WELCOME

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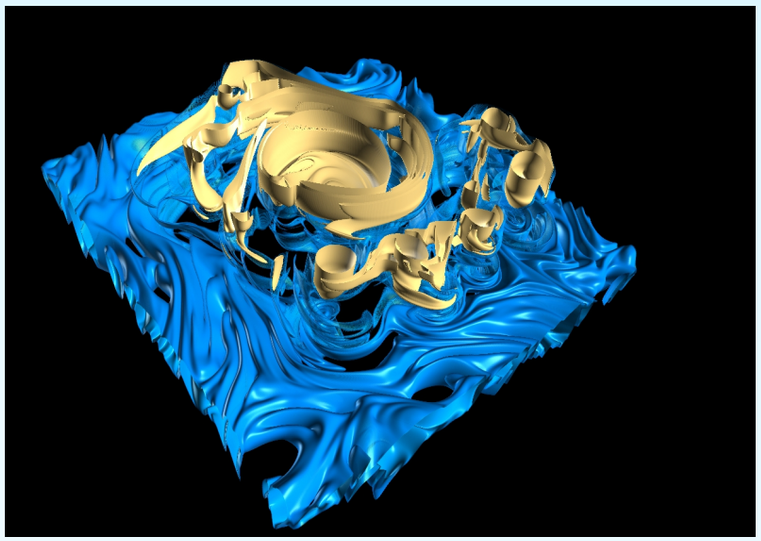
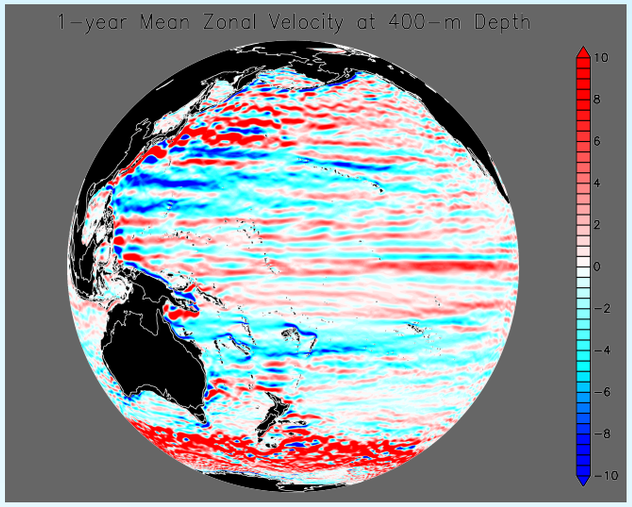
Alain Colin de Verdière and Michel Crepon

Ocean Scale Interactions

Lien made many so significant contributions to this field …



Eddies form zonal jets



… As a recognition, she received in 2006 the **Lorenz award** at the AGU meeting, where she gave a talk on zonal jets. She was very proud to be the first woman, and also the first GFDer to receive this prestigious award.

Ocean Scale Interactions Symposium

Jim McWilliams (UCLA, USA), june, 16, 2014:

«… Her primary passion was fluid dynamics … Lien's aspiration for scientific rigor and insight burned as a steady flame, and this was one of her most admirable qualities…I was her colleague and friend. I miss her company … »

Ocean Scale Interactions Symposium

Lien's concern was also to communicate and pass on her passion for research to other scientists and students.

Joe Pedlosky (Woods Hole, USA), may, 7, 2014:

«... I could imagine her encouraging young people to take heart from the joy she found in her research, in her discoveries and in the way in which searching after the truth of the physical world also served as bridge of friendship with her colleagues ... »

Ocean Scale Interactions Symposium

«But Lien is still and will be always with us. Her radiant and intense personality has left a strong imprint in our community. This imprint is and must remain an inspiration especially for young scientists to achieve new scientific breakthroughs in particular in the understanding of the ocean scale interactions, which is a challenge for the future.»

What do we call

Ocean Scale Interactions ?

