Interactive comment on "Assessing hydrological effects of human interventions on coastal systems: numerical applications to the Venice Lagoon"

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Response to comments by Anonymous Referee #2

Q(General Comments)

The work is interesting as to anticipate the responses of coastal lagoons to human impacts and induced transformations, is essential to manage these important ecosystems. The only way to do it is just applying models based in the knowledge of the processes involved. This paper is a good contribution to the development of this kind of tools and therefore, is worthy to be published. However, some aspects are not clear enough and should be clarified or need more discussion in the ms before publishing. In its present form the paper is quite descriptive and focus on the changes produced in the Venice lagoon, however, the paper would gain in relevance if, using the Venice lagoon as reference could relate the general geomorphologic changes to the hydrological consequences. In this context I point out here some questions:

R(General comments): We would like to thank the reviewer for all the constructive comments, which allows to improve the manuscript, and for bringing these useful citations to our attention. The abstract, the discussion and the conclusions now focus more on the processes than to merely the results.

Q(Specific Comments):

Q(1). According to the abstract, "the absolute values of the exchange between the lagoon and sea increased from 1927 to 2002 (from 3900 to 4600m3 s−1), while the daily fraction of lagoon water volume exchanged decreased". Constitutes this an apparent contradiction? In the discussion is said that "From 1930 to 2002, the water renewal time decreases slightly, as well as the daily fraction of water volume exchanged with the coastal sea. This was mostly due to the deepening of the lagoon and loss of marsh areas in the inner lagoon". Therefore it means that it is attributed to the increase in volume of the lagoon, but how are related both parameters (WRT and daily fraction of water volume exchanged) to produce this result should be clarified in the text and the ecological consequences discussed.

R(1): We specified in the manuscript (in the abstract, in the discussion and in the conclusions) that this apparent contradiction is due to the fact that the loss of morphological heterogeneity in the lagoon (lowering of tidal flats, infilling of tidal channels and reduction of salt marsh areas) enhanced the internal water mixing processes driven by the tide and wind. The flattering of the lagoon had thus a positive effect on the overall renewal capacity of the basin, which counteracts the negative effect induced by the increase in volume.

Q(2). In the same way, "In the future, Venice Lagoon will evolve to a more restricted environment due to sea level rise and periodical closure of the lagoon from the sea during flooding events". But however, "Simulated scenarios of sea level rise showed that under fall-winter conditions the water renewal time will increased considerably especially in the central part of the lagoon". Again, it is an apparent contradiction due probably to spatial heterogeneity, but again it should

be clarified and in the abstract and general conclusions it would be more relevant to underline the process than to merely describe the fact in Venice

R(2): As specified before, we focus more on the discussion of the processes driving the changes. We modified the above mentioned sentence as follows: “In the future, Venice Lagoon will evolve to a more restricted environment due to sea level rise, which increases the lagoon volume, and periodical closure of the lagoon from the sea during flooding events, which reduces the communication with the open sea. Therefore, the flushing capacity of the lagoon will decrease considerably, especially in its central part”.

Q(3). The comparison between successive years is justified on "the heavily modified morphology of the Venice Lagoon" and the simulations are performed on grids with different coastline and bathymetry. These transformations are described very briefly in page or are disperse. The maps on fig 4 only show some new salt marshes or reclaimed areas in the central part since 1970. This is also well described the Mose effect and figure 5 shows the surface covered by different depths. However, other geomorphologic descriptors as total surface, mean depth, perimeter, etc. are lost despite it is recognized that " The evolution of the WRTs is linked to the different situation of the bathymetry, of the lagoon perimeter and of the inlets structure " (see Chubarenko et al., 2005 for some of the more relevant geomorphologic parameters in lagoon modelling) and some of them strongly affect the lagoon ecology (see Perez-Ruzafa et al., 2007). A table summarizing the main geomorphologic changes would be useful to put in context the hydrological transformations.

R(3): The morphological responses to the human interventions are now described more into details. Following the reviewer suggestion, we computed a set of quantitative geo-morphometric parameters: surface, mean depth, volume, extension of salt marshes, total cross section area of the inlets and openness parameter (P_{open}). The values of these parameters for the 1927, 1970, 2002 and 2012 scenarios are listed in Table 1 and discussed at the end of the *Study site* section. Moreover, we better specified in the *Materials and methods* section the set of hydrological parameters derived from model results: water renewal time (WRT), return flow factor (RFF) and daily fraction of lagoon water volume exchanged with the open sea (FVE). The degree of communication with the open sea is usually measured by P_{open}. However, this parameter does not take into account the water volume of the lagoon and the real water exchange through the inlets. Therefore, in this study, the influence of the sea on general lagoon hydrology was estimated by FVE, computed as ratio between the daily flux of water from the sea to the lagoon and the basin volume.

Q(4). In the same context, it is assumed that SLR will produce changes on mean depth and water volume, but no mention is made to total surface, lost of salt marshes and perimeter. Probably the assumption that these parameters are not going to change due to coastal defences built to avoid flooding could be proposed for some areas, but can it be assumed for the entire lagoon?

