WP 4.3 Uncertainties estimation, from global to coastal scales

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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
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 \( \Sigma \) 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
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.

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<tr>
<th>Bias</th>
<th>Drift</th>
<th>Noise</th>
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<tr>
<td><img src="image1" alt="Bias Chart" /></td>
<td><img src="image2" alt="Drift Chart" /></td>
<td><img src="image3" alt="Noise Chart" /></td>
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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,
• 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)