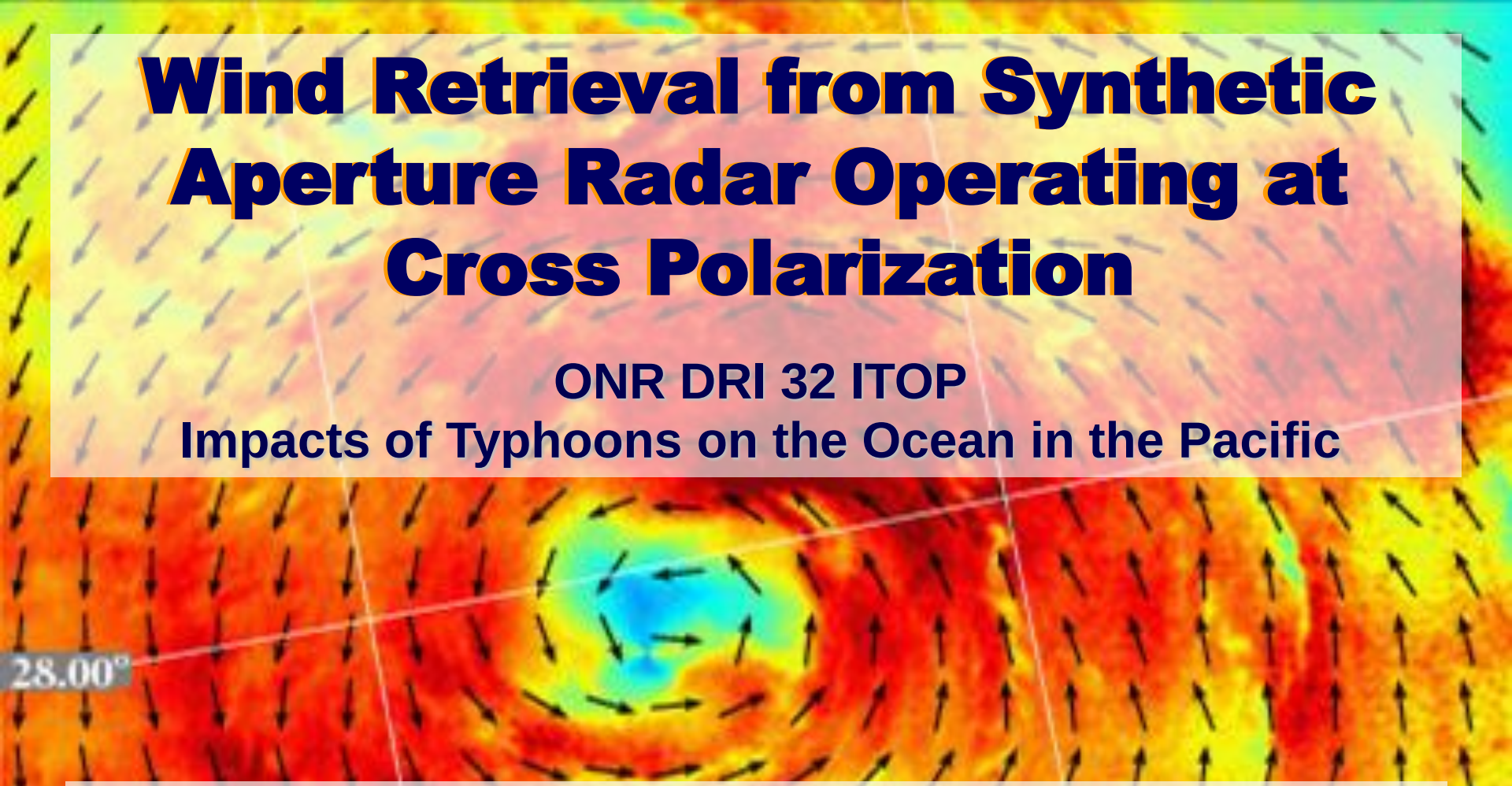
Wind Retrieval from Synthetic Aperture Radar Operating at Cross Polarization

ONR DRI 32 ITOP
Impacts of Typhoons on the Ocean in the Pacific



J. Horstmann[1,2], S. Falchetti[2] C. Wackerman[3], R. Foster[4], M. Caruso[5] and H. Graber[5]

[1]Helmholtz-Zentrum Geesthacht, Germany
[2]Center for Maritime Research and Experimentation, Italy
[3]General Dynamics, USA
[4]APL, University of Washington, USA
[5]Center for Southeastern Tropical Advanced Remote Sensing, USA

Why SAR for Wind Field Retrieval

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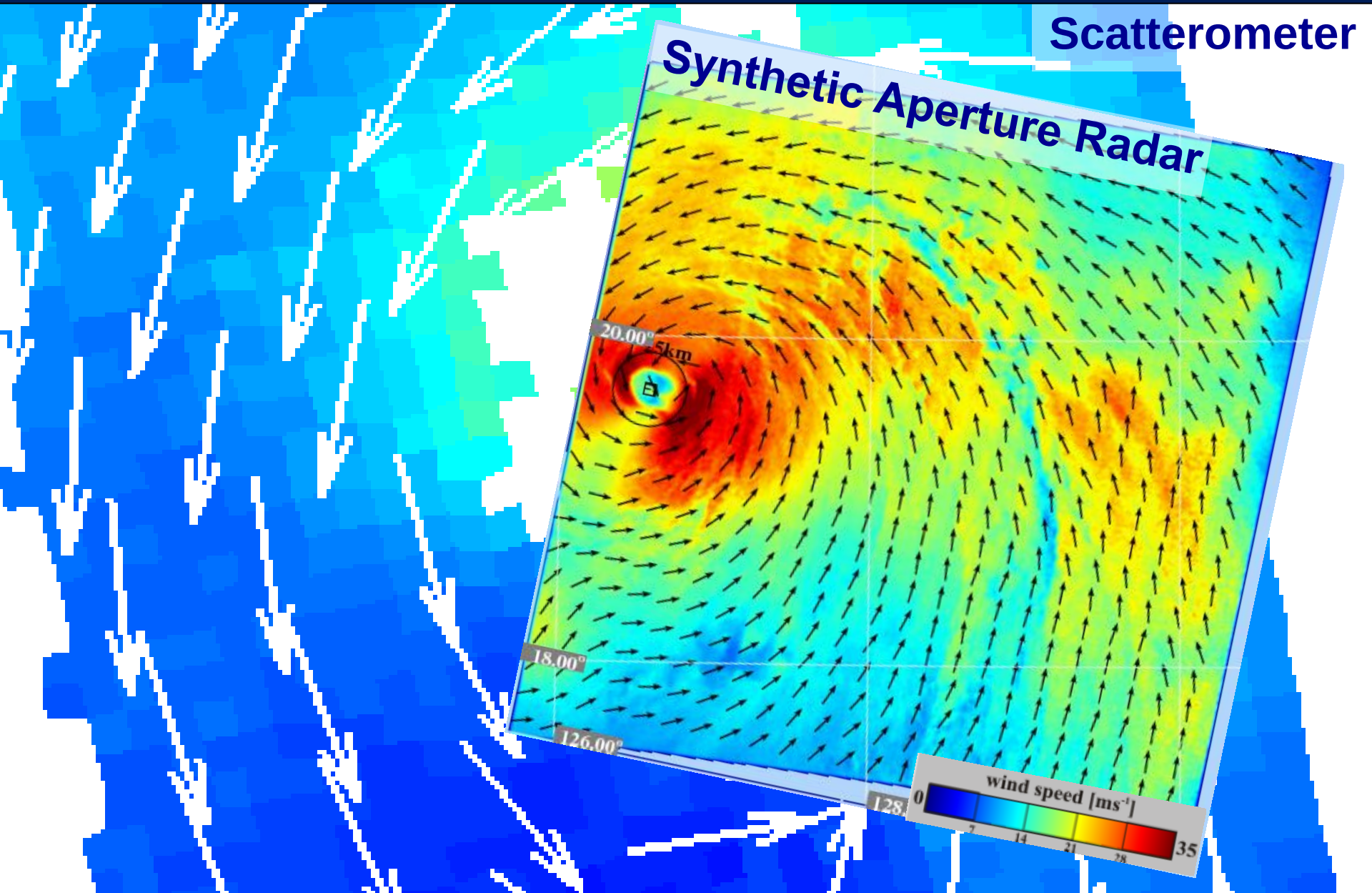
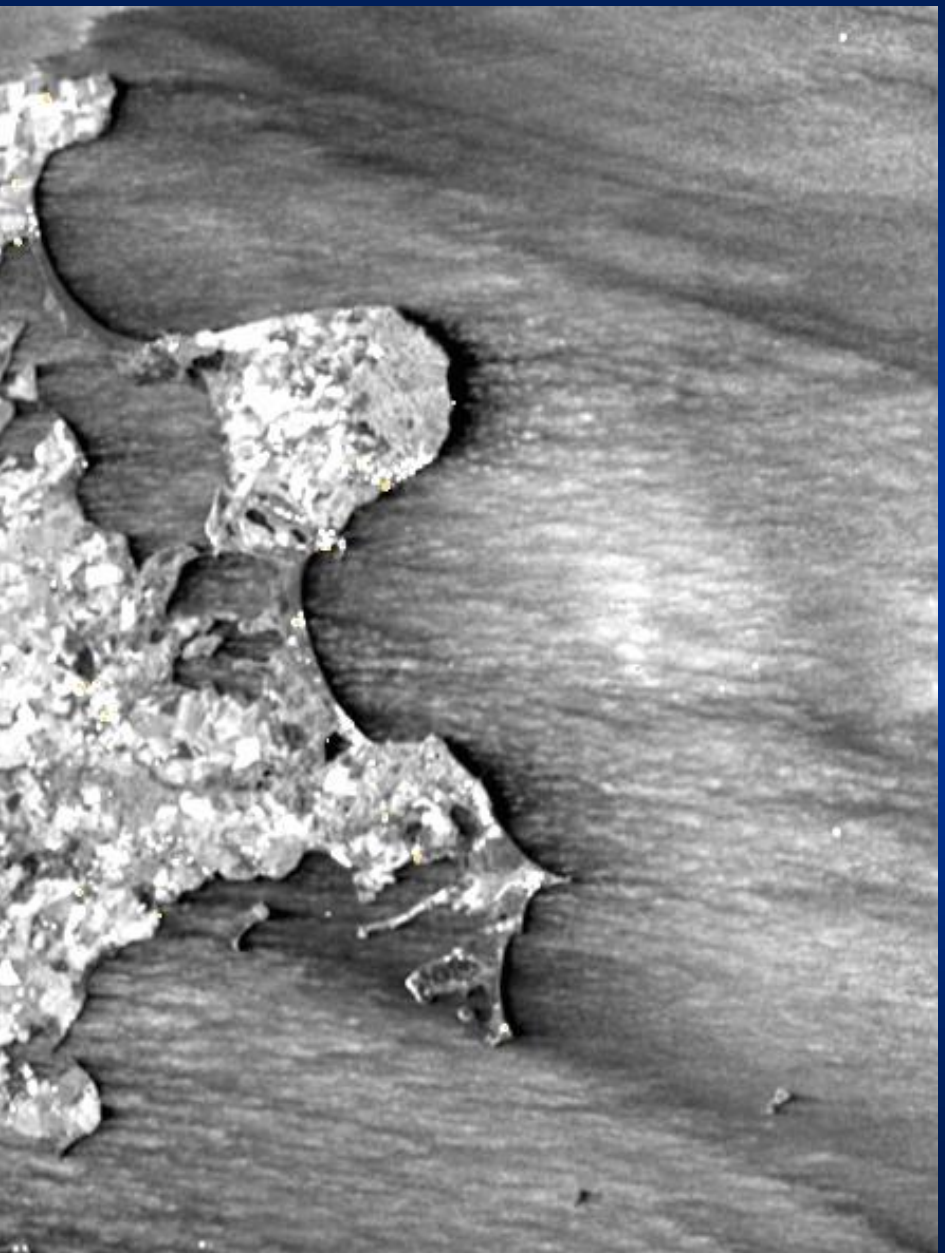


SAR Wind Direction Retrieval via the Local Gradient Method (WiSAR)

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

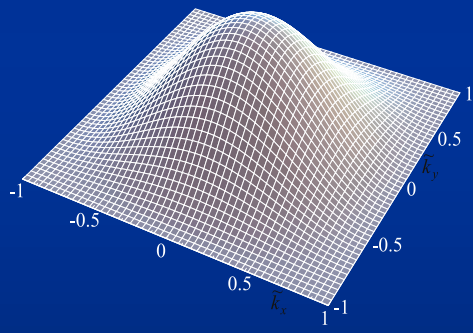


Local Gradient Method

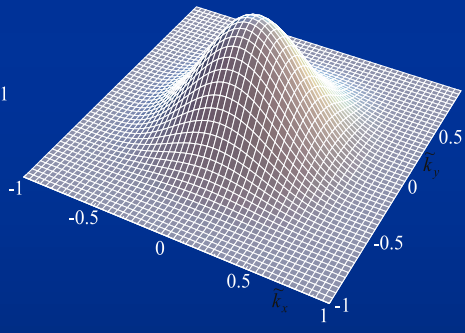
$(B^2 B_{xy}^4)^3$ → Sobel → $(B^2 B_{xy}^4)$ → Φ

Binomial filter

2 dim. B^2 Filter



2 dim. B^4 Filter



Optimized Sobel-Filter

3	0	−3
10	0	−10
3	0	−3

→

3	10	3
0	0	0
−3	−10	−3

→

SAR Wind Speed Retrieval via a Geophysical Model Function (GMF)

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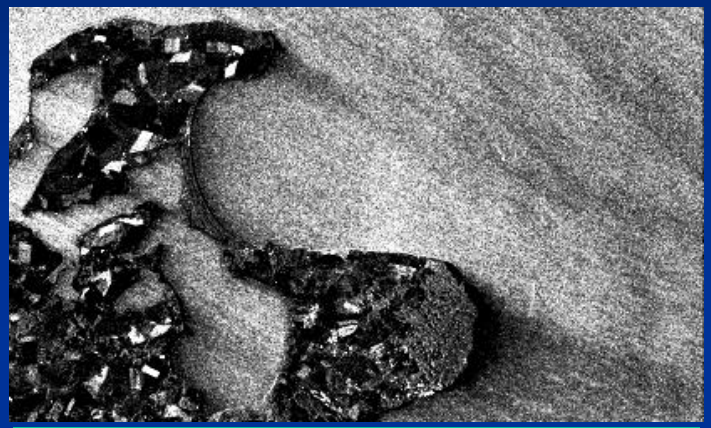
Geophysical Model Function

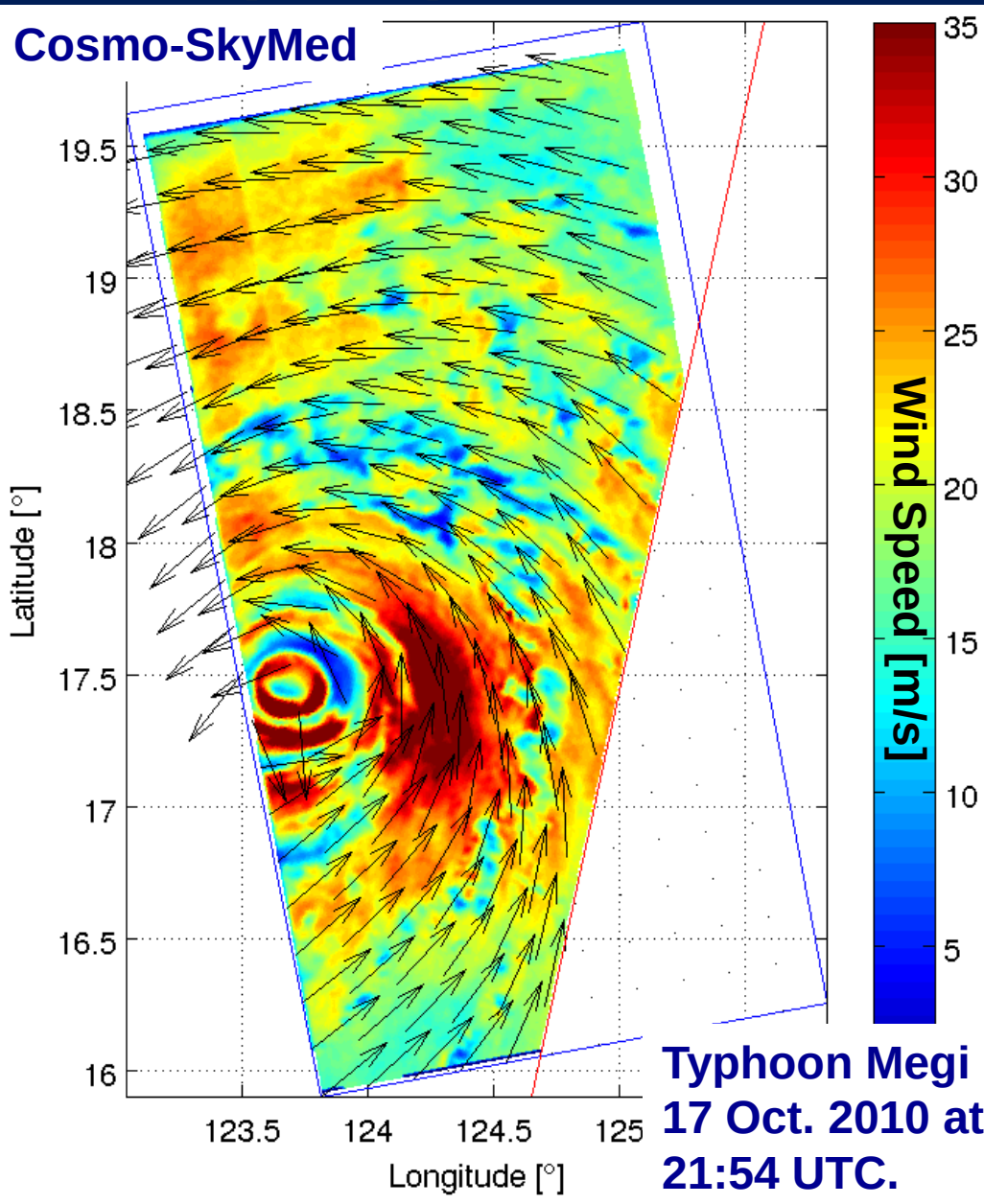


$$\sigma_0^{pol} = a(\theta)u^{\gamma(\theta)}[1 + b(\theta)\cos\phi + c(\theta)\cos(2\phi)]$$

Φ θ u_{10}

GMF for C-, X- and L-band

σ_0



Typhoon Megi
17 Oct. 2010 at
21:54 UTC.

