The MPI Super Volcano project

(2006-2011)

Claudia Timmreck and MPI SV Group

Volcanic super eruptions

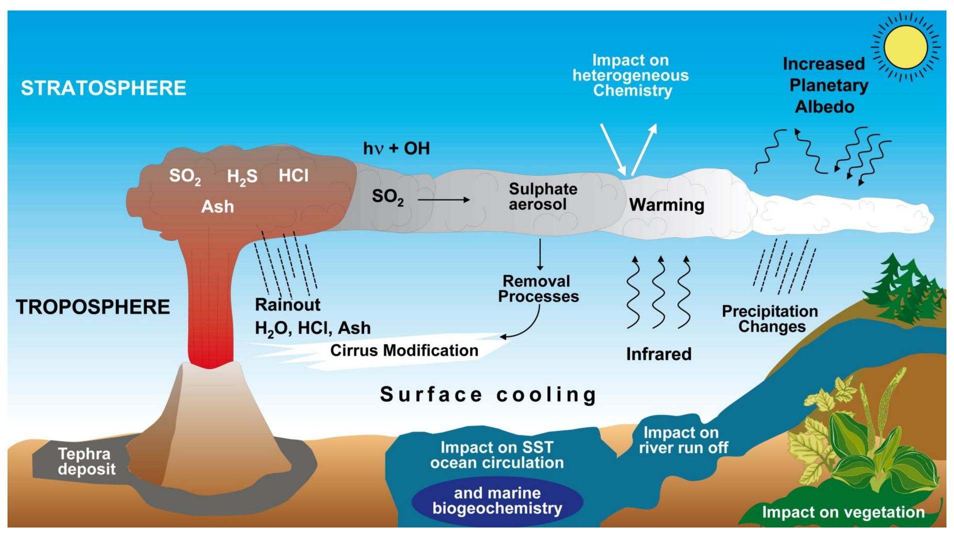

Fig. 1: Schematic overview over the climate effects after a volcanic super eruption.

Volcanic super eruptions (release of > 10^{15}kg magma ~1000 km^3 ash, >1000 Mt SO_2) are very strong but also very rare events. They constitute extremely strong forcing to the Earth system and provide therefore an ideal test bed for the quality and performance of an Earth System model.

The MPI SV project

The project

- Cross-cutting project at the MPI for Meteorology
- Close cooperation with Millennium Project *(PB-Z-107)*
- Collaboration with Univ. Cambridge, IFM-GEOMAR

The task

- Understand the effect of large volcanic eruptions
- Test the model system in extreme circumstances
- Foster the collaboration between the departments

The team

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S. Hagemann, K. Hübner, J. Jungclaus, S. Kinne, T. Kleinen,
K. Krüger, U. Niemeier, D. Matei, D. Metzner, S. Rast,
C. Rodehacke, H. Schmidt, R. Schnur, J. Segschneider,
K. Six, M. Thomas, C. Timmreck (coordinator), M. Toohey,
M. Wiesner, D. Zanchettin

The tools

- MAECHAM5/HAM model
- MPI-ESM

Further Information:

- www.mpimet.mpg.de/en/wissenschaft/working-groups/super-volcanoes.html

Publications

- Timmreck, C. and H.-F. Graf, The initial dispersal and radiative forcing of a Northern Hemisphere mid-latitude super volcano: a model study, Atmos. Chem. Phys., 6, 35-49, 2006
- Thomas, M. A. et al., Simulation of the climate impact of Mt. Pinatubo eruption using ECHAM5. Part-I: Sensitivity to the modes of atmospheric circulation and boundary conditions, Atmos. Chem. Phys, 9, 757-769, 2009.
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- Kokkola, H. et al., Aerosol microphysics modules in the framework of the ECHAM5 climate model – intercomparison under stratospheric conditions, Geosci. Model Dev., 2, 97-112, 2009.
- Niemeier, U. et al., Initial fate of fine ash and sulfur from large volcanic eruptions. Atmos. Chem. Phys., 9, 9043-9057, 2009.
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- Brovkin V. et al., Sensitivity of a coupled climate-carbon cycle model to large volcanic eruptions during the last millennium Tellus B, 62, 674-681, 2010.
- Timmreck, C. et al., Aerosol size confines climate response to volcanic super-eruptions, Geophys. Res. Lett. 37, L24705, doi:10.1029/2010GL045464, 2010.
- Zanchettin, D. et al., Bi-decadal variability excited in the coupled ocean-atmosphere system by strong tropical volcanic eruptions, Climate Dynamics, DOI: 10.1007/s00382-011-1167-1, 2011.
- Toohey M. et al., The influence of eruption season on the global aerosol transport and radiative impact of tropical volcanoes, Atmos. Chem. Phys., 11, 12351-12367, 2011..
- Timmreck C., et al. (2012) Climate response to the Toba eruption: regional changes. Quat Int. 258,30-44.
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- Metzner D., et al. (2012), Radiative forcing and climate impact resulting from SO2 injections based on a 200,000 year record of Plinian eruptions along the Central American Volcanic Arc, . Int J Earth Sci. doi:10.1007/ s00531-012-0814-z.
- Zanchettin D. et al., (2013) Delayed winter warming: a decadal dynamical response to strong tropical volcanic eruptions. Geophys. Res. Lett. DOI: 10.1029/2012GL054403
- Segschneider, J., et al.(2013) Impact of an extremely large magnitude volcanic eruption on the global climate and carbon cycle estimated from ensemble Earth System Model simulations, Biogeosciences, 10, 669-687, doi:10.5194/bg-10-669-2013.

