How reliable are regional sea level trends ?

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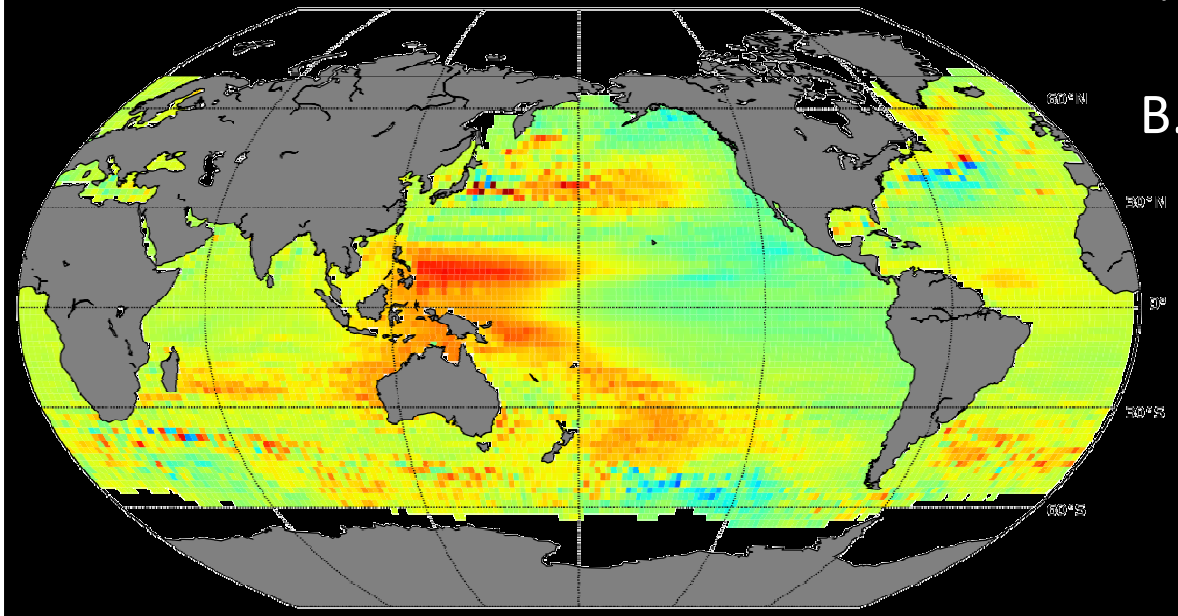

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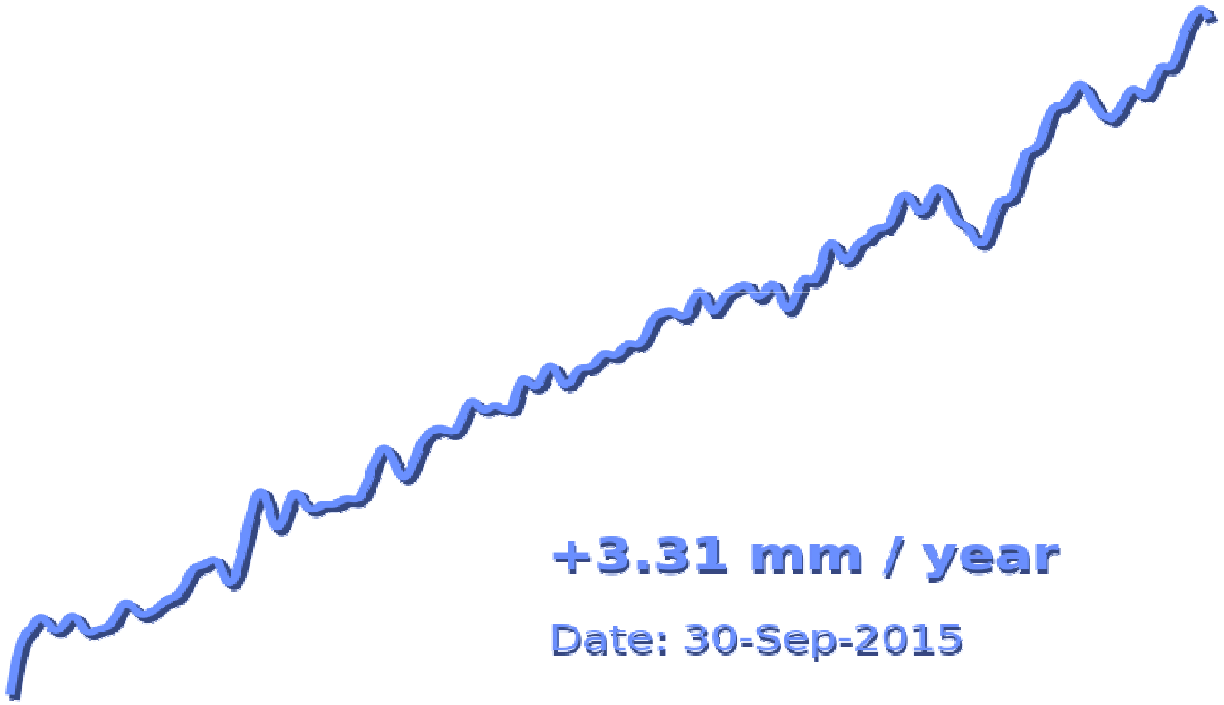
Introduction

- MSL is an essential indicator of climate change,
- In particular, the trend draws much interest,



- What about associated uncertainties ?

