Response to Referee #1

This paper proposes a study of the oceanic circulation in the Golf of Cadiz based on 5 years observation of surface currents (2016-2020) with 4 stations of High-Frequency Radars (HFR) deployed along the southern coast of Portugal. The combined radar stations cover an area of about 200 km along shore and 100 km offshore. The HFR currents are compared and validated with a series of in situ measurements including 3 ADCP moorings and 3 drifters. The analysis is sound and well written. In the end it leads to a complete description of the main circulation pattern and its seasonal variations. I have no core objection to the main results and will only point out weaknesses in the methodology and possible improvements. Also, as an expert of HFR processing rather than oceanography, I will essentially comment on the techniques that are used to extract and validate the HFR surface currents.

We are thankful for the positive evaluation of our work and have replied below (in blue) to all the Reviewer's comments. The revised text is indicated in italic, in between quotes. The line numbers correspond to the revised manuscript.

Main comments

1) In the Abstract it is claimed that the analysis is made from « validated hourly HFR measurements ». However, it seems that the validation and comparisons with in situ measurements is made only with low-pass filtered data corresponding roughly to a daily average (40 hours Butterworth filter). This needs some clarification. In particular, i the EOF decomposition obtained from hourly data or low-pass filtered data?

Reply: The original MS states in Section 4 that the validation of the HFR data is performed with filtered data (for ADCP) and non-filtered data (for drifter).

Following the Reviewer's suggestion, it is now clarified that the EOF analysis was performed with filtered data, while the DINEOF interpolation considered unfiltered data:

Lines 174-175

"*In order to describe the surface current main variability patterns, an empirical orthogonal function (EOF) analysis was applied to the subtidal HFR data following the techniques described in Kaihatu et al. (1998) and Kundu and Allen (1976).*"

Lines 182-186

Since EOF requires the dataset to be free of gaps, the velocity components were interpolated using the Data Interpolating Empirical Orthogonal Functions (DINEOF) method presented in Beckers and Rixen (2003), which is widely used for filing gaps of satellite derived products (Alvera-Azcárate et al., 2005) and is suitable to the case of HFR data (e.g., Hernández-Carrasco et al., 2018; Kokkini et al., 2014). The DINEOF methodology was performed using unfiltered data, *for maps having at least 75% of spatial coverage (against 60% for the mean and STD) to avoid excessive interpolation*. “

Is the interpolation of small gaps (< 6 hours) made within the EOF process or is a preliminary ad hoc filtering?
This could lead to different outcomes.
Reply: The interpolation is done prior to the EOF analysis. The 6h threshold was chosen to avoid excessive interpolation (generally, the flow does not change drastically during that time).

2) As it is well known (Stewart and Joy 1974), the HFR measurement integrates the current over a depth equal to a fraction of the radar wavelength (lambda/8 pi). This make the comparison with ADCP meaningful only if the depth of the measurement cell is comparable. I could not figure out from the manuscript the exact depth of the last bin in the various ADCPs. Could this be stated explicitely and commented ? A difference of measurement
depth between the ADCP could account for part of the difference of performances in the HFR comparison. This information could be given or recalled in Table 1.

Reply: We agree with the Reviewer. This point – and other causes of mismatch between HFR and ADCP velocities - was already mentioned in the original MS (Line 218-220).

Following the Reviewer advice, we have updated the MS with an indication of the ADCP near surface cell depth:

Lines 157-158
For this study, only validated near surface cells (generally within the first 2-4 m from the surface) were considered.

However, we choose not the ADCP cell depth in Table 1 because it is not constant.

3) Figure 4 shows the radial current on a very coarse temporal scale. It seems that during the second half of january 2017 the HFR and ADCP current have significant difference (> 20 cm/s). Is there a reason or proposed explanation for this particular period ? Could subsurface processes and current shears be responsible for this (in relation to the former point regarding
the ADCP measurement depth) ?

Reply: The cause of this temporally limited mismatch is not clear. It may be attributed to any local transient surface layer phenomena, with time scale of few days, that the top bins of the ADCP did not capture In any case, such occurrence is rare and does not challenge the general good correspondence of ADCP and HFR data (as illustrated in Figure 4).

