Surface circulation patterns in the western Gulf of Lion by in-situ detection of Lagrangian coherent structures
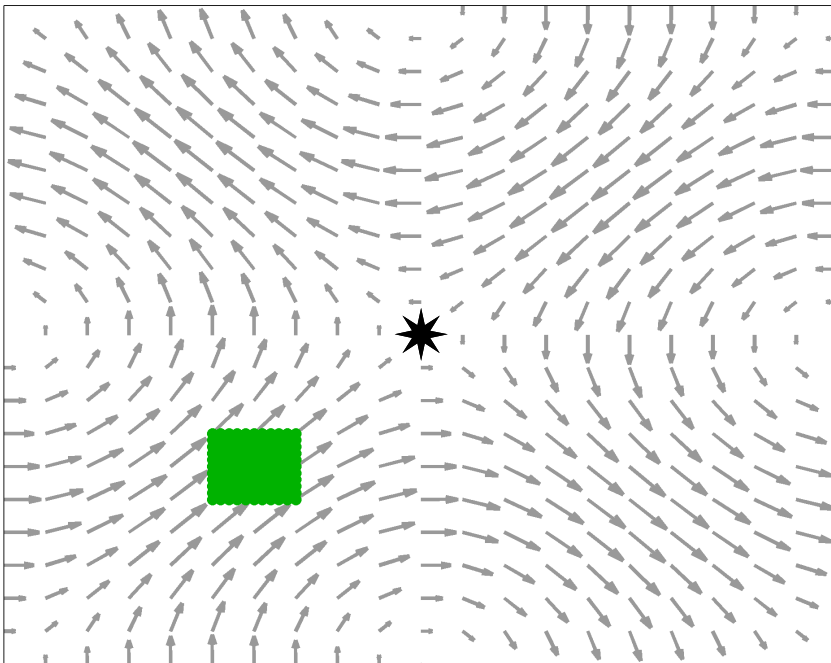
F. Nencioli [1], F. d'Ovidio [2], A.M. Doglioli [1] and A.A. Petrenko [1]

(1) Aix-Marseille Univ., Mediterranean Institute of Oceanography (MIO), 13288, Marseille, Cedex 09, France ; Université du Sud Toulon-Var, MIO, 83957, La Garde cedex, France ; CNRS/INSU, MIO UMR 7294; IRD, MIO UMR235

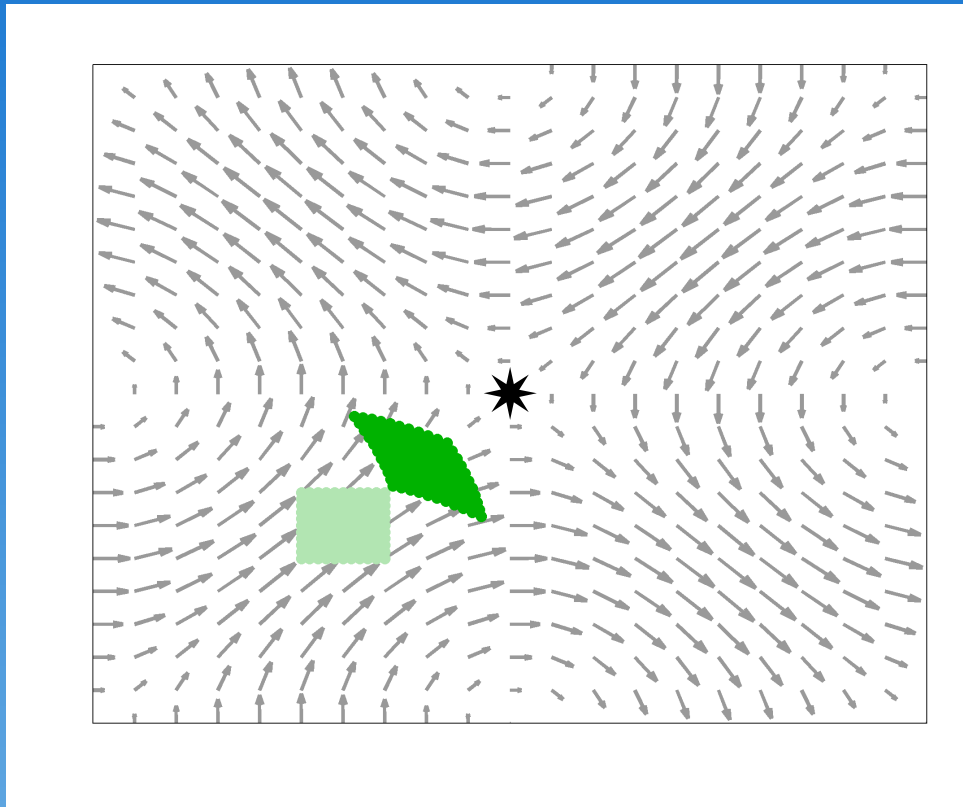(2) Laboratoire d'Océanographie et du Climat: Experimentation et Approches Numeriques, IPSL, Paris, France

CENTRE D'OCÉANOLOGIE DE MARSEILLE

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GlobCurrent Workshop

7-9 March 2012, Brest
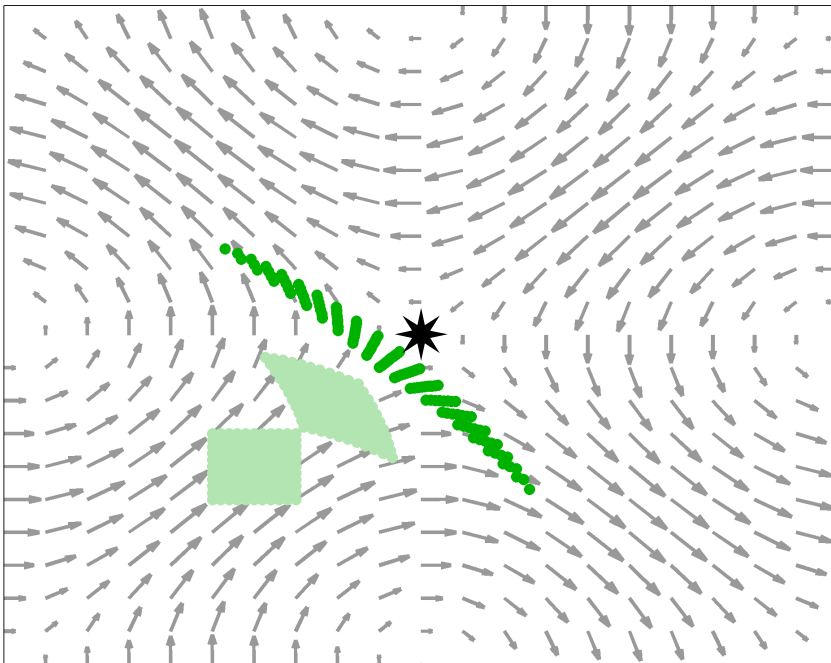
Lagrangian Coherent Structures

- **Lagrangian Coherent Structures (LCSs) important diagnostic: identification of transport preferential directions and barriers**

- **Example: Particle dispersion around an hyperbolic point**

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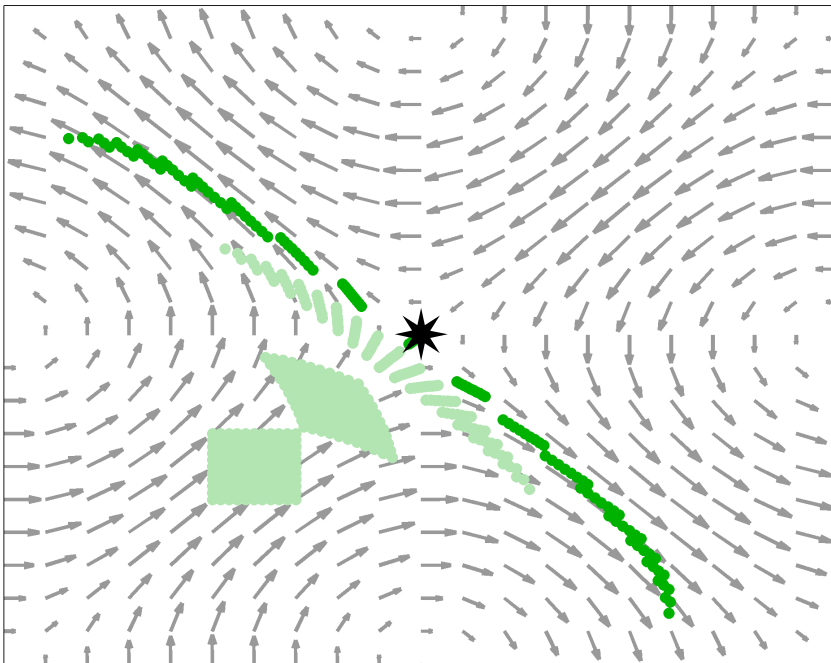- **Example: Particle dispersion around an hyperbolic point**

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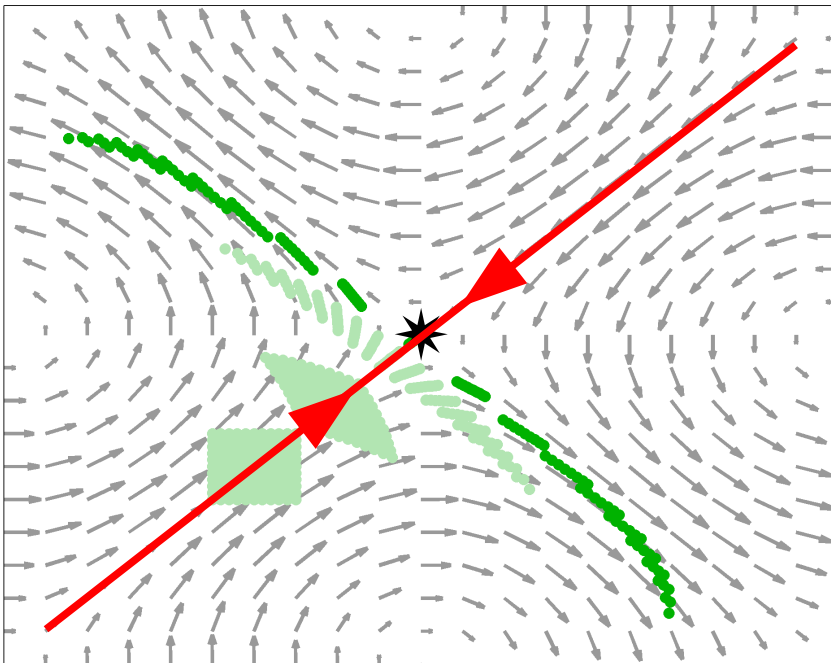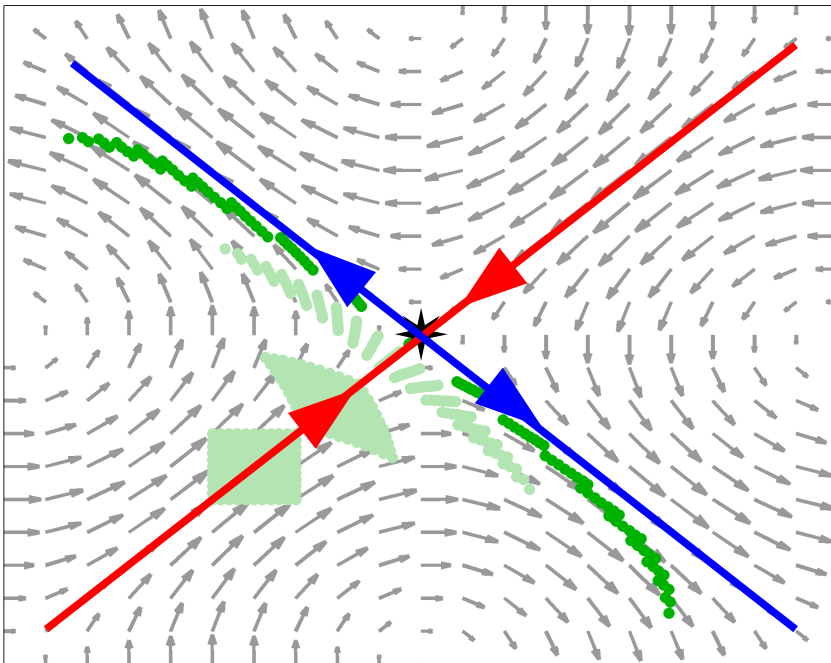- **Example: Particle dispersion around an hyperbolic point**

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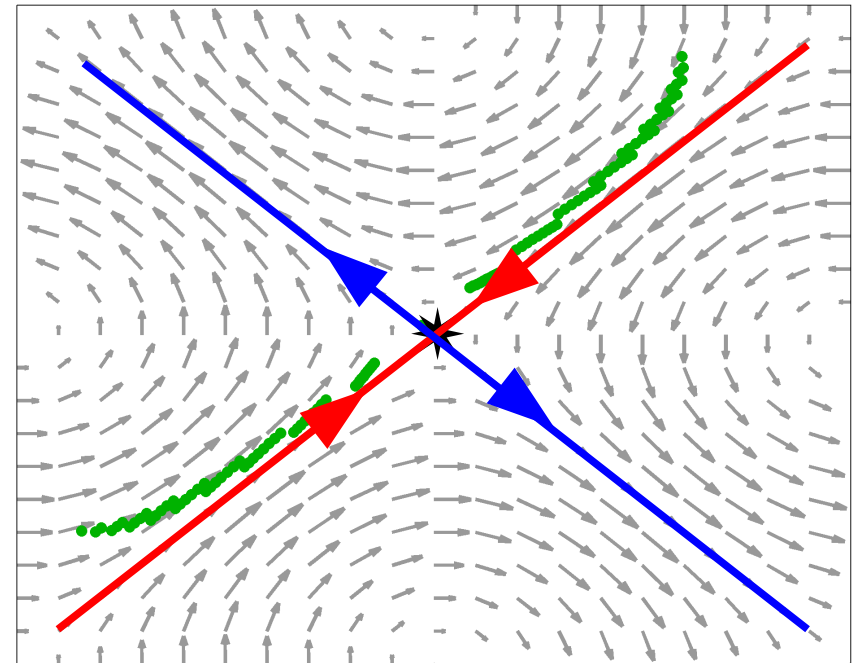- **Example: Particle dispersion around an hyperbolic point**

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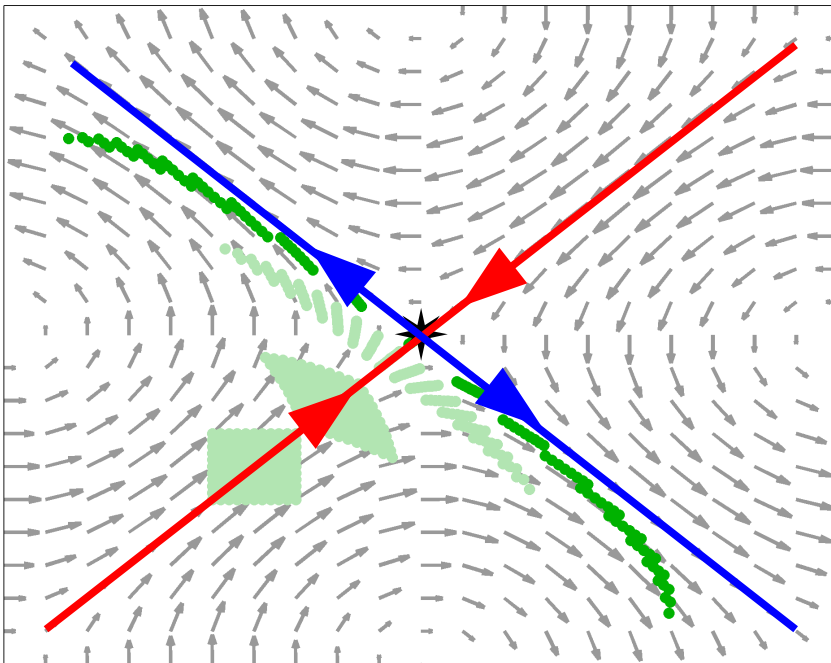- **Example: Particle dispersion around an hyperbolic point**

- **Particles move along and spread across converging direction: Repelling LCS**

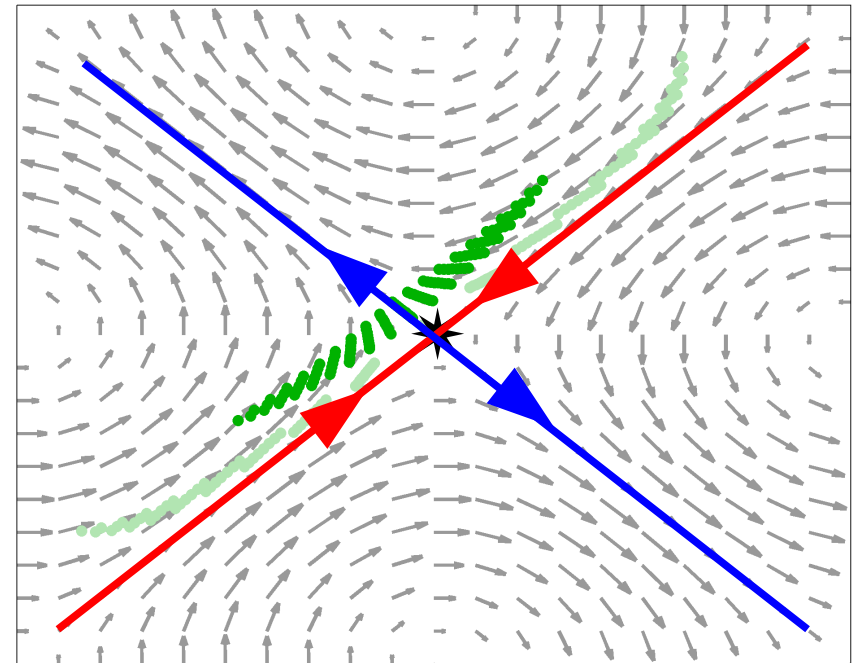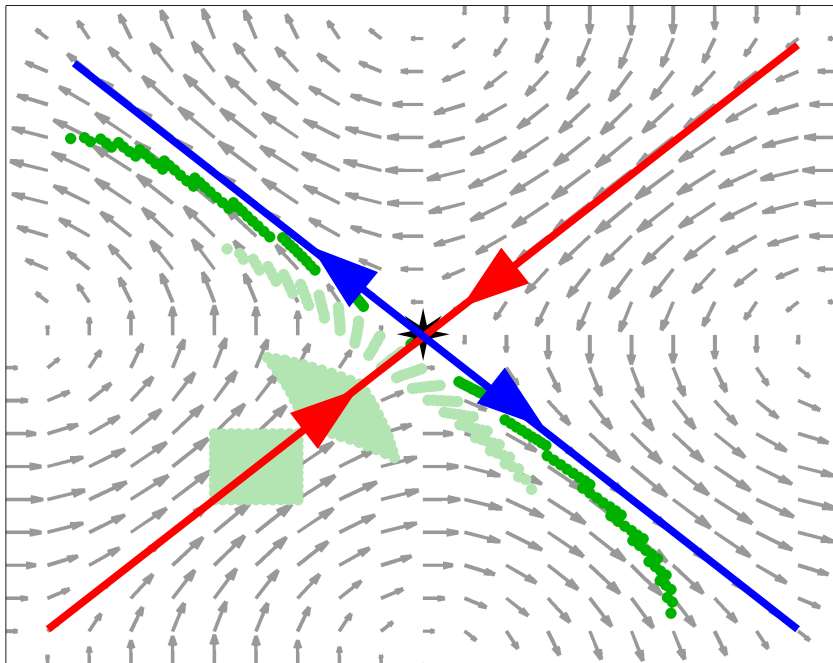# Lagrangian Coherent Structures

