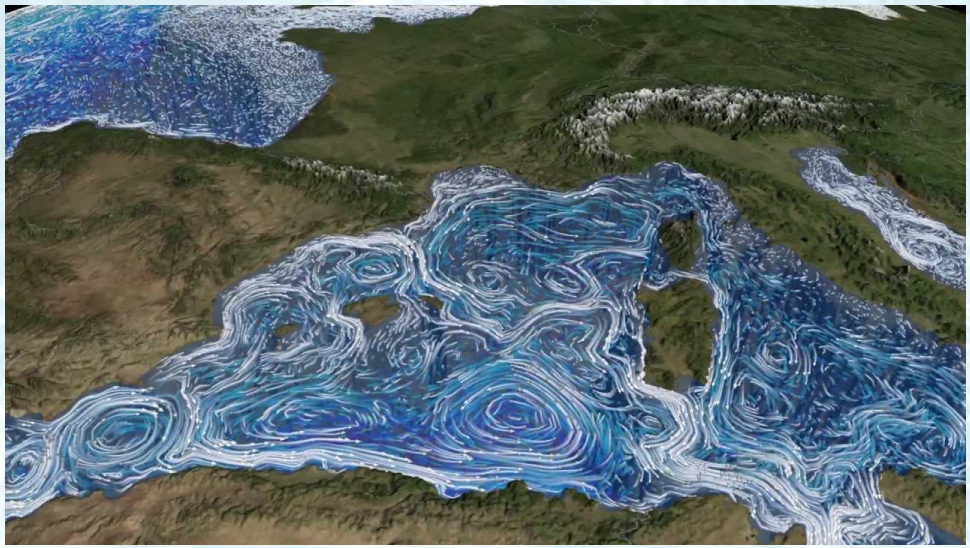
# Modelling the Mediterranean circulation: skills and flaws of present day models



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# The CLIFISH project

**Objectives:**

- Study the effects of climate change, and in particular of the projected changes on physical processes, in the dynamics of nektobenthic populations and fisheries communities
- Identify the strengths and weaknesses of the Mediterranean ocean models in order to get more robust projections for the 21st century
- Gather the largest possible data set of Mediterranean current observations.
- Compare the observations with state of the art climatic hindcast simulations performed by different regional ocean circulation models in the Mediterranean basin.

Public observations data base in homogenized format (open to new contributions)

Regional Climate simulations for the Mediterranean basin

Analysis of projections for the 21st century.

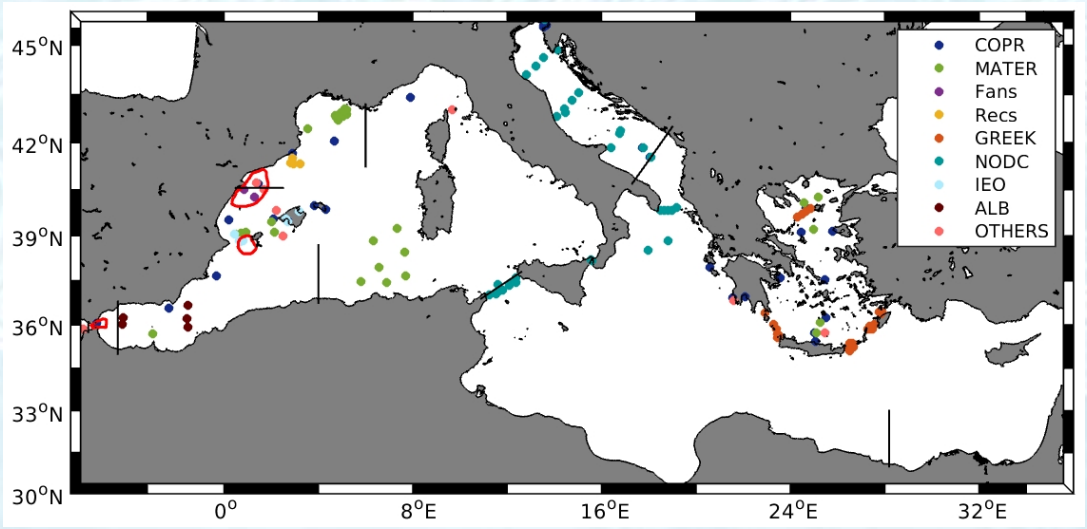
# Observations: moorings

- 155 moorings distributed throughout the basin at depths ranging from 3 to 2000 m.
- Velocity measures based on ADCP and/or current meters. Processed and quality controlled.
- Very variable time coverage: from a few months to several years.

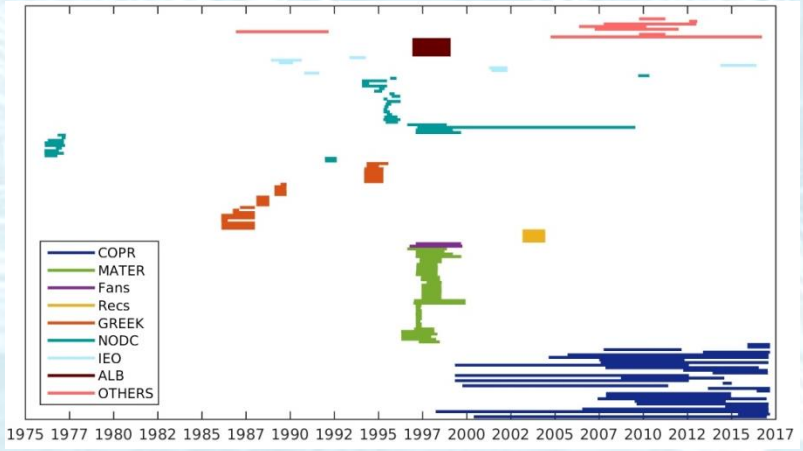
**Data bases used:**

- **Copernicus Med In Situ (marine.copernicus.eu)**
- **EU- MATER Project**
- **FANS project**
- **RECS project**
- **Greek moorings**
- **NODC**
- **IEO**
- **Alborán**
- **Others**

Spatial distribution of the observations



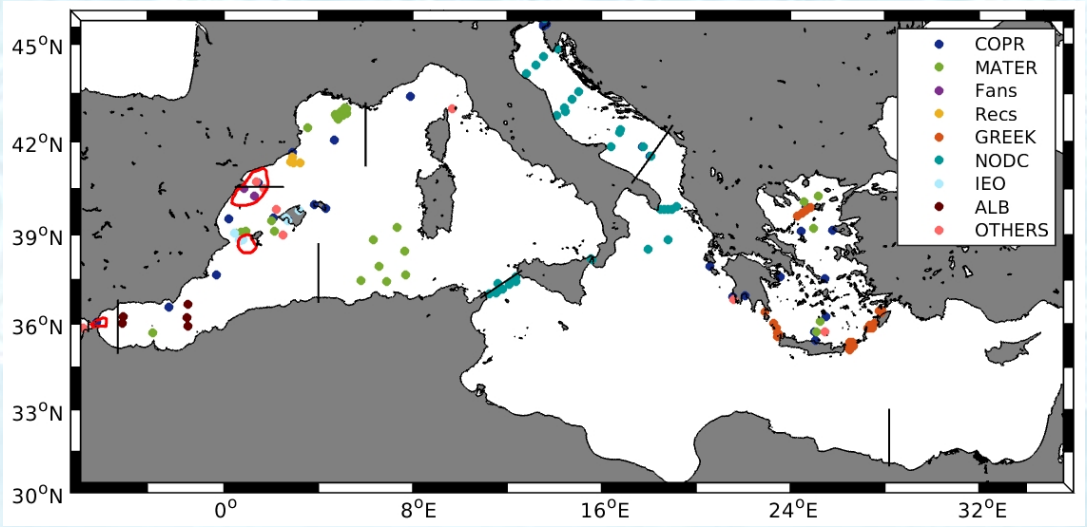

Temporal coverage



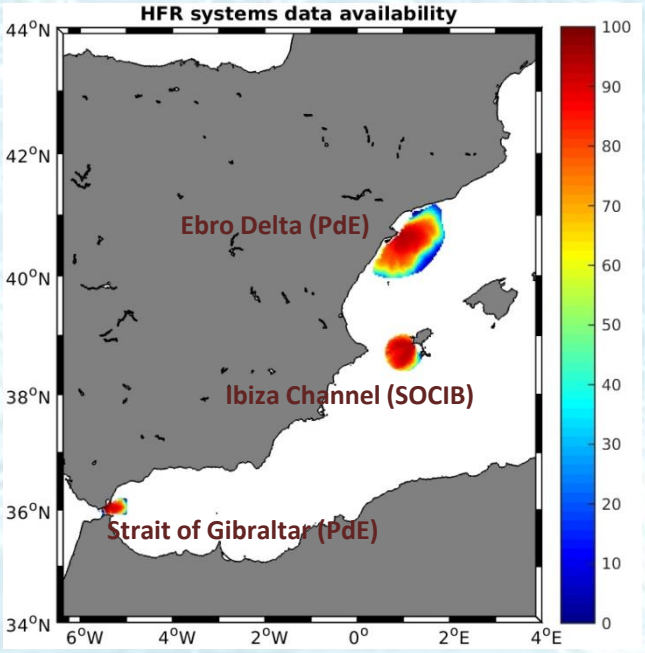
# Observations: HF radar

- Three HFR systems: Strait of Gibraltar, Ebro Delta and Ibiza Channel
- Surface hourly data from 2013 to 2017
- Allows the evaluation of model surface current in more extent domains

