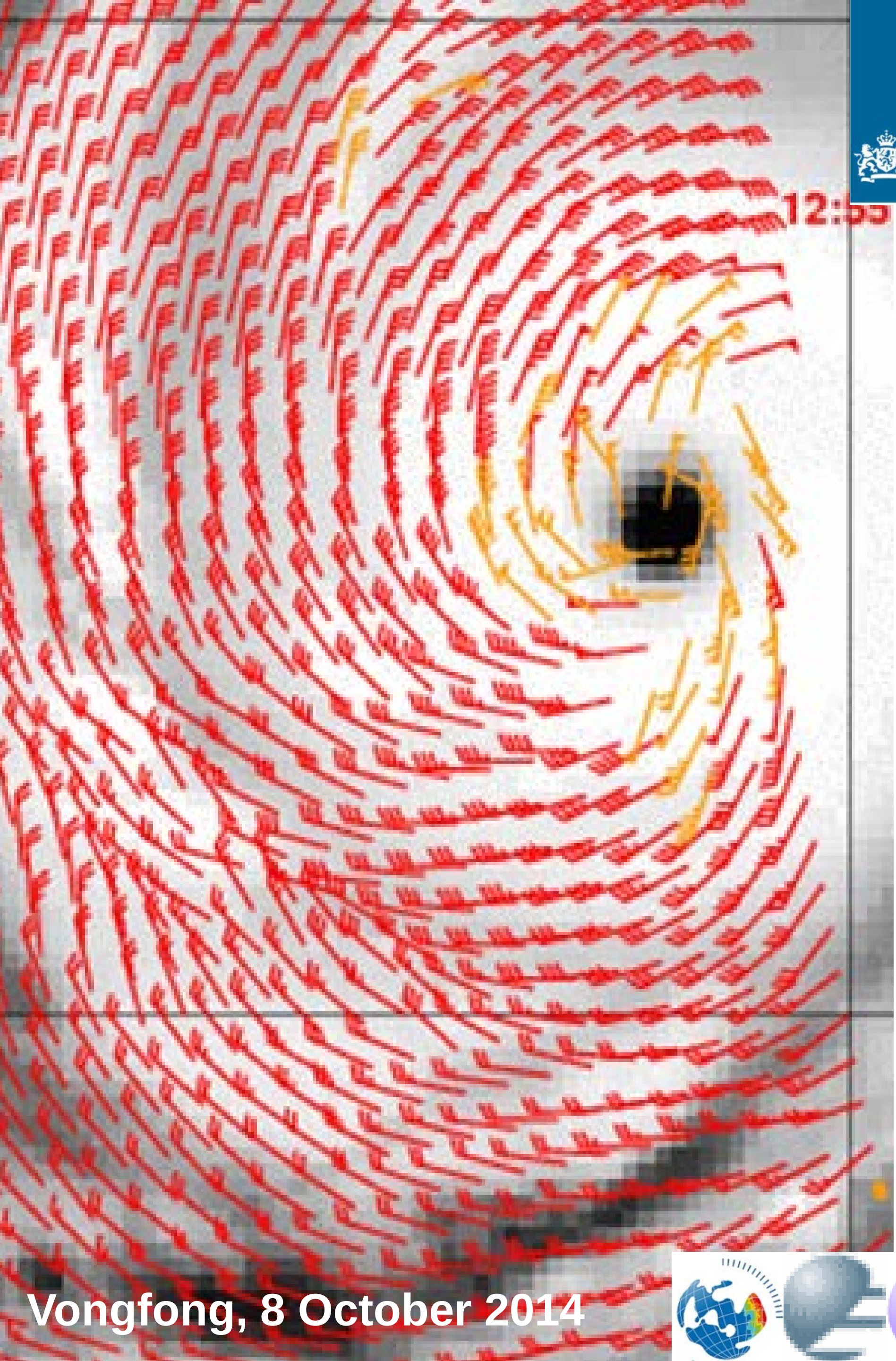

Vongfong, 8 October 2014

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Scatterometer Calibration

Ad.Stoffelen@knmi.nl

Outline

- ASCAT
- ERS

ASCAT SAG recommendations (2012, 2013)

Only those related to SCIROCCO:

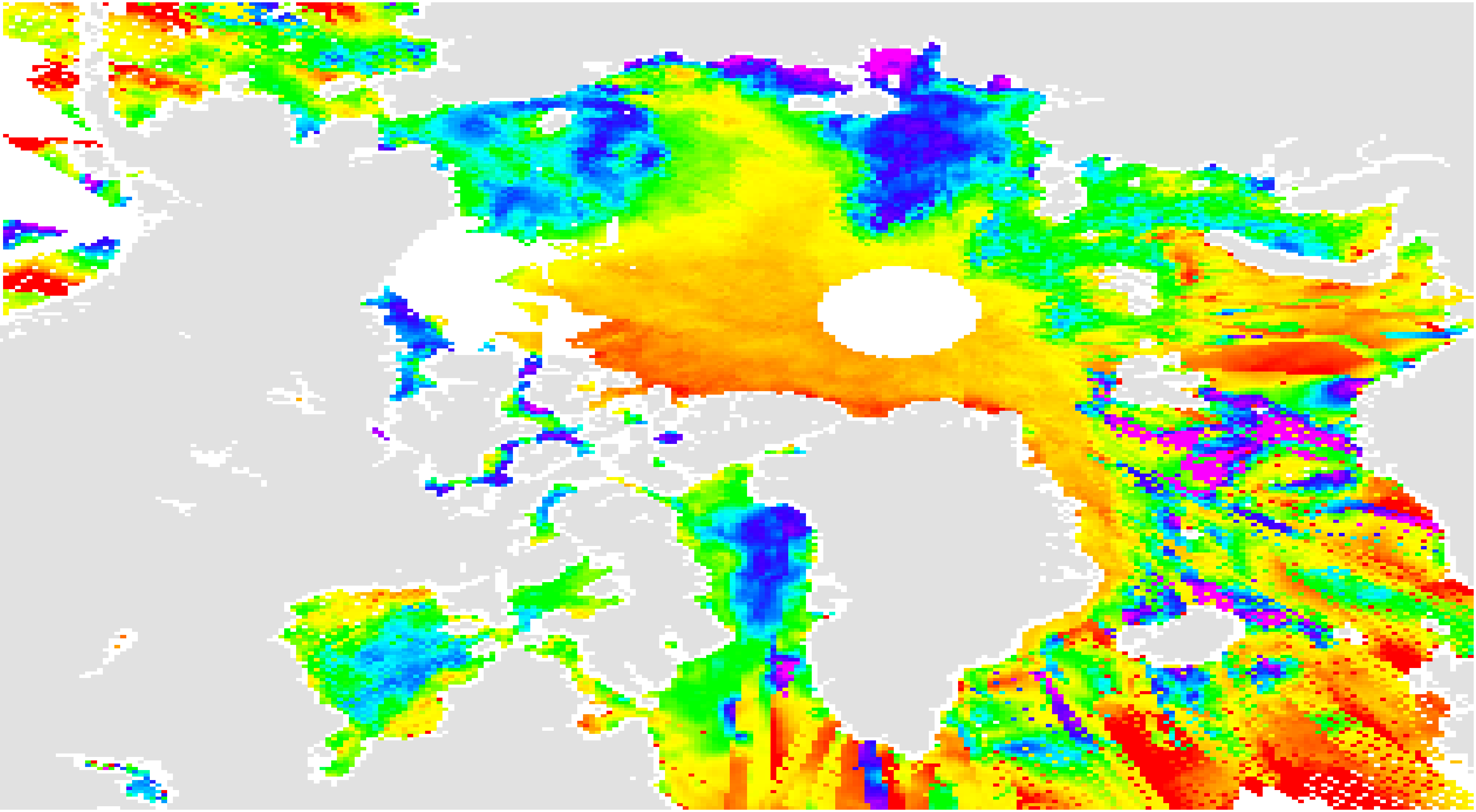
36.1	EUMETSAT /OSI SAF to investigate the effects of corner-reflector signals in the wind data record, particularly in coastal areas	EUM/H/OSI SAF coordination, workshop Q3 2014
36.2	ESA/EUMETSAT to investigate ways to support aspirational innovation applications and use of data to improve the diversity in scatterometer applications.	Role of the SAFs and scientific studies clarified
36.3	The SAG sees the need to keep the ERS SCAT data in the context of exploitation going beyond the need of simple data access and recommends ESA to implement the presented Phase F work plan, including the SIROCCO project and the science market approach.	--
37.1	EUMETSAT/ESA to consider organising C-band scatterometer science conferences on a regular basis.	ESA is expected to lead the organisation of the first conference
37.2	EUMETSAT/ESA to consider a better name for the SCA mission, considering the instrument heritage and the continuity (towards the users) of European C-band Scatterometer data services	Scientists suggested **CSCAT**

- **SCIROCCO action?**

Geophysical Calibration

- Time invariant targets: sea ice, rain forest
  - Determine map of time invariant points and estimate geophysical state (constant $\sigma^0(\theta)$)
  - Estimate beam biases and SD w.r.t. $\sigma^0(\theta)$
-

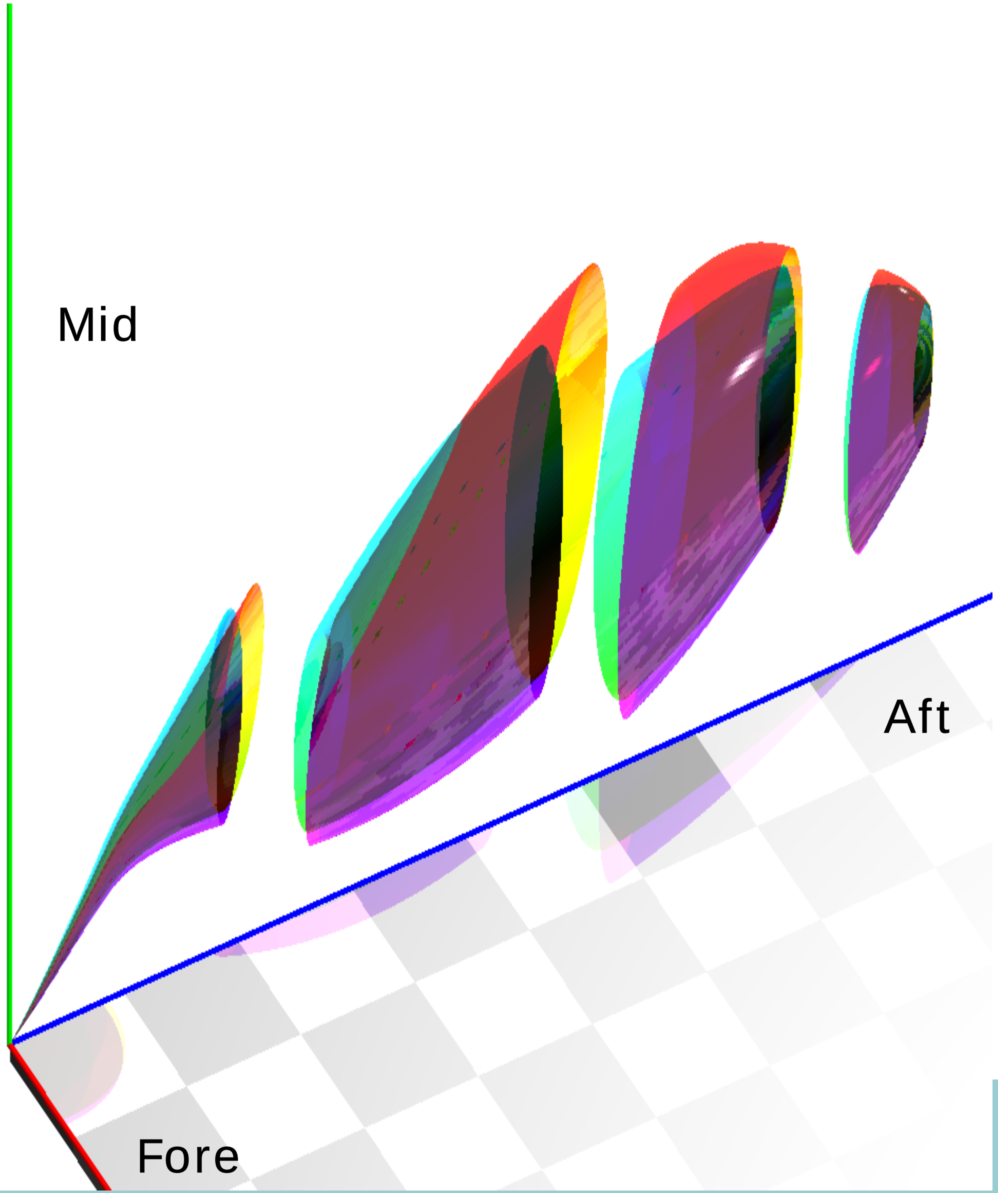
Ice age a



Geophysical Calibration

- Time invariant targets: sea ice, rain forest
  - Determine map of time invariant points and estimate geophysical state (constant $\sigma^0(\theta)$)
  - Estimate beam biases and SD w.r.t. $\sigma^0(\theta)$
- Known subdomain (wind cone, sea ice line)
  - GMFs well-known from ERS; sensor compatibility
  - Only bias and SD normal to surface/line

The cone



- Coherence of measurement data; speed and direction sensitivity confirmed
- Geophysical model function improved; used for SAR and ASCAT

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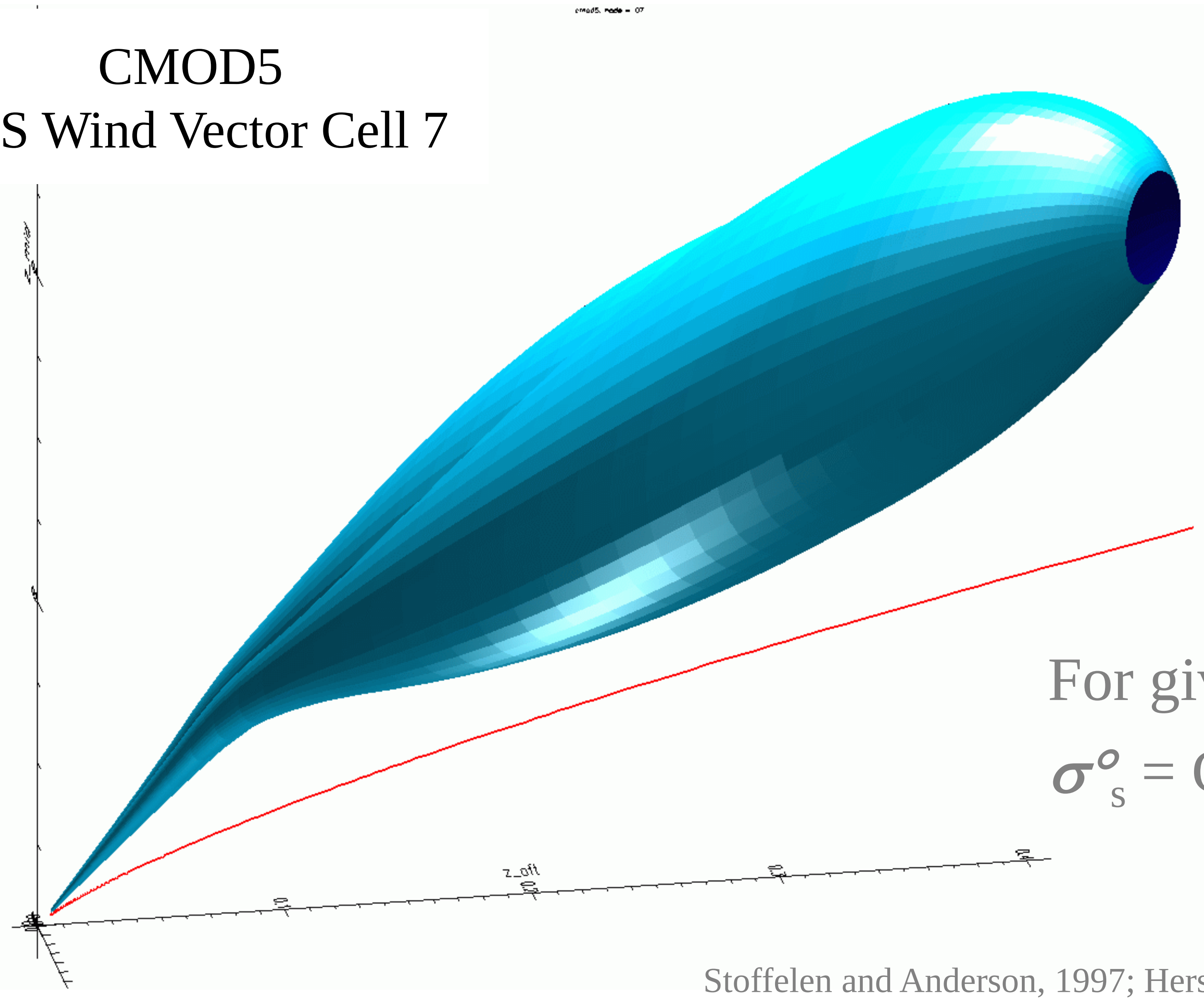
ERS / ASCAT Conical Manifold

