Author's response to the comments on "PROTEVS-MED field experiments: Very High-Resolution Hydrographic Surveys in the Western Mediterranean Sea"

Pierre Garreau et al.

December 15, 2019

General response

First we thank the two referees for their reviews and contributions. As these were minor revisions and as we are non native english speakers, we followed the recommendations of the referees in most cases. Hereafter, the detailed answers to the reviewer #1 and the reviewer #2.

The corrupted file (https://www.seanoe.org/data/00512/62352/data/66880.pdf) corresponding to the quicklooks of first leg of 2017 has been reprocessed, uploaded on the repository and is now downloadable. The full dataset has been also re-checked.

We were also contacted directly by the Seanoe administrator. He suggested to add the DOI of the GOSUD data repository in complement of the already cited paper; It has be added in the references.

Reviewer #1 :

Line 24 "(about 10000 Km)" could be replaced by (total length about 10000 Km)

Done.

Line 28 TermoSalinoGraph (TSG) "CTD casts" could be replaced by Classical full depth CTD stations have been realized.... Please define CTD acronym. I think that the manuscript would benefit of a clear distinction between a CTD (instrument that is included in the towed system as well as in the free fall profiler) and a classical CTD cast performed when the ship stops in a sampling station. At the moment, in this manuscript the term CTD is used for all the classical oceanographic stations and this could generate some confusion.

Done. Thank you for this remark, we tracked CTD in the whole manuscript and removed the confusion between the instrument, the cast and the stations.

Line 29 "objects" may be replaced by "structures"

done.

Line 30 "the aim of the survey. . .." Please consider resentencing

As the main objectives of the surveys has been already defined few line above, this sentence has been removed. In there following statement 'nevertheless' has been also removed. We hope the text is now more fluent.

Line 32 “biological sensors. . ..have been carried out” Please consider resentencing

The concerned sentence has been rephrased as follow :

“When available, biological sensors (Chlorophyll a, Turbidity, Dissolved Oxygen etc.) have been carried out . They provided useful complementary observations about the circulation”

Line 44 “chlorophyll a “ replace with chlorophyll a. Please be coherent throughout the paper

chlorophyll-a will be used for all the paper.

Line 47 “As the scales” might be replasec by “As all these scales” “to develop observations” please replace with“to develop an observation strategy”

done

Line 56-60 Please consider to move here the figure 1 also adding the geographical references mentioned in the text (up to section 3). I would also move to the very first lines the name of the study area.

The figure 1 has been split in two separate figures (figure 1 and figure 2) and a reference to the figure 1 has been added in this paragraph. Therefore the editor will probably put the figure 1 close to this paragraph. Crossed oceanographique features were added one the map

Line 57 “depths under” maybe “below”

done

Paragraph 2.1 Please consider to add a figure showing the Mediterranean Sea and the oceanographic features described in this paragraph, as well as the location of the study area. Please add a description of the deep layer properties, or alternatively rename the paragraph to focus on surface and intermediate circulation and main water masses

See comment above, the figure 1 has been split in two part and repositioned in, the MS.

The paragraph has been changed in “Surface and intermediate circulation” as we focuse on surface and sub-surface observations. If interested by the deeper water circulation, the reader can refer to the cited bibliography.

Line 101 “patchy ocean” maybe “patchy ocean areas”

Done. We agree, only the areas with strong scales interactions interactions exhibit possible patchy patterns.

Line 106 show

corrected

Line 112 because of

corrected

Line 121 high resolution in situ data by glider have also been compared to the new generation salinity products by SMOS satellite as in “Aulicino, G.; Cotroneo, Y.; Olmedo, E.;

Cesarano, C.; Fusco, G.; Budillon, G. In Situ and Satellite Sea Surface Salinity in the Algerian Basin Observed through ABACUS Glider Measurements and BEC SMOS Regional Products. Remote Sens. 2019, 11, 1361".

Thank you for this recent reference. It has been added in the text and in the references list.

Line 129 What you mean with "turning radius"? Is the ability to change direction?

Yes. It is now precised in the sentence :

"… this towed vehicle can handle a turning radius of 2 nautical miles (i.e. gyration speed of 10 degree/min), when the ship change direction."

Line 146 The parenthesis includes both oceanographic features that are described in the dataset and basins. Probably listing just one of the categories would be better.

Done, only basins or geographical areas are now quoted.

Line 148 "weddies" have not been defined before

This unique reference to weddies in our paper is replaced by the more explicit statement : "modal structures composed of WIW.

Line 155 "rapidcast" not mentioned or described before please add a description at lines 127-140 as for SeaSoar or MVP

The following sentence has been added in the abstract, close to the previous short description of the Seasoar and the MVP :

"In 2018, another free fall profiler (a RapidCast) has been tested."

Line 158 "CTD casts" maybe "classical CTD stations"

done

Line 160 "Shom" replace with "SHOM"

done

Line 165-166 Consider removing the inner parenthesis. i.e. "– VMADCP –"

done. Also corrected for (MVP) in the same way.

Line 192-195 NBF and NC have already been defined, please use the acronyms

done

Line 204 ". . .to a strong Mistral gust, part of the cruise. . .."

Done, coma is added.

Line 212 "lagrangian"

corrected

Line 217 "Finite Singular Lyapunov Exponents" consider adding a reference

Instead adding a theoretical paper, the reader can found in Nencioli 2018 for instance, I suggest the following example of the use of FSLE in Med Sea :

d'Ovidio, F., V. Fernández, E. Hernández−García, and C. López (2004), Mixing structures in the Mediterranean Sea from finite−size Lyapunov exponents, Geophys. Res. Lett., 31, L17203, doi:10.1029/2004GL020328.

This reference has been added in the text and in the reference list.

Line 244 "given" or "giving"?

Giving seems me better

Line 280 (latitude and longitude)

corrected

Line 292 "Shom" should be SHOM. Please check throughout the entire manuscript

Done and checked in the whole ms.

Line 294 in the case. . ..which is the more common"

corrected :

in the case. . ..which is the most common

Line 298 "SBE 35's" maybe "SBE 3's"?

Unchanged: SBE 35 is a temperature sensor ideal for use in calibration labs.

Line 319 "available for data" maybe "available for each dataset"

yes, thank you, we agree. And the sentence has been modified.

Line 320 "consists in" maybe "consists in the" "sensor" should be sensors"

done

Line 325 Are the gridded profiles averaged along depth only? The term gridded may confuse the reader

profiles are only vertically resampled and positioned as vertical profile at the mean geographical position of the considered record.The comment is now rewritten as :

"The third level (Level 2, L2) is proposed as gridded, controlled and resampled data in netcdf files (.nc). Gridded dataset for salinity and temperature have been vertically resampled every meter removing spike, spurious values, density inversion when they persist after the first process supplied by the sensor manufacturer. They are then positioned as vertical profiles at the mean geographical position of the considered up or down record"

Line 340 What you mean with "higher temporal resolution"? Please clarify. If the float is enveloped in a structure it would provide longer observations in time.

We hope this new text will be more clear.

"Few Argo floats were also dropped and experienced first Protevsmed dedicated mission with high temporal resolution (daily cycle) and a parking depth adjusted to the observations to maintain the drifters as long of possible in the targeted structures (typically 100 m deep). When the drifter left

the structure, it used the usual Argo standard procedure in the Mediterranean (i.e. a 5-day cycle and a parking depth of 350m).”

5. Overview of the observations As stated in the introduction, here a limited number of sample analysis of the collected data are offered to the reader. Please consider adding a sentence at the beginning of the chapter that clarify this.

In the introduction we replaced some “quicklooks” by “an overview”.

The chapter 5 has been changed :

“5 Overview of selected observations”

Please note that in the text and in the figure caption the availability of extensive quicklooks on the repository is quoted.

Line 356 “When deployed”

Corrected

Line 376 “frequently show”

Corrected

Line 379 ”CTD casts” should be “classical CTD stations”

Done.

Line 379-381 Please add the position of these casts on figure

The exact position of the casts are now given in the figure caption.

Figure 3 Please consider splitting this figure in order to obtain an higher definition for each plot

The aim of this figure and to provide an overview of the results at a glance. We have chosen to keep it. Nevertheless, a more higher resolution version will be proposed for the final version of the paper as the figure have to be uploaded separately

Line 398-401 Please consider resentencing Line 404 “Some transects have been”

corrected

Reviewer #2 :

L25 missing ,

Corrected

L29 "peculiar objects" prefer particular processes ; a MVP

Corrected following the first reviewer suggestion:

"peculiar structures"

L30-32 ... to access even higher resolution the ocean physics (temperature, salinity, currents). Biological sensors were opportunistically used to provide ...

The concerned sentence has been rephrased as follow:

"When available, biological sensors (Chlorophyll a, Turbidity, Dissolved Oxygen etc.) have been carried out . They provided useful complementary observations about the circulation"

Throughout the paper : opportunely -> opportunistically

Ok ,all occurrence of "opportunely" were checked and as opportunistically seems to be pejorative, I prefer to remove this adverb in the paper.

L33 the fine-scale processes

corrected

L35 properly résolve

corrected

L43 connecting ... to ; energy cascades to small scales and reversely

corrected

L44 For instance in the northwestern Mediterranean ; chlorrophyll-a

corrected

L46 vortices

done

L50-55 partly fill these gaps between the large and finer scale dynamics. Since many years, remotely ... observe a large ... soon by the future Surface Water and Ocean ... mission (SWOT), expecting to provide ... small-scale processes ...

thank you for rephrasing

L59 in a context of ocean physics I would use km instead of nautical miles.

done

L63 looks at ; are described

following a request of the first reviewer, "quick looks" has been replaced by "overview".

L66 Oceanic context of the

corrected

L68 is sometimes referred as a "lab-ocean"

unchanged : "pocket ocean" is also used.

L70 "nearby" did you mean close to Land? Accessible?

Accessible seems the better word.

2.1 General circulation : you aren't describing the thermohaline circulation very much...

Yes we focus only on the surface and intermediate circulation. The title has been changed as suggested by the first reviewer.

L74 sub-basin circulation ; what to you mean about dominated? Please rephrase.

The new sentence is :

"The basin or sub-basin dynamics is largely driven by the thermohaline circulation."

L75 basin or sea, not both ; Light (fresh) Atlantic Water

corrected

L76 generally circulates along the continental slope ... western and eastern basins

corrected as suggested

L77 The slope ... Algerian coast

done

L79 and throughout the paper, no caps for western basin etc

ok, we checked and corrected all occurrences

L77-79 These lines fit better to 2.2

Yes, but we can't evoke the Algerian current without is instabilities.

L79 northern part

done

L80 Ligurian Sea ; Northern Current is more often found (please modify consistently throughout the paper).

ok, we checked and corrected all occurrence

L83 (sounds more logic in this order) The generally accepted concept of the Northern Gyre flowing cyclonically around the doming of isopycnals of the deep convection area of the northwestern Mediterranean (please cite a ref about the general circulation). The existence, position and strenght of the return flow of this gyre ...

ok we adopt your formulation :

"The generally accepted concept of the Northern Gyre flowing cyclonically around the doming of isopycnals of the deep convection area of the northwestern Mediterranean Sea. The existence, position and strength of the return flow of this gyre is still under debate."

The well-established publications on circulation in the Western Mediterranean have already been widely cited in this paragraph and are not useful after all the statements.

L84 (LIW), a mode water ...basin entering the western ... , follows pattern (again please provide ref)

corrected and (Millot and Taupier Letage, 2005) ref is added.

L87 This important water mass is marked by a relative ...

modified as suggested

L93 indicator of ; because the scale of surface-intensified eddies in geostrophic bal- ance ranges a few ...

modified as suggested

L95-96 topography ; whose size is close to the local ; observed in the Western Mediterranean (also cite Testor and Gascard 2003, 2006; Bosse et al 2015, 2016)

citation added and text corrected.

L97 contrasted in terms of what? What's the point of reference? Subtropical regions might not be comparable, while polar regions would tend to exhibit similar characteristics with density compensated contrasts.

Ok, this part of the sentence was not useful and *lead to confusion, and has been removed*

L99 Submesoscale (tends to be found in one word in the litterature, please correct throughout the paper)

ok, submesocale has been adopted for the whole paper (except in cited references)

L101 marked by frequent strong wind évents ... northwestern basin ... with the NC and

mesoscale structures and generate ... (No need for PV acronym if not used afterward) ... please the relevant litterature : Bosse 2015, Estournel et al 2016, Giordani et al 2017, Testor et al 2018

references added

L104 a place ; for a long time (cite for instance MEDOC group et al 1979, Schott et al 1996, Houpert et al 2016, Testor 2018)

citation added

L106 both models ... and observations ... show

corrected

L108 due to the deepening of the mixed layer

ok, "mixed layer" is more appropriate

L111-115 ... are only partially resolved by usual ... ; repeated glider lines (instead of glider fleet) ... in the Western Mediterranean, in particular as part of the multi-platform ... MOOSE (rather cite Coppola et al 2019). Intensive targeted ... the dynamics of the deep convection area in the northwestern Mediterranean Sea (Estournel et al 2016).

Thank you for this very recent synthetic publication about MOOSE.

Repeated glider lines are discussed below.

L116 glider lines

done

L117 opportunely

removed ; see remark above (L30-32)

L121-122 please sort references in chronological order

Done

L126 prefer 15-30 km/day than nautical miles

Done

L130 sampling of

Done

Proposition of section/subsection titles: 3 The PROTEVS-MED field experiments 3.1 Objectives 3.2 Cruises

Unchanged; We prefer our organisation.

L146 key regions of the basin ; North Balearic Front

Done. We took also into account the remarks of the first reviewer.

L147 "assessments of numerical simulation" is not very clear... What kind of simulation? How?

The text has been re-sentenced as follow :

"The goal was the assessments of operational numerical simulation of the circulation performed for the Navy."