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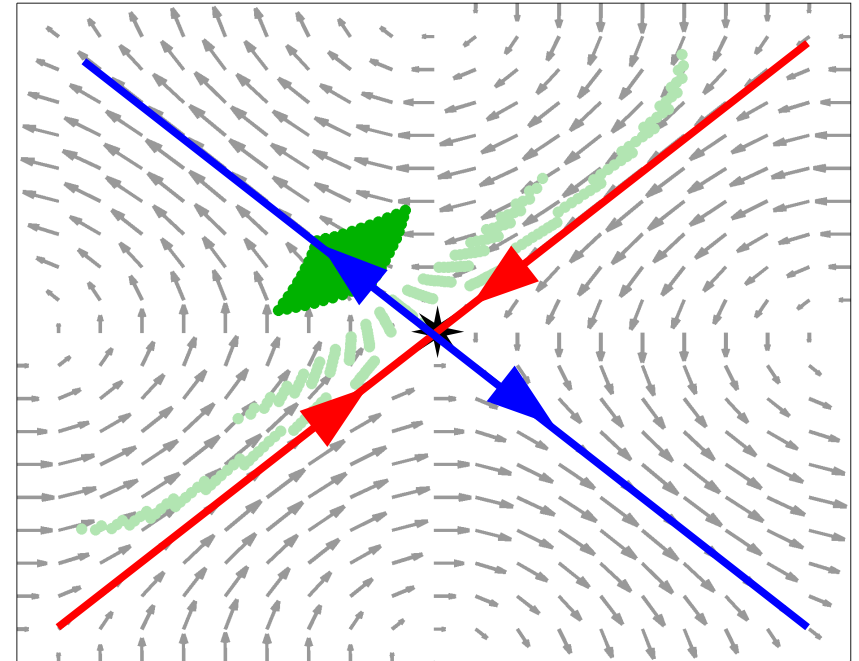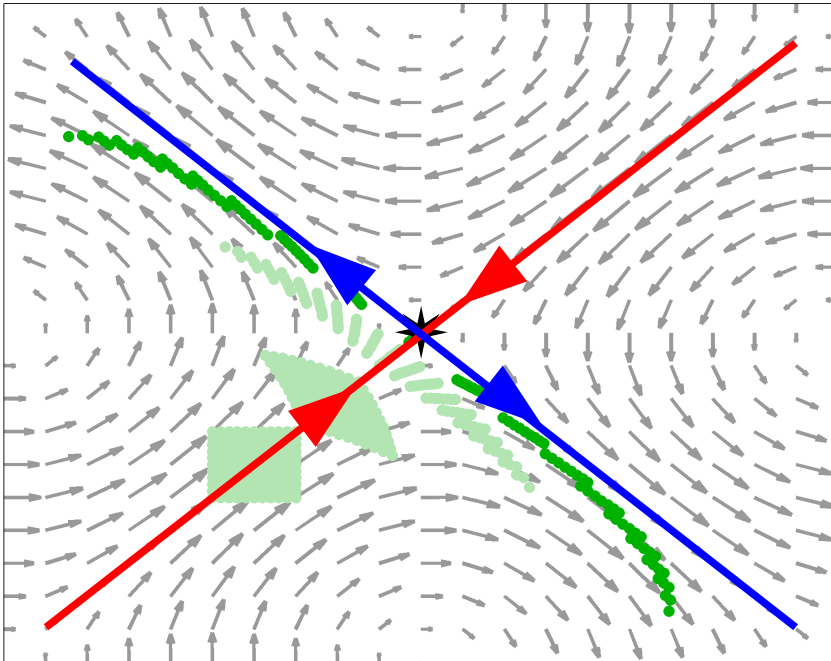
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- **Particles align along diverging direction (transport barrier): Attracting LCS**
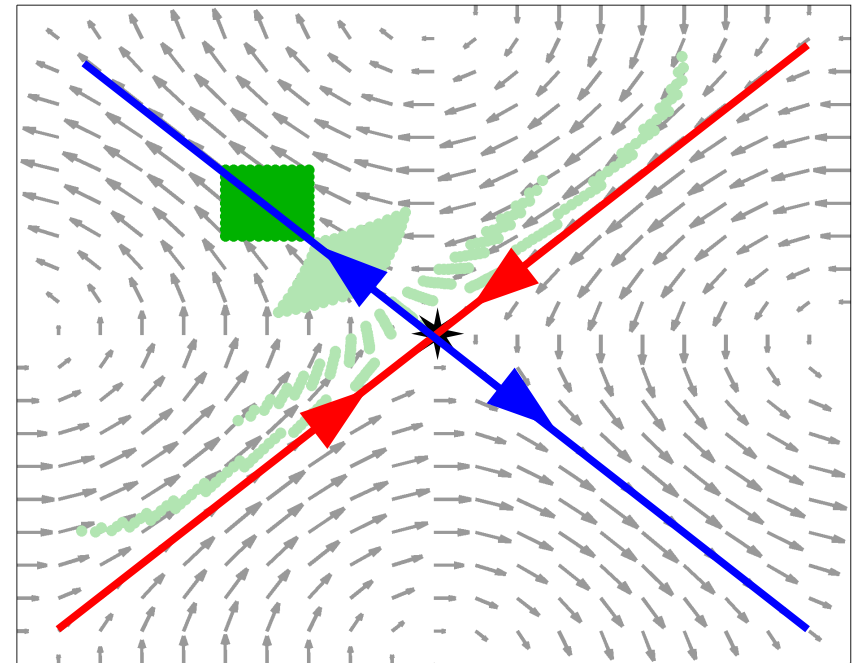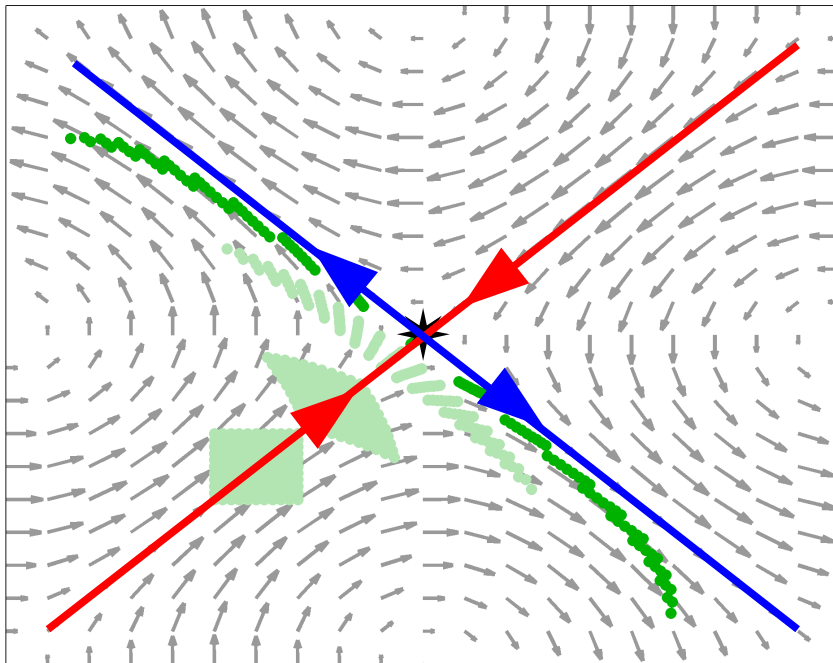
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- **Open ocean**: **LCSs from altimetry velocity fields using Lyapunov Exponents**

- **Detected structures compared to advected tracers**
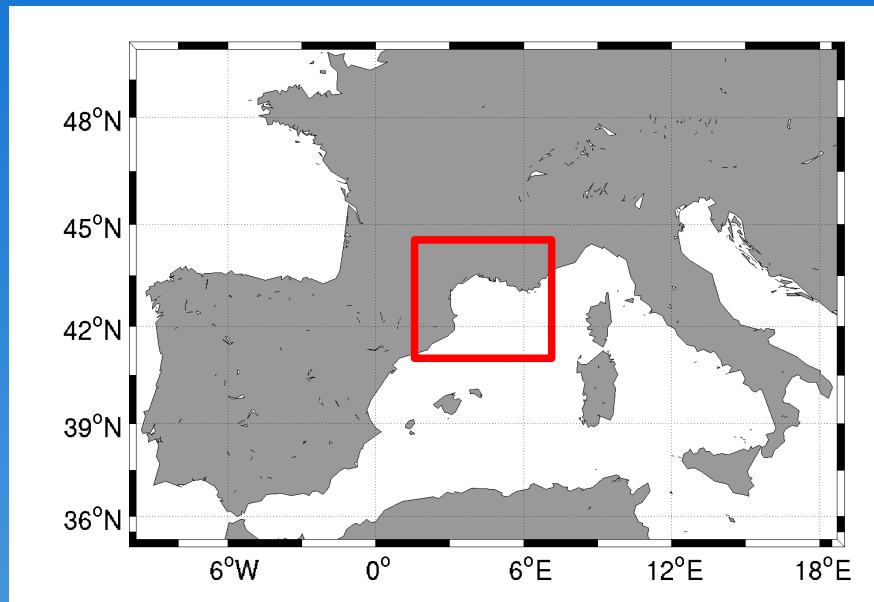
LCSs (red) and SST – SW Mediterranean

(*d'Ovidio et al., 2009*)
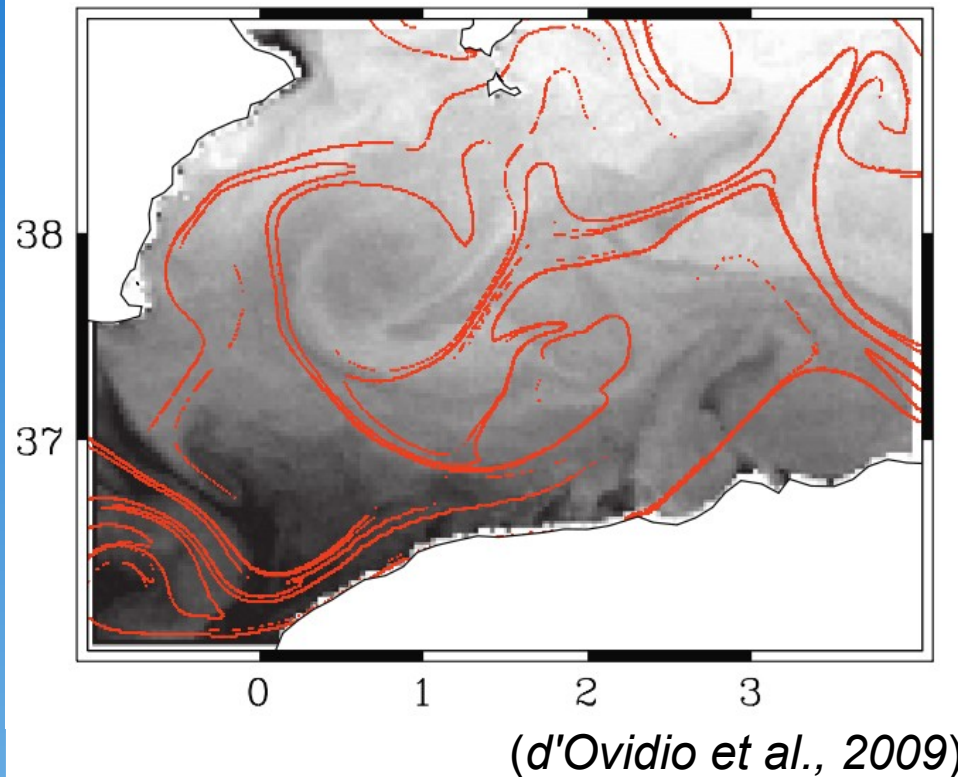
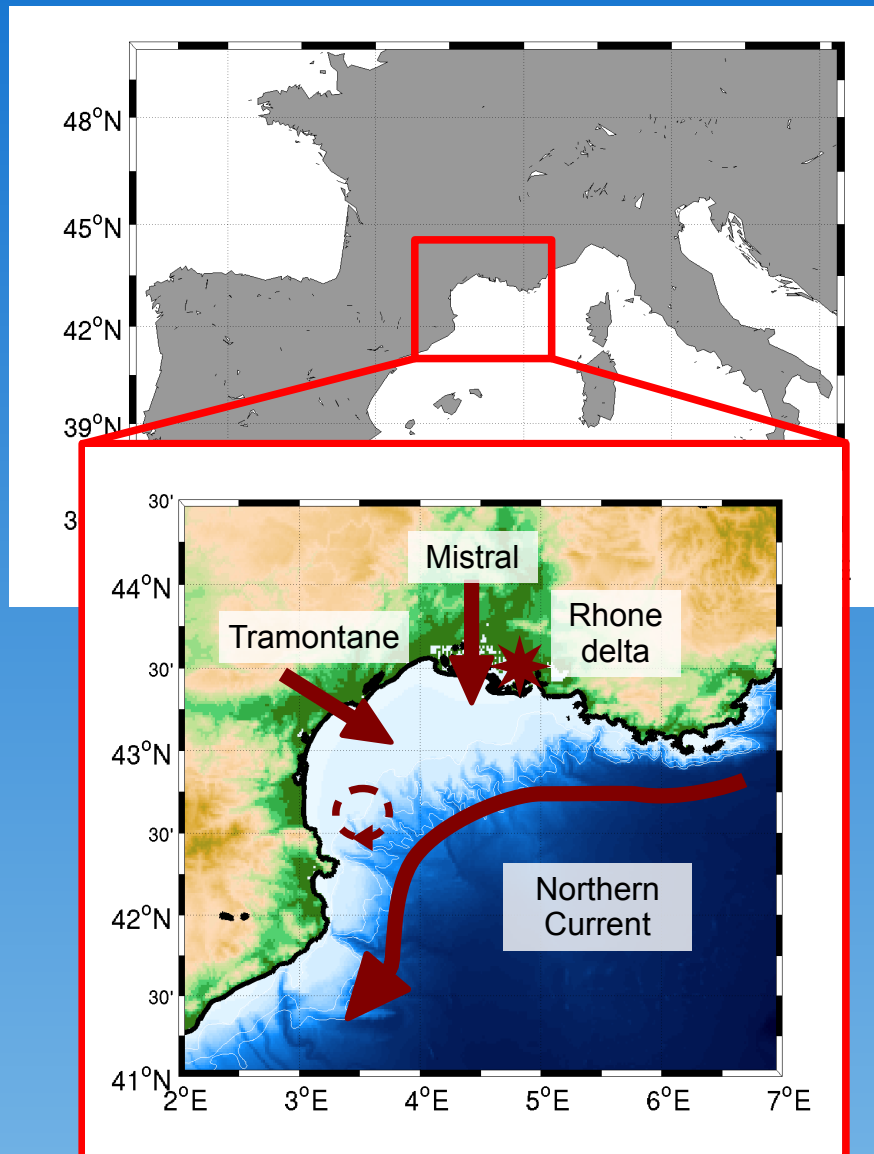**LCSs (black) and Chl – N Atlantic**

(*Lehahn et al., 2007*)
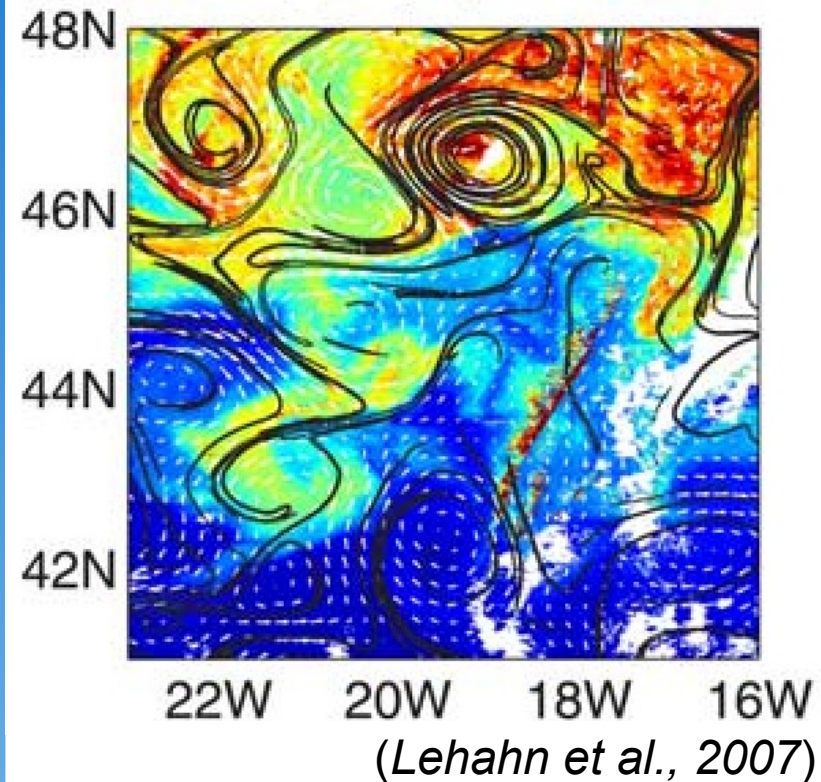
- **Accuracy still relatively untested in coastal areas**

- **Altimetry LCSs compared to *in-situ* LCSs in the Gulf of Lion (GoL)**

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- **Large continental shelf**

- **Three main forcings:**
  - ➔ **Mistral & Tramontane**
  - ➔ **Delta of Rhone river**
  - ➔ **Northern Current**

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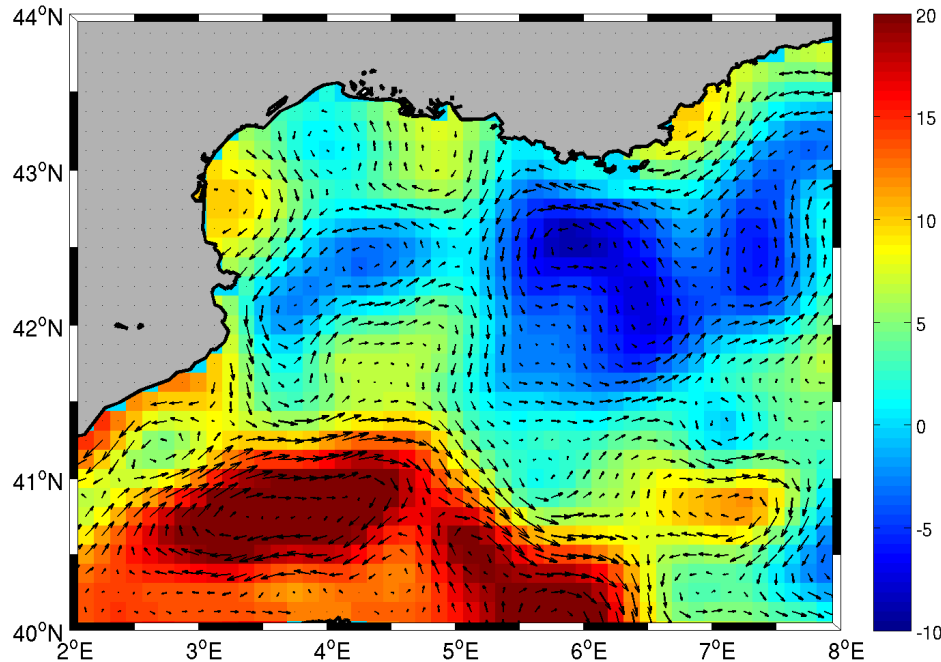- **(Sub)mesoscale anticyclones in the western part**

