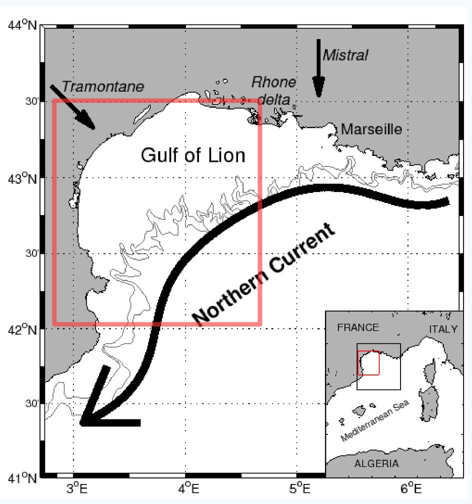
Multi-platform synergy for the direct investigation of ocean fronts: a case study in the North-western Mediterranean

Francesco Nencioli[1,2], Anne A. Petrenko[2], Andrea M. Doglioli[2] and Francesco d'Ovidio[3]

[1] Remote Sensing Group, Plymouth Marine Laboratory, United Kingdom
[2] Aix-Marseille Université, CNRS/INSU, Université de Toulon, IRD, Mediterranean Institute of Oceanography (MIO) UM 110, Marseille, France
[3] Sorbonne Université (UPMC, Paris 6)/CNRS/IRD/MNHN, Laboratoire d'Océanographie et du Climat (LOCEAN), Institut Pierre Simon Laplace (IPSL), Paris, France

1. The Latex10 campaign

➔ Region of study



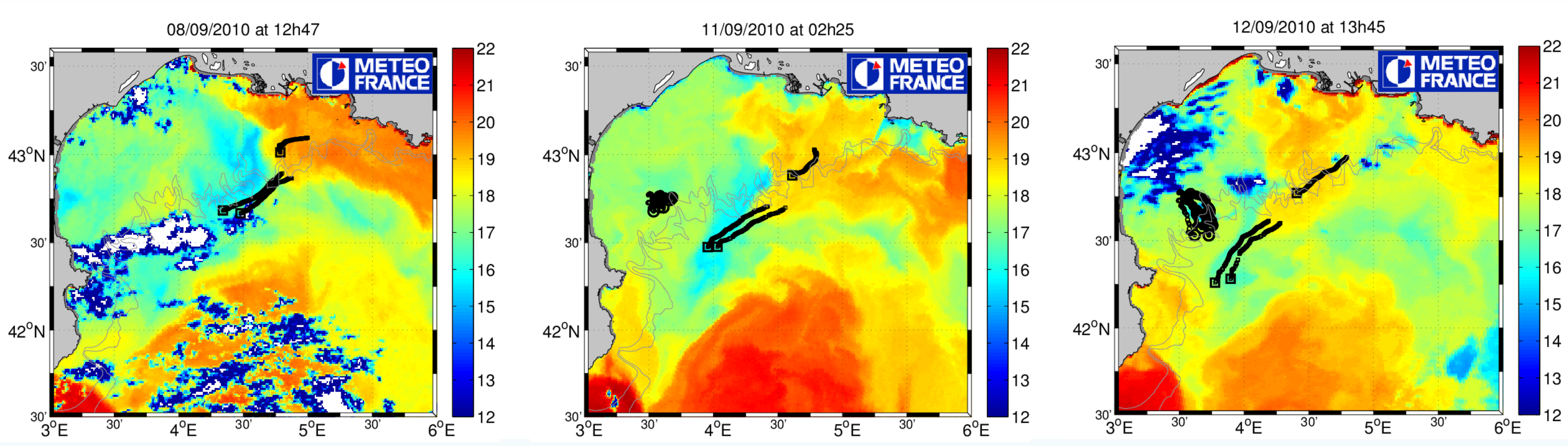
The Gulf of Lion (GoL)

