Towards Establishing A Benchmark Instrument for Microwave Sounders

Lin Lin[1, 2], Fuzhong Weng[3] and Xiaolei Zou[4]

[1] Joint Center for Satellite Data Assimilation, College Park, Maryland, USA
[2] I. M. Systems Group, Inc., Rockville, Maryland, USA
[3] National Environmental Satellite, Data, & Information Service, National Oceanic and Atmospheric Administration, Washington, D. C., USA
[4] Department of Earth, Ocean and Atmospheric Sciences, Florida State University, USA

Outline

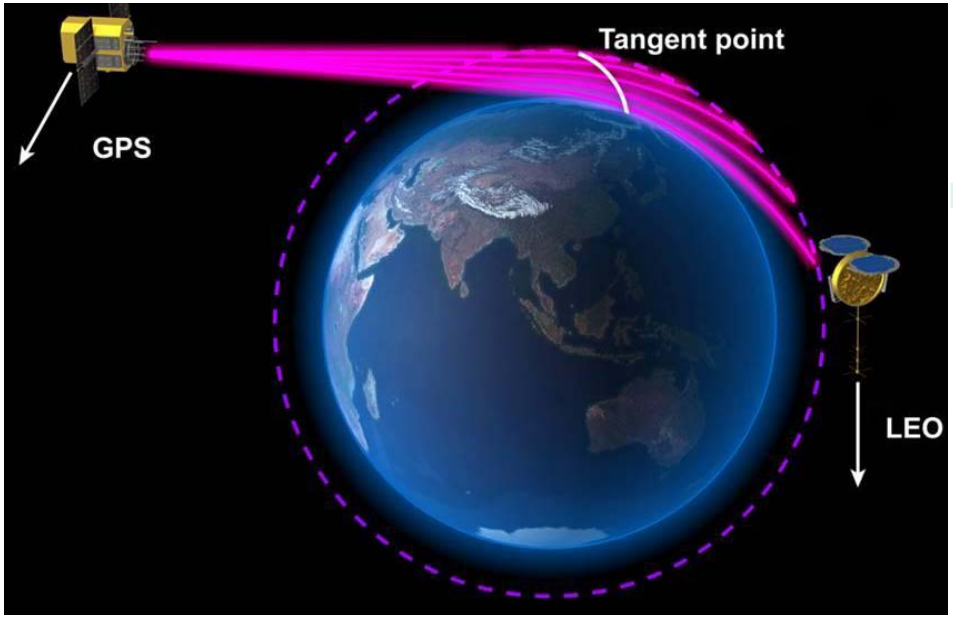
1. Introduction
2. A Brief Description of GPS RO Data
3. GPS RO Derived Scan Bias and Bias Correction
4. MonoRTM Simulations Using Measured and Boxcar SRF
5. Long Term Monitoring of ATMS Bias Characterization Using Collocated COSMIC RO Data
6. Summary

Introduction

- For both NWP and climate applications, it is important to know the satellite instrument's on-orbit accuracy. However, lack of on-orbit truth measurement makes it challenging.
- The Global Positioning System (GPS) Radio Occultation (RO) data have high accuracy and precision on atmospheric temperature, and also have high vertical resolution under all weather conditions.
- Current radiative transfer (RT) models are accurate for ATMS temperature sounding channels since the O_2 absorption coefficient for frequency between 50-70 GHz is accurately derived in lab.
- This research presents a method of using the GPS RO data and atmospheric RT models, such as the U.S. Joint Center of Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) and the line-by-line RT model, to assess ATMS on-orbit accuracy.

A Brief Description of GPS RO

1. High vertical resolution
2. No contamination from clouds
3. No system calibration required
4. High accuracy and precision:
   a. The global mean differences between COSMIC and high-quality reanalyses is ~0.65K between 8 and 30km (Kishore et al. 2008)
   b. The precision of COSMIC GPS RO soundings is ~0.05K in the upper troposphere and lower stratosphere (Anthes et al. 2008)



Collocation of GPS and ATMS

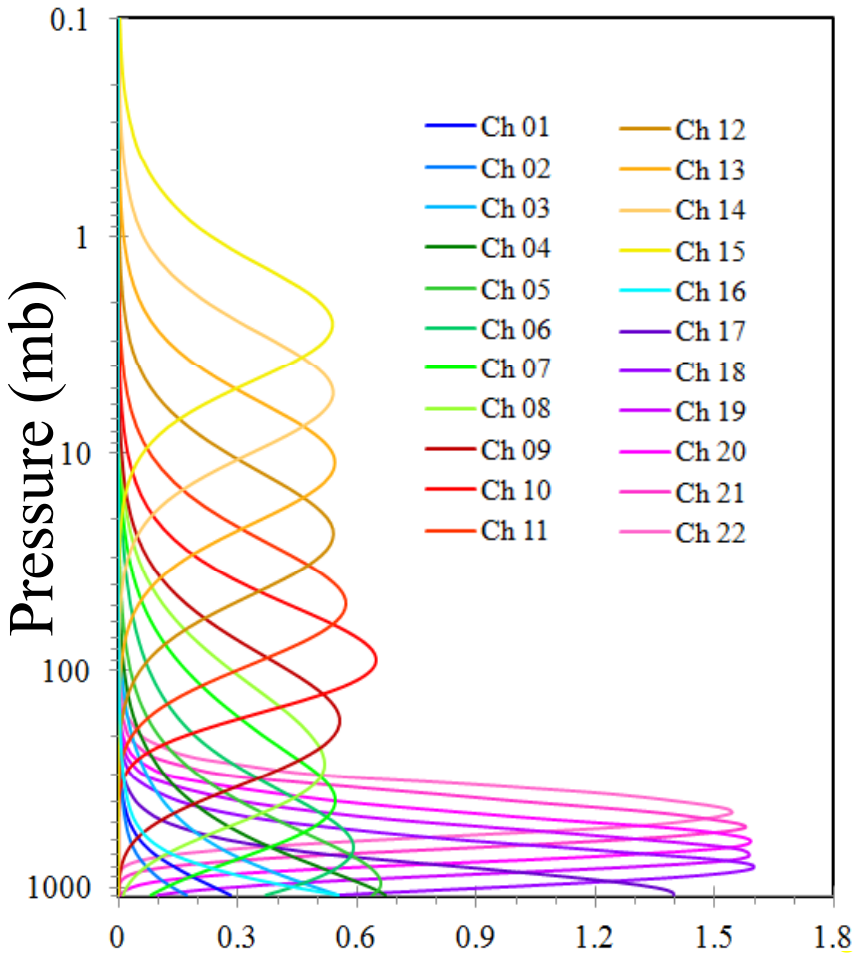
Temporal difference $\leq \pm 3$ hrs

Spatial distance ≤ 50 km

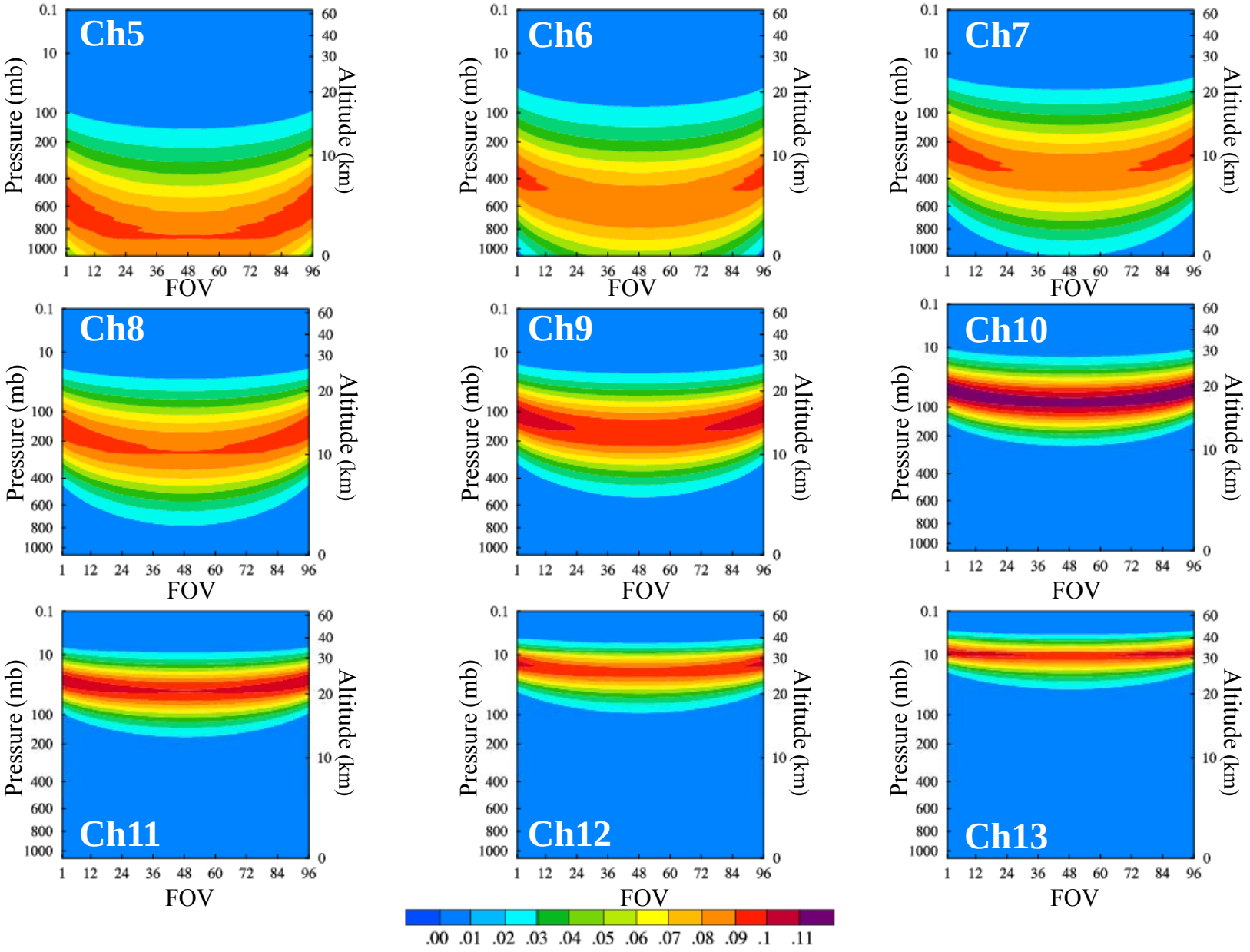
Use COSMIC geolocation at the altitude of maximum WF for spatial collocation

Channel- and FOV- Dependent

ATMS Weighting Function
(U.S. Standard Atmosphere)



ATMS Weighting Function (U.S. Standard Atmosphere)

