Dynamique de processus océaniques de méso- et de submméso-échelle à partir de simulations numériques et de données *in situ*

Marion Kersalé

Soutenance de Thèse – 15 Octobre 2013

Sous la présidence de :	Ivan DEKEYSER
Comité :	Gilles REVERDIN
	Bruno BLANKE
	Annalisa GRIFFA
Directeurs de thèse :	Anne PETRENKO
	Andrea DOGLIOLI

Institut Méditerranéen d'Océanologie
Institut PYTHEAS Observatoire des Sciences de l'Univers Aix-Marseille Université
cnrs
IRD Institut de recherche pour le développement
UNIVERSITÉ DU SUD TOULON VAR

Dynamics of meso- and submesoscale oceanic processes from numerical simulations and *in situ* data

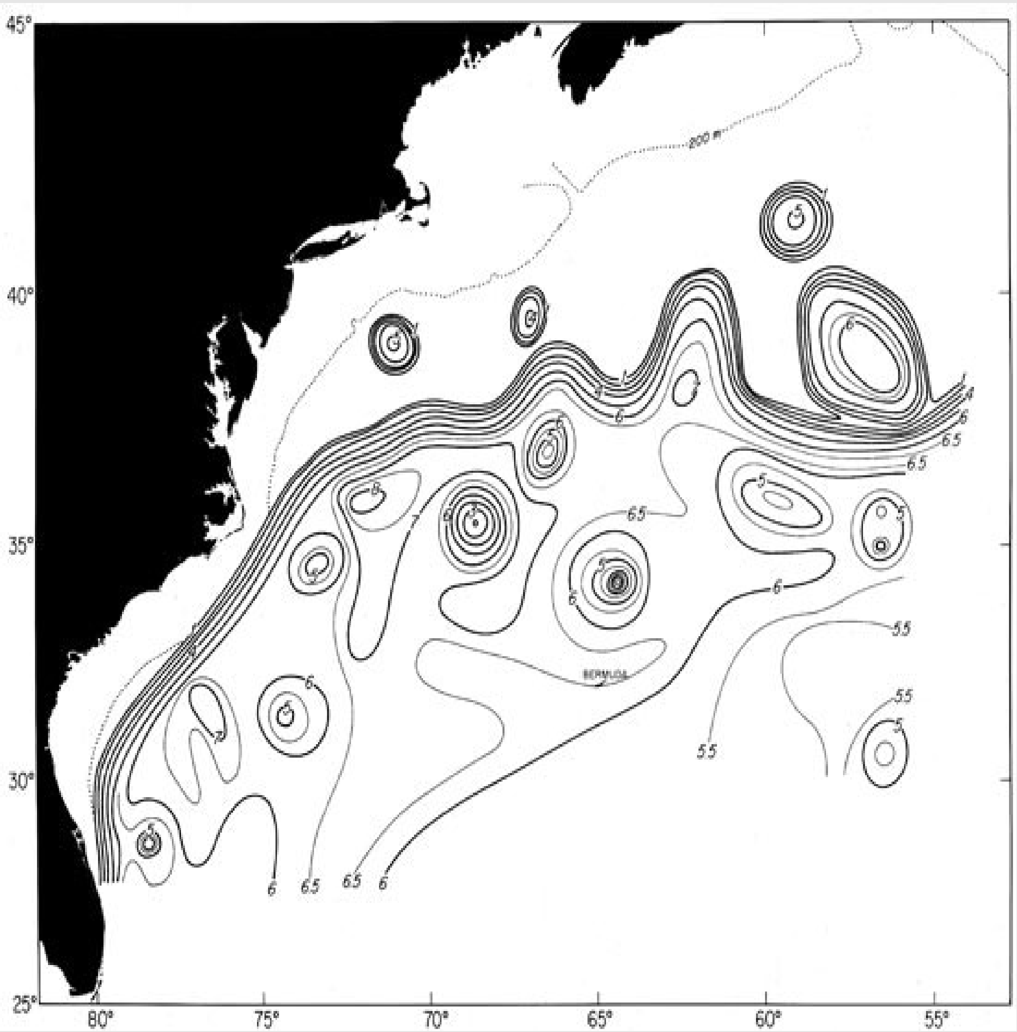
Marion Kersalé

PhD defense – October 15, 2013

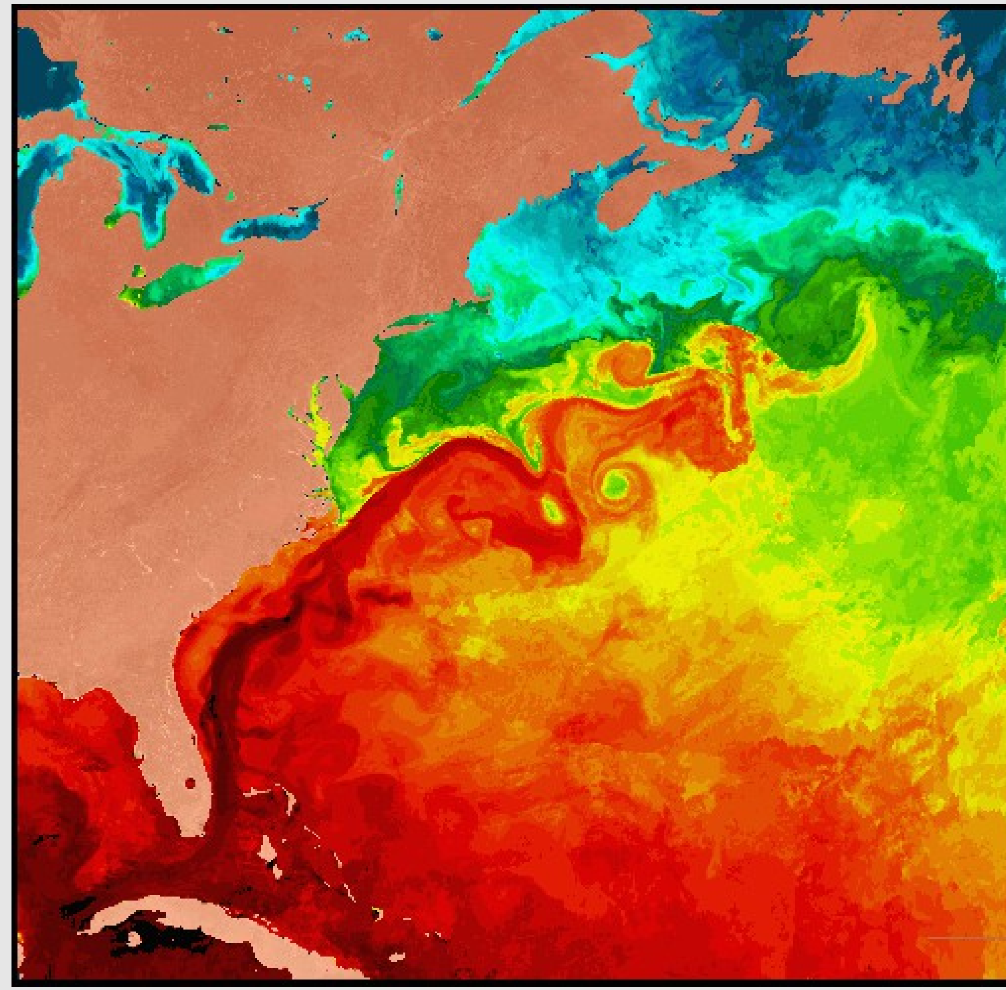
Under the presidence of :	Ivan DEKEYSER
Committee :	Gilles REVERDIN
	Bruno BLANKE
	Annalisa GRIFFA
PhD advisors :	Anne PETRENKO
	Andrea DOGLIOLI

Institut Méditerranéen d'Océanologie
Institut PYTHEAS Observatoire des Sciences de l'Univers Aix-Marseille Université
cnrs
IRD Institut de recherche pour le développement
UNIVERSITÉ DU SUD TOULON VAR

Discovering Gulf stream variability from space



Path of the Gulf Stream from hydrographic and satellite data (1975)

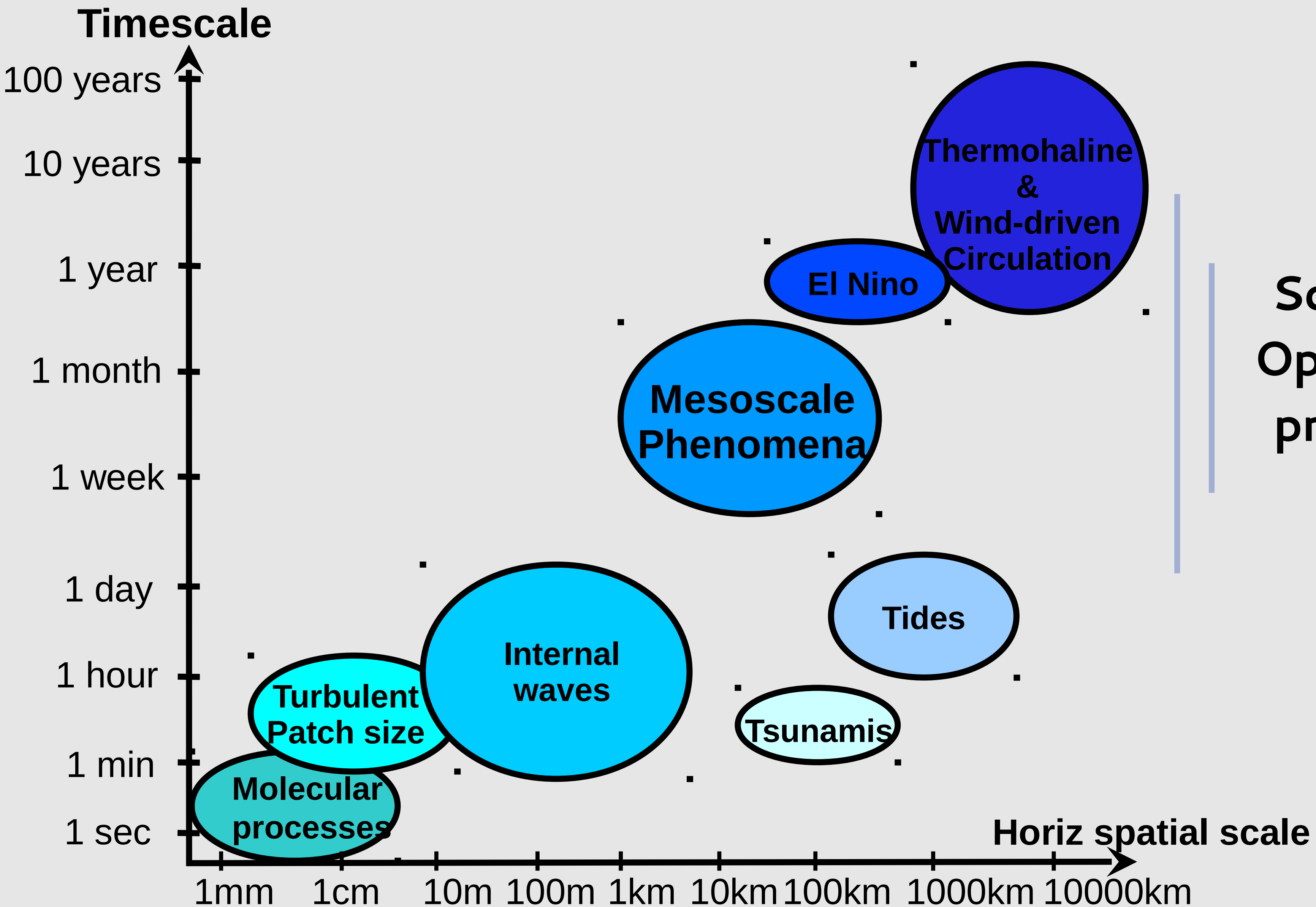


Thermal infrared image of the Gulf Stream ©NASA

Introduction – Time/space scale diagram

Numerous physical processes over a large range of scales

[Stommel, 1963 ; Dickey, 2003 ; Talley et al., 2011]



Scales for Open ocean processes

Introduction – Coastal processes scales

Smaller scales than the open ocean characterization

Large scale flow

Mesoscale

Geostrophic equilibrium

Scales

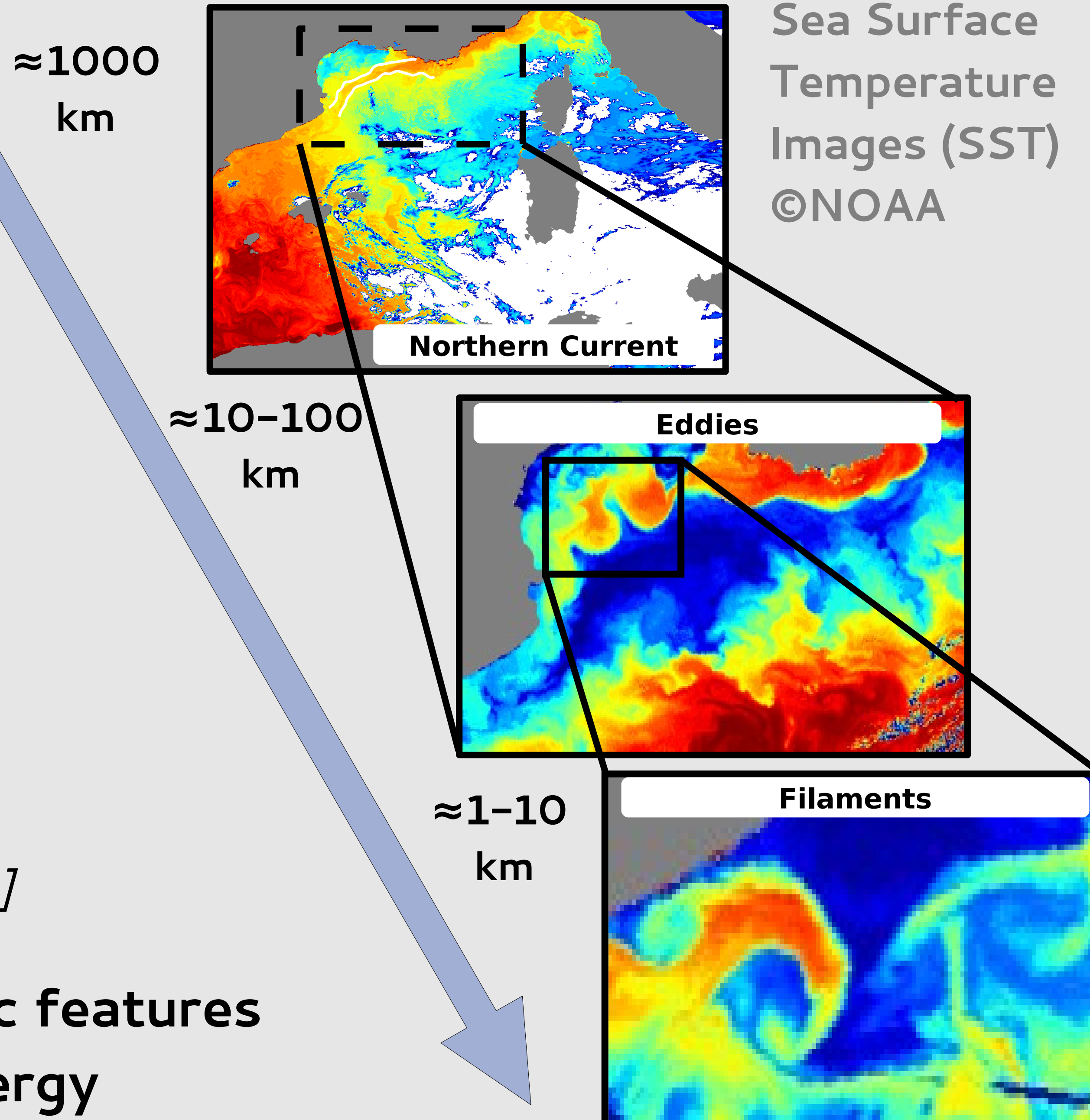
~O(R_d) *[Chelton et al., 1998]*

Submesoscale

Scales < R_d *[Capet et al., 2008]*

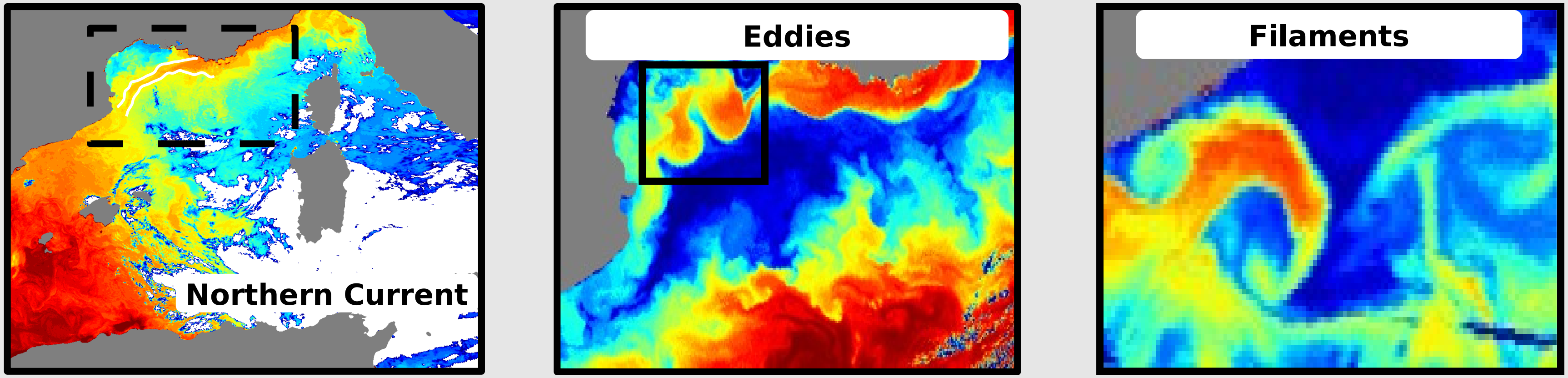
Numerous and energetic features

=> Transfer of energy



Sea Surface Temperature Images (SST) ©NOAA

Forward transfer of energy



Large scale flow ≈1000 km

Mesoscale ≈10–100 km

Submesoscale ≈1–10 km

Baroclinic / Barotropic Instabilities
External forcings

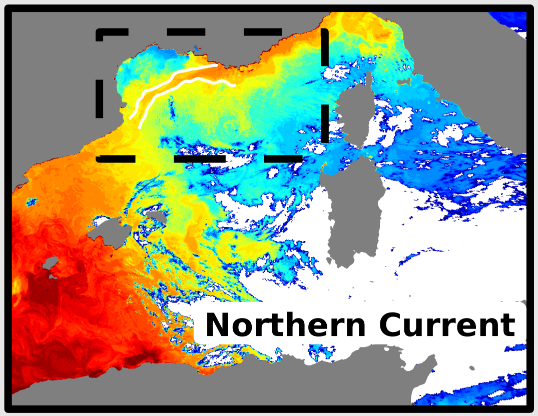
Evolution/Interaction
=> Stretching
Frontogenesis

Turbulent mixing

Processes involve in the forward transfer of energy

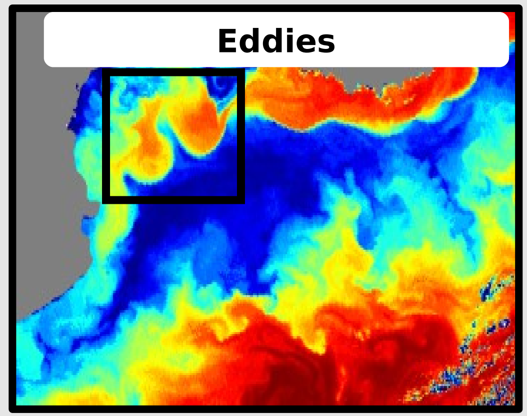
Introduction – Transfer of energy

Forward transfer of energy



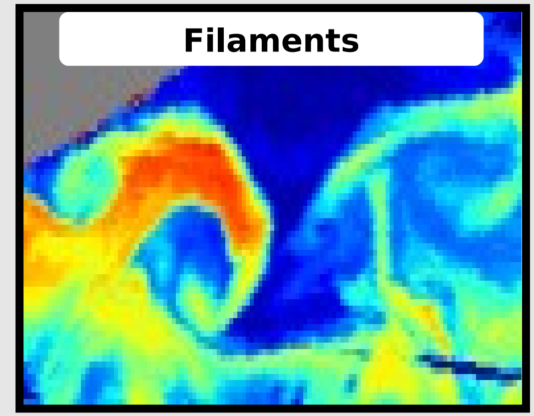
Large scale flow

≈1000 km



Mesoscale

≈10–100 km



Submesoscale

≈1–10 km

Baroclinic / Barotropic
Instabilities
External forcings

Evolution/Interaction
=> Stretching
Frontogenesis

Turbulent
mixing

Processes involve in the forward transfer of energy

Introduction – Deep ocean vs coastal

Hawaiian archipelago

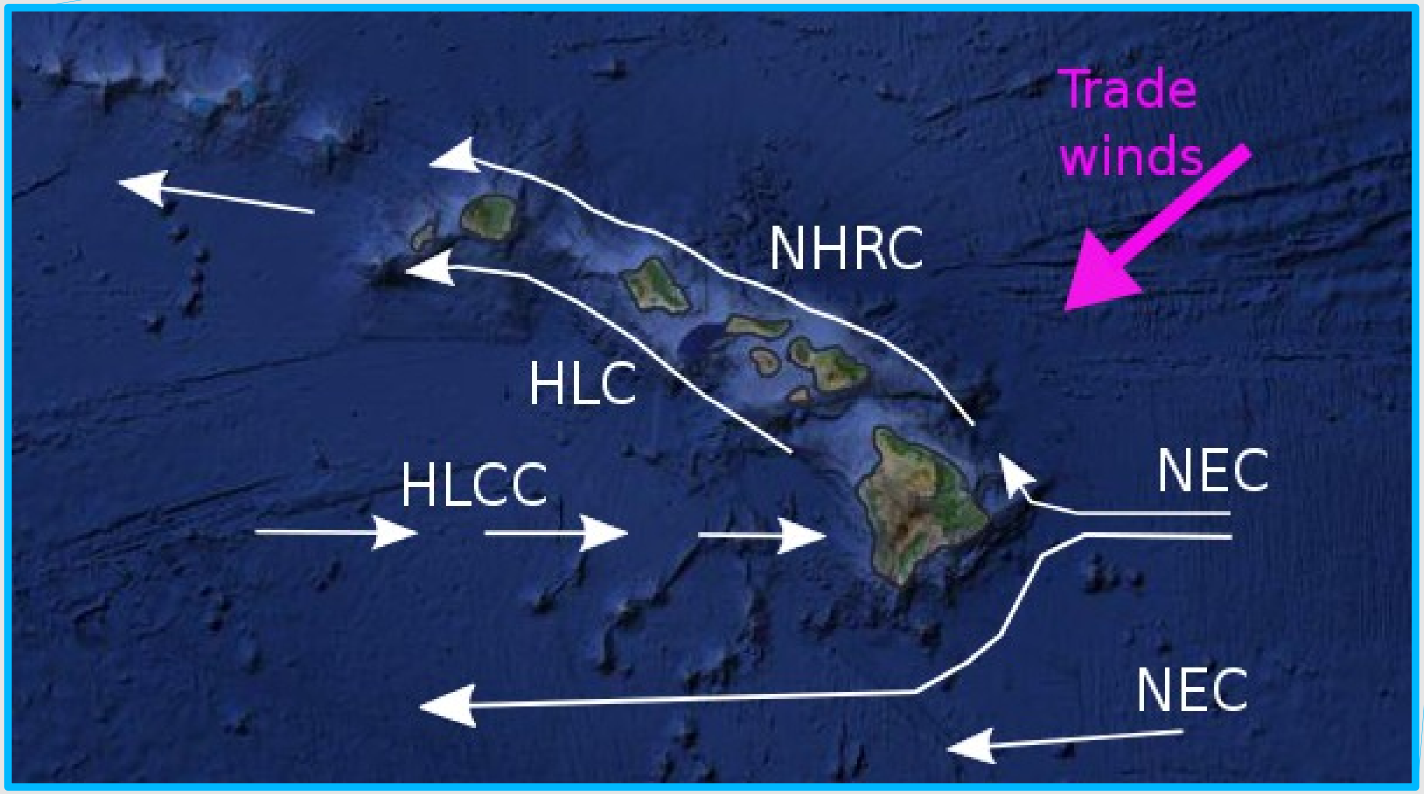
- **Deep ocean** eddies
- **Relative importance** of the external forcings on the **generation of mesoscale eddies**

Gulf of Lion

- **Coastal** eddies
- Process of generation
- Impact of meso- and submesoscale features on **exchanges** and **turbulent mixing**

Hawaiian archipelago

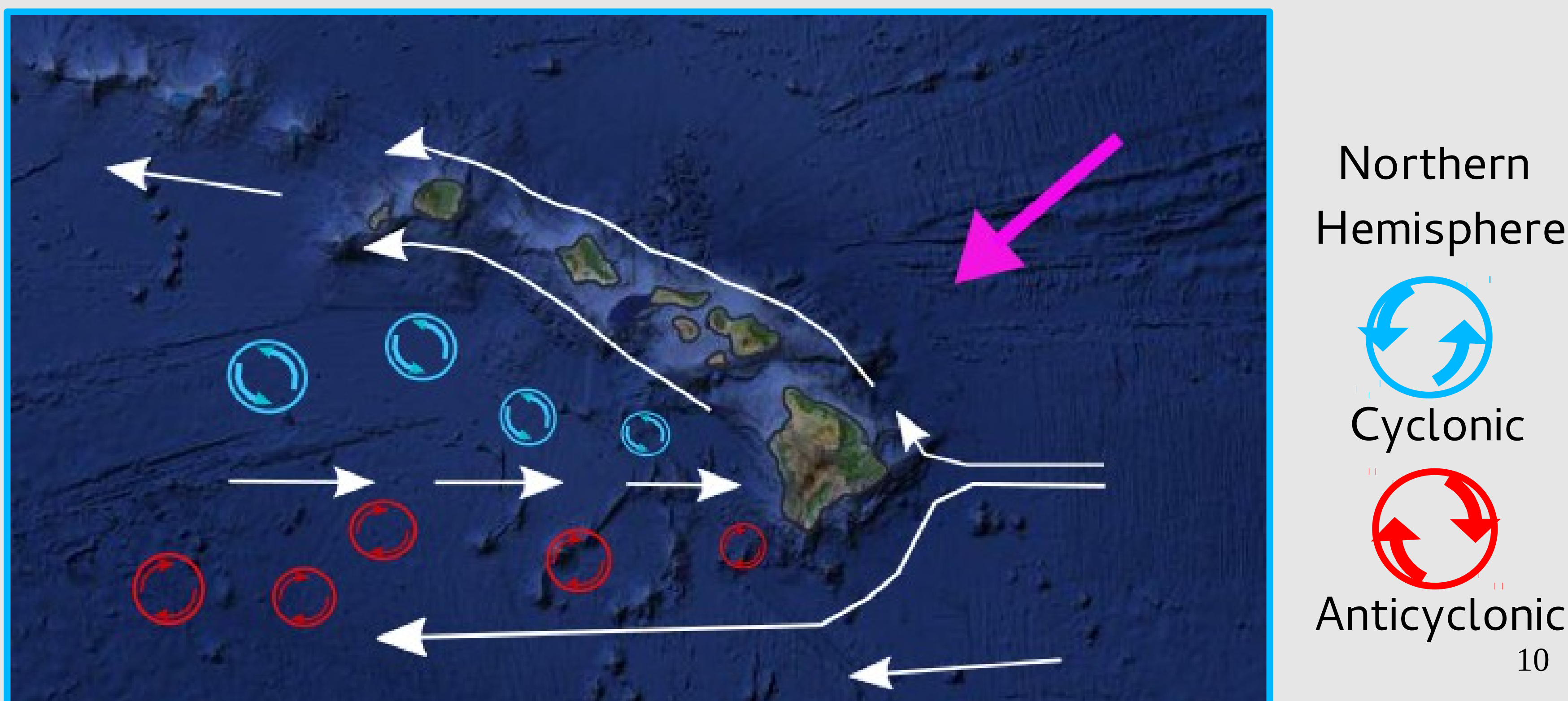
- Complex circulation
- Effects of the archipelago topographic forcing on both the NEC and the trade winds
- The wake is responsible for the formation of the HLCC



