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Interactive comment on "River bulge evolution and dynamics in a non-tidal sea – Daugava River plume in the Gulf of Riga, Baltic Sea" *by* E. Soosaar et al.

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Comment 1: Several parts of the methodology section should be further developed and details should be given about some choices performed. The validity of the satellite remote sensing imagery and numerical modelling methods followed should be proved to accurately detect and reproduce the plume dynamics. The description of the methodology followed both through satellite remote sensing imagery and numerical modelling it is not sufficiently complete and precise to allow their comprehension and reproduction by other experts and therefore the results are not traceable. Section 2.1: The methods to distinguish the turbid water from the clear sea water should be scientifically and

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precisely defined to allow the application of satellite remote sensing imagery to plume detection;

Reply: Additional information was added to the manuscript in order to make the satellite based results reproducible and traceable. Two things that were missing and could help the reader are (1) the reference to the software (BEAM) that was used for image processing and (2) information about the used quality flags for masking invalid pixels. The missing information is now added to the manuscript. The BEAM, along with the algorithms in it, is a standard tool/method for MERIS data processing. The relevant information necessary for the reproduction of the results is as follows: -Satellite sensor- ENVISAT/MERIS - The database from which MERIS images were acquired- http://www.coastcolour.org/data/archive/ -Processing algorithm- C2R algorithm is described in detail by Doerfer and Schiller (2007). The algorithm has been validated in the Baltic Sea region in numerous studies. We added some extra references to the algorithm. -Projection, resolution information- UTM34, 0.3 km -Software package- BEAM (http://www.brockmann-consult.de/cms/web/beam/) -Quality flags that were used in processing- ! l1p_cc_land and ! l1b_invalid and ! l1p_cc_cloud_shadow and ! case2_invalid and ! case2_whitecaps and ! case2_conc_oor and ! l1p_cc_glintrisk and ! l1p_cc_cloud_shadow and ! l1p_cc_cloud_buffer and ! l1p_cc_cloud_ambiguous and ! l1p_cc_cloud and ! sunglint and ! l1p_cc_snow_ice

Comment 2: Section 2.2: It is essential to perform a comparison between satellite imagery results and observations to prove the adequacy and validity of the methods applied;

Reply: The in situ measurements of TSM concentrations or optical properties were not conducted at the time of the study period. Therefore, the algorithm was not directly validated for the specific region and period. However, the C2R algorithm for the Baltic Sea has been validated in numerous previous studies (from Bothnia in the north to the Polish coast in the south, and from the Swedish coast in the west to the Gulf of Finland in the east) (Siitam et al 2014, Attila et al.2013, VaičiÅńtÄŮ et al 2012) and its advantages and disadvantages are known. The C2R algorithm has been proven to be suitable for monitoring of water quality parameters (including TSM). Satellite imagery studies of many river bulges (including Mendes et al. 2014, Horner-Devine et al 2008 etc) have exploited MODIS data, which has been processed with SeaDAS software package and algorithms. However, it is common knowledge, and has been pointed out also by Goyens et al (2013), that standard MODIS atmospheric correction algorithms give poor results in the Baltic Sea compared to other regions of the world ocean. The inaccurate atmospheric correction procedures impact the retrieval of remote sensing reflectance, IOPs and water quality parameters in the Baltic Sea from MODIS imagery using standard processing algorithms (including the ones in SeaDAS). Numerous studies in the Baltic Sea have proved that MERIS is more suitable for water quality monitoring than other sensors (eg. MODIS, Seawifs). This is due to the selection of spectral bands by the MERIS instrument (sufficient spectral resolution in the range of wavelength above 555 nm), which is designed for monitoring optically complex waters like the Baltic Sea (Gitelson et al. 2009). The methods referred to in Mendes et al. (2014) and Horner-Devine et al. (2008) exploit SEADAS, which is not applicable in the Baltic Sea and causes heavy overestimation of water quality parameter values. While the analogous atmospheric correction, IOP and water quality parameter retrieval algorithm for MERIS, the C2R that we used, performs better in the Baltic Sea. Moreover, Mendes et al. 2014 found the normalized water leaving radiance at band 555nm (SeaDAS) to be the most suitable for bulge monitoring as it had sufficiently high correlation (r=0.56 for MODIS/Terra and r=0.60 for MODIS/Aqua) with river discharge. In the MERIS studies mentioned above, the TSM concentrations retrieved with the C2R algorithm from MERIS imagery were correlated with in situ measurements of TSM concentrations. The corresponding correlation coefficients (r) were between 0.72 and 0.87, which is significantly better compared to the Mendes et al (2014) study. Although the numbers are not comparable one-on-one, they impy that the MERIS-based TSM retrieval represents TSM variation in the upper layer reasonably well. Thus, the use of C2R algorithm for MERIS image processing over the Baltic Sea region is justified.

Section 2.2: Why the measurements of Gauja and Lielupe rivers fows were multiplied by 1.05 and 1.87, respectively? How were obtained these numbers? The use of this numbers has to be justified.

Reply: The coefficients are obtained as a ratio between the whole catchment area of those rivers and the catchment area of those rivers up to the place/station where the river flow was measured. Coefficient = whole catchment area / catchment area up to the measured location. Clarification was added in the revised manuscript.

Section 2.3: model calibration and validations results must be presented through comparison with in situ field data, and the model predictions accuracy has to be quantified; additionally, the comparison should prove the models accuracy in simulating the local river plumes dynamics;

Reply: A new section (2.4 Model validation) was added to the revised manuscript.

Section 2.3: The model TSM input used for the river discharges should be characterized (Realistic values? Real values measured in situ? Where?

