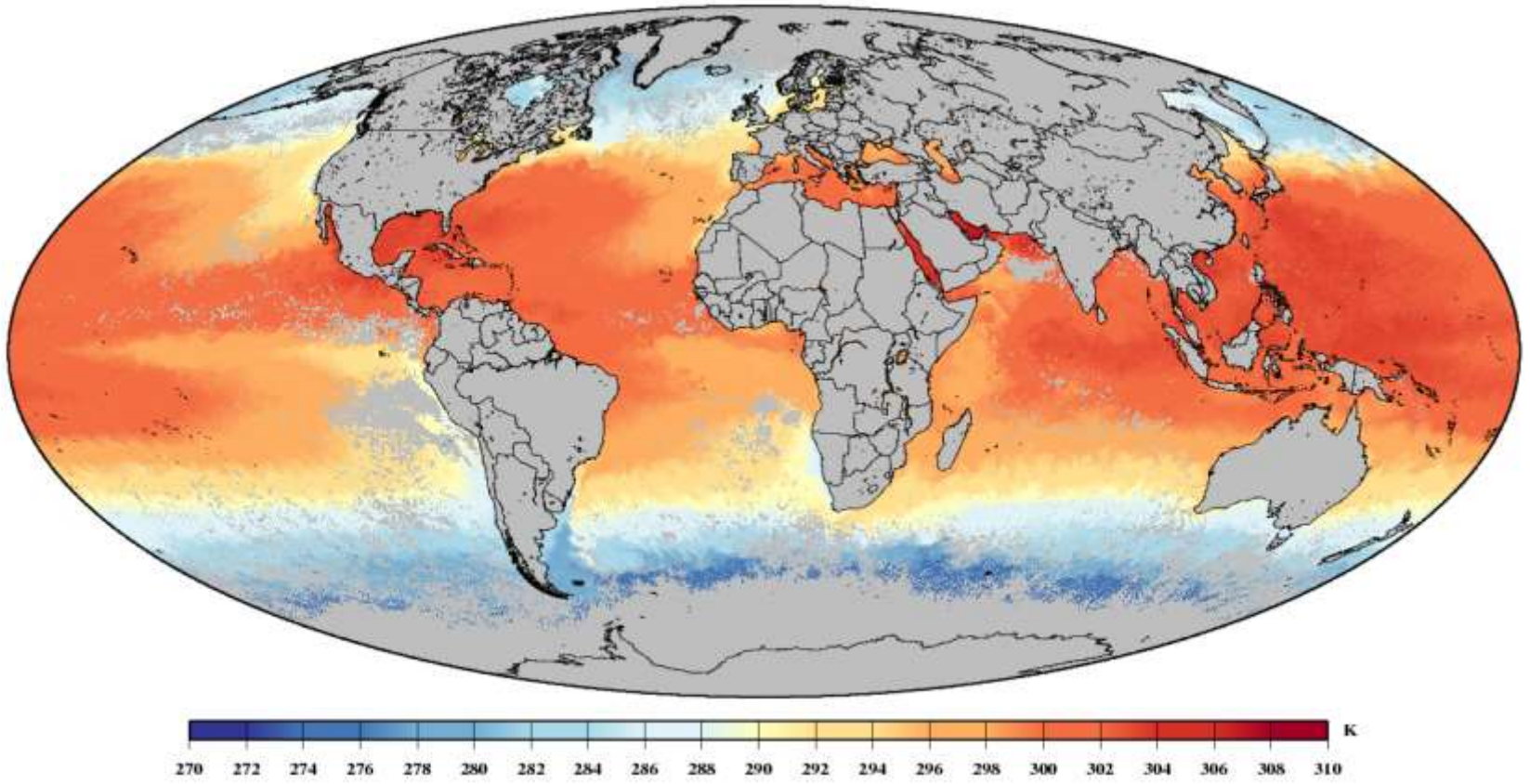
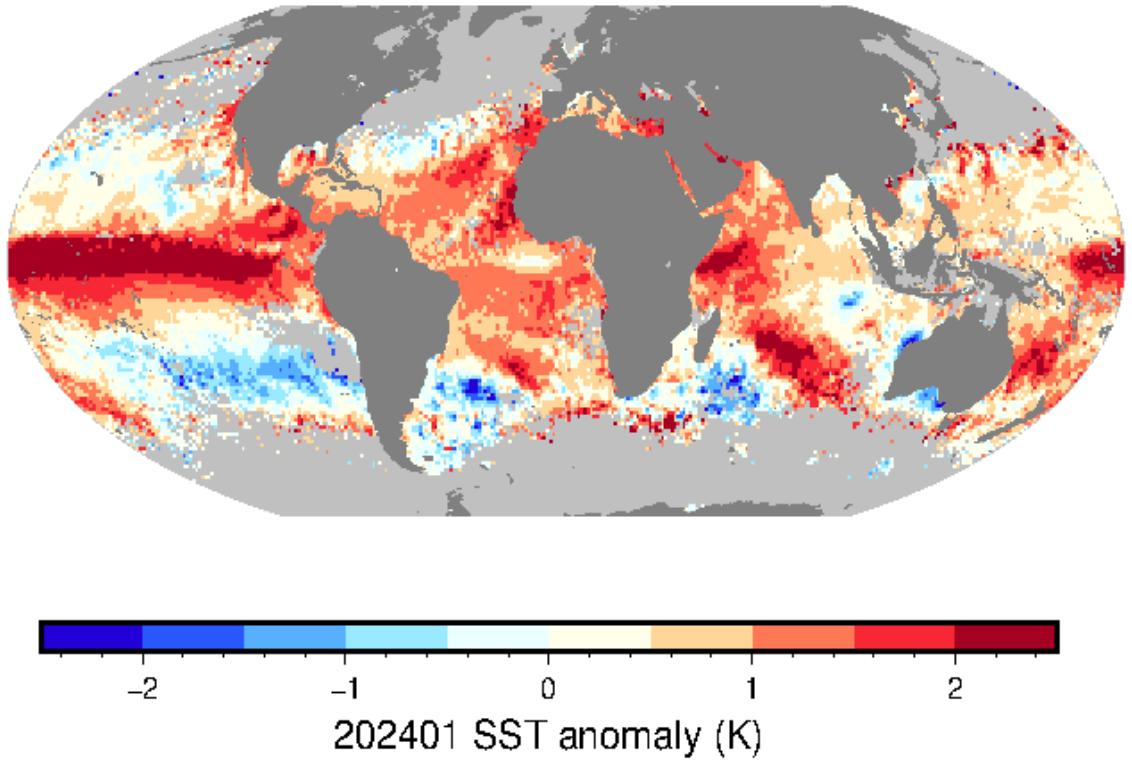
Monitoring sea surface temperature from IASI



Virginie Capelle, Jean-Michel Hartmann, Cyril Crevoisier, Raymond Armante, etc…

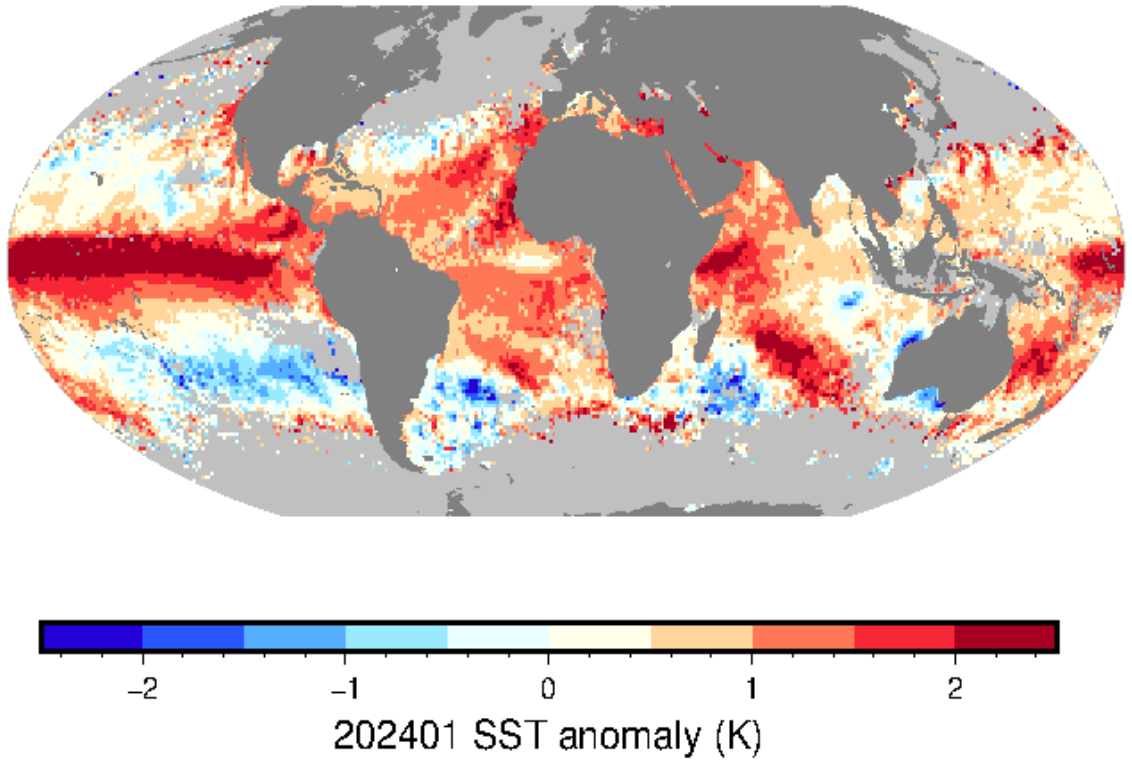
SST is an essential climate variable



Ref: 2008-2020

- In the context of global warming, SST is a key parameter in the long term monitoring of the climate evolution
- Need an **high quality** record, **stable with time**
- Thanks to its **planned long time series** and its **exceptional stability** of both the spectral and radiometric calibrations **IASI can provide valuable contribution**

