



Koninklijk Nederlands  
Meteorologisch Instituut  
*Ministerie van Infrastructuur en Milieu*



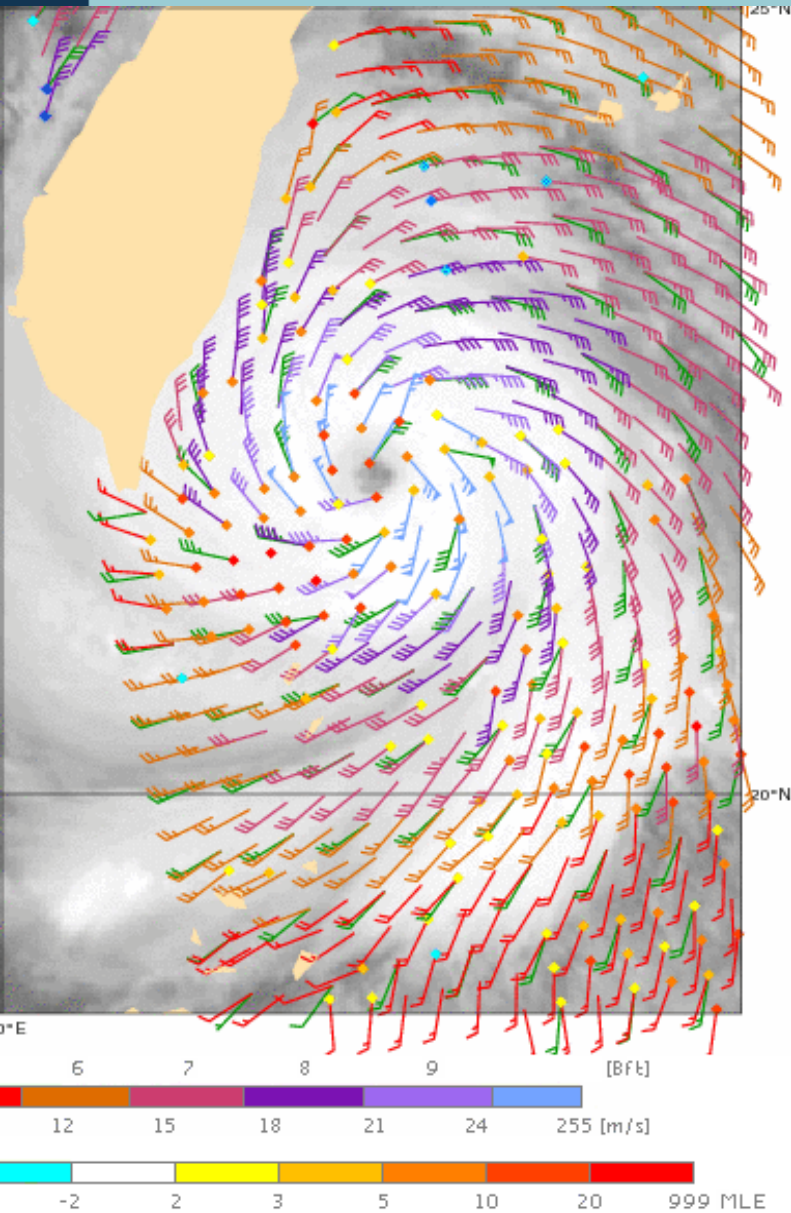
# C-band High and Extreme-Force Speeds CHEFS

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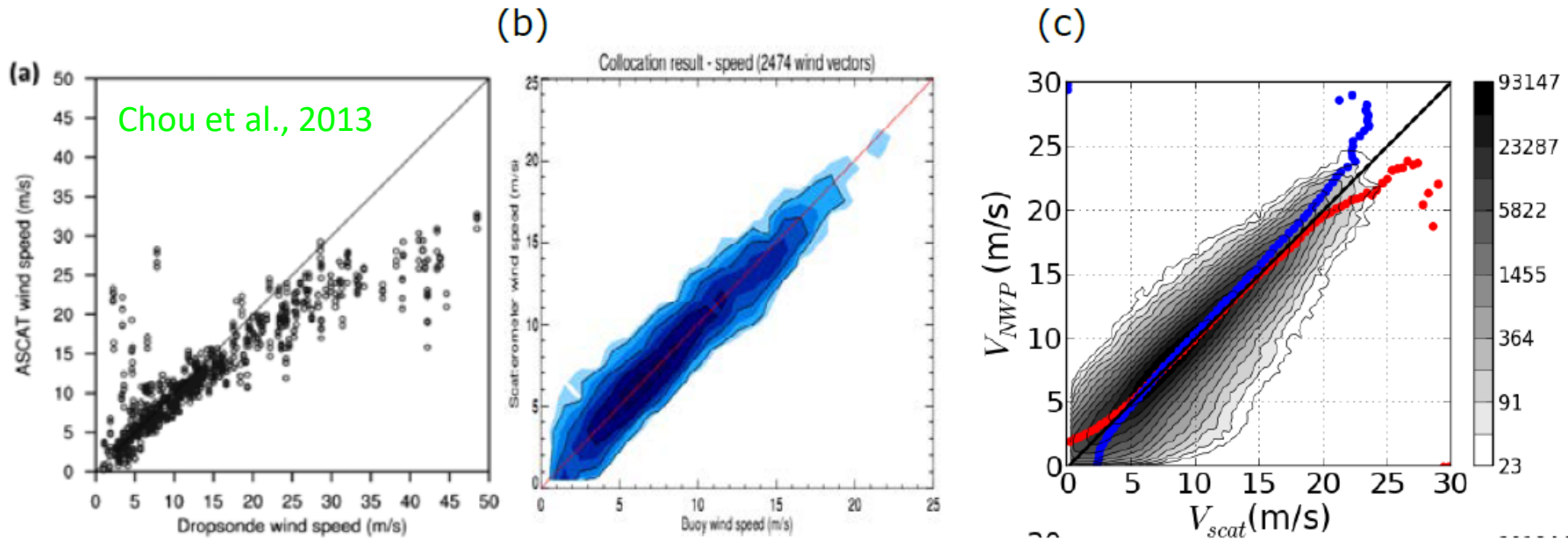
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# EUMETSAT ITT Objectives



- **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.

