SFB 574: Modelling climate effects and feed-backs of past Central and South American major volcanic eruptions

Abstract:

Investigating climate feedbacks is a central research task of the SFB 574 at Kiel University "Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters". Volcanic eruptions play a significant role in the global climate of the Earth and can delay and attenuate the global warming due to anthropogenic climate change. Major volcanic eruptions, which directly inject gases, aerosols and volcanic ash into the stratosphere, have a strong and long lasting impact on the global climate depending on their geographical latitude and their SO_2 and halogen (Cl, Br, I) release.

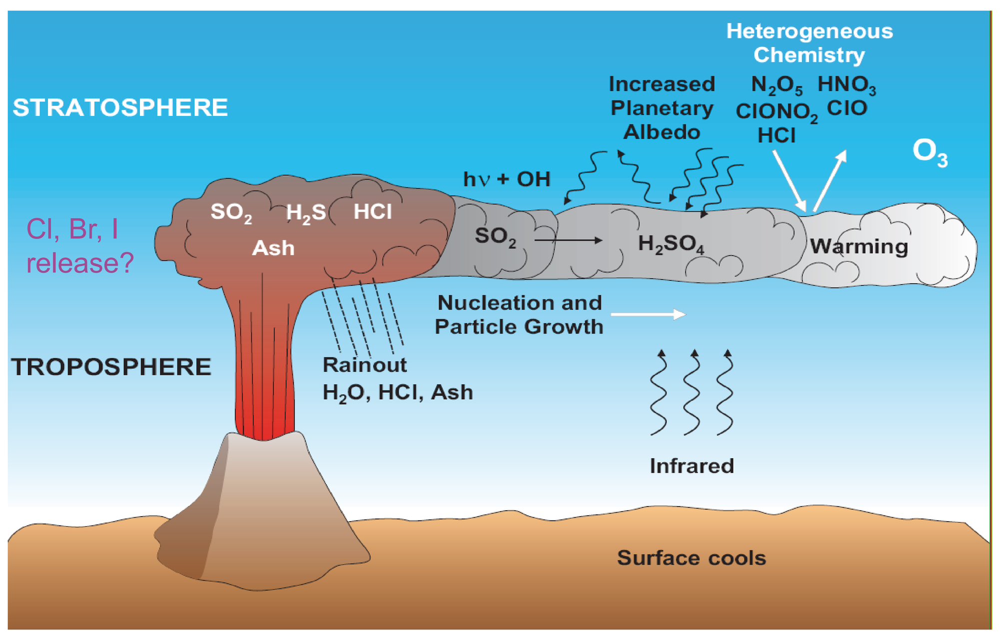
We will use state of the art climate models to study the climate effects and feedbacks of past Central and South American major volcanic eruptions analysed by petrologic methods. Simulations with different complexity of climate models enable us to assess their effect on the paleo and present day climate as well as their possible effect in a future climate scenario. Special emphasis will be placed on the global role of volcanically released halogen species on atmospheric chemistry and the possibility of a volcanically induced pre-industrial Ozone hole. The role of ocean-atmosphere interactions during major volcanic eruptions is an important climate feedback (e.g. ENSO, ocean heat content and sea level response), which will be investigated in more detail.

The climate relevance of major volcanic eruptions from the tropical Central American Volcanic Arc, investigated between 2001 and 2007, covering a time interval between 1950 AD and 191,000 BP, will be assessed with the help of an earth system climate model of intermediate complexity. As soon as volcanic volatile flux data become available from planned work in Chile, the effect of large volcanic eruptions from southern hemisphere mid-latitudes will be considered as well.

Influence of major volcanic eruptions

Major volcanic eruptions are an important source of tropospheric and stratospheric aerosols. They have a:

- considerable influence on radiative, chemical and dynamical processes,
- global impact on climate (longer lasting if they erupt in the tropics),
- impact on the atmosphere-ocean system, which can mask anthropogenic climate forcing temporarily (global warming, sea level rise).



