An Ocean Surface Wind Vector Model Function for a Spaceborne Microwave Radiometer and Its Application

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Presentation Outline

- Dissertation Objective
- Background
  - – Brief history of wind observation from space
  - – Planck's Blackbody radiation
  - – Passive microwave measurement
  - – Active microwave measurement
- ADEOS-II satellite
  - – AMSR $\rightarrow$ brightness temperature
  - – SeaWinds scatterometer $\rightarrow$ wind vector
- Dataset collocation

Presentation Outline -2

- Atmospheric independence
- Passive wind vector model function
  - *A*V-H
  - Model variance
- Model function application
  - Combined passive and fore-look scatterometer for wind direction retrieval
- Conclusion
- List of Publications

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Dissertation Objective

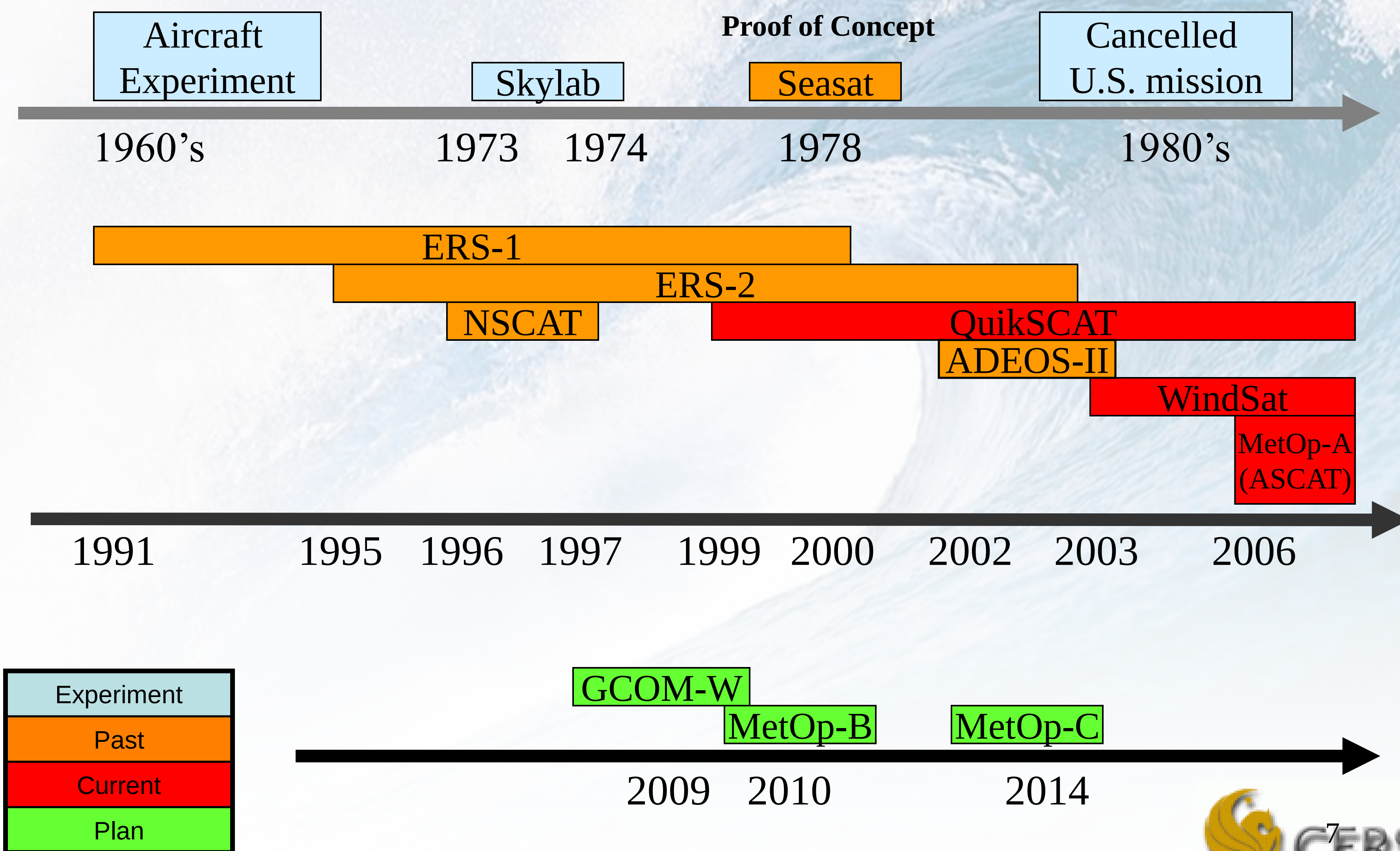
- To characterize the passive wind direction signature for vertical and horizontal polarizations
  - Develop passive wind vector model function
- Secondary objective
  - To evaluate combined passive and active wind direction retrieval
    - Fore-look scatterometer

Background

Why measure ocean vector wind?

- Ocean circulation science
- Weather forecasting
- Long-term global climate change science
- Ship routing
- Coastal flooding
- Oil production
- Fishing production

Wind observation satellite missions

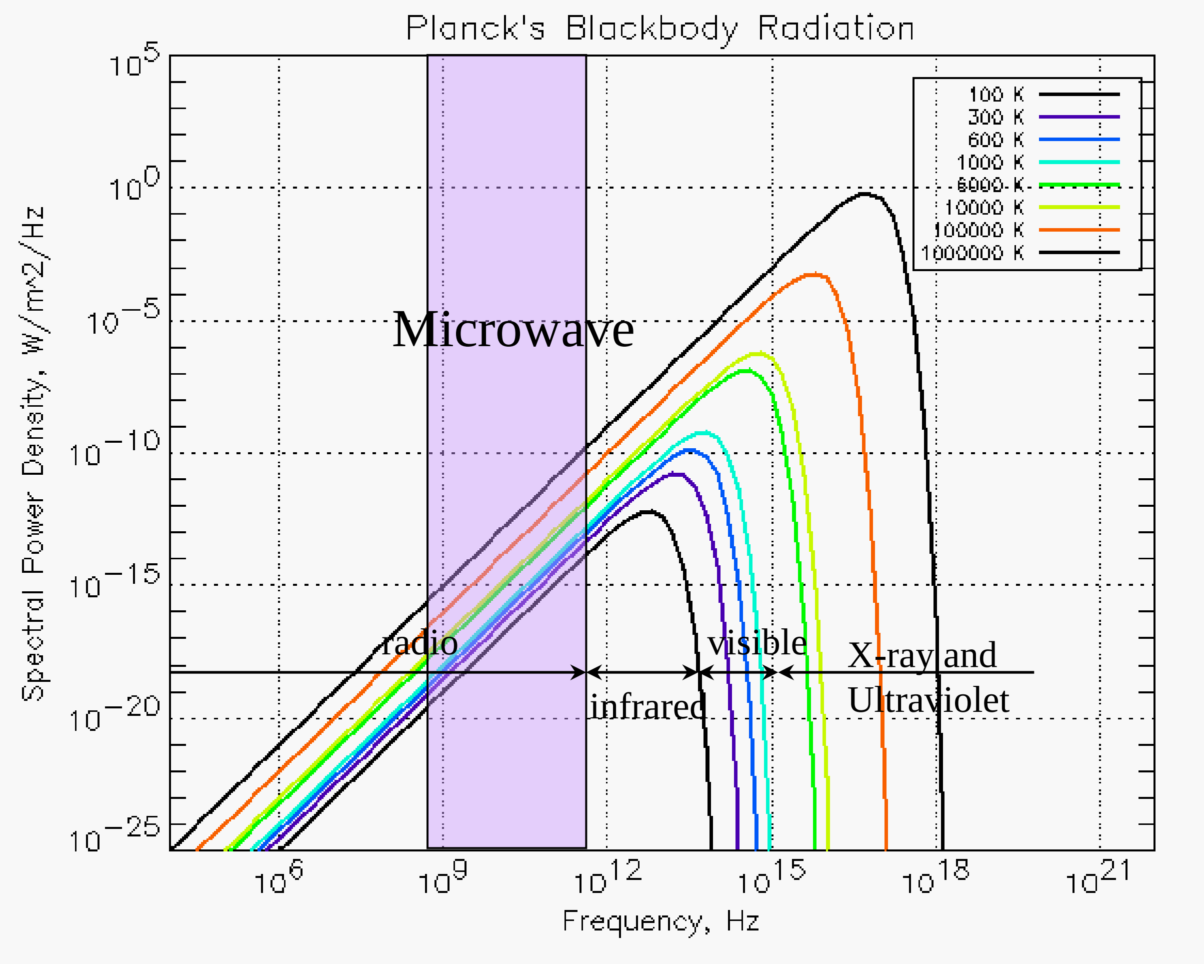


Wind measurement technology

- Active Microwave
  - SASS (Seasat)
  - AMI (ERS-1,2)
  - NSCAT (ADEOS-I)
  - SeaWinds (QuikSCAT, ADEOS-II)
  - ASCAT (MetOp-A)
    - Normalized radar cross-section (NRSC) or sigma-0 (σ^0) measurement

- Passive Microwave
  - WindSat (Coriolis)
    - Polarimetric system
      - 3rd and 4th Stokes parameter
  - **<u>New System</u>**
    - Require only linear polarization (V and H)

Planck's Blackbody Radiation



$$S_f = \frac{2\pi h f^3}{c^2}\left(\frac{1}{e^{hf/kT} - 1}\right)$$

k = Boltzmann's constant

= 1.38×10^{-23} J/K

h = Plank's constant

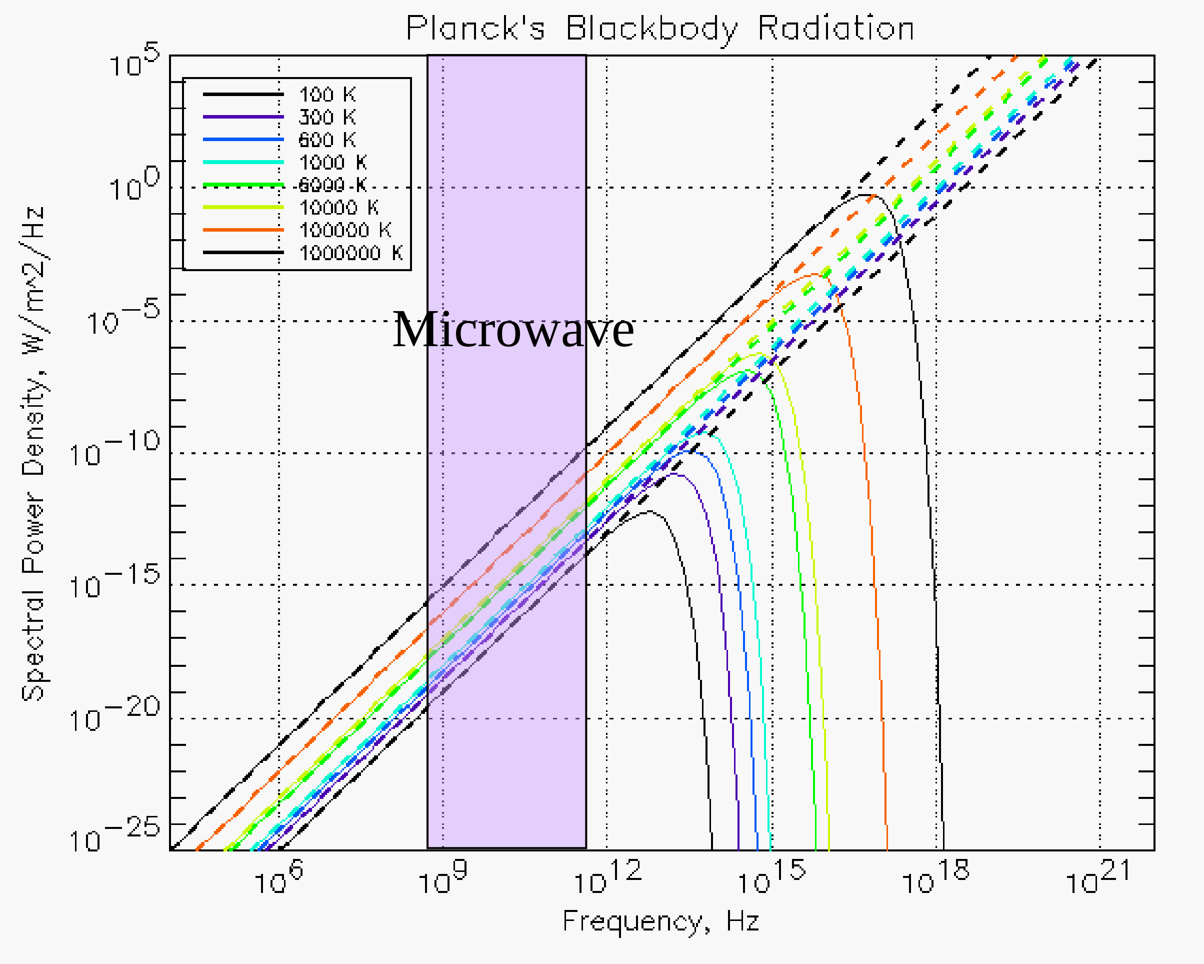
= 6.63×10^{-34} J

c = light speed = 3×10^{8} m/s

f = EM frequency, Hz

T = absolute temperature, K

Rayleigh-Jeans Law



$$S_f = \frac{2\pi h f^3}{c^2}\left(\frac{1}{e^{hf/kT} - 1}\right)$$

Given $hf/kT << 1$

$$e^{hf/kT} - 1 \approx hf/kT$$

$$S_f = \frac{2\pi f^2 kT}{c^2} = \frac{2\pi kT}{\lambda^2}$$

, Watts/m^2/Hz

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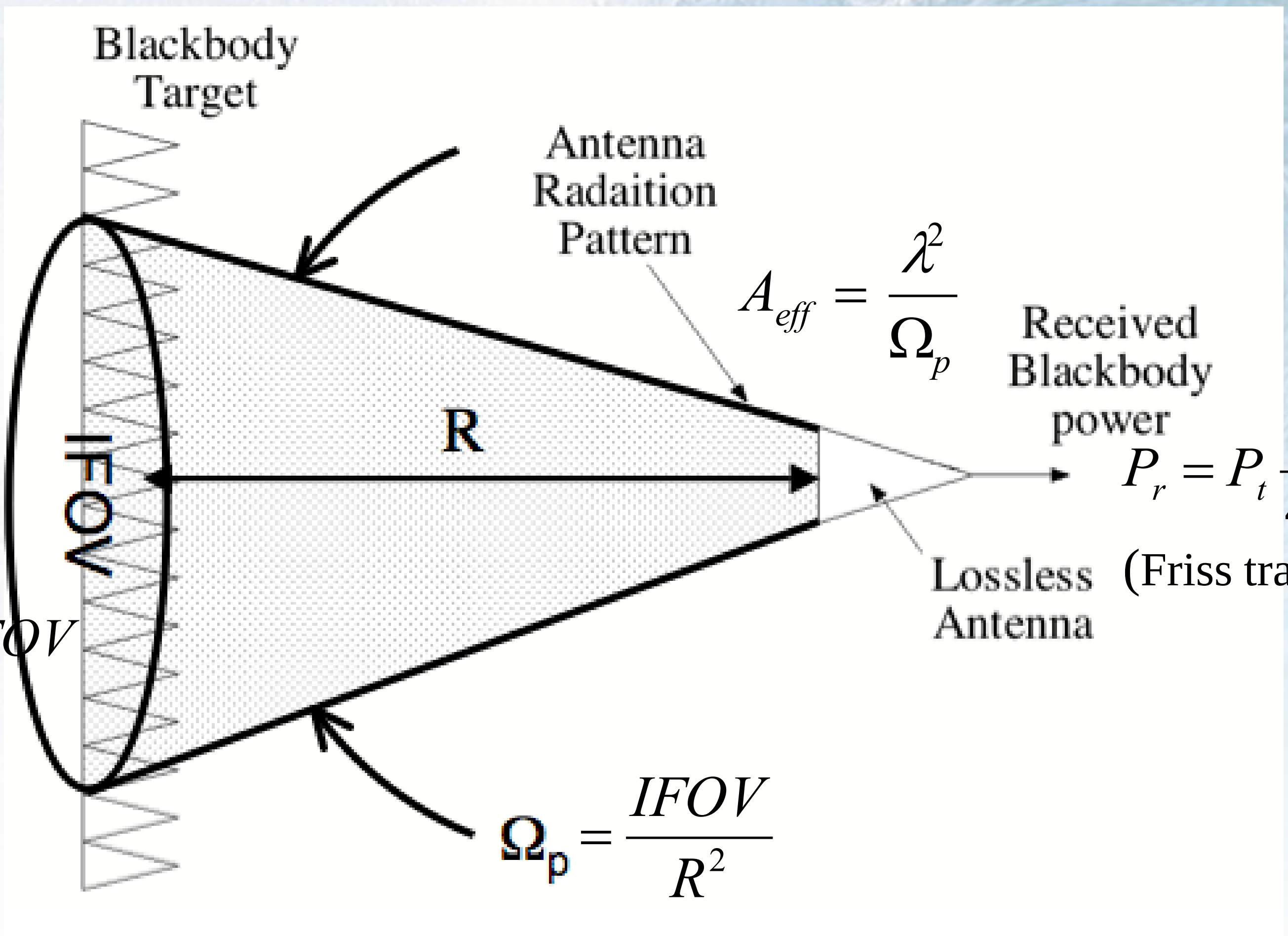
Radiometer Antenna



emission

$$P_t = \frac{2\pi kT}{\lambda^2} IFOV$$

$$A_{eff} = \frac{\lambda^2}{\Omega_p}$$

$$\Omega_p = \frac{IFOV}{R^2}$$

$$P_r = P_t \frac{2}{4\pi R^2} A_{eff}$$

(Friss transmission)

Radiometer received power

- Power density at the radiometer antenna

$$P_r = kT \quad \text{,Watts/Hz}$$

- Power received by the radiometer with system bandwidth B

$$P_r = kTB \quad \text{,Watts}$$

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Brightness Temperature

- For non-blackbody, the equivalent radiometric blackbody temperature defined as

$$T_B = ET_{phy}$$

E = emissivity
T_B = brightness temperature
T_{phy} = physical temperature of the target

