Turbulence measurements with SCAMP in the Gulf of Lion

Turbintermed 2012 Toulon

R. Rainaud, A. Petrenko, A. Doglioli, D. Malengros, F. Nencioli

Introduction

Calculation of K_Z

$$K_Z = K_{Turb} + \kappa_T$$ with $\kappa_T = 1.10^{-7}\ m^2\ s^{-1}$

Vertical profile of K_z

- Evaluation of turbulent intensity :

$$I_T = \frac{\varepsilon}{\nu N^2}$$

N : Brünt-Väisälä Frequency

ν : Molecular kinematic viscosity = $1{,}9.10^{-6}$ m^2/s

- Calculation of K_{Turb} with Shih et al. (2005) criterion :

Shih et al. (2005) $I_T < 7$ $K_{Turb} = 0 \rightarrow K_z = \kappa_T$

Osborn (1980) $7 < I_T < 100$ $K_{Turb} = \Gamma\, \varepsilon\, N^{-2}$ $\Gamma = 0{,}2$ Mixing efficiency

Shih et al. (2005) $I_T > 100$ $K_{Turb} = 2\nu\sqrt{I_T}$

Introduction

Calculation of K_Z

Evolution of turbulent kinetic energy : $E_{CT} = 0{,}5\,\overline{u'_i u'_j}$

$$\frac{dE_{CT}}{dt} = \underbrace{-\frac{\partial}{\partial x_j}\left(\overline{u'_j E_{CT} + \frac{p\,u'_j}{\rho}}\right)}_{T} \underbrace{-\overline{u'_i u'_j}\frac{\partial u_i}{\partial x_j}}_{P} \underbrace{-\frac{1}{\rho_0}\overline{\rho' u_i}\, g\,\delta_{i3}}_{S} + \boldsymbol{\varepsilon}$$

T : Diffusive transport
P : Production
S : Sources or sink by flottability
ε : Viscous dissipation

$$\varepsilon = \frac{c_\varepsilon\, E_{CT}^{3/2}}{l_\varepsilon}$$

c_ε : constant
l_ε : length scale

$$K_Z = C_0\, \sqrt{E_{CT}}\; L$$

Prandtl-Kolmogorov relation

L : length scale
C_0 : constant

Gaspar et al. (1990), in the hydrodynamical model

Determination method of ε

Batchelor method

- Determination with measurement of Batchelor wavenumber k_B (cyc/m)
- Calculation of Batchelor length scale :

$$L_B = (2\pi \boldsymbol{k_B})^{-1}$$

- Calculation of ε :

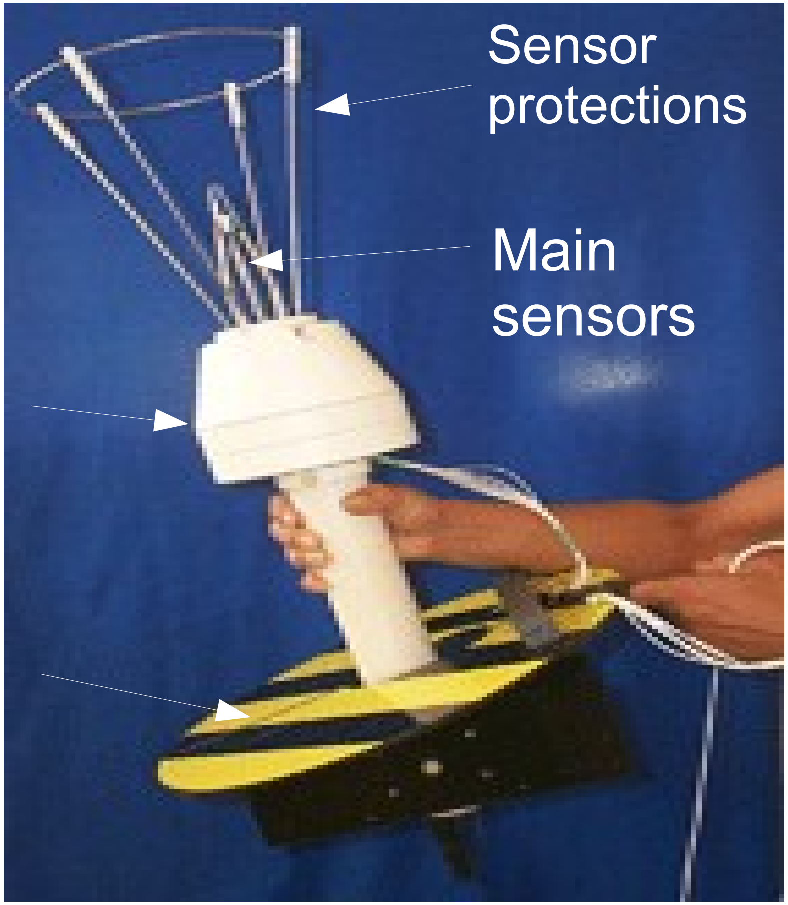
$$\varepsilon = \frac{\nu \kappa_T^2}{L_B^4}$$

Luketina and Imberger (2001)

SCAMP
Self Contained Autonomous MicroProfiler

Float

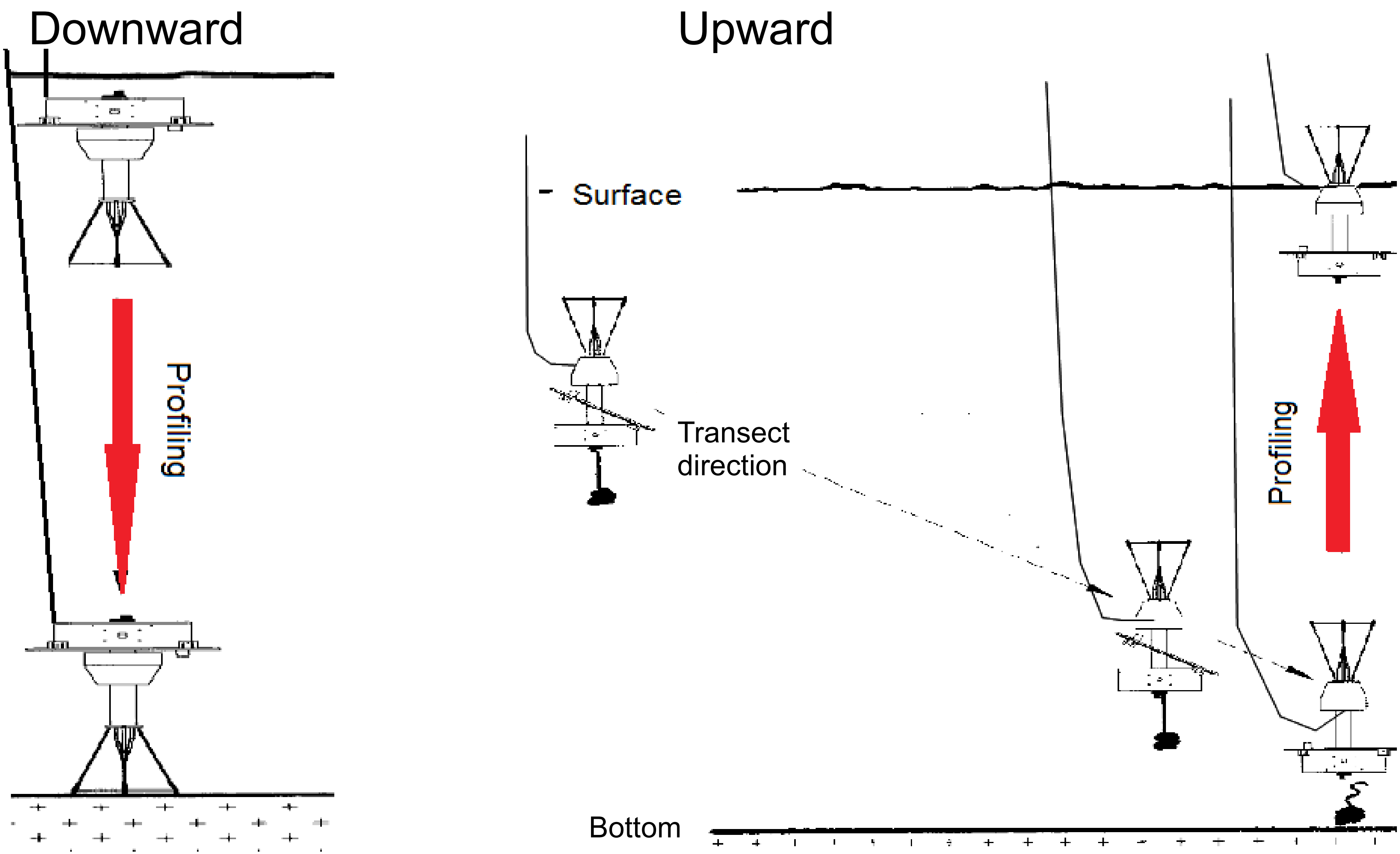
Brake Plate



- Fine scale measurements (≈ 1 mm) of temperature and conductivity
- Frequency sampling : 100 Hz
- Weight : 6 kg
- Travel speed : between 10 and 20 cm/s (settings controlling the flotation)
- Maximum depth : 100 m
- Data analysis : Matlab and source codes (C langage) given by PME

