Analysis of specific water masses transports in the Western Mediterranean in the MEDRYS1V2 twenty-one-year reanalysis

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Objectives :

Gain insights the Western Mediterranean functioning with a focus on water mass exchange and mixing between sub-basins

Approach :

Compute water mass specific tranports and mixing from a twenty-one-year reanalysis (MEDRYS1V2 [1])

Method :

A low computation time algorithm to flag water mass using simple mixing rules, estimate corresponding transports and derive water mass budgets over key areas (Ligurian Sea, Gulf of Lion, Balearic Sea and Algerian basin)

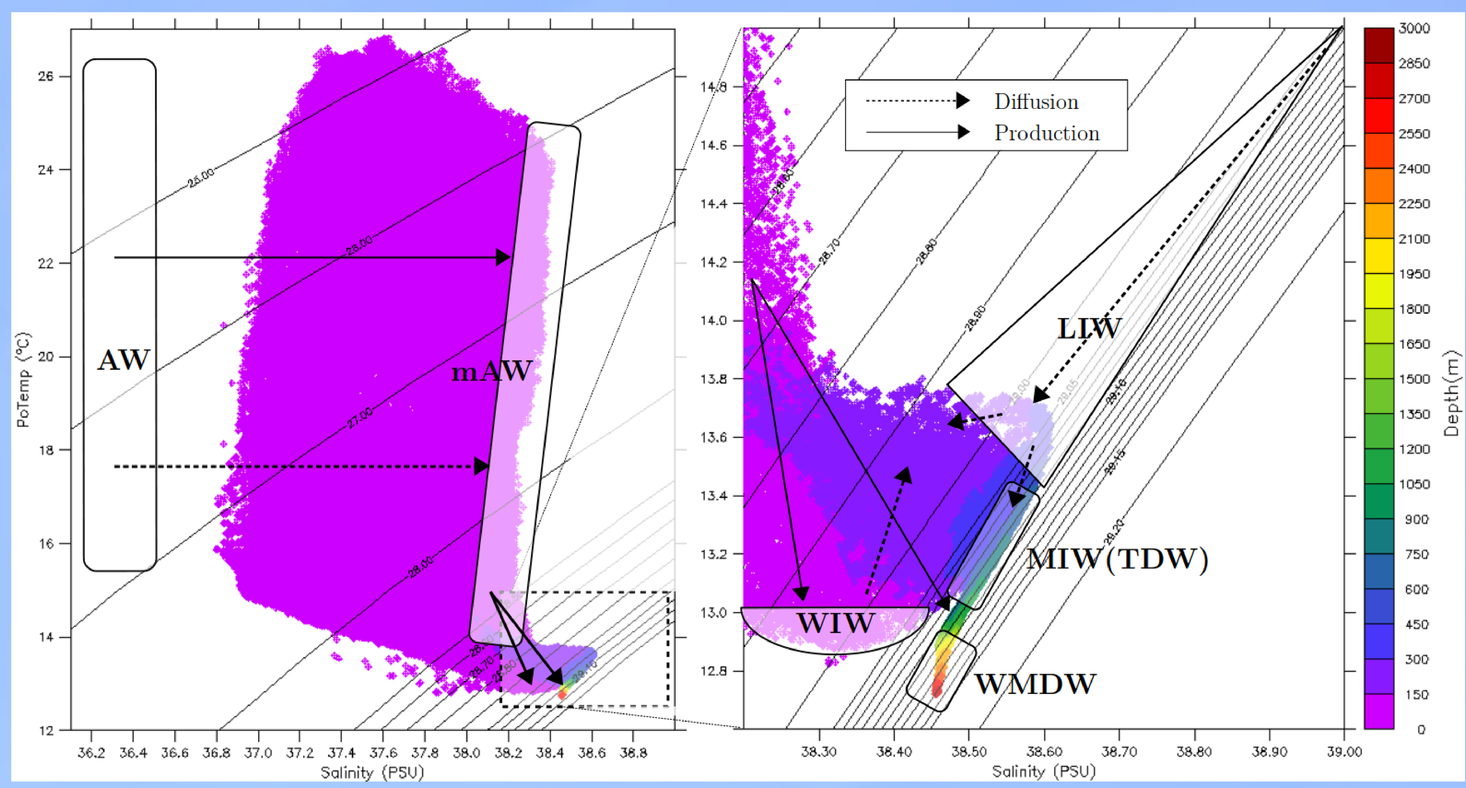

Figure 1. θ-S diagram of the long-term averaged fields from the MEDRYS1V2 in the Algero-provençal basin illustrationg the scheme of fabrication and mixing of the known water masses

Known water mass in the Western Mediterranean [2] (Fig.1):

1) Atlantic Water (AW)
⇒ inflow through the Strait of Gibraltar
2) modified AW (mAW)
