Mechanisms of inter- to multidecadal variability and their implications for climate predictions (MultiCliP)

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1. AIMS

MultiClip aims at **identifying** the **key processes and feedbacks** responsible for **decadal to multidecadal variability** in long term integrations conducted with the Max Planck Institute Earth System Model (MPI-ESM) and at **investigating** their specific **time-scales** as well as their **regional manifestations** and the role of **external forcing**.

MultiClip further aims at **assessing** the dependency of feedbacks and processes on **specific model properties**, such as resolution and complexity, by analyzing existing experiments and dedicated sensitivity experiments.

2. SATE OF PROGRESS OF THE WORK

Comparative investigations on decadal and multidecadal variability have been conducted on dedicated experiments performed with the AGCMs ECHAM5 and ECHAM6[1,2], and on existing simulations performed with the hierarchy of MultiClip Earth System Models including the Millennium setup[3-5], the CMIP5-LR/-P, and the CMIP5-MR setups[6,7].

The conducted investigations included assessments of:

- the stratosphere as a key for wintertime atmospheric response to warm Atlantic decadal conditions[2]
- the realization of regional modes of sea-surface temperature (SST) variability in “millennium” simulations and the relative role of internal variability and external forcing[3]
- the characteristics of the ocean simulations in MPIOM, the ocean component of MPI-ESM[7]
- the representation of the multidecadal variability of North Atlantic SSTs across the MPI-ESM model hierarchy[6]
- influences of background conditions on decadal climate response to strong volcanic eruptions[4]

3. THE STRATOSPHERE AS A KEY FOR WINTERTIME ATMOSPHERIC RESPONSE TO WARM ATLANTIC DECADAL CONDITIONS

A realistic representation of stratospheric processes allows for substantial improvements of simulated decadal and multidecadal climate variability[2]. The use of a stratosphere-resolving climate model (i.e., with model top for the atmospheric component at 0.01 hPa) is strongly recommended.

