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A numerical study on the collision of a Meddy with a seamount

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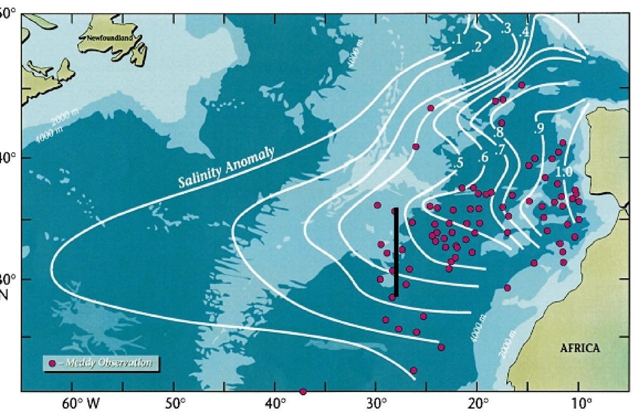
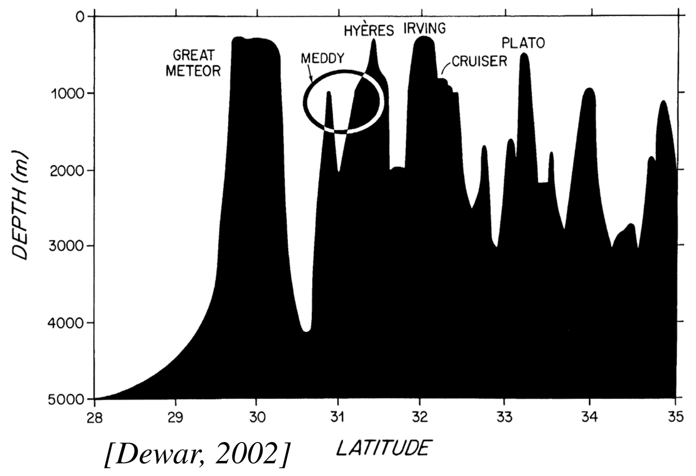
Mediterranean water eddies (Meddies) are prominent hydrological structures of the North Atlantic with significant salinity and temperature anomalies. Meddies can travel far into the ocean interior and interact with abrupt topography. The purpose of this study is to examine the dynamics and the processes involved in the collision of a Meddy with a seamount. The high resolution numerical study of this interaction has been conducted with the Regional Ocean Modeling System (ROMS).

1 Introduction

- The Mediterranean salt tongue is characterized by the presence of numerous anticyclonic eddies named Meddies (Mediterranean eddies).
- During their propagation, the Meddies slowly diffuse salt and heat, or may erode quickly by interaction with abrupt topography.
- During their propagation it is very common that they enter in collision with the Great Meteor chain.



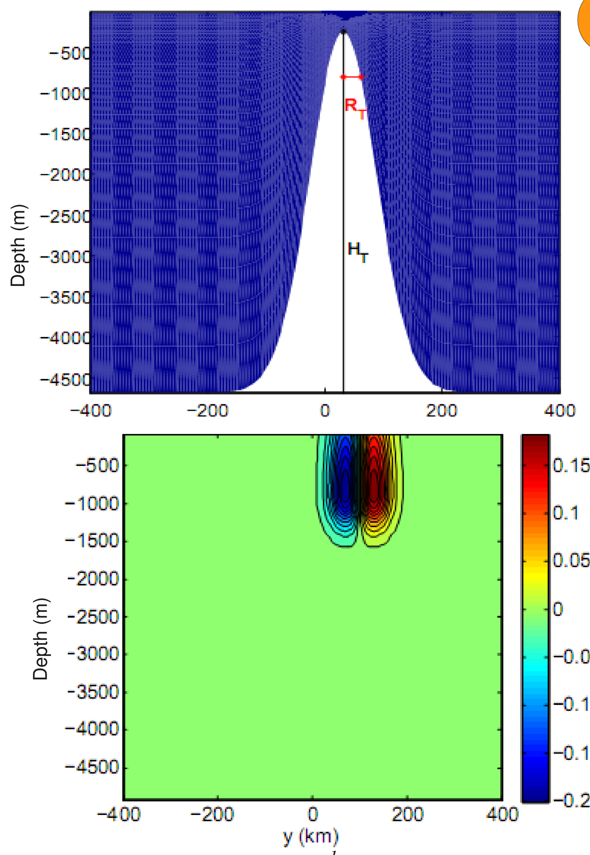
[Richardson & al., 2000]