Reply: TSM concentration in the river water was set to a unit value, as we do not have measurements of TSM concentrations in the river. The passive tracer was released to the GoR as Daugava River load of TSM being proportional to the Daugava River run-off starting from 20 March. Thus, the load is equal to TSM concentration multiplied with river run-off. The latter varying in time, as measured. We added clarification in the revised manuscript.

Section 3.1: the analysis presented should start before the plume establishment (maybe on #17th March) in order to allow the understanding of the plume dynamics in response to the high freshwater discharge event;

Reply: A 3-day spin-up period with a realistic salinity field and a linear increase of river run-off from zero to measured river run-off value on 20 March 2007 was used before including wind forcing on 20 March. Thus, we reached the peak value of freshwater discharge. During the spin-up period the wind speed was high, i.e. between 6 and 12 m/s (Fig. 2). As shown in Section 3.2, the wind of 4 m/s affects the bulge considerably, so we may expect that much stronger wind would mix river water with surrounding water in natural conditions. The satellite image on 20 March shows a much smaller plume and bulge than on the following images (Fig. 4a). Therefore, we suggest that this plume corresponds mainly to the initiation of the plume at midnight between 19 and 20 March when wind speed decreases from 6 to 2 m/s. Checking the sequence of tracer spreading in the numerical model showed that the bulge showing on the satellite image of 20 March (Fig. 4a) was destroyed by moderate wind of 5-6 m/s on 24 March (Fig. 2b). Upwelling favourable wind has significant effect on the bulge evolution, as shown with additional numerical experiments with constant wind from different directions (Fig.6 in revised ms). The plume on 26 March was the result of the reset of the river plume on 24 March. The bulge analysed in the present study started to develop after March 24 at 05:00 and existed for the following 7-8-days. In order to retain the focus of the paper, we concentrated on a single long-lasting bulge evolution event.

Section 3.3: Why was used an ambient water salinity of 6? Please justify this assumption;

Reply: Based on the measurement study carried out between 1973–1995 in the GoR by Raudsepp (2001), long term average value for the salinity in the central GoR was about 6 (Raudsepp 2001, Figure 2b). We added T/S profile, adopted from Raudsepp (2001), to the Figure 1 in revised ms.

Section 3.3: simulations of rivers discharge into a homogeneous GoR with an ambient water salinity should also be performed considering idealized winds of growing intensity to analyse the wind effect in the evolution of the river bulge; without this the discussion and conclusions about the wind effect on the river bulge establishment and evolution are not solid;

Reply: We have made additional simulations with cross-shore and alongshore winds

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of 2 m/s and 4 m/s. We added paragraph and a figure to the revised manuscript.

Section 3.4: without comparison with in situ field data it is impossible to prove that model results are describing the local patterns and physics of the river bulge dynamics; -

Reply: Comparison of in situ data and model simulation results were made and a new section (2.4 "Model validation") has been added to the revised manuscript.

Section 3.4: the selection of threshold values based on visual inspection of TSM concentration maps on the satellite images is subjective and therefore not scientific; moreover, it is not acceptable that this threshold varied from image to image;

Reply: There is no established methodology to determine bulge edge. Multiple previous studies define the bulge edge based on selected constant threshold values. Horner-Devine et al (2006) estimated that a quadratic curve captures the bulge front for the central region but not on the bulge edges. Therefore, a constant 20% buoyancy contour was chosen as a reference value since isolines corresponding to lower buoyancy levels reflect too much variability and become difficult to fit. Gregorio et al. (2011) used reference velocity, 1.7cm/s, to define the coastal current front. Soosaar et al. (2015) defined the bulge edge to be 10% from the discharge depth.

We have removed from the revised manuscript the parts where bulge measures from satellite images are defined, described, calculated and discussed. We kept the bulge measures calculated from numerical model results. We calculated the bulge boundary with different threshold values. Although the actual boundary changes, the dynamics of the bulge does not depend on the selected threshold value. We have added text and modified the Fig 7 in the revised manuscript.

Section 3.4: methods such as those developed by Horner-Devine et al. (2008) or more recently by Mendes et al (2014) based on the normalized water-leaving radiance should be developed and applied for plume detection;

Reply: The methods referred to in Mendes et al. (2014) and Horner-Divine et al. (2008) exploit SEADAS, which is not applicable in the Baltic Sea and causes heavy overestimation of water quality parameter values. While the analogous atmospheric correction, IOP and water quality parameter retrieval algorithm for MERIS, the C2R that we used, performs better in the Baltic Sea. Moreover, Mendes et al. 2014 found the normalized water leaving radiance at band 555nm (SeaDAS) to be the most suitable for bulge monitoring as it had sufficiently high correlation (r=0.56 for MODIS/Terra and r=0.60 for MODIS/Aqua) with river discharge. In the MERIS studies mentioned above, the TSM concentrations retrieved with the C2R algorithm from MERIS imagery were correlated with in situ measurements of TSM concentrations. The corresponding correlation coefficients (r) were between 0.72 and 0.87, which is significantly better compared to Mendes et al. (2014) study. Although the numbers are not comparable one-on-one, they imply that the MERIS-based TSM retrieval represent TSM variation in the upper layer reasonably well. Thus, the use of the C2R algorithm for MERIS image processing over the Baltic Sea region is justified.

We have removed the parts from the revised manuscript where bulge measures from satellite images are defined, described, calculated and discussed.

Section 3.4: Why was assumed that the bulge has a circular shape (equation 2)? This should be justified; -

Reply: Methodology is selected with the aim to maintain consistency with previous river bulge studies (Horner-Devine, 2009; Horner-Devine et al., 2008; Horner-Devine et al., 2006), where bulge radius is calculated assuming a circular shape, although the actual bulge is not circular. We have added clarification to the revised manuscript.

Remaining results, discussion and conclusion sections: as the results are all unproven due to the major flaws previously referred, these sections are purely speculative.

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