How to prepare climate projections?

To account for potential offset and uncertainty of climate projections in MSE-simulations

Bernhard Kühn
Marc Taylor

THÜNEN

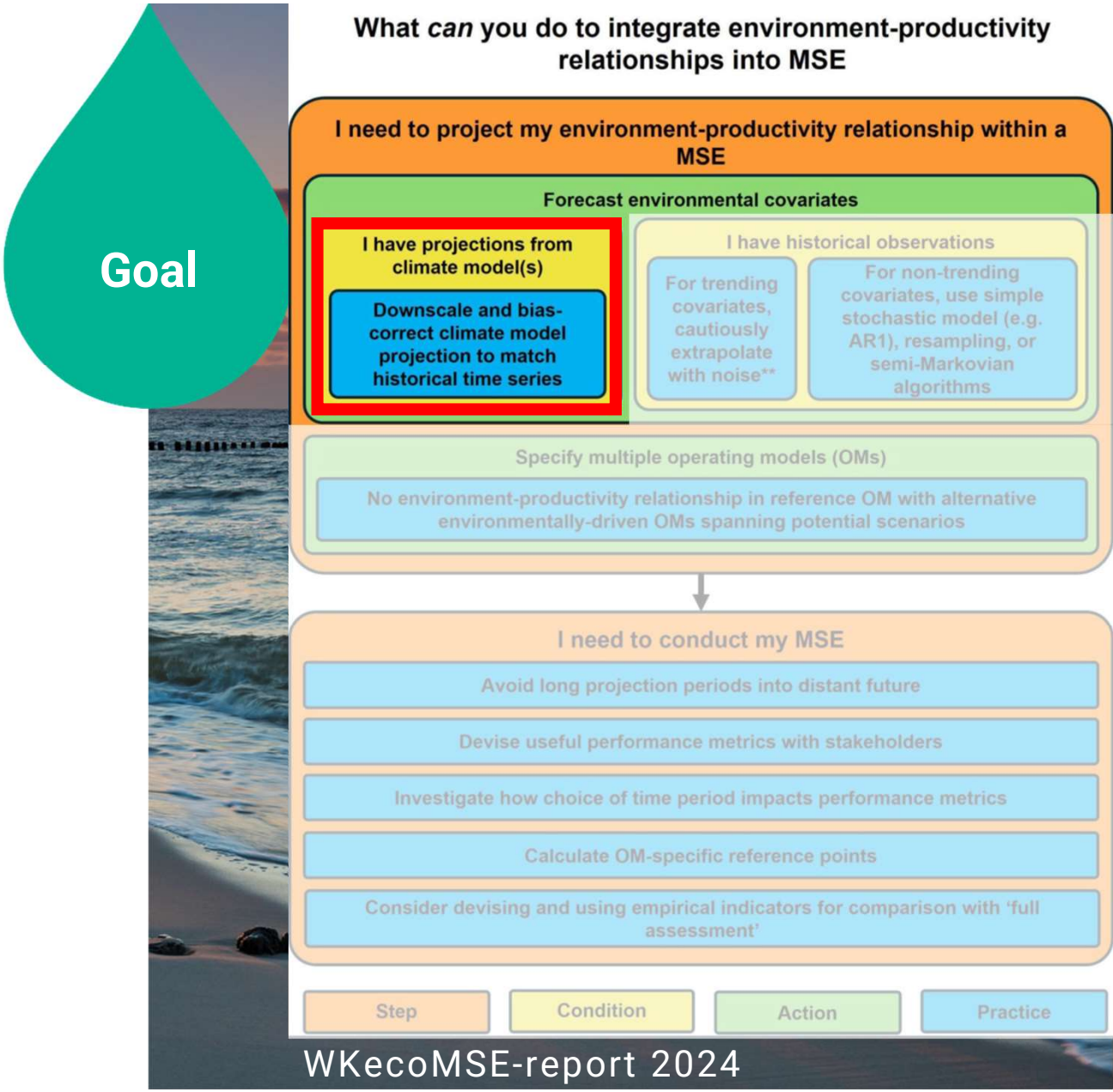
ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

SEAwise has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101000318

Goal

- environmental covariates for the historical part ✓
- Downscaled climate-projection available ✓

What to do now?



