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HIDRA2: deep-learning ensemble sea level and storm tide forecasting in the presence of seiches – the case of the northern Adriatic

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This is a supplementary material for the paper *HIDRA2: deep-learning ensemble sea level and storm tide forecasting in the presence of seiches – the case of Northern Adriatic*, which was removed from the paper due to page limit, but we nevertheless fell it brings further insights into our analysis.

S1 Spectral decomposition of forecasts during storms

In this section, we repeat the analysis from the section of the same name in the main paper, but focus on the behaviour of the SCHISM model. Analyzed historic storms are the same as in the main paper: November and December 2019. We also add an additional event from December 2020.

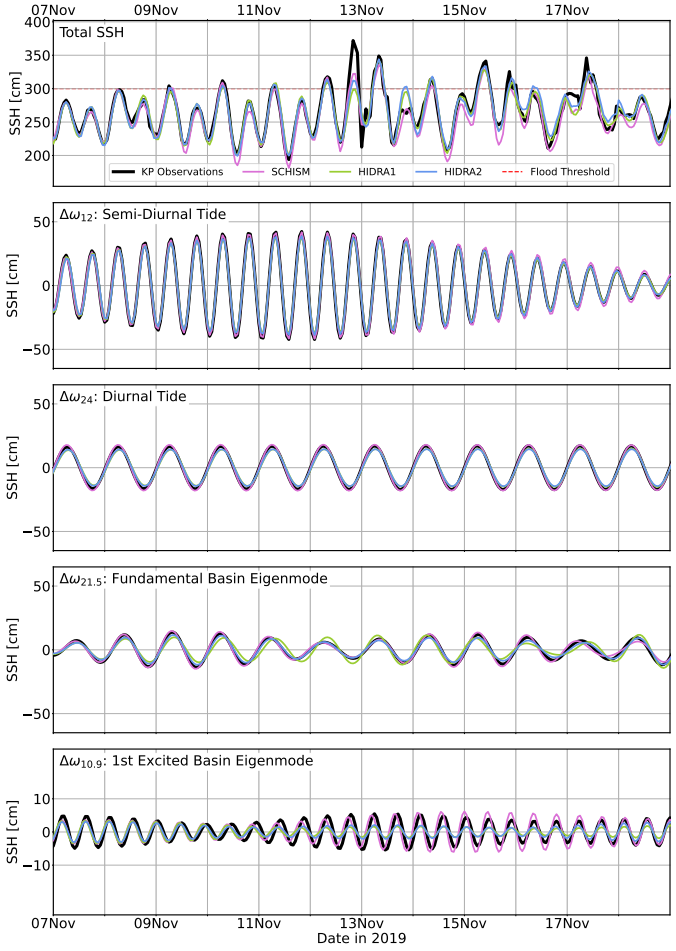

Figure S1. Comparison of total Koper SSH observations and forecasts (top panel) and their Band-Pass Filtered signals (bottom four panels) over four bands, centered around four geophysically relevant periods (semi-diurnal and diurnal tides and two lowest along-axis basin eigenmodes). Time window of the SSH signal spans the 7 November 2019 to 19 November 2019. Note different vertical scale in the bottom $\Delta\omega_{10.9}$ panel.

Figure S1 depicts a comparison of both HIDRA setups and the SCHISM model to total sea level observations in Koper during November 2019. All models in Figure S1 have a solid performance in the $\Delta\omega_{12}$ band. In the band $\Delta\omega_{21.5}$ SCHISM

is closest to the filtered observations, HIDRA2 is quite close in performance, while HIDRA1 seems to be a bit off. SCHISM shows excellent performance in the $\Delta\omega_{10.9}$ band and HIDRAs struggle with resolving dynamics in this band.

