Climate-Mode Initialization for Decadal Predictions

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- Contribution to MiKlip Project -

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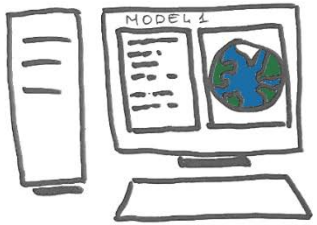
Existing data assimilation and initialization practices



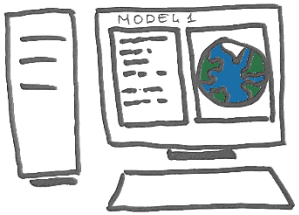
with „**native**“ data assimilation product
observations are directly assimilated
into a prediction system

DATA ASSIMILATION:
gridded ocean, OI, EnKF,
3D-VAR, 4D-VAR,…

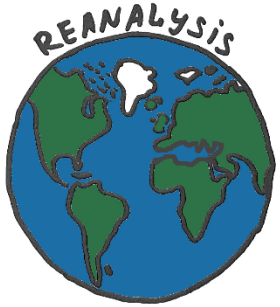
INITIALIZATION:
full field

Existing data assimilation and initialization practices

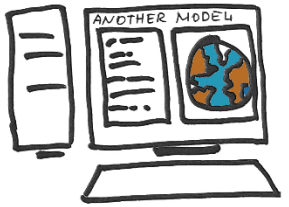
with „**non-native**“ data assimilation product



DATA ASSIMILATION



NUDGING toward REANALYSIS

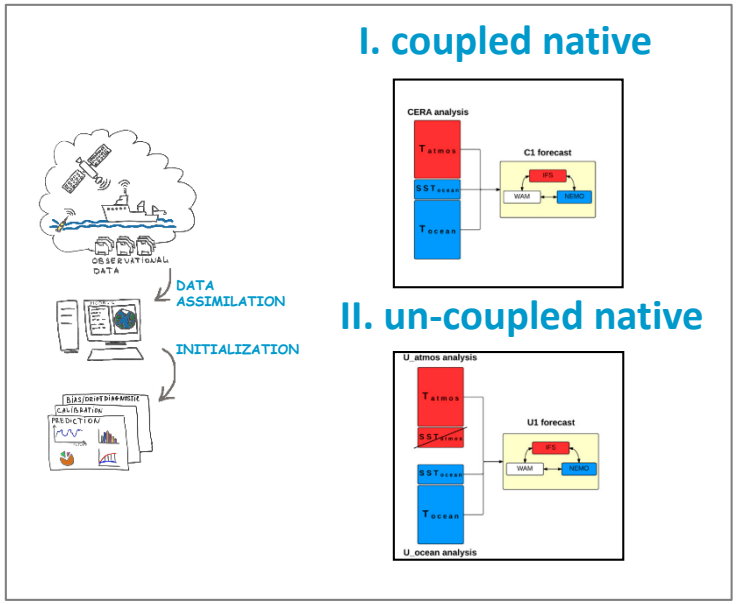


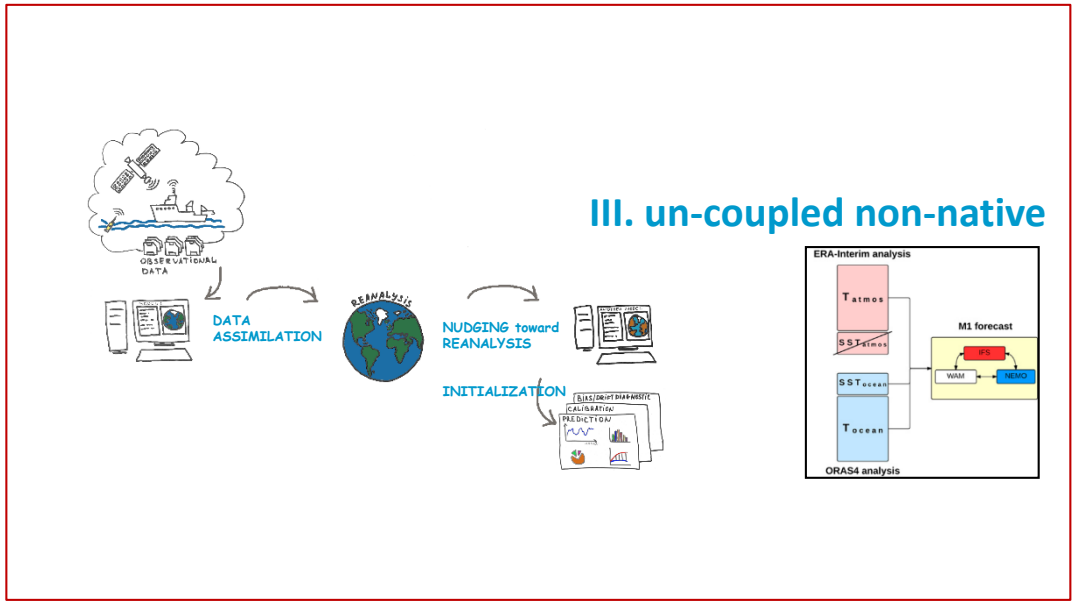
INITIALIZATION:
full field,
anomaly,
flux correction

