Ocean current effects on sea states :

wave heights, slopes, Stokes drift, breaking, fluxes … feedback on remote sensing

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This work is funded by ERC Young investigator award « IOWAGA » and NOPP

Integrated Ocean Waves for Geophysical and other Applications

IOWAGA is mostly funded by FP7-ERC

http://wwz.ifremer.fr/iowaga

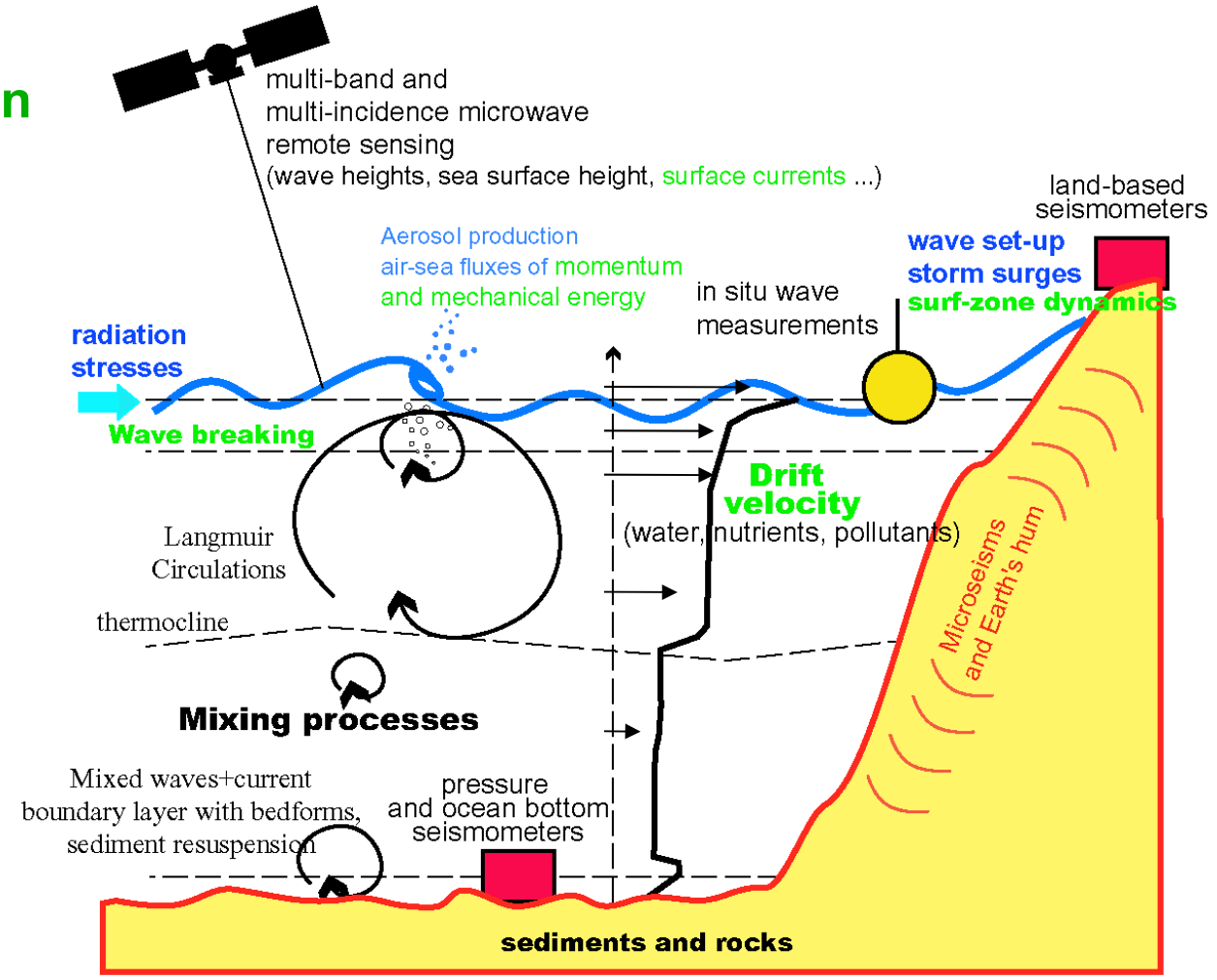
Ifremer

Waves and Earth System sciences

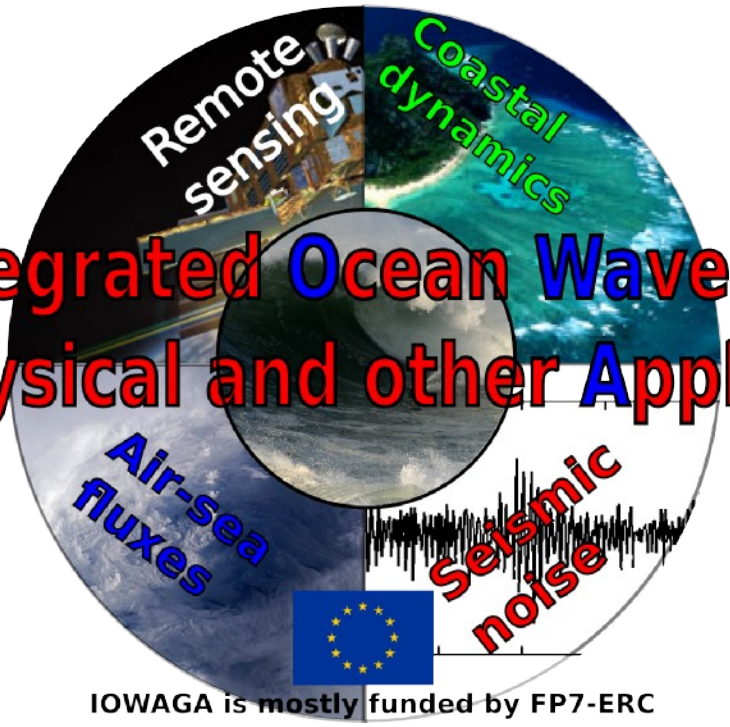
Ocean waves play a leading role at the interfaces :

- **Air-sea**
  - **Land-ocean**
- **Ocean bottom**

+ engineering applications



Waves and Earth System sciences



Integrated Ocean Waves for Geophysical and other Applications

http://wwz.ifremer.fr/iowaga

IOWAGA project started Jan. 2010

→ **integrated** approach

→ interdisciplinary

- partnership with NOAA/NCEP

- over 100 users of IOWAGA products, from NASA (Aquarius processing) to geomorphologists and seismologists.

