The paper describes the impact of assimilation of HF radar data at the Ibiza Channel (Western Mediterranean Sea). The authors assimilate commonly used data sets (Sea surface temperature, sea level anomaly and Argo profiles) in combination with HF radar data. For the HF radar data two options are considered: either assimilating the total currents (derived from the radial currents) or directly assimilating radial currents. Both assimilation experiments are validated against drifter observations. The authors conclude that the assimilation using total currents fits the Lagrangian observations the best.

Comments:

1. There are some general properties about the Kalman-based assimilation systems with transformed observations that should be mentioned to set the context of the study. If the hypotheses of the Kalman filter are verified (in particular the model is linear, error covariances are perfectly known), then the analysis would provide exactly the results under any invertible linear transformation of the observations (provided the observation operator and the obs. error covariance matrix are transformed accordingly).

The assimilation of any additional observation has the impact to reduce the error of the analysis on average. The consequence of these two properties is that the assimilation of transformed observations (possibly using a non-invertible linear transformation) should not be better than the error using the non-transformed observations. In practice this can be shown by considering the observations associated to a zero singular value of the transformation and the observation with a non-zero singular value separately; the observations with a zero singular value are ignored by the transformation (these correspond to radial HF radar observations for which no matching second HF radar observation exist to derive total currents).

Under these, admittedly restrictive, assumptions, the assimilation of radial currents should work better than the assimilation of total currents. Intuitively, this makes sense because all the information of the total currents is already included in the radial currents and the radial currents have additional information not included in the total currents.

However, for real-world experiments there are some assumptions not verified which can lead to the opposite conclusion. In particular, we know that the model is non-linear, observation error covariances are not perfectly known and arbitrary observation operators cannot be specified by most current assimilation systems. Also it is not completely clear if the mapping from total currents to radial currents is a linear process (can you clarify this point?). I suggest that the authors include this additional information to clarify to the reader the motivation of this study.

2. The observational error covariance is a crucial parameter in the assimilation system, which is often not very well known because of the contribution of the representativity error.

Maybe I missed it but I did not see the particular values that were used. It is a bit surprising that the same error covariance values were used for radial currents and total currents. Can you expand this discussion by including the different values of the observational error covariance that were tested in your sensitivity test (line 432)? See also below.

I recommend the publication of this manuscript after revision.

Dear referee,

We would like to thank you for your time to carefully revise the manuscript and for your comments and feedback. The theoretical concerns about the use of Kalman-based assimilation systems with transformed observations are particularly interesting. As suggested, we have further developed this aspect in the introduction of the revised manuscript.

“Theoretically and under the assumptions of linearity and normal distribution of errors in the state dynamics and measurements, as well as in the transformation from radials to totals, the assimilation of radial currents should overperform the assimilation of total currents, since all the information of the totals is included in the radialsand the later contain additional information which is not included in the totals. However, in real-world experiments, these major assumptions are not verified. In particular, the model is non-linear, observation error covariances are not Gaussian and certainly not perfectly known and the transformation from radials to totals also involves nonlinearities. In the literature, both kinds of observations have been assimilated with satisfactory results.”

The transformation from radial to total observations using a unweighted least-square fitting (Lipa and Barrick 1983) is a non-linear process combining several radial observations to reconstruct each total observation.Moreover, the temporal threshold used for radial and total observations to perform the daily mean is different (i.e. 25% for radials and 50% for totals), as we tried to clarify in the text (see below).

Concerning the second point, we would like to shortly explain the procedure followed to set the observation errors. First, we set a total observation error standard deviation of 0.1 m/s for HFR total observations, which accounts both for instrumental and representativity error. This value is consistent with local comparisons against surface currents measurements from a point-wise currentmeter (1.5 m depth) and a downward-looking ADCP (first bin at 5 m depth) carried out by Lana et al., (2016) , which reported a RMSD between 0.07 and 0.12 m/s. This value of 0.1m/s was fixed in our experiments as it yielded to a proper correction of surface currents, without degrading the vertical structure.

Once the observation error was set for HFR total observations, we performed new experiments to evaluate the potential differences between the total and radial observations. Total observations were interpolated and projected to generate synthetic radial observations containing the exact same information as the totals but with a radial-like pattern in the area covered by both antennas.

