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Multiscale and multidisciplinary Marine Rapid Environmental Assessment data collection methodology for operational and forecasting oceanography

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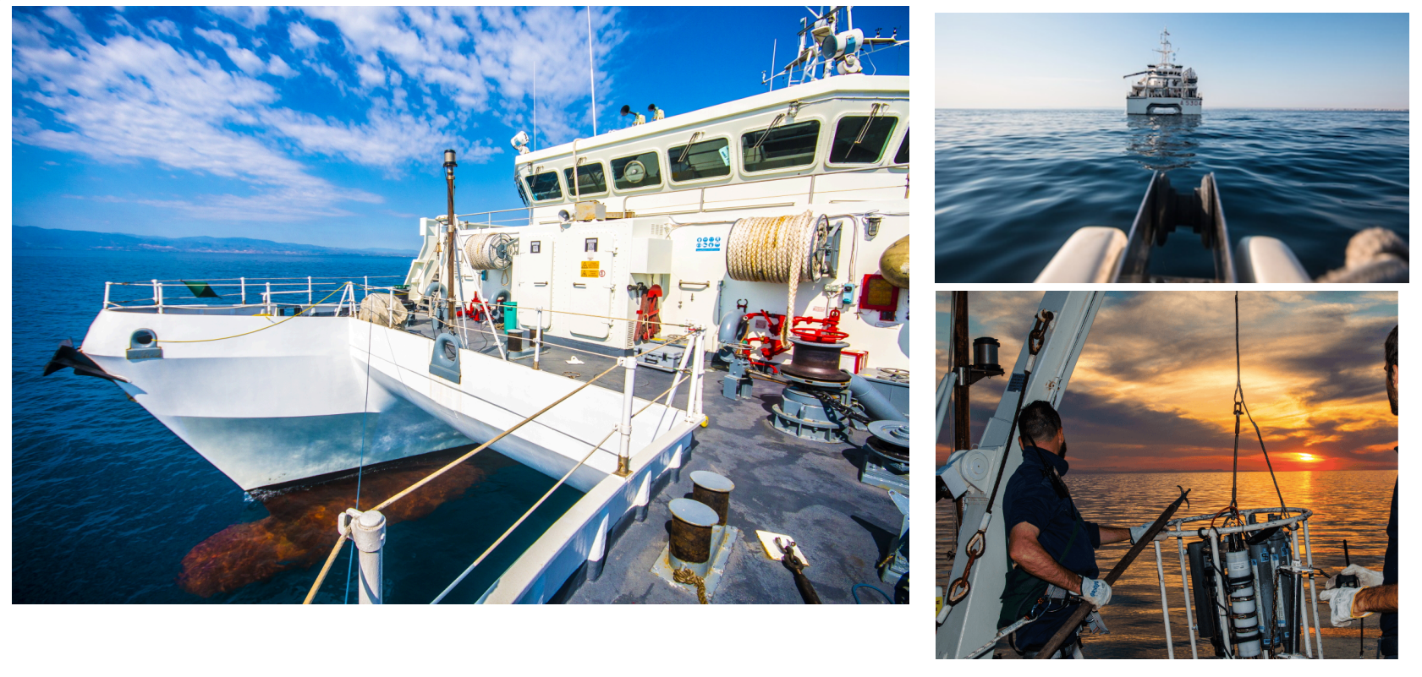
Abstract

The work provides an overview on MREA (Marine Rapid Environmental Assessment) experimental and observational methodology developed in the last years, thanks to the synergies between several multi-disciplinary oceanographic research centers and the Italian Navy Hydrographic Institute.

The approach is based on an optimal strategy (i) to collect evidences on ocean mesoscales and submesoscales with a spatial-and-time synoptic coverage and repeated surveys, (ii) to increase the **skills of ocean forecasting**, producing both initialization and verification datasets for numerical models.

What is MREA?



