« new » parameterization of the (dissipation) source functions

Rationalizing the « art » of tuning a wave model

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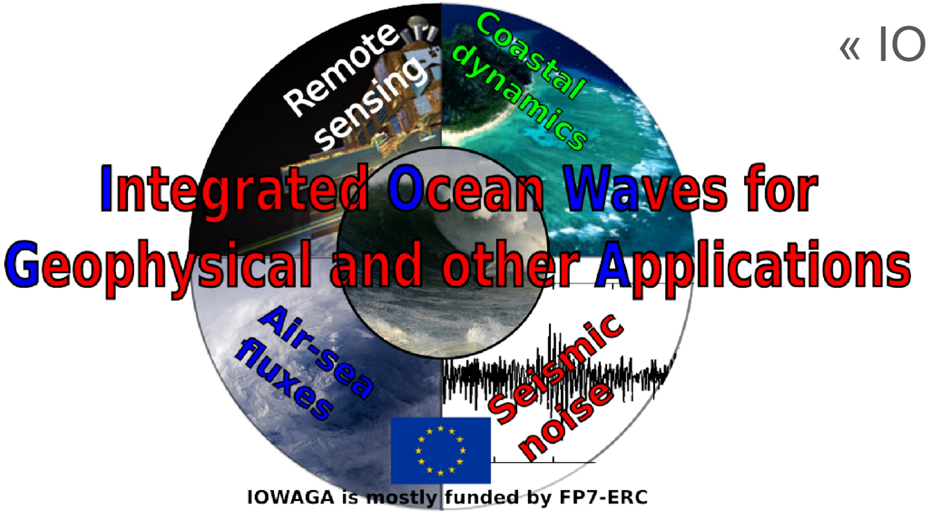
Thanks to : Meteo-France, Globwave, NCEP, ECMWF, Prévimer …

Some recent wave work at Ifremer



http://wwz.ifremer.fr/iowaga

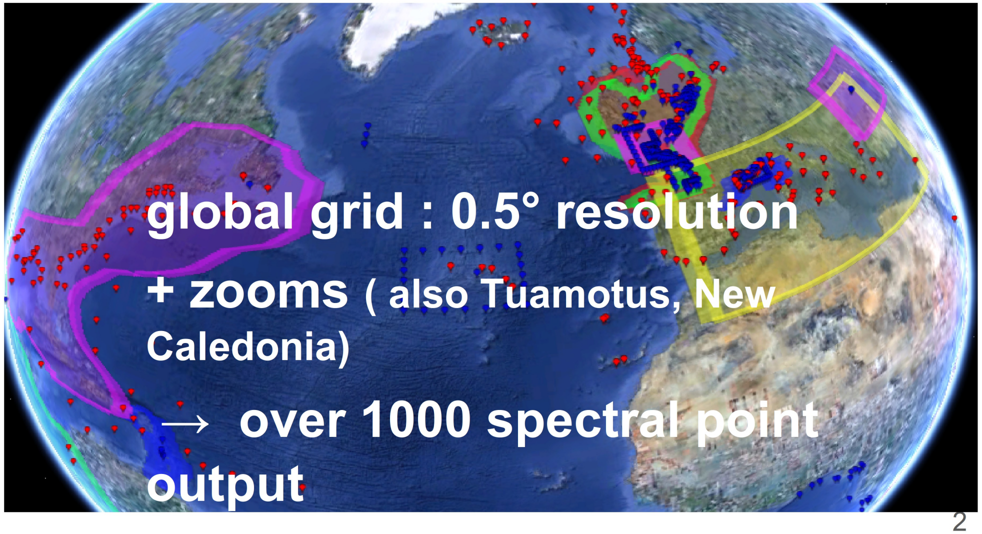
« IOWAGA » integrates observations and models for a more comprehensive an accurate wave parameters for geosciences and engineering.

Supported by European Research Council

Zooms and spectral output in the 1994-2012 hindcast

Output parameters include all air-sea fluxes + sea and swells data …

Global 1999-2012 already online

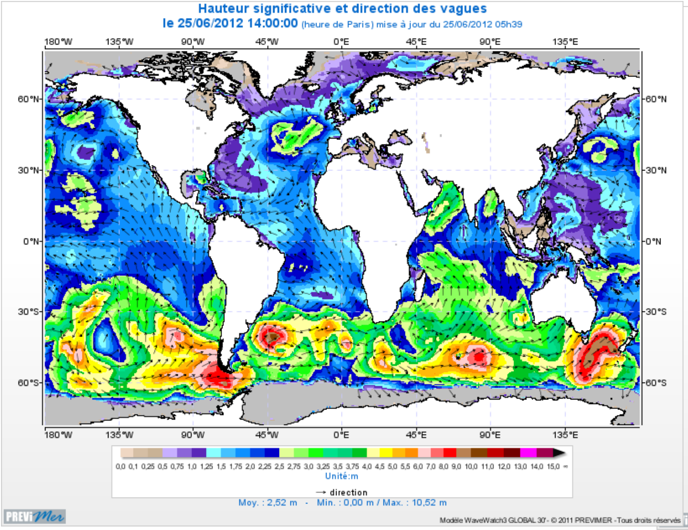


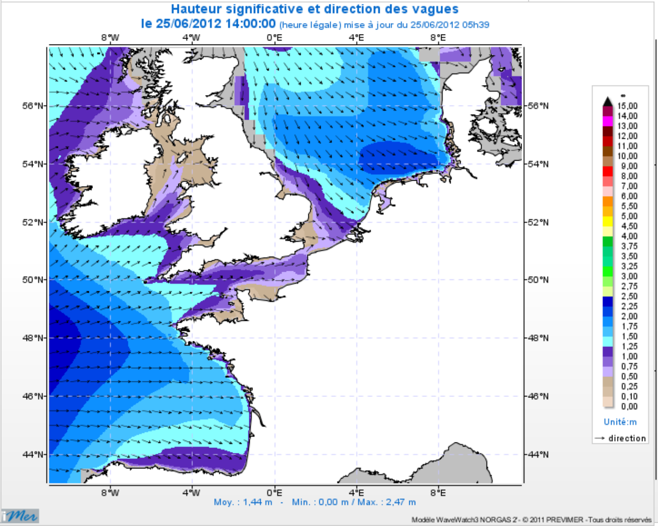
global grid : 0.5° resolution

+ zooms (also Tuamotus, New Caledonia)

→ over 1000 spectral point output

And real-time forecasting …


Hauteur significative et direction des vagues
le 25/06/2012 14:00:00 (heure de Paris) mise à jour du 25/06/2012 05h39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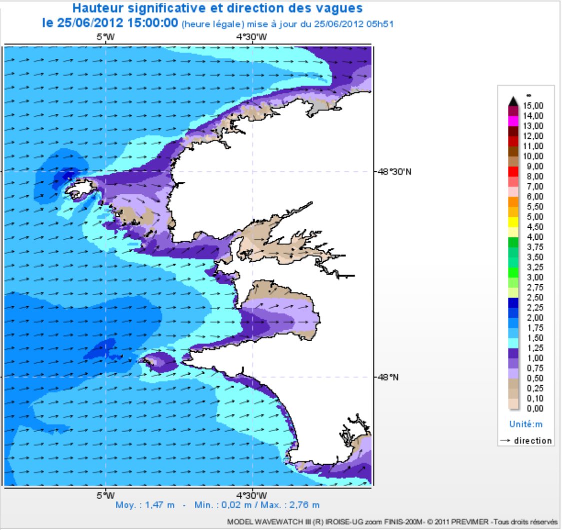
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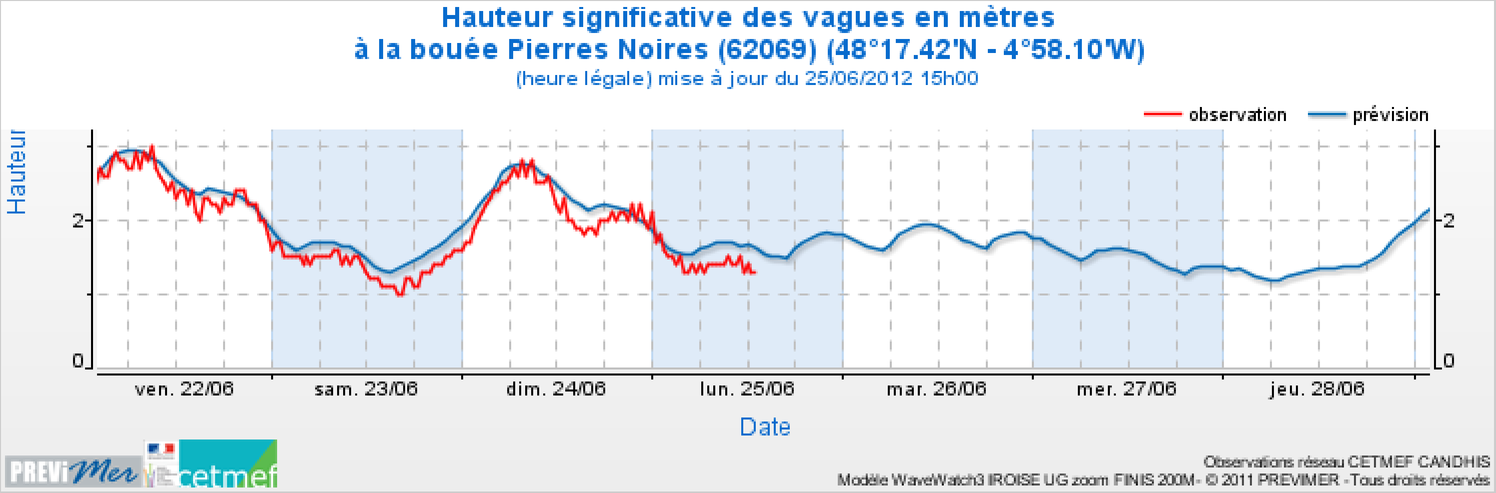
http://www.previmer.org


Hauteur significative des vagues en mètres
à la bouée Pierres Noires (62069) (48°17.42'N - 4°58.10'W)
(heure légale) mise à jour du 25/06/2012 15h00

wwz.ifremer.fr/iowaga

Outline

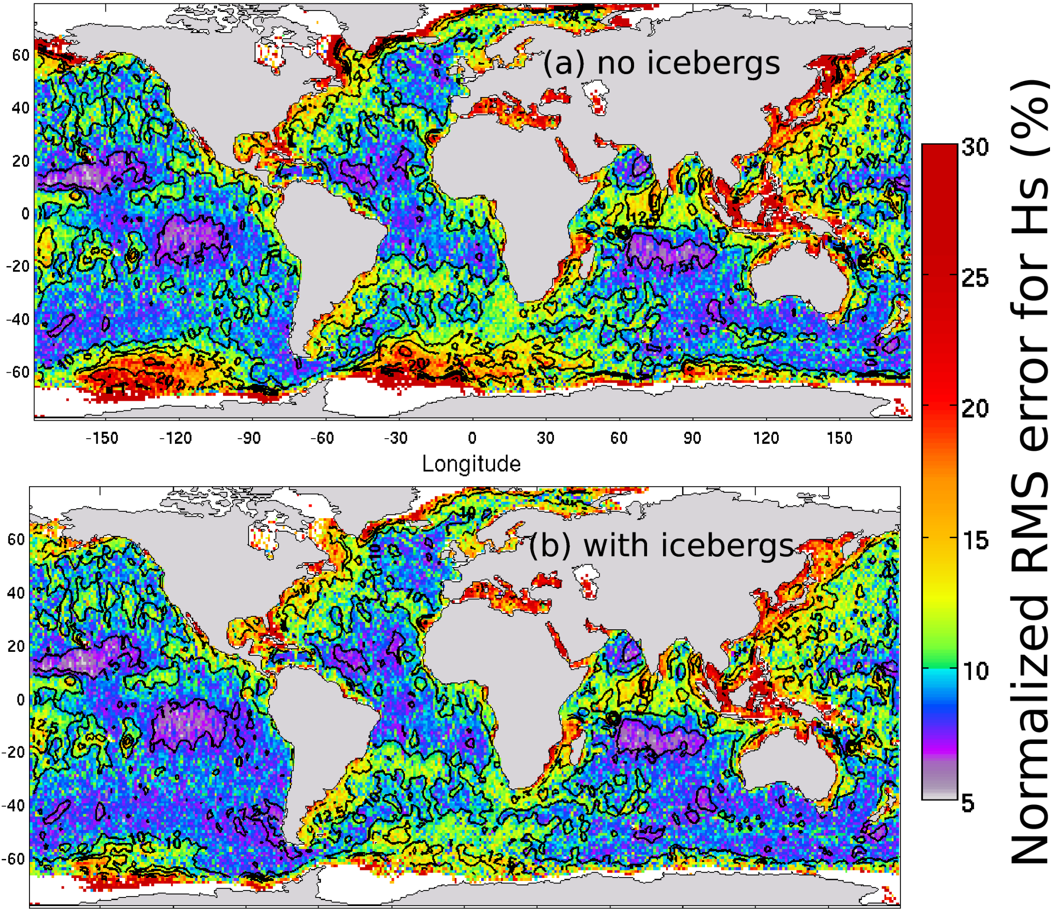
1. Forcing fields : winds, sea ice, currents, icebergs

Linking model behaviour to source term parameters :

2. Swells
3. Working around the peak
    - Relaxation time scales
    - Mean direction & source term strength
4. Inertial range & tail issues
5. Directional spreading
6. Bottom friction

icebergs in Southern ocean

Errors for a 2008 hindcast (Ardhuin et al., Ocean Modelling 2011)



Iceberg concetration and sizes were analyzed from Jason-1 & 2 20Hz waveforms.

