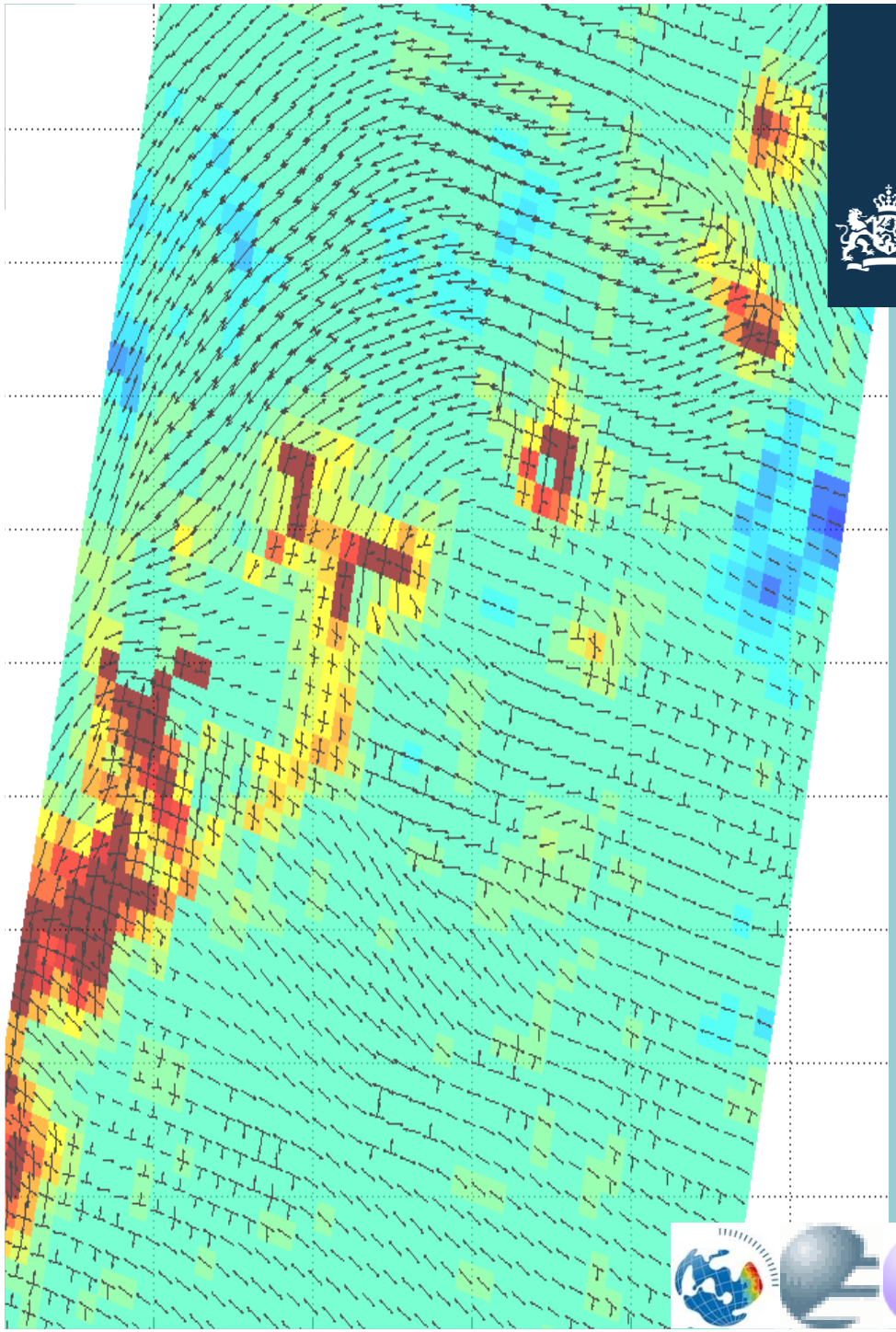

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ERA*

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Ana Trindade (ICM)
Jos de Kloe
Marcos Portabella (ICM)
Maria Belmonte
Greg King (ICM)
Anton Verhoef

ERA*

- Scatterometer winds have non-neglibible sampling errors due to swaths, LTAN and the transient weather
- Blended data series are smoothed spatially to remove “noise”
- Climate scientists use, e.g., ERA-interim
- KNMI produced ERA-interim U10S at full resolution
- ERA-interim is interpolated to scatterometer WVCs
- Difference PDFs between ERA and scatterometers are locally accumulated to correct ERA-interim; these identify:
  - NWP artefacts
    - Lack of ocean current
    - Excessive mixing in stable air (Randu)
    - Lack of ocean eddy-scale structure (Chelton)
    - Poor tropical dynamics, particularly convective scales
  - Scatterometer artefacts, presumably small

Wind stress

- 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 σ, 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)

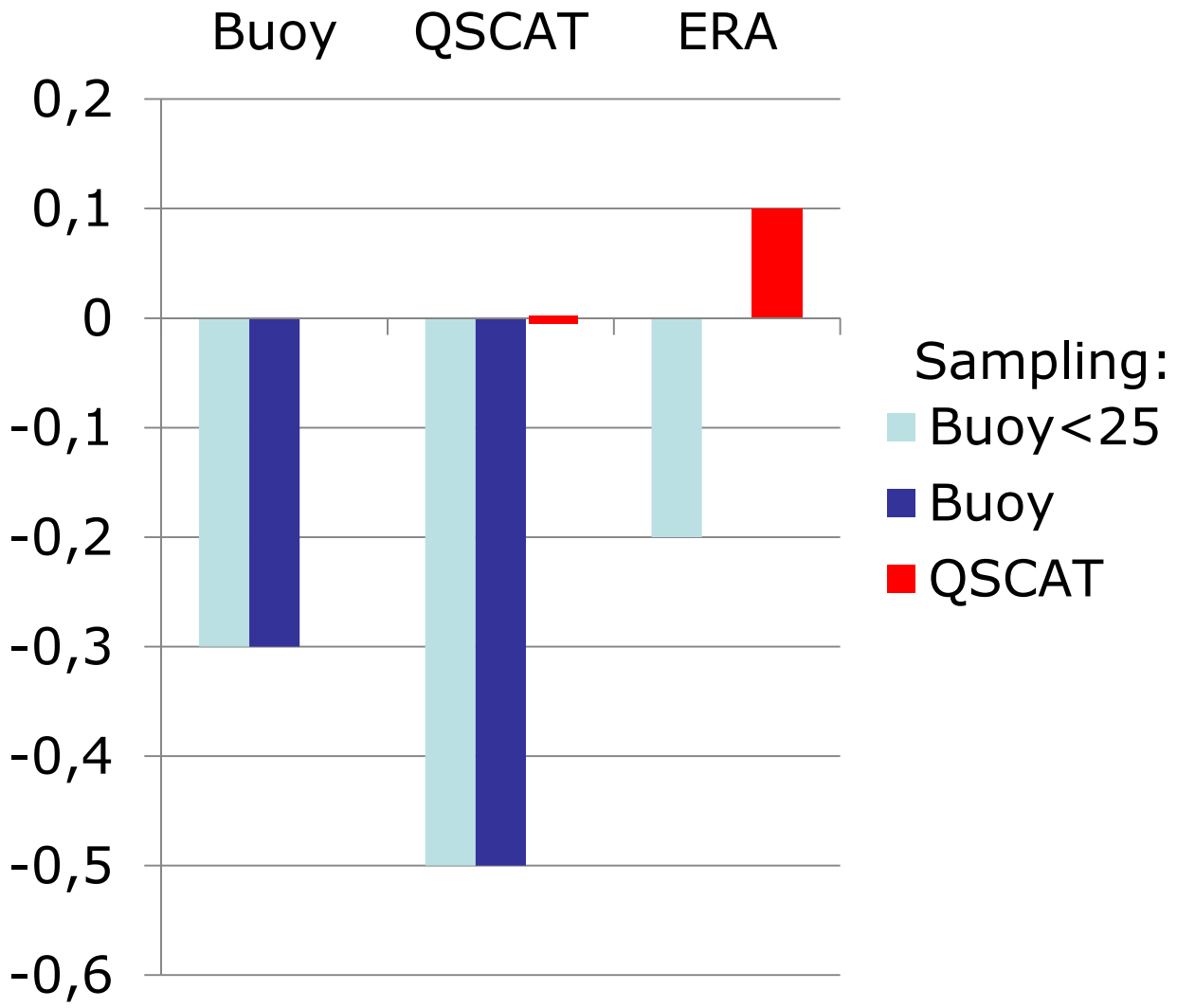
- Stress-equivalent wind, $\boldsymbol{u}_{10S} = \sqrt{\rho_{air}} \cdot \boldsymbol{u}_{10N}/\sqrt{\rho_0}$, is suggested to be a better input for backscatter GMFs, since more closely related to $\boldsymbol{\tau}$

ECMWF ERA-interim U10S

- ECMWF ERA-Interim wind forecast data will be used as a reference for users, to initialize the ambiguity removal step and to monitor the data records; ERA analyses are not independent from ERS, QSCAT, etc., but forecasts are!
- ERA-Interim data are available over the entire period (in fact from 1979 to present) and produced with a single version of ECMWF's Integrated Forecast System, i.e., is a climate reference
- ERA-Interim fields are retrieved without interpolation error on a reduced Gaussian grid with approximately 79 km spacing
- Although data from the operational model are available at higher resolution for most periods, they have varying characteristics over time so we will not use them (up to 0.2 m/s mean changes)
- ERA-Interim does not have equivalent neutral 10m winds (U10N) nor U10S archived; we compute them from the real 10m winds, SST, T and q using a stand-alone implementation of the ECMWF model surface layer physics (tested using real 10m and U10N winds from the operational model) and put them available at KNMI

Climate trends 1999-2009

- Required accuracy is 0.1 m/s per 10 years (GCOS)
- Trends sampled at buoys are different from global trends sampled by QSCAT or ERA
- Moored buoys are **absolutely** needed for satellite calibration
- Moored buoys do not represent the global climate (SH lacking)
- Satellites can measure global climate change

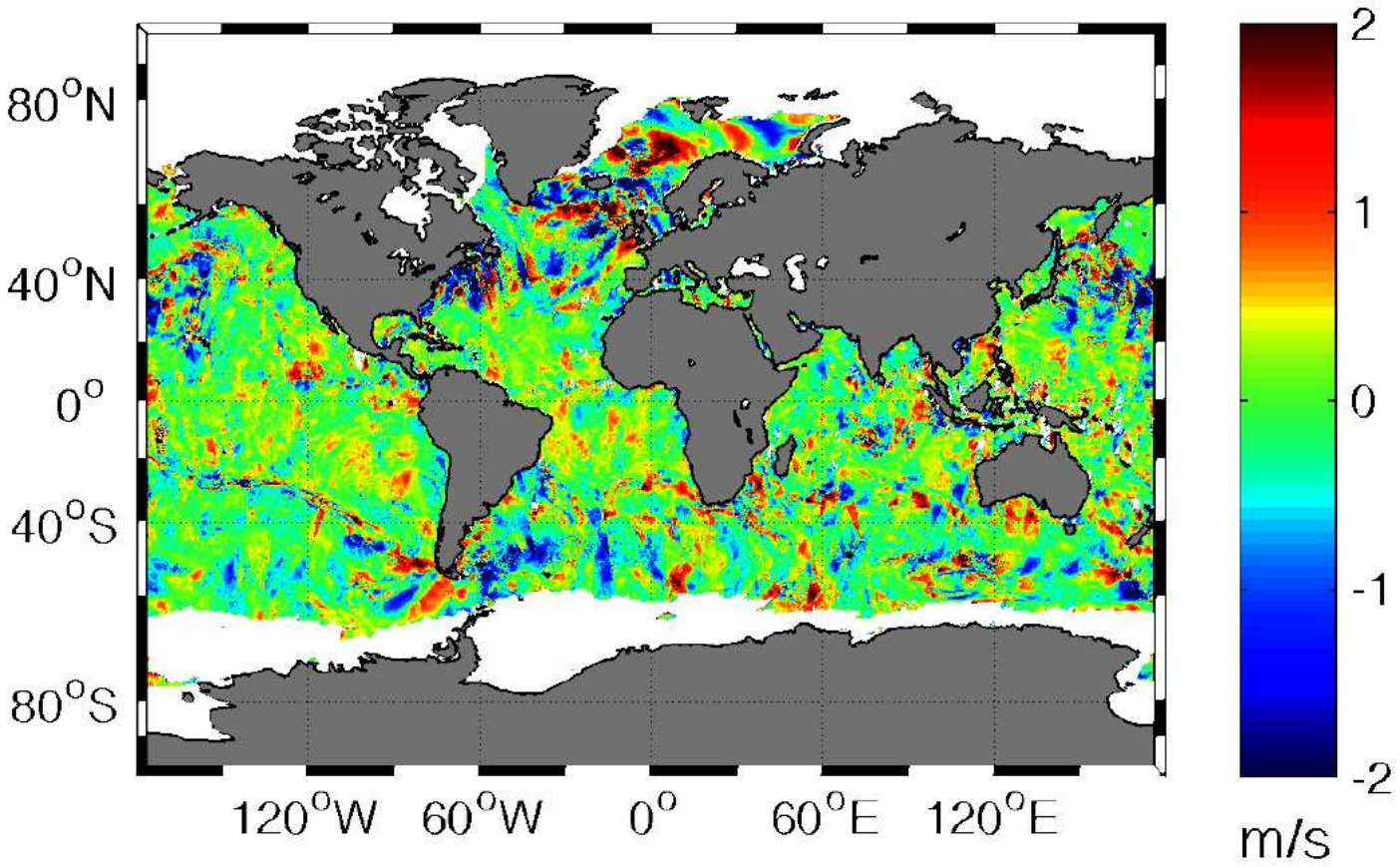


Sampling error

- 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 U10S 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

Blending error?