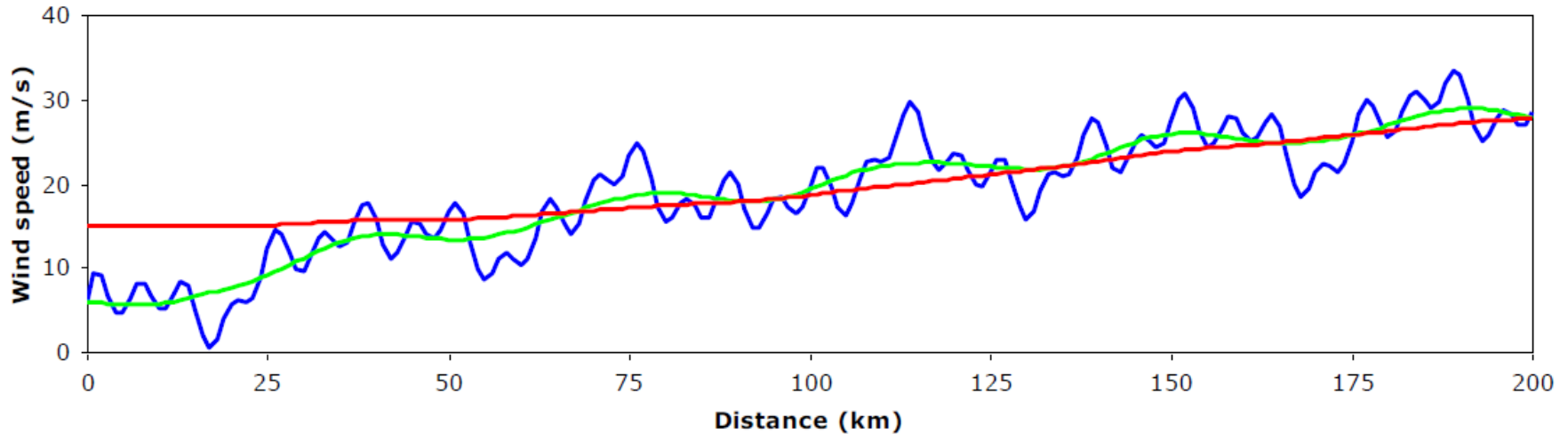
# Inconsistencies



**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 representation differences.**

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

# Schematic of wind speed from ECMWF model, buoy and ASCAT

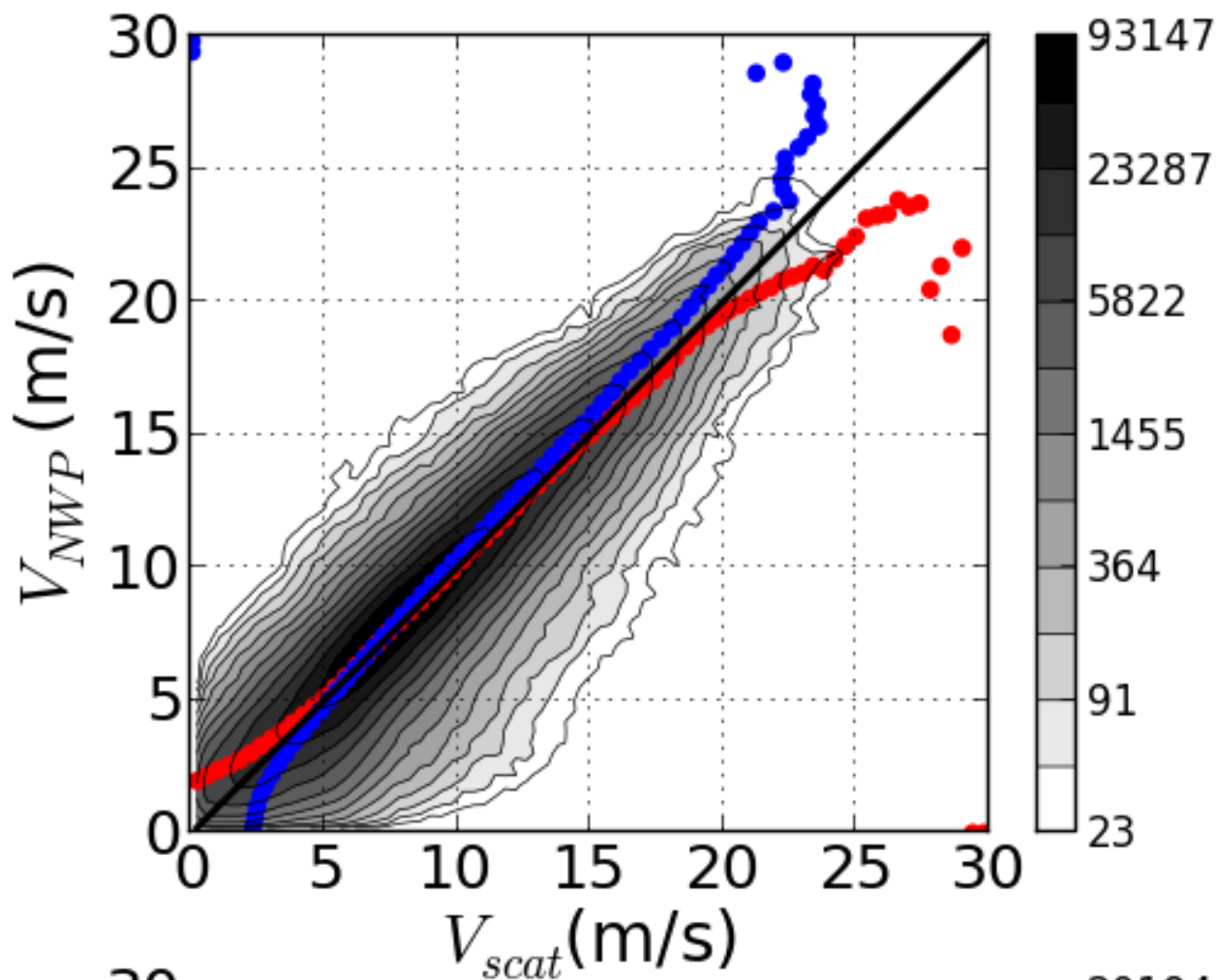


- 1-minute sustained winds can be much higher than scatterometer winds (factor of 2?)
- An in situ wind PDF is quite different from a scatterometer and ECMWF wind PDF, particularly at the extremes; PDFs cannot be directly matched
- An in situ measurement is NOT surface truth for a scatterometer WVC wind; we need scale-dependent analysis

# Truthful?



- A binned result, e.g.,  $\langle y|x \rangle$  or  $\langle x|y \rangle$ , is not meaningful if it is not known how faithful  $x$  represents  $y$  in terms of physical phenomena and time and space aggregation
- Particularly at the extremes of the PDF
- scatter plots are essential



# Triple collocation (scat scale)

SDE [m/s]	Scatterometer		Buoys		ECMWF	
	$\epsilon_u$	$\epsilon_v$	$\epsilon_u$	$\epsilon_v$	$\epsilon_u$	$\epsilon_v$
25 km RapidScat	0.64	0.67	1.33	1.38	1.17	1.15
50 km RapidScat	0.56	0.53	1.41	1.47	1.06	1.07

$$u_i = a_i(t_i + \delta_i + b_i), \quad \epsilon = \langle \delta \rangle, \quad i = (\text{in situ}, \text{scat}, \text{NWP})$$

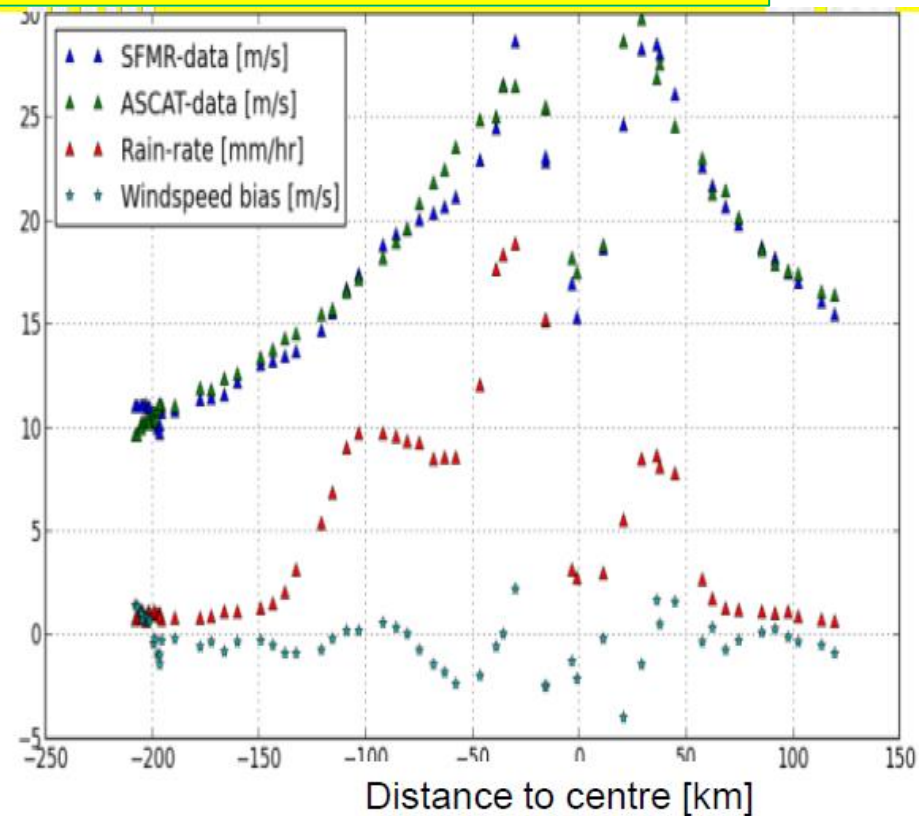
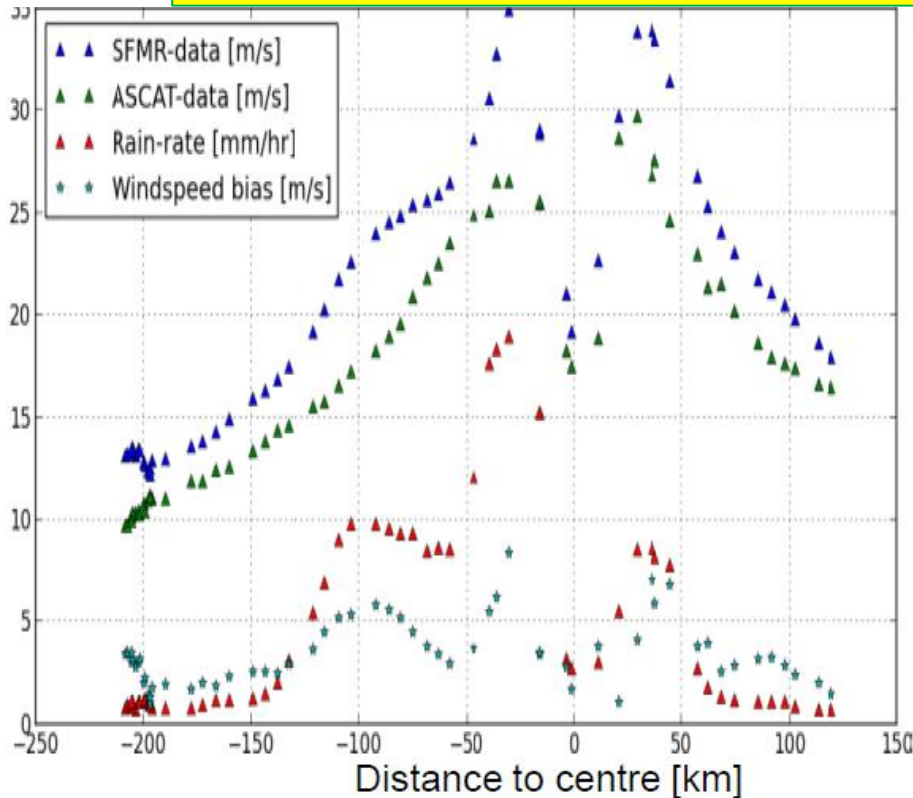
1. In situ buoy errors are in itself small ( $\sim 0.1$  m/s), but variability over 50 km results in  $\sim 1.5$  m/s vector variance at the surface due to atmospheric turbulence at modal winds
2. Collocation distance is 25 km here; larger collocation distances result in larger buoy validation errors
3. A month of buoy data is needed to obtain statistical significance over 150 buoys for a scatterometer with a 1700 km wide swath
4. Campaigns provide much less data than in situ data do
5. ECMWF errors decrease as the scale of the measurement increases
6. RSCAT was calibrated with one week of ECMWF winds, as ECMWF calibration factor ( $a_{NWP}$ ) is known, however SST . . .