L148 please avoid modal weddies which is not defined earlier ; surface and subsurface mode water eddies (including SCV)

Following also the comment of reviewer #1 the text has rephrased as follow :

"- to identify and follow peculiar mesoscale structures such as surface eddies, modal structures composed of WIW, submesoscale coherent vortices (SCV) meanders and filaments and explore their signatures on the sea surface height (altimetry) and their acoustic impact (i.e. through their modulation of the sound propagation speed)."

L149 meanders and filaments

Done, see above.

L151 observe and characterize

Done

L155 prefer platform to vectors... Also in other occurrences in the paper L158 across strong thermocline ; shipborne CTD casts.

Done and checked for the whole manuscript.

L161 SHOM?

Caps are now used for SHOM in the whole manuscript (following also the comment of reviewer #1)

L164 ship CTD

TSG is an appropriate term for ship CTD (see for example Gaillard et al., 2015). Nevertheless for this occurrence of the acronym in the MS, the sentence has been modified as follow :

"Ship board routinely acquired data (Vessel Mounted Acoustic Doppler Current Profiler - VMADCP- and ThermoSalinoGraph -TSG-) were also included in this database"

L166))

corrected

L168 dataset of all

corrected

L171 to detect and track mesoscale structures during the cruises.

We agree, suggested precisions were added

L178 paid to cross-slope transects

Corrected

L180 please refer to table 2. Apparently surface drifters were deployed during every cruise. Since it is not only the case for the first one, it feels odd to mention it here and not for the others.

The use of surface and argo drifters is now quoted at the end of the previous paragraph. Therefore the mention is here removed.

L183 Balearic Sea (please check capital letters for the rest for the rest of the paper).

Done

L185 therefore led ; mostly carry out ship CTD casts

Corrected ; CTD casts has been replaced by CTD stations following the comment of reviewer #1

L188 with caution, as they caused an excessive ...

corrected

L193 origin of the NC where the flow through the Corsica Channel and the WCC join.

Modified as suggested

L194-195 This latter ... current. I am not sure about what the authors are trying to say here.

We hope the following sentence is more clear:

The behaviour and the origin of the WCC was also explored along the western coast of Corsica.

L195 in early spring

corrected

L196 to capture an Algerian Eddy

corrected

L198 also provides insights about ; Northern Current

corrected

L203 eddy tracking tool

corrected

L204 consecutive to a strong Mistral gust, …

corrected

L206 (WIW) formation were ... ; A SCV was

corrected, WIW acronym is now defined above and the repetition of "water" also is removed.

L212 release

corrected

L213 what is the acronym of SPASSO?

SPASSO acronym is quickly available on the associated web site. Moreover the SPASSO functions are described in the sentence. Therefore we remove SPASSO from the text.

L215 mushrooms-like structures -> do you mean dipolar structures ? ; fronts ; focus was given to the area south of Mallorca where

done (3 corrections)

L216 a front was detected ; Lagrangian diagnosis

corrected

L218 "A Lagrangian round-trip strategy" I don't know what this is...

Surface drifters were dropped at biological key points in the area and revisited few time a day by the ship in order to follow the phyto- and zooplankton during a diurnal cycle following the so marked water mass. As this strategy concern the biological part of the cruise, not included in this data paper we chose to simplify the sentence as follow :

A Lagrangian strategy was specifically set up in order to study the structure and growth rate (at 24 hours time scale) of the various phytoplankton groups as defined by flow cytometry measurements as in Marrec et al. (2018).

A full description of the strategy is expected in another paper devoted to the biological results.

L230 a RDI 150khz ... Was the LADCP profiles acquired by a pair of those instruments?

No, the rosette was equipped only with one ADCP. *The text ins therefore unchanged*

L232 LADCP data were processes following thé inversion mehod of Visbeck (2002).

Modified , thank you for the precision.

L236 The main instrument used was a SeaSoar ...

Already indicated in the §3. We prefer our redaction.

L238 a WET Labs WetStar chlorophyll-a fluorometer

corrected

L239 attached to ; profiled cable ?

The concerned sentence has been simplified as follow ;

"The SeaSoar was trawled at 9 knots by a profiled cable""

L240 give scale in km

done 1 nautical mile ~2 km

L242 range of sampling ; real-time

corrected

L244 please provide km too ; crossing numerous and various structures ... (see section 5), ... fine-scale patterns

done 5500 nautical miles ~ 10.000 kilometres

modified following suggestions.

L248 Avoid the use of underscore while refering to cruise name in the text and be consistent throughout the paper ; During the PROTEVS-MED 2017 cruise, a ...

Ok, checked for all the MS

L250 half a

corrected

L251 when the instrument is surfacing

corrected

L253 what is the conclusion of the comparison?

L258 allowed for real-time

corrected

L259 what is the horizontal resolution in km?

With a resolution similar to the seasoar (about 2 km)

L263 what do you mean by "induct"? ; contributed

"induct" is not the correct word. "Inlet" is now used. See Gaillard et al (2015) for complement about the protocol.

Contributed **:** *corrected*

L271 on R/Vs Pourquoi pas ?, Atalante, Beautemps Beaupré ; are 150kHz and 38kHz Ocean Surveyor by RDI Teledyne

corrected

L291-292 ship CTD and SeaSoar ; SHOM? (please be consistent with capital letters) ; bath, whose temperature can ...

no, it's mean all CTD used during the cruises, the "all" is added in the sentence.

Shom : corrected

bath, whose : corrected

L298 with SBE 35's : do you mean by several SBE 35? In that case how many?

The "s" is removed. The SHOM labs is equipped with 2 baths and 3 SBE 35's but the common protocol request only one SBE 35.

L304 tested against Autosal and Portasal salinometers.

Corrected as suggested

L310 the provider ? You mean collaborators who provided the instruments ? An easy process would be to compare in the TS space the data from MVP and RapidScan with calibrated ship CTD casts...

Unfortunately, we don't have an access to any pre- or post-calibration for the MVP or the RapidCast sensors. The only one calibration we had was the one provided by the constructor. Of course a comparison with other measurement in the vicinity remain possible. Note, that as mentioned in the MS, we focus more on the structures than on absolute values.

The following sentence is now added :

but a comparison with the results of calibrated SBE sensors can be carried out..

L320 Level 0 (L0) consisting in ... Level 1 (L1) displaying ... standards units and corrected from eventual drift of sensors ... Level 2 (L2) proposed as ...

done

L334 and the corresponding author? Or provide an adresse/url to get the data. It would be nice to have a contact point without having to look for it.

An email address is provided : data-support@shom.fr

L338 also 100m

Right, 2 drifters with holey socks positioned at 100 m were dropped in 2018. modified in the MS

L339 Lagrangian

corrected

L340 deployed with dedicated sampling rate. Please specify the range of temporal sampling, of the parking depth, and for how long.

Done, information also requested by the reviewer #1; the new redaction is :

"Few Argo floats were also dropped and experienced first PROTEVS-MED dedicated mission with high temporal resolution (daily cycle) and a parking depth adjusted to the observations to maintain the drifters as long of possible in the targeted structures (typically 100 m deep). When the drifter left the structure, it used the usual Argo standard procedure in the Mediterranean (i.e. a 5-day cycle and a parking depth of 350m)."

L344 (see table 2)

modified as suggested

L356 provided ... It was also possible to simultaneously observe.

Corrected, thank you for the tense correction.

L357 "showing the predominance ... (few kilomètres)." Without further demonstration, I would remove that strong and general assessment. (In general, please use past tense for data description and present for interpretation.)

OK, the sentence is rephrased in a less strong and more general way. Nevertheless this observation is important in the framework of the future SWOT program. Even at relatively small scale (in the range of 10 km) the dynamics follow mainly the geostrophic (or cyclogeostrophic) balance. The new redaction is now:

… "showing the importance of the geostrophic balance even at small scale (in the range of 10 km)"

L358 were patchier

corrected

L360 appeared ... described and are actually made of

tense is now corrected. Commonly is preferred to actually in the new redaction.

L362 dual-core anticyclonic eddy was observed

corrected

L363 three-core eddy was also

modified as suggested

L364 remains to be investigated

modified as suggested

L365 pre-existing eddies

modified as suggested

L366 reveal filaments and layered structures due to submesoscale (ageostrophic) dy- namics

We prefere our sentence; not modified.

L367 symmetric instabilties -> what about stirring by the mesoscale eddy field, fronto- genesis ...? There is no evidence here of one prevalent process... Please draw instead a list of relevant potential mechanisms.

Frontogenesis is added. Stirring is evoked in the next sentience.

L369 Northern ; a SCV of LIW was observed south of Toulon. Do you have evidence of swirling currents by VMADCP?

Yes***. The sentence are now :***

"In the North Current, stirring appeared in both tracers and velocity fields and an SCV formed by LIW detached in front of Toulon (figure 3c) was observed as confirmed by observed swirling velocities on VMDCP records. It was also topped by a surface cyclonic gyre."

L371 was paid to the NC

tense corrected

L372 SCVs generated in the deep convection area.

Ok we agree

L375 of the deep convection area

ok geographical position is not useful. removed

L376 showed small-scale structures likely formed by convection ; the north to the south

corrected as suggested

L378 convection chimney

corrected as suggested

L380 double-diffusive processes ; please cite existing references related to double- diffusion in the Western Mediterranean.

(Onken, R., Brambilla, 2003) is added

L382 Cap Creus

corrected as requested

L384 cold water originating from the Gulf of Lion's shelf (please correct Gulf of Lion in future 1 too) ; The WIW was progressively entrained and mixed with the AW and LIW while flowing south ; Please add a word and a reference to dense shelf water cascading (e.g. Durrieu de Madron et al, 2013).

modified as suggested

Clearly it is not shelf water cascading as described by Durrieu de Madron, but a density adjustment of a water masses that will probably form WIW. Nevertheless the suggested reference is added to highlight the differences in the processes.

L397 the fine-scale dynamics

modified as suggested, very is removed

L401 It also complements the repeated glider lines maintained in the framework of the MOOSE observatory (Coppola et al, 2019) and is usefull to design future combined multi-plarform experiments.

modified as suggested after typing errors corrections.

L403 different instruments to obtain high-resolution

modified as suggested

L404 transects have been

corrected

L405 has only been tested and used as …

modified as suggested

L409 perfect tool to identify mesoscale structures ...

ok, drive out is replaced by identify

L410 down to

modified as suggested

L411 describe important surface and subsurface dynamical features.

modified as suggested

L413 free-fall instrument, its setting is lighter

modified as suggested

L415 equation and hydrography.

modified as suggested,

L417 of the sensors ... , this experiment of fast and ... revealed ... (Garreau et al, 2018)

modified as suggested,

L429-430 and the back and forth ... fruitfull. Not clear, please rephrase.

May be synergy is more a more conceptual formulation. The new versionof the sentence is now :

In situ observations of ageostrophic dynamics remain rare and the synergy between these observations and theory, and then between these observations and modelling, should be very fruitful.

Reference :

P Testor, JC Gascard : Large-scale spreading of deep waters in the Western Mediter- ranean Sea by submesoscale coherent eddies, Journal of physical oceanography 33 (1), 75-87, 2003

added

P Testor, JC Gascard, Post-convection spreading phase in the Northwestern Mediter- ranean Sea, Deep Sea Research Part I: Oceanographic Research Papers 53 (5), 869- 893, 2006

added

Bosse, Circulation générale et couplage physique-biogéochimie à (sous-) mésoéchelle en Méditerranée Nord-Occidentale á partir de données in situ, PhD thesis, Sorbonne- Université, 2015

This Phd thesis is in french. We prefer citing the publications of the same author (5 citations)

Giordani et al, A PV-approach for dense water formation along fronts: Application to the Northwestern Mediterranean, JGR, 2017

Medoc group, Observation of Formation of Deep Water in the Mediterranean Sea, 1969.Âa˘NatureÂa˘227,Âa˘1037–1040 (1970) doi:10.1038/2271037a0

added

Schott et al, Observations of deep convection in the Gulf of Lions, northern Mediter- ranean, during the winter of 1991/92, JPO 1996

added

Coppola, L., P. Raimbault, L. Mortier, and P. Testor (2019), Monitoring the environment in the northwestern Mediterranean Sea,Âa˘Eos, 100,Âa˘https://doi.org/10.1029/2019EO125951

added

DurrieudeMadronetal,InteractionofdenseshelfwatercascadingandopenâĂŘsea convection in the northwestern Mediterranean during winter 2012, GRL 2013

added

PROTEVS-MED field experiments: Very High-Resolution Hydrographic Surveys in the Western Mediterranean Sea

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Abstract: From 2015 to 2018 four field experiments (7 legs) have been performed in the Western Mediterranean Basin during winter or early spring. The main objectives were the assessment of high-resolution modelling, the observation of mesoscale structure and associated ageostrophic dynamics. Thanks to the intensive use of a towed vehicle undulating in the upper oceanic layer between 0 and 400 meter depth (a SeaSoar), a large amount of very high resolution hydrographic transects (total length about 10.000 km) have been performed, observing mesoscale dynamics (slope current and its instabilities, anticyclonic eddies, sub-mesoscale coherent vortices, frontal dynamics, convection events, strait outflows) and sub-mesoscale processes like stirring, mixed layer or symmetric instabilities. When available, the data were completed with velocities recorded by Vessel Mounted Acoustic Doppler Current Profiler (VMADCP) and by surface salinity and temperature recorded by ThermosalinoGraph (TSG). Classical full depth CTD (Conductivity, Temperature, Depth) stations~~casts~~ have also been performed giving the background hydrography of the deeper layers when focusing on peculiar structures~~objects~~. In 2017, a free fall profiler (an MVP-200) has been deployed to manage even higher horizontal resolution~~.~~ ~~The aim of the survey was the dynamics and attention were paid to temperature, salinity and currents~~. In 2018, another free fall profiler (a RapidCast) has been tested. ~~Nevertheless,~~ When available, biological sensors (chlorophyll-a, turbidity, dissolved oxygen etc.) have been carried out . They provided useful complementary observations about the circulation. ~~biological sensors (Chlorophyll-a, Turbidity, Dissolved Oxygen etc.) have been opportunely carried out as they are able to provide complementary observations about the circulation.~~ This data set is an unprecedented opportunity to investigate the very fine-~~-~~scale processes as the Mediterranean Sea is known for its intense and contrasted dynamics. It should be useful for modellers (who reduce the grid size below a few hundred meters) and expect to properly resolve ~~catch~~ finer scale dynamics. Likewise, theoretical work could also be illustrated by in situ evidence embedded in this data set. The data are available through SEANOE repository (https://doi.org/10.17882/62352; Dumas et al., 2018).