What type of data to use for the history, what type of data to use for the future?

General description

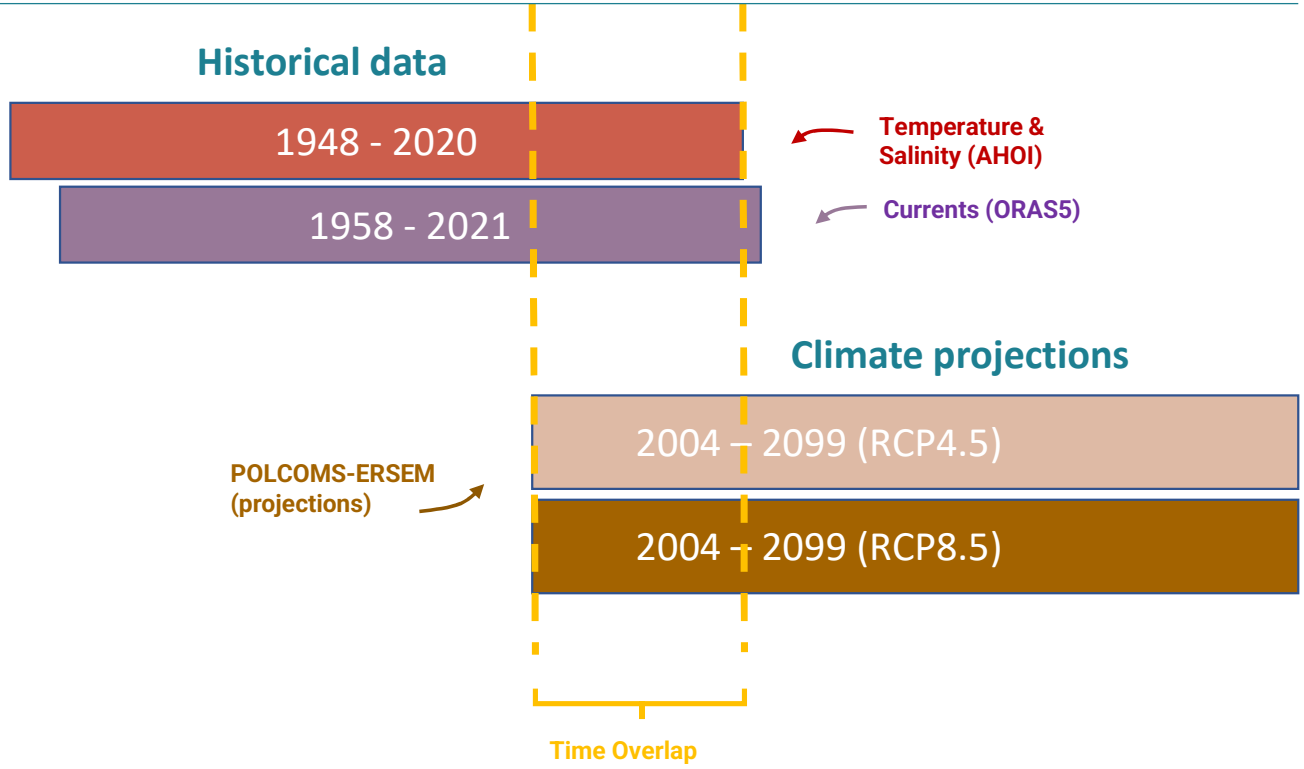
Historical data

- Use of observational data or reanalysis to capture the interannual signal
- Data sources that span a large historical period (1960/70s – now)
- Data that has an aquivalent in the respective future projection

Climate projections (future data)

- RCP4.5 and RCP8.5 climate projections from a regionally-downscaled ocean model

Timespan of available data (e.g. North Sea)



How to link historical and future data?

