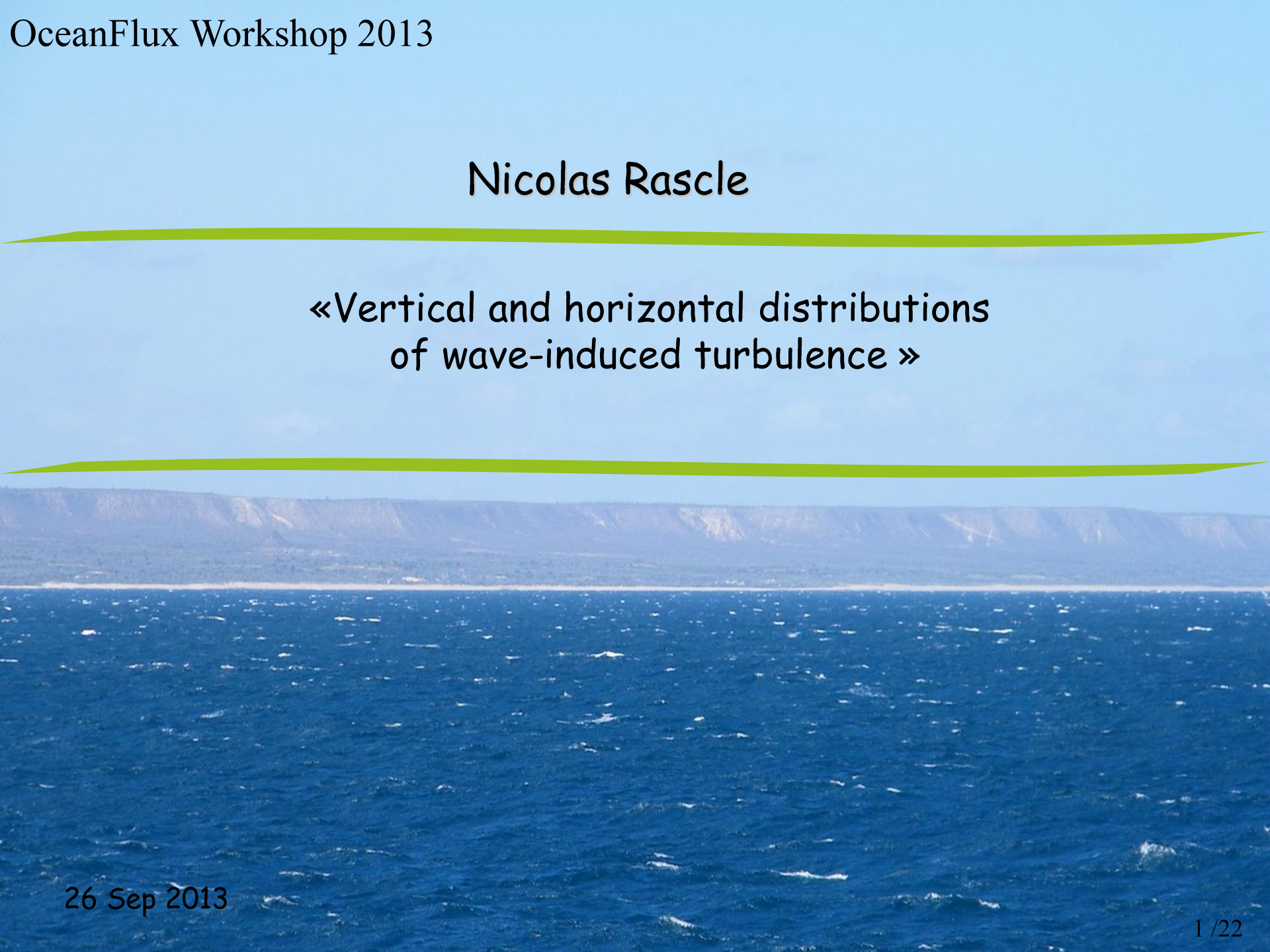
Nicolas Rascle

«Vertical and horizontal distributions of wave-induced turbulence »



26 Sep 2013

Nicolas Rascle

«Vertical and horizontal distributions of wave-induced turbulence »

Background: PhD thesis on wave/current interactions in 2007

Position: postdoc at IFREMER, Brest, France

Funding: European Space Agency MESO3D project (Support To Science Element)

Collaborations: Remote sensing expertise: Bertrand Chapron, Fabrice Collard,
Wave expertise: Fabrice Ardhuin,
Ocean expertise: Patrice Klein, Xavier Capet, Aurélien Ponte

«Vertical and horizontal distributions of wave-induced turbulence »

Surface turbulence, transfer velocities…

Wider problematic: the **near-surface dynamics**

Mixing, Air-sea fluxes, Currents, Remote sensing…

Coherent description of the surface layer as a coupled system **ocean/atmosphere + waves**

Introduction

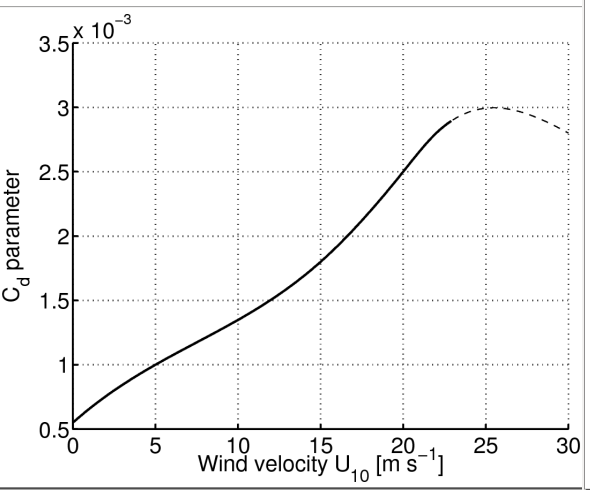
A description of the surface layer as an **ocean/wave/atmosphere** coupled system

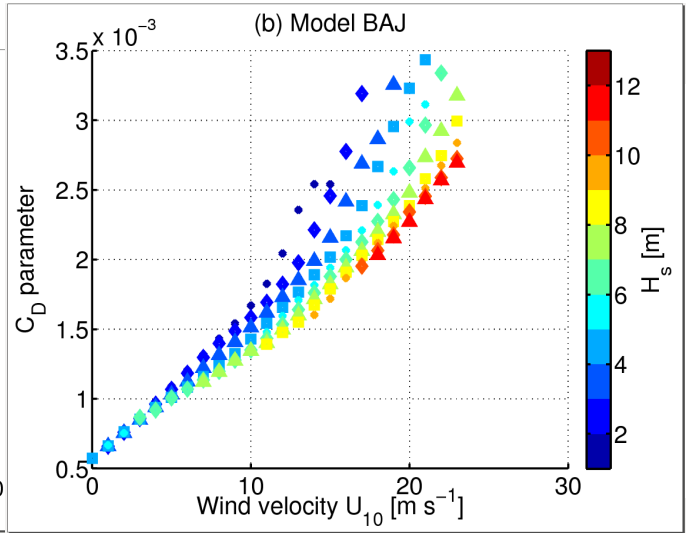
Example: air/sea momentum exchange and drag coefficient Cd

