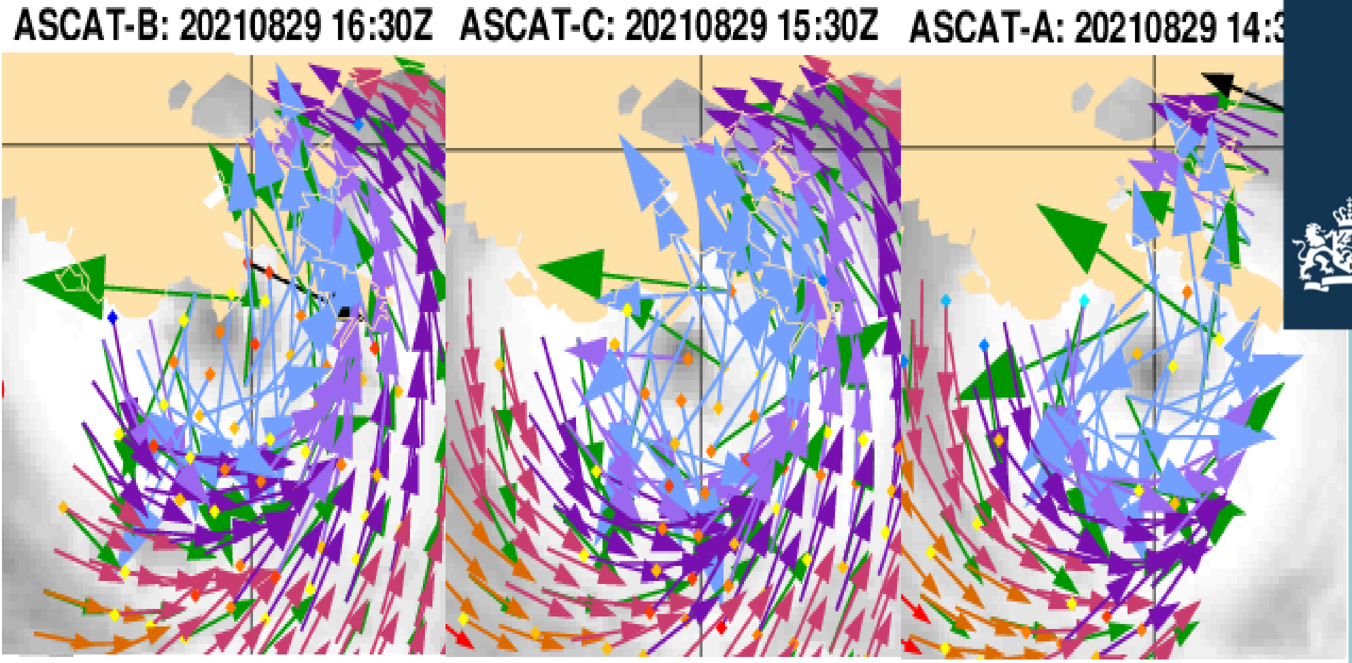
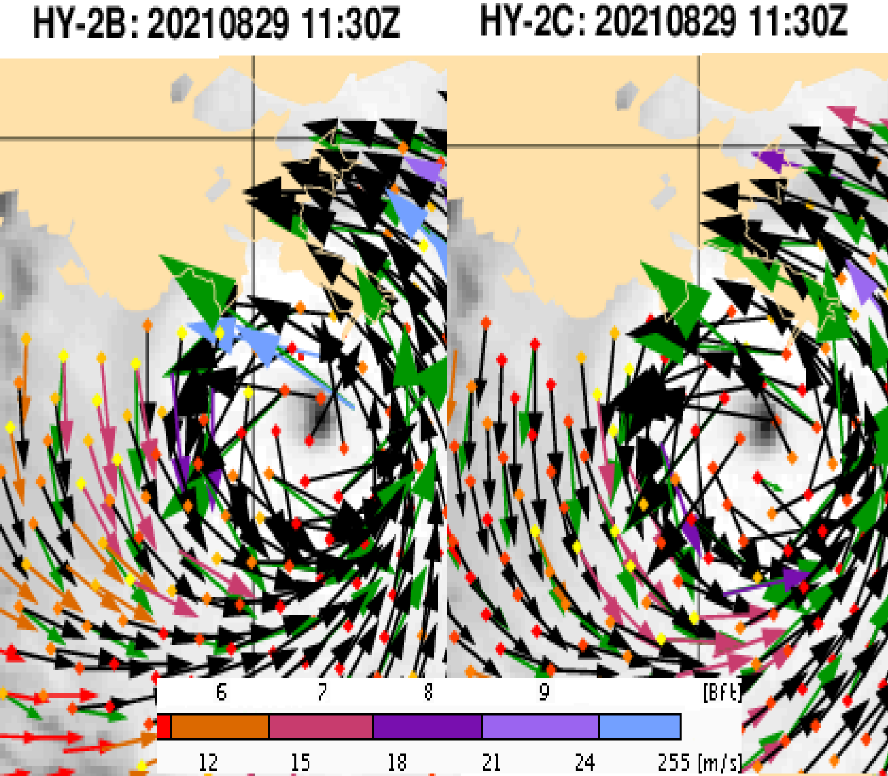




Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

Microwave Scatterometers

Ad.Stoffelen@knmi.nl

CGMS chair Ocean Surface Winds Task Group, IWWG

EUMETSAT OSI SAF, Ida land-fall news story
EU Copernicus Marine Core Services

Wind Quality

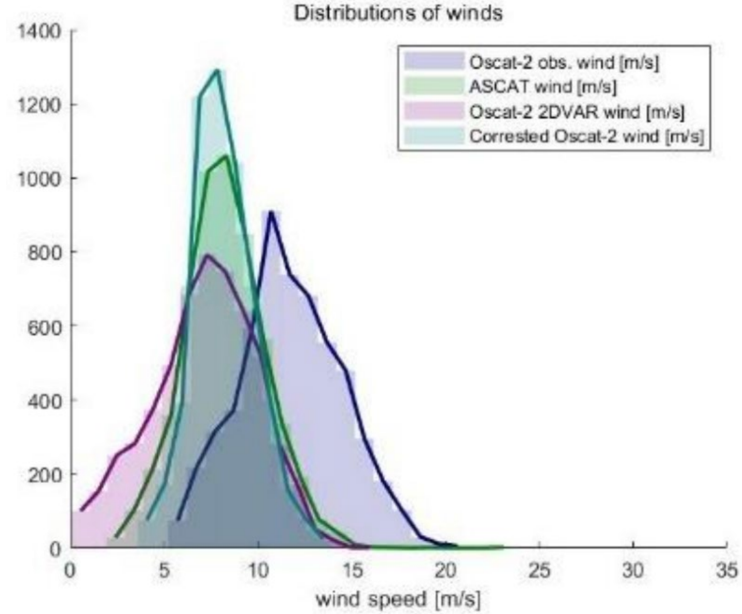
Quadruple Collocation Analysis of In-Situ, Scatterometer, and NWP Winds

Jur Vogelzang & Ad Stoffelen,
https://doi.org/10.1029/2021JC017189

Subset	Buoys		ASCAT-A		ScatSat		ECMWF	
	σ_u	σ_v	σ_u	σ_v	σ_u	σ_v	σ_u	σ_v
bAS	1.03	1.12	0.41	0.49	0.78	0.65	--	--
bAE	1.06	1.15	0.34	0.41	--	--	0.94	1.03
bSE	1.09	1.21	--	--	0.72	0.59	0.92	1.03
ASE	--	--	0.43	0.49	0.76	0.65	0.90	0.98
range	0.06	0.09	0.09	0.08	0.06	0.06	0.04	0.05

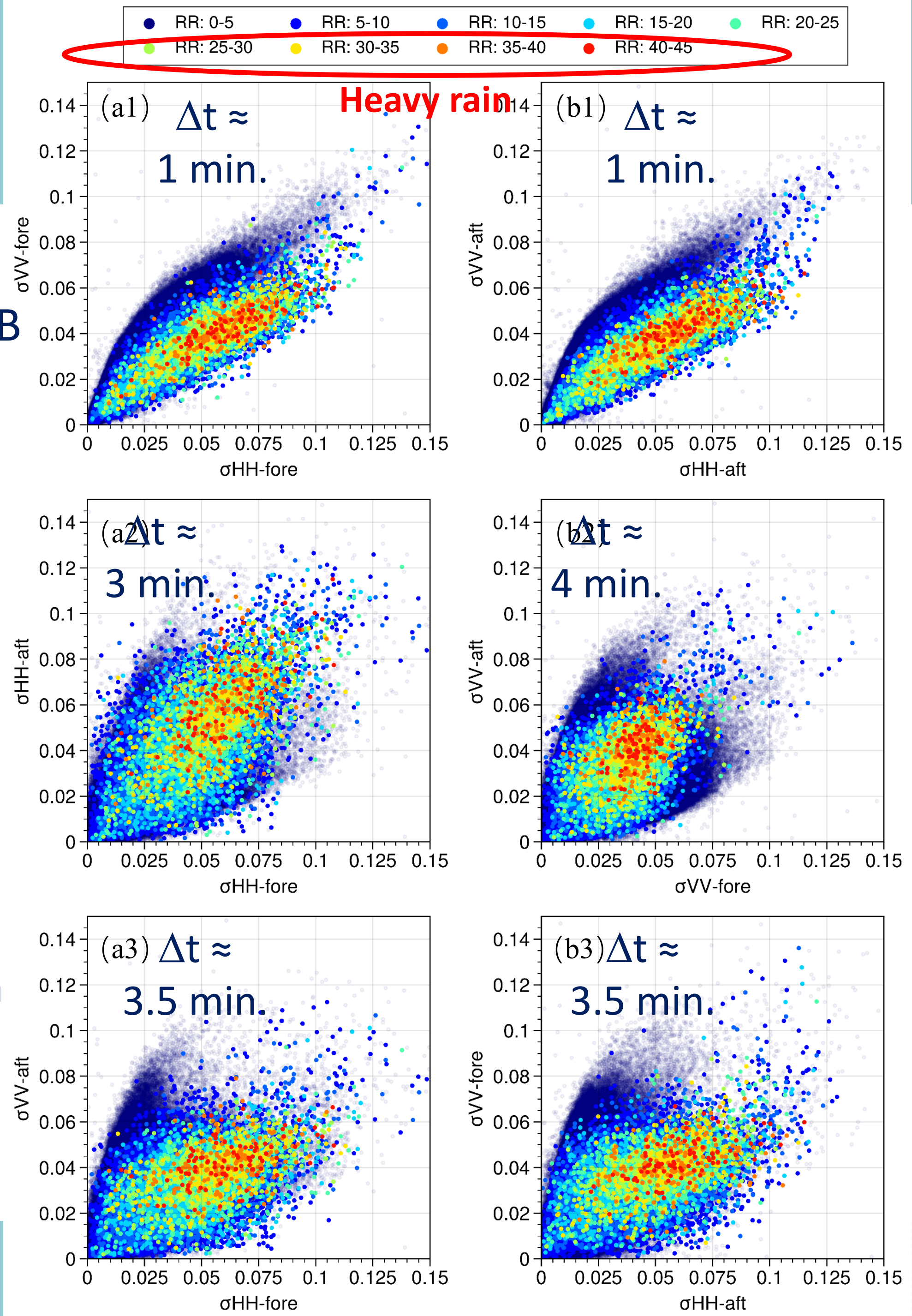
Support vector machine tropical wind speed retrieval in the presence of rain for Ku-band wind scatterometry