Outline



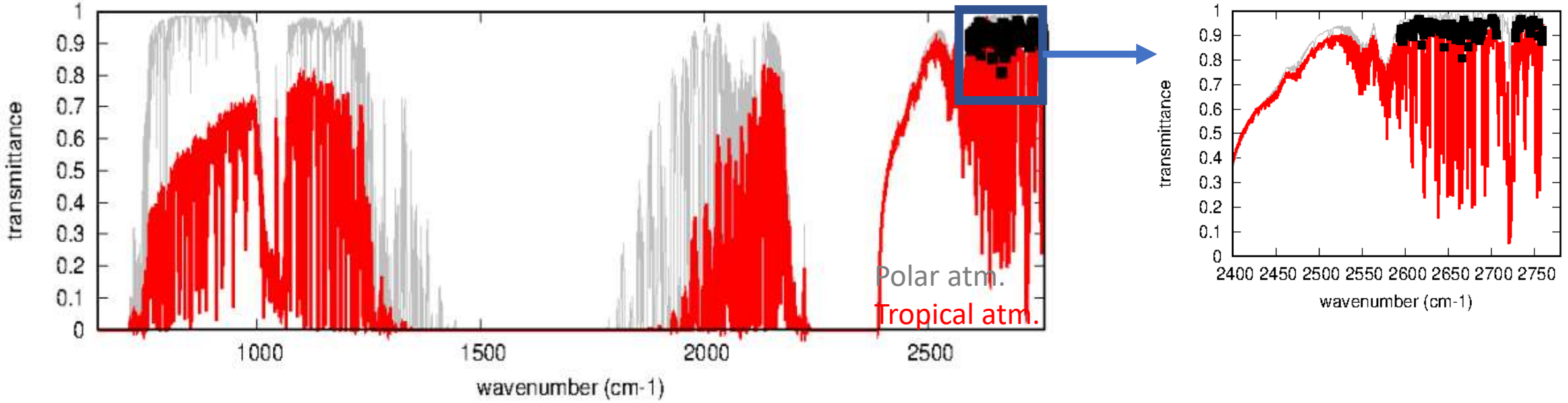
1. How derive a high quality record of SST from IASI ?
2. Validation against in-situ measurements
3. Evolution of the SST on the 2007-2024 period

Ref: 2008-2020

How the SST is retrieved?

Objective: Provide a **full physics** retrieved SST, **independent** of in-situ measurements or models + **day-night consistent**.

- **Use only highly transparent channels ($\tau s > 0.9$)**
  $\Rightarrow$ avoid errors due to the limited knowledge of the T and H_2O profiles and/or of the H_2O continuum
- 185 channels selected in the region 3.92-3.62µm (2550-2760cm^{-1})



How the SST is retrieved?

Objective: Provide a **full physics** retrieved SST, **independent** of in-situ measurements or models + **day-night consistent**.

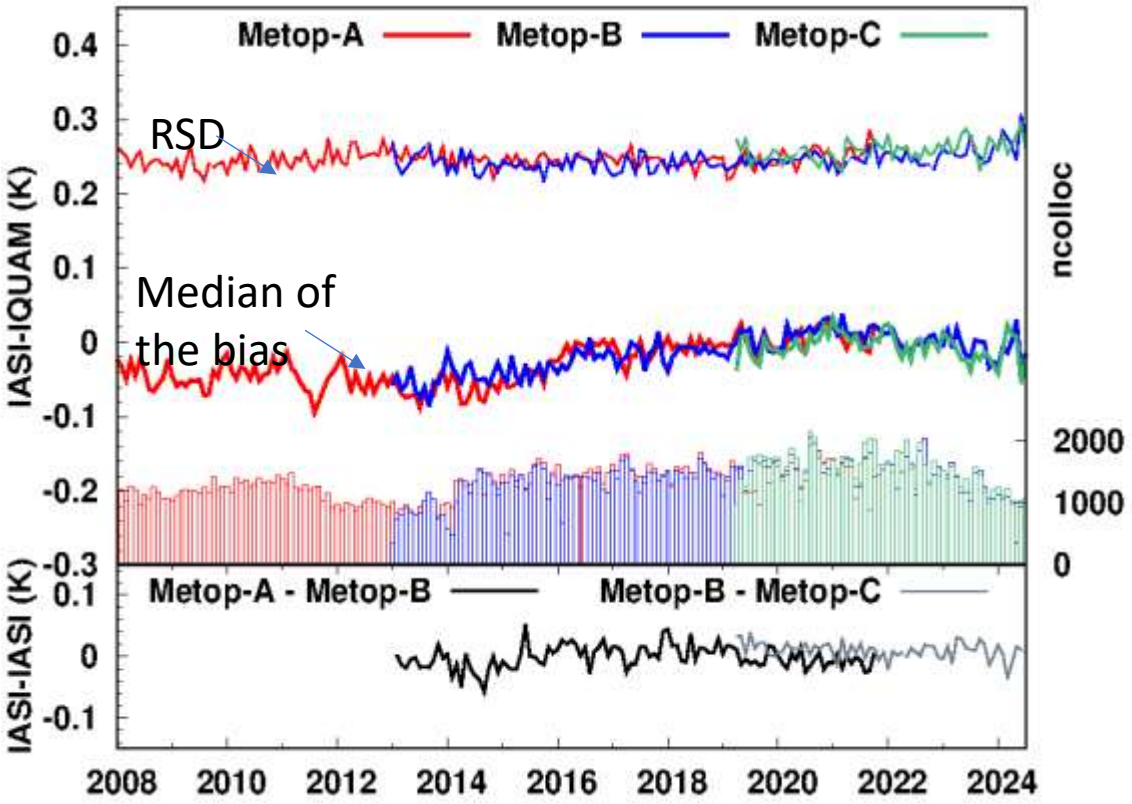
1. **Independent clouds screening** (empirical tests using only IASI BT and AVHRR BT) + aerosol screening by stand alone method
2. Atmospheric conditions (T, H_2O profiles) are constrained from a proximity recognition in the TIGR database
3. **RTE is solved for each of the selected 185 channels** selected in the region 3.92-3.62µm (2550-2760cm^{-1}), providing 185 values of SST
4. **These are finally averaged to reduce drastically the radiometric noise for nightime observations**
   - ❖ For Daytime observations, SST and the solar contribution are simultaneously estimated by least-square method from these 185 values.

See : Capelle et al, RSE, 2022; Capelle and Hartmann, RSE, 2022

IASI SST assessment with drifter network (IQUAM)

- IASI skin temperatures are converted to drifter temperature (bulk) using :
  - Fairall 96 cool-skin estimates for night and day + ECMWF warm-layer parametrization for day
  - Both depend on wind and Fluxes => taken from ERA5

Main results of the IASI SST assessment (Capelle et al, RSE, 2022; Capelle and Hartmann, RSE, 2022) :



❖ **High precision and accuracy for both day and night:**

- Overall IASI-drifter **median bias < 0.05K**
- Overall IASI-drifter **RSD ~0.25K** for night**, ~0.3K** for day

❖ **High stability :**

- **Trend of the bias < 0.05K.decade^{-1}**
- Trend of the RSD < 0.01K.decade^{-1}

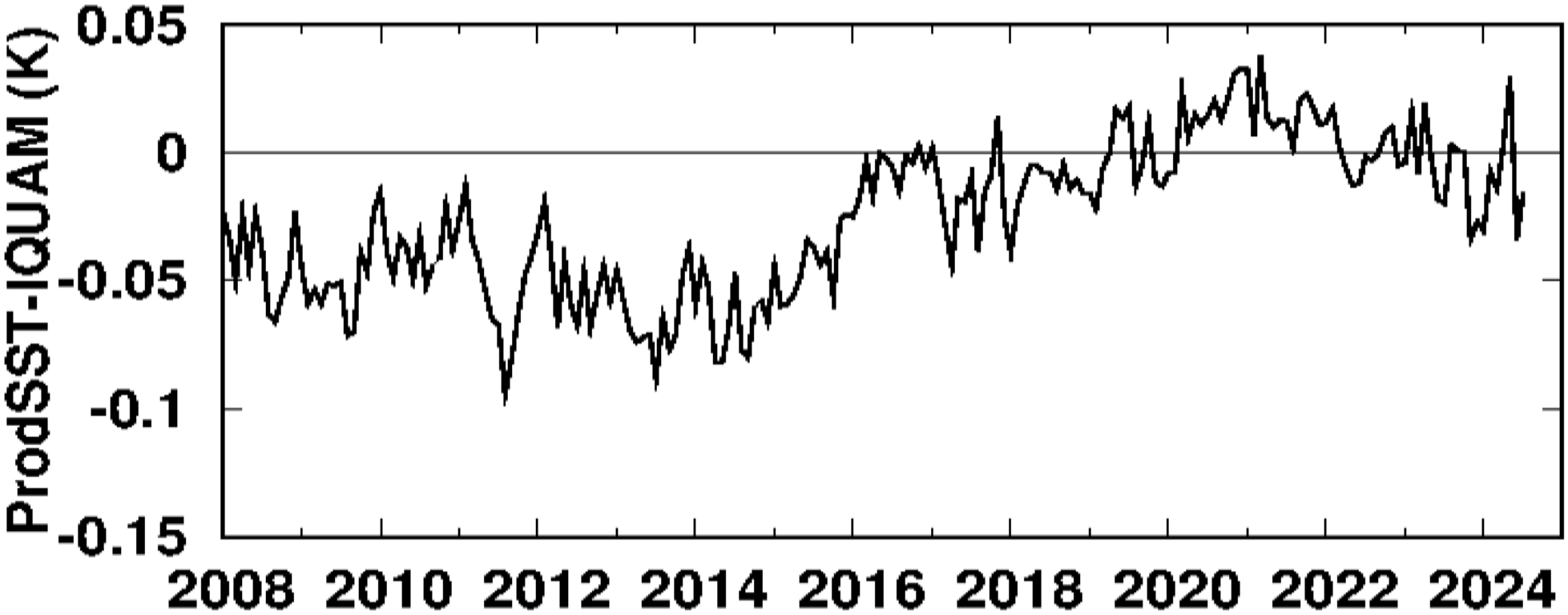
❖ **Strong coherency of the time series:**

