

# DISENTANGLING THE GENERATION MECHANISMS OF STRONG AND LONG-LIVED ANTICYCLONIC MESOSCALE EDDIES IN THE BALEARIC SEA

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## Anticyclonic mesoscale eddies generation area

### ■ South:

- ✓ Atlantic Jet feeds the gyres and the AC
- ✓ Fresh northward Atlantic inflows

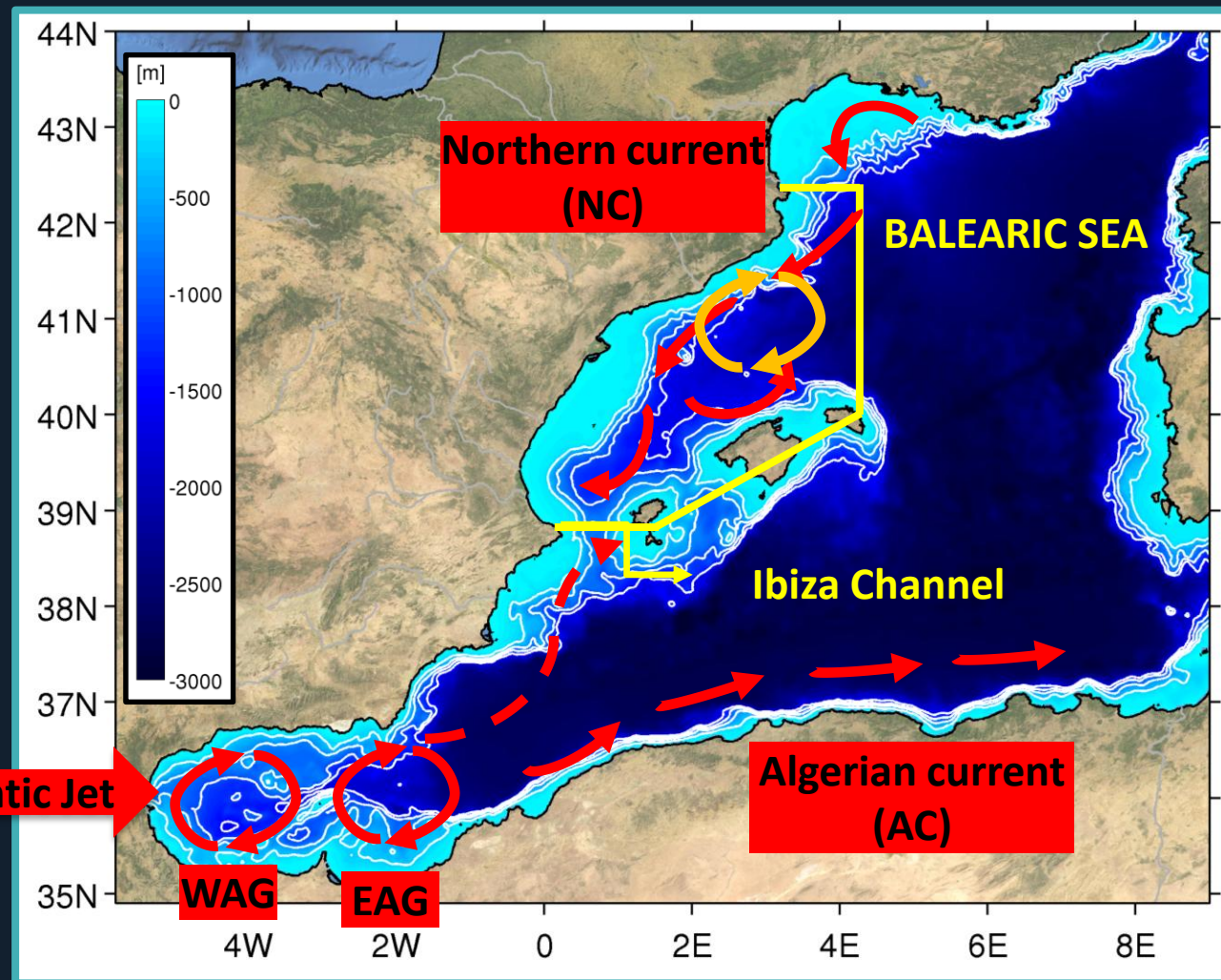
### ■ North:

- ✓ NC flows along the Gulf of Lion and the Iberian coast

### ■ Ibiza Channel:

- ✓ Fresh Atlantic waters ( $S < 37.5$ ) VS. salty Mediterranean waters ( $S > 37.5$ )

## WESTERN MEDITERRANEAN SEA

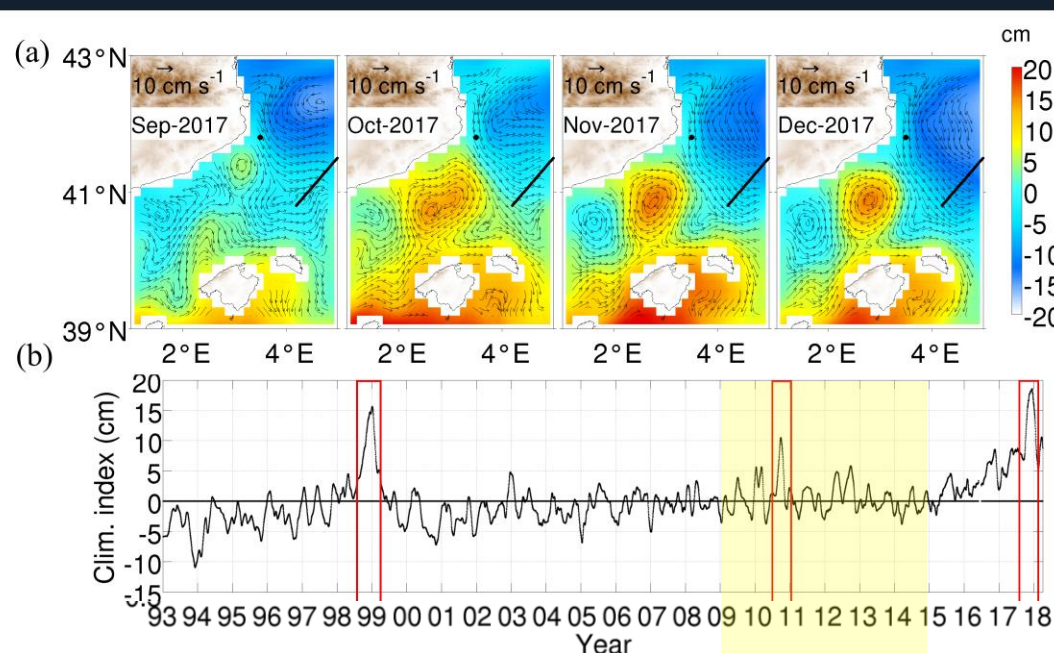




## *“Anticyclonic eddy anomaly (AEA): impact on the boundary current and circulation in the western Mediterranean Sea”*

*Copernicus Marine Service – Ocean State Report [Aguiar et al. 2019]*

- Report the presence of a long-lived eddy in fall 2017
- AEA: index based on altimetry to detect anticyclonic eddies with lives > 2 months
- AEA: sea level spatially-averaged within an area defined by calculating the mean contour of all the anticyclonic eddies detected by an eddy identification and tracking algorithm developed by Mason et al. (2014).



