Manuscript os-2016-85: "Observed and Modelled Mixed-Layer Properties on the Continental Shelf of Sardinia"

Reply #2 to Reviewer #2

(a) 4DVAR vs. Objective Analysis

This manuscript is a contribution to the REP14-MED Special Issue. A major intent of this Special Issue is to test, evaluate, and compare the performances and forecast skills of different assimilation methods. Amongst others, there will be two other manuscripts applying 4DVAR and the Ensemble Kalman Filter to the same data set.

The author of the 4DVAR paper (A. Funk) has already performed several model runs both using OA and 4DVAR. The major results of his test were:

- Using 2 outer and 50 inner loops, the CPU time using 4DVAR is at least one order of magnitude larger than the CPU time of using OA.
- If data are assimilated only for a few days (and this is the case in the present manuscript where data are only assimilated 7 – 12 June), 4DVAR is **not** superior to OA.

Moreover, a successful implementation of 4DVAR requires a lot of experience, and I know from many colleagues that they failed. I was told that even an experienced modeler from Rutgers University did not succeed to run 4DVAR using a large glider data set. I also doubt that the tasks for this manuscript can be managed by just a "few simulations with a 4DVAR" scheme: 4DVAR is a *variational* scheme which perturbs the initial conditions, surface boundary conditions, and lateral boundary conditions *randomly* and based on some statistical constraints. In this study, however, these conditions are modified *deterministically* and I do not see how 4DVAR could tackle this issue. At best, a (weak constraint) 4DVAR scheme might be applied to Series E to assess the sensitivity to the background vertical diffusivity.

Action: Reference to A. Funk will be added, perhaps as "personal communication"

(b) large eddy viscosity and diffusivity

You are right – the horizontal diffusivity and viscosity values are too high. These values originated from precursor model tests with a coarser resolution, and they were not adjusted when the grid was refined.

Action: All 24 model runs will be repeated but using now 5 m^2s^{-1} for the diffusivity and 1 m^2s^{-1} for the viscosity.

(c) citation of previous works

Action: references to previous works will be added

(d) better description of methodology
see below 6, 7, 8, 9, 10, 11

(1) – P3, L1: reference to Fig. 2
The experimental area is described in detail in in Onken et al. (2016) which is another paper in the REP14-MED Special Issue.
Action: I will add a reference.

(2) – P4, L5-19: "Section 3 is methodological ..."
The intention for L5–19 was not to anticipate any results; these lines were just written to emphasize the challenge for the model attempts to reproduce the observed features.
Action: Instead of moving the lines to the top of Section 4, it is suggested to include another figure in this place which shows the observations.

(3) – P4, L11: Celsius vs. Kelvin
I used $^{\circ}C$ for absolute temperatures and K for temperature differences; this is common use in the scientific world. See
`https://en.wikipedia.org/wiki/Kelvin#Use_in_conjunction_with_Celsius`:
In science and engineering, degrees Celsius and kelvins are often used simultaneously in the same article, where absolute temperatures are given in degrees Celsius, but temperature intervals are given in kelvins. E.g. "its measured value was 0.01028 C with an uncertainty of 60 K."

This practice is permissible because the degree Celsius is a special name for the kelvin for use in expressing relative temperatures, and the magnitude of the degree Celsius is exactly equal to that of the kelvin.[10] Notwithstanding that the official endorsement provided by Resolution 3 of the 13th CGPM states "a temperature interval may also be expressed in degrees Celsius",[4] the practice of simultaneously using both "C" and "K" is widespread throughout the scientific world. The use of SI prefixed forms of the degree Celsius (such as "C" or "microdegrees Celsius") to express a temperature interval has not been widely adopted.
Action: As also the other Reviewer raised this issue, I will use $^{\circ}C$ throughout in the revised version of the manuscript.

(4) – P4, L21-22: not clear ... rephrase ...
Action: Agreed.

(5) – P4, L24: estimate Rossby radius
This does not appear to be necessary. The very detailed study of Grilli and Pinardi (1998, MTP News, Vol. 6, p4) provides calculations of the Rossby radius for the entire Mediterranean and for all seasons.
Action: None

(6) – end of P4: no description about CTDs ... gliders
The desired descriptions are included in Onken et al. (2016) which is another paper in the REP14-MED Special Issue.

