Inter-calibration and validation of observations from ATMS and SAPHIR microwave sounders

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Outline

- Radiometric and Geometric Errors
- ATMS and SAPHIR instruments
- Inter-calibrating SAPHIR and ATMS
- Validating SAPHIR and ATMS observations using radiosonde data
- Validating ATMS temperature sounding channels using GPS-RO profiles
- Geolocation Errors
- Conclusion

Radiometric and Geometric Errors

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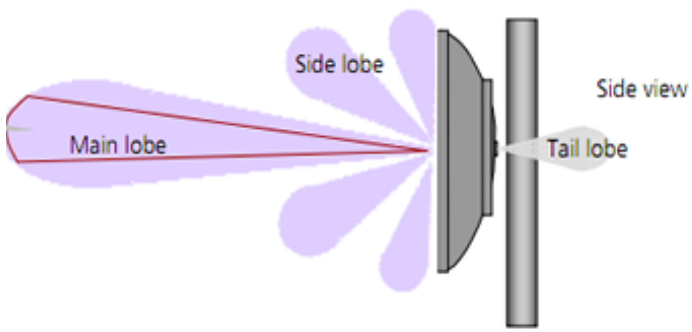
Radiometric Errors

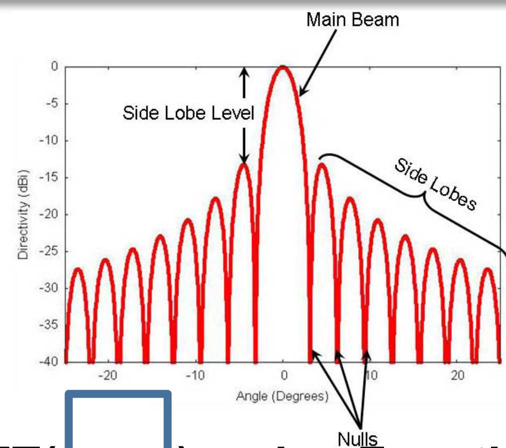
- Change in Antenna Reflectivity and Emissivity
- Imperfect Electronics: APC, Oscillators, Amplifiers, ...
- Radio Frequency Interference (RFI)
- Uncertainty in Warm Load Temperature
- Non-linearity in the Calibration
- Pre- and Post-processing Errors

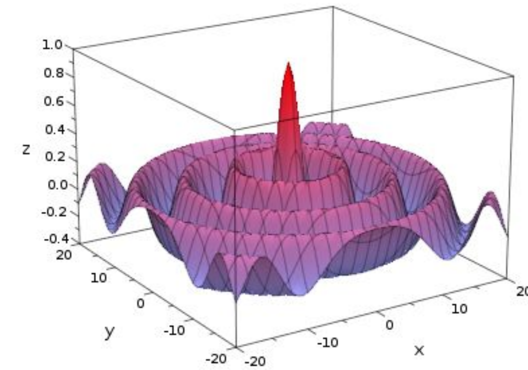
Geometric Errors

- Antenna and/or Feedhorn Misalignment
- Satellite Attitude Offset
- Satellite Clock Offset and Timing Error
- Error in Ephemeris Data
- Anomaly in Scan-drive Motor
- Error in Sensor Modelling

A Simple Case: Antenna Pattern







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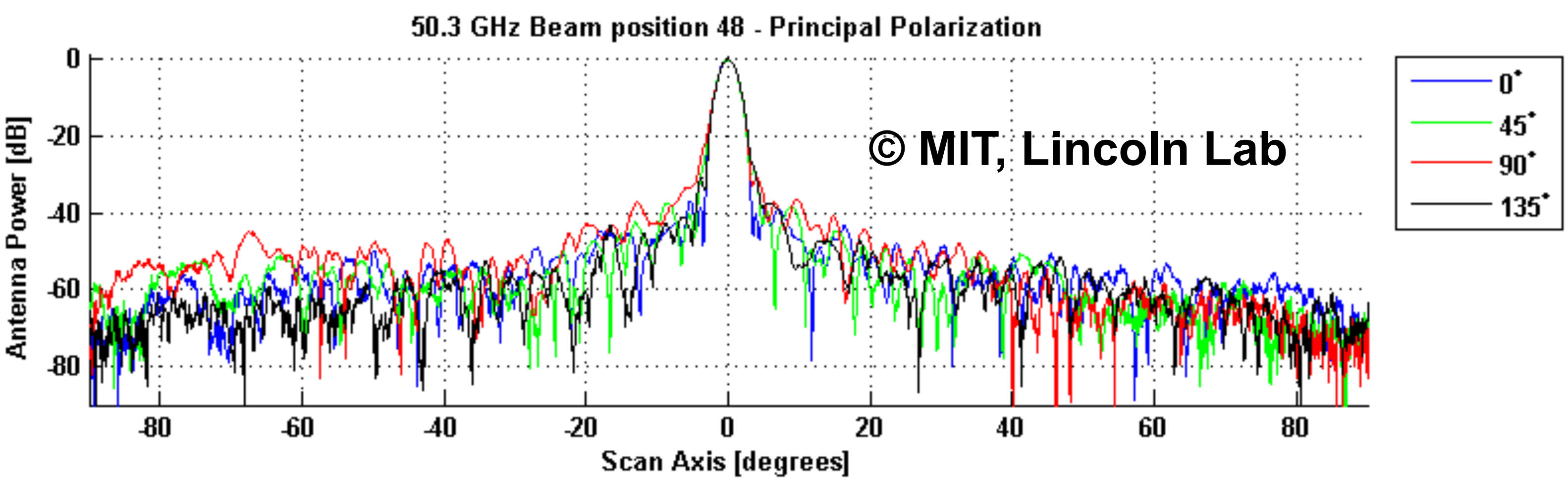
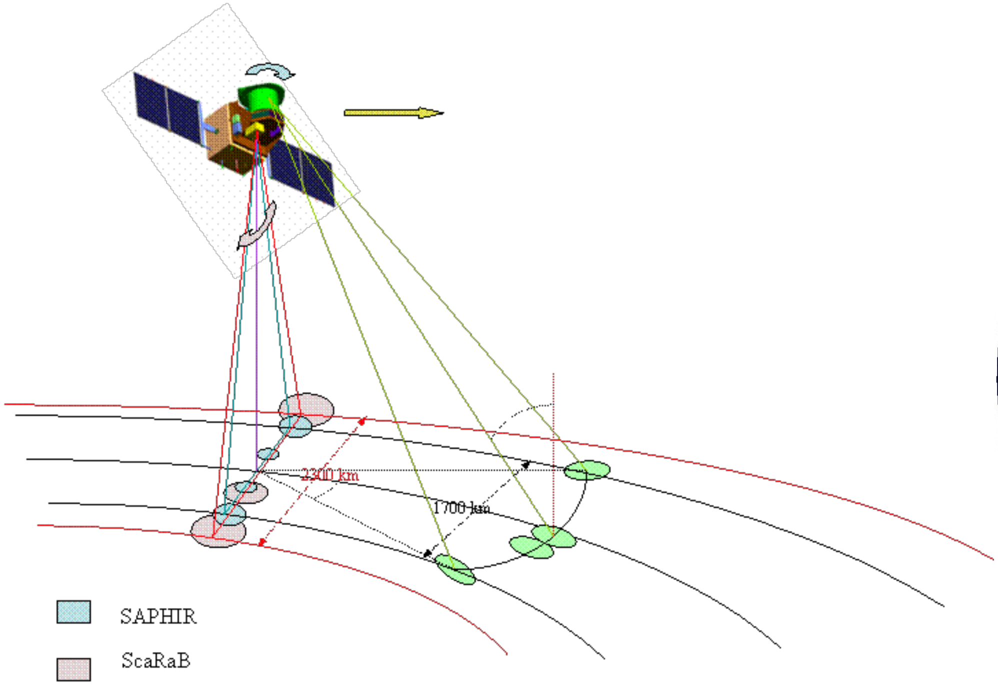
FT( ) = sinc Function