## Spatial distribution of the observations



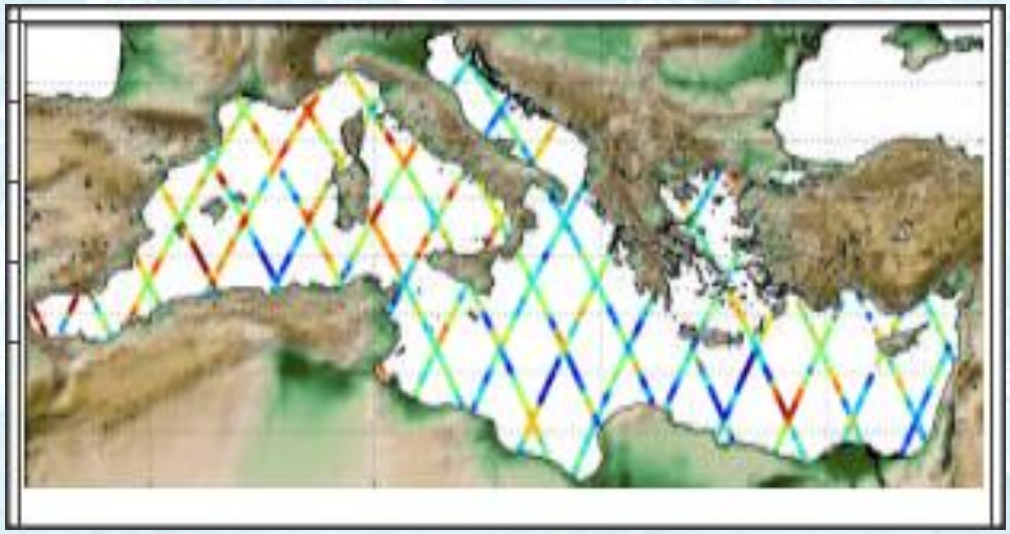

## HFR data availability



# Observations: satellite altimetry data

- Absolute Dynamic Topography along satellite tracks (1993 – 2016) from AVISO dataset
- Derived geostrophic velocities from AVISO gridded product
- SSH extracted from the models along tracks, demeaned, detrended and seasonal cycle substratcted
- Eddy Kinetic Energy  (EKE) computed from the along track geostrophic velocities of the models

Satellite tracks

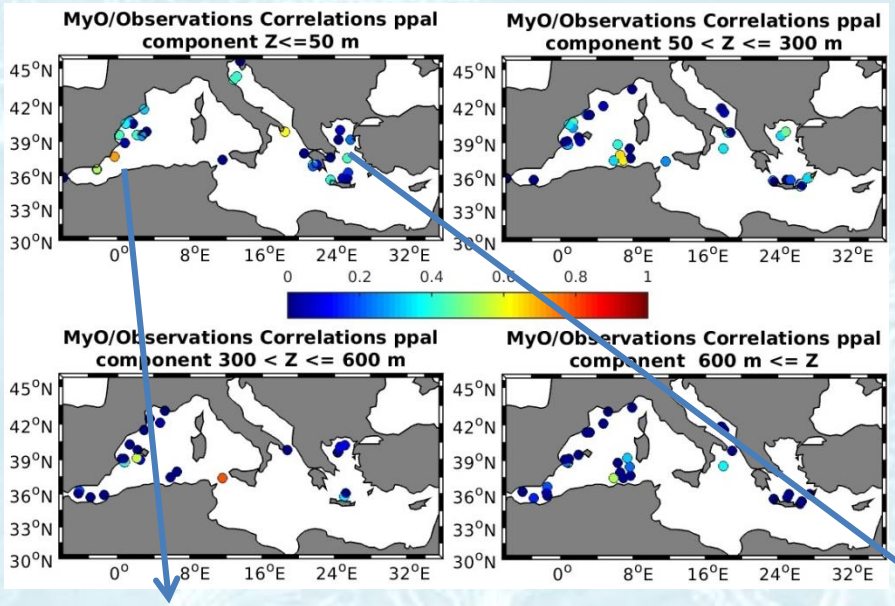


# Models and simulations

| Simulation/model | Horizontal resolution | Temporal resolution | Vertical resolution | Boundary forcing | Atmospheric Forcing |
|---|---|---|---|---|---|
| COPR (NEMO) | 1/16 x 1/16 degrees 6 – 7 km | Daily 3D U and V from 01/01/1987 - 31/12/2014 | 72 uneven vertical levels 3 m max resolution 1.5 m shallowest level | Daily T, S and velocity fields from global model + assimilation of T/S vertical profiles and satellite SLA | ERA-Interim |
| NM12 (NEMO) | 1/12 x 1/12 degrees 8 – 9 km | Daily 3D U and V from 01/01/1987 - 31/12/2010 | 50 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation to Levitus climatology in a buffer zone + SSH dumping | ARPERA-V2 |
| MDY (NEMO) | 1/12 x 1/12 degrees | Daily 3D U and V from 01/10/1992 - 30/06/2013 | 72 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation and SSH dumping ORAS4 reanalysis + Assimilation of SSH (AVISO, T and S (CORA4) | ALDERA |
| ENS1250 (NEMO) | 1/12 x 1/12 degrees 8 – 9 km | Daily 3D U and V from 01/01/2003 - 31/12/2013 | 50 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation to Levitus climatology in a buffer zone + SSH dumping | ARPERA-V2 |
| ENS1275 (NEMO) | 1/12 x 1/12 degrees 8 – 9 km | Daily 3D U and V from 01/01/2003 - 31/12/2013 | 75 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation to Levitus climatology in a buffer zone + SSH dumping | ARPERA-V2 |
| ENS3650 (NEMO) | 1/36 x 1/36 degrees 2 – 3 km | Daily 3D U and V from 01/01/2003 - 31/12/2013 | 50 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation to Levitus climatology in a buffer zone + SSH dumping | ARPERA-V2 |
| ENS3675 (NEMO) | 1/36 x 1/36 degrees 2 – 3 km | Daily 3D U and V from 01/01/2003 - 31/12/2013 | 75 uneven vertical levels 1 m max resolution 0.5 m shallower level | T/S relaxation to Levitus climatology in a buffer zone + SSH dumping | ARPERA-V2 |
| ROMWMED32 (ROMS) | 1/32 x 1/32 degrees 3 – 4 km WMED | Daily 3D U and V from 01/01/2003 - 31/12/2012 | 32 terrain – following sigma levels | NEMOMED 12 | NCEP – CSFR |
| SYM (SYMPHoNIE) | 1/32 x 1/32 degrees 3 – 4 km WMED | Daily 3D U and V from 25/05/2011 – 03/04/2017 | 32 terrain – following sigma levels | | |

