Preparation of environmental data

With a focus on linking the environment to a biological process for integration into MSEs

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ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

SEAWISE

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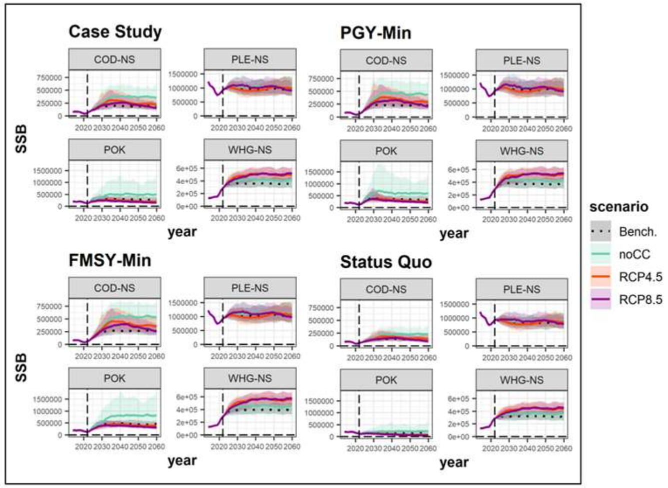
Goal

- Explicitly incorporating future climate change effects in MSE simulations (learn how to do this in this workshop)

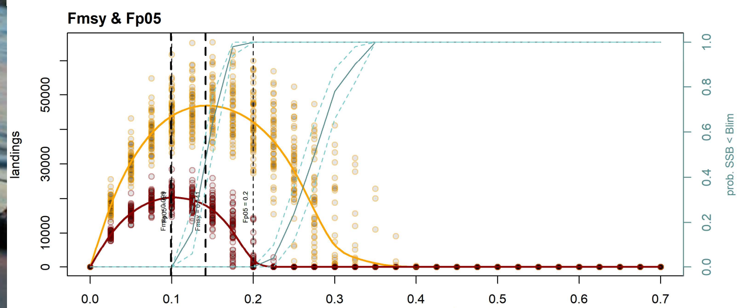
How do we get there?

What environmental data to use and how to prepare it?

