



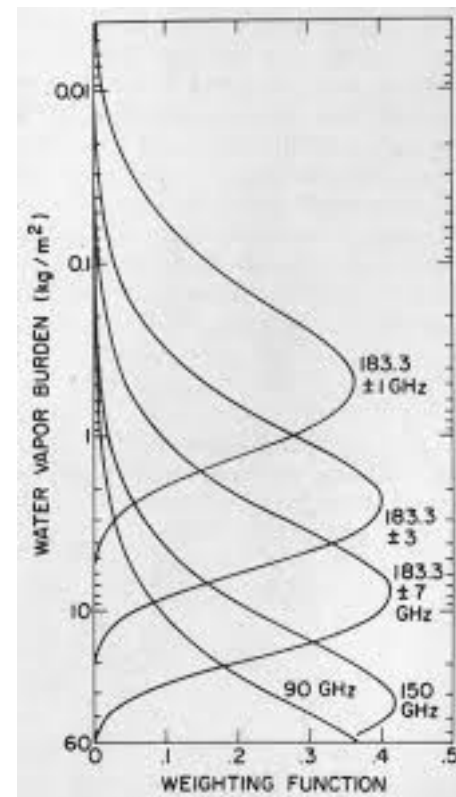
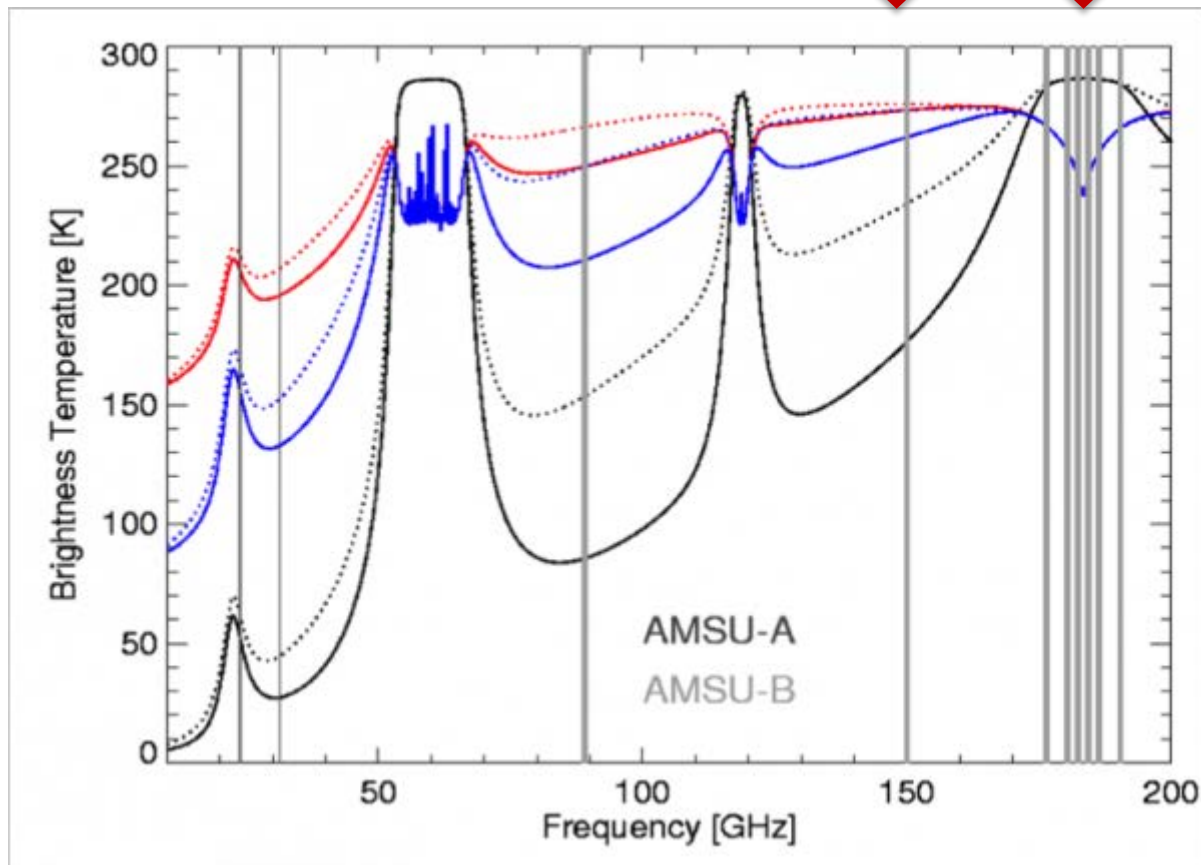
Millimeter (183 GHz) and Submillimeter-Wave (640 GHz) Channels for Long-Term Upper- Tropospheric Cloud Ice

Dong L. Wu¹, Jie Gong^{1,2}, and Tao Wang^{1,3}

1. NASA Goddard Space Flight Center
2. Universities Space Research Association (USRA)
3. Earth System Science Interdisciplinary Center (ESSIC), U of Maryland



Millimeter-Wave Sounding Channels



Rosenkranz et al (1982)