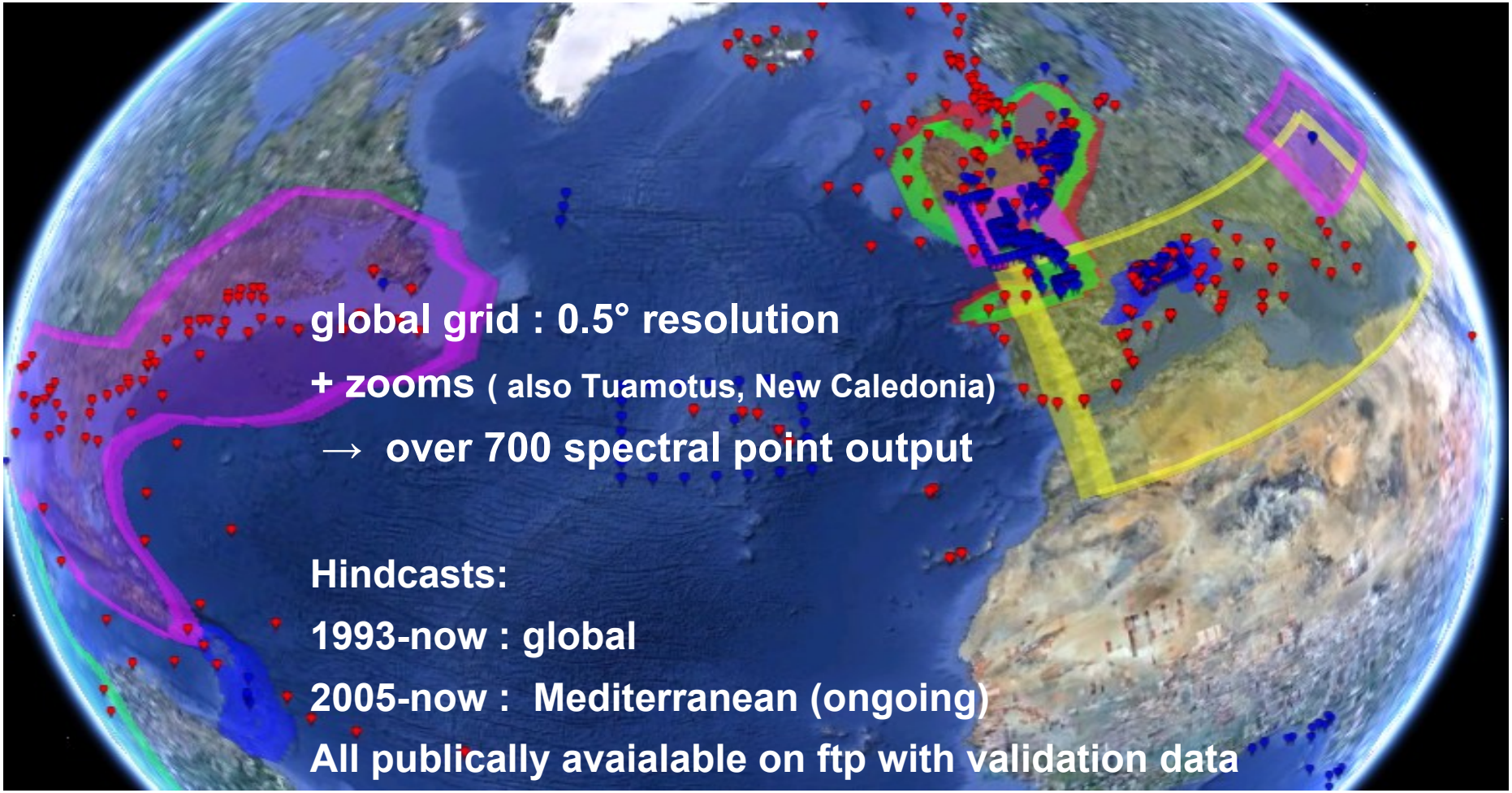
1

Numerical wave models at global scales :

Do we need ocean currents ? What for ? At what scale ?

1. wave models at global scale

Zooms and spectral output points in the 10 year IOWAGA hindcast
Output parameters include all air-sea fluxes + sea and swells data …

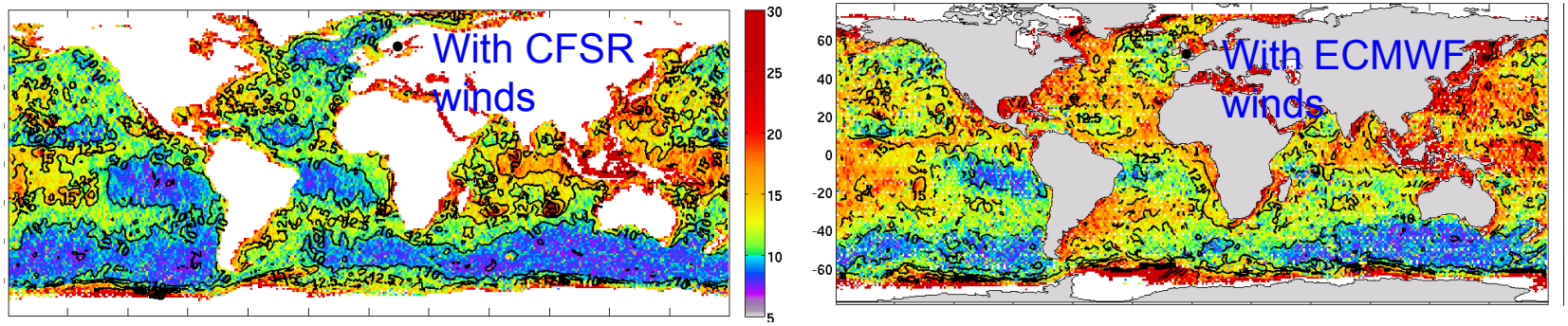


1. wave models at global scale

The most dramatic improvement in wave modeling over the last 10 years has been obtained by

1) improved forcing fields :

- Winds : amazing improvements in NWP analyses, especially ECMWF – issues remain in coastal areas and for high winds – and re-analyses, especially CFSR (NCEP-NCAR, Saha et al. 2010).



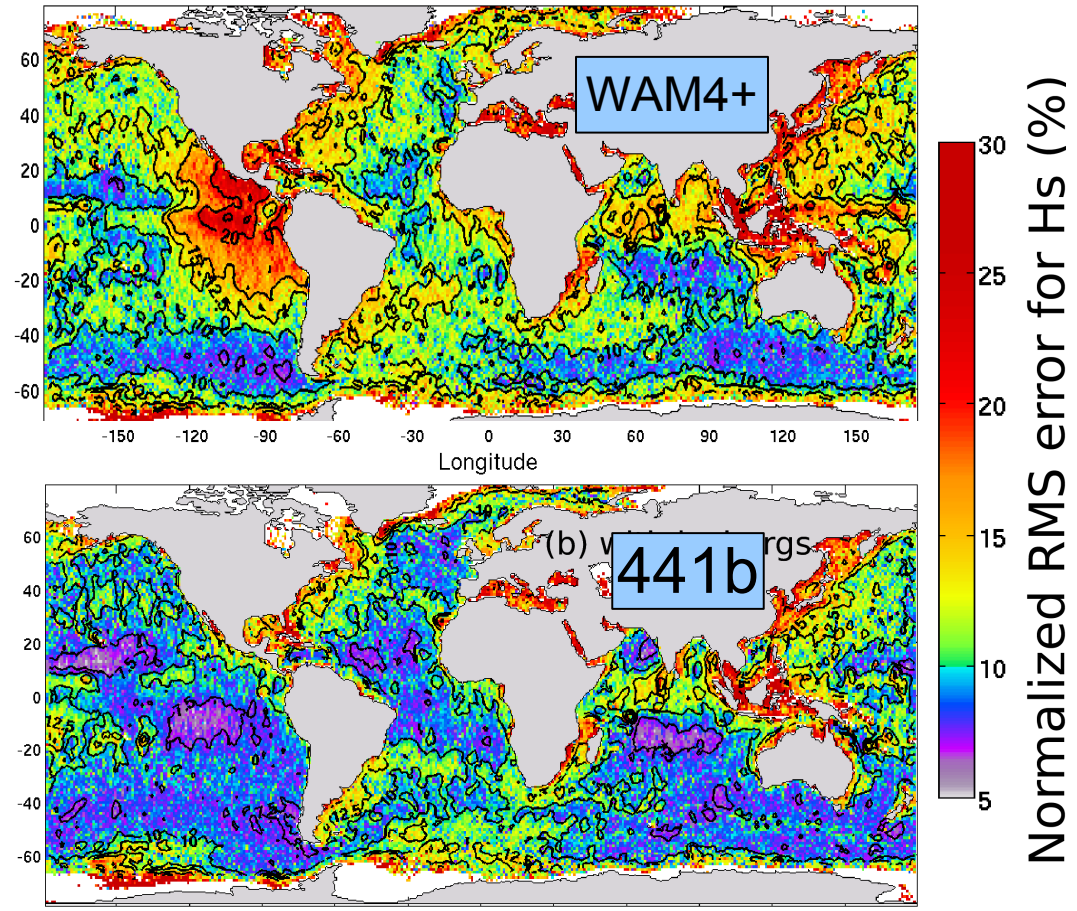
Normalized RMS error map for significant wave height: red > 20% (poor), blue < 10% (very good).

Results the IOWAGA modelling system (Tolman 2008, Ardhuin et al. 2010, 2011) for year 2004, all available on our ftp server.

- Icebergs (detected by Jason-1, Ardhuin et al. Ocean Modelling, 2011)

1. wave models at global scale

2) improved parameterizations



Global average of NRMSE for 2008:

13.8% : WAM Cycle 4 (Janssen 1994)

13 % ?? : Tolman & Chalikov (1996)

12.7% : WAM4+ (Bidlot et al. 2005)

Used in ECMWF WAM (updated in 2009)

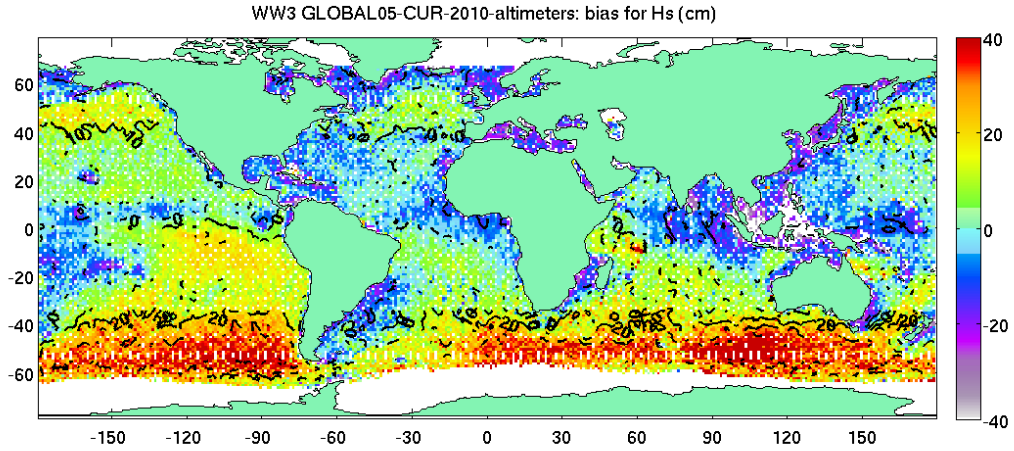
11.1 % : TEST441b
(Ardhuin et al. 2009)
Now used at Météo-France

