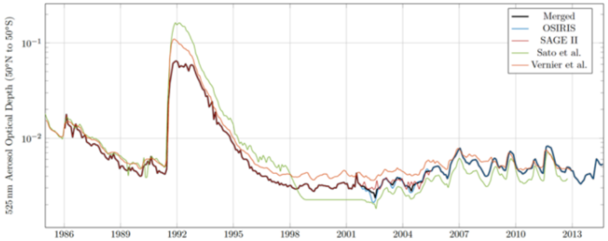
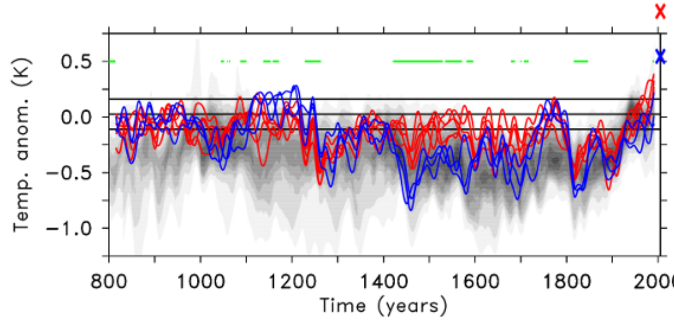
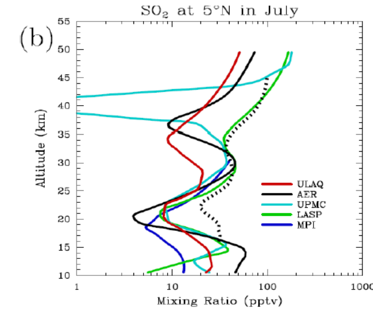






VolMIP: The CMIP6 model intercomparison project on the climatic response to volcanic forcing

Co-chairs: Davide Zanchettin[1], Claudia Timmreck[2], Myriam Khodri[3]

1 : University of Venice, Italy, 2: MPI for Meteorology, Hamburg, Germany, 3: IRD/IPSL/Laboratoire d'Océanographie et du Climat, France,

Zanchettin, D et al. .: The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP): Experimental design and forcing input data, Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-68, in review, 2016

Potsdam SSiRC workshop 25. 4. 2016

Università Ca'Foscari Venezia

Max-Planck-Institut für Meteorologie

Institut Pierre Simon Laplace

Volcanoes and climate in a sketch

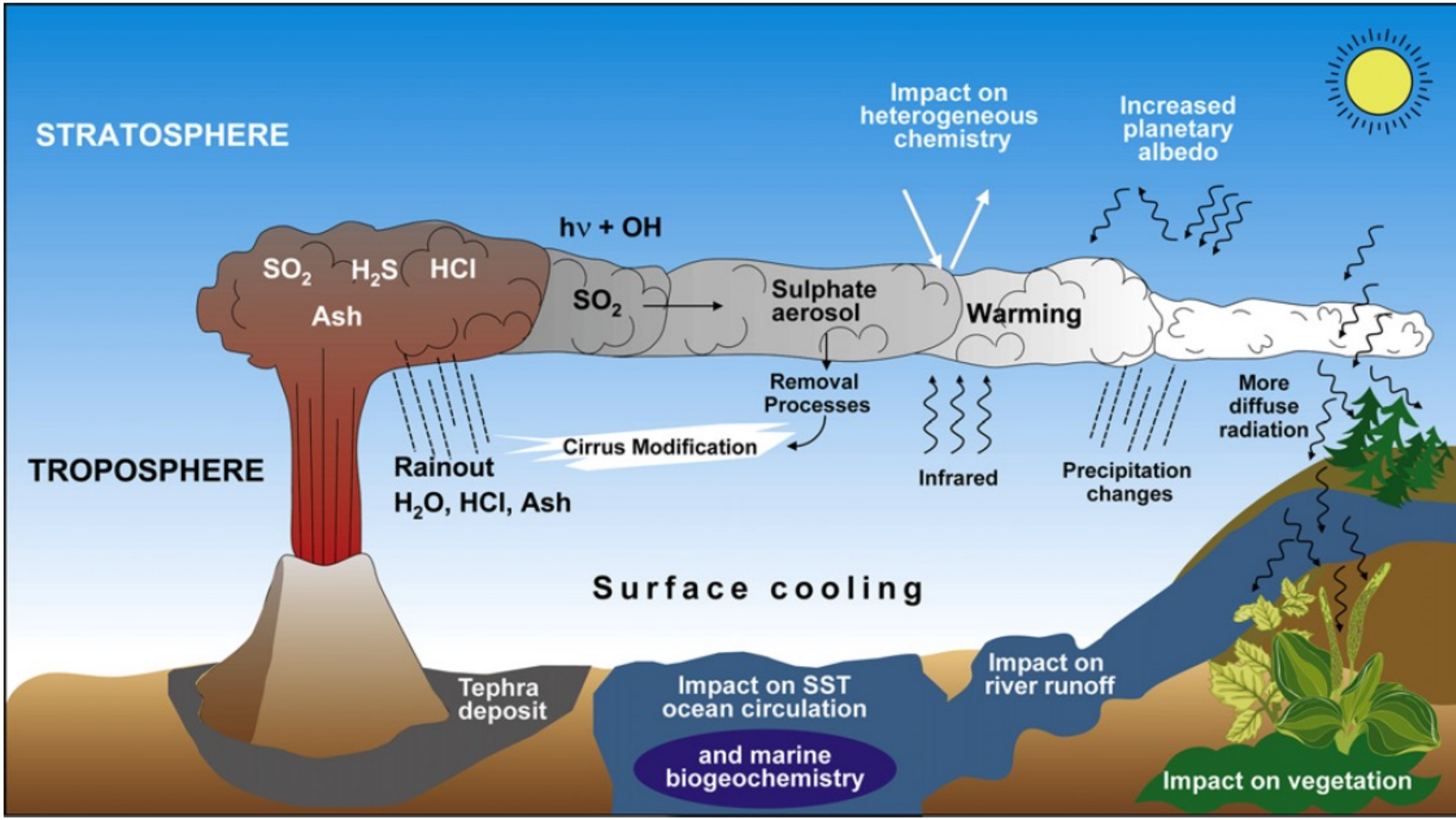
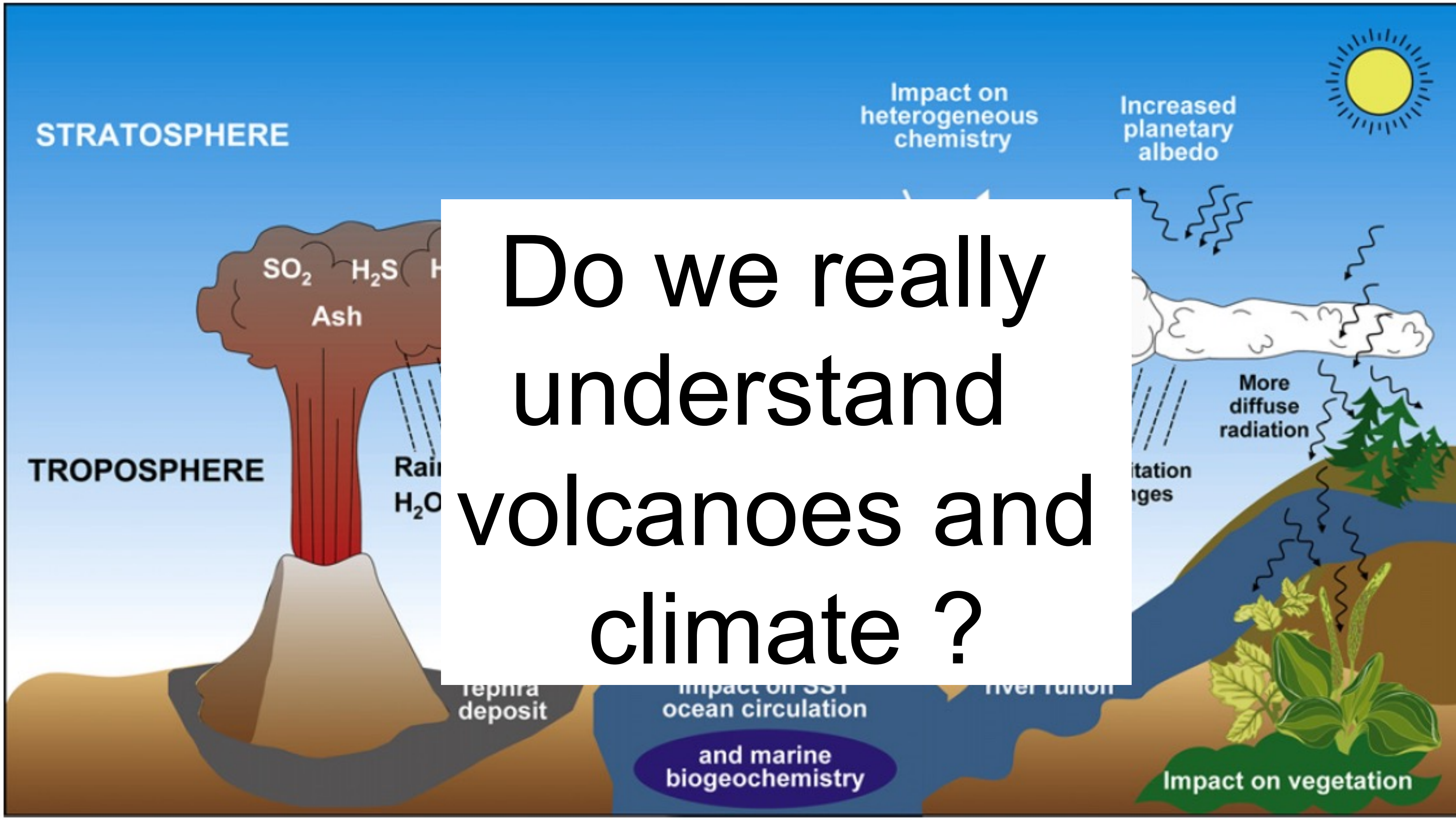