Manufactured by PME-Precision Measurement Engineering, California

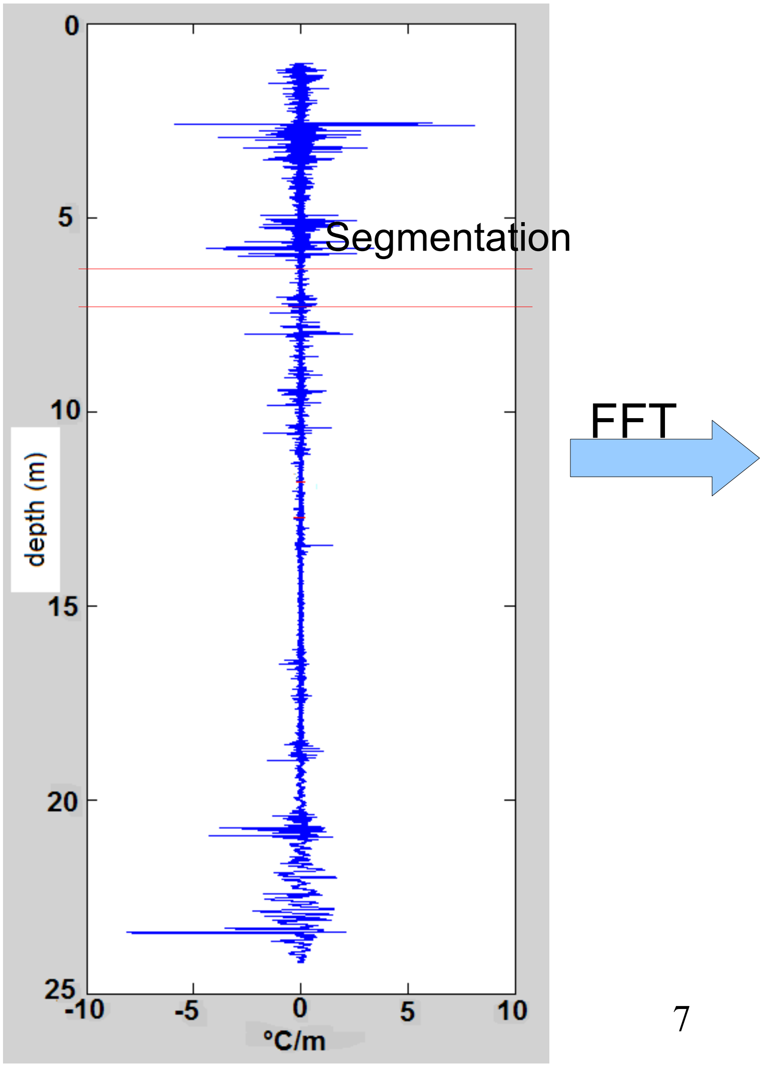
SCAMP
Types of profile



Data process

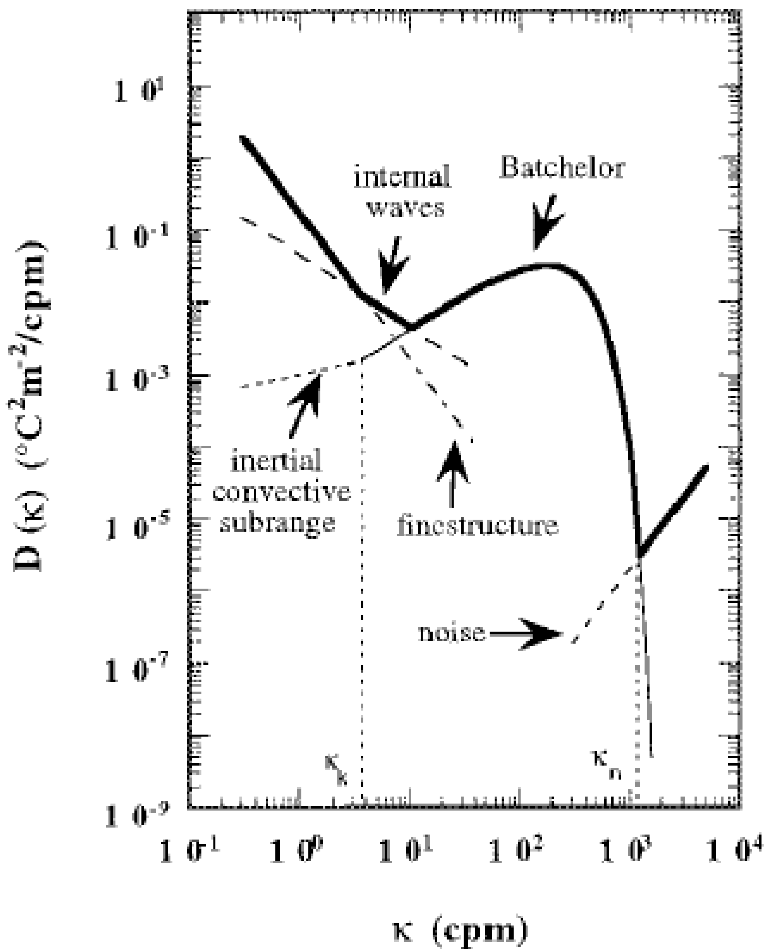
- Speed range : 10 - 15 cm/s
- Measurement frequency (Fast probe) : 100 Hz
- Segmentation : process pack of 1000 measurements (Modification with respect to PME default segmentation)
- Vertical profile of ε and Kz with segmentation every meter

Vertical gradient profile of temperature



Batchelor spectrum

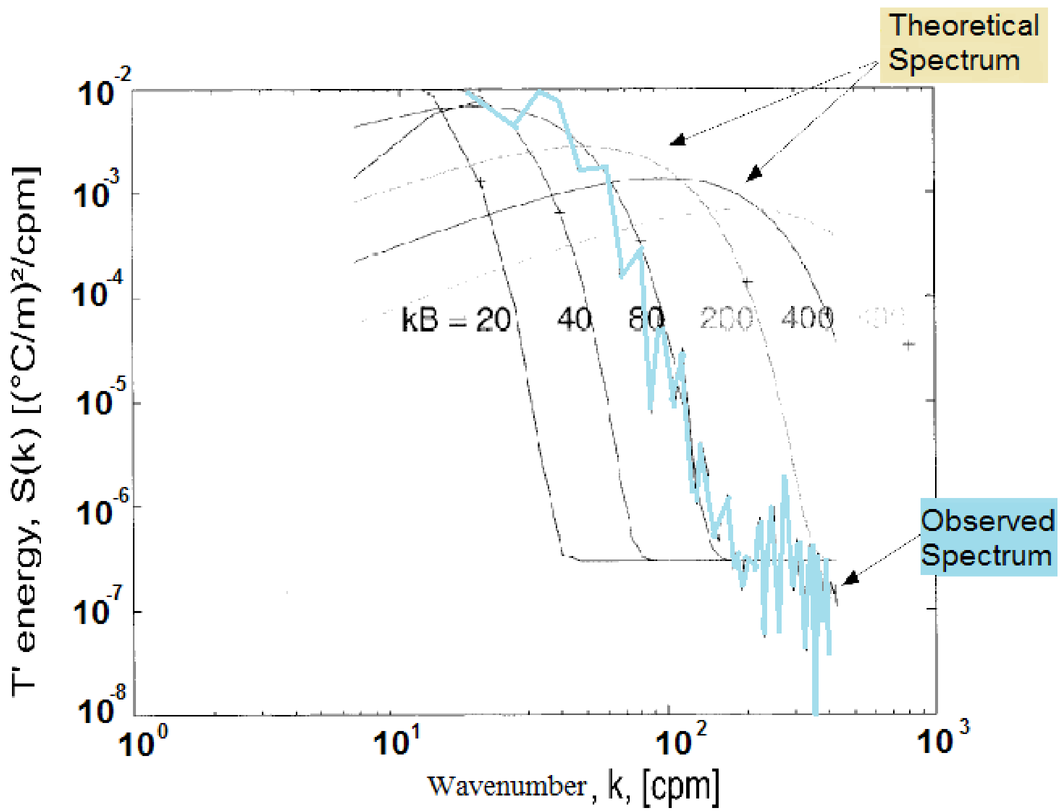
Fourier Transform for every segment



From Luketina and Imberger (2000)