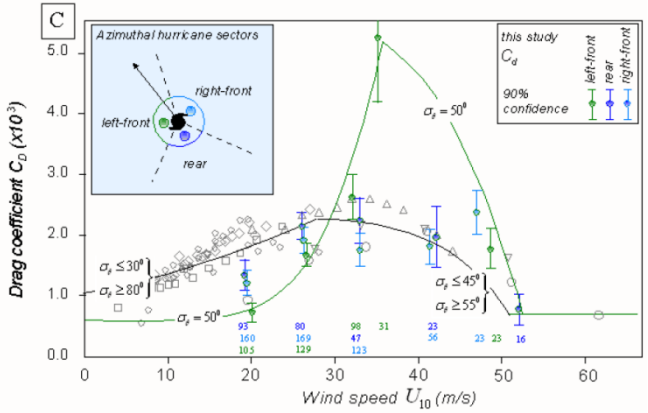
Zeroth order: Cd (U10) — no wave variability

First order: Cd (U10, wave age) — wind sea variability

Second order: Cd (U10, waves) — swell and mixed sea effects







Important to identify how far we are: observations / theories / models (like WW3) ?

…and for the mixing?

Introduction

For the **mixing** / **near-surface turbulence**:

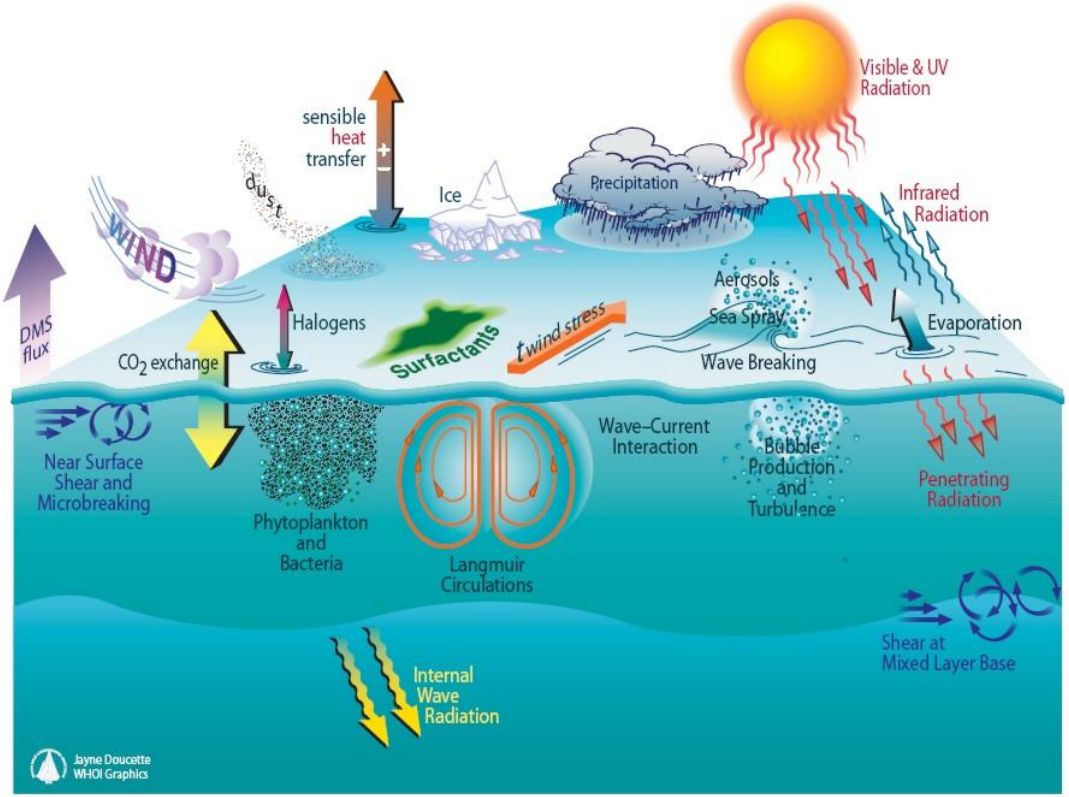
•Energy flux from wind to waves: 70 TW

(energy flux from wind to geostrophic currents: 1 TW)

•90% of the energy from wind to waves ends up in the ocean, only little is stored in waves

→ Huge amount of energy available for upper ocean mixing

→ The generation of turbulence by wave breaking > other sources (direct wind stress, convection, tides, rain,…)



Introduction

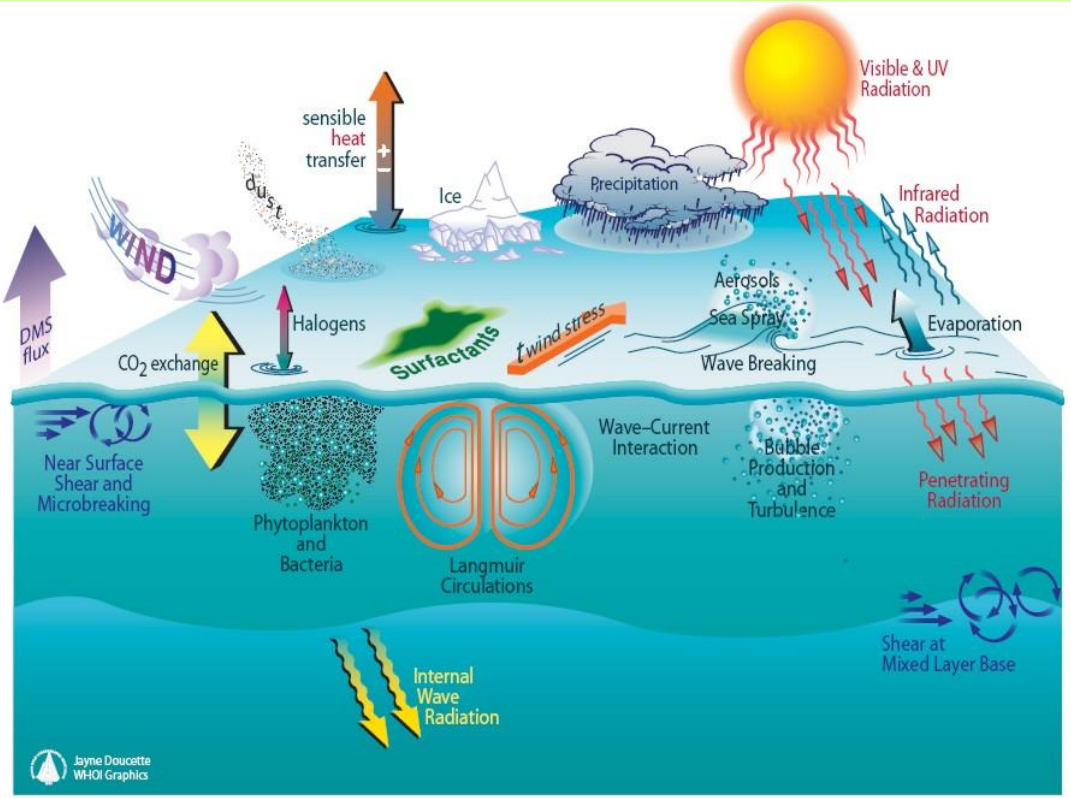
Outline of my talk: Questions are:

1.How much energy is injected?

2.How deep does it go? Mixed layer deepening?

3.The horizontal distribution of the injection?

…in observations, in theoretical understanding and in a modelling strategy with WW3



1) Overall wave breaking turbulence

Surface flux of turbulence Φ_{oc} = integral of wave dissipation $S^{ds}(k,\theta)$

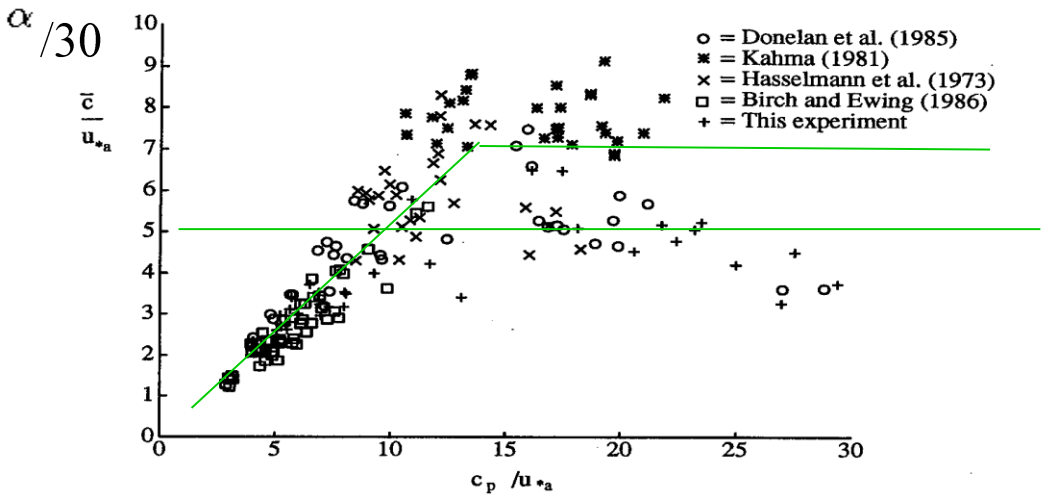
$$\frac{\mathrm{d}}{\mathrm{d}t}E(k,\theta) = S^{in}(k,\theta) + S^{nl}(k,\theta) + S^{ds}(k,\theta)$$

Well constrained and validated

Different parameterizations

(Scaled with the wind cube $\Phi_{oc} = \alpha u_*^3$)

Wind input estimates from observed wave spectra:



α =150

FIG. 8. The ratio $\bar{c}/u_{*a}$ versus wave age, c_p/u_{*a}. (From Terray et al. 1996)

1) Overall wave breaking turbulence

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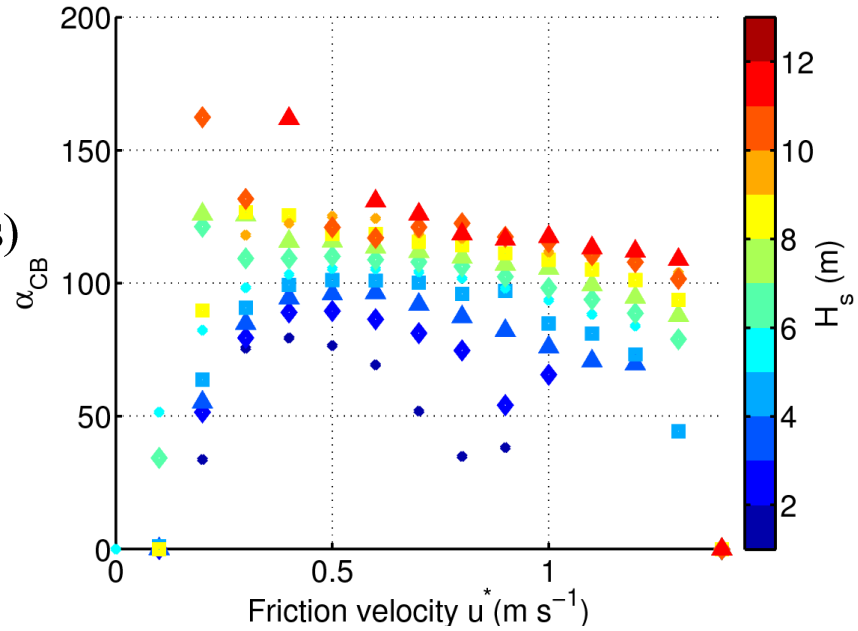
Another indirect estimation from a wave model which reproduces large waves, small waves (mss) and offers a (coherent?) description with wind input and wave dissipation.

(Ardhuin et al 2009)



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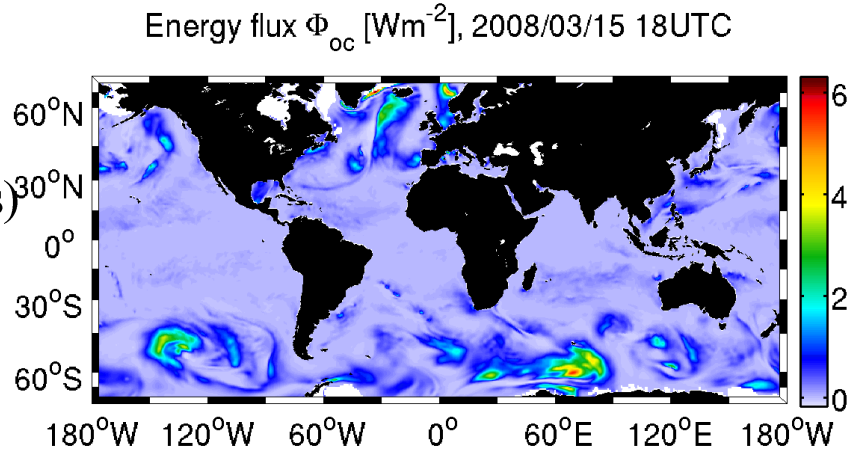


2) Vertical distribution of mixing

How deep is that near-surface turbulence injected?