1 Introduction

Progress in numerical modelling and conceptual approaches both emphasized the importance of fine scale processes in connecting the ocean interior to with the atmosphere, driving the energy cascade to small scales and reversely - (McWilliams, 2016) and shaping the biochemical cycles and biodiversity distribution (Lévy et al., 2012; Lévy et al., 2018). For instanceinstance, in the Northwestern Mediterranean Sea, cChorophyll- -a filaments near the external boundary of the North Current in the Ligurian Sea are generated by frontal instabilities (Niewiadomska et al., 2008) and coherent vortices vortex may act efficiently both as biological barriers and drivers of plankton diversity (Bosse et al., 2017; Rousselet et al., 2019). As all thethese scales interactions are ubiquitous, it is of crucial importance to develop an observations strategy to get insight simultaneously of the large scalelarge-scale dynamics, the mesoscale and the sub-mesoscale processes. Unfortunately, it is not straightforward to reach this objective using conventional cruise strategies leading to a lack of in situ observations of fine scale processes. Due to their synoptic view, satellite observations partly fill partly the gap between encompassing together large and finer scale scale dynamics and finer structures. Since many years, rRemotely sensed observations of surface temperature, ocean colours or altimetry exhibit since many years a large spectrum of processes with various cut off scale (from around 70 km for the altimetry down to some tens of meters for imagery). Some of these limits will be pushed back soon by: as for the future SWOT (Surface Water and Ocean Topography) (SWOT) satellite, mission will; it is expectinged to provide substantial improvement for small scales processes having a sea surface height signature (d'Ovidio et al., 2019).

The data presented hereafter are a contribution to very high-resolution observations of the top oceanic layer and are freely available on SEANOE repository: https://doi.org/10.17882/62352 (Dumas et al., 2018). Long transects of the first 400 m below depths under the surface was sampled with a horizontal resolution in the range of two kilometres one nautical mile in the Western Mediterranean Sea. The hydrographic and dynamics background of this region is given in section 2. The objectives and implementation of the surveys are presented in section 3. The details of the measurements (platformvectors, sensors, methodology, metrology, data control, ancillary data) are reported in section 4. To illustrate the potentiality of the dataset, an overview, some quick looks of the observed processes are displayed in section 5. Lessons learned during surveys and summary are displayed in section 6.

2 Oceanic contexts of the in Western Mediterranean Sea

The Mediterranean Sea is often referred as a “pocket ocean” exhibiting many processes that are met pervasively and are of primary interest in the functioning of the global ocean (Robinson et al. 2001). It thus provides the opportunity to investigate a large panel of oceanic features in a relatively restrained and accessible ~~nearby~~ area. Therefore, the PROTEVS-MED cruises potentially caught a multitude of physical processes in the ~~North~~ Western Mediterranean Sea (figure 1).

2.1 Surface and intermediate ~~Thermohaline~~ circulation

The basin or sub-basin ~~scale~~ dynamics ~~circulation~~ is largely driven~~ominated~~ by the thermohaline circulation. The Mediterranean Sea is a semi enclosed evaporation basin ~~sea~~ including areas of intermediate to deep convection. Ligth (fresh) ~~Less dense (and fresher)~~ Atlantic Water (AW), inflowing through the Gibraltar Strait generally circulates along the continental slope~~roughly in cyclonic way~~ in both w~~W~~estern and ~~Levantine~~ eastern basins (Millot and Taupier Letage, 2005). The~~is~~ slope current is unstable along the Algerian Coast and generates anticyclonic eddies called Algerian Eddies (AE) that spread AW in the southern half of the w~~W~~estern b~~B~~asin called Algerian Basin (Escudier et al., 2016a; Puillat et al.; 2002). In the n~~N~~orthern part of the w~~W~~estern b~~B~~asin, the AW composed East Corsica Current (ECC) and West Corsica Current (WCC) join in the Ligurian sea to form the Northern Current (NC) that flows along the slope until the Balearic Sea (Millot et al., 1999; Send et al., 1999). The existence and the strength of a return branch of this current along the North Balearic Front (NBF) between Menorca Island and Corsica Island is still under debate despite the generally accepted concept of a Northern (cyclonic) Gyre, in agreement with the doming of isopycnals in the central part of this sub-basin. The Levantine Intermediate Water (LIW) which is a modal water formed in winter in the eastern basin ~~and~~ entering into the western basin through the Sicilian Strait, follows more or less the same cyclonic circulation pattern (Millot and Taupier Letage, 2005). It spreads out into the northern part of the western basin between 400 and 800 m depths and is found sporadically within the Algerian Basin. This important water mass is marked ~~It is spotted~~ by a relative subsurface maximum of temperature and salinity.

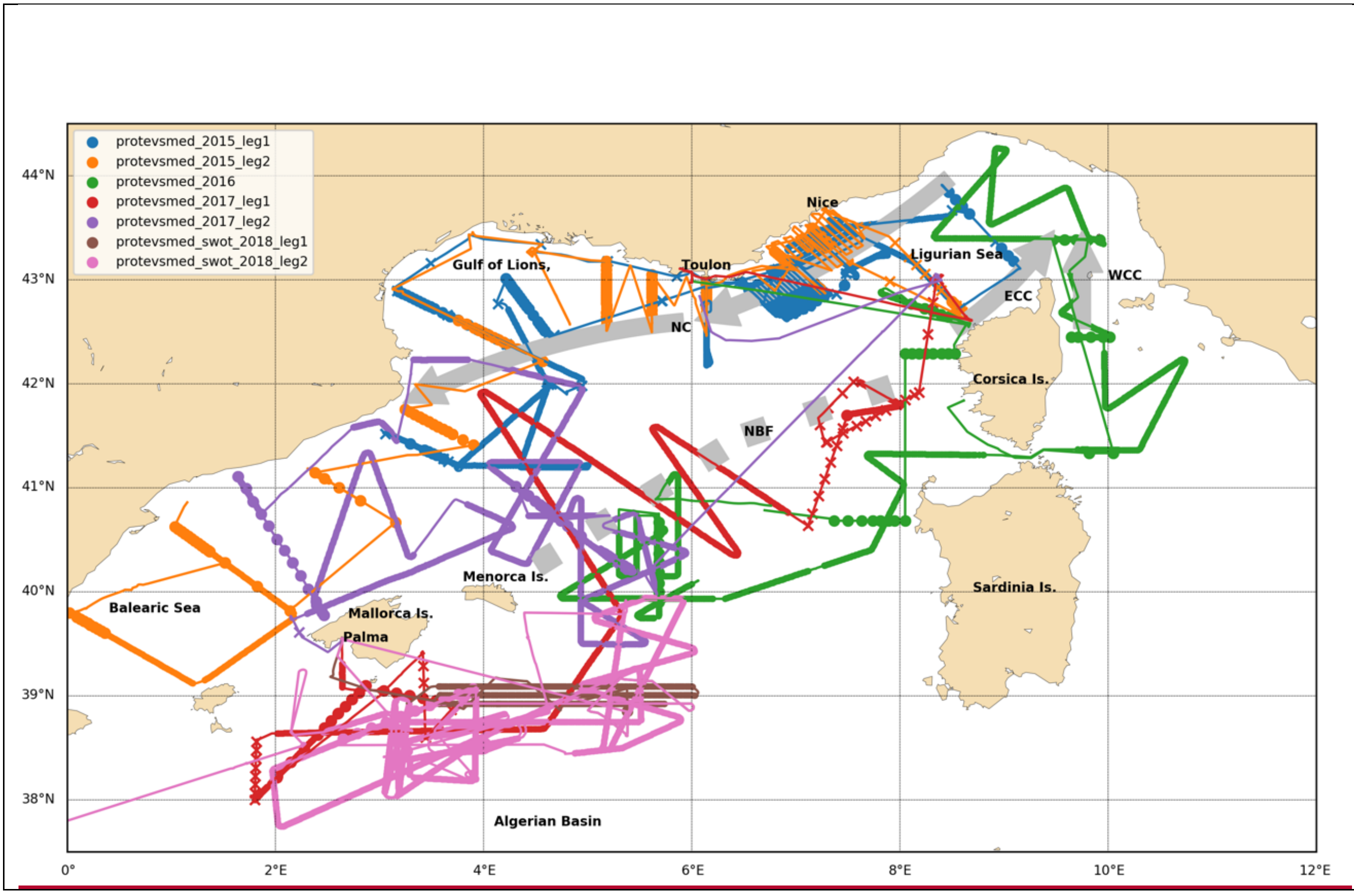

Figure 1 : Map of PROTEVS-MED cruises. Dynamical features, North Balearic Front (NBF), East Corsica Current (ECC), West Corsica Current (WCC) and Northern current (NC) are depicted in grey.

2.2 Mesoscale structures

As in the global ocean the mesoscale dynamics is ubiquitous within the Mediterranean basin; it plays a major role in redistributing water masses and has been evidenced by remote sensing for a long time (Millot et al., 1990). In the Western Basin, the first internal radius of deformation spans in the range of 6 km in the Northern Gyre and of 16 km in the Algerian Basin (Escudier et al., 2016b). It is an indicator of ~~for~~ the typical size of the mesoscale activity because the scale of surface intensified eddy in geostrophic balance range~~sizes a range in~~ few deformation radii. As a result of ocean-atmosphere exchanges, of large structures instabilities or of flow-topographies interactions, Submesoscale Coherent Vortices, hereafter named SCV (Mc Williams,1985), whose ~~with~~ sizes are currently close to the local radius of deformation, have been observed in the Western Mediterranean (Testor and Gascard 2003; Bosse et al., 2015, 2016). Eddies, meanders, filaments and fronts are typically smaller ~~and more contrasted~~ than in the world ocean.

2.3 Sub mesoscale structures.

There are strong interactions between mesoscale structures thus generating intense stirring, layered structures and patchy ocean areas. Air-Sea exchanges are marked by frequent ~~by a succession of~~ strong events (Tramontane and Mistral gusts for instance in the northwestern b~~B~~asin); they interact with the NC and mesoscale structures and ~~in~~ generat~~e~~~~ing~~ sinks or sources of potential vorticity ~~(PV)~~, thus leading to ageostrophic dynamics (Bosse 2015; Estournel et al., 2016; Giordani et al., 2017; Testor et al., 2018).

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Besides, the north western mediterranean basin is known to be the place of deep convection events which has been studied for a long time and even taken as one of the paradigms of deep oceanic convection (Medoc Group et al., 1970; Schott et al., 1996; Houpert et al., 2016; Testor et al., 2018) Marshall and Schott 1999). Both modelling (Jones and Marshall, 1993, 1997) and observations (Bosse et al., 2016, Margirier et al., 2017) ~~data~~ show~~s~~ that deep convection is highly favourable to the production of fine scale structures at submesoscale whether they are due to deepening of the mixed layer ~~fronts~~ during winter or to postconvection restratification.

2.4 Previous high-resolution observations

The finest part of the mesoscale dynamics often escapes the usual sampling strategy (CTD arrays, glider deployments) because of being short lived, small in size and quickly advected. The development in the last decade of gliders fleet revealed nevertheless the mesoscale variability in the Western Mediterranean Basin.
Recent field experiments based on the multi-platform integrated monitoring program MOOSE (Coppola et al. 2019~~Houpert et al., 2016~~) or on intensive targeted experiment HYMEX (Estournel et al., 2016) have revisited the hydrography and the dynamics of the North-Western part of the Western Basin. A strategy of regular and repeated gliders lines ~~routes~~ as well as dedicated deployments allowed to characterize the variability of the dynamics and to describe crossed ~~opportunely sampled~~ fine scale structures. Bosse et al. (2015; 2016) inventoried the Submesoscale Coherent Vortices (SCV) and their contributions to water mass redistribution. With data issued from the same strategy, Margirier et al. (2017) characterized the convection plumes in the Gulf of Lions. Testor et al. (2018) summarized the observations of convection during the dedicated experiment HYMEX. Multi-platform strategies including gliders, mooring, combined cruises (Ruiz et al., 2009;~~-~~ Pascual et al., 2017; Petrenko et al., 2017; Knoll et al., 2017; Onken et al., 2018~~; Pascual et al., 2017; Petrenko et al., 2017; Knoll et al., 2017; Ruiz et al., 2009~~; Troupin et al., 2019), or colocation with altimetric tracks (Borrione et al., 2016; Heslop et al., 2017; Aulicino et al., 2018;~~,~~ Aulicino et al., 2019; Carret et al., 2019) can provide part of the missing synoptic view.

The capability of changing the glider's trajectory at any time has not often been used in a small-scale context because its horizontal velocity remains low (in the range of 15-30 km~~24 nautical miles~~ /~~per~~ day), preventing any rapid assessment of a detected small structure. Despite this lack of synopticity,

Cotroneo et al. (2015; 2019) adapted a glider trajectory to a remote sensed observed Algerian Eddy and Current. Conversely the SeaSoar horizontal velocity is 10 times faster than the glider one~~-~~. T~~; besides, t~~his towed vehicle can handle a turning radius of 2 nautical miles (i.e. gyration speed of 10 degree/min) when the ship change direction. It allows a strategy based on long exploratory transects as the ship velocity is close to its transit velocity and of~~n~~ intensive sampling on particular detected structures. Due to heavy logistics involvement, the use of SeaSoar remained scarce in the Western Mediterranean Sea. Allen et al. (2001; 2008) observed an oblate lens of 20 km radius, 150 m thick, centred at 250 m depth during the OMEGA-2 field experiment in fall 1996. Salat et al. (2013) reported Seasoar transects in the Gulf of Lions after the convection in spring 2009. The Seasoar was also used during one leg of the ELISA field experiment devoted to the Algerian Eddies (Taupier-Letage et al., 2003) but only the mesoscale features have been reported.
A free fall recovered platform~~vector~~, the Moving Vessel Profiler (MVP-200) has a lighter logistics but requires a lower vessel velocity to reach depths equivalent to those reached with the SeaSoar: that is to say 2-4 knots to go down 400 m~~eter~~ deep~~epths~~. In the Western Mediterranean Sea, the MVP was deployed during OSCAHR cruise allowing a detailed study of a cyclonic structure in the Ligurian Sea (Rousselet et al., 2019) and in situ estimation of the sea surface height for a comparison with along track satellite data (Meloni et al., 2019).

