Modelling Global Mean Sea Level (GMSL) estimation and uncertainty quantification for drift and acceleration

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Motivation

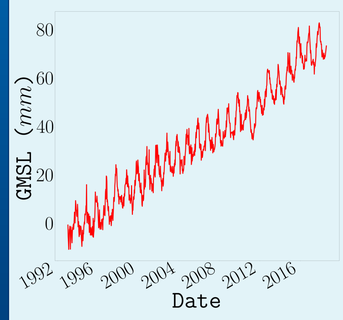
Rise in GMSL causes population displacement (coastal and island communities), loss of cultivable land area, increased damage due to extreme events.

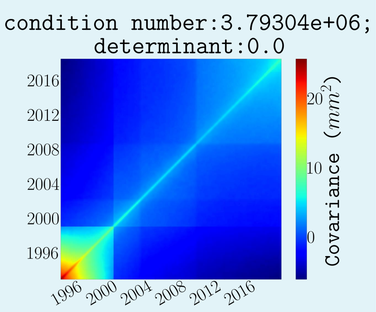
Improving its modelling and uncertainty quantification helps data driven decision making on adaptation and mitigation of its effects.

Data

Averages over 10 days of 25 years of satellite altimetry measurement of GMSL are considered.

The covariance matrix suggested in [1] for measurement uncertainty is assumed at first to correctly represent the covariance of the data.





Model 1: definition

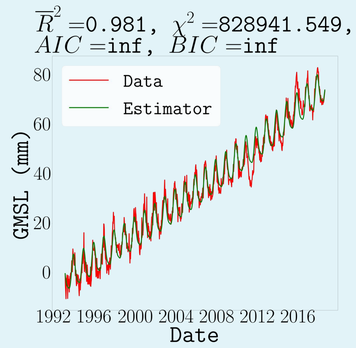
A linear model including season, drift and acceleration, and covariance structure for measurement is considered in [2]:

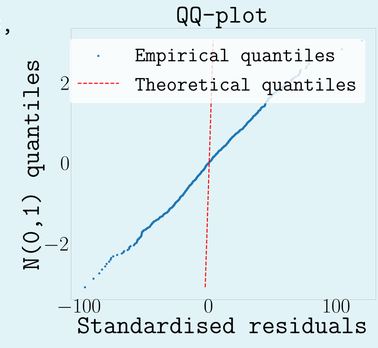
$$Y_j = \gamma_1(t_j - T_1)1_{t_j \geq T_1} + \gamma_2(t_j - T_2)^2 1_{t_j \geq T_2} + \alpha \cos(t_j) + \epsilon_j.$$

Model 1: fit and validation

Statistical model validation shows that the probability to observe this data sample under this model is small.

The model fails to include extreme events (e.g., 2010 Tsunami [3]), and chaotic behaviour of GMSL.



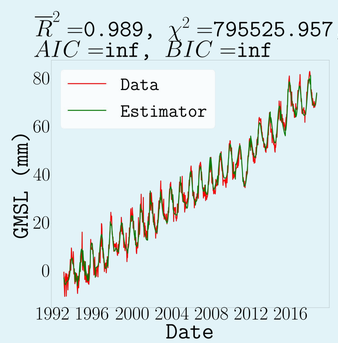


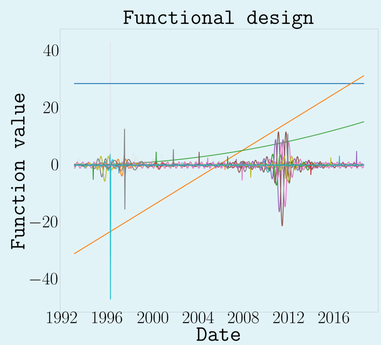
Model 2: including extreme events

A sparse model is incorporated and fitted using LASSO:

$$Y_j = M_1 + \sum \beta_{\omega,\phi} \psi_{\omega,\phi}(t_j).$$

The model fits properly extreme events (see 2010) but the model still is not statistically validated under this dataset.





Next steps

- Characterise the chaotic aspect of GMSL and include it in the estimation of systematic behaviour: $Y_j = M_2 + W(t_j)$, where W is a stochastic process to be determined;
- Detect change points linked to climate change (apparition of trend, then acceleration) and quantify uncertainty on their detection and location;
- Statistically test whether extreme deviations from trend are becoming more frequent/have larger amplitude.

Recommendations

- Implement toolkits for model validation methods;
- Encourage collaboration between observationalists, statisticians and metrologists to quantify trend uncertainties more robustly;
- Implement a framework for considering natural variability in trend uncertainties.

Bibliography

[1] Henri et al. *Effect of the processing methodology on satellite altimetry-based global mean sea level rise over the Jason-1 operating period,* 2014

[2] Ablain et al. *Uncertainty in satellite estimates of global mean sea-level changes, trend and acceleration,* 2019

[3] Fasullo et al. *Australia's unique influence on global sea level in 2010—2011,* 2013

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FUNDED BY BEIS

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