Multi-Mission Sea Level Trends

How uncertain are regional sea level trends ?

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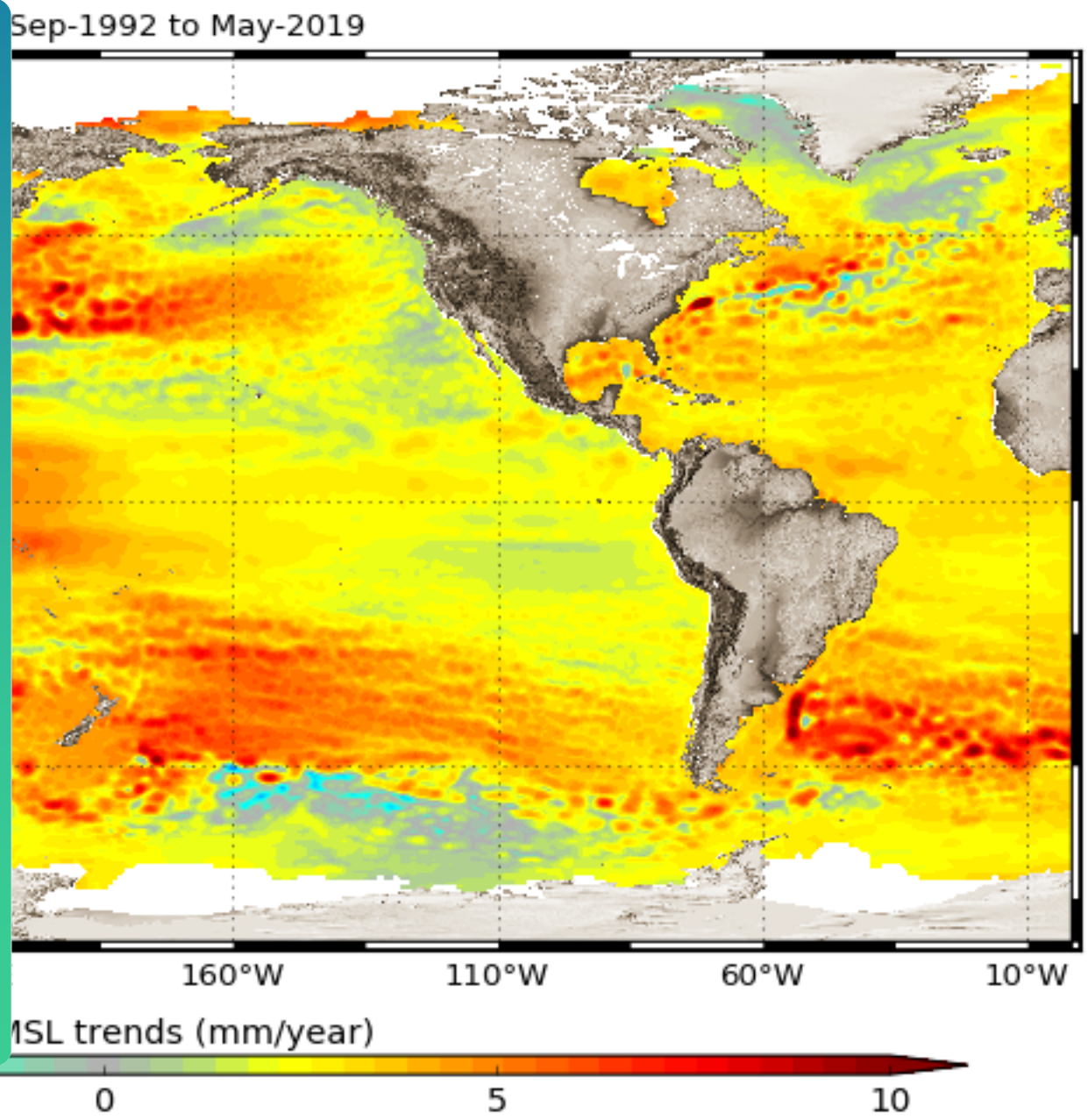