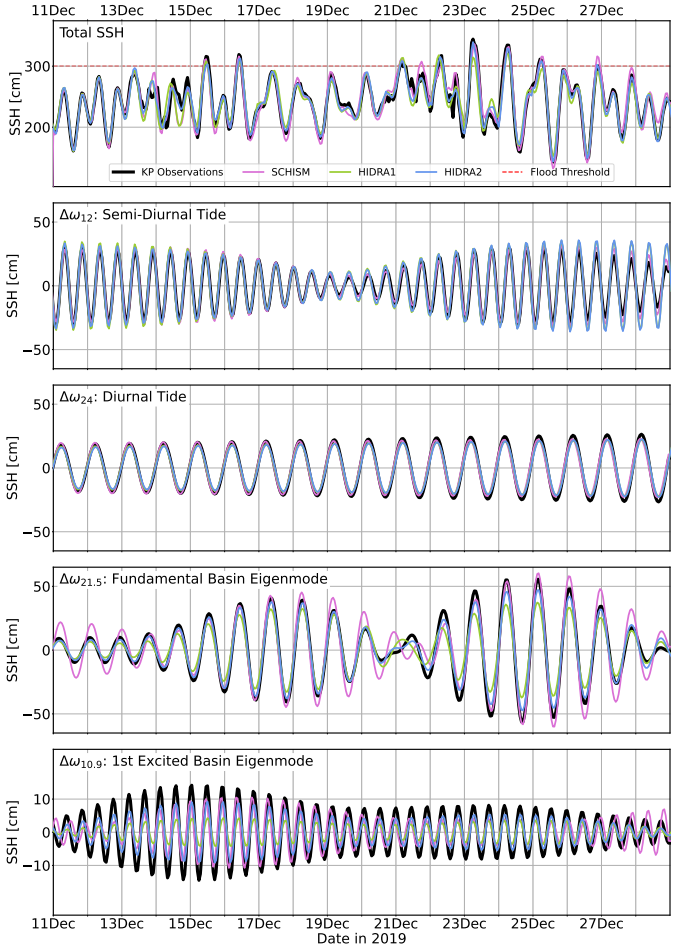

Figure S2. Same as Fig. S1, but for December 2019 coastal floods.

Similar remarks can be made regarding the December 2019 coastal flooding, depicted in Fig. S2. Between 15 and 17 December SCHISM performed comparable to HIDRA models but somewhat underestimated the peaks after 23 December (top panel). It is not obvious which dynamic processes were responsible for this underestimation since they seem to lie outside of the bands considered in this analysis.

In the $\Delta\omega_{21.5}$ band, HIDRA2 and SCHISM predictions most closely resemble the observations, with SCHISM overshooting 19 and 23 December and HIDRA2 underestimating slightly after 23 December. In the $\Delta\omega_{10.9}$ band SCHISM seems most reliable, followed by HIDRA2. This behaviour of SCHISM and HIDRA2 is consistent with the power spectrum analysis where SCHISM shows best overall performance in the $\Delta\omega_{10.9}$ band but overestimates the energy in $\Delta\omega_{21.5}$ band.

The December 2020 events are shown in Fig. S3 (comparison of HIDRA and SCHISM) and Fig. S4 (comparison of HIDRA and NEMO). Coastal flood on 8 December 2020 is significantly underestimated in HIDRA1 and even more so in NEMO. HIDRA2 demonstrates much better performance. The decomposition of the sea level signal into $\Delta\omega_i$ bands indicate that tidal bands are predicted well in all three models. The leading cause of NEMO model SSH underestimation clearly lies in

the misrepresented amplitude of the fundamental basin seiche. This is, interestingly, also an example of where SCHISM has problems reconstructing $\Delta\omega_{10.9}$ band.