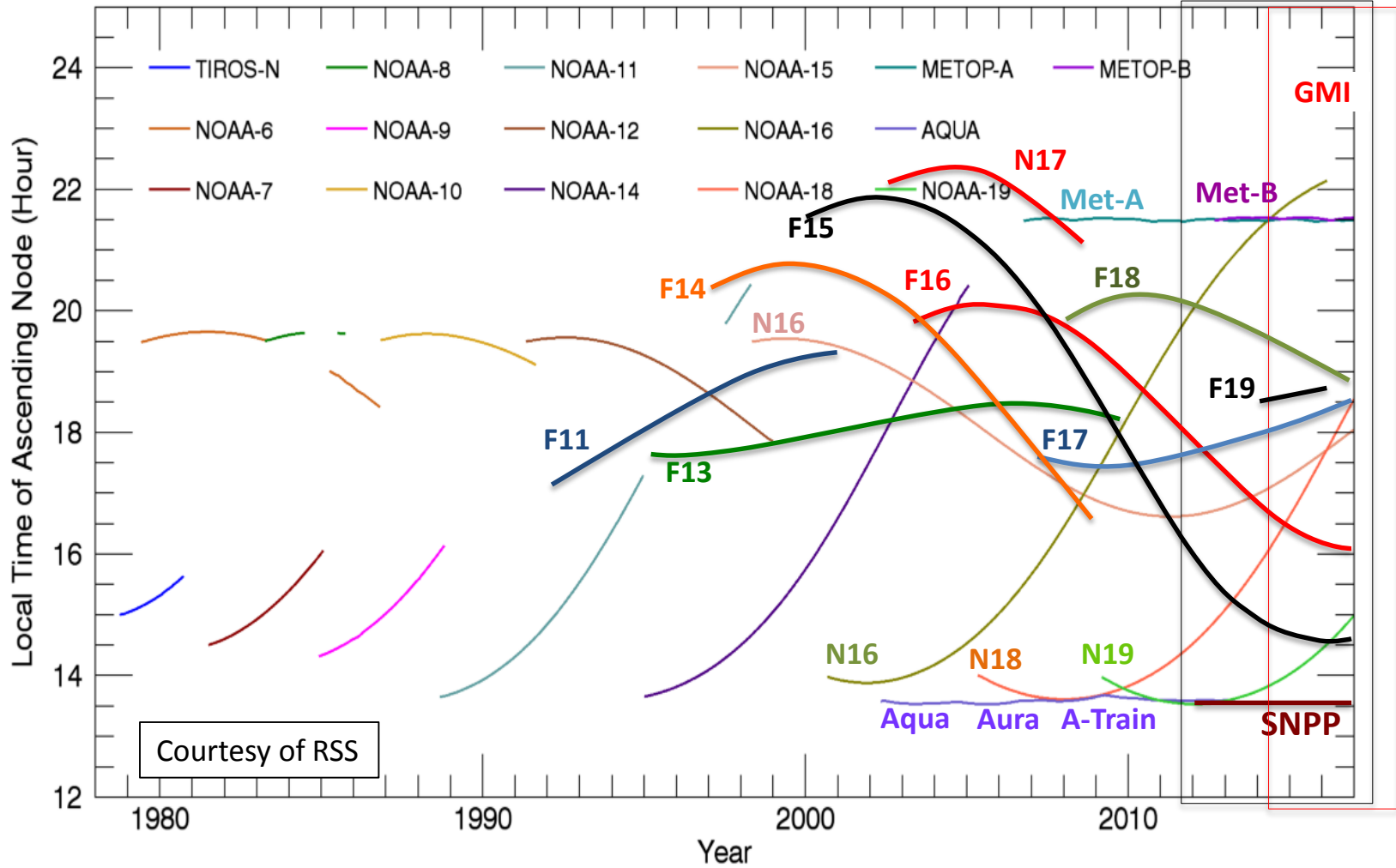
Channels of Longest Record: 183 ± 3 and $190/183\pm 7$ GHz

Satellite (Instrument)		NASA S-NPP (ATMS)	NASA GPM (GMI)	Megha-Tropique (SAPHIR)	NOAA 15-17 (AMSU-B)	NOAA 18-19 (MHS)	EumetSat MetopAB (MHS)	DMSP F16-18 (SSMIS)	DMSP F11-15 (SSM/T2)
Freq/GHz (Polarization)	H ₂ O & Cloud	183 ± 7 (H)	183 ± 7 (H)	183 ± 7 (H)	183 ± 7 (V)	190 (V)	190 (V)	183 ± 7 (H)	183 ± 7 (H)
	H ₂ O & Cloud	183 ± 3 (H)	183 ± 3 (H)	183 ± 3 (H)	183 ± 3 (V)	183 ± 3 (H)	183 ± 3 (H)	183 ± 3 (H)	183 ± 3 (H)
	Window & Cloud	165.5 (H)	166 (H,V)	183 ± 11 (H)	150 (V)	157 (V)	157 (V)	150 (H)	150 (H)
Eq. Crossing Time in 2016		13:30	Varying	Varying	14:00-22:00	~18:00/ ~14:30	21:30	16:00-20:00	15:00
Scan Type		Cross-Track	Conical	Cross-Track	Cross-Track	Cross-Track	Cross-Track	Conical	Cross-Track
Footprint (km)		20x16 to 68x30	4.4x7.3	6x6 to 10x10 to 23x15	20x16 to 64x27	20x16 to 64x27	20x16 to 64x27	13x16	50x48 to 192x81



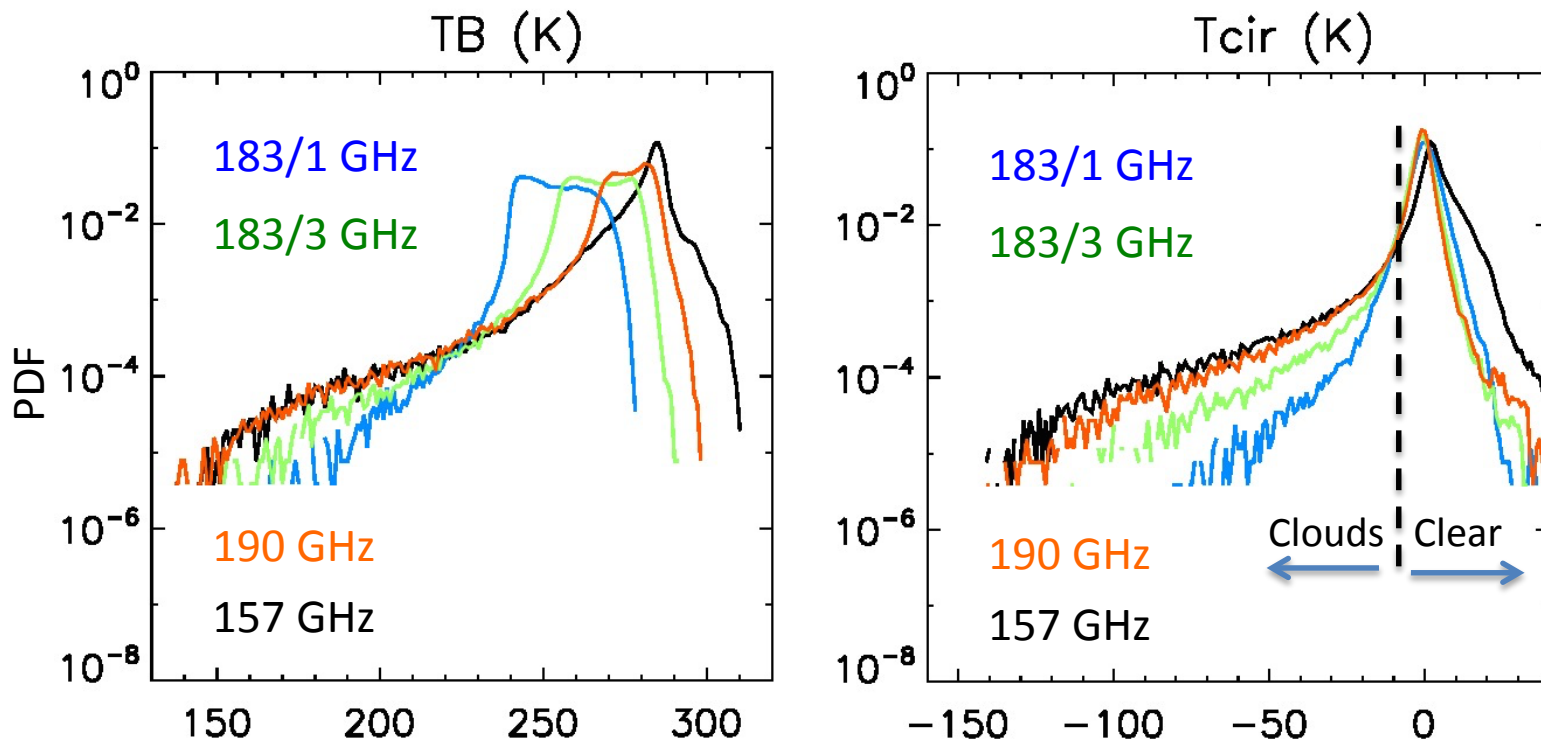
Last Updated Mon Apr 17 06:20:35 2017

Mega-Tropiques (2-3x in 12 h)