Action: I will add a reference.

(7) – P5, Sec3.2: include number of experiments, Table
Action: A Table will be provided in the revised version.

(8) – P5, L22: provide rx0 and rx1 parameters
Action: Agreed.

(9) – P6 L27: discuss COSMO
Action: Agreed.

(10) – P7, L1 : describe OA method
OA is a common method in meteorology and oceanography to interpolate data from irregularly spaced locations to a fixed grid. Meanwhile, this is text book stuff (e.g. Thomson and Emery, Data Analysis Methods in Physical Oceanography, Elsevier, 2014, 680 pp.). Therefore, formulae will no be provided.
Action: Up-to-date references will be added.

(11) sensitivity of OA to W and C
In a sensitivity study of another paper in the REP14-MED Special Issue (Onken 2017, in preparation), a window size W=48 hours was found to provide the best forecast skill.

You are right, the isotropic correlation is a strong assumption especially close to the coast. The OA package used in this study offers only the possibility to use an isotropic correlation or a non-isotropic correlation, specifying the meridional and zonal correlation scales separately. However, the non-isotropic scales will then be applied to each grid point in the model domain which then will bias the results in areas distant from the coast. According to the observations, predominantly meridonal currents are prevailing only in a 10-km wide stripe along the Sardinian coast while the rest of the 180-km wide model domain is characterized by an eddy field with alternating currents. Here, the usage of a non-isotropic correlation scale would definitely deteriorate the results. Hence, an isotropic scale for the entire domain appears to be the best choice.
Action:

- Reference to Onken (2017) will be added
- Choice of isotropy will be discussed.

(12) – P7, L23: rephrase
Action: Agreed.

(13) – P8, L9: lack of salinity measurements
The validation data set of mooring M1 does not contain salinity measurements. Therefore, only temperature can be validated.
Action: I will make it clearer

(14) – P8, L9: Celsius vs. Kelvin
see above (3)

(15) – P8, L9: why this method?
The most common methods for definition of the mixed-layer are based on a temperature or density difference criterion. In the main framework of this study, only the temperature criterion is appropriate because salinity (for density calculation) is not available from the observations at M1. The maximum gradient method in Figs. 10 and 16 is only used in order to demonstrate that the gradients are weaker in the model.
<u>Action:</u>

- Definition of mixed-layer depth: references will be added
- Maximum gradient method: no change **or** remove the corresponding images

(16) – P8, L18: Table
see above (7)

(17) – P8, L25: Table
see above (3)

(18) – P9, L26–29: rephrase and expand
<u>Action:</u> Agreed.

(19) – P11, L10 and L14: "much better" not so evident
<u>Action:</u> Agreed.

(20) – P12, L7: 0.81m depth
0.81 m is the depth of the uppermost Starmon sensor (cf. Table 1).
<u>Action:</u> I will make it more clear in the revised version.

(21) – P12, L22: define hatted variables
The hatted variables are the amplitudes. This is written in line 22.
<u>Action:</u> None

(22) – P12, L29 and L32: inertial peak
Yes, the inertial peak is (theoretically) at 18.7 hours but it is not detected in the observations. It is not clear to me why you can't follow the argument.
<u>Action:</u> I will check once more.

(23) – P13, L24: rho-grid
The first (i.e. the *last* because counting levels starts at the bottom) vertical grid point of the rho-grid is **below** the sea surface. The sea surface is the last grid point of the w-grid.
<u>Action:</u> I will make it clear.

(24) – P13, L29: ... simulations too viscous
see above (b).

(25) – P14, L4: "almost perfectly" ...

Action: Agreed.

(26) – Figs. 2, 3, 4: meridional and zonal extensions of figures
Action: This can easily be done.

(27) – Fig 8a, 12a, 14a, 17a, 20a: Celsius vs. Kelvin
see above (3)

(28) – Fig. 9, 13, 15, 18: Celsius vs. Kelvin
see above (3)

(29) – Fig. 19: Celsius vs. Kelvin
see above (3)

(30) – Fig. 20: Celsius vs. Kelvin
see above (3)

(31) – Fig. 21: indicate inertial frequency
Action: Agreed.

(32) – P4, L2: turnS out
Action: Agreed.