3 Objectives and achievement of the field experiments.

The main scientific objectives of the cruises were threefold:

- to assess the large-scale circulation features of the Western Mediterranean Basin, evaluating the water masses and the fluxes at different key points in the basin (t~~T~~he Ligurian Sea, the Balearic Sea, ~~North Current, The East and We~~the Northern Tyrrhenian Sea~~st Corsica currents~~, the North Balearic front area ~~t~~and~~,~~ the Algerian Basin). The ~~final~~ goal was the ~~some~~ assessment~~s~~ of~~-~~ operational numerical simulation of the circulation performed for the Navy.
- to identify and follow peculiar mesoscale structures such as surface eddies, modal structures composed of Winter Intermediate Water (WIW), ~~weddies,~~ submesoscale coherent vortices (SCV) meanders and ~~or~~ filaments and explore their signatures on the sea surface height (altimetry) and their acoustic impact (i.e. through their modulation of the sound propagation speed).
- to observe and characterize ~~interpret~~ the submesoscale dynamics such as ageostrophic stirring, symmetric instabilities, mixed layer instabilities, subduction and convection.

Clearly, the main part of the present dataset is not devoted to track any climatic change in water mass properties; the SeaSoar, the MVP or the Rapidcast are rapid moving platform ~~vector~~s leading to acquire less precise temperature, conductivity and above all deduced salinity data than standardized CTD's protocol. MVP and RapidCAST are equipped with unpumped sensors and the three tools reach high ascending or descending velocity (above 2m/s) that leads to inescapable thermal lag issues across sharp fronts. Readers interested in this topic should only use the classical CTD stations ~~casts~~ data.

Four cruises were conducted between 2015 to 2018 by the “Service Hydrographique et Océanographique de la Marine” (SHOM~~Shom~~) in the Western Mediterranean Basin, during winter or early spring, managing mainly the towed undulating vehicle SeaSoar to investigate the sub-surface (0-400m) layer. When the deployment of this vehicle was either unsafe (over shallow water) or even impossible (due to rough meteorological conditions, breakdown of winch or vehicle) or when complementary observations were requested (e.g. go below 400m or getting water samples for biochemical analysis), CTD casts were rather performed. Ship board r~~R~~outinely acquired data (Vessel Mounted Acoustic Doppler Current Profiler ~~-(~~VMADCP~~-)~~ and ThermoSalinoGraph ~~-(~~TSG~~-)~~) were also included in this database.~~.~~

We present here in a synthetic dataset all~~ the~~ data recorded during the cruises (figure 2~~1~~; table 1). Complementary data used to the cruise design, to adapt on field the strategy or to interpret results (altimetric tracks, remote sensed sea surface temperature or chlorophyll-a) are available on CMEMS servers (http://marine.copernicus.eu). An eddy detection tools called AMEDA (Le vu et al., 2017) has also been used to detect and track structures during the cruises. ~~-~~Surface and Argo drifters were also dropped during the cruises and data are available on companion datasets (table 2).

PROTEVS-MED~~protevsmed~~	2015_leg1 07-01 / 24-01	2015_leg2 16-04 / 03-05	2016 22-03 / 04-04	2017_leg1 27-01 / 07-02	2017_leg2 11-02 / 23-02	swot_2018_leg1 23-04 / 26-03	swot_2018_leg2 30-04 / 18-05
SEASOAR	**2290 km 1137 profiles**	**329 km 263 profiles**	**2090 km 1369 profiles**	**1858 km 706 profiles**	**620 km 1162 profiles**	**615 km 411 profiles**	**2830 km 2381 profiles**
MVP				**153 km 813 profiles**	**188 km 708 profiles**		
RAPIDCAST						**22 km 92 profiles**	**167 km 71 profiles**
CTD	**62 profiles**	**151 profiles**	**47 profiles**	**17 profiles**	**27 profiles**	**1 profile**	**12 profiles**
LADCP	**56 profiles**	**137 profiles**	**47 profiles**	**18 profiles**	**26 profiles**		**3 profiles**
XBT	**30 profiles**	**22 profiles**		**39 profiles**	**1 profile**		
VMADCP 38kHz	**2676 km**					**1071 km**	**4118 km**
VMADCP 150kHz	**3036 km**	**3688 km**		**2705 km**	**5384 km**	**1068 km**	**4128 km**
TSG	**3756 km**	**3861 km**	**3744 km**	**2999 km**	**3011 km**	**1212 km**	**4984 km**

Table 1: Summary of performed transects, profiles and routinely acquired data. Cumulated length of transects and total numbers of vertical profiles are displayed.

The first cruise called **PROTEVS-MED~~rotevsmed~~ ~~–~~2015_leg1** took place from 7 to 24 January 2015 on board of the RV *Pourquoi Pas?*. Its ~~The~~ main objective was the dynamics of the N~~orth~~ C~~urrent~~ from the Ligurian Sea to the Gulf of Lions and the associated meso- and submeso-scale processes. Attention has been paid to cross-slope transects ~~across the slope~~ in~~of~~ the Gulf of Lions, in order to examine the behaviour of the North Current and the exchanges across the shelf break. An intensive survey of the North Current between Toulon and Nice was performed.~~completed by drifting buoys deployment.~~

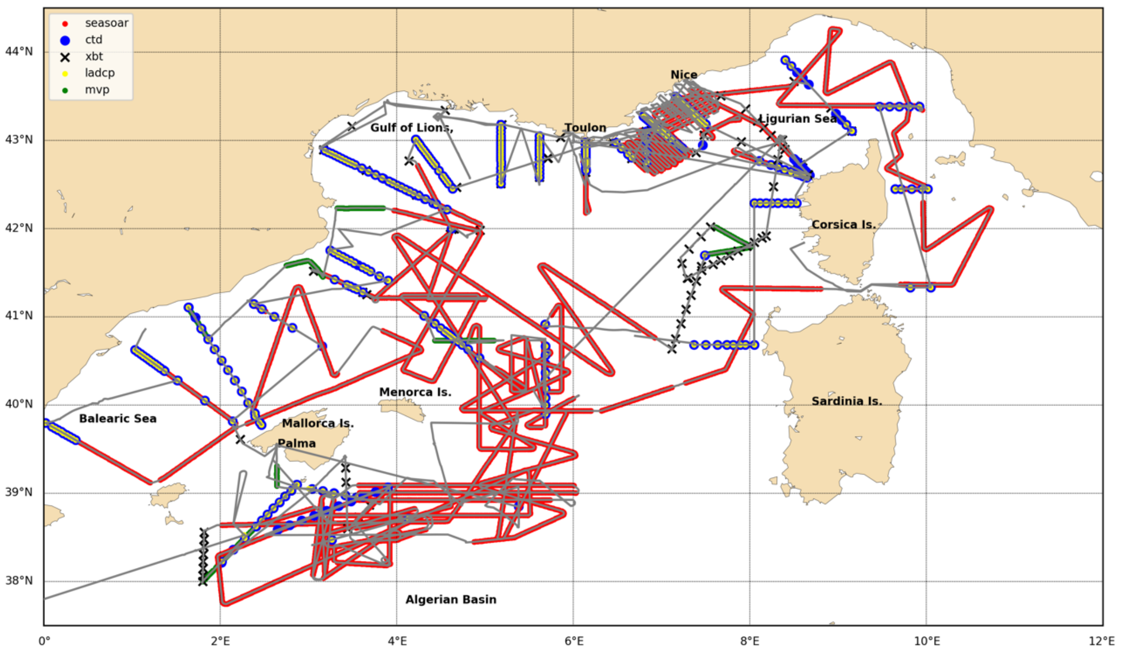
The second leg, **PROTEVS-MED ~~rotevsmed~~_2015_leg2**, was carried out on the RV *Beautemps-Beaupré* from 16 April to 3 May 2015. It started in the Balearic S~~s~~ea and investigated the slope current from Ligurian Sea to Balearic Sea. During this cruise, the SeaSoar trawl failed early, just after three transect acquisitions in the Balearic Sea describing the hydrology relative to the cyclonic circulation and its associated mesoscale structures. This has ~~led~~ therefore led to carry out mostly CTD stations~~casts~~ and VMADCP 150 kHz records. In particular, a dense array of CTD casts was then performed within the North Current between Nice and Toulon. The PROTEVS-MED ~~protevsmed~~_2015_leg2 survey was characterized by a proliferation of jellyfish, the CTD measurements are to be taken with caution as they caused an~~: a jellyfish on the sensors results in~~ excessive smoothing of temperature and salinity. When too large ~~great~~ differences appeared between the values at the ascent and descent, the profiles have been flagged 4 (bad value that can be corrected)

The second campaign~~,~~ **PROTEVS-MED ~~rotevsmed~~_2016**~~,~~ took place on the RV *Beautemps-Beaupré* from 22 March to 4 April 2016. It was designed to focus on the origin of the N~~orthern~~ C~~urrent~~ where the flows through ~~which is known to be fuelled by~~ the Corsica Channel ~~flow~~ and the W~~estern~~ C~~orsica~~C join ~~Current~~. The behaviour and the origin of the WCC was also explored along the western coast of Corsica ~~The latter is connected in a more or less clear manner to the North Balearic Front (NBF) and the continental slope current~~. Besides unveiling part of the complex hydrological structure of the NBF in~~at~~ early spring, the PROTEVS-MED ~~rotevsmed~~_2016 survey allowed to capture ~~catch~~ an A~~a~~lgerian E~~e~~ddy in interaction with the NBF. Garreau et al. (2018) described in details its original double core structure: a superposition of two water masses of different origin spinning together. The survey provides also scenes and insights about ~~on~~ the way both components of the Northern Current merge together to the north of the Corsica Channel during ~~the~~ early spring.

The third campaign **PROTEVS-MED ~~rotevsmed~~_2017** held from 27 January to 7 February (**leg1**) and from 11 February to 23 February (**leg2**) on board the R/V *Atalante*. This survey was devoted to explore eddies detected by altimetry in the North Balearic Front and to assess an eddy tracking~~ed~~ tool (Le Vu et al., 2017). Transects across the North Balearic Front revealed the complexity of this transition zone. In order to escape rough sea state consecutive ~~sequential~~ to a strong Mistral gust~~,~~ part of the cruise was dedicated to the investigation of the Balearic Sea and the outflow of coastal fresher and colder water mass from the Gulf of Lions. Back to the deep-sea area, partial convection and ~~Western Intermediate~~

Water (WIW) formation of water were recorded. An SCV was were thoroughly observed, north of the Balearic front.

The fourth and last field experiment, **PROTEVS-MED-SWOT Protev_smed_swot 2018** was conducted in the framework of SWOT Preparatory Phase from 23 April to 26 April (**leg1**) and from 30 April to 18 May (**leg2**) south from Balearic Islands on board the R/V *Beautemps-Beaupré.* The first leg (**leg1)** performed a general overview of the oceanic situation followed by a more intensive survey (**leg2)** planned on the basis of daily releases of near real-time satellite imagery, altimetry, and lLagrangian analyses, performed on land by use of a dedicated– the SPASSO package (http://www.mio.univ-amu.fr/SPASSO/-, as in Nencioli et al., 2011; de Verneil et al., 2017)**.** Satellite data of altimetry, sea surface temperature and ocean colour revealed ubiquity throughout the cruise period of very fine oceanic structures such as dipolars mushrooms-like structures or tenuous fronts. A special focus was stressed on the sSouth of Mallorca where a frontsal zone were has been detected by altimetry-derived currents and diagnosis (e.g. Finite Singular Lyapunov Exponents; d'Ovidio et al., 2004), by contrasted surface chlorophyll-a concentrations and confirmed by high frequency flow cytometry analyses of phytoplankton performed onboard (data not included in the present dataset). A Lagrangian round-trip strategy was specifically set up in order to study the structure and growth rate (at 24 hours time scale) of the various phytoplankton groups as defined by flow cytometry measurements as in Marrec et al. (2018). Last, it is noticeable that a companion campaign (PRE-SWOT) managed by IMEDEA-SOCIB held in the same area and during the same period on board of RV *Garcia Del Cid* (not included in the present dataset, see Barceló-Lull et al., 2018).


