Alert for LARge volcanic eruptions in Medium term climate prediction (ALARM)

BMBF programme Mittelfristige Klimaprognosen (MiKlip)

Contribution to Module B: Process description and modelling 01LP1130A/B

The ALARM project

The aim

- Development of a volcano module for the MiKlip medium term climate prediction system
- Investigating the direct radiative effect of large volcanic eruptions on climate
- Understanding the role of dynamical coupling between stratosphere and troposphere for the medium term climate response to large volcanic eruptions

The team

- C. Timmreck, H. Schmidt, M. Bittner, R. Athmer
  MPI für Meteorologie, Hamburg
- K. Krüger, M. Toohey, S. Bancalá
  GEOMAR, Kiel

Contact:

- claudia.timmreck@zmaw.de (01LP1130A)
- kkrueger@geomar.de (01LP1130B)

Recommendations for the MiKlip system

The volcano module for the MiKlip prediction system (DS1) is postponed by a few months due to a delay in the release of ECHAM6-HAM by the ETHZ. Therefore, **we plan to test an intermediate solution with hindcasts for a major volcanic eruption (e.g. Pinatubo) in order to be able to quickly react if a major volcanic eruption occurs in the next months.** This intermediate solution encompasses the calculation of the volcanic aerosol optical parameters with the global ECHAM5/HAM, and its prescription as external forcing in the forecast system.

:MPI-ESM-LR and MPI-ESM-MR react qualitatively similar in the middle atmosphere to natural and anthropogenic forcings (Schmidt et al., 2013). However, quantitatively the responses to volcanic and ENSO forcing seem more realistic in the MR configuration. **We advise to use the MR model for NH winter predictions after large major eruptions.**

Background conditions are not only a source of additive noise for post-eruption decadal climate variability, they also actively influence the mechanisms involved in the post-eruption decadal evolution (Zanchettin et al., 2013b). Hence, for **the decadal prediction of volcanic induced climate perturbations, a precise specification of the initial state of the climate system and of all forcing factors is important.**

Publications

- Bancalá, S.; Krüger, K.; Giorgetta, M.T he preconditioning of major sudden stratospheric warmings. J. Geophys. Res., Vol.17, No. D4, D04101 http://dx.doi.org/10.1029/2011JD016769
- Timmreck C. Modeling the climatic effects of volcanic eruptions, invited review, Wiley Interdisciplinary Reviews: Climate Change 2012.
- Charlton-Perez AJ, … K Krüger, M. Toohey,.. et al., On the lack of stratospheric dynamical variability in low-top versions of the CMIP5 models , J. Geophys. Res. (in revision), 2012.
- Schmidt, H., Rast, S., Bunzel, F., Esch, M., Giorgetta, M. A., Kinne, S., Krismer, T., Stenchikov, G., Timmreck, C., Tomassini, L.,and Walz, M. The response of the middle atmosphere to anthropogenic and natural forcing in the CMIP5 simulations with the MPI-ESM. JAMES accepted 2013.

Together with MiKliP-MULTICLIP:

- Zanchettin D., C. Timmreck, O. Bothe , S. Lorenz, G. Hegerl, H.-F Graf, J. Luterbacher and J. Jungclaus, Delayed winter warming: a decadal dynamical response to strong tropical volcanic eruptions. Geophys Res. Lett. DOI: 10.1029/2012GL054403 2013a.
- Zanchettin D., O. Bothe, H.-F Graf, S. Lorenz, J. Luterbacher, C. Timmreck and J. Jungclaus, Background conditions influence the decadal climate response to strong volcanic eruptions. JGR accepted, 2013b.

Additional References:

Charlton A. J., et al., A new look at stratospheric sudden warmings. Part II. Evaluation of Numerical Model Simulations. Journal of Climate, 20. 471–488, 2007.
Gleixner, S., et al., Southern Annular Mode response to volcanic eruptions in the MPI-ESM, poster presentation, 3ICESM, Hamburg, 2012.
Krüger, K., Do large tropical volcanic eruptions influence the Southern Annular Mode?, oral presentation, AGU Chapman conference, Selfoss, Iceland, 15 June, 2012.
Manzini, E., M.A. Giorgetta, M. Esch, L. Kornblueh, and E. Roeckner, The influence of sea surface temperatures on the Northern winter stratosphere: Ensemble simulations with the MAECHAM5 model. J. Climate, 19, 3863-3881.2006
Toohey, M., K. Krüger, C. Timmreck, S. Gleixner, Dynamical responses to volcanic aerosols in the stratosphere and troposphere, poster presentation, 3ICESM, Hamburg, 2012.

