The impact of ocean bottom morphology on the modelling of long gravity waves from tides and tsunami to climate

Christian Le Provost and **Florent Lyard**

Laboratoire d'Etudes en Géophysique et Océanographie Spatiale
LEGOS / UMR CNRS-CNES-IRD-UPS
Observatoire Midi-Pyrénées
Toulouse
Christian.Le-Provost @cnes.fr

Scope of this presentation

The impact of ocean bottom morphology on the dynamic modelling of the oceans, including climate and tsunami prediction

- Ocean basin morphology is a major controlling parameter of the ocean dynamics.
- We address here its impact on long gravity waves:

tides, storm surges and tsunamis.

- Why "climate" in the title?

related to the *tidally induced ocean vertical mixing* which could play in the maintenance and control of the global thermohaline circulation, *hence on the long-term impact of the ocean tides on the climate*

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Content

(1) Impact of ocean basin morphology on tides.

(2) Impact of ocean bathymetry on storm surges.

(3) Bathymetry and tsunamis.

(4) Bathymetry, gravity waves and climate

(1) Impact on TIDES

The deterministic character of the tides allows one to easily illustrate how modelling of long gravity wave in the ocean is dependant upon

- the shape and depth of the ocean basins:

1.1- *Ocean tides are near resonance*: $\lambda = \sqrt{gH}\,T$

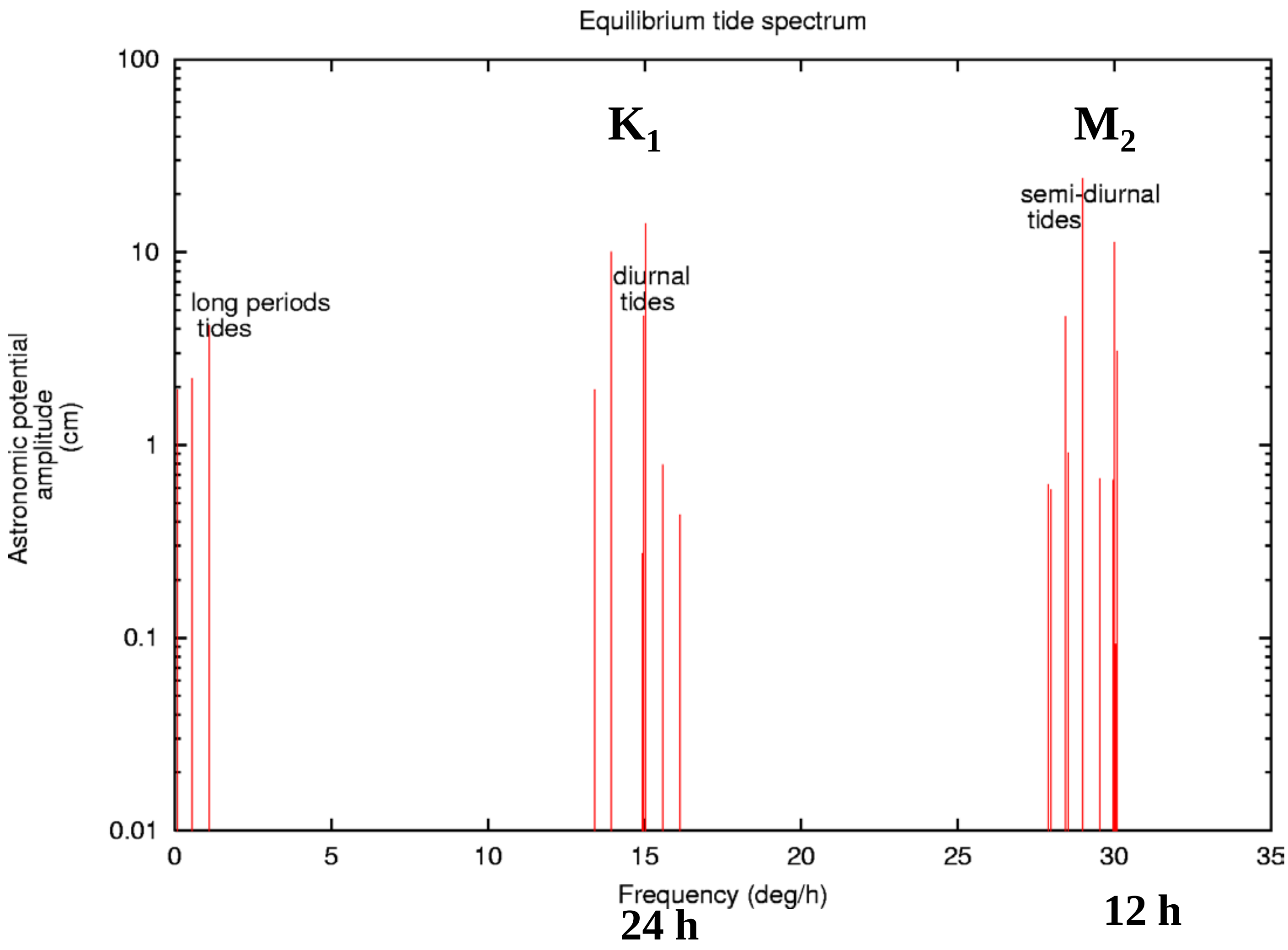
1.2- *Ocean tides are partly dissipated in shallow waters*

- the slope of seamounts,
mid ocean ridges
and continental shelf breaks.