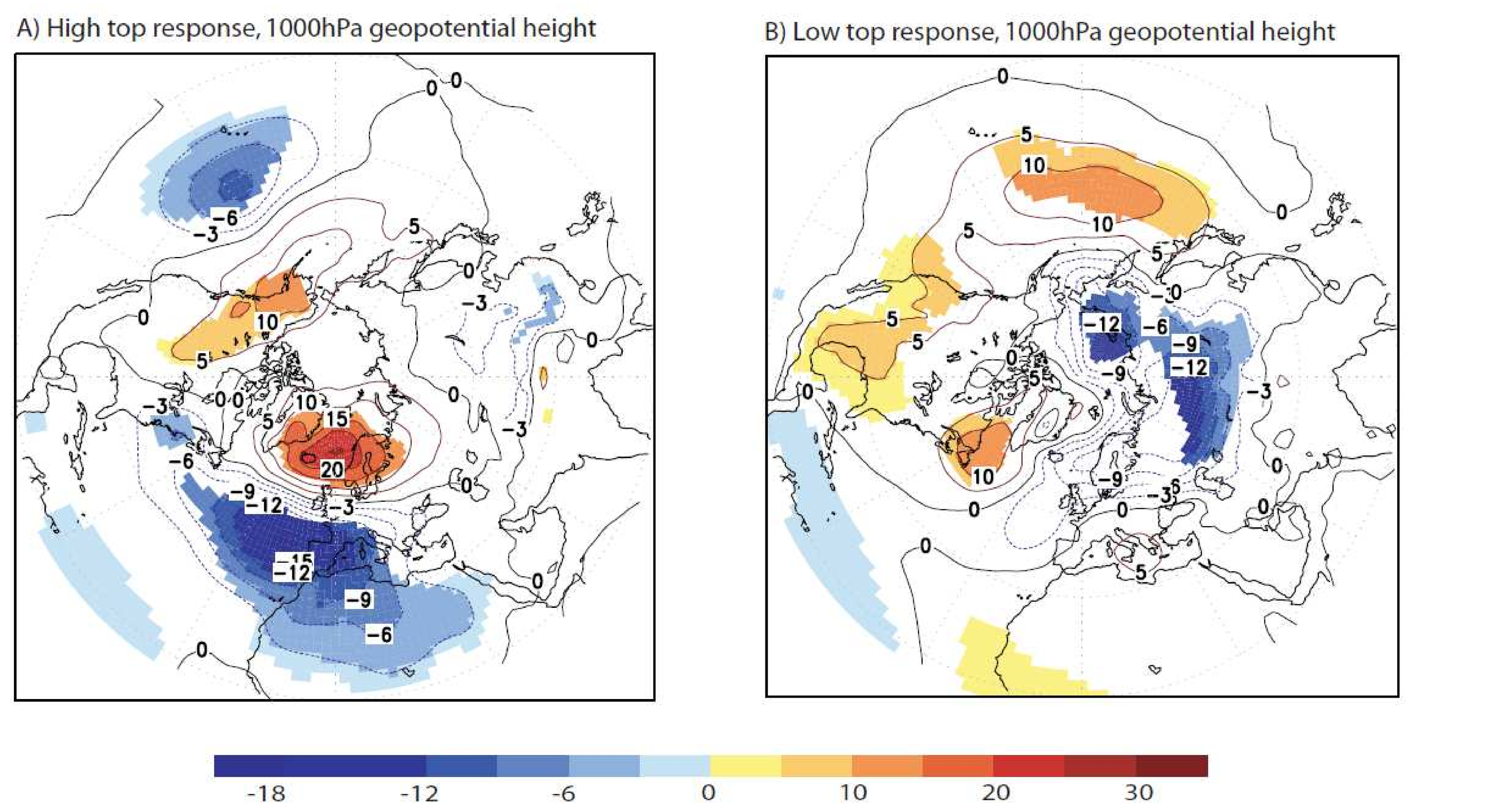
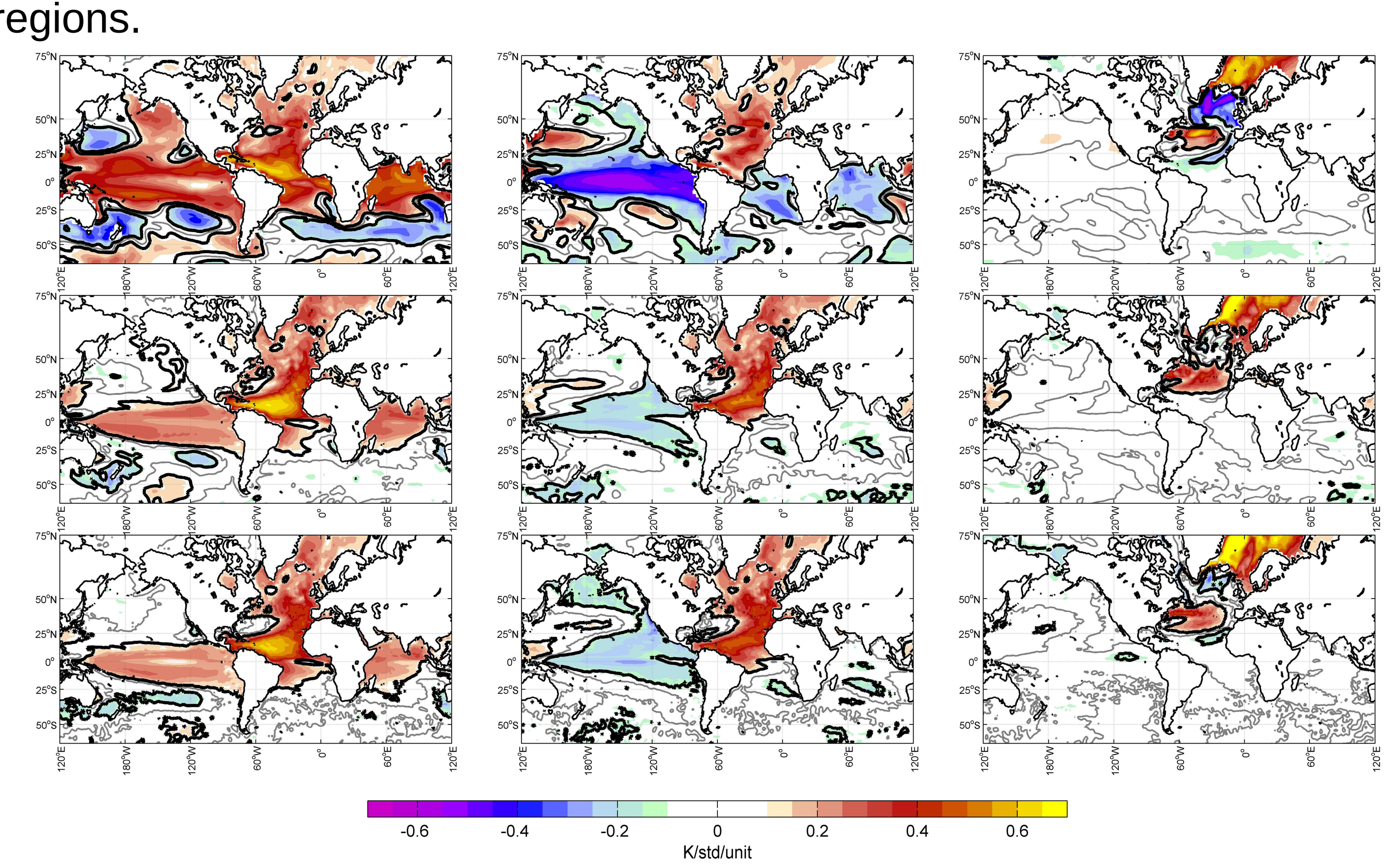