Test different harvest control rules e.g. in a mixed fisheries context



Changes in Reference points with climate change

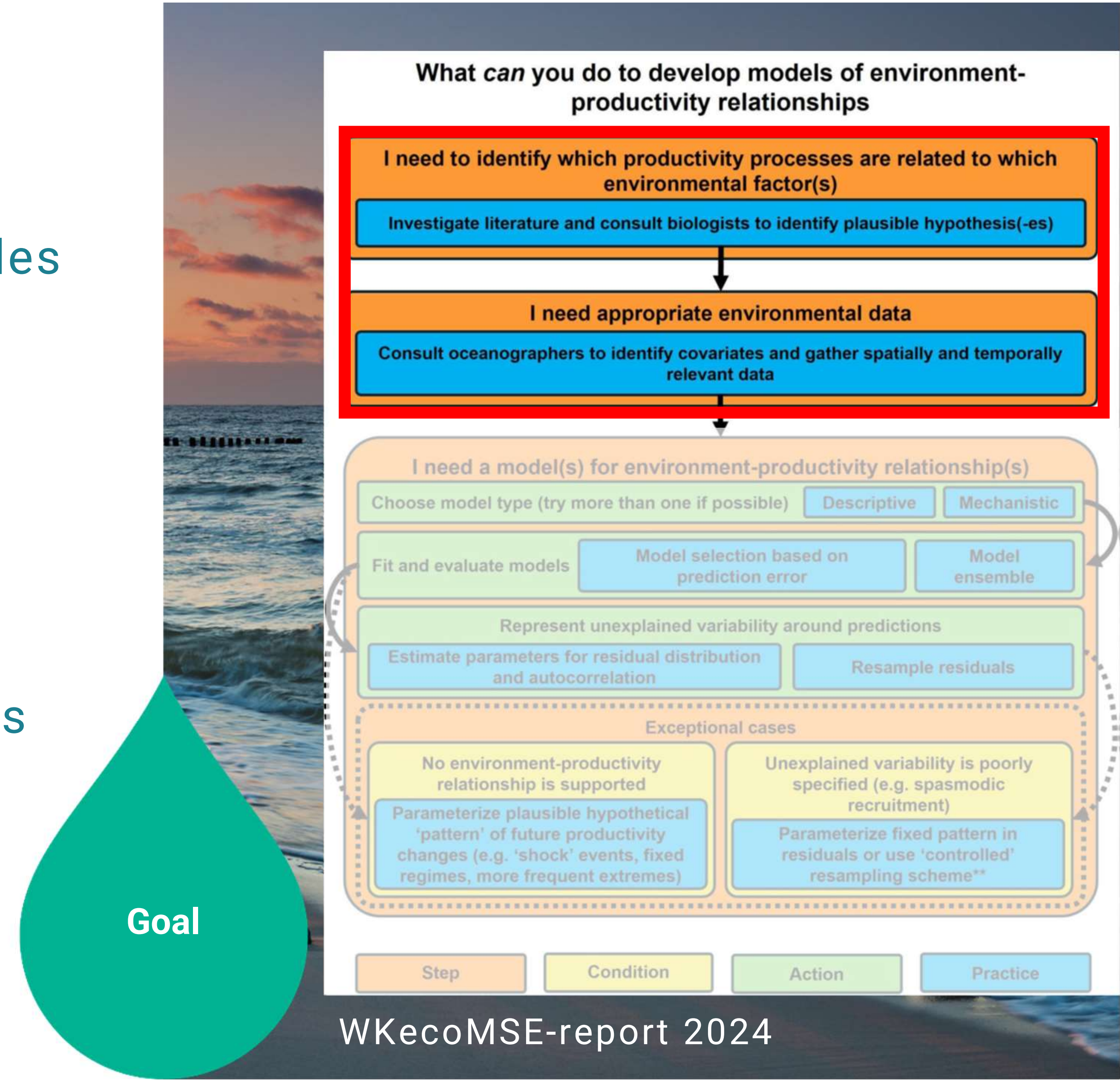


Goal

Where are we?

- Identify relevant env. variables for your species/biological process of interest

- Choose appropriate environmental data
  - Availability (hist./proj.)
  - Plausibility (scales)
  - Modelled vs. observations

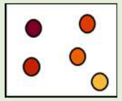


Types of environmental data & what to use

Historical data:

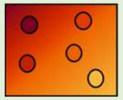
Ok to use!

Observations :



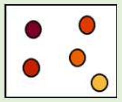
(raw data like CTD-measurements, argo floats, measurements at specific stations, remote satellite measurements…)

Physical-statical interpolations:



(gridded interpolated observations like AHOI, World Ocean Atlas…)

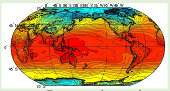
Reanalysis (observations + model aka data assimilation)



Observations

e.g. HadISST2 SST, OSTIA SIC, EN4 in-situ, AVISO DT2014 SLA

+



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Atmospheric Forcing

e.g. ERA-interim

+

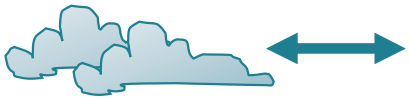
Ocean model

e.g. NEMO

+ …

e.g. additional sea-ice model

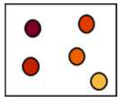
Coupled model runs (coupled atmosphere-ocean model)



Atmospheric model

Ocean model

vs.



Observations

- Atmosphere and ocean model exchange information in real time
- Calibrated to match observations, with the goal of reproducing/ analyse the mean climatology, rather than **interannual pattern**

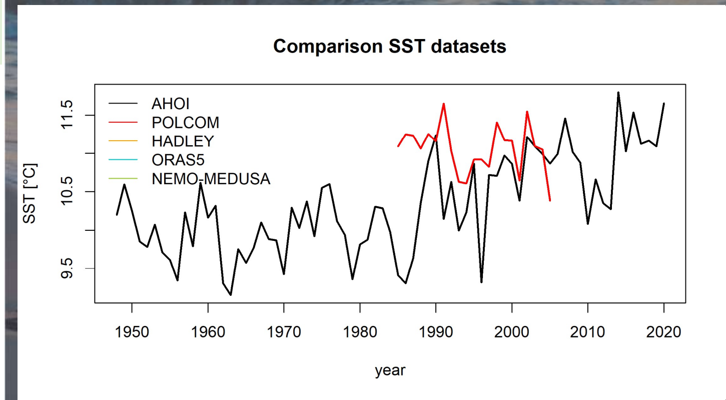
Future data:

Climate projections (RCPs, SSPs)

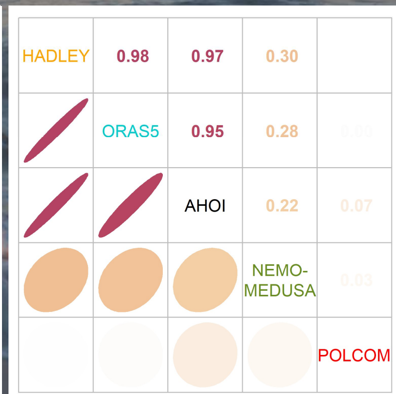
= **Coupled run!**

(often initialised with observations/reanalysis)