# On WVC scale

$V_{\text{SFMR}}$

$V_{\text{SFMR}} - \ln(\text{RainRate}) - \ln(V_{\text{ASCAT}})$



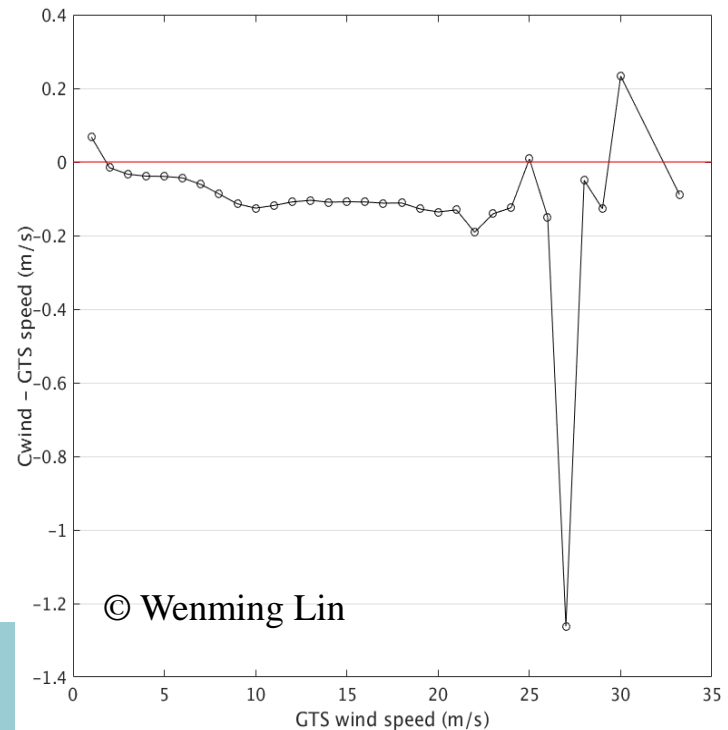
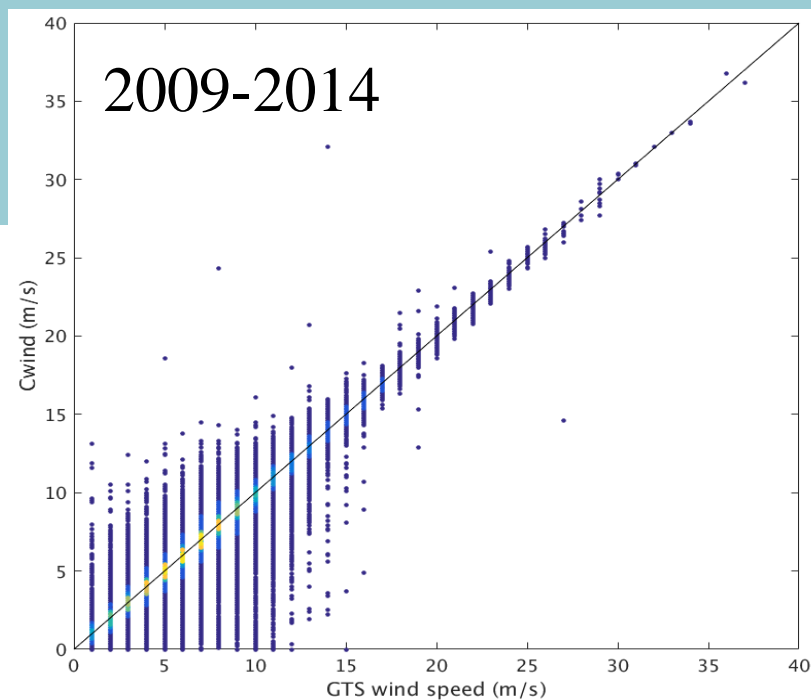
- CMOD5 winds are lower than SFMR (VV pol) => add  $\ln(V_{\text{ASCAT}})$  ?
- CMOD5 winds equal buoy winds for 15 to 20 m/s; which to trust ?
- SFMR winds go up when it rains =>  $-\ln(RR)$ ;

# Way forward

- KNMI got stuck due to
    - » Disconnect between modal (buoy) and extreme regime (SFMR)
    - » Lack of SFMR calibration (SST, wind, rain)
  - GPS dropsondes provide true measure of local 10m wind; how true ? Somehow comparable to 1-min winds?
  - GPS dropsondes calibrate SFMR 10m winds on its basic footprint; similar representation ? Scatter ?
  - Calibrated SFMR data are integrated over a scatterometer WVC length to provide a resource for satellite scatterometer calibration; is a 1D (radial) average sufficient ? Probably it is
  - Can SFMR integration to a WVC provide guidance to the sub-WVC variability ? Needed to understand relationship WVC and 1-min. winds and to better assign hurricane categories
- Error attribution in all steps

# Compare NRT to archive

- GTS: last 10 minutes of hour
- Anything >10-minute values in hurricanes not suitable
- GTS data appears useful potentially (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?

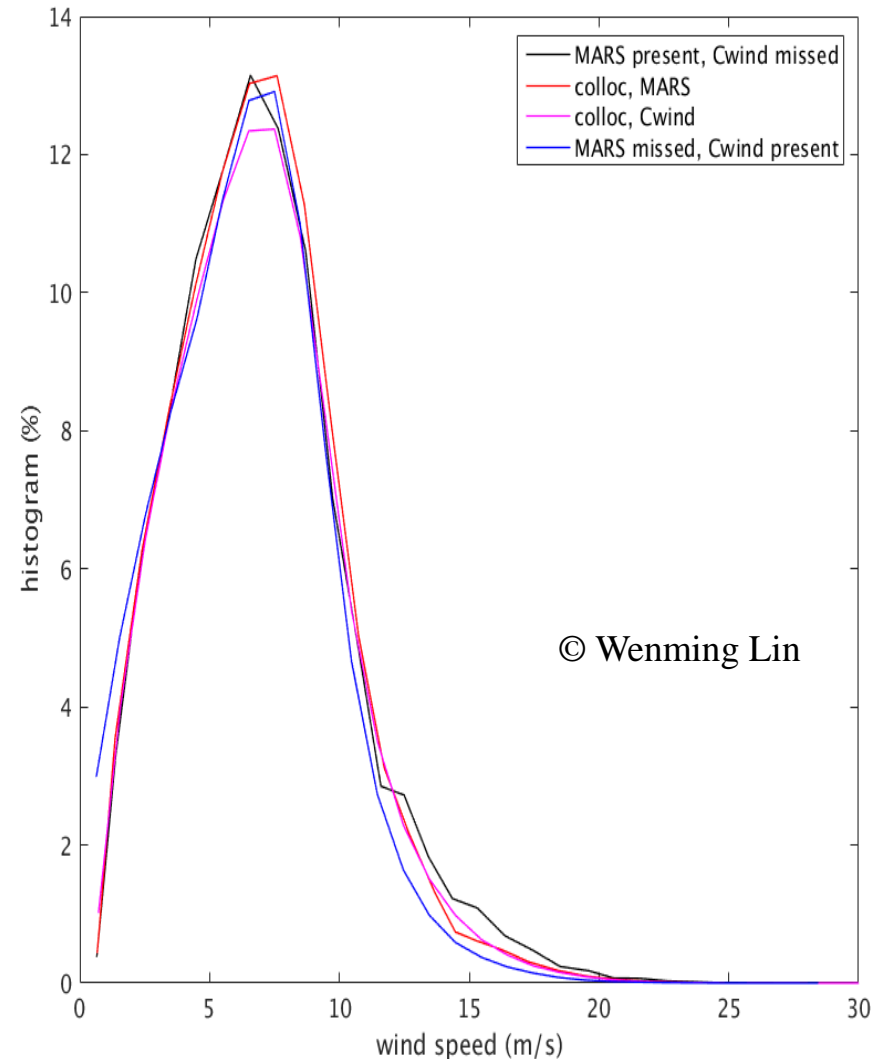




# Number of extremes

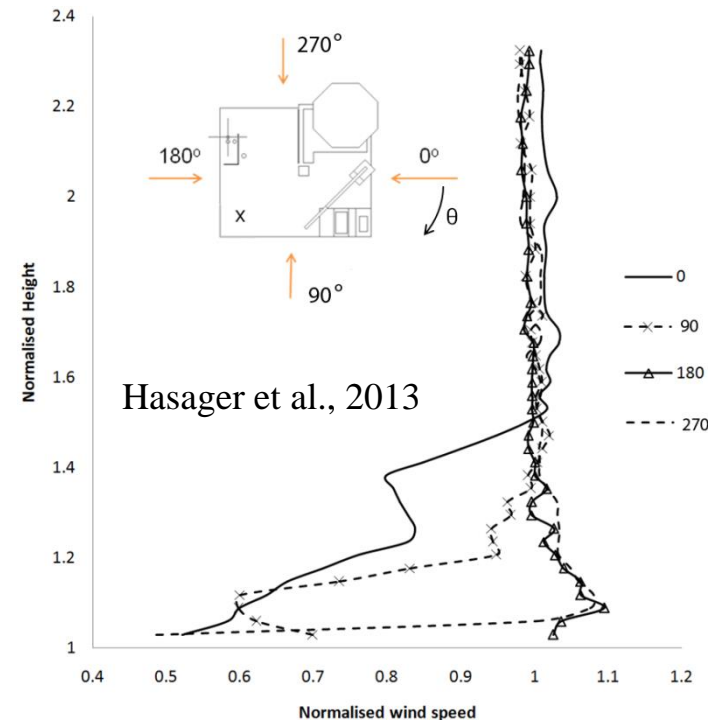
Wind speed PDF of archived buoy winds collected from NDBC, TAO, PIRATA and RAMA (Cwind), as collocated with the same data received by GTS at ECMWF (called MARS; purple), vice versa (red), Cwind PDF if no GTS found (blue) and vice versa (black). Red and purple correspond to 3.2 million collocations, black 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
- Issues with anemometer and T-sensor height inconsistencies