4) The RMSD between HFR and drifter measurements is very large (~ 25 cm/s in norm). Due to the motion of drifter I think the comparison with daily HFR currents is not very meaningful and should rather be done with hourly data. Furthermore, the drifters having no drogue, they are more sensitive to wind and near-surface current and therefore faster than the average current over the HFR integration depth (see for example Dumas et al., Ocean Dynamics 2020 for HFR comparisons with drifters with and without drogues). All in one, the drifters do not appear to be a relevant validation tool in this context.

Reply: Subtidal data are hourly, not daily. In any case, the analysis was conducted with the non-filtered hourly data as suggested by the Reviewer. The drifters provide the unique available dataset for comparison with HFR data offshore. Therefore, despite some limitations (and we fully agree with the Reviewer about that, as mentioned in Lines 231-233), we prefer to let this analysis in the MS. Overall, the general skill scores are within the range of values presented in the literature.

5) Did you perform self-consistency tests to assess the validity and accuracy of the EOF reconstruction ? See for example Bourg & Molcard Ocean Dynamics 2021 for such kind of procedure.

Reply: The validity and accuracy of EOF modes 1 and 2 are tested separately with HFR measurements in Figures 10, 14 and 15, providing consistent, expected correspondences:
- In Figure 10 the reversed phase (±180°) of mode 1 coincides with broadly eastwards currents over the entire TrW (in red).
- In Figure 14 the conditioned mean map is computed from periods with mode 2 phase between -65° and 65° and the resulting map coincides with the (in phase) mode 2 spatial map.
- In Figure 15, cyclonic eddies are only detected when mode 2 is in phase and with significant amplitude.

Minor remarks :

• Line 133 p 5: « ...is estimated from adjacent valid measurements ». I do not understand this statement. If the angle between radials is less than 20 degree, it will be more or less the same with adjacent measurements ?
Reply: The valid measurements nearby used for interpolation have an angle > 20º, as now indicated in the revised MS:

Lines 132-134
"At regions where the radials from two antennas make an angle ≤ 20°, the orthogonal velocity component cannot be estimated accurately (Chapman et al., 1997; Paduan and Washburn, 2013) and is estimated from adjacent valid measurements (i.e., with radial angle > 20º; CODAR, 2004a, 2004b)."

• Line 134 p 5: « The 2 references CODAR a,b seem to be incomplete. Are these tutorials, manuals, preprints?

Reply: We are thankful to the Reviewer for noticing this. The references refer to CODAR's software manual and were updated accordingly.

"Codar: About Baseline Interpolation, Manual 2004a. http://support.codar.com/Technicians_Information_Page_for_SeaSondes/Docs/Informative/Baseline_Interpolation.pdf."