⇒ saltier AW due to evaporation and mixing with Mediterranean resident surface waters
3) Western Intermediate Water (WIW)
⇒ wind cooled mAW over the Gulf of Lion and Catalan shelves in winter
4) Levantine Intermediate Water (LIW)
⇒ incoming from Eastern Mediterranean
5) Mediterranean Intermediate (MIW) or Tyrrhenian Deep Water (TDW)
⇒ convection of mAW/WIW/LIW in winter over the Gulf of Lion area and sinking of LIW in the southern Tyrrhenian Sea
6) Western Mediterranean Deep Water (WMDW)
⇒ deep convection of all other water masses in winter in the Gulf of Lion area

Water Masses flagging

Figure 2 shows how :
- AW (36,1 PSU) and mAW (38,45 PSU) are flagged using a salinity fraction.
- WIW is flagged from mAW using a temperature fraction between 12,6°C and 13,1°C.
- LIW (39,1 PSU) is flagged using two salinity fractions, over (with mAW) and under 29,06 kg.m^{-3} (WMDW).
- WMDW (38,48 PSU) is flagged with others using salinity and density fractions (for $\sigma_\theta < 29{,}11$ kg.m^{-3}).
- MIW ($29{,}06 < \sigma_\theta < 29{,}11$ kg.m^{-3}) is flagged using a density fraction.