# Other references?

- +ve and -ve wind flow distortion around platforms
- Verification shows differences to platforms 2x higher as to buoys; what is this scatter? Does it cause bias? Useful as calibration reference?
- Platform motion (ships)

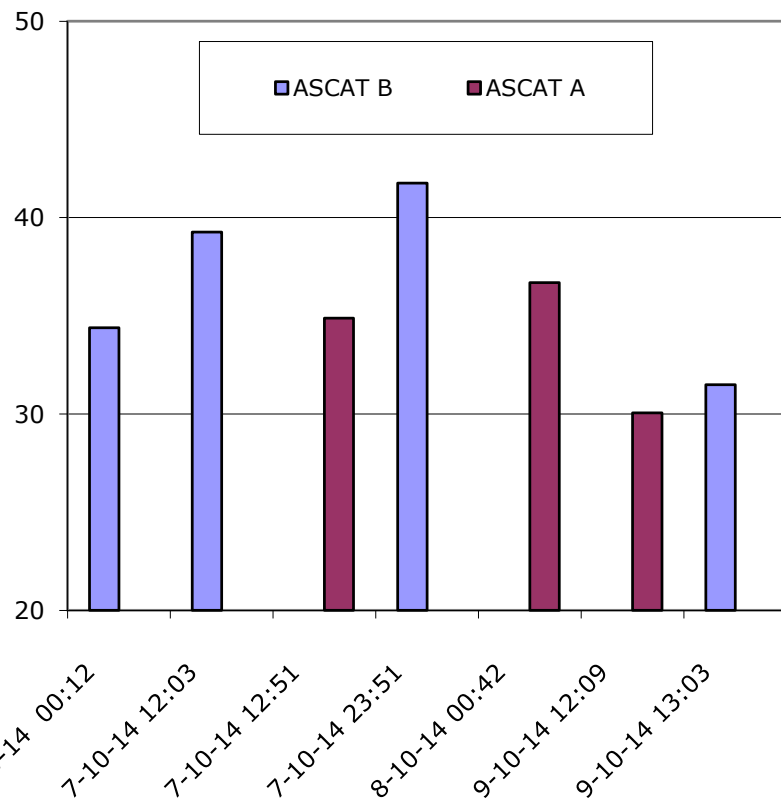




# Dropsondes

- 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  $20 \text{ ms}^{-1}$  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  $20 \text{ ms}^{-1}$ , 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 may exist occasionally to explore biases and scatter (2018 campaign with 1 UKMO buoy at 45 knots 😊).

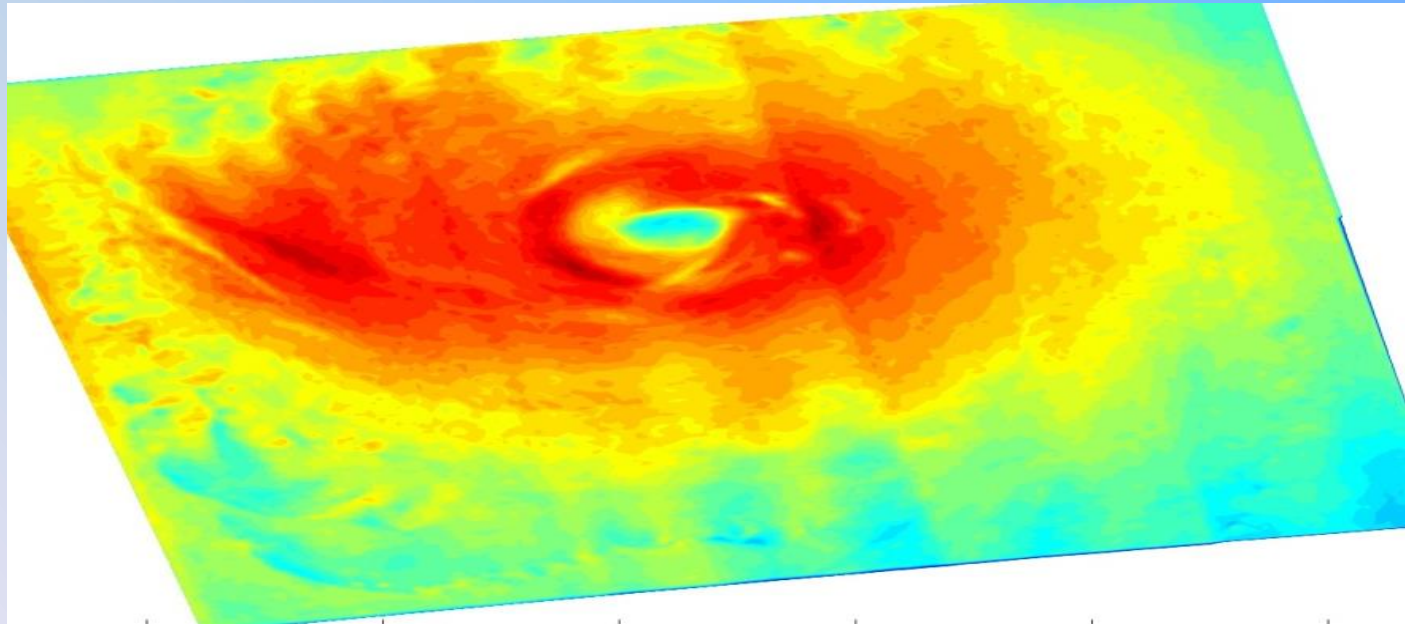
# Improve calibration



- Peak around midnight on 7/8 October 2014 of 42 m/s (150 km/h)
- ASCAT-A appears low as compared to ASCAT-B
- Current calibration bias B-A of 0.1 dB (0.1 m/s)
- Required accuracy is 0.2 dB
- Due to GMF saturation, 0.1 dB at 40 m/s is 4 m/s !
- For extremes more careful instrument calibration is needed
- Next generation ASCAT will have VH pol. channel



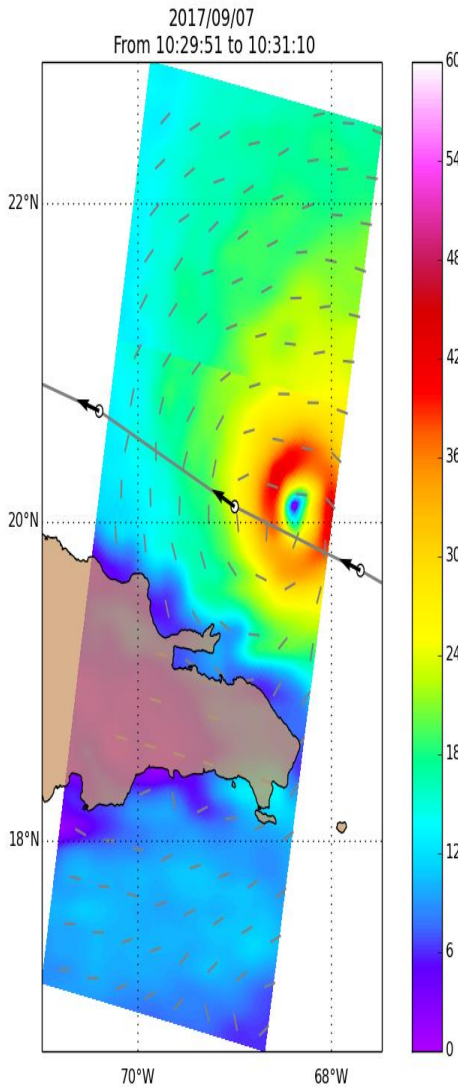
# Retrieving Extreme wind speeds using C-band instruments