3D => Bessel Function

Reciprocity = receive and transmit properties of an antenna are identical



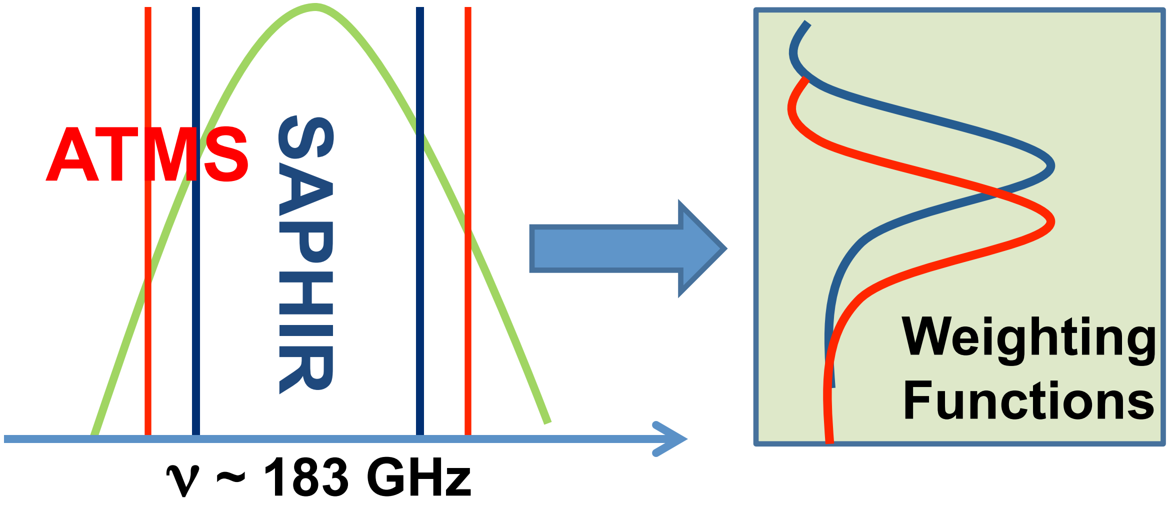
Megha-Tropiques

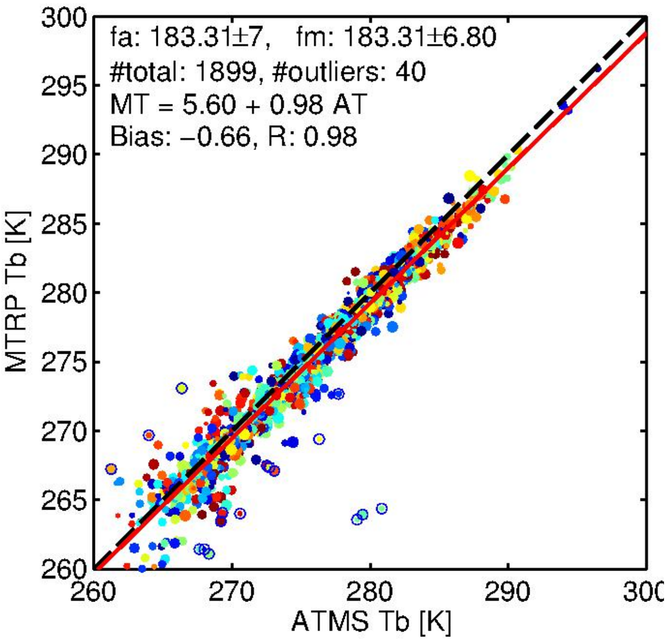


- A microwave imager (MADRAS) to study precipitation and cloud properties (SSM/I type, with an additional channel at 157 GHz).
- A microwave sounding instrument for the atmospheric water vapor (SAPHIR - 6 channels in the 183 GHz band).
- A radiometer for measuring outgoing radiative fluxes at the top of the atmosphere (ScaRaB).

Inter-calibrating SAPHIR and ATMS

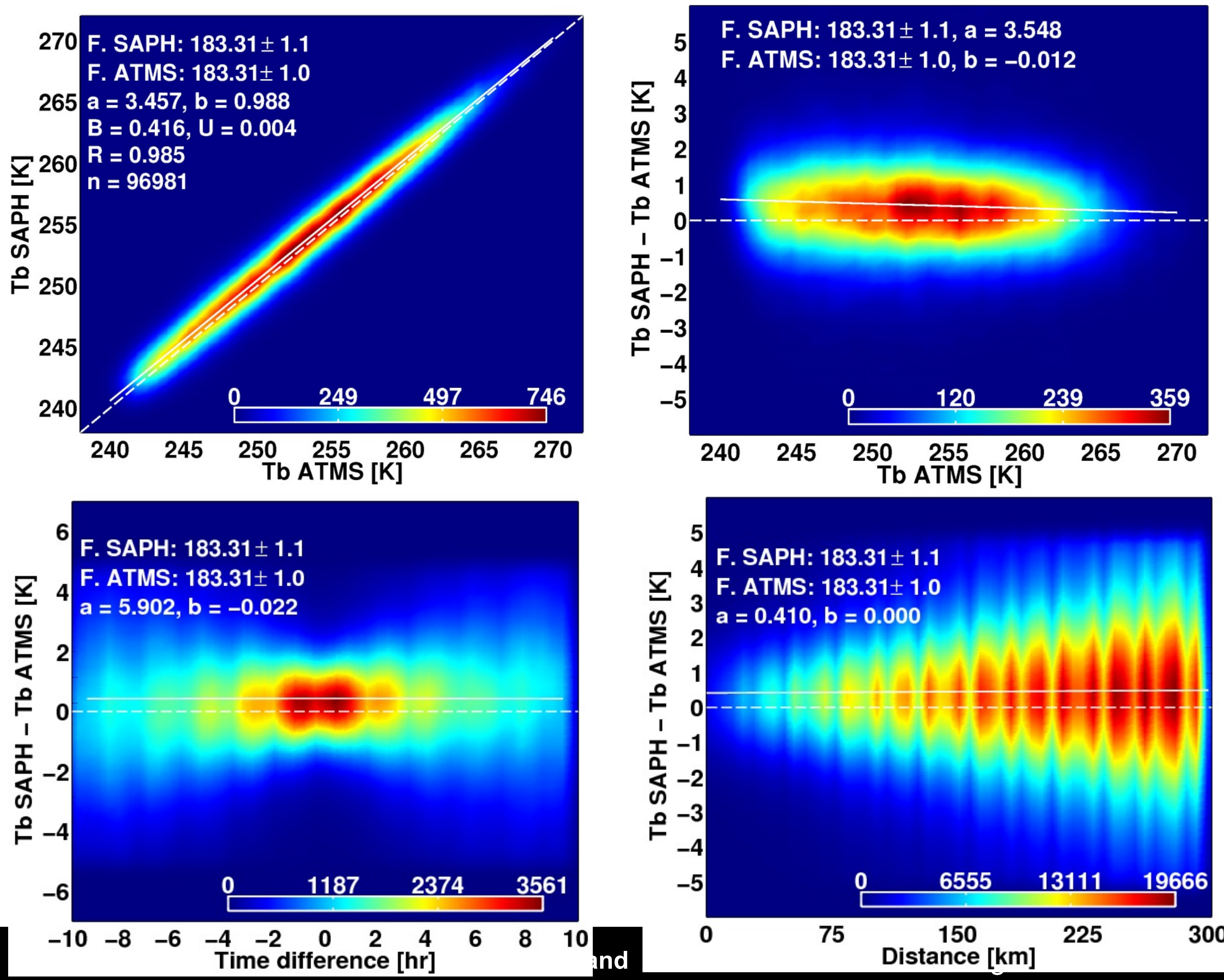
SAPHIR vs. ATMS





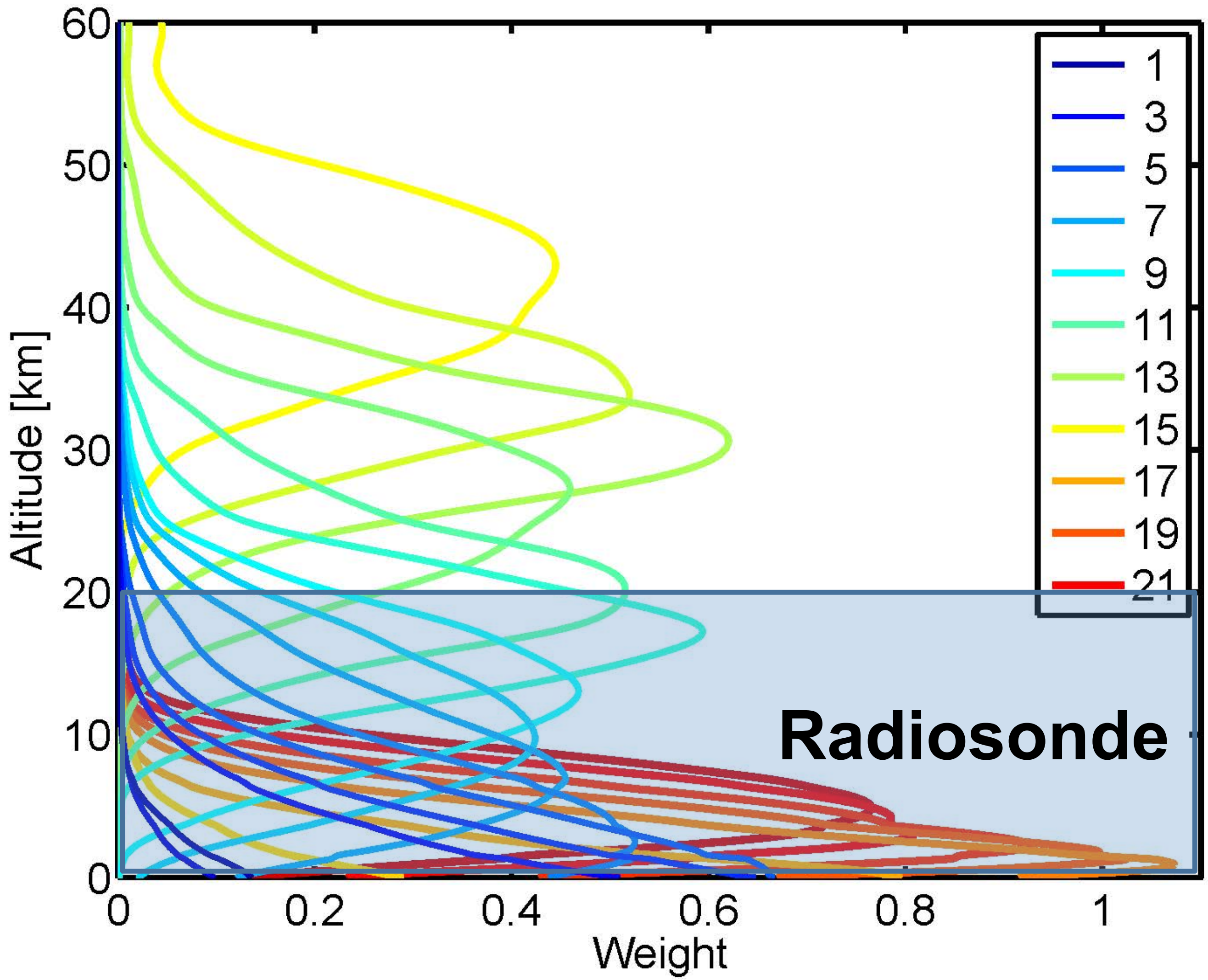
ATMS	SAPHIR	Bias (Obs)	Bias (Sim)	Obs - Sim
183±7.0	183±6.8	-0.68	-0.42	-0.26
183±4.5	183±4.2	-1.56	-0.91	-0.65
183±3.0	183±2.8	-1.23	-0.93	-0.30
183±1.0	183±1.1	+0.42	+0.90	-0.48