Figure 1 – The winter (JFM) 1000 hPa geopotential height simulated in response to the 1951-1960 warm conditions in the Atlantic with a model (A) including the whole stratosphere (high-top, until ~80km) and (B) the one only partly resolving it (low-top, until ~30km). Only values significant at the 90% level are shaded (from [2]).

4. REPRESENTATION OF ATLANTIC MULTIDECADAL VARIABILITY IN MPI-ESM

Simulated multidecadal variability of North Atlantic sea-surface temperatures (NASSTs) relate to multiple physical processes whose representations depend on model characteristics such as resolution and complexity[6]. Different NASST signal generation and propagation pathways (e.g., through teleconnections) imply different skills in reproducing NASST-related decadal climate variability for different regions.

Figure 2 – Regression patterns of standardized global sea surface temperatures on three differently-defined AMV indices (columns) calculated for millennial unperturbed simulations conducted with the COSMOS-Millennium version of ECHAM5/MPIOM (top row), MPI-ESM-P (middle row) and MPI-ESM-MR (bottom row). Thick contours individuate regions where the regression is significant at p<0.05 accounting for autocorrelation in the series. Adapted from [6].



5. CHARACTERISTICS OF OCEAN SIMULATIONS IN MPIOM

MPI-ESM-P/-LR and MPI-ESM-MR display similar features in the representation of oceanic features, such as surface temperature and salinity, water mass distribution, large-scale circulation, and heat and fresh water transports[7]. The use of MPI-ESM-MR is recommended if improved representation is required of specific processes/features, such as, e.g., the interior water mass properties in the Atlantic Ocean and the Agulhas and Equatorial current systems

