



# RSS Version-7

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# Overview: RSS Version 7 Ocean Products

- Intercalibrated multi-platform suite
- More than 100 years of combined satellite data





# Documentation

- Version 6

- Wentz, 2010: The Version-6 Calibration of SSM/I, RSS Report 102210.

- [http://www.remss.com/papers/tech\\_reports/Wentz\\_SSMI\\_Version6\\_Calibration.pdf](http://www.remss.com/papers/tech_reports/Wentz_SSMI_Version6_Calibration.pdf)
    - From our homepage: Support > Papers and Publications > RSS Tech Reports
    - Also available from NCDC webpage

- Version 7

- Meissner and Wentz, 2012: The Emissivity of the Ocean Surface Between 6-90 GHz Over a Large Range of Wind Speeds and Earth Incidence Angles

- IEEE TGRS August 2012 issue
    - Open Access OA distribution: downloadable free of charge by anybody

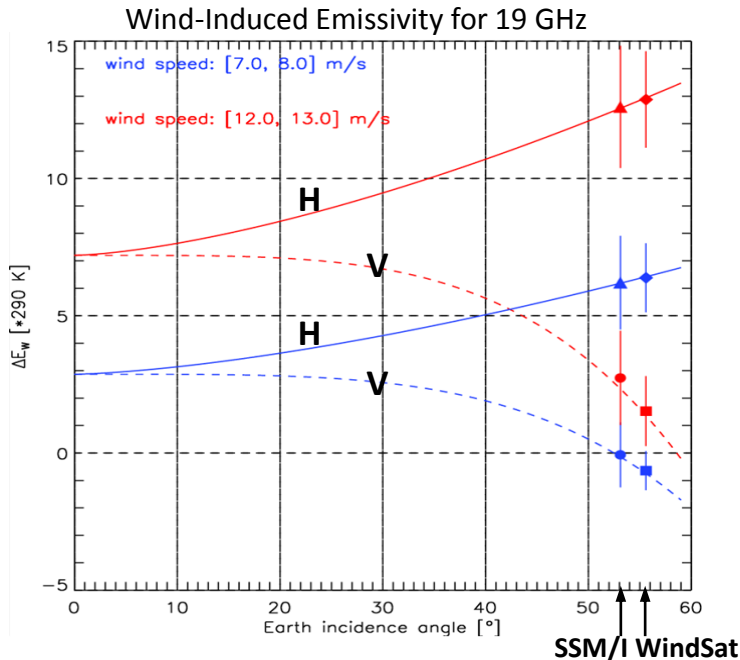
Our technical reports and papers can be found on our website:  
<http://www.remss.com/support/publications.html>



# Outline of Presentation

- Version 7 RTM
  - Model for dependence of wind-induced emissivity on EIA
  - Water vapor absorption model
- Closure tests
  - Correction of receiver nonlinearity for F08
- Calibration results
  - APC coefficients: spillover and cross-polarization leakage
  - Hot load adjustment in terms of solar geometry
- Version 7 retrievals
  - Rain rate
  - New: winds through rain

# Wind-Induced Emissivity vs Earth Incidence Angle



$$\frac{\partial T_B}{\partial \theta_i} = \frac{\partial T_{B,spec}}{\partial \theta_i} + \frac{\partial \Delta T_{B,atmos}}{\partial \theta_i} + \frac{\partial \Delta T_{B,wind}}{\partial \theta_i}$$

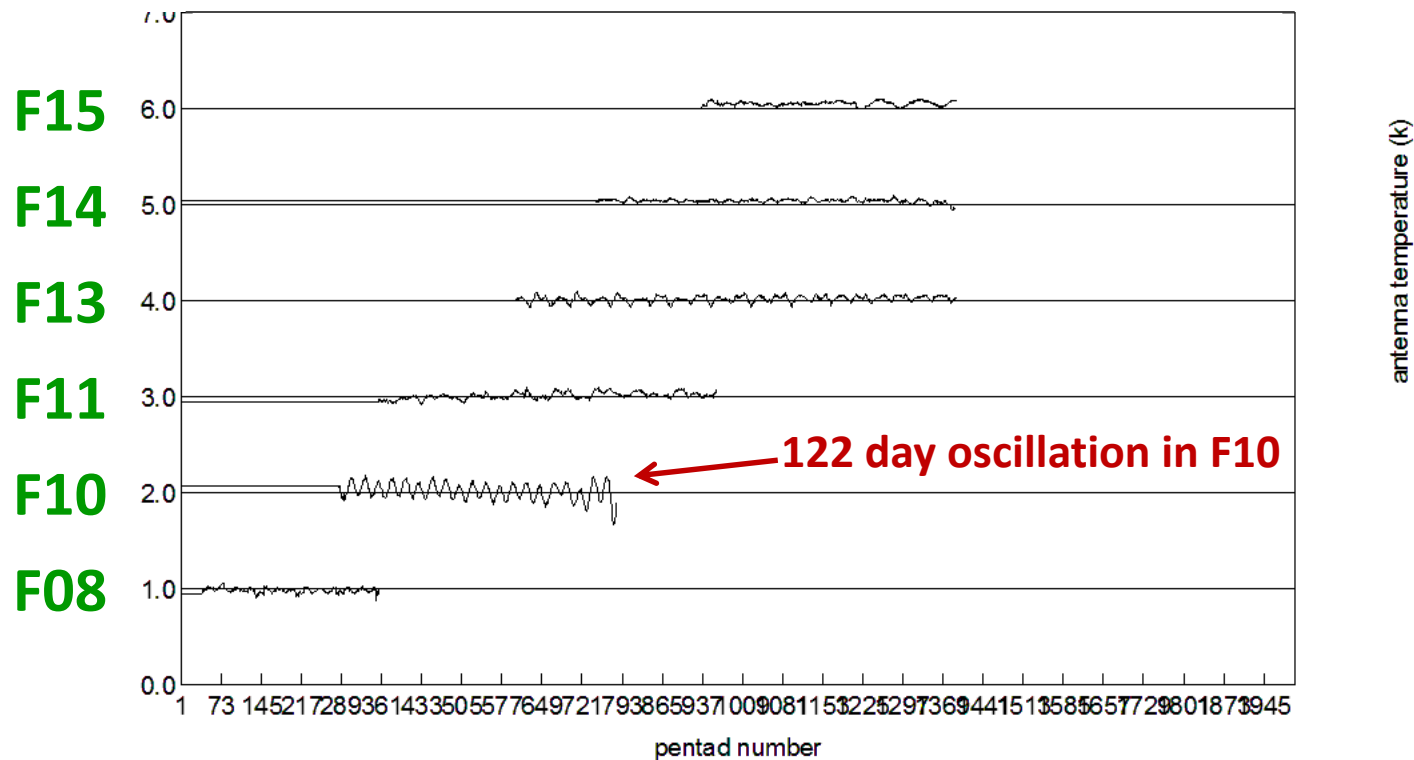
$$\left. \frac{\partial \Delta T_{B,wind}}{\partial \theta_i} \right|_{V-Pol} = 0 \text{ near } \theta_i = 55^\circ$$

- To compare satellites,  $T_A$  need to be normalized to a constant EIA using RTM
- Wind-induced component of the emissivity depends strongly on EIA
  - Positive for H-pol; For V-pol, it becomes negative around 55 deg
- Existing sensors cover a range of EIA:
  - SSM/I: 53.2 deg, SSMIS: 53.1 deg, WindSat: 50-56 deg, AMSR-E: 55 deg, TMI: 52.8 deg
- Documented in *Meissner and Wentz [2012]*
- We will provide RTM code to US investigators; contact Thomas Meissner
- Sending code to DoD Office of Security Review for ITAR approval for general release