- Received power becomes

$$\boxed{P_r = kT_B B}$$

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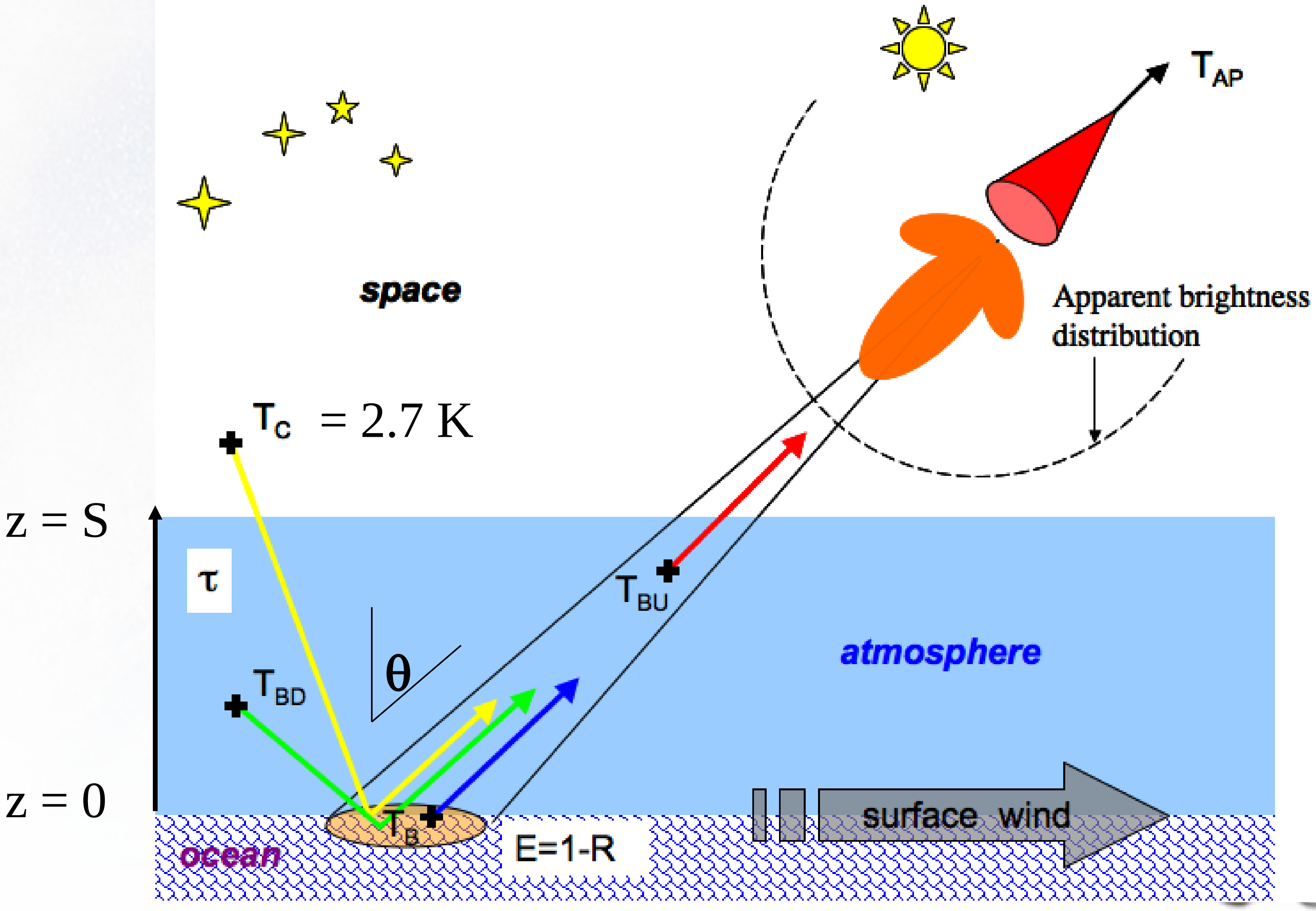
Radiative Transfer Model (RTM)



Ocean Brightness Temperature

- Power emitted and reflected from ocean surface is strongly polarized
- Emissivity is depend of the air/sea boundary power reflection coefficient

$$E = 1 - R = 1 - |\rho|^2$$

$$\boxed{T_B = E \cdot SST}$$

SST = sea surface temperature

$$\rho_V = -\left(\frac{\varepsilon_r \cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\varepsilon_r \cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right)$$

$$\rho_H = -\left(\frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right)$$

ε_r = dielectric constant of sea water

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Atmospheric brightness temp.

- Atmospheric emission is isotropic and non-polarized
- Emissivity characterize by atmospheric absorption coefficient, α(z), Neper/m (assume non-scattering)

$$T_{BU} = \int_0^{\infty} \alpha(z) T(z) \tau(z, S) dz$$

$$T_{BD} = \int_0^{\infty} \alpha(z) T(z) \tau(0, z) dz$$

$$\tau(z_1, z_2) = \exp\left(-\int_{z_1}^{z_2} \alpha(z) dz \right)$$

= atmospheric transmissivity

T(z) = atmospheric physical temperature profile

Atmospheric brightness temp. -2

- Special case for homogeneous atmosphere

$T(z) \approx T = \text{constant}$
$\alpha(z) \approx \alpha = \text{constant}$

- Up-welling and down-welling brightness temp is approximated:

$$T_{BU} = T_{BD} \approx \int_0^S \alpha \cdot T \cdot e^{-\alpha \cdot z} dz = (1 - e^{-\alpha \cdot S})T$$

$$\tau = \tau(0, S) = e^{-\alpha \cdot S}$$

= total atmospheric transmissivity

$$\boxed{T_{BU} = T_{BD} \approx (1 - \tau)T}$$

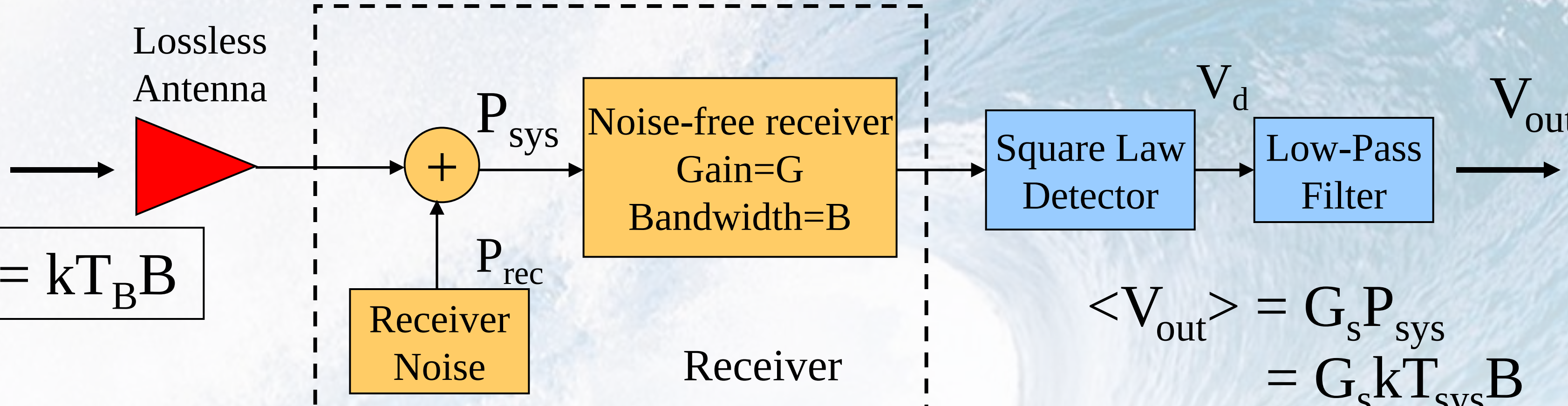
Apparent brightness temperature

- Total brightness temperature "seen" by radiometer antenna:

$$T_{AP} = \underbrace{T_{BU}}_{\text{upwelling component}} + \underbrace{\tau R(1+\Omega)(T_{BD} + \tau T_C)}_{\text{scattering component}} + \underbrace{\tau E \cdot SST}_{\text{surface component}}$$

Ω= roughen surface scattering factor due to wind speed

Radiometer System



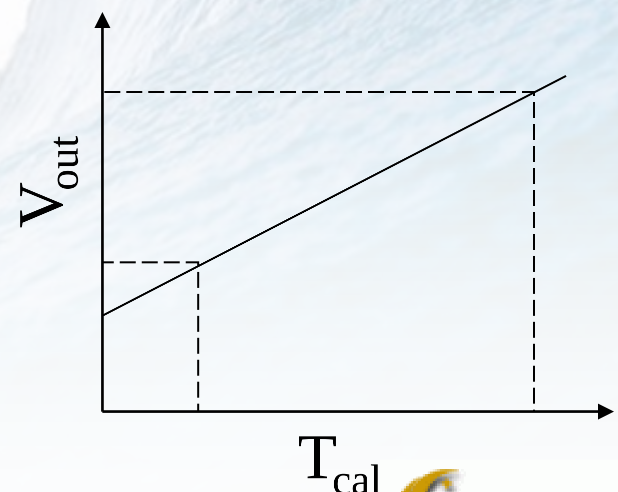
$$P_A = kT_B B$$

$$\langle V_{out} \rangle = G_s P_{sys}$$
$$= G_s k T_{sys} B$$

$$P_{sys} = P_A + P_{rec} = kT_{sys} B$$

$$T_{sys} = T_B + T_{rec}$$

$$\Delta T_{sys} = \frac{T_{sys}}{\sqrt{B\tau}} = \text{measurement standard deviation}$$



Scatteromery

- Scatterometer is a radar instrument designed primarily to measure ocean vector wind (speed and direction)
- Backscatter signal is relatively insensitive to the atmosphere except for present of rain
- Basic Radar Equation:

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

$$\overline{P_r} = \frac{\lambda^2}{(4\pi)^3} \int \frac{P_t G^2 \sigma^0 dA}{R^4}$$

σ = radar cross-section

$$\sigma^0 = \left\langle \frac{\sigma_i}{\Delta A_i} \right\rangle$$ = normalized radar cross-section (NRSC)

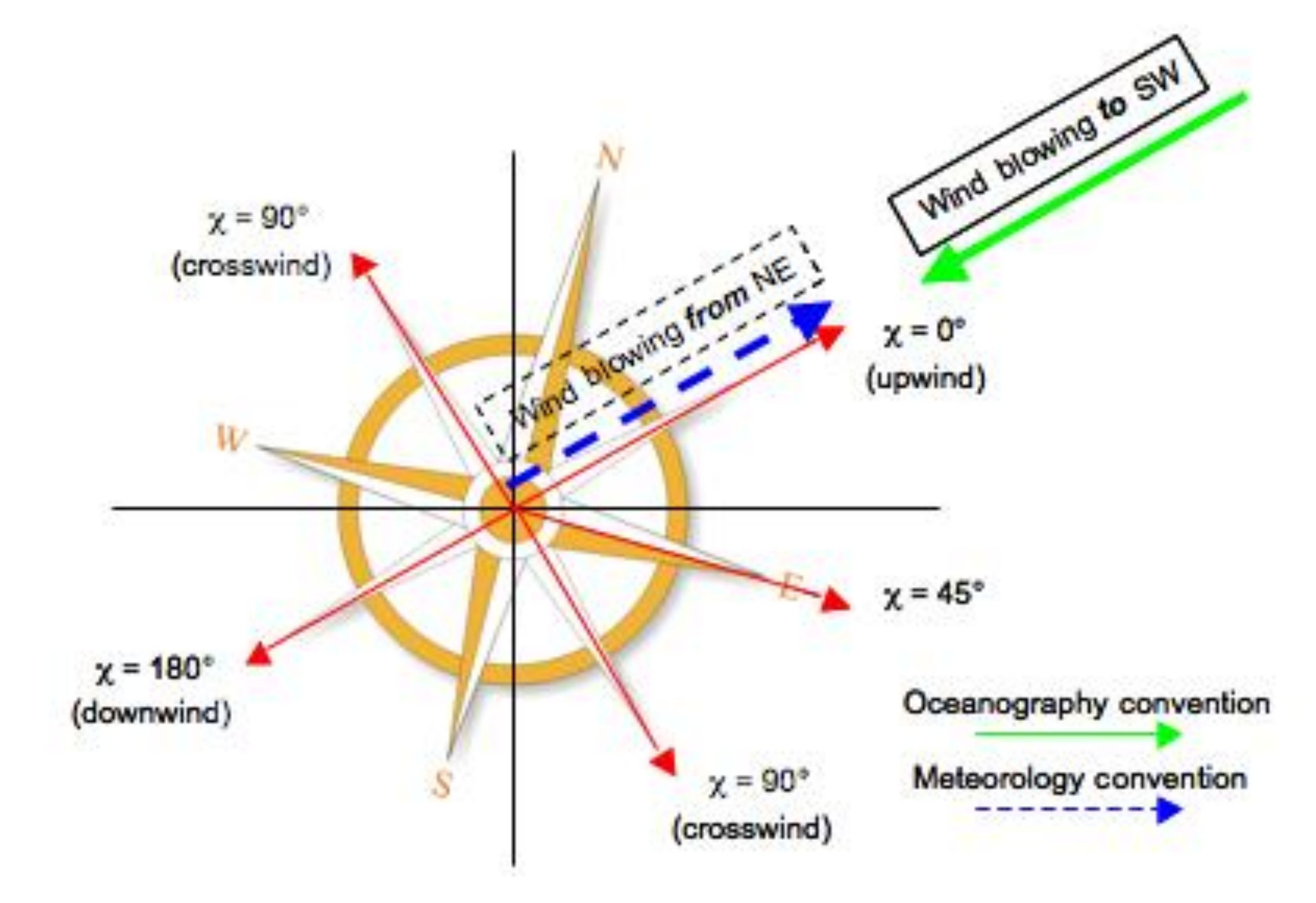
Geophysical Model Function

- Empirical relationship between σ^0 and wind vector is known as GMF
- GMF may be modeled as two harmonic cosine functions

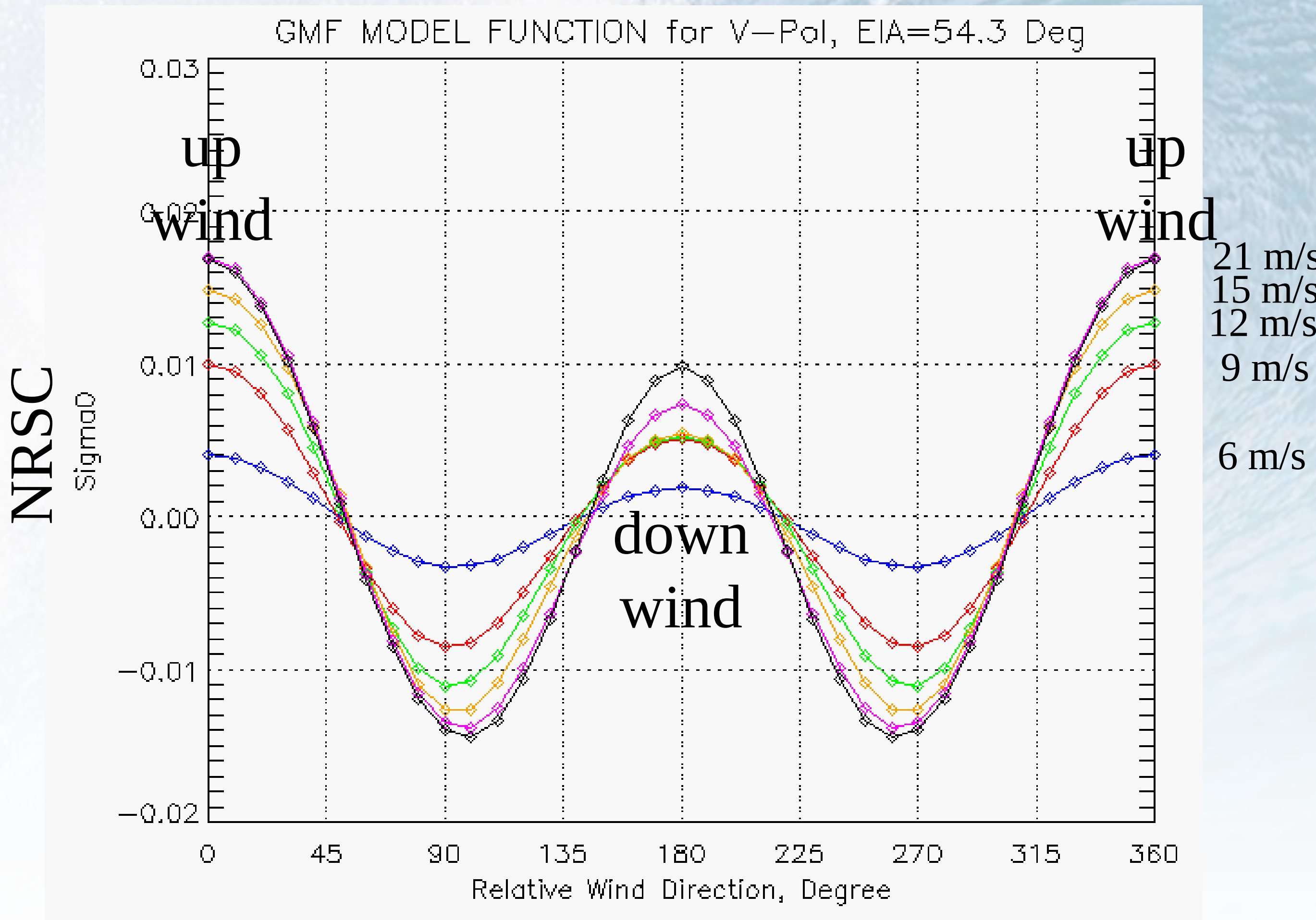
$$\sigma^0 = C_0(wspd) + C_1(wspd)\cos(\chi) + C_2(wspd)\cos(2\chi)$$

- GMF is also a function of incidence angle and observed polarization

Relative Wind Direction (χ)

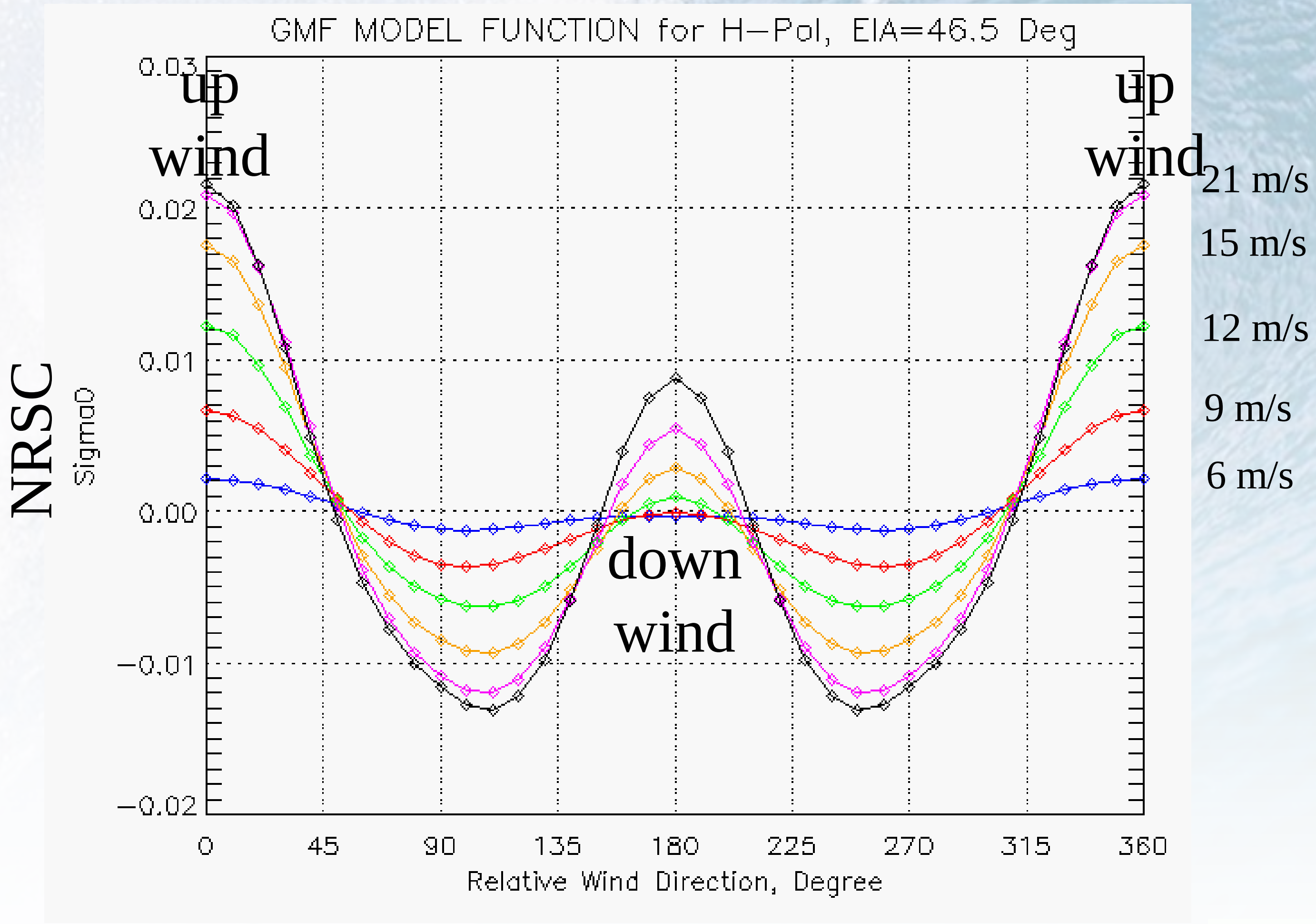


GMF for Scat V-Pol
(C_o mean removed)



