Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

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CSIC
Consejo Superior de Investigaciones Científicas

ICM Institut de Ciències del Mar

C-band High and Extreme-Force Speeds -- CHEFS --

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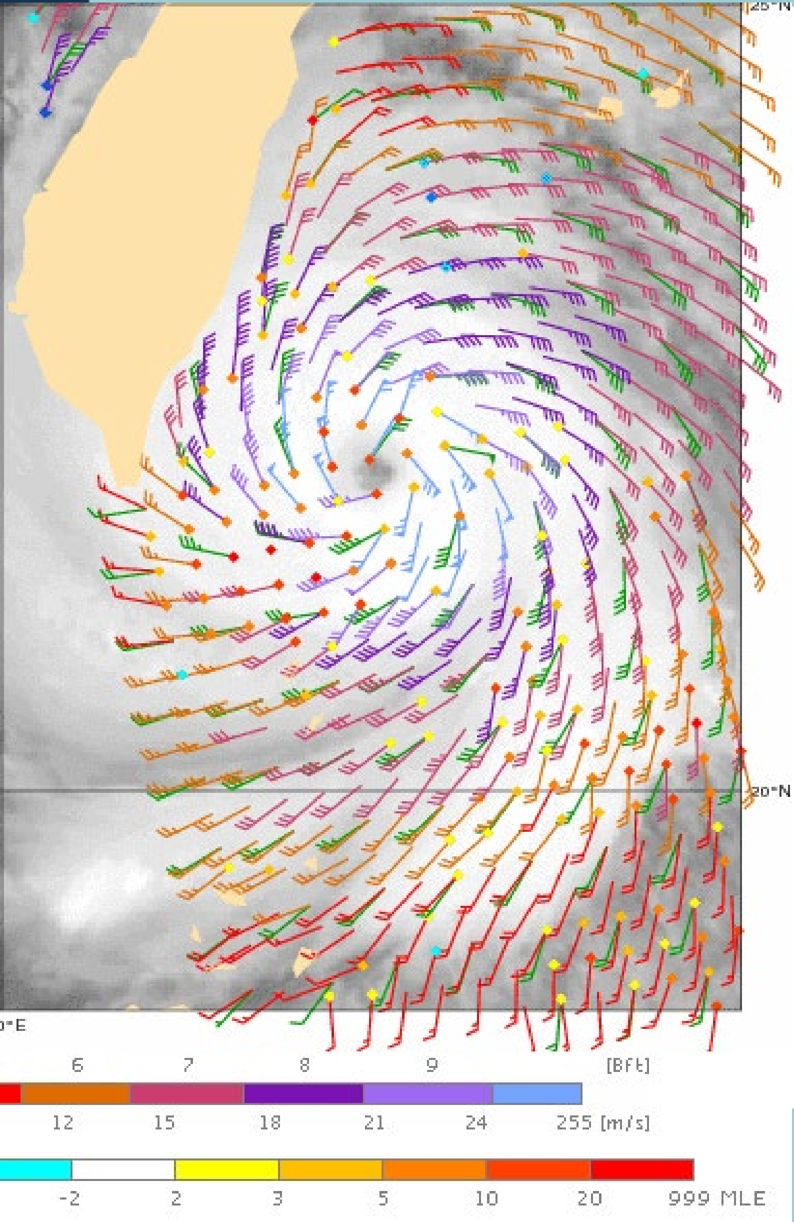
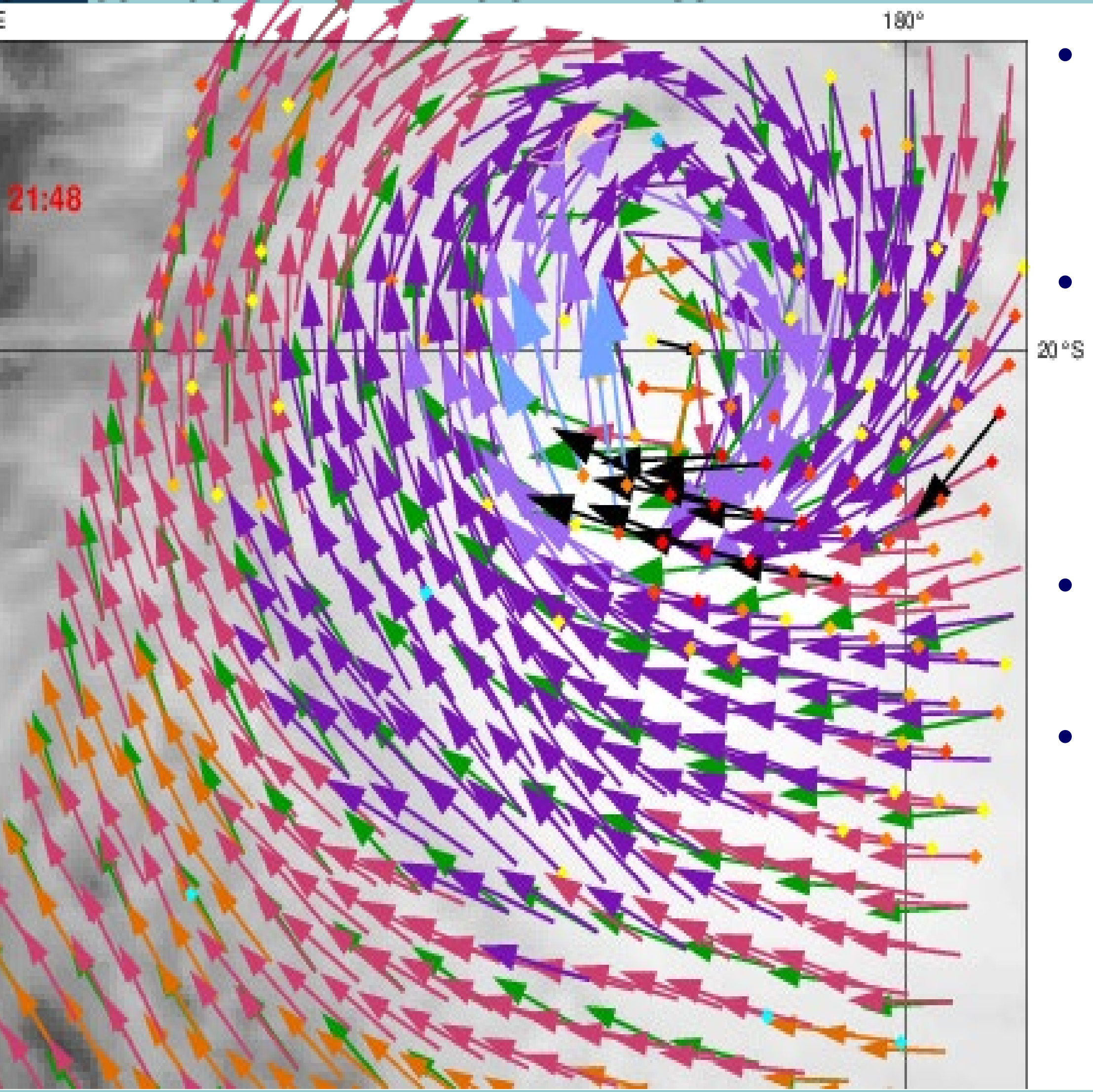
CHEFS Objectives



- **VH GMF**: The understanding of the future C-band VH information contribution to high and extreme wind retrievals from C-band scatterometer missions;
- **Spatial scaling** of extremes: The definition of spatial scaling issues and related consequences for product sample resolutions and validation approaches;
- **Understanding** of extremes: To further understanding of satellite remote sensing of high and extreme wind conditions over the ocean.

- In-situ wind speed reference needed for all extreme wind products, from satellites, reanalyses to NWP models

CHEFS



- EUMETSAT ITT 16/166
  - Extreme winds calibration
  - VH test data
- KNMI
  - EPS-SG design and VH
  - GMF and retrieval
  - Calibration strategy
- ICM
  - Scatterometer science
- IFREMER
  - SAR wind retrieval
  - Data lab, L-band, GMF

CHEFS

- ✓ 12 -> 29 months parallel efforts at KNMI, ICM and IFREMER
- ✓ Select and collect satellite observations at VH, VV and HH
- ✓ Select and collect in-situ reference wind speed data and ancillary geophysical information
- ✓ Collocate radar parameters from satellite with geophysical parameters from reference data
- ✓ Assess Sentinel-1 VH beam response to extreme winds
- ✓ Revisit the VH GMF; compare to passive L-band
- ✓ Assess wind variability effects, notably on the SAR signal (VV and VH)
- ✓ Cal/Val of SFMR with dropsonde wind data
- ✓ Define day-1 SCA processing method
- ✓ Generate SCA test data and validation

In-situ wind speed reference?

Inconsistencies

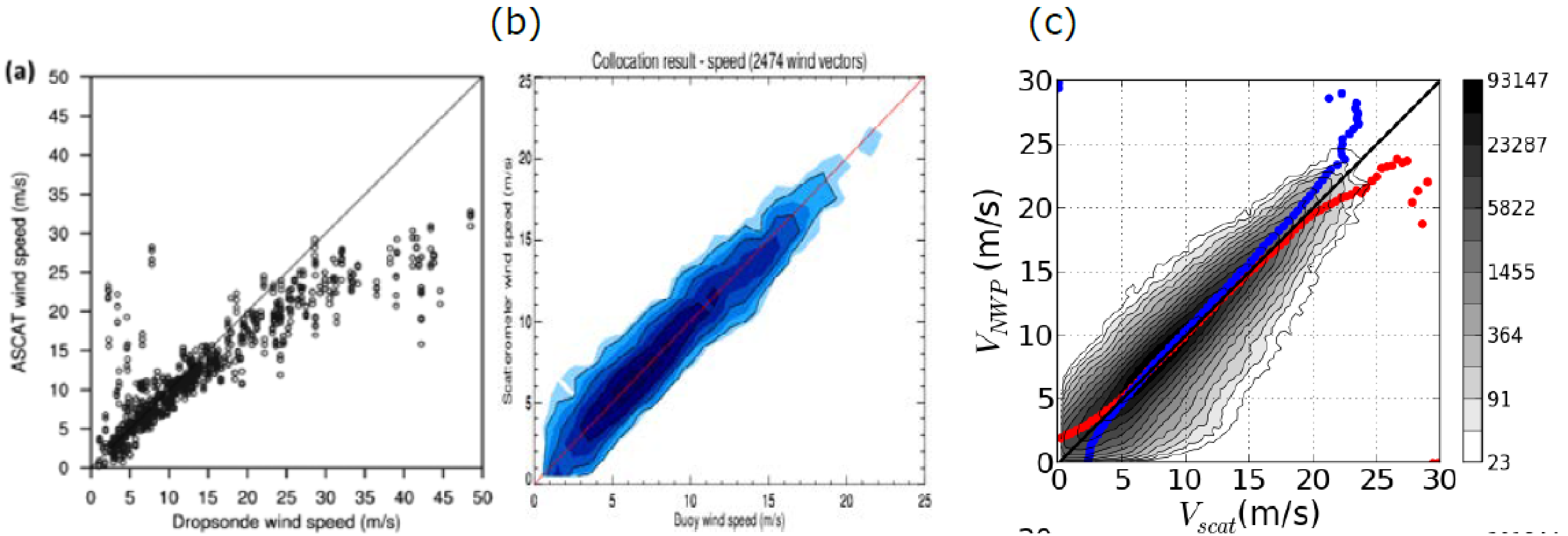


Figure 3.3: ASCAT wind speed scatter plots of a) ASCAT versus drop sondes (from [37]), b) ASCAT versus moored buoy winds and c) ECMWF NWP winds versus ASCAT. Using drop sondes, moored buoy winds and NWP references above 15 m/s may result in discrepancies due to height and position reprepresentation differences.

- Are dropsondes too high, or moored buoys and ECMWF too low at 20-25 m/s ?