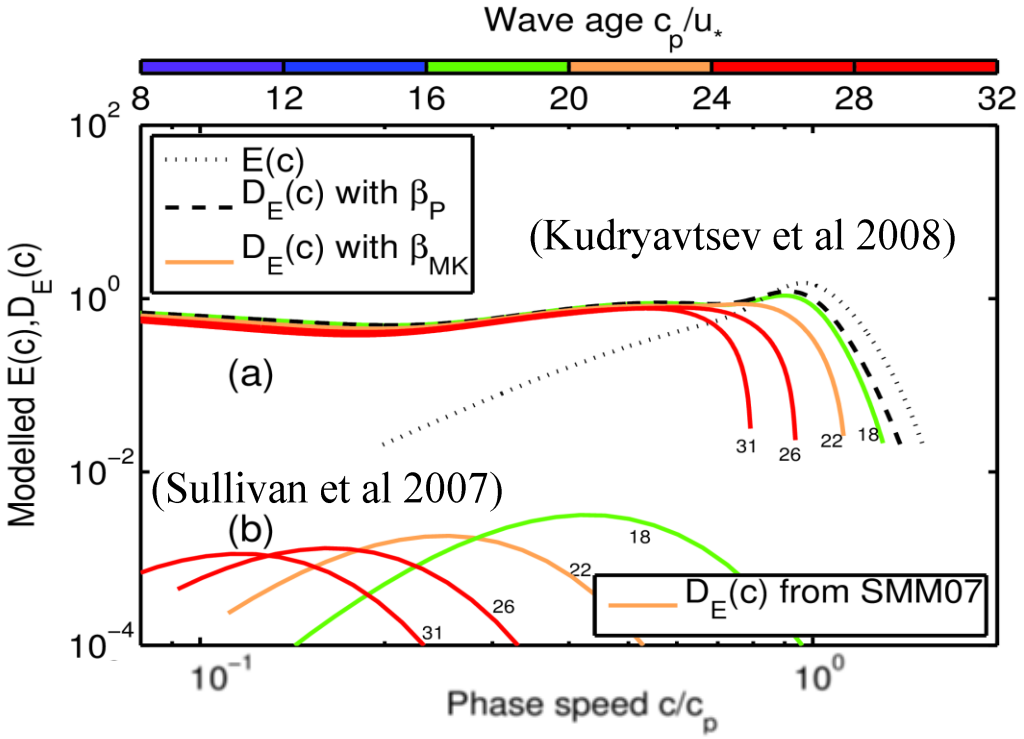
1) Size of the waves releasing energy
2) Assign an injection depth to each individual breaker
3) Resulting TKE dissipation rates

2) Vertical distribution of mixing

Near-surface turbulence:

1) Size of the breaking waves:
Which waves are breaking ?

In models



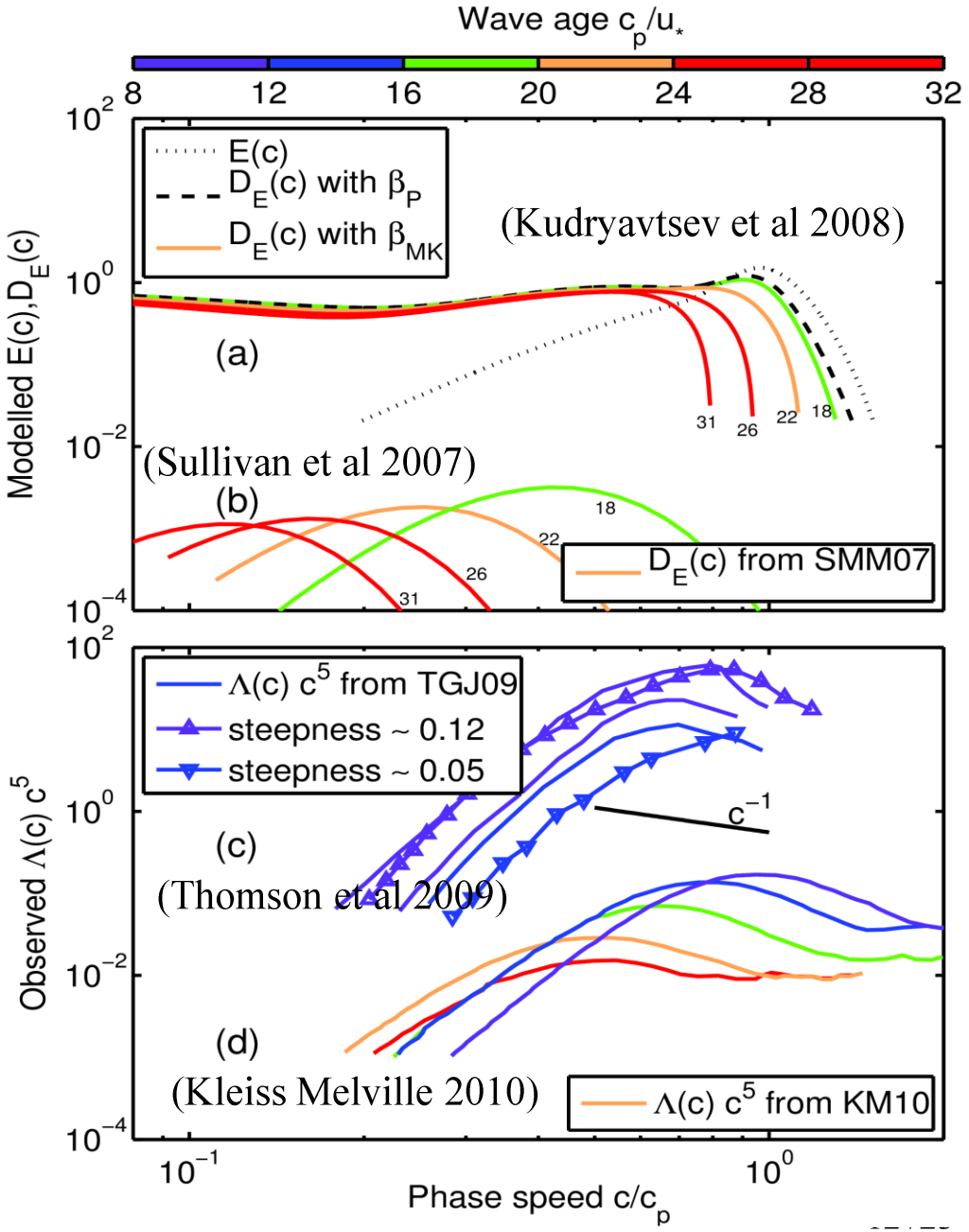
2) Vertical distribution of mixing

Near-surface turbulence:

1) Size of the breaking waves:
Which waves are breaking ?

