The Usage of Scatterometer Data at ECMWF

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Overview

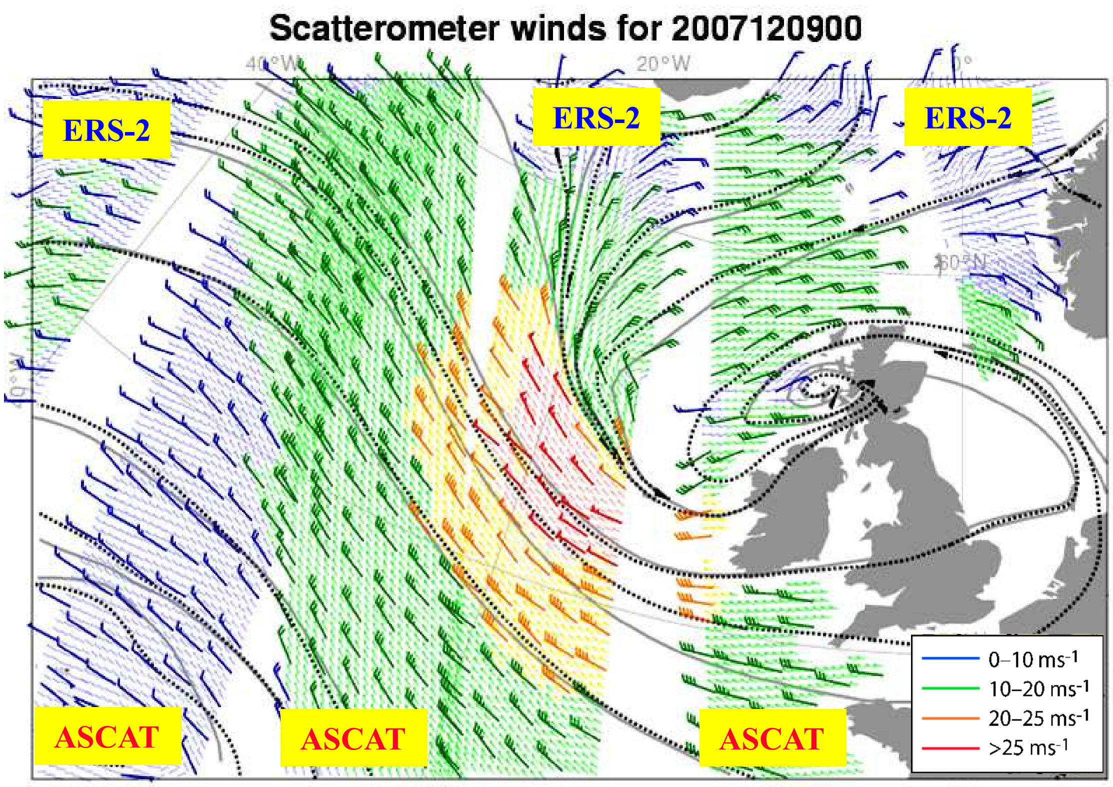
- Usage/Inter-comparison of scatterometer data
- Stability effects
- CMOD5.N
- Operational change in usage of QuikSCAT
- Ocean currents

ECMWF WINDS USED FOR STATISTICS ARE FIRST GUESS,

(I.E., START POINT OF THE 4D-VAR ANALYSIS)

EXCEPT FOR STREAMLINES

Usage of Scatterometer data at ECMWF



6-hour window

Surface-wind streamlines:
ECMWF analysis
ECMWF First-Guess

Dark barbs: used
Light barbs: not used

Operational assimilation:

- **Coverage almost every 6 hours**
- **ERS-2 (June 1996)**
- **QuikSCAT (Jan 2002)**
- **ASCAT (June 2007)**

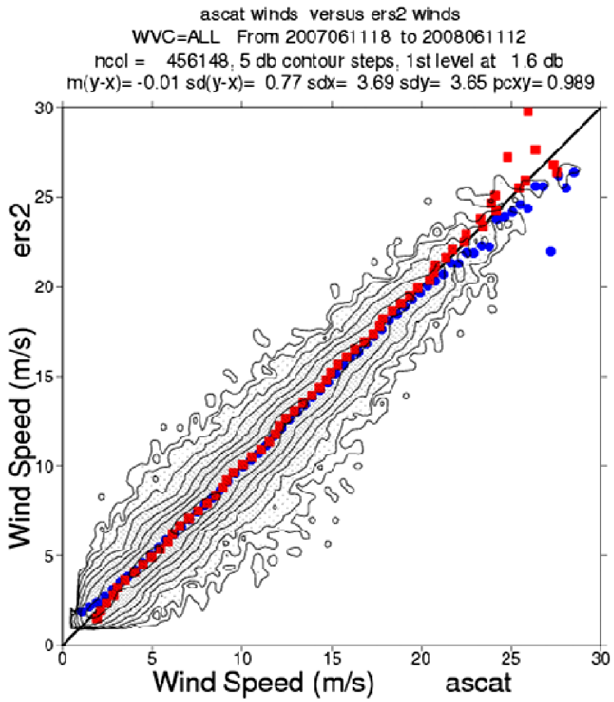
Wind product:

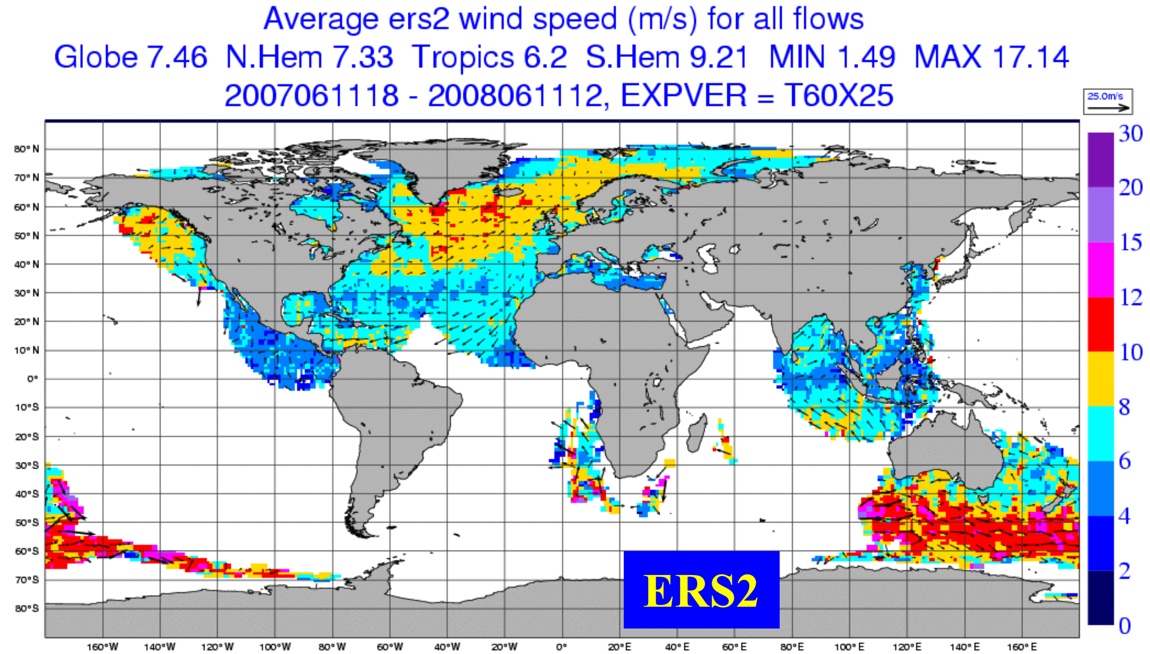
- **Invert winds in-house**
- **Apply bias correction**
- **Quality control, thinning**

Observation operator:

- **As vector wind at 10m height**
- **Neglect stability effects**
- **As wind in absolute frame**

