The Usage of Scatterometer Data at ECMWF

Hans Hersbach, ECMWF

Overview

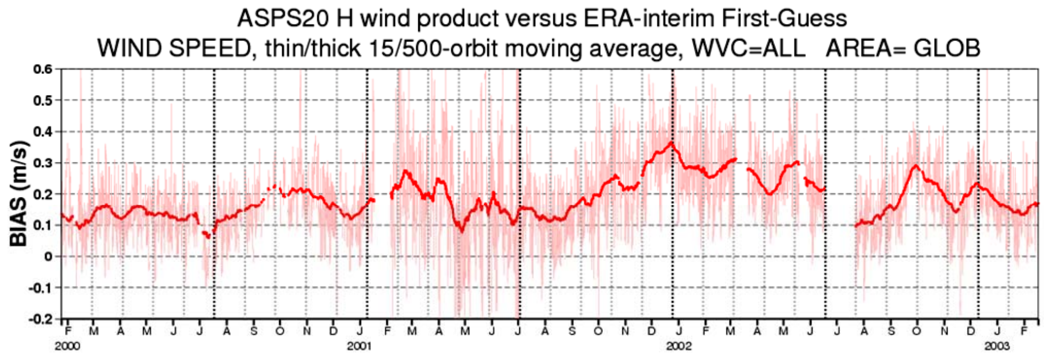
- **Support to the ERS-2 reprocessing**

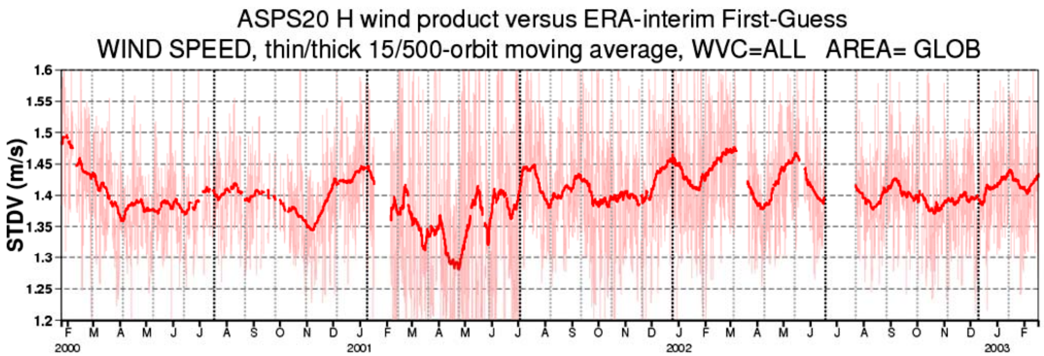
- **The relation between stress and 10m-wind**
  - **Stability effects**
  - **Ocean currents**
  - **Potential wave-state effects**
  - **Potential density effects**

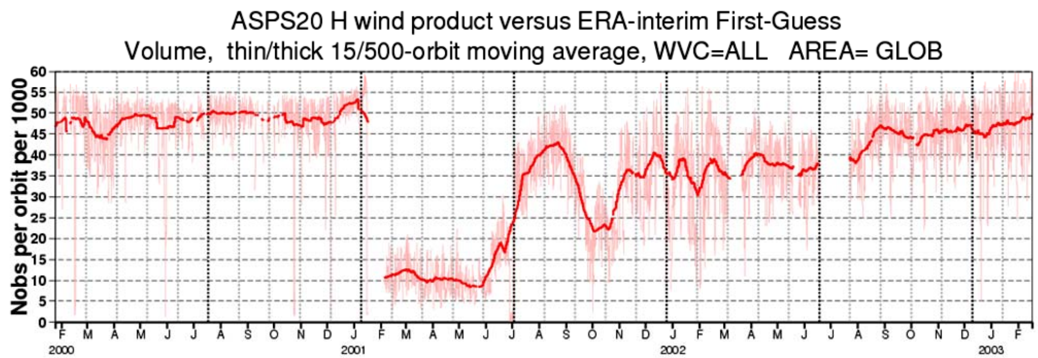
- **Collocation between ASCAT and the ENVISAT altimeter**

- **Final remark**

The ERS wind reprocessing







Re-processing is underway:

- ✓ASPS20, by ESRIN
- ✓N and H res product
- ✓Data after 2001 incidence first
- ✓Processed Feb 2001 - Feb 2003

Comparison with ECMWF:

- ✓In general, nominal
- ✓Data less period first

ECMWF

The relation between stress and 10m wind

- It is believed that scatterometer data is sensitive to stress
- In practise it is often used/interpretated as 10m wind

- In 4D-var, a more proper treatment involves the adaptation of the observation operator

The relation between stress and 10m wind

Scatterometer is sensitive to stress, but GMF is tuned to 10m wind.

$$\vec{\tau} = \rho_a u_* \vec{\mathbf{u}}_*$$

$$\vec{\mathbf{u}}(z) = \frac{\vec{\mathbf{u}}_*}{\kappa}\left\{\ln\left(\frac{z+z_0}{z_0}\right) - \Psi_{\mathrm{M}}\left(\frac{z+z_0}{L}\right) + \Psi_{\mathrm{M}}\left(\frac{z_0}{L}\right)\right\} + \vec{\mathbf{u}}_{\mathrm{oc}},$$

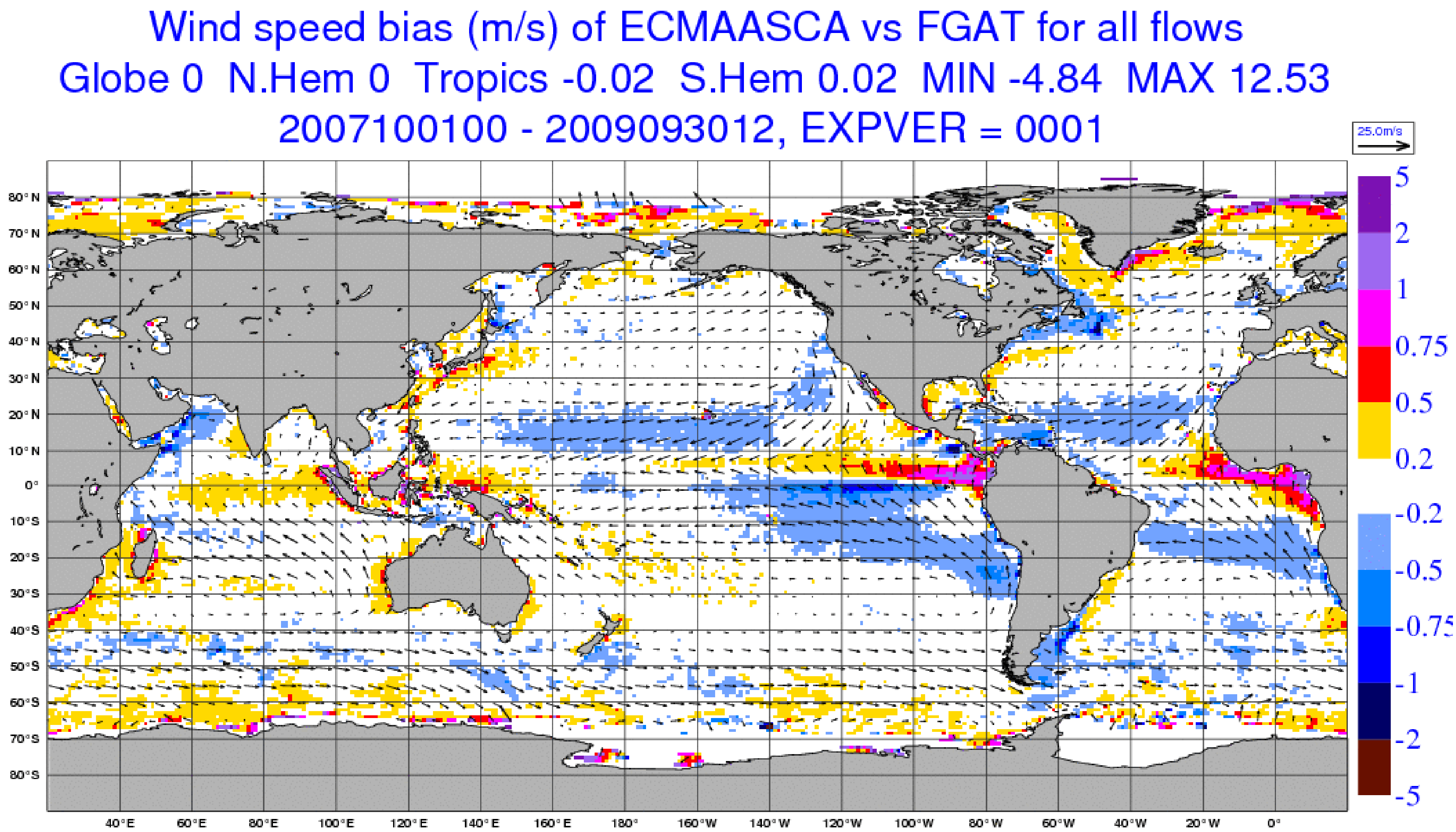
$$z_0 = \alpha_{\mathrm{M}}\frac{\nu}{u_*} + \alpha_{\mathrm{ch}}\frac{u_*^2}{g}.$$