- What does a mean daily satellite wind represent physically?
- Sampling error is substantial
- Tracks are visible
- Transient weather appears as noise
- Diurnal cycle removed
- Time resolution in ERA is lost



THE COLOR MAP DEPICTS THE WIND SPEED DIFFERENCES BETWEEN A DAY OF THESE SCATTEROMETER-SAMPLED ECMWF WINDS AND UNIFORMLY SAMPLED ECMWF WINDS.

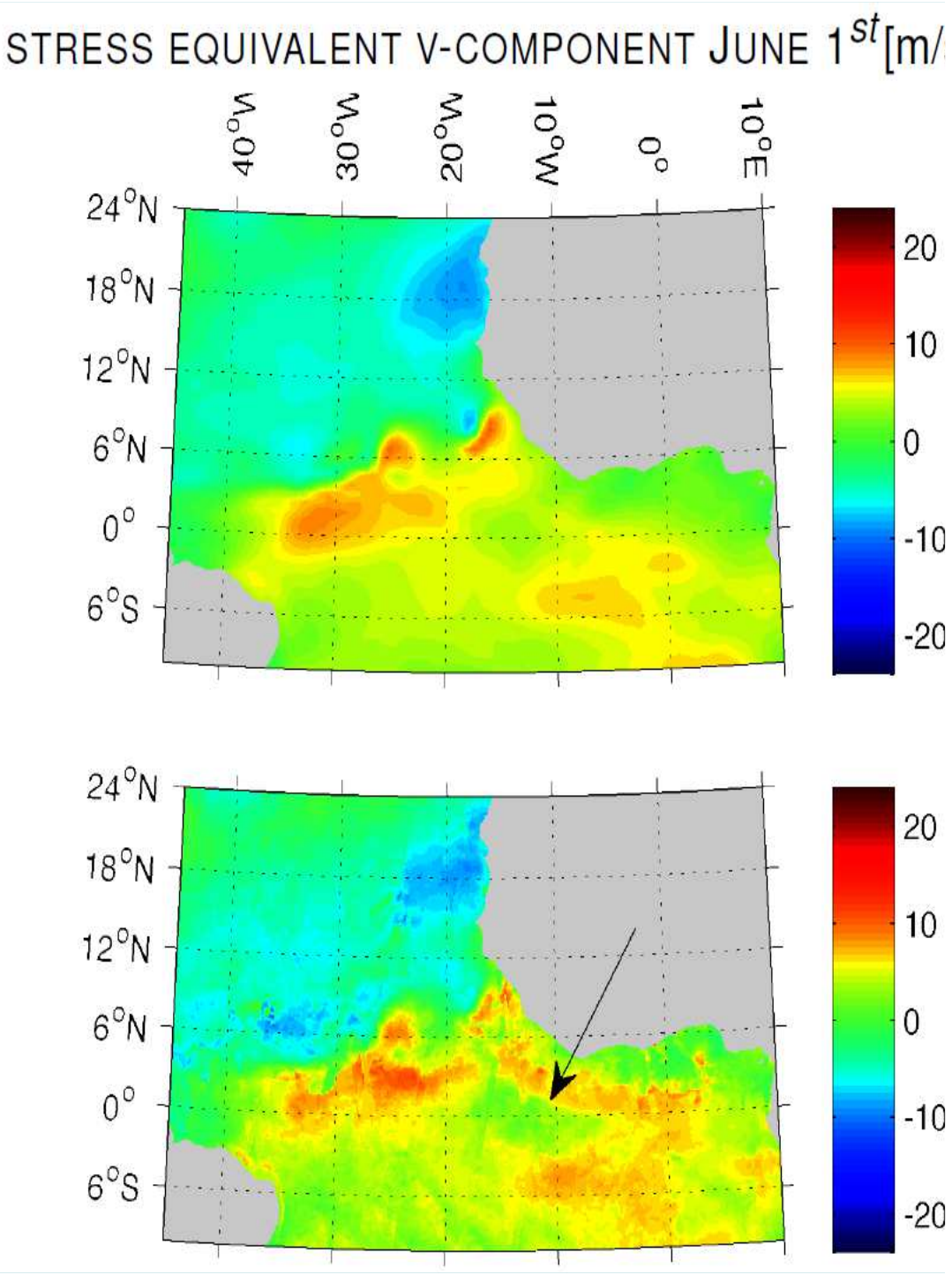
ERA* interim surface winds (U10s*)

- Full temporal resolution (transients, diurnal cycle):
  U10s*(t) = U10s(t) + small scale variability correction
- Full (scatterometer) spatial resolution, incremented weekly:
  Correction = (U10s[scatt] - U10s[ERA])(t) and its SD(t)
- Scatterometer data will provide information on smaller scales
- This "noise" contains information on the eddy scale for ocean currents, wind variability due to moist convection, coastal interaction and systematic parameterization errors in surface fluxes

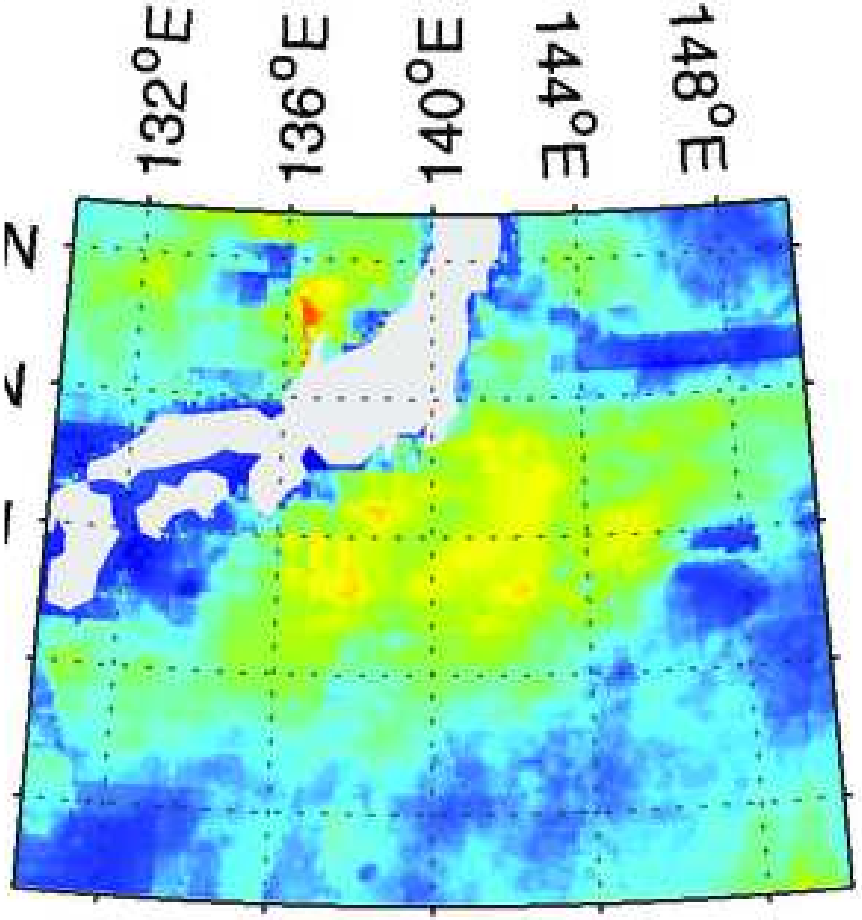
Users would widely benefit from an observation-based wind stress forcing data set with high spatio-temporal resolution in a standard projection.

ERA* Details

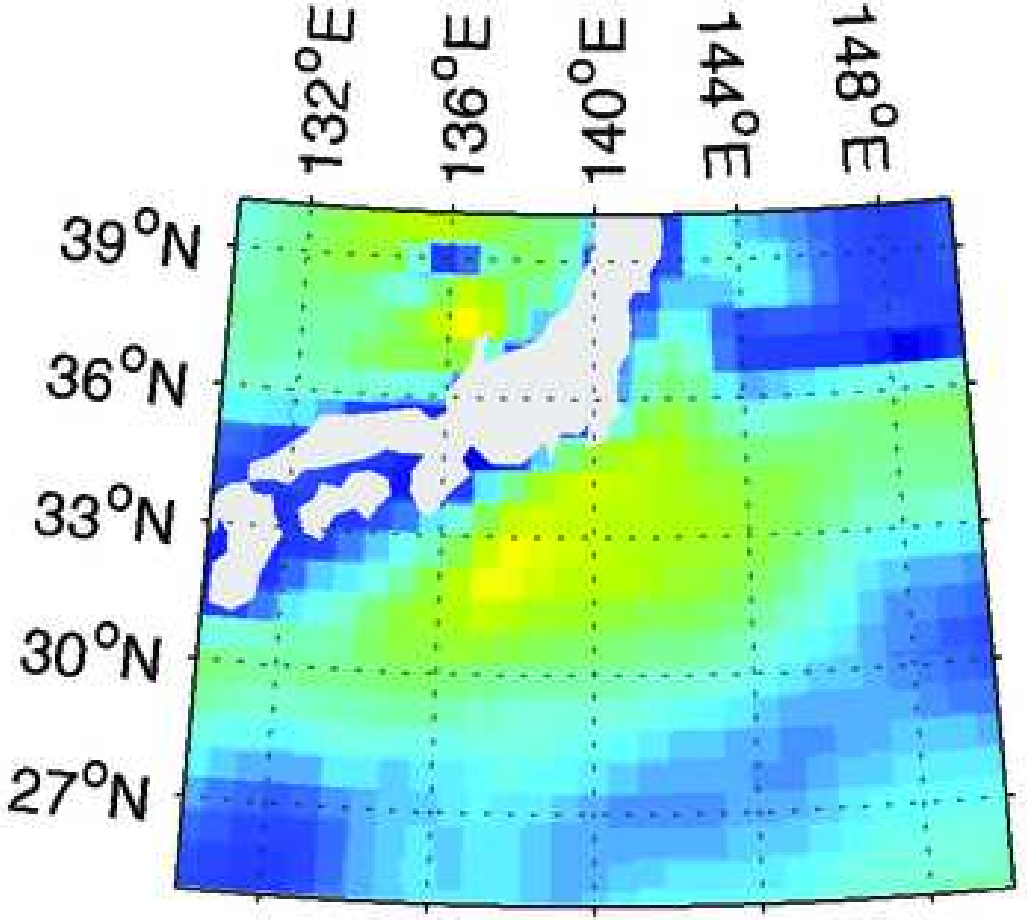
- ERA*(bottom) shows a clear meridional wind effect south of the African coast and another effect south of the equator
- Moist convection?
- Needs further spatial and temporal analysis
- Test implications for curl and divergence



ERA* Details



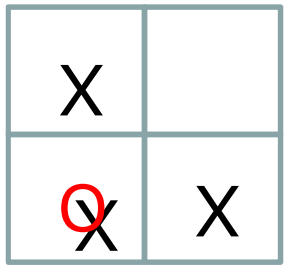
ERA*



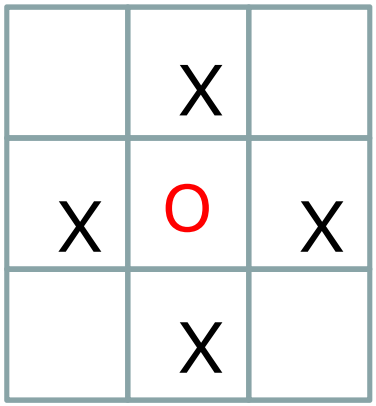
ERA

x,y curl and div?