CMOD5
ERS Wind Vector Cell 7

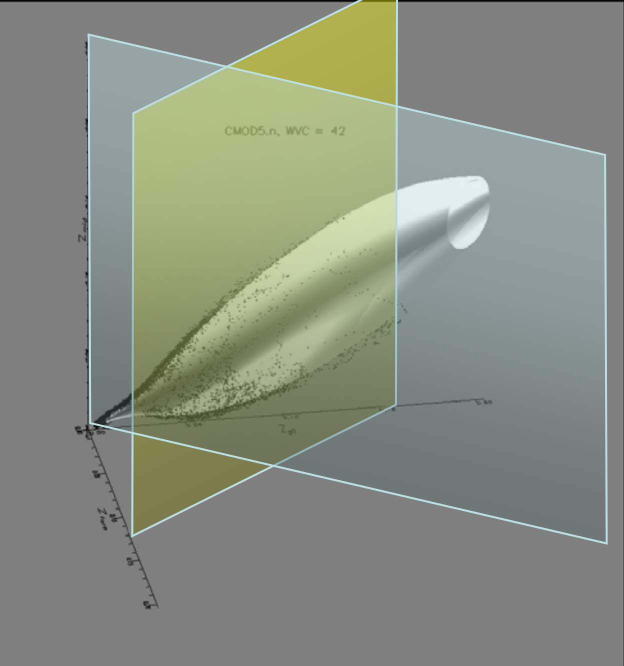


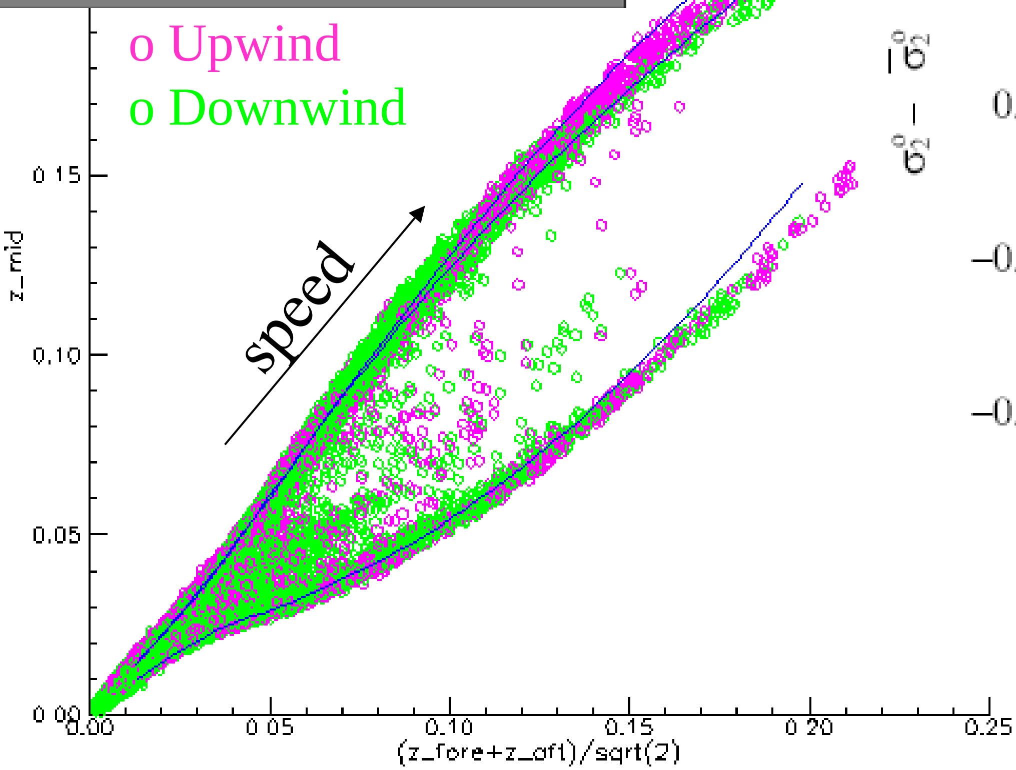
For given θ_S

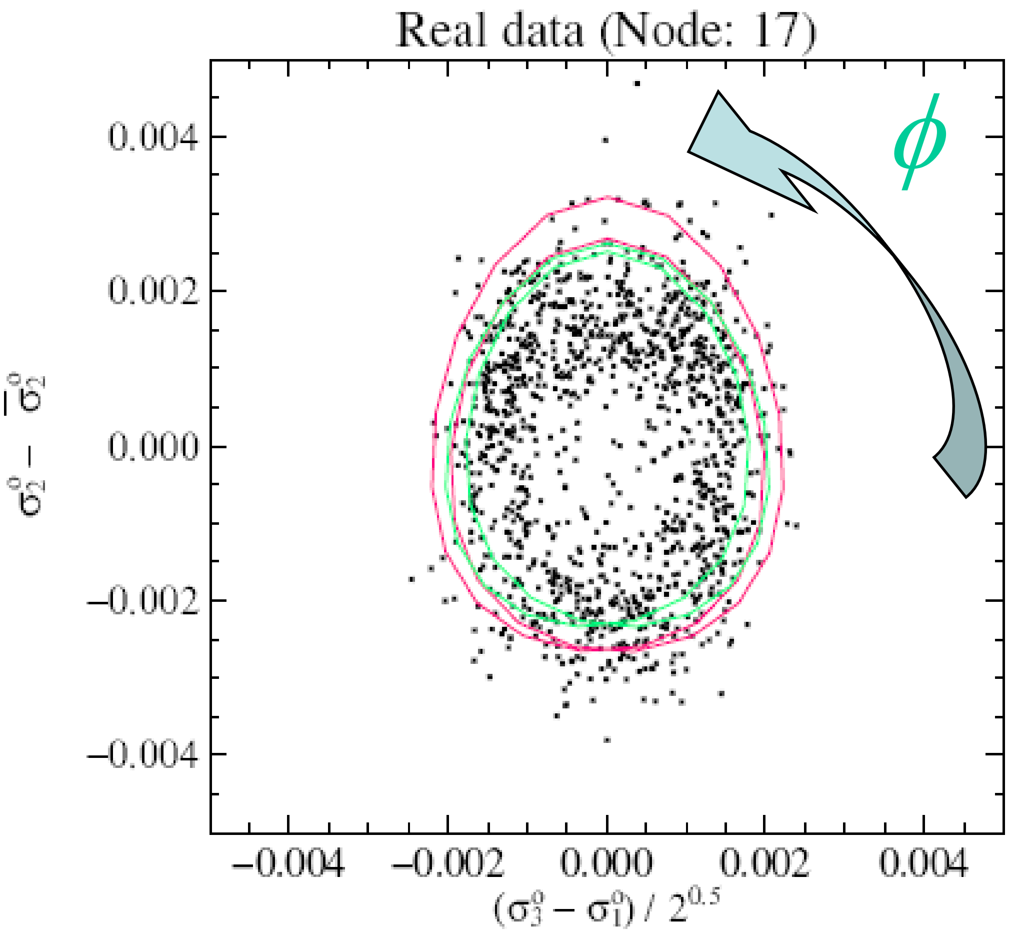
$\sigma^o_s = \mathrm{GMF}(\mathbf{v}_s)$

Stoffelen and Anderson, 1997; Hersbach et al, 2006

Cone analyses

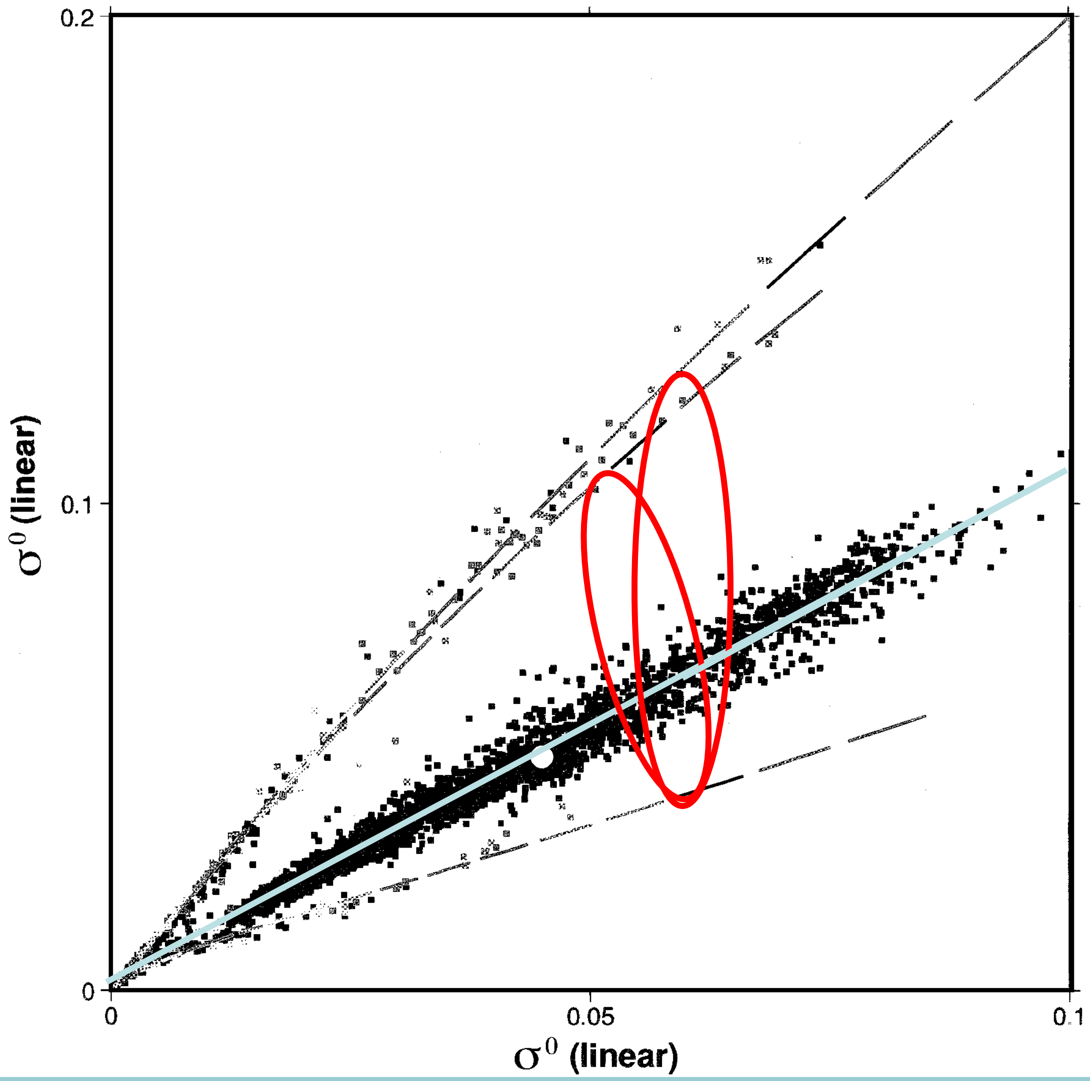






Stoffelen and Anderson, 1992+

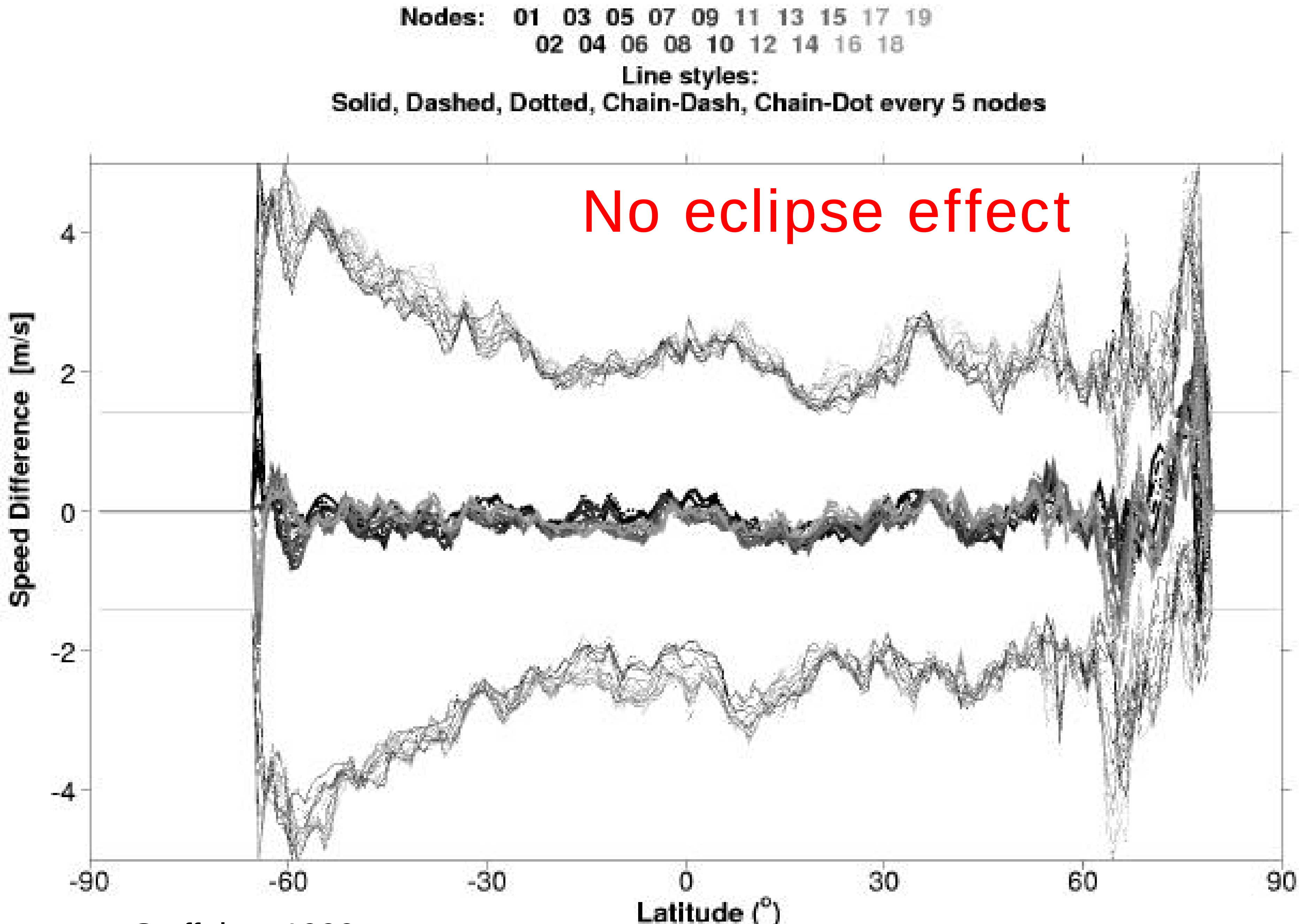
ERS heritage



- CMOD5 wind cone
- Sea ice model
- Ocean σ^0 calibration
- Wind calibration
- Wind processing

Geophysical Calibration

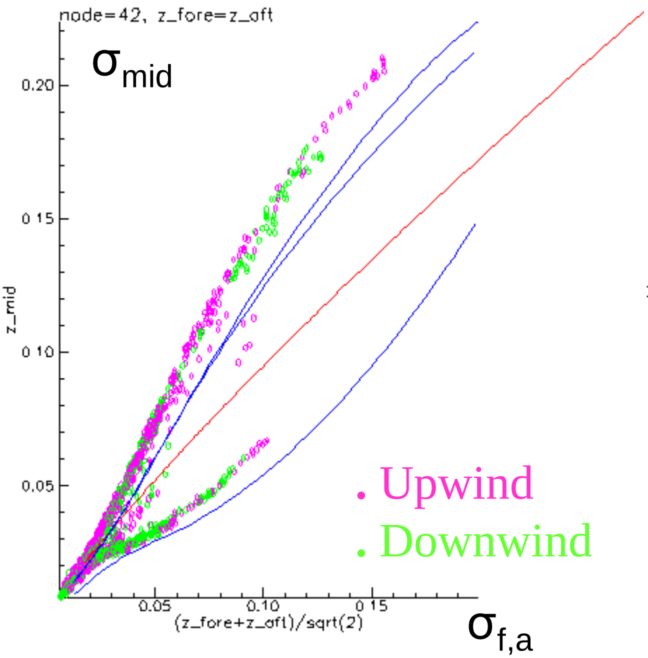
- Time invariant targets: sea ice, rain forest
  - Determine map of time invariant points and estimate geophysical state (constant $\sigma^0(\theta)$)
  - Estimate beam biases and SD w.r.t. $\sigma^0(\theta)$
- Known subdomain (wind cone, sea ice line)
  - GMFs well-known from ERS
  - Only bias and SD normal to surface/line
- Predictable geophysical state
  - Ocean calibration; NWP winds; fast
  - NWP wind calibration by triple collocation; slow



