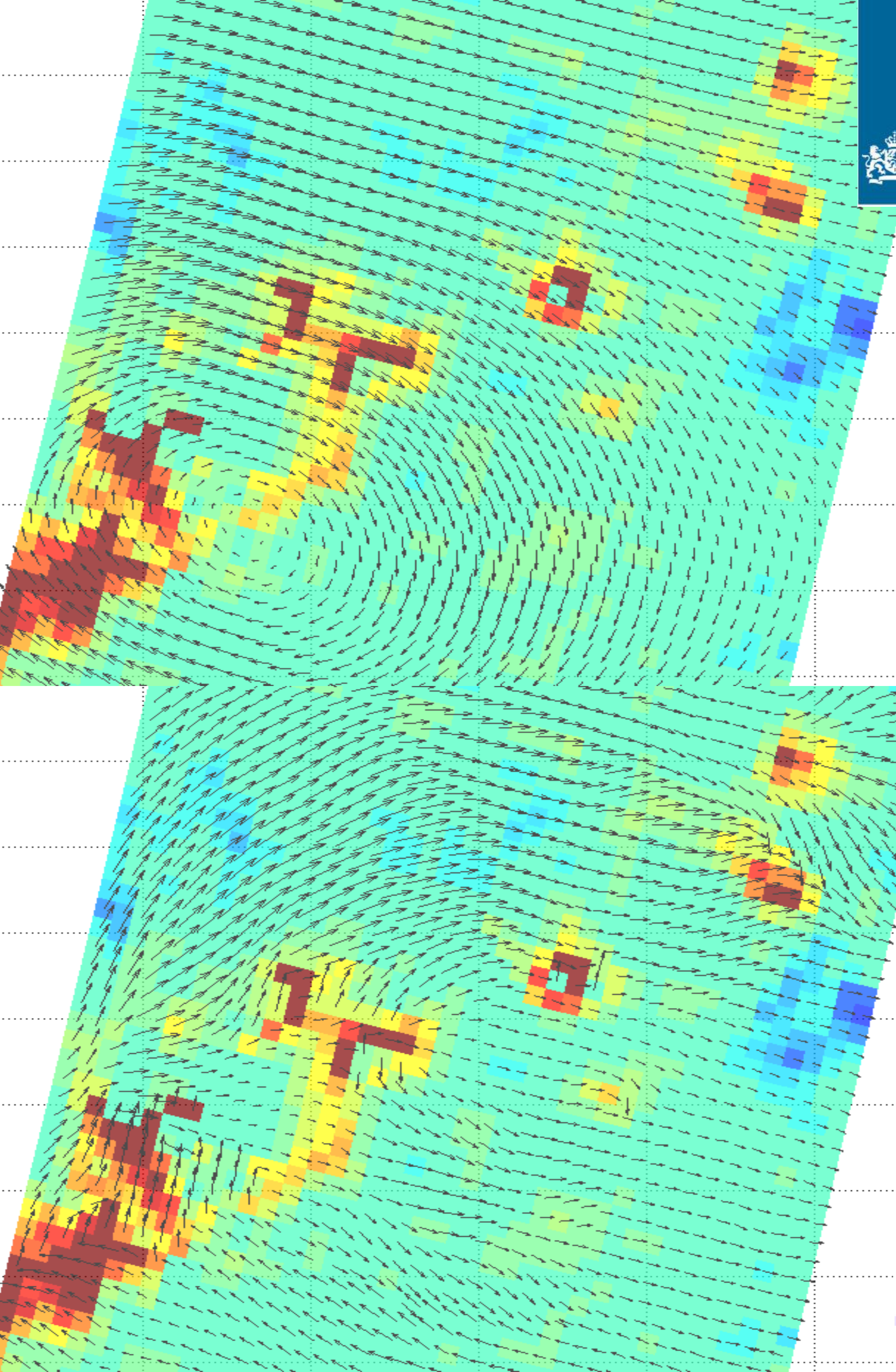

# Do Differences between NWP Model and EO Winds Matter?

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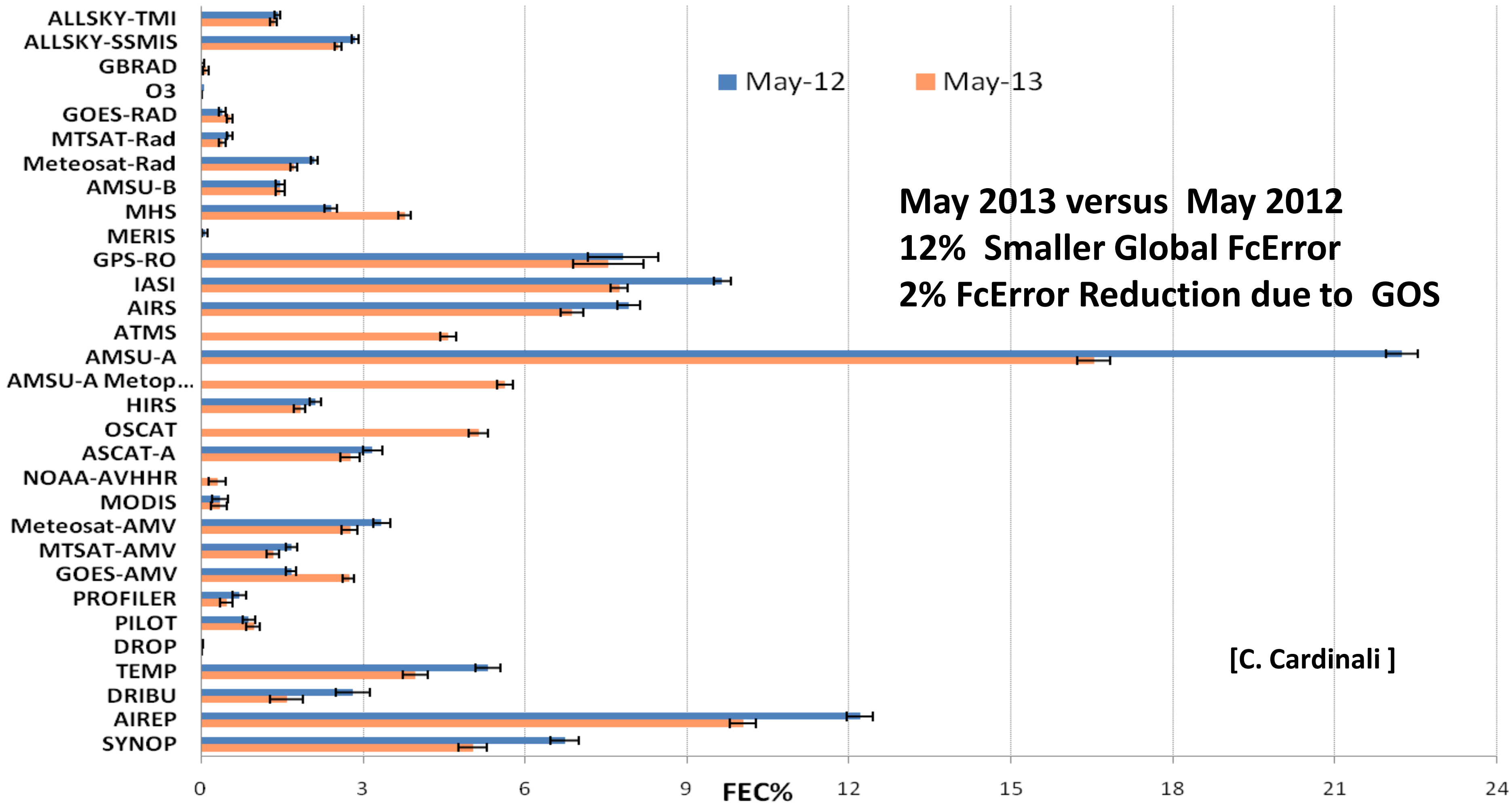
Anton Verhoef, Jos de Kloe,
Jur Vogelzang,
Jeroen Verspeek, Greg King,
Wenming Lin,
Marcos Portabella
Ana Trindade

# Substantial NWP Forecast Error Reduction by Scatterometers

➢ Much information is lost in data assimilation; only a few % used



# Van Gogh first to depict $k^{-5/3}$

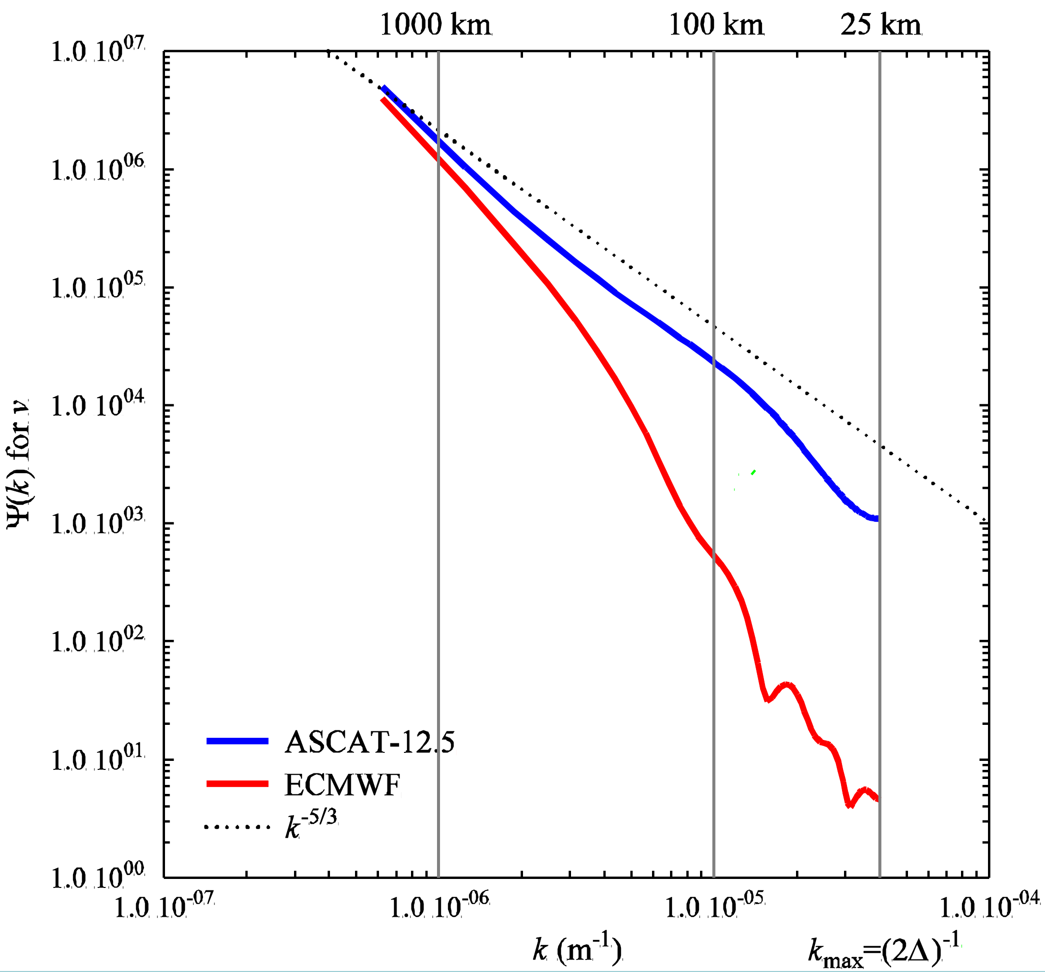
Two Mexican physicists, <u>José Luis Aragón</u> and <u>Gerardo Naumis</u>, have examined the patterns in Vincent van Gogh's

