(wave) dissipation source terms and whitecap statistics:

Can numerical wave models be of any use for GHG fluxes?

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Outline

1. Ocean waves in « Earth system sciences »

2. Wave dissipation parameterizations

3. Linking parameterizations and observations

4. Model output variables that may be linked to GHG fluxes

5. perspectives

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1. Ocean waves in Earth system sciences.

Air-sea GHG fluxes are one of the many variables that are impacted by **ocean waves**.

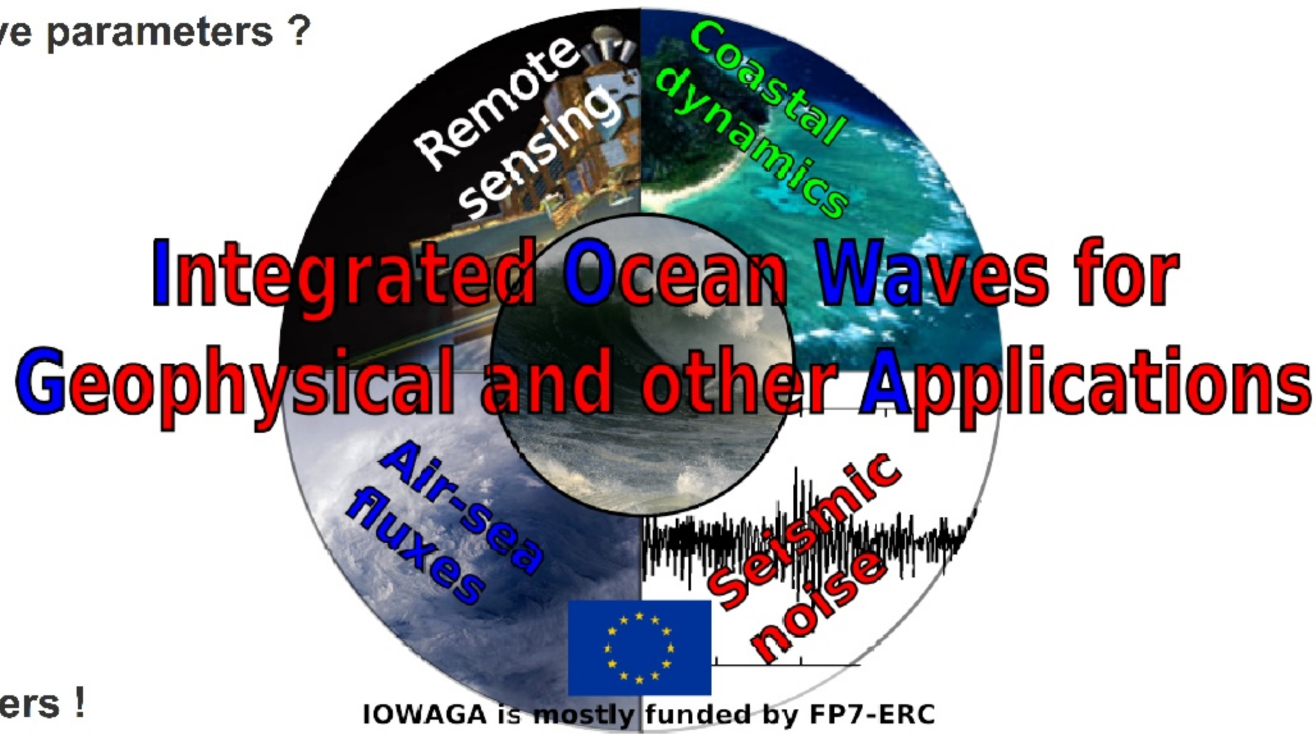
Do we know enough about waves to properly parameterize wave effect on such fluxes?

How consistent are different wave parameters ?

- wave **breaking statistics**
- **mean square slopes**

broader perspective

of the « IOWAGA » project.



