IMT Atlantique
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Ifremer

Ocean Warming contribution to Sea level rise

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1. Context

Sea level change :

Lots of processes

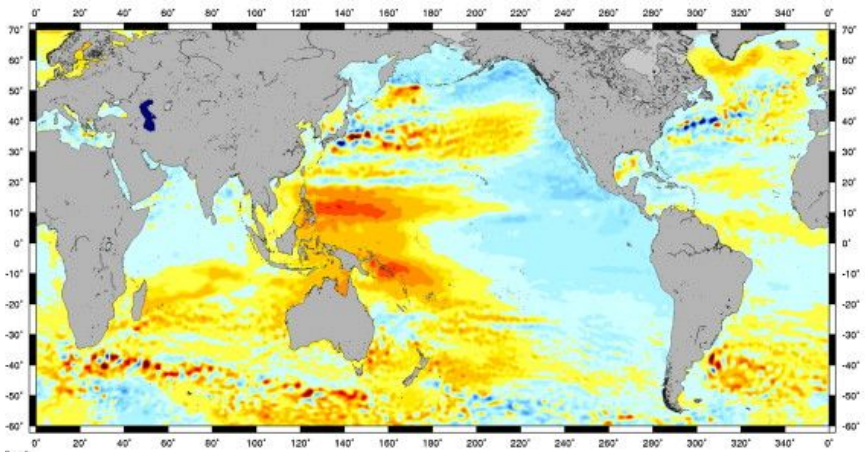
Usually we think that the main process is the **ice melting**

It’s is not the **primary drive** of regional **trend**

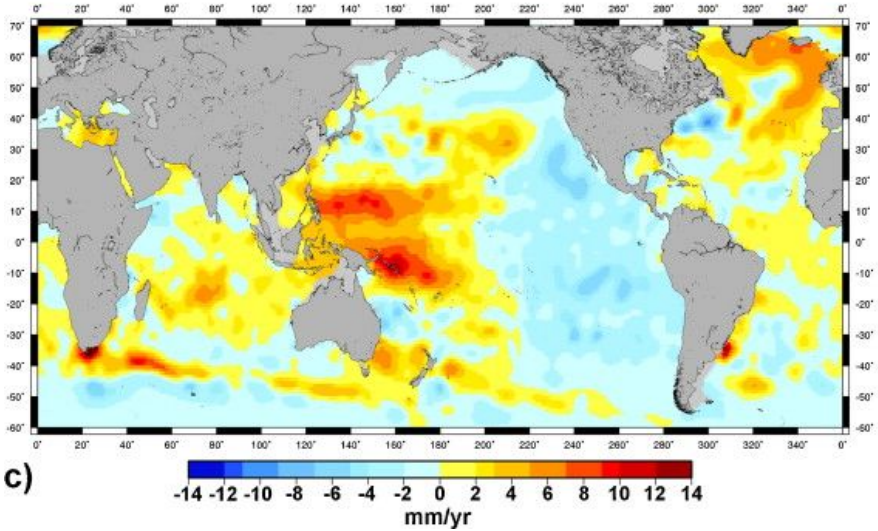
Sea level increases because of **changes in currents** (dynamic effect) and because of **ocean density changes** (steric effect).

Objective : Compute ocean **density changes contribution** to Sea level rises

Demonstrate that it is the **primary driver of regional trends**



Sea Level trend anomaly for 1993-2010



Steric sea level trend for 1993-2010

1. Context

Steric sea-level changes

Definition : **Steric effects** arise from the spatial arrangement of atoms

In our case :

- Effects coming from temperature change : Thermosteric
- Effects coming from salinity change : Halosteric

Density of seawater is a **function** of **temperature and salinity** (amongst others) **:**

- ➢ **Changes** of these **state properties** implies **changes of density**, and changes of density **implies** a **changing water column size**
- ➢ Exemple : Warmer water (saltier water) is less (more) dense so the water column of this water will be higher (lower)

2. Dataset

EN4: quality controlled subsurface ocean temperature and salinity profiles and objective analyses

The EN4 dataset consists of two products:

- Observed subsurface ocean temperature and salinity profiles with data quality information
- Objective analyses formed from the profile data with uncertainty estimates

Sea_surface_height : Sea-surface altimetry data from The Copernicus Marine Environment (monthly)

gsw.geo_strf_dyn_height() is used to calculate dynamic height anomaly

3. Experiments

3.1 Study of spatial correlation

Spatial correlation : We calculate the **correlation coefficients** of the real sea level heights and the sea level heights only affected by steric effect in all over the world from a specific time serie (1998 -2018, one sample every two years).

Eventually, we will have a global map with value of each pixel presents how does the steric effect contributes to the sea level rise in this particular position.

3. Experiments

3.2 The trend of steric effect sea level rise and anomaly sea level rise

Another alternative to calculate the contribution of steric effect to sea level rise is through comparing the **trends** of real sea level rise and the sea level anomaly caused by the steric effect.

To obtain these trends we employ **linear regression** of sea level height and time to find out how sea level vary each year.

Then we store the two trend values of each position to create two map of trend respectively.

Final, we compare the difference of these two maps to show the contribution of steric effect to sea level rise.