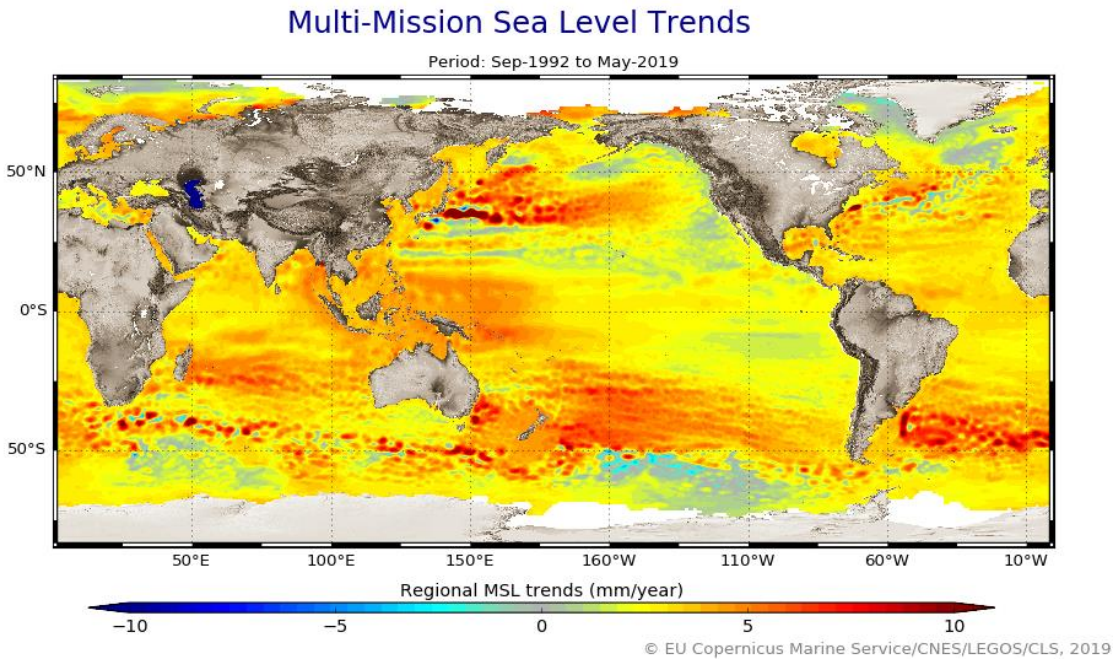
Context and goals

GMSL trend and acceleration uncertainties

- Ablain et al., 2019,
- From an error budget approach,
- comprehensive error description,
- consistent uncertainty estimates,

Large regional SLR variability

- Can we use a similar methodology ?
- Can we constrain the error bugdet at regional scales ?
- What does that mean for regional trend uncertainty levels ?



Why does it matter ?

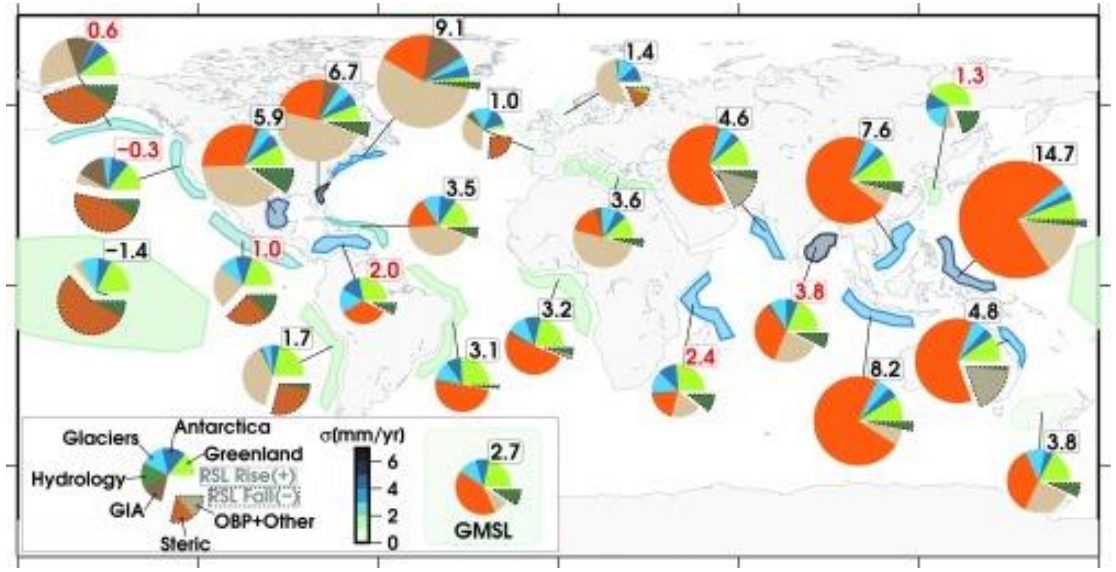
regional budget studies

regional sea level rise detection and attribution

as a data provider error should come with the data

"Quantitative uncertainty information should be provided with the observations."