After McCormick et al.1995

Climate modelling of major volcanic eruptions

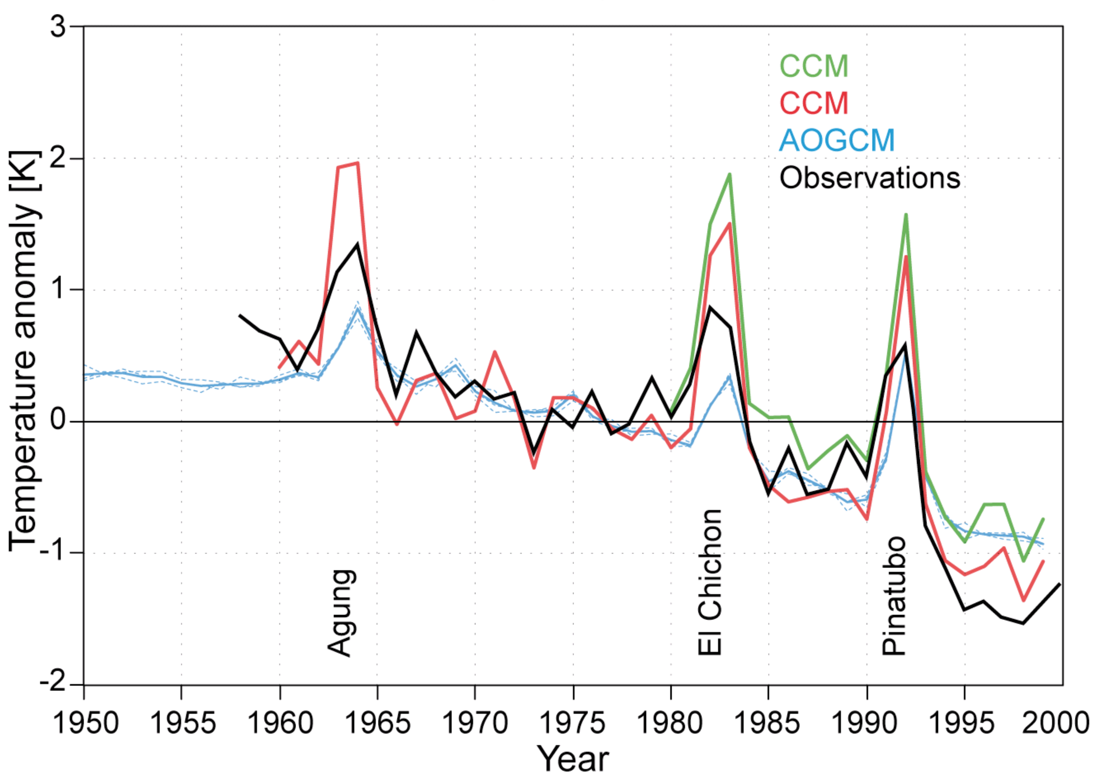
Climate models

Coupled Atmosphere Ocean General Circulation Model (AOGCM):
- ECHAM5 MPIOM 1.0
Low top model: lid at 30km
(Röckner et al. 2006; Jungclaus et al. 2006)
- Experimental setup
GHG forcing (IPCC) including 9 volcanic eruptions from 1860-1999
Simplified volcanic forcing: interacting with radiation

Coupled Chemistry Climate Model (CCM1/CCM2)
- Atmosphere: MAECHAM4 CHEM
High top model: lid at 80km
(Steil et al. 2003; Manzini et al. 2003)
- Experimental setup
GHG (IPCC), CFCs (WMO), observed SST, QBO and solar cycle forcing including 3 volcanic eruptions from 1960/80-1999
Simplified volcanic forcing: interacting with radiation and chemistry

