Submesoscale vertical transport at the Eastern Alboran Front

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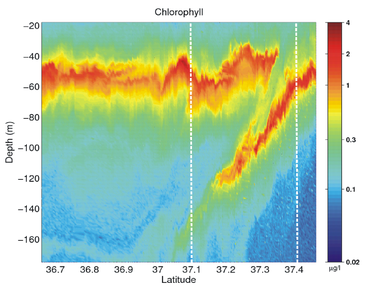
1. SCIENTIFIC MOTIVATION AND FIELD EXPERIMENT

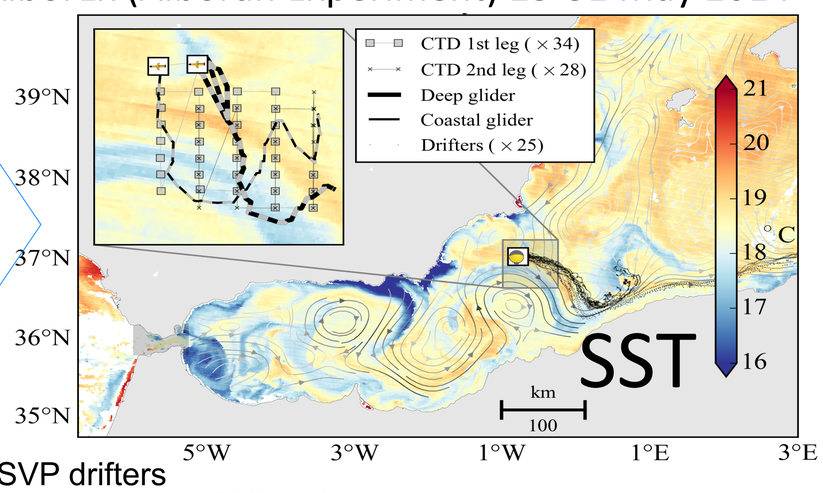
The Eastern Alboran Sea is where Atlantic inflow encounters Mediterranean water and forms a sharp front that exhibits strong frontal dynamics. Gliders operating across this front observed dramatic subducted tongues of high chlorophyll (Ruiz et al. 2009).



This large vertical excursion of chl cannot be explained by quasigeostrophic dynamics inferred from observations