Relative Wind Direction

GMF for Scat H-Pol
(C_o mean removed)



Relative Wind Direction

Retrieval Algorithm

- Scatterometer requires backscatter measurements from multiple direction (fore and aft) to resolve wind direction
- Retrieval algorithm is based on maximum likelihood estimation (MLE)

$$\zeta = \sum_i \frac{\left(\sigma_i^0 - GMF(wspd, \chi)\right)^2}{Variance_{\sigma_i^0}(wspd, \chi)}$$

- Require nudging and median filtering to select a unique wind vector (known as direction ambiguity removal)

ADEOS-II Satellite

- AMSR
  - Dual-Polarization Multi-frequency:

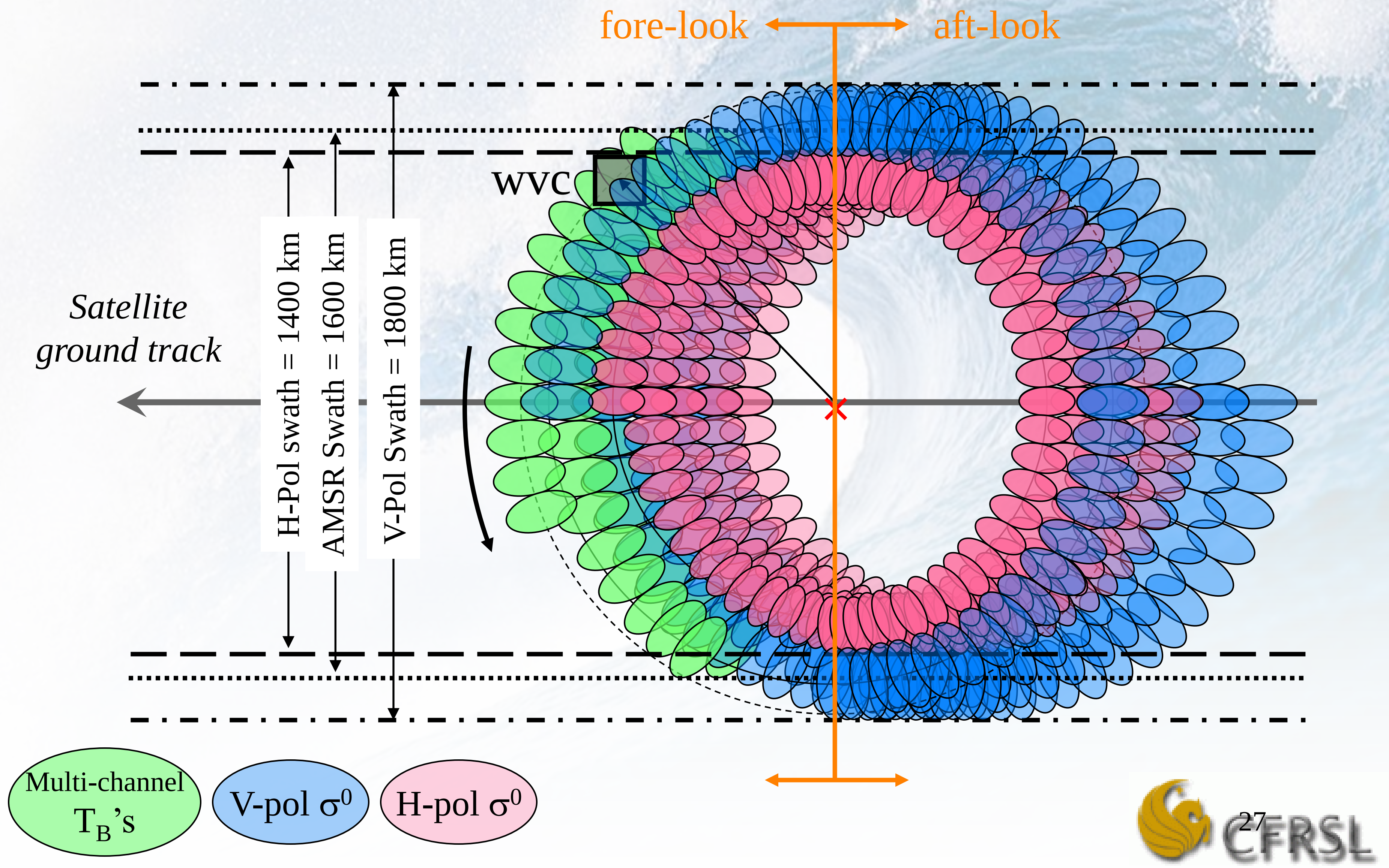
    6.9, 10.7, 18.7, 23.8, 36.5, 89.0 GHz
  - incidence angle: 55°
  - Integration time: 2.6 ms
  - Bandwidth:

    100-3000 MHz
- SeaWinds
  - Dual-Polarization 13.4 GHz, 110 W, 189 PRF
  - incidence angle:

    54° V-pol,

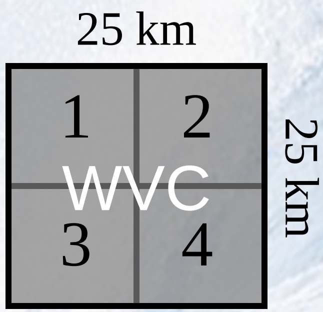
    46° H-pol
  - 18 RPM
  - Bandwidth: 250 kHz

Measurement Geometry

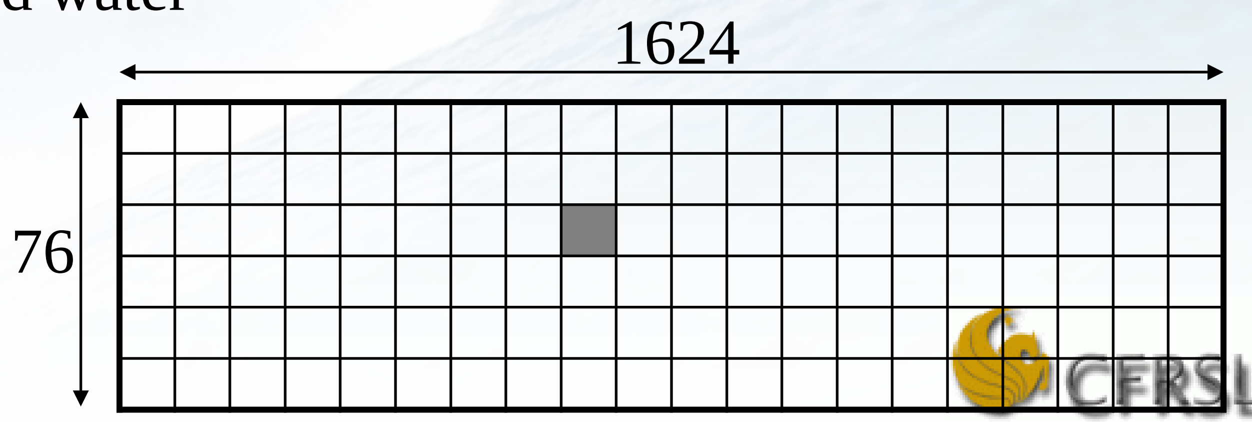


Satellite data product

- AMSR
  - Overlay L2A product
    - Brightness Temp. (T_B): 10, 18, 37 GHz
    - Water vapor
    - Cloud liquid water
    - Rain
    - SST

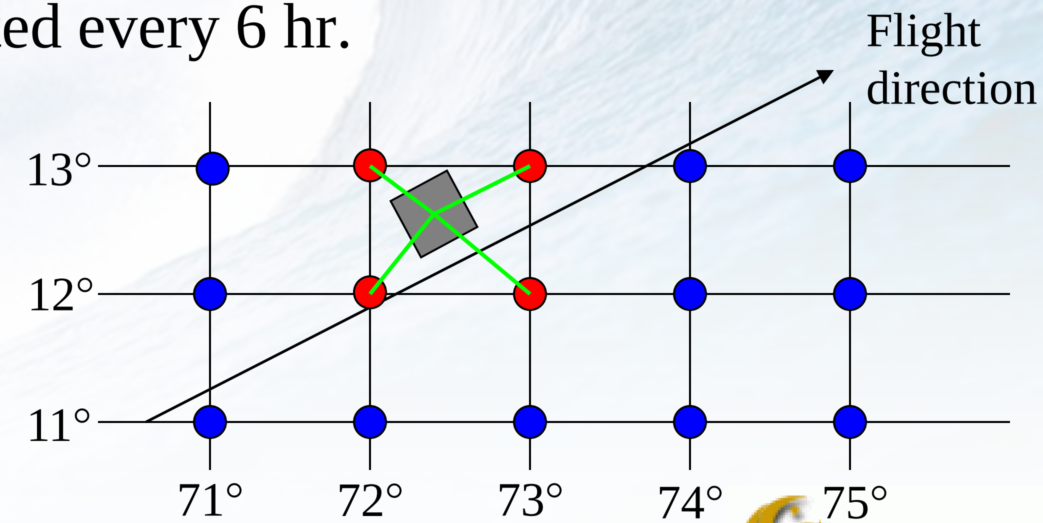


- SeaWinds
  - L2A product
    - Sigma-0
  - L2B product
    - Wind speed
    - Wind direction



Other required data

- AMSR azimuth
  – Calculated from AMSR measurement geometry, scan radius (940 km) with WVC location
- Sea surface temperature (SST)
  - NCEP's Global Data Assimilation System (GDAS)
  - Global map generated every 6 hr.
  - 1° × 1° resolution



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Data Match-Ups

- AMSR and SeaWinds data were automatically collocated
- GDAS's SST match-up required additional work
  - Four point interpolation surrounding AMSR WVC's quadrants
- Average AMSR parameters into single WVC's
- All data were match-up over entire mission period of Apr - Oct, 2003
- Filtered out rain and high cloud liquid water (<0.1mm)

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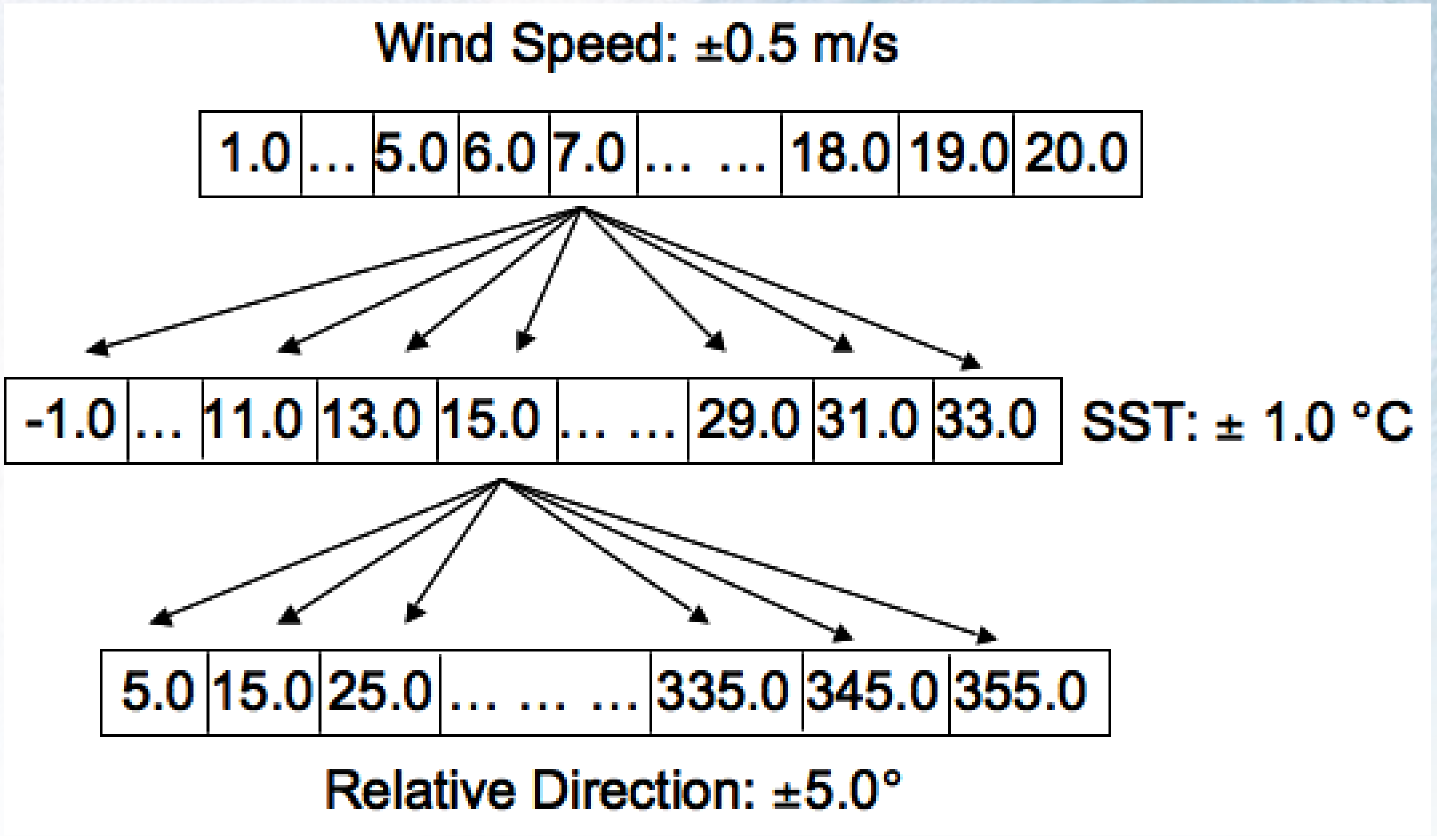
Binned Data Scheme



RTM Assumption

- Atmosphere is homogeneous: Temp. profile and absorption is constant

$$T_{BU} = T_{BD} = (1-\tau)T$$

- Air/Sea temperature is the same: Effective temperature

$$T = SST = T_{eff}$$

$$\boxed{T_{BU} = T_{BD} = (1-\tau)T_{eff}}$$

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RTM Assumption -2

$$T_{AP} = \underbrace{T_{BU}}_{\text{upwelling component}} + \underbrace{\tau R(1+\Omega)(T_{BD} + \tau T_C)}_{\text{scattering component}} + \underbrace{\tau E \cdot SST}_{\text{surface component}}$$

$$upwelling = T_{BU} = (1-\tau)T_{eff} = T_{eff} - \tau T_{eff}$$

$$scattering = \tau R T_{BD} + \tau R \Omega T_{BD} + \tau^2 R(1+\Omega)T_C$$

$$= \tau R(1-\tau)T_{eff} + \tau R\Omega(1-\tau)T_{eff} + \tau^2 R(1+\Omega)T_C$$

$$= \tau R T_{eff} - \tau^2 R T_{eff} + \tau R\Omega(1-\tau)T_{eff} + \tau^2 R(1+\Omega)T_C$$

$$surface = \tau E \cdot SST = \tau(1-R)\cdot T_{eff} = \tau T_{eff} - \tau R T_{eff}$$

negligible

$$T_{AP} = T_{eff} - R\tau^2 T_{eff} + R\tau\Omega(1-\tau)T_{eff} + R\tau^2(1+\Omega)T_C$$

$$T_{AP} \approx (1 - R\tau^2)\cdot T_{eff}$$

Atmospheric cancellation

- The brightness temperature for vertical and horizontal polarization may represented as:

$$T_{BV} = (1 - R_V \tau^2) T_{eff}$$

$$T_{BH} = (1 - R_H \tau^2) T_{eff}$$

- Define a new parameter, ***A*** as a ratio of V and H-pol

$$\boxed{A \equiv \frac{R_H}{R_V}}$$

- Changes in brightness temperature with respect to atmospheric transmissivity

$$\partial T_{BV} = -2 R_V \tau T_{eff} \partial \tau$$

$$\partial T_{BH} = -2 A R_V \tau T_{eff} \partial \tau$$

$$\boxed{\frac{\partial (A T_{BV} - T_{BH})}{\partial \tau} = 0}$$

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"*A*" Parameter

- Linear combination of V and H brightness temperature is independent of atmosphere

$$\boxed{AT_{BV} - T_{BH}}$$

$$AT_{BV} - T_{BH} = A(1 - R_V \tau^2)T_{eff} - (1 - R_H \tau^2)T_{eff}$$

$$= (A - 1)T_{eff} - (AR_V - R_H)\tau^2 T_{eff}$$

(the term $(AR_V - R_H)$ is struck through in red and marked 0)

$$\boxed{A = \frac{T_{BH} - T_{eff}}{T_{BV} - T_{eff}}}$$

$$T_{eff} = SST$$

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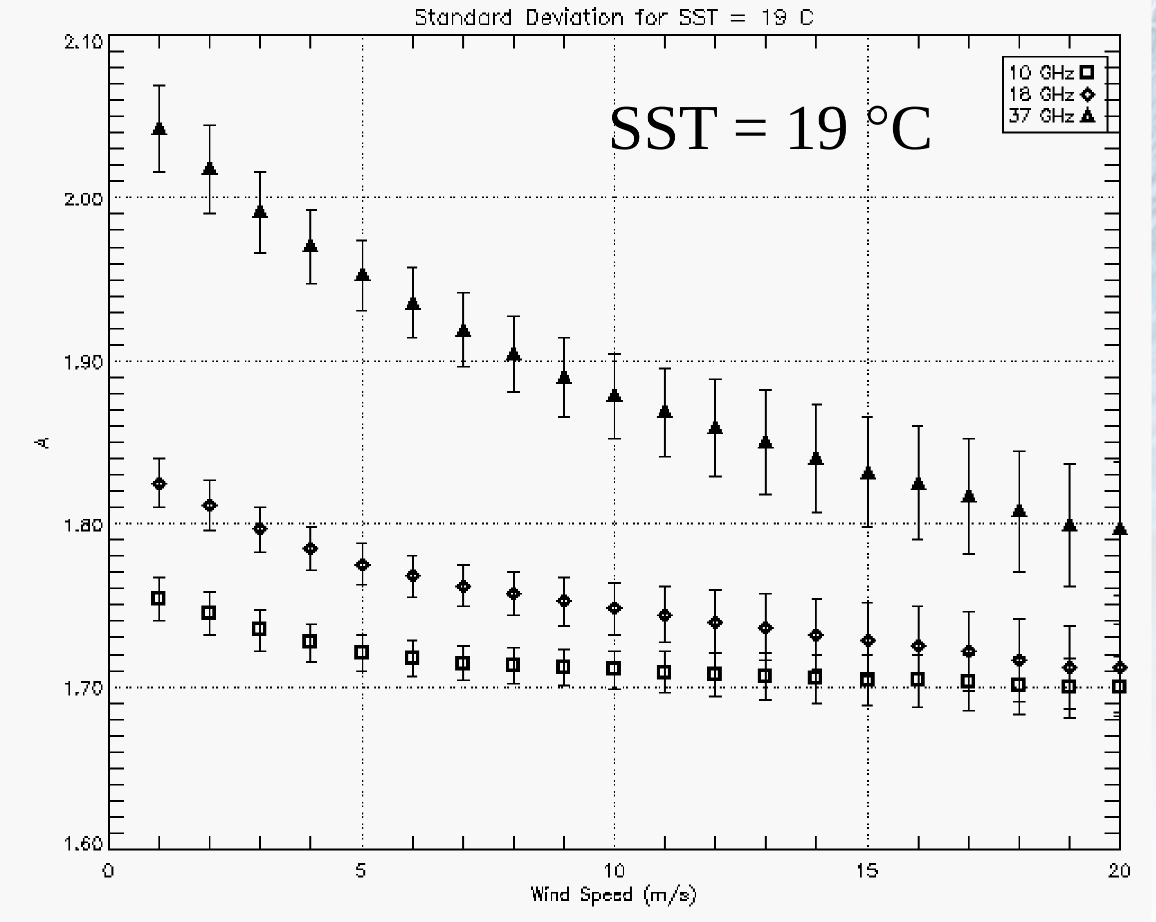
"*A*" Parameter -2

