

# **SeaWinds Radiometer (SRad) Brightness Temperature Calibration/Validation**

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# Presentation Outlines

- Background
- Principles of Scatterometry/Radiometry
- Revealed Tb differences - Need for Asc/Dsc Corrections
- Radiometric Calibration Procedure
- SRad/AMSR Empirical Asc/Dsc Correction
- Validation of Empirical Correction with independent data-set.
- Conclusions

# Background

- SeaWinds is a satellite-borne radar scatterometer used to remotely sense oceanic surface winds
  - Launched June 1999 on the low-earth polar orbit QuikSCAT satellite
- Issue
  - When rain occurs the antenna noise increases
  - Approx. 10% of wind retrievals are corrupted by rain
- Resolution
  - Previously, CFRSL developed a signal processing algorithm to measure the antenna noise and “flag” rain contamination
    - MS theses: Mehershahi, 2000 & Susanj 2000

# Background cont.

- A second SeaWinds instrument launched on Japan's Advanced Earth Observing Satellite in December 2002
  - This thesis concerns the evaluation of the SeaWinds Radiometer (SRad) on ADEOS-II

# Thesis Objective

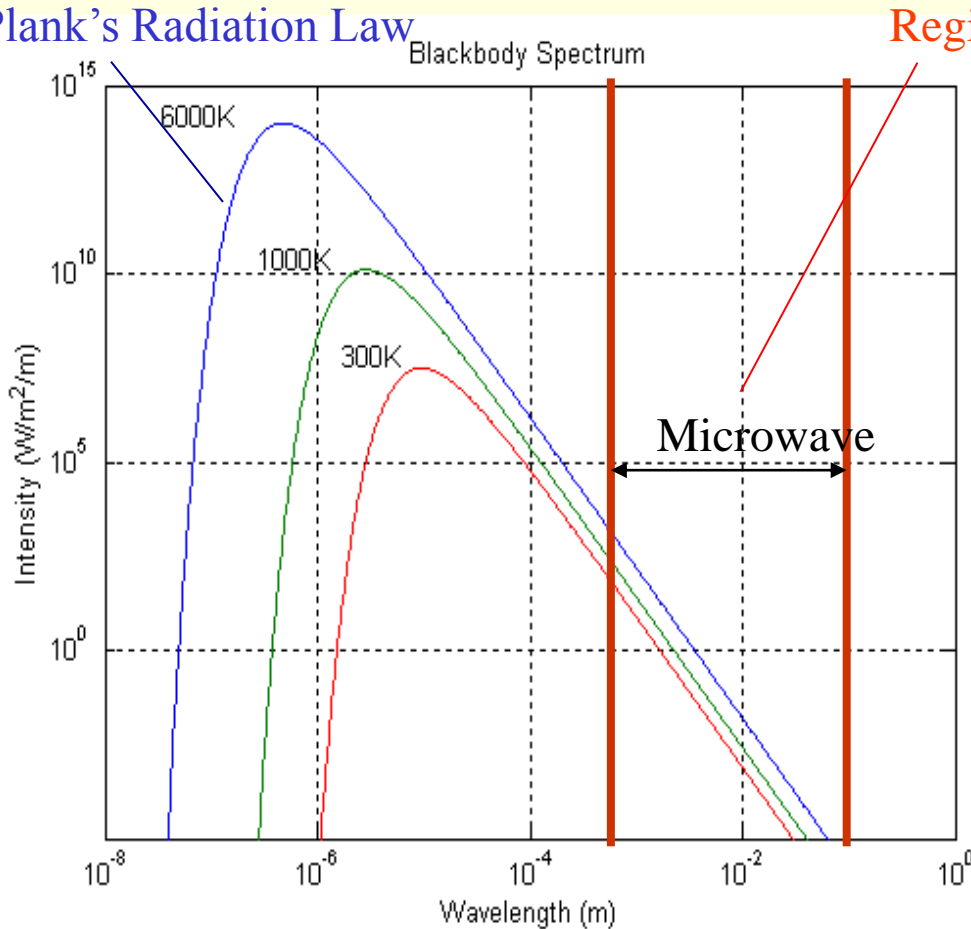
- Radiometric calibration of the SeaWinds Radiometer (SRad) on ADEOS-II
  - Evaluate previous QuikSCAT Radiometer (QRad) transfer function
  - Tb cross-calibration with the Advanced Microwave Scanning Radiometer (AMSR) also on ADEOS-II
- Validate SRad brightness temperature (Tb) measurements over ocean using independent AMSR equivalent Tb's

# Principles of Scatterometry/Radiometry

# Black Body Radiation

According to thermodynamic principles, all matter at temperatures greater than absolute zero absorb and emit non-coherent EM energy.

## Planck's Radiation Law



Planck's law:

$$S(\lambda) = \frac{2\pi hc^2}{\lambda^5} \frac{1}{e^{\frac{ch}{\lambda kT}} - 1}$$

Where:  $h$  = Planck's constant  
 $k$  = Boltzmann's constant  
 $c$  = Speed of light  
 $T$  = Physical temperature

Rayleigh-Jean's Approximation

(valid over microwave region):

$$S(\lambda) \approx \frac{2\pi ckT}{\lambda^4}$$

# Microwave Radiometry

- Blackbody power is:

$$P_{blackbody} = k * T_{phys} * Bandwidth$$

microwave antenna measures equivalent blackbody power

For non-blackbodies, microwave brightness temperature,  $T_b$ , of a medium is:

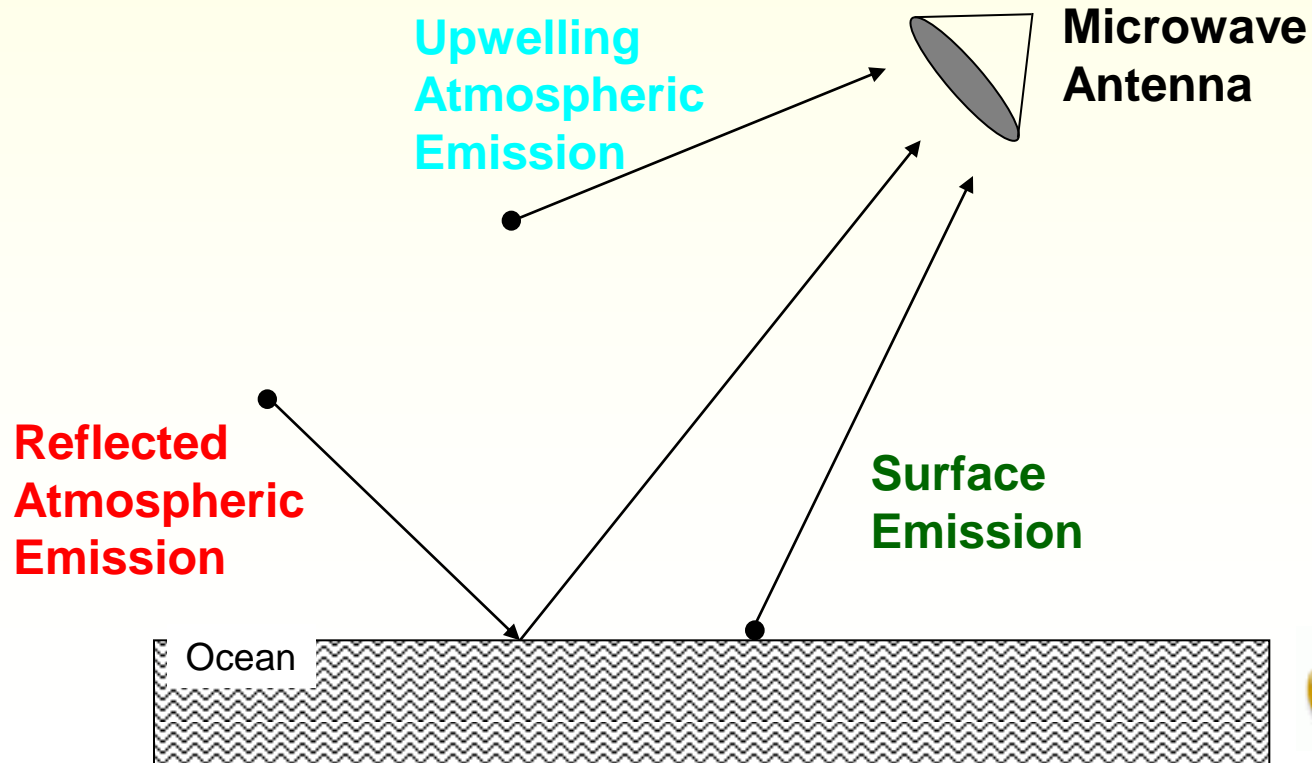
$$T_b = \varepsilon T_{Phys}$$

where:

- Brightness temperature is the equivalent blackbody temperature
- $\varepsilon$  is the emissivity, which varies with
  - EM wavelength
  - Incidence angle and Polarization
  - Complex index of refraction

# Microwave Brightness Temperature over Ocean

- Measured brightness temperature:
  - Upwelling atmospheric emission
  - Downward atmospheric emission reflected by the sea surface
  - Ocean emission