# Normalizing EIA: Version 6 RTM

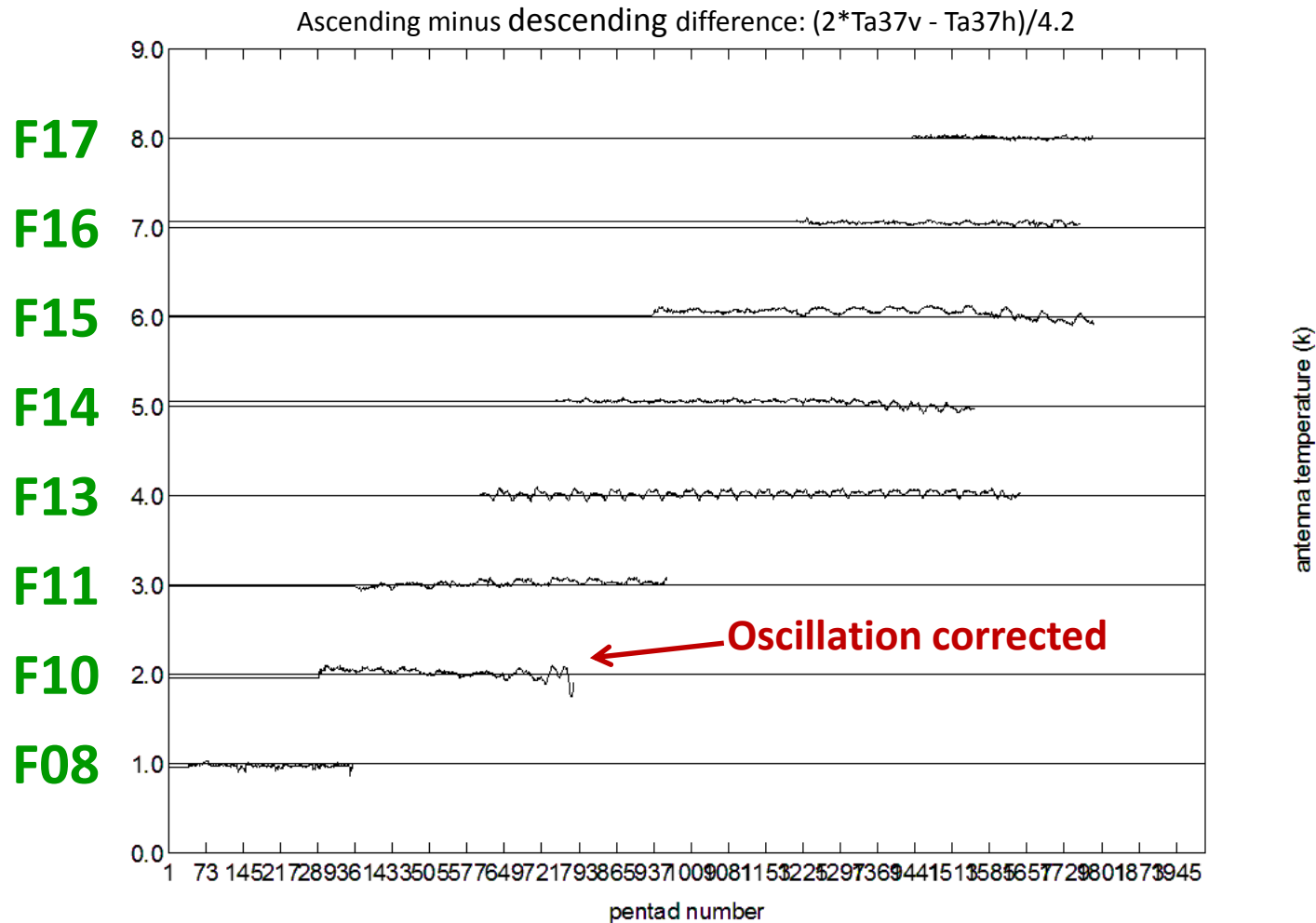
- Plot shows ascending minus descending difference of global pentad averaged antenna temperature for each SSM/I satellite (each offset by 1K)
- Antenna temperatures have been normalized to same incidence angle using V6 RTM
- Since the PM-AM  $T_A$  difference is mostly due to atmosphere [Wentz, 2010], the combination 2V-H is used to remove contributions from the atmosphere
- Scaled to eia perturbations:  $Y = (2 * T_{a37v} - T_{a37h}) / 4.2$
- F10 shows a very clear 122 day oscillation, the period of precession of the perigee
- Same curve is shown in The Version-6 Calibration of SSM/I, RSS Tech. Rpt., Oct. 2010.





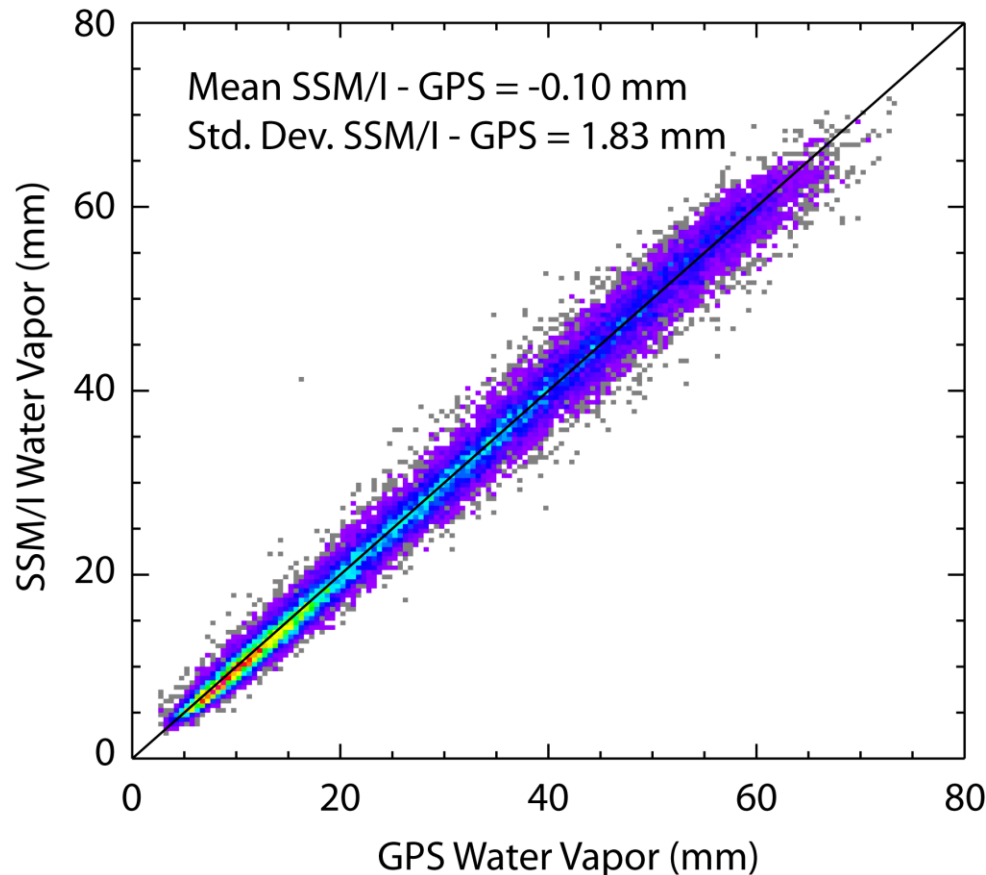
# Normalizing EIA: Version 7 RTM

- Antenna temperatures normalized using the Version-7 RTM (with the new model for the dependence of wind-induced emissivity on EIA) do not show the oscillation
- This result was a surprise. The RTM7 was adjusted to give consistent results over the EIA range for SSM/I, TMI, AMSR-E, WindSat, and SSMIS (50-56 deg).