- *A* parameter has Gaussian distribution
- *A* was found as a function of wind speed (wspd) and sea surface temperature (SST)



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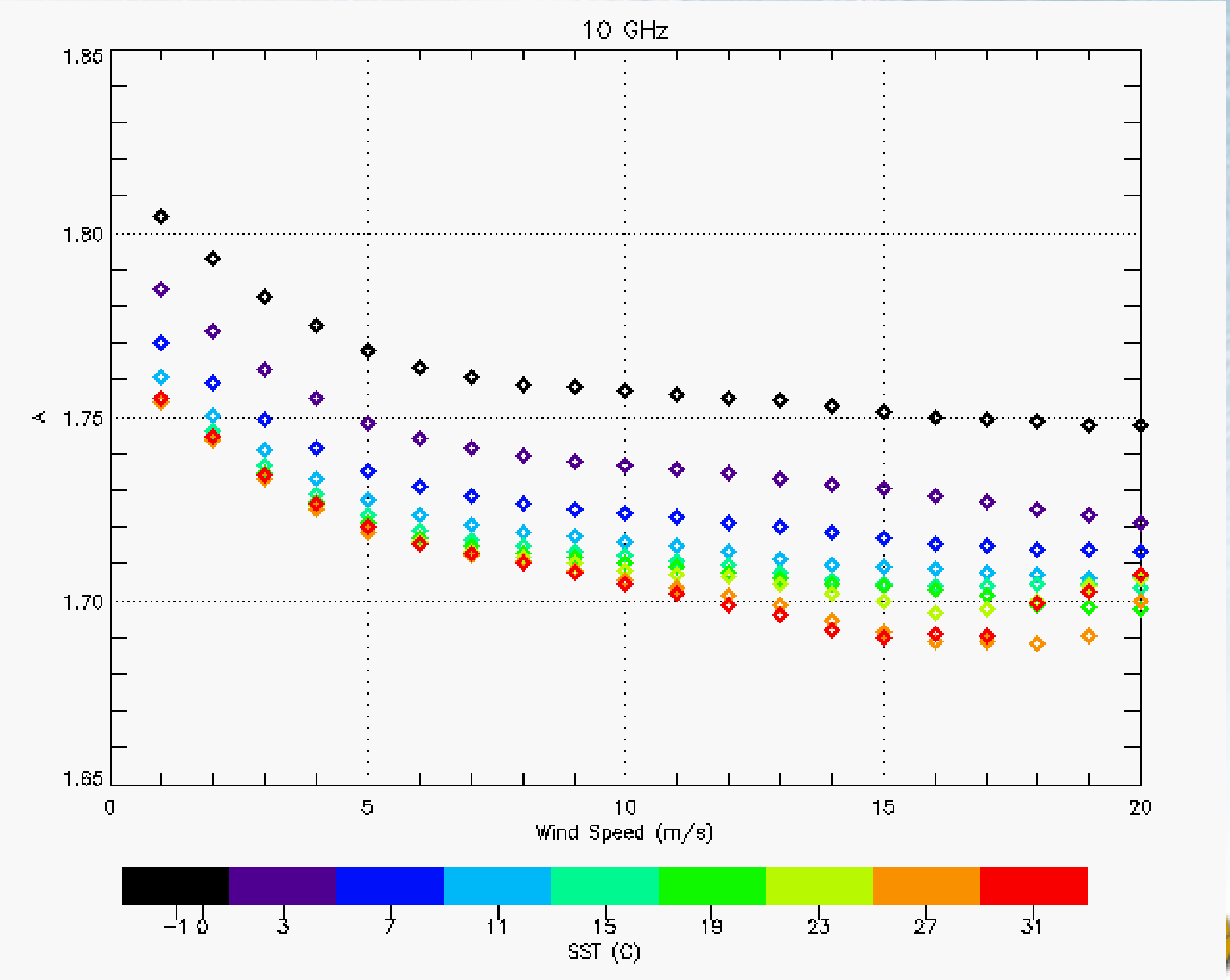
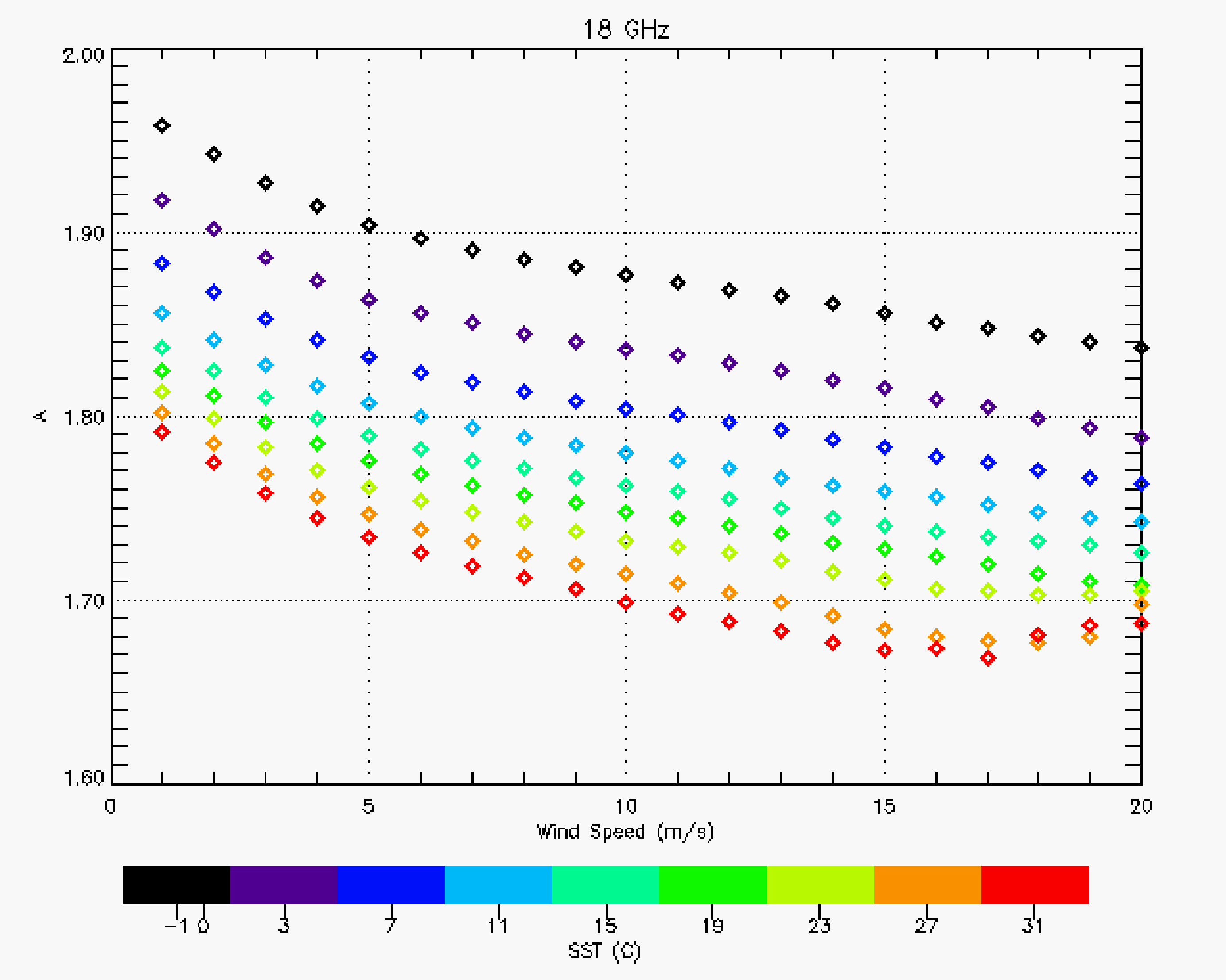
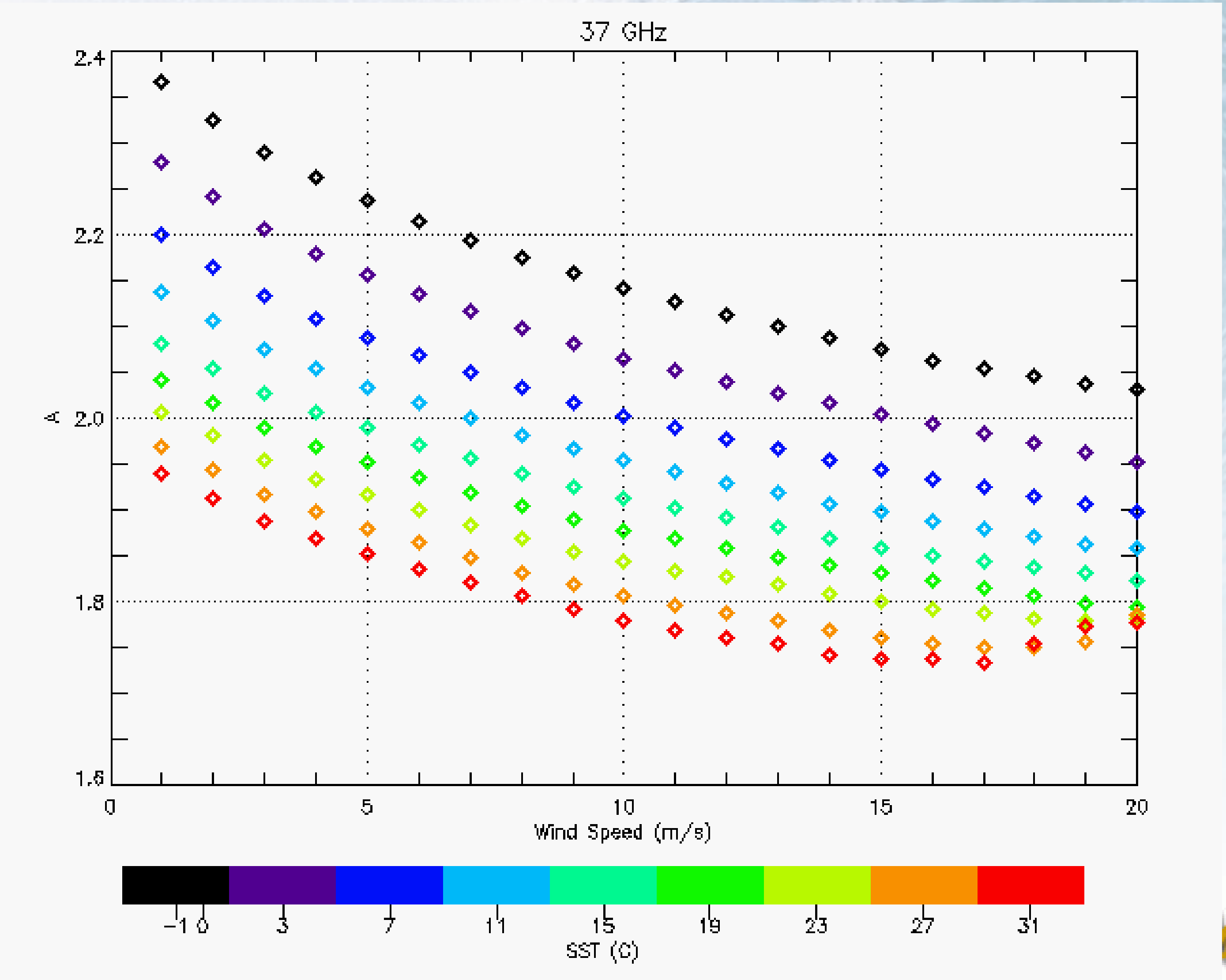
A parameter for 10 GHz



A parameter for 18 GHz



A parameter for 37 GHz



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Model Function Procedure

- ΔT_{BV}-T_{BH} (ΔV-H) was found as a function of wind speed, wind direction and SST
- ΔV-H is model as a linear sum of each components

$$\Delta T_{BV} - T_{BH} = \underbrace{F(SST) + C_0(WSPD)}_{dc} + C_1(WSPD)\cdot COS(\chi) + C_2(WSPD)\cdot COS(2\chi)$$

- Wind directional signal modeled as two harmonic cosine function

$$\boxed{F(WDIR) = C_0(WSPD) + C_1(WSPD)\cdot COS(\chi) + C_2(WSPD)\cdot COS(2\chi)}$$

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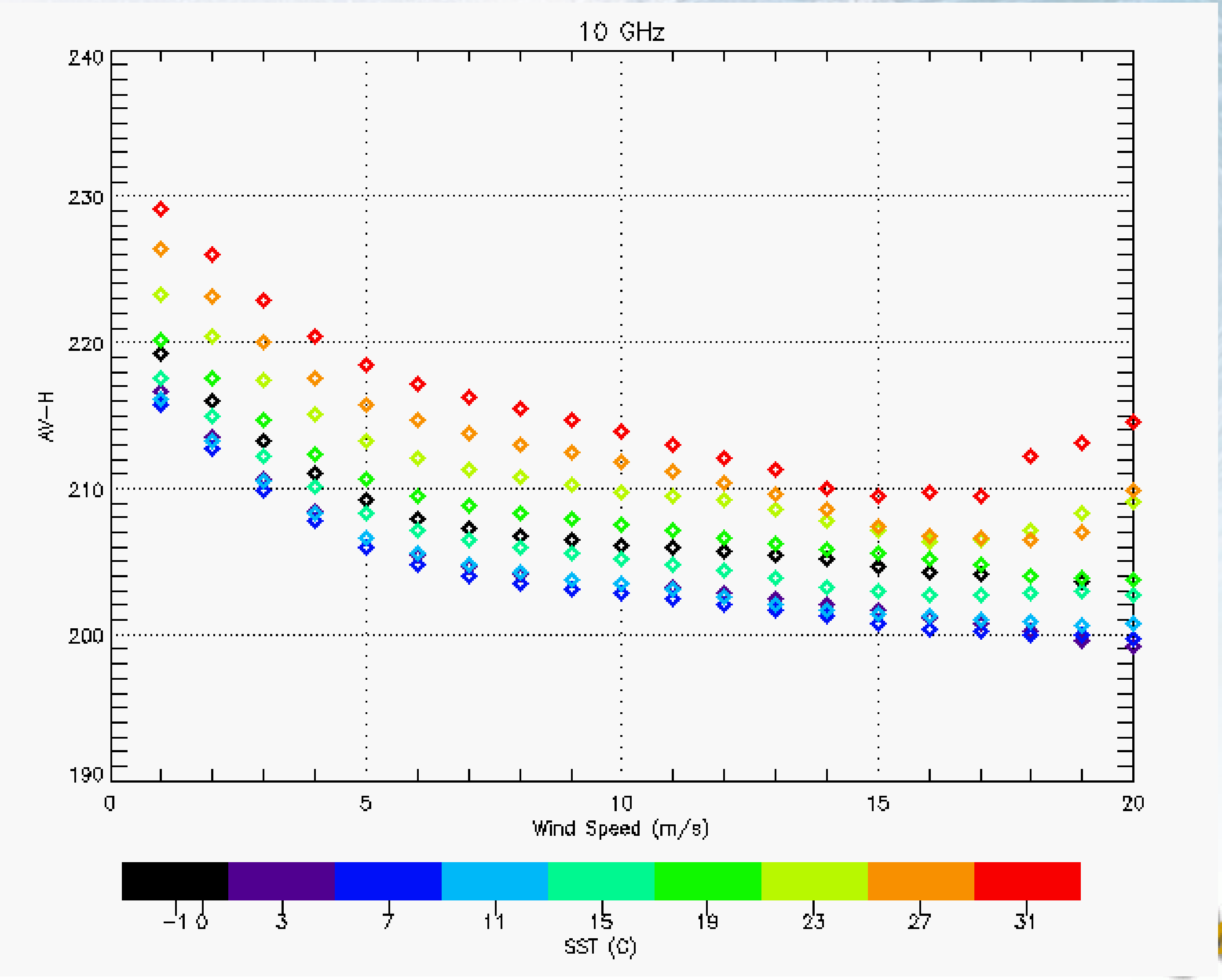
AV-H for 10 GHz