seasoar
ctd
xbt
ladcp
mvp
Nice
Gulf of Lions,
Toulon
Ligurian Sea
Corsica Is.
Menorca Is.
Sardinia Is.
Balearic Sea
Mallorca Is.
Palma
Algerian Basin
44°N
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42°N
41°N
40°N
39°N
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0°
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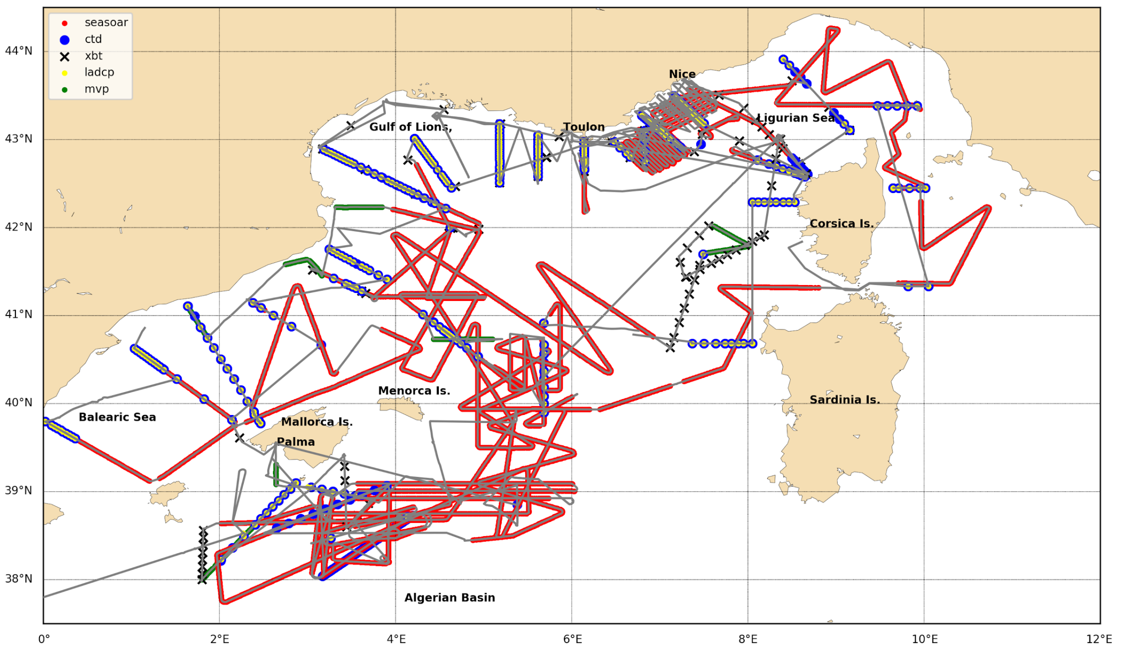
8°E
10°E
12°E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Balearic Sea
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39°N
38°N
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2°E
4°E
6°E
8°E
10°E
12°E

Figure 2 : Map of PROTEVS-MED cruises and instruments deployed; TSG is available for all the ship trackFigure 1: Map of Protevsmed cruises (a) and instruments deployed (b); TSG is available for all the ship track.

4 Data, Methods and Quality Controls

4.1 CTD casts and LADCP

The CTD casts were performed with the Sea-Bird SBE-9 instrument mounted in a General Oceanics 12-places rosette frame fitted with 12 Niskin bottles. Sometimes an RDI 150 kHz current profiler was also implemented on the rosette and then LADCP (Lower Acoustic Doppler Current Profiler) performed measurements during the cast. Standard hydrographic procedures for CTD casts were applied. When available, LADCP recorded data were processed following the inversion method using the software ofdeveloped by Visbeck (2002).

4.2 Seasoar deployments

The SeaSoar is a towed undulating vehicle designed and built by Chelsea Instruments. Two Sea-Bird SBE-9 (with SBE-3 temperature and SBE-4 conductivity sensors) instruments were mounted on either sides of the SeaSoar. When available, a WET Labs chlorophyll *a* WetStar WET Labschlorophyll-a fluorometer, both oxygen sensor (SBE-43) and optical properties sensor (WET Labs C-Star) were deployed. The SeaSoar was trawled at 9 knots, linked to the board by a profiled cable. It was undulating between the surface and 400m below the surface under optimal conditions with a horizontal resolution in the range of ~ 2 km1 nautical mile. Rough sea states, lateral currents, strong vertical shears can degrade the performance of the vehicle and reduce the vertical range of exploration between 20 and 360m. As the software allows real on time visualisation of the ongoing transect, it is a perfect tool to scan the upper oceanic layer where meso- and sub-mesoscale dynamics are is the most intense. A total of 10.000 kilometres 5400 nautical miles of transects crossing numerous and various plenty of different structures has been yet recorded during the four cruises, givingen the unique opportunity to explore the fine scales patterns of the upper layer of the western basin.

4.3 MVP deployments

During the PROTEVS-MED rotevsmed 2017 surveys a Moving Vessel Profiler (MVP200) - a computer controlled winching system that can deploy and recover a sensor from a ship that is underway - was deployed for finer transects. The sSensor was an AML CTD embedded in a free fall fish. At 2-4 knots, it was possible to monitor the 0-400 m layer with a horizontal resolution ~ less than 1 kmof a half nautical mile. To remove spurious salinity values due to bubbles when the instrument fish is surfacing, the minimum pressure for valid record was set to 1 decibar. A peculiar transect has been monitored using successively SEASOAR, MVP and CTD casts given the opportunity to compare the three techniques.

4.4 RapidCast deployments

During PROTEVS-MED ~~Protevs~~2018 a free fall CTD system, called rapidCast (Teledyne Marine ; http://www.teledynemarine.com/rapidcast) was tested for three transects near Balearic Islands. It was equipped with the "rapidCTD - Underway Profiler" proposed by Valeport. A bluetooth communication allowed ~~the~~ real-time evaluation of each profile when the probe is surfacing near the ship deck. This system sampled the water layer from 0 to 400m with a navigation speed in the range of 5-6 knots and a resolution similar to the SeaSoar (about 2 km).~~.~~

4.5 TSG

During the cruises, a Seabird SBE-21 ThermoSalinoGraph recorded the sea surface temperature and conductivity. The inlet ~~in duct~~ was equipped with a SBE 38 thermometer. The recorded sea surface temperature and salinity contributed to the Global Ocean Surface Underway Data (GOSUD) program (Gosud, 2016). The metrological traceability and the data treatment are insured according to the procedures described in Gaillard et al. (2015) which explains the delayed mode processing of datasets and presents an overview of the resulting quality. The calibrations are complemented with rigorous adjustments on water samples leading to reach a salinity accuracy of about 0.01 or less.

4.6 VMADCP

The hardwares used, their configurations and the way they are carried out are similar on ~~both~~ R/V Pourquoi Pas ?, R/V L'Atalante and Beautemps Beaupré. The VMADCPs are 150 kHz and 38 kHz ~~of the type~~ Ocean Surveyor by RDI Teledyne~~: the R/V hull is equipped with two antennas one at 150 kHz and the other 38kHz~~. They are both monobloc antennas using beam forming process to form four beams oriented towards 30° from the vertical. Nominally, they emitted a ping per second from which ensemble are built to get~~ a~~ less noisy profiles. Two ensembles are routinely processed:

- a Short-Term Average (hereafter noted STA)~~,~~ which gathers and averages~~d~~ the pings of two-minute window. It makes ensemble of 120 pings at least,
- a Long-Term Average (noted LTA) made of 600 pings or averaged over ten minutes.

The series of geometric transformations necessary to pass from beam coordinate along beam data to absolute geographic coordinate and geophysical velocity are performed thanks to VMDAS software from RDI Teledyne. It combines the position (latitude and longitude) from the DGPS Aquarius and Octans central with the PHINS inertial navigation system form IXSEA (that provides vessels attitude data: pitch, roll, heaving) to provide synchronised single ping earth coordinates data (file .ENX) and short- and long-term ensemble (STA / LTA).

This native format (.STA/.LTA) were ~~are~~ also processed with WinAdcp in order to extract and provide only significant (i.e. with a satisfactory signal/noise ratio) data that are additionally formatted to text file.

Note that data processed by CASCADE software can be requested on Sismer repository, collecting and processing progressively all VMADCP from French research vessels (https://sextant.ifremer.fr/record/60ad1de2-c3e1-4d33-9468-c7f28d200305/en/index.htm).

4.7 Data metrological traceability and calibration

SBE 9 temperature and conductivity sensors deployed on all CTD ~~and Seasoar~~ were calibrated before and after each campaign or at least once a year in the SHOM~~Shom~~'s thermo-regulated baths, whose~~; its~~ temperature can be stabilized to less than 1 mK (peak to peak) during control and calibration operation. Such a procedure allows the monitoring of sensors drifts between calibrations and the detection of anomalies. In the cases sensors have kept a good linearity, which is the most ~~more~~ common, data are corrected with offset-slope coefficients. Figure 3~~2~~a ~~shows~~show the review of corrections applied on data at 15 °C, after the calibrations of SBE 3 sensors used for PROTEVS-MED campaigns. Figure 3~~2~~b shows the review of corrections applied at 40 mS cm^{-1} after the calibrations of SBE 4 sensors.
The temperature of the thermo-regulated bath is monitored with SBE 35~~'s~~ which is ~~are~~ used as laboratory reference temperature sensors. They are linked to the International Temperature Scale of 1990 (ITS-90) thanks to calibrations performed once a year in a triple point of water cell and in a melting point of Gallium. These reference cells are regularly calibrated by the French National Metrology Institute (NMI) LNE-CNAM. The calibration expanded uncertainty of SBE 3 sensors is between 1.8 and 2.3 mK according to the residual linearity errors of SBE 3's.
Conductivity calibration of SBE 4 sensors is made in the same bath during the temperature calibration. Seawater samples are taken in the bath and tested against ~~with one~~ Autosal and ~~one~~ Portasal salinometers. The calibration procedure and the propagation of uncertainties to the calculated salinities from SBE 9 data are described in Le Menn (2011). Practical salinity expanded uncertainty varies from 0.0032 to 0.0034. In 2015, the SHOM~~hom~~ laboratory took part in the JCOMM intercomparison for seawater salinity measurements (JCOMM, 2015) showing that Autosal and Portasal measurements are within ± 0.001 compared to other participating laboratories. Note that the same process was done~~,~~ in the framework of an international network~~,~~ for the TSG data of the French Research Vessel (see §4.5 and table 2). Unfortunately, the MVP and the RapidCast sensors were not available for such a common process and were calibrated directly by the constructor~~provider~~, but a comparison with the in situ records with calibrated SBE sensors can be carried out. As the optical properties and oxygen concentration were used as tracer only, no calibration process was performed.

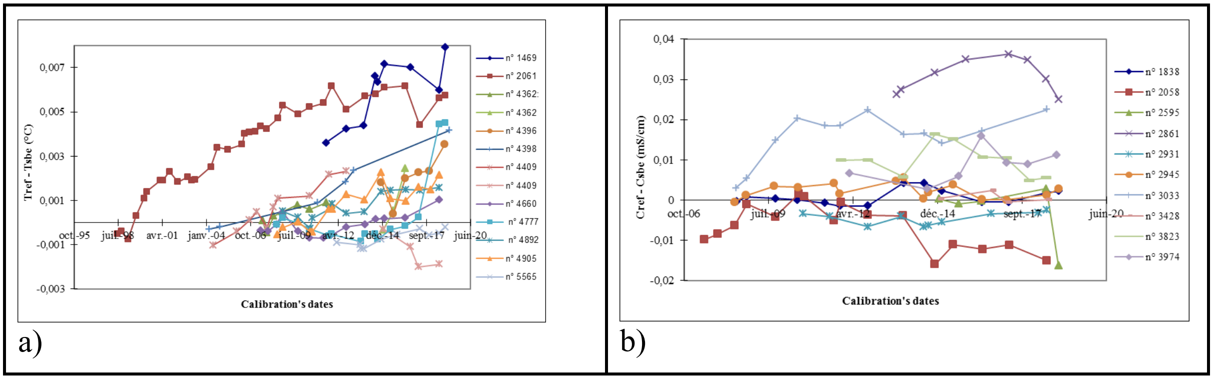

Figure 3~~2~~ (a) review of corrections applied on data at 15 °C, after the calibrations of SBE 3 sensors. (b) review of corrections applied on data at 40 mS cm^{-1}, after the calibrations of SBE 4 sensors.

4.8 Data processing levels

Three levels of processing are available for each dataset :

- ~~The first one (~~Level 0~~,~~ (L0) consists in the direct output of sensors at full temporal resolution;
- ~~The second level (~~Level 1~~,~~ (L1) displaying data in ascii (.csv) or netcdf (.nc) files are only processed from the software of the constructor, keeping the full resolution and computing the derived variables into standard units. Recent instrumental system (AML and Valport probes) directly provides level 1 files. L1 files are corrected from eventual drift of sensors;
- ~~The third level (~~Level 2~~,~~ (L2) is proposed as gridded, controlled and resampled data in netcdf files (.nc). Gridded dataset for salinity and temperature have been resampled vertically every meter removing spikes, spurious values, density inversions when they persist after the first process supplied by the sensor manufacturer. They are then positioned as vertical profiles at the mean geographical position of the considered up or down record.

Temperature and salinity data were also compared to the historical data in the neighbourhood of the profiles or transects using the validated CORA database distributed by the Copernicus Marine and Environment Service (Cabanne et al., 2013; Szekely et al., 2017). PROTEVS-MED ~~Protevsmed~~ data are not yet included in this database but will be transmitted for a future release.
All gridded profiles or transects have been plotted for a visual quality check and are available as “quick looks” on the repository. Level 1 (L1) and (or) level 2 (L2) dataset are released in the present database. Level 0 (L0) remain available in constructor format upon request to the data providing institution (SHOM; data-support@shom.fr).

4.9 Companion datasets.

During the field experiments, surface drifters with holey socks located at 100m, 75m, 50m or 15 m depth were deployed given the opportunity at the beginning of their track to perform a Llagrangian survey of observed structures.

Few Argo floats were also dropped and experienced first PROTEVS-MED dedicated mission with high temporal resolution (daily cycle) and parking depths adjusted to the observations to maintain the drifters as long as possible within the targeted structures (typically 100 m deep). After the drifter left the structure, it used the usual Argo standard procedure in the Mediterranean (i.e. a 5-day cycle and a parking depth of 350 m). Few Argo floats were also dropped and experienced Protevsmed dedicated profile (higher temporal resolution, parking depth into the targeted structure, etc.) at the beginning of their mission before shifting to the usual Argo standard procedure in Mediterranean Sea (i.e. 5 days cycle and parking depth set to 350m). Already stored in dedicated and accessible stable repositories, they can be found using their WMO identifiers (World Meteorological Organisation) (see table 2). Ancillary data can be found on different repositories selecting date and locations corresponding to PROTEVS-MED Protevsmed surveys.