Inter-comparison ERS-2 and ASCAT



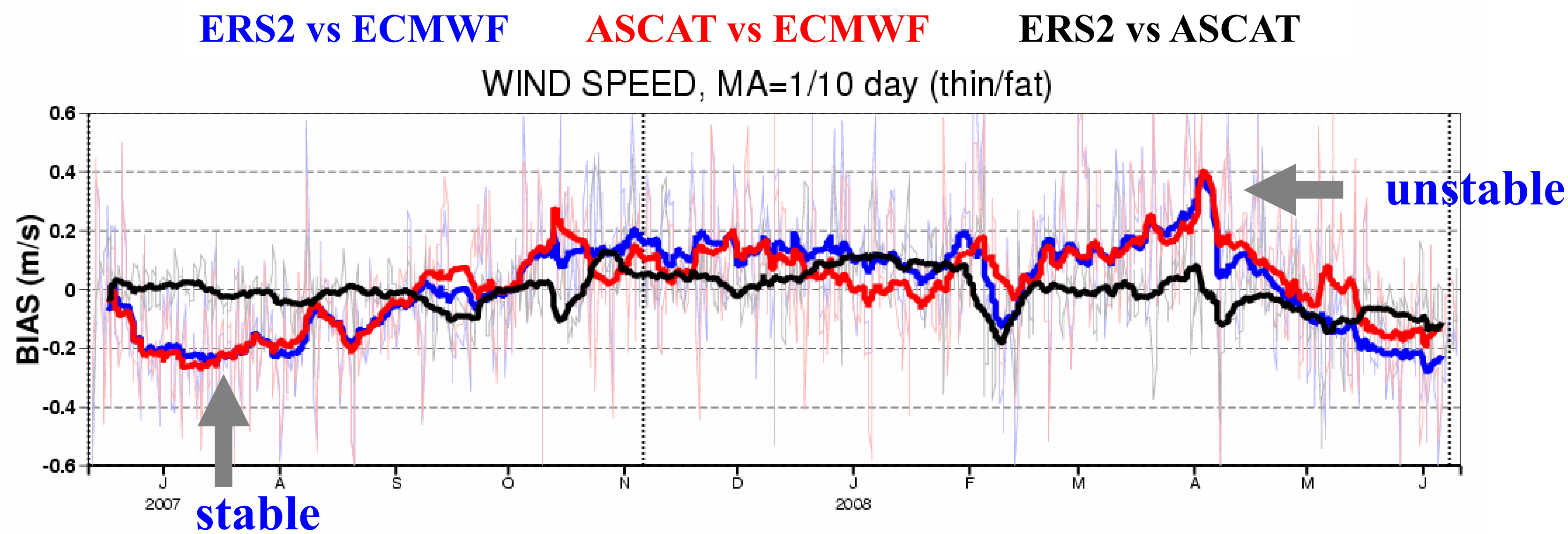


Wind speed errors ~ 0.5 m/s

Relative error in wind direction larger

- **Mainly due to ERS-2**

Time series for collocation set

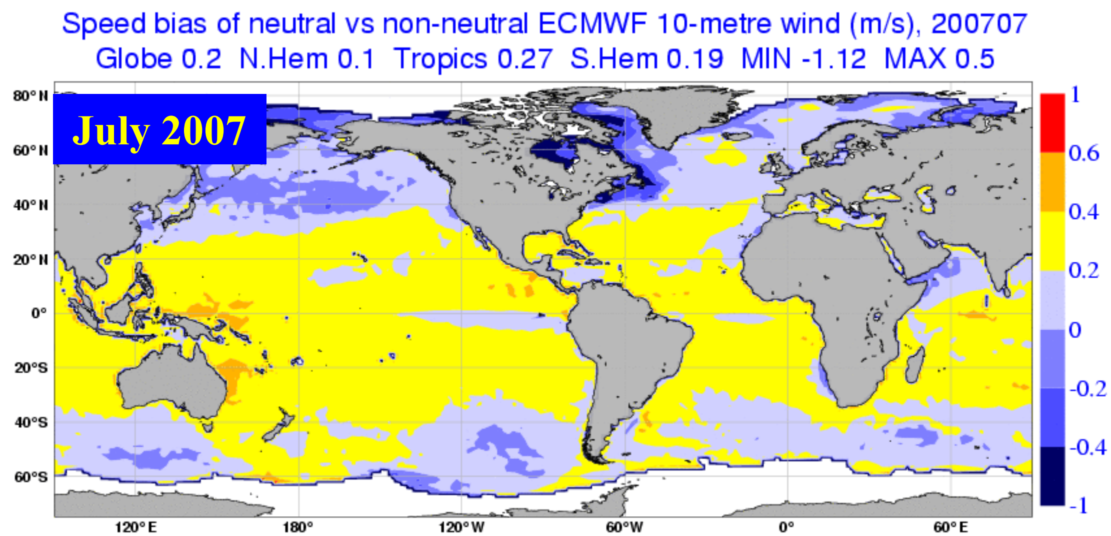


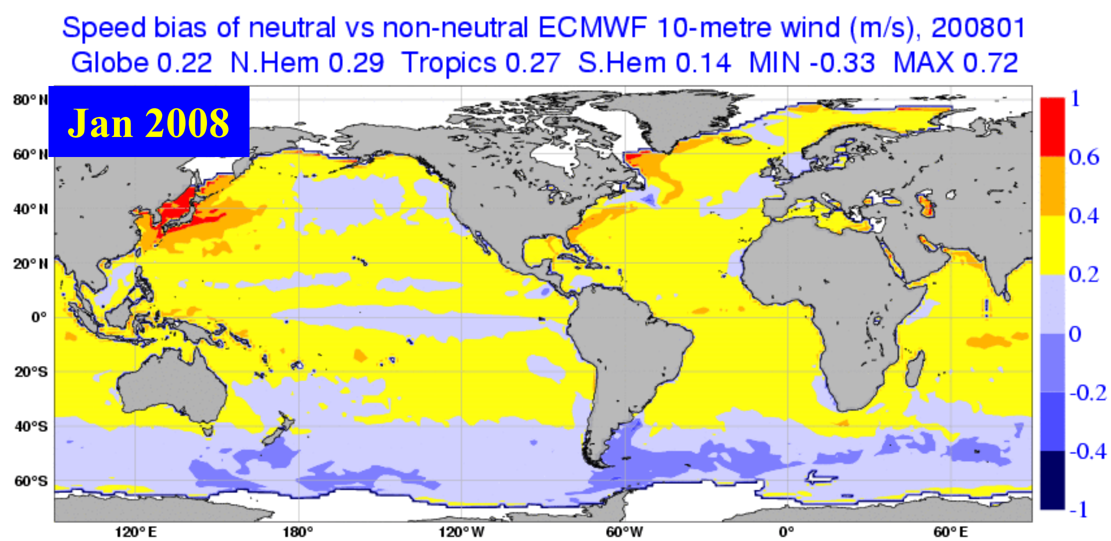
Seasonal bias of ERS2 vs ECMWF, ASCAT vs ECMWF:

- **Due to stability effects, …,**
- **Not really issue for ERS2 vs ASCAT**
  - ✓ **Allows for monitoring of both products in one go**

ECMWF

ECMWF neutral vs non-neutral wind speed



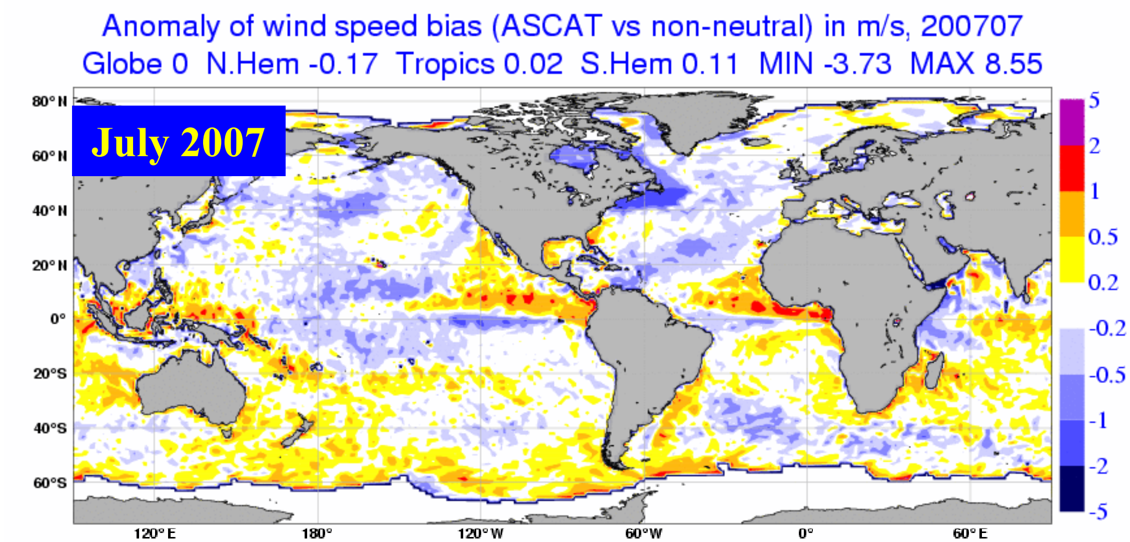


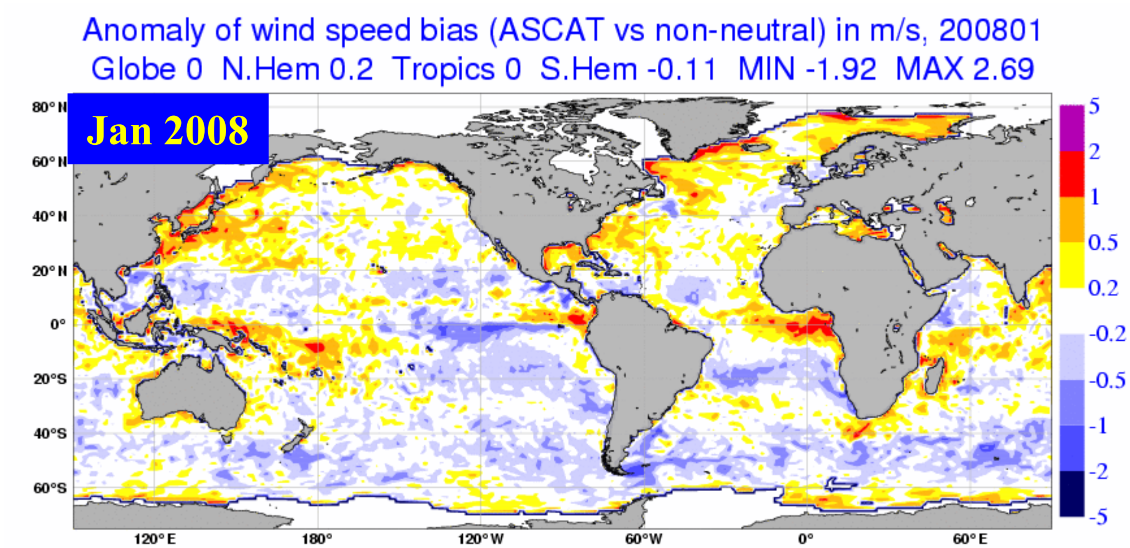
Neutral ~0.2 m/s stronger

- **Summer: stable (warm air, cold ocean)**
- **Winter: unstable (cold air, warm ocean)**