Ocean Scale Interactions

Oceanic flows have a strong turbulent and chaotic nature

@ **Ocean dynamics involves a large range of scales, from 10m up to 10000 km, and all these scales may interact leading to a transfer of energy between these scales.**

@ **The question is: what are the physical mechanisms that allow this transfer of energy and what are the consequences of this transfer of energy on the large oceanic scales ?**

@ **The answer mostly depends on the density of observations and on the computer power available !**

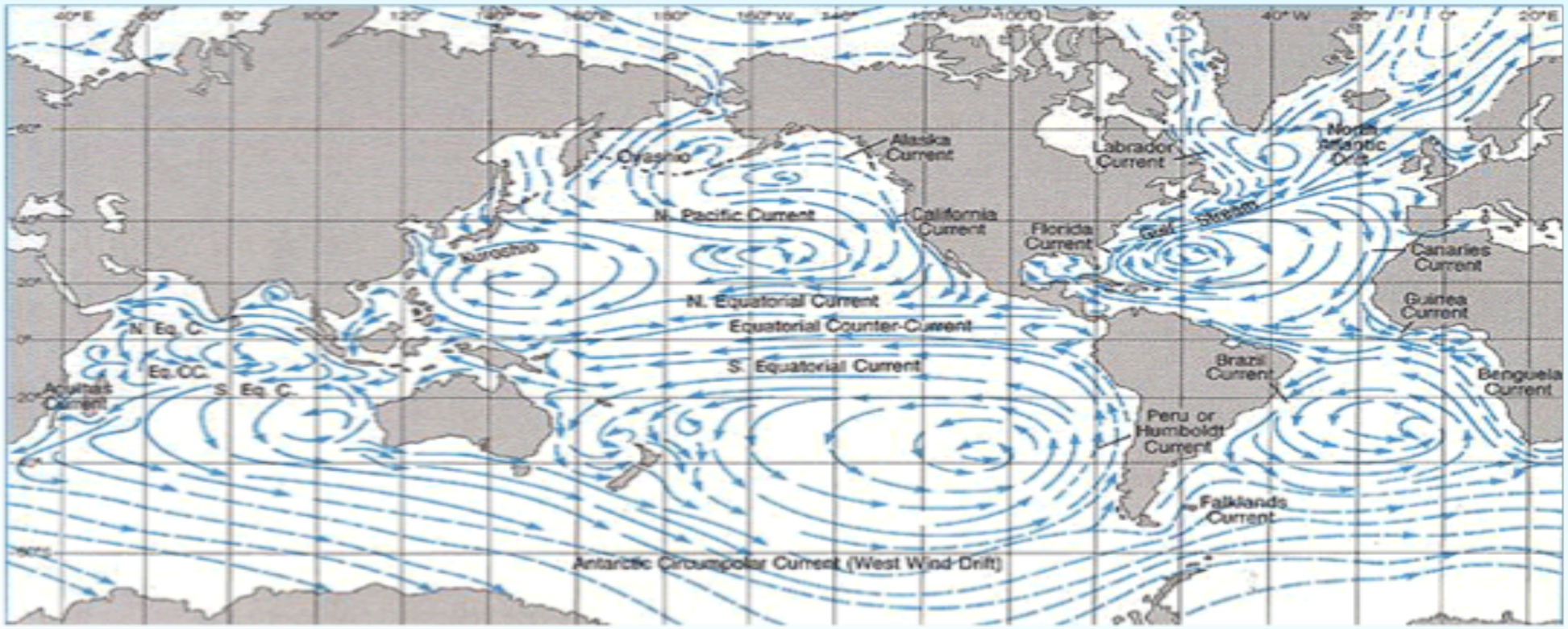
To illustrate this problem, let us examine the …

Evolution of our knowledge of ocean dynamics from 40 years ago up to now and what are Lien's contributions

(more details on Lien's contributions are given in Alain's talk) …

40 years ago, modelling studies using a space grid of 100-200 km and global observations available allowed only to correctly represent physical structures with a size of O(1000km).