SAPHIR vs. ATMS

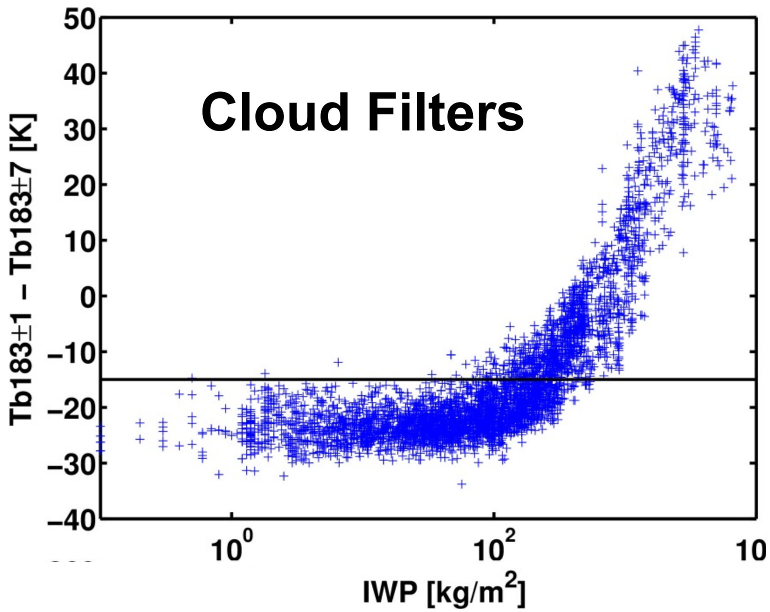


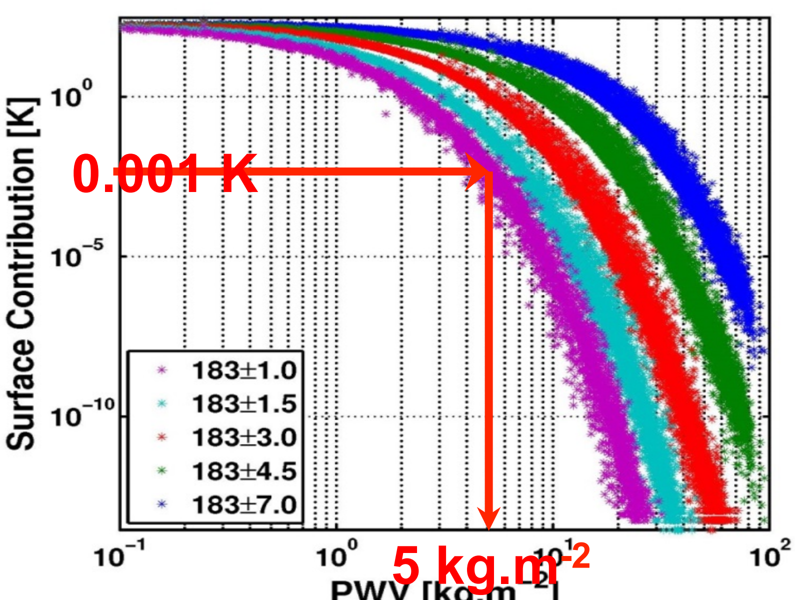
Validating using radiosonde data

ATMS Weighting Functions

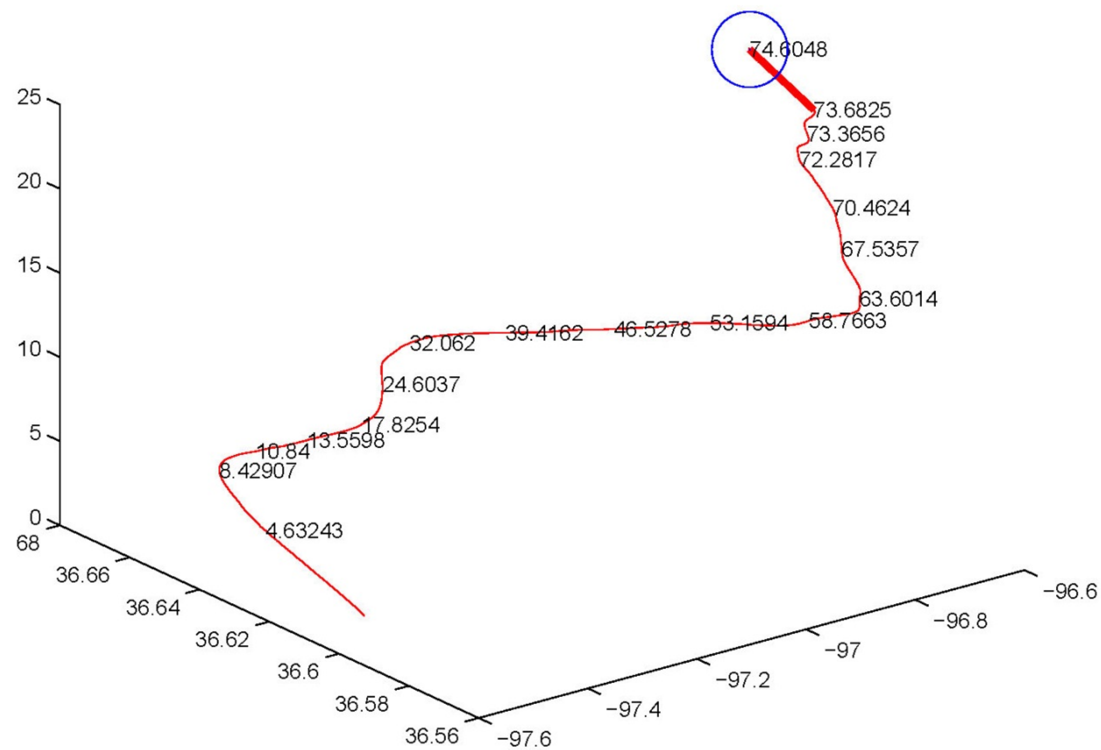


Cloud and PWV Filters

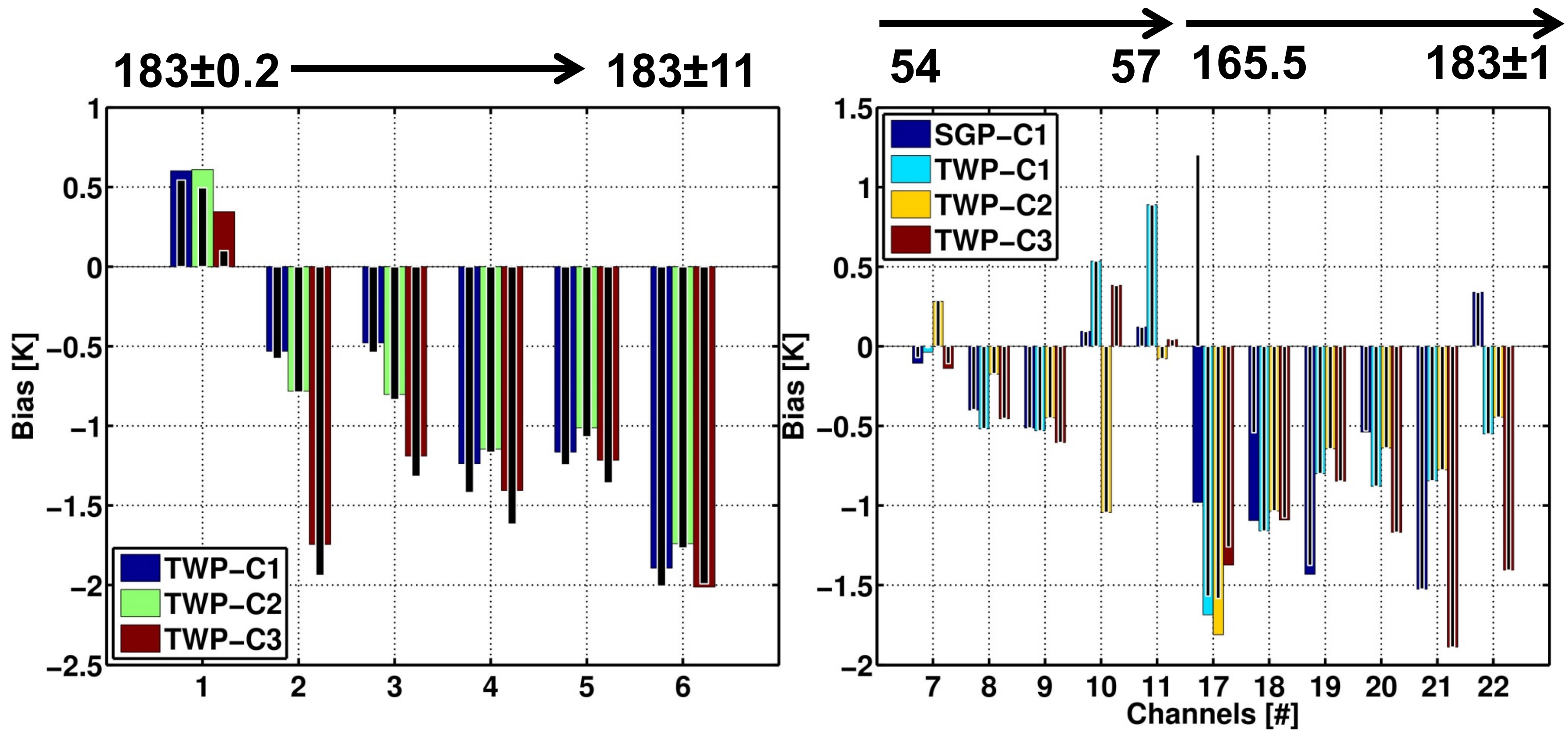




Filter for balloon drift



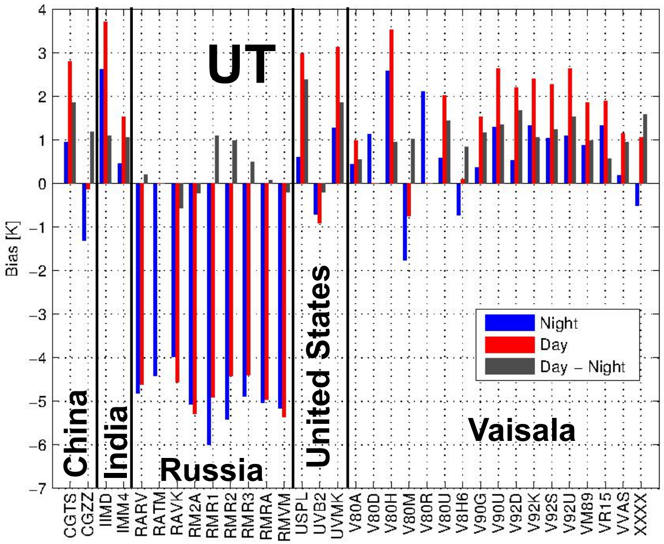
Validating Using ARM Data

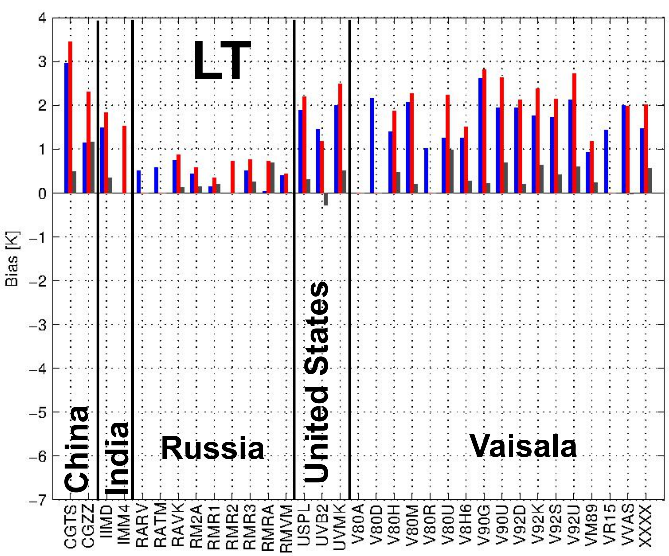


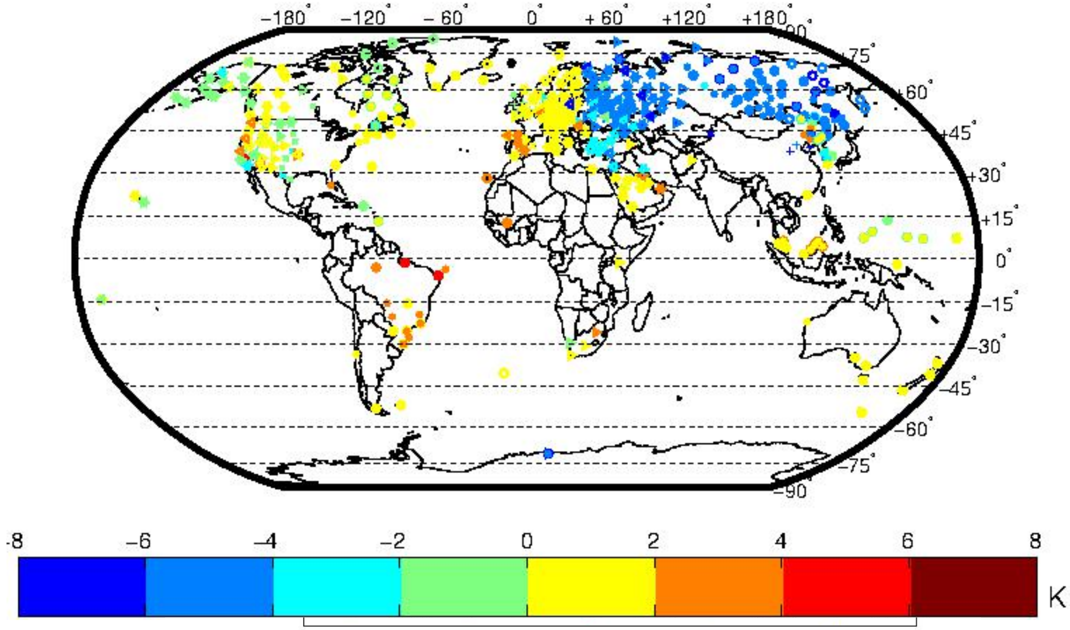