ECMWF

ASCAT vs ECMWF non-neutral wind





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- **Summer: stable (warm air, cold ocean)**
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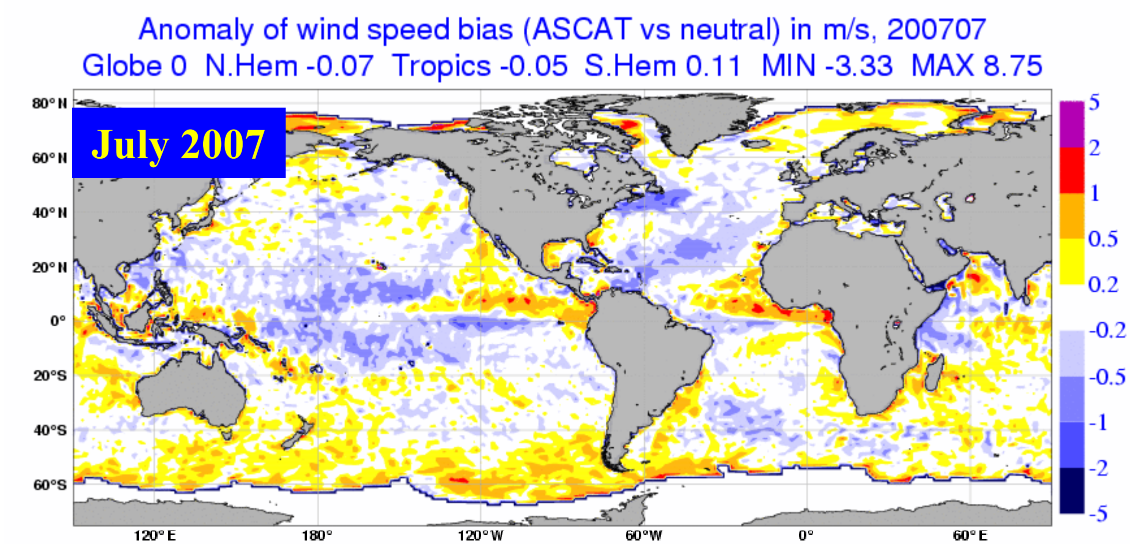
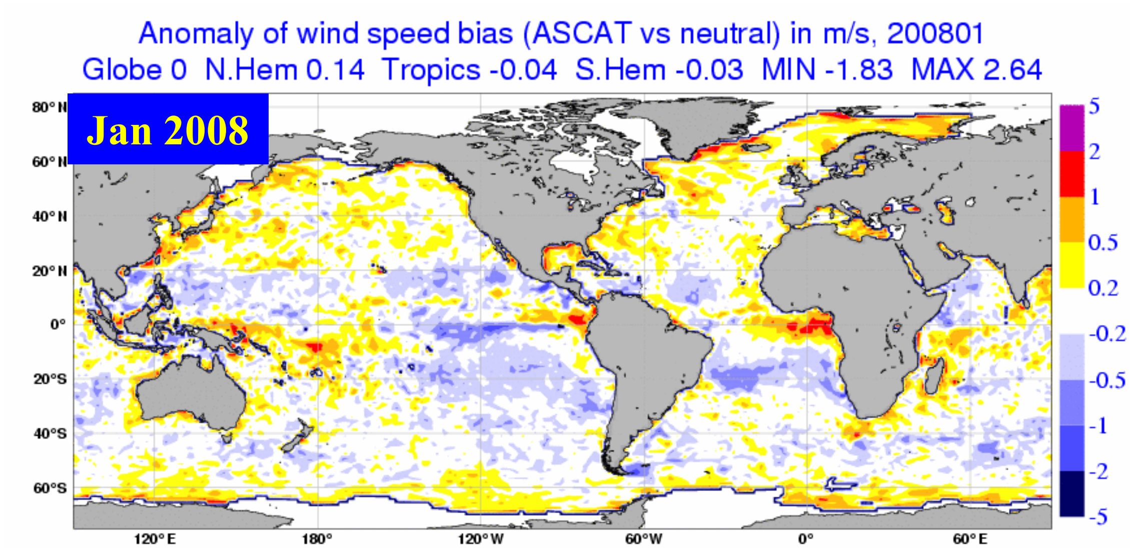
Bias correlates with stability

ASCAT vs ECMWF neutral wind





Neutral ~0.2 m/s stronger

- **Summer: stable (warm air, cold ocean)**
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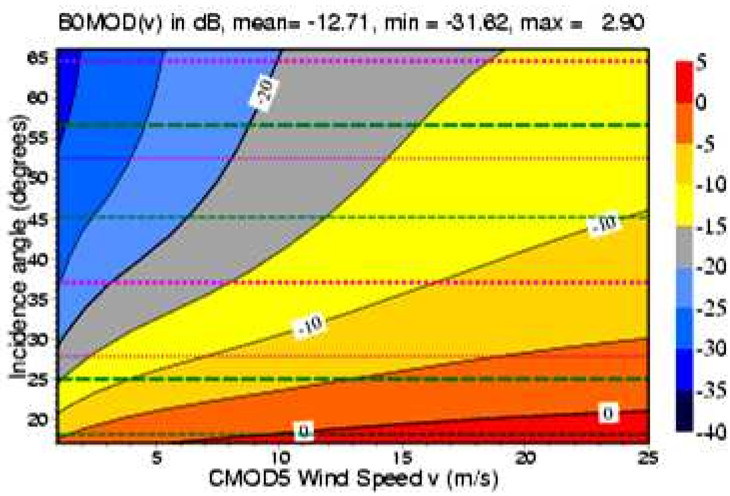
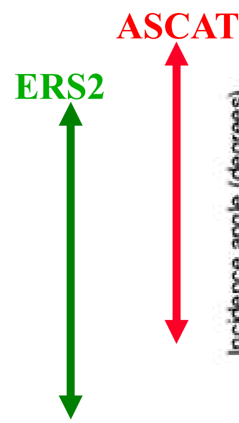
Bias correlates with stability

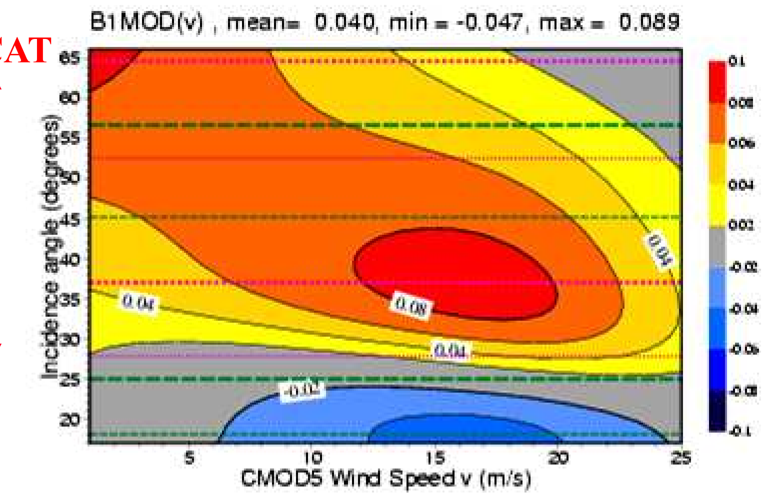
Residual effects:

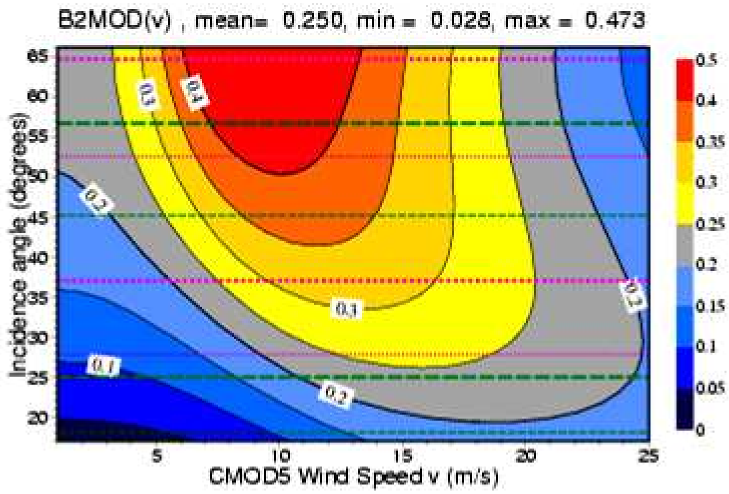
- **Stability dependent model error**
- **Other model errors**
- **Ocean currents**
- **Sea state effects**

CMOD5.N









CMOD5:

- Tuned to non-neutral wind (~0.2 m/s)
- Biased low to buoys by ~ 0.5 m/s

CMOD5N:

- Tune to neutral wind
- Shift: CMOD5N = CMOD5 + 0.7 m/s
- By refit of its 28 coefficients

- Good comparison ERS2/ASCAT with ECMWF neutral wind speed

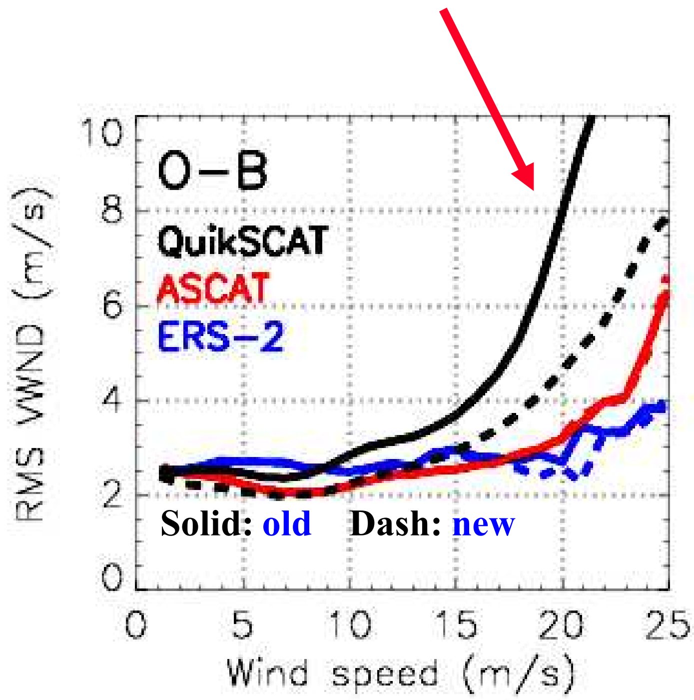
ECMWF

Usage of 4 ambiguities from QuikSCAT

ASCAT/ERS-2: two ambiguous wind solutions
QuikSCAT: four solutions

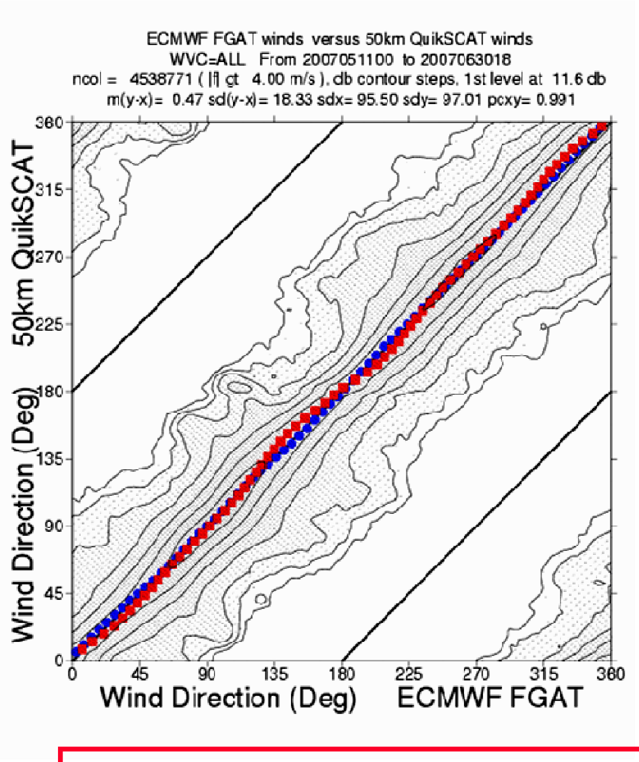
Departure statistics for QuikSCAT

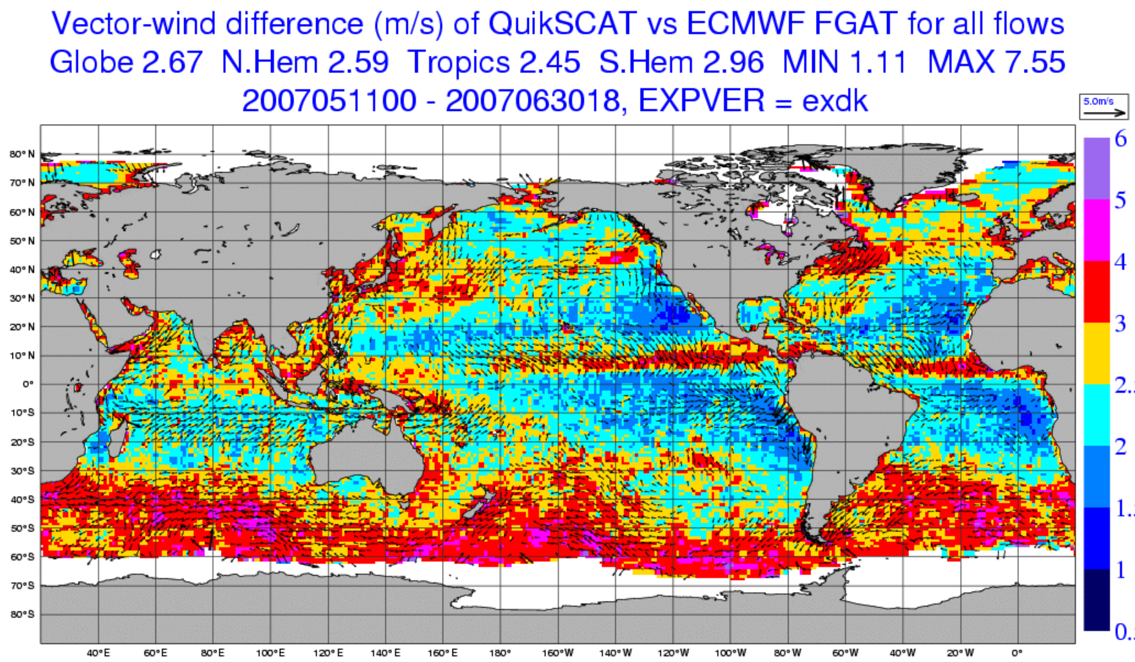
- **Not optimal, especially for strong winds**
- **Improves when select from 4 wind solutions**
- **Some positive impact on forecast skill**
- **Introduced on 3 June 2008**



