Ku-band Geophysical Model Functions and SST

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$$\sigma^0 = \mathrm{GMF}(V_{10s}, \phi, SST, \theta, p, \lambda, \ldots)$$

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The Effects of the Variations in Sea Surface Temperature and Atmospheric Stability in the Estimation of Average Wind Speed by SEASAT-SASS

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ABSTRACT

Wind speeds from the scatterometer (SASS) on the ocean observing satellite SEASAT averaged over 2° latitude by 2° longitude and a 92-day period are compared with wind speeds from ship reports in the western North Atlantic and the eastern North Pacific, where the concentrations of ship reports are high and the ranges of atmospheric stability and sea surface temperature are large. The comparison results are consistent for each region and for the combined data. Scatterometer winds are found to be generally higher than ship winds. The systematic dependences of the difference between scatterometer winds and ship winds on sea surface temperature and atmospheric stability are identified. The quality of ship reports is not ideal but should not depend on atmospheric stability or sea surface temperature. The systematic dependences, therefore, may reflect the characteristics of scatterometer winds.

Multivariate regressions are used to extract the independent effects of different factors on the wind speed differences. The difference between scatterometer winds and neutral winds from ship reports increases with increasing atmospheric stability and the trend is more prominent under stable than unstable conditions. By replacing neutral winds with observed winds, the stability dependence is reduced. At low wind speeds, the wind difference is found to depend also on sea surface temperature, probably due to temperature dependent factors, such as water viscosity, which are not included in the SASS model function. This dependence is greatly reduced at wind speeds higher than 8 m s^{-1}. After the systematic dependence is removed from the scatterometer winds, the rms difference between the scatterometer winds and the neutral winds from ship reports was reduced from 1.7 to 0.9 m s^{-1}.

The scatterometer measures backscatter from ocean surface short waves. The results of this study call for better understanding of the energy input from the atmosphere to the short waves, which may depend on atmospheric stability and the dissipation of this energy through processes that may be affected by temperature dependent fluid properties (e.g., viscosity and surface tension).

NSCAT-5 GMF

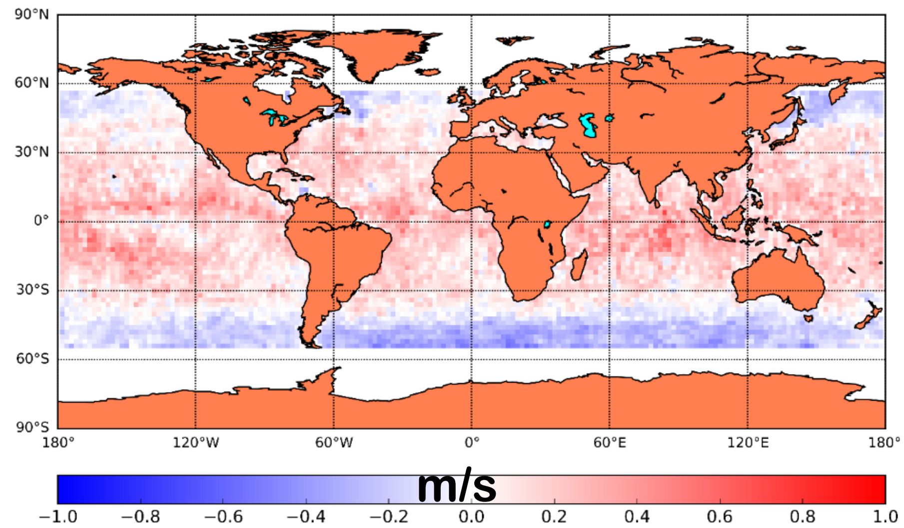
- The intercalibration among scatterometers:
  - between Ku- and C-band instruments
  - between different Ku-band scatterometers, needs one GMF

- Improve wind direction modulation
- improve wind speed dependency
- improve incidence angle dependency
- Include SST dependencies which depend on wind speed, incidence angle, and polarization

- Wind reference: collocated ASCAT winds or NWP winds

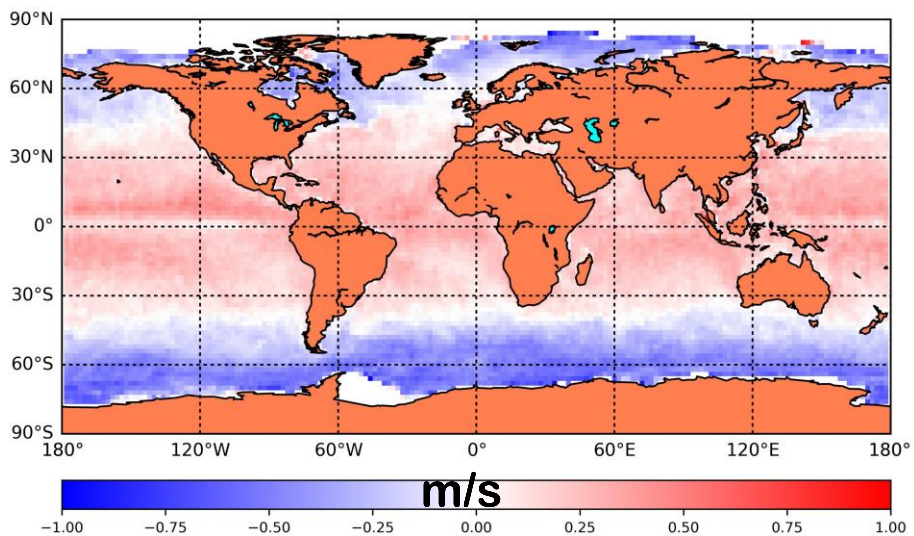
Wind speed biases between Ku- and C-band scatterometers