SAR-Retrieved Winds (co-pol) in Comparison to QSCAT and SFMR

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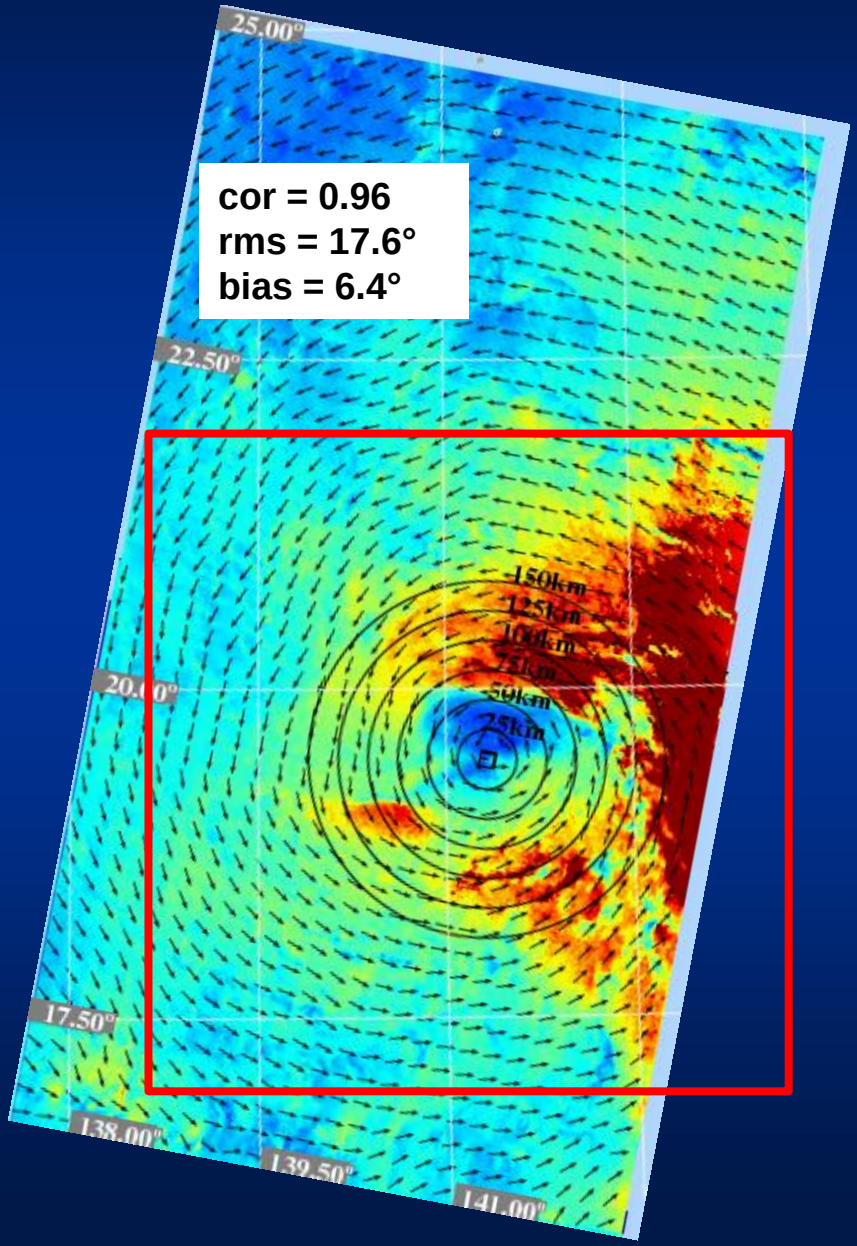
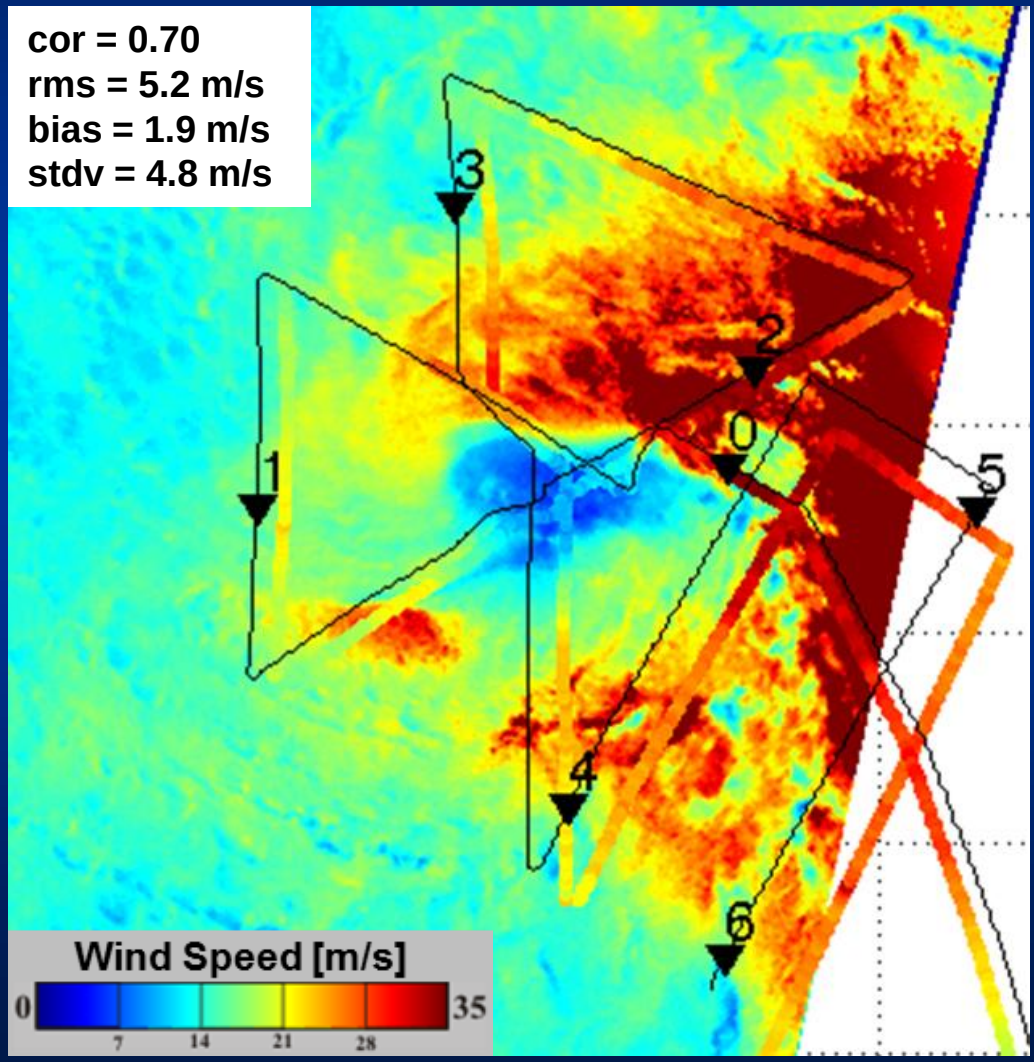
Zentrum für Material- und Küstenforschung

Typhoon Malaksa
20 Sep. 2010 at 20:29 UTC





Estimation of Wind Field Uncertainties and GMF Limitations

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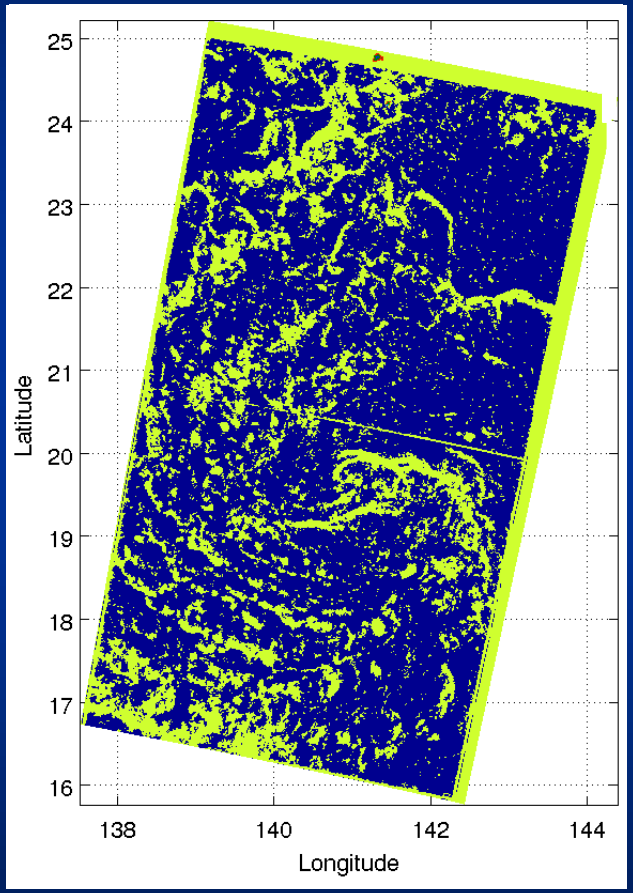
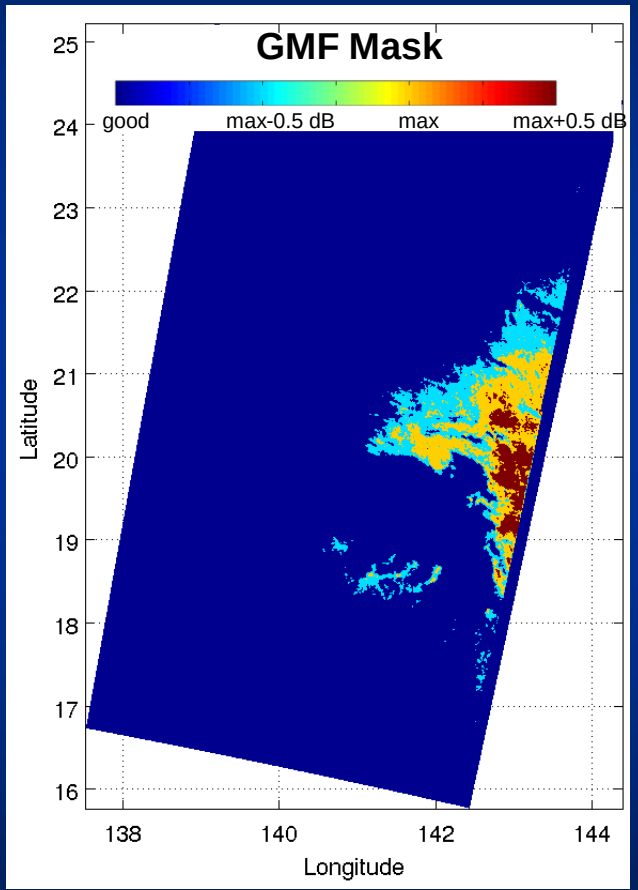
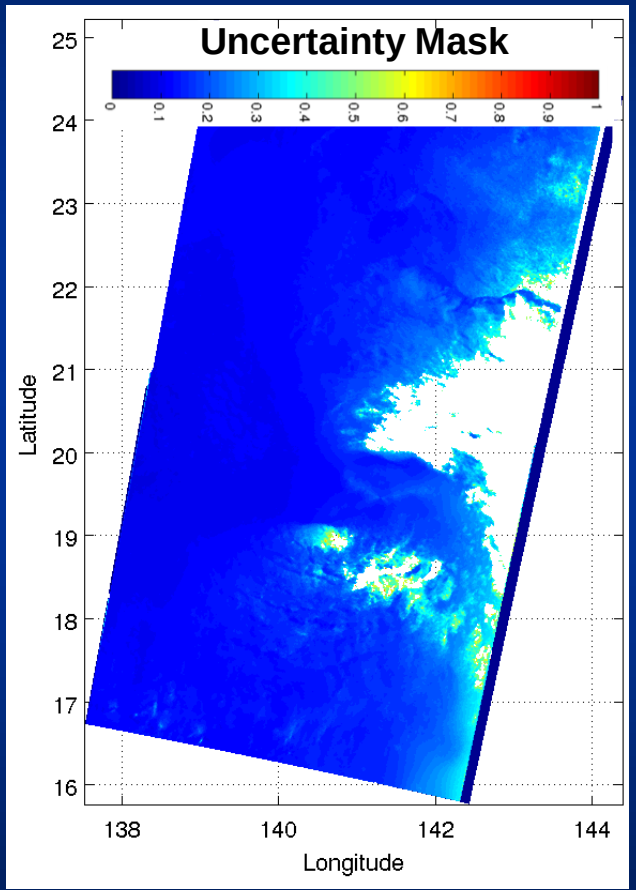


SAR wind field



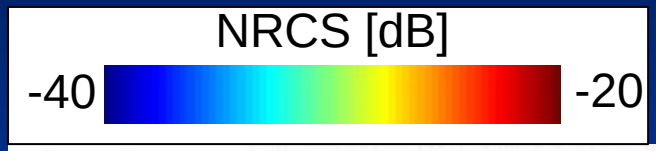
Limitation of GMF definition

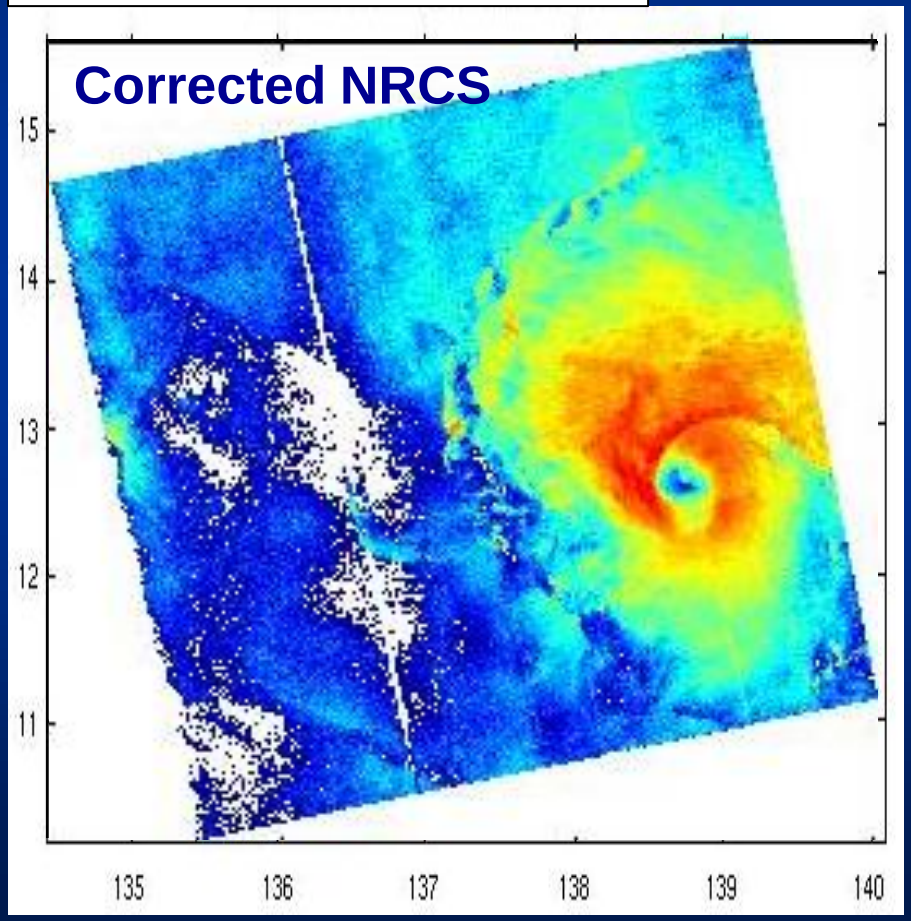


Wind speed uncertainty

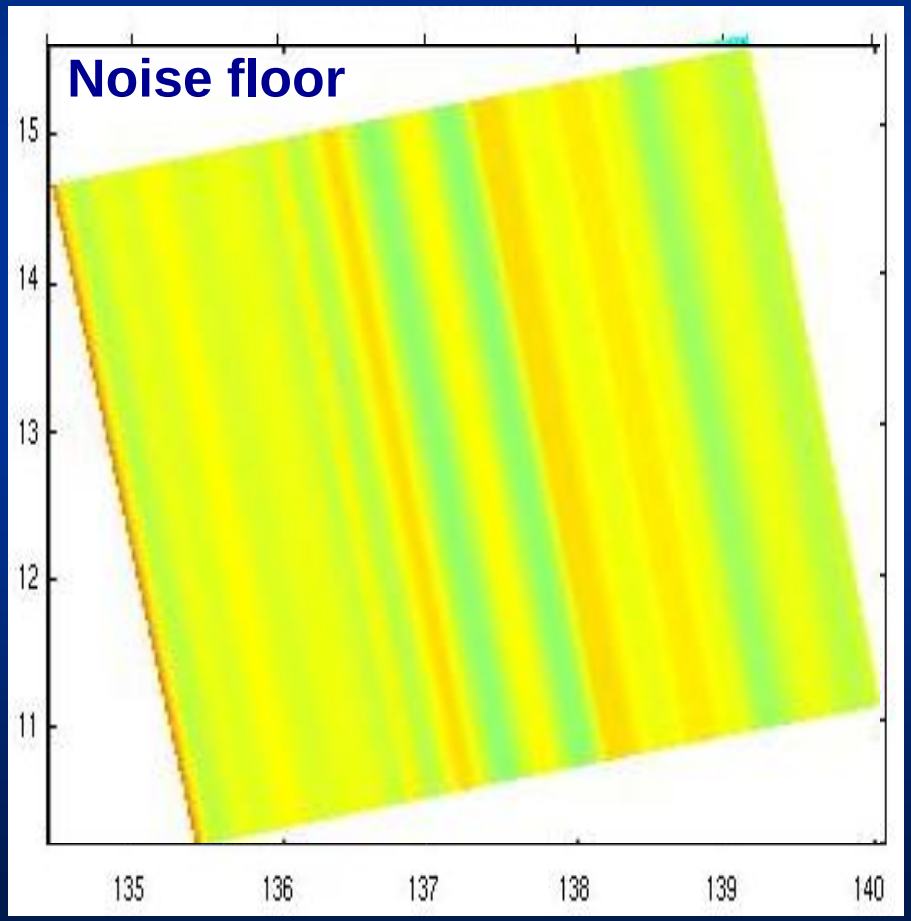
Noise Correction of Radarsat-2 Cross Pol NRCS

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung





Radarsat-2 HV image of Typhoon Megi 17. Sep 2010



Dependence of NRCS on Wind Speed (Including Noise Floor)