(Tournadre & al. 2008, 2012)

Processing of Topex & Envisat is now under way

(thanks to funding by CNES).

2

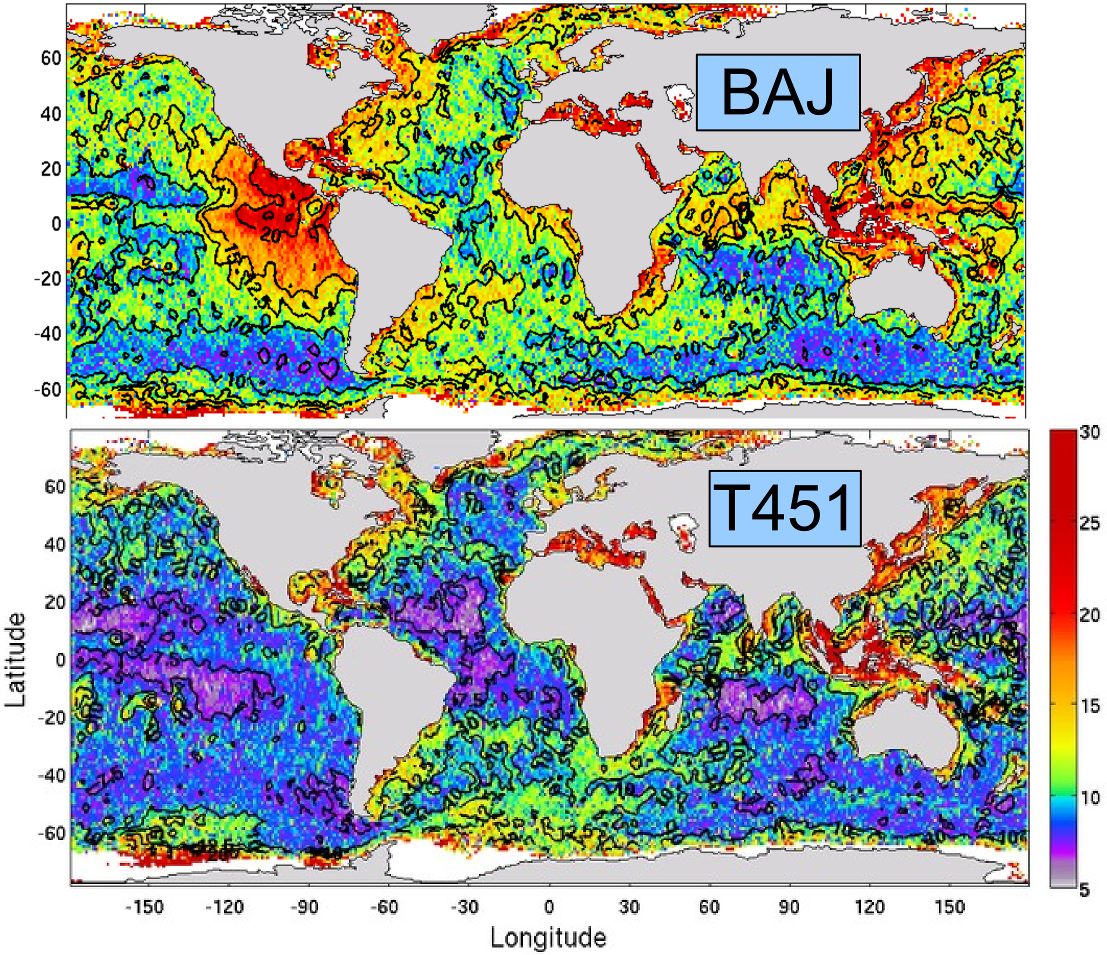
Swells

2. Global wave model errors

b. swells

Swell dissipation : the weakest link …

TEST451 vs BAJ for year 2008



Global average of NRMSE:

10.5 % (TEST451)

12.7% (Bidlot et al. 2005)

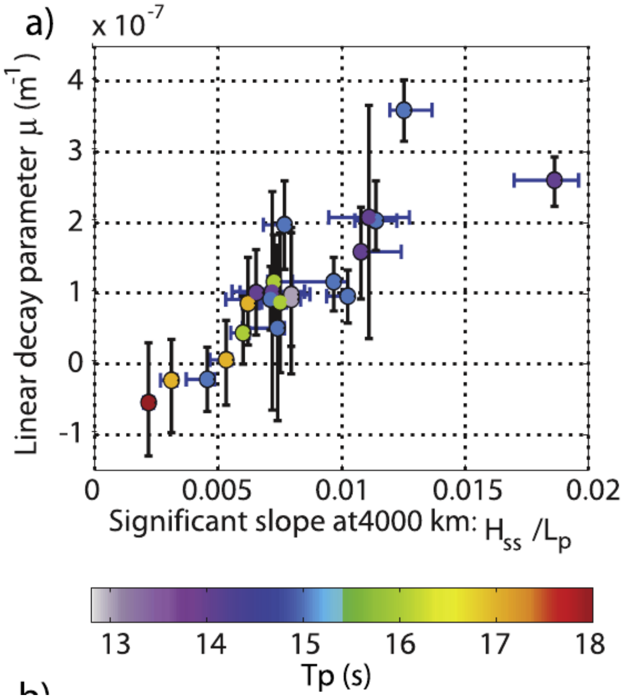
13.8% (WAM4)

15.2% (Tolman & Chalikov)

2. Swell dissipation :

From observations to parameterization

Following swells across oceans → significant dissipation for steep swells



Ardhuin et al., GRL 2009

$$\mu = -\frac{\mathrm{d}(\alpha \sin \alpha E_s)/\mathrm{d}\alpha}{R(\alpha \sin \alpha E_s)}$$

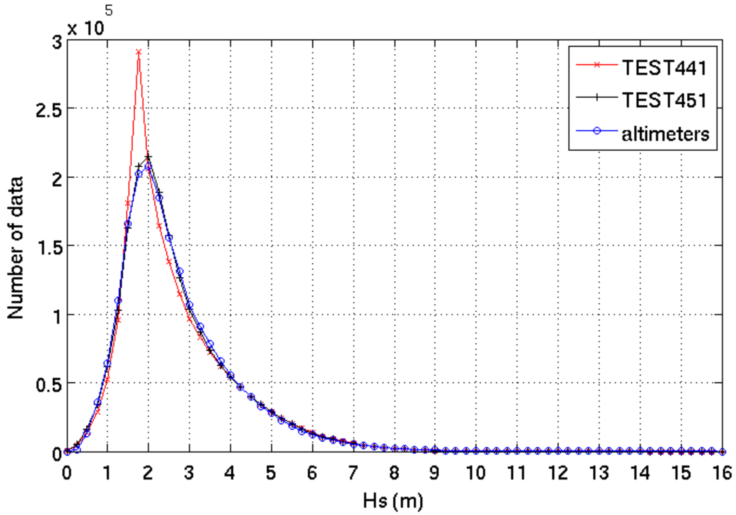
Laminar theory (Dore 1978) : $S_{\mathrm{out}}(k,\theta) = -C_{\mathrm{dsv}}\frac{\rho_a}{\rho_w}(2k\sqrt{2\nu\sigma})F(k,\theta)$

Analogy with bottom boundary layer : $S_{\mathrm{out}}(k,\theta) = -\frac{\rho_a}{\rho_w}(16 f_e \sigma^2 u_{\mathrm{orb}}/g)F(k,\theta)$

2. Swell dissipation :

From observations to parameterization

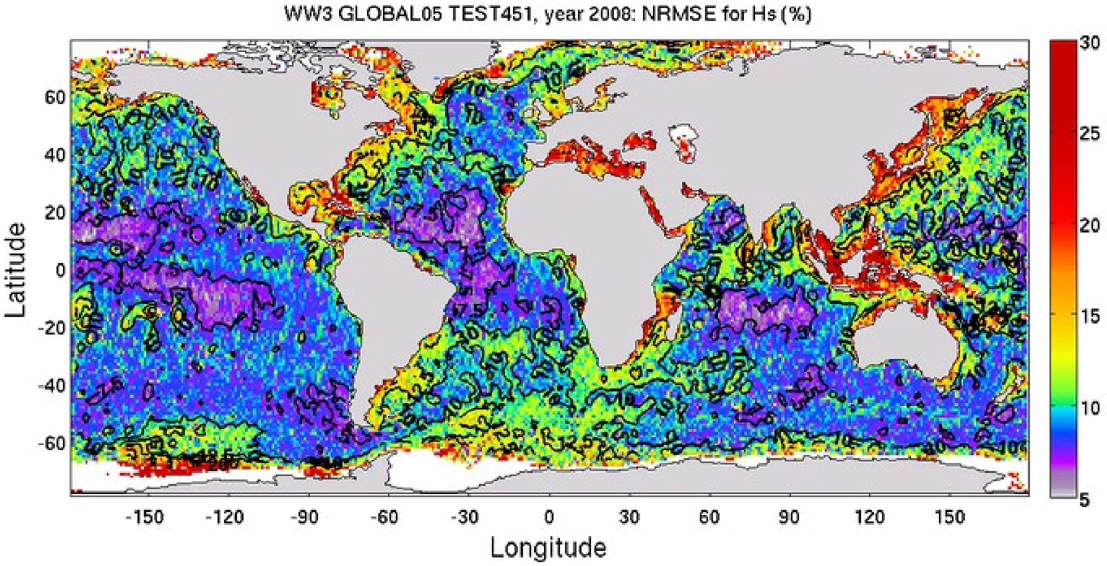
TEST441: unrealistic pdf of Hs around 2 m (thanks to D. Vandemark, UNH) :

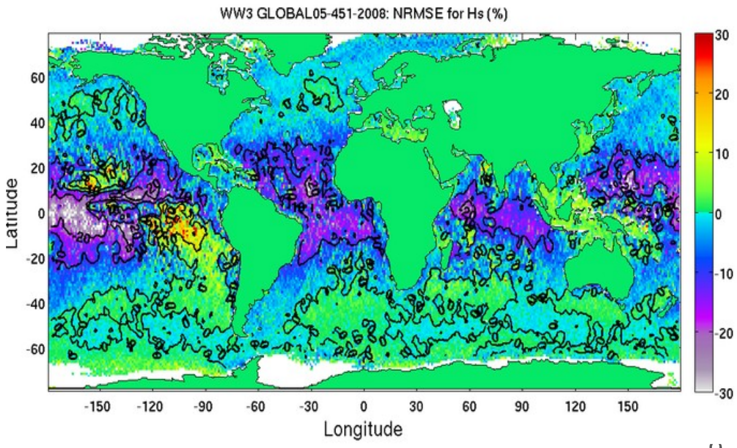


TEST451 : smoothing of the

laminar → turbulent transition

This improved swell dissipation (TEST451) reduced errors by up to 30% for Hs





2. Swell dissipation :

From observations to parameterization

This quick fix is calling for

- More data analysis (possibly using the automated swell analysis by R. Husson)
- LES modelling of oscillatory boundary layer

- Further tests and comparisons of alternative parameterizations

  (Janssen 2004 ...)