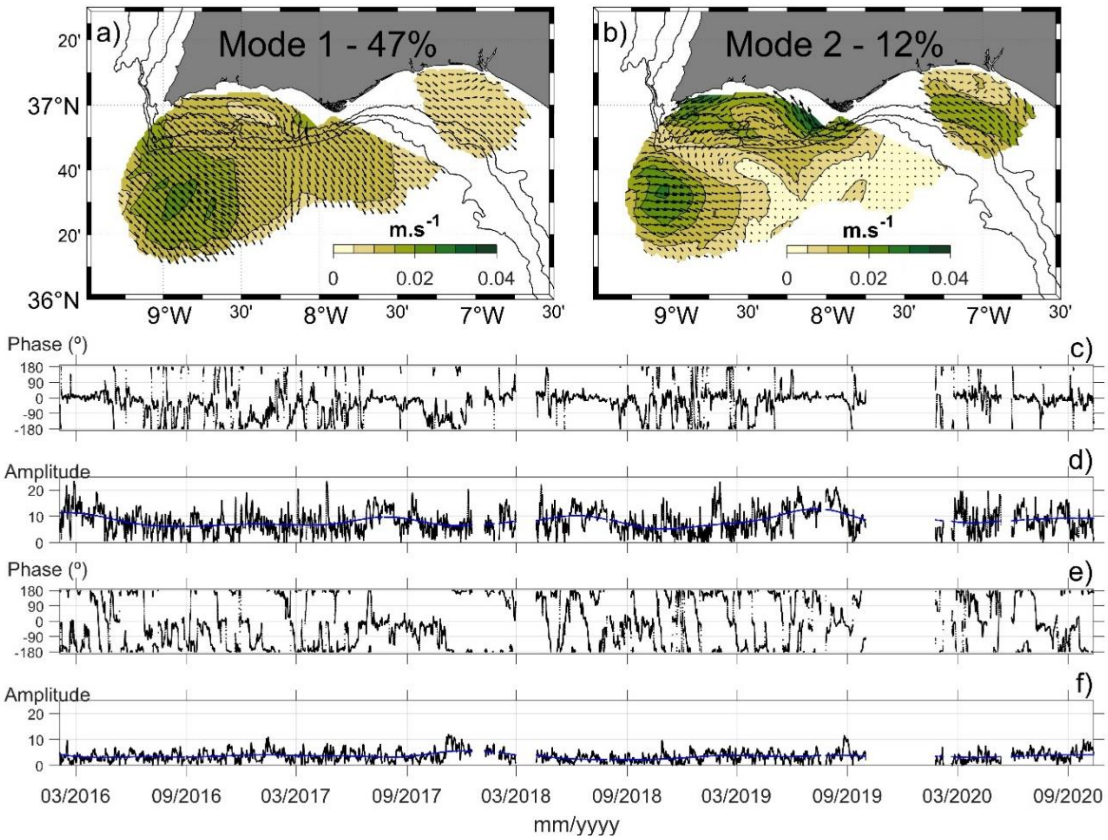
"Codar: Obtaining Total Current Velocities from Radials, Manual 2004b: http://support.codar.com/Technicians_Information_Page_for_SeaSondes/Docs/Informative/Combining_Radials.pdf."

• The EOF method which is employed (Alvera 2005, Beckers and Rixen 2003) is today commonly referred to as « DINEOF ».

Reply: We are grateful for this comment. Following the reviewer's suggestion, we have included the commonly used name in the revised MS.
See Lines 183 and 185.

• At view of Fig 5 and Fig 6 on the EOF decomposition it seems than the mean field is included in Mode 1, which is 47 % of the variance. Can you please clarify whether Mode 1 in Fig 6 is a velocity anomaly or not? Also please specify the scales and units in the plots. The amplitude of Mode 1 ranges from 0 to 20, this makes big values in the end when multiplying by the amplitudes of Mode 1 or 2.

Reply: No spatial or temporal mean is removed for the EOF analyses, similar to the references cited in the text. Following the Reviewer's suggestions, the units are now indicated in Figure 7 (see below) and are explained with more detail in the revised caption.



