Higher Education and Research Institute in Aeronautics and Space, ISAE-SUPAERO, Toulouse, FRANCE

Post-doctoral research position

Enhancing Coastal Monitoring, Predicting Extreme Storm Events, Coastal Erosion and Sea Level Changes with Artificial Intelligence

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Context and motivation

Nearly three-quarters of the world's largest cities are located in coastal areas. This number is expected to increase in the coming years, as coastal areas are particularly attractive. However, as population density and economic activities increase, coastal areas are changing and degrading, from anthropogenic pressures and natural hazards such as extreme events which cause marine flooding and wave erosion, which will increase with climate change (Melet et al., 2018).

The ability to track and forecast the evolution of the physical characteristics of coastal areas over time is an important factor in coastal development, risk mitigation and overall coastal zone management. Climate change can exacerbate existing risks through sea level change and increasing storm severity. Changes brought by new climate conditions push the boundaries of existing models, making extreme events and long-term changes difficult to observe and forecast. There is a growing need for data-driven continuous observation and forecasting models of coastal areas.

One of the challenges of coastal monitoring is that local observation data for coastal zones can be lacking. For example, traditional bathymetry measurements are obtained using echo-sounding techniques which are considered expensive and are not possible for certain regions. Remote sensing tools such as satellite imagery can be used to estimate bathymetry using incident wave signatures and physical inversion models of waves. Satellite sensors provide low-cost, near-global ocean monitoring, with synoptic views of large areas, relatively high resolution, frequent revisits, and the ability to obtainlong time series (Bersgma et al., 2019).

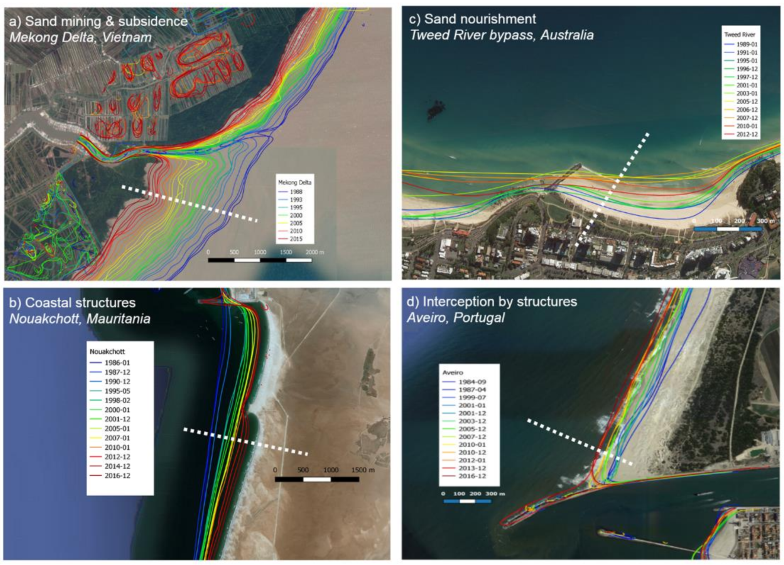

Figure 1: Evolution of satellite-derived shorelines in four cases which demonstrate beach erosion and accretion due to human interventions (Luijendijk et al., 2018)

Artificial intelligence and specifically the field of deep learning is especially suited for data-driven observation and forecasting, especially for the analysis of data from satellite arrays. A growing body of recent work has applied deep neural networks to satellite image classification and segmentation for a variety of applications (Liu et al., 2017; Ma et al., 2019). These approaches often use deep learning to identify features in satellite images, such as the detection of vehicles. Forecasting of short-term events such as weather and long-term events such as ENSO have also been recently performed with deep neural networks and have demonstrated impressive prediction ability (Ham et al., 2019).

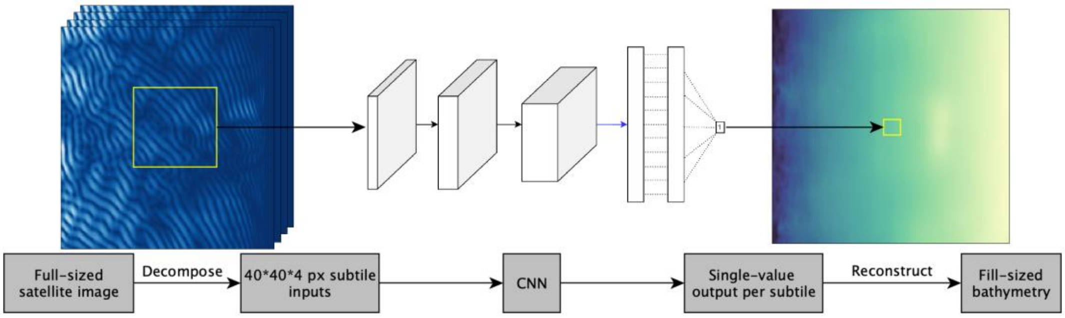

Figure 2: Satellite-derived bathymetry estimation using deep neural networks (publication pending)

In ongoing work, we have applied deep neural networks to coastal bathymetry estimation using satellite images (Figure 1). This deep learning method rivals existing physics-based methods for bathymetry estimation with the ability to estimate depths beyond those possible with inversion methods. The computational cost of this method allows for live estimation of bathymetry based on recent satellite images and we are currently testing the capabilities of this method on specific test sites. In collaboration with the French Space Agency CNES and Observatoire Midi-Pyrénées OMP, we will advance this model to estimate not only bathymetry but also sea state from satellite images which will allow for wave modelling.

