Ocean Sci. Discuss., 12, C958–C968, 2015
www.ocean-sci-discuss.net/12/C958/2015/

Ocean Science
Discussions
Open Access

Interactive comment on "A combined quality-control methodology in Ebro Delta (NE Spain) high frequency radar system" *by* P. Lorente et al.

P. Lorente et al.

plorente@puertos.es

Received and published: 21 October 2015

First of all, many thanks to Dr. Guillaume Charria for the number of useful comments that will help to significantly improve the quality of the final version of this manuscript. In relation to the specific suggestions:

Regarding comment 1: In the introduction, close geographical studies can be mentioned (Marmain's papers in Med Sea; Solabarrieta et al., 2014 in Bay of Biscay; ...).

We have added the suggested references in the following paragraphs: "In addition, the credibility of HF radar data has been previously tested in extensive validation studies, including direct comparisons of HF radar-derived surface currents with moored

ADCP's, point-wise current meters or drifters (Graber et al., 1997; Kaplan et al., 2005; Cosoli et al., 2010; Solabarrieta et al., 2014)."

"Other emerging uses include the validation of operational ocean forecasting systems or assimilation into numerical coastal circulation models (Marmain et al., 2014; Stanev et al., 2015)." And the references are:

Solabarrieta, L., Rubio, A., Castanedo, S., Medina, R., Charria, G. and Hernández, C.: Surface water circulation patterns in the southeastern Bay of Biscay: New evidences from HF radar data, Continental Shelf Research 74, pp. 60–76, 2014.

Marmain, J., Molcard, A., Forget, P. and Barth, A.: Assimilation of HF radar surface currents to optimize forcing in the North Western Mediterranean sea, Nonlin. Processes Geophys., Vol. 21, pp. 659-675, 2014.

Stanev, E.V., Ziemer, F., Schultz-Stellenfleth, J., Seemann, J., Staneva, J. and Gurgel, K.W.: Blending Surface Currents from HF Radar Observations and Numerical Modelling: Tidal Hindcasts and Forecasts, Journal of Atmospheric and Oceanic Technology, Vol. 32, pp. 256-281, 2015.

Regarding Section 3.2 - p. 1922 / l. 13: Why in the qualification part, only May to October 2014 has been considered as for the exploration of current fields, the whole year is considered. Please mention some reasons for this choice.

As reflected in section 2.2., verbatim: "It should be noted that current and wind records from B1 are only available from 1 May to 31 October 2014". This is the main reason to limit the validation exercise with the moored current meter to that specific 6-month study period. Since the statistical results obtained are significantly good, within tolerance ranges and in accordance with those previously reported in the literature, it seems reasonable to infer that HF radar performance was accurate during the previous period (January-April 2014). Equally, it seems to be also reasonable to expect a consistent radar performance during the last part of the year (November and December 2014) since no breakdown or anomaly in radar site status were detected, neither changes in the surrounding environment which could negatively impact on the precision of the measured antenna beam pattern (APM, implemented in December 2013) and hence, on the quality of HF radar-derived current data.

Furthermore, the results derived from the annual Quality-Control (QC) of diagnostic parameters (section 4.1) supports the fact that the overall performance of the HF radar system and the health of the three radar sites were solid and consistent, as stated in the Conclusions.

The previous statements reinforce why 1-year long of HF radar data has been chosen to explore and describe the main characteristics of the surface current flow in Ebro River Delta. In addition, a selection of an entire annual cycle provides a more comprehensive insight into the oceanographic features of this relevant marine protected area.

Regarding Section 3.2 - p. 1922 / l. 27-28 A filter is applied on the data and then considered for validation. Is it possible to describe or to overview the quality of the unfiltered products? Maybe it does not make sense due to the uncertainty in the measurements but then it has to be clearly mentioned.

Of course it is possible. Actually, they have already provided in Figure 4. This Figure shows the statistical results for raw (unfiltered) products, as stated in the corresponding Figure 4 caption:

“Figure 4. (a) Angular position of Ebro Delta HF radar sites respect to B1 buoy location. Angle values are measured counter-clockwise from East, indicating arc limits and buoy direction. (b-d) Correlation (solid line) and RMSE (dashed line) between unfiltered radial currents estimated by B1 buoy and those measured by three HF radar sites, SALO (b), ALFA (c), and VINA (d), using calibrated antenna patterns for a 6-month period May-October 2014. Vertical dotted line represents the angular position of B1. Vertical red solid line denotes the angular position of maximum correlation (CORR),

which is gathered with the associated RMSE and bearing offset ($\Delta\alpha$) values.”