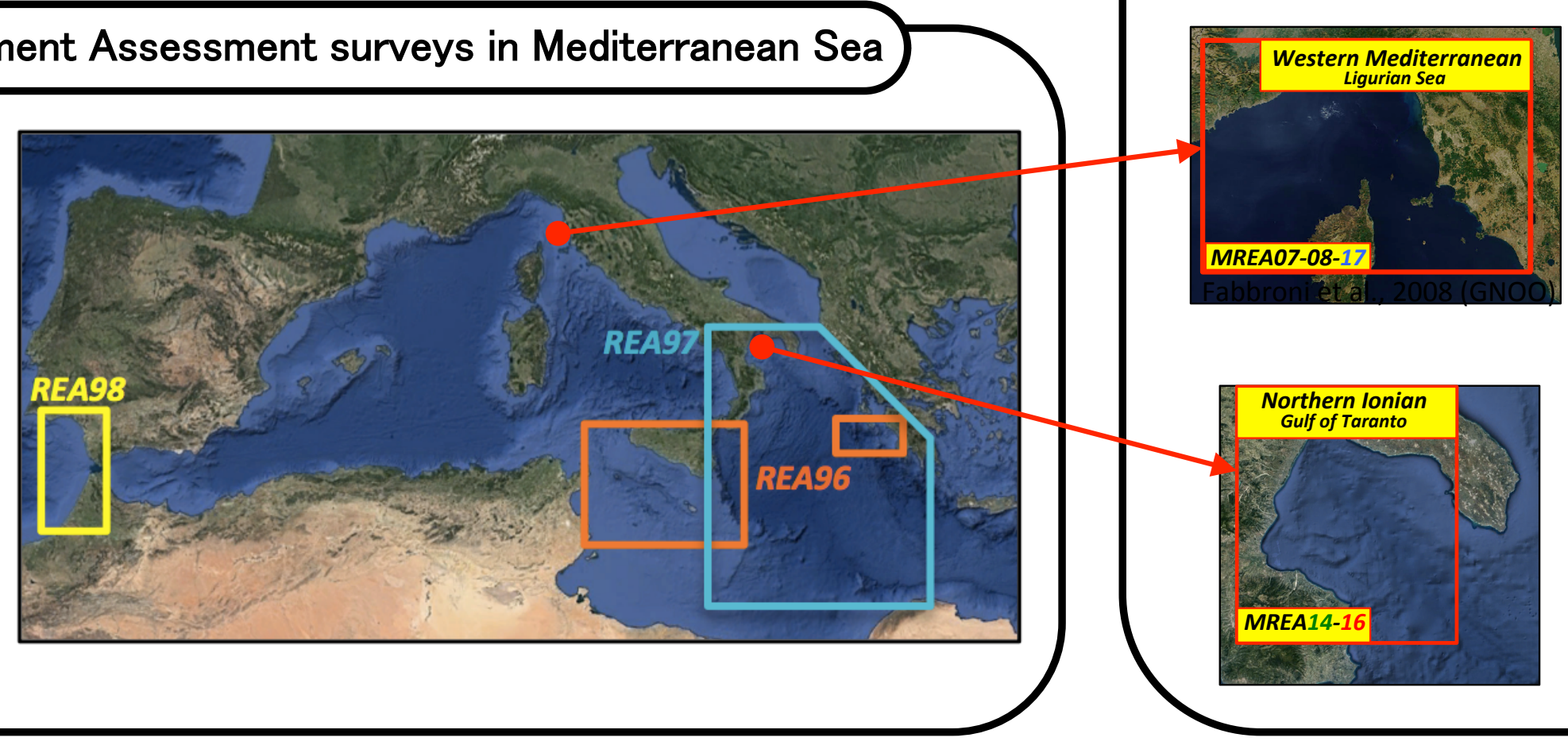
- The **Marine Rapid Environmental Assessment** is a methodology to collect marine data useful to improve our **knowledge of the marine state** and **specific dynamical processes** and increase skill of **ocean forecasting** and analyses.
- It was developed in the late **1990s** to collect synoptic oceanographic data relevant for **nowcasts, forecasts and derived applications** by **Robinson and Sellschopp** (2002).
- Data collection and analysis has to be developed which considers **synoptic time scales** and repeated surveys to produce both initialization and verification data sets.
- MREA is one of the optimal experimental strategies to collect definitive evidence on ocean mesoscales for improving knowledge and **forecast** skill.

"The concept of Rapid Environmental Assessment (REA) is to provide environmental nowcasts and forecasts accurate and efficient enough to support operational activity in any arbitrary region of the global coastal ocean, and to respond to operational assessment requests effectively on very short notice. Ocean science and technology today are rapidly evolving and recognized as generally involving interdisciplinary processes and interactions on multiple scales in space and time" (Robinson et al., 1999).

State-of-art

The historical Rapid Environment Assessment surveys in Mediterranean Sea

Starting from the experiences of the so-called REA (Rapid Environmental Assessment) implementations in Mediterranean areas in late 1990s (Robinson and Sellschopp, 2002), here we illustrate our three MREA strategies, progressively improved and adapted to the physical processes to be investigated.



The Italian MREA experiments

The Italian MREA experiments were thought to contribute to:

- the definitive set up of a **rapid CTD and ADCP collection** strategy in different regions of the Italian marine EEZ and other areas of particular strategic interest;
- the **study of surface and near surface processes** that couple waves and currents, physical and biochemical processes, from the coastal to the open ocean.
- demonstrate and validate the **numerical model downscaling** from large scale operational and forecasting oceanography products.

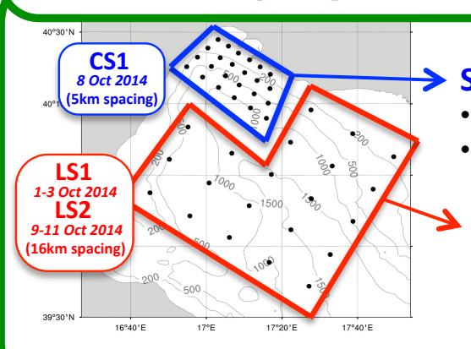
MREA website mrea.sincem.unibo.it

MREA14 - Gulf of Taranto (October 2014)

Pinardi et al., 2016: Nat. Hazards Earth Syst. Sci., 16, 2623-2639, 2016

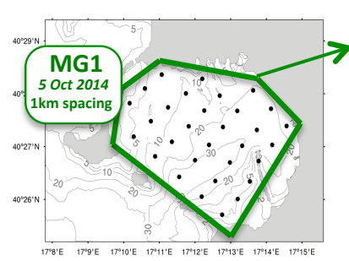
① The sampling strategy

Period: 1-10 October 2014



Shelf-coastal scale surveys (CS1)
- Average **400m** deep
- Mean station distance: **5km**

Large scale surveys (LS1 and LS2)
- **Quasi-synoptic timescale**
- Average **800m** deep
- **Repetition** of stations in LS2 (large-scale changes on a **weekly basis**)
- Mean station distance: **16km** (~**Rossby radius of deformation** for the EastMed)

