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Time-varying trends in regional sea level from tide gauge data

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Sea level rise affects many people living in coastal areas and therefore knowledge and understanding of contemporary changes is necessary. One of the primary observational datasets is represented by tide gauge records. We propose a new method to estimate trends from tide gauge data by using a state space formulation, which couples the direct observations to a predefined state space model by using a Kalman filter. The model consists of a time-varying trend and seasonal cycle, and variability induced by several physical processes, such as wind, atmospheric pressure changes and teleconnection patterns. This model has two advantages over the classical least-squares method that uses regression to explain variations due to known processes: a seasonal cycle with time-varying phase and amplitude can be estimated, and the trend is allowed to vary over time. This time-varying trend consists of a secular trend and low-frequency variance that is not explained by any other term in the model. As a test case, we have used tide gauge data from stations around the North Sea over the period 1980-2013. The time-varying trend clearly shows a large decadal variability that would not emerge from a classical least-squares approach. To validate whether our model is correctly explaining the observed variance, we have compared our results against time-series where the variability has been predicted by the Dutch Continental Shelf Model (DCSM), a 2-dimensional storm surge model that estimates the effects of wind, pressure and tides. Trends obtained from the DCSM-corrected run show patterns at inter-annual and decadal scales that are very similar to the trends obtained with our state space model. The mean trends over the period 1980-2013 are also very similar for both models, but there are significant differences when these estimates are compared to results from a classical least-squares analysis.