=>Vision of the ocean dynamics 40 years ago

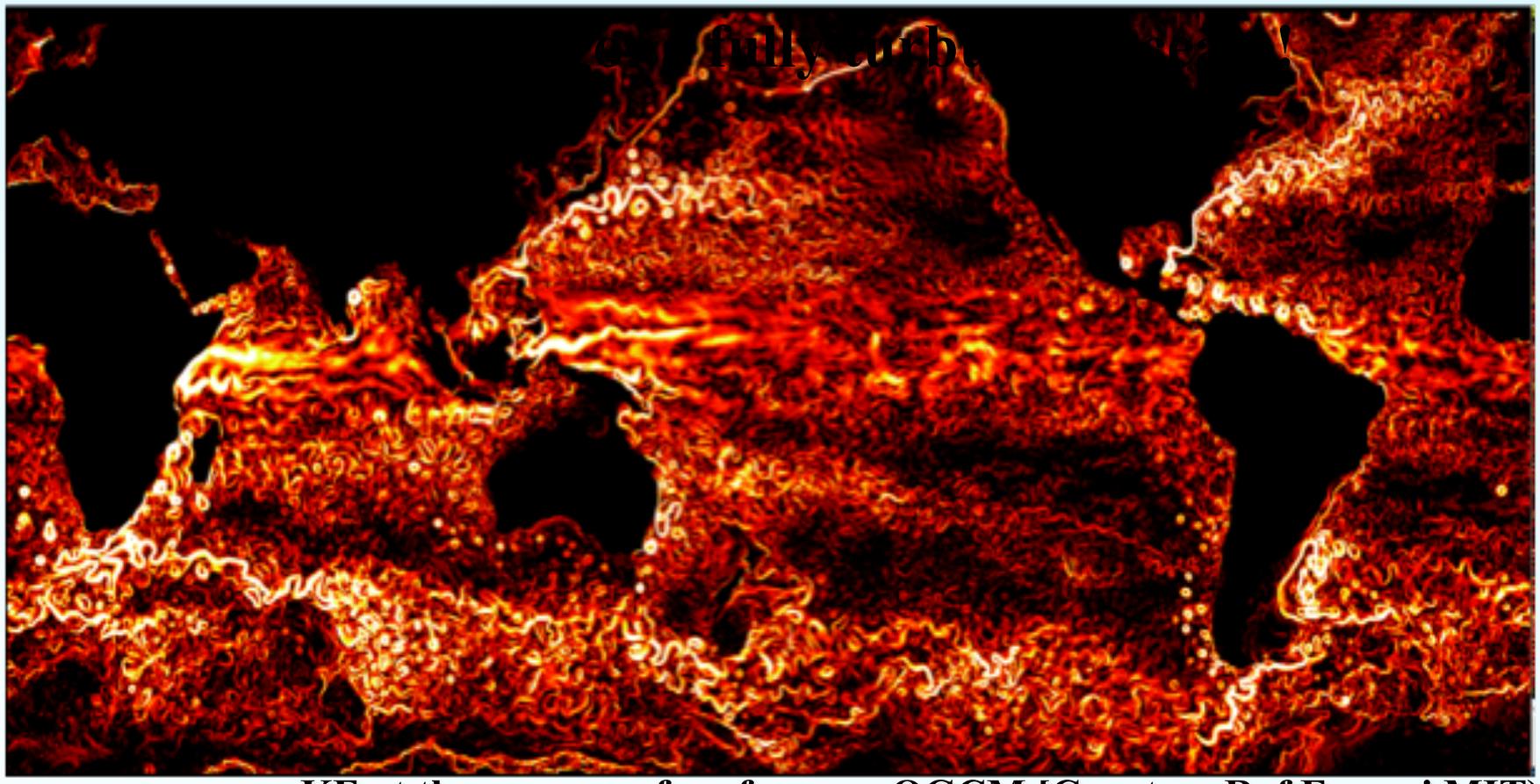


10m — 1000km — 10000km

This vision of the ocean dynamics significantly changed in the 80's and 90's …

… Increase of the computer power (CRAY machines) and of the density of observations (satellite altimeters: TOPEX/POSEIDON, JASON, …) allowed to study the scale interactions over a larger range of scales (from100km up to 10000km). The new vision indicated that all the oceans are **crowded with a large number of mesoscale eddies (200 km)**

=> 80% of the total kinetic energy !



KE at the ocean surface from an OGCM [Courtesy Raf Ferrari MIT)