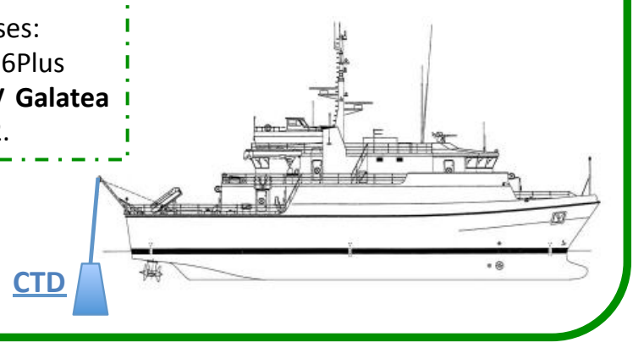


Shelf-coastal-harbour scale surveys (MG1)
- Average **15m** deep
- Shelf-coastal area of the Mar Grande (heavily human impacted harbor area)
- Mean station distance: **1km**

② Measurements

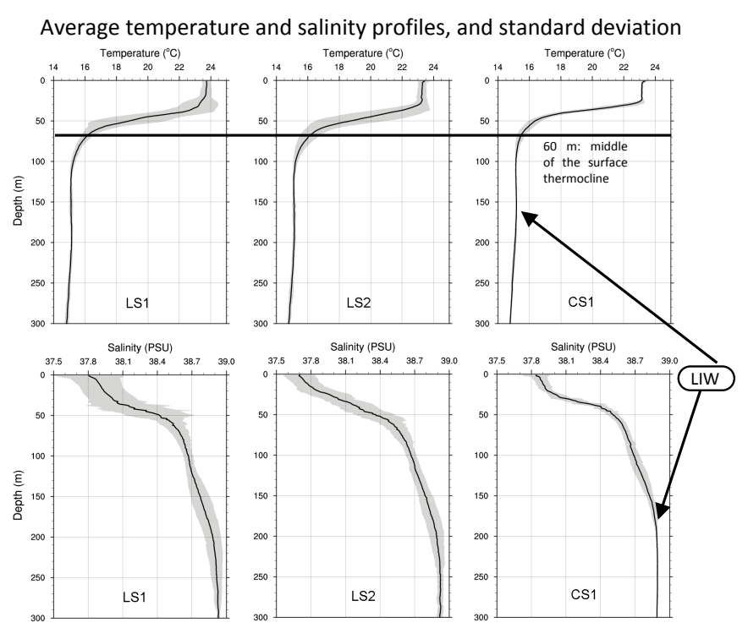
Oceanographic cruises:
- CTD Idronaut 316Plus

on board of the **RV Galatea** for LS1, CS1 and LS2.

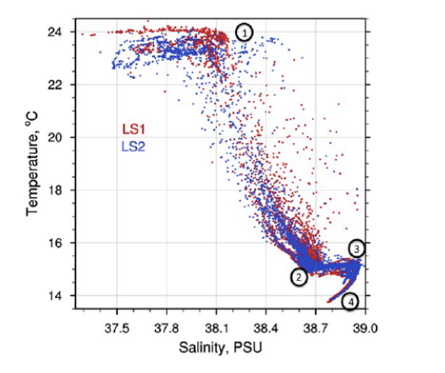


③ Thermohaline structures

Average temperature and salinity profiles, and standard deviation



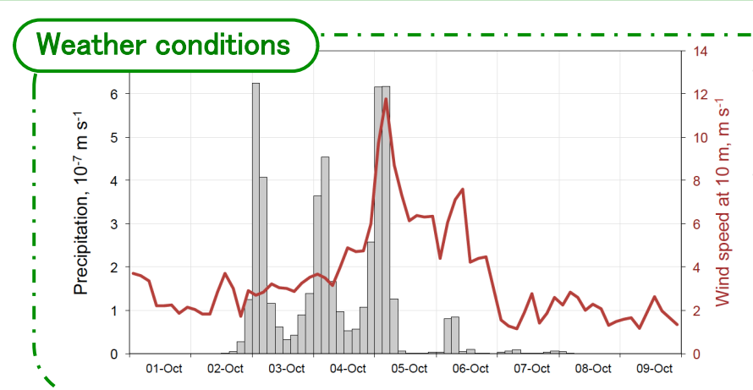
- Typical **end-of-summer stratification of temperature** in the eastern Mediterranean (mixed layer down to 30m and a seasonal thermocline with a temperature gradient of about 10°C)



Four water masses can be detected.
① Surface water mass: low salinity and almost constant temperature).
② Thermocline water type: mixing of the surface waters and MLIW;
③ MLIW type: salinity and temperature increase with respect to the (2).
④ Deep water mass type: temperatures lower than 14°C and relatively low salinities, probably of Adriatic origin.

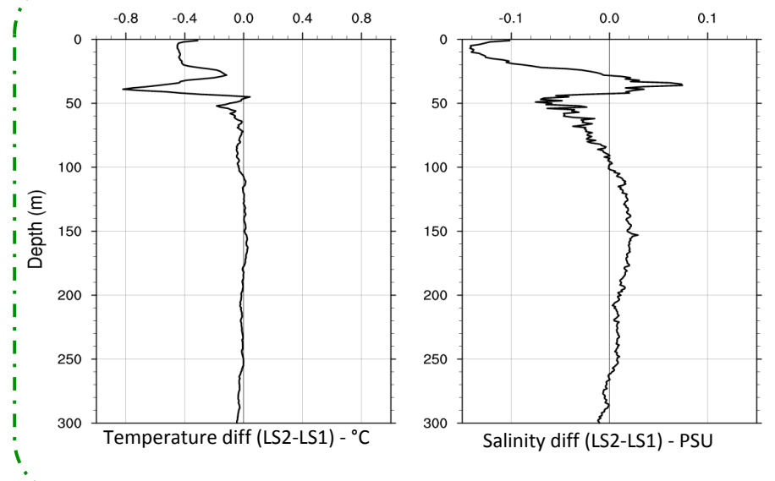
- **Modified Levantine Intermediate Water (MLIW)**: between 100 and 300m → subsurface salinity maximum.

