High resolution neodymium characterization along the Mediterranean margins and modeling of εNd distribution in the Mediterranean basins.

M. Ayache, J.-C. Dutay, T. Arsouze, J. Beuvier, S. Révillon, and C. Jeandel

Laboratoire des Sciences du Climat et de l'Environnement (LSCE), IPSL, CEA/UVSQ/CNRS, Orme des Merisiers, Gif-Sur-Yvette, France.

Correspondence to: M. Ayache (mohamed.ayache@lsce.ipsl.fr)

We thank the anonymous reviewer #2 for her/his constructive comments on the manuscript. We have carefully considered all questions and concerns raised. The structure of our reply is as follows; each comment from the anonymous reviewer is recalled in blue, and our reply in black.

4.3 The εNd distribution

Authors seems to insist that the main features of εNd distribution in the Mediterranean are well reproduced assuming only the BE operating Nd oceanic source. Authors also admit that the reproduced results are apparently more radiogenic than the in-situ data reported by Tachikawa et al. (2004). Although I partly agree that their model successfully reproduced some features of the distribution, I have two concerns on their approach. First, I am not quite sure whether the number and locality of in-situ data for comparison is sufficient or not. The data reported by Tachikawa do not cover whole the Mediterranean; the data are localized in the eastern and western parts, and almost no data in the central part. I do not think these data are sufficient for verifying the simulated results. I have found one depth profile at station Ville-franche (43° 24'N,7° 52'E) located in the central part (Henry et al., 1994), which seems to show great shifts from the simulated data. I do not understand why authors neglect this data and believe that authors should discuss the data. Second, in my opinion, the evaluation on contribution of dust and river inputs should be more quantitative. In discussion section (p12 L31), authors claim that an incorporation of dust and river inputs should solve the discrepancy between simulated results and in-situ data. This does not say anything because besides BE processes these two inputs exclusively control Nd flux. Although I agree that it is not so easy to incorporate dust and river inputs into simulation, authors is highly expected to add more quantitative comments on these inputs, say, how much additional Nd with low εNd is required to lower the simulated results.

We agree with the referee that more in-situ data (as those currently acquired in the framework of the GEOTRACES MEDBLACK programme) should help improving in the knowledge of Nd and its isotope cycles in the Med Sea to better constrained the fluxes of solid material and exchange between the continental margin and open ocean, as mentioned in the paper (see P14-L11-14). In this study we have evaluated the model result against published observations: Tachikawa et al., 2004 d, , and following the reviewer suggestion we added the mentioned data from Henry et al. (1994) and Vance et al. (2004) to the statistic estimation of tau from Fig.4 (see the new Fig.4 and new Fig.5). We added the station of Ville-franche (43° 24'N,7° 52'E) from Henry et al. (1994) in Fig.5a, 5b et 5d (see the new Fig.5). However this vertical profile is not showed in Fig.5d, 5e, because it is situated far away from the E-W section in the southern part of western basin. Some new data from Meteor 84/3 cruise in 2011 (Montagna et al,. in prep) will soon be available, but as they are still not published we could not use them in our manuscript. However, confronting these new data with our model experiment do not change any of our conclusions (personal communication).

Second, the purpose of this work is to test the impact of the BE on the Nd IC distribution in the Med Sea starting from the global expertise of Nd modeling by Arsouze et al., (2007, 2009) and by using a realistic representation of the margin Nd IC exclusively compiled from in situ data. Nevertheless this approach simulates a too radiogenic value in the Med Sea; this bias will likely be corrected once the dust and river inputs will be included in the model. As the reviewer mentioned, is not so easy to incorporate dust and river inputs into simulation, because this requires another modeling approach completely different from the adopted method here (i.e. we should simulate the Nd total concentration instead of εNd, and a fully prognostic coupled dynamical/biogeochemical model to represent the scavenging of Nd in the surface water and the remineralisation in the deep layer). This is an ongoing work which aims at explicitly representing and quantifying the different sources and sinks implied in the oceanic cycle of the Nd. The results of this second approach will be addressed in a coming paper.

A sentence was added to the text in the revised manuscript about the possible reasons for the data-model decoupling for the LIW eNd values (see §5).

