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Ocean Science
Discussions

Interactive comment on "A wind-driven nonseasonal barotropic fluctuation of the Canadian Inland Seas" *by* C. G. Piecuch and R. M. Ponte

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Response to interactive comment on "A wind-driven nonseasonal barotropic fluctuation of the Canadian Inland Seas" by Anonymous Referee #1

SUMMARY OF MANUSCRIPT

Reviewer Comment (RC): Piecuch and Ponte investigate nonseasonal oscillations of the surface of the Canadian Inland Seas (CIS) using a combination of satellite data, records from a tide gauge, and a barotropic numerical model. They specifically focus on oscillations of spatial scales O(200km) and timescales O(month) that are resolved by the satellite data. The lowpass filtering discards the influence of eddies, tides and

other coastal waves. Other signals from the inverse barometer effect and seasonal processes are removed from the data prior to the analyses. The satellite-derived bottom pressure data averaged over the CIS is correlated with a coastal tide gauge, suggesting the existence of a spatially coherent (i.e. bay-wide) oscillation of the surface. The authors further examine this coherent oscillation with the help of a quasi-global prognostic model forced with realistic wind stress. The model accurately reproduces the variability from the satellite and tide gauge, and an EOF analysis confirms the existence of a spatially-coherent mode. Correlation analyses and sensitivity experiments suggest that the mode is primarily driven by wind stress over Hudson Strait, with modifications by local wind stress and topography.

GENERAL COMMENTS

RC: The manuscript is well written and represents a good account of the analyses and their key results. The manuscript convincingly shows that the coarse GRACE data can be useful in regional studies of marginal seas, something I have not seen before. The study highlights a spatially-coherent oscillation driven by remote winds and modified by local winds and topography. Such an oscillation was suggested by the same authors in an earlier article (Piecuch and Ponte GRL 2014) but the present article provides a dynamical explanation for the oscillation. I do not have any particular concern regarding the manuscript but I suggest below minor modifications that should improve the manuscript.

RECOMMENDATION

RC: I recommend the acceptation of the manuscript after minor revision (see "Specific Comments" below).

Author Response (AR): We appreciate your thoughtful comments on and assessment of our manuscript. The manuscript will be revised based on your comments as well as those of the other reviewer. More immediately, you will find a detailed, point-by-point response to all of your comments herein below.

SPECIFIC COMMENTS

RC: Section 2.1.1 (Satellite gravimetry): Please state explicitly the spatial resolution of the GRACE data (1 degree?), and how Hudson Bay is represented at this resolution (e.g. 8x8 grid points).

AR: The Release-05 GRACE ocean bottom pressure estimates are provided on a regular 1-degree latitude/longitude grid. At this resolution, Hudson Bay and James Bay are together represented by 75 grid cells (∼9x9) while Foxe Basin is represented by 11 grid cell (∼3x3). These details will be included in the manuscript revision.

RC: Section 3.1 (Model framework): The authors write "The setup solves the primitive equations on a moderate-resolution (0.5deg x 0.5deg) spherical polar grid". Please replace "moderate" by "coarse" since such resolution barely resolves Hudson Strait (2 grid points). In fact, it was a surprise to me that the model could reproduce the observed variability (Fig.3) with such a coarse grid.

AR: We will replace "moderate" by "coarse" in the manuscript revision.

RC: Section 3.1 (Model framework): The authors write "We use a constant equation of state". It is not clear what the authors mean. Constant and uniform density? Horizontally-varying constant density?

AR: We use a universal constant value for density of 1029 kg/mˆ3. This clarification will be made in the manuscript revision.

RC: Fig.3a: The authors write "ocean bottom pressure summed over the Canadian Inland Sea from GRACE [...] and the barotropic model". Just to be sure that we are on the same page, you have bottom pressure values varying in space and in time, for both GRACE and for the barotropic model. Let's call them pb_grace(lon,lat,t) and pb_model(lon,lat,t). Then, according to the figure caption, you *sum* pb_grace and pb_model over their respective grid. Well, it makes no sense to *sum* the values if pb_grace(lon,lat,t) and pb_model(lon,lat,t) are on different grids (especially if we are

dealing with a spatially-coherent oscillation, i.e. same sign over the domain). Was it really a sum, or was it an average? Or perhaps you interpolated pb_grace and pb_model over a common lon-lat grid prior to the summation?

AR: We apologize for this confusion due to poor word choice, which gives the appearance that we are comparing apples to oranges. As the reviewer anticipates, what we call a summation in these lines is in fact an average. Also, to ensure that we are comparing apples to apples, as hinted in the original text (p. 2345 ll. 15-17), prior to computing model averages in this case, the simulated fields are spatially filtered with same 500-km Gaussian smoother that is used in the GRACE post-processing, and then interpolated onto the GRACE grid. These points will all be made more explicitly clear in the revised manuscript.