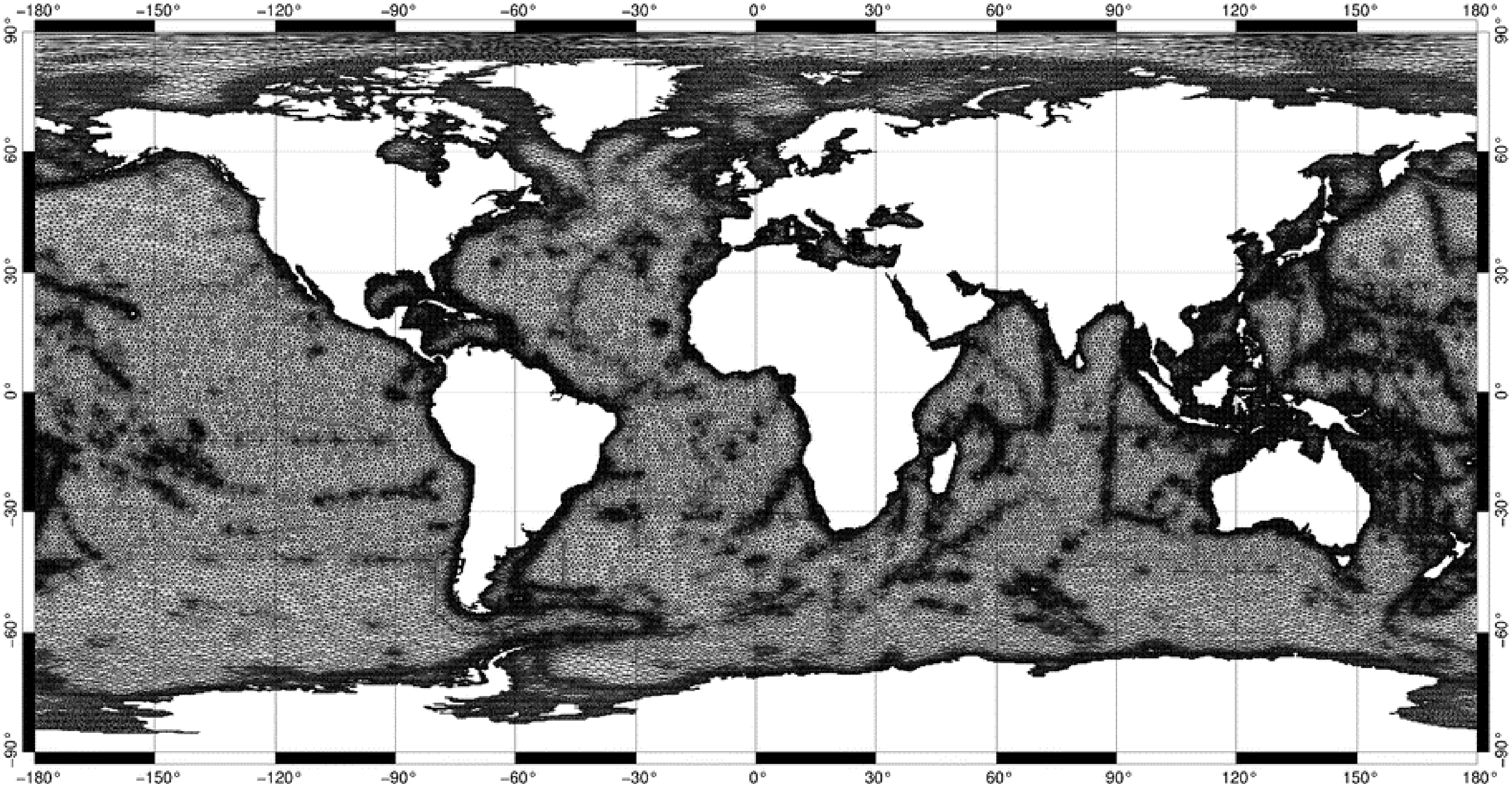
1.3- *Topographic trapped waves*

1.4- *Internal tides*

The tidal spectrum



FES2002 Finite Element Grid



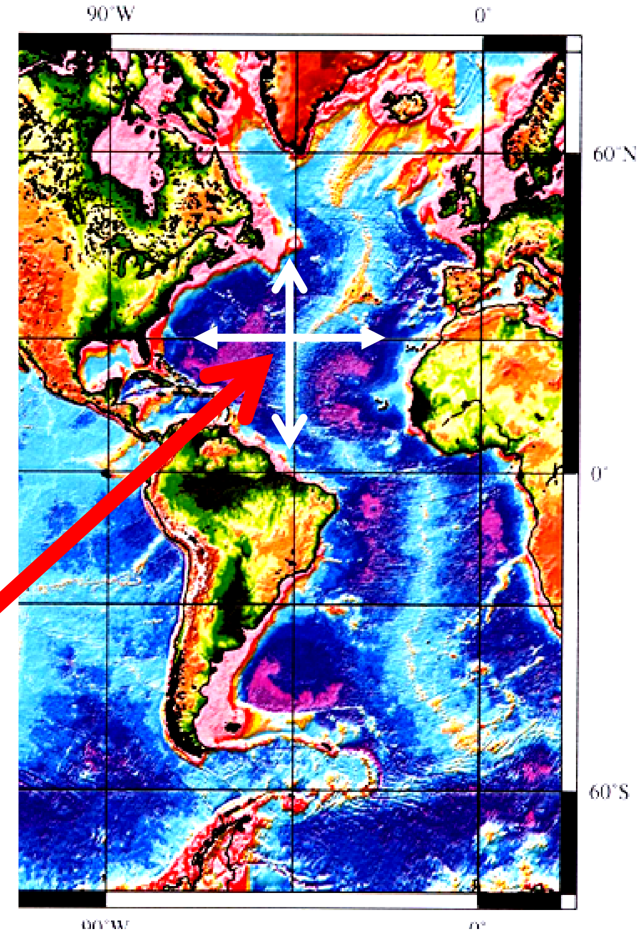
Only input: **ocean bathymetry**
astronomical forcing

tuned parameters: **bottom friction**
internal wave transfert

Horizontal resolution: **between 50 km and 7 km**

Impact of the shape and depth of the ocean basins

1.1 Ocean tides are near resonance

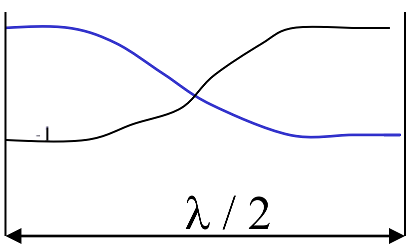


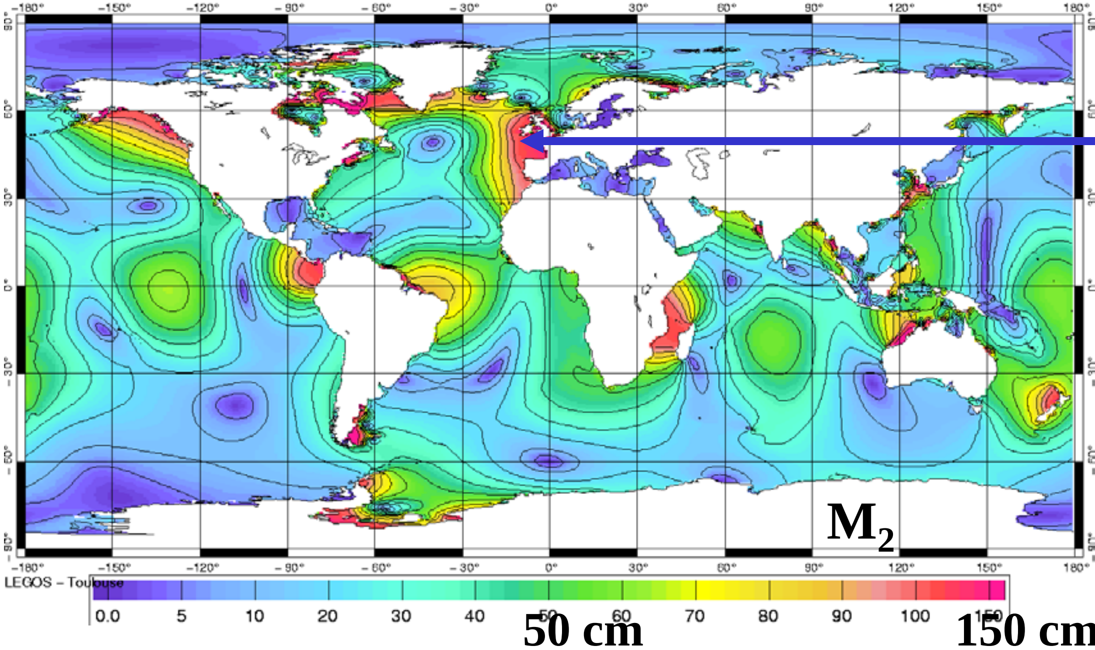
The North Atlantic Basin corresponds to a resonant half wavelength system for the semidiurnal tides