C. Merchant, Fiduceo outcome



Rietbroek et al., 2015

Input data

C3S sea level grids

- Inherits from Sea Level CCI,
- Stability oriented,
- From 1993 to 2018

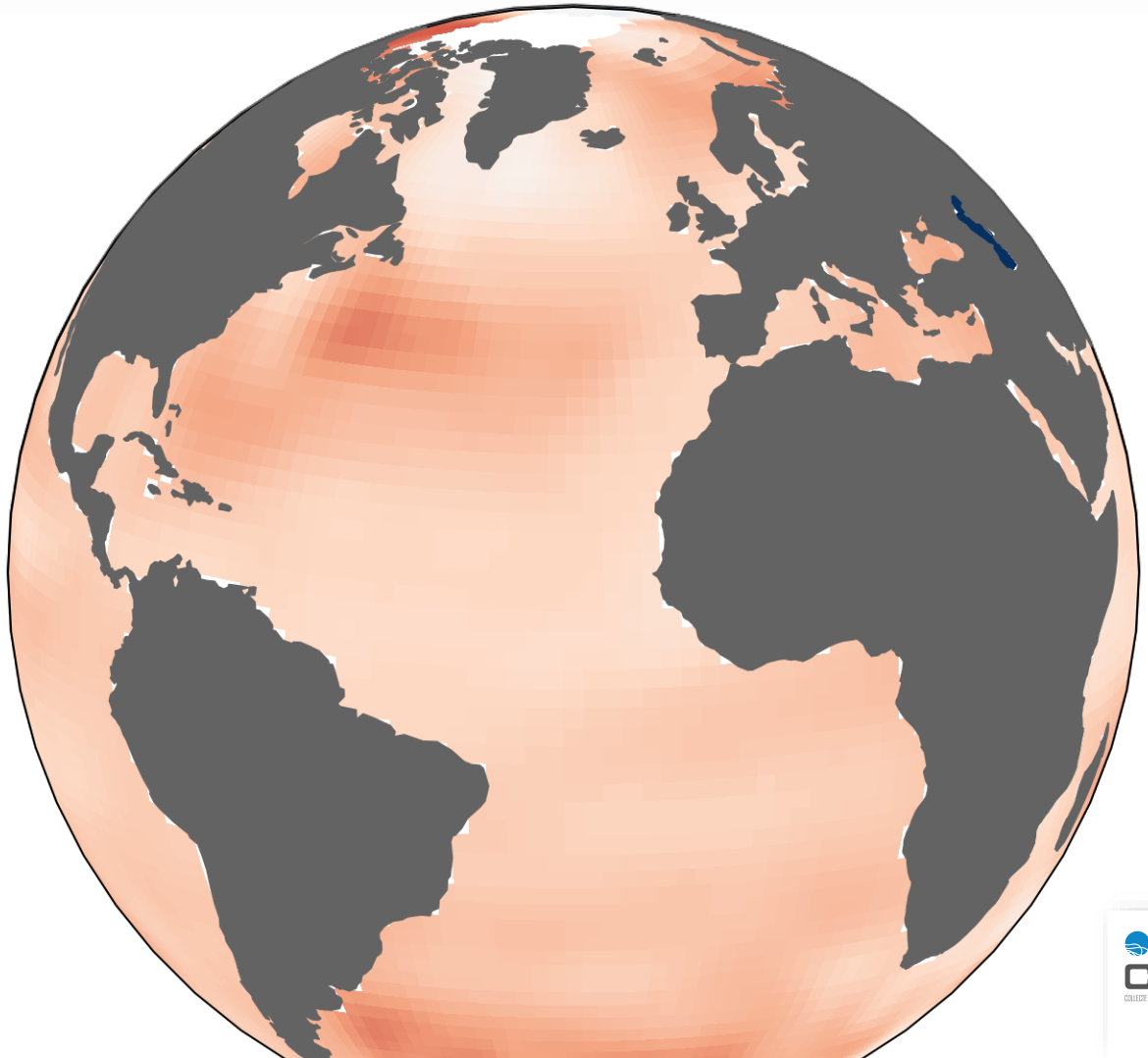
Spatial filter

- Remove mesoscale signals,

Yearly averages and sub-sampling

- Filter high frequency variability,
- Reduce problem dimension,

NOT corrected for a TOPEX-A drift



Uncertainty estimation

Extended OLS formulation

$$\hat{\beta} \sim N(\beta, (X^t X)^{-1}(X^t \mathbf{\Sigma} X)(X^t X)^{-1})$$

Where $\mathbf{\Sigma}$ is the error covariance matrix

Approach

- For each grid cell
- Estimate local error budget,
- Fill the error covariance matrix accordingly,
- Derive local uncertainty on SL trend

Limitations

- No spatial error covariances, time only
- For trends only
- Altimetry errors only, no natural variability

Filling the error covariance matrix

Three elementary error constituents

Correlated errors

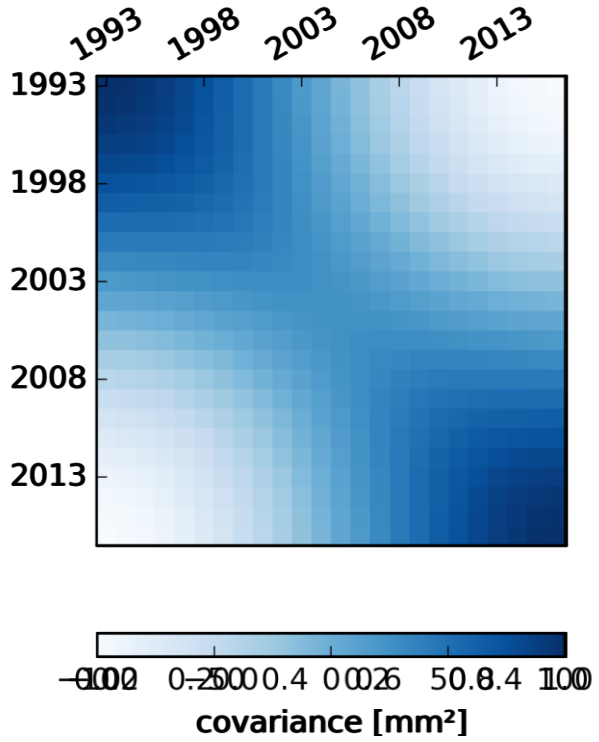
- Decaying covariance,
- Amplitude & time scale