Volcanic impact on stratospheric circulation

The multilinear regression method has been applied to study the response of the middle atmosphere to volcanic forcing in the MPI-ESM CMIP5 historic simulations (Figure 1). The temperature response to volcanic eruptions shows the typical pattern of a tropospheric cooling and a warming in the low to mid-latitude lower stratosphere. A consistent feature of the MPI-ESM-MR/MPI-ESM-LR configurations is a significant warming in the Northern Hemisphere (NH) winter high-latitude upper stratosphere. The meridional temperature signal from volcanic forcing is reflected in the westerly wind anomalies in large parts of the stratospheric high-latitudes.

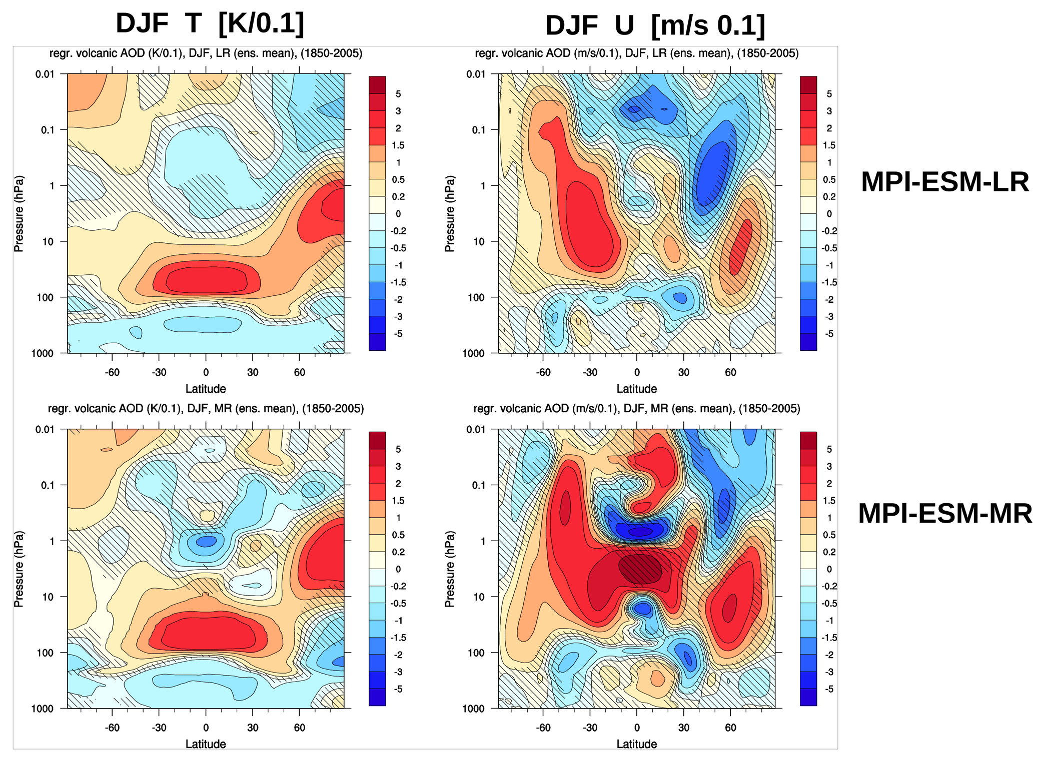


Figure1: Regression coefficients obtained from the regression of DJF mean temperatures (left) and zonal winds (right) with respect to the AOD of stratospheric volcanic aerosol. Values are calculated from CMIP5 historical simulations with MPI-ESM-LR (top) and MPI-ESM-MR (bottom). Units are K/0.1 and m/s/0.1, respectively. A global mean AOD of 0.1 is close to the value assumed after the 1991 eruption of Mt. Pinatubo (Schmidt et al., 2013).

In DJF this leads to an increase of the NH polar night jet, which is significant only in MPI-ESM-MR, and a decrease of the Southern Hemisphere (SH) summer easterlies. However, both MPI-ESM configurations underestimate the strong observed response of the NH winter stratosphere to volcanic forcing in comparison to observations (Figure 2a). The average response of CMIP5 models for the stratospheric NH winter is insignificant. None of the models shows a response as strong as observed. (Figure 2b). Whether this is due to a deficit in the CMIP5 volcanic aerosol data sets or due to differences in the physical feedbacks is currently under investigation.