→ As you do not have any observations or forcing to use for the future, there is the explicit need to include atmosphere-ocean coupling



obs./reanalysis



projections

Preparation of environmental data

- Historical data and future projections come in the form of a 3d (lat,lon, time) or 4d (+ depth) spatio-temporal field → needs to be aggregated to have a time series of the env. process

Spatial averaging
→ Over certain life-cycle related regions of interest

simple
More informed
Easy to interpret

complex
More Data-driven
Harder to interpret

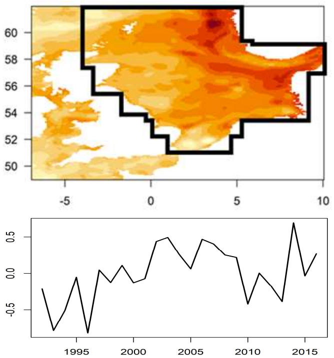
EOF/PCA-analysis

EOT-analysis

Spatial-Clustering

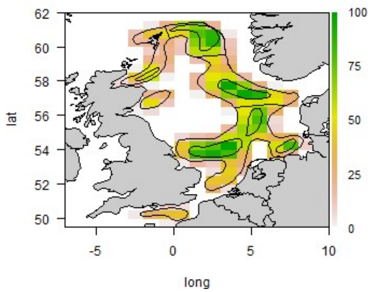
...

Spatial averaging **over whole domain**

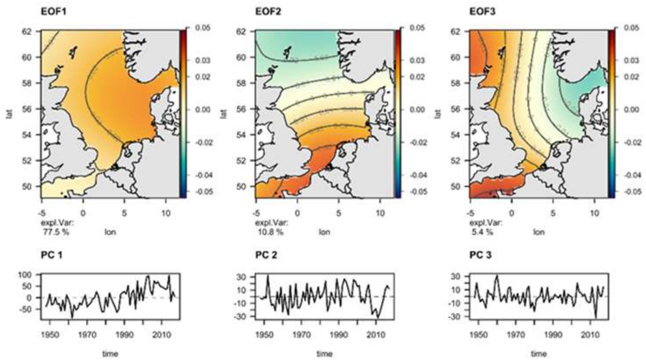


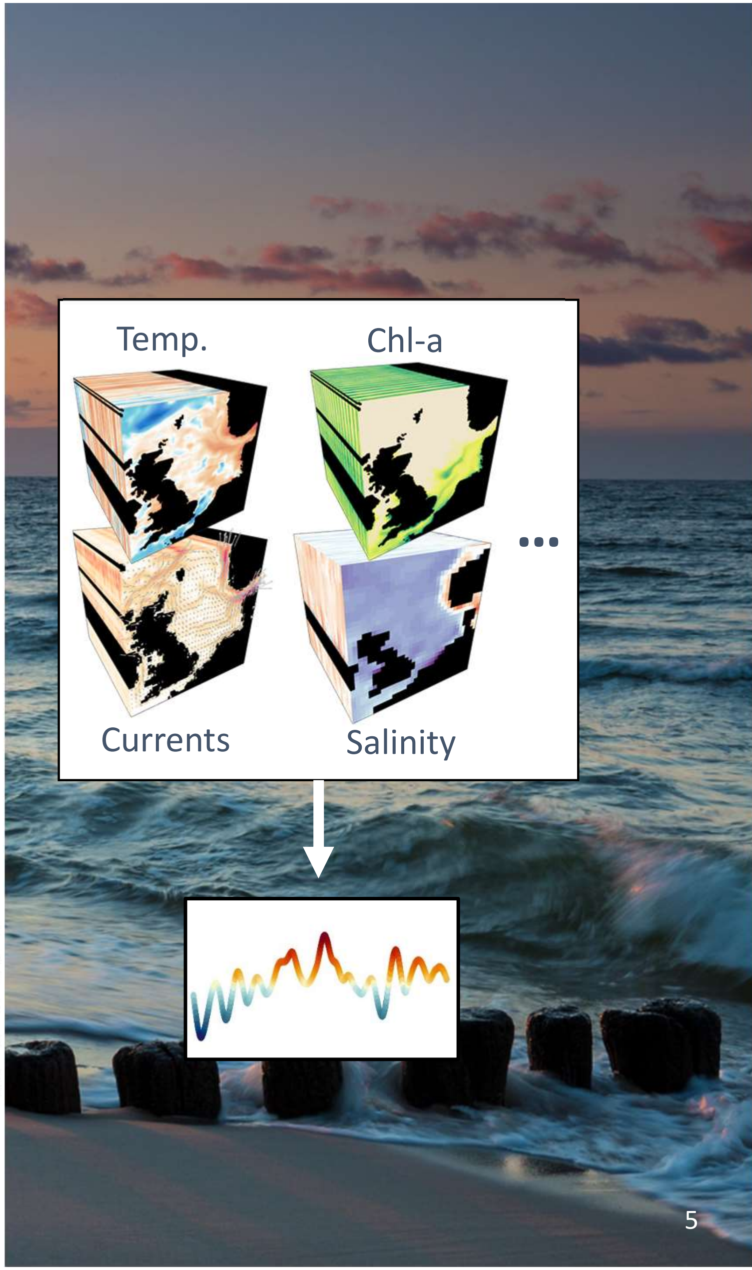
Informed spatial averages **over certain areas**

