Ocean Sci. Discuss.,
doi:10.5194/os-2016-106-AC3, 2017

Ocean Science Discussions

Interactive comment on "Medium-term dynamics of a Middle Adriatic barred beach" *by* Matteo Postacchini et al.

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Received and published: 1 March 2017

We appreciate Reviewer #2' comments, which have been taken into due account to improve the clarity and quality of the manuscript. The comments from the Reviewer below are in italic font and our point-by-point responses are in bold.

General Comments

Summary: This submission investigates medium-term morphodynamics of a barred beach along the Middle Adriatic coast of Italy using annual bathymetric surveys and offshore wave buoy data. Previous studies of similar beaches have focused on short and long-term dynamics, leaving medium-term behavior relatively unstudied. A better understanding of the connections between wave climate and changes in nearshore *morphology is needed to improve models that predict storm effects (flooding), beach erosion, or how shoreline protection structures will affect a beach. The authors utilize well-tested data sources (bathymetric surveys and wave buoy from Italian wave measurement network) to examine dynamics on a neglected timescale, medium-term. However, the bathymetric data was collected only once per experimental year, and in my opinion, this limited data set imposes restrictions on the authors' interpretation of the results. Namely, there is insufficient data to separate the possible effects of short term changes due to winter storms from medium-term changes due to medium-term wave climate. See Specific Comments section for further comment.*

We agree with the Reviewer that only some surveys are available in the period of operation of the wave buoy. However, it should be noticed that the medium-term climate is not a mean climate, but the sum of storms and calm states occurring during the considered time period. Each of these states does give a specific contribution to the overall morphological variation observed in such a period. Hence, we do not want to separate the short-term from the medium-term effects, rather we want to discuss the cumulative effects of all events occurring in that time range. In addition, such an analysis is useful to demonstrate that the beach evolution can be predicted also when a limited number of surveys is available, which is typical for coastal municipalities.

Further, it is worth noting that the choice to analyze the medium-term response depends on a number of reasons, mainly: i) when analyzing two consecutive surveys, the distinction between the morphological effects induced by a storm and those induced by calm states is difficult, ii) (short-lasting) winter storms play an important role on the beach dynamics, but this can also be said for typical (long-lasting) summer conditions and infragravity waves, iii) the Adriatic Sea is a long and semi-enclosed basin, characterized by waves coming from multiple directions, even during a specific storm.

All of the above points suggest to account for a relatively long time range for a

proper estimate of the bar dynamics. Further details are provided in the following responses.

Abstract and Title: Abstract explains context and main findings clearly and concisely. The title is appropriate, although upon first reading, the phrase "medium-term dynamics" was unfamiliar. After reading the abstract, I learned that medium-term is a timescale that is longer than short-term (days) and shorter than long-term (years/decades), on the order of seasons or annual. If there is a way to be more clear in the title that medium-term is a timescale, that would be encouraged, but this change is not essential.

We prefer to keep the title as it is, as many literature works include the words "medium term" in their titles (e.g., De Vriend et al., 1993[1]; Kuriyama 2002[2]).

Organization: This paper is generally well organized. One recommendation- Explain Dean-type beach stability analysis earlier. It is not addressed until the discussion, but it is first mentioned in the "Description of the Site" and then used to explain longshore variability in the "Results". It would be helpful to present the equation with its explanation earlier, so the reader knows where this stable beach shape characterization comes from and why it is relevant for understanding other changes to the beach morphology.

We agree with the Reviewer on this point. Hence, we will introduce equation (4) and a brief discussion on the equilibrium profile in Sect.2 ("Description of the Site").

[1]De Vriend, H. J., Zyserman, J., Nicholson, J., Roelvink, J. A., Pechon, P., & Southgate, H. N. (1993). Medium-term 2DH coastal area modelling. Coastal Engineering, 21(1-3), 193-224.

[2]Kuriyama, Y. (2002). Medium-term bar behavior and associated sediment transport at Hasaki, Japan. Journal of Geophysical Research: Oceans, 107(C9).

Specific Scientific Comments
Assessment of Medium-term dynamics: Wave climate and nearshore morphology are strongly linked and it is valuable to reveal this relationship over various time scales and environments. The authors focus on a sandy barred beach, chosen for its similarity to many other beaches worldwide, over medium-term time scales. The wave data presented here is sufficient for medium-term analysis. However, a description of the original form of the wave buoy data (time series, hourly product, wave spectra?) and the methods used to further process this data should be specified for the sake of reproducibility.

