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Introduction to sea level variability in the context of the South West Indian Ocean

14/09/2022

Angela Hibbert, with thanks to Phil Woodworth

Flood waters in Antananarivo in March 2017 from Tropical Cyclone Enawo.
(AP Photo/Alexander Joe)

Sources of sea level variability

Sea levels vary on different time scales and for different reasons:

- Tsunamis (10s of minutes to an hour)
- Seiches (minutes to hours)

} 1 min sampling or less

- Tides (diurnal, semi-diurnal, mixed)
- Storm surges (few days)

} 5 to 15 min sampling

- Seasonal cycle (annual, semiannual)
- Mean sea level changes (months – millennia)

Tide gauges can measure all of these features provided they offer high frequency sampling and long (>30yr) duration

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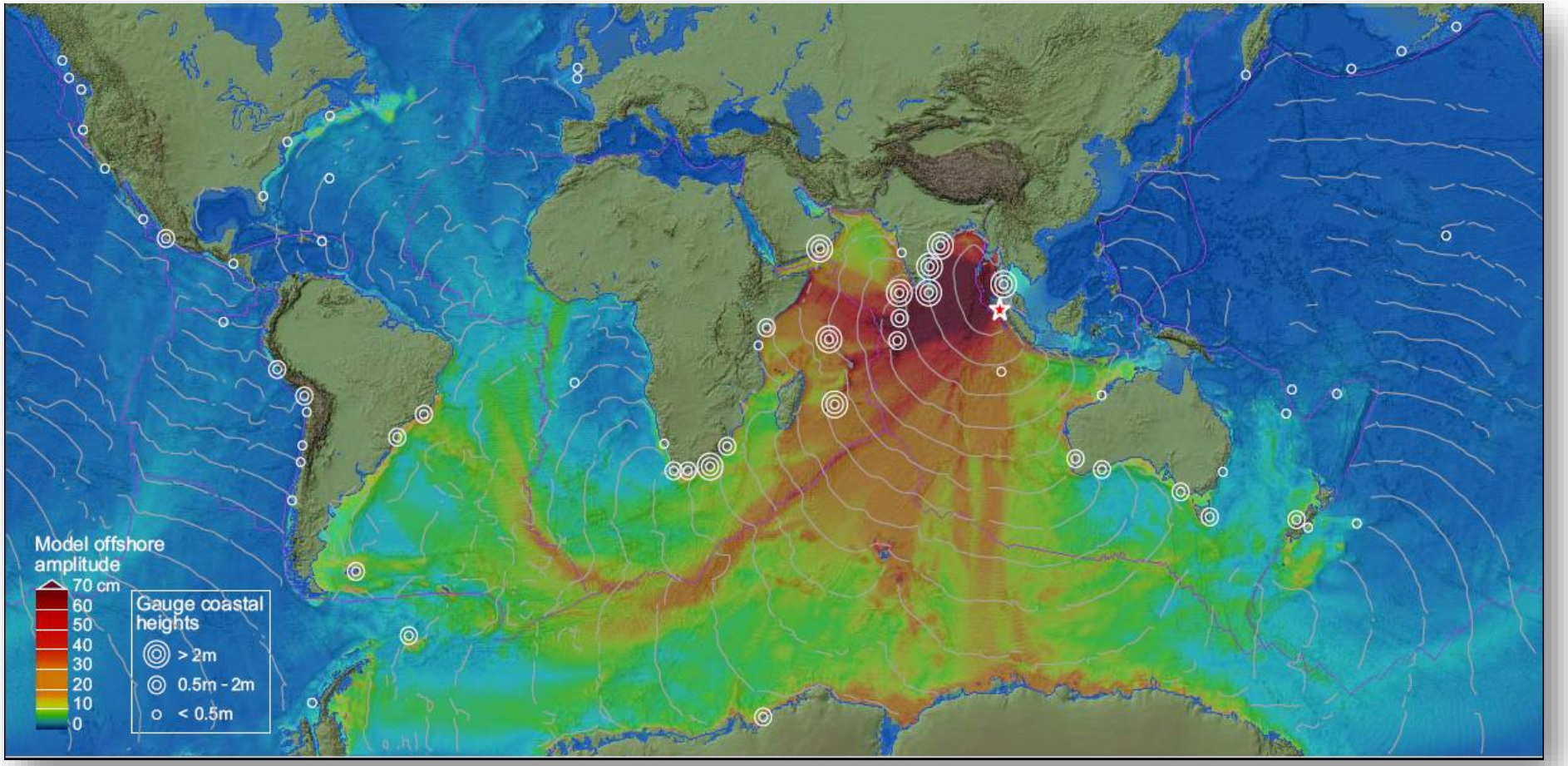
Tsunamis

Tsunamis

Caused by undersea earthquakes, submarine landslides, terrestrial landslides, volcanic eruptions, asteroid and comet impacts, man-made explosions.