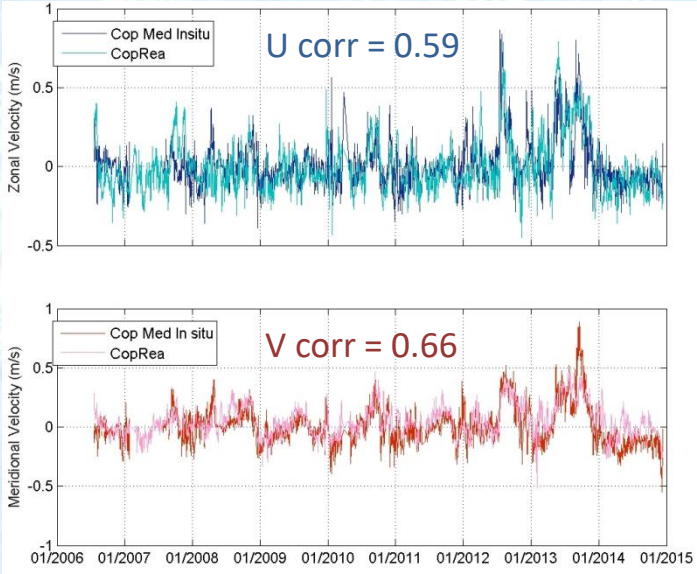
# Models validation: moorings

## COPR Correlation

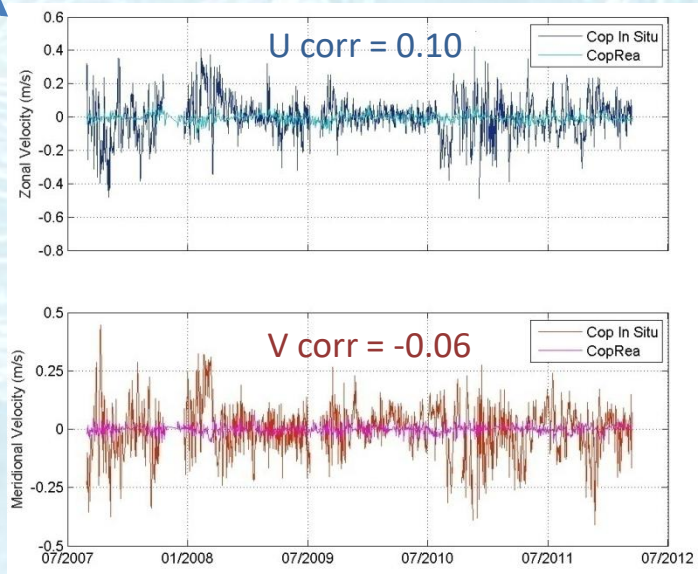



- For most of the moorings correlation < 0.4 (many < 0.2).
- Better results in the Western Mediterranean, specially along the Iberian slope.
- Correlation decreases with depth.

## Cabo de Palos station Z = 3 m

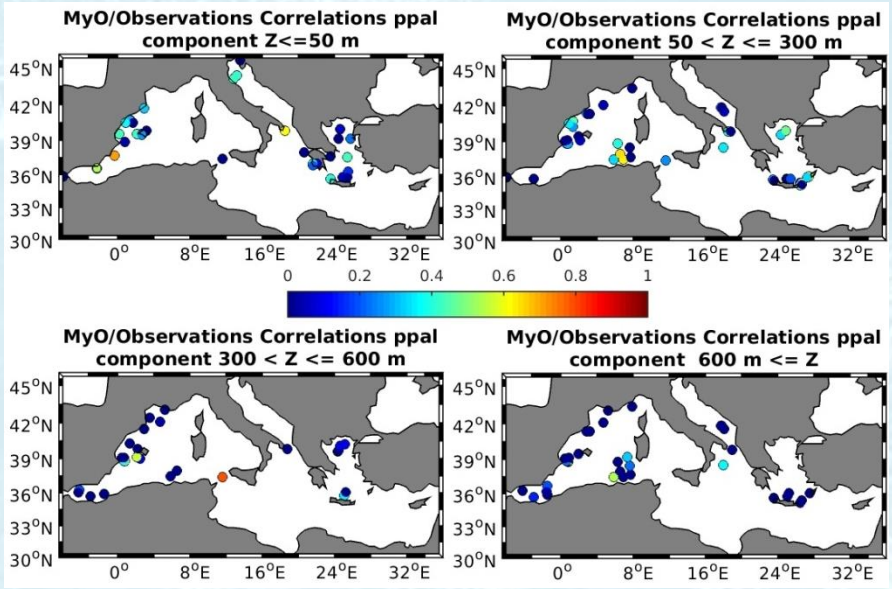



## SKYRO station Z = 3 m

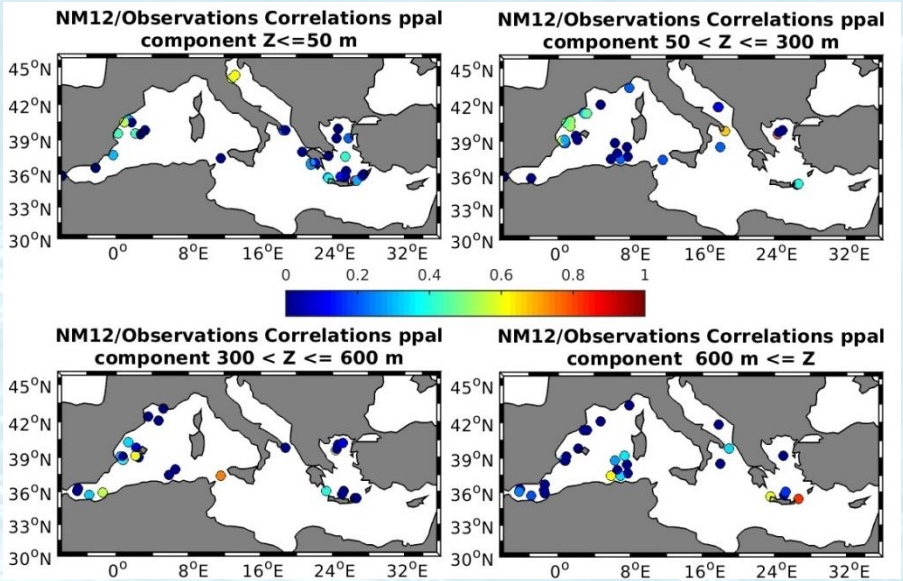


# Models validation: moorings

## COPR Correlation

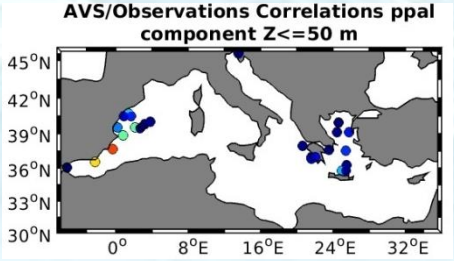



## NM12 Correlation

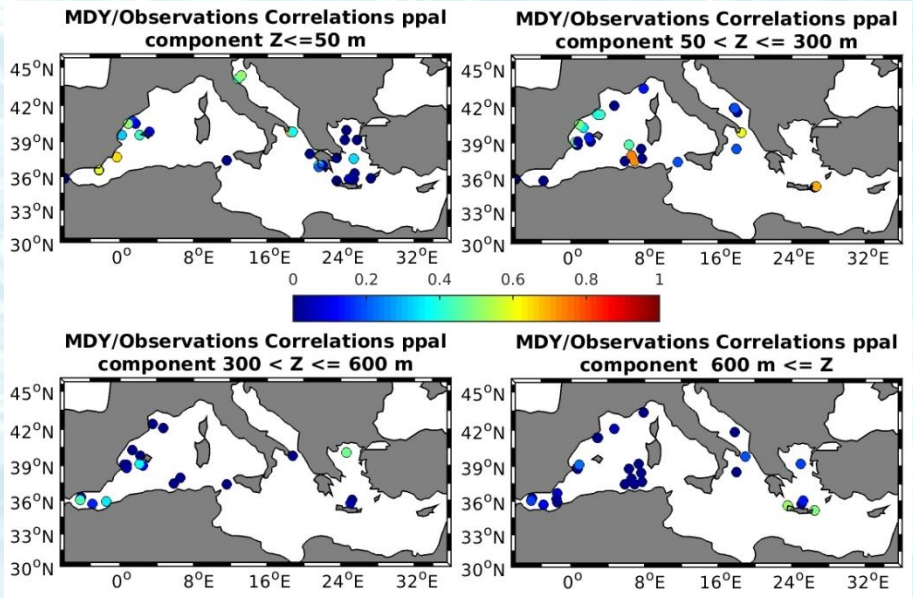



- Results for the rest of the models in the same line
- Satellite observations don't improve the results