Relation to initialization shock

- *Mulholland et al 2015:* an effect of using non-native un-coupled reanalyses on initialization shocks (in the form of spurious waves, transports, flux exchange) in short-term predictions:
- Dynamical imbalances between
  - initial state and prediction system
  - initial state (ocean) and initial state (atmosphere)

  can lead to initial shocks and eventually to loss of prediction skill

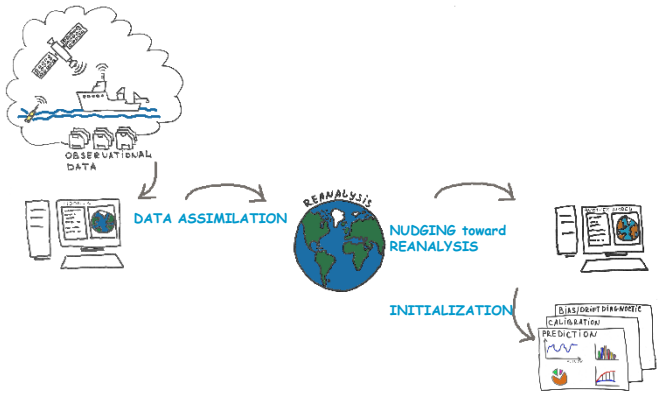


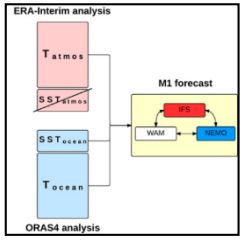


- What is the effect of this on the skill of decadal predictions?

Attempt to make initial states coming from “non-native” reanalysis to be compatible with the prediction system

Nudging un-coupled non-native reanalyses





Aim

→ improve prediction skill

→ eliminate initialization shock between the ocean initial state and the prediction system based on MPI-ESM-LR
(recent studies on initial shock for MPI-ESM-LR: Pohlmann et al 2016, Kroeger et al 2017)

Approach

→ reshape observed modes of variability (ORAS4) to fit model modes (MPI-ESM-LR)

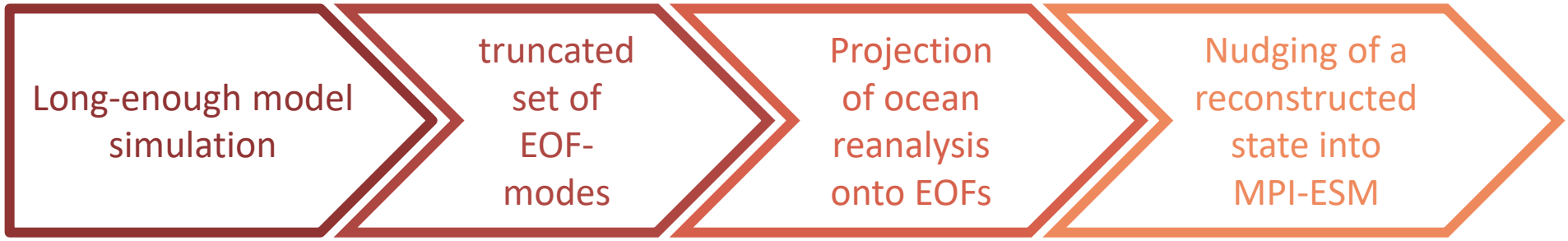
Previous studies: Mode-initialization or filtering initial state