Need for high-resolution observations and multi-sensor approaches

AlborEx (Alboran Experiment) 25-31 May 2014

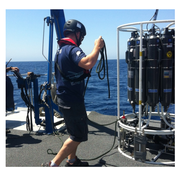


3 Argo floats

25 SVP drifters
VM-ADCP

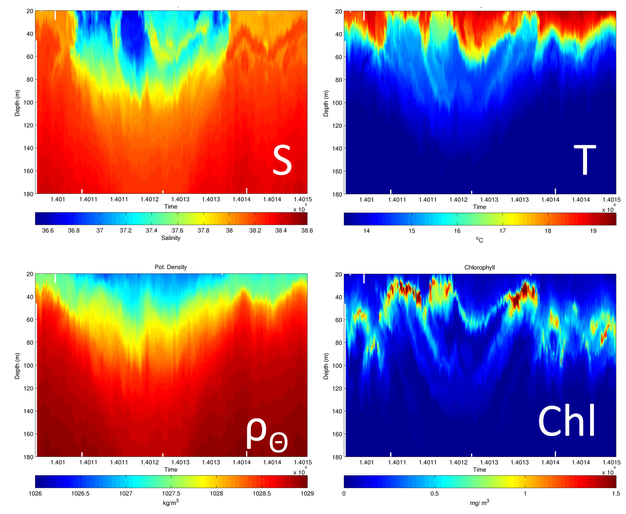
Chl/nutrients

80 CTDs



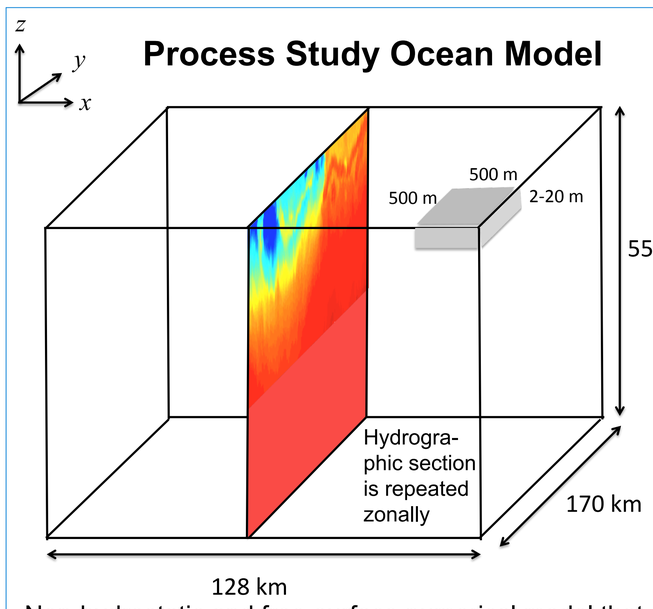
2 gliders

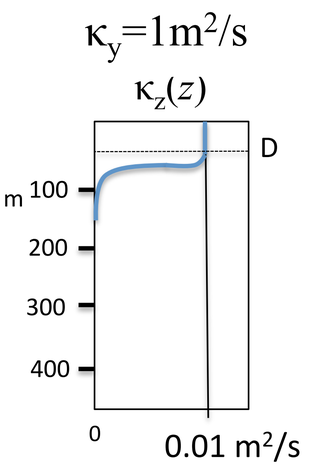
Coastal glider



Large vertical excursions of different tracers were again captured by gliders. **Are they caused by submesoscale mixed layer instabilities?**

Process Study Ocean Model





$$D = 0.4/f\sqrt{\tau/\rho_0}$$

Non-hydrostatic and free-surface numerical model that simulates the volume-preserving flow of a rotating and stratified fluid under the Boussinesq approximation (Mahadevan et al. 1996). The front is initialized in thermal-wind balance using a hydrographic glider section extended with output from the Western Mediterranean Operational Model. Viscous dissipation with constant eddy viscosities.

2. NUMERICAL MODEL CONFIGURATION TO ISOLATE THE IMPACT OF FRONTAL DYNAMICS ON VERTICAL TRANSPORT

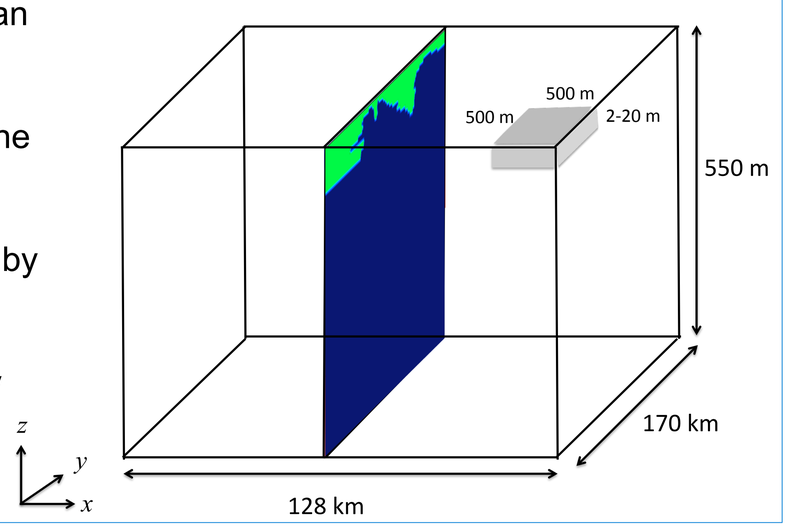
Various mechanisms, such as frontal dynamics, Ekman pumping and symmetric instability, can drive vertical motion explaining the large vertical excursion of tracers.
We configure a 3D numerical model to test the following counter hypotheses:

H_0: tracer subduction tongues are explained by frontal dynamic without atmospheric forcing.