ΔV



RapidSCAT - ASCAT

ΔV

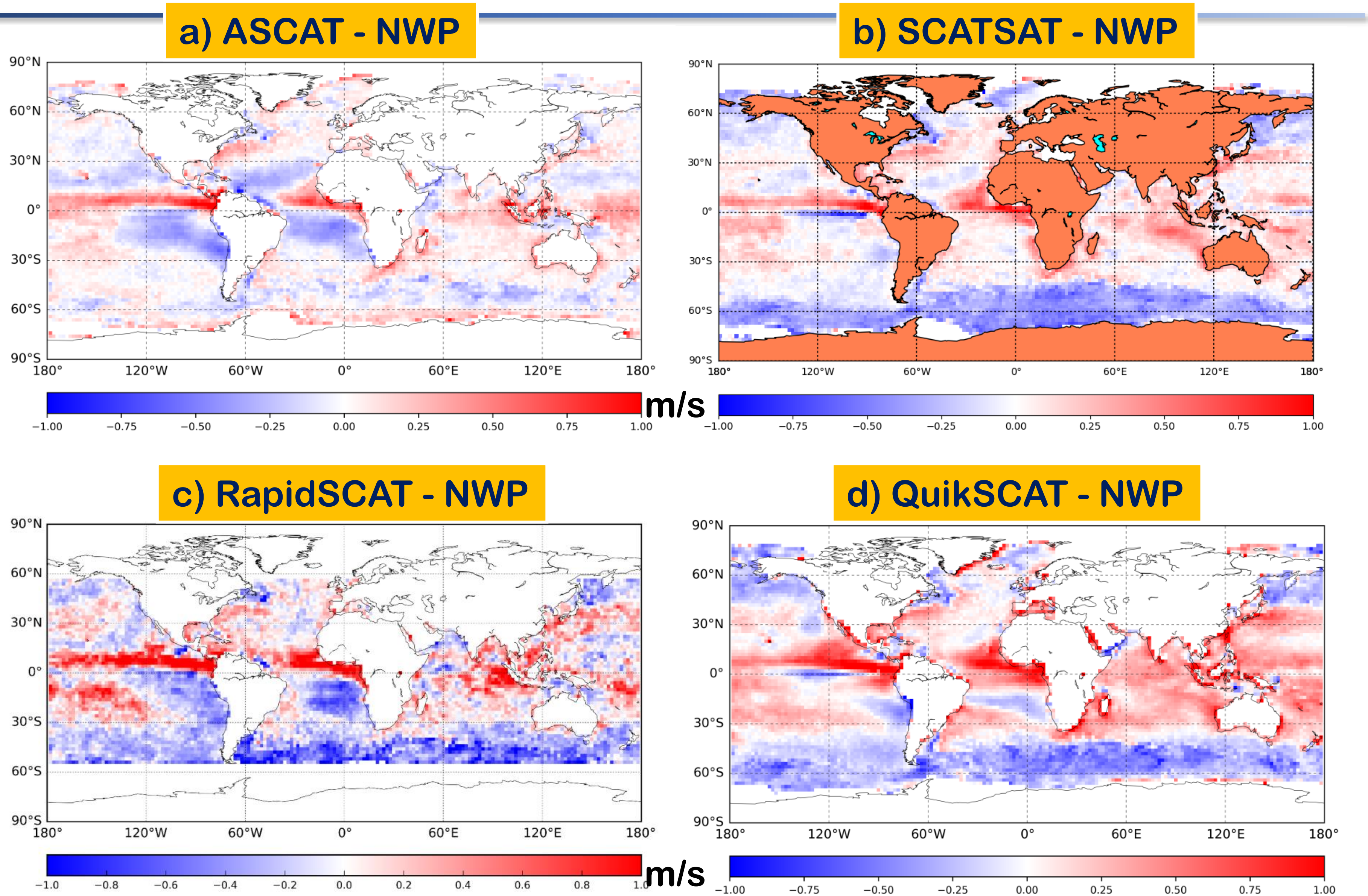


SCATSAT - ASCAT

Stronger?

SST effects

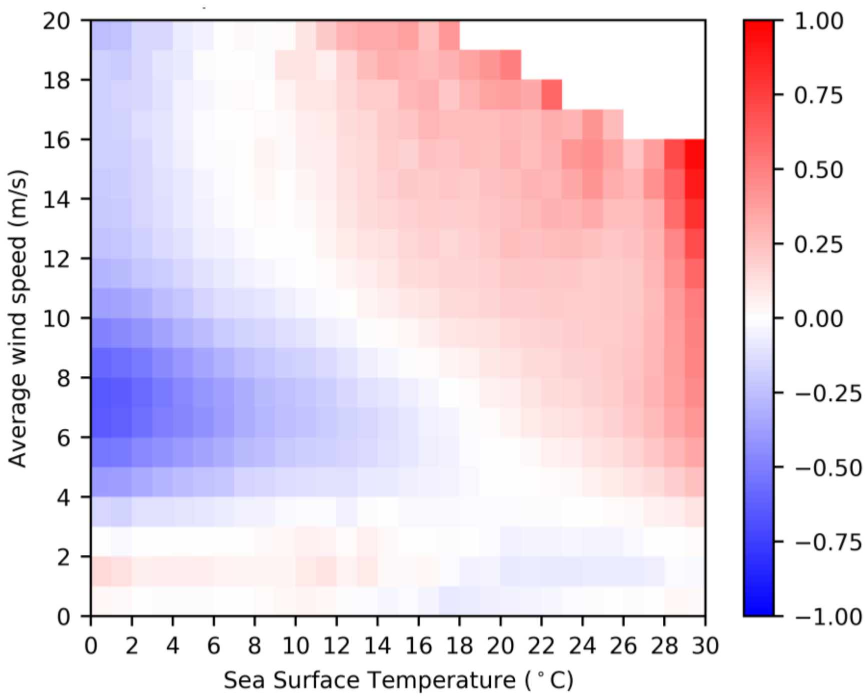
Vscat - Vnwp



SST effects on Ku-band backscatter measurements

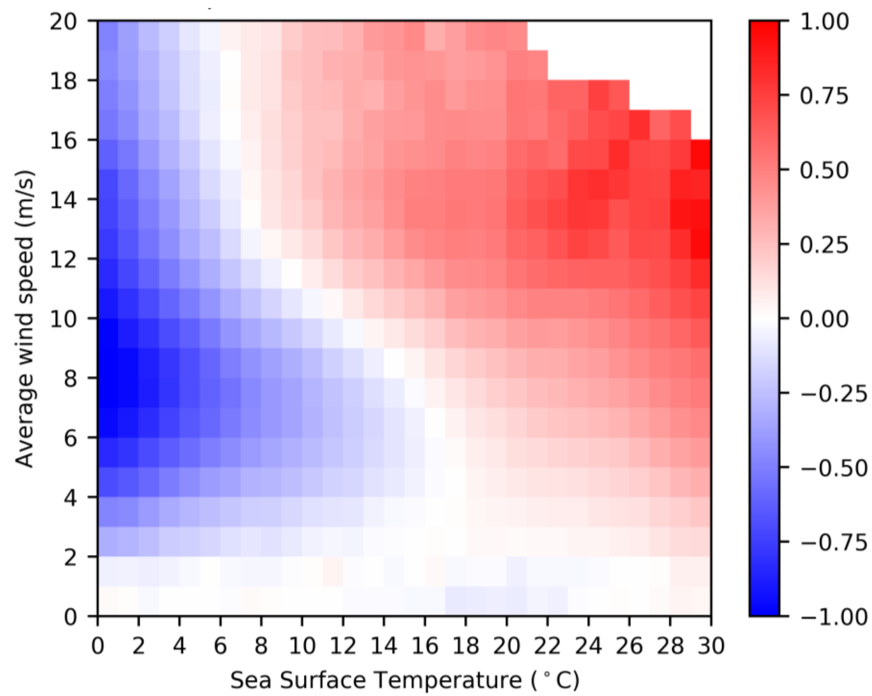
SST effects on Ku-band backscatter are wind speed dependent and more pronounced in VV than in HH at higher incidence angles!

