Regionalisation of ocean climate indicators

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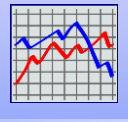
The regionalisation of ocean climate indicators
Why?

Unique patterns in different regions

Regional trends compared to global



Why

Isolate the mechanisms and drivers

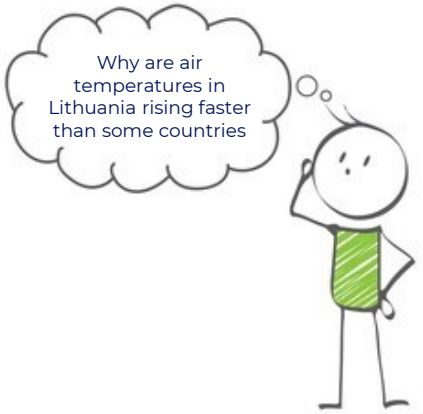
Provide stakeholders with data to develop policies to address local challenges

Ocean climate indicators may have local and a remote influence

AMOC slowdown	Alters European Weather
Warmer North Atlantic Ocean	Changes in European weather
Melting Arctic sea ice	Changes to atmospheric circulation and more extreme weather

We also need to tailor the ocean indicator to the question we are trying to answer

Local Irish Sea changes in SST may be the best indicator



Remote changes in Arctic Sea Ice and North Atlantic Ocean temperatures may be influencing changes in the atmospheric circulation and jet stream patterns, leading to warmer than average temperatures over Lithuania

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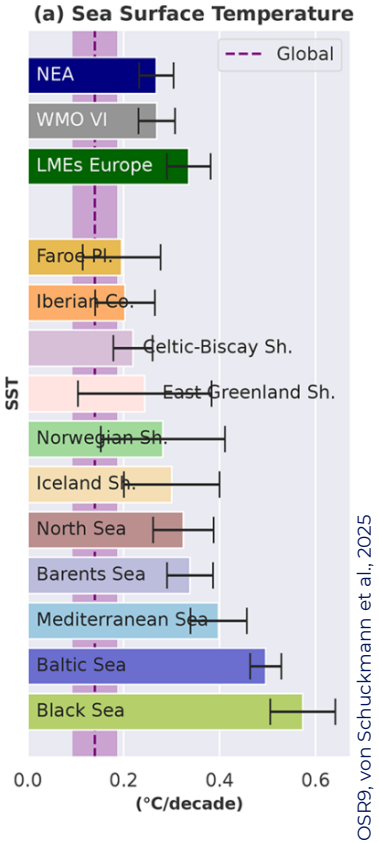
The regionalisation of ocean climate indicators
How?

The 5 steps to follow:

1. Define a context
2. Look for data availability
3. Check data robustness
4. Process data
5. Analyse and interpret the outcome



A **case-study** in the northeastern Atlantic and adjacent seas taken from the 9th Ocean State Report (OSR) will accompany each step to illustrate the process

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The regionalisation of ocean climate indicators
How? Defining a context

The very first step of the *regionalisation of ocean climate indicators* should be the **definition of the context**

- "What question do I want to answer?" will help me understand what are my needs:
  - Which **variable**(s) is or are relevant for my study?
  - What is my **region** of interest? Do I need a single point observation, an area-averaged indicator? Do I need to look at spatial patterns?
  - What are the relevant **timescales** in play? How far back in time do I need my data to go?
- To help me in this task, I will have to go through **literature**: the same queries might have been raised in a different region or for a different time period

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The regionalisation of ocean climate indicators
Case study Northeastern Atlantic and adjacent seas

Question: "How fast did the northeastern Atlantic and adjacent seas warm over the last 40 years, in the context of global ocean warming?"

- **Variables**: I need the sea surface temperature (SST) in the northeastern Atlantic and adjacent seas and in the global ocean
- **Region**: I need a definition of the northeastern Atlantic and adjacent seas, I will use area-averaged indicators, so I don't need a fine spatial resolution
- **Timescales**: I need data over the last 40 years, with no need of fine temporal resolution (monthly or yearly are good, daily are not needed)

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How? Looking for data availability

Now that I have *defined the context* of my study, I can start looking for **data availability**

