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Interactive Comment

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

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Many thanks to the anonymous reviewer for taking her/his time to read the manuscript and also for sharing her/his point of view in the Open Discussion Forum. In relation to the specific suggestions:

Regarding comment 1: This work presents a quality control methodology for HF radars applied to observations in the area of Ebro Delta. This is a useful study, which could be beneficial for future use of HF radar data. However the paper is too long; it presents a lot of well-known details of HF radars from other papers. It has to be substantially shortened, particularly the first part.

The new version of the manuscript has been shortened in order to fulfil reviewer2's request, trying to avoid redundant information presented in sections 1, 3 and 5. Some explanatory paragraphs and the bibliographic references shown in the introduction have been kept to provide a basic background for non-expert readers.

Regarding comment 2: Furthermore, the geophysical relevance is not well explored and the presentation is sometimes misleading (difficult to differentiate between what authors and others have done).

Some modifications have been carried out in order to strengthen the discussion of results and to better explore the geophysical relevance of this study. For instance, according to reviewer3's recommendation, Figure 12 has been added with the aim of investigating the relative contribution of local wind as forcing mechanism. Particular emphasis has been placed to explore the link with the principal component of the second EOF mode of HF radar surface currents (depicted in Fig. 10-c).

Figure 12-a shows wind principal axes as derived from 6-month (May-October 2014) wind data measured by B1 buoy. Figure 12-b presents the principal components of the first EOF mode from B1 wind (red) and the second EOF mode of CODAR currents (blue), filtered with a 1-day moving mean. The amplitudes are normalized by their respective standard deviations. Equally, Figure 12-c shows the principal components of the second EOF mode from B1 wind (red) and the second EOF mode of CODAR currents (blue). As reflected from the associated correlation coefficients (0.47 and 0.67, respectively), the degree of agreement of the principal components is significant. This underlines the close relationship between HF radar mode-2 variability and the variability of local wind.

Regarding the presentation, the authors have modified several sections of the article with the aim of avoiding any confusion about what has been achieved in this paper and what has been previously done.

Specific comments:

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Regarding comment 3: Caption Fig. 2. Please don't repeat here what you say in text.

Ok. Redundant information has been removed from Figure 2 caption.

Regarding comment 4: The presentation of section 4.2, as it is now, is too technical. Much of what is shown in this section can be considered as the same information presented in a different way. I wonder if Taylor diagram is not sufficient to explain most of what has been found. Perhaps the rest can be briefly summarized in text.

The section 4.2 focuses on the validation of radar measurements with independent in situ observations by means of the evaluation of direction-finding capabilities and the angular distribution of radial velocity uncertainties. This approach has been previously adopted by a vast number of previous research works published in scientific journals (Emery et al., 2004; Paduan et al., 2006; Cosoli et al., 2010; Liu et al., 2014), not only on technical reports. Therefore, we honestly consider this section is not too technical and it suits the scope of the Special Issue. The information provided in Figures 4-7 is not redundant but relevant and complementary, as it is shown:

Figure 4, related to validation of radial vectors, focuses on bearing offset determination and directional accuracy.

Figure 5, related to validation of radial vectors, shows the degree of agreement between radar-derived and current meter radial vectors, for the radar arc point closest to B1 buoy location.

Figure 6, related to validation of low-pass filtered total vectors, reflects the concordance between radar-derived and current meter total vectors, for the radar regular grid point closest to B1 buoy location and for a 6-month period (May-October 2014). In addition, monthly averaged values for both instruments are presented with the aim of characterizing the basic features (at sub-inertial temporal scale) of the shelf-slope jet flowing southwestwards.

Figure 7, related to validation of unfiltered total vectors, analyses HF radar performance

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and accuracy on a monthly basis in order to check the consistency and robustness of radar data.

Since the other two reviewers have not pointed out any drawback or deficiency in section 4.2, we honestly consider that it should remain as it currently is.