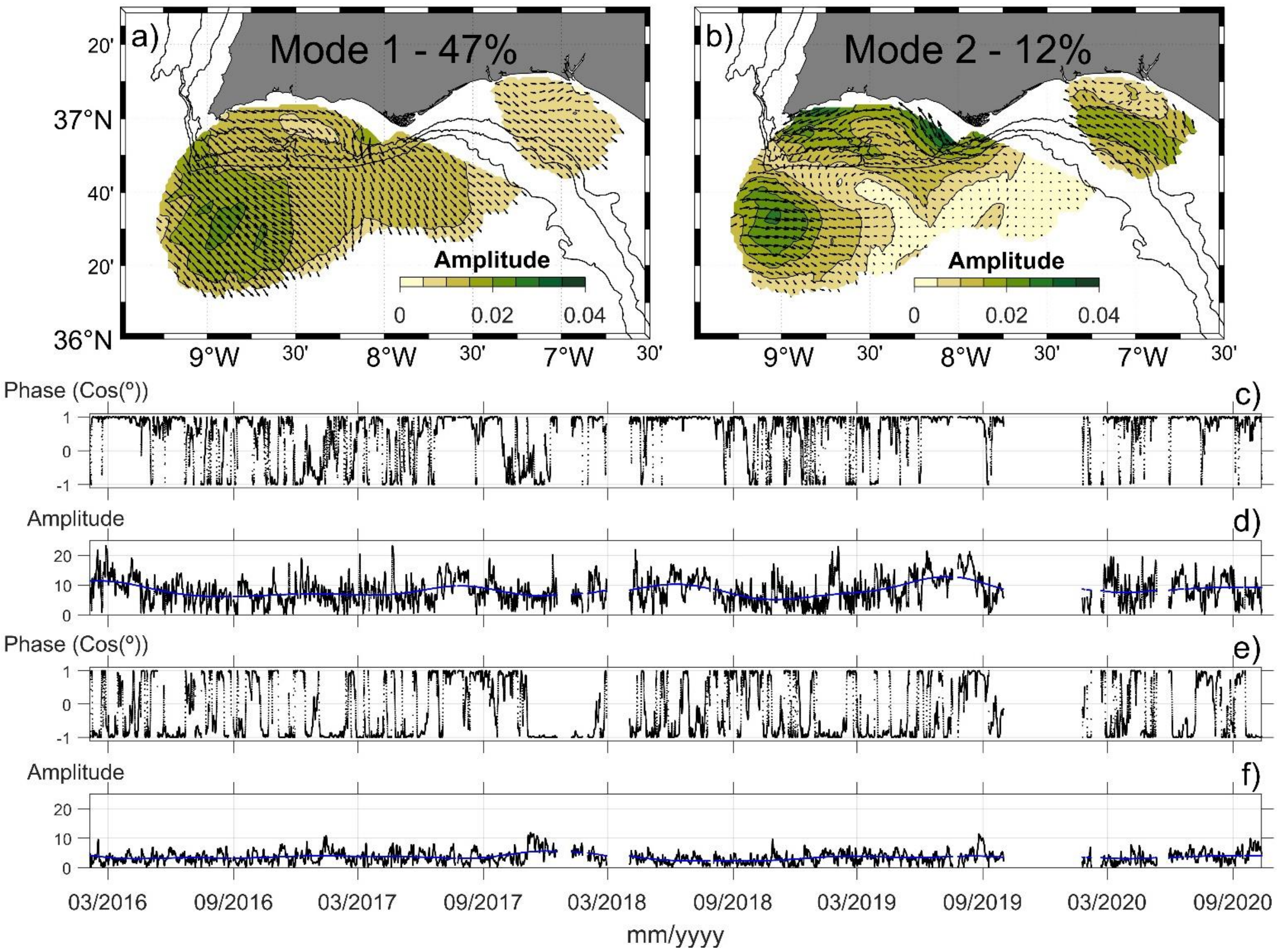
Lines 304-305

"The reconstructed velocity for each mode corresponds to the local spatial value multiplied by the dimensionless amplitude and rotated of the respective phase angle."

The high amplitude values are counterbalanced by the small values on the spatial maps: for example, the maximum value of Mode 1spatial map is 0.022 $m.s^{-1}$, which gives about 0.5 $m.s^{-1}$ when multiplied by the maximum temporal amplitude (23.25). This value corresponds well to the observed max value (0.6 $m.s^{-1}$) in Figure 12.

• Regarding the phase ambiguity (180/-180) in Figure 7, this could be circumvented by plotting the cosinus or by unwrapping the phase.

Reply: We are thankful for the recommendation, but after experimenting (see figure below) we believe that the original figure shows better the patterns we point out (In particular the periods when the phase oscillates around 0).



• As noticed by the authors the phase of the spatial modes is close to 0 or ± 180 degree in Figure 7. Is this a criterion of correctness for the EOF decomposition? Otherwise can one expect arbitrary values for this phase?

Reply: The reference to phase = 0 or ± 180 is not a criterion for the correctness of the method. It is used to indicate that the pattern represented by the spatial mode is recurrent as well as its complete reversal (when the phase is 180).