- In order to get the best understanding of my raised question, I will try to *use all capacities available*: if possible, I will use multiple datasets
  (with in mind that I want to check for their **agreement**)
- There are many kinds of data:
  - **in-situ** observations
  - **satellite** observations
  - **reanalyses** based on observations and modelisation
  - model **simulations**
- For many kinds of datasets, many ways of access!
  - Some are available on **open platforms** (ex: Copernicus Marine, ESGF), some need to go on **production centres' platforms**, and sometime the only way through is **contacting authors**, as datasets might not be already published yet
  - Here again, as data localisations are given in papers, **literature** will help me to find my path
- Data availability is also a matter of spatiotemporal availability inside the dataset
  - In-situ observations **lack** of measurements, especially in the more distant past
    (this can also affect the confidence of reanalyses for certain places at certain times)

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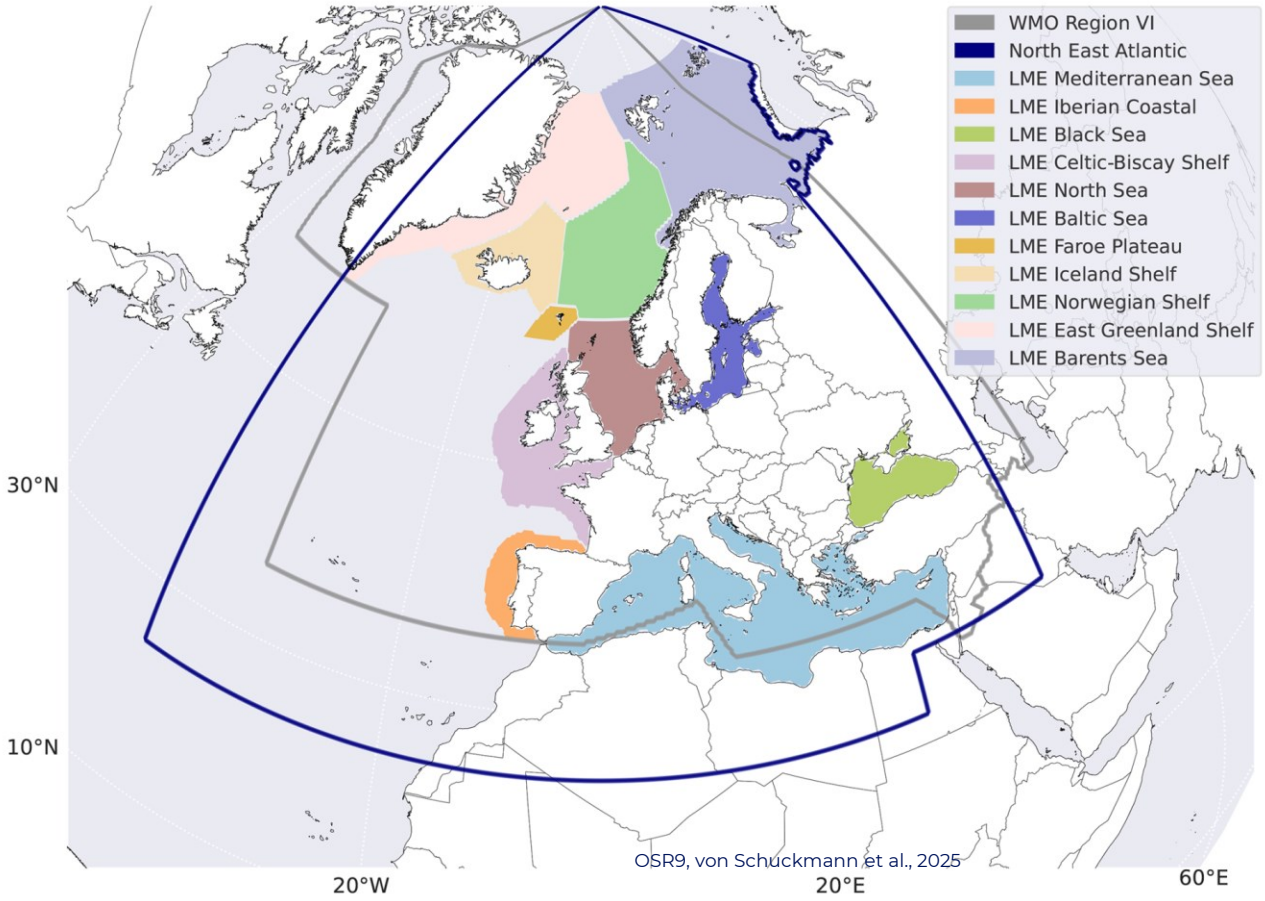
Case study Northeastern Atlantic and adjacent seas