SAPHIR vs ARM

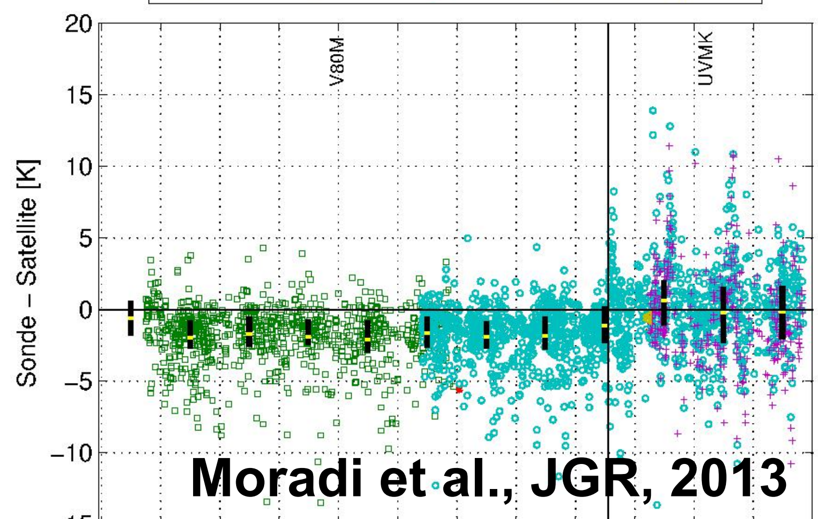
ATMS vs ARM

Error in IGRA humidity profiles





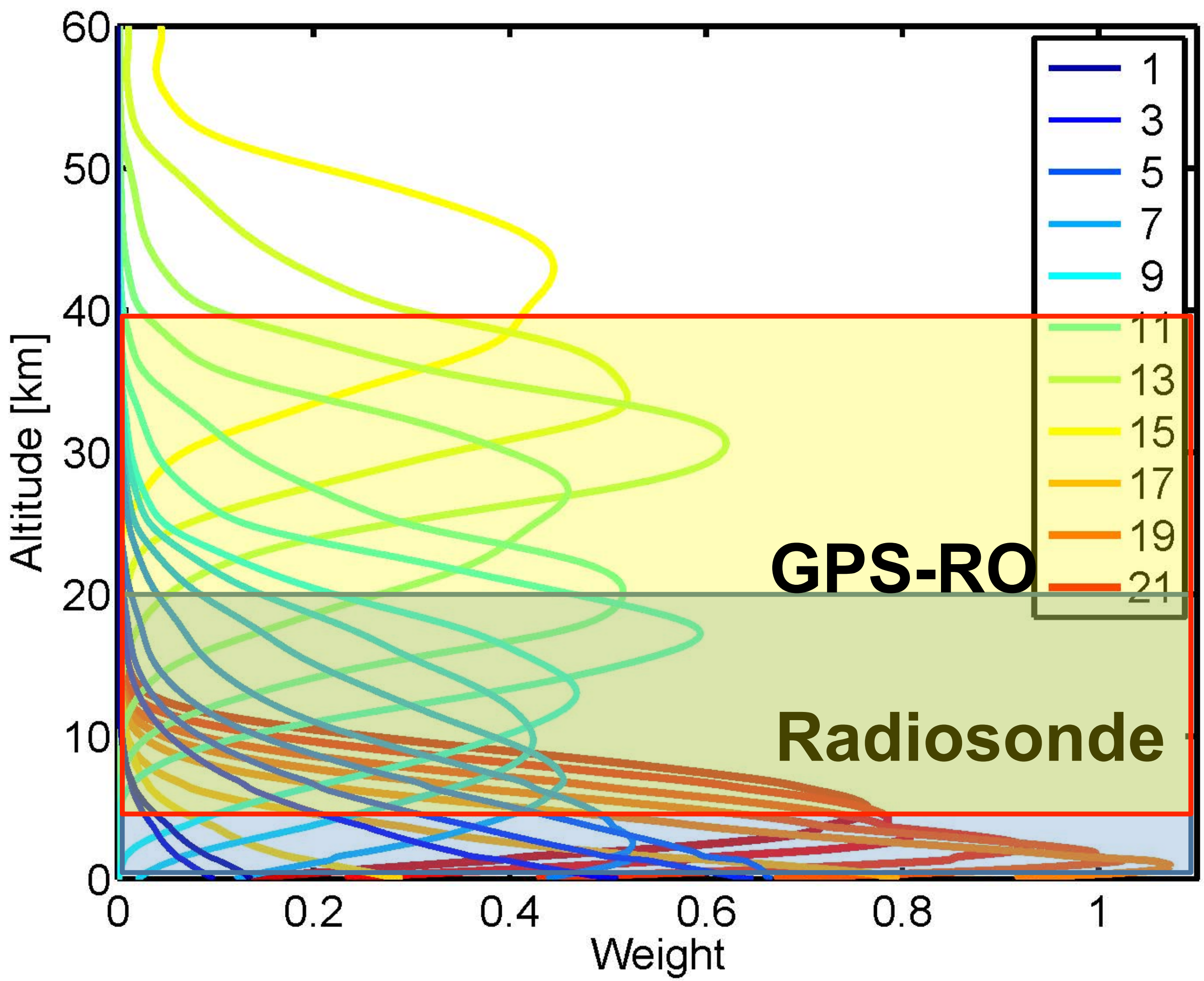




Moradi et al., JGR, 2013

Validating using GPS-RO data

ATMS Weighting Functions



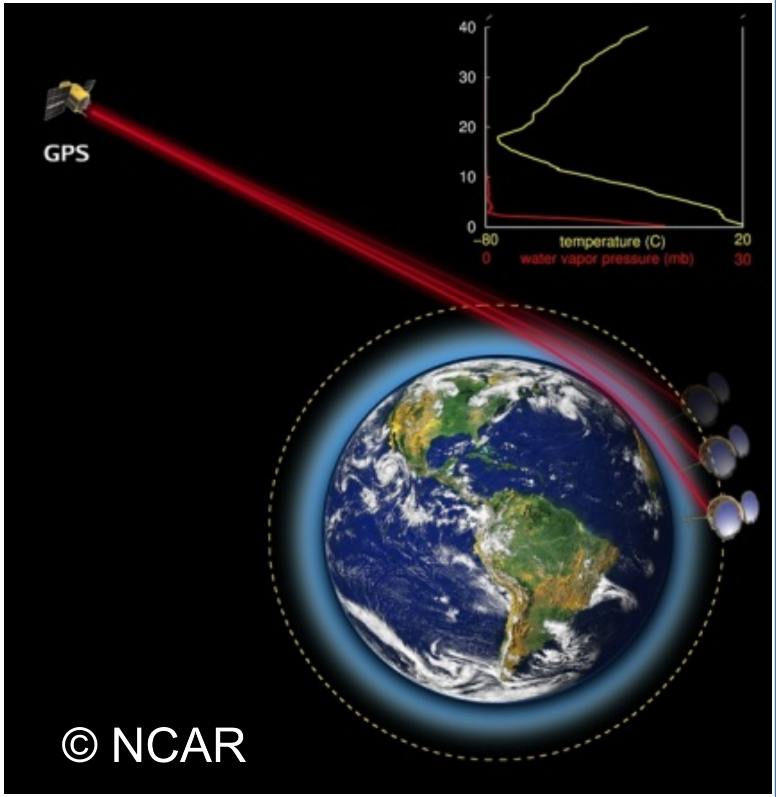
GPS Radio Occultation Data

- Radio signals transmitted by Global Positioning System (GPS) satellites are received by a receiver on a LEO satellite

