

# EXPLORING THE DARK

NIOZ - Royal Netherlands Institute for Sea Research

Prof. Leo R.M. Maas  
Professor of Ocean Wave Dynamics  
presents

## **INTERNAL WAVES AFFECT INTO THE DEEP OCEAN**

in cooperation with

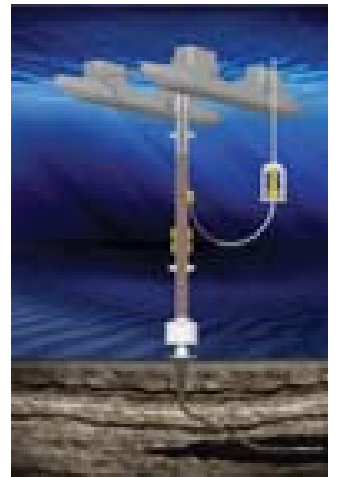
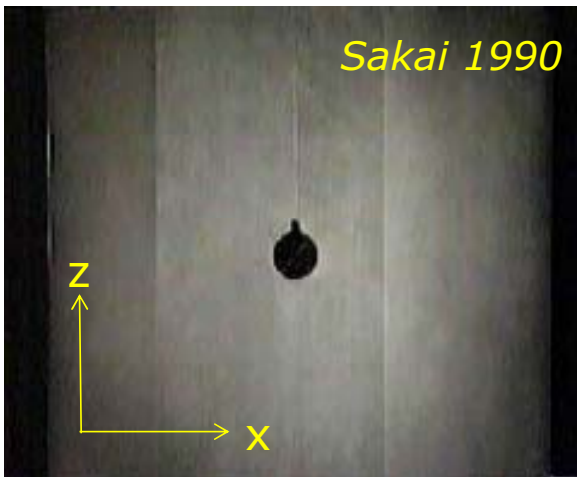
NIOZ – Netherlands Institute for Sea Research  
& IMAU - Utrecht University

14 March 2013



## The deep sea is *continuously stratified*

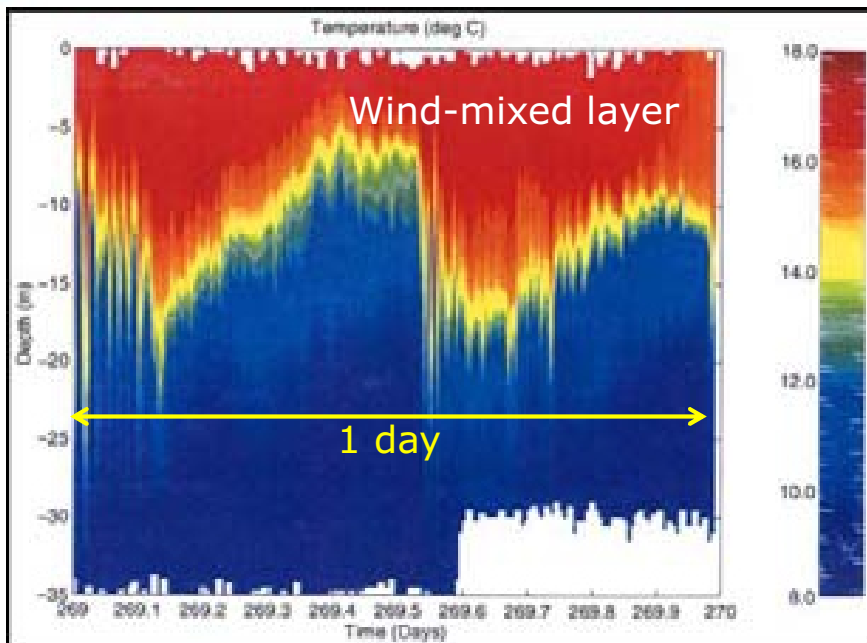
- Internal waves



- Oblique wave propagation (angle  $q$  set by frequency)
- Sheared currents**: affect corals, dispersion, risers