Regarding comment 5: The discussion of results is a complex mixture of results from other authors and present study. One example is in p. 1930 "The jet is intensified in October as a result of the increase of the mesoscale activity (Font et al., 1995), reaching ultimately a peak strength in December". I would suggest that you tell "your story" as seen in your results and then say what agrees and disagrees with previous studies. More important is however to say what is the new finding originating from this new data set. Section 4.3.2 You say "The buoyancy input introduced by large estuarine outflows, together with topographic effects, lead to the development of the aforementioned anticyclonic coastal eddy on the southern side of the delta." Can you decipher this from the HFR observations? Please, concentrate your presentation on what you find in your observations and tell us what new we learn from them.

Before the referenced sentence in section 4.3.2, the following paragraph can be found in section 4.3.1: "A coastal anticyclonic eddy can also be observed in radar data, confined south of Ebro Delta mouth (Fig. 9 – a, b, c). This well-documented hydrodynamic feature is due to the interaction of the buoyancy-driven flow with the topography, reinforcing the shelf/slope front that drives the general circulation to the south-southwest (Font et al., 1990; Salat et al., 2002)."

Firstly, the authors state what can be observed from HF radar data. Then, the finding is confronted with evidences from previous researches focused in the same study area using instrumentation different from HF radar, later providing the reported explanation and referencing those works.

Aligned with the suggestion above ('tell "our story" and they say what agrees or disagrees with previous studies'), the paragraph has been rewritten:

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“A coastal anticyclonic eddy can also be observed in radar data, confined south of Ebro Delta mouth (Fig. 9 – a, b, c). This hydrodynamic feature has been well-documented in previous studies (Font et al., 1990; Salat et al., 2002), which stated the interaction of the buoyancy-driven flow with the topography as triggering source of the clockwise gyre, eventually reinforcing the shelf/slope front that drives the general circulation to the south-southwest.”

Regarding comment 6: “Temporal variation in the strength of these three EOF modes is represented by their corresponding time coefficients”. Better use the accepted name for these coefficients.

The aforementioned sentence has been modified accordingly:

“Temporal variation in the strength of these three EOF modes is represented by their corresponding time coefficients (also called principal components), shown in Fig. 11.”

Regarding comment 7: In this part I wonder what would be the result (% of variance) if you work with filtered data and compare with, say MyOcean/Copernicus product.

Although the radar-model comparison exercise is still underway and perhaps the question is out of scope of the present manuscript, preliminary results indicate a close HF radar-IBI agreement in terms of EOF analysis and variance explained for raw (unfiltered) surface current data. The three dominant modes of variability for Ebro Delta HF radar (IBI model) account for the 46.1% (49.2%) of the variability, with the first mode explaining the 26.1% (26%), the second mode represents the 15.3% (17.2%) and the third mode accounts for the 4.7% (6%).

Regarding the EOF spatial patterns, the first two modes derived from HF radar data and IBI model outputs are pretty similar, with the main differences arising from the third EOF mode: although both introduce complexity to the rather uniform surface patterns described by the first two modes, they do it in distinct ways. In the case of the HF radar, a clear divergence of the flow can be detected in the southernmost part of the

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spatial domain (Fig. 10-d), whereas IBI-derived mode 3 (not shown) reveals a complete clockwise eddy, with the associated core slightly displaced to the south-west part of the domain.

Regarding comment 8: Because CODAR is not the only HF radar system I wonder whether the proposed methodology is applicable or not applicable to WERA. Lots of literature on some quality control issues for WERA were recently presented by Stanev et al. (2015). I mention this work because error estimates (statistics) are very important for data assimilation, and perhaps you have to mention this useful aspect of your research in your revised manuscript.

The authors are fully aware of the existence of several radar systems on the market, not only CODAR or WERA. The assessment of radar data accuracy and development of quality control (QC) procedures implemented at various stages of data processing are ongoing research areas, regardless of the manufacturer.

In this context, significant efforts are currently underway to identify occasional non-realistic radar current vectors (defined as spikes, spurious values or corrupted data and to implement individual QC index. A considerable number of QC works with WERA systems have been published and are indeed cited in the present manuscript (see below), since they are perfectly valid for any type of HF radar system, and vice versa: QC methodologies with CODAR systems are also applicable to other kind of radar systems since they rely on fundamentally similar physics and Doppler processing algorithms to infer the range and radial velocity of the scattering surface.