SCATSAT/HH minus ASCATB



wind retrieval based on HH measurements

SCATSAT/VV minus ASCATB



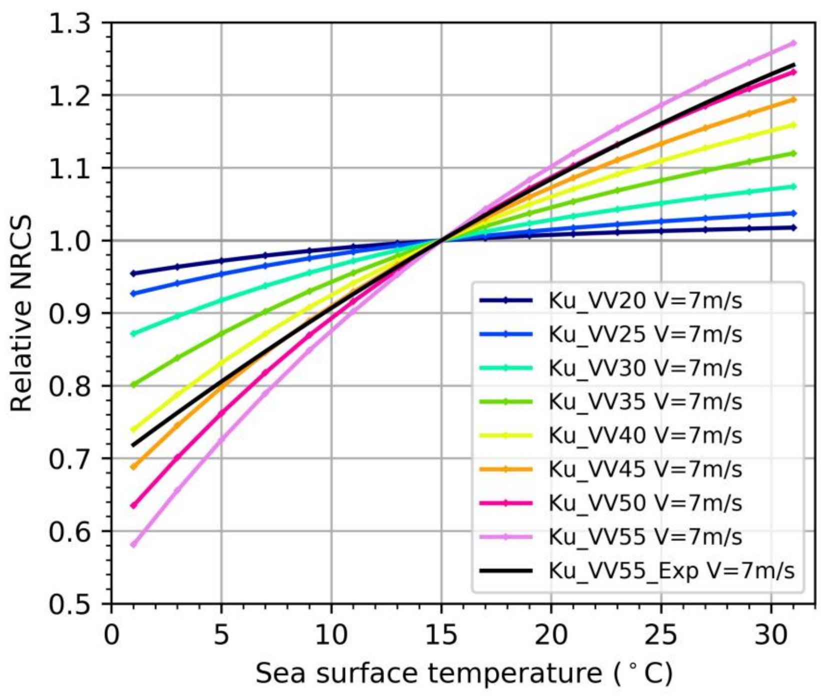
wind retrieval based on VV measurements

SST effects on Ku-band NRCS measurements

A **physics-based radar backscatter model (PRBM)** (Z. Wang, A. Stoffelen, et al., 2017) is used to simulate NRCS at various (U, θ, pol, SST) conditions.

PRBM = Wave spectrum (Kudryavtsev) + Analytical approximate model (SSA2D)

Relative variations of NRCS against SST at different incidence angles:



Ku-band, 7m/s, upwind, VV

NSCAT-5 GMF

- How to build an SST-dependent GMF for Ku-band scatterometer wind retrievals?

Basic formulation of an SST-dependent GMF

NSCAT-5 GMF:

Wind speed dependency

Wind direction modulation

$$\sigma_p^0(V,\phi,\theta,T) = A_{0p}(V,\theta,\mathrm{T}_0) * \sum_{i=1}^{N} A_{1p}(V,\theta)\cos(i\phi) * y_p(V,\theta,\Delta T) \qquad (1)$$

SST effects

$$y_p(V,\theta,\Delta T) = 1 + B_{1p}(V,\theta) * \Delta T + B_{2p}(V,\theta) * \Delta T^2 \qquad (2)$$

$$\Delta T = T - \mathrm{T}_0(\mathrm{V})$$

Wang et al., 2017, JGR.

Basic formulation of an SST-dependent GMF

NSCAT-5 GMF at fixed incidence angle,

i.e. for SCATSAT, RapidSCAT, QuikSCAT, etc.:

$$\sigma_p^0(V,\phi,T) = A_{0p}(V,\mathrm{T}_0) * \sum_{i=1}^{N} A_{1p}(V)\cos(i\phi) * y_p(V,\Delta T) \qquad (1)$$

SST effects

$$y_p(V,\Delta T) = 1 + B_{1p}(V) * \Delta T + B_{2p}(V) * \Delta T^2 \qquad (2)$$

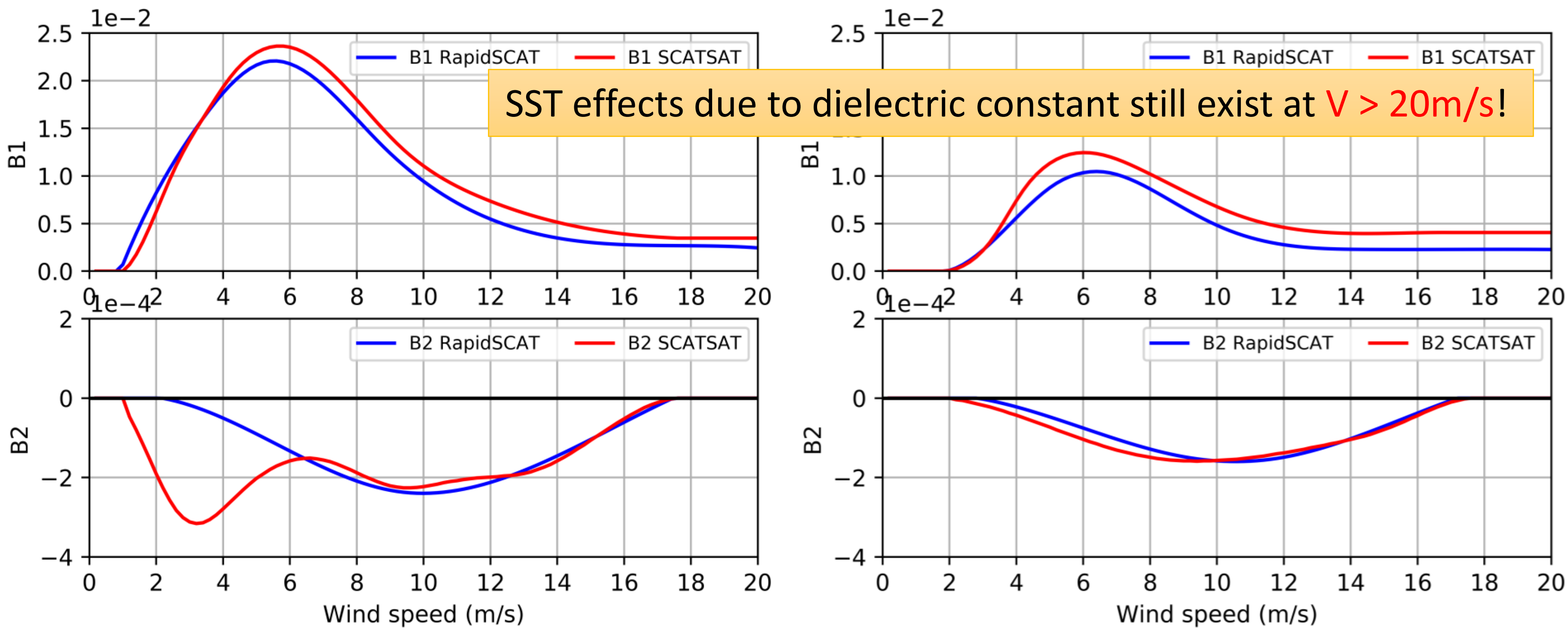
$$\Delta T = T - \mathrm{T}_0(\mathrm{V})$$