***Starry Night***

**They found that the PDF of luminosity follows the -5/3 scaling law, as introduced later by Kolmogorov and as observed on atmospheric scales < 500 km**

**See *Plus e-zine* for more information.**

# Spatial resolution




- Spectral analysis of collocated fields
- ASCAT near expectation ($k^{-5/3}$)
- NWP lacks resolution, both in analysis and forecast
- Verification of variances and resolution by averaging products (e.g., QSCAT 100km vs 25km, ASCAT 25km vs 12.5km) and triple collocation

See also Vogelzang et al., JGR, 2011

# Spatial Structures

- $k^{-5/3}$ and $k^{-3}$ spectra imply specified forms of spatial correlations
- Investigate correlations in different dynamical regimes
- ASCAT 12.5km shows most variation in variance of $k^{-5/3}$

King et al., 2014

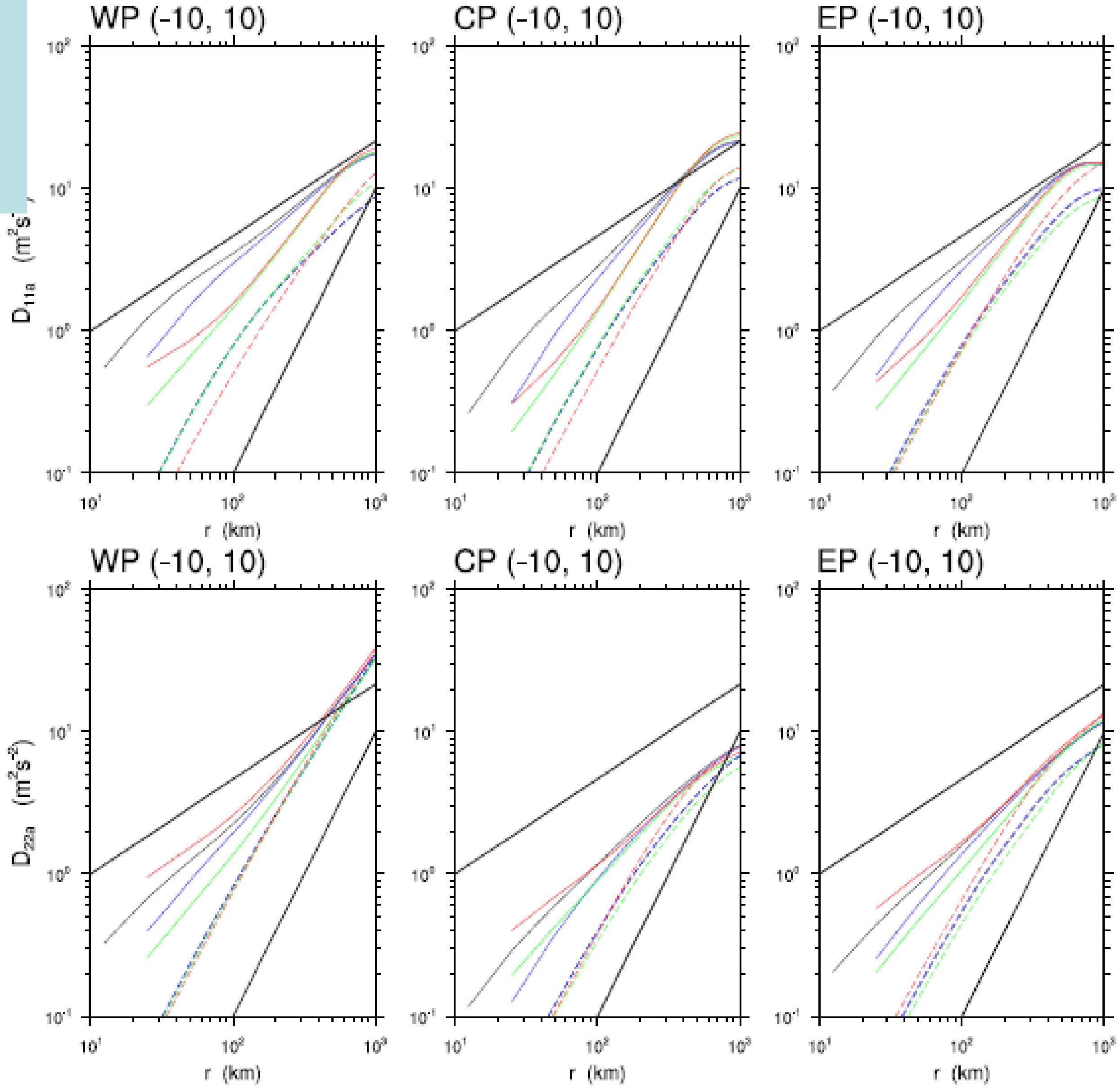
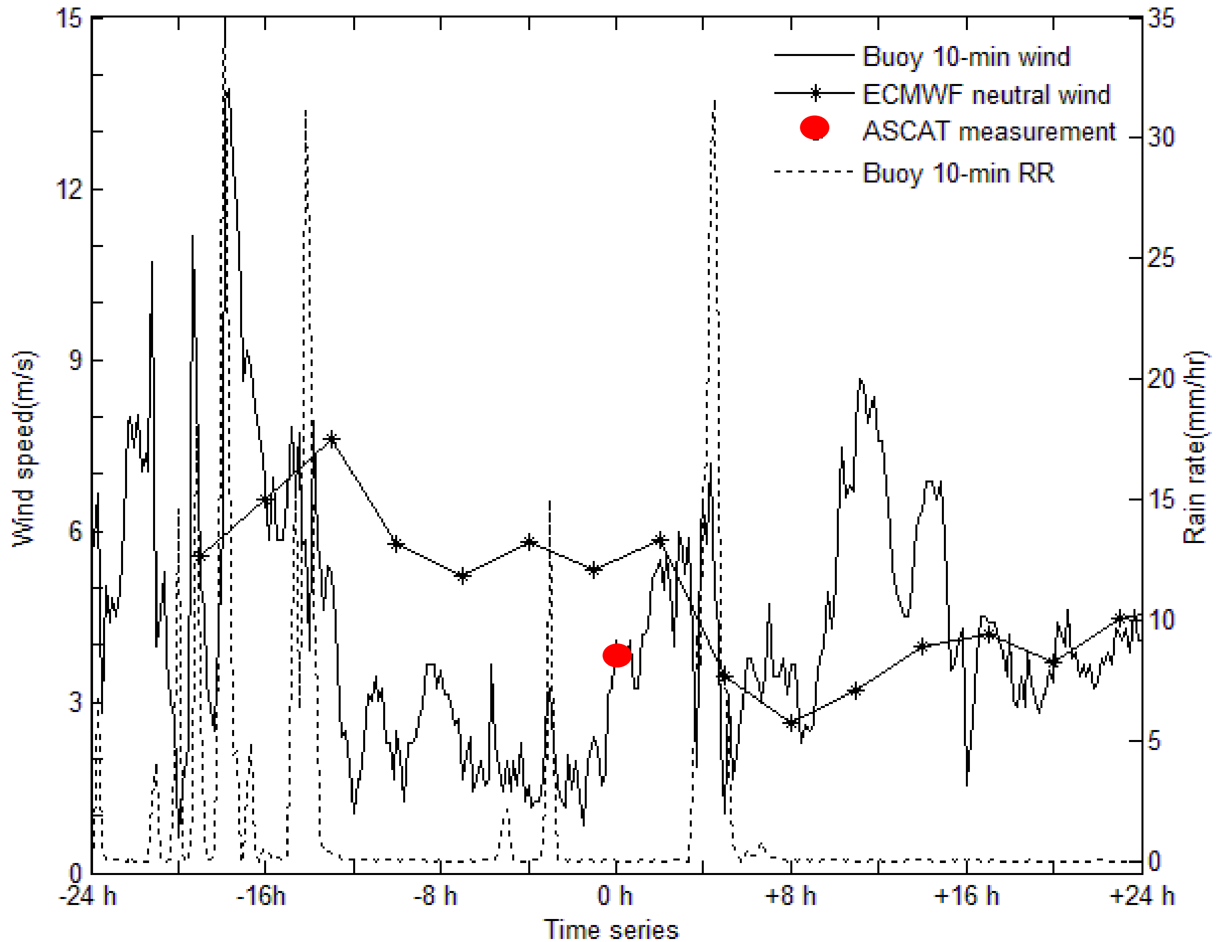


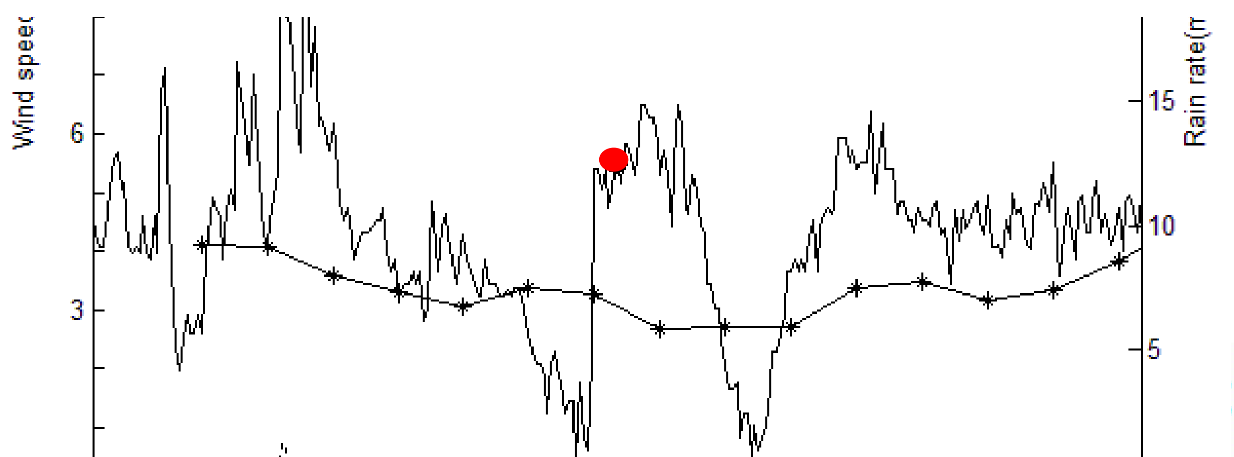

Figure 6: Second-order structure functions for latitudes (-10, 10). Also shown are the structure functions for NWP background winds (dashed) for the same sampling. The thick solid lines are theoretical structure functions for $r^{2/3}$ and $r^2$ scaling.