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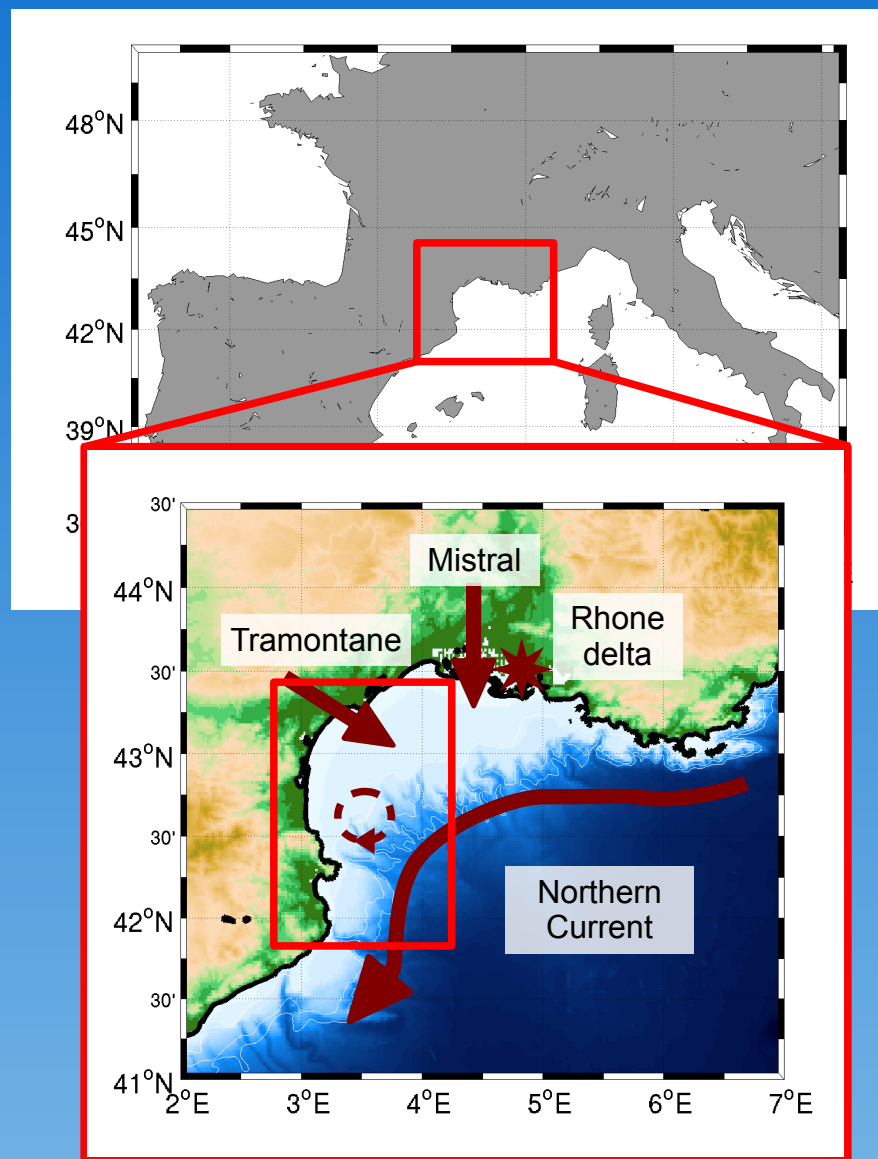
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Lagrangian Transport Experiment
Latex10, September 1-24, 2010
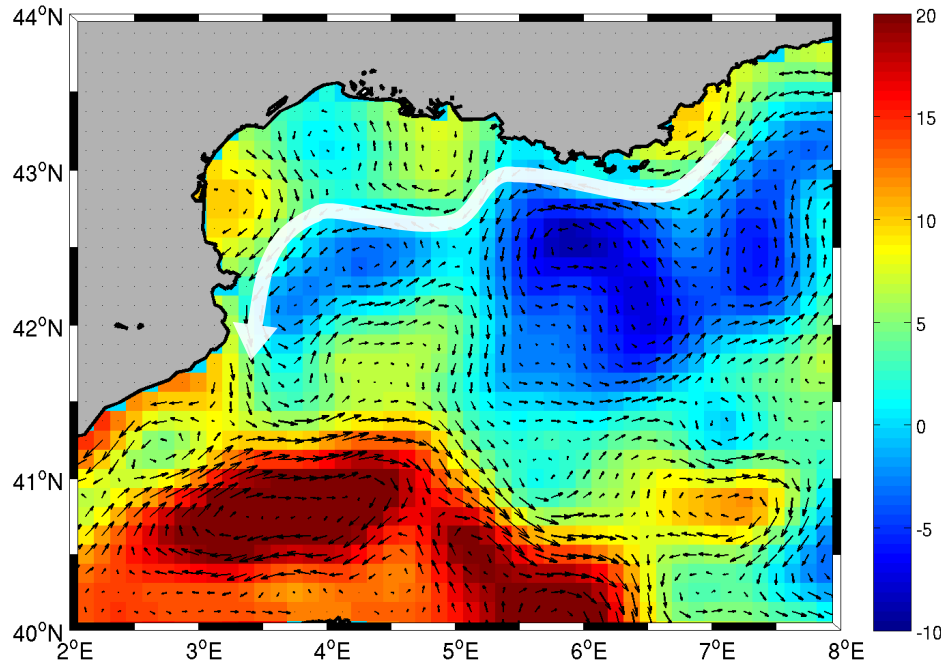
Transport and biogeochemistry in the western part of the GoL
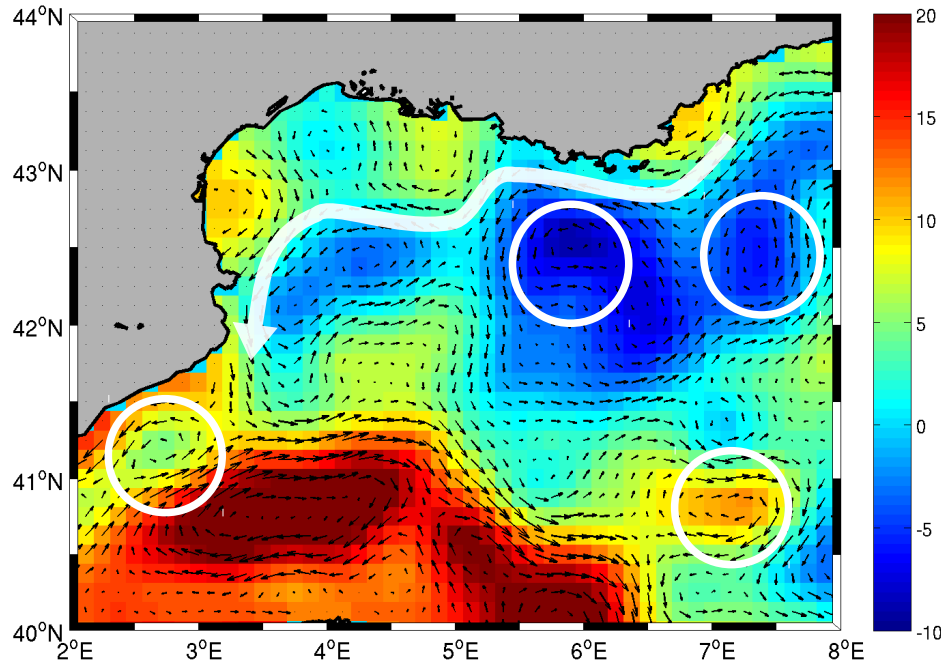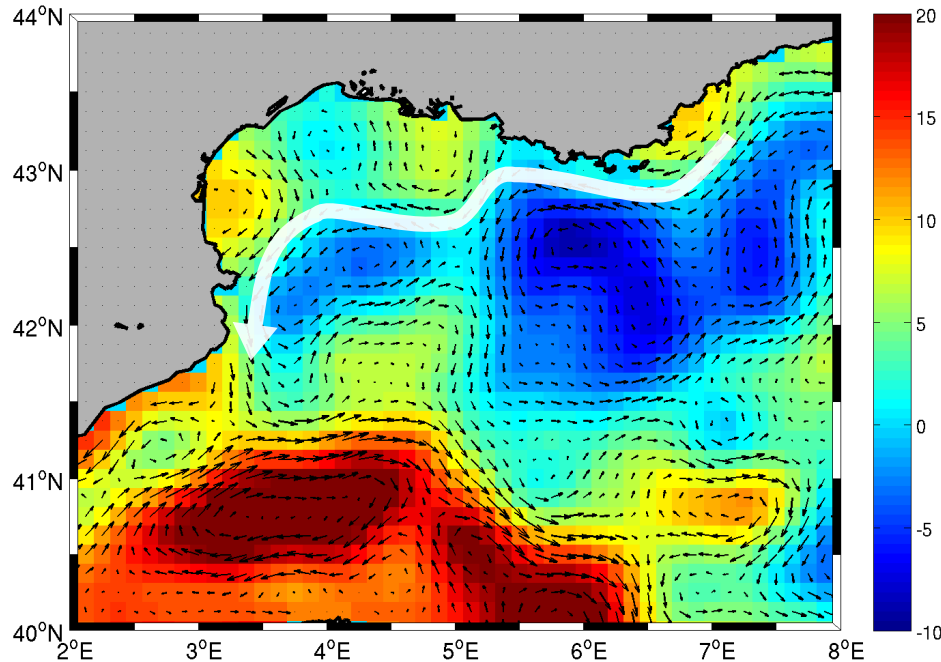
- **Altimetry LCSs from AVISO velocities using Finite-size Lyapunov exponents analysis (FSLE; *d'Ovidio et al., 2004*)**

- **Geostrophic surface velocity fields derived from SSH**

- **1/8 degree, daily**

AVISO SSH (shaded) & velocity vectors
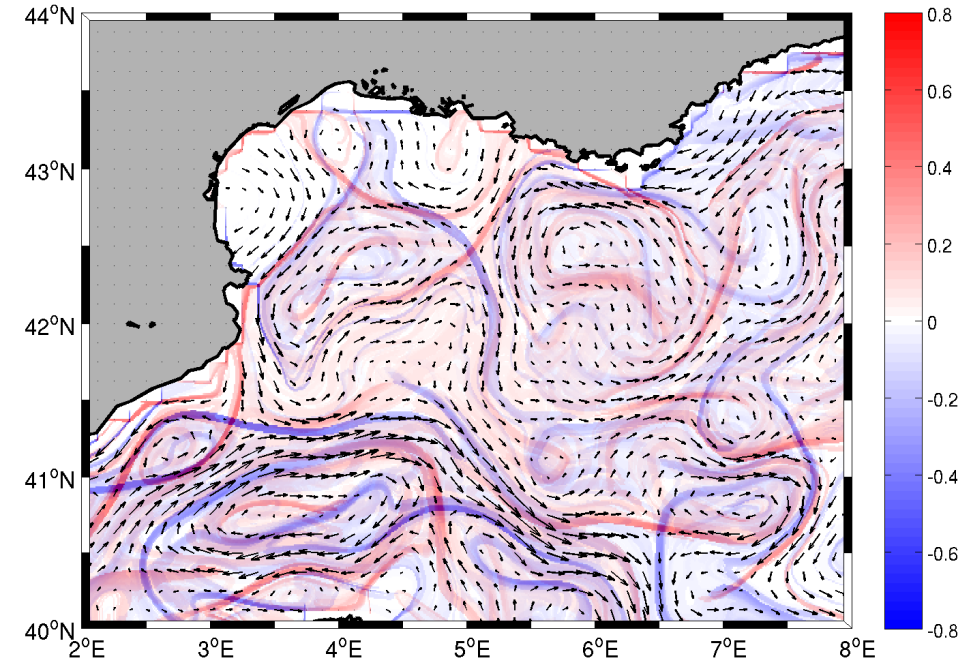September 18, 2010

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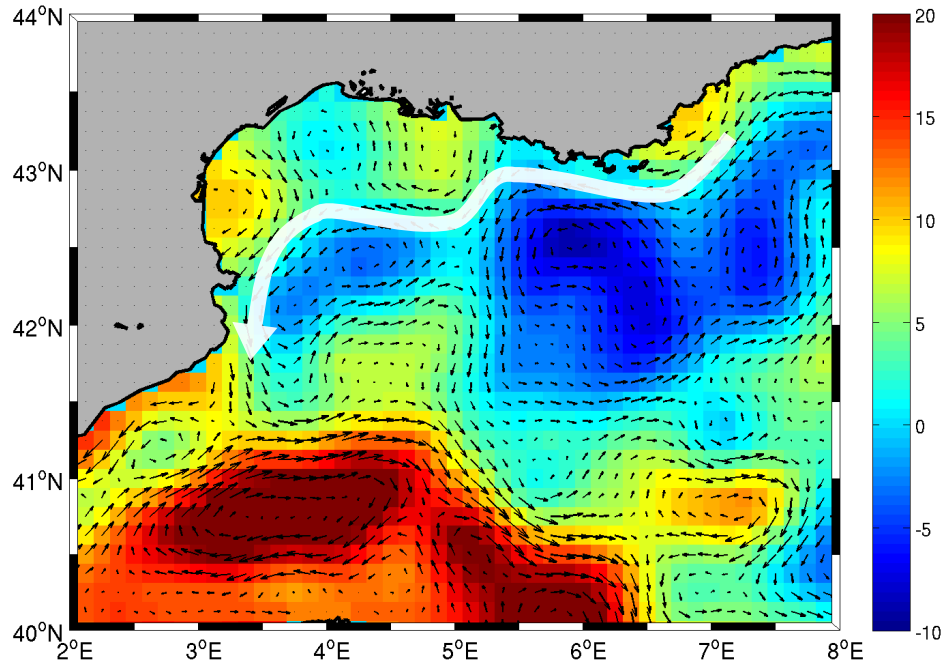**AVISO SSH (shaded) & velocity vectors**
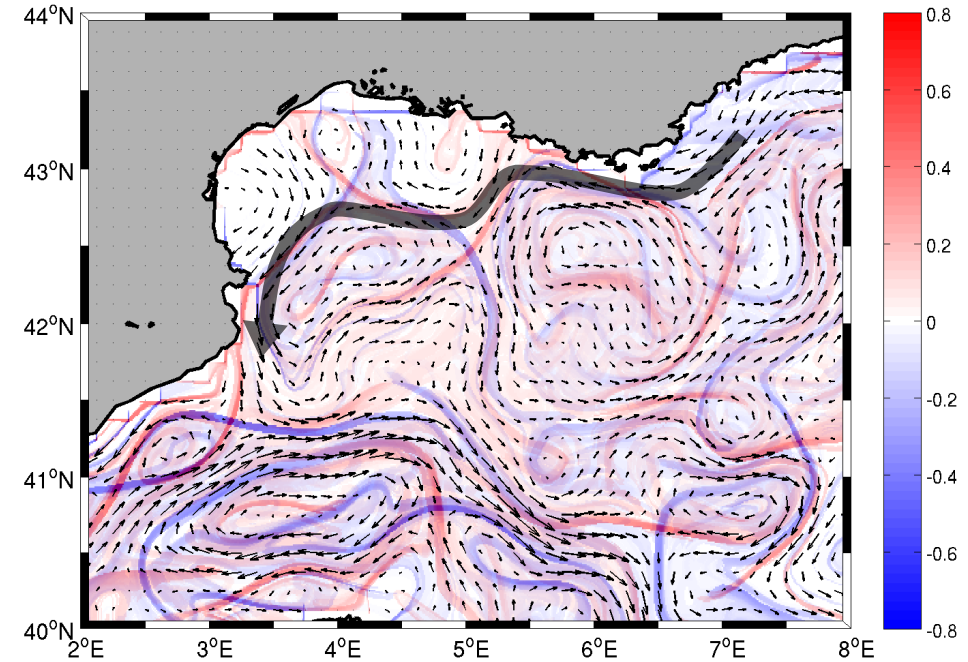**September 18, 2010**

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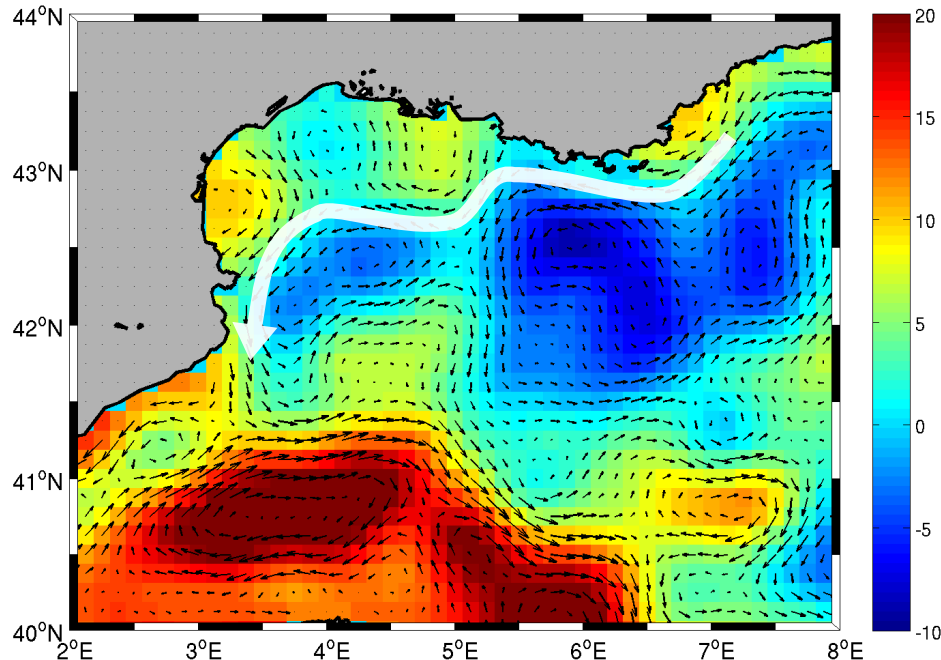**AVISO SSH (shaded) & velocity vectors September 18, 2010**

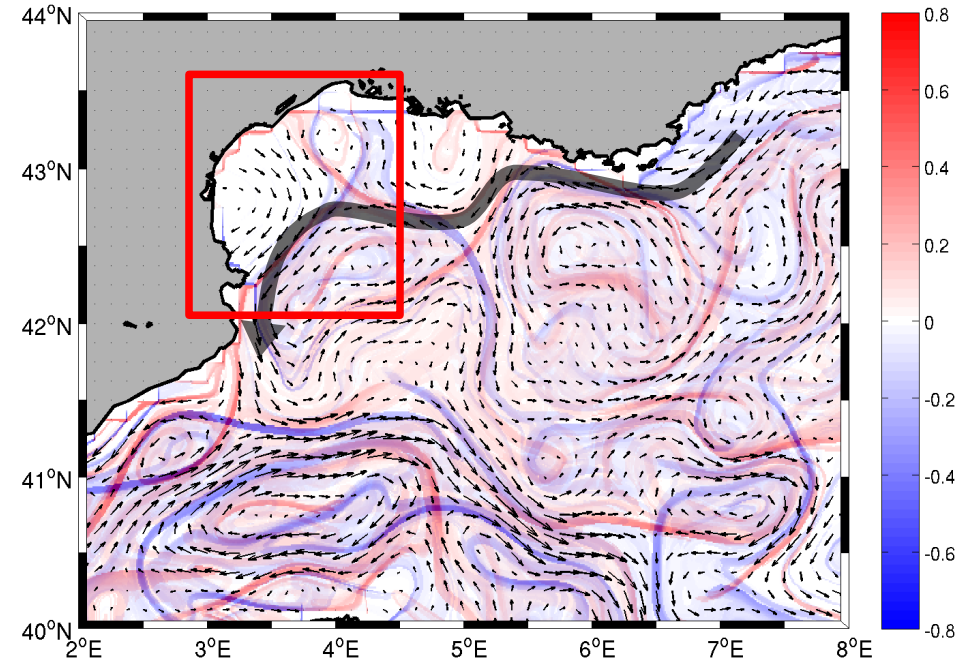**Attractive (blue) & Repulsive (red) LCSs from FSLE (day^{-1})**

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In-situ LCSs

Latex10 Adaptive Sampling Strategy for detection of *in-situ* LCSs:

1. Position of large scale LCSs estimated from altimetry derived FSLE

2. *In-situ* deployment of drifters

3. Mapping of *in-situ* velocities (hull mounted ADCP)

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Deployment of 3 drifter arrays:

➔ **Lyap01** (September 12)

➔ **Lyap02** (September 18)

➔ **Lyap03** (September 21)