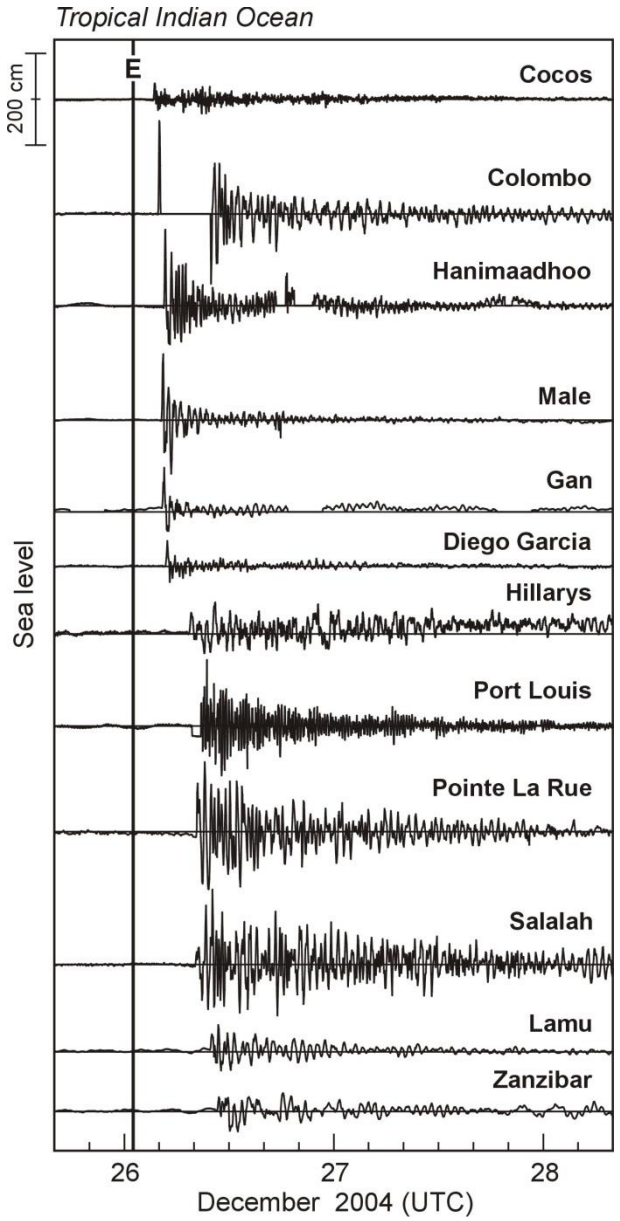


26 December 2004 Sumatra tsunami

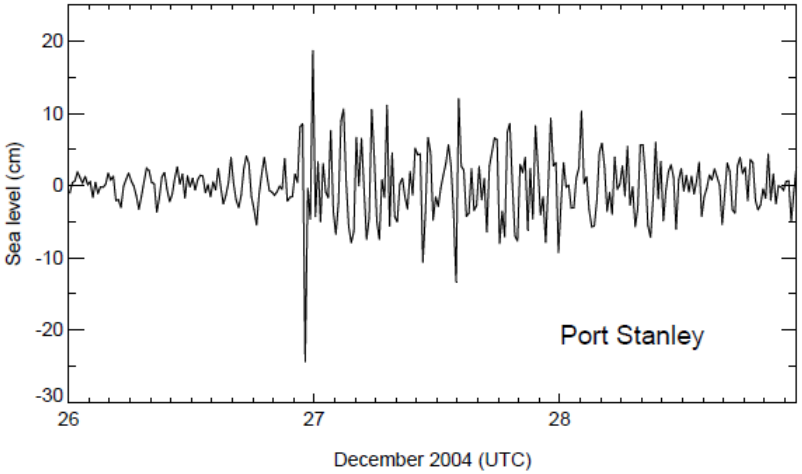
Tsunamis

Amplitudes can vary from a few mm to tens of metres, depending upon the source, proximity and ocean depth

Indian Ocean gauges



South Atlantic

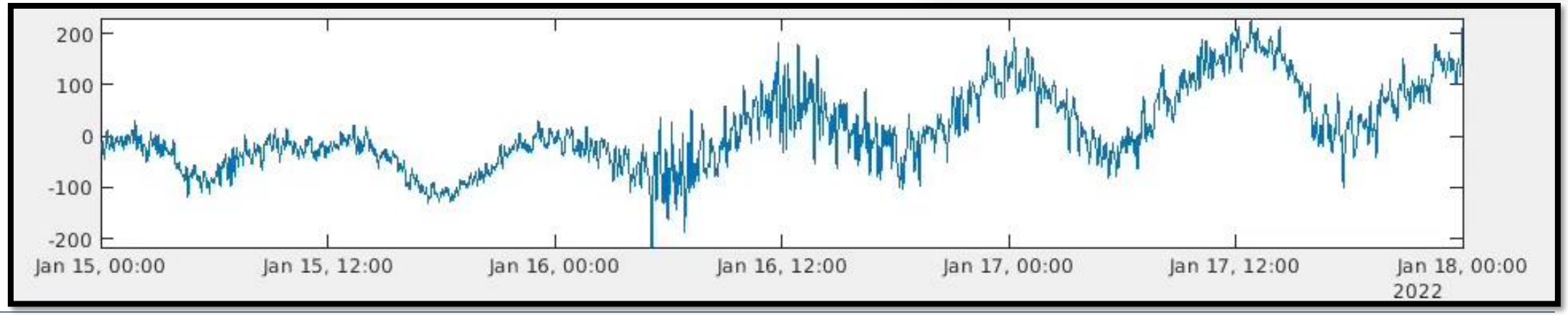


The 26 December 2004 tsunami was observed in tide gauge records on many coastlines

Tonga Tsunami,

Hunga-Tonga eruption
04:14:45 GMT, 15 January
2022

Sea level height (mm) at Newlyn



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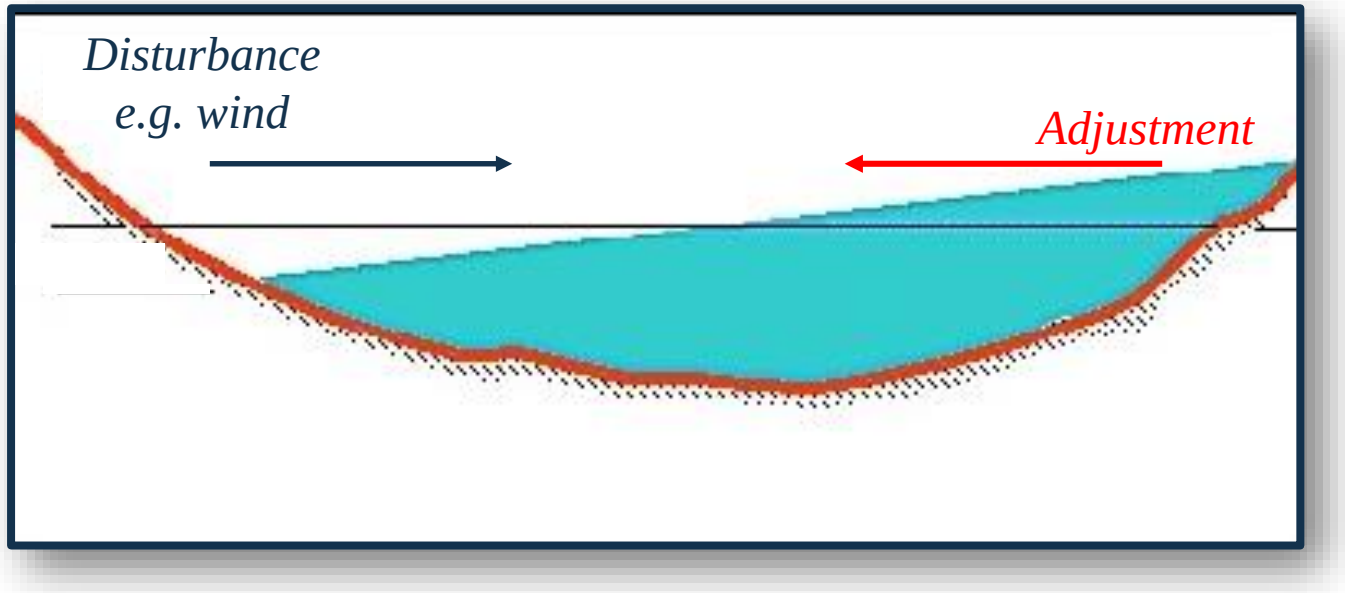
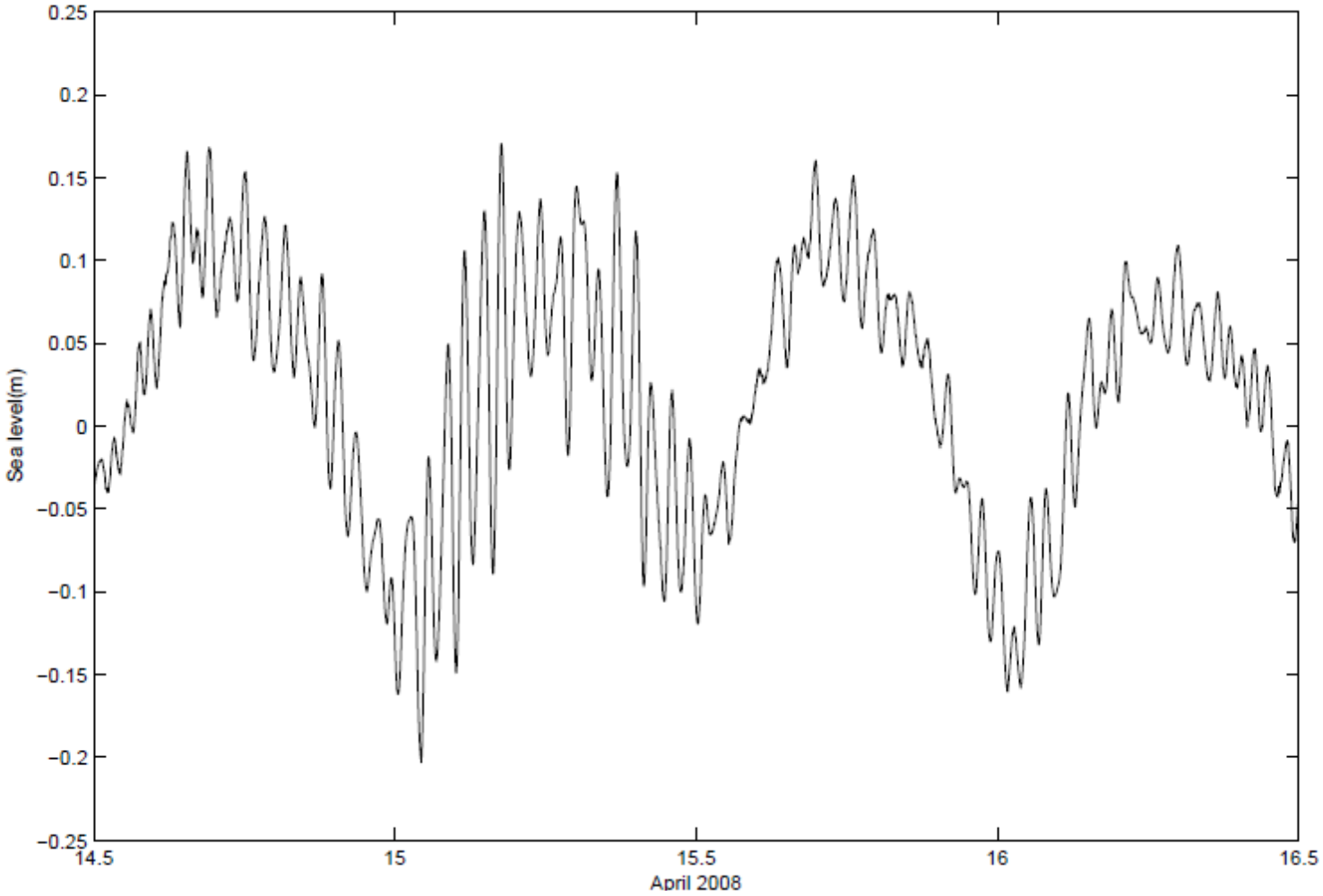
Seiches