# Tropical variability

1. NWP models lack air-sea interaction in rainy areas
2. ASCAT scatterometer does a good job near rain
3. Convective updrafts and downbursts missed out
4. Hughly affects air-sea exchange

- ➢ Portabella et al., TGRS, 2011

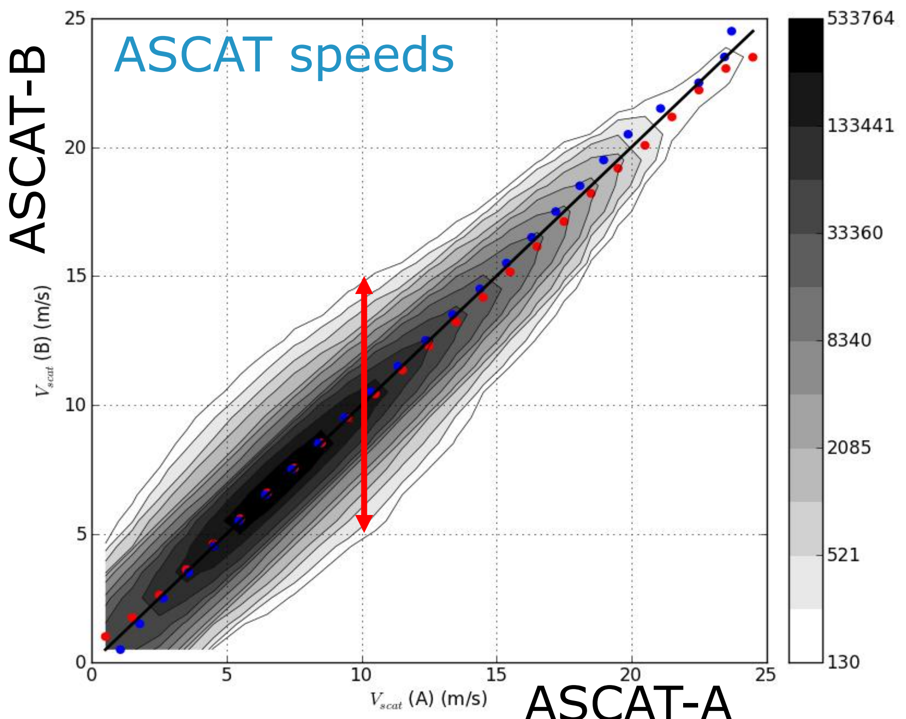


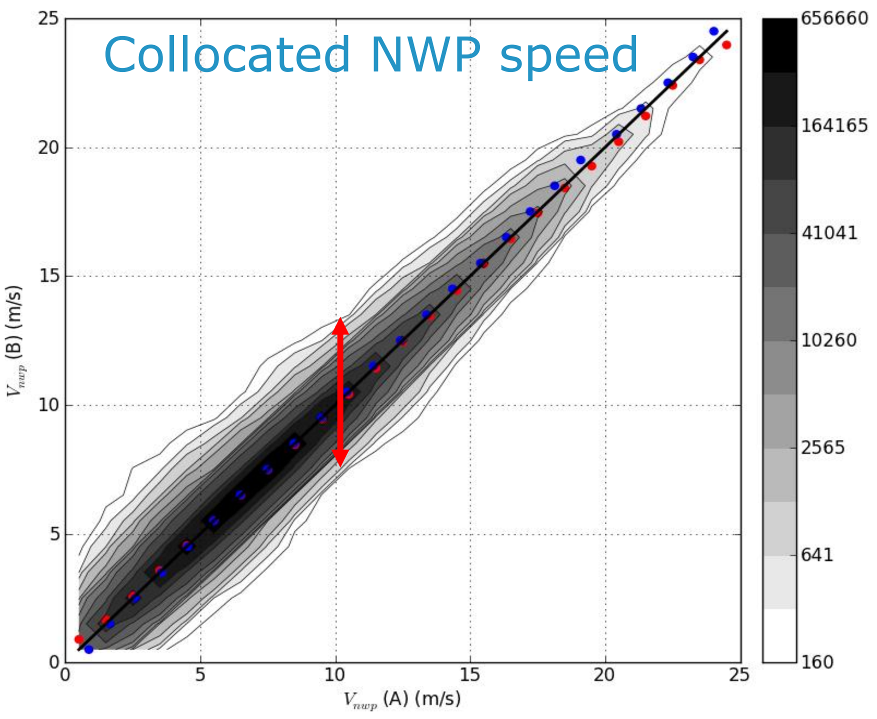



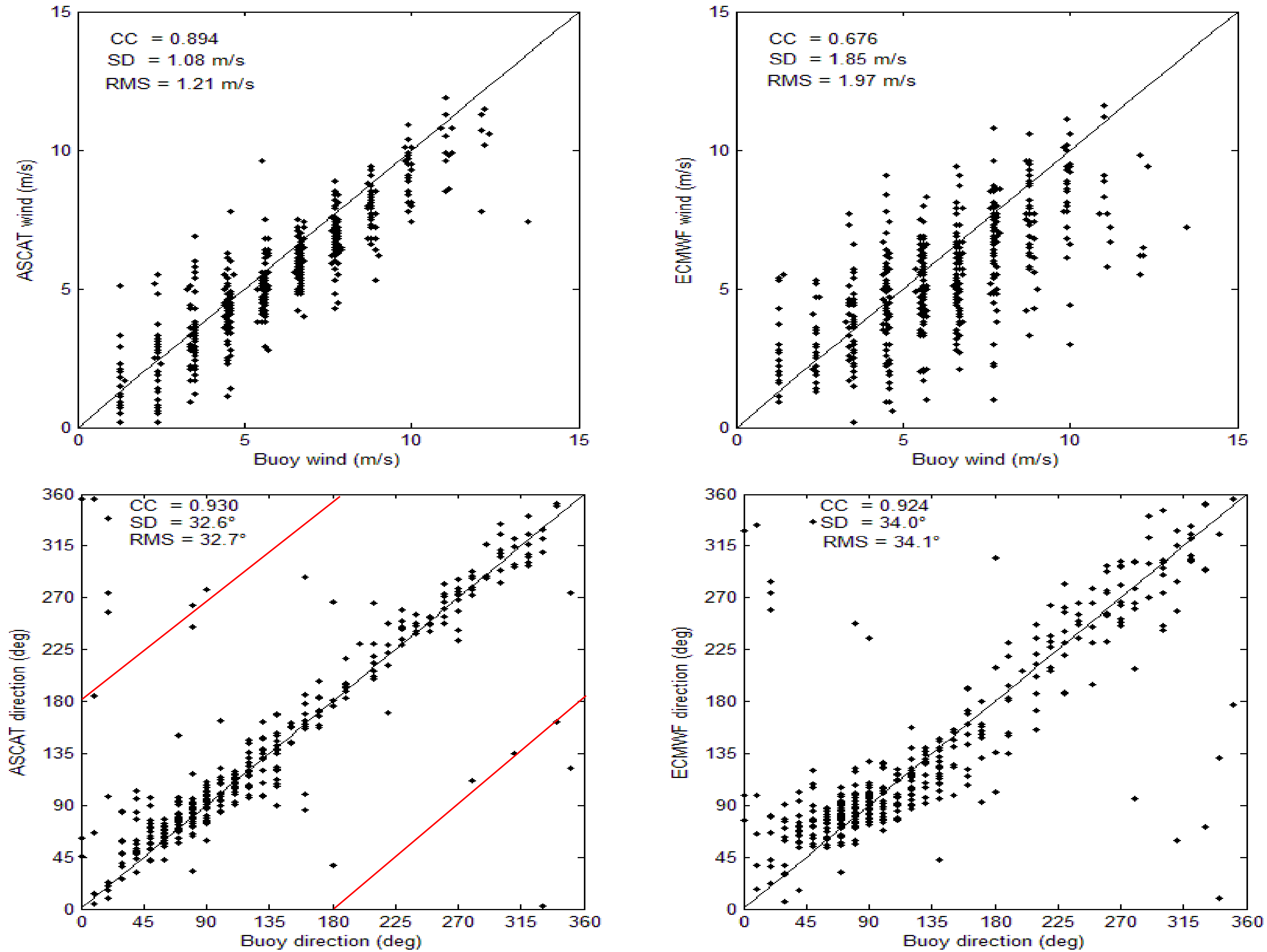
# ASCAT-A ASCAT-B collocation

• Global, $\Delta t$=50min.

➢Small spread in NWP due to 50 minutes time difference (smooth winds)
➢Changes over time in ASCAT are much larger (e.g., convection),
➢Exchanges will also be faster than in global NWP models