Figure 1 from Timmreck 2012 | **Schematic overview over the climatic effects of very large volcanic eruptions**

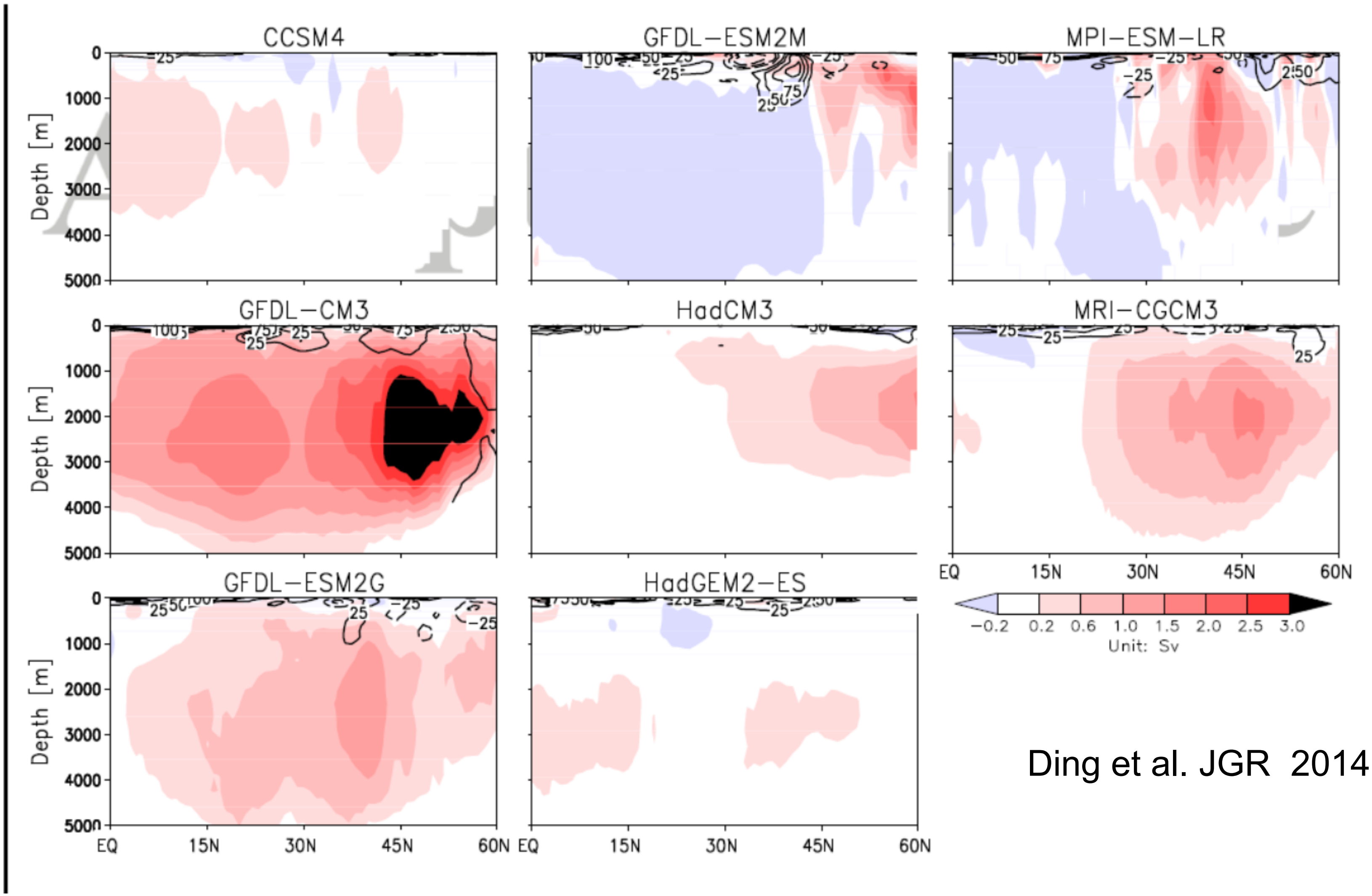
Volcanoes and climate in a sketch



Do we really understand volcanoes and climate ?