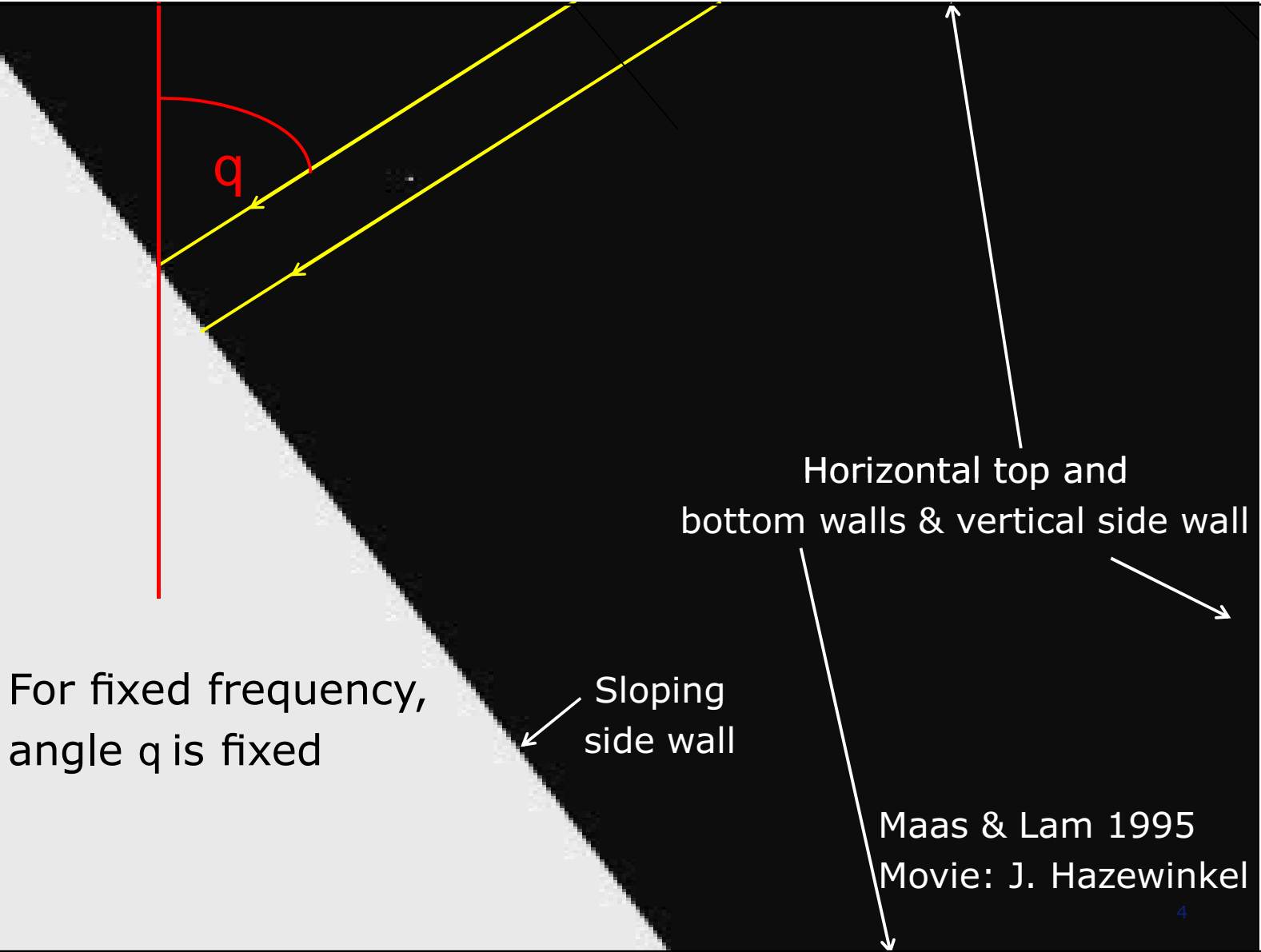


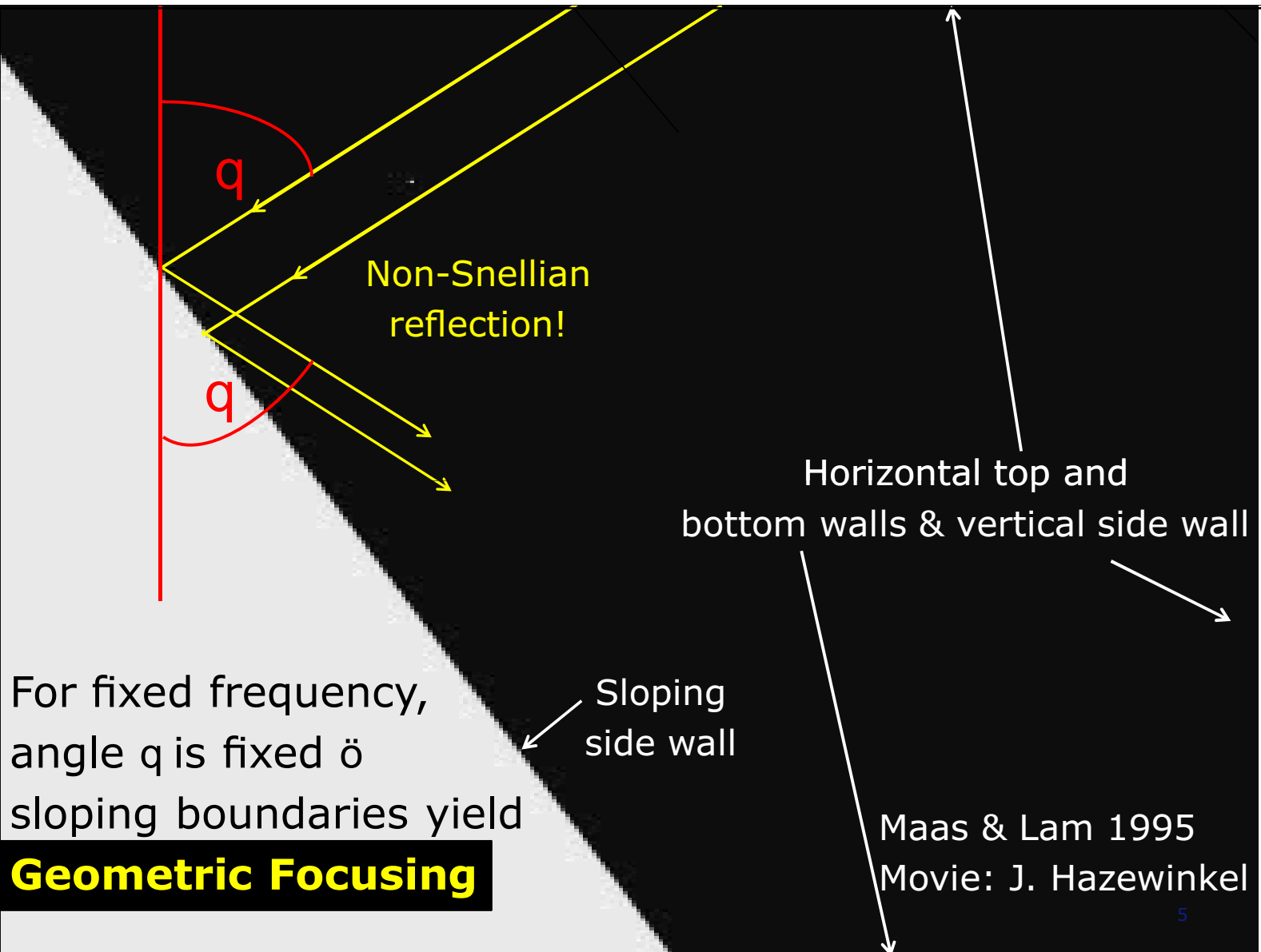
## Two-layer stratification near ocean surface