Weather conditions



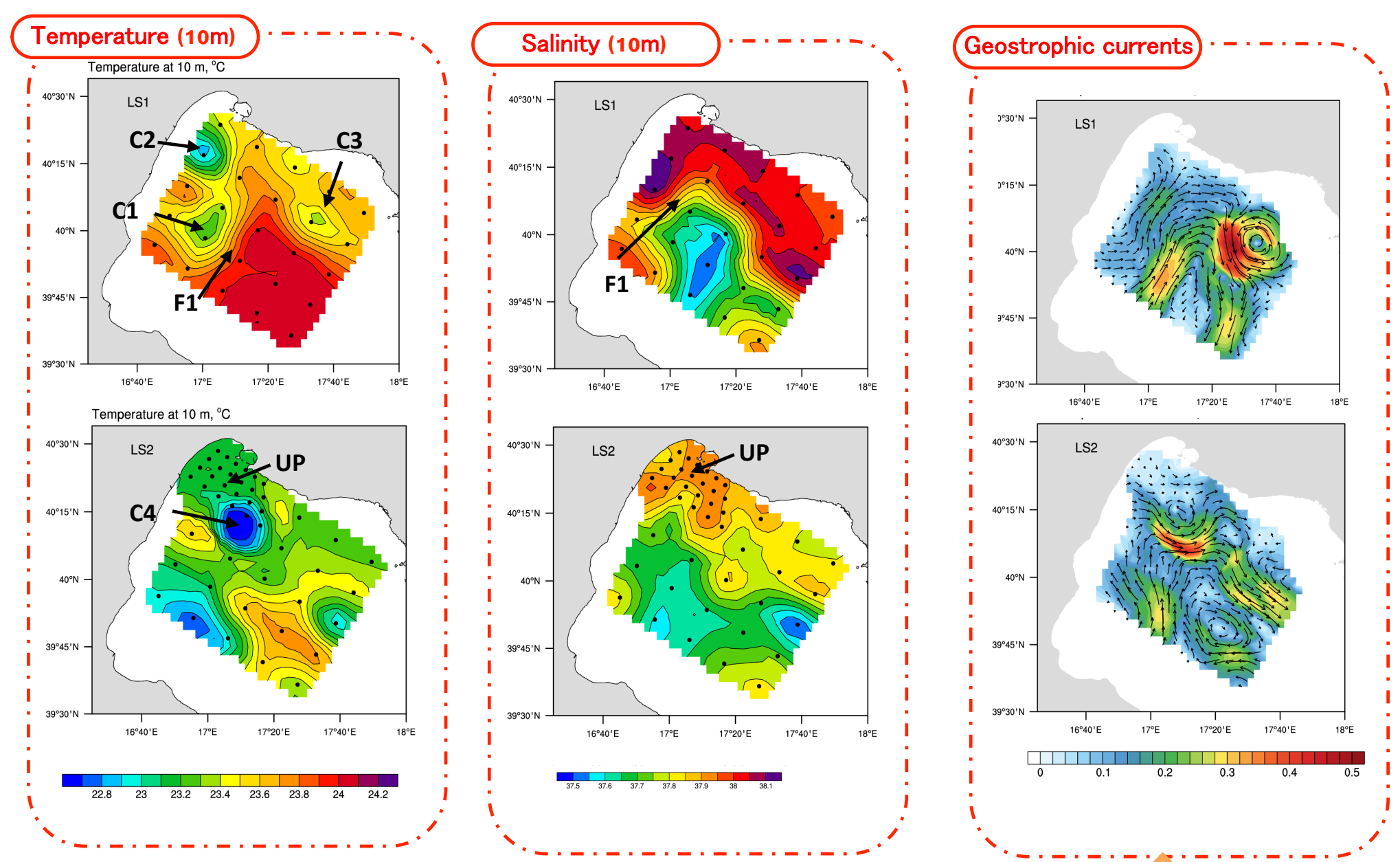
- Area average **precipitation** and 10m **wind magnitude** (COSMOME model)
- The weather conditions deteriorated after 4 October and large winds developed on 5 October while precipitation started 3 October and continued until 5 October.

Difference in T and S



- Impact of precipitation.
- Changes in a 1-week period (between LS1 and LS2) in the first 100m of the water column
- LS2 colder and fresher than LS1 (-0.5°C and -0.1 PSU)
- LS2 mixed layer depth decreased by about 5 m, leading to a 0.8°C difference in temperature at 40m.

④ Objective analysis on T/S and geostrophic currents



Upper mixed layer **temperature** and **salinity** mapping.
- **LS1**: frontal structure (F1). Cold core eddies (C1, C2 and C3) are present north of the frontal structure.
- **LS2**: Disappear F1. Smaller eddies formed. Cyclonic eddy (C4)

LS1: surface currents, turning clockwise around the anticyclonic gyre, are characterized by jets, i.e., intensified rim current segments.

LS2+CS1: meandering rim current → baroclinic–barotropic instability and eddy growth. Submesoscale structure.

Companion papers on modelling

①***Federico et al., 2017***: Coastal ocean forecasting with an unstructured grid model in the southern Adriatic and northern Ionian seas, , Nat. Hazards Earth Syst. Sci., 17, 45-59, doi:10.5194/nhess-17-45-2017.

Keywords: Operational forecasting system, unstructured-grid modelling, Downscaling

②***Gaeta et al., 2016***: A coupled wave–3-D hydrodynamics model of the Taranto Sea (Italy): a multiple-nesting approach, Nat. Hazards Earth Syst. Sci., 16, 2071-2083, doi: 10.5194/nhess-16-2071-2016.