Biases

- Anti-correlates before/after bias
- Amplitude and timing,

Drifts

- Covarying over the whole time series
- Amplitude

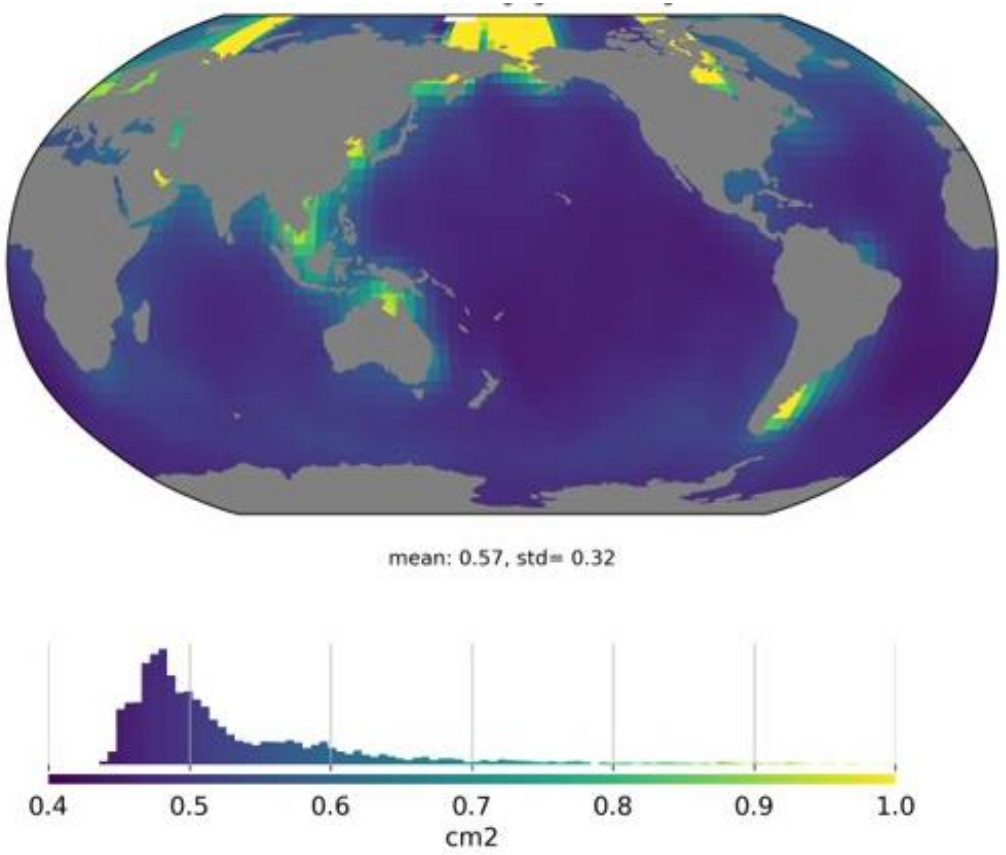


Under a no cross-covariance hypothesis, we sum individual contributions

Error budget

Medium frequency errors

- Correlated at T < 1yr
- geophysical corrections,
- Orbit errors,
- Derived from Xovers and Xcal empirical corrections,
- Can’t be inferred from signal at regional level

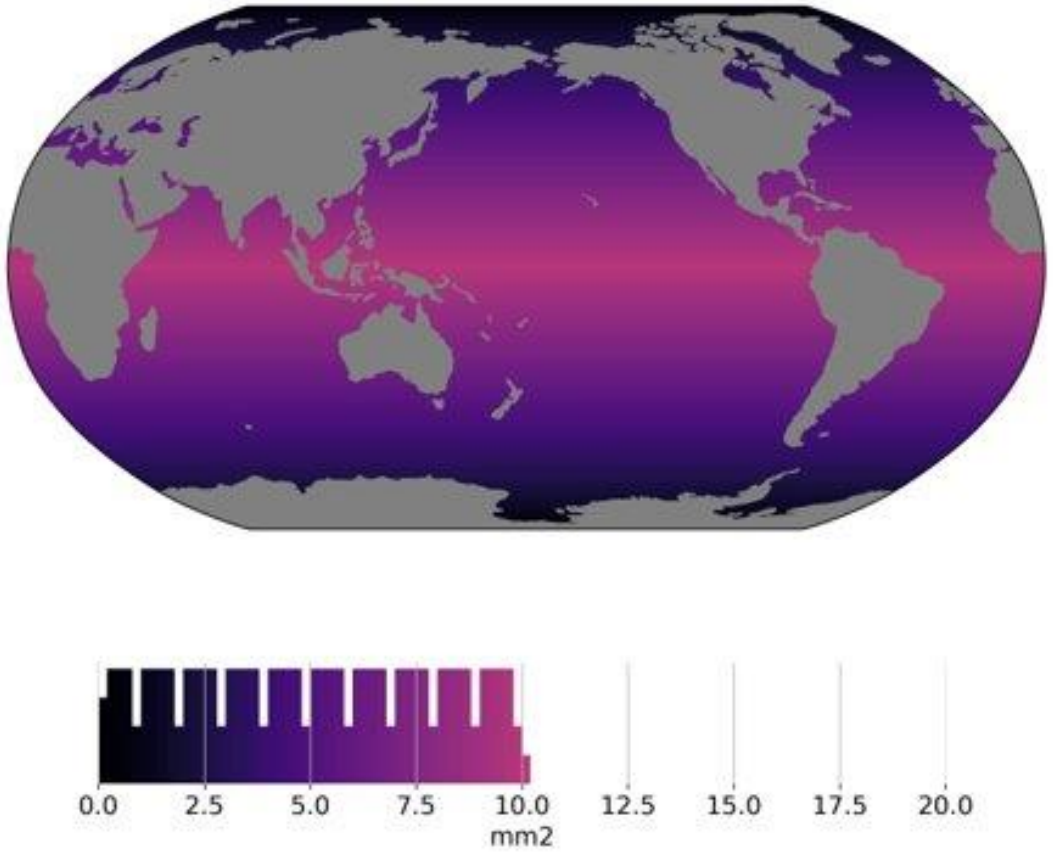


Error budget

Medium frequency errors

Large frequency errors – wet troposphere

- Accounting for long term WTC errors
- Correlated at T = 10 yrs
- Scaled to the variance in radiometer minus model differences,
- Latitude dependent (more error in the tropics)
- eg Thao et al. 2014, Legeais et al. 2014