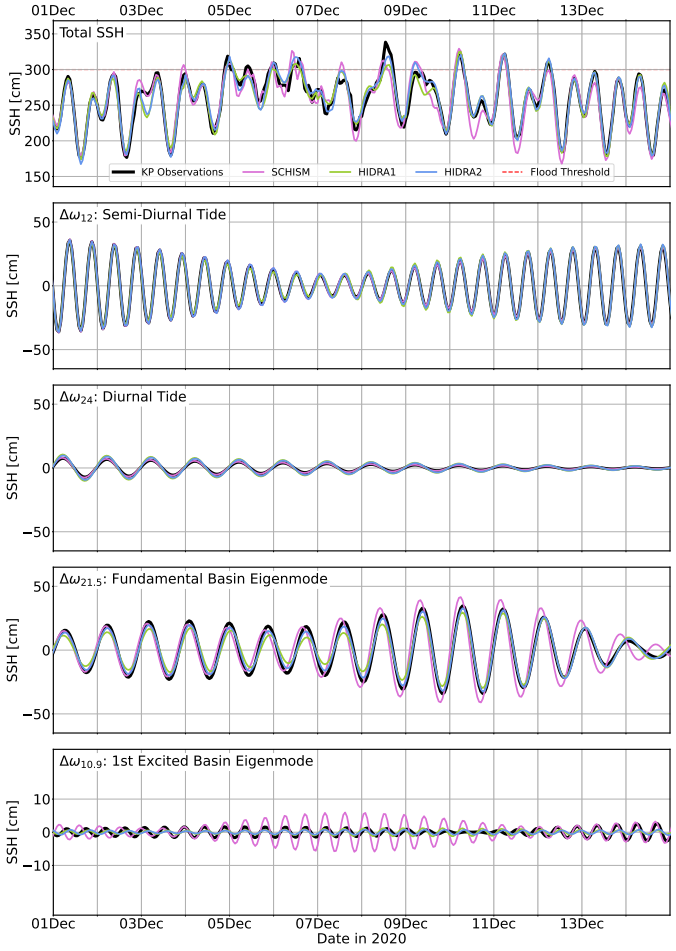

Figure S3. Same as Fig. S1, but for December 2020 coastal floods.

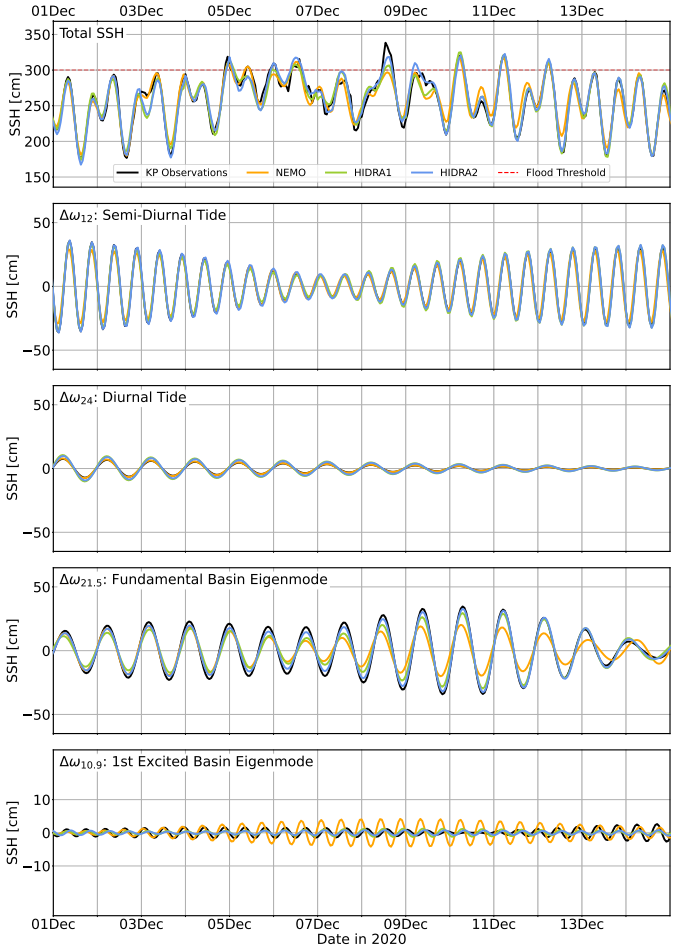

Figure S4. Same as Fig. S1, but for December 2020 coastal floods. A comparison to NEMO model.