3

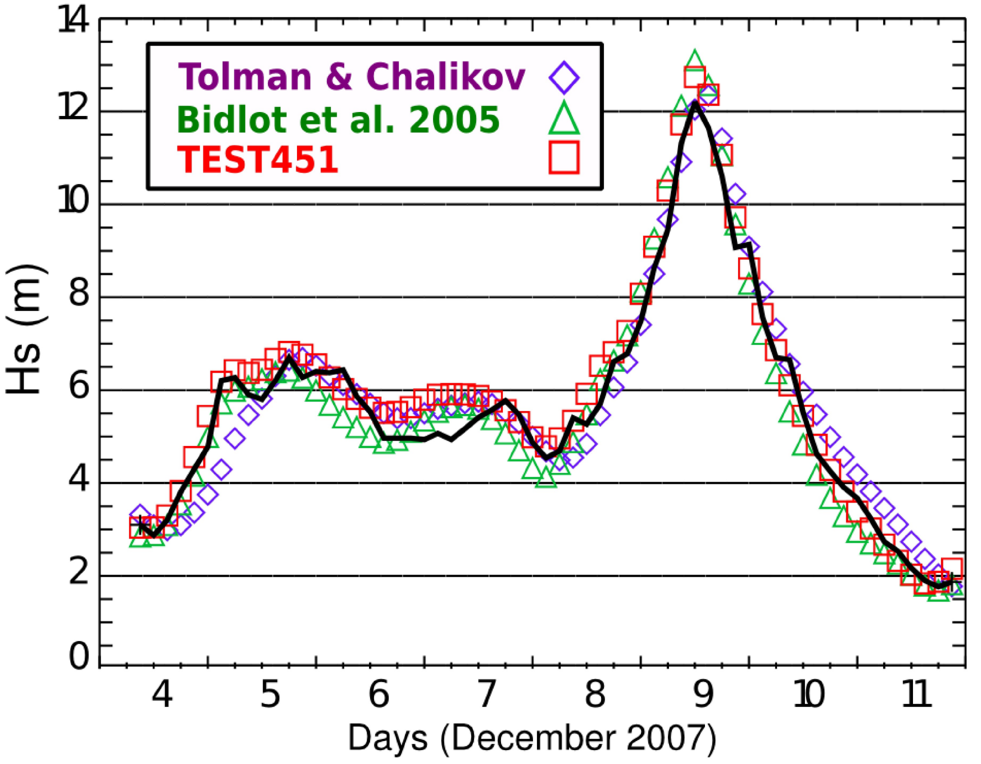
Working around the peak

3. Working around the peak relaxation time scales

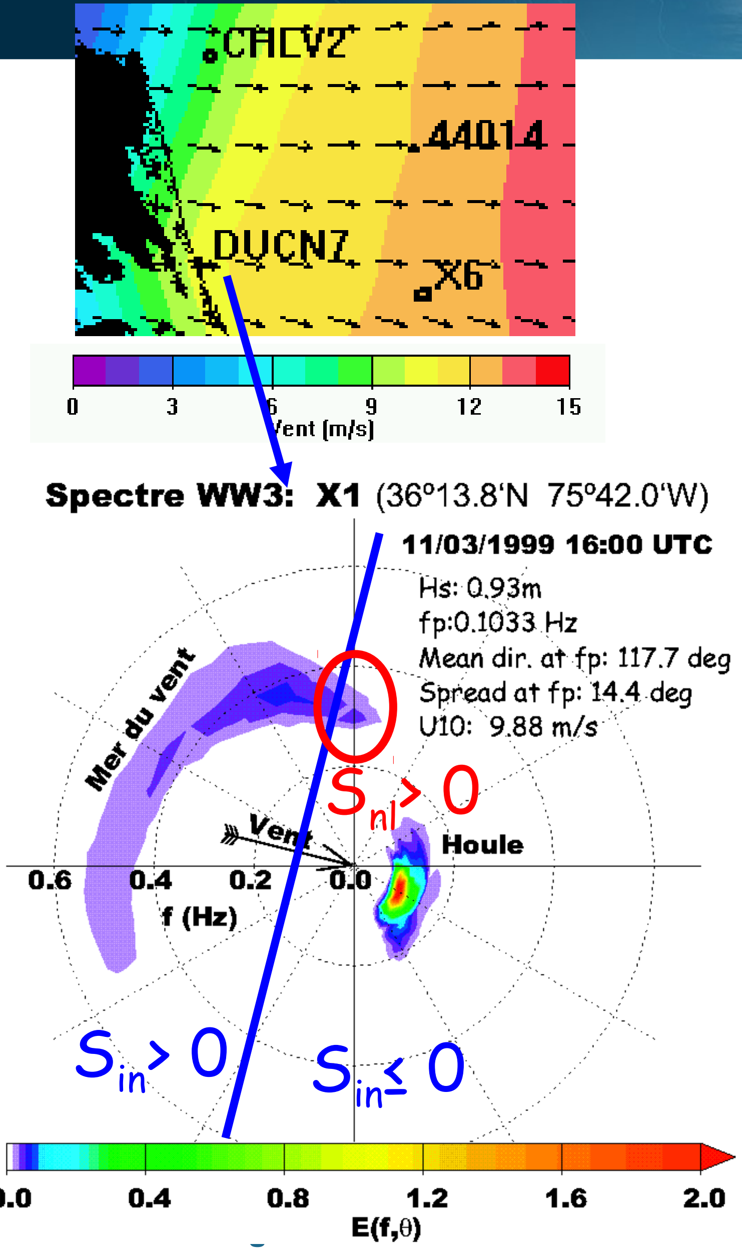
Before arguing about functional forms (is Sdis ~ E^2 ….?)

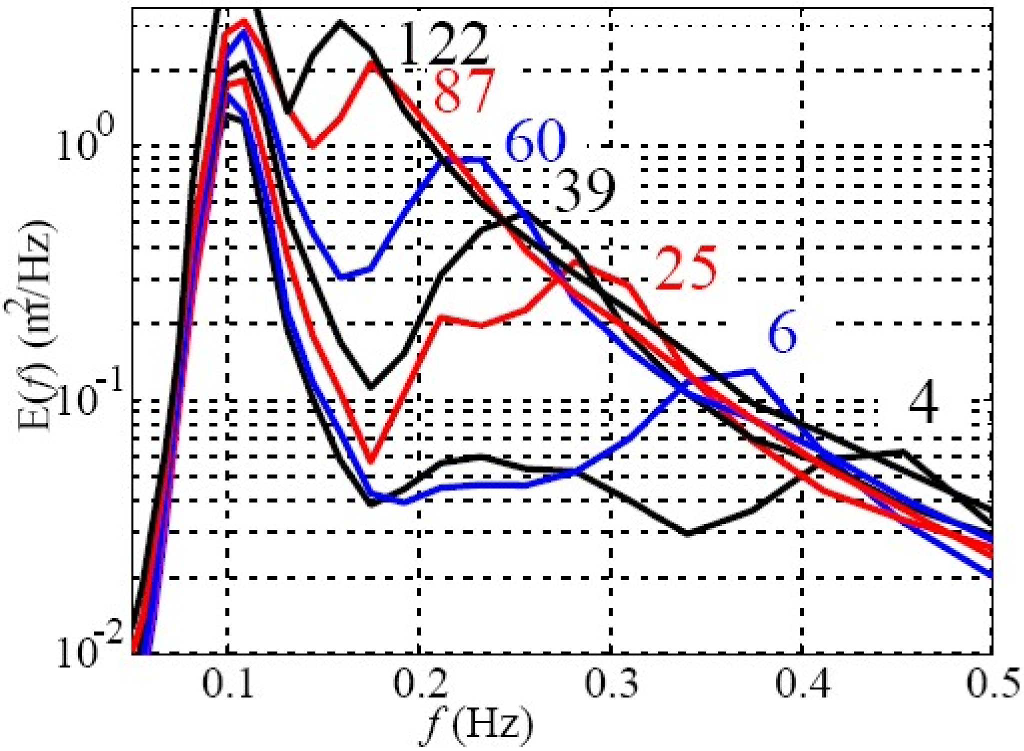
It is always possible to get normal fetch-limited growth with any wind input by retuning the dissipation rate … but weak source terms will give large relaxation times that are larger. Here is one example from East Atlantic buoy 62163 …

		NRMSE (%):	RMSE:	Bias (%):	Corr.(r):	S. I.(%):
Tolman & Chalikov	◇	9.3	0.566	1.43	0.9707	9.1
Bidlot et al. 2005	△	8.5	0.517	–1.42	0.9834	8.3
TEST451	□	7.1	0.435	3.93	0.9897	5.9



3. Spectral shapes



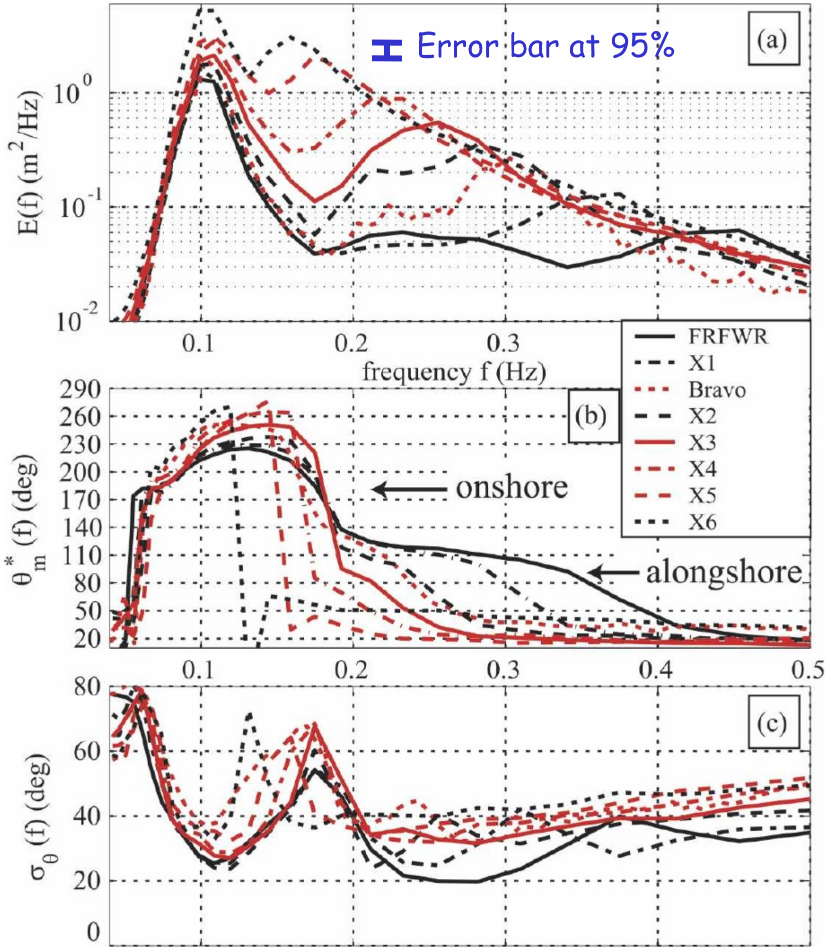


Situation on November 3, 1999
(Ardhuin et al. JPO 2007)

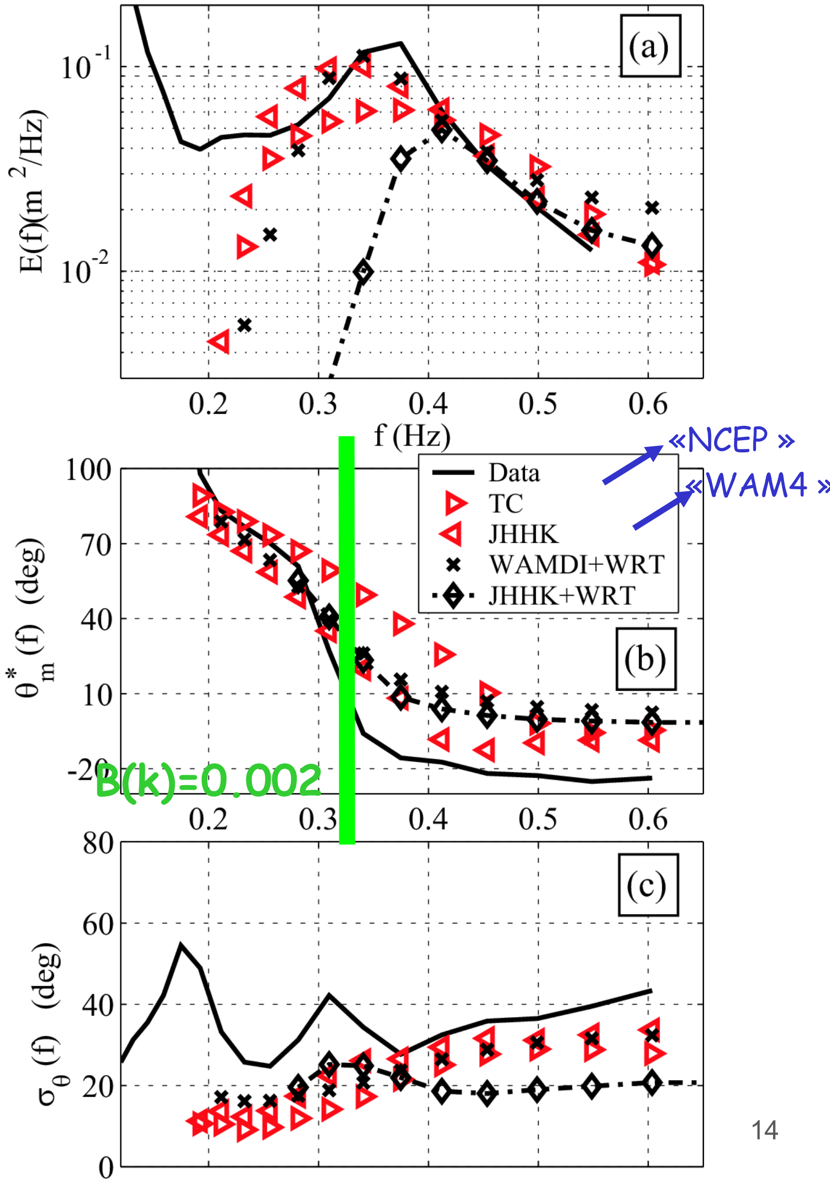
3. Spectral shapes

Observations

(1800 degrees of freedom per 0.05 Hz band)



