EGU24-3445

Are multi-decadal sea-level oscillations augmenting rates of mean sea level?

Erin Robson, Luke Jackson, Sophie Williams

Department of Geography, Durham University, Durham, U.K, DH1 3LE. (erin.e.robson@durham.ac.uk)

Sharing is encouraged

Durham University

1. Motivation

Internal climate variability causes an increase or decrease in both global and regional sea level. On short timescales, this variability can temporarily amplify or reduce long-term sea-level change [1]. On longer timescales, although the effect of anthropogenic forcing on sea-level change is without question, the nature of multi-decadal sea-level oscillations are less understood [2].

The objective of this research is to use Empirical Mode Decomposition (EMD) to identify the dominant periodicities of mean sea-level oscillations. Periods quantified from this analysis can be compared with periodicities of recognised modes of internal climate variability, to determine causal factors of multi-decadal sea-level oscillations.

↳ By attributing global and regional multi-decadal sea-level oscillations to climate modes, we can better our understanding of how low-frequency variability associated with internal oscillations may augment patterns of long-term sea-level change.

2. Methods

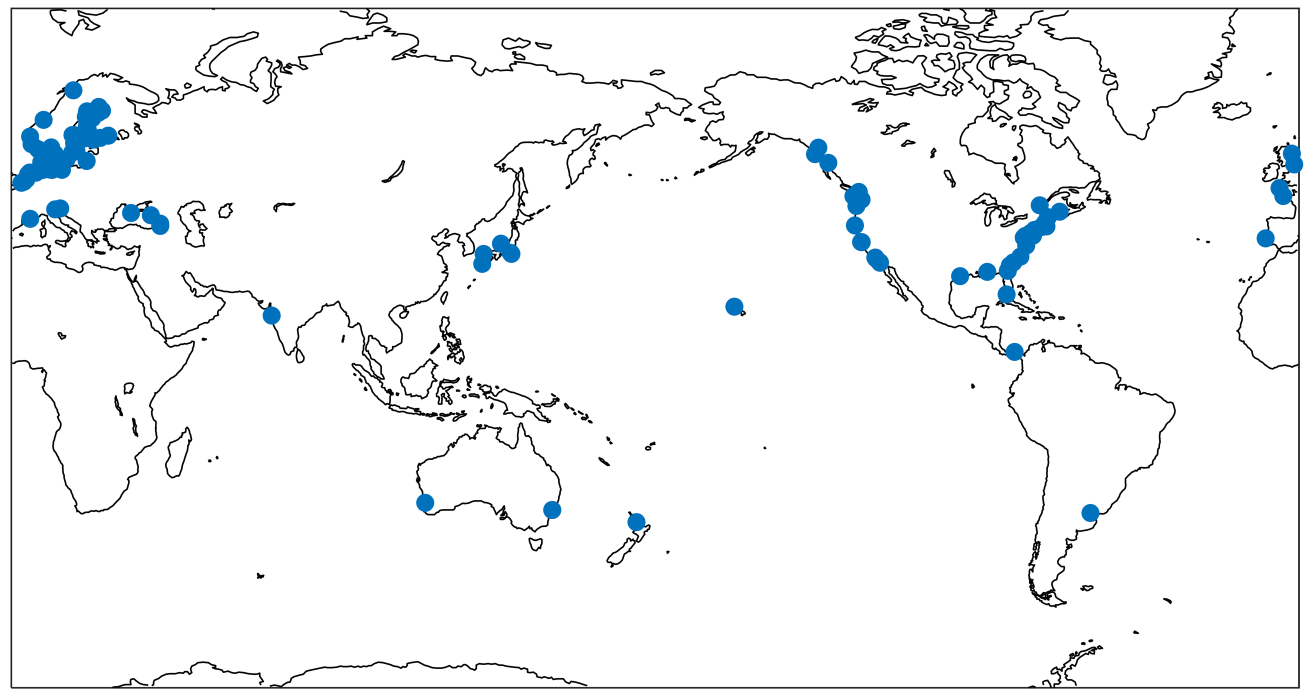

Fig. 1: Map of tide gauge locations.

Annual tide gauge records from the Permanent Service for Mean Sea Level (PSMSL) [3] selected using criteria: **timeseries must be ≥80% complete, with a minimum record length of 80-years** (Fig. 1) [2;4]. Remaining gaps in RLR timeseries interpolated using splines.