	ARGO float WMO identifier http://www.ifremer.fr/argoMonitoring/	SVP surface drifter WMO identification number (holey sock depth) http://www.jcommops.org/dbcp/	TSG ThermoSalinoGraph (platform identifier) http://www.gosud.org
PROTEVS-MED protevsmed 2015_leg1	**6901707** **6901708**	**6100536 (50m)** **6100537 (50m)** **6100538 (50m)** **6100539 (50m)** **6100540 (50m)**	**FMCY**
PROTEVS-MED protevsmed 2015_leg2		**6100863 (50m)** **6100864 (50m)** **6100865 (50m)** **6100866 (50m)** **6100867 (50m)**	**FABB**
PROTEVS-MED protevsmed 2016		**6101525 (75m)** **6101526 (75m)** **6101527 (75m)** **6101528 (75m)** **6101529 (50m)** **6101530 (50m)** **6101531 (50m)** **6101532 (50m)** **6101533 (50m)** **6101534 (50m)** **6101535 (50m)** **6101536 (50m)** **6101537 (50m)** **6101538 (50m)**	**FABB**

		6101539 (50m) **6101540 (50m)** **6101541 (50m)** **6101542 (50m)** **6101631 (50m)**	
PROTEVS-MED ~~protevsmed~~ 2017_leg1	**6902764** **6902765** **6902767**	**6101634 (50m)** **6101639 (50m)** **6101635 (50m)** **6101637 (50m)** **6101636 (50m)** **6101643 (50m)** **6101641 (50m)** **6101647 (50m)**	**FNCM**
PROTEVS-MED ~~protevsmed~~ 2017_leg2		**6101648 (50m)** **6101633 (50m)** **6101638 (50m)** **6101640 (50m)** **6101632 (50m)** **6101642 (50m)**	**FNCM**
PROTEVS-MED- ~~protevsmed~~ SWOT ~~swot~~ 2018_leg1	**6902844**	**6101669 (50m)** **6102612 (50m)** **6101677 (100m)** **6102613 (100m)**	**FABB**
PROTEVS-MED-SWOT ~~protevsmed_swot~~ 2018_leg2		**6101671 15m** **6101678 15m** **6101672 15m** **6102615 15m** **6101670 50m** **6101674 50m**	**FABB**

table 2 : WMO index of Argo-float and surface drifters (SVP) dropped during PROTEVS-MED ~~Protevsmed~~ surveys. Surface temperature and salinity recorded by ThermoSalinoGraph (TSG) are tagged by ship identifier. All data are available from the CORIOLIS website http://www.coriolis.eu.org/Data-Products/Data-Delivery/Data-selection by entering the WMO numbers in the field 'Platform codes', adjusting the time period of interest (e.g., 01/01/2018 to 30/06/2019), and clicking on 'refresh'. The web interface displays the trajectories of the buoys, profilers or TSG and can be used to find additionally opportunity data. The data can then be downloaded in NetCDF format.

5 Overview of the selected observations

When d~~D~~eployed together, VMADCP and SeaSoar provided a unique synoptic view along ~~of a~~ transects. It was ~~is~~ also possible to observe simultaneously the density and the velocity fields in the sub-surface layer, showing the importance ~~predominance~~ of the geostrophy even at fine scale (in the range of 10 km~~few kilometres~~). The temperature and salinity fields were ~~are~~ patchier than expected but the thermal expansion and the saline contraction coefficient of sea water often compensate and lead to a smoother density (and thus dynamical) field. The structure of observed anticyclonic eddies appeared~~s~~ also more complex than formerly described and were~~are~~ commonly ~~currently~~ composed of many different water masses. Eddies with similar altimetric or surface thermal signatures can ~~hydrographically~~ be very different hydrographically. For instance, a dual~~-~~-core anticyclonic eddy - ~~has been~~ observed east of Menorca Island in March 2016 (figure 4~~3~~a), was composed of a superposition of Winter Intermediate Water and Atlantic Water and~~,~~ in May 2018~~,~~ a three- cores ~~levels~~ eddy has been detected (figure 4~~3~~b). The exact process of their formation ~~remain~~remainss to be investigated~~still debated~~. One can invoke the coalescence of pre-existing -eddies~~objects~~, the extraction of water masses from neighbouring structures or ageostrophic processes. Measurements reveal submesoscale (ageostrophic) dynamics both in the eddy cores (upwelling/downwelling) and at eddy edges (symmetric instabilities, frontogenesis). Intra-pycnocline structures, subducted, stirred or locally formed were commonly observed at the edge of gyres.

In the Northern Current, stirring appeared in both tracers and velocity fields and an SCV formed by LIW detached in front of Toulon (figure 4~~3~~c) was observed as confirmed by observed swirling velocities on VAMDCP records. It ~~Note that the anticyclonic SCV~~ was also topped by a surface cyclonic gyre ~~as confirmed by VMADCP record (not shown here)~~. Currents were routinely recorded and a particular attention was ~~has been~~ paid to the Northern Current dynamics as shown (figure 4~~3~~d).

The fine structure of the NBF showed the interaction between the front and the SCV's generated in the deep -convection area~~Northern part of the Basin~~. In the NBF, a shift between a surface layer front and a deep front is revealed. As long as most of the experiments presented here were performed during late winter or early spring in the vicinity of deep~~the north western~~ convection area, they frequently showed~~s~~ small scale structures that are likely- formed by convection~~post convective~~. For instance, from the n~~N~~orth to the s~~S~~outh on figure 4~~3~~e one can observe successively the - probably partial - convection area, the formation of SCVs composed of WIW in the mesoscale adjustment area around the convection chimney, the surface thermal front and finally a deeper front at 40.6° N.

Over the abyssal plain ~~next~~ near~~to~~ the bottom, classical CTD station~~casts~~ highlighted different Western Mediterranean Deep Waters (WMDW)~~-~~; besides, under the LIW layer, where the profiles foster double diffusion~~ive~~ process, staircases in temperature and salinity were commonly observed (Onken and Brambilla 2003) (figure 4~~3~~f).

MVP transects performed in February 2017, in front of C~~c~~ap Creus, across the Blanes Canyon, and off Barcelona showed cold water diving along the Catalan shelf and slope (figure 4~~3~~g). The WIW observed ~~existing~~ along the Catalan slope was relatively fresh and cold water originating ~~in-flowing~~ from the Gulf of Lion's shelf.

The WIW was progressively entrained and mixed with the AW and LIW while flowing southwards, in a less intense way than dense water cascading described by Durrieu de Madron et al. 2013.

~~The WIW took progressively place between the Atlantic Waters (AW) and the LIW as they flowed southwards.~~

Similar and extensive quick looks of all Seasoar, MVP, or Rapidcast transects and XBT, CTD profiles are plotted and available as additional resources on the data repository.

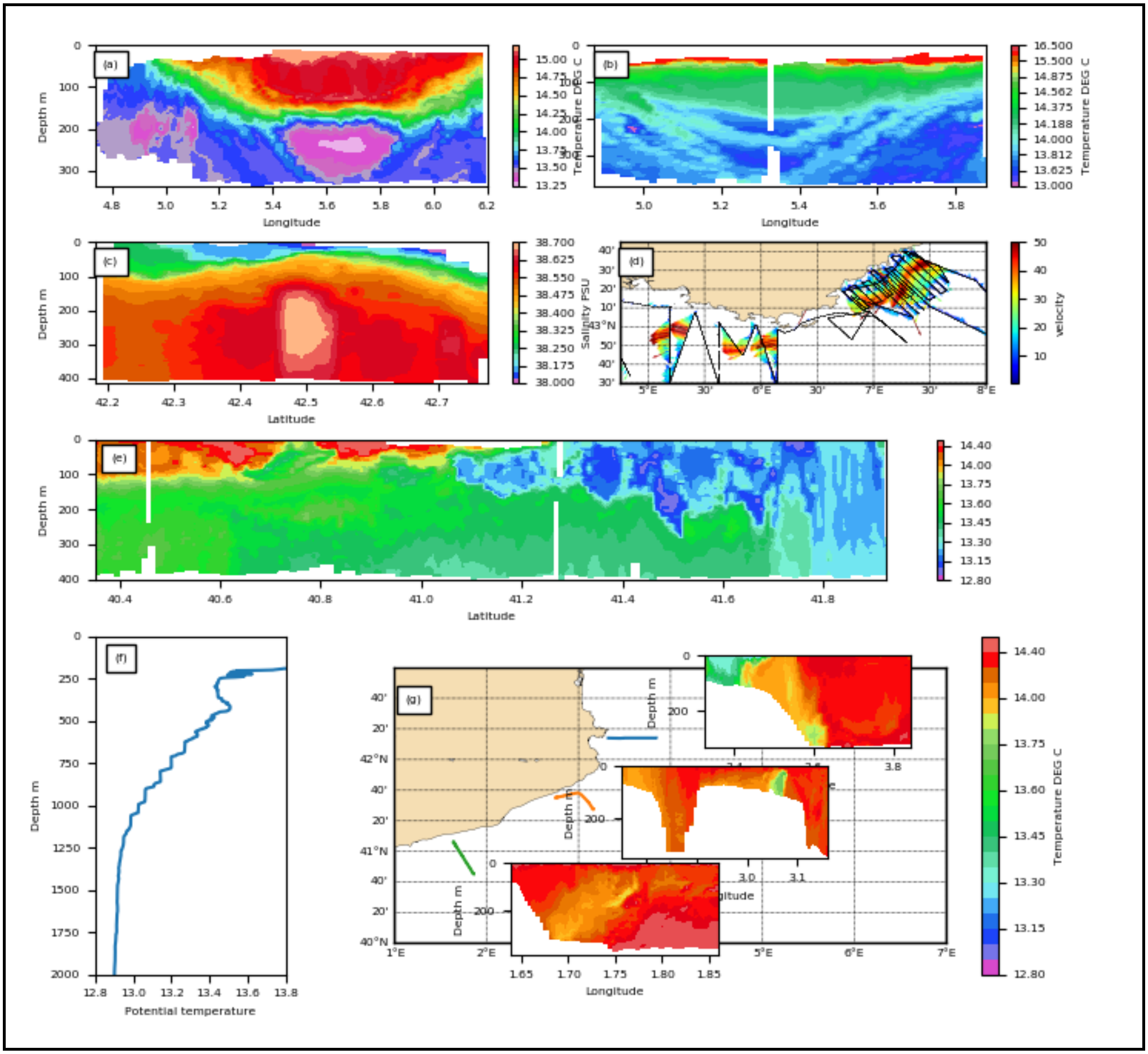

Figure 4 :3. Overview of some transects or profiles recorded during the PROTEVS-MEDProtevsmed fields experiments: (a) Dual core eddy in NBF in 2016 (39.96N:4.74E- 39.93N:6.20E), (b) Three layered eddy in Algerian Bassin (38.5N:4.87E – 38.75N:5.88E ; 2018), (c) SCV of LIW front of Toulon (42.17N:6.14E – 42.78N:6.10E ; 2015), (d) North Current position and intensity (2015), (e) cross frontal (NBF) transect (40.35N:6.43E - 41.92:4.01E ; 2017), (f) staircase in temperature front of Sardinia (2016), vein of cold water from the Gulf of Lion on Catalan sea (40.68N:7.5E ; 2017). The reader will find similar quick looks of the transects for all the surveys into the data repository.

6 Conclusions

The PROTEVS-MED dataset available through an unrestricted unique repository is an unprecedented opportunity for the community to approach the ~~very~~ fine-scale dynamics in the Western Mediterranean Sea and more largely the sub-mesoscale dynamics associated with strong mesoscale dynamics. In the framework of the high-resolution altimetry this dataset can help to characterize the scales of fine structures in the Western Mediterranean Sea and to design combined experiments using high resolution i~~I~~n-s~~S~~itu measurements (Seasoar or MVP) and altimetry with the future SWOT satellite (d'Ovidio et al., 2019). It also complements the repeated glider lines maintained in the framework of the MOOSE observatory (Coppola et al, 2019) and is useful to design future combined multi-platform experiments. ~~It should be complementary data set to usual glider one and useful to design future combined surveys.~~

During these campaigns, one ~~we~~ had the opportunity to deploy different instruments ~~devices~~ to obtain temperature, salinity and possibly other parameters profiles. Some transects have~~s~~ been performed successively using CTD and Seasoar (all surveys) or using CTD, Seasoar and MVP-200 (PROTEVS-MED ~~Protevsmed~~ 2017). Easy to manage, the Rapidcast has only been ~~only~~ tested and used~~used for test and~~ as instant spare in 2018 when the Seasoar failed. It produced a similar result to the Seasoar in temperature and salinity. The SeaSoar is heavy to manage, needs a consequent research vessel for the winch system, a constant watch on its navigation and calm sea state for ~~water~~ launch~~ing~~ and recovery. Once deployed, the machine can stay at sea for days. Thanks to the required ship velocity (about 9 knots), the SeaSoar remains a perfect platform ~~machine~~ to identify~~drive out~~ mesoscale structures before examining them in detail. It explores the oceanic surface layer down ~~up~~ to 400 m deep which is sometimes a little bit too short in Mediterranean context, missing deeper part of AEs or deep SCVs but sufficient to ~~describes the~~ describe important surface and subsurface dynamical features~~main part of the dynamics~~. For the same depth range ~~a~~an MVP-200 requires a ship velocity about 2-4 knots and is then more devoted to short transect with higher horizontal resolution. As it is a free-fall platform~~vector~~, its setting ~~up~~ is lighter, despite regular inspection of the cable and winch every 10 hours. In any case, when exploring a structure in detail, a CTD network remains necessary, at least to have a valid reference level for the thermal wind equation and hydrography.