**SOCIB MODEL**

**2009-2015**

**High-resolution hindcast simulation**

- Three events: 1998 [Pascual et al. 2002], 2010 and 2017

## High-resolution free run hindcast simulation

[Aguiar et al. submitted]



WMOP

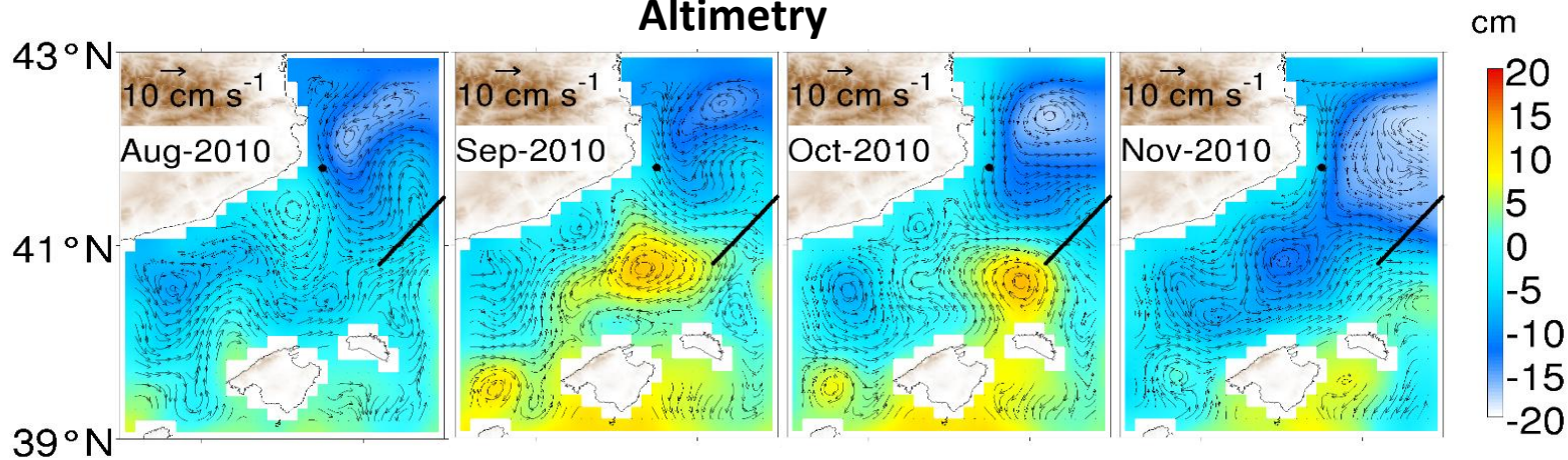
- Ocean Energy budget
  - ✓ generation mechanisms of eddies?
  - ✓ potential causes?

## Western Mediterranean Operational model

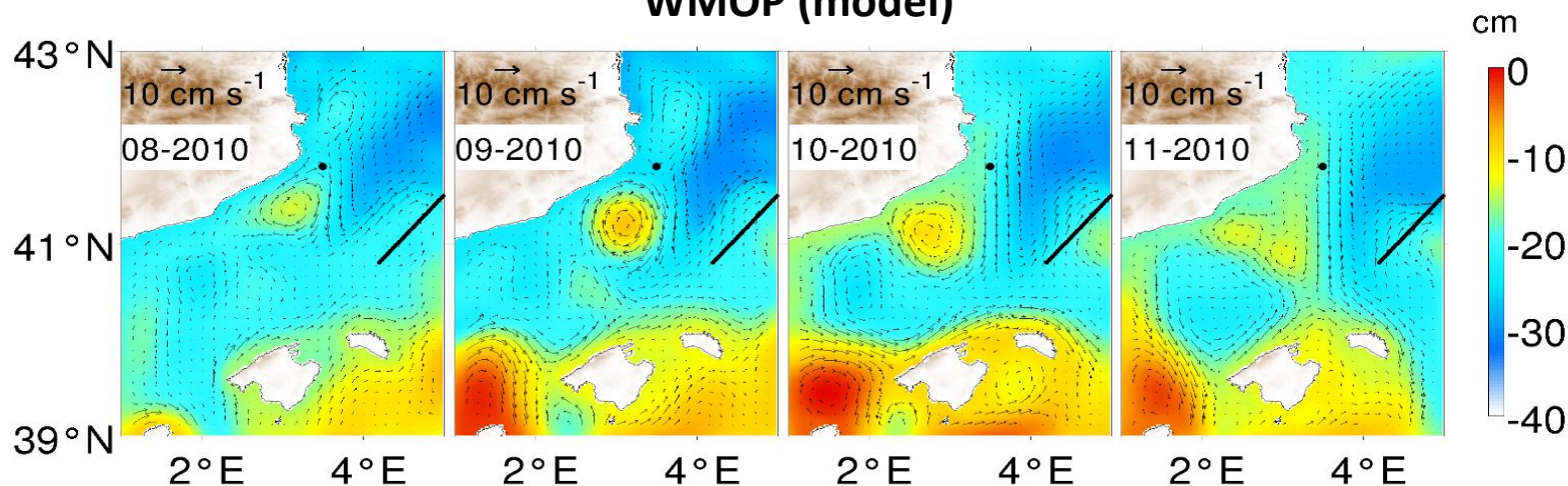
[Juza et al. 2016; Mourre et al. 2018]

Spatial domain	Western Mediterranean (Gibraltar to Sardinia-Corsica)
Horizontal & vertical resolution	2km ( $\sim 1/50^\circ$ ) 32 $\sigma$ -levels
Data assimilation	No (free run)
Atmospheric forcings	HIRLAM model (3h, 5km)
Initial & boundary conditions	CMEMS Med Rea (1/16deg, daily)

## Altimetry



## WMOP (model)



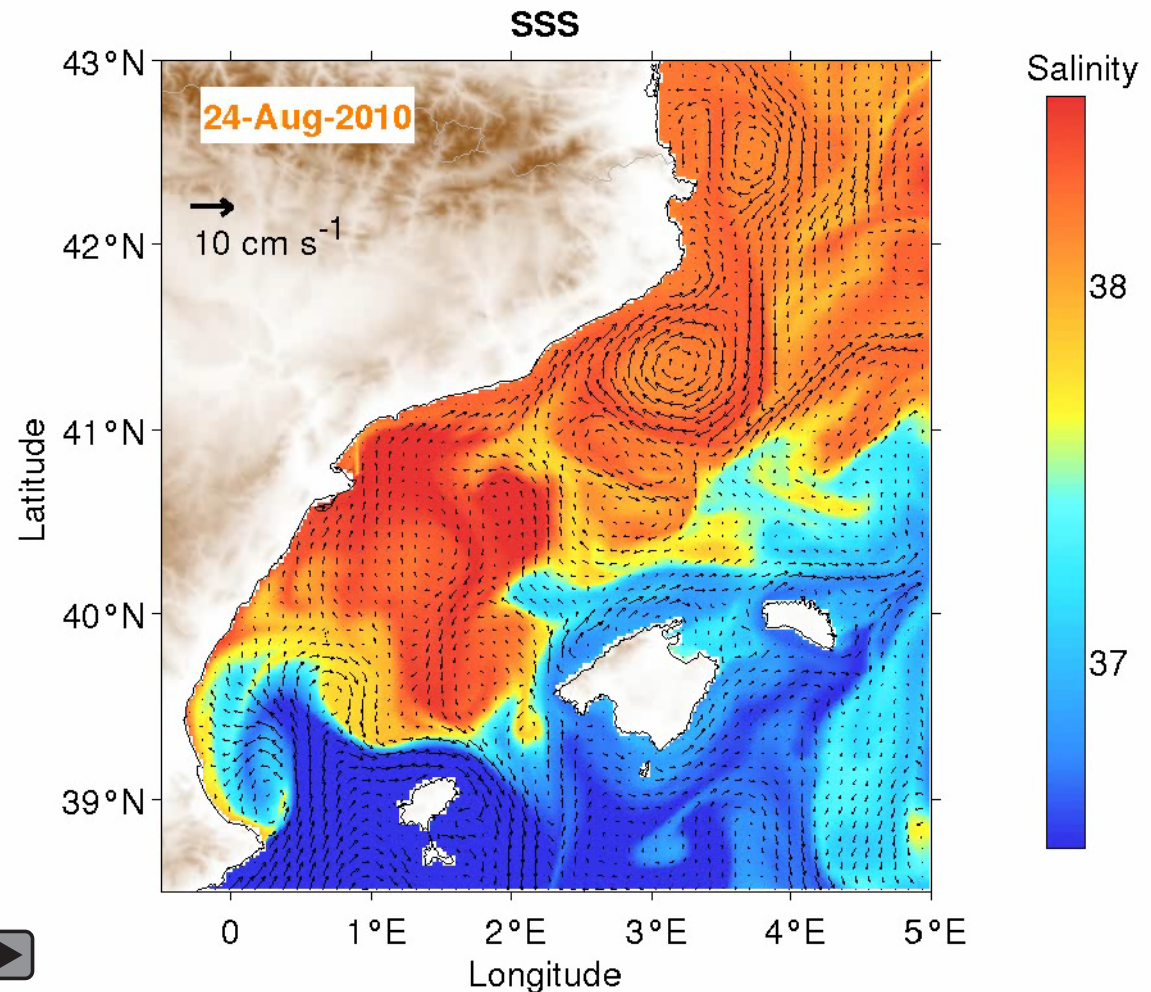
✓ WMOP will be used to investigate the energy fluxes associated with this eddy