This ERC-funded effort provides
Improved wave models and
hindcast databases...
over 30 different output parameters !
http://tinyurl.com/iowagaftp

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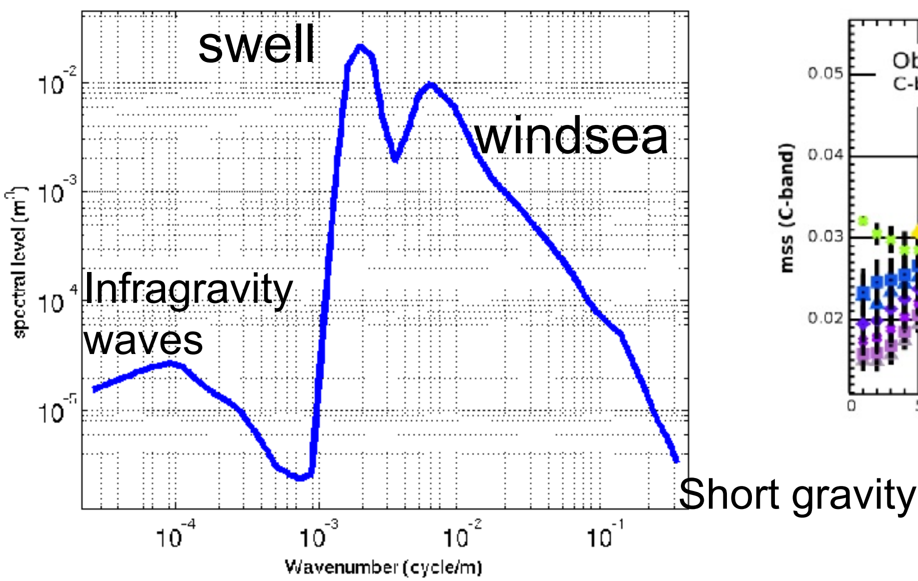
2. Wave dissipation parameterizations

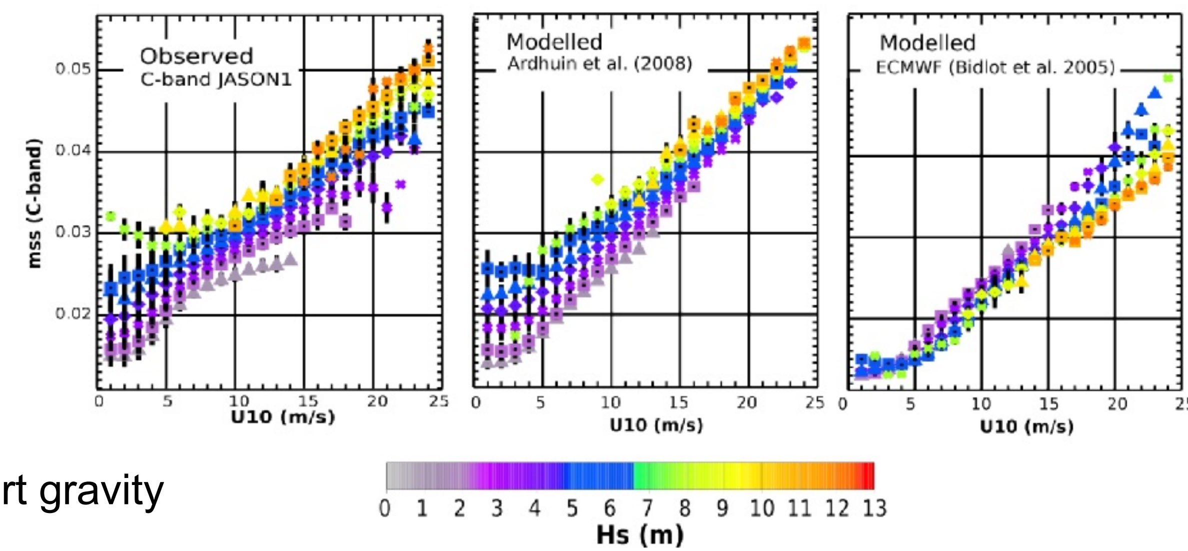
a) the « storage term » : the wave spectrum

Numerical wave models are first designed to estimate « dominant » wave parameters (Hs, Tp … with wavelengths from 30m to 1km).