Helmholtz-Zentrum Geesthacht
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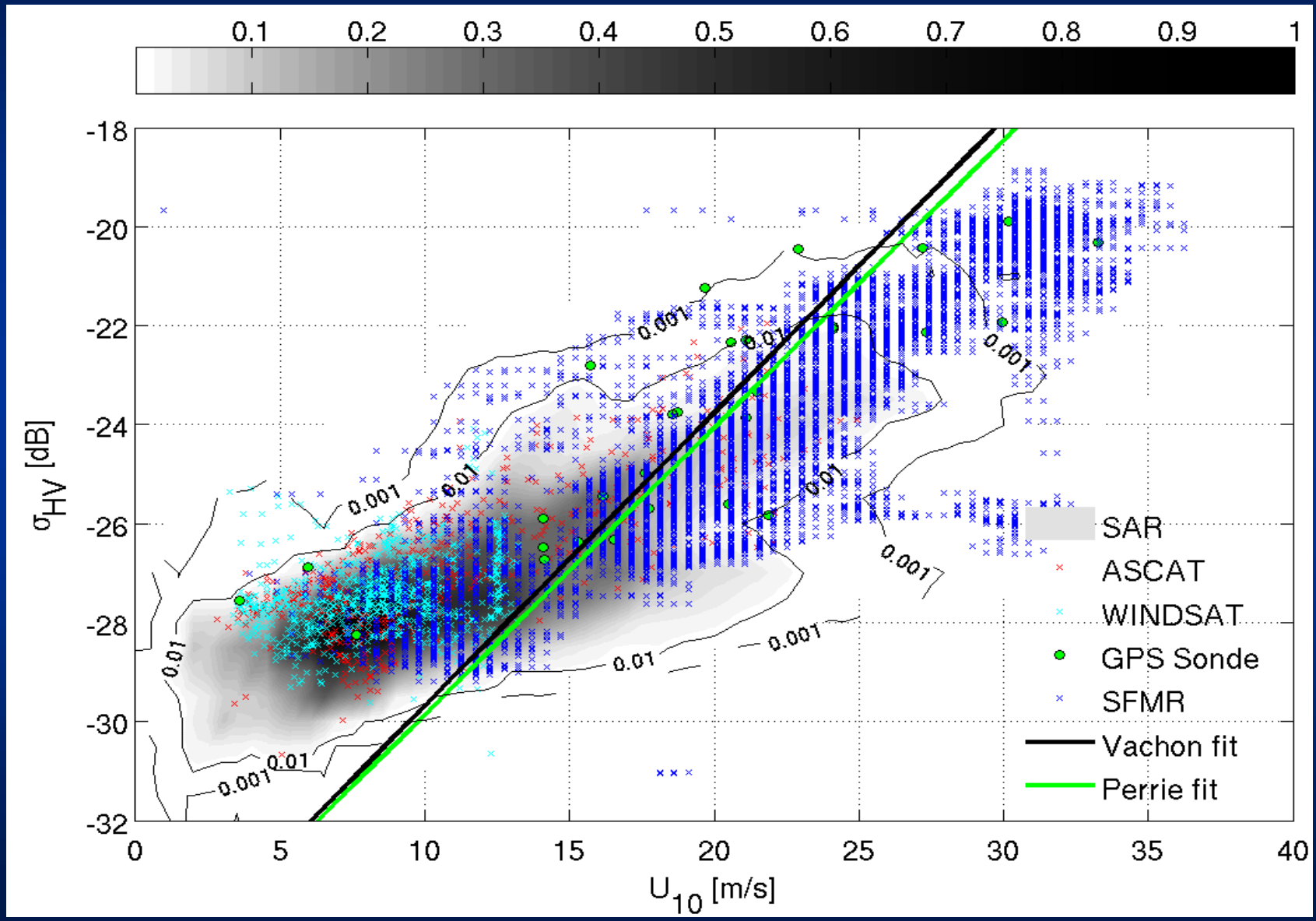
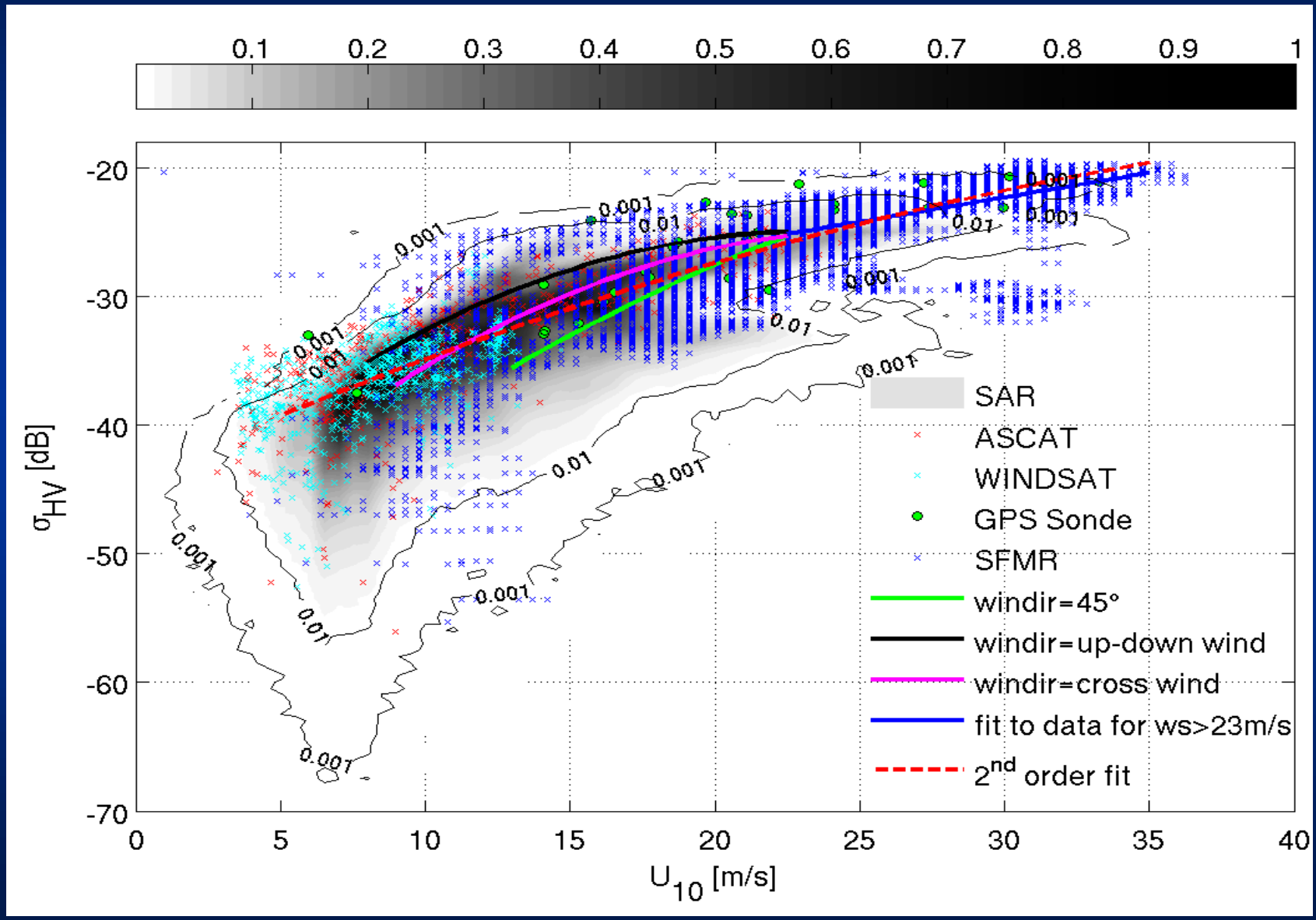


Dependence of NRCS on Wind Speed (Noise Floor removed)

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Additional Dependencies of Cross-pol NRCS

Helmholtz-Zentrum Geesthacht
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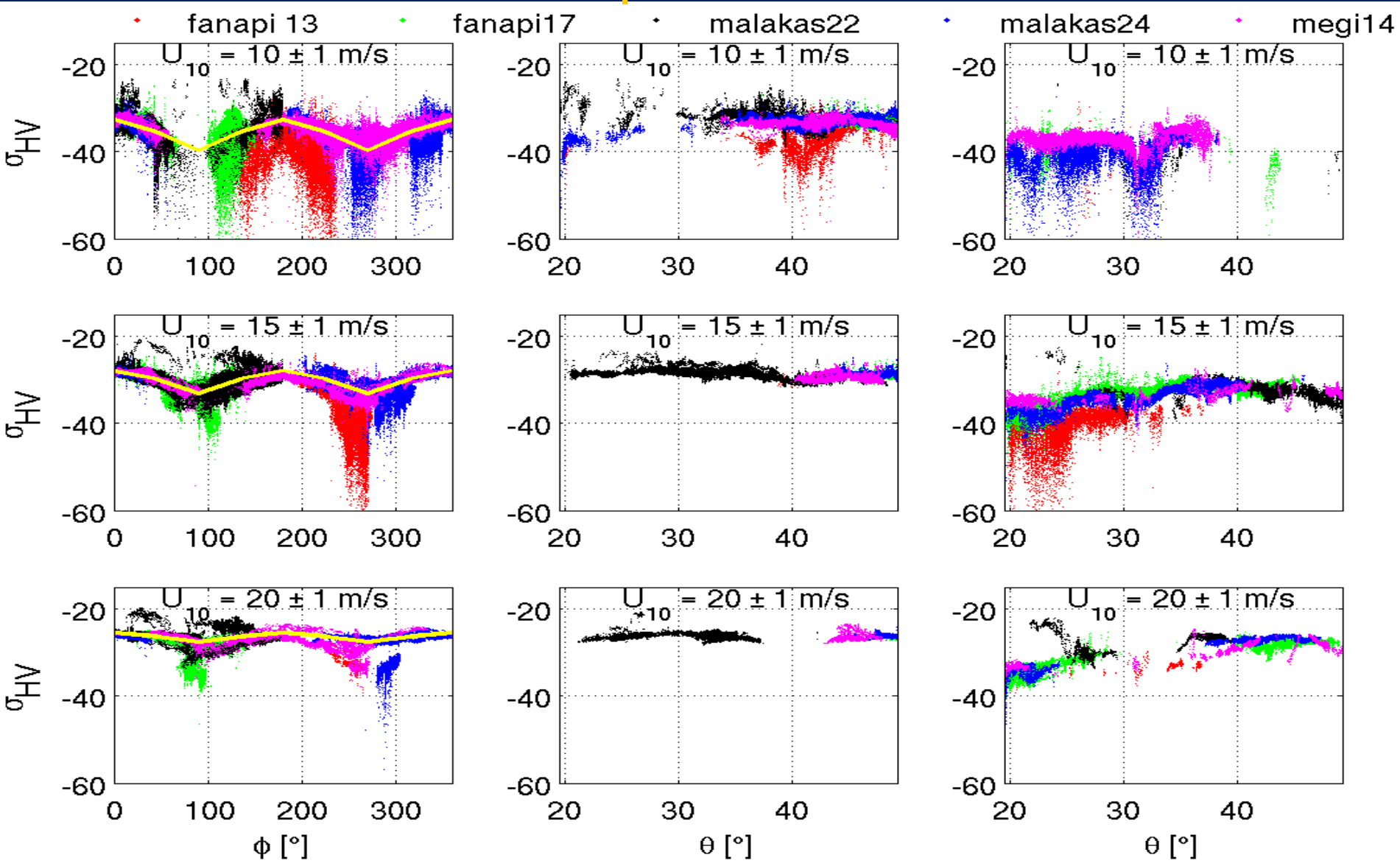

Modelling of the NRCS Excluding Cross Talk

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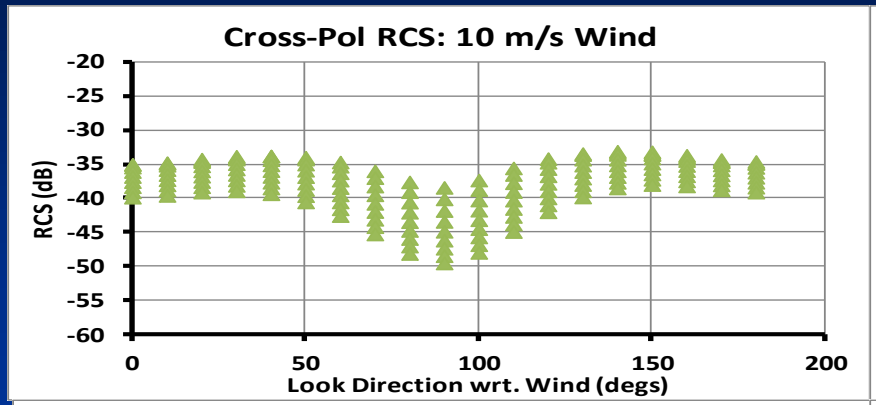
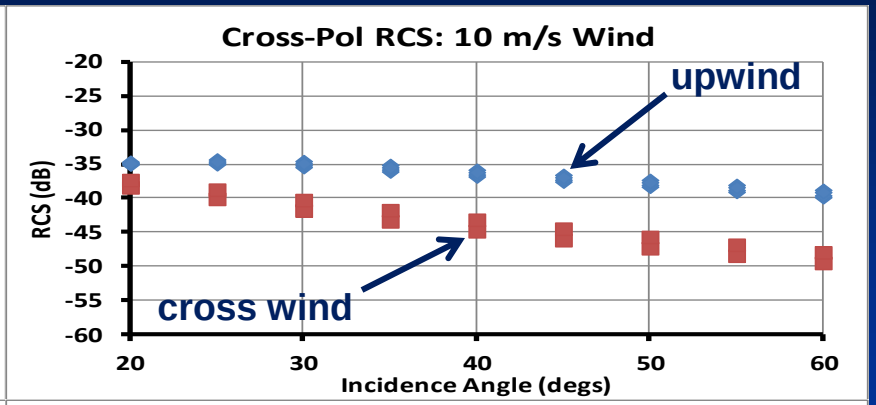
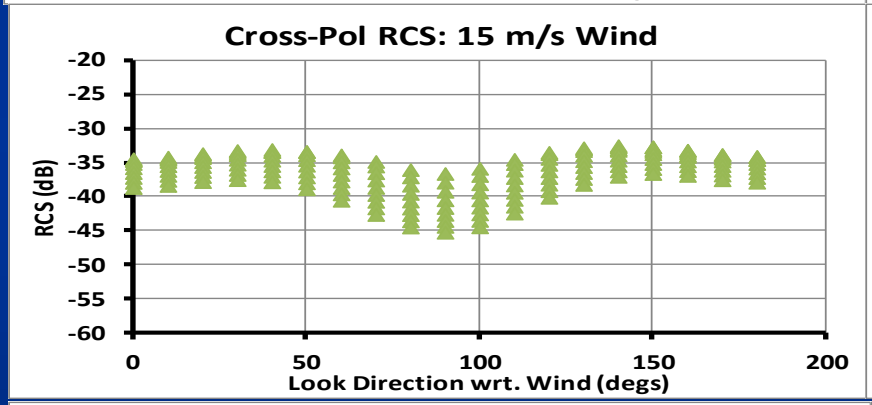
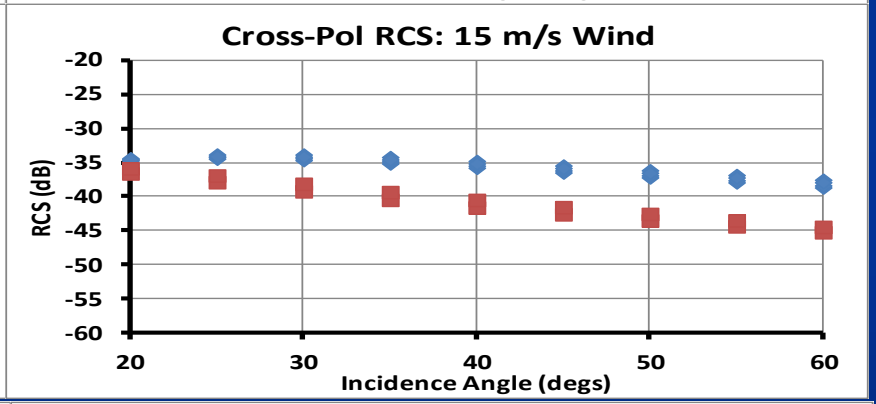
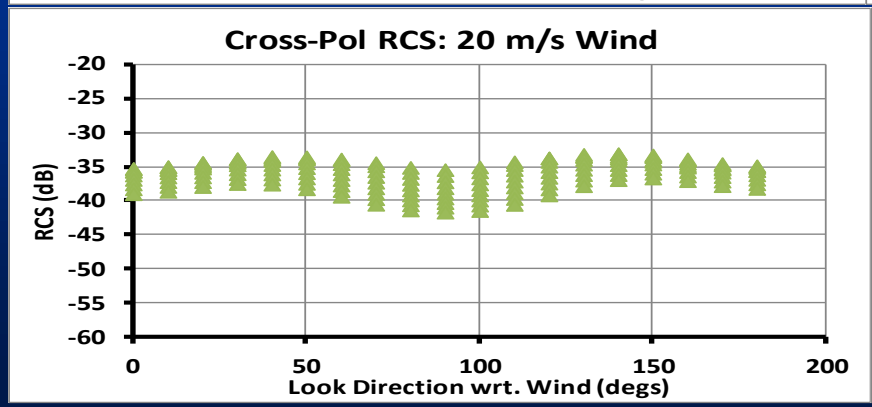
Zentrum für Material- und Küstenforschung

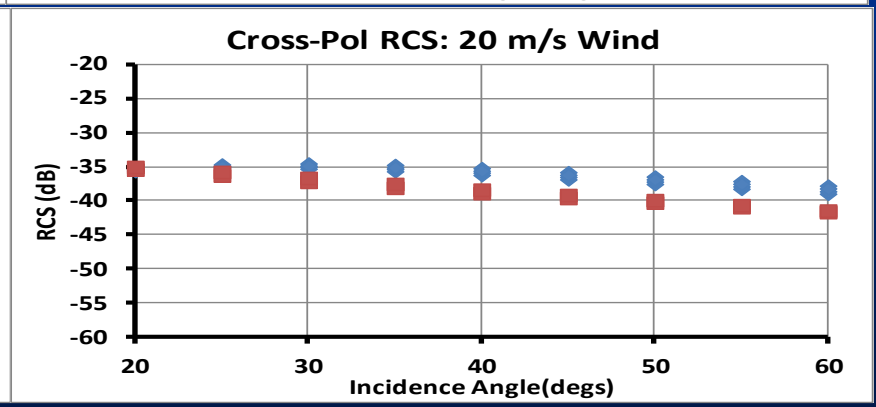






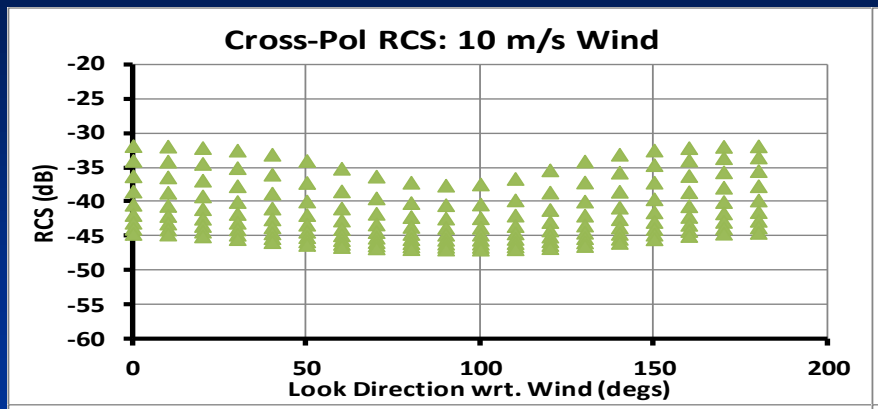


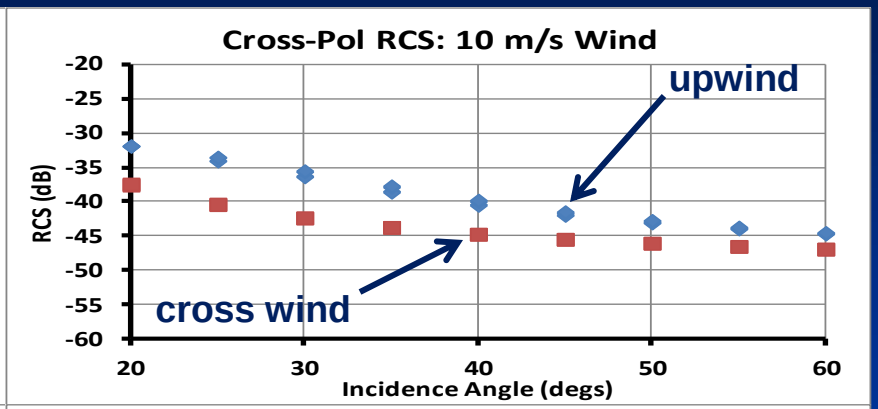


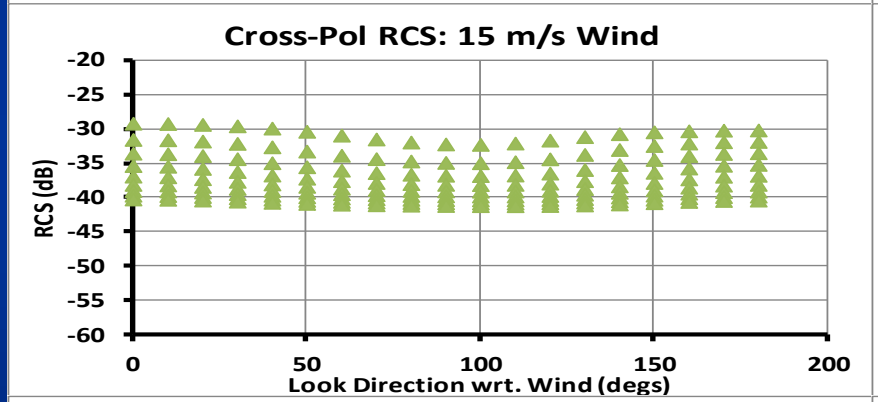


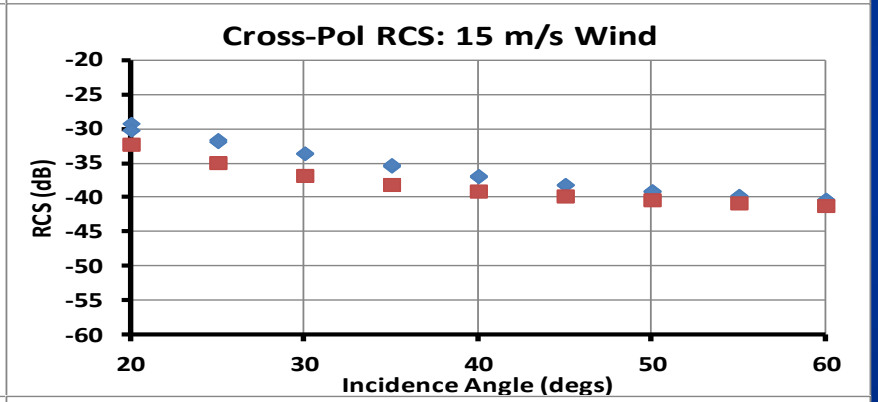
Modelling of the NRCS Including Cross Talk (-32 dB Isolation)