→ WMOP reproduces a long-lived anticyclonic eddy in the BS in 2010 with a similar area of formation as the observed eddy and a similar life time (yet with a slightly different evolution)



- Early-August:
  - anticyclonic eddies formed upstream Cap de Creus
  - development of the eddy
- Mid-August:
  - eddy fully developed
- September:
  - strong Atlantic water inflows through Ibiza Channel
- End-October:
  - Eddy splits and disappears

## WMOP: Sea Salinity Surface and currents

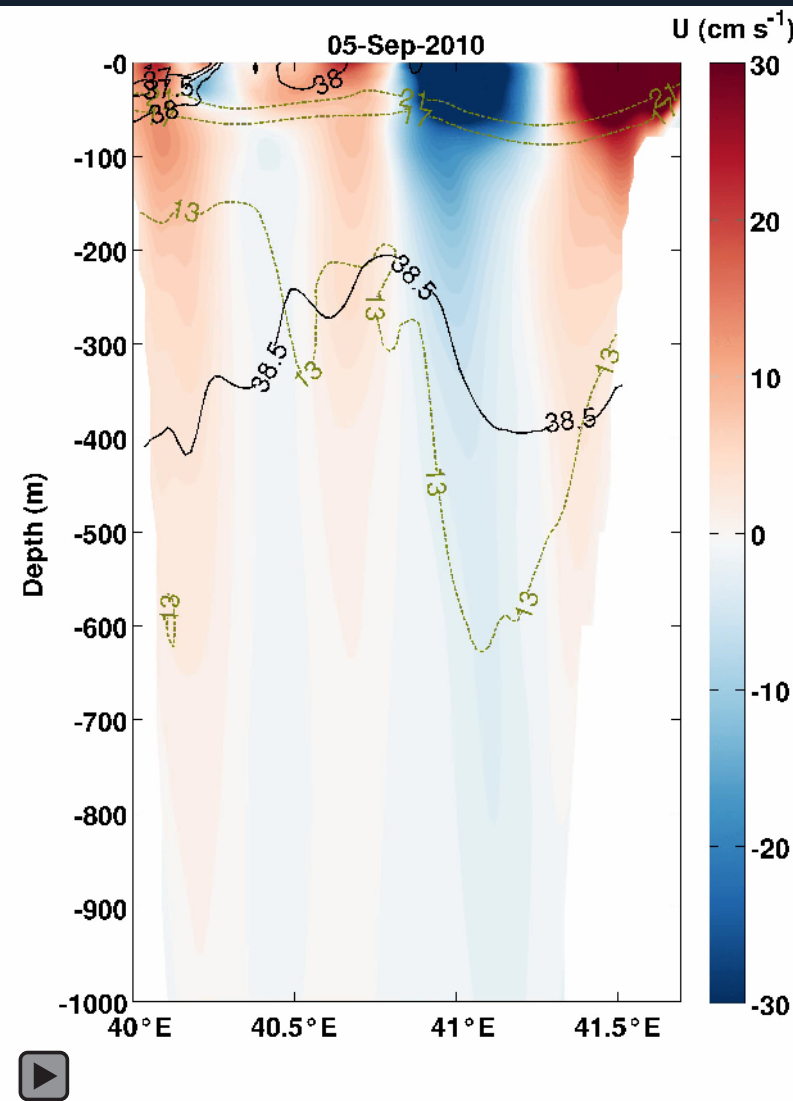
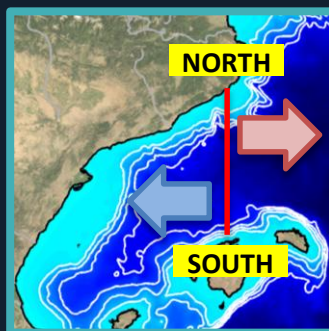


φ size: 70 - 100 km

Duration: ~2.5 months



- The maximum velocities are reached in the **surface layers** with values over **30 cm·s<sup>-1</sup>**.
- The influence of the eddy reaches **1000 m depth**, with smaller velocities in depth
- The **13°C** isotherm, located between 200-400m depth at the beginning of the event, reaches the **600 m isobath** at the end, in concordance with the downward velocities related to anticyclonic eddies.
- Freshwater input at the southern side of section in end-September-October.



SOUTH

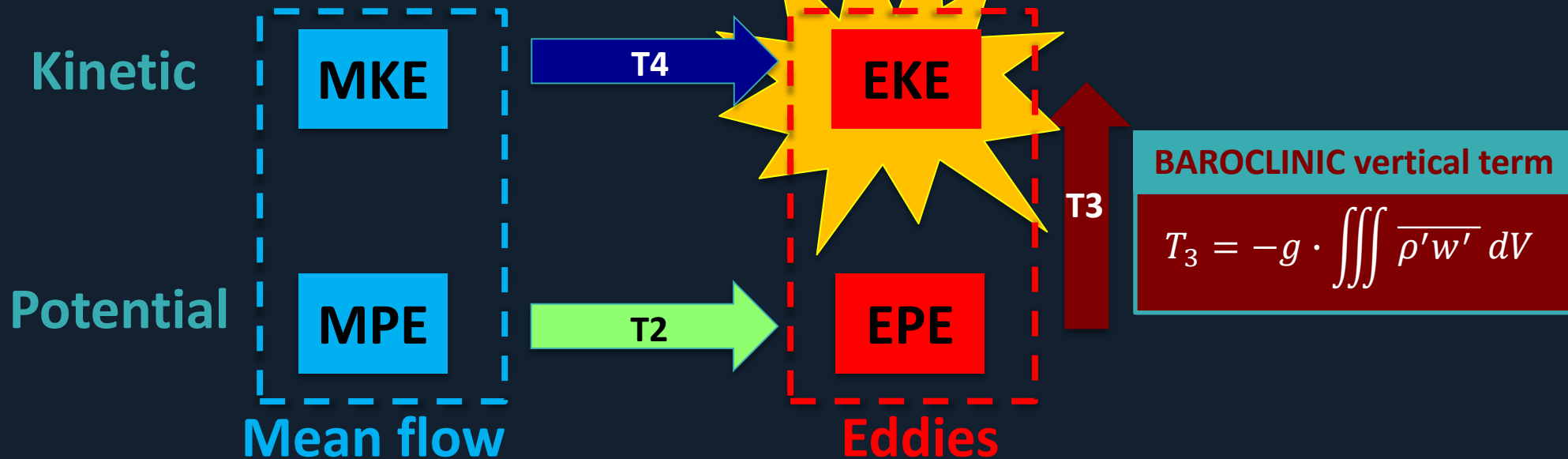
NORTH

How is the energy transferred from the mean flow into the eddy field?