ECMWF

Effect on vector wind (~ cost function)
Quikscat use 2 wind solutions

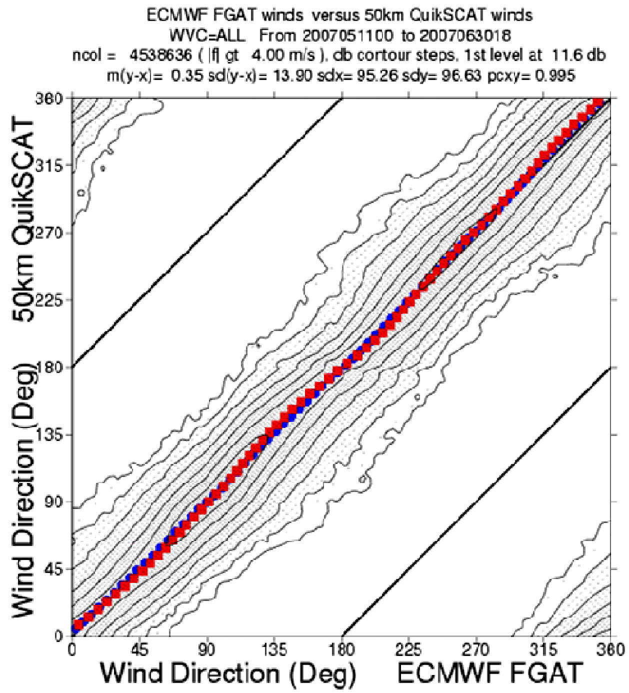


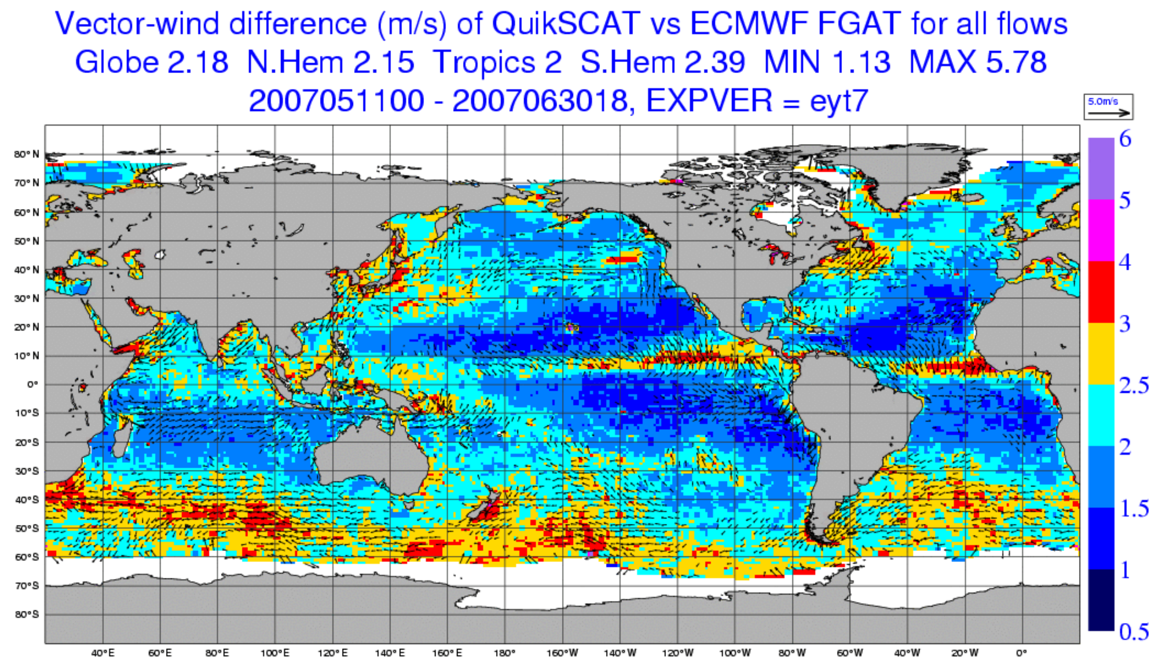


(O-B) STDV	wind speed	wind direction
QSCAT (2 amb)	1.31 m/s	18.3 Deg
QSCAT (4 amb)	1.28 m/s	13.9 Deg
ASCAT	1.29 m/s	14.3 Deg

ECMWF

Effect on vector wind (~ cost function)
Quikscat use 4 wind solutions





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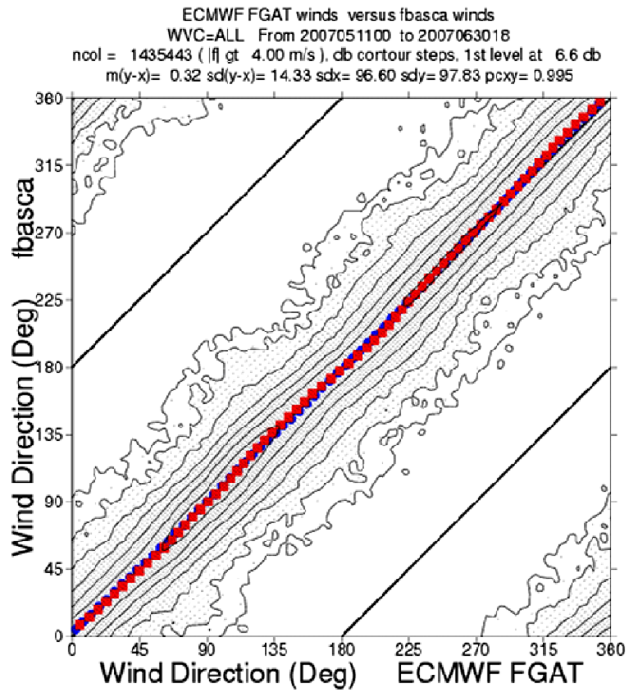

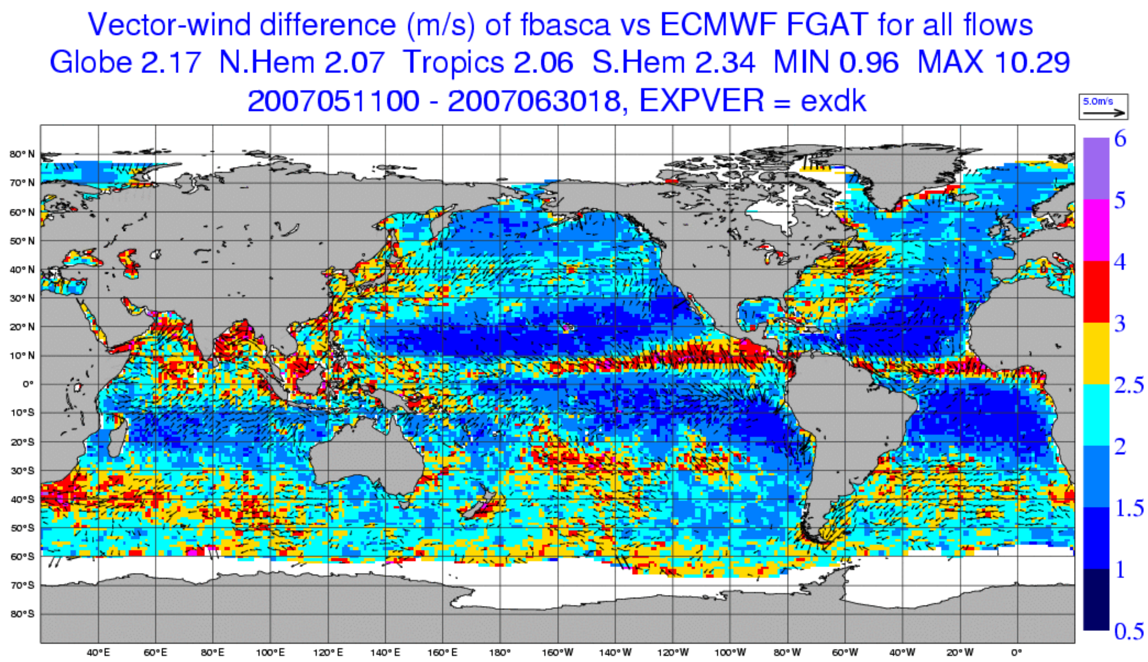

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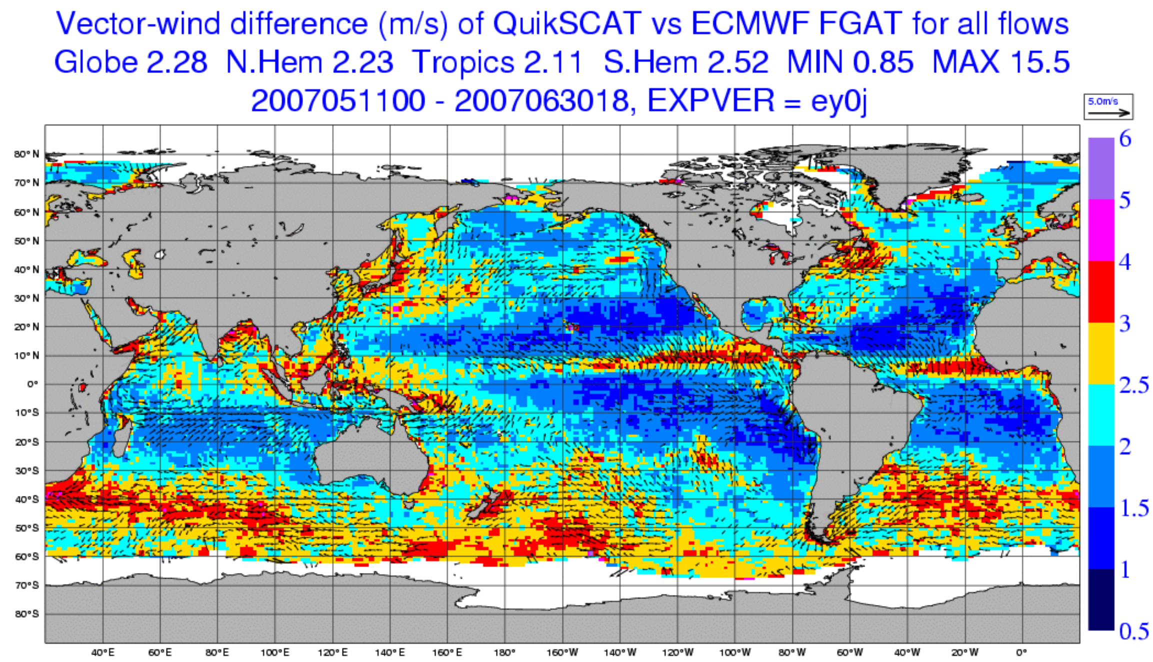
ECMWF