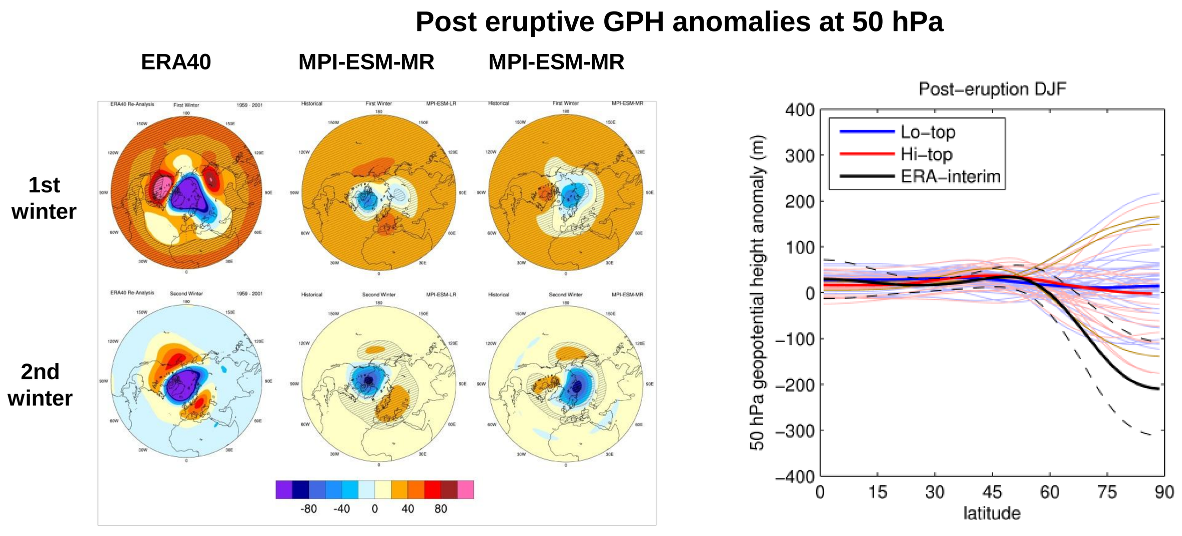


Figure 2: 50hPa NH DJF GPH anomalies (gpm) left: in MPI-ESM CMIP5 historical simulations. Composites for 7 eruptions and in ERA40 reanalysis data, right: after the El Chichon and Pinatubo eruptions in 19 historical CMIP5 simulations blue lines indicate "Low-top" and red "High-top" models. Brown lines the MPI-ESM-LR runs (modified from Charlton-Perez et al., 2013).

The impact of large tropical eruption on stratospheric circulation has been tested with the MPI-ESM-LR und MAECHAM5-HAM for different SO_2 emissions. For extremely strong volcanic eruptions, a significant positive Southern Annular Mode (SAM) is simulated (Figure 3). Observations from the last decades indicate no, or only a weak SAM signal for moderate to strong volcanic eruptions, which is consistent with the model simulations.

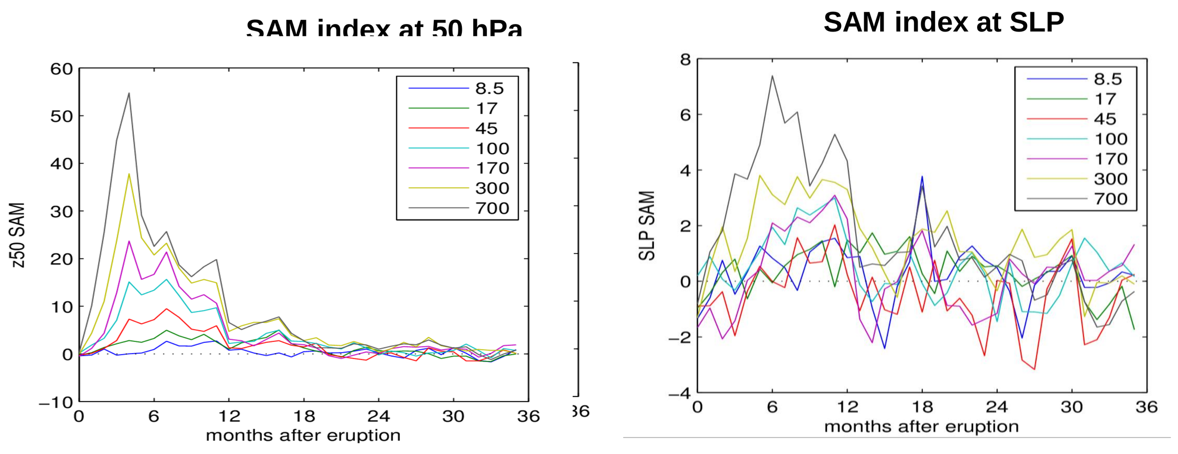


Figure 3 SAM Index for different tropical volcanic eruption strengths in MAECHAM5-HAM simulations at 50 hPa (left) and at sea level (Krüger et al.,2012).