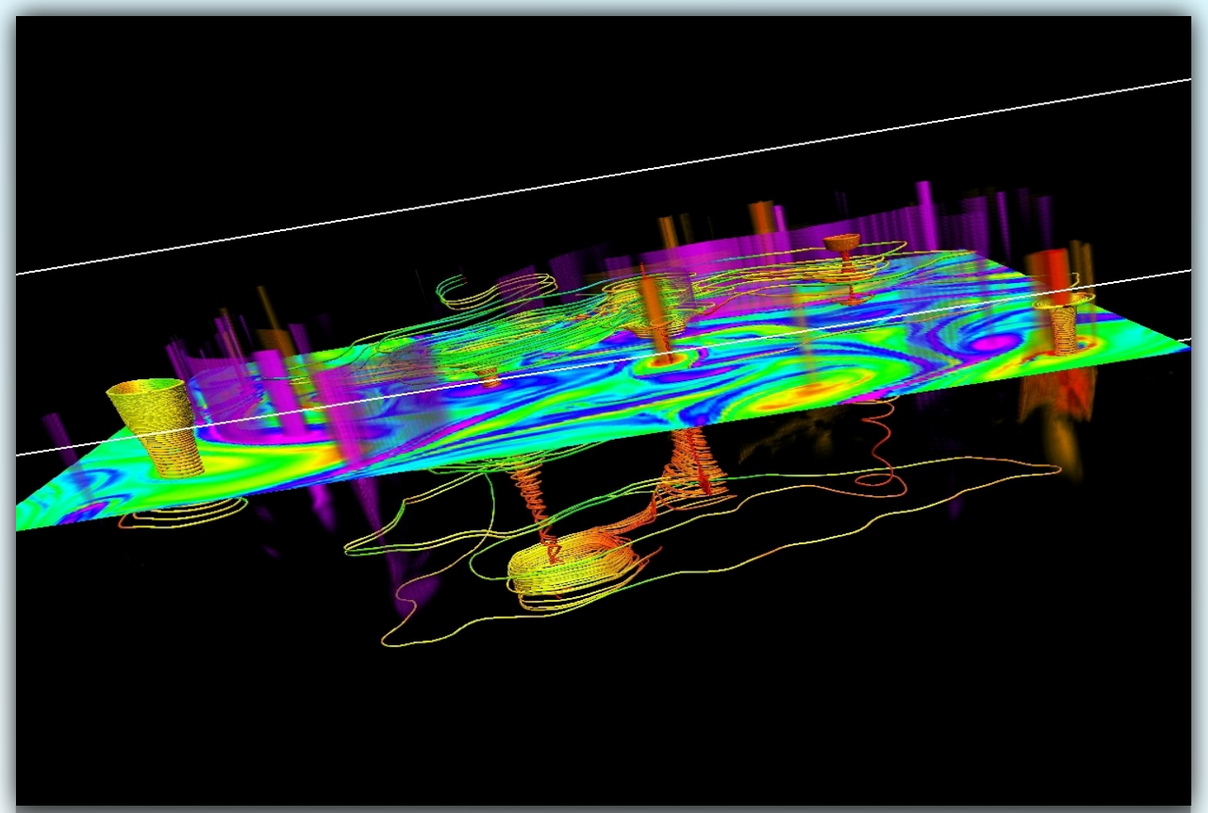
Ocean Scale Interactions

Theoretical and modelling efforts by Lien and others revealed that these **mesoscale eddies** (cyclones and anticyclones produced by the instability of the large-scale circulation) strongly impact the transport of heat from the equator to the poles and the large-scale ocean circulation itself through the ocean scale interactions

Lien's important and original contributions:

« **3D impact** of the **mesoscale eddy turbulence** on the larger scales »: Charney isotropisation

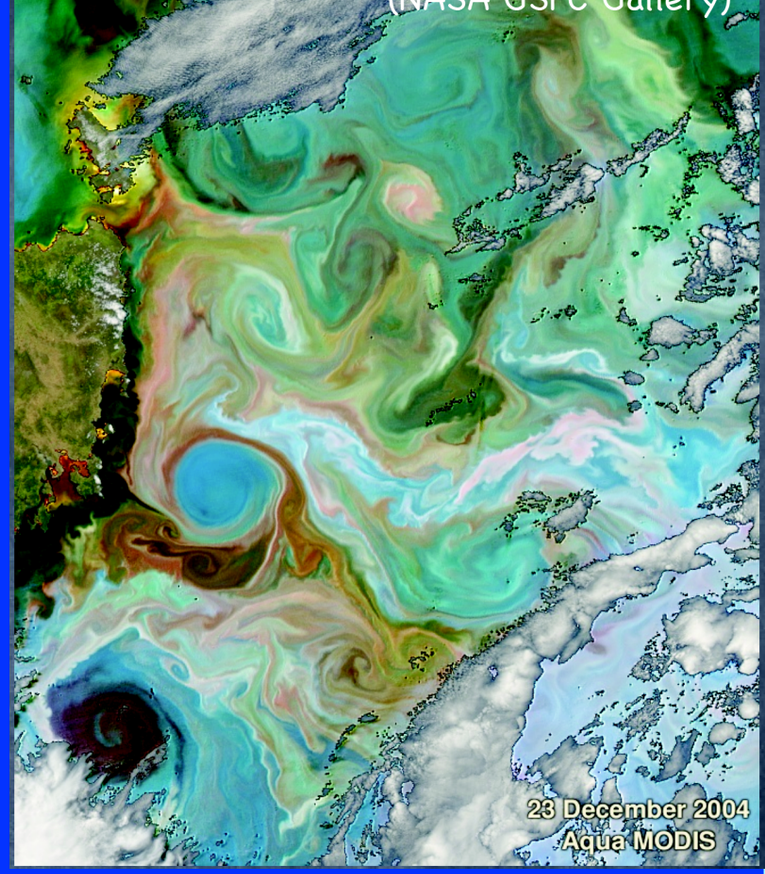
(see details in Alain's talk …)