In Lorente et al. (2014) and Lorente et al. (2015), both referenced in the manuscript, raw and low-passed time series were compared for Gibraltar and Galicia HF radar systems, respectively. The main aim was to check if the statistical metrics would improve after removing the high-frequency “tidal noise”. If so, the differences buoy-HF radar can be interpreted in terms of random errors and the wind influence on a diurnal time-scale.

In the present work with Ebro Delta HF radar system, the 6-month (May-October 2014) time series of hourly estimations were low-pass filtered not only for the aforementioned reasons but also for a visualization reason: a 6-month raw time series would be too noisy and degree of agreement could not be qualitatively inferred.

Regarding Section 3.3 - p. 1923 / l. 23: In this sentence we wonder what is the nature of "raw radar time series" but it is explained later in Section 3.3 - p. 1924 / l. 8-9. Is it possible to detail it before?

Of course it is possible. We have modified the indicated sentence in order to clarify the meaning of “raw time series”:

“To this purpose, maps of the Eulerian mean current field have been constructed at monthly time scale from the raw (unfiltered) radar time series on a subsampled grid”

Regarding Section 3.3 - p. 1924 / l. 12 Could you define/quantify the "significant" portion (even if it is detailed later in the paper)?

Since EOFs are purely statistical, each EOF mode’s statistical significance must be evaluated. Several rules of thumb have been previously proposed indicating when an EOF is likely to be subject to large sampling fluctuations. In the present work, error estimates based on temporal decorrelation scales have been calculated according to North et al. (1982):

$\delta(\lambda i\ )= \lambda i^*(2/N)(1/2)$

Where δi is the eigenvalue for mode i, and N is the number of degrees of freedom determined using a conservative two-day decorrelation time-scale, following Münchow and Chant (2000). If the confidence intervals from the error estimates of any modes overlap, the modes may be non-orthogonal and can not be considered distinct. Such modes are thus excluded from the EOF analysis and then, the first previous modes can be considered to contain "a significant portion of the total variance", as stated in the manuscript.

Here, only the first three EOF modes are statistically significant according to the mode selection rule and truncation criterion suggested by North et al. (1982). The first, second and third modes are distinct; however, the fourth mode is not since its error bars overlap with those of mode 5 (not shown). The first three EOF modes cumulatively account for the 46.1% of the variance for the raw (unfiltered) hourly time series of surface currents. Longer convergence rate is observed for higher-order modes since 150 EOF modes are required to reach the 95% cumulative variance threshold. The modes 4 and 5 represent the 3.66% and 3.24% of the variance, respectively. They are so close in terms of explained variance that the respective error bars clearly overlap, and then they must be left out.

To clarify this issue, a small paragraph has been inserted in section 3.3, summarizing the explanation presented above.

Finally, in section 4.3.2 has been also inserted the following explanatory piece of text: "Since the EOF analysis has been performed on the unfiltered data set containing relevant high-frequency spatiotemporal variability, the first three EOFs cumulatively account only for the 46.1% of the total variance (26.1%, 15.3% and 4.7%, respectively). Only the first three EOF modes are statistically significant according to the mode selection rule and truncation criterion suggested by North et al. (1982). The first, second and third modes are distinct and uncorrelated; however, the fourth mode is not since its error bars overlap with those of mode 5 (not shown). Therefore, higher order modes will not be further addressed here as they represent a combination of unresolved high-

frequency motions or noise (Cosoli et al., 2012a)."

References:

North, G.R., T.L. Bell, R.F. Cahalan and F.J. Moeng: Sampling errors in the estimation of empirical orthogonal functions, Mon. Wea. Rev. 110, pp. 699-706, 1082.

Münchow, A. and R.J. Chant: Kinematics of inner shelf motions during the summer stratified season off New Jersey, J. Phys, Oceanogr., 30, pp. 247-268, 2000.

Regarding Section 4.1 - p. 1924 / l. 19 For non-expert, would it be possible to detail a bit more in the text, for example, SNR3 (I noticed that it is mentioned in Table 1 but it would helpful to also have it in the text).

Yes, of course it is possible. We have added the following paragraph in the introduction (before section 4.1) to provide a more detailed definition of this parameter:

"One of the radial metrics that offers the most potential benefits as reliability indicator is the Signal-to-Noise Ratio of sea-echo at the monopole (SNR3), since it has been previously proved to be a valid indicator of both radar site status and onset of HF radar system malfunction (Cosoli et al., 2012b; Roarty et al., 2012)."

Regarding Section 4.1 - p. 1925 / l. 3: Following the same idea, could you shortly develop the "limitations in the MUSIC algorithm"?