- Before looking at the availability of SST datasets, I decide to look for a definition of the northeastern Atlantic and adjacent seas
  - I will use 3 products:
    - The WMO delineation of Europe (grey)
    - The northeastern Atlantic and adjacent seas, covering all European economic zones, as defined in the 8th OSR (blue)
    - The Large Marine Ecosystems (LME) that are located in the region, taken all together (shown in dark green, not on the map), or individually (other colours)
  - Delimiting a region of interest involves making choices



Note that: depending on the context, regions might be delimited based on socio-economical and political priorities, instead of physical characteristics

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The regionalisation of ocean climate indicators
Case study Northeastern Atlantic and adjacent seas

- Now that I have defined my region of interest, I need to look for SST datasets that (i) cover the northeastern Atlantic and adjacent seas, but also some that cover the global ocean, and (ii) cover the last 40 years
  - I will use 4 observations products:
    - OSTIA
      - SST_GLO_SST_L4_REP_OBSERVATIONS_010_011: 10/1981 to 12/2023, reprocessed satellite observations, from EU Copernicus Marine Service Product (2023a)
      - SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001: 01/2024 to 01/2026 analysed satellite observations, from EU Copernicus Marine Service Product (2023b)
    - OISST
      - Optimum Interpolation Sea Surface Temperature: 09/1981 to 01/2026, processed in-situ and satellite observations, from Huang et al. (2020)
    - ESA-CCI
      - SST_GLO_SST_L4_REP_OBSERVATIONS_010_024: 09/1981 to 12/2024, reprocessed satellite observations, from EU Copernicus Marine Service Product (2021)
    - ODYSSEA
      - SST_GLO_PHY_L4_MY_010_044: 01/1982 to 12/2024, intercalibrated satellite observations, from EU Copernicus Marine Service Product (2024j)
      - SST_GLO_PHY_L4_NRT_010_043: 12/2020 to 01/2026, intercalibrated satellite observations, from EU Copernicus Marine Service Product (2023d)

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How? Checking for data robustness

Now that I am aware of the *context* and have my *data* ready, I need to **check their robustness**

- Ideally, each dataset should be provided with a **confidence interval**, as there might be uncertainty:
  - resulting from *potential measurement errors* (in-situ),
  - coming from *assumption* made in the *processing* of data (in-situ and satellite),
  - originating from a *lack* of observed data to build the dataset (reanalysis),
  - linked to the use of *multiple simulations* to produce the data (reanalysis and modelisation)
- Unfortunately, many products are **lacking** this information, which strengthens the need to **maximise the use of available capacity** in order to access the *agreement* in between datasets
- Going through the **literature**, I will be able to identify potential *weaknesses* of certain datasets

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Case study Northeastern Atlantic and adjacent seas

- ✓ Datasets are based on satellite observations, and are daily gap-free maps covering the entire globe, at various resolutions (0.05° to 0.25°), starting in 1981 or 1982
  - All the datasets used cover the globe for the last 40 years, with no missing values in time or space
    - The spatiotemporal resolution exceeds my requirements
  - However, there was no confidence interval distributed with some datasets
    - This is counterbalanced by the use of 4 data sets
- ✓ The literature shows **good trust** in their use for the region of interest and for the global ocean

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The regionalisation of ocean climate indicators
How? Processing data

I have now *checked all available data* for my *context*, it is time to **process** them

- If I need to apply specific calculations to my multiple datasets, different approaches are possible:
  1. Look at each dataset individually (apply the calculations to each dataset)
  2. Look at the datasets as an ensemble:
     i. The calculations **can take data with a confidence interval** as input: in that case I can compute an ensemble average and variance to be used from now on onwards for calculations
     ii. The calculations **cannot account for uncertainties** in the input: in that case I will apply the calculations to each dataset, and then figure out an ensemble average and variance
- If my data come from gridded products, but I need area-averaged values, I will compute the **latitudinal weighted mean** for each dataset individually
- If my context requires the study of spatial patterns, and I have multiple relevant datasets ready with different resolutions, I might want to fit all datasets on a common grid
  - If I decide to interpolate data on a finer mesh, I must keep in mind that it might induce biases
    - In particular, I have to be very careful with grid cells on the coasts (higher process uncertainty)
  - The coarse mesh is often the one chosen, even if it degrades some of the datasets quality

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Case study Northeastern Atlantic and adjacent seas

- I will proceed as follows:
  1. Compute all regional latitudinal weighted averages for each dataset
  2. Compute the decadal trend over the 40 years for each dataset
  3. Figure out an average trend, and the 95% confidence interval based on my 4 datasets

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The regionalisation of ocean climate indicators
How? Analysing and interpreting

I have now *proceeded* all *relevant available data* for my *context*, it's time to *analyse* and *interpret* the results!