This relation depends on:

- **Stability** ***(Hersbach, Jtech 2010)***
- **Ocean current** ***(Kelly 2001)***
- **Air density** ***(Bourassa)***
- **Charnock parameter, depends on sea state** ***(Janssen 1991)***

The resulting, tuned GMF corresponds to average, effective values, which may be a function of wind speed.

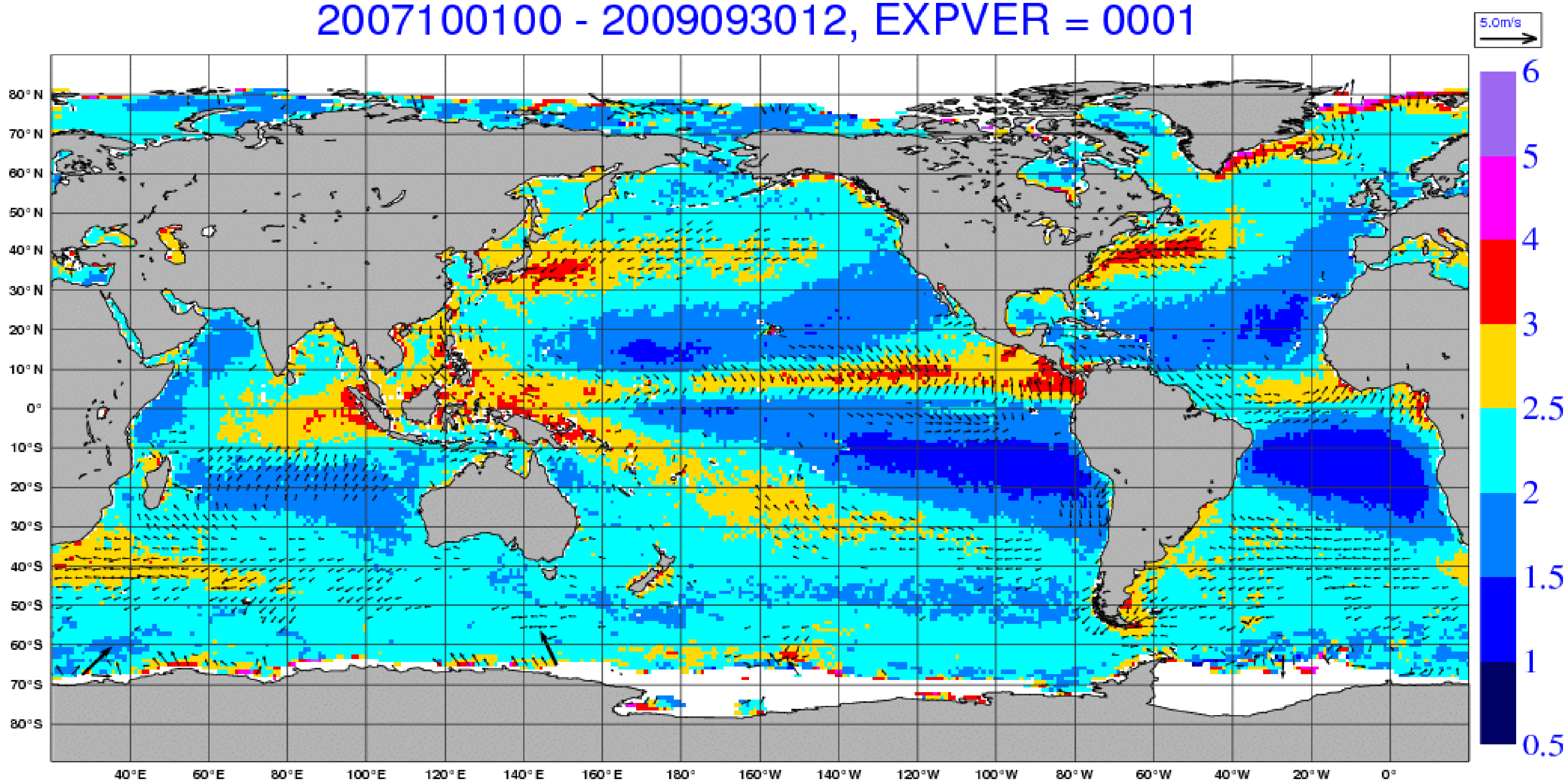
ASCAT vs ECMWF FGAT, 200710-200909



ECMWF

ASCAT vs ECMWF FGAT, 200710-200909

Vector-wind difference (m/s) of ECMAASCA vs FGAT for all flows
Globe 2.17 N.Hem 2.2 Tropics 2.12 S.Hem 2.2 MIN 0.75 MAX 15.84
2007100100 - 2009093012, EXPVER = 0001



ECMWF

Adaptation of the ECMWF observation operator for neutral wind and ocean current

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

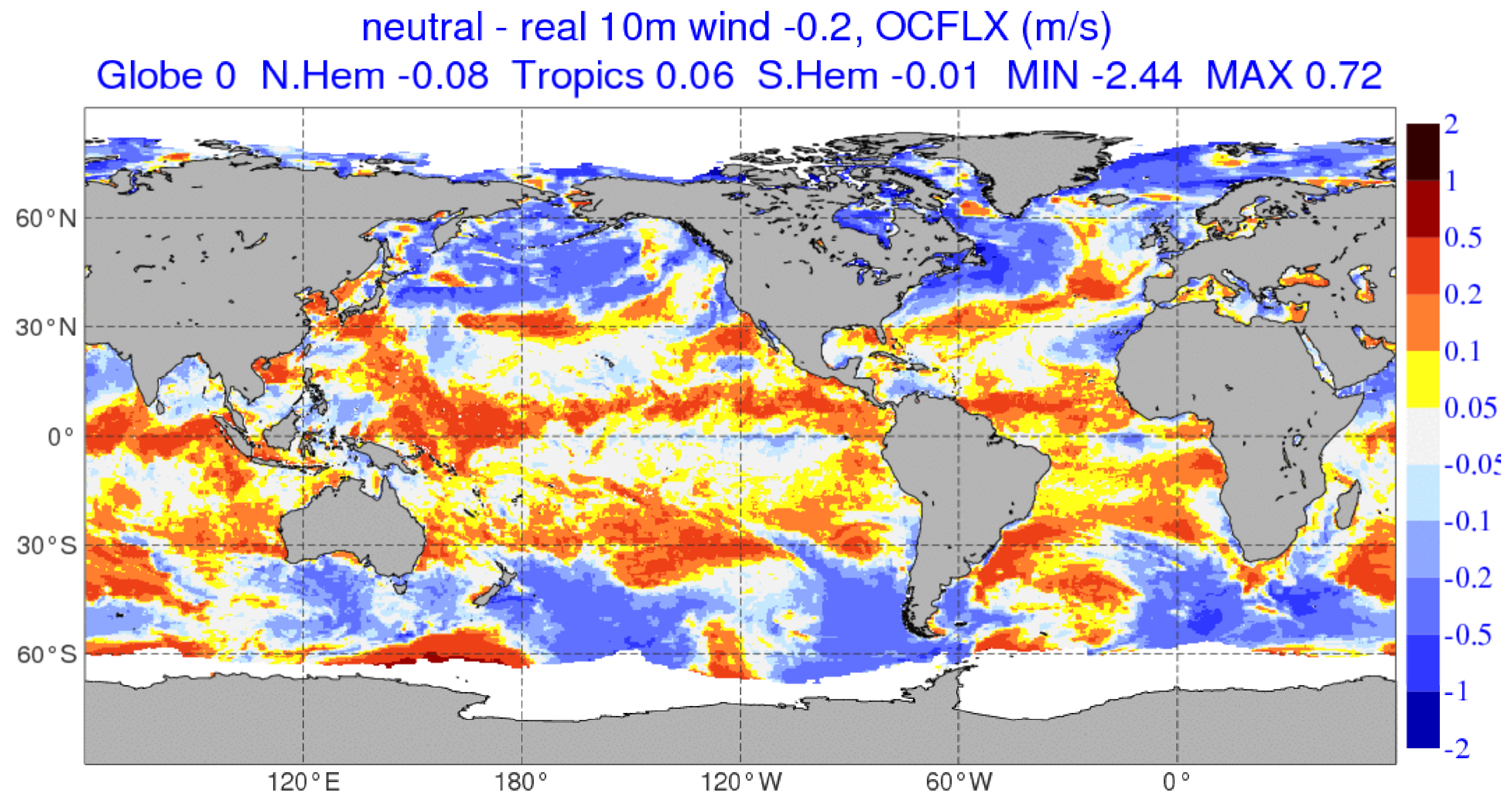
$$R = R(z_{\text{obs}}/z_L, z_0, \text{stability}), \qquad R = 1, \text{ for } z_{\text{obs}} = z_L.$$