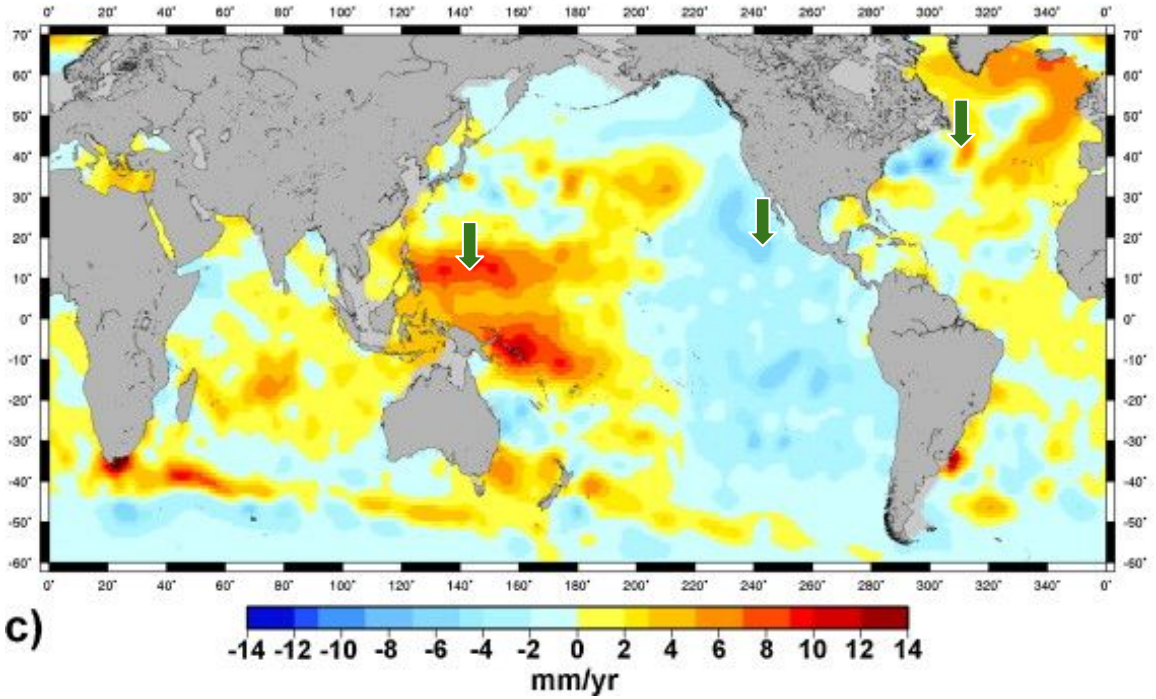
3. Experiments

3.3 Time series study of steric height anomaly for specific points

Comparison of **steric effects** with **temperature** changes and **salinity** changes

Selection of 3 specific points which seems interesting :

- West Pacific
- East Pacific
- North Atlantic

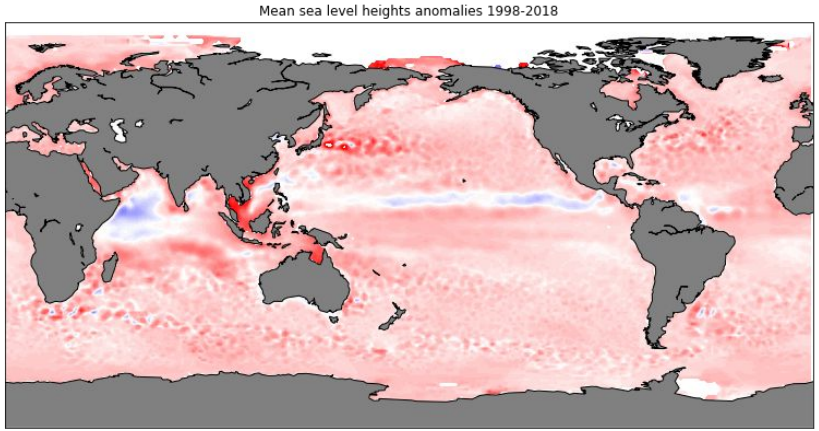


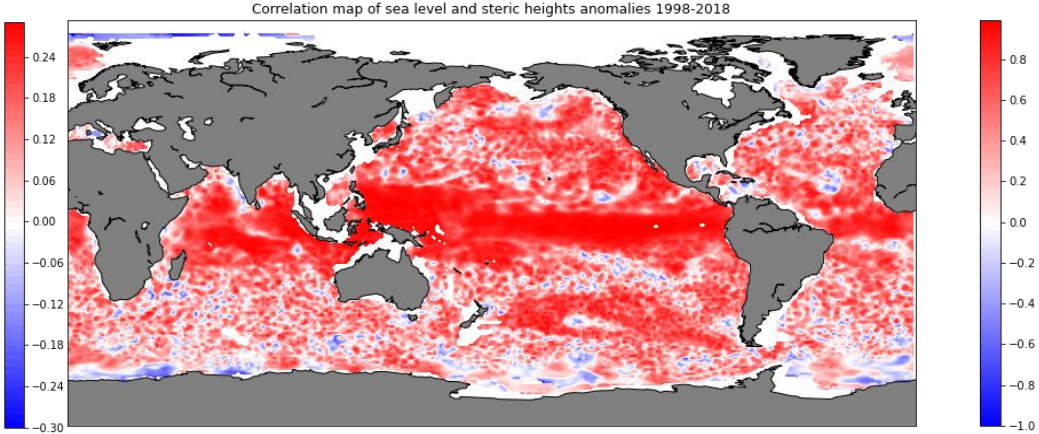
Temporal correlation : we calculated the correlation of the **whole maps** between **anomaly** sea level heights and **steric** sea level heights from a specific time series (1998 -2018, with one sample every two years).