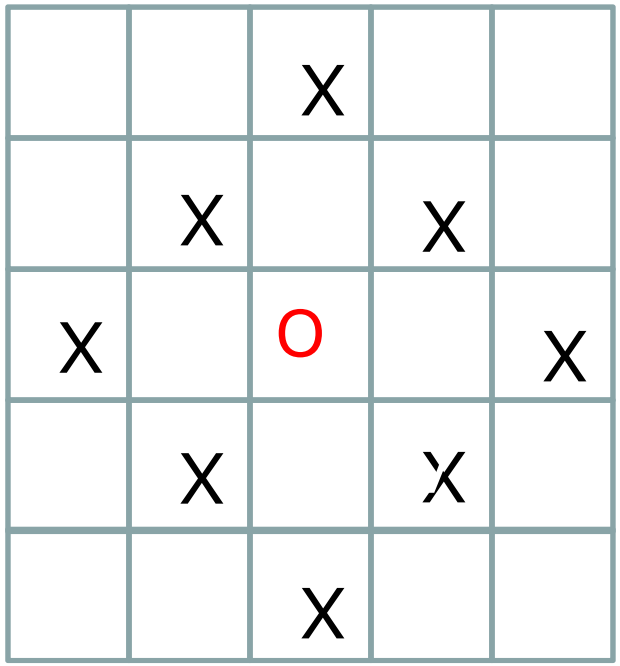
- Curl and div products imply smoothing



Non-centered
Asymmetric

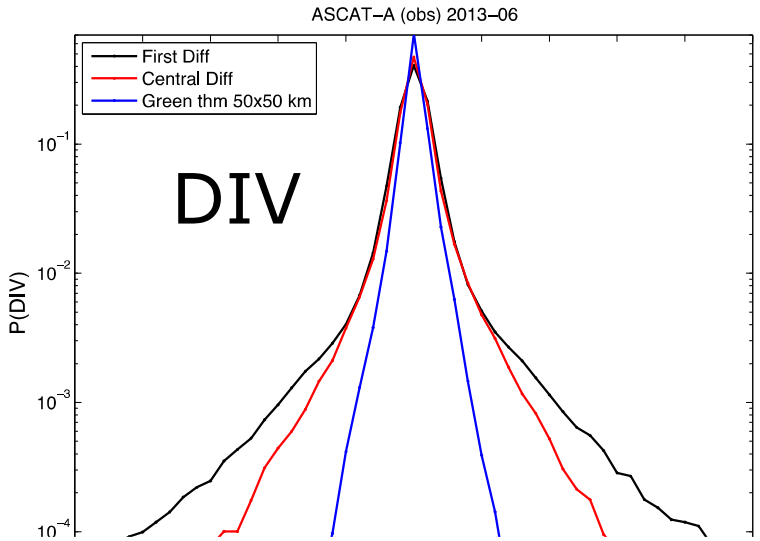


Centered
Symmetric

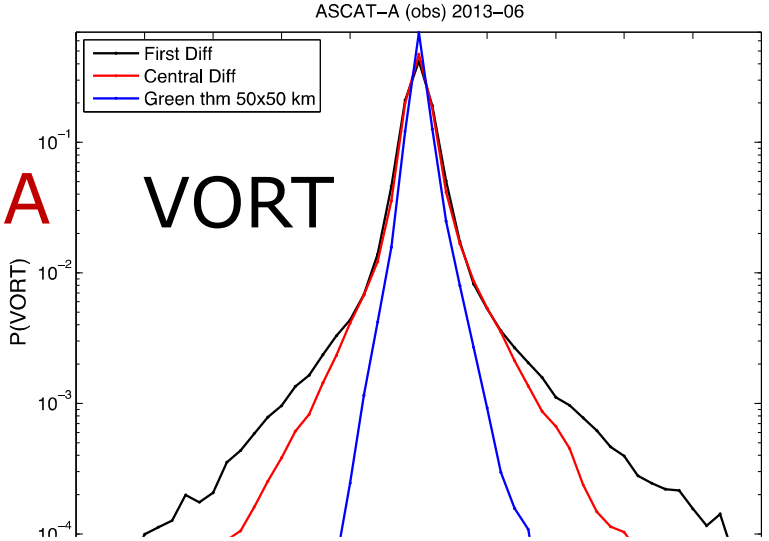


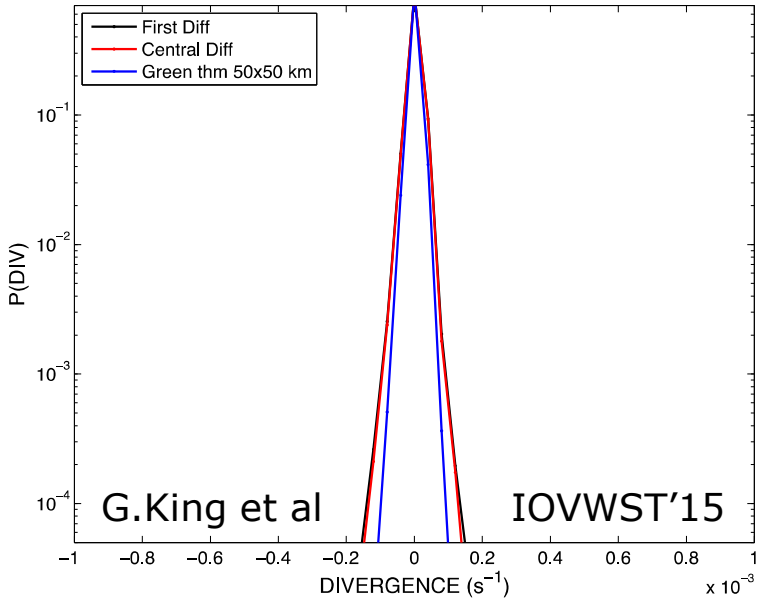
Integral methods

PDFs of DIV and VORT

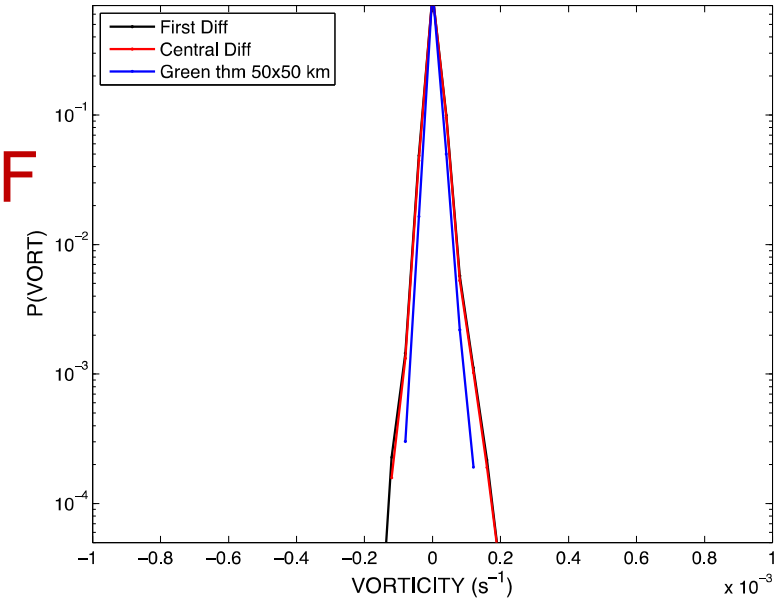


ASCAT-A



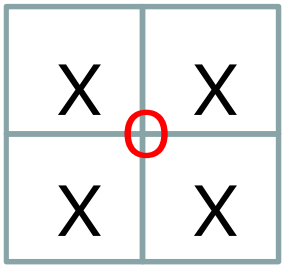


ECMWF



Attractive alternative?

We suggest:

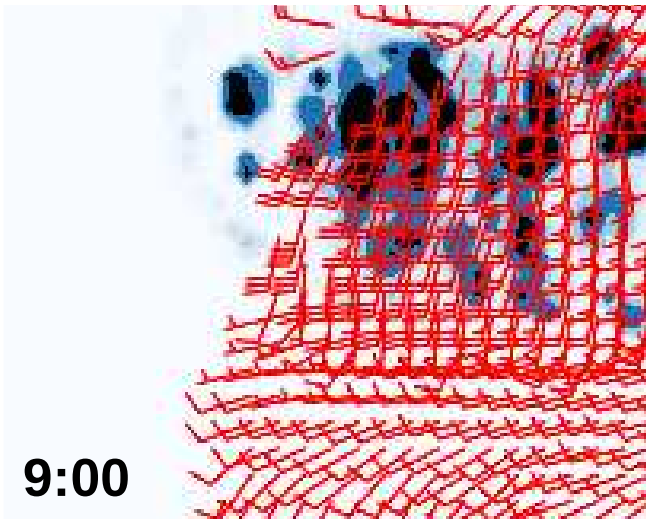


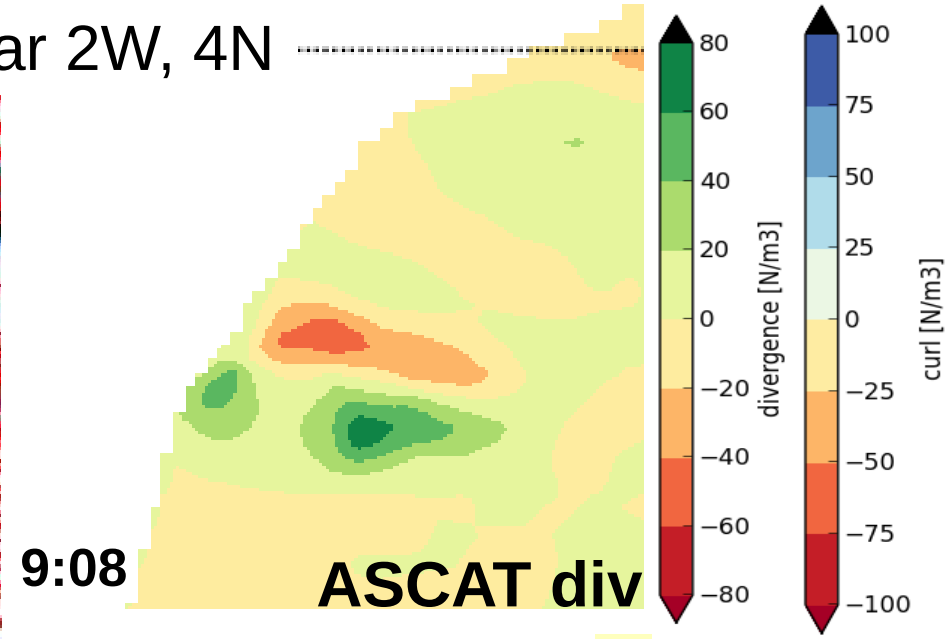
Centered
Symmetric

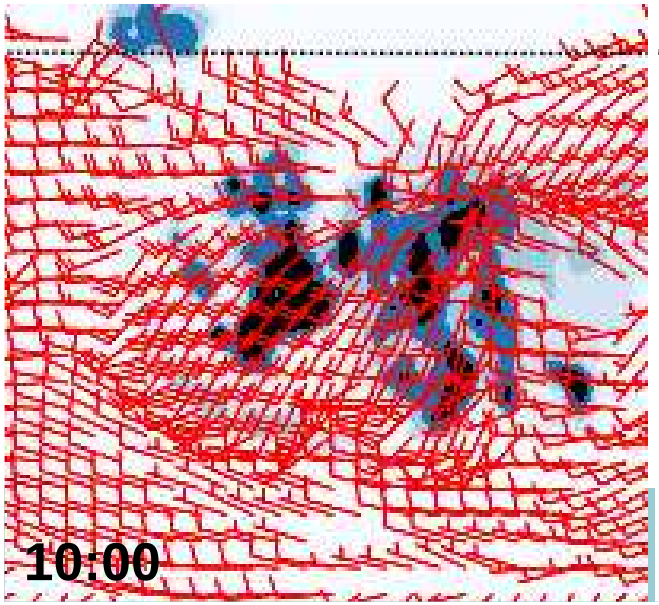
- If the change in wind over one WVC (Δx) is typically larger than the noise (δu) , as is the case for good SNR, then this 4-point scheme delivers du/dx of accuracy $\delta u/\Delta x$, if Δx is known
- Wind rot and div are then $\sqrt{2}$ larger (stress rot and div are worse)
- So, if 12.5-km sampling has good SNR for wind, this method will work well on the 25-km product generally
- However, for large signals (in moist convection), 12.5 km could work too!
- In case of one missing point, an asymmetric 3-point scheme may be adopted on the lagged grid, at the expense of additional noise