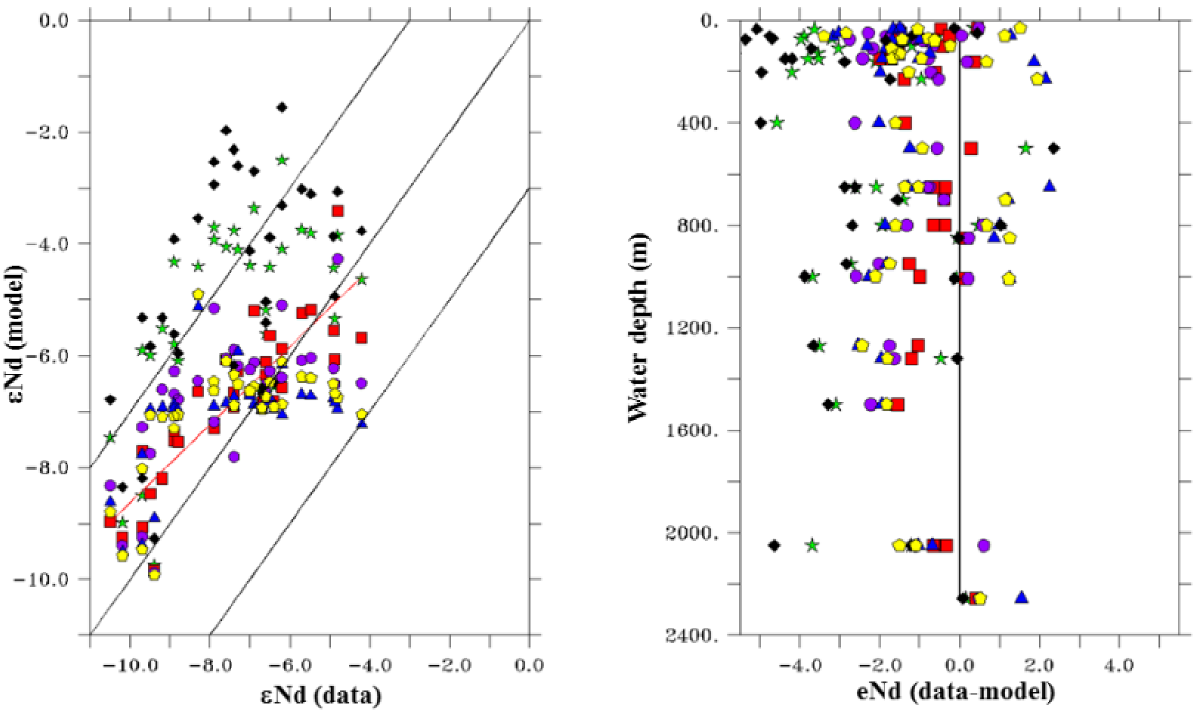

Fig.4. Model/data comparison for the 6 simulations performed with different relaxing time at the steady state (see Tab.3) and the in-situ data from Tachikawa et al., (2004) and Vance et

al., (2004): **(a)** model-data correlation, red line is the linear regression from EXP2. Diagonal black lines are lines εNd (modeled) = εNd (data), εNd (modeled) = εNd (data) + 3 εNd and εNd (modeled) = εNd (data) −3 εNd. **(b)** model/data comparison as a function of depth, black solid line represents the data from Tachikawa et al., (2004) and Vance et al., (2004) and Henry et al., (1994).