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

$$\textbf{scatterometer}: \quad \vec{\mathbf{u}}^{\text{mod}} = \vec{\mathbf{u}}_{\text{rel}}(z_{\text{obs}}) = R\,(\vec{\mathbf{u}}_{\mathbf{L}} - \vec{\mathbf{u}}_{\text{oc}})$$

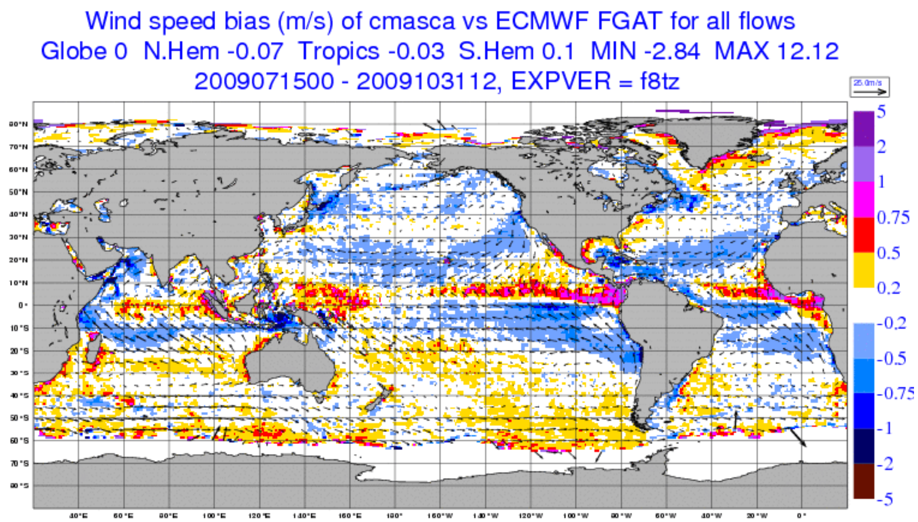
$$\textbf{buoy/ship}: \quad \vec{\mathbf{u}}^{\text{mod}} = \vec{\mathbf{u}}_{\text{abs}}(z_{\text{obs}}) = R\,\vec{\mathbf{u}}_{\mathbf{L}} + (1-R)\,\vec{\mathbf{u}}_{\text{oc}}$$

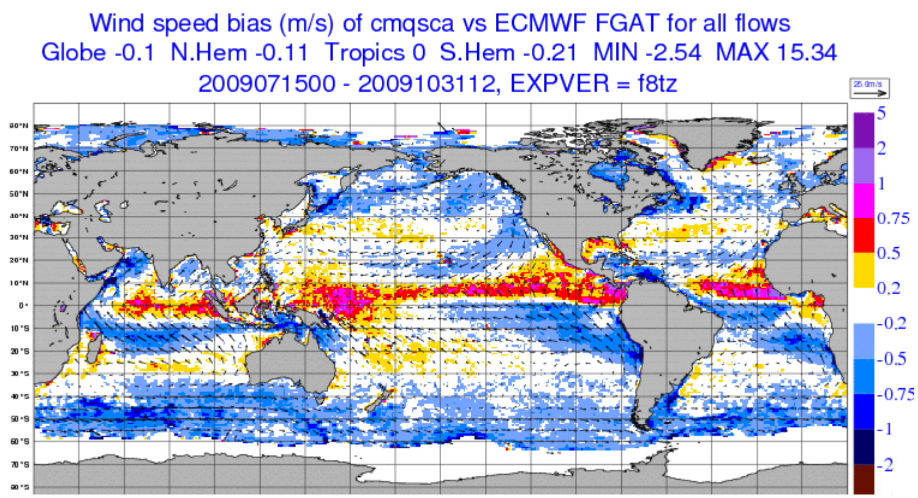
Stability effects: use observation operator for neutral wind



ECMWF

Stability effects: use observation operator for neutral wind





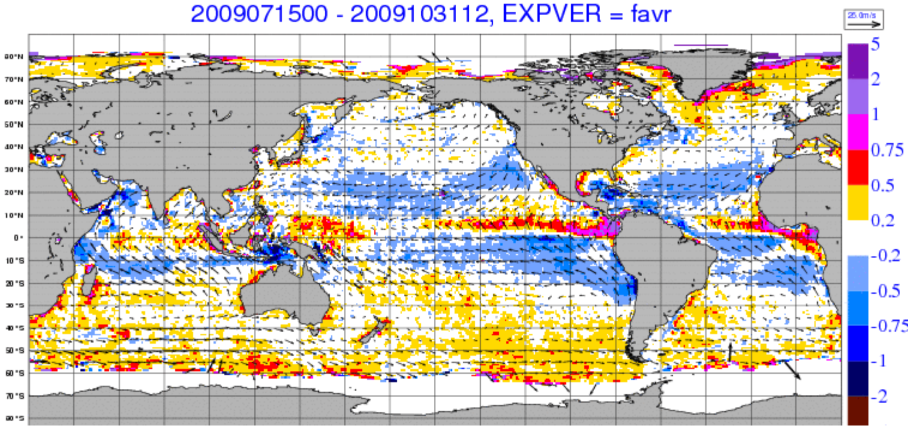
Impact study

- ✓**T511, 109 cases in Autumn 2009**
- ✓**Use CMOD5.N for ASCAT/ERS-2**
- ✓**Add 0.2 m/s to QuikSCAT (note that QuikSCAT wind is inverted/corrected in-house)**

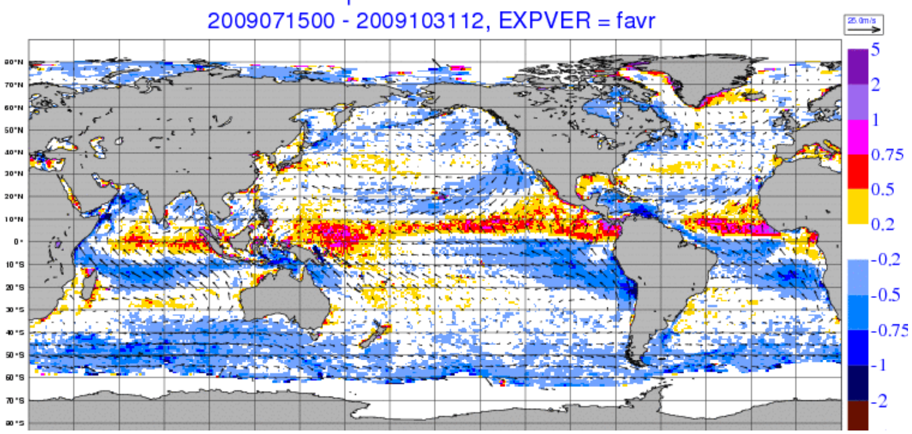
ECMWF

Stability effects: use observation operator for neutral wind

Wind speed bias (m/s) of cmasca vs ECMWF FGAT for all flows
Globe 0.03 N.Hem 0 Tropics -0.05 S.Hem 0.16 MIN -2.62 MAX 12.31
2009071500 - 2009103112, EXPVER = favr