$\lambda = T\sqrt{gH}$

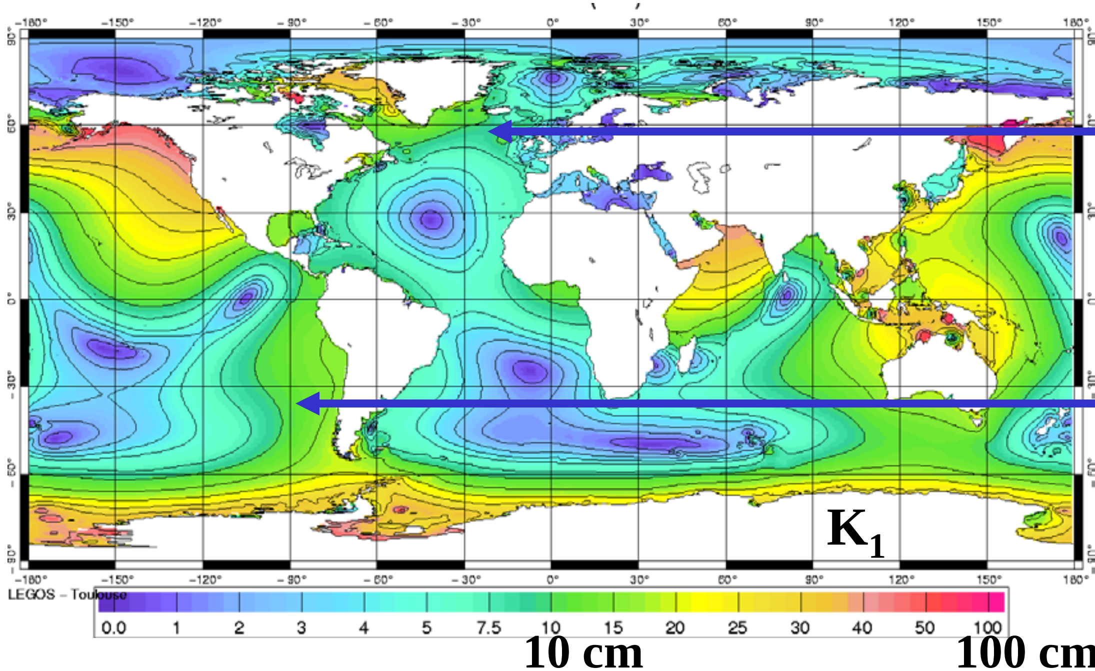
H = 4000 m ➔ $\lambda / 2 = 4500$ km

T_{M2} = 12 h 25 min



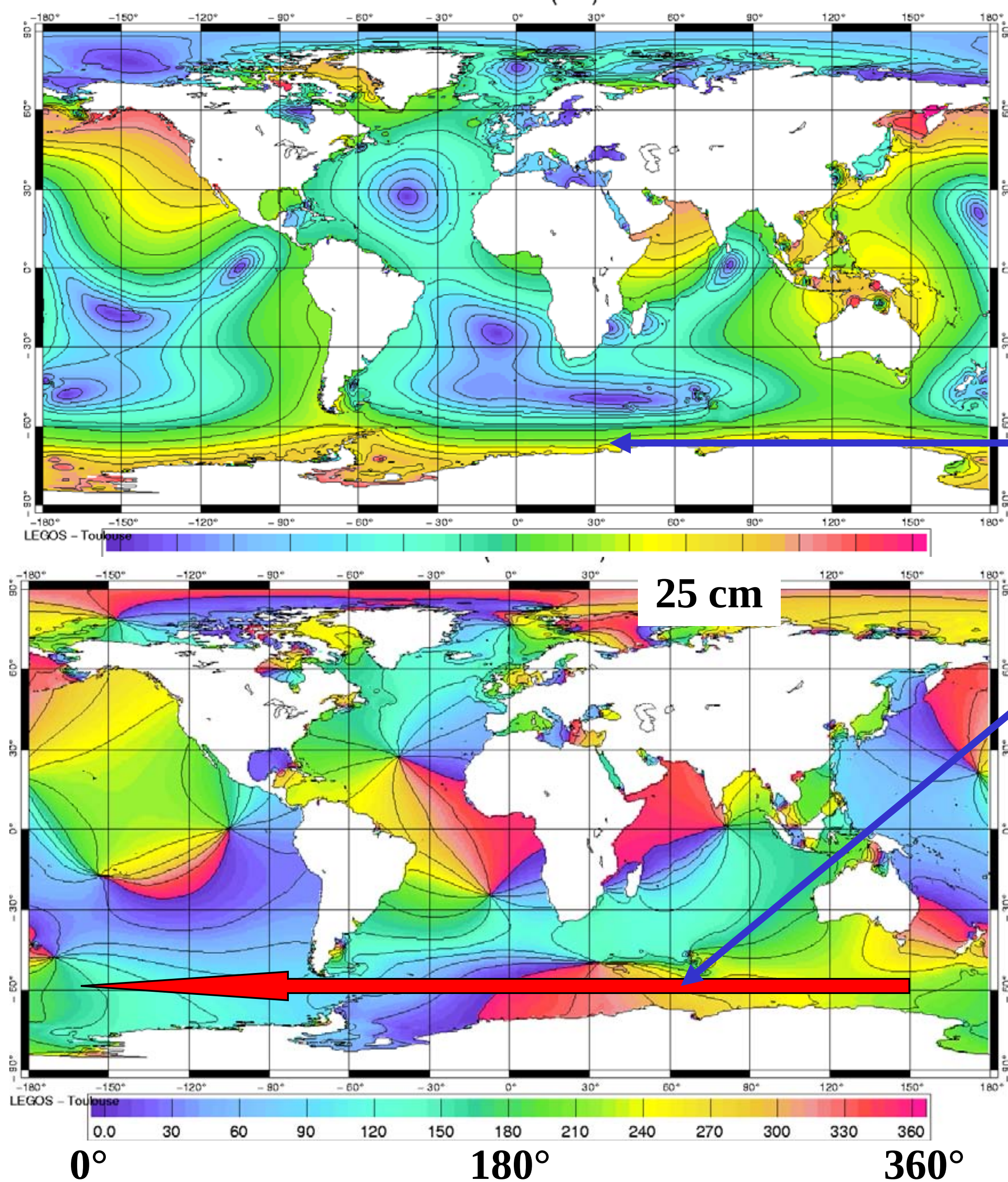


In the North Atlantic, the semi-diurnal M_2 tidal amplitude is of the order of 1 metre



In the same basin, the diurnal K_1 tide does not exceed a 10 th of cm although the astronomical forcing intensity might allow much more.

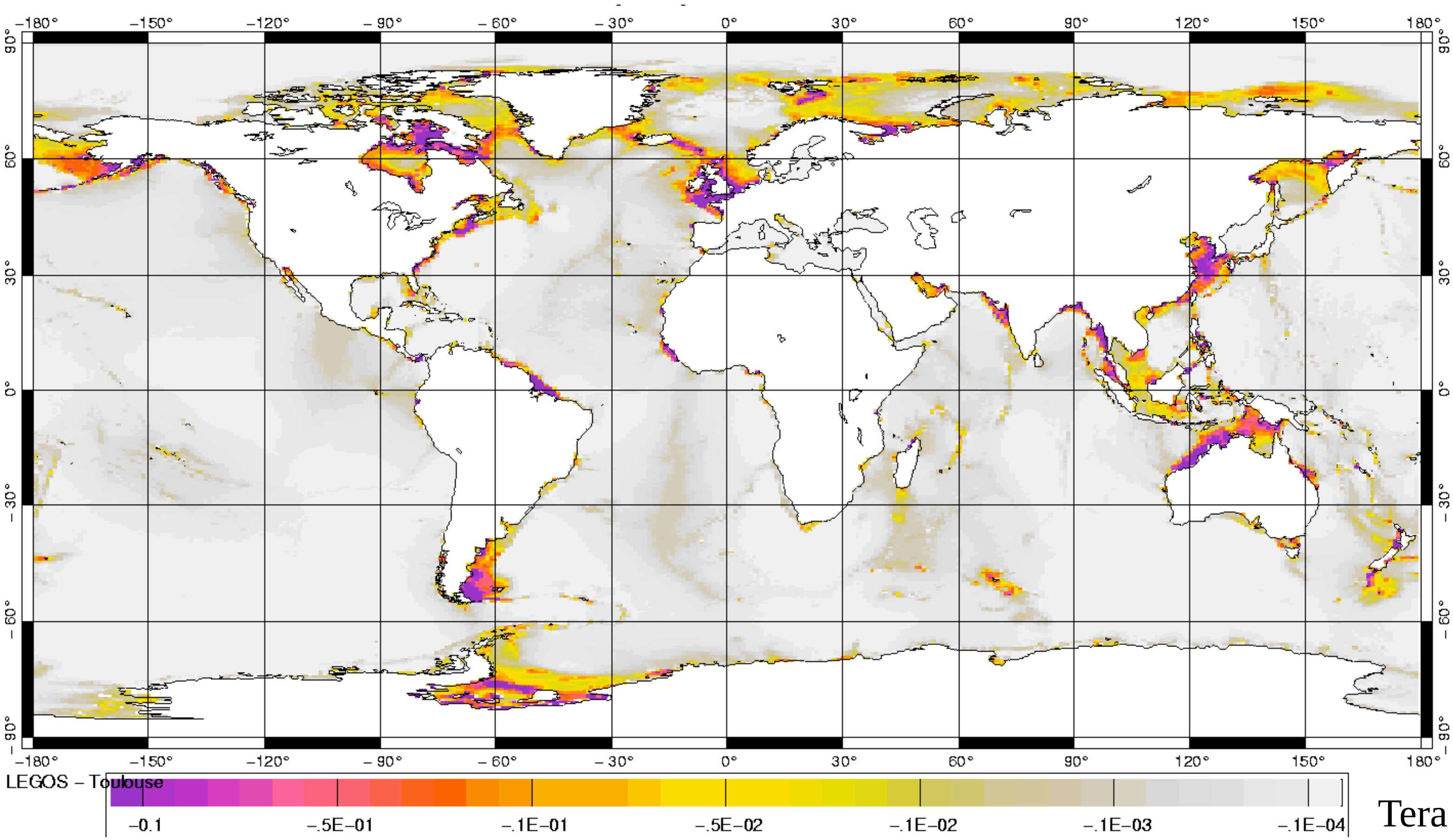
By contrast, this wave find enough space in the Pacific ocean to develop



Diurnal K_1

Moreover, the diurnal constituents are characterized by a circumpolar topographically trapped KELVIN wave

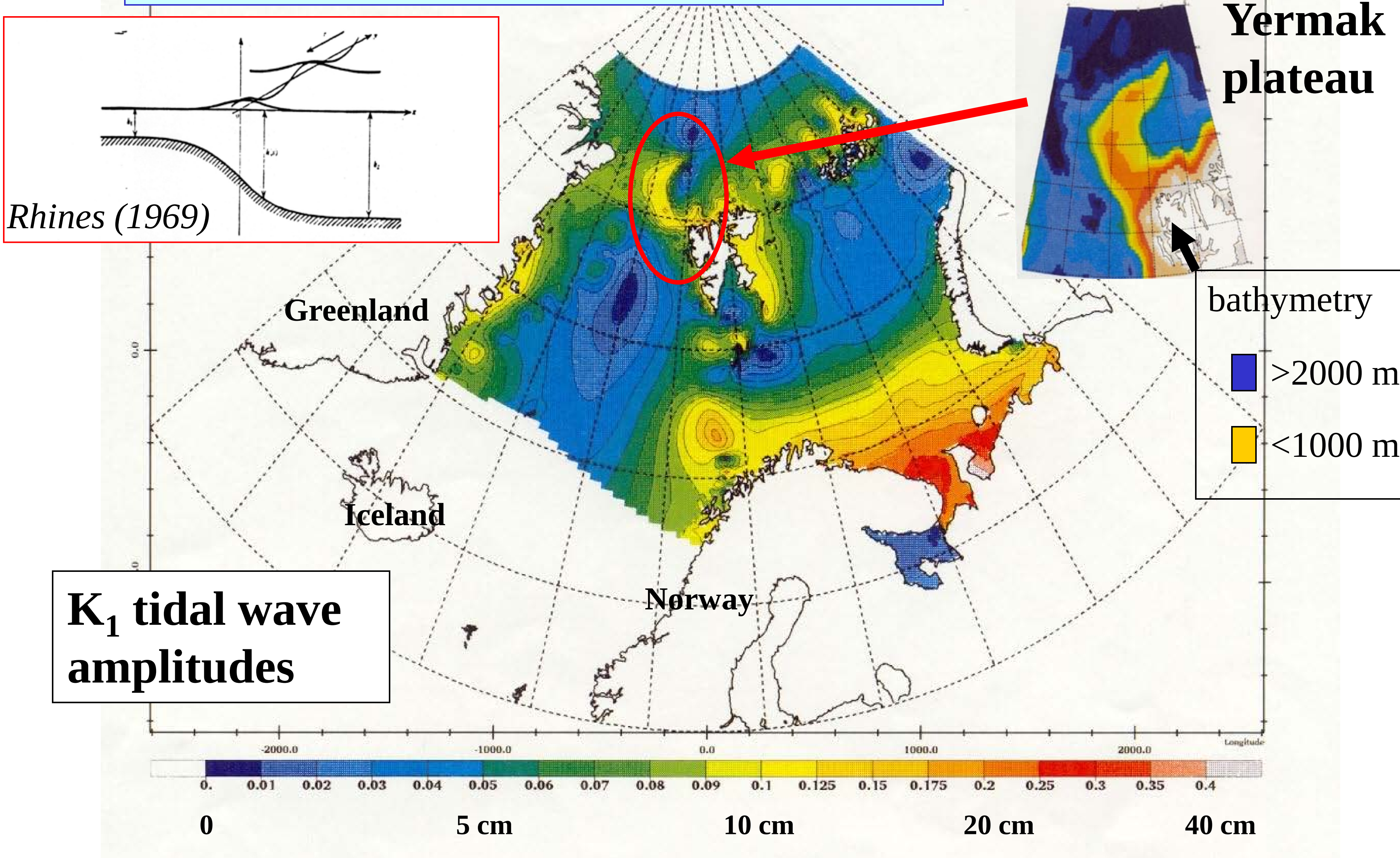
1.2 Impact on tidal dissipation through bottom friction