- Large continental shelf
- Mistral/Tramontane main wind forcings:
- Northern Current dynamical barrier to cross-shelf exchanges

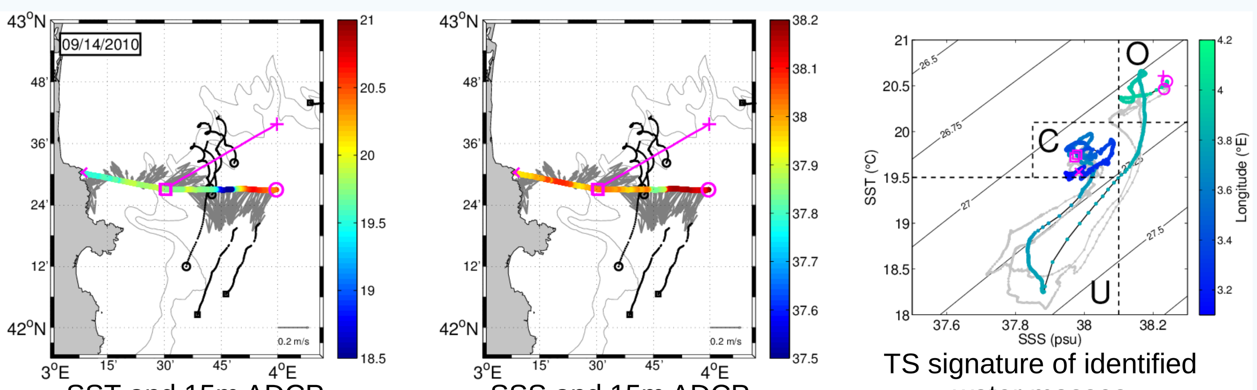
Latex10 campaign ()

- September 1-24, 2010; western part of the GoL
- **Adaptive sampling strategy** to focus on (sub)mesoscale dynamics

➔ Remote sensing, Lagrangian and ship-based observations



- AVHRR pseudo-SST
- 14 SVP Lagrangian drifters (15-m drogue)
- Underway surface temperature and salinity
- Hull-mounted ADCP



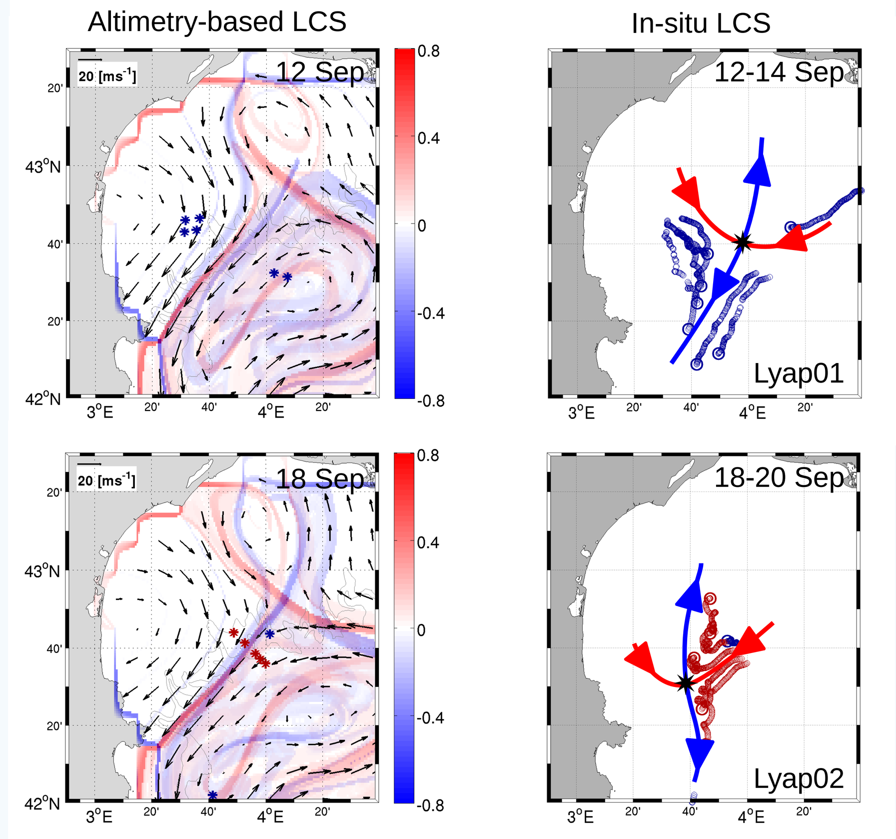
SST and 15m ADCP — SSS and 15m ADCP — TS signature of identified water masses