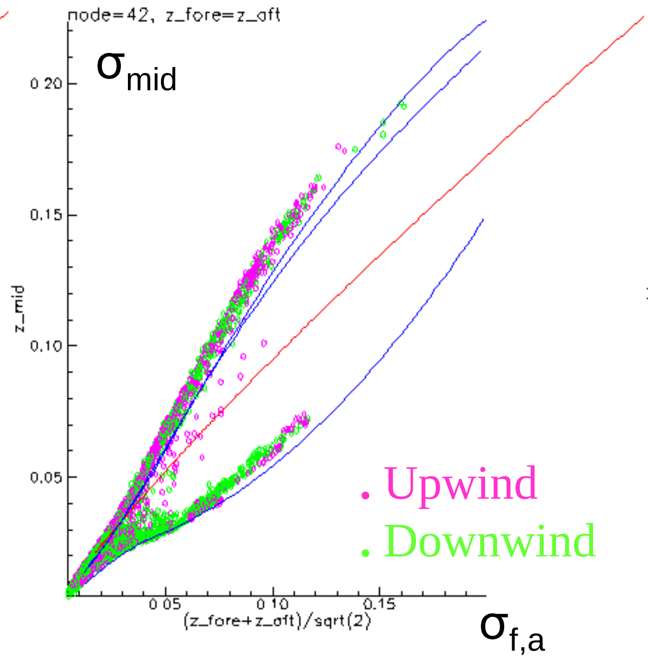
Stoffelen, 1999

Level 1b evolution versus KNMI corrections

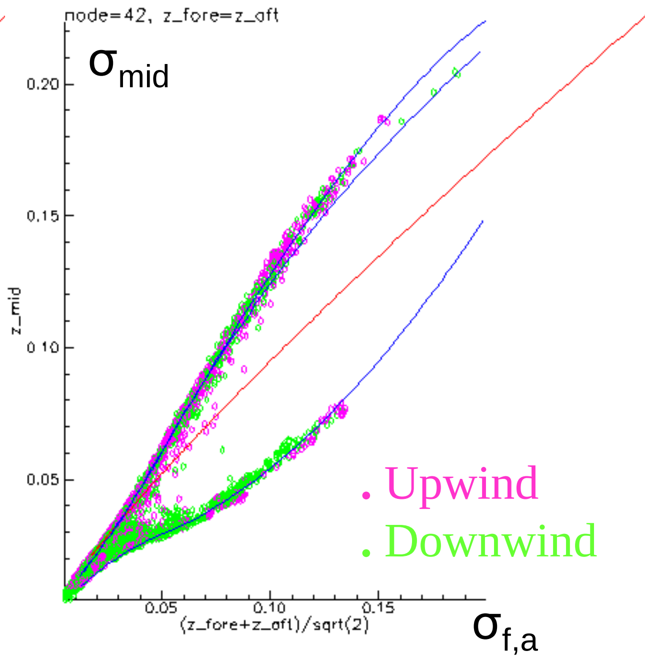
Vertical cut for WVC #42



Level 1b 1st release



Level 1b latest release

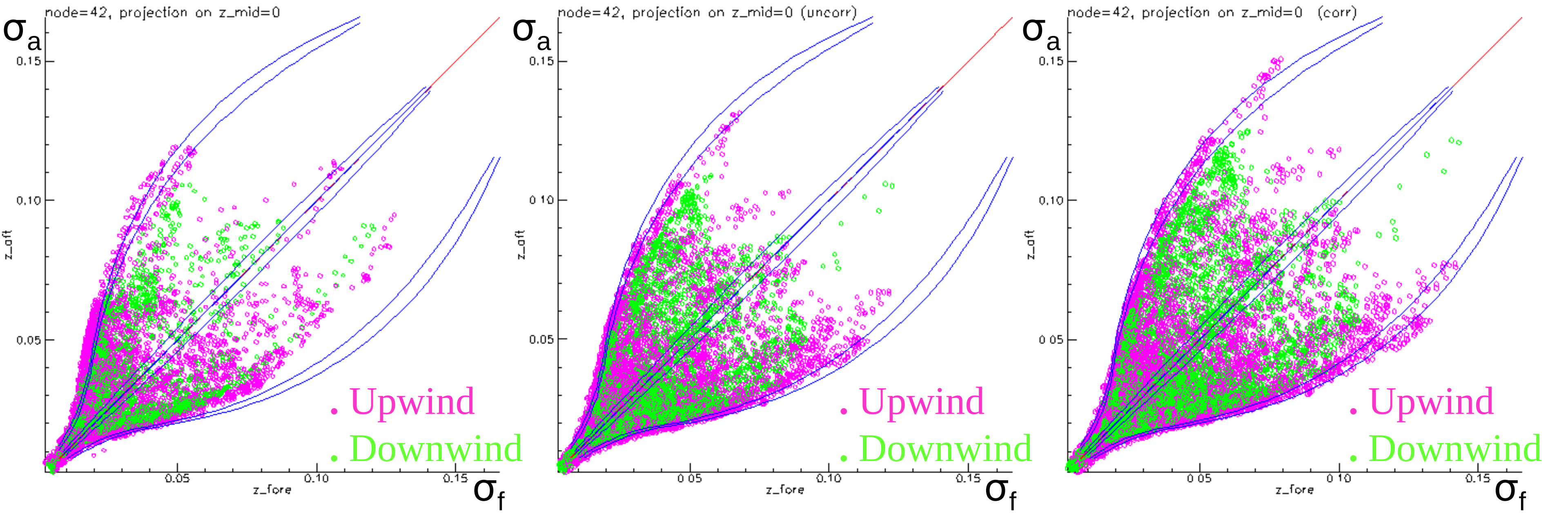


KNMI total correction

- **CMOD5.5 is well fitted despite ERS extrapolation**

Level 1b evolution versus KNMI corrections

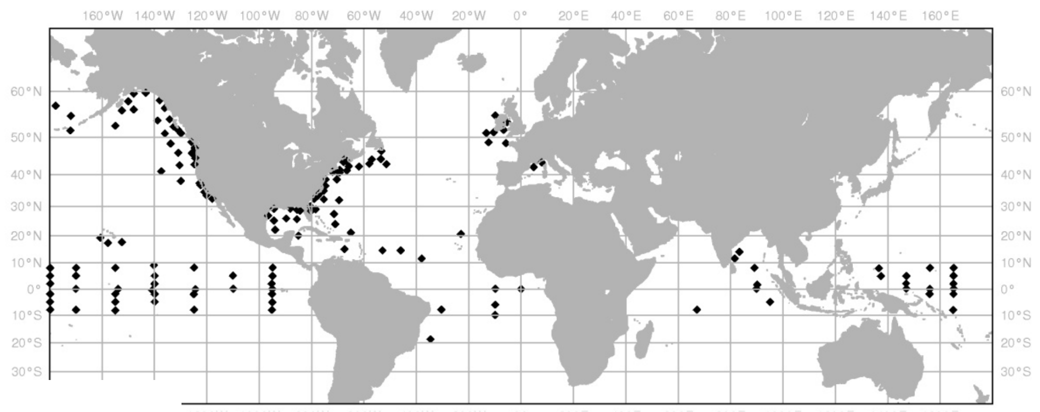
Horizontal projection for WVC #42

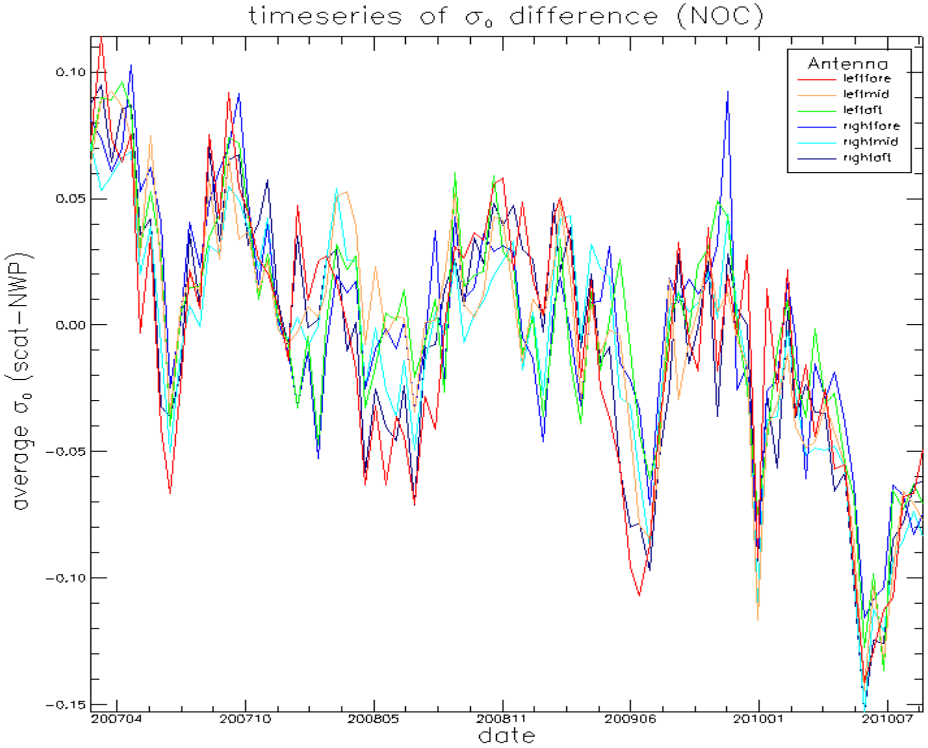


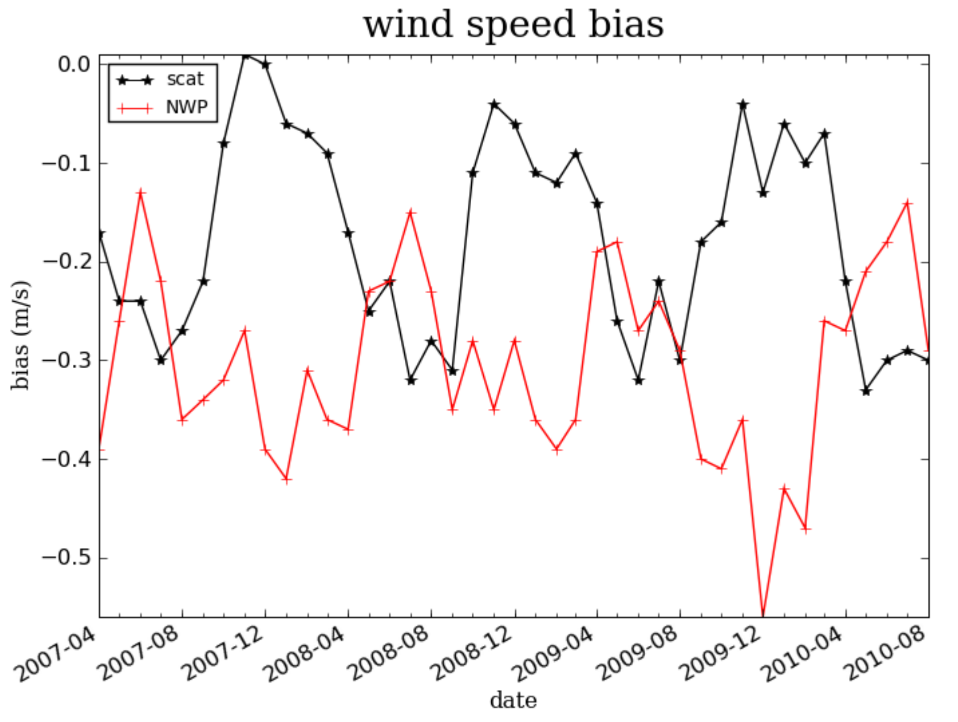
Level 1b 1st release   ***Level 1b latest release***   ***KNMI total correction***

ASCAT stability - Ocean calibration

- Trends of 0.1 m/s just visible (10 year req.)



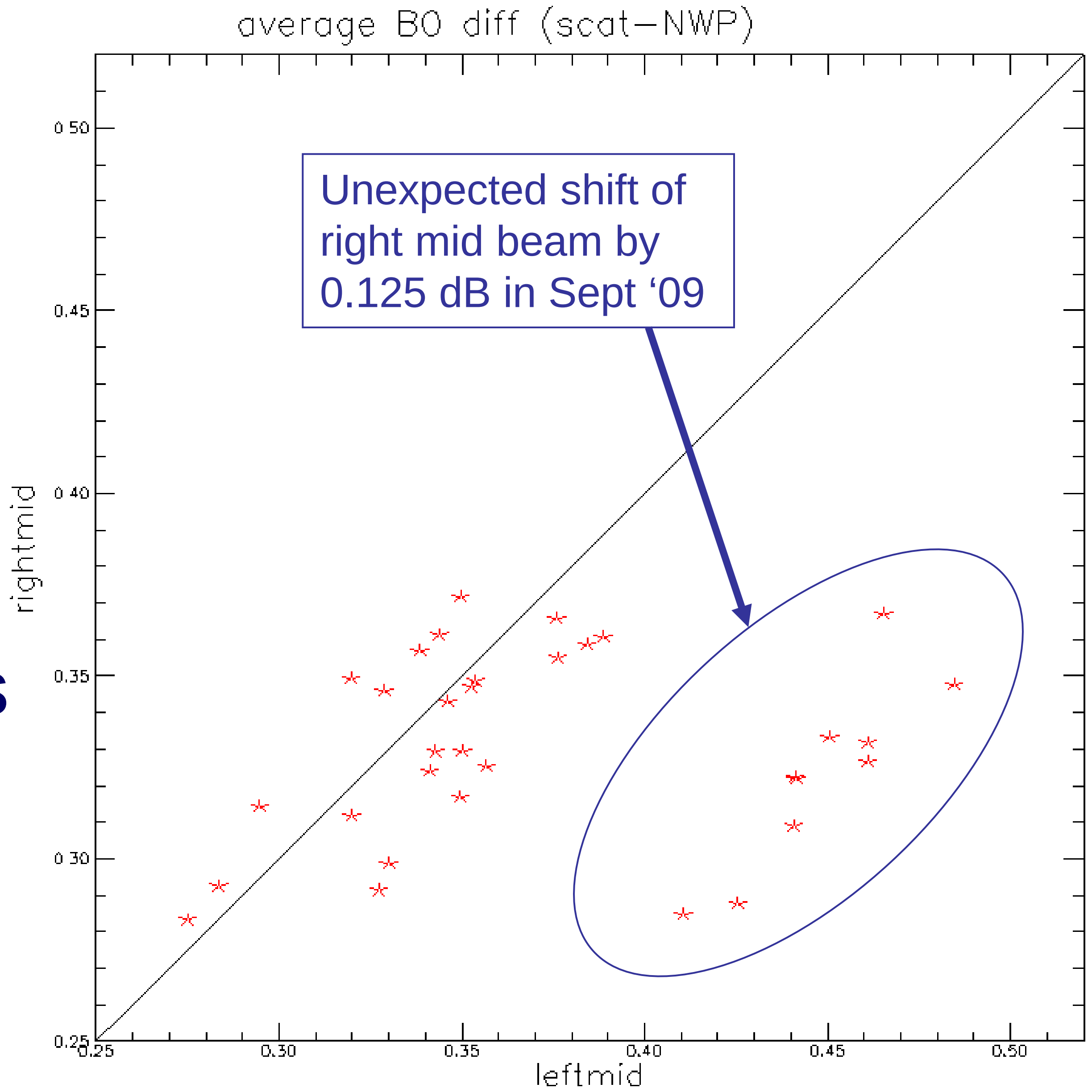




NOC stable

- Weather shift is identical for opposing ASCAT beams
- Small biases may be detected

See also Freilich et al.



Detailed cone analysis

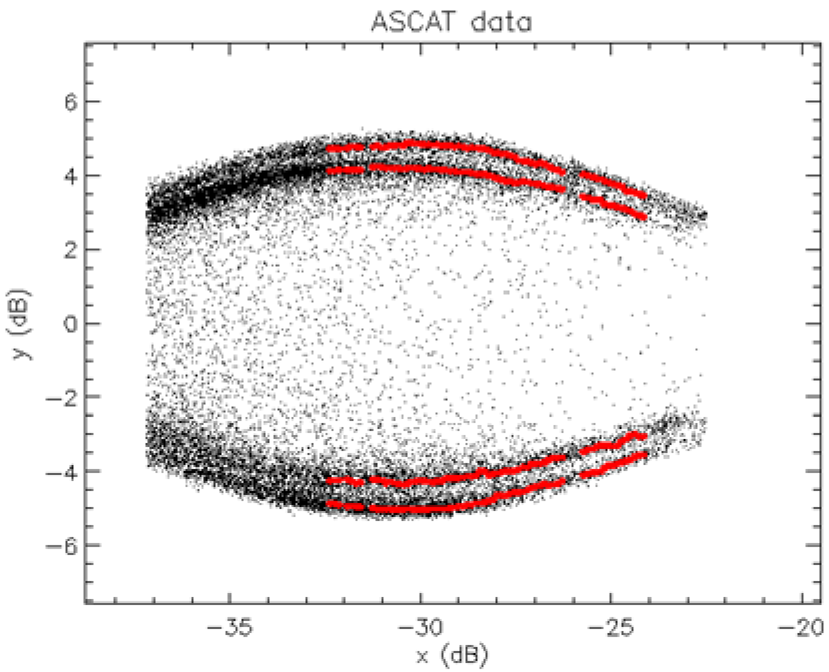


Figure 5. ASCAT data (black) and position of peak density (red) in multiple slices along the x axis.

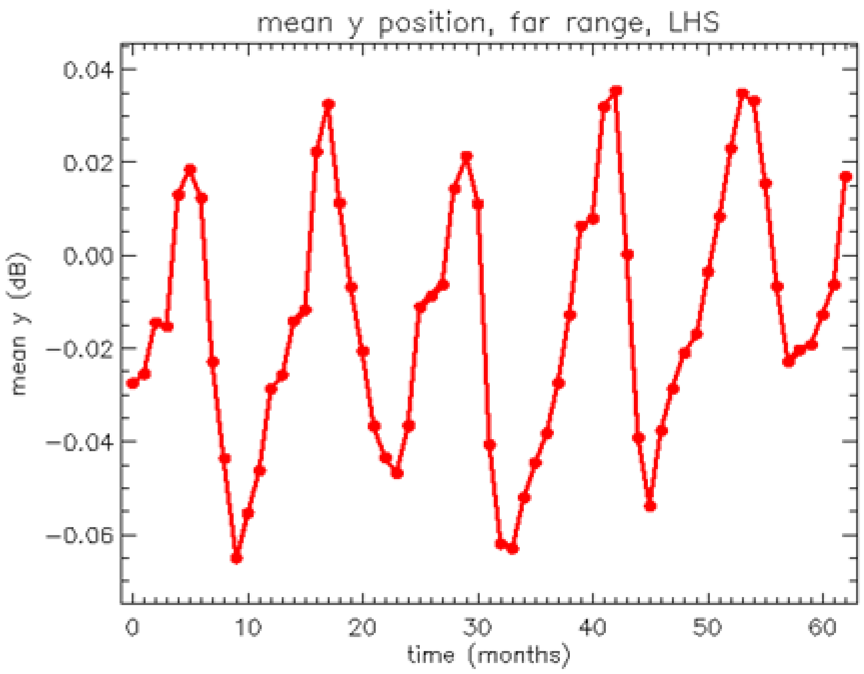
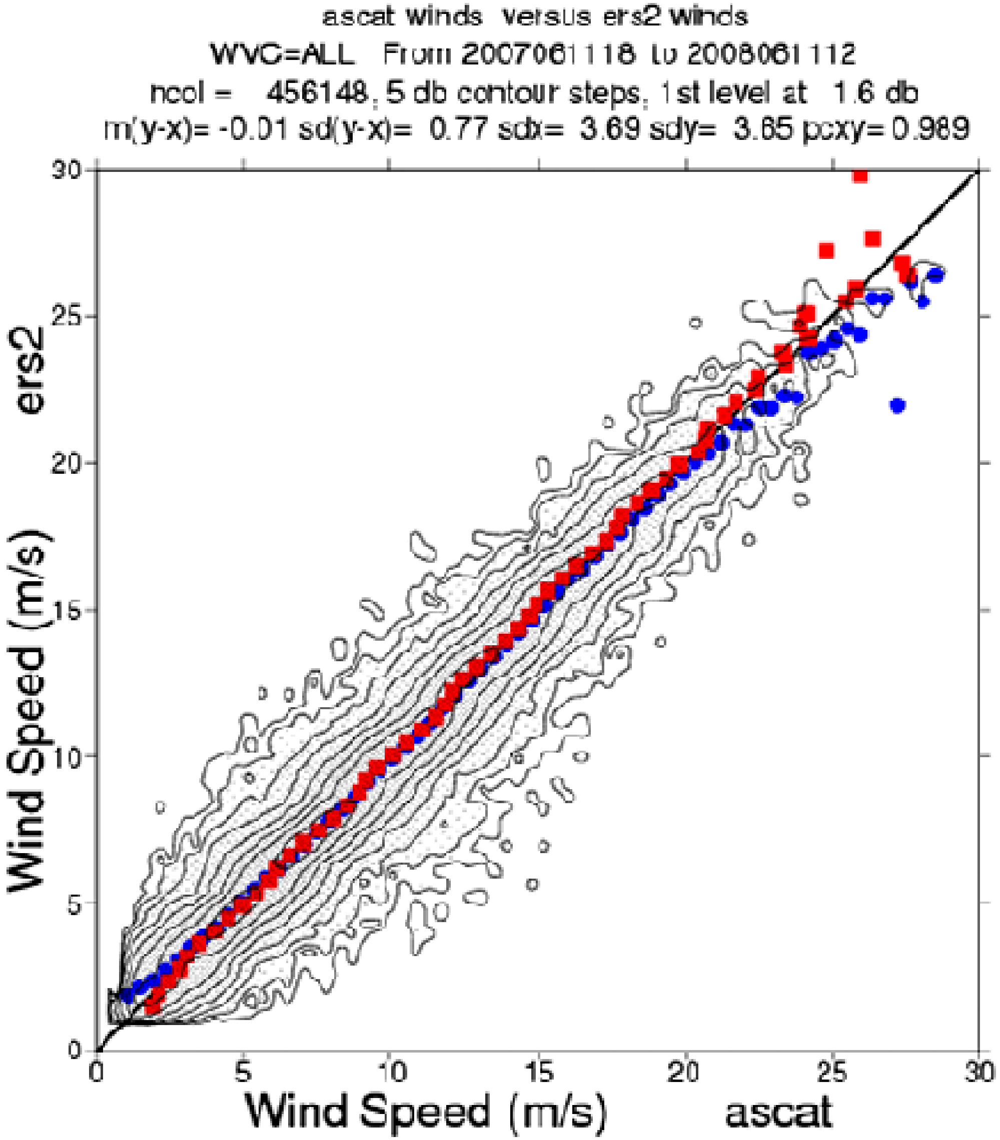


Figure 6. Time series of the mean y position of the ocean cone.

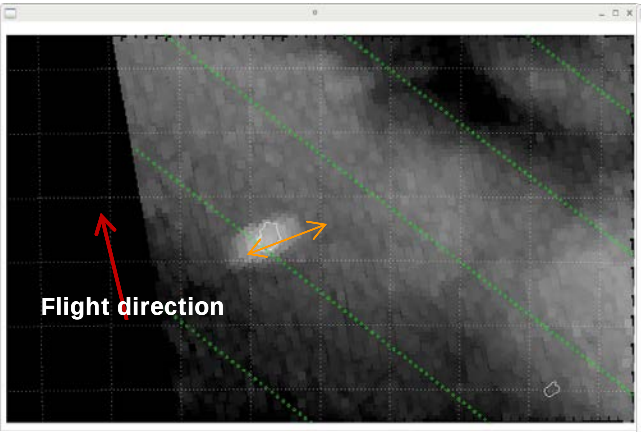
ASCAT follows ERS success

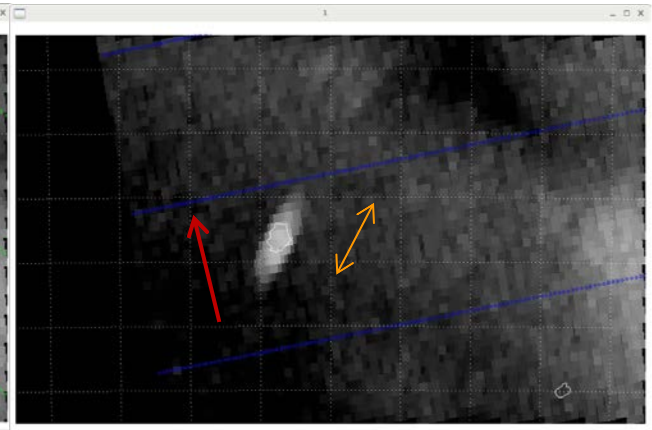
1. AMI scat heritage
2. ASCAT and ERS winds are really very similar
3. 99% correlation after wind calibration
4. Small equipartitioned random speed error of about 0.5 m/s is partially due to time/space collocation of 30 min/20 km resp.

Hersbach, 2007



NRCS re-sampling issues



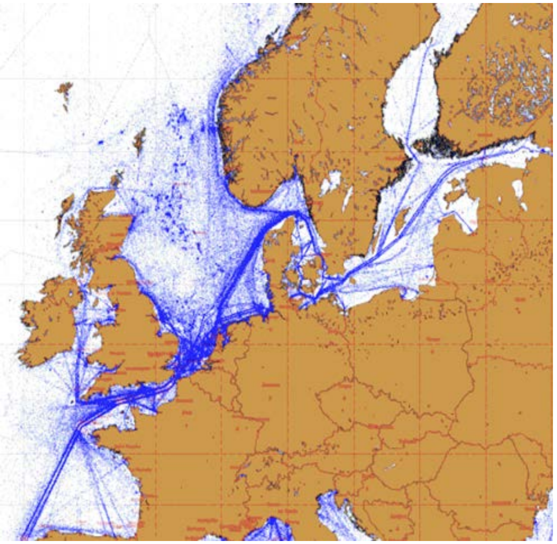


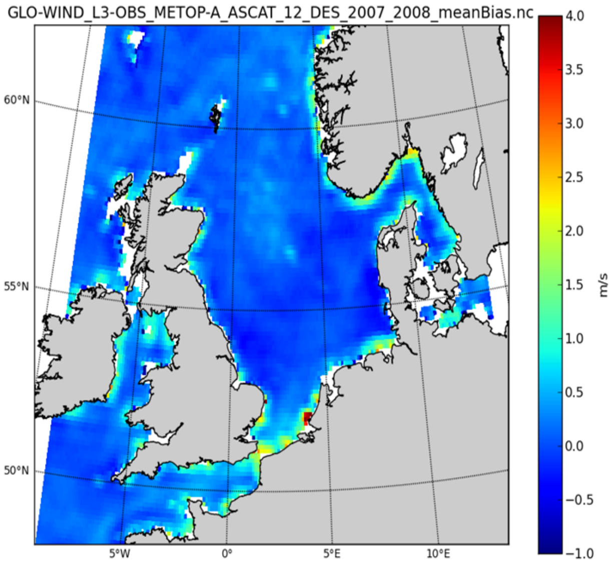
What is the scale of the spatial variability represented in the ASCAT measurements?