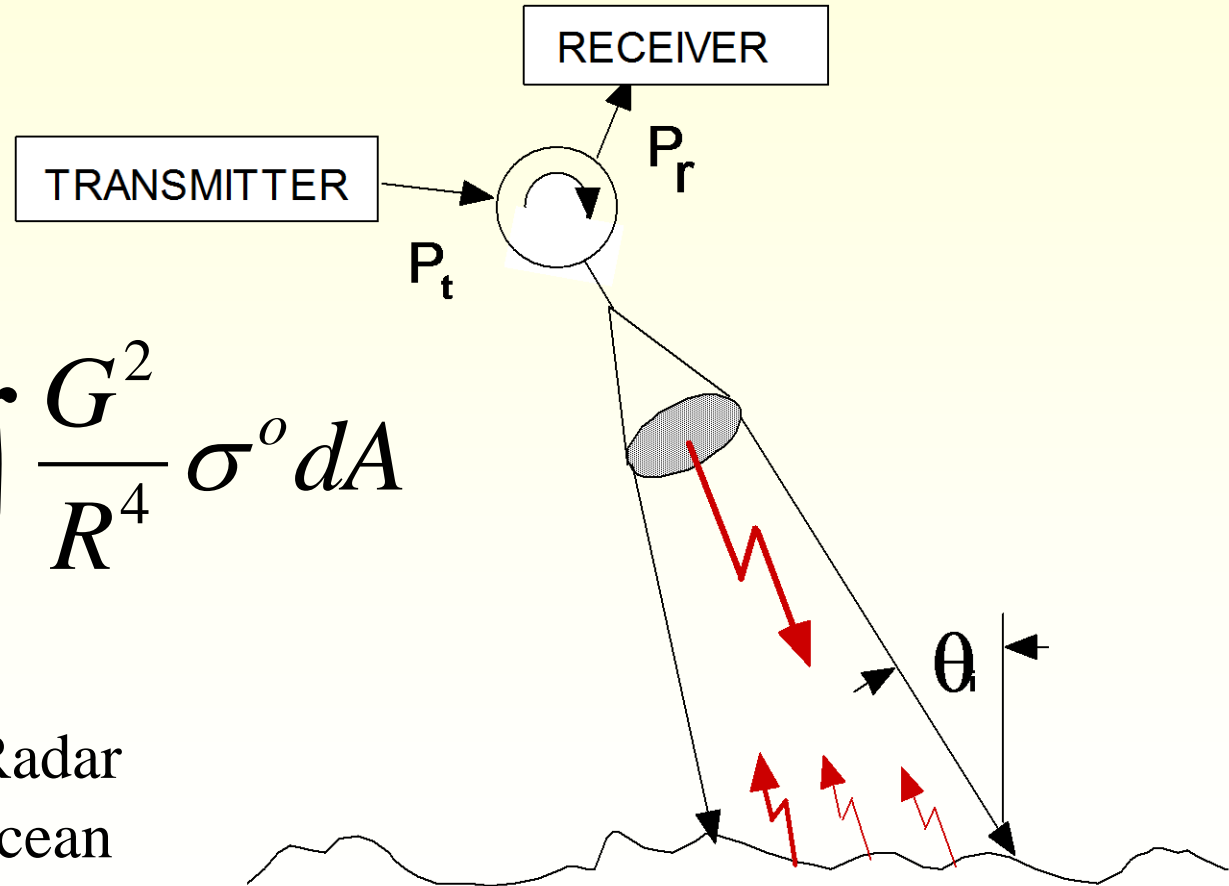


# Satellite Microwave Scatterometer

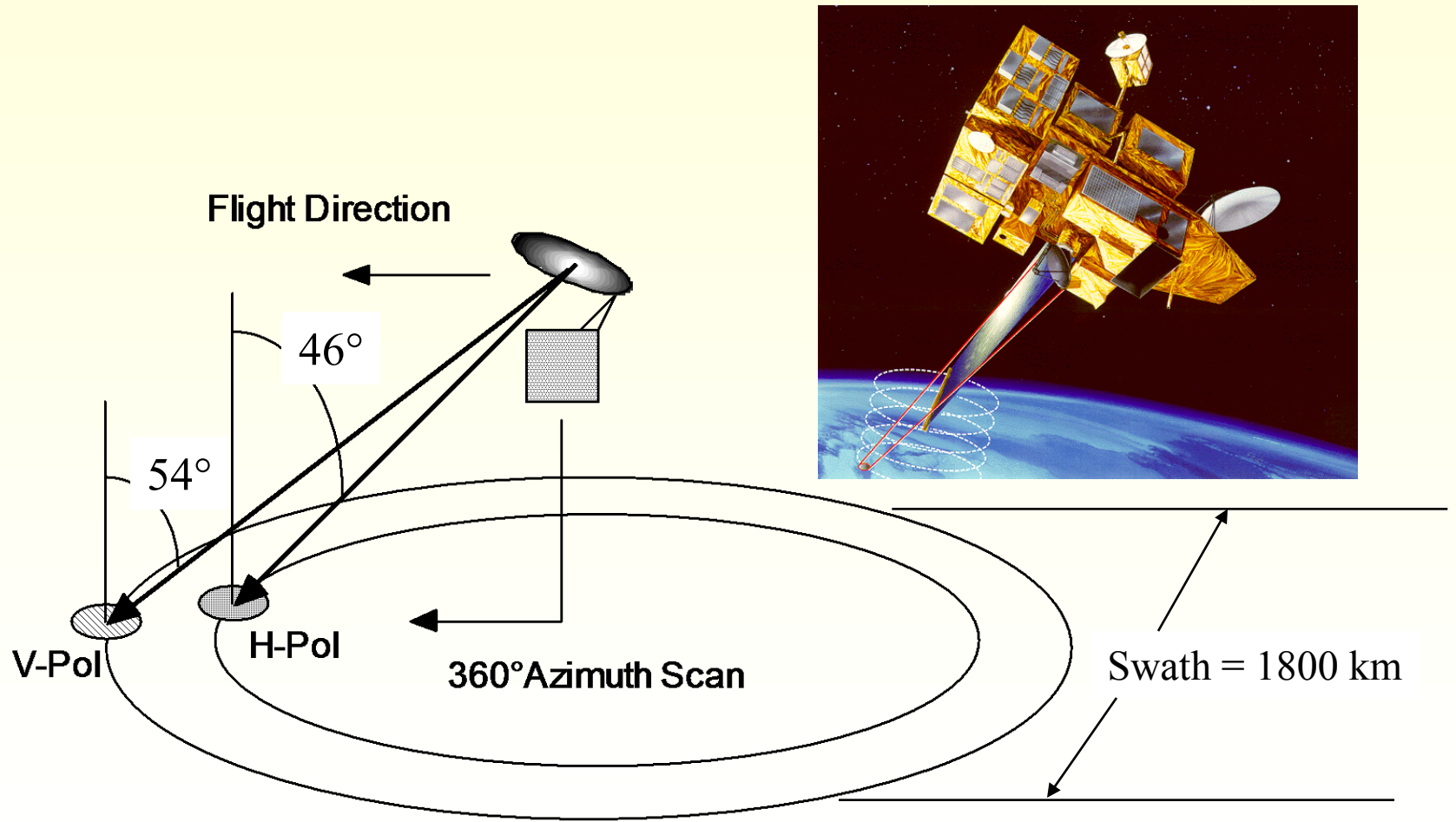
- Radar Equation

$$P_r = \frac{P_t \lambda^2}{(4\pi)^3} \iint_A \frac{G^2}{R^4} \sigma^o dA$$

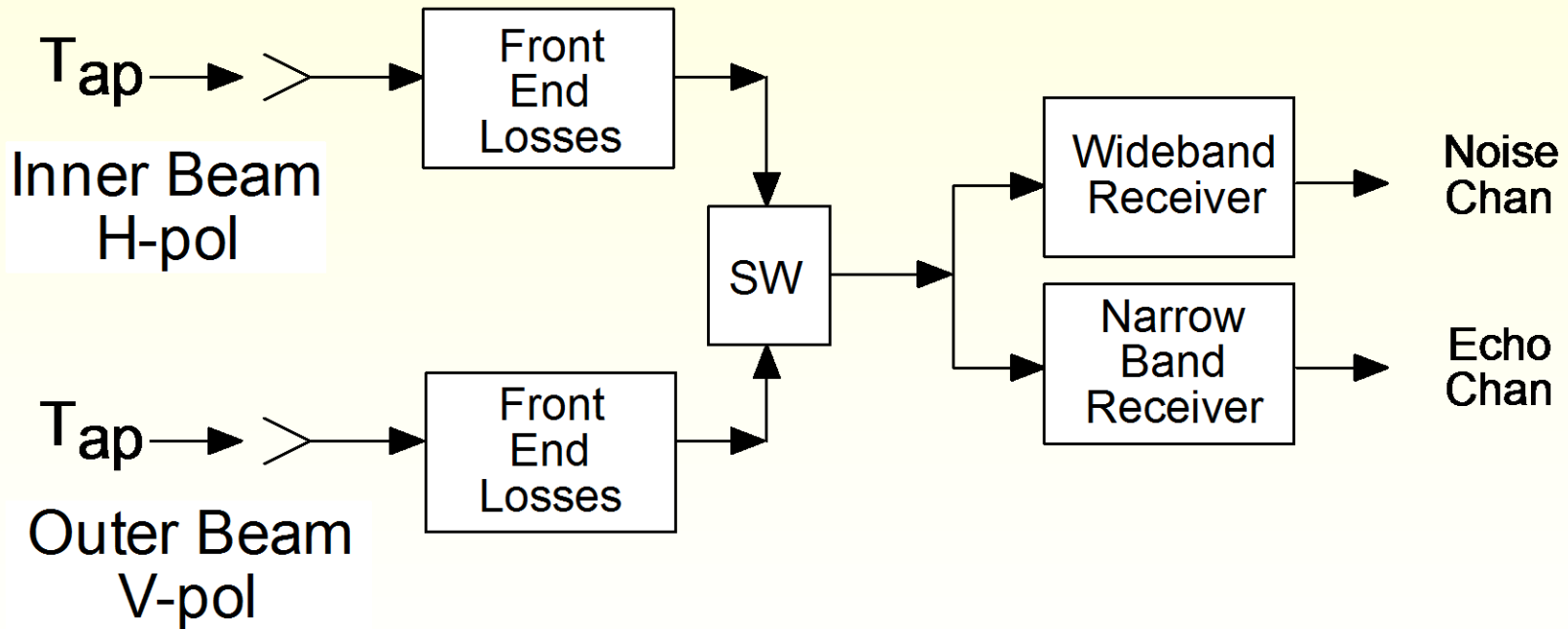
- $\sigma^o \Rightarrow$  Normalized Radar Cross-section of the ocean surface



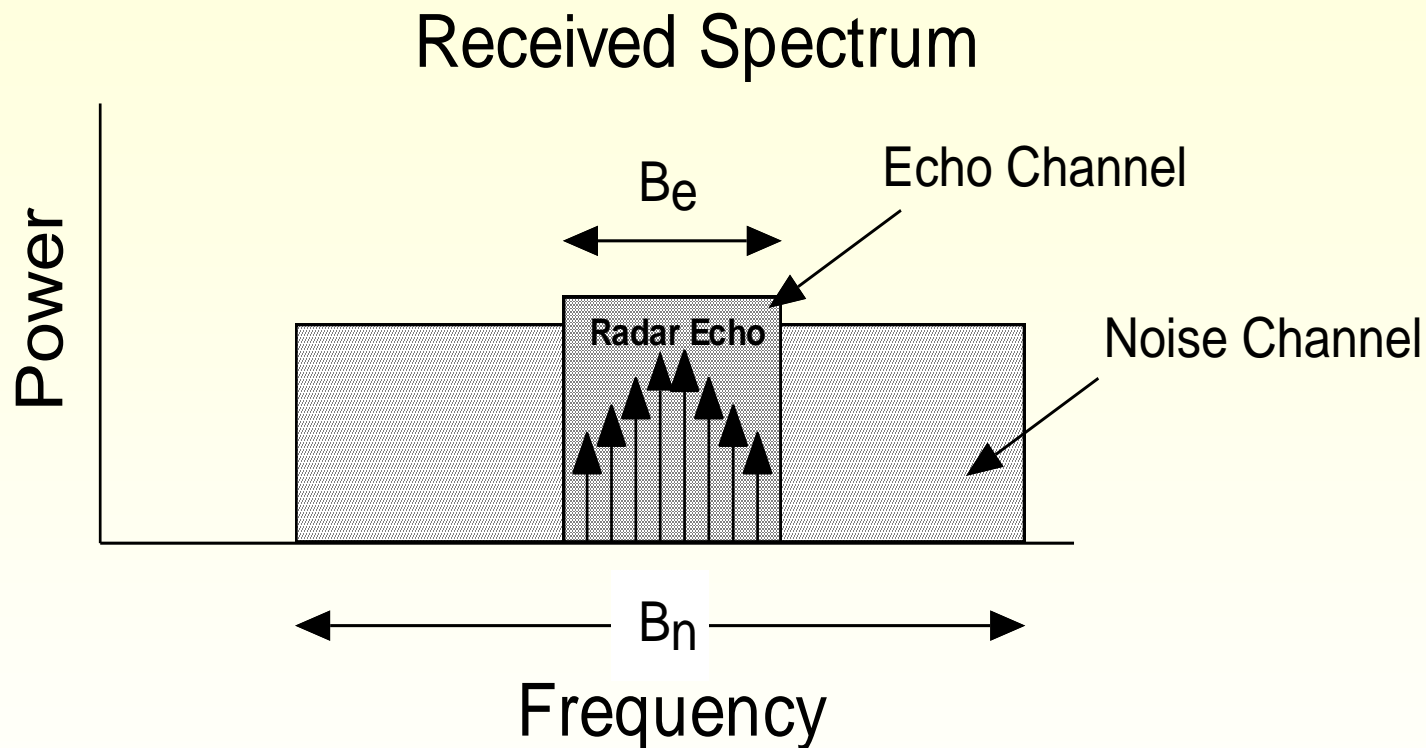
# Geometry of SeaWinds Scatterometer on ADEOS-II