RC: Fig.4: Is the EOF shown in the figure similar to the Helmholtz mode of an oscillator? (LeBlond and Mysak 1978, Wright et al. JGR 1987). Wright et al. estimate the frequency of this normal mode to be around 3.4 days.

AR: We would hesitate to say that the EOF mode shown in our figure is similar to the Helmholtz resonant mode, e.g., pointed out by Wright et al. (1987). First, the time scales are very different. Wright et al. (1987) focus on a variation with a period of ∼3.5 days whereas we consider much lower frequency (monthly) fields. Also, the spatial structure of the mode that we consider and the one studied by Wright et al. (1987) are qualitatively different. As noted in our original text (p. 2346, l. 24 ff.), the mode that we see has higher amplitudes over the deep interior than along the shallow boundary. In contrast, the variation studied by Wright et al. (1987) has higher amplitudes along the coast than over the interior of the basin (see their Fig. 6), similar to what would be expected for the case of continental shelf waves. For these reasons, we believe that it would be unnecessary and tangential to include discussion of the Helmholtz mode, e.g., previously pointed out by Wright et al. (1987).

RC: Fig.4 (typo in caption) "The NAO time series is taken" FROM THE "National

Oceanic and Atmospheric...".

AR: Thank you for pointing out this typo. This will be corrected in the manuscript revision.

RC: Section 3.4 (Forcing and dynamics): The authors write "we compute correlations between the expansion coefficients and nonseasonal zonal and meridional wind stress". Have the authors tried to correlate the expansion coefficients and the bottom pressure of the barotropic model? If you tried, did you qualitatively recover the results of Fig.4a,b in Piecuch and Ponte GRL 2014?

AR: By computing the correlation coefficient at each grid cell between the local nonseasonal ocean bottom pressure/sea level and the principal components of the leading mode from the model, one does indeed qualitatively reproduce the essence of Fig. 4a,b from Piecuch and Ponte (2014). See the attached figure (which shows the aforementioned correlation coefficients when they are statistically significant). In the barotropic numerical simulation, the CIS EOF mode is in phase with nonseasonal variations in the Mediterranean Sea but out of phase with those over the mid-latitude North Atlantic Ocean and in parts of the North Sea, all as in Piecuch and Ponte (2014). Quantitative differences are apparent, though, when comparing this attached figure to Piecuch and Ponte (2014): because our results are not spatially smoothed in this figure here, much more regional detail is evident that cannot be seen in Piecuch and Ponte (2014), for example, clear constraining of the variability by the topography of the Mid-Atlantic Ridge; possibly since we have not simulated behavior north of 79N, our figure here does not show a statistically significant in phase relationship between the CIS and regions just east of Greenland (cf. Piecuch and Ponte 2014 Fig. 3). In the interest of not adding any additional figures, we would prefer not to include something like this figure in the revised manuscript. Rather, we intend to include parenthetical mention of some of these points above in the manuscript revision.

Interactive comment on Ocean Sci. Discuss., 11, 2337, 2014.

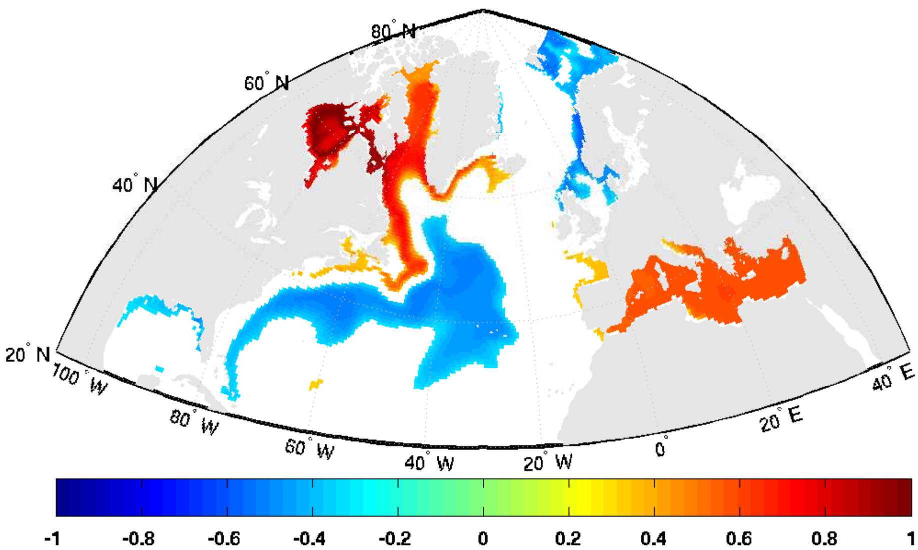

Fig. 1. Correlation coefficient between modeled nonseasonal pointwise sea level/ocean bottom pressure and the expansion coefficients from the first EOF mode over the Canadian Inland Seas.