WP 4.3 Uncertainties estimation, from global to coastal scales

B. Meyssignac, LEGOS
P. Prandi, CLS

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European Space Agency

Context

- Accurate description of sea level uncertainties is essential:
  - To detect climate signals, not measurement artifacts,
  - To contribute to budget closure studies,
  - To contribute to detection & attribution studies.
  - To contribute to the estimate of Earth energy Imbalance

- History of GMSL uncertainty analysis (Ablain *et al.*, 2009, 2015) from an empirical error budget approach,

- SL-CCI Bridging Phase outcomes:
  - estimation of an error variance-covariance matrix (Ablain *et al.*, 2019),
  - Its dissemination to users,
  - Ensemble approach for coastal sea level uncertainties.

SLCCI+ Goals

- Characterization of altimetry errors from global to local scales
  - Development, production & distribution of an ensemble of GMSL,
  - Estimation of regional errors in sea level trends,
  - Estimation and distribution of regional uncertainty in sea level trends,
  - Strategy for the development of a regional error variance-covariance matrix

Mathematical elements

- Let the MSL time series be expressed as the sum of a forced response and error

$$Y = AX + E$$

- The least squares estimator of A is given by

$$\hat{A} = (X^t X)^{-1} X^t Y$$

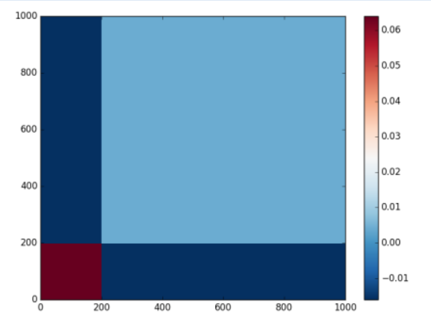
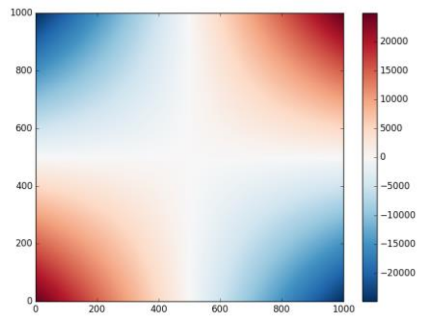
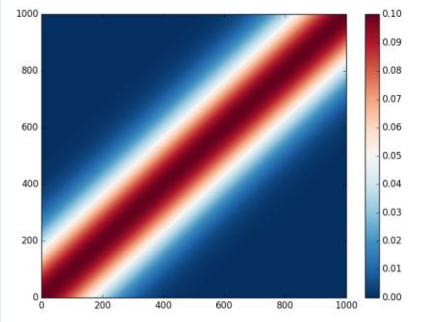
- If Σ is the error covariance matrix, then variance-covariance of $\hat{A}$ is given by

$$\Omega_{\hat{A}} = (X^t X)^{-1} X^t \Sigma X (X^t X)^{-1}$$

- If $\Sigma = \sigma I_n$ (errors are independent and identically distributed) then this is a simple OLS

Error covariance modelling

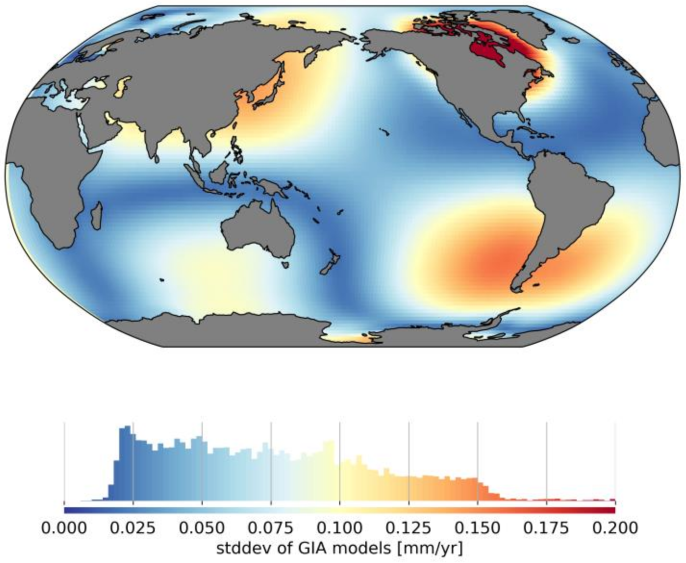
- The error covariance is built from the sum of individual error terms,
- Three types of errors are modeled,
- Each contribution is scaled to our current (empirical) knowledge about systematic errors.