# SRad Simplified Functional Diagram



# SeaWinds Received Power Spectrum



antenna noise = noise chan pwr - echo chan pwr

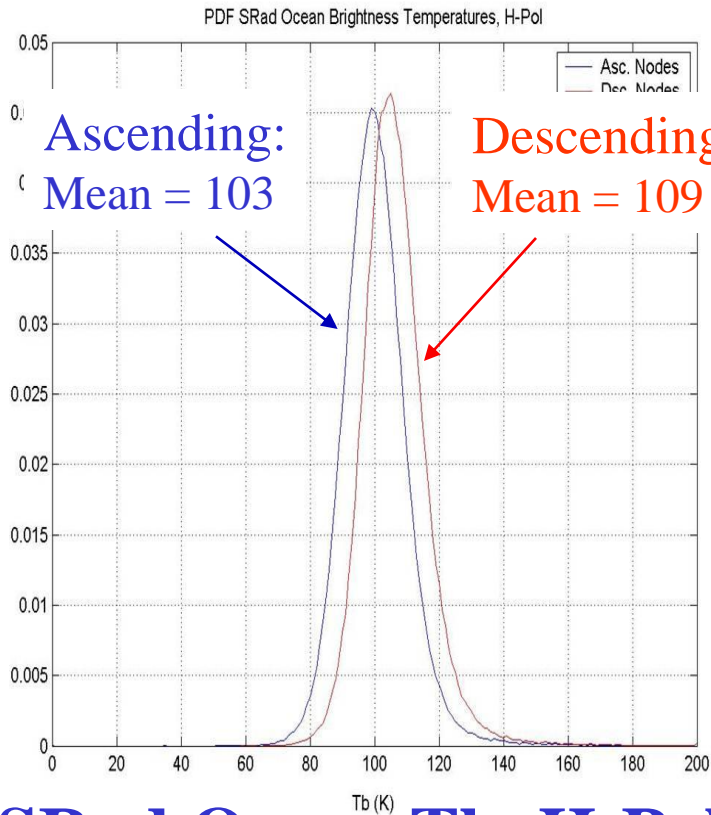
# Early On-orbit Check-out of SRad

# Revealed Anomalous Tb Differences

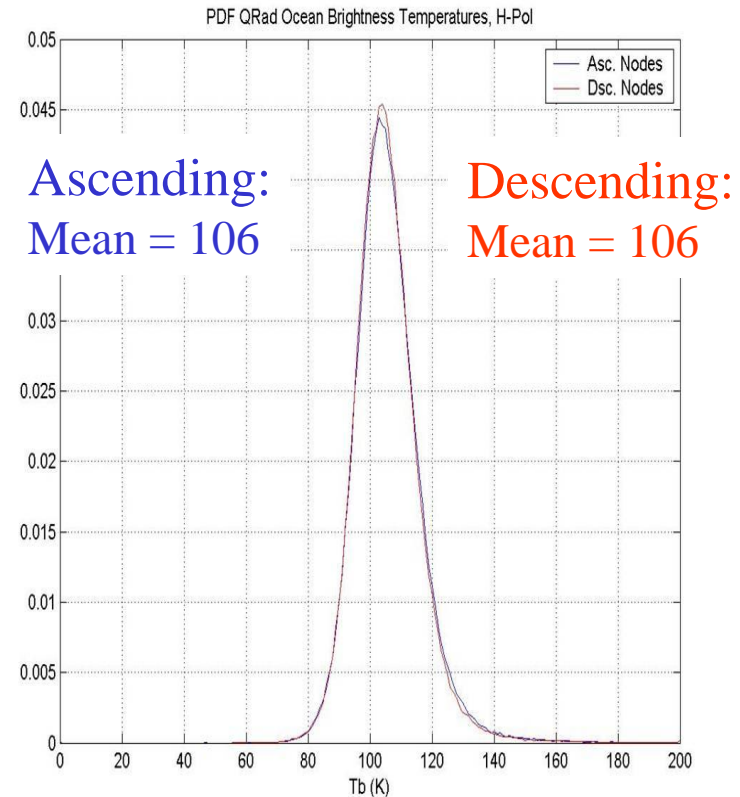
## Ascending & Descending Orbit Segments

- Compared 3-days averages of asc/desc revs for QRad and SRad
  - QRad 3-day average ascending and descending Tb's were equal, but
  - SRad ascending Tb's were colder by  $\sim 5$  K
    - Both polarizations exhibited this anomaly

# SRad Ascending / Descending $T_b$ Anomaly (3-day ocean avg)

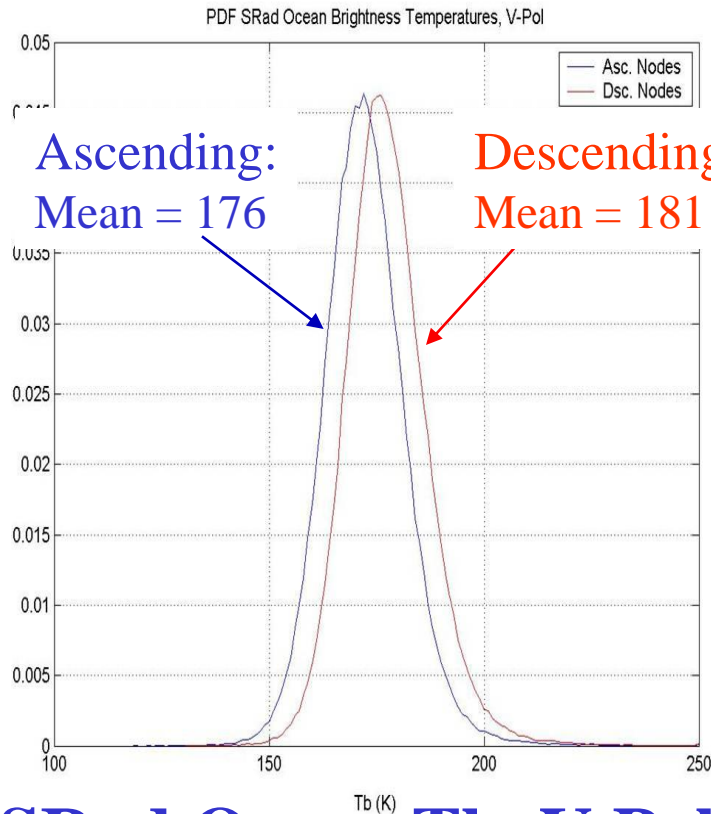


**SRad Ocean  $T_b$ , H-Pol**

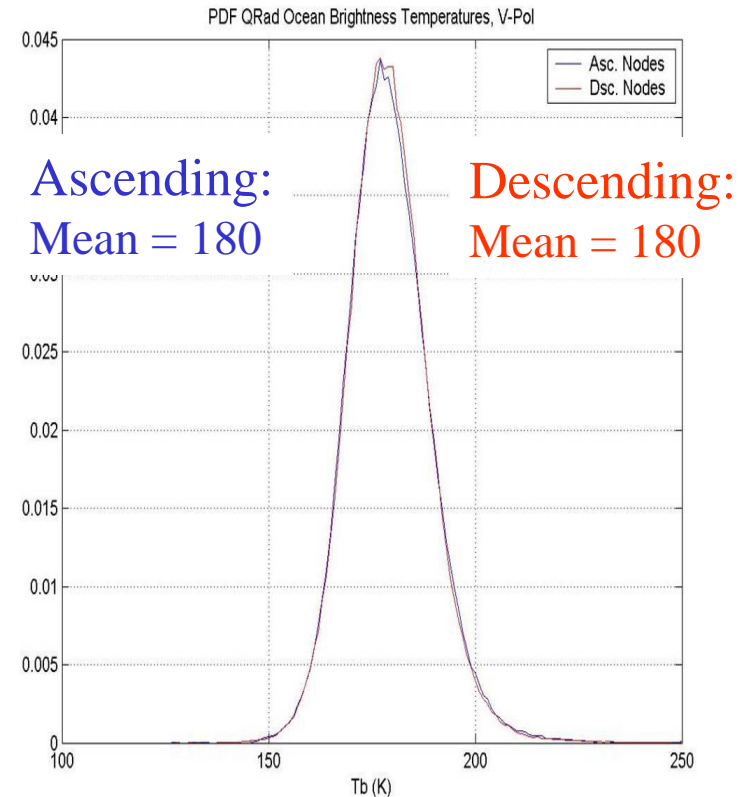


**QRad Ocean  $T_b$ , H-Pol**

# SRad Ascending / Descending $T_b$ Anomaly (3-day ocean avg)



**SRad Ocean  $T_b$ , V-Pol**



**QRad Ocean  $T_b$ , V-Pol**

# Ascending-Descending Tb Anomaly



DS



AS



ADEOS-II  
(SRad)



QSCAT  
(QRad)

Radiometric Calibration  
Procedure:  
Cross-calibration of SRad &  
AMSR Brightness Temperatures

# Why calibrate the instrument ?

- SeaWinds not intended for radiometric measurements - does not have usual “hot” and “cold” internal brightness temperature calibration sources.

## Calibration Approach

- Use Advanced Microwave Scanning Radiometer (AMSR) and compare simultaneous Tb.

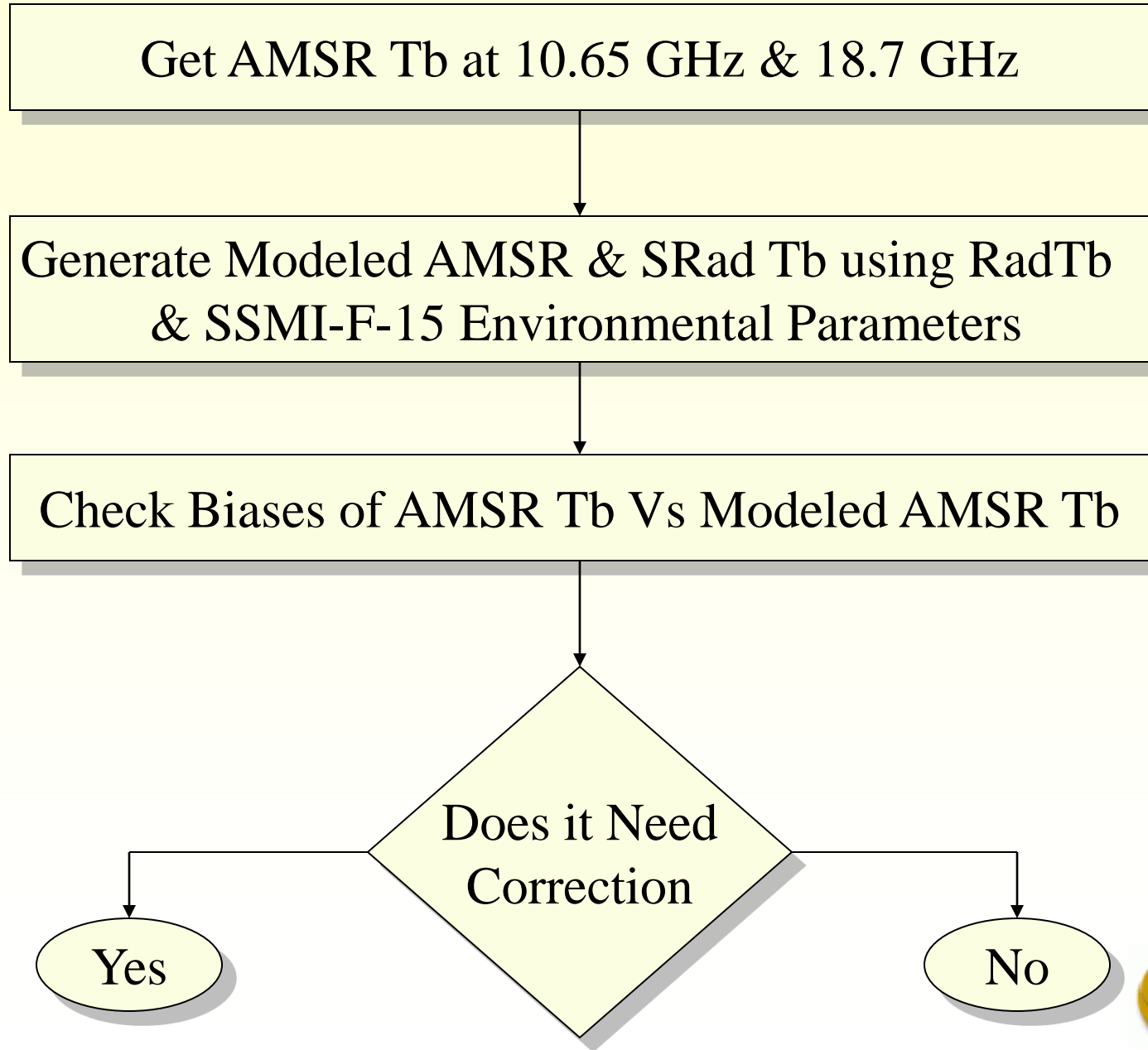
# Advanced Microwave Scanning Radiometer (AMSR)