Which are the dominant mechanisms for EKE production?

$$T_4 = -\rho_o \cdot \iiint \overline{u'u'} \cdot \left( \frac{\partial \bar{u}}{\partial x} \right) + \overline{u'v'} \cdot \left( \frac{\partial \bar{v}}{\partial x} + \frac{\partial \bar{u}}{\partial y} \right) + \overline{v'v'} \cdot \left( \frac{\partial \bar{v}}{\partial y} \right) dV$$

**BAROTROPIC horizontal term:** shear/horizontal gradients of mean flow

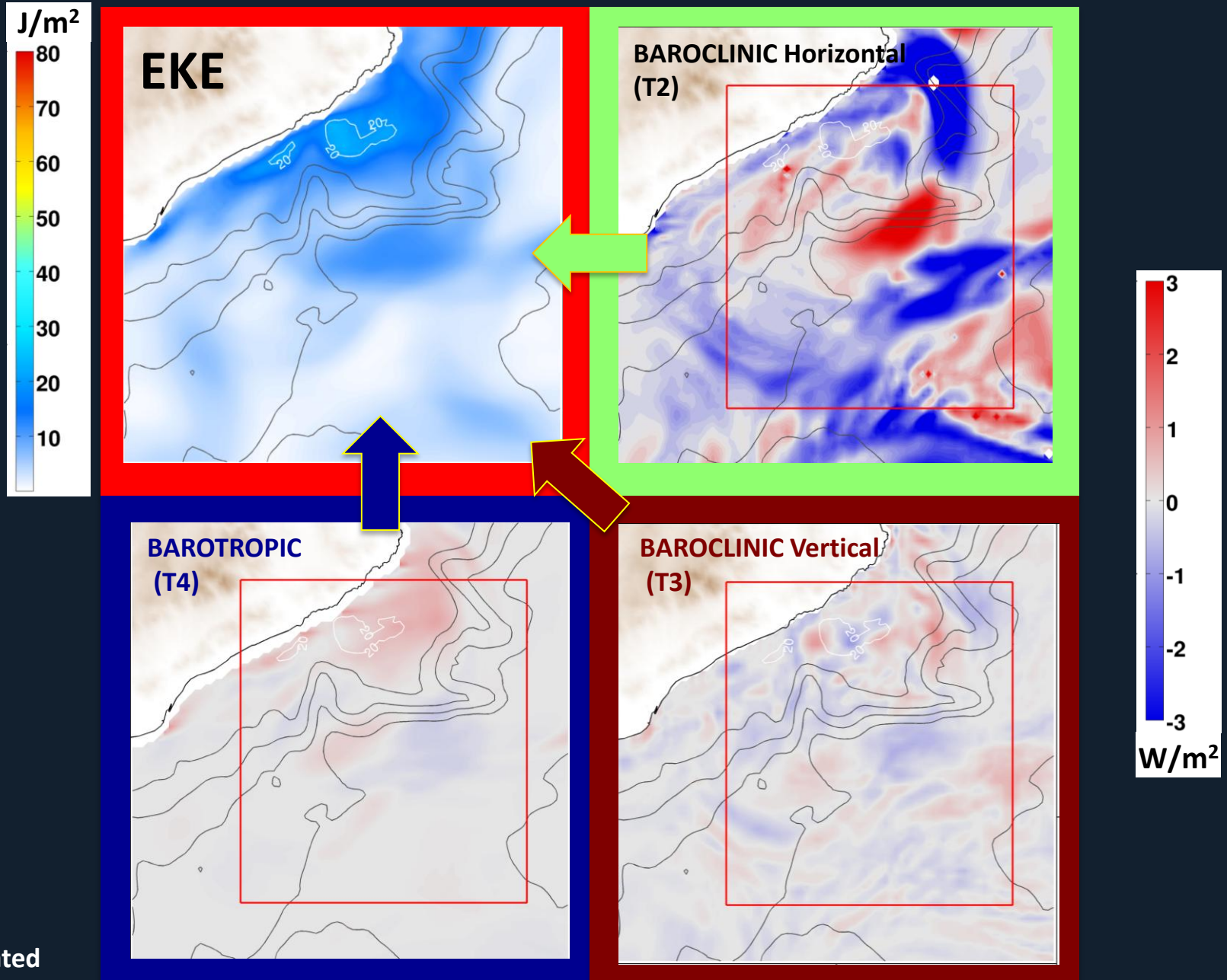


**BAROCLINIC horizontal term:**  
horizontal gradients of density

$$T_2 = -\frac{g^2}{\rho_o \bar{N}^2} \iiint \overline{u'\rho'} \cdot \left( \frac{\partial \bar{\rho}}{\partial x} \right) + \overline{v'\rho'} \cdot \left( \frac{\partial \bar{\rho}}{\partial y} \right) dV$$

# 5. Energy budget: spatial distribution

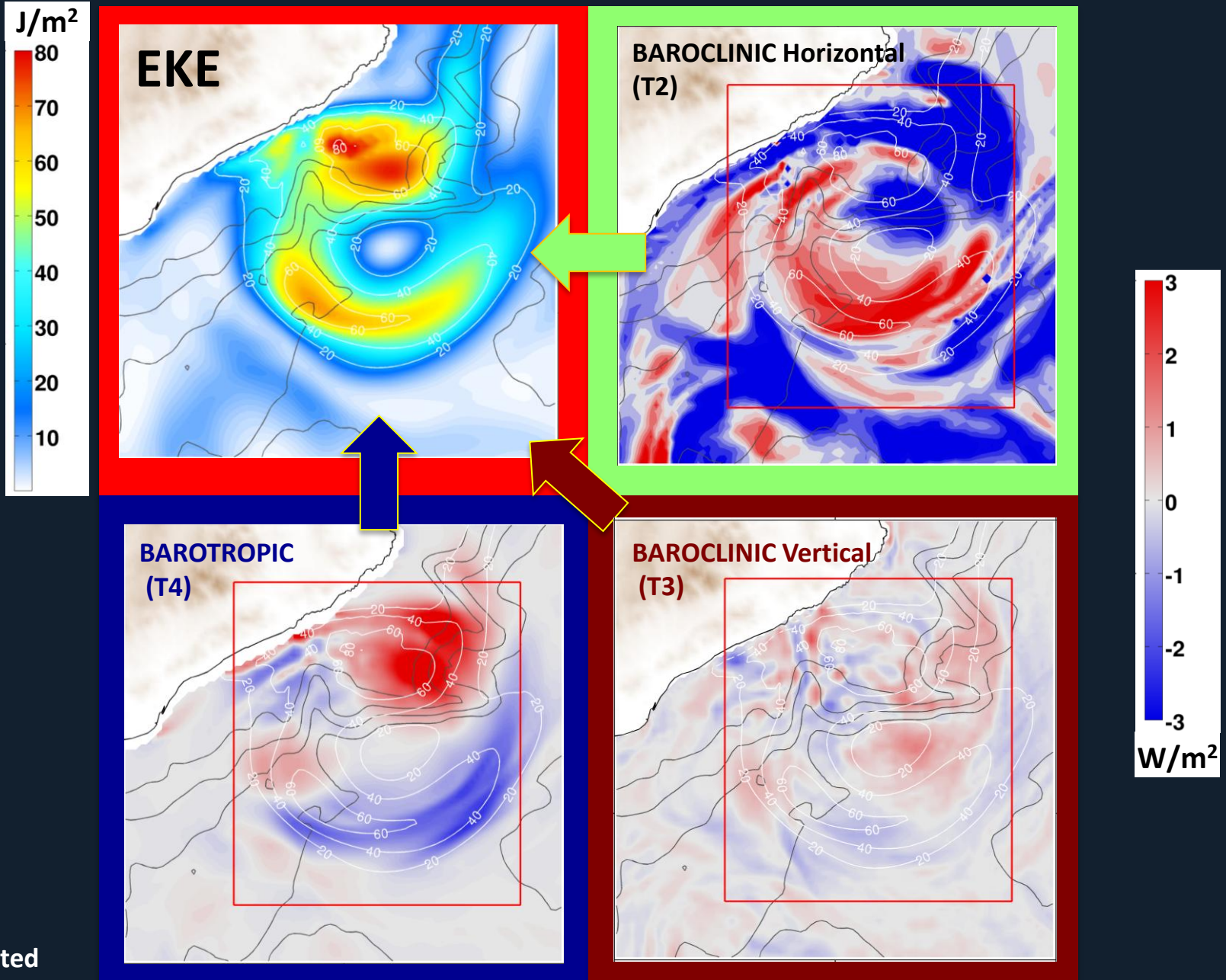
1<sup>st</sup>- 15<sup>th</sup>  
August