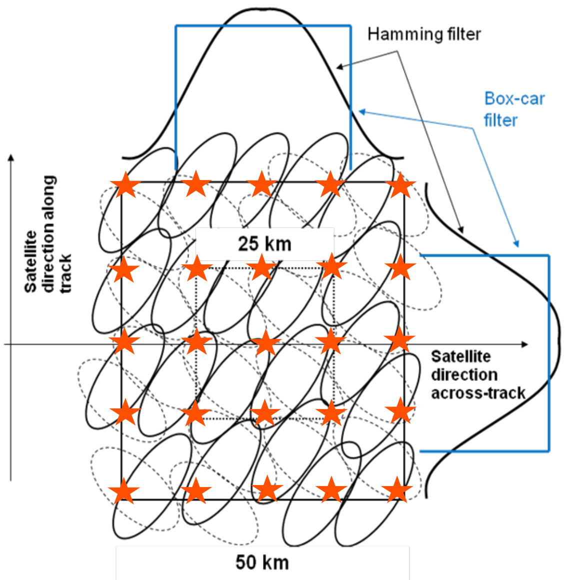
- exploring and understanding the measurement system spatial resolution limits

Does the backscatter processor adequately represent this spatial variability for the different natural targets?

- exploring different re-sampling strategies, spatial averaging filters and grids

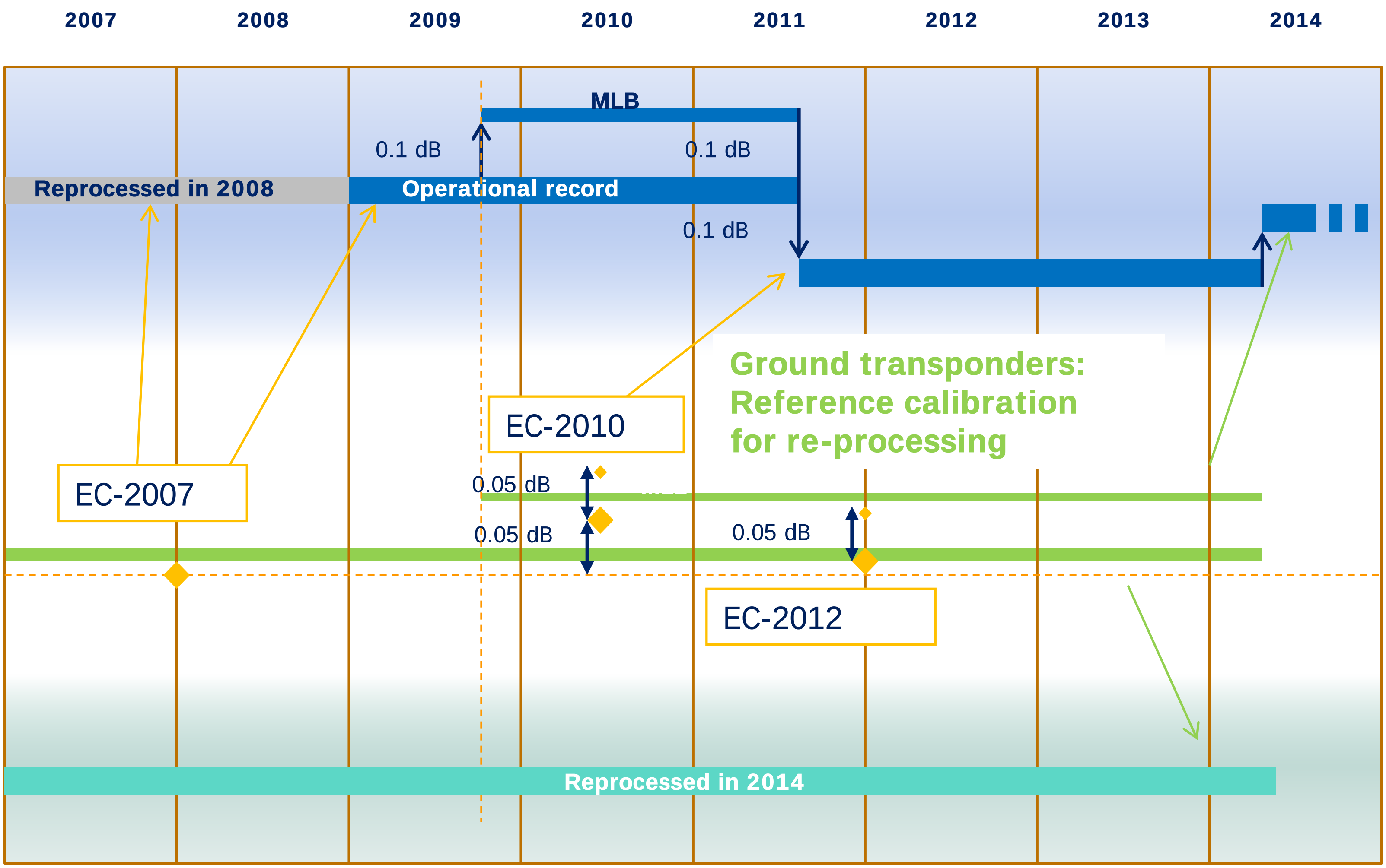




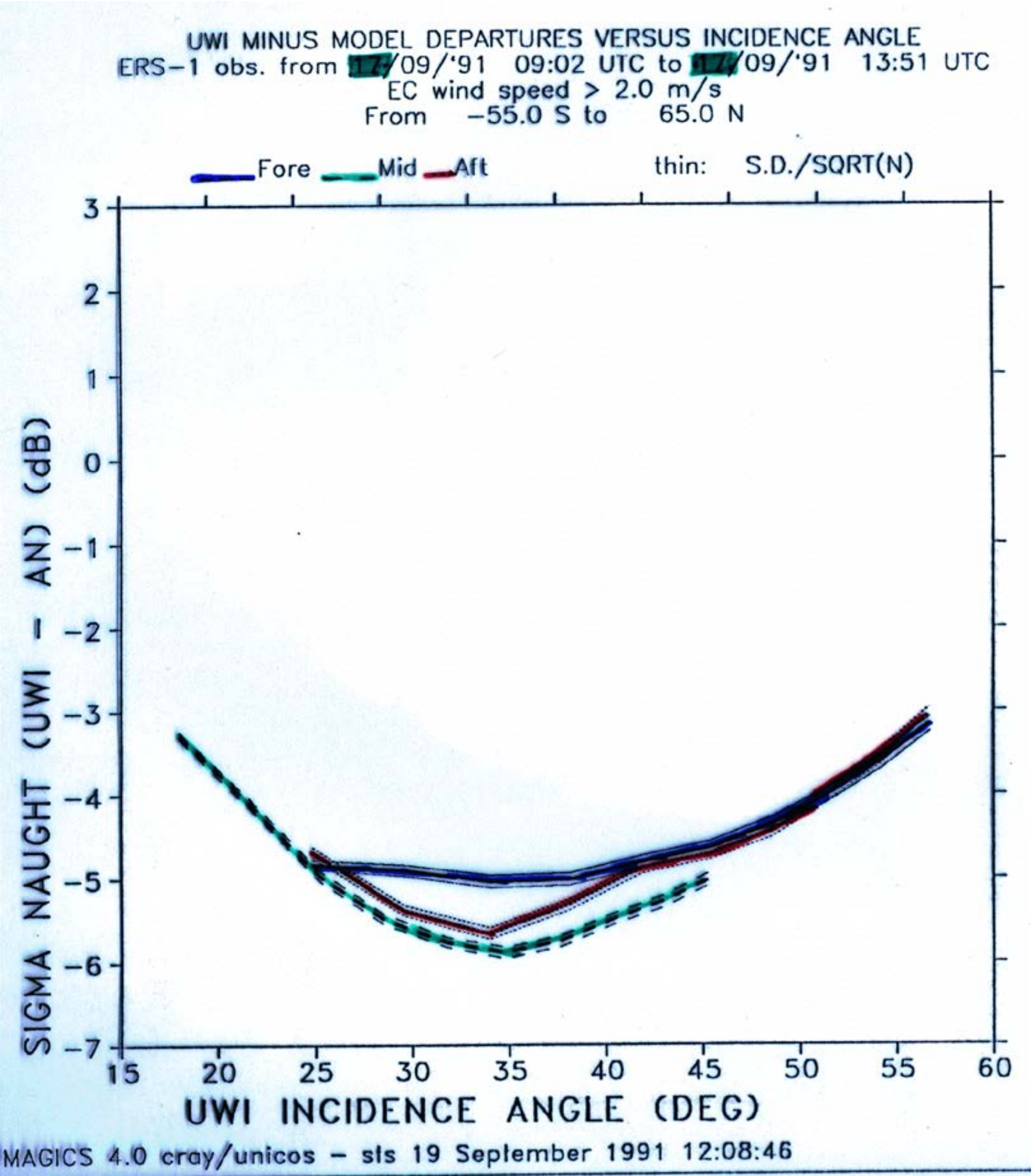


esa EUMETSAT

Long-term ASCAT-A calibration model



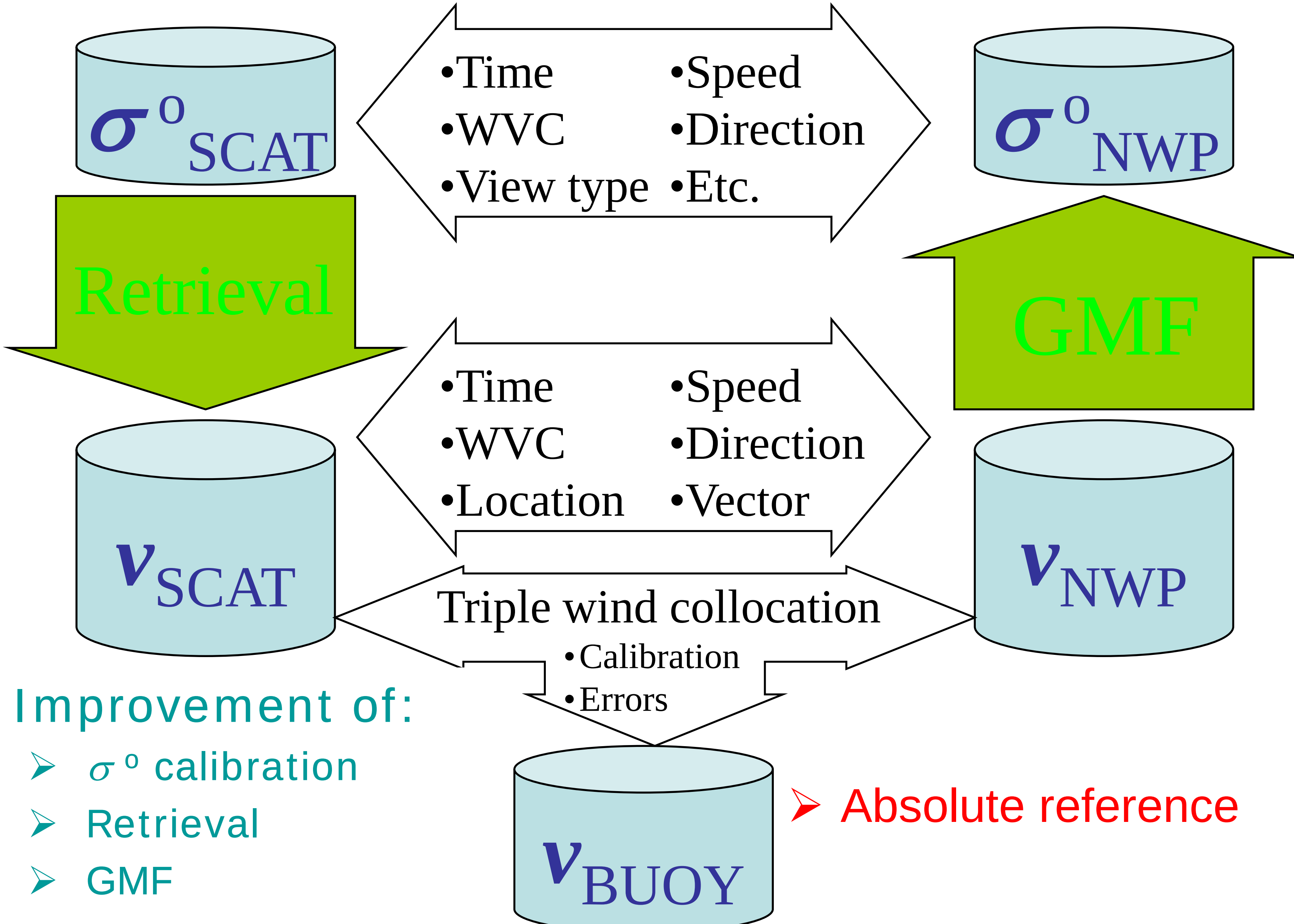
At the ERS-1 Launch …….



1. ESA scientist position at ECMWF for ERS-1
2. I found great mismatch between ESA data and ECMWF wind and backscatter !

- Who is wrong ?
- Solved by ocean calibration!

Ocean Calibration Overview



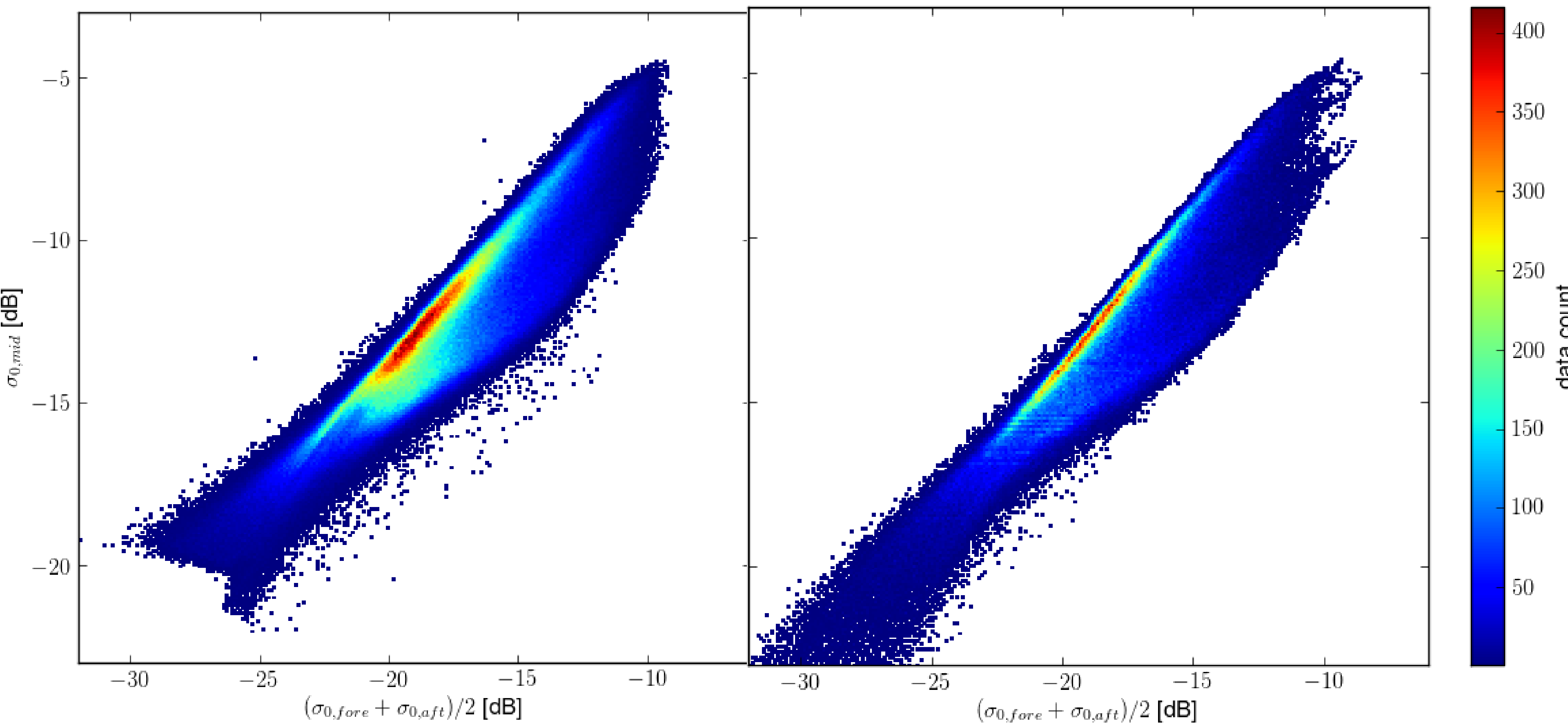
- Improvement of:
  - σ^o calibration
  - Retrieval
  - GMF

- Absolute reference

NWP Ocean Calibration

- Based space backscatter; double harmonic only
- on measured minus ECMWF simulated backscatter with CMOD5.n
- z Filter to uniform ECMWF wind direction PDF in all speed bins
- Prone to ECMWF wind direction errors: ~0.1 dB
  - Seasonally (weather) dependent
  - Avoid trade latitudes (verified by simulation)

ERS vs ASCAT in Jan.