Introduction – Area of study I

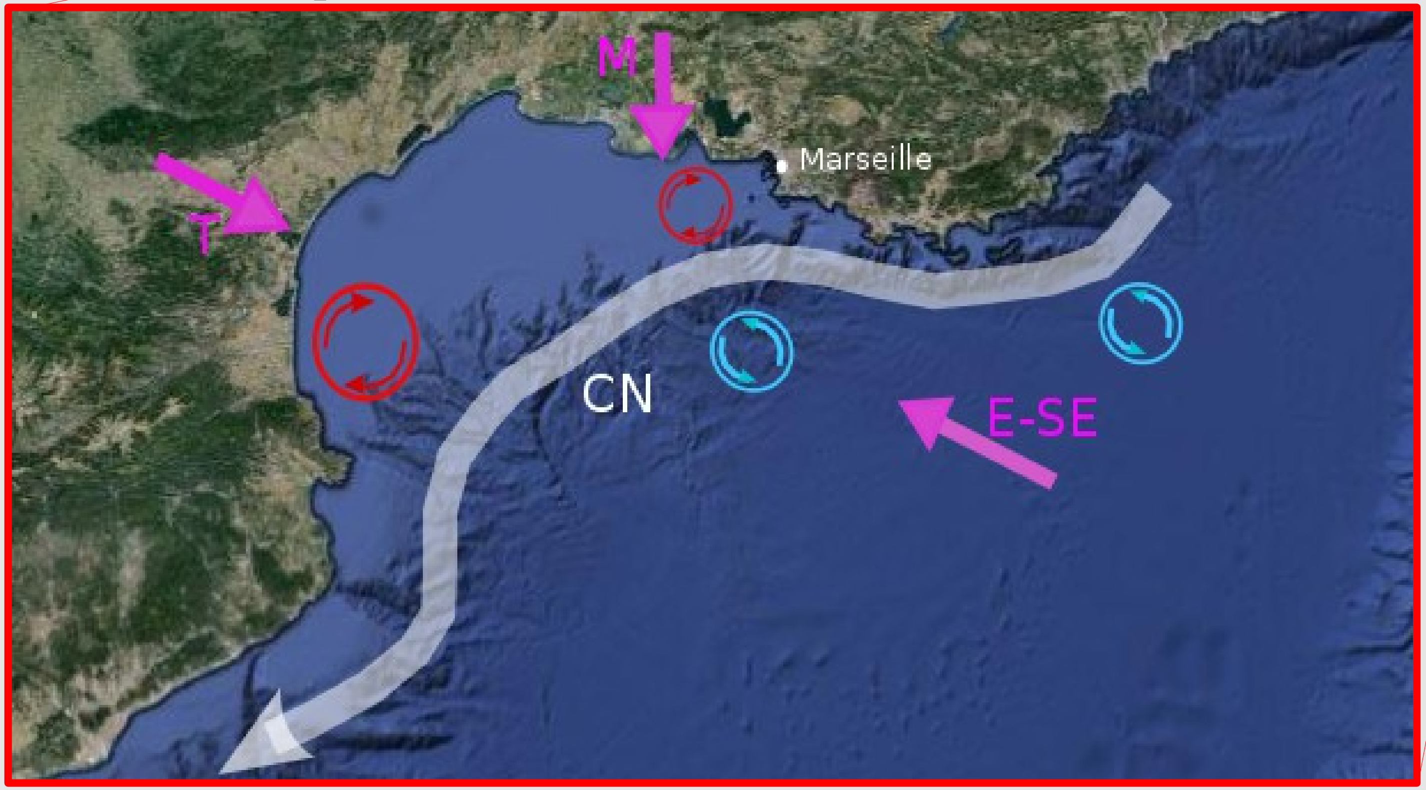
Mesoscale activity in the lee of the islands

- Cyclonic/Anticylonic eddies North/South the HLCC *[Lumpkin, 1998]*
- Classical mechanism of formation of eddies in the lee of an obstacle
- The wind stress variations drive divergent and convergent Ekman transports in the upper layer of the ocean *[Patzert, 1969; Chavanne, et al., 2002]*



Gulf of Lion (GoL)

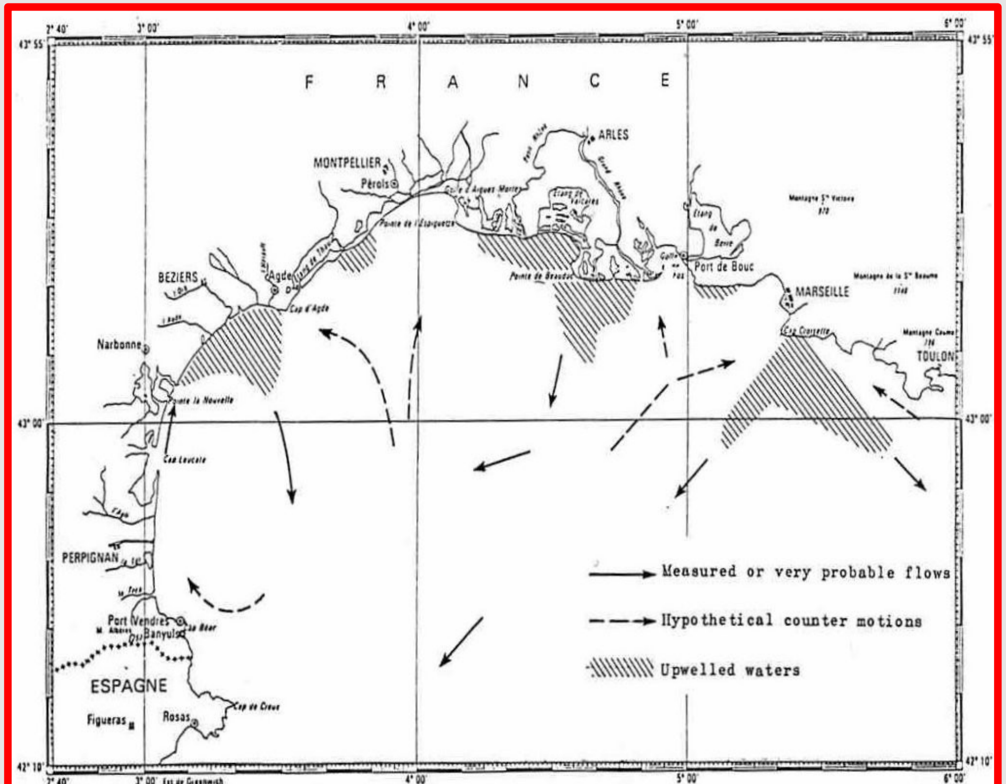
- Hydrodynamics complex and highly variable *[Millot, 1990]*
- Influenced by the NC effective dynamical barrier
- Recurrent generation of mesoscale eddies [Petrenko, 2003; Hu et al., 2009; Allou et al., 2010; Schaeffer et al., 2011]



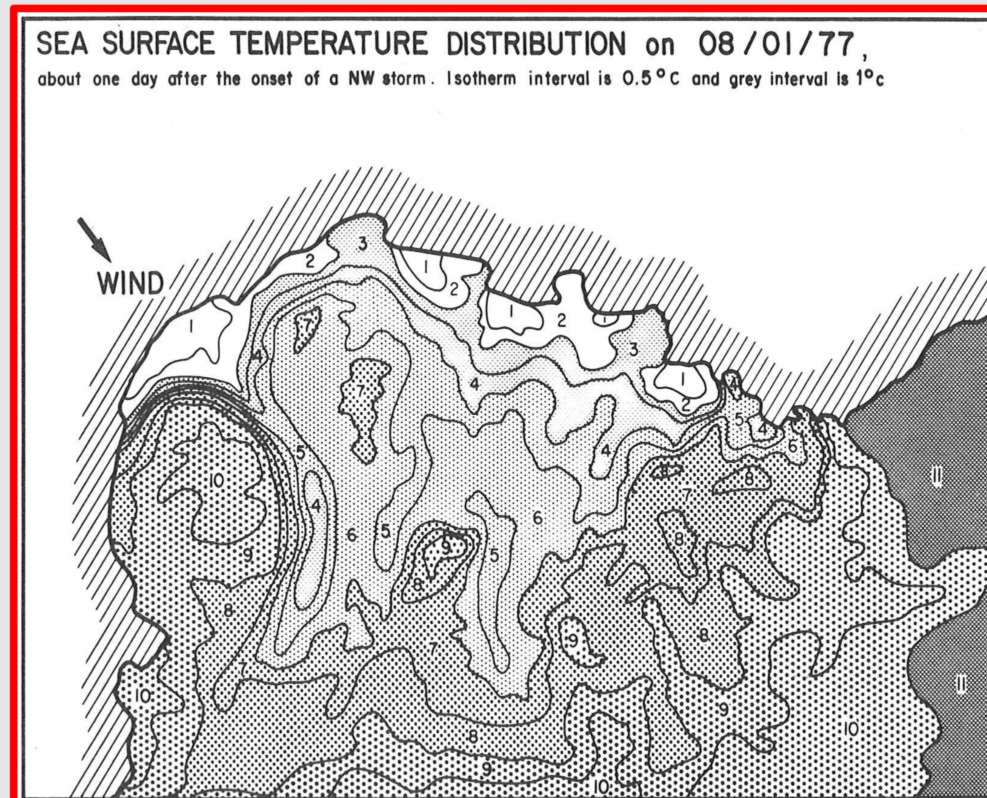
Mesoscale activity in the western part of the GoL

- First observation of an anticyclonic circulation
- LATEX (**LA**grangian **Tr**ansport **Ex**periment) Project

  Understand influence of coastal mesoscale eddies



Scheme of the circulation using mooring data [Millot, 1979]



Sea Surface Temperature Images (SST) [Millot, 1982]

Plan

Part I – Tools for study mesoscale features

Numerical codes
In situ experiments
} Strategies

Part II – Characteristics of mesoscale eddies

Eddy center detection
Horizontal characteristics
Vertical characteristics

Part III – Forcings and generation

Forcing sensitivity – Wind sensitivity
Process of generation
Generation of submesoscale structures
Impact on coast-offshore exchanges

Part IV – Study of turbulent mixing

In situ experiment
Calculation of diffusion coefficients
Lagrangian experiment

Conclusion & perspectives

Mesoscale activity

Submesoscale

Turbulence

Plan

Part I – Tools for study mesoscale features

- Numerical codes
- In situ experiments

} Strategies

Part II – Characteristics of mesoscale eddies

- Eddy center detection
- Horizontal characteristics
- Vertical characteristics

Part III – Forcings and generation

- Forcing sensitivity – Wind sensitivity
- Process of generation
- Generation of submesoscale structures
- Impact on coast-offshore exchanges

Part IV – Study of turbulent mixing

- In situ experiment
- Calculation of diffusion coefficients
- Lagrangian experiment

Conclusion & perspectives

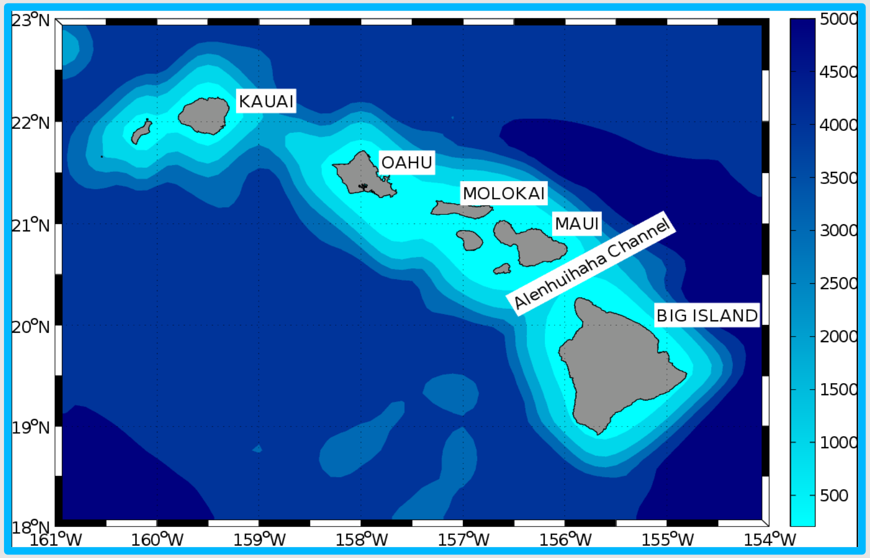
Mesoscale activity

Submesoscale

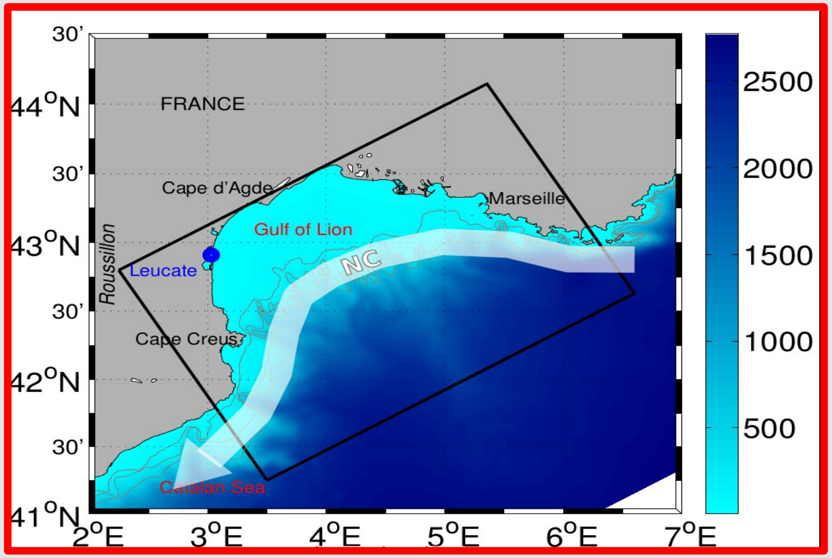
Turbulence

Part I – Numerical codes

Hawaiian archipelago – ROMS



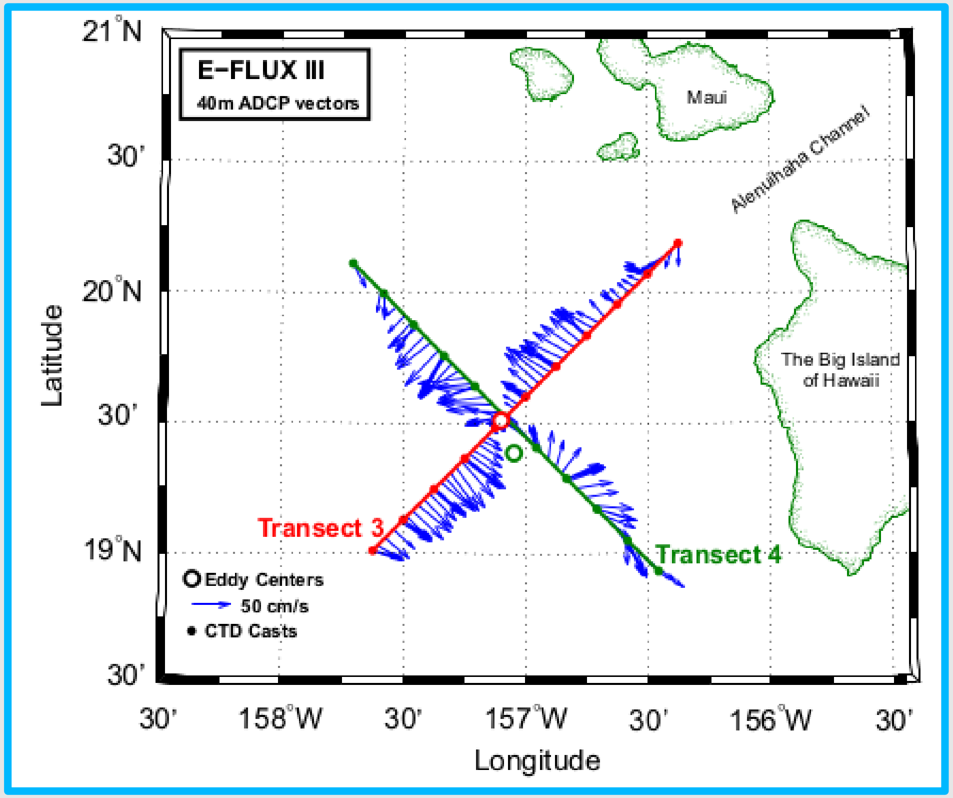
Gulf of Lion – Symphonie



Model domains with realistic bathymetry [m]

	ROMS	Symphonie
Type	Climatology – 10 years	Realistic – Year 2009
Resolution	1/10° (~10km)	1km
Horizontal grid	Arakawa C	
Vertical grid	30 Sigma	40 sigma-z hybrid
Bathymetry	ETOPO	EPSHOM
Closure Scheme	Large et al. [1994]	Gaspar et al. [1990]
Atmospheric forcings	COADS/QuikSCAT	Météo-France Aladin
Boundaries	Radiation BC - WOA	Radiation BC - MFS
Initialization	WOA	Restart Hu et al. [2009]

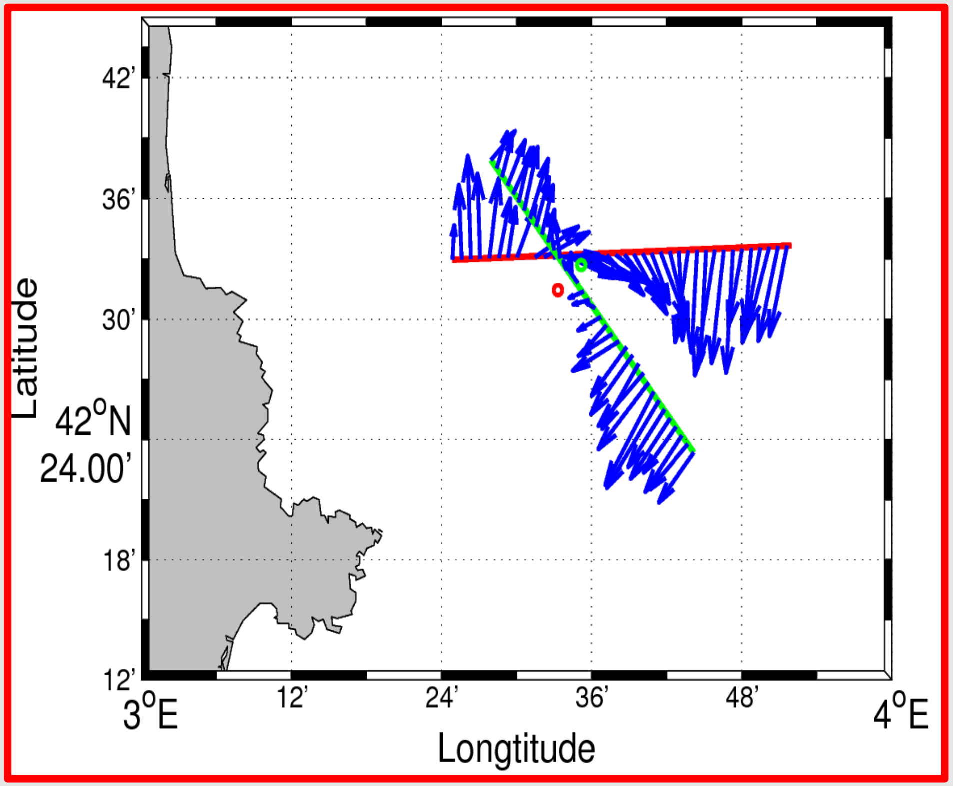
Hawaiian archipelago – E-Flux III
March 10–27, 2005



ADCP current vectors at 40m depth [Nencioli et al., 2008]

- Sampling of a cyclonic mesoscale eddy: **Opal** [Dickey et al., 2008]

Gulf of Lion – Latex09 campaign
August 24–28, 2009



ADCP current vectors at 15m depth

- Sampling of an anticyclonic mesoscale eddy: **Latex-09 eddy**

Part I – Strategies

Hawaiian archipelago

Climato. forcings

Wind *Topo* *Currents*

In situ data

Model

Opal characteristics ⟷ Numerical eddies characteristics

Validate the model and find the best set up

What is the **relative importance** of the forcings on the **generation of mesoscale eddies?**

Gulf of Lion

Realistic forcings
Year 2009

In situ data

Model

Latex-09 characteristics ⟷ Numerical eddy characteristics

Find a similar numerical eddy at the same period

What is the **generation process** of the Latex-09 eddy?

Plan

Part I – Tools for study mesoscale features

- Numerical codes
- In situ experiments

Strategies

Part II – Characteristics of mesoscale eddies

- Eddy center detection
- Horizontal characteristics
- Vertical characteristics

Part III – Forcings and generation

- Forcing sensitivity – Wind sensitivity
- Process of generation
- Generation of submesoscale structures
- Impact on coast-offshore exchanges

Part IV – Study of turbulent mixing

- In situ experiment
- Calculation of diffusion coefficients
- Lagrangian experiment

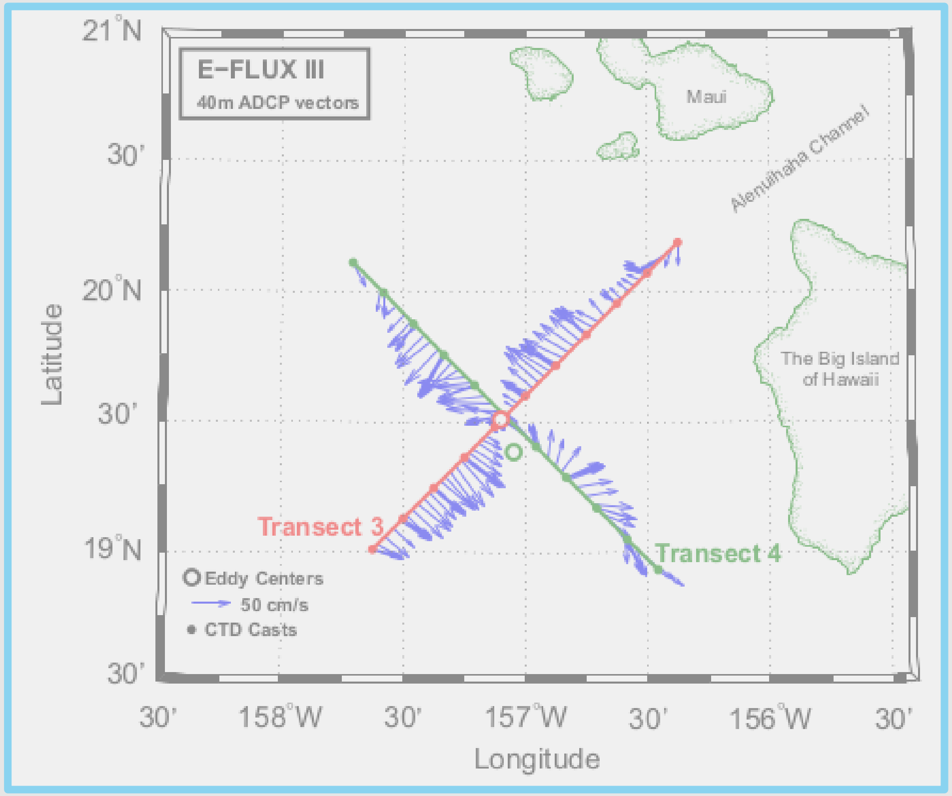
Conclusion & perspectives

Mesoscale activity

Submesoscale

Turbulence

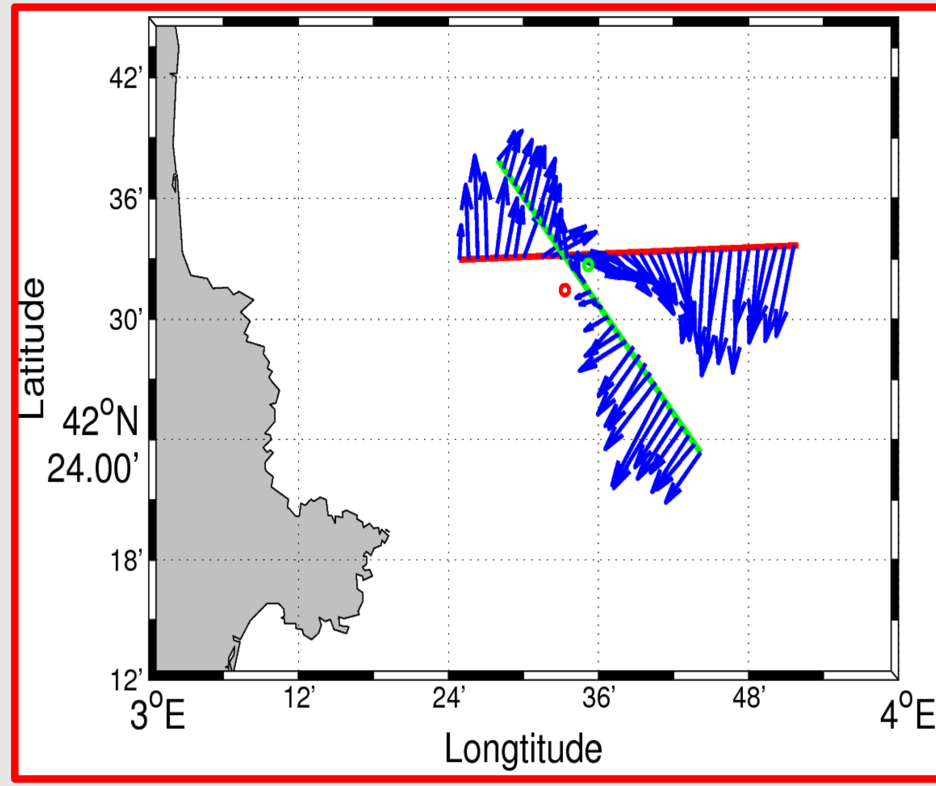
Hawaiian archipelago – E-Flux III
March 10–27, 2005