In the introduction section, there is already a sentence that provides some details: "As MUSIC is employed to resolve ocean surface current structure (Schmidt, 1986), limitations in its performance are related to potentially suspect velocity outputs." As previously stated by De Paolo and Terril (2007): "For a given range cell and a given Doppler cell (and thus a given radial current velocity), the MUSIC algorithm can produce a maximum of two bearing solutions. Any more bearing in that range cell with the same radial current velocity will be left out, producing a gap where there is no solution. This is an inherent limitation of using MUSIC with the compact antenna design, with the statistics of the gaps depending on the environmental input". Complementarily, Cosoli et al. (2012) showed that “in the majority of the cases anomalous values were associated with poor SNR values”.

Therefore, low SNR3 values due to either environmental noise or interferences can lead to ambiguities in the estimation of the direction of arrival (DOA) function performed by MUSIC algorithm. Such ambiguities, based on the existence of more than two bearings in a given range cell with the same current velocity, produce gaps in HF radar spatial coverage (as reflected in Figure 3-b).

To clarify this point, we have added the following sentences to the manuscript:

“SNR3 reached extremely low values, leading to a drastic reduction in the radar spatial coverage presumably related to an inherent limitation of MUSIC algorithm, namely, the extraction of a maximum of two bearing solutions for a given range cell and a given radial current velocity. In this context, poor SNR3 values associated with potential interferences or environmental noise can lead to ambiguities in the estimation of the direction of arrival (DOA) function performed by MUSIC algorithm. Such ambiguities, based on the existence of more than two bearing solutions, eventually produce gaps in HF radar spatial coverage since the additional solutions are excluded.”

References:

De Paolo, T., and Terrill, E.J.: Skill assessment of resolving ocean surface current structure using compact-antenna-style HF radar and the MUSIC direction-finding algorithm, Journal of Atmospheric and Oceanic Technology, 24: 1277–1300, 2007.

Cosoli, S., Bolzon, G., and Mazzoldi, A.: A Real-Time and Offline Quality Control Methodology for SeaSonde High-Frequency Radar Currents, Journal of Atmospheric and Oceanic Technology, 29, pp. 1313–1328, 2012b.

Regarding Section 4.2 - p. 1926 / l. 28: The lag between minimum RMSE and correlation is clearly observed. Could you explain why there is this difference between the efficiency in RMSE and correlation?

As previously stated in section 3.2, “In absence of direction-finding errors (DF), maximum CORR and minimum RMSE values should be found over the arc point closest to B1 location. In presence of DF, the bearing offset is thus expressed as the angular difference between the arc point with maximum correlation and the buoy location.”

Since the HF radar system is not completely perfect, we have found small direction-finding errors in each radar site (Figure 4), rated at lower than 8áţŠ. Although such errors are small and in accordance with the typical values previously reported (Emery et al., 2004; Paduan et al., 2006), they impacted slightly on the relative position between the maximum correlation and the minimum RMSE, explaining the observed lag. In absence of DF, no lag would be found.

By overall consensus, the bearing offset is defined as the angular difference between the maximum correlation and the buoy location, although other criterion could have been used, i.e., the angular distance between the minimum RMSE and the buoy location. We chose the first option to follow the worldwide accepted methodology.

Section 4.2 - p. 1928 / l. 21-24: For the Taylor diagram (Fig. 7), results will be clearer to read and to interpret if you consider using the normalised (in standard deviation) version of the diagram. Examples are available in Taylor (2001) in Figure 5 or Figure 8.

According to our own experience with model data comparisons, normalized pattern statistics are significantly clearer and easier to interpret especially when trying to summarize on a single Taylor diagram a variety of fields (i.e., temperature, salinity, surface currents, etc.). Since the units of measure are different, statistics benefit from the fact of being nondimensionalized, leading to a more simplified graph.

However, we modestly consider that this is not the case. As only one type of field has been considered (HF radar-derived surface currents), we honestly think that the Taylor diagrams used in the present study are more appropriate because information relative to the monthly variability of measurements (standard deviation) and the monthly mismatch radar-buoy (RMSE) are clearly exposed. In the case of normalized Taylor diagrams, RMSE values disappear and the standard deviation of the reference is always plotted at unit distance from the origin, resulting in an excessively plain diagram where only correlation coefficients remain unchanged. In this context, we would like to show all the statistical information obtained.

Section 4.2 - p. 1929 / l. 21-25: In spectra, how do you explain a larger energy in high frequency (mainly CW spectra) in HF radars as the buoy has most probably an higher sampling frequency?