Uncertainties on global MSL

– Several reviews of uncertainty sources:

  • Ablain et al. 2009 & 2015

	Spatial scales	Temporal scales	Altimetry errors	User requirements	
R	Global MSL	Long-term evolution (> 10 years)	< 0.5 mm year^{-1}	0.3 mm year^{-1}	
Dyna		Interannual signals (< 5 years)	< 2 mm over 1 year	0.5 mm over 1 year	
	Regional MSL	Annual signals	< 1 mm	Not defined	
		Long-term evolution (> 10 years)	< 3 mm year^{-1}	1 mm year^{-1}	
Total		Annual signals	< 1 cm	Not defined	

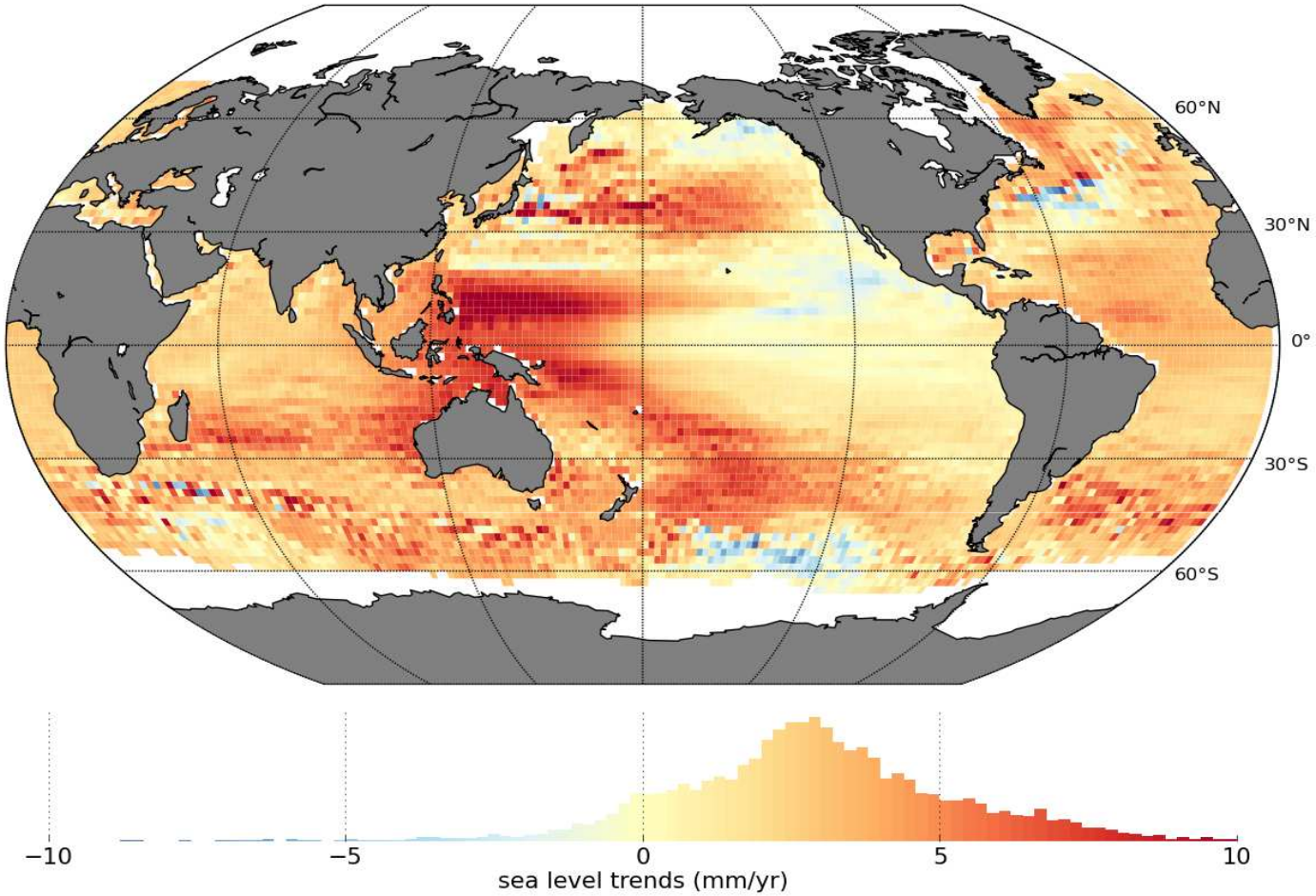
)3 to 2008

)l of 90%

– Among others (Henry et al., Couhert et al., Legeais et al., …)

– Results in 0.5 mm/yr on GMSL, higher on RMSL

Objectives



- What are the uncertainties at each grid point ?
- Can we estimate a map of uncertainties ?