[Dewar, 2002]

2 Numerical model

- The numerical simulation are performed with the IRD version of the model ROMS [Shchepetkin & al., 2005]. We use a closed square domain of 800 x 800 km² with a resolution of 1/20°. There are 30 sigma levels on the vertical. A β-plan approximation is used. Lateral and atmospheric forcings are not considered.
- The idealized topography is a flat bottom with a Gaussian shaped seamount.
- With regards the Meddy, analytical functions have been developed in order to create the initial numerical model fields.

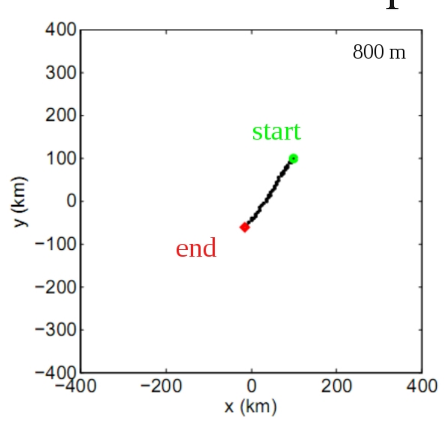


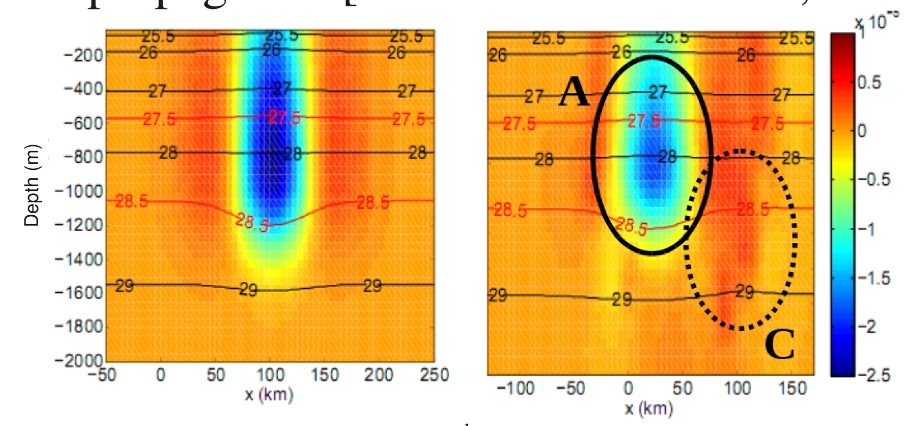
Vertical sections of the seamount (top) and the zonal velocity field [ms^{-1}] of the Meddy (bottom)

3 Reference Meddy – No Obstacle

- The first simulation is performed to understand the evolution and the structure of the Meddy without obstacle. The Meddy moves clearly southwestward.
- This drift can be explain by: the beta effect, the advection of surrounding fluid and the stretching and squeezing changes [Cushman-Roisin, 1994].
- Hetonic interactions can explain this propagation [Morel & McWilliams, 1997].

Track of the center of the Meddy defined as a local minimum of relative vorticity

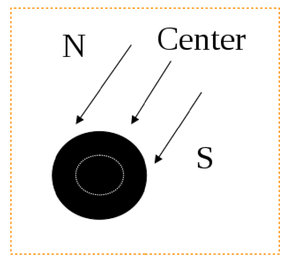




Vertical sections of relative vorticity [s^{-1}] after 1 day (left) and 91 days (right)