Continous data product (history + future) e.g. NEMO-MEDUSA

1980 – 2099 (RCP4.5)

1980 – 2099 (RCP8.5)

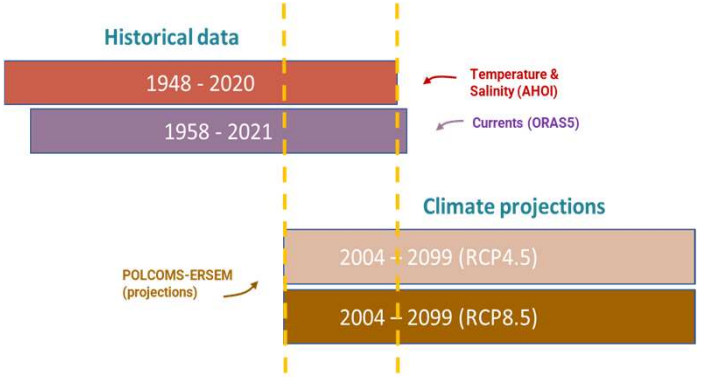
→ **Just continue!**

(and be aware that for the historic period the interannual pattern might be not perfectly resolved)

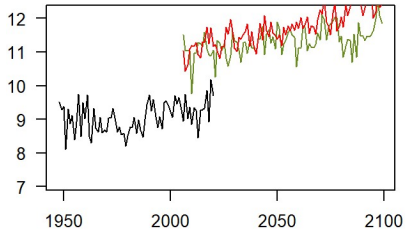
Different data product for history and future

→ **Bias correction needed!**

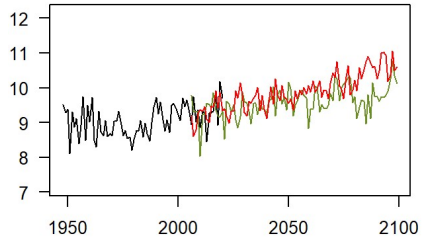
- Correct for the offset and/or different variance of historical and future data



Raw temperature



Bias-corrected temperature

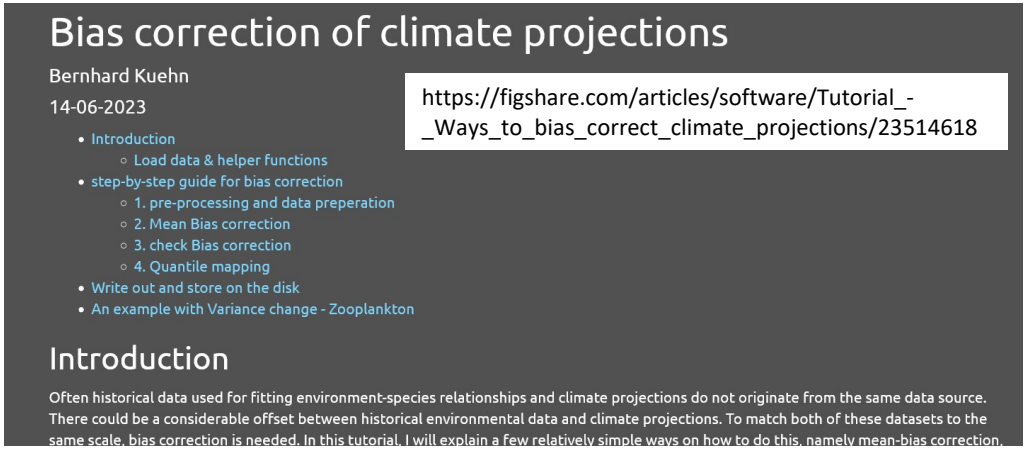


How to link historical and future data?