SST dependencies for RapidSCAT and SCATSAT measurements

$55.2 \pm 3.0°$ (VV)
$48.8 \pm 3.0°$ (HH)

RapidSCAT < SCATSAT

58° (VV)
49° (HH)



SST effects due to dielectric constant still exist at V > 20m/s!

VV

HH

For fixed incidence angle:

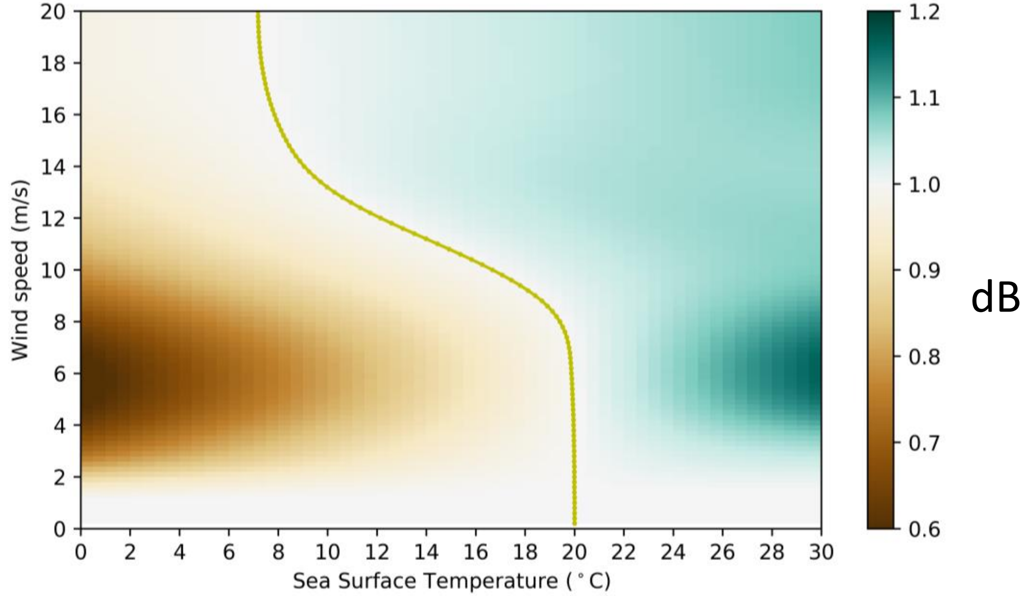
$$y_p(V, \Delta T) = 1 + B_{1p}(V) * \Delta T + B_{2p}(V) * \Delta T^2$$