2. In-situ Lagrangian coherent structures

➔ Recursive drifter array deployments

- LCS computed in near-real time from AVISO velocities (daily; 1/8 degree)
- Deployment of 3 drifter arrays (Lyap01, Lyap02, Lyap03) to investigate LCS along continental slope
- In-situ LCS from dispersion patterns

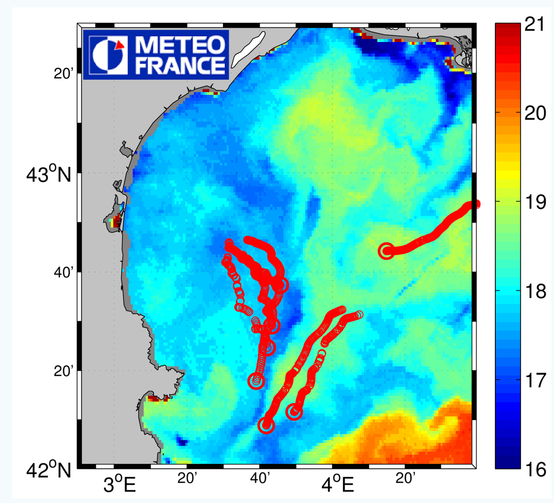
- **Migration of in-situ LCSs and hyperbolic point tracked for two weeks**
- LCS reliable diagnostic also in coastal regions
- Altimetry-based LCS show some limitations in coastal regions
- **In-situ LCS associated with a strong thermal front**



Reference: Nencioli F., F. d'Ovidio, A. Doglioli and A. Petrenko, (2011), *Surface coastal circulation patterns by in-situ detection of Lagrangian Coherent Structures*, Geophys. Res. Lett., Vol 38, L17604. doi:10.1029/2011GL048815

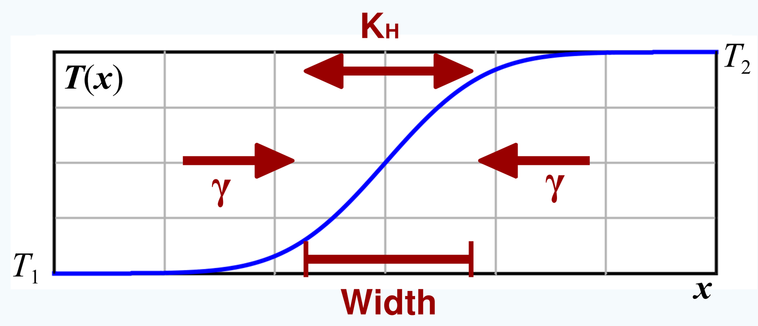
➔ Characteristics of the Latex10 front

- Convergence of warmer (open NW Mediterranean) and colder (western GoL shelf) water masses
- Mostly compensated
- Coastal corridor through which shelf waters left the GoL
- Multiple sections collected across the front
- Used for direct quantification of:
  - ➔ **Cross-front eddy-diffusivity**
  - ➔ **Along-front cross-shelf fluxes**



3. Horizontal diffusivity

➔ Analytical solution of cross-front profile



- **Main hypothesis**: front width from balance between two competing processes
  1. Convergence by mesoscale straining (γ)
  2. Mixing by small-scale turbulence (parametrized by eddy diffusivity K_H)