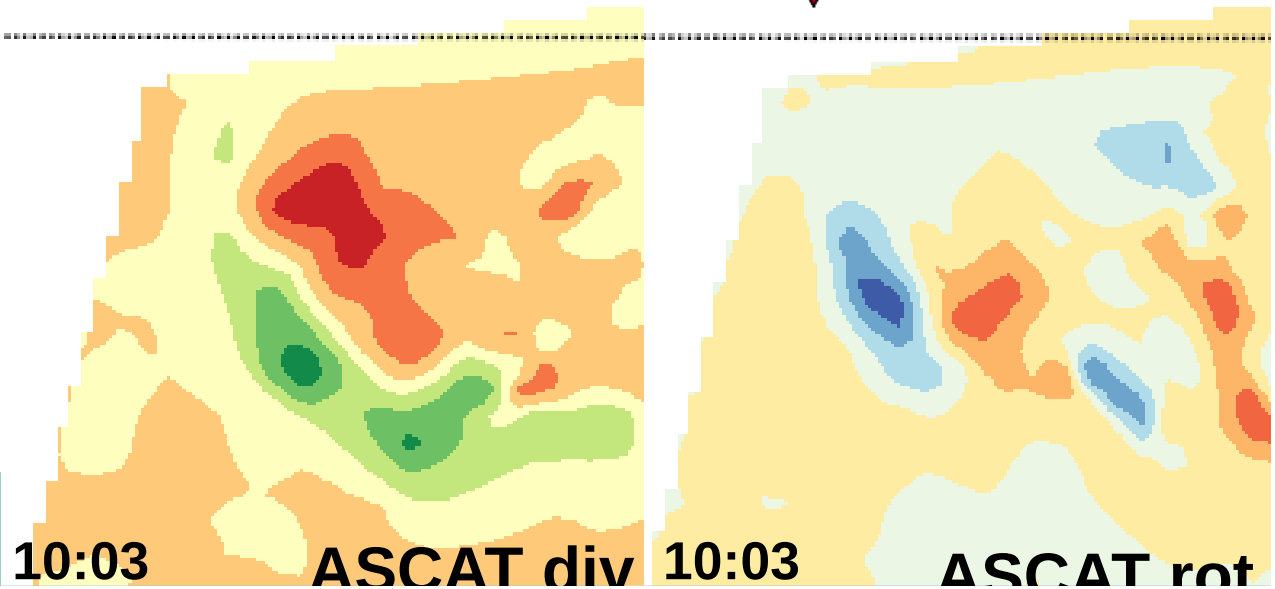
Developing gust band

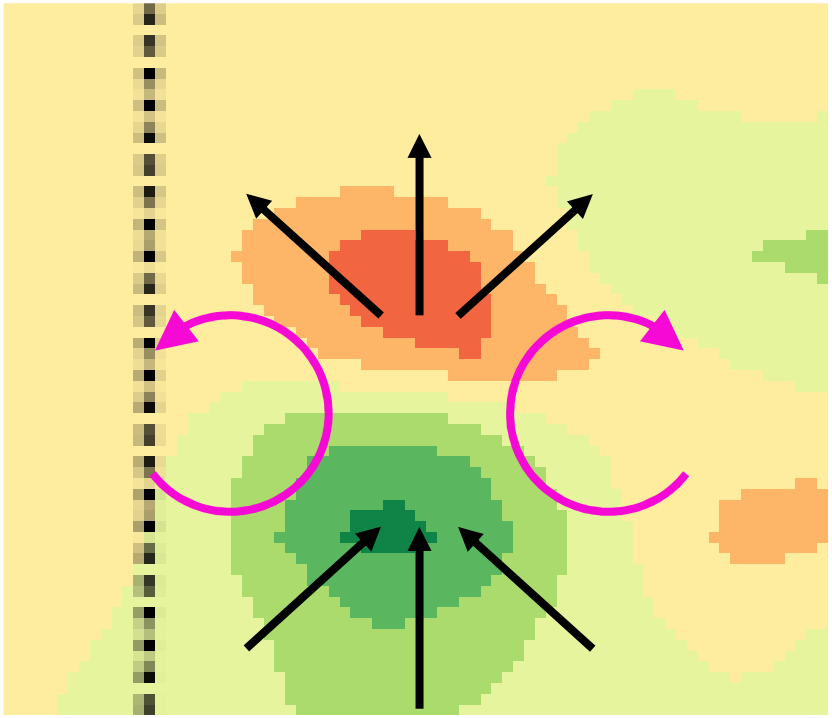
25 February 2014, near 2W, 4N

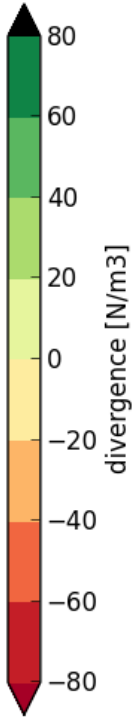


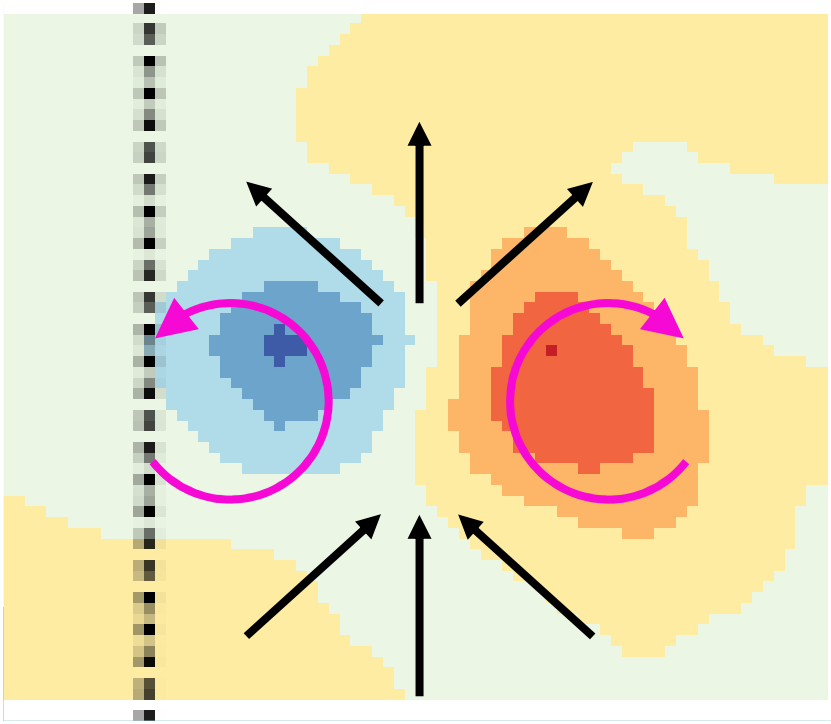


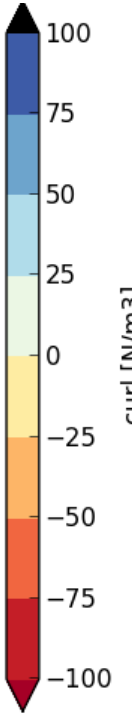


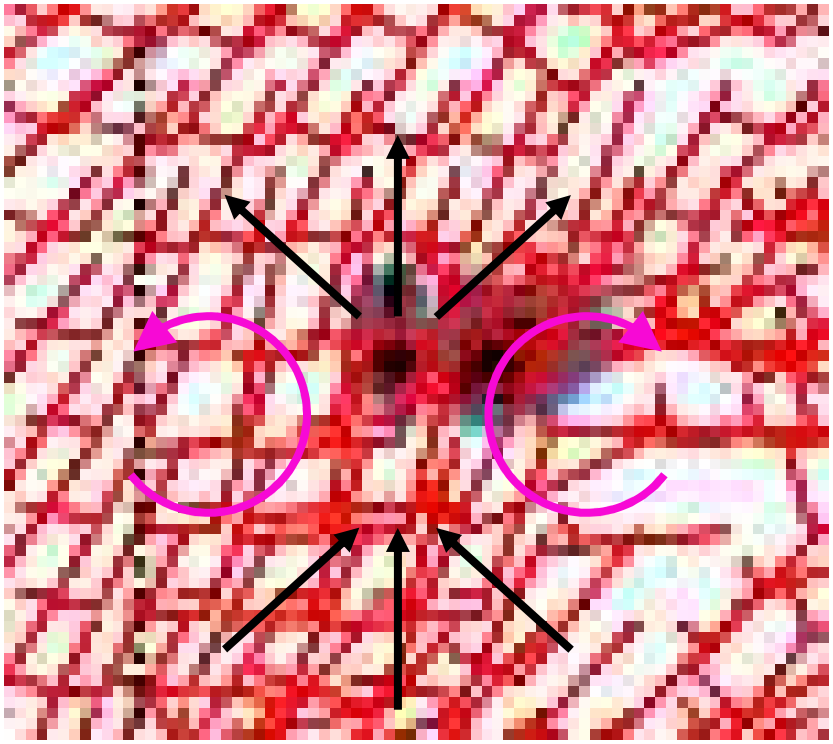






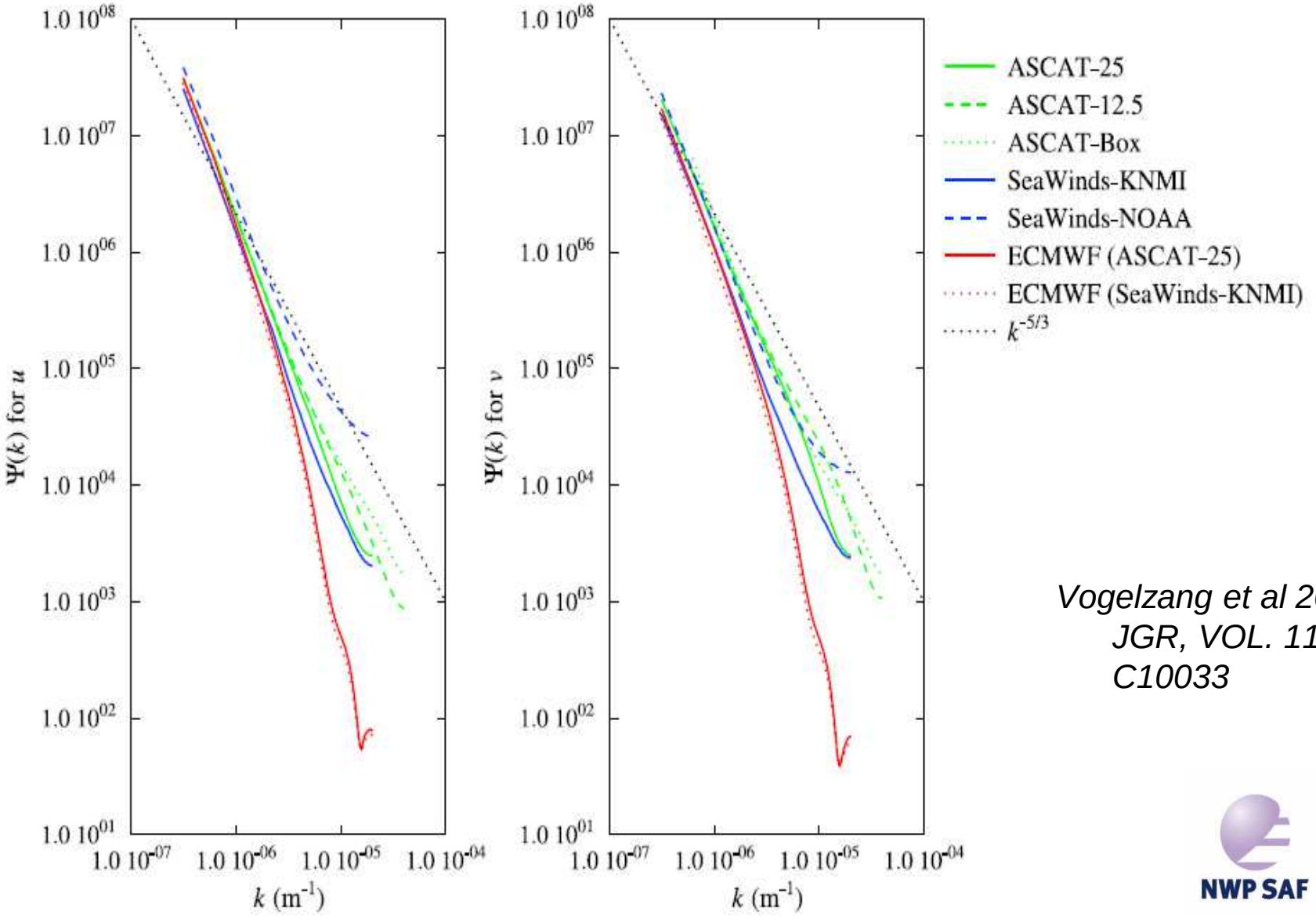






- Convergence and curl structures associated with convective cell
- Inflow convergence
- Precipitation is associated with wind downburst
- Shear zones with curl (+ and -)