Dynamical coupling between troposphere and stratosphere

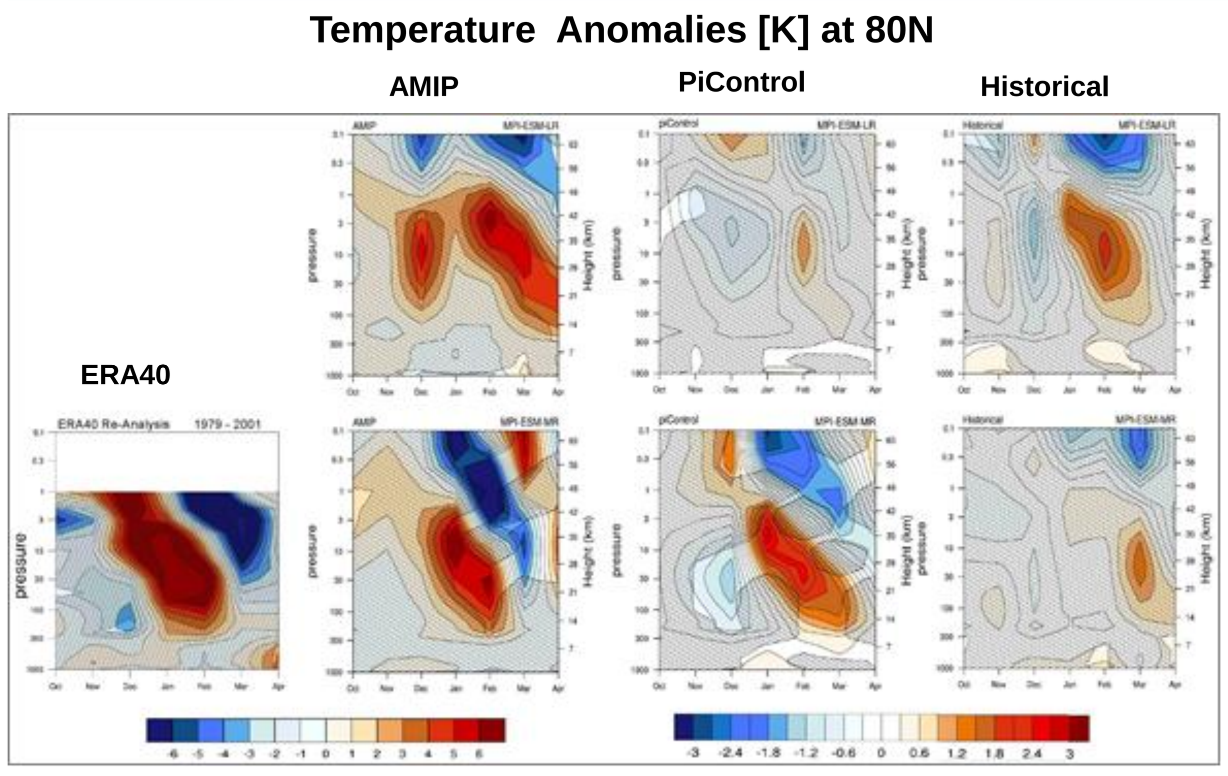
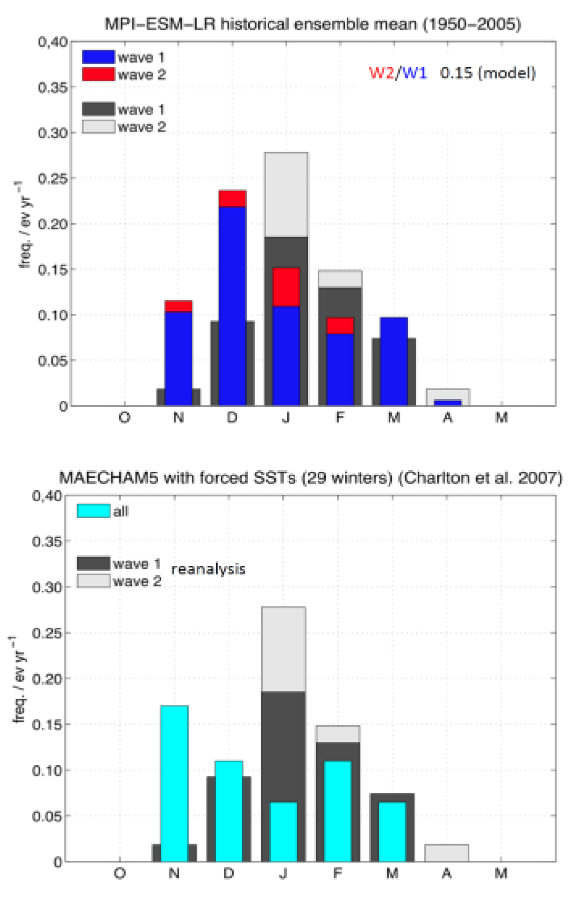