Both instruments employed in this work (HF radar and current meter) provide quality-controlled hourly averaged current velocity vectors. Therefore, there is no difference in terms of sample frequency. However, the current meter measures at a nominal depth of three meters, whereas HF radar derived maps are representative of current velocities in the upper first meter of the water column. In this context, it seems reasonable to suspect that radar estimations are influenced by energetic high-frequency processes related to air-sea interaction like highly variable and strong wind gusts, which are not contained in sub-surface current estimations provided by the current meter.

To clarify this point, a brief comment has been added to the new version of the manuscript: "Finally, a drop of energy and later flattening about 2 cpd are common for the CW components of both B1 and radar spectra, although the latter presents larger energy at that frequency band. Radar surface estimations are influenced by energetic high-frequency processes related to air-sea interaction like highly variable and strong wind gusts, which are not fully contained in sub-surface current estimations provided by the current meter."

Section 5 - p. 1935 / l. 22: In my opinion, numerical models provide a "quantitative" picture of the 3D dynamics.

Since we fully agree with this comment, "qualitative" has been replaced by "quantitative".

As a general comment, it would be useful to have the three timelines of the measurements to see gaps in the time series.

This useful suggestion has been taken into account: a specific section (section-c) has been added to Figure 1 to illustrate the continuity of the records (from HF radar sites and B1 buoy) employed in the present study.

Technical corrections In Abstract: My Ocean IBI - IBI acronym to be detailed.

The sentence has been replaced by: "Future works should include the use of verified HF radar data for the rigorous skill assessment of operational ocean circulation systems currently running in Ebro estuarine region like IBI (Iberia–Biscay–Ireland) regional system, implemented within the frame of MyOcean projects and the Copernicus Marine Environmental Monitoring Service (CMEMS)."

Figure 1: HFR1 and B1 not visible

Figure 1 has been replaced by a new one with the aim of highlighting HFR1 and B1 locations and solving the reported issue (see Figure 1, above)

p. 1941: belowlisted => below listed

Done!

p. 1941: Diagnose => Diagnosed

Done!

Interactive comment on Ocean Sci. Discuss., 12, 1913, 2015.

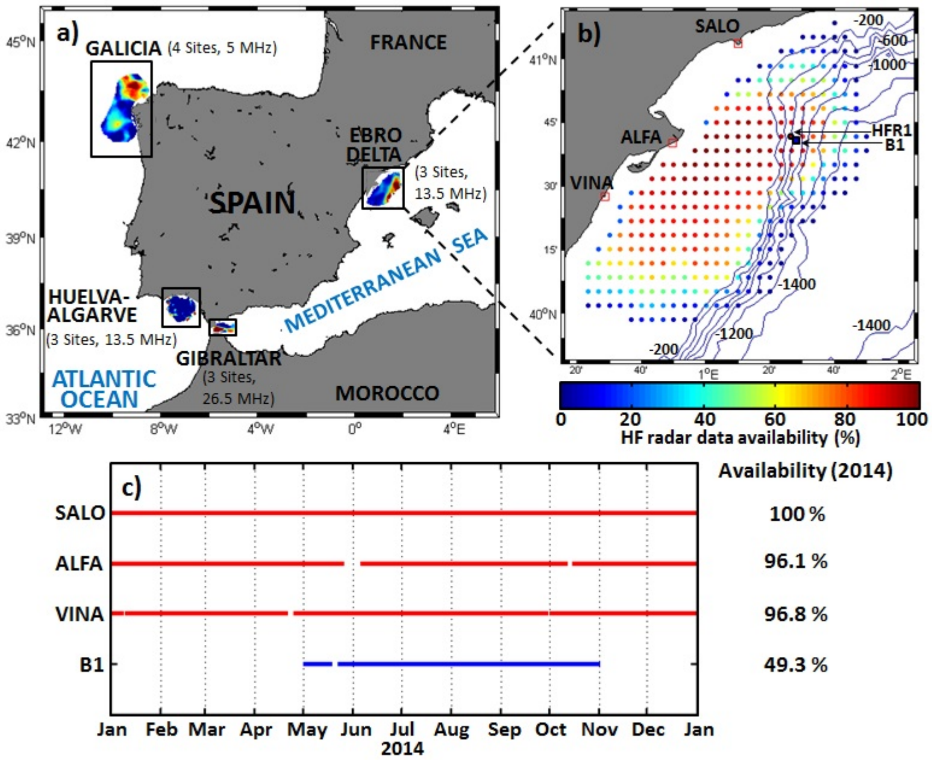

Fig. 1. (c) Time lines of HF radar sites (red) and B1 buoy (blue) current data availability for 2014.