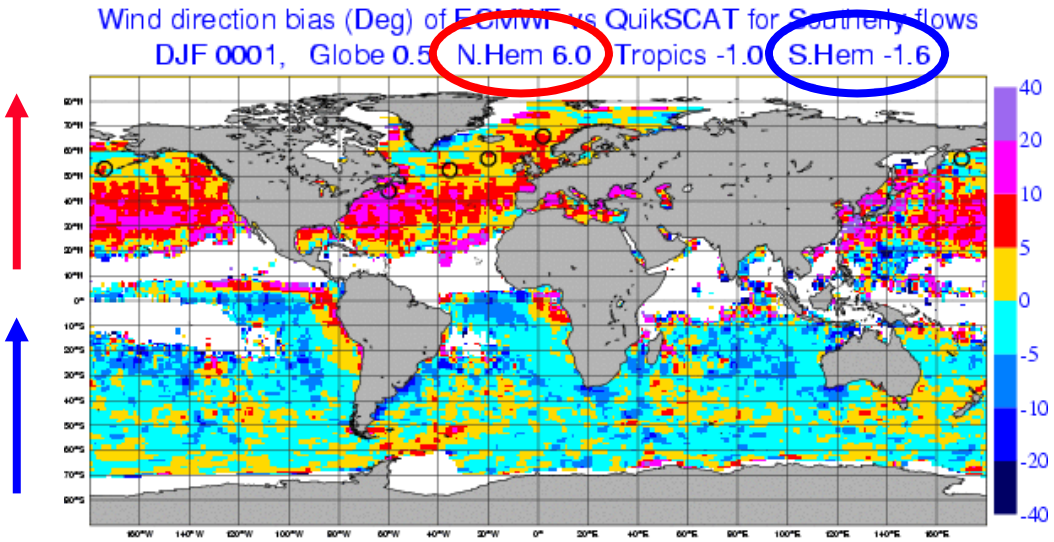
Resolution

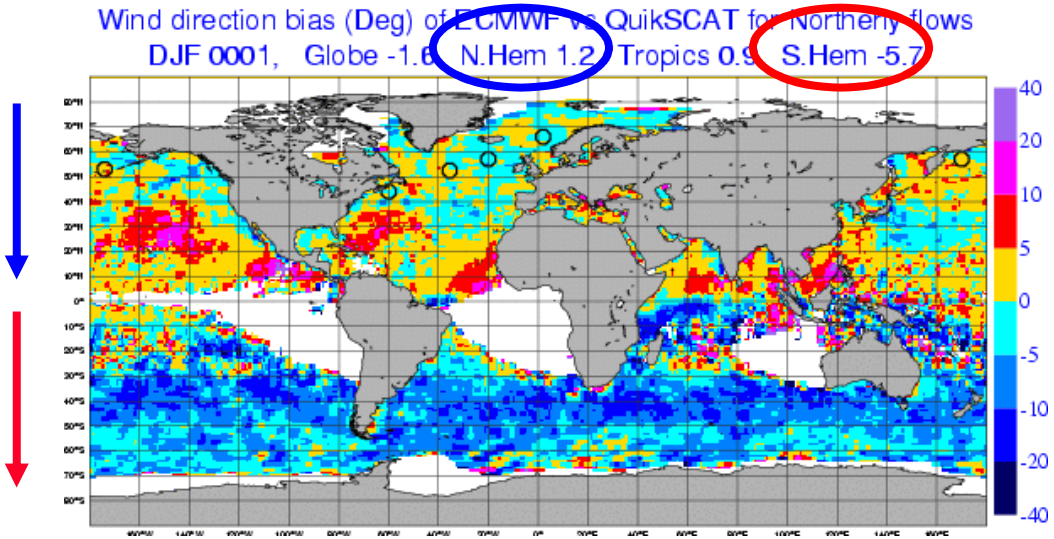


Vogelzang et al 2011, JGR, VOL. 116, C10033

NWP SAF OSI SAF

Lack of cross-isobar flow in NWP





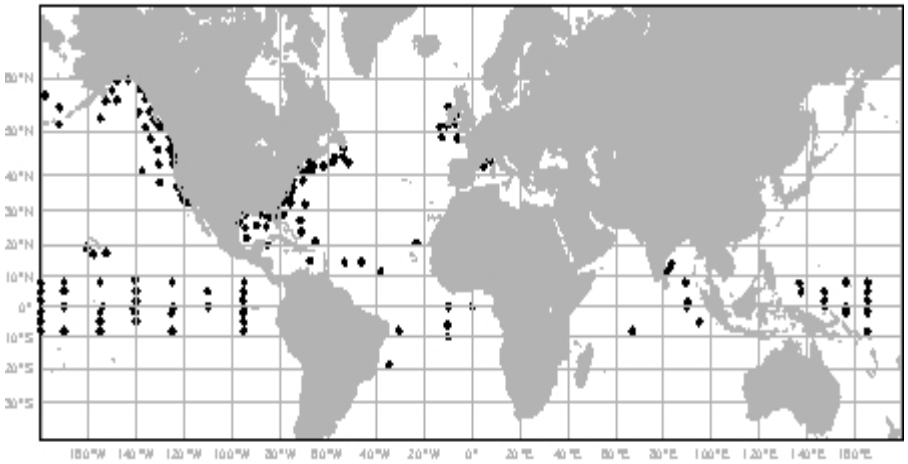
QuikSCAT vs model wind dir
Stratify w.r.t. Northerly, Southerly wind direction.
(Dec 2000 – Feb 2001)

- **Large effect warm advection**
- **Small effect cold advection**
- **Similar results for NCEP**

A. Brown et al., Sandu et al.

(R) Hans Hersbach

Triple collocation



Data from November 2012 to January 2013

- Errors on scatterometer scale
- A and B very similar

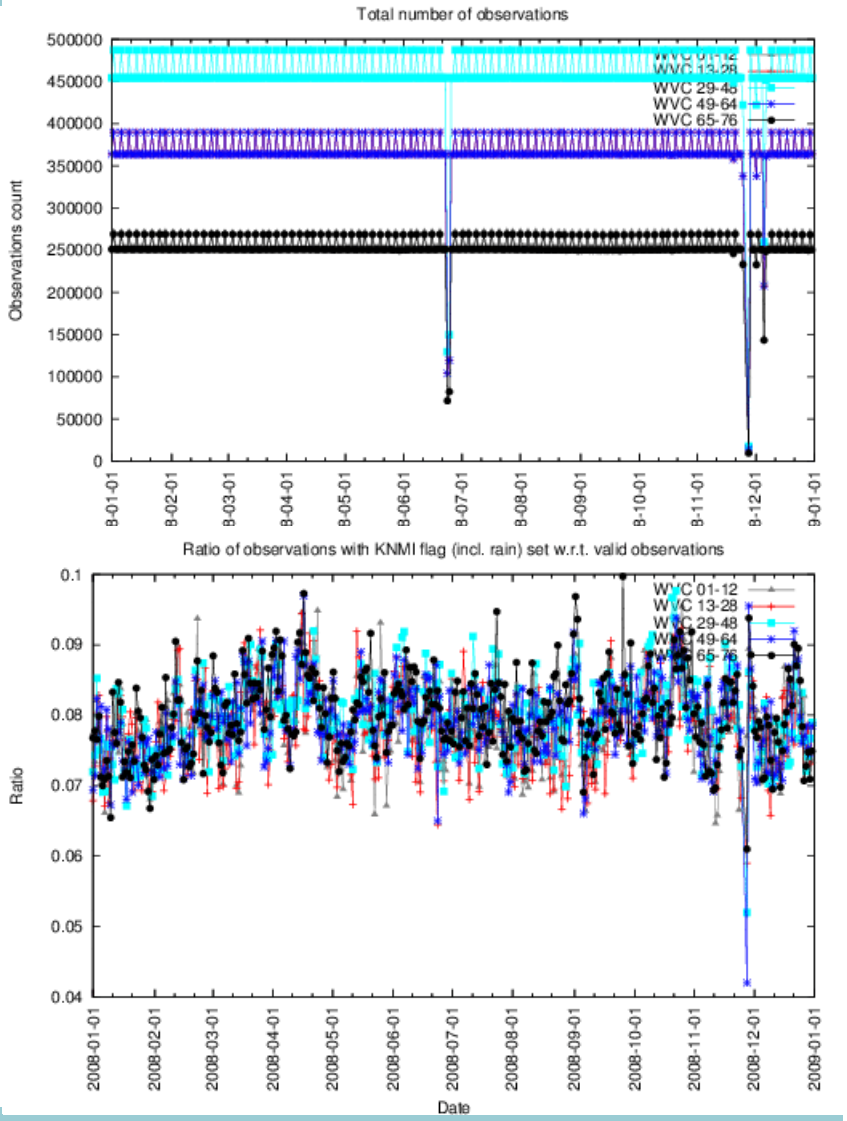
	Scatterometer		Buoys		ECMWF	
m/s	σ_u	σ_v	σ_u	σ_v	σ_u	σ_v
ASCAT-A 25-km	0.63	0.71	1.21	1.35	1.39	1.44
ASCAT-B 25-km	0.63	0.66	1.26	1.39	1.38	1.42
ASCAT-A Coastal	0.76	0.84	1.18	1.34	1.54	1.57
ASCAT-B Coastal	0.81	0.79	1.24	1.35	1.53	1.57

Planning (Reprocessing)

- We plan to re-process the following inter-calibrated data sets linked to OSI SAF plans
- Metop-A ASCAT winds and ice probabilities, 25 km and 12.5 km Coastal, 2007-2013, data set to become available in 2015
- QuikSCAT SeaWinds winds and ice probabilities, 50 and 25 km, 1999-2009, data set now available
- ERS-1 and ERS-2 winds, 25 km, 1991-2001, availability depending on the ESA SCIROCCO project to provide consistency between ERS and ASCAT backscatter records (2016)
- Oceansat-2 OSCAT winds and ice probabilities, 50 and 25 km, 2009 to 2014, to be reprocessed in 2016
- Perhaps HY2A winds from 2011 to 2015
- In this way we can create a continuous ERA* ocean winds data record from 1991 to today

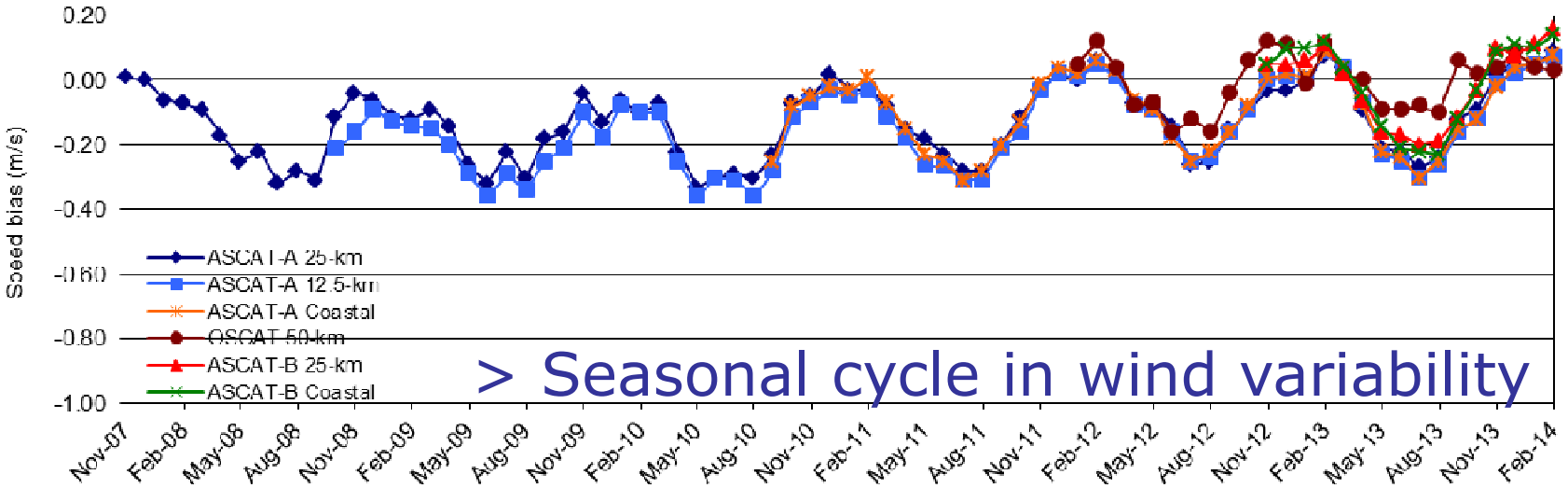
Monitoring

- Exploit NRT experience
- Daily averages of several parameters are plotted over the entire time range in order to detect any missing data or anomalies
- Different parts of the swath are considered separately
- Important quality indicators are wind speed difference w.r.t. ECMWF winds, mean MLE and number of QC-ed WVCs
- Weekly ocean calibration
- Deviations in product quality (anomalies) usually appear as a step in one or more of the plots



Monitoring - Buoy Collocations

- Monthly statistics of scatterometer winds vs. buoy winds are being made
- Plot below shows the buoy statistics of several near-real time OSI SAF wind products over time, the same will be done in the reprocessing and this will help to get optimal calibration of data from different instruments.