Figure 5: Zonal mean temperature anomalies (in K) at 80N for El Nino Winter in ERA40 reanalysis data (left) and in different CMIP5 simulations; from left to right: ECHAM6 AMIP period (1979-2008), pi-Control (average over 1000 years) and historical runs. The upper panels show anomalies in the MPI-ESM LR, the lower ones in the MR version. Non significant signals are hatched.

Warm ENSOs have a strong impact on the polar stratosphere in NH winter (Manzini et al., 2006). Enhanced planetary wave activity leads to a polar warming in the stratosphere, which propagates downwards from 1hPa to about 300hPa during winter (October to April). MPI-ESM-MR AMIP simulation results are comparable to ERA40 reanalysis data, whereas in the LR resolution, the warm anomaly appears later in winter and propagates slower downwards (Figure 5). In the coupled model, an impact of El Niño on the polar stratosphere is only apparent in the piControl MR simulations. Neither the LR resolution in piControl, nor either resolutions of the historical CMIP5 simulations show any significant impact of El Niño.



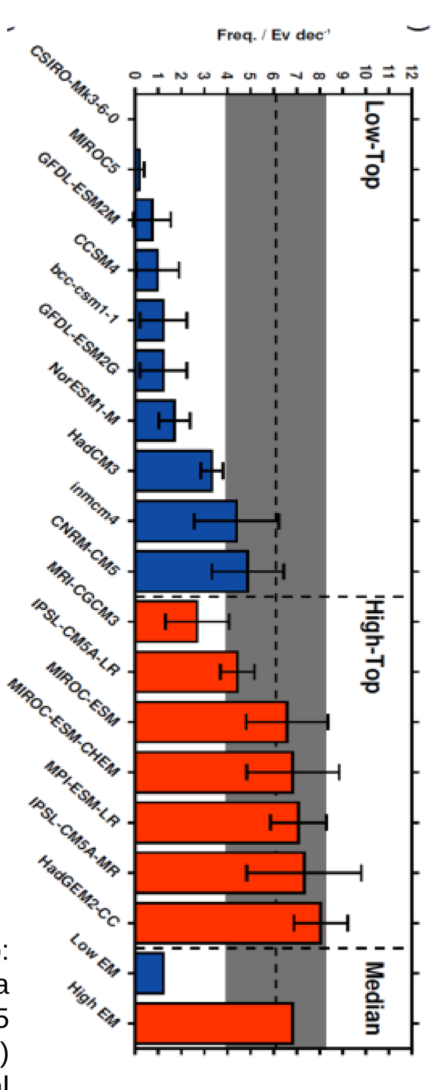


Figure 4: (left) mSSW frequency (ev/ yr) top: for MPI-ESM-LR and ECMWF reanalysis data (grey bars), below for MAECHAM5 (distribution from Charlton et. al. 2007); (right) mSSW frequency (ev/ dec) for historical CMIP5 simulations models (Charlton-Perez et al., 2013).

The simulation of major sudden stratospheric warmings (mSSWs) is important for the realistic coupling of the atmospheric layers. MPI-ESM-LR shows a good overall distribution of mSSWs during NH Winter (Figure 4). However, it still tends to produce too many early events during November and December (as prev. MAECHAM5). The reasons for this are still unclear.

Max-Planck-Institut für Meteorologie
FONA Mittelfristige Klimaprognosen BMBF
MiKlip
GEOMAR Helmholtz Centre for Ocean Research Kiel