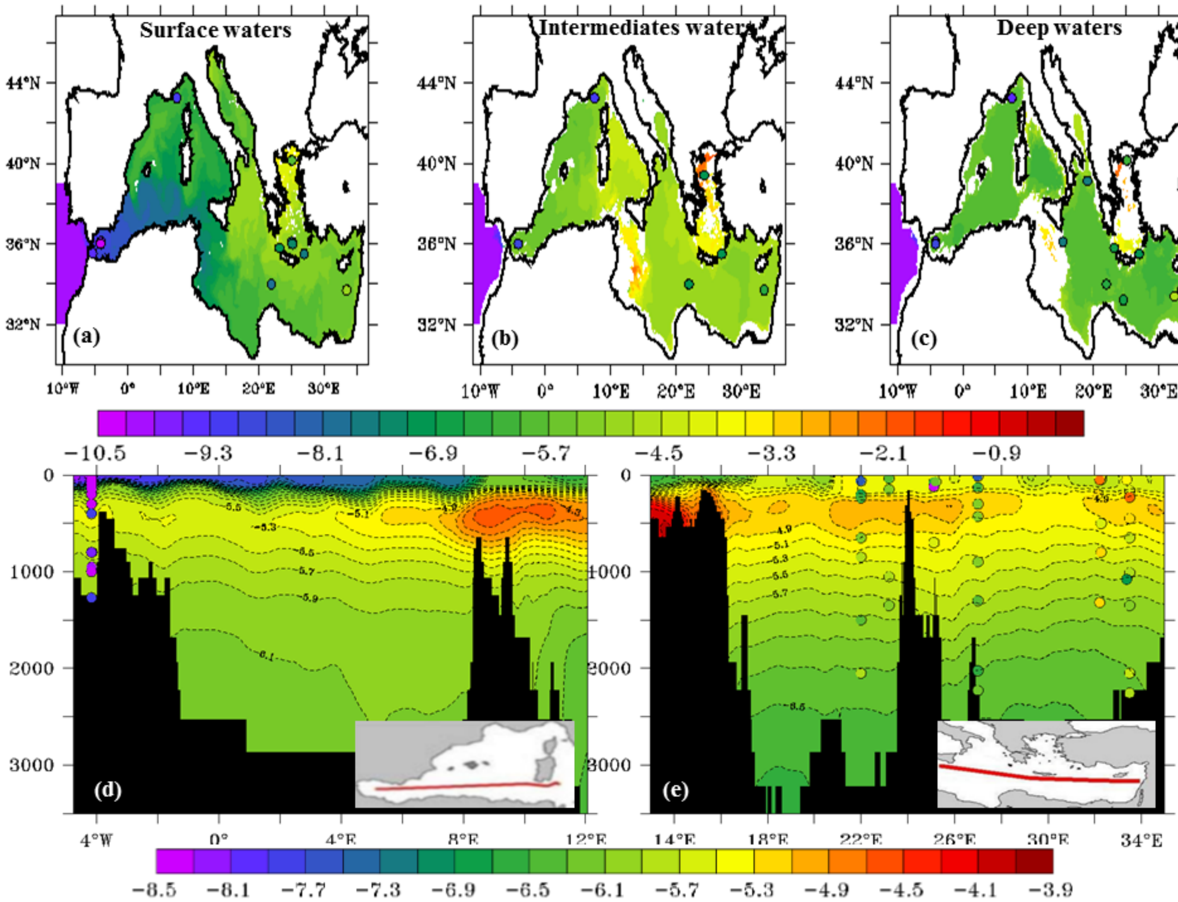

Fig.5. Output of model from EXP3 (t =3 months) at the steady state. Upper panel: horizontal maps for surface waters (a), intermediate waters (b), and deep waters (c). Lower panel E-W section in WMed (d), and EMed (e), whereas colour-filled dots represent in situ observations (Tachikawa et al., 2004; Vance et al., 2004; Henry et al., 1994). Both use the same colour scale.

4.4 The inter-annual variability

Although I found this is an interesting approach, I wonder how authors verify the results. Are there any marine samples recording the EMT events or any chances to observe the EMT in near future?

As detailed by Roether et al. (1996, 2007), the EMT was a temporary change in the EMDW formation that occurred when the source of this deep water switched from the Adriatic Sea to the Aegean Sea during 1992–1993. In a previous evaluation of the same dynamical model used in this study (Ayache et al., 2015), we have shown that the NEMO-MED12 model simulate correctly the EMT even with its corresponding penetration of tracers into the deep water in early 1995. Especially the transient evolution of the tracer age in the eastern basin revealed that the renewal of the bottom water masses is correctly simulated after the EMT (Ayache et al., 2015).

Hence, and by using the same model circulation (as in Ayache et al., 2015), and starting from the simulated steady state distribution of εNd, we have made this sensitivity test to see the response of Nd IC to this well documented event of EMT, as showed in Fig. 7 and Fig.8. This test gives a useful diagnostic on the long term variability of Med Sea to explore if an EMT-type event occurred in the past (Roether et al., 2014; Gacic et al., 2011).

Nd measurements will be performed on deep and intermediate corals in the med sea (Paleomex project, Mistrals/France). These new data will provide some information about past Mediterranean circulation, for more than hundred years ago. Our modeling efforts will represent a support to detect if some "EMT-like" events have occurred in the past.

Technical corrections

p5 L16; "24" of "24N" should not be superscript. Also correct for HNO3 and HClO4

Done (see § 2.1.2).

p5 2.1.2; According to this section, the authors analyzed Nd IC of several sediment sample. Unfortunately, however, I could not understand how the Nd IC data are used in the model. I have checked Appendix 1 and could not find out. Please clarify this point.

Additional analyses of surface sediments were done, in order to improve the EarthChem dataset in key areas (e.g., Sicilian strait). And to complete this dataset in the areas with low spatial resolution of available data, the localization of this stations are showed in red in Fig.1.

For the sake of clarity a new column has been added to table. 1, with the results of the analyzed sediment samples (see new Tab.1), this core tops of sediments collected along a given margin (Fig.1) are directly in contact with the water masses and therefore representative of the signatures of the sediments supposed to "contaminate" the waters flowing along them. We applied the resulted isotopic signature analyzed in this study, in the Sicilo-Tunisian, Libyan, and Egyptian margins age based on the Nd model-age relationships (Allegre,2005; Goldstein et al., 1984, 1997; O'Nions et al., 1979).