In models

In whitecaps observations

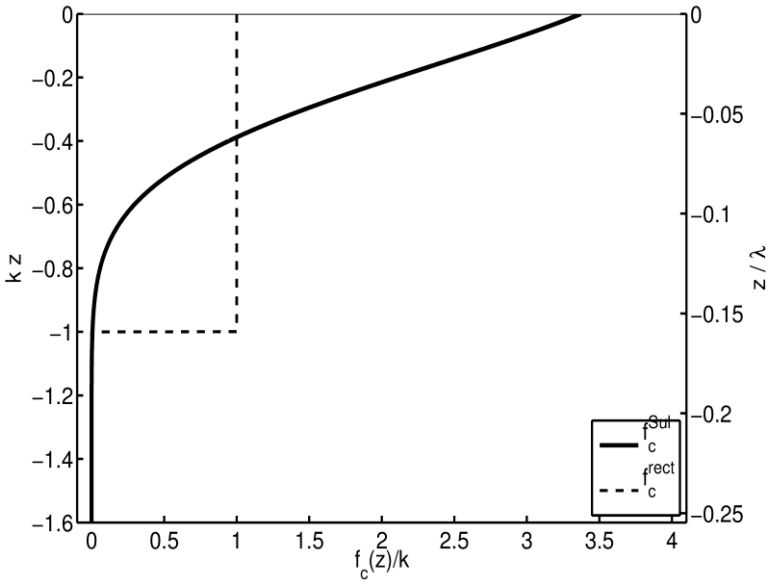


2) Vertical distribution of mixing

Near-surface turbulence:

1) Size of the breaking waves:
2) Depth of individual breakers

Observations: injection to $z \approx 1/k$



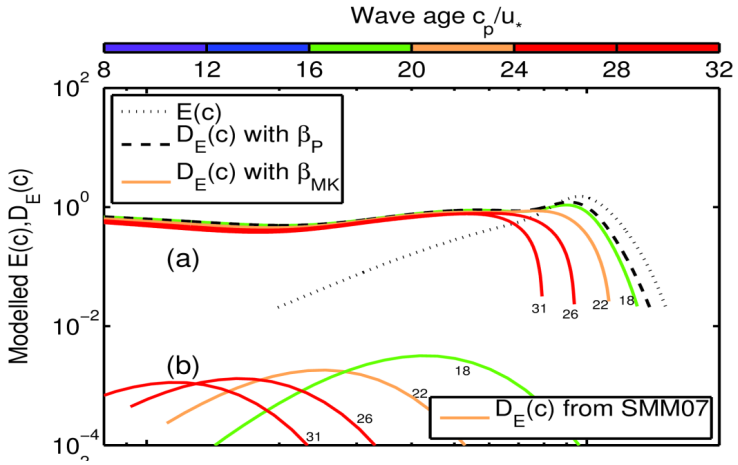
(Melville et al 2002)

2) Vertical distribution of mixing

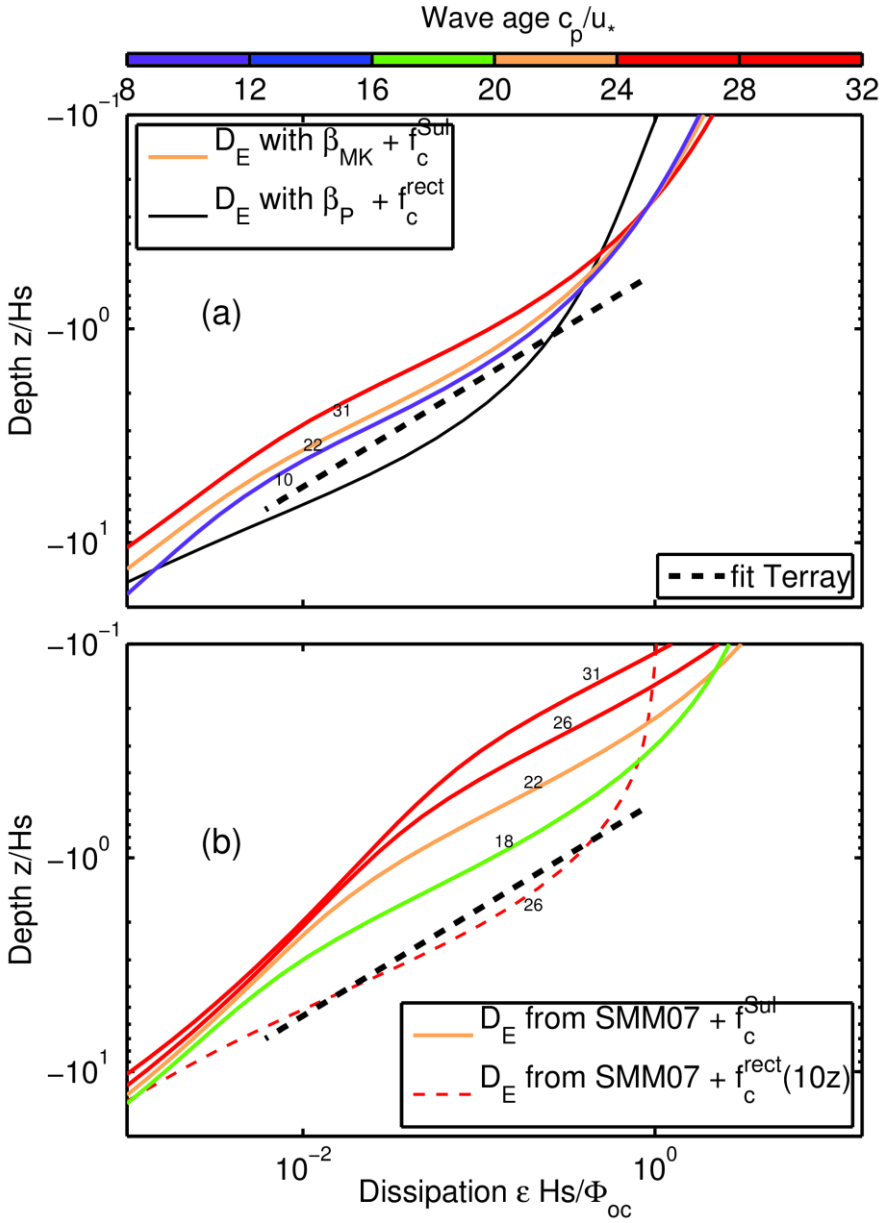
Near-surface turbulence:

1) Size of the breaking waves:
2) Depth of individual breakers
3) Resulting TKE dissipation rates

Depth reduced by 2-3 for developped waves



Depth reduced by 10 for developped waves



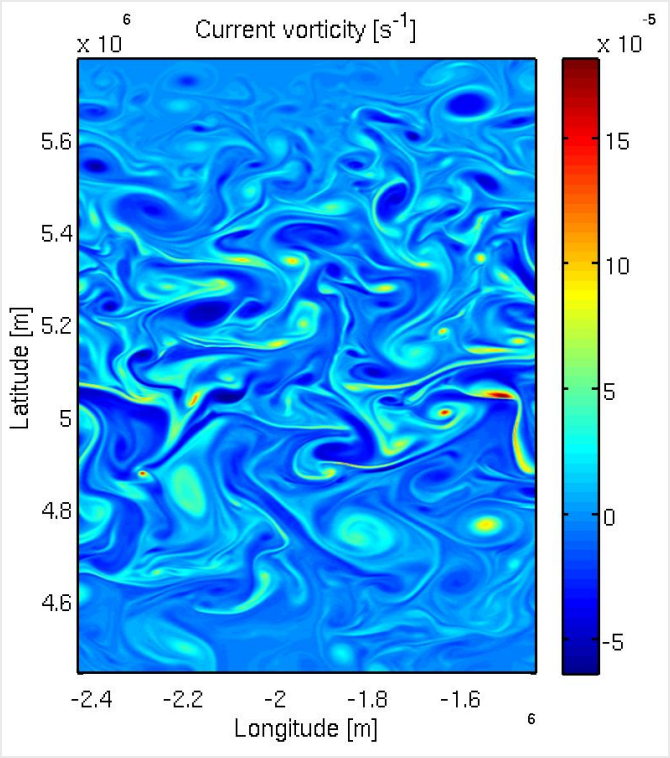
2) Vertical distribution of mixing

Wave-induced near-surface turbulence:

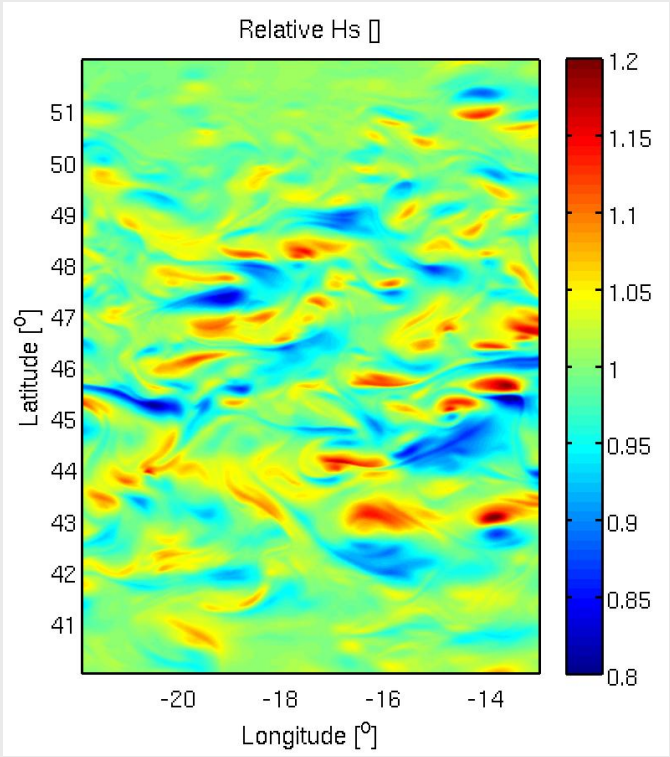
The injection depth is still unknown, in particular its variability with wave age.
Do young waves mix deeper or shallower than old waves?
We are still at the “zeroth order”!

3) Horizontal distribution of mixing

The ocean is a not horizontally uniform.
What is the impact of mesoscale (eddies) and submesoscale (fronts) structures on the turbulence injection (and on the ocean/waves/atmosphere coupling)?



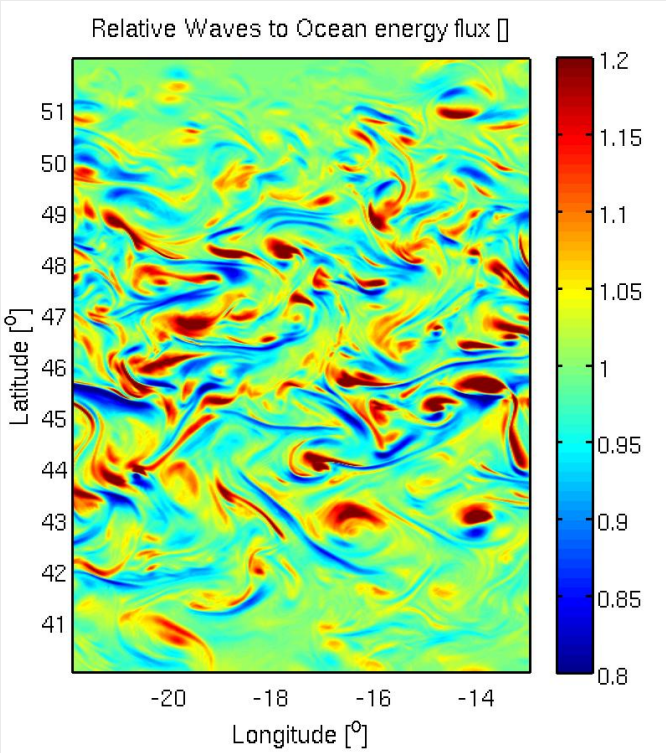
Input surface current



Hs from a wave model (WW3)
(Ardhuin et al 2009)

3) Horizontal distribution of mixing

The ocean is a not horizontally uniform.
What is the impact of mesoscale (eddies) and submesoscale (fronts) structures on the ocean/waves/atmosphere coupling?