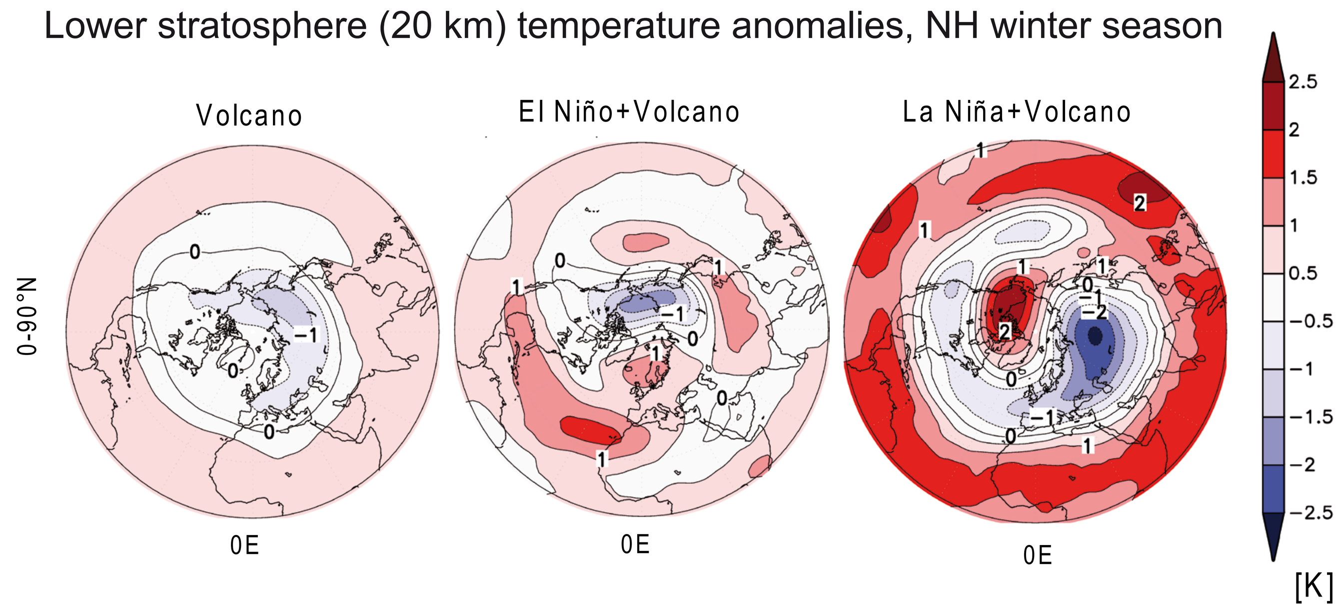
Global temperature anomaly

Lower stratosphere (20 km), annual mean



Atmosphere-ocean feedbacks after volcanic eruptions

Lower stratosphere (20 km) temperature anomalies, NH winter season

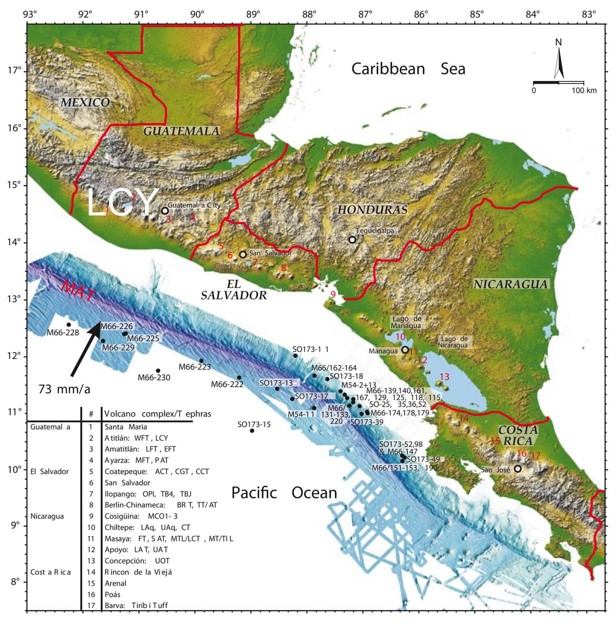


=> The atmosphere shows a different response after volcanic eruptions due to El Niño and La Niña events (different Arctic Oscillation pattern).
=> The hypothesis that volcanic eruptions trigger El Niño events is not supported.

SFB 574: petrologic method to derive halogen emissions

Working area

Los Chocoyos
15°N 91°W
(Guatemala)