Figure 1 from Timmreck 2012 | **Schematic overview over the climatic effects of very large volcanic eruptions**

Volcanoes and climate: Uncertainties in long term response



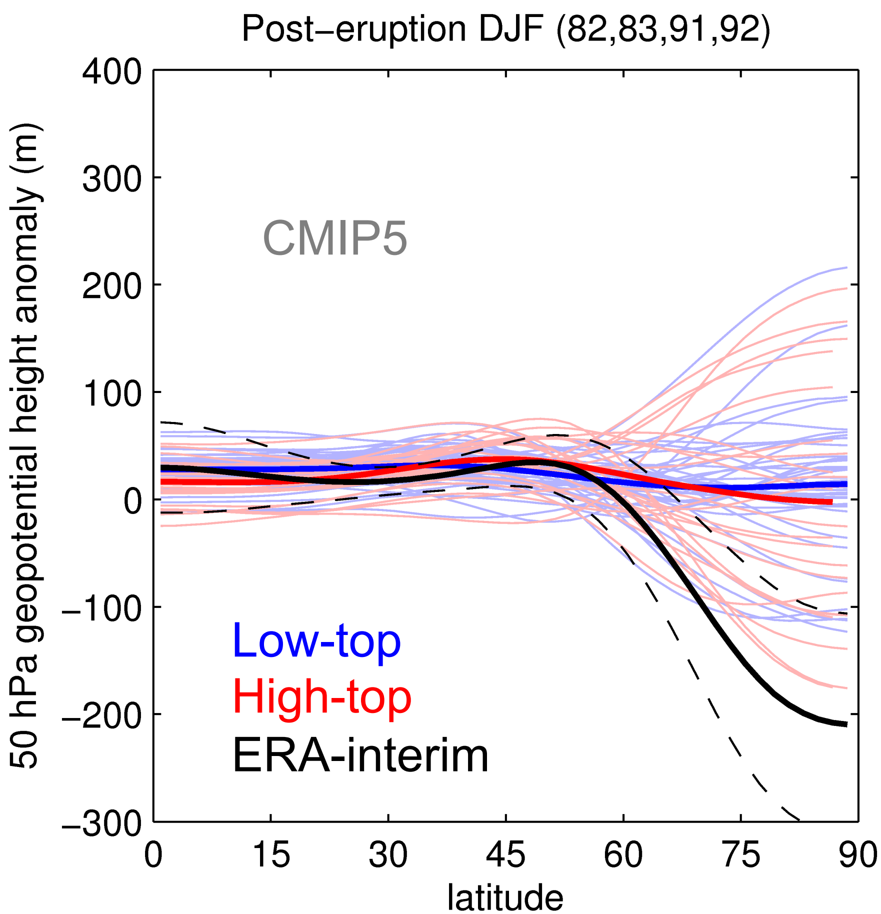
Ding et al. JGR 2014

Response of the Atlantic meridional overturning circulation (AMOC) after Krakatoa

Volcanoes and climate: Uncertainties in NH winter dynamics

Recent work (EGU presentations by A. Robock and M. Bittner) challenges previous work that CMIP5 models general fail to capture the NH dynamical winter response

However CMIP5 models seems to underestimate vortex strengthening in the first two winters after the El Chichón and the Mt. Pinatubo eruption