5 times

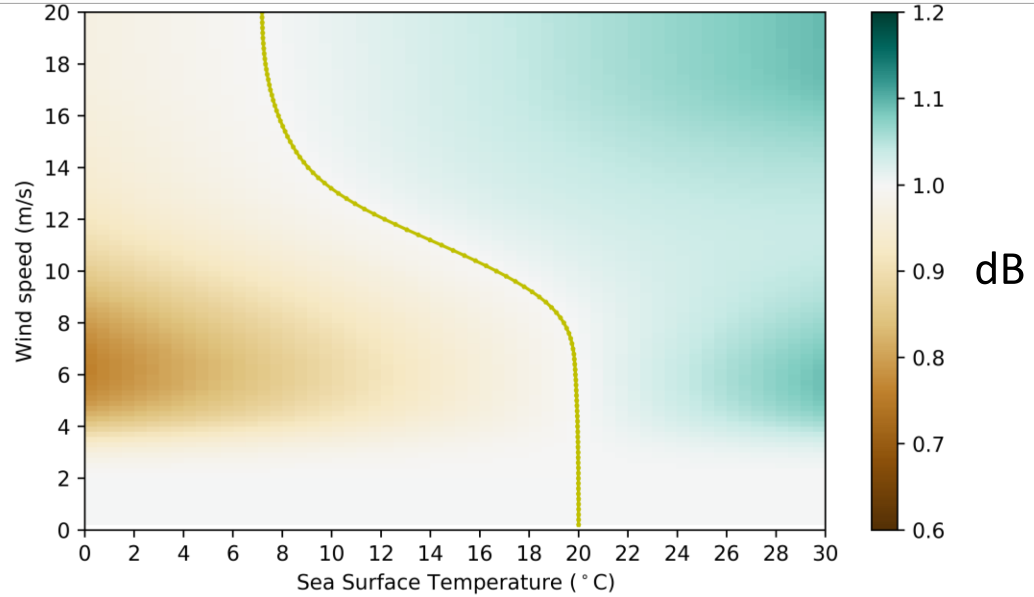
SST dependency for RapidSCAT

$$T_0(V)$$

VV

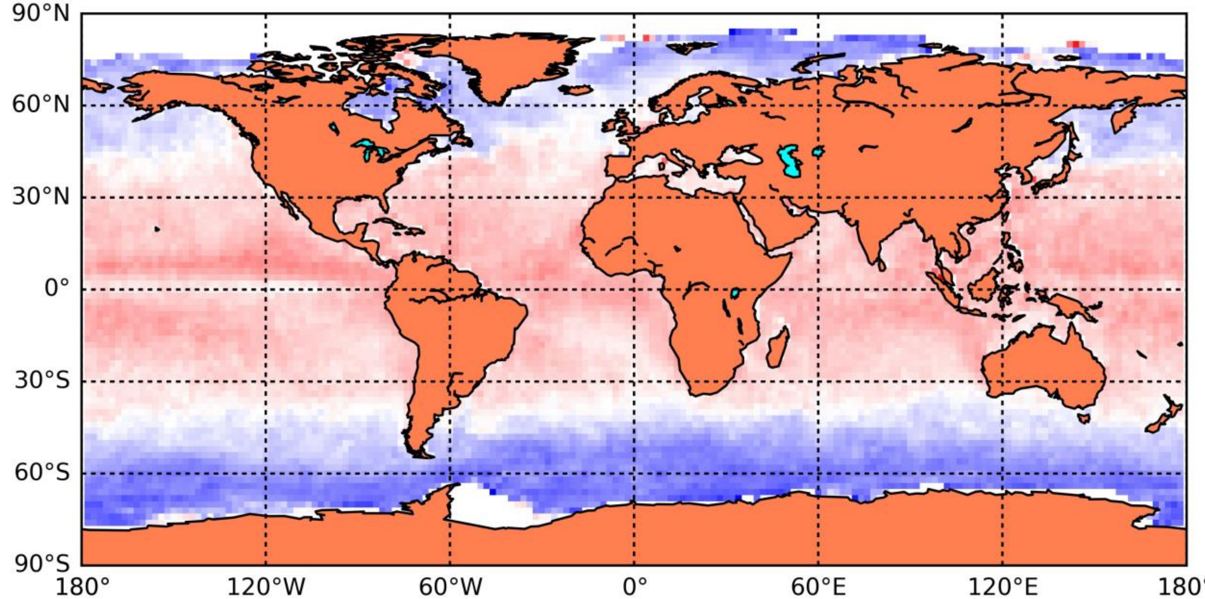


HH

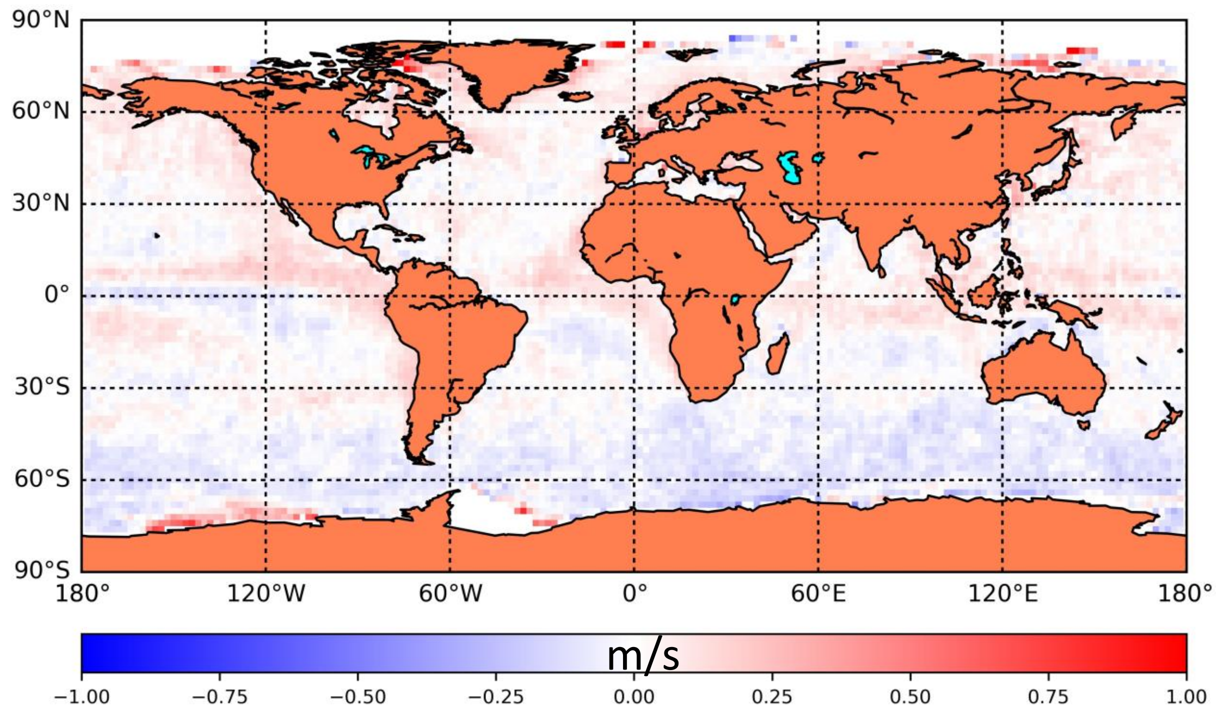


SCATSAT

NSCAT-4 GMF



NSCAT-5 GMF



SST effects on the future CFOSAT scatterometer

θ-dependent variation

For the first time, the WVCs are measured at diverse θ by the Ku-band SCAT.

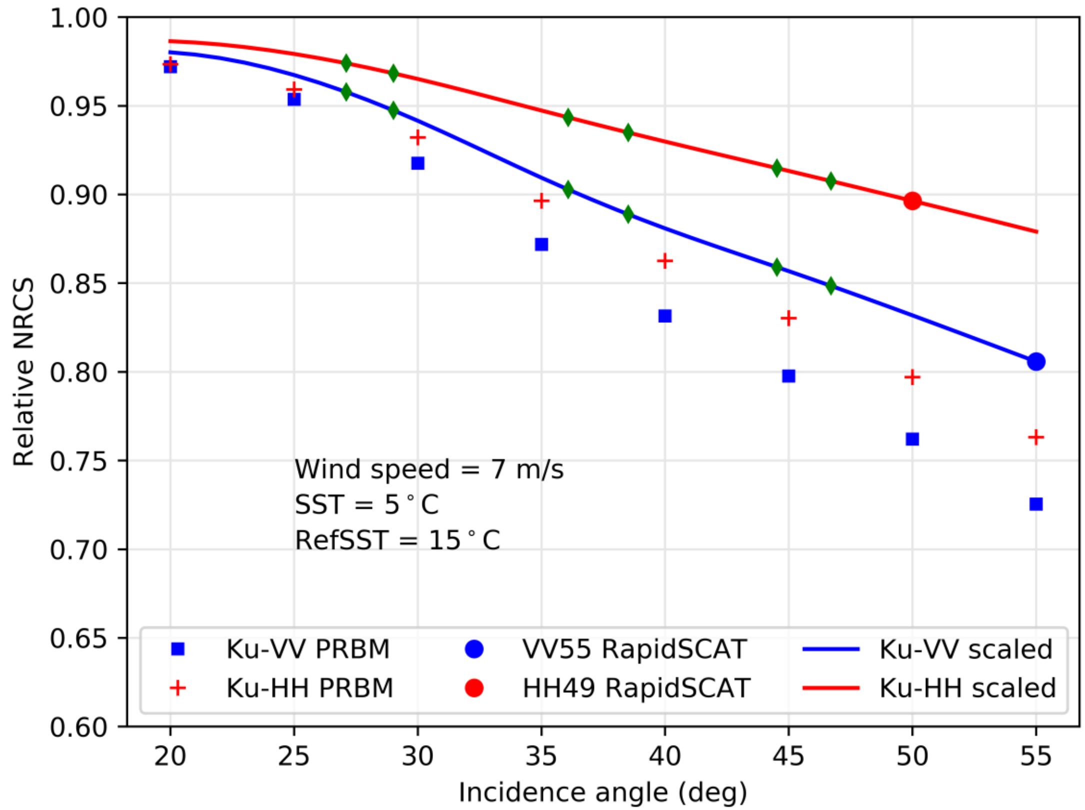
The SST effects are more pronounced at higher θ.