- **In numerical weather predictions:**
  - Normal modes: obtaining correctly balanced initial state by filtering initial conditions to deal with interior-gravity waves: *e.g., Williamson (1976), Ballish (1981) and many, many others*
  - Temporal filtering: using EOFs to filter out the components that are difficult to predict: *Branstator et al. (1992)*
  - Error growth rates: *e.g., Boer (1984)*

- **In seasonal predictions:** coupled modes initialization: *Kirtman et al (COLA, 2005-2008)*

- **In decadal predictions:** avoid introducing anomalies that are out of the model internal variability range: *Volpi et al 2016,* phase initialization: *SPECS (Caian et al)*

Climate-mode initialization recipe based on MPI-ESM



15 members of historical simulations spanning 1958-2005

(in total 720 October temperature and salinity anomalies)

EOF-analysis on temperature and salinity anomalies

EOF-modes and variance explained in the reconstruction depend on the weighting choice made during EOF analysis

Input: ORAS4 T&S anomalies

Output: filtered ORAS4 T&S anomalies

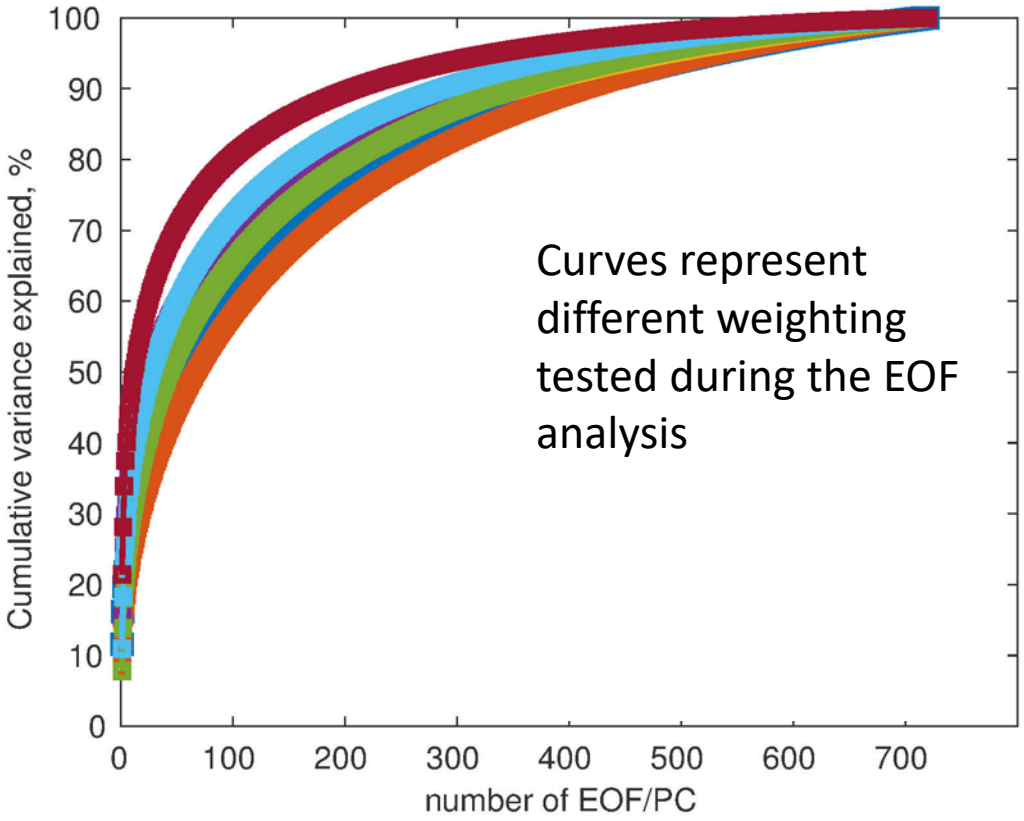
filtered ORAS4 T&S anomalies
+
MPI-ESM October-monthly means

over 1960-2015

For comparison:
traditional anomaly initialization with
→ October-nudging
→ 12 months nudging