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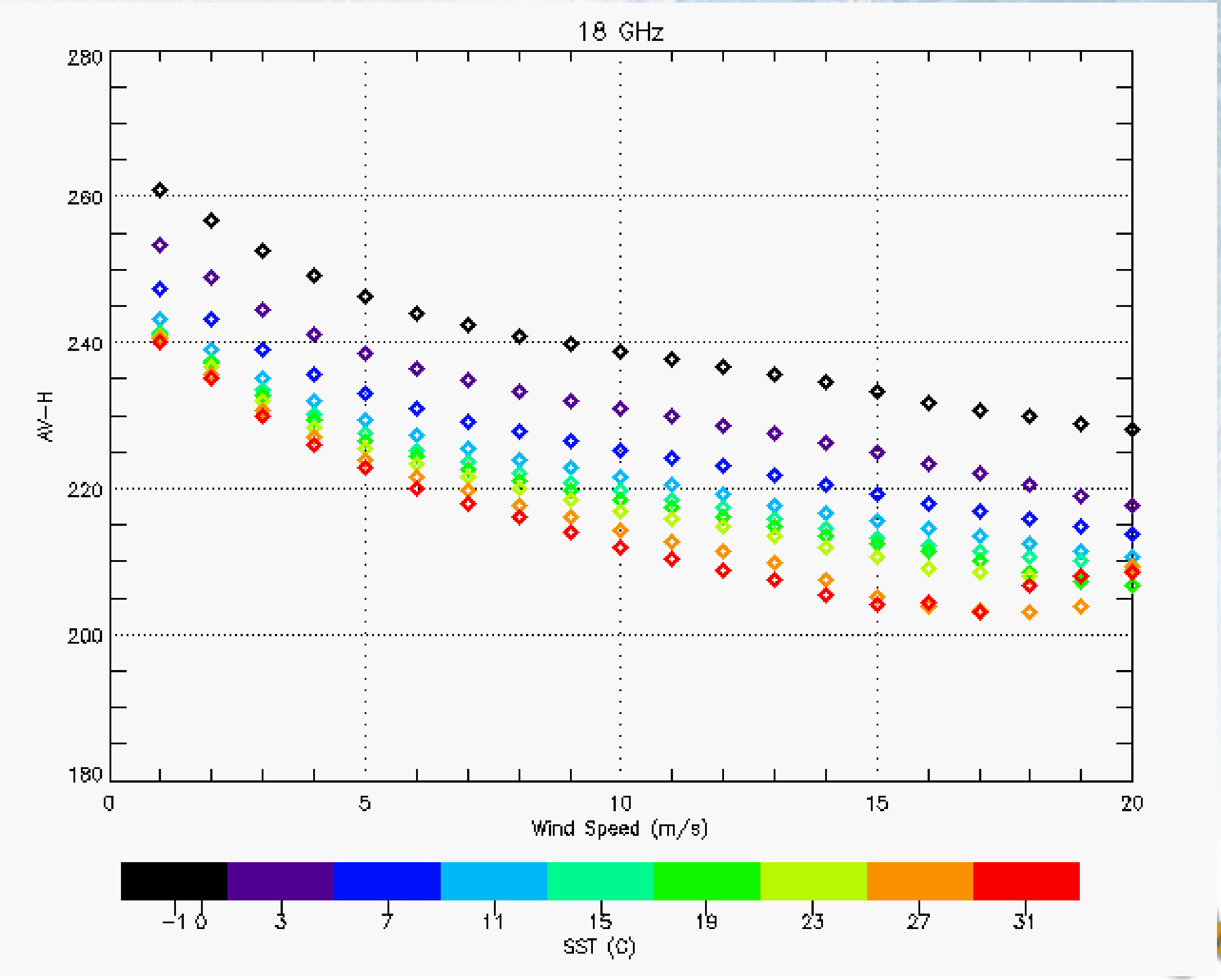
AV-H for 18 GHz



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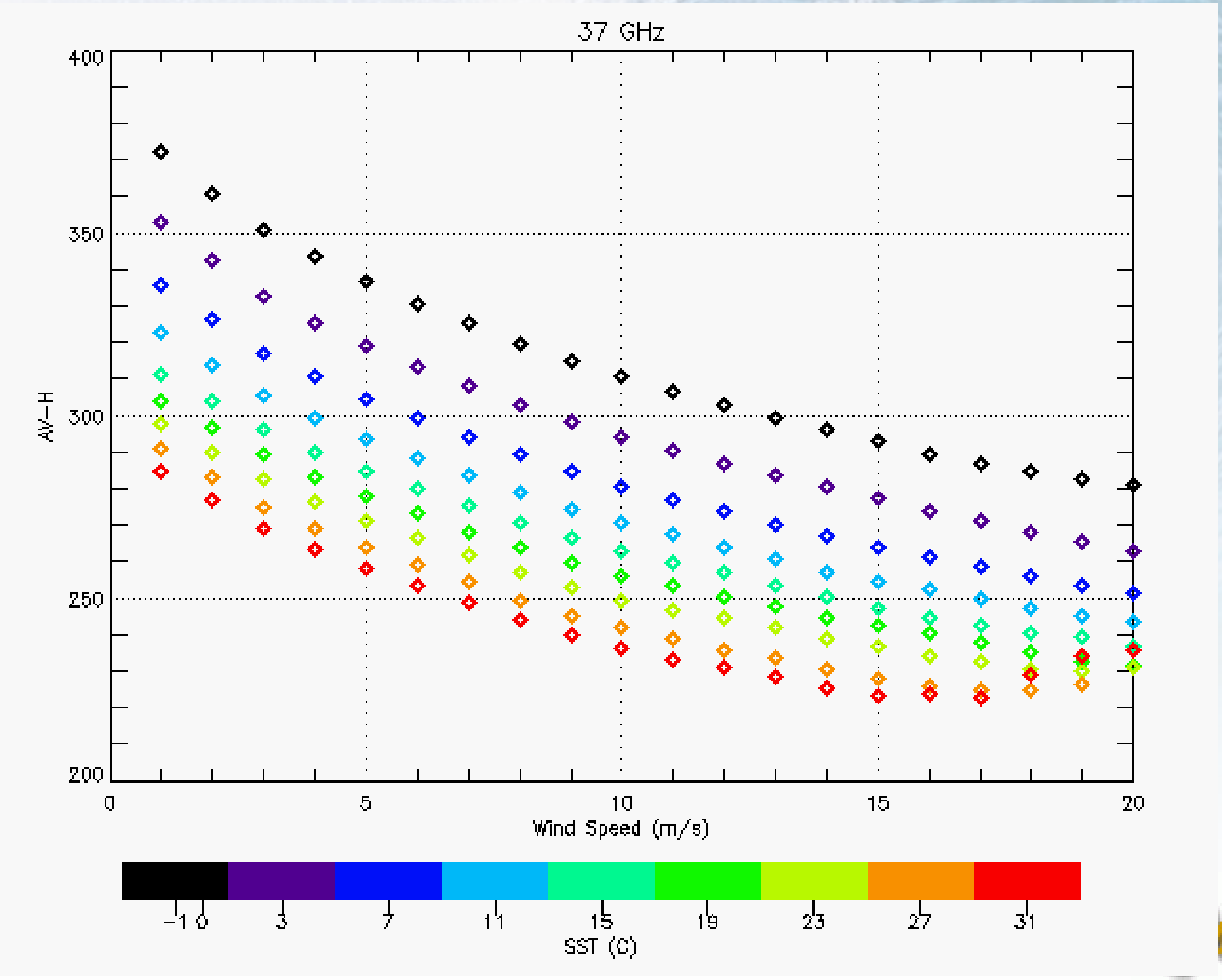
AV-H for 37 GHz



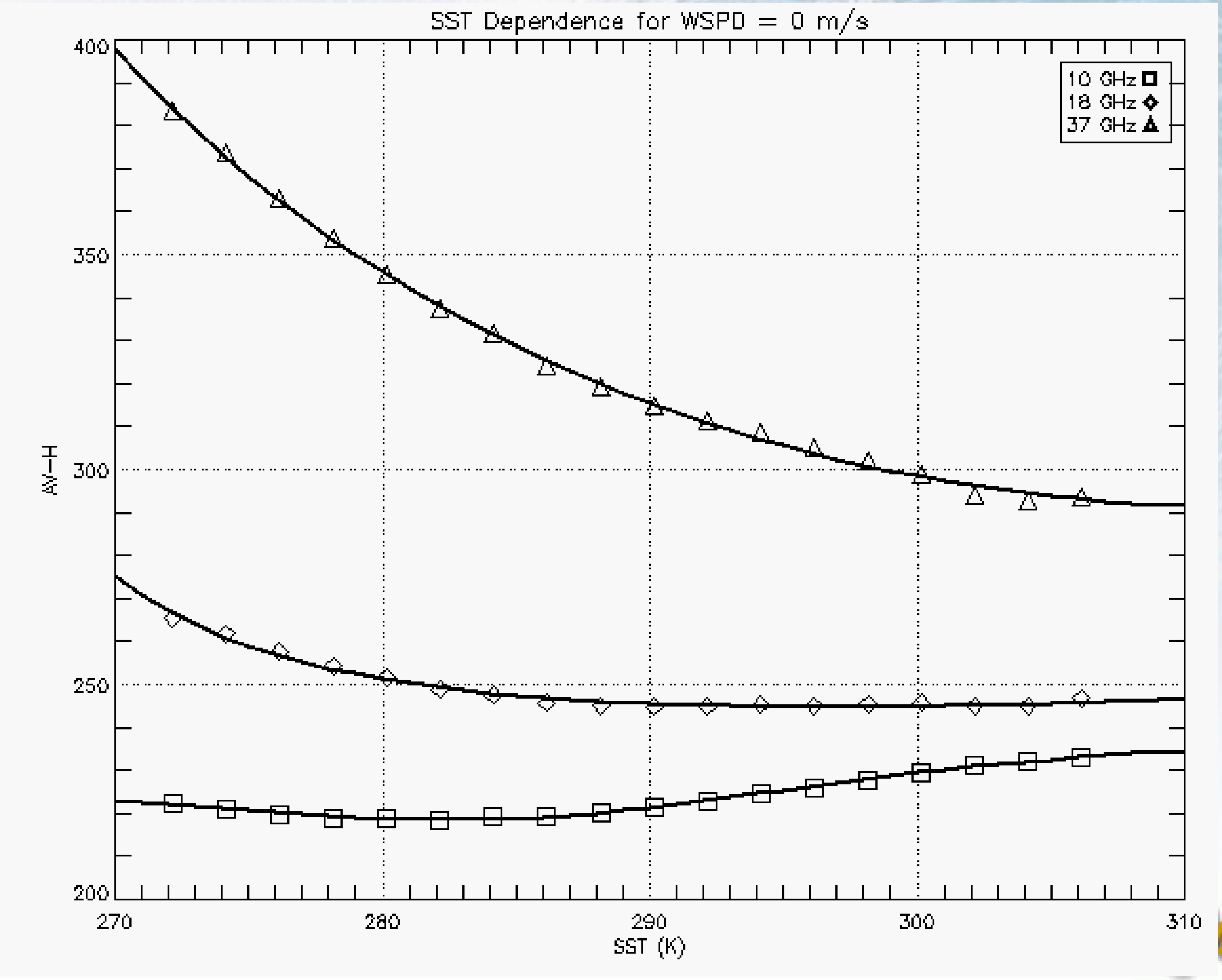
Procedure -2

- Assume sea surface is smooth: wind speed = 0 m/s
- *A*V-H become a function of only SST

$$AT_{BV} - T_{BH} = F(SST) + \cancelto{0}{C_0(WSPD)} + \cancelto{0}{C_1(WSPD)} \cdot COS(\chi) + \cancelto{0}{C_2(WSPD)} \cdot COS(2\chi)$$

- This initial *F(SST)* found from extrapolation to zero wind speed values
- Appropriate function that best describes the measurement is found

Initial *F(SST)*



Procedure -3

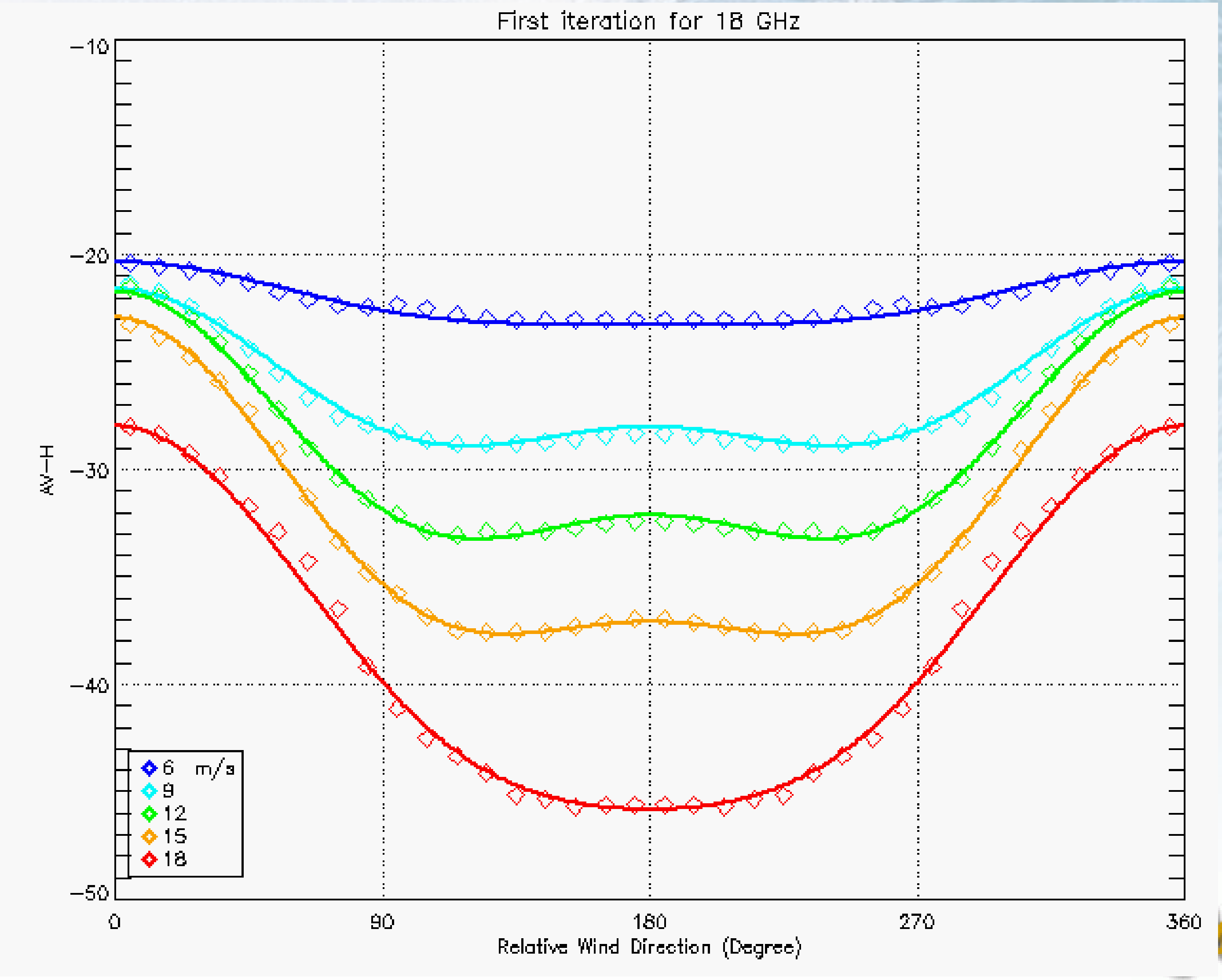
- Subtract *A*V-H from initial *F(SST)*.
- Remaining *A*V-H become a function of wind speed and direction

$$(AV-H)-F(SST)=F(WDIR)$$

- Find regression to the measurement in the form:

$$F(WDIR)=C_0(WSPD)+C_1(WSPD)\cdot COS(\chi)+C_2(WSPD)\cdot COS(2\chi)$$

First iteration *F(WDIR)*



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Procedure -4

- The *C*'s coefficient was found for discrete values of wind speed bin
- Regression fit was found for each of the *C*'s coefficient. *F(WDIR)* is found for all wind speed values.
- Iterative process has established

$$(AV - H) - F(WDIR) = F(SST)$$

Model Equations

$$AT_{BV} - T_{BH} = F(SST) + C_0(WSPD) + C_1(WSPD) \cdot COS(\chi) + C_2(WSPD) \cdot COS(2\chi)$$

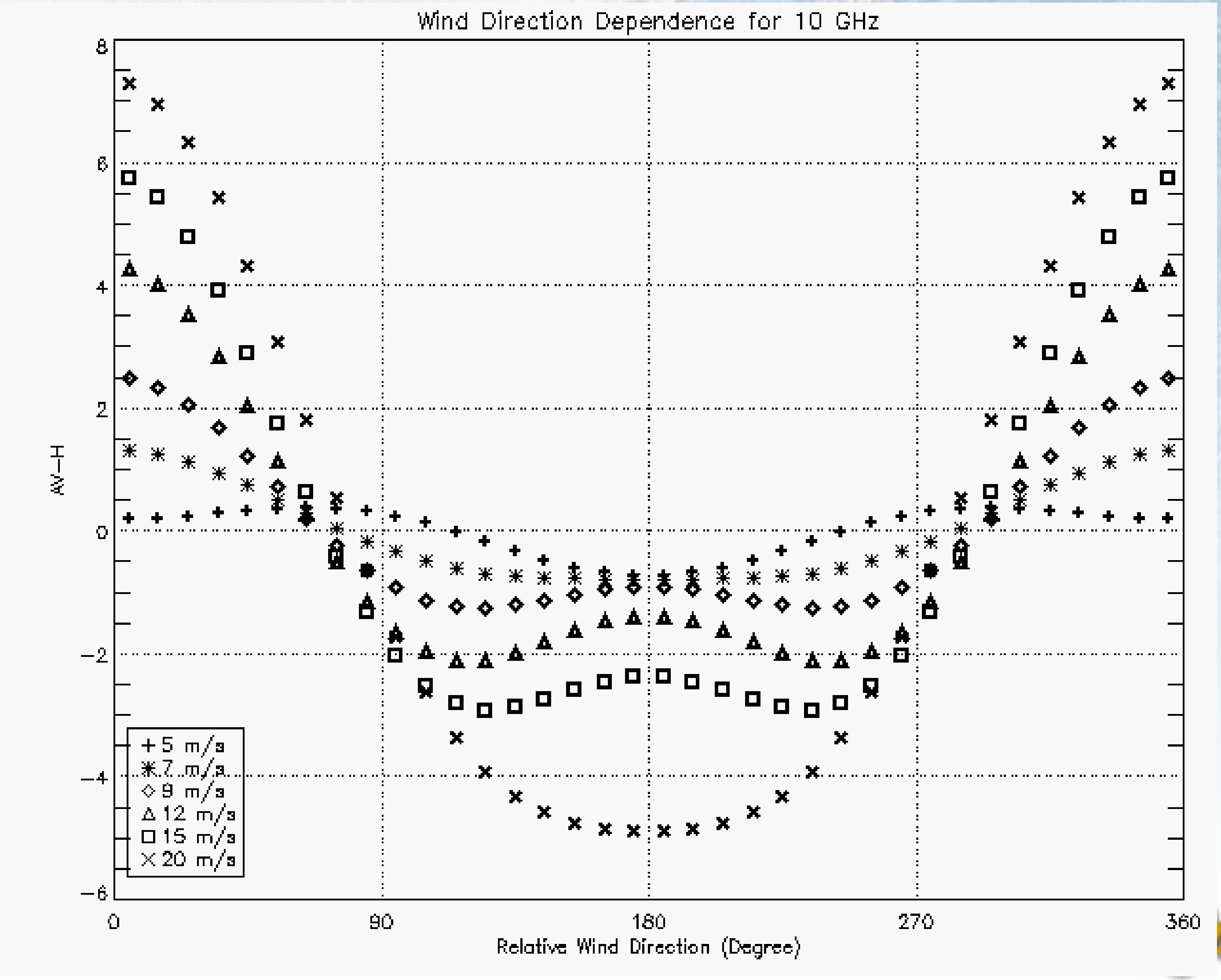
		F(SST)	C_0(WSPD)	C_1(WSPD)	C_2(WSPD)
AMSR Channel	10 GHz	$\frac{a+c\cdot x+e\cdot x^2}{1+b\cdot x+d\cdot x^2}$ **	$\frac{a+c\cdot x+e\cdot x^2+g\cdot x^3}{1+b\cdot x+d\cdot x^2+f\cdot x^3}$	$\frac{a+c\cdot x}{1+b\cdot x+d\cdot x^2}$ *	$\frac{a+c\cdot x+e\cdot x^2}{1+b\cdot x+d\cdot x^2}$ *
	18 GHz	$\frac{a+c\cdot x}{1+b\cdot x}$ **	$\frac{a+c\cdot x+e\cdot x^2+g\cdot x^3}{1+b\cdot x+d\cdot x^2+f\cdot x^3}$	$\frac{a+c\cdot x}{1+b\cdot x+d\cdot x^2}$ *	$\frac{a+c\cdot x+e\cdot x^2}{1+b\cdot x+d\cdot x^2}$ *
	37 GHz	$\frac{a+c\cdot x}{1+b\cdot x}$ **	$\frac{a+c\cdot x+e\cdot x^2+g\cdot x^3}{1+b\cdot x+d\cdot x^2+f\cdot x^3}$	$\frac{a+c\cdot x}{1+b\cdot x+d\cdot x^2}$ *	$\frac{a+c\cdot x+e\cdot x^2}{1+b\cdot x+d\cdot x^2}$ *

* First four points was excluded. ** Last point was excluded.