Xingou Xu & Ad Stoffelen
https://doi.org/10.5194/amt-2021-200

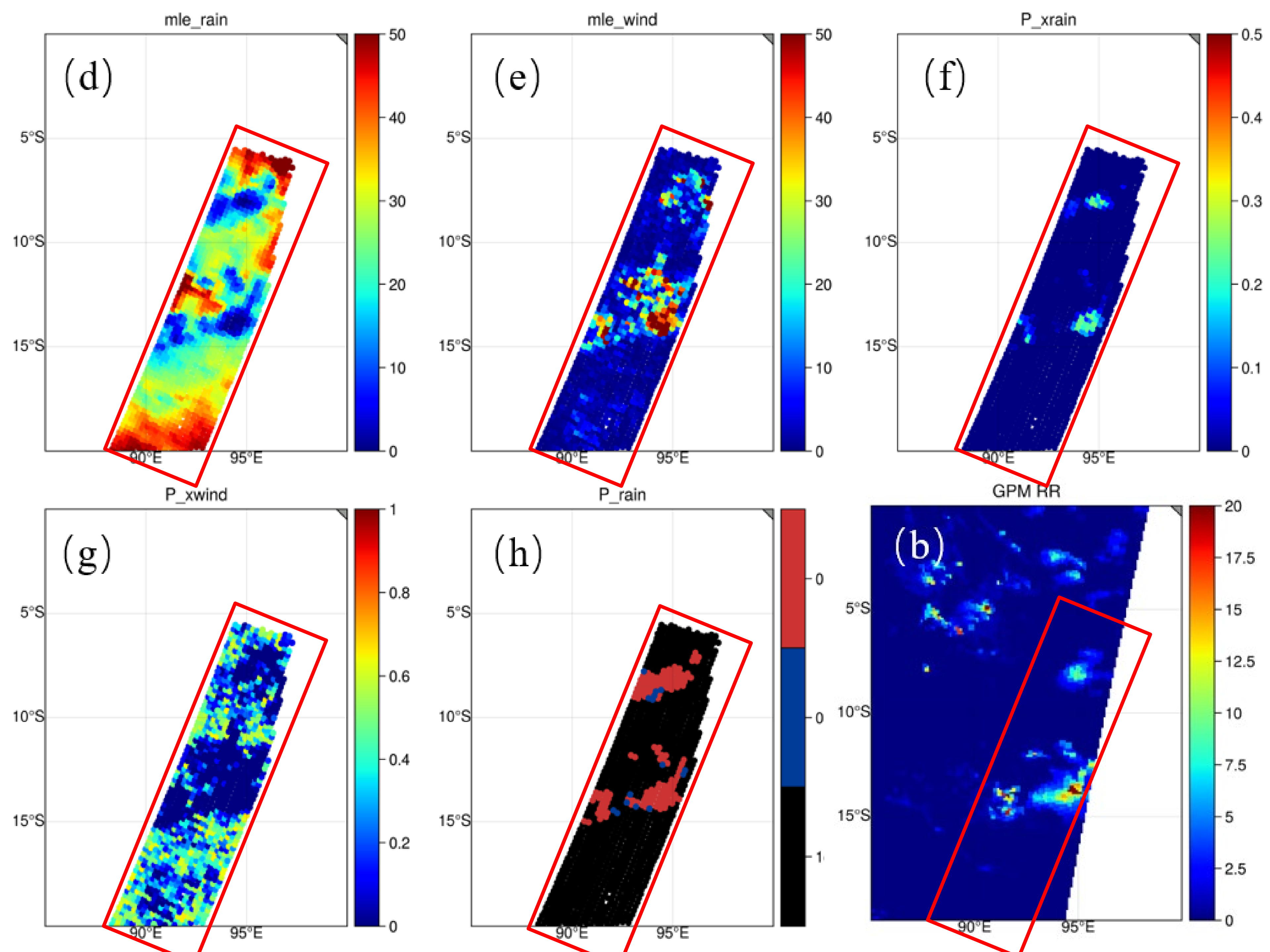


Bayesian rain detection

- Ku-band rain problem
- VV and HH heavy rain at about 0.05 dB
- Some spread in NRCS, correlated in VV and HH, when close in time
- More noisy after more time
- Diversity in azimuth cause wind values to disperse
- Mixed wind/rain cases will be more dispersed too (lower rain rates)
- Heavy rain appears rather independent of wind
- We may be able to distinguish 4D rain and wind PDFs in a Bayesian retrieval
- Hence improve Ku wind GMF
- And possibly correct winds for rain



Zhao et al., submitted



mle_rain
(d)
mle_wind
(e)
P_xrain
(f)
P_xwind
(g)
P_rain
(h)
GPM RR
(b)
5°S
10°S
15°S
90°E
95°E
0
10
20
30
40
50
0.1
0.2
0.3
0.4
0.5
0.2
0.4
0.6
0.8
1
2.5
5
7.5
10
12.5
15
17.5
20

Intercalibration with better QC

Brief Introduction of Datasets

☑ ASCAT-B 25km NRT
☑ ASCAT-C 25km NRT

☑ HSCAT-B 50km NRT (NOC: +0.62(HH), -0.63(VV))
☑ HSCAT-C 50km NRT (NOC: -1.17(HH), -1.32(VV))
☑ HSCAT-D 50km NRT (NOC: -0.34(HH), -0.12(VV))

☑ HSCAT-B 50km Rep01 (new NOC: +0.71(HH), -0.41(VV))
☑ HSCAT-C 50km Rep01 (new NOC: -1.01(HH), -1.11(VV))
☑ HSCAT-D 50km Rep01 (new NOC: -0.26(HH), -0.14(VV))

- NSCAT-4ds GMF
- SST Corr.
- -mixqc

☑ HSCAT-B 50km Rep02 (new NOC: +0.52(HH), -0.56(VV))
☑ HSCAT-C 50km Rep02 (new NOC: -1.19(HH), -1.26(VV))
☑ HSCAT-D 50km Rep02 (new NOC: -0.45(HH), -0.30(VV))

- NSCAT-**4ds.hy2** GMF
- SST Corr.
- **-mixqc**

- NWP data are taken from BUFR files, i.e., the same as NRT processing used!
- Time period: Dec. 01, 2021 ~ April 30, 2022
- SST data are taken from ERA5 at analysis time.
- NSCAT-4ds.hy2 GMF was made using CDF matching tech. based on collocated ascatb and hscatc+d winds
- New NOC was calculated using NSCAT-4ds.hy2 GMF and NWP winds contained in BUFR files.

Wang et al., in progress

Intercalibration with better QC

Conclusions and discussions

- ✓ NRT products: Significant inconsistencies of wind speeds are found between ASCAT and HSCAT! I confirmed that this is NOT caused by resolution difference (25/50km).
- ✓ Rep01: By using new NOC, winds among HSCAT-B, C, and D become more consistent, but NOT close enough to ASCAT.
- ✓ Rep02: By making and using the new NSCAT-4ds.hy2 GMF and compute corresponding NOC, winds from HSCAT and ASCAT show good agreements! However, wind speed below 2 m/s or above 20 m/s still show relative noticeable difference!
- ✓ **The products of ASCAT NRT and HSCAT Rep02 can be the best version choices as sea surface wind inputs to OSE2?**
- ✓ **The residual biases (i.e., depend on instrument or WVCs) are acceptable, and we can move on to the next step?**

More details are given in following slides!

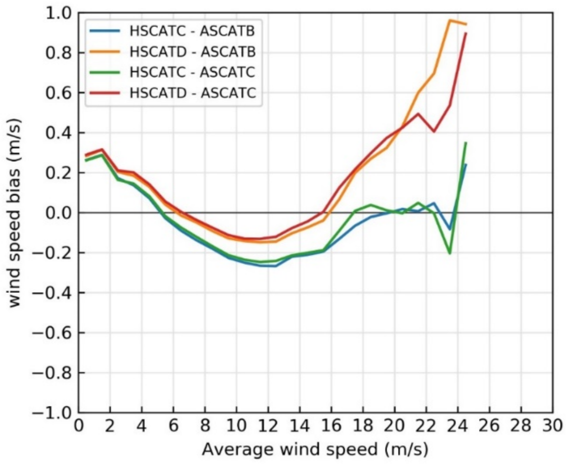
Wang et al., in progress

Intercalibration with better QC

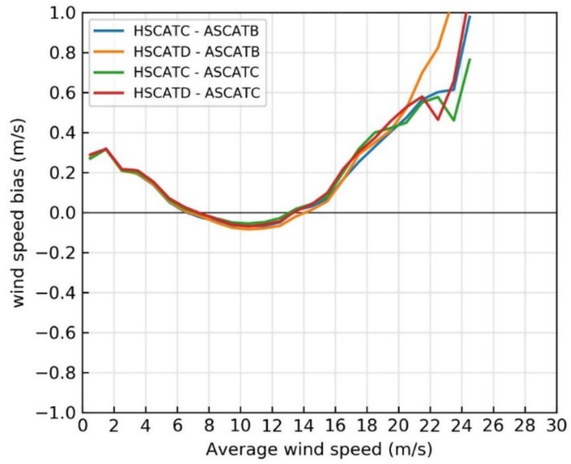
Collocated ASCAT and HSCAT winds!