Theoretical spectrum of temperature vertical gradient

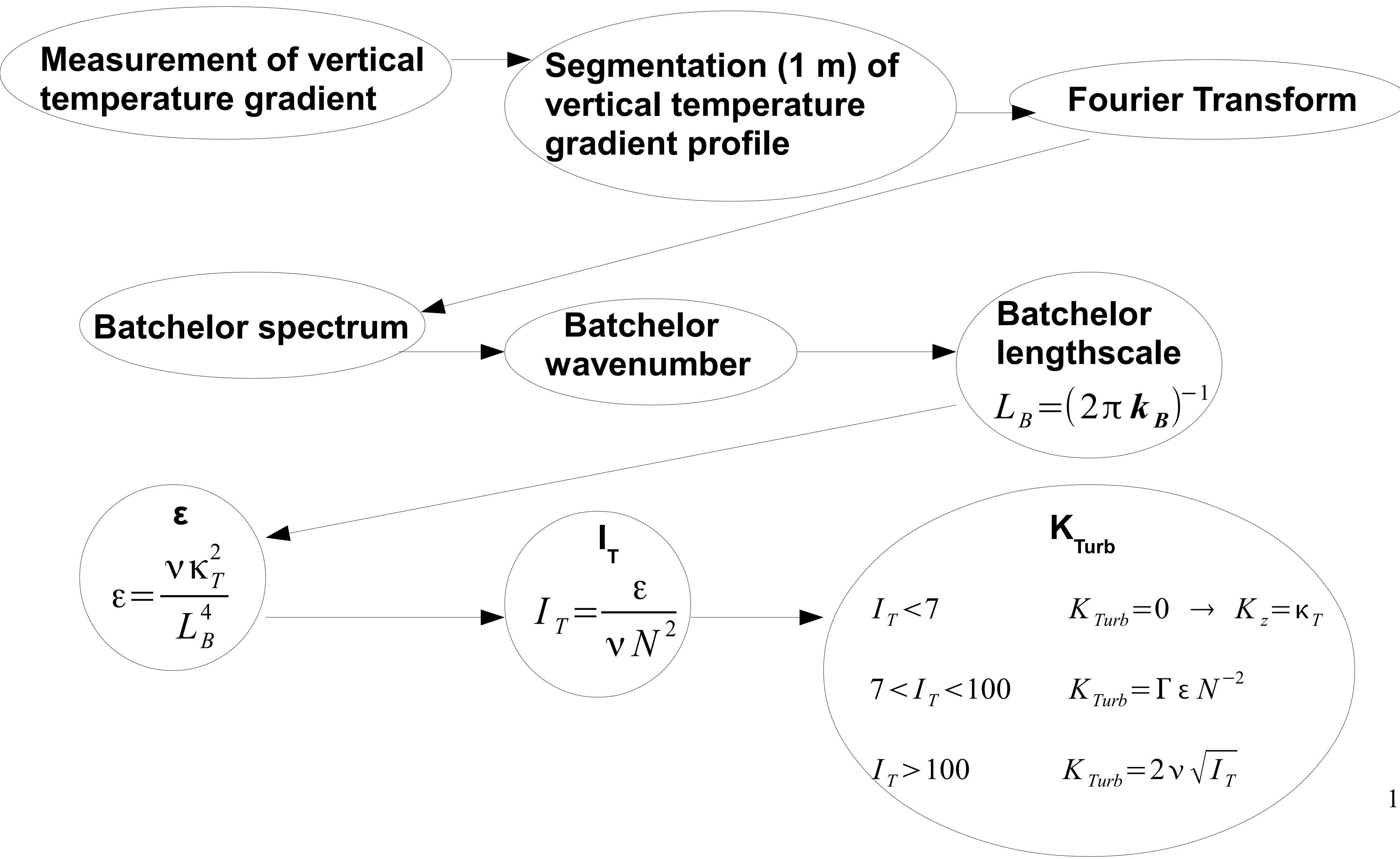
Batchelor spectrum



Comparison of observed Batchelor spectrum with theoretical Batchelor spectra

→ Obtain Batchelor wavenumber k_B

Method summary

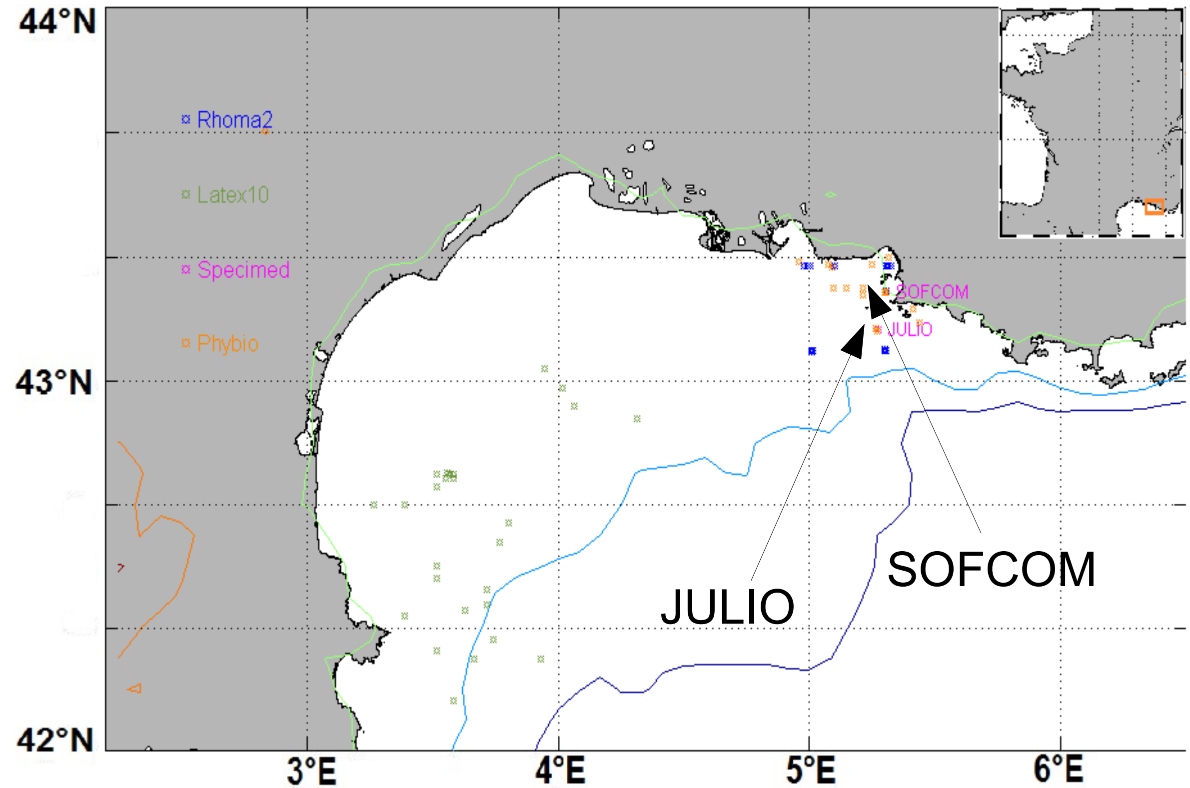


Database

4 campaigns between 2010 and 2011:

- 2010 (South Western of Gulf of Lion):
  Latex10

- 2011 (Noth Eastern Gulf of Lion):
  Rhoma2
  Phybio
  Specimed



Main stations of North Eastern of Gulf of Lion :

- SOFCOM : French national station network with measurements collected for decades

