou, 2013: 30-year atmospheric temperature trend derived by one-dimensional variational data assimilation of MSU/AMSU-A observations. *Clim. Dyn.*, DOI: 10.1007/s00382-013-2012-5.