- Time diff. ≤ 45min
- Spatial distance ≤ 50*0.7071km

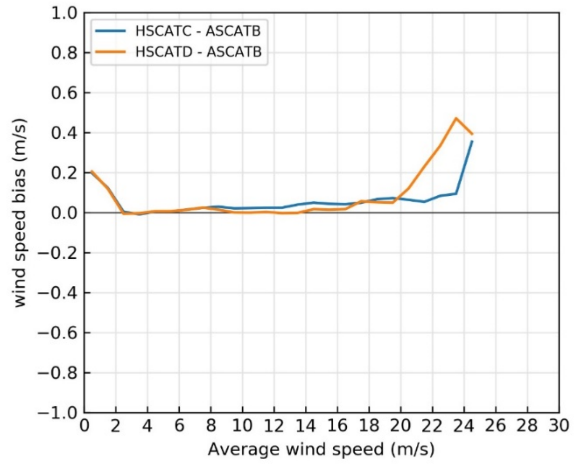
HSCAT NRT



HSCAT Rep01



HSCAT Rep02



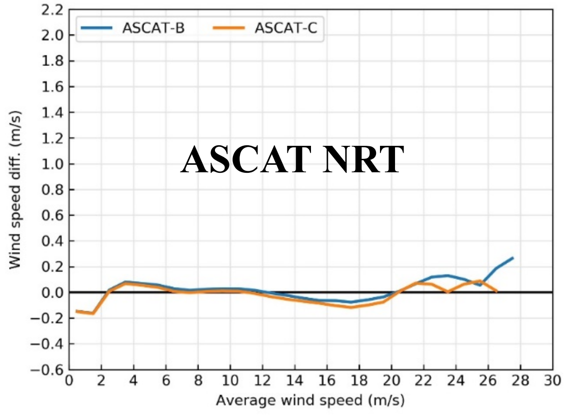
Wang et al., in progress

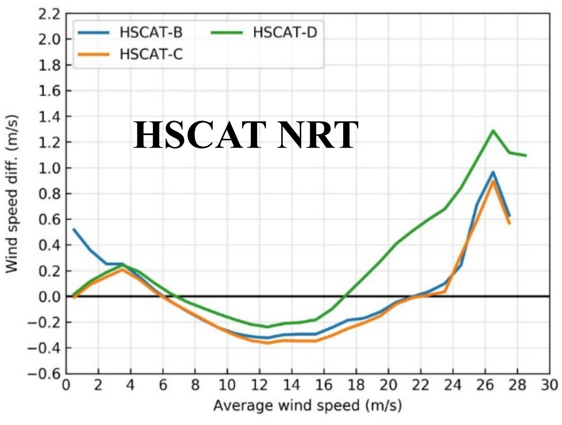
Intercalibration with better QC

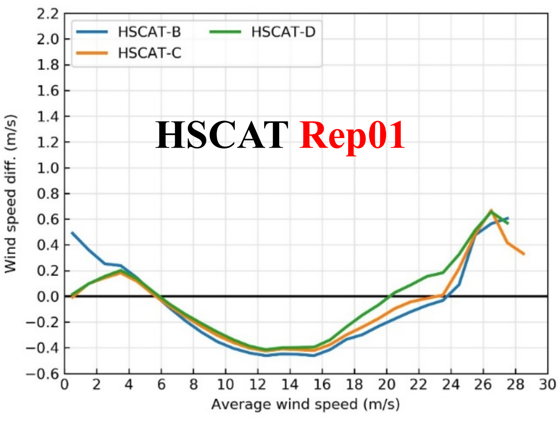
Comparing to the same NWP winds!

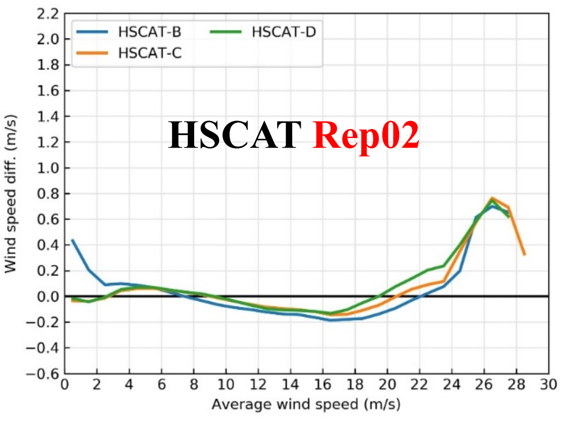
☑ It is clear that: HSCAT Rep02 is better.

☑ Wind speed dependent wind seed biases are reduced, and the curves of HSCAT become more similar to ASCAT curves.