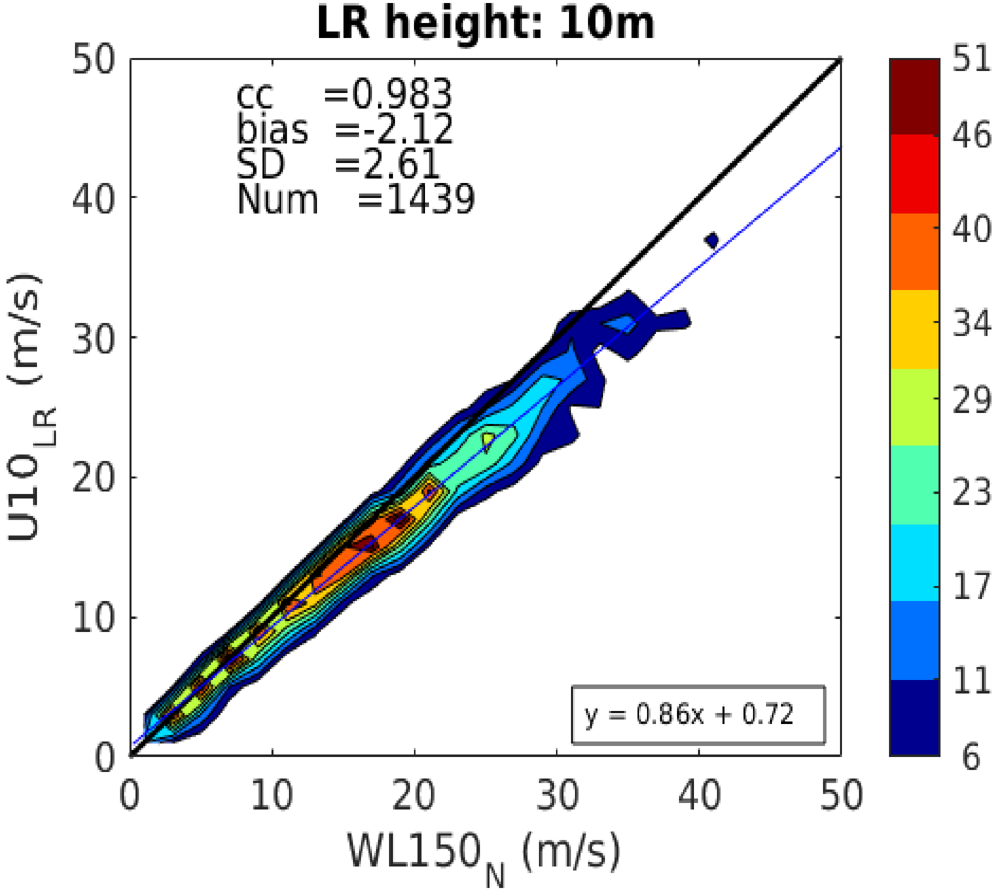
In-situ wind speed reference?

Dropsondes

- Dropsondes form the basis for further assessments dedicated to the high and extreme winds conditions
- Dropsondes are compared against SFMR and SAR on the local scale and with ASCAT and ERA5 on larger scales
- Direct comparison of moored buoys and dropsondes is unlikely.
- Dropsondes will be segregated in different vertical sampling, in different profile (shear) conditions and in different drift conditions
- The scatter in dropsonde winds at 20 ms^{-1} versus ASCAT winds is relatively large and the dropsonde profile fits to compute 10-m winds from dropsondes will be evaluated and used for QC
- Since ASCAT retrievals have good relative accuracy around 20 ms^{-1}, they will be used as a (relative) reference to understand biases and scatter in both moored buoys and dropsondes
- Collocations of SFMR with moored buoys exist occasionally to explore biases and scatter, but this remains pending

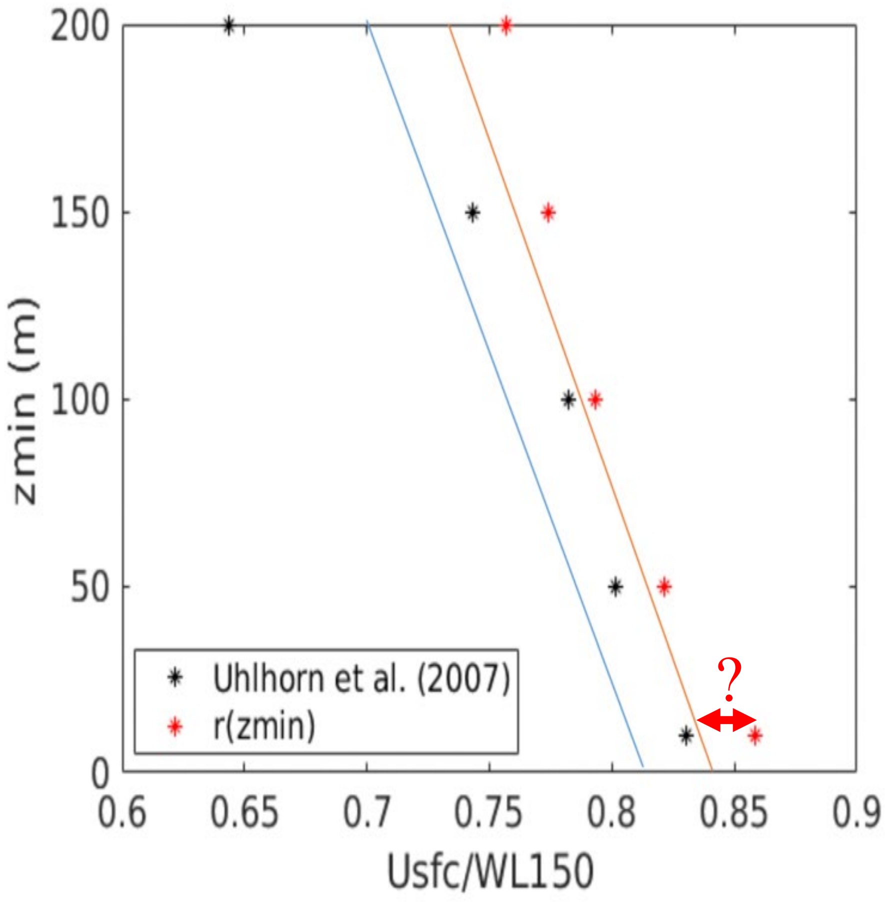
WL150

- Used in operational practice to estimate maximum 1-minute sustained 10-m winds, $U10_{M1mS}$
- Dropsonde lowest reading at 10-15 m altitude
- WL150 mean altitude 80-90 m
- Linear fit consistent with WL150: 0.85 from Uhlhorn et al. (2007)
- Vertical averaging in WL150 enhances cyclone representation
- Measured U_{10S} however best for instrument calibration
- U_{10S} needs position, speed and acceleration
- Deceleration high near surface



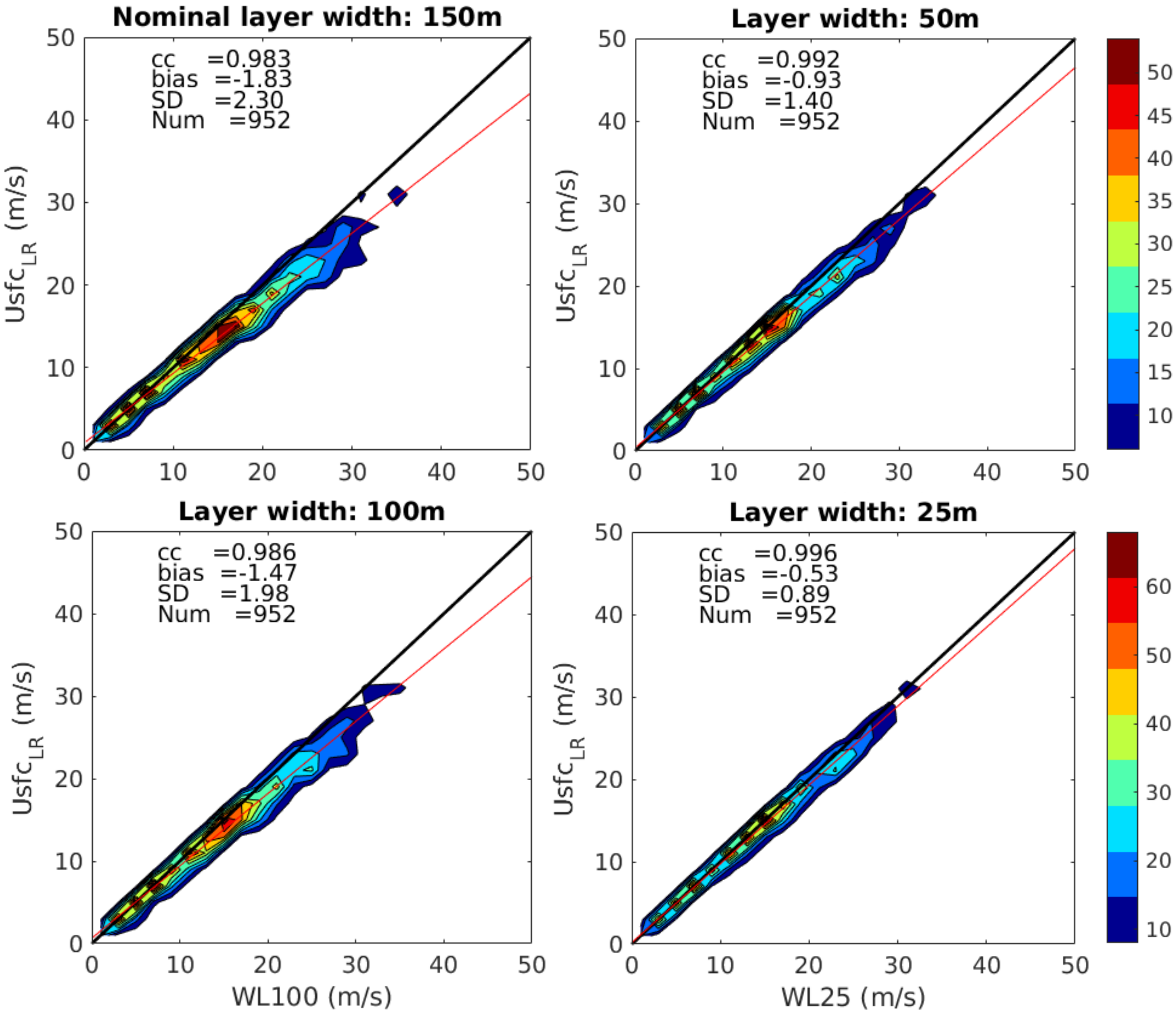
Logarithmic profile

- In a log profile
  z_0 = 5 mm ,u^* = 1.58 m s^{-1} and
  z_0 = 1 mm, u^* = 1.3 m s^{-1} lead to
  U_{10LR} = 30 m s^{-1}
- Corresponding $U10_{LR}/WL150_N$ is 0.81 and 0.84 resp. (plot)
- Corresponding $U15_{LR}/WL150_N$ is 0.85 and 0.87 respectively
- A shift in the 10m value may be due to
  - No log profile (e.g., due to waves)
  - GPS position lag, hence speed and acceleration error and 10-m wind measurement error
- Such errors are speed dependent

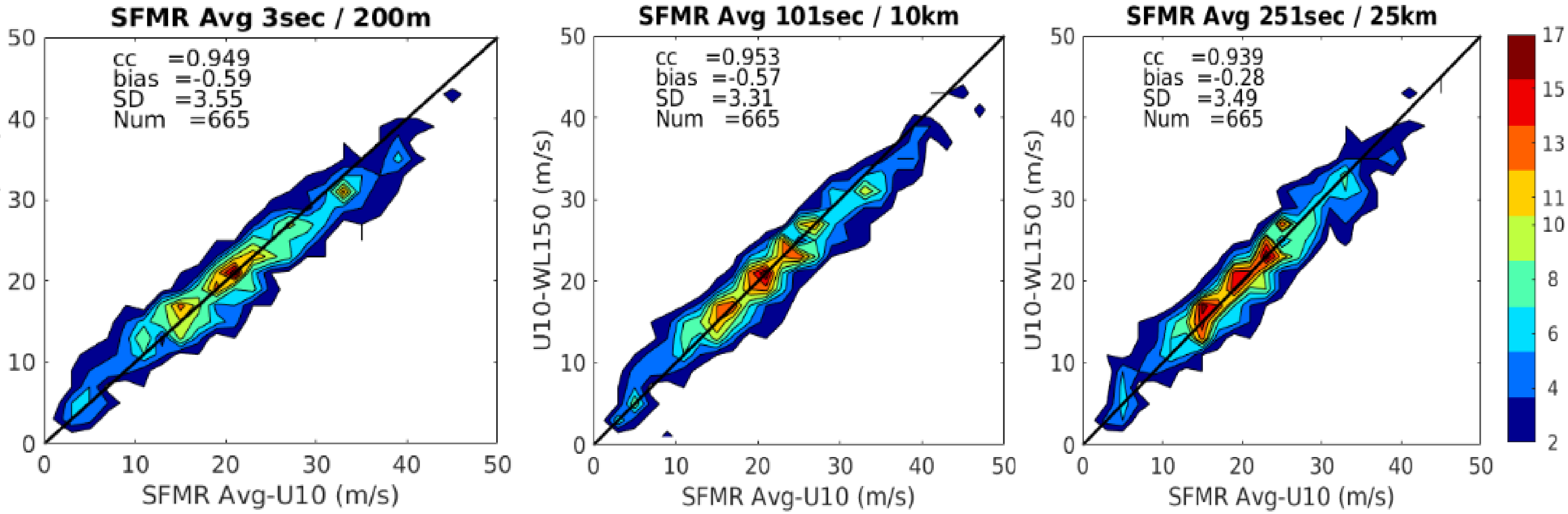


WL25-WL150

- The thinner the averaging layer, the lower variance
- Little variance in the lowest 25m, hence little sign of variability due to waves
- Note that due to the log profile and strong deceleration close to the surface, the dropsonde is integrating in the vertical