Bias	Drift	Noise
		

From global to regional errors

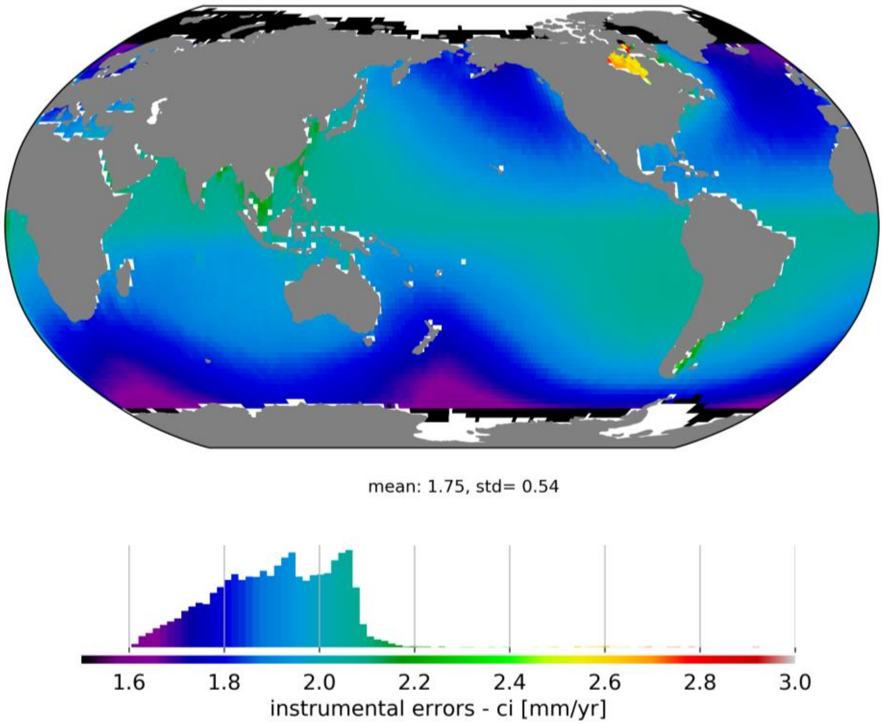
- Based on Bridging Phase outcomes,
- Main error sources are the same at global and regional scales => we apply a regional value at each grid point.

- Example: the GIA correction
  - Globally, GIA correction is uncertain by 0.05 mm/yr (Spada, 2017)
  - Locally, large scale correlated patterns up to 0.2 mm/yr



Regional trends uncertainties

- Preliminary trend uncertainty map
- No internal variability accounted for,



Space/time error structure

- As a first step, regional errors are estimated at each grid point independently,
  - No description of spatial error covarianace

- A comprehensive error description should include **time and space** covariance,
  - One big matrix (n_times*n_grid_points)^2

- This is impossible a priori with a 1/4° resolution on a daily basis
- Reflexion on a smoothed (in time and space) and subsampled variance-covariance matrix

Ensemble approach

- SLCCI-BP: ensemble of coastal SL,
- Built using a set of geophysical corrections,
- Ensemble spread used to derive uncertainties.

- SLCCI+
  - Addition of new standards/corrections (retracking algorithms),
  - Estimate reliability of results to the initial ensemble (bootstrap/leave one out)