(spawning grounds, nursery grounds, feeding grounds, along migratory paths)



EOF-analysis

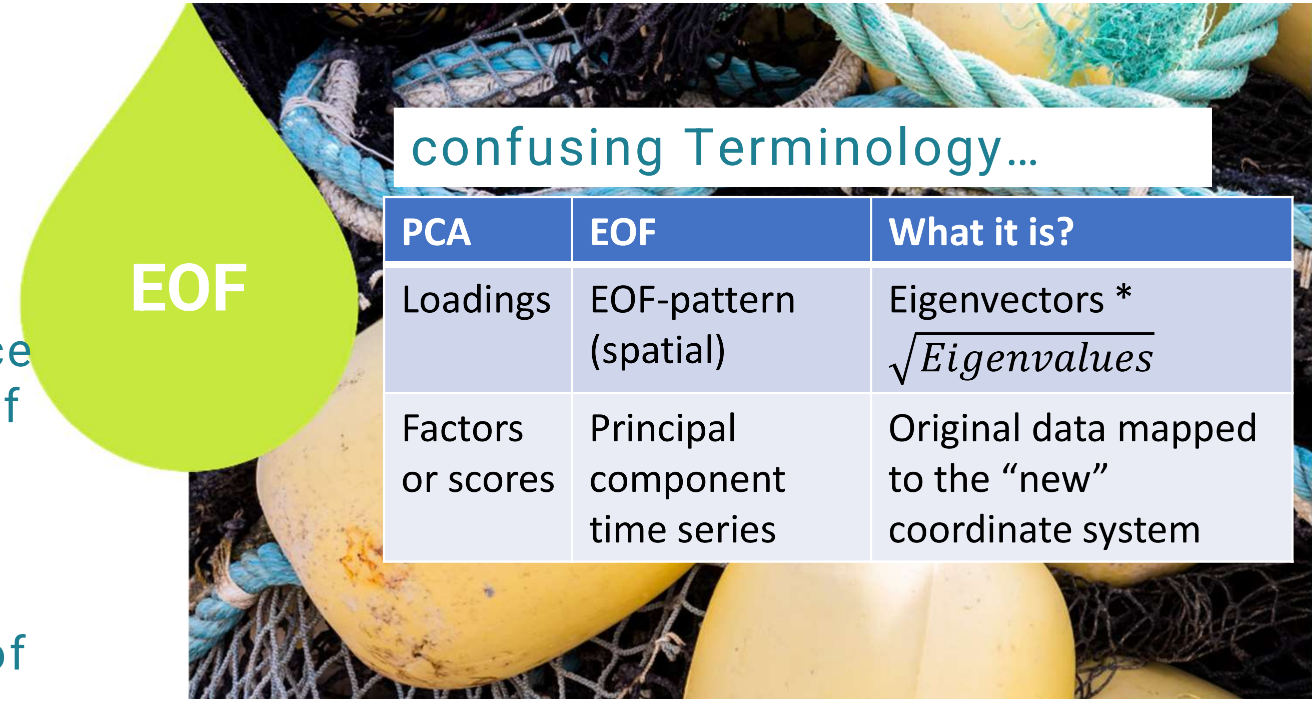




EOF/PCA

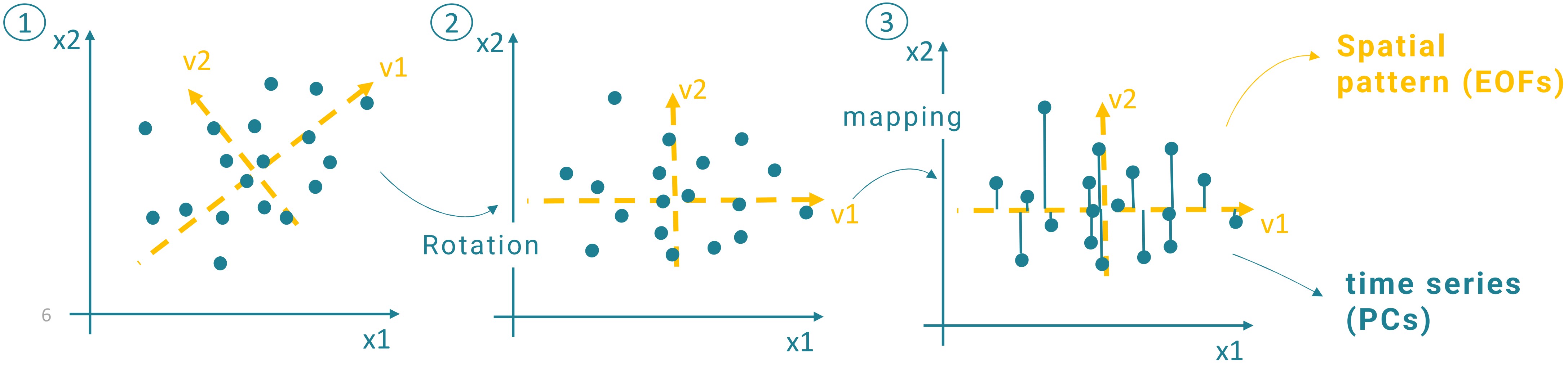
– Empirical orthogonal functions/Principal component analysis

- Linear dimension reduction to reduce a high dimensional field into a set of Eigenvalues (variance λ) + Eigenvectors (directions v)
- Can be understood of rotating your coordinate-system in the direction of the largest variance in your data



confusing Terminology…

PCA	EOF	What it is?
Loadings	EOF-pattern (spatial)	Eigenvectors * $\sqrt{Eigenvalues}$
Factors or scores	Principal component time series	Original data mapped to the “new” coordinate system