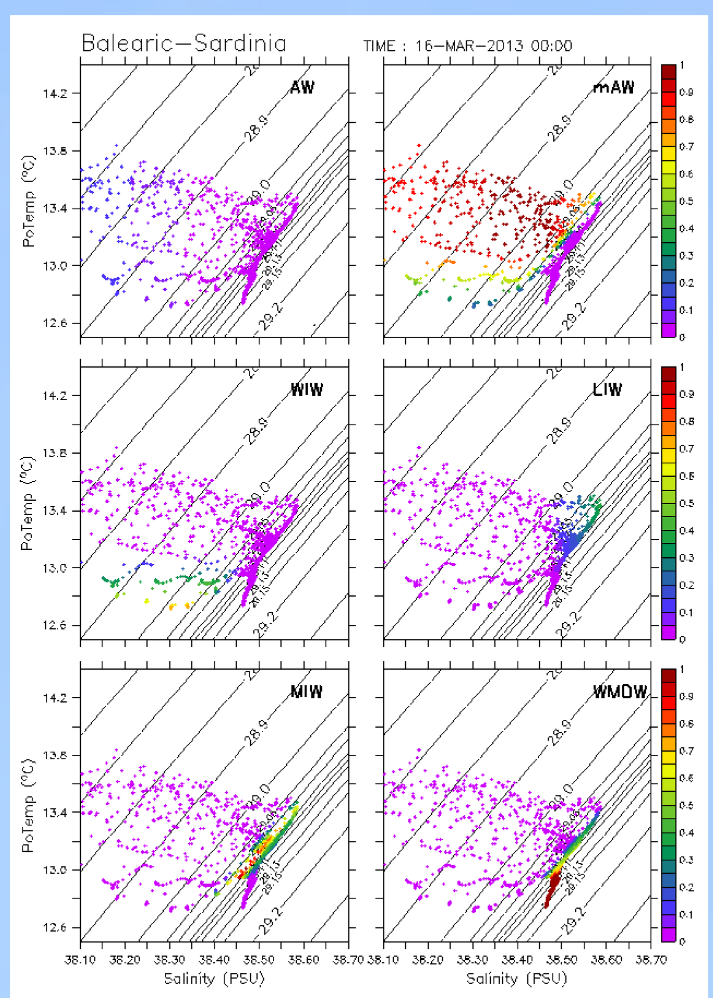

Figure 2. Example of a daily TS diagram (March 16, 2013) with flagged water masses (∅) along a transect form Menorca to the South of Sardinia

Daily analysis

In figure 3, flagged AW properly overlays mAW.

Flagged WIW preferentially flows along Menorca.

Flagged LIW preferentially follows the Sardinian coast.

WMDW is the deepest.
MIW properly floats over WMDW.

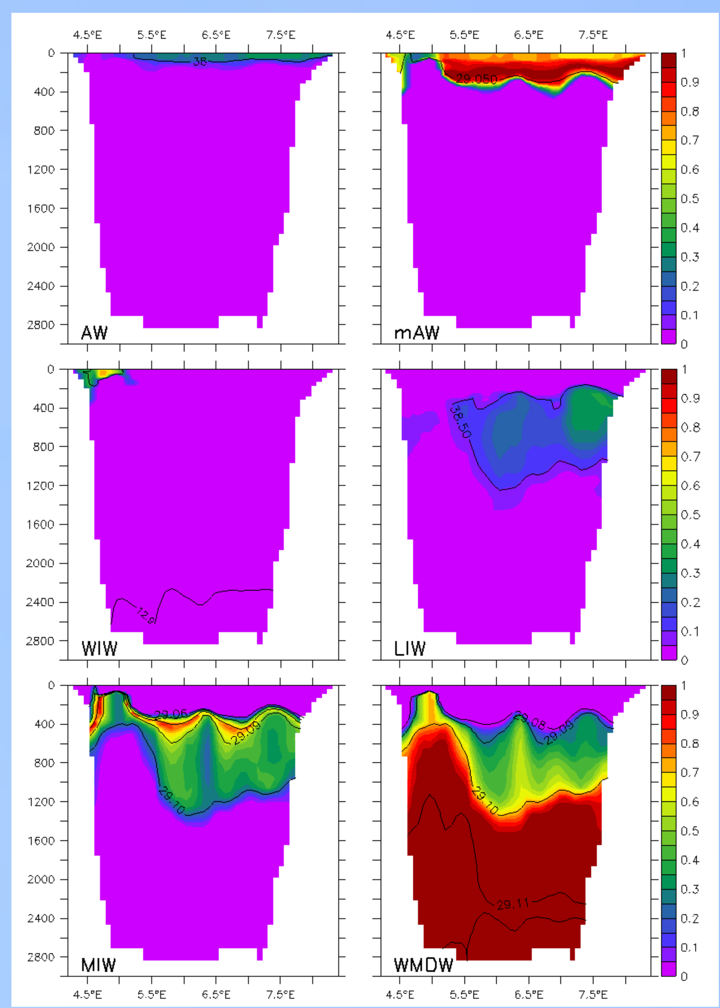

Figure 3. Daily water masses' vertical distribution (∅) corresponding to the example showed Fig. 2

Transport estimates

AW flows in the Algerian Current within the Algerian Eddies.

mAW is mixed and flows in the Northern Current.

WIW, WMDW and MIW are created in the Provençal Basin.

LIW comes from Eastern Basin.