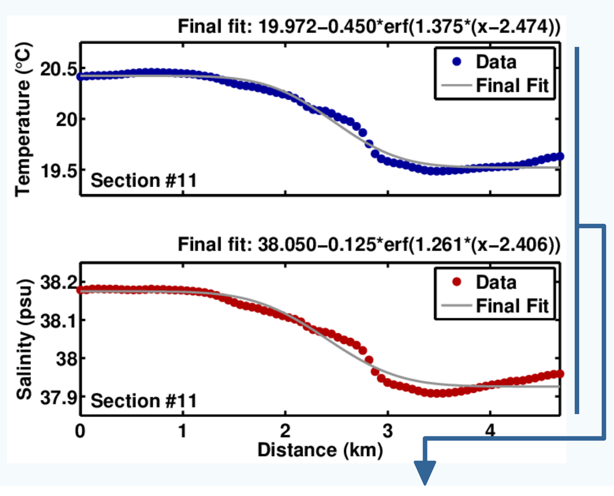
- Analytical expression for front profile (from solution of steady state cross-front advection-diffusion equation)

$$T(x) = \frac{T_2 + T_1}{2} + \frac{T_2 - T_1}{2}\,\mathrm{erf}\left(\frac{1}{\sqrt{2}}\sqrt{\frac{\gamma}{K_H}}\,(x-\mu)\right)$$

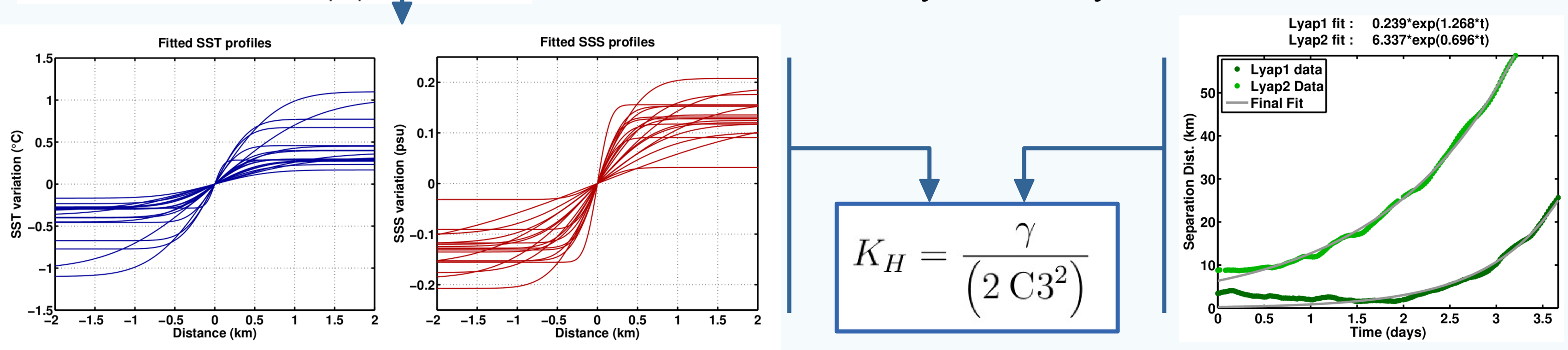
Width parameter C3

- From front width (C3) and strain rate (γ) is possible to quantify eddy diffusivity (K_H)