Tutorial to do it in R:

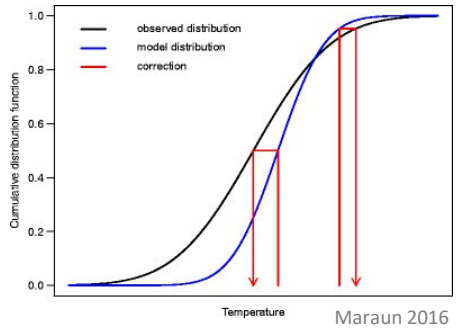
Bias correction:

- Bias correct future projections to match with historical data



Different methods to do this:

- Delta method (mean-bias correction)
- Quantile mapping (Q-mapping)



Maraun 2016

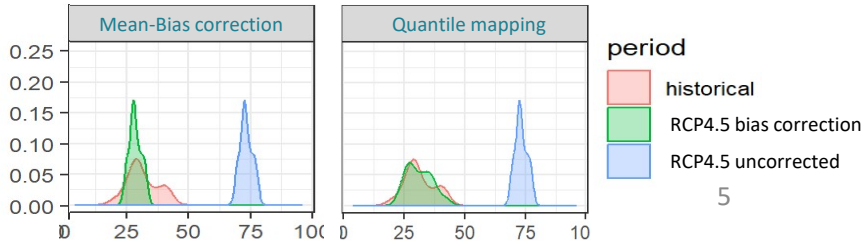
Mean-Bias correction

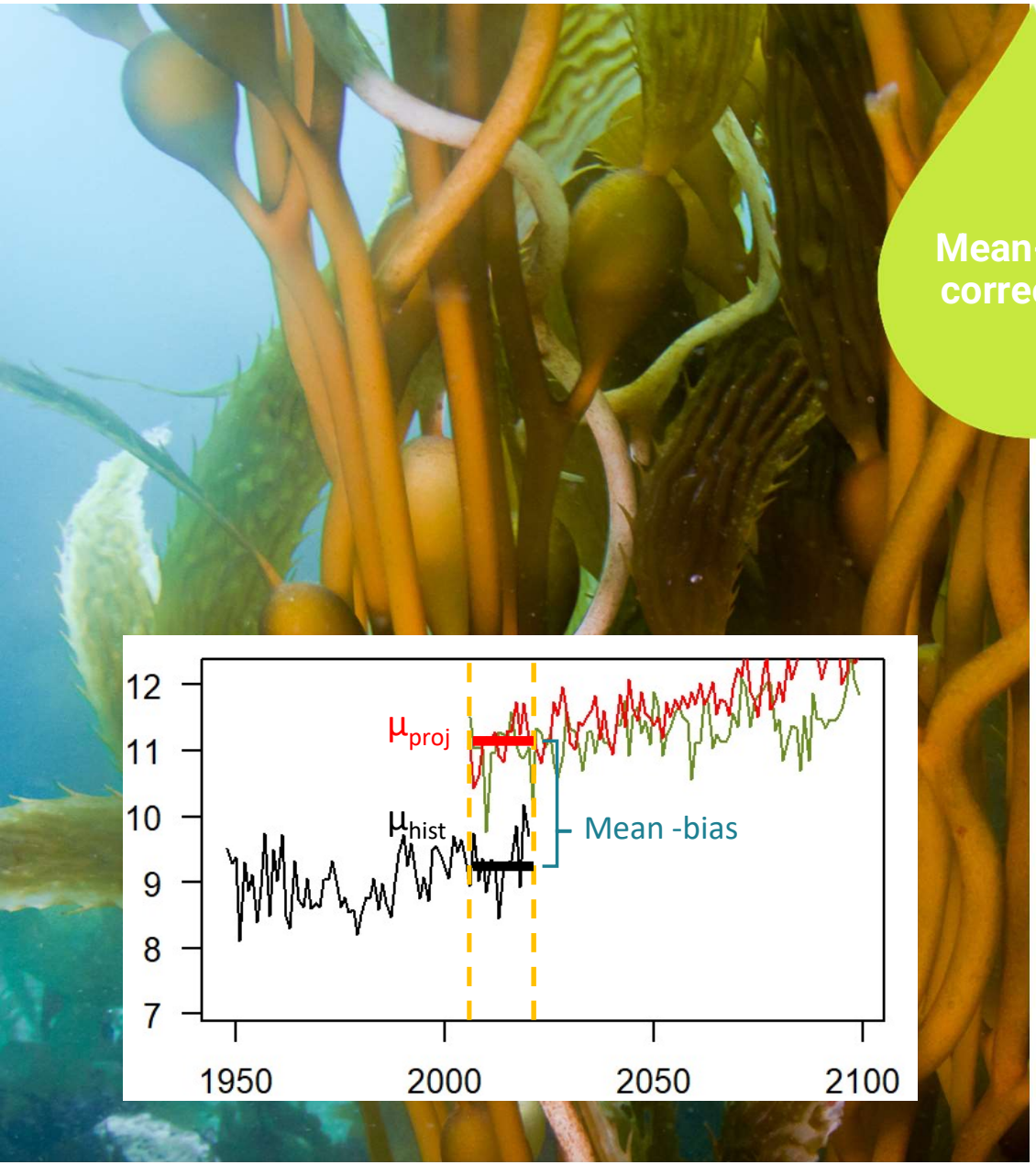
- Just remove the mean-bias (offset) between historical and future data (for each grid-point in the case of spatio-temporal data)
- e.g. by calculating the offset in an overlapping period