Wind speed bias (m/s) of cmqsca vs ECMWF FGAT for all flows
Globe -0.08 N.Hem -0.05 Tropics -0.03 S.Hem -0.17 MIN -2.42 MAX 15.64
2009071500 - 2009103112, EXPVER = favr



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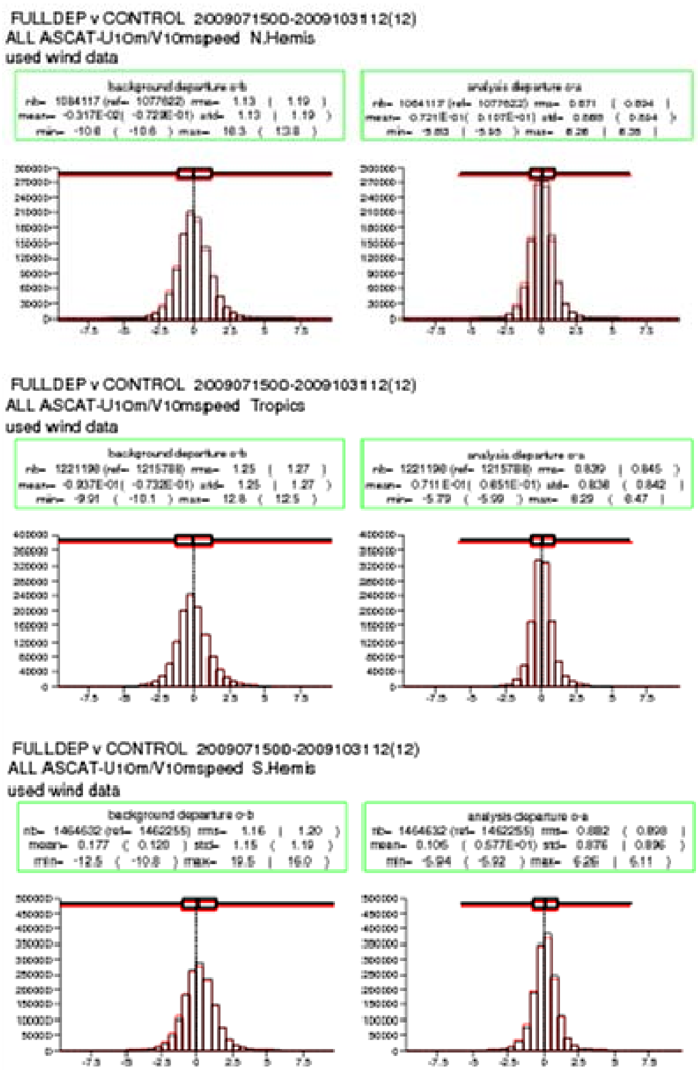
Obs vs model (o-b, o-a):

✓**o-b bias reduced in several expected areas**

ECMWF

Stability effects: use observation operator for neutral wind



Impact study

✓T511, 109 cases in Autumn 2009
✓Use CMOD5.N for ASCAT/ERS-2
✓Add 0.2 m/s to QuikSCAT
(note that QuikSCAT wind is inverted/corrected in-house)

Obs vs model (o-b, o-a):

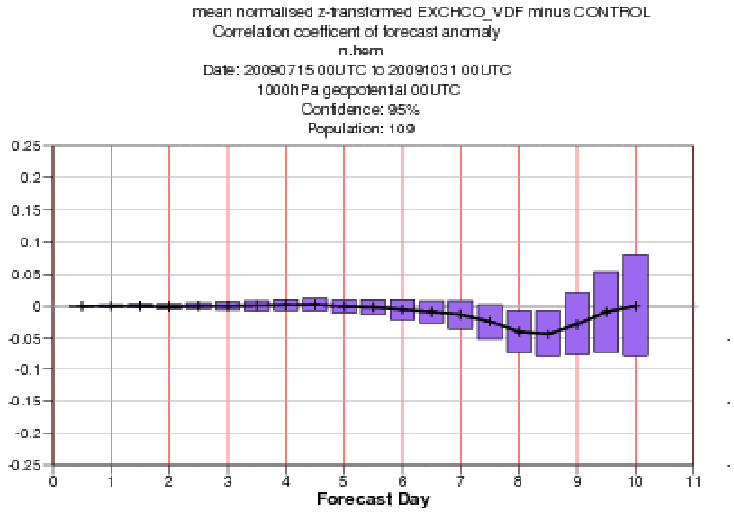
✓o-b bias reduced in several expected areas
✓ o-a and o-b STDV
✓ reduced for wind speed
✓ especially in NH

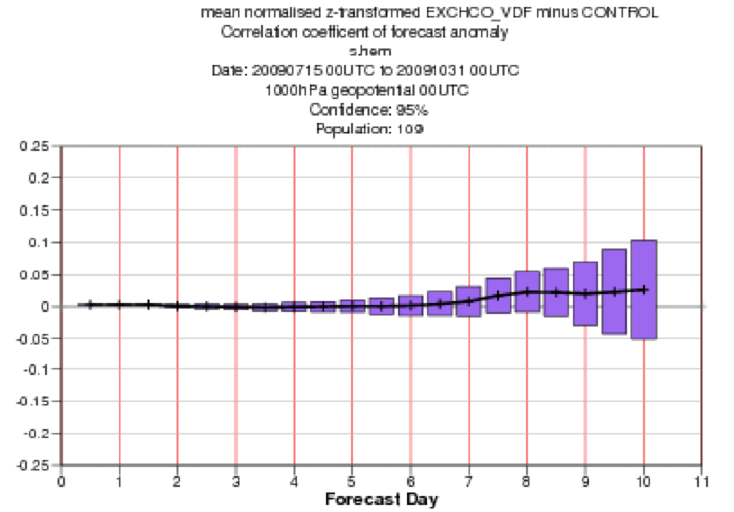
Impact on forecast skill:

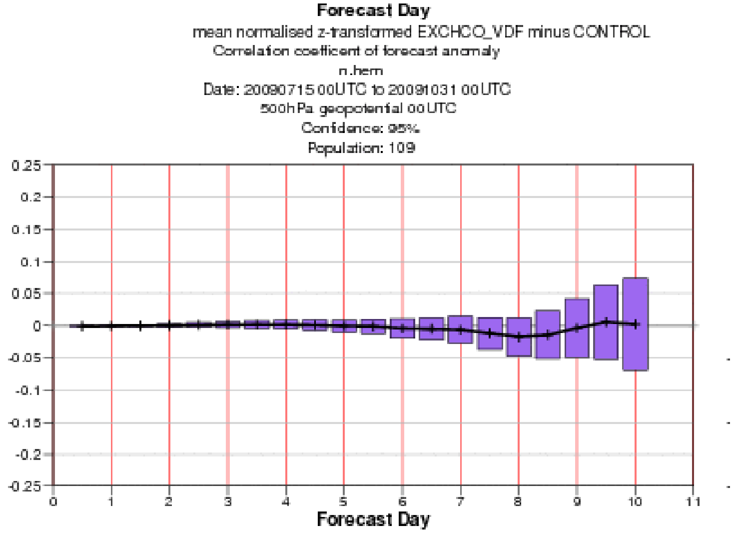
✓Rather "neutral".