↓

Empirical Mode Decomposition (EMD) [5-6] applied to produce **Intrinsic Mode Functions (IMFs)** for each tide gauge (Fig. 2)

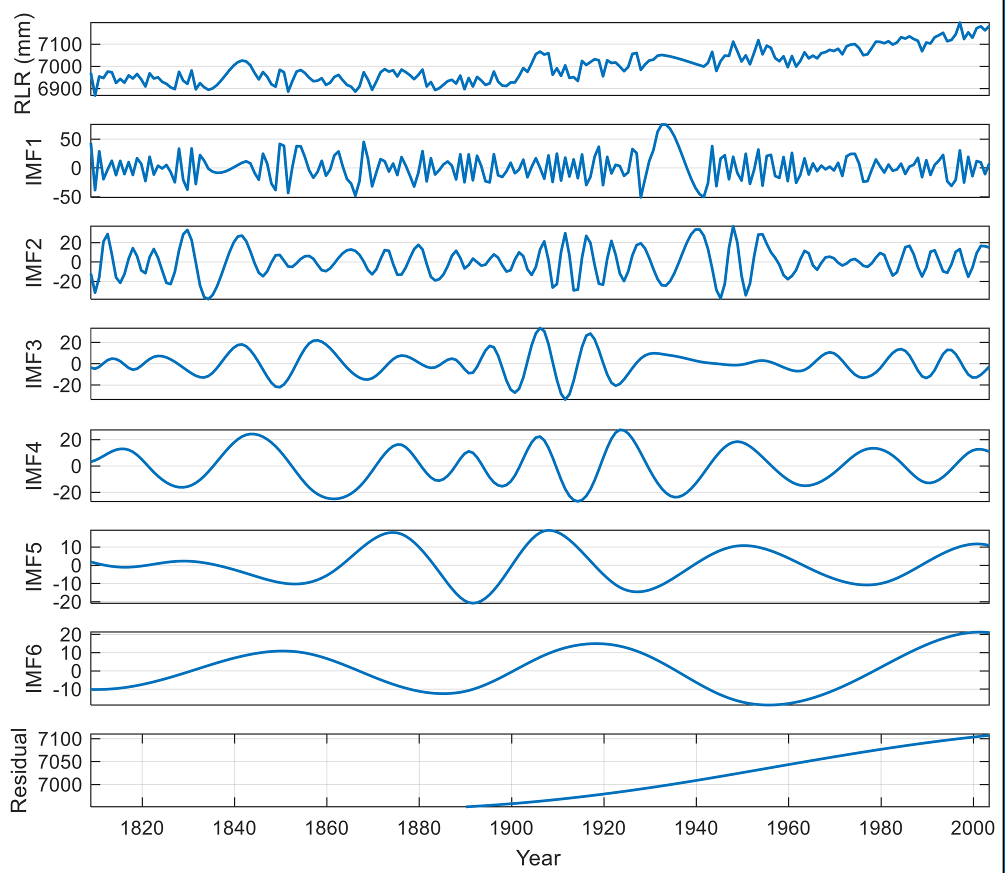

Fig. 2: Intrinsic mode functions (IMFs) for Brest, produced using EMD.

↓

Turning points in IMFs, and their corresponding annual values identified for each tide gauge (Fig. 3). **Time interval** between consecutive turning points (years) calculated, and multiplied by 2 to capture the entire wave period.

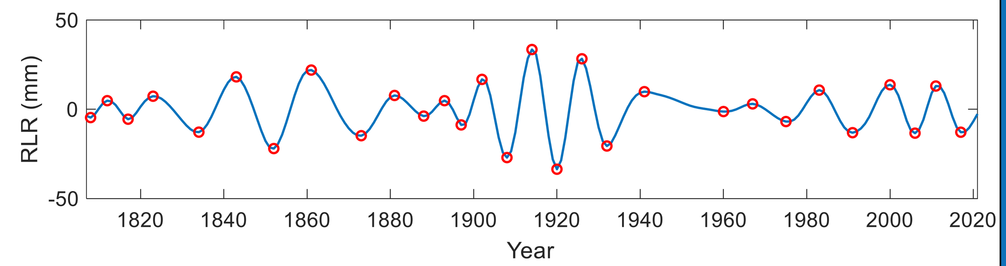

Fig. 3: Identified turning points for IMF 3, Brest.