Mathematical approach

- At each grid point, we solve for the linear system

$$Y = XA + E$$

- The solution is given by

$$A = \left[X^T C^{-1} X\right]^{-1} \left[X^T C^{-1} Y\right]$$

- And the variance-covariance of model parameters

$$\Omega = \left[X^T C^{-1} X\right]^{-1}$$

Allows the determination of model parameter uncertainties

Mathematical approach

- C is the variance-covariance of the errors,

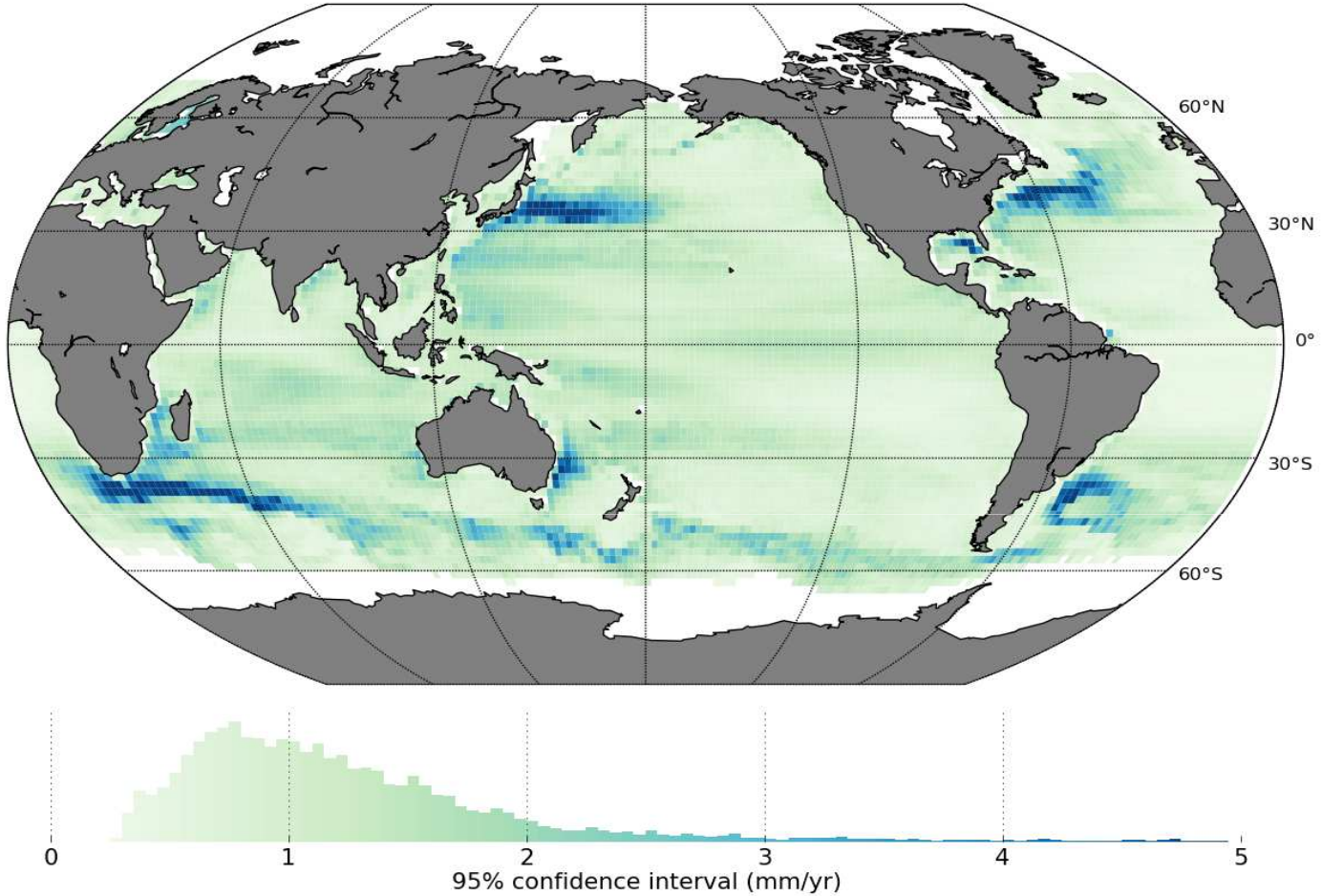
- a common simplification is to use

$$C = \sigma \mathrm{I}_n$$

Which is simply the OLS solution (independent and identically distributed errors)

- Here, we populate the C matrix using reasonable assumptions on the error structure (GLS solution) and estimate 95% c.i. on trends

A useful reference: OLS



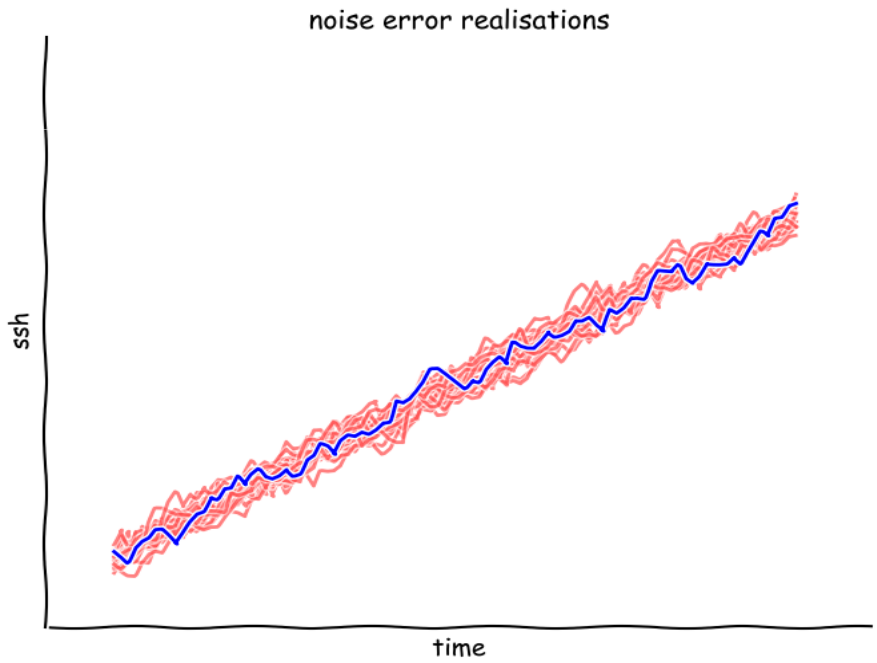
- Signature of ocean variability
- Uncertainties generally ranging from 0.5 to 1.5 mm/yr