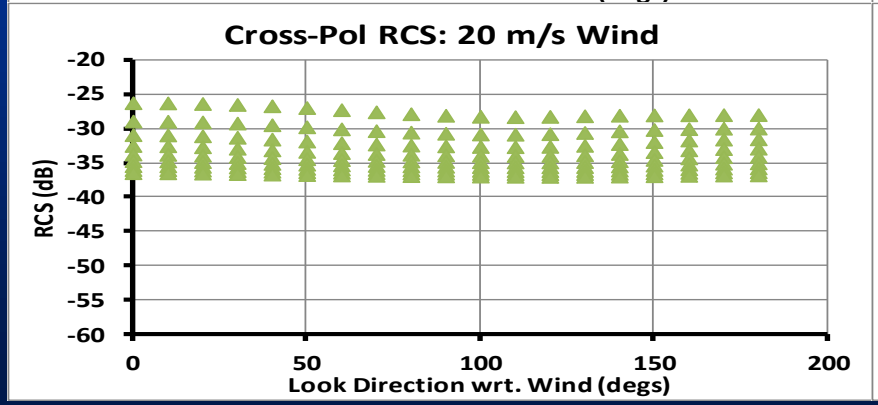
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

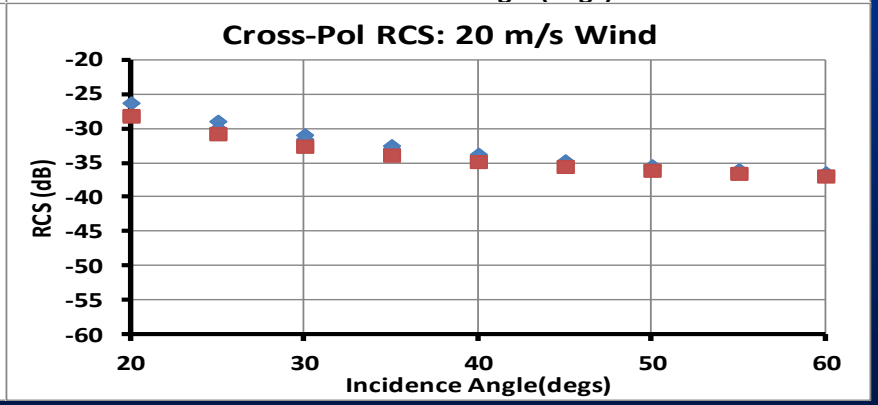












Radarsat-2 Crosspol (HV) Retrieved Wind Speeds

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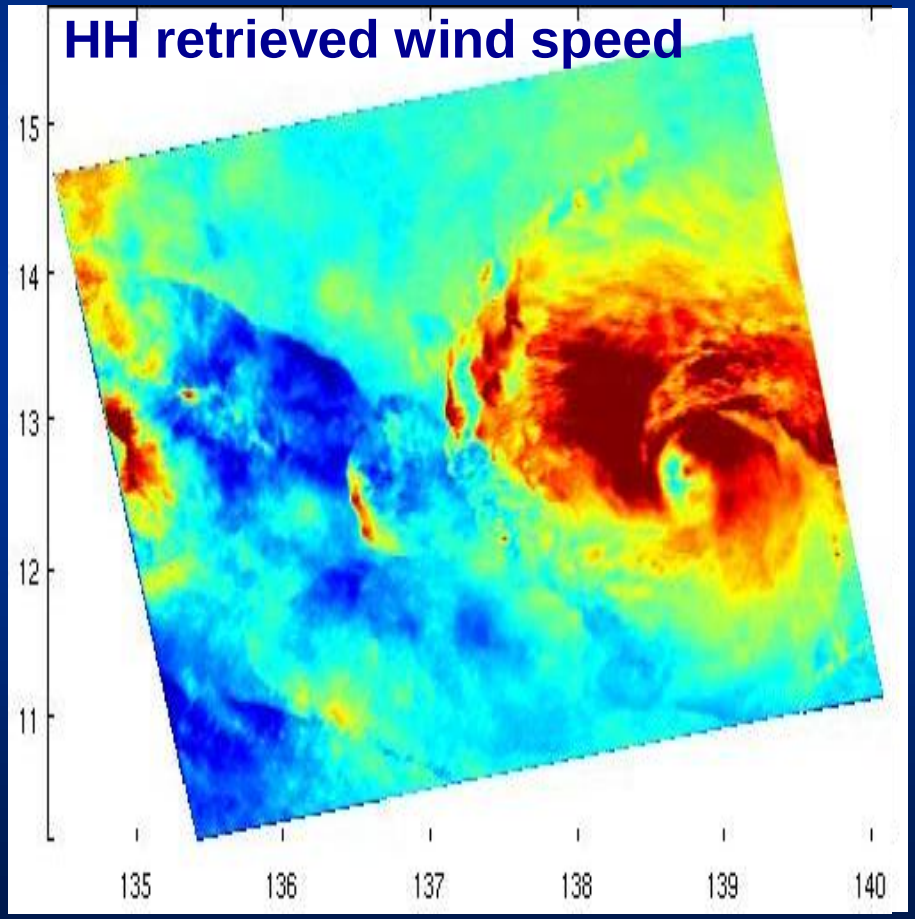
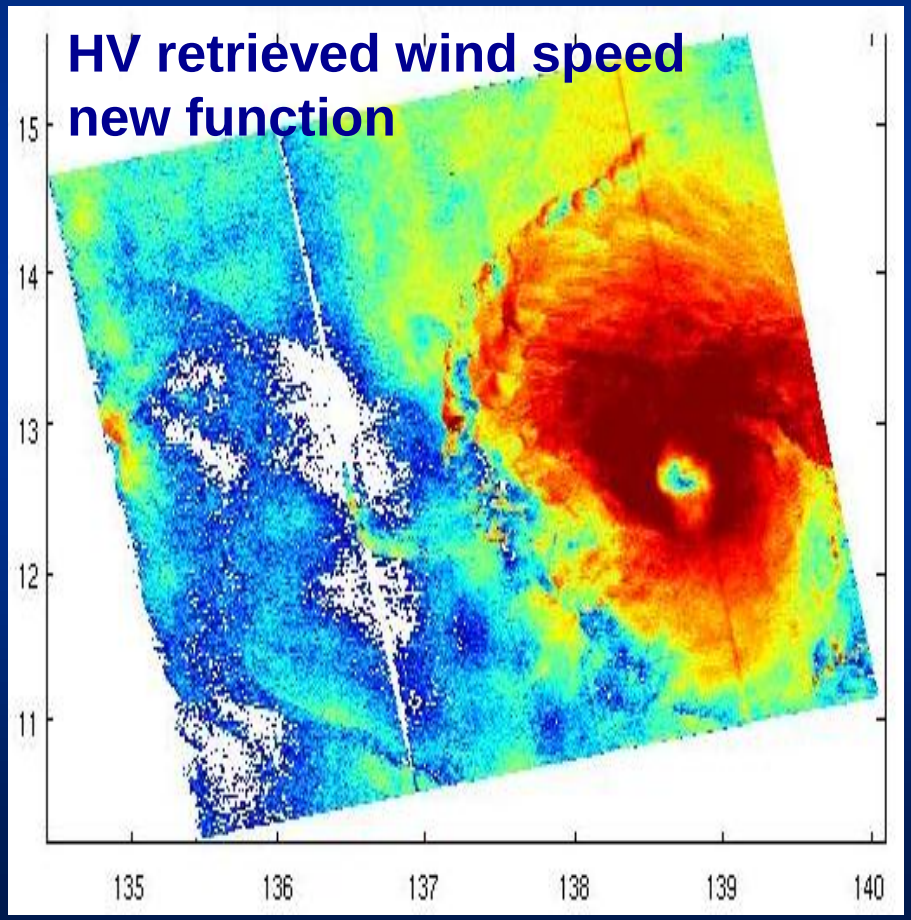
Zentrum für Material- und Küstenforschung

Radarsat-2 HV image of Typhoon Megi 17. Sep 2010

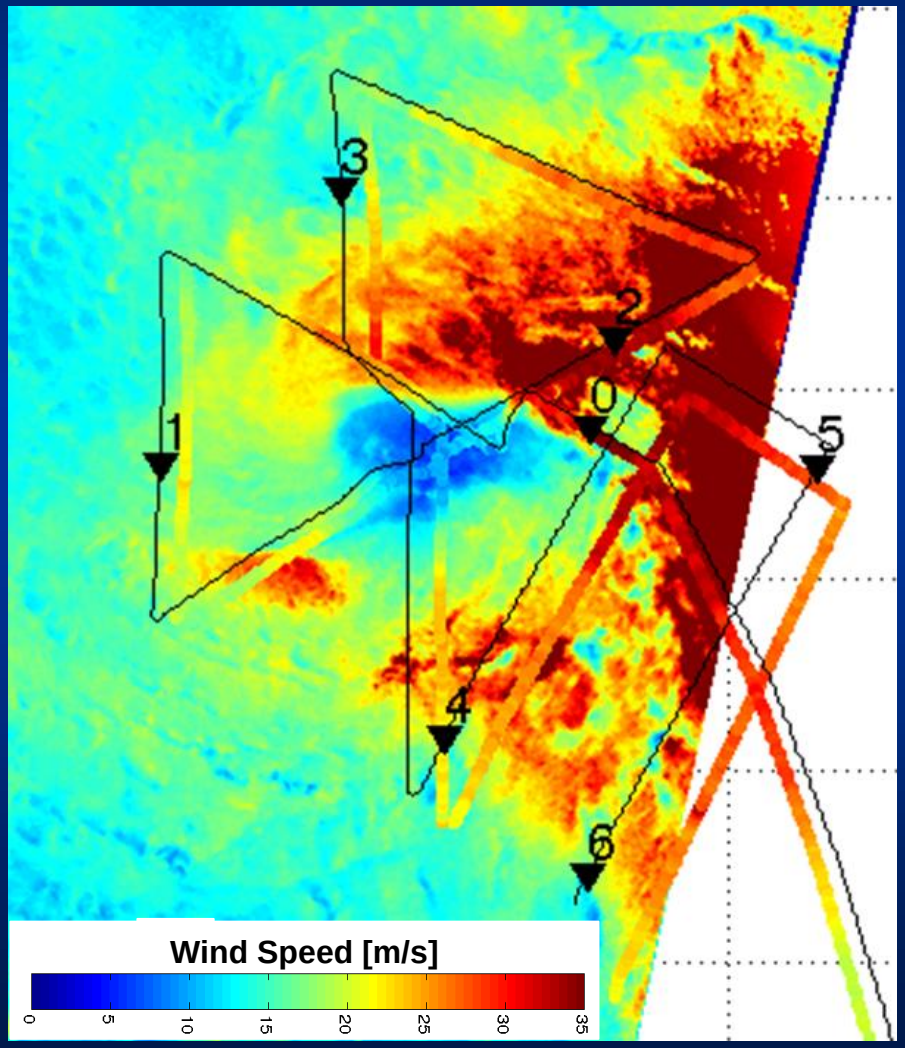


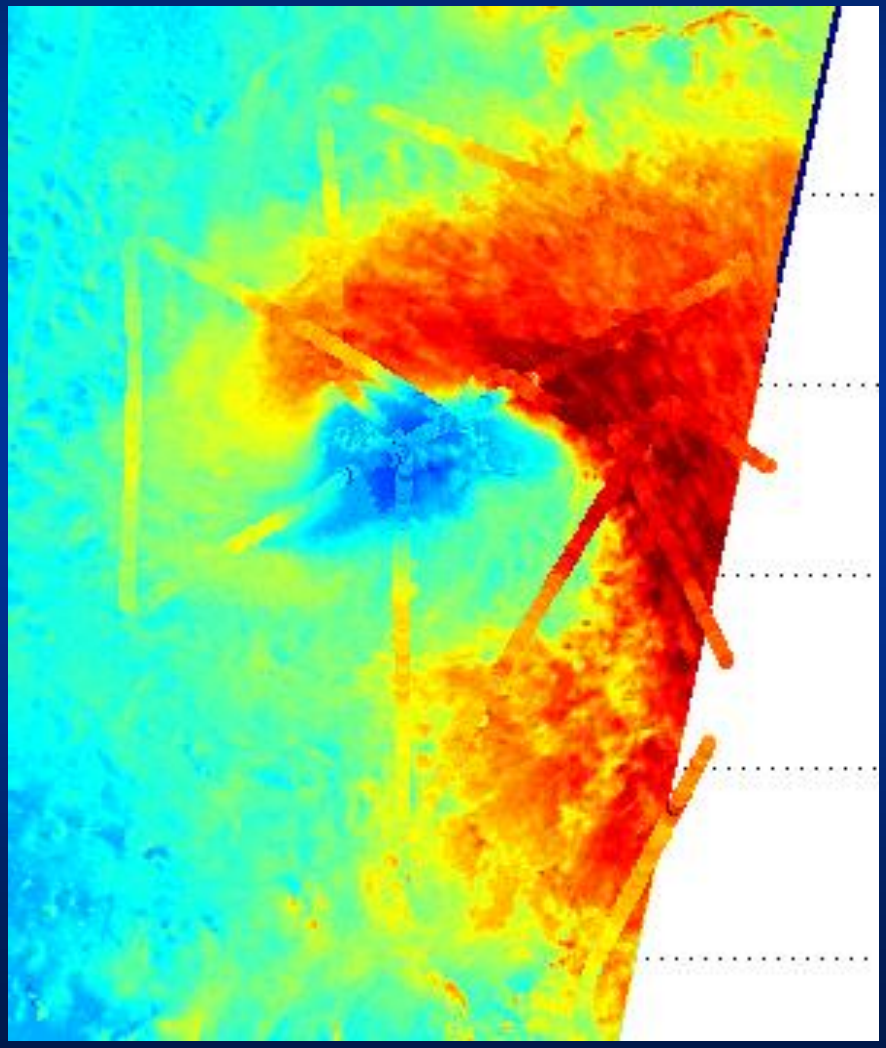


Comparison of Co- and Cross-pol Retrieved Wind Speeds to SFMR

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

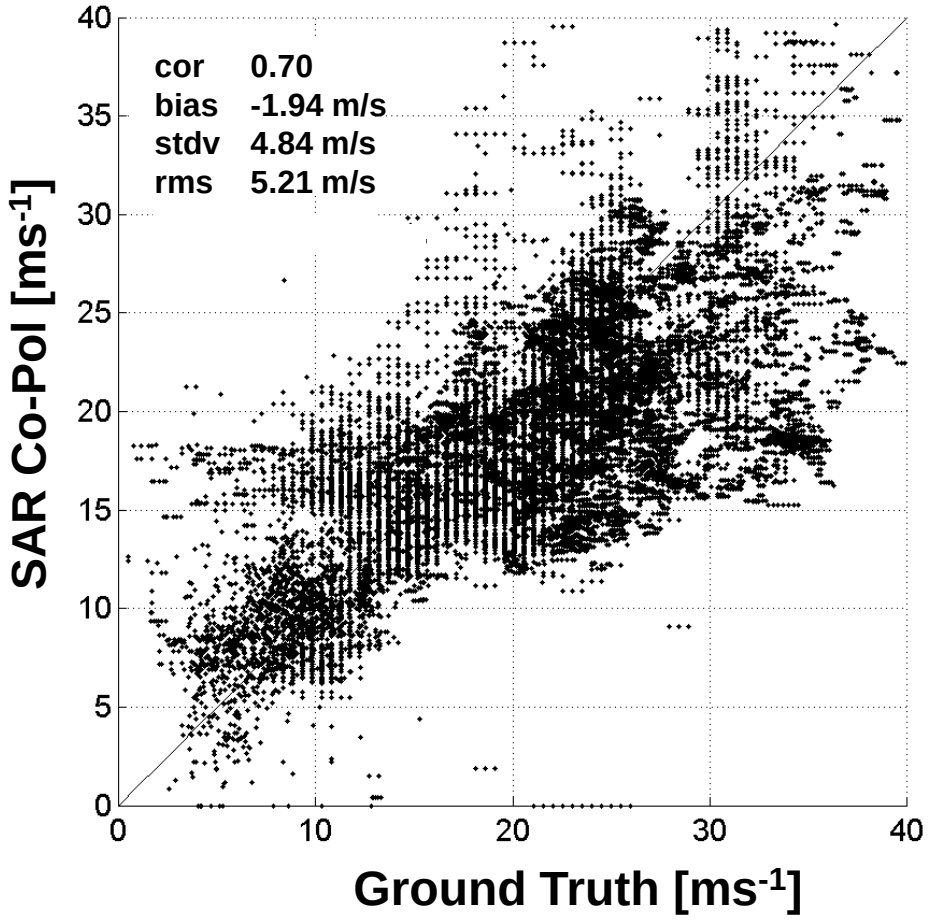
Typhoon Malaksa
20 Sep. 2010 at 20:29 UTC