Despite the suspected lack of accuracy of the sensors due to the velocity of the platform~~vector~~s (Seasoar, MVP, RapidCast), this experiment of~~it is demonstrated in these datasets that~~ fast and high-resolution sampling revealed~~s~~ fine oceanic patterns never described before in the Western Mediterranean. In situ observations of ageostrophic dynamics remain rare and the synergy between these observations and theory, and then between these observations and modelling, should be very fruitful. ~~In situ observations of ageostrophic dynamics remain scarce and the back and forth between these observations and theory, then between these observations and modelling should be very fruitful.~~ These data should contribute to the knowledge of small scales and fill some of the gaps in observing system in the Mediterranean Sea (Tintore et al., 2019). As numerical modelling gain in resolution (in the range of~~(until a~~ few hundred meters), the simulation of sub-mesoscale processes (layering, subduction, stirring, vertical velocities) is therefore expected and this dataset, providing data at similar scales, is an opportunity to validate the secondary simulated circulation.

Authors contributions

Louazel S., Correard S., Garreau P., and Dumas F. designed and conducted the field experiments as PI. Marc Le Menn managed the calibration and the metrological traceability of SBE sensors. Valerie Garnier has carefully checked the dataset. All co-authors carried them out, participated to the cruise or processed the data. Garreau P. and Dumas F. prepared the manuscript and the data with contributions from all co-authors.

Competing interests.

The authors declare that they have no conflict of interest.

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Data Availability and Repository

Data are freely available on SEANOE repository (https://doi.org/10.17882/62352; Dumas 2018). Some parts of the data are already under investigations or publications; the authors would appreciate collaboration proposals. For a first overview quick looks of all Seasoar, MVP, or Rapidcast transects and XBT, CTD profiles are available in catalogues on the repository.

Seasoar, MVP, RapidCast, CTD, LADCP and XBT data are stored in both CSV (ASCII) and Netcdf files for "L1" (directly extracted from the instrument or constructor software), in Netcdf for "L2" (resampled every meter) files;

For TSG, the present database provides only L1 files; L2 (validated and resampled data) are available on dedicated repository (see table 2).

For the sake of simplicity, VMADCP files were concatenated over each cruise duration to provide a single file per cruise; for a given cruise, the data are a function of time and depth within the single file dedicated to the cruise

Data are displayed by cruises and instruments and the syntax is :

intrument_data-type_cruises_starting-date-of-record_index.file-type , where
instruments = ctd,seasoar,ladcp,xbt,rapidcast,mvp,vmadcp_xxx
data-type = “L1” or “L2”
cruises = cruise and leg name
date = the date of the first record in the file.
index = sequential index of this kind of profile recorded during the cruise.
file-type = csv(.csv) or netcdf(.nc)

Additionally, data extracted from on-board automatic acquisition are provided in Netcdf file for the ship navigation. Future PROTEVS-MED PROTEVS_MED experiments are scheduled and results will be added to the repository.

References

Allen, J.T., Smeed, D.A., Tintoré, J., Ruiz, S.: Mesoscale subduction at the Almeria–Oran front: Part 1: Ageostrophic flow. Journal of Marine Systems 30, 263–285. https://doi.org/10.1016/S0924-7963(01)00062-8, 2001.

Allen, J. T., Painter, S. C., & Rixen, M.: Eddy transport of Western Mediterranean Intermediate Water to the Alboran Sea. *Journal of Geophysical Research: Oceans*, *113*(C4), C04024. https://doi.org/10.1029/2007JC004649, 2008

Aulicino, G., Cotroneo, Y., Ruiz, S., Sánchez Román, A., Pascual, A., Fusco, G., Tintoré, J., Budillon, G.: Monitoring the Algerian Basin through glider observations, satellite altimetry and numerical simulations along a SARAL/AltiKa track. Journal of Marine Systems 179, 55–71. https://doi.org/10.1016/j.jmarsys.2017.11.006, 2018.

Aulicino, G.; Cotroneo, Y.; Olmedo, E.; Cesarano, C.; Fusco, G.; Budillon, G. In Situ and Satellite Sea Surface Salinity in the Algerian Basin Observed through ABACUS Glider Measurements and BEC SMOS Regional Products. *Remote Sens.* **2019**, *11*, 1361. **https://doi.org/10.3390/rs11111361**

Barceló-Llull, B., Pascual A., Díaz Barroso L., Sánchez-Román A., Casas B., Muñoz C., Torner M., Alou E., Cutolo E., Mourre B., Allen J., Aulicino G., Cabornero A., Calafat N., Capó E., Cotroneo Y., Cyr F., Doglioli A., d'Ovidio F., Dumas F., Fernández J.G., Gómez Navarro L., Gregori G., Hernández-Lasheras J., Mahadevan A., Mason E., Miralles A., Roque D., Rubio M., Ruiz I., Ruiz S., Ser-Giacomi

E. and Toomey T.: PRE-SWOT Cruise Report. Mesoscale and sub-mesoscale vertical exchanges from multi-platform experiments and supporting modeling simulations: anticipating SWOT launch (CTM2016-78607-P). 138 pp. https://digital.csic.es/handle/10261/172644, 2019

Borrione, I., Falchetti, S., Alvarez, A.: Physical and dynamical characteristics of a 300m-deep anticyclonic eddy in the Ligurian Sea (Northwest Mediterranean Sea): Evidence from a multi-platform sampling strategy. Deep Sea Research Part I: Oceanographic Research Papers 116, 145–164. https://doi.org/10.1016/j.dsr.2016.07.013, 2016

Bosse, A., Testor, P., Mortier, L., Prieur, L., Taillandier, V., d'Ortenzio, F., Coppola, L.: Spreading of Levantine Intermediate Waters by submesoscale coherent vortices in the northwestern Mediterranean Sea as observed with gliders. J. Geophys. Res. Oceans 120, 1599–1622. https://doi.org/10.1002/2014JC010263., 2015

Bosse, A., Testor, P., Houpert, L., Damien, P., Prieur, L., Hayes, D., Taillandier, V., Durrieu de Madron, X., d'Ortenzio, F., Coppola, L., Karstensen, J., Mortier, L.: Scales and dynamics of Submesoscale Coherent Vortices formed by deep convection in the northwestern Mediterranean Sea. J. Geophys. Res. Oceans 121, 7716–7742. https://doi.org/10.1002/2016JC012144., 2016

Bosse, A., Testor, P., Mayot, N., Prieur, L., D'Ortenzio, F., Mortier, L., Goff, H.L., Gourcuff, C., Coppola, L., Lavigne, H., Raimbault, P. : A submesoscale coherent vortex in the Ligurian Sea: From dynamical barriers to biological implications. Journal of Geophysical Research: Oceans 122, 6196–6217. https://doi.org/10.1002/2016JC012634, 2017

Cabanes, C., Grouazel A., von Schuckmann K., Hamon M., Turpin V., Coatanoan C., Paris F., Guinehut S., Boone C., Ferry N., de Boyer Montégut C., Carval T., Reverdin G., Pouliquen S., and Le Traon P.Y: The CORA dataset: validation and diagnostics of in-situ ocean temperature and salinity measurements, Ocean Sci., 9, 1-18, https://doi.org/10.5194/os-9-1-2013, 2013

Carret, A., Birol, F., Estournel, C., Zakardjian, B., Testor, P: Synergy between in situ and altimetry data to observe and study Northern Current variations (NW Mediterranean Sea). Ocean Science 15, 269–290. https://doi.org/10.5194/os-15-269-2019, 2019

Coppola, L., P. Raimbault, L. Mortier, and P. Testor : Monitoring the environment in the northwestern Mediterranean Sea, *Eos, 100,* https://doi.org/10.1029/2019EO125951 2019.

Cotroneo, Y., Aulicino, G., Ruiz, S., Pascual, A., Budillon, G., Fusco, G., Tintoré, J.: Glider and satellite high resolution monitoring of a mesoscale eddy in the algerian basin: Effects on the mixed layer depth and biochemistry. Journal of Marine Systems. https://doi.org/10.1016/j.jmarsys.2015.12.004, 2019

Cotroneo, Y., Aulicino, G., Ruiz, S., Sánchez Román, A., Torner Tomàs, M., Pascual, A., Fusco, G., Heslop, E., Tintoré, J., Budillon, G.: Glider data collected during the Algerian Basin Circulation Unmanned Survey. Earth System Science Data 11, 147–161. https://doi.org/10.5194/essd-11-147-2019, 2019

Durrieu de Madron, X., Houpert, L., Puig, P., Sanchez-Vidal, A., Testor, P., Bosse, A., Estournel, C., Somot, S., Bourrin, F., Bouin, M.N., Beauverger, M., Beguery, L., Calafat, A., Canals, M., Cassou, C., Coppola, L., Dausse, D., D'Ortenzio, F., Font, J., Heussner, S., Kunesch, S., Lefevre, D., Le Goff, H., Martín, J., Mortier, L., Palanques, A., Raimbault, P. : Interaction of dense shelf water cascading and open-sea convection in the northwestern Mediterranean during winter 2012. Geophysical Research Letters 40, 1379-1385. , 2013.

de Verneil, A. de, Rousselet, L., Doglioli, A.M., Petrenko, A.A., Moutin, T.: The fate of a southwest Pacific bloom: gauging the impact of submesoscale vs. mesoscale circulation on biological gradients in the subtropics. Biogeosciences 14, 3471–3486. https://doi.org/10.5194/bg-14-3471-2017, 2017

d'Ovidio, F., V. Fernández, E. Hernández-García, and C. López (2004), Mixing structures in the Mediterranean Sea from finite-size Lyapunov exponents, *Geophys. Res. Lett.*, **31**, L17203, doi:10.1029/2004GL020328.

d'Ovidio, F., Pascual, A., Wang, J., Doglioli, A.M., Jing, Z., Moreau, S., Grégori, G., Swart, S., Speich, S., Cyr, F., Legresy, B., Chao, Y., Fu, L., Morrow, R.A: Frontiers in Fine-Scale in situ Studies: Opportunities During the SWOT Fast Sampling Phase. Front. Mar. Sci. 6. https://doi.org/10.3389/fmars.2019.00168, 2019

Dumas, F., Garreau, P., Louazel, S., Correard, S., Fercoq, S., Le Menn, M., Serpette, A., Garnier, V., Stegner, A., Le Vu, B., Doglioli, A., Gregori, G.: PROTEVS-MED field experiments: Very High Resolution Hydrographic Surveys in the Western Mediterranean Sea. SEANOE. https://doi.org/10.17882/62352, 2018

Escudier, R., Mourre, B., Juza, M., Tintoré, J.:Subsurface circulation and mesoscale variability in the Algerian subbasin from altimeter-derived eddy trajectories. J. Geophys. Res. Oceans 121, 6310–6322. https://doi.org/10.1002/2016JC011760, 2016a

Escudier, R., Renault, L., Pascual, A., Brasseur, P., Chelton, D., Beuvier, J.: Eddy properties in the Western Mediterranean Sea from satellite altimetry and a numerical simulation. Journal of Geophysical Research: Oceans 121, 3990–4006. https://doi.org/10.1002/2015JC011371, 2016b

Estournel, C., Testor, P., Taupier-Letage, I., Bouin, M.-N., Coppola, L., Durand, P., Conan, P., Bosse, A., Brilouet, P.-E., Beguery, L., Belamari, S., Béranger, K., Beuvier, J., Bourras, D., Canut, G., Doerenbecher, A., Durrieu de Madron, X., D'Ortenzio, F., Drobinski, P., Ducrocq, V., Fourrié, N., Giordani, H., Houpert, L., Labatut, L., Lebeaupin Brossier, C., Nuret, M., Prieur, L., Roussot, O., Seyfried, L., Somot, S.: HyMeX-SOP2: The Field Campaign Dedicated to Dense Water Formation in the Northwestern Mediterranean. Oceanography 29, 196–206. https://doi.org/10.5670/oceanog.2016.94, 2016

Gaillard, F., Diverres, D., Jacquin, S., Gouriou, Y., Grelet, J., Menn, M.L., Tassel, J., Reverdin, G.: Sea surface temperature and salinity from French research vessels, 2001–2013. Scientific Data 2, 150054. https://doi.org/10.1038/sdata.2015.54, 2015

Garreau, P., Dumas, F., Louazel, S., Stegner, A., Le Vu, B.: High-Resolution Observations and Tracking of a Dual-Core Anticyclonic Eddy in the Algerian Basin. *Journal of Geophysical Research: Oceans* 123, 9320–9339. https://doi.org/10.1029/2017JC013667, 2018

Giordani, H., Lebeaupin-Brossier, C., Léger, F., Caniaux, G. : A PV-approach for dense water formation along fronts: Application to the Northwestern Mediterranean. Journal of Geophysical Research: Oceans 122, 995–1015. https://doi.org/10.1002/2016JC012019 , 2017.

Gosud : GOSUD -Global Ocean Surface Underway data. SEANOE. https://doi.org/10.17882/47403 2016

Heslop, E.E., Sánchez-Román, A., Pascual, A., Rodríguez, D., Reeve, K.A., Faugère, Y., Raynal, M.: Sentinel-3A Views Ocean Variability More Accurately at Finer Resolution. Geophysical Research Letters 44, 12,367-12,374. https://doi.org/10.1002/2017GL076244, 2017

Houpert, L., Durrieu de Madron, X., Testor, P., Bosse, A., D'Ortenzio, F., Bouin, M.N., Dausse, D., Le Goff, H., Kunesch, S., Labaste, M., Coppola, L., Mortier, L., Raimbault, P.: Observations of open-ocean deep convection in the northwestern Mediterranean Sea: Seasonal and interannual variability of mixing and deep water masses for the 2007-2013 Period. *Journal of Geophysical Research: Oceans.* https://doi.org/10.1002/2016JC011857, 2016

JCOMM, 2015: Pilot intercomparison project for seawater salinity measurements, final report. World Meteorological Organization (WMO) ; Intergovernmental Oceanographic Commission : *JCOMM technical report* n° 84. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwiwl9DZ1drkAhUN6OAKHTZ5BVUQFjAAegQIBRAB&url=https%3A%2F%2Flibrary.wmo.int%2Findex.php%3Flvl%3Dnotice_display%26id%3D17098&usg=AOvVaw0vKzR29aSHFtFLIagpY0vo, 2015

Jones, H., Marshall, J.: Convection with Rotation in a Neutral Ocean: A Study of Open-Ocean Deep Convection. J. Phys. Oceanogr. 23, 1009–1039. https://doi.org/10.1175/1520-0485(1993)023<1009:CWRIAN>2.0.CO;2, ., 1993.