Charlton-Perez et al., 2013

Volcanoes and climate: Uncertainties in proposed mechanism

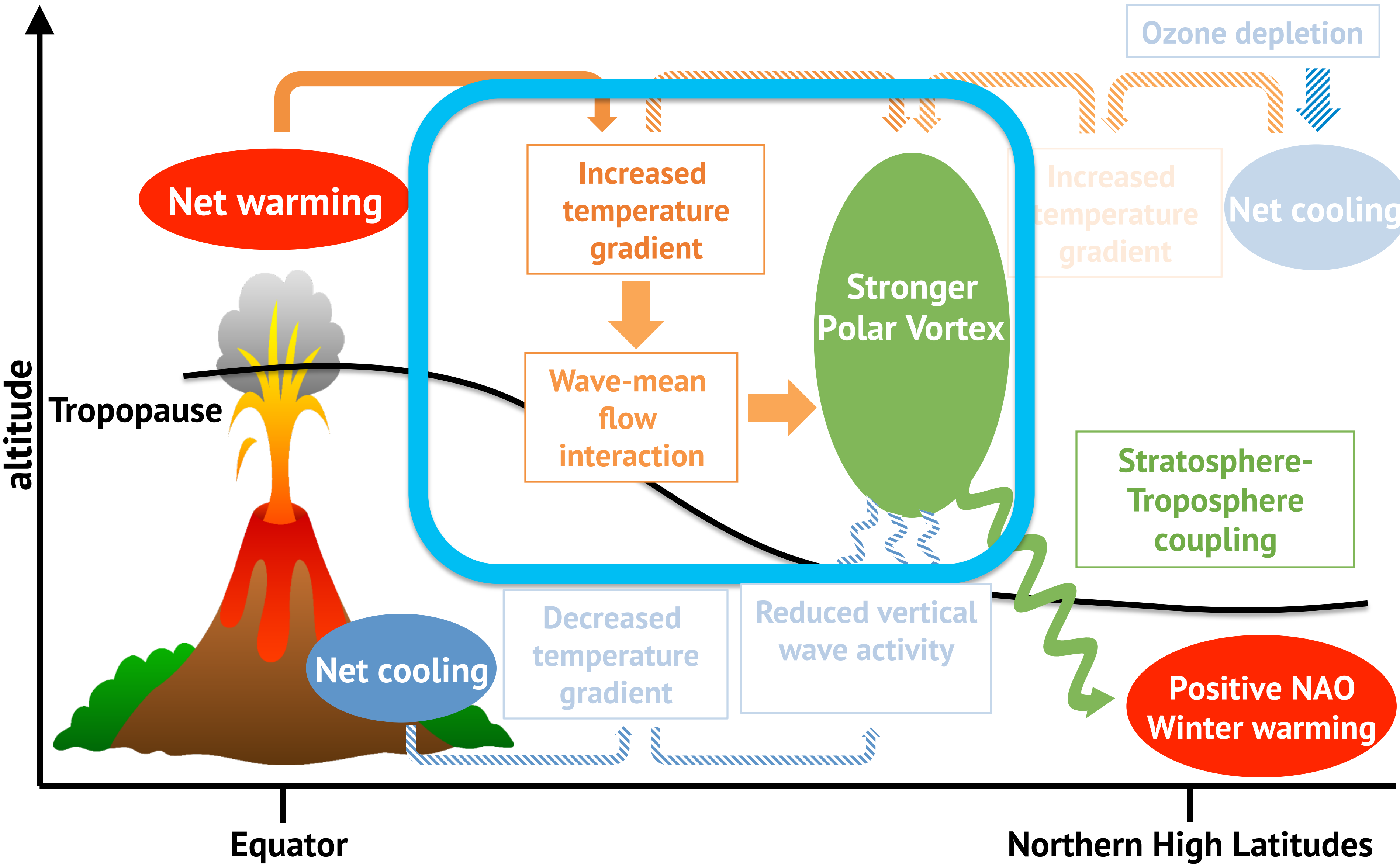


Figure courtesy of M. Bittner

Volcanoes and climate: Uncertainties in temperature response

Forcing

Implementation of Forcing

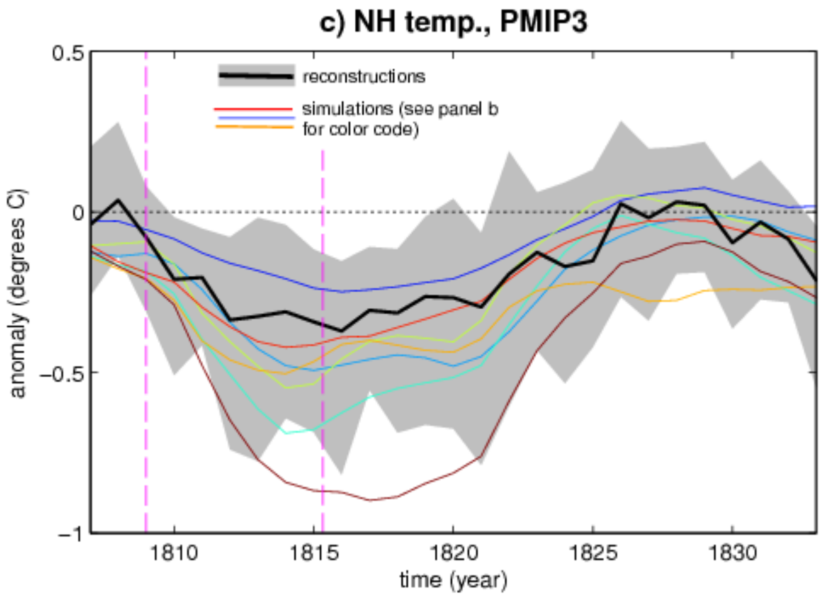
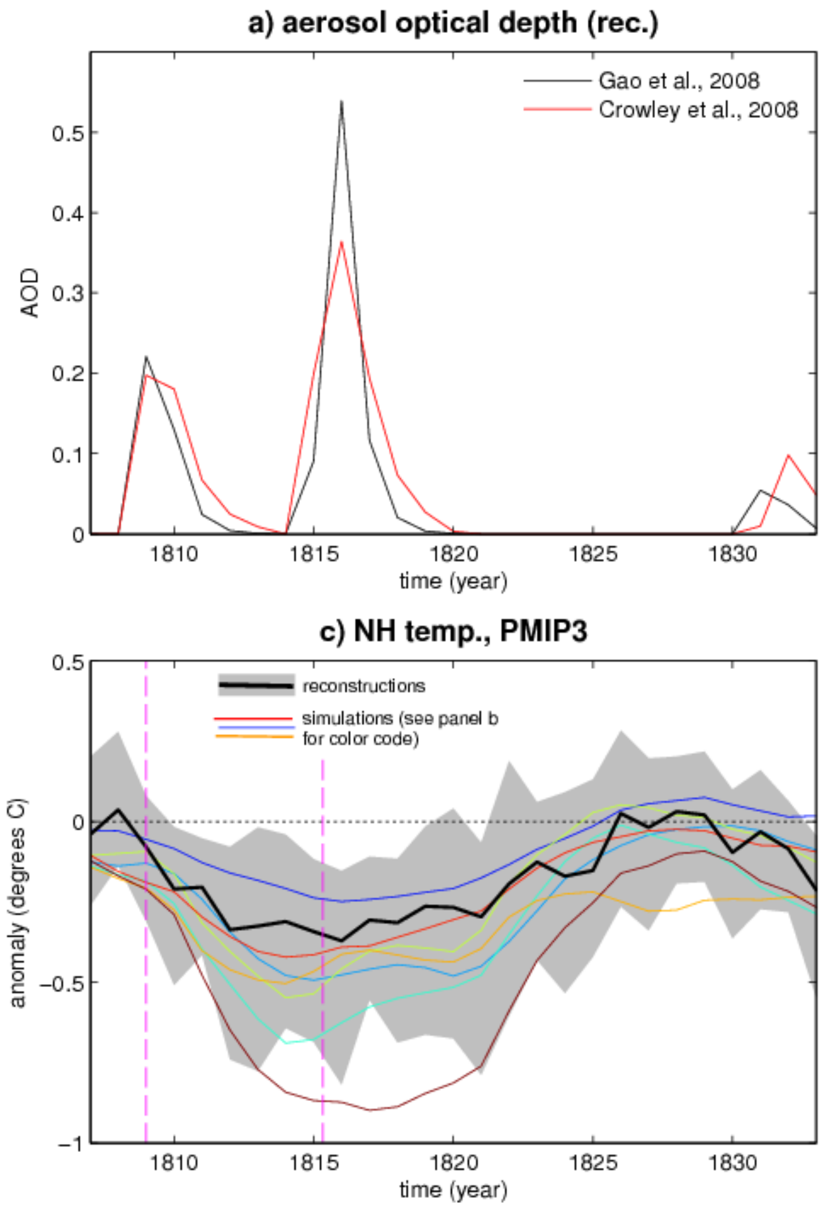


Figure 1 from Zanchettin et al., 2015 |

Natural variability

Volcanoes and climate: Uncertainties in temperature response

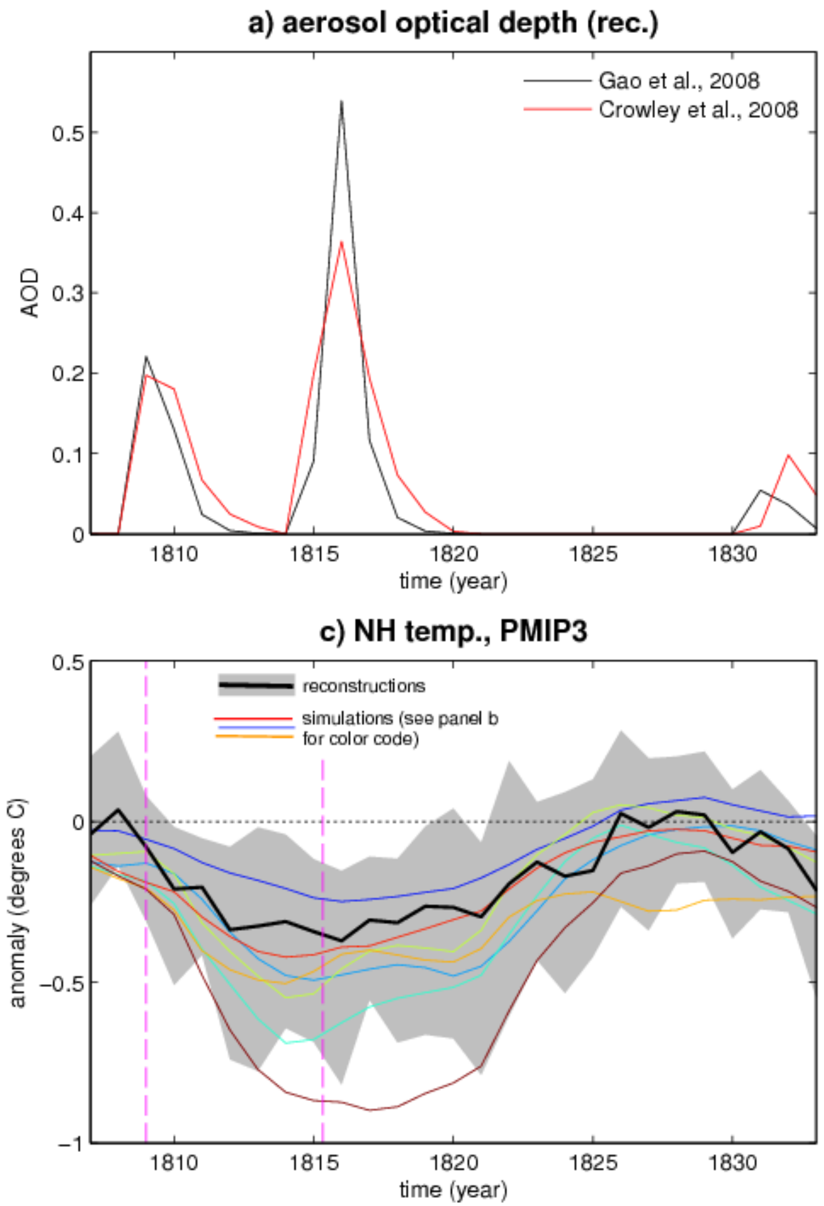


Implementation of Forcing

Natural variability

Figures from Zanchettin et al., 2015 |

Volcanoes and climate: Uncertainties temperature response



Natural variability

Figures from Zanchettin et al., 2015 |

Volcanoes and climate: Uncertainties in temperature response

“ **Uncertainties grow considerably for events that occurred in the more remote past** […] which contribute substantially to our understanding.” [*Zanchettin et al., 2015*]

