

# UNCORRECTED SATELLITE DERIVED SHORELINE ASSIMILATION IN EQUILIBRIUM SHORELINE MODEL

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## INTRODUCTION

Understanding and predicting sandy shoreline evolution over the next decades is key to effective conservation and management of coastal ecosystems. Although skillful and efficient on cross-shore transport dominated sites (Splinter et al. 2014), reduced complexity equilibrium shoreline models strongly rely on data for the calibration of the free parameters and are thus restricted to a few well monitored sites in the world. Publicly available satellite imagery has cradled a new approach in remote sensing providing long term high temporal resolution shoreline data with global coverage (Vos et al., 2019). Satellite derived shoreline (SDS) positions however come with uncertainties that challenge their usability especially in meso- macrotidal, high energetic coasts, where horizontal position errors can exceed 30 m (Castelle et al. 2021). Such uncertainties so far prevented their use for shoreline model calibration and further hindcast and predict shoreline change on the timescales from days to decades. In the present work we explore the challenges and opportunities stemming from the availability of optical satellite imagery and their use in equilibrium shoreline modelling. First, we assess the applicability of uncorrected SDS in model calibration at challenging coasts, assuming no a priori knowledge of the site. Successively, a data assimilation routine is used to investigate the links between the model's free parameter evolution and environmental conditions.

## METHODOLOGY

A hybrid two-step approach is adopted here aiming to assess the usability and extract information from uncorrected SDS data through a calibration step and further explore the links between model parameter evolution and environmental conditions through a data assimilation step. A timeseries of uncorrected alongshore averaged SDS data  $\bar{W}_s$ , was computed from instantaneous waterlines extracted over a 4km alongshore window at Truc Vert beach (France, Atlantic coast), using the freely available python toolkit CoastSat (Vos et al, 2019). The  $\bar{W}_s$  dataset was compared by Castelle et al, (2021) to the alongshore averaged +1.5 m above mean sea level (AMSL) shoreline proxy  $\bar{S}_{IS}$ , derived from in-situ RTK DGPS surveys and showed a RMSE exceeding 30 m. The state-of-the-art equilibrium shoreline model proposed by Davidson et al (2013) was calibrated using the  $\bar{W}_s$  dataset and validated against the  $\bar{S}_{IS}$  dataset. A simulated annealing non-linear optimization algorithm proposed by Bertsimas (1993) was used to find the best fit model parameters, assuming no a priori knowledge of the simulated coastal environment. To ensure the no a priori knowledge assumption, the range of the investigated model free parameters extended beyond the limits found in the

literature. Finally, the data assimilation routine implemented by Ibaceta et al (2020) was applied to investigate the temporal variability of the model free parameters and their correlation with the environmental conditions. A forty-year dataset of alongshore averaged uncorrected SDS was assimilated in the model which was forced by the freely available ERA5 dataset described in Hersbach et al (2023).

## MODEL CALIBRATION

In Figure 1, the results of the model calibration are depicted. The model has been calibrated over a five-year period and validated against the subsequent six-year period. The experiment was repeated 10 times to account for the stochastic nature of the simulated annealing algorithm and ensure repeatability of the results. The results of the experiment are summarized in terms of performance metrics in the legend of the figure for both the calibration and validation periods. The two datasets used for the calibration and validation of the model are also depicted in the figure in red circles and blue dots for the  $\bar{W}_s$  and  $\bar{S}_{IS}$  respectively.

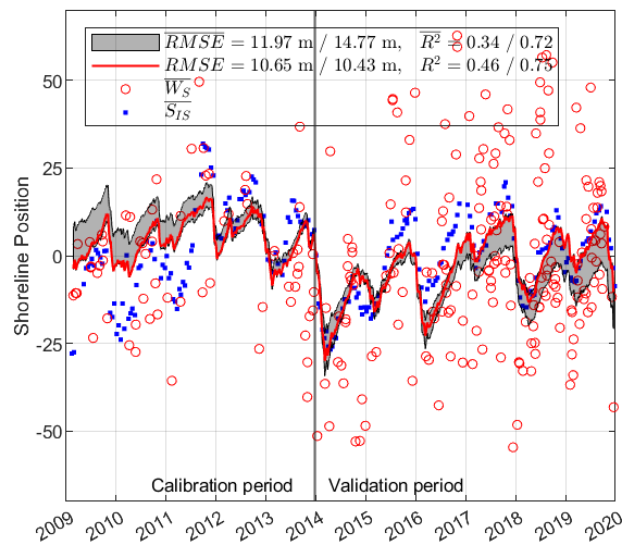


Figure 1 - Calibration results using the  $\bar{W}_s$  data (red circles) and validating against the  $\bar{S}_{IS}$  data (blue dots). The grey area indicates the range of predicted shoreline position from an ensemble of 10 simulations, while the red line is the optimal solution. The performance metrics are indicated in the legend as RMSE and coefficient of determination.