LCSs from array dispersion patterns

September 12, 2010
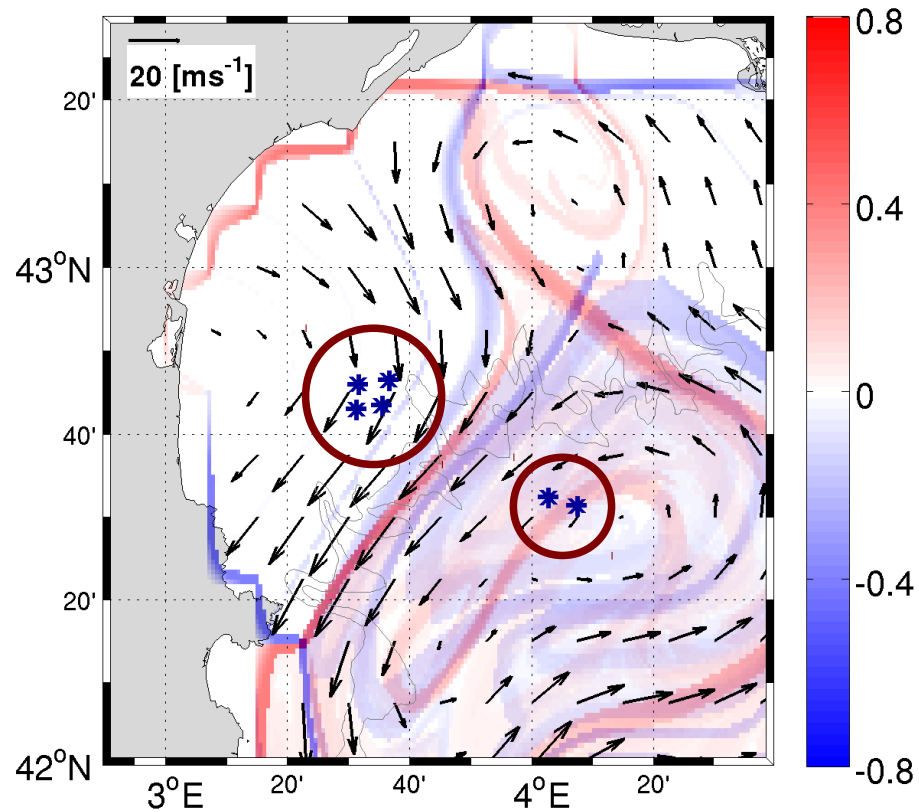- Altimetry geostrophic velocity vectors
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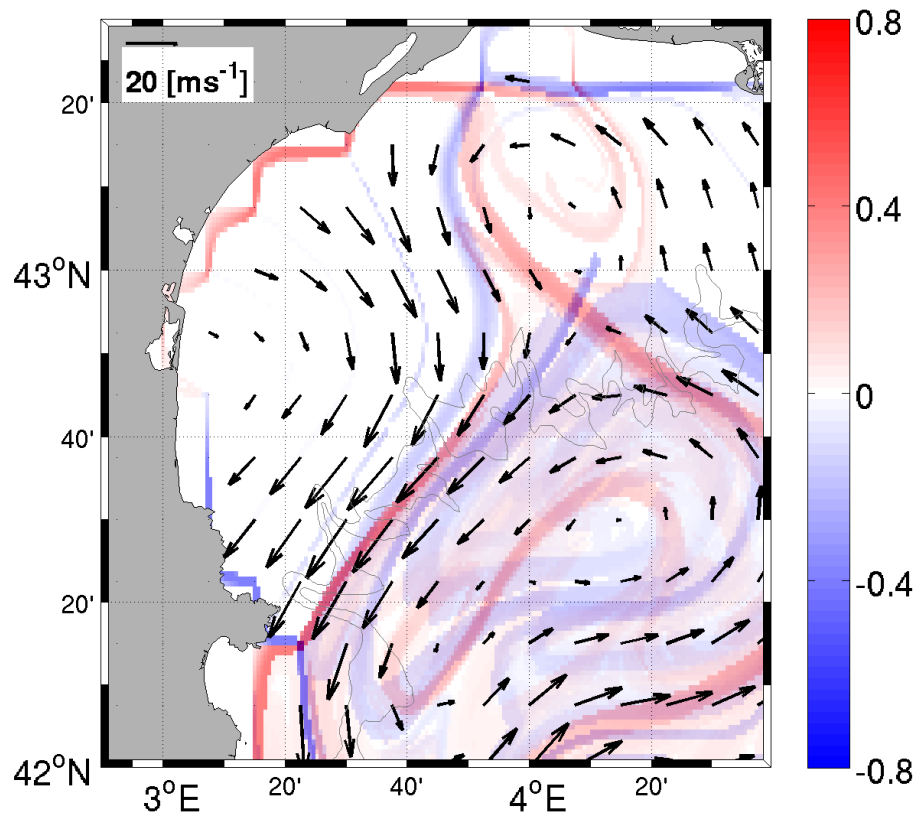
September 12, 2010
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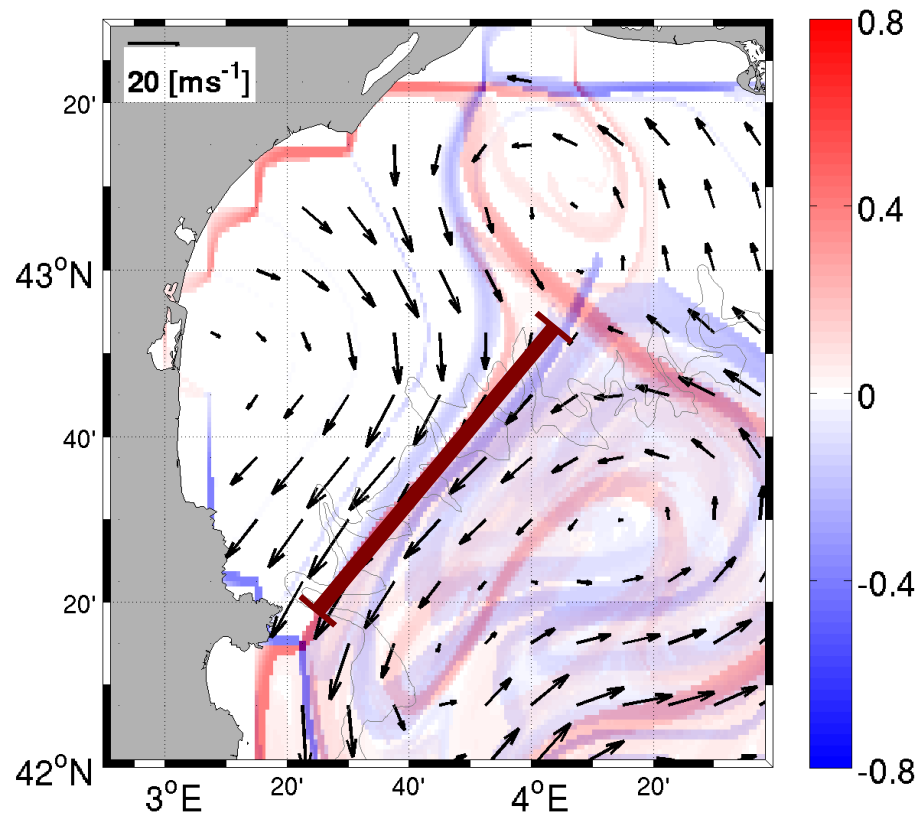
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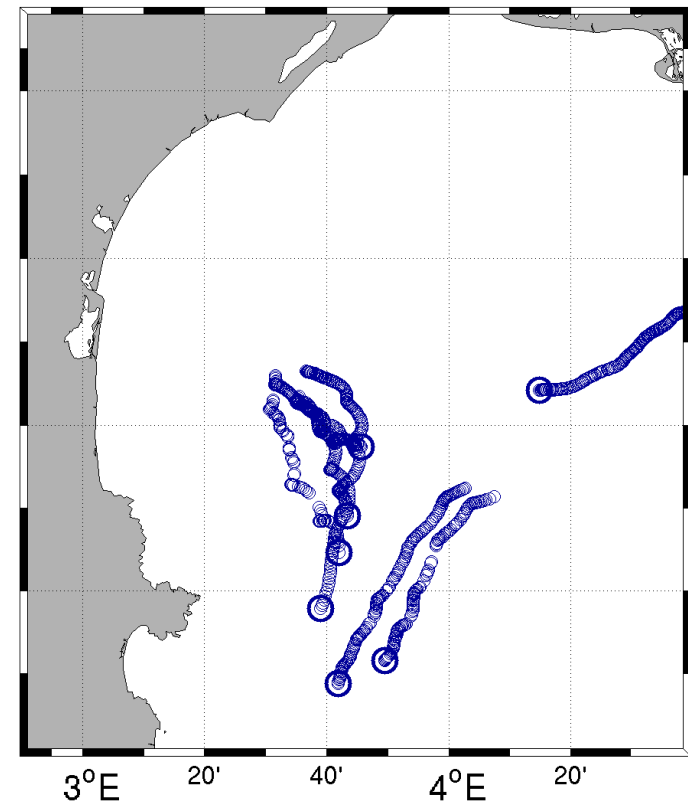- Initial position of drifter array

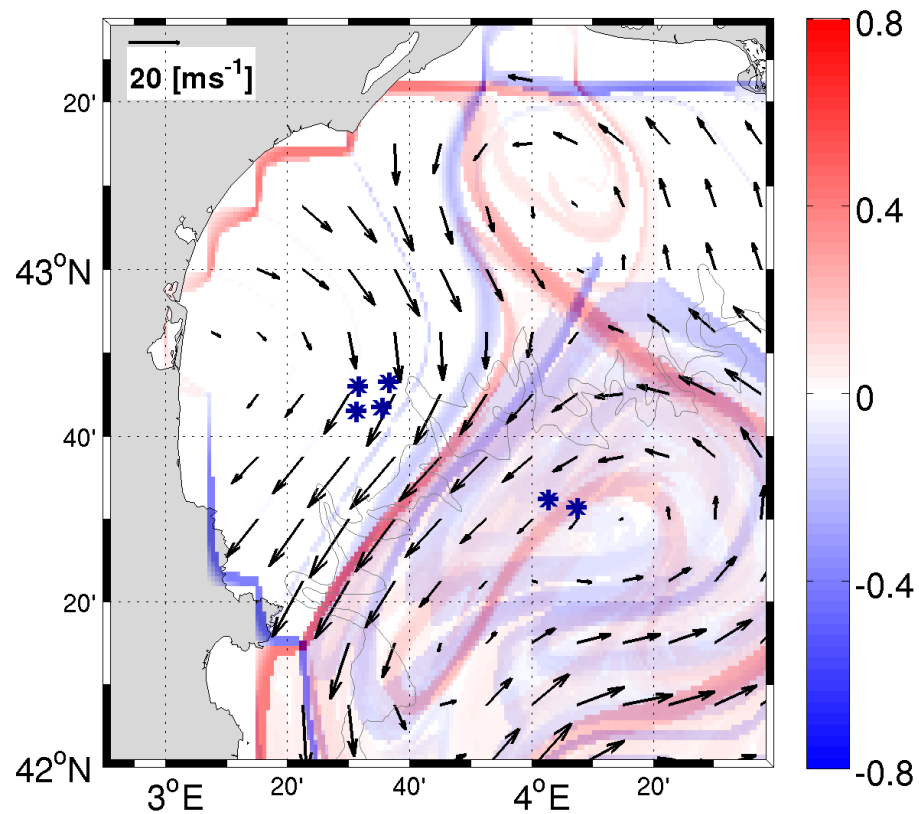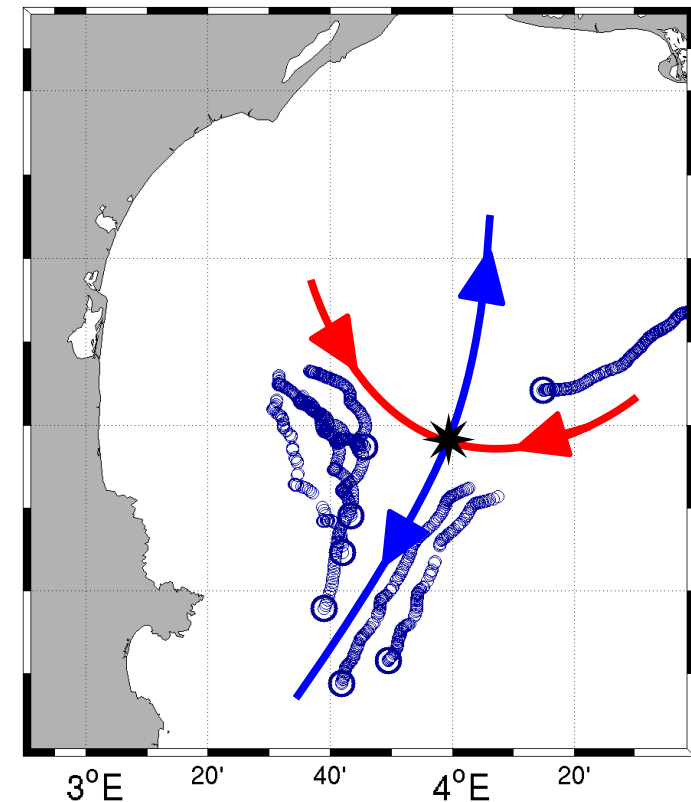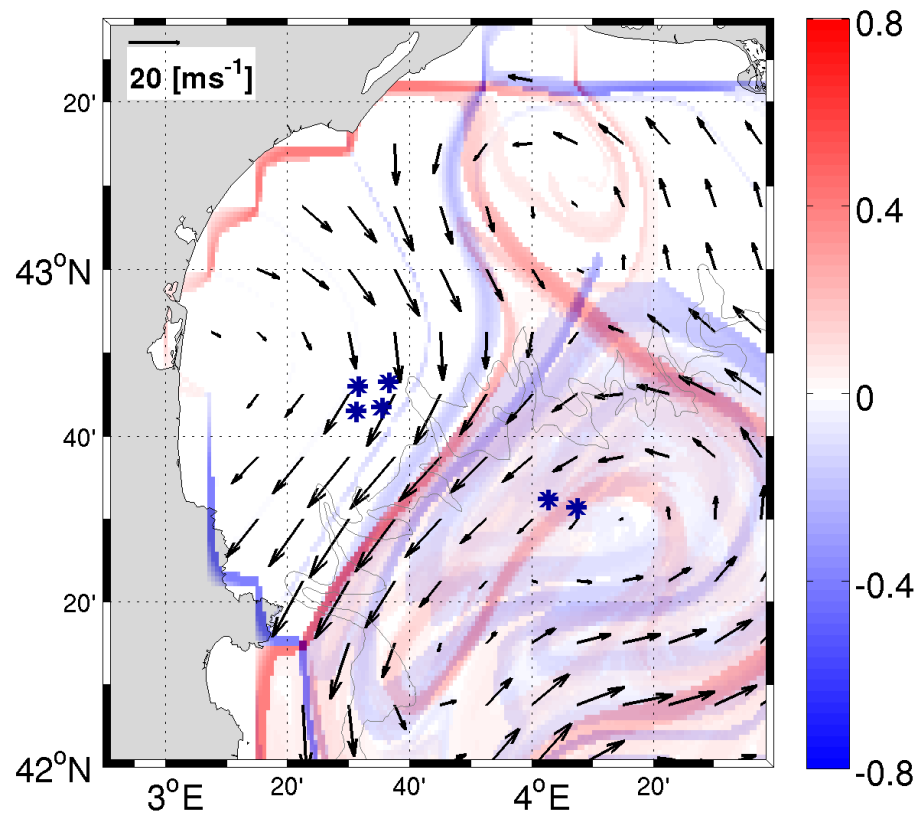**September 12, 2010**
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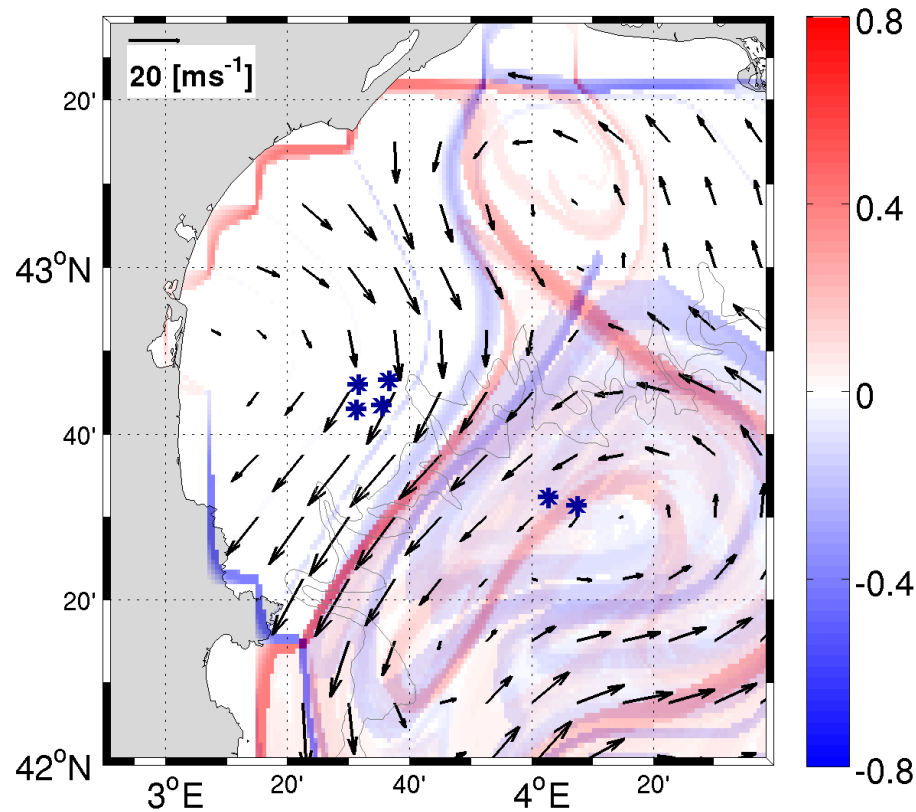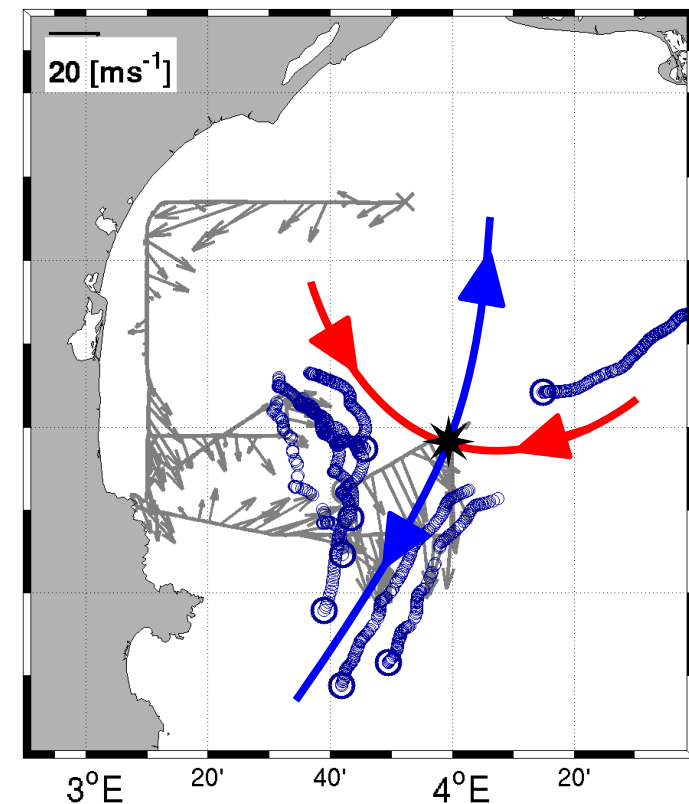
September 12-14, 2010
- Drifter trajectories