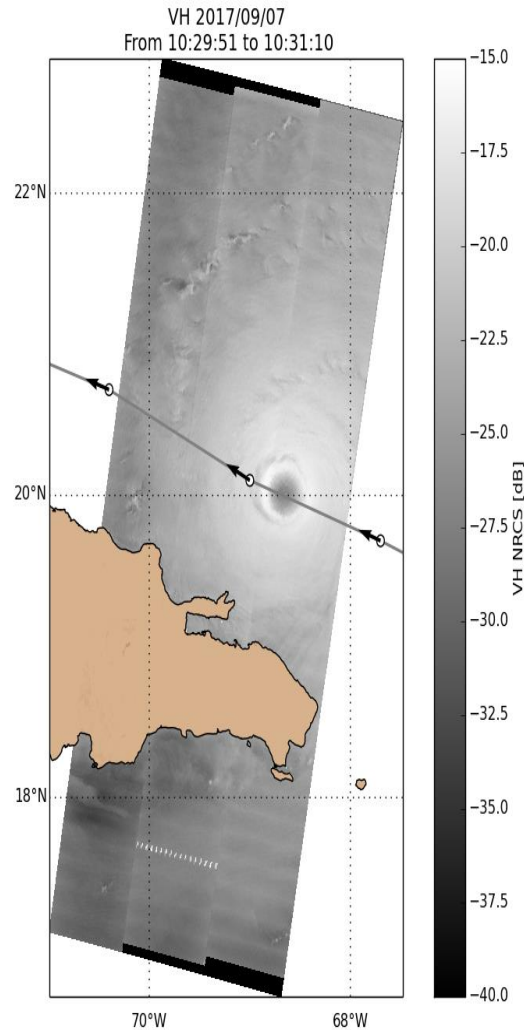
Gerd-Jan van Zadelhoff, Ad Stoffelen, P. Vachon, J. Wolfe,  
J. Horstmann, M. Belmonte Rivas, F. Fois

van Zadelhoff et al. (amt-7-437-2014)

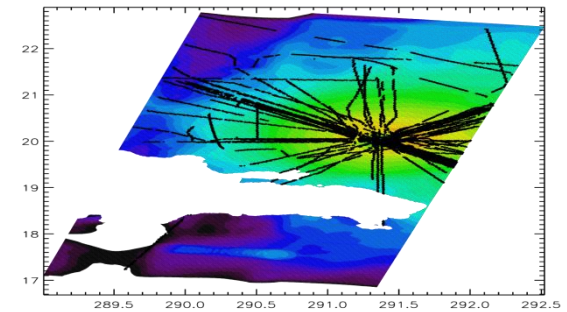
# Irma – 2017/09/07 10:30 UTC



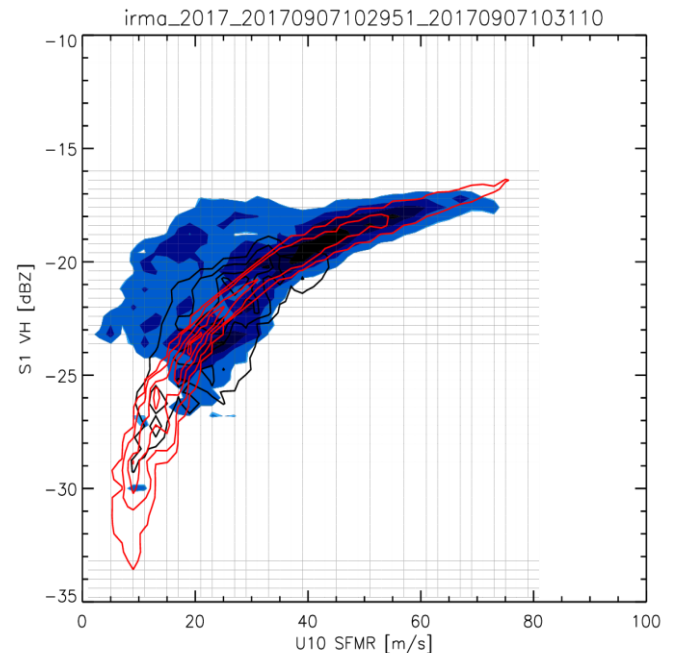
Model wind speed  
(Mouche 2017)



S1 VH measurement



Collocated SFMR flight legs



S1 VH – SFMR U10 collocation

(RS2 –SFMR (van Zadelhoff et al. 2014)

Mouche et al. 2017

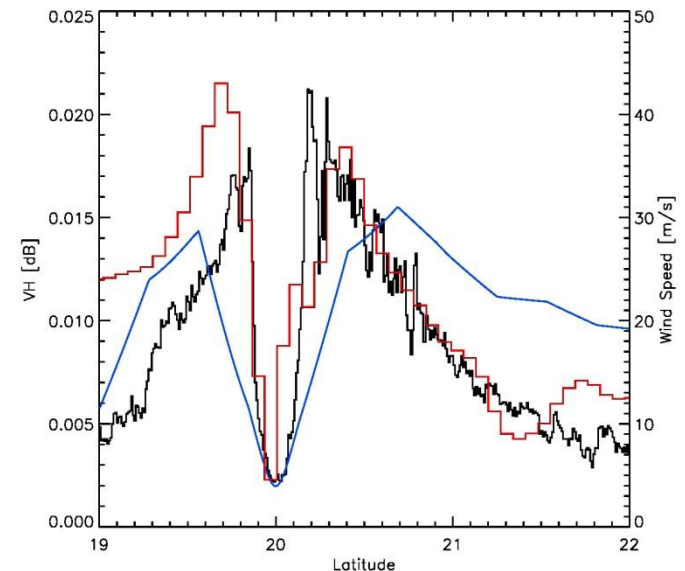
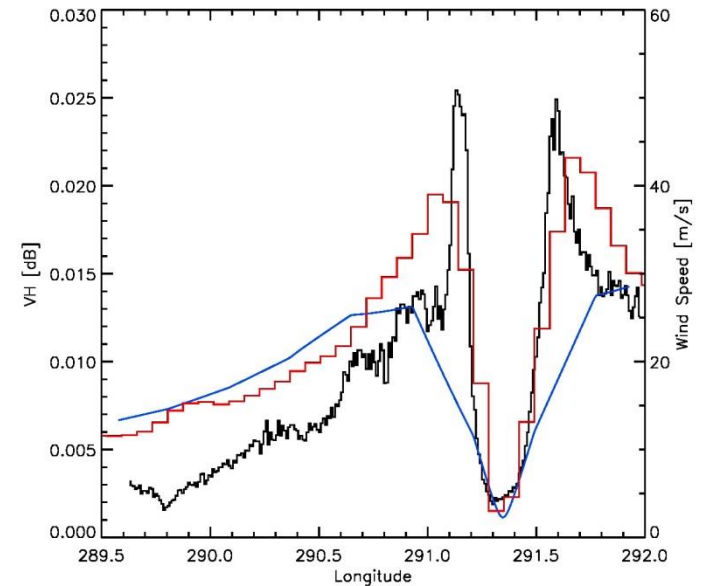
# Using ECMWF/ERA5 data for the VH-GMF

- ECMWF model data can be used to check incidence angle and wind direction dependence to derive the GMF.
- ERA5 was the preferred data set → the resolution and model are constant for the S1 & RS2 datasets
- However the ERA5 resolution is too low to enable comparisons close to the hurricane eye.
- To the right two slices) are shown for hurricane IRMA:

VH-slice

ECMWF (oper.) (grid: F1280)

ERA-5 (grid : N320)



# CHEFS

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



# Meet at 18:00 P31?

- Collect issues for obtaining a consolidated extreme wind reference
- Collect contributions to obtaining a consolidated extreme wind reference
- Define a way forward beyond CHEFS
- You are most welcome!