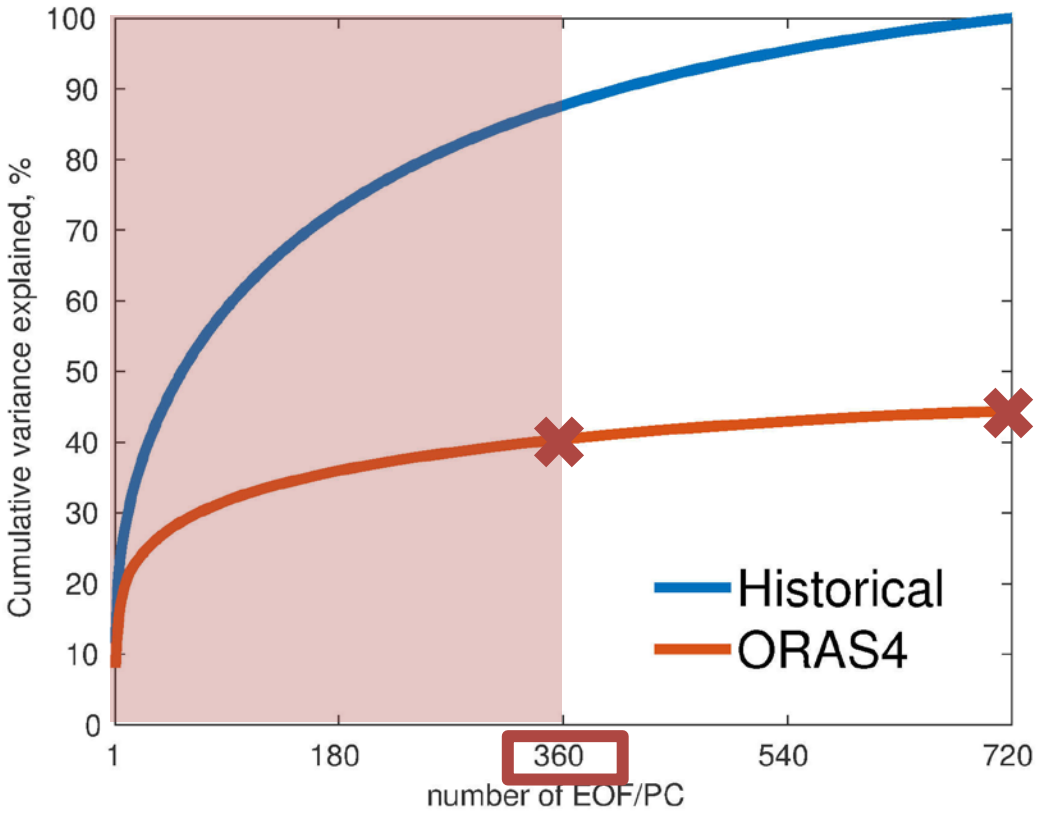
EOF-modes: weighting choice

Long-enough model simulations → **EOF-modes** → Projection of ocean reanalysis onto EOFs → Nudging of a reconstructed state into MPI-ESM



- weighting T&S by their contribution to density changes is chosen
  - it led to the highest amount of variance explained in the reconstructed reanalysis