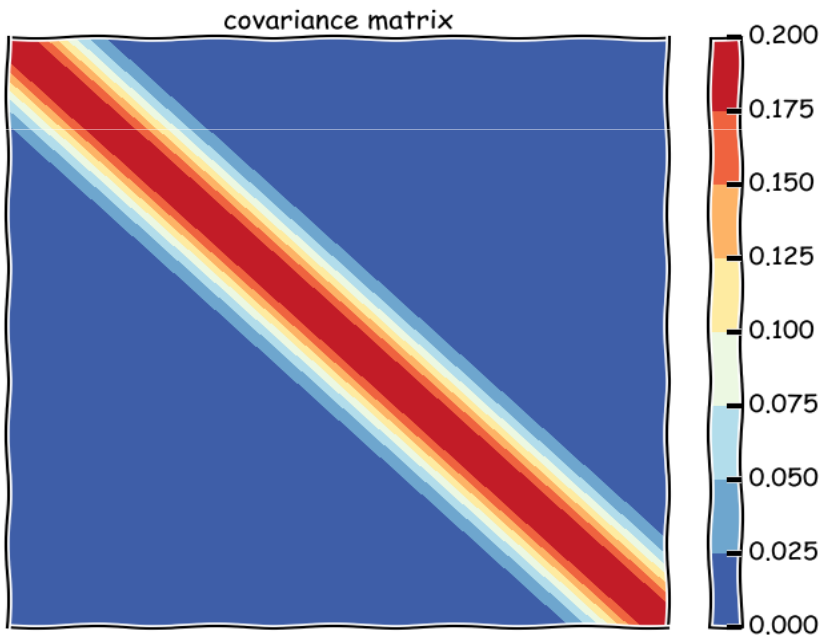
Error covariance model

- 3 error models are used:
  - noises,
  - biases,
  - drifts.
- At each grid cell, the total covariance is a sum of these « elementary » covariances.
- Based on a priori assumptions on errors at this point.

Noise

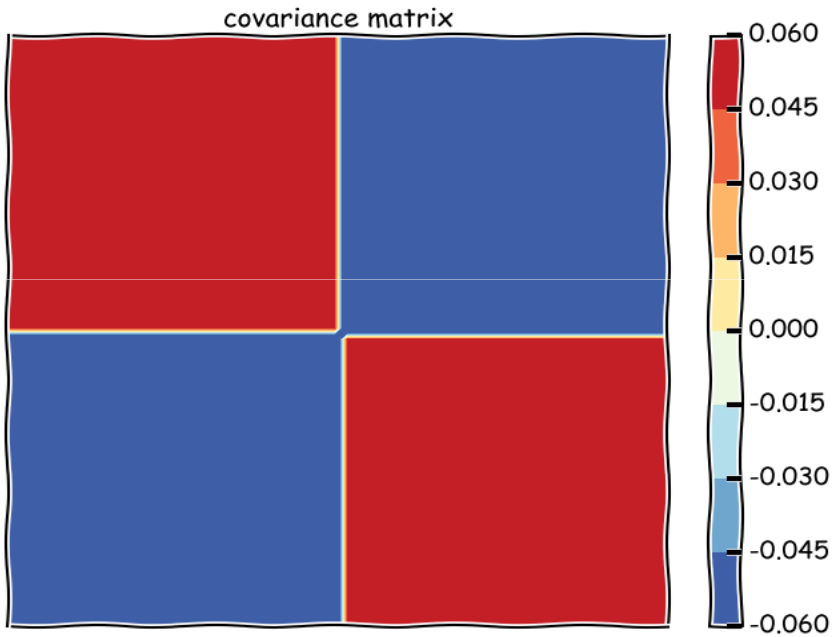
- Accounts for high frequency errors in altimeter data
  - With autocorrelation,
  - Without heteroskedasticity,