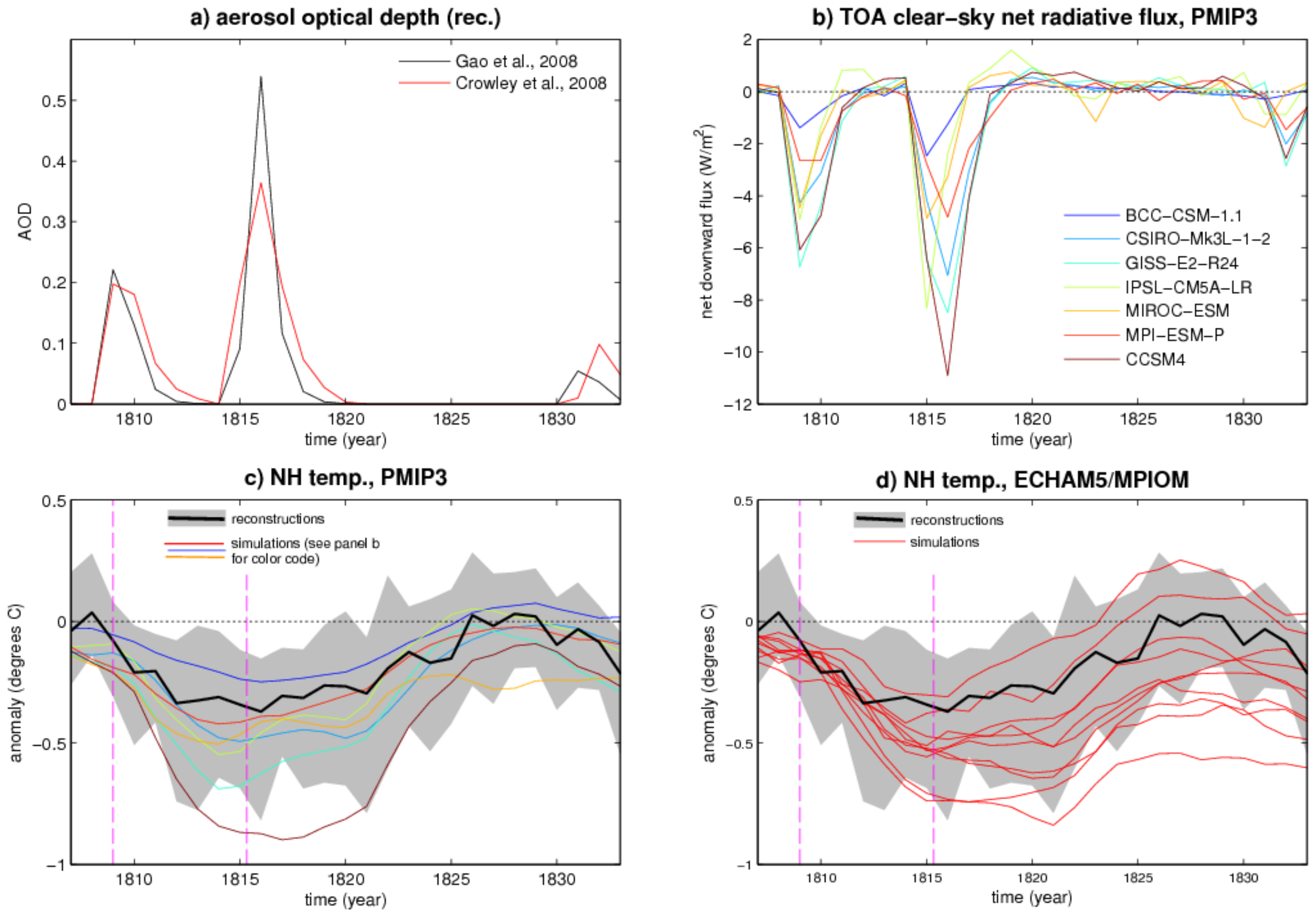
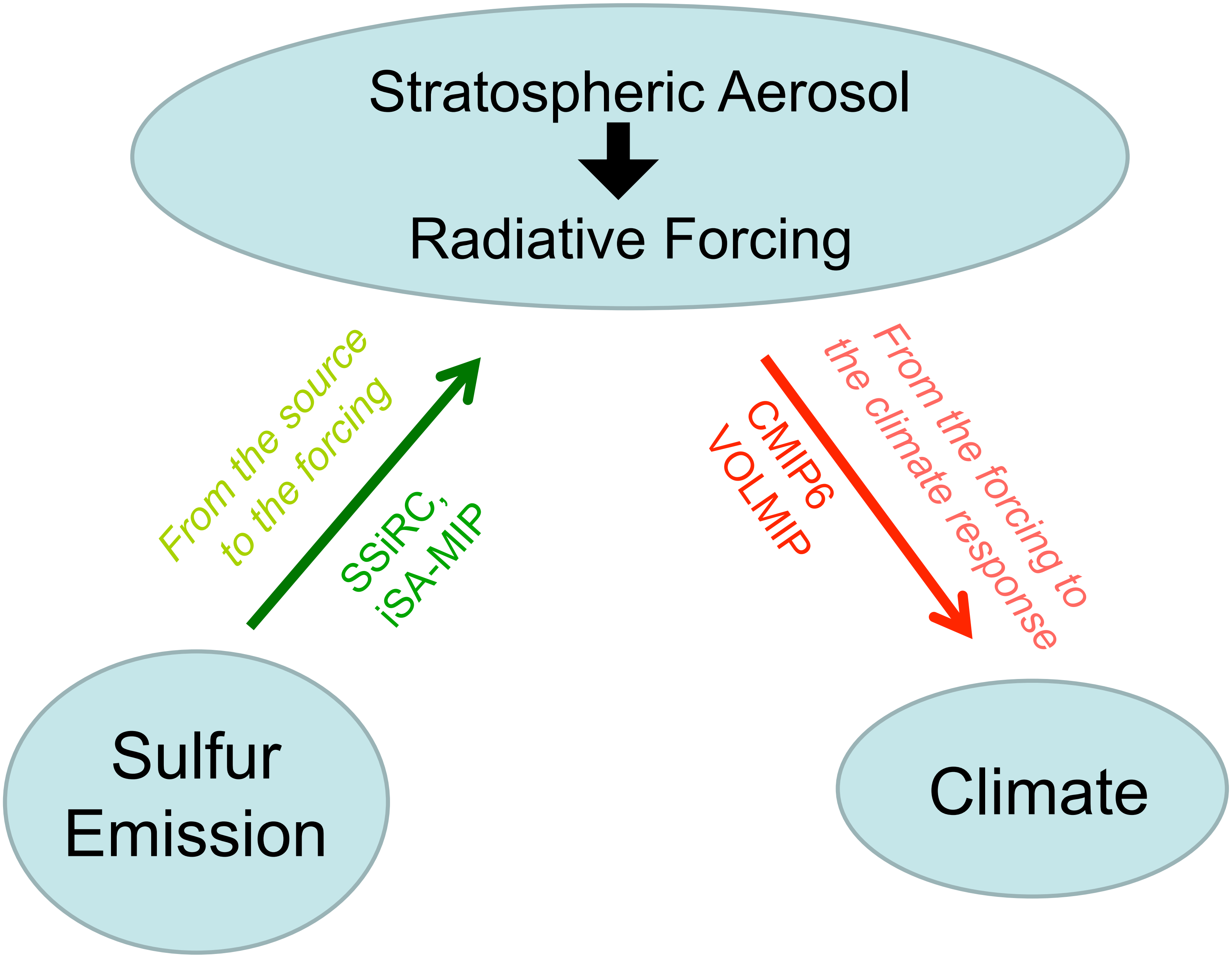