- The finer the regional scale, the higher the potential role of **internal variability** in the indicator: risk of masked long-term signal
  - **Longer-term datasets**, if available, will provide a broader view of the implications at play (ex: forcing vs. internal variability)
    - If the region of interest is not too small, GCM simulations are a good tool to add some long-term context to observations, as they start in 1850
  - As previously multiple times mentioned, the **literature** is my best ally: it will guide me in understanding the contributing factors to what I observe
  - I might want to **contact specialists** who are familiar with my area of interest to assist me

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The regionalisation of ocean climate indicators
How? Analysing and interpreting

I have now *proceeded* all *relevant available data* for my *context*, it's time to *analyse* and *interpret* the results!

- If I am using multiple products, I might want to have a careful look at the confidence intervals:
  - Do the datasets agree and show a signal I can communicate on with confidence?
  - If the confidence interval is large, can I explain this disagreement?
    - In some cases, there can be a disagreement in the sign of change of my indicator

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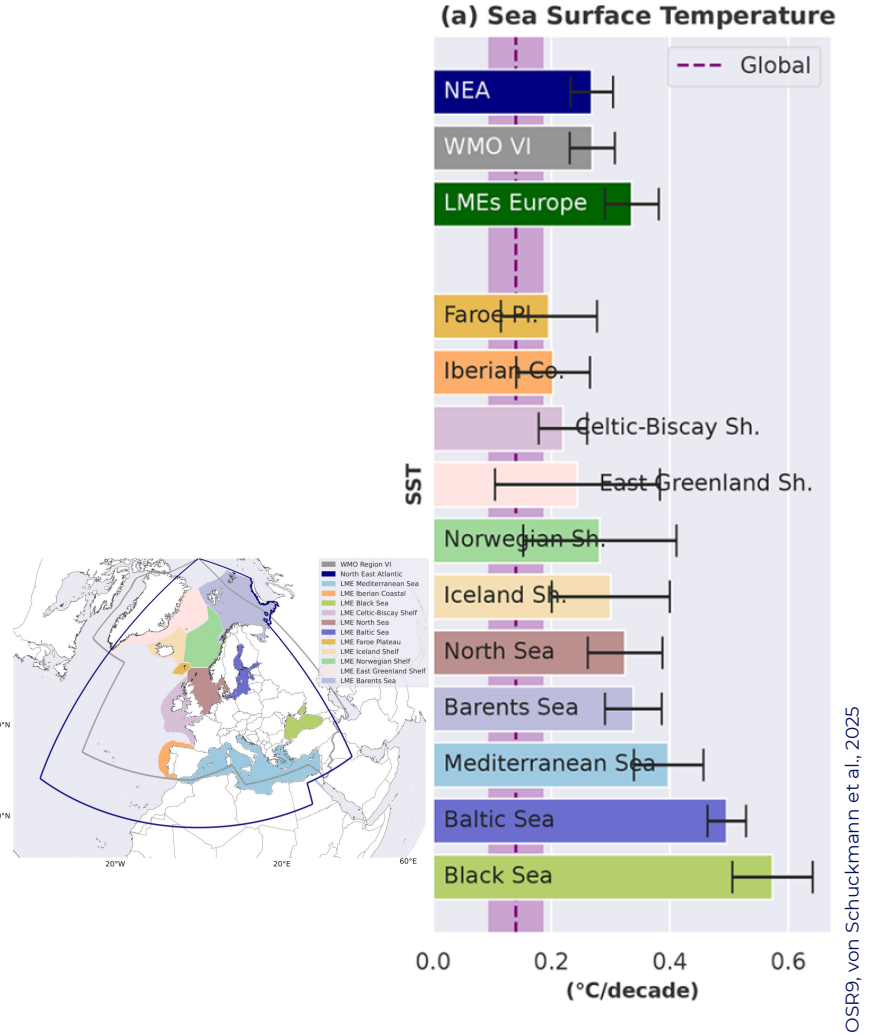