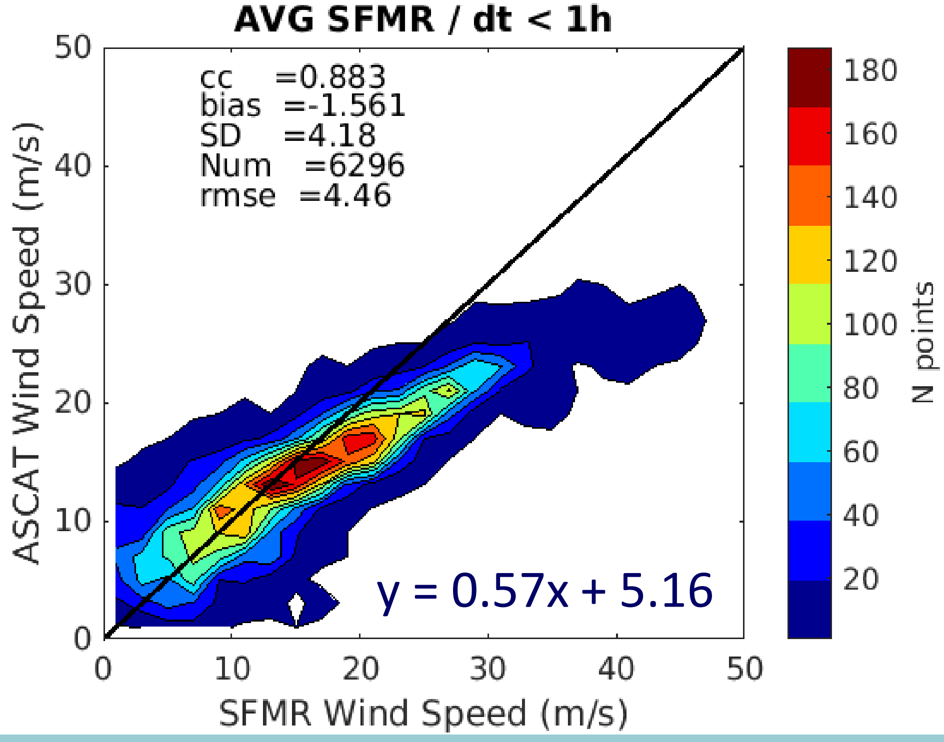
Averaging / Distance

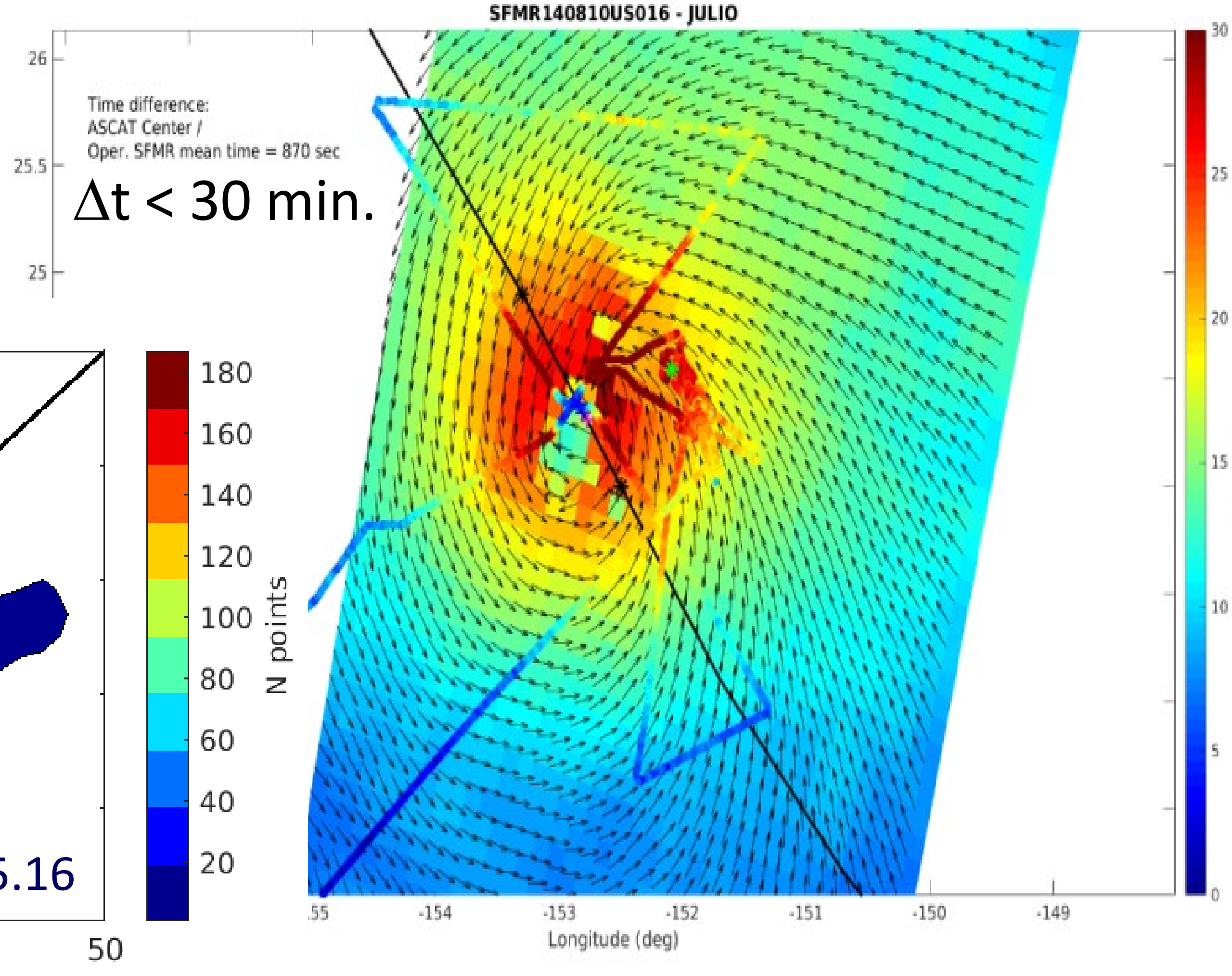


- Best correspondence over 10 km
- 10 km is the typical distance between SFMR measurement location and dropsonde 10-m wind

ASCAT-VV SFMR comparisons

- Storm centered
- SFMR relatively high
- SFMR and ASCAT VV correlate well
- SFMR outlier tracks

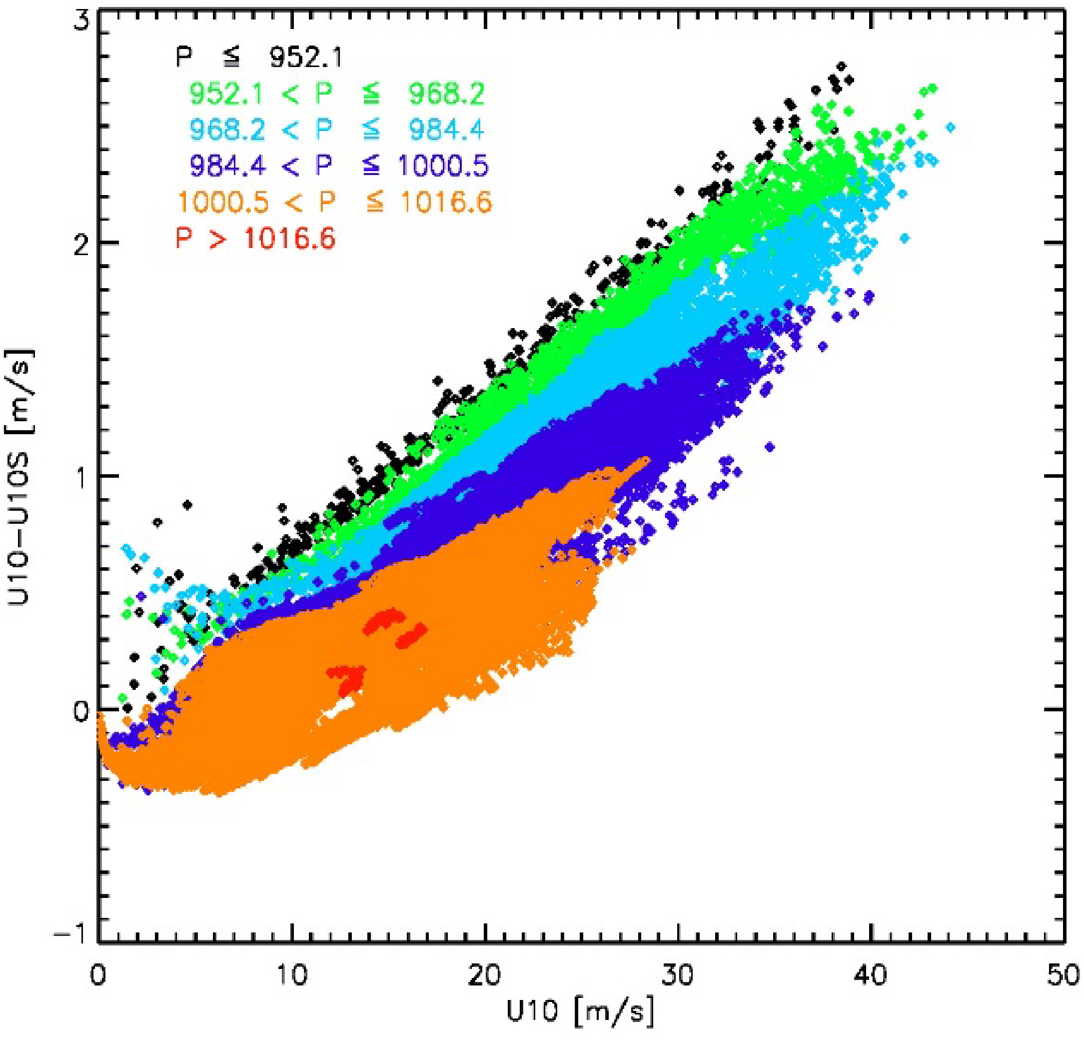




Stress-equivalent winds in TCs

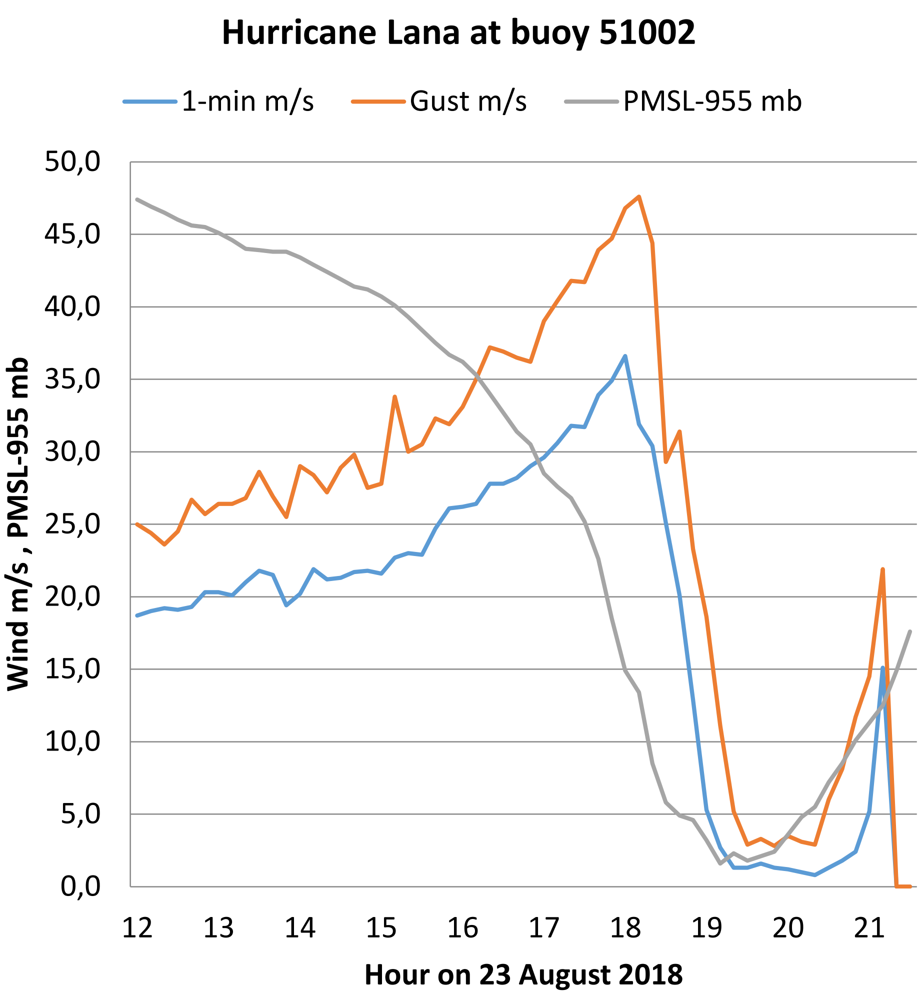
- Only near tropical cyclones (TC)
- Pressure and humidity affect air mass density
- Particularly near TC centres
- At extreme winds up to a few m/s (5%)