10.6 % : TEST451 (March 2012)

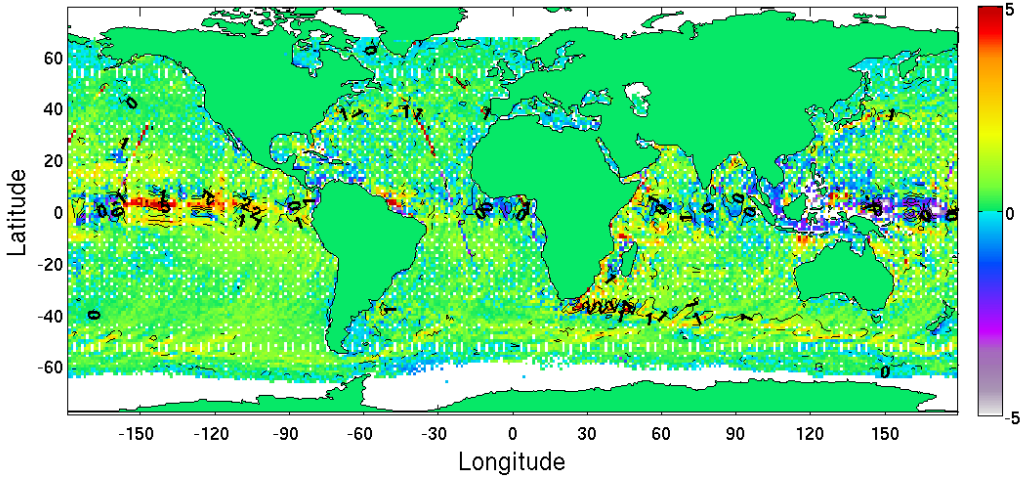
(all using same forcing)

1. wave models at global scale :

Including currents from Mercator PSY3



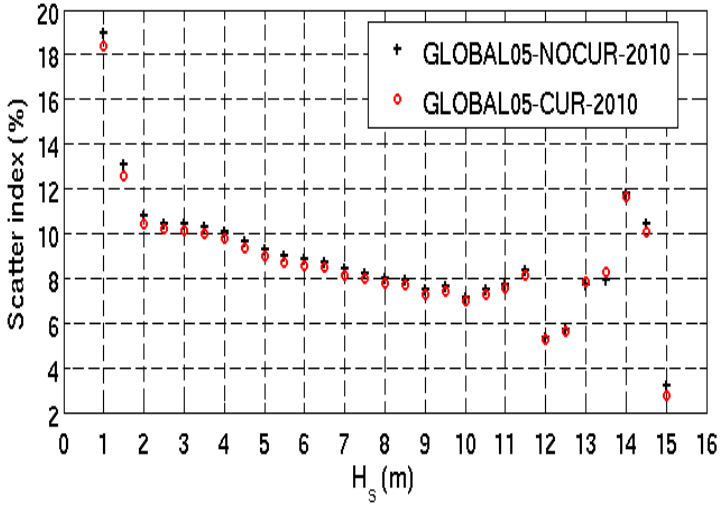
Red : much better, blue : worse



There was already a clear signature of currents on global scales (Rascle et al. OM 2008) : using Mercator PSY3.

But it is really getting better : SI reduction by 0.4 points (4%) on average.

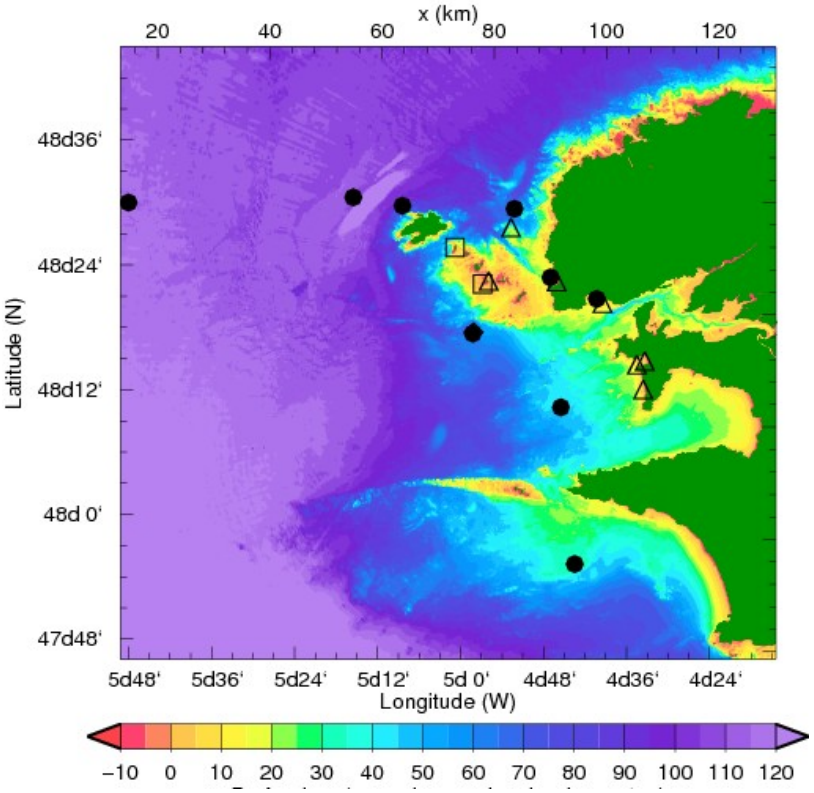
We are now getting a global mean error under 10%.