Seiches



- Standing wave (a combination of 2 waves travelling in opposite directions)
- Due to resonant behaviour in bays, harbours etc
- They can be set off by rapid meteorological changes, earthquakes, landslides, tsunamis etc
- Similar to water sloshing from side to side in a bath tub

In practice, seiches occur in all sea level records and can be readily identified given high frequency sampling



Seiches at Trincomalee Bay, east coast of Sri Lanka

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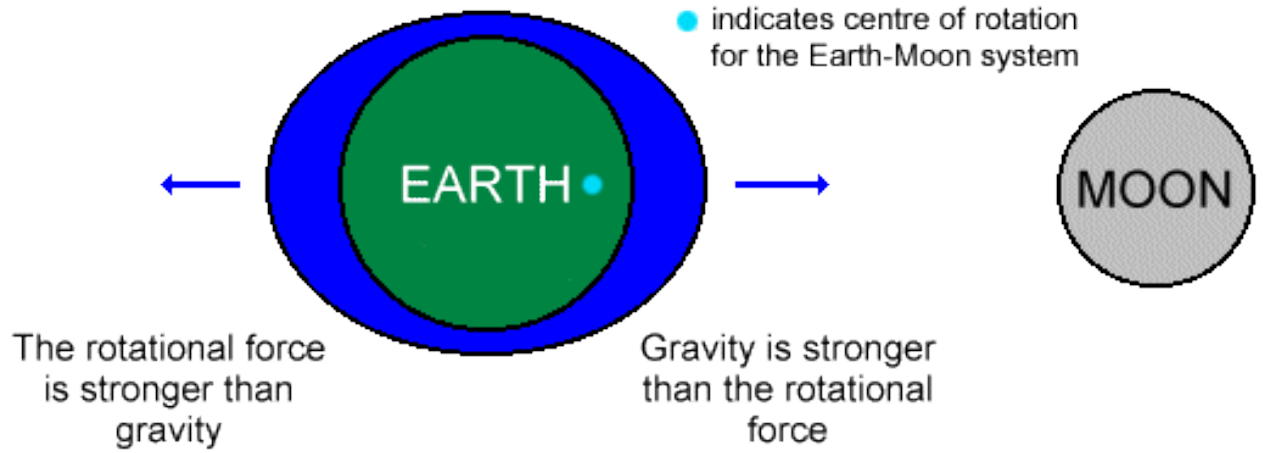
Tides

Tides

Periodic movements of the sea surface related to regular movements of the Moon-Earth and Earth-Sun systems



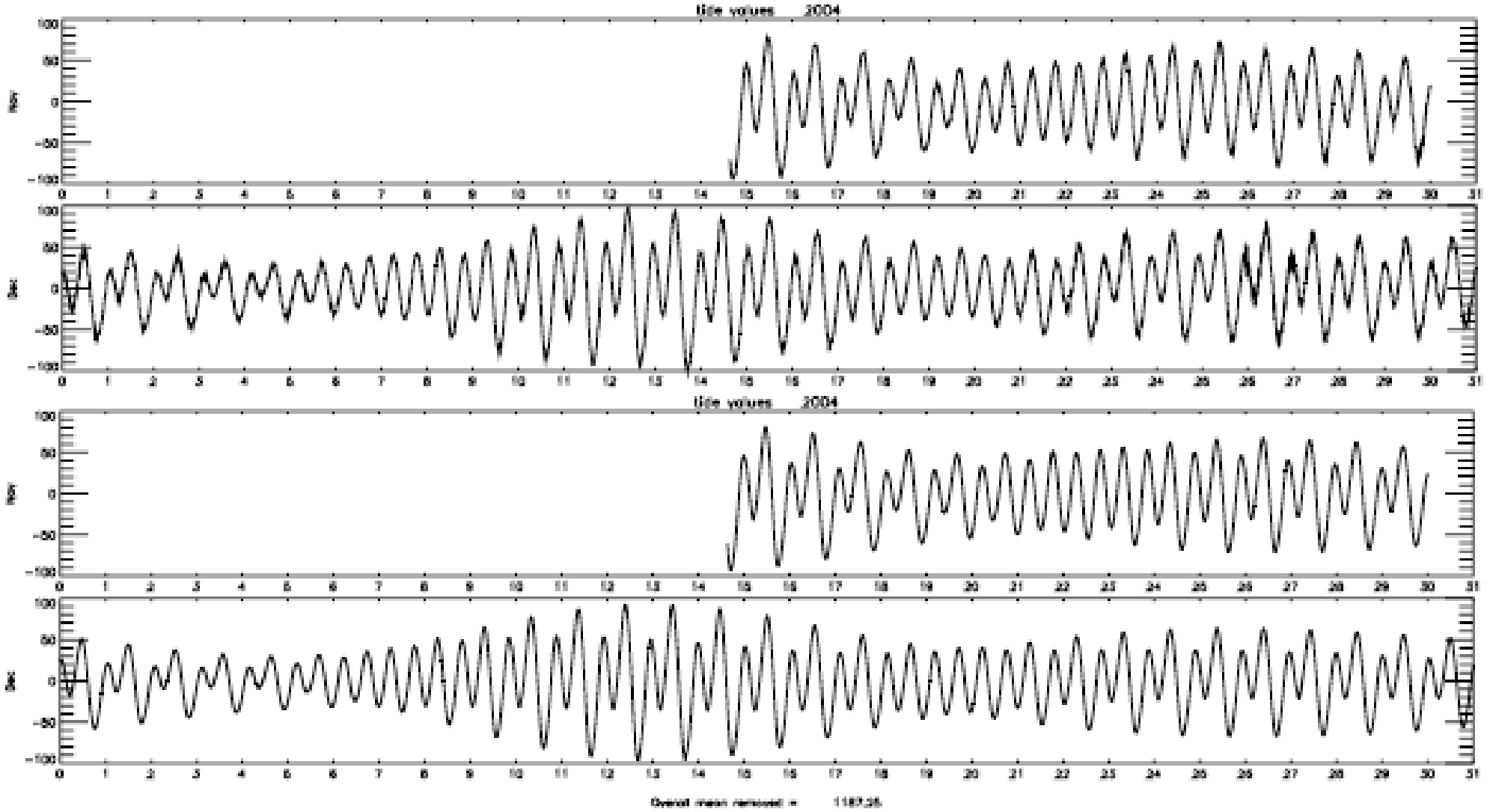
- They are large amplitude and tend to dominate other changes in sea level
- They differ from place to place