Figure 1 from Zanchettin et al., 2015| **Uncertainty in radiative forcing and climate response for the early-19th-century eruptions. Different models and forcing inputs (c) and internal climate variability (d) similarly contribute to simulation-ensemble spread**

Tackling the uncertainties: A modeling approach



VolMIP – Model Intercomparison Project on the climatic response to Volcanic forcing

in a nutshell:

VolMIP is a CMIP-endorsed activity which defines a common protocol focused on **multi-model assessment of climate models‘ performance under strong volcanic forcing conditions**.

VolMIP defines a set of *idealized* volcanic perturbations based on historical eruptions

Volcanic forcing is implemented through prescribed aerosols optical parameters **derived from radiation parameters of documented eruptions**.

The experiments are designed as ensemble simulations, with sets of **initial climate states sampled from an unperturbed preindustrial simulation (piControl)**.

Several models have already committed to perform VolMIP core experiments, including CanESM, CESM, EC-Earth, FGOALS, GISS, IPSL, MIROC-ESM, MPI-ESM, MRI-ESM1.x, NorESM and UKESM.

http://www.volmip.org/

Experimental design

VolMIP experiments are designed based on a twofold strategy

	VolShort	**VolLong**
FOCUS	the seasonal-to-interannual atmospheric response to a 1991 Pinatubo-like volcanic eruption disentangling the role of surface cooling and stratospheric warming for the short-term atmospheric dynamical response impact of volcanic forcing on seasonal-to-interannual climate predictability (with DCPP)	long-term (up to the decadal time scale) climate response to very strong volcanic eruptions (like Tambora, Laki) signal propagation pathways of volcanic perturbations within the coupled atmosphere-ocean system
INITIAL CONDITIONS	ENSO, QBO, AMOC, NAO, polar vortex	ENSO, AMOC

Identification of consensus forcing input data for both types of experiments is an integral part of VolMIP

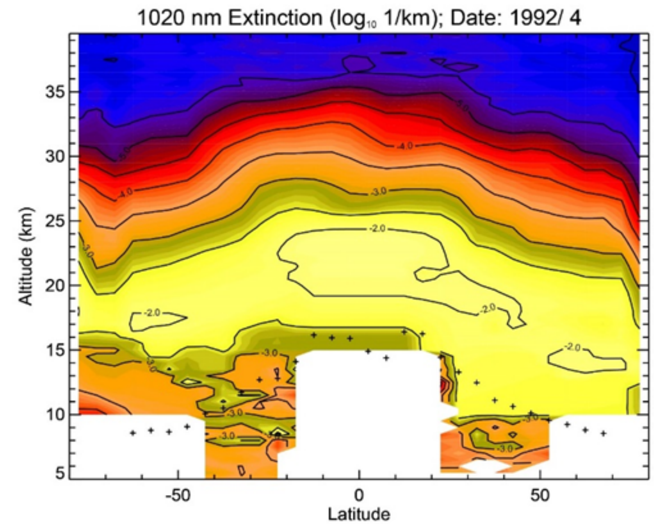
VolMIP core (Tier 1) experiments

Name	Aim	Ens. Size	Length	Forcing
VolShortEQFull	accurately estimate **uncertainty in simulated responses** to volcanic forcing comparable to the amplitude of internal interannual variability	25	3	CMIP6 stratospheric aerosol data set (Thomason et al., 2015) for the volcanic forcing of the 1991 Pinatubo eruption which is set up for the CMIP6 *historical* simulation
VolShortEQstrat	**isolate the impact of stratospheric warming** by volcanic aerosols	25	3	Prescribed perturbation to the total (LW+SW) radiative heating rates seeking to mimic the local impact of aerosol
VolShortEQsurf	**isolate the cooling of the surface** by mimicking the attenuation of solar radiation by volcanic aerosols	25	3	Either via prescribed TOA clear sky SW flux or via restoring of the surface albedo
VolLongSEQ	designed to realistically reproduce the radiative forcing resulting from the 1815 Tambora eruption	9	20	consensus forcing under identification

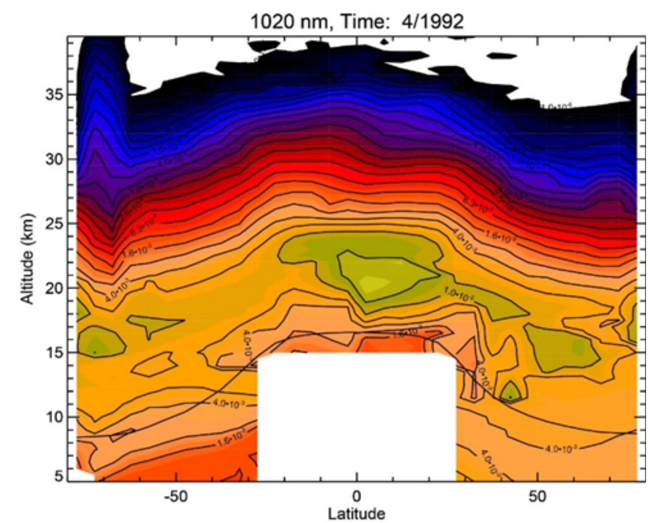
Well-defined volcanic forcing for VolLSHORT (Pinatubo)

Pinatubo forcing data from the improved CMIP6/CCMI long-term stratospheric aerosol database Thomason et al. in prep for GMD

- Pinatubo
  - SAGE II profiles terminated as high as 25 km in the immediate aftermath of the eruption
  - Development a methodology for using IR measurements by CLAES to fill
  - Generally increases low latitude optical depth
- High latitudes
  - Past ‘gap-free’ aerosol climatologies used unrealistic extrapolations/-interpolations to fill the winter high latitudes
  - A new method using equivalent latitudes and Equivalent latitude pdfs as a function of latitude has been implemented to provide a superior high latitude analysis



