Responses to Referee #1:

Specific comments:

1 – The document lacks coherence giving the feeling that is a collection of separated texts and not part of a structured discussion. This is partially reflected in the parts of the text used as introductions, which are vague and do not properly describe the contents that follow. Last paragraph of Section 1 can be extended to give more information about the aspects covered in the paper. Introduction for Section 2 only describes sections 2.1, 2.2 and 2.5. Section 2.4 is mention but nothing is said about the methodology described and 2.3 is omitted. Introduction for section 3 has no relation with any of the following sub-sections as there is no mention to HF radars or assimilation methods.

To provide a more coherent review as asked by both referees, we have modified the structure of the manuscript and profusely modified the introduction and summary sections. Moreover, to better communicate the two aspects of the review we have modified the title of the manuscript: "Remote sensing of ocean surface currents: A review of what is being observed and what is being assimilated". We have renamed the subsections in Section 2 (see below). The previous section 2.3 " Tracer phase: singularity analysis" has been merged with the previous section 2.5 " Potential vorticity inversion: synergy of sensors" now called "2.4 Currents from a single tracer image". We have introduced a new section 3 called "Retrieval from High Frequency Radars" where we include a short description of this technology for remote sensing of the ocean velocity field and their associated temporal and spatial resolution.

More importantly, the last phrase of the abstract suggests that the ocean currents obtained with the methods described in section 2 are going to be then the examples for the assimilation methods described in section 3. However, all examples from section 2 refer to large scale current estimations while section 3 describes the assimilation of HF currents, which are confined to areas close to the shore. This aspect gives the paper a feeling of disconnection between section 2 and 3 that needs to be addressed. That can be either clearly describing and justifying this approach in the appropriate sections of the text (abstract, introduction, etc) or providing data assimilation applications with currents obtained with the methods described in Section 2.

There are no experiments assimilating global velocity fields as the ones derived in Section 2. There are two regional experiments assimilating OSCAR currents with mixed results. Therefore, most of the experiments assimilating ocean currents correspond to coastal systems. We have modified the title and the introduction to clarify this issue. The Summary outlines some potential options to make the bridge between the open ocean estimates of surface currents with the coastal applications.

2 – I do acknowledge that it is simply impossible to cover all the aspects of the methods described by the paper. However, it would be good to mention which are relevant and are not possible to cover. Here I outline some examples but I encourage the authors to indicate the ones they consider more relevant based on their expertise. For example:

i) The estimation of the error of a satellite derived product is important to have a measure of the

confidence on the data. This is particularly important if the data is going to be used for data assimilation applications, where an accurate specification of the observation error covariance matrix (R) is critical. Authors indicate which sources of information might be more prone to have high errors, but no indication on how estimate them is given.

We agree with you that error estimation is a key issue particularly if you are thinking in assimilating these data. This is an extremely difficult question to answer, specially in the case of remote sensing products. For most of the methods described in Section 2, an estimation of the resulting error depends on many factors, which are not always independent. There are instrumental errors (which in the case of remote sensing is not clear at all mainly due to the lack of in situ validation for many radiometers); representativeness errors (that arise when comparing averaged retrievals with point-wise measurements); interpolation errors (which are a function of the geometry of the sampling and the interpolation methods and parameters); and errors in the validity of the dynamical assumptions, which change in space and time. The manuscript already contains information about the error sources with citations of the published work on this matter. However, we have included an additional comment that summarizes the importance of such an issue in the Summary section.

ii) The background error covariance matrix Pf, estimated by EnKF methods usually suffers from an under sampling problem (off diagonal terms are noisy due to the fact that not enough ensemble members are used). To overcome this some localisation needs to be applied to this matrix. May be something about this can be mentioned in the text?

iii) The estimation of the B matrix for 4DVAr algorithms is a non-trivial problem. May be some methodologies can be indicated?

In the reviewed literature these issues have been dealt differently by different authors. In both cases we have included a statement pointing out each one of these issues in particular.

3- Some parts of the text have a feeling of urgency, with confusing phrases and typos, while others are well written in a language that is clear and easy to follow. May be more time can be spent in correcting this before sending the document to the next revision interaction?

I have indicated all the typos I have found in the comments section below. For some of these typos is difficult to understand how they were allowed in the presented version of the manuscript.

We apologize. The new version of the paper has been inexhaustibly checked. We have tried to correct all the typos.

4 - Section 3.1 (page 20, line 8) feels more like part of the introduction for section 3. Authors may want to consider appending it to the introduction instead of having it as a separate sub-section.

You are right. We have moved part of this section to the introduction and we have rewritten it as a new Section focusing on HF radars.