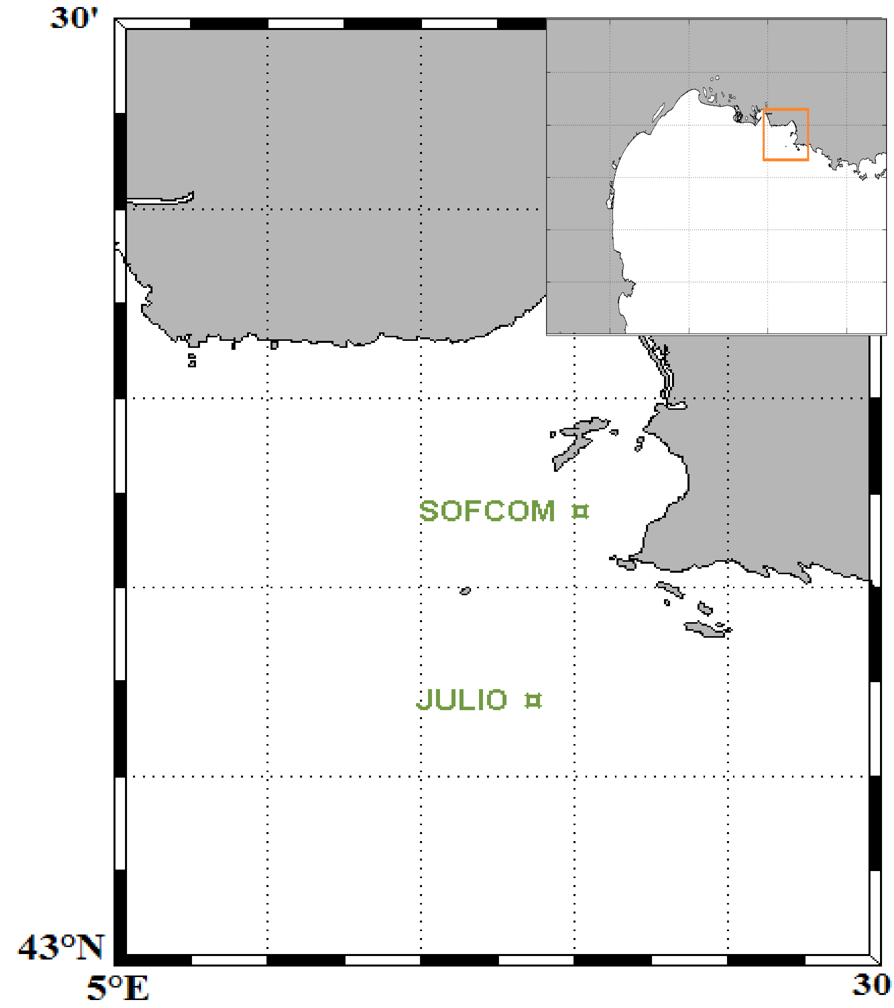
- JULIO : Station of the MOOSE system

SCAMP measurements 2011

SPECIMED Project

Dates of measurements :

- 08 February
- 10 March
- 19 April
- 03 May
- 22 June (SOFCOM)
- 11 July (JULIO)
- 13 September
- 18 October



Stations of measurements :

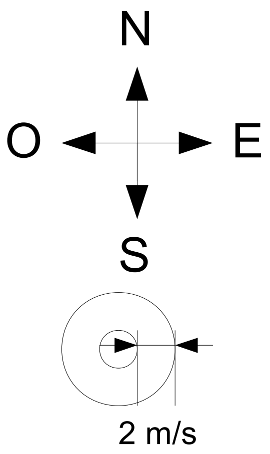
- SOFCOM : 5,29°E – 43,24°N (60 m depth, bay)
- JULIO : 5,26°E – 43,14°N (100 m depth, coast)

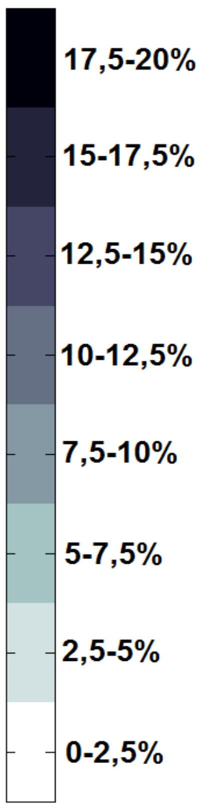
Objectives

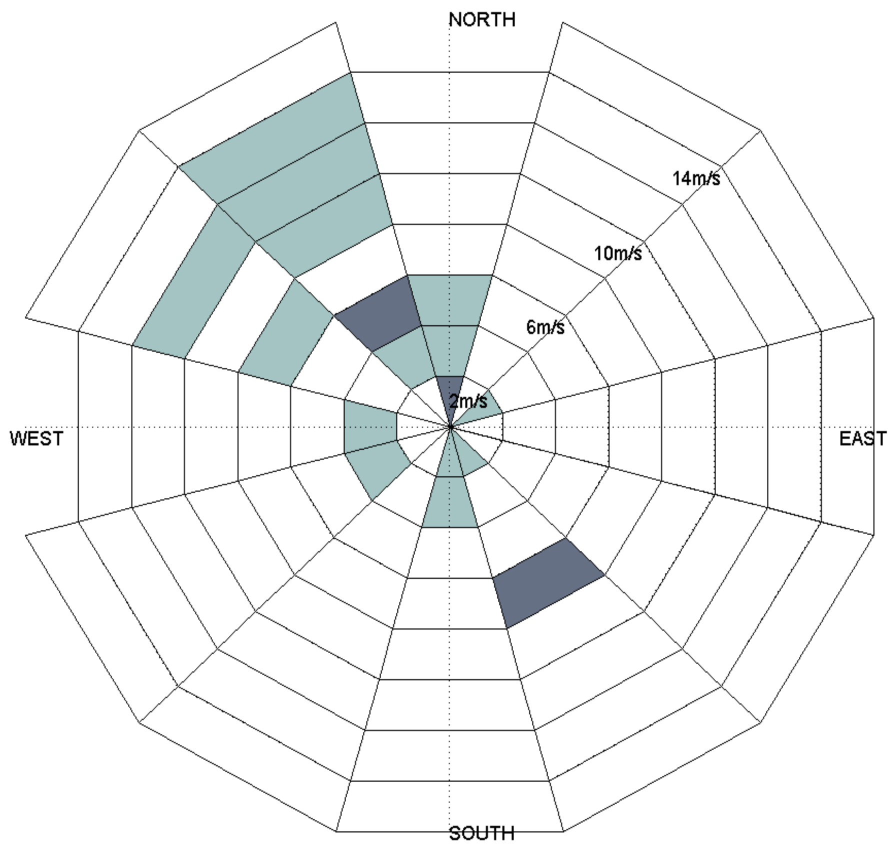
To determine a seasonality of mixing in the study area

To characterize the difference between bay and coast

Wind data







Wind rose of 13/09 (SOFCOM)