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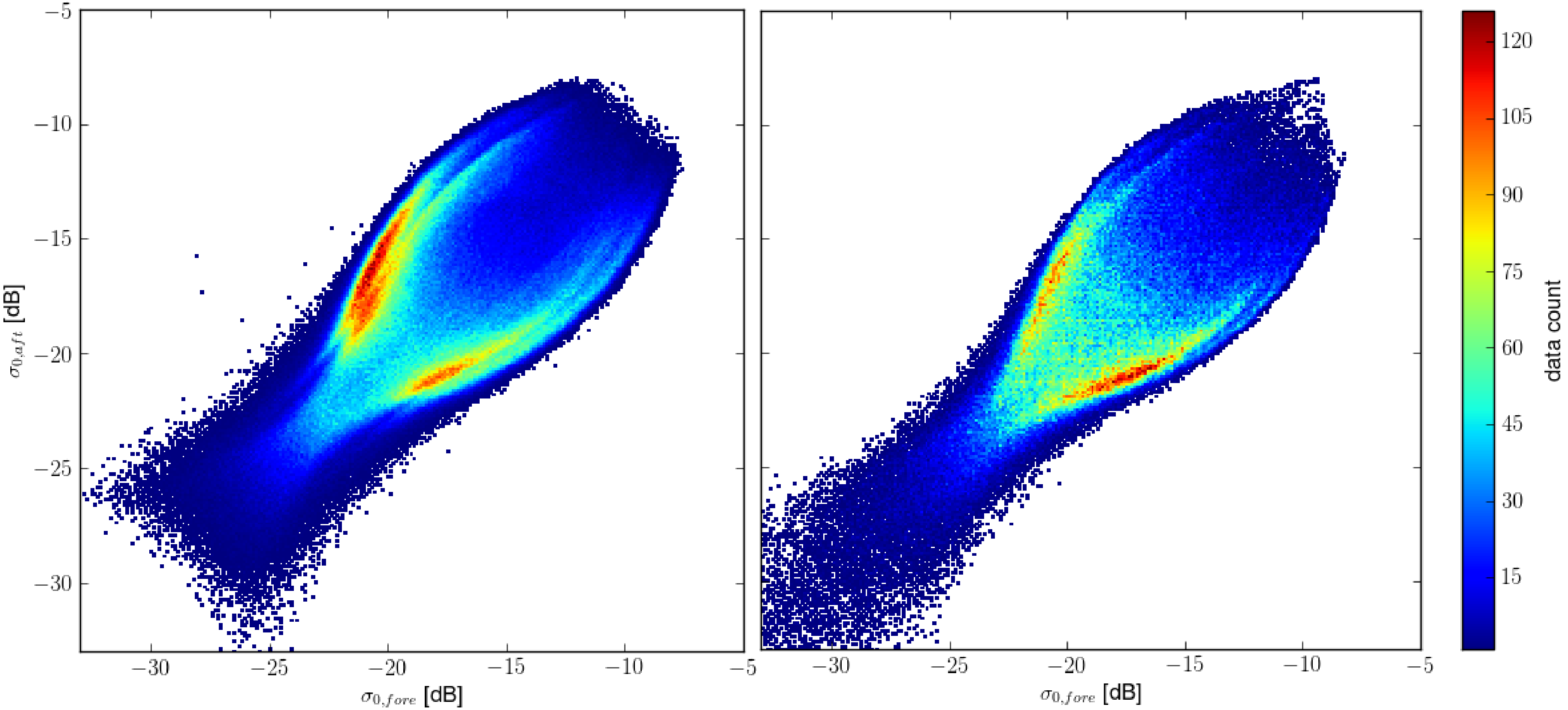
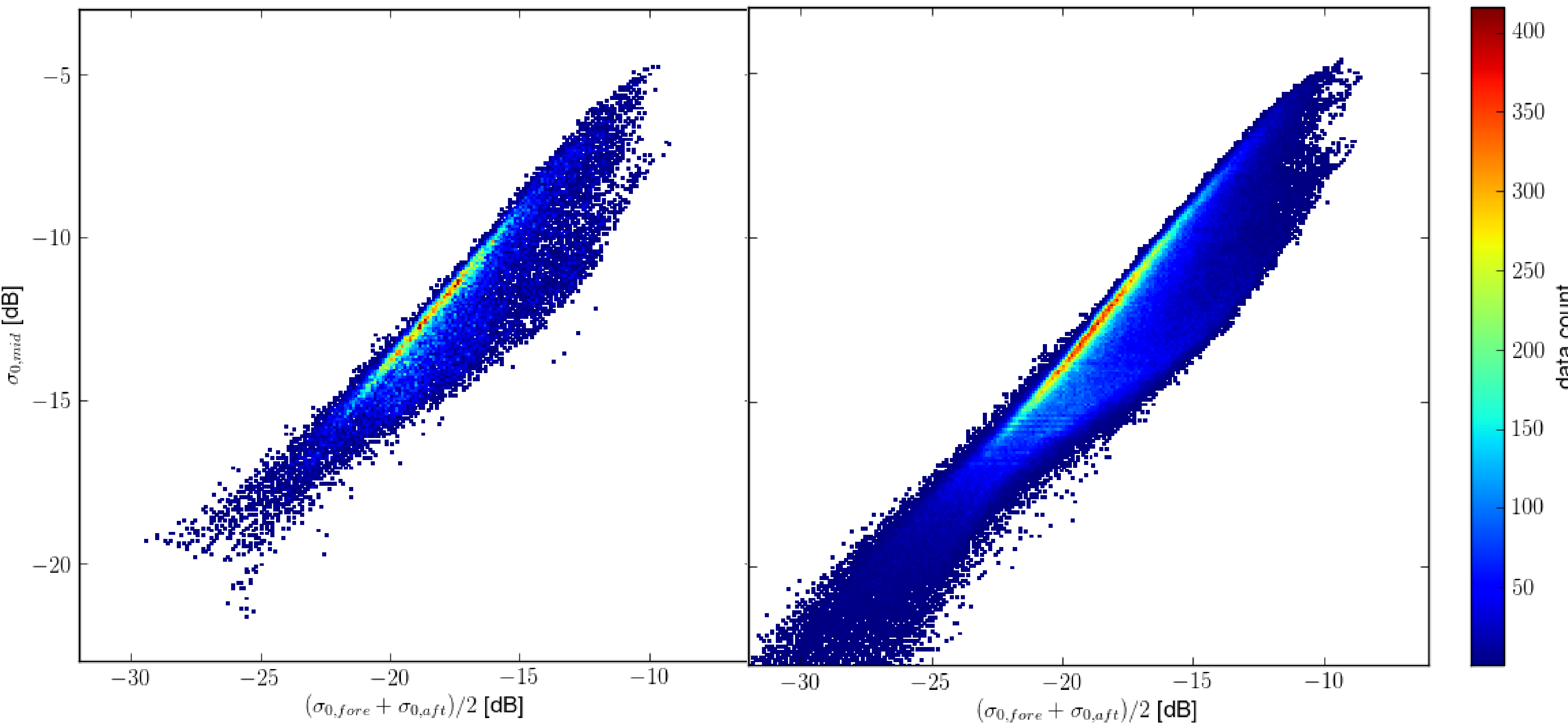
ERS vs ASCAT in Jan.

- Need to read more data



ERS vs ASCAT in Jan.



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ERS vs ASCAT in Jan.

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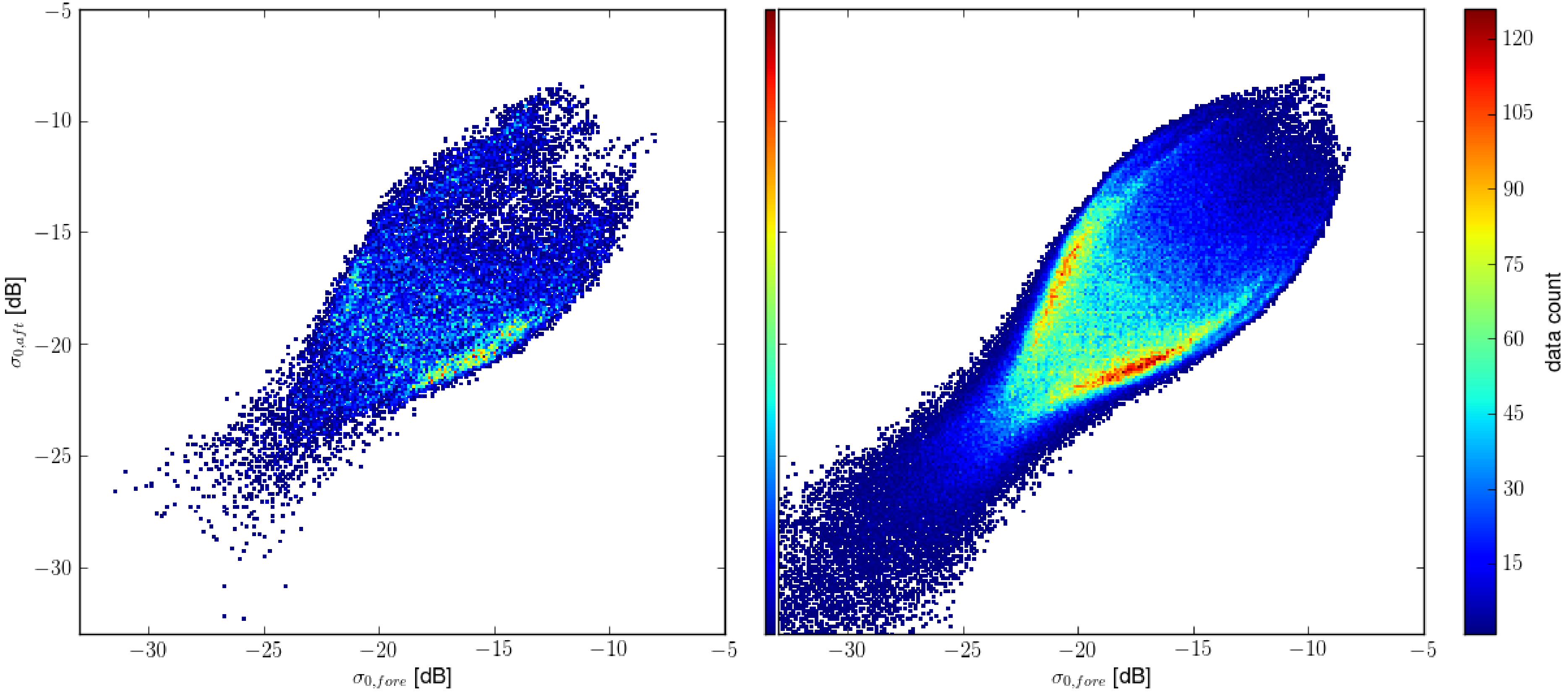

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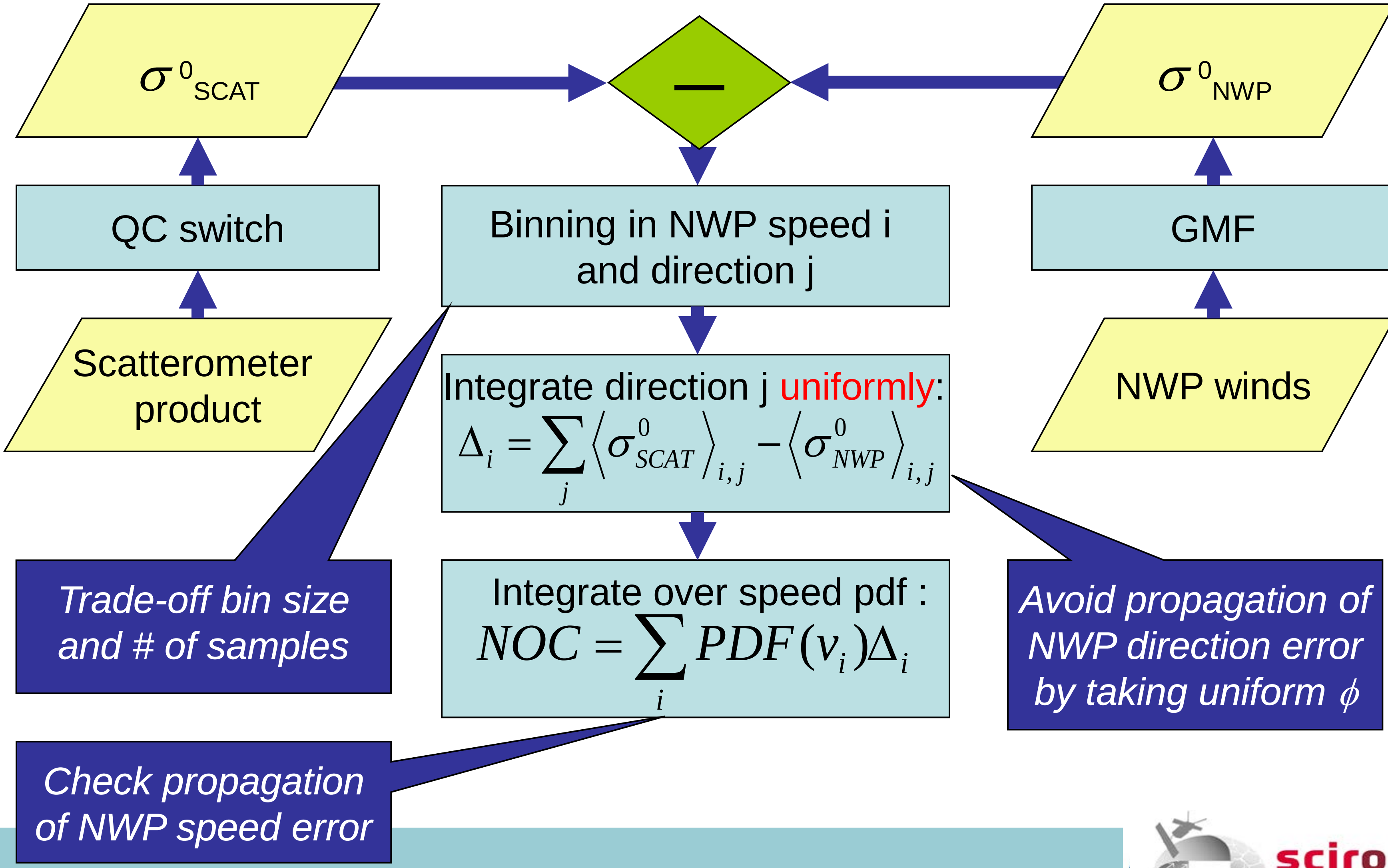
NWP Ocean Calibration



NWP Ocean Calibration

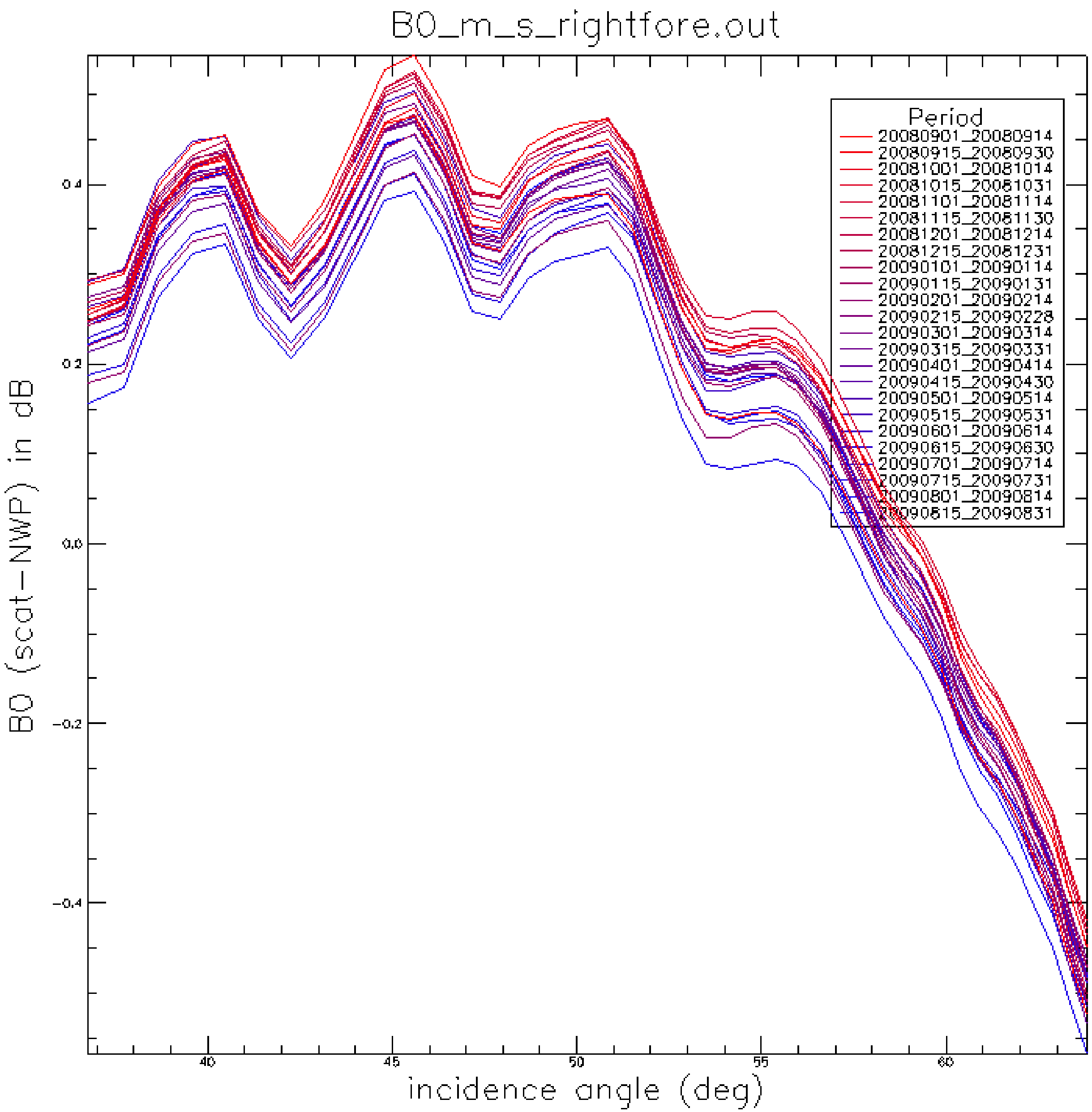
- Based on measured minus ECMWF simulated backscatter with CMOD5.n
- z space backscatter; double harmonic only
- Filter to uniform ECMWF wind direction PDF in all speed bins
- Prone to ECMWF wind direction errors: ~0.1 dB
  - Seasonally (weather) dependent
  - Avoid trade latitudes (verified by simulation)

Conclusions / prospects 2009 SAG

- Despite its limitations NOC has lowest distance to cone and best winds (lower than ops AWDP VOC correction tables)
- NOC shows
  - Steep inner mid beam bias (unphysical) ? Beam fall-off ?
  - Mid beams biased low w.r.t. all fore/aft: 0.15 dB ? Due to higher θ range for same mean θ ?
  - Although right fore and left aft see very similar wind PDFs, they differ by about 0.1 dB ?
- NOC θ-dependent fits generally worse in wind, MLE and MS verification than WVC-dependent tables; 3-t calibration does not (yet) improve wind retrieval
- Wind direction and detailed WVC dependence in progress
- Analyse NOC over a month (reduce noise)
- Try objective calibration with MLE by modal analysis and simulation; also useful for GMF improvement

