Spatio-temporal modelling for global sea level change

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1. Introduction and framework

Motivation

Future sea level rise (SLR) is one of the most serious consequences of climate change. Traditionally, the Earth system components that contributes to SLR were treated separately and often led to inconsistencies between discipline-specific estimates of each part of the sea level budget.

Our project aims at producing a physically-based, data-driven solution for the complete coupled land-ocean-solid Earth system that is consistent with the full suite of observations, prior knowledge and fundamental geophysical constraints.

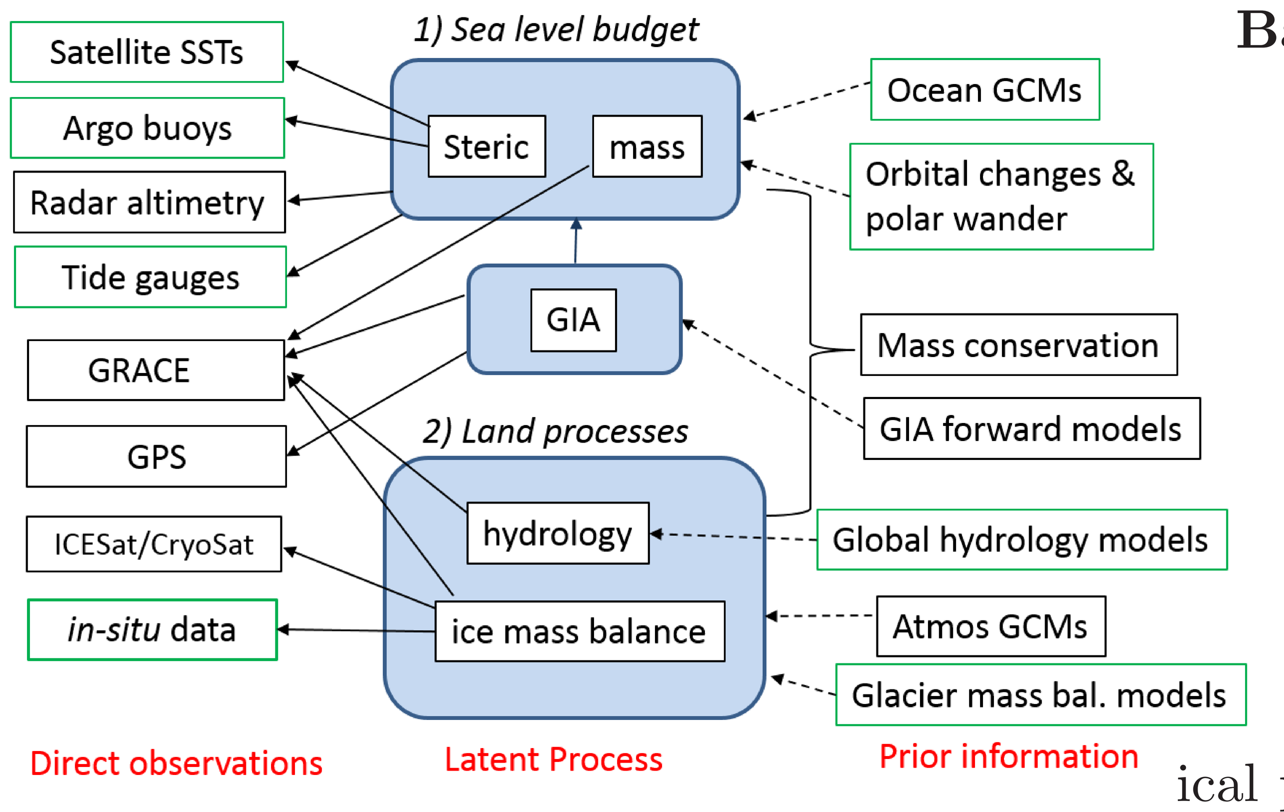

Figure 1: BHM framework for solving SLR

Bayesian Hierarchical Model (BHM)