Wind rose on 2.5 days

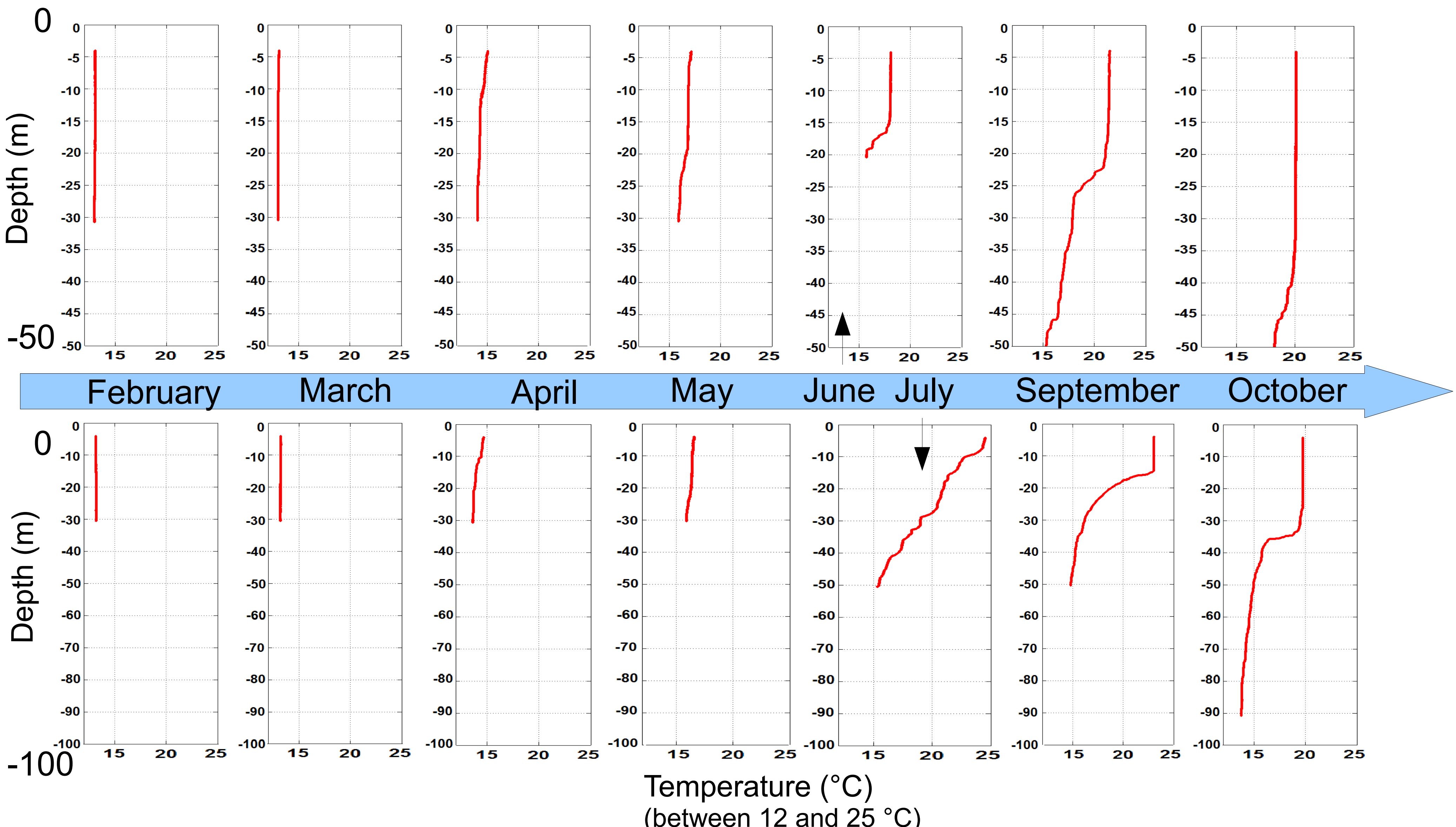
Wind data given by Météo France and calculated with ALADIN model

Temporal resolution : 3 h

Spatial resolution : 10 km (interpolation to 1 km)

Temperature

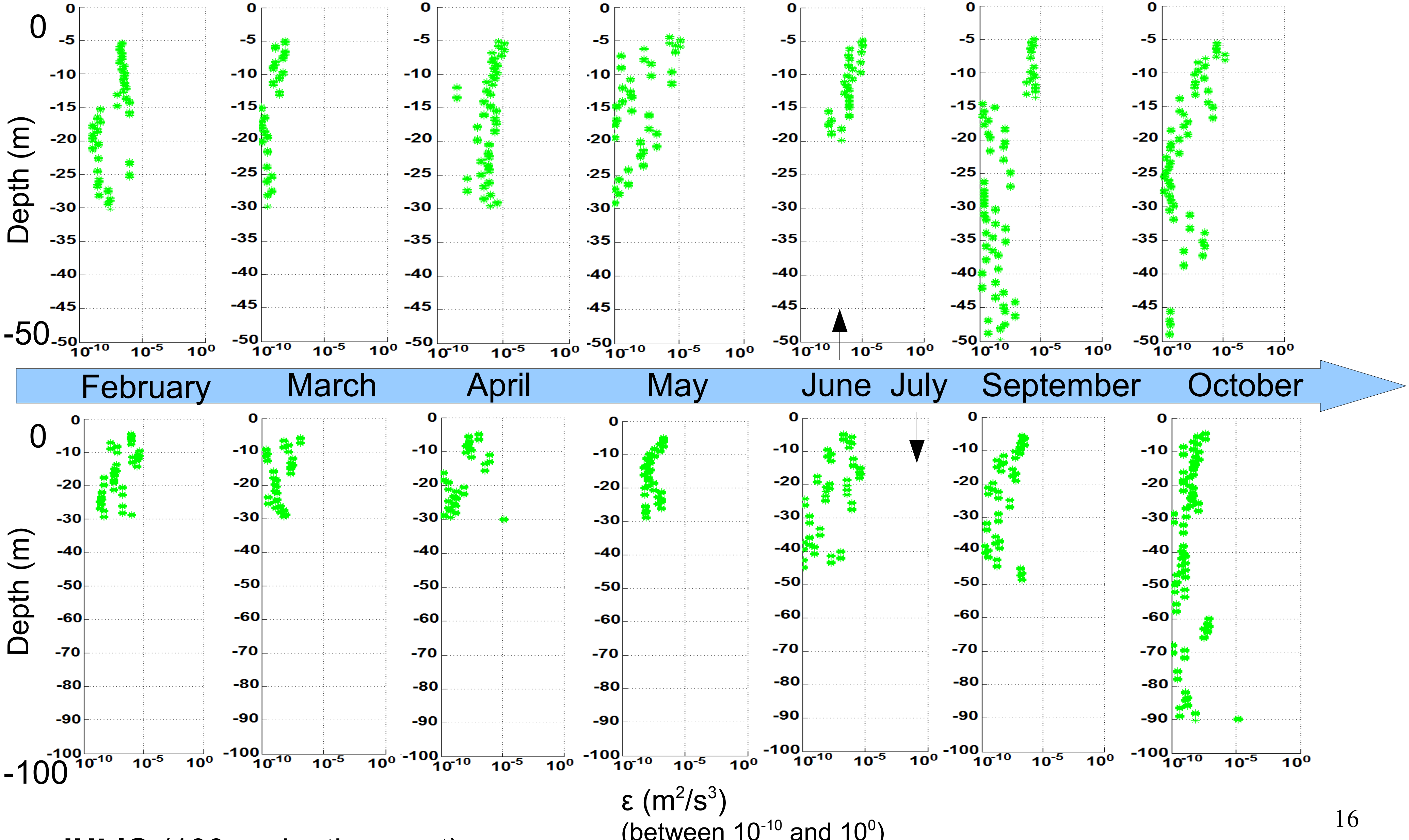
SOFCOM (60 m depth, bay)



JULIO (100 m depth, coast)

ε

SOFCOM (60 m depth, bay)

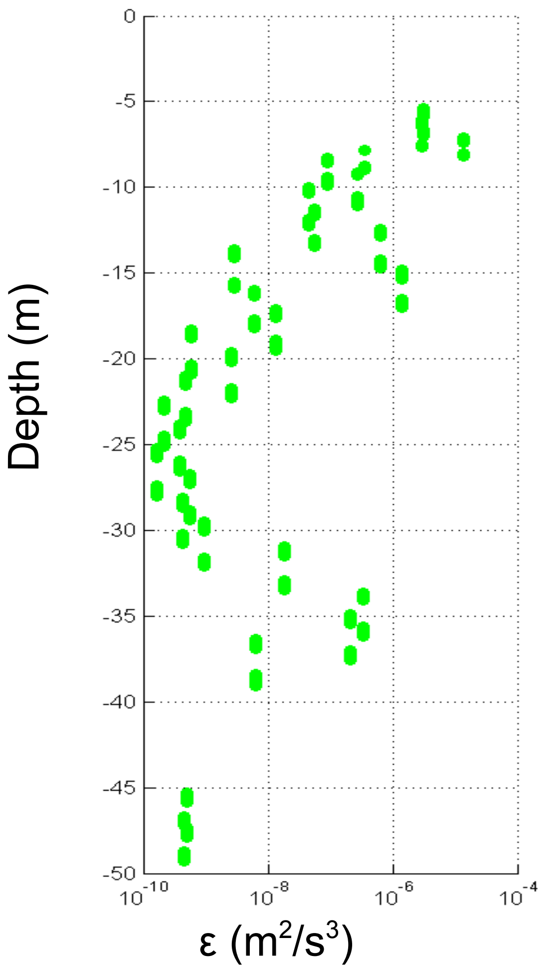


JULIO (100 m depth, coast)