For the sake of clarity, an example of the collected wave data will be illustrated and discussed. Further, the used approach will be better described.

The authors acknowledge that beach morphology is "dynamic throughout the year, especially during sea storms driven by NNE winds" (p. 3, line 30). Given this variability, it is necessary to be able to distinguish short-term variability from medium-term variability in order to assess the connection between medium-term wave climate and beach morphology. The bathymetric surveys were collected in different months/seasons each year: June/Summer 2006, February/ Winter 2010, February/Winter 2011, April/Spring 2012, March/Spring 2013. The authors explain that the two types of winds (ESE and NNE) can happen during the same season, and that in the study region, winters are stormy and summers are calm. The winter surveys would therefore be more susceptible to short-term variability due to storms, which is not distinguishable given the limited bathymetric data set. The summer bathymetric surveys are perhaps more representative of medium-term dynamics, because the beach is not subjected to the magnitude or frequency of short-term, high impact events during that season. Since the literature shows and the authors admit that significant bathymetric changes can occur over the course of a single storm, and there is no information given to put each survey in this short-term context, it is not correct to assume that the "snapshot" of bathymetry seen *in the data is representative of the medium-term dynamics. The authors should pursue supplementary data (perhaps short-term wave data analysis) to provide context for the bathymetry surveys used in this study.*

We partially agree with the Reviewer on this point. We know that the bar dynamics strictly depend on short-term events, i.e. storms, as already described in important literature works[3,4], and observed in the studied site[5]. However, the bar dynamics also depend on long-lasting calm states, these occurring in both summer and winter[5]. Since the bar behavior under stormy conditions has already been analyzed in depth, based on either field or laboratory experiments, we here describe the cumulative effects of a series of sea states, i.e. both severe and calm states occurring throughout a significantly long period (about one year), with the aim to illustrate a more comprehensive bar dynamics. It is worth noting that the surveys collected in February 2011 and May 2013 are similar, while surveys collected in February 2011 and February 2010 are significantly different (e.g., see Fig.2), this further demonstrating the independence of the bathymetry on a specific month, and confirming its dependence on the cumulative effects of the wave climate between two consecutive surveys. Finally, preliminary results on the morphological response of the beach of Senigallia subject to a winter storm have already been presented[5,6,7] and a more detailed analysis will be pre-

[3]Ruessink, B.G., Houwman, K.T., & Hoekstra, P. (1998). The systematic contribution of transporting mechanisms to the cross-shore sediment transport in water depths of 3 to 9 m. Marine Geology, 152(4), 295-324.

[4]Ruessink, B.G., & Terwindt, J.H.J. (2000). The behaviour of nearshore bars on the time scale of years: a conceptual model. Marine Geology, 163(1), 289-302.

[5]Brocchini M., Calantoni J., Postacchini M., Sheremet A., Staples T., Smith J., Reed A.H., Braithwaite III E.F., Lorenzoni C., Russo A., Corvaro S., Mancinelli A., & Soldini L. (2017). Comparison between the wintertime and summertime dynamics of the Misa River estuary, Marine Geology, 385, 27-40.

[6]Calantoni J., Sheremet A., Brocchini M., Postacchini M. (2016). EsCoSed: observations of morphodynamics during Bora at the mouth of the Misa River, 9th International Conference on Multiphase Flow (ICMF). http://www.aidic.it/icmf2016/webpapers/

[7]Palmsten M.L., Calantoni, J., Brocchini M., Soldini L. & Postacchini M. (2016). Sand bar behavior in a mixed

sented in a dedicated work in the near future.

All of the above will be better clarified in the text and, for the sake of clarity, the temporal evolution of the wave characteristics between two consecutive surveys will be illustrated and analyzed.

The authors present current theory, based on peer-reviewed and published field and laboratory measurements, for predicting bar migration based on wave conditions. This theory states that steeper, larger waves promote a seaward shift of the bar and less steep, smaller waves promote a shoreward shift of the bar. The bar migration pattern results presented in this study agree with previous findings. However, agreement with the theory is limited due to insufficient bathymetric data to definitively ascribe morphological changes over a particular year to medium-term wave climate alone (i.e., lacking evidence that short-term wave climate is not contaminating the bathymetric surveys).

We partially agree with the Reviewer. We know that only few surveys are available, but the medium-term bathymetric changes are ascribed to the medium-term climate, which includes both short-term events (like storms) and longer states (like calm conditions). Hence, the medium-term changes derive from the cumulative effects of both severe and calm states occurring during the considered temporal range. These considerations will be implemented in the manuscript.