Supports *interfacial waves*

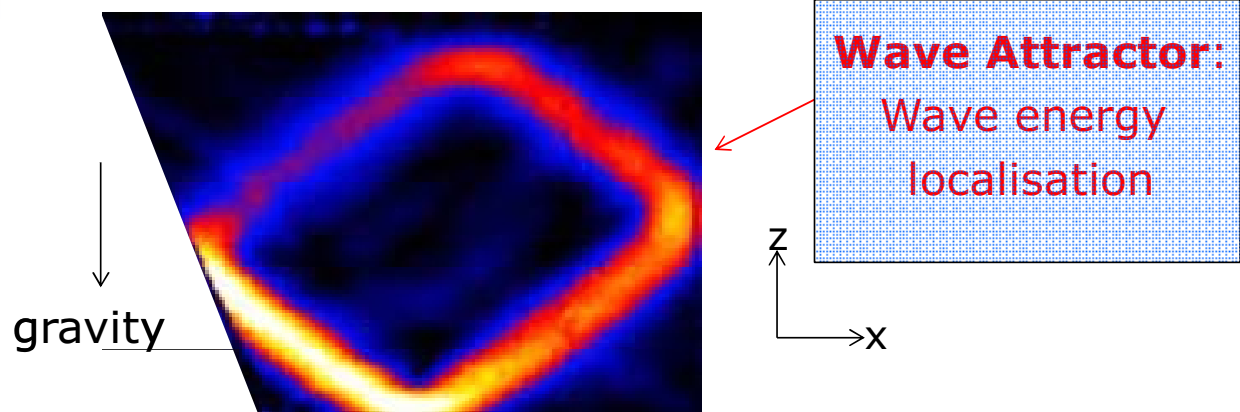
NOAA







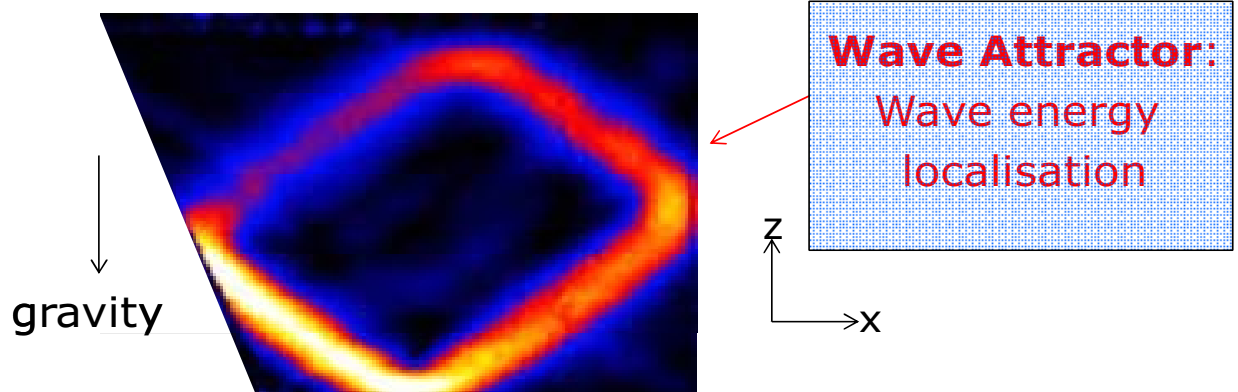
# Internal wave localisation: optical visualisation



Laboratory experiment in uniformly-stratified fluid



# Internal wave localisation: optical visualisation



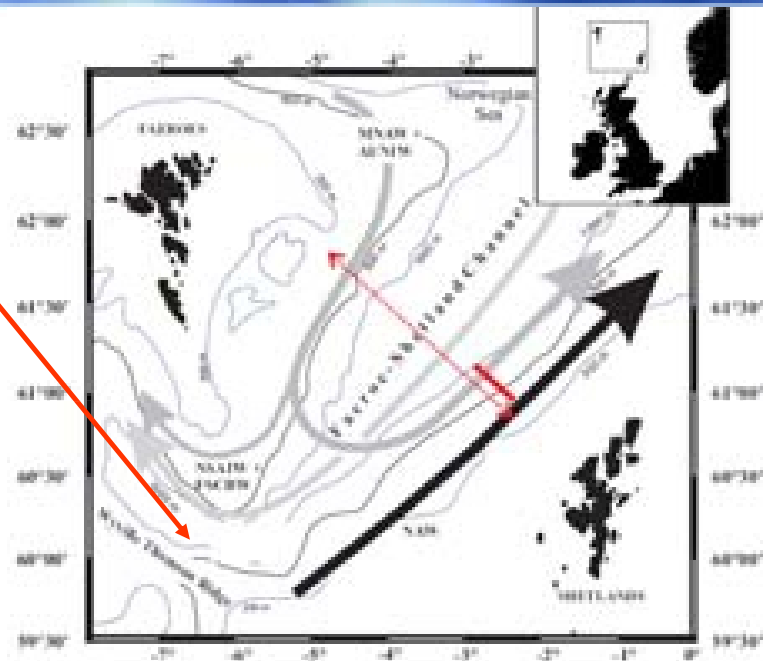
Laboratory experiment in uniformly-stratified fluid

But, in deep sea, no comparable spatial  
observational resolution



## Ad hoc information: Rocky motion in Faroe Shetland Channel

Sherwin (1991): Submarine, working at 400m depth, frequently subject to "underwater storm"