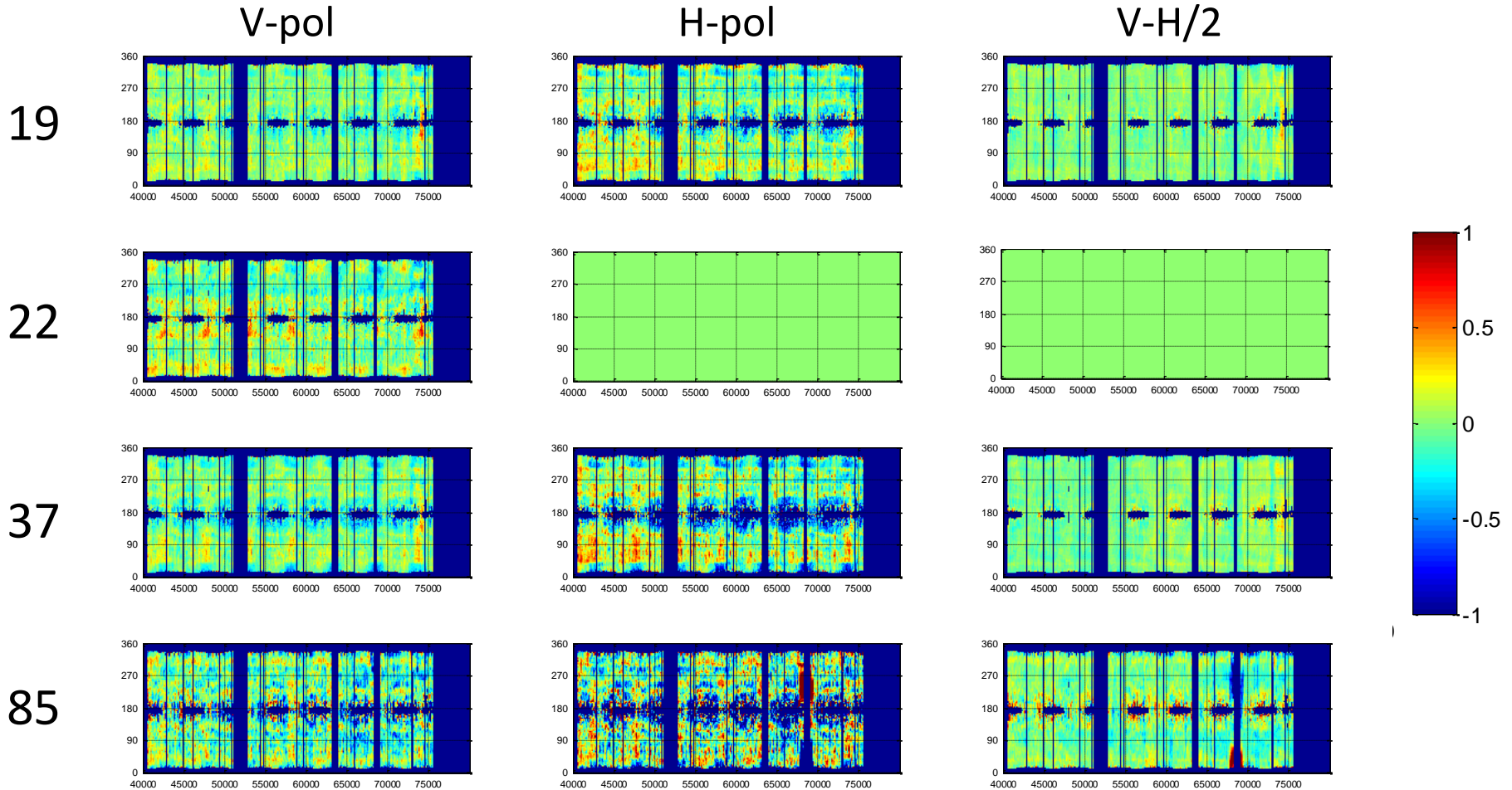
# Water Vapor Absorption



- Version-6
  - Vapor absorption: *Wentz and Meissner* [2000]
  - Oxygen absorption: *Rosenkranz* [1998]
- Version-7
  - Vapor absorption re-derived for consistency across all sensors over the full range of water vapor
    - SSM/I, SSMIS: 19.35, 22.235, 37.0 GHz
    - AMSR-E: 18.7, 23.8, 36.5 GHz
    - WindSat: 18.7, 23.8, 37.0 GHz
    - TMI: 19.35, 21.25, 37.0 GHz
  - Vapor continuum absorption changed
    - Foreign-broadened increased 10%
    - Self-broadened reduced by  $0.375 \cdot \text{frequency}(\text{GHz})^{**0.15}$
  - New continuum model is very close to latest version of MonoRTM
  - Vapor in the range of 50-60 mm is increased by about 1%, and vapor > 60 mm is increased by about 2-3%
  - V7 vapor retrievals agree better with GPS-derived vapor at high vapor values
    - Based on 14 ground-based GPS stations on small islands providing 30K collocations