➔ Estimate front width and strain rate

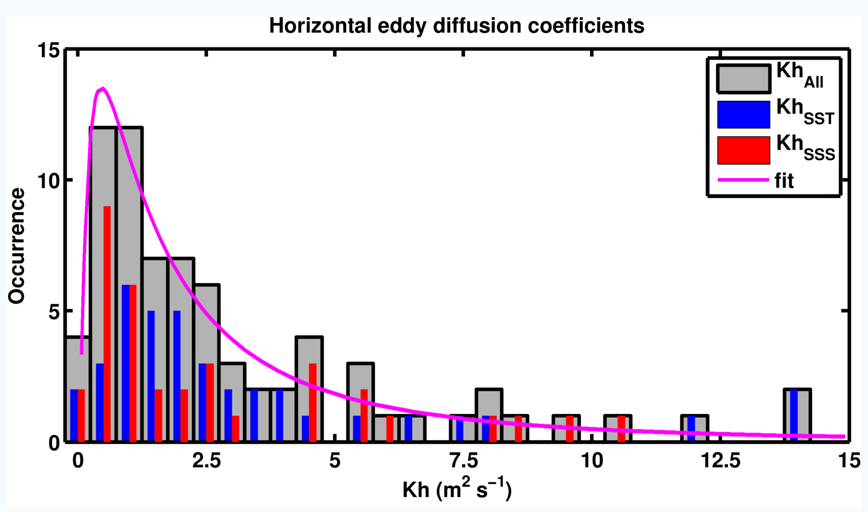


- Front widths estimated by fitting analytical solution to 19 observed cross-front profiles of SST and SSS (*left*)
- Strain rate computed from exponential separation rate of Lyap1 and Lyap2 Lagrangian drifters (*bottom right*)
- The two are combined to obtain 76 estimates of horizontal eddy diffusivity