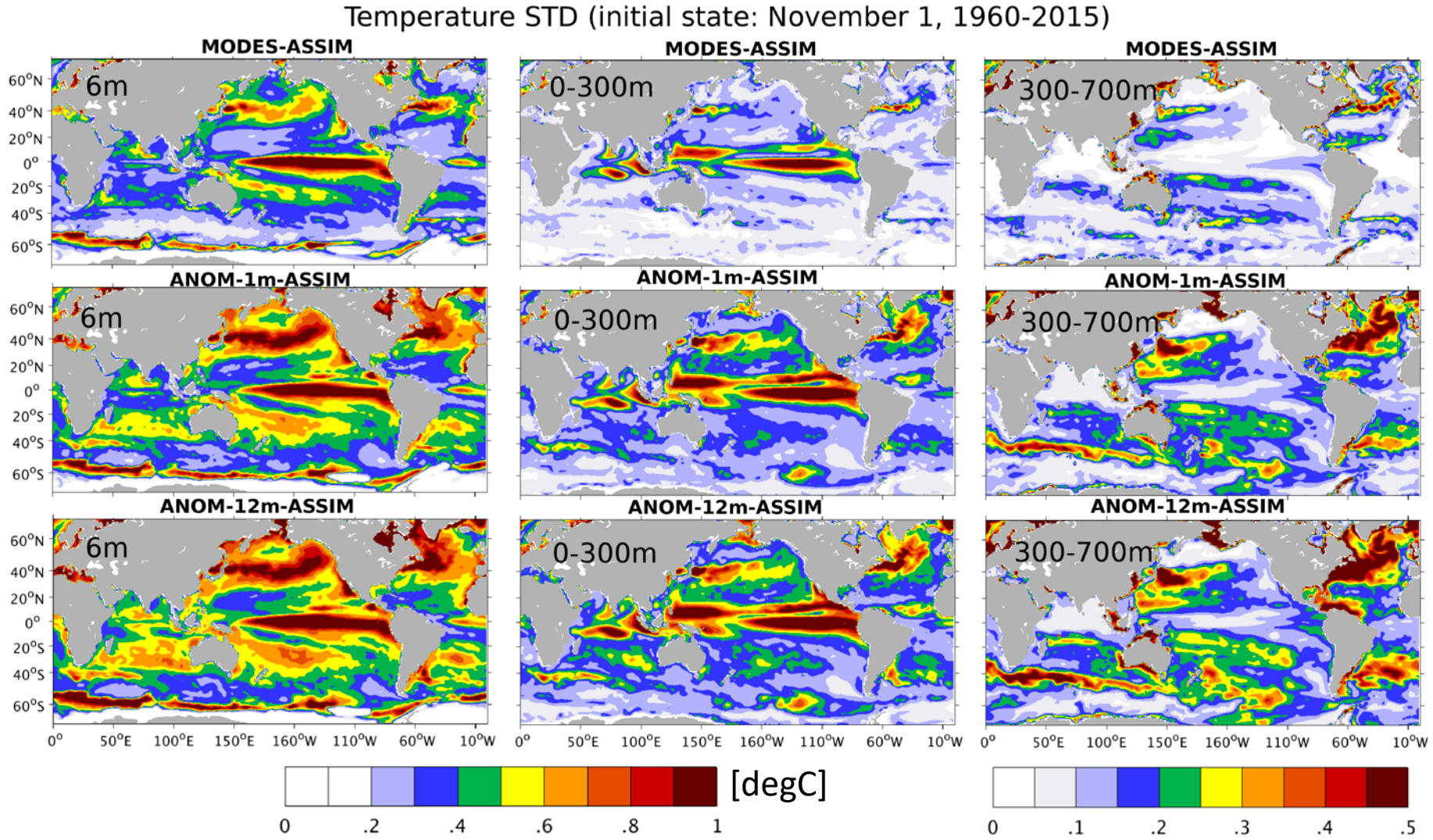
EOF-modes: truncation level choice



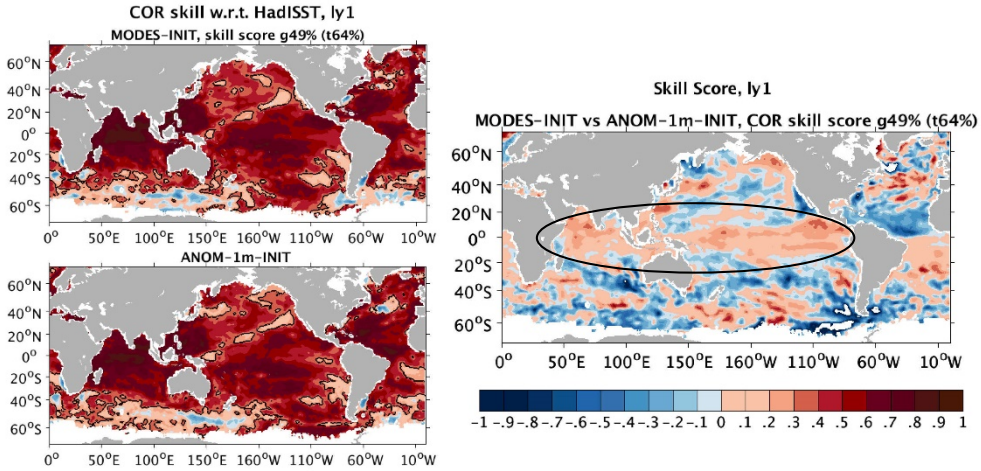
- ORAS4-reconstruction retains 45% of σ^2 (66% of standard deviation)
- 3% truncation level cuts off 360 EOF-based modes