➢ Needs to be accounted for



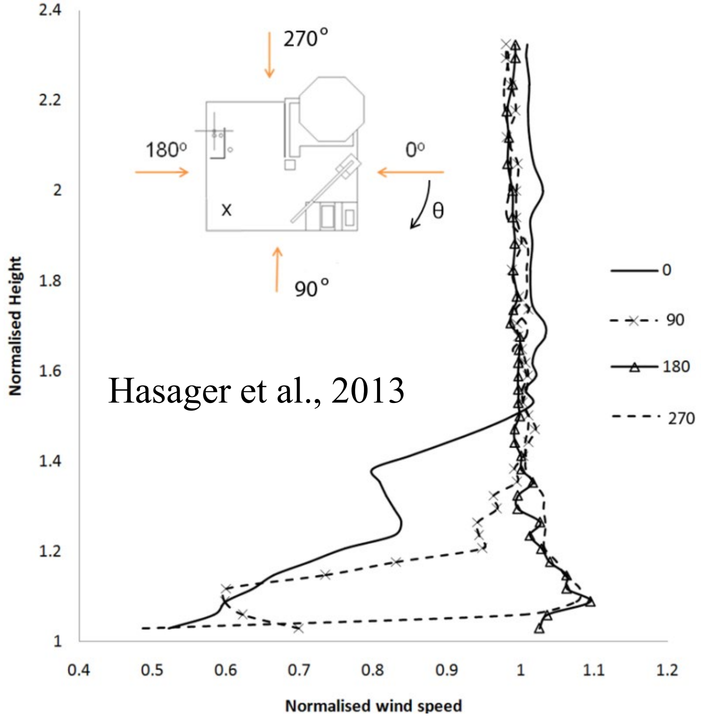
Moored buoys

- Best controlled resource for in-situ wind speed calibration at moderate and high winds
- Work well up to 25 m/s as verified with wind tower
- Dynamically corrected platform winds
- Claims of ocean wave shielding lead to non-substantiated sources (WP2)



Other references?

- +ve and –ve wind flow distortion around platforms
- Verification shows differences to platforms 2x as high as to buoys; what is this scatter? Does it cause bias? Useful as calibration reference?
- Platform motion (ships)
- Errors are not well controlled, larger than for moored buoys and tend to be environmentally dependent



Compare NRT to archive

- GTS: last 10 minutes of hour
- icoads.noaa.gov/ 10-minute values "super-obbed" into hourly values

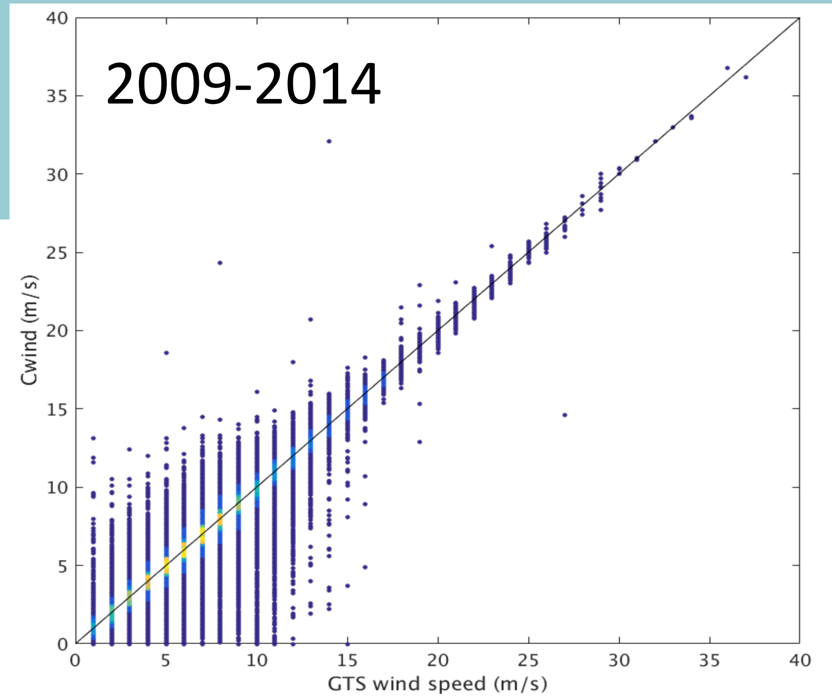
➢ GTS is best resolved data

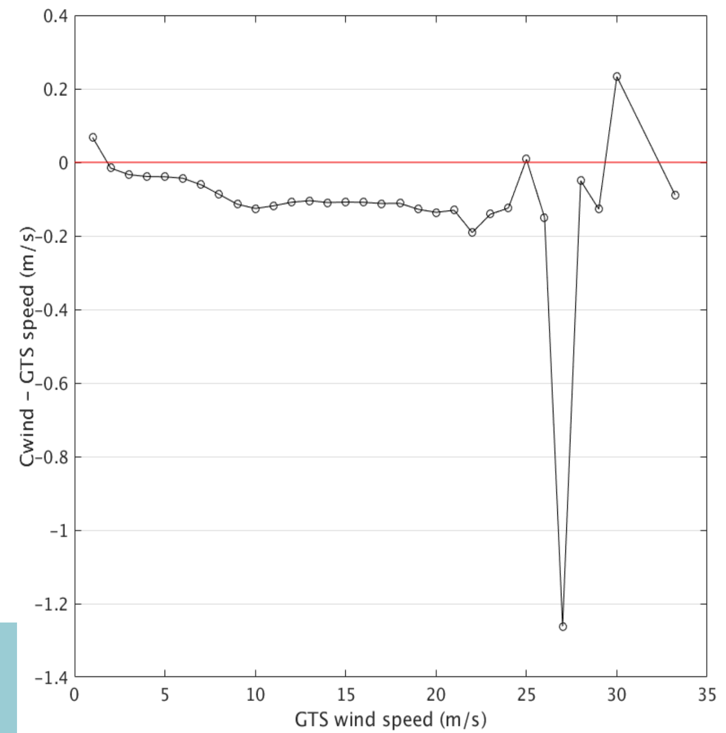
➢ Averaging causes asymmetric scatter, small (negligible) bias

➢ Stress-equivalent wind causes small bias

➢ Triple collocation analysis of the wind characteristics of different types of moored buoys in terms of height and mooring against ECMWF and/or ASCAT wind references

➢ Sea state?

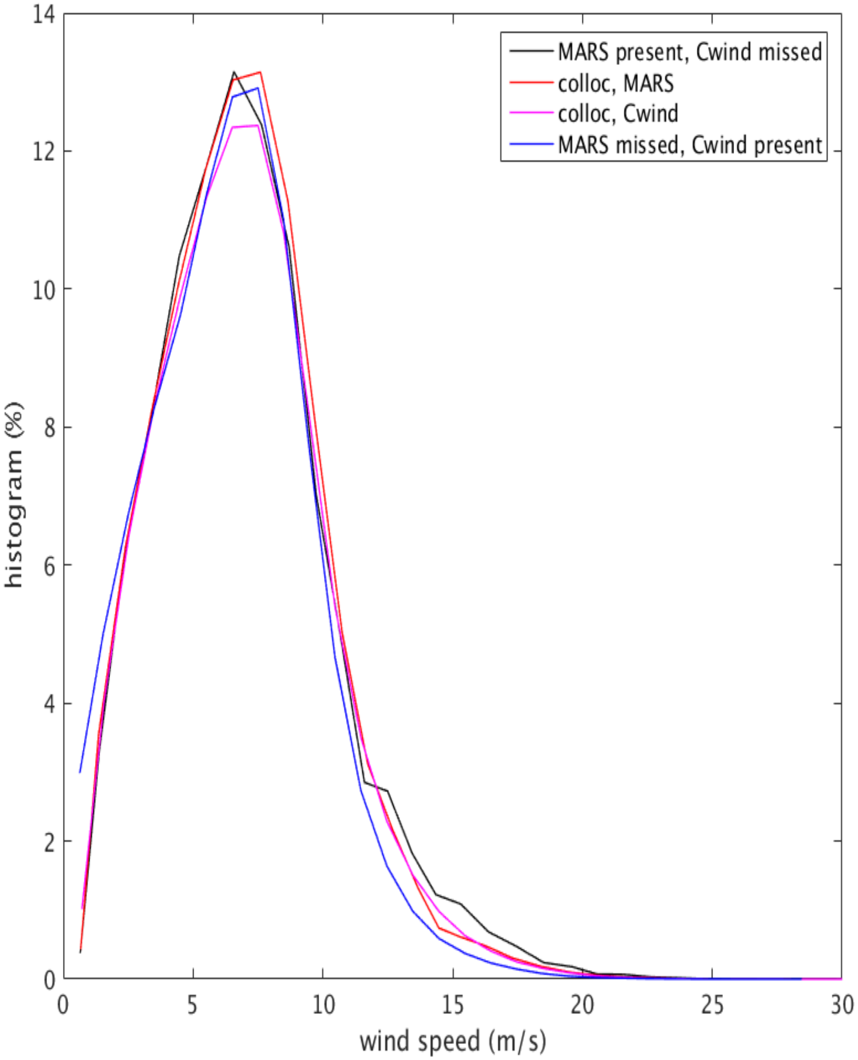




Number of extremes

Wind speed PDF of archived buoy winds collected from NDBC, TAO, PIRATA and RAMA (Cwind), as collocated with the same data received by GTS at ECMWF (called MARS; purple), vice versa (red), Cwind PDF if no GTS found (blue) and vice versa (black). Red and purple correspond to 3.2 million collocations, black to 3.3 million points and blue to 1.7 million. Collocation is considered successful when location, hour and heights match.

- MARS data base is largest and has most extremes in PDF



Key citation used to support possible buoy wind biases below true value for U > 10-15 m/s;

Also Zeng and Brown (1998) Using UWPBL

ACCOUNTING FOR SURFACE-WAVE DISTORTION OF THE MARINE WIND-PROFILE IN LOW-LEVEL OCEAN STORMS WIND MEASUREMENTS

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Abstract

Marine wind measurement at three heights (3.0, 4.5, and 5.0 m) from both moored and drifting buoys during the Ocean Storms Experiment are described. These winds are compared with each other, with winds from ships, from subsurface ambient acoustic noise, and from the analyses of three numerical weather prediction centers. In the mean, wind directions generally differ by only a small constant offset of a few degrees. No wave influence on the wind direction is evident, because the differences are not systematic and with few exceptions, they are less than the expected error. After correcting for some apparent calibration and instrument bias, the Ocean Storms wind speeds display similar behavior when compared to the analyzed wind products. There is excellent agreement up to a transition wind speed between 7 and 10 m s(-1), above which all me measured winds tend to be relatively low. The transition speed is found to increase with anemometer height, so this behavior is interpreted as being due to the distortion of the wind profile by surface waves. The wave effects are shown to be profound. By increasing the stress by 40% or more in high winds, the corrections are shown to be essential for numerical models to simulate the oceanic response to storm events. The Ocean Storms corrections are used to construct functions describing wave influence on both the vertical wind shear and the mean wind speed profile. These functions can only be regarded as crude approximations because the Ocean Storms data are far from ideal for determining them. However, they can be used to assess potential influences of surface waves on any low-level wind measurement.