The **goal** of this experiment was to get a **trend** of this correlation **in time**.

4. Results

4.1 Correlation map

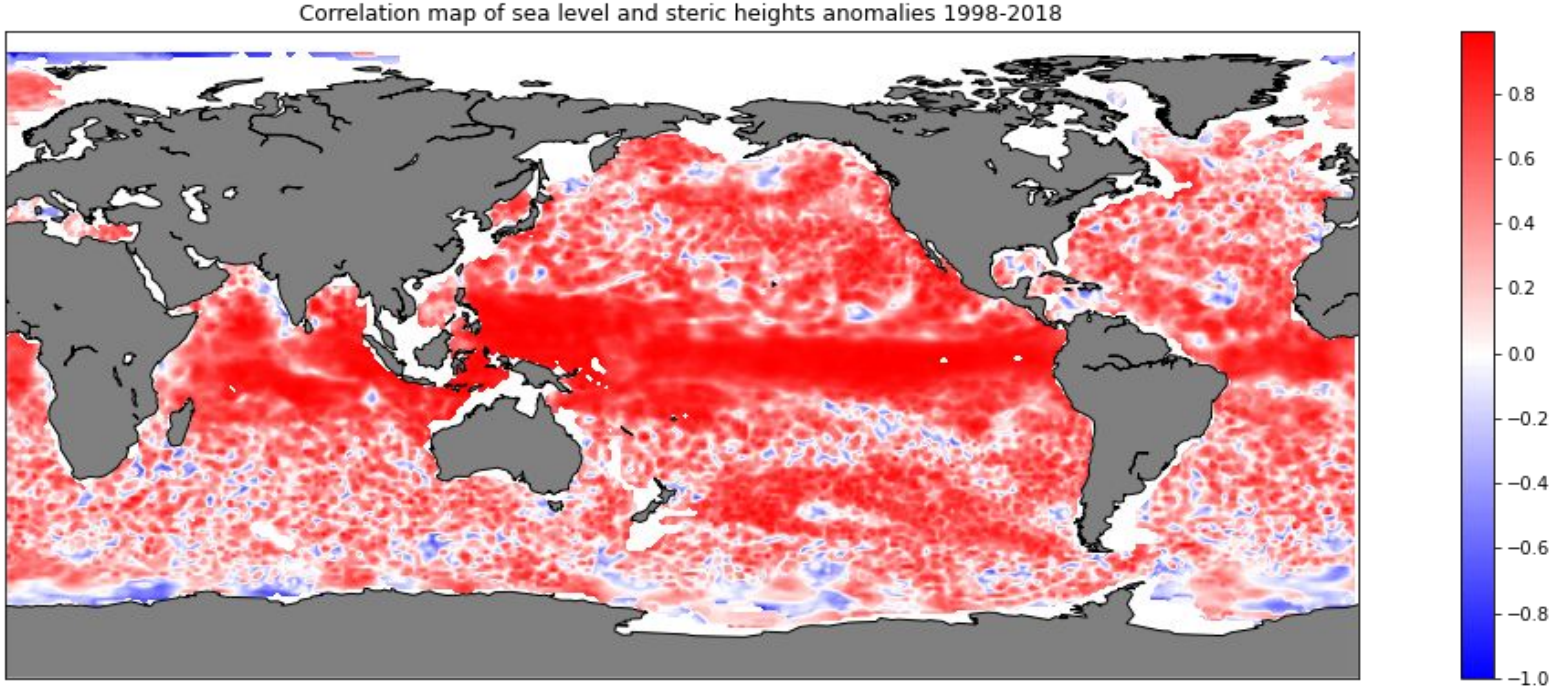




- ➔ Correlation is mainly positive
- ➔ Variations of spatial correlation
- ➔ Patterns of sea level anomalies can be found in correlation map