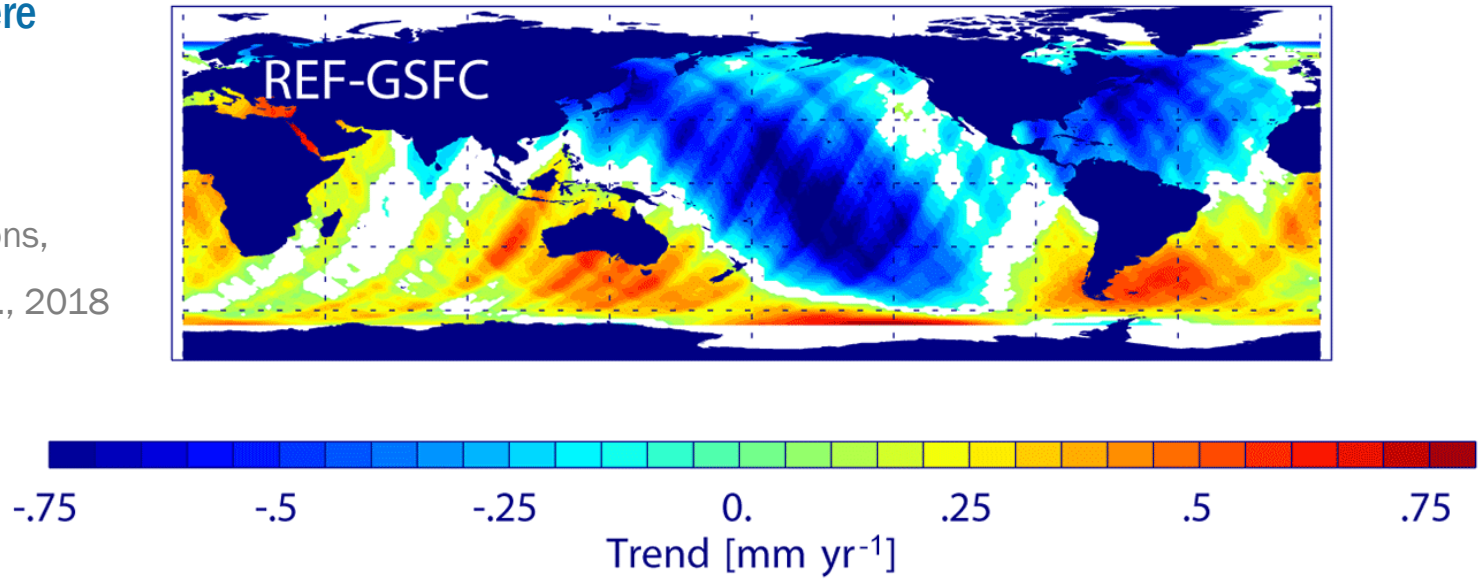
Error budget

Medium frequency errors

Large frequency errors – wet troposphere

Orbit drift

- Uniform at 0.33 mm/yr
- Includes gravity field and ITRF contributions,
- From Couhert et al., 2015, Rudenko et al., 2018
- Likely conservative estimate



Error budget

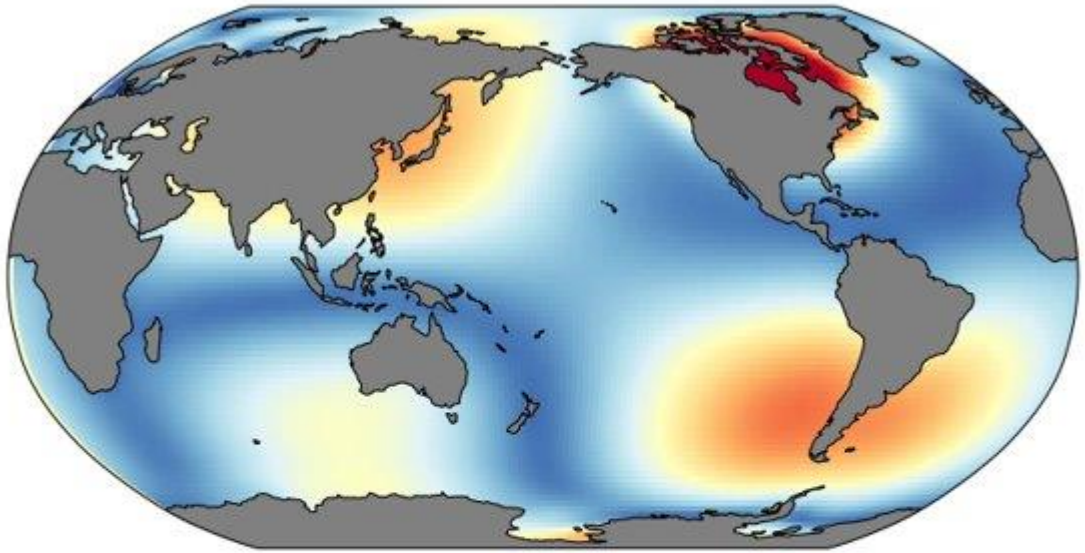
Medium frequency errors

Large frequency errors – wet troposphere

Orbit drift

GIA

- Should be corrected for detection of present day changes,
- 0.3 mm/yr +/- 0.12 globally,
- Large regional variations
- Derived from spread of different runs (Spada, 2017)