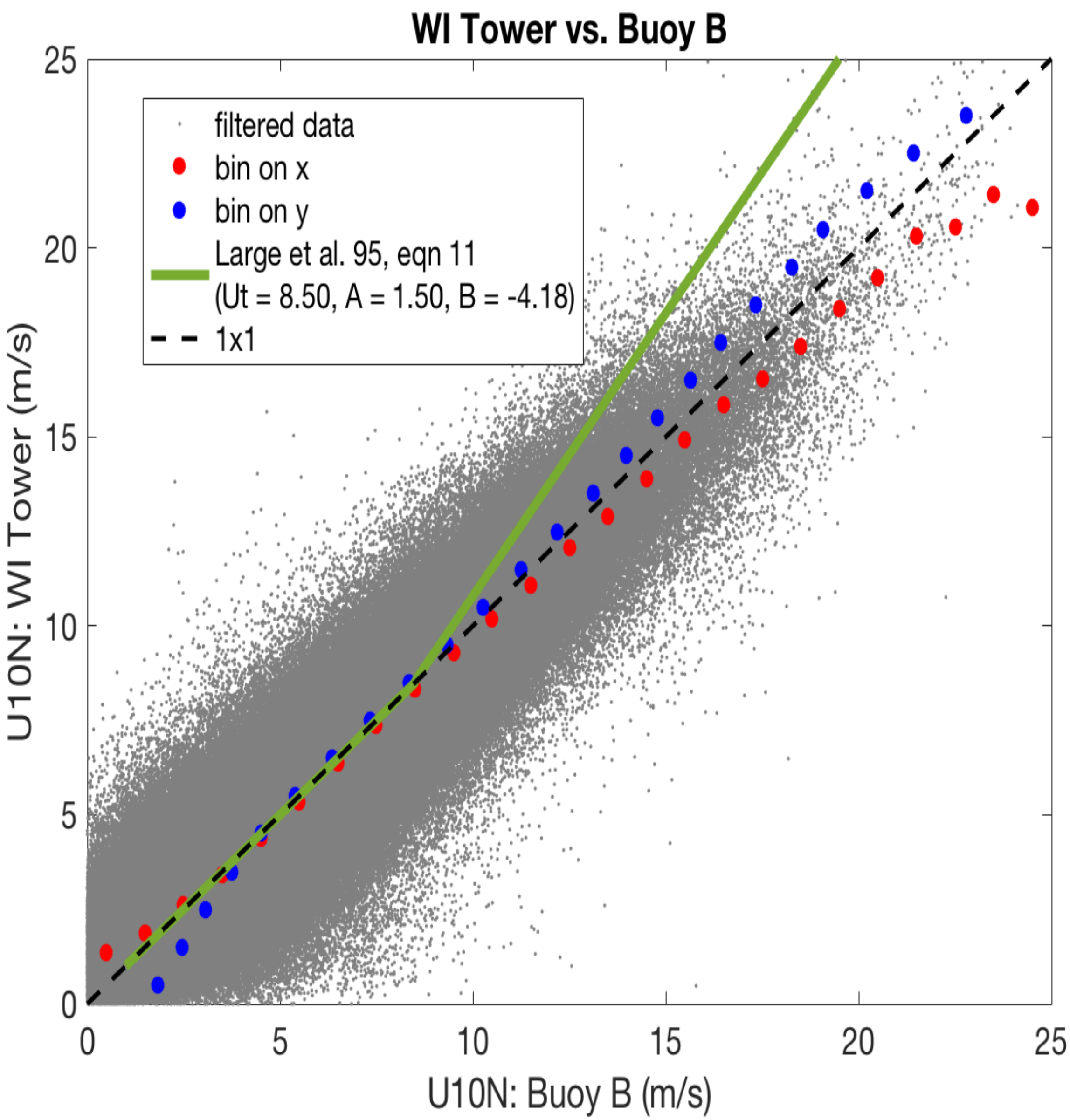
Keywords

KeyWords Plus: DISPLACEMENT HEIGHT; STRESS; MOORINGS; MODELS; LAYER; ARRAY

Typical citation-support for the high wind buoy wind error issue/disclaimer
(Peterson et al., 2017): "The wind speed, wind gust and wind direction were measured at 4 m height with a Gill WindSonic wind sensor (Fugro OCEANOR AS, 2007). **It has been shown that during rough seas, due to sheltering effects and elevation changes, wind measurement by buoys can be negatively biased** (e.g. **Large et al., 1995**; Zeng and Brown, 1998). Here, no attempt is made to compensate for a potential bias in the data set; that is left to the user. "

Results: 10 m neutral winds compared

University of New Hampshire



Orthogonal (TLS) fits

All winds

y = 0.97x +0.27 ; R = 0.92

Winds > 10

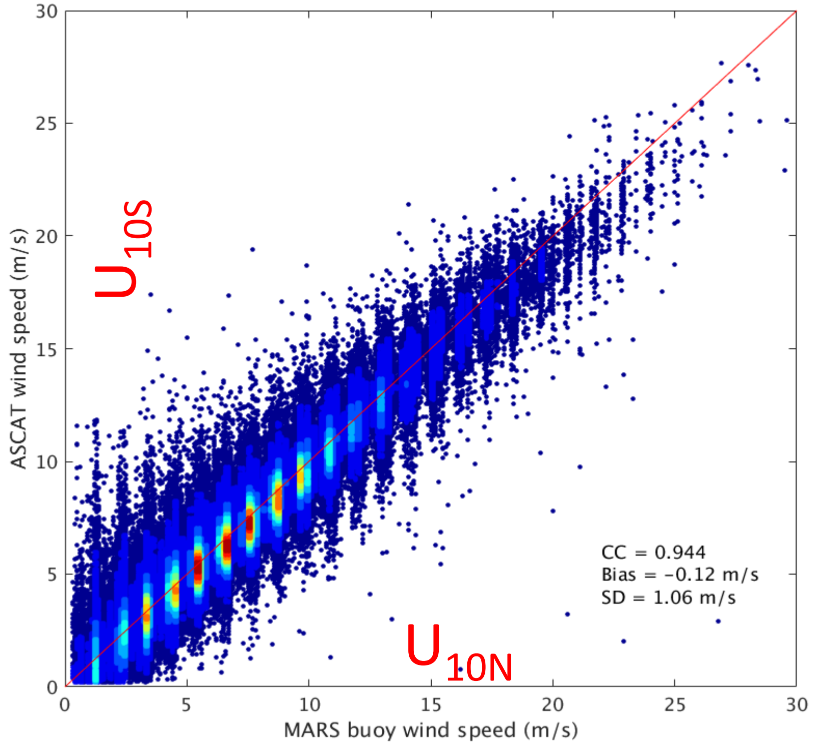
y = 0.99x + 0.14 ; R = 0.81

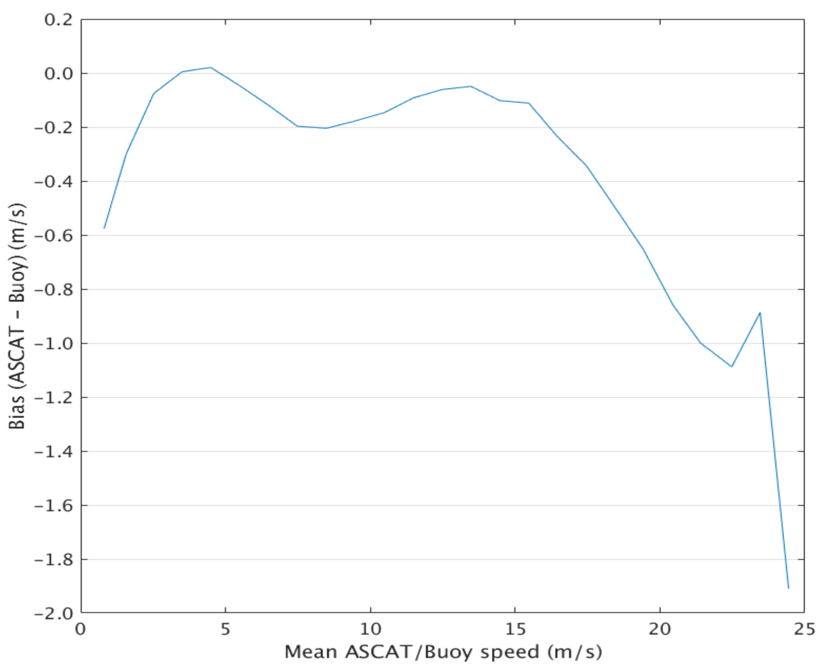
Filtering applied on dU/dt per Gilhousen, 1987, due to distance (24 km)

ASCAT versus buoys

- ASCAT U_{10S} low with respect to buoy U_{10N}
- PMSL = 980 mb implies ~1 m/s error
- Stress-equivalent wind computation needs to be done

Triple collocation	Buoy		ASCAT		ECMWF	
	u	v	u	v	u	v
Scaling factor	1	1	1.00	1.00	1.00	1.02
Bias correction	0.00	0.00	0.12	-0.03	0.18	0.03
SD error ECMWF scale)	1.32	1.35	0.90	0.97	1.13	1.18
SD error (ASCAT scale)	1.13	1.16	0.57	0.68	1.33	1.37