## AVS Correlation

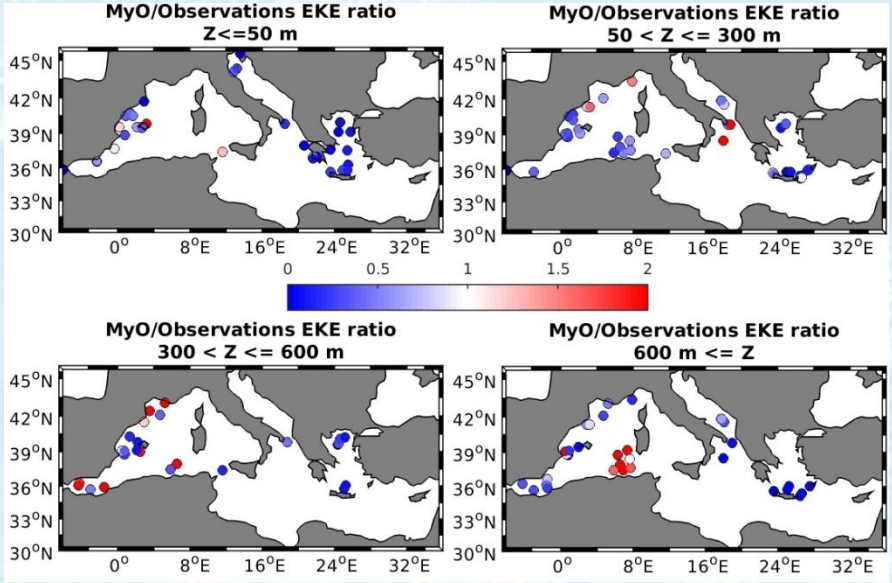



## MDY Correlation

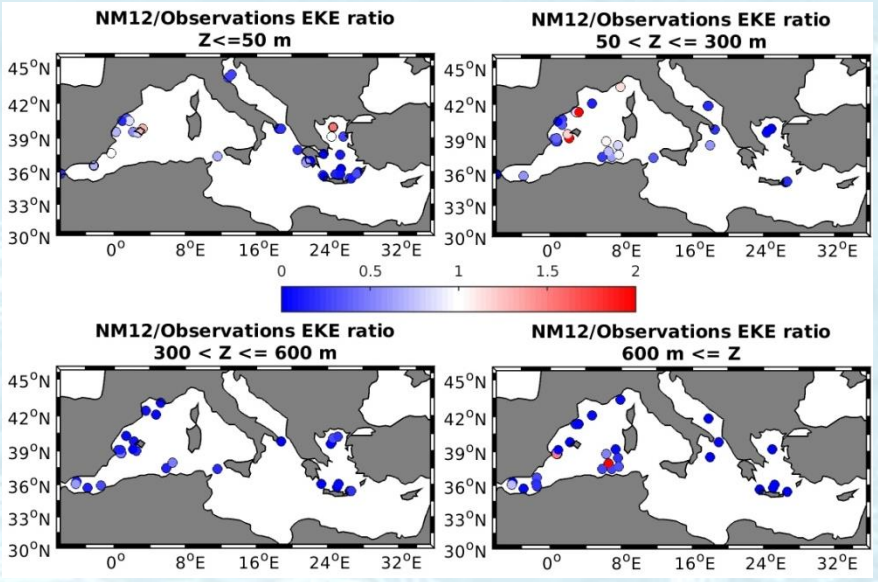


# Models validation: moorings

## COPR EKE ratio

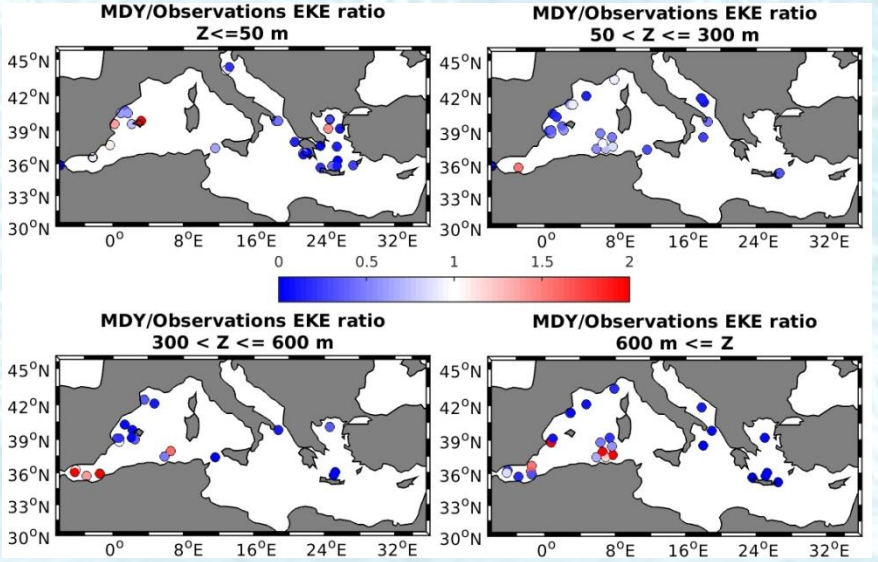



## NM12 EKE ratio

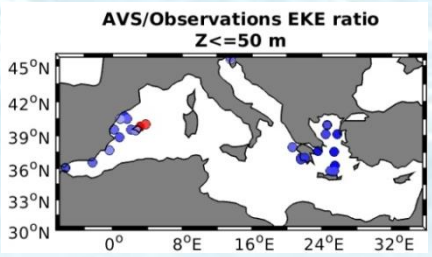



- EKE generally underestimated by the models, only in a few mooring the ratio is close to one.
- Better results in the western basin.