September 12, 2010
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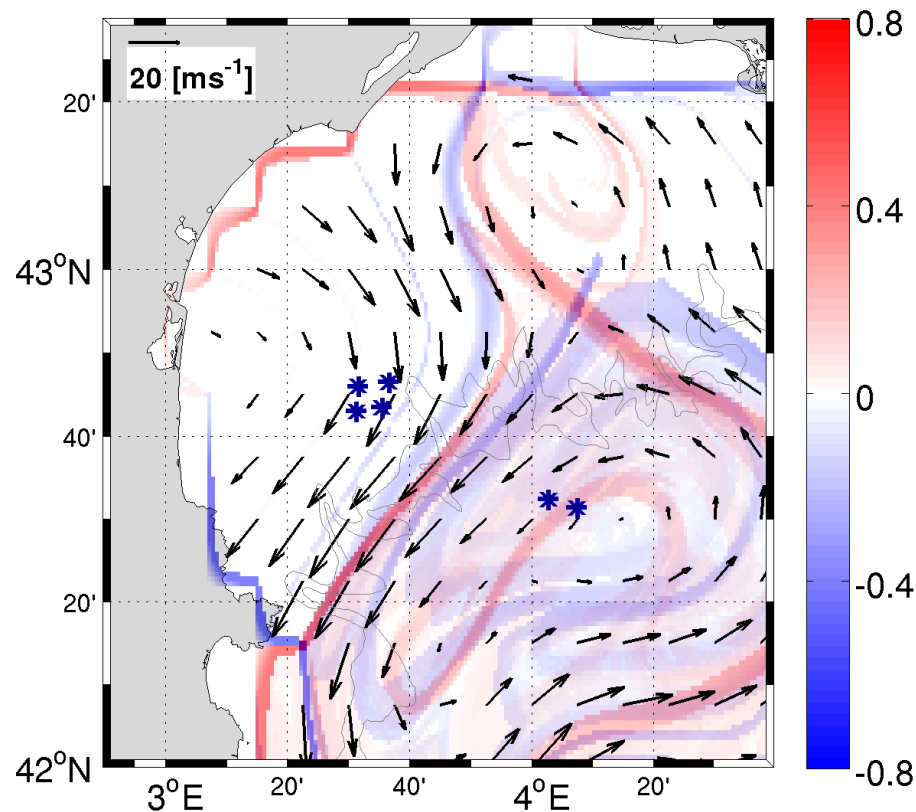- Initial position of drifter array

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- *In-situ* LCSs

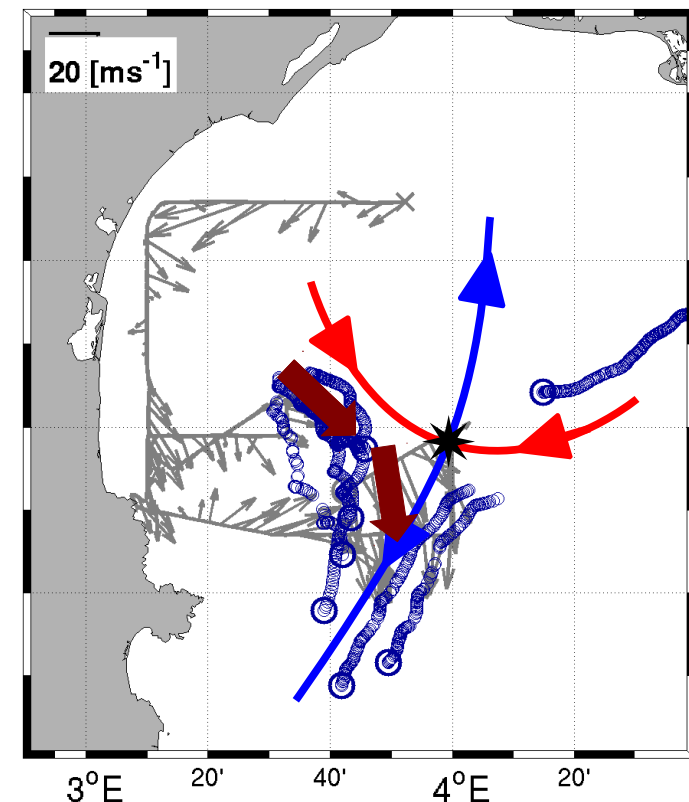- **Repelling LCS on the continental shelf not detected**

September 12, 2010
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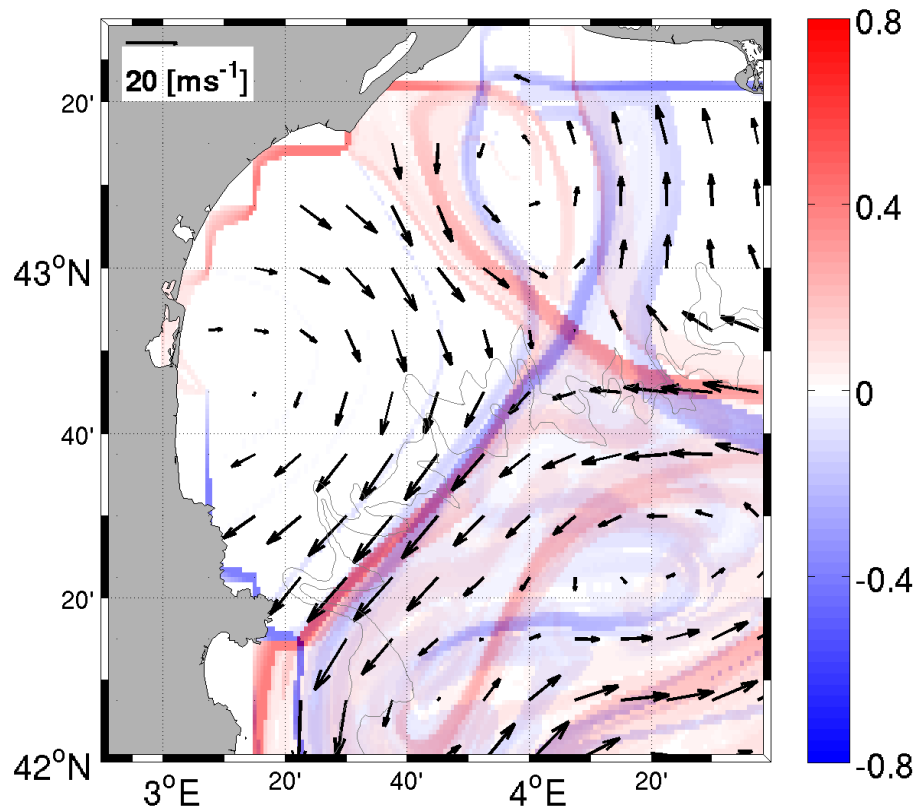
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September 12, 2010
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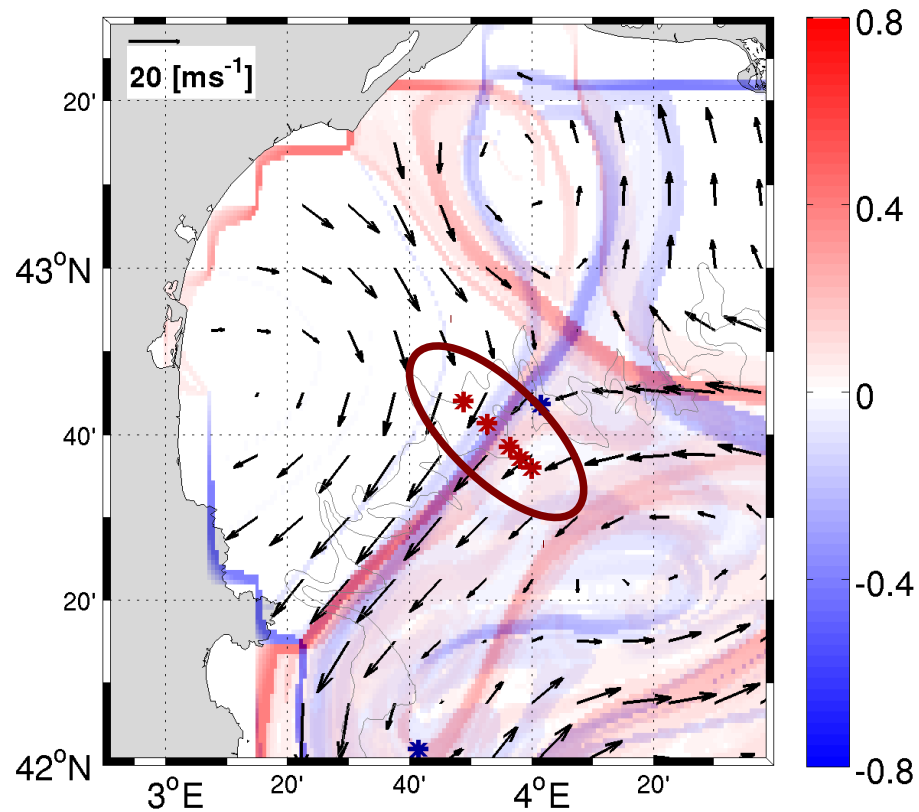- **Confirmed by ADCP velocities**

September 18, 2010
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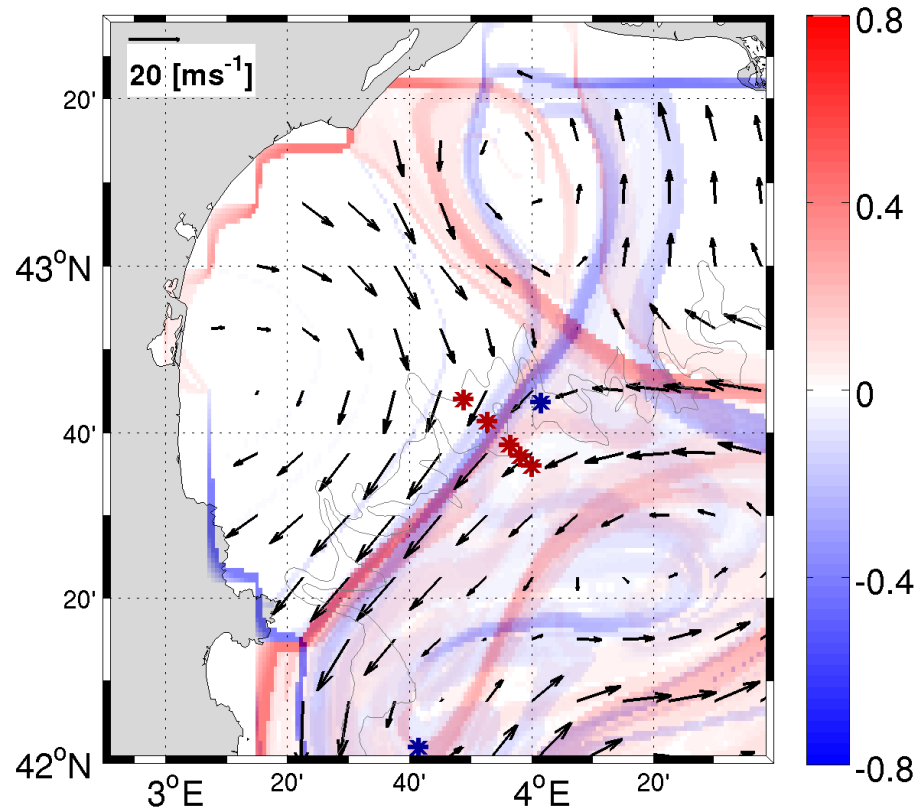• Satellite structures similar to Sept. 12

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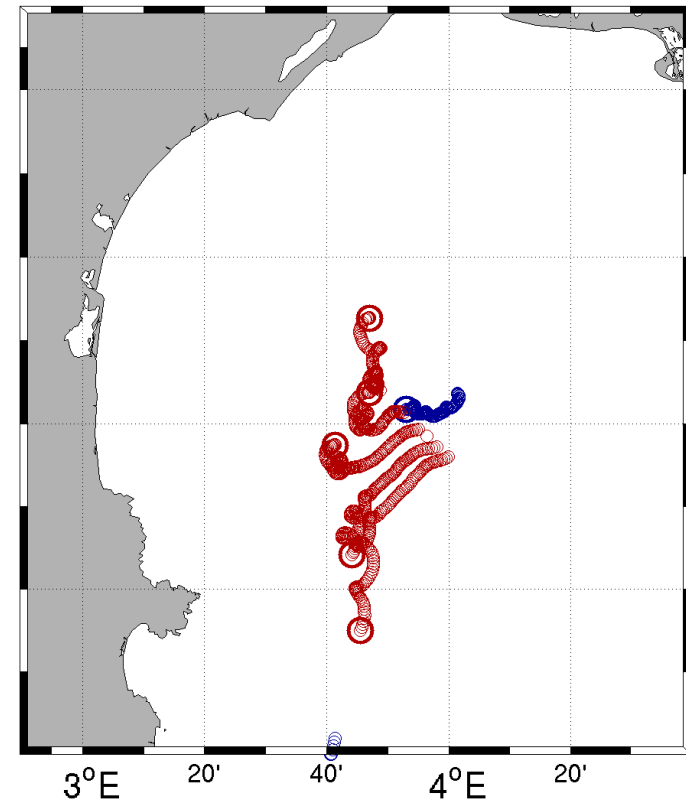• **Satellite structures similar to Sept. 12**

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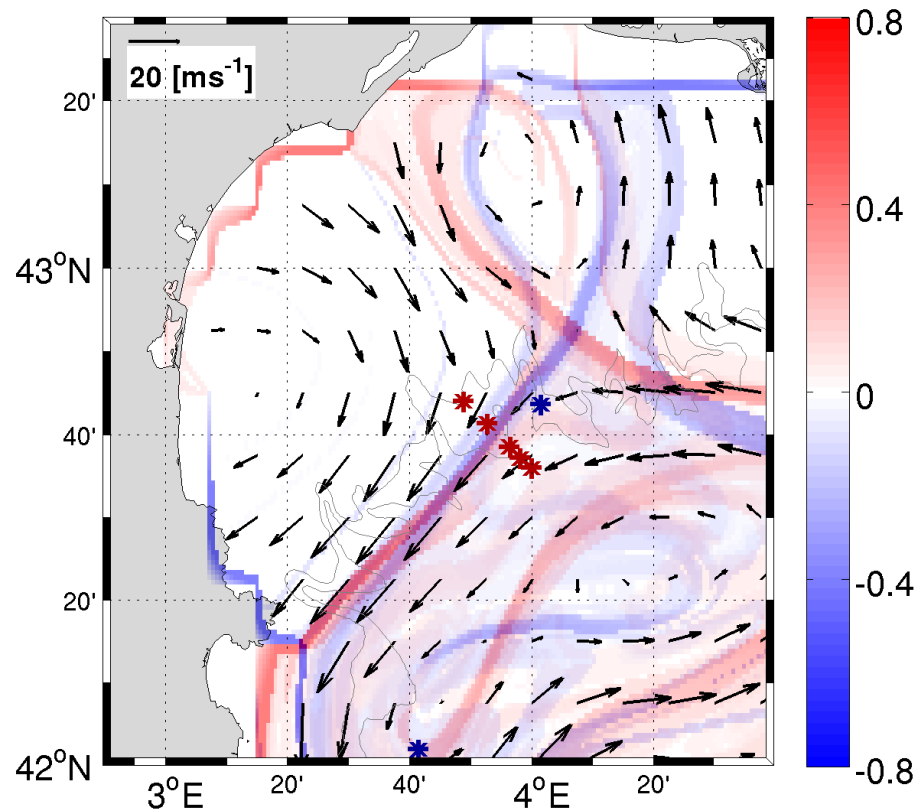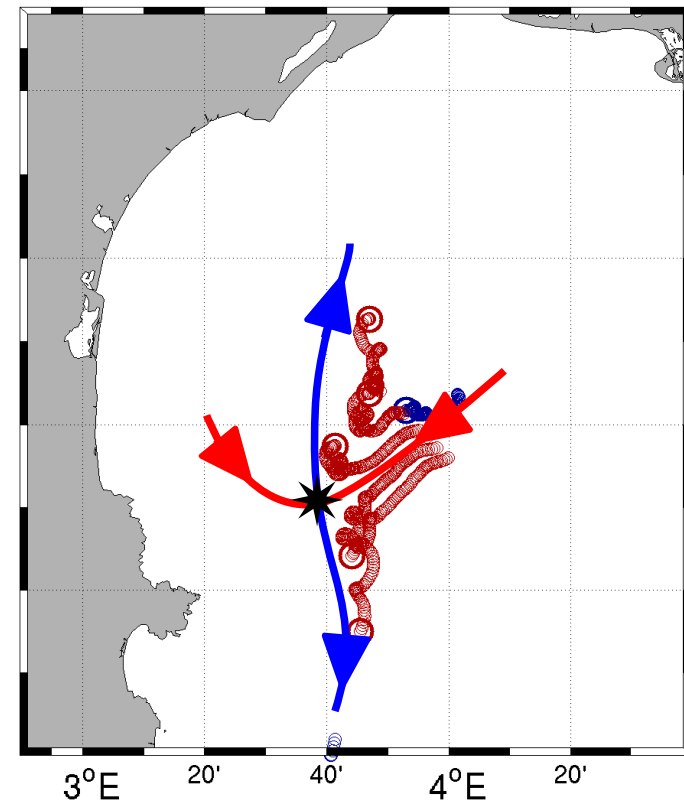- Initial position of drifter array

September 18-20, 2010
- Drifter trajectories

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Lyap02 – Sept 18 - 20

September 18, 2010
- **Altimetry geostrophic velocity vectors**
- **Attractive (blue) & Repulsive (red) LCSs**
- **Initial position of drifter array**

September 18-20, 2010
- **Drifter trajectories**
- *In-situ* **LCSs**

- **Satellite structures similar to Sept. 12**

- **Accurate identification of LCSs and hyperbolic point**

September 18, 2010
- Altimetry geostrophic velocity vectors
- Attractive (blue) & Repulsive (red) LCSs
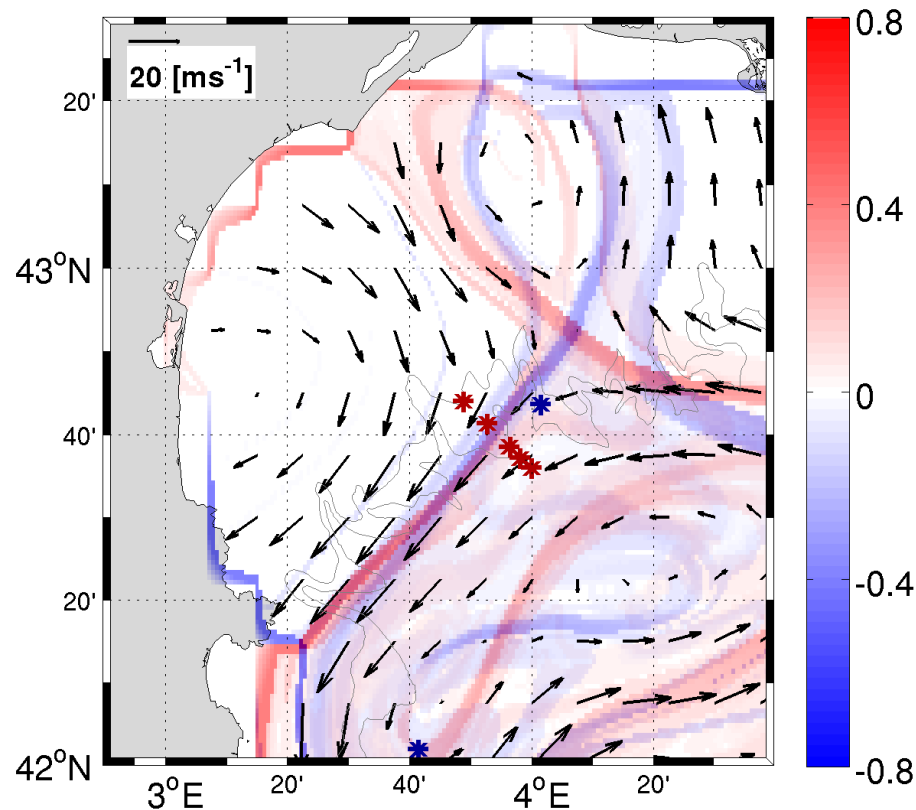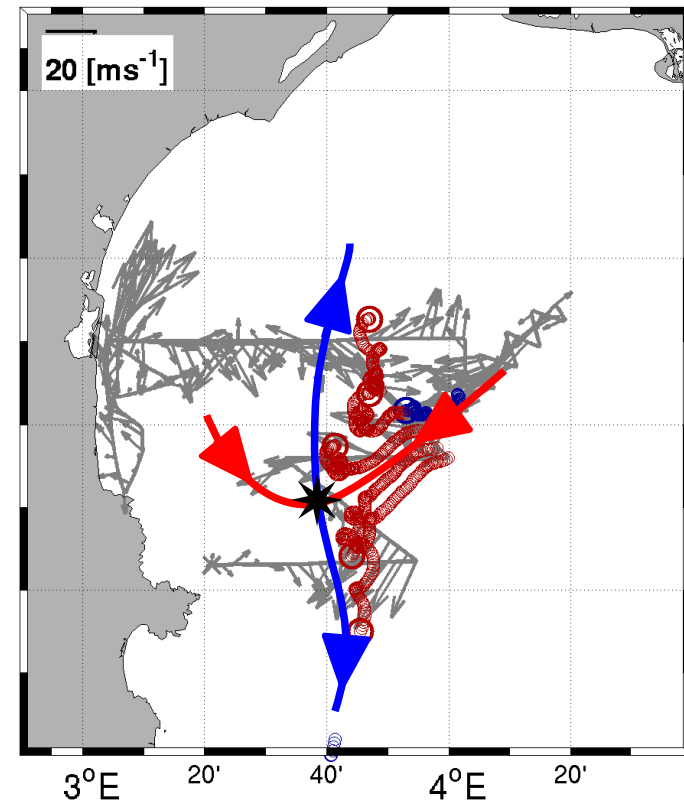- Initial position of drifter array