- Metop-Metop monthly grid differences ~0K
- Standard deviation of 0.25K

IQUAM database: https://www.star.nesdis.noaa.gov/

The challenge of monitoring the stability of the time series

Analysis of SSTs-drifters time series



⇒Trend of the bias > 0.005K.decade^{-1} satisfying

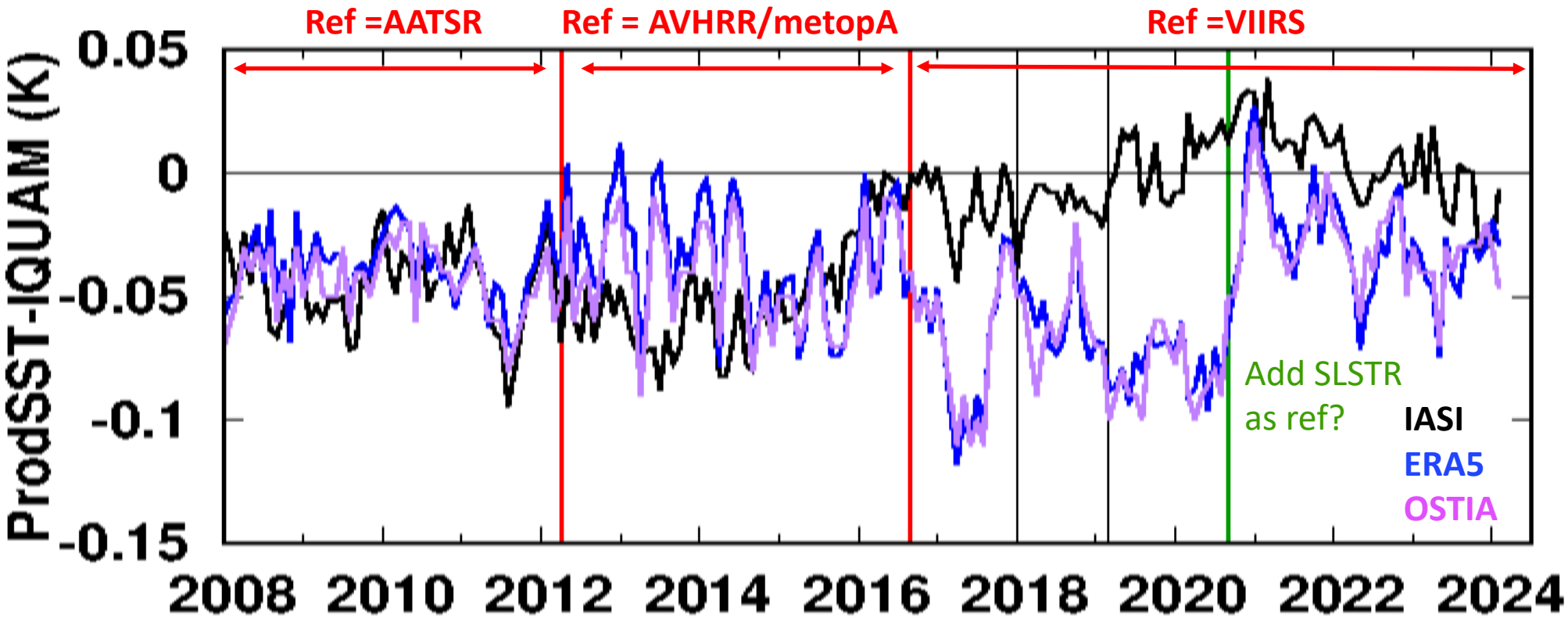
⇒But: two modes in the time series

⇒Might be coming from drifters or the distribution of the collocations

⇒ **No perfect reference dedicated to the validation of long term monitoring**

COMPARISONS WITH OTHER SST PRODUCTS: OSTIA/ERA5

Analysis of SSTs-drifters time series



OSTIA = high resolution SST from satellites (AMSR2, AVHRR, SEVIRI, VIIRS, SLSTR) and in situ data.

ERA5 = use OSTIA as boundary conditions

- Higher variability for OSTIA/ERA5 than IASI after 2012
- Abrupt jumps for OSTIA/ERA5 at each change of the reference sensor used for the bias-correction of the satellite SST products (see *Good et al, remote sensing, 2020*)
- **Such discontinuities may have an impact when analyzing the SST times series**
- **On contrary to classic SST products, IASI can provide an absolute estimation of SST**

Do IASI SSTs fit the quality requirements for advanced climate applications ?

- ✓ **Minimum length of record** : 15 years **> 17 years (metop-A, metop-B, metopC…)**
- ✓ **Precision**: better than 0.1K **=> <0.05K**
- ✓ **stability**: better than 0.05K.decade-1 **=> <0.05K.decade^{-1}**
- ✓ **Homogeneity** : Inconsistencies between sensors <<0.1 K. **=> diff metop-A/metop-B or metop-B/metop-C ~0K; standard deviation : 0.25K**
- ✓ **independency from other dataset :**
  - ➢ To allow independent validation
  - ➢ To confirm (or not!) any observed evolution of the temperature

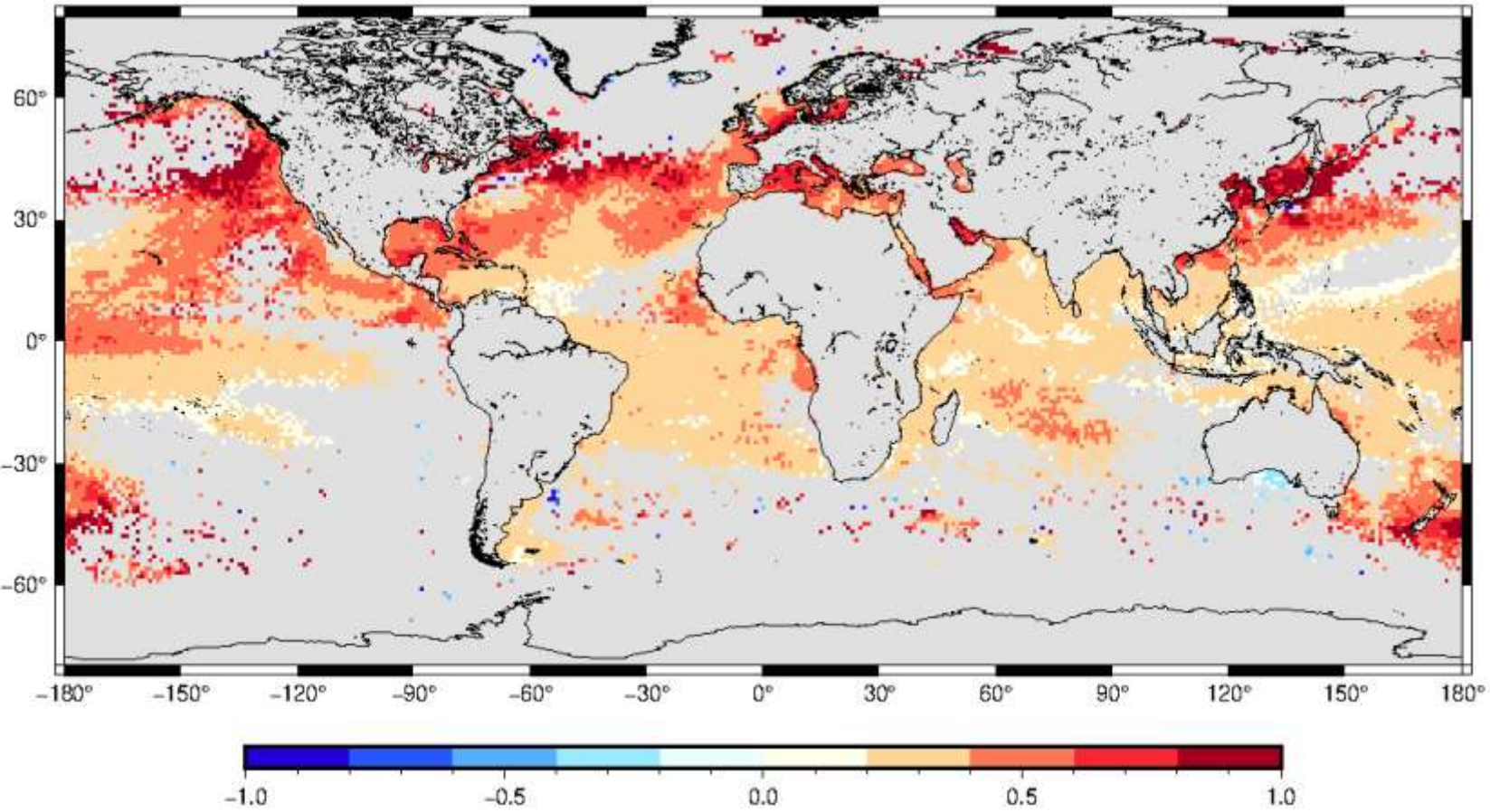
=> Our dataset is compatible with climate application