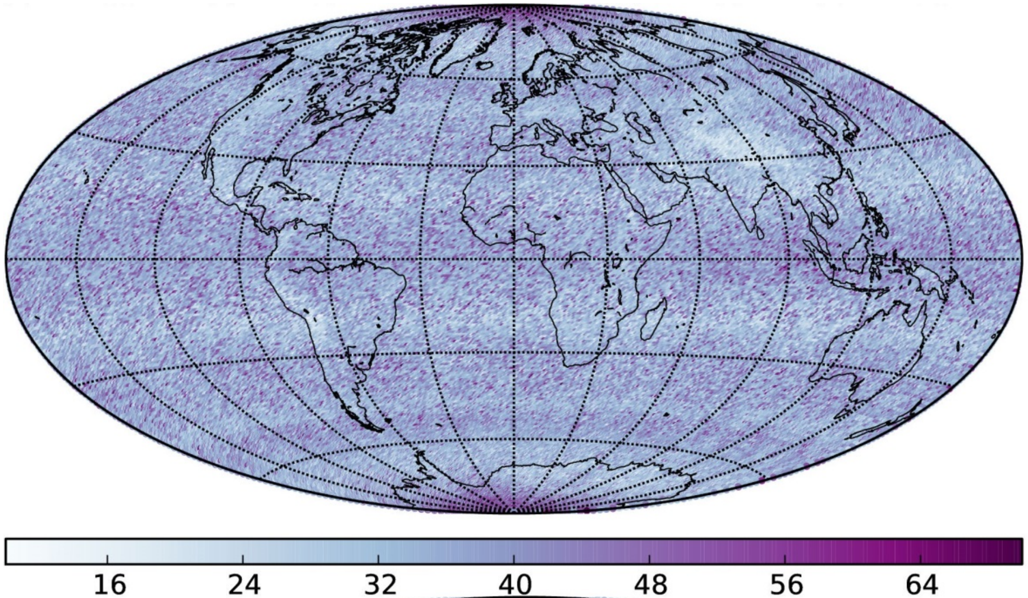
- Temperature and water vapor profiles are derived from bending angles using a-priori profiles and inversion techniques

- Raw GPS-RO data (time delay) have very high accuracy in the upper troposphere and lower stratosphere (500 hPa to 40 km) but different

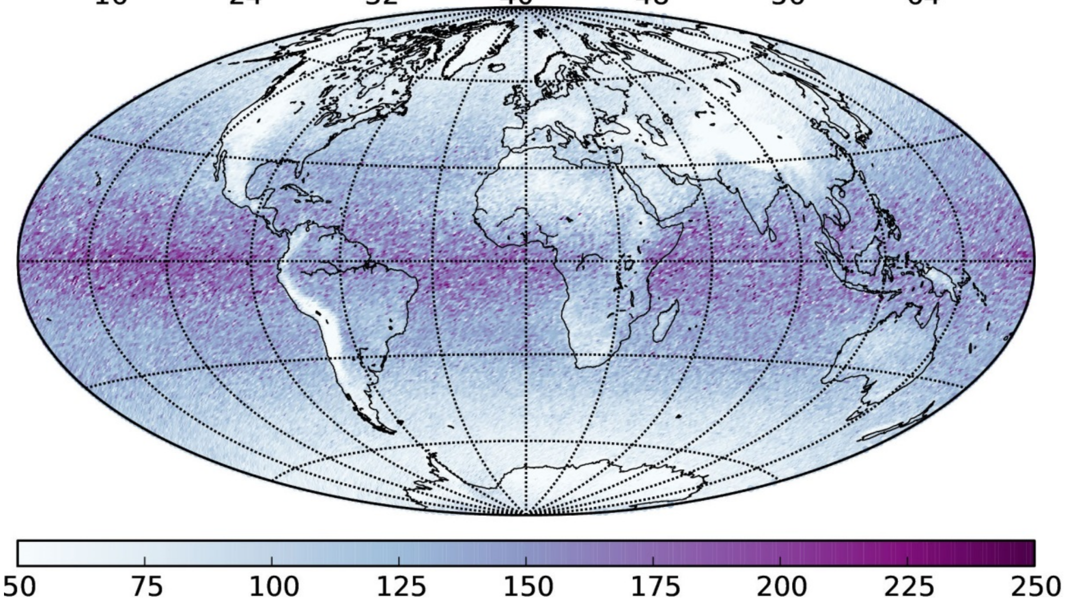
- errors and uncertainties are introduced during inversion to the atmospheric state variables