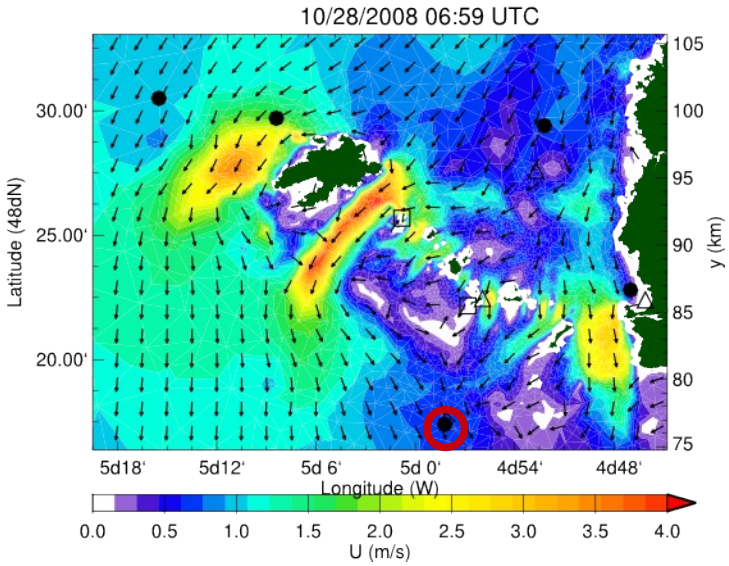


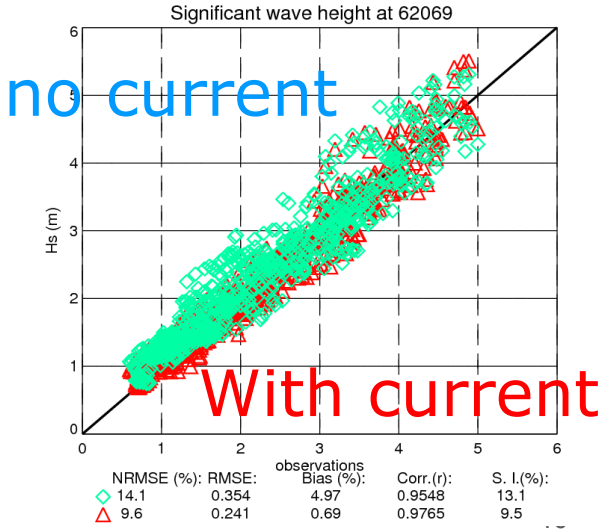
2

Numerical wave models at coastal scales

2. Coastal currents and waves



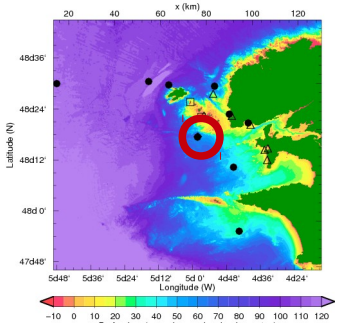


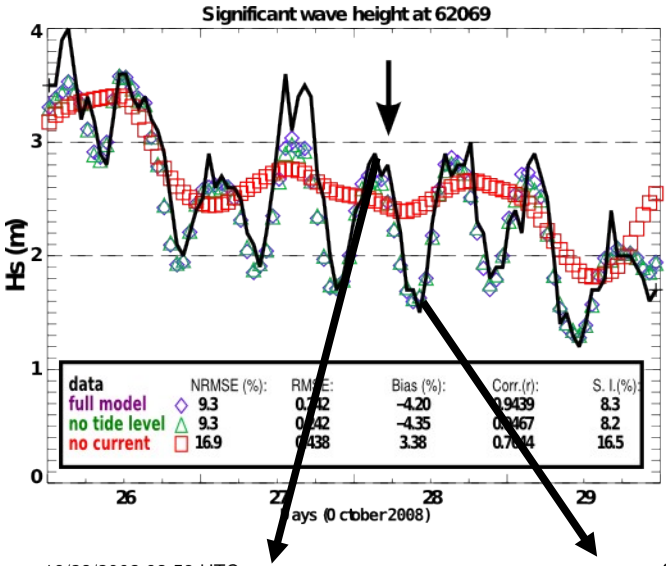


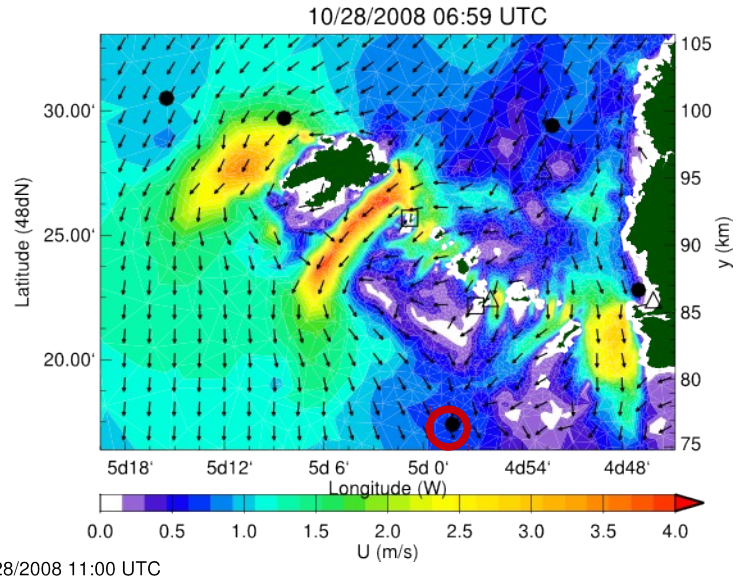
Coastal sea states in macrotidal areas are strongly influenced by currents... not just where the currents are strong

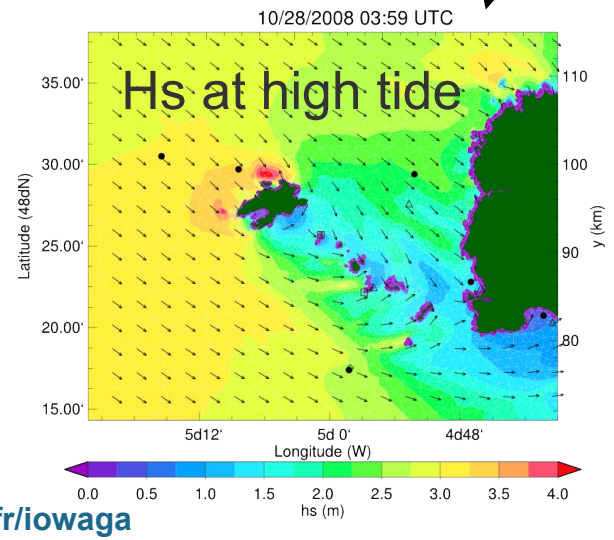
2. Coastal currents and waves

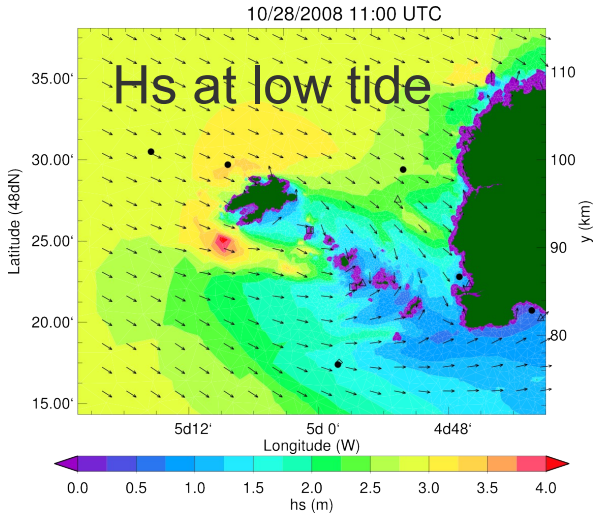
Model very good at buoy 62069 (for 2006-2011, RMSE for Hs is 12%, 11% for Tm02)… but why?