Ohring et al, Bull. Am. Meteorol. Soc., 2005; Merchant et al., Advance in Space Science, 2008; O'Carroll et al., Front. Mar. Sci , 2019,

Evolution of the sea surface temperature over the 2007-2024 period

Evolution of the sea surface temperature over the 2007-2024 period

Geographic analysis of the SST evolution



Linear trends of IASI SST anomalies (in °C.decade^{-1}) at the 95% confidence level or more for 2007-2024 (night)

⇒ **trend >0.2°C.d^{-1} over the quasi totality of the Ocean**

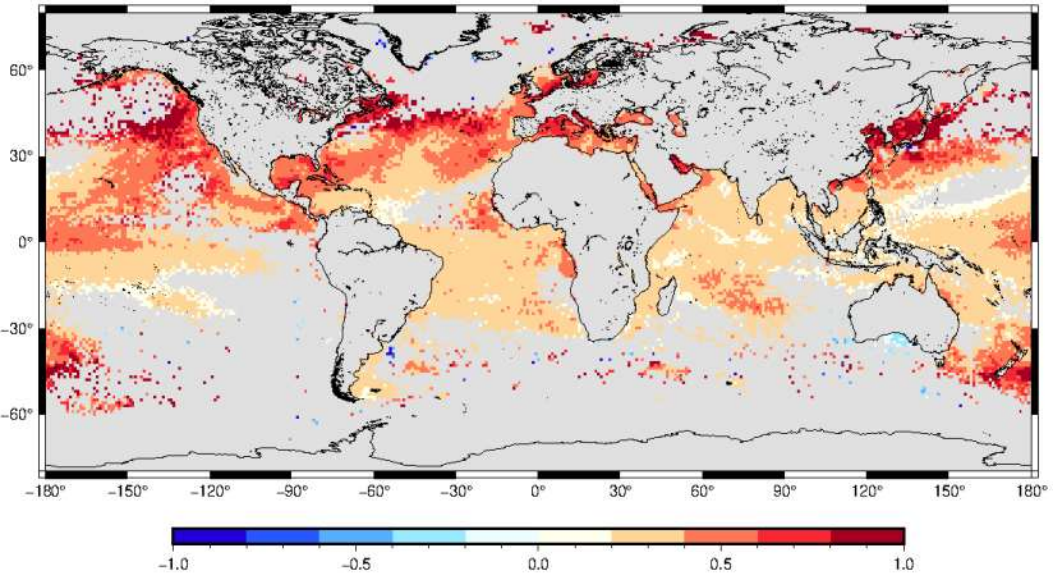
⇒ **increase more pronounced for the Pacific and in the Northern hemisphere (coast of US, Eu, Asia…)**

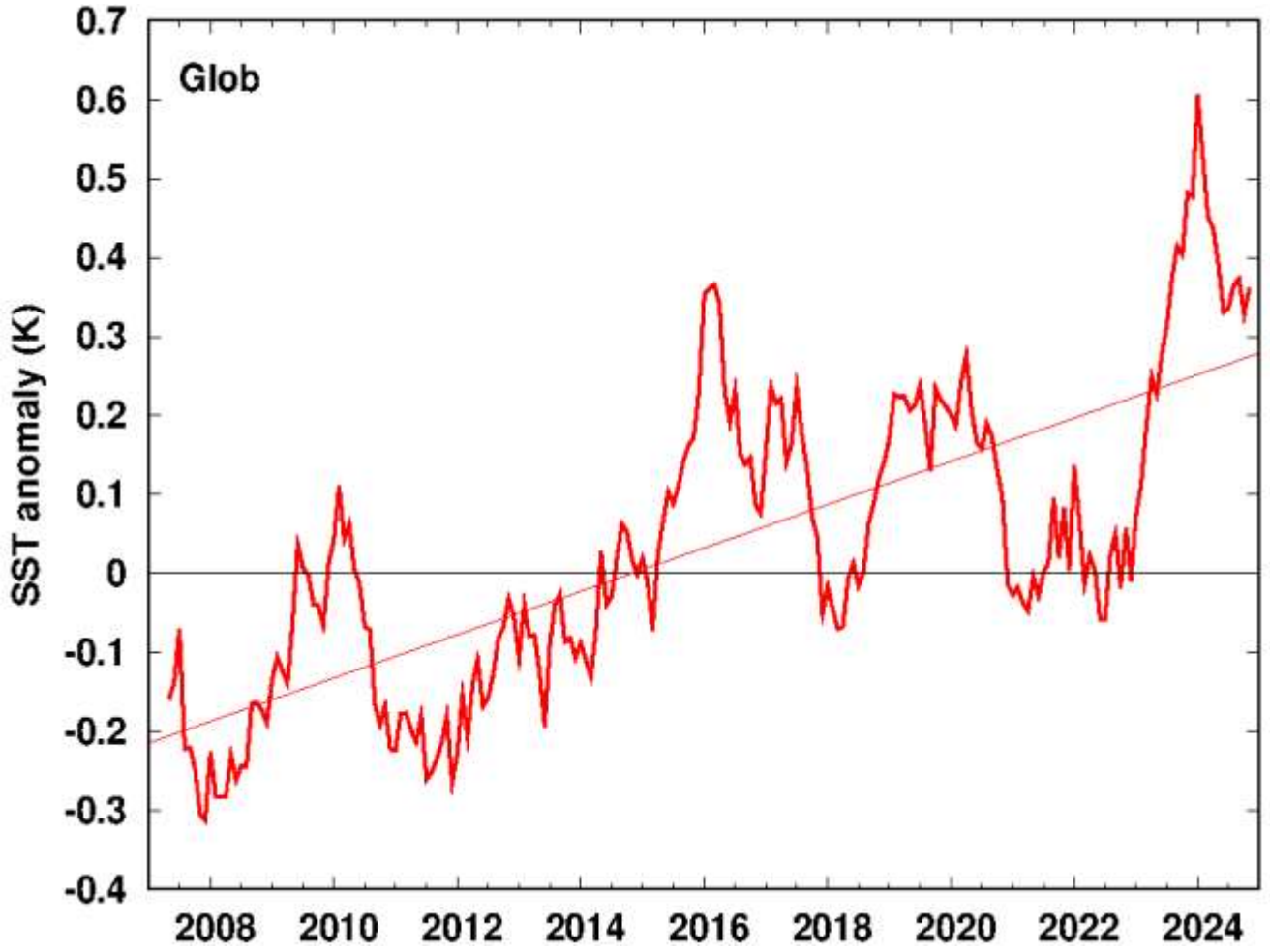
⇒ **almost no negative significant trend**

ref: metop A sur 2008-2020

Evolution of the sea surface temperature over the 2007-2024 period

Global analysis of the SST evolution:





- Regular increase of the temperature since 2007
- Trend estimates: 0.27K.decade^{-1} (err =0.02K/d^{-1}
- After 2015, SST anomalies always positive
- Since mid-2023, SST are the highest over the IASI period

Evolution of the sea surface temperature over the 2007-2024 period

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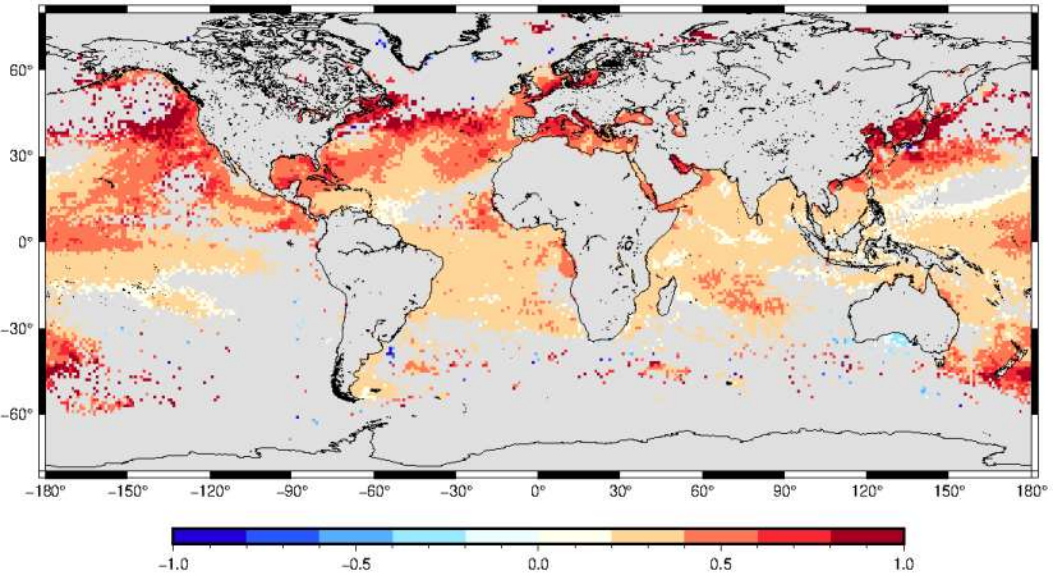