Error bar at 95%



«NCEP »

«WAM4 »

B(k)=0.002

3. Working around the peak relaxation time scales

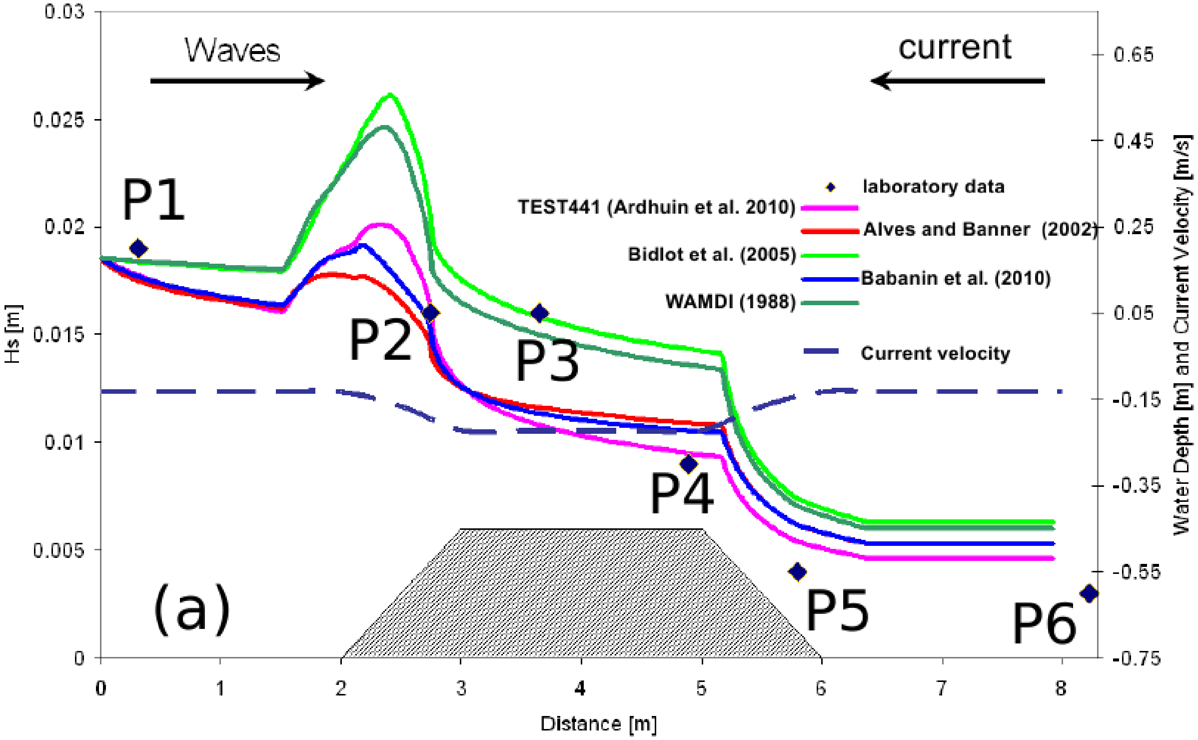
So getting the right magnitude of Sin and Sds can be controlled by some data.

And then the functional dependence becomes important too :
Komen et al 1984 : mean steepness, senstive to swell and spectral width (issue in blocking conditons).

Strict saturation :
local in spectral space

« smoothed » saturation
(Banner et al. 2010)

« scale-integrated saturation »
(Filipot & Ardhuin 2012)



4

Inertial range and tail issues

3. Inertial range and tail issues

Practical issues

Why should we care about waves at f > 2 fp ?

- Feed-back through stress
- Stokes drift
- Remote sensing …

Example of scatter indices for Tm02, operational analyses (May 2012):

buoy	ECMWF	METFR	SHOM
62081	7.50	7.04	6.85
NEATL	13.30	12.6	12.08
NRDIC	13.32	11.60	10.89
NSEA	11.63	10.23	9.41
WMED	**13.59**	11.27	**9.84**

Random errors in SHOM's system in WMED are 30% lower than ECMWF !!!
Same for Stokes drift (Ardhuin et al. , JPO 2009)

3. Inertial range and tail issues
need for cumulative / sheltering effects

Threshold for omni-directional saturation should increase with frequency (Banner et al. 2002). Several directional « normalizations » have been proposed :

A(θ) in Babanin , …

I have argued that we could use an orbital velocity projected in one direction …

Using a dissipation based on saturation : more dissipation and/or less input is needed beyond 2-3 times fp.

- Banner and Morison (2007, 2010),
- Ardhuin et al. (2008, 2010)
- Tsagareli (2008), Babanin et al. (2007, 2010)

This can be calibrated using 2nd (Tm02), 3rd (Uss) and 4th (mss) moments … which looked pretty good we looked at all the output parameters …

3. Inertial range and tail issues

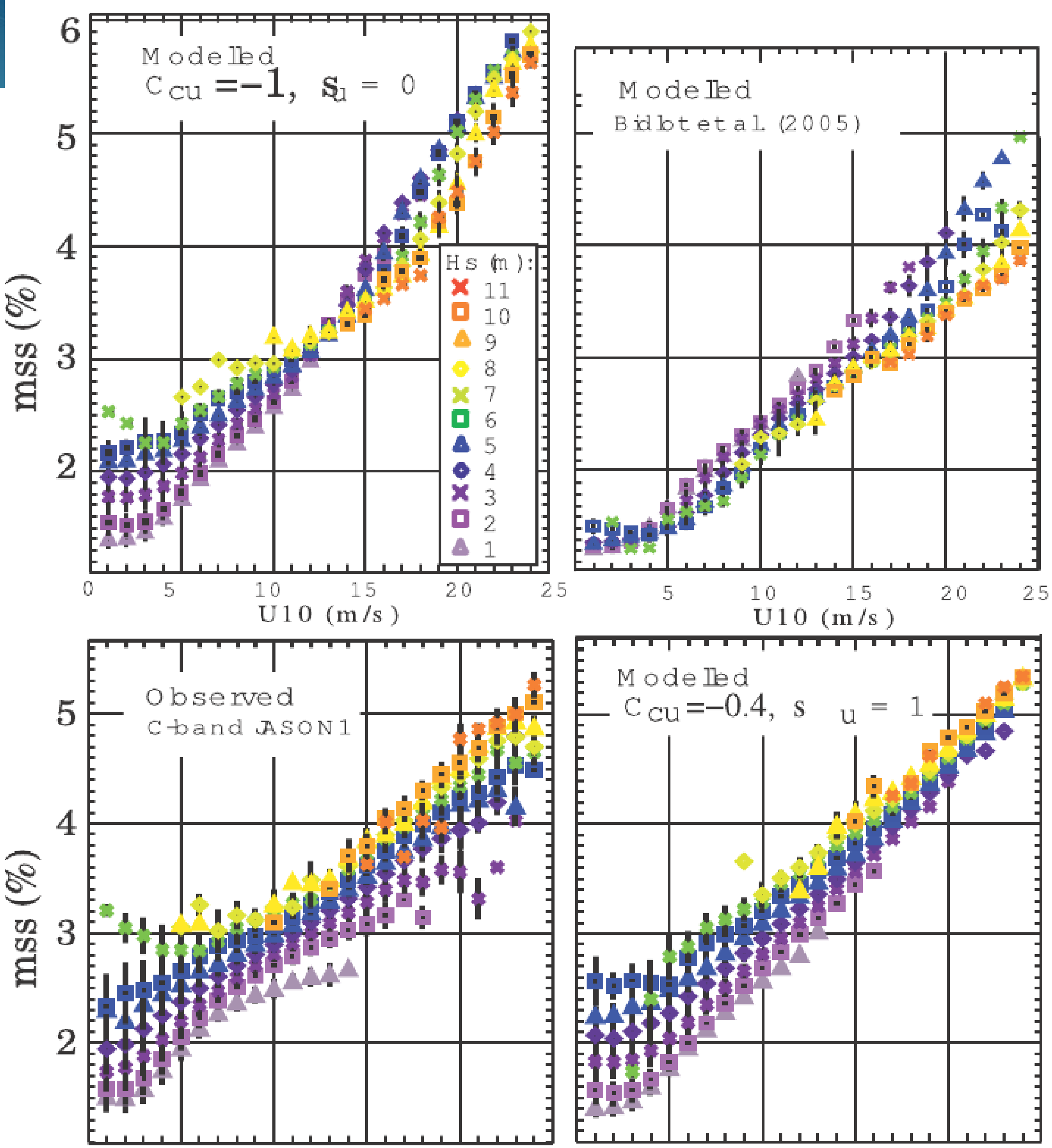
cumulative / sheltering

Interpretation of altimeter nadir NRCS in terms of mean square slope :

Diagnostic of cumulative and sheltering effects.

Same result with X-band or L-band brightness temperatures.

Or buoy data …



mss increases with Hs for a fixed wind speed.

3. Inertial range and tail issues

need for cumulative / sheltering effects

Problem solved ??

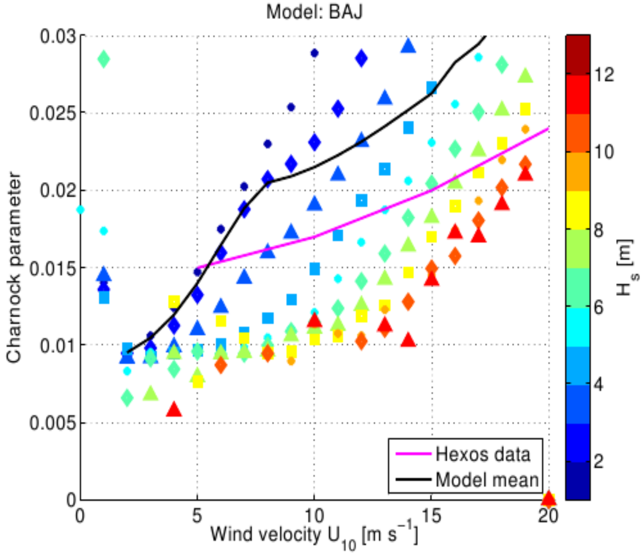
If mss is OK then wind stress should be OK …

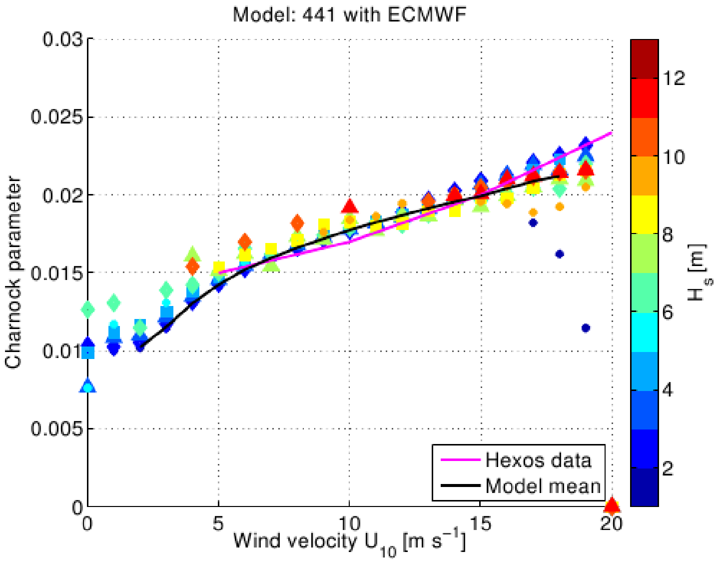
… not quite yet !

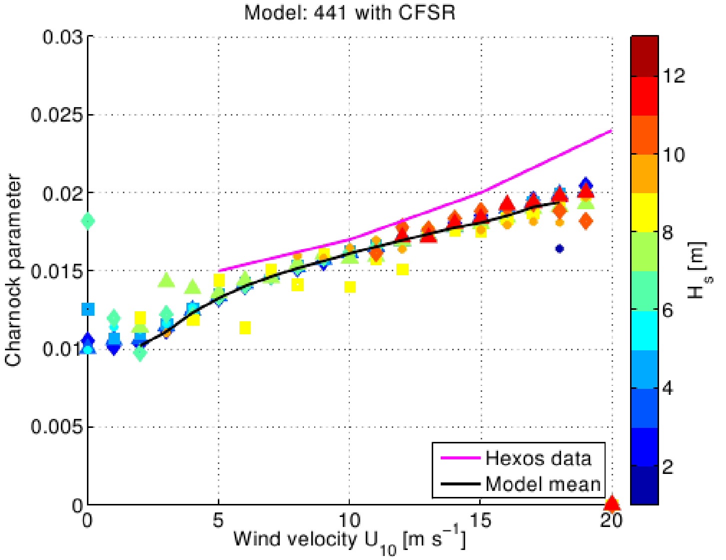
3. Validation of model output

Wind stress

Our Banner&Morison-style reduction of u_star kills the WAM4 dependence on wave age...







