

# The Usage of Scatterometer Data at ECMWF

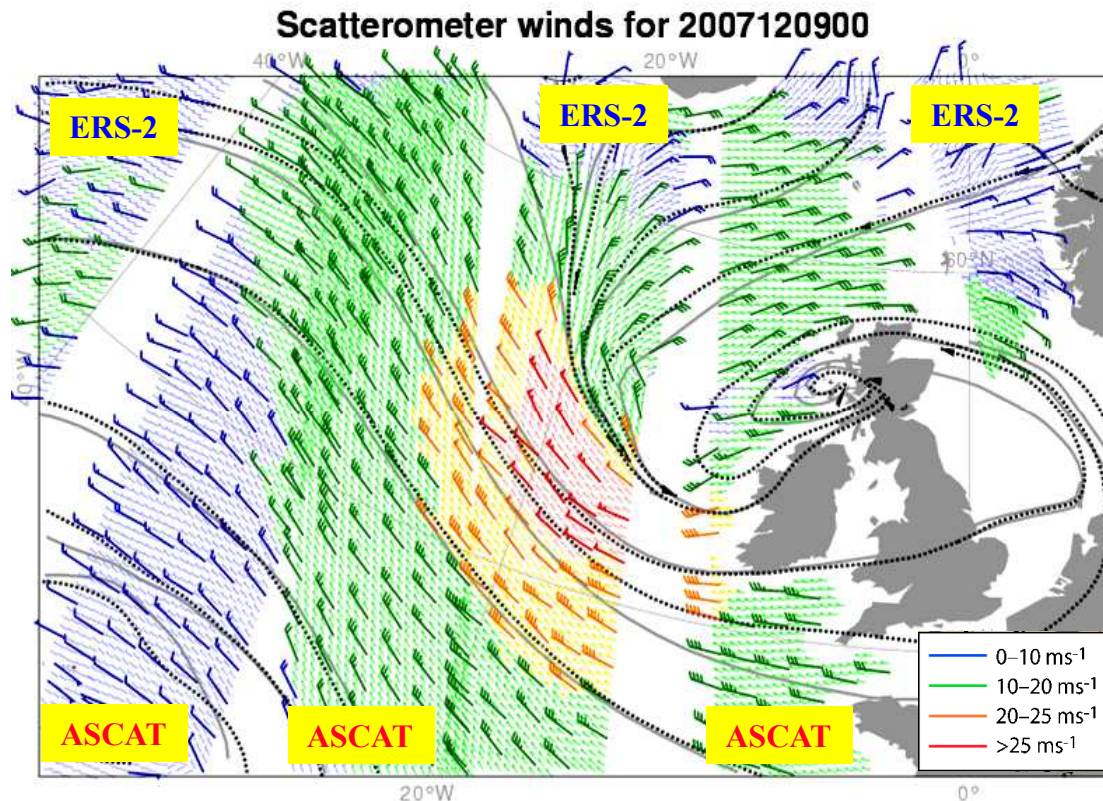
Hans Hersbach, ECMWF

## 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



## Operational assimilation:

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

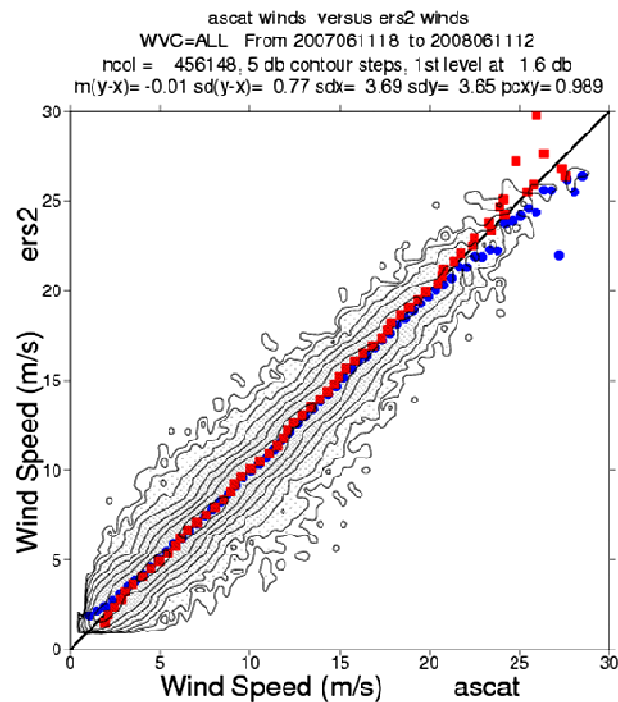
## Wind product:

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

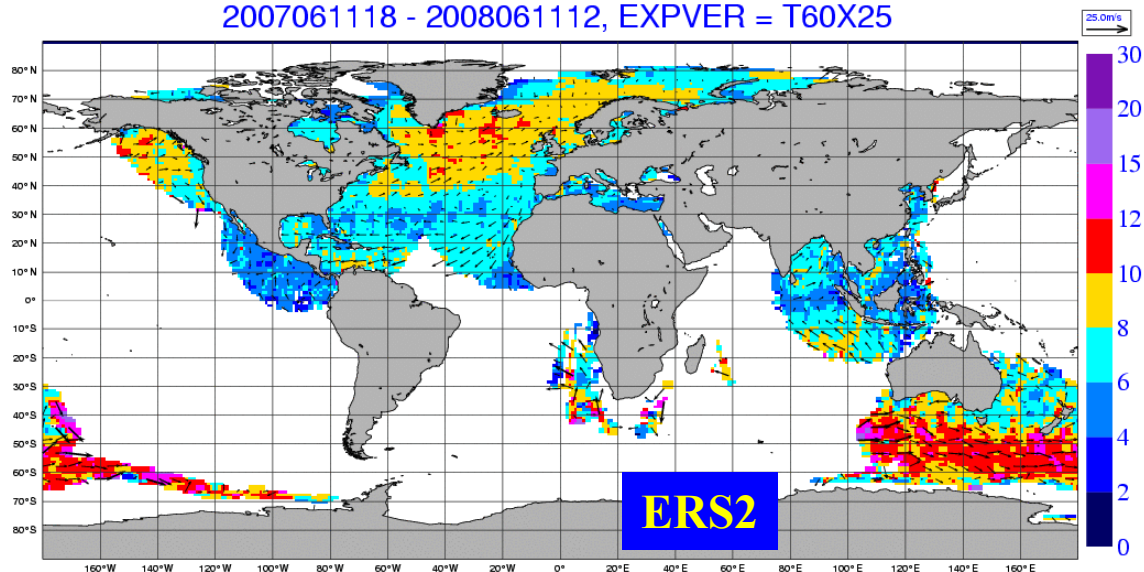
## Observation operator:

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

# Inter-comparison ERS-2 and ASCAT



Average ers2 wind speed (m/s) for all flows  
Globe 7.46 N.Hem 7.33 Tropics 6.2 S.Hem 9.21 MIN 1.49 MAX 17.14  
2007061118 - 2008061112, EXPVER = T60X25