## MDY EKE ratio

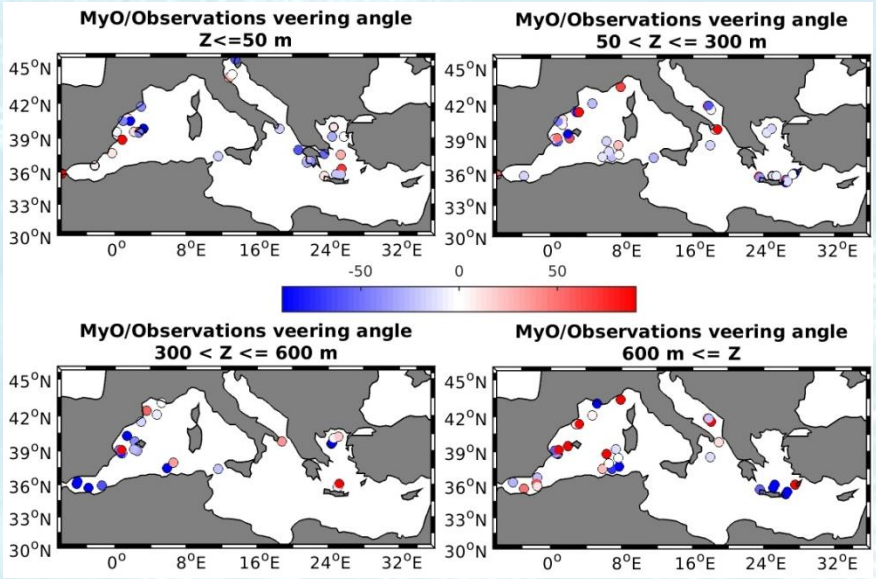



## AVS EKE ratio

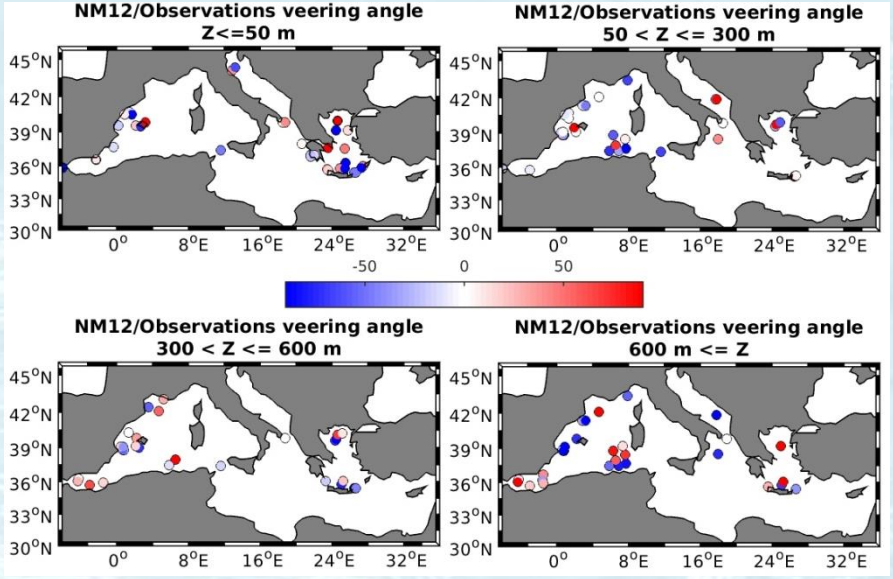


# Models validation: moorings

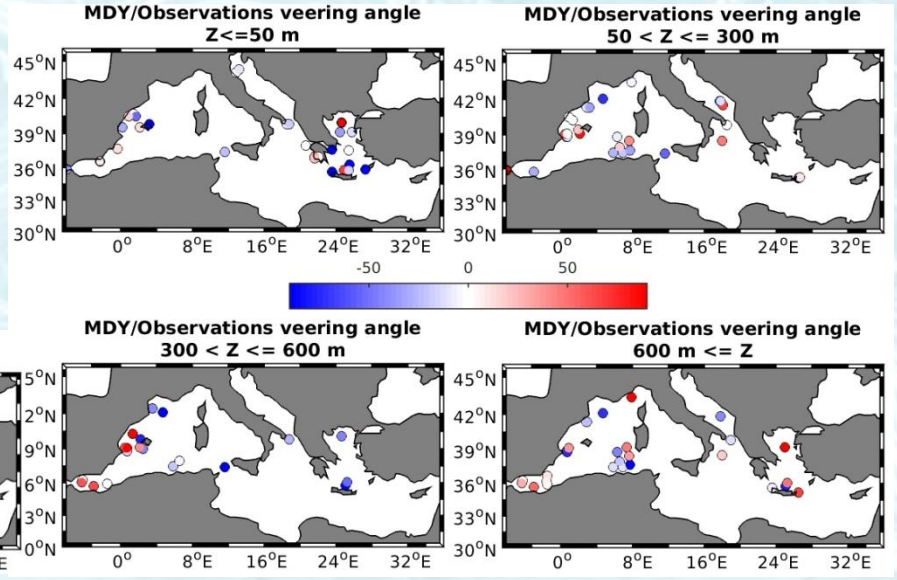
## COPR veering angle




## NM12 veering angle



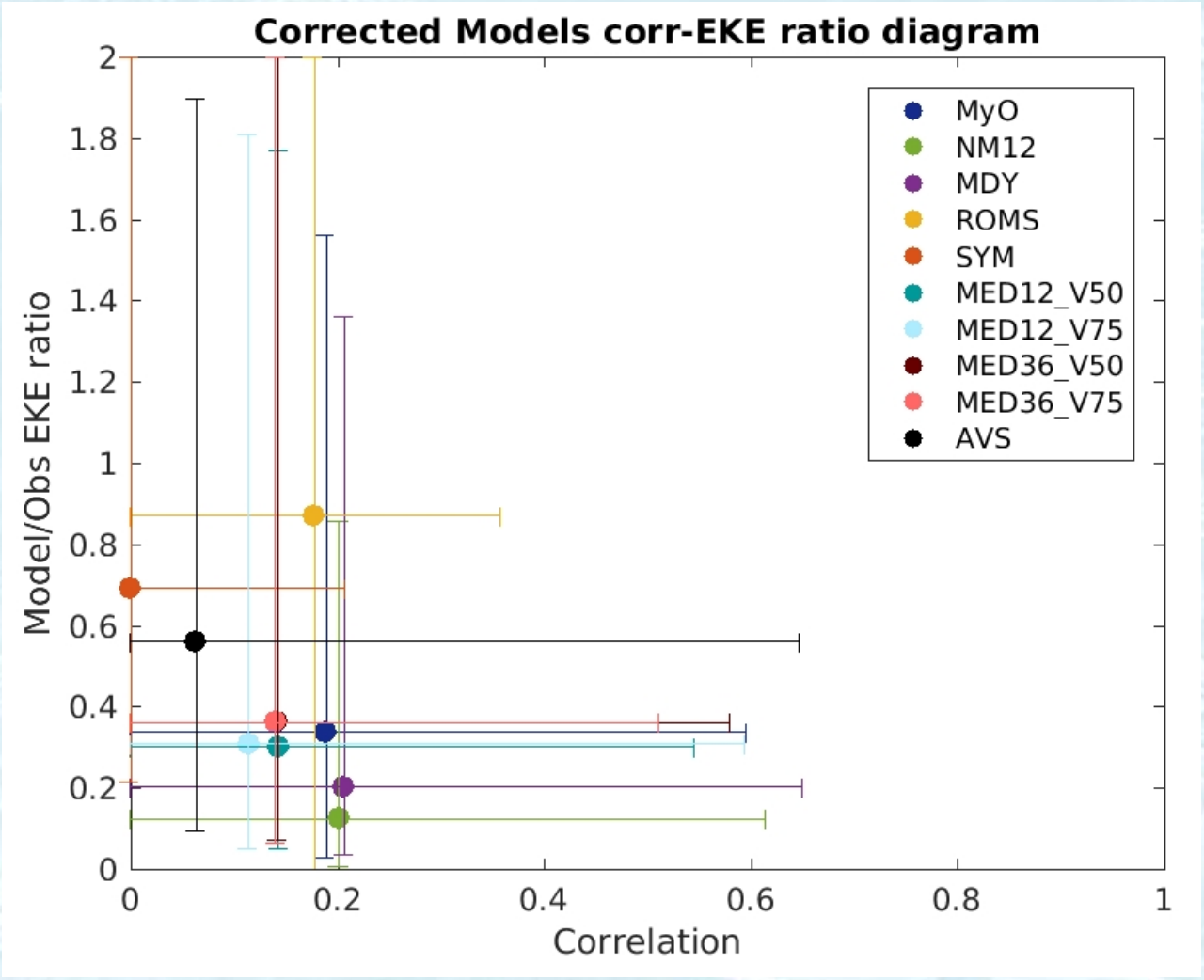

## MDY veering angle




- In general, the representation of the current direction is good for all the models.
- Accuracy decreases with depth.
- AVS show also good results

## AVS veering angle

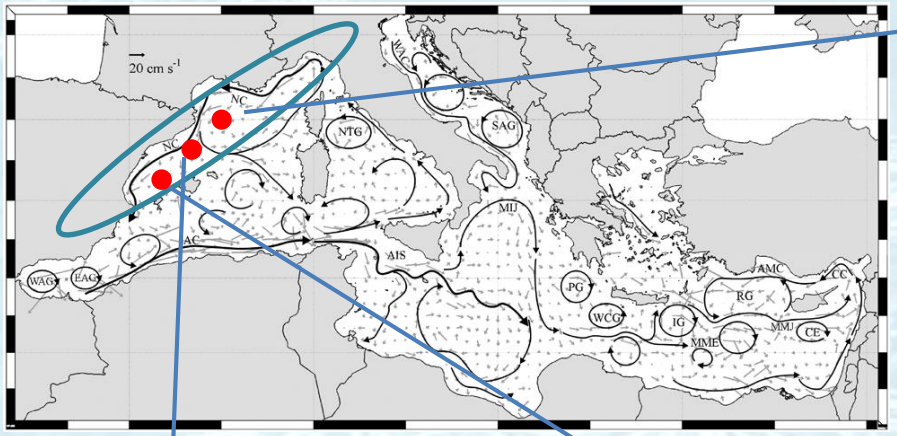
# Models validation: moorings




- Median correlation between 0.07 (SYM) and 0.26 (MDY).
- Median EKE ratio between 0.13 (NM12) and 0.85 (ROMS).
- In general very poor results for all the simulations.