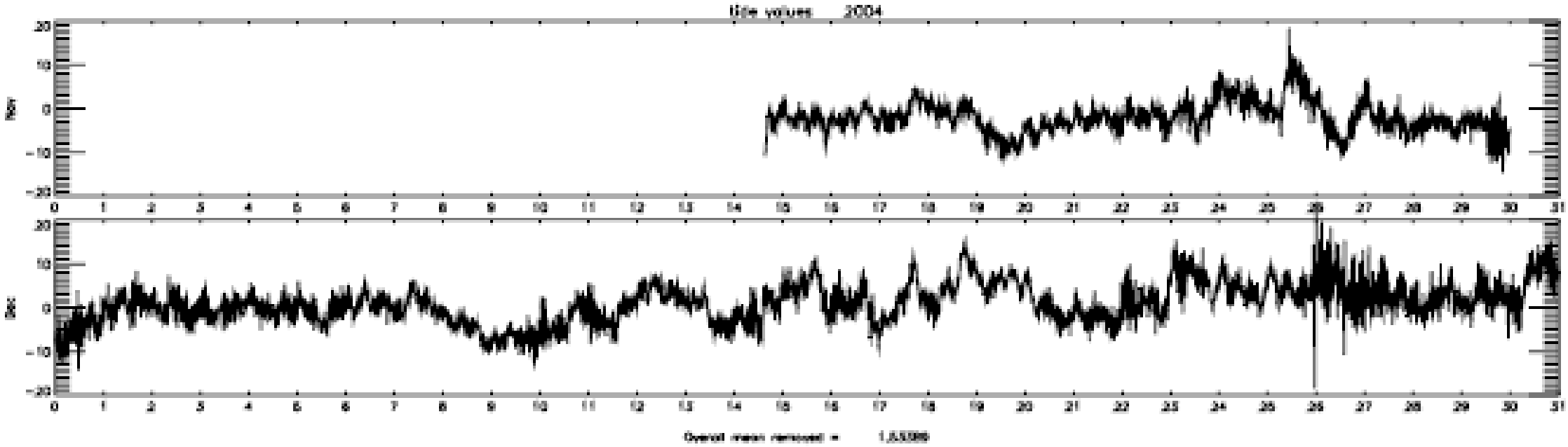
Tides are large amplitude and often dominate a sea level record

An example from Port Stanley Nov-Dec 2004

Total Sea Level

Tide



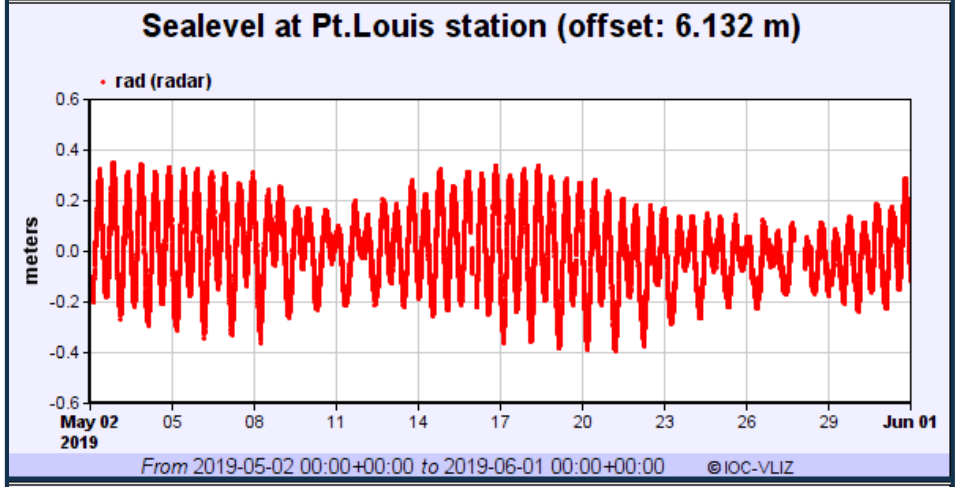


Non-tidal record shows:

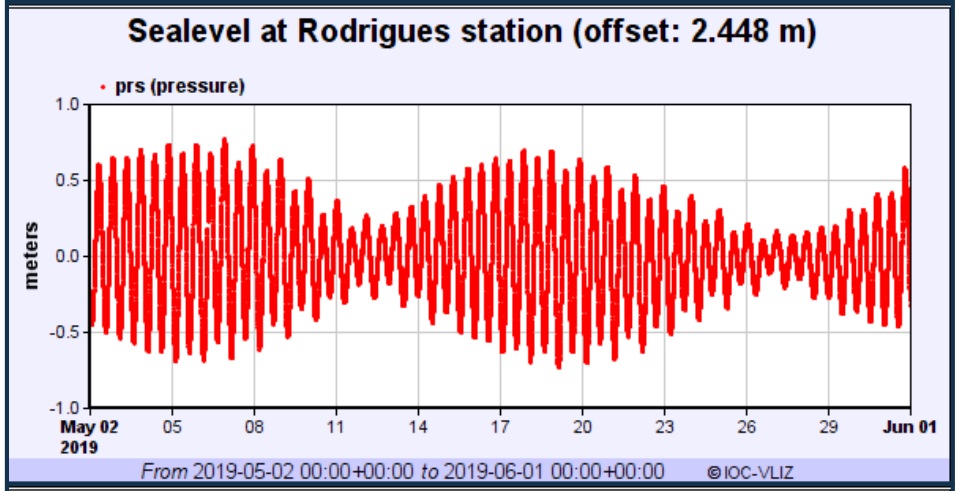
1. No big storm surges (Southern Hemisphere summer)
2. A lot of high-frequency noise of a few cm due to harbour seiches
3. On 27 December arrival of the Sumatra tsunami (15 cm or so)

➔ None of this is evident from looking at the total measured record.