Energy flux from wind to ocean

3) Horizontal distribution of mixing

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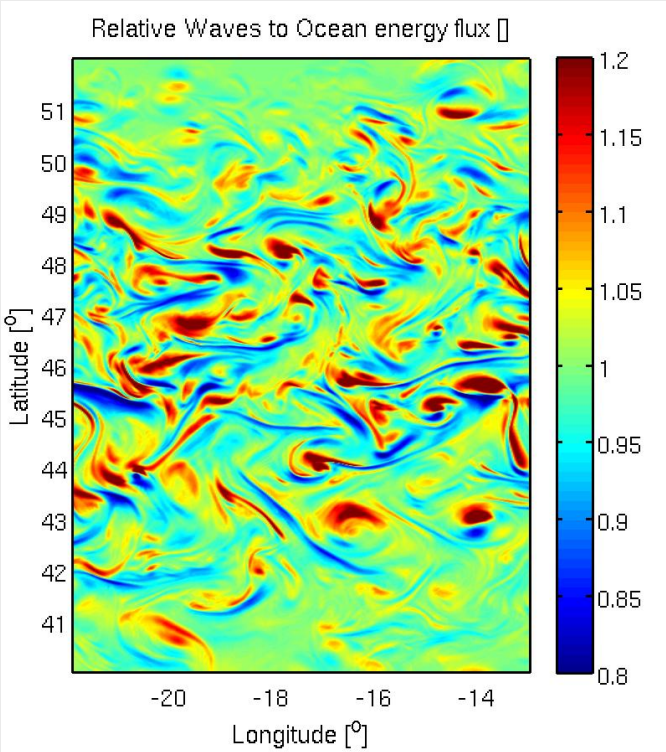
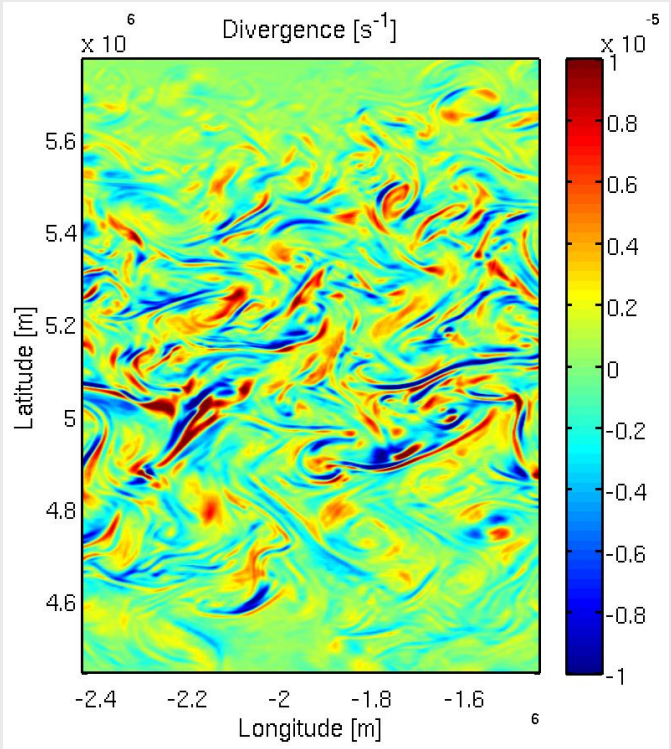


Energy flux from wind to ocean



Surface current divergence

3) Horizontal distribution of mixing

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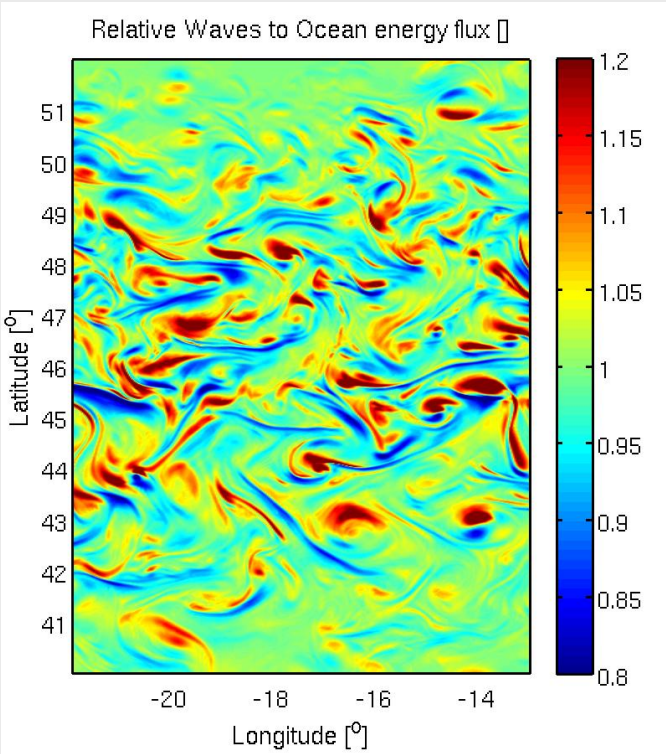

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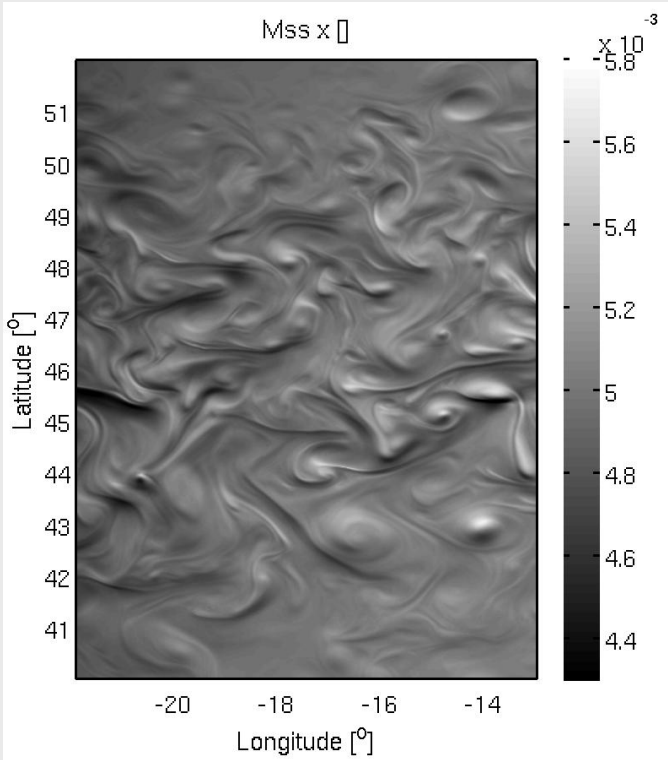