## DATA ASSIMILATION

In Figure 2, preliminary results of the parameter variability

investigation are presented. The shoreline change estimates are depicted together with the SDS observations in the upper panel of the figure. The model free parameters namely the accretion/erosion celerity  $c^a/c^e$  and the beach memory  $\phi$ , are depicted in the three lower panels of the figure. The variability of the model parameters was calculated using the Ensemble Kalman Filter methodology presented in Ibaceta et al (2020).

### DISCUSSION

Although the SDS dataset used show large uncertainties, the calibrated model has an error slightly above 10 m and manages to reproduce 75% of the observed variability. The model calibrated using the in-situ shoreline  $\bar{S}_{IS}$  dataset performs slightly worse having a RMSE of 13 m and capturing 72% of the observed variability in the validation period. This result indicates that the simulated annealing algorithm is capable of finding the optimal solution even when applying a very challenging dataset with large uncertainties. Such model skill is very promising and suggests strong potential for the use of SDS data in cross shore transport dominated sites lacking in-situ data.

The preliminary results of the model free parameters variability study show an interannual pattern that should be further investigated. Understanding the correlation between environmental conditions and parameter variability would enable us to explore the potential of non-stationary model applications for future shoreline predictions.

To the authors' knowledge the current study constitutes one of the first successful applications of uncorrected SDS data for the calibration of an equilibrium shoreline model in a high-energy, meso- macrotidal environment like Truc Vert. Given that Truc Vert is a challenging site for SDS, the adopted methodology shows potential for global applications at cross-shore transport dominated sites.

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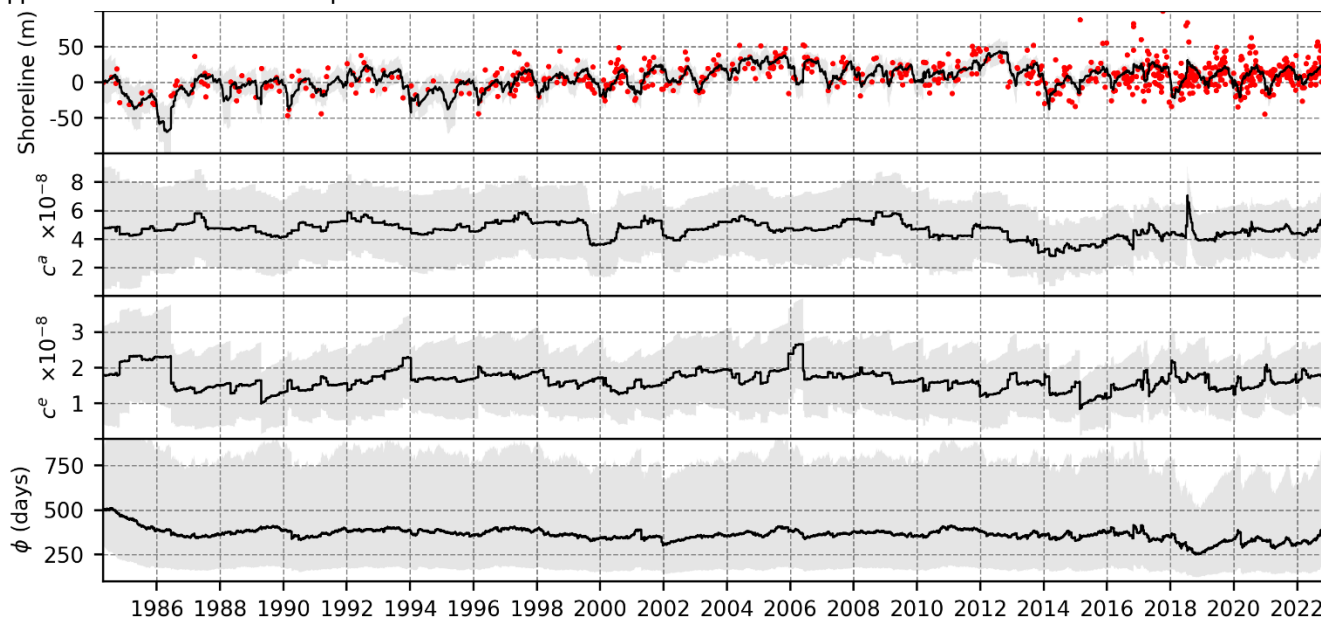


Figure 2 - Ensemble Kalman Filter application. Satellite derived shoreline observations (red dots) plotted in the upper panel together with the shoreline estimates obtained from the model. The following panels illustrate the variability in the model free parameters. The black line is the mean solution of an ensemble of  $n = 500$ , while the grey areas indicate the uncertainty defined by the standard deviation of the ensemble.