Drift in GPS Profiles

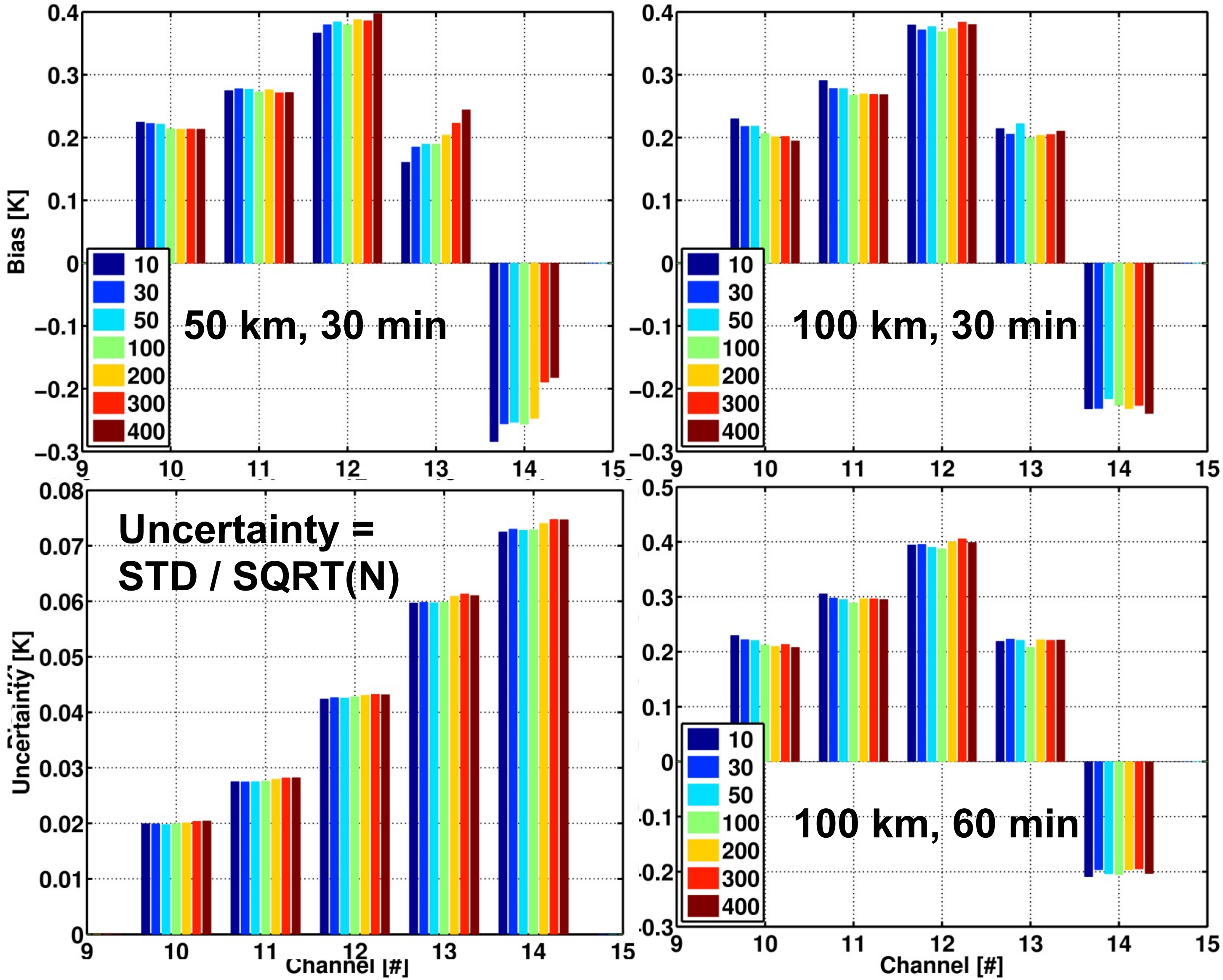


From 400 hPa to 100 hPa

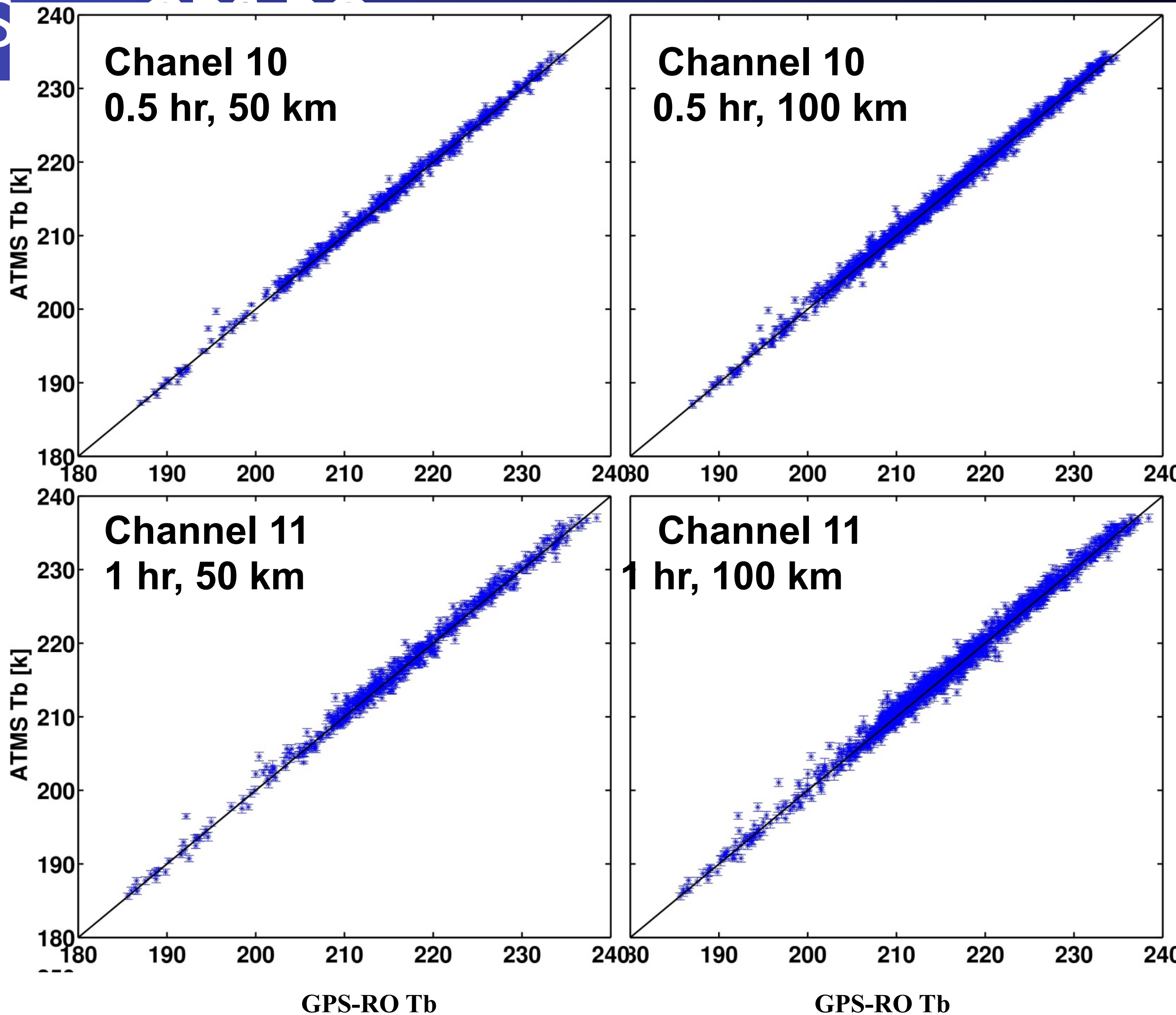


From ground To 400 hPa

ATMS vs. GPS RO



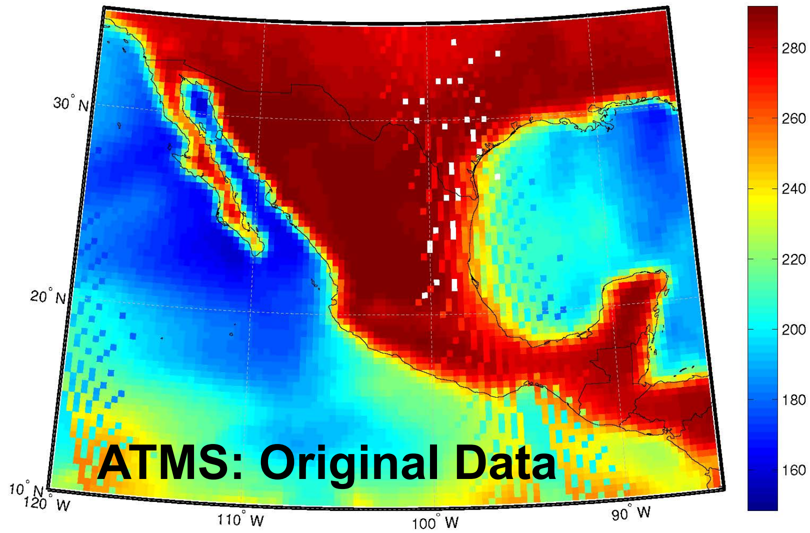
ATMS

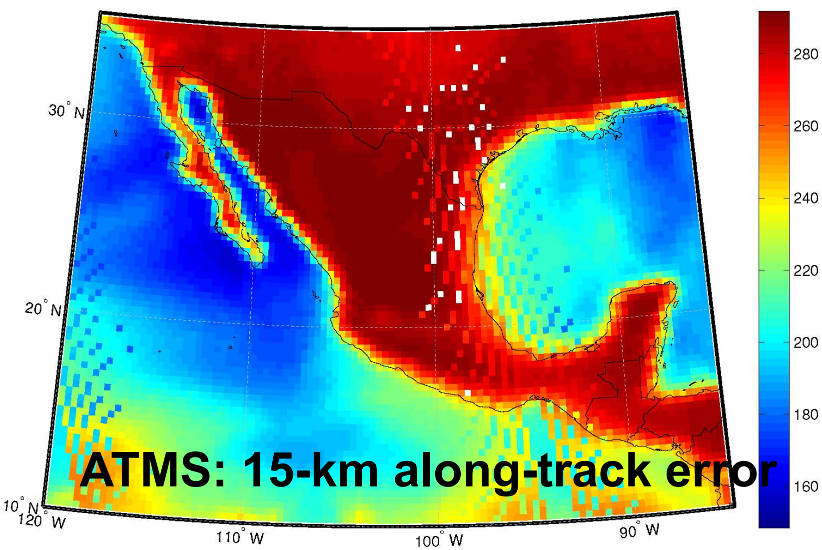


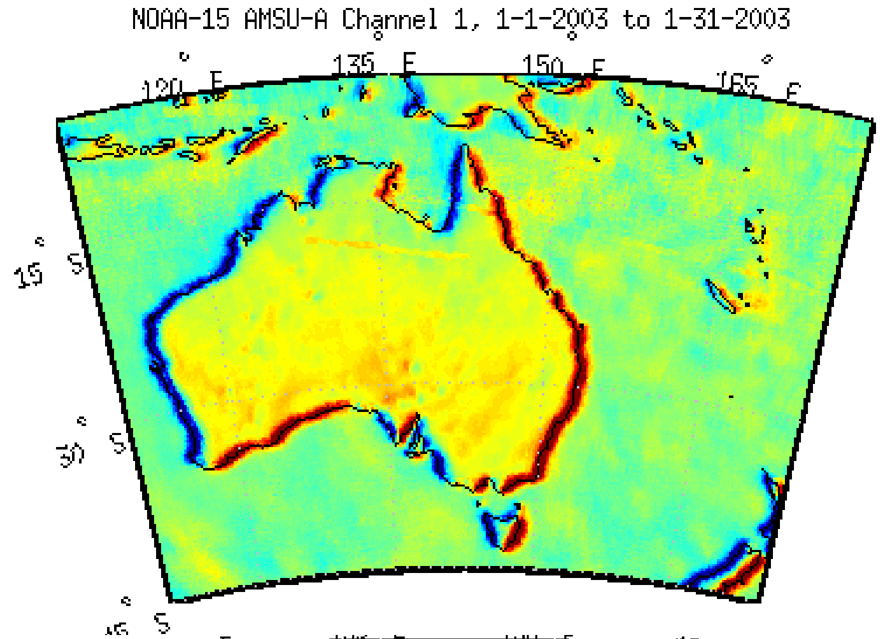
Chanel 10
0.5 hr, 50 km
Channel 10
0.5 hr, 100 km
Channel 11
1 hr, 50 km
Channel 11
1 hr, 100 km
ATMS Tb [k]
ATMS Tb [k]
GPS-RO Tb
GPS-RO Tb
180
190
200
210
220
230
240