Relative vorticity field with cyclones (red) and anticyclones (blue) on a 2D horizontal plane + 3D float trajectories

Access to high resolution satellite images, such as SST and color images. These images reveal not only mesoscale eddies (200km) but also smaller scales (1 km-40 km) called submesoscales.

Unfortunately these HR images do not provide any dynamical information on submesoscales



Ocean color image near Tasmania coast

Ten years ago, numerical models were unable to explicitly resolve these submesoscales because of the space grid considered. This explains that their impact was parameterized as a dissipation of kinetic energy.

dissipation?

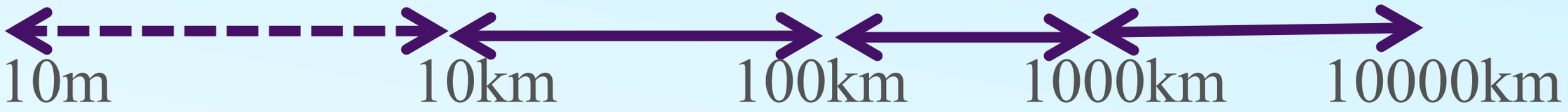
10m ⟷ **100km**

But this vision has again strongly evolved in the last ten years …

Ocean Scale Interactions

In 2003 a new generation of supercomputers (ES) allowed to consider the scale interactions on a much larger range of scales: 10 km up to 10000km.

« For Lien and I, and Sylvie, that was the beginning of a new and exciting adventure ... »



The Earth Simulator

=> Our first results published in 2007:

Impact of scales (10km-100km) is **NOT** a dissipative one! These scales are the signature of **SOURCES** of kinetic energy, a part of which feeds up mesoscale eddies and larger scales ! They explain