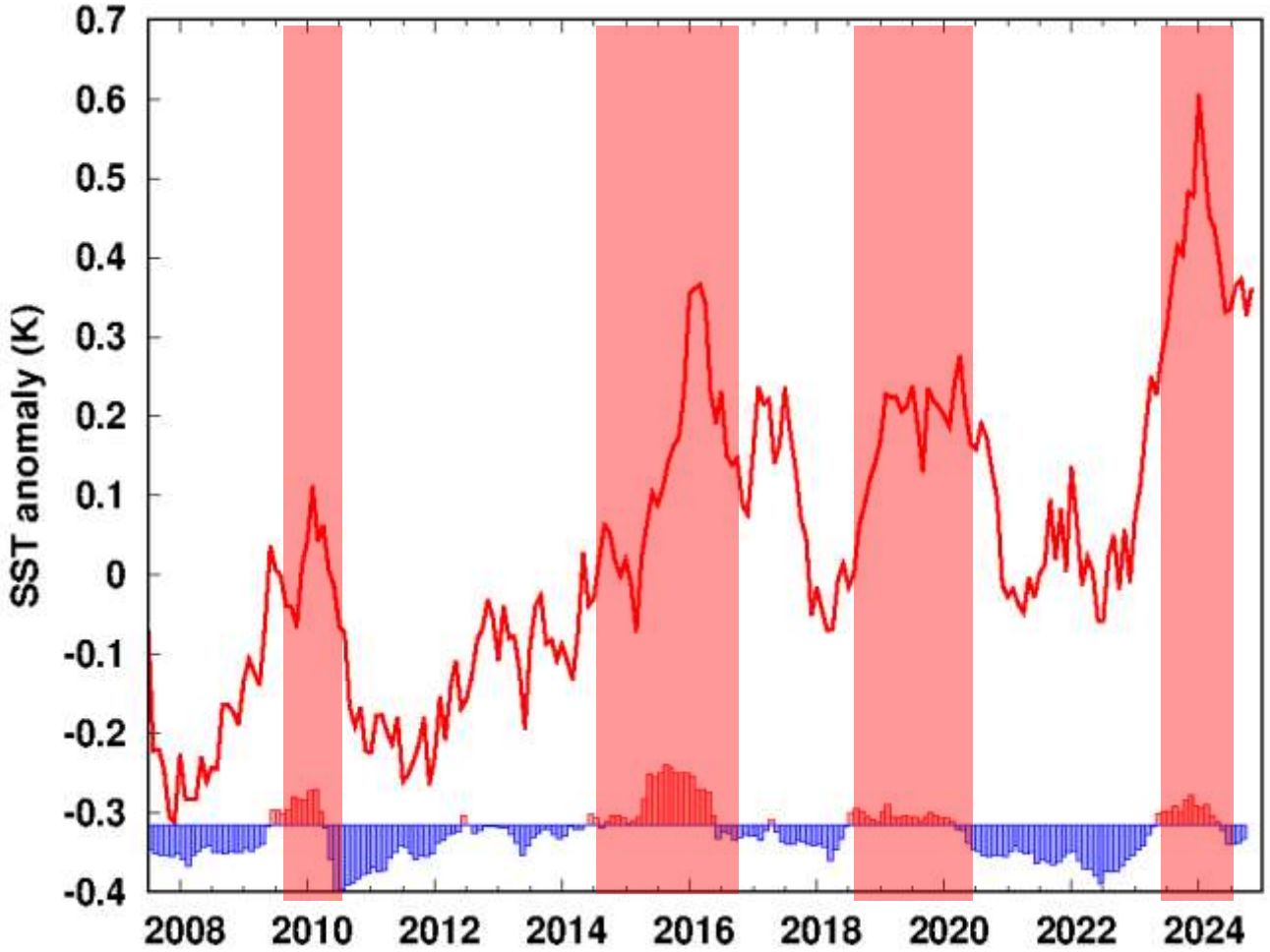

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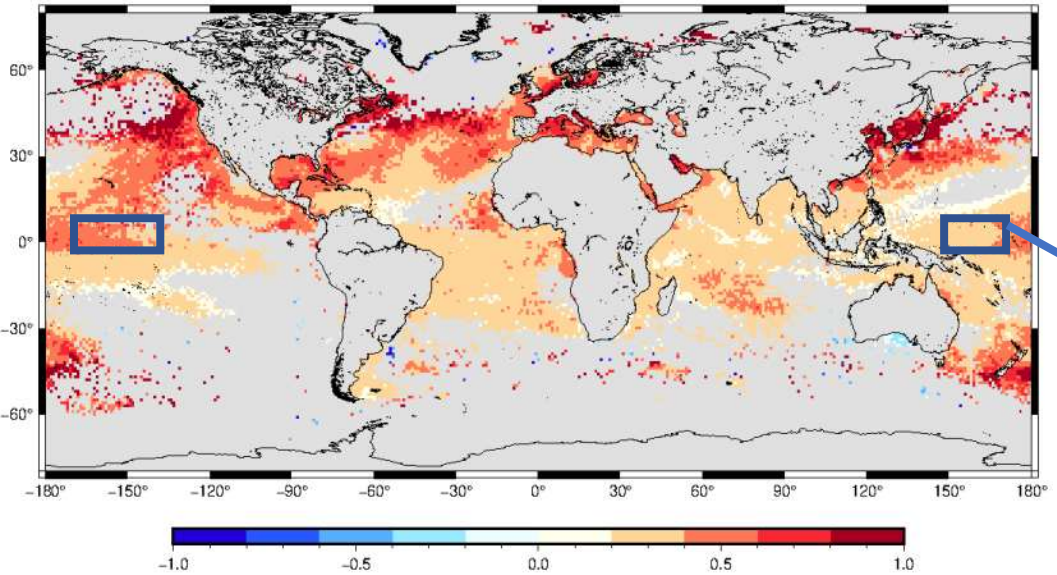
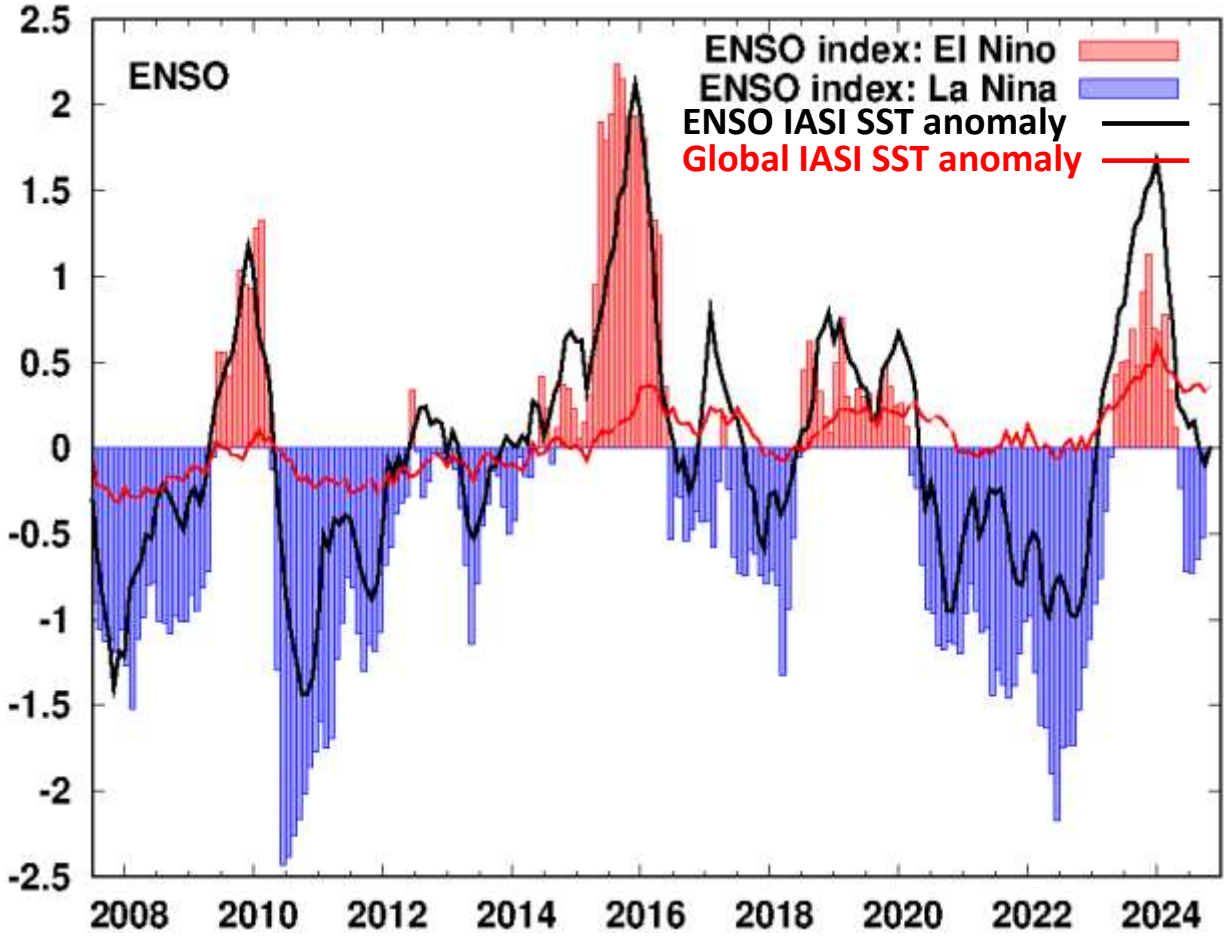
- Trend estimates: 0.27K.decade^{-1} (err =0.02K/d^{-1})
- After 2015, SST anomalies always positive
- Since mid-2023, SST are the highest over the IASI period
- Large peaks of anomalies in 2009-2010, 2015-2016, 2019-2020 and 2023-2024 linked to El Nino episode