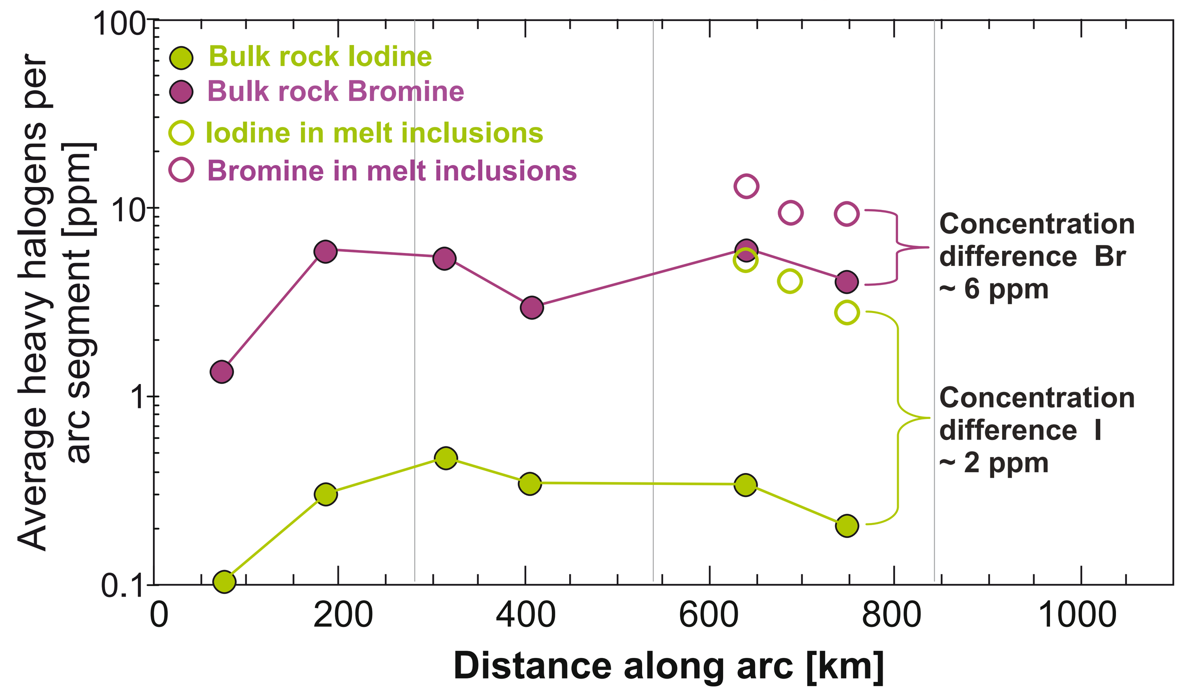


Our field work focussed on the Central American Volcanic Arc (CAVA) that runs parallel to the Middle American Trench from Costa Rica to Guatemala.
Between 2001 and 2007 we studied 22 major volcanic centres along the CAVA. The names of numbered volcanoes are listed at the lower left.

Heavy halogen emissions from large volcanic eruptions: Potential impact on stratospheric ozone layer

Major volcanic eruptions directly inject halogens into the stratospheric ozone layer. Bromine is known to be about two orders of magnitude more efficient than chlorine in destroying stratospheric ozone but reliable analyses of heavy halogen concentrations in ashes and glass inclusions are only possible using a combination of SYXRF microprobe and pyrohydrolysis followed by ICP-MS analysis. First results from melt inclusions and degassed matrix glasses of Nicaraguan tephras show

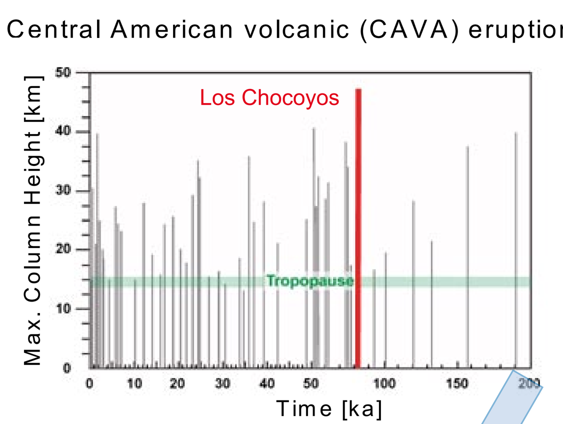
=> Emission of 1 to 150 kt I and 2 to 450 kt Br per felsic Nicaraguan eruption into the atmosphere (Total range of 8 large eruptions)



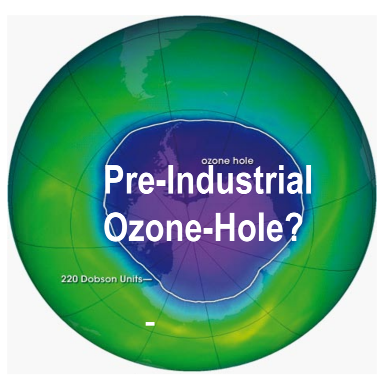
Along-arc Br and I variations in felsic glasses compared to average concentrations in Nicaraguan felsic melt inclusions.

SFB 574: proposed work

Climate effects and feedbacks of Central American and Chilean volcanic eruptions using petrologically determined emission rates



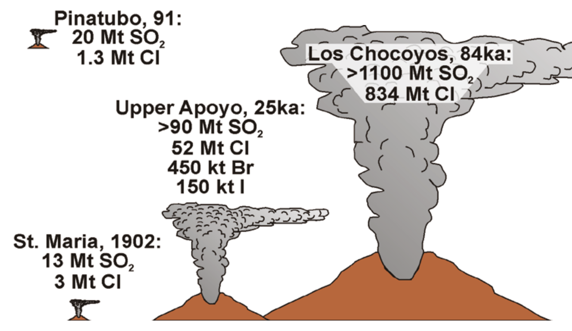
Role of volcanic released halogens on the atmosphere in paleo, present, future climate?