ADCP current vectors at 40m depth [Nencioli et al., 2008]

- Sampling of a cyclonic mesoscale eddy: **Opal** [Dickey et al., 2008]

Gulf of Lion – Latex09 campaign
August 24–28, 2009



ADCP current vectors at 15m depth

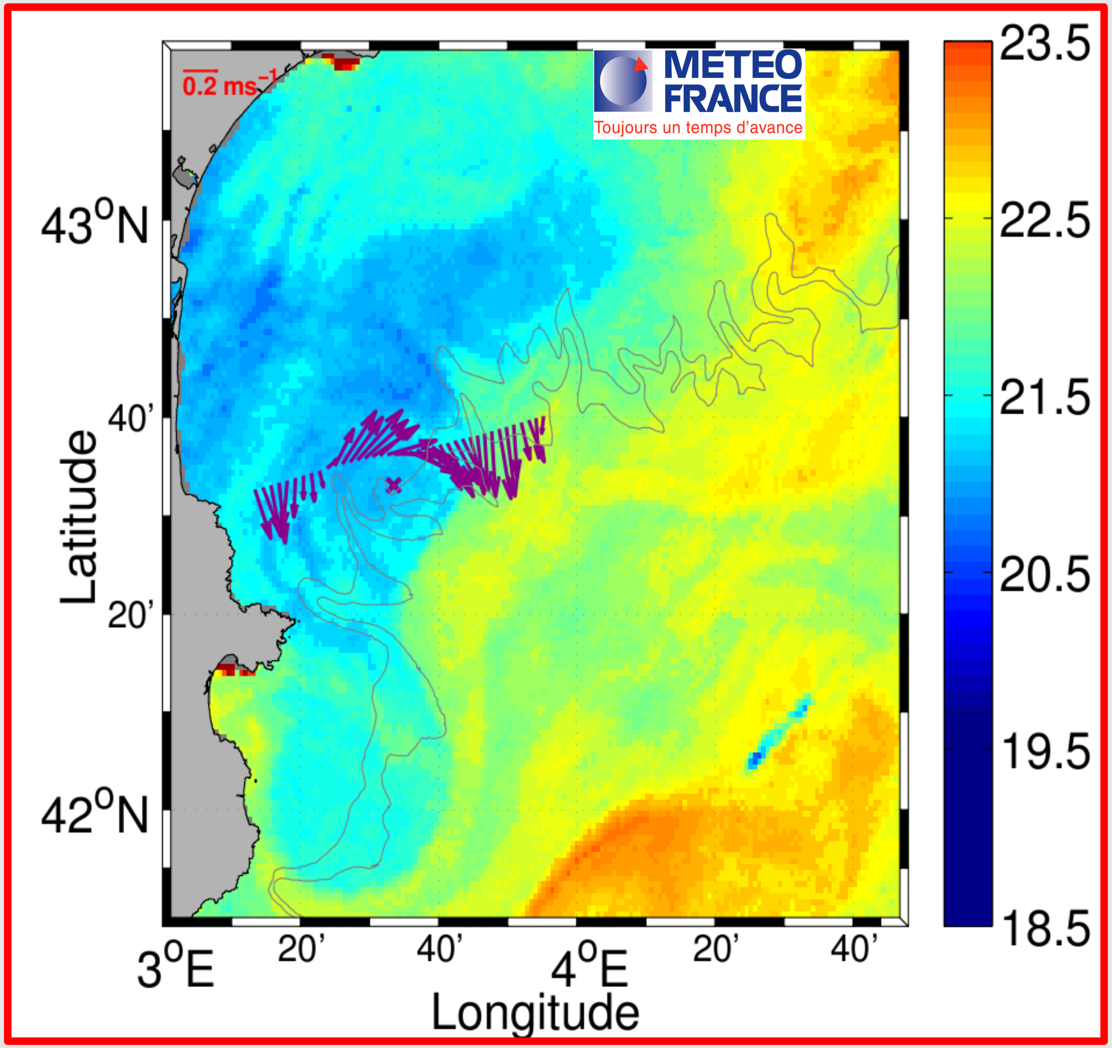
- Sampling of an anticyclonic mesoscale eddy: **Latex-09 eddy**
- Ships, surface drifters, and satellite sensors

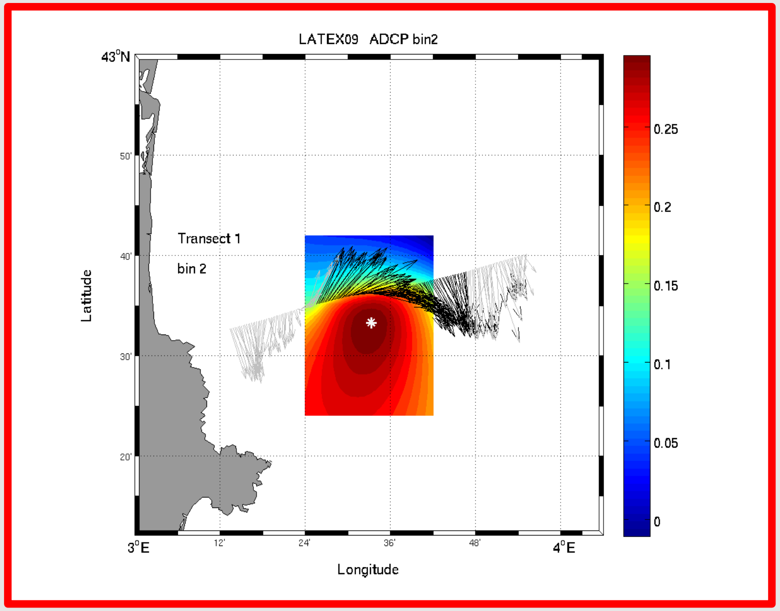
Eddy center detection

Transect 1

Latex09 campaign

ADCP 15m depth – SST (°C) August 28





Center of the eddy :

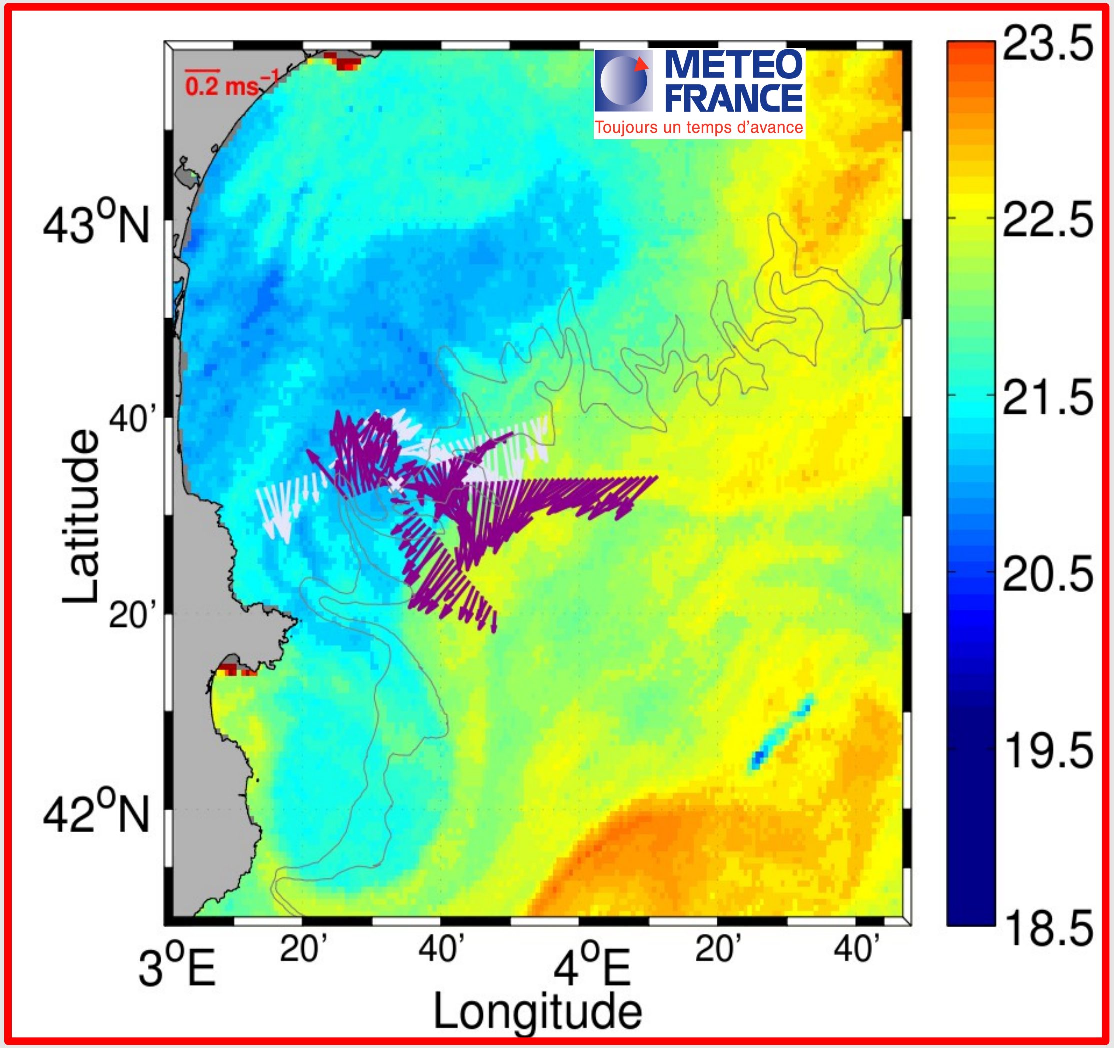
Grid point for which the mean tangential velocity computed from the nearest ADCP records is maximum [Nencioli et al., 2008]

Horizontal Characteristics

Latex09 campaign

ADCP 15m depth – SST (°C) August 28

Transect 1-2-3-4

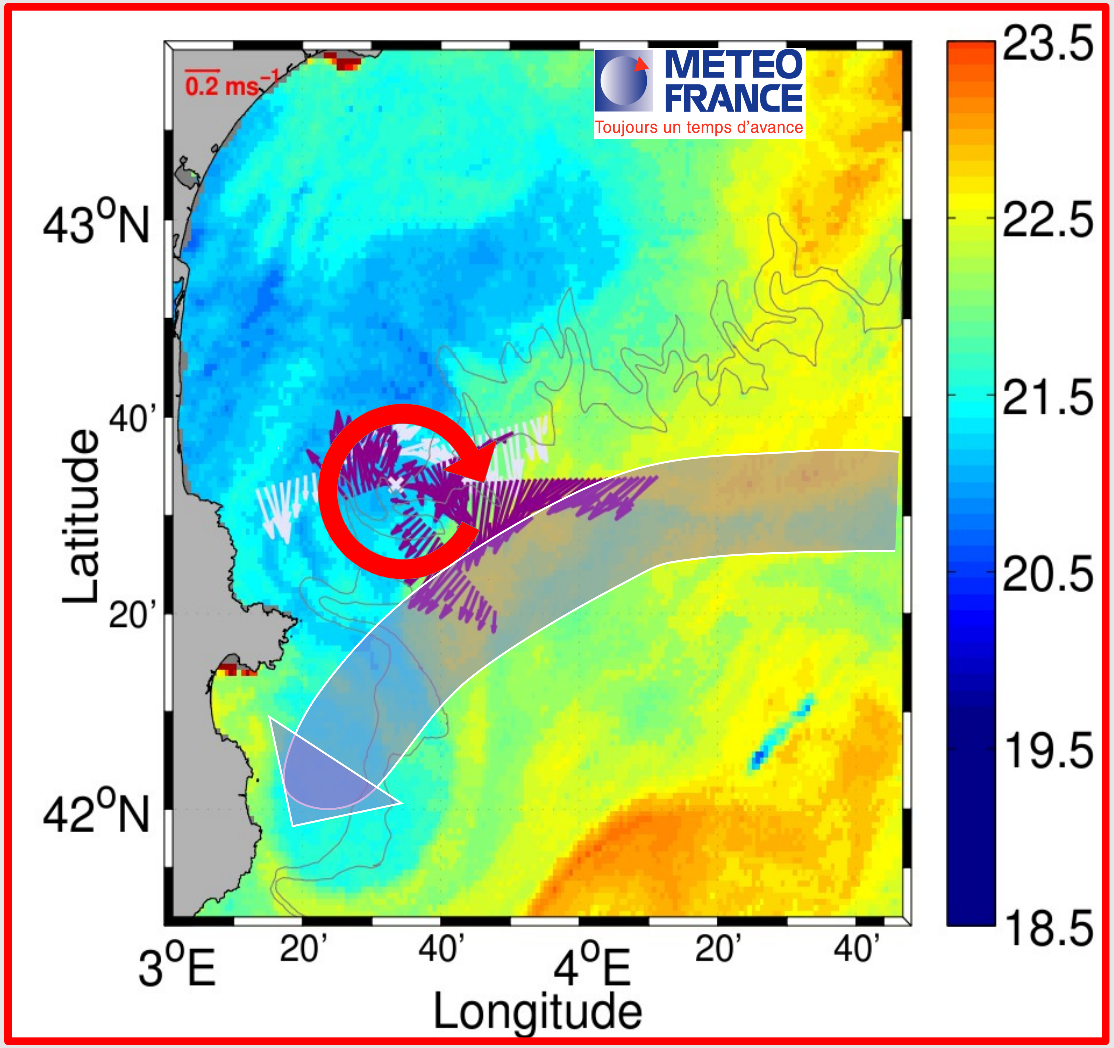


Horizontal Characteristics

Latex09 campaign

ADCP 15m depth – SST (°C) August 28

Transect 1-2-3-4



Anticyclonic circulation

V_{max} ~ 0.4 m.s^{-1}

T ~ 3 days

Center:

3°34'E – 42°33'N

Presence of the NC

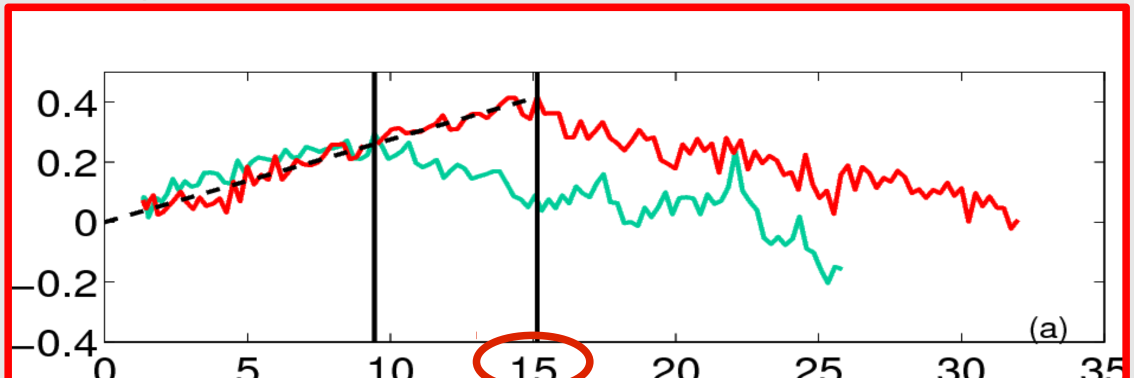
[Kersalé et al., 2013]

Horizontal Characteristics

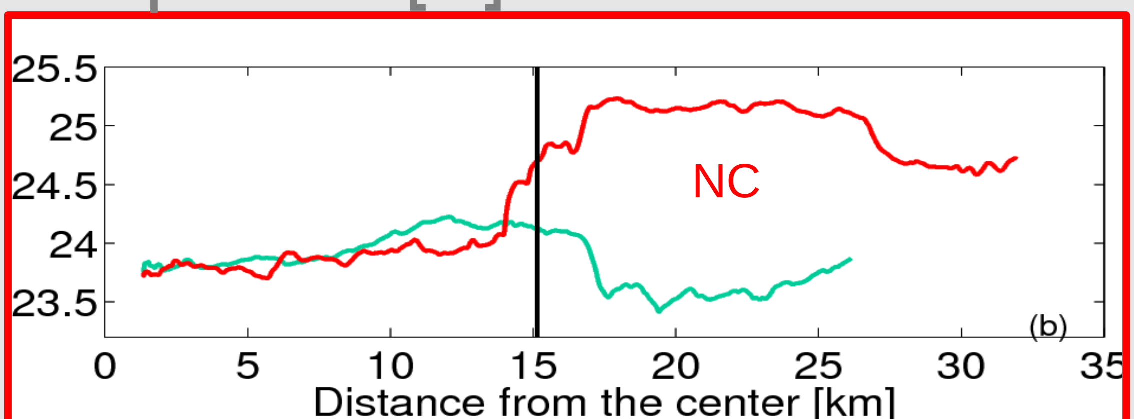
Transect 3

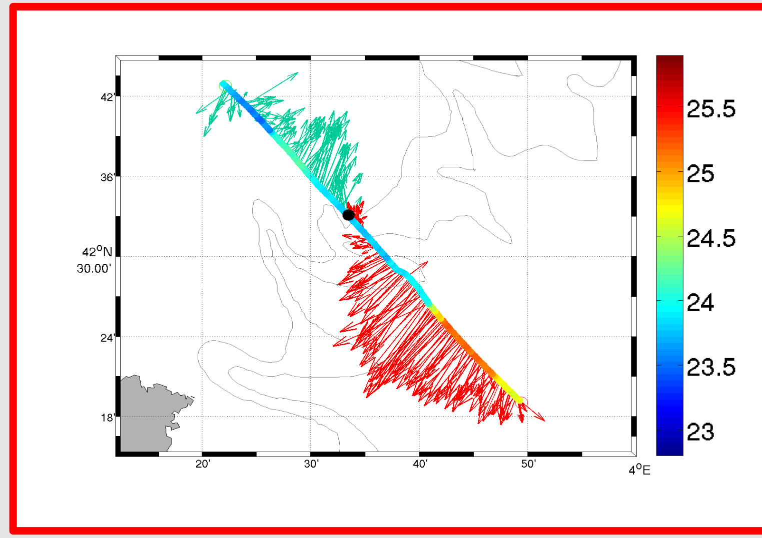
Tangential component decomposition with respect to the position of the center [Nencioli et al., 2008]

Tangential velocity [m s^{-1}]



Temperature [°C]





Latex09 campaign

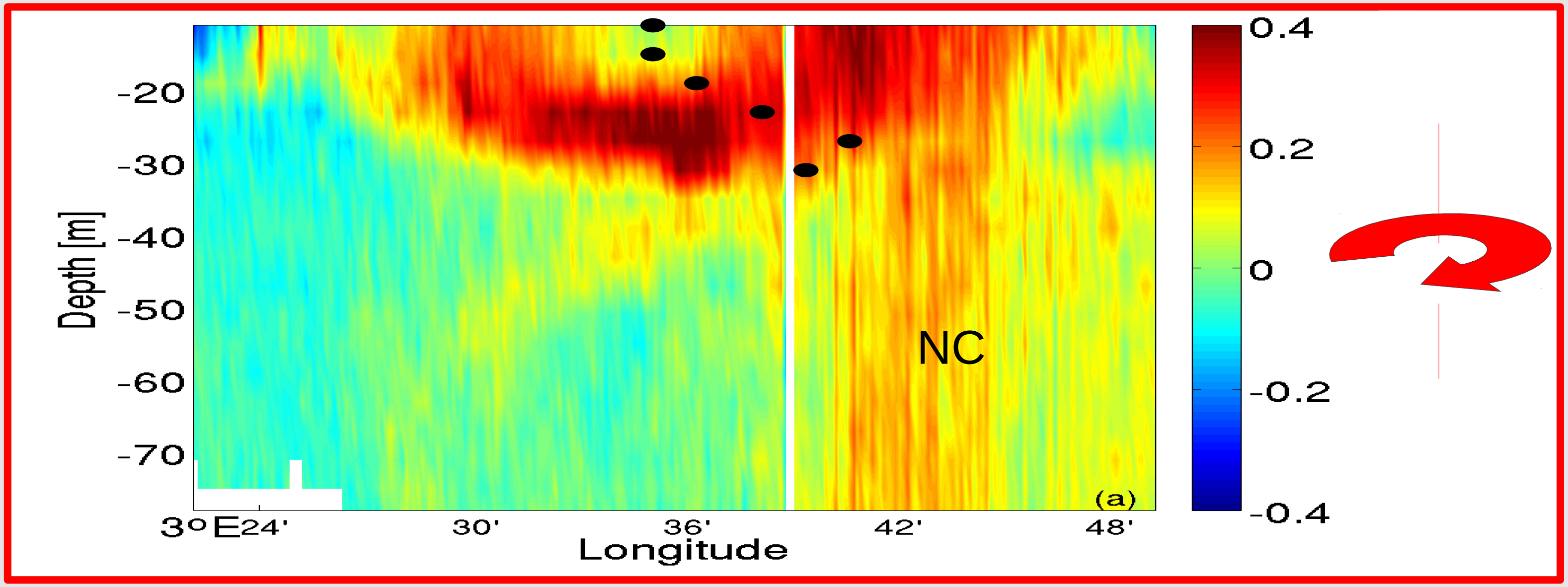
ADCP 15m depth – SST (°C)

$$\mathbf{D}_{\mathbf{eddy}} = \bar{\mathbf{D}} \pm \sqrt{\mathbf{D}_{\mathbf{var}}}$$

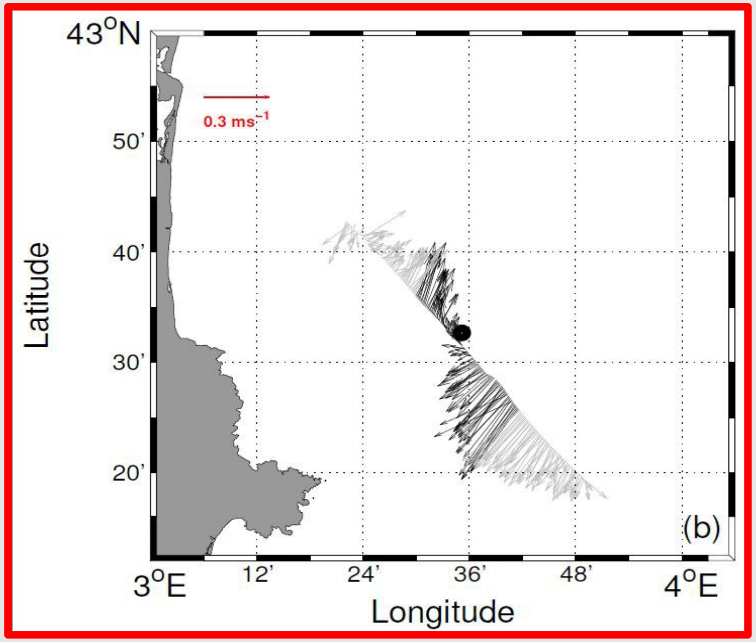
$$\mathbf{D}_{\mathbf{eddy}} = \mathbf{22.7 \pm 1.2\ km}$$

Part II – Characteristics

Vertical Characteristics

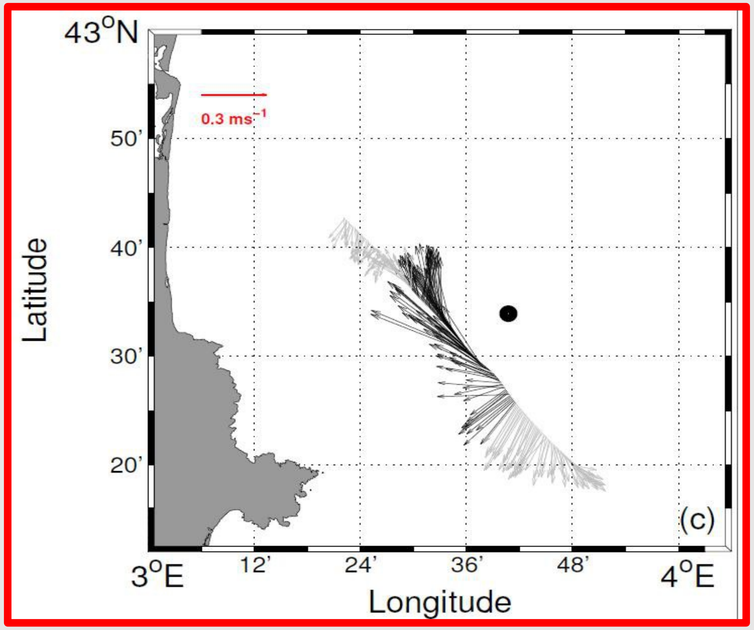


Vertical section of the absolute tangential component of the horizontal current (m s^{-1}) for Transect 3



ADCP current at
15 m depth
27 m depth

Depth $_{max}$
30-35 m



Conclusions – Part II

- Near real- time determination of eddy center

- Local **characterization** of coastal **mesoscale** features

- Horizontal and vertical characteristics

Solid body rotation

Tilted axis of rotation

Plan

Part I – Tools for study mesoscale features

- Numerical codes
- In situ experiments

Strategies

Part II – Characteristics of mesoscale eddies

- Eddy center detection
- Horizontal characteristics
- Vertical characteristics

Part III – Forcings and generation

- Forcing sensitivity – Wind sensitivity
- Process of generation
- Generation of submesoscale structures
- Impact on coast-offshore exchanges

Part IV – Study of turbulent mixing

- In situ experiment
- Calculation of diffusion coefficients
- Lagrangian experiment

Conclusion & perspectives

Mesoscale activity

Submesoscale

Turbulence

Strategies

Hawaiian archipelago

Climato. forcings

Wind *Topo* *Currents*

In situ data

Model

Opal characteristics

Numerical eddies characteristics

Validate the model and find the best set up

What is the **relative importance** of the forcings on the **generation of mesoscale eddies?**

Gulf of Lion

Realistic forcings
Year 2009

In situ data

Model

Latex-09 characteristics

Numerical eddy characteristics

Find a similar numerical eddy at the same period

What is the **generation process** of the Latex-09 eddy?