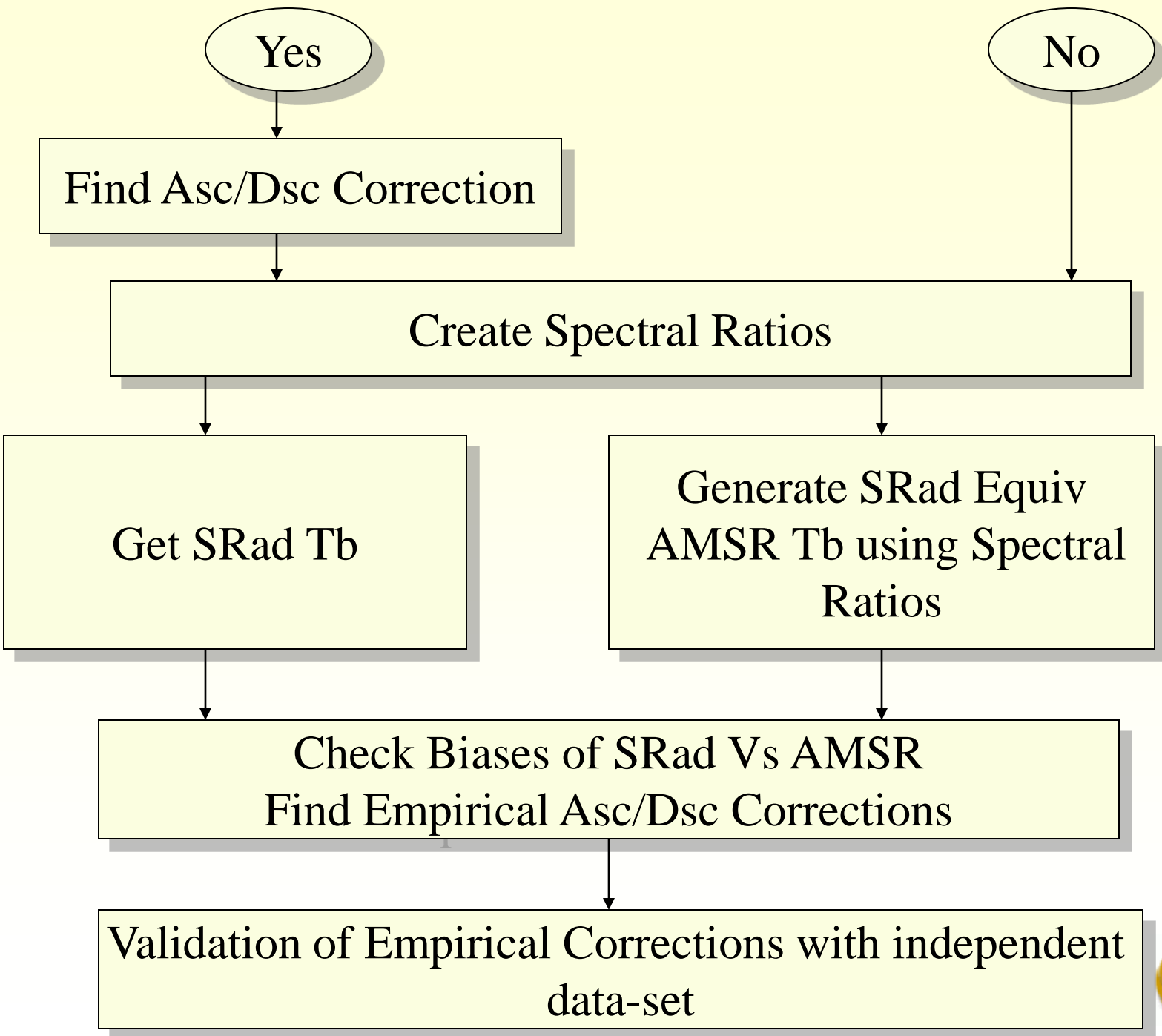
- Multi- frequency microwave radiometer
  - 6.9, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz
  - Vertical and Horizontal polarizations
  - Incidence angle =  $55^\circ$

## SeaWinds Scatterometer

- Specialized active microwave sensor
  - Ku-band, 13.4 GHz
  - Vertical and Horizontal polarizations
  - Incidence angle
    - » H-Pol =  $46^\circ$
    - » V-Pol =  $54^\circ$

# Procedure Algorithm





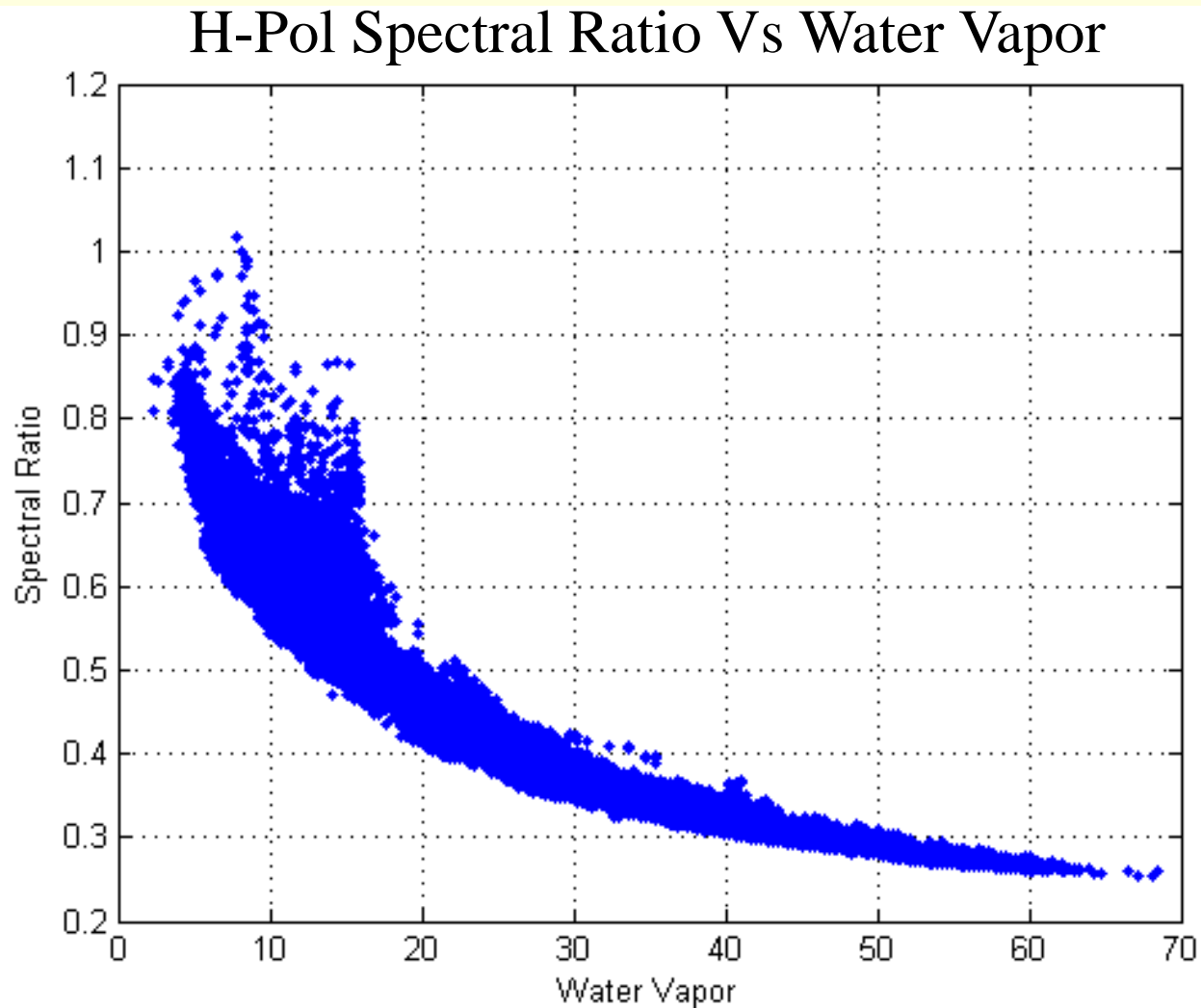
# Model AMSR/SRad Tb

RadTb was run with:

- SRad incidence angles (H-Pol=46deg V-Pol=54deg) – get SRad Tb at 13.4 GHz
- AMSR incidence angle of 55deg with 2 freq
  - get AMSR Tb at 10.65GHz & 18.7GHz
- Environmental pars from NCEP and SSMI
  - SST, Water Vapor, Cloud Liquid & Wind Speed

$$(\textit{specratio}) = \frac{(T_{13.4} - T_{10.65})}{(T_{18.7} - T_{10.65})}$$

- Spectral Ratios were found to be a function of predominantly Water Vapor (WV)

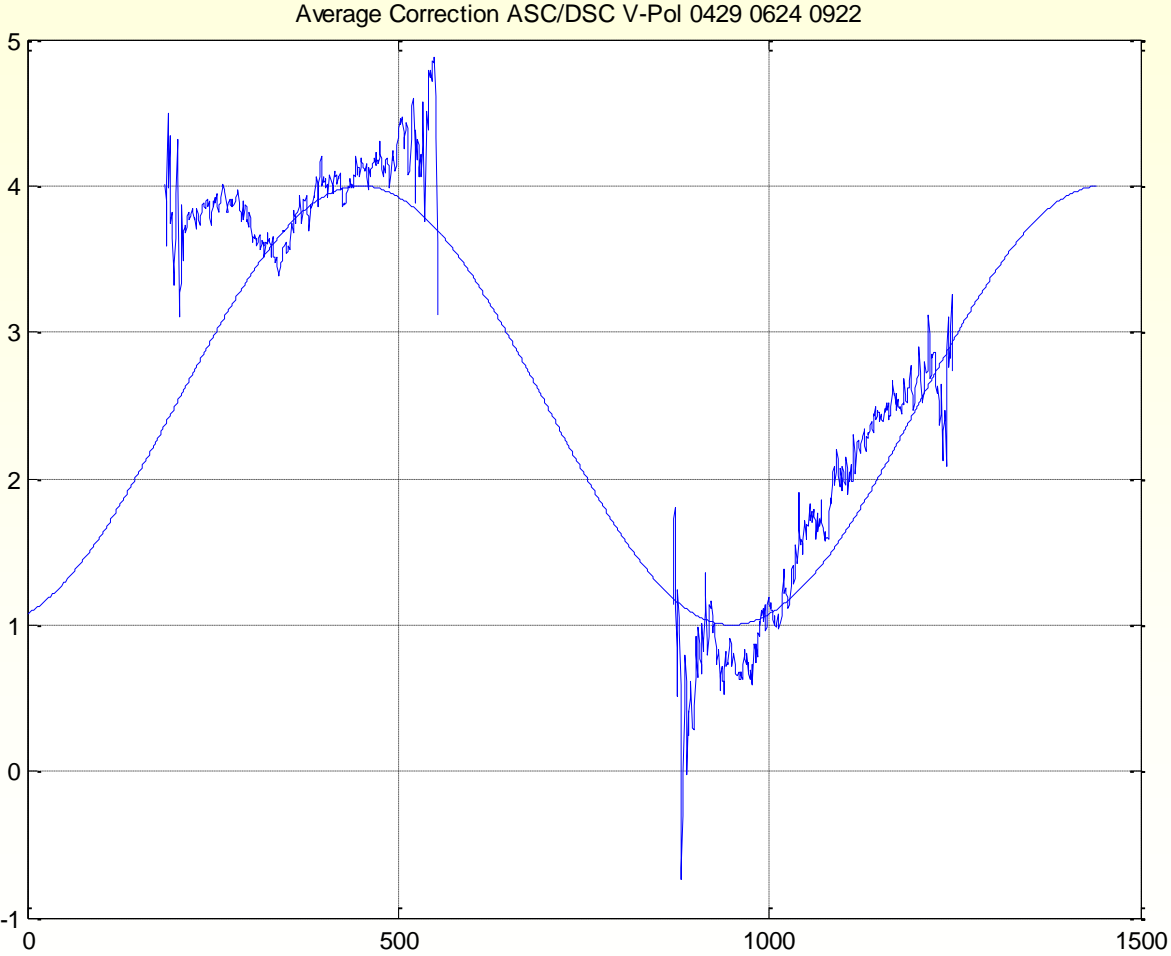


# AMSR Asc/Dsc Correction

# AMSR Asc/Dsc Correction H-Pol



# AMSR Asc/Dsc Correction V-Pol



# Generate SRad Equiv AMSR Tb using Spectral Ratios

- SRad Equiv AMSR Tb (at 13.4 GHz) was generated from AMSR 10.65 & 18.7 GHz Tb's using Spectral Ratio