Tables: Table 1 & 2: The authors claim it is best to use wave statistics based on the maximum percentage of energy flux over the time interval of interest. This is a fair decision. However, based on the Figure 3 wave roses and Table 1 statistics, there is not always a single band where the energy flux is concentrated. For 2010-2011 especially, the energy flux seems evenly split between $H_{m0} = 1.5 - 2.0m$ *(energy flux distribution % of 16.56) and* $H_{m0} = 3.0 - 3.5m$ *(energy flux distribution % of 16.02).*

sediment environment, Ocean Sciences Meeting. https://agu.confex.com/agu/os16/meetingapp.cgi/Paper/89790

The authors decide that the dominant waves were about $H_{m0} = 1.75m$. Looking at the wave rose for 2010-2011 there are strong peaks in both the ESE (25%) and NNE (20%) directions. Yet, when summarizing the 2010-2011 period, the authors choose ESE for this time interval. The 2011-2012 and 2012-2013 conditions were truly dominated by one type of wind event over the other, so the assumptions made by the authors for those time intervals are justified. Perhaps a more nuanced bimodal analysis of 2010-2011 is warranted, especially if these bulk wave climate characteristics are used to explain changes in beach morphology.

We thank the Reviewer for this comment, which suggests us to clarify the procedure used for the statistic analysis. In particular, it is worth noting that the choice of the ESE forcing is justified by its predominance on the other wave directions, though ESE slightly dominates on NNE forcing. In brief, if we roughly hypothesize that, in 2010-2011, ESE and NNE waves provided the same energy per unit time, the bars would have migrated onshore (due to ESE forcing) for a reasonable time, and offshore (due to NNE forcing) for a slightly smaller time. The balance is an onshore bar migration.

The choice of H_{m0} and T_m derives from the below-described procedure:

- **first, the wave climate during the whole time range is analyzed (i.e., including both storms and calm states) to obtain the energy distribution of Fig.3,**
- **then, the most energetic direction is chosen (in our case the choice is always restricted to ESE or NNE),**
- **finally, the chosen direction (i.e., the 105–135^o sector for ESE or the 15–45^o sector for NNE) is analyzed to obtain the most probable wave characteristics (H_{m0} and T_m, respectively shown in Tabs.1 and 2).**

The above considerations will be implemented in the manuscript.

Figures: Figure 6a shows normalized bar height versus normalized bar width with fits for outer and inner bar (essentially steepness curves (H_{bar}/W_{bar}) showing how bar geometry changes from outer to intermediate bars). The fits are presented for 2010 and 2013, but not for the other three years of data, leaving the reader questioning whether these trends are consistent.

The fitting lines have only been plotted for two years because the other data provide weak best-fit curves. This point will be discussed in the new version of the paper.

Furthermore, if the goal is to show that medium-term bar dynamics are strongly linked to medium-term wave climate, it is important to present plots that relate bar features (or changes in bar features) to wave climate metrics (like Table 3, but is visual plot form).

We thank the Reviewer for their precious comment. We will try to plot bar feature changes against the wave climate.

Figure 6b shows that the cross-shore area of the bar increases southward. A shift in the grain size distribution is the explanation given for the alongshore trend in the equilibrium beach profile. Since grain size distribution is a consideration throughout the authors' analysis of the results, plotting cross-shore bar area versus some grain size distribution metric would be more useful.

We partially agree with the Reviewer. In fact, direct measures of sediment size are few and old if compared to the available surveys[8]. However, we will try to produce a graphical output to investigate the sediment-size behavior using the indirect measure obtained from the equilibrium Dean profile.

[8] Lorenzoni, C., Mancinelli, A., and Soldini, L.: Caratteristiche sedimentologiche del litorale a Nord di Ancona. Analisi del movimento delle ghiaie (in Italian), in: Atti dell'Istituto di Idraulica dell'Università di Ancona, Università di Ancona, Ancona, p. 54, 1998a.

Technical Comments
Fluency: Although it is apparent that English is the second language of the authors, this does not inhibit the reader's ability to understand this research and its conclusions. There are only a few places where grammar issues impede the authors' message. Listed below are the sentences where a second pass at phrasing would be beneficial. p. 7, line 10 - p. 8, line 3 p. 16, lines 1-7 p. 18, lines 15-20

These points will be amended.

Equations: Mathematical formulae, symbols, abbreviations, and units are correctly defined and used. References: The number and quality of references is appropriate.

We thank the Reviewer for their approval.

Interactive comment on Ocean Sci. Discuss., doi:10.5194/os-2016-106, 2017.

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Discussion paper