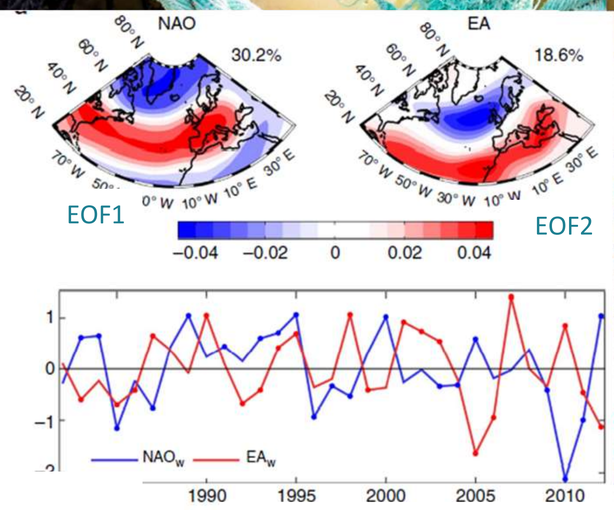
EOF/PCA

– Empirical orthogonal functions/Principal component analysis

EOF

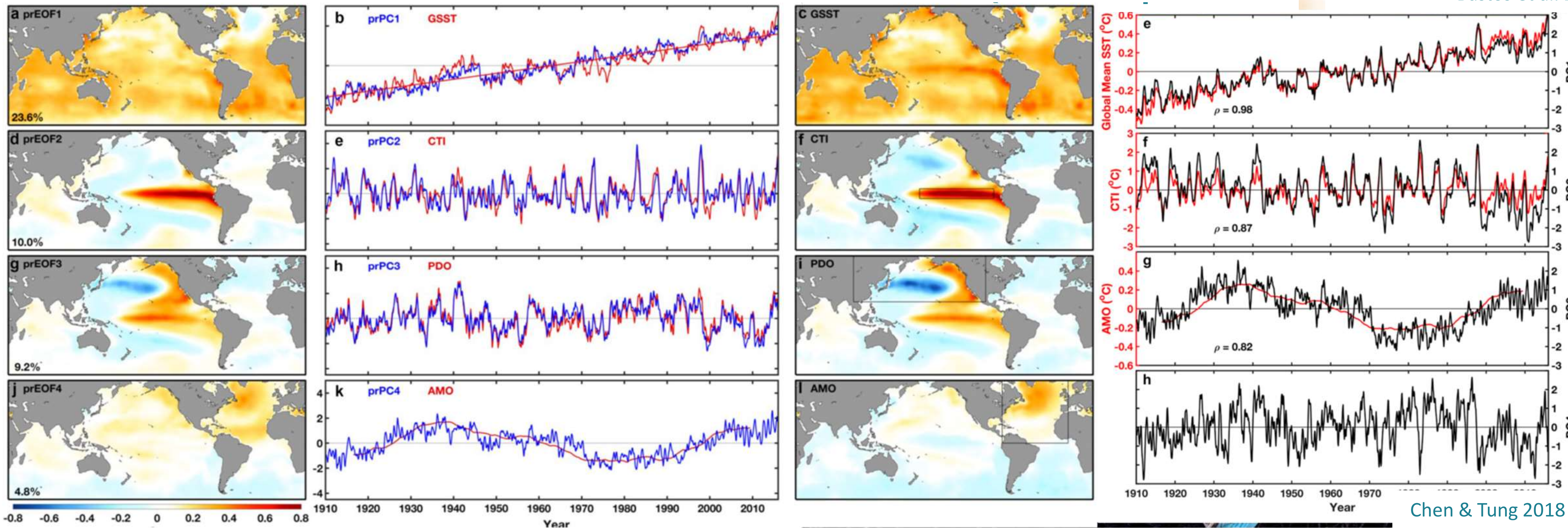
Examples:

North Atlantic Oscillation (NAO) & East