In this project, we aim to predict shoreline evolution at multiple time scales. Building on our existing work with deep learning, this method will allow for short-term prediction of extreme event-induced erosion and recovery and long-term climatic forecasting of wave and sea level driven changes. By continuously integrating new data, the model will adapt to novel conditions brought about by climate change and will aid in the understanding of changing conditions in coastal areas.

Position description and tasks

The goal of this project is to build deep learning forecasting models using the existing observation as a base. To validate this model we will focus on two scales. For short time scales, our objective is to accurately predict extreme storm events such as hurricane Katrina and cyclone Xynthia. For longer time scales, we aim to predict coastal erosion and sea level changes. We expect that a data-driven model based on deep neural networks will be able to accurately predict at these different time scales and have begun the creation of the training dataset necessary for this task.

Sentinel-2, the ESA optical high resolution mission, offers 5-day revisits worldwide at 10 m resolution. Shoreline data was detected over monthly composites using Google Earth Engine and interpolated over a 14,000 alongshore shorelines vector during the period from 2015 to present. Ocean forcing can be considered as a combination of waves action and sea level. Waves are extracted from ERA5 (ECMWF) reanalyses. Finally, sea level is a combination of regional altimetry anomaly with dynamic atmospheric correction (surges due to wind and pressure available from the AVISO dataset) and tidal influence (using the FES2014 model). Both the shoreline and ocean drivers data are already processed and made available for this project.

The three main tasks of this project are as follows:

- Task 1: neural network training. In this task, the prediction model will be developed and trained on the available data. Neural network architecture and training hyperparameters will be determined based on training quality.

- Task 2: application to multiple timescales. The trained network will be evaluated on real cases, specifically the prediction of the evolution of hurricanes and cyclones and on the longer timescale forecasting of coastal erosion.
- Task 3: study of model uncertainty. In this final phase, the model will be evaluated on known test cases to determine its predictive uncertainty. With this modification, the model will be able to not only forecast upcoming events but give an estimate of uncertainty for the predictions.

References

Melet, Angélique, et al. "Under-estimated wave contribution to coastal sea-level rise." *Nature Climate Change* 8.3 (2018): 234-239.

Bergsma, Erwin WJ, Rafael Almar, and Philippe Maisongrande. "Radon-Augmented Sentinel-2 Satellite Imagery to Derive Wave-Patterns and Regional Bathymetry." *Remote Sensing* 11.16 (2019): 1918.

Luijendijk, Arjen, et al. "The state of the world's beaches." *Scientific reports* 8.1 (2018): 1-11.

Liu, Qingshan, et al. "Learning multiscale deep features for high-resolution satellite image scene classification." *IEEE Transactions on Geoscience and Remote Sensing* 56.1 (2017): 117-126.

Ma, Lei, et al. "Deep learning in remote sensing applications: A meta-analysis and review." *ISPRS journal of photogrammetry and remote sensing* 152 (2019): 166-177.

Ham, Yoo-Geun, Jeong-Hwan Kim, and Jing-Jia Luo. "Deep learning for multi-year ENSO forecasts." *Nature* 573.7775 (2019): 568-572.

Requirements for the applicant

We are looking for an enthusiastic researcher for this study, interested in earth observation and artificial intelligence. A PhD degree in either planetary science or computer science is required and a background in numerical models is required. Experience in deep learning will be highly appreciated.

Eligibility: the candidates must

- possess a PhD degree for less than five years on the date of application submission
- not have resided in France after September 1st, 2019, and have exclusively nationality of one of the following eligible countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hong-Kong, Hungary, Iran, Ireland, Island, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New-Zeland, Norway, Poland, Portugal, Romania, Russia, Singapour, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taïwan, United Kingdom, United States of America

Duration: at least 1 year starting from January 2021.

Application deadline: June 17, 2020

Applicants should submit a cover letter, presenting their motivation, a detailed curriculum vitae, a list of publications, title and abstract of PhD dissertation, contact information of at least one academic reference and all relevant details to Dr Dennis Wilson (dennis.wilson@isae-supaero.fr), copying Mikhaïl Stepanov (mikhail.stepanov@isae-supaero.fr). **For more information** please contact Dr Dennis Wilson.

The preselected candidate will have to finalize the application to the **"Make Our Planet Great Again"** French government initiative fellowship with our support before July 5, 2020.
See https://www.campusfrance.org/en/financing-12-month-post-doctoral-research-contracts