Zanchettin D., et al. (2013) Background conditions influence the decadal climate response to strong volcanic eruptions. J. Geophys. Res. (accepted)

Submitted:
Toohey, M., K. Krüger and C. Timmreck, Volcanic sulfate deposition to Greenland and Antarctica: a modeling sensitivity study submitted to JGR (under revision)

The Big Scientific Questions

Can a very large volcanic eruption „super eruption“ disturb the climate system over a longer time scale or even push the system into another state ?

Do nonlinearities in the climate system limit or enhance the impact of a huge volcanic disturbance ?

Accomplishments

Insights into the behavior of the Earth System

- Climate effect of larger volcanic eruptions are weaker and smaller than previously thought *(PB-Z-410)*
- The global temperature signal is determined by the strength of the SO_2 emission and not by the latitude of the eruption.
- Post-eruption oceanic and atmospheric anomalies describe a decadal fluctuation in the coupled ocean–atmosphere system *(PB-Z-103).*
- Improved description of processes acting on multidecadal timescales is pivotal to constrain the climate response to the 1809 and Tambora tropical eruptions (*PB-Z-104).*
- Radiative heating from volcanic ash cause rotation of volcanic cloud, which influences the transport in the first days on local scale.
- Eruption season has a significant influence on aerosol optical depth and clear-sky shortwave (SW) radiative flux anomalies and for large volcanic eruption also on the all sky SW flux anomalies
- Annular mode response after volcanic eruption increases logarithmically with increasing eruption magnitude.
- Deposition of sulphate to the Antarctic polar ice sheet is strongly dependent on eruption magnitude
- Mt. Pinatubo eruption causes the observed delay of the QBO cycle in 1991/1992**.**
- Post-eruption sea ice anomalies show strong hemispheric differences dependent on the magnitude of the eruption.
- Bare soil coverage is strongly increasing after a very large volcanic eruption with fewer trees and more grass.
- Post-eruption atmospheric CO_2 anomalies are explained mainly by changes in land carbon storage in the initial phase. In the longer term, the ocean compensates for the atmospheric carbon loss *(PB-Z-417).*

Made a System

- Climate effect of future volcanic eruptions can be estimated from the geographical location, strength and duration time of a volcanic eruption
  - Improvement of the ECHAM radiation scheme
  - Adaption of the global aerosol model HAM to stratospheric processes
  - Development of a volcanic ash module
  - Implementation of volcanic forcing in the MPI-ESM

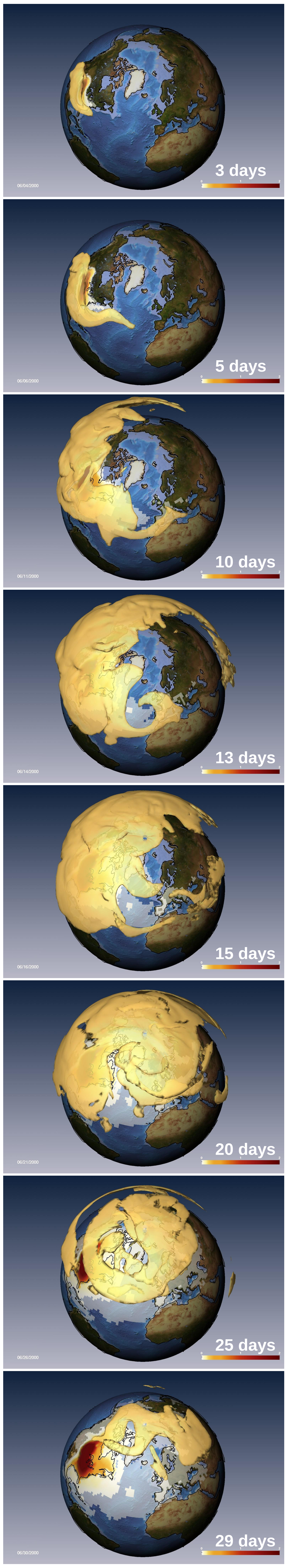
Established a workflow across the institute

- 15 scientists from all departments
- Cross departmental publication

Developed Expertise

- 16 publications, 1 submitted, several in preparation
- More than 75 conference contributions
- New projects:
- SFB57/C5 (DFG), IMPLICC (EU FP7), MIKLIP ALARM (BMBF)
- Contribution to the WMO CCMVAL Assessment Report
- Special sessions EGU 2009/2020/2011
- Chapman Conference on Volcanism and the Atmosphere 2012

The pictures on the right show the simulated initial distribution of the Yellowstone volcanic cloud and the corresponding accumulated ash deposition at the surface. We are grateful to Michael Boettinger, DKRZ for visualising the simulated volcanic eruption clouds in such a brilliant way.



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