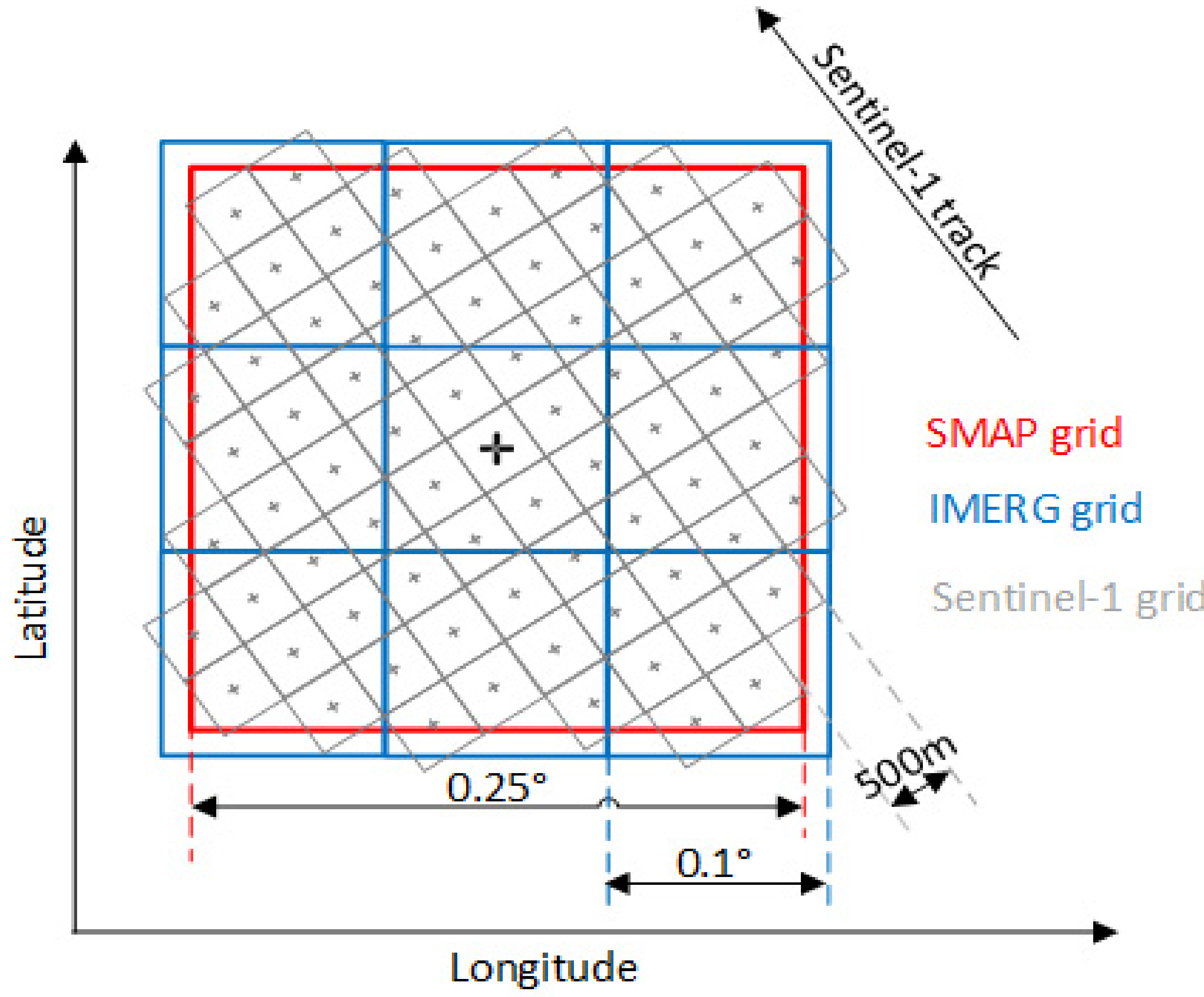


Synthetic Aperture Radar

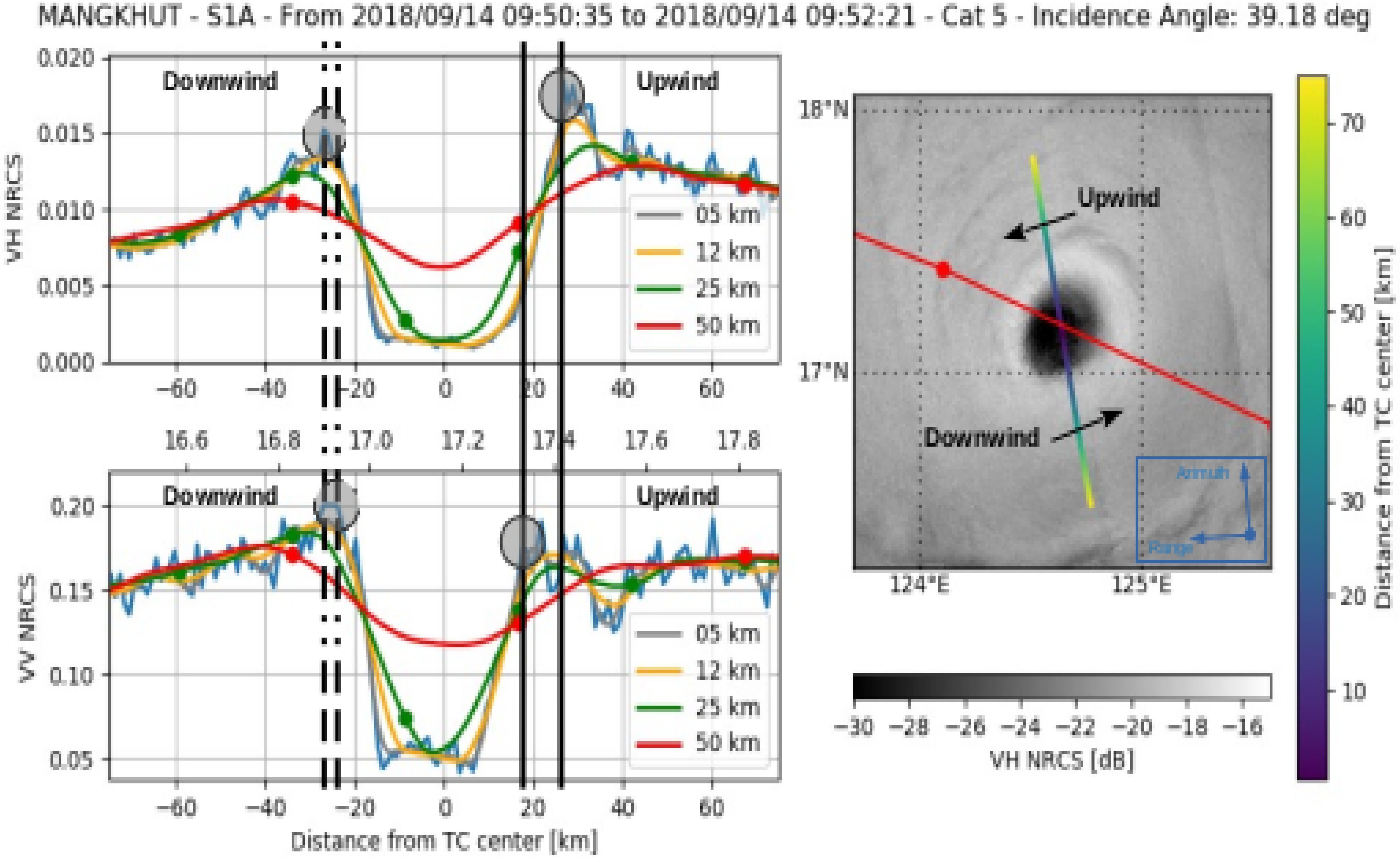
- High resolution, multi-polarization backscatter, but at low temporal resolution and poor calibration relative to scatterometers
- Ideal for spatial scaling and VV, HH, VH and Doppler GMF studies
- 2018/19 has seen an active hurricane season and IFREMER informed that several S1 acquisitions of hurricanes have been made. Note that IFREMER collected all Sentinel-1 SAR data from the existing archive - to get everything acquired before and in addition of SHOC. Additional acquisitions over 2019/2020
- Some NOAA hurricane flights far out into the Caribbean and therefore suitable SFMR and dropsonde collocations
- NOAA 2019 winter campaign cancelled
- ESA S1 over typhoons in the South West Indian Ocean in 2017/18/19; China acquires 4-5 acquisition by GF3 SAR in the China Sea (cf. ESA Dragon). CHEFS linked SMOS-STORM
- Some RadarSat hurricane data through the French ordering system
- Allowed late acquisitions to enter the CHEFS results
- Use ERA5

Caution grid comparisons

- 0.25-degree box-car average of SAR. At the equator the 2-sigma value of the spatial resolution of a box-car window is 0.25/sqrt(3)= 0.14 deg. or 16 km
- 40-km resolution of SMAP comparable to a 60-km box-car averaging