Solutions :

Reduce sheltering ? Change the stress table ?

What should we tune this to ?

ECMWF probably has the answer

5

Directional spreading

5. Directional spreading

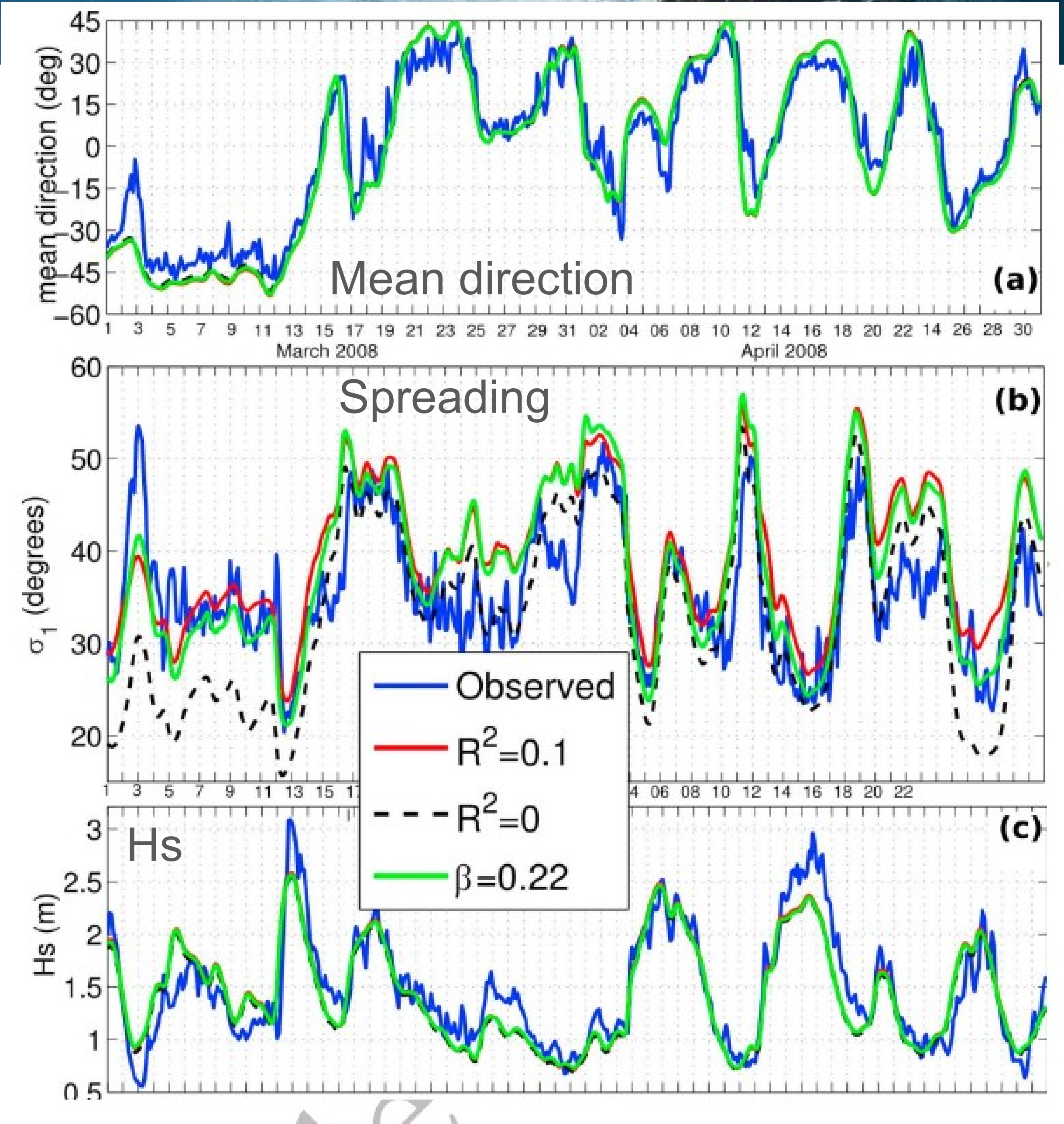
TEST441 was tuned to give good directional spreads for SHOWEX...

And it generally works well for open ocean buoy but bias close to shore :

Here buoy 51201 (Waimea, HI)

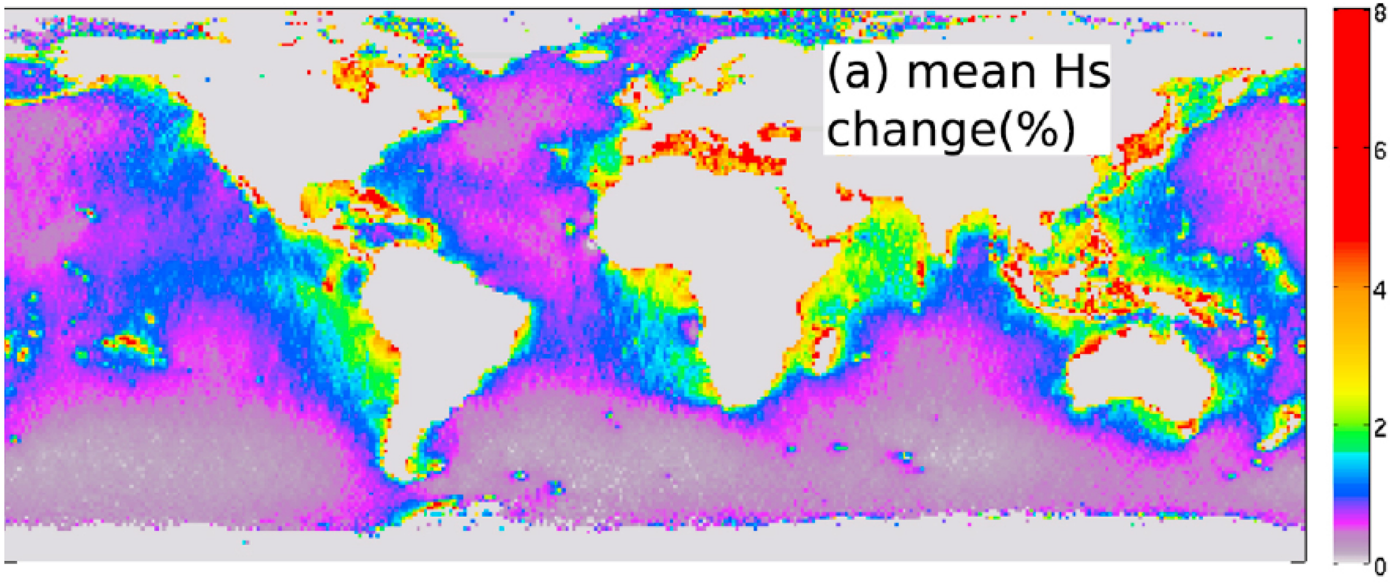
Coastal reflection is needed !!

Ardhuin & Roland (JGR in press)



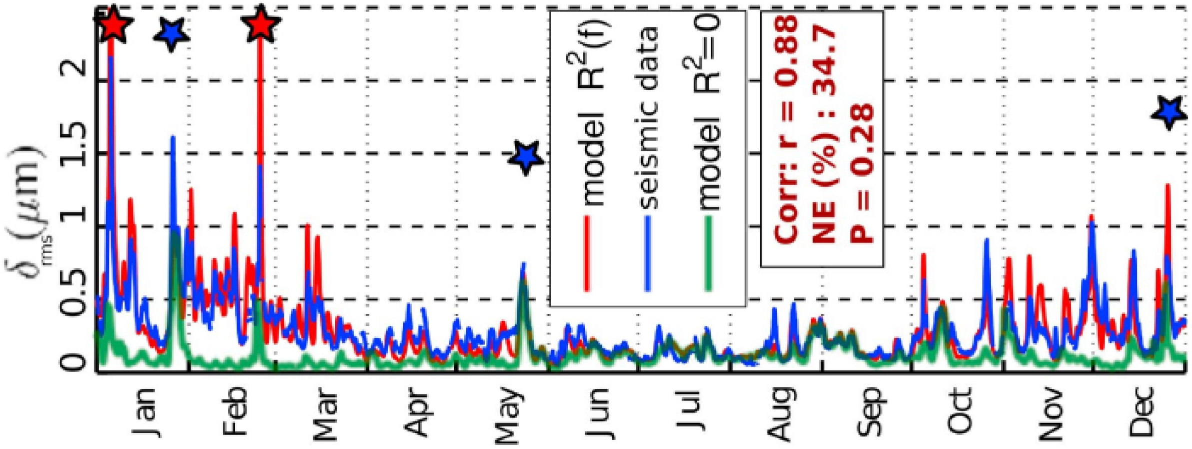
5. Directional spreading

Impact of 10% reflection on Hs (10 % is rather large)



Not too important for Hs...

But extremely important for seismic noise



Ardhuin et al. (JGR 2011, 2012)

5. Directional spreading

In return, can we learn something about waves from seismic noise ?
(Farrell and Munk 2008, 2010 ; Duennebier & al. 2012)

$$E(f,\theta) = E(f)M(f,\theta) \qquad I(f) = \int_0^{\pi} M(f,\theta)M(f,\theta+\pi)\mathrm{d}\theta$$

In theory, noise is proportional to :

$$F_{p2,\mathrm{surf}}(\mathbf{K} \simeq 0, f_s) = \rho_w^2 g^2 f_s E^2(f) I(f)$$

(the coefficient depends on bottom properties ….)

So $I(f)$ ~ noise / $E^2(f)$

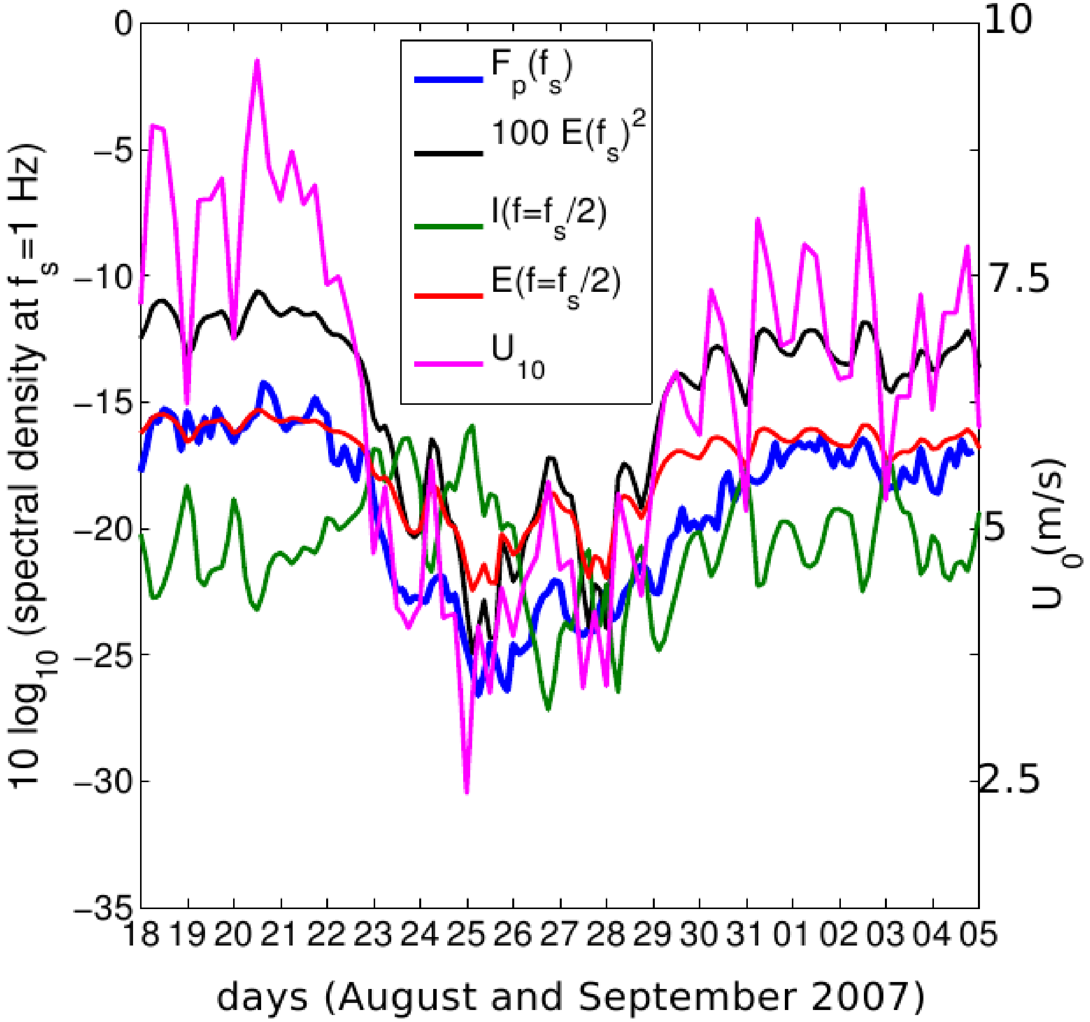
Can the model do this ?