# Models validation: progressive vectors

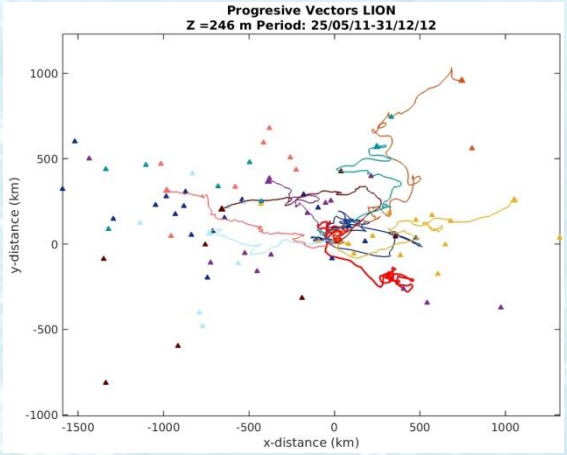
## Northern current



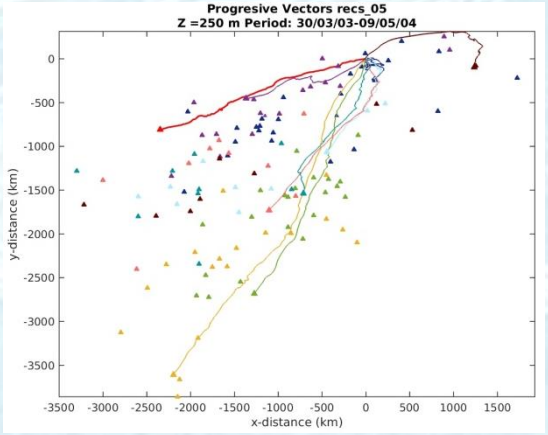

*Poulain, P.M. et al. Oceanography 2013*

LION station Z = 246 m

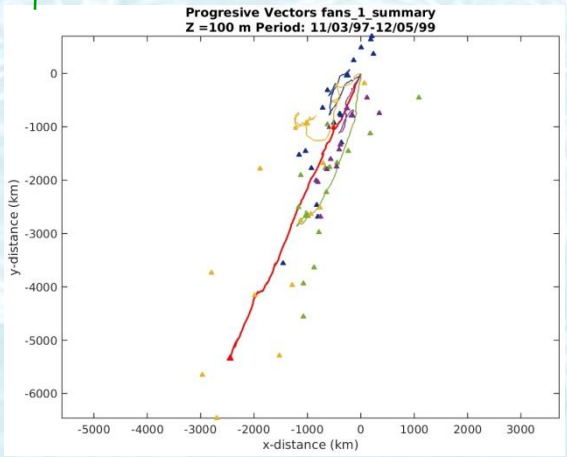
- OBS
- COPR
- NM12
- MDY
- ENS1250
- ENS1275
- ENS3650
- ENS3675
- ROMS
- SYM
- AVS



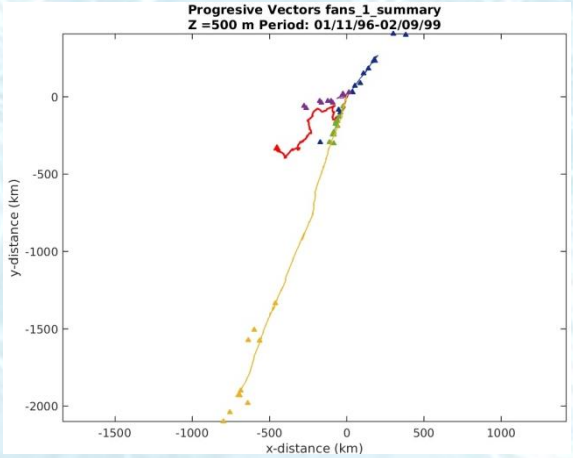

Recs 5 station Z = 250 m




Fans 1 station Z = 100



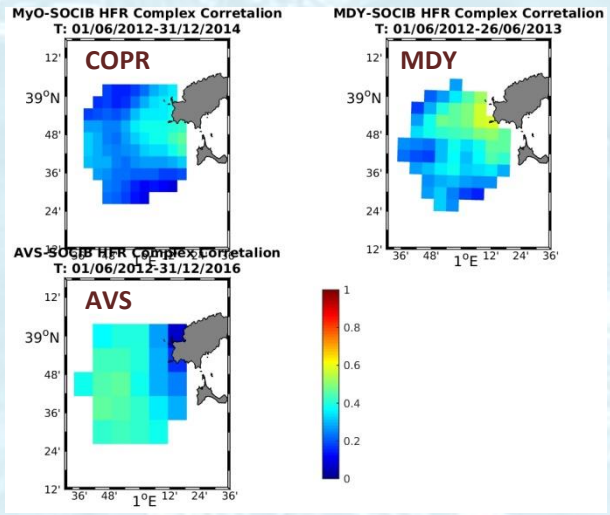

Z = 300 m



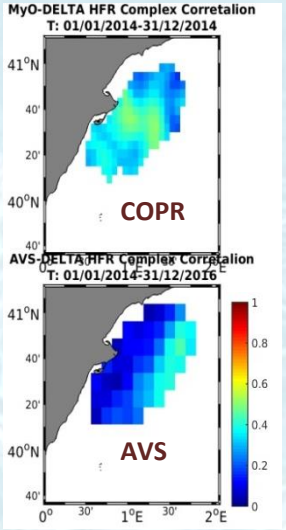
# Models validation: HF radar

- Results analogous to those of the moorings: low correlation and underestimated variability. Exception at the Strait of Gibraltar

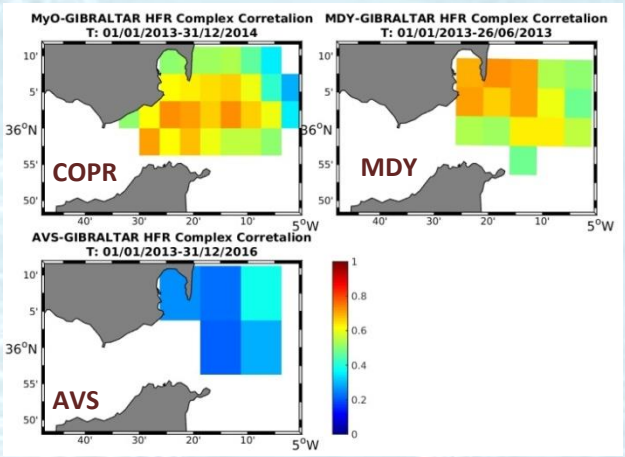
## Ibiza Channel HFR complex correlation