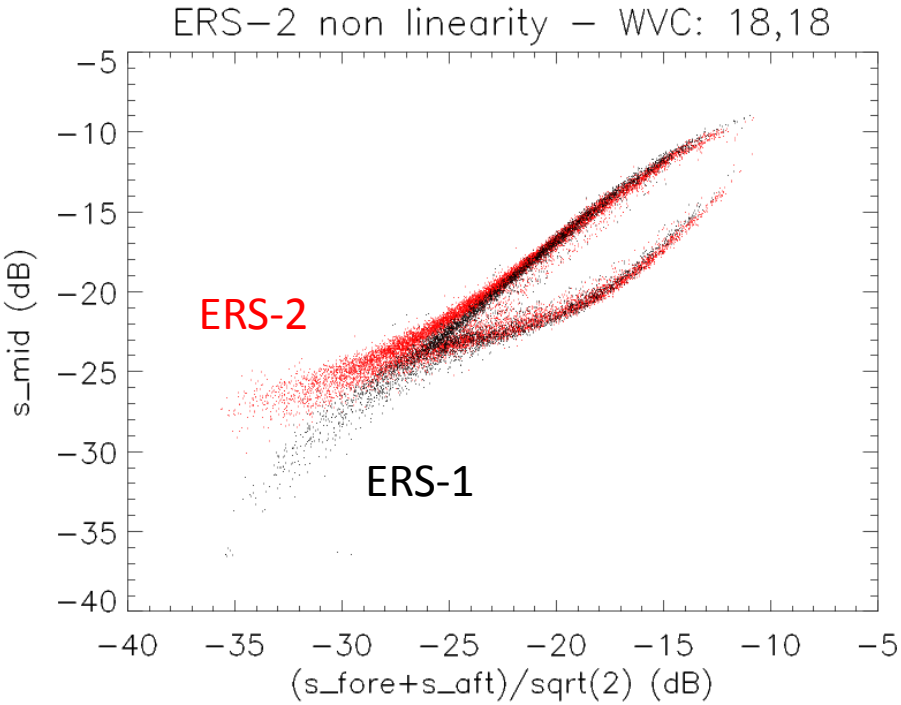
> Seasonal cycle in wind variability

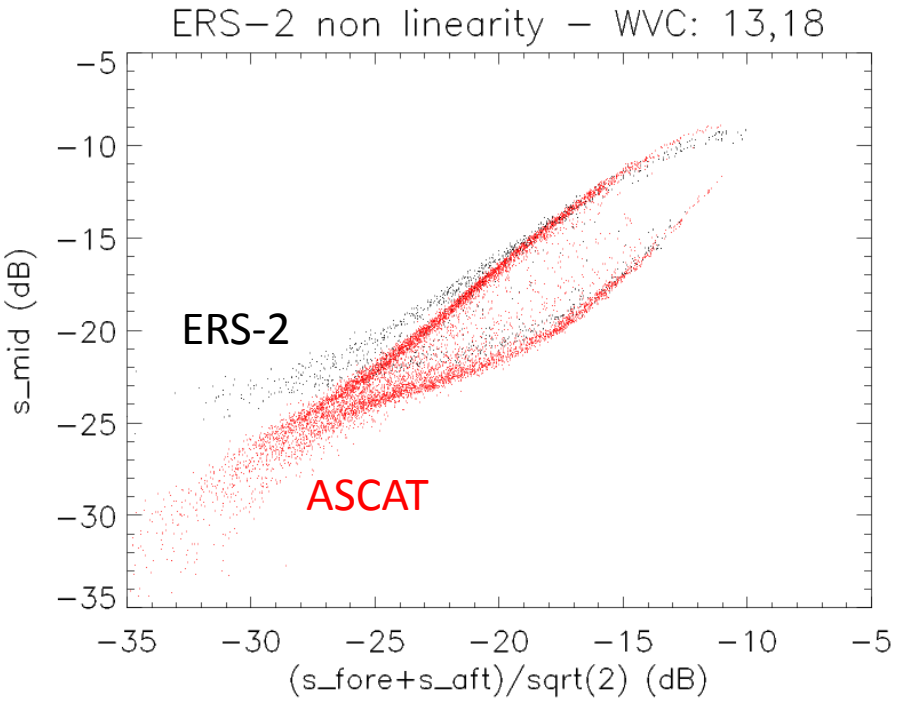
- Reprocessing – software and calibration

- Reprocessing will be done using the wind processing software packages which are publicly available in the NWP SAF (AWDP, PenWP and its predecessors)
- Data from different sensors will be inter-calibrated using buoy winds, ECMWF model winds and established methods, such as triple collocation
- Our goal is to calibrate the winds to a level as close as possible to the moored buoy winds
- Follow GCOS guidelines

ERS1=ERS2=ASCAT?

- ERS-2 non-linearity
  - At low incidence angles (low backscatter)
  - Impact on CMOD5, as this is ERS heritage



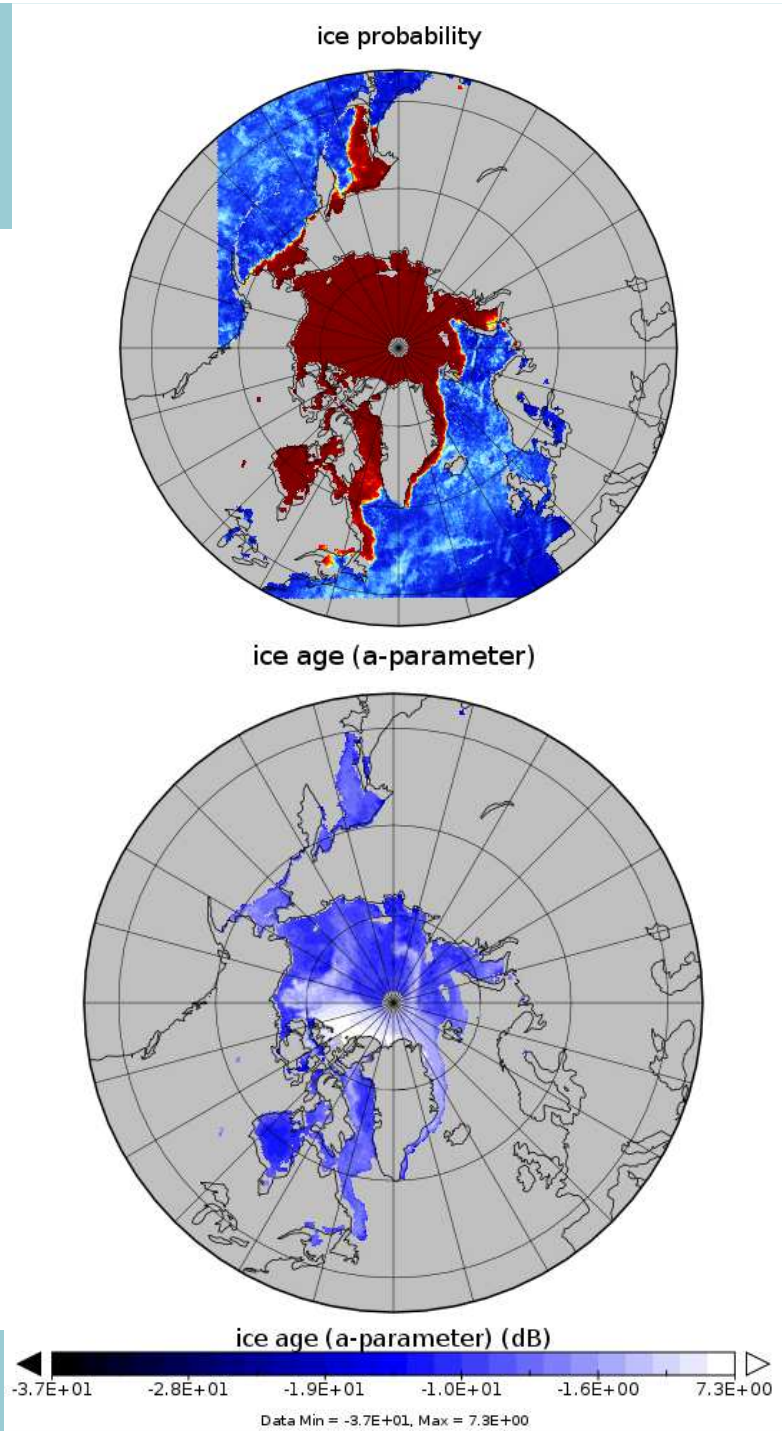


Wind and stress products and formats

- Level 2 swath backscatter, wind and ice data will be provided in BUFR format, identical to the near-real time data
- Level 2 swath data for wind, stress, rotation and divergence in NetCDF
- All NetCDF data according to the climate (CF) conventions
- Separate level 2 products for wind/stress on one hand and rotation/divergence on the other hand are considered since the swath grids are slightly different and to maintain continuity in the current NetCDF level 2 products
- Level 3 data on lat/lon grid for wind, stress, rotation and divergence in NetCDF
- Working on Level 4 ERA*
- Data will be archived and made available in the EUMETSAT Data Centre, EU MyOcean archive and PO.DAAC (TBC)

Ice maps

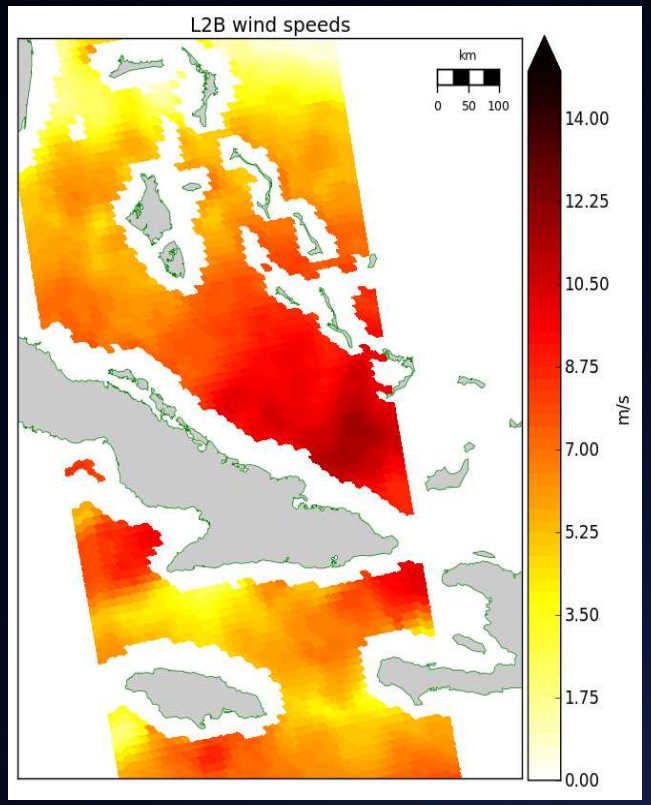
- Ice probability and ice age (A-parameter, albedo) are computed as part of the Bayesian ice screening procedure
- Daily ice maps in Polar Stereographic projection will be made available in NetCDF format
- The format is according to the NetCDF-CF conventions



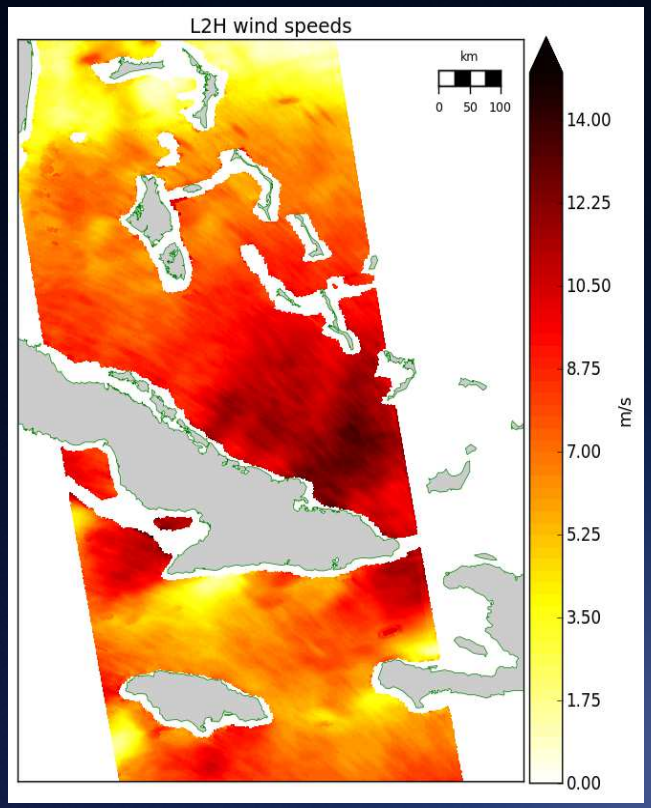
To do

- Reprocess ASCAT (2015) and ERS (2016)
- Refine ERA* procedure
- Validate ERA* mean and instantaneous corrections with buoys
- Validate wind difference variances at buoys
- Check diurnal dependency of mean and variances across scatterometers (ASCAT, QSCAT, OSCAT)
- Invite β users, GlobCurrent, Copernicus
- After U10S, repeat for curl and divergence
- Provide visibility to ERA*
- Find support for Ana