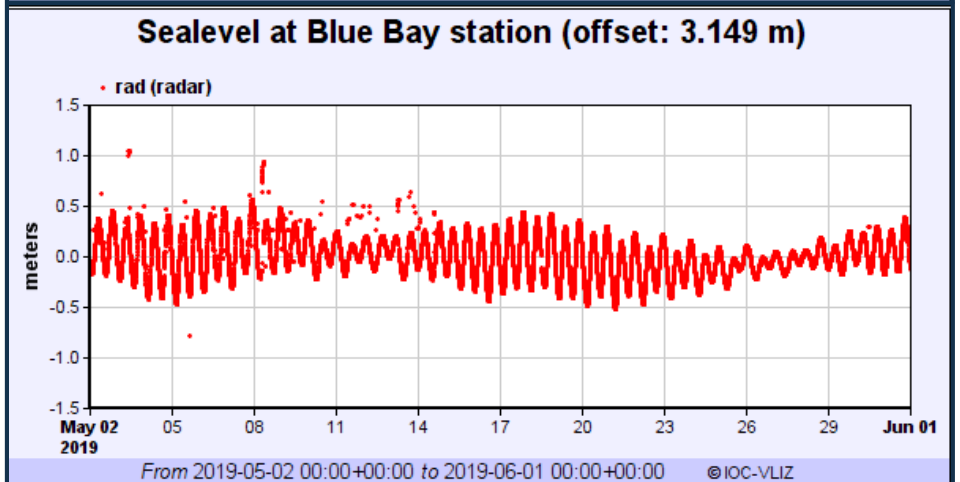
Tides differ from place to place



Mixed – mainly semidiurnal

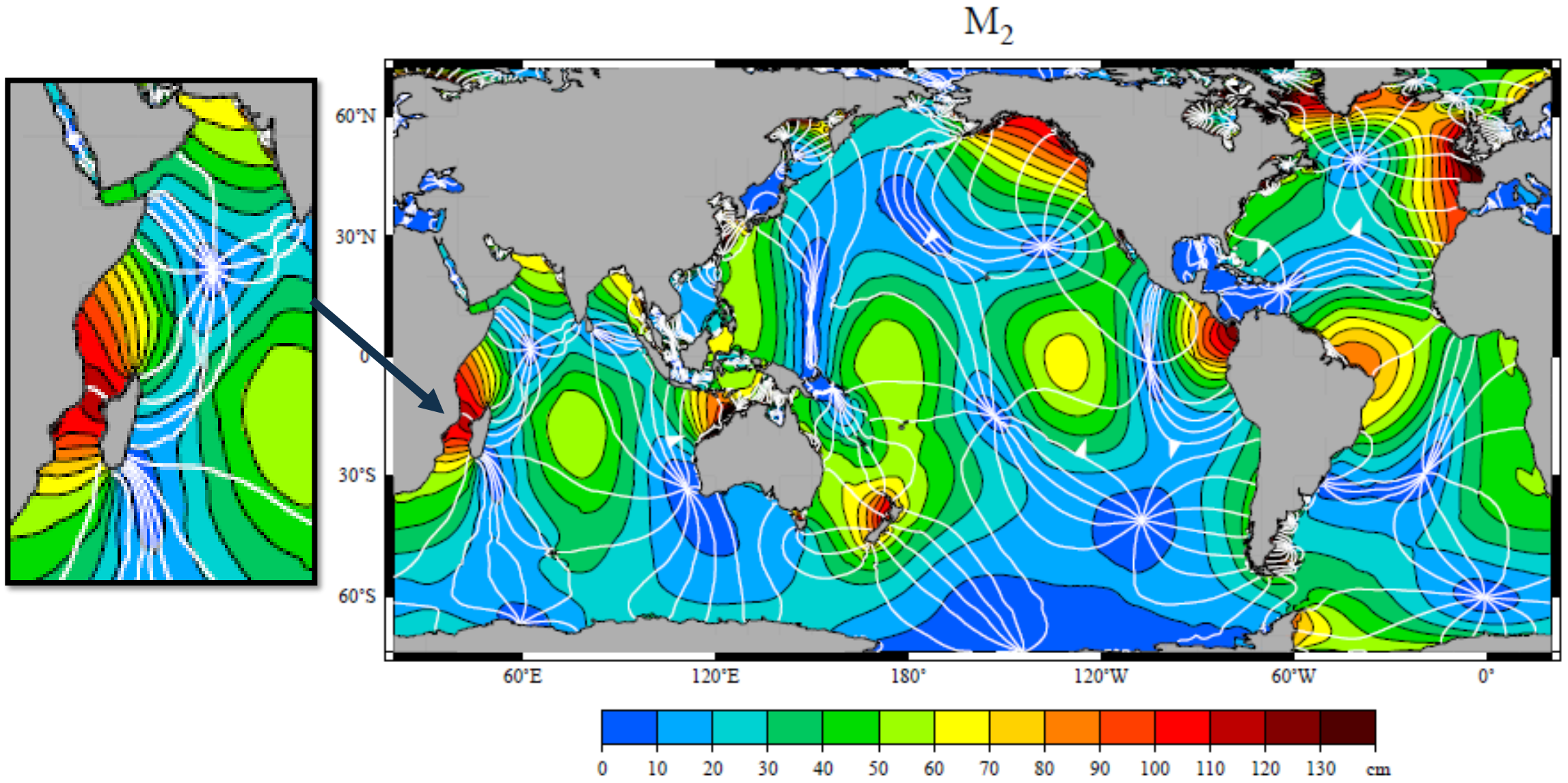


Semi-diurnal



Shallow water distortions

Tides differ from place to place



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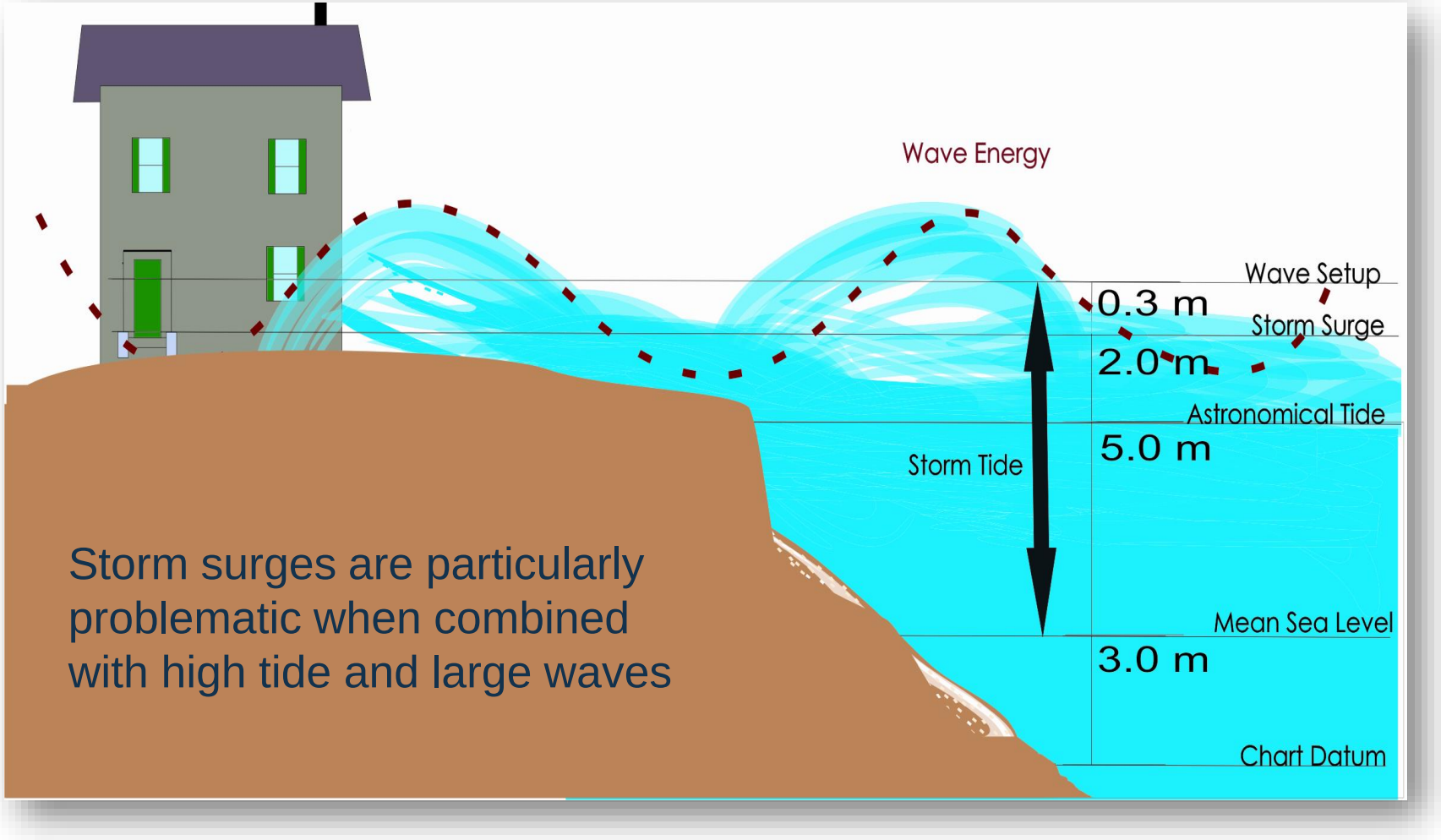
Storm Surges