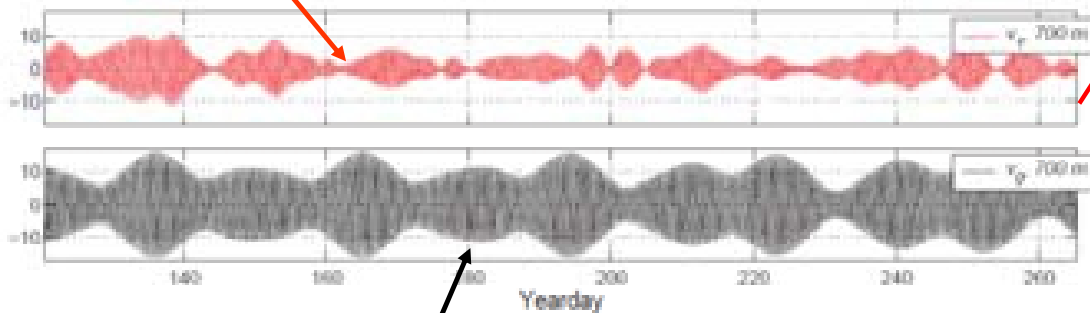
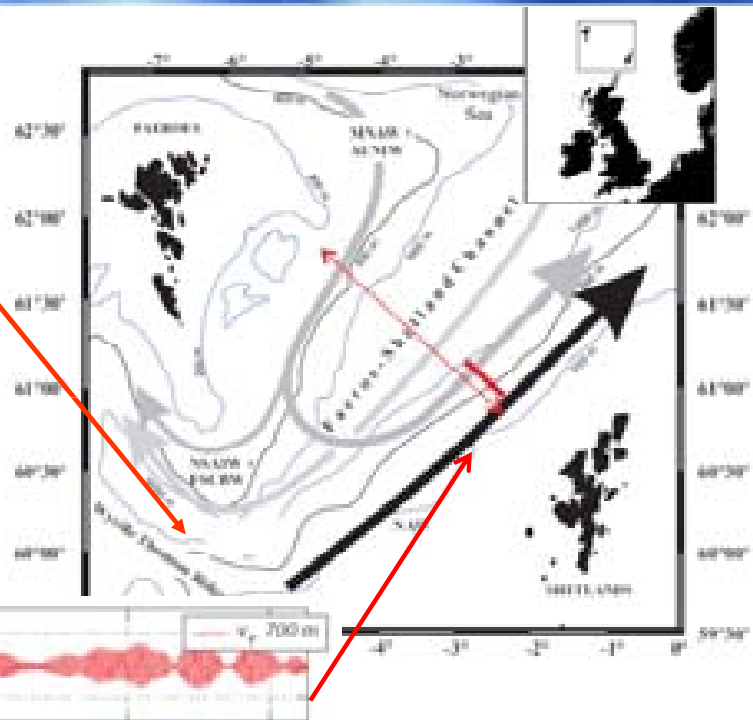


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## Intermittency

Internal tide (vertically varying part of current)



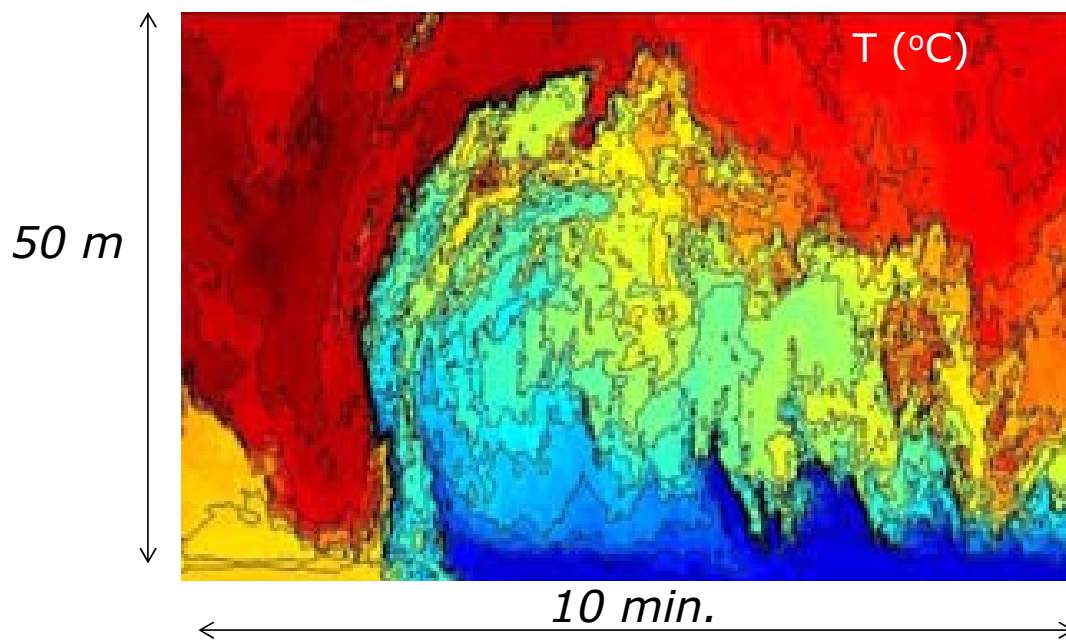
*Hosegood and van Haren 2006*

Surface tide (vertically uniform currents)