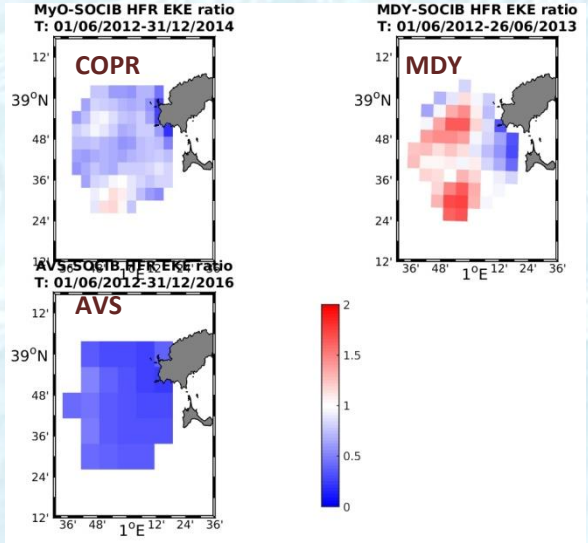

## Ebro delta HFR complex correlation



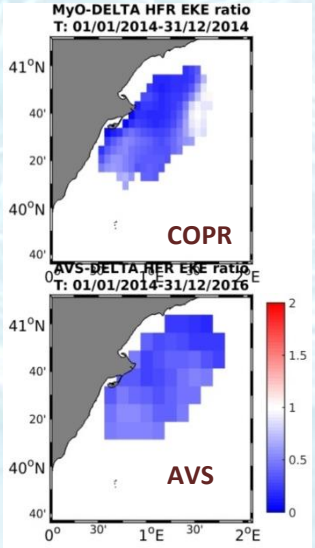

## Strait of Gibraltar HFR complex correlation



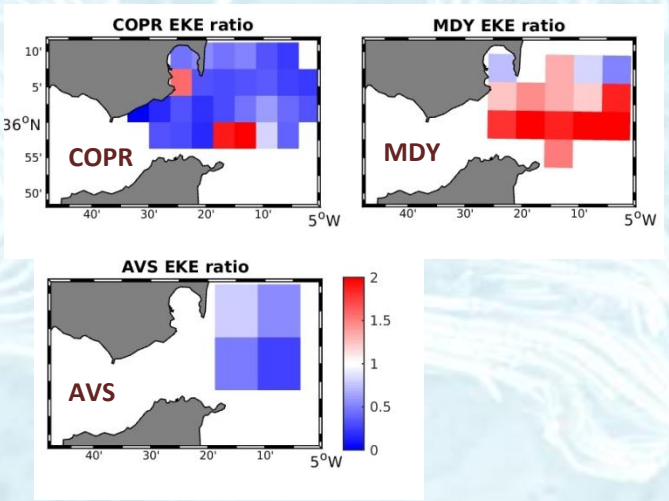

## Ibiza Channel HFR EKE ratio




## Ebro Delta HFR EKE ratio

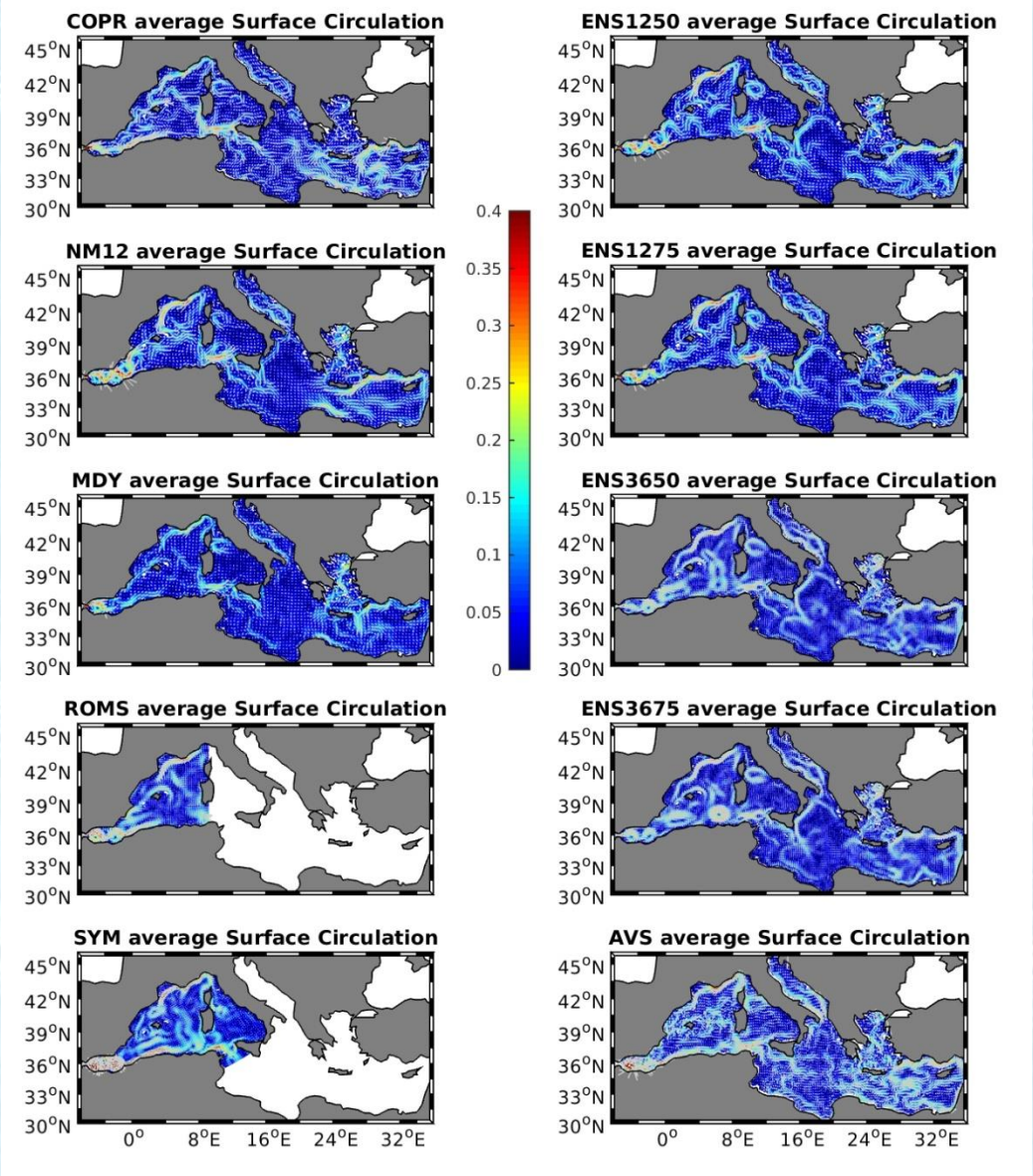



## Strait of Gibraltar HFR EKE ratio



# Models intercomparison

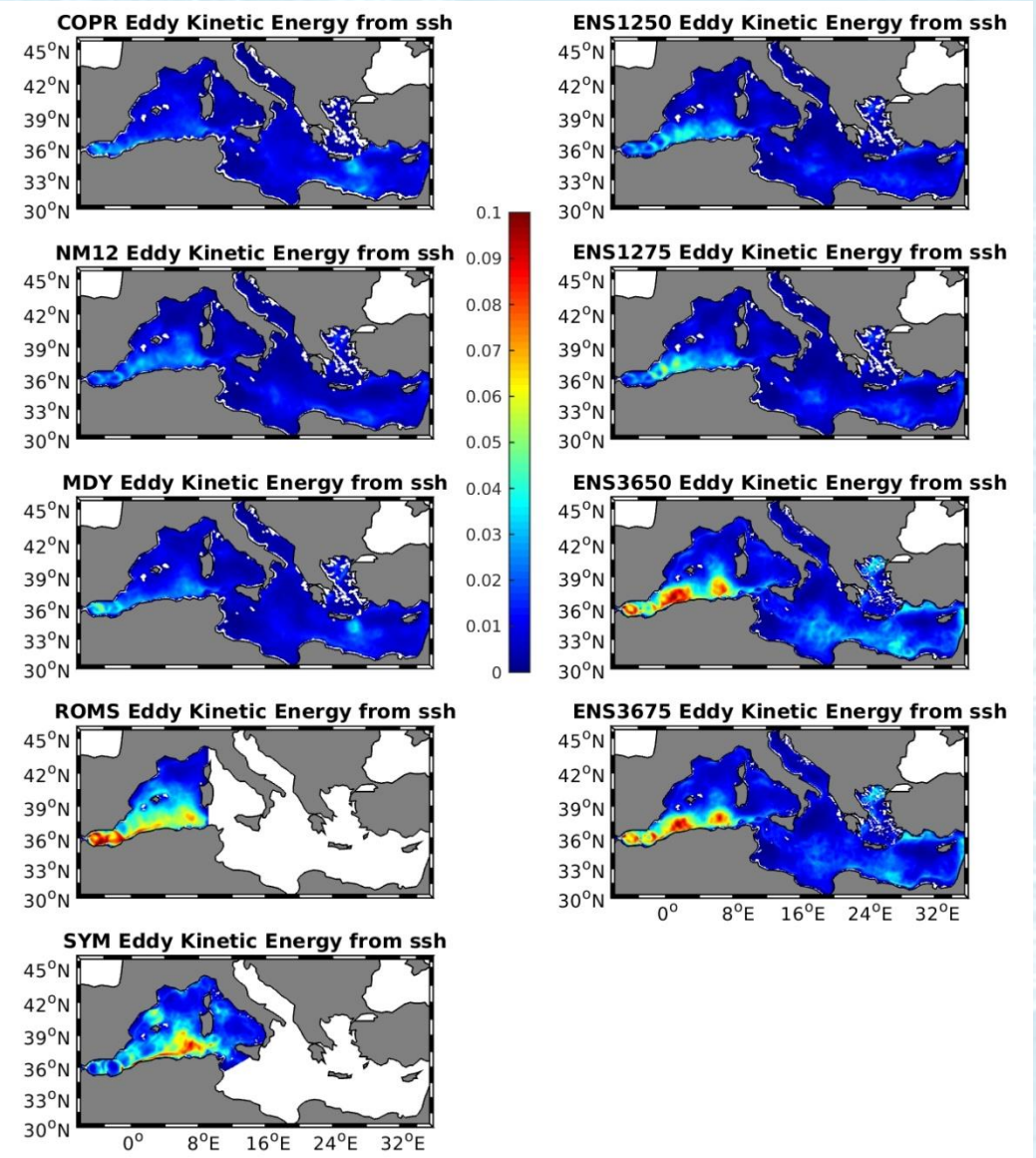
## Surface circulation




- The general circulation of the basin is similar in all the simulations.
- Large differences in the small scale.
- The increase of the resolution leads to an increase in the intensity of the currents
- Satellite products highly underestimates the current velocity.