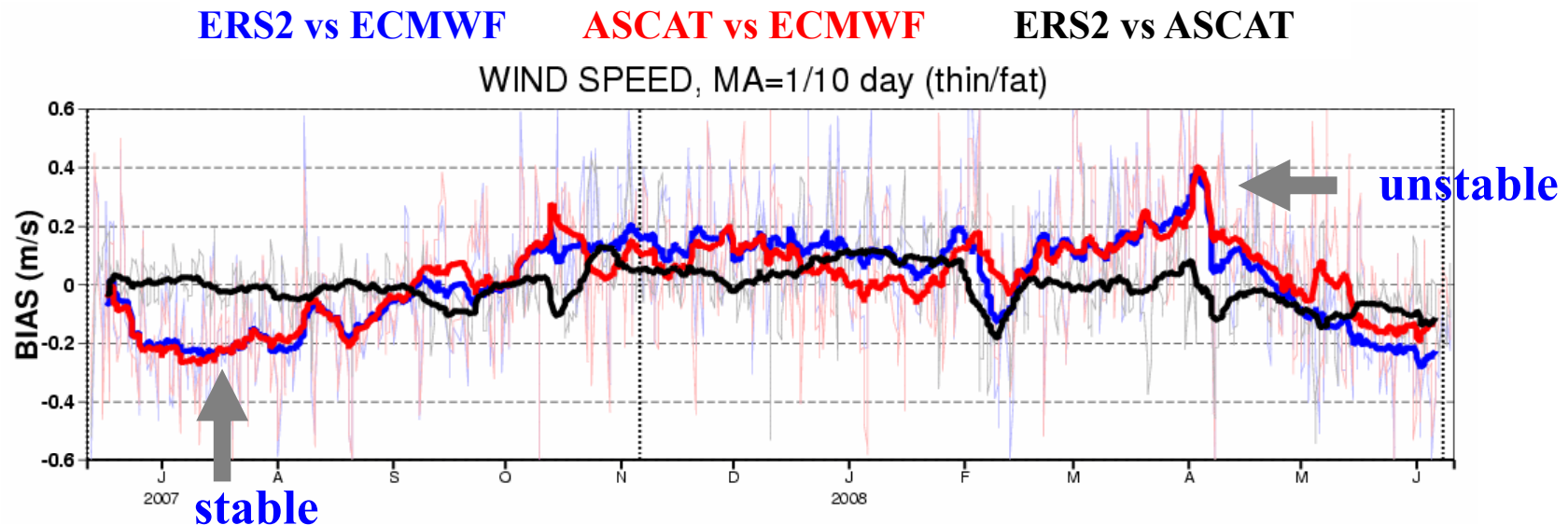


Wind speed errors  $\sim 0.5$  m/s

Relative error in **wind direction** larger

- Mainly due to ERS-2

# Time series for collocation set



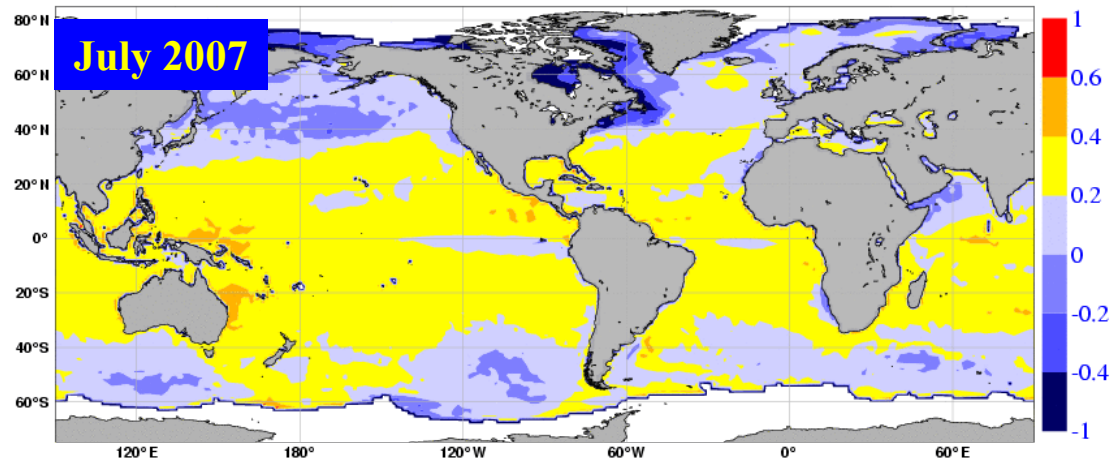
## Seasonal bias of ERS2 vs ECMWF, ASCAT vs ECMWF:

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

# ECMWF neutral vs non-neutral wind speed

Speed bias of neutral vs non-neutral ECMWF 10-metre wind (m/s), 200707

Globe 0.2 N.Hem 0.1 Tropics 0.27 S.Hem 0.19 MIN -1.12 MAX 0.5



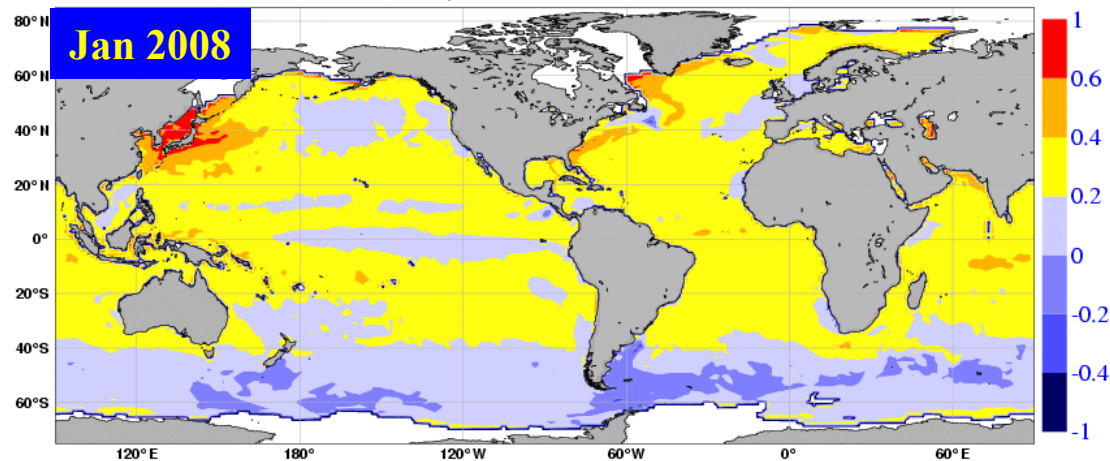
**Neutral ~0.2 m/s stronger**

➤ **Summer: stable**  
(warm air, cold ocean)

➤ **Winter: unstable**  
(cold air, warm ocean)

Speed bias of neutral vs non-neutral ECMWF 10-metre wind (m/s), 200801

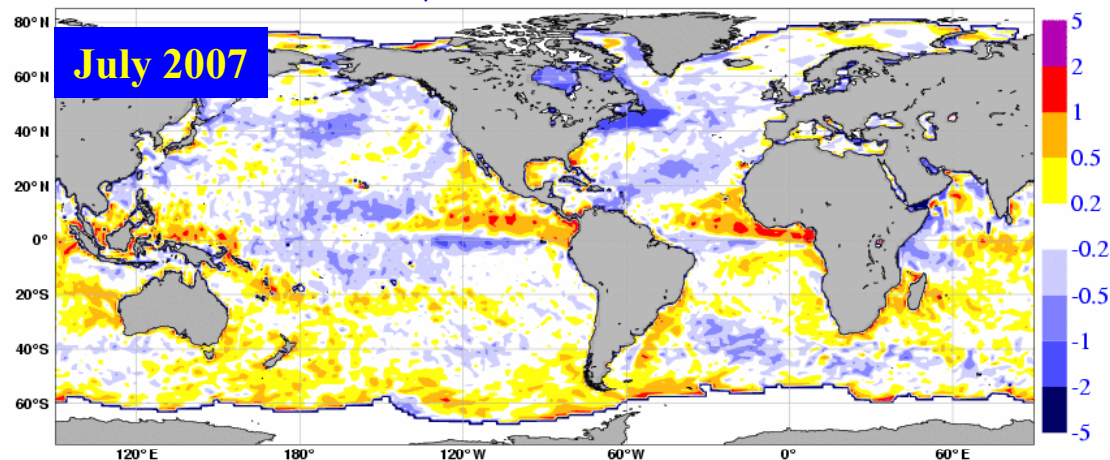
Globe 0.22 N.Hem 0.29 Tropics 0.27 S.Hem 0.14 MIN -0.33 MAX 0.72





# ASCAT vs ECMWF non-neutral wind

Anomaly of wind speed bias (ASCAT vs non-neutral) in m/s, 200707  
Globe 0 N.Hem -0.17 Tropics 0.02 S.Hem 0.11 MIN -3.73 MAX 8.55