# F13-WindSat Intersatellite Comparison

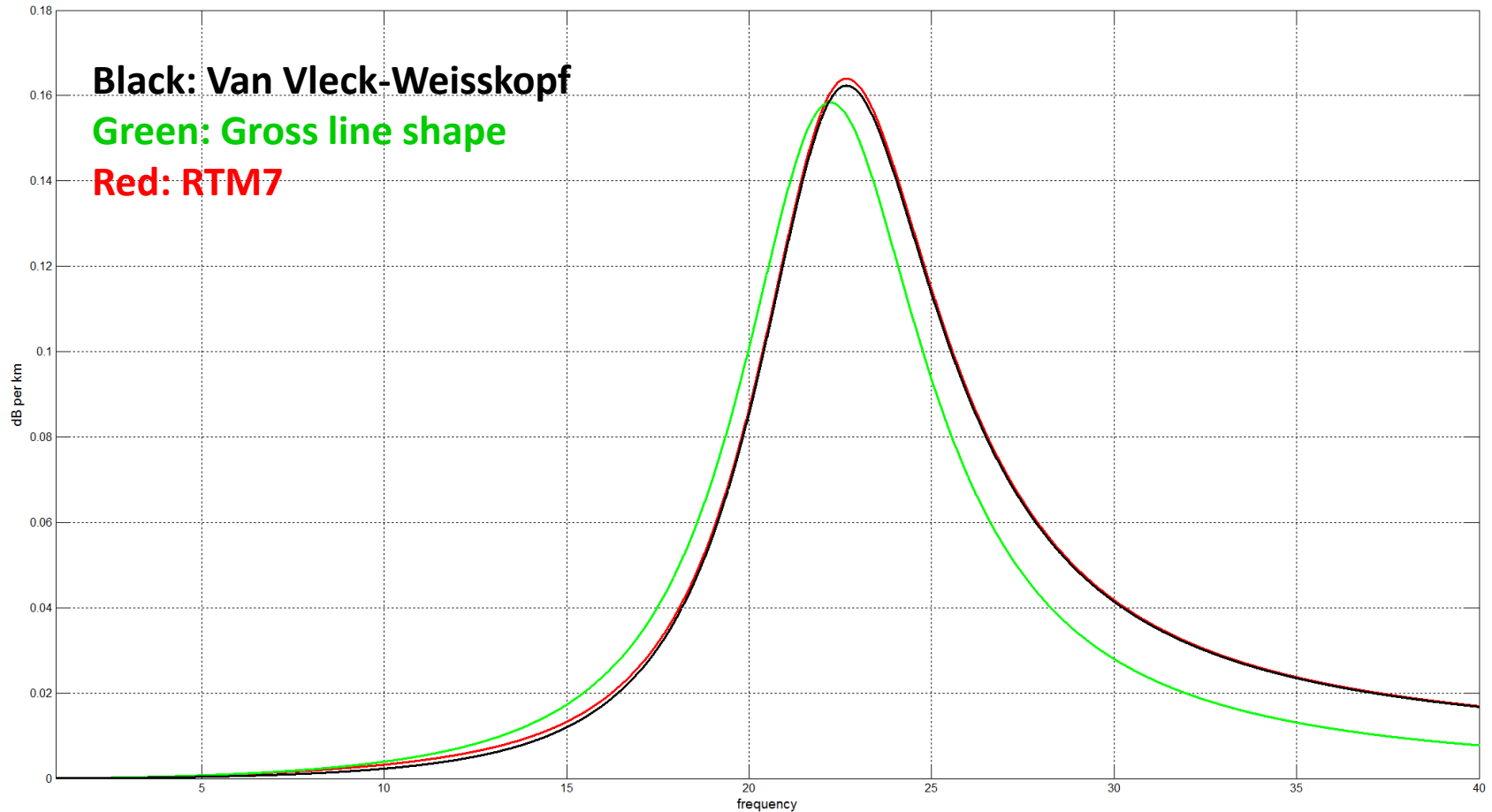


F13  $T_A$  versus RTM  $T_A$  from WindSat retrievals

If vapor line was just a bit off, you would see gradients from equator to poles



# Water Vapor Absorption Line

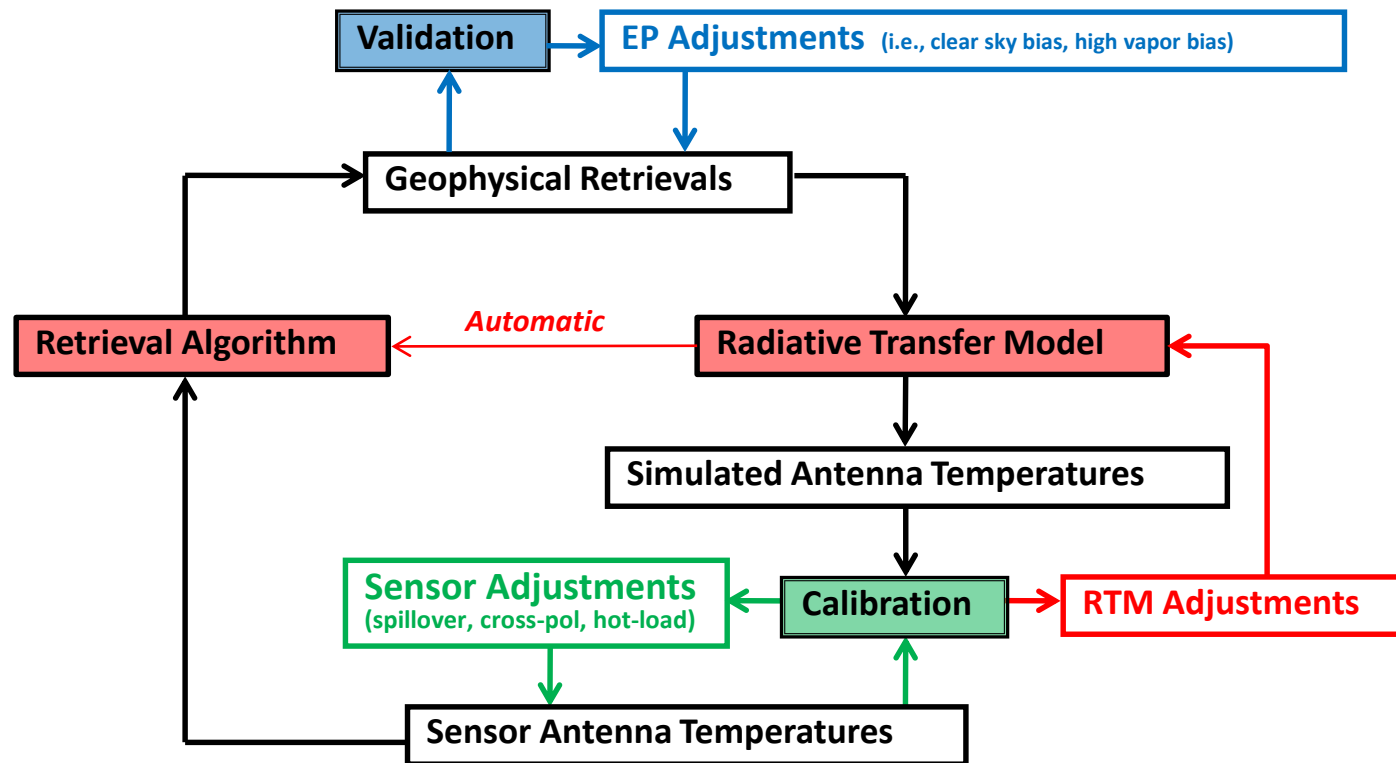




# Summary of Version 7 RTM

- The basic formulation for the RSS RTM is given by *Wentz* [1997] and *Wentz and Meissner* [2000]. Although the basic formulation has remained the same, the following components of the model have been updated to obtain the current V7 RTM:
  - Dielectric constant for sea water [*Meissner and Wentz*, 2004]
  - Wind-induced emissivity model [*Meissner and Wentz*, 2012]
  - Modifications to *Liebe et al.* [1992] oxygen absorption model
    - The non-resonance continuum temperature exponent was changed from 0.8 to 1.5
    - The oxygen continuum was slightly increased (only significant above 37 GHz).
  - Modifications to *Rozenkranz* [1998] water vapor absorption models
    - A small change (about 1%) to the shape of 22 GHz absorption line
    - A significant decrease in the water vapor continuum at frequencies above 19 GHz. The overestimation of the Liebe water vapor continuum in the 37-90 GHz range was first reported by *Wentz* [1997] and more recently confirmed by *Payne et al.* [2011].
  - New sea-surface tilted facet scattering model
- The modifications that we have made to the *Liebe's* oxygen absorption model and *Rozenkranz's* water vapor absorption model are small but important
  - The modifications are small in the sense that they fall within the experimental error of the laboratory and field experiments on which the original models are based.