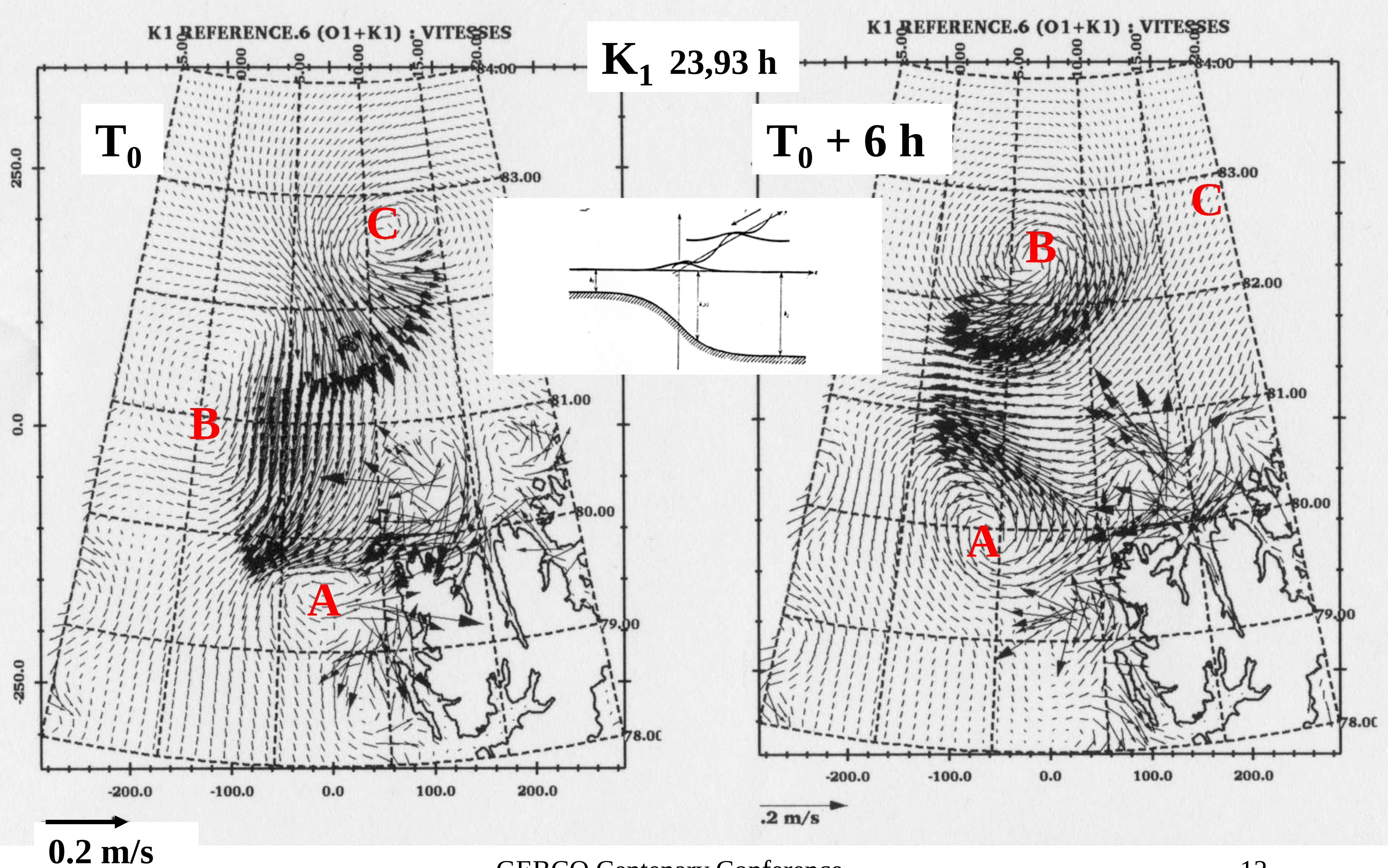
Tera Watts

For the M2 tide, 2/3 of the energy (1.5 TW) is dissipated by bottom friction, mainly over continental shelves