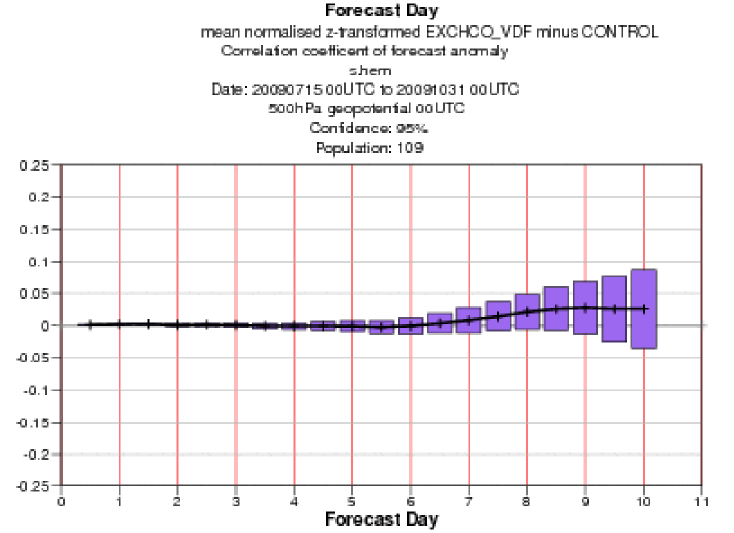
ECMWF

Stability effects: use observation operator for neutral wind









ECMWF

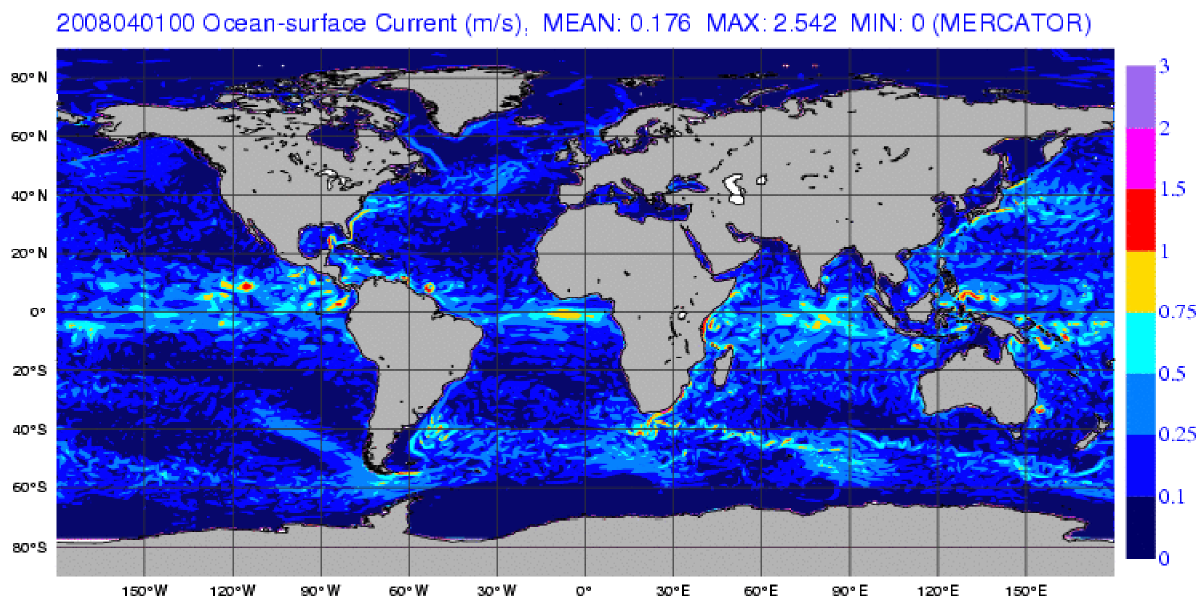
The effect of ocean current

(Hersbach and Bidlot, 2009)

The effect of ocean current

- ECMWF Operational NWP model is not coupled with an ocean model
- Import ocean current from external source to asses its effect
  - ✓Mercator product

- Force ECMWF lower boundary condition with ocean current
- Ingest ocean current in coupled ocean-wave model as well
- For SCATT use observation operator as described above

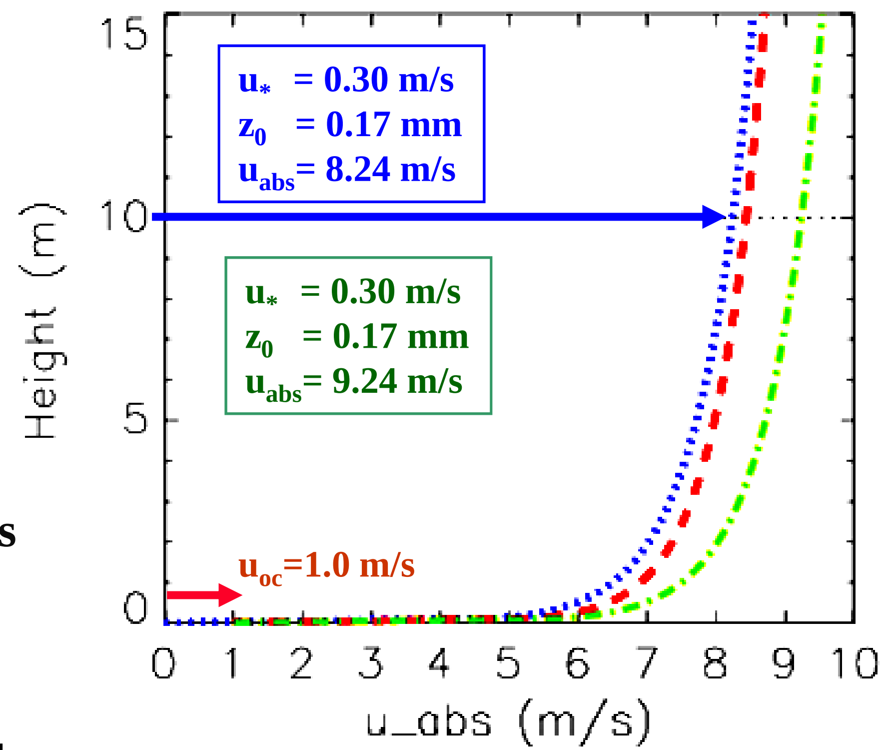


ECMWF

The combined effect of ocean current forcing and assimilation of scatterometer wind

Denote the original 10m ECMWF absolute wind by: $u_{ECMWF}(10)$
Is it affected by ocean current?

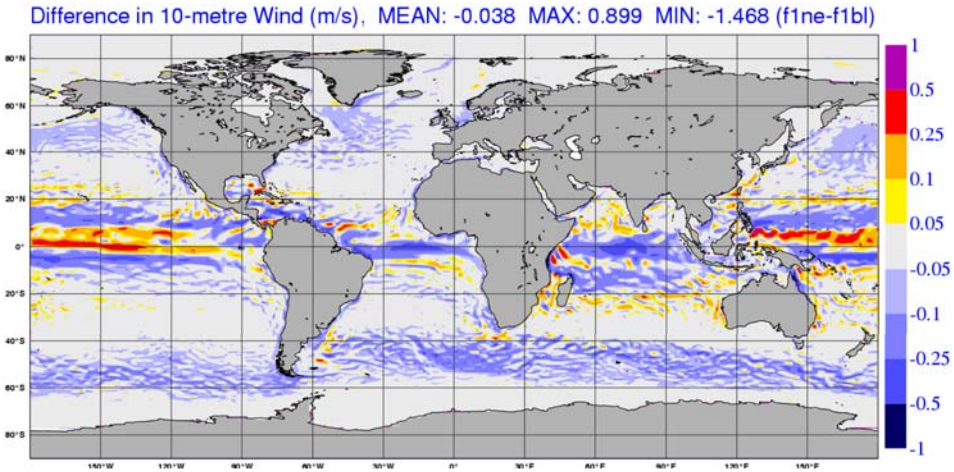
Small adjustment for $u_{abs}(10)$, due to:
- **'Forcing' of winds in free atmosphere**
- **Usage of moored buoy, ship observations**
- ✓ **Confirm value of $u_{ECMWF}(10)$**



- **Small adjustment for $u_{rel}(10)$, due to:**
  - **When relative speed decreases, friction decreases, $u_{abs}(10)$ increases**
  - **Usage of scatterometer data**
    - **Enforcing stress at surface**
    - **$u_{ECMWF}(10)$ appears relative wind**