… no, modelled I(f) varies too much.
Is the model wrong … or is the theory insufficient ?

5. Directional spreading

Measured noise at 0.5 to 1 Hz is proportional to E(f) …

(see also Ardhuin et al. JGR 2012)



Bidlot et al. (2005) gives the same variability of if I(f), but 10 dB lower levels.

Is breaking making noise at 1 Hz ???

6

Bottom friction

3. Movable bed bottom friction

- Quadratic drag law by Hasselmann & Collins (1968) …. does not work (Hasselmann & al. 1973)

- Empirical fit to measured attenuation (1973)

$$S_{\mathrm{fric},J}(\mathbf{k}) = -\Gamma E(\mathbf{k}) \frac{(2\pi f)^2}{g^2 \sinh^2(kH)};$$

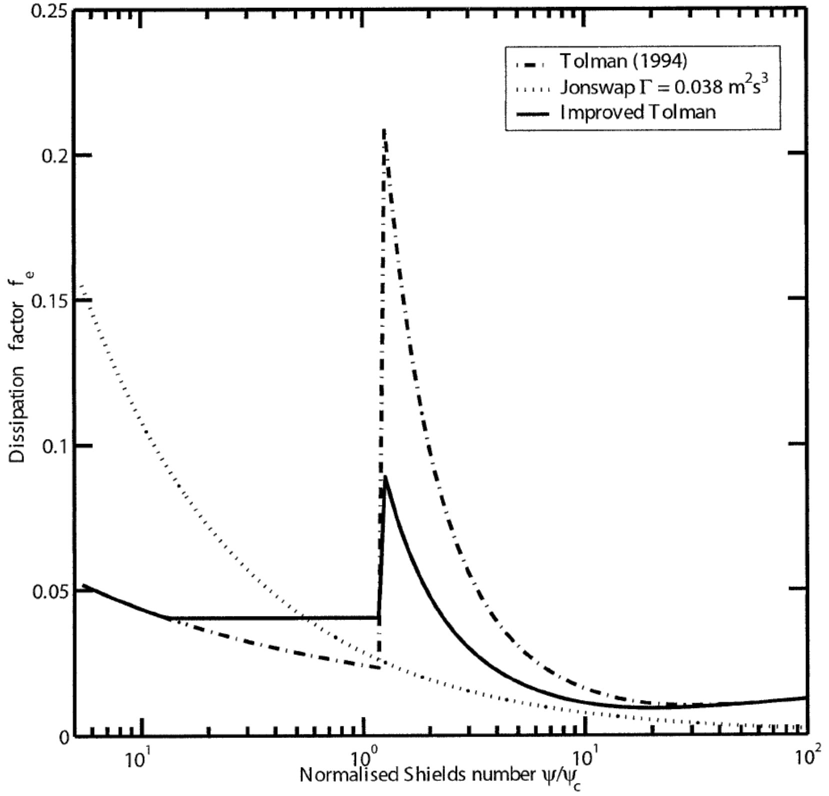
OK on average … but we know better :

Oscillatory boundary layer theory :

Reichardt (1951), Kajiura (1968) …

Grant and Madsen (1979) …

$$S_{\mathrm{fric}}(\mathbf{k}) = -f_e u_b E(\mathbf{k}) \frac{(2\pi f)^2}{2g \sinh^2(kH)}$$

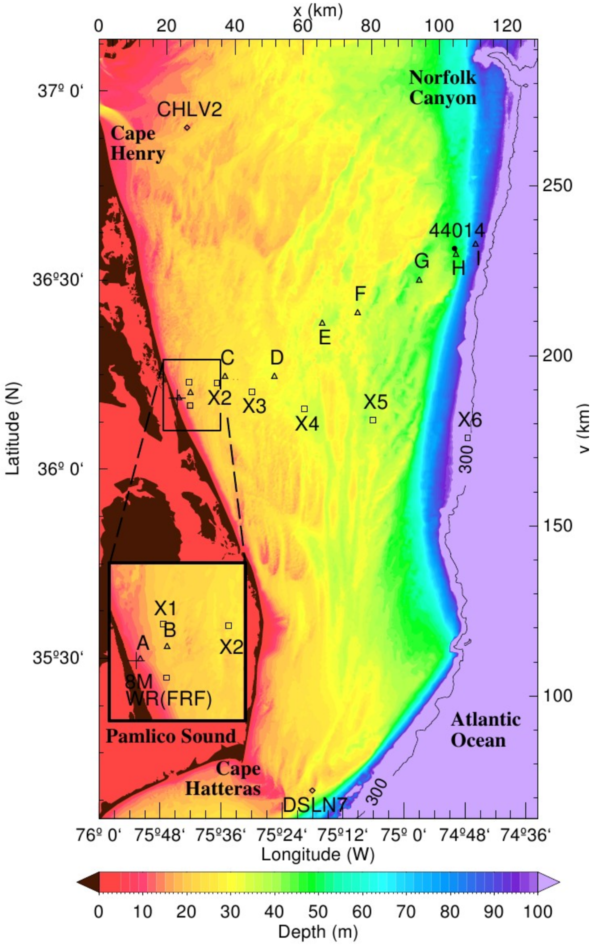


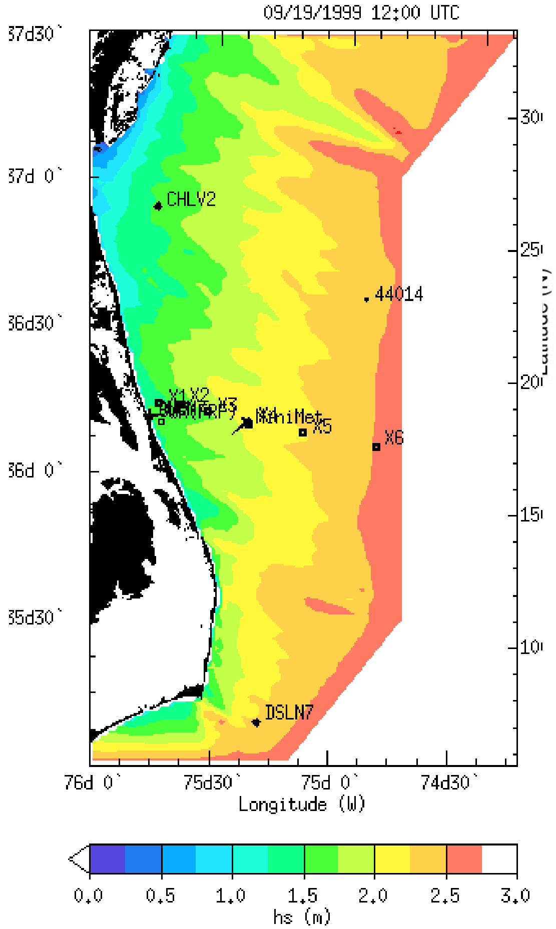
- The friction factor decreases as a_{orb} / z_0 increases

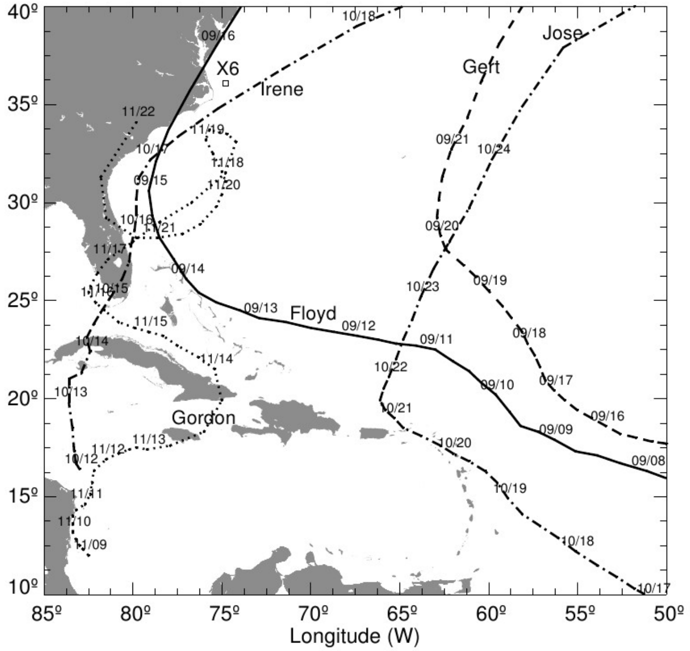
- The roughness is modified by waves for movable beds

4. Movable bed bottom friction : SHOWEX hindcast

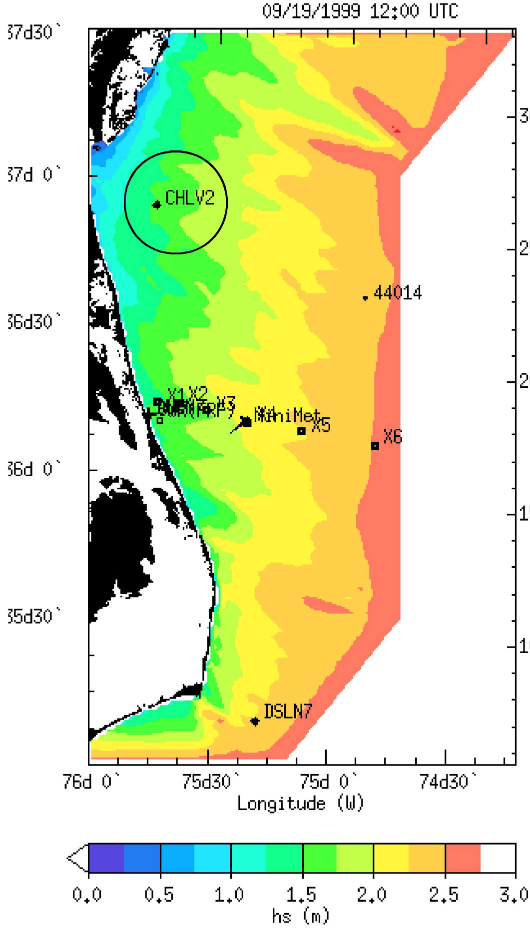
First realistic validation of movable bed friction was performed by Ardhuin et al. (JPO 2001, 2003) using a « swell only model » with a coarse grid. Here this is repeated with WAVEWATCH III .



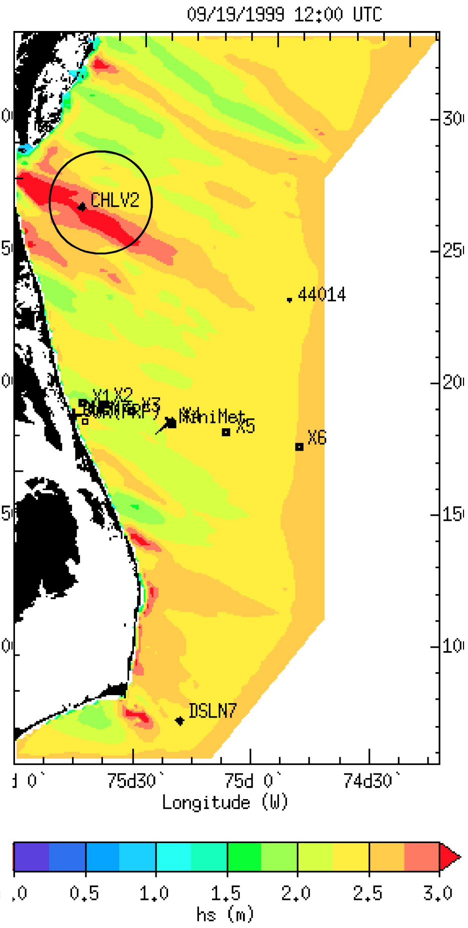




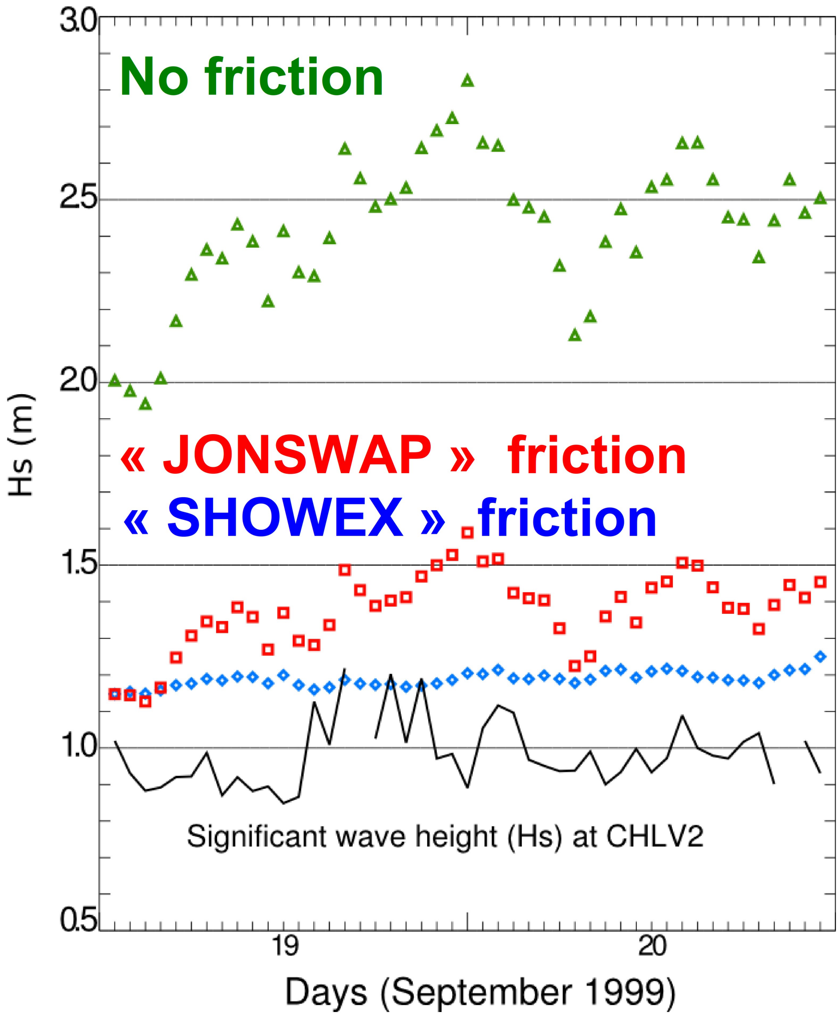
4. Movable bed bottom friction : SHOWEX hindcast