What do we initialize with?

Standard deviation of initial temperature state @ different depth levels from the November 1st snapshots



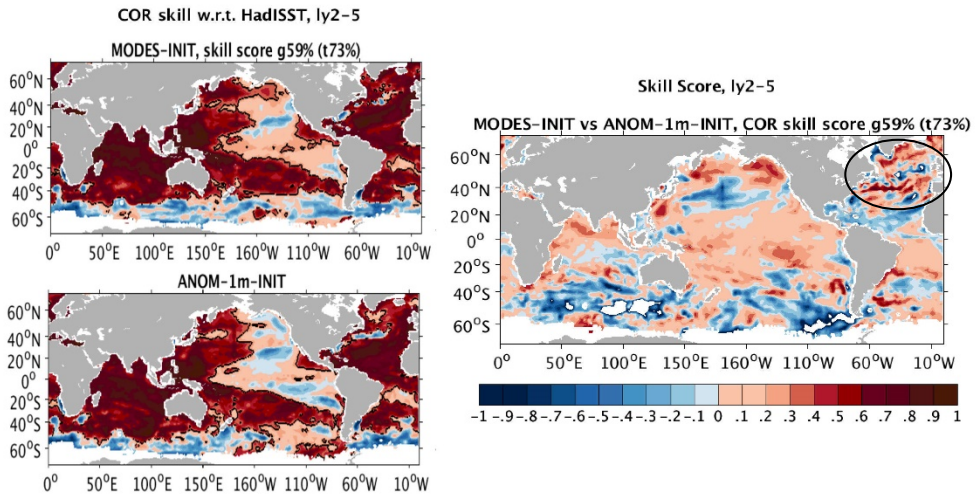
Surface temperature correlation skill and skill score: MODE-INIT versus ANOM-INIT



LEAD YEAR 1

Further investigations of the Pacific Ocean:

- ENSO skill ✓
- zonal momentum balance ✓



LEAD YEARS 2-5

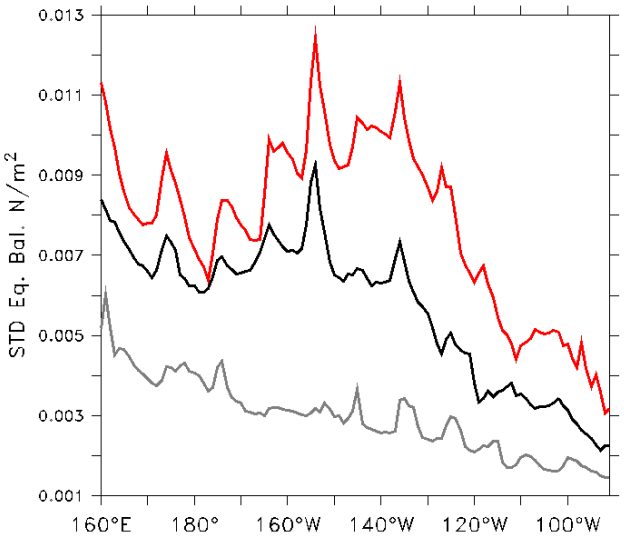
Further investigations of the Atlantic Ocean:

- climate indices (NASPG, AMOC@25N) ✗
- Gulf Stream path *?*
- ↗ SST skill *trend ?*

Zonal momentum balance of the upper equatorial Pacific

between pressure gradient force and zonal wind stress **in the first month after initialization**

$$A_v \frac{\partial u}{\partial z} = \frac{1}{\rho_0}\left(\tau_x - \int_0^z \frac{\partial P}{\partial x} dz\right)$$