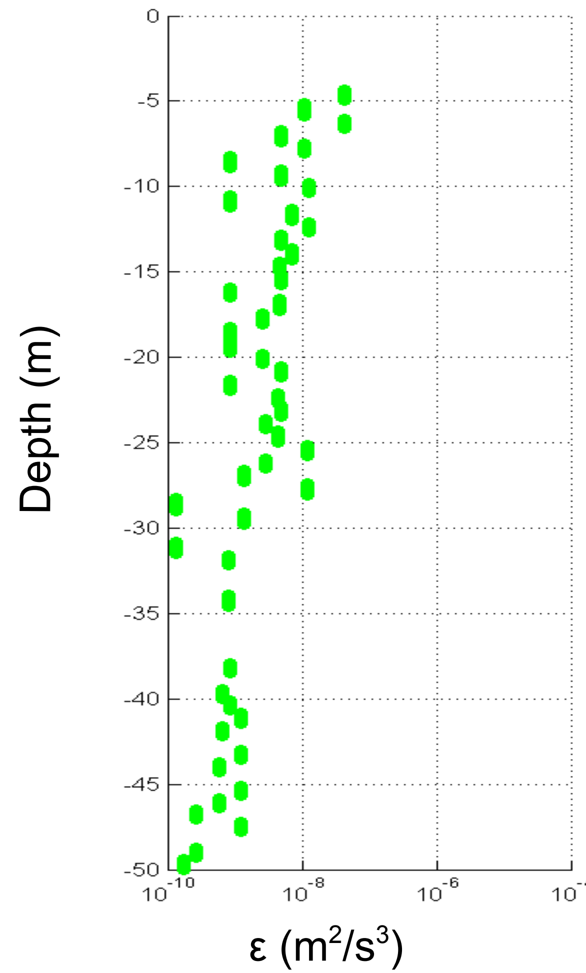
ε

October

SOFCOM (bay)



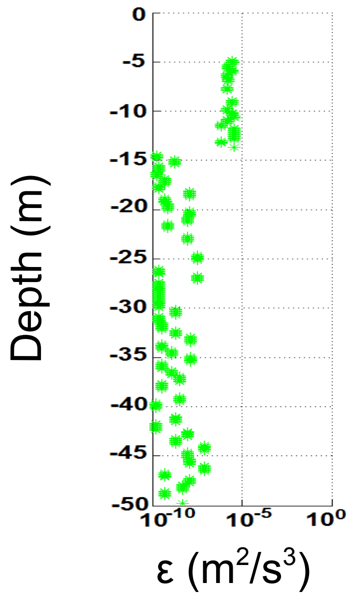
JULIO (coast)



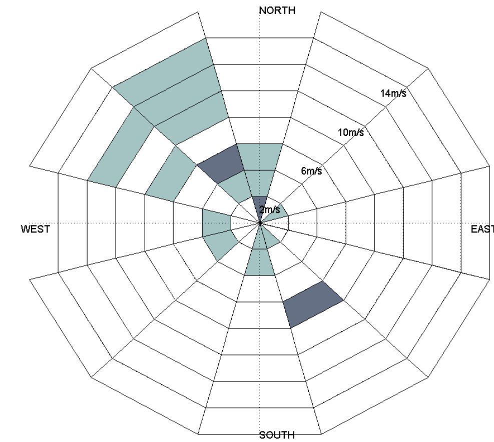
From 1 to 2 order of magnitude between bay and coast (above 20 m)

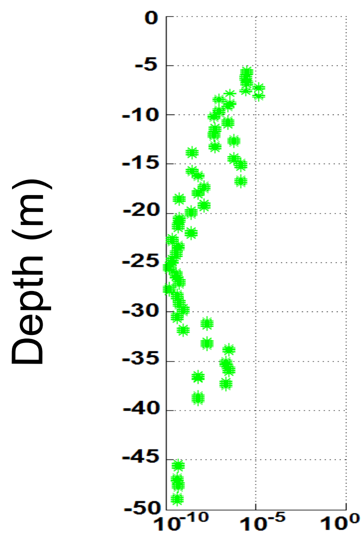
ε

SOFCOM (bay)