Biases

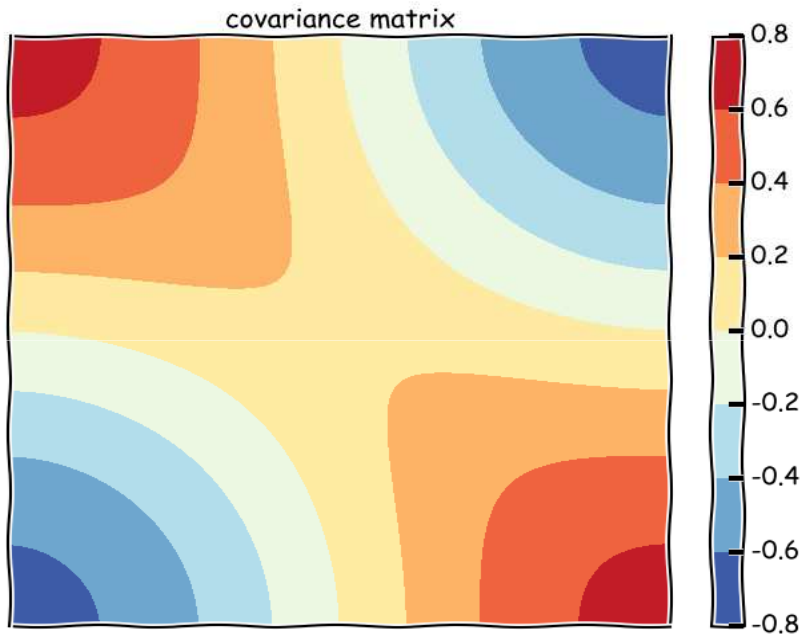
- Accounts for uncertainties when linking one mission to another,



Depends on the position (bias uncertainty may vary geographically)

Drifts

- Accounts for uncertainties on long-term stability of the record

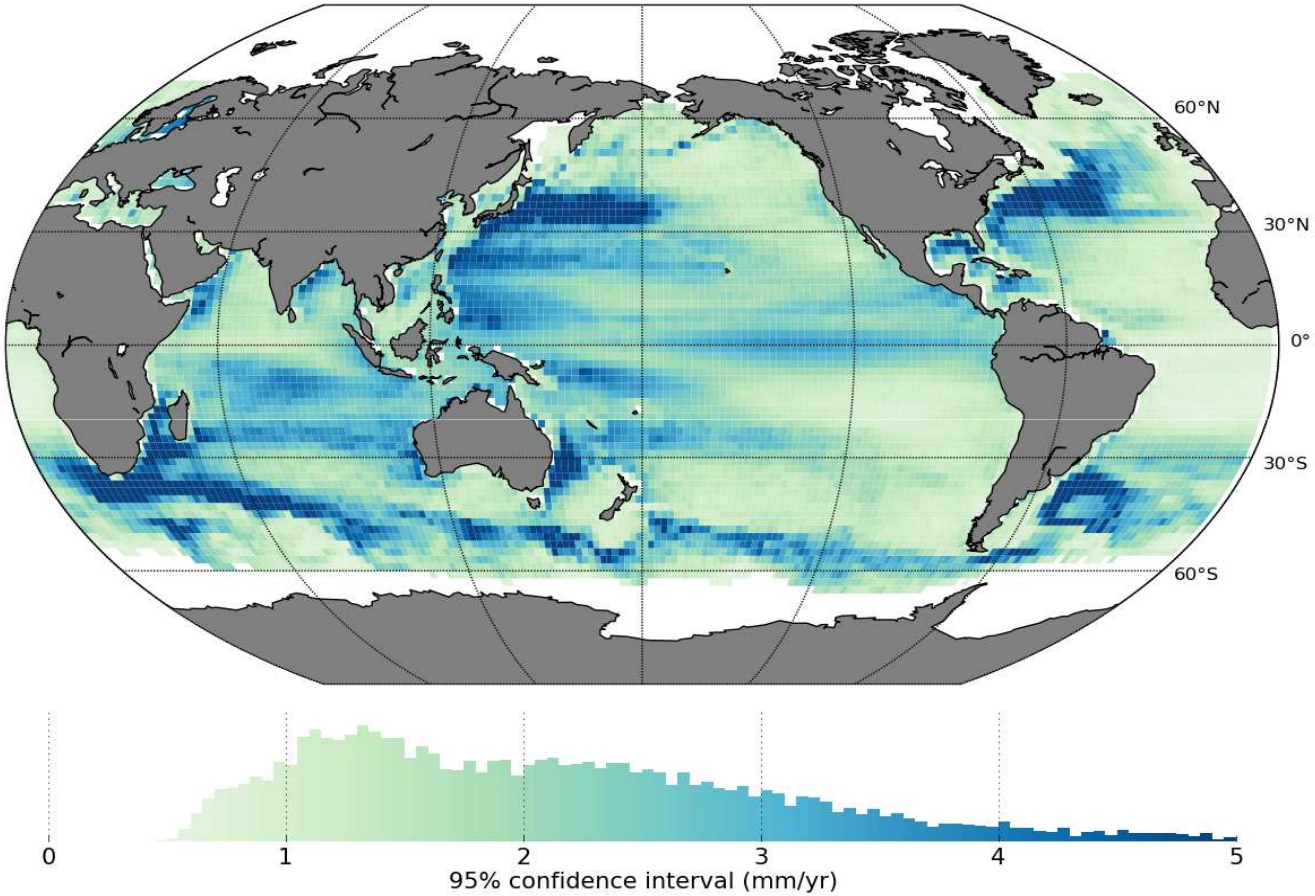


- Mainly due to orbits (Couhert *et al.*, 2015)
- And radiometer drifts (Legeais *et al.*, 2014)