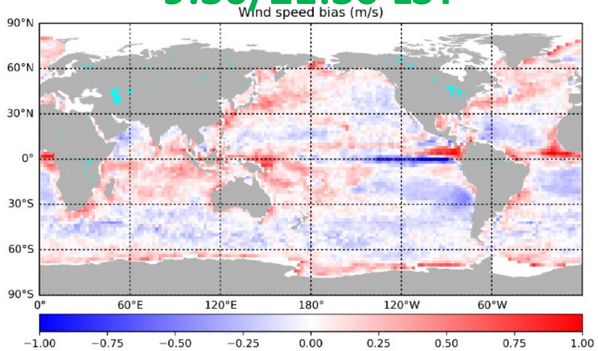


Wang et al., in progress

Intercalibration with better QC

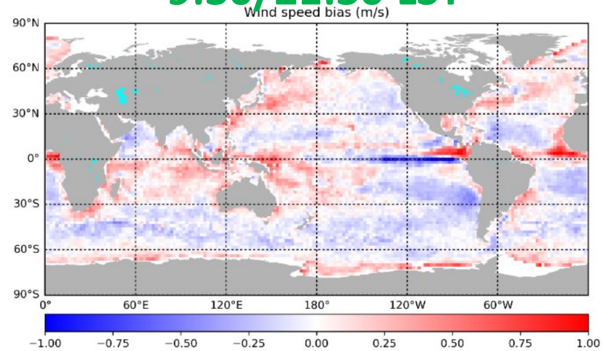
Wind speed biases of SCA - NWP

9:30/21:30 LST

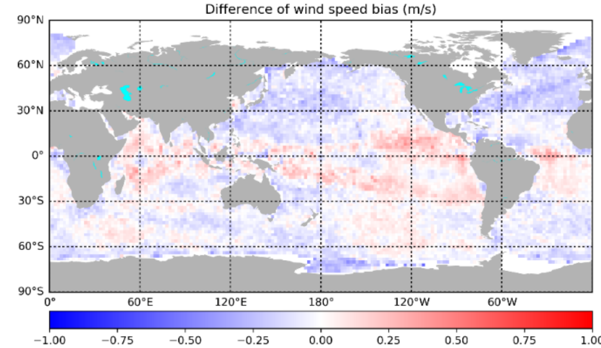


ASCAT-B NRT

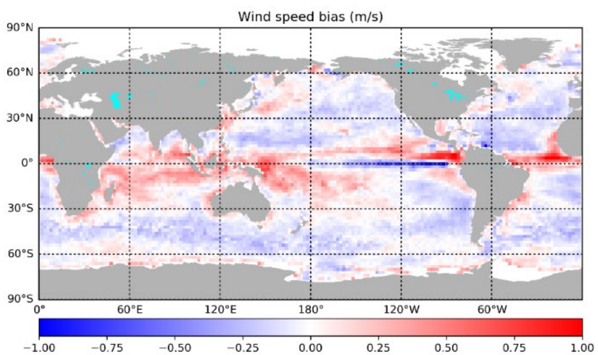
9:30/21:30 LST



ASCAT-C NRT

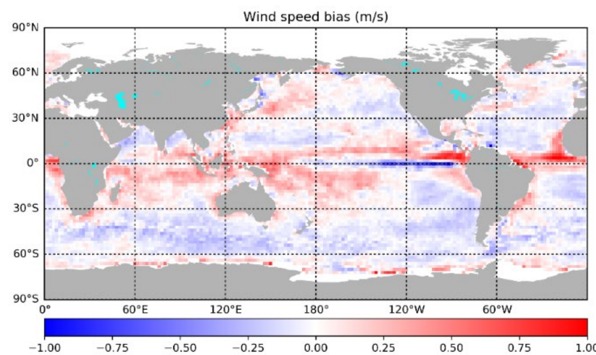


ASCAT-B/NRT – HSCAT-B/Rep02



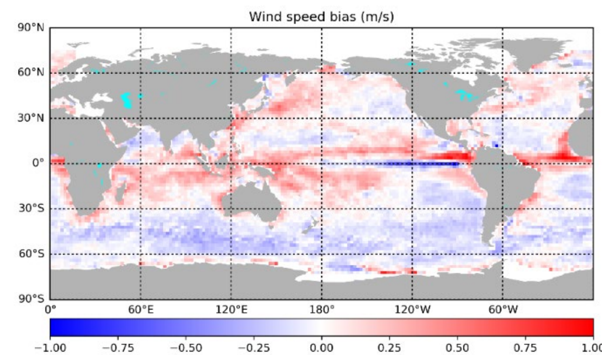
HSCAT-B Rep02

6:00/18:00 LST



HSCAT-C Rep02

Not sun-synchronous



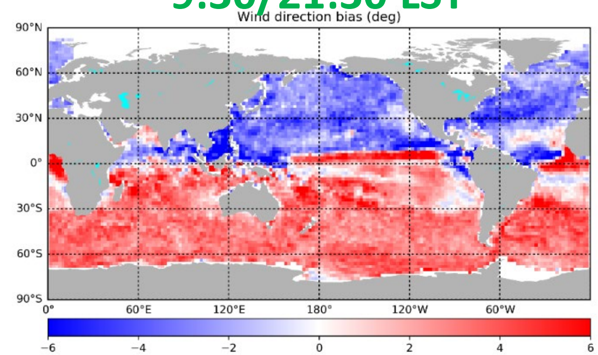
HSCAT-D Rep02

Not sun-synchronous

Wang et al., in progress

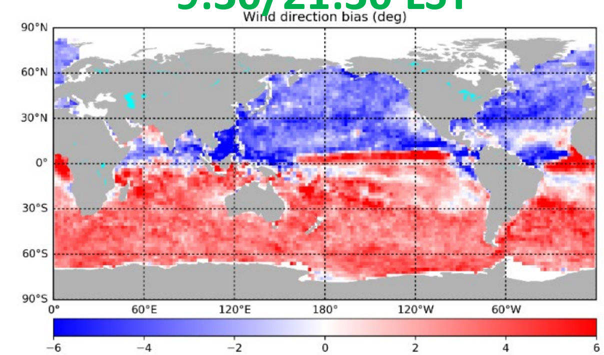
Wind direction biases of SCA - NWP

9:30/21:30 LST

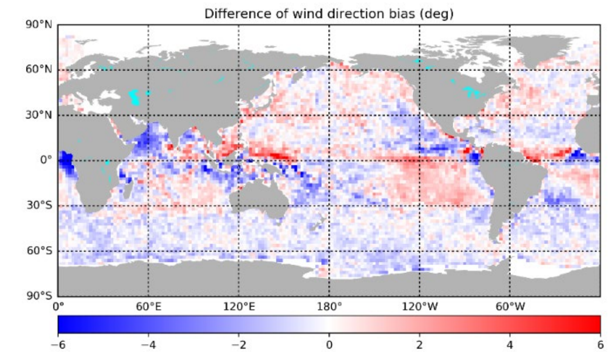


ASCAT-B NRT

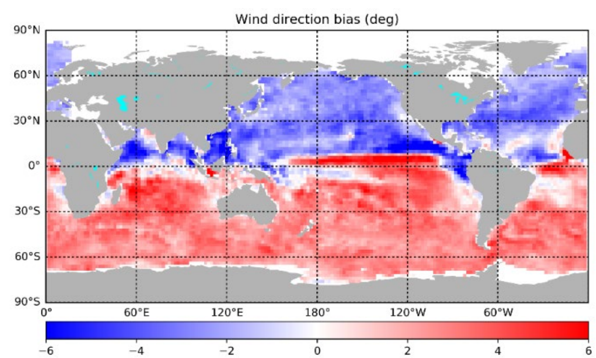
9:30/21:30 LST



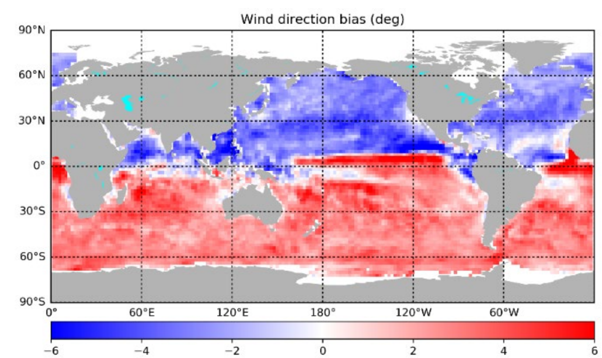