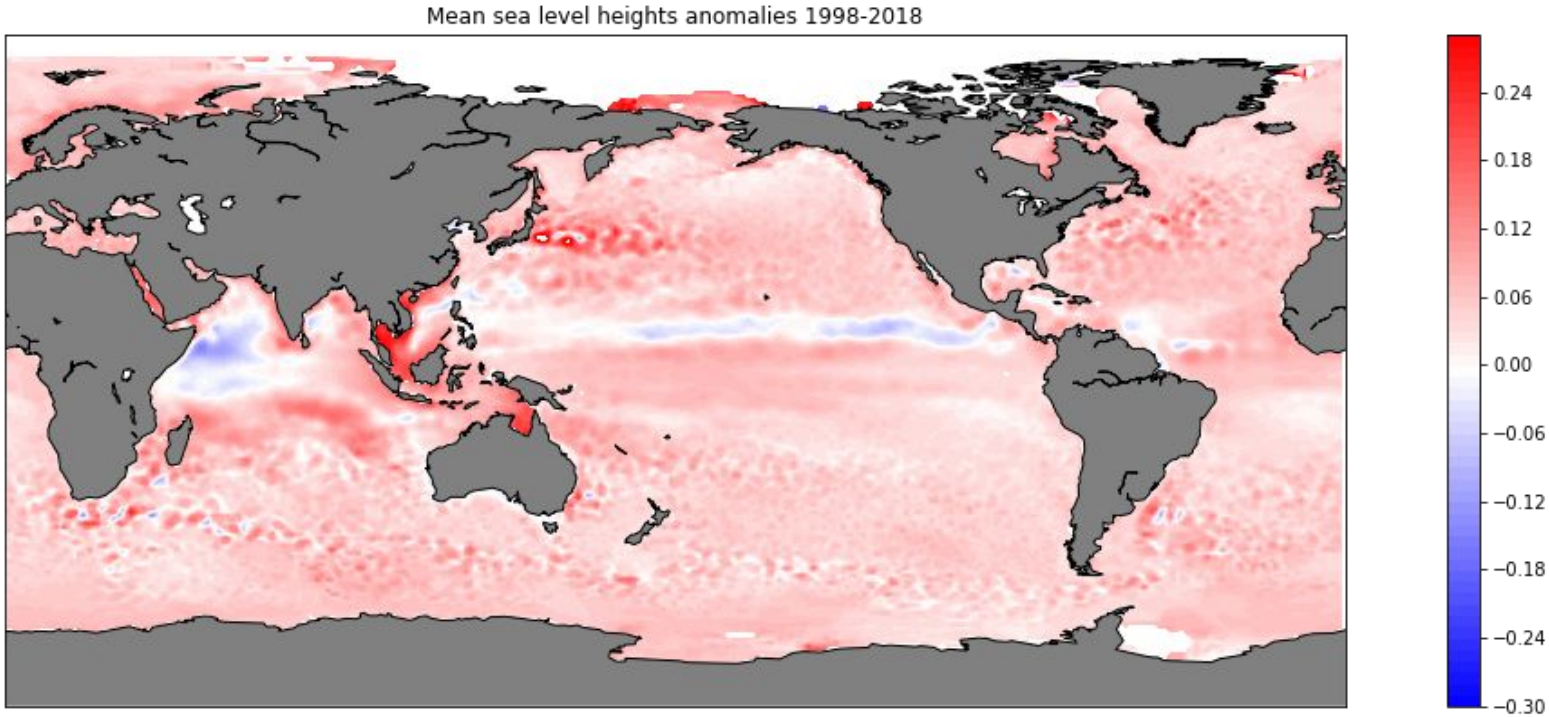
4. Results

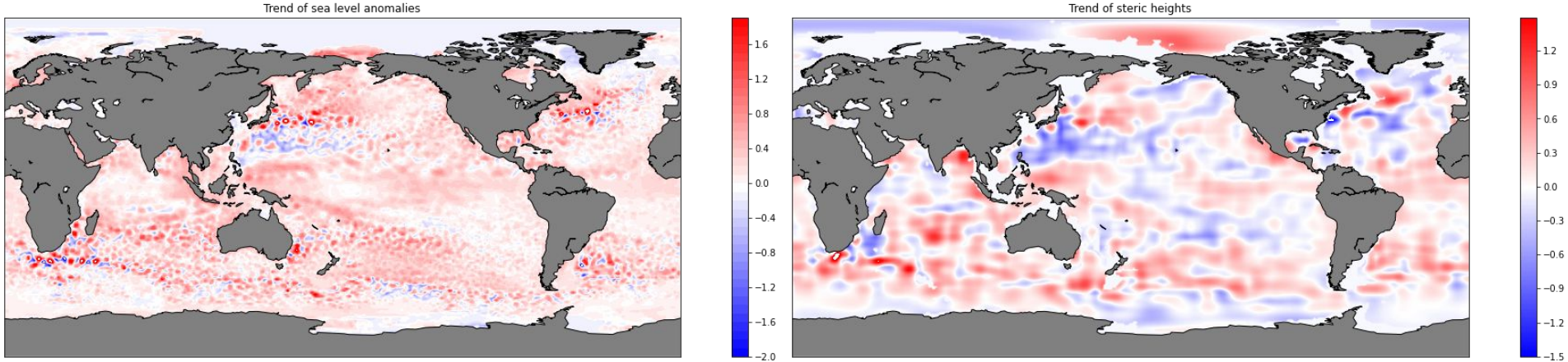
4.1 Correlation map



4. Results

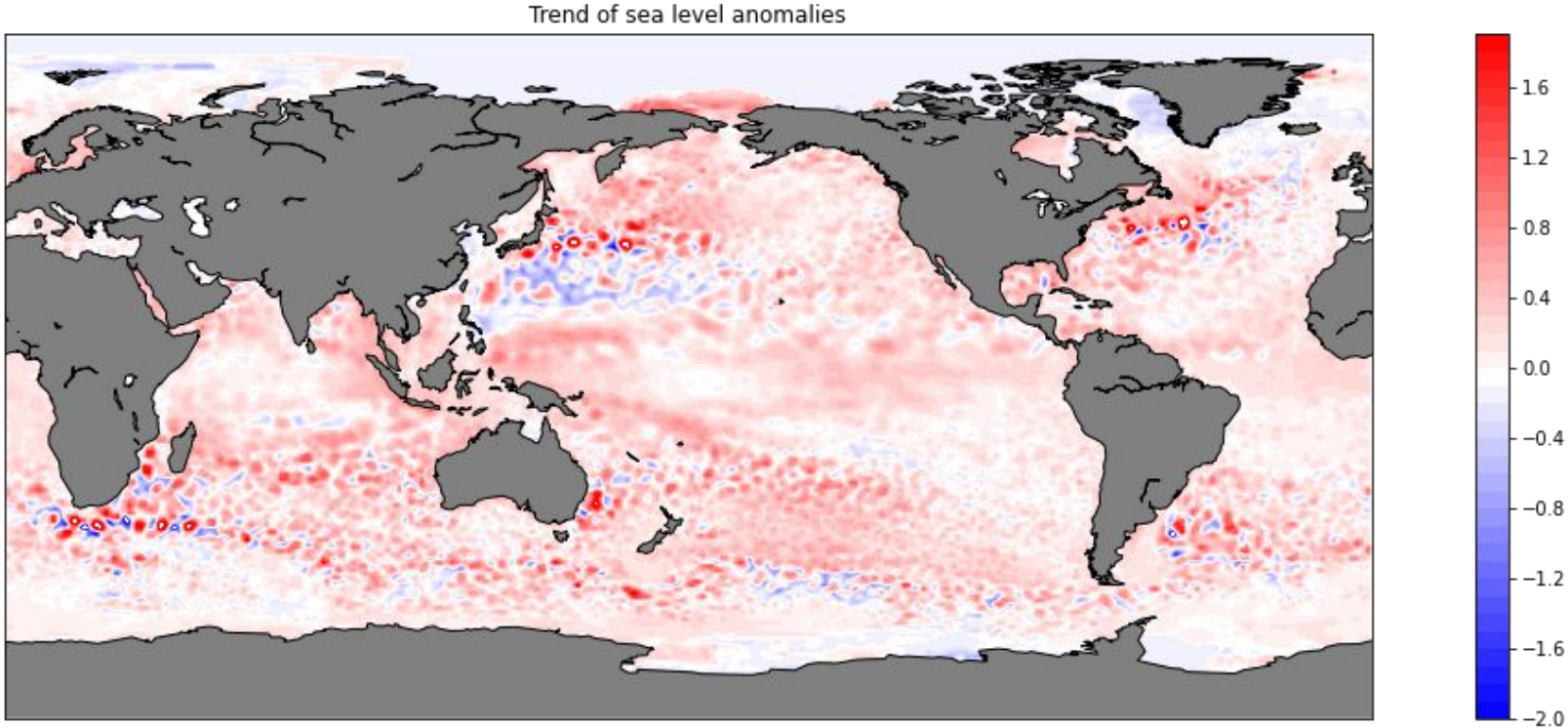
4.1 Correlation map

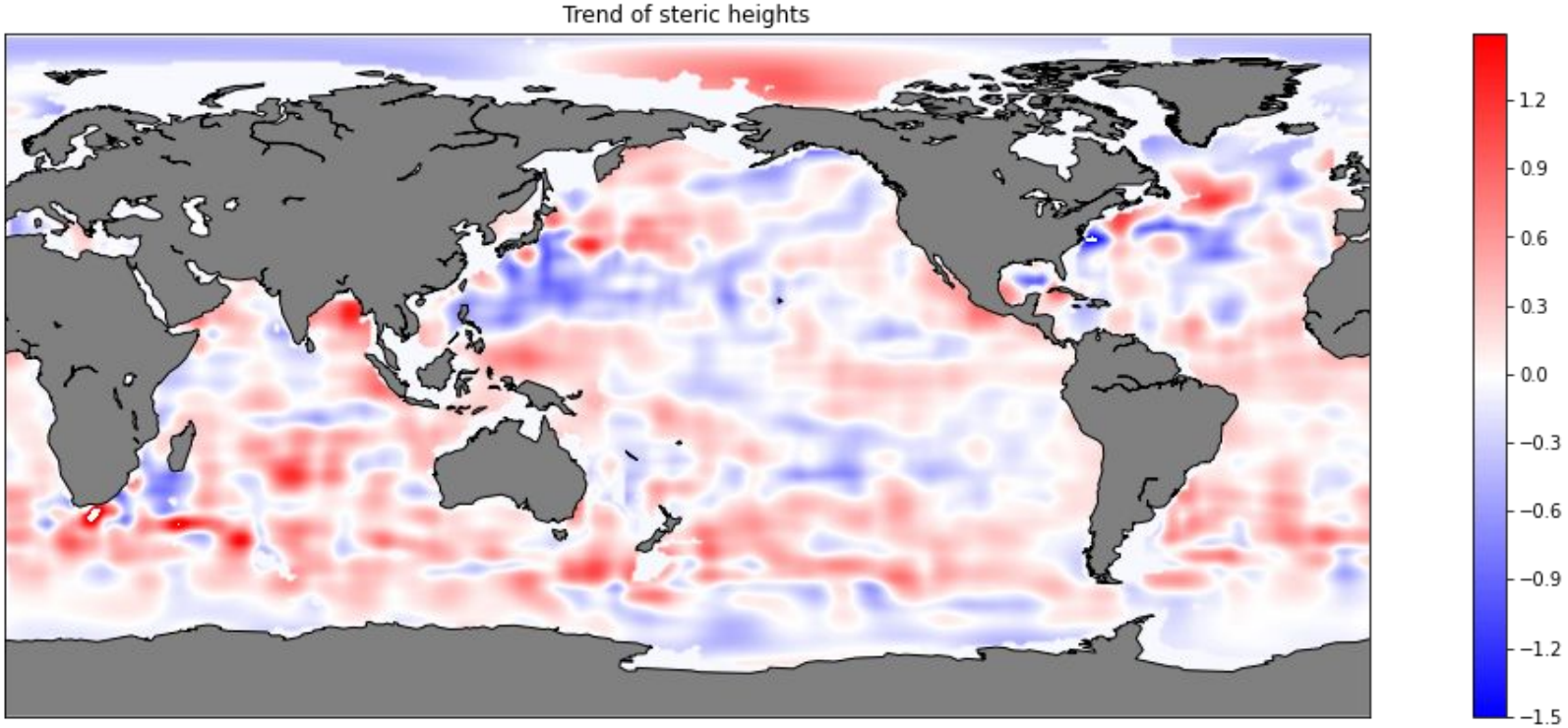




Main patterns of sea level anomalies trends are found in steric heights trends

Sea level anomalies variations are followed by **steric heights variations**

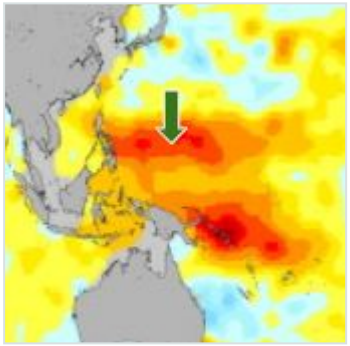

Trend of sea level anomalies
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0