Atlantic Pattern (EA):



Bastos et al. 2016

Rotated-EOF to represent more “physical modes”:



Chen & Tung 2018

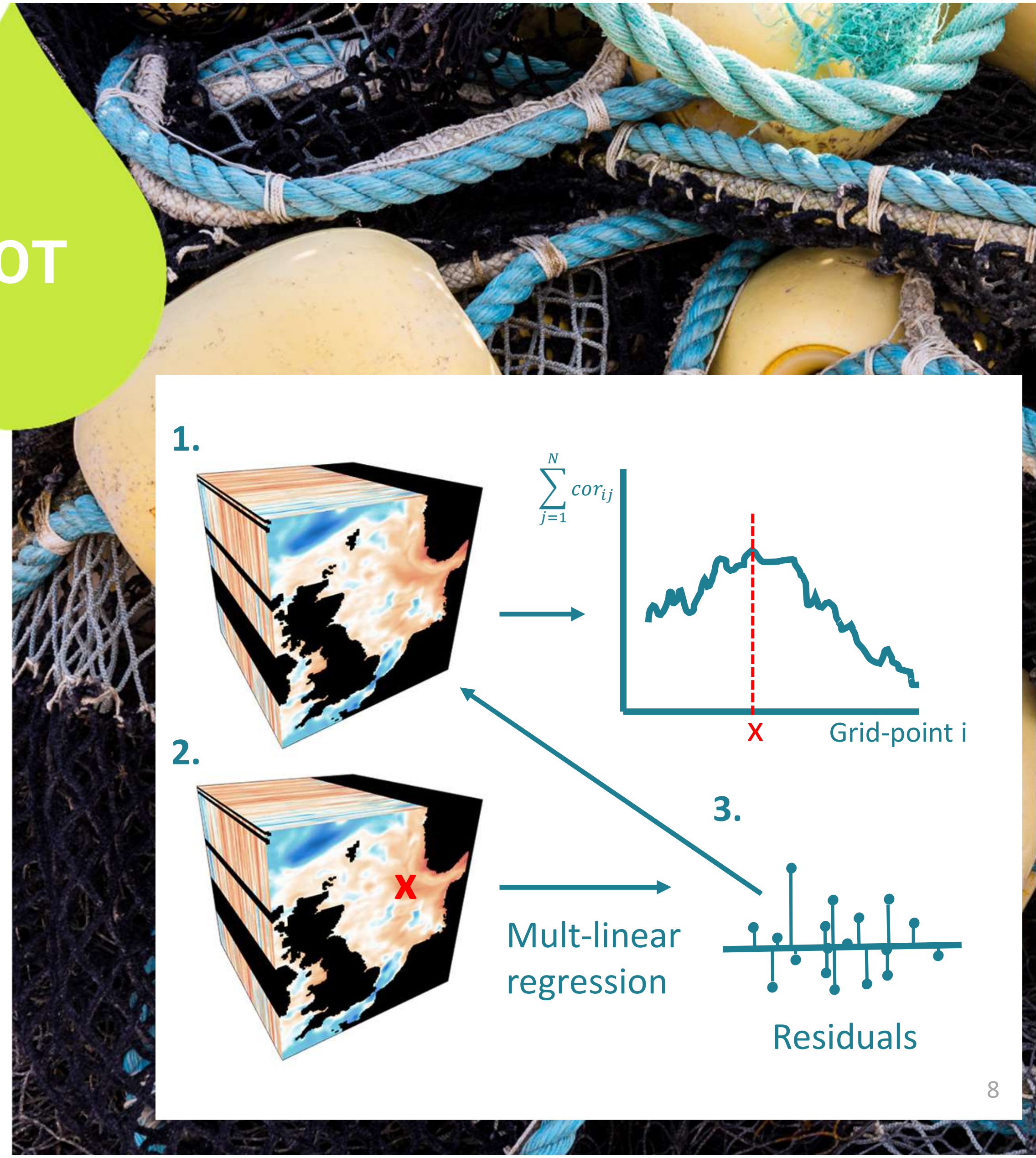
EOT– empirical orthogonal teleconnections