Accounting for system errors

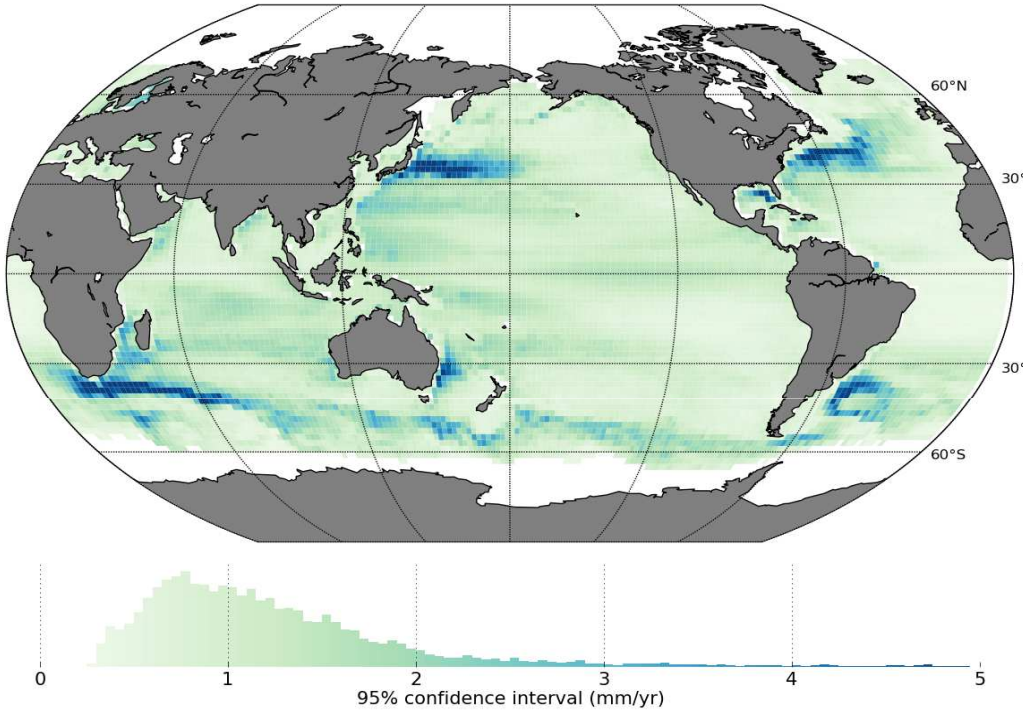
Assumptions:

- Orbit drift (1 mm/yr),
- Tropo drift (0 to 2 mm/yr, latitude dependent),
- biases errors between missions,
- High frequency correlated noise (2 months)