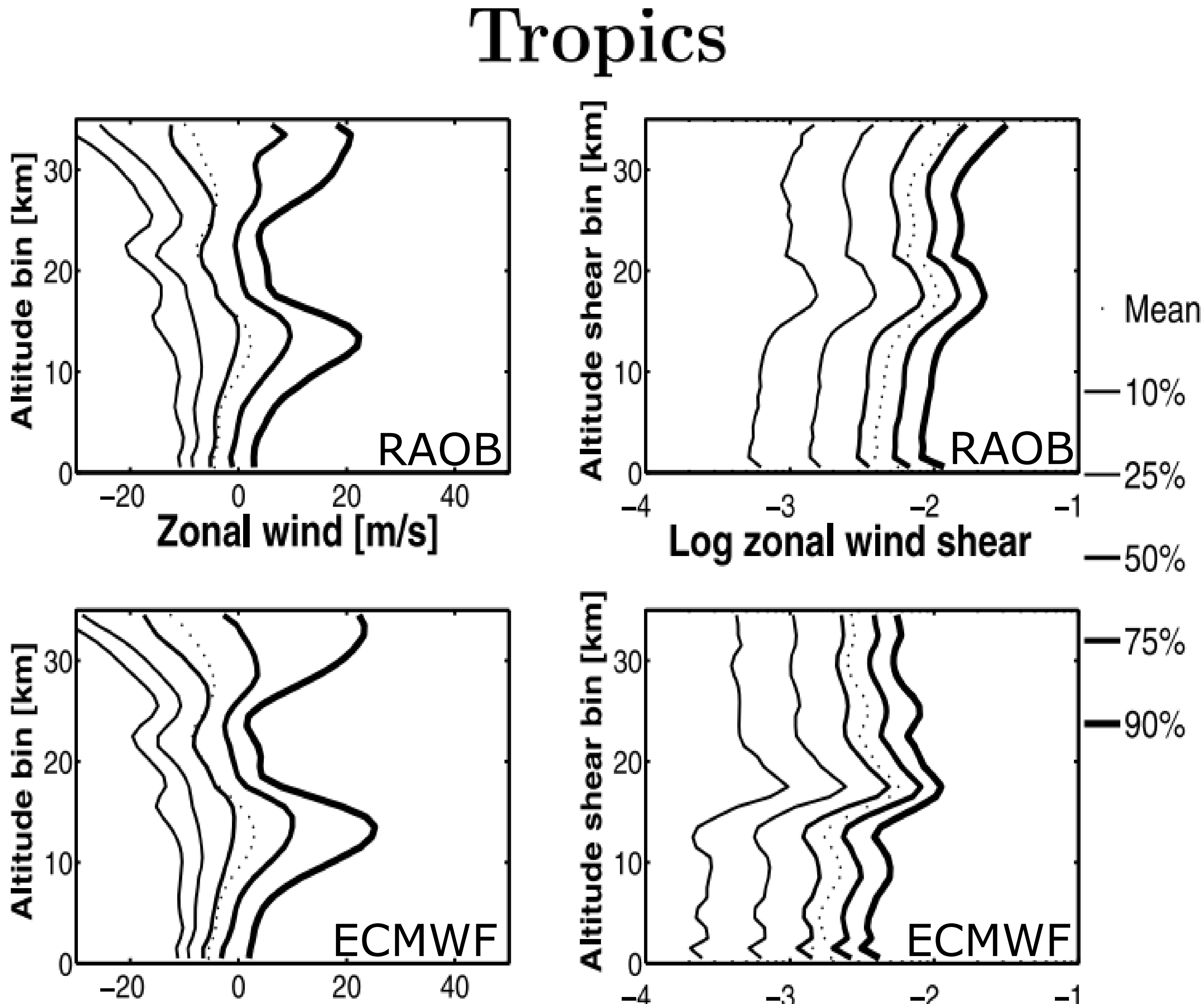



ASCAT 25 km (selected) winds closer to buoy winds than ECMWF winds in rainy areas (**buoy rain data**).

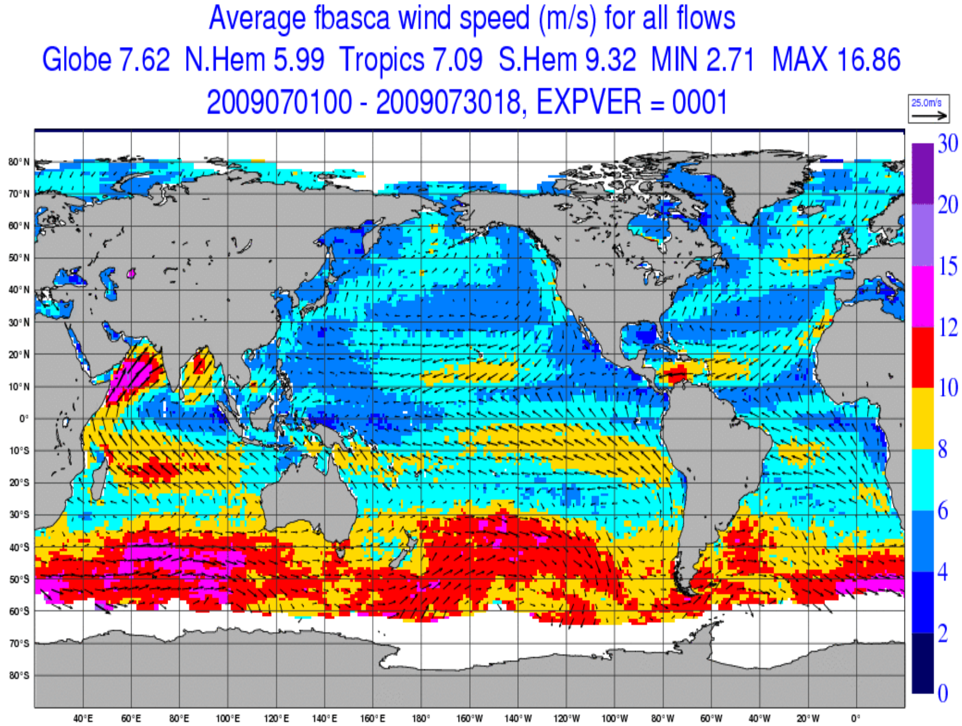
# Hi-res radiosonde shear

- Tropical tropopause shear in ECMWF model strongly variable
- RAOBS have much more shear