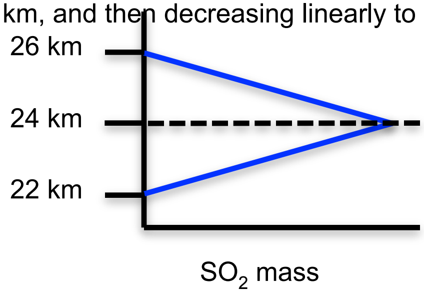
CMIP 5 Analysis for April 1992 Filled using subtropical lidar data



CMIP 6 Analysis for April 1992 Filled using tropical CLAES data (note change in contour levels and coloring)

Well-defined volcanic forcing for VolLongSEQ

Coordinated assessment of radiative forcing uncertainties for VolLongS60EQ using aerosol climate models (activity leader: *Myriam Khodri, IPSL*)

Parameters	Values for Tambora
Eruption date	April 1, 1815
SO_2 emission	60 Tg SO_2
Erupt. length	24 hours
Latitude	Centered at the equator
QBO phase at time of erupt.	Easterly phase (as for Pinatubo and El Chichón)
SO_2 height injection	Same as Pinatubo, 100% of the mass between 22 and 26 km, increasing linearly with height from zero at 22 to max at 24 km, and then decreasing linearly to zero at 26 km. 
SST	Climatological from preindustrial control run
Other radiative forcing	Preindustrial CO_2, other greenhouse gases, tropospheric aerosols (and O_3 if specified)
Duration	5-years long to get the tail of the distribution
Ens. size	5 members

Output Parameters *Monthly, zonal average* *At model resolution in latitude and vertically*
Total stratospheric AOD at λ = 525 nm and 1020 nm (at each latitude)
effective radius, extinction, single scatter albedo, and asymmetry factor (at each grid-point)

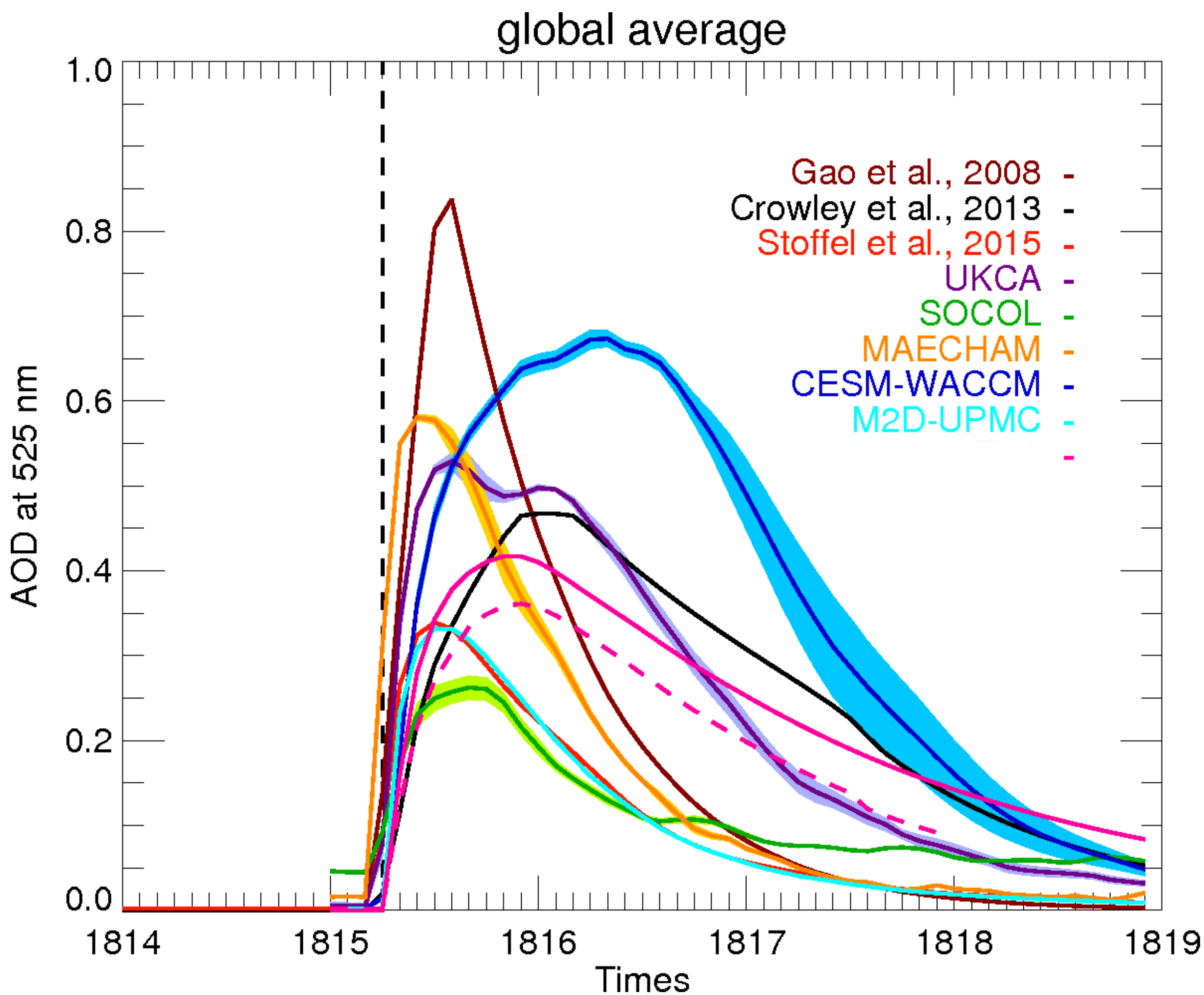
- Global aerosol model outputs deliverable: Deadline October 2015

Participants:

UM-UKCA, **ECHAM5-HAM**, **UPMC-2D WACCM-CARMA**, **AER-2-D**, **GISS ModelE2**

Well-defined volcanic forcing for VolLongSEQ

Coordinated assessment of radiative forcing uncertainties for VolLongSEQ using aerosol climate models (activity leader: *Myriam Khodri, IPSL*)



Modal models:
UKCA, MAECHAM,CESM-WACCAM

Bin models:
M2D-UPMC, SOCOL

Understanding the differences between the global aerosol model results, aerosol size play an important role **->** **ISA-MIP**