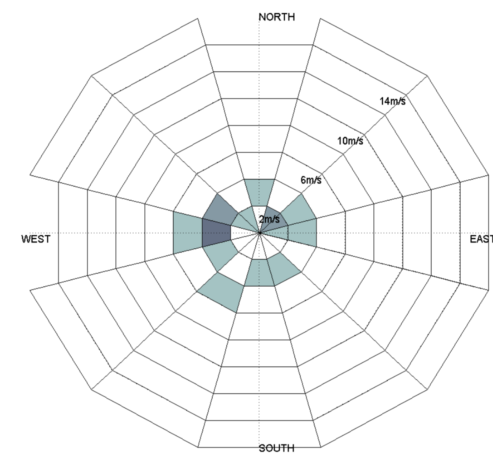


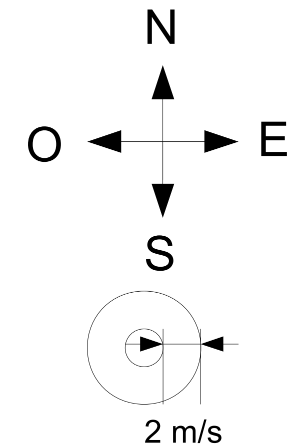
September

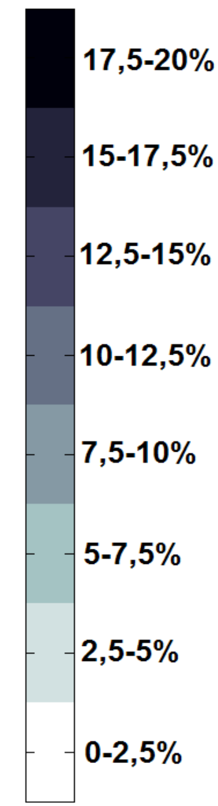




October

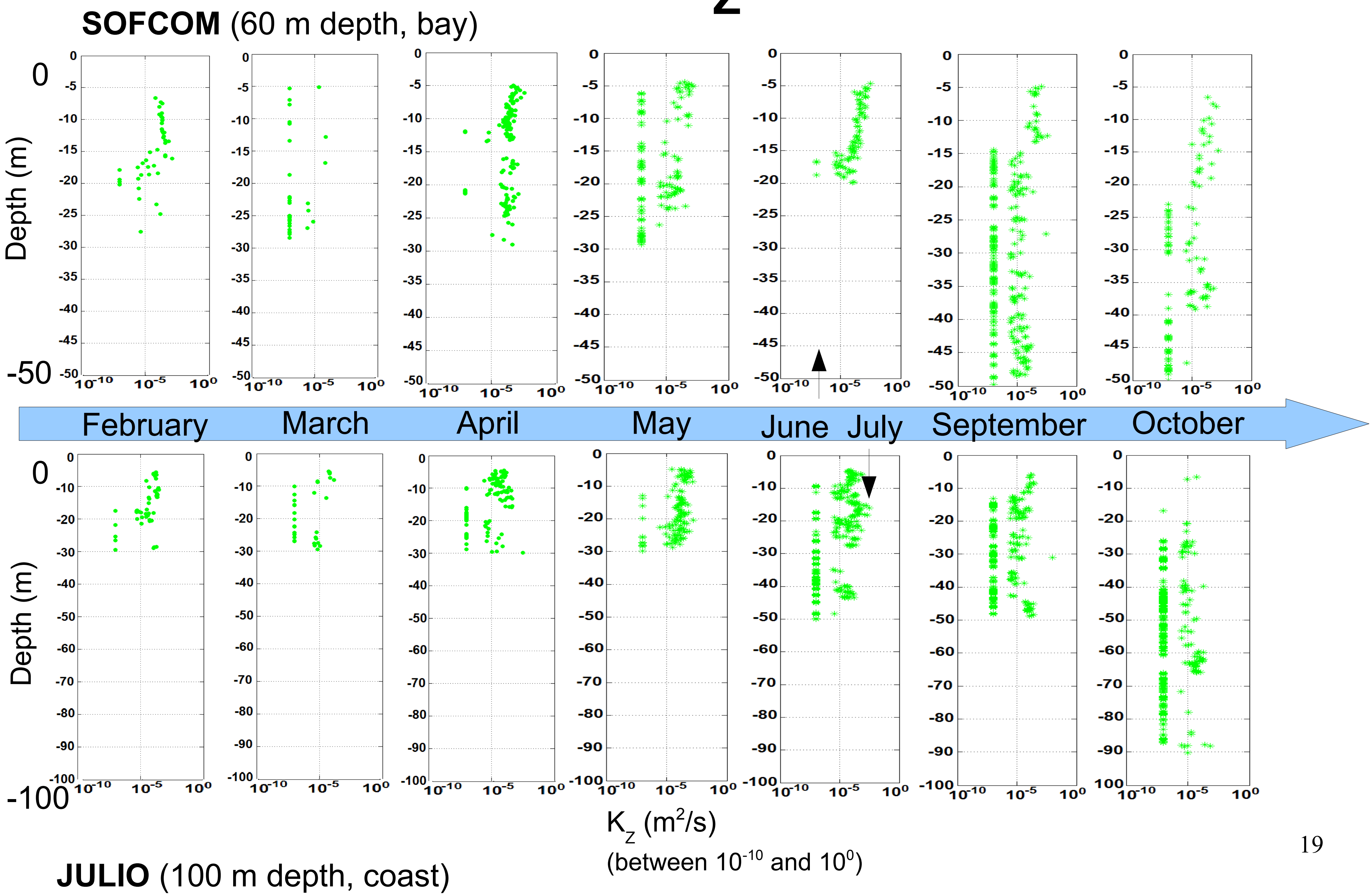






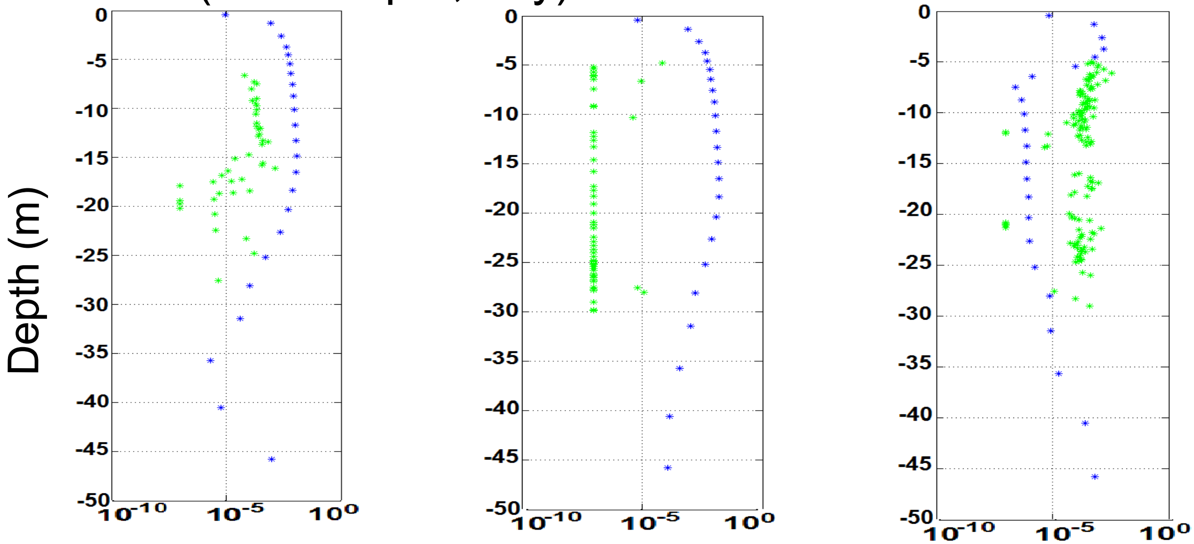
Bay : after a strong wind, net difference between above and under 15 m (almost 4 orders of magnitude)

K_Z


SOFCOM (60 m depth, bay)
Depth (m)
0
-50
February
March
April
May
June
July
September
October
Depth (m)
0
-100
K_Z (m^2/s)
(between 10^{-10} and 10^0)
JULIO (100 m depth, coast)

K_Z : Comparison SCAMP/Model

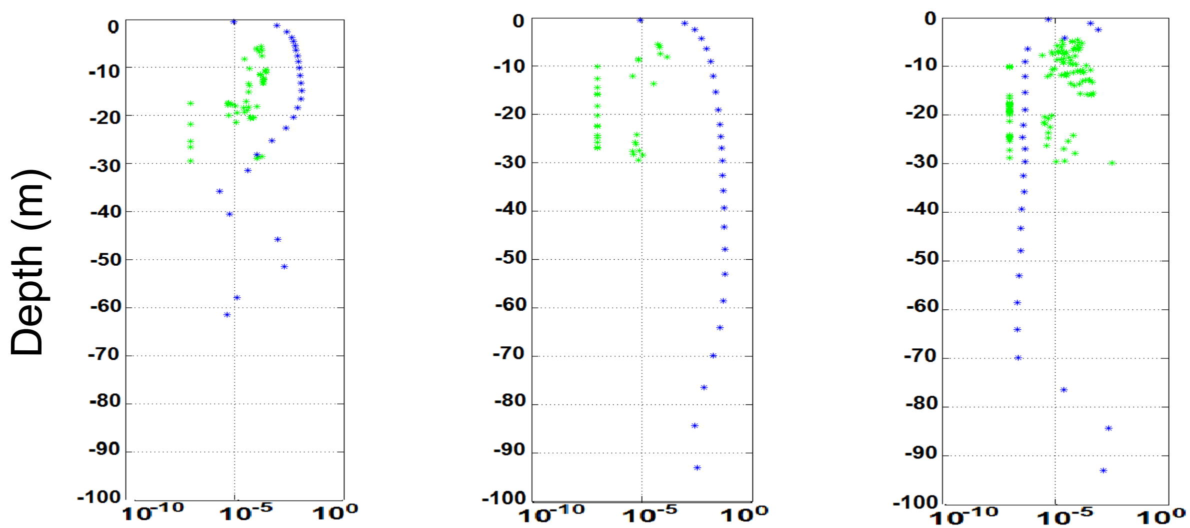
SOFCOM (60 m depth, bay)



February | March | April

$$K_Z\, Model \neq K_Z\, Scamp$$

especially in the surface layer



K_z (m^2/s)

SCAMP Measurements

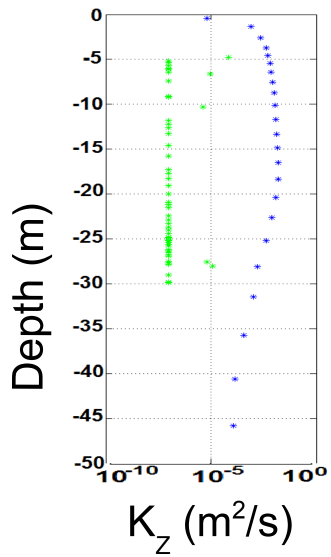
Gaspar et al. (1990) scheme

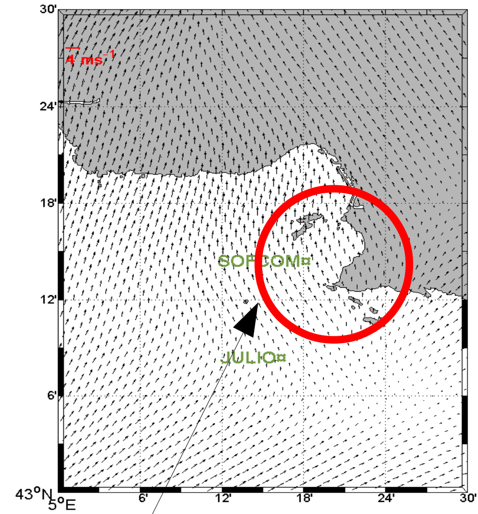
JULIO (100 m depth, coast)

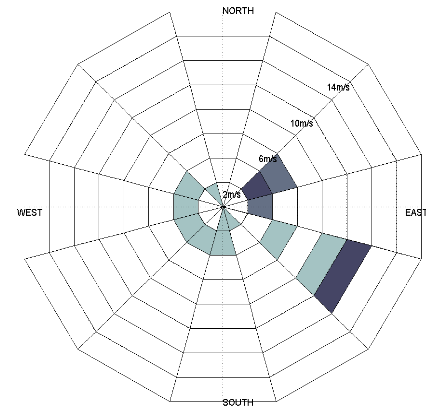
K_z : Comparison SCAMP/Model

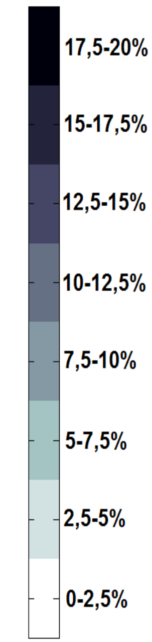
SOFCOM (bay)