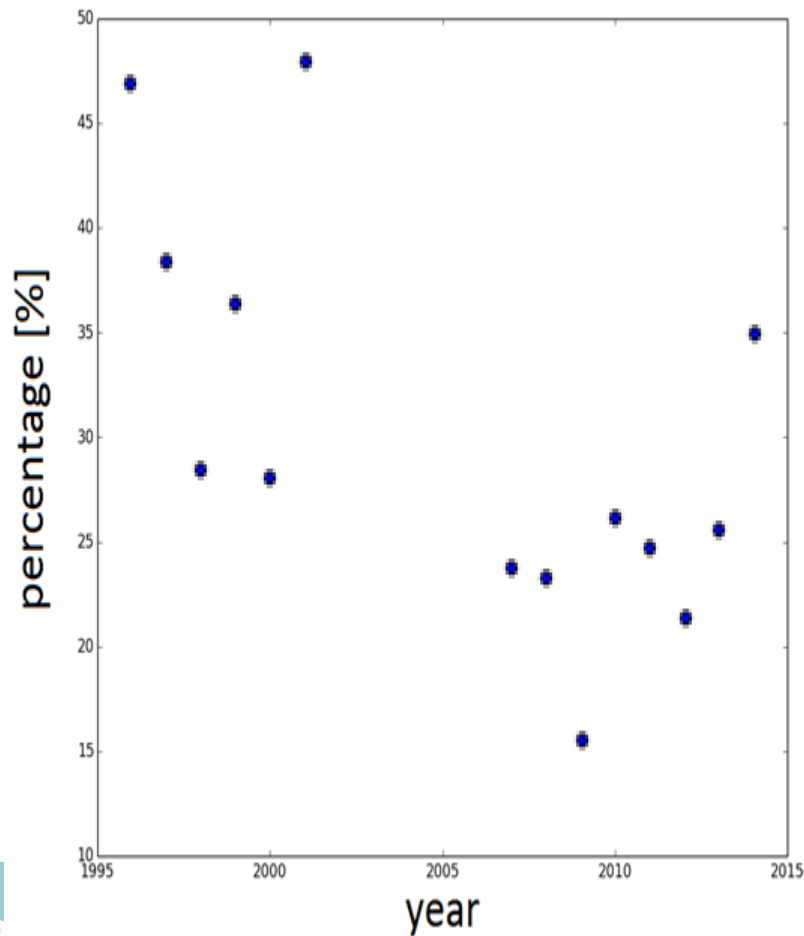


# **Backup Slides**

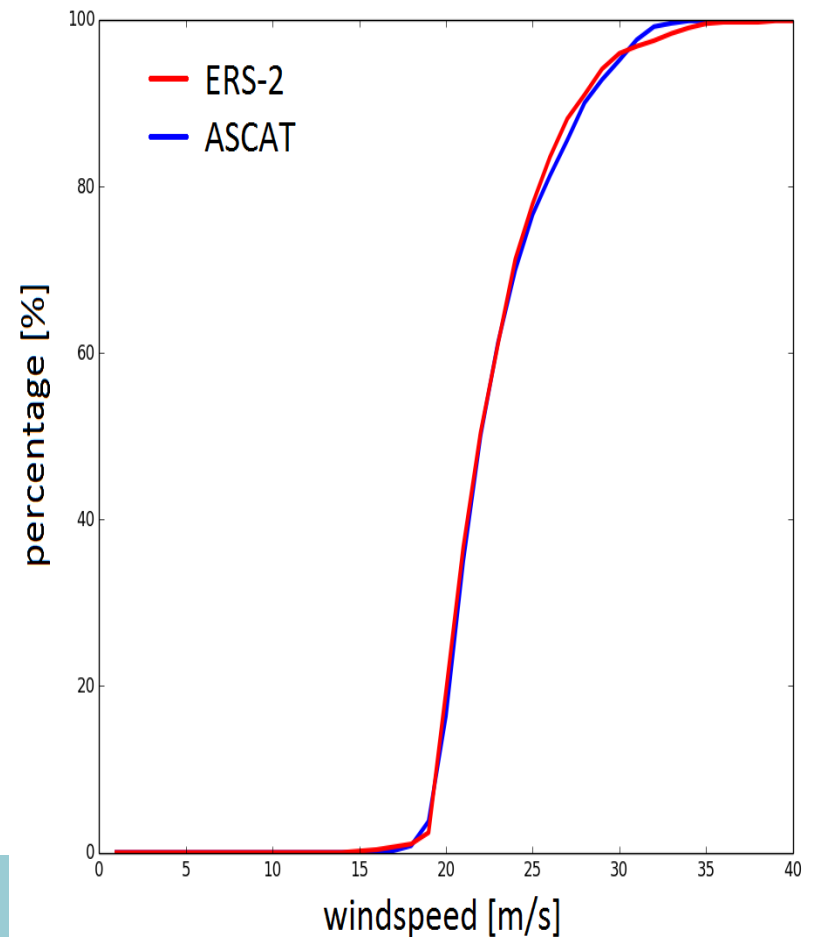
# Climate extremes



PERCENTAGE OF HURRICANES  
> 20 M/S IN ERA-INTERIM FOR  
SCAT WINDS > 20 M/S



ACCUMULATED PDF OF  
SCATTEROMETER WINDS  
ABOVE 20 M/S





# 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  $\sigma$** , and e.m. sea properties (assumed constant)
- Air-sea momentum exchange is described by  $\tau = \rho_{air} u_* \mathbf{u}_*$ , the stress vector; depends on air mass density  $\rho_{air}$ , friction velocity vector  $\mathbf{u}_*$
- Surface layer winds (e.g.,  $\mathbf{u}_{10}$ ) depend on  $\mathbf{u}_*$ , atmospheric stability, surface roughness and the presence of ocean currents
- Equivalent neutral winds,  $\mathbf{u}_{10N}$ , depend only on  $\mathbf{u}_*$ , surface roughness and the presence of ocean currents and is currently used for backscatter geophysical model functions (GMFs)
- Stress-equivalent wind,  $\mathbf{u}_{10S} = \sqrt{\rho_{air}} \cdot \mathbf{u}_{10N} / \sqrt{\rho_0}$ , is suggested to be a better input for backscatter GMFs, since more closely related to  $\tau$

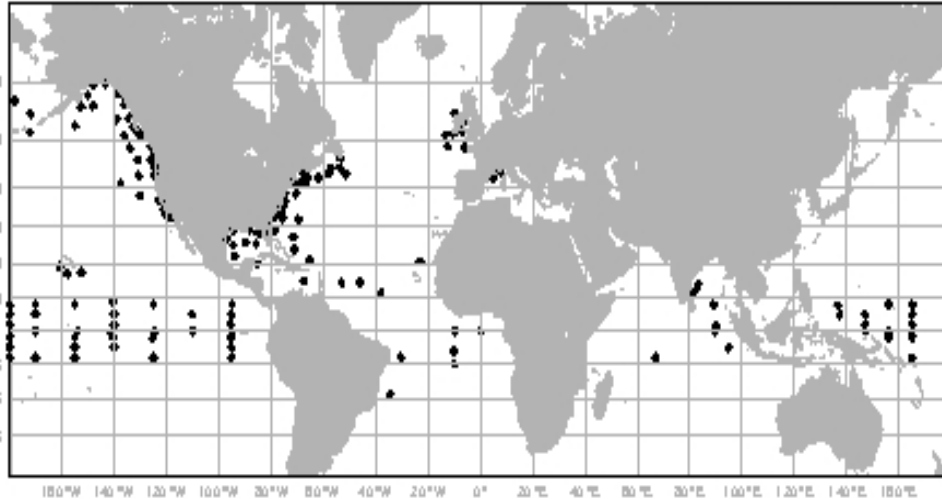


# How good are these winds?

## Triple collocation errors

ASCAT, buoy and ECMWF data from winter 2012/ 2013

- Small scatterometer wind errors on scatterometer scale
- All scatterometers have very similar local quality
- Buoys measure local variability



	Scatterometer		Buoys		ECMWF	
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	m/s	$\sigma_u$	$\sigma_v$	$\sigma_u$	$\sigma_v$	$\sigma_u$	$\sigma_v$
ASCAT-A 25-km		0.63	0.71	1.21	1.35	1.39	1.44
ASCAT-B 25-km		0.63	0.66	1.26	1.39	1.38	1.42