$$Tb_{13.4} = Tb_{10.65} + \textit{specratio} * (Tb_{18.7} - Tb_{10.65})$$

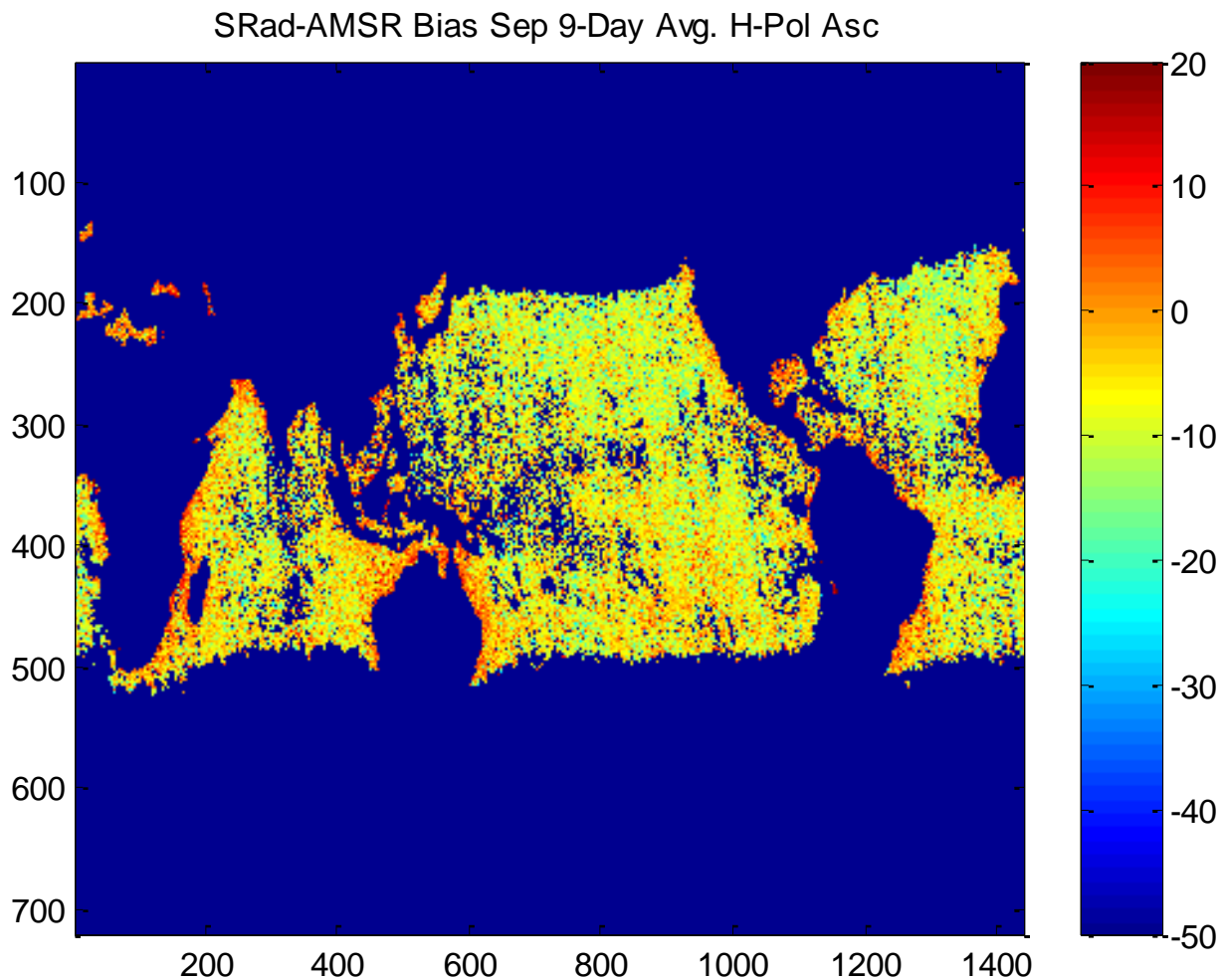
# SRAD/AMSR Tb Differences

- Calculate Tb differences (biases) between SRad Equivalent AMSR Tb and SRad Tb for both polarizations and ascending/descending orbits
- Model Tb biases as a three-term Fourier series of orbit latitude
  - Latitude range for one orbit includes ascending and descending segments =  $2 \times 180^\circ$

# SRad/AMSR Biases Along Longitude

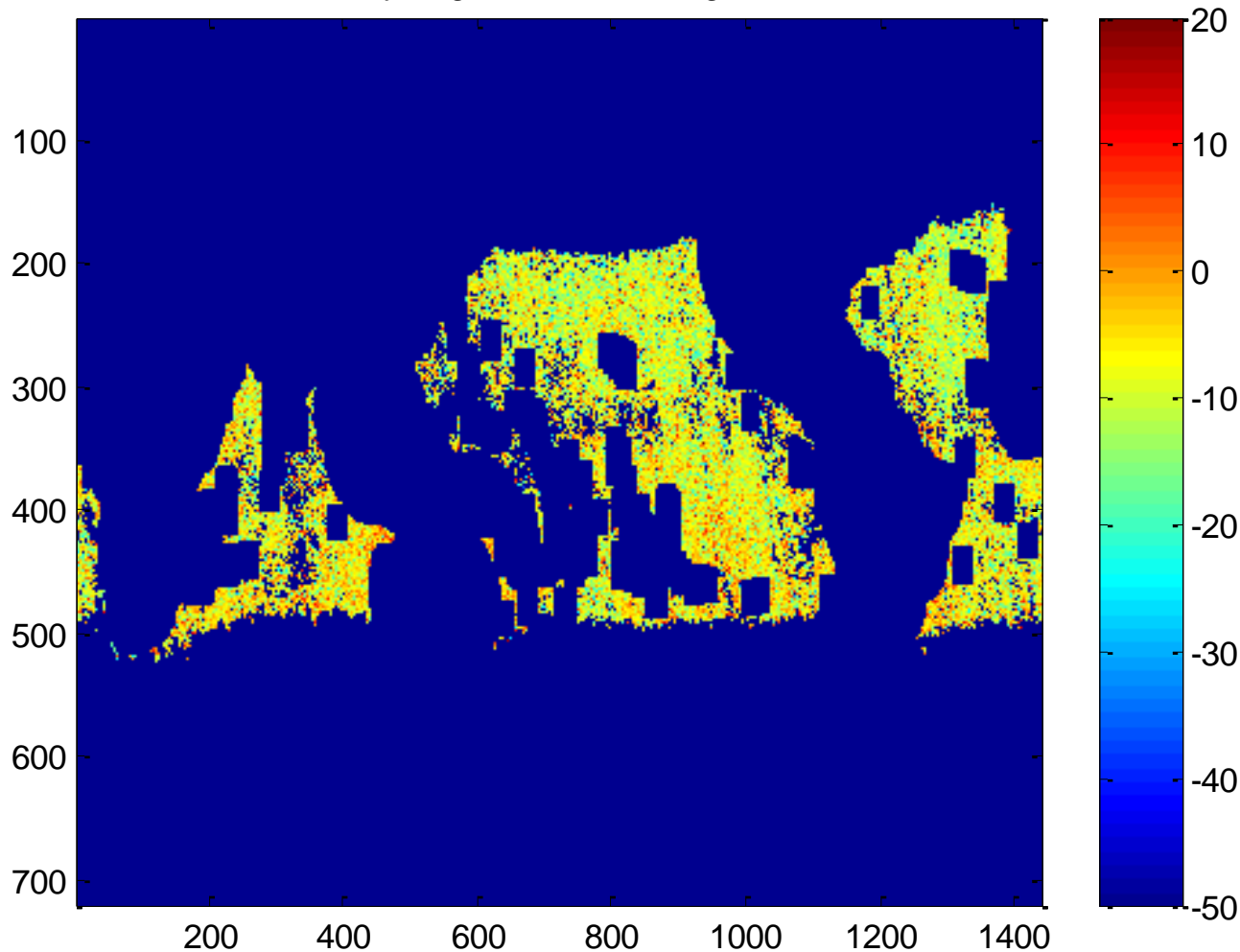
- There were variations in Tb biases with longitude because of the temperature differences along land/ocean boundaries
  - Caused by antenna pattern differences between SRad and AMSR
  - Land is radiometrically “hot” compared to ocean
- New “conservative” land mask created to eliminate of land effects