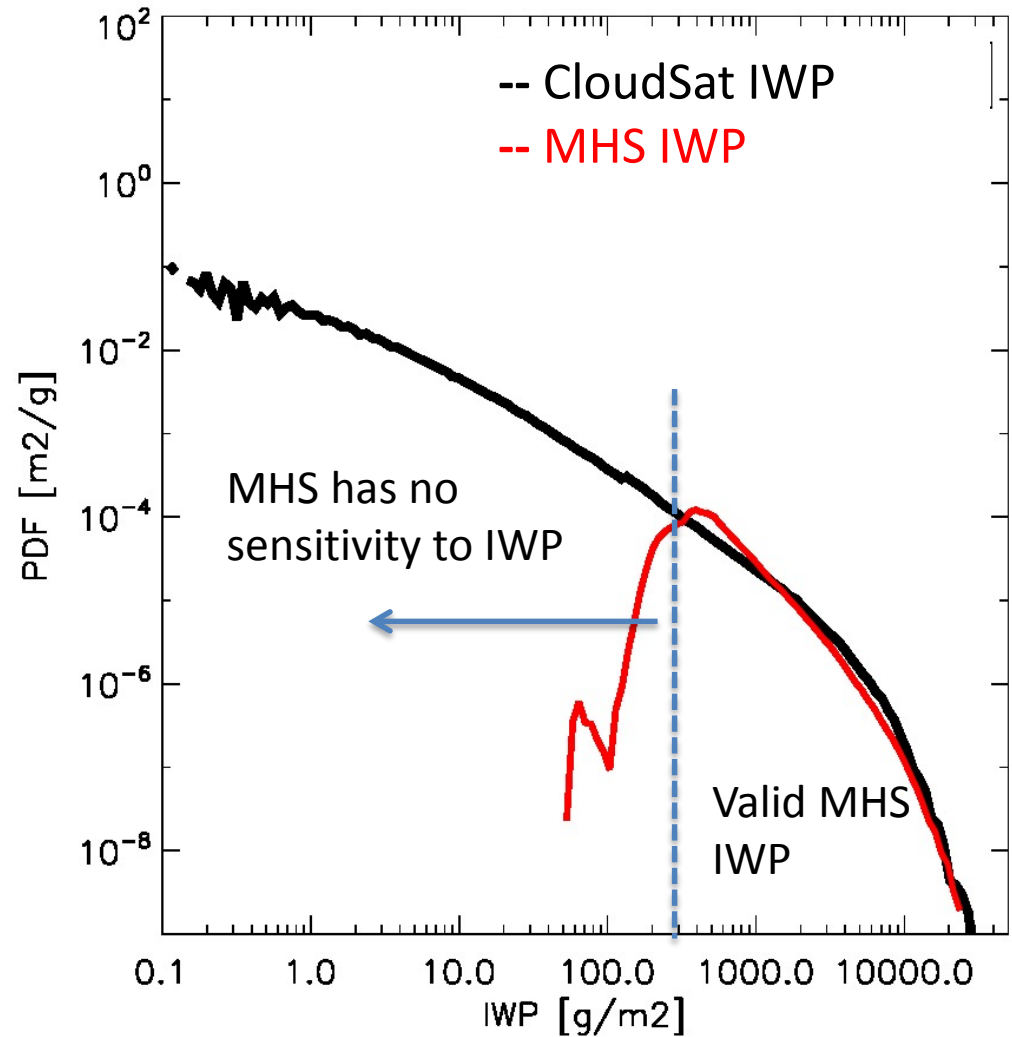
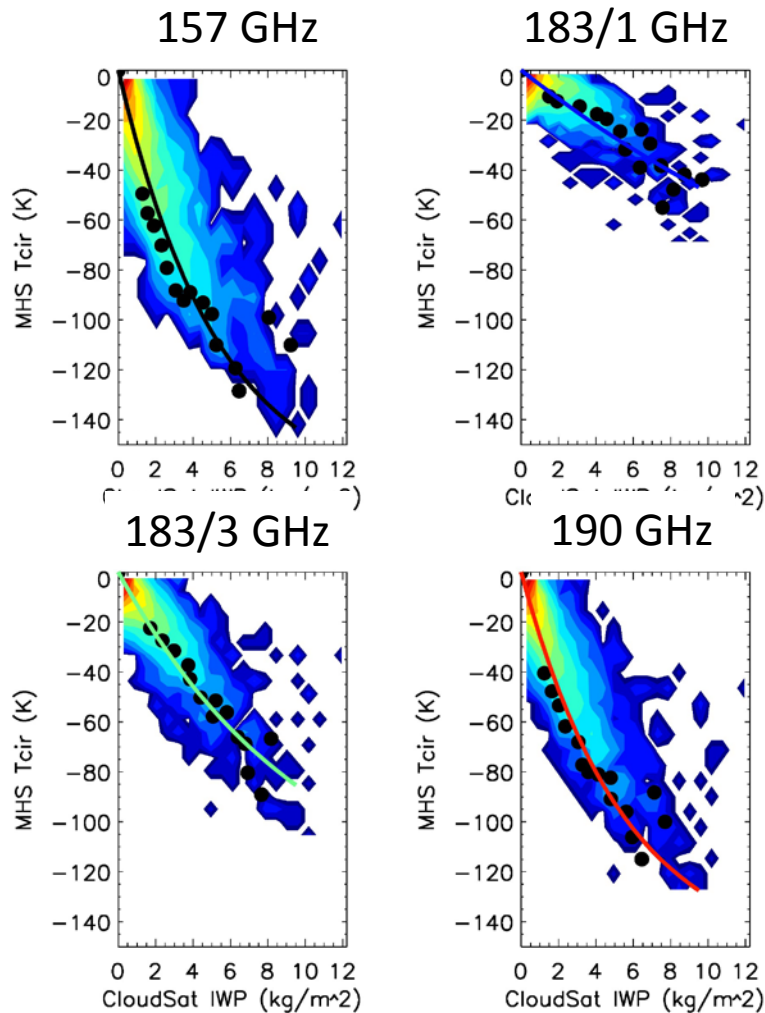
$$T_{cir} = TB - TB_{clear}$$