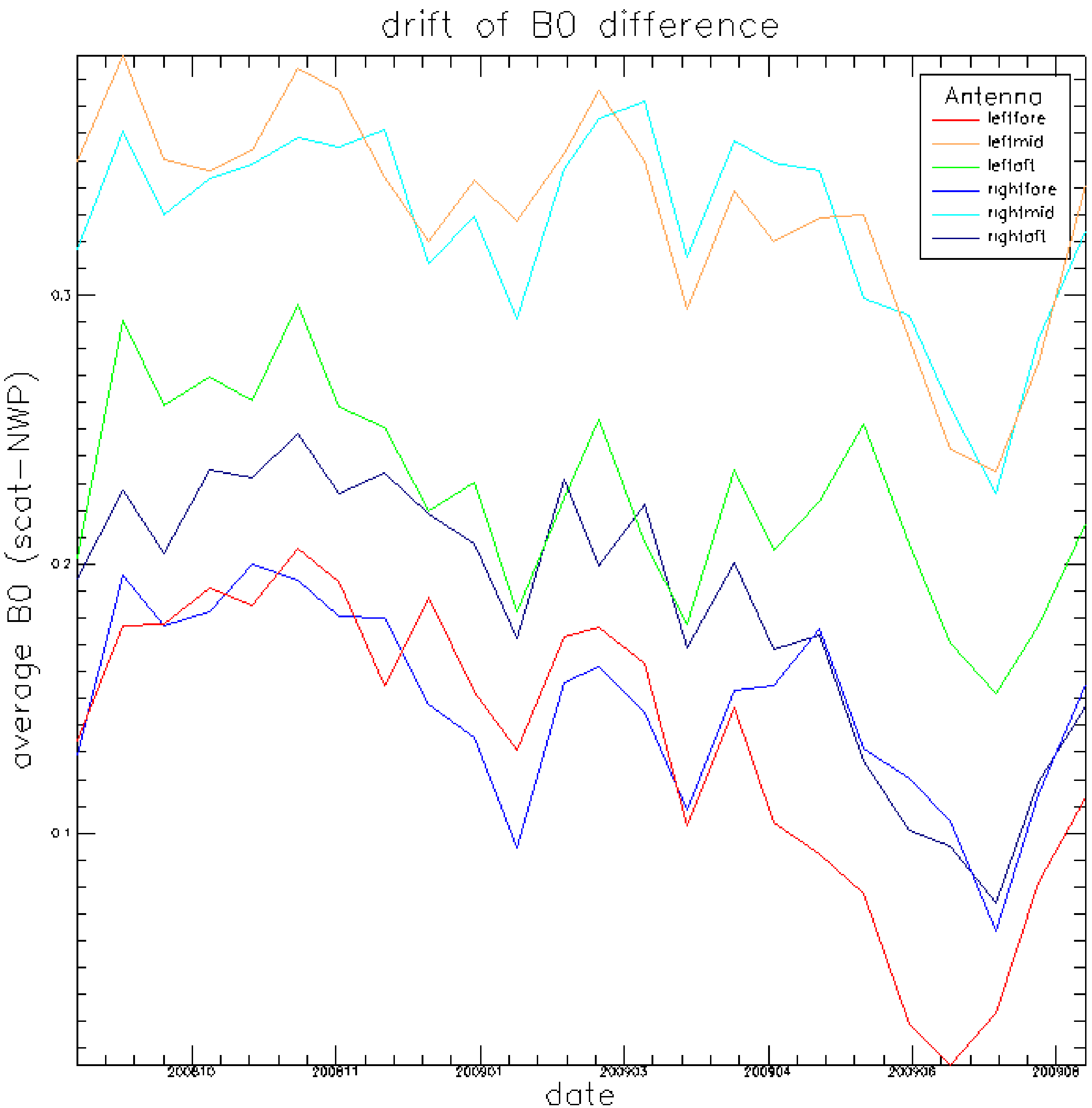
NOC pattern

- Same relative antenna pattern every two weeks
- Vertical weather shift



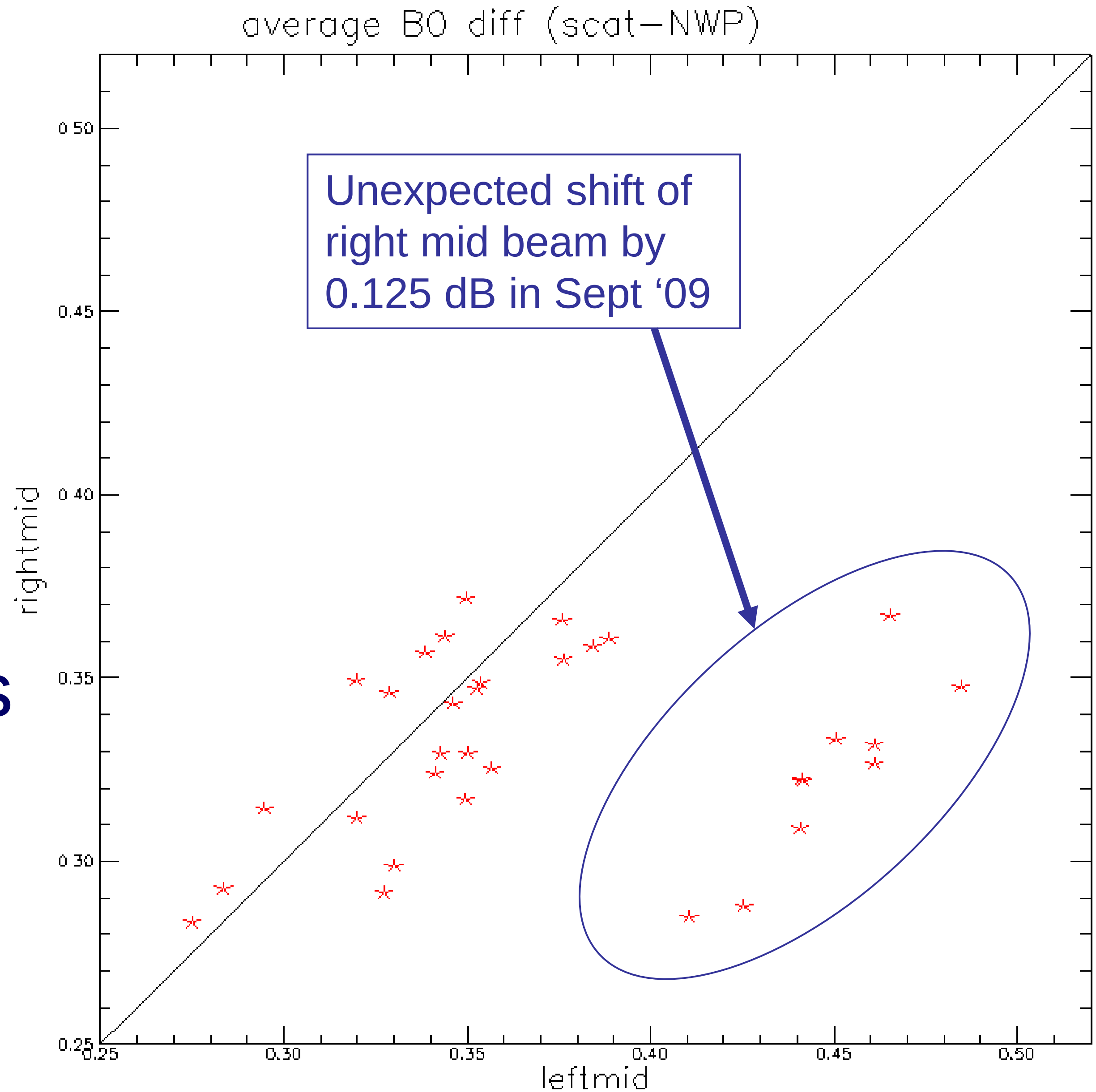
Annual cycle in NOC

- 0.2 dB variation due to weather over a year
- Opposite beams group together tightly since they see the same backscatter PDF due to weather



NOC stable

- Weather shift is identical for opposing ASCAT beams
- Small biases may be detected

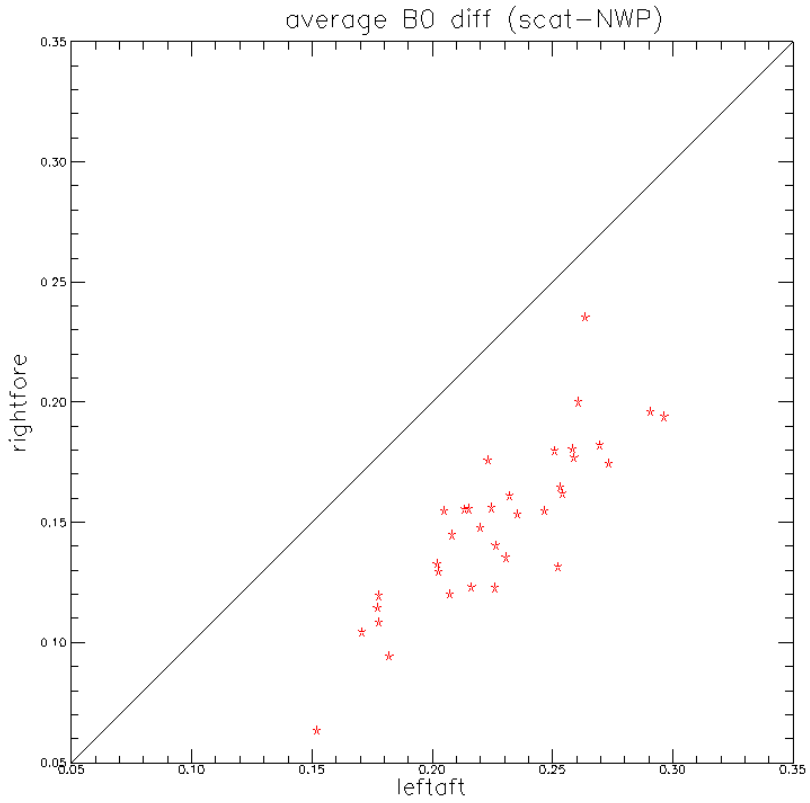


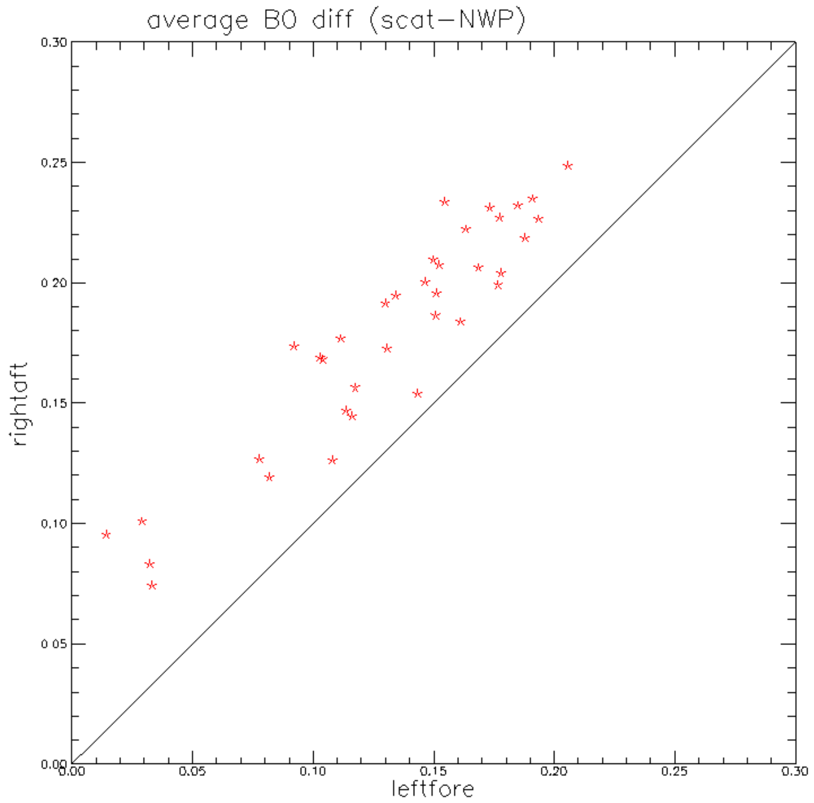
See also Freilich et al.

Interbeam bias

- Bias in other beams ?

Right fore = Left aft

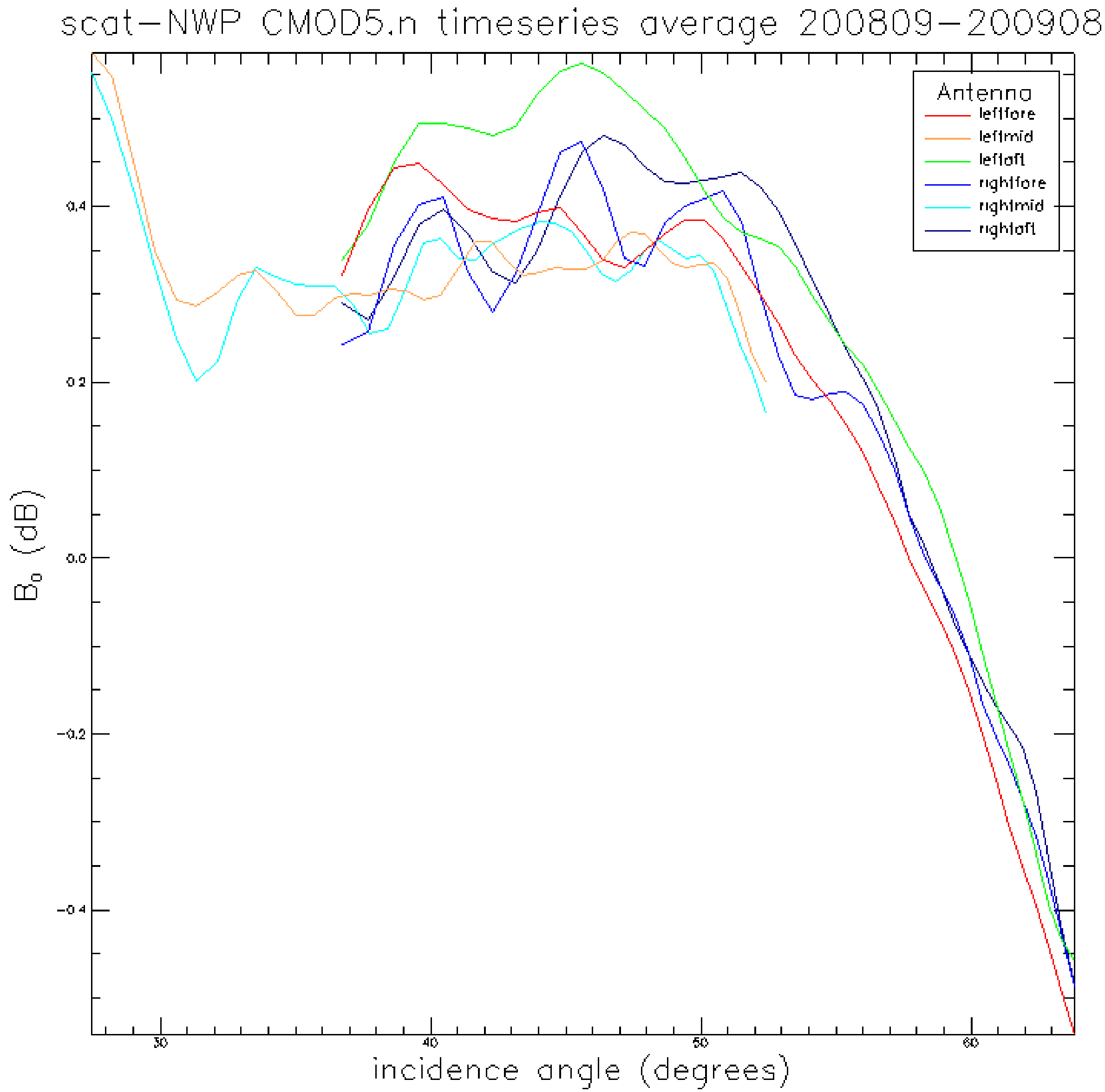




Right aft = Left fore +0.06 dB

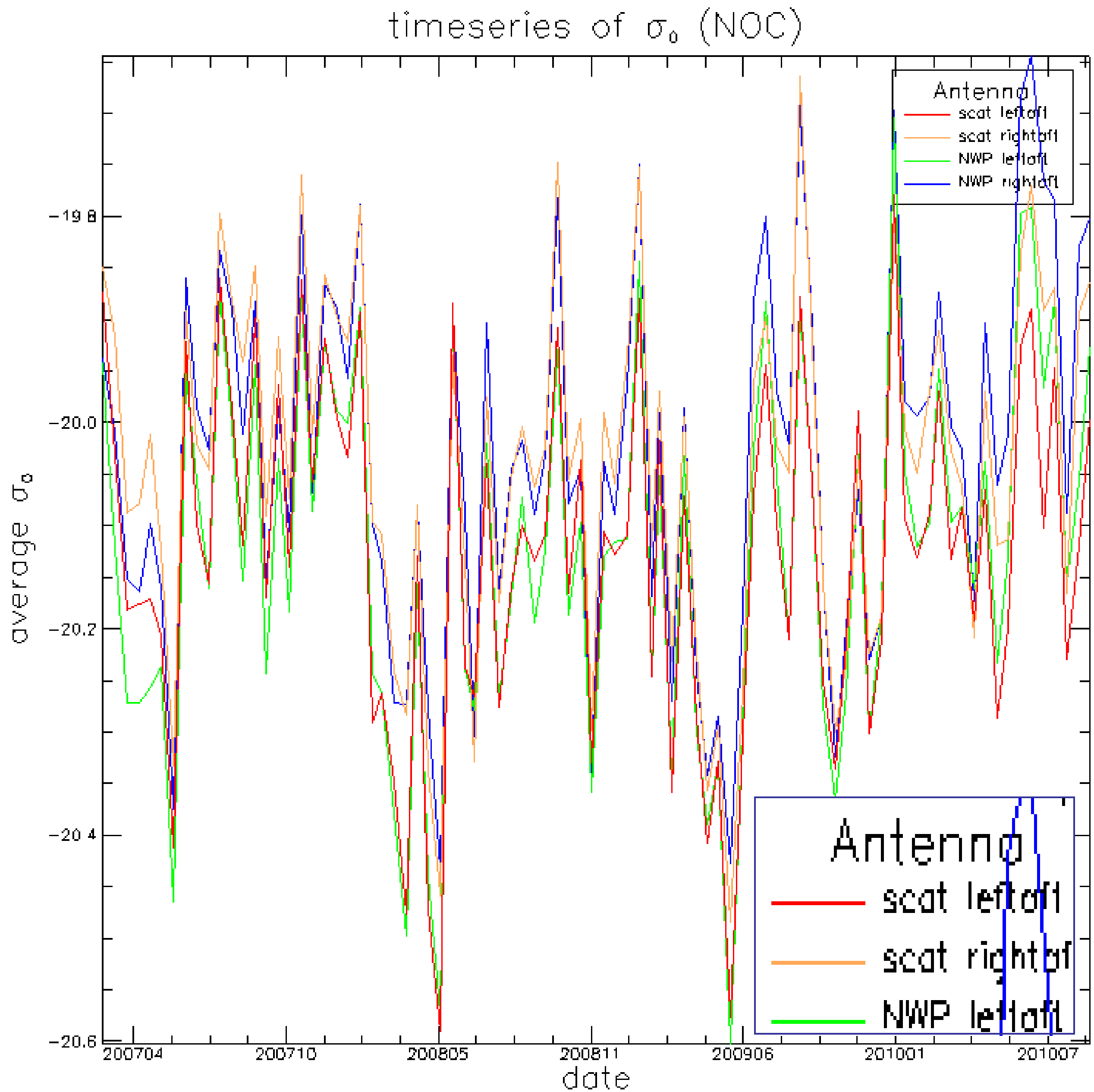
Annual mean

- Annual mean OC correction tables provide improved winds lower and more symmetric MLE and improved QC in AWDP as compared to MS



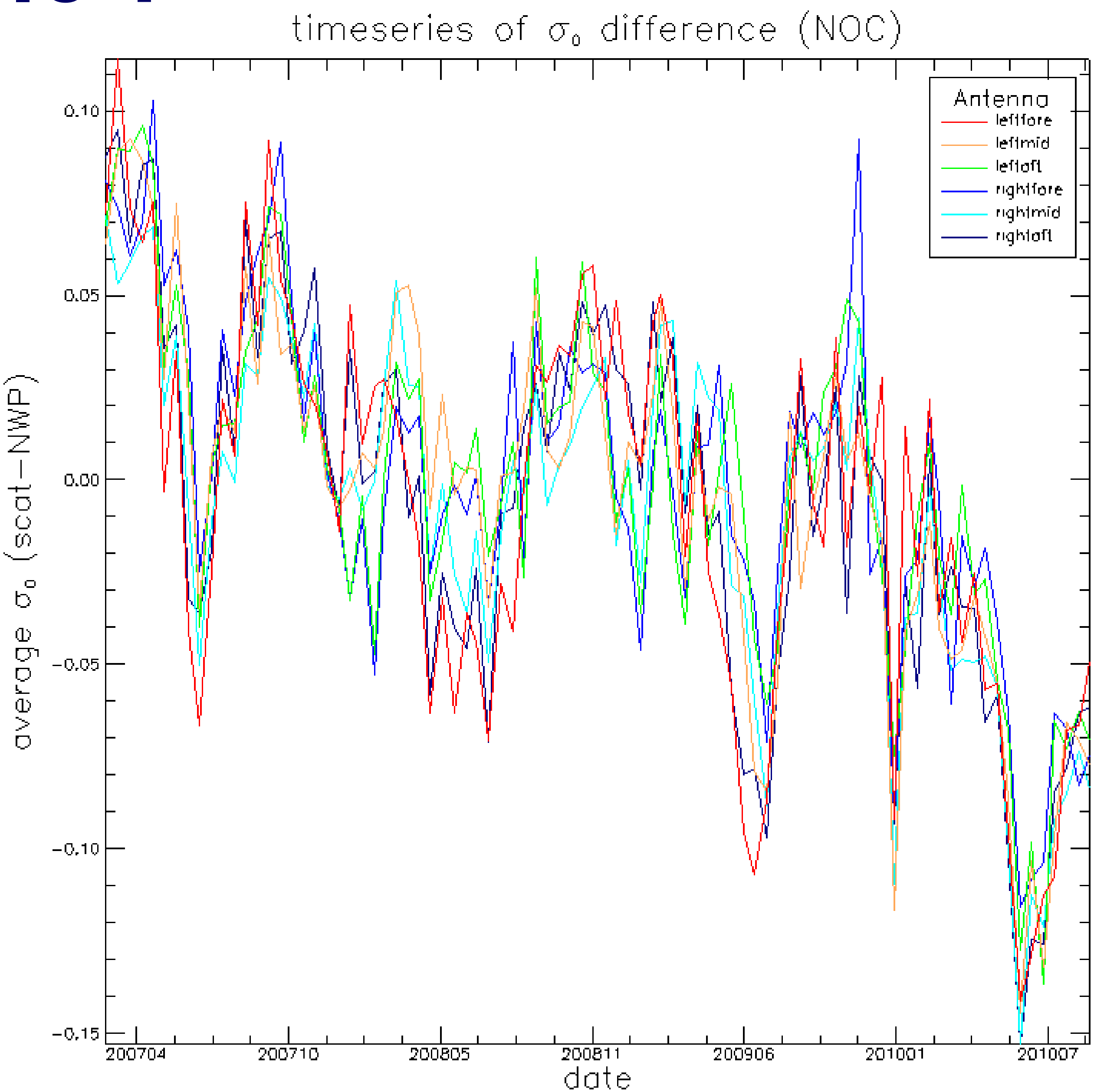
σ^0 over time

- All L1 calibrations “undone”
- General decrease of 0.05 dB per year
- Is ECMWF stable ?