$$K_H = \frac{\gamma}{(2\,C3^2)}$$

➔ Quantify horizontal eddy diffusivity

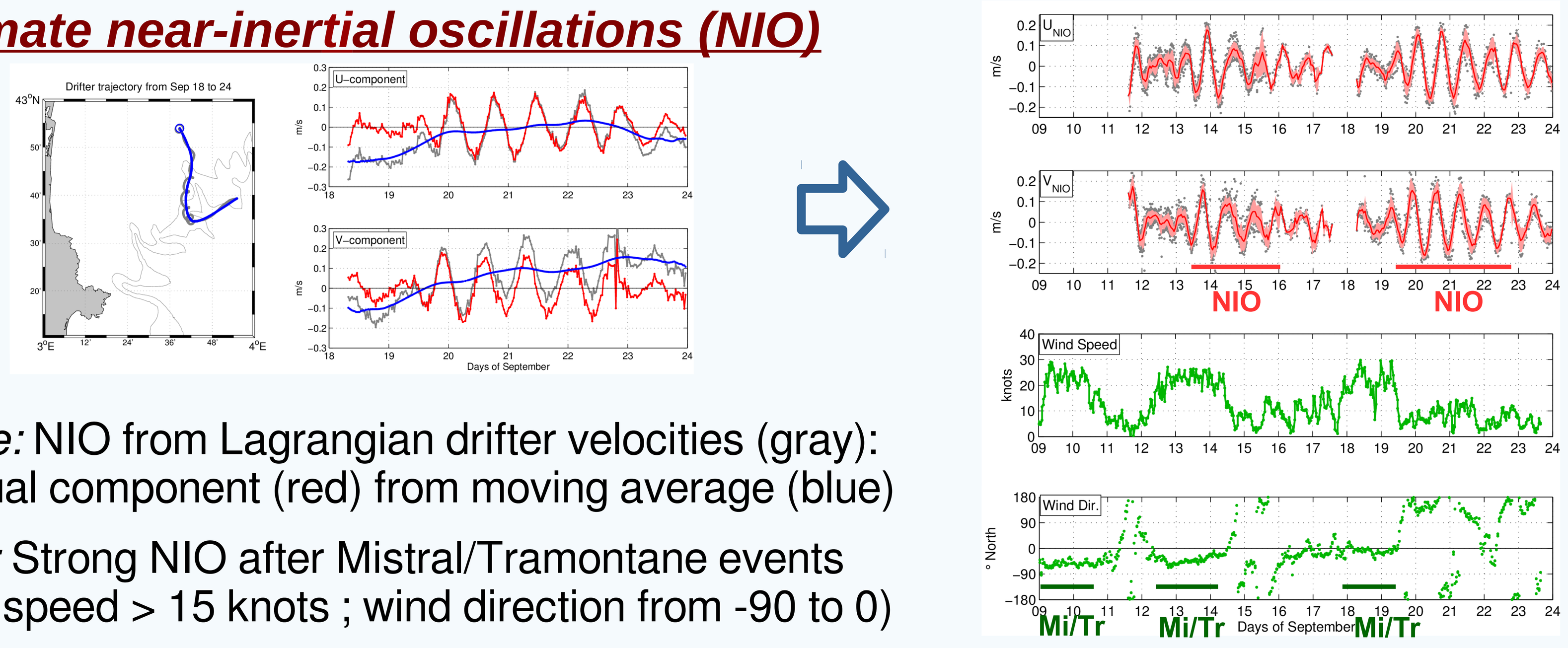


- Log-normal distribution
- **70% of values between 0.4 – 5 $m^2\,s^{-1}$**
- Front widths range from 1 to 4 km
- K_H values similar for SST and SSS fronts

Reference: Nencioli, F.; d'Ovidio, F.; Doglioli, A. M. & Petrenko, A. A. *(2013) In situ estimates of submesoscale horizontal eddy diffusivity across an ocean front*, J. Geophys. Res.-Oceans, 118, 7066-7080. doi:10.1002/2013JC009252

4. Cross-shelf exchanges

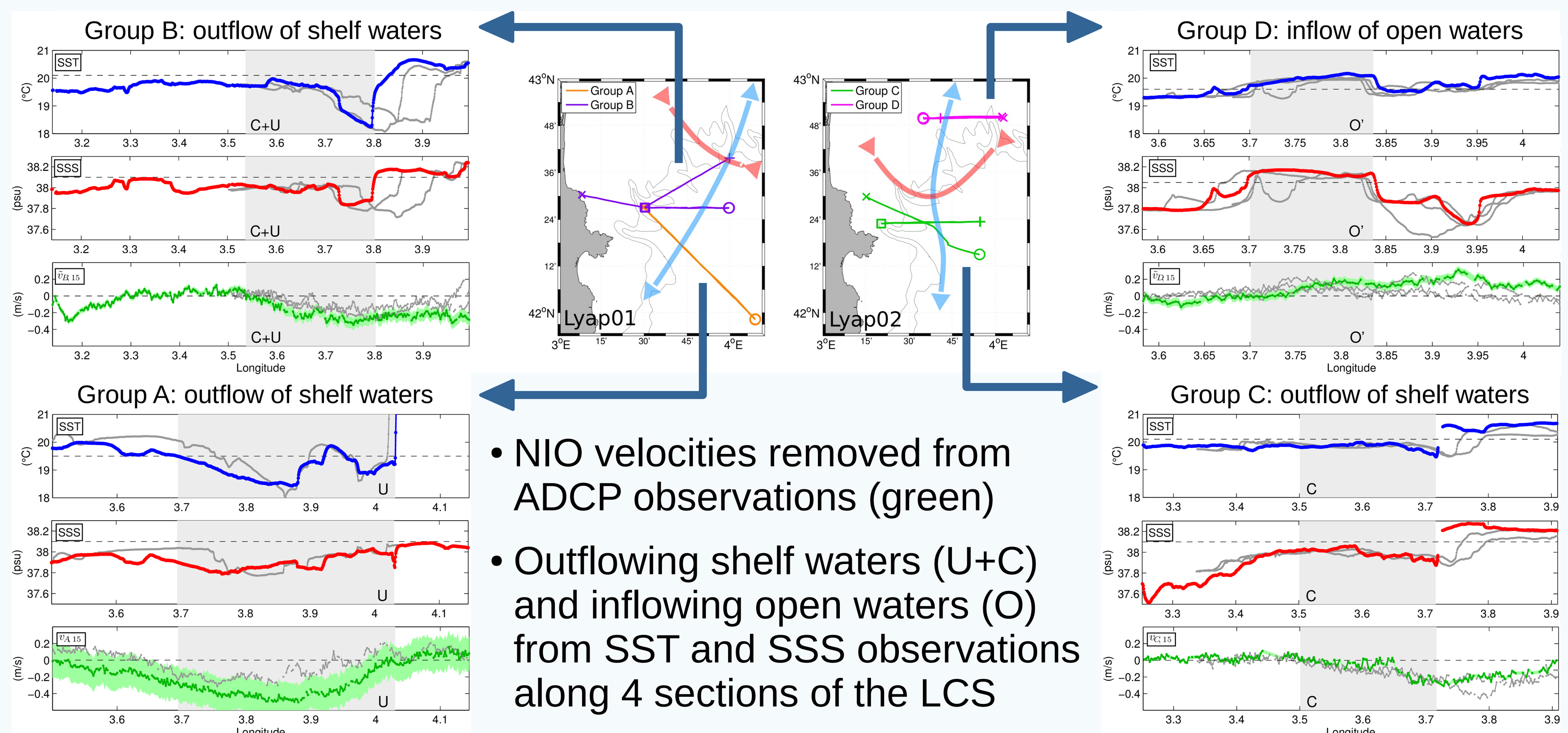
➔ Estimate near-inertial oscillations (NIO)