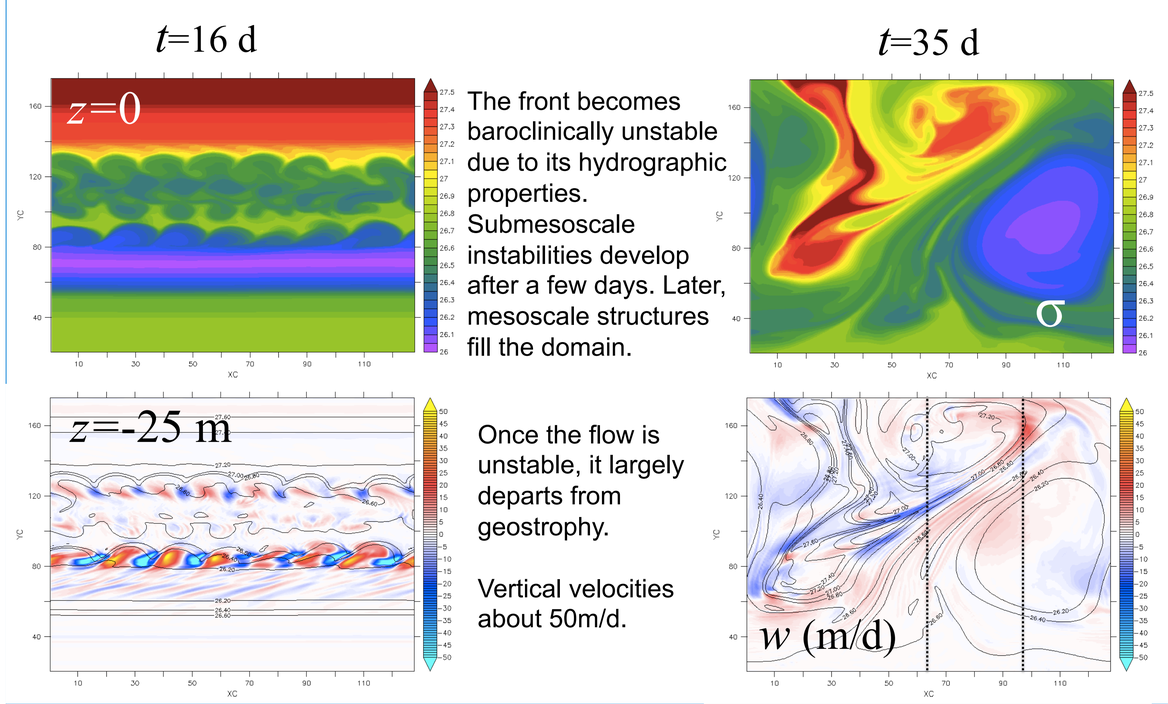
H_1: tracer subduction tongues are caused by other phenomena

Tracers initialized

Mixed layer tracer (chl-like)
Tracer homogeneous within a mixed layer, which depth is defined using a density criteria.



3. OBSERVED FRONT TRIGGERS (SUB-)MESOSCALE FRONTAL DYNAMICS WITHOUT ATMOSPHERIC FORCING

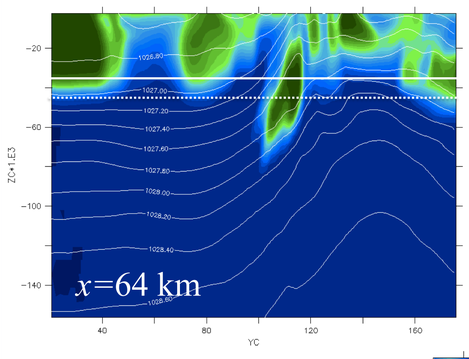


The front becomes baroclinically unstable due to its hydrographic properties. Submesoscale instabilities develop after a few days. Later, mesoscale structures fill the domain.

