Simulation of the mantle and crustal helium isotope signature in the Mediterranean Sea using a high-resolution regional circulation model

M Ayache, J-C Dutay, P Jean-Baptiste, and E Fourré

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 anonymous Referee#2 for her/his constructive comments and suggestions, which have helped to improve the manuscript. We have carefully considered all questions and concerns raised.

Reply to Referree#2

This manuscript presents a high resolution model of the Helium isotopes in the Mediterranean Sea. The authors are using a state of the art model (NEMO) on an area of scientific interest to help bring new knowledge to the scientific community. They offer new values for the Helium isotopes ratio in the Mediterranean Sea which will help modelers of the biogeochemical cycles and the climate better understand the sources of Helium, and constrain the initial conditions for the numerical simulations. Helium studies are useful in the climate simulation community to help describe the ventilation and age of the water masses. While I appreciate the benefit of better constraining these values and command the authors for their work, I think it may be useful to discuss the practical limitations that such work faces when gathering, compiling and synthesizing available data.

The authors use strong words to describe the quality of their findings, which contrasts with the less than optimal datasets they have at their disposal and the practical limitations and simplifications that a modeler has to make when setting up their study.

Response: The conclusion was modified accordingly to stress those limitations (see §7, line 414).

1/ Page 2009: in the delta ^{3}Hesw: what does SW mean?

Response: We have used SW for "Sea Water". However, this not necessary in this context so we decided to remove the 'sw' subscript for the sake of clarity.

2/ Page 2009: the value of ratio of ^{3}He/^{4}He seems intuitive.

Response: All the $^{3}He/^{4}He$ values cited in page 2009 are well established values taken from the literature.

3/Page 2010: discuss a negative ratio.

Response: There are no negative ratios (which would make no sense) but only negative $\delta^{3}He$. Negative $\delta^{3}He$, according to its definition as the percentage deviation from the atmospheric ratio, simply means that the $^{3}He/^{4}He$ ratio is lower than the atmospheric ratio. In the ocean, (slightly) negative ratios (around –1.5%) are found in surface waters due to the slightly lower solubility of ^{3}He relative to ^{4}He, and in some deep waters of intra-continental seas such as the Mediterranean (see introduction) due to the addition of crustal ^{4}He from the seafloor and sediment cover.

3a/ Residence time? Ventilation? He from the bomb: distribution linked to circulation: discuss.

Response: The concept of residence time and ventilation are widely used in the oceanographic and tracer community. We added a short definition (with proper references) for those readers not familiar with this (see §1, line 81). Concerning tritiugenic helium (from bomb tritium), we refer to our recent paper (Ayache et al., 2015).

4/Page 2010: Since then helium isotopes... : the authors first refer to a date at which the 3He was discovered then proceed to explain the cycle of the element. "Then" seems to refer to the injection of 3He, not to the time at which it was discovered (^{3}He is being used to trace circulation since it was discovered in 1970 not since it was injected at mid ocean ridges).

Response: This sentence has been changed for the sake of clarity, see §1, line 77.

5/Page 2011: "represent the ventilation of deep waters". The concept of ventilation of water masses should be explained earlier. I think it would help with statements such as that of p 2010 line 1-3.

Response: See response to point n°3a.

6/ The authors alternate the use of "helium" and "^{3}He" throughout the manuscript. Be consistent.

Response: Helium classically designs the sum of both ^{3}He and ^{4}He isotopes, in practise equal to ^{4}He due to the very low isotopic $^{3}He/^{4}He$ ratio in terrestrial samples. He-3 and/or He-4 design the specific isotope which is discussed.

7/ Page 2012: "the exchanges with the Atlantic Ocean are performed through a buffer". I am not familiar with the term buffer used in this context. Rephrase?

Response: NEMOMED12 covers the whole Mediterranean Sea plus a buffer zone including a part of the near Atlantic Ocean (See Figure). The exchanges with the Atlantic Ocean are performed through a buffer zone. From 11°W to 7.5°W, 3D fields relaxed towards in-situ data.

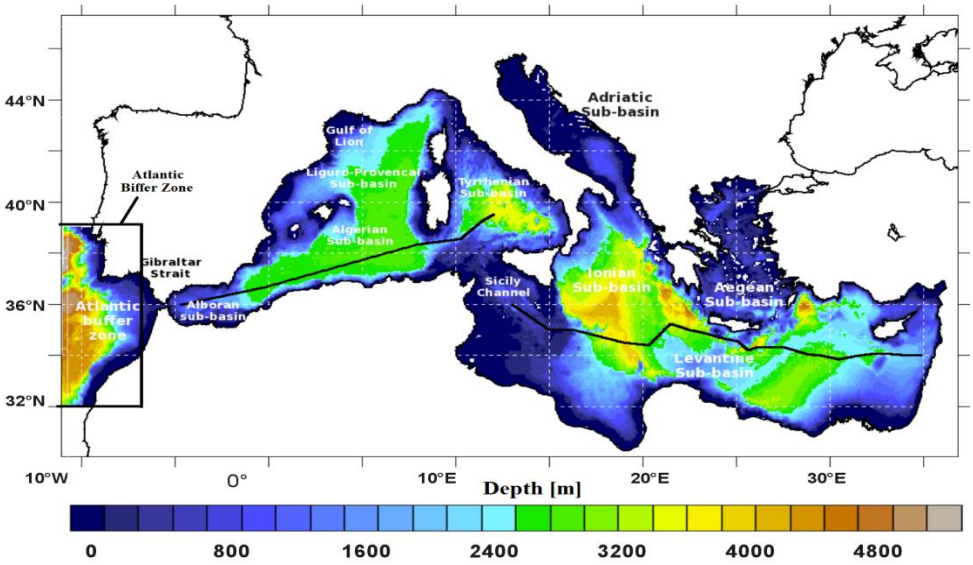

Figure 1. Map of the NEMO-MED12 model domain and bathymetry with location of the main Mediterranean sub-basins. The solid lines represent the trans-Mediterranean sections of the R/V Meteor cruises (used in Fig. 4 and 5).