# 5. Energy budget: spatial distribution

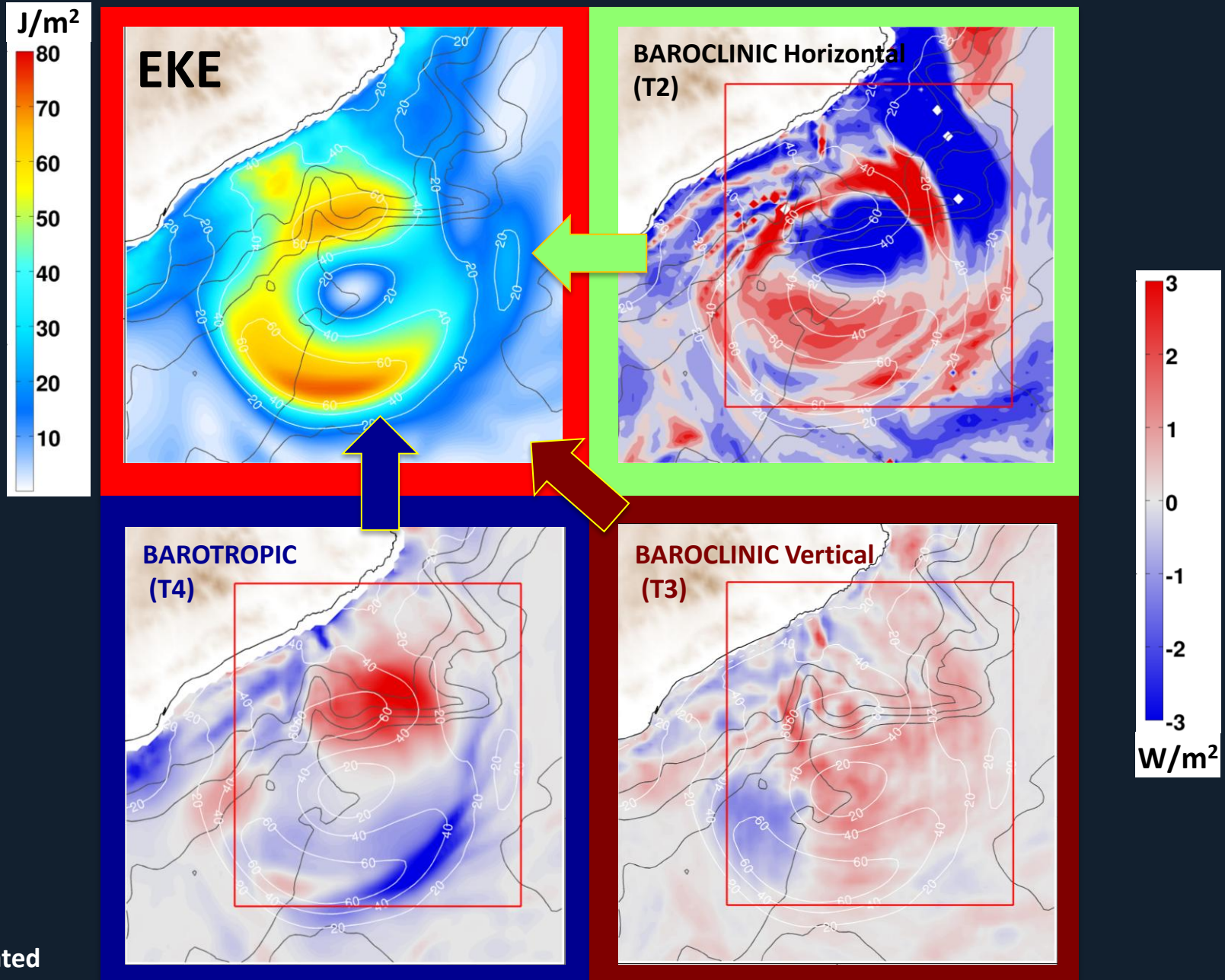
1<sup>st</sup>- 15<sup>th</sup>  
September





# 5. Energy budget: spatial distribution

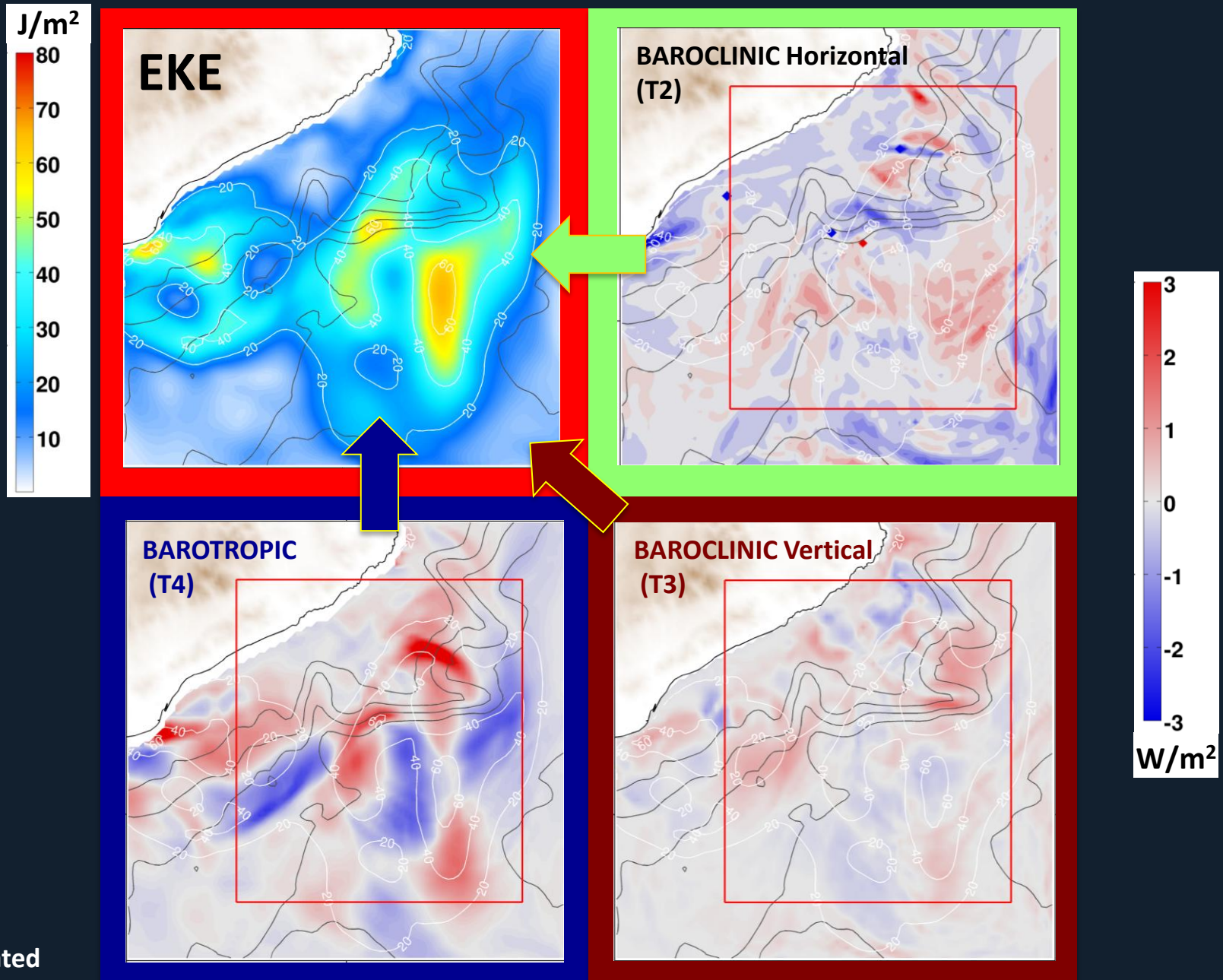
1<sup>st</sup>- 15<sup>th</sup>  
October