September 18-20, 2010
- Drifter trajectories
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- 15m ADCP velocity vectors

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September 18, 2010
- Altimetry geostrophic velocity vectors
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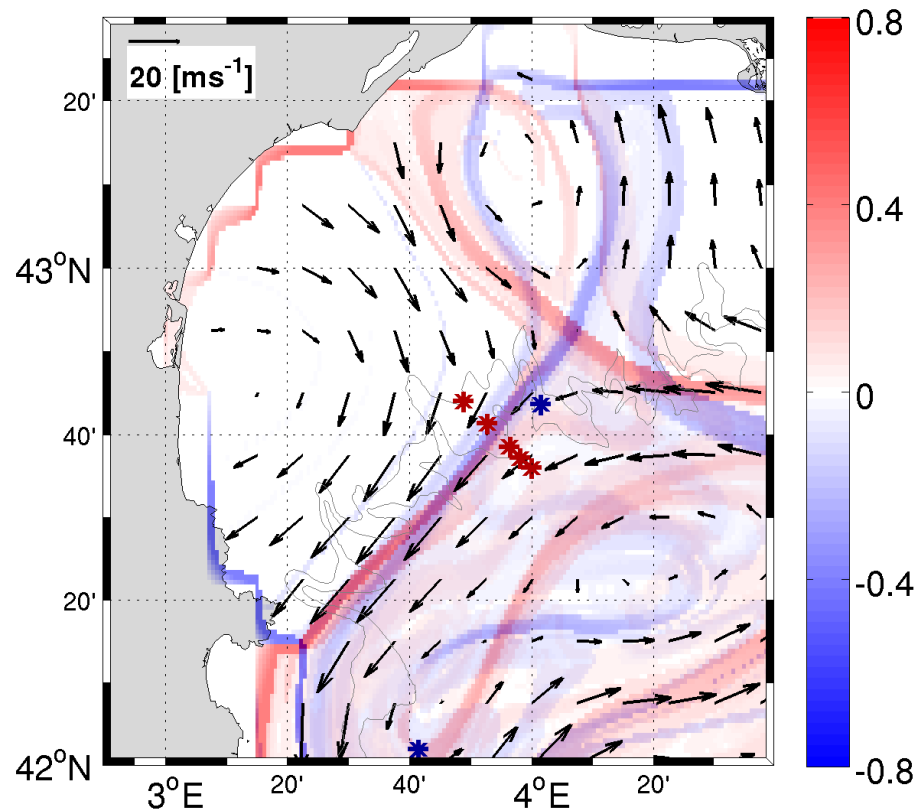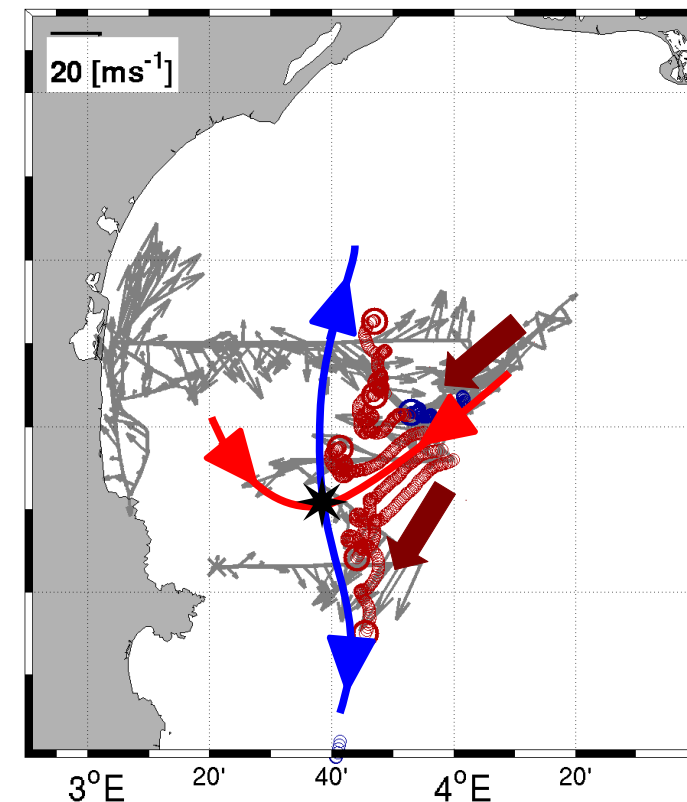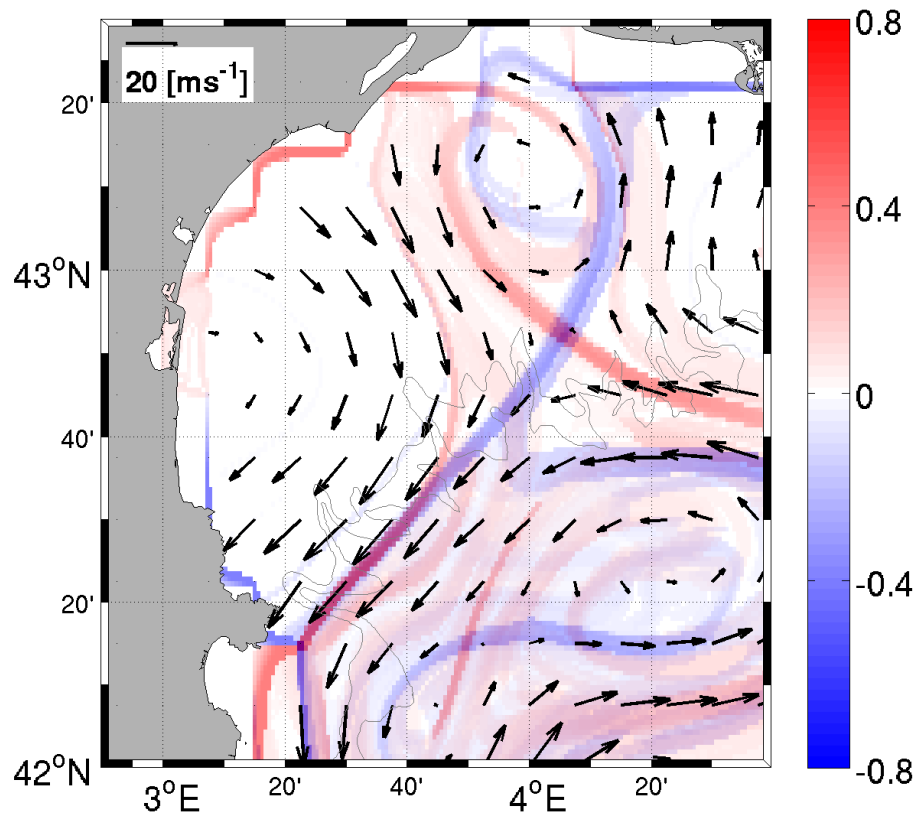- Initial position of drifter array

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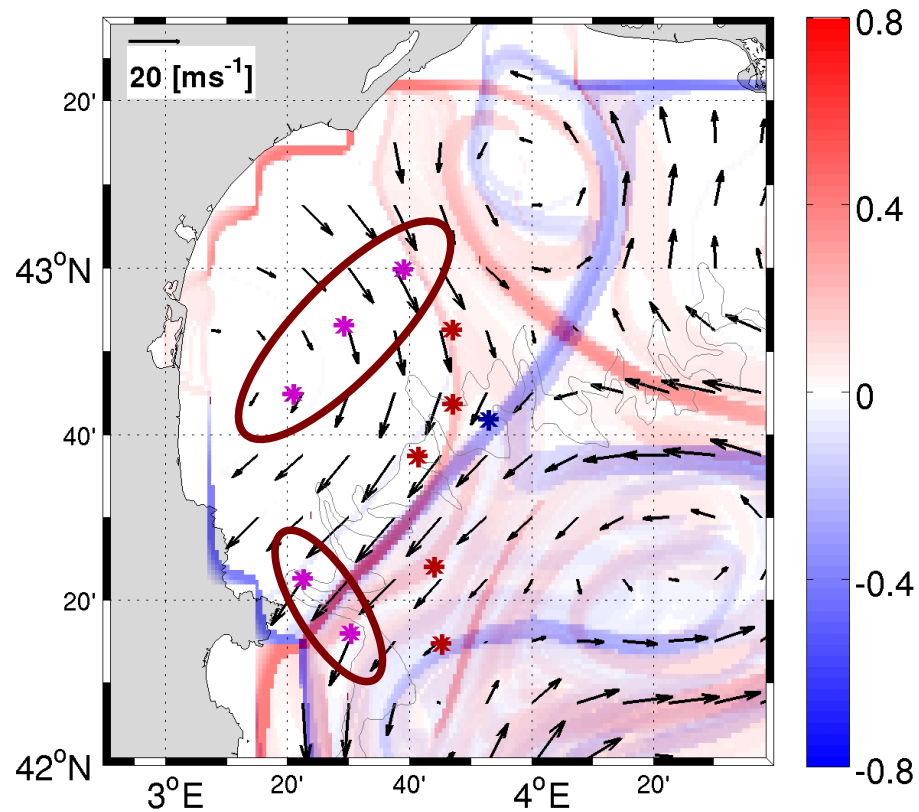
September 21, 2010
•Altimetry geostrophic velocity vectors
•Attractive (blue) & Repulsive (red) LCSs

• Satellite structures similar to Sept. 12
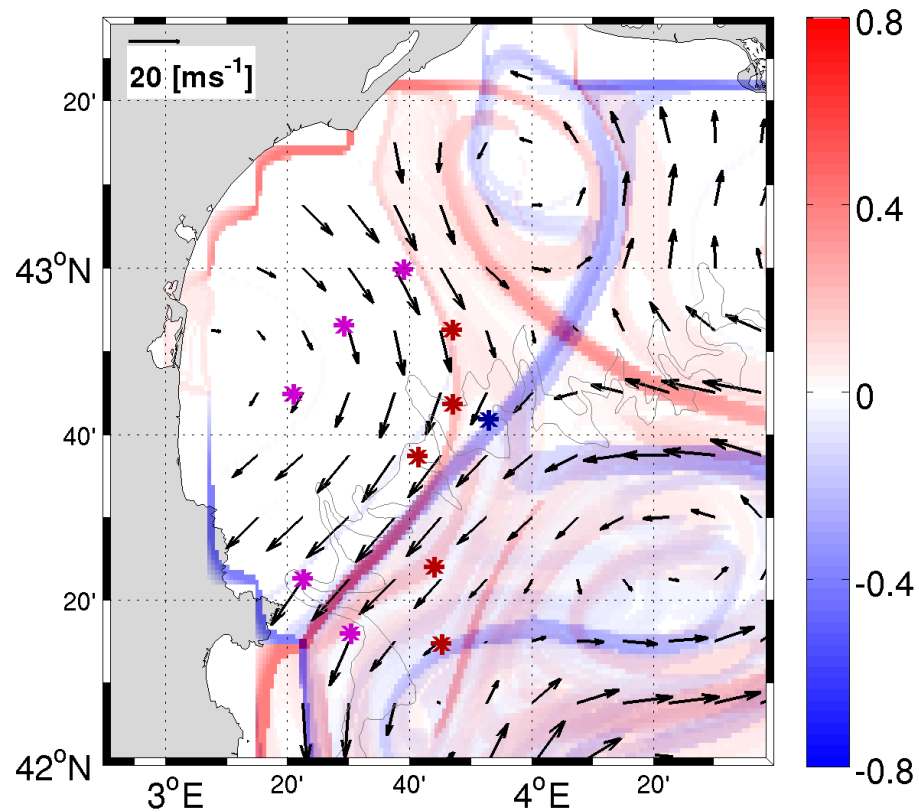
September 21, 2010
- Altimetry geostrophic velocity vectors
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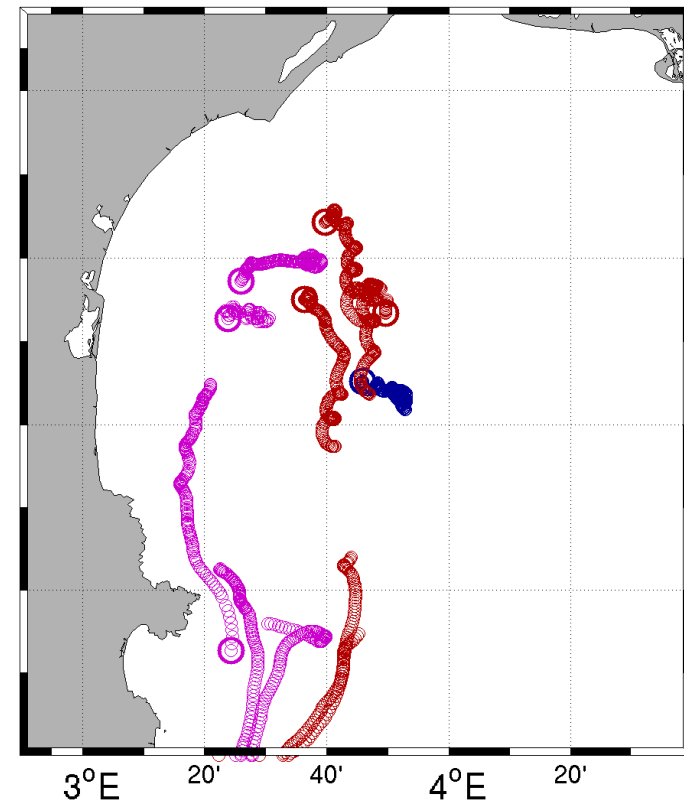- **Satellite structures similar to Sept. 12**

September 21, 2010
- Altimetry geostrophic velocity vectors
- Attractive (blue) & Repulsive (red) LCSs
- Initial position of drifter array

September 21-24, 2010
- Drifter trajectories

- **Satellite structures similar to Sept. 12**

Lyap03 – Sept 21 - 24

September 21, 2010

- Altimetry geostrophic velocity vectors
- Attractive (blue) & Repulsive (red) LCSs
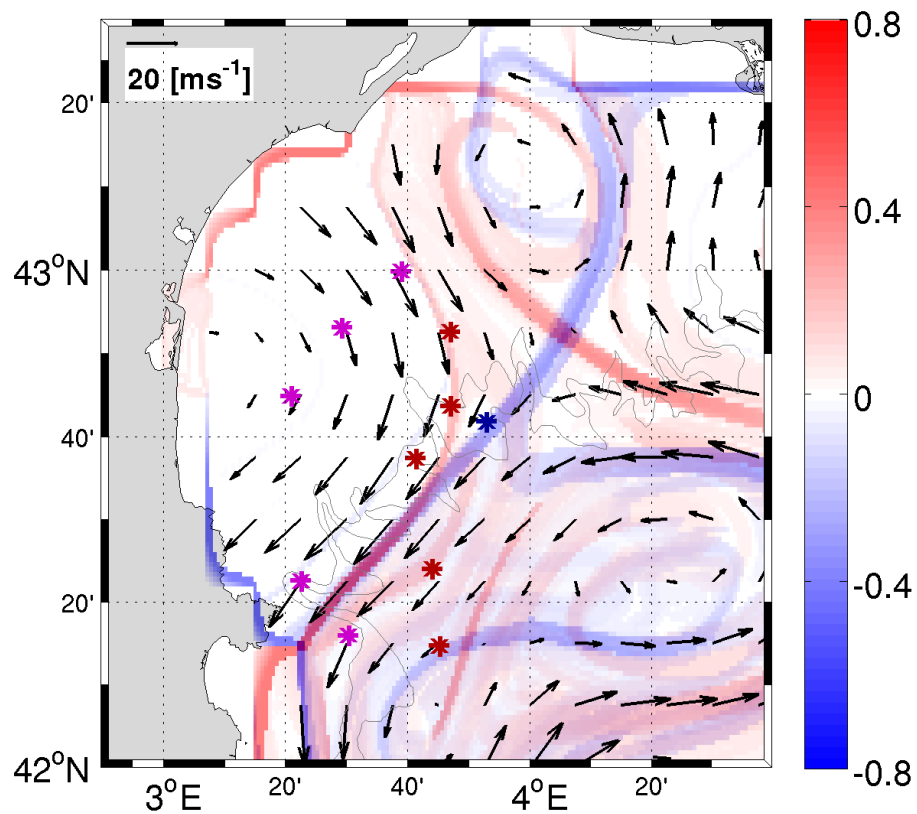- Initial position of drifter array

September 21-24, 2010

- Drifter trajectories
- *In-situ* LCSs

- **Satellite structures similar to Sept. 12**
- **Cyclonic circulation on the continental shelf**
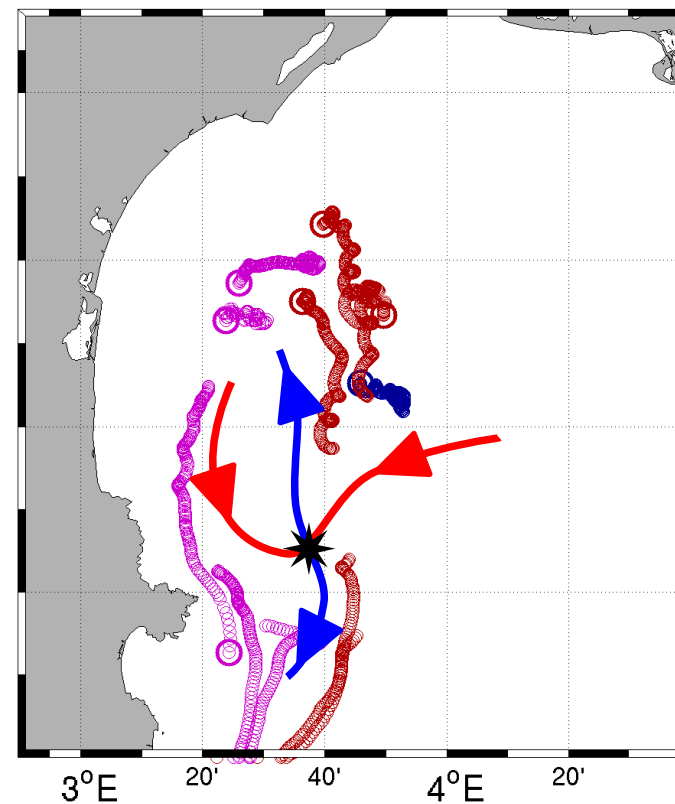
Lyap03 – Sept 21 - 24