Quantile mapping

- Try to match the eCDF (empirical distribution function of the data)

  → allows to correct for differences in the variance





Mean-Bias correction

- Simple way to correct for the difference in mean between two time series/ spatial grids

steps:

1. decide on a time period for which to remove the mean bias (offset) e.g. the mutual overlapping period
2. calculate the mean for the historical time series and the projected time series in this overlapping period & calc. bias

$$bias = \mu_{proj} - \mu_{hist}$$

3. remove the offset from the projection

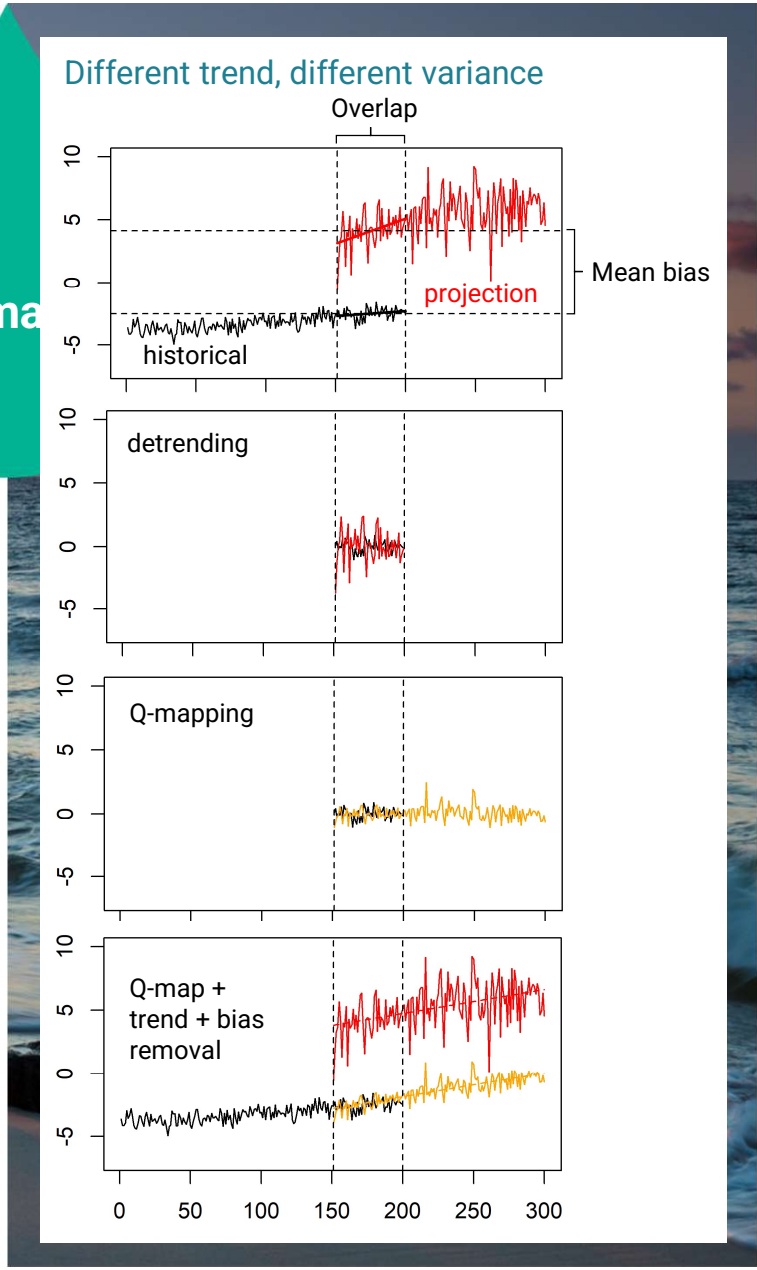
$$ts_{proj,corrected} = ts_{proj,raw} - bias$$