The WERA works referenced in the present article are the following:

Gomez, R., Helzel, T., Petersen, L., Kniephoff, K., Merz, C.R., Liu, Y., and Weisberg, R.H.: Real-time quality control of current velocity data on individual grid cells in WERA HF radar, Oceans 2014, Taipei, pp. 1-7, 2014.

Gomez, R., Helzel, T., Merz, C.R., Liu, Y., Weisberg, R.H., and Thomas, N.: Improve-

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ments in ocean surface radar applications through real-time data quality-control, Conference: Current, Waves and Turbulence Measurement (CWTM), IEEE/OES, Florida, USA, March 2015.

Liu, Y., Weisberg, R.H., and Merz, C.R.: Assessment of CODAR SeaSonde and WERA HF Radars in Mapping Surface Currents on the West Florida Shelf, Journal of Atmospheric and Oceanic Technology, 31, 1363–1382, 2014.

Wyatt, L.: Improving the quality control and accuracy of HF radar currents, IEEE Oceans 2015, Genova, pp. 1-9, 2015.

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.

As it can be seen, Stanev et al. (2015) has been included in the reference section, and the following sentence added to the Introduction:

“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).”

Regarding comment 9: Page 1914, Line 10: “The main goal of this work is to present a combined QC methodology for the specific case of Ebro HF radar (although easily expandable to the rest of PdE radar systems)”. Related to the previous comment, I wonder how applicable the method is to tidally-dominated environments.

As previously mentioned, this QC methodology is applicable to any HF radar system, regardless of the manufactures and/or the environment, since they all rely on fundamentally similar physics and Doppler processing algorithms to infer the range and radial velocity of the scattering surface. Actually, this approach has been applied to the four HF radar systems operated by Puertos del Estado (see Figure 1-a), included the network deployed in Galicia (NW Spain, a tidally-dominated region) or the network deployed in the Strait of Gibraltar, where the most important sources of transport variability are the diurnal and semi-diurnal constituents. The four HF radar systems are routinely monitored on the dedicated website mentioned in the manuscript.

Regarding comment 10: Page 1919, Line 20: “representative of current velocities in the upper first meter of the water column”. Please specify under which conditions this 1m is valid.

HF radar data are representative of a certain depth of the water column. Such depth is related to the nominal radar frequency at which HF radar system operates and also to ocean wavelength. As reflected in the attached CODAR Table (below), the significant wave height at which second order spectra saturates the first order and no current measurements possible is 13 metres, for the specific case of Ebro delta HF radar system (13.5 MHz).

Regarding comment 11: Page 1920, Line 20: “current velocity vectors at a nominal depth of three meters” How well this combines with 1m mentioned above?

In section 4.2, the following piece of text can be found:

“Instrument-to-instrument comparisons present intrinsic limitations since both devices operate differently and at distinct nominal depths. A fraction of observed radar-B1 differences can thus be explained in terms of different sampling strategies on disparate time and space scales (Ohlmann et al., 2007). In this context, many of the uncertainties associated with HF radar technology are geometric in nature. Apart from the instrumental noise, other sources of potential errors in vector currents might be the sub-grid horizontal shear, the geophysical variability within the water column (Graber et al, 1997) and some specific processes, namely, the Stokes drift, the Ekman drift and baroclinity (Paduan et al., 2006).”

Therefore, the differences observed between HF radar data and point-wise current

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meter observations must be carefully interpreted since the vertical shear resulting from seasonal stratification might play a significant role during the validation exercise. No additional changes have been introduced in the paper since we consider this point has been clearly exposed.

Regarding comment 12: Section 3.3 can be substantially shortened and integrated with Section 4. We are afraid that there is a conflict between this suggestion and both reviewer1 and Dr. Cosoli's recommendation:

"An interesting EOF analysis is presented, with the complex-valued approach, though some authors suggest using the real-valued approach. They are presented as statistically significant- however no information is given on the confidence levels or on the degrees of freedom to support this statement" The following paragraphs have been inserted in section 3.3 in order to provide further details about the significance of the three EOF modes selected in the present study: "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 and uncorrelated. Such modes are thus excluded from the EOF analysis and hence only the first previous modes can be considered to contain a significant portion of the total variance and to properly reproduce the observed surface current fields."