## Internal wave breaking

Breaking internal wave observed using 100 very accurate & fast temperature sensors at several 100 m depth

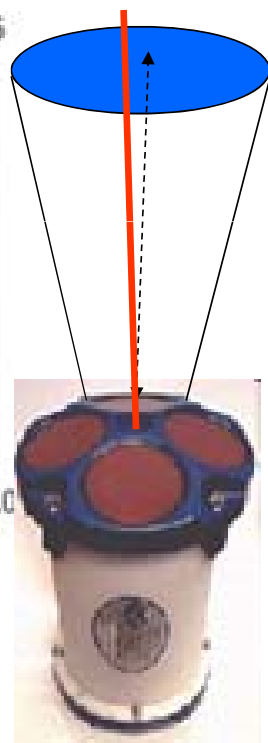
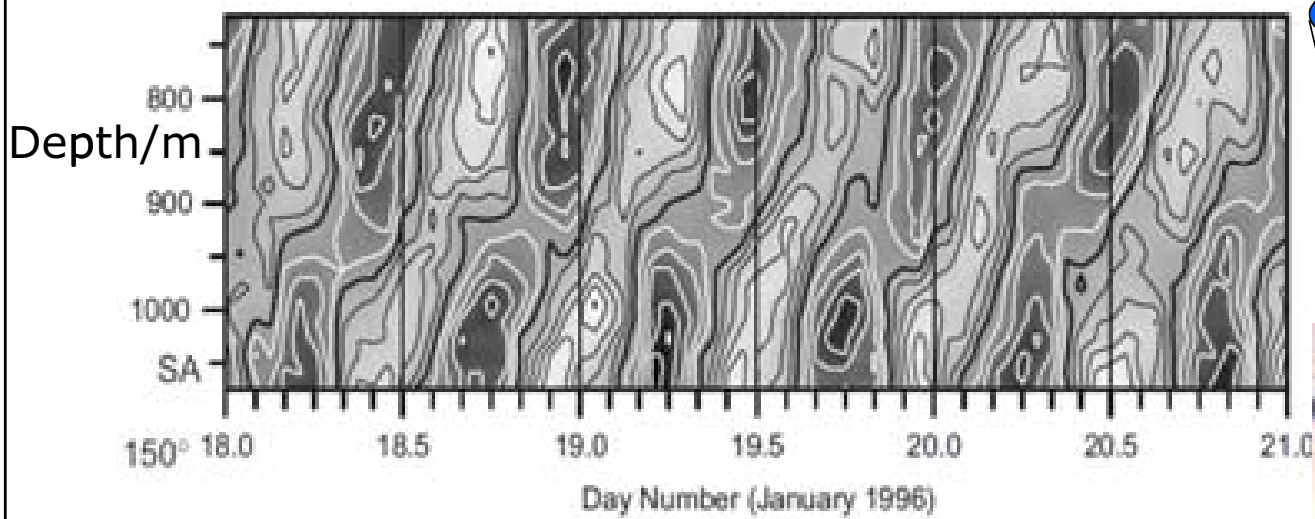


Effect on riser, bottom, pollution?

*van Haren 2011*



# ADCP velocity observation: snapshot



Restricted to 3D  
velocity observation  
along **line** segment

*Van Aken et al 2007*

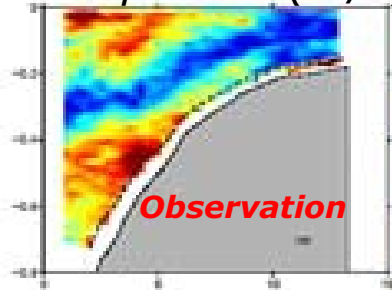
Acoustic Doppler Current Profiler



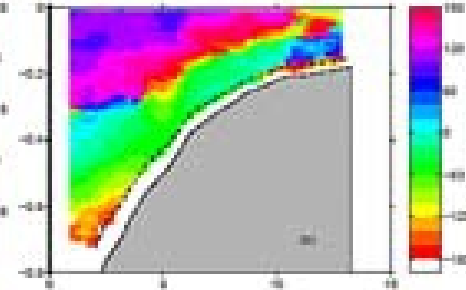
# Oblique wave propagation in Bay of Biscay