Storm surges

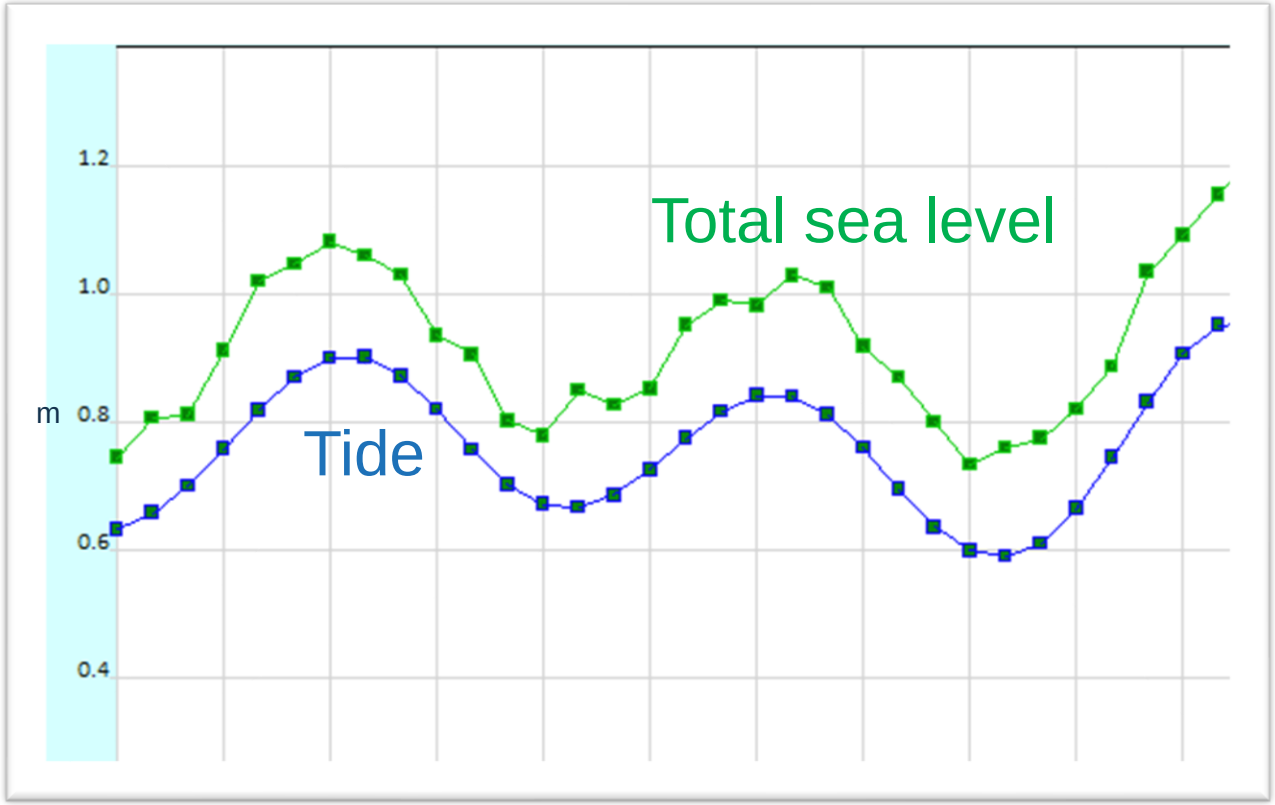
Due to a combination effects of low air pressure (1 mbar reduction raises sea level by 1 cm, known as the Inverse Barometer Effect) and wind stress in shallow water



Storm surges and tropical cyclones

Surges are key events in Madagascar e.g.

- Bingiza Feb 2011
- Giovanna Feb 2012
- Enawo Mar 2017
- Ava Jan 2018
- Eliakim Mar 2018
- Dumazile Mar 2018