# SRad/AMSR Biases along Land/Ocean Boundaries (9-Day Average)

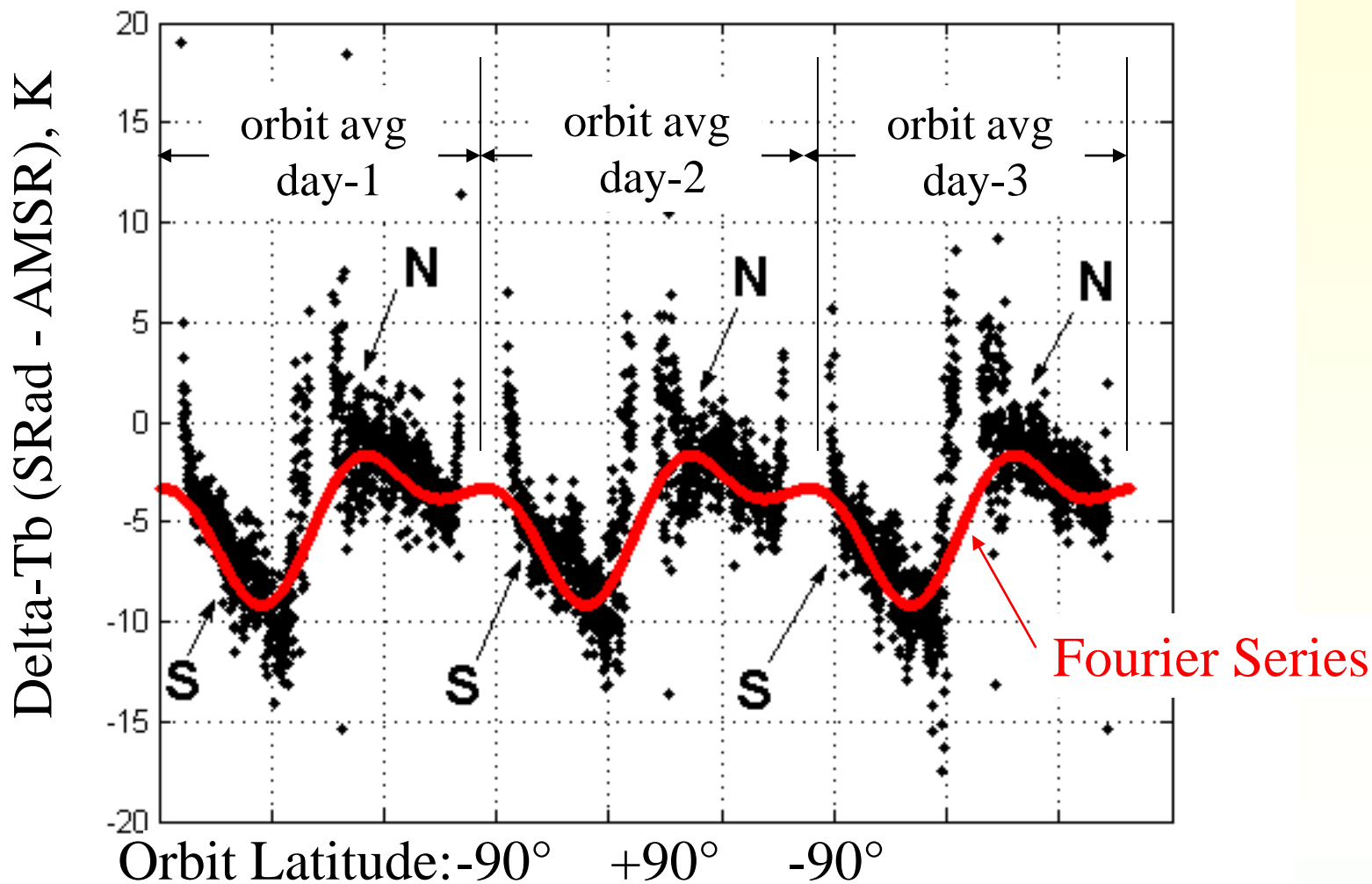


# SRad/AMSR Biases after applying Conservative Land Mask

SRad-AMSR Bias 9-Day Avg H-Pol Asc using conservative LandMask



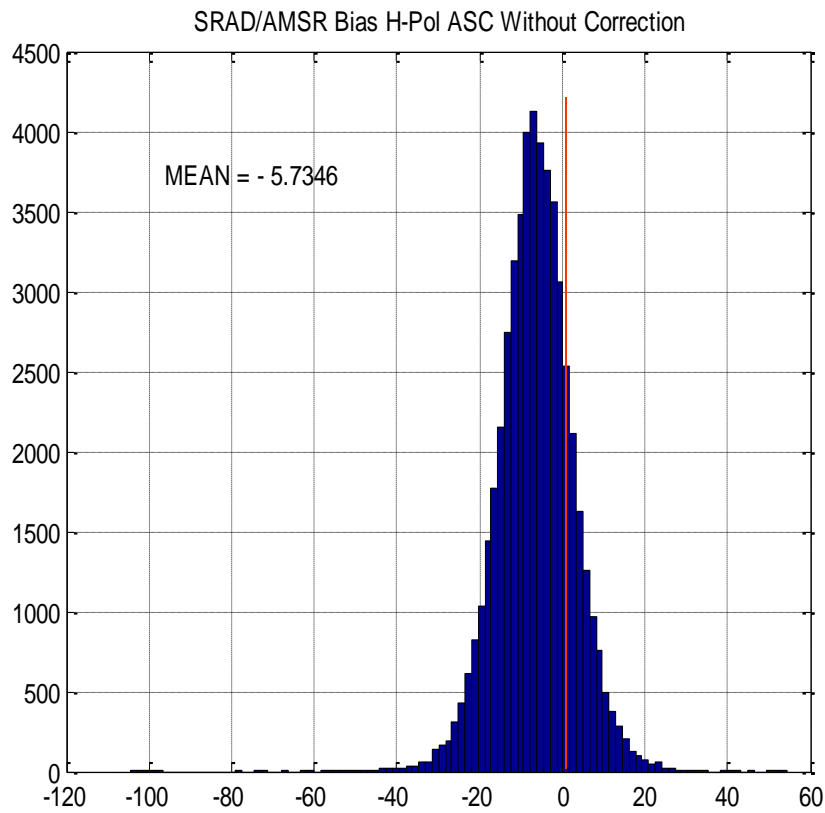
# SRad Asc/Dsc Tb (H-Pol) Correction Orbital Pattern, Average for 3-days



# SRad/AMSR Bias H-Pol Ascending

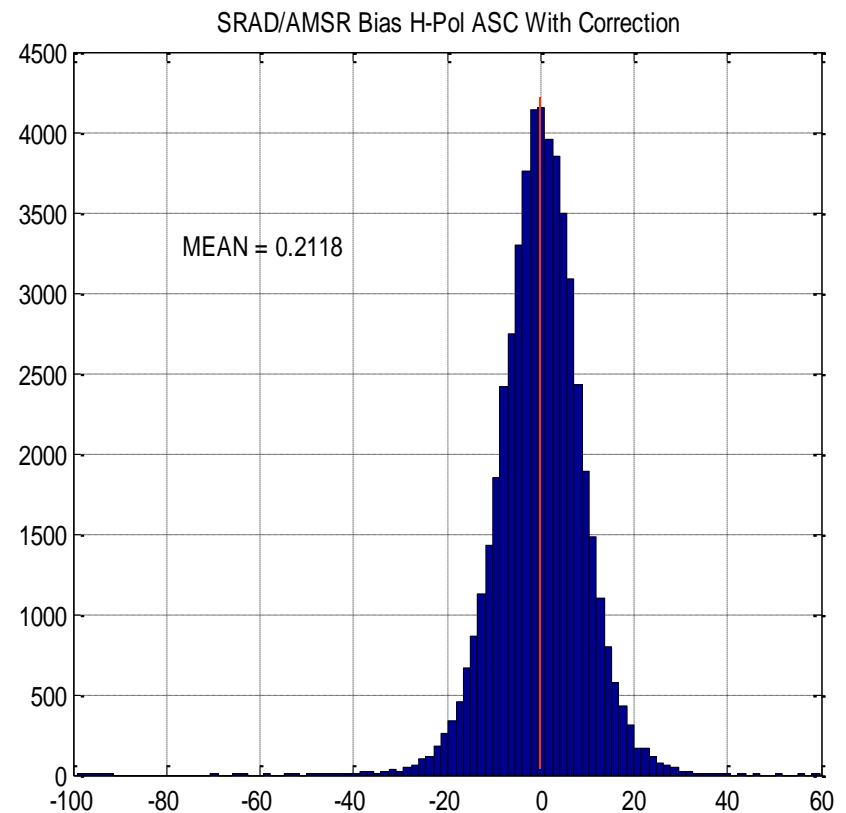
Without Correction

Mean = -5.7346



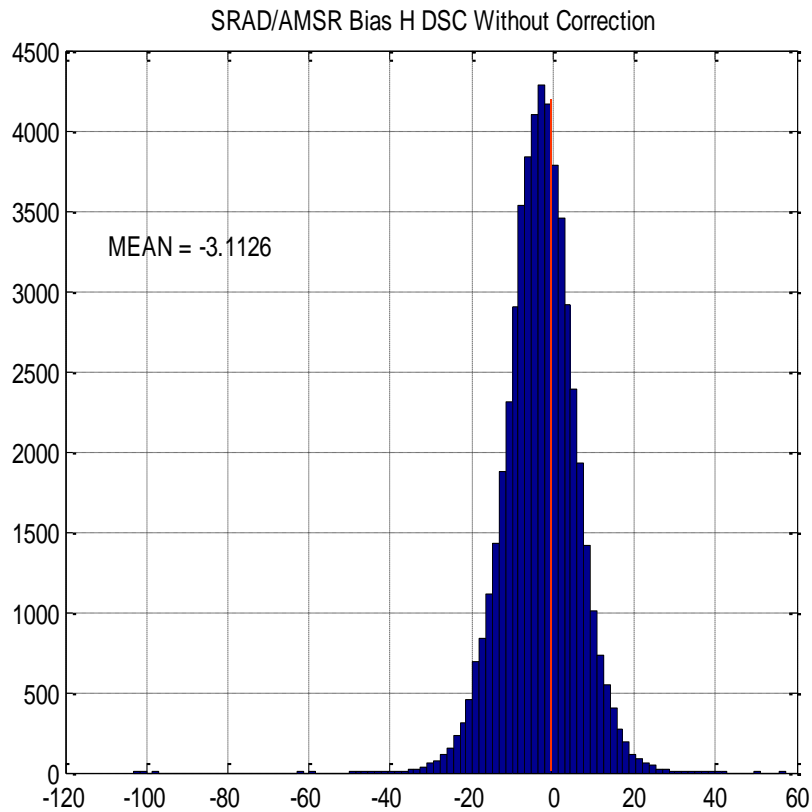
With Correction

Mean = 0.2118

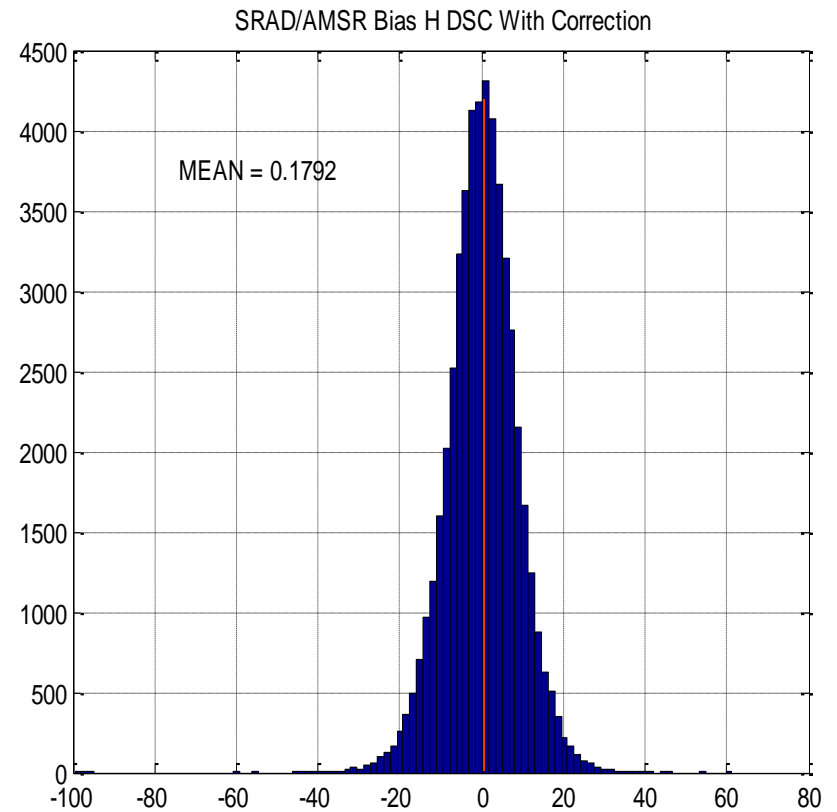


# SRad/AMSR Bias H-Pol Descending

Without Correction  
Mean = -3.1126



With Correction  
Mean = 0.1792



# SRad/AMSR Asc/Dsc Tb Biases

	Mean (K)	STD (K)	# pts
H-pol Asc	-5.7	3.0	52,253
V-pol Asc	-6.4	2.7	66,584
H-pol Dsc	-3.1	2.3	52,031
V-pol Dsc	-1.6	2.3	67,545