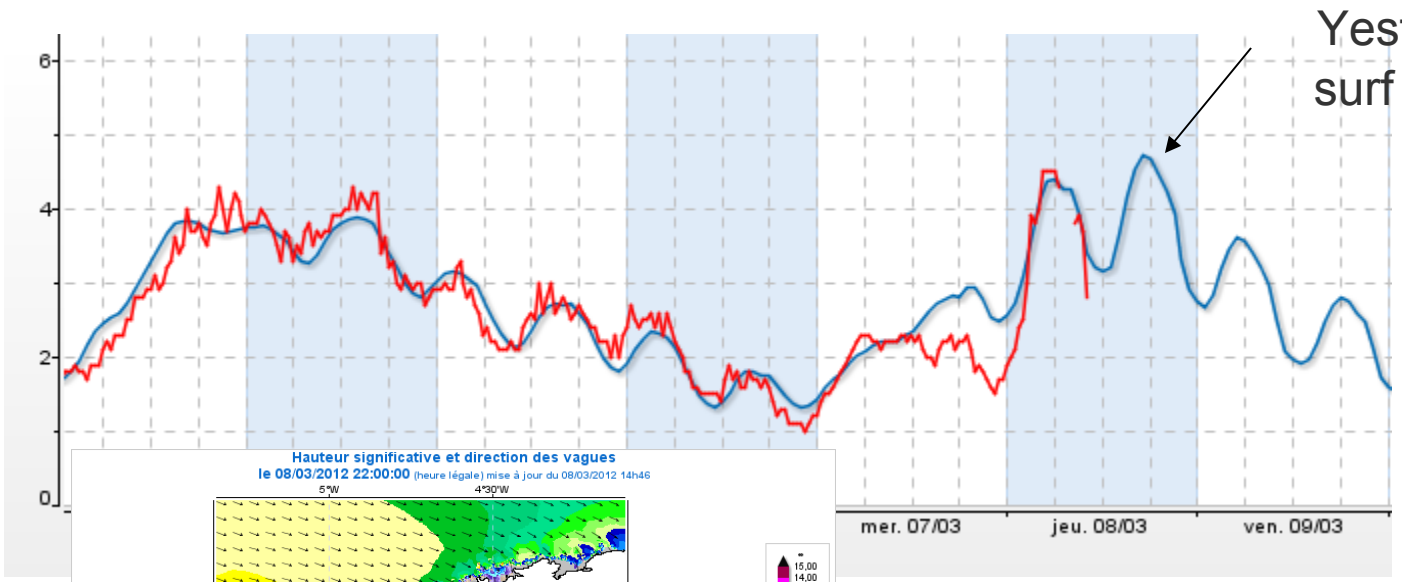


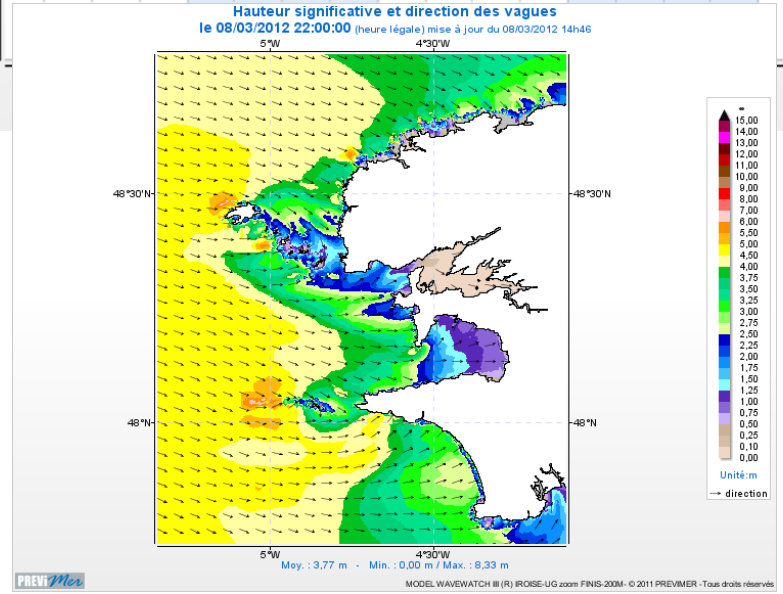


Advection + refraction enhance the island shadow

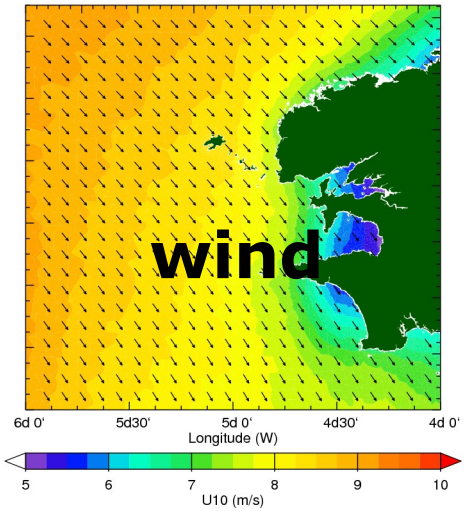
2. Coastal currents and waves

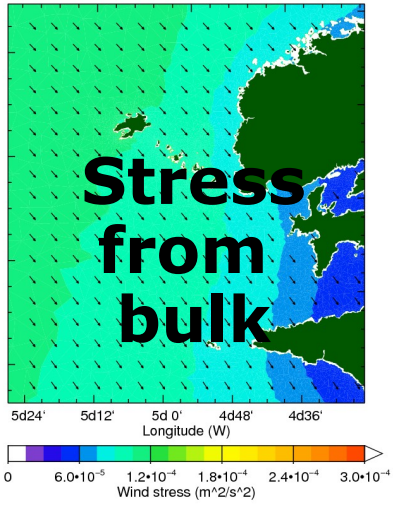
And it is like that all the time …



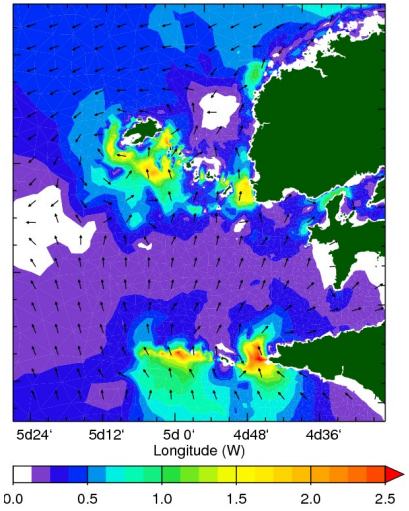


Consequence on air-sea fluxes …

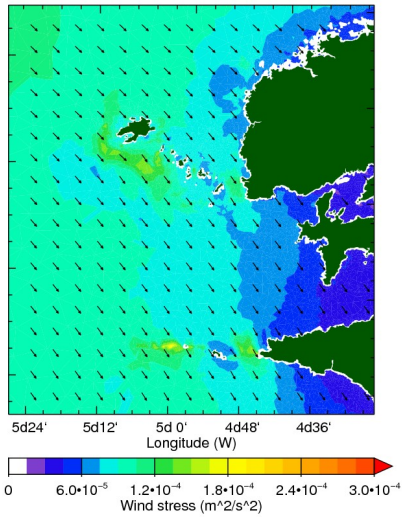


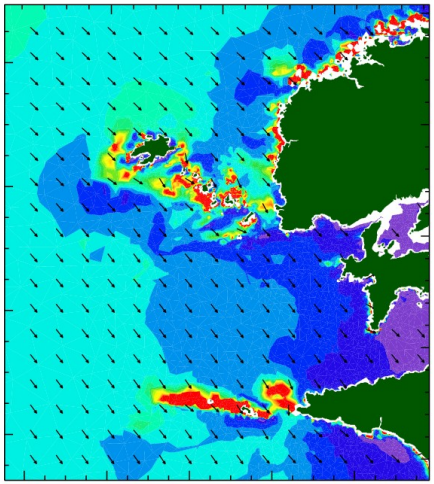


current



stress

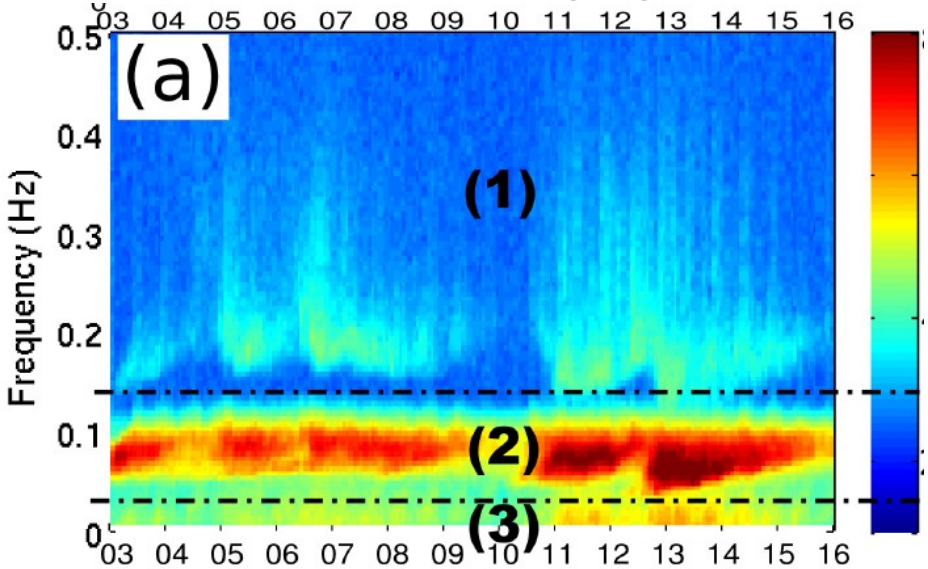




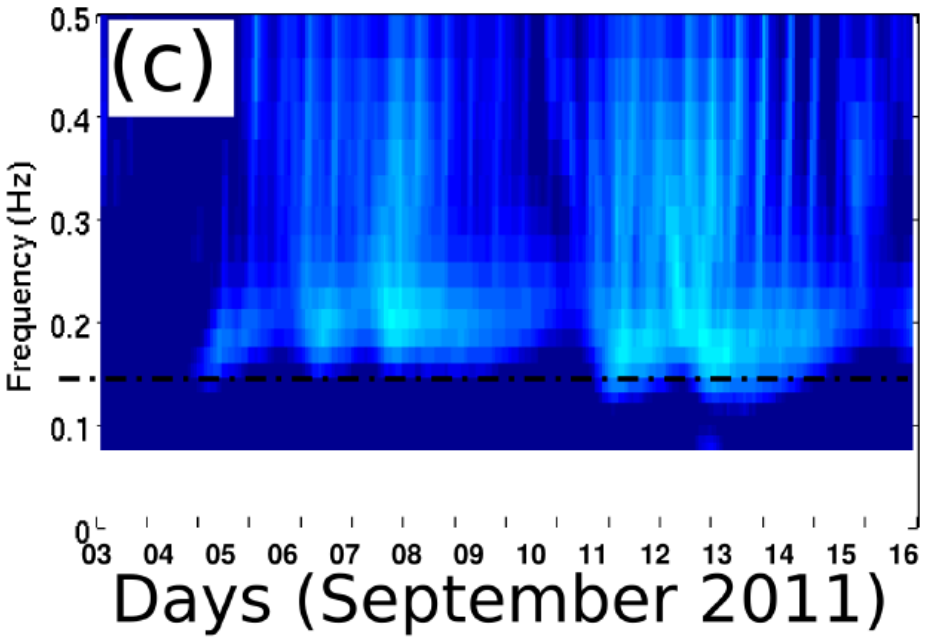
effective stress (momentum dumped by ocean wave dissipation)

Signature of currents in 2nd order wave spectrum :