Model Coefficients

		F(SST)	C_0(WSPD)	C_1(WSPD)	C_2(WSPD)
AMSR Channels	10 GHz	a= 253.8939018 b= -0.007207942 c= -1.827465510 d= 1.3108e-05 e= 0.003314763	a= 0.517115747 b= -0.140174737 c= -3.734401755 d= 0.003843883 e= 0.787061774 f= 0.003616502 g= -0.101162061	a= -0.653431016 b= -0.042740230 c= 0.205632786 d= 0.001052848	a= -1.395843862 b= -0.073649495 c= 0.283917140 d= 0.002780937 e= -0.008776347
	18 GHz	a= 234.5302360 b= -0.003810786 c= -0.898157560	a= -0.268136601 b= -0.110325789 c= -3.522010565 d= 0.043939984 e= -0.167645682 f= 0.000277041 g= -0.075276385	a= -2.095456244 b= -0.039566361 c= 0.508449429 d= 0.001709247	a= -2.2041331797 b= -0.068904176 c= 0.501358865 d= 0.002615589 e= -0.017071887
	37 GHz	a= 193.3863684 b= -0.004205115 c= -0.907046083	a= 3.246690433 b= 0.139539136 c= -13.19966520 d= -0.006413733 e= 0.318536521 f= 0.000286851 g= -0.022678385	a= -5.056542254 b= -0.008215836 c= 1.147747275 d= 0.001194255	a= -2.019721861 b= -0.086047248 c= 0.430587232 d= 0.002842379 e= -0.015823182

Model Function for 10 GHz



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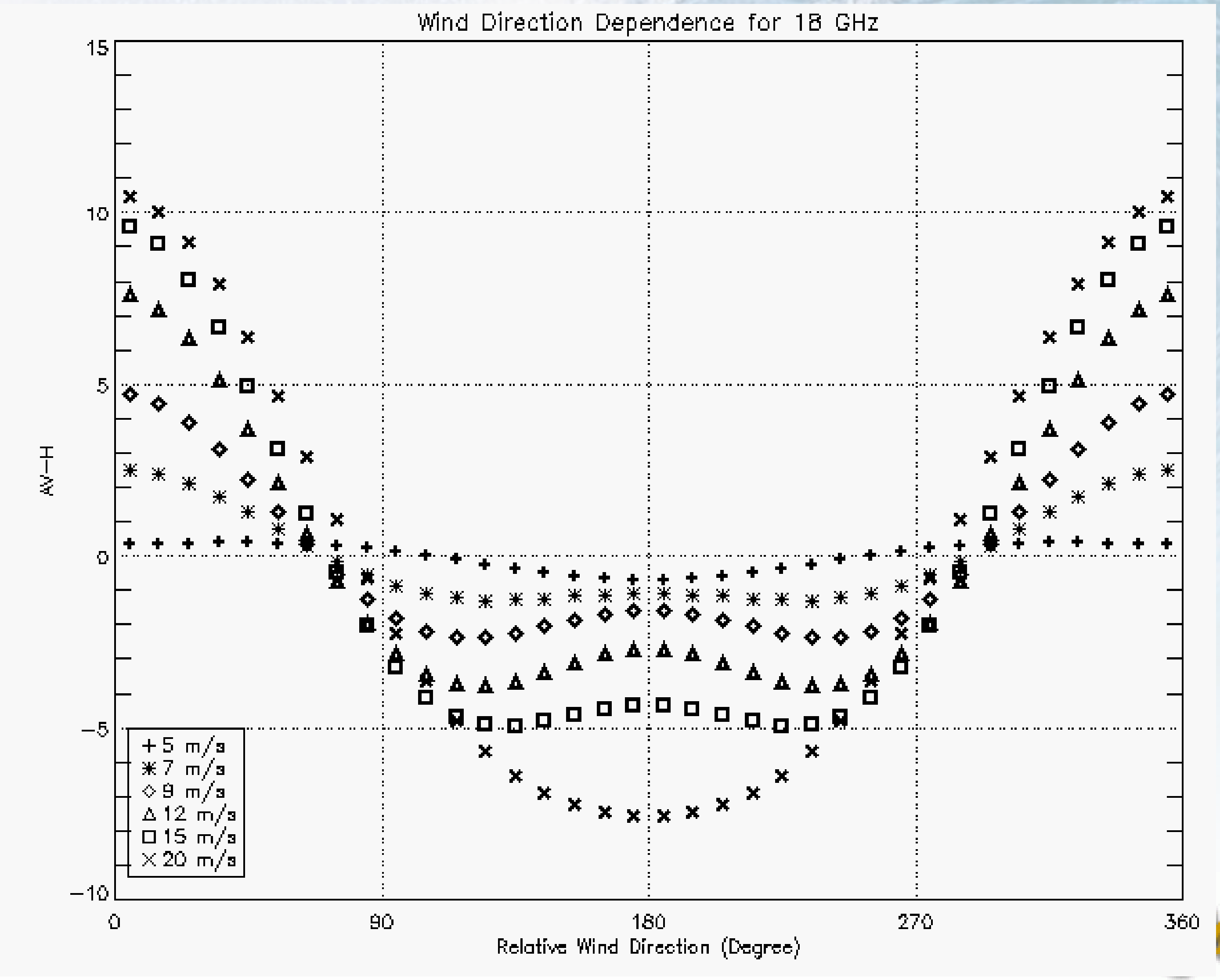
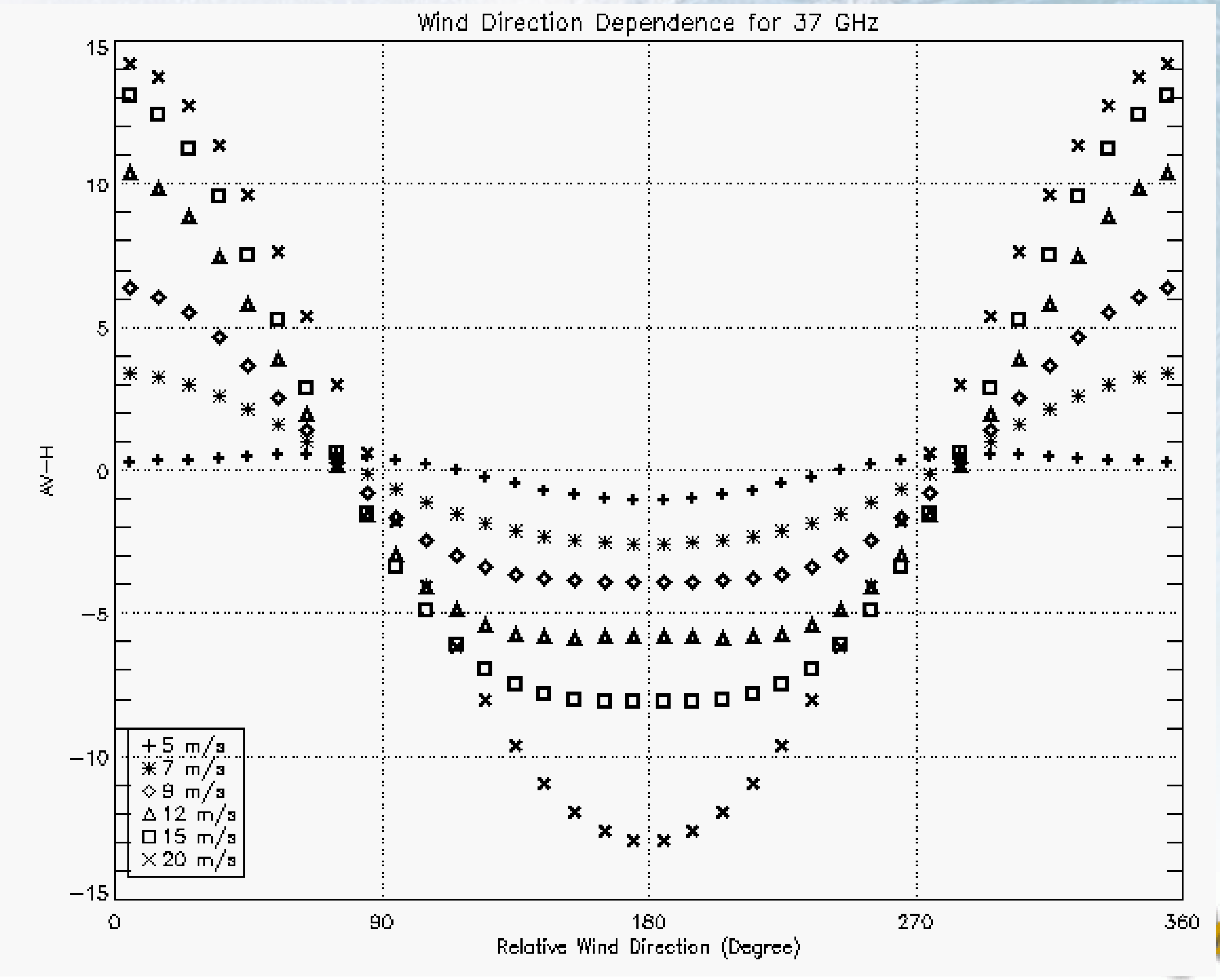
Model Function for 18 GHz



Model Function for 37 GHz



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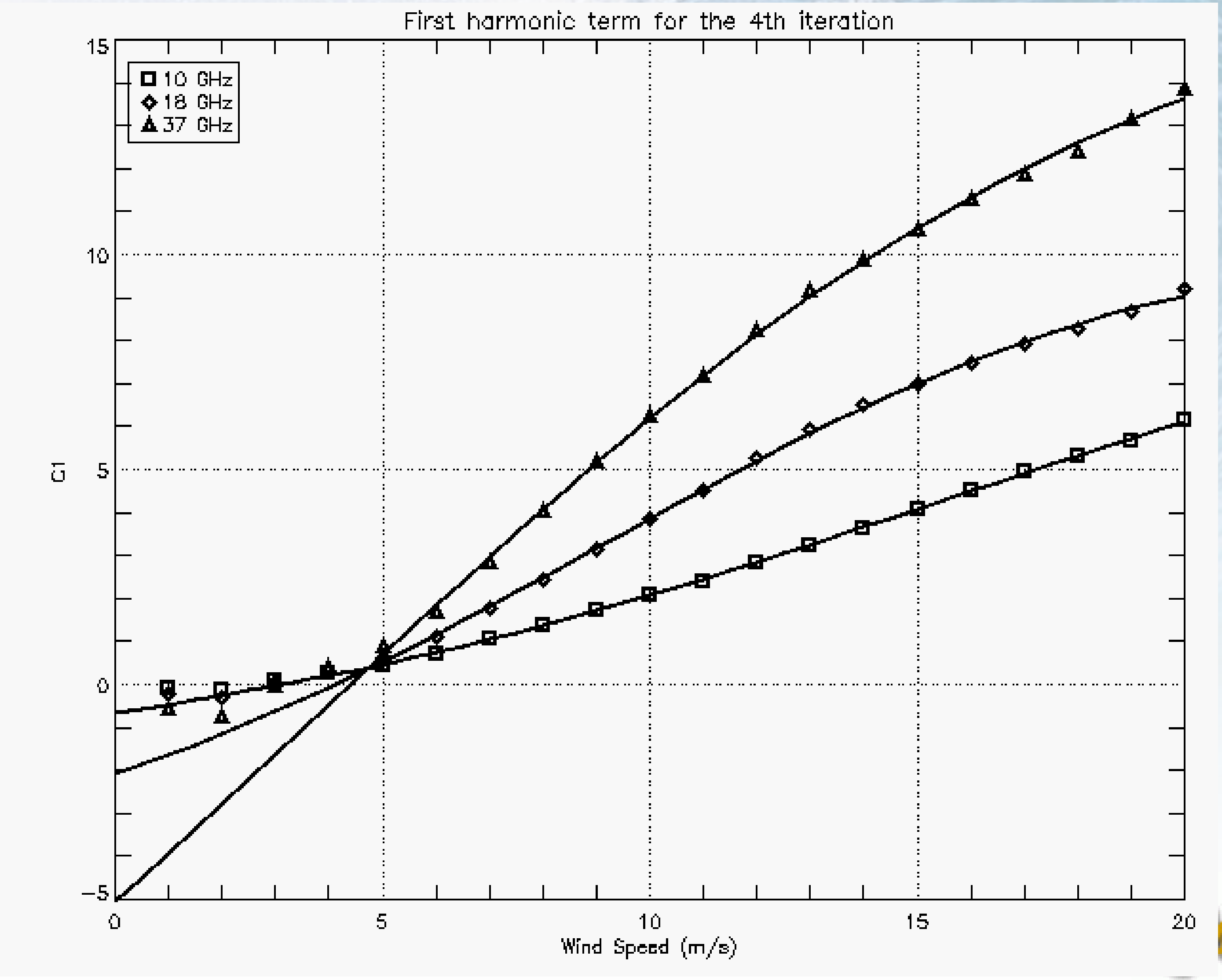
Coefficient C_1



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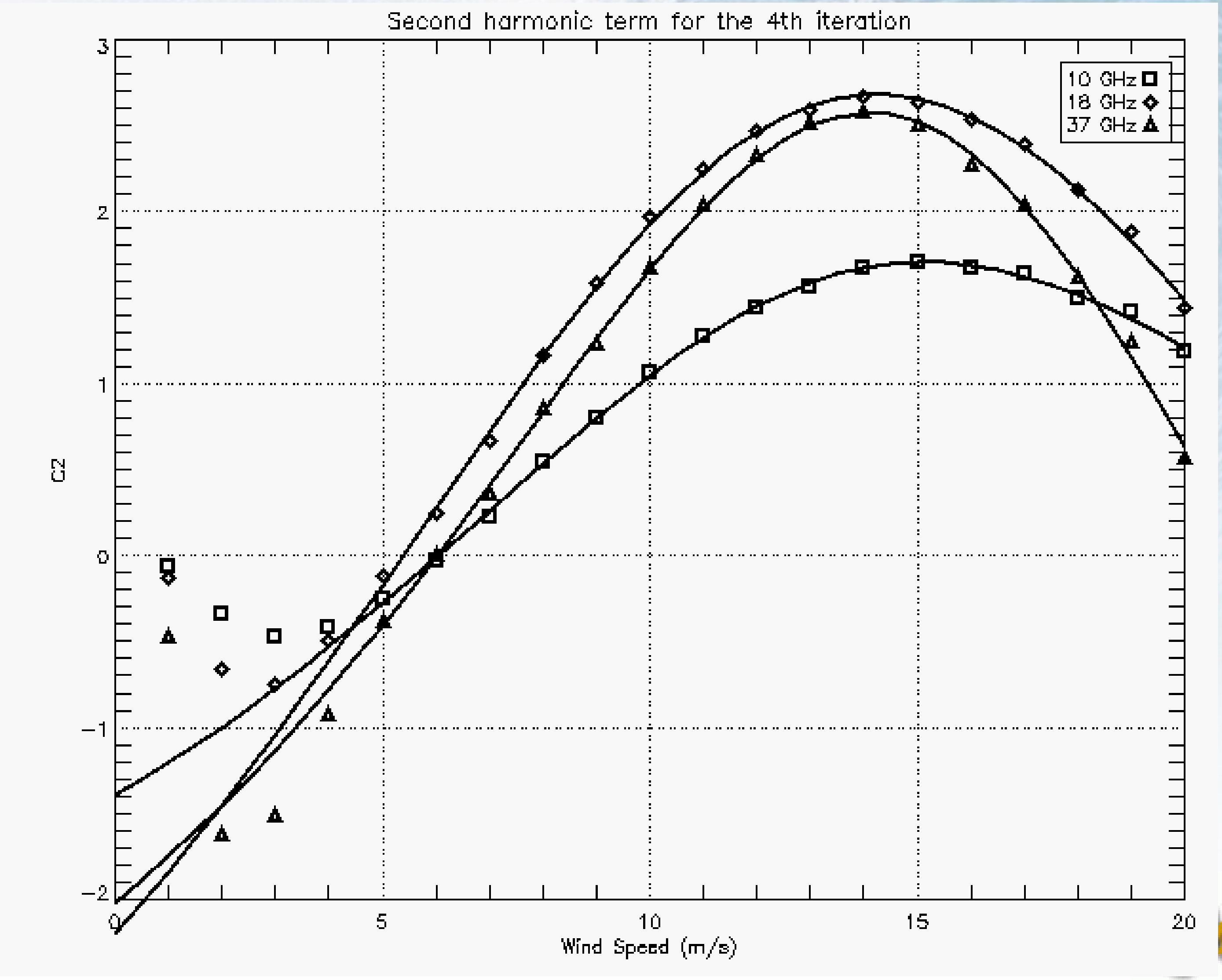
Coefficient C_2