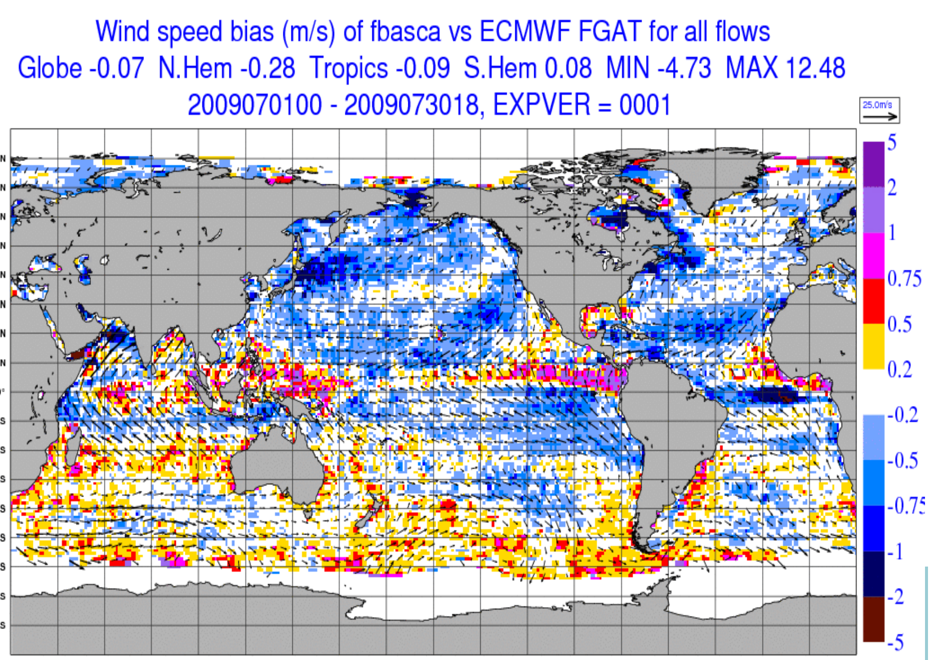
Houchi et al. 2010

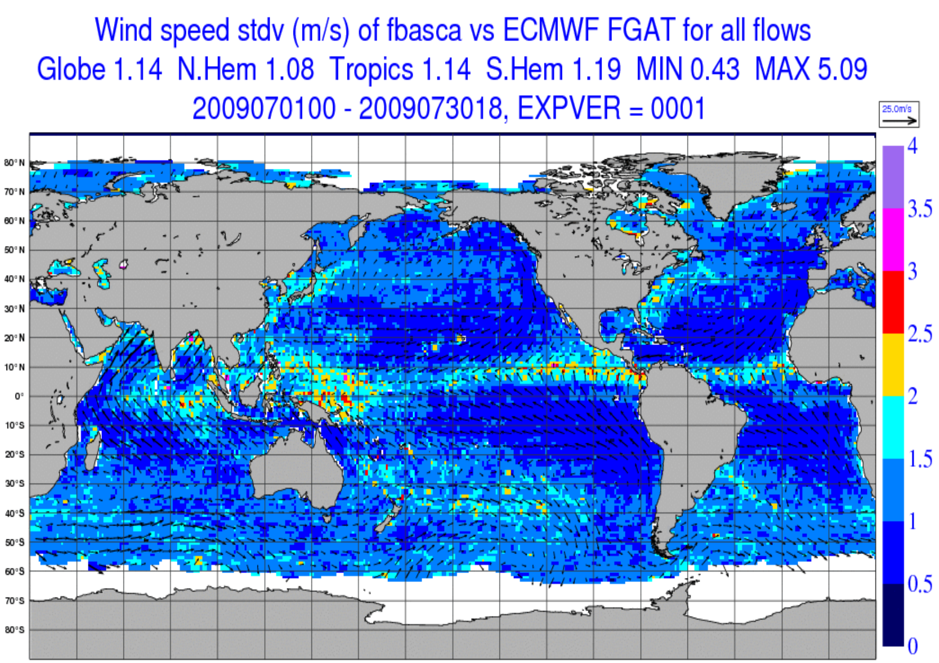


# ASCAT, July 2009

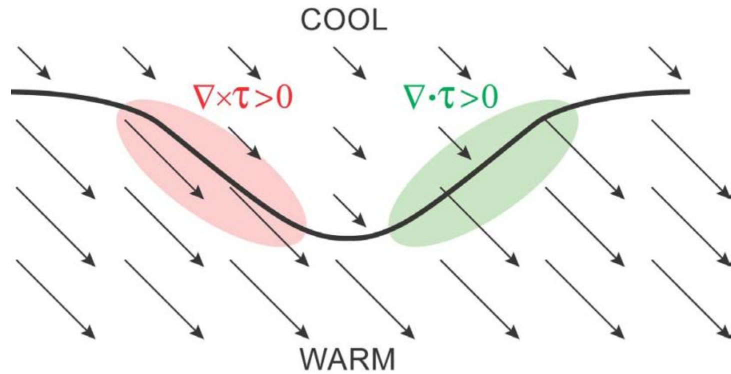



- ➢ ITCZ biases and SDs are large

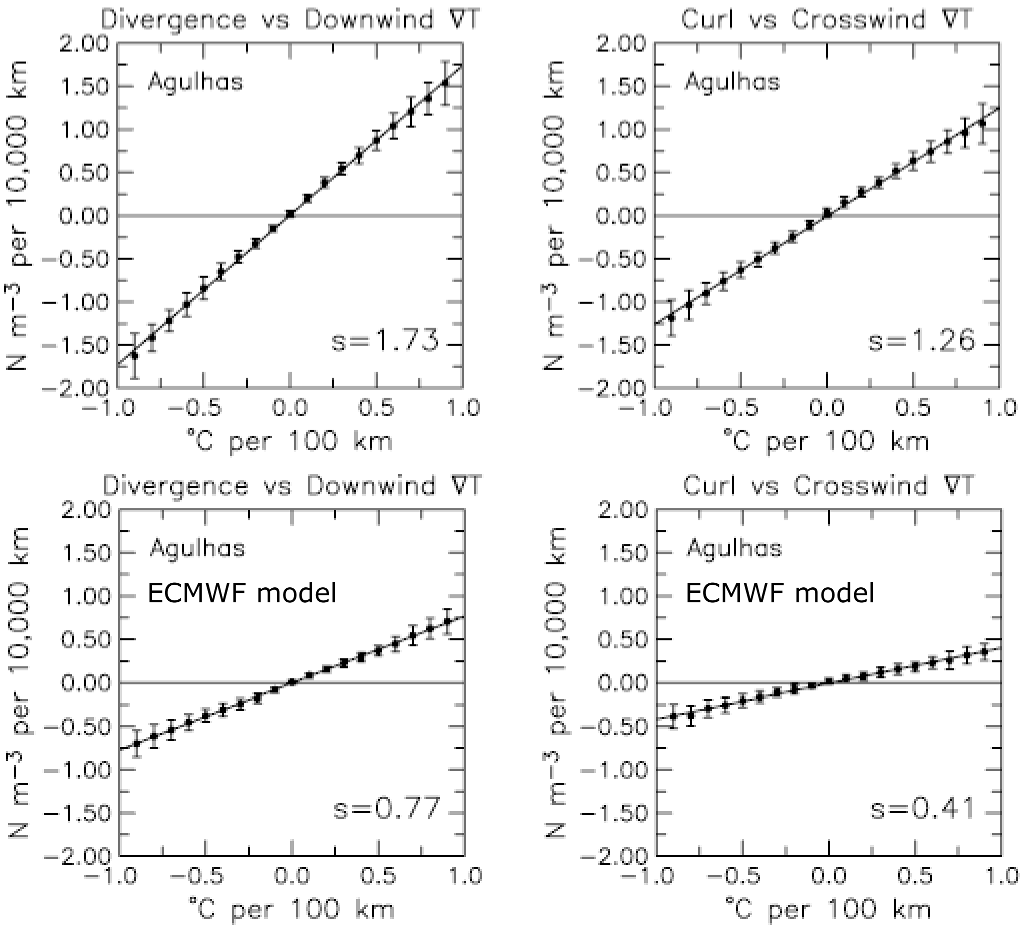


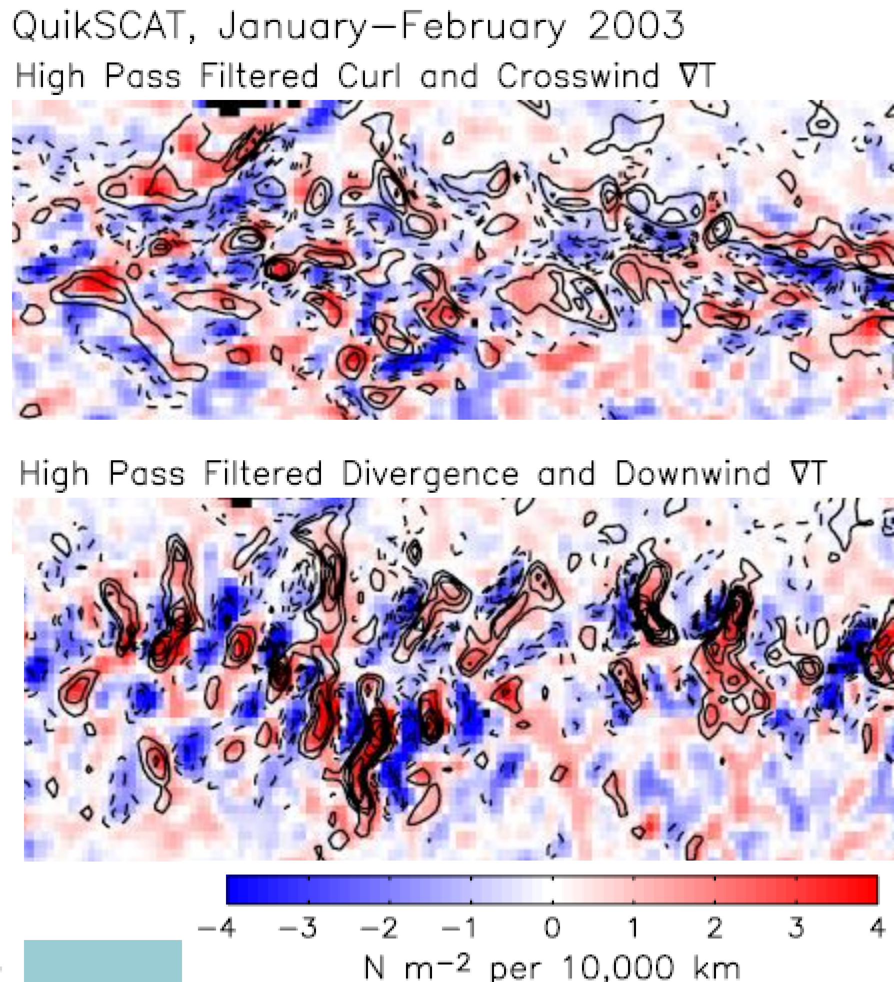



# Air-sea interaction
# ECMWF too weak

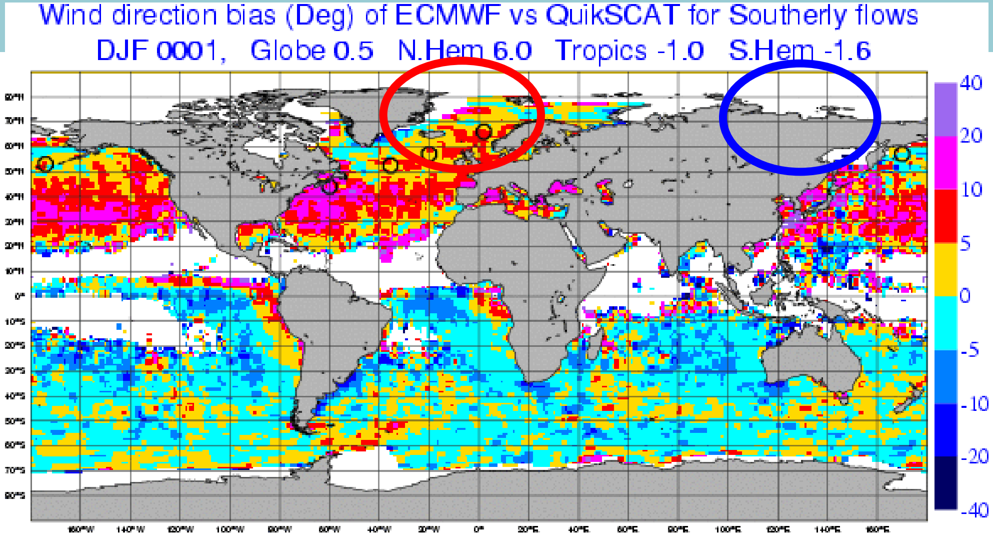


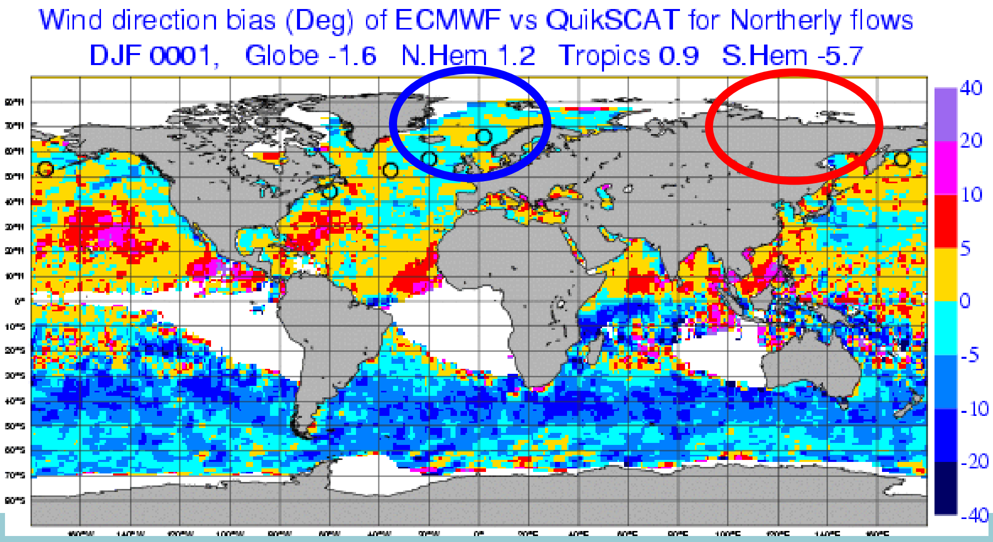

Chelton et al., Science



# Lack of NWP cross-isobar flow




QuikSCAT vs model wind dir
Stratify w.r.t. Northerly, Southerly wind direction.
(Dec 2000 – Feb 2001)