Relative importance of the forcings

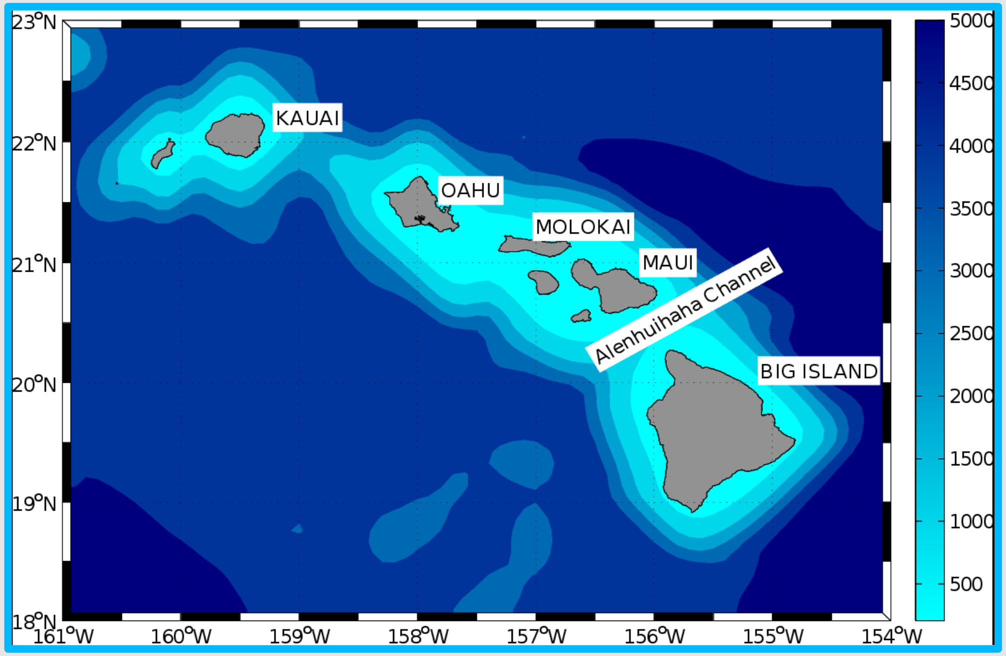
	Wind Forcing	Advection	Drag coeff.
Run-A	none	Ugeo	Cd
Run-B	none	2Ugeo	Cd
Run-C	QuikSCAT	none	Cd
Run-D	QuikSCAT	Ugeo	none

Inadequacies :

Run-A & Run-B (No wind forcing)
Ocean circulation not realistic
Intensity of the eddies is too low

Run-C (No advection)
Stationary eddies- No expected westward drift

Run-D (No Drag. Coeff)
Eddies too large



[Kersalé et al., 2011]

Relative importance of the forcings

	Wind Forcing	Advection	Drag coeff.
Run–A	none	Ugeo	Cd
Run–B	none	2Ugeo	Cd
Run–C	QuikSCAT	none	Cd
Run–D	QuikSCAT	Ugeo	none

Inadequacies :

Run–A & Run–B (No wind forcing)

Ocean circulation not realistic

Intensity of the eddies is too low

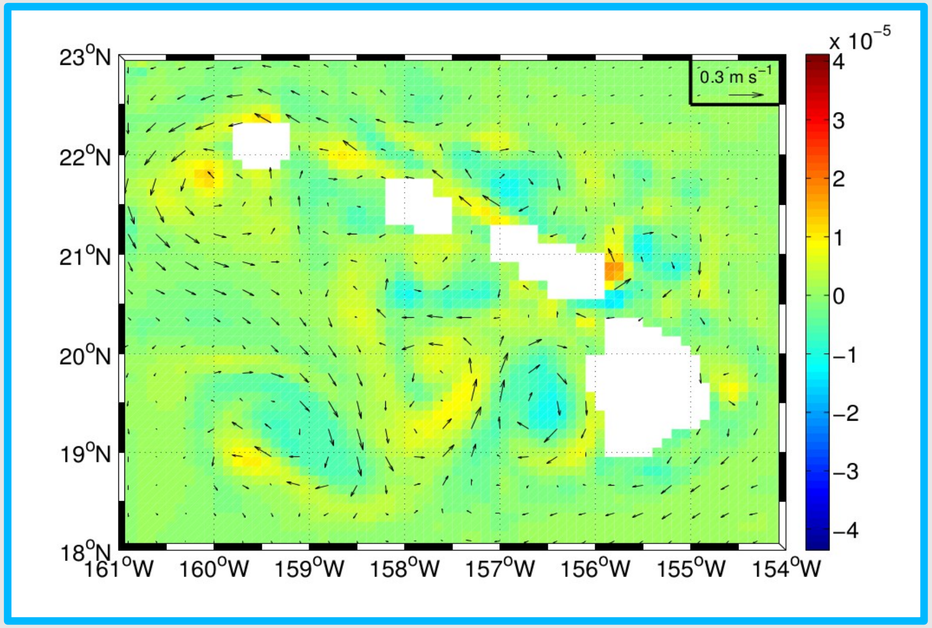
Run–C (No advection)

Stationary eddies- No expected westward drift

Run–D (No Drag. Coeff)

Eddies too large

Relative vorticity field (s^{-1}) at 20m depth



[Kersalé et al., 2011]

Relative importance of the forcings

	Wind Forcing	Advection	Drag coeff.
Run-A	none	Ugeo	Cd
Run-B	none	2Ugeo	Cd
Run-C	QuikSCAT	none	Cd
Run-D	QuikSCAT	Ugeo	none

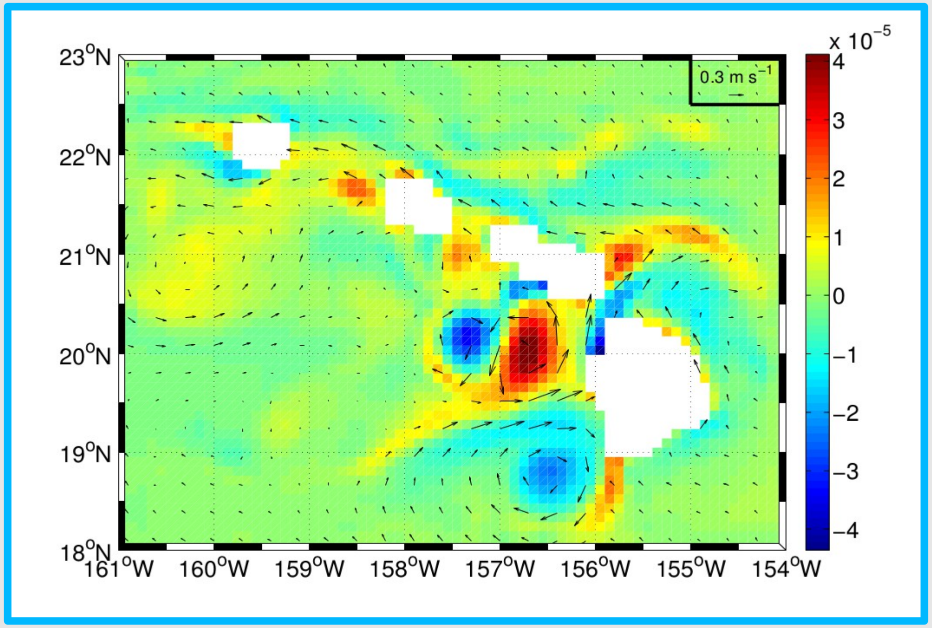
Inadequacies :

Run-A & Run-B (No wind forcing)
Ocean circulation not realistic
Intensity of the eddies is too low

Run-C (No advection)
Stationary eddies- No expected westward drift

Run-D (No Drag. Coeff)
Eddies too large

Relative vorticity field (s^{-1}) at 20m depth



[Kersalé et al., 2011]

Relative importance of the forcings

	Wind Forcing	Advection	Drag coeff.
Run-A	none	Ugeo	Cd
Run-B	none	2Ugeo	Cd
Run-C	QuikSCAT	none	Cd
Run-D	QuikSCAT	Ugeo	none

Inadequacies :

Run-A & Run-B (No wind forcing)

Ocean circulation not realistic

Intensity of the eddies is too low

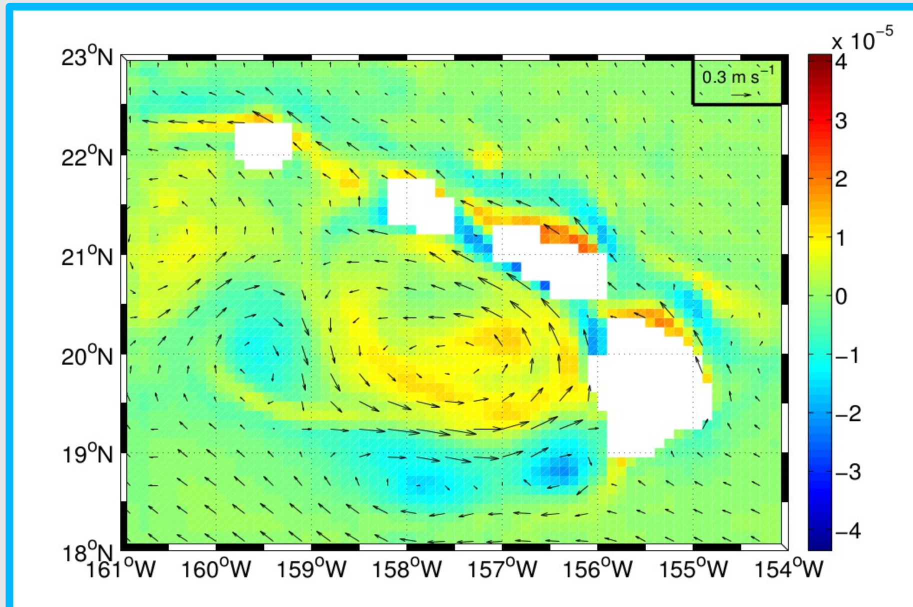
Run-C (No advection)

Stationary eddies- No expected westward drift

Run-D (No Drag. Coeff)

Eddies too large

Relative vorticity field (s^{-1}) at 20m depth

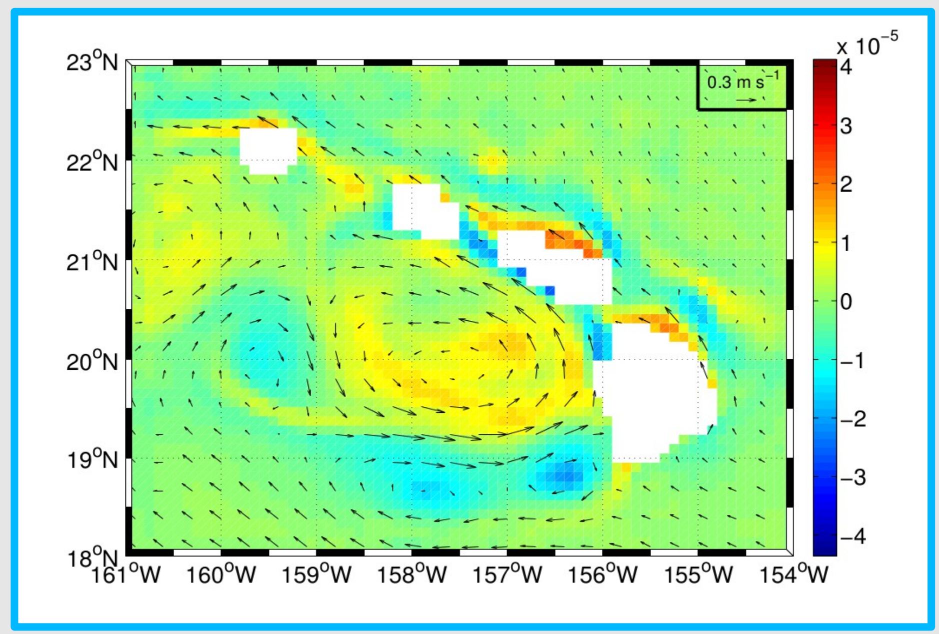


[Kersalé et al., 2011]

Relative importance of the forcings

	Wind Forcing	Advection	Drag coeff.
Run–A	none	Ugeo	Cd
Run–B	none	2Ugeo	Cd
Run–C	QuikSCAT	none	Cd
Run–D	QuikSCAT	Ugeo	none

Relative vorticity field (s^{-1}) at 20m depth



Inadequacies :

Run–A & Run–B (No wind forcing)

Ocean circulation not realistic

Intensity of the eddies is too low

Run–C (No advection)

Stationary eddies- No expected westward drift

Run–D (No Drag. Coeff)

Eddies too large

➡ **Cumulative effect of the three forcings**

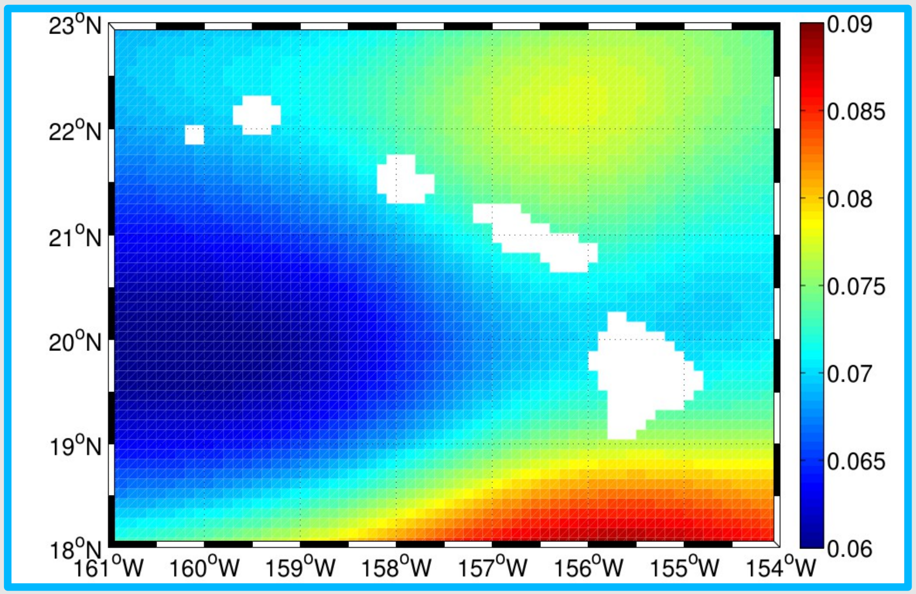
[Kersalé et al., 2011]

Resolution of wind forcing

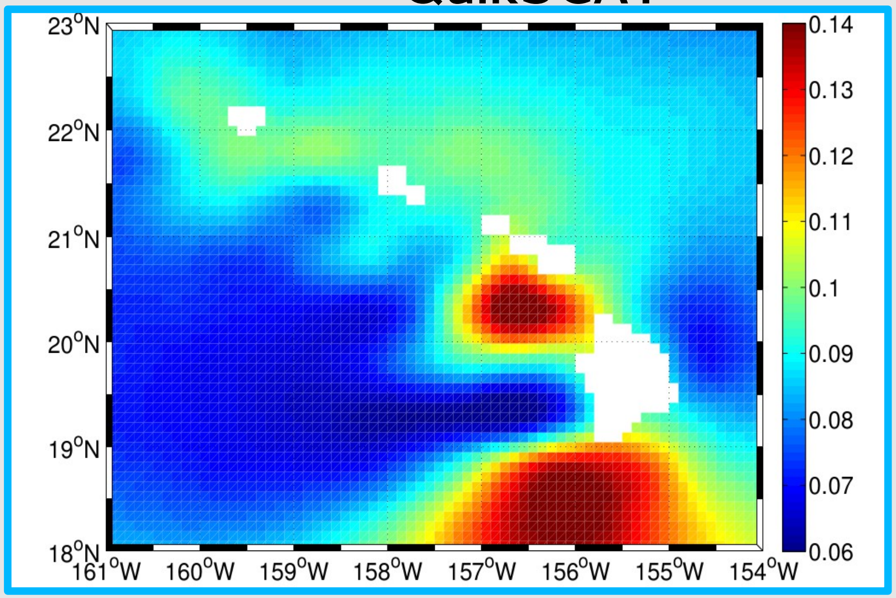
	Wind Forcing	Advection	Drag coeff.
Run–E	**COADS (1/2°)**	Ugeo	Cd
Run–F	**QuikSCAT (1/4°)**	Ugeo	Cd

Performed numerical experiments

COADS



QuikSCAT

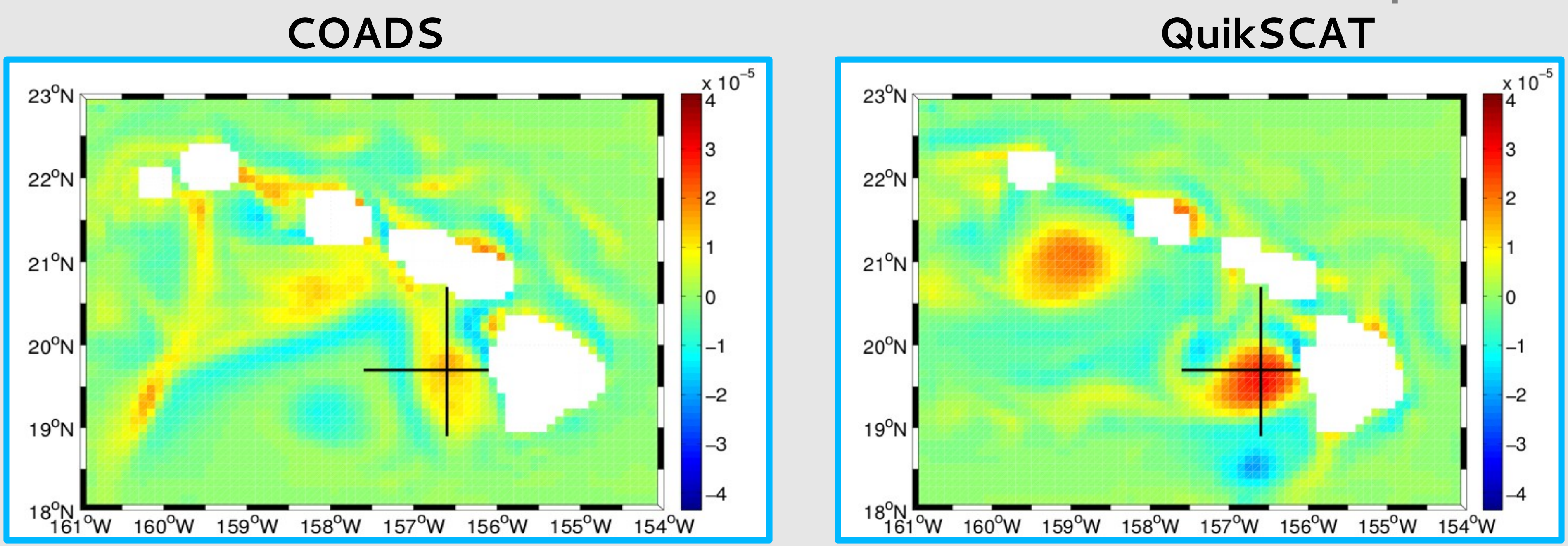


Annually–averaged wind stress values [Nm^{-2}]

Resolution of wind forcing

	Wind Forcing	Advection	Drag coeff.
Run–E	**COADS (1/2°)**	Ugeo	Cd
Run–F	**QuikSCAT (1/4°)**	Ugeo	Cd

Performed numerical experiments

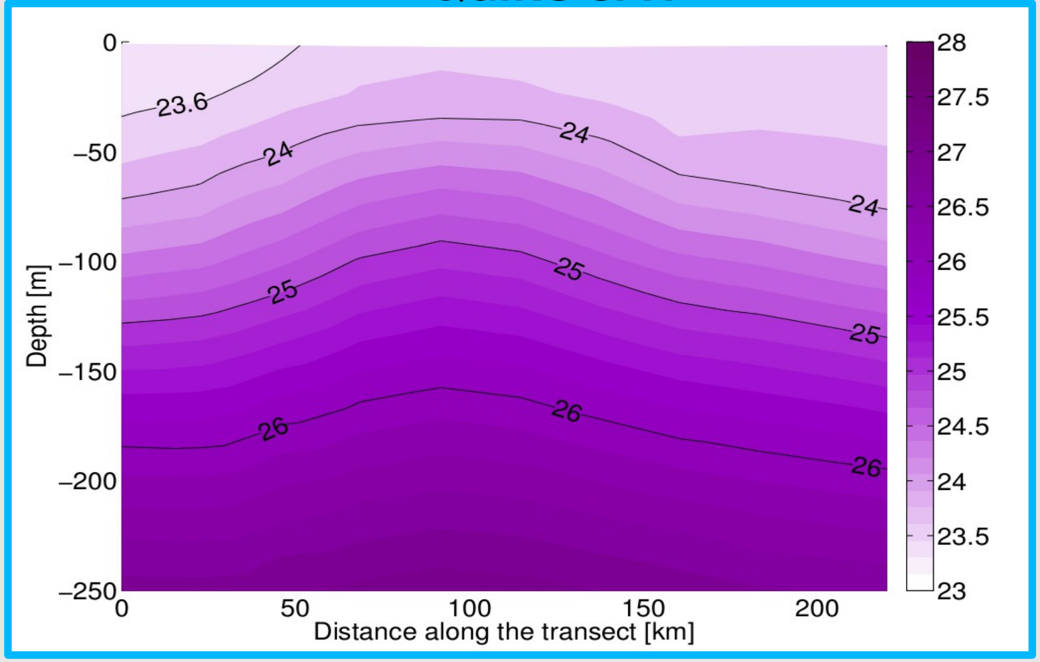


Relative vorticity field (s–1) at 20m depth

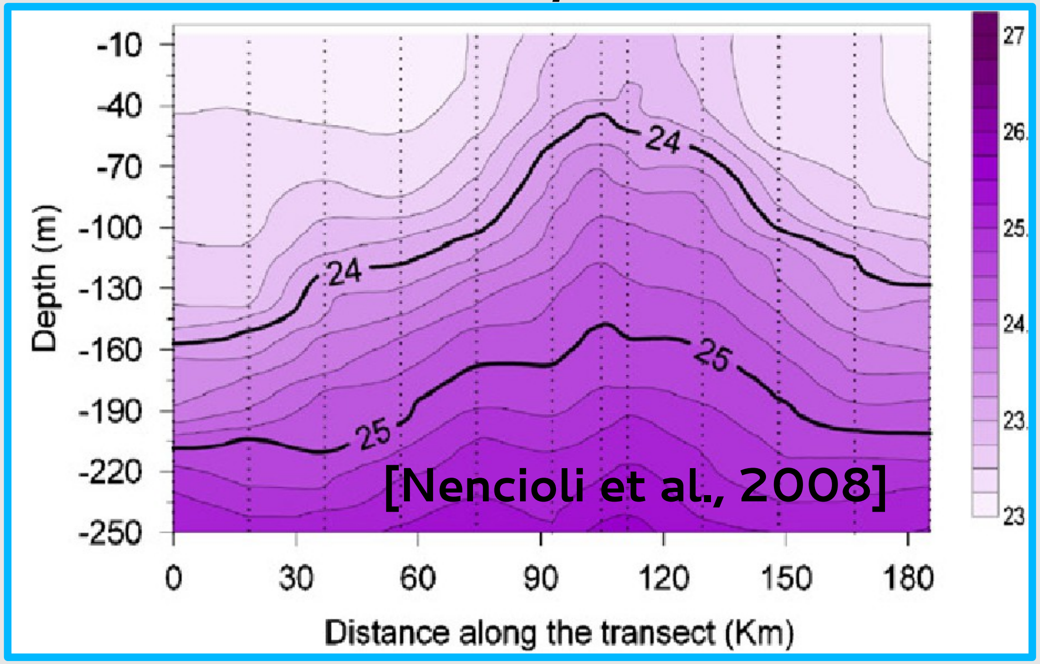
- **Ocean circulation realistic**
- Focus on **numerical cyclones** chosen because they are spatially and temporally representative of **cyclone Opal** studied during the E-FLUX III

Part III – Forcings and generation

QuikSCAT



Opal



Transect of density (kg m^{-3}) + isopycnes

	COADS	QuikSCAT	Opal
Isopycnal outcrop.	$\sigma_{t23.6/23.8}$	$\sigma_{t23.6/23.8}$	$\sigma_{t23.6}$
Depth impact (m)	130±70	>250	>250
Diameter (km)	180±20	180±30	180-200
Velocity (m s^{-1})	0.3±0.05	0.53±0.09	0.6

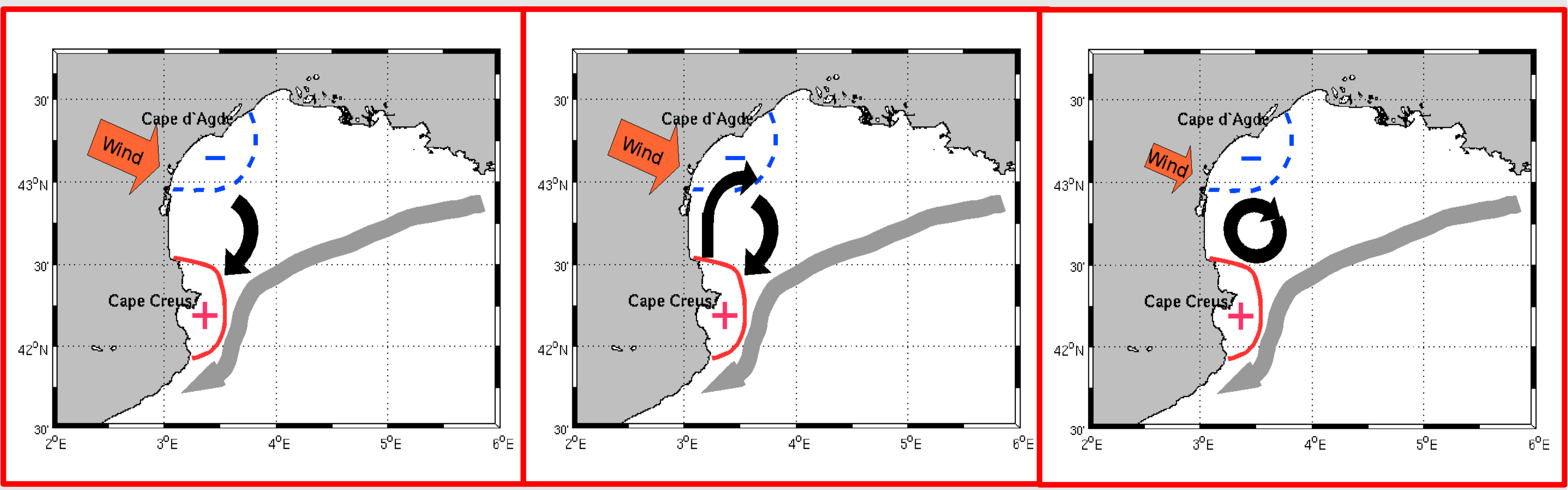
Good representation of mesoscale features in the simulation forced by QuikSCAT

➡ **Importance of wind-forcing spatial resolution**

Hypothesis of generation

Mesoscale eddies in the western part of the GoL
2001-2008 [Hu et al., 2011]

2 conditions : → Persistent & strong northwest wind
→ Strong stratification



Process of generation
[Hu et al., 2011]

Strategies

Hawaiian archipelago

Climato. forcings

Wind *Topo* *Currents*

In situ data

Model

Opal characteristics

Numerical eddies characteristics

Validate the model and find the best set up

What is the **relative importance** of the forcings on the **generation of mesoscale eddies?**