September 21, 2010
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- Attractive (blue) & Repulsive (red) LCSs
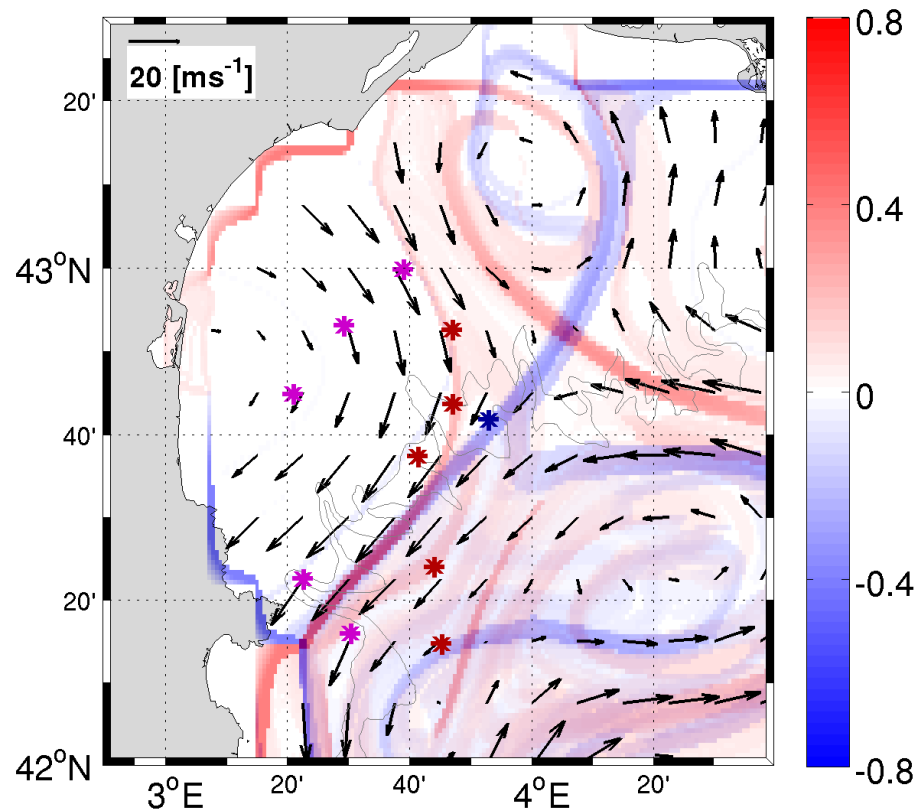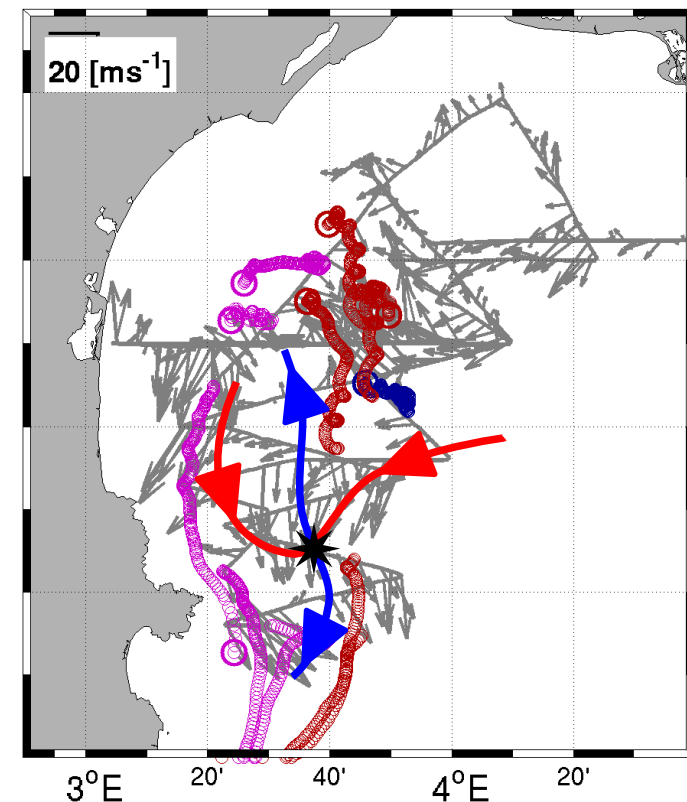- Initial position of drifter array

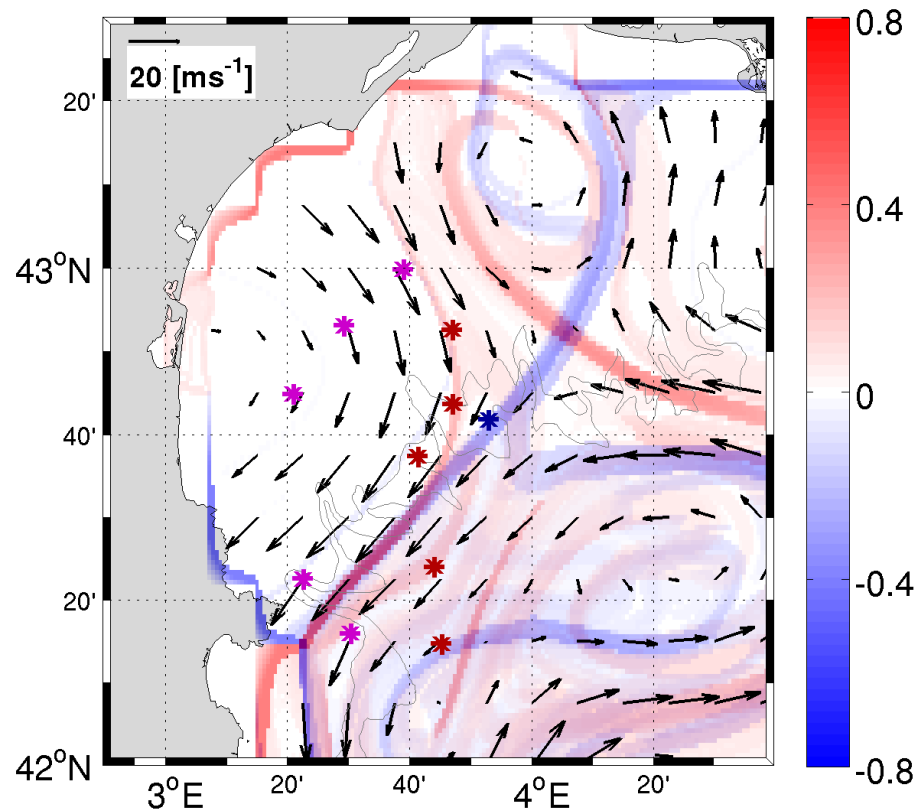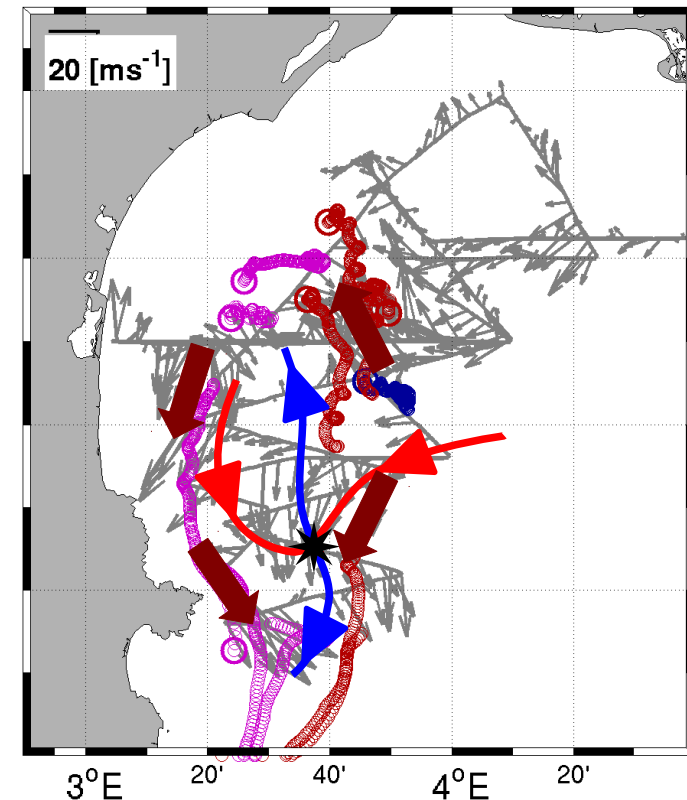**September 21-24, 2010**
- Drifter trajectories
- *In-situ* LCSs
- 15m ADCP velocity vectors

- **Satellite structures similar to Sept. 12**

- **Cyclonic circulation on the continental shelf**

- **ADCP indicate presence of southward coastal jet**

Lyap03 – Sept 21 - 24

September 21, 2010
- **Altimetry geostrophic velocity vectors**
- **Attractive (blue) & Repulsive (red) LCSs**
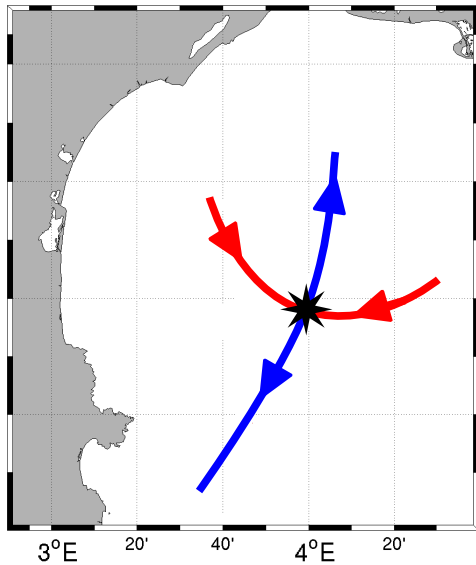- **Initial position of drifter array**

September 21-24, 2010
- **Drifter trajectories**
- ***In-situ* LCSs**
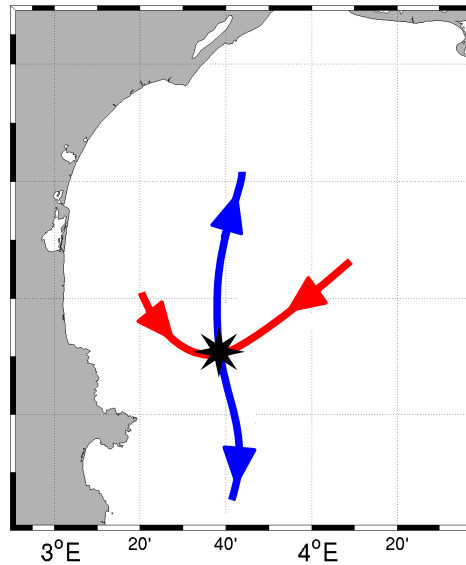- **15m ADCP velocity vectors**

- **Satellite structures similar to Sept. 12**

- **Cyclonic circulation on the continental shelf**

- **ADCP indicate presence of southward coastal jet**

Hyperbolic point migration
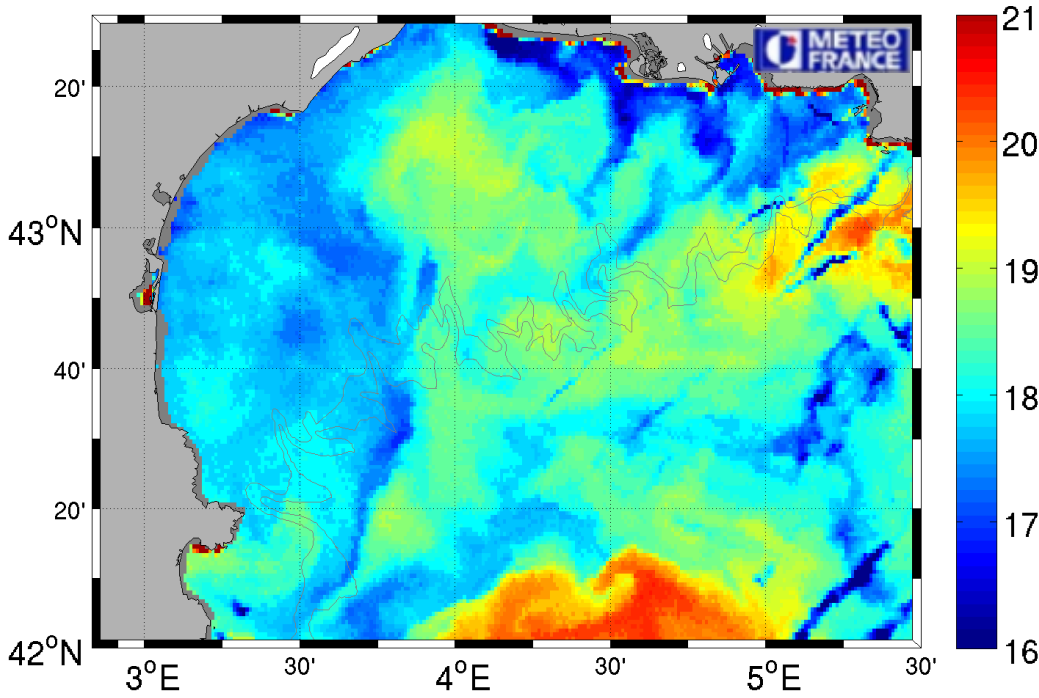

- **In-situ LCSs tracked for two weeks (September 12-24)**

- **Hyperbolic point translational speed ~ 5 cm sec^{-1}**

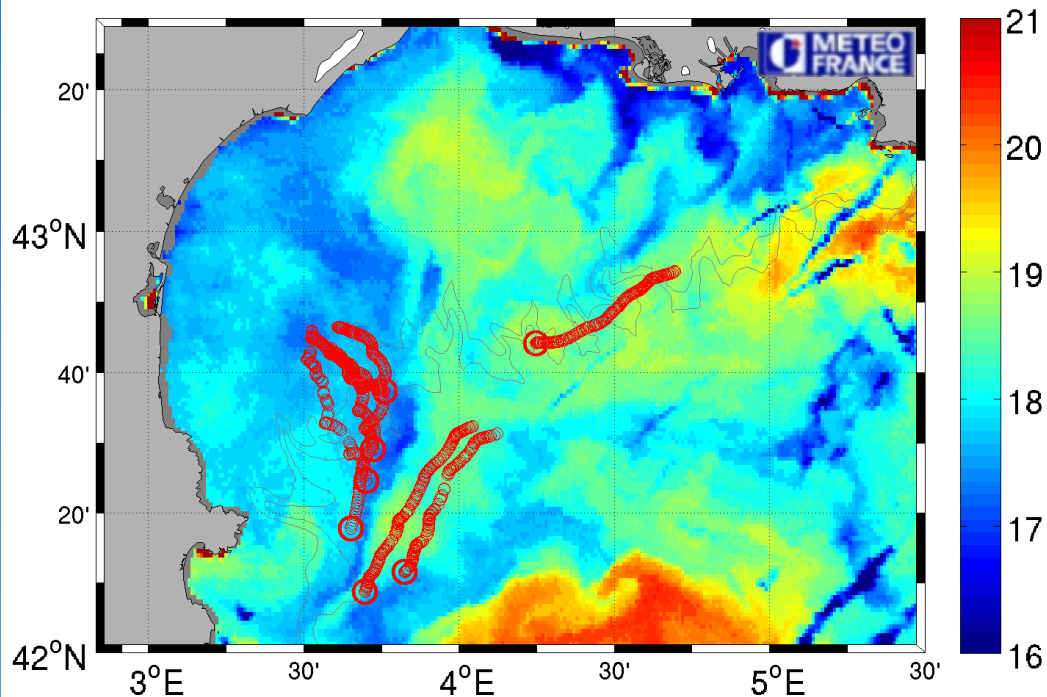- **Slower than advection speed: satisfied basic condition for FSLE analysis!!!**

September 14, 2010

•AVHRR SST field

September 14, 2010

- AVHRR SST field
- Lyap01 drifter trajectories

- In-situ LCSs associated with a front (NC and coastal waters)
- They identify coastal corridor along which water exit the GoL
- Importance of those structures to study cross-shelf exchanges

September 14, 2010

- AVHRR SST field
- Lyap01 drifter trajectories

Northern Current

METEO FRANCE
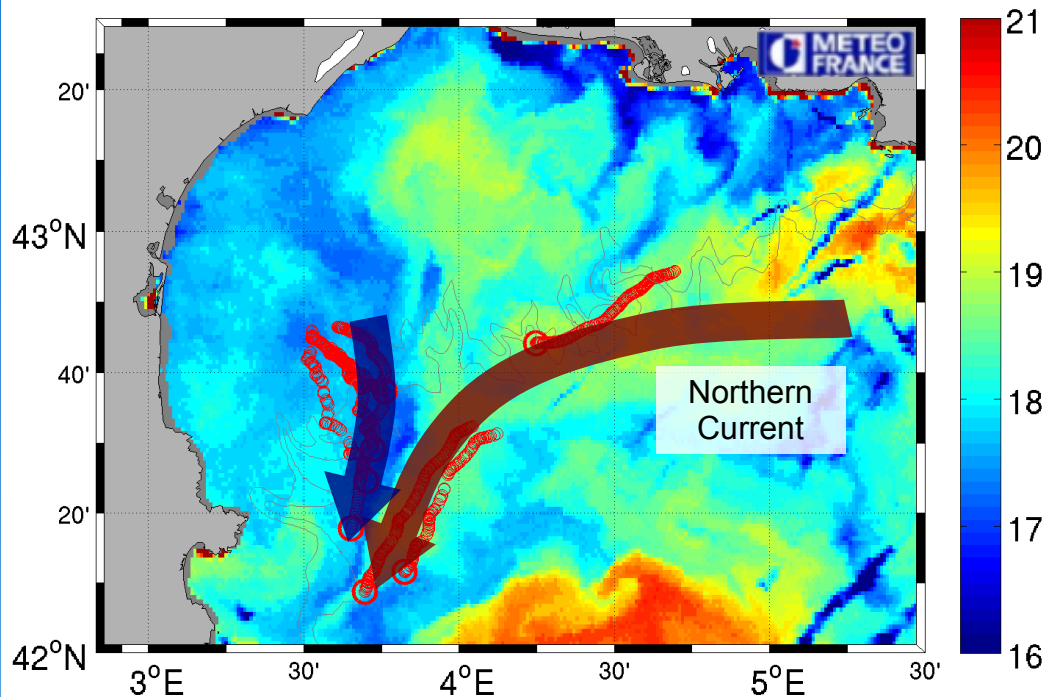
- In-situ LCSs associated with a front (NC and coastal waters)
- They identify coastal corridor along which water exit the GoL
- Importance of those structures to study cross-shelf exchanges

September 14, 2010

- AVHRR SST field
- Lyap01 drifter trajectories

September 14, 2010

- MODIS Chlorophyll concentrations
  (4 km resolution)
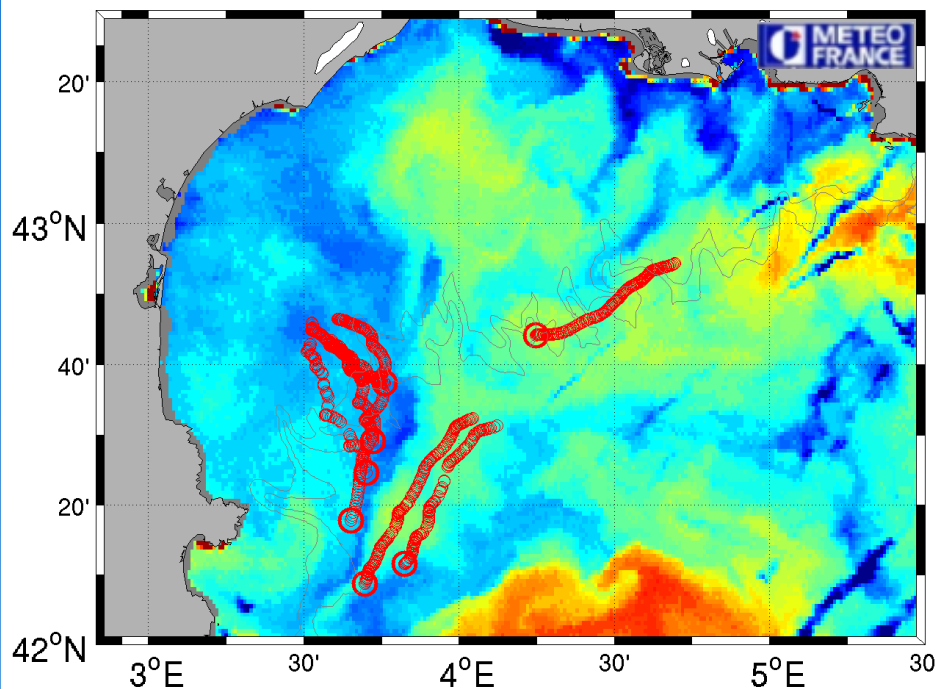