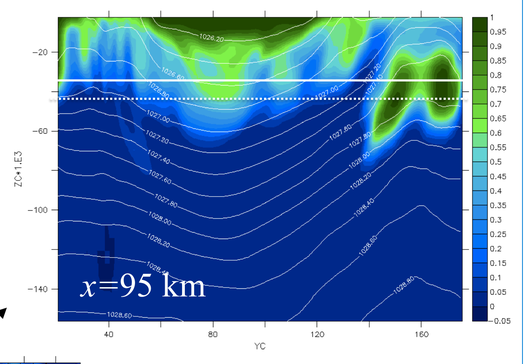
Once the flow is unstable, it largely departs from geostrophy.

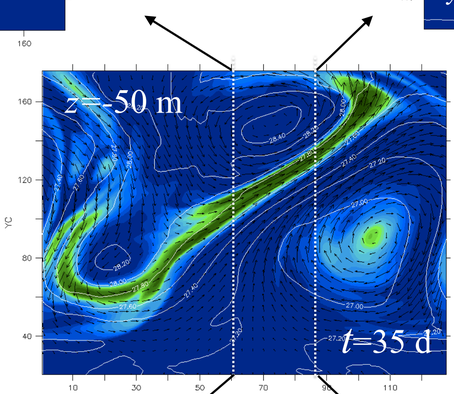
Vertical velocities about 50m/d.

4. MODELLED SUBDUCTION TONGUES



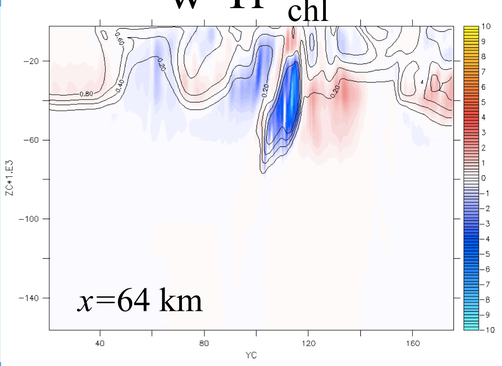
Mixed-layer tracer penetrates deeper than its initial distribution in the form of tongues aligned with isopycnals.





$w' = w - \langle w \rangle_{xy}$
$Tr' = Tr - \langle Tr \rangle_{xy}$

$w'Tr'_{chl}$



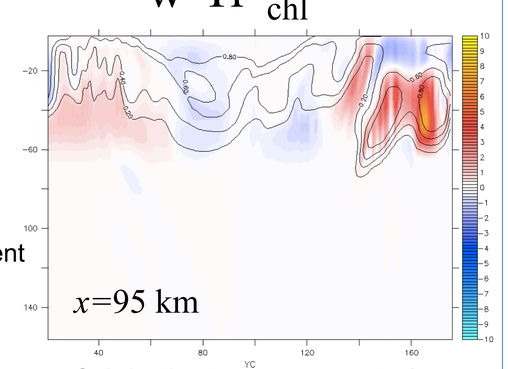
Subduction tongues are formed through downwelling where large vertical velocities are negative.

Vertical fluxes of tracers

Positive: downgradient
Negative: countergradient

After downwelling, the tracer filaments due to lateral stirring.

$w'Tr'_{chl}$



Subduction tongues are not always observed where they are being formed. This is because horizontal advection rapidly removes the tracer from its downwelling region.

5. CONCLUSIONS

- A high-resolution multi-platform experiment in the Eastern Alboran Sea captured remarkable subduction tongues in the vicinity of a sharp front.
- A Process Ocean Study shows that the front is strong enough to become baroclinically unstable in the absence of atmospheric forcing.
- Large vertical velocities resulting from frontal dynamics explain subduction tongues of a chl-like tracer.

FUTURE WORK

Could downwelling and lateral advection of a chl-like tracer combined with upwelling of a NO3-like tracer explain subsurface production driven by nutrients?

Ruiz et al. (2009): Vertical motion in the upper ocean from glider and altimetry data, *Geophys. Res. Lett.*, 36, L14607, doi:10.1029/2009GL03856.
Mahadevan et al. (1996): A nonhydrostatic mesoscale ocean model: Part I: Well-posedness and scaling.