- Method developed by Van den Dool et al. 2000 as an interpretable alternative to EOF-analysis (ts-pattern at a specific location)
- Based on multiple-linear regression

Steps:

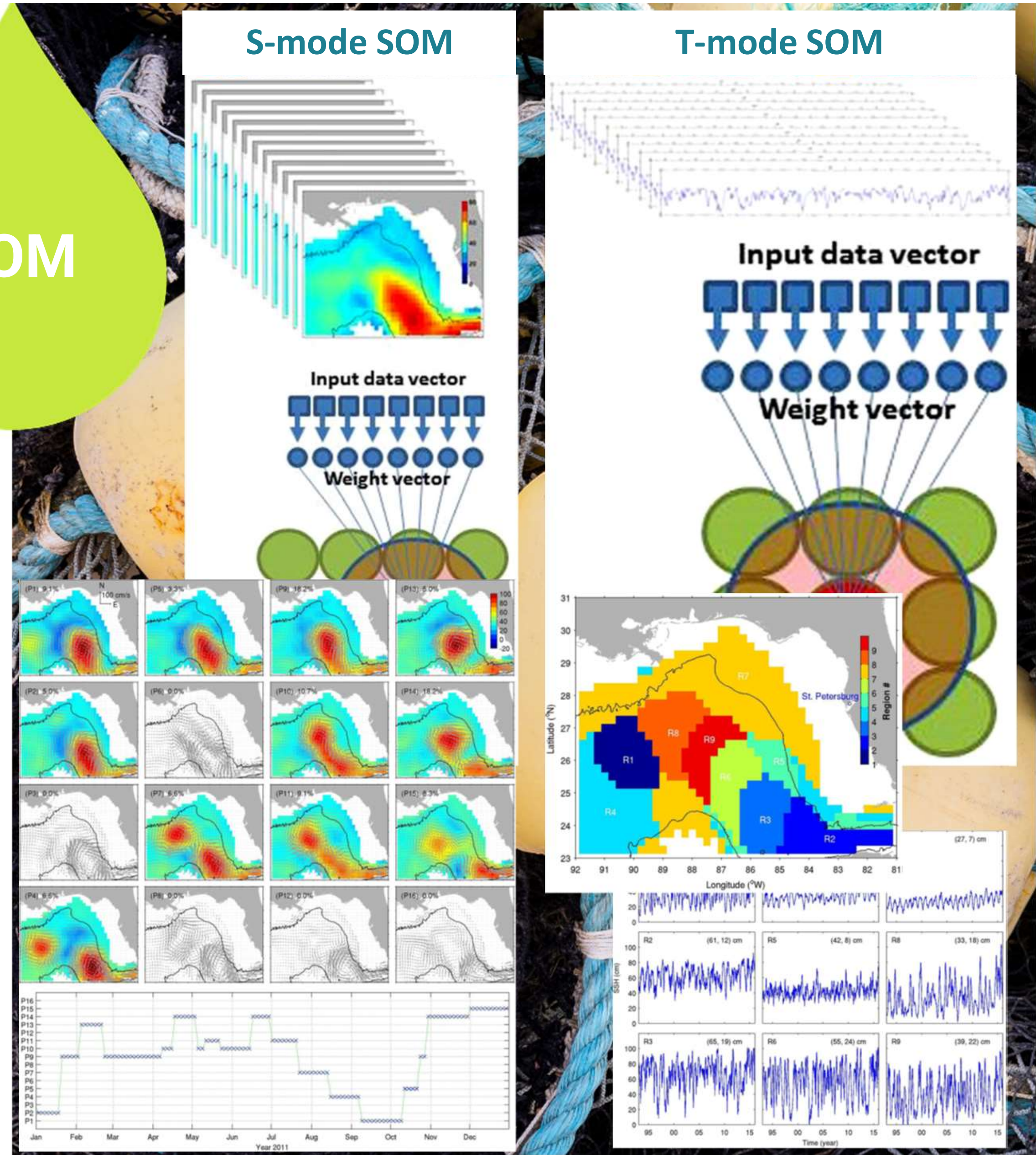
1. Find the point in space that explains most of the variance of the field by brute force (sum. of cor. with all other points)
2. Regress this point to the field
3. Take the residuals of this procedure as new input to derive the second mode and so on …