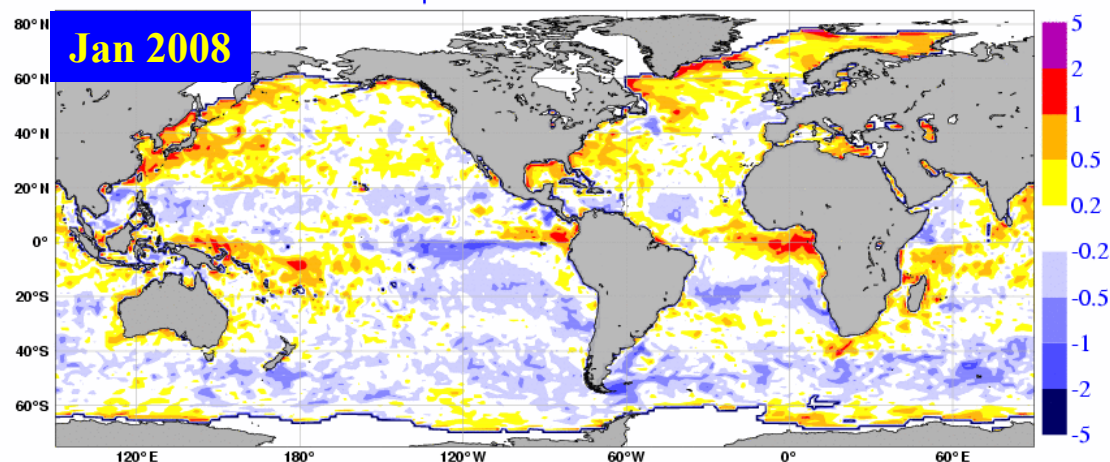


**Neutral ~0.2 m/s stronger**

➤ **Summer: stable**  
(warm air, cold ocean)

➤ **Winter: unstable**  
(cold air, warm ocean)

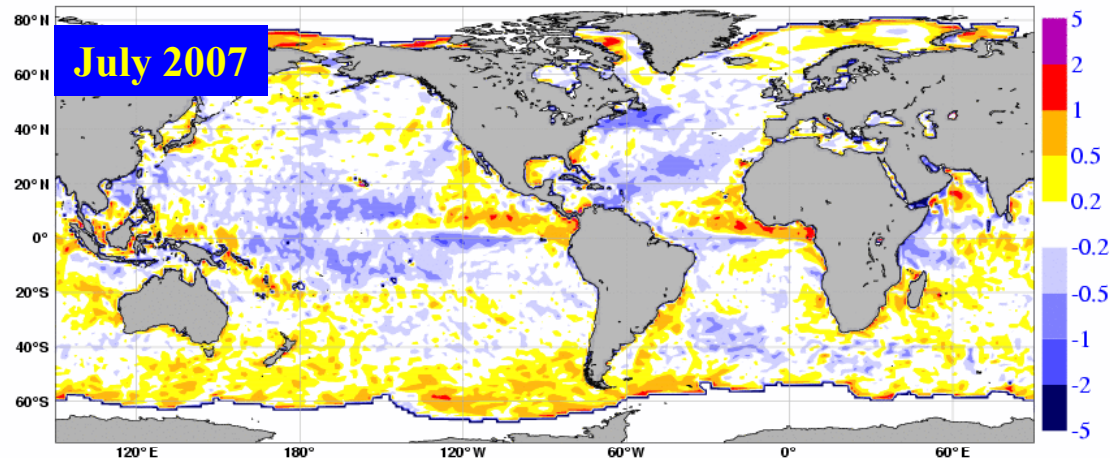
Anomaly of wind speed bias (ASCAT vs non-neutral) in m/s, 200801  
Globe 0 N.Hem 0.2 Tropics 0 S.Hem -0.11 MIN -1.92 MAX 2.69



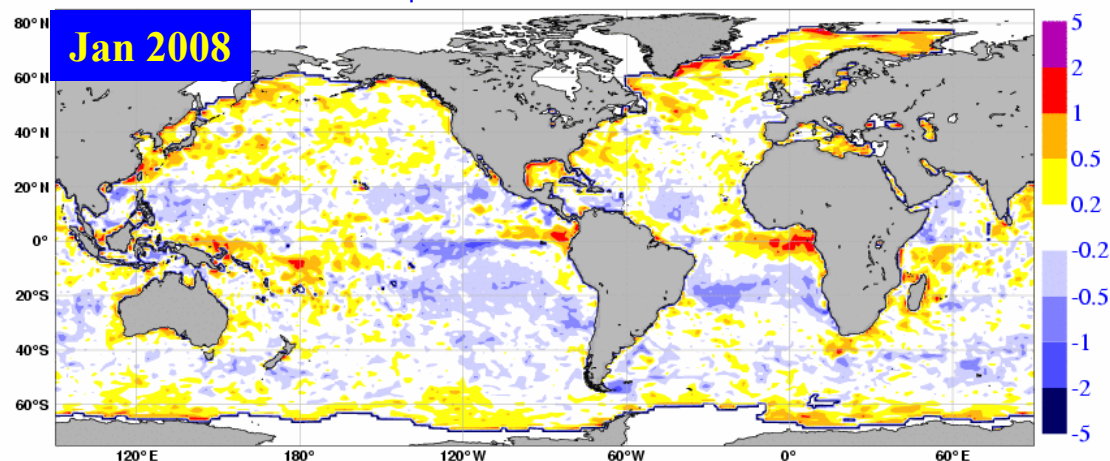
**Bias correlates with stability**

# ASCAT vs ECMWF neutral wind

Anomaly of wind speed bias (ASCAT vs neutral) in m/s, 200707  
Globe 0 N.Hem -0.07 Tropics -0.05 S.Hem 0.11 MIN -3.33 MAX 8.75



Anomaly of wind speed bias (ASCAT vs neutral) in m/s, 200801  
Globe 0 N.Hem 0.14 Tropics -0.04 S.Hem -0.03 MIN -1.83 MAX 2.64



**Neutral ~0.2 m/s stronger**

➤ **Summer: stable**  
(warm air, cold ocean)

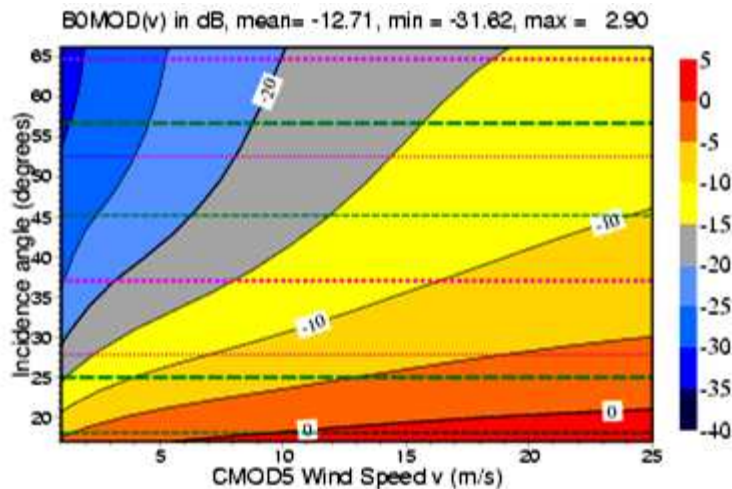
➤ **Winter: unstable**  
(cold air, warm ocean)