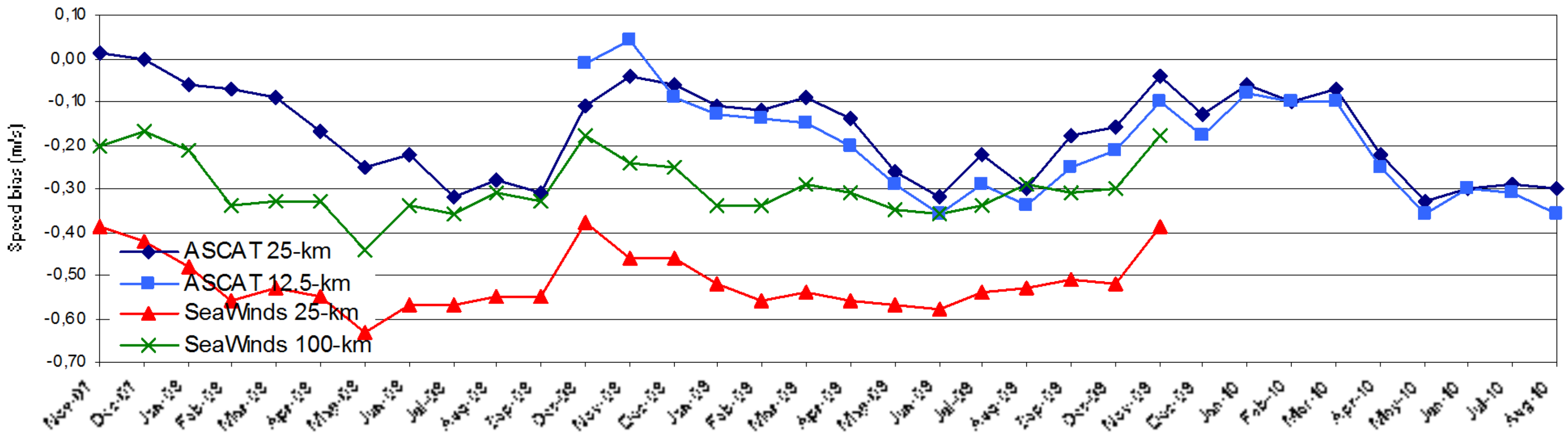


ASCAT stable ?

- All L1 calibrations “undone”
- General decrease of 0.05 dB per year
- Is ECMWF stable ?



Buoy verification



- All L1 calibrations “undone”, U10N undone
- Effects of 0.05 m/s per year hard to detect after 3 years
- 2007 to be extended

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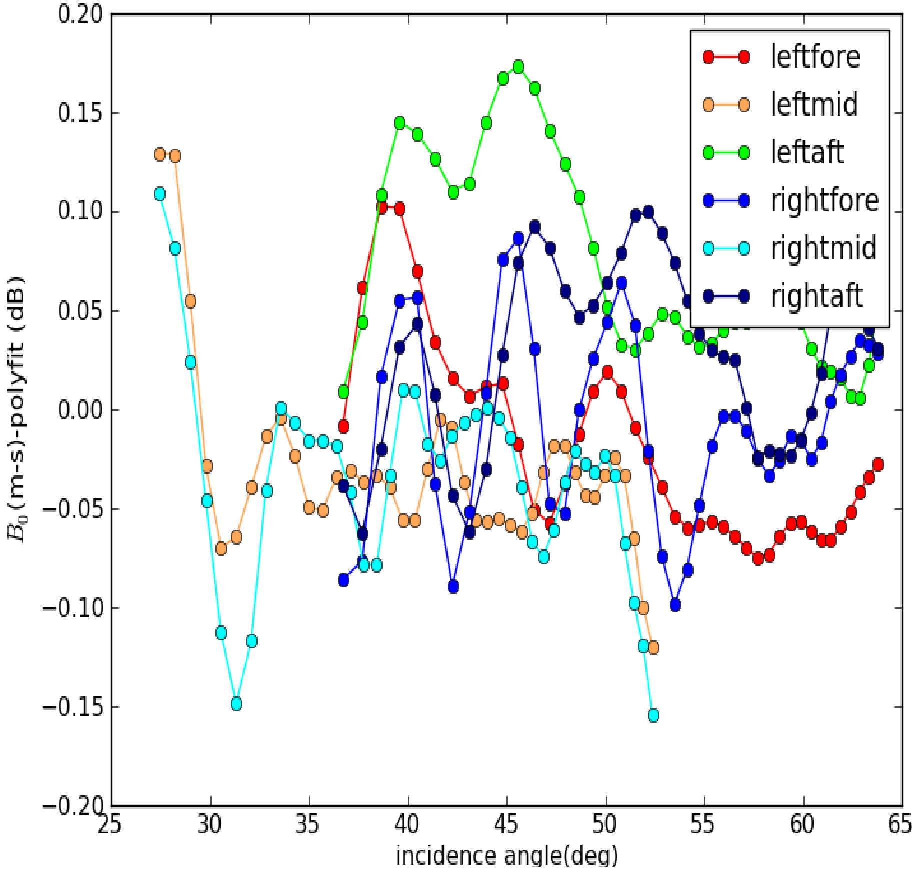
Next steps

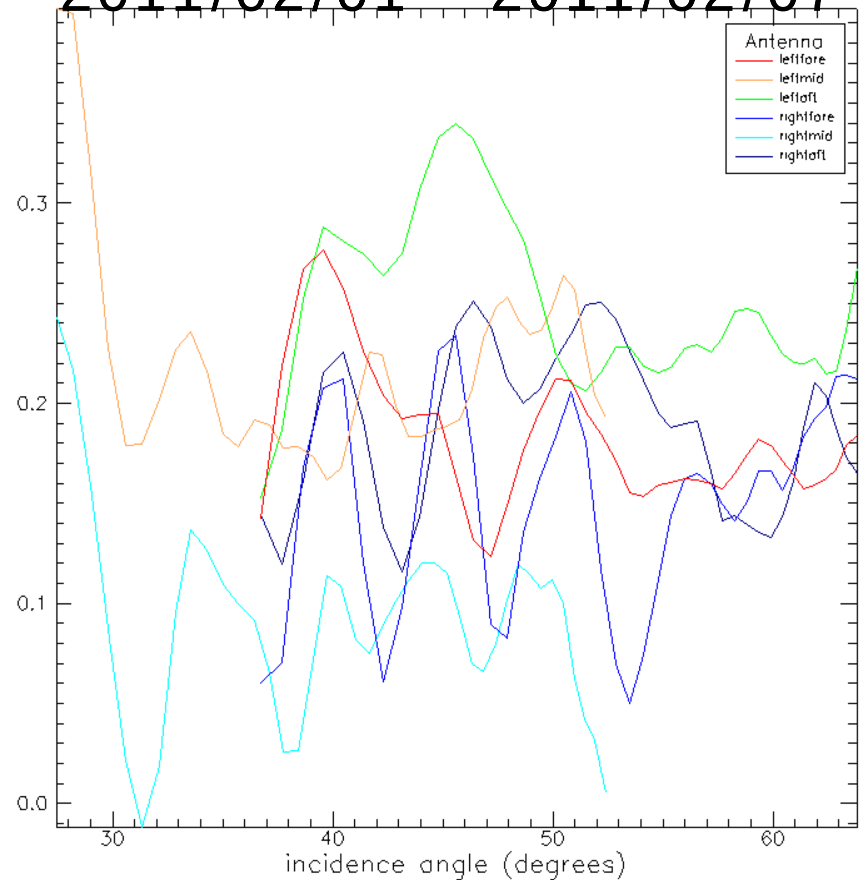
- Implement NOC table in operations
- NOC for coastal product vs 12.5-km product
- Calibrate winds after NOC in operations
- Transfer incidence-angle dependent NOC into GMF
- Update residual NOC AWDP correction table according to L1b calibration updates
- Compare to ERS NOC
- Scope for Full Resolution NOC ?
- Try NOC on sea ice and soil moisture ?

Reproducability ASCAT NOC

2008/09 - 2009/08



2011/02/01 – 2011/02/07

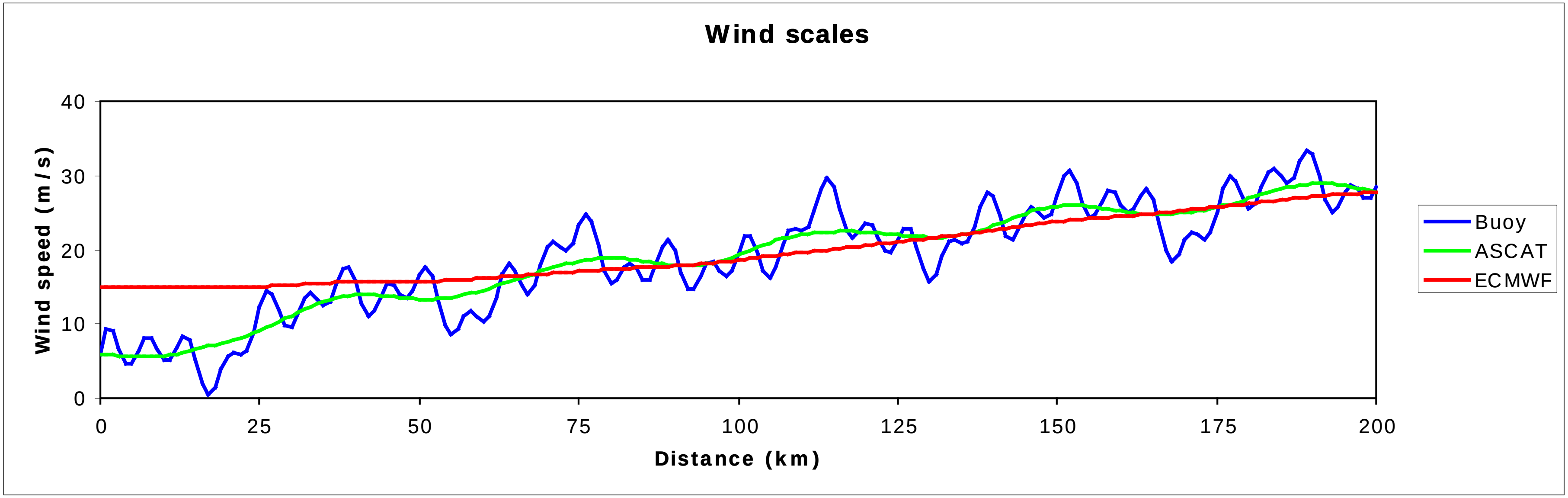


- Patterns identical to within 0.1 dB
- But vertically shifted

Verspeek et al., 2011

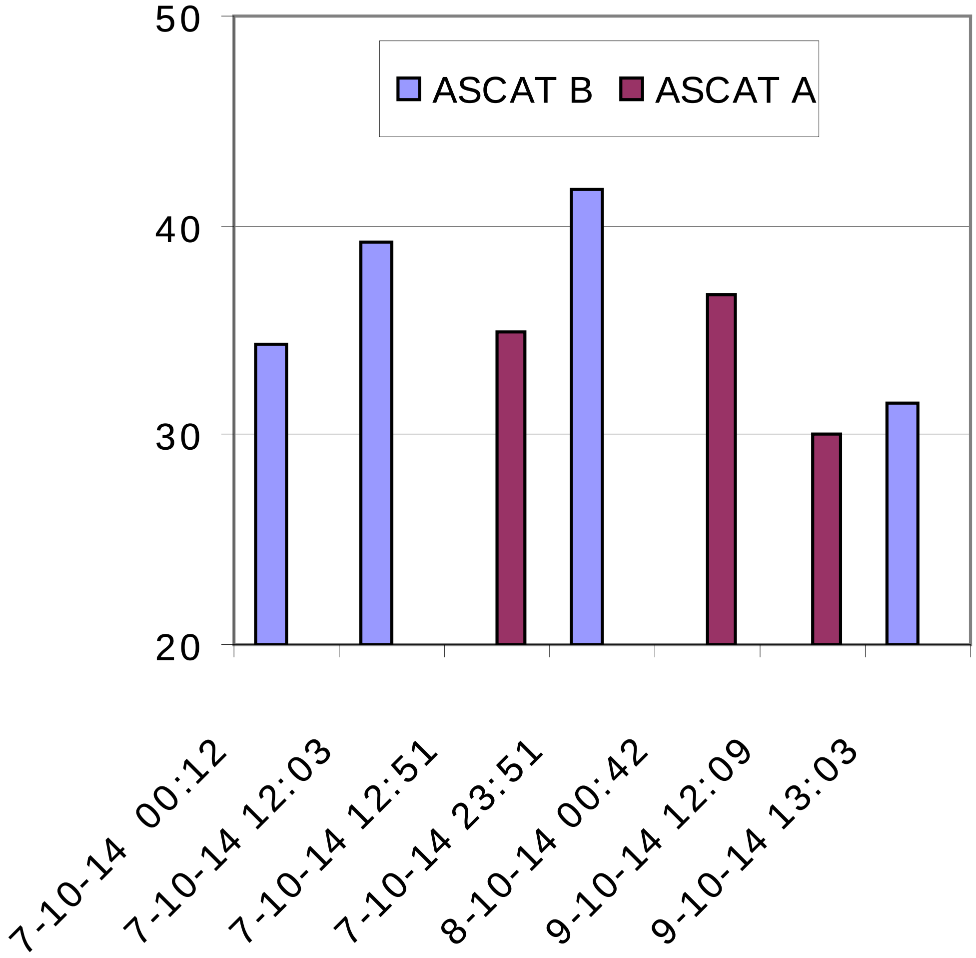
➢ Can NOC be a standard for all scatterometers ?

Spatial representation



- Satellite scatterometers estimate area-mean (WVC) winds using empirical GMFs
- 25-km areal winds are less extreme than 1- or 10-minute sustained in situ winds (e.g., from GPS dropsondes / buoys)
- So, extreme in situ winds should be higher than extreme scatterometer winds (allow for gustiness factor)
- Hurricane scales are based on 1/10-min. maximum winds, but cannot be really verified on ground!

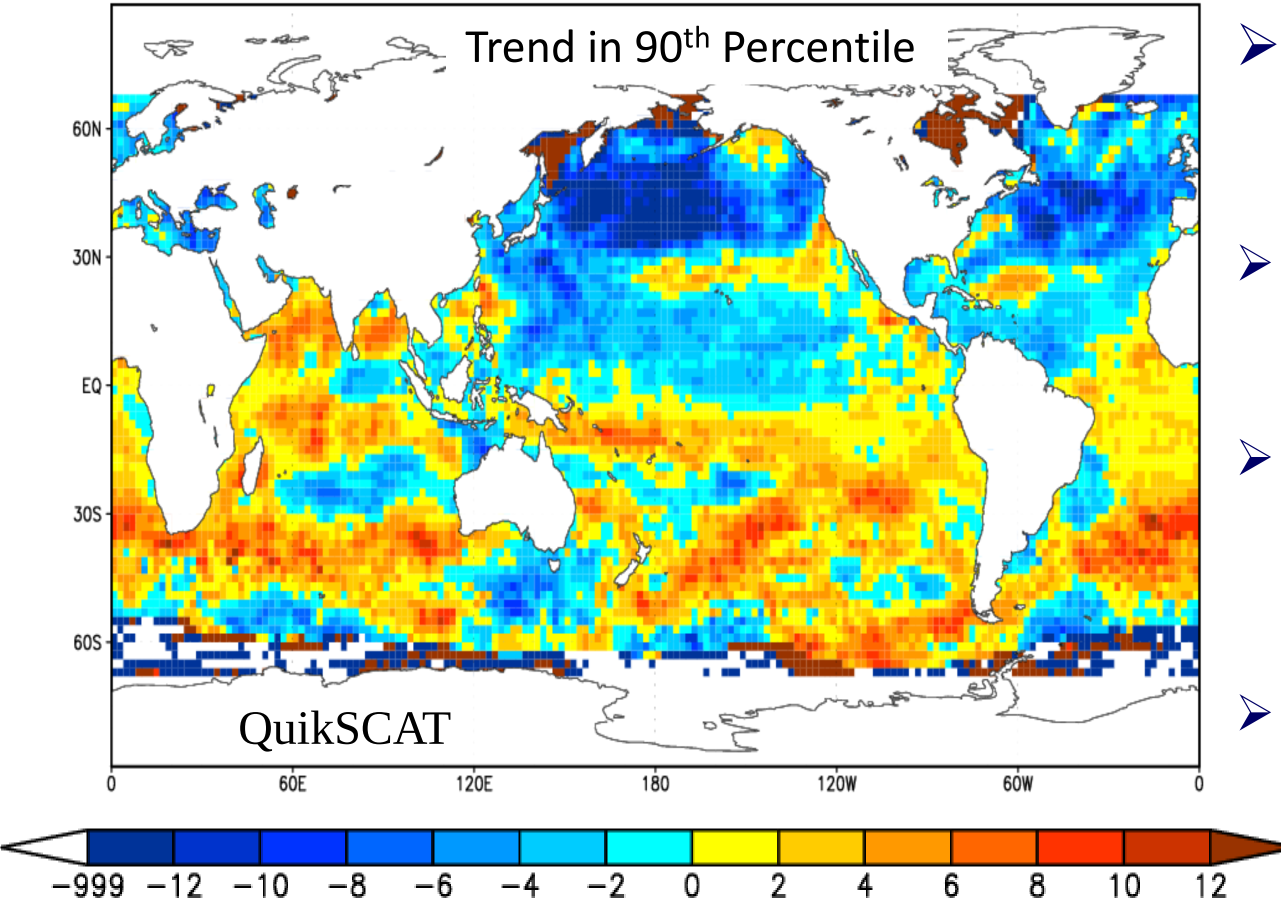
ASCAT hits on Vongfong



- 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

Trends in extreme wind speed



Trend in Wind Speed (in 0.1 m/s per 10 year)

- Controversy in trends of mean and extremes
- Wentz, F. J., and L. Ricciardulli, 2011, *Science*
- Young, I. R., S. Zieger, and A. V. Babanin, 2011: *Science*
- Poster Stoffelen et al. on QuikScat CDR: unexplained 0.1 m/s decadal falling trend of mean wind ?