The assimilation of these total and synthetic radial observations using the same observation error led to almost identical results in surface fields and vertical structure, with complex correlation of 0.92 and a RMSD of 0.02 m/s obtained between both analysis fields in the HFR grid points. Based on these results we decided to use the same observation error for both types of observations.

The last paragraph of the discussion has been expanded to include this explanation.

Minor comments:

Line 130: This is a bit confusing. Maybe you can expand this part: "It sometimes happens that there are enough radial observations to compute the total observation for most of the periods but with none of those radial observations satisfying the temporal threshold by itself."

The phrase has been reformulated as follows:

“Daily means of radials and totals are computed independently for each data type from the hourly observations. For the total currents the daily mean is only considered at grid points for which at least 50% of hourly measurements are both available and flagged as good, as also used by Lorente et al. 2015. In the case of the radials, a threshold of 25% is considered for computing the daily mean. As stated above, at each grid point, the hourly total currents are calculated using all available radial observations within a radius of 6 km. Consequently, some total observations

could be computed using different radial grid points within this radius for each hour that individually do not satisfy the threshold of 50% imposed for the total velocities. Therefore, using the same threshold to calculate the daily means of both observations could lead to patches with available reconstructed daily mean total currents but no daily mean radials available. This is the reson why we decided to use a less restrictive threshold to have better radial spatial coverage, consistent with that of the total observations in the area covered by both antennas. "

Equation 3: The notation is a bit odd as you have a vector on the left hand side and a scalar on the right hand side.

This has been corrected. Vectors of zonal and meridional velocity observations and angles are highlighted in bold.

Line 202: Notice that the nudging is not applied to the velocity fields: quite surprising. Did you also test nudging the velocity field?

No, we did not test nudging the velocity field. Nudging velocity fields can be problematic since it can significantly perturb the model balance equations. This is the reason why we decided to do it only towards T, S and SSH.

Indeed, we think that obtaining such a degree of correction on surface currents when applying the nudging only towards T, S and SSH is a relevant result. It means that surface current assimilation can correct T, S and SSH fields that, after ingestion and adjustments by the model dynamics, in turn improves the representation of surface currents. This point is specifically discussed in the third paragraph of the discussion.

Equation 5: ss: should it be upper-case SS?

Thanks. It has been changed for coherence with the rest of the manuscript.

Table 2, Table 4: can you also include the RMS (without normalization)? Can you also include in this table a validation metric which is sensitive to the direction of the current, not only the speed of the current? (e.g. the RMS error of u and v components individually?)

It has been included in both Tables 2 and 4.

Line 305: diffusion term: how large is the diffusion coefficient? And how was it determined?

The diffusion coefficient we used is $50 m^2/s$. This value was determined empirically based on the virtual particle dispersion after a few days in comparison to the dispersion of available real drifters in the Balearic Sea. It was successfully used in other studies with the WMOP model (Cabanellas Reboredo et al. 2019, Ruiz-Orejon et al. 2019, Compa et al., 2020, Kersting et al., 2020).

In the present study, we use the center of mass of 1000 particles to calculate the mean separation distance. We have verified that the results are not significantly affected by the value of the diffusion coefficient, which has a significant impact on the spread of the trajectories but not on the path of the mean trajectory

Following the reviewer's advice, this has been included in the new version of the manuscript as:

*"After each advection step the diffusion is imposed using a random distribution with a diffusion coefficient of 50 m^2/s, in line with recent Lagrangian studies using this model (*Cabanellas

Reboredo et al. 2019, Ruiz-Orejon et al. 2019, Compa et al., 2020, Kersting et al., 2020*). We have verified that the results are not significantly affected by the value of the diffusion coefficient, which has a significant impact on the spread of the trajectories but not on the path of the mean trajectory.“*

Line 432: "The observation error is considered equal for total and radial currents in this study. ..." This is quite surprising as one would expect the radials a bit noisier and the total currents error variance should depend on the location (among others due to GDOP). Can the paragraph be expanded? Can you also include the value of the observational error covariance?

As stated above, the choice of the observation error variance for radial observations was the result of model experiments simulating radials from a given set of total observations. The dependence of the error with the location or the availability of either one or two antennas is discussed in the manuscript. We agree that the representation of the observation error could be refined in our system, also by including correlated observation errors, even if our knowledge of these errors is still somehow limited. It is an interesting aspect that should be evaluated in future studies.