Recent efforts → extended capabilities to longer (up to 30 km, Ardhuin et al., submitted) and shorter waves (Banner & Morison OM 2010, Ardhuin et al. JPO 2010).

Not yet consistent with short gravity and capillary wave transition (Yurovskaya et al., JGR in press).





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2. Wave dissipation parameterizations (continued)

$$\frac{\partial E(\mathbf{k})}{\partial t} + \boldsymbol{\nabla}_{\mathbf{x}} \cdot \left(\mathbf{C}_g E(\mathbf{k})\right) + \boldsymbol{\nabla}_{\mathbf{k}} \cdot \left(\mathbf{C}_k E(\mathbf{k})\right) = S_{\mathrm{in}}(\mathbf{k}) + S_{\mathrm{nl}}(\mathbf{k}) + S_{\mathrm{dis}}(\mathbf{k})$$

b) the « flux term » : the dissipation source term

Wave breaking (micro-breakers and whitecaps) are important for GHG fluxes and are related to the dissipation rate of waves and the shape of the spectrum.

- dominant wave breaking can be parameterized (Banner et al. JPO 2000). Are wave models good enough to be used for this ?
- shorter breaking wave properties are more elusive (Banner et al. JPO 2002, Mironov 2009)

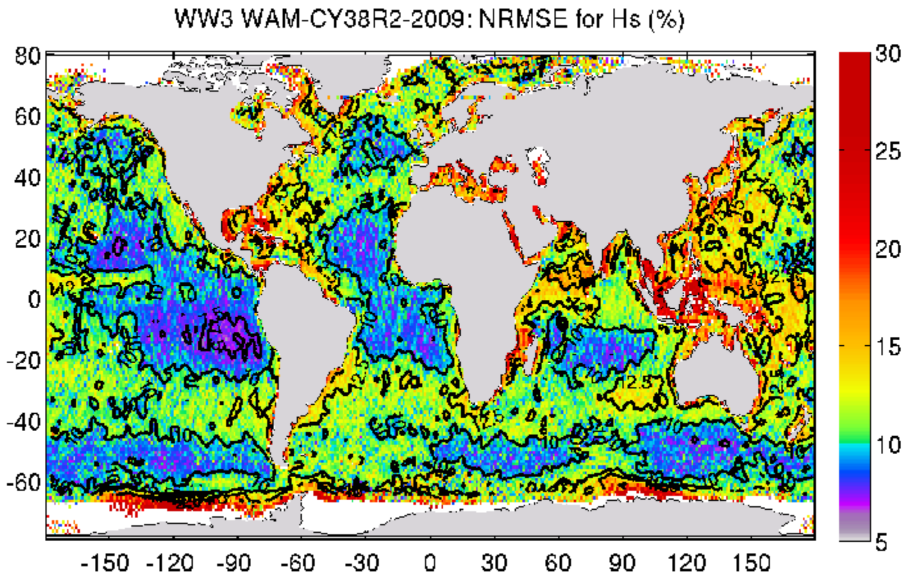
Dissipation is parameterized as a
dissipation rate per unit length of breaking front (e.g. Duncan 1981)
times a spatial and spectral density of breaking front length (Phillips 1985) $\Lambda(C)$
this $\Lambda(C)$ can also be expressed as a breaking probability times a crest length density.