OSR9, von Schuckmann et al., 2025

- Northeastern Atlantic and adjacent seas
  - In NEA, regional mean sea surface ocean warming are higher than the global trends, with rates of $+0.27 \pm 0.04$ °C per decade between 1982 and 2024
  - There is a strong agreement in between datasets (small confidence interval) and in between region delimitations (NEA, WMO VI, and European LMEs)
- European Large Marine Ecosystems
  - Ocean change is not uniform: semi-enclosed basins, such as the Baltic, Black, and Mediterranean seas, are experiencing the most rapid warming due to limited exchange with the open ocean
  - The Faroe Plateau, Iberian coast, and Celtic-Biscay Shelf show lower warming rates compared to other European seas, though they still exceed the global average
    - These regions lie close to the open Atlantic, where long-term warming interacts with pronounced internal variability (Årthun et al., 2021; Jackson et al., 2022)

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Take-home messages & recommendations

- The investigation of climate change on regional oceanic climate indicators is **challenged** by the fact that the role of **internal variability** increases as temporal and spatial scales become smaller and more localised
- **Make a good use of literature** to guide *defining the context*, *finding* data, *checking* their *relevancy*, *processing* them, and *analyse* and *interpret* the results
- **Maximize the use of available capacities** to strengthens the robustness of the conclusions
  - Unless the literature explains why one dataset is an outlier that should not be used in the study
    (this information therefore deserves to be included in the study communication)