Error budget

Medium frequency errors

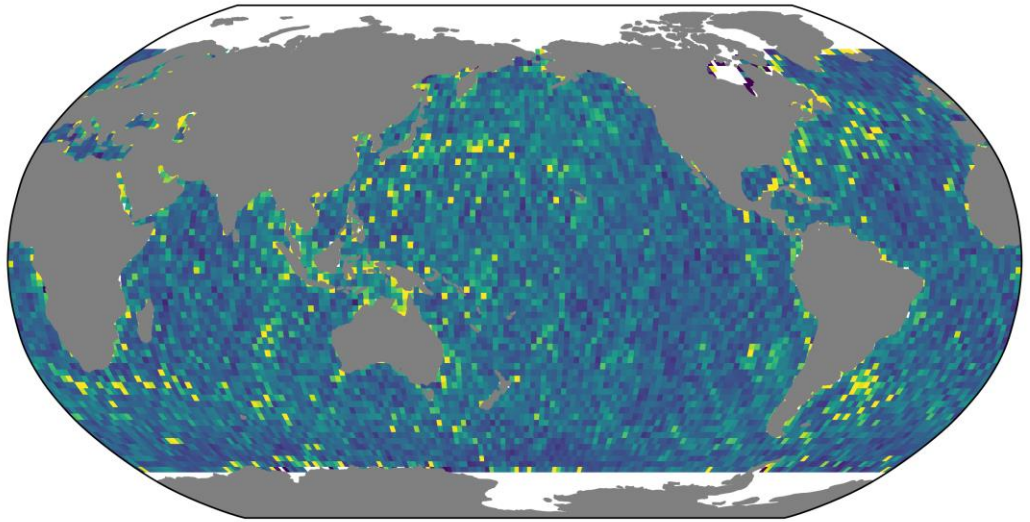
Large frequency errors – wet troposphere

Orbit drift

GIA

Biases

- 10 mm for TP-A/TP-B & TP-B/J1,
- 6 mm for J1/J2 and J2/J3,
- No indication of a spatial pattern,
- See also Zawadzki et al., 2018



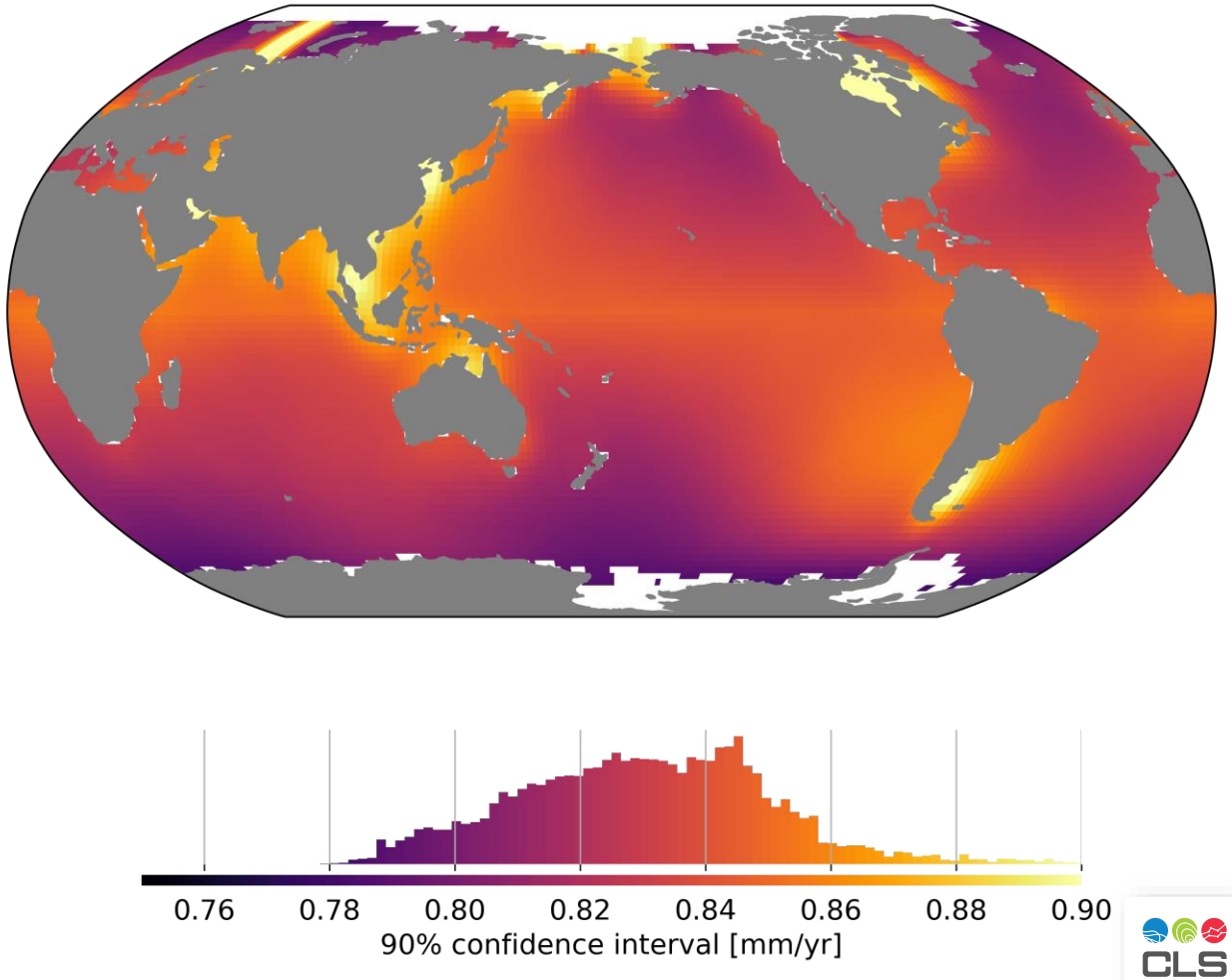
Confidence levels

Given at 90% confidence level

- For SL trends,
- Could be applied to any metric (acceleration, …)