5- I urge the authors to review the description of the “innovation vector” and the “K”matrix at page 23 (lines 2 to 6), as it seems particular non-standard. To my understanding the “innovation vector” represents the departures between the observations and the model converted to the observations space. “K” represents the weighs of the linear combination between model and observation defined by the values of Pf and R. Finally, the term K[y-Hx] represents the increments that applied to the background field, gives an optimal analysis provided Pf and R.

This part of the text has been completely rewritten in the new version of the manuscript.

Technical comments:

We have completely rewritten the text and most of the following comments are no longer valid although we took all of them into consideration. In what follows you will find those comments that are still relevant for the content of the version.

P1L3 – “synoptically at global scale” -> “globally at synoptic scale” perhaps more appropriate?

After consideration of your suggestion we have modified the statement as follows: “First, no observing system is able to provide direct measurements of global ocean currents at synoptic scales.”

P1L18, P14L9, P14L15, P17L24, P19L1 – It seems awkward to use “on the other hand” without a preceding phrase with “on one hand”. May be “Conversely” or “On the contrary” can be considered?

The mentioned uses of “On the other hand/side” have been modified as follows: P1L18: “Furthermore”; P14L9: “However, while ...”; P14L15: “With respect to the chlorophyll concentration”; P17L24: (removed); P19L1: “Conversely”.

P1L22 to L24 – I suggest to re-phrase as: “For example, coastal HF radars are able to resolve rapid changes and, although the number of HF radars has rapidly increased in the last decades, their coverage remains limited”.

Thanks. We have modified the statements according to your suggestion.

P1L25 – Short statement about a new topic that is then not mentioned again. Perhaps more can be said about moorings. P2L7 – “acoustic currentmeters” have not been introduced. Are the ones at L4? If so, please clarify.

In the introduction, for completeness, we have made a historical overview of the technologies used to measure ocean currents and mooring-based instruments mentioned as a key source of in situ

information, mainly in the past. Nevertheless, the focus of the paper is on remote sensing retrieval of surface currents surface currents where moorings play a relative minor role specially with respect the spatial resolution. We have added a new figure (figure 3) comparing the capabilities of each observational technology to measure sea surface currents (according to the GOOS panel) to highlight the advantages of remote sensing (satellites and HF radars) in terms of spatial and time coverage.

P2L20 – “resulting climatological fields” suggests that it is immediate to obtain them from observations. I would rephrase indicating that the climatological fields are calculated with the observations, sometimes using numerical models and data assimilation to provide a physical coherence for the gaps.

To better focus on the goal of the review we no longer talk about “climatologies”

P4L13 – The equation is wrong ("L" should be below), please correct . Also, include in the numbering system.

We have corrected the equation and now corresponds to equation number 1.

P6L22 – Please, indicate what is the “fast evolving structure at the Alboran Sea”.

We have modified the statement in the new version.

P19L23 – Is it, may be, “km” -> “m”?

We refer to hundreds of kilometers. It has been written explicitly to avoid confusion.

P22L22 – Not all the terms of the eq are described in the following paragraph. Particularly, matrices R and Pf. Please correct.

The missing descriptions have been added.

P22L25 – “vecor” -> “vector”. Actually, all the following occurrences are wrong (more than 10) which made me consult three dictionaries to ensure that “vecor” wasn0t an accepted variant of “vector”. Please, correct.

We apologize. All this has been corrected.

P22L28 – The comment about the notation seems pointless from the mathematical point of view. In

any case, a different letter “y” is used to highlight the fact that “x” indicates a vector in the model space and “y” indicates a vector in the observation space.

Rephrased and the text has been shortened.

P23L9 – “covariance matrix” –> “error covariance matrix”.

P23L12 – “covariance matrix” –> “error covariance matrices”.

Added.

P23L20 – Alpha is also known as the “inflation factor” and is needed because EnKF methods tend to be underdispersive and lose spread cycle after cycle. There for, an “inflation factor” is needed to make up for the loose of spread. Consider rephrasing.

Rephrased: “The parameter α, known as \textit{inflation factor}, is introduced to scale the weight of the ensemble versus the observations, to take into account the effect of the model error, and to avoid the collapse of the covariance matrix.”

P24L10 – “Vessel Traffic Service” case has not been introduced. Does it come from Breivik and Saetra (2001)? If so, please indicate it in the text.

Rephrased: “The low cost of the EnOI made possible to have a 6-hour forecast within 45 minutes since the data acquisition time.”

P26L26 – “control variance B” -> “model error covariance B”. Also, this matrix has the same meaning as Pf in the EnKF. Please, indicate it in the text.

We do not agree. The control variance is the same as the model error covariance only when the control vector is the initial condition. If the control vector contains variables or parameters other than the initial condition, the control variance differs from the model error variance. To avoid confusion, we have added the following text: “Note that if the initial model state is the only control variable, then control variance matrix $\vec{B}$ should be equal to the model error covariance $\vec{P}^f$ used in the EnKF.”