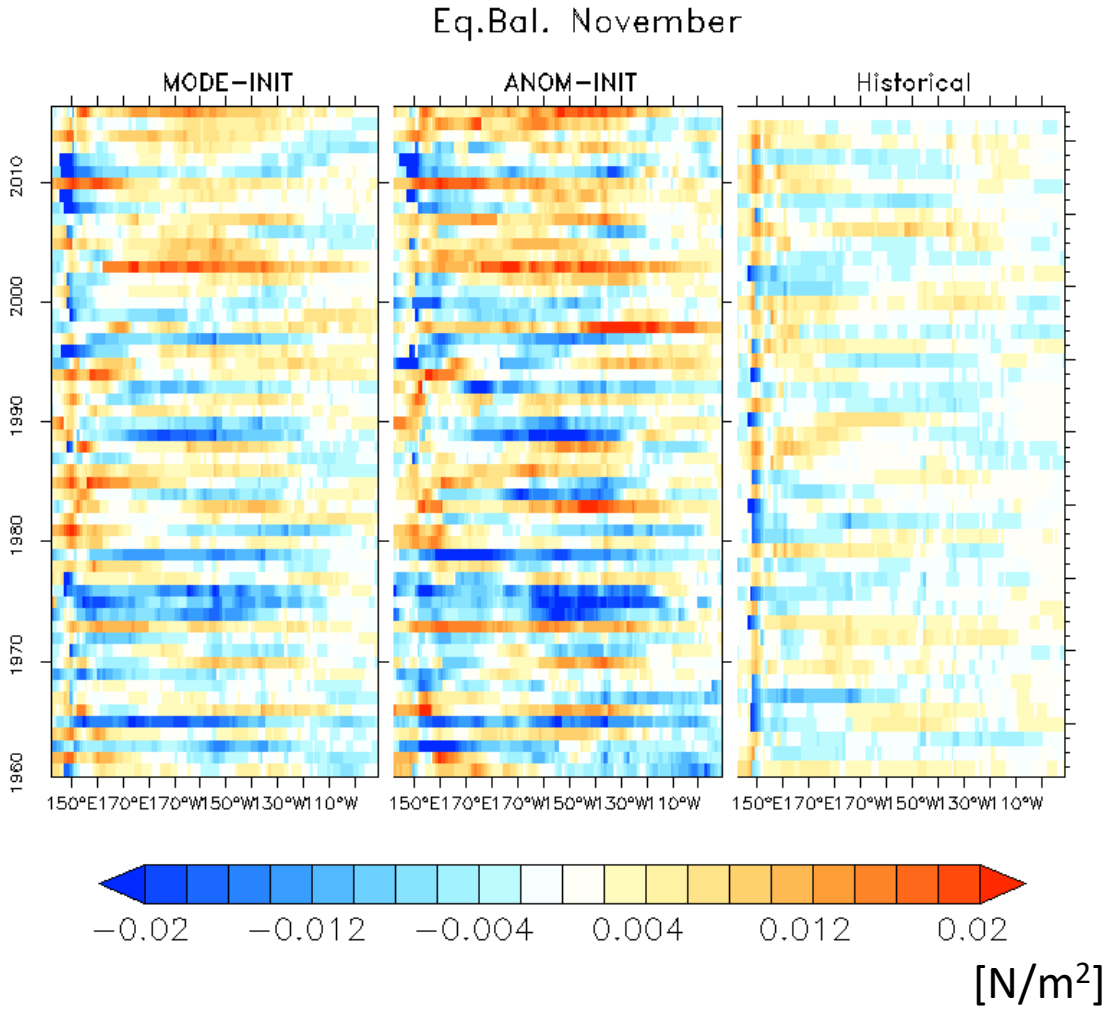


STD of eq. balance for

Historical simulation __

MODE-INIT __

ANOM-INIT __



Summary for MODE-INIT: an attempt to make initial states coming from "non-native" reanalysis to be compatible with the prediction system

Aim

improve prediction skill

by eliminating initialization shock

Approach

reshape observed modes of variability (ORAS4) to fit model modes (MPI-ESM-LR)

Performance as compared to anomaly initialization

improves temperature skill in the tropical Pacific for short time scales

improves zonal momentum balance in the Eq.Pacific

has "mixed success" in the North Atlantic

Opportunities to develop further:

- regional EOF-modes instead of global ones
- larger EOF space
- different truncation (EOFs with long time scales)

Thank you very much for your attention!