$$
\begin{aligned}
\boldsymbol{y}|\boldsymbol{\beta}, \boldsymbol{x}, \boldsymbol{\theta} &\sim \mathcal{N}(\boldsymbol{P}(\boldsymbol{\beta})\boldsymbol{x}, \boldsymbol{\Sigma_{obs}}),\\
\boldsymbol{x}|\mathcal{A}, \boldsymbol{X}, \boldsymbol{\theta} &\sim \mathcal{N}(\mathcal{A}\boldsymbol{X}, \boldsymbol{Q}^{-1}(\boldsymbol{\theta})),\\
\boldsymbol{X}(\boldsymbol{s})|\boldsymbol{\theta}, &\sim \mathcal{GP}(\boldsymbol{\mu}(\boldsymbol{s}), k(\boldsymbol{s}, \boldsymbol{r}; \boldsymbol{\theta})),\\
\boldsymbol{\beta} &\sim \mathcal{N}(\boldsymbol{\mu_\beta}, \boldsymbol{\Sigma_\beta}),\\
f(\boldsymbol{\theta}) &\sim \mathcal{N}(\boldsymbol{\mu_\theta}, \boldsymbol{\Sigma_\theta}).
\end{aligned}
$$

where $\mathcal{A}$ is a linear operator that maps physical process $\boldsymbol{X}$ into the observation space and $\boldsymbol{P}$ represents the relationship between the observations and the latent processes.

2. Big data challenges

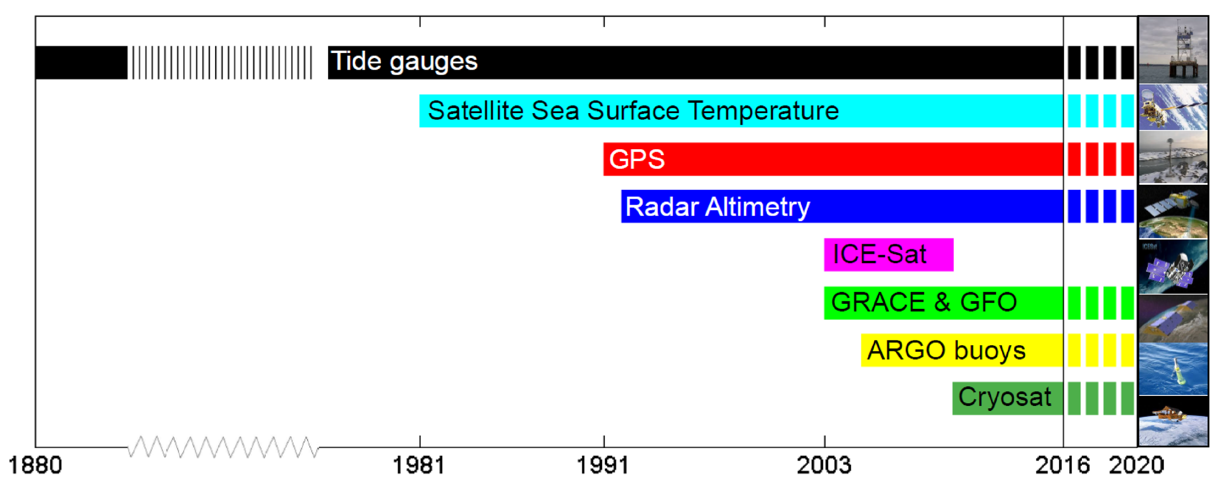

Figure 2: Temporal coverage of the observations.

- Massive volume of data sets with uncertainty in error estimates.
- Inconsistent temporal coverages and frequencies between the data sets.
- In-situ and satellite measurements exhibit various spatial footprints.
- Different spatially-varying mesh grids in high resolutions for SPDE approximation.