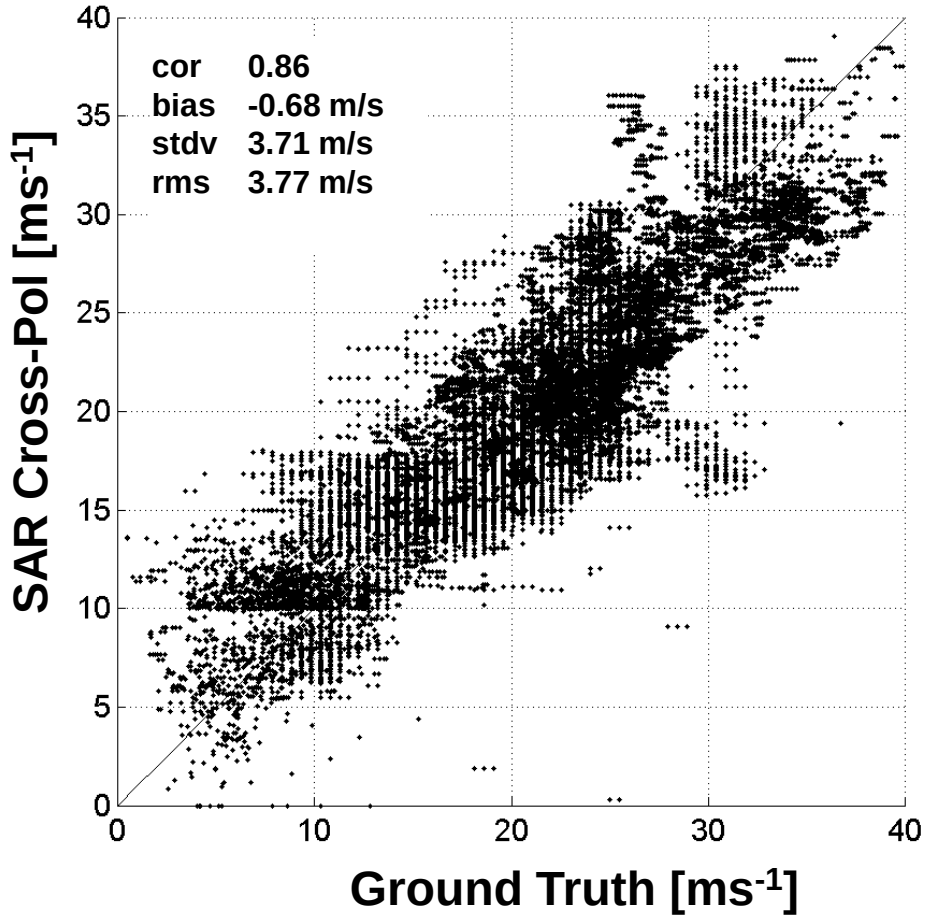




Validation of Co-pol and Cross-pol GMF with SFMR and Dropsondes

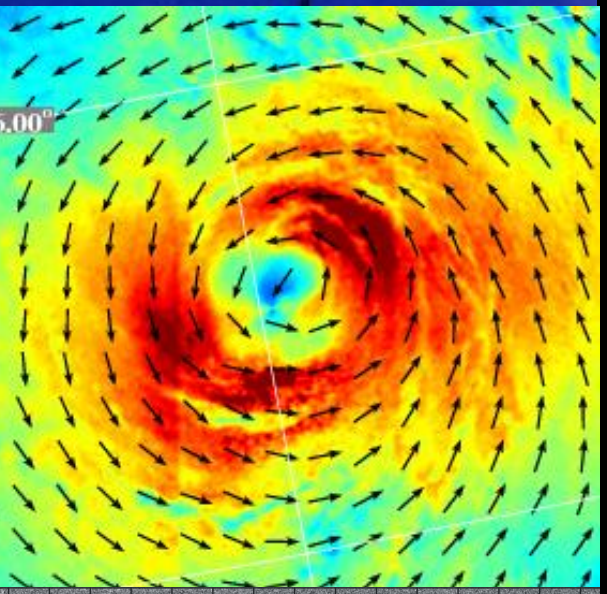
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

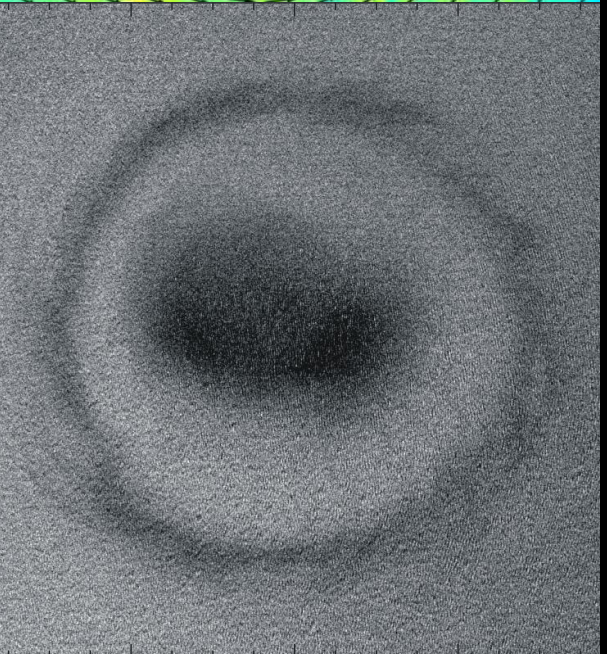




Horstmann et al., TOS 2013

Summary & Outlook





SAR wind directions from orientation of linear features (rms of 18°, lack of inflow)

Filters have been developed to flag:

- non wind induced areas
- areas with uncertain wind speeds

C-band cross pol GMF developed (significantl improvement in high wind speeds >25 m/s)

Further investigation of cross pol with respect to wind direction and incidence angle

Merging of co-pol and cross pol retrieved winds

What about rain under cross pol?

Comparison of Co- and Cross-pol Retrieved Wind Speeds to SFMR

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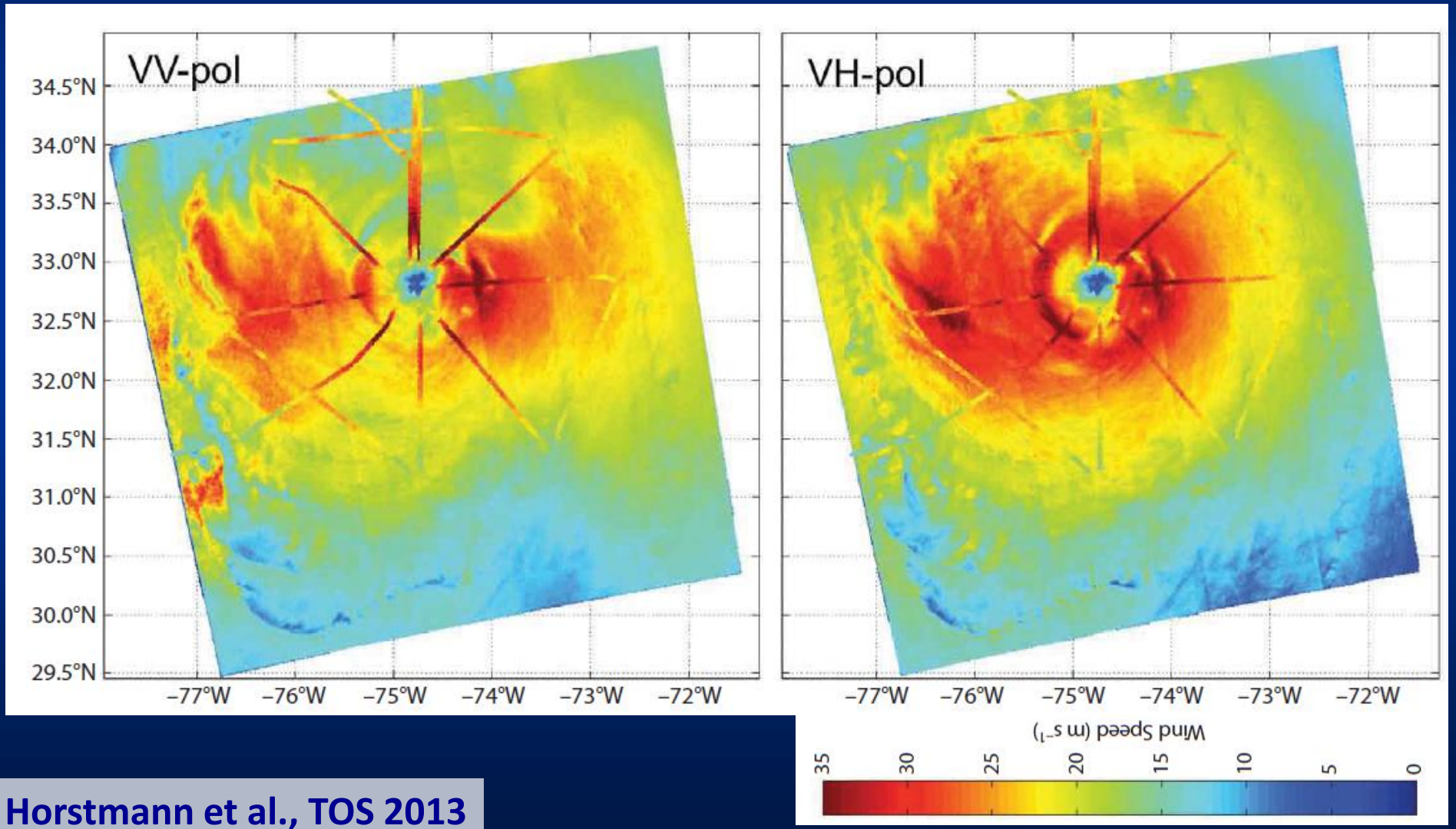
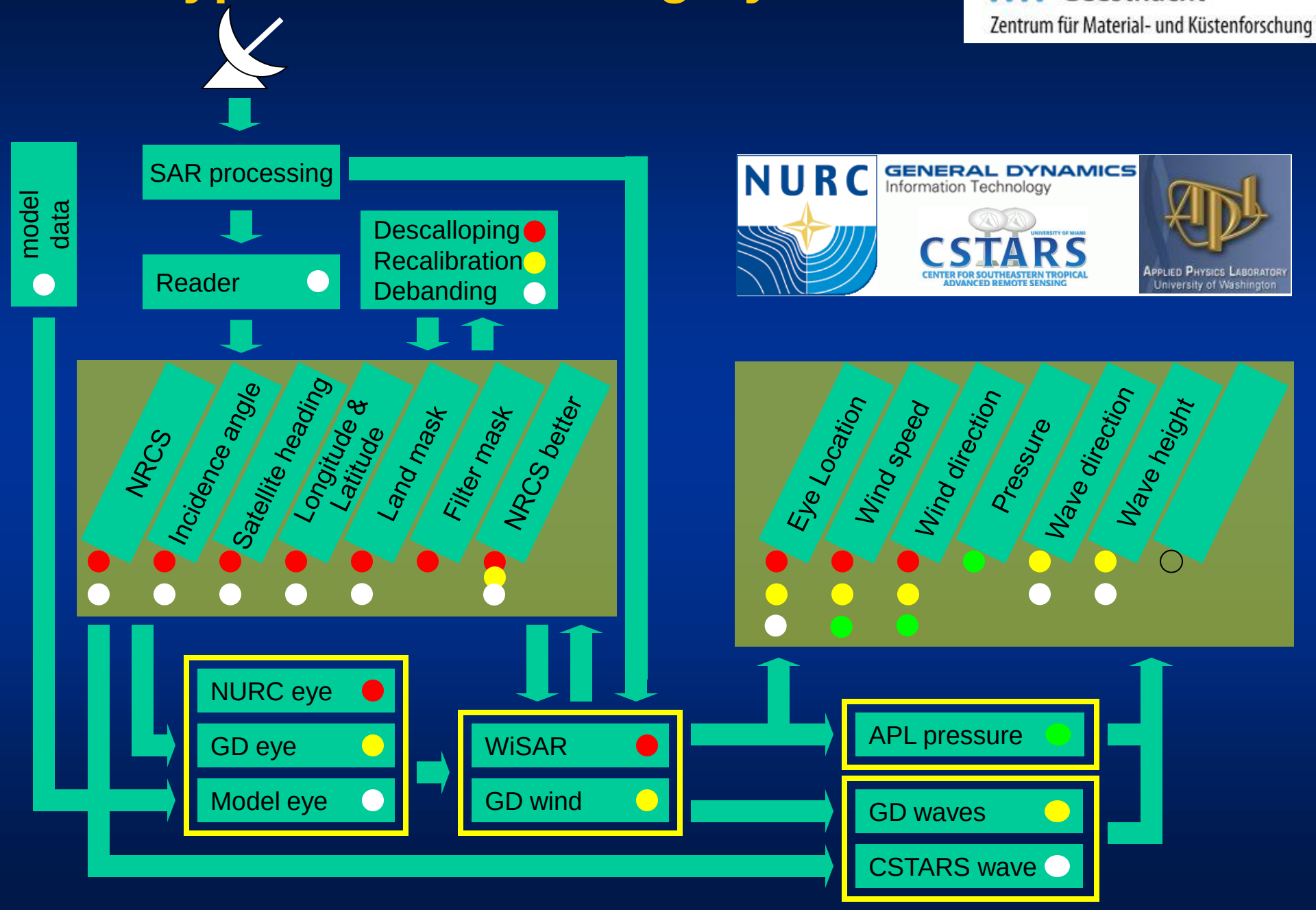
Zentrum für Material- und Küstenforschung

Hurricane Earl **2 Sep. 2010 at 22:59 UTC**



Horstmann et al., TOS 2013

SAR Typhoon Processing System



Automated Removal of Sensor Artifacts and Careful Calibration

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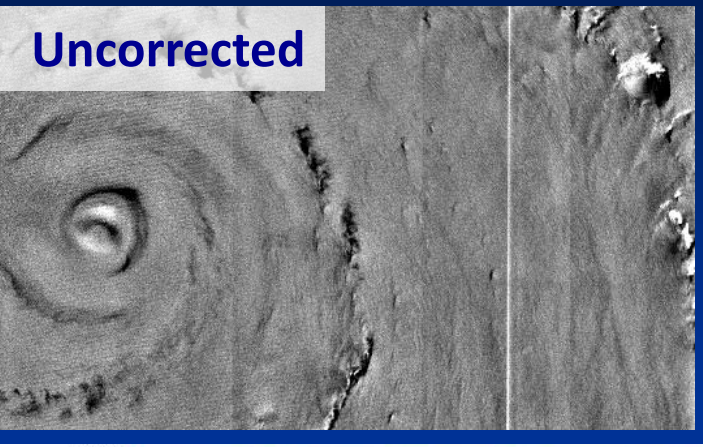
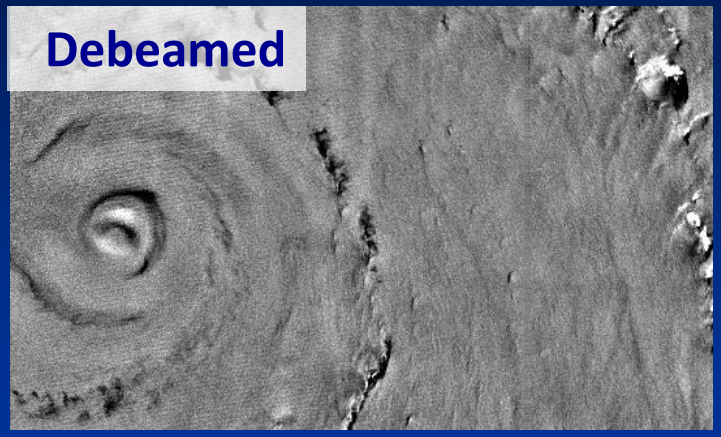
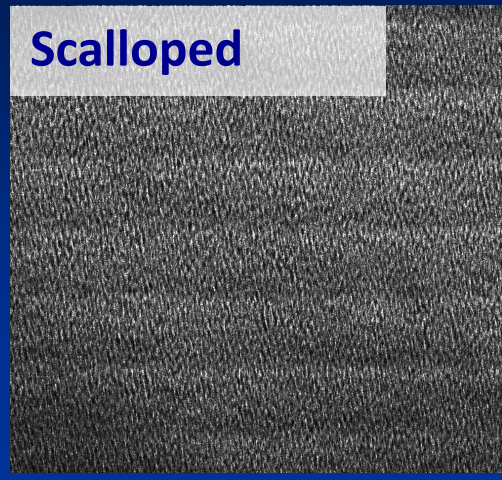
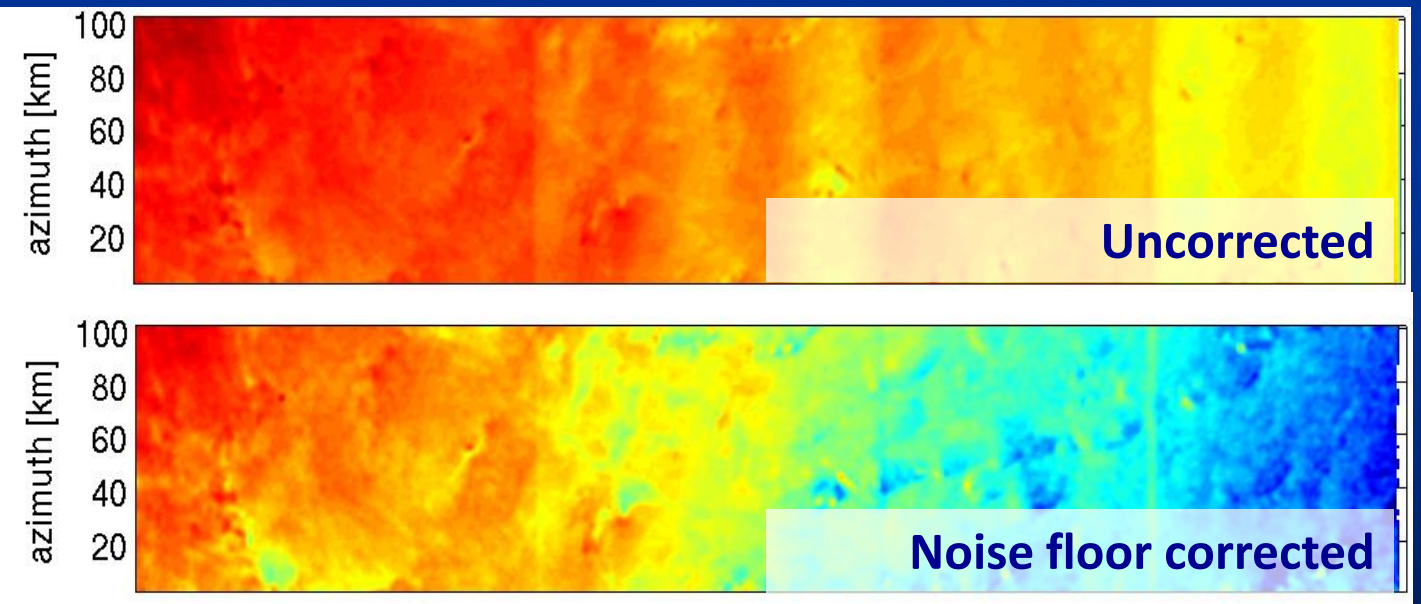
Zentrum für Material- und Küstenforschung