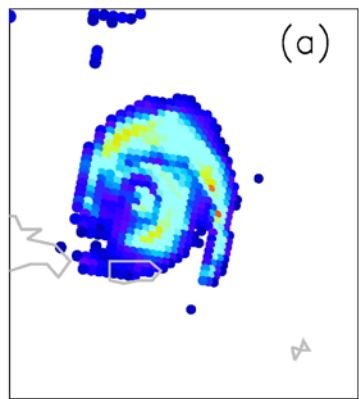
CloudSat-Constrained MHS IWP Retrieval

$$T_{\text{cir}} = T_{\text{cir}0} \cdot (1 - e^{-\text{IWP}/H})$$

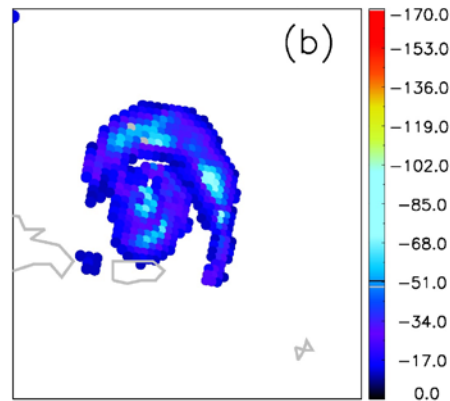




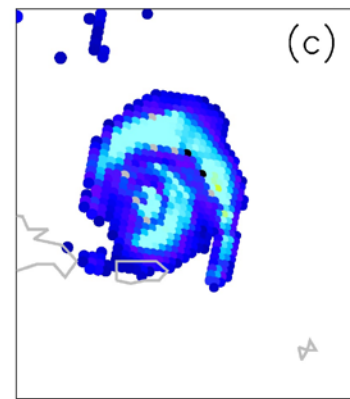
Tcir_157 GHz



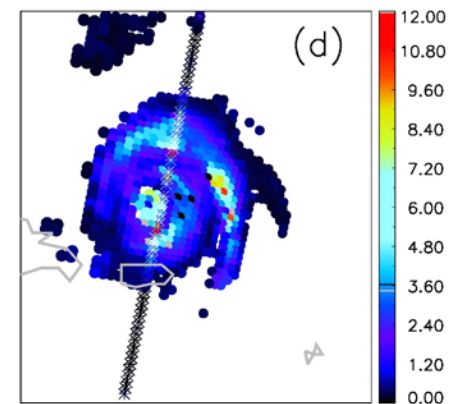
Tcir_183/3 GHz (K)



Tcir_190 GHz



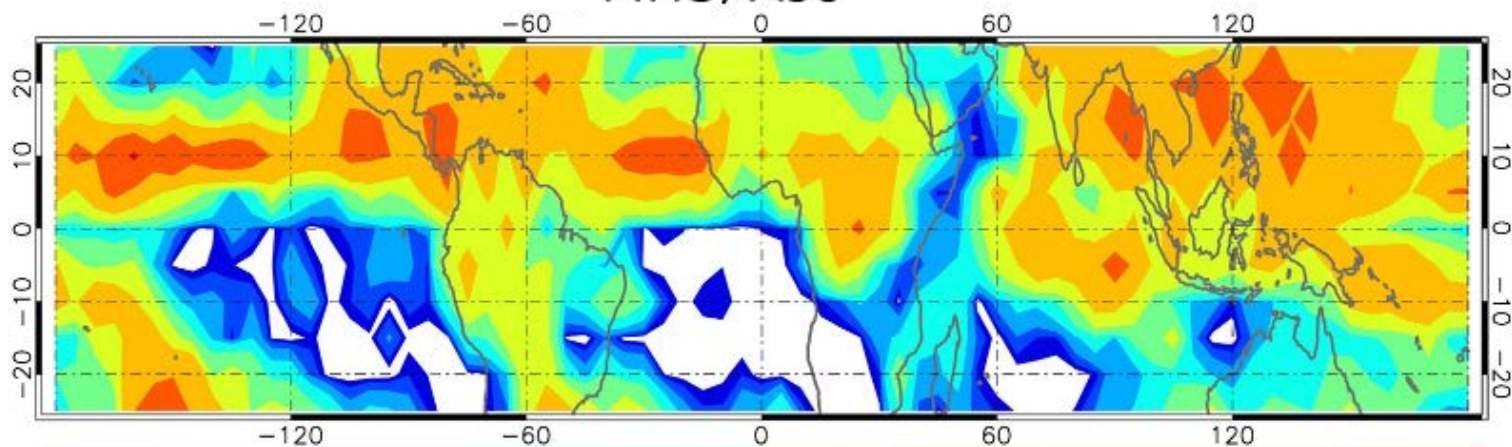
IWP (kg/m²)



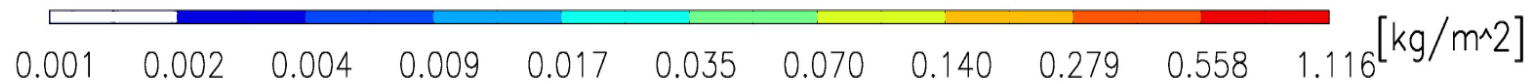
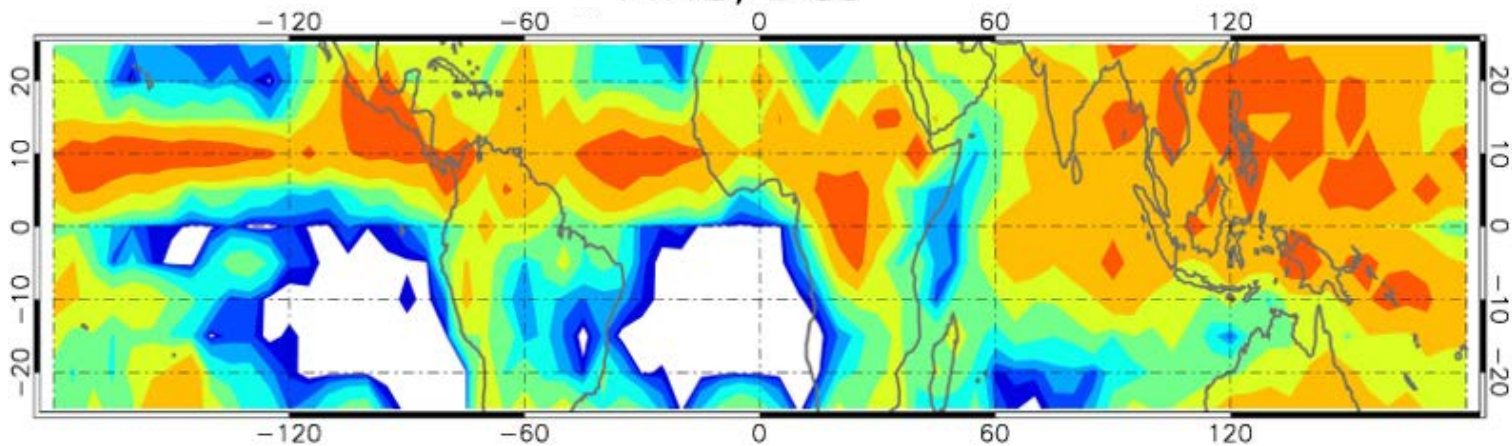
Hurricane Earl (August 31, 2010)