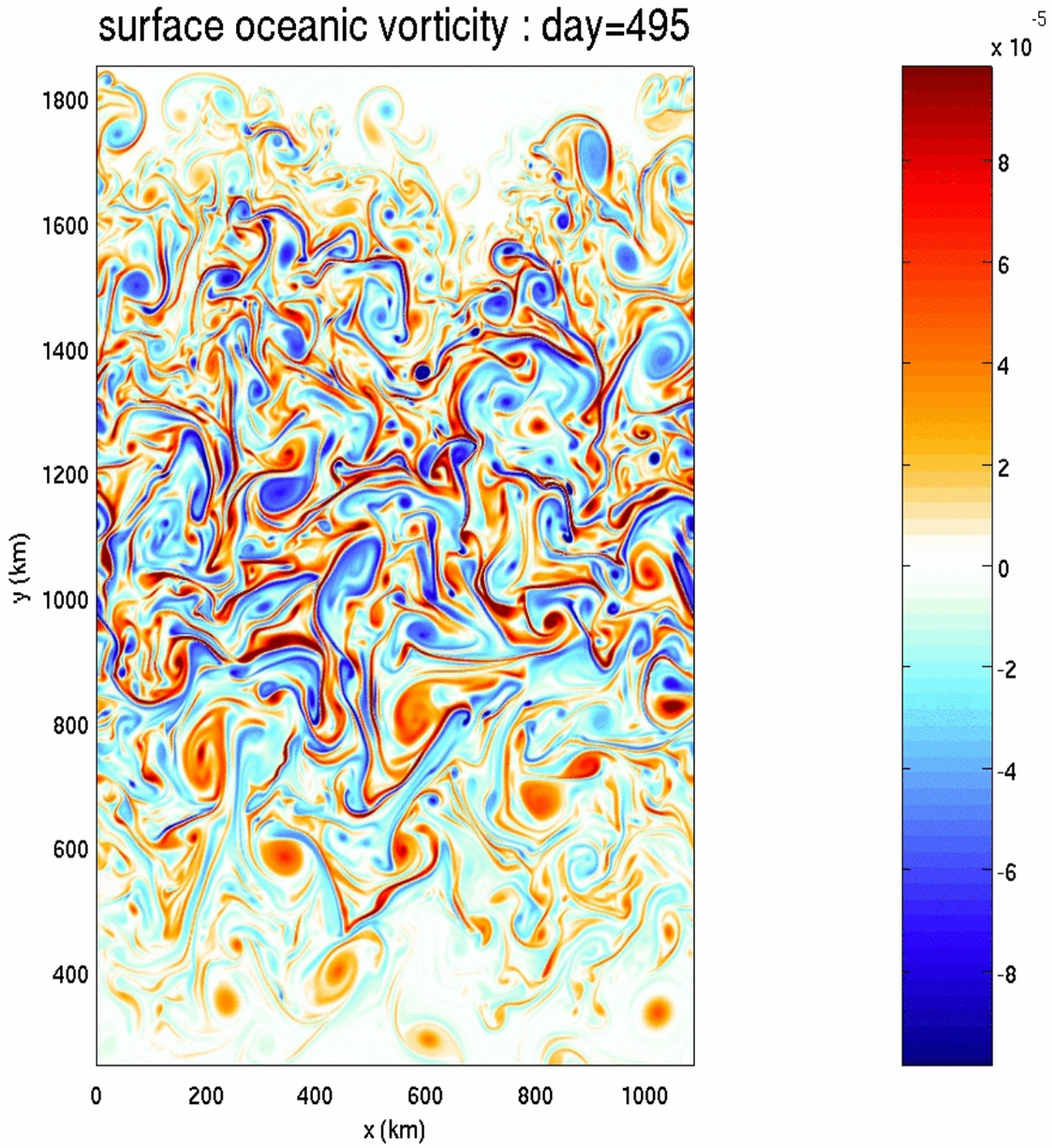
50% of the vertical velocity field

First simulations : mesoscale and submesoscale ocean turbulence using a space grid of 1km and 100 vertical levels in large domain (2000km*3000km*5000m)

- **Source of kinetic energy at small scales (10km) mostly result from frontal, ML and inertial instabilities.**

- **These small-scale structures subsequently merge leading to larger eddies (200km) and/or zonal jets.**

(d'Orgeville, Hua et al.'07, Klein, Hua et al. '08, Hua et al.'08, Menesguen, Hua et al.'09, Levy et al.'10, …)



Ocean Scale Interactions

Lien's important and original contributions:

@ « **3D impact** of the submesoscale turbulence on mesoscale eddies and larger scales»

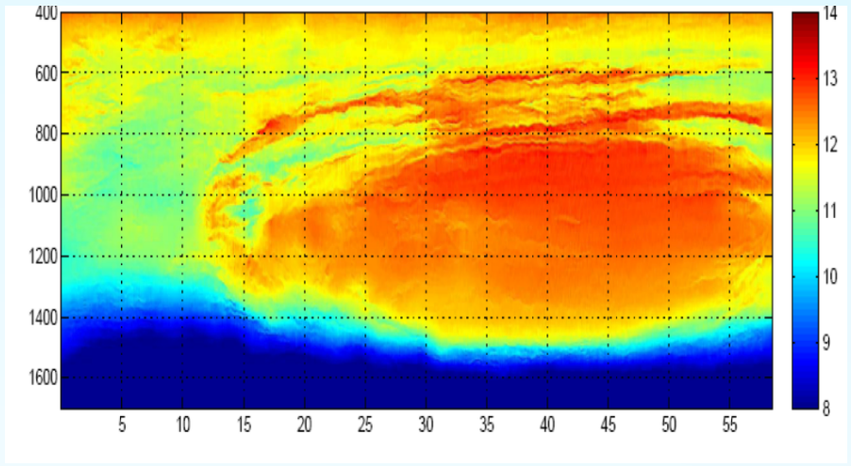
@ « Impact of small scales (**inertial instability**) on the **equatorial dynamics** »

(see Alain's and Eric's talks …)

All these results indicate that these scales (10km up to 10000km) have to be explicitly taken into account to represent the ocean circulation ! This was unexpected !