(a) Original algo - before correction

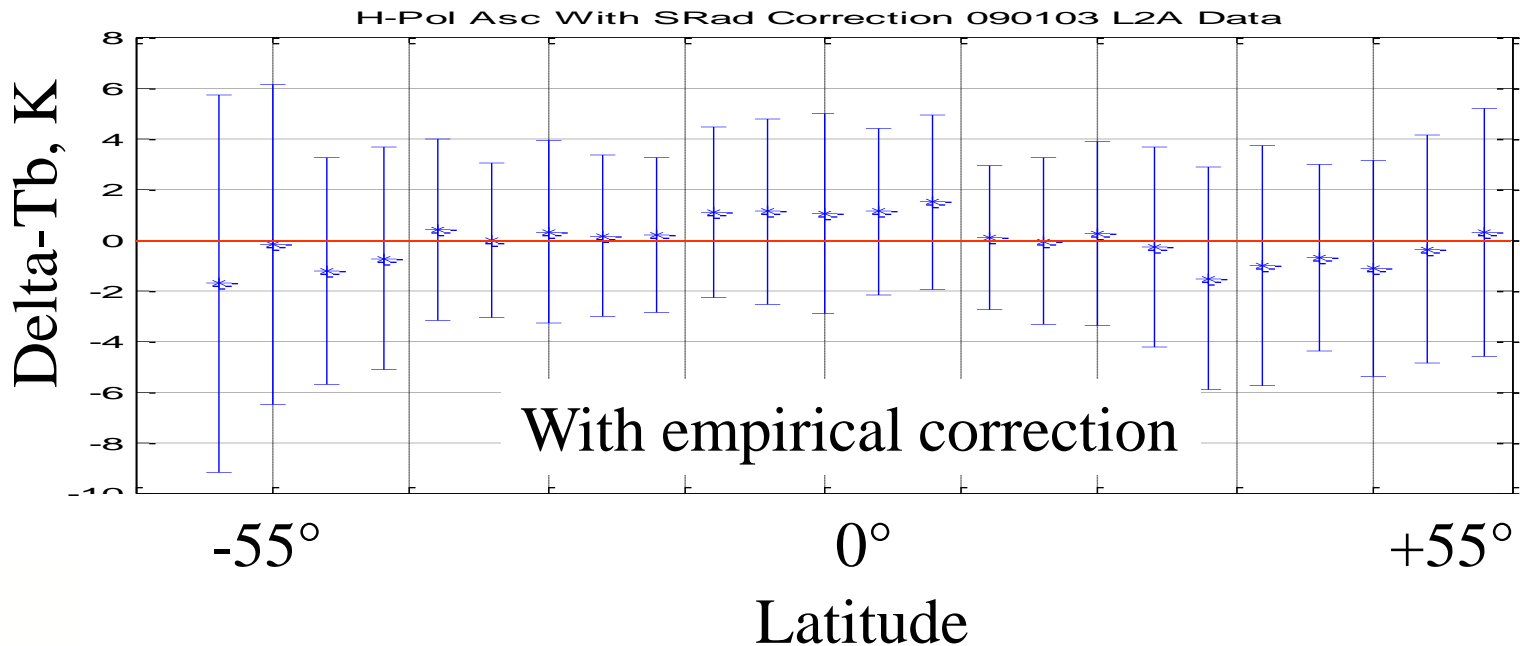
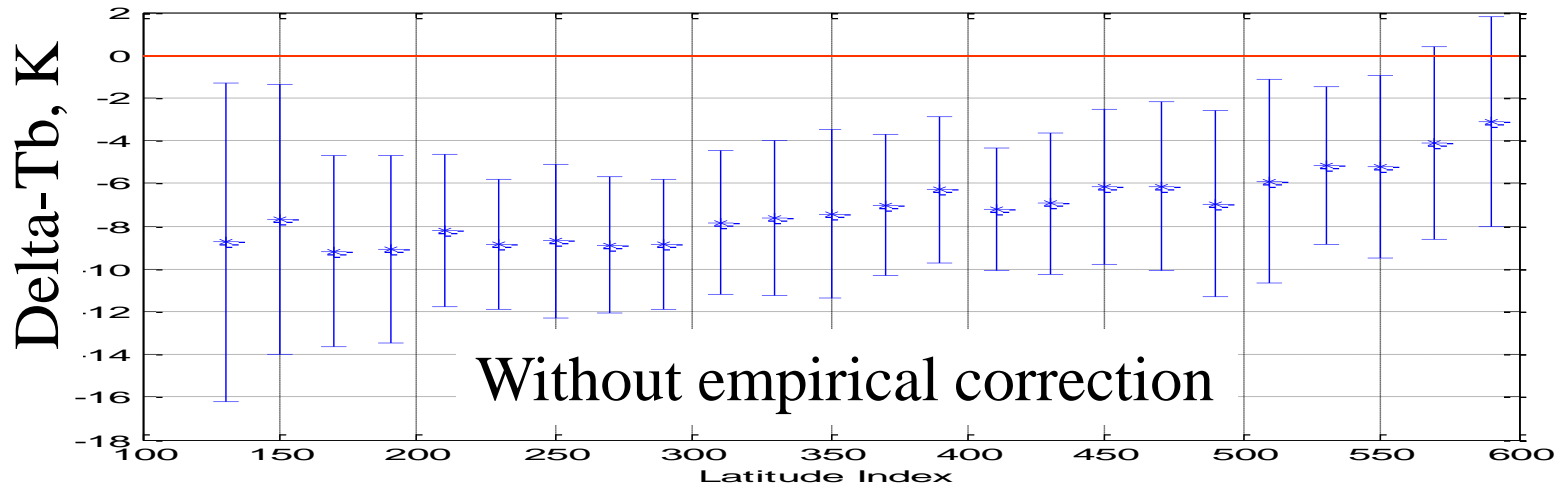
	Mean (K)	STD (K)	# pts
H-pol Asc	0.21	3.0	52,253
V-pol Asc	0.41	2.1	66,584
H-pol Dsc	0.18	2.3	52,031
V-pol Dsc	0.70	2.3	67,545

(b) Revised algo - after correction

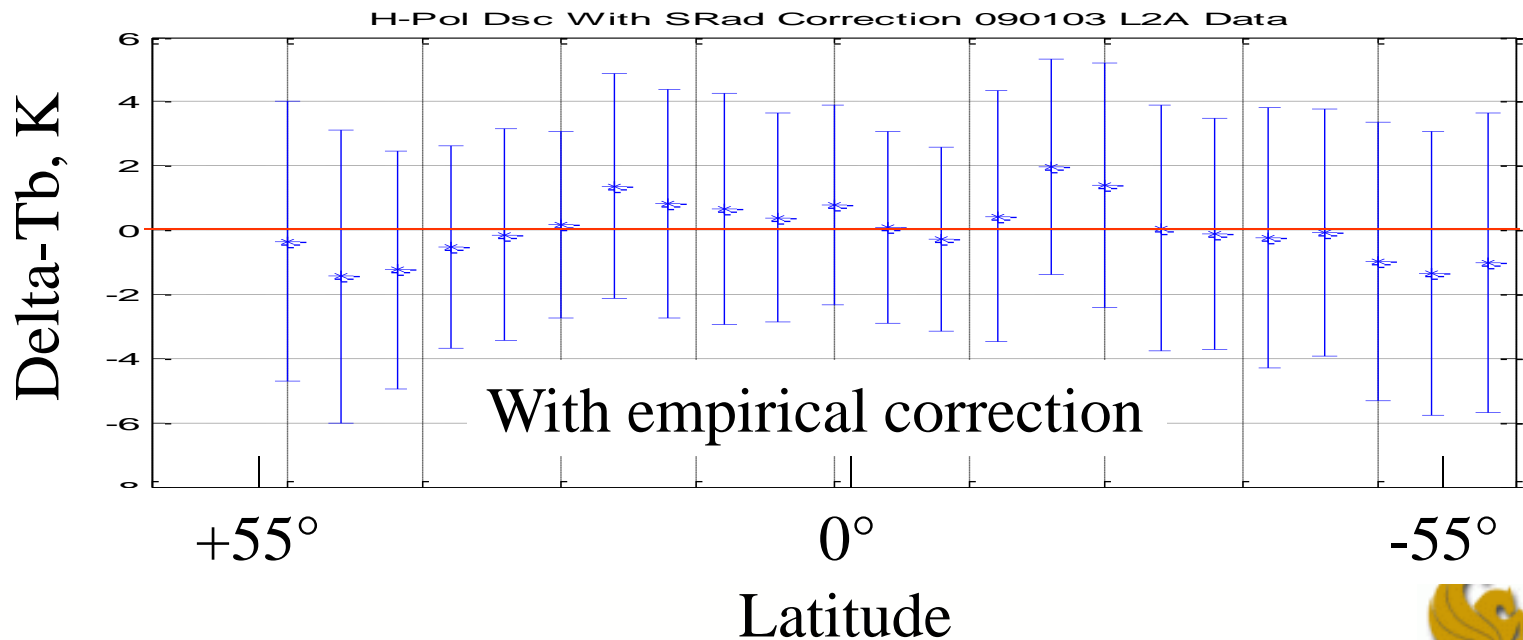
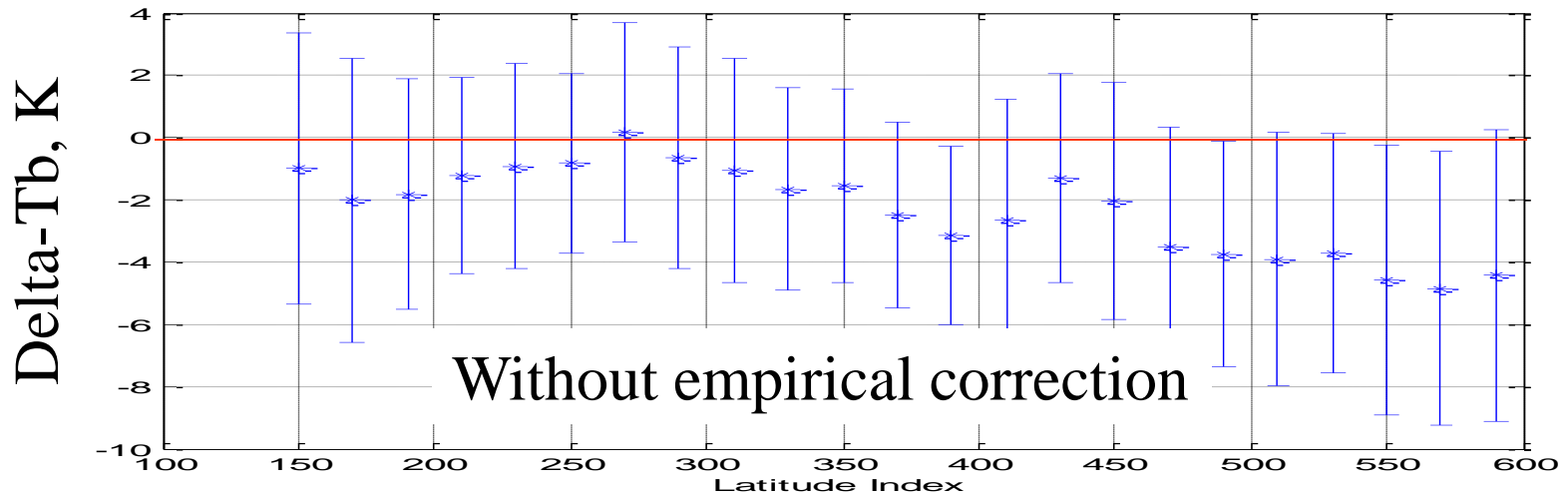
# SRad Tb Algorithm Validation

- Validation of refined SRad Tb algorithm through independent comparisons between SRad and AMSR
- After empirical correction, ocean delta Tb bias is reduced to approx  $\pm 2$  K over latitude compared to a peak value of -10 K before correction