Average effect on Analysis surface winds

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



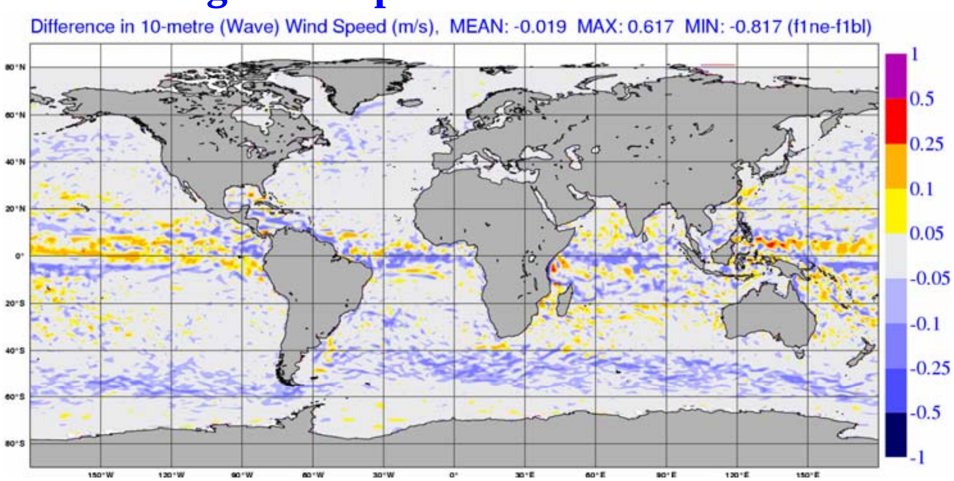
T511 (40km) assimilation impact study, ocean waves 55km

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

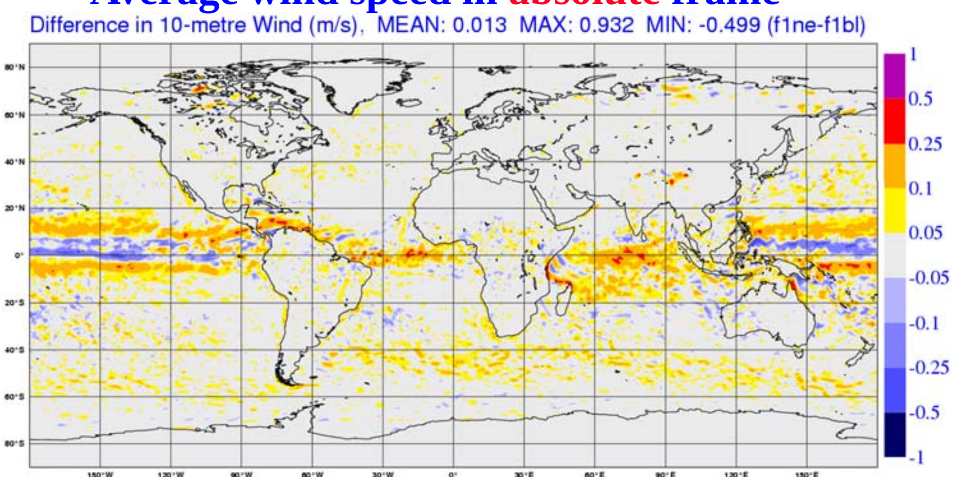
- ➢Effect on relative winds limited
- ➢Absolute winds receive about 50% from ocean currents

- ➢Forecast score neutral to slightly negative

Average wind speed in relative frame



Average wind speed in absolute frame



The potential effect of sea state and air density

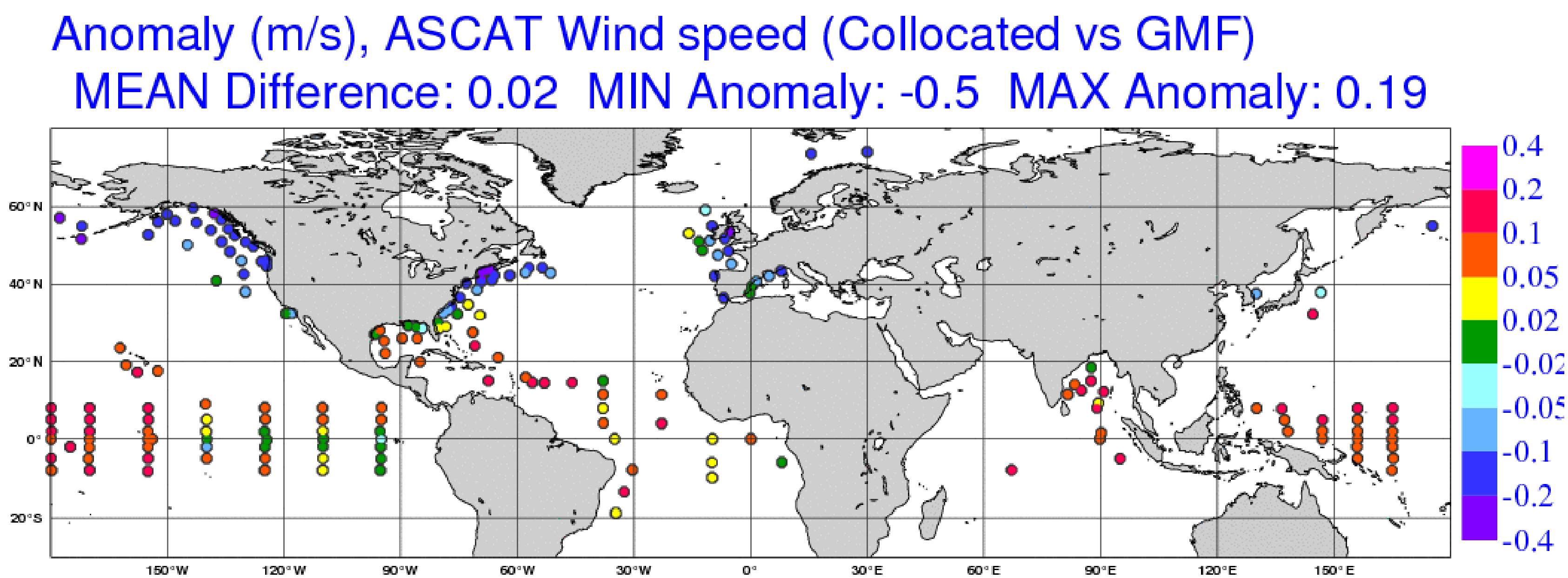
Air-density and sea-state effects on scatterometer wind

In the Tropics, scatterometer data seem to have a negative bias compared to buoys

- **May be induced by consistent differences in air density and sea state**

$$\vec{\tau} = \rho_a u_* \vec{\mathbf{u}}_*$$

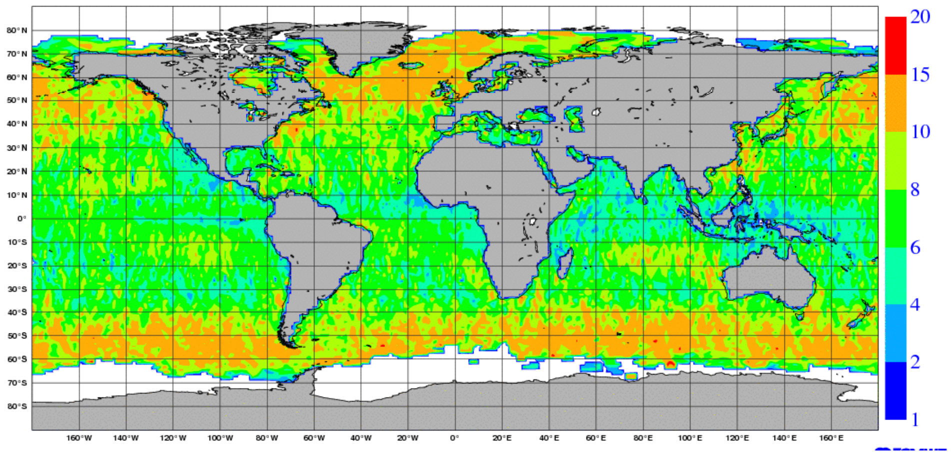
- **Scatterometer relates to stress.**
  - **Lower air density (Tropics) relates to higher winds.**
  - **10% Pole vs Tropics, gives 5%, or ~0.4 m/s**