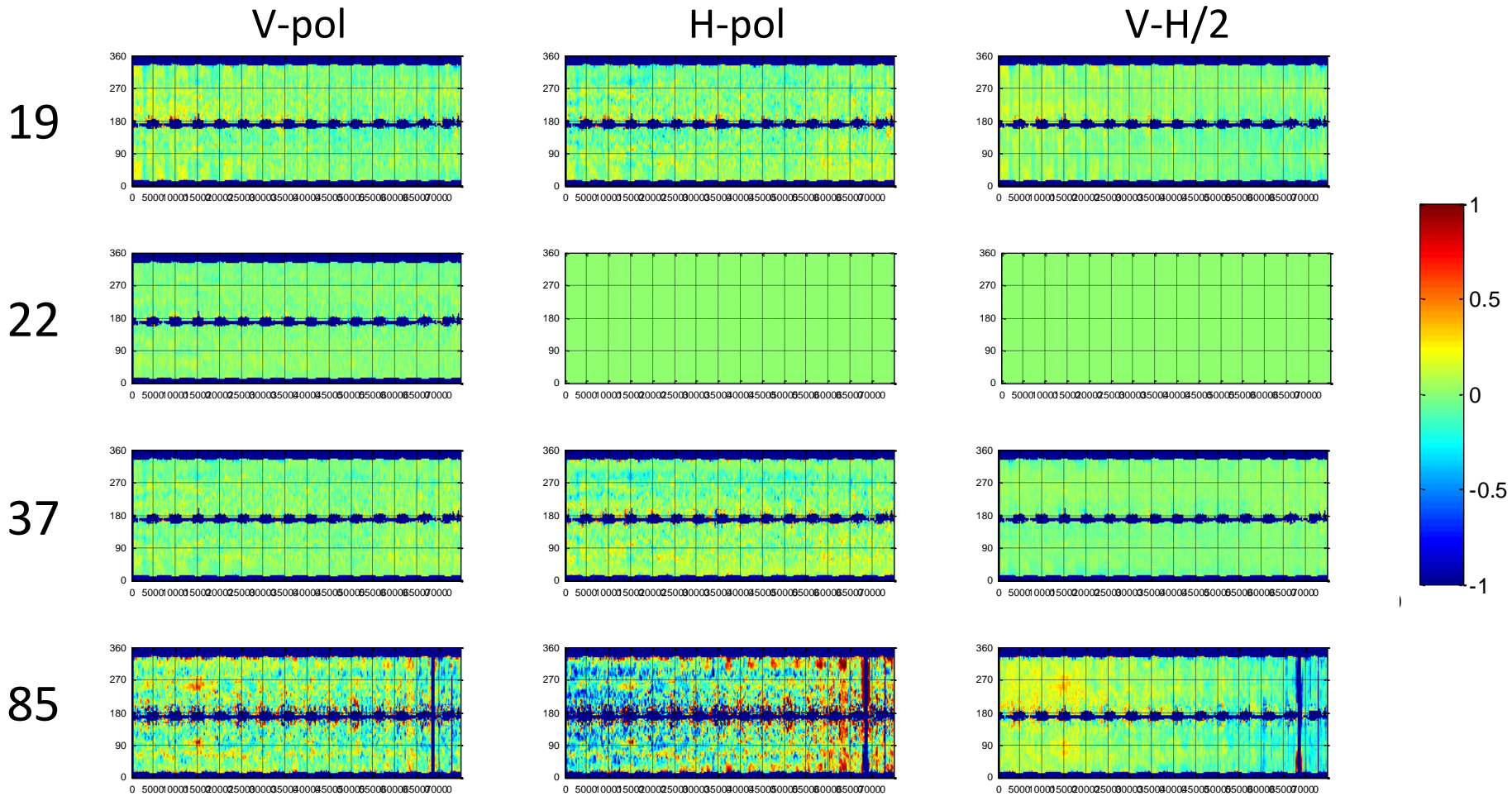
# Closure Tests



- Compare measured  $T_B$  with RTM  $T_B$  from retrieved Environmental Parameters
  - Three EP: wind speed, water vapor, cloud water
  - Seven  $T_B$ : 19V, 19H, 22V, 37V, 37H, 85V, 85H
  - $T_B$  differences should be very small, so this becomes a very sensitive indicator of previously undetected problems
  - Advantage: does not require collocated satellite data, does not rely on model data
  - Disadvantage: retrieval algorithm mixes frequencies, requires careful interpretation



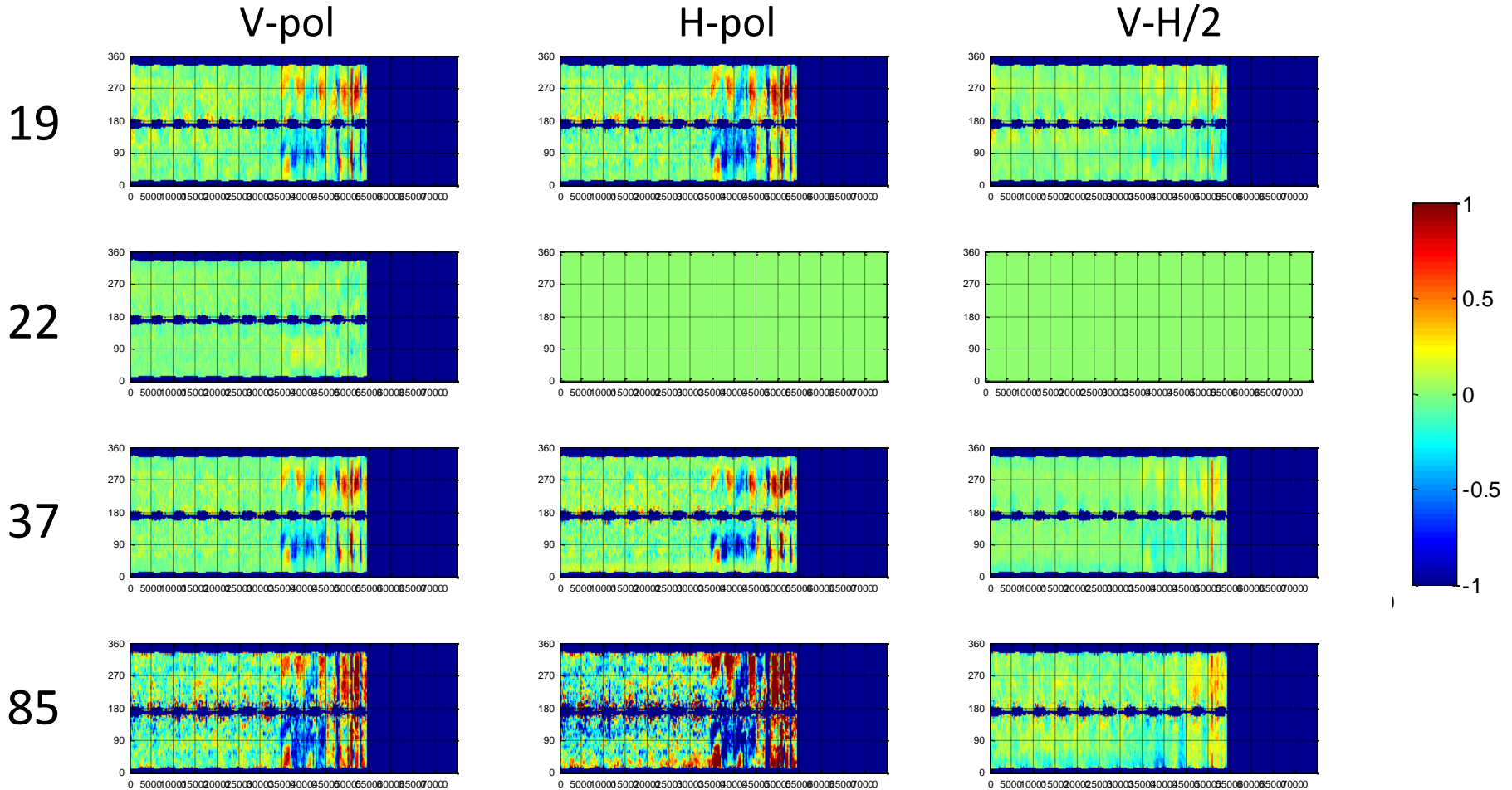
# F13 Closure



Plots of  $T_A$  difference versus orbit and orbit angle  
Closure for F13 is very good