Quantile-mapping (Q-map):

- Doing a Q-mapping directly on the raw data is not trend-preserving
- Therefore one needs to do several pre-processing steps to get meaningful results

steps:

1. decide on a time period to base the quantile mapping on - aka the 'correction time period' → remove the individual trends from both the historical part and projection in this 'correction time period'
2. perform Quantile mapping on this trend-corrected data
3. remove the trend from the whole projection period (e.g. 2006 - 2100)
4. apply this fitted Qmap-model to this trend corrected data for the whole projection period
5. calculate the mean-bias (same as for the delta correction method above) for the chosen 'correction time period'
6. add everything back together: the qmapped-projection - the mean bias + the projection trend



Uncertainty in future environmental data

Uncertainty

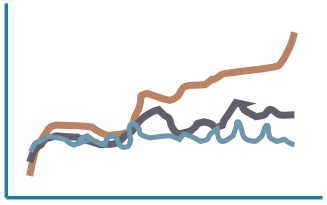
Various different climate models

→ **Between-model variability/uncertainty**

POLCOMS-ERSEM

MPIOM

NEMO-MEDUSA



Only one climate model

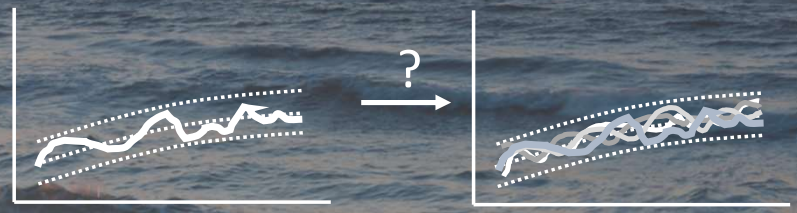
→ **within-model variability/uncertainty**

POLCOMS-ERSEM

- Sometimes only one future climate model output available

→ Only one time series (aka realisation) of e.g. temperature available

- In a stochastic MSE simulation, we need more than one realisation to run Monte-Carlo simulations

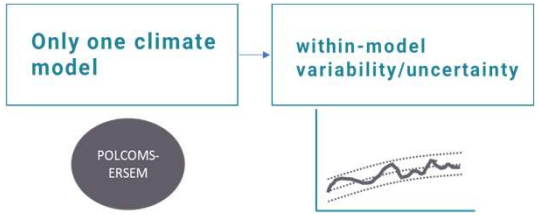


One realisation

several realisations preserving trend and autocorrelation of the data

- Idea is now: **create realisations that capture the variability and autocorrelation of the original time series, but also relationships between different variables** (cross-correlations between e.g. temperature and salinity)

Uncertainty in future environmental data



Use Bayesian Vector Autoregressive models (BVARs) to create new (artificial time series) that preserve trend, autocorrelation and cross-correlations of the original data