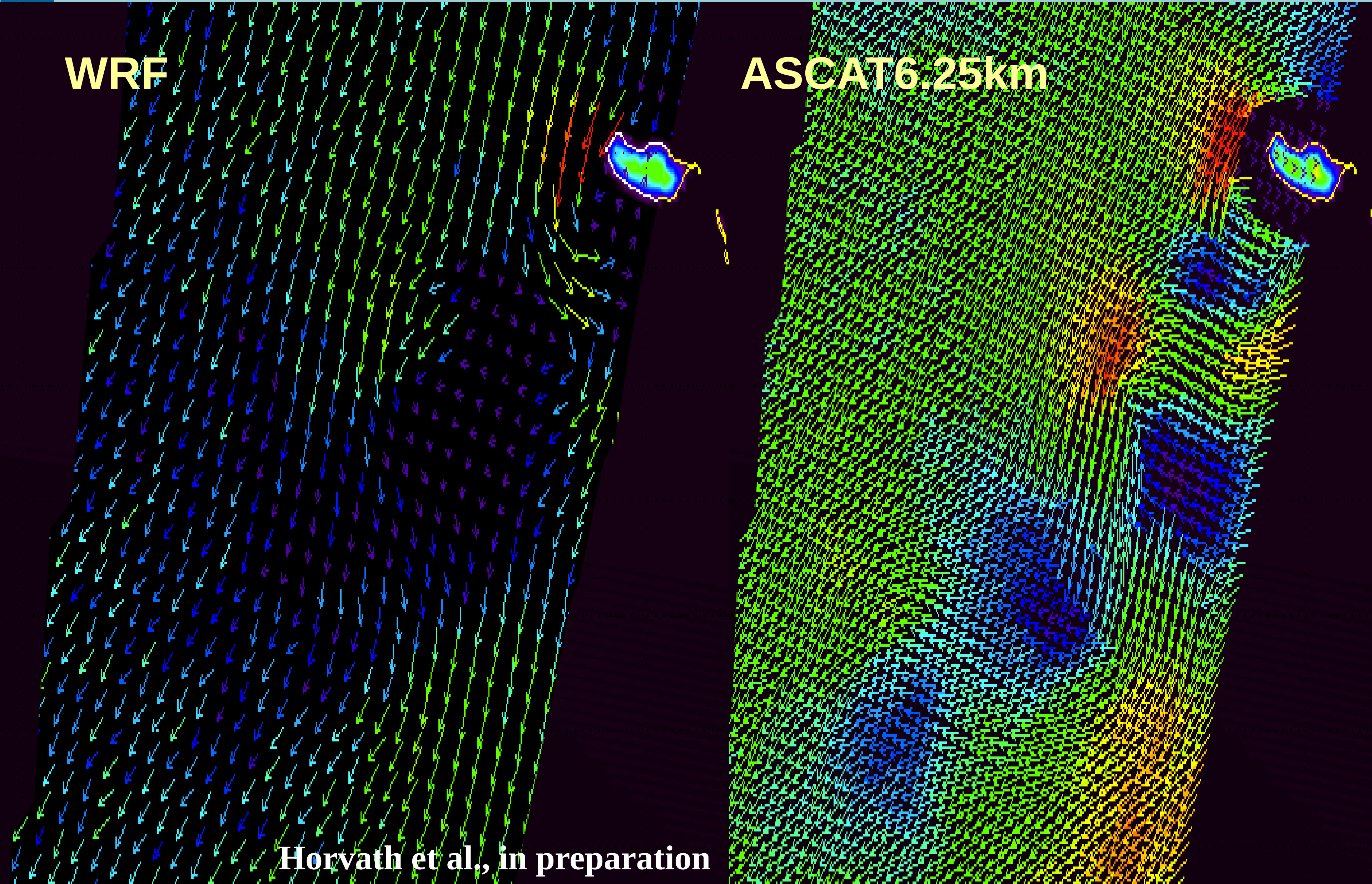
- Large effect warm advection
- Small effect cold advection
- Similar results for other models

***A. Brown et al., 2005***

***Hans Hersbach, ECMWF (2005)***

***Sandu et al., 2013***

# Higher resolution




Horvath et al., in preparation

# NWP model comparison

Global NWP models

- Lack scales below 200 km
- Lack convection and associated wind downbursts
- Have a weak diurnal cycle
- Lack air-sea interaction
- Are rather neutral stability and show large direction errors
- Are rather inaccurate on the ocean eddy scale
- Are relative to the fixed earth rather than the moving water

Regional models

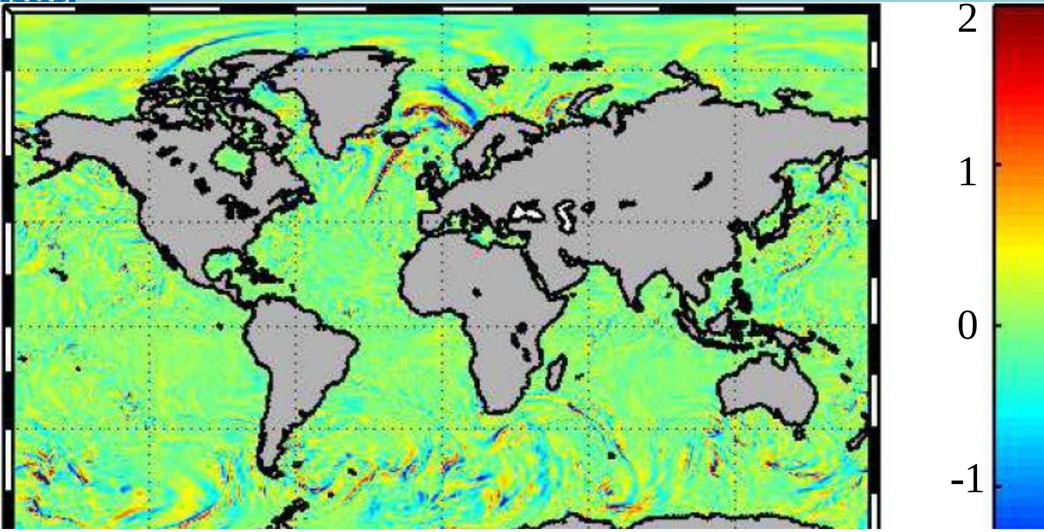
- Need improved PBL, surface layer and moist convection parameterisations

- How to proceed and better use observations?

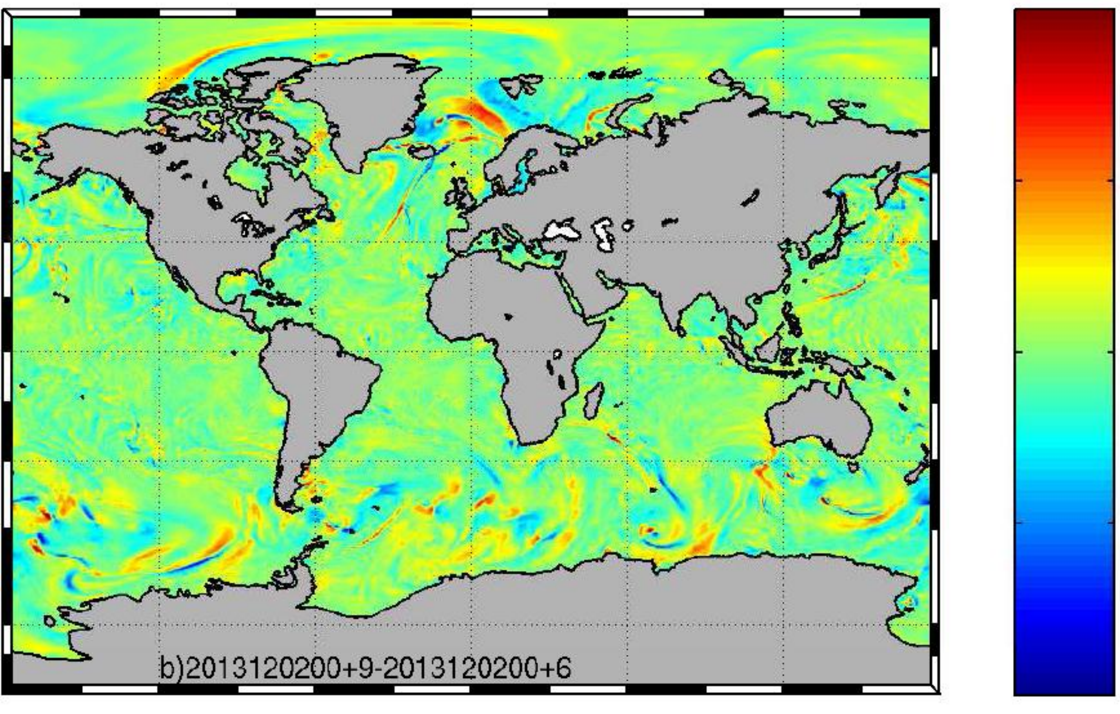
# Sampling error

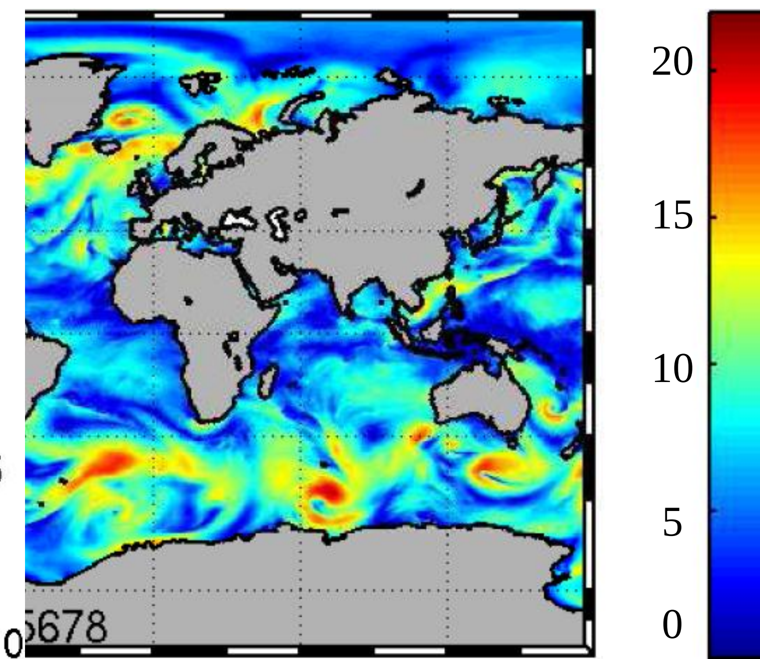
- All scatterometers sample the atmosphere spatially and temporally in a non-uniform way due to swath geometry and QC (rain); this causes substantial sampling errors
- ERA-interim U10N is collocated in time and space with all (valid) scatterometer winds and processed to the same L2 and L3 products
- Users may thus compare the spatial and temporal mean ERA-interim values as sampled by the scatterometer with uniformly sampled ERA-interim values in order to obtain an estimate of the sampling error fields of the scatterometer
- Improved spatial and temporal averages are thus obtained by subtracting the estimated sampling error from ERA-interim from the scatterometer climatology