Effect on vector wind (~ cost function)
New Quikscat stream, use 4 wind solutions



- ➢Use new JPL rainflag,
- ➢Rather than flag used at ECMWF:

(NOF index, Mp_rain_prob)

ECMWF

Usage of ocean current in the ECMWF forecast system

In the constant stress layer (Monin-Obukhov), enforce the correct boundary condition:

$$\frac{\partial \vec{\mathbf{u}}_{\mathrm{abs}}}{\partial z} = \frac{\vec{\mathbf{u}}_*}{\kappa(z+z_0)}\ \varphi_D\left(\frac{z+z_0}{L}\right), \qquad \vec{\mathbf{u}}_{\mathrm{abs}}(z=0) = \vec{\mathbf{u}}_{\mathrm{oc}}. \tag{1}$$

Define $\vec{\mathbf{u}}_{\mathrm{rel}}$ as (1), but with boundary condition: $\vec{\mathbf{u}}_{\mathrm{rel}}(0) = 0$.
Then:

$$\vec{\mathbf{u}}_{\mathrm{abs}}(z) = \vec{\mathbf{u}}_{\mathrm{rel}}(z) + \vec{\mathbf{u}}_{\mathrm{oc}}. \tag{2}$$

- (2) is valid for all values of z in the constant stress layer, including $z = 10\mathrm{m}$.
- $\vec{\mathbf{u}}_{\mathrm{rel}}(z)$ is related to the surface stress $\tau = \rho_a u_*^2$,
  e.g., for the neutral case ($\varphi_D = 1$):

$$\vec{\mathbf{u}}_{\mathrm{rel}} = \frac{\vec{\mathbf{u}}_*}{\kappa} \ln\left(\frac{z+z_0}{z_0}\right)$$

$z_0 = \alpha_{\mathrm{M}} \frac{\nu}{u_*} + \alpha_{\mathrm{ch}} \frac{u_*^2}{g} \sim 0.01$ to 1 mm is the roughness length.

- It is the stress, so $\vec{\mathbf{u}}_{\mathrm{rel}}$ that should be used to force the ocean-wave model

Usage of ocean current/neutral wind in the ECMWF assimilation system

Adaptation of the scatterometer cost function:

$$J_o^{\text{scatt}}(\vec{\mathbf{u}}^{\text{mod}}, \text{scatt}) = \frac{||\vec{\mathbf{u}}^{\text{mod}} - \vec{\mathbf{u}}^{\text{scatt}}||^{\mathbf{2}}}{\sigma_0^2}$$

Here, $\vec{\mathbf{u}}^{\text{mod}}$ is the scatterometer observation operator.
It is determined from the wind $\vec{\mathbf{u}}_L$ at lowest model level z_L (Geleyn 1988):

$$\vec{\mathbf{u}}_{\text{rel}}(z_{\text{obs}}) = R\vec{\mathbf{u}}_{\text{rel}}(z_L),$$

where

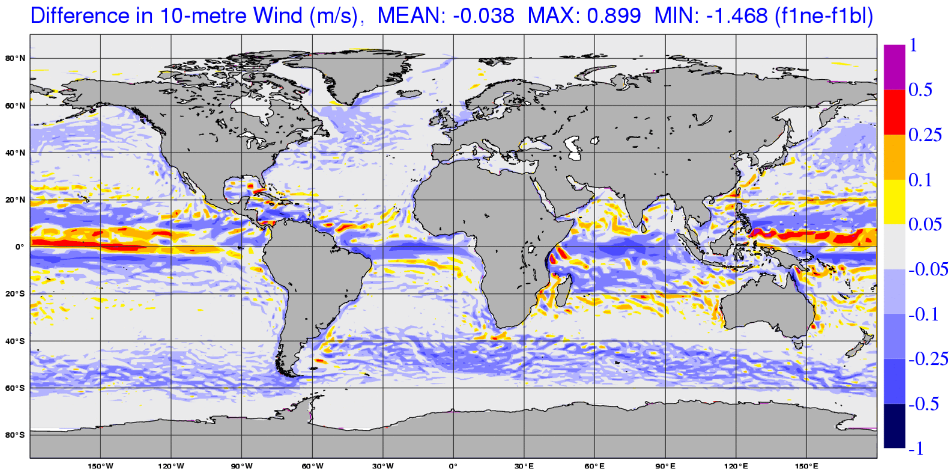
$$R = R(z_{\text{obs}}/z_L, z_0, \text{stability}), \qquad R = 1, \ \text{for} \ z_{\text{obs}} = z_L.$$

Since now $\vec{\mathbf{u}}_L = \vec{\mathbf{u}}_{\text{abs}}(z_L)$, rather than $\vec{\mathbf{u}}_{\text{rel}}(z_L)$

$$\begin{aligned} \textbf{scatterometer}: \quad & \vec{\mathbf{u}}^{\text{mod}} = \vec{\mathbf{u}}_{\text{rel}}(z_{\text{obs}}) &= R\,(\vec{\mathbf{u}}_{\mathbf{L}} - \vec{\mathbf{u}}_{\text{oc}}) \\ \textbf{buoy/ship}: \quad & \vec{\mathbf{u}}^{\text{mod}} = \vec{\mathbf{u}}_{\text{abs}}(z_{\text{obs}}) &= R\,\vec{\mathbf{u}}_{\mathbf{L}} + (1-R)\,\vec{\mathbf{u}}_{\text{oc}} \end{aligned}$$

Average effect on Analysis surface winds

$$||\vec{\mathbf{u}}_{\mathrm{ECMWF}}(10) - \vec{\mathbf{u}}_{\mathrm{oc}}|| - ||\vec{\mathbf{u}}_{\mathrm{ECMWF}}(10)||$$



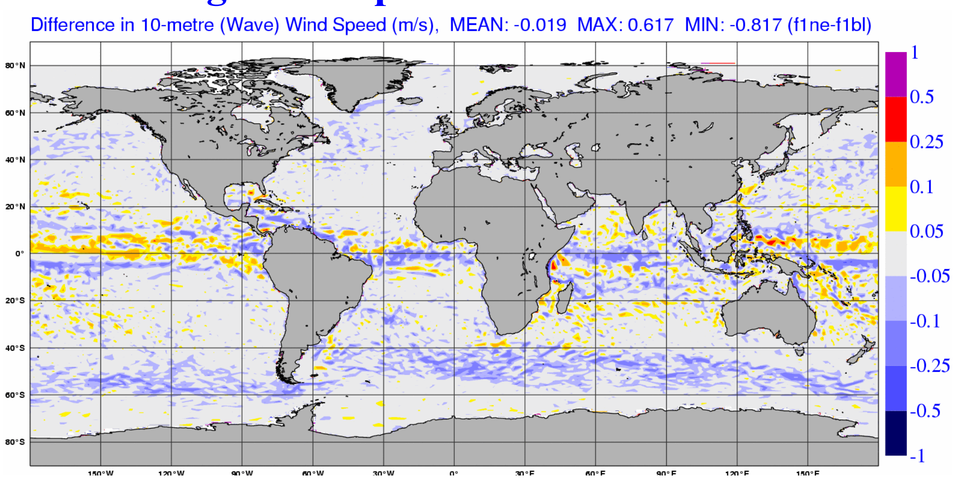
T511 (40km) assimilation impact study, ocean waves 55km

- ✓Use currents from Mercator
- ✓17 March – 30 April 2008

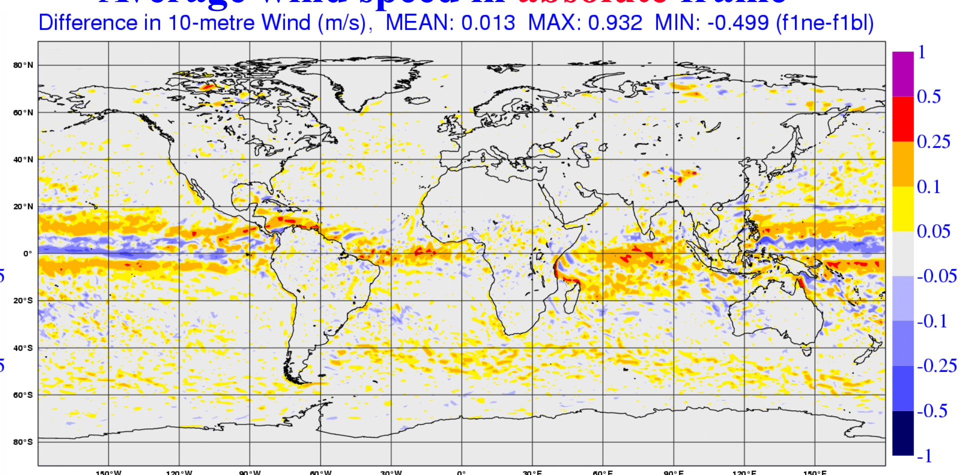
- ➢Effect on relative winds limited
- ➢Absolute winds receive about 50% from ocean currents