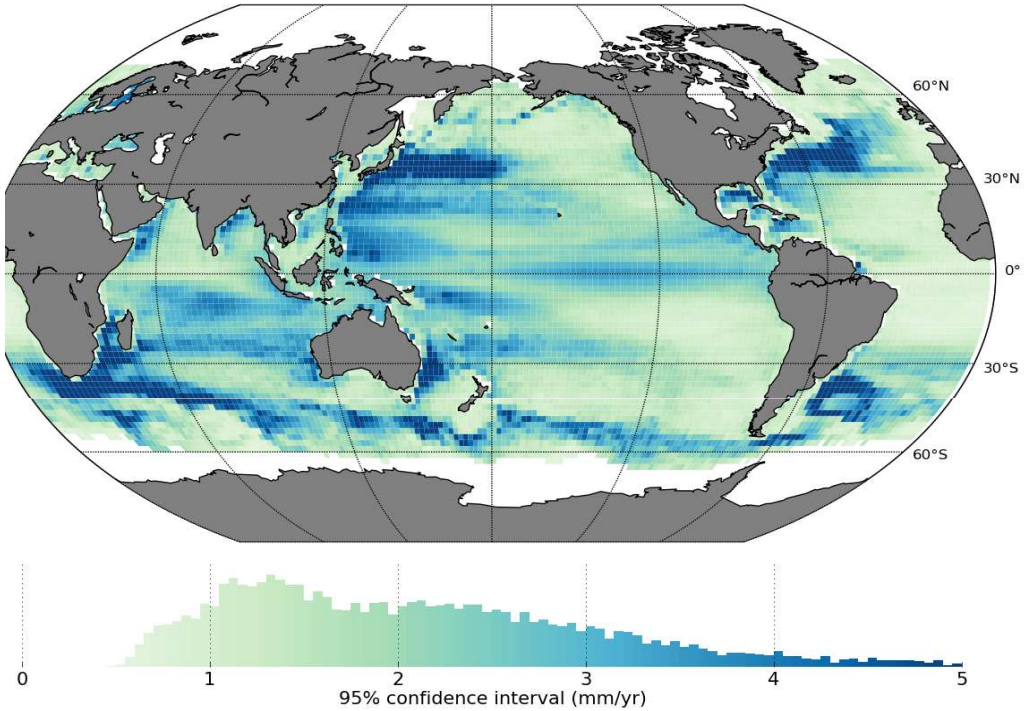


Comparing to OLS solution

OLS

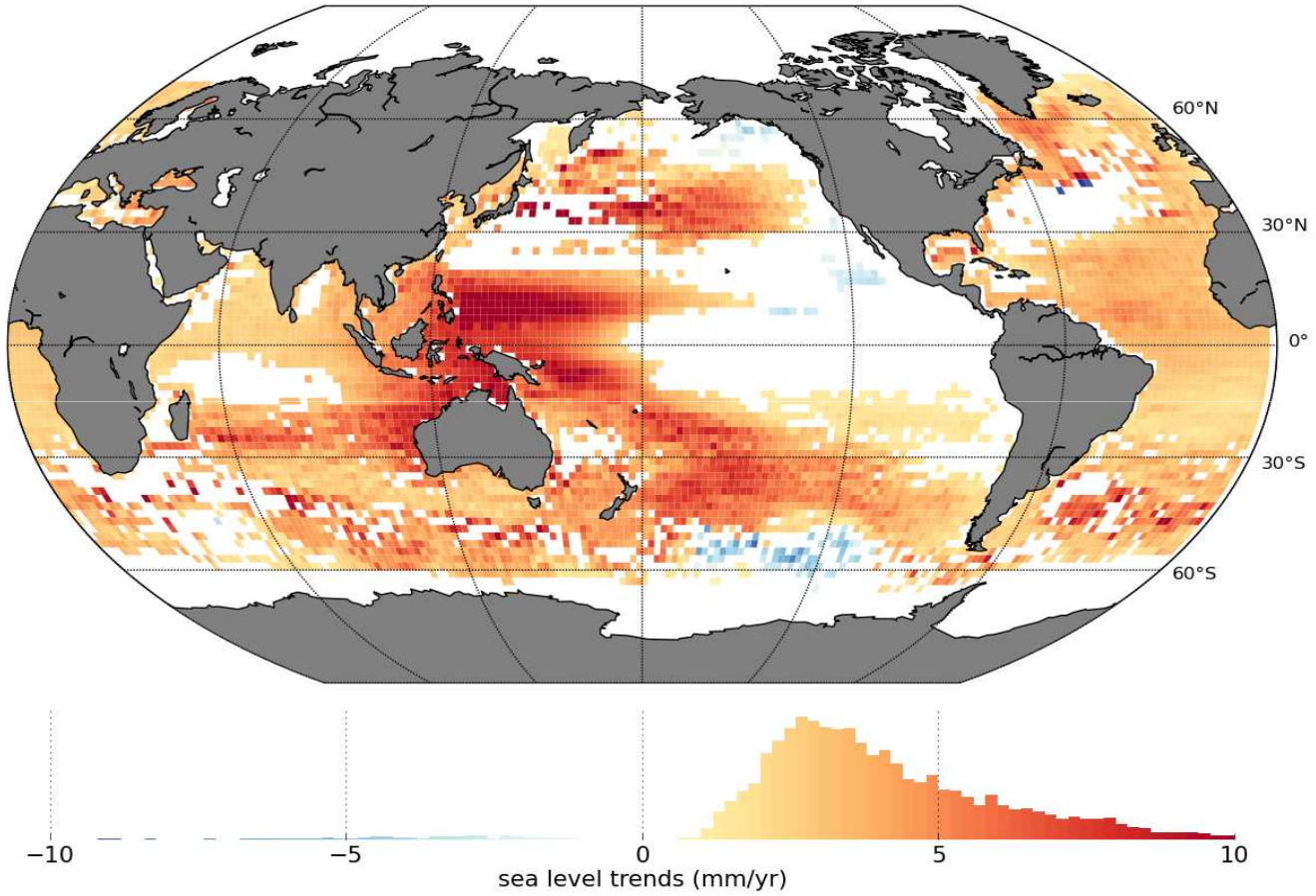


Full covariance



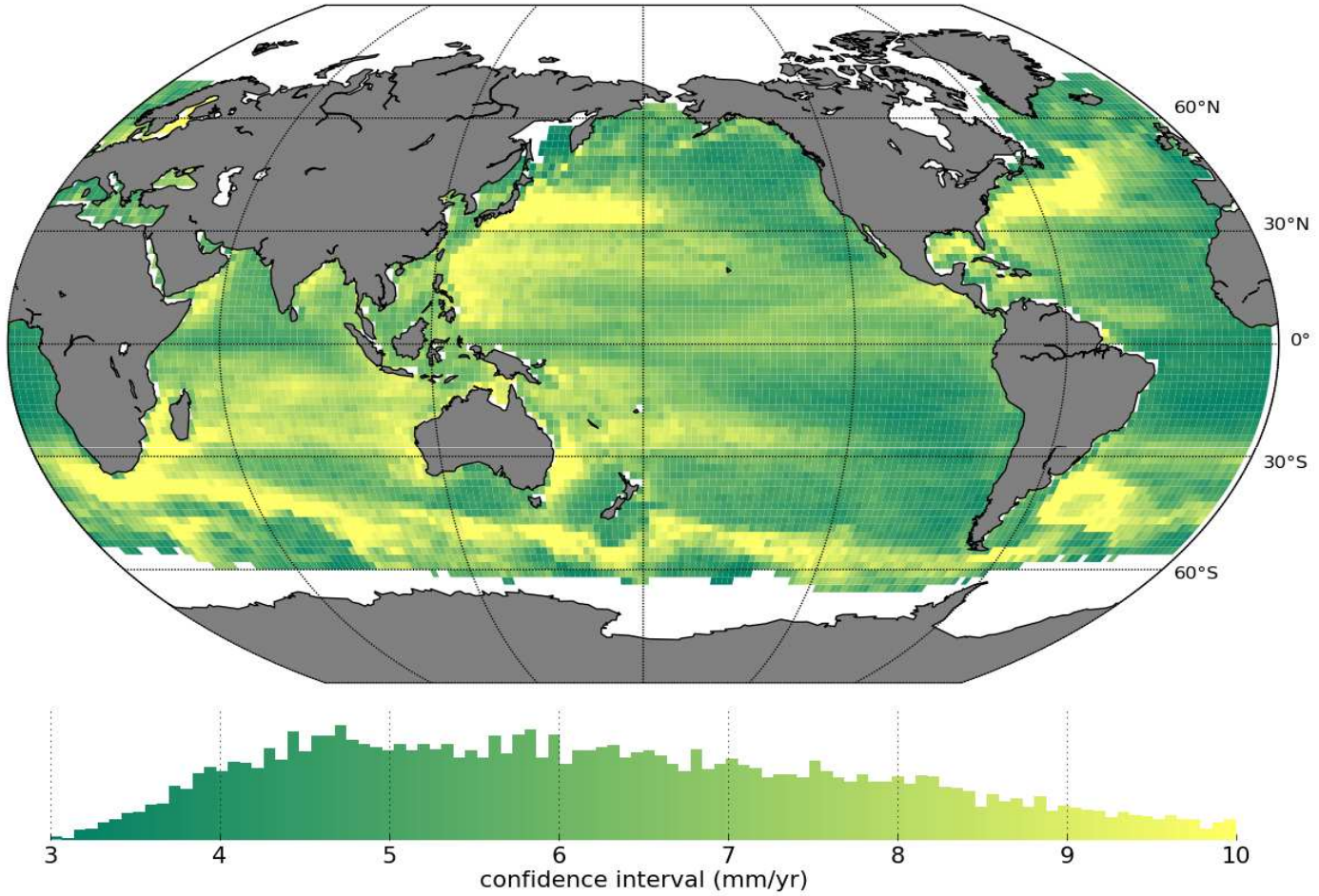
Significant trends

Places where we can reject the hypothesis that there is no trend



67 % of the ocean

Including ocean variability



Conclusions

- Method provides a map of trend uncertainties,
- Systematic uncertainties range between 1 to 3 mm/yr
- More realistic confidence interval than OLS,

- Results depend on the *a priori* description of errors,
  - Il the error model is wrong, the results are