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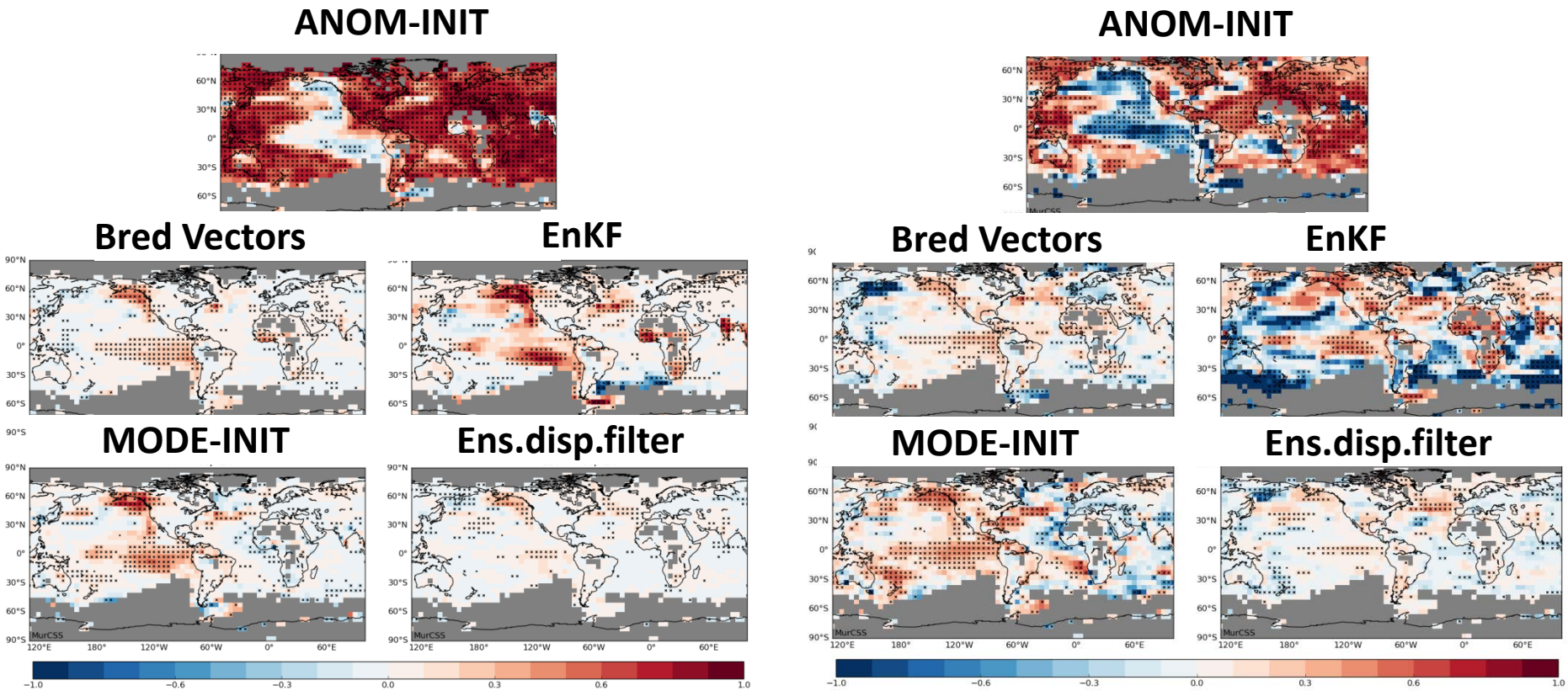
Surface temperature skill for lead years 2-5

Comparison of MiKlip methods (including MODE-INIT) with anomaly initialization

ANOM-INIT correlation skill
&
Correlation difference to ANOM-INIT

ANOM-INIT MSESS w.r.t. climatology
&
MSESS w.r.t. ANOM-INIT



Polkova et al 2018 (submitted to JAMES)