↓

Time intervals used to determine **periodicities** of oscillations. Distribution of periodicities from each IMF plotted and represented as a probability density function (PDF) and kernel density estimation (KDE), for each tide gauge (Fig. 4). From these, dominant periodicities identified (*see section 3*).

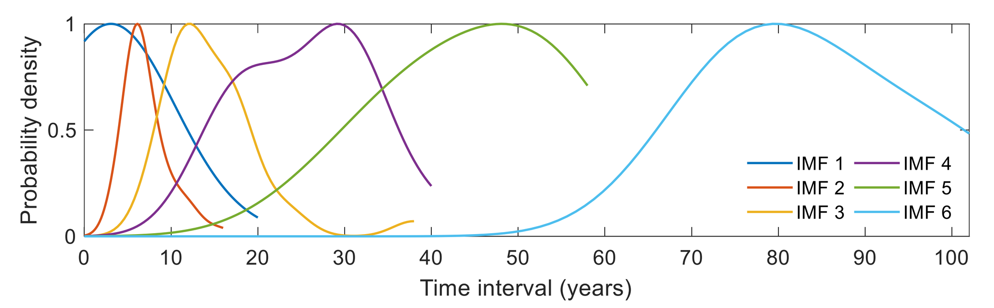

Fig. 4: Distribution of periodicities from each IMF, for Brest.

3. Periodicities

3.1 Global mean sea-level variability

Fig. 5 shows periodicities identified in each tide gauge shown in Fig. 1. Concatenating periods for all 121 tide gauges displays the **global** distribution of periodicities.

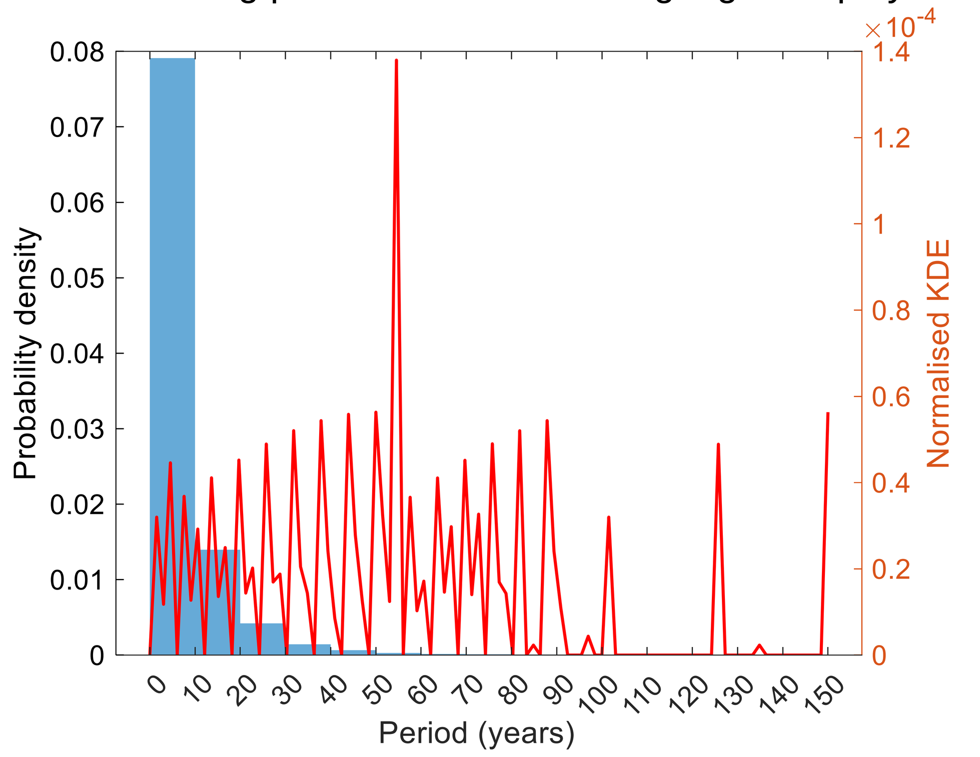

Fig. 5: Histogram (blue bars), and KDE (red line) for all periodicities, for all 121 tide gauges. KDE normalised based on the number of occurrences of each period value.