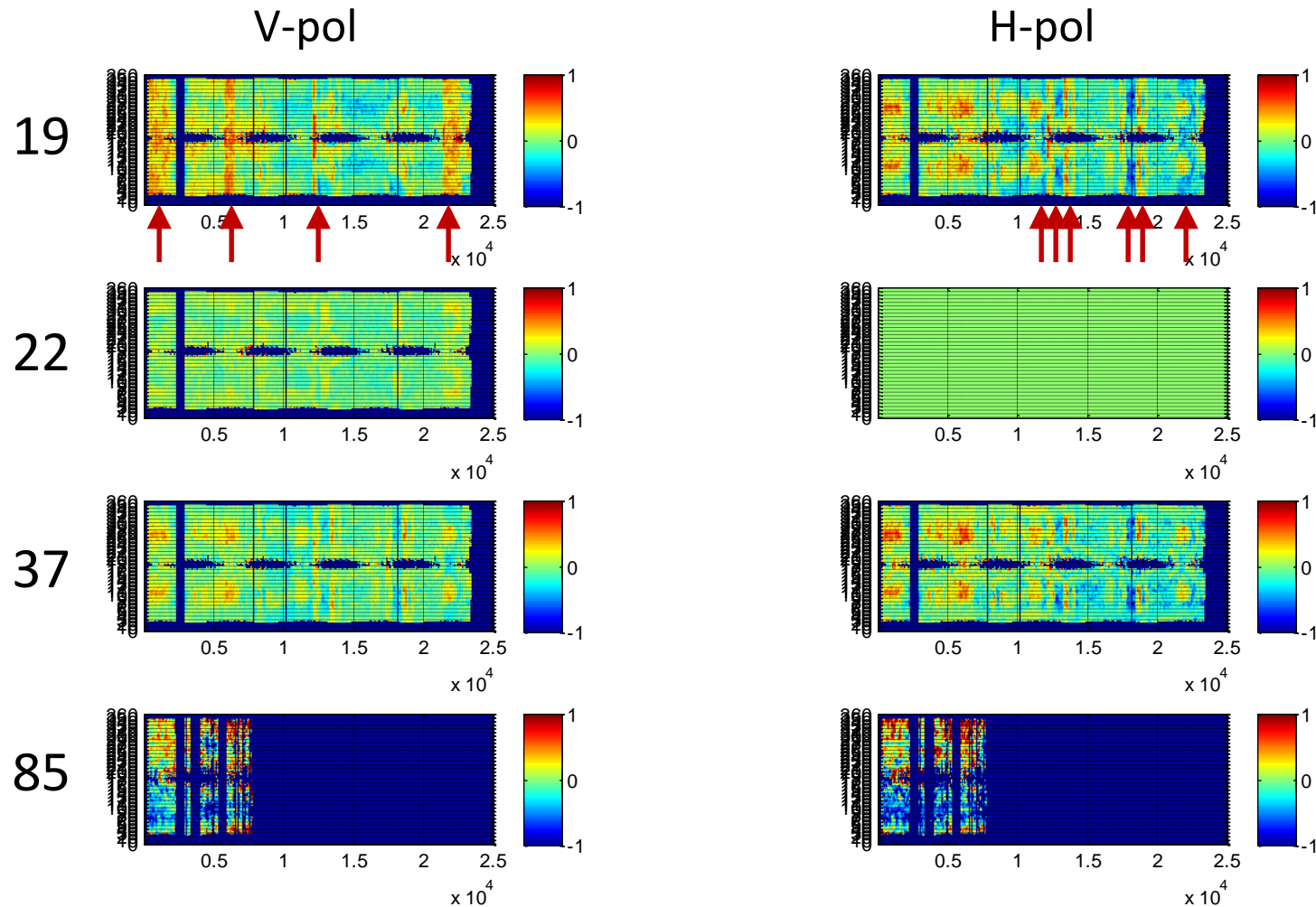


# F15 Closure Showing RADCAL





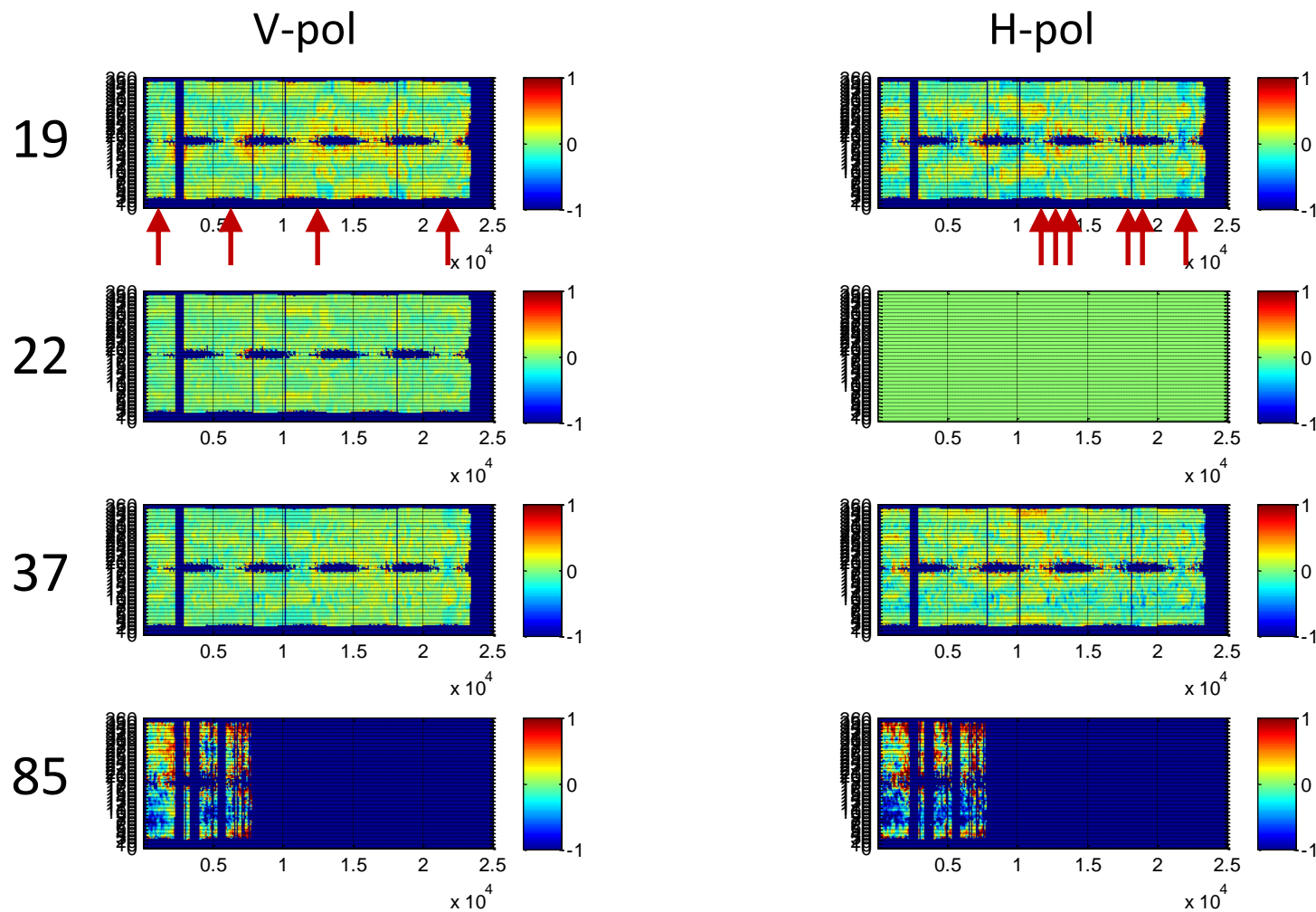
# F08 Closure: Before Correction for Nonlinearity



- This shows the result of the F08 closure with no correction applied.
- The red bars in 19V are also apparent in F08–F10 inter-satellite comparisons.
- To some extent the correlation of the errors among the channels is due to the fact this is a closure result.