MHS, Asc



MHS, Des

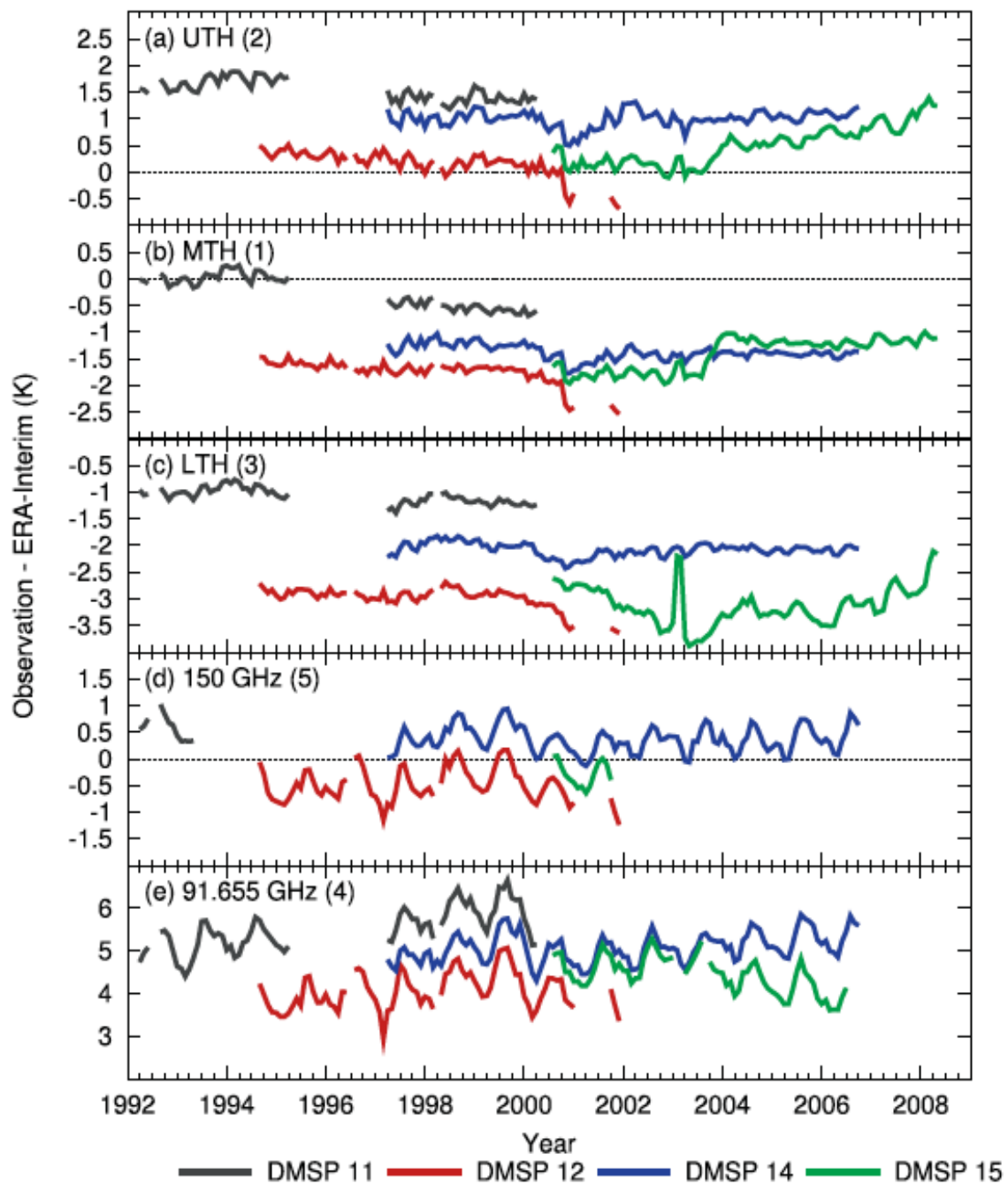




Inter-sensor calibration

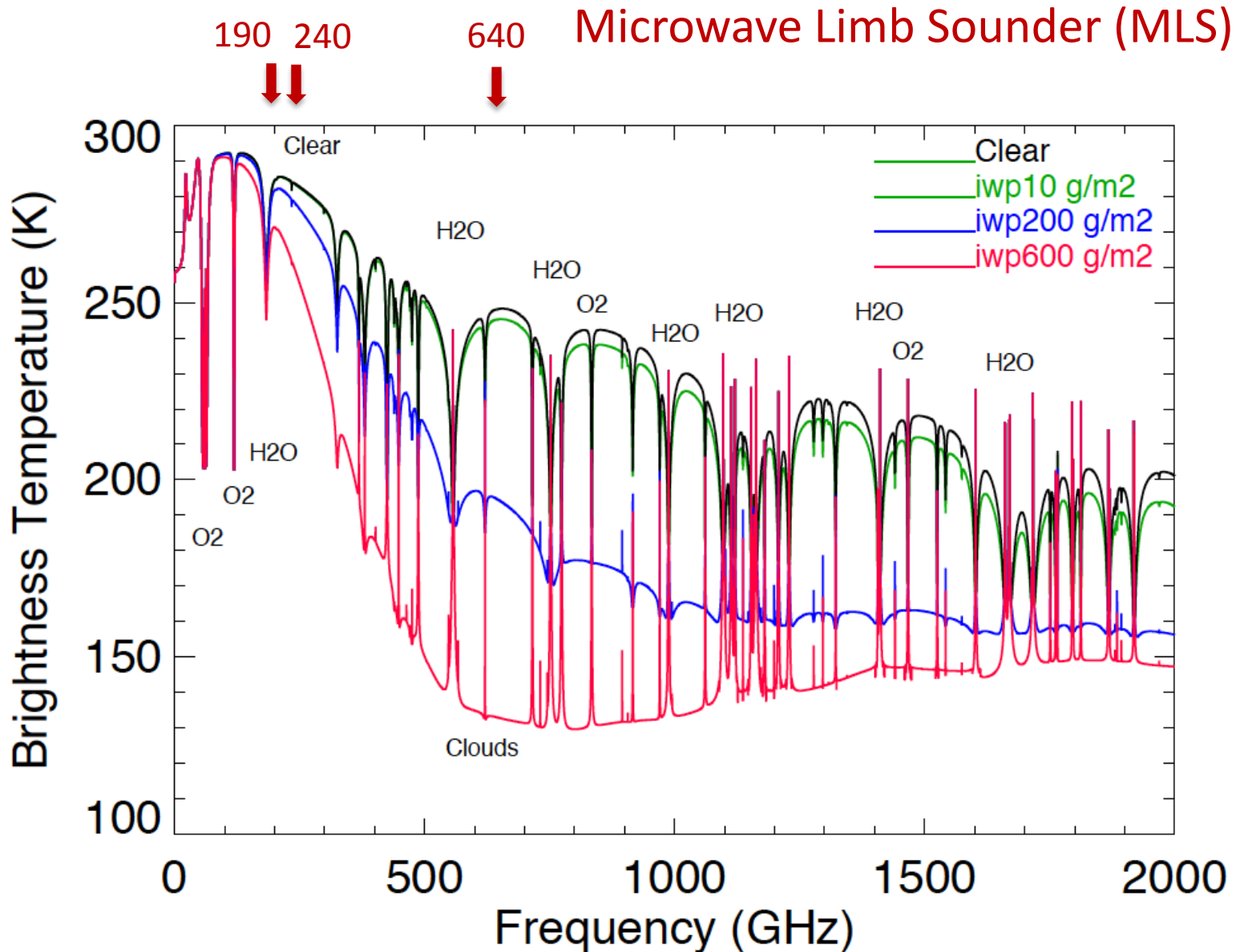
- ERA-Interim and RRTOV to determine radiometric biases (Kobayashi et al., 2017)
- Simultaneous nadir overpasses (SNOs) (Cao et al., 2004; John et al., 2013)