High resolution winds and coastal masking



Nominal winds



Winds using LCR < -20 dB

(R. Lindsley)

Next step: dynamically chosen Land Contaminati on Ratio (LCR) threshold

$$\mathrm{LCR} \triangleq \frac{\iint_{\mathrm{land}} h_i(x,y)\,dx\,dy}{\iint_{\mathrm{SRF}} h_i(x,y)\,dx\,dy} \approx \boxed{\frac{\sum_{x,y} L[x,y]h_i[x,y]}{\sum_{x,y} h_i[x,y]}}$$

land	$\mathrm{LCR} = 1$
ocean	$\mathrm{LCR} = 0$
mixture	$0 < \mathrm{LCR} < 1$

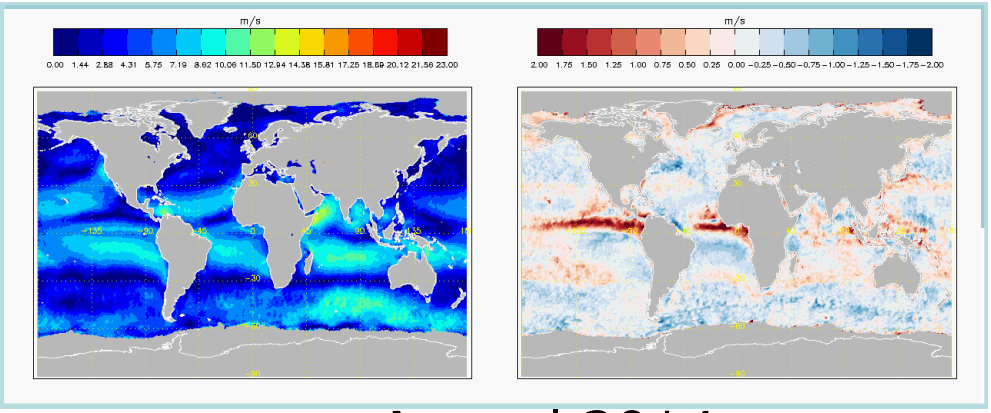
Summary

- U10S climate data records will be created from several scatterometer missions spanning 25 years in total
- Focus will be on a proper inter-calibration of the various data records
- The latest versions of wind processing software will be used to get state of the art wind products
- Information will be provided to estimate sampling errors
- Wind and ice map data will be provided by various archives both in BUFR and user-friendly NetCDF-CF formats

- Work on NetCDF-CF standards and internationally agreed DOIs
- Copernicus Marine Environment Monitoring Service supports L3 and L4 product developments

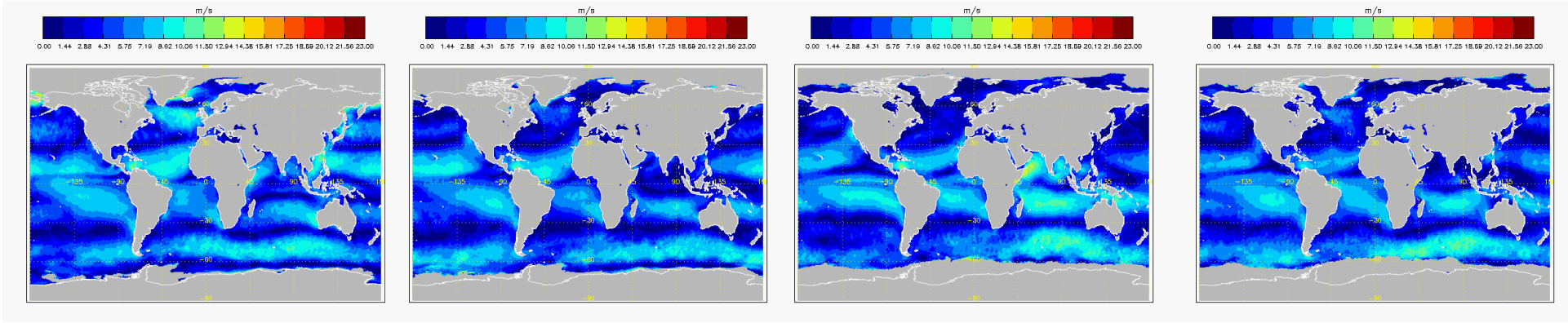
- scat@knmi.nl
- www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/
- www.myocean.eu
- podaac.jpl.nasa.gov/ (TBC)

Wind Speed

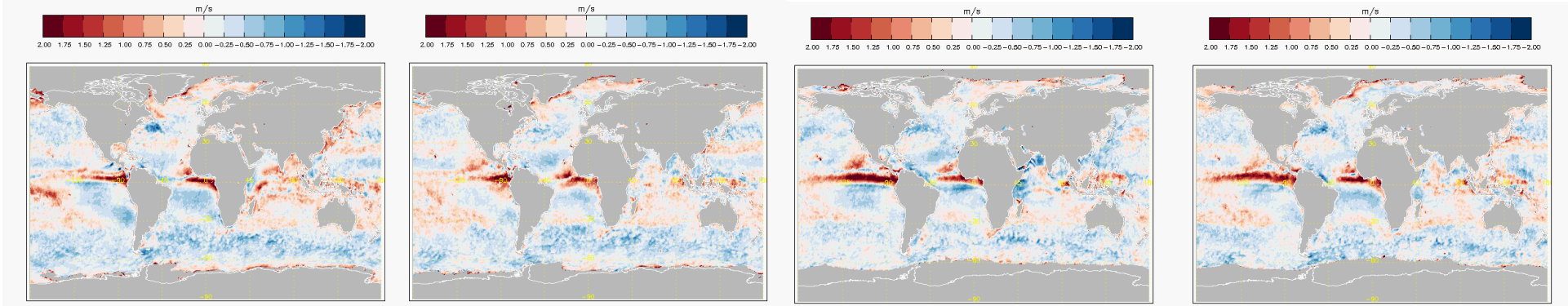


ASCAT

Annual 2014

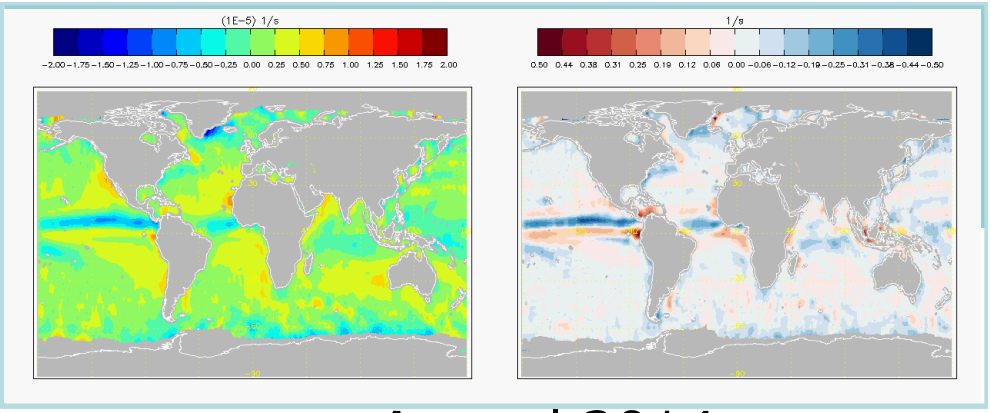


DJF MAM JJA SON



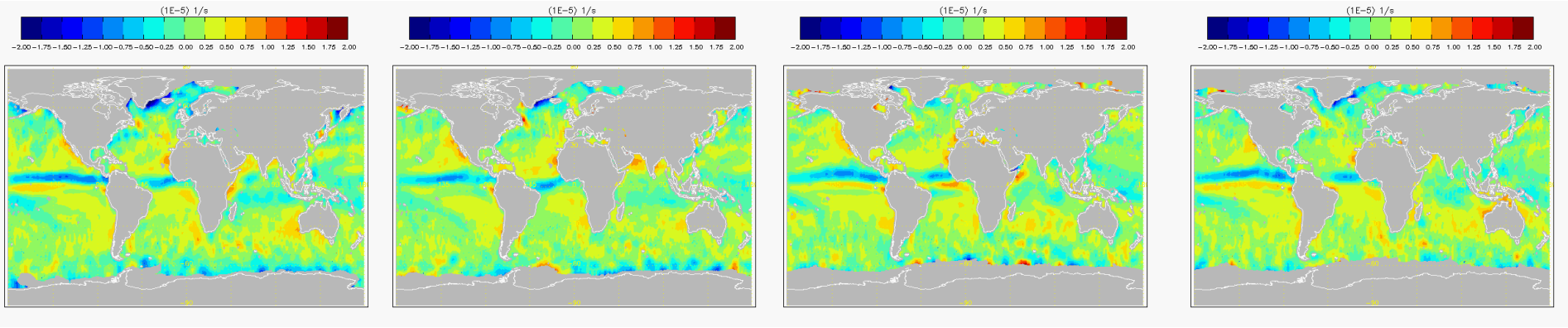
Anomaly (ASCAT-NWP)