KDE of periodicities normalised (Fig. 5-7) based on the count of each period value, to identify the **dominant periodicities.**

- Fig. 5 shows a range of periodicities, with a minimum of 1.5-years, and a maximum of 150-years (Kungsholmsfort, Sweden).
- From Fig. 5, dominant periods identified as: 4.5, 7.5, 13.6, 19.7, 25.7, 31.8, 37.8, 43.9, 50, 54.5, 63.6, 69.6, 75.8, 81.8, 87.8, 101.5, 125.5, and 150-years.
- Most dominant period = 54.5-years.

3.2 Regional mean sea-level variability

Tide gauges initially divided by region, into **northern hemisphere** (NH) (Fig. 6a), and **southern hemisphere** (SH) (Fig. 6b) locations. Dominant periodicities (peaks) identified in table 1.

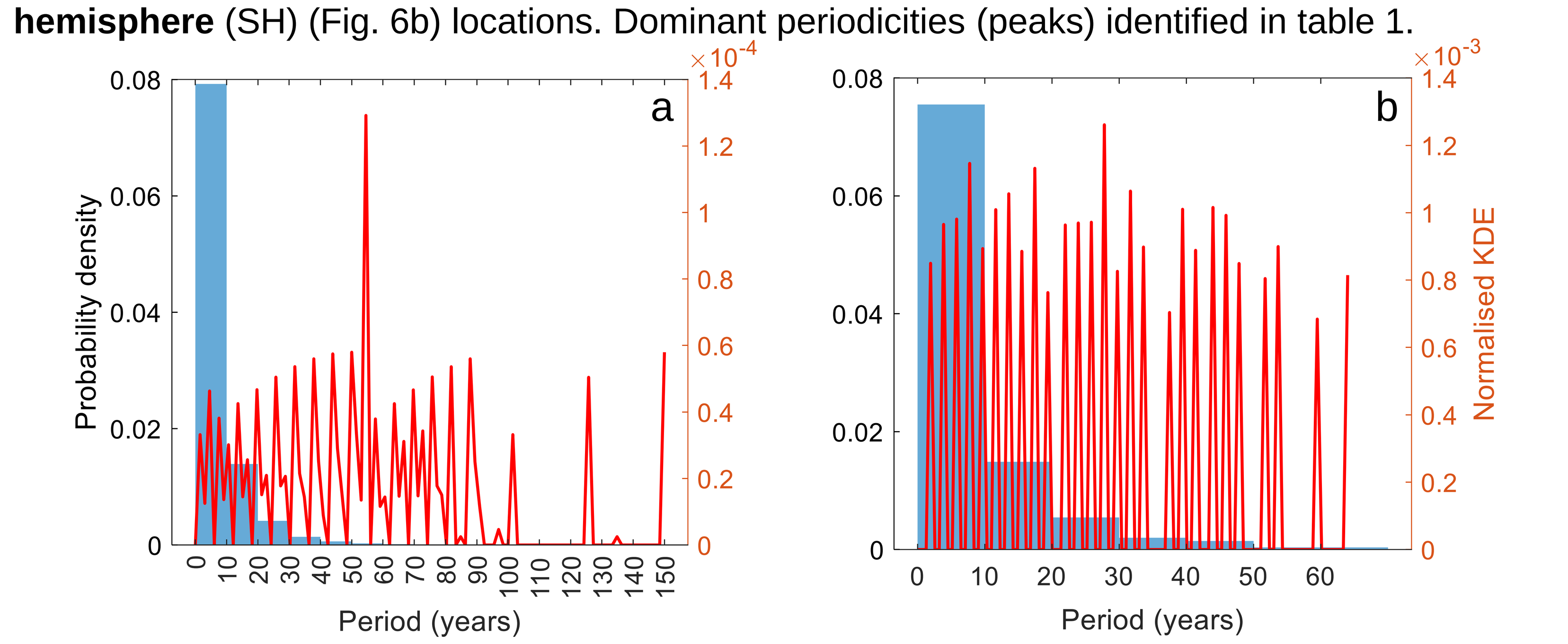

*Fig. 6: Histogram (blue bars) and KDE (red line) for periodicities for **(a)** Northern Hemisphere, **(b)** Southern Hemisphere. KDE normalised based on the number of occurrences of each periodicity value.*

Identified dominant periodicities (years)																
Northern hemisphere	4.5	13.6	19.6	25.7	31.8	37.8	43.9	50	54.5	63.6	69.7	75.8	81.8	101.5	125.7	150
Southern hemisphere	1.9	3.9	5.8	7.6	13.6	17.4	22 ± 0.1	24± 0.1	25.9	27.7	31.7	39.4	43.9	45.8	53.7	64

Table 1: Identified periodicities (years) for each hemisphere (see Fig. 6).