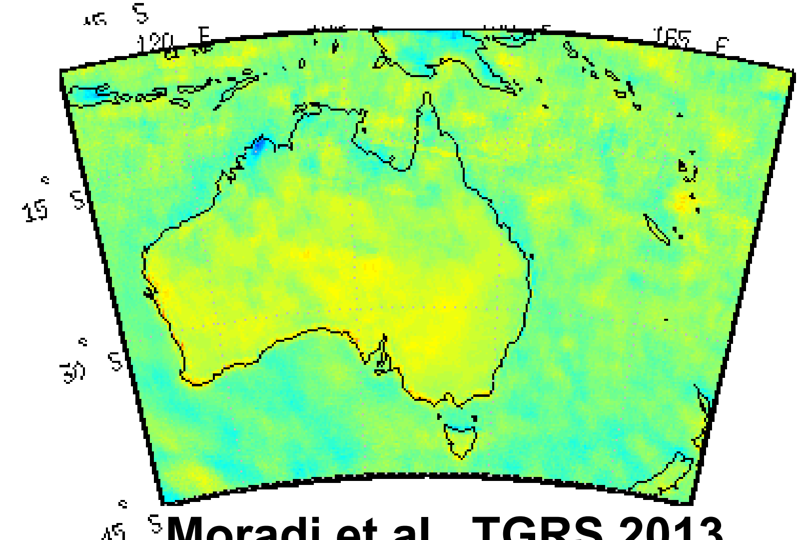
Geolocation Error

Characterization: Asc - Des



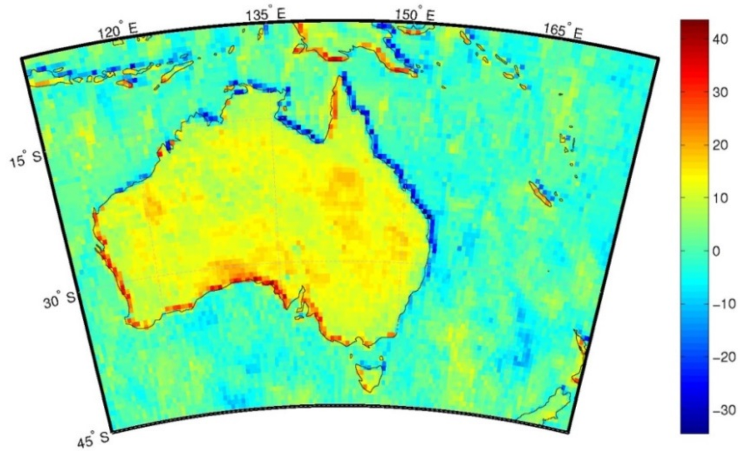




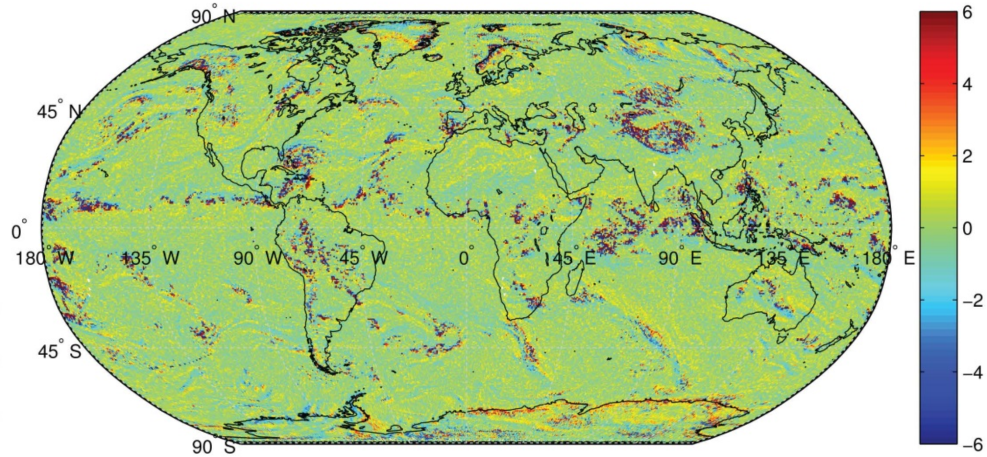


Moradi et al., TGRS 2013

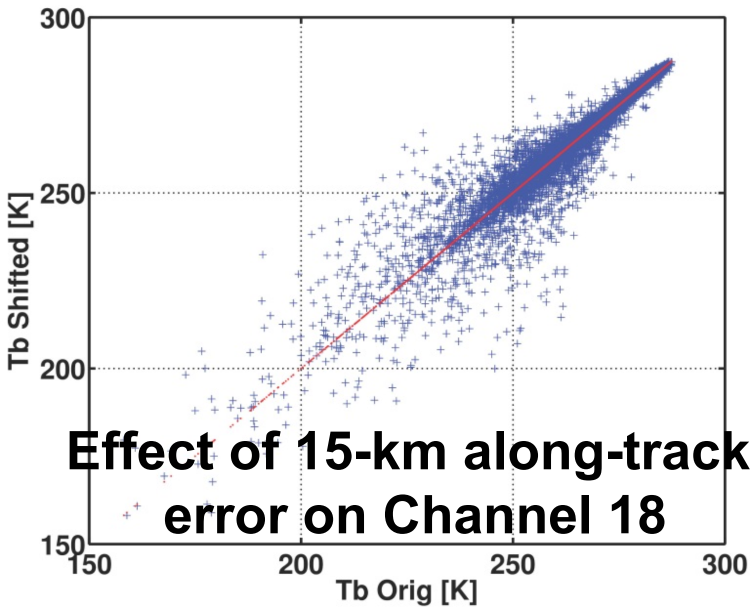
Effect of Geo Error on Obs



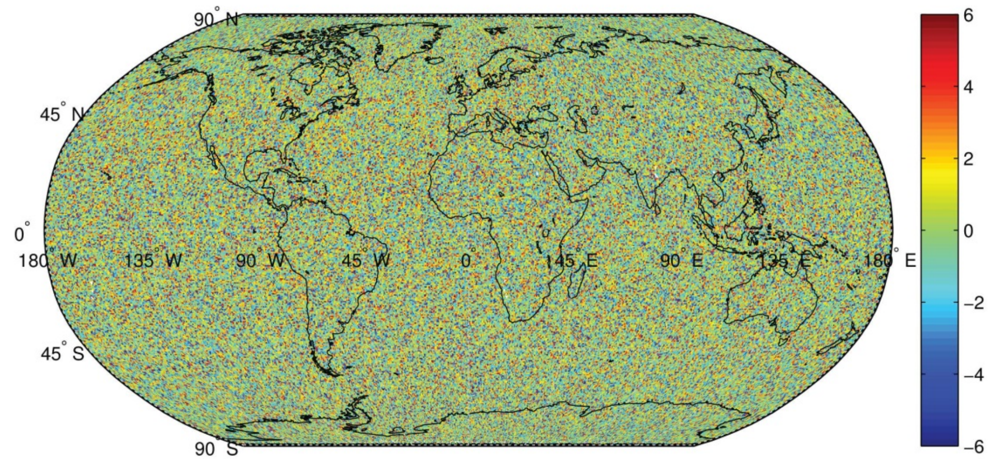
ATMS Chan 3: Geolocation Error



Effect of 15-km along-track error on Channel 18



Effect of 15-km along-track error on Channel 18



Effect of 15-km along-track error on Channel 15

Conclusions

- SAPHIR and ATMS observations show very good consistency
- SAPHIR provides a great opportunity for inter-calibrating MW WV channels on POES satellites or to transfer the calibration among the POES satellites
- There is still a lack of reference datasets for validating MW satellite observations
- Radiosonde data can only be used to evaluate the overall bias in the WV channels and cannot precisely detect the magnitude of the bias
- GPS-RO data provide a good opportunity for validating observations from upper troposphere and lower stratosphere but the difference between GPS-RO and satellite observations cannot be translated as absolute bias in the satellite data
- The window channels cannot still be validated because of uncertainty in the surface emissivity
- The accuracy of geolocation data is very important for many of the MW channels including surface sensitive, water vapor and stratospheric channels