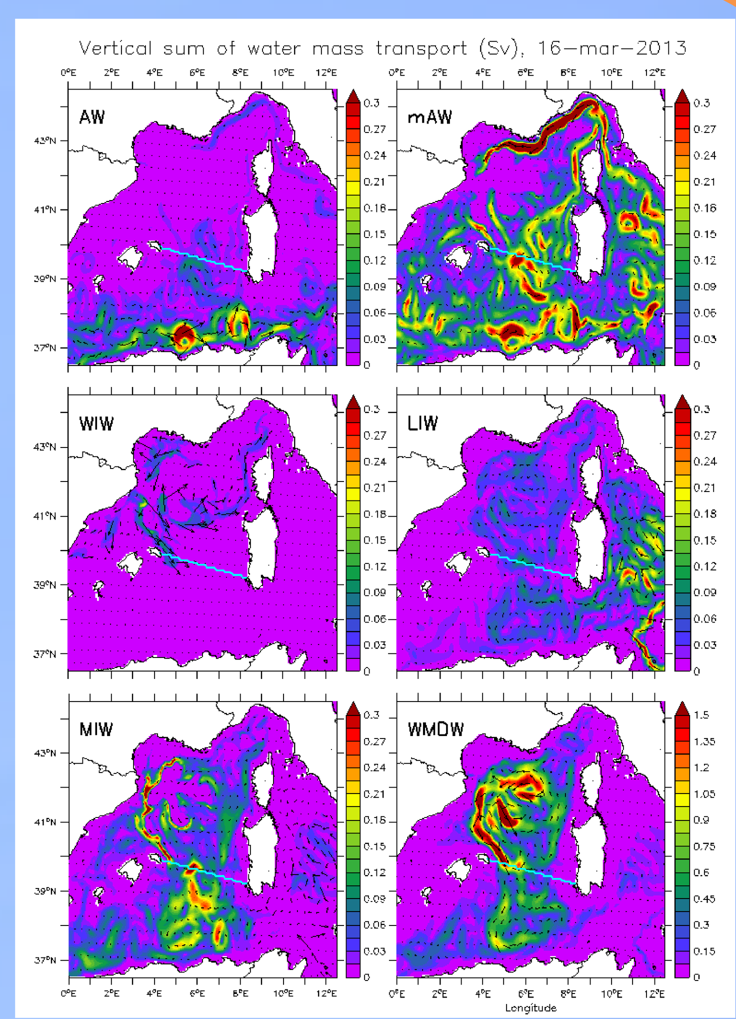

Figure 4. Depth-integrated flagged transports (Sv). Transect of figure 2 & 3 in light blue.

Example of the Gulf of lion area : detection of convection events

The total transport is balanced between each sections closing the box, the residual for each water mass means production if positive and destruction if negative.

MAW destruction leads to WIW production every winter.

Deep convection is detected on known years of deep water formation (1999, 2005, 2013). There is a production of WMDW from mainly mAW during winters with strong winds (together with preconditioning and LIW presence).

During years with no WMDW formation, its mixing added to intermediate convection leads to formation of MIW.

The deep formation rate for winter 2013 is consistent with previous studies [3][4].