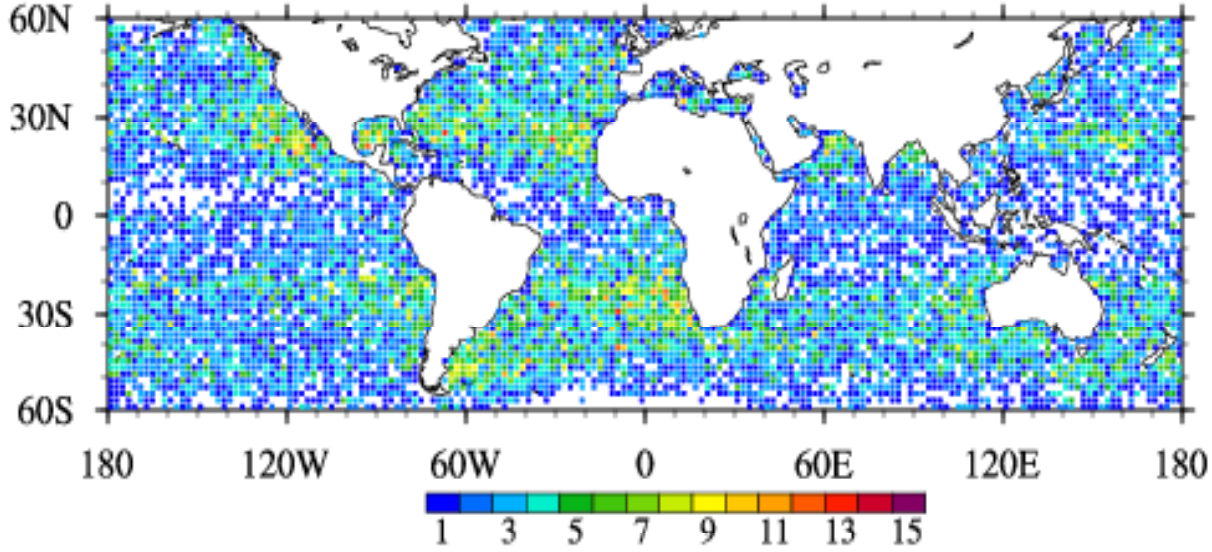


Distribution of Matchups

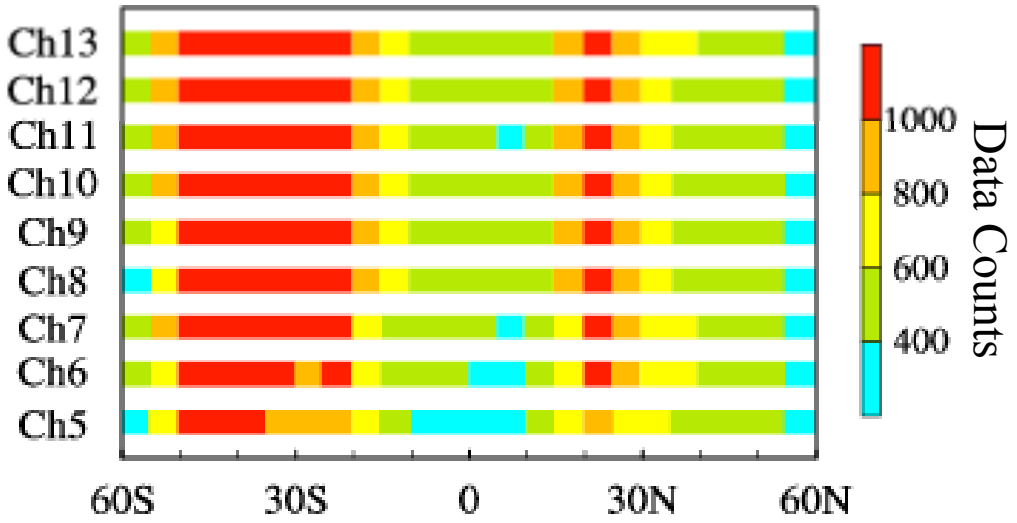
Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Jun. 30, 2012

Channel 6:
16,701 in total

Similar patterns
for other channels
5, 7-13.

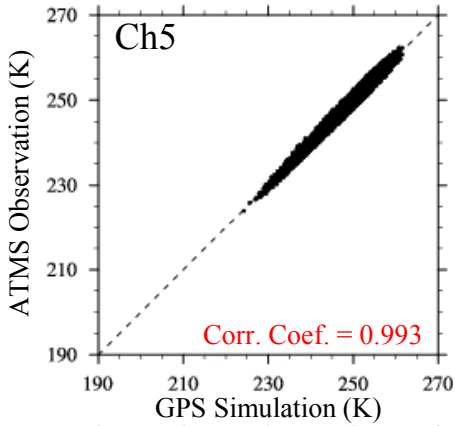


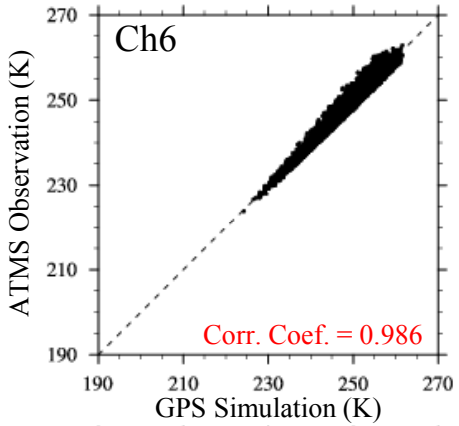
Latitudinal Distribution

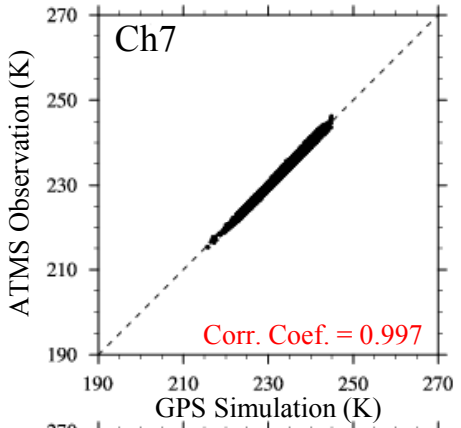


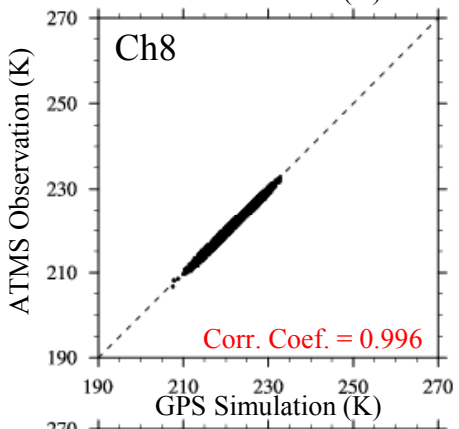
Most collocated data are located in subtropical in Northern Hemisphere and middle latitudes in Southern Hemisphere.