Gulf of Lion

Realistic forcings
Year 2009

In situ data

Model

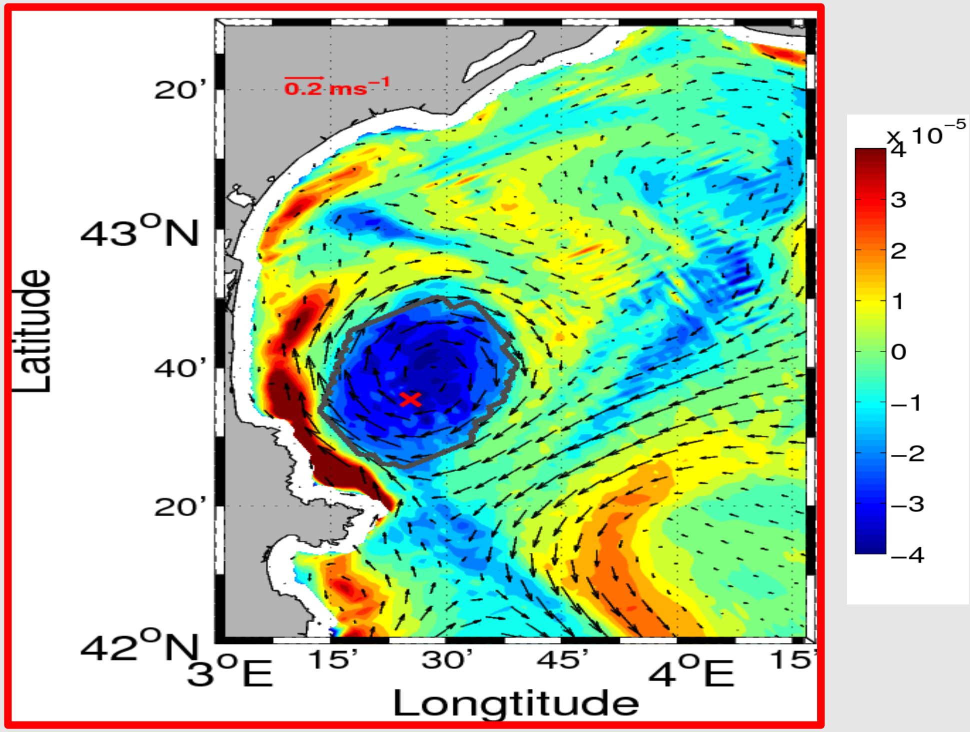
Latex-09 characteristics

Numerical eddy characteristics

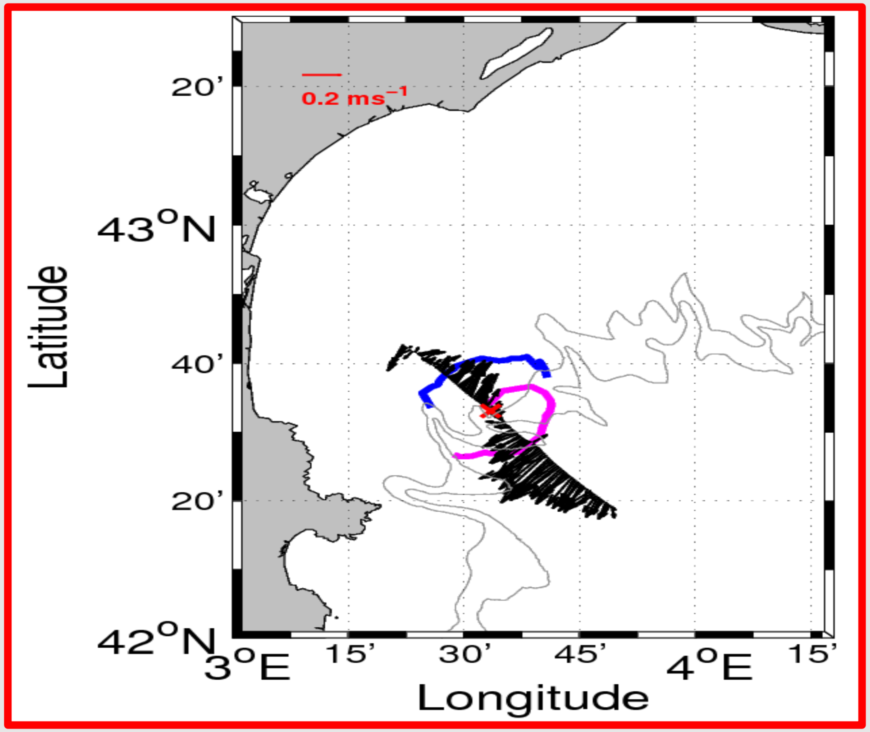
Find a similar numerical eddy at the same period

What is the **generation process** of the Latex-09 eddy?

Part III – Forcings and generation



Eddy detected by wavelet analysis [Doglioli et al., 2007] – Relative vorticity [s^{-1}] 15m depth August 27



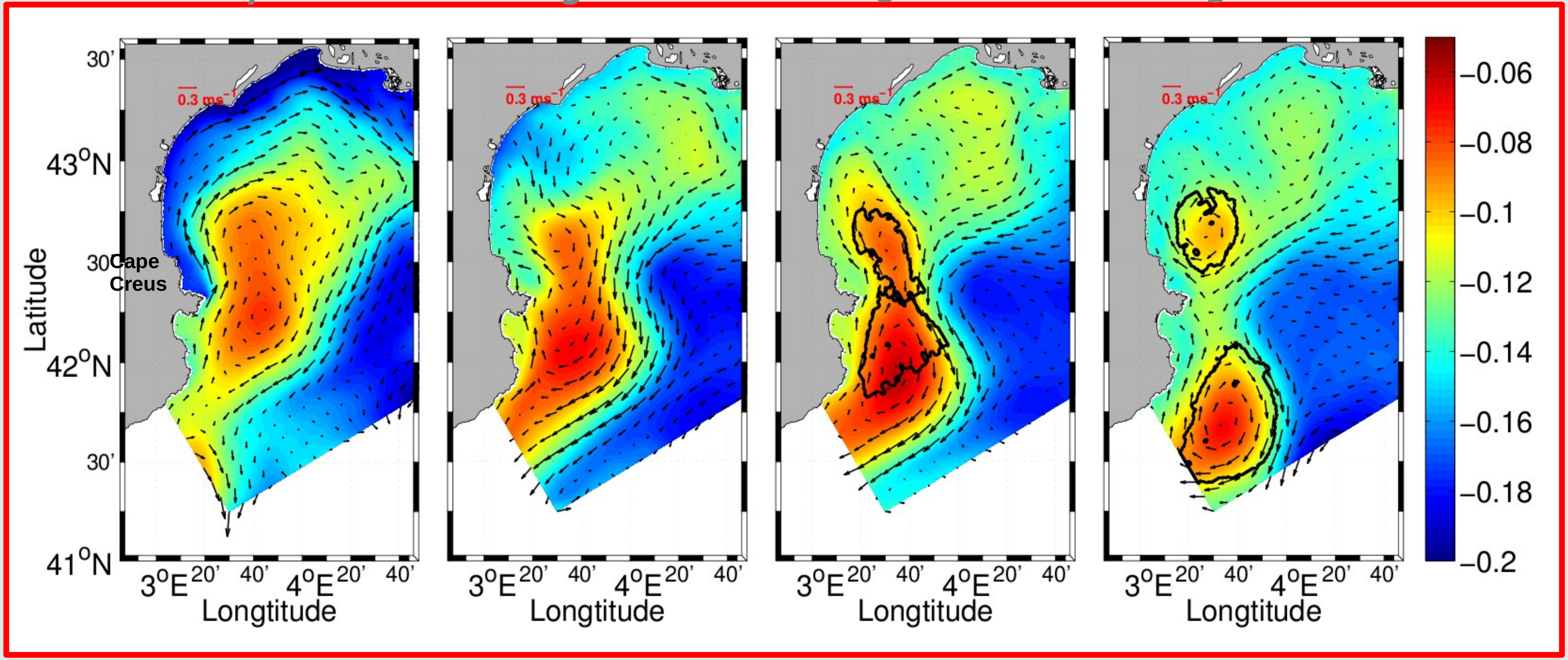
Latex09 ADCP data August 27 +Buoys from August 26–29

	Model	Data
Center	3°26'E – 42°36'N	3°34'E – 42°33'N
Depth impact (m)	37	35
Diameter (km)	28.6±1.4	22.7±1.2

➡ **Similar eddy found in the numerical results**

Eddy Generation Process

July 20 August 8 August 16 August 27



Eddies detected by wavelet analysis – Sea Surface Height [m]

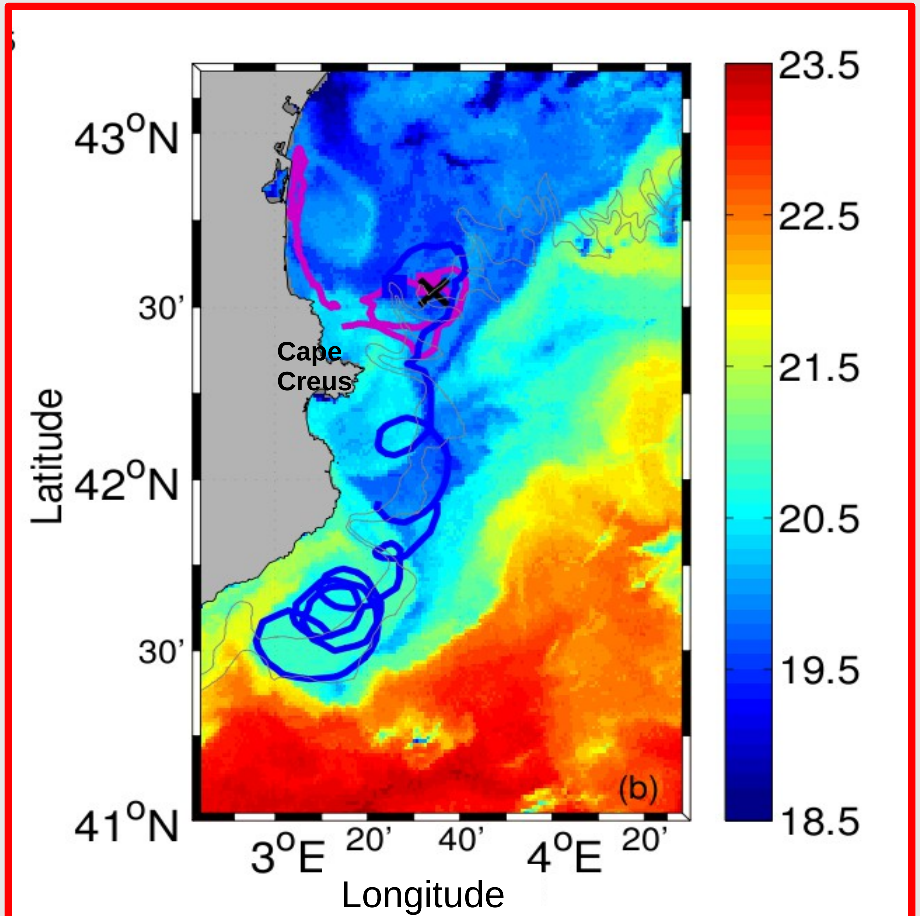
- Pushing and squeezing of an anticyclonic circulation between a meander of the NC and the coast
- Separation in two structures

New Generation Process of the Latex-09 eddy

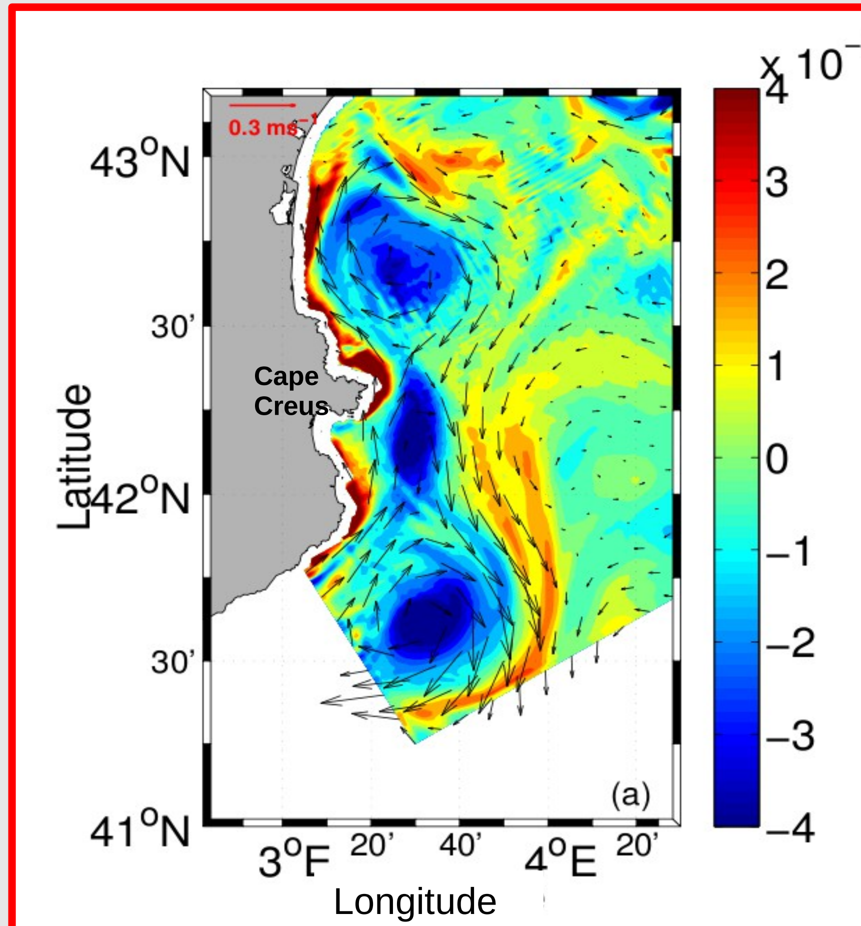
[Kersalé et al., 2013]

Post Generation dynamics

Latex09 feeds the Catalan eddy



SST (°C) September 12
+Buoys from August 26– September 12

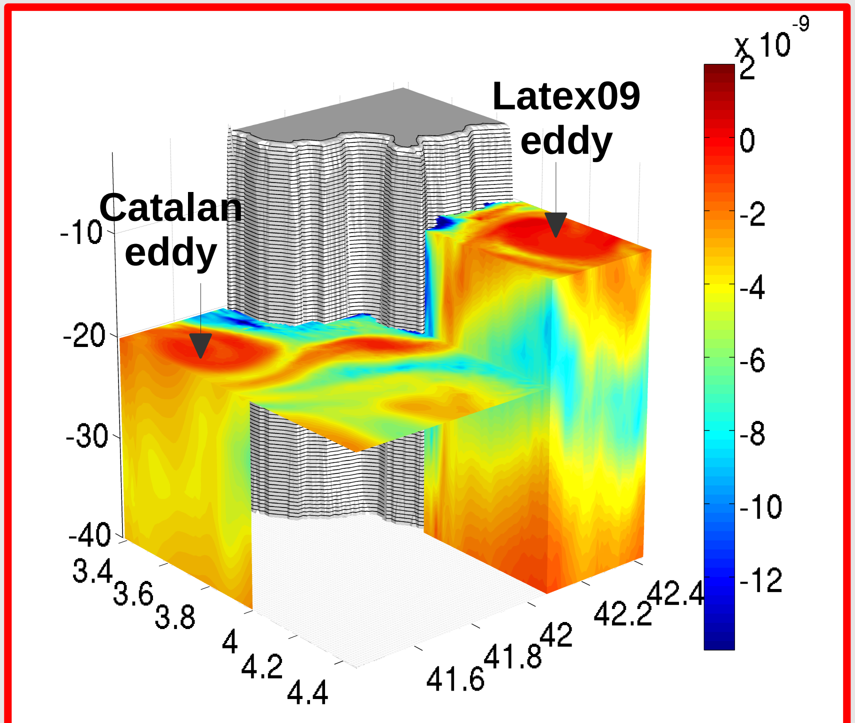


Relative vorticity [s^{-1}]
20m depth September 3

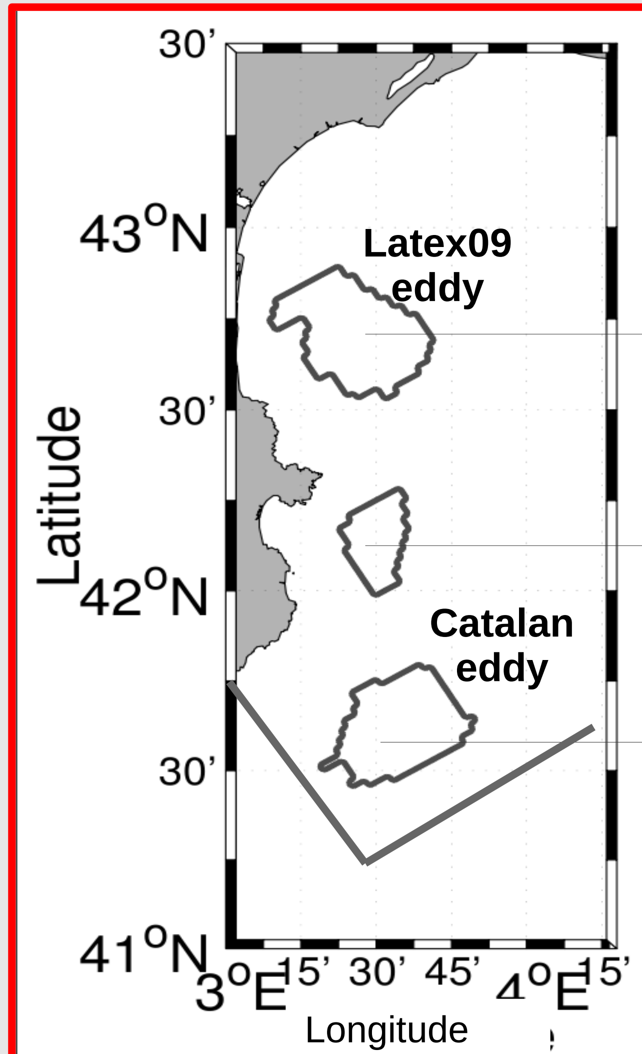
Drifter trajectories explained by the generation of a submesoscale transient structure

Latex09 – Loss of mass

Potential vorticity [kg.m^{-4}.s^{-1}] in 3D on September 3



Eddies detected by wavelet analysis



Loss of mass 41%

33% of the Latex09 eddy's mass

Gain of mass?

Interactions between the two eddies lead to a transfer of mass and vorticity from the GoL to the Catalan shelf

Conclusions – Part III

- **Cumulative** effects of external forcings
- Importance of **wind** forcing **resolution**

Synergy of model results and *in situ* data

- New **generation process** of eddies

  in the western part of the Gulf of lion
- **Observation** of transient **submesoscale** structure
- **Exchanges** between coastal areas

Plan

Part I – Tools for study mesoscale features

- Numerical codes
- In situ experiments

Strategies

Part II – Characteristics of mesoscale eddies

- Eddy center detection
- Horizontal characteristics
- Vertical characteristics

Part III – Forcings and generation

- Forcing sensitivity – Wind sensitivity
- Process of generation
- Generation of submesoscale structures
- Impact on coast-offshore exchanges

Part IV – Study of turbulent mixing

- In situ experiment
- Calculation of diffusion coefficients
- Lagrangian experiment

Conclusion & perspectives

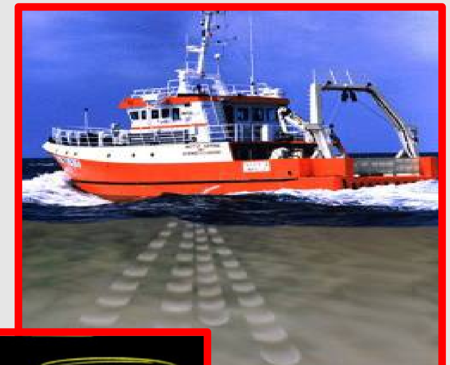
Mesoscale activity

Submesoscale

Turbulence

In situ experiment – Field campaign Latex10

- Western part of the GoL
- September 1-24, 2010
- No anticyclonic eddy in the area



2 Research Vessels
ADCP
Thermosalinometer

Satellite observations

CTD

SF6

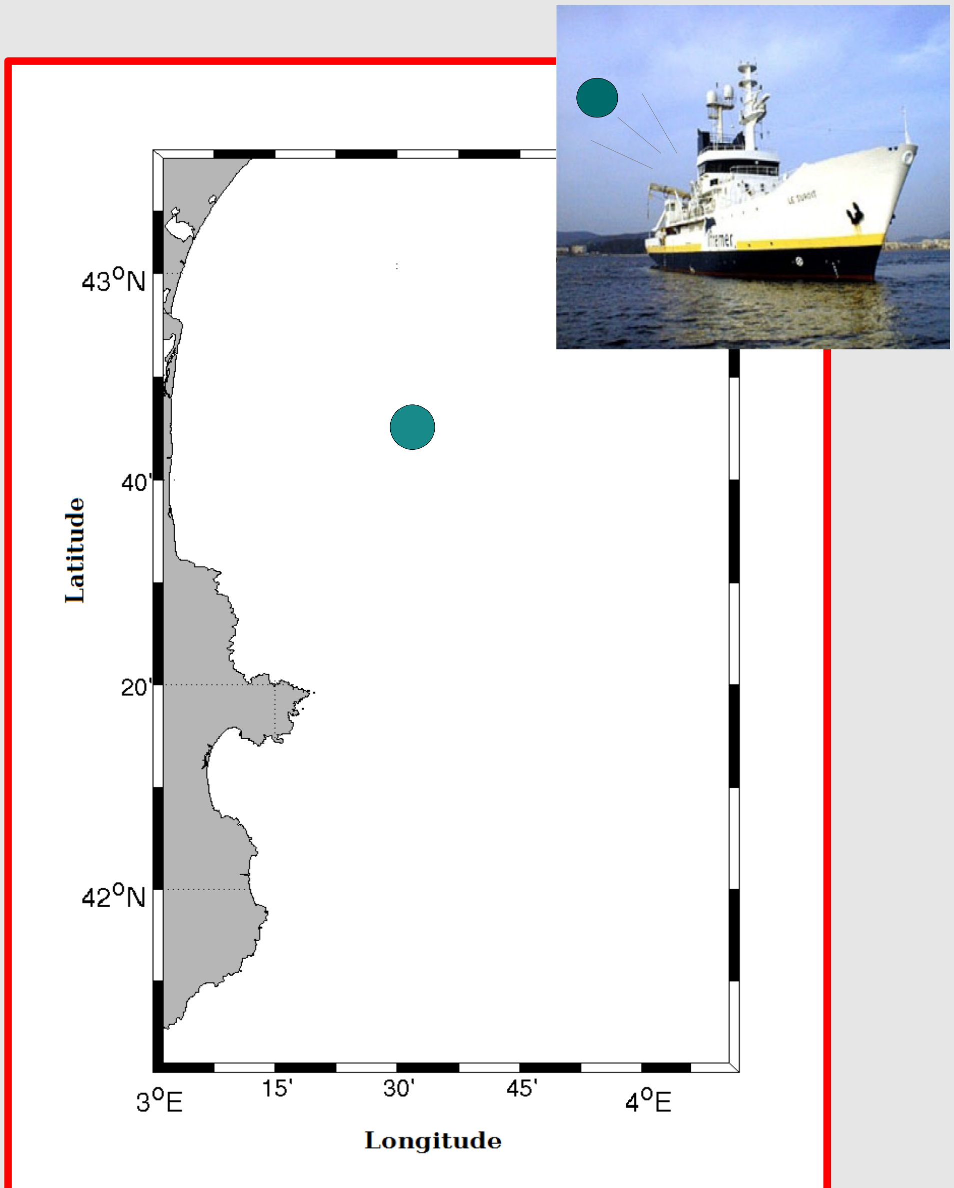
Lagrangian floats

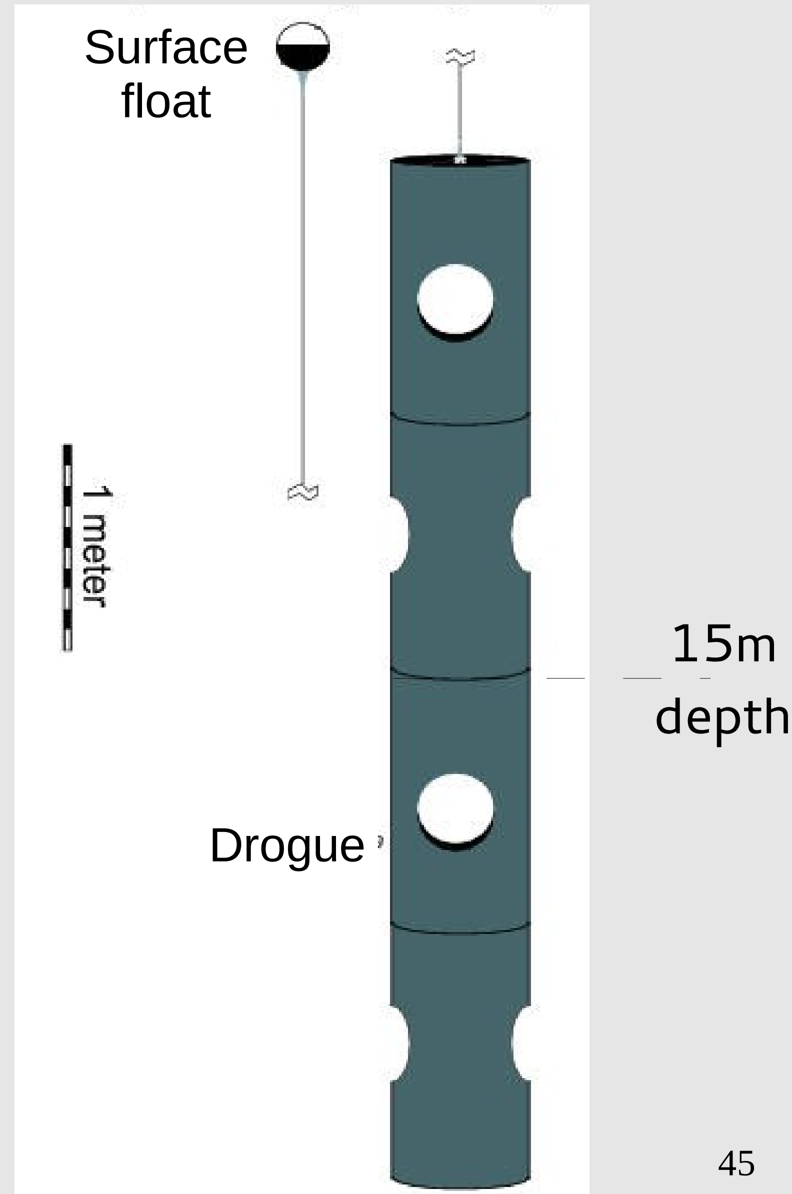
Further characterization of the **turbulent mixing** in a coastal environment

[Kersalé et al., in review]