Tab.1. Coordinates and results of the studied cores together with water depth

Cruise	Years	Longitude (°E)	Latitude (°N)	Depth (m)	ε_{Nd}
ETNA80	1980	11.48	36.30	263	-10.09
		13.44	33,23	736	-10.92
DEDALE	1987	25.59	33.51	3020	-8.15
NOE	1984	30.01	32.19	1465	-4.49
		30.1	31.53	495	-3.92
Sicily strait	2003	12.57	37.30	29.5	-11.67
		14.37	36.36	87.4	-11.05
		14.22	36.16	488.2	-11.22
		12.32	36.56	117	-8.06

p15-p17 References; Some unnecessary information, such as link to paper, is shown. Should be deleted.
Done (see references)

p17 L10; This reference is from EPSL. Please write down the correct journal information.
Herrmann, M. J. and Somot, S, 2008 paper is published in Geophysical Research letters

Figure 5; "EXP3" should be "EXP2".

Corrected

Appendix 1; What "" and "Ï¸T" stand for? Please explain. I could not find a list of reference for Appendix 1. Please add somewhere.

We have added the list of reference used in Appendix 1, in a new Excel file (more than 600 references)

λ for longitude and φ for latitudes, corrected in the new version.

References

Allegre, C.: Géologie Isotopique., Belin ed, Paris, 2005.

Arsouze, T., Dutay, J. C., Lacan, F., and Jeandel, C.: Modeling the neodymium isotopic composition with a global ocean circulation model,Chemical Geology, 239, 165–177, doi:10.1016/j.chemgeo.2006.12.006, 2007

Arsouze, T., Dutay, J.-C., Lacan, F., and Jeandel, C.: Reconstructing the Nd oceanic cycle using a coupled dynamical – biogeochemical model, doi:10.5194/bgd-6-5549-2009, 2009

Ayache, M., Dutay, J.-C., Jean-Baptiste, P., Beranger, K., Arsouze, T., Beuvier, J., Palmieri, J., Le-vu, B., and Roether, W.: Modelling of the anthropogenic tritium transient and its decay product helium-3 in the Mediterranean Sea using a high-resolution regional model, Ocean Science, 11, 323–342, doi:10.5194/os-11-323-2015, 2015

Henry, F., Jeandel, C., Dupré, B., and Minster, J.-F.: Particulate and dissolved Nd in the western Mediterranean Sea: Sources, fate and budget, Marine Chemistry, 45, 283–305, doi:10.1016/0304-4203(94)90075-2, 1994

Gacic, M., Civitarese, G., Eusebi Borzelli, G. L., Kova cevic, V., Poulain, P.-M., Theocharis, A., Menna, M., Catucci, A., and Zarokanellos, N.: On the relationship between the decadal oscillations of the northern Ionian Sea and the salinity distributions in the eastern Mediterranean, Journal of Geophysical Research, 116, C12 002, doi:10.1029/2011JC007280, 2011.

Goldstein, S., O'Nions, R., and Hamilton, P.: A Sm-Nd isotopic study of atmospheric dusts and particulates from major river systems, Earth and Planetary Science Letters, 70, 221–236, doi:10.1016/0012-821X(84)90007-4, 1984.

Goldstein, S., Arndt, N., and Stallard, R.: The history of a continent from U-Pb ages of zircons from Orinoco River sand and Sm-Nd isotopes in Orinoco basin river sediments, Chemical Geology, 139, 271–286, doi:10.1016/S0009-2541(97)00039-9, 1997.

O'Nions, R. K., Evensen, N. M., and Hamilton, P. J.: Geochemical modeling of mantle differentiation and crustal growth, Journal of Geophysical Research, 84, 6091, doi:10.1029/JB084iB11p0609, 1979.

Roether, W., Manca, B. B., Klein, B., Bregant, D., Georgopoulos, D., Beitzel, V., Kovacevic, V., and Luchetta, A.: Recent Changes in Eastern Mediterranean Deep Waters, Science, 271, 333–335, doi:10.1126/science.271.5247.333, 1996

Roether, W., Klein, B., Manca, B. B., Theocharis, A., and Kioroglou, S.: Transient Eastern Mediterranean deep waters in response to the massive dense-water output of the Aegean Sea in the 1990s, Progress in Oceanography, 74, 540–571, doi:10.1016/j.pocean.2007, 2007

Tachikawa, K., Roy-Barman, M., Michard, A., Thouron, D., Yeghicheyan, D., and Jeandel, C.: Neodymium isotopes in the Mediterranean Sea: Comparison between seawater and sediment signals, Geochimica et Cosmochimica Acta, 68, 3095–3106,doi:10.1016/j.gca.2004.01.024, 2004

Vance, D., Scrivner, A. E., Benecy, P., Staubwasser, M., and Henderson, G. M.: The use of foraminifera as a record of the past neodymium isotope composition of seawater, Paleoceanography, 19, doi:10.1029/2003PA000957, 2004.