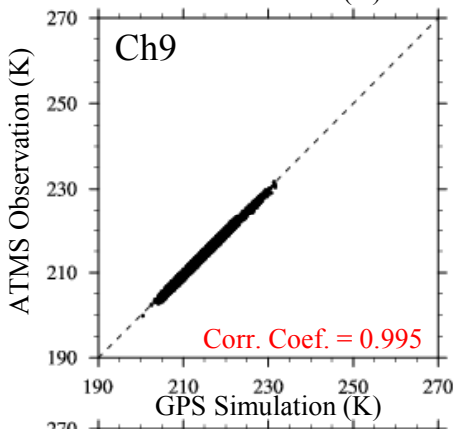
ATMS Observation and GPS Simulation

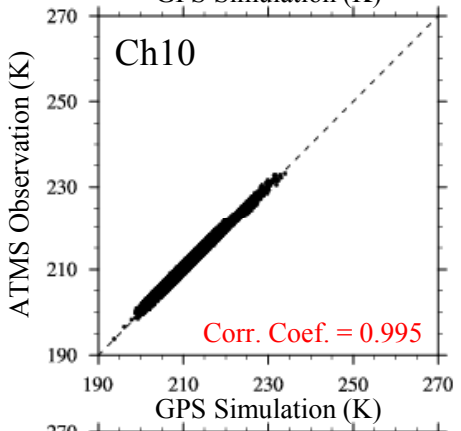


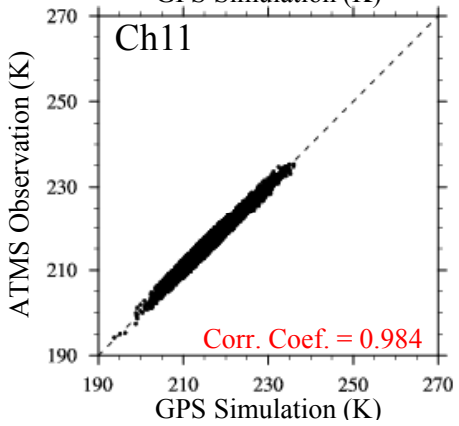


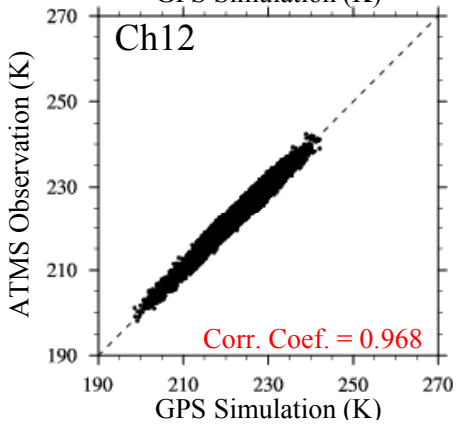


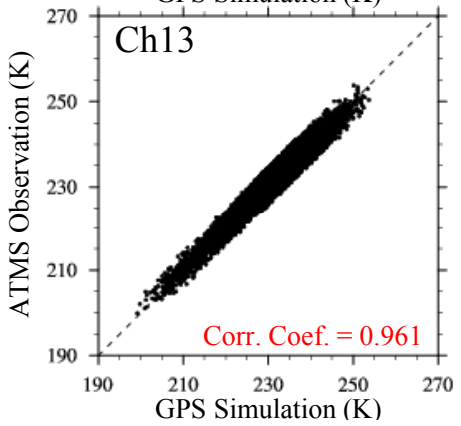




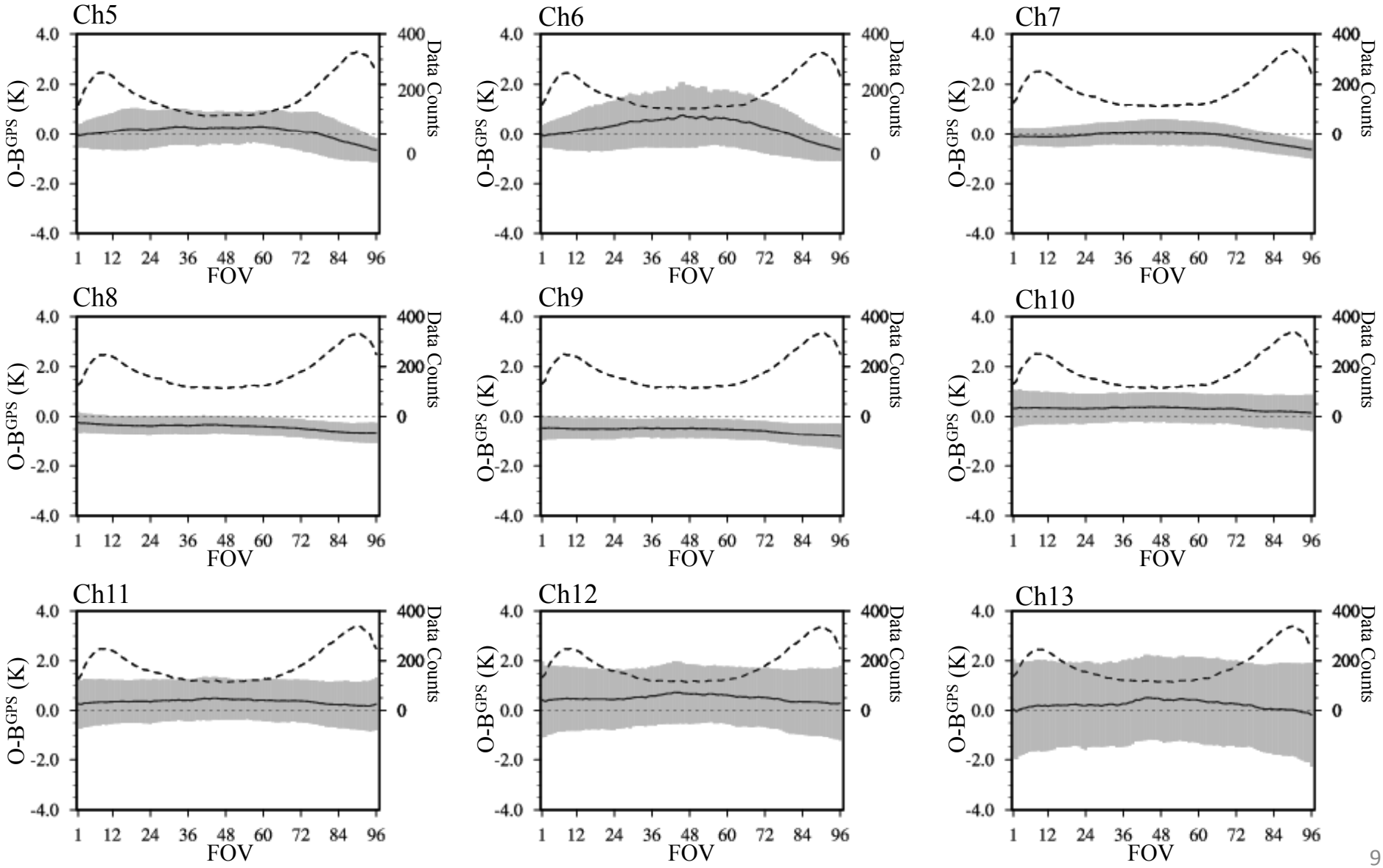






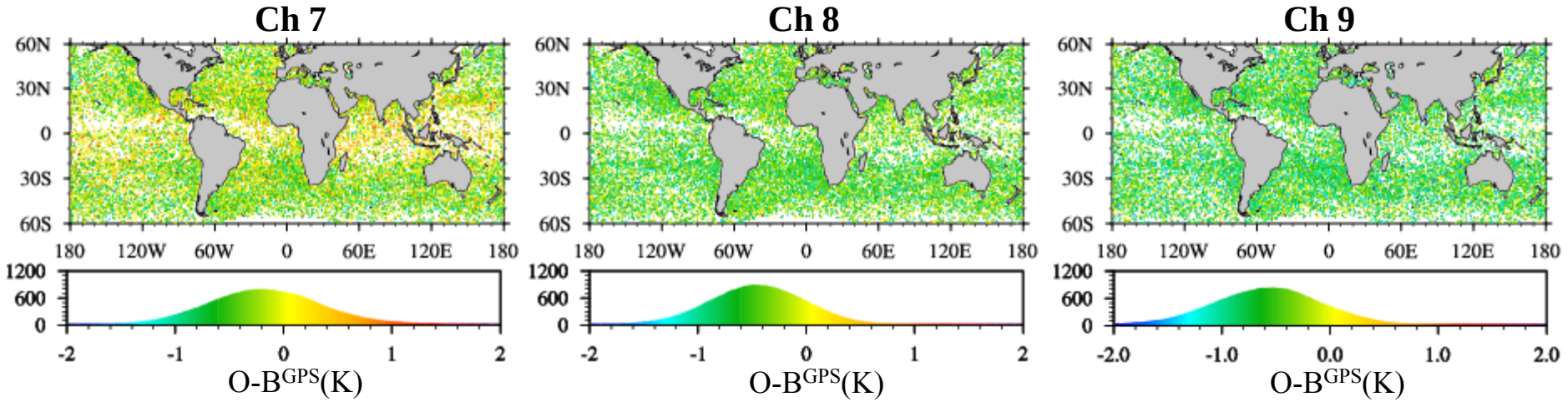


GPS RO Derived Scan Bias

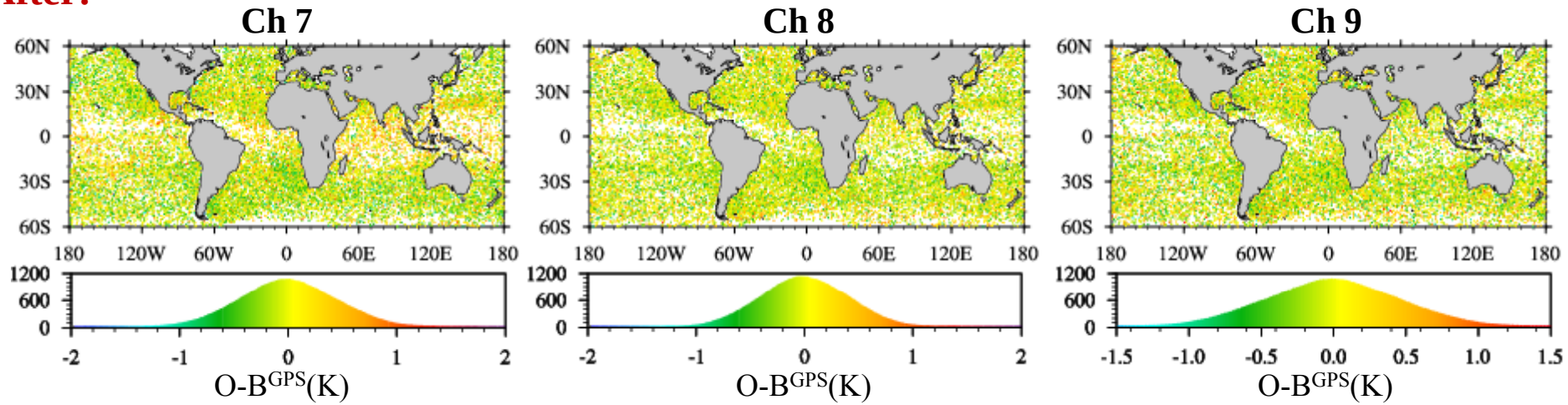


Bias Before/After Scan Bias Correction

Before:

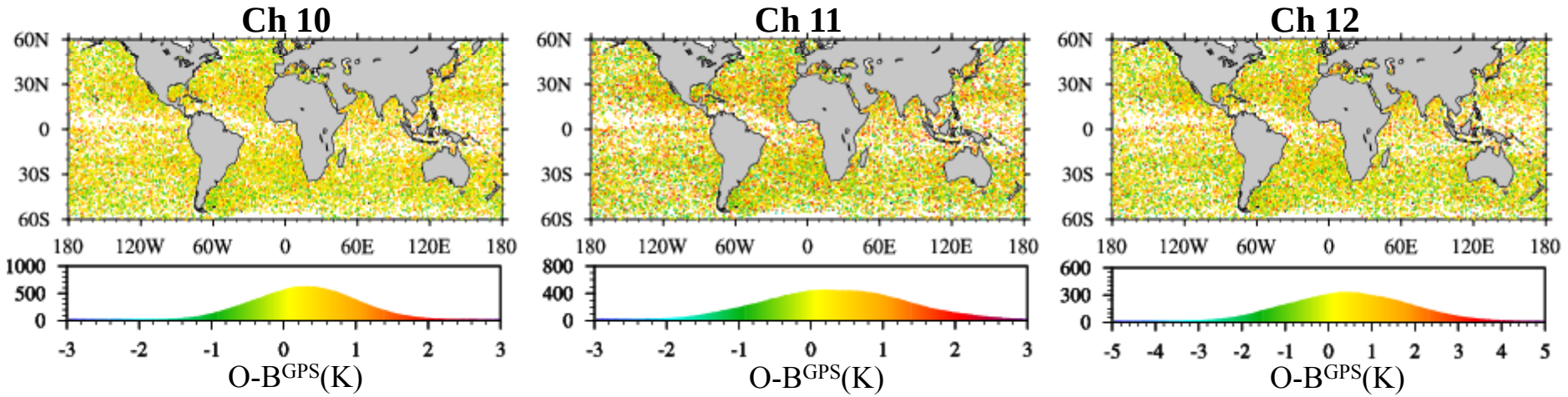


After:

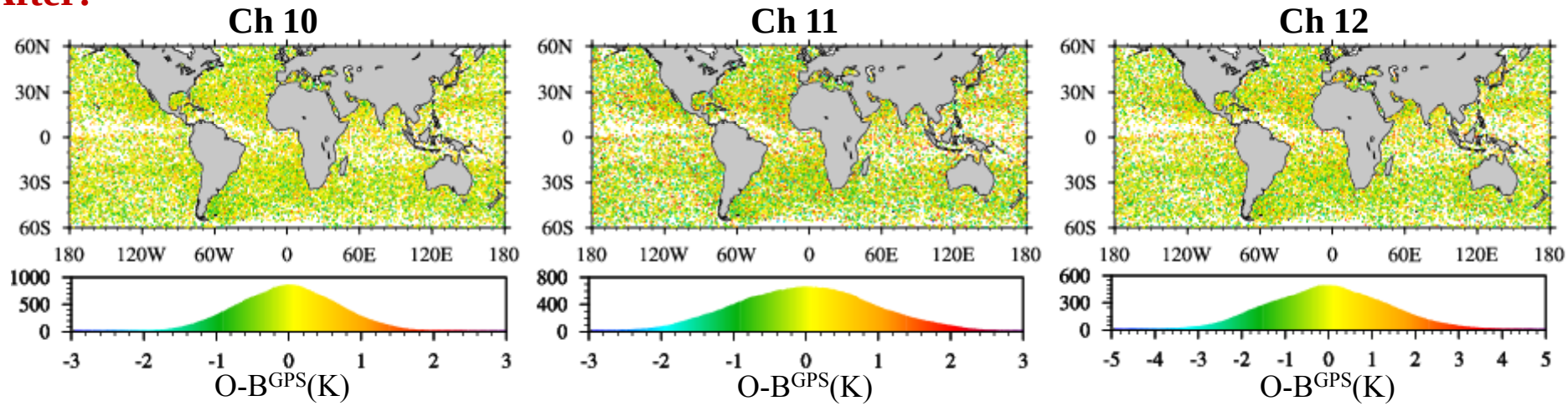


Bias Before/After Scan Bias Correction (Cntd')

Before:

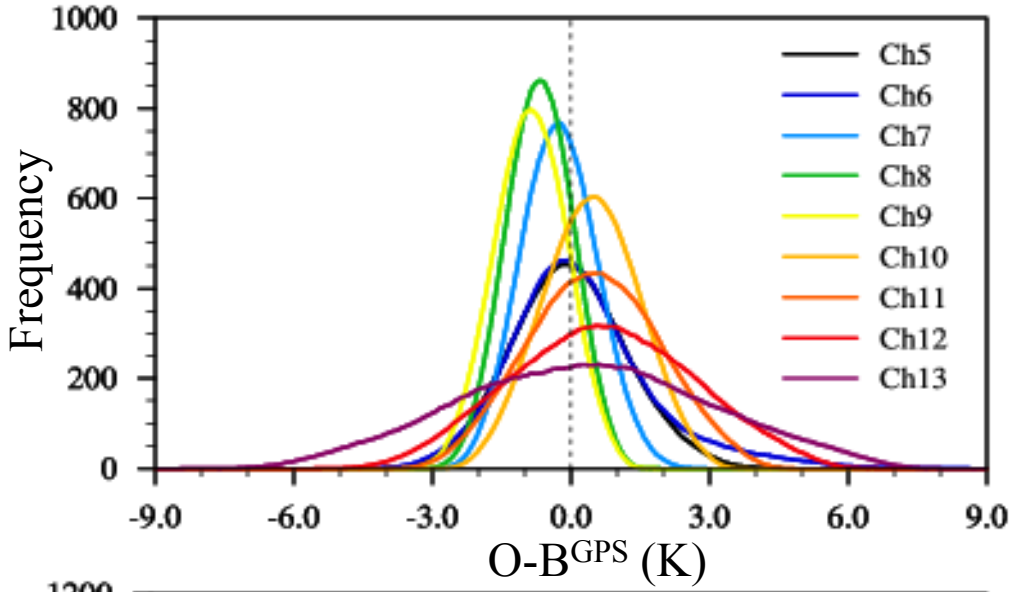


After:



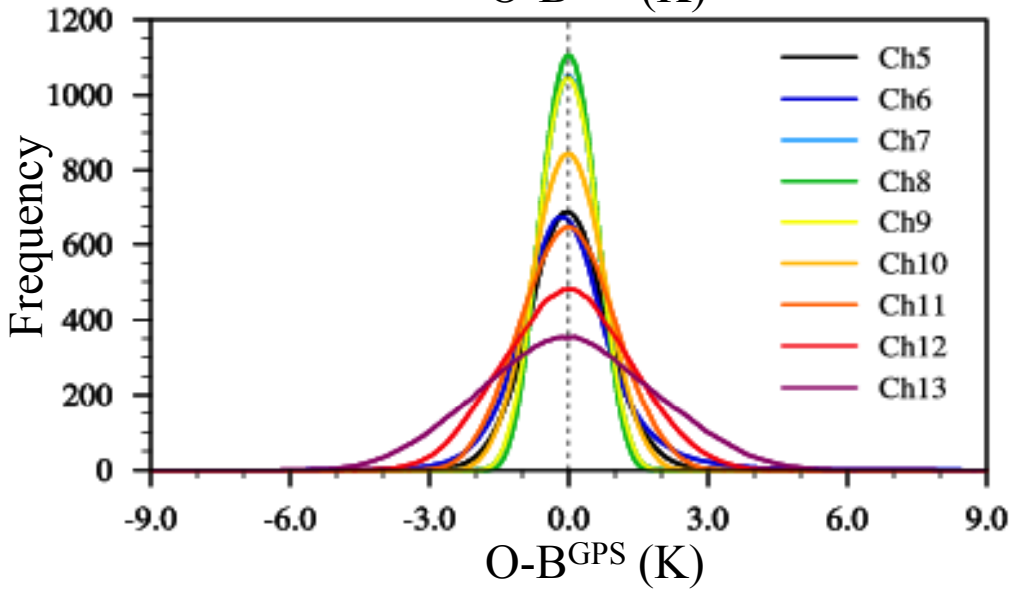
PDF of Bias Before/After Scan Bias Correction

Before:



Different channels have different biases (i.e., in PDF).

After:



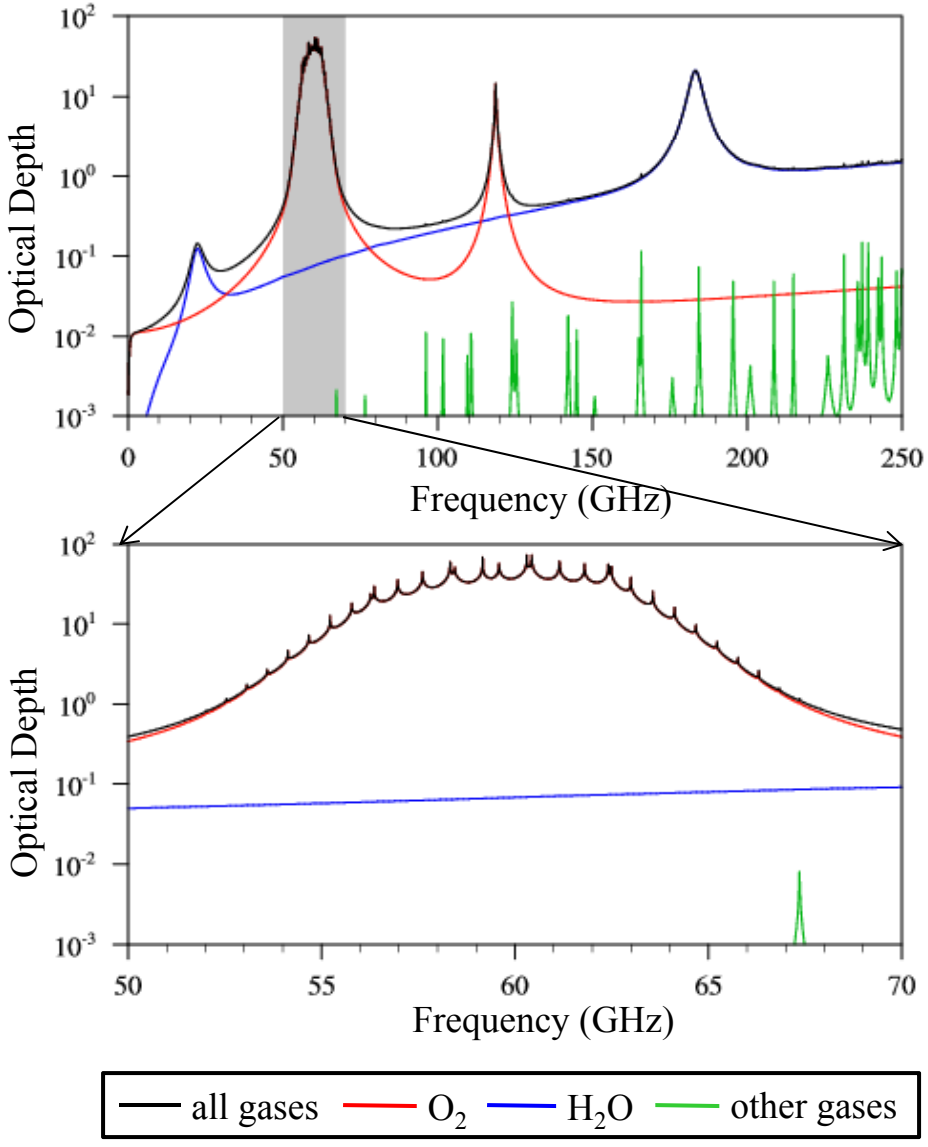
After calibrated using GPS RO data, biases of all channels are very close to normal distribution.

More, magnitudes of these calibrated biases are about an order smaller than the original TDR data.

MonoRTM

- A line-by-line (LBL) radiative transfer calculation
- Accurate atmospheric spectroscopy data base
- Only gaseous absorption
- Vertical stratification

For microwave sounding channels at 50-60 GHz, the O_2 absorption band can be best simulated under a cloud-free atmosphere using the LBL calculation.

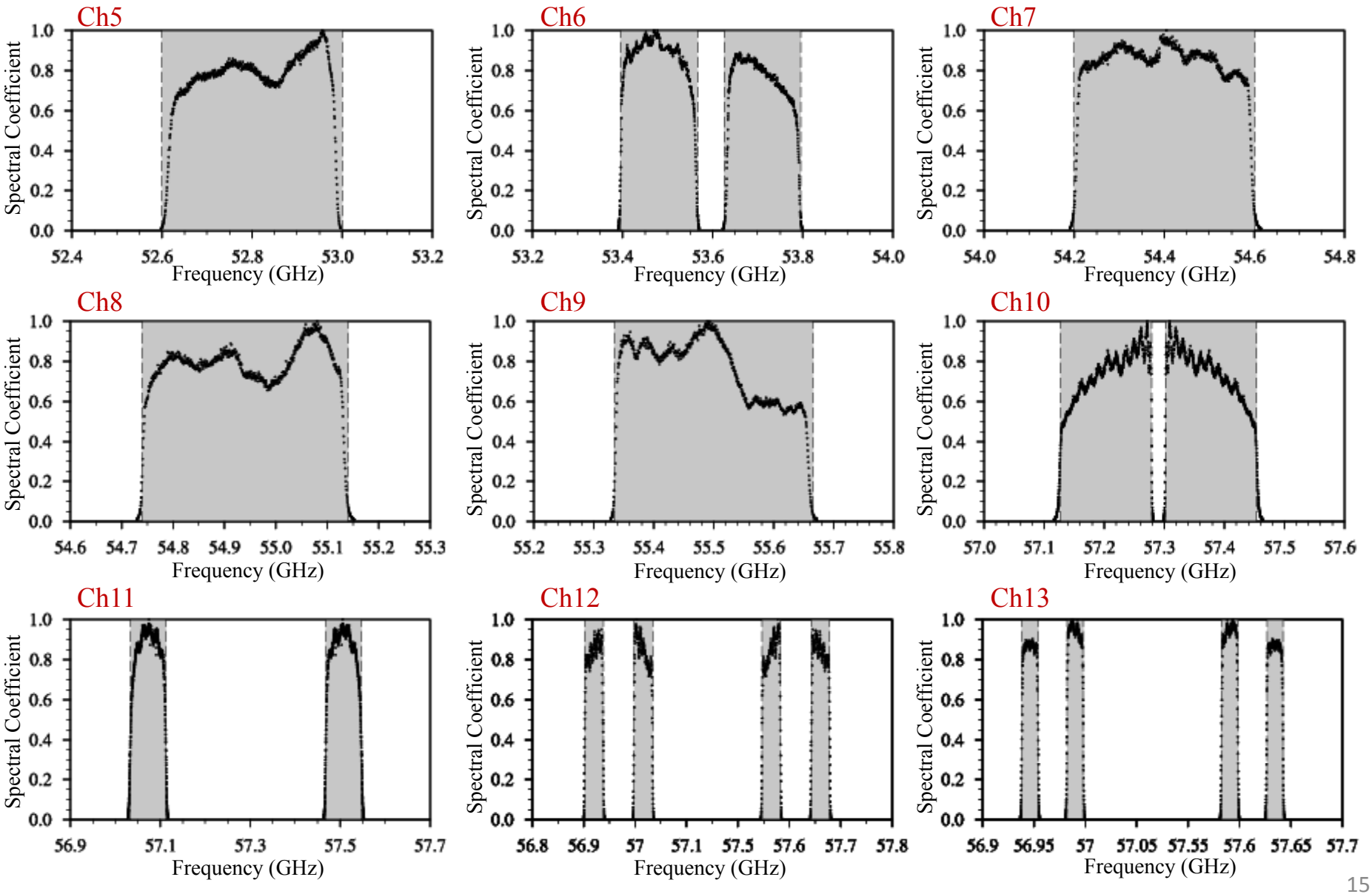


Total Number of Absorption Lines Used in ATMS SRFs Before/After -20dB Truncation

ATMS Channel Number	Number of Line		Frequency Resolution (mHz)
	Original	**-20dB**	
5	1001	664	0.600
6	2002	1188	0.300
7	1001	708	0.600
8	1001	705	0.600
9	1001	690	0.500
10	2002	1788	0.185
11	2002	1422	0.125
12	2002	982	0.165
13	2002	1004	0.075