"+" and "■" are simulations at different θ based on the PRBM;

The "●" and "●" are empirical data for SST effects in VV55 and HH49 respectively.

Red and blue lines are scaled from simulated to empirical data, and **used as estimations of SST effects to the RFSCAT.**

12 "◆" indicating diverse θ in one WVC measured by the RFSCAT.

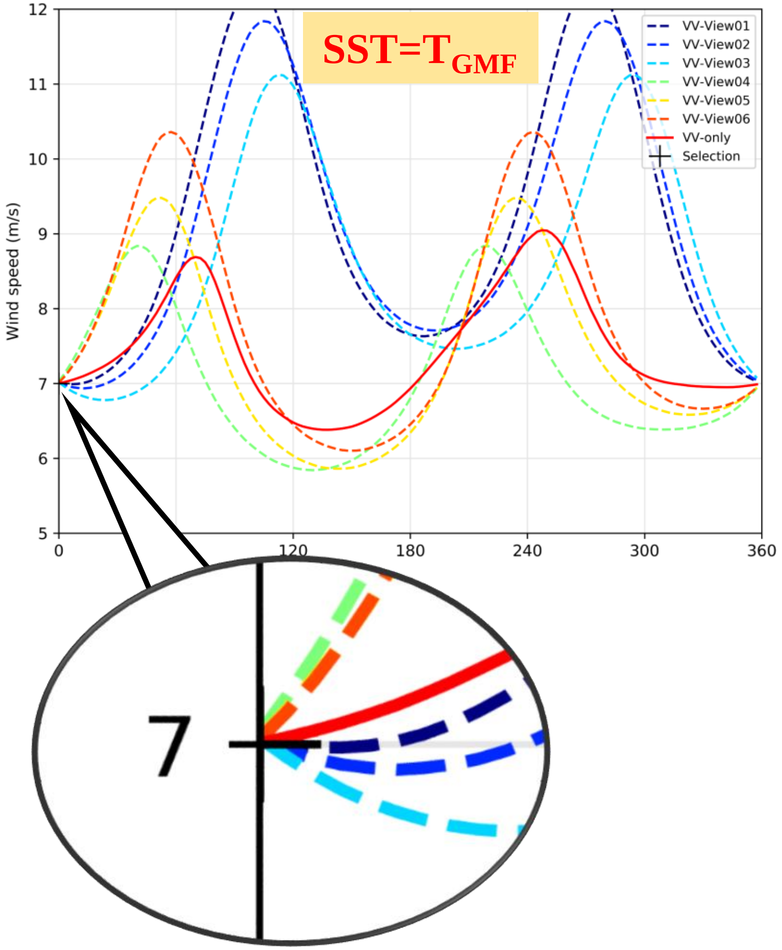


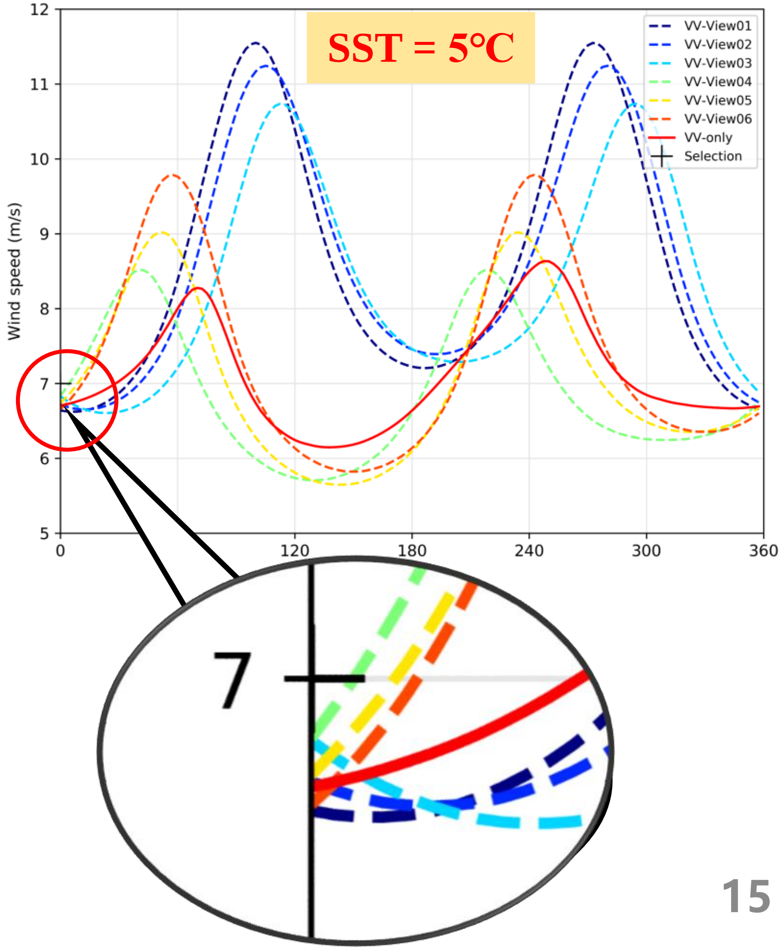
Ku-band, 7m/s, upwind, SST=5℃, VV(HH)

Noise-Free wind inversion **WITH** SST effects

For the CFOSAT/RFSCAT winds at low SST, the SST effects will cause:

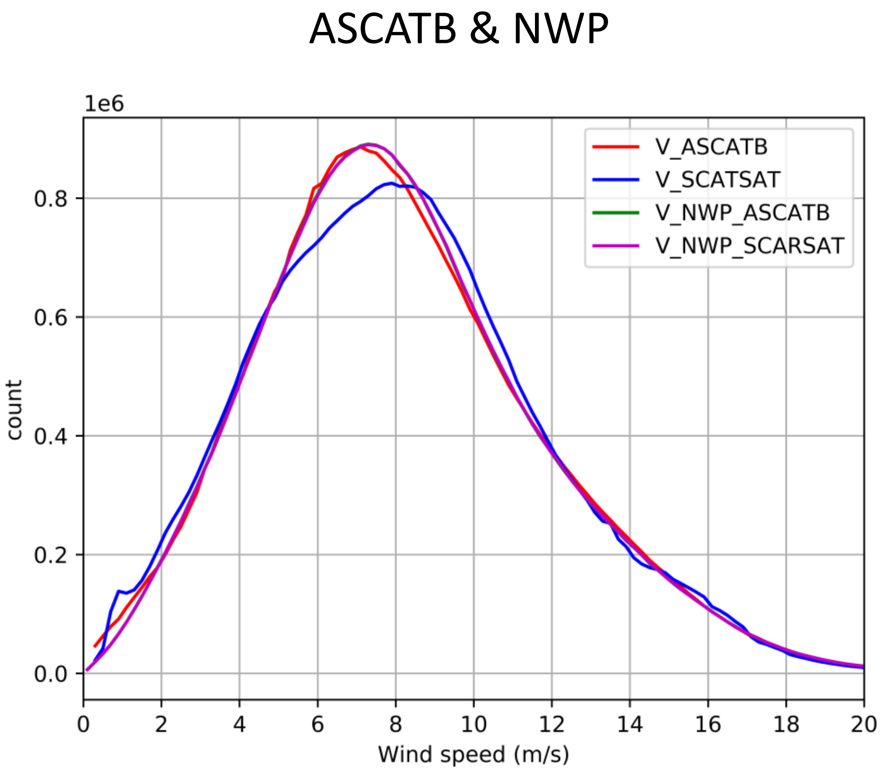
- **negative wind speed bias;**
- **larger wind inversion residuals.**

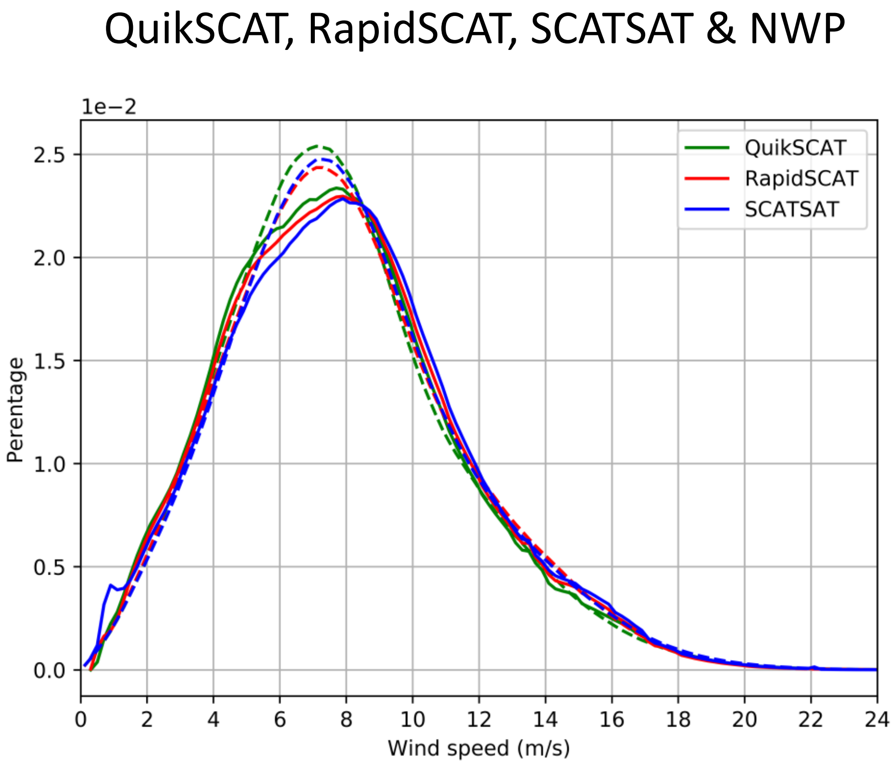




- Wind speed dependency as a function of wind speed and incidence angle!

Different wind speed PDFs!





CFOSAT/RFSCAT and HY2/SCAT will show similar problem!!!

A more accurate Ku-band GMF is urgently needed!

Conclusions and outlook

- SST-dependent GMFs have been developed for the Ku-band RapidSCAT and SCATSAT, and will be done for NSCAT and HY-2C/SCAT?