Median value 0.83 mm/yr

- Ranging from 0.75 to 1 mm/yr
- Twice as much as the GMSL trend uncertainty (0.38 mm/yr, from Ablain et al., 2019)



Significant trends

Compare trends with confidence levels

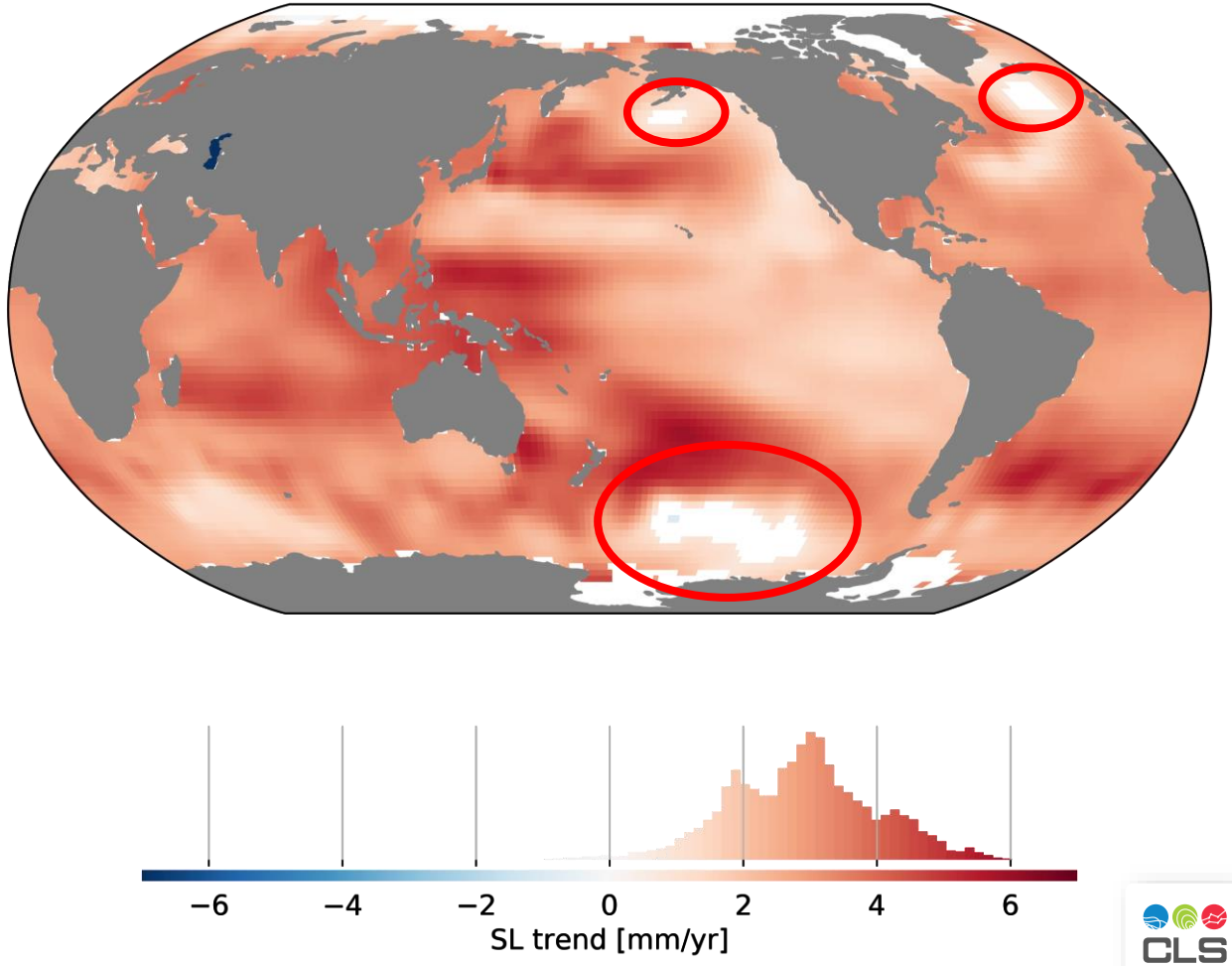
- Significant if trend > uncertainty
- t-test

98% of the ocean experiences significant rise

- Over 1993-2018
- For a filtered C3S dataset

Few non significant patches

- Southern Pacific Ocean,
- Northern Atlantic Ocean



Sensitivity analyis

Results depend error budget accuracy

- Main contributions are here,
- We may omit some contributions,
- Simplified error covariance description

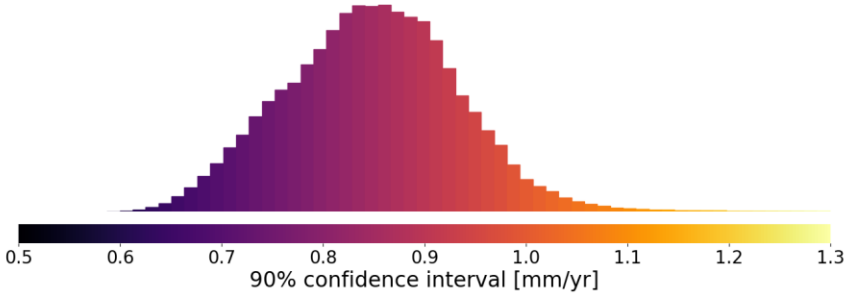
How sensitive is the uncertainty estimate ?