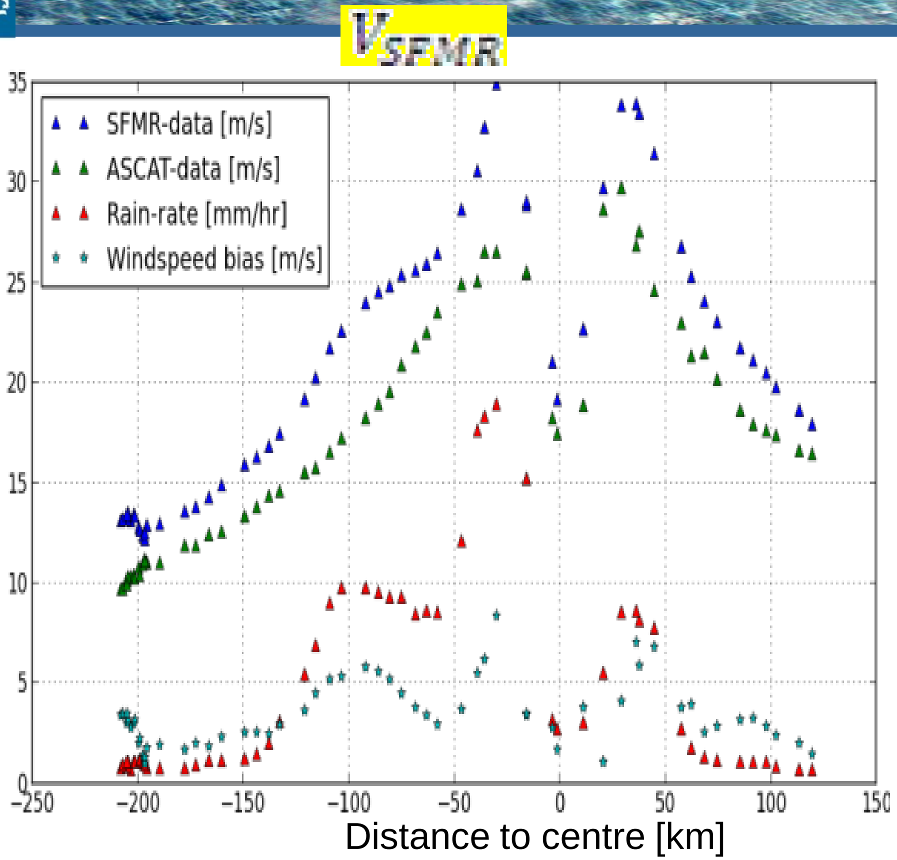
Figure by Jason Keefer and Mark Bourassa, FSU

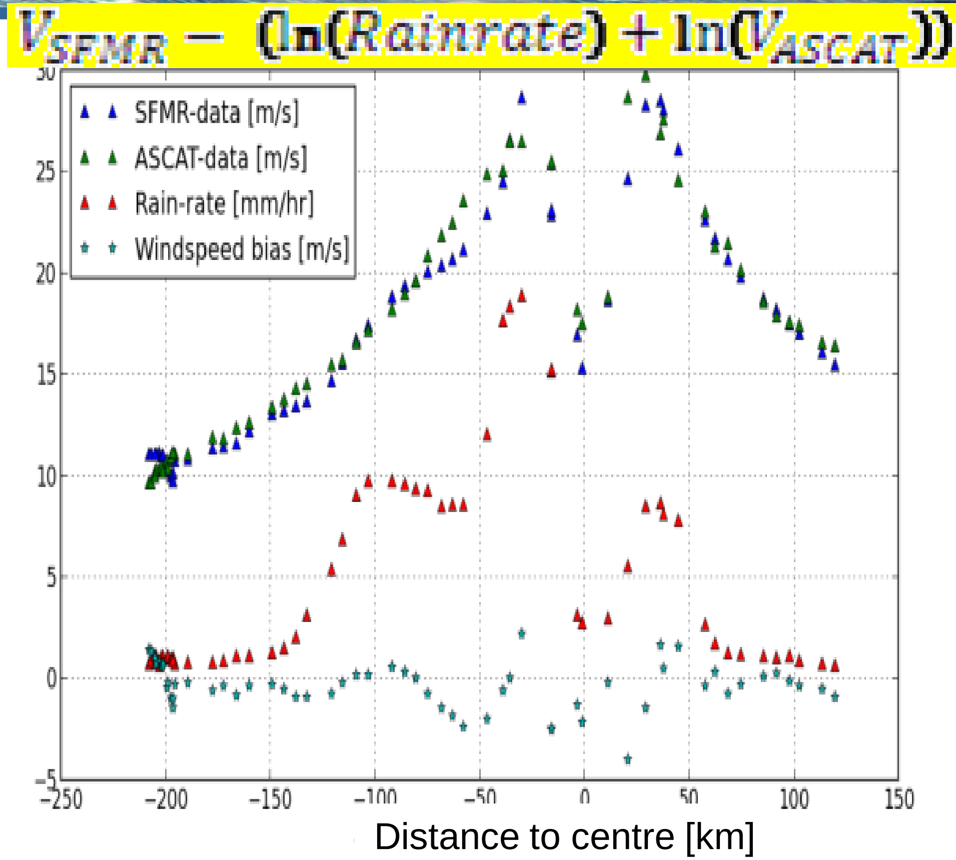
Calibration Strategy Extremes

1. GPS dropsondes provide true measure of local wind
2. GPS dropsondes calibrate SFMR on its basic footprint
3. Calibrated SFMR data are integrated over a scatterometer WVC length to provide a resource for satellite scatterometer calibration

- Error attribution in all steps

SFMR versus ASCAT





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

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Wind stress ECV

- Radiometers/scatterometers measure ocean roughness
- Ocean roughness consists in small (cm) waves generated by air impact and subsequent wave breaking processes; depends on water mass density ρ_{sea}= 1024±4 kg m^{-3} 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)

- $\sqrt{\rho_{air}} \cdot \boldsymbol{u}_{10N}$ is suggested to be a better input for backscatter GMFs

(under evaluation by IOVWST)

GCOS needs for FCDR

1. Full description of all steps taken in the generation of FCDRs and ECV products, including algorithms used, specific FCDRs used, and characteristics and outcomes of validation activities
2. Application of appropriate calibration/validation activities
3. Statement of expected accuracy, stability and resolution (time, space) of the product, including, where possible, a comparison with the GCOS requirements
4. Assessment of long-term stability and homogeneity of the product
5. Information on the scientific review process related to FCDR/product construction (including algorithm selection), FCDR/product quality and applications
6. Global coverage of FCDRs and products where possible
7. Version management of FCDRs and products, particularly in connection with improved algorithms and reprocessing
8. Arrangements for access to the FCDRs, products and all documentation
9. Timeliness of data release to the user community to enable monitoring activities
10. Facility for user feedback
11. Application of a quantitative maturity index if possible
12. Publication of a summary (a webpage or a peer-reviewed article) documenting point-by-point the extent to which this guideline has been followed

- What about L1 ERS data ?

GCOS-143 (WMO/TD No. 1530)

Users FCDR/ECV stress

- Oceanography, eddy scale winds (MyOcean)
- Re-analyses (data assimilation uses wind)
- IOVWST; process studies (air-sea momentum exchange, cyclones, extreme winds, convection, tropical circulation, ...)
- Climate, fluxes (incl. carbon)
- Design, policy-makers, wind energy, adaptation, ..

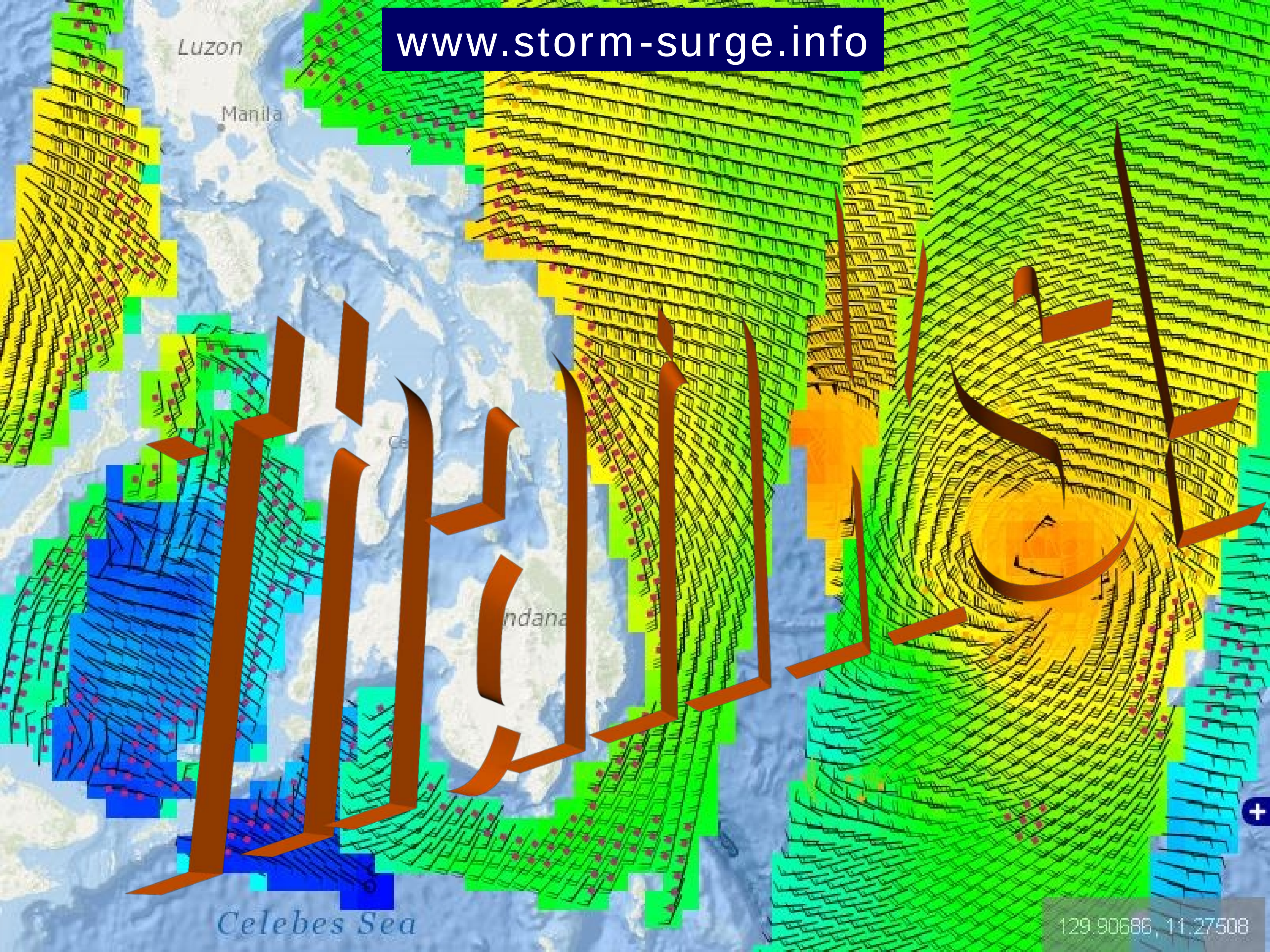
- We need to serve these users

ECV status

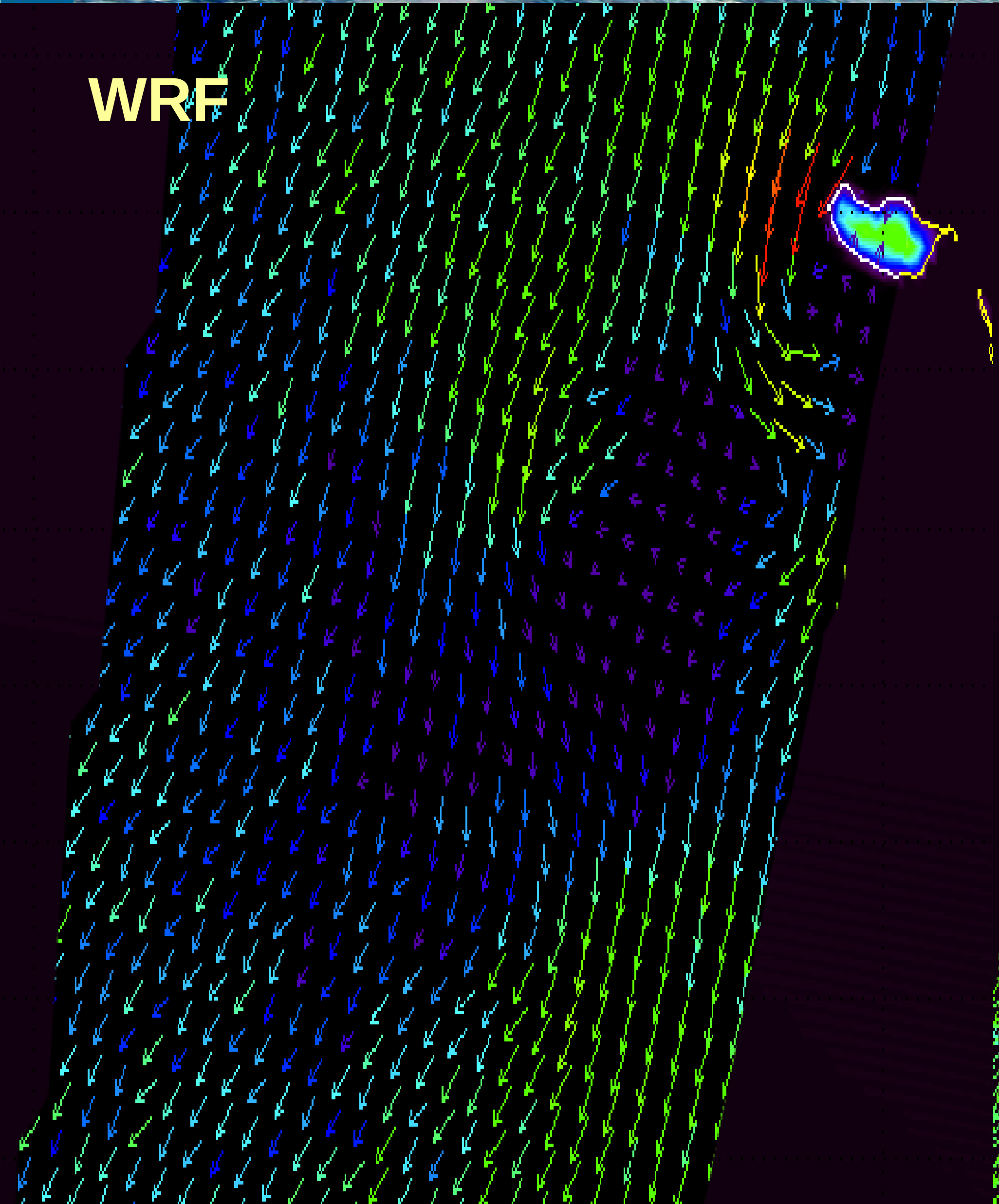
- Several producers (a.o. OSI SAF) provide OVW CDRs, which are defensible by their own verification metric
- These products cannot be easily understood nor combined by the user community
- Mature (5) stable products exist over long times, but not reprocessed according to GCOS guidelines; some uncoordinated RP plans exist
- Matchup data bases exist too, but by producer
- Moored buoys are the main reference, but lacking in open ocean
- Quality metrics and assessment standards (software) exist too by producer, but resolution, wind scale, wind quality to be coordinated/agreed
- An IOVWST has been set up last year, which could address ECV coordinated needs when mandated as such
- CEOS Virtual Constellation coordinates satellites/products

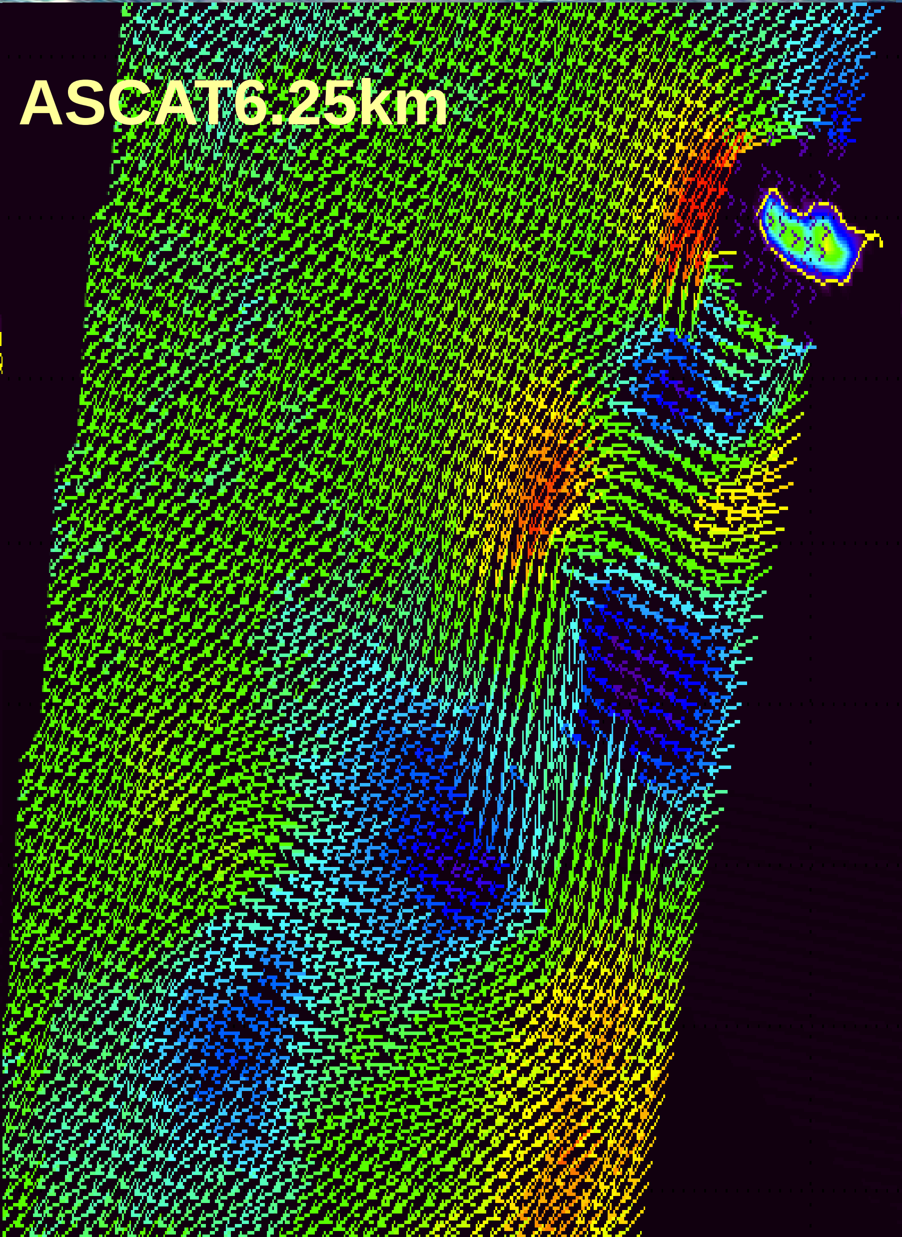
Summary

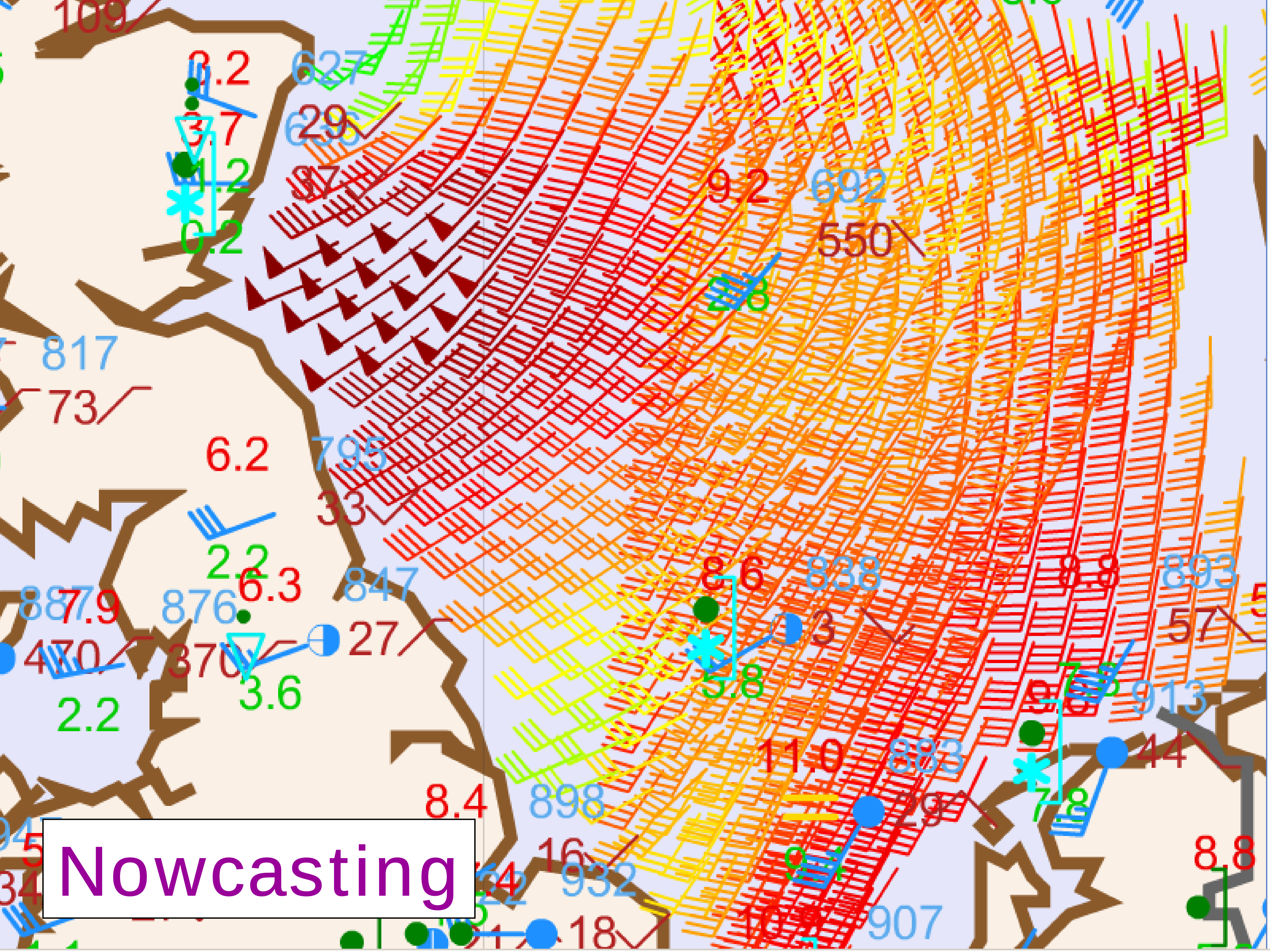
- Vacancy
- Test ERS


www.storm-surge.info
Luzon
Manila
Celebes Sea
129.90686, 11.27508

Higher resolution






Nowcasting

Vongfong 46 m/s at 6 km