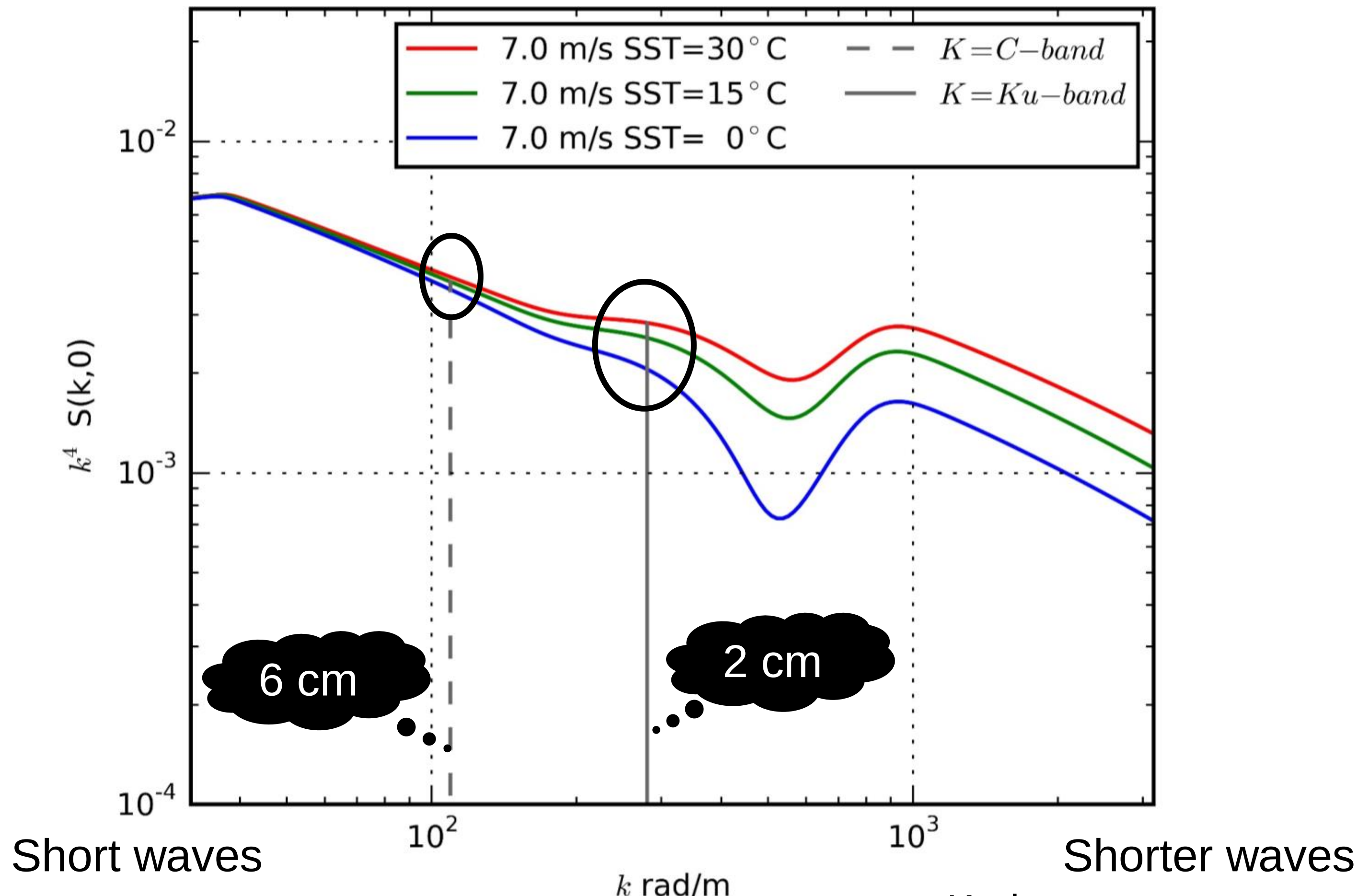
- NSCAT-5 GMF, including the SST parameter, is aimed to be used for wind retrievals from all Ku-band scatterometers. However, NSCAT-4 GMF errors that depend on wind speed, wind direction and incidence angle should be removed using one wind reference.

- The SST effects will cause disagreements between CFOSAT/RFSCAT measurements and NSCAT-4 GMF, and complicate the wind retrieval and QC processing.

Thank you for your attention!

Physics-based explanation

The dynamic viscosity of water decreases with SST, and, because of viscous dissipation, influences the distribution of gravity-capillary waves on the ocean surface.



Kudryavtsev curvature spectrum

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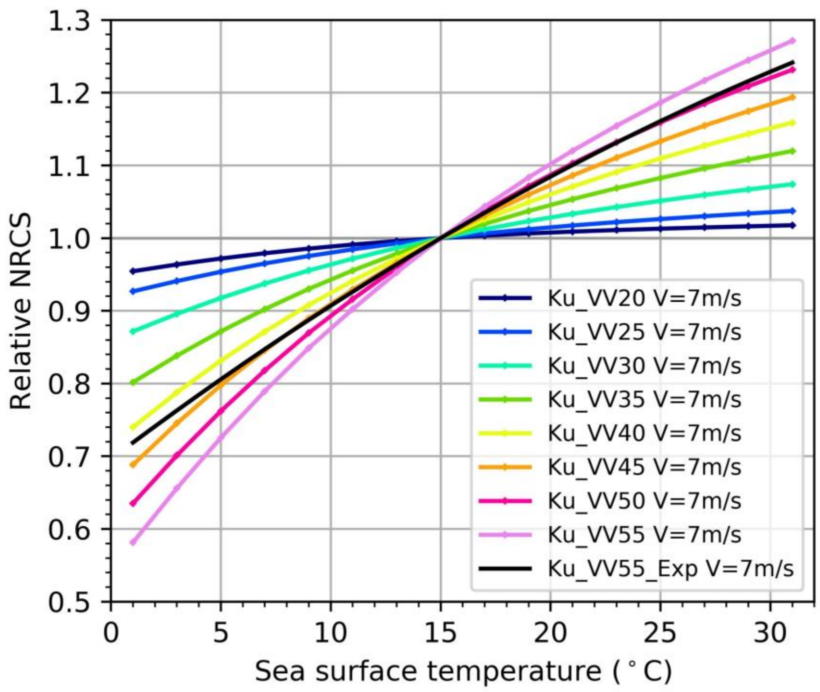
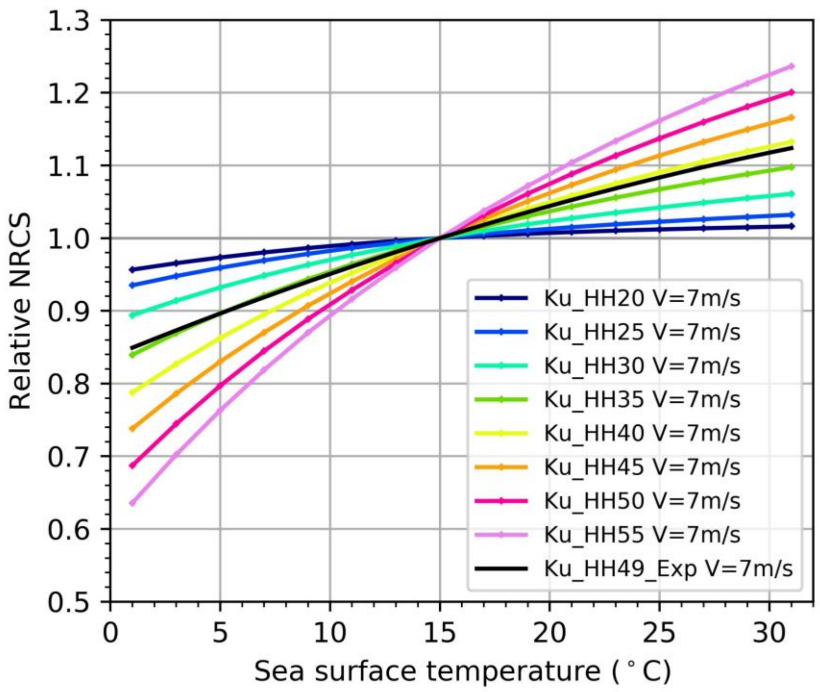


Ku-band, 7m/s, upwind, VV



Ku-band, 7m/s, upwind, HH