Kobayashi et al. (2017)



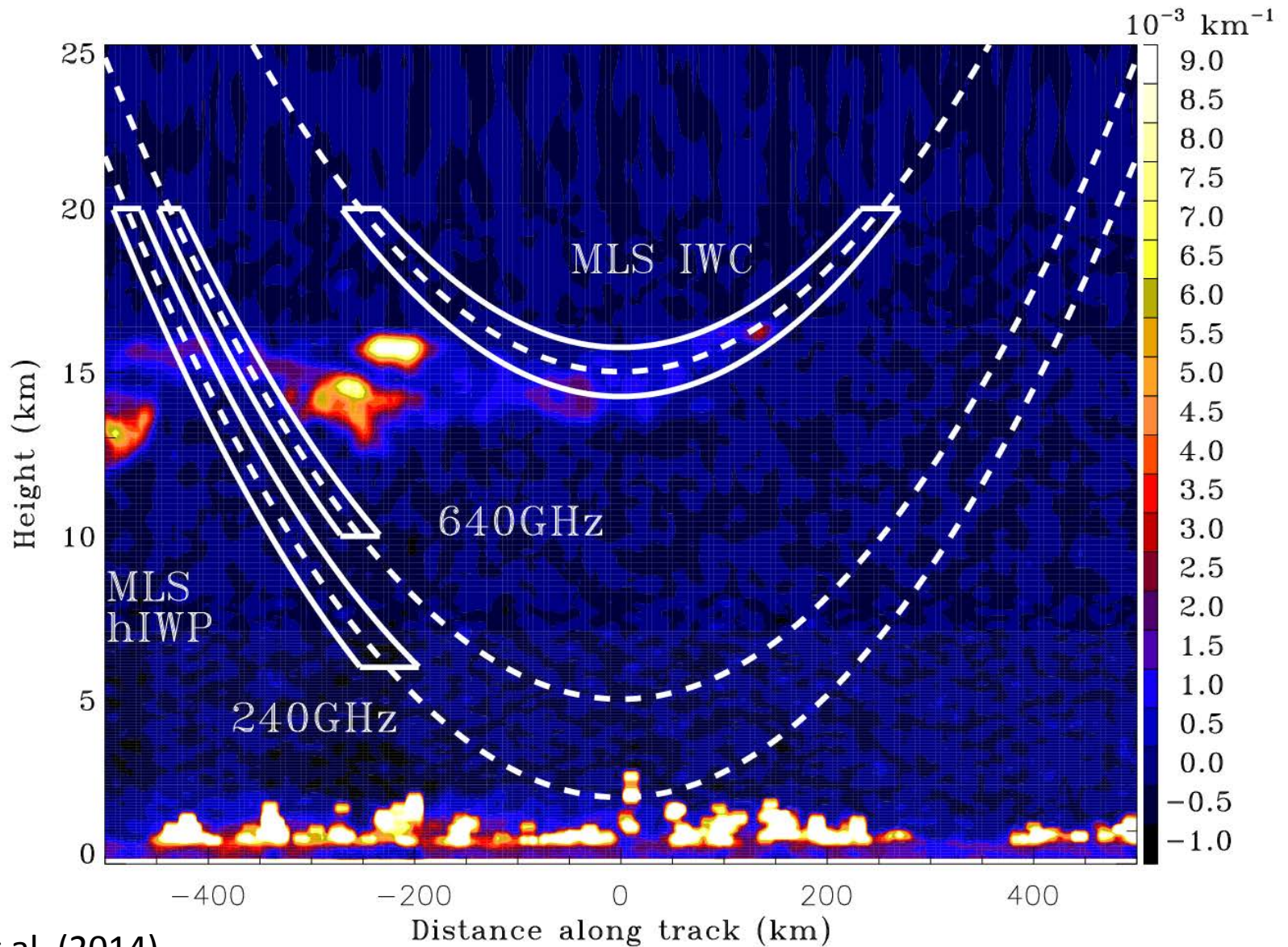


A-Train MLS Submillimeter-Wave Cloud Scattering and CALIPSO Lidar Cloud Ice



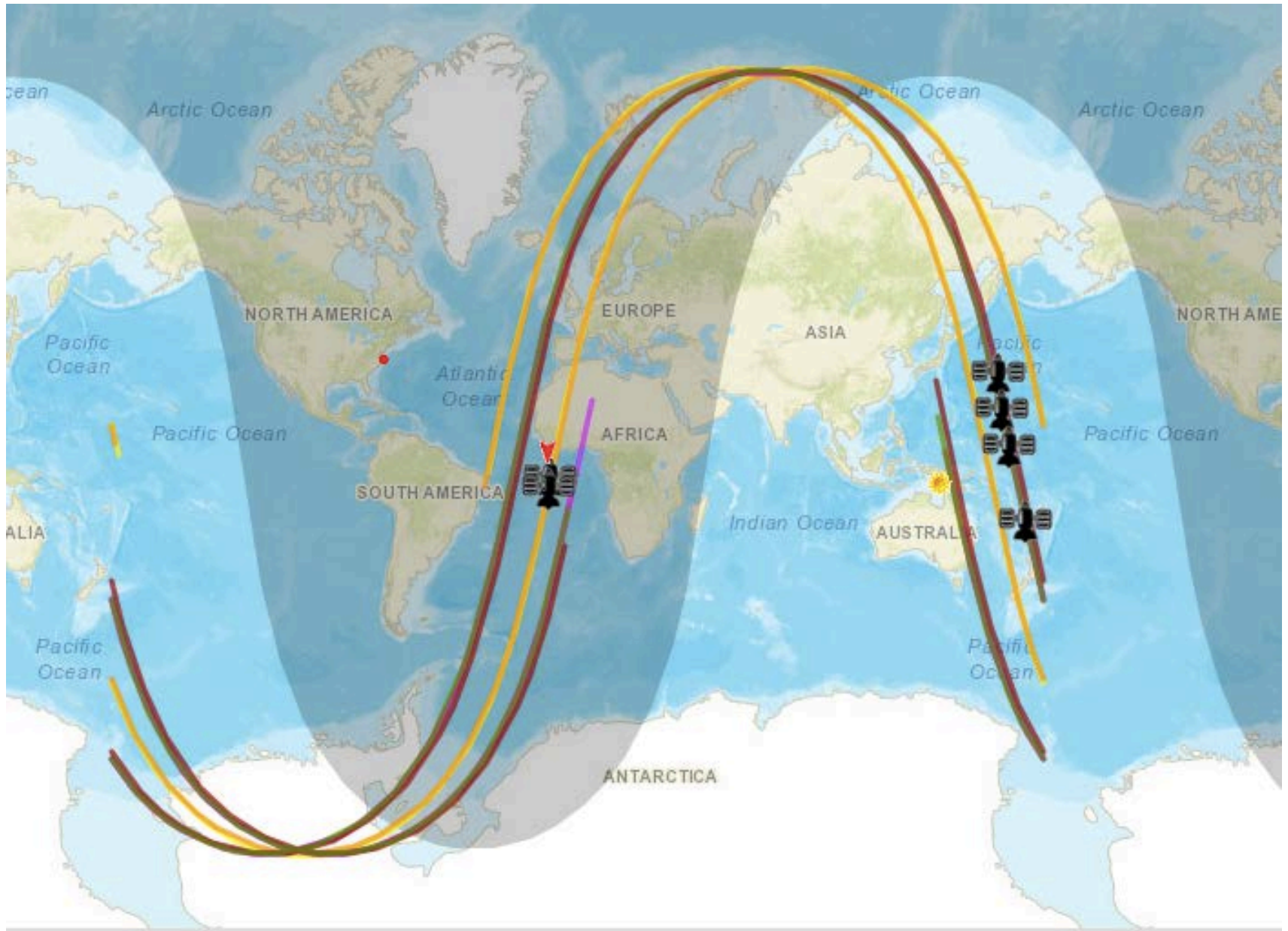


Microwave Limb Sounder (MLS) and CALIOP IWC





A-Train on 15 Oct 2018 (After CC Departure)