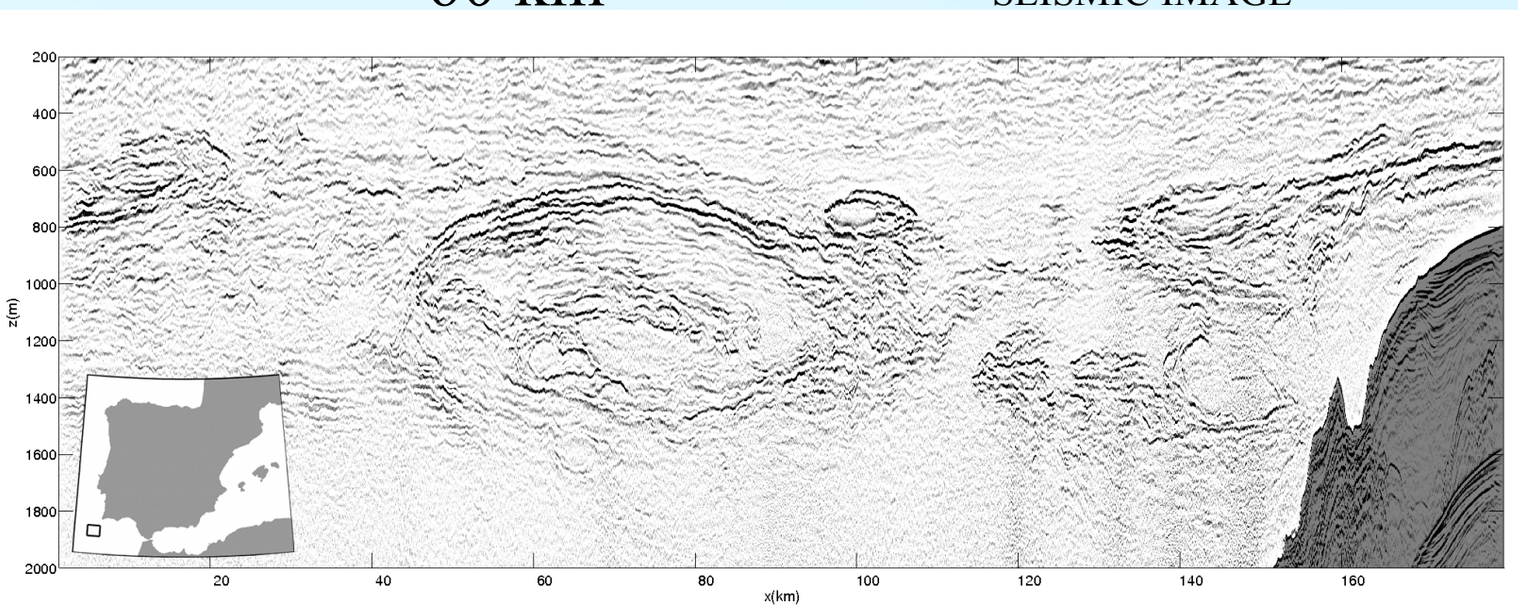
Ocean Scale Interactions

In recent years, Lien wanted to examine **a new range of scales (100m to 100km),** more precisely to understand the physical mechanisms explaining the features revealed by seismic images such as the layers surrounding mesoscale eddies. Are they the signature of dissipation mechanisms? She was the first scientist to intensively explore this new area and this is presently an ongoing work.



60 km

SEISMIC IMAGE



10m **100m** **100km** **10000km**

Ocean Scale Interactions Symposium

There is still a lot of work to do in this field and the future looks very promising with the next supercomputers and new observing systems (SWOT, …) …

In that context, the symposium will address these ocean scale interactions (from 100m up to 10000km), including some aspects related to the ocean-atmosphere interactions. This will be done through five sessions. Each session will focus on the state of art, the challenges ahead, the next scientific questions and the methods to address them.

One such method, that Lien advocated and that may inspire young scientists, is to analyse very high resolution data - obtained from in-situ, satellite observations and supercomputers – **using a dynamical framework based on Geophysical Fluid Dynamics ideas.**

Ocean Scale Interactions Symposium

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