Tide gauges further separated by **ocean basin** [2], into North (NA) (Fig. 7a) and South Atlantic (SA) (Fig. 7c) North (NP) (Fig. 7b) and South Pacific (SP) (Fig. 7d), and Indian Ocean (IO) (Fig. 7e). Using dominant periodicities from Fig. 5, **common periodicities** across basins identified in table 2.

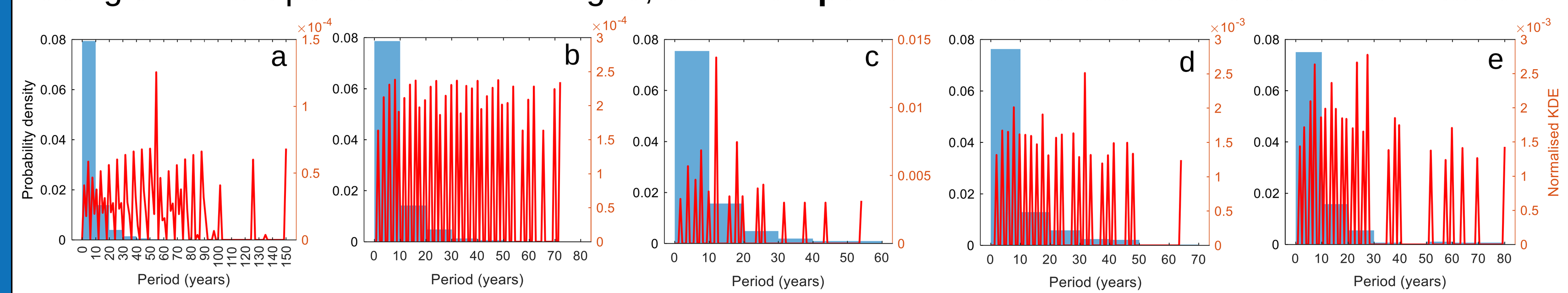

*Fig. 7: Histogram (blue bars) and KDE (red line) of all periodicities for: **(a)** North Atlantic, **(b)** North Pacific, **(c)** South Atlantic, **(d)** South Pacific, **(e)** Indian Ocean. KDE normalised by count of each periodicity value.*

	Dominant periodicities (years) from Fig. 5																	
	3.5 ± 1.0	7.6 ± 0.4	13.7 ± 0.1	18.6 ± 1	25.7 ± 2	31.6 ± 0.4	37.6 ± 0.3	43.6 ± 3.0	51 ± 2.0	54 ± 0.7	63 ± 3.0	69.6 ± 2.0	75.7 ± 3.0	81.8	87.8	101.5	125.7	150
N. Atlantic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
N. Pacific	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓					
S. Atlantic	✓	✓		✓	✓	✓	✓	✓		✓								
S. Pacific	✓	✓		✓	✓	✓	✓	✓			✓							
Ind. Ocean	✓	✓	✓		✓		✓		✓		✓	✓						

Table 2: Periodicities (years) identified for each ocean basin (see Fig. 7). Checks show where similar periods have been identified in multiple basins.

4. Discussion

4.1 Common periodicities

The periodicities identified in the mean sea level records (Fig. 5-7) represent the **temporal frequencies of sea-level oscillations.**

- 63.6-year global mean sea level (GSML) oscillation (Fig. 5) is in-line with existing studies [2;7] that examine low frequency global mean sea-level variability and identify a ~60-year GMSL oscillation.
- Though identified in GMSL, a ~63-year period is not found in all ocean basins (table 2).
- The most dominant period of 54.4-years (Fig. 5) is in-line with [8], who approximate the periodicity of a distinct GMSL oscillation to be between 50 and 60-years.
- The 63.6-year periodicity identified in the NA (table 2) is consistent with other studies [2;9] which have identified a ~60-65-year NA sea-level oscillation, using sea-level accelerations.
- Smaller 20-30-year periodicities in global and regional records (Fig. 5-7, table 1-2) are consistent with other research, which has identified bi-decadal sea-level oscillations alongside, and rather than, ~60 to 80-year multi-decadal variability [9-10].

4.2 Possible causal factors

On decadal and multi-decadal timescales, sea-level changes may be attributed to distinct **modes** of internal oceanic and atmospheric variability (Fig. 8).