Bingiza 13-14 Feb 2011, measured at Toamasina tide gauge

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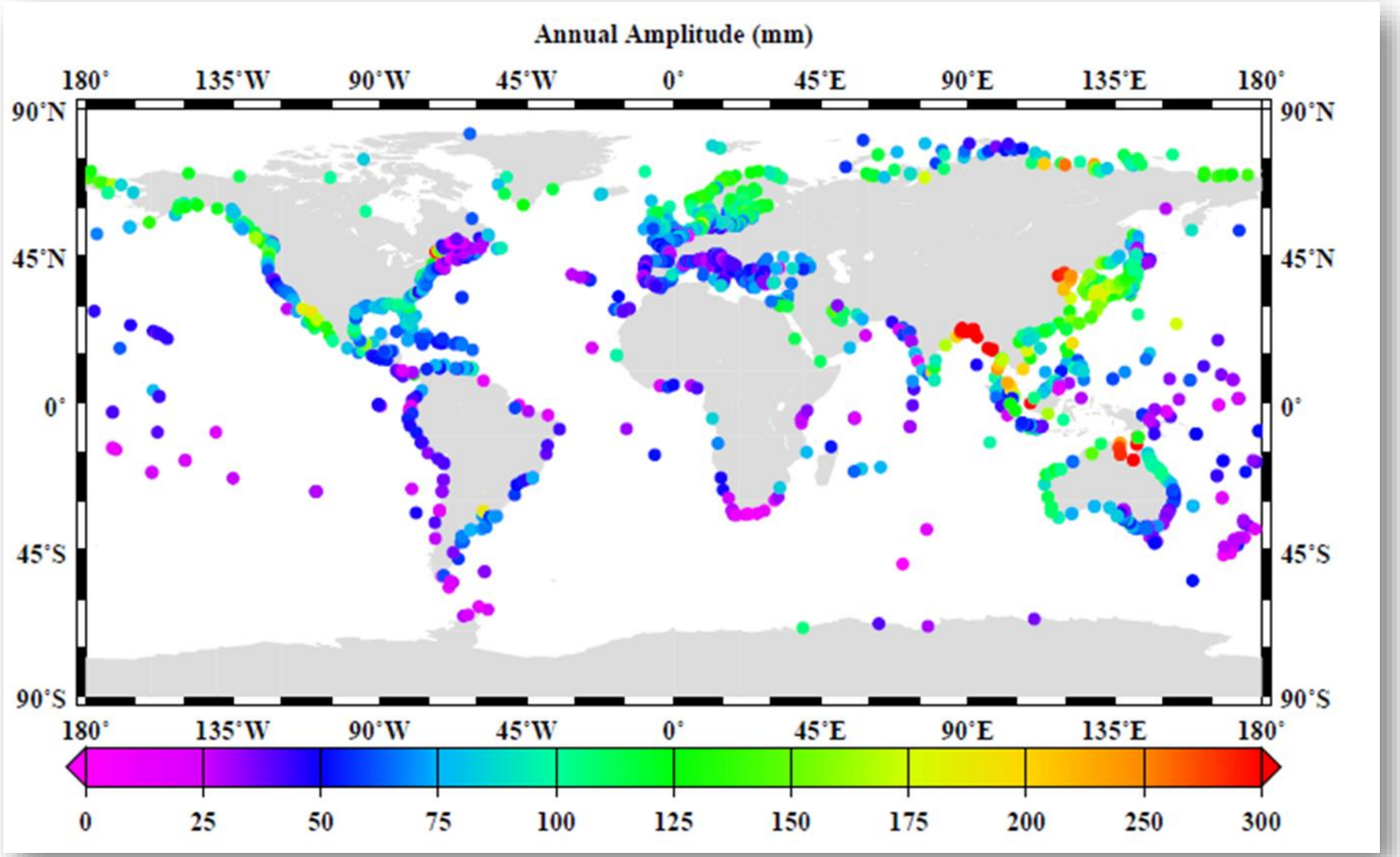
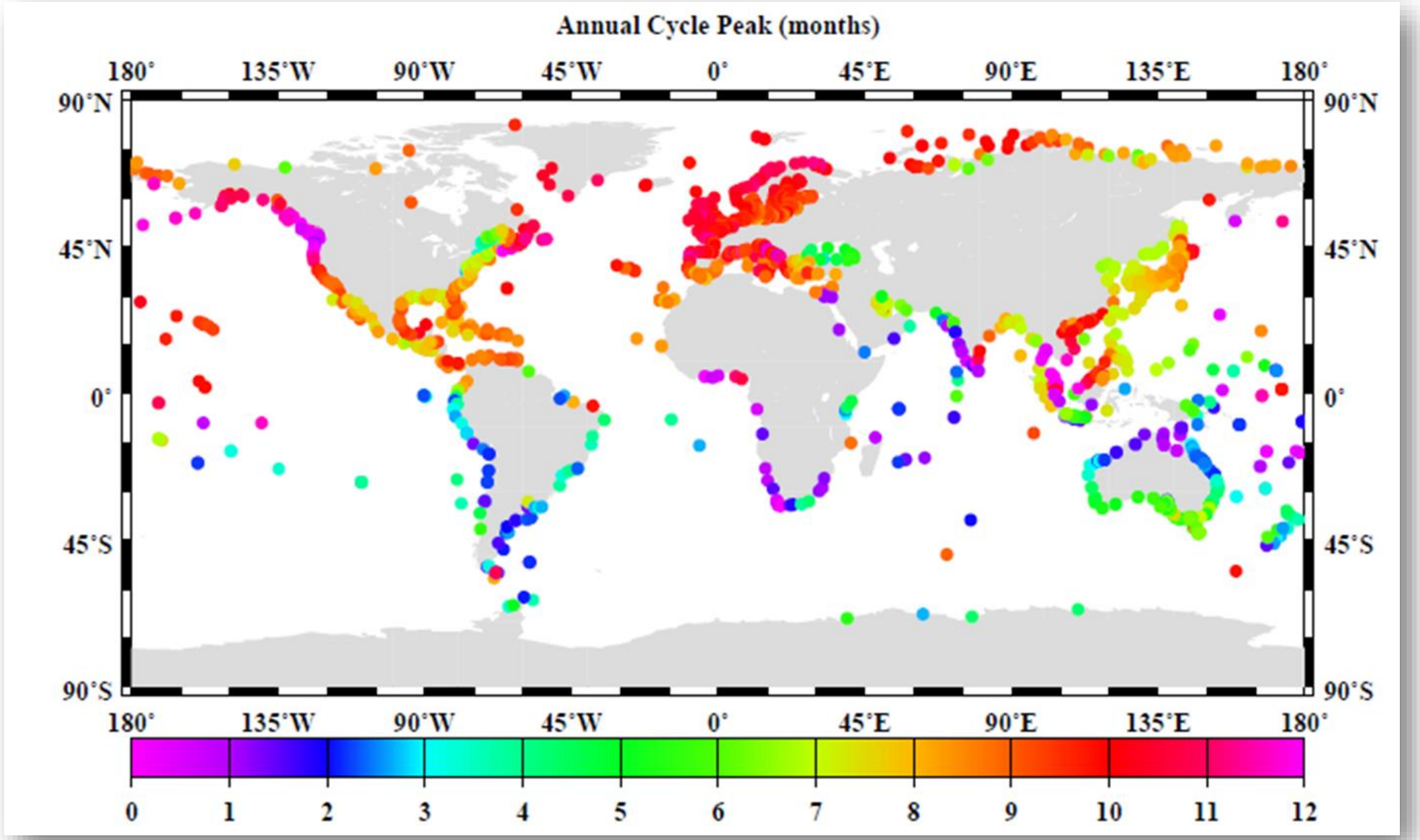
Seasonal Cycle


Annual Amplitude (mm)
180°
135°W
90°W
45°W
0°
45°E
90°E
135°E
180°
90°N
45°N
0°
45°S
90°S
0
25
50
75
100
125
150
175
200
250
300


Annual Cycle Peak (months)
180°
135°W
90°W
45°W
0°
45°E
90°E
135°E
180°
90°N
45°N
0°
45°S
90°S
0
1
2
3
4
5
6
7
8
9
10
11
12

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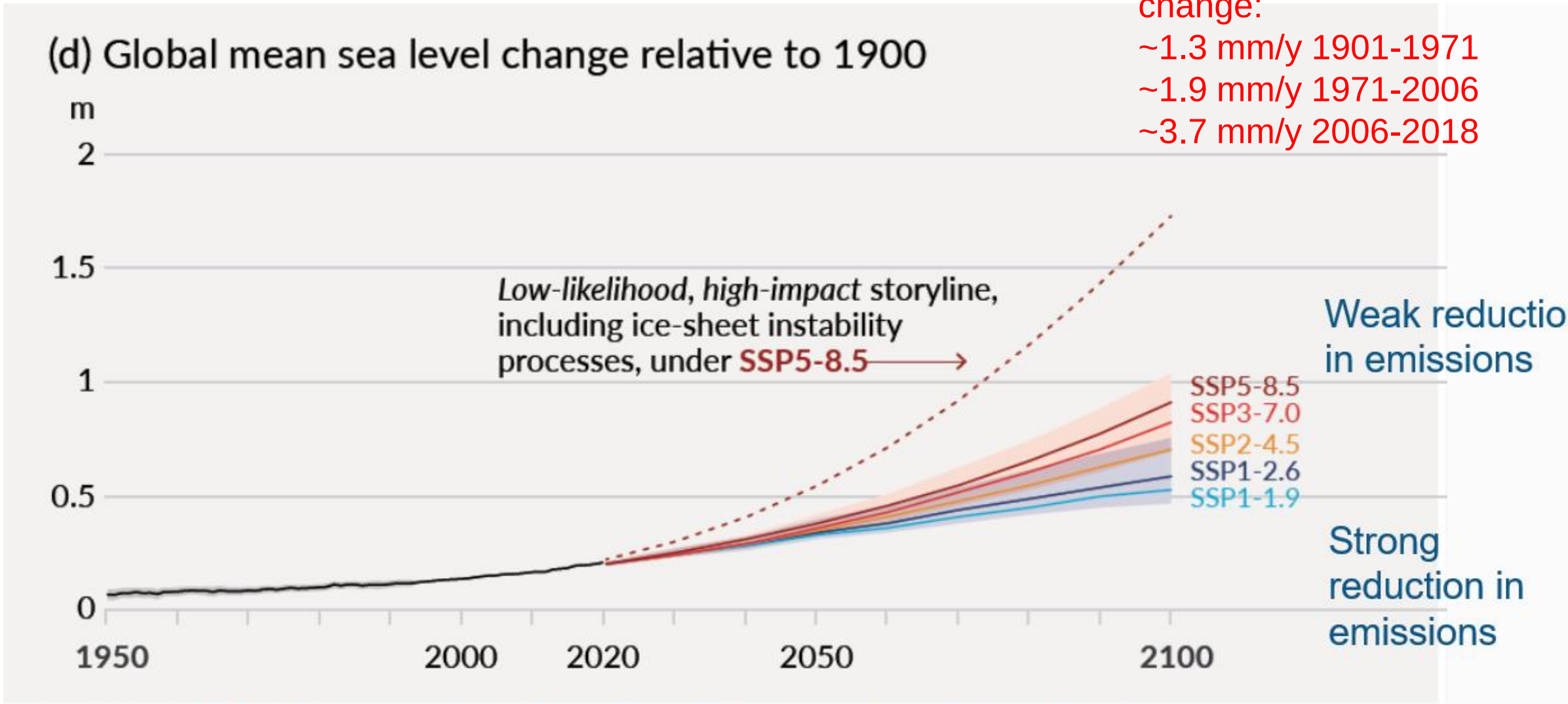
Long term trends