**Bias correlates with stability**

**Residual effects:**

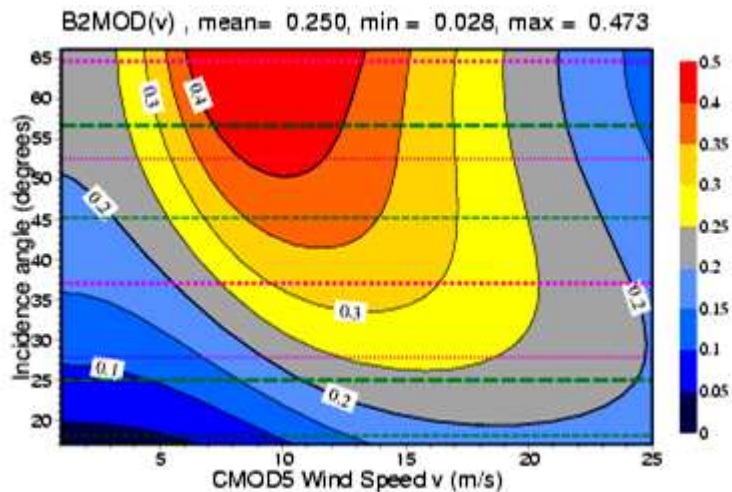
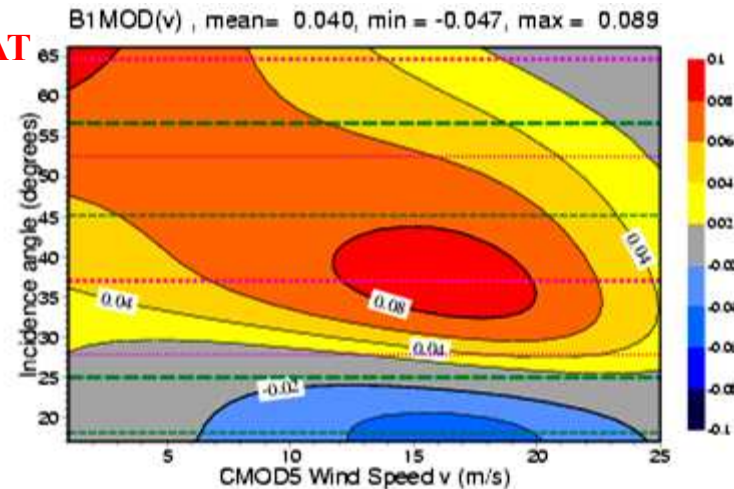
- **Stability dependent model error**
- **Other model errors**
- **Ocean currents**
- **Sea state effects**

# CMOD5.N



ERS2

ASCAT



## CMOD5:

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

## CMOD5N:

- Tune to neutral wind
- Shift:  $\text{CMOD5N} = \text{CMOD5} + 0.7$  m/s
- By refit of its 28 coefficients
- Good comparison ERS2/ASCAT with ECMWF neutral wind speed



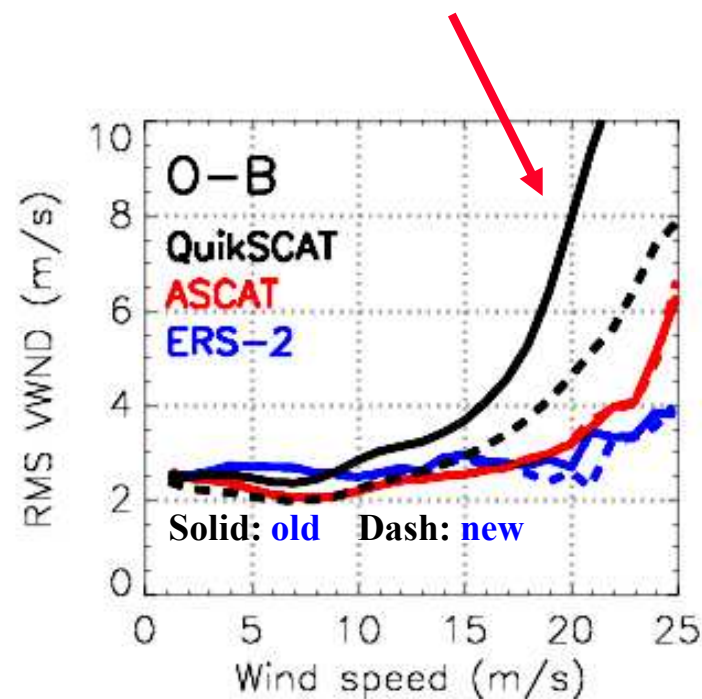
# Usage of 4 ambiguities from QuikSCAT

ASCAT/ERS-2: two ambiguous wind solutions

QuikSCAT: four solutions

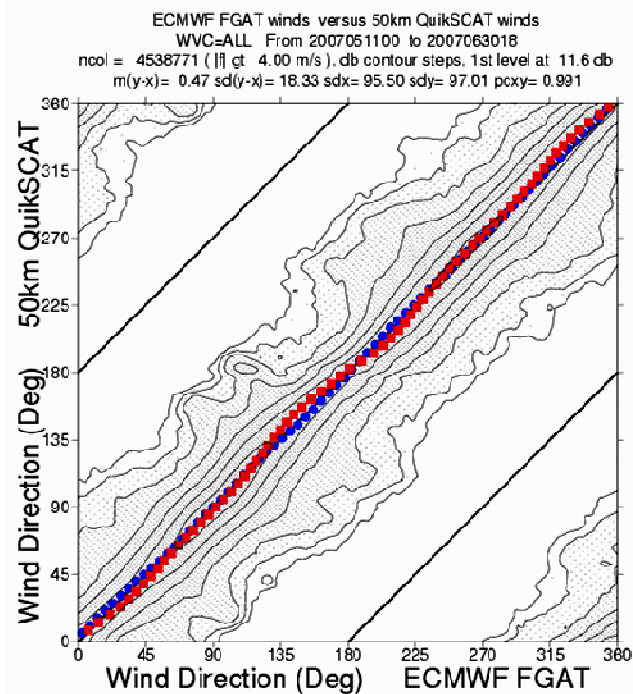
## Departure statistics for QuikSCAT

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

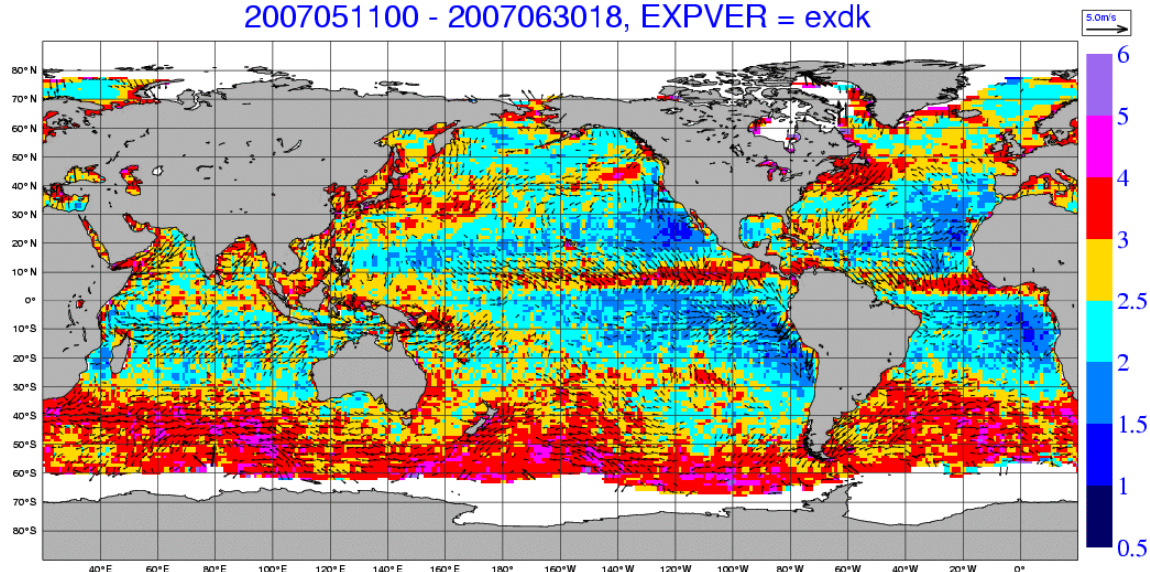


# Effect on vector wind (~ cost function)

## Quikscat use 2 wind solutions



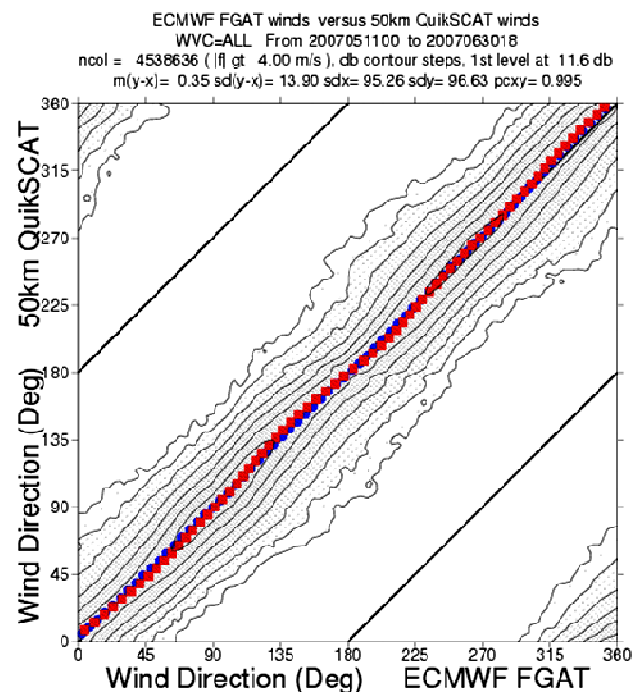
Vector-wind difference (m/s) of QuikSCAT vs ECMWF FGAT for all flows  
Globe 2.67 N.Hem 2.59 Tropics 2.45 S.Hem 2.96 MIN 1.11 MAX 7.55  
2007051100 - 2007063018, EXPVER = exdk