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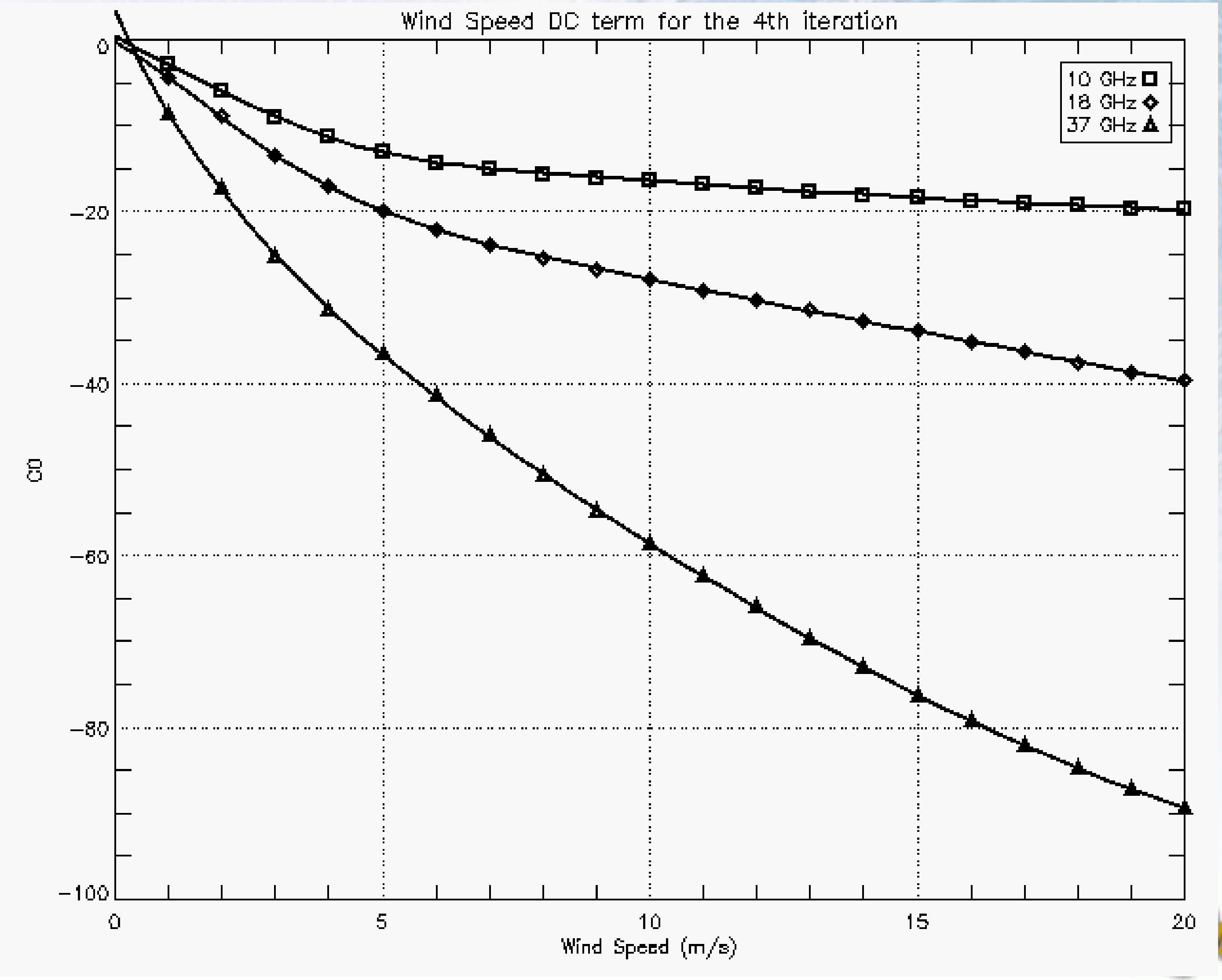
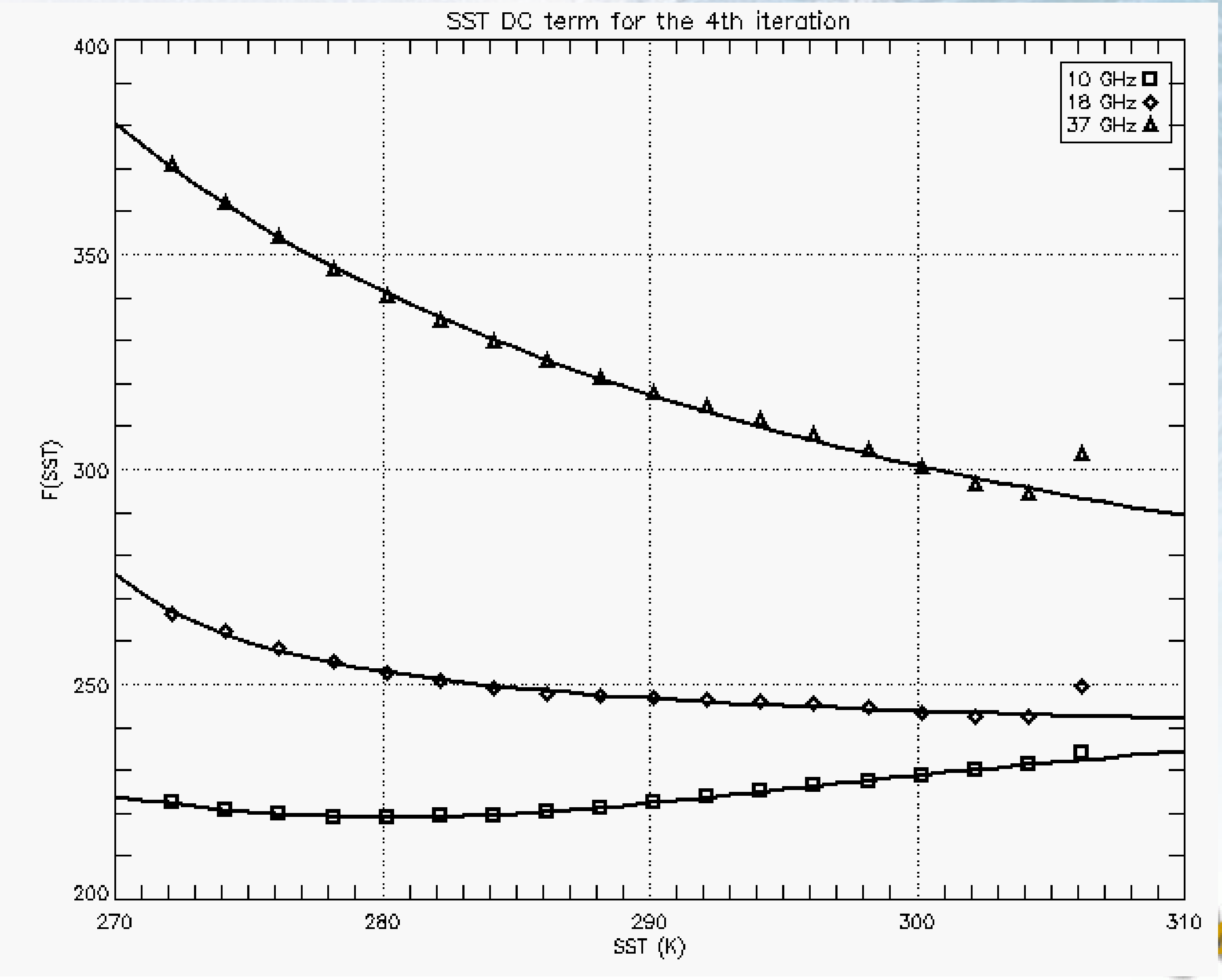
Wind speed dependence dc



SST dependence dc



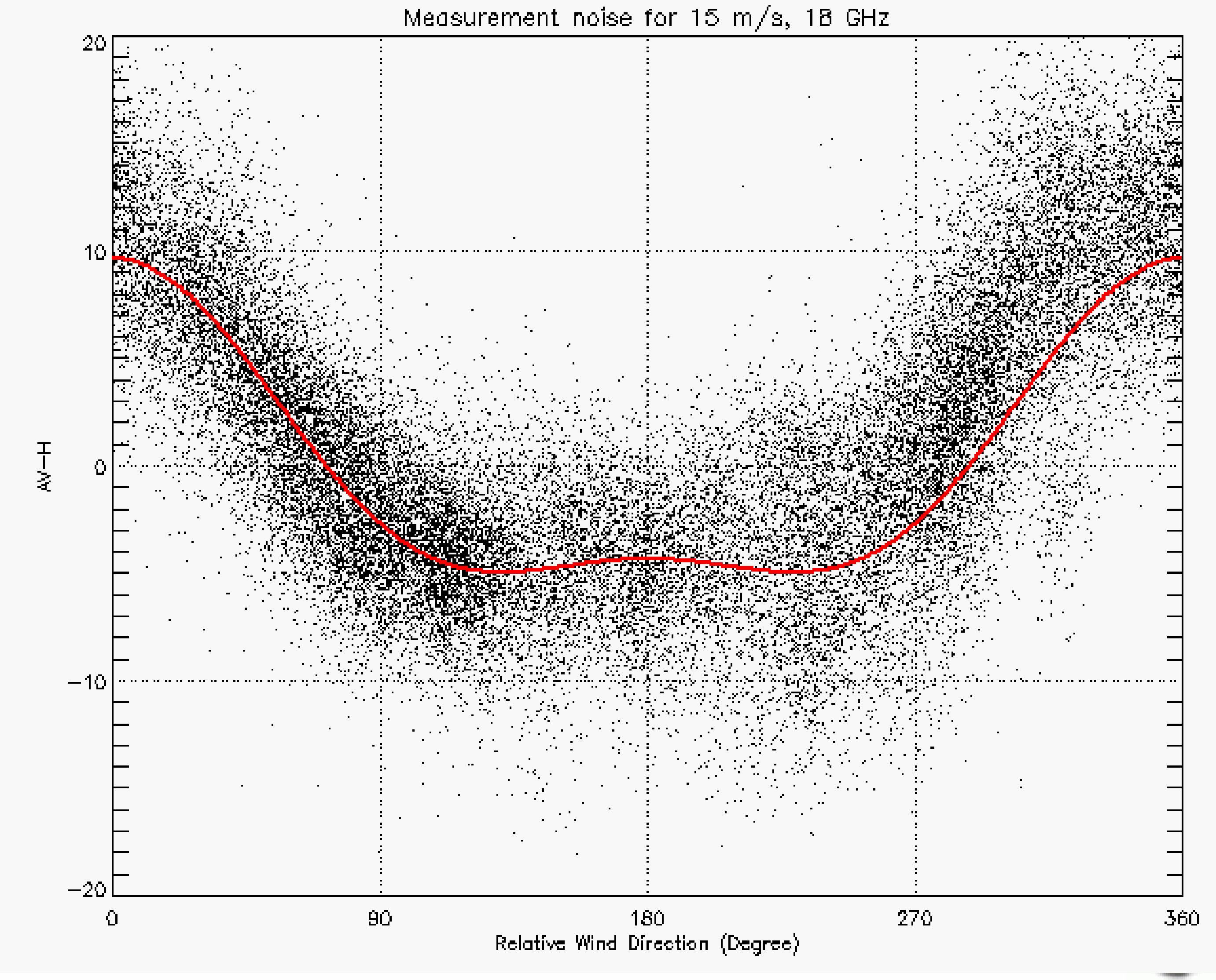
Model standard deviation

- Directional model standard deviation was found as a function of relative direction and wind speed
- Standard deviation was model the same way as the model function in the form

$$STD = C_1(WSPD) \cdot COS(\chi) + C_2(WSPD) \cdot COS(2\chi)$$

- Same regression process was repeated

Measurement Noise



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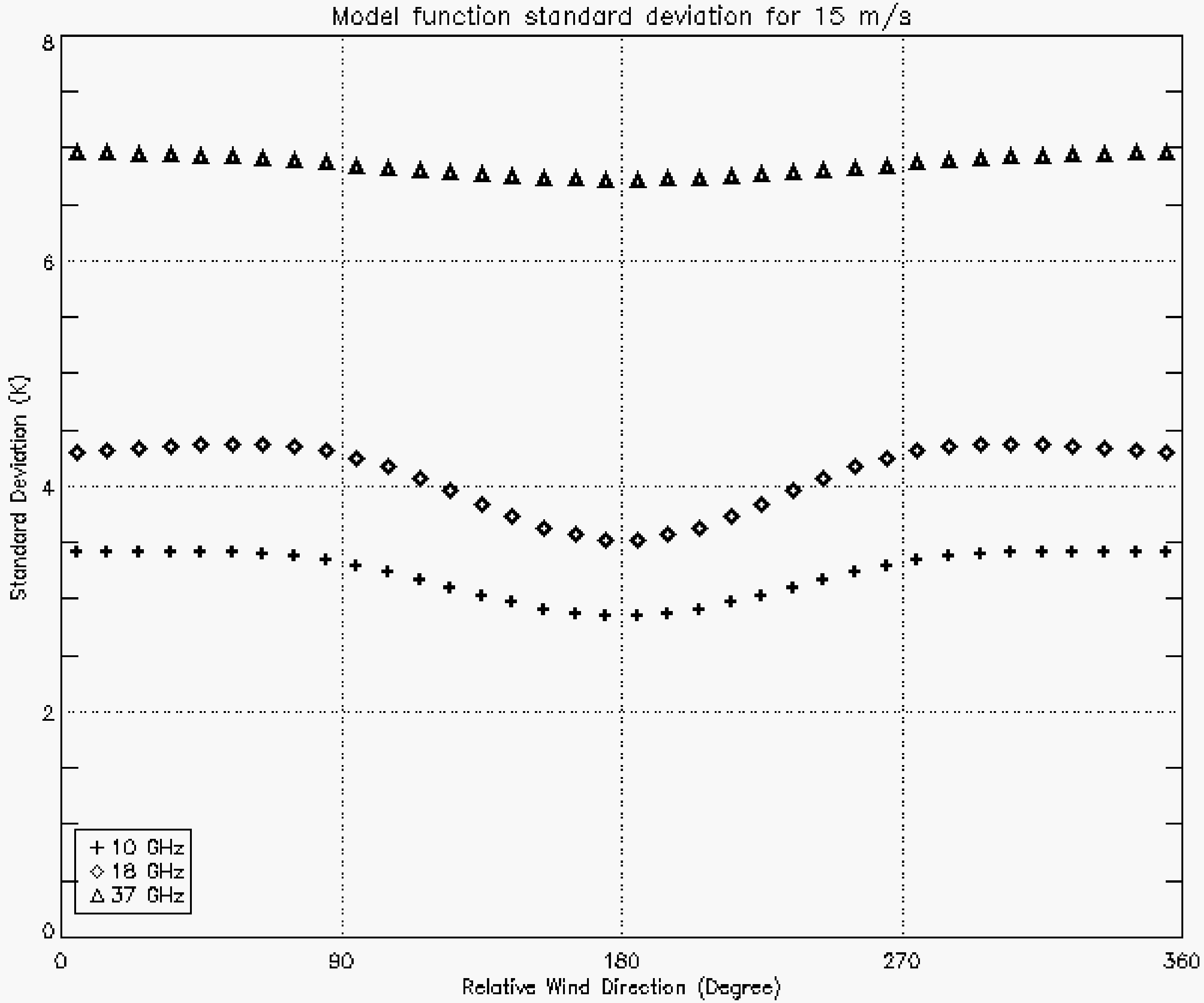
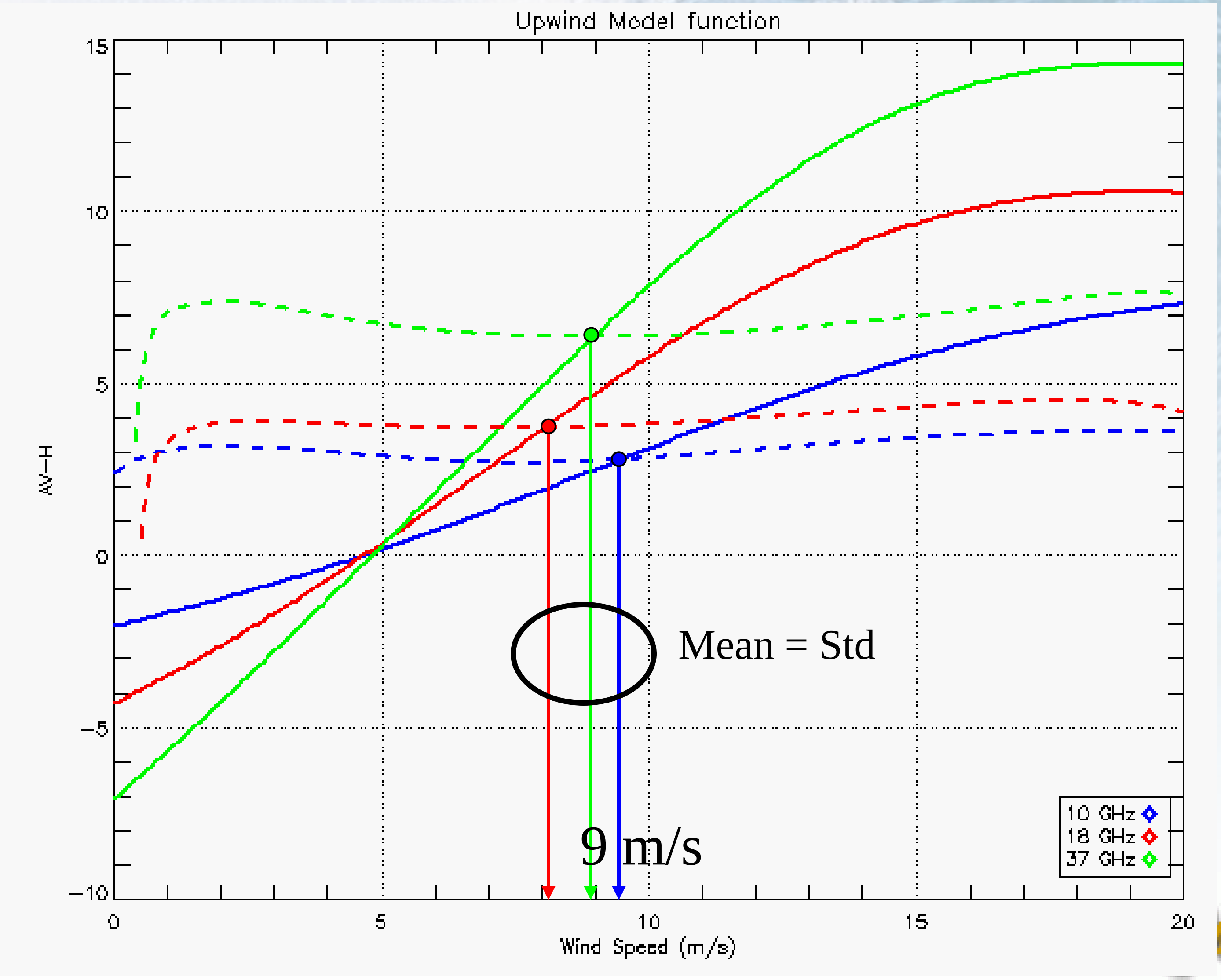
Standard deviation



Standard deviation for Upwind



Wind Vector Retrieval

- Wind vectors are ideally retrievable using the model function for *A*V-H measurement and given SST
- Retrieval algorithm based on maximum likelihood estimation (MLE)

$$\zeta = \sum_{freq=10,18,37GHz} \frac{\left(AVH_{Meas} - AVH_{Model}(wspd, rel.dir, SST)_{freq}\right)^2}{Variance_{AVH}(wspd, rel.dir)_{freq}}$$