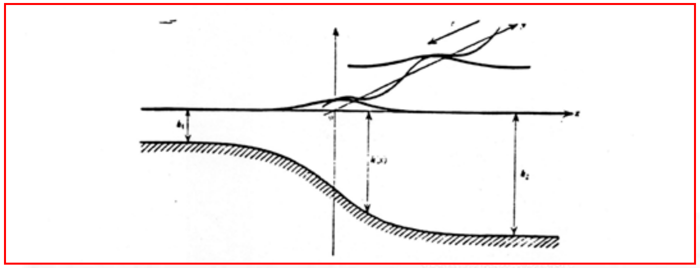
1.3 Topographic trapped waves

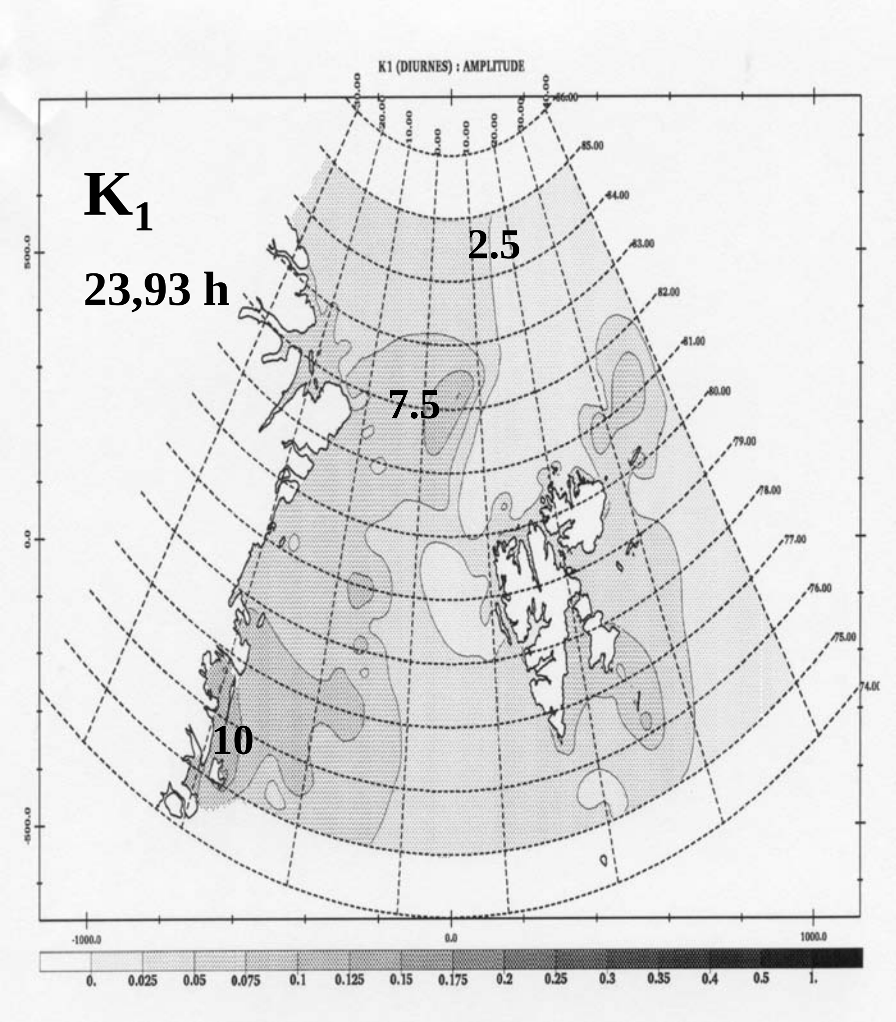


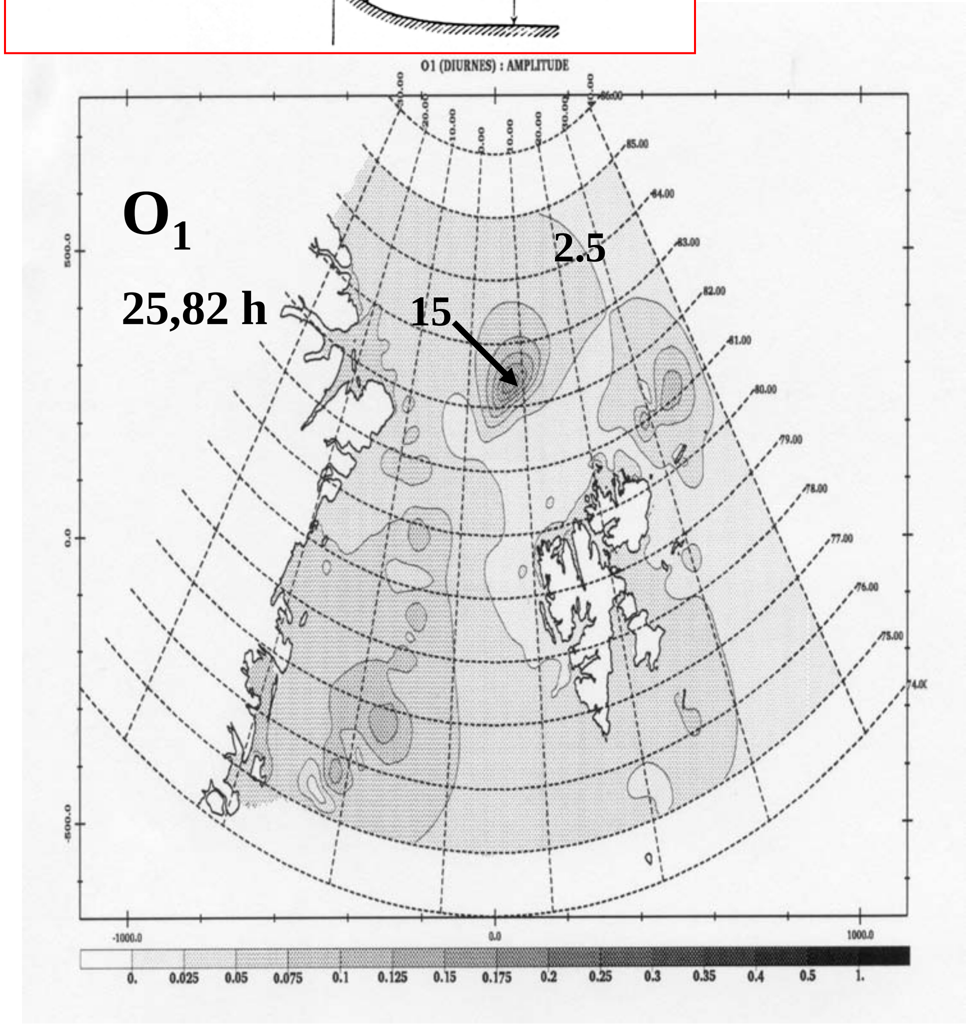
Topographic trapped waves ==> Strong currents



Impact of the slope of the topography

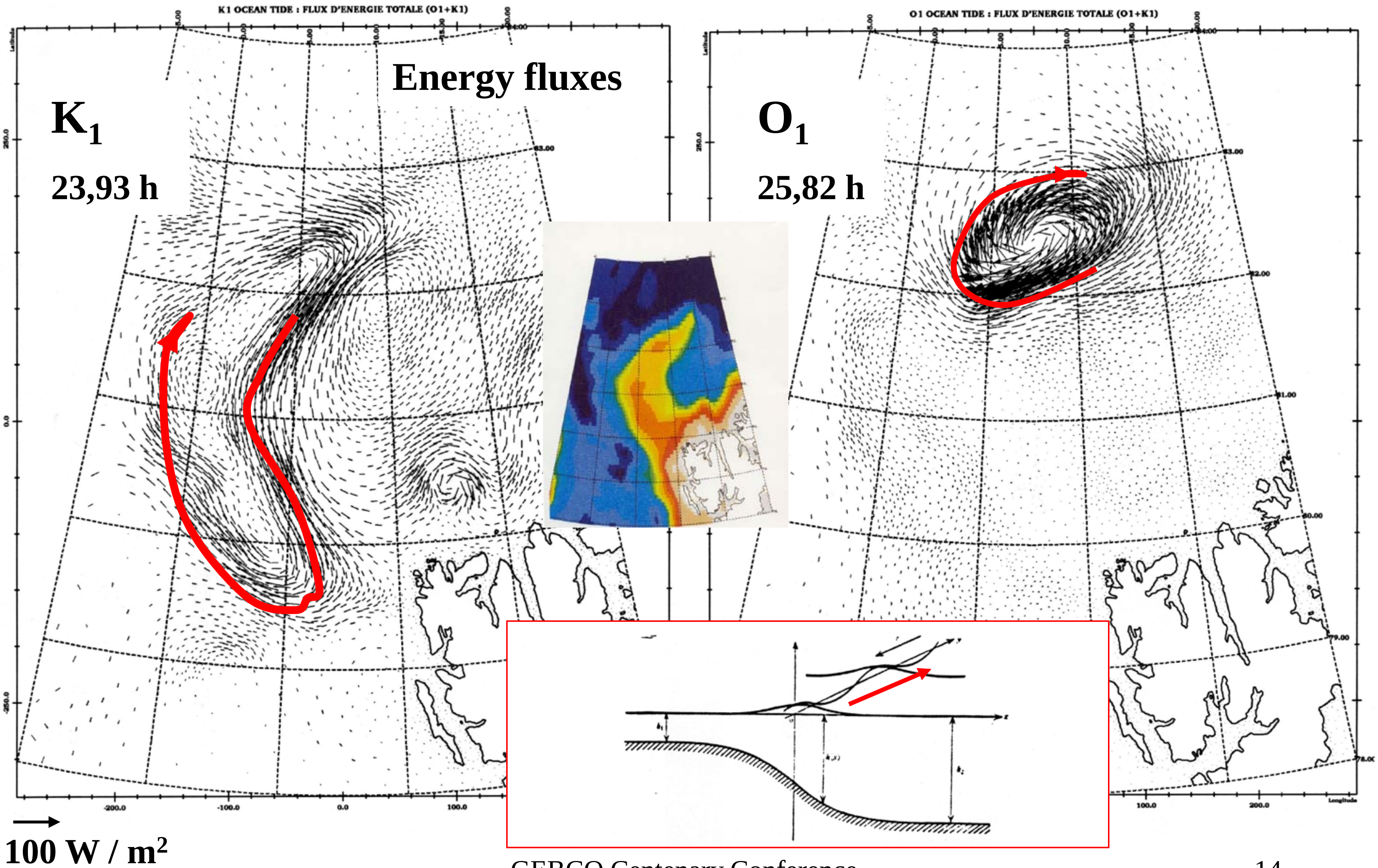






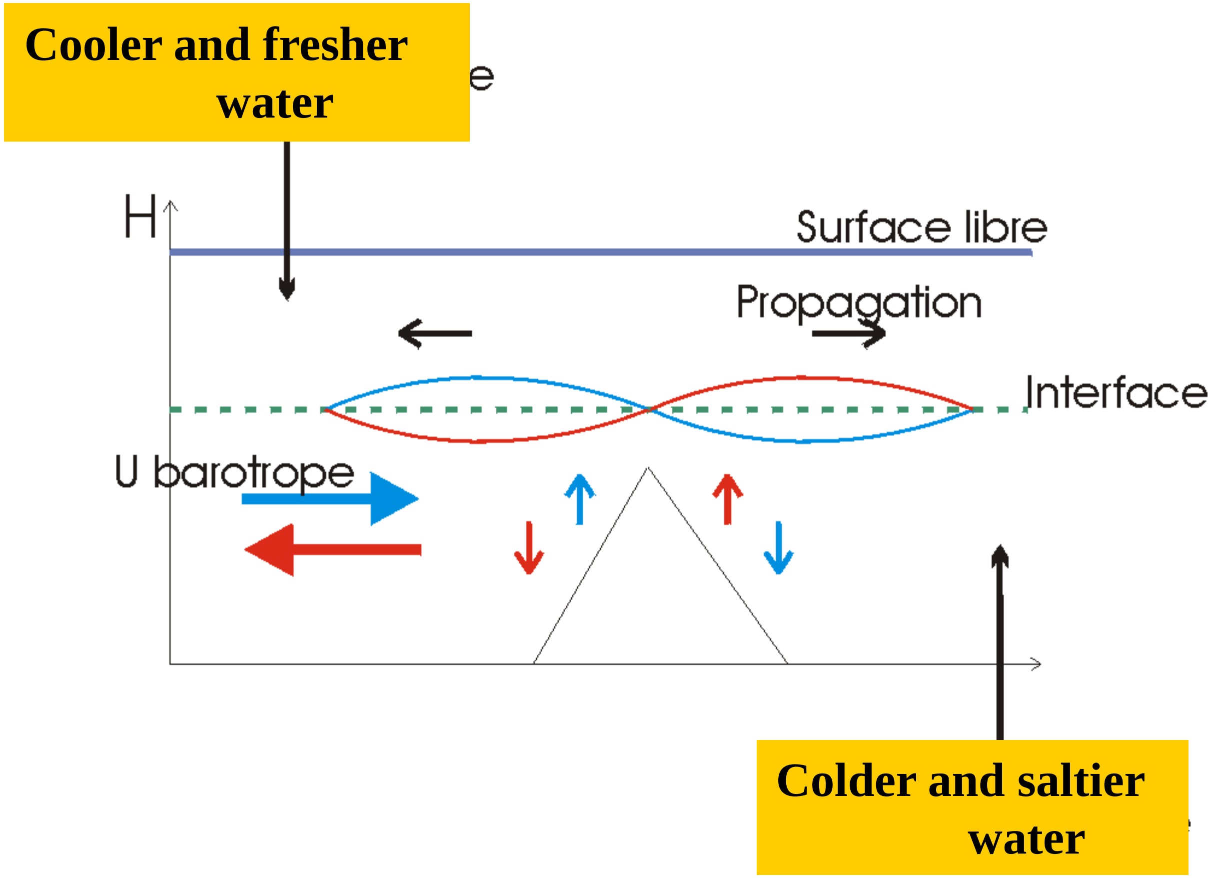
Amplitudes (cm)