From $\Lambda(C)$ one may recover a whitecap coverage and a mean foam thickness
(Reul & Chapron 2003)

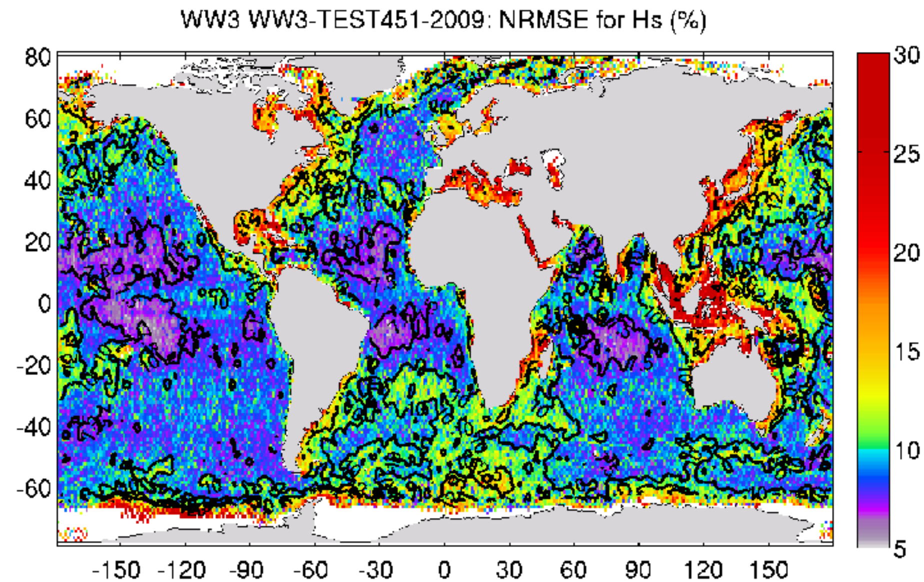
2. Wave dissipation parameterizations (continued)

This type of parameterization can produce more accurate wave heights (and mean periods) than earlier forms based on a mean steepness (Hasselmann 1974... : these have spurious windsea-swell interactions).

Errors for Hs against altimeters :



Old form
(ECMWF WAM, no assimilation)



« New » form
(Ifremer WAVEWATCH, no assimilation)

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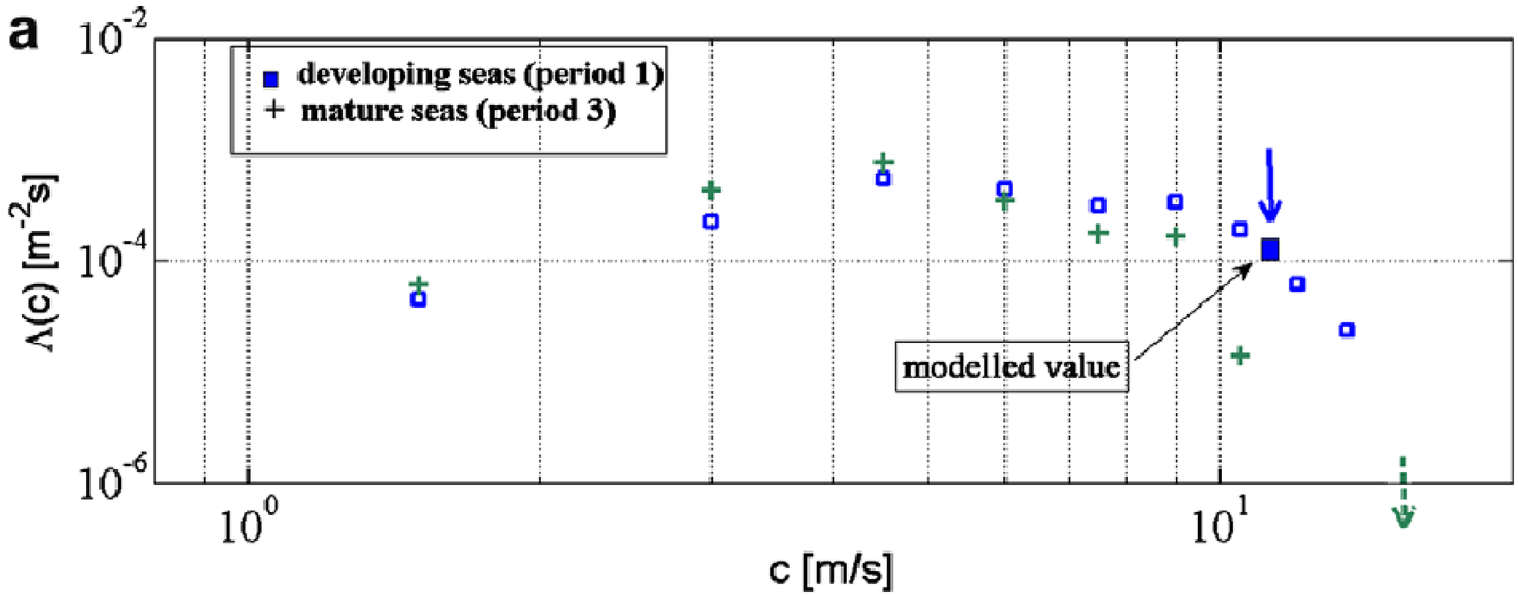
3. Linking parameterizations and observations