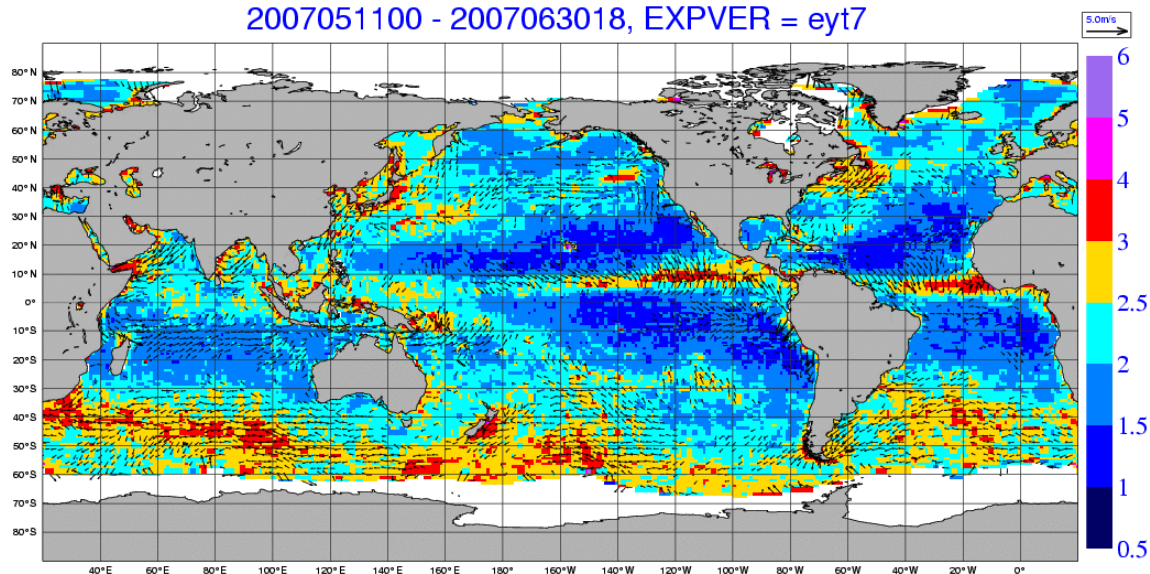
(O-B) STDV	wind speed	wind direction
QSCAT (2 amb)	1.31 m/s	18.3 Deg
QSCAT (4 amb)	1.28 m/s	13.9 Deg
ASCAT	1.29 m/s	14.3 Deg

# Effect on vector wind (~ cost function)

## Quikscat use 4 wind solutions

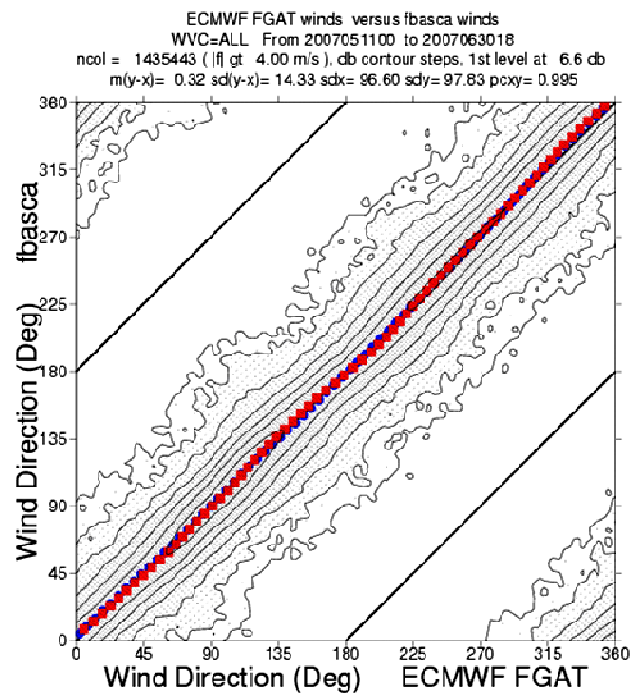


Vector-wind difference (m/s) of QuikSCAT vs ECMWF FGAT for all flows  
Globe 2.18 N.Hem 2.15 Tropics 2 S.Hem 2.39 MIN 1.13 MAX 5.78  
2007051100 - 2007063018, EXPVER = eyt7

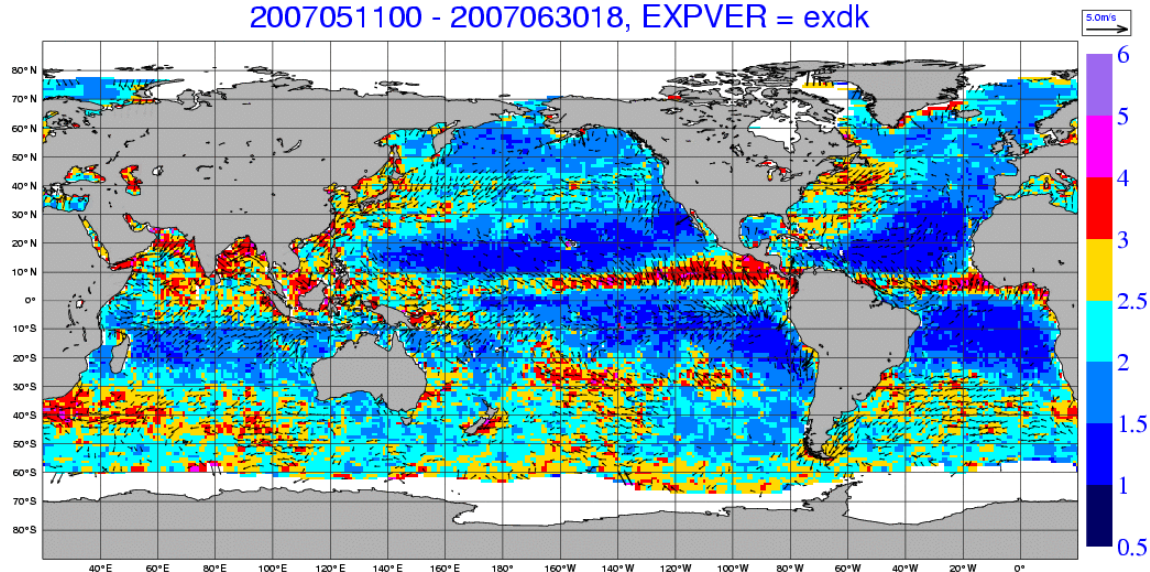


(O-B) STDV	wind speed	wind direction
QSCAT (2 amb)	1.31 m/s	18.3 Deg
QSCAT (4 amb)	1.28 m/s	13.9 Deg
ASCAT	1.29 m/s	14.3 Deg

# Effect on vector wind (~ cost function) ASCAT



Vector-wind difference (m/s) of fbasca vs ECMWF FGAT for all flows  
Globe 2.17 N.Hem 2.07 Tropics 2.06 S.Hem 2.34 MIN 0.96 MAX 10.29  
2007051100 - 2007063018, EXPVER = exdk