Record of SBE26 pressure gauge. 100 m depth



model of 2nd order pressure

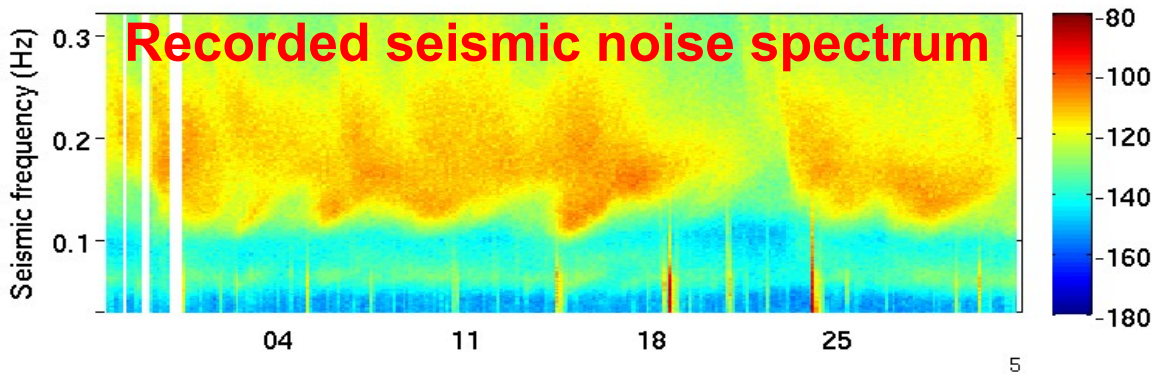


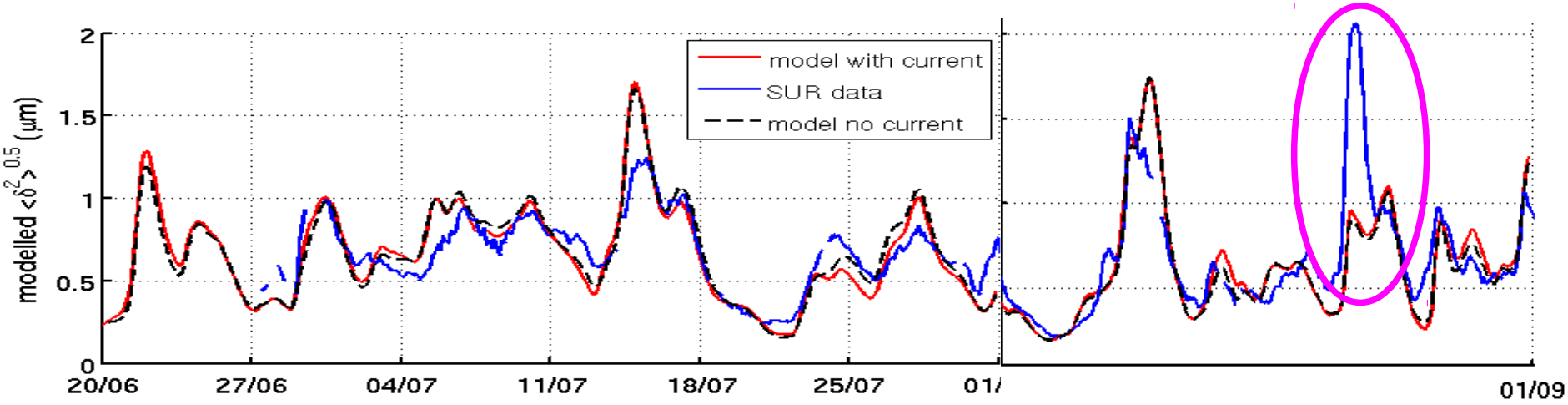
Data courtesy of Louis Marié and SHOM (FROMVAR 2011)

This pressure signal (1) is the source of the seismic noise …

Modelling the impact of currents on seismic noise off South Africa

- Seismic data from Sutherland, South Africa (data from IRIS/IDA)
- Mercator PSY3 currents, ECMWF winds, global 0.5° WAVEWATCH III set-up





3

Conclusions …

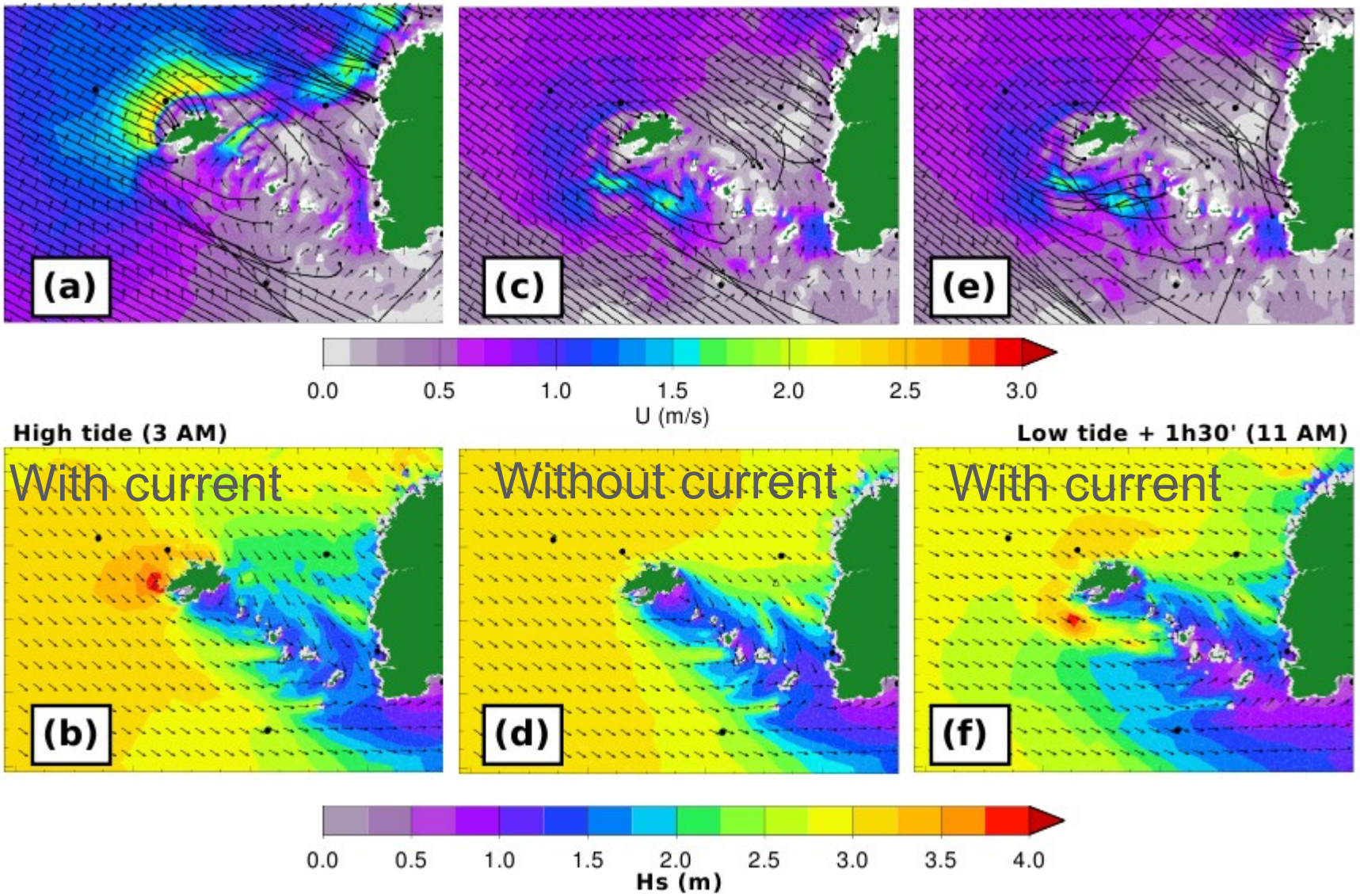
Conclusions

- **Global wave models are getting better**
  - Better forcing (analysis, forecasts, reanalysis)
  - new forcings (icebergs, soon ocean currents)
  - Better parameterizations (mainly dissipation)
  - New « products » : air-sea fluxes, seismic noise, sources, whitecap statistics, infragravity wave forcing …

- **All this is sensitive to currents.**
  - Gradients are very important : 10 km can be important for dominant waves, tidal currents must be included.
  - Effects of smaller scales? (ongoing work)
  - Verification of whitecap statistics ?
    (part of Oceanflux-ghg sponsored by ESA)

- **Tidal currents well modeled**
  → **benchmark for testing SAR, wave models …**