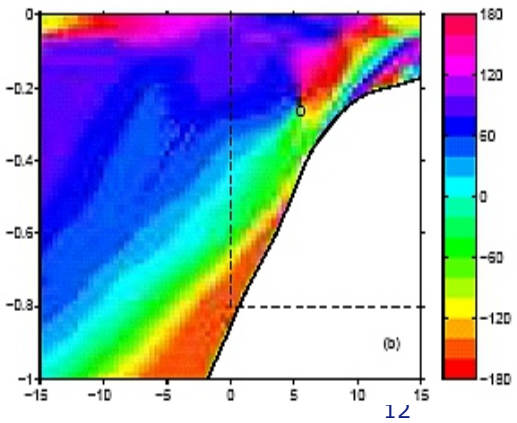
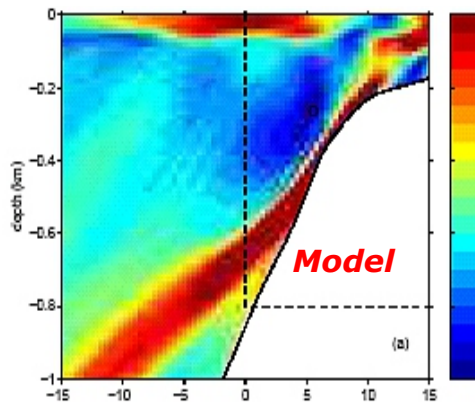
Amplitude (m/s)



Phase



Repeated transect,  
towed ADCP  
Internal tidal beam:  
observation and model



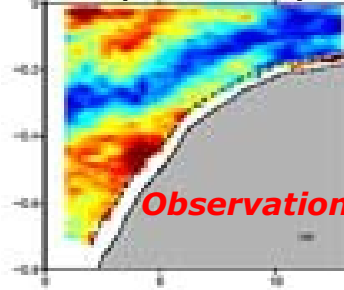
Lam et al 2004



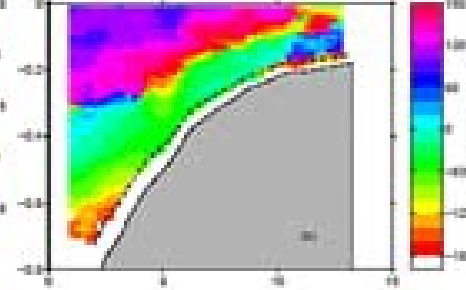
# Oblique wave propagation in Bay of Biscay



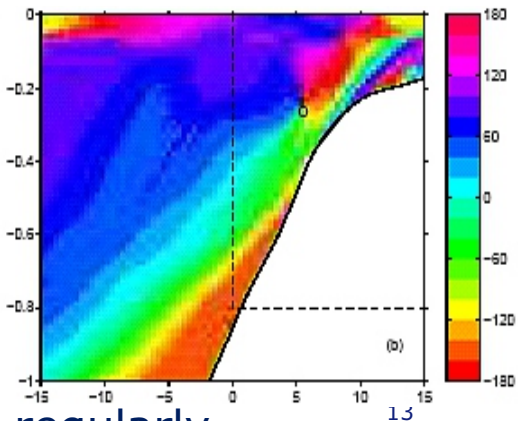
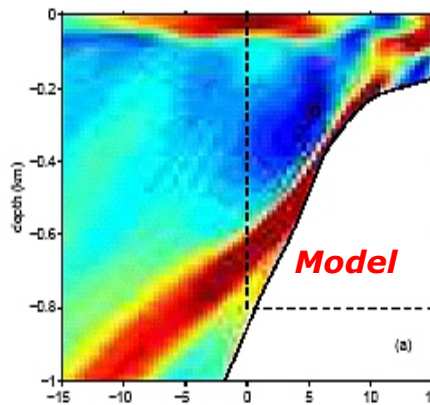
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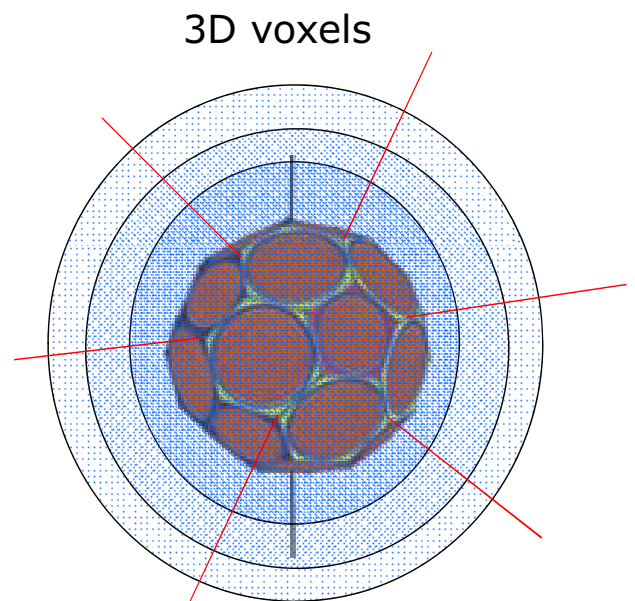
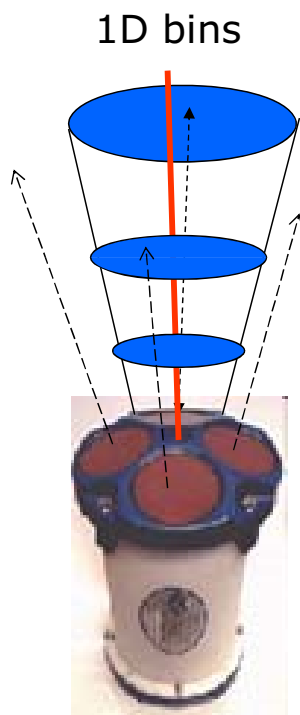
## Problem