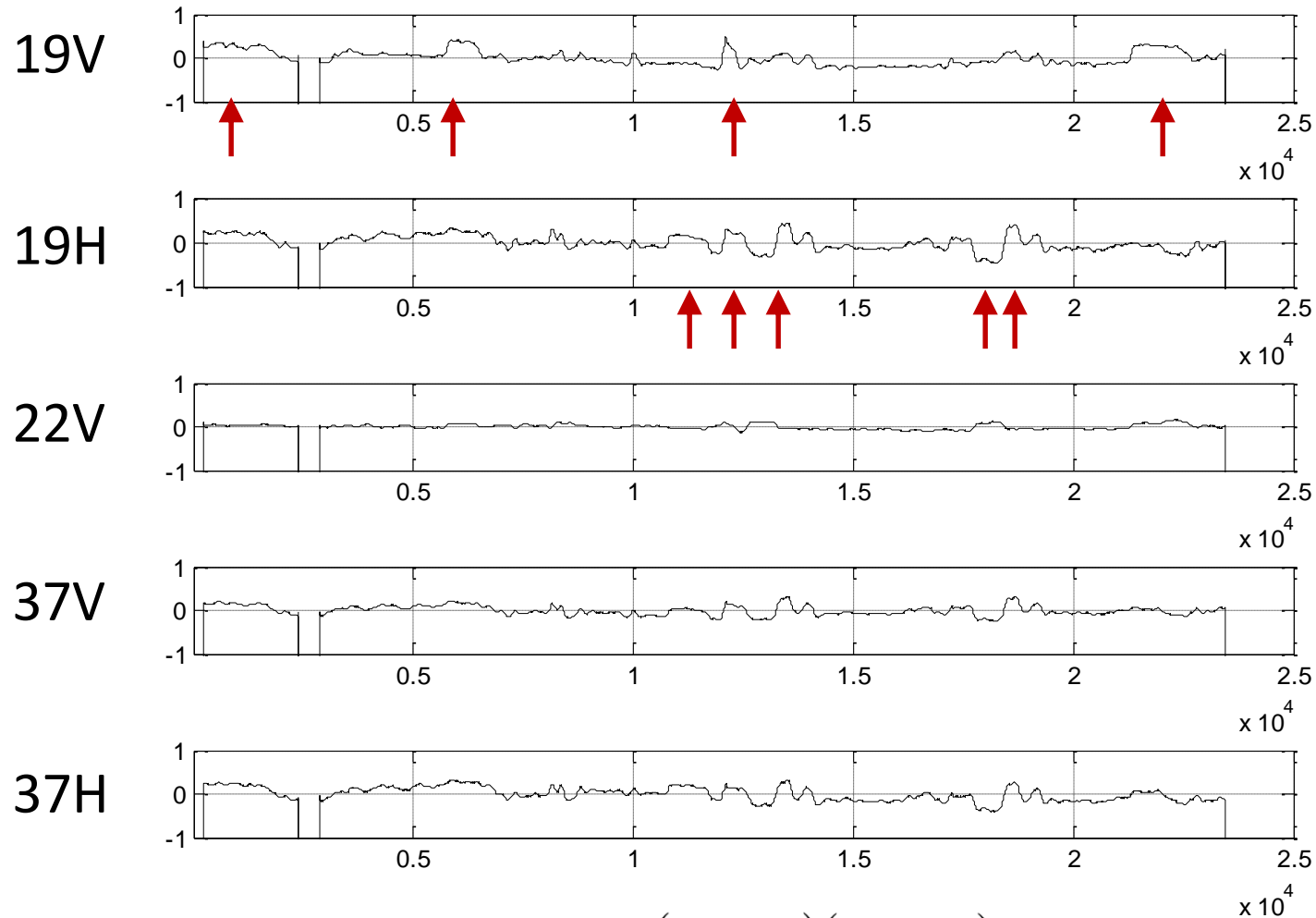


# F08 Closure: After Correction





# F08 Correction For Receiver Nonlinearity



$$\Delta T_{A,nonlin} = C_{v,h} \frac{(T_A - T_C)(T_H - T_A)}{(\bar{T}_A - T_C)(T_H - \bar{T}_A)}$$



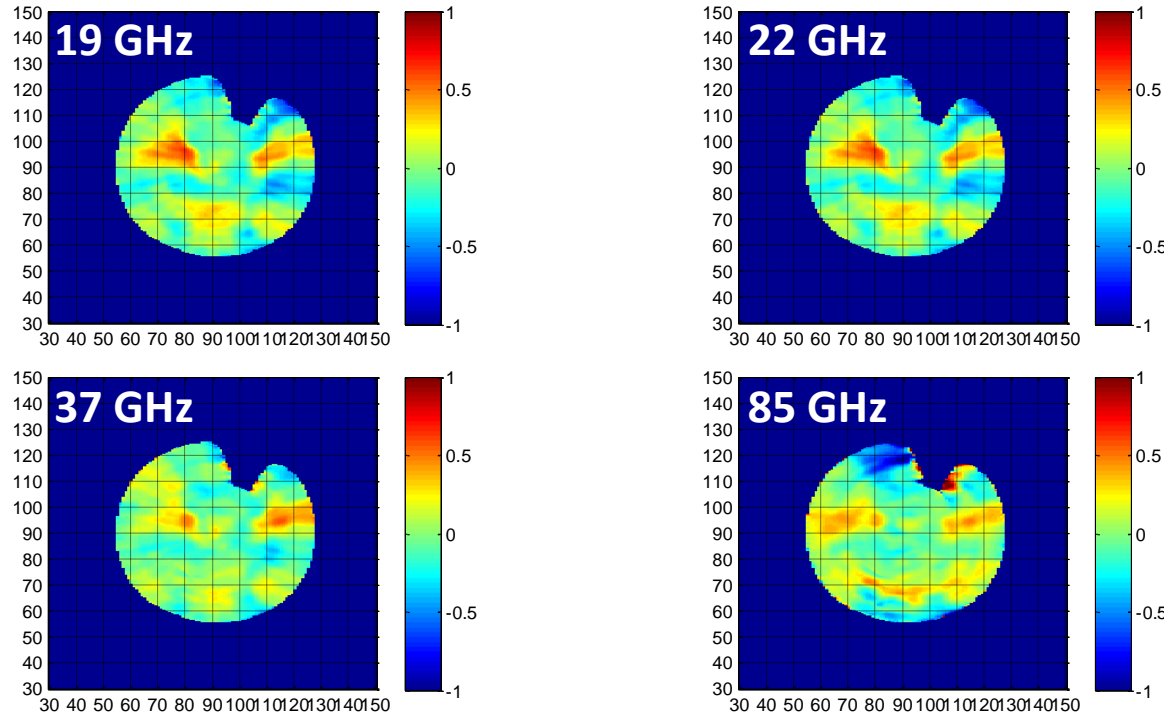
# Change in Mean $T_B$ Due to Change in APC

	19V	19H	22V	37V	37H	85V	85H
F08	0.678	0.218	0.216	0.439	0.536		
F10	0.028	-0.132	0.029	-0.380	-0.368	0.105	-0.192
F11	-0.015	0.184	-0.201	-0.037	-0.081	-0.785	-0.844
F13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F14	0.298	0.085	0.270	-0.344	-0.073	-0.037	-0.055
F15	0.294	-0.064	-0.104	-0.408	0.080	0.157	0.090

- These values are the difference between:
  - $T_B$  calculated using F13 APC for all SSM/I
  - $T_B$  calculated using different APC for each individual satellite
- Differences are generally small (<0.5 K) except for F08
- Differences for F11 are currently being investigated



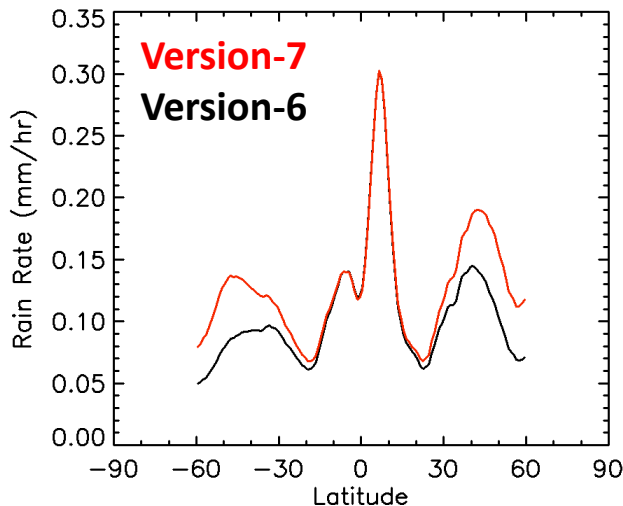
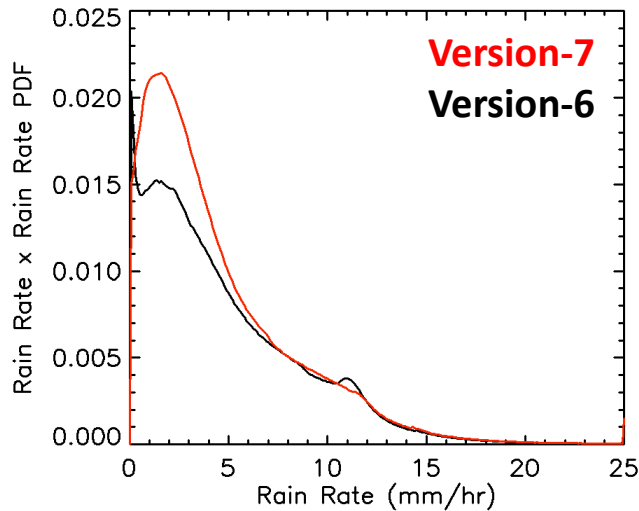
# Hot Load Adjustment for F13