Evolution of the sea surface temperature over the 2007-2024 period

The east-central equatorial Pacific region



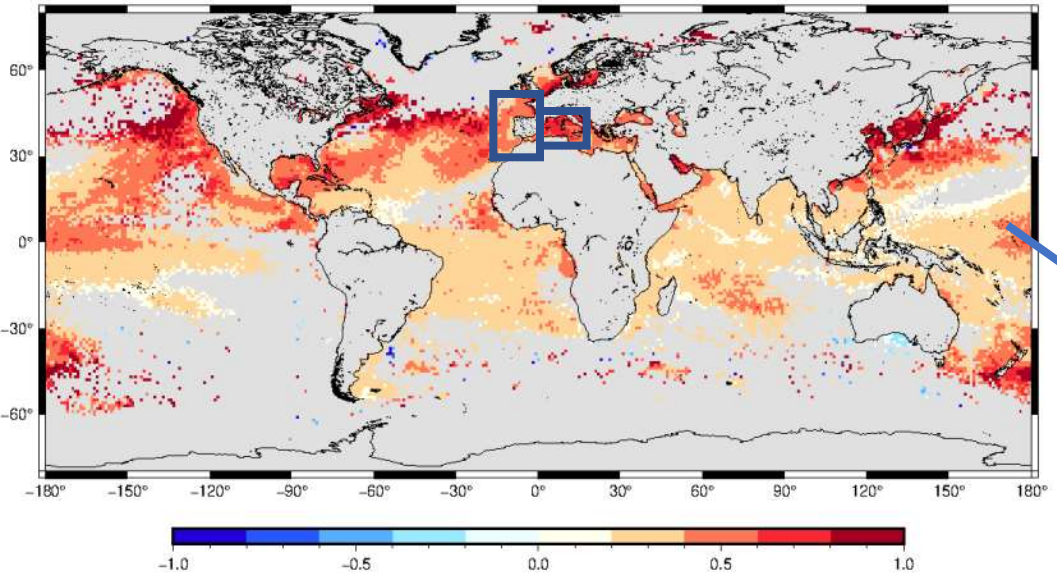


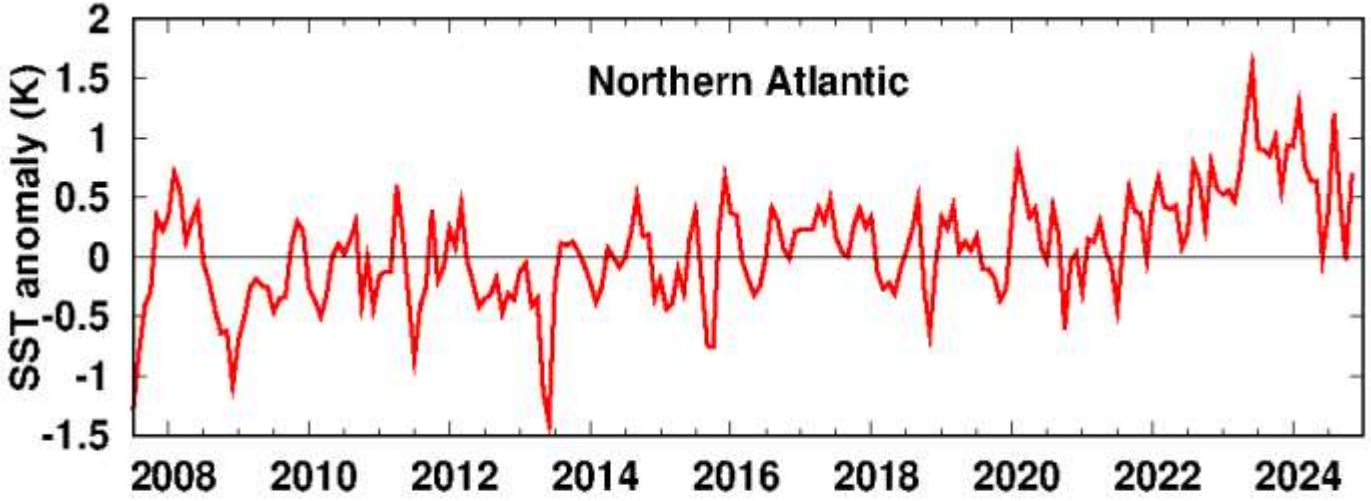
- The El Niño/Southern Oscillation (ENSO) is a large-scale ocean-atmosphere climate phenomenon
- One of the main driver of climate variability, in particular in Equatorial Pacific
- ENSO index is calculated from SLP, SST, wind and OLR
- IASI SST anomalies perfectly correlated to ENSO index
- Characterized by large SST anomalies (>2K).

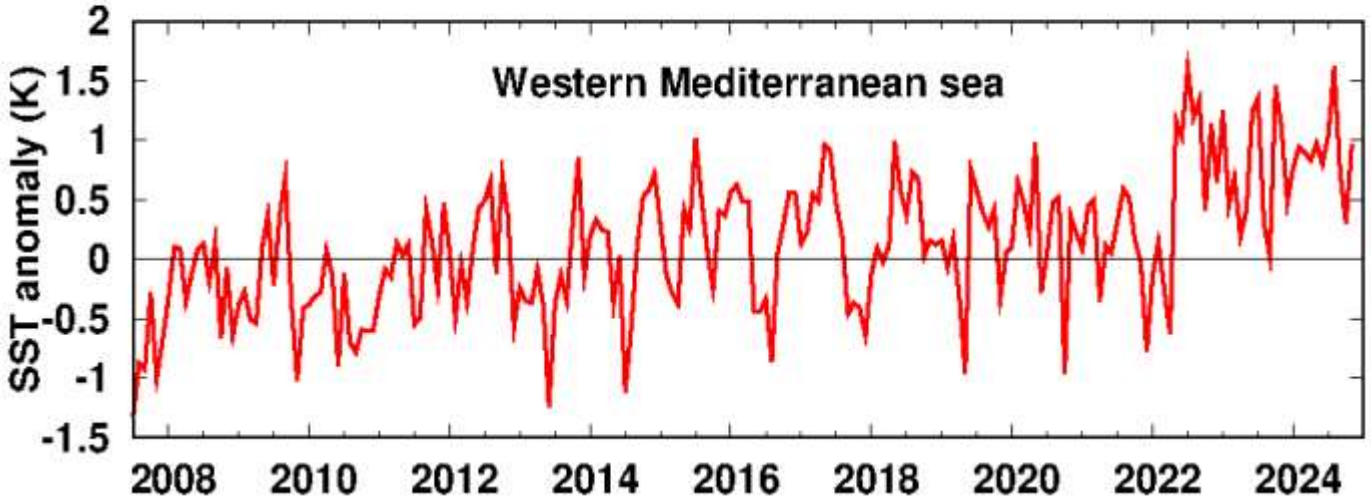
=> The 2023-2024 episode was moderate and cannot explain entirely the strongest global anomaly observed for winter 2023-2024

Evolution of the sea surface temperature over the 2007-2024 period

Geographic analysis of the SST evolution: European Coast



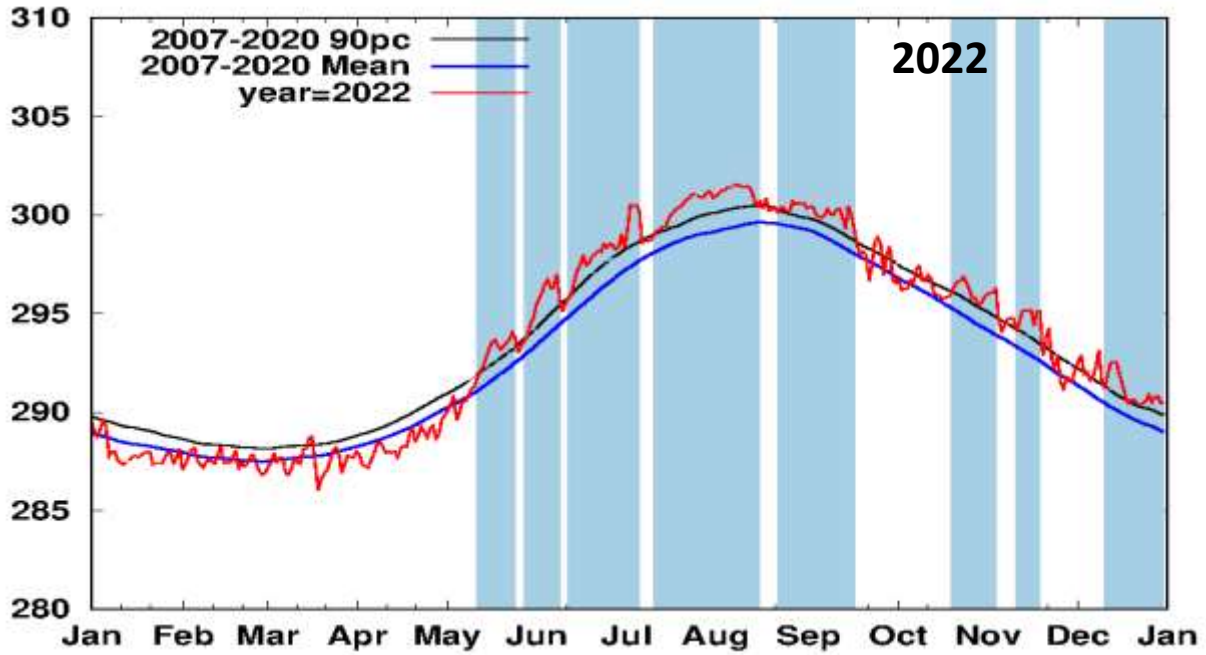




- Stable region until 2022 and constant warming since then
- The whole year 2023 and 2024 are exceptional
- Succession of large anomalies, over several days => marine heatwaves episode