# Models intercomparison

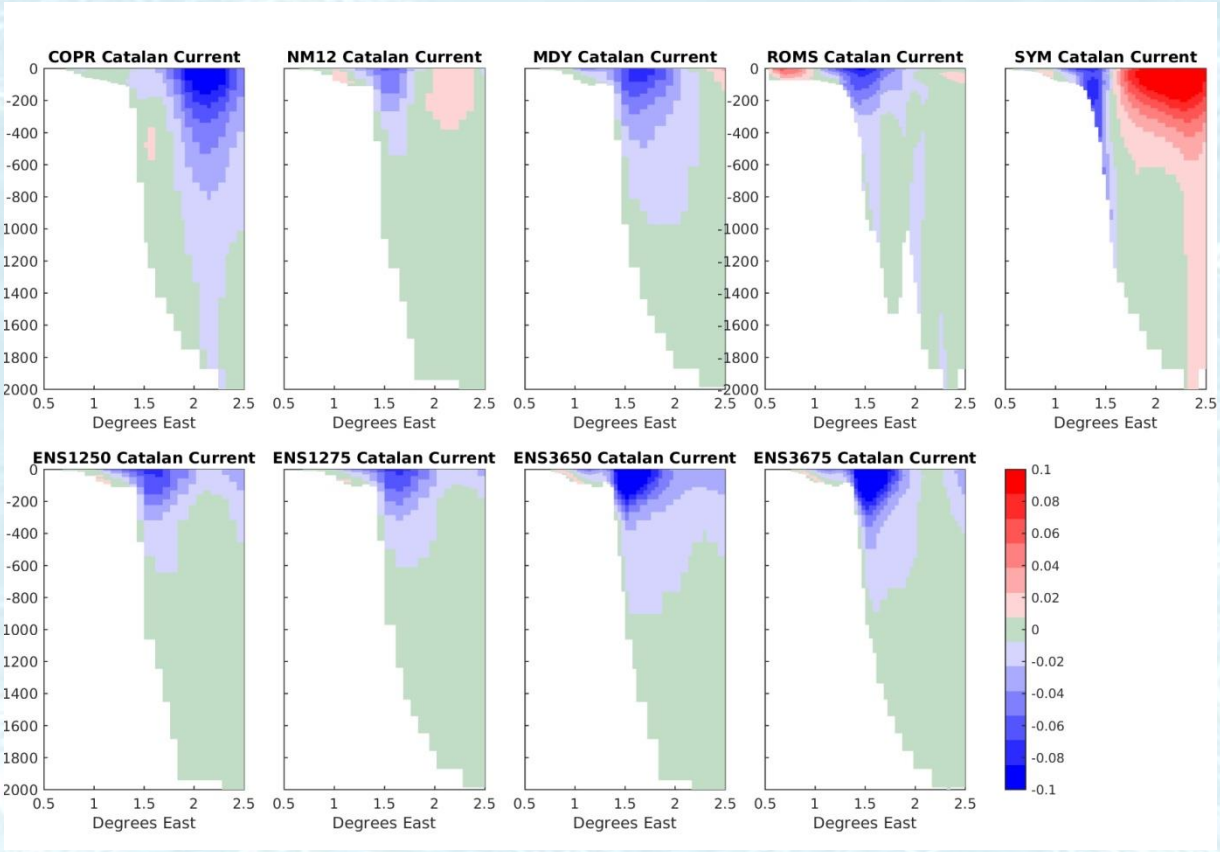
## Surface Eddy Kinetic Energy

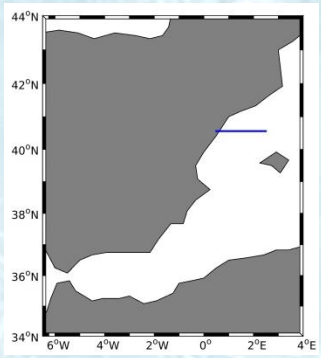



- The variability of the current is stronger in the simulations with higher resolution.
- The mesoescale activity is misrepresented, specially on the simulations with lower resolution.

# Models intercomparison

## Catalan Coast section



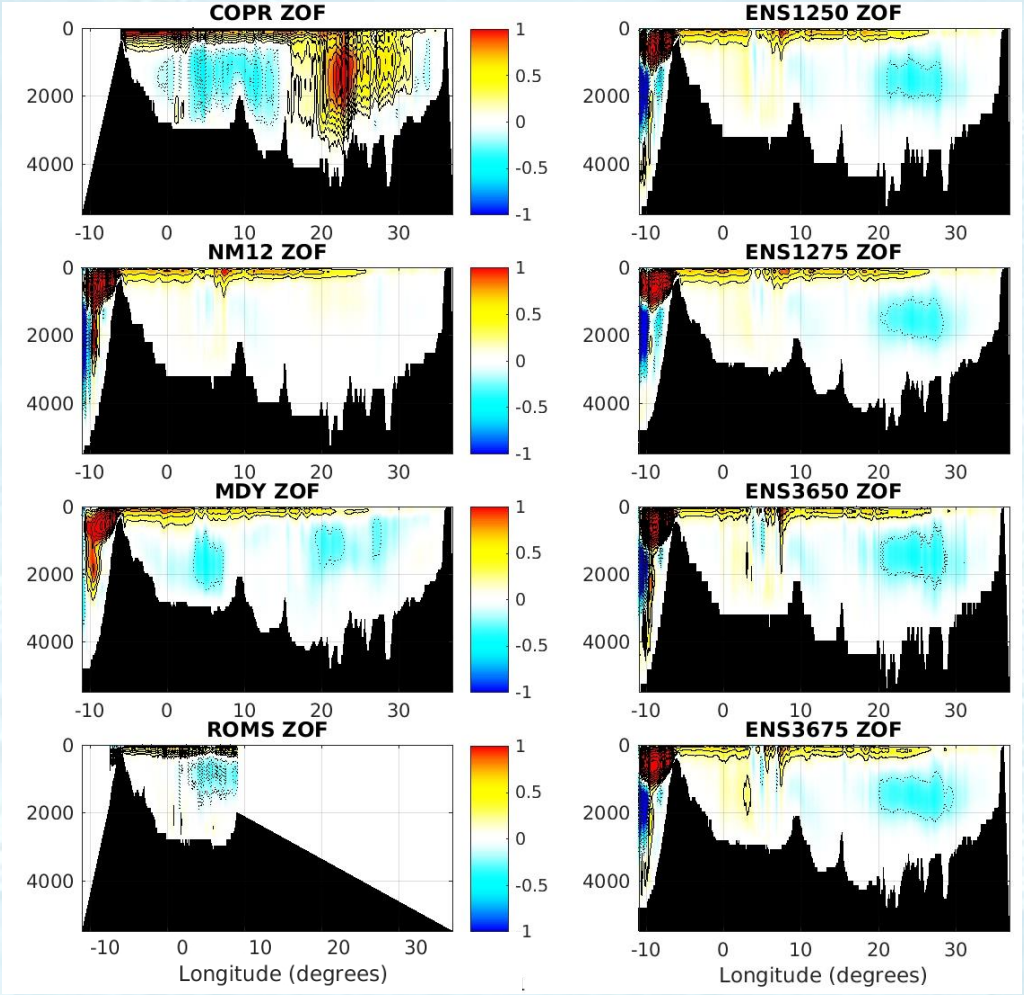




- Very different representation of the current among simulations.
- Disagreement in position extension, intensity and depth.
- Barotropic component  not captured by some models.

# Models intercomparison

Zonal Overturning Function

$$ZOF(x,z) = -\int_{h_{bot}}^{z}\int_{y_S}^{y_N} u(x,y,z)\,dydz$$




- All simulation shows the basin-wide general vertical anti-cyclonic gyre between 100-150 m and 300-600 m.
- Recirculation in the Eastern basin different among simulations : cyclonic for ENS and MDY, ani-cyclonic (and very strong) for COPR and null for NM12.
- Recirculation in the Western basin only COPR, MDY and ROMS.

# Conclusions

- A comprehensive compilation of in-situ observations of currents have been generated and quality controlled and is available for analysis.
- At present, a large number of regional climate simulations are available for the Mediterranean with different numerical codes, spatial resolutions and with/without data assimilation.
- However, large discrepancies are found in the characterization of Mediterranean circulation compared to observations and also among models. This is true both for the daily variability and also for the statistics
- Some large scale features are well captured by the models but not all of them. Also, regional and local features are in general not captured by the models.
- The mesoscale activity, important for the nutrients and larvae transport, is underestimated in all the products.
- These errors are expected to be persist in the projections for the XXI century. This means that the qualitative aspects of the climate change effect in the circulation will be present but the quantitative values will not be accurate.

# Ongoing work

- Gathering of model projections from different institutions.
- Analysis of the projected temperature and salinity fields
- Critical assessment of projections of currents in the light of these results.