  - Accurate error covariance description is crucial

- With time, the CI will reduce

Outlook

- Introduce noise heteroskedasticty,

  i.e. larger errors on TOPEX than Jason-2 ?

- Introduce natural ocean variability

  i.e. given the natural low frequency variabilty of SL, can we detect climatic trends ?

  or are the patterns observed likely to be stable in time (*e.g.* Meyssignac et al. 2012) ?

Questions ?

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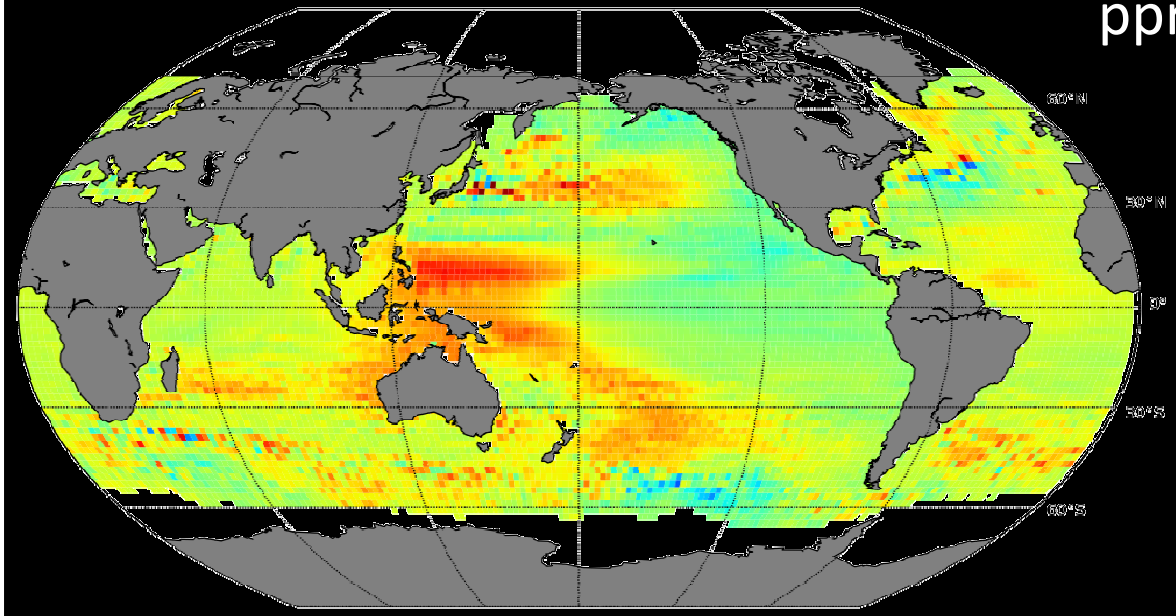

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