Literature:

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E. V. Stanev, F. Ziemer, J. Schulz-Stellenfleth, J. Seemann, J. Staneva, and K.-W. Gurgel, 2015: Blending Surface Currents from HF Radar Observations and Numerical Modeling: Tidal Hindcasts and Forecasts. J. Atmos. Oceanic Technol., 32, 256–281.

As previously mentioned, this work has been included in the reference section and the following sentence added to the Introduction:

“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).”

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

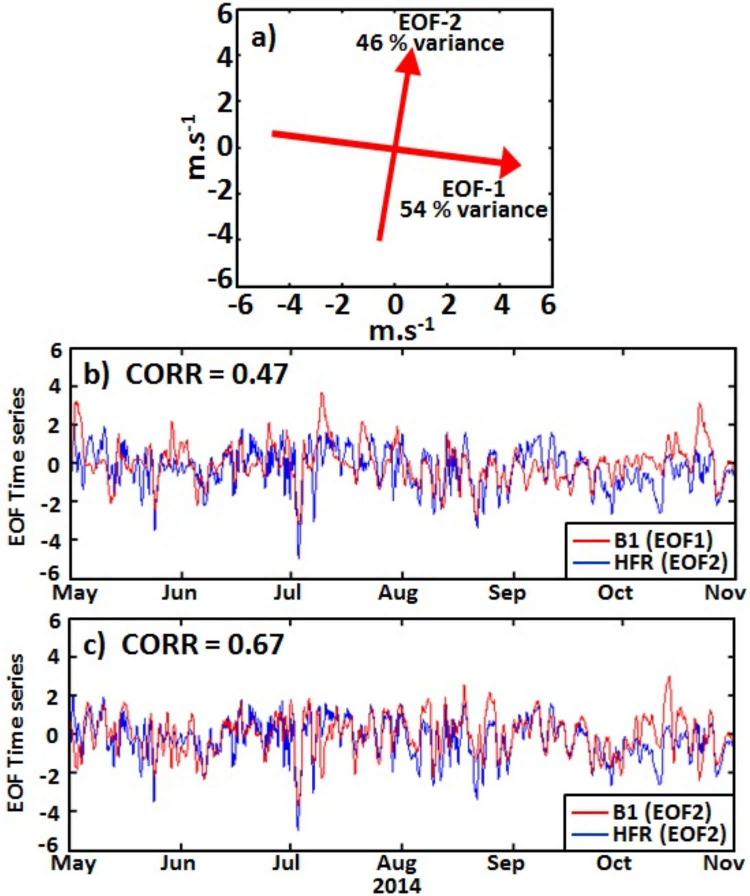

Fig. 1. Figure 12

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Interactive Discussion

Discussion Paper

SeaSonde Operational Performance vs. Frequency

Radar Frequency (MHz)	Radar Wavelength (m)	Ocean Wavelength (m)	Ocean Wave Period (s)	Depth of Current[1] (m)	Typical Range[2] (km)	Typical Resolution[3] (km)	Typical Bandwidth (kHz)	Upper $H_{1/3}$ Limit[4] (m)
5	60	30	4.5	2	175-220	6-12	15-30	25
12	25	12.5	2.5	1-1.5	60-75	2-5	25-100	13
25	12.5	6	2	.5-1	35-50	1-3	50-300	7
48	6	3	1.5	<.5	15-20	.25-1	150-600	3

1. Depth averaged current
2. Range based on 40W avg power output. Salinity, wave climate and RF noise may affect this.
3. Based on bandwidth approval only - no system limitations - higher resolution will cause some range loss
4. Significant Waveheight at which 2nd order spectra saturates 1st order and no current measurements possible

qualitas instruments

Fig. 2. SeaSonde Operational Performance versus Frequency

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