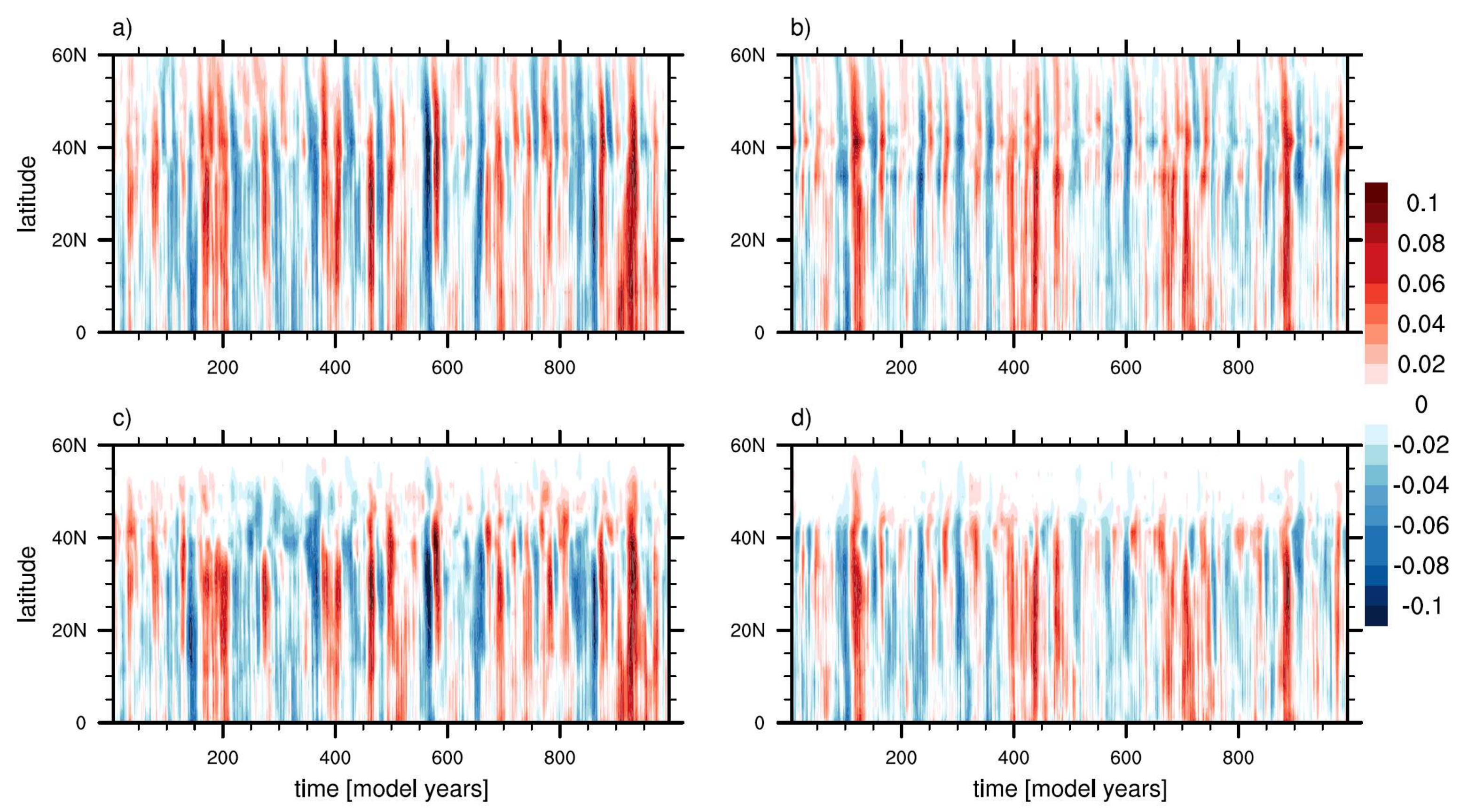


Figure 3 – Ocean advective heat transport anomalies (PW) from the PICTRL simulations: (a, b) total heat transport, and (c, d) heat transport contribution from the meridional overturning circulation for (left) MPIESM-LR, and (right) MPI-ESM-MR. All data sets were smoothed using an 11yr running mean (from [7]).

6. INFLUENCES OF BACKGROUND CONDITIONS ON DECADAL CLIMATE RESPONSES TO STRONG VOLCANIC ERUPTIONS

Background conditions (i.e., the initial climate state and the presence of additional forcing factors), and especially the state of the deep ocean actively influence the mechanisms involved in the decadal climate evolution following external perturbations such as strong volcanic eruptions[4]. Background conditions should appropriately be accounted for in the design of prediction tools for the decadal climate response to volcanic forcing, such as that planned in ALARM.