ASCAT-C NRT



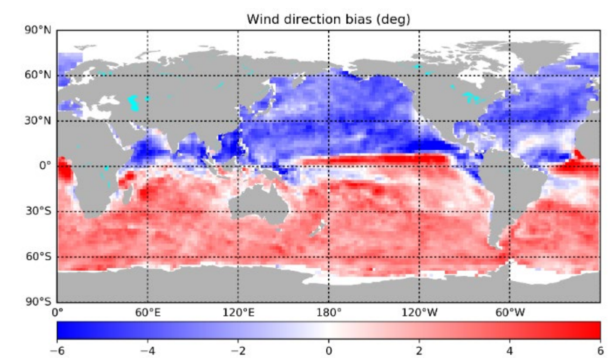
ASCAT-B/NRT – HSCAT-B/Rep02



HSCAT-B Rep02
6:00/18:00 LST



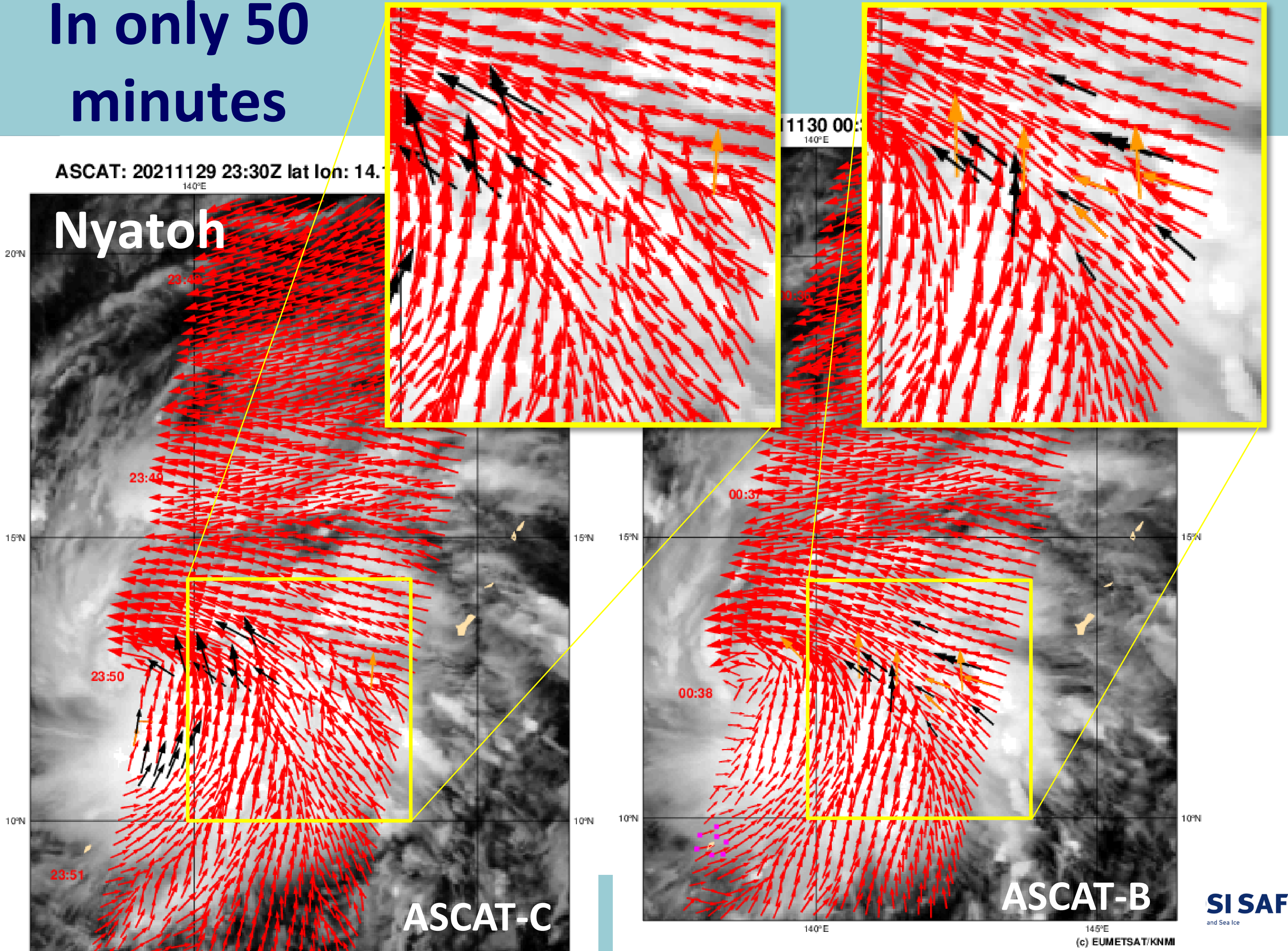
HSCAT-C Rep02
Not sun-synchronous



HSCAT-D Rep02
Not sun-synchronous

Wang et al., in progress

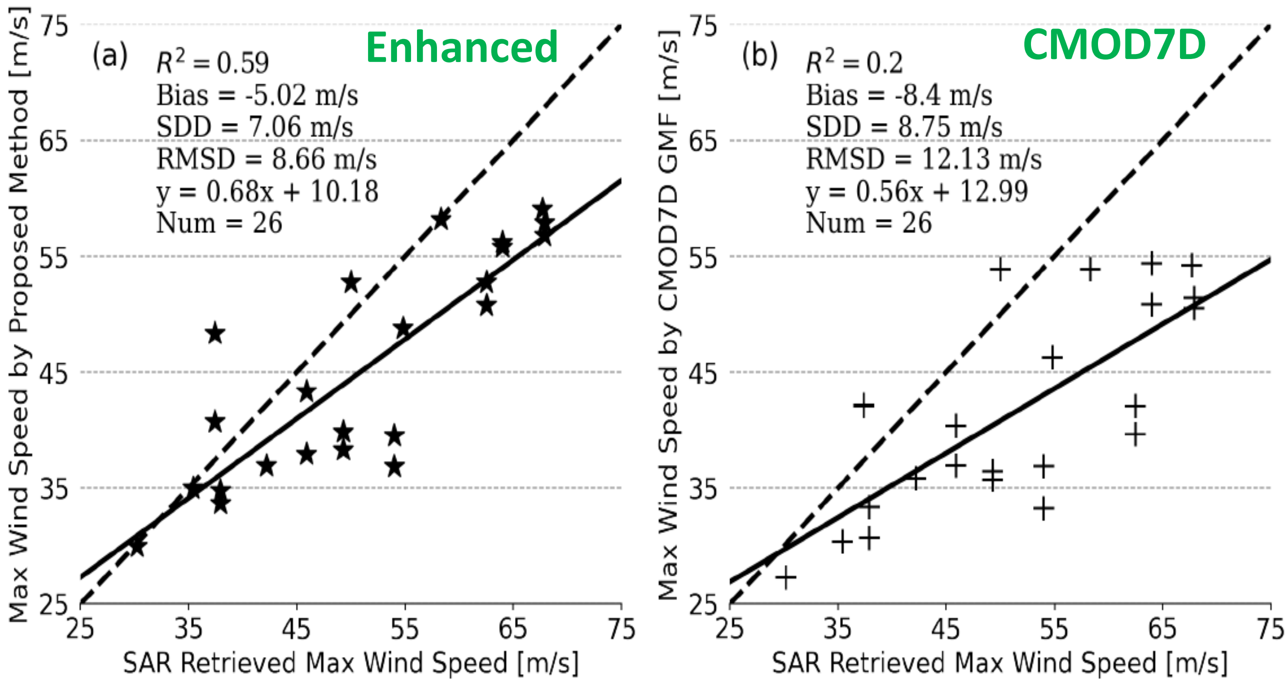
In only 50 minutes



SI SAF

1-min. maximum sustained winds

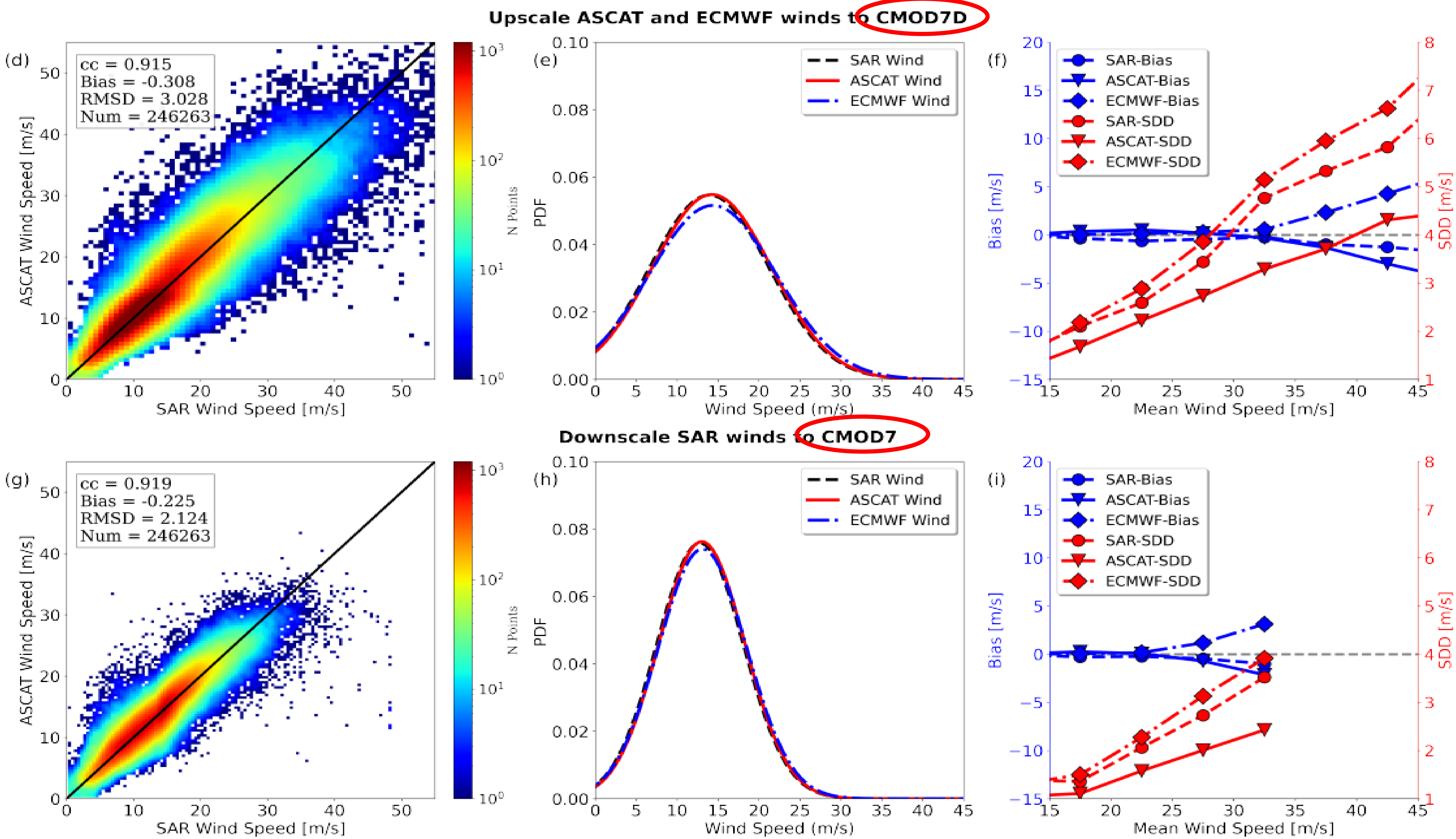
- Standard for hurricane category advisories
- Based on dropsonde wind speed scale – CMOD7D GMF for ASCAT
- Scatterometers blur the maximum eyewall winds
- Develop guidance for 1-minute maximum sustained winds for ASCAT
- Fit simple Rankine vortex to ASCAT winds:



Ni et al., 2022

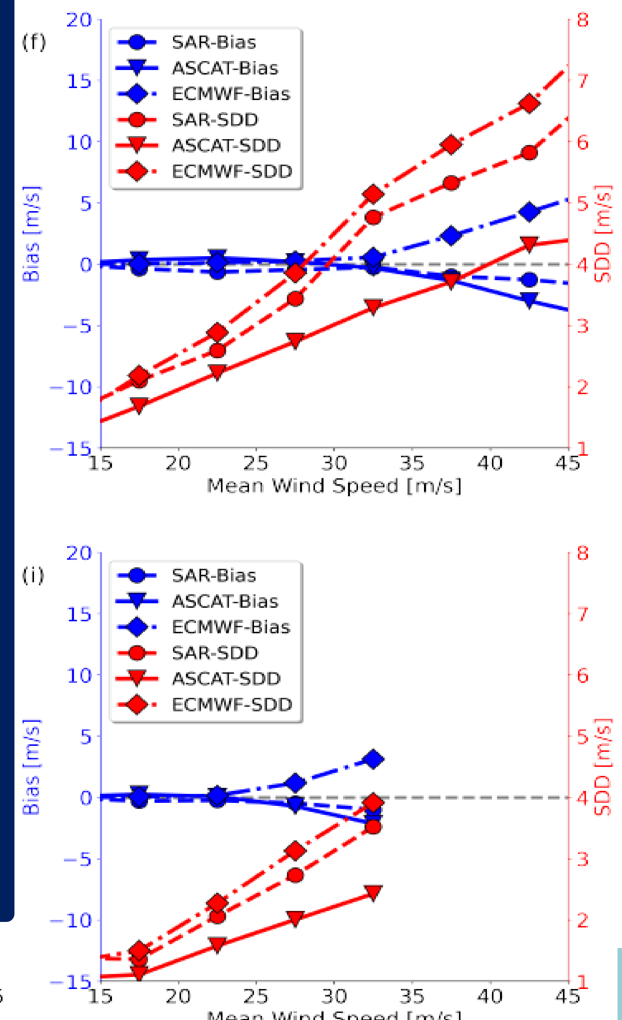
ASCAT, ECMWF and SAR speed scale

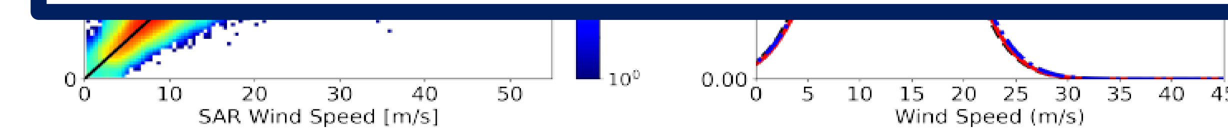
- Triple speed collocation ASCAT, SAR, ECMWF for matching