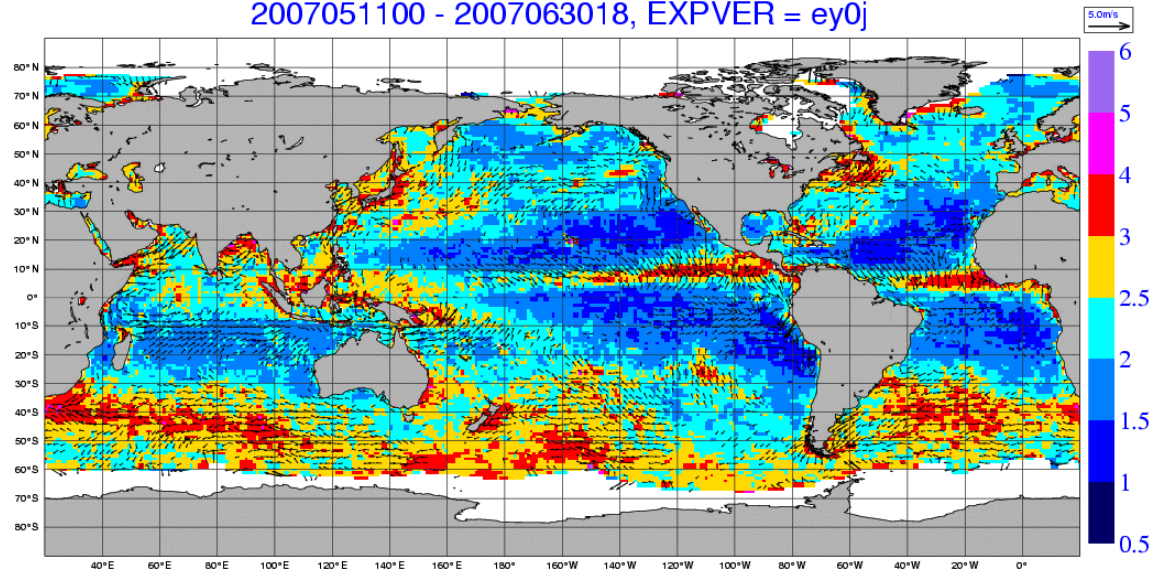
(O-B) STDV	wind speed	wind direction
QSCAT (2 amb)	1.31 m/s	18.3 Deg
QSCAT (4 amb)	1.28 m/s	13.9 Deg
ASCAT	1.29 m/s	14.3 Deg



# Effect on vector wind (~ cost function)

## New Quikscat stream, use 4 wind solutions

Vector-wind difference (m/s) of QuikSCAT vs ECMWF FGAT for all flows  
Globe 2.28 N.Hem 2.23 Tropics 2.11 S.Hem 2.52 MIN 0.85 MAX 15.5  
2007051100 - 2007063018, EXPVER = ey0j



- Use new JPL rainflag,
- Rather than flag used at ECMWF:  
(NOF index, Mp\_rain\_prob)

# Usage of ocean current in the ECMWF forecast system

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

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

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

Then:

$$\vec{u}_{\text{abs}}(z) = \vec{u}_{\text{rel}}(z) + \vec{u}_{\text{oc}}. \quad (2)$$

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

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

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

- It is the stress, so  $\vec{u}_{\text{rel}}$  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:

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

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

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

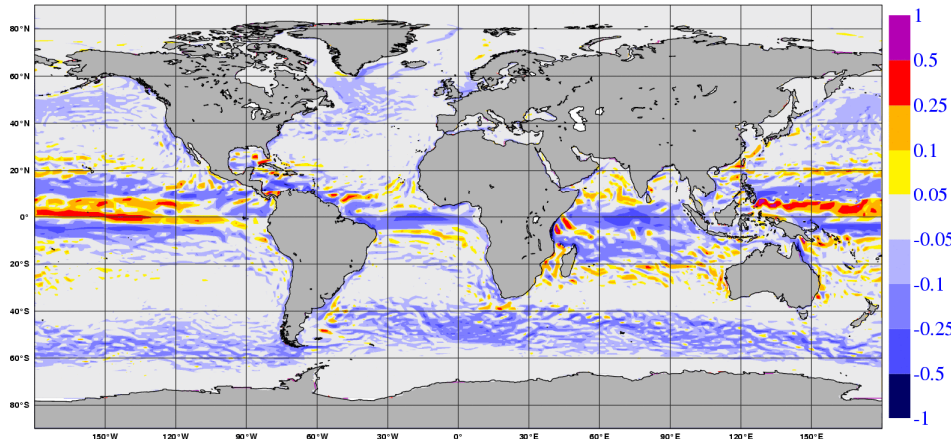
Since now  $\vec{\mathbf{u}}_L = \vec{\mathbf{u}}_{\text{abs}}(z_L)$ , rather than  $\vec{\mathbf{u}}_{\text{rel}}(z_L)$

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

# Average effect on **Analysis** surface winds

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

Difference in 10-metre Wind (m/s), MEAN: -0.038 MAX: 0.899 MIN: -1.468 (f1ne-f1bl)



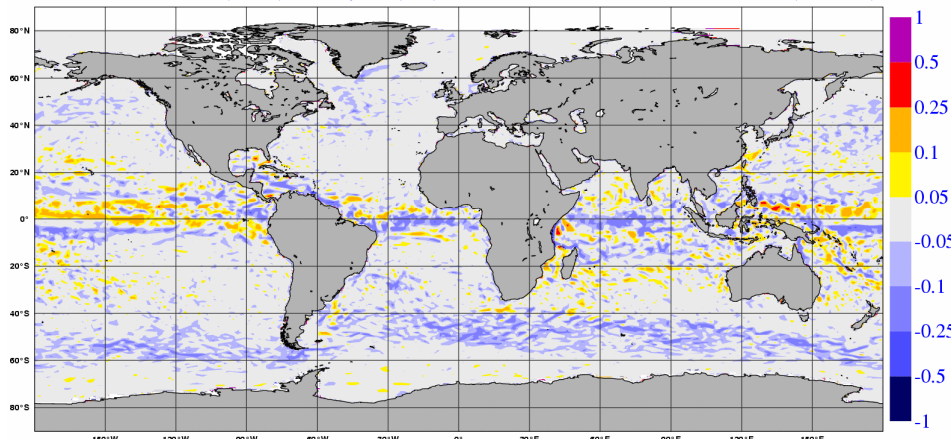
**T511 (40km) assimilation impact study, ocean waves 55km**

- ✓ 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

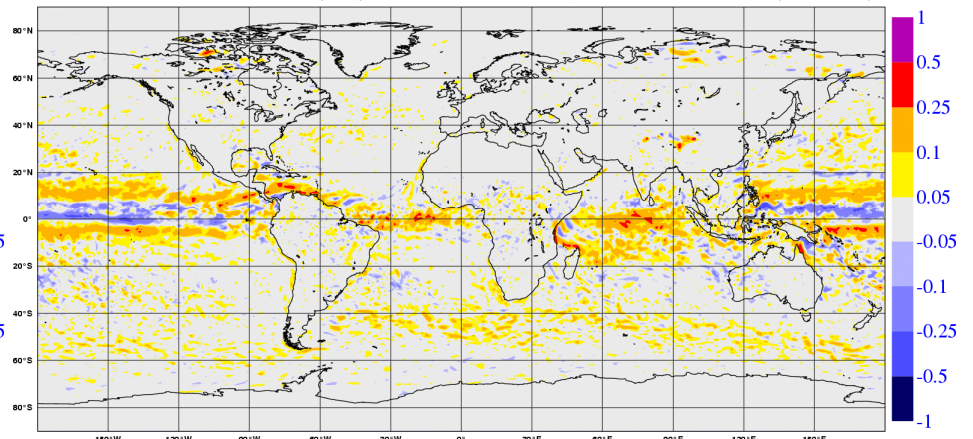
## Average wind speed in **relative** frame

Difference in 10-metre (Wave) Wind Speed (m/s), MEAN: -0.019 MAX: 0.617 MIN: -0.817 (f1ne-f1bl)