This sentence has been rephrased in the revised manuscript, (, see §2, line 124).

8/The datasets used in the manuscript cover very different time periods. The temperature and salinity for the Mediterranean sea are prescribed from climatology covering the period 1955-1965. NEMO-MED12 is forced at the surface by ARPERA daily fields of the momentum evaporation and heat fluxes over the period 1958-2013. For the SST a relaxation term is applied to the heat flux. How having 2 different periods for those 2 data source affect the analysis? For the Atlantic buffer the initial state is set from the WOA 2005. How are the possible mismatches in the field values treated?

Response: The physical simulation used here is similar to that described in Beuvier et al. (2012b); Palmiéri et al., (2015); Ayache et al., (2015).

It is initiated in October 1958 with temperature and salinity data representative of the 1955–1965 period using the MEDATLAS dataset (MEDAR/MEDATLAS-Group,2002;Rixen et al.,2005). For the Atlantic buffer, initial conditions are taken from the 2005 World Ocean Atlas for temperature (Locarnini et al.,2006) and salinity (Antonov et al.,2006).

Boundary conditions are also needed to specify physical forcing for the atmosphere, freshwater inputs from rivers and the Black Sea and exchange with the adjacent Atlantic Ocean. For the atmosphere, NEMO-MED12 is forced with daily evaporation, precipitation, radiative and turbulent heat fluxes, and momentum fluxes from the ARPERA data set (Herrmann and Somot, 2008), all over the period 1958–2008. The ARPERA forcing constitutes a 56-year, high-resolution forcing (50 km, daily data) with a good temporal homogeneity (see Herrmann et al.,2010, for more details about the post-2001 period).

To reduce the effect of the initial conditions, we have run a very long spin-up simulation, and we have analysed the outputs only after the steady state situation (after almost 500 years of simulation).

8'/ Page 2014: Each component has a characteristic $^{3}He/^{4}He$ value: can you please elaborate? Or describe the distribution and values so that it is not left to the reader to do so.

Response: For the isotopic characteristics of each component, the reader needs to refer to the introduction and Fig. 1.

9/ Page 2015: Paragraph 3.3: it feels repetitive. It seems that the authors explain the sources of helium repeatedly throughout the paper. While I appreciate the thoroughness of the authors in describing the source mechanism and listing references, I am not sure it is necessary to repeat this throughout the manuscript. Referring the reader to Fig1 cartoon diagram- may be more useful at this point.

Response: this comment is somewhat contradictory with comment 8'/ right above. In paragraph 3.3 we explain why the crustal helium is so important in the Mediterranean Sea, especially for those readers not familiar with helium isotopes.

10/ In the eastern Mediterranean: table 2: why not give the value of the ^{3}He release rate? Authors list the ratio, and ^{4}He rate, why not give the ^{3}He rate?

Response: The ^{3}He release rate is simply the product of the ^{4}He release rate multiplied by the $^{3}He/^{4}He$ ratio. Therefore we feel that an additional column with the ^{3}He release rate will be somewhat redundant.

11/ Page 2016: typo: needs a "." before "For the Marsili seamount"

Response: Done.

12/ Page 2017. In the 4.1 paragraph. "very similar": well, ... seems to overestimate..

Response: We rephrased this sentence in the revised manuscript, (see §5.1, line 271).

13/ Page 2019: LIW: could you remind the reader what it is?

Response: LIW= Levantine Intermediate Water. This was clarified in the revised manuscript (see §5.3.2, line 320).

14/Page 2019: paragraph 4.3: the notion of "correctly representing" is too vague. The paper would benefit from the use of statistics at this point.

Response: We agree with the referee that a more quantitative analyses would be of interest. Figures 7b and 7c show a comparison of average vertical profiles along Meteor M5 section, which provide quantified estimations of the deviation against observations allowed the identification of the main water masses present in the Med sea (like the Levantine Intermediate Water). Additional quantitative comparison between data and the simulation was added to the text (see §5.3, line 338);

15/ Page 2020: typo: Crisisin?

Response: Done.

16/ Page 2023: "It is essential if we are to improve our ability to predict the future evolution of the Mediterranean Sea under the increasing anthropogenic pressure it is suffering." While I do understand and agree with this statement, are NEMO simulations coupled to a real atmospheric model? it seems to be that it is a bit difficult to do ocean only simulations for climate modelling purposes.

Response: NEMO is the oceanic component of the regional modelling platform MORCEMED (Model of the Regional Coupled Earth system) focusing on the Mediterranean basin. Based on coupling of existing regional models of the various components of the Earth system (ocean, continental land masses, atmospheric composition) and interfacing with the IPSL's global climate model to study the evolution of the Mediterranean sea under the increasing anthropogenic pressure (Drobinski et al., 2012). (See §7, line 420.)

17/ Figure 2 caption: remind the reader which area the Meteor Cruise looks at, as there are not lat/long reference on the figure.

Response: As indicated in the caption of Fig.2, the location of the Meteor sections are shown in the inset maps.

18/ Figure 4 caption: there is a typo: double "the".

Response: Done

There is no explanation about how the straight lines are obtained from the dotted clouds on subfig C/ and D/.

Response: Fig.4c and 4d: As indicated in the caption, the straight lines represent the average of all individual measured or modelled points (represented by the "dotted clouds").

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