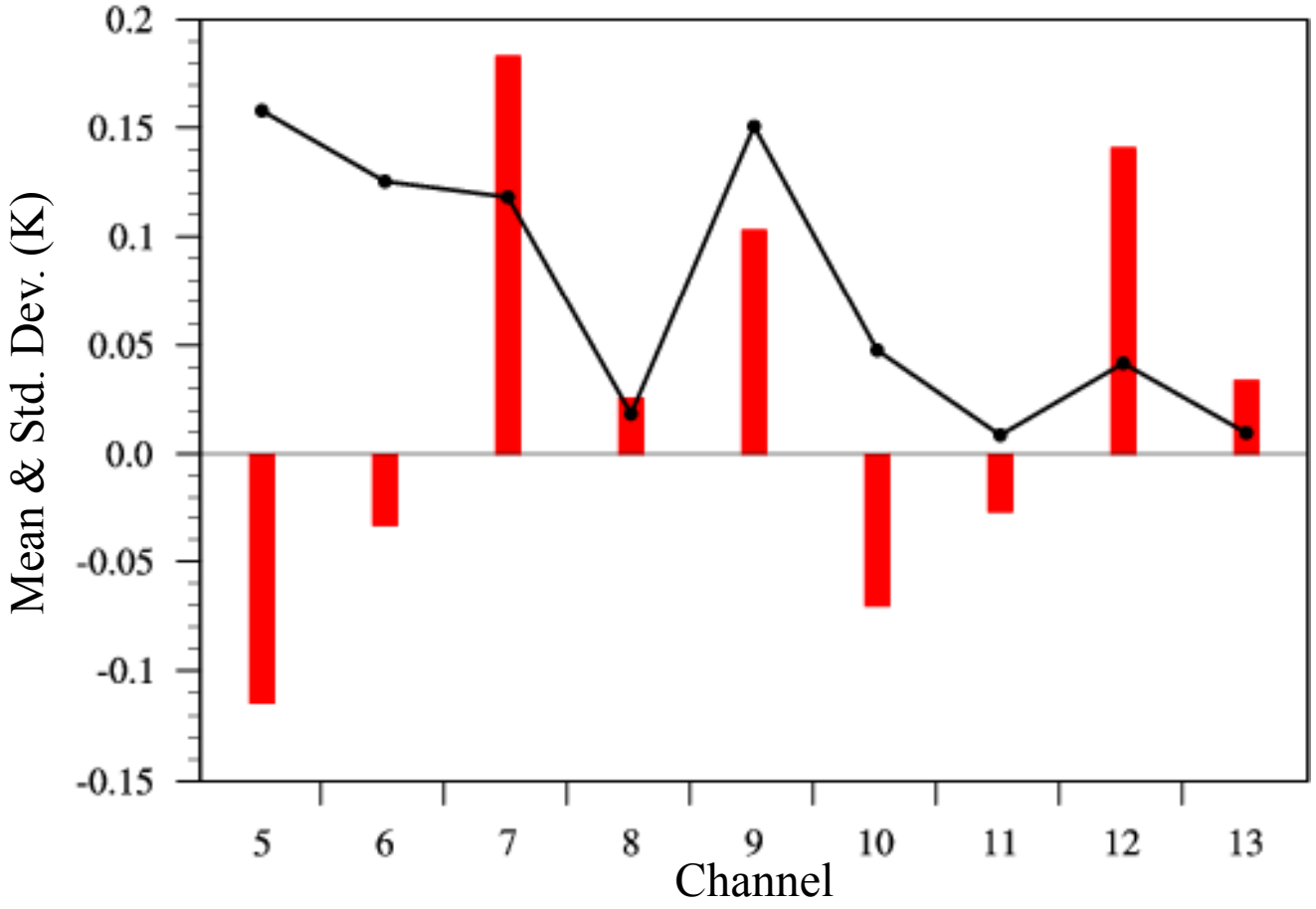
- To save computational time, the SRF is truncated at -20dB to keep the 99% of the maximum SRF for each band of each channel.
- Compared to 256 lines for Boxcar SRF, the number of lines for truncated measured SRF is at least tripled for each channel.

SRFs after the -20dB Truncation for CP at 20°C



MonoRTM Simulation (M^{SRF}-M^{BoxCar})

Data from January 2012

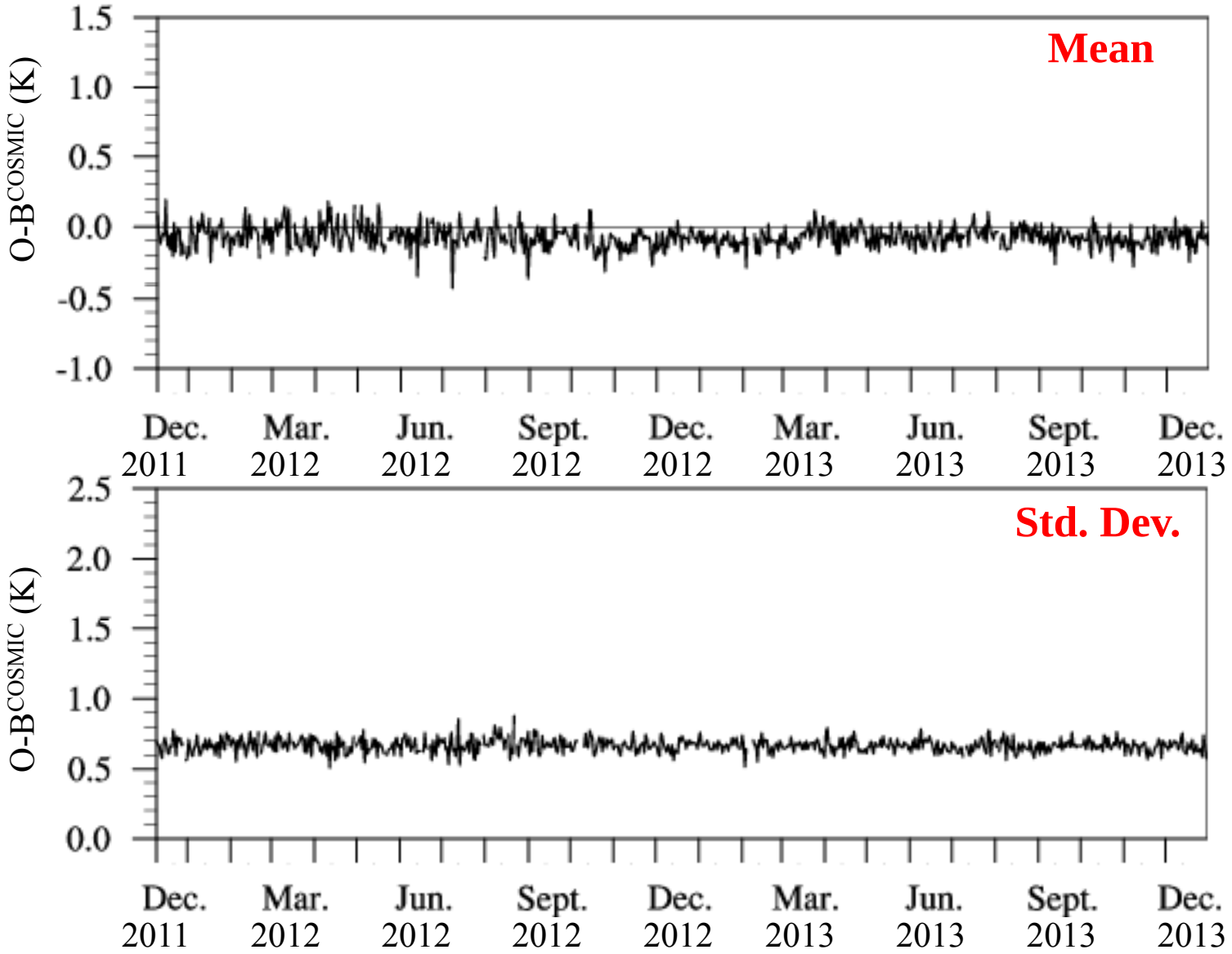


The mean difference is within ± 0.2K.
The Std. Dev. is within 0.2K.

Long Term Monitoring of ATMS Bias Characterization Using Collocated COSMIC RO Data

Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

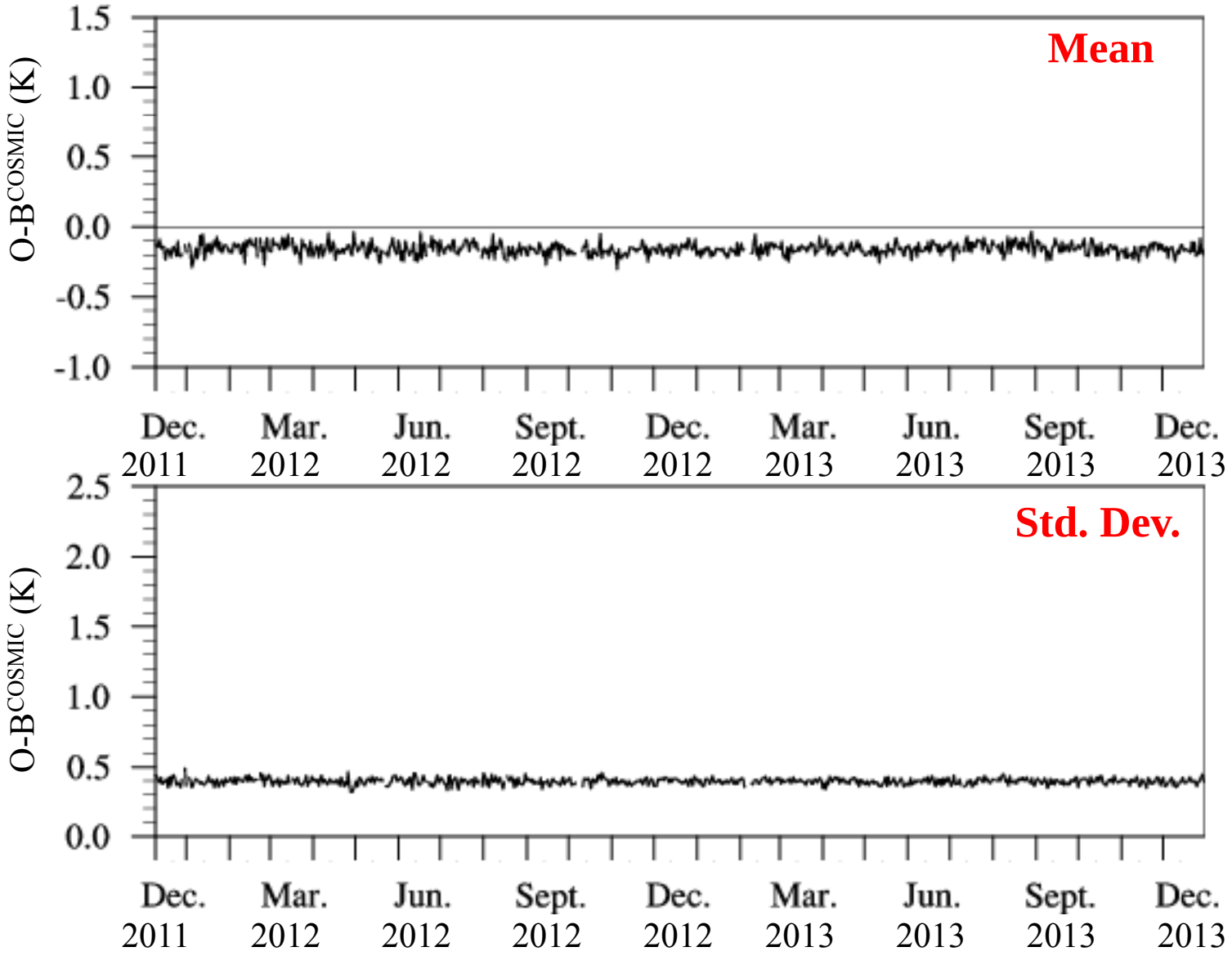
Ch 6



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

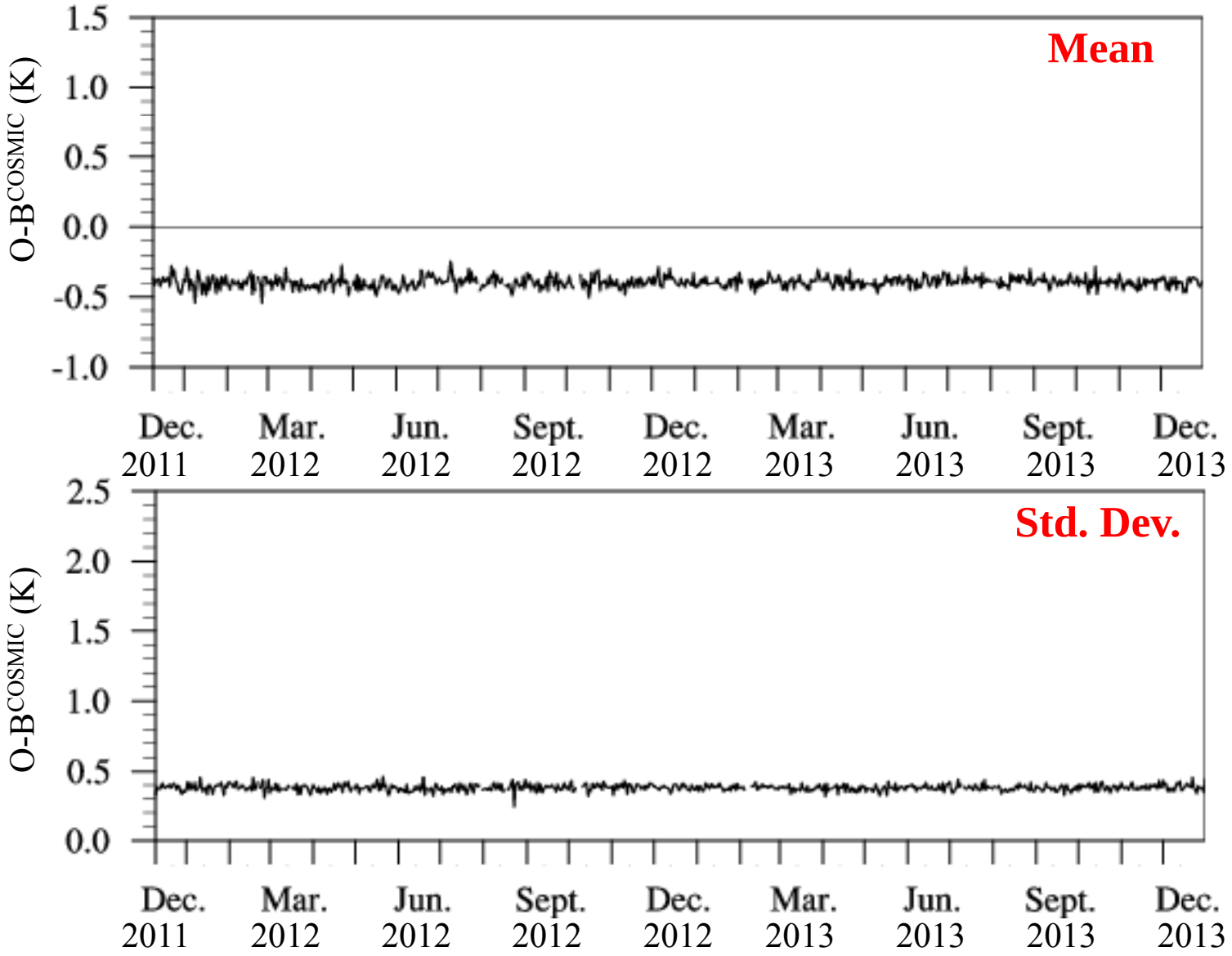
Ch 7



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60^{o}S ~ 60^{o}N, Dec. 10, 2011 ~ Dec. 31, 2013

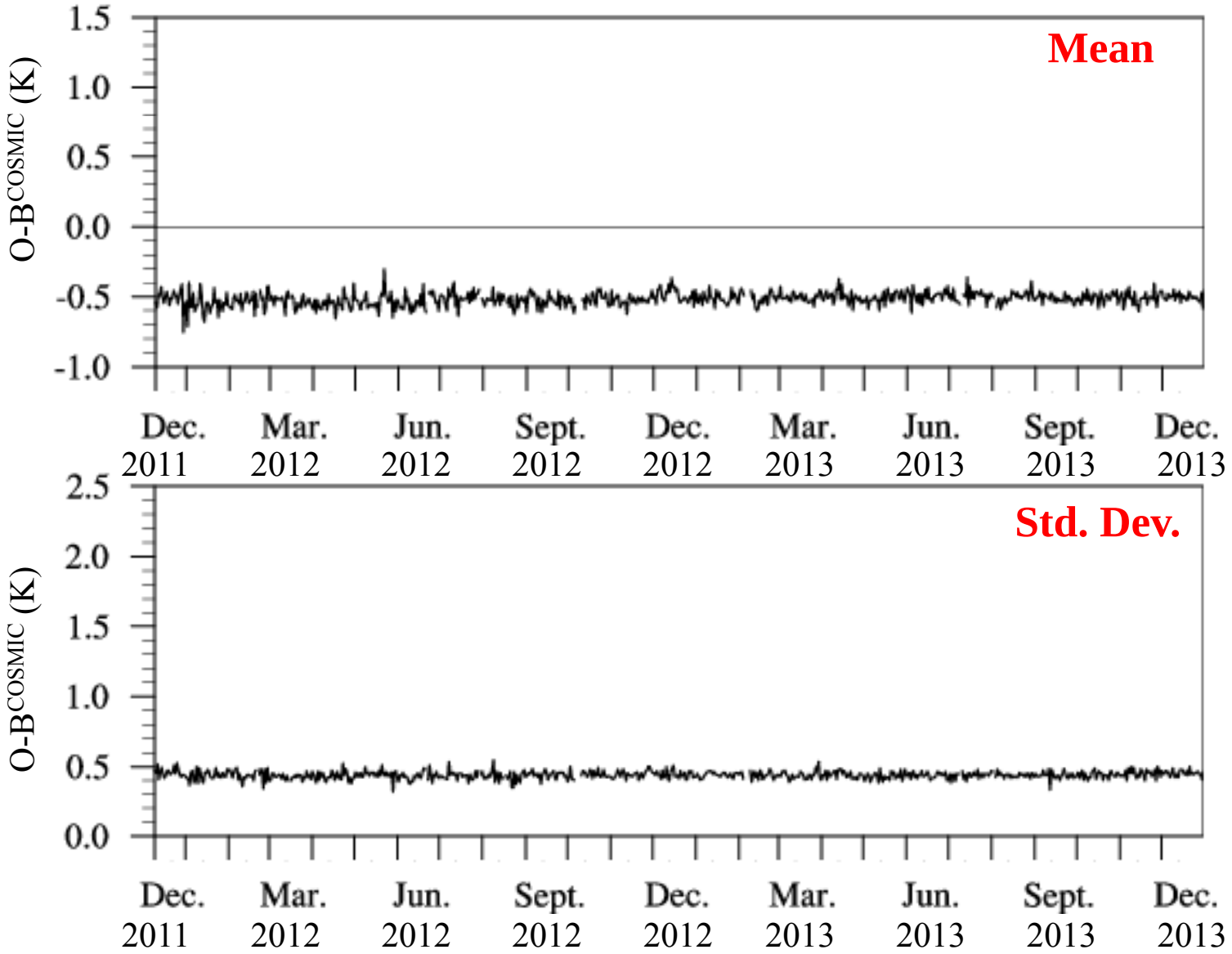
Ch 8



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60^{o}S ~ 60^{o}N, Dec. 10, 2011 ~ Dec. 31, 2013