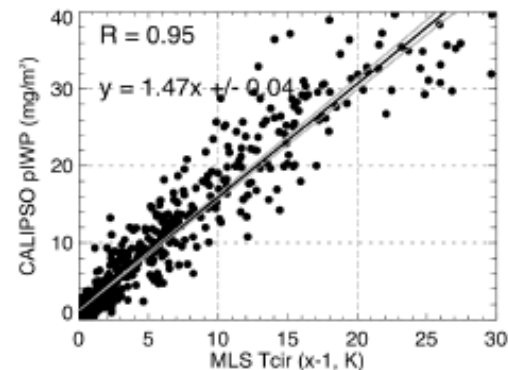
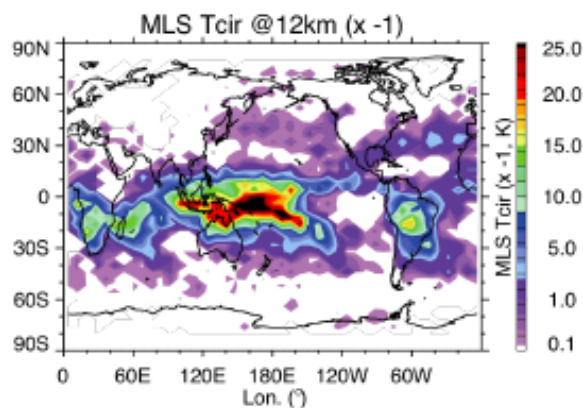
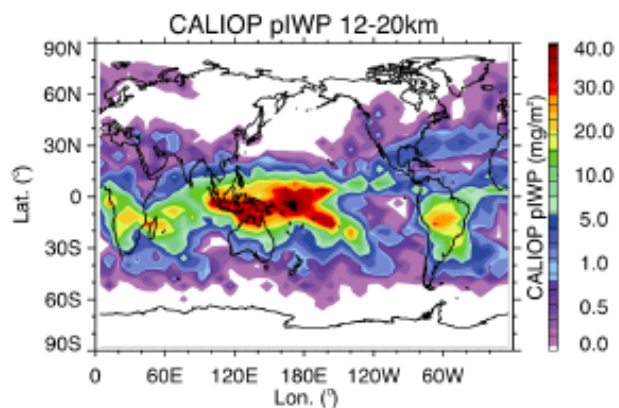




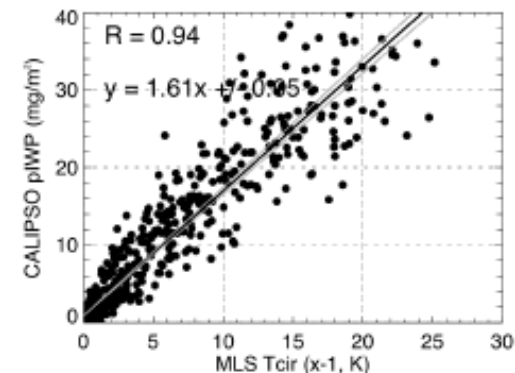
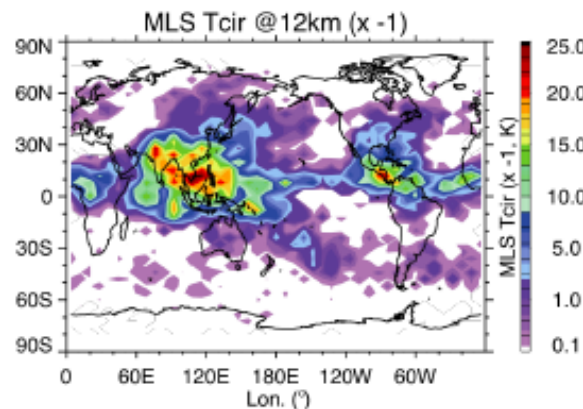
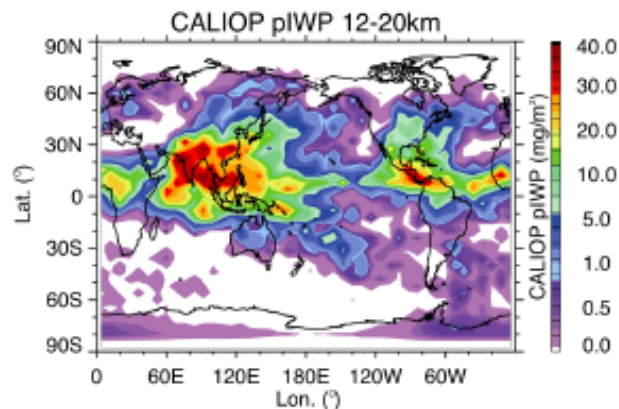
MLS 640 GHz:
CALIOP lidar:

Sensitive to cloud ice scattering at $z > \sim 12$ km
Partial column of ice water path (pIWP) for $z > 12$ km

2010 January



2010 July

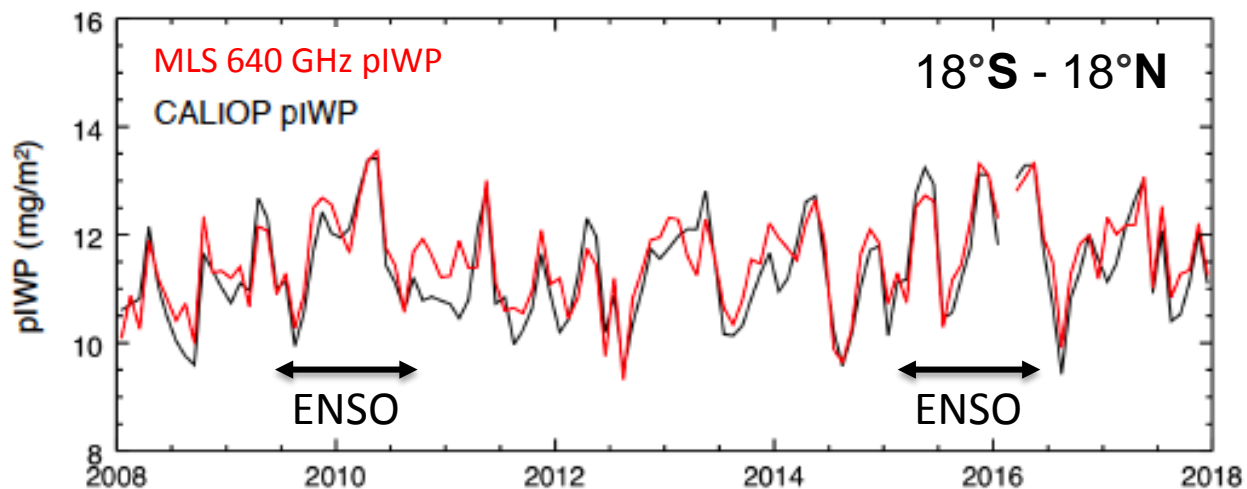
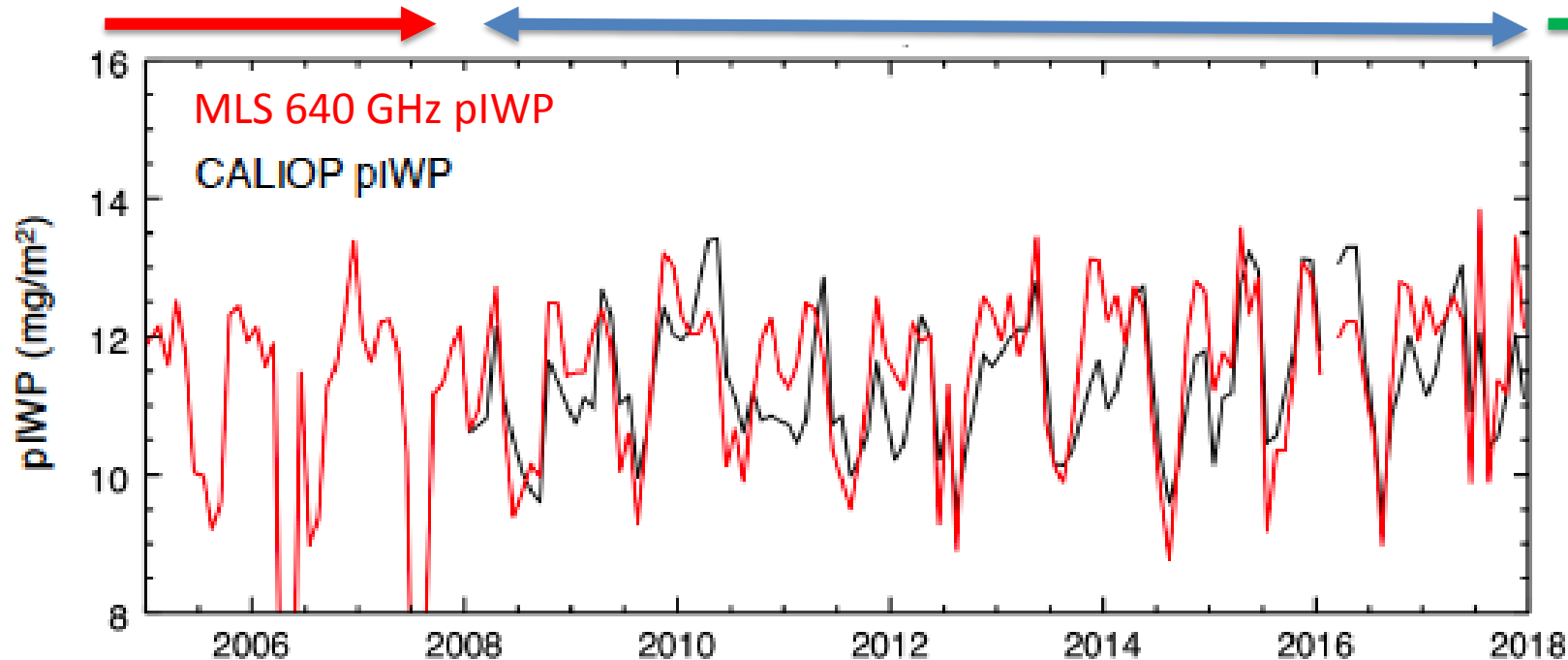




**Aura/MLS
(Launched in 2004)**

Aura/MLS and CALIPSO Overlap

**CALIPSO
Departure
from A-Train**





Summary

- Approaches for cloud ice from passive mm- and submm-wave sensors:
 - CloudSat-constrained cloud ice retrievals from 183/3 and 190 GHz
 - CALIOP-constrained cloud ice retrievals from 640 GHz
- Continuity of cloud ice monitoring from long-term, consistent passive microwave sensors