- ➢Forecast score neutral to slightly negative

Average wind speed in relative frame

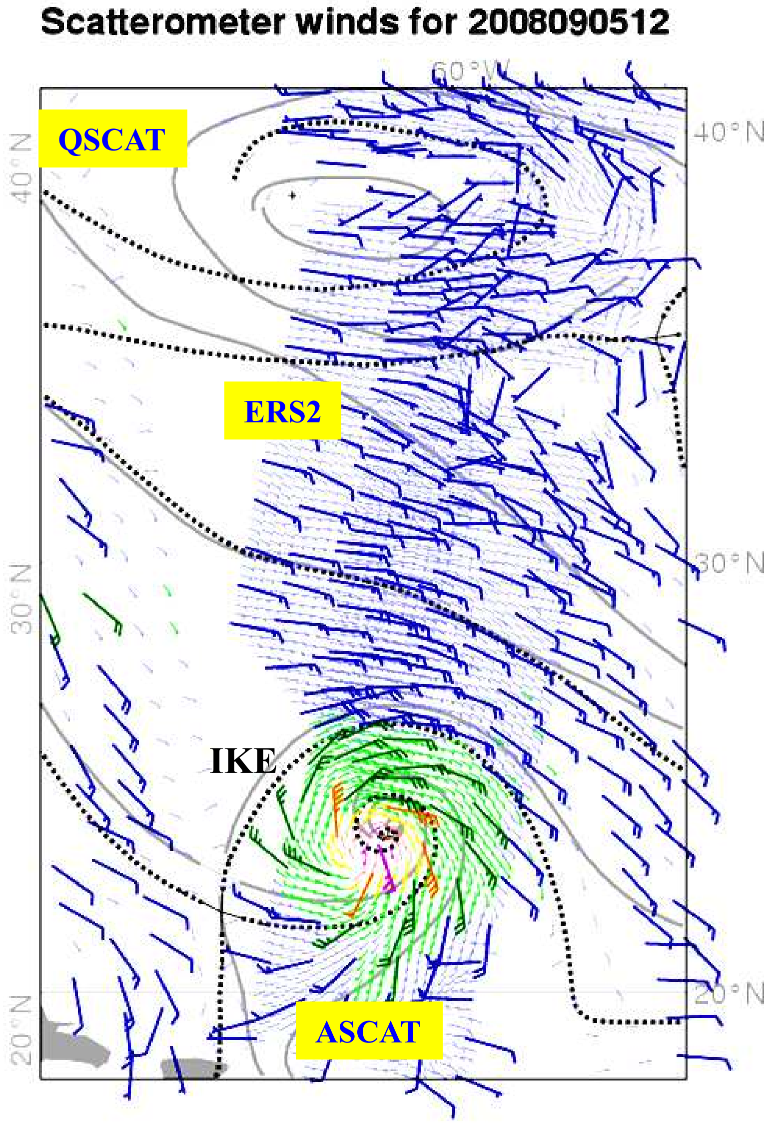


Average wind speed in absolute frame



ECMWF

Summary/outlook



ERS-2 data looks fine

Recent operational change at ECMWF:

✓**3 June 2008: usage of 4 wind solutions for QuikSCAT**

Pending changes

✓**Processing of new QuikSCAT stream**

✓**ASCAT EARS, soil moisture**

Ongoing research

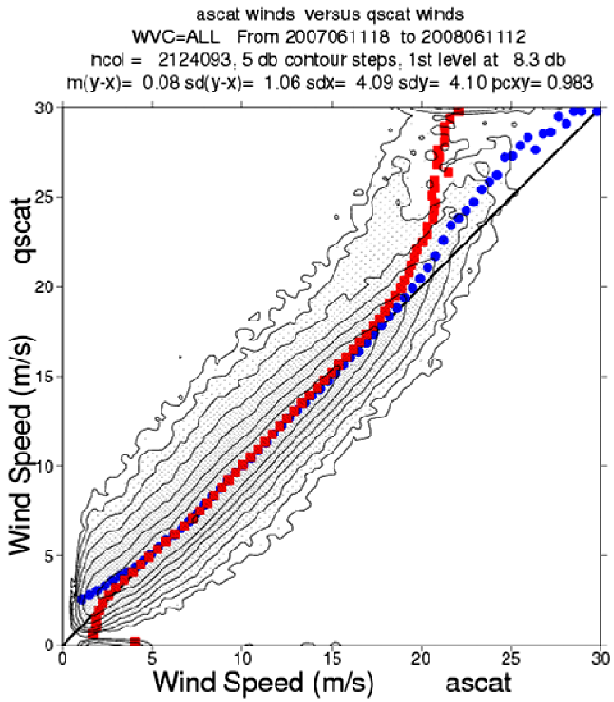
✓**Include option for ocean currents and neutral winds in SCAT observation operator**

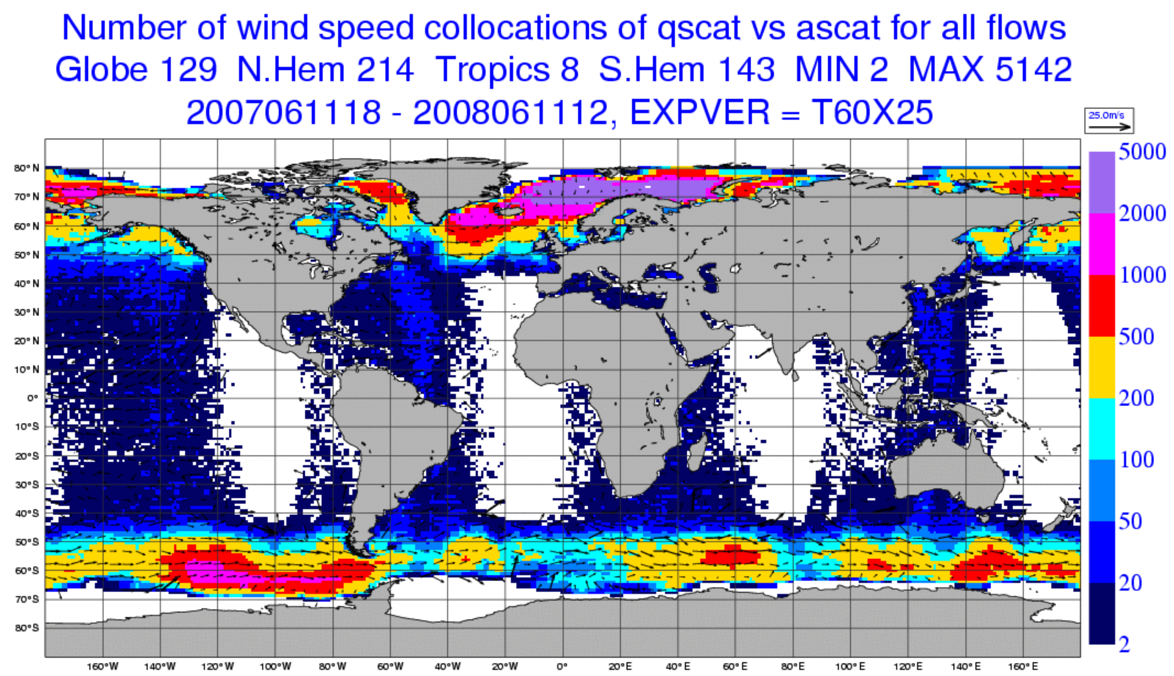
(switch in next model cycle)

ECMWF

BACK UP SLIDES

Collocation QuikSCAT and ASCAT





ECMWF

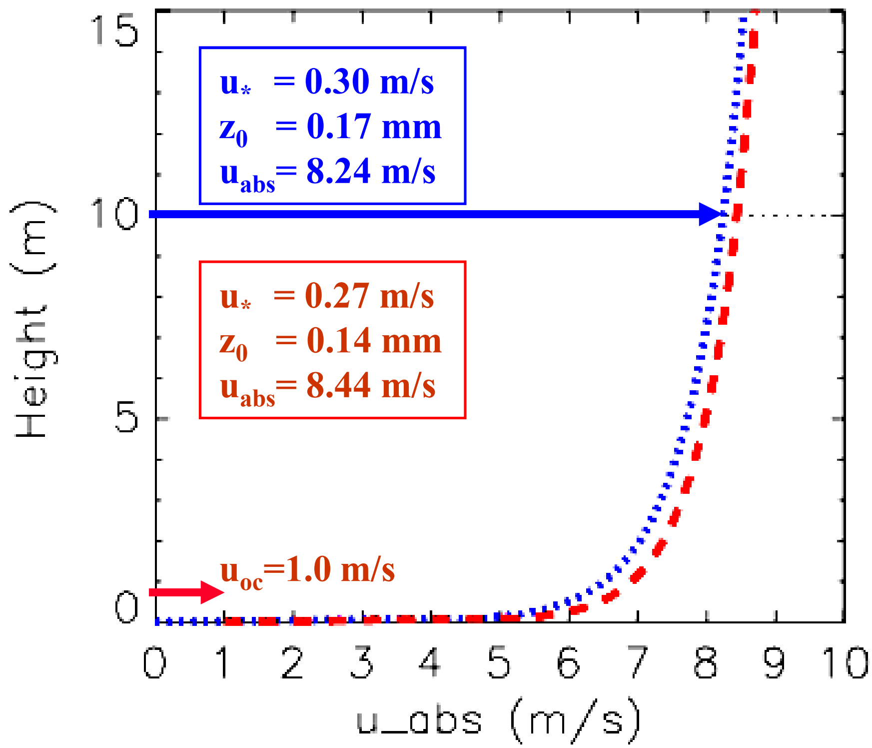
The effect of ocean current on 10m wind

ECMWF 10m wind (in absolute frame) is a popular product

- **Since ocean currents are not incorporated in the operational ECMWF model usually, 10m relative winds are constructed as:**

$$\vec{\mathbf{u}}_{\mathrm{rel}}(10) = \vec{\mathbf{u}}_{\mathrm{ECMWF}}(10) - \vec{\mathbf{u}}_{\mathrm{oc}}.$$