But is there any link to observable breaking parameters ?

- measurements of $\Lambda(C)$: Gemmrich et al. (2008)

- model evaluation : Banner and Morison (2010), Leckler et al. (2013)



We need more data ! → On-going stereo-video experiments (see poster by F. Leckler)

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4. model output variables that may be linked to GHG fluxes

In the meantime, what can we do ?
Is there any sea state parameter that can do better than wind speed ?
What data can we use for validation (wcc is difficult, see poster by J. Hanafin)
- use radiometer data (proxy for foam coverage and thickness)
… but the winds used to drive the model have some inconsistencies …

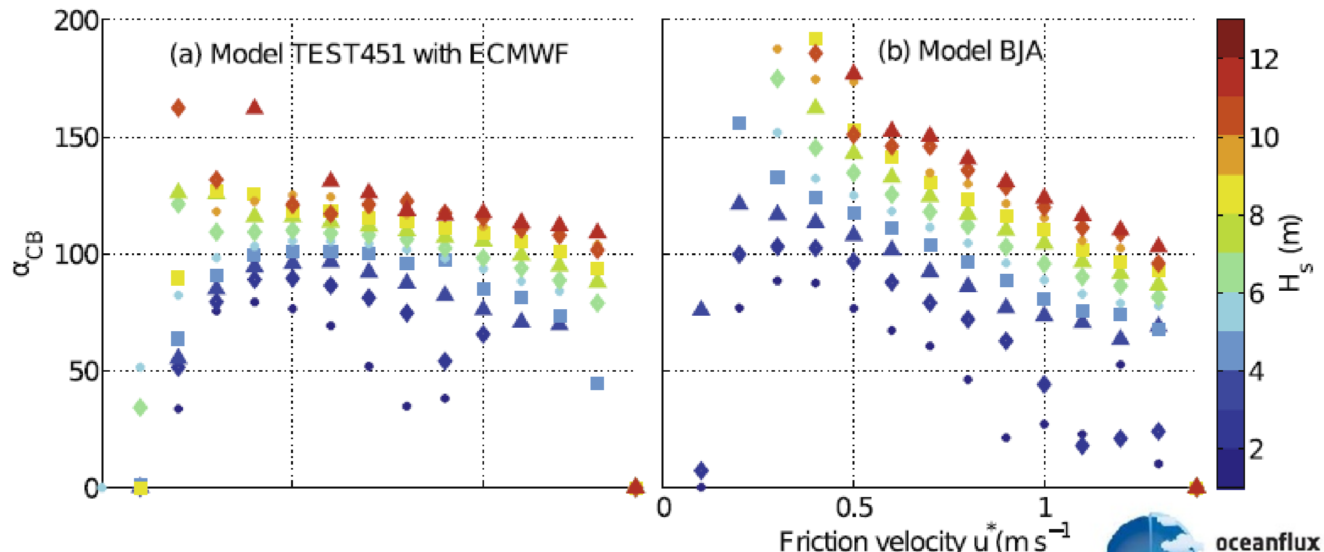
We can look at this kind of plot :
parameter (wind, Hs) where Hs is a proxy for « wave age »
… but be careful with swells !