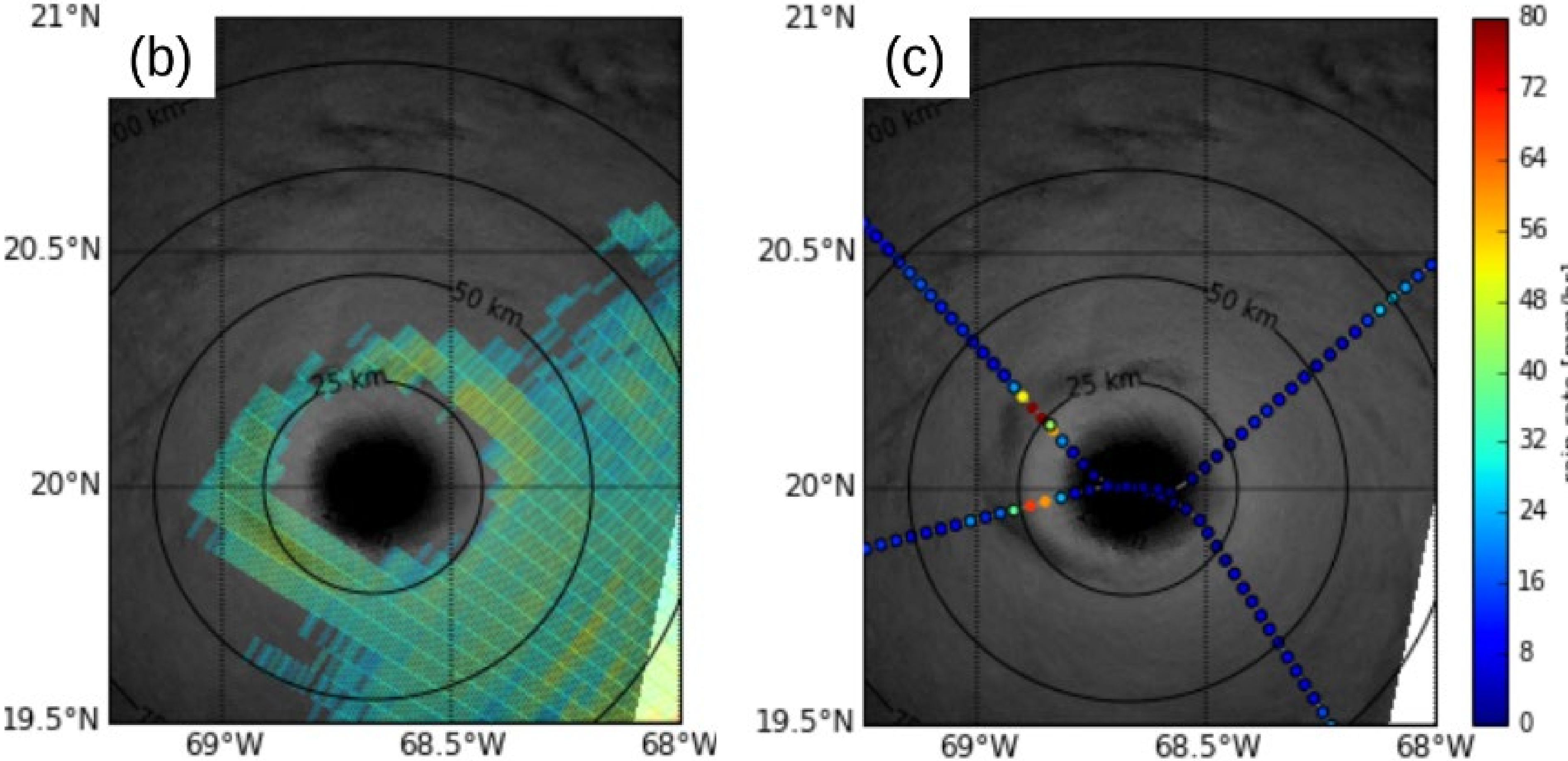


SAR aggregated NRCS



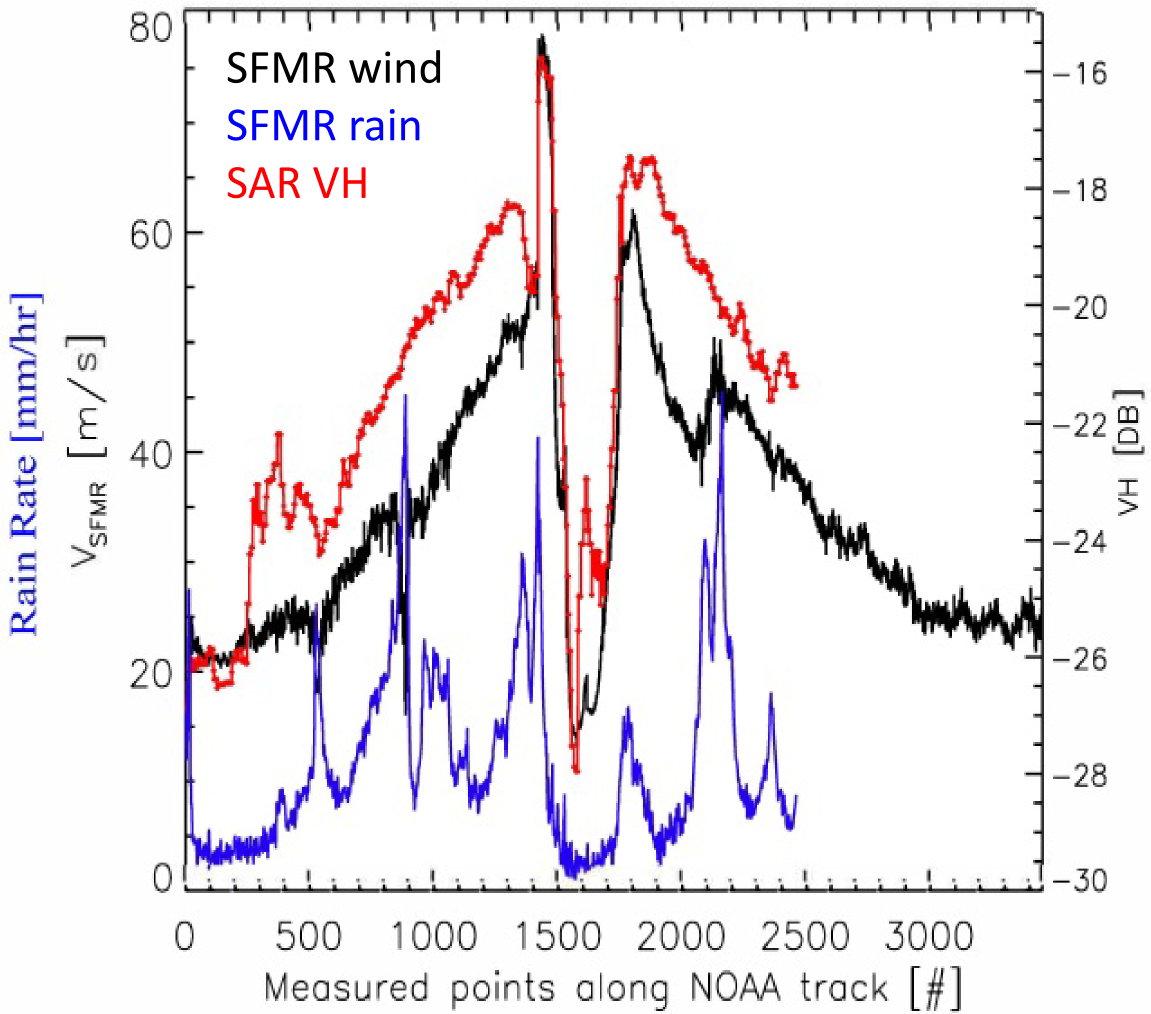
NEXRAD/SFMR Rain on VH SAR

- Rain clouds difficult to quantitatively estimate



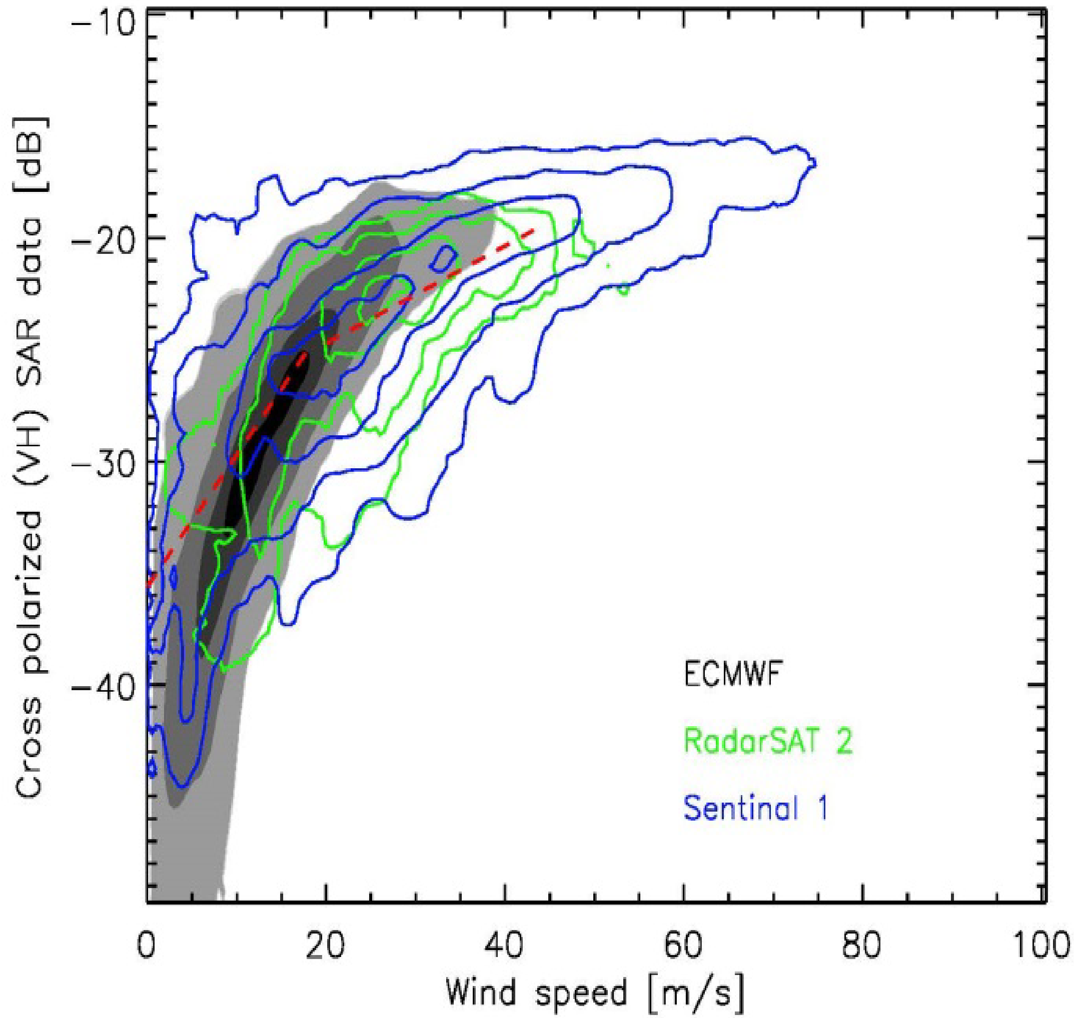
SFMR & SAR VH collocations

- Storm-relative and storm motion corrected
- Rain effects evident on SFMR wind and SAR VH

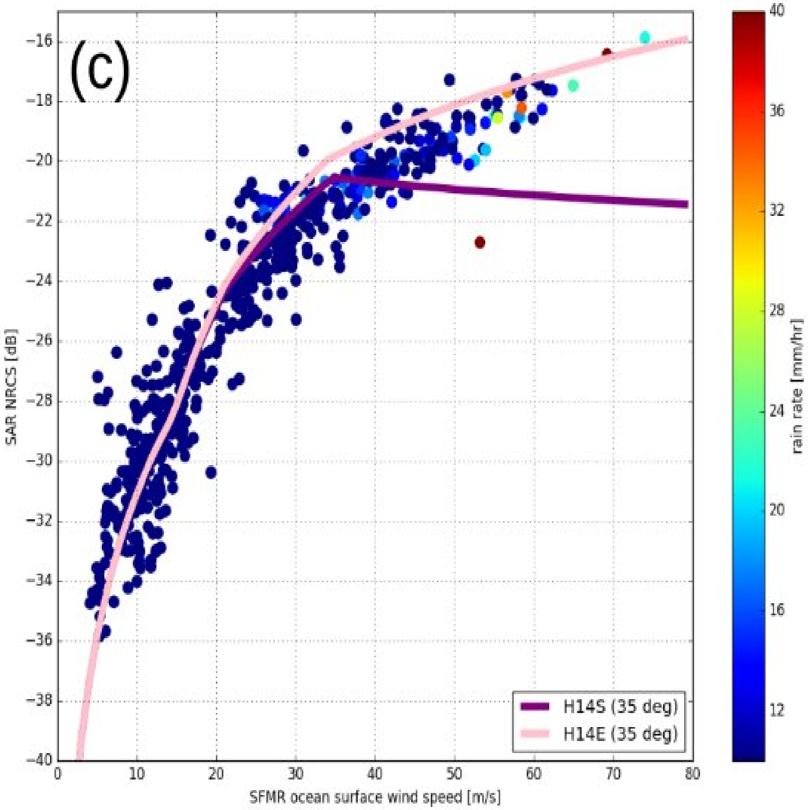


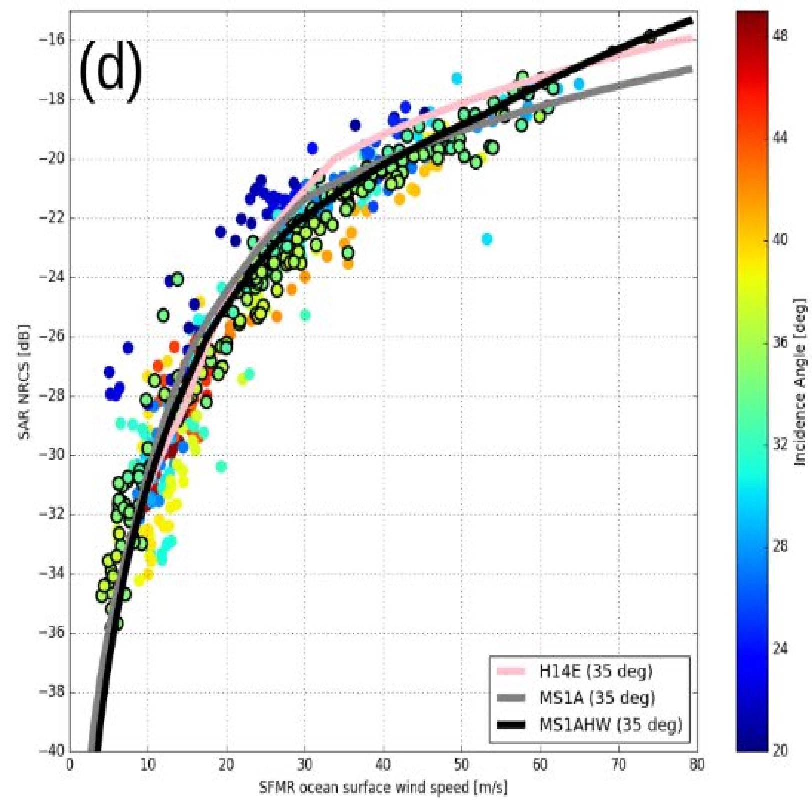
ECMWF, SFMR & SAR VH collocations

- Storm-relative and storm motion corrected
- Sentinel-1 SAR VH consistent with RadarSat
- Sentinel-1 SAR very useful addition with respect to RadarSat
- Upsloping until 75 m/s



Incidence angle and rain

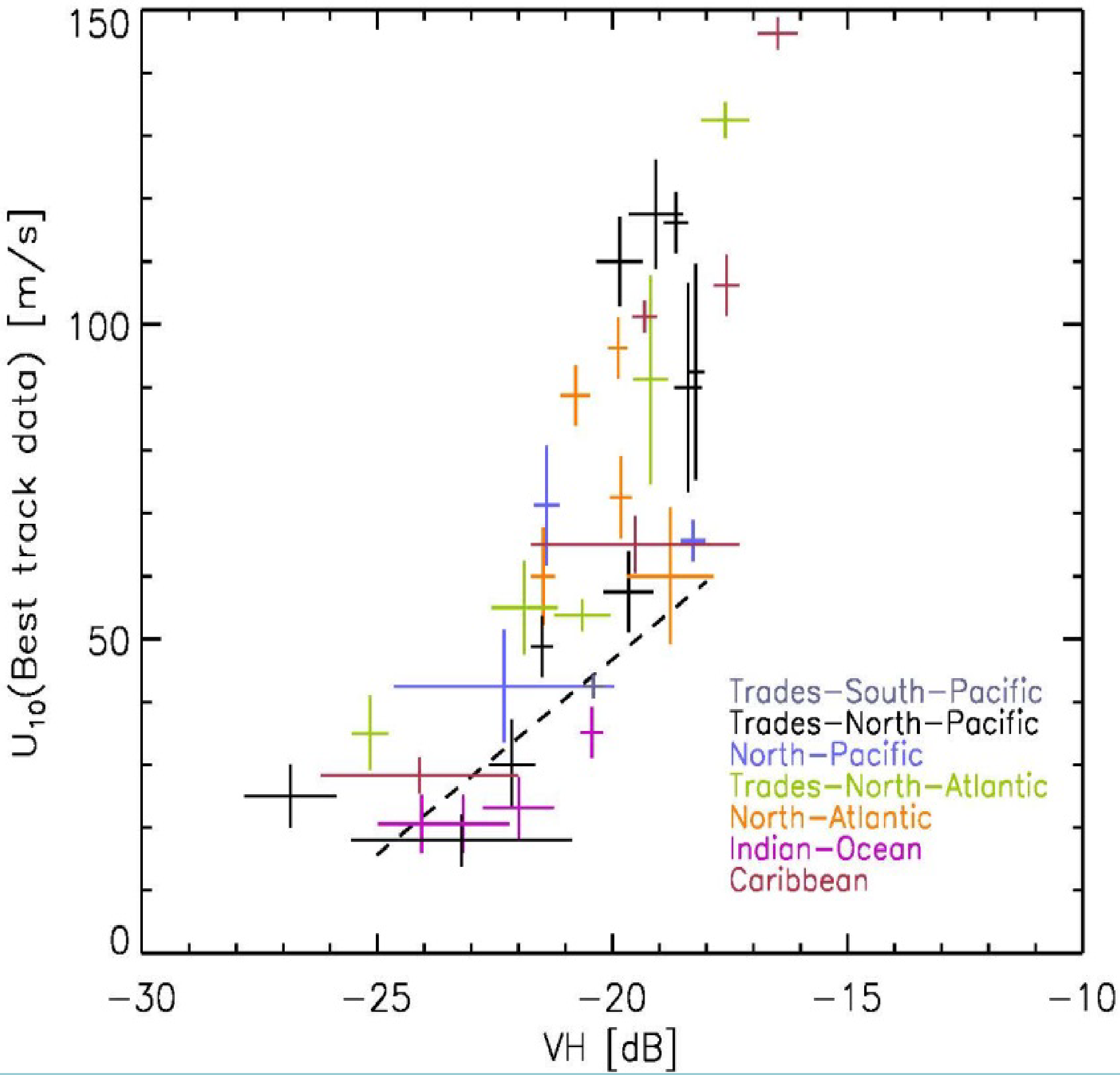




- Some rain effect noticeable by incidence angle
- Incidence angle effect more pronounced (beyond calibration uncertainty)