\*200 m depth-integrated

# 5. Energy budget: spatial distribution

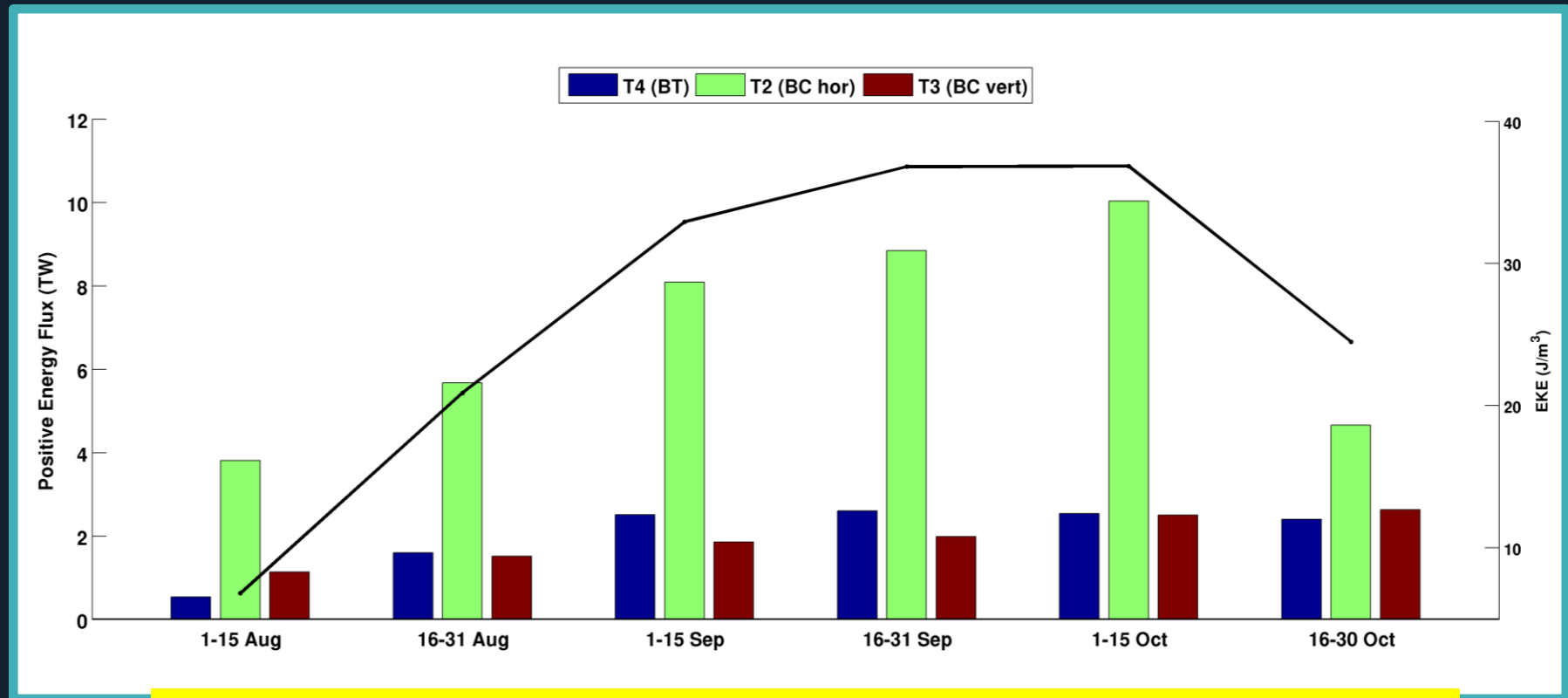
1<sup>st</sup> - 15<sup>th</sup>  
November



\*200 m depth-integrated

Which is the dominant mechanism during the 2010 event?

## Temporal evolution of the spatially-averaged-energy terms

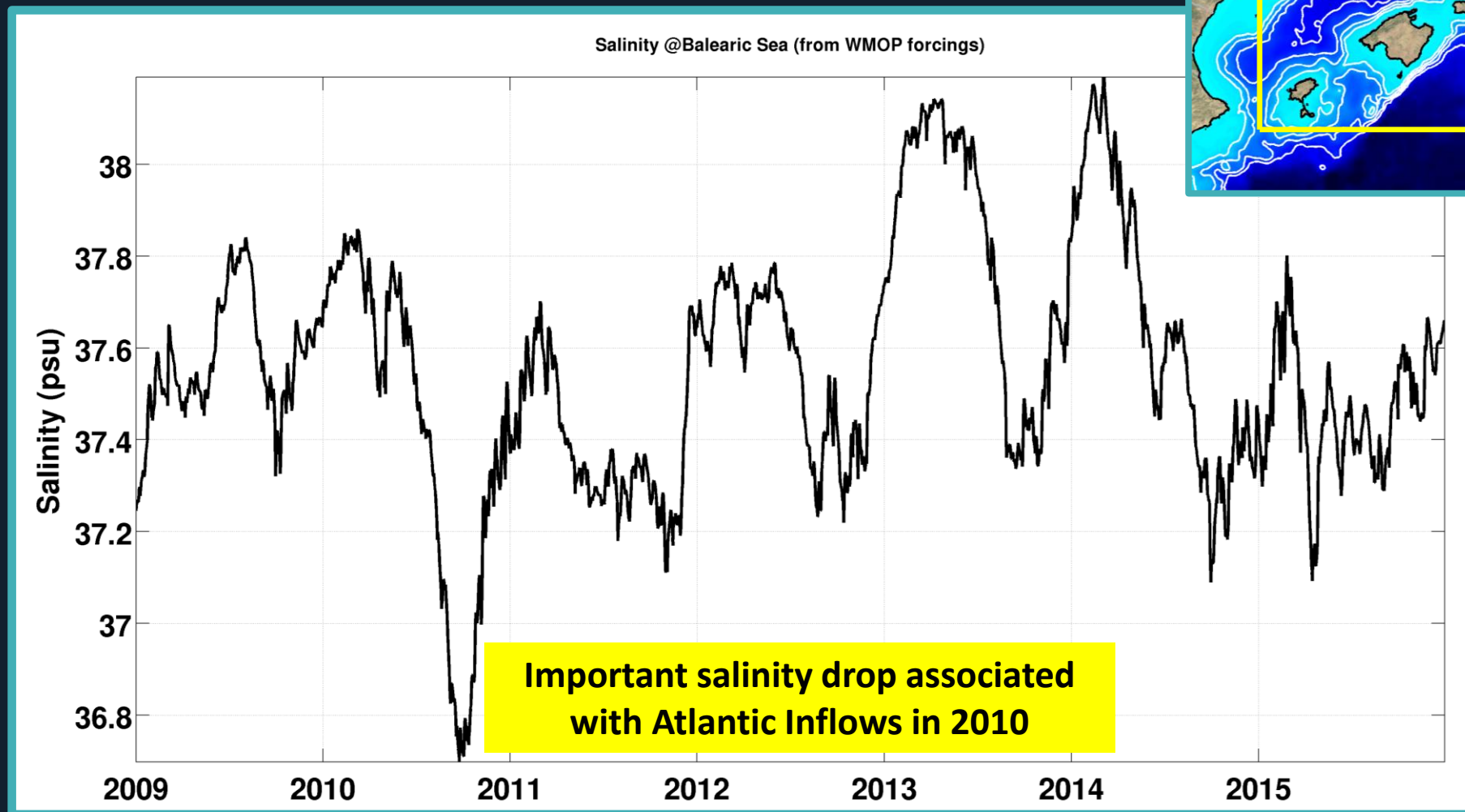
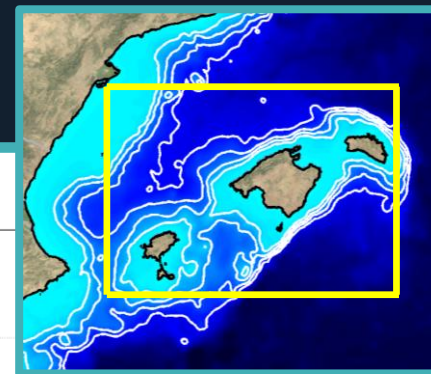