Marine heatwaves in the Western part of the mediterranean

Marine heatwave: 5 consecutive days, at least, with SST above the daily 90th percentile of the SST record for a given location



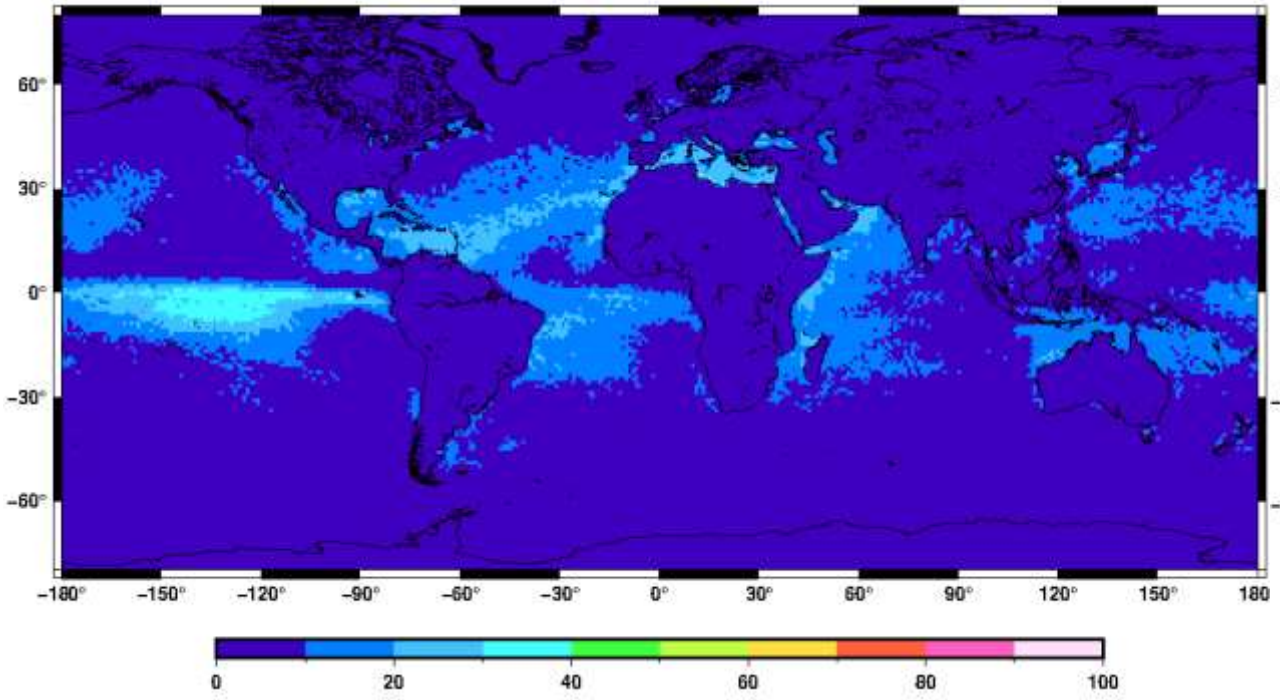
- MHWs are caused by a range of processes operating across different spatial and temporal scales, from localized air–sea heat flux to large-scale climate drivers

- These heatwaves can alter marine ecosystems structure and functioning
  - **they need to be monitored carefully**

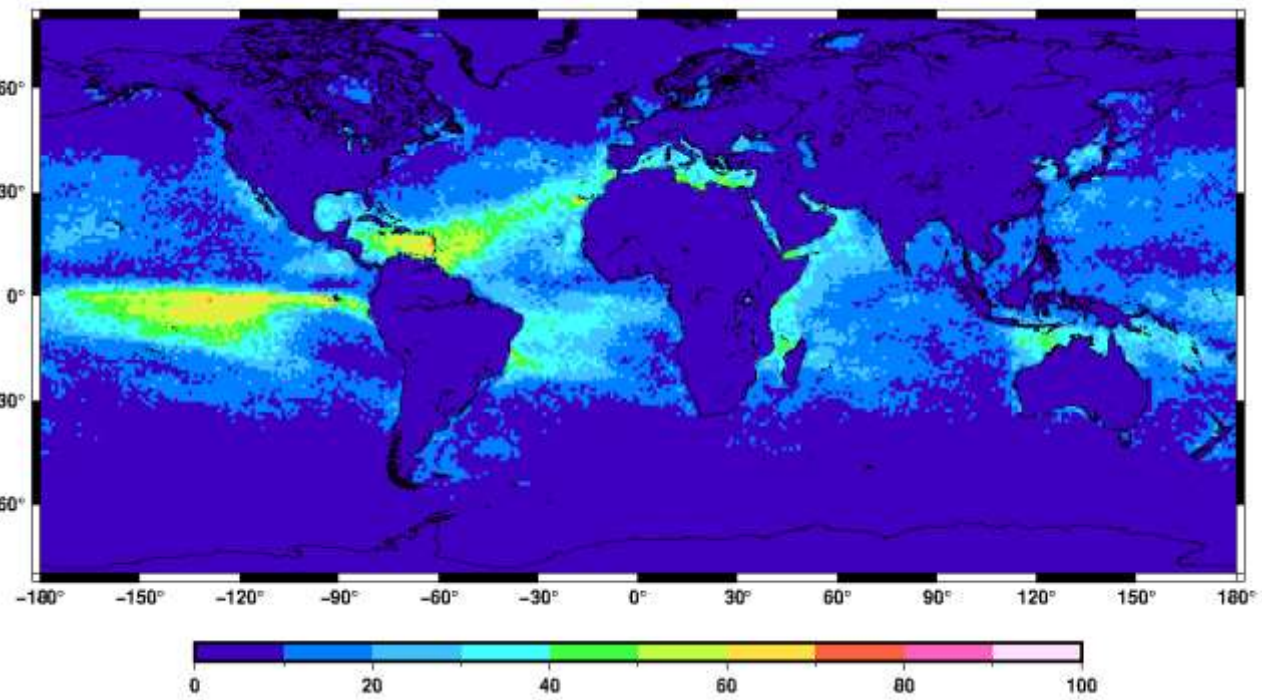
Marine heatwaves : global distribution

Number of days per year under heatwave episode:

Mean on 2007-2024



Standard deviation



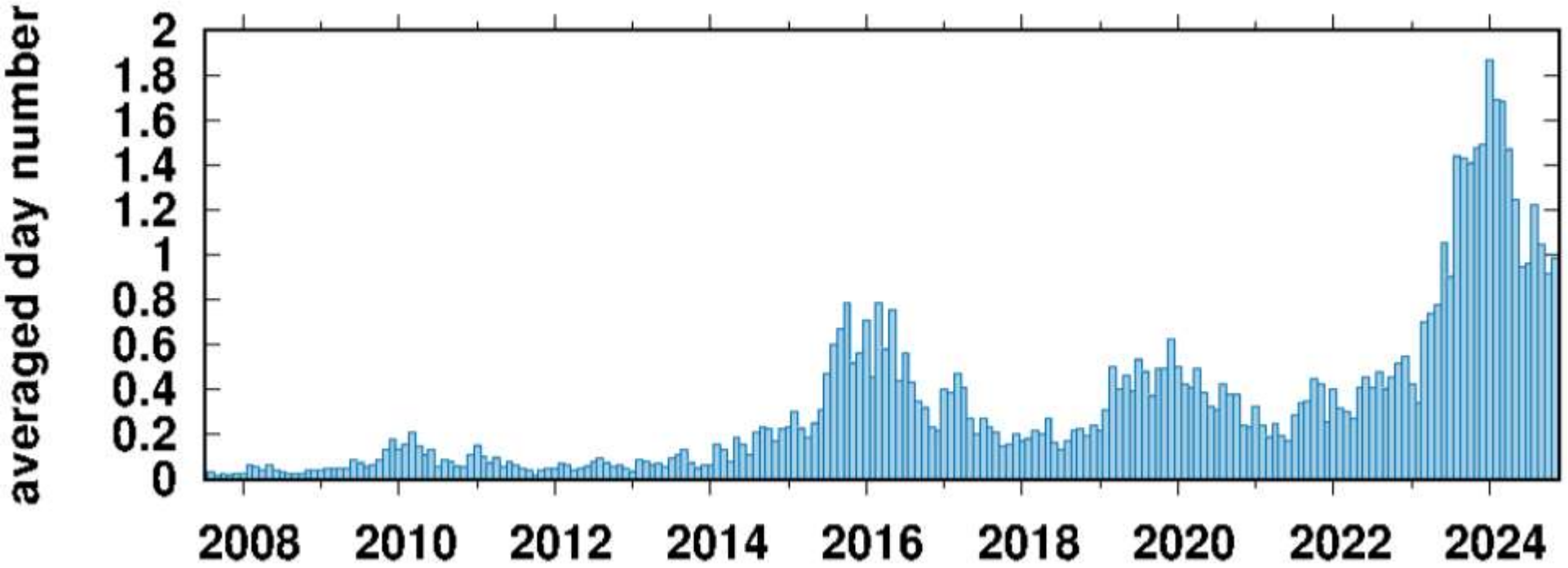
⇒ **Principally in Tropic and northern midlatitudes**

⇒ **Mean is low, because a few years are concerned**

⇒ **Standard deviation is large, highlighting the large interannual variability**