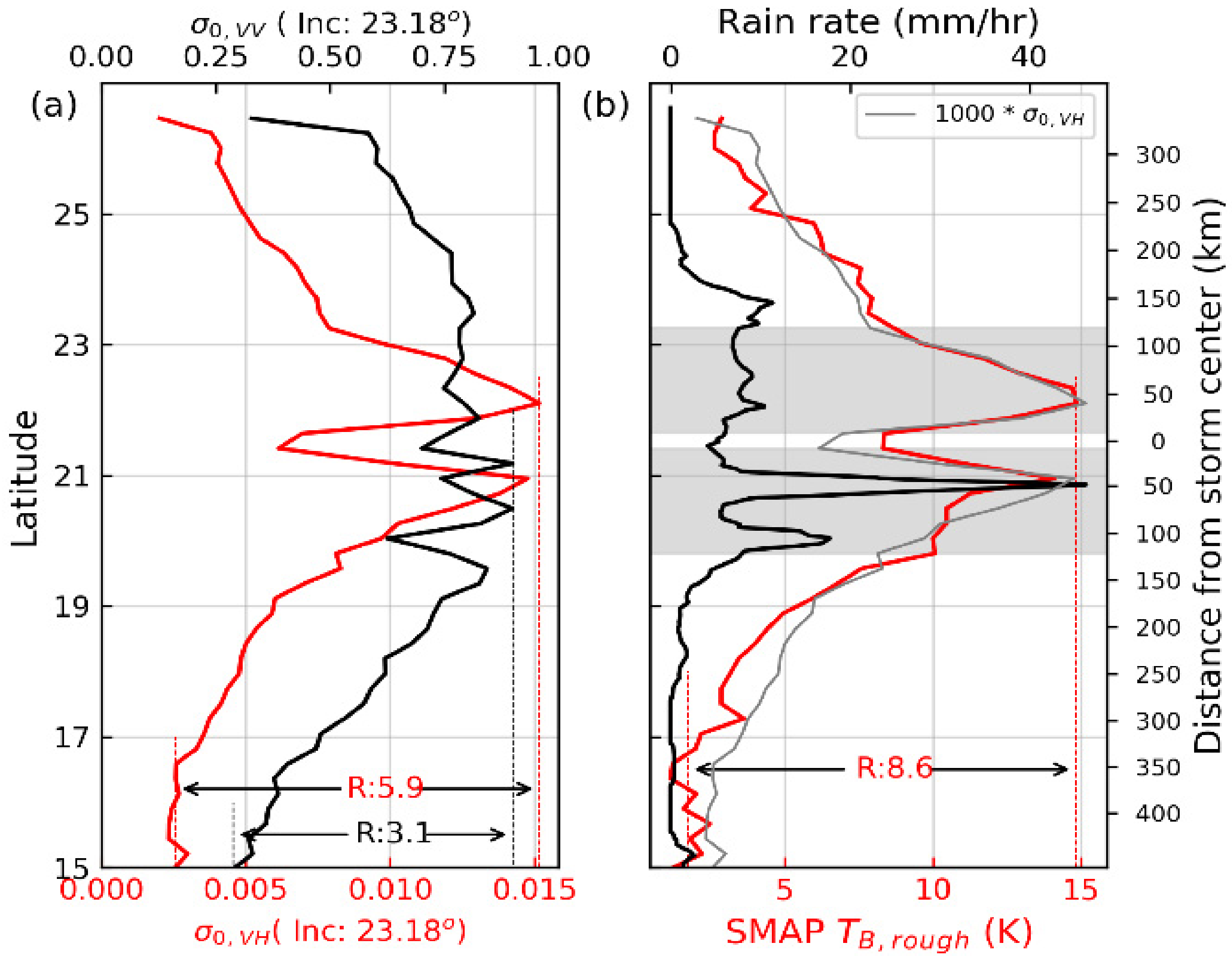
1-min maximum sustained winds

- VH-GMF retrieved velocities between the 0.995 and 0.9995 %-iles (x bar)
- SD over 24 hr in y bar
- BEST track data set depends on available observations, which depends on basin



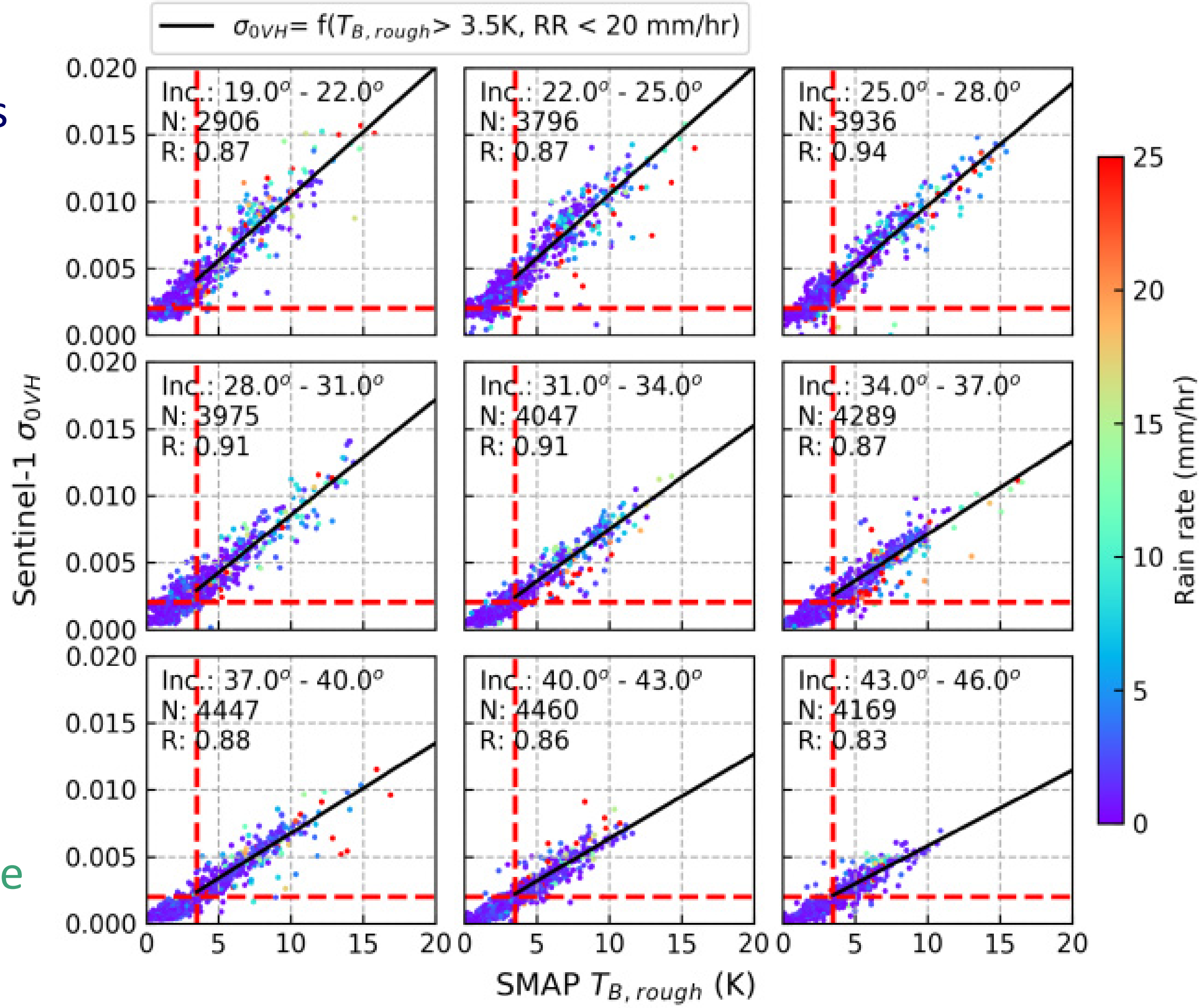
VV, VH and L-band T_B

- L T_B is very close to $1000^*\sigma^0_{VH}$
- σ^0_{VV} appears related to rain peaks, but σ^0_{VH} not
- Wind direction effect?



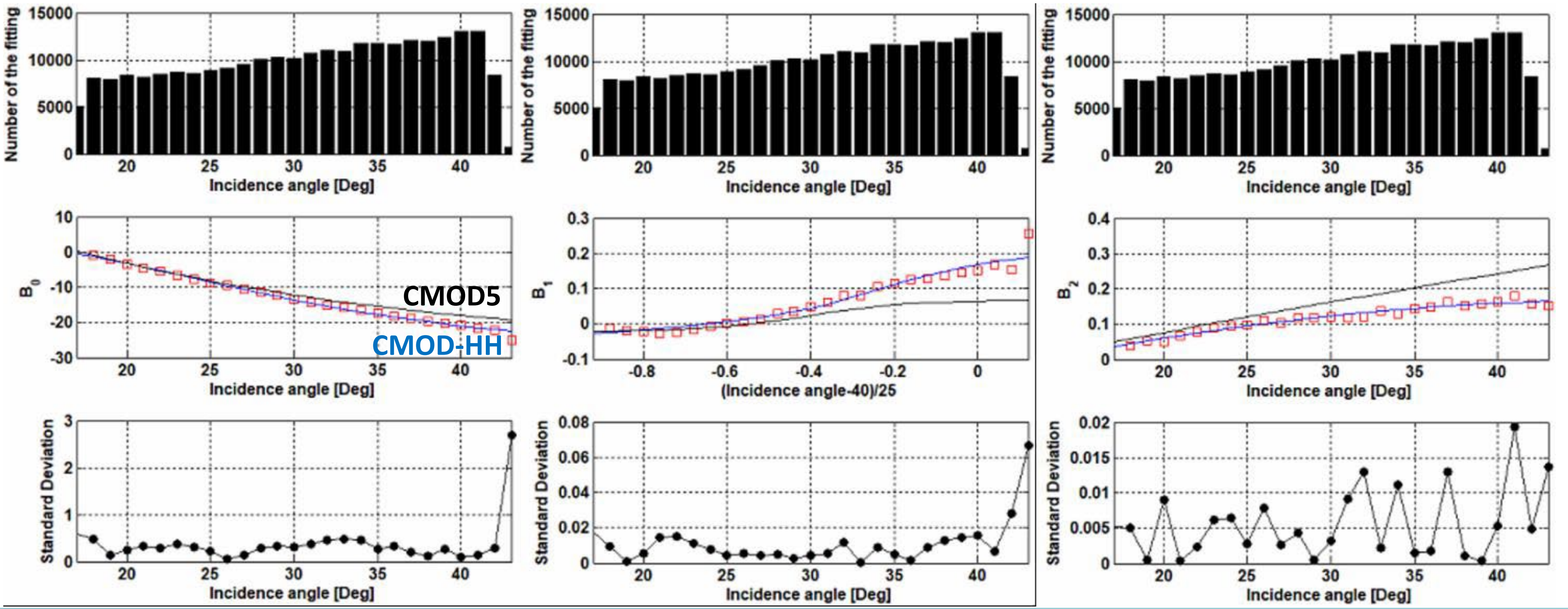
VH and L-band T_B

- Linear dependency
- Theoretically not obvious to relate Bragg to L T_B
- Measurement accuracy will determine quality of L-band and VH extreme winds
- High rain enhances VH NRCS at 19-22 and 40-43 degrees
- High rain reduces VH NRCS at 22-25 and 31-34 degrees
- SCA VH is excellent choice for extremes



GMFs

- Select a VH GMF for SCA
- A first HH GMF based on RadarSat has recently been published:
  Biao Zhang et al., 2019, GRSL-01248-2018.R1
- Will be tested in OSI SAF



Recommendations

- Use dropsonde U_{10S} rather than WL150
- Log-profile analysis
- Investigate speed-dependent deceleration error dropsondes at 10 m
- Convert buoys, dropsondes and model winds to U_{10S}
- Investigate different buoy types and possible wave effects on buoy measurements
- Investigate direct buoy-dropsonde collocations > 15 m/s
- After in-situ wind speed calibration, SFMR needs adaptation, as well as all satellite sea surface winds
- It furthermore will allow NWP model drag parameterization tuning
- Closer collaboration with JCOMM, satellite wind producers and ECMWF will be very beneficial to consolidate the in situ, satellite winds and NWP community practices
- Refine ASCAT calibration, VV GMF (cone) and retrieval at high/extreme winds
- Extend SAR and NOAA campaigns for refined geophysical studies

Conclusion

- We still lack a consolidated in-situ wind speed reference
- Affects satellite & NWP products and hurricane advisories!
- Confidence in moored buoys up to 25 m/s
- U10S needed
- Questions drop sondes?
- ASCAT VV correlates well at high winds
- SCA VH excellent choice