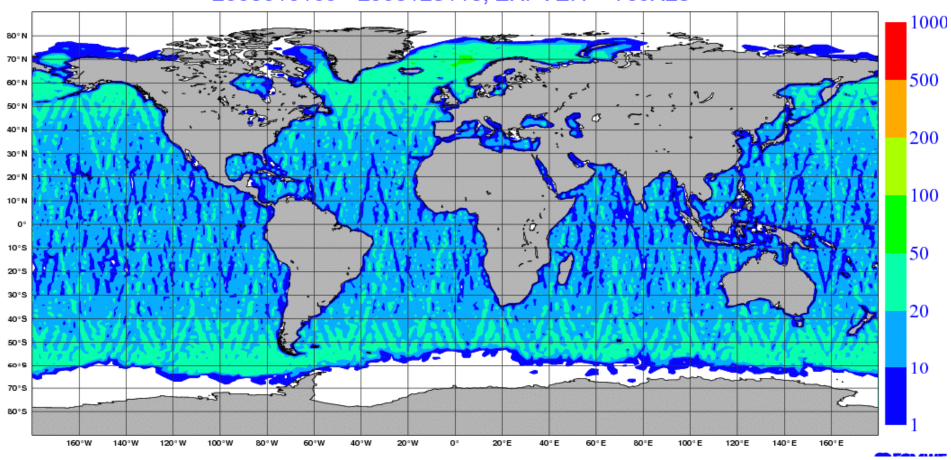


ECMWF

Collocation study

Collocation between ASCAT and ENVISAT altimeter data





Light scatterometer winds seem to be Stronger than ECMWF winds.

Which of the two is more correct?

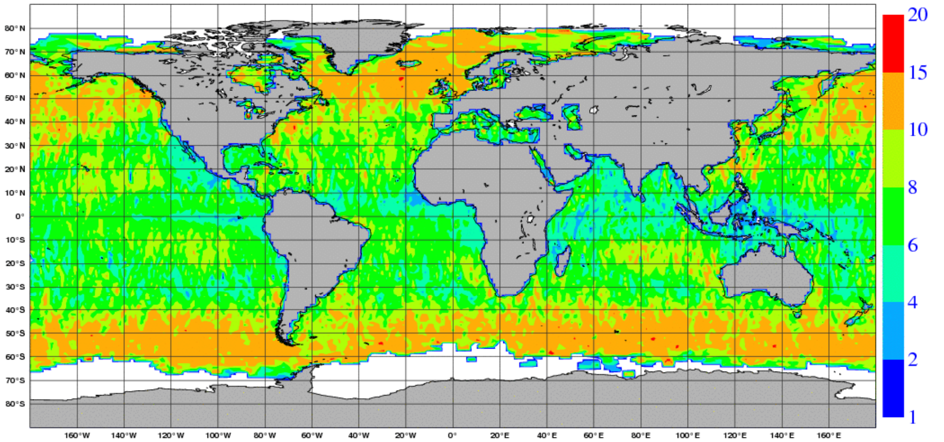
Compare results with another data set

ENVISAT altimeter wind speed
Superob'd to 75km *(Abdalla, 2007)*
Wind product calibrated on:
- **Global ECMWF wind**
- **Buoy for fine tuning**

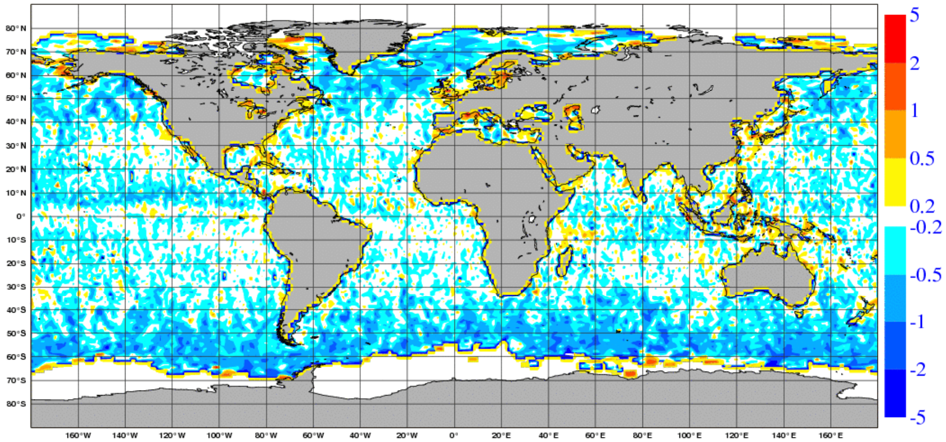
ECMWF

Collocation between ASCAT and ENVISAT altimeter data

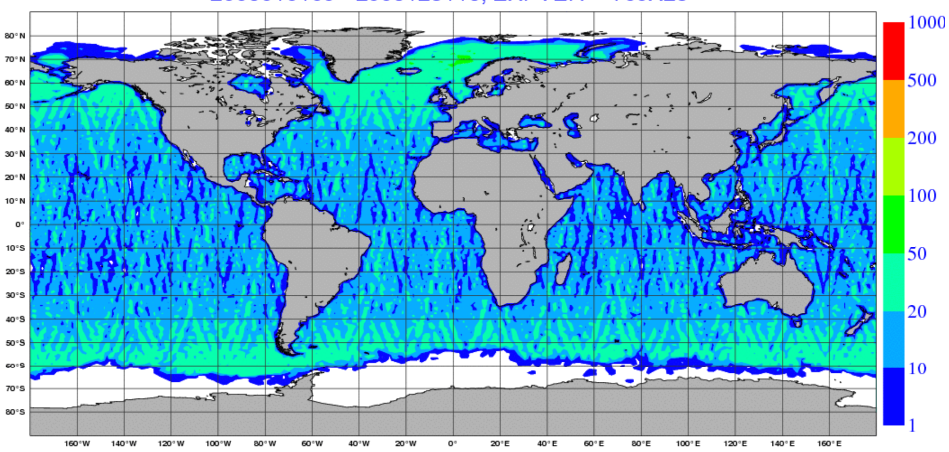
Average (m/s) ENVALT (Observed 10-metre wind speed)
Globe 7.75 N.Hem 8.46 Tropics 6.5 MIN 1.19 MAX 19
2008010100 - 2008123118, EXPVER = T60X25



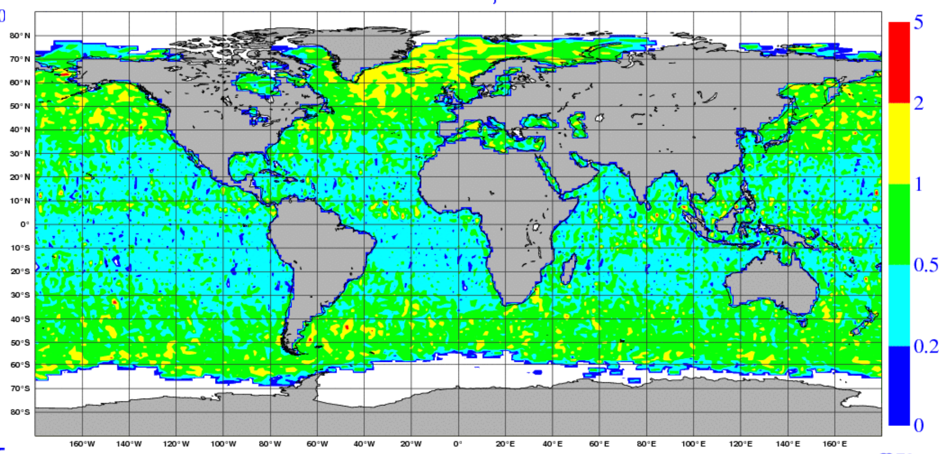
Bias (m/s) of ODBASCA vs ENVALT (Observed 10-metre wind speed)
Globe -0.21 N.Hem -0.15 Tropics -0.11 MIN -5.83 MAX 4.34
2008010100 - 2008123118, EXPVER = T60X25