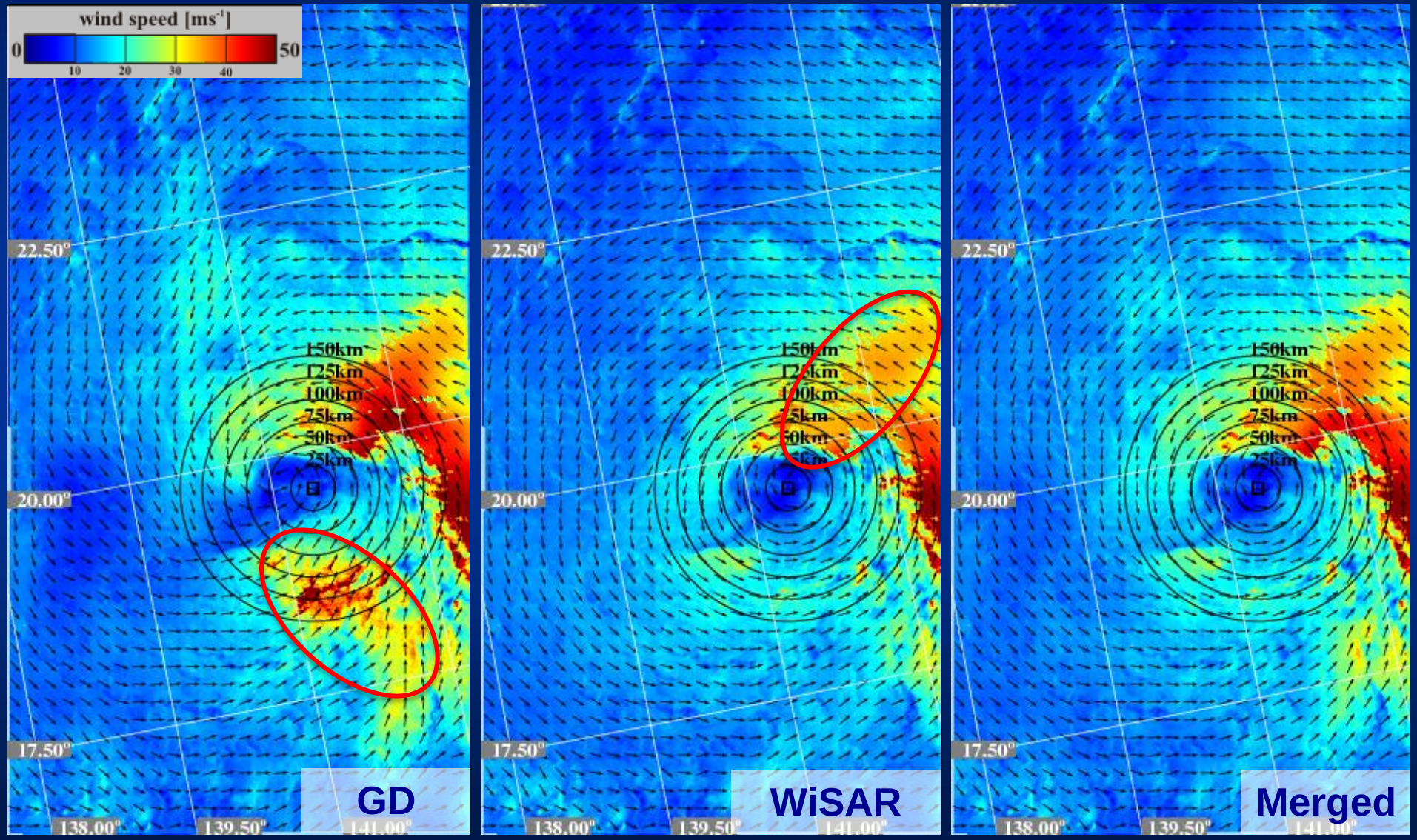


Horstmann et al., TGARS submitted

Romeiser et al., TGARS 2012

Merging Wind Directions from GD with WiSAR

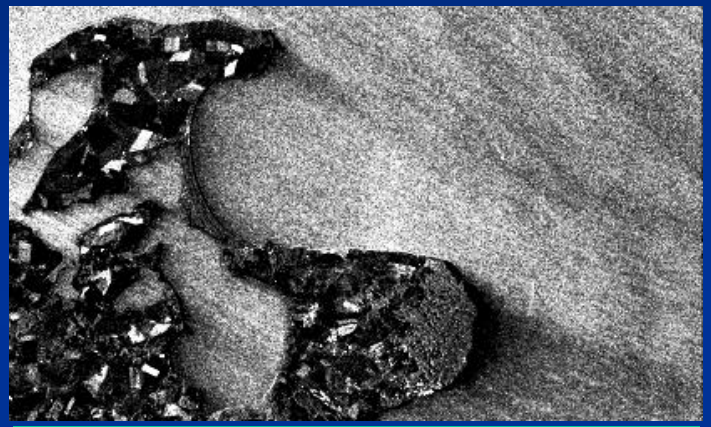
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



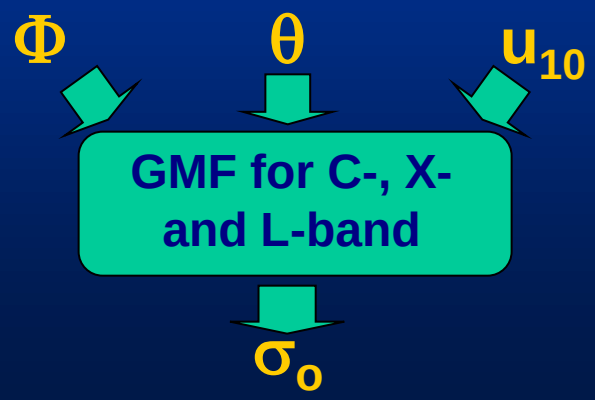
General Approach for Ocean SAR Wind Field Retrieval (WiSAR)

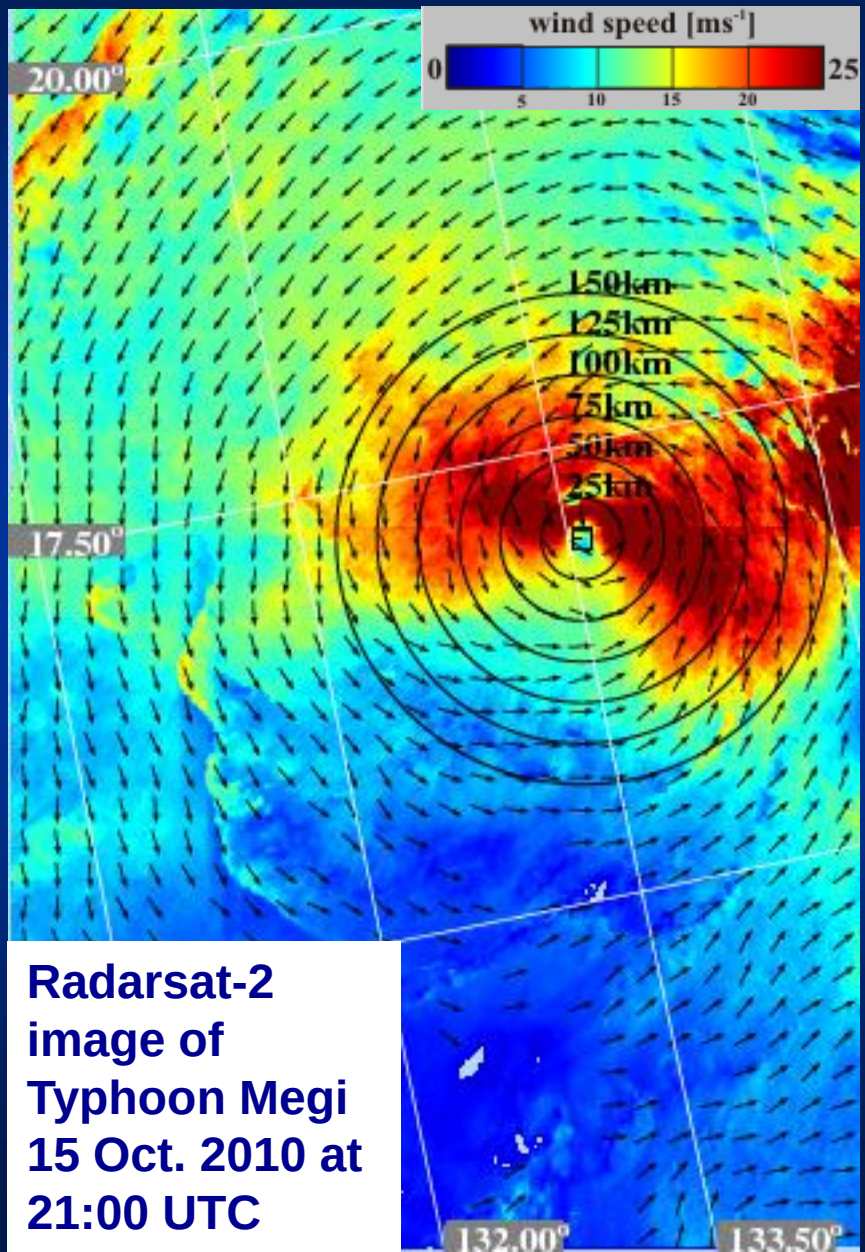
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Geophysical Model Function



$$\sigma_0^{pol} = a(\theta)u^{\gamma(\theta)}[1 + b(\theta)\cos\phi + c(\theta)\cos(2\phi)]$$

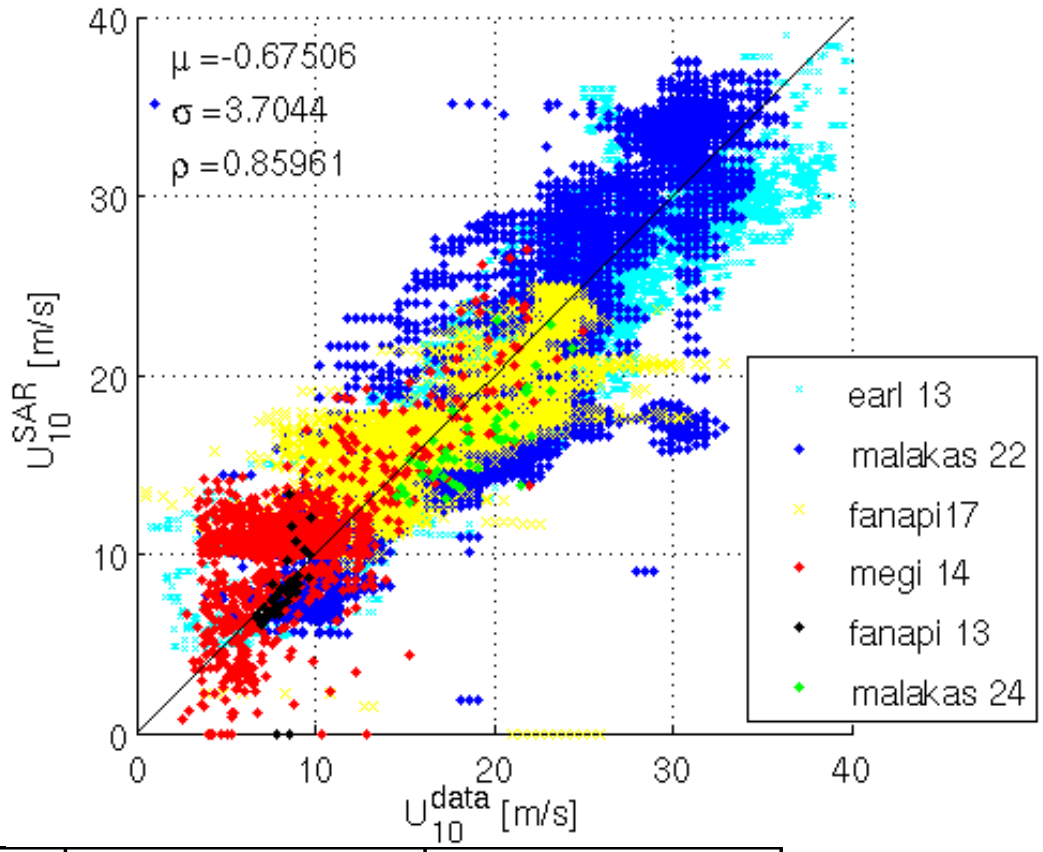




Radarsat-2 image of Typhoon Megi 15 Oct. 2010 at 21:00 UTC

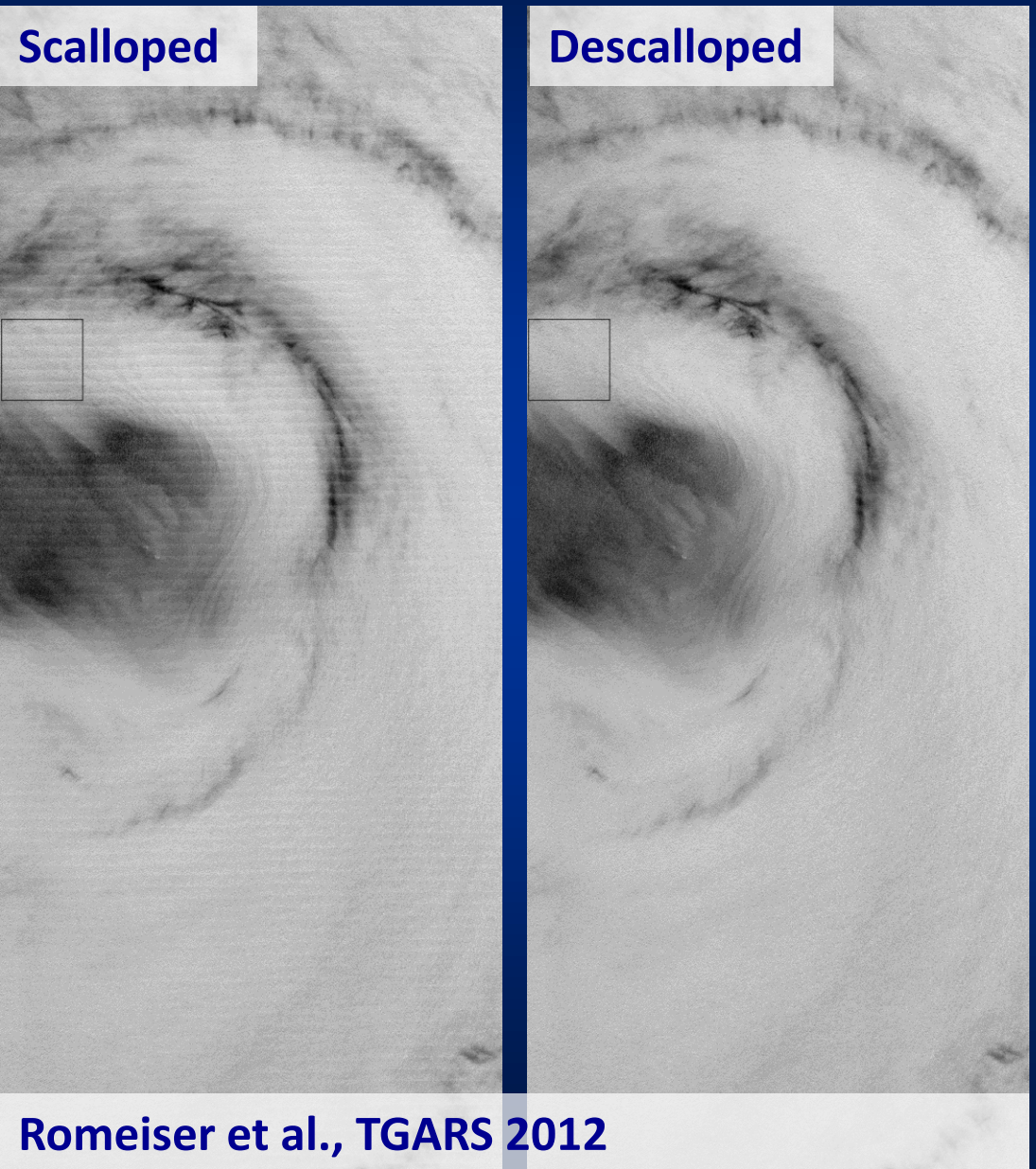
Comparison of Co- and Cross-pol Retrieved Wind Speeds to SFMR

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

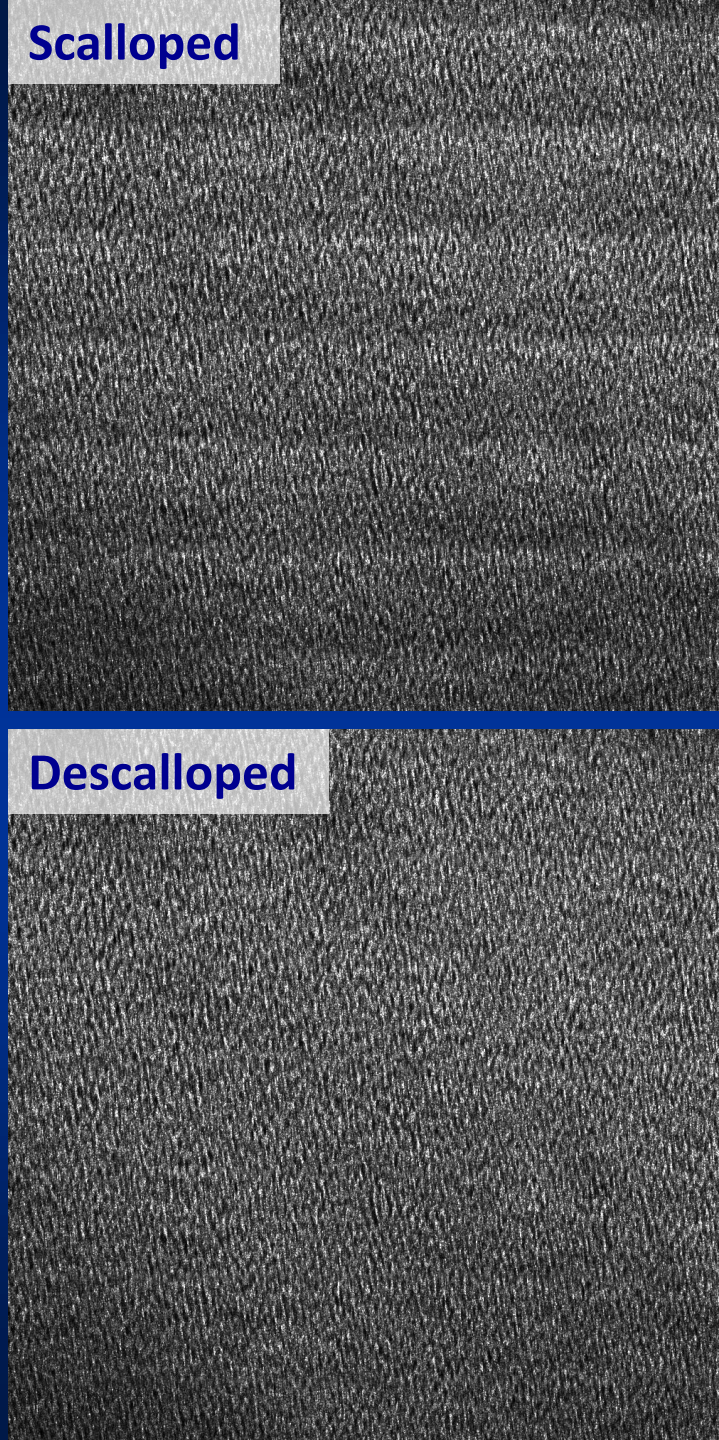


GMF	Bias [m]	Standard Deviation [m]	Correlation
Co pol GMF	0.4	6.42	0.75
HV GMF	0.11	3.75	0.83
HV GMF wind direction dependent	-0.69	3.79	0.85
VH GMF	-1.48	3.22	0.8