Energy flux due to breaking

$$\Phi_{oc} = \frac{\rho_a^{3/2}}{\rho_w^{1/2}} \boxed{\alpha_{CB}} u^{*3}$$

(Craig & Banner 1994)

(Rascle & Ardhuin 2013)



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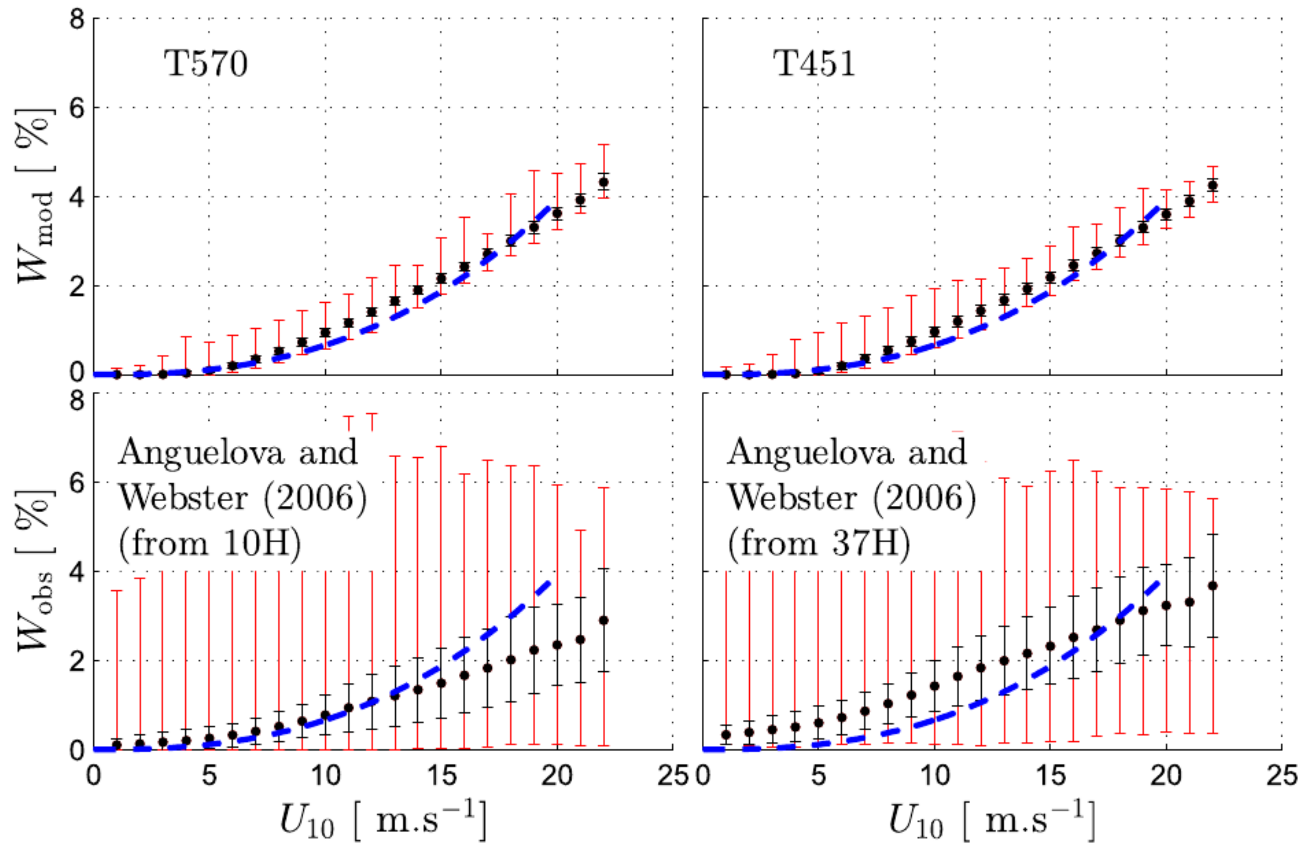
4. model output variables that may be linked to GHG fluxes