Impact of the slope of the topography

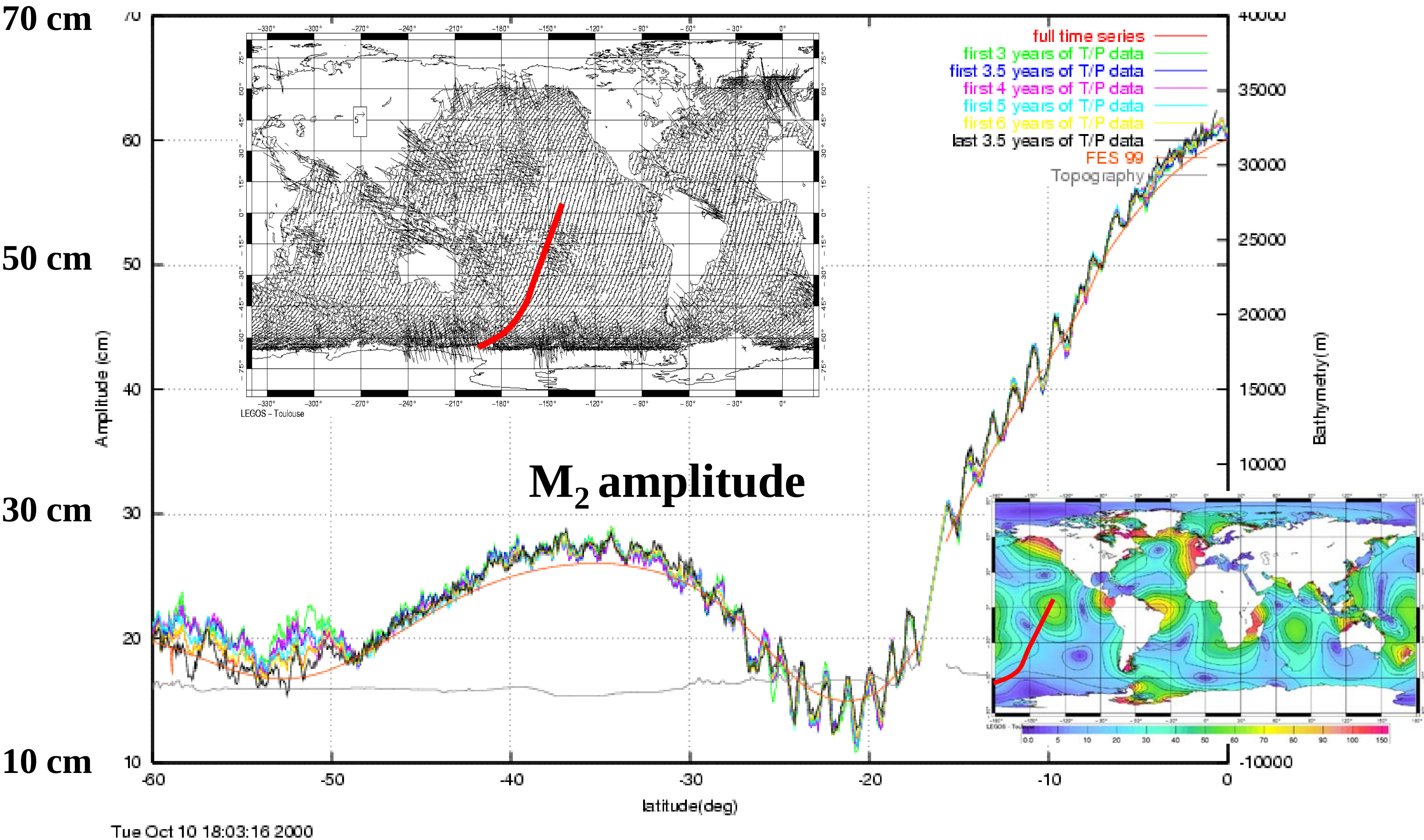


1.4 The internal tides

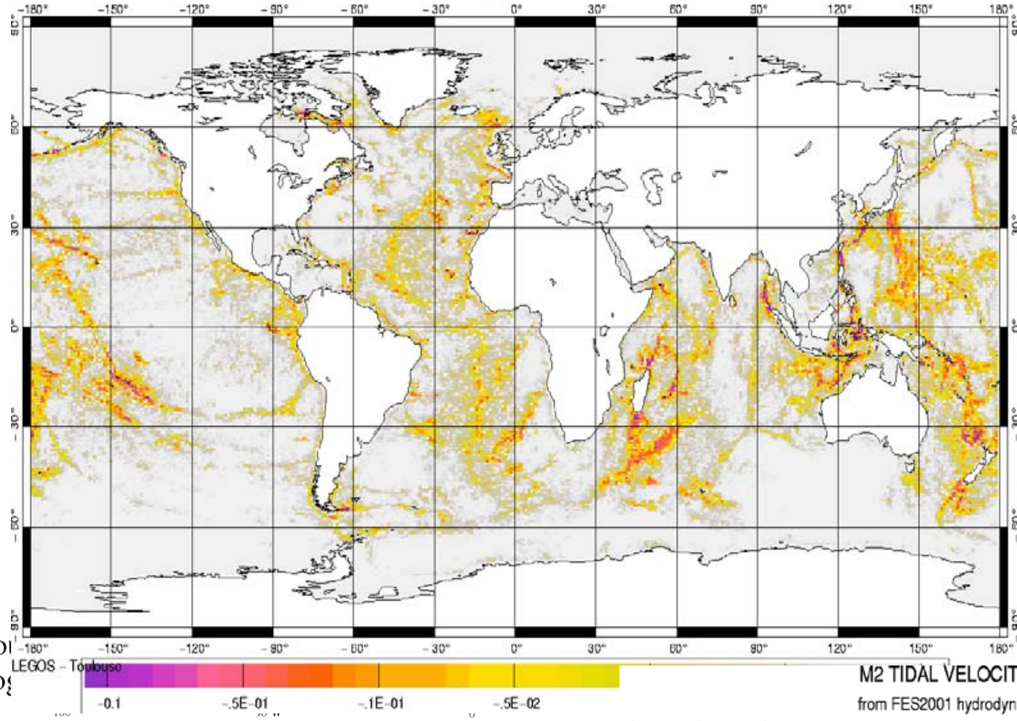
They are excited by the interaction
of the barotropic tidal currents with the bottom topography



Internal tidal waves are observed by satellite altimetry



M_2 tidal energy transfer to internal tides

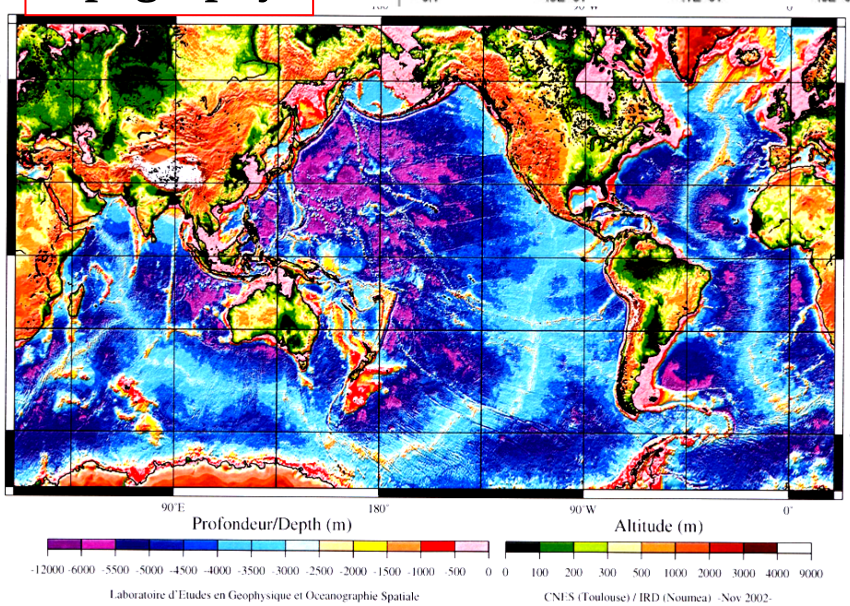


Internal wave drag:

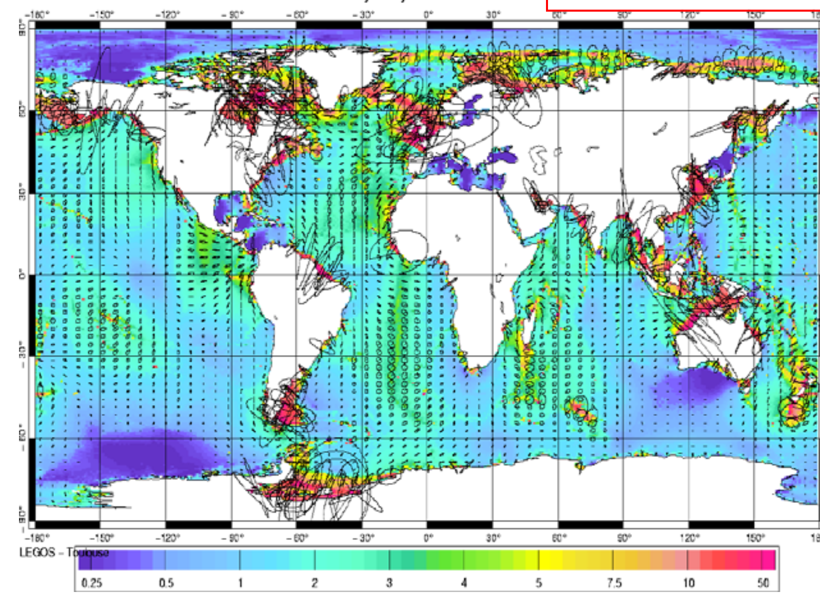
$$F_{wd} = - C_D \rho_0 K_{-1} N \left(\overrightarrow{\mathrm{grad}}\, H \,.\, \vec{U} \right) \overrightarrow{\mathrm{grad}}\, H$$

For the M_2 tide, 1/3 of the energy is dissipated through internal tides

Bottom topography



Barotropic tidal velocities (cm/s)



2 cm/s **5 cm/s** **10 cm/s**

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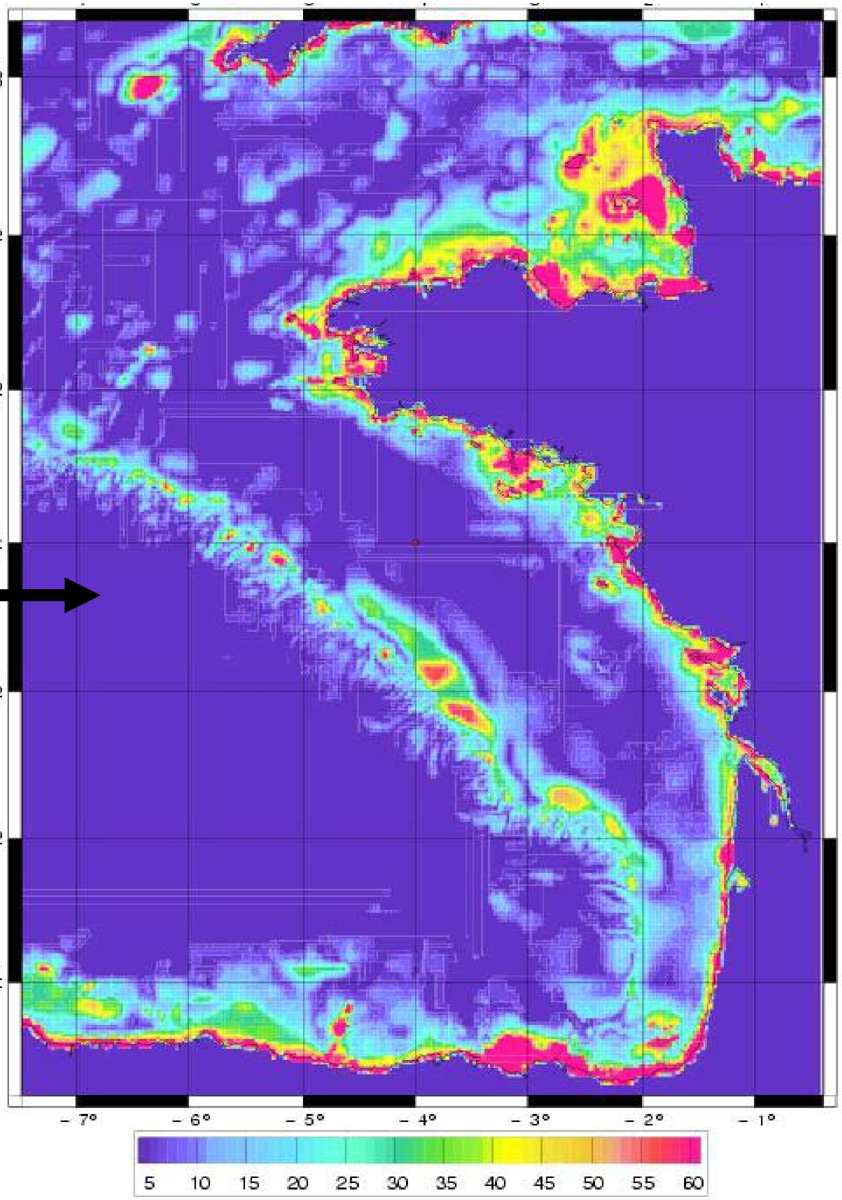
Impact of bathymetric errors on gravity wave propagation

Example:

Rms dispersion of gravity wave speed ($\sqrt{gH}$) estimates corresponding to 6 bathymetries SHOM, ETOPO2, Smith and Sandwell, Terrain base



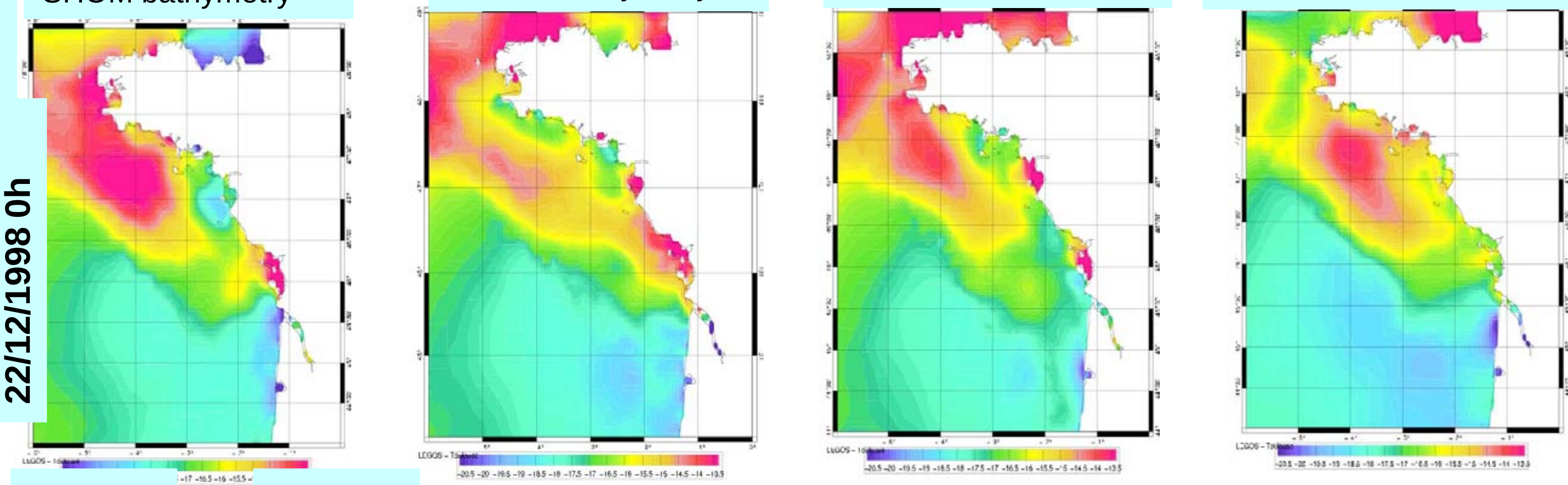
5 30 60 (%)