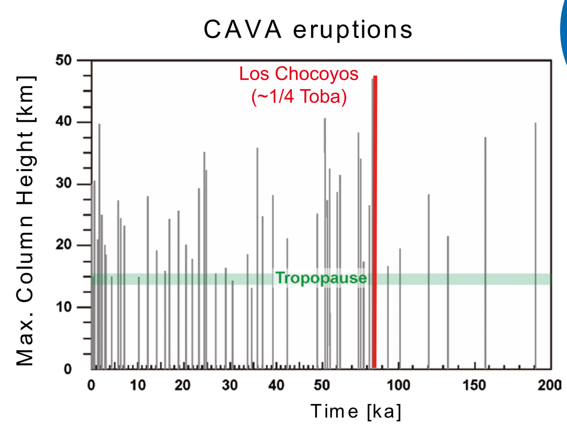
Realistic volcanic forcing will be simulated with a CCM using input data from the SFB 574 phase I and II:

- column height,
- SO_2 emissions,
- halogen emissions,
- CO_2 and CH_4 fluxes.

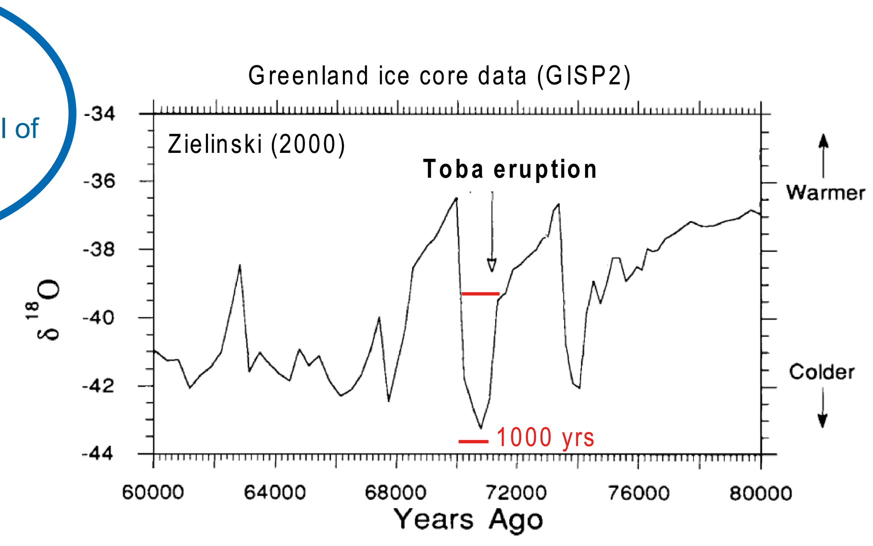
Sensitivity studies for different volcanic SO_2 emissions



Paleo climate relevance of Central American and Chilean volcanoes



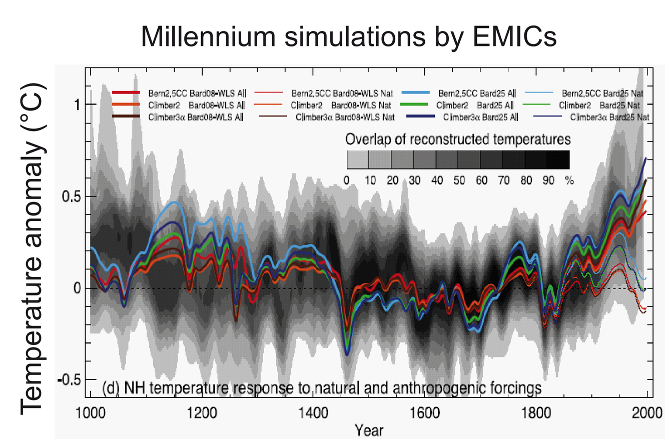
Centennial to millennium time scales?
I+II: Climate signal of CA vs. Chilean eruptions?



SO_2 flux
Optical depth
Radiative forcing

Earth Climate System
Model of Intermediate
Complexity (EMIC)

Millennium simulations by EMICs



200,000 yrs

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