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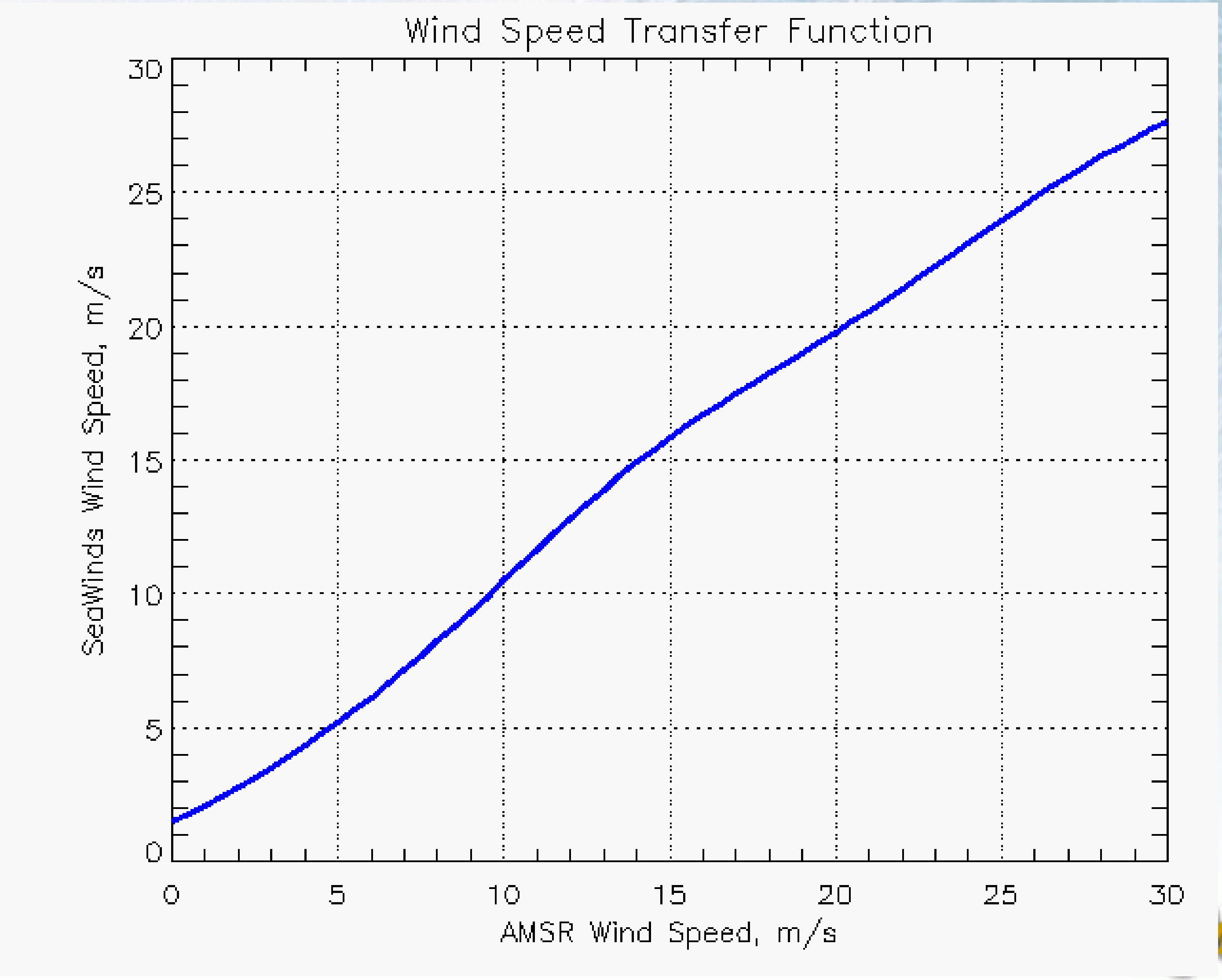
Wind Vector Retrieval -2

- In practice measurements standard deviations are relatively high for wspd < 9 m/s
- Wind retrieval from *A*V-H alone will not achieve required accuracy
- *A*V-H brightness may be combined with the other measurements to be able to retrieve wind vector

Combined Active/Passive retrieval

- Use favorable geometry measurements of AMSR's T_B and SeaWinds' σ^0 on ADEOS-II
- Only fore-look σ^0 measurements were used
  - Assess usability of *A*V-H model function
  - Simplifies instrument design
    - Adds two feed and electronics to multi-channel conical scanning radiometer
- Given SST available from GDAS, and known wind speed retrieved from SeaWinds scatterometer

Wind speed transfer function



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Active/Passive Algorithm

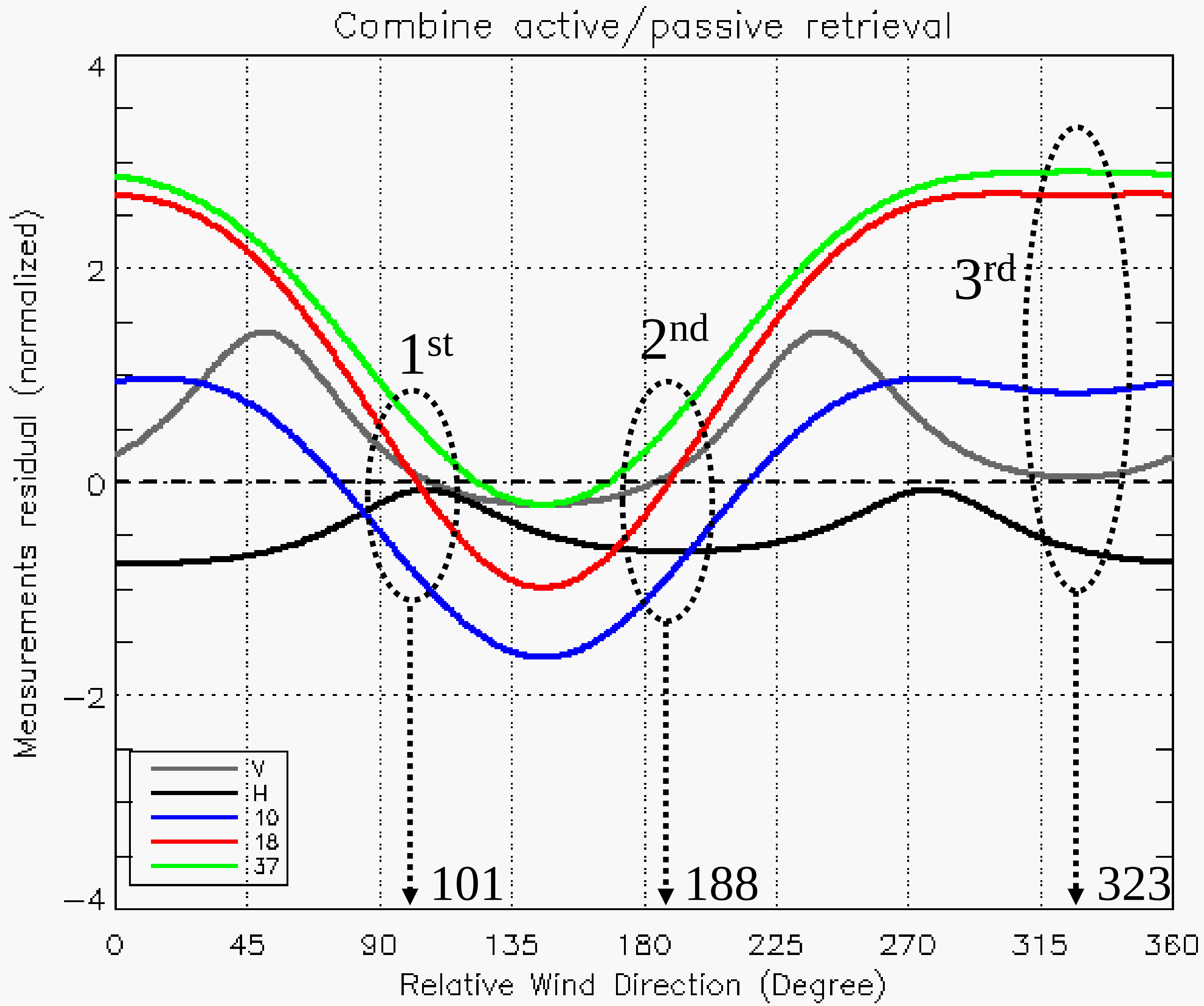
$$\zeta = \sum_{freq=10,18,37GHz} \frac{\left(AVH_{Meas} - AVH_{Model}(wspd,\chi,SST)_{freq}\right)^2}{Variance_{AVH}(wspd,\chi)_{freq}} + \sum_{pol=V,H} \frac{\left(\sigma_0 - GMF(wspd,\chi)_{pol}\right)^2}{Variance_{\sigma_0}(wspd,\chi)_{pol}}$$

$$\chi = azimuth - direction$$

Wind direction ambiguities

- Wind direction solution is not unique - caused by biharmonic nature of the model functions
- Wind direction solutions were kept up to four and ordered according to the inverse values of MLE
  - i.e. 1st ranked solution corresponds to minimum MLE value, 2nd ranked is the second minimum, …
- Of these ambiguities, only one of the solutions is the “correct” wind direction

Measurements residual



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Wind Retrieval Comparison

Active/Passive Retrievals

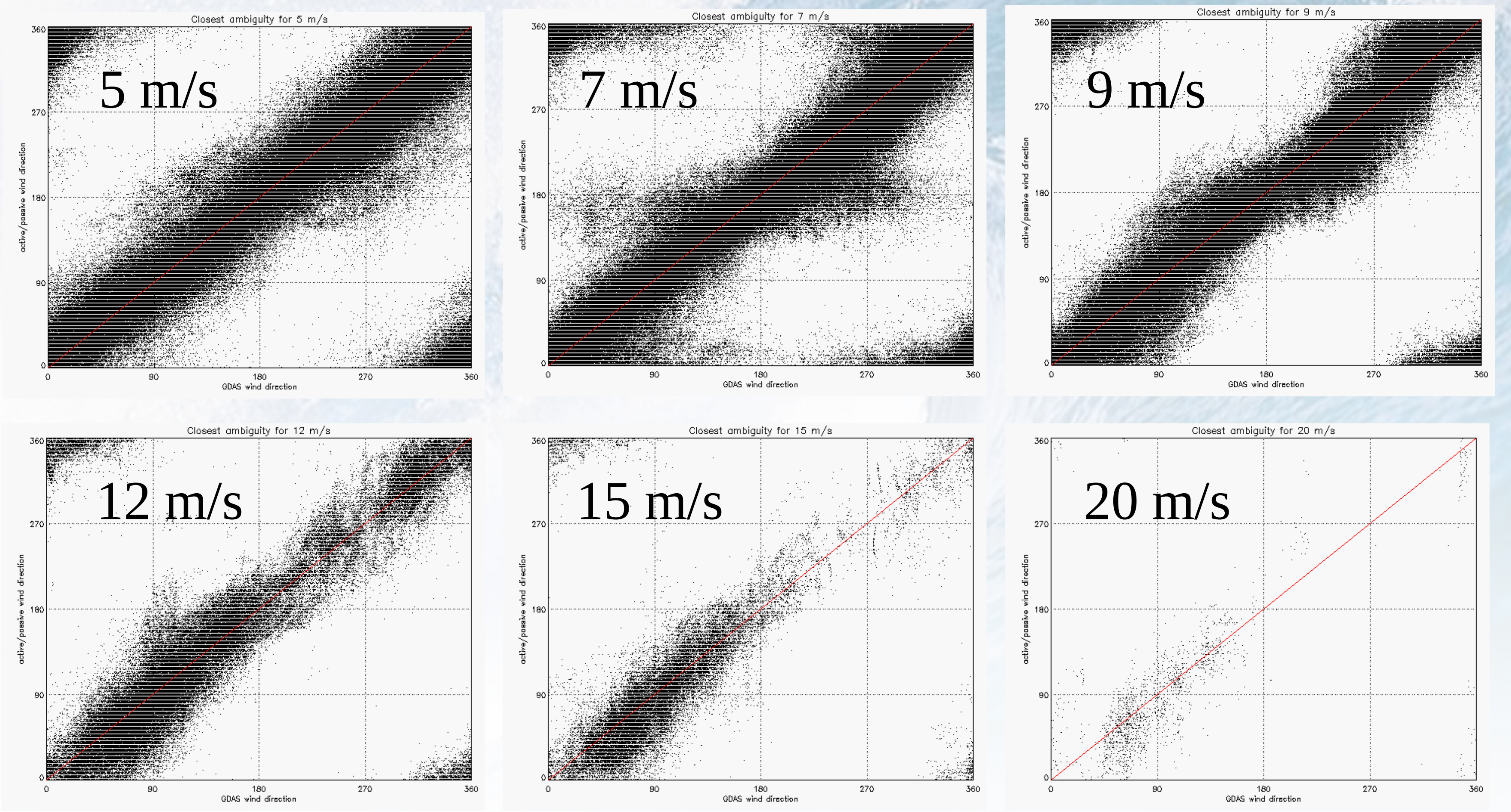
- For best case scenario, ambiguities were compared to the known surface truth and the closest direction solution was selected
- GDAS was used as the surface truth (independent source)

Active fore-look

- Wind direction comparisons were also made for the "closest" solution retrieved without using passive AV-H measurements

Closest Ambiguity Comparison

Active/Passive direction



GDAS direction

Closest solutions comparison

Wind Speed (meter/sec)	Number of Points	Closest Ambiguities: Standard Deviation Error	
		Passive + fore-look Scat	Only fore-look Scat
5	337493	20.8°	14.1°
7	441818	23.6°	10.8°
9	309717	17.4°	9.0°
12	99563	17.5°	9.0°
15	33520	17.1°	9.5°
20	1680	19.1°	13.7°

Current scatterometer is capable of wind speed measurement of 3-20 m/s

- wind speed accuracy: 2 m/s
- wind direction accuracy: 20°

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Instrument Skill

- The instrument skill is a metric to determine the performance of the wind ambiguity removal based upon ambiguity ranking
- The higher the probability that 1^{st} ranked solutions are the closest solution, the greater the skill of the instrument
- Usually in four-look scatterometry, the 1^{st} and 2^{nd} ranked solutions are the most probable closest wind vector

Skill Comparison

Wind Speed (meter/sec)	Closest Ambiguity Ranking							
	Passive + fore-look Scat				Only fore-look Scat			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
5	30 %	35 %	23 %	13 %	26 %	30 %	29 %	15 %
7	30 %	34 %	23 %	13 %	22 %	27 %	32 %	18 %
9	30 %	37 %	27 %	6 %	25 %	27 %	33 %	15 %
12	61 %	28 %	10 %	1 %	50 %	30 %	13 %	7 %
15	82 %	15 %	2 %	1 %	63 %	29 %	5 %	3 %
20	91 %	9 %	0 %	0 %	69 %	25 %	2 %	4 %

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Skill Comparison

Wind Speed (meter/sec)	Closest Ambiguity Ranking							
	Passive + fore-look Scat				Only fore-look Scat			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
5	30 %	35 %	23 %	13 %	26 %	30 %	29 %	15 %
7	30 %	34 %	23 %	13 %	22 %	27 %	32 %	18 %
9	30 %	37 %	27 %	6 %	25 %	27 %	33 %	15 %
12	61 %	28 %	10 %	1 %	50 %	30 %	13 %	7 %
15	82 %	15 %	2 %	1 %	63 %	29 %	5 %	3 %
20	91 %	9 %	0 %	0 %	69 %	25 %	2 %	4 %

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Active/Passive Skill Improvement

Wind Speed (m/s)	Skill improvement (1st and 2nd rank combined)	Standard deviation	
		Only fore-look Scat	Passive + fore-look Scat
5	9 %	14.1 °	20.8 °
7	15 %	10.8 °	23.6 °
9	15 %	9.0 °	17.4 °
12	9 %	9.0 °	17.5 °
15	5 %	9.5 °	17.1 °
20	6 %	13.7 °	19.1 °

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Conclusion

- Linear combination of vertical and horizontal brightness temp. (*A*V-H) is a function of only surface parameters
  - *A* is a f(Freq, pol, SST and wind speed)
  - Effects of atmosphere cancel
  - Large DC bias is f(Freq, pol, SST and wind speed)

- Empirical relationship between *A*V-H and surface parameter is defined for wind vector and SST.

Conclusion -2

- Measurement noise (deltaTb) dominantes over wind directional signal for wind speed < 9 m/s
  - May prevent wind retrieval using passive measurement alone
- Combined active and passive has been investigated with fore-look geometry
  - Closest ambiguity shows that retrieval achieves wind direction accuracy of < 20 °
  - However, wind direction accuracy degrades compared to closest fore-look active measurement alone
  - But, instrument skill is higher (than using fore-look active measurement alone)

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List of Conf. Publications

- Jones, W.L., Soisuvarn, S., Kasparis, T., and Ahmad, S., “Combined Active And Passive Microwave Sensing Of Ocean Surface Wind Vector From TRMM”, AGU Spring Meeting, May 28-31, 2002, Washington, DC
- Jones, W. L., Soisuvarn, S., Kasparis, T., Ahmad, S. and R. Meneghini, “Ocean Surface Wind Speed Measurements Using The TRMM Precipitation Radar”, International Tropical Rainfall Measuring Mission (TRMM) Science Conference, Jul 22-26, 2002, Honolulu, HA.
- Soisuvarn, S., Jones, W. L. and T. Kasparis, “Combined Active And Passive Microwave Sensing Of Ocean Surface Wind Vector From TRMM”, Oceans '02 MTS/IEEE, Oct 29-31, 2002, Biloxi, MS.
- Soisuvarn, S., Jones, W. L. and T. Kasparis, “Combined Active And Passive Microwave Sensing Of Ocean Surface Wind Vector From TRMM”, IGARSS '03, Jul 21-25, 2003, Toulouse, France.
- Soisuvarn, S., Jones, W. L. and T. Kasparis, “Validation Of Ocean Surface Wind Vector Sensing Using Combined Active And Passive Microwave Measurement”, IGARSS '04, Sep 20-24, 2004, Anchorage, AK.

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List of Conf. Publications -2

- Soisuvarn, S., Jones, W. L., T. Kasparis, “Ocean Surface Wind Vector Retrievals Using Active And Passive Microwave Sensing On ADEOS-II”, IGARSS '05, Jul 25-29, 2005, Seoul, Korea
- Jones, W. L., and S. Soisuvarn, “A Novel Active and Passive Microwave Remote Sensing Technique for Measuring Ocean Surface Wind Vector”, Oceans '05 MTS/IEEE, Sep 18-23, 2005, Washington, DC
- Soisuvarn S., Jones, W. L, and Z. Jelenak, “A Novel Oceanic Wind Vector Measurement from ADEOS-II using Combined Active and Passive Microwave Techniques”, AGU Joint Assembly, Baltimore, Maryland, 23-26 May 2006
- Soisuvarn S., Jones, W. L, and Z. Jelenak, “Development of Oceanic Wind Vector Model Function for AMSR Radiometer on ADEOS-II Satellite”, Proc. IEEE IGARSS-06, Aug. 28 - Sept. 1, 2006, Denver, CO.

Refereed Publications

- W. Linwood Jones, Jun D. Park, **Seubson Soisuvarn**, Liang Hong, Peter Gaiser and Karen St. Germain, "Deep-Space Calibration of WindSat Radiometer", *IEEE Trans. GeoSci. Rem. Sens.*, Vol. 44, N0. 3, Mar 2006
- **S. Soisuvarn**, Z. Jelenak and W. L. Jones, "An ocean surface wind vector model function for a spaceborne microwave radiometer," IEEE Trans. Geosci. Remote Sensing (submitted Sept 2006; under peer review)