# Transient weather

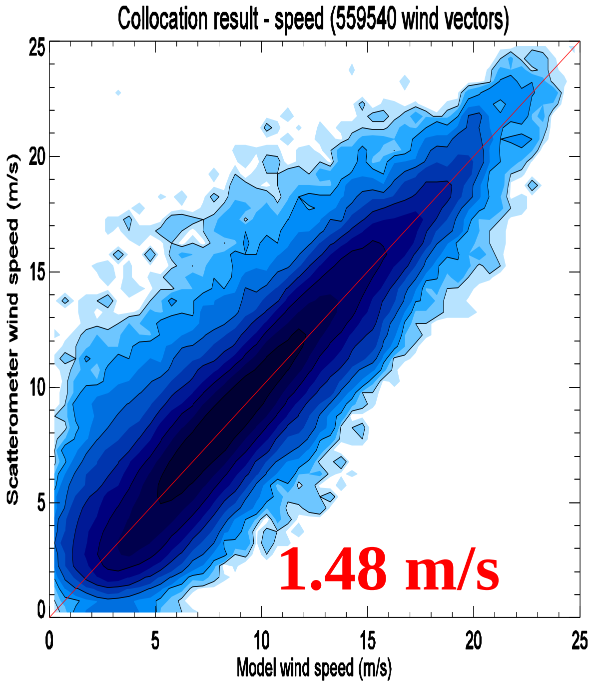


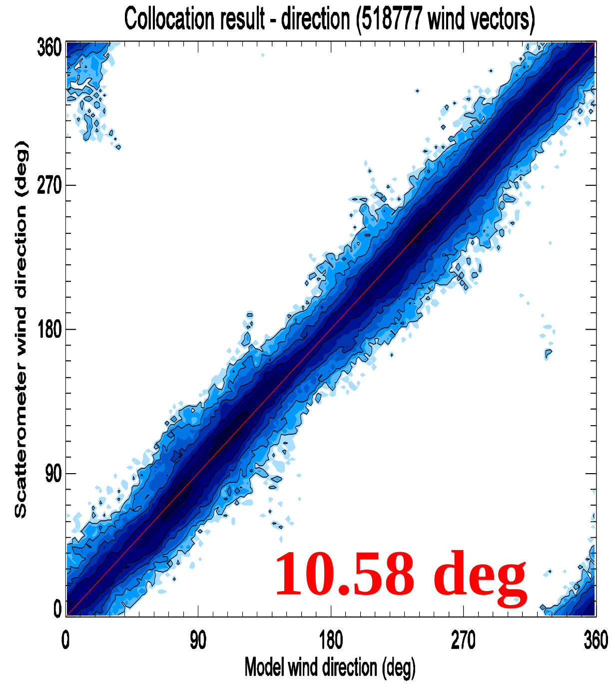

- Ocean forcing changes substantially over a few hours (~10%)
- Account for the large time changes
- Spatial interpolation to a convenient grid may cause similar effects



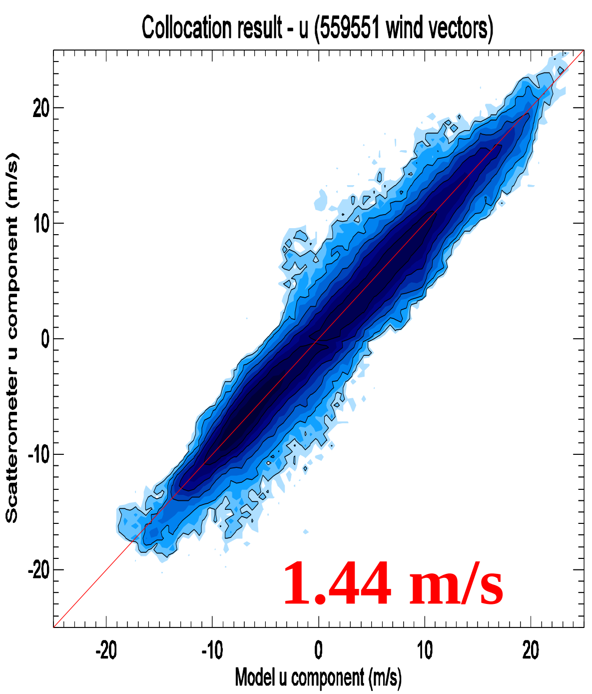



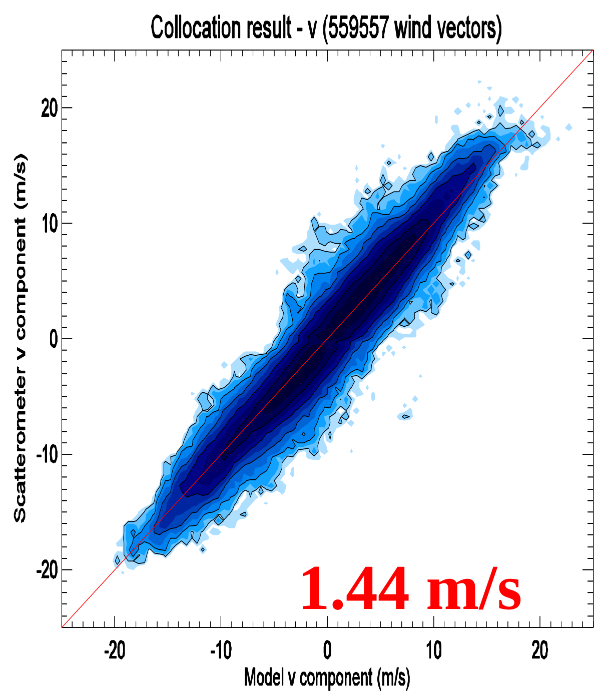
# KNMI HY2A vs ECMWF




- NWP ocean calibration (standard for wind processing)
- Speed, direction and vector components
- Outlier detection




- Small scales evolve fast, so when we want to determine (initialize) them in 4D, we will need many observations!
- EO data is needed to validate and improve NWP parameterisations

# Summary

- NWP winds improve in time, but still today turbulence, PBL and convection processes show systematic biases
- NWP biases are the result of a careful tuning process and not easy to correct
- PBL and mesoscale processes determine local dynamical conditions and local climate change sensitivity
- Excellent EO data exists on surface winds and stresses
- These depict processes important to improve understanding of Weather and Climate models
- Compare closely time and space collocated NWP and EO sources to analyse differences
- Compare satellite-sampled climatologies with uniformly sampled climatologies to obtain satellite sampling errors
- Include ocean currents

# Overview

- Differences
- Importance

# Triple collocation result

| Scatterometer Scale Error SD | U m/s | V m/s |
|---|---|---|
| Buoy | 1.21±0.02 | 1.23±0.02 |
| ASCAT | 0.69±0.02 | 0.82±0.02 |
| ECMWF | 1.54±0.02 | 1.55±0.02 |
| Representativeness | 0.78±0.02 | 1.00±0.02 |
| **ECMWF Scale Error SD** | **U m/s** | **V m/s** |
| Buoy | 1.44±0.02 | 1.59±0.02 |
| ASCAT | 1.05±0.02 | 1.29±0.02 |
| ECMWF | 1.32±0.02 | 1.18±0.02 |

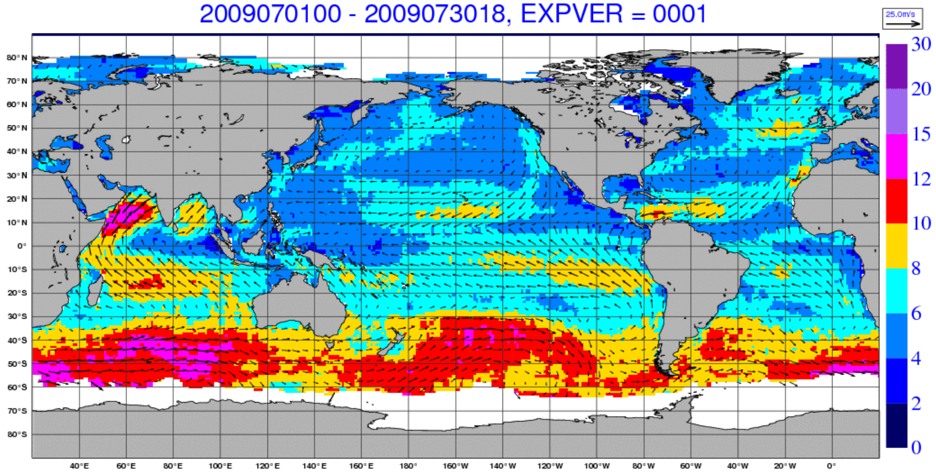
| Trend | U m/s | V m/s |
|---|---|---|
| ASCAT | 0.99 | 0.99 |
| ECMWF | 0.97 | 0.96 |

- ASCAT winds are very accurate
- ASCAT error SD is smaller than representativeness vector error SD
- Buoy errors appear large (current, wind variability)
- ECMWF winds appear smooth and biased low on average
- In nasty weather much larger deviations will occur (see Marcos P.)

See also Vogelzang et al., JGR, 2011

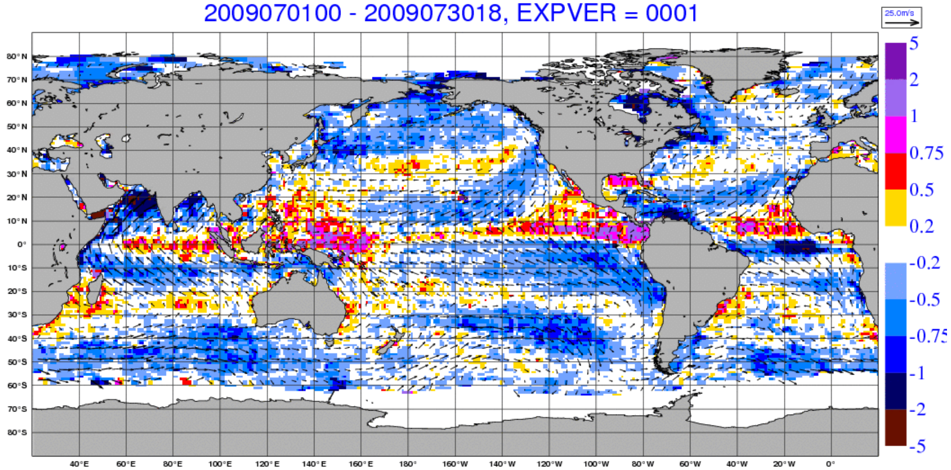
# Geographical statistics for QuikSCAT, July 2009

Average QuikSCAT wind speed (m/s) for all flows
Globe 7.31 N.Hem 5.64 Tropics 6.78 S.Hem 9.09 MIN 2.17 MAX 16.12
2009070100 - 2009073018, EXPVER = 0001

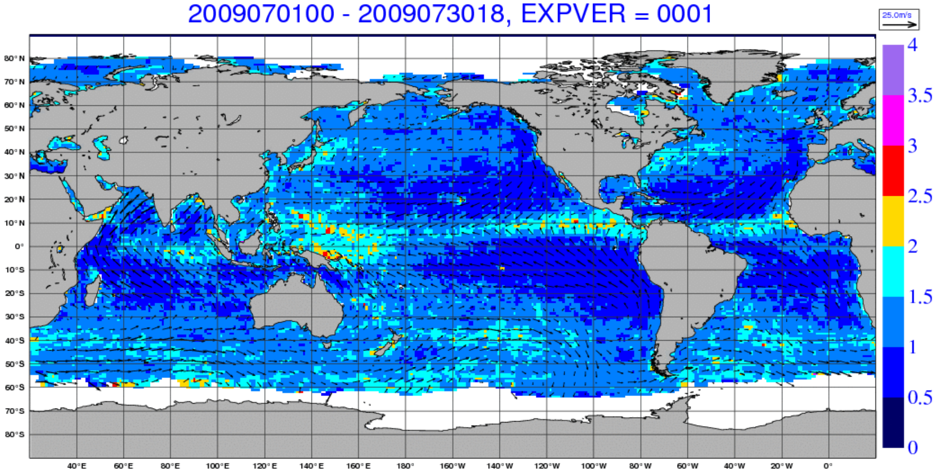



- ➢ **Rain flag removes stronger winds for QuikSCAT**
- ➢ **There are some regional differences**