Waves mean square slope

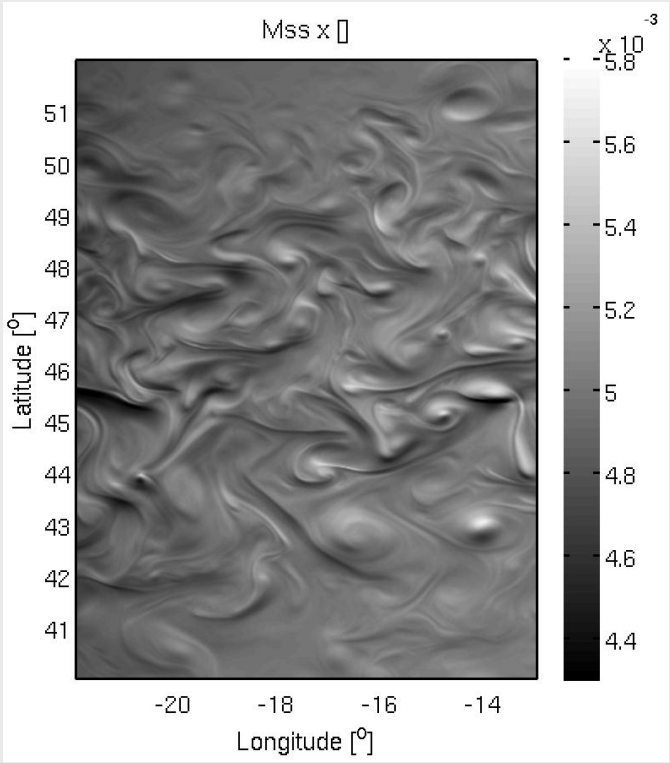
3) Horizontal distribution of mixing

The ocean is a not horizontally uniform.
What is the impact of mesoscale (eddies) and submesoscale (fronts) structures on the ocean/waves/atmosphere coupling?

In theoretical models (of short waves)
TKE flux ~ mss
~ current divergence

In wave models (WW3) (longer waves)
TKE flux ~ alongwind mss
~ alongwind current gradient

Observations:
roughness images



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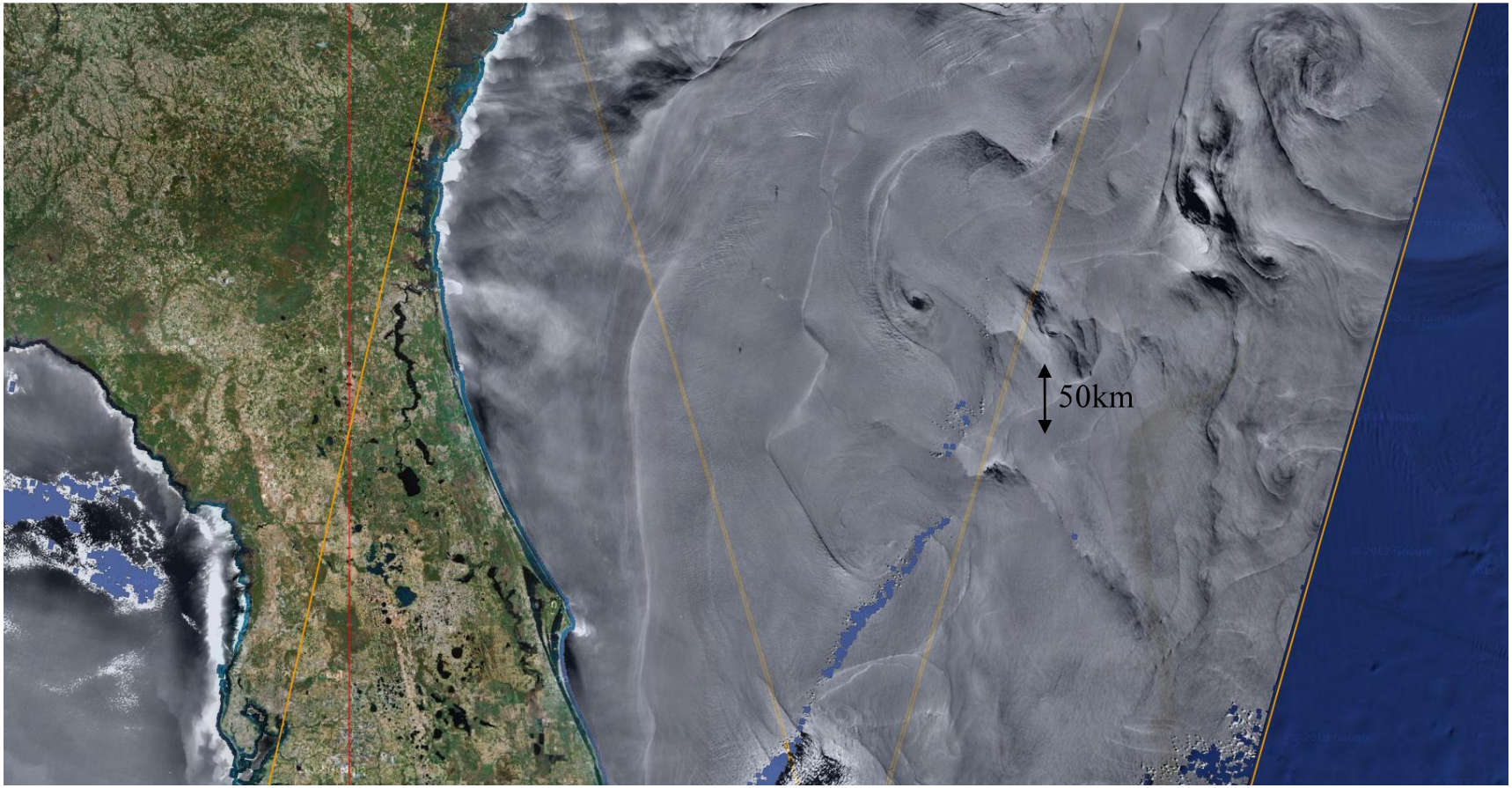

Surface roughness from Meris glitter

Conclusion

The uppermost turbulence is mainly injected by breaking waves.

1) We approximately know how much energy is overall injected.
   Increases with wave age
   Observations / theory / models

2) There is still no consensus on the vertical extent of the energy injection.
   Depends on the wave age? Observations / theory?

3) Turbulence injection is expected to be largely "patchy" in relation to atmospheric wind features but also to surface current submesoscale features.
   Theory / models. Observations?

All should be part of a coherent description with coupled ocean/waves/atmosphere. (drag / short waves / long waves / mss / wave breaking)

Impact on the transfer velocity / gas fluxes estimations?

Thank you