Number of collocations of ODBASCA vs ENVALT (Observed 10-metre wind speed)
Globe 9 N.Hem 7 Tropics 9 MIN 0 MAX 64
2008010100 - 2008123118, EXPVER = T60X25

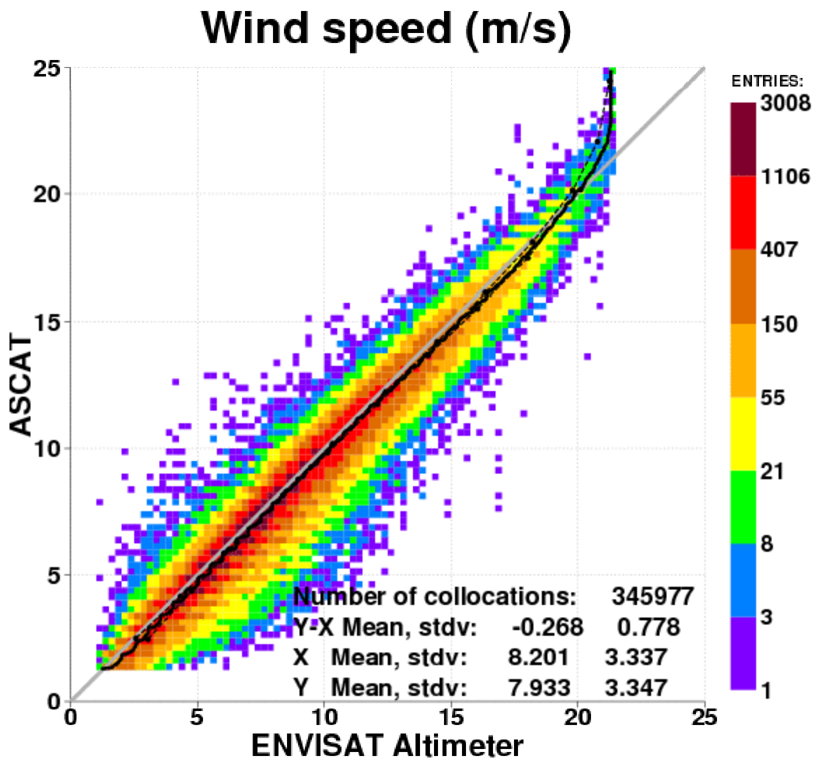


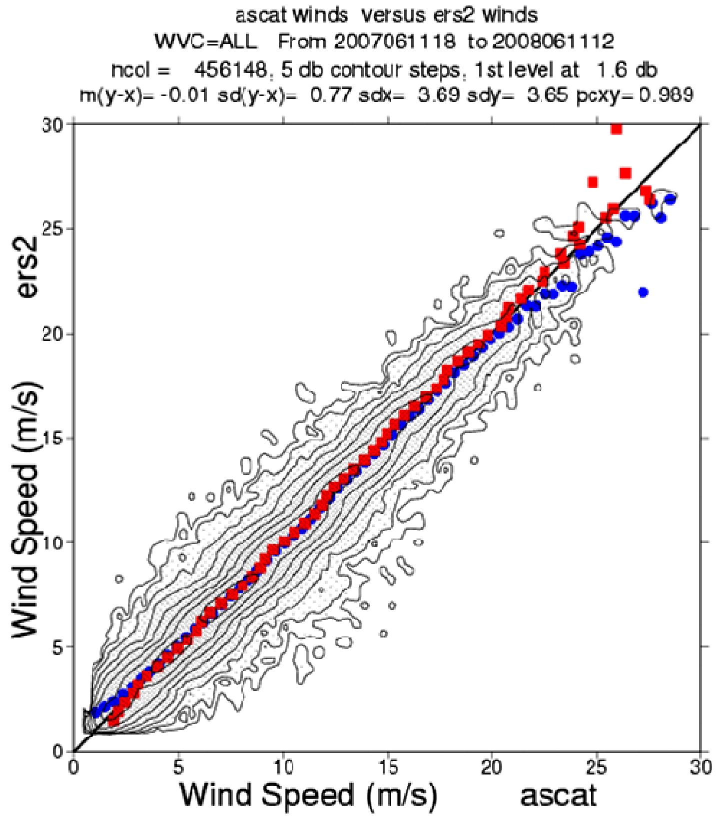
Stdv (m/s) of ODBASCA vs ENVALT (Observed 10-metre wind speed)
Globe 0.53 N.Hem 0.62 Tropics 0.42 MIN 0 MAX 3.89
2008010100 - 2008123118, EXPVER = T60X25



ECMWF

Collocation between ASCAT and ENVISAT altimeter data

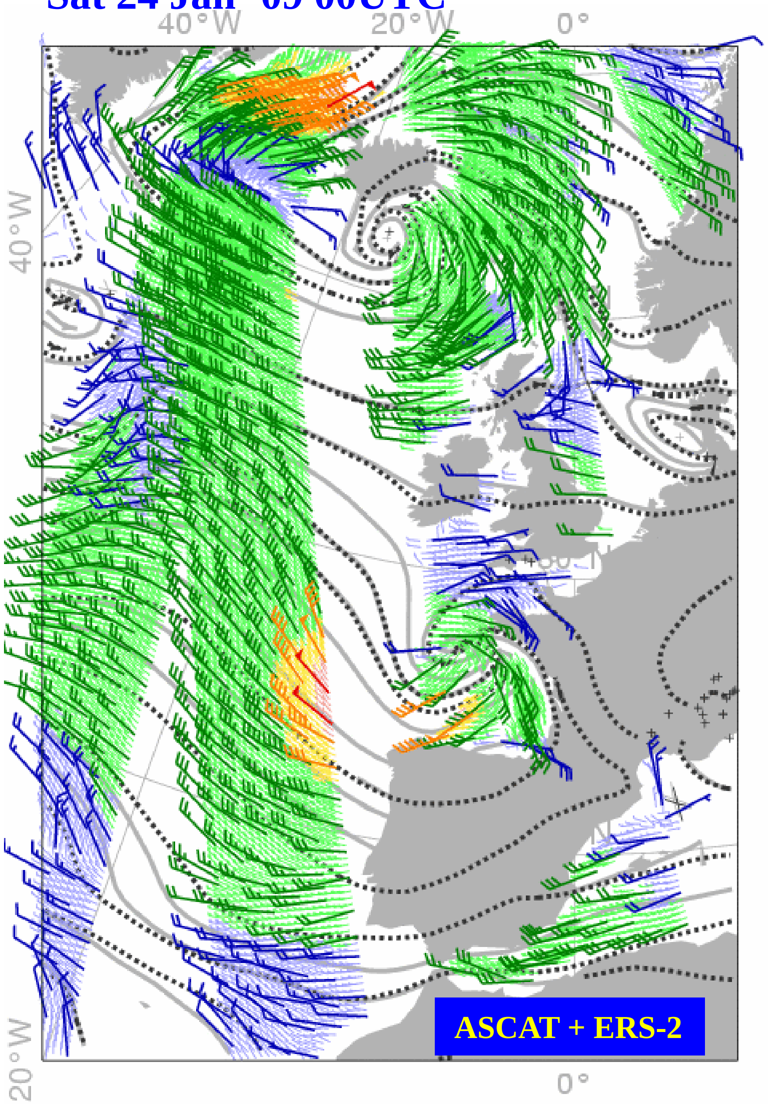




ECMWF

Summary/final remarks

Sat 24 Jan '09 00UTC



Scatterometer data from ERS-2 is routinely Assimilated and monitored

- ✓**Support ERS Recalibration Feb 2000- Feb 2003 N, H resol**

Recent changes in operational system

- ✓**Assimilation of EARS ASCAT**
- ❖**Failure of QuikSCAT (Nov 2009)**

Pending changes (Autmn 2010)

- ✓**Scatterometer as neutral wind**
- ✓**WindSAT (V, H pol radiances)**

Ongoing research

- ✓**Observation operator for ocean current is available. Input: Mercator,..,?**
- ✓**Density, sea state effects**

Inter-calibration:

- **ERS-2, ASCAT, ENVISAT o.k.**
- **QuikSCAT – ASCAT to be revisisted**