March
(Strong wind)



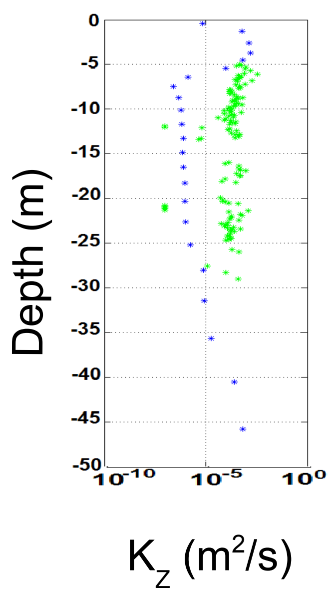


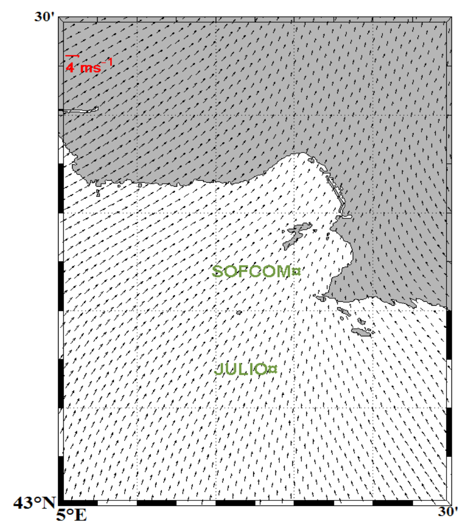


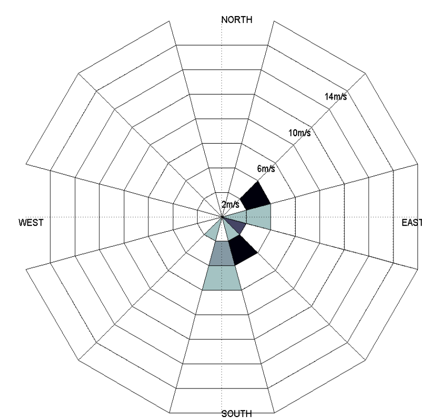


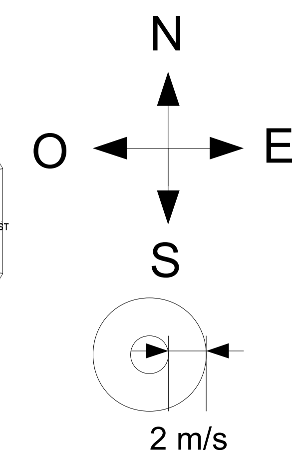
No orography protection effect in ALADIN

April
(Weak wind)









Conclusion and perspectives

- No seasonality of mixing during 2011
- Differences of ε don't impact K_z
- Presence of important gradient of K_z under 20 m when Shih et al. 2005 criterion is applied
- Important difference between K_z measured with SCAMP and K_z calculated with SYMPHONIE
- At bay, overestimation of mixing in SYMPHONIE probably due to the low spatial resolution of ALADIN wind forcing

- Other method to calculate ε, with Thorpe scale (in progress)
- Turbulence for wind typical scenario

Thank you for your attention

Extra slides

Another method to determine ε

Thorpe Method

- Measurement of Thorpe length scale L_{Th} with SCAMP
- Calculation of ε Thorpe (2005) formula:

$$\varepsilon = c_1 L_{Th}^2 N^3$$

c_1 = 0,8 : constant

SYMPHONIE

$$l_\varepsilon = \frac{\sqrt{2}}{E_{CT}^{1/2}\ N}$$

$$\varepsilon = \frac{c_\varepsilon\ E_{CT}^{3/2}}{l_\varepsilon}$$

$$c_\varepsilon = 0{,}7$$

$$L = l_\varepsilon$$

$$K_{Turb} = C_0\ \sqrt{E_{CT}}\ \ L$$

$$C_0 = 0{,}1$$

Gaspar et al. (1990)

Wind rose

Wind rose showing wind speed, direction and frequency on 2.5 days

Approximation :

$$\frac{du}{dt} \approx K_z \frac{\partial^2 u}{\partial z^2}$$

⇒

Order of magnitude study:

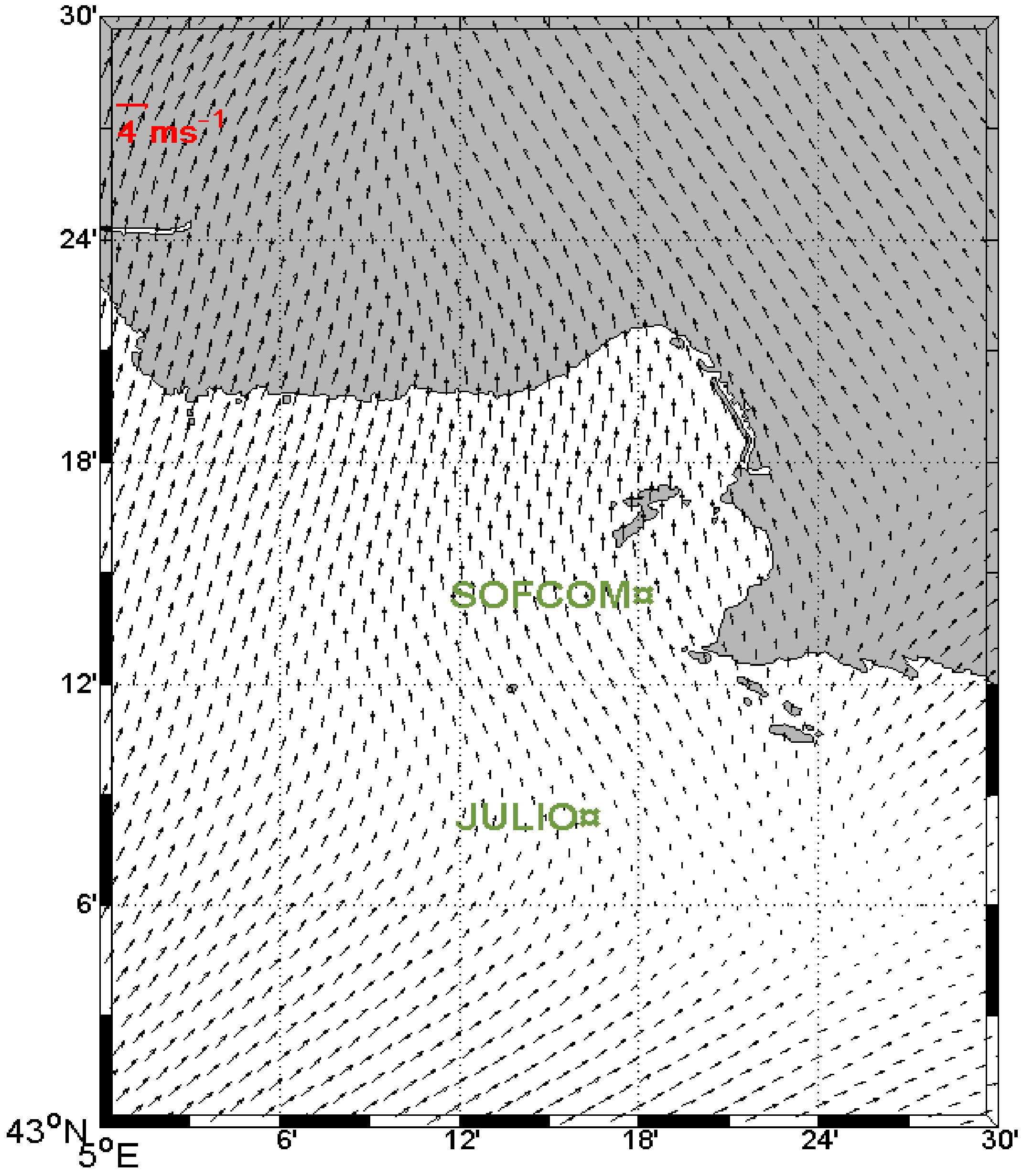
$$\frac{U}{T} \approx K_z \frac{U}{z^2} \Rightarrow T \approx \frac{z^2}{K_z}$$

z : Ekman depth where u(z) = 4% of u(0)

$$z = \pi \sqrt{\frac{2\ K_z}{f}}$$

⇒ $T \approx 2.5\, days$

Wind map



Shih et al. 2005 criterion