# (SRad - AMSR) H-pol delta-Tb Asc

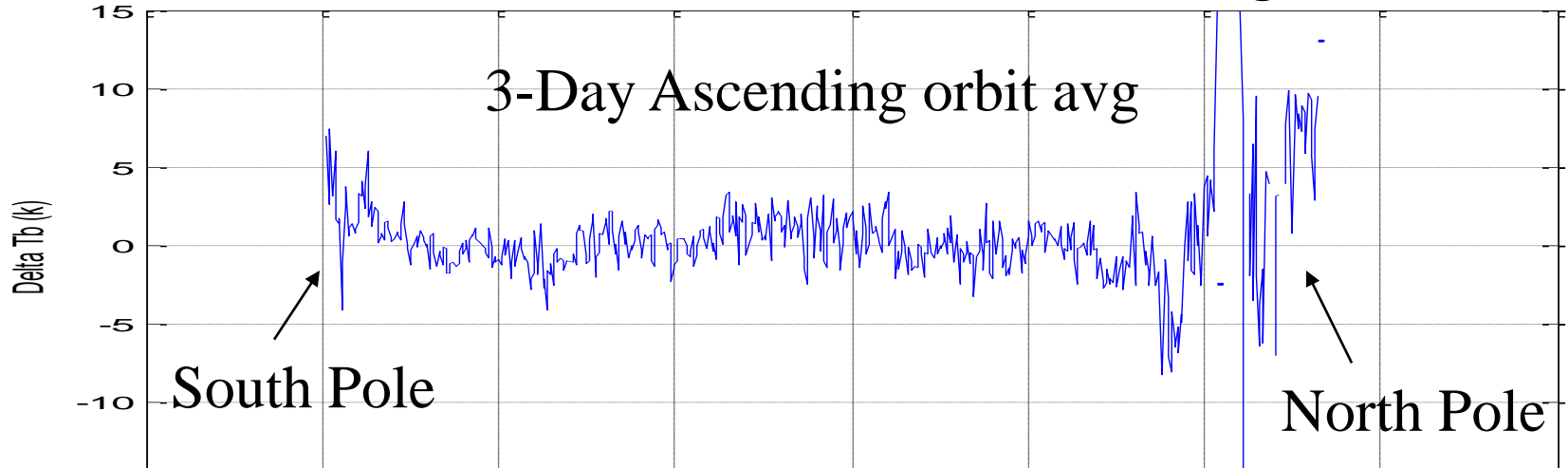


# (SRad - AMSR) H-pol delta-Tb Dsc

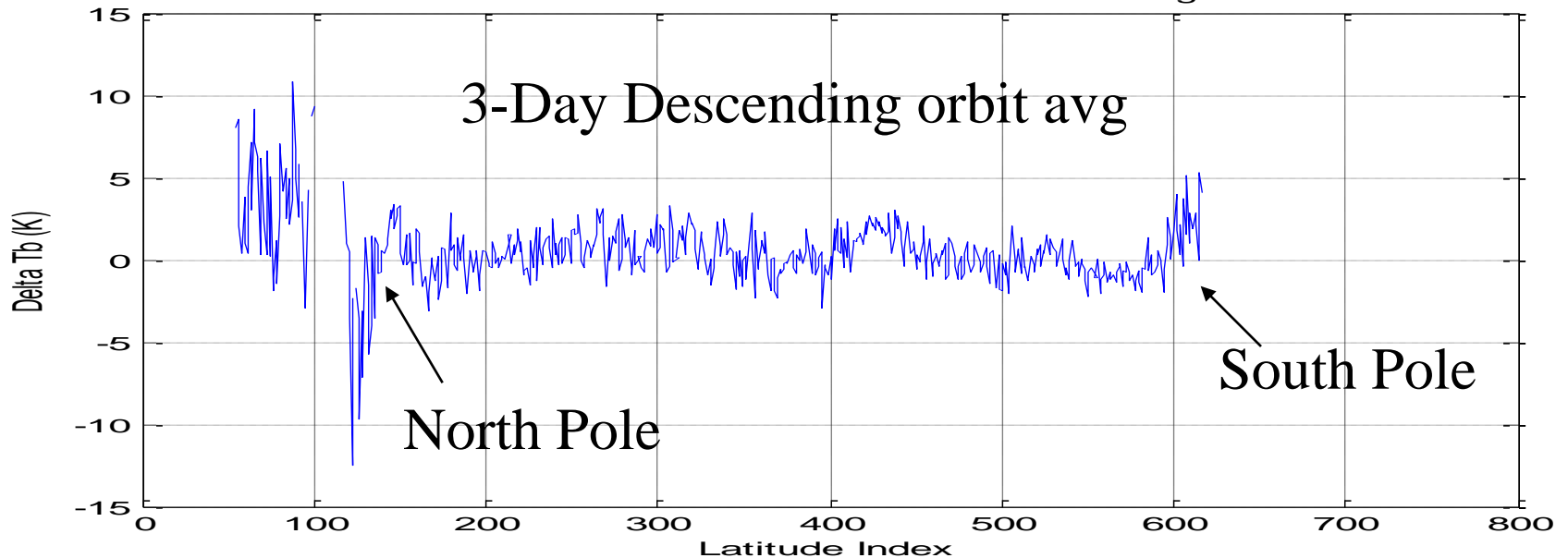


# SRad Tb Algorithm Validation, Zonal Average Ocean delta $T_b$

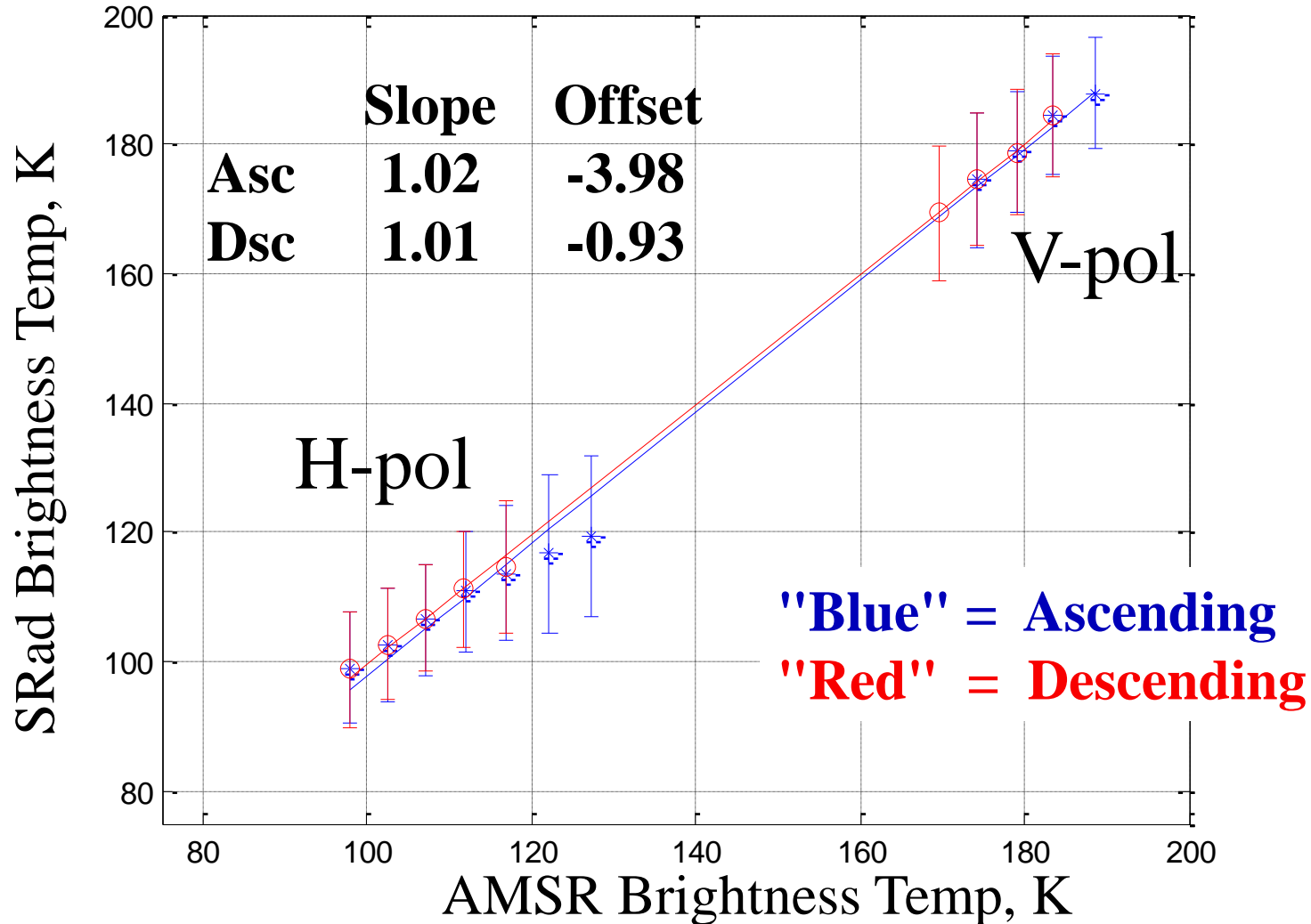
SRad-AMSR Tb Vs Latitude H-Pol Ascending



SRad-AMSR Tb Vs Latitude Descending



# SRad Tb Algorithm Validation, Sept. 1, 2003 - Asc/Dsc Segments

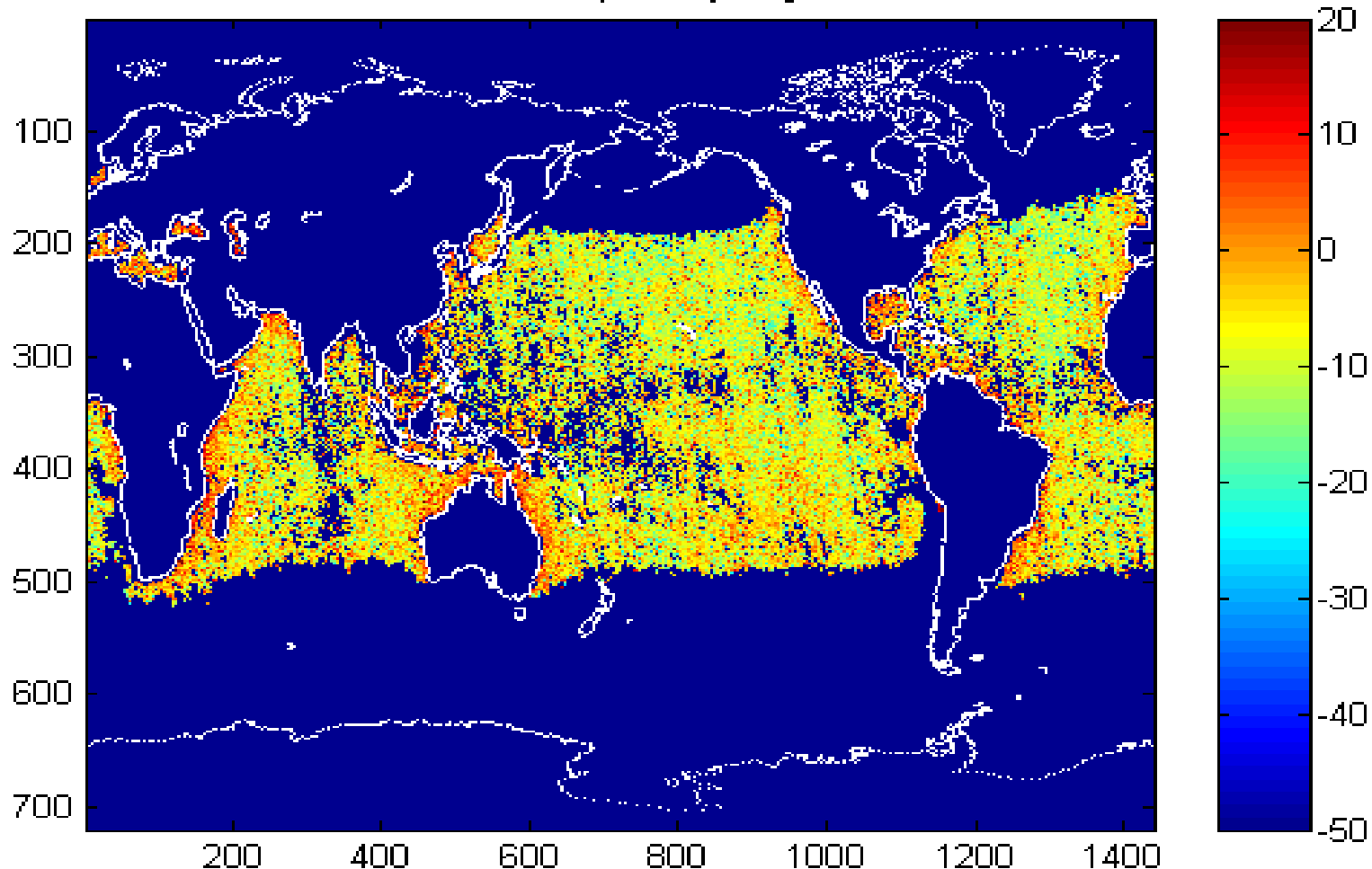


# Conclusions

- Empirical Tb corrections are developed for SRad using AMSR simultaneous ocean Tb comparisons
  - Function of orbit position (latitude, Asc/Dsc)
- After applying empirical correction, results demonstrate that good quality SRad brightness temperatures are obtained over the oceans.

# SRad/AMSR Biases along Land/Ocean Boundaries (9-Day Average)

SRad-AMSR Bias Sep 9-Day Avg. H-Pol Asc



# SRad/AMSR Biases after applying Conservative Land Mask

SRad-AMSR Bias 9-Day Avg H-Pol Asc using conservative LandMask

