Geophysical Research Abstracts
Vol. 21, EGU2019-13100, 2019
EGU General Assembly 2019

A combined orthogonal decomposition and polynomial chaos methodology for data-based analysis and prediction of coastal dynamics

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This work aims at investigating the feasibility of purely data-based prediction approach, by bringing together field measurements, mathematical tools and physical intuition. The objective is, in one shot, to perform an in-depth data analysis, including sensitivities to various forcing parameters, and to propose an efficient prediction tool.

The analyzed data is measured in the context of a power plant water intake monitoring. The purpose of the water intake channel is to ensure enough water supply for the cooling process of the power plant. When the volume capacity of the channel is below a certain threshold, the production power of the plant is reduced in order to avoid any residual heat that could not be evacuated. As a consequence, the performance of the power plant can be insufficient for the needs of the region in which it settles, inducing supplementary costs of electricity delivery.

The water intakes can be subject to diverse environmental solicitations that modify their cooling capacity, namely sediment arrivals that represent a clogging risk. In a coastal area for example, the sediments are stirred up due to the waves effect, and transported by the tidal currents into the channel. This process can be amplified during low tide levels, resulting in a higher sediment volume entering the channel. Therefore, costly dredging operations are often necessary, and must be optimized with enough anticipation.

The characterization of the sediment dynamics within this context is still a challenge, due to the strong non-linearity and interactions of different phenomena. In order to better understand the physical processes, bathymetric measurements of the channel are assured on a regular basis, along with meteorological and hydrodynamic surveys (waves, wind, tidal levels). The aim is therefore to establish a dynamical model that predicts the bed elevations, from the knowledge of the previous state and the several forcing parameters.

Firstly, a Proper Orthogonal Decomposition (POD) is applied to the two-dimensional bathymetric data set, in order to analyze its spatial patterns called the POD basis. The POD basis terms, when added, explain the observed dynamic. They are multiplied by a set of time dependent coefficients, which variance is directly linked to that of the original field. The time coefficients can be linked to environmental parameters via an adapted statistical model. In this study, a Polynomial Chaos Expansion (PCE) is used. The constructed PCE is able to give a future estimation for each of the temporal coefficients, from the knowledge of the forcing variables. The predicted temporal coefficients are then multiplied by the corresponding POD basis terms, and summed up in order to reconstruct a full prediction of the bathymetry. Furthermore, the influence of each forcing parameter and its interactions is estimated via sensitivity indices calculated on the basis of the statistical model.

The outcome of this study is a ready-to-use predictive data-based model, as well as an automatic step-by-step algorithm and methodology that could be transposed to similar configurations.