Wind speed bias (m/s) of QuikSCAT vs ECMWF FGAT for all flows
Globe -0.15 N.Hem -0.21 Tropics -0.1 S.Hem -0.18 MIN -4.32 MAX 3.15
2009070100 - 2009073018, EXPVER = 0001

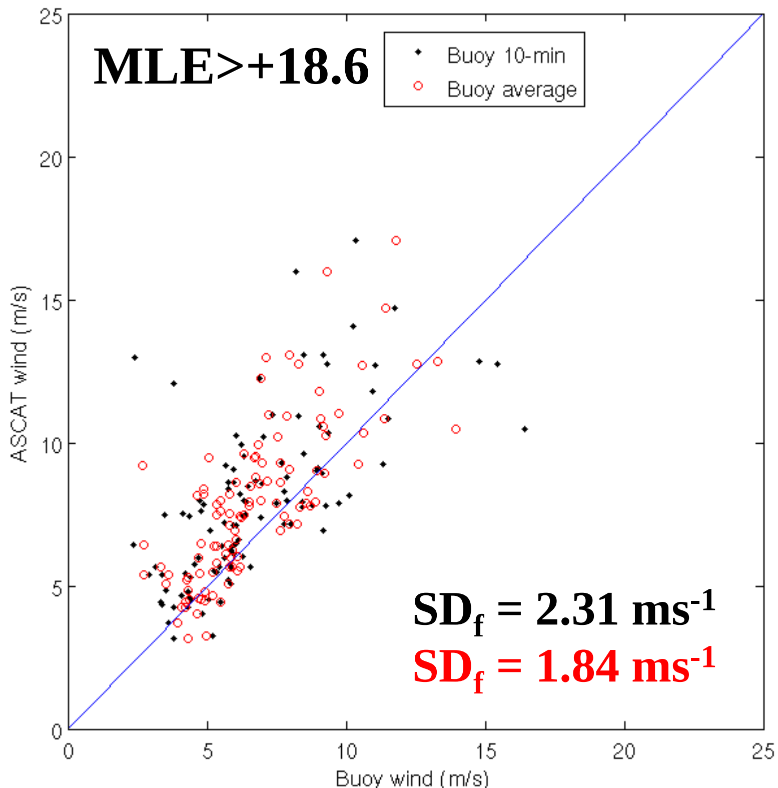


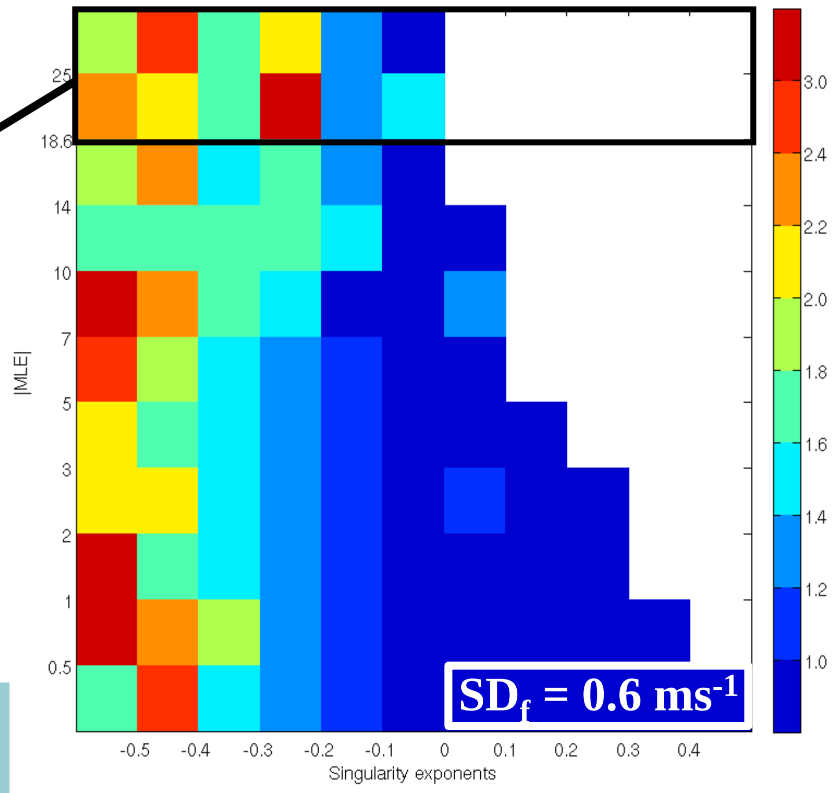

Wind speed stdv (m/s) of QuikSCAT vs ECMWF FGAT for all flows
Globe 1.2 N.Hem 1.16 Tropics 1.15 S.Hem 1.28 MIN 0.45 MAX 4.24
2009070100 - 2009073018, EXPVER = 0001



# QC: Which error is acceptable?

- We can produce winds with SD of buoy-scatterometer difference of 0.6 m/s, but would exclude all high-wind and dynamic air-sea interaction areas
- The winds that we reject right now in convective tropical areas are noisy (SD=1.84 m/s), but generally not outliers!
- What metric makes sense for QC trade-off?



EO ocean surface vector winds are accurate and can represent small scales, while ocean surface winds from global atmospheric models are rather uniform in space and time. This is, small scale processes of mixing and convection are not well represented in NWP models. EO winds are shown to show both more time and space variation, which obviously impact implied air-sea interaction. Moreover, NWP models show systematic differences with EO vector winds and stresses in ocean forcing. These differences will be high-lighted and their effect in different applications discussed.

The presence EO ocean surface vector winds (OVW) allows their comparison with independent NWP winds. Global models provide precisely collocated meteorological and ocean surface data for every EO measurement. Such comparisons are stratified by either EO instrument variables or atmospheric model or ocean surface variables. This provides insight in the nature of systematic and random differences, which may have statistical or physical origin and are evaluated in time, space (incl. spectral analysis) and as a function of the diverse system parameters in order to obtain error models of the OVW sets.

To further support these error analyses, EO OVWs may be collocated among each other or may be collocated with in situ OVWs in order to verify the statistically and physically based OVW error models, both EO and NWP. This results in triple in-situ - EO - NWP collocation data sets that are analyzed.

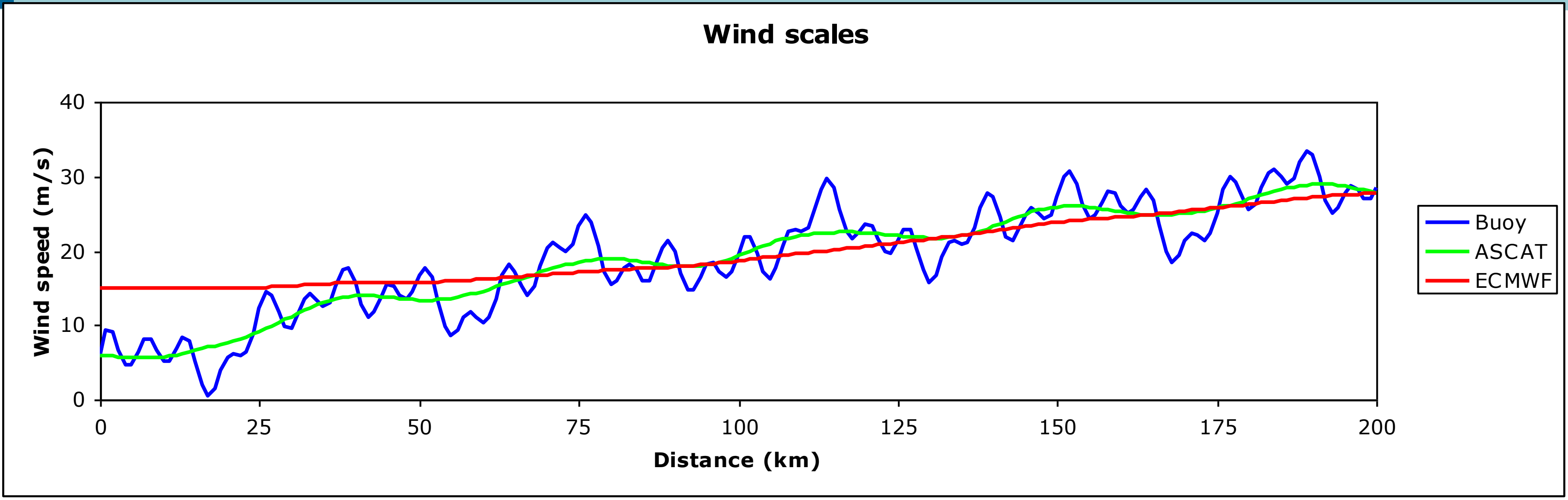
These analyses are performed on EO geophysical observation level (L2), but also for higher level products in order to evaluate the consistency of the errors at different levels of aggregation. In particular, EO sampling errors due to non-uniform time and space sampling need evaluation.

Results show that EO equivalent-neutral 10m (U10N) OVW are biased with respect to their atmospheric buoy or model equivalents due to air mass density. EO OVW do not measure air density, while NWP U10N depends on it. This factor is easily corrected for, since air mass density is well known. Moreover, EO OVWs show enhanced wind variability, particularly in the tropics near convection and in the storm track regions, where air-sea interaction is prominent. Also, larger EO OVW variability is found near SST gradients than in atmospheric models. On the other hand, monthly-mean EO OVWs show substantial sampling bias, but where these may be corrected by differently sampled NWP fields. Another results is that NWP models allow generally too much mixing in the stably stratified boundary layer, which causes typically 10-degree direction biases in warm air advection over cold waters, i.e., for all northward flow in the northern hemisphere. This leads undoubtedly to systematic error in ocean current forcing.

In conclusion, analyses of air-sea interaction based on EO, NWP and in-situ OVW data show large effects of differences in representation of physical and dynamical processes across the oceans, with both random and systematic effects on the air-sea interaction. These processes include mixing, turbulence and convection and appear over large ocean areas, thus affecting many ocean applications.

Moreover, several statistical effects are at play in comparing EO and NWP OVWs, which are well high-lighted in the past. A prominent statistical error after EO OVW aggregation is due to the non-uniform sampling by satellites as further elaborated in this contribution.

# Spatial representation




- We evaluate area-mean (WVC) winds in the empirical GMFs
- 25-km areal winds are less extreme than 10-minute sustained in situ winds (e.g., from buoys)
- So, extreme buoy winds should be higher than extreme scatterometer winds
- Extreme global NWP winds should be generally lower due to lacking resolution (over sea)