Removal of SAR artifacts e.g. Scalloping



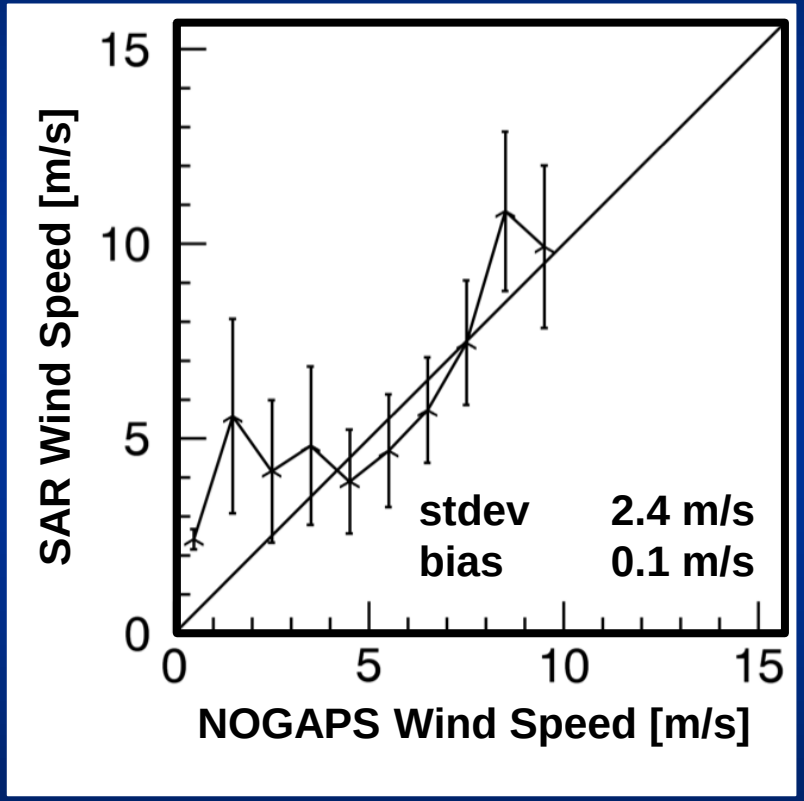
Romeiser et al., TGARS 2012



Development of X-band GMF for Wind Speed Retrieval

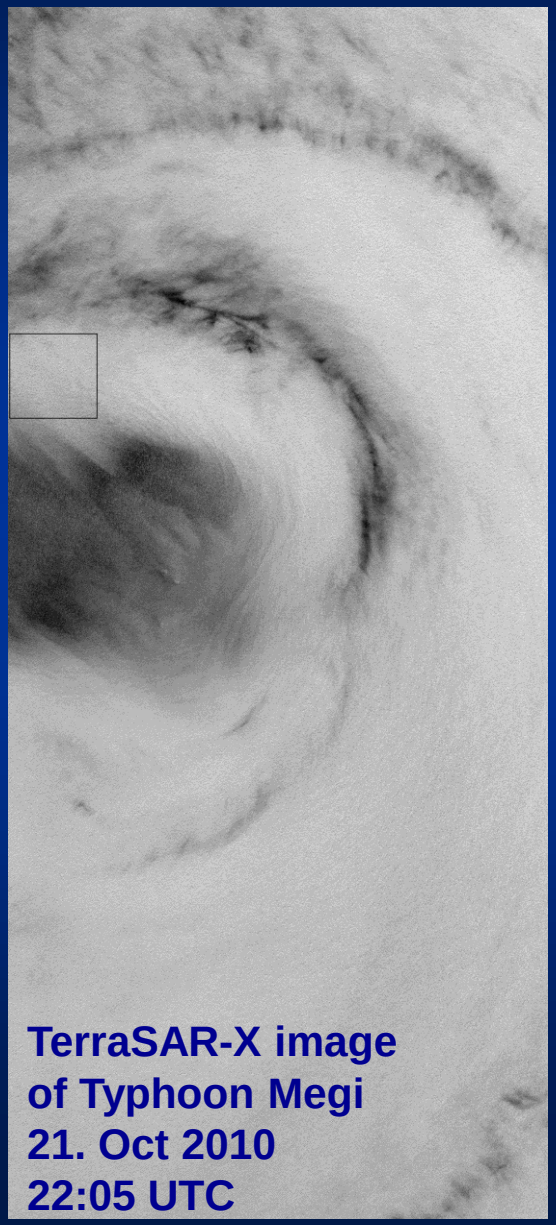
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Validation for Moderate Winds

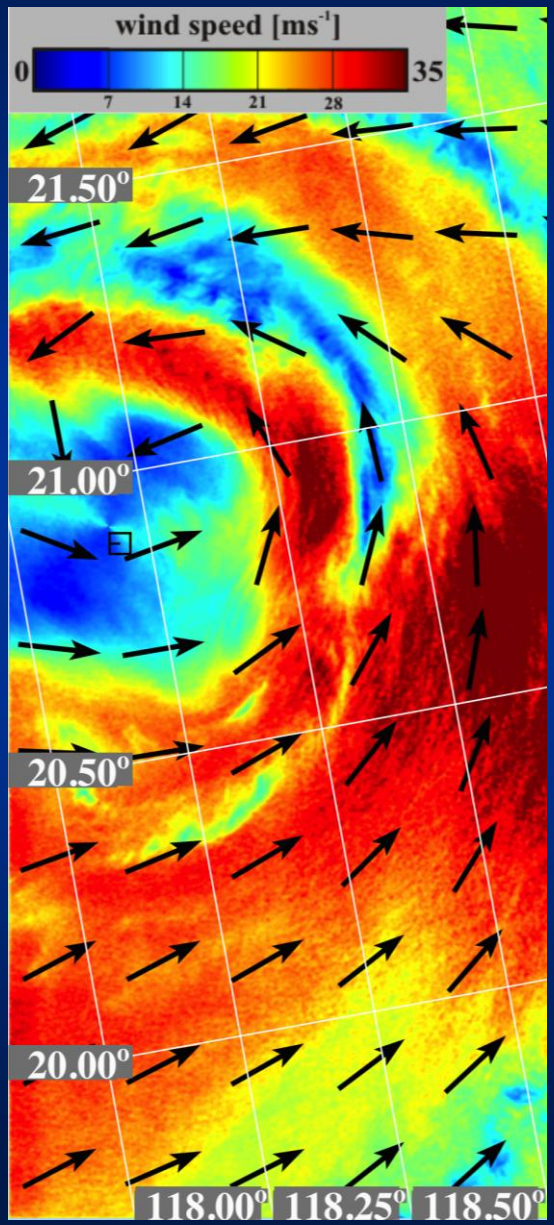


36 Cosmo-SkyMed imagery
25 km grid (782 co-locations)

Thompson et al., JGR 2012

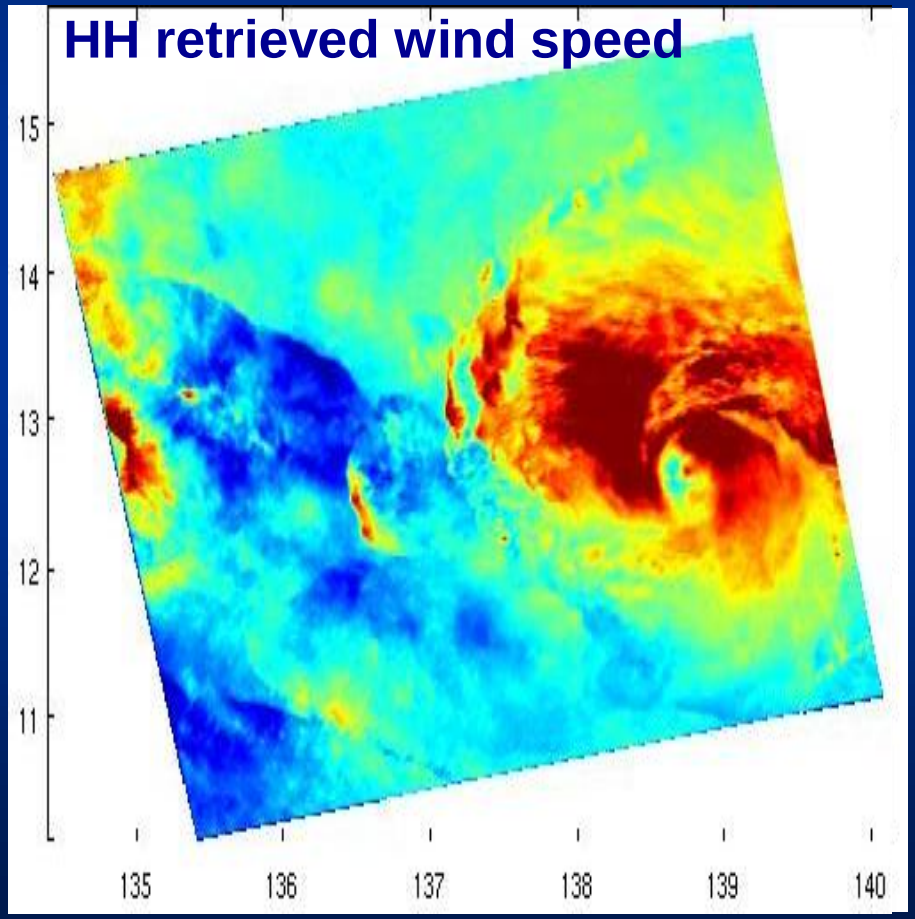


TerraSAR-X image
of Typhoon Megi
21. Oct 2010
22:05 UTC

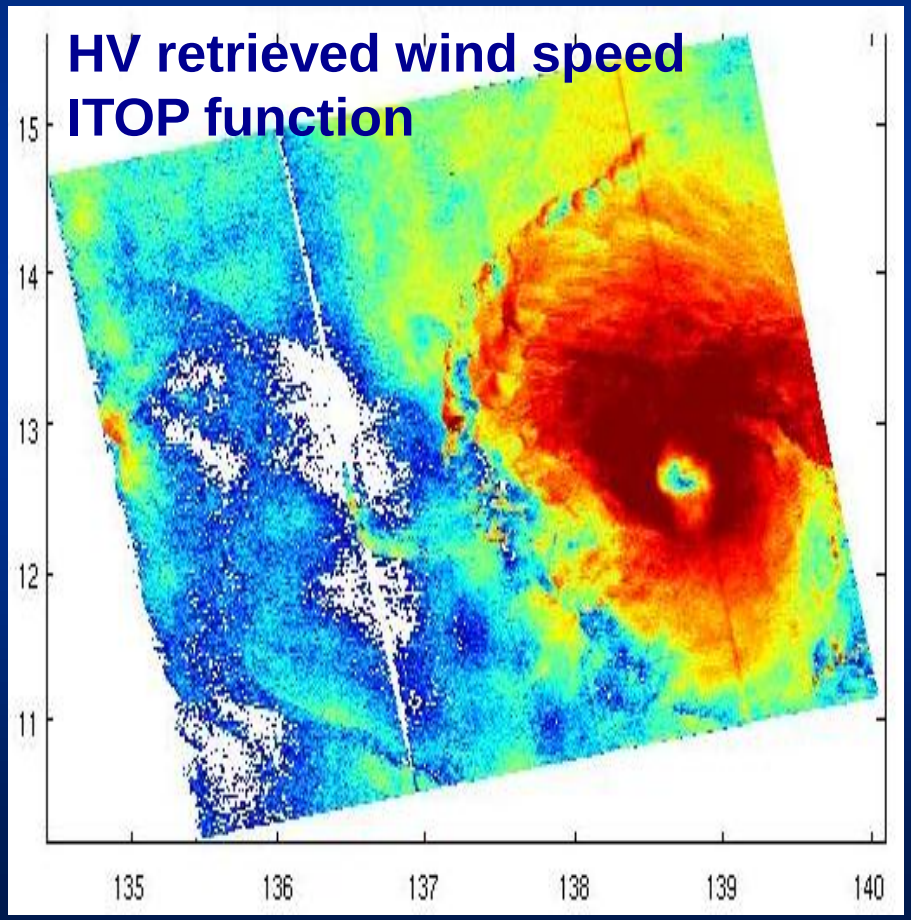


Development of Cross-pol GMF Fit to SAR Co-pol Winds

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung



Radarsat-2 HV image of Typhoon Megi 17. Sep 2010

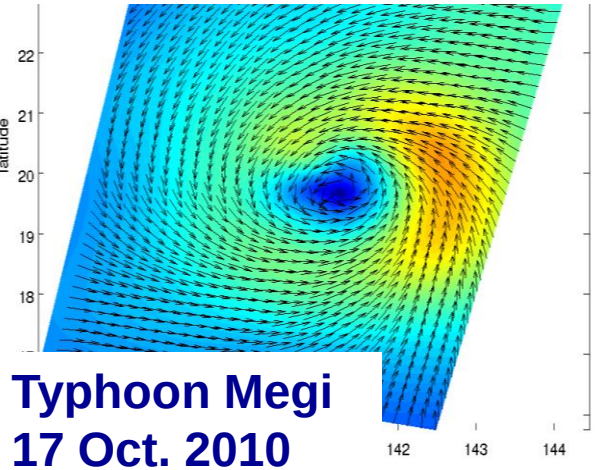


Ongoing and Outlook

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

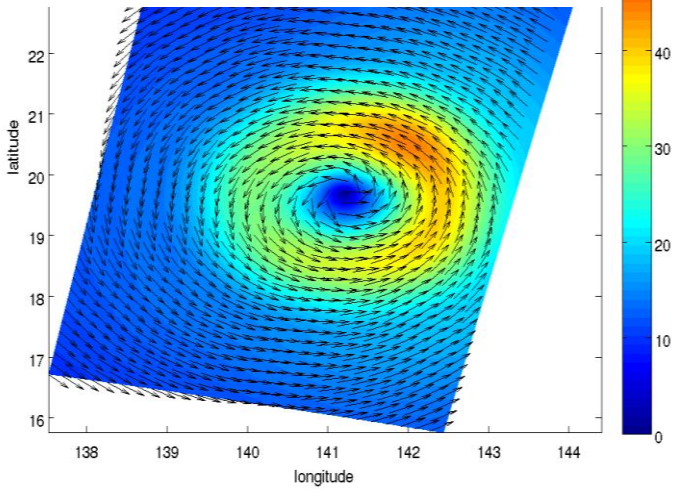
Ingestion of SAR wind fields into HWIND

HWIND with in situ and SFMR

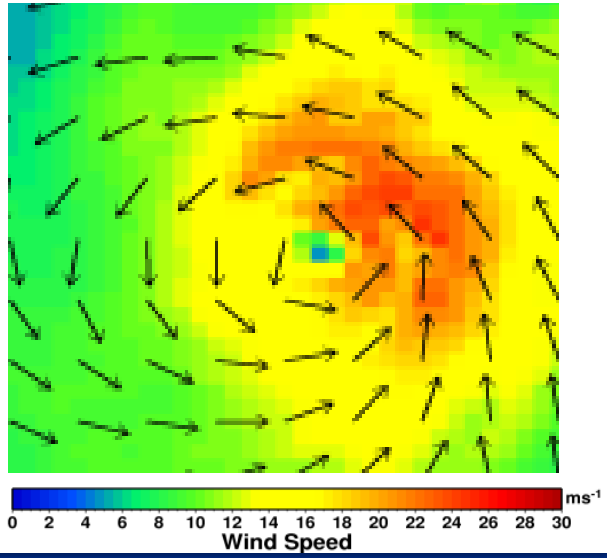


Typhoon Megi
17 Oct. 2010

HWIND solely with SAR wind field



ECMWF winds



- Validation of the X-band GMF at high wind
- Investigation of X-band cross pol
- Merging of the co- and cross pol information for a even better wind product
- Including wave information in the wind retrieval

Validation of SAR-Retrieved Wind Directions with QuikScat Winds

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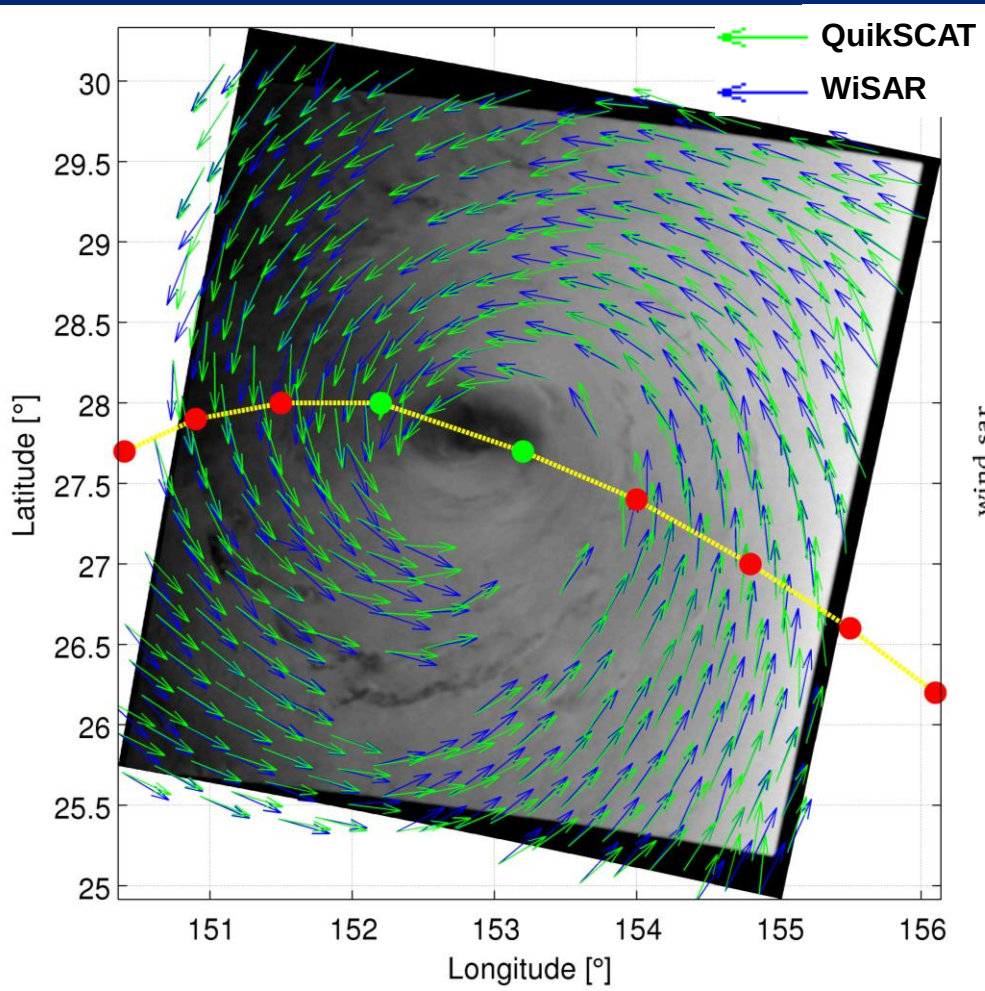