- **How would ECMWF absolute 10m wind change after currents are incorporated?**



In free atmosphere effect is expected to be small

- **Due to the small roughness length**
- **10m absolute wind would not change too much About 10-20%?**
- **Note: when stress goes down, abs. wind goes up**

The combined effect of ocean current and assimilation of scatterometer wind

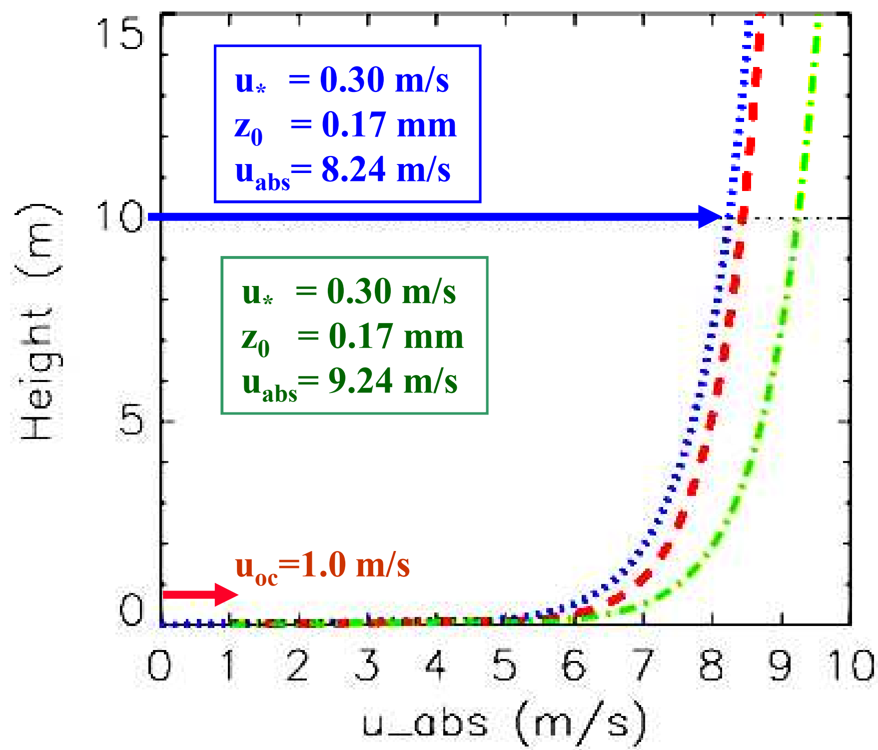
Denote the original 10m ECMWF absolute wind by: $u_{ECMWF}(10)$

Small adjustment for $u_{abs}(10)$, due to:

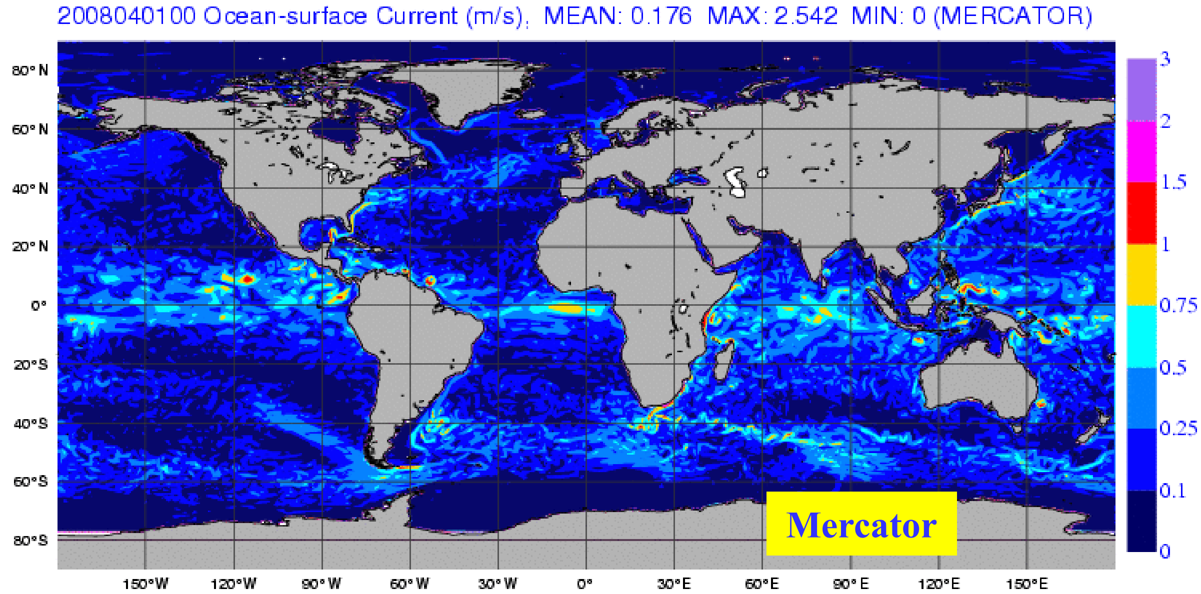
- ➢‘Forcing’ of winds in free atmosphere
- ➢Usage of moored buoy, ship observations
- ✓Confirm value of $u_{ECMWF}(10)$

Small adjustment for $u_{rel}(10)$, due to:

- ➢Usage of scatterometer data
- ▪Enforcing stress at surface
- ▪ $u_{ECMWF}(10)$ appears relative wind



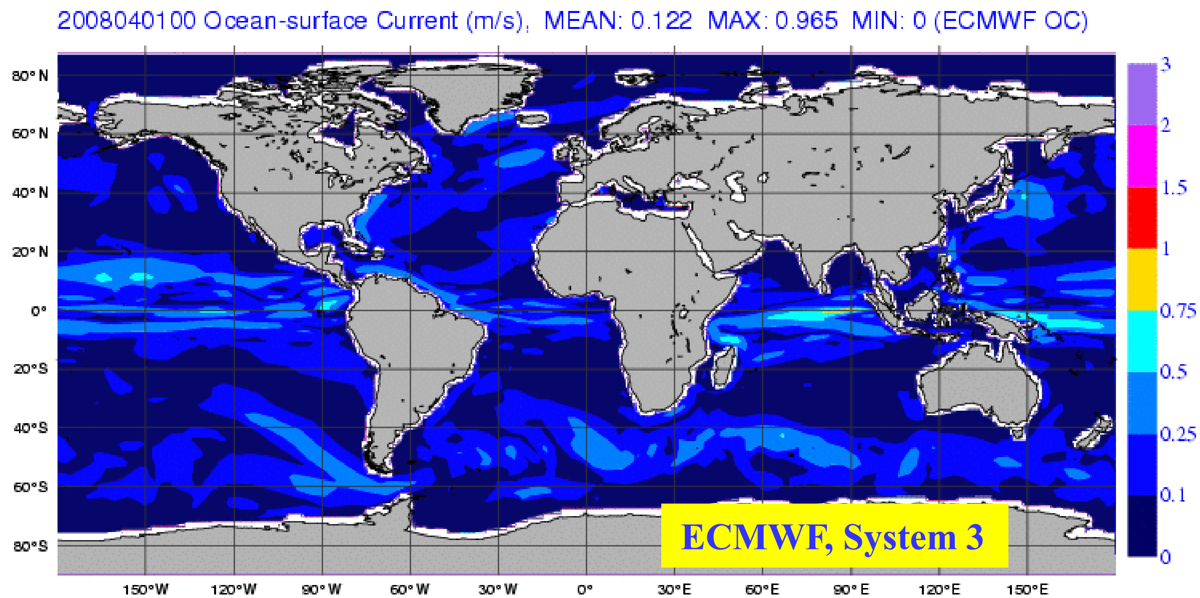
ECMWF



Mercator vs ECMWF (system 3)

Mercator:

- More small-scale structures
- About 40% stronger
- Realistic?



ECMWF (system 3):

- Larger response to instantaneous wind field

ECMWF