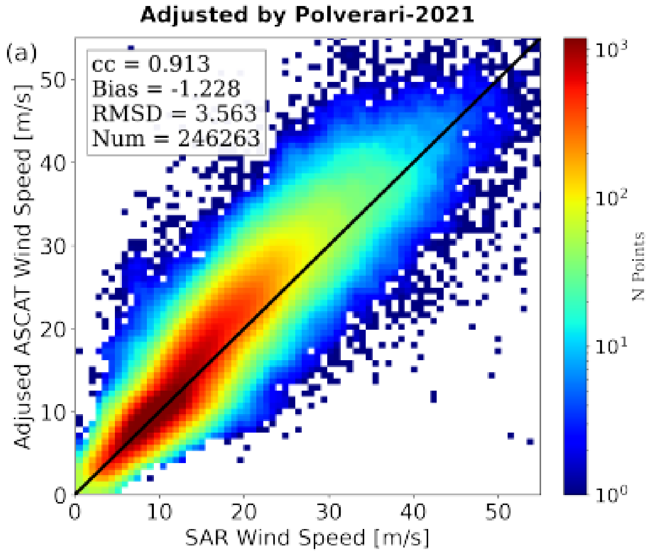
ASCAT, ECMWF and SAR speed scale

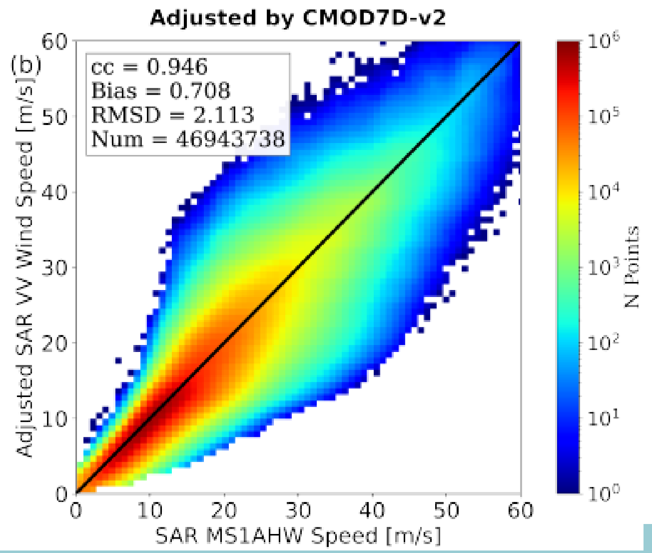
- Triple speed collocation ASCAT, SAR, ECMWF for matching
- Top: CMOD7Dv2 speed scale
- Bottom: CMOD7
- Mean wind speed is reference for accurate binning
- Biases small
- ASCAT error smallest at ~10%
- SAR has more speed structure
- ECMWF is smooth and wide



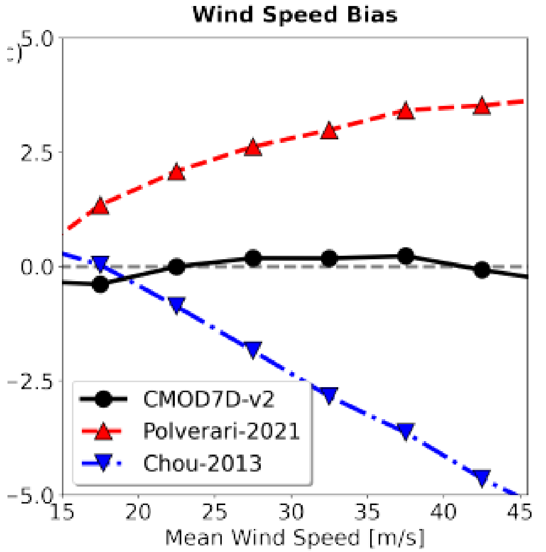


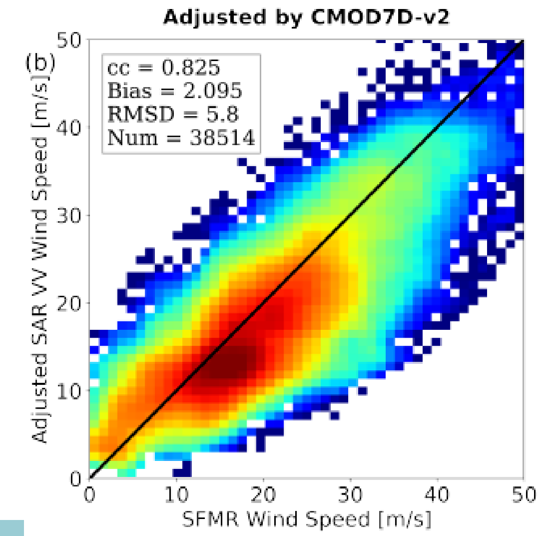
Comparing to SFMR/dropsondes





- Chou et al. adjusted to dropsondes
- Polverari et al. matched SFMR
- SAR VV and ASCAT match well with the same GMF after spatial matching
- SFMR and SAR spread substantially with RMSD of 5.8 m/s
- SFMR appears difficult to calibrate

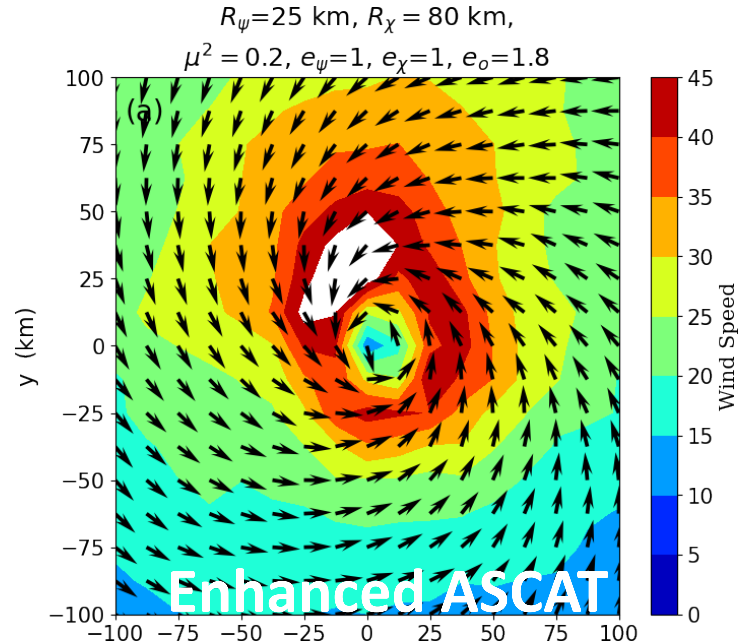


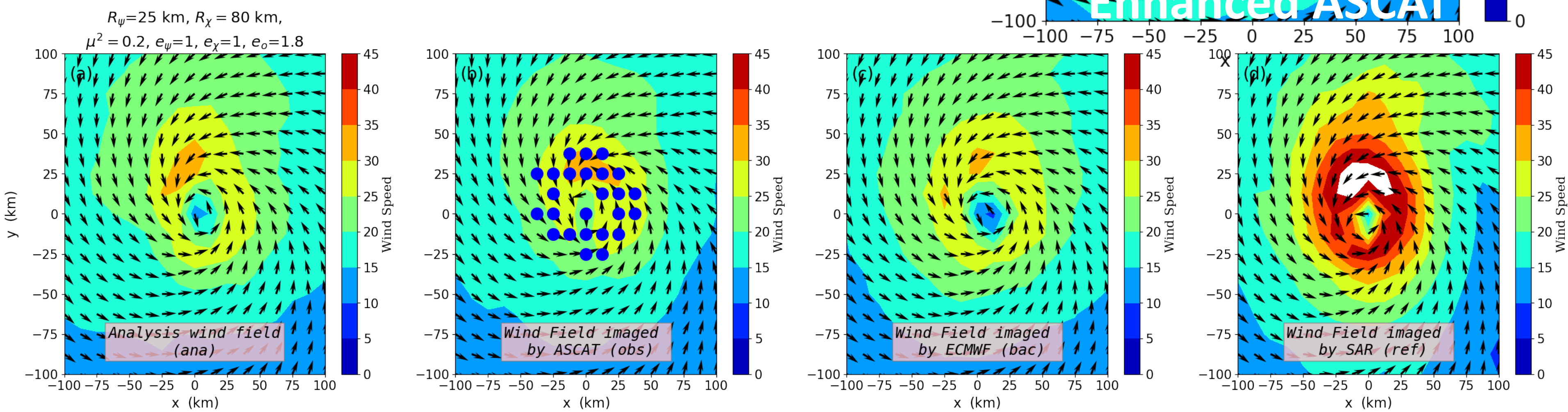


Ni et al., in review

2DVAR (with adjusted speeds)

- In development
- Storm-centered background (max. R^2 centre)
- Empiricial “hurricane” spatial structure functions
- Sensitivity test for varying radii and rot/div ratio
- Now 12.5 km product, later 5.6 km
- Wind speed scaling is last step





Ni et al., in preparation

GMF summary

- Empirical GMFs are very accurate
- ASCAT is very stable and its winds very accurate too
- Rain effects influence Ku-band GMFs, while collocations with ASCAT allow improved rain screening and hence a better Ku wind GMF
- Persistent ECMWF model biases in U10s vector are consistent between sun-synchronous and non sun-synchronous instruments and consistent between C- and Ku-band scatterometers
- ECMWF U10s errors are very substantial and violate the BLUE paradigm in data assimilation; a bias correction scheme is in progress, incl. ML
- Dropsondes and SFMR need further investigation to obtain an accurate wind speed reference as comparisons are noisy, while moored buoy calibrations in the 20-25 m/s regime appear reliable
- Satellite wind measurement instruments can be calibrated irrespective of the wind speed reference used at the extremes and rescaled if need be
- GMFs appear spatial resolution independent, while extremes are not