- Existence and impact of IWs experienced regularly
- Only 1-D measurements available
- No instrument for 3D measurement available

Lam et al 2004



## Method: development of 3D current profiler



Acoustic Doppler Current Profiler

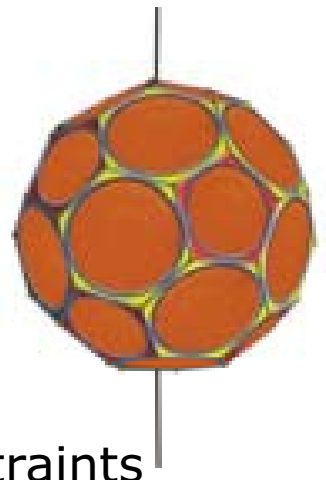


## Method: development of 3D current profiler

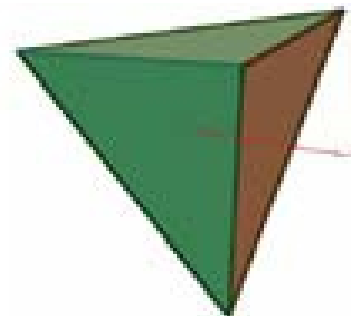
*Method:* Buckyball, or

Tetraeder profiler:

- 16 to 32 transducers
- 24 to 60 centre lines
- singleclock
- many mass conservation constraints



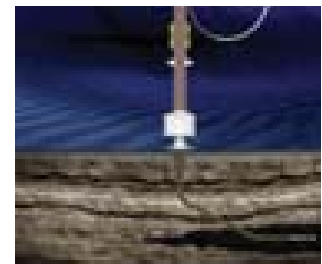
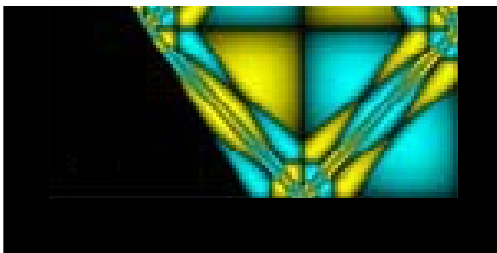
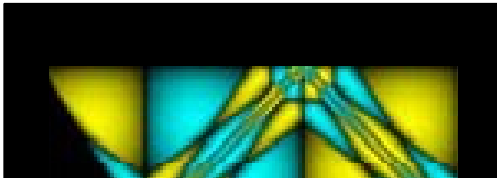
*Assets:* spatial resolution  
internal wave,  
turbulent motions  
infer forces





## When Exploring the Dark...

consider internal waves:  
from *Theory*, through *spatially resolving observations*,  
to *impact on offshore structures...*



**Relevance for:**  
Marin JIP Mona Risa  
Gulf of Mexico

**Tentative partners in Maritime 2013 proposal :**



**MARIN**



**ING**  
MERWEDE



**YOU?**

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