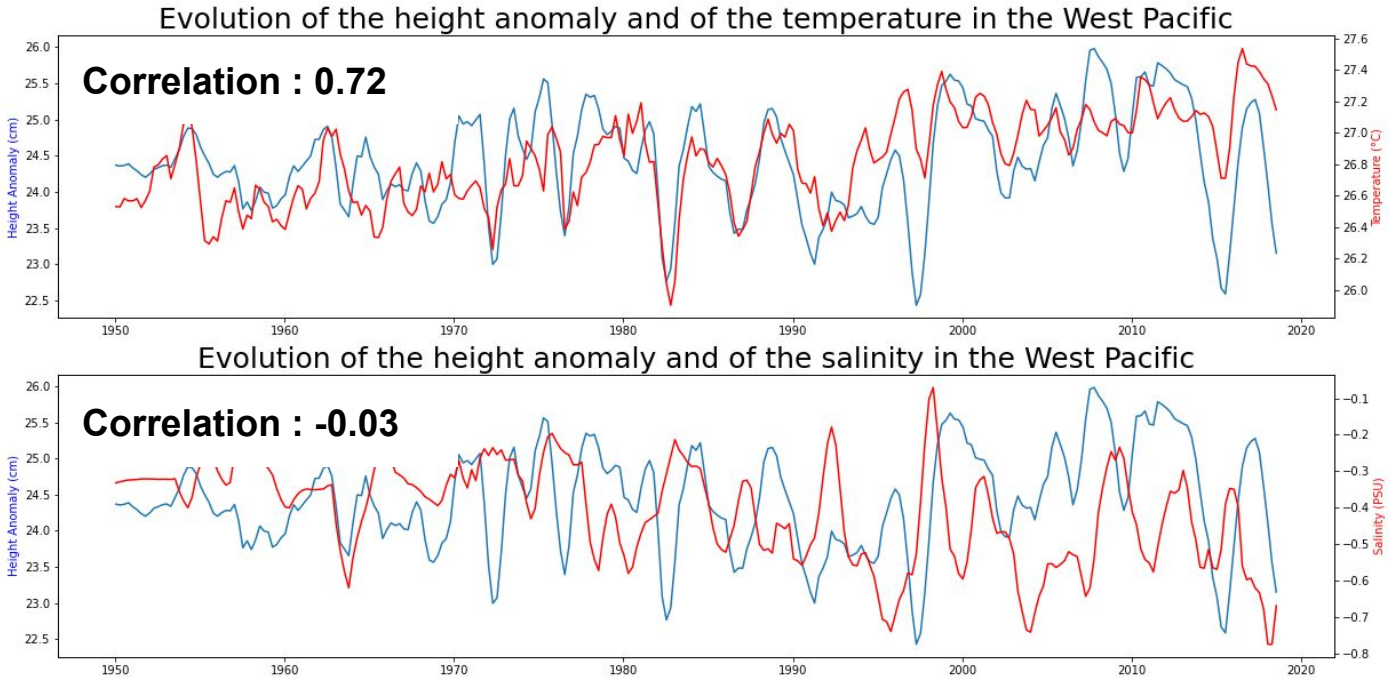

Trend of steric heights
1.2
0.9
0.6
0.3
0.0
−0.3
−0.6
−0.9
−1.2
−1.5

4. Results

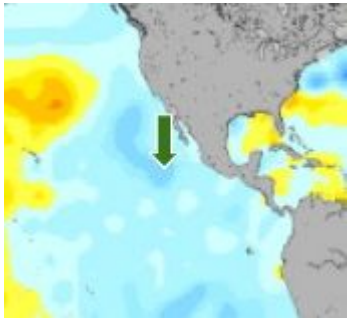
4.3 Time series study of steric height anomaly for specific points