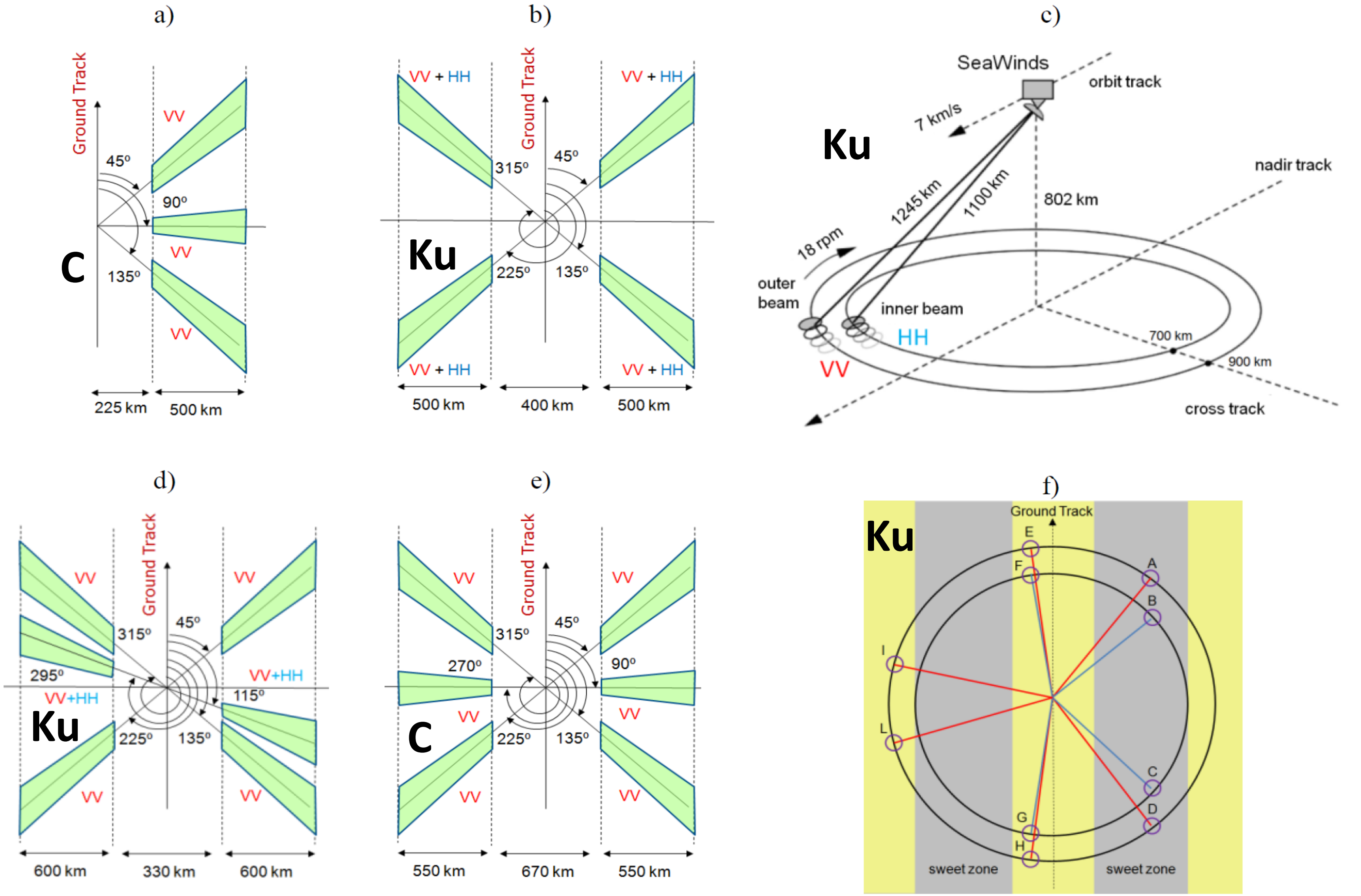
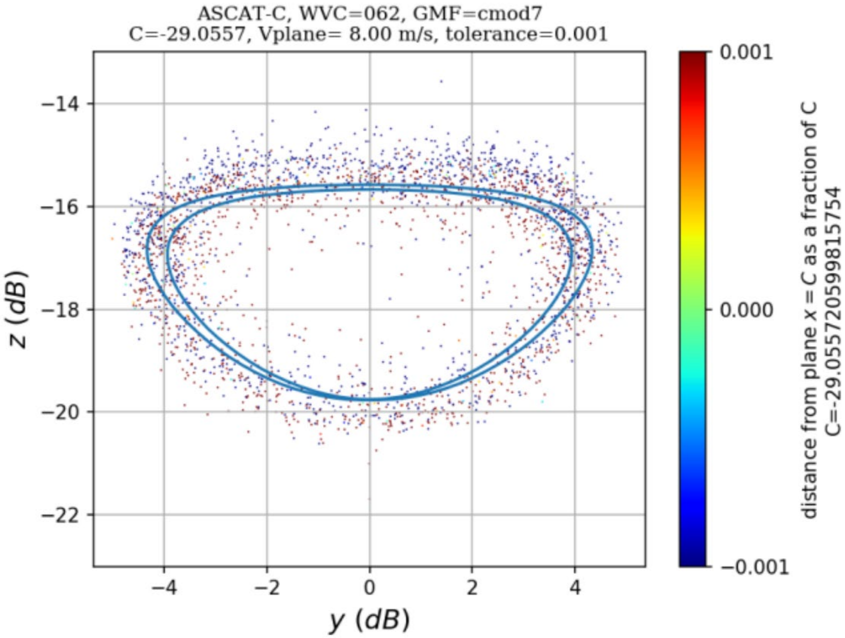


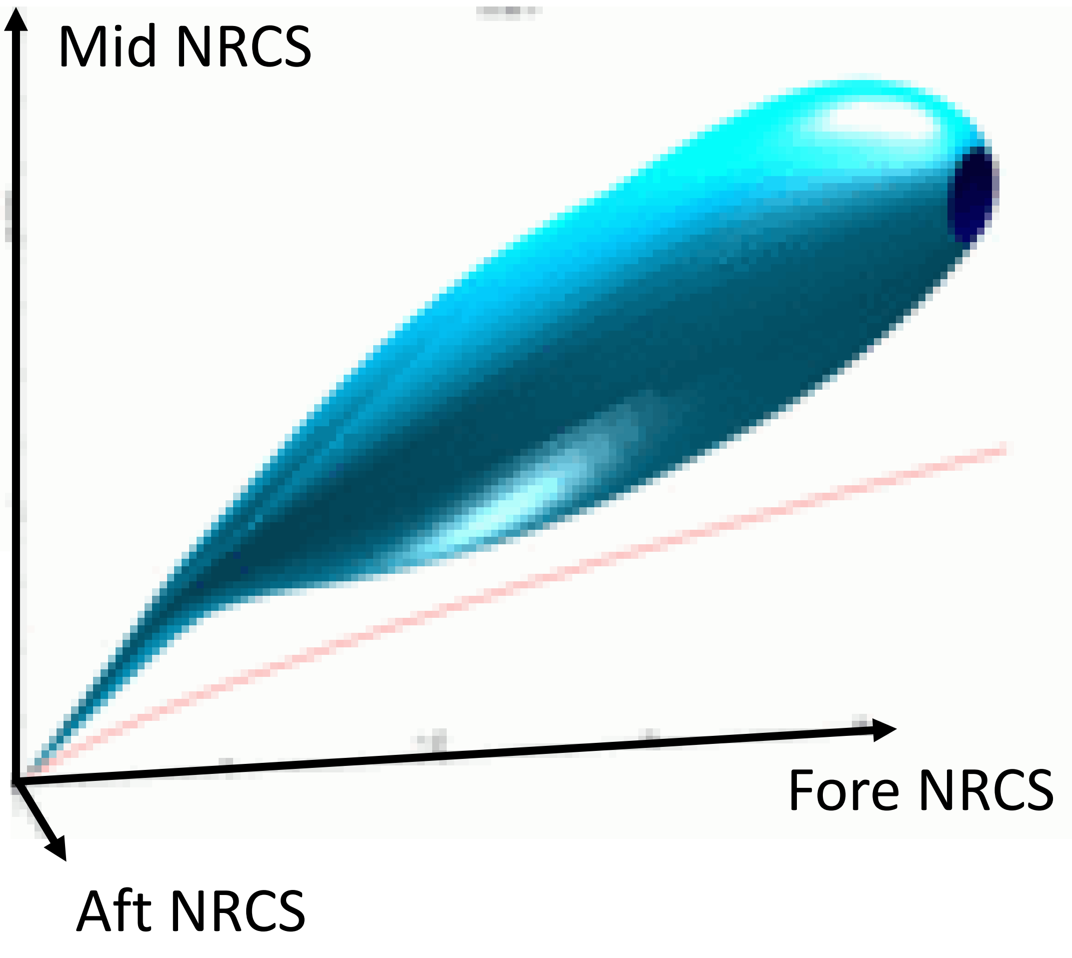
Fig. 1.4 *Sketch of the microwave illumination patterns of: a) AMI (ERS-1/2); b) SASS (SeaSat-A); c) and f) SeaWinds, Oceansat-2 SCAT and HY-2A; d) NSCAT; e) MetOp ASCAT-A and B. The case a), b), d) and e) correspond to a fan beam geometry whereas c) and f) correspond to a pencil beam geometry.*

Franco Fois, PhD thesis, 2015

Cone metrics for ERS and ASCAT

- Exists for every across-track WVC
- Is determined by physics, an amplitude and a direction (U10s)
- Mapping for a given set of θ of co-pol to intercalibrate instruments/years/ . . .
- Diagnostic for NRCS noise, GMF, wind retrieval, QC





Satellite μw scatterometers

- Ground-based transponders are inaccurate for quality monitoring, but provide ball-park calibration for ASCAT
- The rain forest has a daily cycle of about 15% in μw backscatter; it may be used for stability monitoring at given LTAN
- Land targets are affected by moisture events (dew, rain)
- Ice/snow targets may be stable for months, years or decades, but will be affected by T>0 / rain (climate change)
- No absolute calibration, but
  - Very stable instruments within 0.1 dB (2%)
  - Cone metrics provides order 0.02 dB calibration for ASCAT (0.02 m/s)
  - Excellent relative calibration between instruments and over time
  - Non sun-synchronous satellite references for intercalibration (Wang et al., 2021)
  - Excellent and consistent GMFs at used wavelengths, polarizations and angles
  - Many close C- and Ku-band collocations, allowing improved GMFs and consistency
  - Reasonable control on ancillary parameters: SST, stability, waves, rain, . . .
  - Well-known and controlled in situ and NWP references (except for extremes)
  - Generic C- and Ku-band processors

➢ Use ASCAT-B 2013 cone metrics as calibration reference for all scatterometers?