Jones, H., Marshall, J.: Restratification after Deep Convection. J. Phys. Oceanogr. 27, 2276–2287. https://doi.org/10.1175/1520-0485(1997)027<2276:RADC>2.0.CO;2, 1997

Knoll, M., Borrione, I., Fiekas, H.-V., Funk, A., Hemming, M.P., Kaiser, J., Onken, R., Queste, B., Russo, A.: Hydrography and circulation west of Sardinia in June 2014. Ocean Science 13, 889–904. https://doi.org/10.5194/os-13-889-2017, 2017

Le Menn, M.: About uncertainties in practical salinity calculations. *Ocean Science*, *7*(5), 651-659. https://doi.org/10.5194/os-7-651-2011, . 2011

Le Vu, B., Stegner, A., Arsouze, T.: Angular Momentum Eddy Detection and Tracking Algorithm (AMEDA) and Its Application to Coastal Eddy Formation. *J. Atmos. Oceanic Technol*. 35, 739–762. https://doi.org/10.1175/JTECH-D-17-0010.1, 2017

Lévy, M., Ferrari, R., Franks, P.J.S., Martin, A.P., Rivière, P.: Bringing physics to life at the submesoscale. Geophysical Research Letters 39. https://doi.org/10.1029/2012GL052756, 2012

Lévy, M., Franks, P. J., & Smith, K. S.: The role of submesoscale currents in structuring marine ecosystems. *Nature communications*, *9*(1), 4758., 2018

Marshall, J., Schott, F. : Open-ocean convection: Observations, theory, and models. Rev. Geophys. 37, 1–64. https://doi.org/10.1029/98RG02739, 1999

McWilliams, J.C.: Submesoscale, coherent vortices in the ocean, Rev. Geophys., 23(2), 165, doi:10.1029/RG023i002p00165, 1985

McWilliams James C.: Submesoscale currents in the ocean. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences 472, 20160117. https://doi.org/10.1098/rspa.2016.0117, 2016

Medoc Group : Observation of Formation of Deep Water in the Mediterranean Sea1969. Nature 227, 1037–1040. https://doi.org/10.1038/2271037a0 ,1970.

Meloni, M., Bouffard, J., Doglioli, A.M., Petrenko, A.A., Valladeau, G.: Toward science-oriented validations of coastal altimetry: application to the Ligurian Sea. Remote Sens.Envir., 224, 275-288, https://doi.org/10.1016/j.rse.2019.01.028, 2019

Margirier, F., Bosse, A., Testor, P., L'Hévéder, B., Mortier, L., Smeed, D.: Characterization of Convective Plumes Associated With Oceanic Deep Convection in the Northwestern Mediterranean

From High-Resolution In Situ Data Collected by Gliders. Journal of Geophysical Research: Oceans 122, 9814–9826. https://doi.org/10.1002/2016JC012633, 2017

Marrec, P., Grégori, G., Doglioli, A.M., Dugenne, M., Della Penna, A., Bhairy, N., Cariou, T., Hélias Nunige, S., Lahbib, S., Rougier, G., Wagener, T., Thyssen M.: Coupling physics and biogeochemistry thanks to high resolution observations of the phytoplankton community structure in the North-Western Mediterranean Sea. Biogeosciences, 15, 1579-1606, doi:10.5194/bg-15-1579-2018, 2018

Millot, C., Taupierletage, I., Benzohra, M.: The Algerian Eddies. Earth-Sci. Rev. 27, 203–219. https://doi.org/10.1016/0012-8252(90)90003-E, 1990

Millot, C.: Circulation in the Western Mediterranean Sea. Journal of Marine Systems 20, 423–442. https://doi.org/10.1016/S0924-7963(98)00078-5, 1999

Millot, C., Taupier-Letage, I. : Circulation in the Mediterranean Sea, in : The Mediterranean Sea, Handbook of Environmental Chemistry, edited by: Saliot, A., Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 29–66. https://doi.org/10.1007/b107143, 2005

Nencioli, F., d'Ovidio, F., Doglioli, A.M., Petrenko, A.A. : Surface coastal circulation patterns by in-situ detection of Lagrangian coherent structures. Geophysical Research Letters 38. https://doi.org/10.1029/2011GL048815, 2011

Niewiadomska, K., Claustre, H., Prieur, L., d'Ortenzio, F.: Submesoscale physical-biogeochemical coupling across the Ligurian current (northwestern Mediterranean) using a bio-optical glider. Limnology and Oceanography 53, 2210–2225. https://doi.org/10.4319/lo.2008.53.5_part_2.2210 . 2008

Onken, R., Brambilla, E. : Double diffusion in the Mediterranean Sea: Observation and parameterization of salt finger convection. Journal of Geophysical Research: Oceans 108. https://doi.org/10.1029/2002JC001349 , 2003.

Onken, R., Fiekas, H.-V., Beguery, L., Borrione, I., Funk, A., Hemming, M., Hernandez-Lasheras, J., Heywood, K.J., Kaiser, J., Knoll, M., Mourre, B., Oddo, P., Poulain, P.-M., Queste, B.Y., Russo, A., Shitashima, K., Siderius, M., Thorp Küsel, E.: High-resolution observations in the western Mediterranean Sea: the REP14-MED experiment. Ocean Science 14, 321–335. https://doi.org/10.5194/os-14-321-2018, 2018

Pascual, A., Ruiz, S., Olita, A., Troupin, C., Claret, M., Casas, B., Mourre, B., Poulain, P.-M., Tovar-Sanchez, A., Capet, A., Mason, E., Allen, J.T., Mahadevan, A., Tintoré, J.: A Multiplatform Experiment to Unravel Meso- and Submesoscale Processes in an Intense Front (AlborEx). Front. Mar. Sci. 4. https://doi.org/10.3389/fmars.2017.00039, 2017

Petrenko, A.A., Doglioli, A.M., Nencioli, F., Kersalé, M., Hu, Z., d'Ovidio, F.: A review of the LATEX project: mesoscale to submesoscale processes in a coastal environment. Ocean Dynam., 67:513, https://doi.org/doi:10.1007/s10236-017-1040-9, 2017

Puillat, I., Taupier-Letage, I., Millot, C.: Algerian Eddies lifetime can near 3 years. Journal of Marine Systems 31, 245–259. https://doi.org/10.1016/S0924-7963(01)00056-2, 2002

Robinson, A. R., Leslie W. G., Theocharis, A. and Lascaratos, A.: Mediterranean Sea Circulation, Encyclopedia of Ocean Sciences, Academic, London, vol. 3, chap., pp. 1689–1705, doi:10.1006/rwos.2001.0376, 2001

Rousselet L., Doglioli, A.M., de Verneil, A., Pietri, A., Della Penna, A., Berline, L., Marrec, P., Gregori, G., Thyssen, M., Carlotti, F., Barillon, S., Simon-Bot, F., Bonal, M., d'Ovidio, F. and Petrenko, A.A.: Vertical motions and their effects on a biogeochemical tracer in a cyclonic structure finely observed in the Ligurian Sea. J.Geophys.Res., 124, https://doi.org/10.1029/2018JC014392, 2019

Ruiz, S., Pascual, A., Garau, B., Faugère, Y., Alvarez, A., Tintoré, J.: Mesoscale dynamics of the Balearic Front, integrating glider, ship and satellite data. Journal of Marine Systems, Coastal Processes: Challenges for Monitoring and Prediction 78, S3–S16. https://doi.org/10.1016/j.jmarsys.2009.01.007, 2009

Salat, J., Emelianov, M., Frail, E., Latasa, M.: After deep water formation: sinking and spreading or reorganising phase, including upwelling? Rapp. Comm. int. Mer Médit.40. http://www.ciesm.org/online/archives/abstracts/pdf/40/PG_0175.pdf, 2013

Schott, F., Visbeck, M., Send, U., Fischer, J., Stramma, L., Desaubies, Y. : Observations of Deep Convection in the Gulf of Lions, Northern Mediterranean, during the Winter of 1991/92. J. Phys. Oceanogr. 26, 505–524. https://doi.org/10.1175/1520-0485(1996)026<0505:OODCIT>2.0.CO;2 , 1996.

Send, U., Font, J., Krahmann, G., Millot, C., Rhein, M., Tintoré, J.: Recent advances in observing the physical oceanography of the western Mediterranean Sea. Progress in Oceanography 44, 37–64. https://doi.org/10.1016/S0079-6611(99)00020-8, 1999

Szekely, T., Gourrion, J., Pouliquen, S., Reverdin, G.: CORA, Coriolis Ocean Dataset for Reanalysis. SEANOE. http://doi.org/10.17882/46219, 2016

Taupier-Letage, I., Puillat, I., Millot, C., Raimbault, P.: Biological response to mesoscale eddies in the Algerian Basin. Journal of Geophysical Research: Oceans 108. https://doi.org/10.1029/1999JC000117, 2003

Testor, P., Gascard, J.-C. : Large-Scale Spreading of Deep Waters in the Western Mediterranean Sea by Submesoscale Coherent Eddies. J. Phys. Oceanogr. 33, 75–87. https://doi.org/10.1175/1520-0485(2003)033<0075:LSSODW>2.0.CO;2 , 2003

Testor, P., Gascard, J.-C. :Post-convection spreading phase in the Northwestern Mediterranean Sea. Deep Sea Research Part I: Oceanographic Research Papers 53, 869–893. https://doi.org/10.1016/j.dsr.2006.02.004 , 2006.

Testor, P., Bosse, A., Houpert, L., Margirier, F., Mortier, L., Legoff, H., Dausse, D., Labaste, M., Karstensen, J., Hayes, D., Olita, A., Ribotti, A., Schroeder, K., Chiggiato, J., Onken, R., Heslop, E., Mourre, B., D'Ortenzio, F., Mayot, N., Lavigne, H., de Fommervault, O., Coppola, L., Prieur, L., Taillandier, V., Durrieu de Madron, X., Bourrin, F., Many, G., Damien, P., Estournel, C., Marsaleix, P., Taupier-Letage, I., Raimbault, P., Waldman, R., Bouin, M.-N., Giordani, H., Caniaux, G., Somot, S., Ducrocq, V., Conan, P.: Multiscale Observations of Deep Convection in the Northwestern Mediterranean Sea During Winter 2012-2013 Using Multiple Platforms. J. Geophys. Res. Oceans 123,1745-1776 https://doi.org/10.1002/2016JC012671, 2018

Tintore, J., Pinardi, N., Álvarez-Fanjul, E., Aguiar, E., Álvarez-Berastegui, D., Bajo, M., Balbin, R., Bozzano, R., Nardelli, B.B., Cardin, V., Casas, B., Charcos-Llorens, M., Chiggiato, J., Clementi, E., Coppini, G., Coppola, L., Cossarini, G., Deidun, A., Deudero, S., D'Ortenzio, F., Drago, A., Drudi, M., El Serafy, G., Escudier, R., Farcy, P., Federico, I., Fernández, J.G., Ferrarin, C., Fossi, C., Frangoulis, C., Galgani, F., Gana, S., García Lafuente, J., Sotillo, M.G., Garreau, P., Gertman, I., Gómez-Pujol, L., Grandi, A., Hayes, D., Hernández-Lasheras, J., Herut, B., Heslop, E., Hilmi, K., Juza, M., Kallos, G., Korres, G., Lecci, R., Lazzari, P., Lorente, P., Liubartseva, S., Louanchi, F., Malacic, V., Mannarini, G., March, D., Marullo, S., Mauri, E., Meszaros, L., Mourre, B., Mortier, L., Muñoz-Mas, C., Novellino, A., Obaton, D., Orfila, A., Pascual, A., Pensieri, S., Pérez Gómez, B., Pérez Rubio, S., Perivoliotis, L., Petihakis, G., de la Villéon, L.P., Pistoia, J., Poulain, P.-M., Pouliquen, S., Prieto, L., Raimbault, P., Reglero, P., Reyes, E., Rotllan, P., Ruiz, S., Ruiz, J., Ruiz, I., Ruiz-Orejón, L.F., Salihoglu, B., Salon, S., Sammartino, S., Sánchez Arcilla, A., Sánchez-Román, A., Sannino, G., Santoleri, R., Sardá, R., Schroeder, K., Simoncelli, S., Sofianos, S., Sylaios, G., Tanhua, T., Teruzzi, A., Testor, P., Tezcan, D., Torner, M., Trotta, F., Umgiesser, G., von Schuckmann, K., Verri, G., Vilibic, I., Yucel, M., Zavatarelli, M., Zodiatis, G.: Challenges for Sustained Observing and Forecasting Systems in the Mediterranean Sea. Front. Mar. Sci. 6. https://doi.org/10.3389/fmars.2019.00568, 2019

Troupin, C., Pascual, A., Ruiz, S., Olita, A., Casas, B., Margirier, F., Poulain, P.-M., Notarstefano, G., Torner, M., Fernández, J.G., Rújula, M.À., Muñoz, C., Alou, E., Ruiz, I., Tovar-Sánchez, A., Allen, J.T., Mahadevan, A., Tintoré, J.: The AlborEX dataset: sampling of sub-mesoscale features in the Alboran Sea. Earth System Science Data 11, 129–145. https://doi.org/10.5194/essd-11-129-2019, 2019

Visbeck, M.: Deep Velocity Profiling Using Lowered Acoustic Doppler Current Profilers: Bottom Track and Inverse Solutions. J. Atmos. Oceanic Technol. 19, 794–807. https://doi.org/10.1175/1520-0426(2002)019<0794:DVPULA>2.0.CO;2, 2002