Ocean-dynamic sea-level variability

- The 63.6 to 81.8-year periodicities identified in the NA share the same temporal frequency as the **Atlantic Multidecadal Oscillation (AMO)** [2;8].
- 20 to 30-year periodicities found in the Pacific basin (Fig. 7b-d) align with the periodicity of the **Pacific Decadal Oscillation (PDO)** [1].
- ~18-year periodicity identified in multiple ocean basins (Fig. 7a-e) (Table 2) may be attributable to the 18.6-year **lunar nodal cycle** [11].

Atmosphere-driven sea-level variability

- Lower periodicities of 2 to 8-years (table 1-2) align with the periodicity of the **El Nino Southern Oscillation (ENSO)** [1;12].

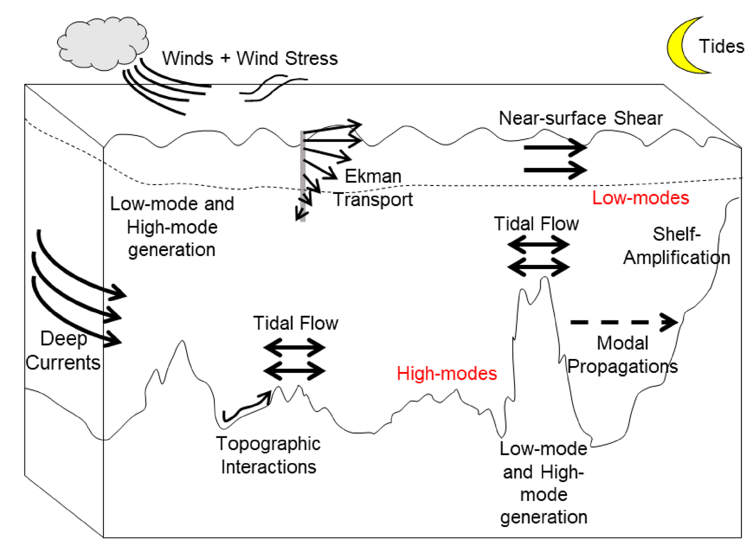

Fig. 8. A schematic of the primary mechanisms driving ocean-mixing and associated sea-level changes. Adapted from Whalen et al. (2020).

5. Summary

We have used EMD to separate both global and regional mean sea level timeseries into a series of IMFs and, from these, have identified the dominant periodicities of sea-level oscillations in long tide gauge records. Periodicities that have been identified, have been provisionally compared with temporal frequencies of recognised modes of climate variability.

5.1 What next?

- Use of **high-resolution proxy-based sea level reconstructions**.
  - To extend the spatial coverage of sea-level records. There is spatial bias when using the PSMSL database (Fig. 1) as most suitable records are located in the NH (96%), and the NA basin (77%).
  - To test the feasibility of using EMD as a method to identify oscillations in different sea-level timeseries records.
- Compare distribution of periodicities on east and west margin of ocean basins.
- Sensitivity analyses.
- Relate identified sea-level oscillations to rates of sea-level change.

References

1. Hamlington et al. (2019). *Journal of Geophysical Research: Oceans*, 124(4), pp.2750–2768.
2. Chambers et al. (2012). *Geophysical Research Letters*, 39(18).
3. Holgate et al. (2013). *Journal of Coastal Research*, 22(3), pp.493-504; Permanent Service for Mean Sea Level (2024). *Retrieved 23 Jan 2024.*
4. Watson (2017). *Journal of Coastal Research*, 33(1), pp.23–38.
5. Huang et al. (1998). *Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, 454(1971), pp.903–995.
6. Jackson and Mound (2010). *Geophysical Research Letters*, 37(14).
7. Jevrejeva et al. (2008). *Geophysical Research Letters,* 35(8).
8. Sturges and Douglas (2011). *Journal of Geophysical Research: Oceans,* 116(C6).
9. Kengison and Han (2014). *Journal of Geophysical Research: Oceans,* 119(12), pp. 8749-8766.
10. Frankcome and Dijksta (2009). *Geophysical Research Letters,* 36(15).
11. Baart et al. (2012). *Journal of Coastal Research,* 280, pp. 511-516.
12. Hamlington et al. (2015). *Journal of Geophysical Research: Oceans,* 120(6), pp. 3970-3986.

EGU Outstanding Student & PhD candidate Presentation contest