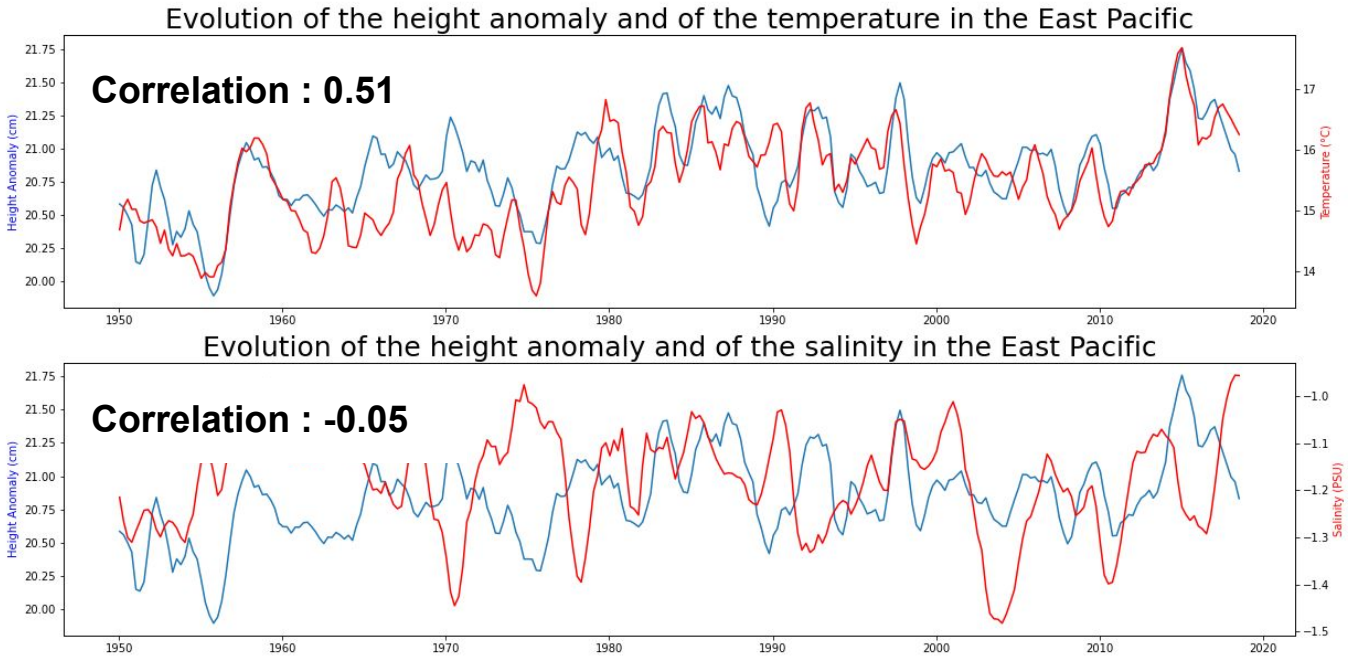
Point A :
West Pacific





Point B :
East Pacific

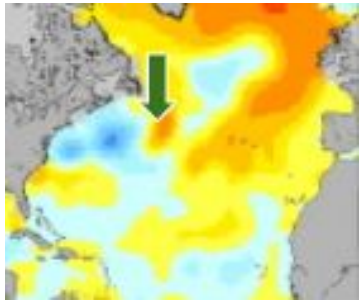


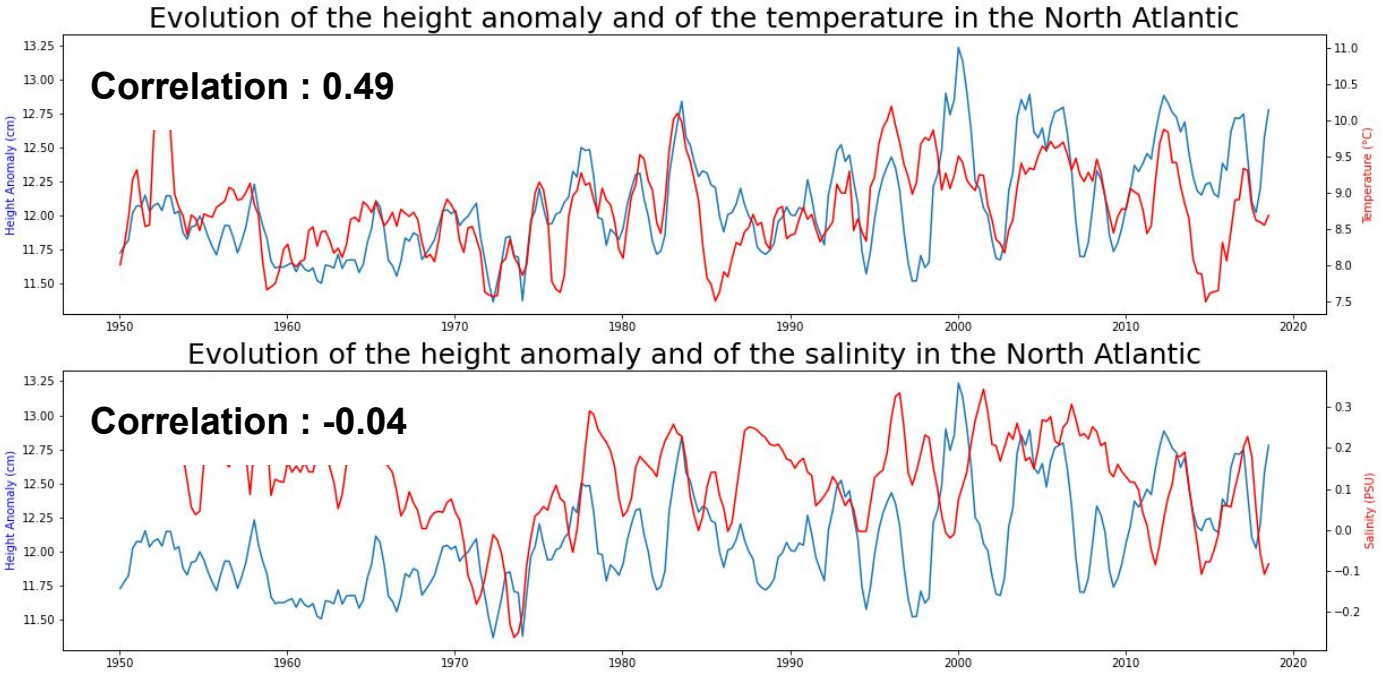


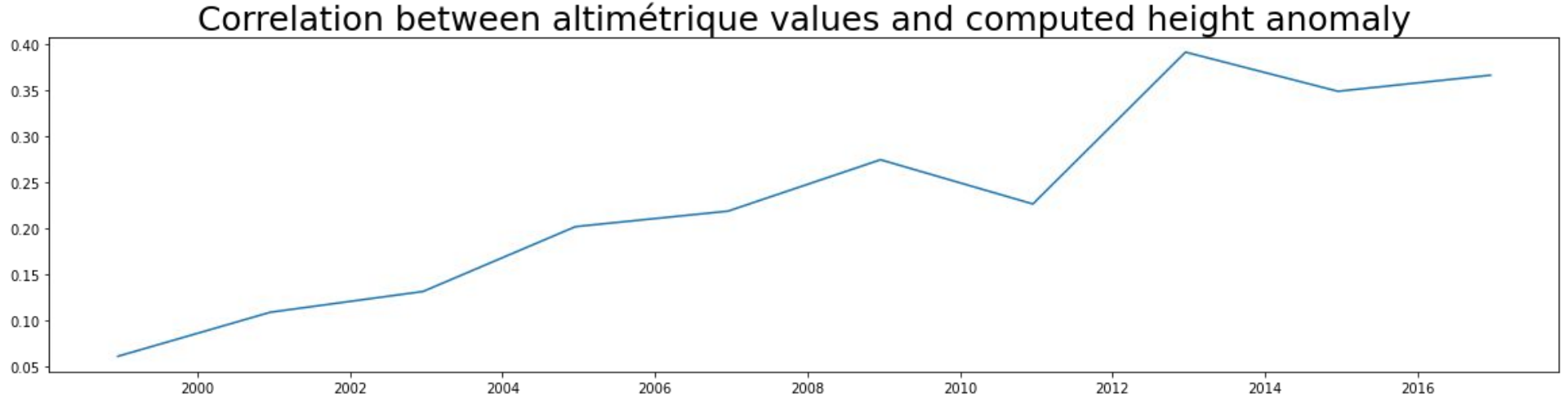
4. Results

4.3 Time series study of steric height anomaly for specific points

Point C :
North Atlantic






Correlation between altimétrique values and computed height anomaly
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
2000
2002
2004
2006
2008
2010
2012
2014
2016

Conclusion

In conclusion, **ocean warming** is one of the main factors contributing to **sea level rise**. **Melting of glaciers** and **ice caps** are also significant factors contributing to sea level rise.

The **thermosteric effect**, caused by changes in **ocean density** due to changes in **ocean temperature**, is the primary driver of sea level rise in some regions, particularly in the **subtropical and tropical regions**.

It is important to note that sea level rise is a **complex phenomenon** that varies **regionally**. In addition, the rate of sea level rise has **accelerated in recent years**, due mostly to the acceleration of ocean warming.

Thanks for your attention!

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