**Baroclinic instabilities growth in time and increase the  
EKE  $\rightarrow$   $\uparrow\uparrow$  life of eddies**



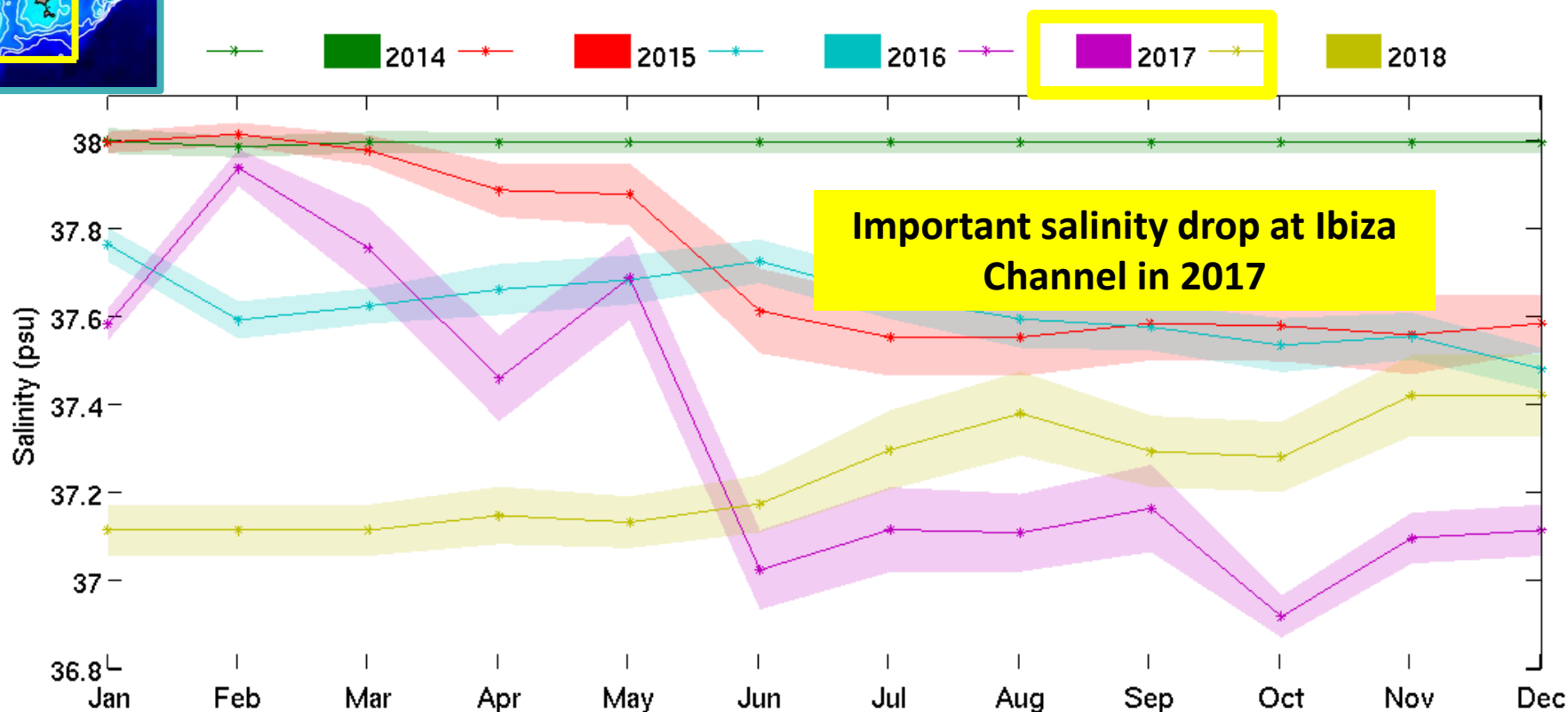
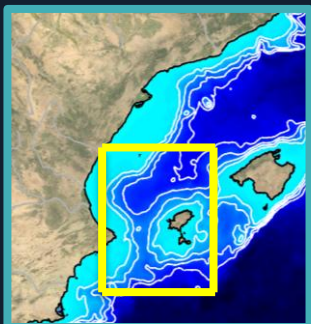
Salinity 2010

WMOP spatially-averaged salinity

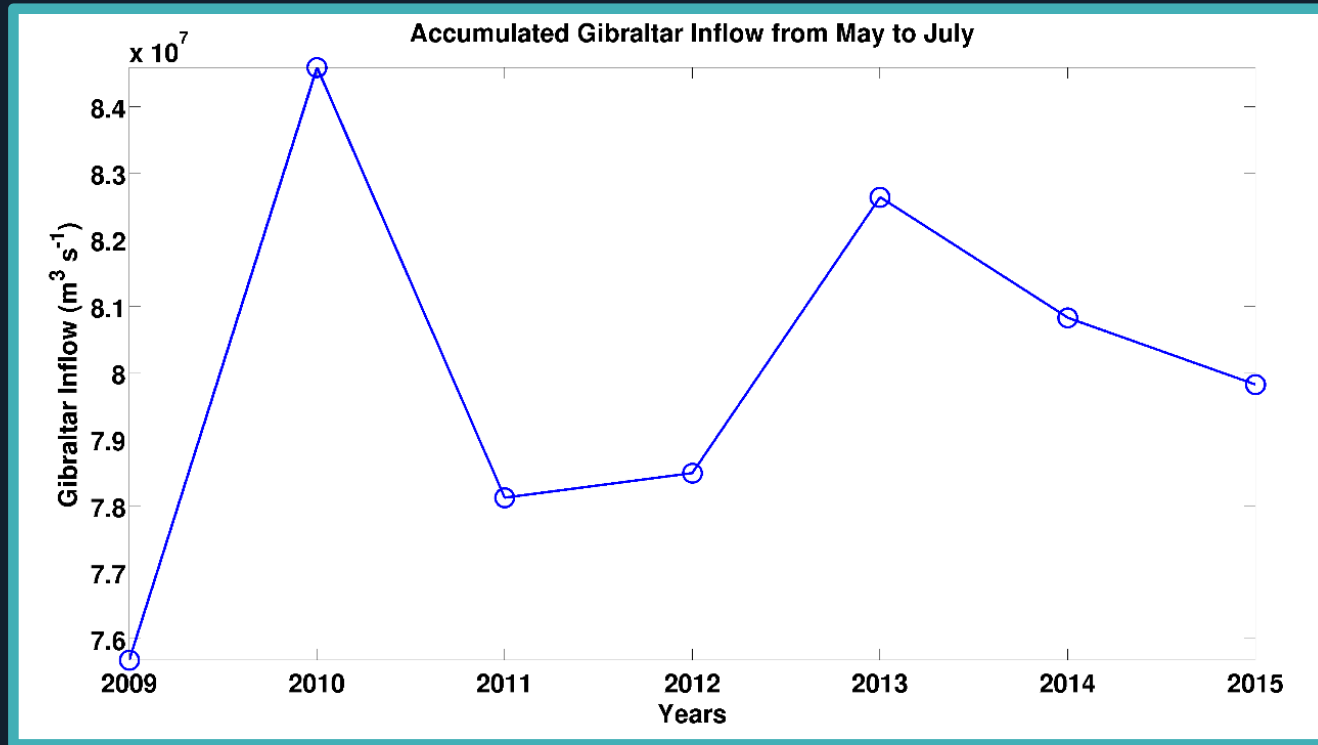




## Salinity 2017

spatially-averaged SSS from **ARGO floats** (2014 -2017)

## Atlantic Inflows from WMOP



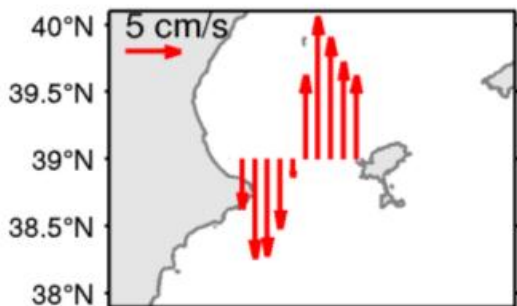
Prieto et al., 2015:

Presence of portuguese man-of-war (*Physalia Physalis*) in the Mediterranean during 2010 due to intense westerly winds (1.5 - 4 times higher than the long-term-average).