Keywords: Multiple nesting, wave-currents coupling, harbour scale

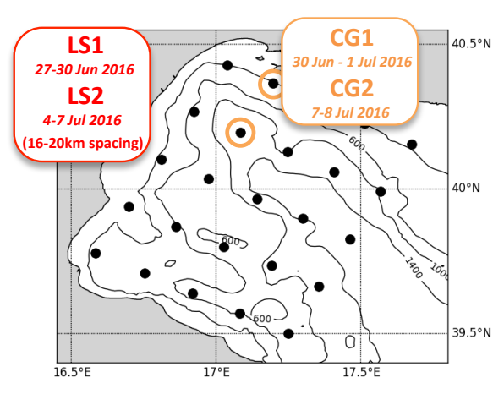
③***Trotta et al., 2017***: Multi-nest high resolution model of submesoscale circulation features in the Gulf of Taranto, *subm. Ocean Dynamics*, 2017

Keywords: Relocatable ocean model, multiple nesting, submesoscale

Reversal of large-scale circulation
in Gulf of Taranto
in certain periods of the year
From anticyclonically-oriented in Autumn (MREA14) and cyclonically-oriented in Summer (MREA16)

MREA16 - Gulf of Taranto (June-July 2016)

① The sampling strategy



Period: 27 June - 7 July 2016

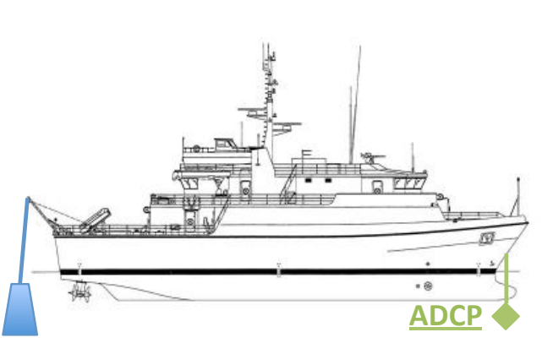
Large scale surveys (LS1 and LS2).
- **Quasi-synoptic timescale**
- Average **800m** deep
- **Repetition** of stations in LS2 (large-scale changes on a **weekly basis**).
- Increased mean station distance to cover the entire Gulf: **16÷20 km** (~**Rossby radius of deformation** for the EastMed)

Daily cycle survey (CG1-CG2).
- 24 hours survey in the same station, repeated every 2 hours to detect internal waves and daily cycle of T/S
- Sampling depth **160 m**

② Measurements

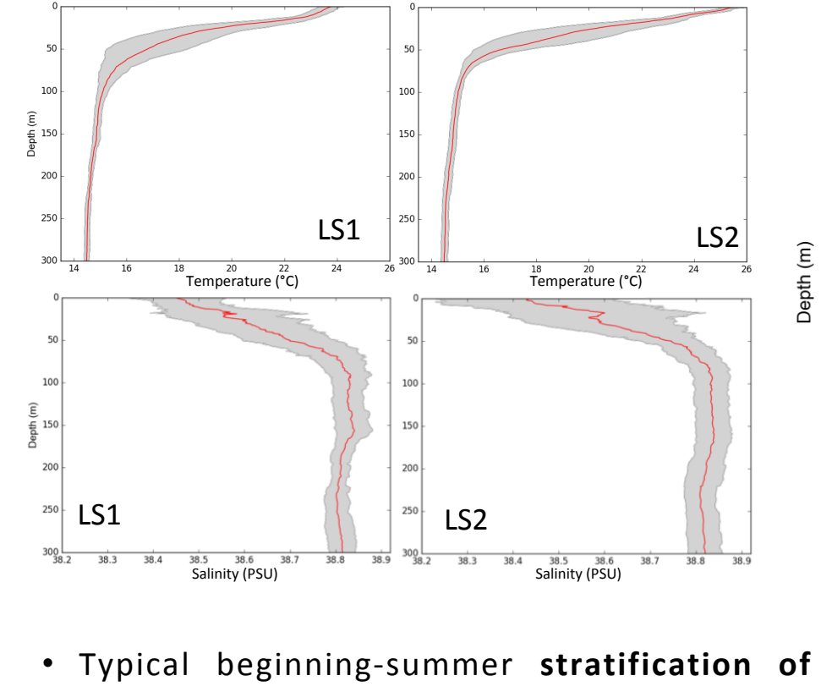
Oceanographic cruises:
- CTD Idronaut 316Plus
- ADCP Teledyne RD Rio Grande 600 khz (installed between the ship hulls – catamaran)