Impact on storm surge models

MOG2D

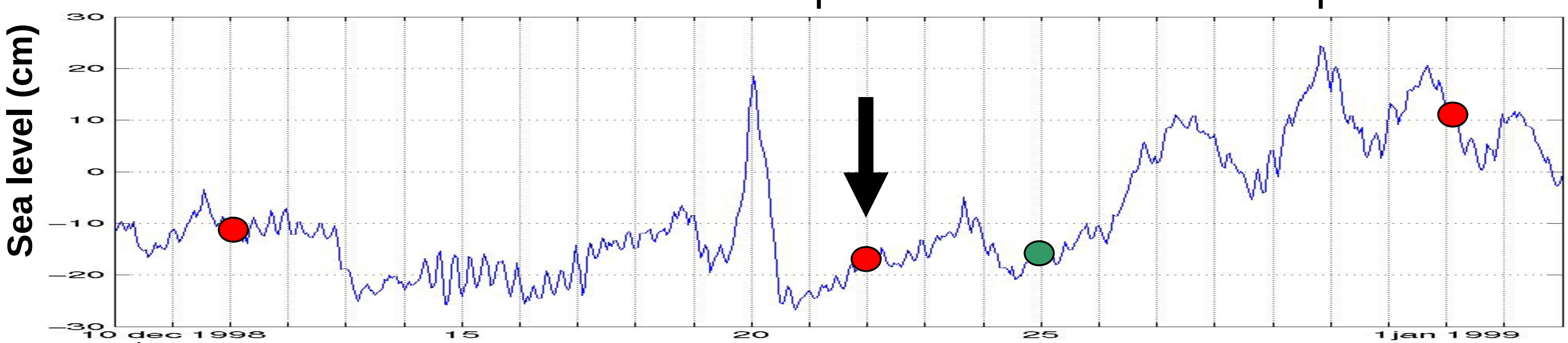
Sea level
22/12/1998 0h

SHOM bathymetry | ETOPO bathymetry | SMITH&SANDWELL | TERRAIN BASE bathymetry



-21 cm   -13 cm

Detided sea level time series at a point located on the European shelf



30 cm
0
-30 cm

10 dec 1998   15   20   25   1 jan 1999

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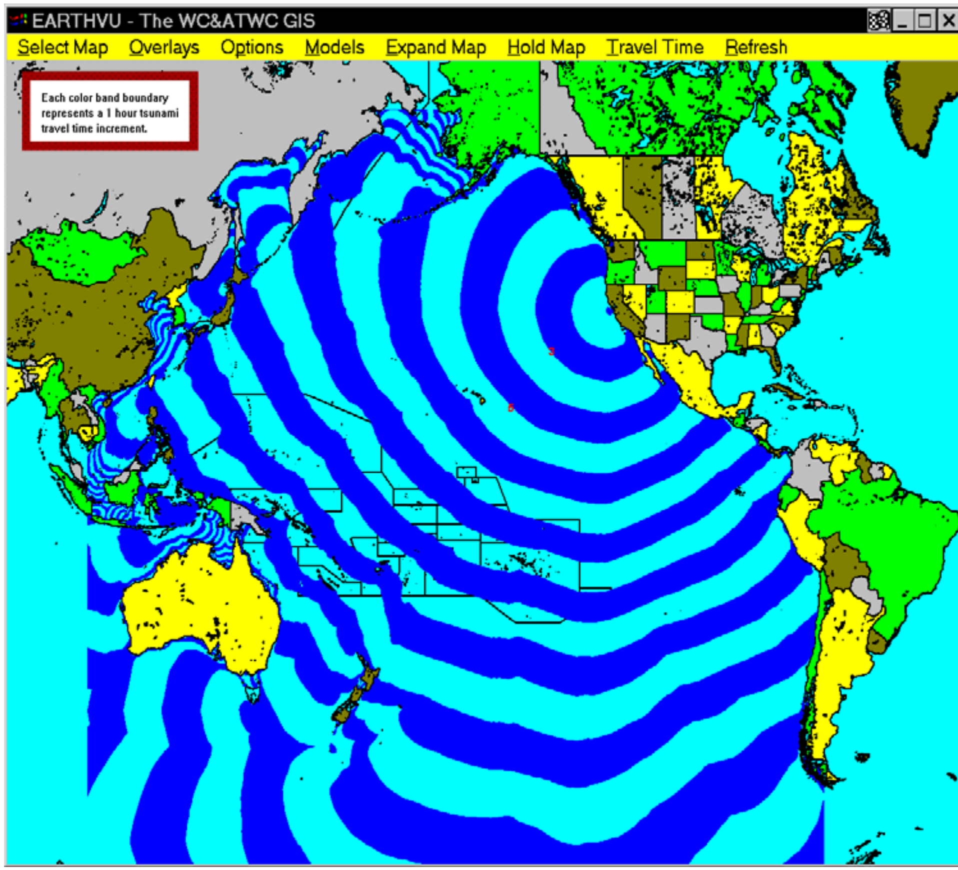
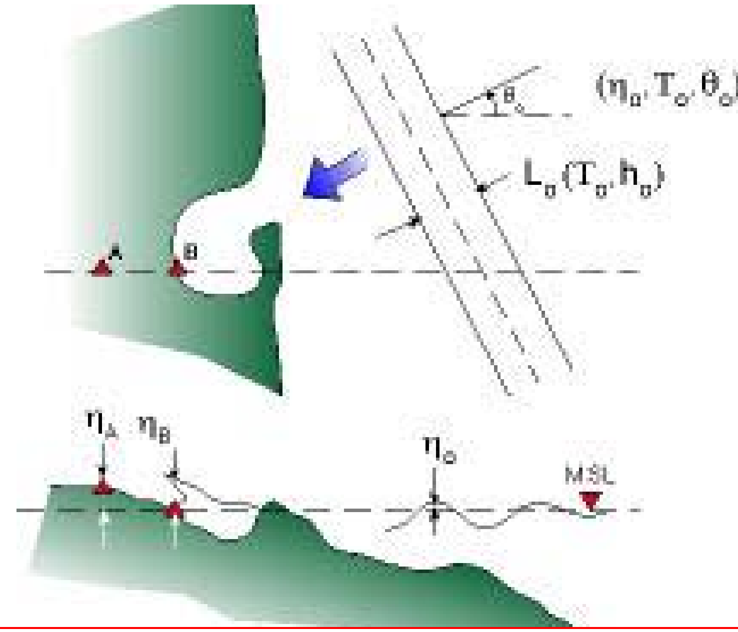
3. Bathymetry and Tsunamis





Typical
- speed 700 to 900 km/h
- period 10 min to 2 hours
- wavelength 100 to 1000 km
- amplitude up to 30 m
- inland extent up to 300 m or more

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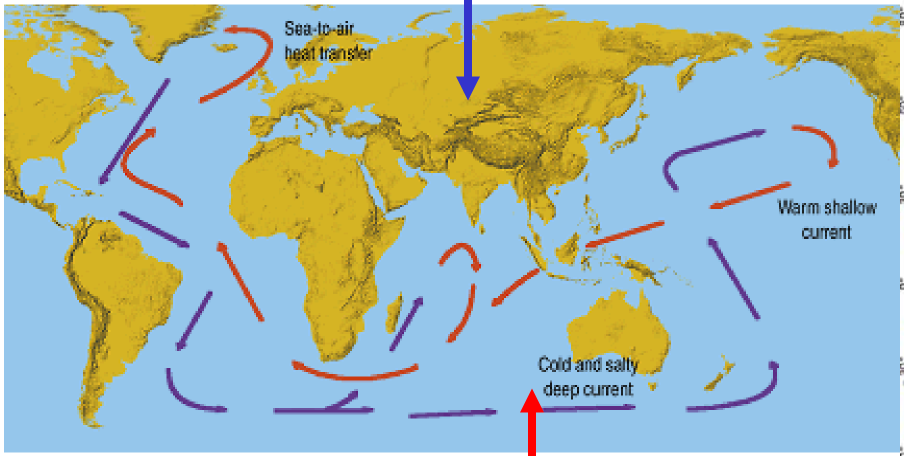
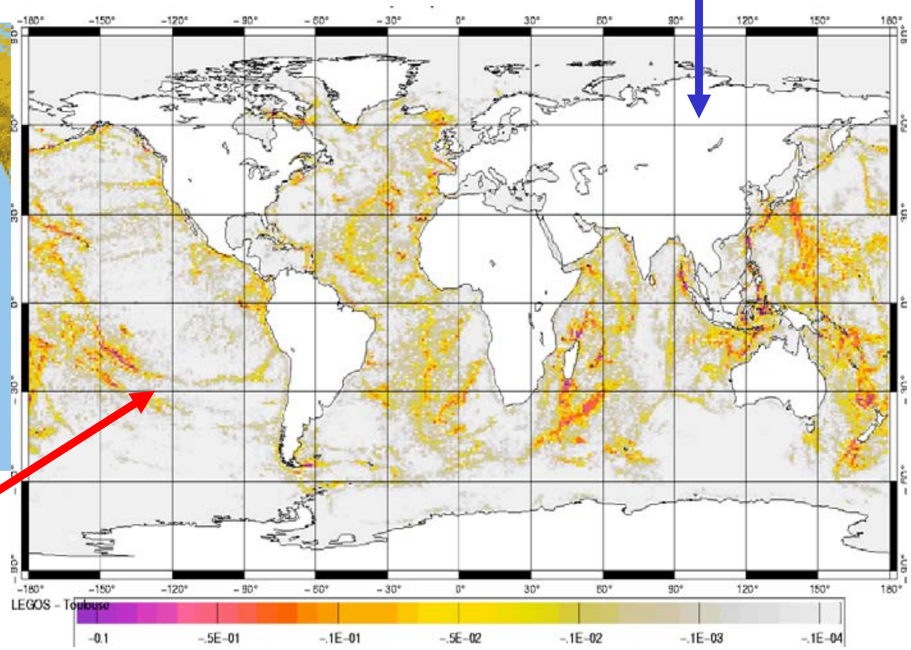
4 - Bathymetry, gravity waves and climate

tidally induced ocean vertical mixing

➔ maintenance and control of the global thermohaline circulation

hence on the long-term impact of the ocean tides on the climate





Time scales !!! **1000 years** **12h**

Munk 1966
Egbert and Ray (2000)
Lyard and Le Provost (2002)
Munk and Wunsch (1998)

GOT99:	0.73 TW
TPXO:	0.83 TW
FES2002:	0.82 TW

CONCLUSIONS

•Ocean depth control the propagation speed of gravity waves and their wave length
➔uncertainties on the bathymetry is a major problem for tide, storm surge and tsunami modelling, **specially over continental shelves**

•Shallow water bathymetry is a key parameter controlling dissipation

Impact on the earth rotation

• Shallow water topography, coastal shoreline and near shore inland topography are crucial for tsunami modelling

• Bottom topography but even more bottom slopes are a key for :

- energy trapping which occurs over sea mounts, mid ocean ridges, shelf breaks
  ➔ strong local currents on short scales, difficult to observe

- generation of internal waves
  ➔clear impact on tidal dissipation energy balance
  ➔but also on deep ocean mixing and thermohaline circulation,
  ➔ and possibly on the climate of our planet.