R(4): We specified in the manuscript (section *Simulations set-up*) that “It is reasonable to assume that SLR will modify the mean depth and volume, but it will not change the lagoon surface since its perimeter is heavily anthropized. The aptitude of salt marshes to keep pace with SRL is a debated topic, but it has been generally found that wetlands can counteract accelerated sea level rise only in areas with high sediment input (Day et al., 2011). Therefore, since river sediment input in the Venice Lagoon is almost absent (Day et al., 1998), we assumed no accretion and vertical elevation gain of salt marshes with future SLR.

Q(5). The most conspicuous changes in WRT spatial distribution showed in figure 4 are between 1970 and 2000. Which are the main geomorphologic changes related to it? The maps do not show any evident change in perimeter or surface.

R(5): As specified in the response to question 3, we better described the morphological changes. Lagoon perimeter and surface did not change from 1970 to 2000. We specified in the manuscript that the most conspicuous changes in WRT spatial distribution showed in Fig. 4 between 1970 and 2000 can be explained by the effects of the excavation of Malamocco-Marghera navigation channel in 1966-1969 (30-50 Mm^3 of sediments disposed in landfill areas outside the lagoon) that is probably the main cause of the severe erosion of tidal flats (average deepening of 40 cm) in the central lagoon in that period of time. Probably due to recent construction of artificial salt marshes the WRT increased in the northern part of the lagoon

Q(6). Some aspects of the functioning of MoSE structures are not clear. It is said that "Model results show that sea level rise and the closure of the MoSE gates increase the lagoon volume and reduce water fluxes through the inlets". The reduction in water fluxes is expected, but an increase in volume seems contrary to the expected effect of MoSE which are designed to prevent increases of sea level inside the lagoon.

R(6): We concur with the referee that this statement was not clear and therefore we modified as follow: “Model results show that sea level rise increases the lagoon volume and the closure of the MoSE gates reduces water fluxes through the inlets”.

Q(7). In the same context than 6, during the flooding events MoSE will be closed to prevent sea level rise inside the lagoon. However, "the Porto di Piave Vecchia channel is not planned to be closed during high water events" How it is expected that this channel affect the mean water level in the Venice lagoon. Will no affect it to the effectiveness of MoSE?

R(7): The flux of water through the Porto di Piave Vecchia channel influences the water renewal time in the northern part of the lagoon, but it has a negligible effect on the mean water level in the lagoon. We specified it in the manuscript.

Q(8). In the discussion, authors relate the expected increase in WRT with changes in benthic communities that can be overlapped or hidden by changes in trophic status. Eutrophication is also related to hydrological conditions and WRT. However, in all this discussion a factor of scale is missing. Some other Mediterranean lagoons show similar patterns and changes in benthic assemblages, related to modification in the inlets and changes in water interchanges and eutrophication processes with similar consequences than in Venice lagoon (see for example descriptions for the Mar Menor lagoon in Perez-Ruzafa et al., 1991, 2012) but with a change in the scale of WRT and sea lagoon fluxes of one order of magnitude (De Pascalis et al., 2012). How two lagoons with WRT, as different as days and near a year, can be quite similar in many aspects and show similar species richness and gradients, and changes in a few days in residence time can produce similar effects than changes in months?

R(8): In which sense? About spatial scale our generalization are at the lagoon-scale, the only possible for the general hypothesis we did. About temporal scale, our idea is to connect, in broad terms, changes in biological communities to the possible effects that the change in WRT can have on the environmental medium. The decrease of water exchange, with the same inputs in the system, can result in an accumulation, beyond that of pollutants, nutrients and catabolites which produce a certain state of eutrophication which can generate a certain state of saprobity. Therefore the saprobity is given by the balance between self-purification, inputs

and export of organic matter and catabolites from the system. As far as balances are concerned, depends on the scale of the system if the effects will be produced by days or months of increased WRT as exposed in Tagliapietra et al., (2012). With regard to the composition and structure of the communities and their diversity, they depend on many factors, including the WRT gradient and saprobity that are in our view important but not the only ones. Important are the general hydrodynamics and diversity of habitats of the basin, its connectivity with more or less biodiverse areas, its geographic location, the anthropogenic pressures, such as fisheries, salinity and, last but not least, the interactions between individuals and species. The role played by hydrographic variations of the habitat, induced for example by the change of lagoon-sea fluxes could modify the zooplankton population dynamics since they can alter the structure of plankton communities by importing both opportunistic neritic phytoplankton species (e.g. Chaetoceros), which find favourable environmental conditions for their blooms inside the lagoon, and mesozooplankton organisms, which then exploit lagoon resources, increasing the top-down control on phytoplankton dynamics. The balance between freshwater inputs and marine water inflows is also a relevant factor, since it defines the spatial extension of environmental conditions in which plankton communities can develop. This is the reason why comparisons of the effects of WRT can only be qualitative and for this we can compare between different lagoons patterns and tendencies, but not the absolute values, except after careful evaluation and normalisations. Here, the problem not arise because, for speculative purposes, all other factors unchanged only change the renewal time and "predict" the effects within a single lagoon.

Q(9). The discussion on r vs. K strategists is interesting, but probably not too accurate in coastal lagoons (see a paper in press but on line from Perez-Ruzafa et al in press).

R(9): We modified this part of the discussion considering the suggested publication. Anyway, according to the comment of the first referee we shortened the discussion about r and K strategies.

Christian Ferrarin (on behalf of all authors)