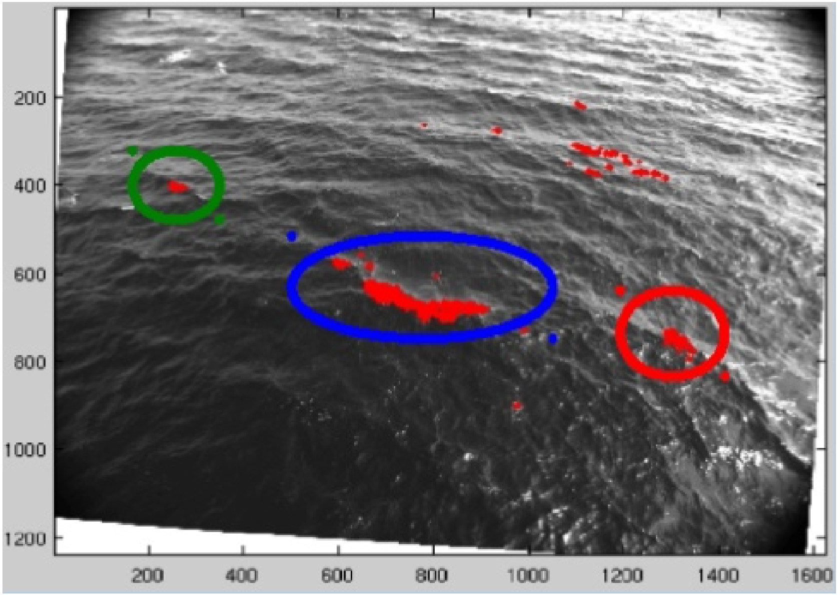
Direct estimate of wcc ? (Leckler et al. 2013)

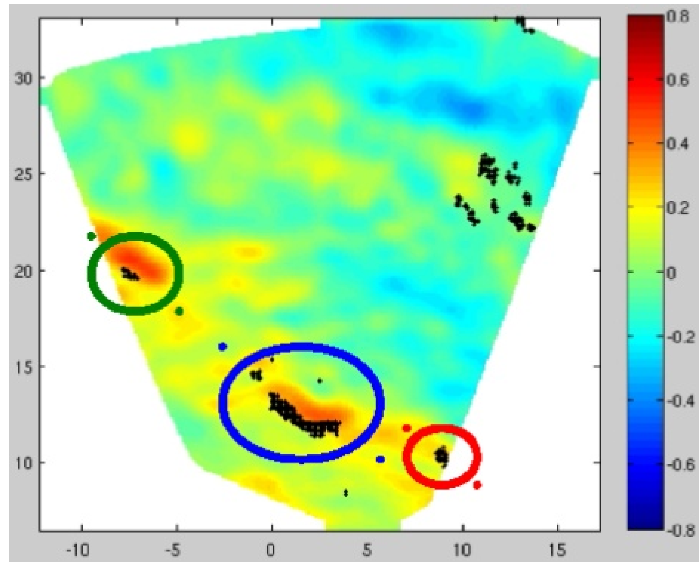
Using Reul & Chapron for breaking width : depends only on wind speed.



5. Perspectives

A) We need more data, of a kind that is compatible with today's parameterizations :





B) We need to relate space-derived brightness temperatures in all bands to breaking parameters …

4. model output variables that may be linked to GHG fluxes

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