## Average wind speed in **absolute** frame

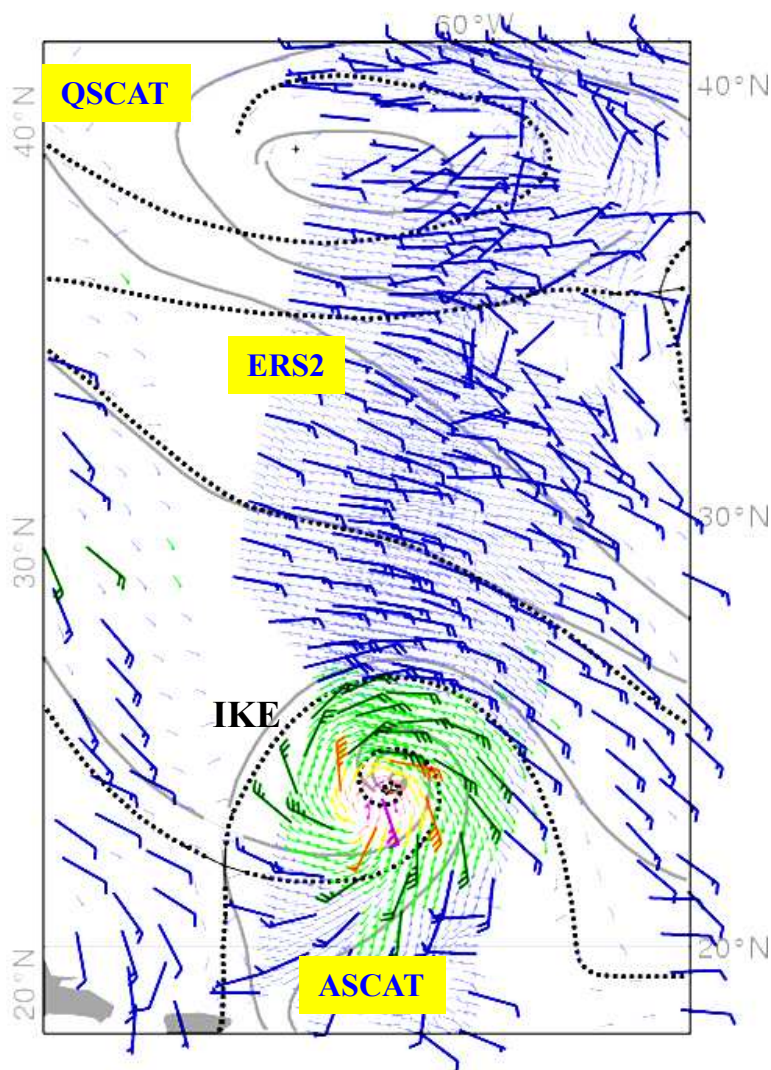
Difference in 10-metre Wind (m/s), MEAN: 0.013 MAX: 0.932 MIN: -0.499 (f1ne-f1bl)





# Summary/outlook

Scatterometer winds for 2008090512



**ERS-2 data looks fine**

**Recent operational change at ECMWF:**

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

**Pending changes**

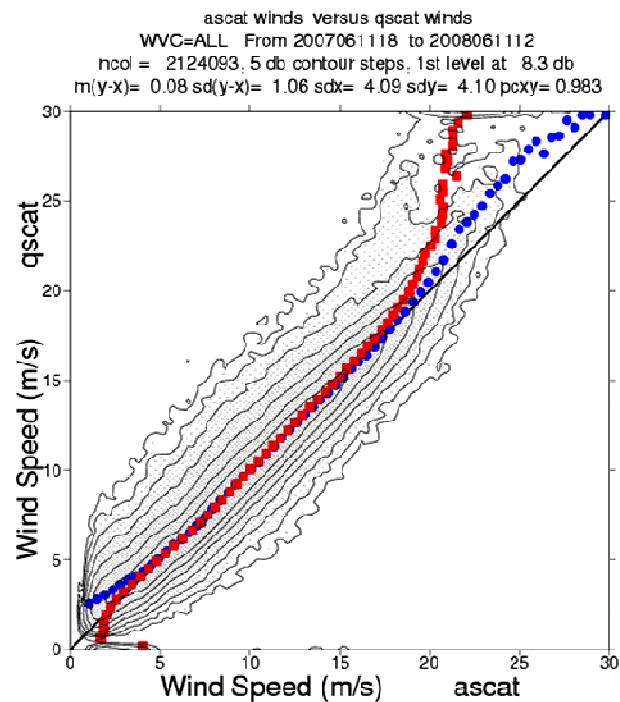
- ✓ Processing of new QuikSCAT stream
- ✓ ASCAT EARS, soil moisture

**Ongoing research**

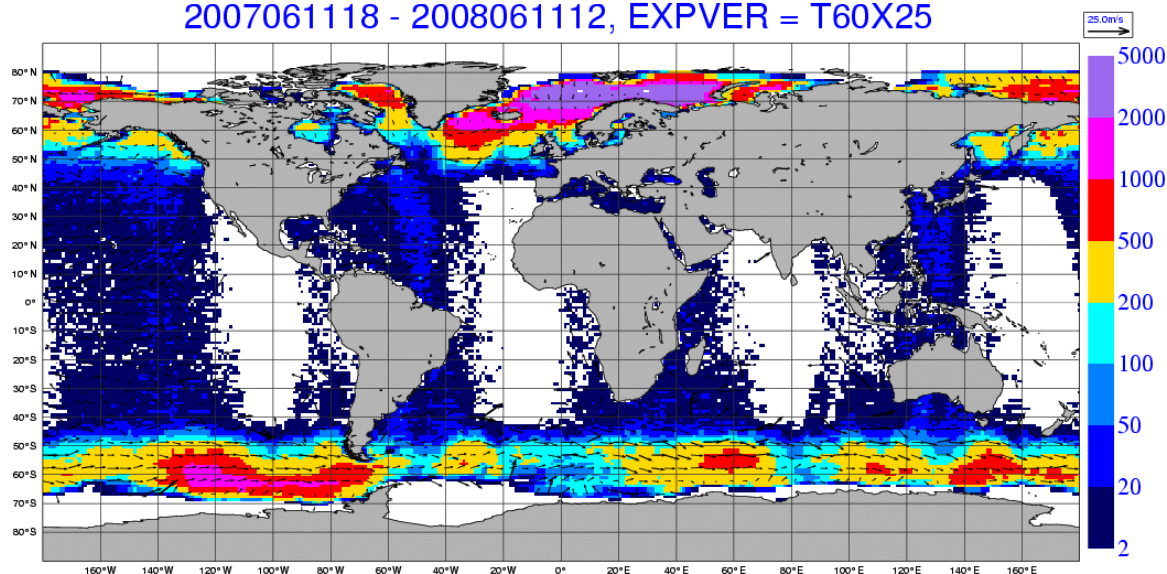
- ✓ Include option for ocean currents and neutral winds in **SCAT** observation operator  
(switch in next model cycle)

# BACK UP SLIDES

# Collocation QuikSCAT and ASCAT



Number of wind speed collocations of qscat vs ascat for all flows  
Globe 129 N.Hem 214 Tropics 8 S.Hem 143 MIN 2 MAX 5142  
2007061118 - 2008061112, EXPVER = T60X25



# The effect of ocean current on 10m wind

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

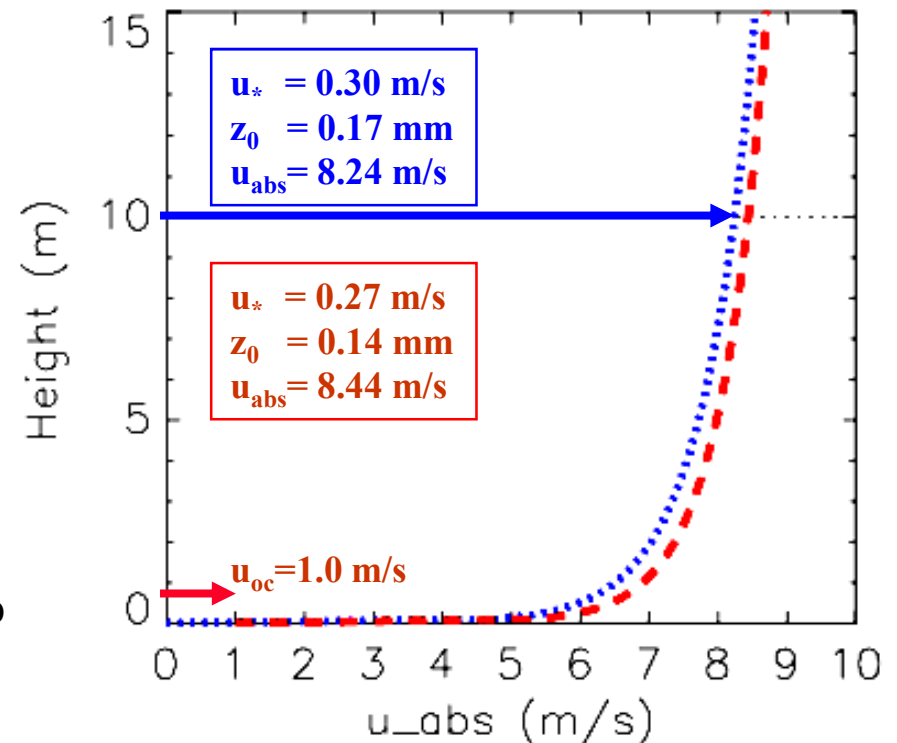
- Since ocean currents are not incorporated in the operational ECMWF model usually, 10m relative winds are constructed as:

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

- 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

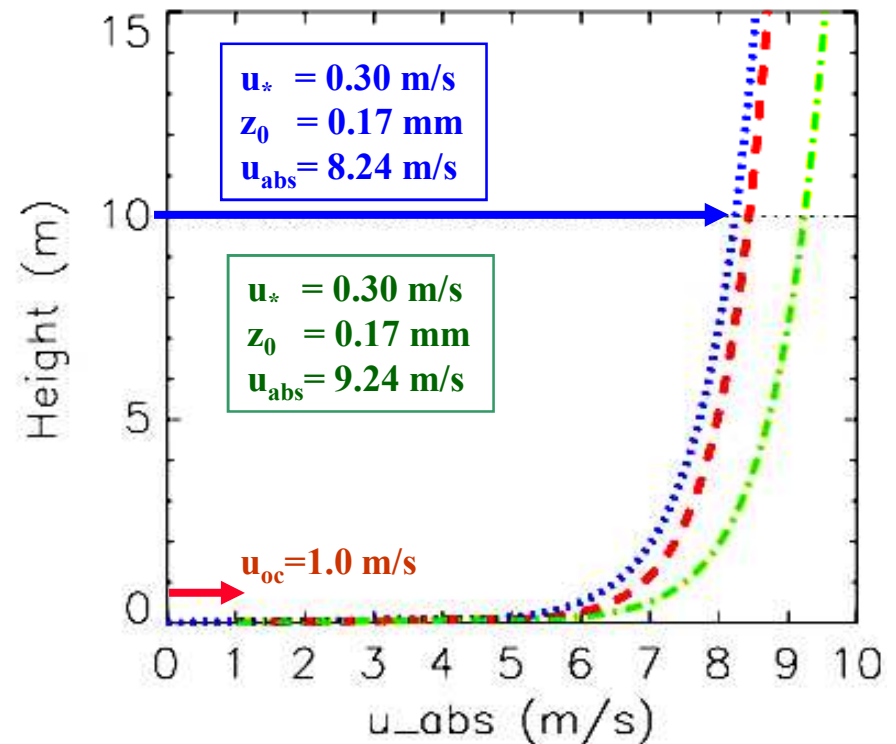
Denote the original 10m ECMWF absolute wind by:  $u_{\text{ECMWF}}(10)$

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

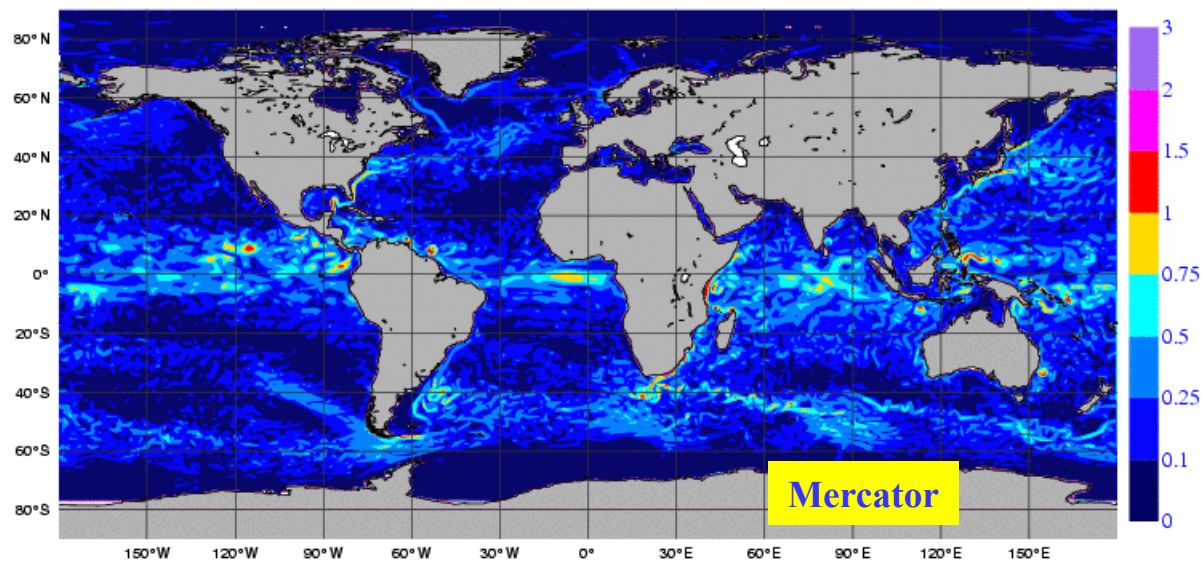
- 'Forcing' of winds in free atmosphere
- Usage of moored buoy, ship observations
- ✓ Confirm value of  $u_{\text{ECMWF}}(10)$

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

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



2008040100 Ocean-surface Current (m/s), MEAN: 0.176 MAX: 2.542 MIN: 0 (MERCATOR)

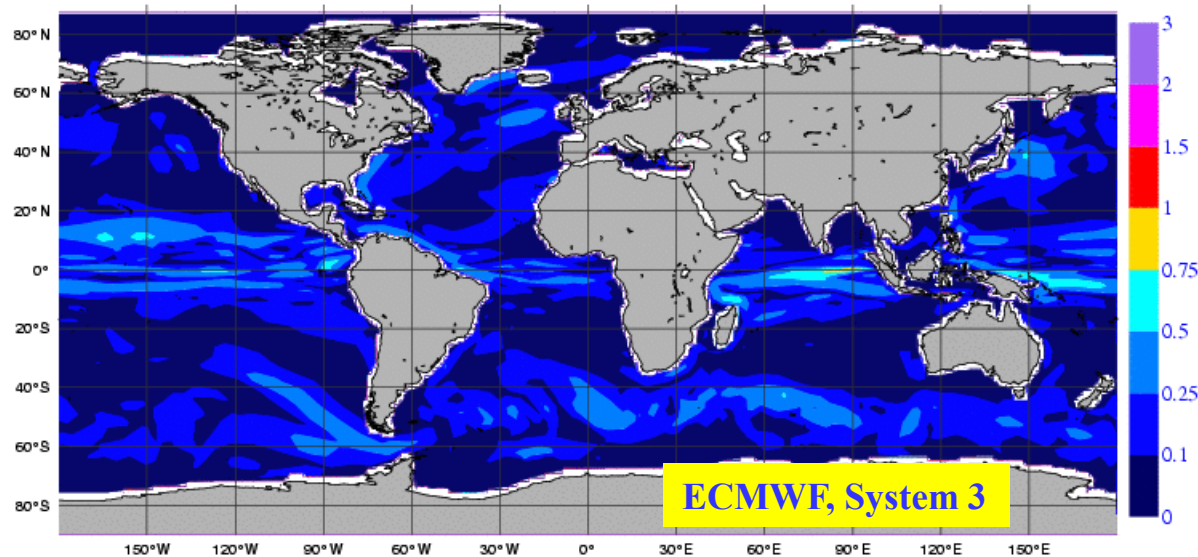


## Mercator vs ECMWF (system 3)

### Mercator:

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

2008040100 Ocean-surface Current (m/s), MEAN: 0.122 MAX: 0.965 MIN: 0 (ECMWF OC)



### ECMWF (system 3):

- Larger response to instantaneous wind field