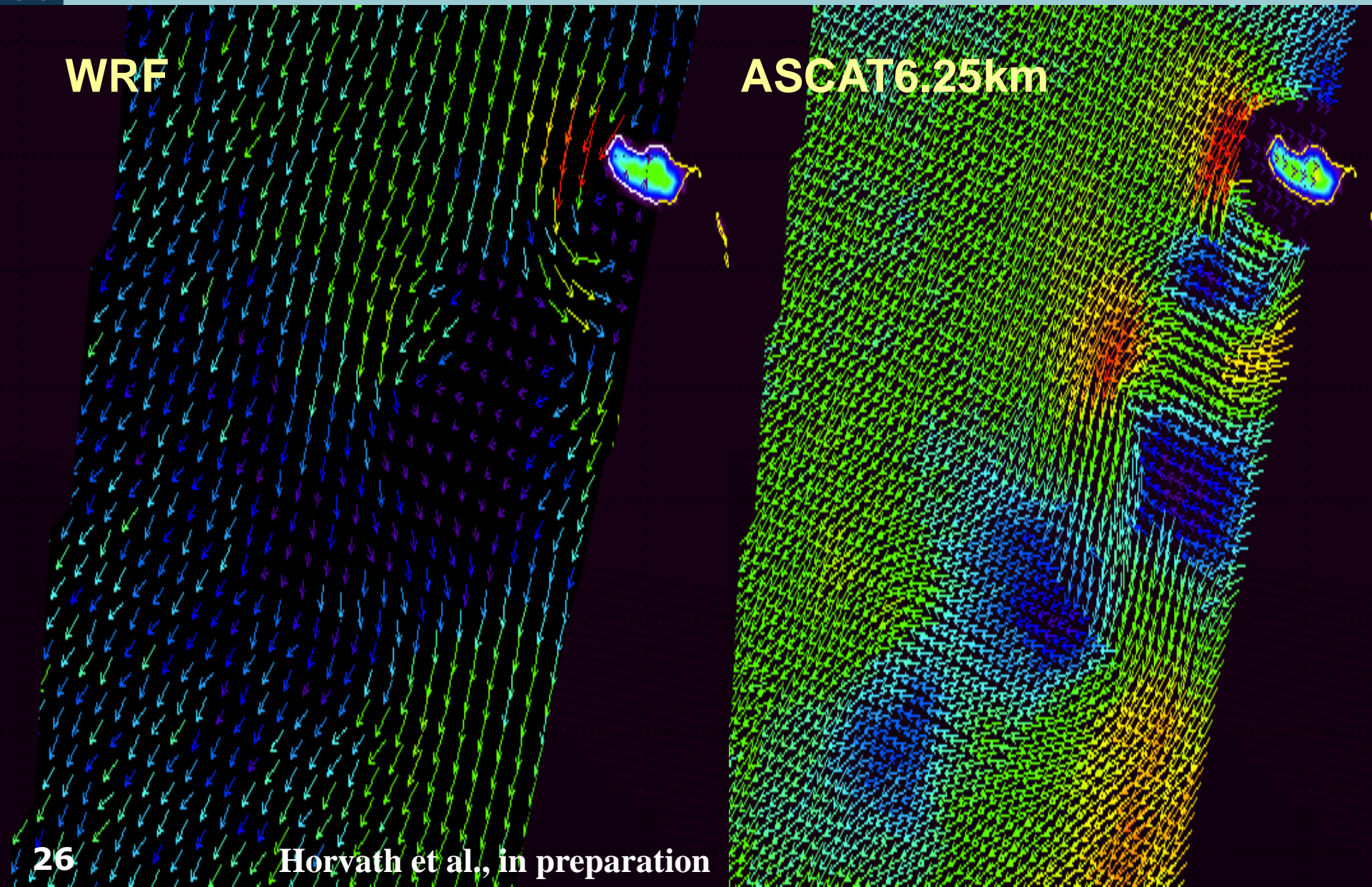


# Observations and Models



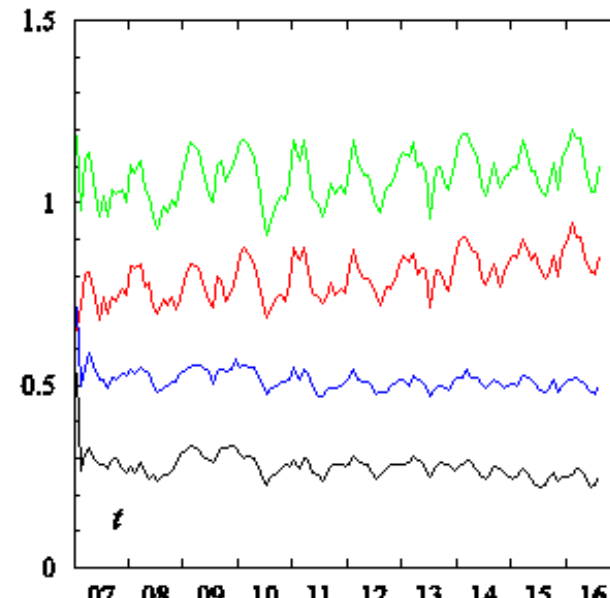
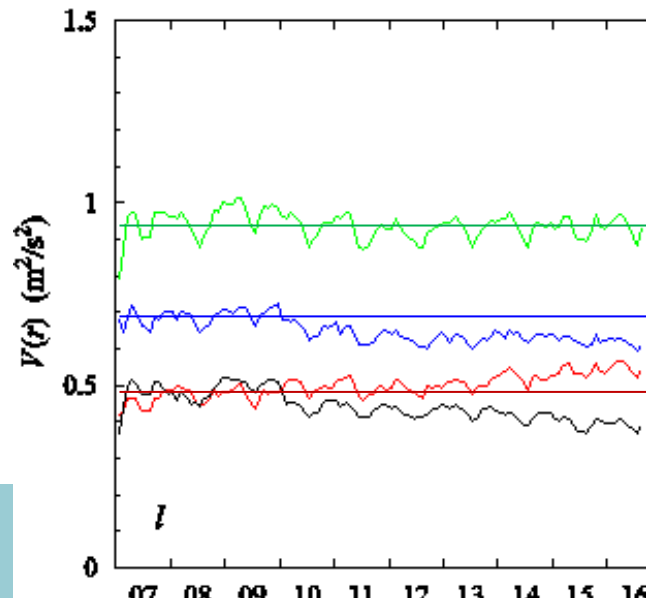
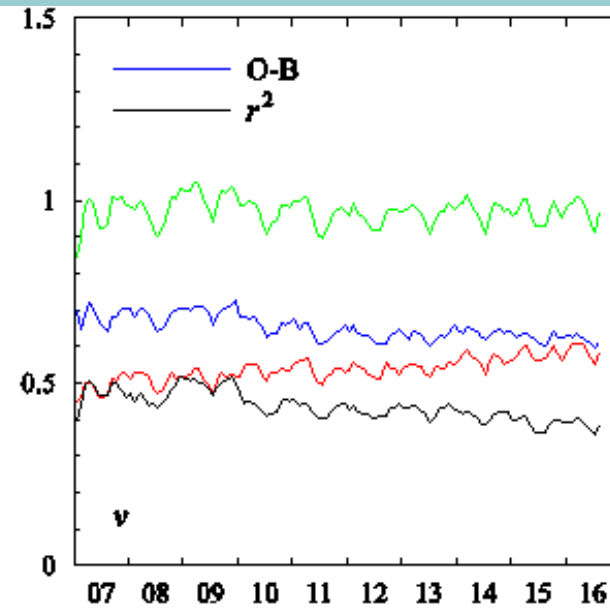
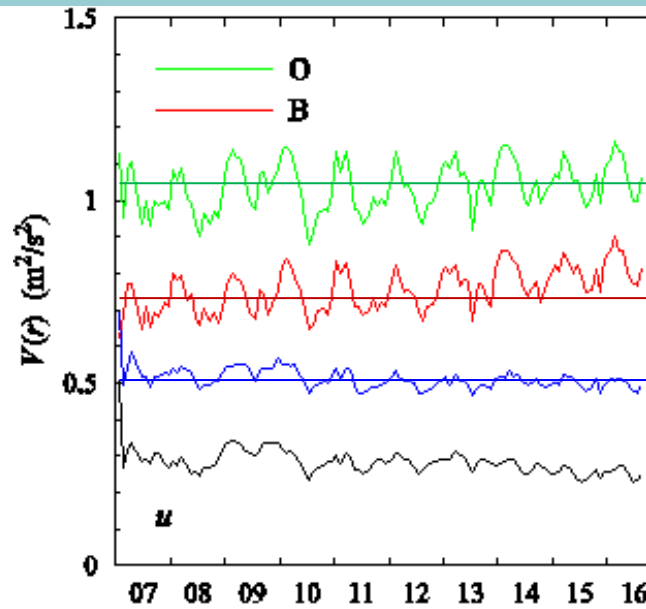
WRF

ASCAT6.25km

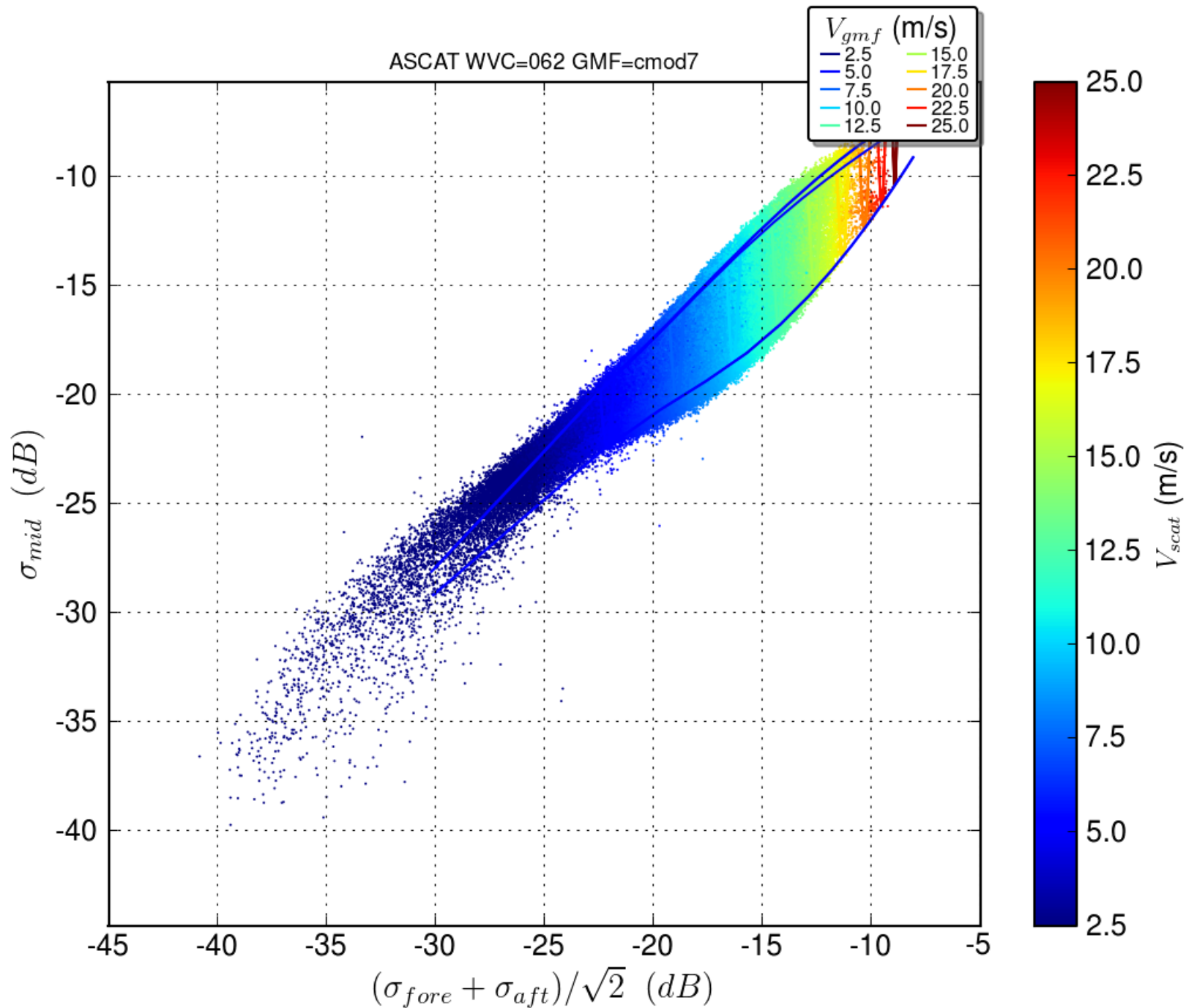


# ECMWF OPS improves

- Scatterometer  $\sigma$  variance under 200 km constant
- $<200$ -km variance  $B$  increases to 80% (u), resp. 60% (v) of  $\sigma$
- O-B decreases, particularly for v
- $l \approx v$  and  $u \approx t$ , but  $u \neq v$  and  $l \neq t$