Wind Divergence

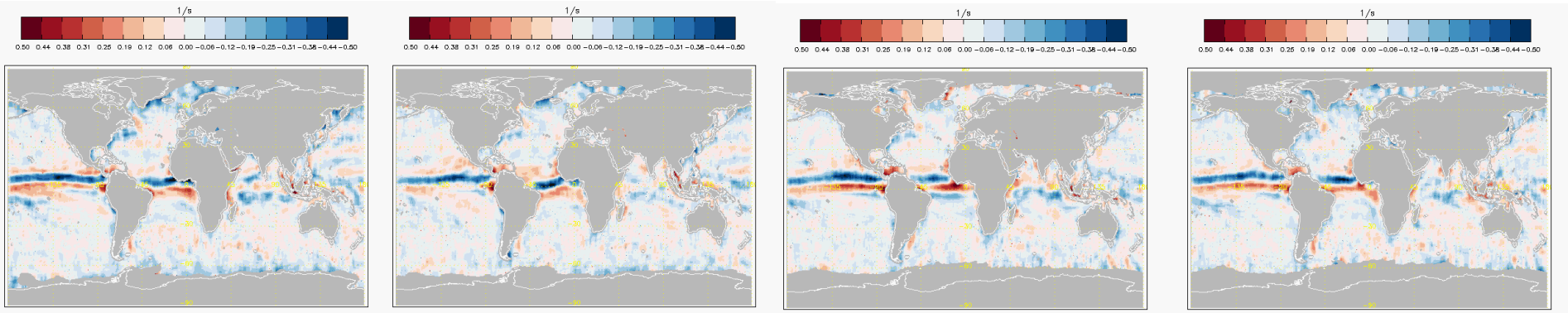


ASCAT

Annual 2014

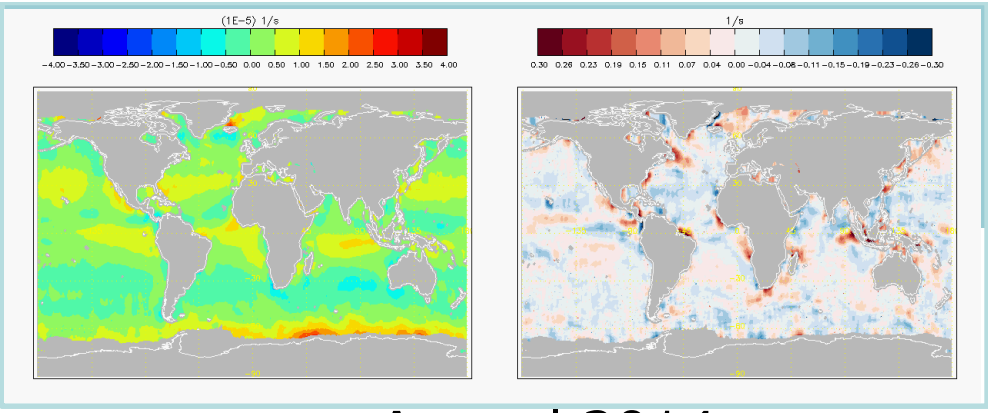


DJF MAM JJA SON



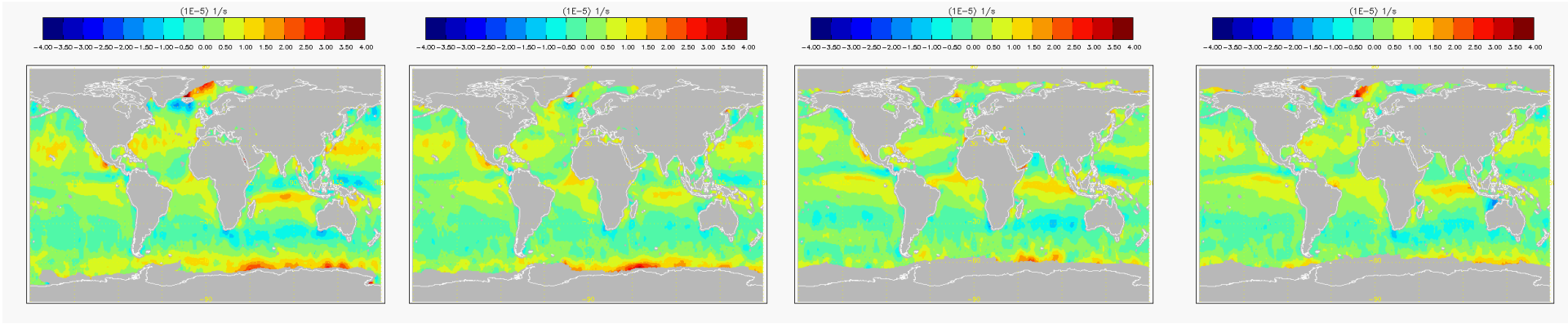
Anomaly (ASCAT-NWP)

Wind Curl



ASCAT

Annual 2014



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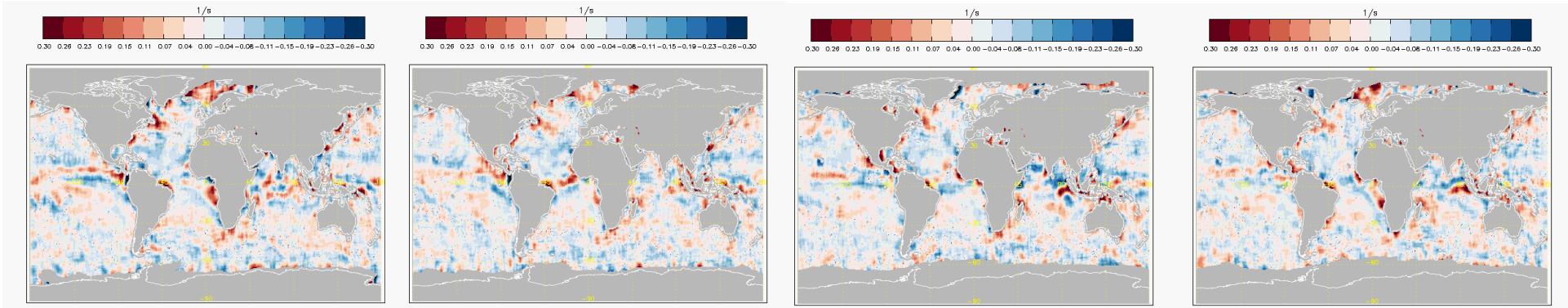
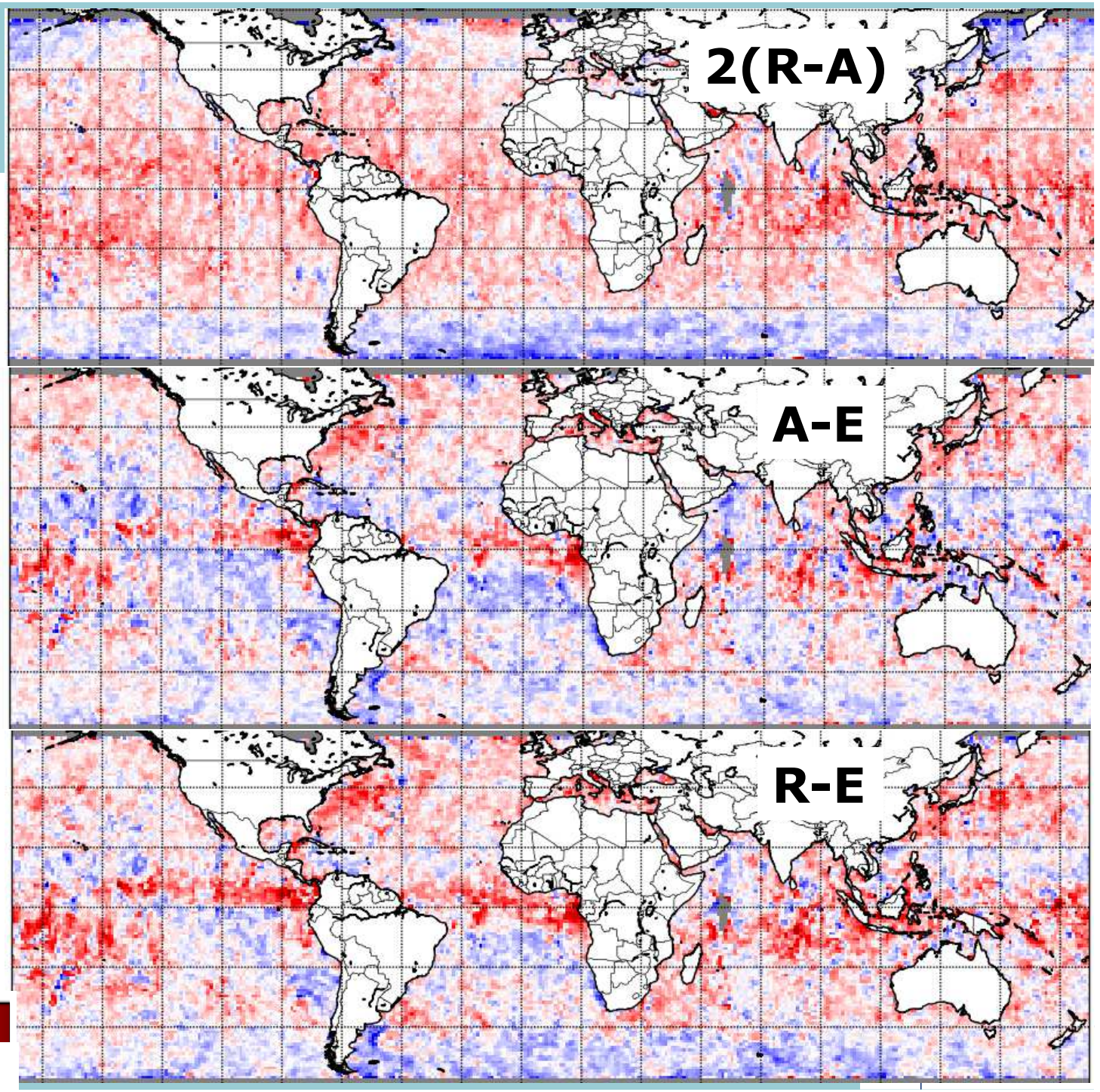


Anomaly (ASCAT-NWP)

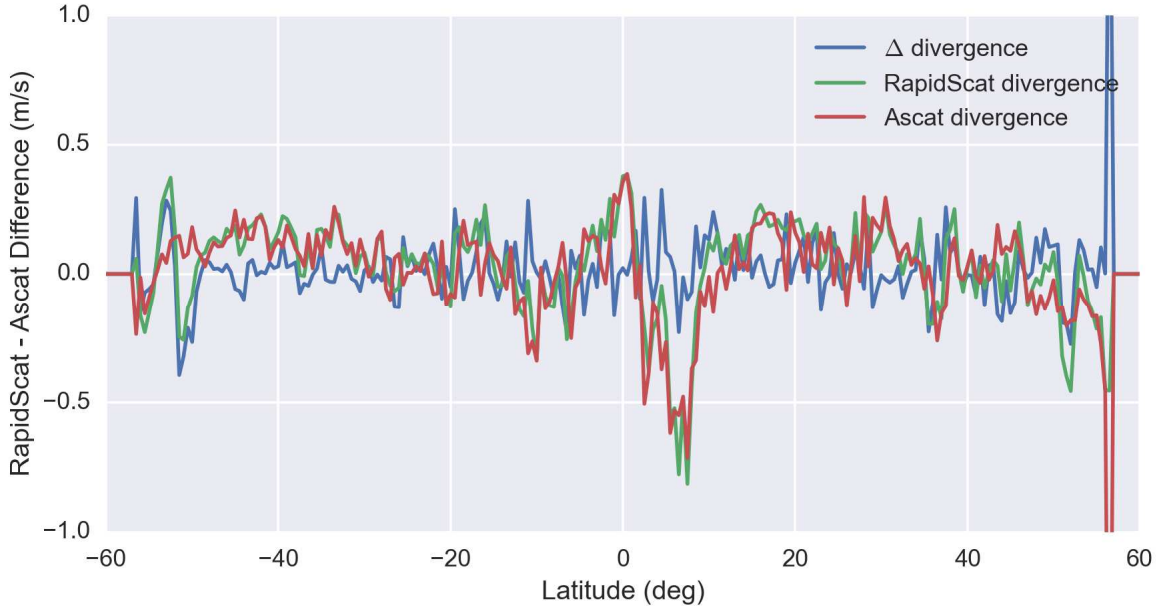
All Δs

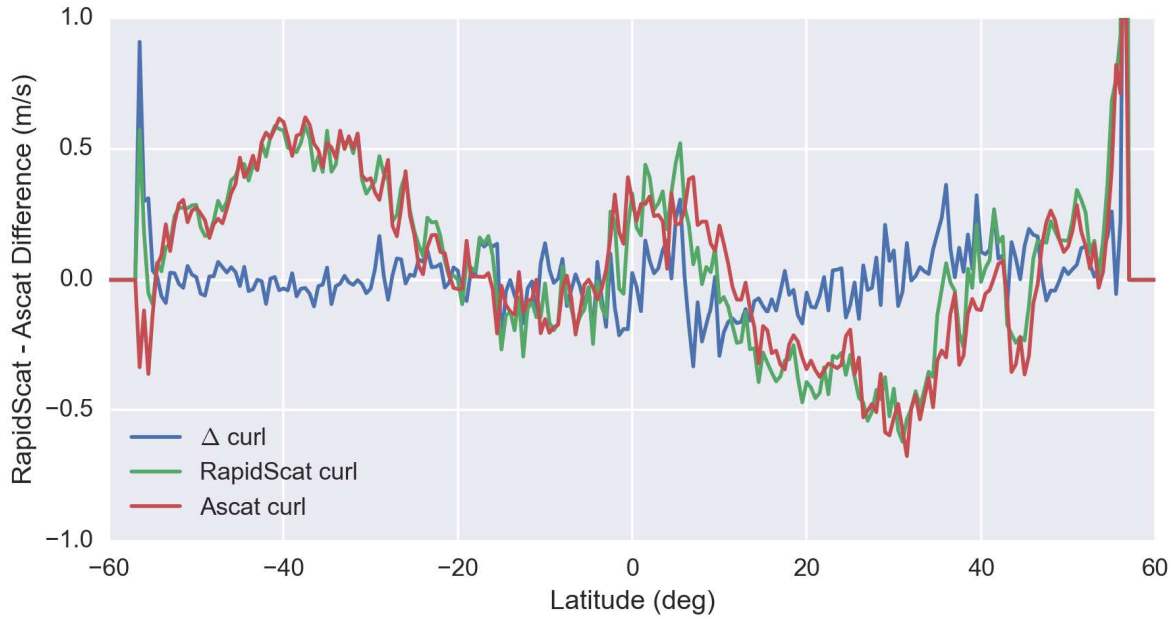
- All WVCs accepted by both
- A/RSCAT rejects 1/10%
  - High latitude low bias RSCAT
  - Convection stands out vs ECMWF
  - RSCAT and ASCAT much agree on small scales! (must be wind, no rain!)
  - RSCAT little more red though in tropics (rain?)
  - Currents?



Zonally Averaged Wind Divergence and Curl

- C- and Ku-band winds are very similar
- Also, curl and divergence show very similar latitudinal variation
- Not hindered by a Ku-band rain effect





E.Rodriguez

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 (LLCJ), surface layer and moist convection parameterisations

- NWP community: Continuous validation and improvement of models and data assimilation