on board of the **RV Aretusa** for LS1 and LS2, CG1 and CG2

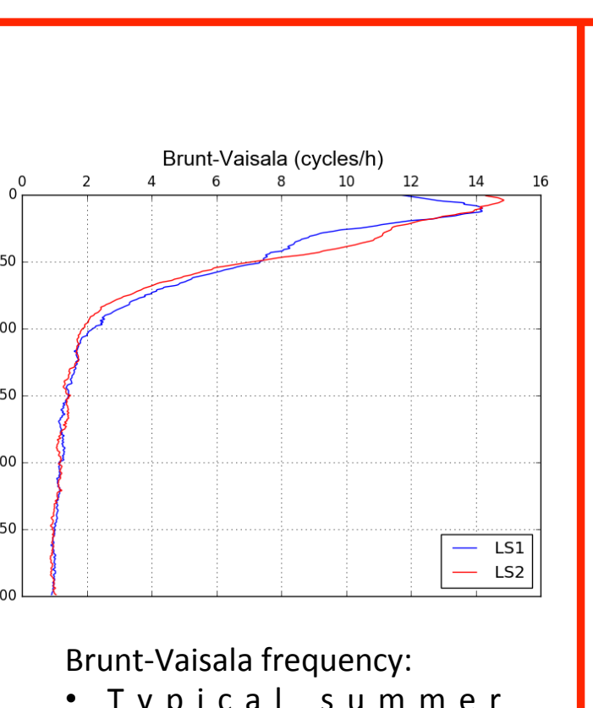


③ Thermohaline structures

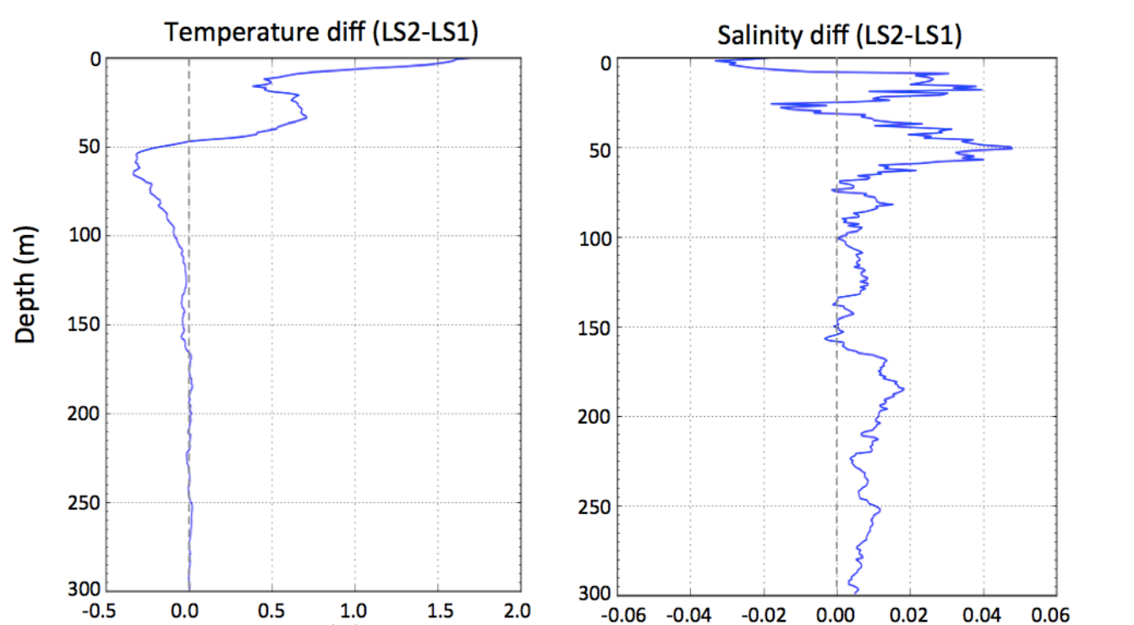
Average temperature and salinity profiles, and standard deviation



- Typical beginning-summer **stratification of temperature** in the eastern Mediterranean.
- Increase of surface temperature from LS1 to LS2 and higher stratification
- Variability in thermocline: higher variability for LS1
- Local peak of salinity at 30 m