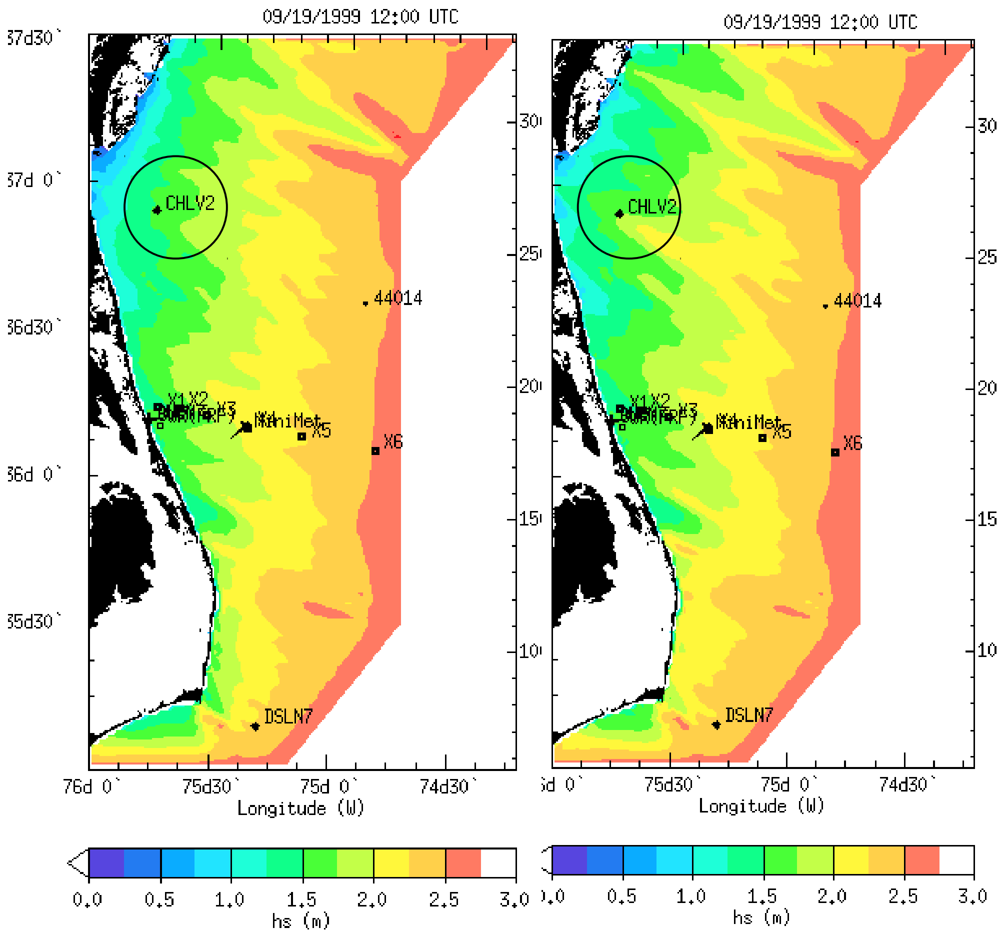
« SHOWEX » friction



No friction



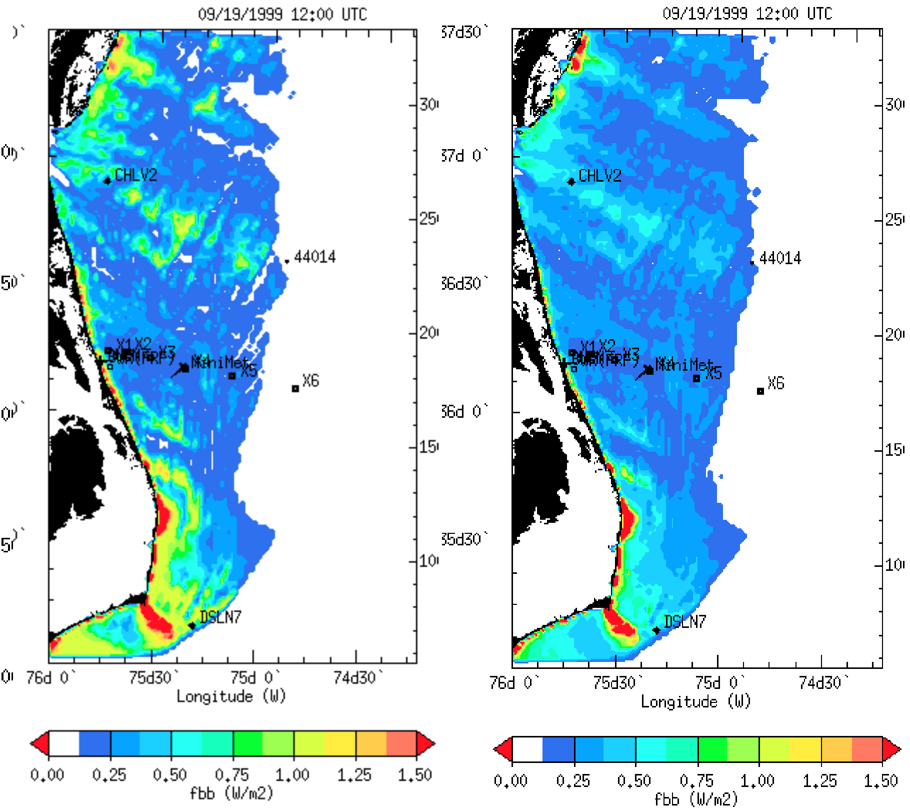
4. Movable bed bottom friction : SHOWEX hindcast



« SHOWEX »

« JONSWAP »

Hs (m)



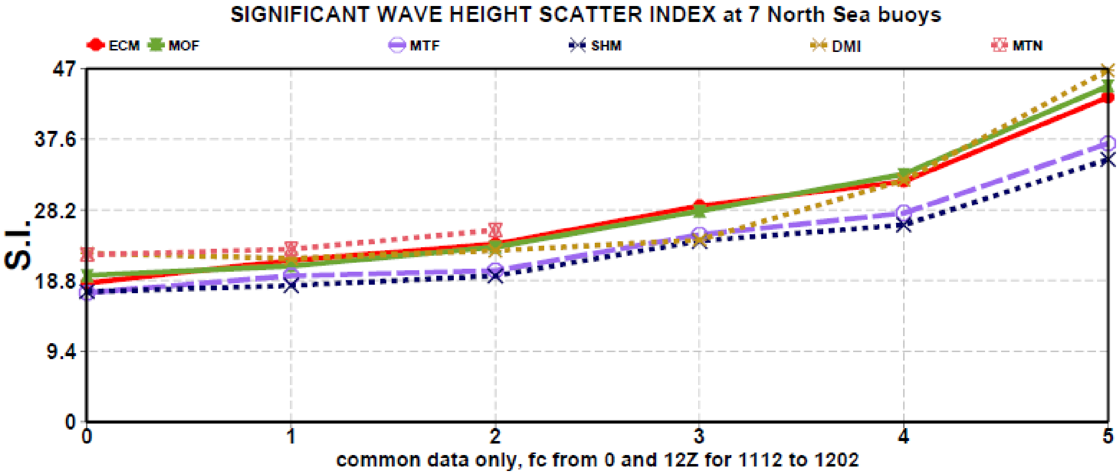
« SHOWEX »

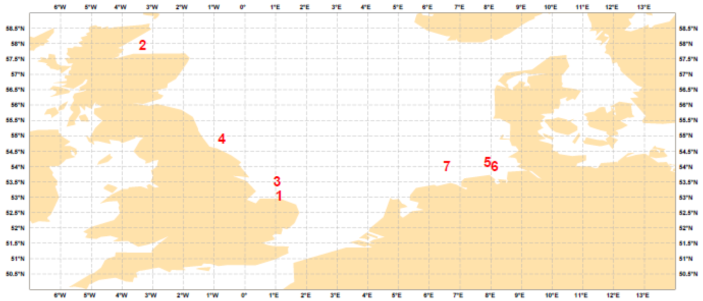
« JONSWAP »

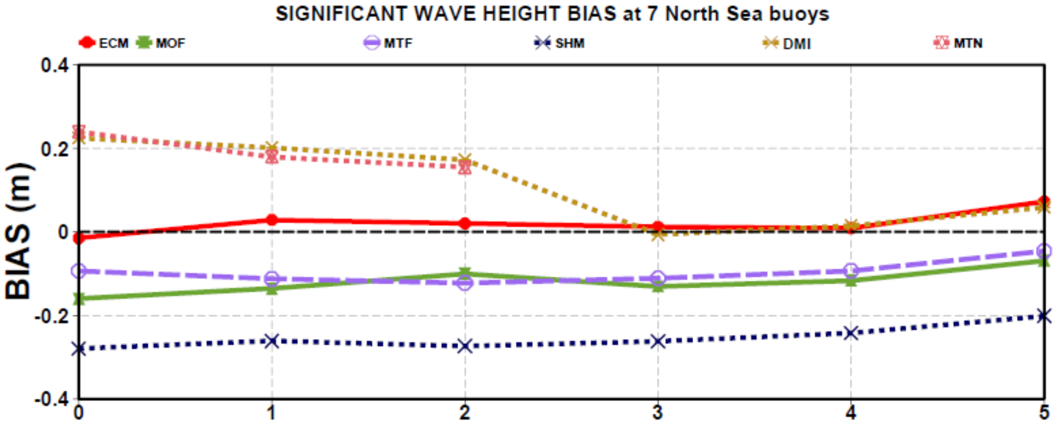
Dissipation rate in WBBL (W/m^2)

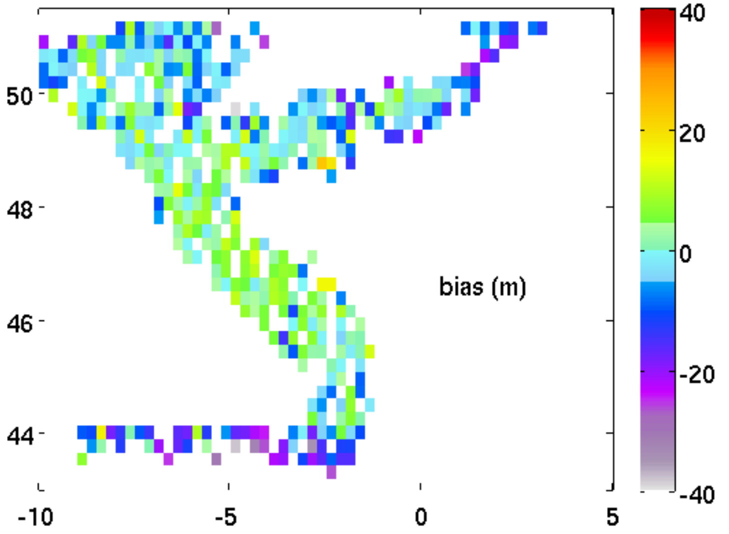
4. Movable bed bottom friction : Southern North Sea & Channel

The main motivation comes from errors in the wave model : low S.I. but negative bias in the North Sea (plots by J. Bidlot, available on JCOMM web site).