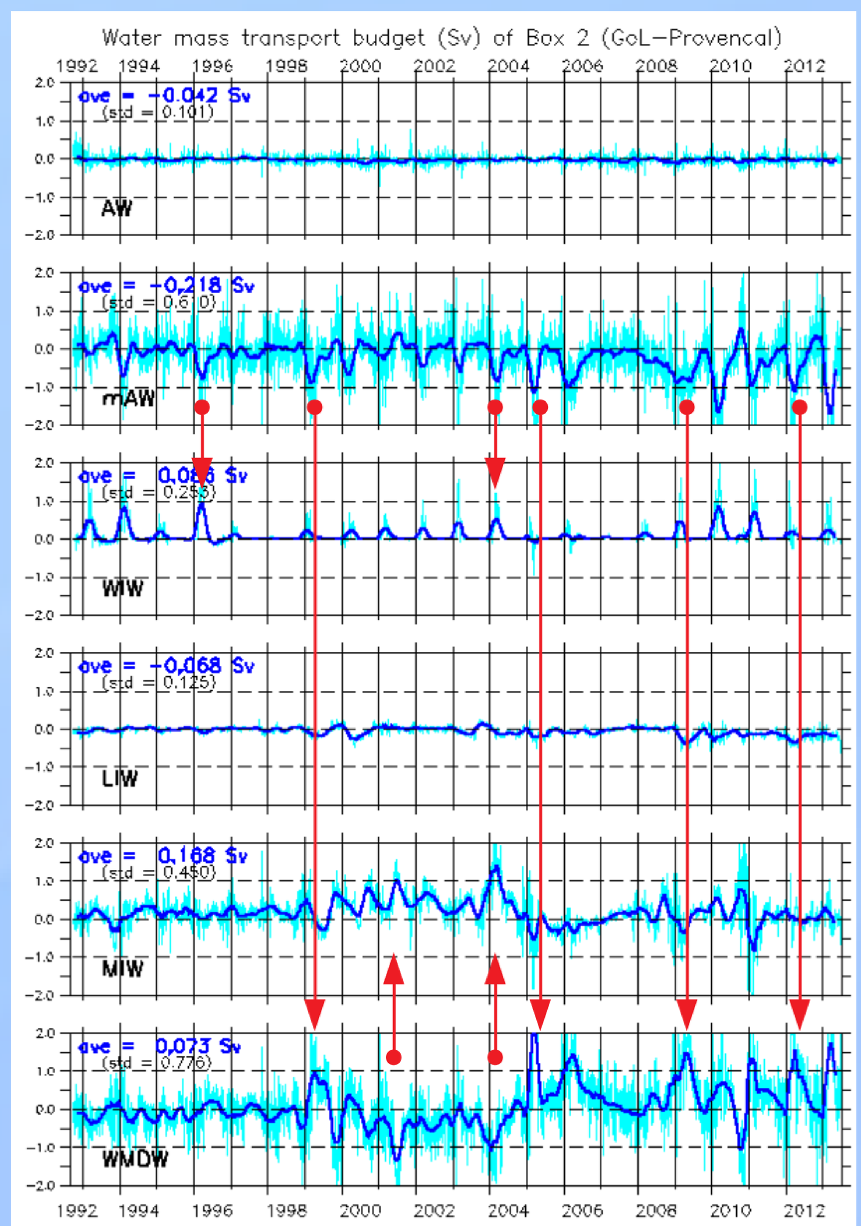

Figure 5. Water mass transport's budget over the Gulf of Lion area from 1992 to 2013 ; daily (light blue) and low pass (90 days, dark blue) filtered time series.

Water Mass balance reveals mixing

On figure 6, the average transport of AW across transects is computed. This allows to estimate its mean circulation.

AW properly comes from the Strait of Gibraltar and flows toward Eastern Mediterranean.

The total mixings, or exchanges between all water masses are showed on table 1.

Provencal basin forms deep water from mAW.

mAW is created in the Algerian Basin.

NBF zone mixes WMDW.

Western Mediterranean creates all other waters from AW and LIW.