In situ experiment – Field campaign Latex10

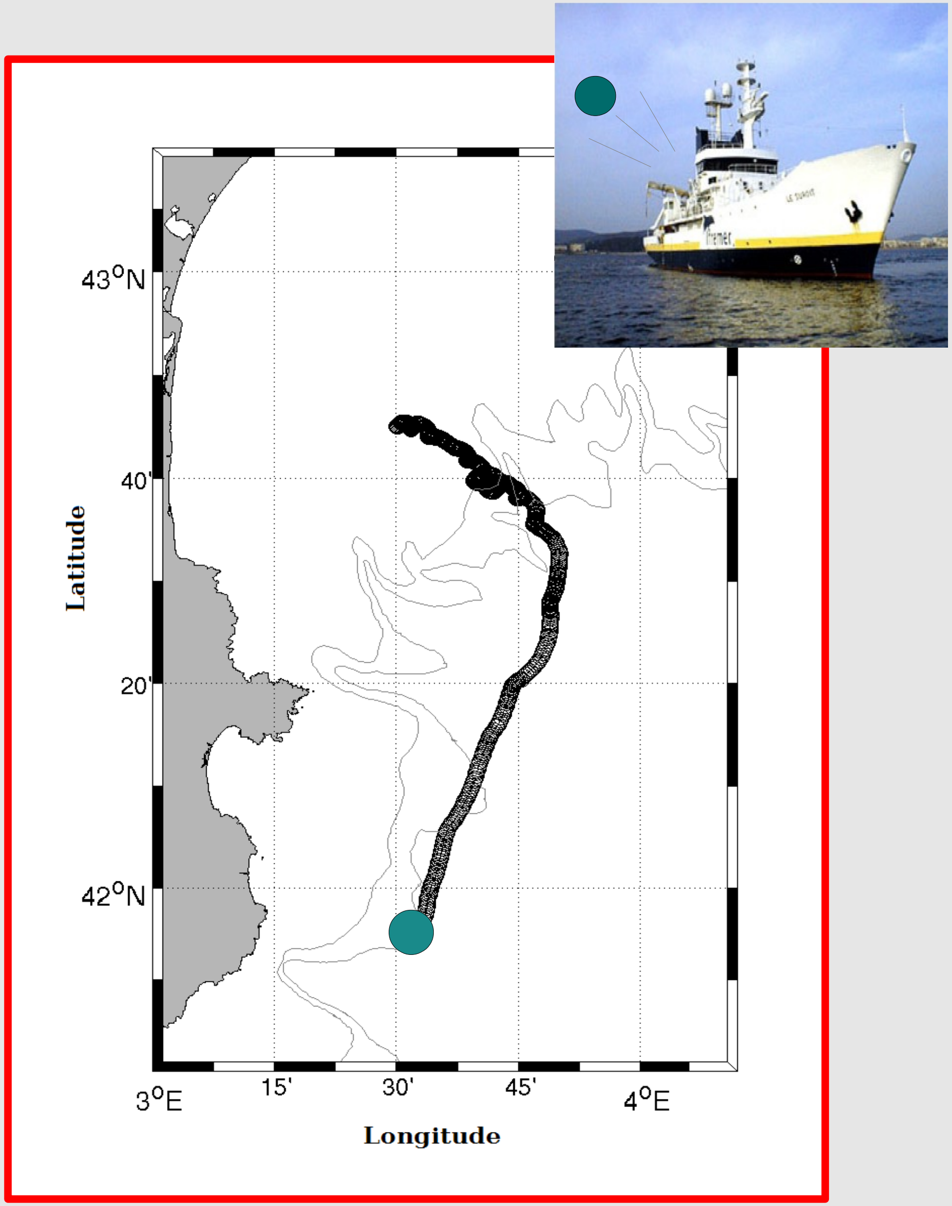
Lagrangian float

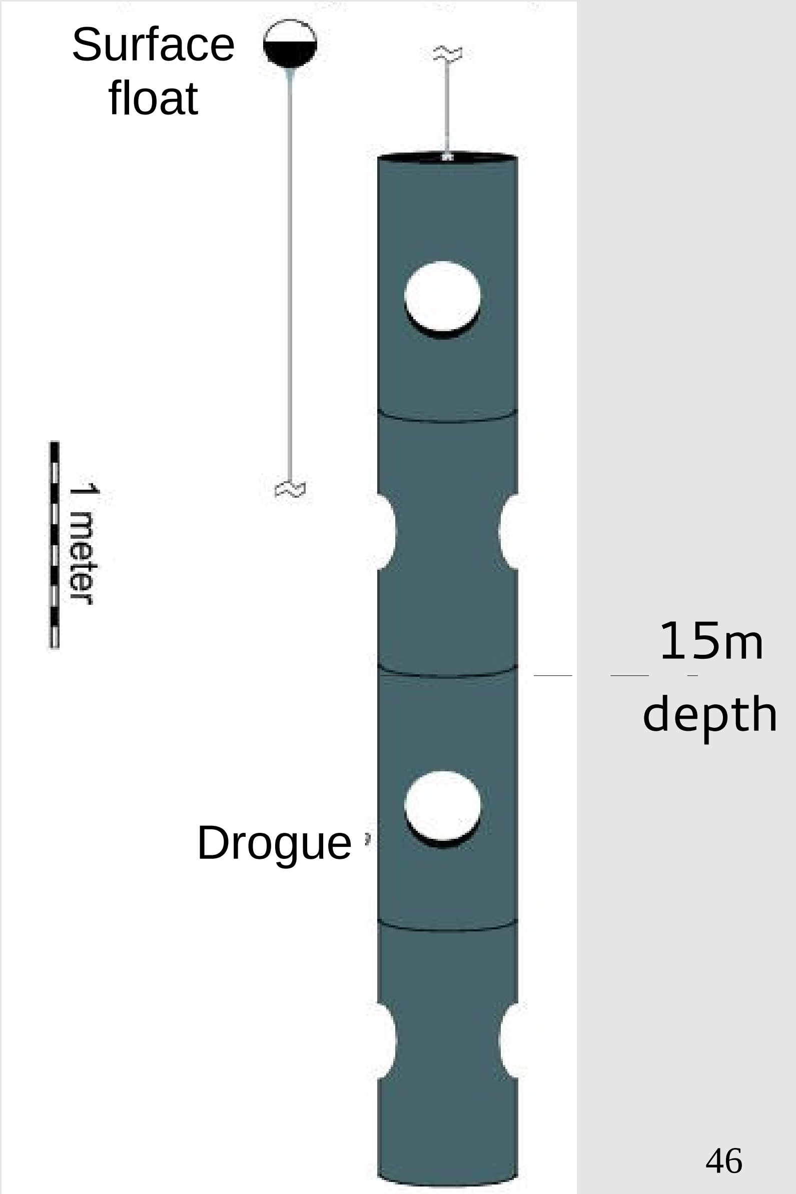




In situ experiment – Field campaign Latex10

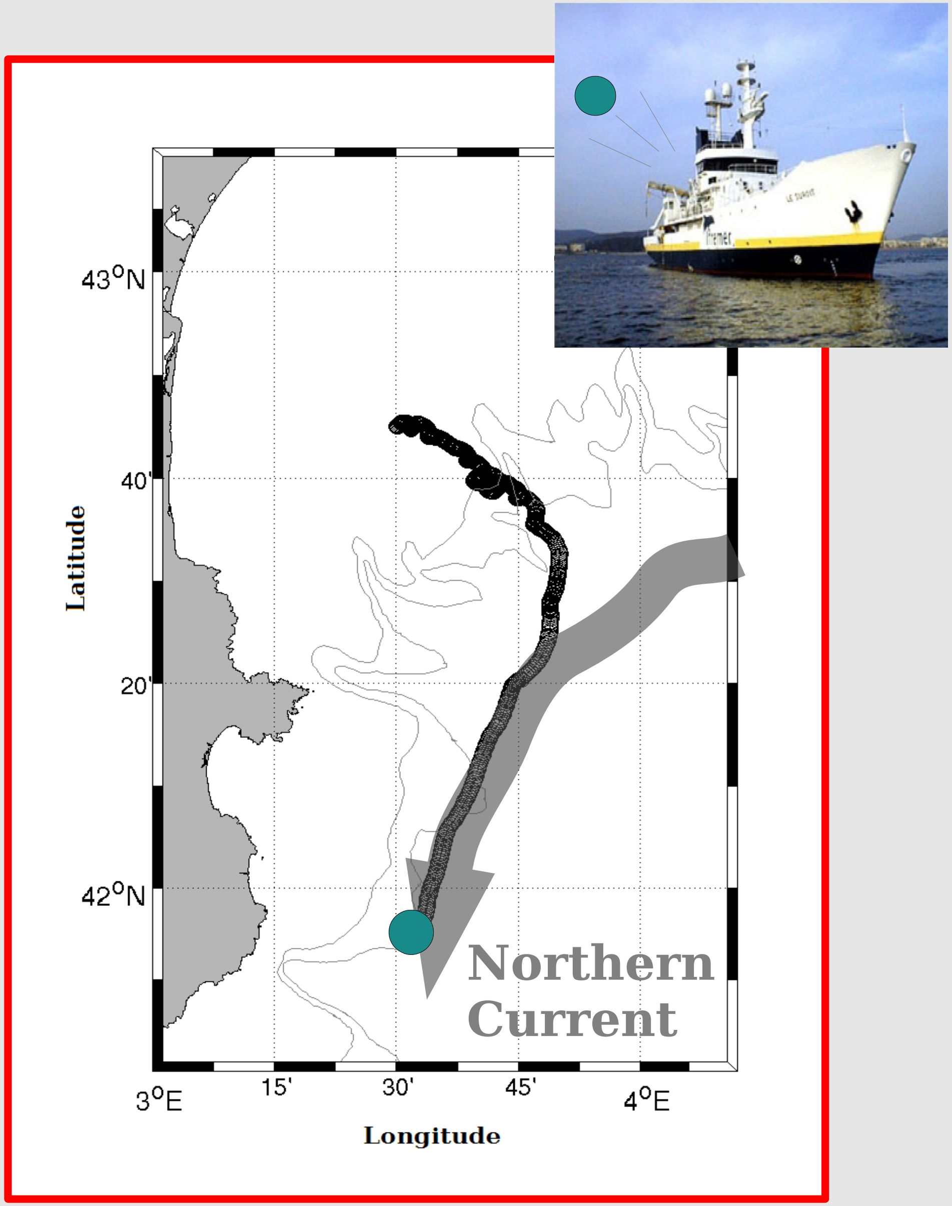
Lagrangian float

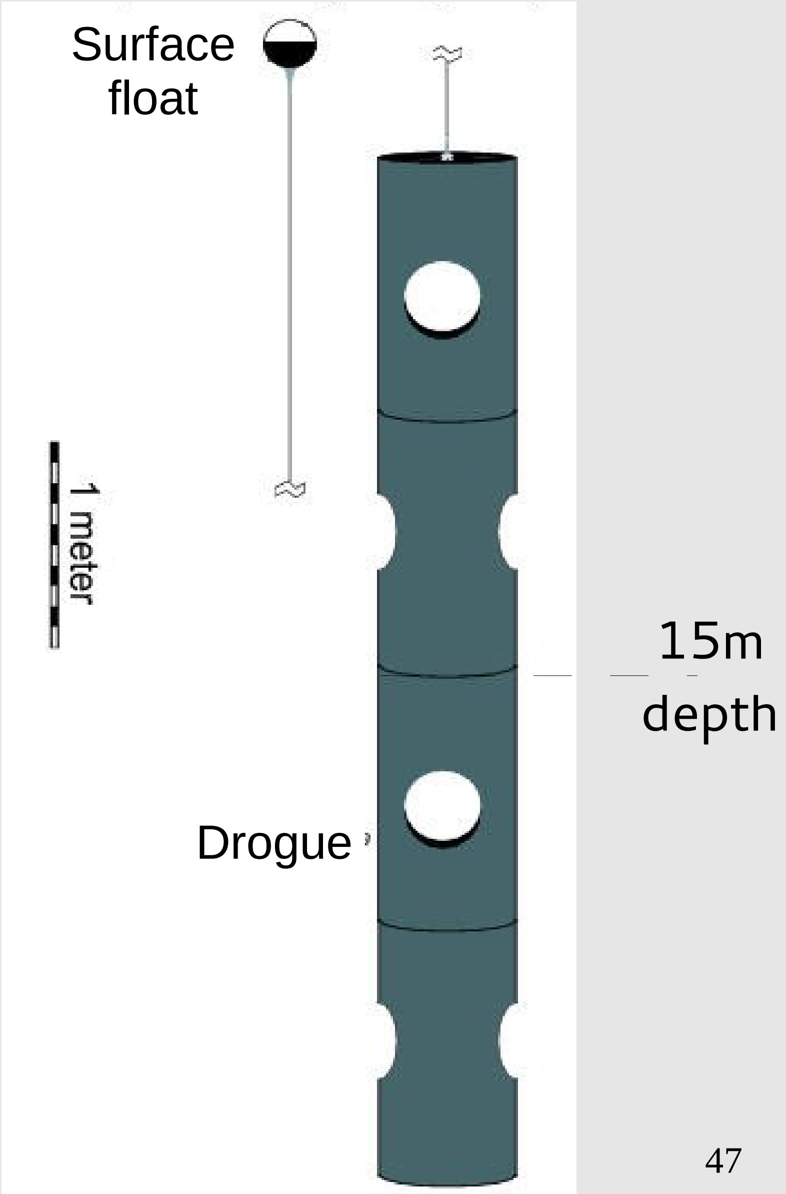




In situ experiment – Field campaign Latex10

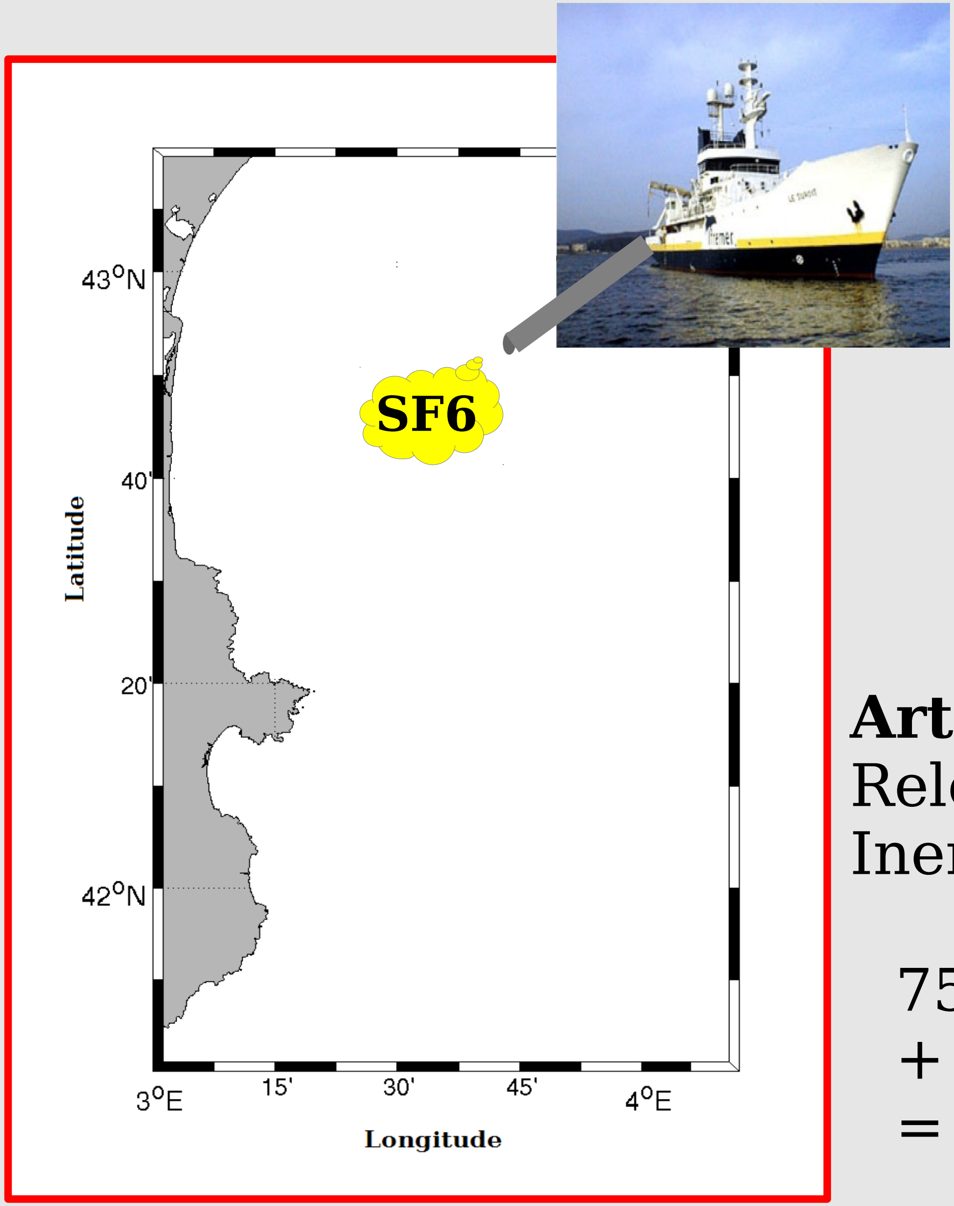
Lagrangian float





In situ experiment – Field campaign Latex10

SF6 – Sulfur Hexafluoride



Artificial patch :

Release of seawater satured with SF6

Inert tracer

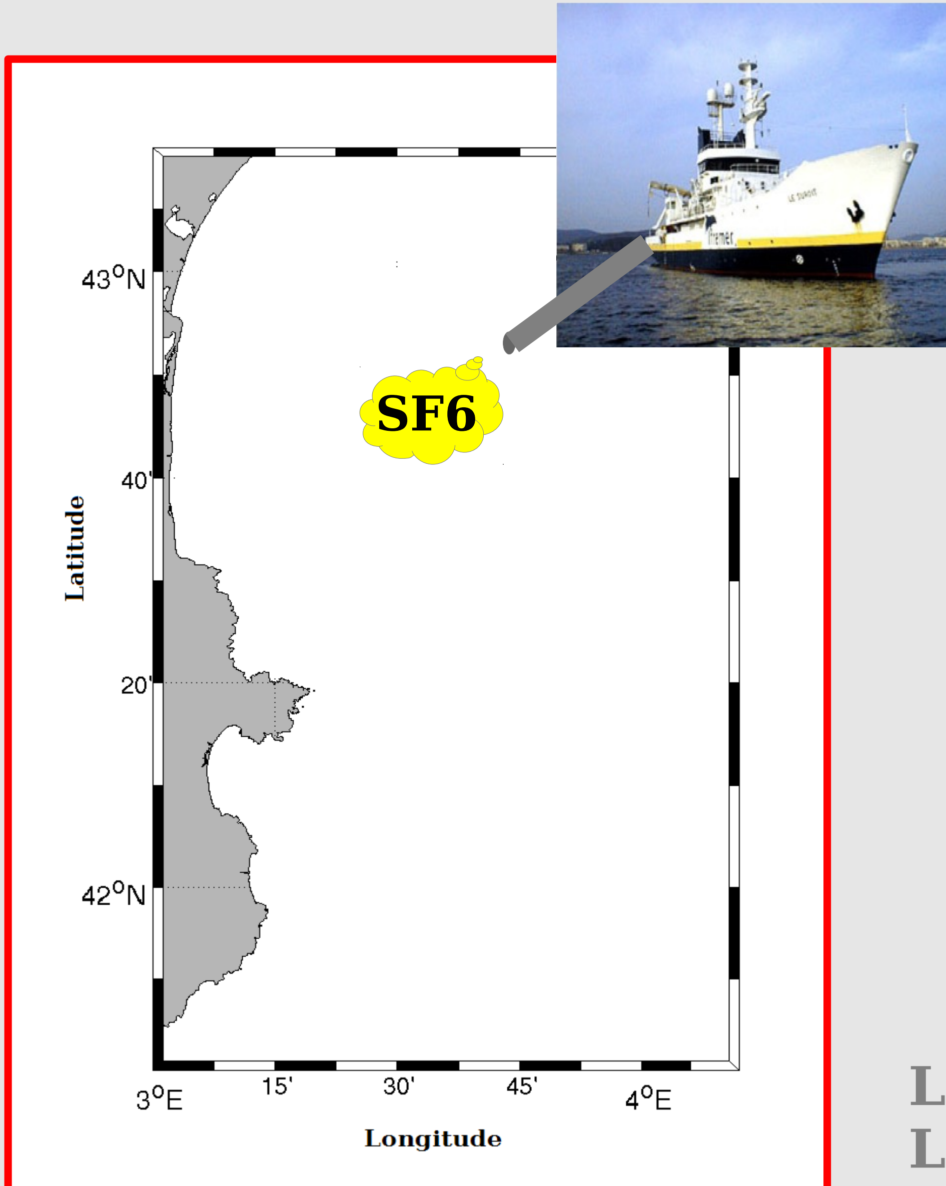
7500 L steel tank of seawater

\+ Injection of pure SF6 gaz

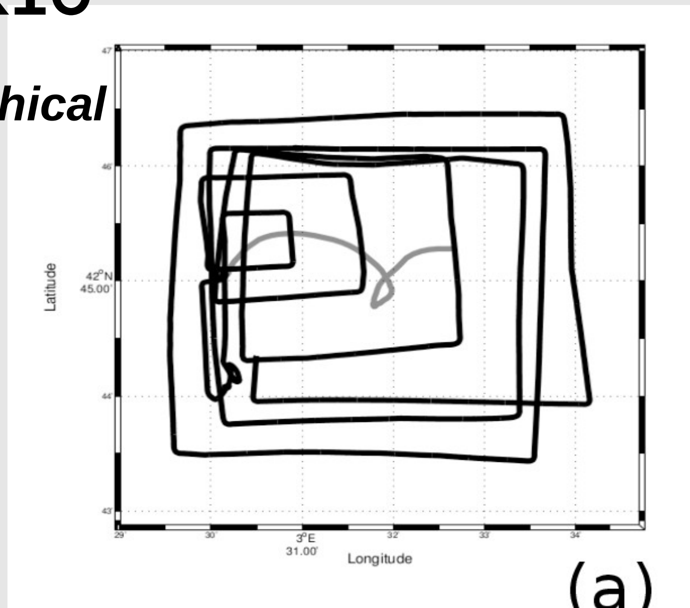
= Satured SF6 solution

In situ experiment – Field campaign Latex10

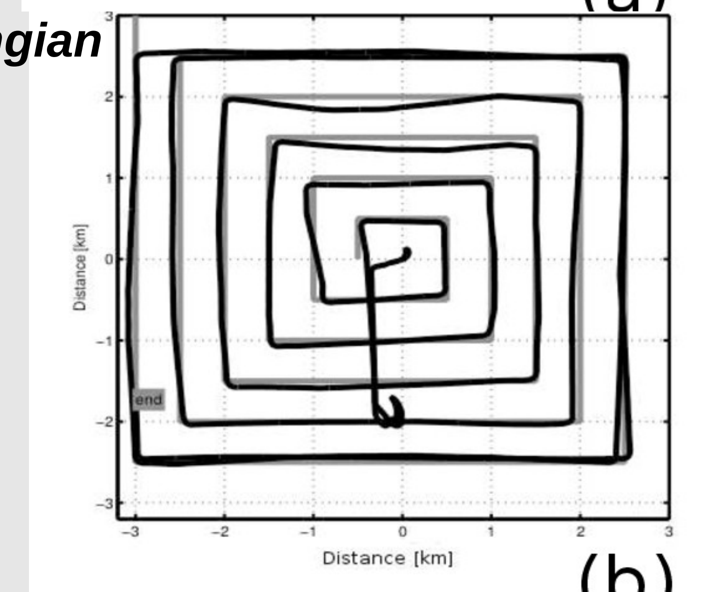
SF6 – Sulfur Hexafluoride



Geographical Ref.



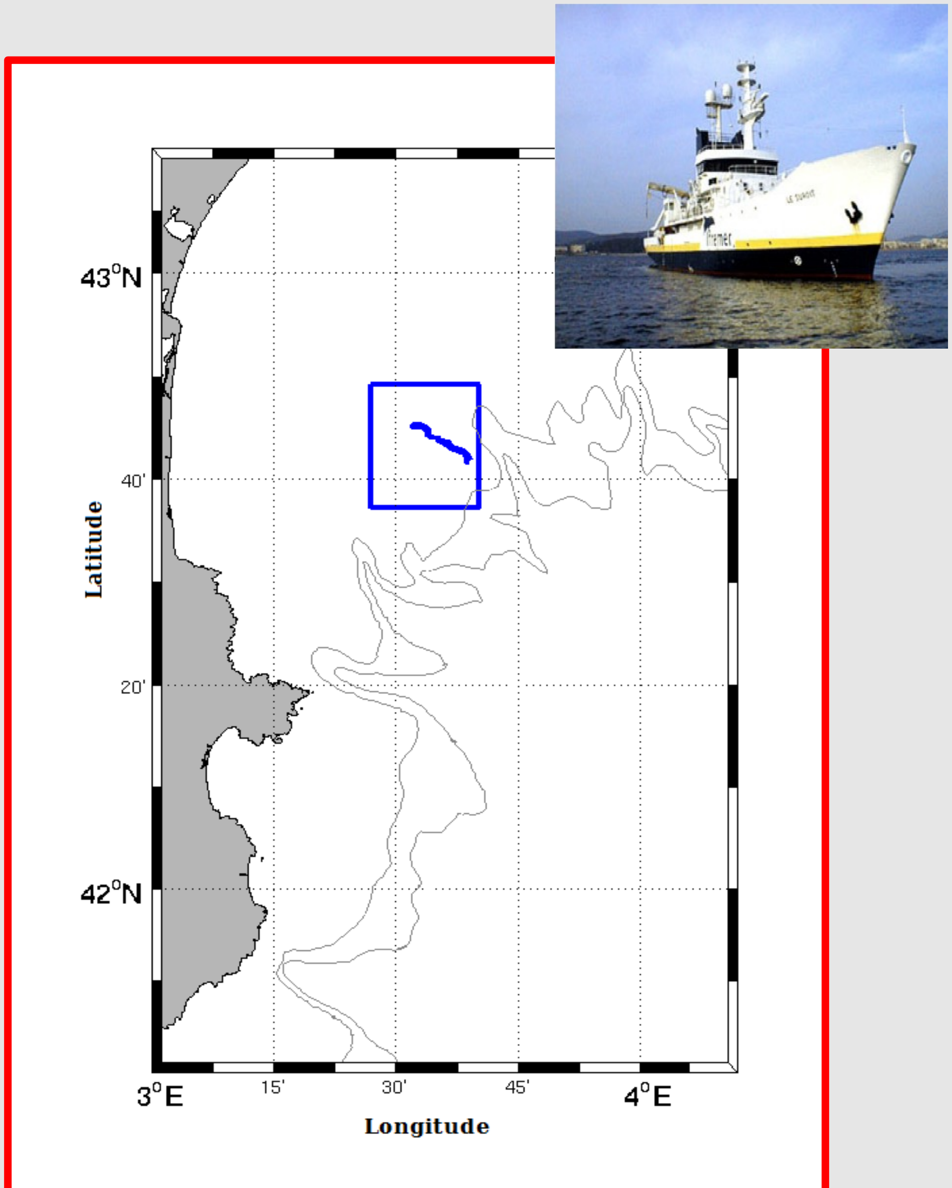
Lagrangian Ref.