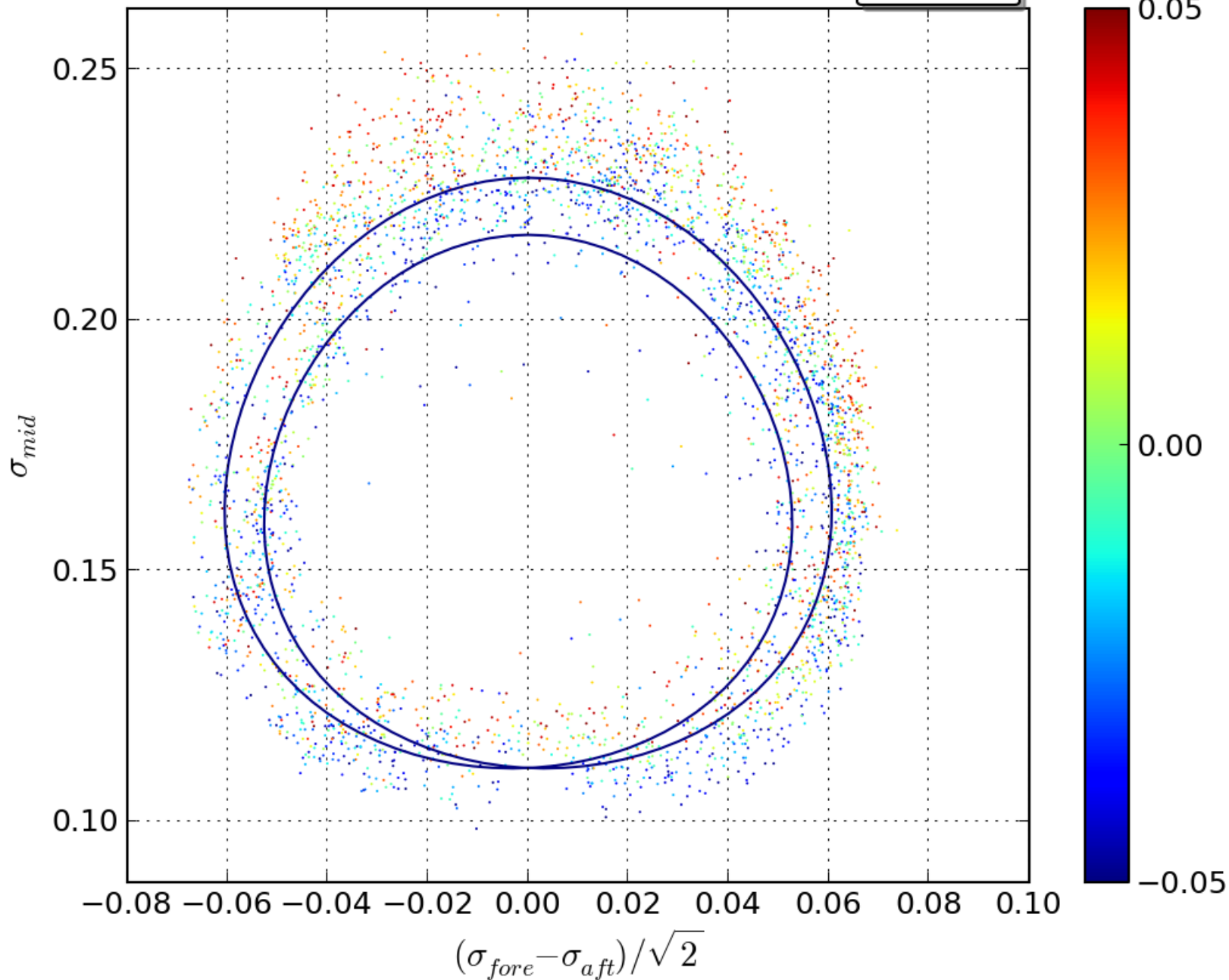


ASCAT WVC=062 GMF=cmod7

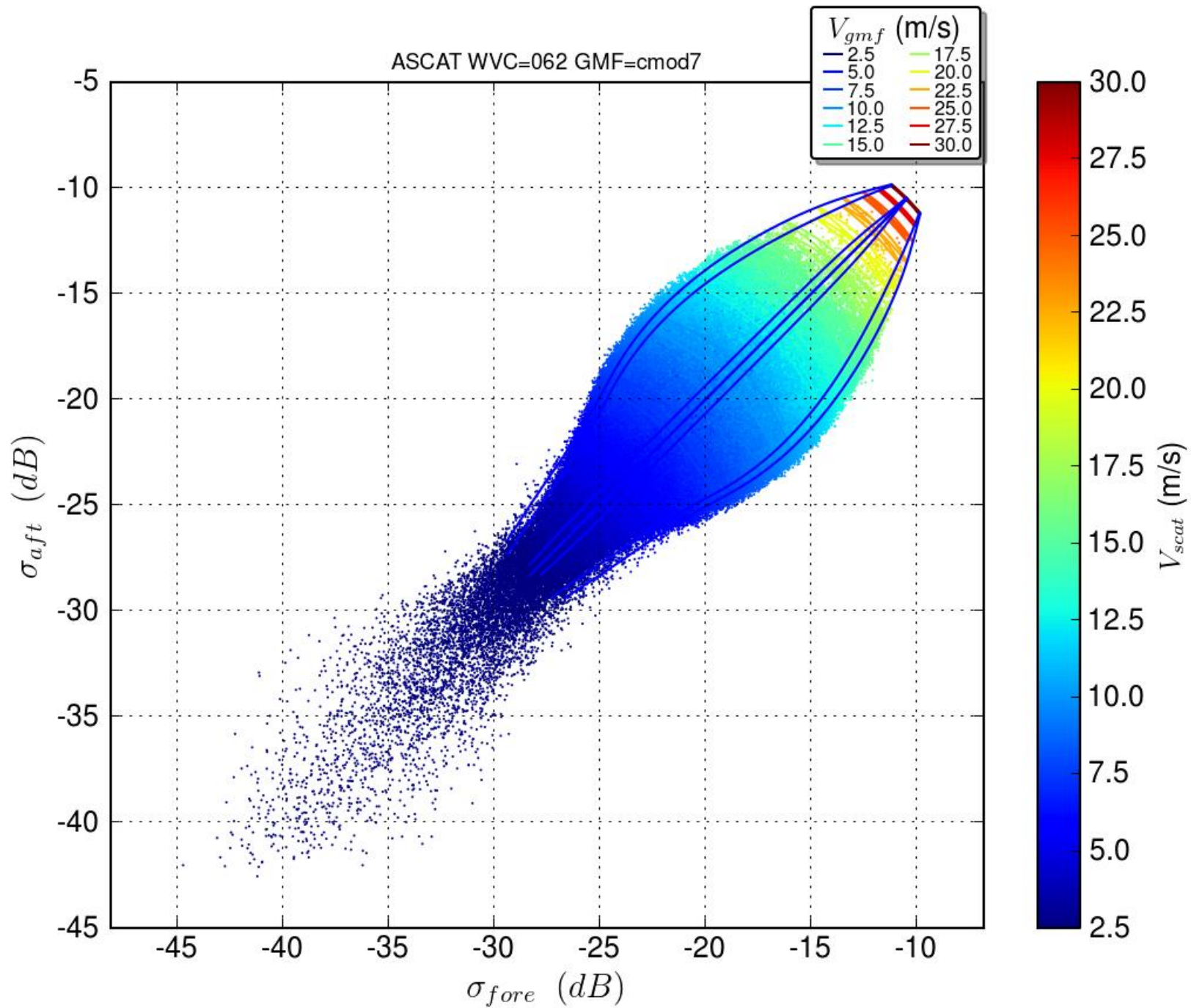


ASCAT WVC=062 GMF=cmod6

$V_{gmf}$  (m/s)  
— 15.0



distance from plane  
 $((\sigma_{fore} + \sigma_{aft}) / \sqrt{2} - C) / C, C = 0.16032025975$



# Faraday rotation

- Ionospheric rotation of e.m. radiation phase
- $V \Rightarrow aV + (1-a)H$   
 $\Rightarrow a(VV + VH)$   
 $+ (1-a)(HV + HH)$   
 $\Rightarrow a[aVV + (1-a)VH$   
 $+ aVH + (1-a)VV]$   
 $+ (1-a)[aHV + (1-a)HH$   
 $+ aHH + (1-a)HV]$
- All detected H for VH:  
 $aVH + (1-a)HH$
- For small VH, substantial HH contamination may occur
- Depends on sun, LTAN
- RadarSat, S1