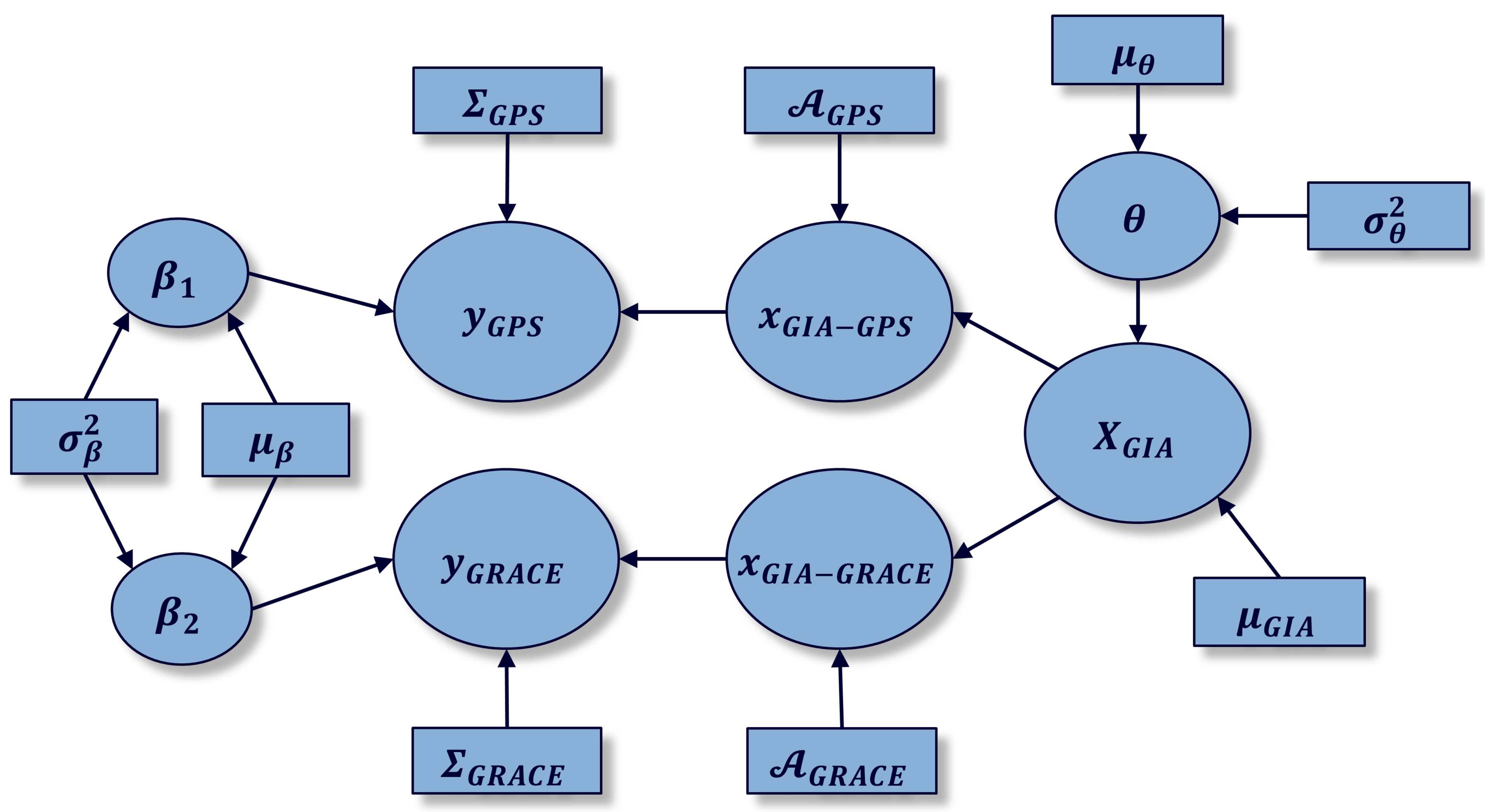

Figure 3: Graphical model for the GIA.

3. Example: the glacio-isostatic adjustment (GIA)

With my current design of implementation, the approximation to (??) is not accurate enough and show a substantial variability. Therefore, only the fitting of the residual obtained from a GLM model is presented here.

The approximate MLEs of are $\rho = 0.2308$, $\sigma^2 = 0.7028$, and they can be reused for constructing weights in GLM. Note the range of ρ is about $(-0.25, 0.25)$. The estimated ρ shows a strong positive correlation.

References

4. Future Work

- Assume presence-only data [?]
- Joint modelling the 277 species
- Occurrences collected at lower resolution with substantial variation in explanatory variables over the region
- Occurrence data collected at different resolutions [?]
- Elaboration of the spatial covariance structure

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Keep in touch

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