Thanks for your attention

Sunrise in Northern Sweden after a two-month long polar-night

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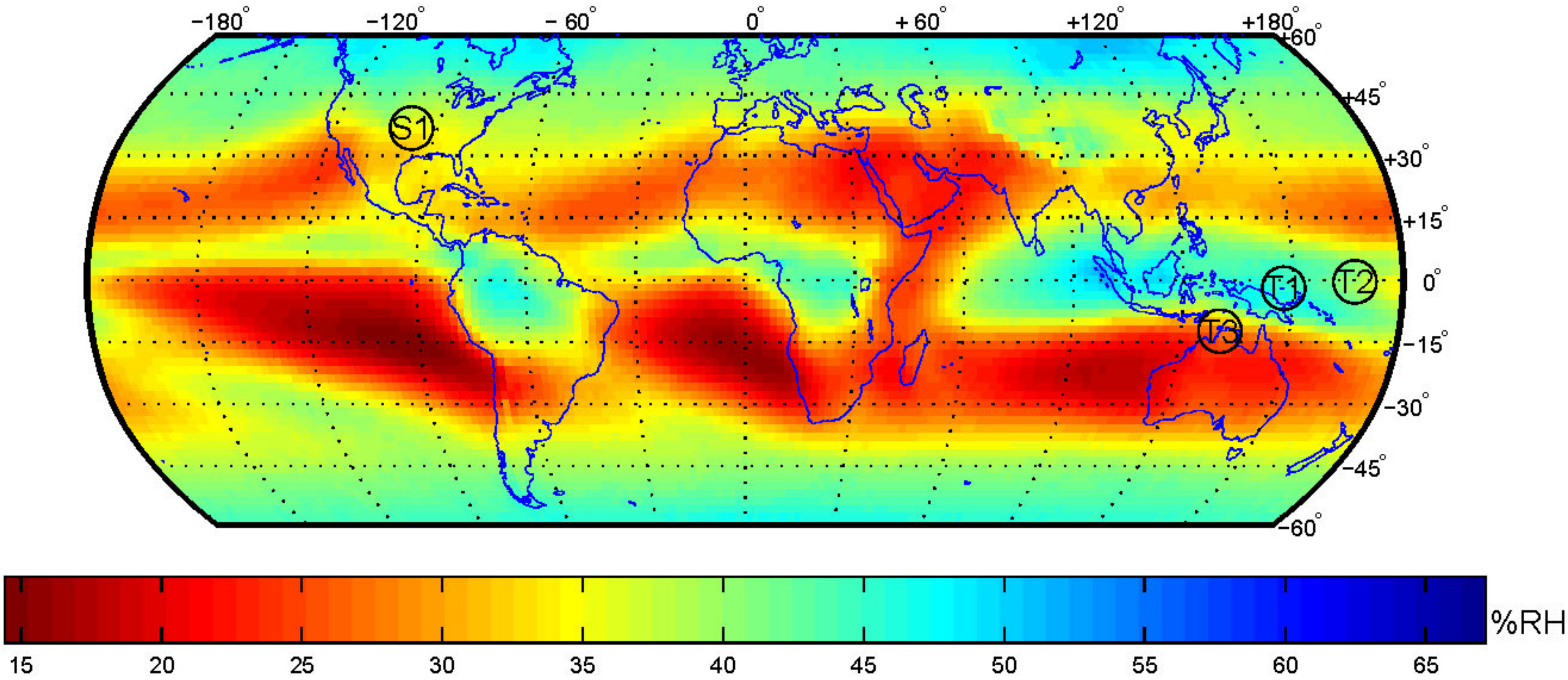
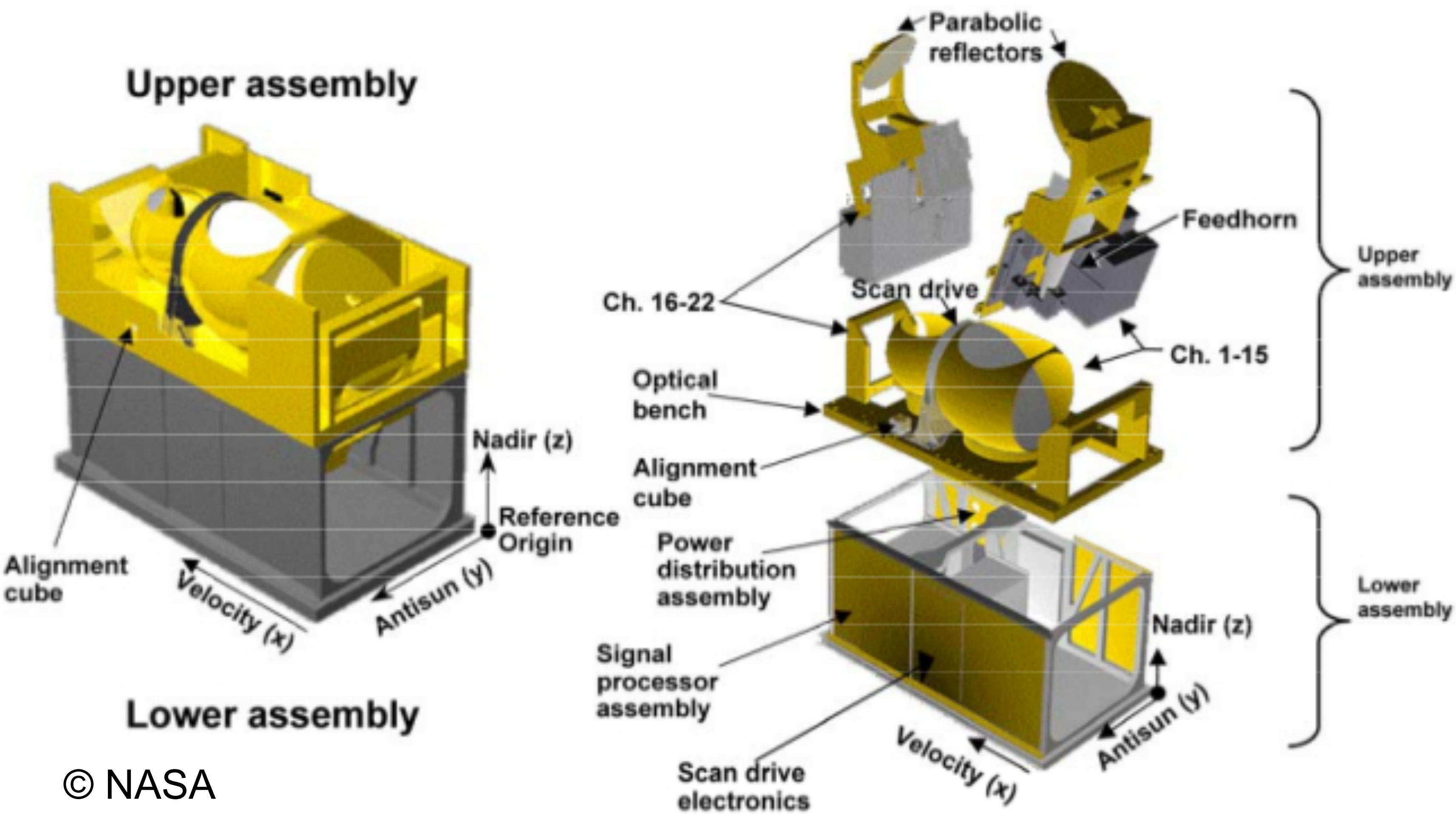
ARM Stations



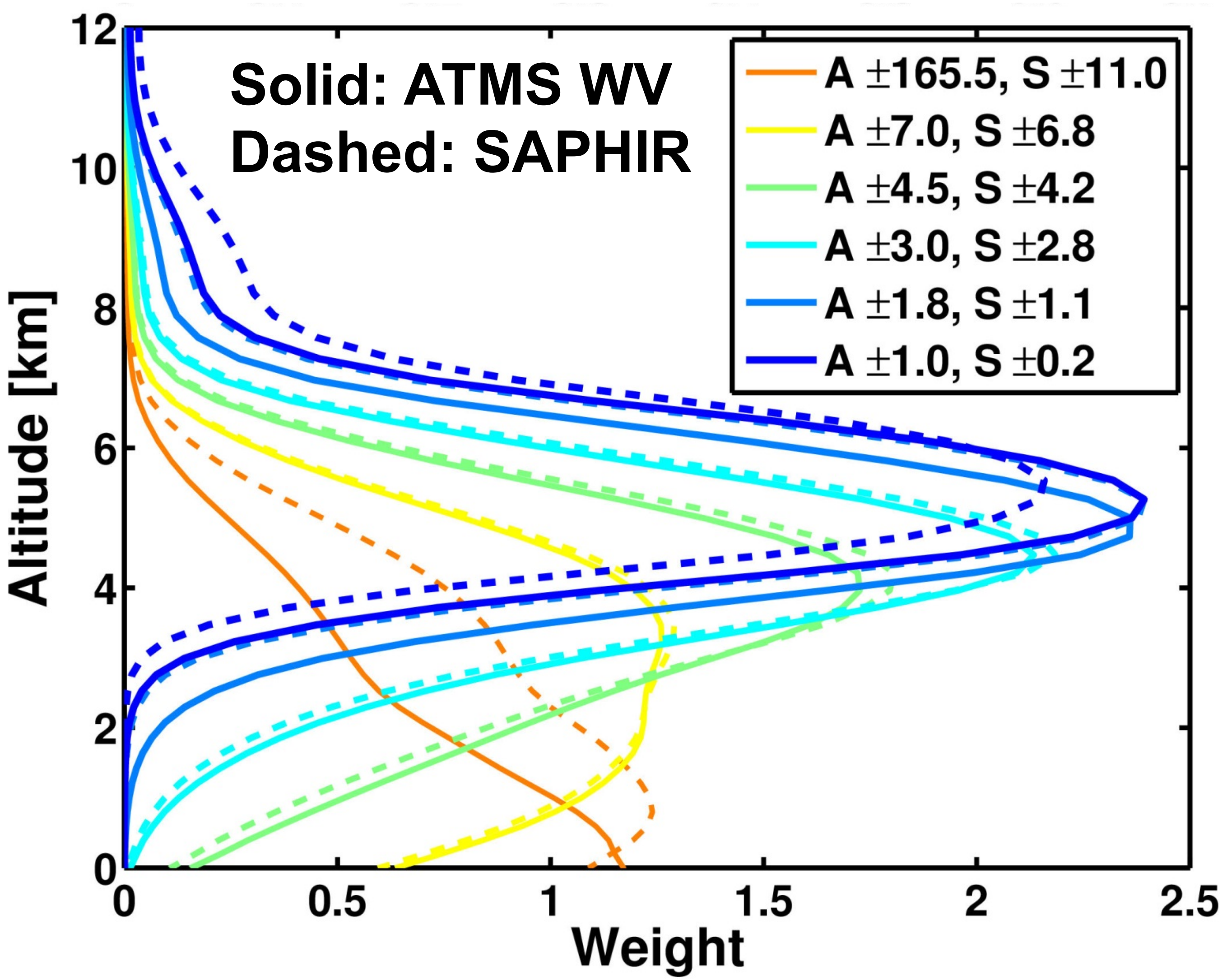
Moradi et al., JGR, 2010, DOI: 10.1029/2010JD013962

ATMS (AMSU+MHS)

- ATMS: Advanced Technology Microwave Sounder
- 22 channels, almost all AMSU-A and MHS plus a few additional channels



SAPHIR/ATMS WF



SAPHIR Specifications

Megha-Tropiques Orbital Characteristics ©CNES

Orbit	Altitude	Inclination	Period	#rev/day
Circular	867 km	20°	102.16 min	14

Saphir Channels

Channel N°.	Central frequencies (GHz)	Bandwidth (MHz)	radiometric sensitivity (estimated by calculation)	polarisation
S1	183,31 ± 0.20	200	1,82 K	H
S2	183,31 ± 1.10	350	1,01 K	H
S3	183,31 ± 2.70	500	0,93 K	H
S4	183,31 ± 4.00	700	0,88 K	H
S5	183,31 ± 6.60	1200	0,81 K	H
S6	183,31 ±11.00	2000	0,73 K	H

Saphir Instrument Characteristics

Pixel interval /y (nadir)	10	km
Earth pixel Number of pixels (Earth)	128	
Incidence angle (ground)	<50	deg.
Swath	1661	km
Extreme pixel size /x	21.96	km
Extreme pixel size /y	14.29	km
Average pixel size /x	13.3	km
Average pixel size /y	11.3	km
Average pixel size	12.3	km
Scan interval (/x)	10	km
Rotation period	1.639	s
Rotation frequency	0.61	Hz