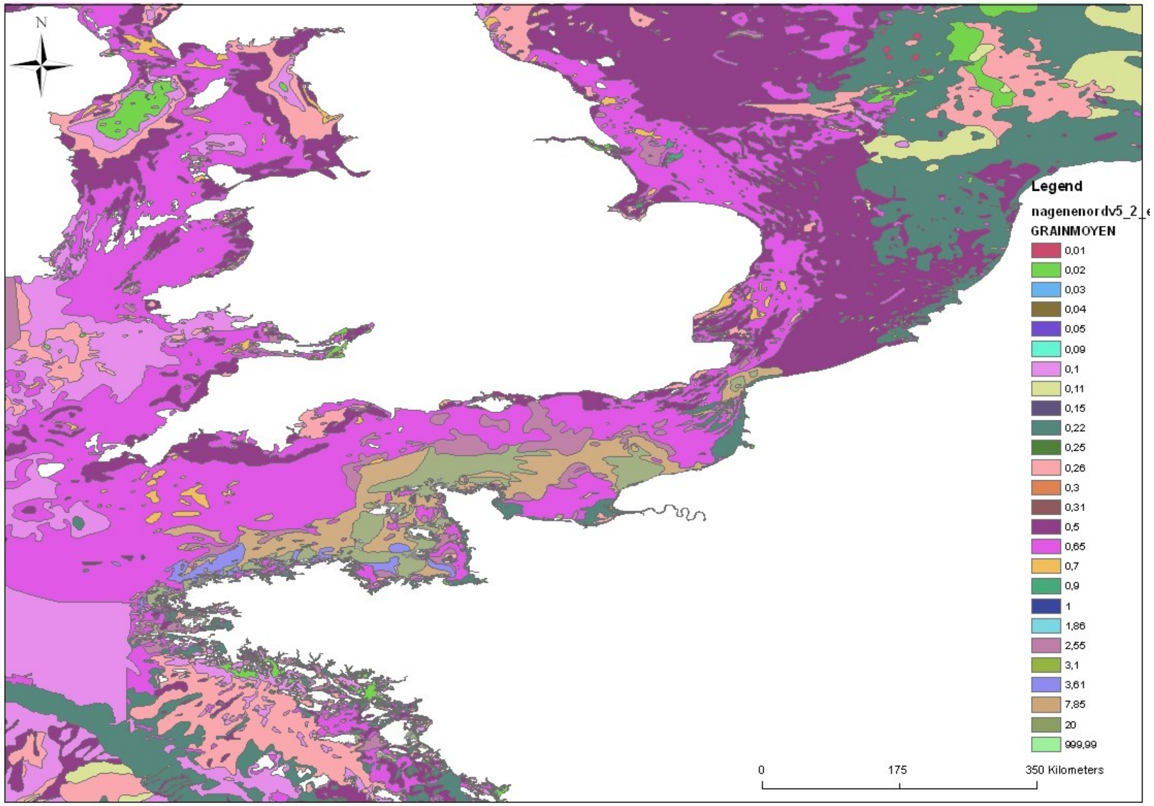






3. Southern North Sea and Channel hindcast

First we have to define the sediment properties : here using the SHOM global database on sediment cover (Garlan et al.).

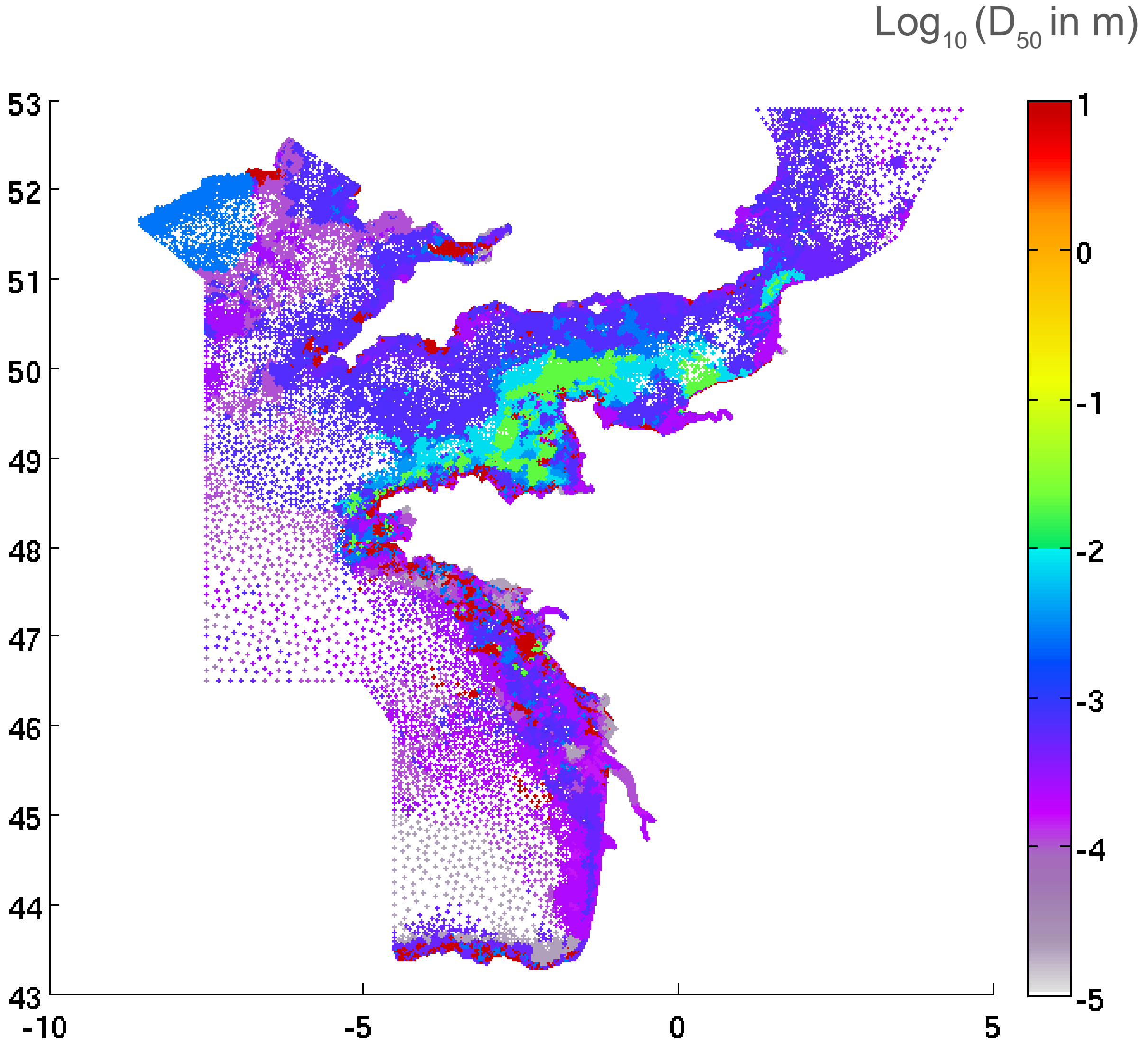


D_{50} (mm)

3. Southern North Sea and Channel hindcast

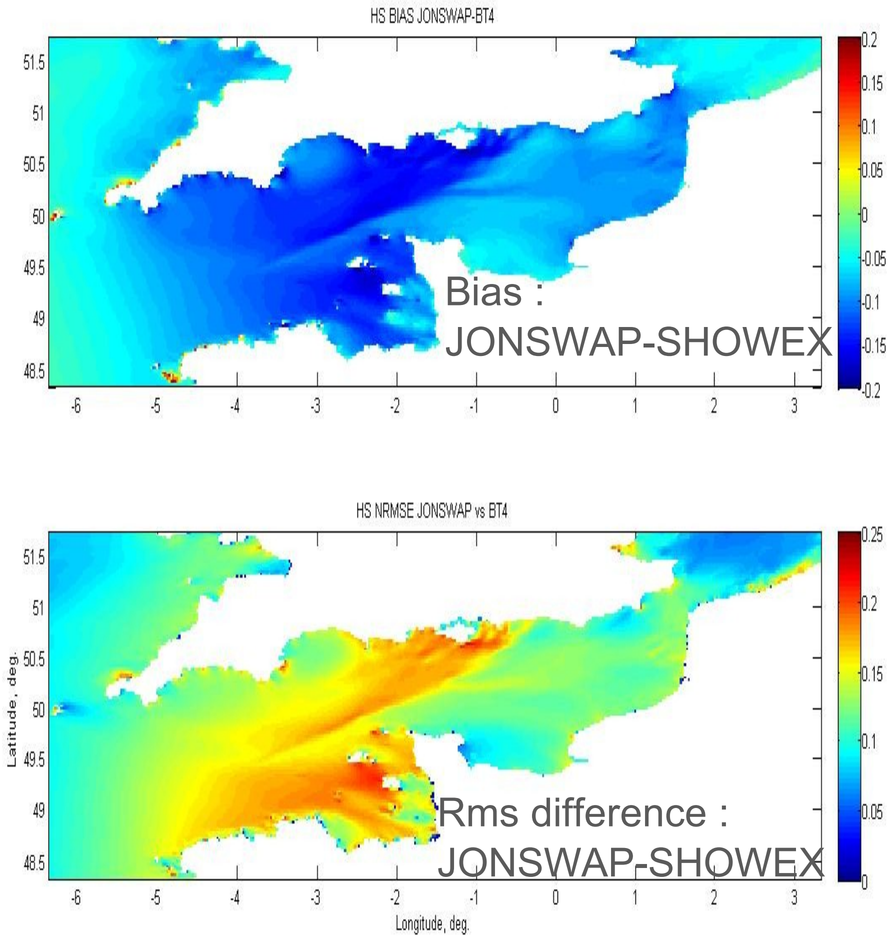
First we have to define the sediment properties : here using the SHOM global database on sediment cover (Garlan et al.   ).

This is on the 110 k node grid used twice a day for wave forecasting using WAVEWATCH III version 4.05 (www.previmer.org)



3. Southern North Sea and Channel hindcast

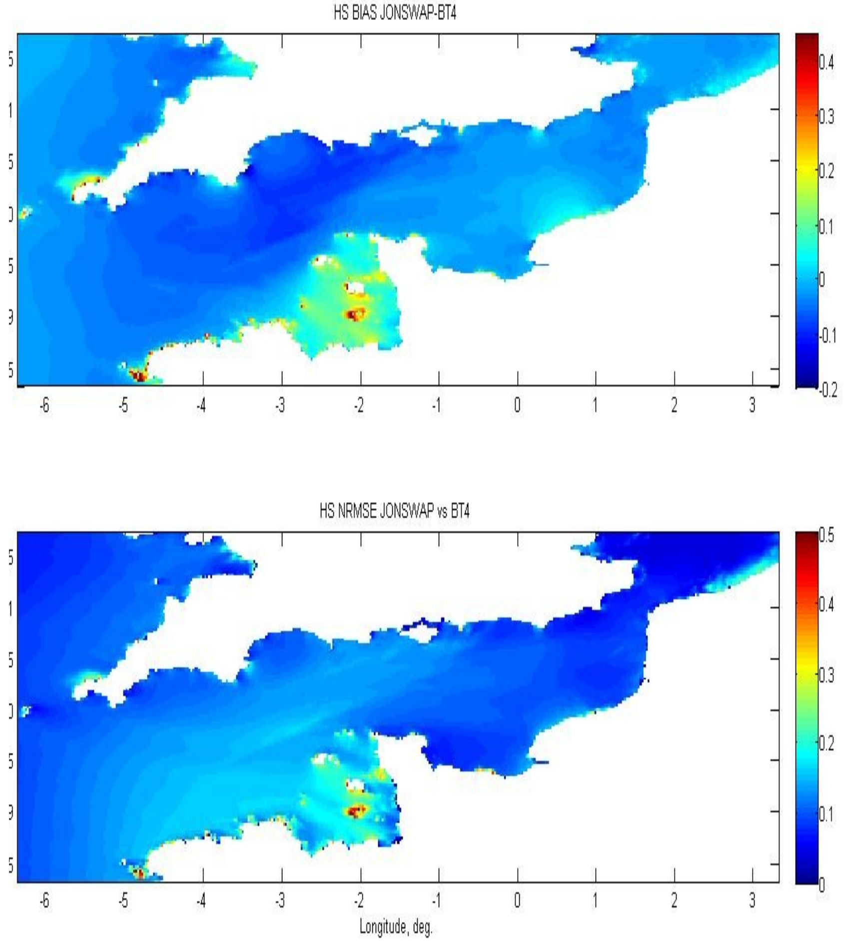
Original « SHOWEX » parameterization
(Ardhuin et al. JPO 2003)



Bias :
JONSWAP-SHOWEX

Rms difference :
JONSWAP-SHOWEX

modification of background roughness (when ripples are not formed) : important for rocks and coarse sediments (gravel, pebbles)



Back to my outline : recommendations

1. Forcing fields : icebergs

2. Swells : MOST IMPORTANT... theory and DNS needed
3. Working around the peak : relaxation time scales
4. Inertial range & tail issues : get rid of Komen et al.

   How do we validate stress ? (coupled model...)
5. Directional spreading : reflection. Use of noise data ?
6. Bottom friction : use bottom types and roughness