2. Coastal currents and waves

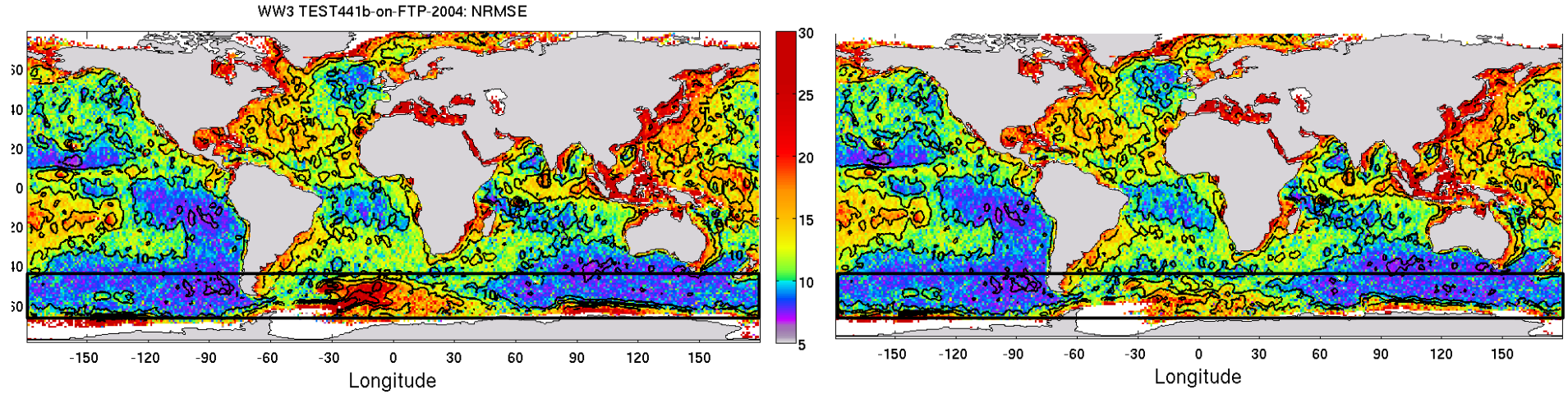


1. recent improvement in wave models : global scale

The most dramatic improvement in wave modeling over the last 10 years has been obtained by

1) improved forcing fields :

- Icebergs (Ardhuin et al. Ocean Modelling, 2011)



No icebergs :

bias in latitude band

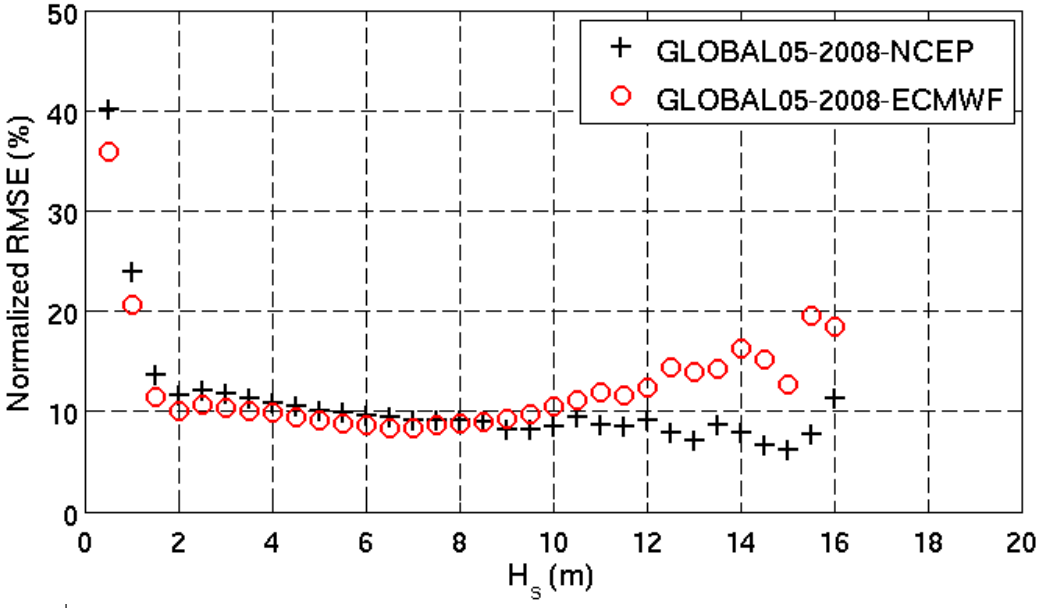
65 to 45 °S

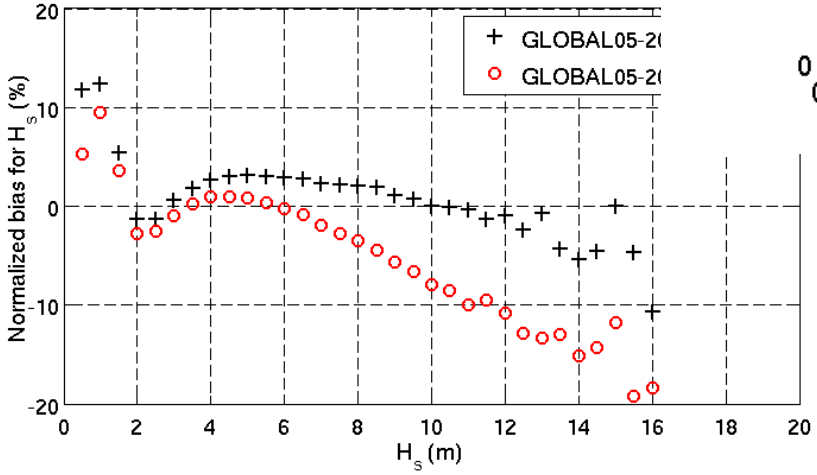
with icebergs

1.a recent improvement in wave models : global scale

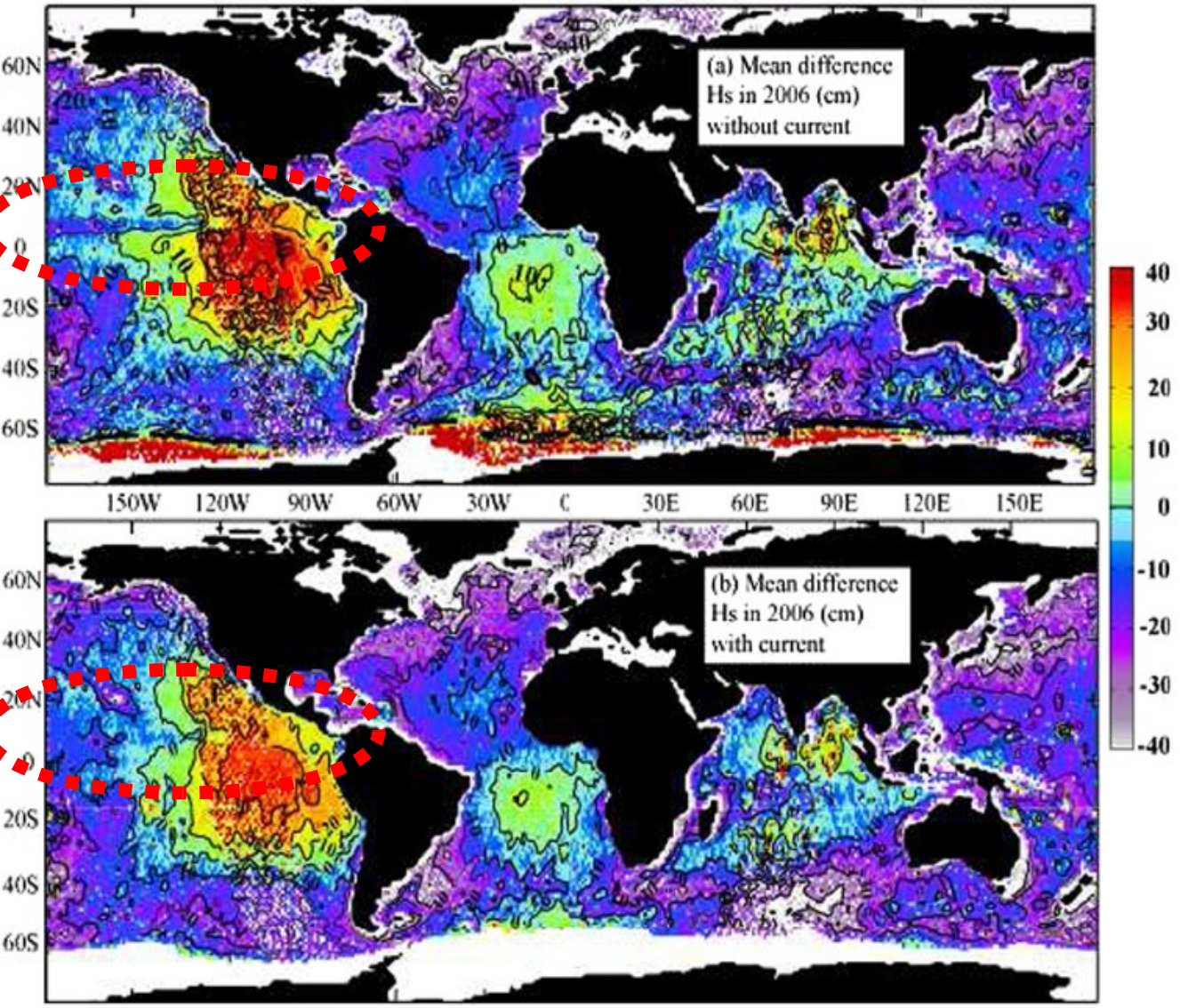
Contrary to some widespread belief, the most extreme waves are best predicted …

… and it critically depends on the extreme winds …





1. wave models at global scale



Signature of currents ?