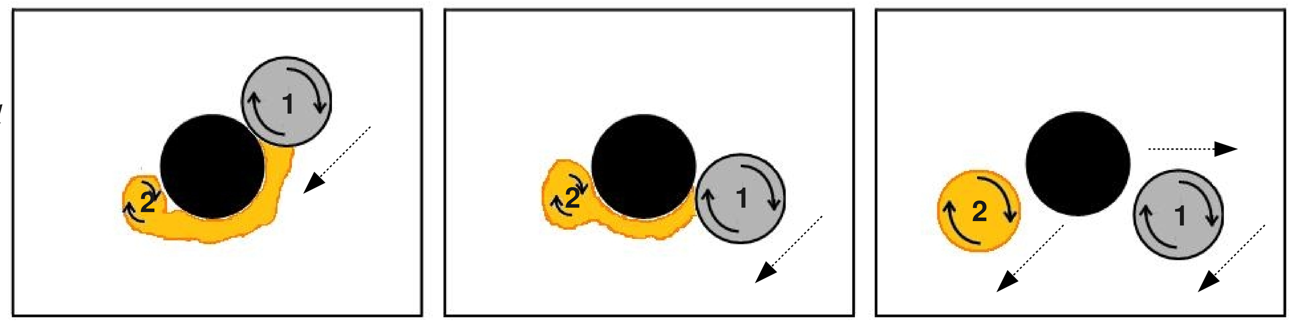
4 The collision

- A seamount is placed in the path of the reference Meddy. The exact position of the seamount center is adjusted to have a southern, northern or central impact.



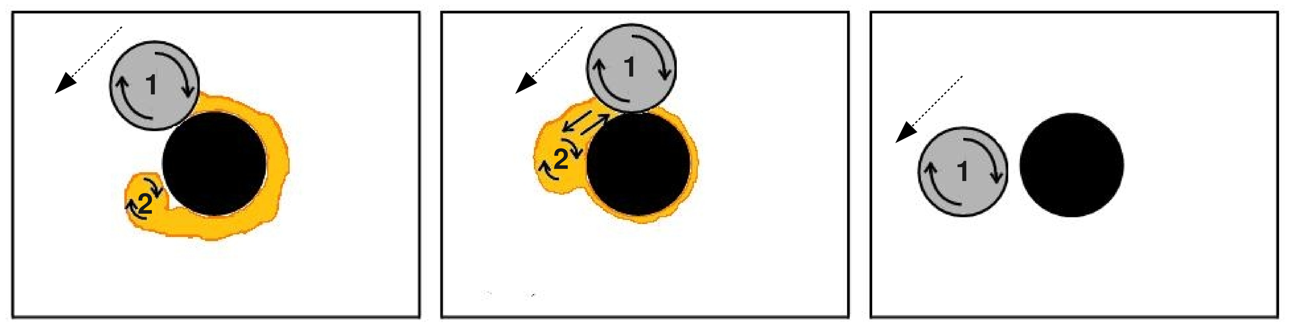
- In all cases, the Meddy survives the encounter and bifurcates into two separate vortices: a main Meddy (1) and a secondary Meddy (2). At the time of the impact, a cyclonic vorticity tongue is formed around the seamount.
- For a southern and central impacts, the two Meddies drift southwestward as independent structures.

Southern and central Impacts



- For a northern impact the main Meddy merged with the secondary Meddy. This Meddy continues to drift southwestward as a single coherent structure.

Northern Impact



Conclusion

Meddy – Southwestward propagation + hetonic interaction

Collision with the seamount
Bifurcation process

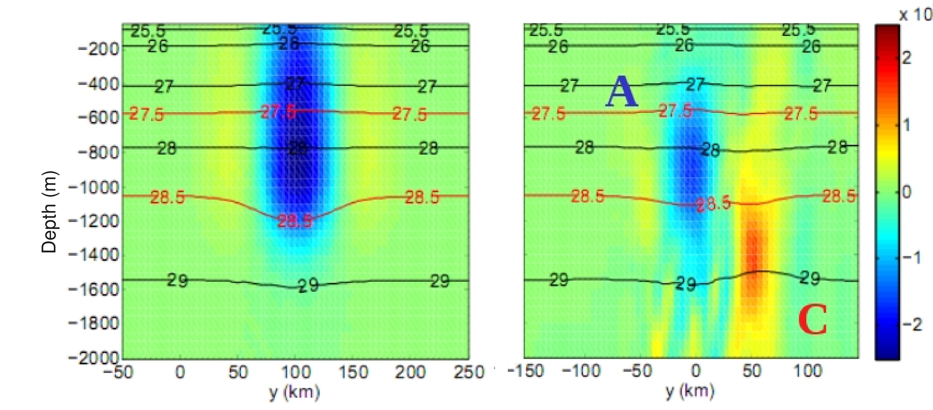
Main Meddy – Hetonic structure accelerated

Secondary Meddy – Von-Karman vortex street

North impact ➡ Processes of aggregation between the main Meddy and the secondary Meddy