Explore the impact of error budget changes

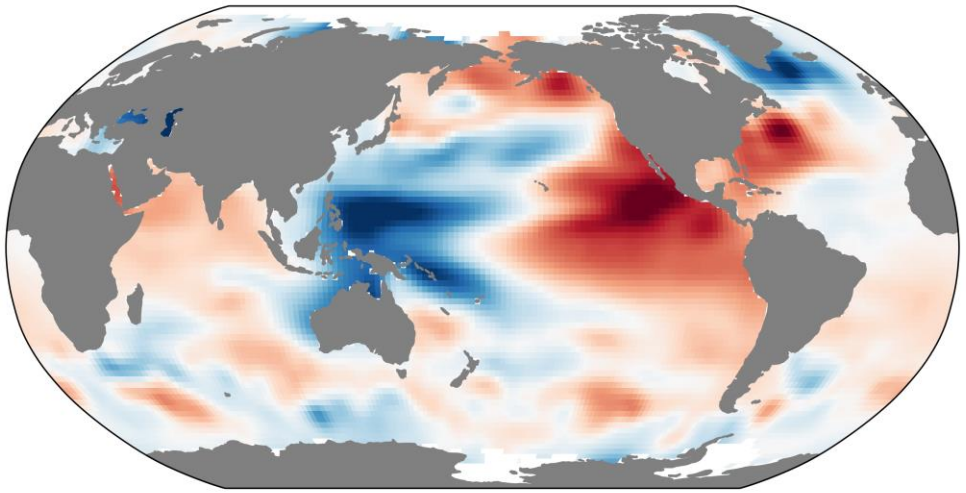
- Draw in range of « plausible » error values
- Main drivers are orbit drift and low-freq decorrelation scales

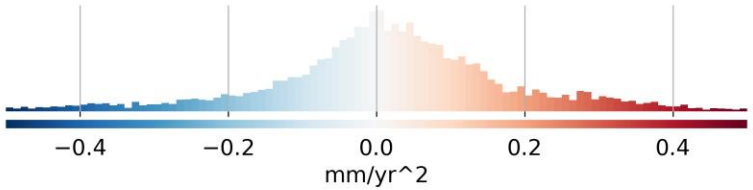
Despite uncertainty changes, trends remain significant

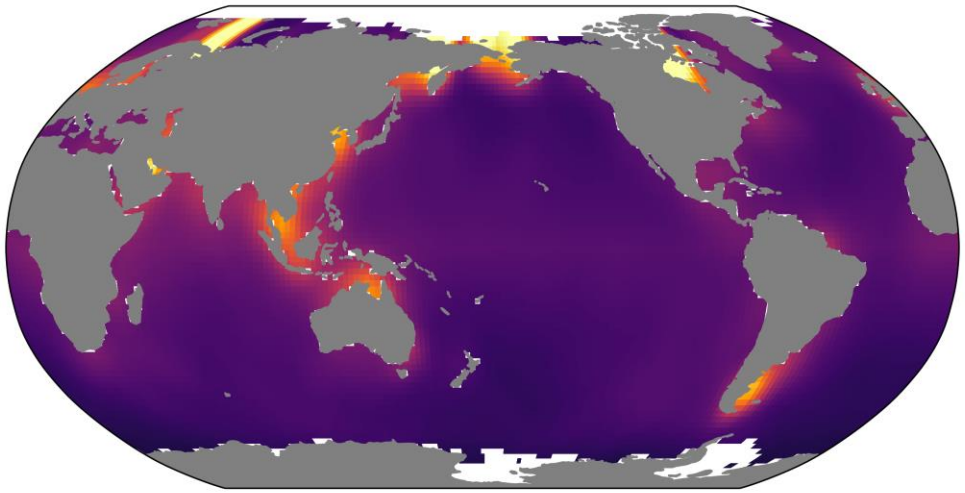
- Values ranging from 0.6 up to 1.5 mm/yr,
- With little impact on the ratio of significant trends (96 to 99%)

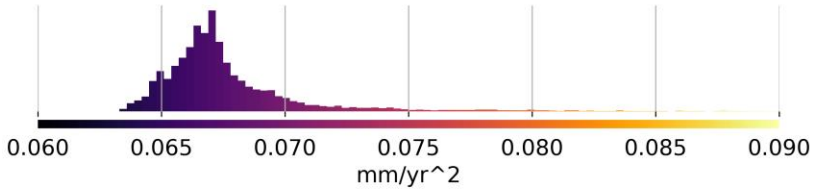


Regional SL accelerations - WIP









Acceleration uncertainty is generally below 0.07 mm/yr^2

Accelerations are dominated by natural ocean variability

Conclusions & Future work

Quantitative confidence levels on regional trends

- Accounts for temporal error covariance,
- Arising from measurement system errors only,
- Based on current knowledge of regional altimeter error budget,
- Should be revisited according to new findings,
- Sensitivity study suggests current results are robust,

Foreseen upgrades

- Improve representation of orbit errors,
- Introduce heteroskedasticity,
- Consider spatial error covariance,
- Provide a full space/time error covariance matrix and/or ensemble of realisations,
- Include internal variability