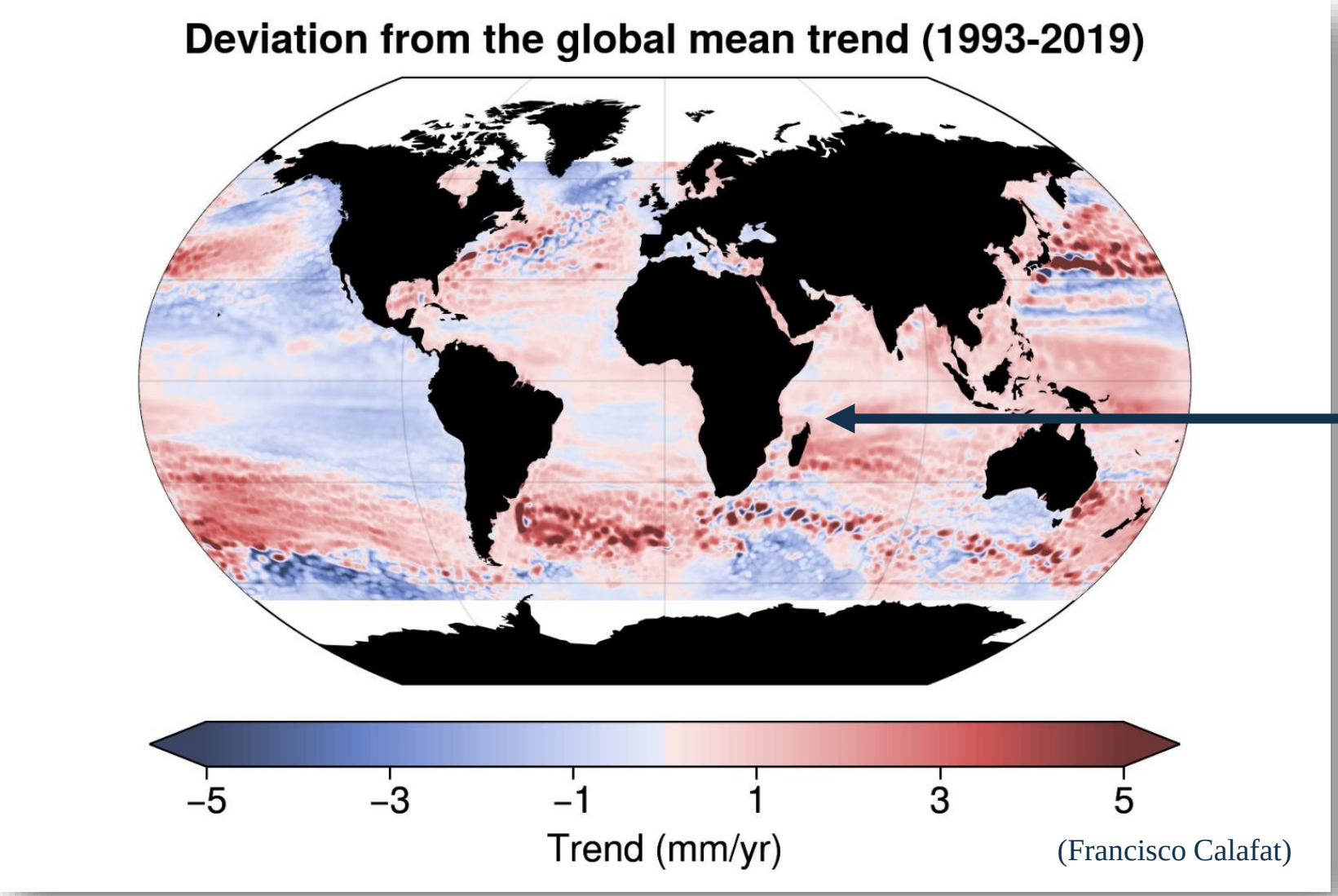
Global Mean Sea Level Trends

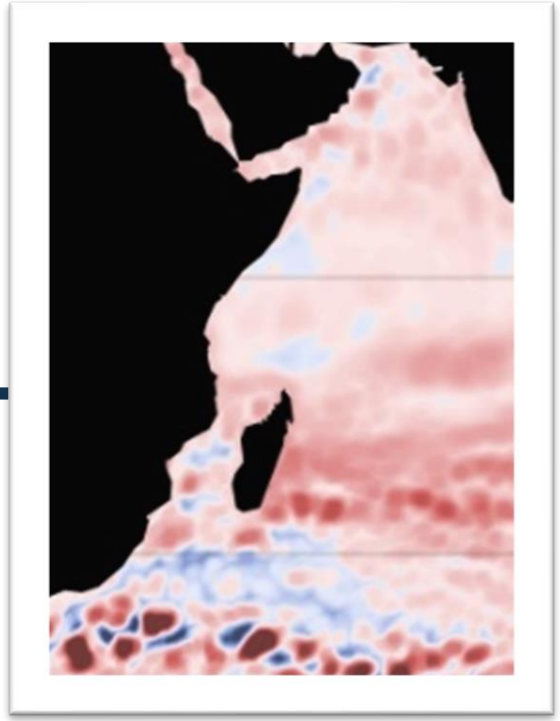
Observed rates of change:
~1.3 mm/y 1901-1971
~1.9 mm/y 1971-2006
~3.7 mm/y 2006-2018



IPCC (2021), WGI, Summary for Policymakers; https://www.ipcc.ch/report/ar6/wg1

Sea level rise is not uniform





Due to changes in water density, ocean circulation, melting of land ice, atmospheric pressure etc.

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Why do we need to understand sea level variability?

Why do we need to understand sea level variability?

Different sea level phenomena can co-occur, leading to major flooding events.

- Tsunamis
- Seiches
- Tides
- Storm surges
- Seasonal cycle
- Mean sea level changes

If we improve our understanding of these individual features, we can improve their predictability and mitigate against potential worst case scenarios

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Thank you for listening

Any questions?