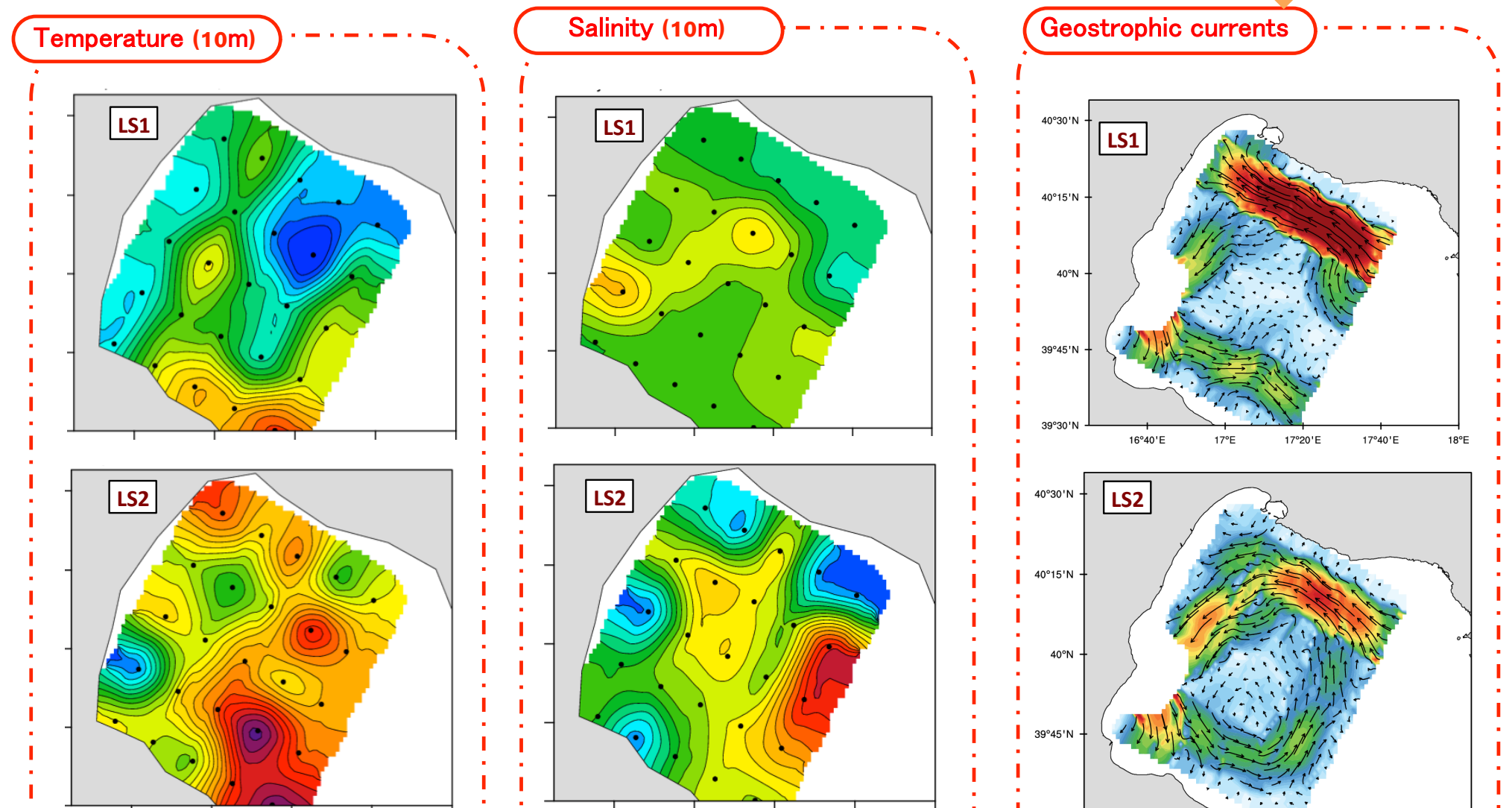


Brunt-Vaisala frequency:
- Typical summer stratification: 8-15 cycles/h between 0-50m.
- LS2 higher stratified than LS1 between 0-50m.



- Changes in a 1-week period (between LS1 and LS2) in the first 110m of the water column
- LS2 warmer (air temperature) than LS1 between 0-50m, and colder than LS1 between 50-100m. Surface: LS2-LS1=+1.5°C; -0.03 PSU (fresher: rain event).

④ Objective analysis on T/S and geostrophic currents

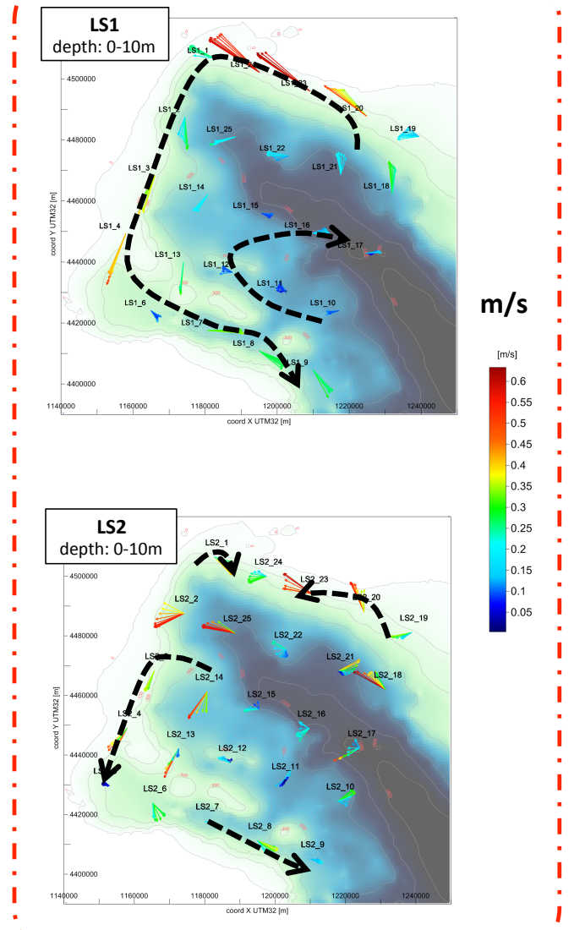


- Increasing of temperature from LS1 to LS2
- In LS2, warmer and saltier waters at the south-eastern corner. Incoming waters in the Gulf confines and closes the large-scale cyclonic gyre.
- Fresher inputs in the coastal waters of Basilicata (Bradano and Basento rivers) and Calabria (Crati river) highlighted in LS2 (inland precipitations)
- Salinity drop in LS2 due to precipitations (e.g. Porto Cesareo)

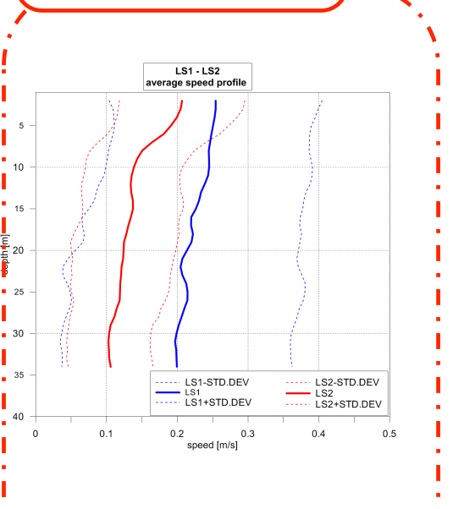
- Basin scale cyclonic gyre
- North-eastern front in LS1 strengthens coastal circulation stream
- In LS2, in the shelves of Taranto: coastal anti-cyclonic gyre.
- Possible formation of submesoscale structures (which can be well solved by a high-resolution sampling scheme)

⑤ Surface currents (ADCP)

Surface currents



Velocity profile



The analysis of the average (LS1, LS2) vertical current profiles confirms the weakening of the cyclonic circulation between LS1 and LS2 surveys