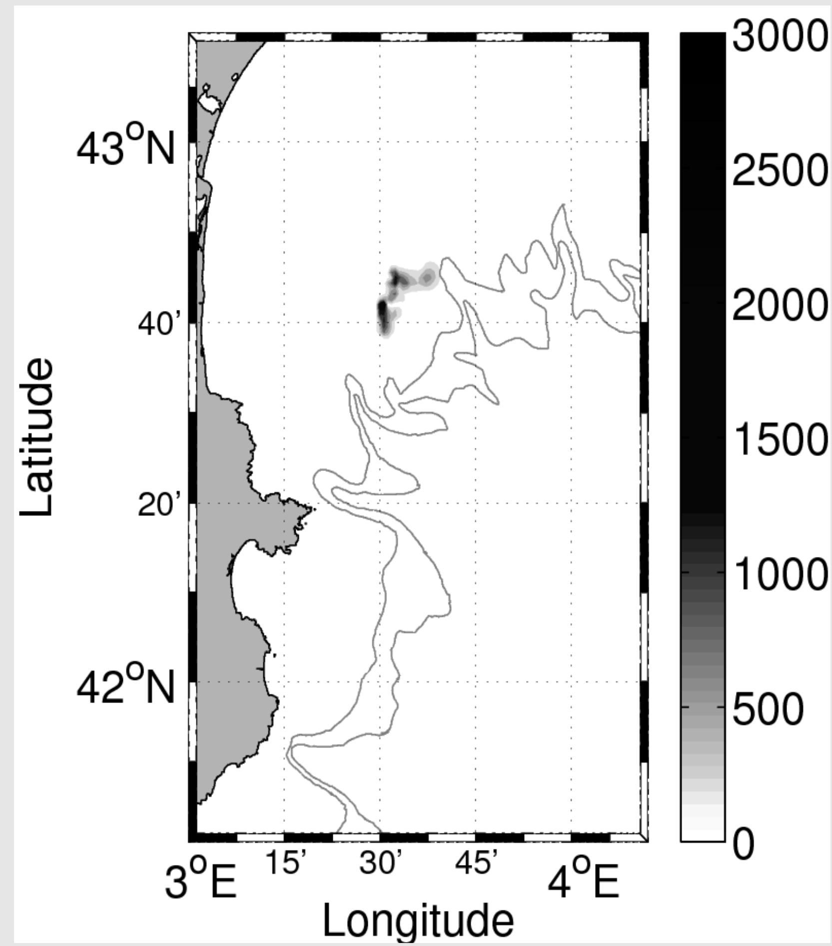


Lagrangian release
Latex tools package
Doglioli et al. [2013]

In situ experiment – Field campaign Latex10

SF6 – Sulfur Hexafluoride





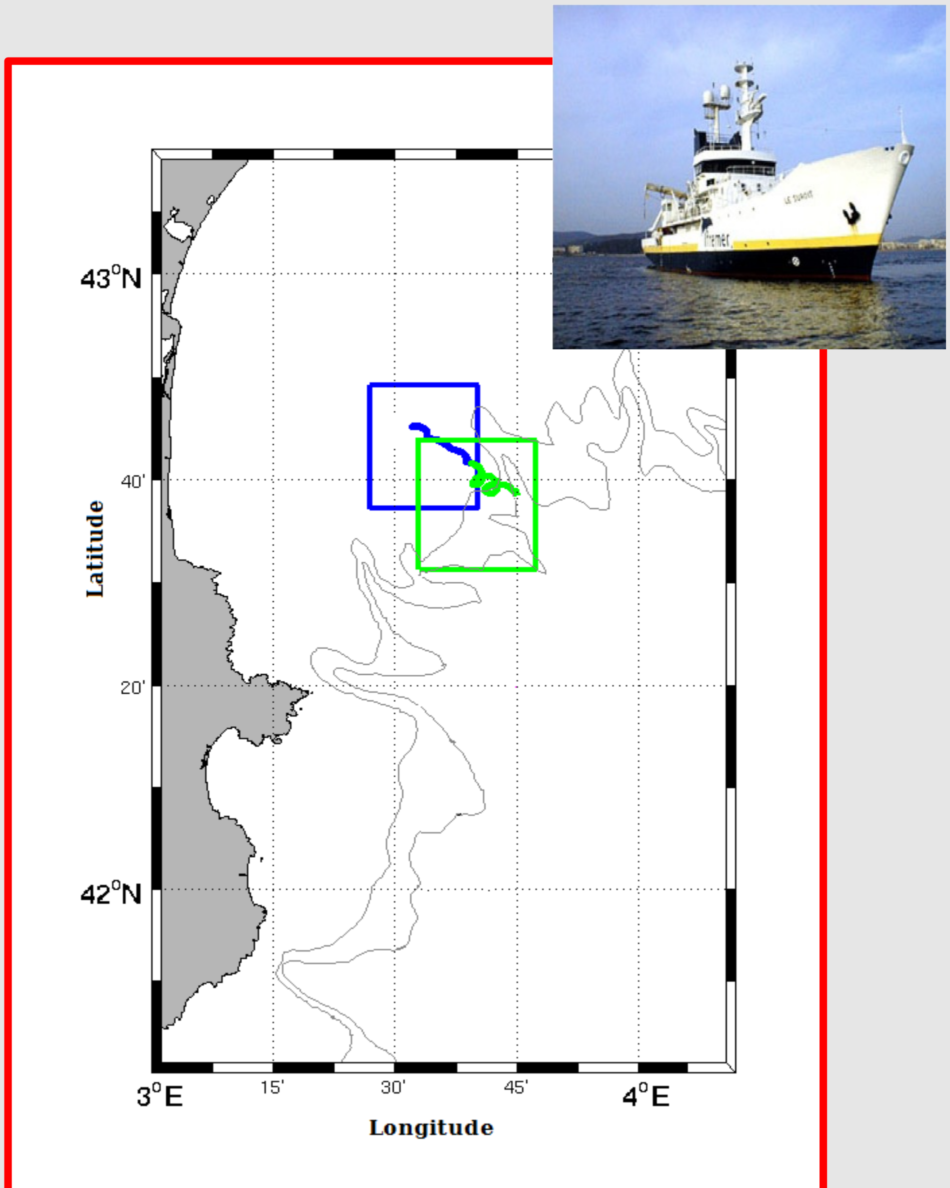
Mapping 1

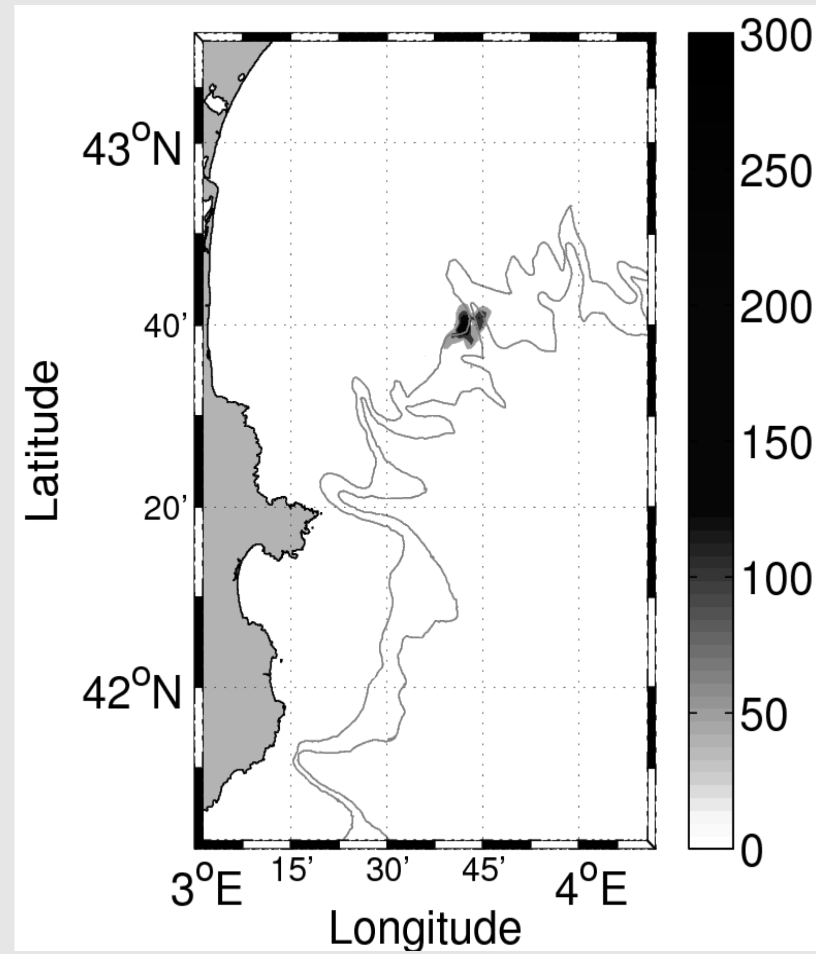
Concentration of SF6 [fmol l^{-1}]

1 day after the release

In situ experiment – Field campaign Latex10

SF6 – Sulfur Hexafluoride





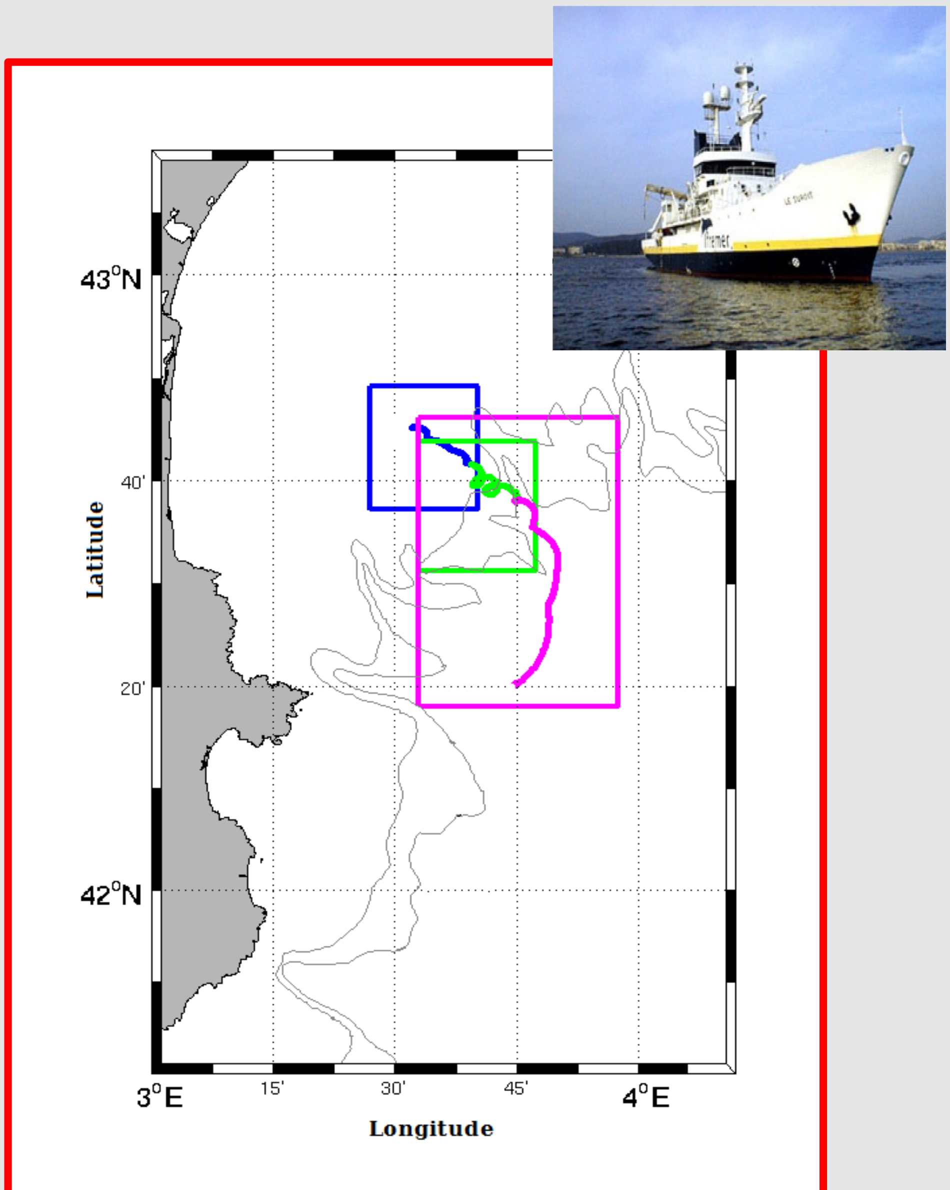
Mapping 2

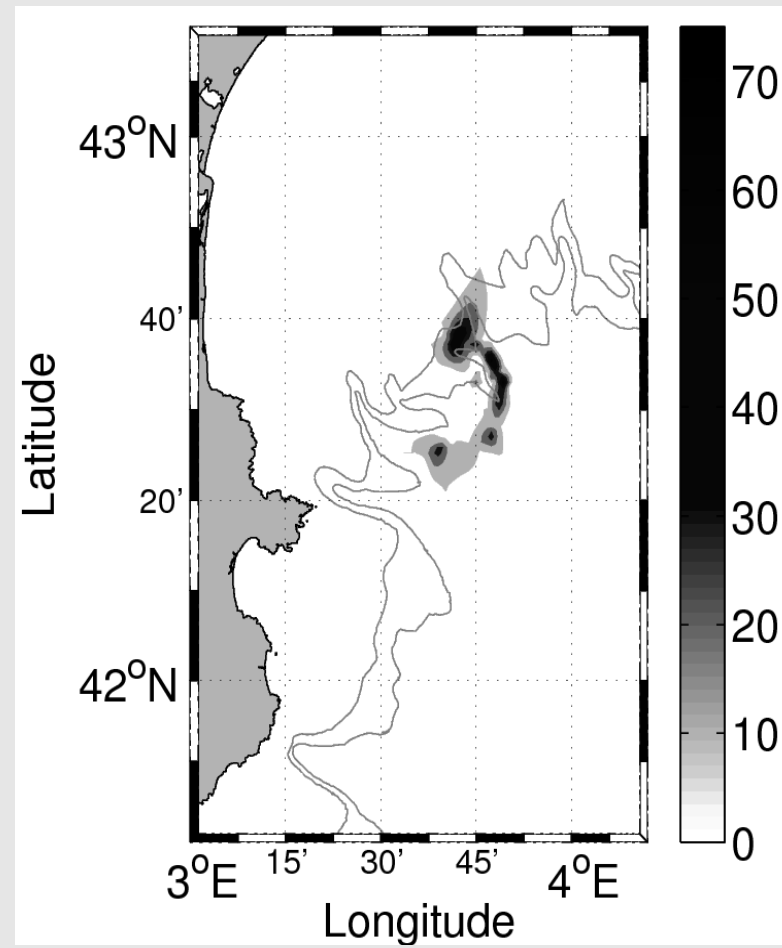
Concentration of SF6 [fmol l^{-1}]

2 days after the release

Part IV – Study of turbulent mixing

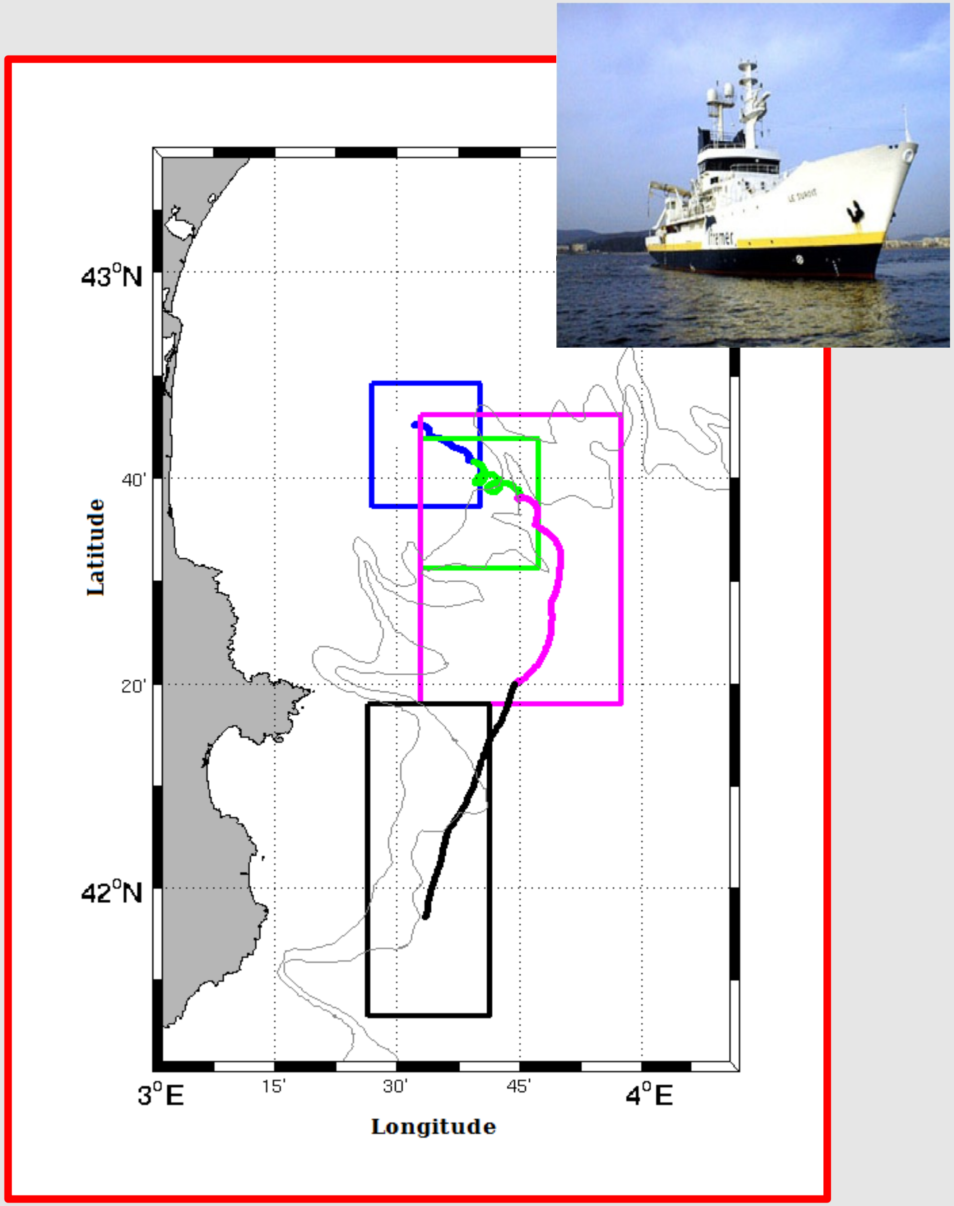
In situ experiment – Field campaign Latex10
SF6 – Sulfur Hexafluoride

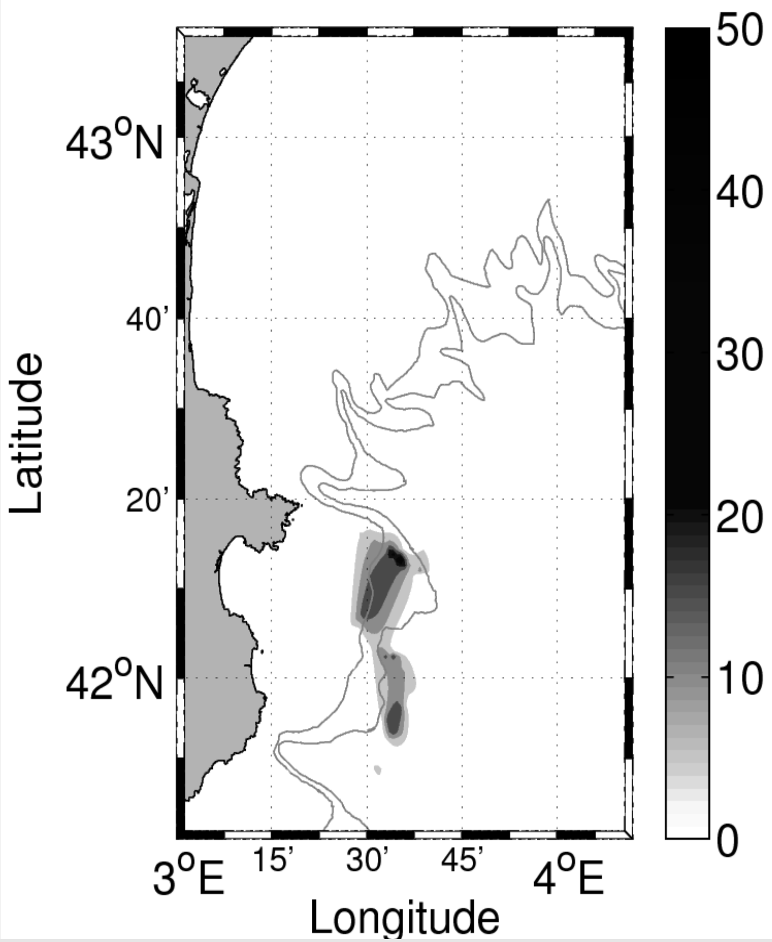




Mapping 3
Concentration of SF6 [fmol l^{-1}]
5 days after the release

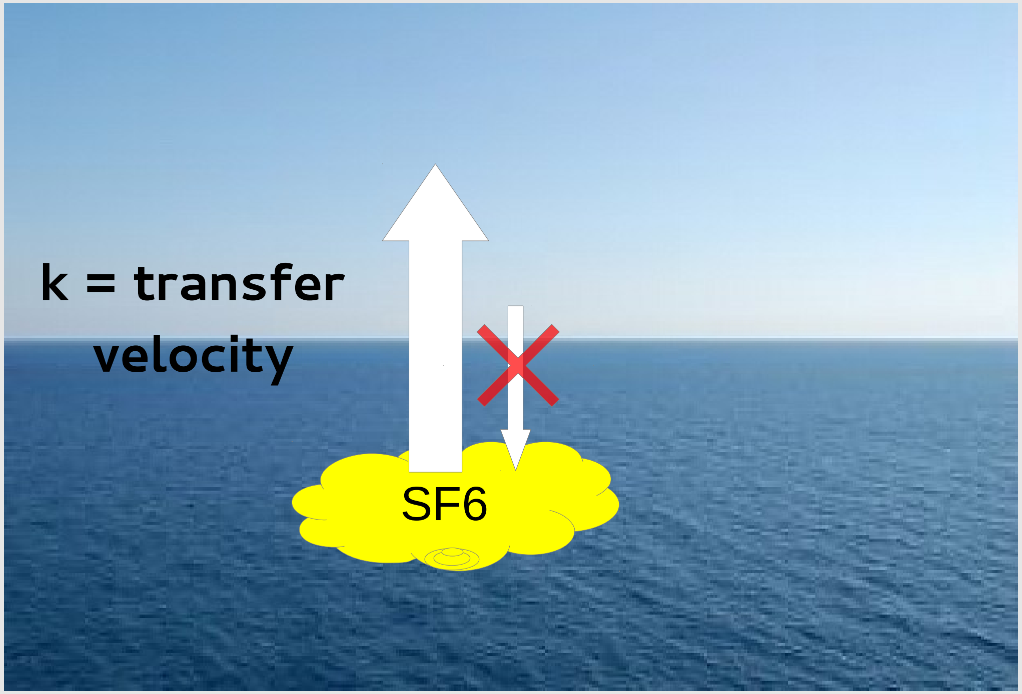
In situ experiment – Field campaign Latex10
SF6 – Sulfur Hexafluoride





Mapping 4
Concentration of SF6 [fmol l^{-1}]
7 days after the release

Atmospheric loss



- No external source

Patch is supersaturated with respect to the atmosphere

- Loss of SF6 at the surface of the water column due to atmospheric loss

- Variation of SF6 with time due to atmospheric loss modeled as a negative exponential function :

$$C(t) = C_0 e^{\frac{-k}{z_{mix}} t}$$

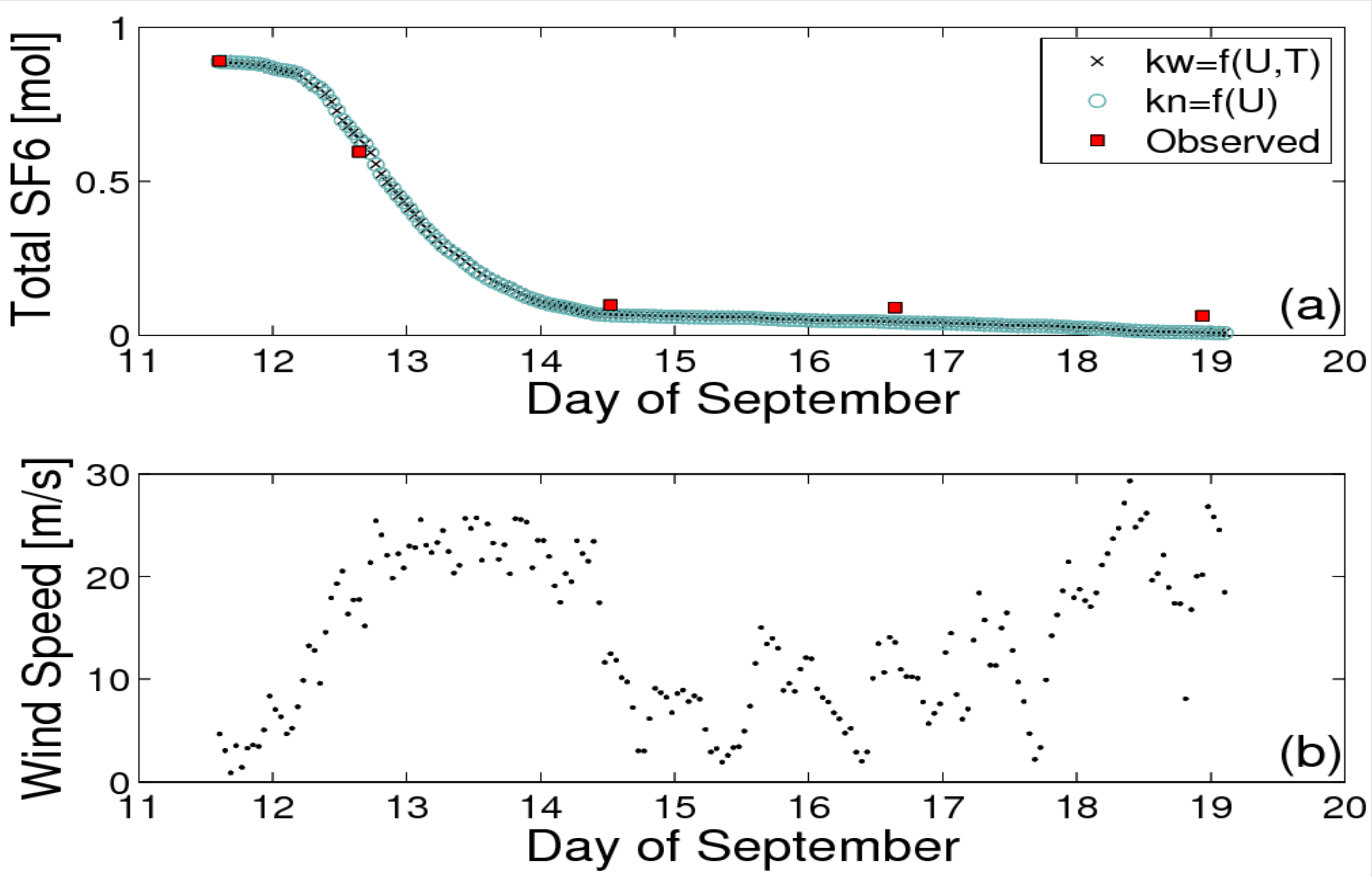
C_0 : released concentration SF6

z_{mix} : Depth mixed layer

k : 2 parameterizations for the transfer velocity

Hypothesis : SF6 homogeneous in the mixed layer

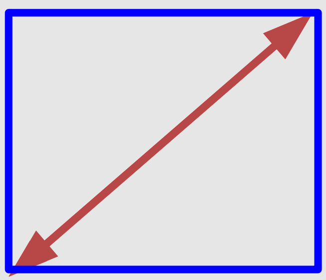
Atmospheric loss



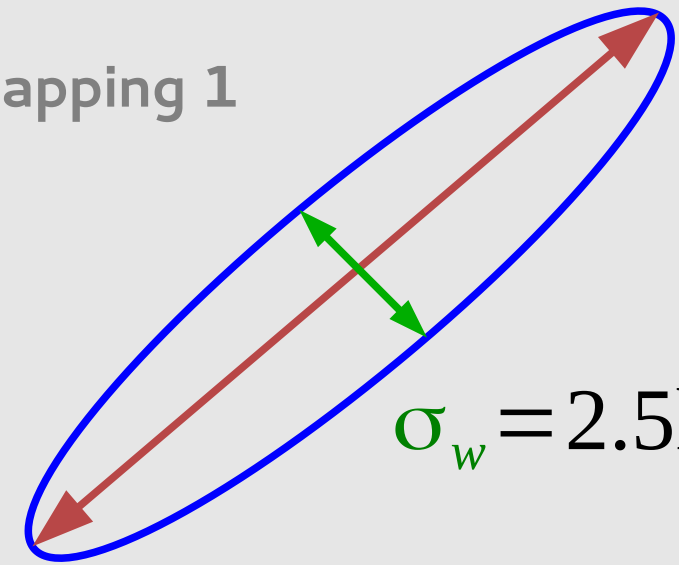
- 2 modeled curves superimposed => Importance of the turbulent diffusivity related to the wind speed
- Good agreement of the observed quantities of SF6