- In-situ LCSs associated with a front (NC and coastal waters)
- They identify coastal corridor along which water exit the GoL
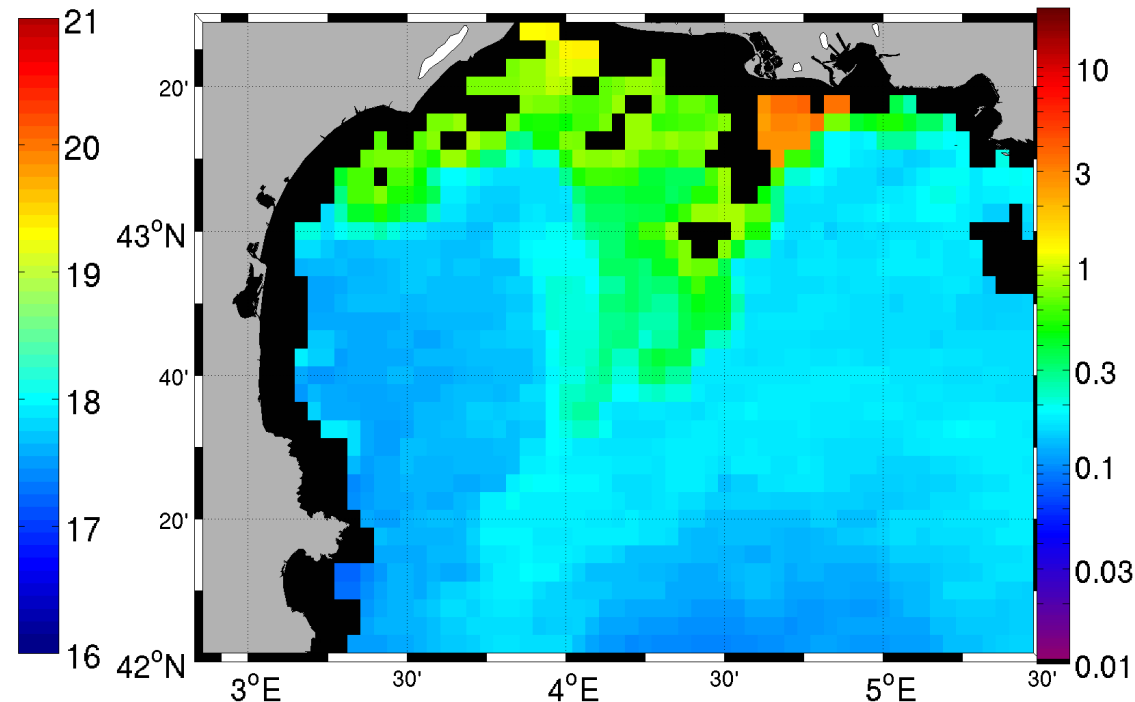- Importance of those structures to study cross-shelf exchanges
- Importance of those exchanges for biogeochemistry

- **Adaptive sampling strategy allowed to detect and track *in-situ* LCSs for two weeks**

- **Translational speed of hyperbolic point satisfies assumption for FSLE analysis**

- **LCSs identified a corridor along which coastal waters left the continental shelf of the GoL**

- **Altimetry LCSs showed some limitations in the coastal region**

- **Corrections are required to improve coastal transport analysis from altimetry velocity fields**

Improving Altimetry Products

Trajectory comparison between Latex08 drifters and syntetic drifters from different altimetry products:
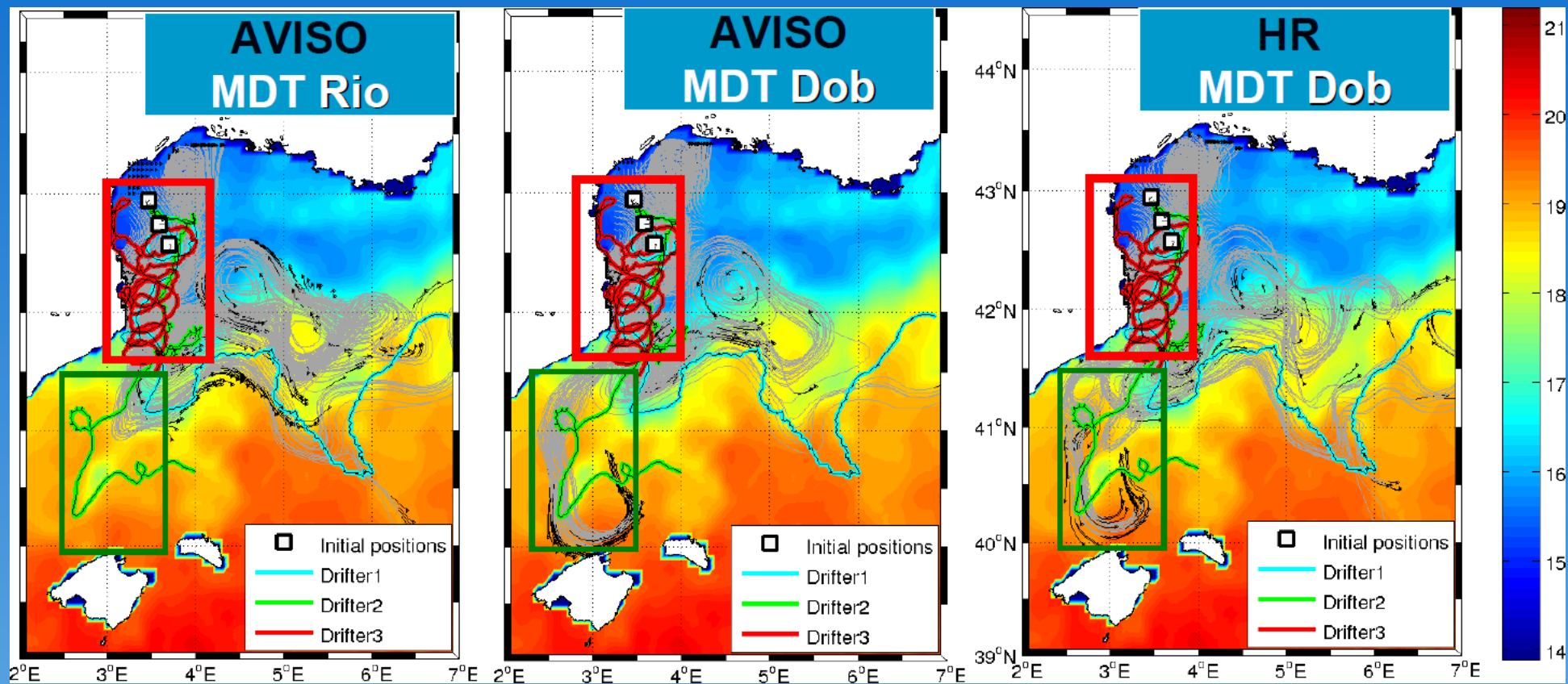
Regular AVISO   Dobricic MDT   Dobricic MDT + HR interp. scales

In Collaboration with J. Bouffard (also Postdoc at LOPB; CNES/JellyWatch)

- **Still many aspects to tune (i.e. temporal/spatial correlation) + new missons**
- **LCS used as a diagnostic for new altimetry products (comparison numerical simulation vs. satellite LCSs)**

References

F. Nencioli, F. d'Ovidio, A. Doglioli, A. Petrenko
Surface coastal circulation patterns by in-situ detection of Lagrangian Coherent Structures.
Geophysical Research Letters, 38, L17604, doi:10.1029/2011GL048815
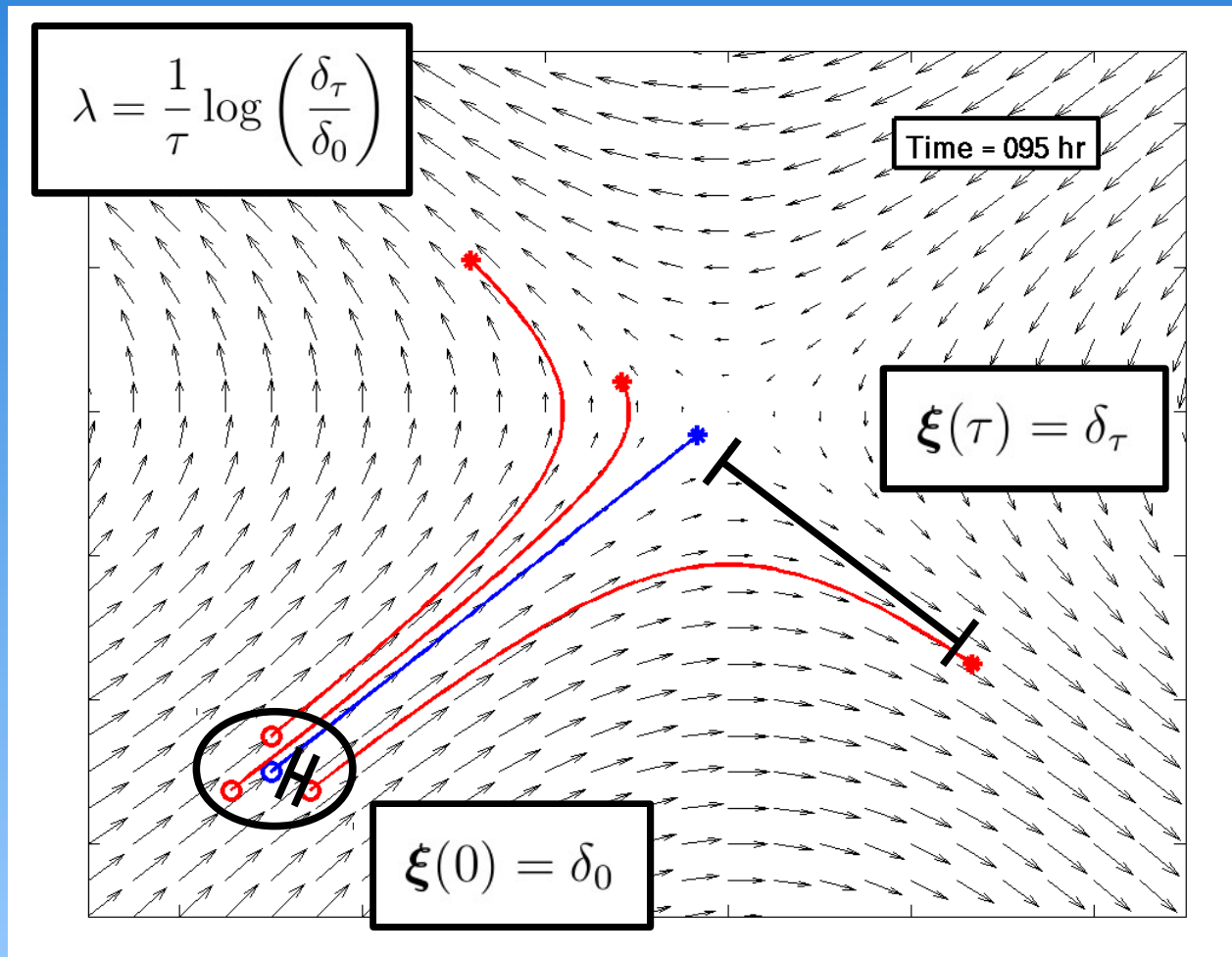
LATEX website: *www.com.univ-mrs.fr/LOPB/LATEX*

EXTRA SLIDES

- **Finite-size Lyapunov exponent method (d'Ovidio, 2004):**

$$\lambda = \frac{1}{\tau} \log \left(\frac{\delta_\tau}{\delta_0} \right)$$

Time = 095 hr

$\boldsymbol{\xi}(\tau) = \delta_\tau$

$\boldsymbol{\xi}(0) = \delta_0$

➔ **Triplets at each grid point**

➔ **Advected with a 4th order RK (fwd, bkw)**

➔ **Linear interpolation in time and space**

➔ **Integration stopped when one particle reaches final separation distance**

Lyap02 – Sept 18 - 20

September 18, 2010
- AVISO geostrophic velocity vectors
- Attractive (blue) & Repulsive (red) LCSs
- Initial position of drifter array
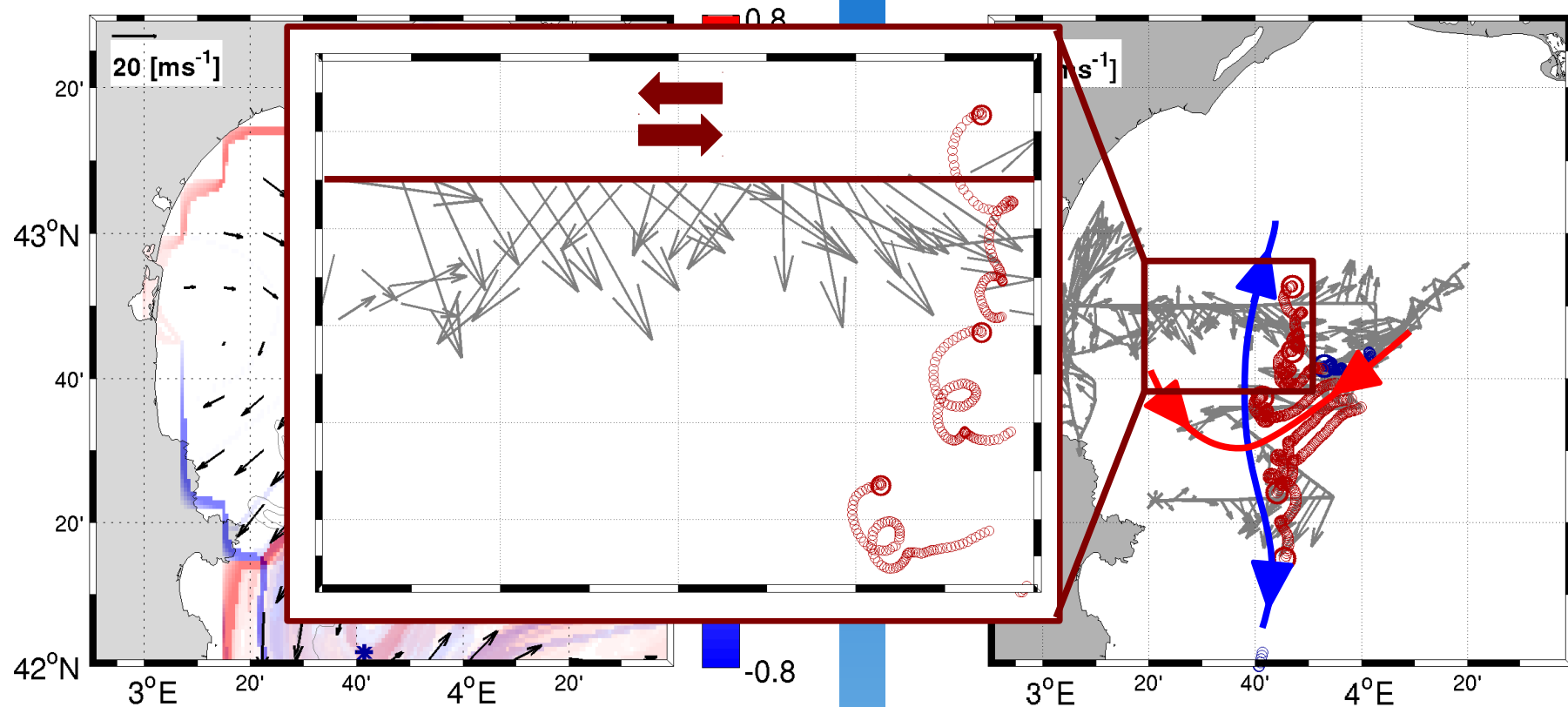
September 18-20, 2010
- Drifter trajectories
- *In-situ* LCSs
- 15m ADCP velocity vectors

- **Satellite structures similar to Sept. 12**
- **Lyap02 confirms *in-situ* structures from Lyap01**
- **Limits of ADCP velocities due to Near Inertial Oscillations (NIOs)**
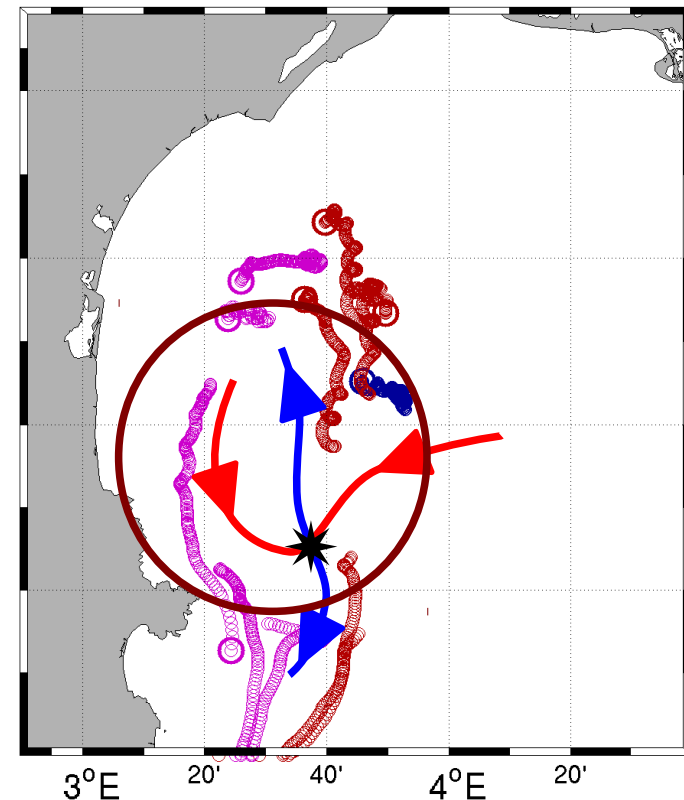
Lyap03 – Sept 21 - 24

September 21, 2010
- AVISO geostrophic velocity vectors
- Attractive (blue) & Repulsive (red) LCSs
- Initial position of drifter array
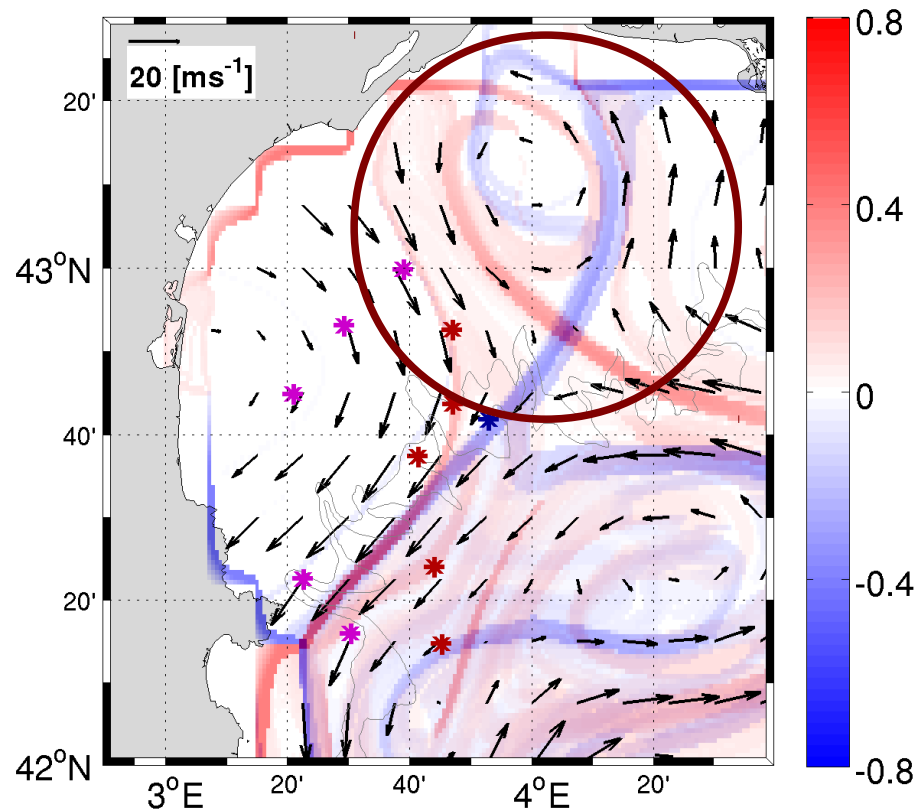
September 21-24, 2010
- Drifter trajectories
- *In-situ* LCSs

- **Satellite structures similar to Sept. 12**
- ***In-situ* LCSs similar to satellite NW**