Marine heatwaves : time variability

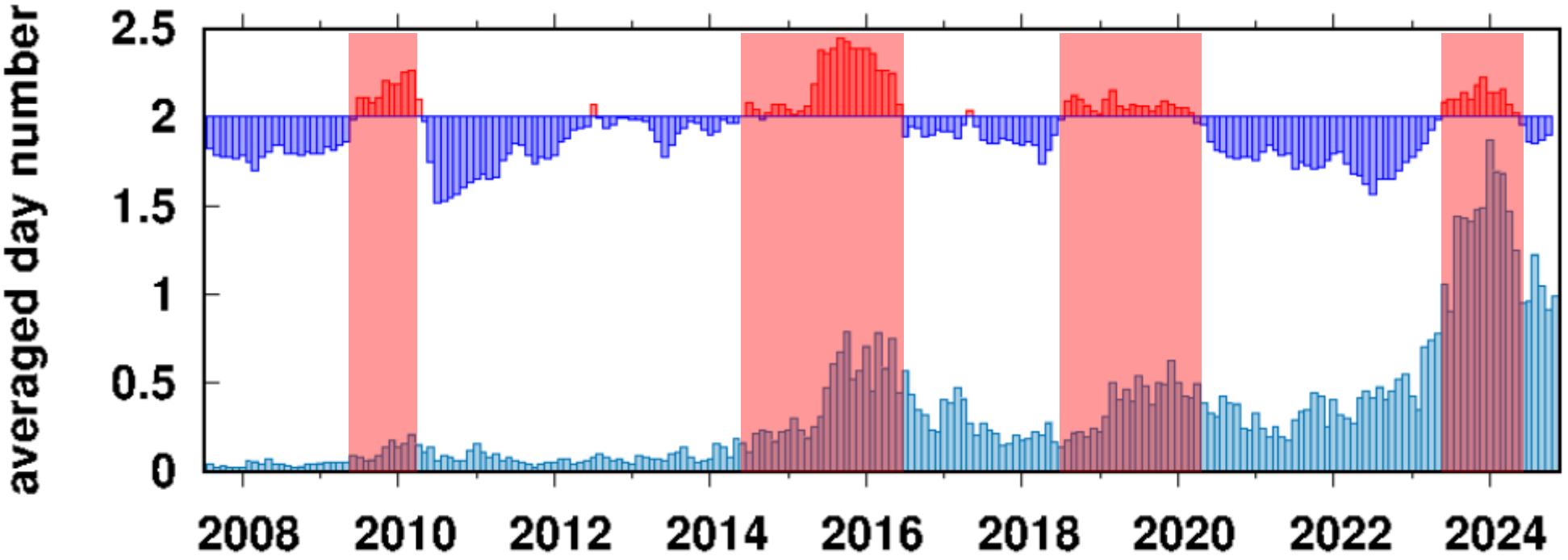
Days under heatwave frequency for the whole globe



⇒ **Principally after 2016, with a peak from 2023**

Marine heatwaves : time variability

Days under heatwave frequency for the whole globe

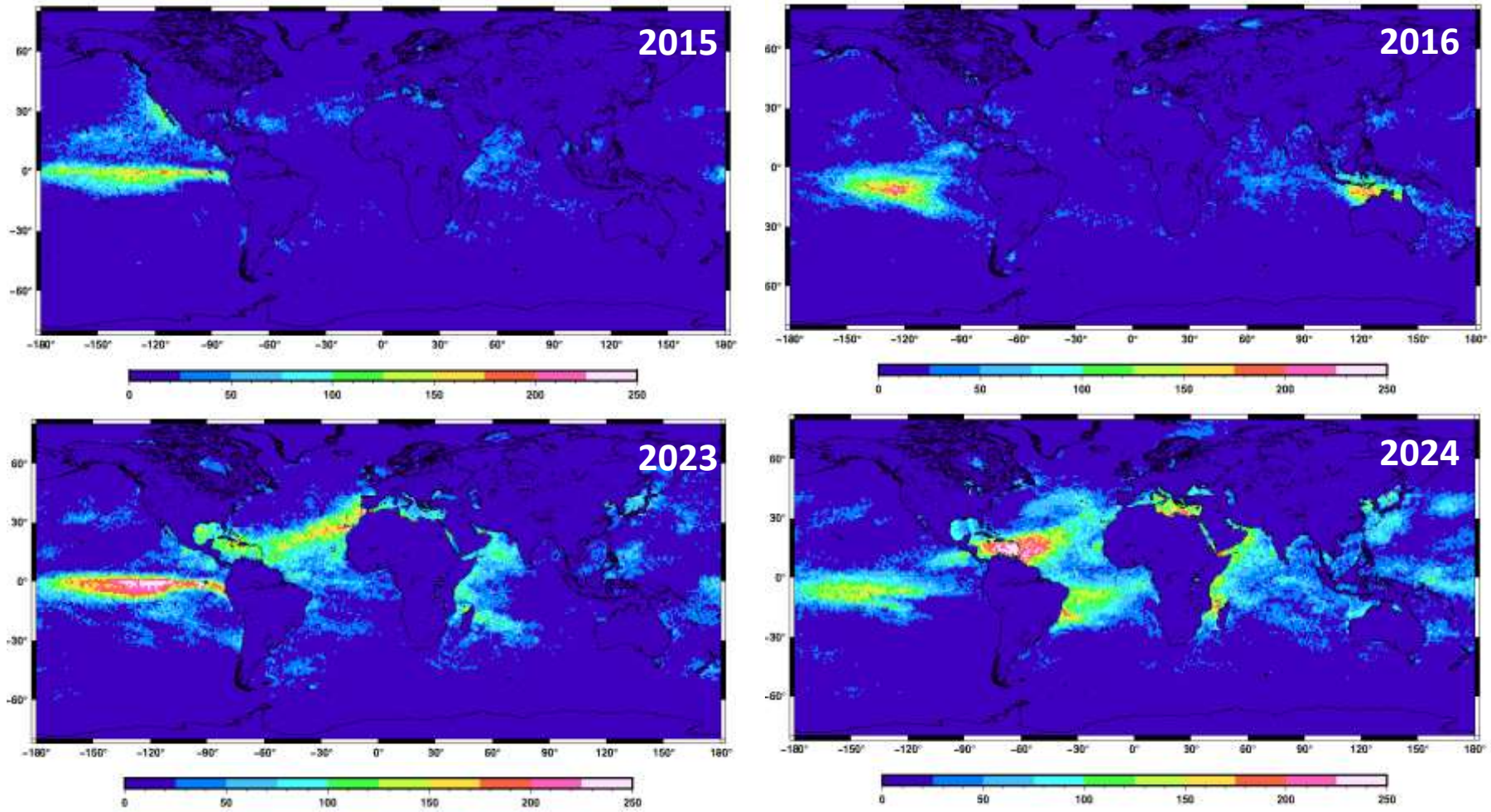


⇒ **Principally after 2016, with a peak from 2023**

⇒ **Globally linked to El Nino episode in period and intensity**

⇒ **Not for 2023-2024 episode : moderate El Nino but large Heatwaves**

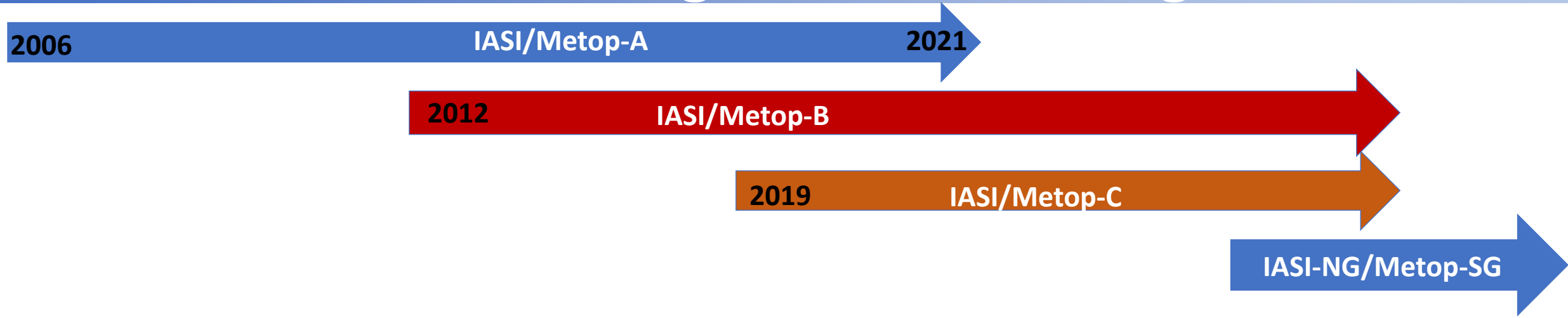
Number of days under heatwave per year for two El Nino episode



2015-2016 and 2023-2024 were both El Nino episode but :

- For 2015-2016, **the strongest epidode**, heatwaves occur principally in the ENSO region
- For 2023-2024, Tropical and Northern midlatitudes Atlantic is strongly concerned
- **It highlights the unprecedent warming of the Atlantic, since 3 years, which must be carefully analyzed and understood**

Toward a long term monitoring



- **The excellent spectral and radiometric characterization of IASI allows:**
  - **To derive a highly precise and stable over time SST dataset, with precision largely better than the original specifications**
  - **To extend the time series after the lifetime of one single instrument by combining the three Metop, without any bias correction.**

- **It opens the opportunity of long term monitoring with IASI-NG**
  - **Requires a precise inter-calibration between IASI and IASI-NG suites**

❖ **Data are available on AERIS: https://iasi.aeris-data.fr/sst/**