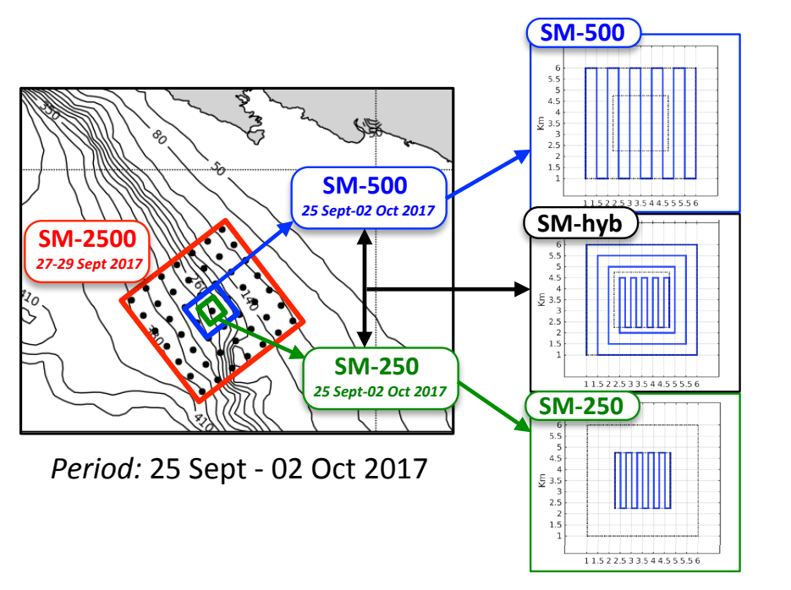
- The geostrophic circulation pattern derived from the CTD objective-analysis mapping techniques has been verified with the ADCP measurements
- The analysis on circulation fields confirms the presence of possible submesoscale structures, which can be well solved by a high-resolution sampling scheme.

- 1m meter submerged
- 1m vertical resolution
- 10 min profiling with ensambles every 5 sec.

MREA17 - Ligurian Sea (Sept-Oct 2017)

① The sampling strategy

The next campaigns planned in Autumn 2017 in the framework of **LOGMEC experiment**, leaded by CMRE, will investigate the **submesoscale** fields in Ligurian Sea (Western Mediterranean).



Period: 25 Sept - 02 Oct 2017

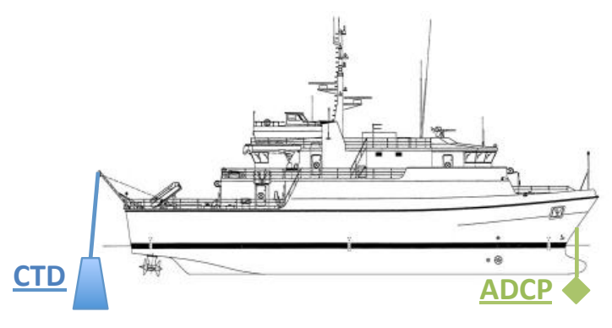
- The campaigns (SM-2500, SM-500 and SM-250) will adopt new approaches, consisting in use of sampling schemes with **increasing spatial resolution**.
- The **multiscale-multidisciplinary** aspects are addressed combining **remote sensed data** with **unmanned underwater vehicles** and **shipborne instrumentations** equipped with multidisciplinary sensors. This will allow to capture possible **submesoscale structures** and simultaneously characterize the **large scale dynamics**.

② Measurements

SM-2500

Oceanographic cruises:
- CTD Idronaut 316Plus
- ADCP Teledyne RD Rio Grande 600 khz (installed between the ship hulls – catamaran)

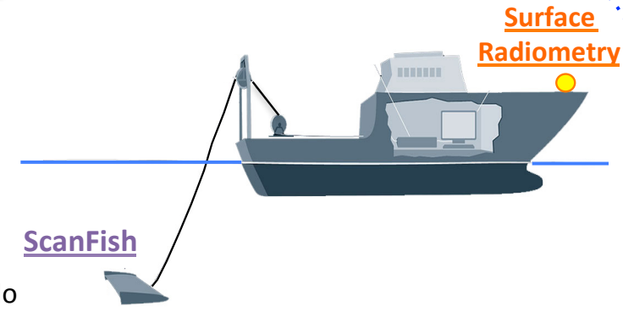
on board of the **RV Aretusa** for **SM-2500**



SM-500 SM-hyb SM-250

Oceanographic cruises:
- ScanFish with sensors
  - SBE 43 Dissolved Oxygen,
  - ATLANTIC OCR 504
  - 2 CTD pumped
  - ECO Puck
- Surface radiometry (ASD FieldSpec)

on board of the CRV Leonardo for SM-500, SM-hyb and SM-250



Concluding remarks

- The **Marine Rapid Environmental Assessment** methodology has been developed, progressively improved and refined with standard protocols for the on-board operations.
- The **sampling methodology** has been strengthened in the last years integrating (i) the classical CTD data collection with additional simultaneous measurements of (ii) currents by means of vessel-mounted ADCP, (iii) optical properties of sea surface with radiometric surface measurements and (iv) underwater remotely operated towed ScanFish vehicles, equipped with CTD, oxygen and light sensors.
- The methodology has been verified to be **relocatable** in **different areas** (Ligurian Sea and Gulf of Taranto), at **multiple scales** (from large- to meso- to submeso-scale).
- The MREA data collections have allowed (i) **supporting operational and forecasting oceanography** (producing both initialization and validation datasets and increasing the the forecasting skills), and (ii) **performing process study** (e.g. the possible formations of sub-mesoscale structures, the reversal of circulation in certain periods of the year from anticyclonic to cyclonic in Gulf of Taranto).