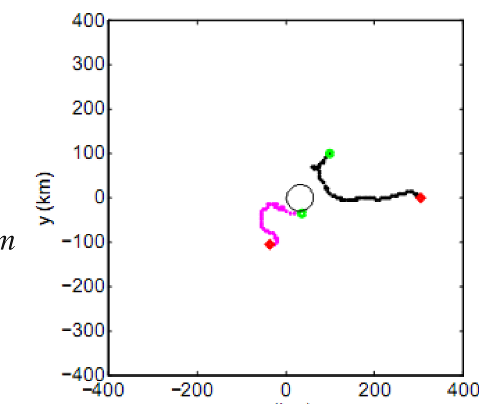
5 Meddy – Center impact

- The organization of the vorticity structure of the main Meddy quickly evolves toward a hetonic structure.
- The change into a hetonic structure is so marked that a stable structure emerges and propagates eastward. This structure is call a modon.



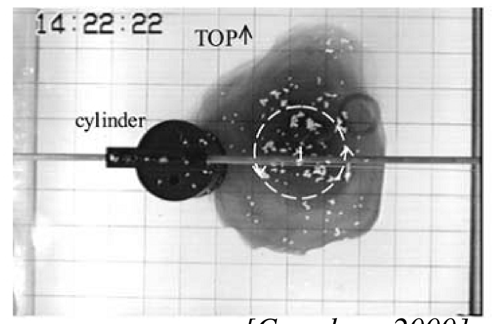
Vertical sections of relative vorticity [s^{-1}] after 1 day (left) and 121 days (right)

Track of the centers of the Meddies defined as a local minimum of relative vorticity



6 Comparison with laboratory experiments of Cenedese (2002)

- Idealized laboratory experiments of a cyclonic vortex interaction with a vertical cylinder were conducted. Cenedese used a 2D approach and, due to laboratory constraints, cyclonic vortices. She then extrapolated her results to anticyclonic vortices.



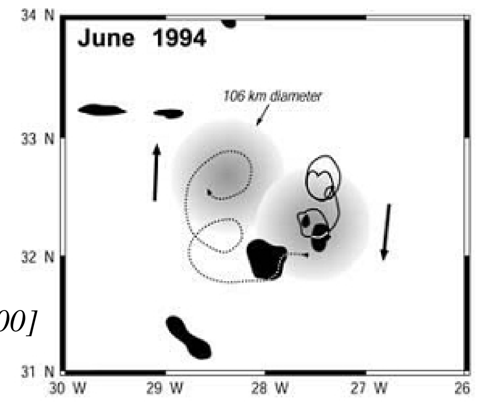
[Cenedese, 2000]

[Cenedese, 2002]		This study
Formation of a **steamer counterclockwise** around the cylinder	✔	Formation of a **cyclonic vorticity tongue counterclockwise** around the seamount
Formation of a **new vortex in the lee** of the cylinder	✔	Formation of a **secondary Meddy in the lee** of the seamount
Bifurcation for **northern and central impacts**	X	**Bifurcation** for **southern and central impacts**

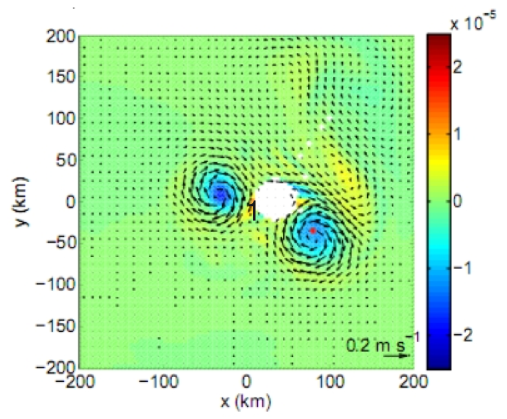
- In both cases the new vortex formed is generated by a mechanism similar to the Von-Karman vortex street.

7 Comparison with the observation of Richardson and al. (2000)

- The last simulation, which simulates a central impact with the Irving seamount, allows us to compare our results with the observation of Richardson & al. (2000).
- From this observation they supposed that it is possible for a Meddy to survive a collision and to continue into two independent eddies (bifurcation hypothesis).



[Cenedese, 2000]



Horizontal section of relative vorticity [s^{-1}] at 800 m depth

- Our results are in good agreement with this observation confirming the hypothesis of bifurcation.

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