Above: NIO from Lagrangian drifter velocities (gray): residual component (red) from moving average (blue)

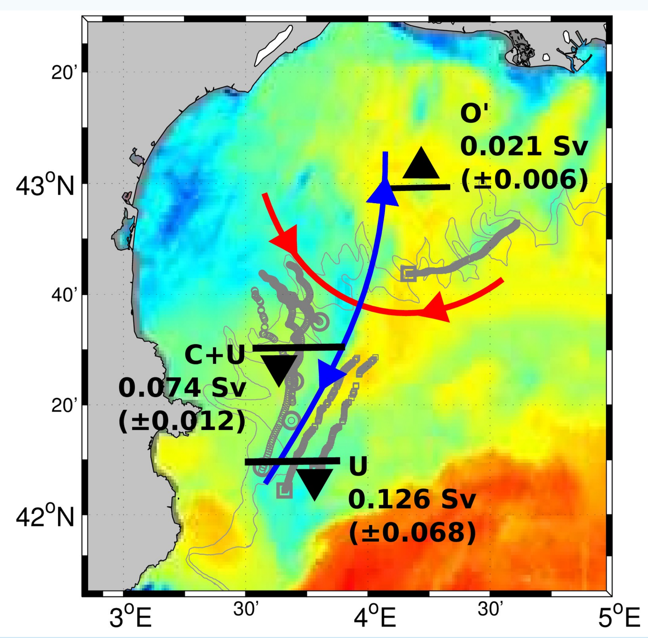
Right: Strong NIO after Mistral/Tramontane events (wind speed > 15 knots ; wind direction from -90 to 0)

➔ Identify outflow from continental shelf and inflow from open sea



- NIO velocities removed from ADCP observations (green)
- Outflowing shelf waters (U+C) and inflowing open waters (O) from SST and SSS observations along 4 sections of the LCS

➔ Quantify cross-shelf exchanges along the front



- Section fluxes estimated as $\sum_{i=1}^{n} (\tilde{v}_{tr,15})_i\,(\Delta l)_i\,\Delta z$

- Total volumes exchanged within the upper mixed layer (0 to 22.8 m) during front lifetime (2 weeks):
  - ➢ **Outflow of shelf waters 90 km^3**
  - ➢ **Inflow of open waters 25 km^3**
- 3 to 4 of such events are sufficient to completely renew the upper mixed layer of the whole GoL

Reference: Nencioli F., A. Petrenko and A. Doglioli, *Diagnosing cross-shelf transport along an ocean front: an observational case study in the Gulf of Lion*, J. Geophys. Res.-Oceans, *Submitted*

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