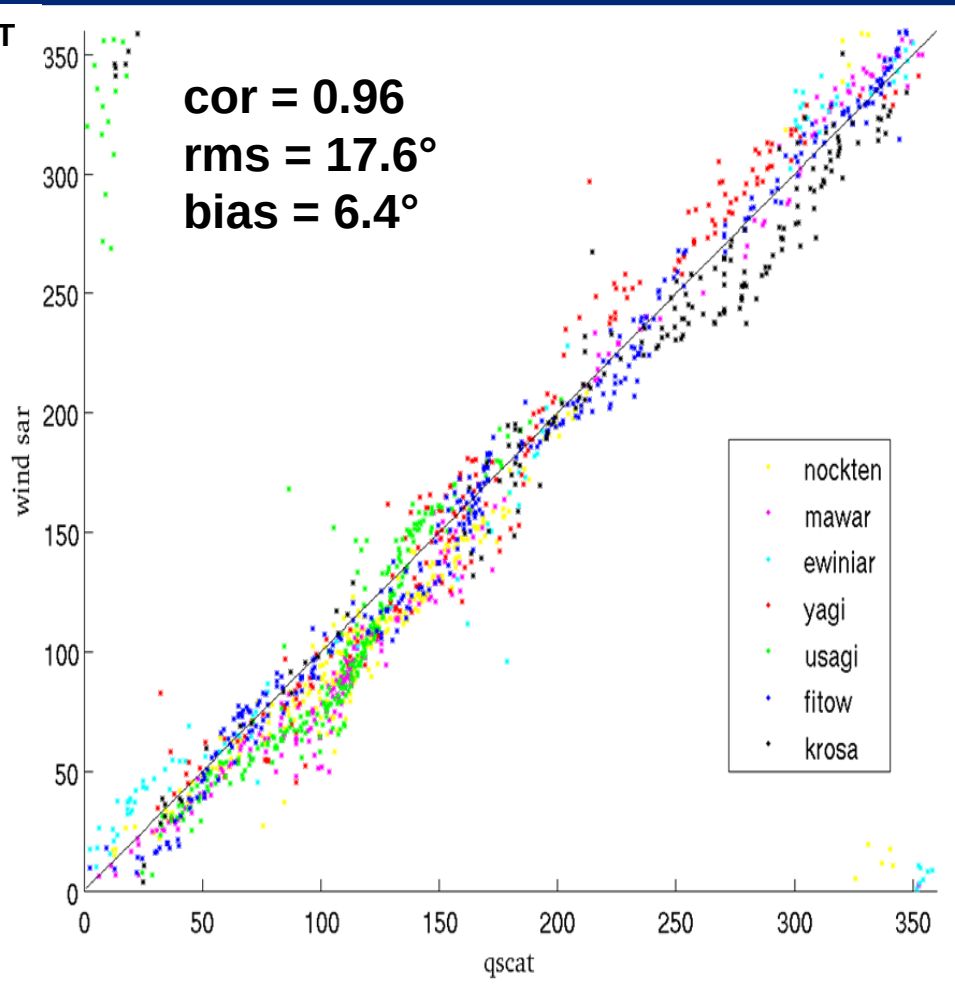

Horstmann et al., TOS 2013

Noise Correction of Radarsat-2 Cross Pol NRCS

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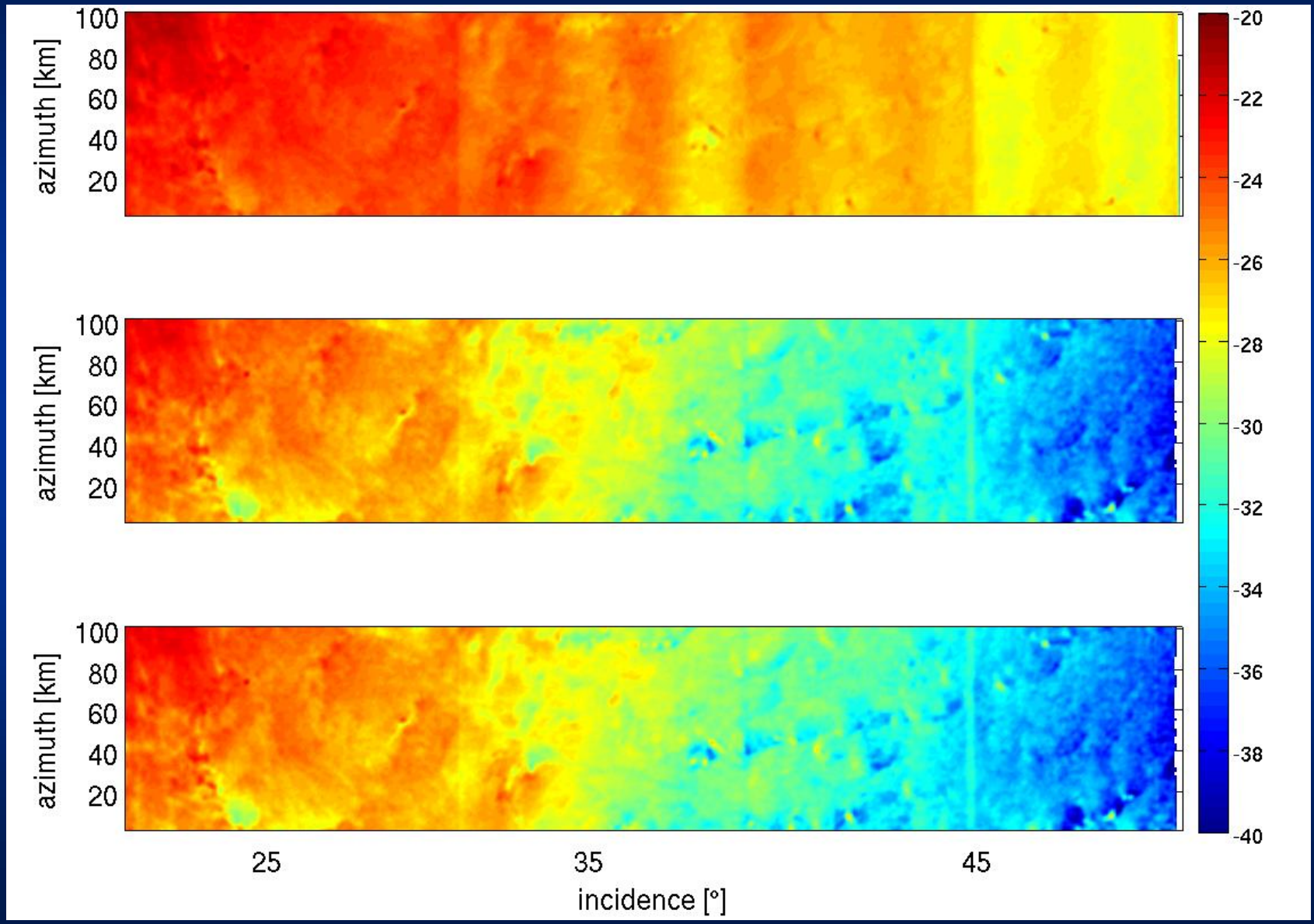
Zentrum für Material- und Küstenforschung



Comparison of Co- and Cross-pol Retrieved Wind Speeds to SFMR

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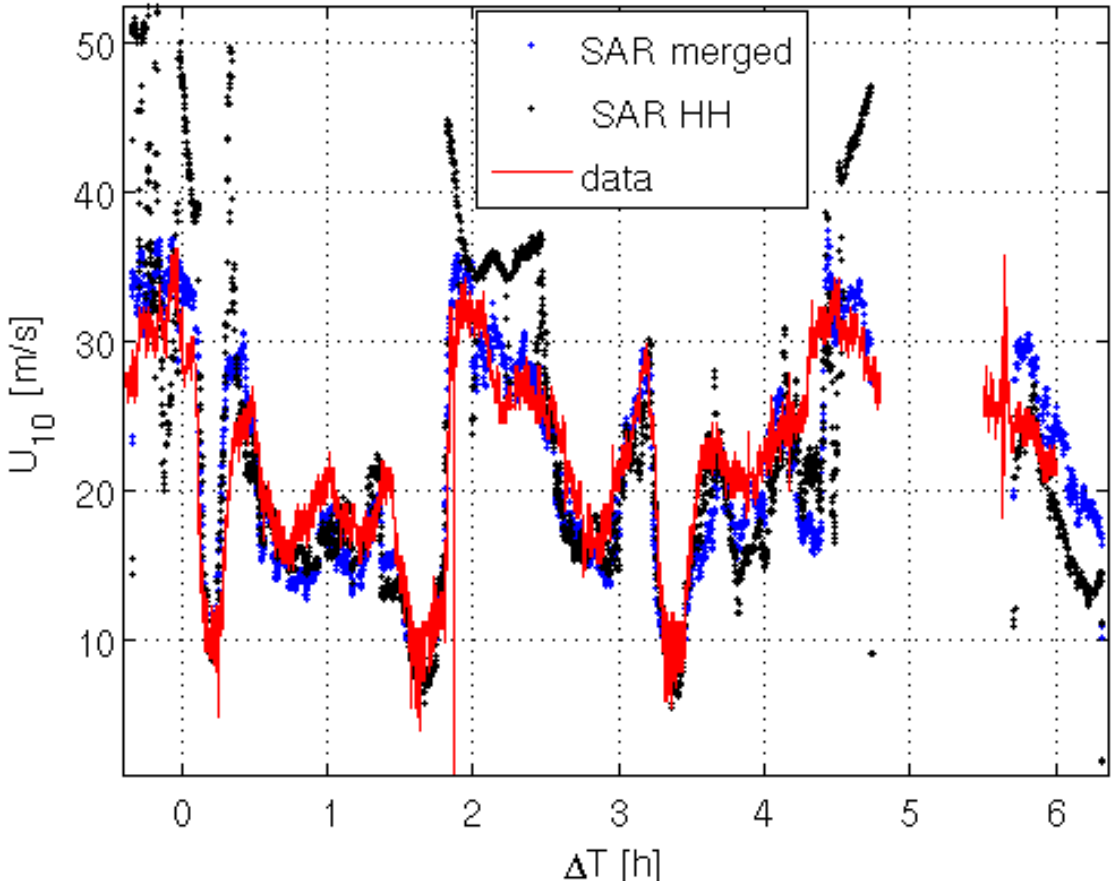

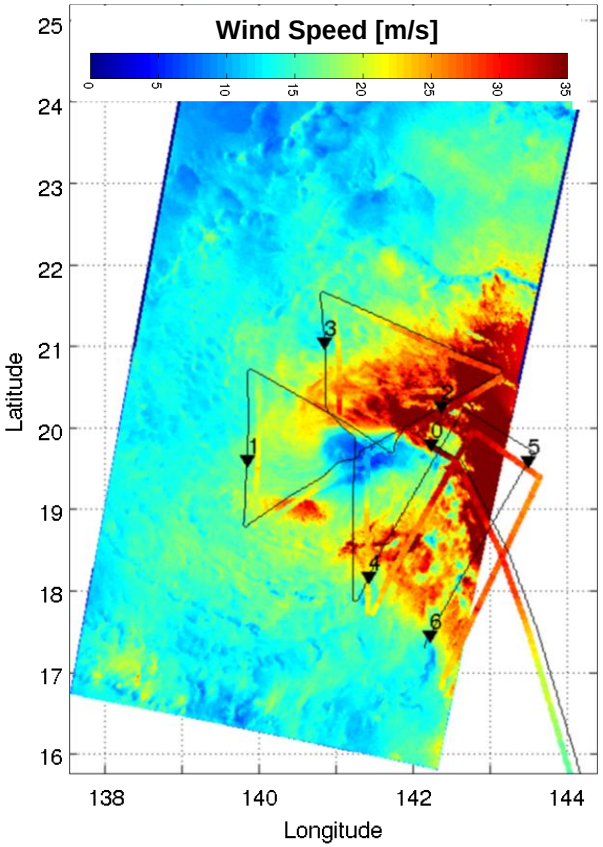

SAR-Retrieved Wind Field and Comparison to QuikScat data

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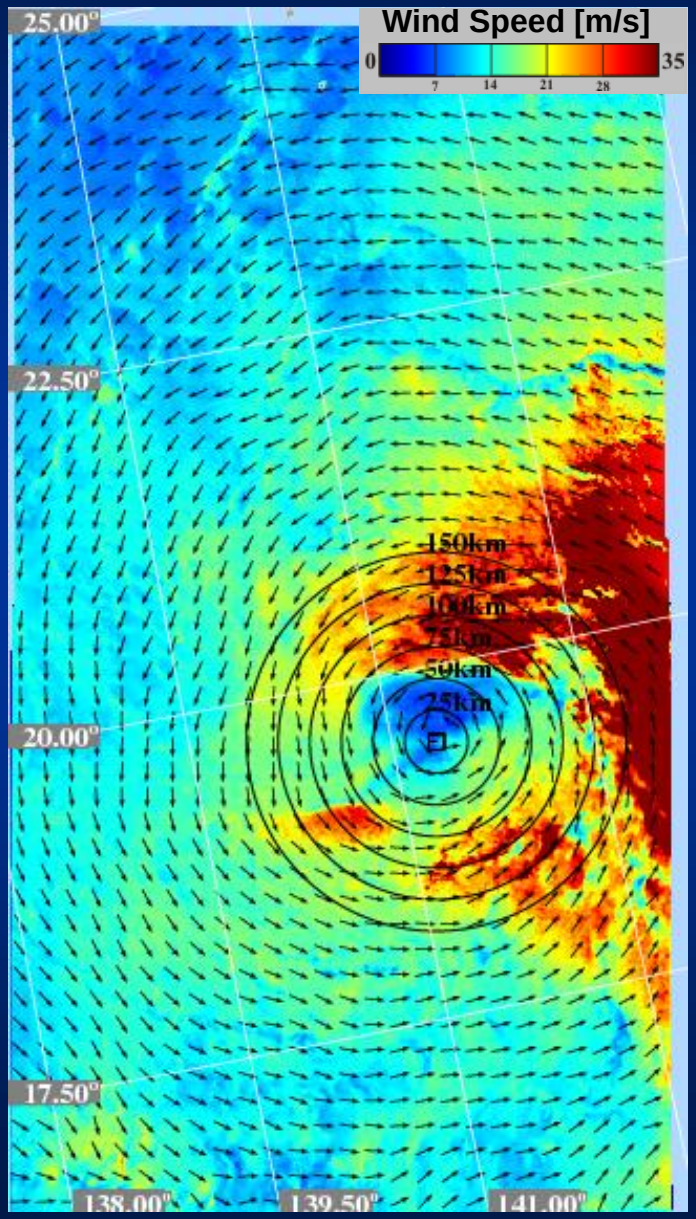

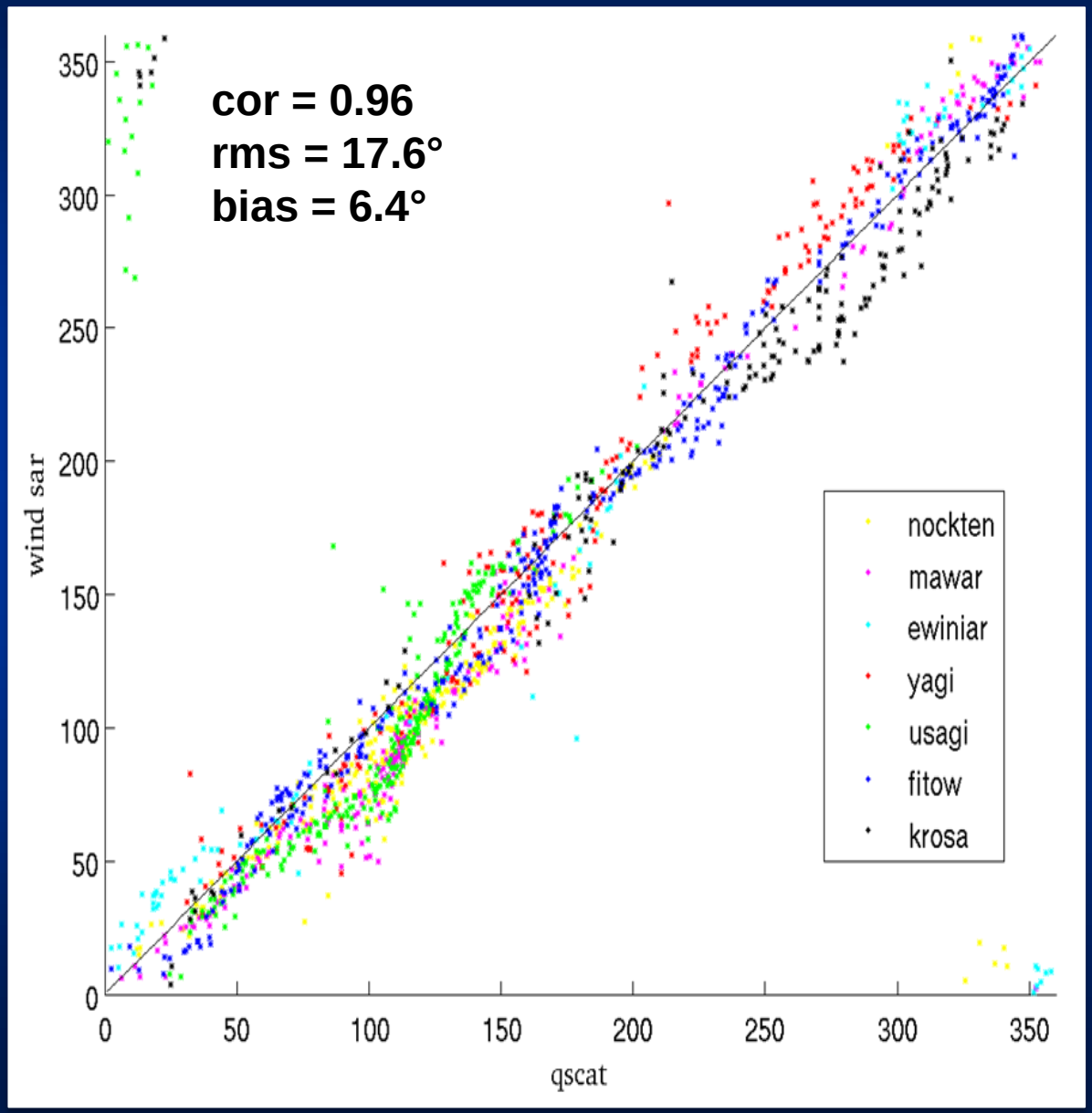

Comparison of Radar Retrieved Wind speeds to *in situ* Measured

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$\sigma_0 \xrightarrow{\text{GMF}} u_{10}$ assuming 10 min mean neutral wind at 10 m

$u_{10} \rightarrow u_0$ assuming neutral stability

$u_0 \xrightarrow{\text{TC 3.x}} u_{\text{in situ}}$ taking available information on stability

Estimation of Friction Velocity from Radar Measurements via GMF

$\sigma_0 \xrightarrow{\text{GMF}} u_{10}$ assuming 10 min mean neutral wind at 10 m

$u_{10} \xrightarrow{\text{TC 3.x}} u^*$ assuming neutral stability

Noise Correction of Radarsat-2 Cross Pol NRCS

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