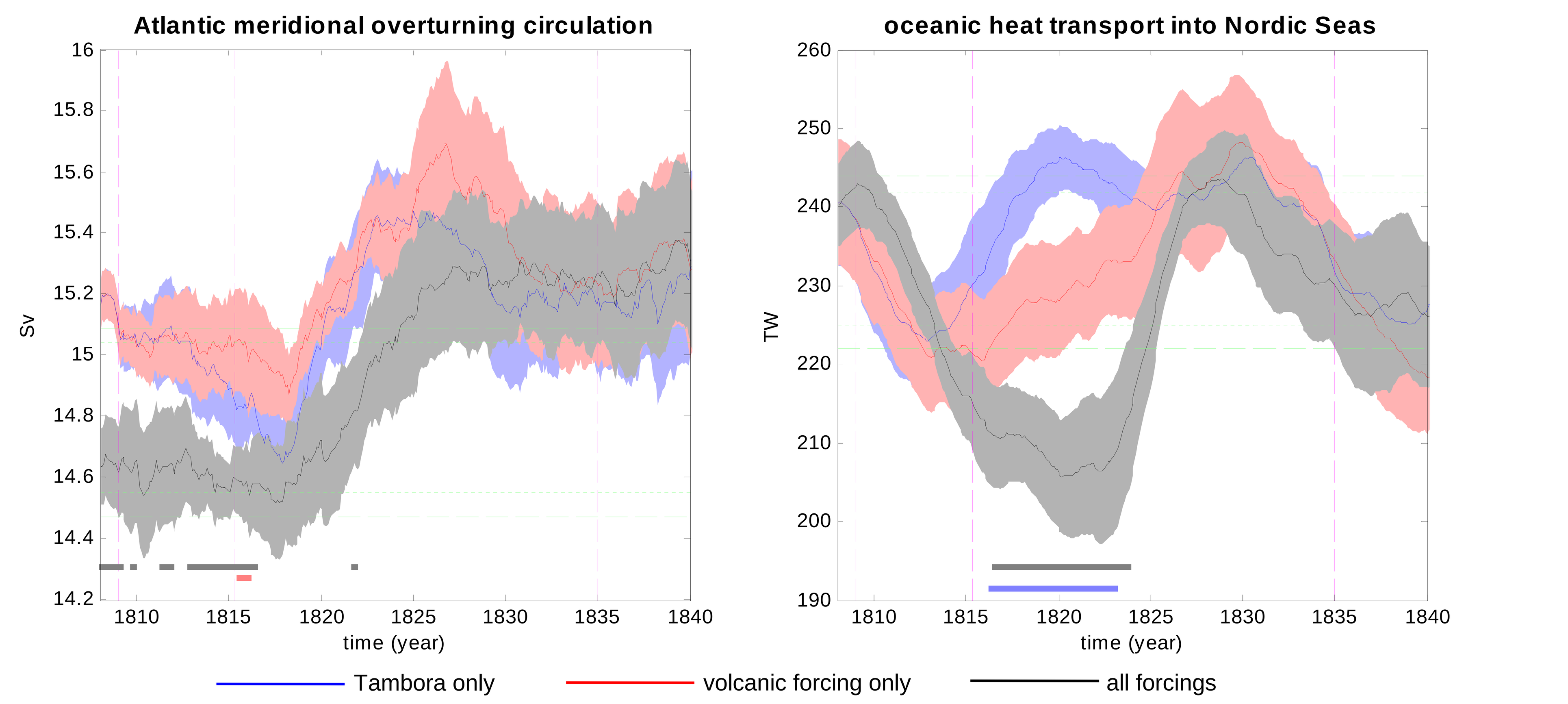


Figure 4 – Simulated oceanic evolution around the 1815 Tambora eruption in three climate simulation ensembles differing in the ensemble-mean initial state and in the applied forcing. Lines (shading): mean (1-σ standard error of the mean). Green dashed lines (inner dotted lines): 5th-95th (10th-90th) percentile intervals for signal occurrence in the control run. Magenta vertical lines indicate the occurrence of the 1809, Tambora and Cosiguina eruptions. Bottom rectangles indicate periods when there is a significant difference between an ensemble (color same as for time series plots) and the other two. Units in panel a) [b), d)] are 1 Sv = 106 m^3s^{-1} [1 TW = 10^{12} W]. Adapted from [4].

7. PUBLICATIONS

- [1] Bader, J., et al. (2012) Atmospheric winter response to a projected future Antarctic sea-ice reduction: a dynamical analysis. Clim. Dyn., doi:10.1007/s00382-012-1507-9
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- [3] Zanchettin, D., Rubino, A., Matei, D., Bothe, O., and J. H. Jungclaus (2012) Multidecadal-to-centennial SST variability in the MPI-ESM simulation ensemble for the last millennium. Clim. Dyn., doi:10.1007/s00382-012-1361-9
- [4] Zanchettin D., et al. (2013) Background conditions influence the decadal climate response to strong volcanic eruptions. Accepted for publication in J. Geophys. Res. Atm.
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- [6] Zanchettin D., O. Bothe, W. Müller, J. Bader, and Johann H. Jungclaus (2013) Different flavors of the Atlantic Multidecadal Variability. Clim. Dyn., doi:10.1007/s00382-013-1669-0
- [7] Jungclaus JH, et al. (2013) Characteristics of the ocean simulations in MPIOM, the ocean component of the Max Planck Institute Earth System Model. Under review in JAMES, special issue The Max Planck Institute for Meteorology Earth System Model

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