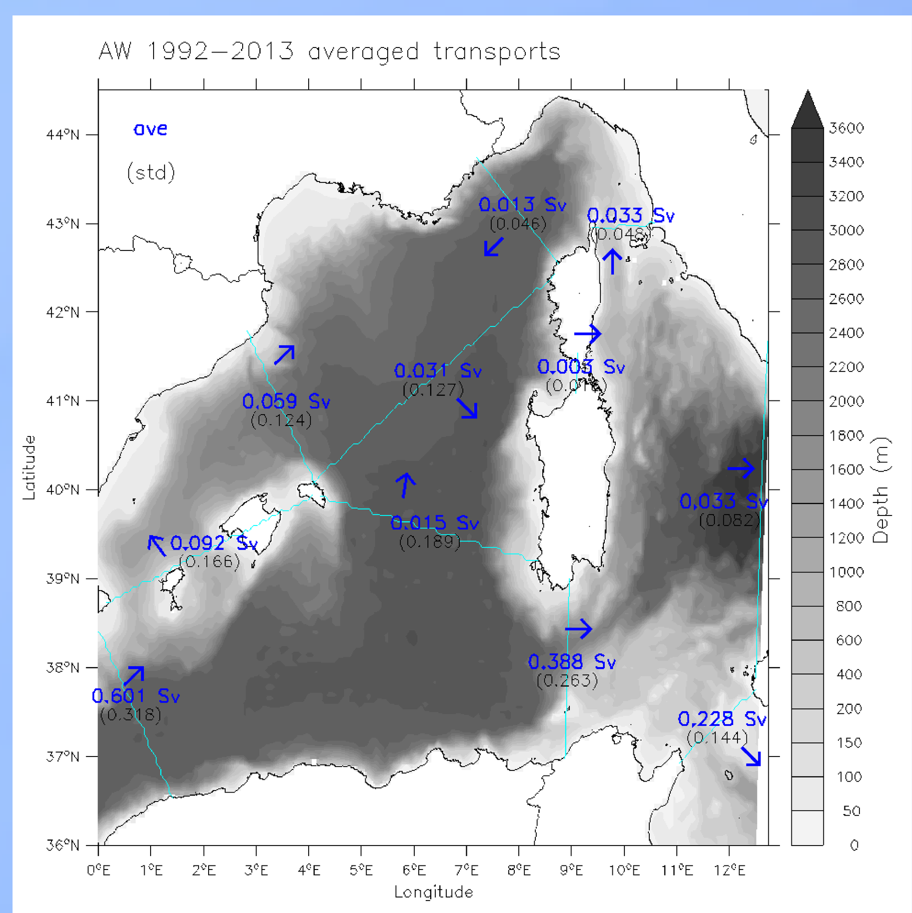

Figure 6. AW transport averages and standard deviation (Sv) for each transects from 1992 to 2013.

	Ligurian	Provencal	Balearic	NBF Zone	Algerian	Total
AW	-1,99	-4,19	-3,33	-4,27	-10,49	-24,27
mAW	3,04	-21,78	7,30	9,92	20,93	19,41
WIW	0,03	8,57	-4,74	-1,39	-2,27	0,20
LIW	-0,15	-6,85	-2,14	-1,21	-13,33	-23,68
MIW(TDW)	-1,91	16,77	-5,51	14,86	-2,62	21,59
WMDW	0,95	7,25	8,27	-18,11	7,20	5,56
Total	-0,03	-0,23	-0,15	-0,20	-0,58	-1,19

Table 1. Water mass transports' budgets (Sv) for each sub-basin from 1992 to 2013. Destruction in blue and production in red.

Conclusion and add-ons

⇒ Our method well follows the litterature and known circulation of water masses in the Western Mediterranean.

⇒ We are able to calculate the transformation of all waters on average climatological budgets.

⇒ This study shows how the method is able to monitor and measure one-off mixing episodes of deep water formation.

⇒ This algorithm makes it possible to characterize, compare and assess several different numerical solutions.

[1] Millot C., Taupier-Letage I. (2005) Circulation in the Mediterranean Sea. In: Saliot A. (eds) The Mediterranean Sea. Handbook of Environmental Chemistry, vol 5K. Springer

[2] Hamon M., Beuvier J., Somot ., Lellouche J.-M., Greiner E., et al.. (2016) Design and validation of MEDRYS, a Mediterranean Sea reanalysis over the period 1992–2013. Ocean Science, EGU

[3] Testor, P., Bosse, A., Houpert, L., Margirier, F., Mortier, L., Legoff, H., Conan, P. (2018). Multiscale observations of deep convection in the northwestern Mediterranean Sea during winter 2012–2013 using multiple platforms. JGR : Oceans

[4] Waldman, R., S. Somot, M. Herrmann, A. Bosse, G. Caniaux, C. Estournel, L. Houpert, L. Prieur, F. Sevault, and P. Testor (2017), Modeling the intense 2012–2013 dense water formation event in the northwestern Mediterranean Sea: Evaluation with an ensemble simulation approach, JGR : Oceans

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