Tests with Mercator PSY3 system

Yes : bias in the tropics …

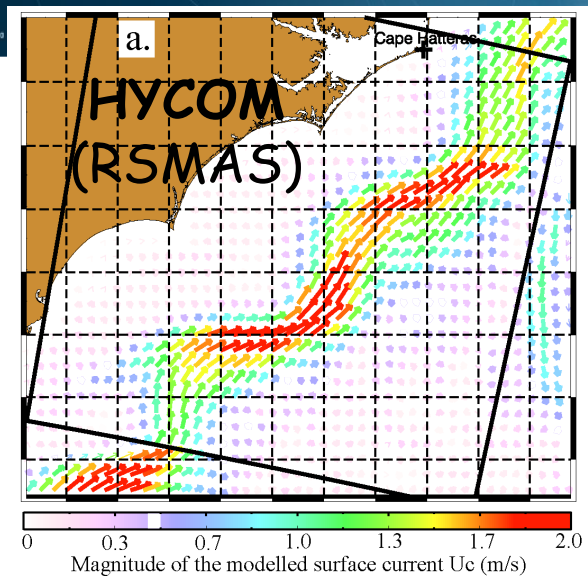
(Rascle et al, 2008 using old model set-up : old parameterization, no icebergs …)

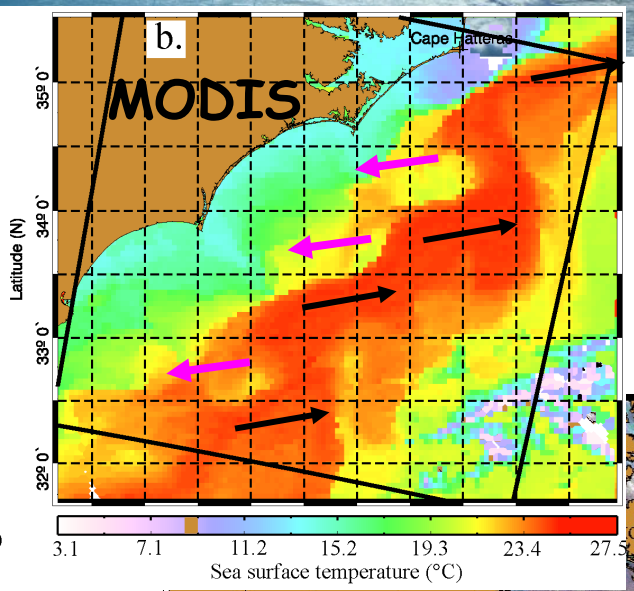
See also reports by Bidlot et al.

Hower, small impact on global errors …

Is there a problem with the wave model ?

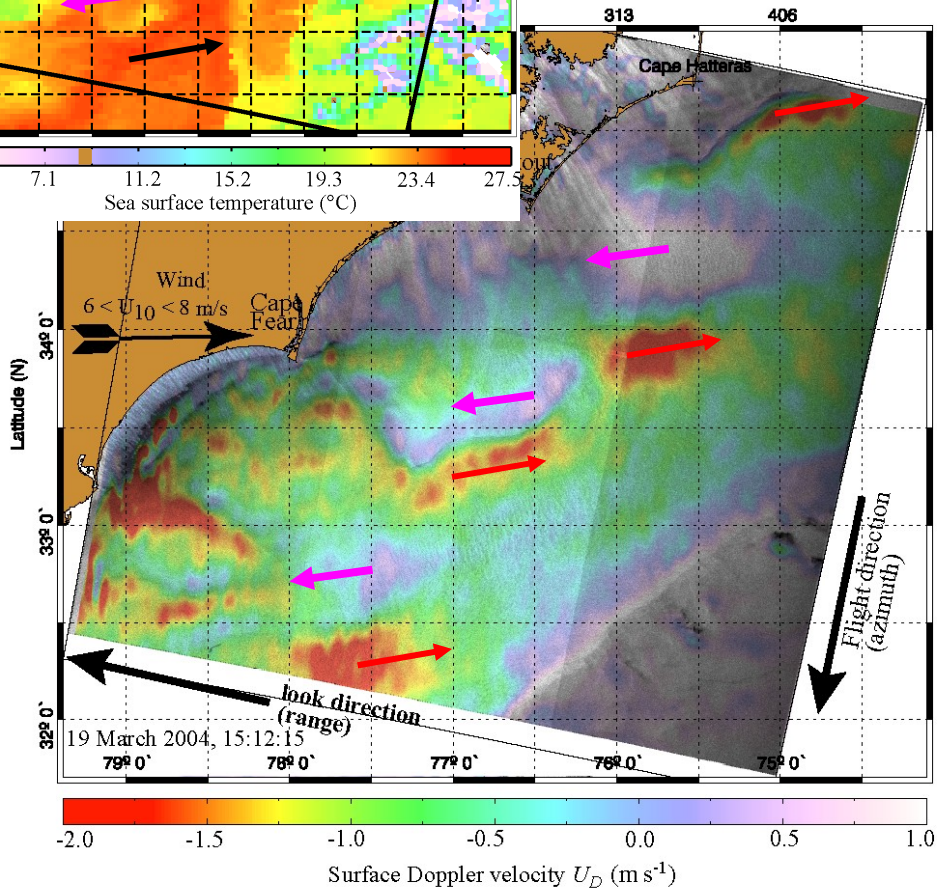
Are the models currents well resolved ?





Surface Doppler velocity

wide-swath image
ENVISAT's ASAR
19 March 2004
(Chapron et al. 2005)



3. Beyond the significant wave height

Surface Stokes drift

The improved dissipation is also very important for high frequency waves, which is very important for the surface Stokes drift.

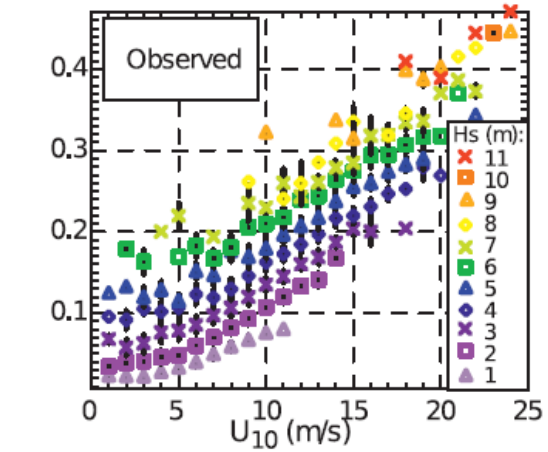
This is a validation using 2 years of spectra from buoy 46005 off Washington State

(US West Coast)

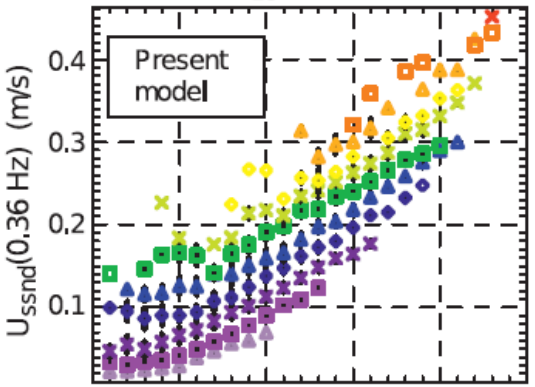
In practice the surface Stokes drift is close to

$$U_{ss}(f_c) \simeq 5.0 \times 10^{-4} \left[1.25 - 0.25 \left(\frac{0.5}{f_c} \right)^{1.3} \right] U_{10} \times \min\{U_{10}, 14.5\} + 0.025(H_s - 0.4). \quad (7)$$

(Ardhuin et al., JPO 2009)



« TEST441 »



« WAM4.5 »