- a Vector-Autoregressive process (VAR) is basically the multivariate version of an autoregressive process (AR)
- Model a variable based on own lagged influences and past influences of other variables
- Bayesian estimation allows for constraining coefficients and a more stable fitting procedure

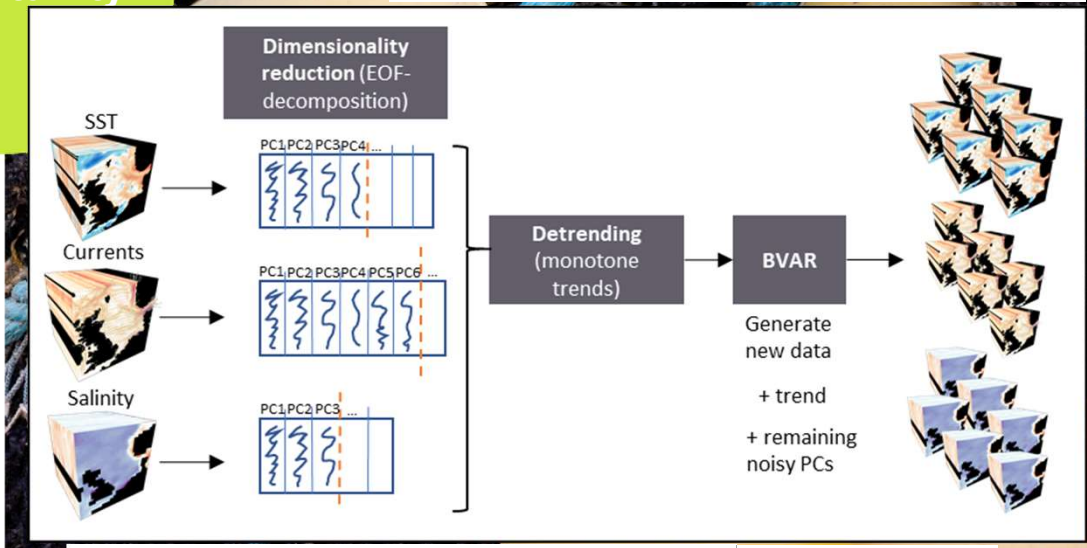
Tutorial to do it in R:

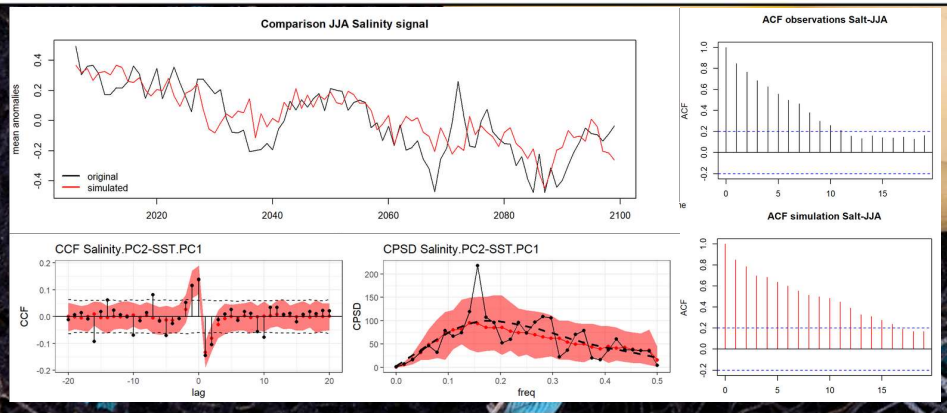
How to generate multiple runs from climate projections?

30-08-2023

Bernhard Kuehn

https://figshare.com/articles/software/Tutorial_-_Capture_uncertainty_of_climate_signals_via_Bayesian_Vector_Autoregression/23546127





Summary

Steps to prepare environmental data for the explicit consideration in MSEs:

1. **Choose adequate data** for the history, which can be complemented with available time series of future climate change

2. **Bias correction** if needed

3. Address future **incorporation of climate variability/uncertainty**