- Difference between F13  $T_A$  (V-H/2 ) and RTM  $T_A$  from WindSat EP, plotted versus Sun azimuth (x-axis) and elevation (y-axis)
- Assumption: hot load correction is the same for V and H polarization
- 85 GHz is shown, but not used: 37 GHz used in its place
- 19 GHz is used for 22 GHz
- Will provide hot load adjustment in data file



# Version 7: Rain Rate Retrievals



- Version-6
  - Beamfilling correction: *Hilburn and Wentz* [2008]
  - Depends on
    - Ratio 19/37 GHz attenuation
    - Footprint size
- Version-7
  - Implementation in V6 caused spike to occur at very low rain rates at threshold where 19/37 ratio exceeds theoretical value for uniform rain
  - Beamfilling correction in V7 turns on smoothly with 19/37 ratio
  - This change increased contribution from light rain rates and affects the extratropics
  - Tropics: V7 and V6 agree to within 1%
  - Extratropics: V7 > V6 by 32%
  - Globally: V7 > V6 by 16%
  - V7 rain retrievals agree better with coastal GPCC gauges

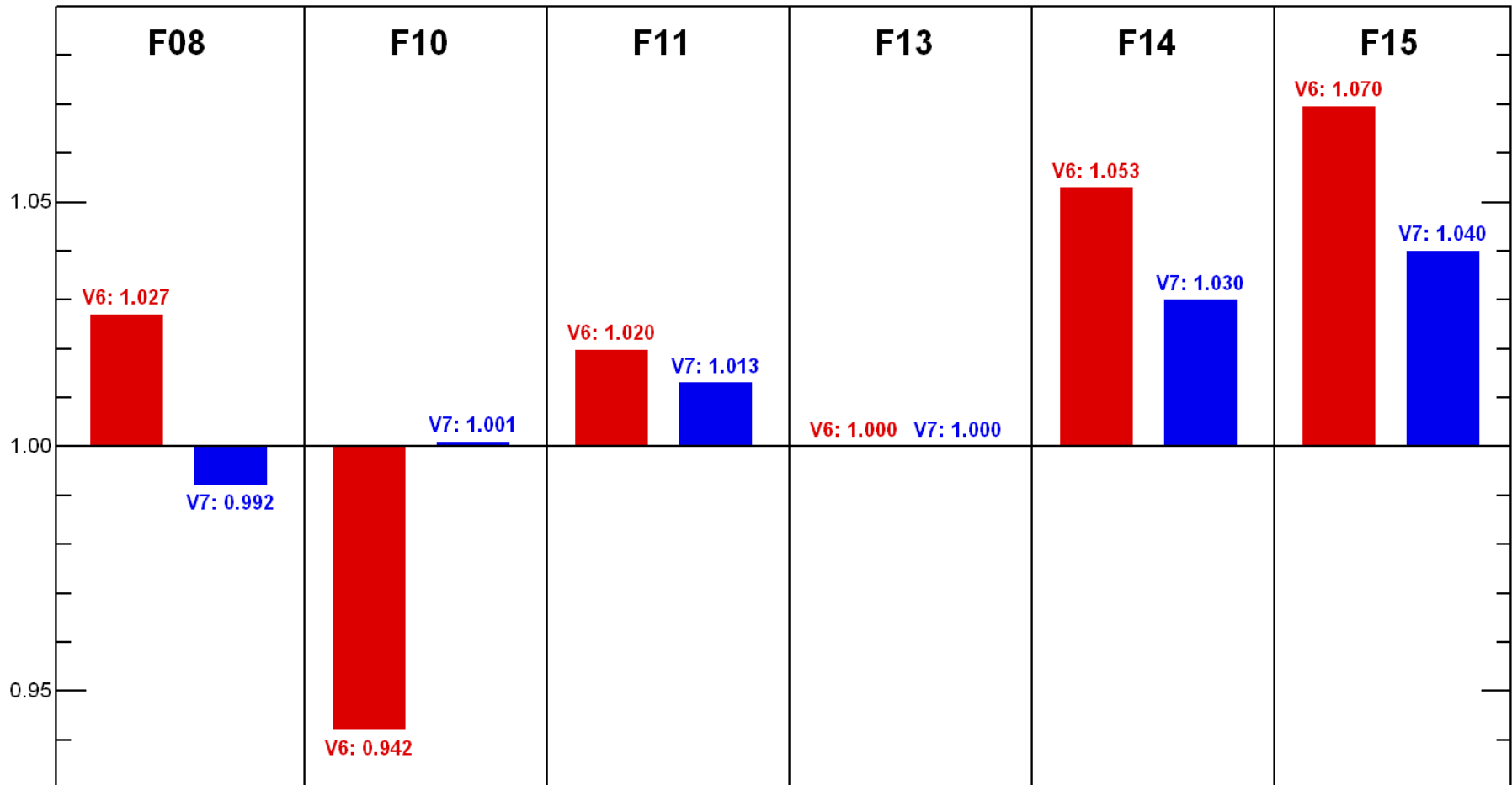


# Version-7 Rain Rates are Better Intercalibrated

Intersatellite merging parameters are calculated as in *Mears et al.* [2003]

**Version-6** values are from *Hilburn and Wentz* [2008]

**Version-7 is shown in blue**





# New in V7: Winds Through Rain

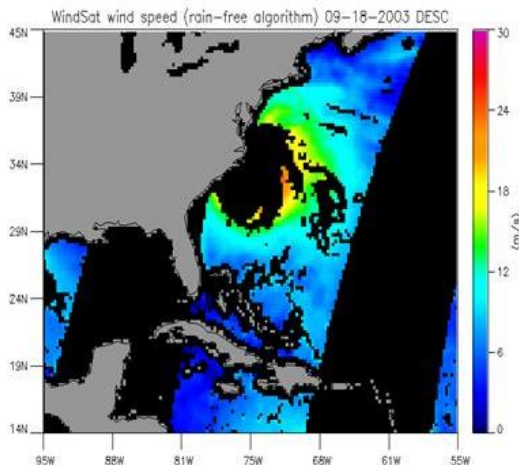
- No-rain algorithm
  - Physical algorithm
  - Based on radiative transfer model (RTM)
  - Trained from Monte Carlo simulated TB
- Wind speed in rain algorithms
  - Statistical or hybrid algorithms
  - Trained from match-ups between measured TB and HRD H\*Wind in rainy conditions
  - Utilizes spectral difference (6.8 GHz versus 10.7 GHz) in wind/rain response of measured brightness temperatures
  - Same method is used by NOAA aircraft Step Frequency Microwave Radiometers (SFMR) to measure wind speeds in hurricanes
  - C-band (7 GHz) required: WindSat, AMSR-E, GCOM
  - Possible with only X-band (11 GHz): TMI, GMI

## ***Radiometer winds in rain:***

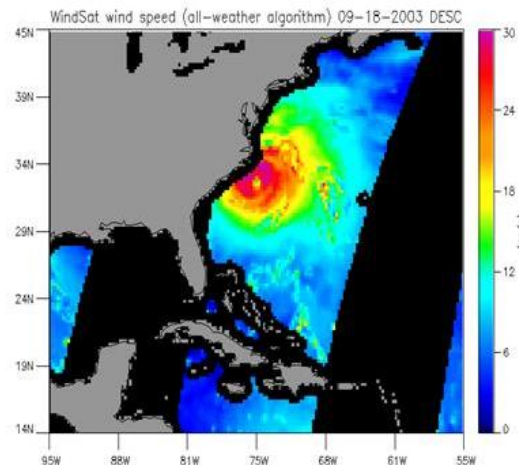
T. Meissner + F. Wentz,

*IEEE TGRS 47(9), 2009, 3065 - 3083*

### Rain-free WindSat



### All-weather WindSat



### Rain rate