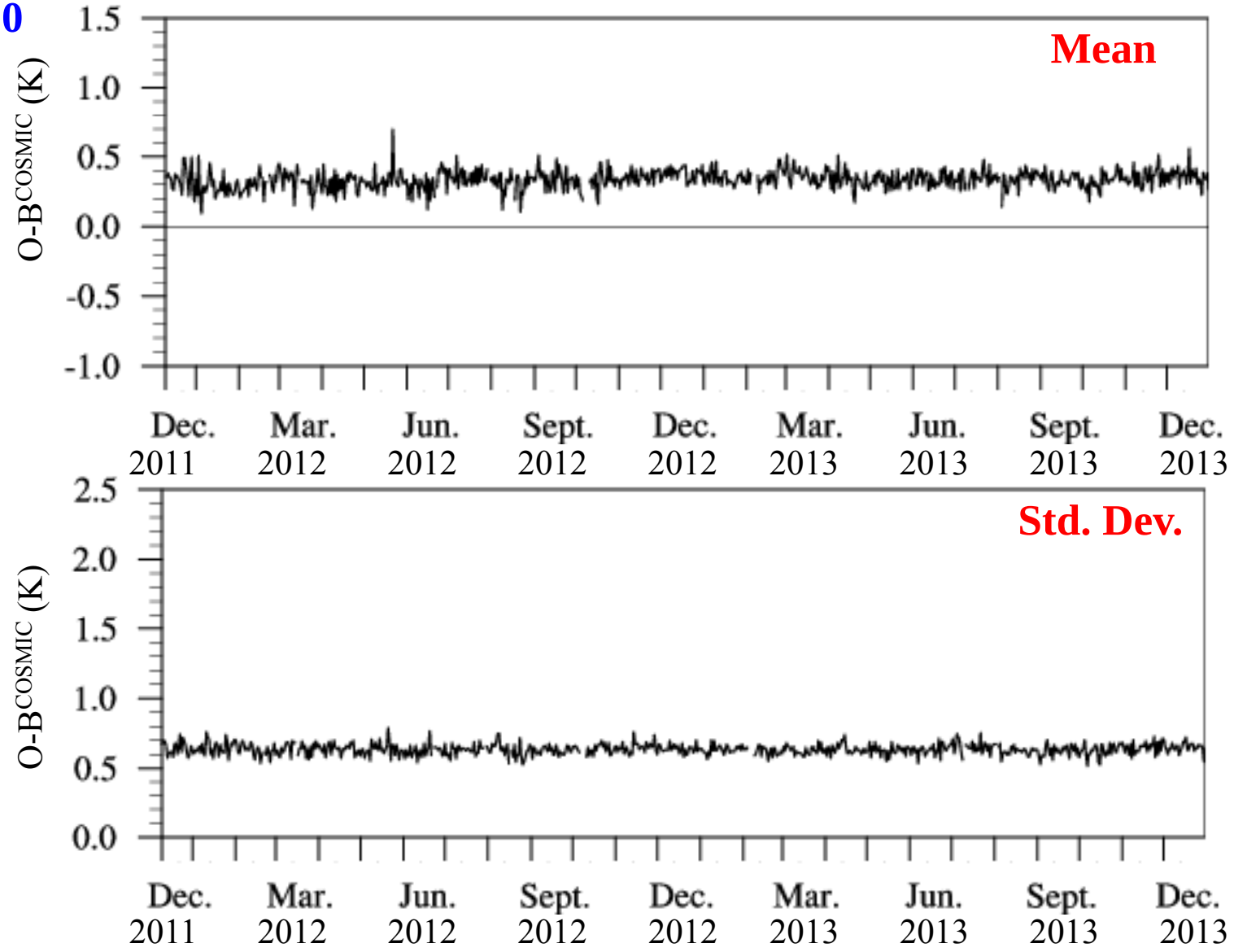
Ch 9



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

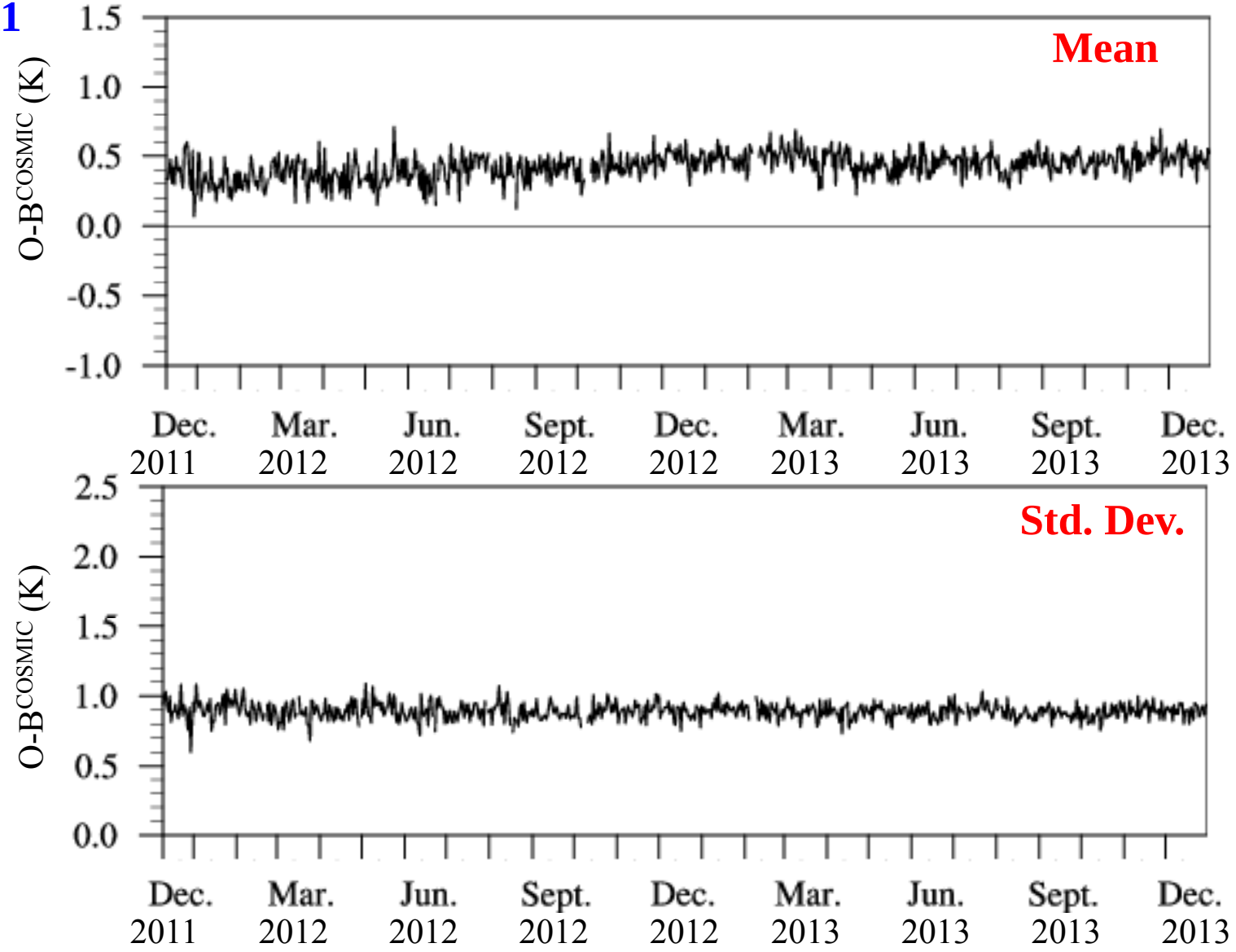
Ch 10



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

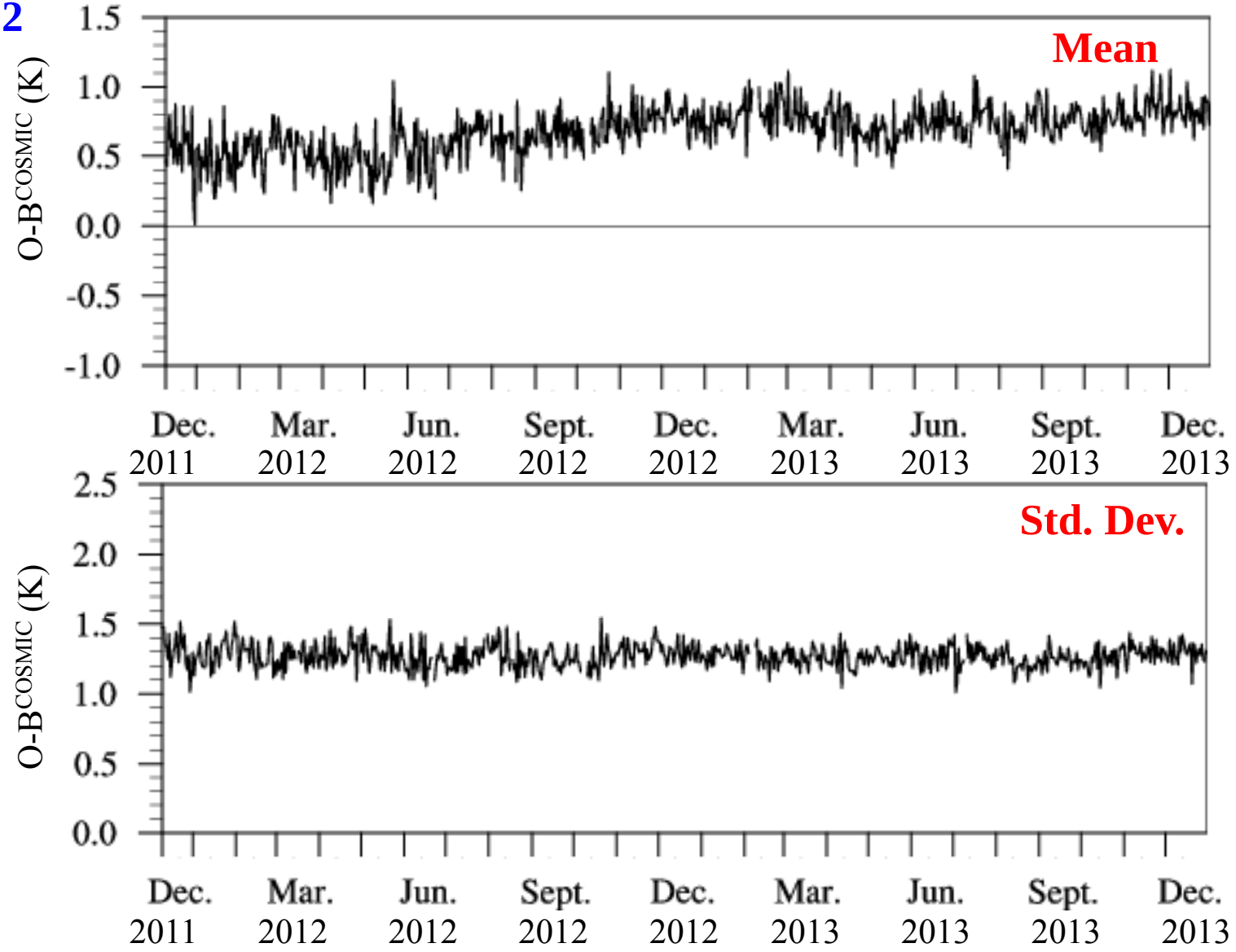
Ch 11



Daily Mean and Std. Dev. of O-B^{COSMIC}

Clear-sky, over ocean, 60^{o}S ~ 60^{o}N, Dec. 10, 2011 ~ Dec. 31, 2013

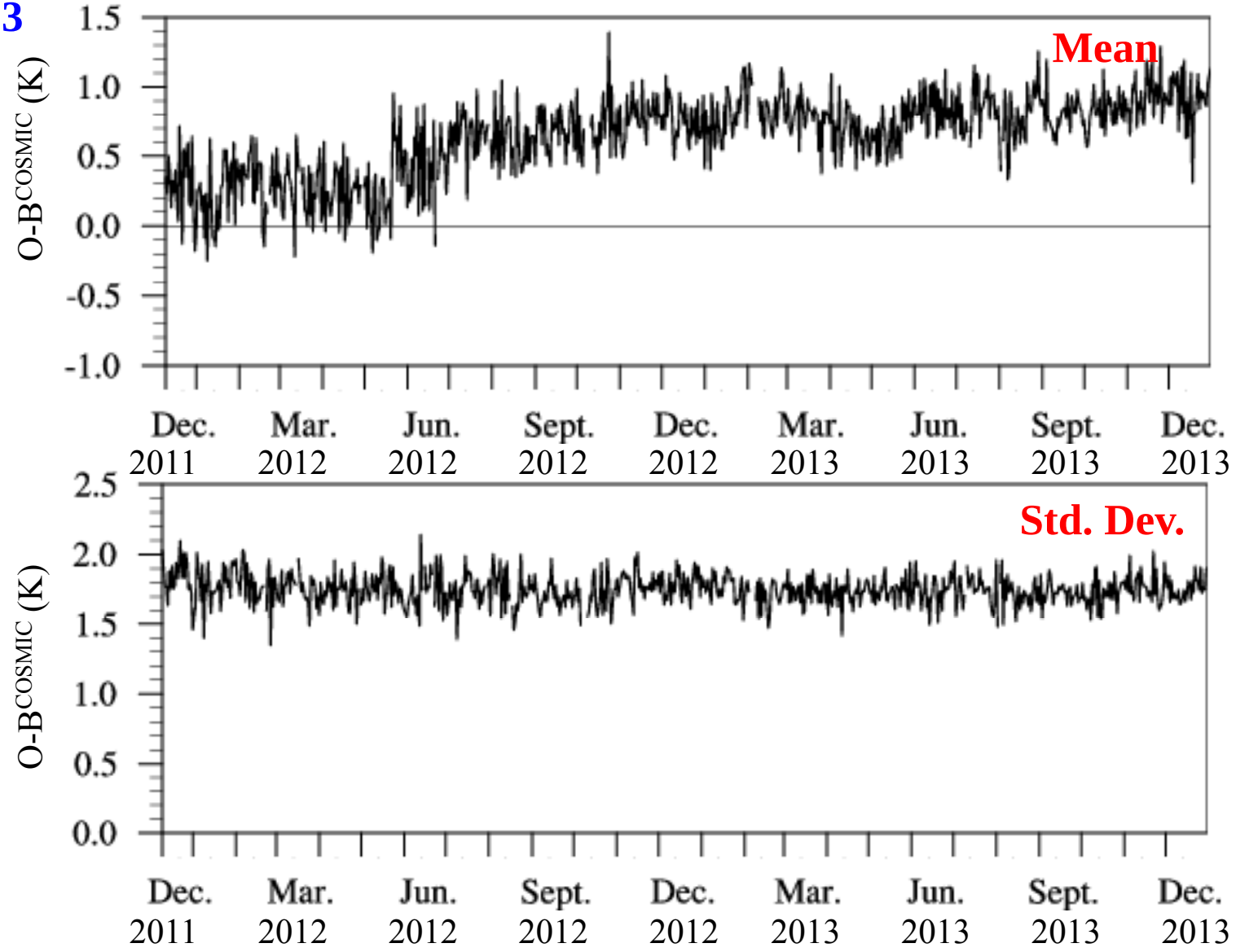
Ch 12



Daily Mean and Std. Dev. of O-B^{COSMIC}

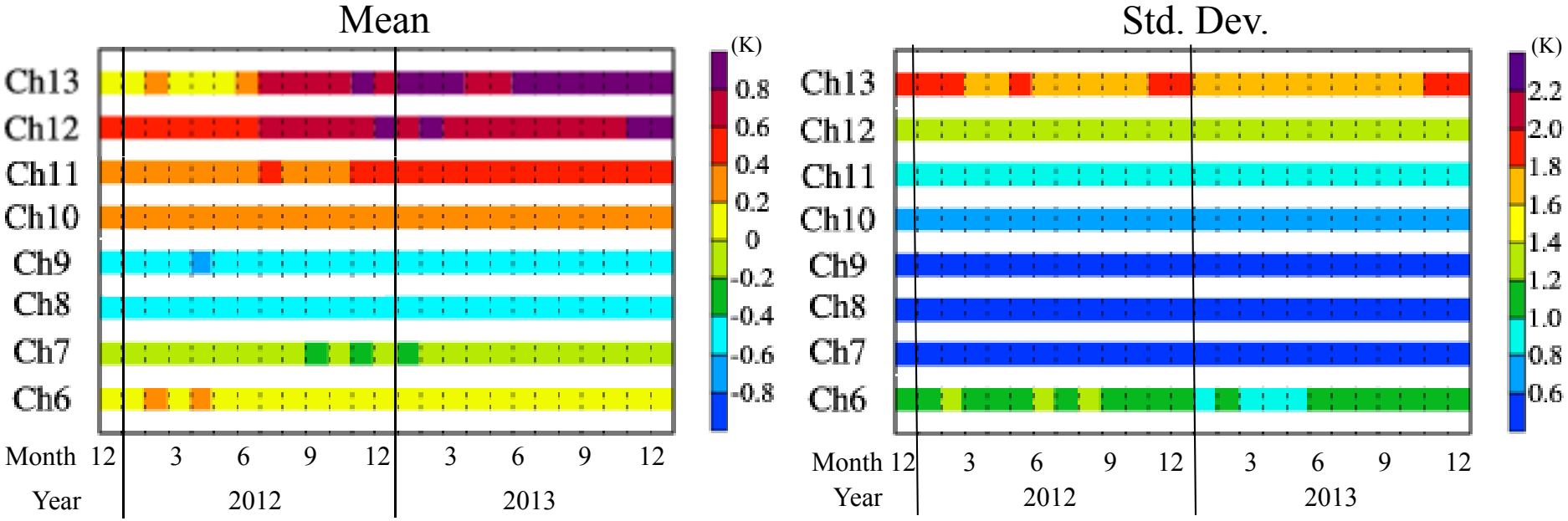
Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

Ch 13



Monthly Mean of O-B^{COSMIC}

Clear-sky, over ocean, 60°S ~ 60°N, Dec. 10, 2011 ~ Dec. 31, 2013

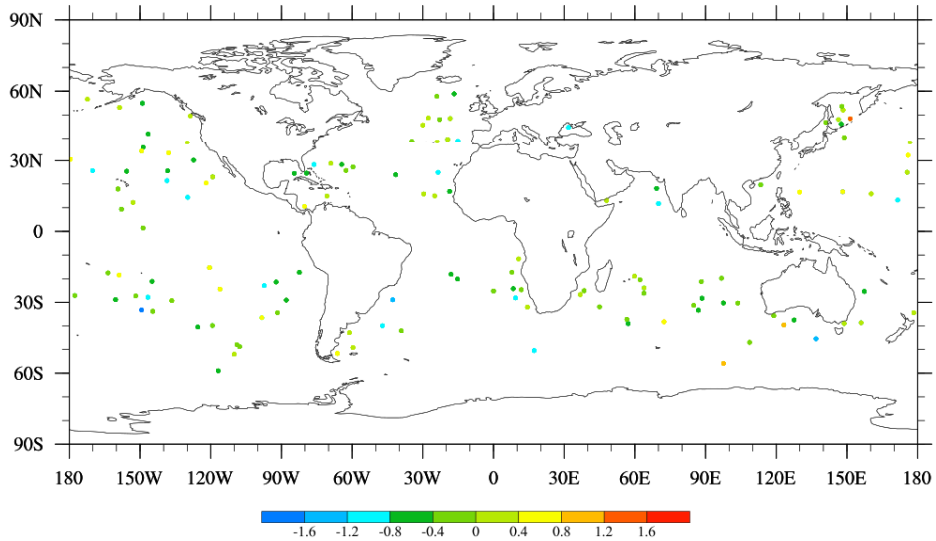


Channels 6 to 11 show consistently stable mean O-B and standard deviation.

Monitoring of ATMS Bias Characterization

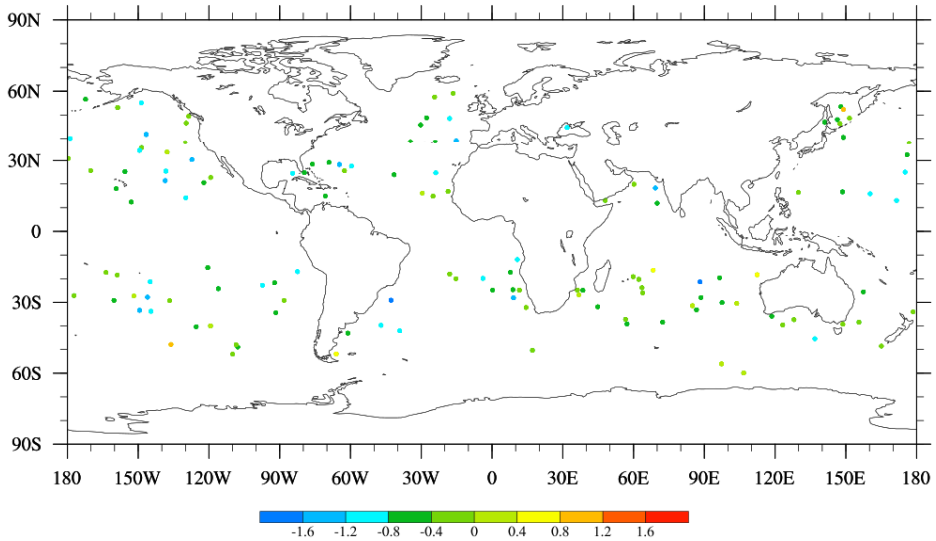
O-B for ATMS Ch.7 54.4 GHz 2014-05-11

(clear-sky, over ocean, 60°S-60°N)



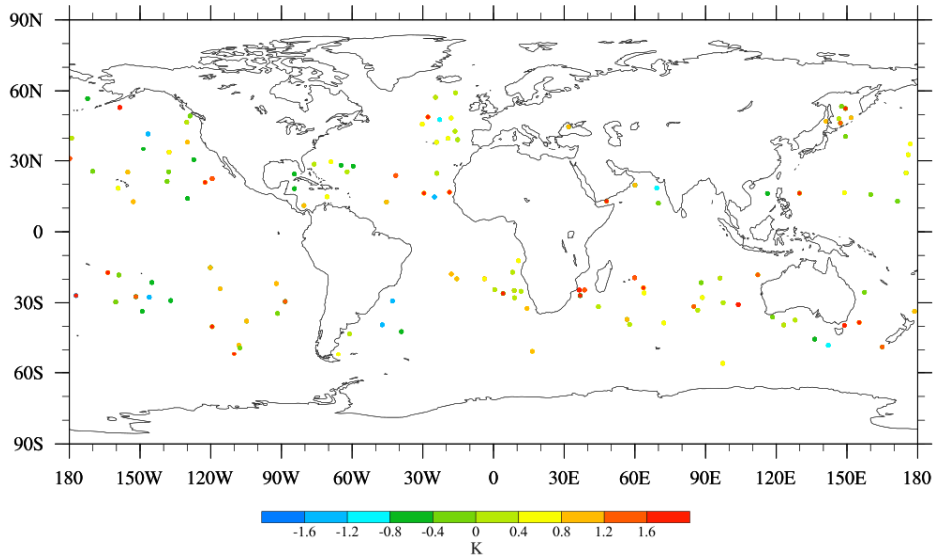
O-B for ATMS Ch.9 55.5 GHz 2014-05-11

(clear-sky, over ocean, 60°S-60°N)



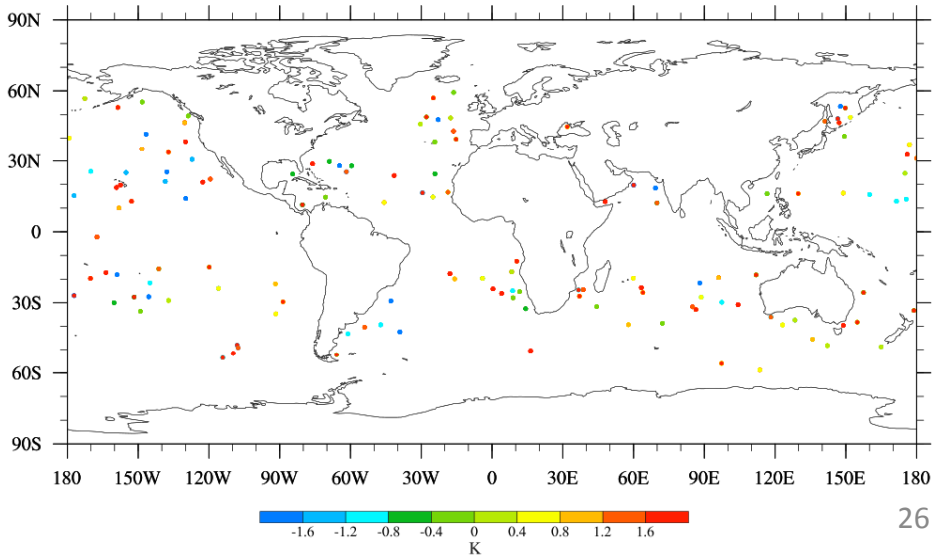
O-B for ATMS Ch.11 57.29034± 0.217 GHz 2014-05-11

(clear-sky, over ocean, 60°S-60°N)



O-B for ATMS Ch.13 57.29034± 0.3222± 0.022 GHz 2014-05-11

(clear-sky, over ocean, 60°S-60°N)



Summary

- Since Dec. 2012, COSMIC RO data are collocated with ATMS observations for channels 5-13. Clear-sky conditions over ocean within 60^{o}S~60^{o}N are examined.
- ATMS global BT biases for channels 5-13 derived from GPS RO are asymmetric to scan angle and within ±0.7K. After scan bias correction, the biases become Gaussian, and the magnitudes are one order smaller.
- The SRF comparison presents biases less than ±0.2K. It suggests that forward RTM should either use the measured SRFs or remove the model biases introduced by the Boxcar SRFs that currently used in CRTM.
- Moreover, the biases and standard deviations of channels 6-11 are stable and consistent with each other; but for channels 12 and 13 their biases increase since July 2012.
- To deduce a long-term climate trend with high accuracy, precision, stability, and consistency, this study can significantly contribute to a better refined post-launch calibration of ATMS, and future integration of ATMS data into long-term satellite climate data records (CDRs).