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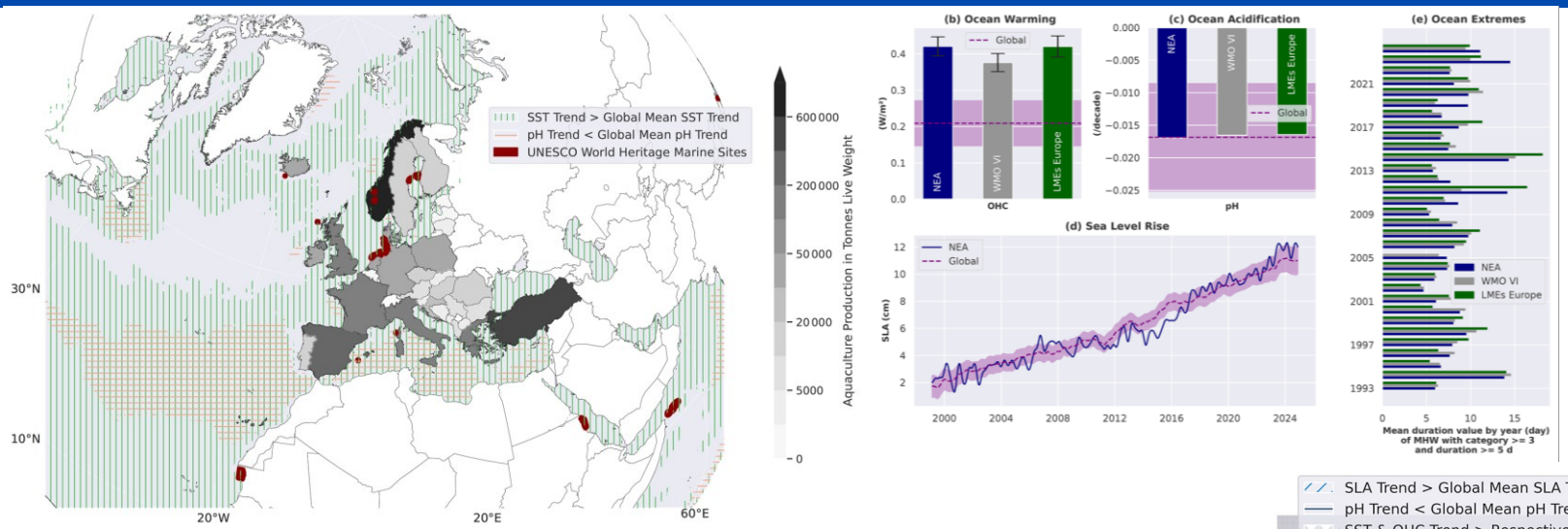
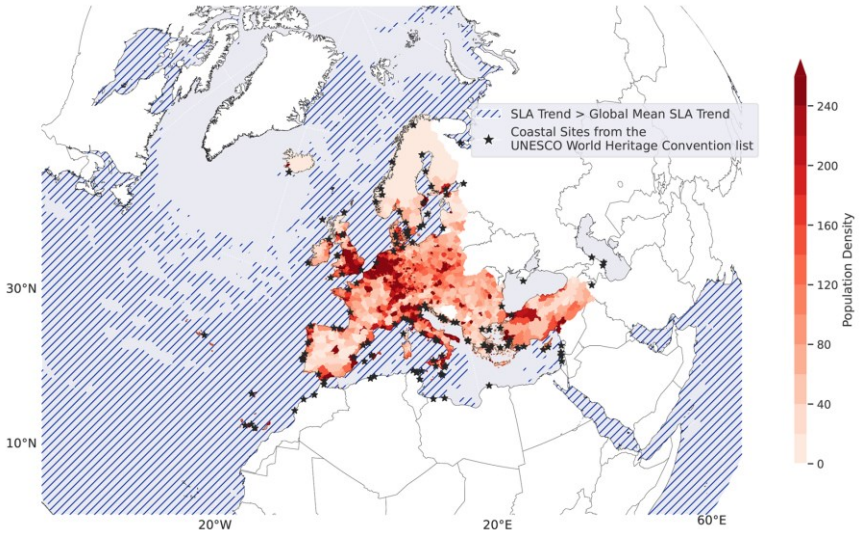
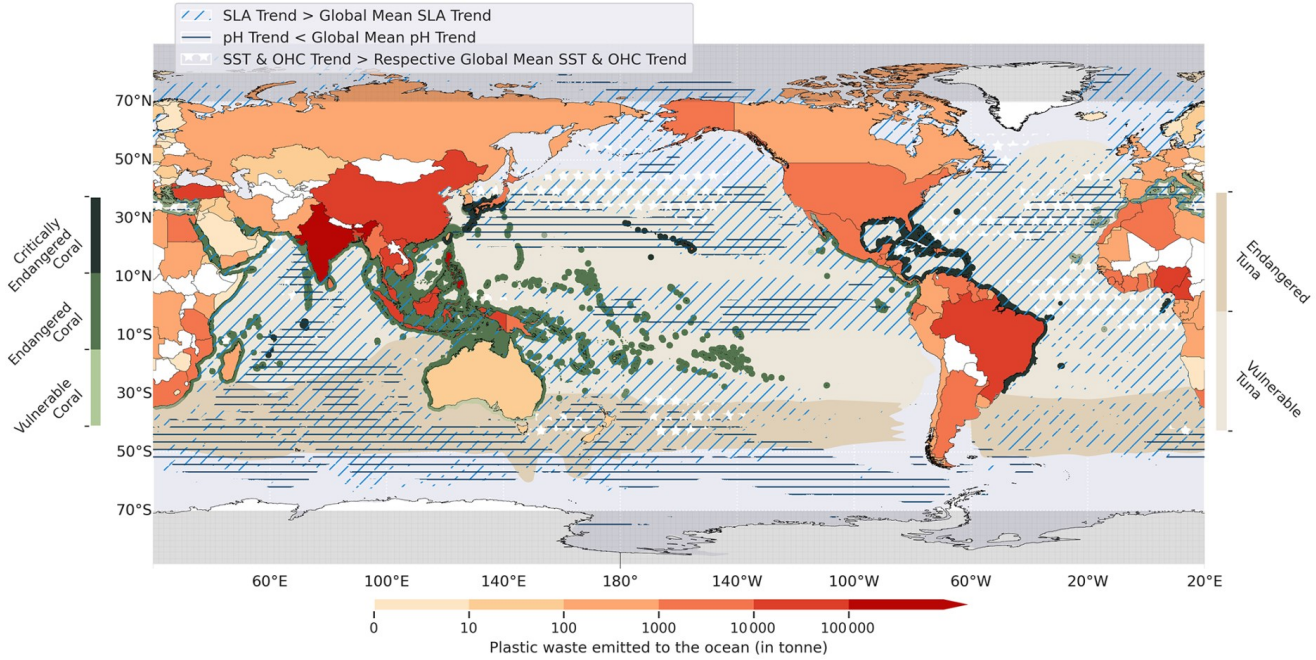
More examples of regionalisation in the 9th OSR







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