Van den Dool, H. M., Saha, S., & Johansson, A. (2000). Empirical orthogonal teleconnections. *Journal of Climate*, *13*(8), 1421-1435.



Spatial clustering:
e.g. SOM – self-organising map

- Clustering – combining similar vectors to a **discrete set of patterns**
- SOM = Neural-network clustering analysis developed by Kohonen in the 80s
- Finds a lower-dimensional mapping of high-dimensional data while preserving the topography of the data
- Spatial version made popular through a series of articles from Liu & Weisberg et al. (2005, 2011, 2016)



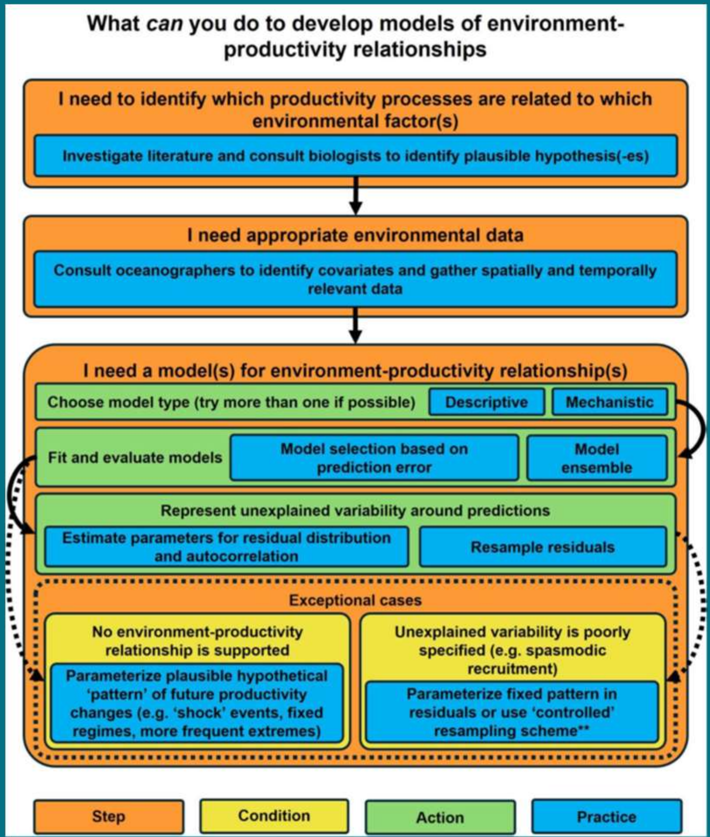
Kohonen, Teuvo (1988). "Self-Organization and Associative Memory". Springer Series in Information Sciences. 8. ISBN 978-3-540-18314-3.

Liu, Y., and R. H. Weisberg (2005), Patterns of ocean current variability on the West Florida Shelf using the selforganizing map, J. Geophys. Res., 110, C06003

Liu, Y., R. H. Weisberg, S. Vignudelli, and G. T. Mitchum (2016), Patterns of the loop current system and regions of sea surface height variability in the eastern Gulf of Mexico revealed by the self-organizing maps, J. Geophys. Res. Oceans, 121, 2347–2366,

Liu, Y., & Weisberg, R. H. (2011). A review of self-organizing map applications in meteorology and oceanography. *Self-organizing maps: applications and novel algorithm design*, *1*, 253-272.

Summary



- Know your historical/projection data
- Dimension-reduction/clustering algorithms are a tool that can help to "get the most out of your data"
- **But**, be sure to match your environmental data & the biological process of interest correctly
- When in doubt, always go back to the literature or ask skilled oceanographers

Summary