Calculation of the horizontal diffusion coefficient

Release → Mapping 1



$\Delta t = 22\text{h}$



$\sigma_w = 2.5\text{km}$

δ

$\sigma_l(t) = 7.5\text{km}$ → $\sigma_l(t+\Delta t) = 11.4\text{km}$

Strain rate

$$\delta = \frac{\ln \dfrac{\sigma_l(t)}{\sigma_l(t+\Delta t)}}{\Delta t}$$

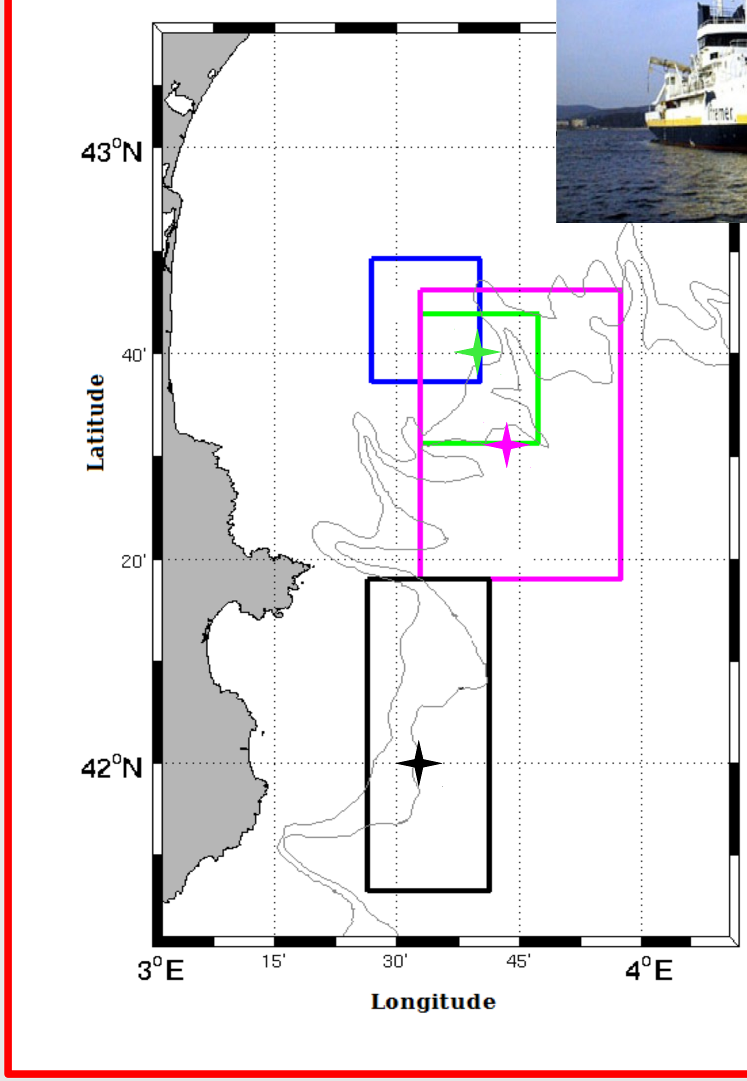
$$K_h = \sigma_w^2 \delta = 7.6\, m^2 s^{-1}$$

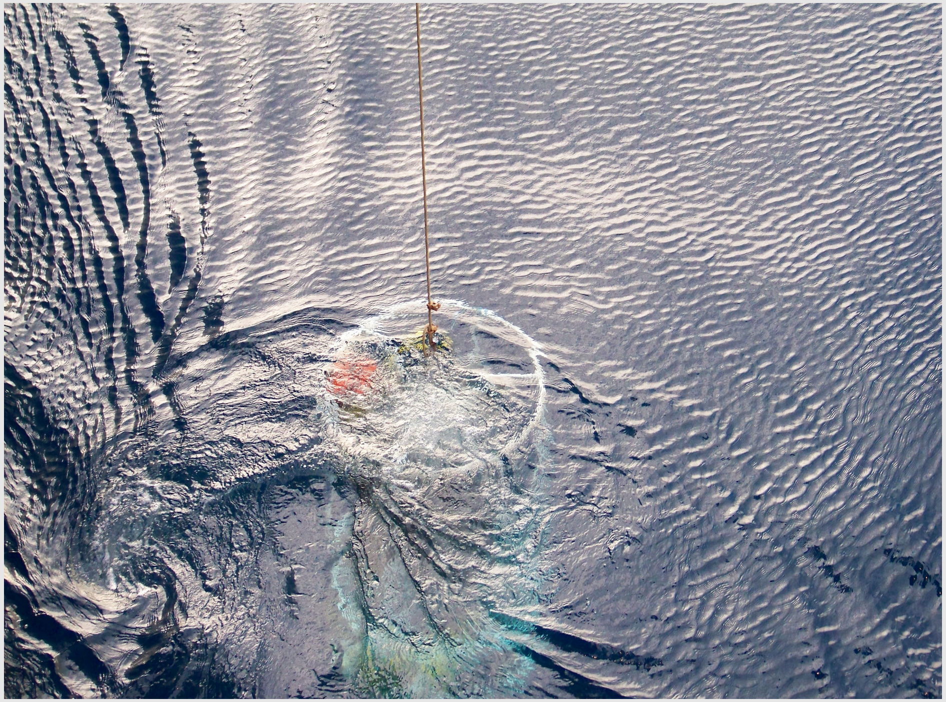
Determination for horizontal scale < 2.5 km

for temporal scale < 2 days

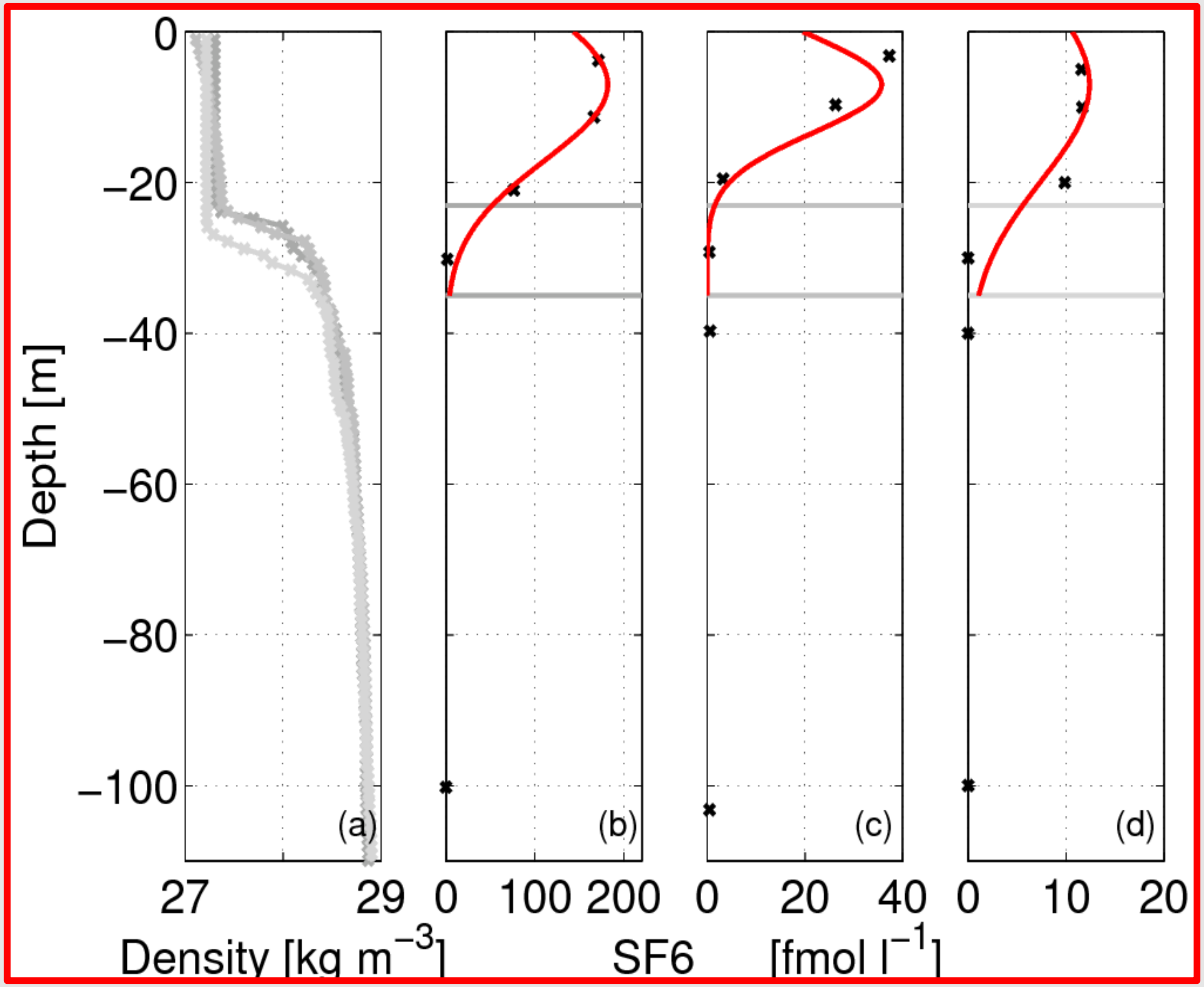
Calculation of the vertical diffusion coefficient

CTD – Niskin bottles used to sampled SF6





Calculation of the vertical diffusion coefficient

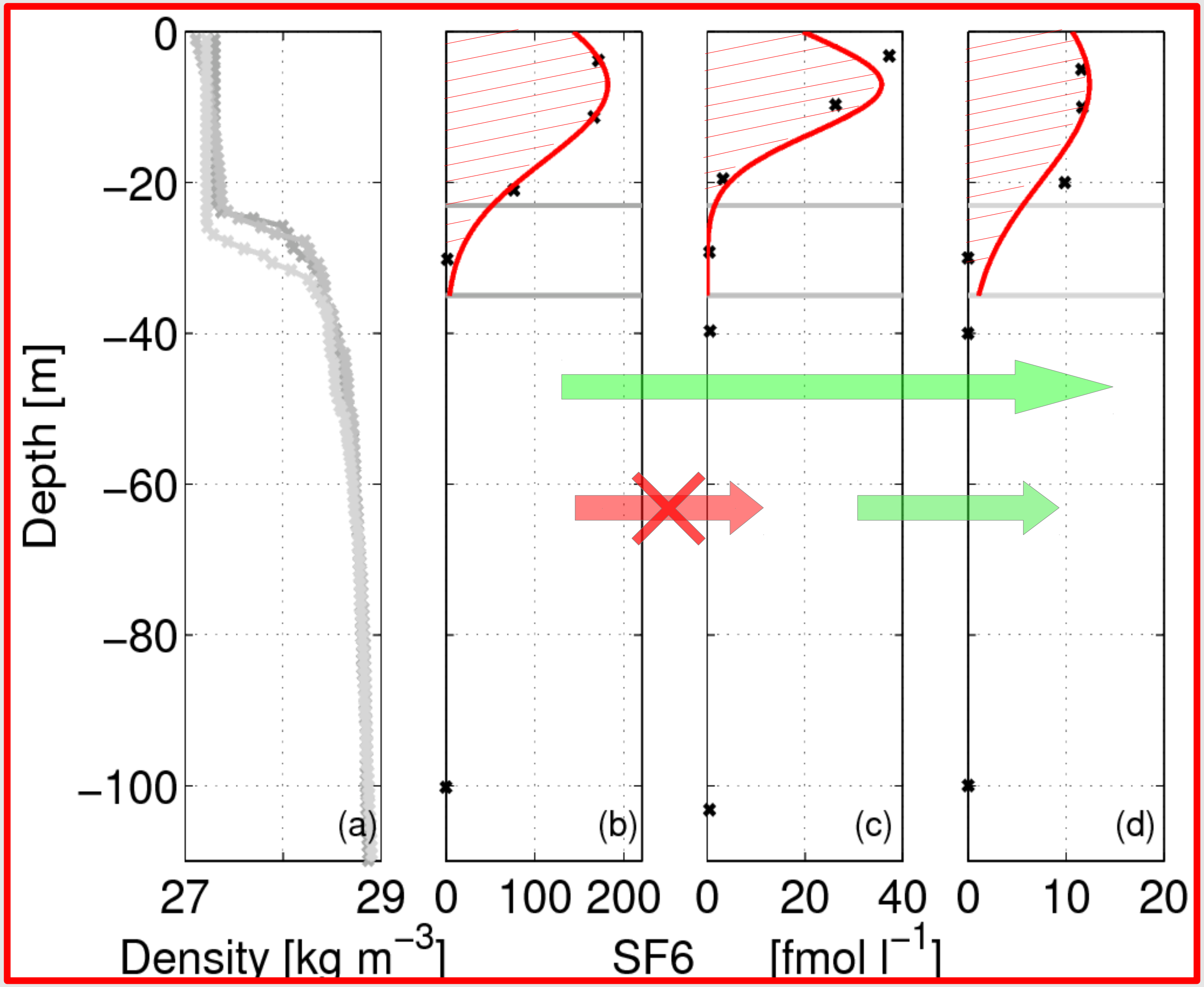


- Gaussian shape for the tracer distribution with depth
- Evolution of the variance of the Gaussian

$$K_z = \frac{\sigma^2}{2\Delta t}$$

$$K_z = 1.4 \pm 0.6\, cm^2 \; s^{-1}$$

Calculation of the vertical diffusion coefficient

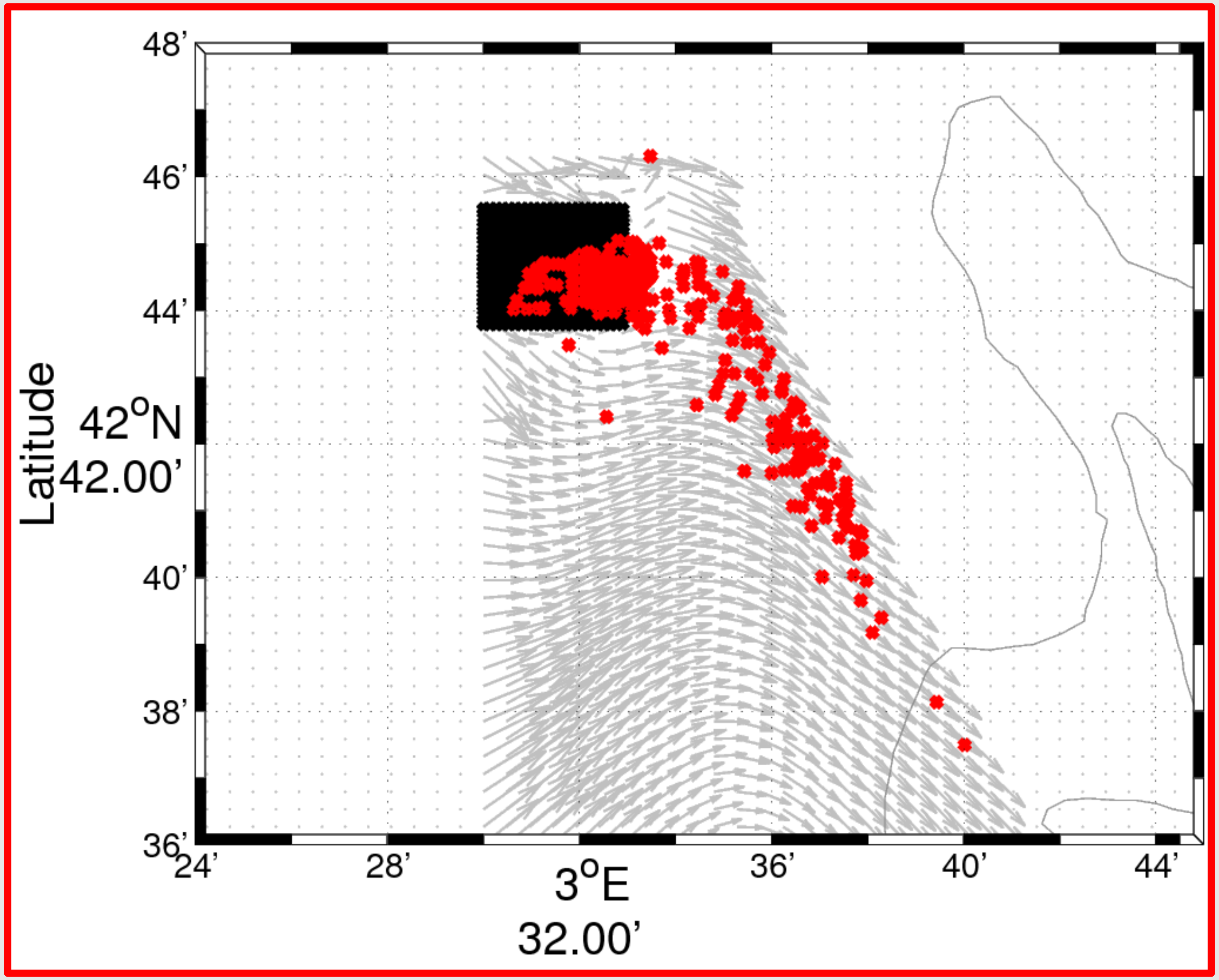


- Gaussian shape for the tracer distribution with depth
- Increase of the second moment M2 of the SF6 profiles with time

$$M_2 = \frac{\int C (z - z_0)^2 \partial z}{\int C \partial z}$$

$$K_z = \frac{1}{2} \frac{\partial M_2}{\partial t} = 1.2 \pm 0.7\, cm^2 \;\; s^{-1}$$

Lagrangian experiment



- Tracer release experiments simulated using a numerical model
- Test estimates of horizontal diffusivities

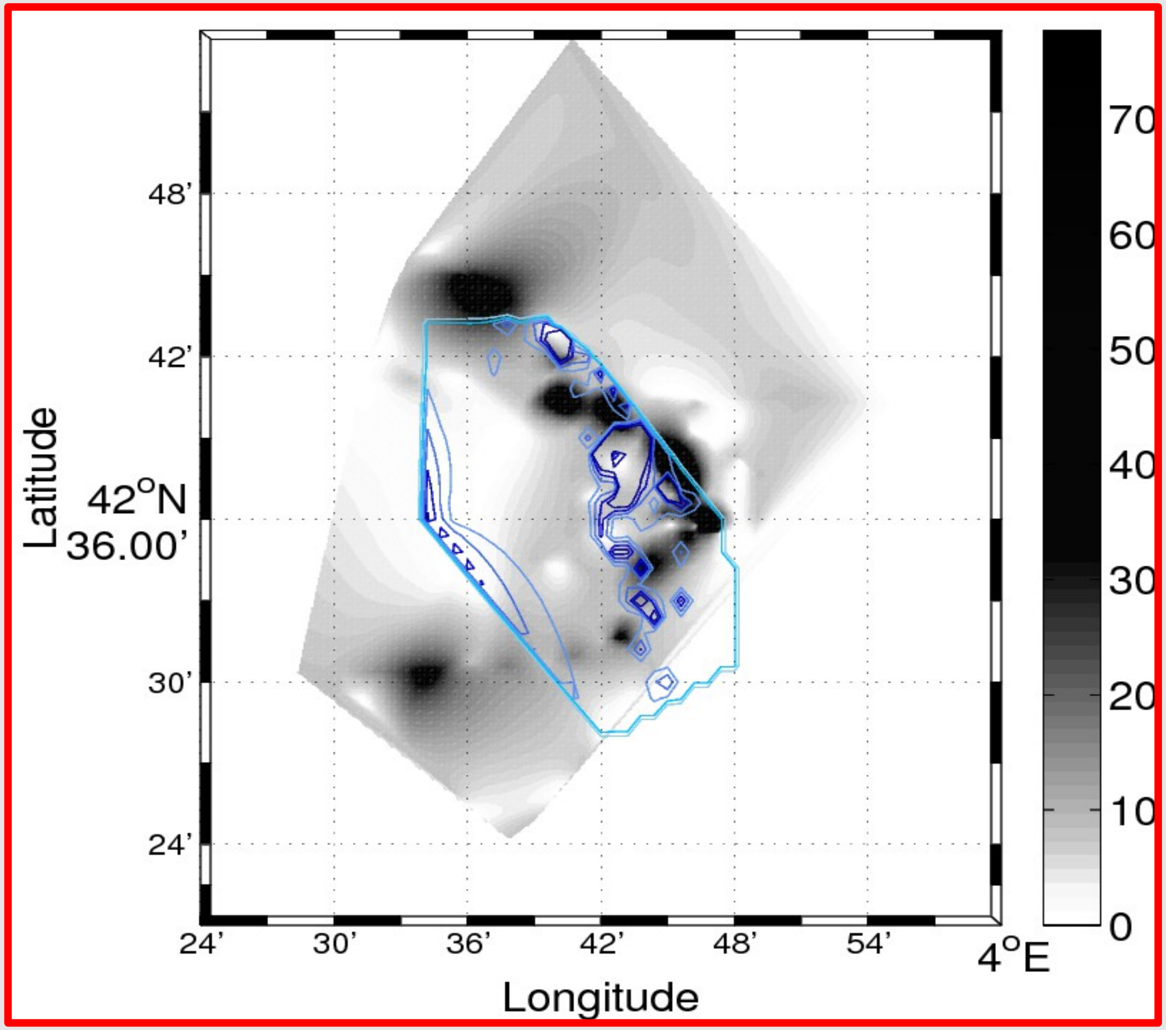
- Motion of 10 000 particles
- Classic random walk model
- Input velocity field : interpolated ADCP velocities

■ Initial position of the particles (end of the release)

• Final position of the particles (end of mapping 1)

→ Input velocity field

Lagrangian experiment



- Good agreement between the positions of in situ and numerical patches
- Comparison of the total patch areas
  Numeric: 273 km^2
  In situ: 381 km^2

Mapping 3

Gray scales [SF6]$_{\text{in situ}}$ – Contour [SF6]$_{\text{num.}}$

Conclusions – Part IV

- Investigation of the **turbulent mixing** in a **coastal** environment in the western part of the Gulf of Lion
- **Quantification** & **validation** of the **gas exchange** from the ocean to the atmosphere
- **Estimation** of **turbulent mixing** coefficients
- **Test** of the **horizontal** diffusivity coefficient in **Lagrangian experiments**

MAIN CONCLUSIONS

- **Comprehension** of **mesoscale dynamics** on two areas
- **Cumulative** effects of external forcings - Importance of **wind resolution**
- Local **characterization** & analysis of **generation processes** of **mesoscale** features
- **Exchanges** between coastal areas : **Observation** of transient **submesoscale** structure
- **Synergy** of **model** results and ***in situ*** data
- **Estimation** of **turbulent mixing** coefficients in a **coastal** environment

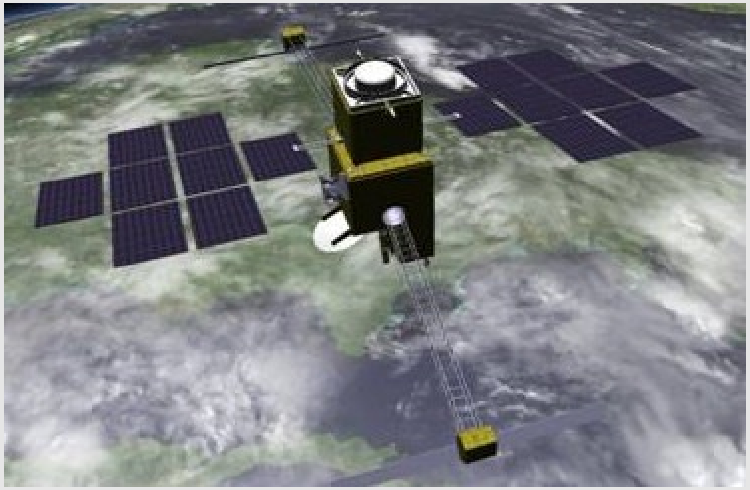
PERSPECTIVES

Short term perspectives

- Tracers distribution & connectivity between regions
- Quantification of coast offshore exchanges with Lagrangian tools
- New regional altimetry products => Precision on coastal areas

Long term perspectives

- Use of numerical field output Symphonie test and validate the SWOT data (GoLSWOT)



- Latex campaign strategies applied in already scheduled campaigns : GoLSWOT and P2B2M
- Local & regional impact on ecosystems

THANKS