Stress-equivalent wind

- Radiometers/scatterometers measure ocean roughness
- Ocean roughness consists in small (cm) waves generated by air impact and subsequent wave breaking processes; depends on gravity, water mass density, surface tension s, and e.m. sea properties (assumed constant)
- Air-sea momentum exchange is described by $\boldsymbol{\tau} = \rho_{air}\, u_* \boldsymbol{u}_*$, the stress vector; depends on air mass density ρ_{air} , friction velocity vector $\boldsymbol{u}_*$
- Surface layer winds (e.g., $\boldsymbol{u}_{10}$) depend on $\boldsymbol{u}_*$, atmospheric stability, surface roughness and the presence of ocean currents
- Equivalent neutral winds, $\boldsymbol{u}_{10N}$, depend only on $\boldsymbol{u}_*$, surface roughness and the presence of ocean currents and is currently used for backscatter geophysical model functions (GMFs)

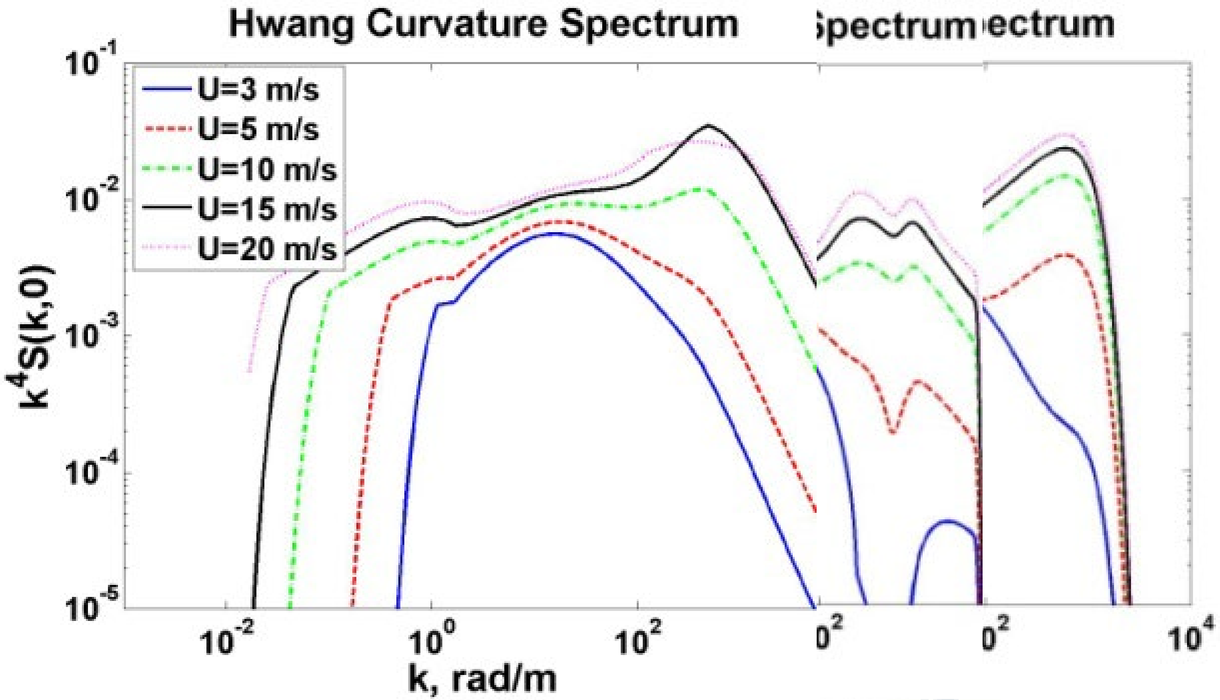
- $\boldsymbol{u}_{10S} = \sqrt{\rho_{air}} \cdot \boldsymbol{u}_{10N} / \sqrt{\rho_0}$ is now used to be a better input for backscatter GMFs (stress-equivalent wind)
- This prevents regional biases against local wind references
- U10s shows no significant ancillary dependencies on, e.g., long ocean waves (TBC)

Intercalibration and standardization

- Our premise is that for given wavelength, polarization and geometry, σ^0 should be identical in identical geophysical conditions and independent of instrument settings
- We develop generic L2 wind processing for calibrated instrument data
- Noise properties do however affect σ^0 diagnostics, so we develop noise models too to better understand our retrievals and diagnostics
- KNMI is particularly interested to remove (σ^0 –dependent) instrument biases as they interfere with Ku-band wind and SST dependencies (Stoffelen et al., 2017; Wang et al., 2017; Belmonte et al., 2017)
- Comparison of ScatSat with QSCAT, RSCAT and OSCAT behavior for given Geophysical Model Function GMF and NWP input to obtain consistency
- CFOSAT, HY-2 and WindRad scatterometers will follow (Wang et al., 2021)

Satellite μw scatterometers

- Bragg scattering interference of microwaves and ocean waves
- Hydrodynamic ocean short-wave modulation, choppy wave model
- Wave-wind interaction, wave boundary layer (scatterometers see no long waves so far)
- The short wave spectrum is dominated by breaking waves and their dissipation for modal and higher winds
- Crucial to describe the short wave spectrum, but rather complex
- Use satellite data
- Wave shadowing and interference at grazing incidences
- Specular reflection dominates
at smaller incidence angles
(geometric optics)



Uncertainty

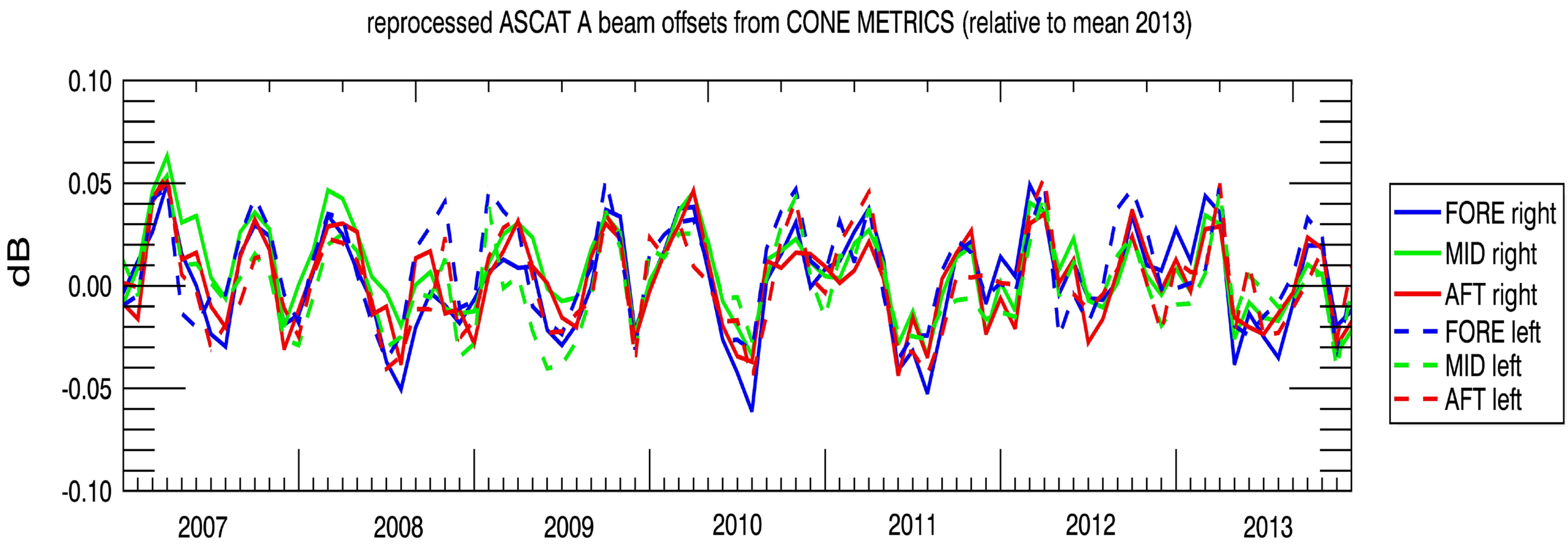
- Users are interested in stability and consistency of L2 geophysical products, e.g., detect 0.1 m/s trends over 10 years
  - Cone metrics provides order 0.02 dB calibration for ASCAT (0.02 m/s)
- Cone spread over ocean to provide ocean spatial variability, which is found equal to wind variability (wind downbursts, turbulence, convection)
- Related to Kp too (Kp is the σ^0 SD)
- Can be segregated into geophysical and instrument (error) contributions

- Wind retrieval quality is in stress-equivalent wind, correcting for air stability and mass density effects, which are not seen in ocean microwave EO
- Scatterometer wind retrievals are very consistent after intercalibration of backscatter values and GMFs

- Physically-based models are useful to describe/understand behaviour at different wavelengths and polarizations, but fed by empirical satellite data characterization to improve accuracy
  - Wavelength dependency
  - Wind azimuth and speed dependency
  - Polarization/incidence dependency
  - Doppler

ASCAT is very stable

- ASCAT-A beams stay within a few hundreds of a dB (eq. to same value in m/s)
- Cone position variation due to seasonal wind variability (reduced with u10s)
- ➢ Improve ASCAT attitude knowledge? (cf. Long, 1998)
- ➢ Asset for Ku-band scatterometer developments; radiometers
- ➢ Reference for NWP reanalyses
- ➢ Can method be applied for other scatterometers?



Maria Belmonte et al., 2017

Training/interaction

- Training Course Applications of Satellite Wind and Wave Products for Marine Forecasting
  vimeo.com/album/1783188 (video)
- Forecasters forum
  training.eumetsat.int/mod/forum/view.php?f=264
- Xynthia storm case
  www.eumetrain.org/data/2/xynthia/index.htm
- EUMETrain ocean and sea week
  eumetrain.org/events/oceansea_week_2011.html (video)
- NWP SAF scatterometer training workshop
  nwpsaf.eu/site/software/scatterometer/
- Use of Satellite Wind & Wave Products for Marine Forecasting
  training.eumetsat.int/course/category.php?id=46 and others
- Satellite and ECMWF data vizualisation
  eumetrain.org/eport/smhi_12.php?
- MeteD/COMET training module
  www.meted.ucar.edu/EUMETSAT/marine_forecasting/