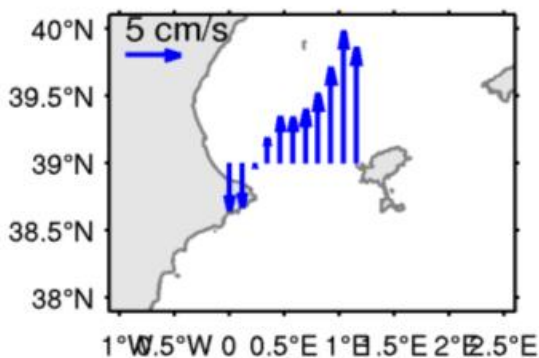
**2010: Intense Gibraltar flows from May to July**

# Transport at Ibiza Channel

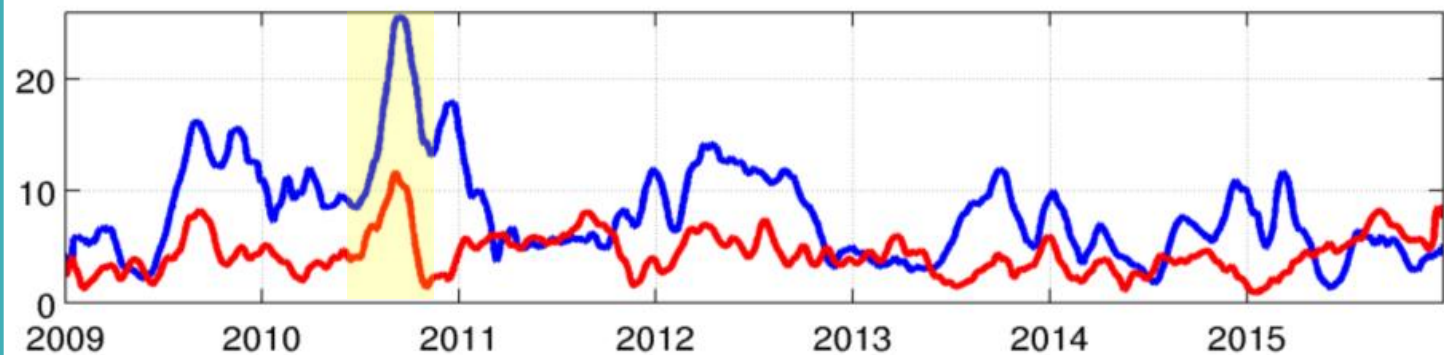
### Ibiza – Altimetry



### Ibiza – WMOP



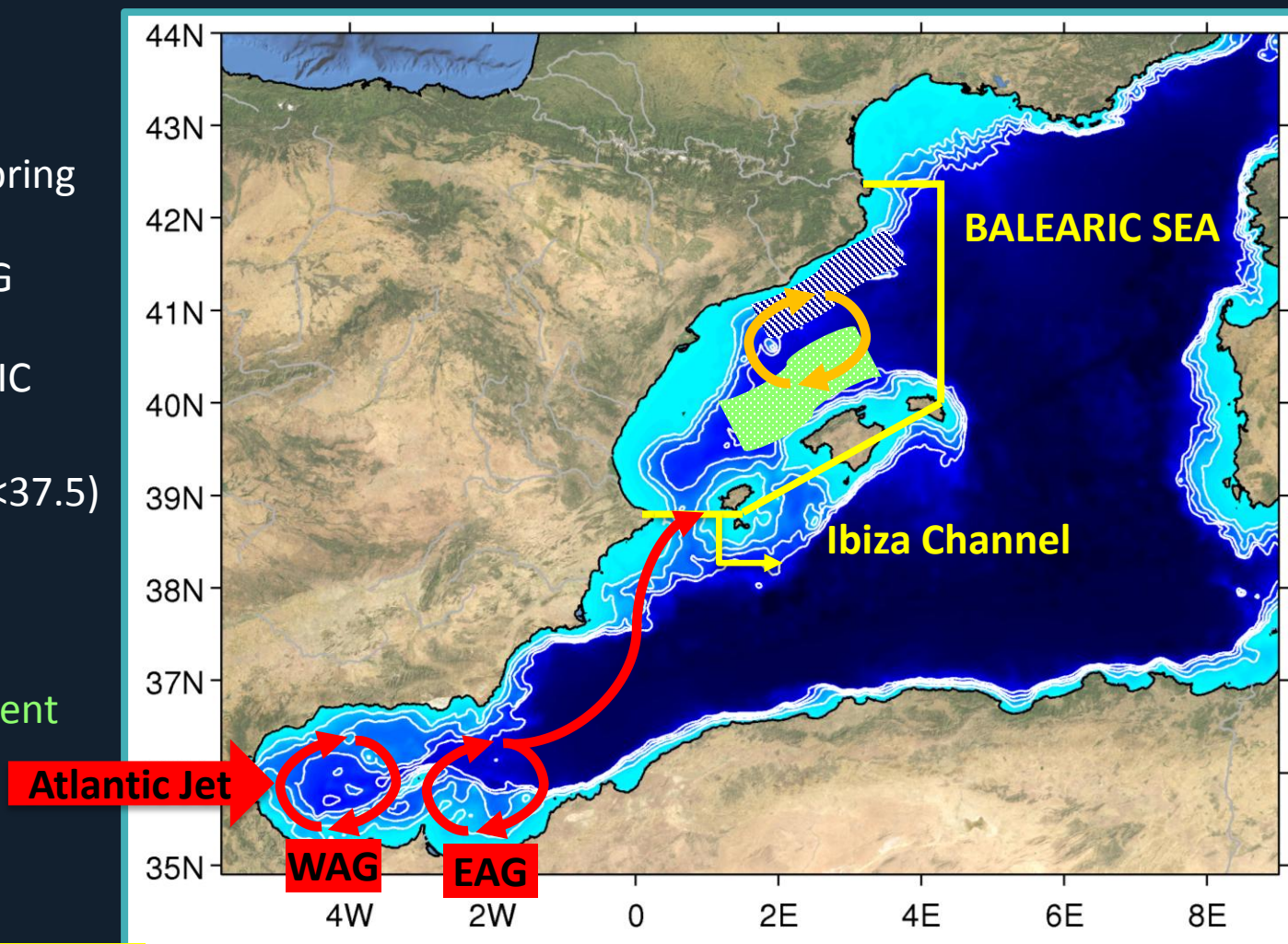
### Northward Transport (in $10^3 \text{ m}^2/\text{s}$ ) $r=0.32$



**Intensification of the northward transport**

# Possible scenario for long-lived eddies in the Balearic Sea

- (1) BT instabilities
- (2) ↑↑ Atlantic inflow during spring
- (3) Intensification of WAG&EAG
- (4) ↑↑ Northward transport in IC
- (5) ↑↑ Atlantic recent Water ( $S < 37.5$ )  
&  
↓↓ of Salt in the BS
- (6) ↑↑ extra BC horizontal gradient (T2)
- (7) Extra input of EKE



**Long-lived eddies in the BS**





THANKS FOR YOUR ATTENTION

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