Figure courtesy of M. Khodri

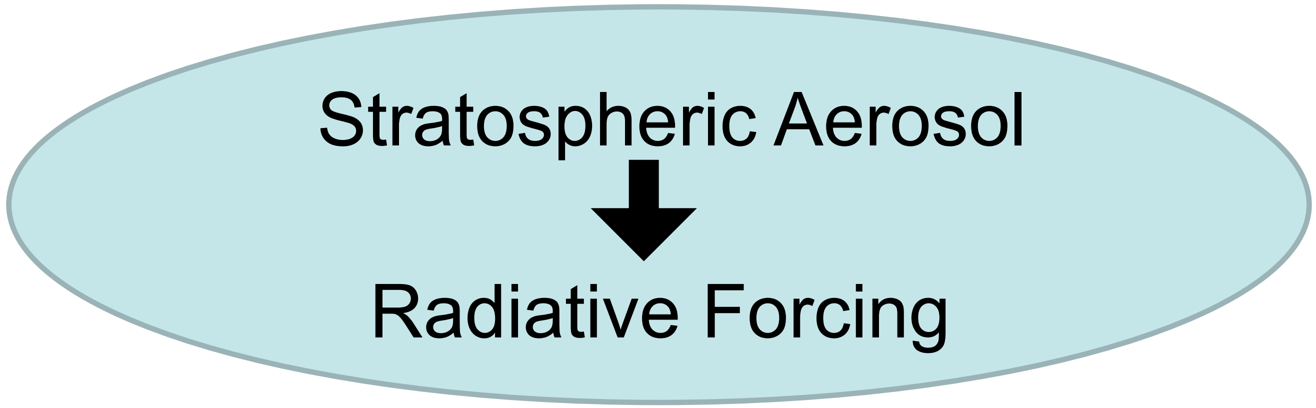
Next steps …

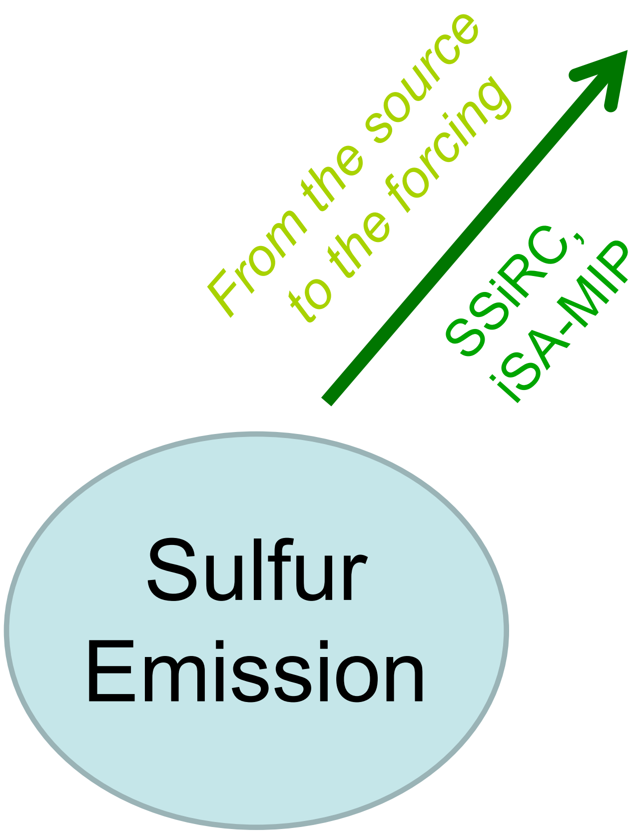
- **Doing science:**
  - Finalization of experiments -> GMD Discussion paper
  - Performing the model experiments
  - Exchange with the CMIP6 community
  - Constraining volcanic forcing uncertainties from past records -> PAGES ViCS

  - Constraining volcanic forcing uncertainties from global aerosol models
  - Understanding the inter model spread in the Tambora simulations

SSIRC ISA-MIP

Tackling the uncertainties: SSIRC tasks





SSIRC workshop and ISA-MIP

- Discussion with the community
- Posters presentations
- Breakout group: Wednesday 16:30-18:30

- **Goal : Finalization of the experiments**

SSiRC aerosol model intercomparisons

with interactive stratospheric aerosol modules

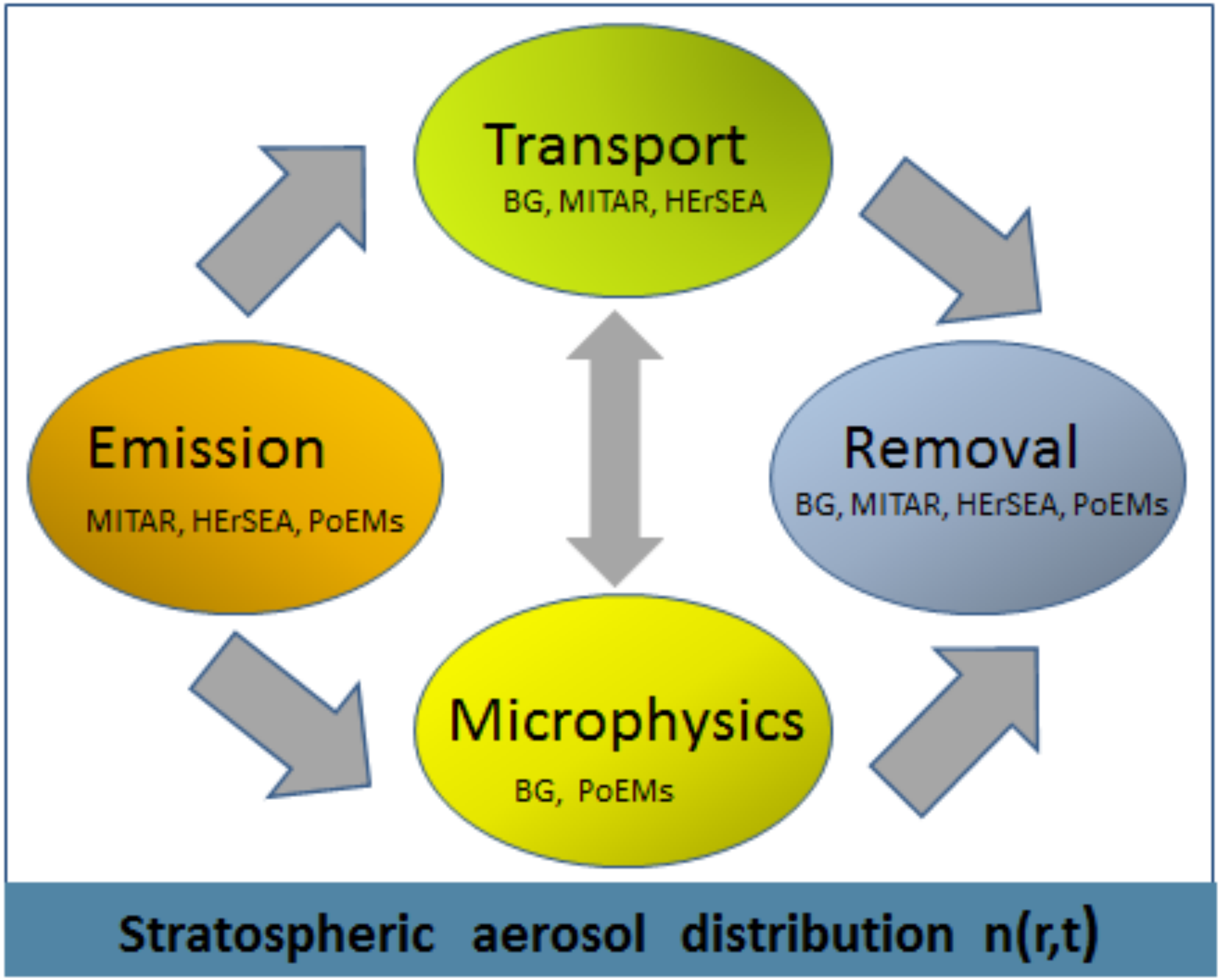
(co-chairs: *Claudia Timmreck, Graham Mann*)

Coordinated experiments to intercompare simulated stratospheric aerosol properties, assess volcanic SO_2 emissions & quantify uncertainty in predicted volcanic forcings:

Background Stratospheric Aerosol	*D. Weisenstein; J. English, v. Aquila*	10 year climatology to understand sources and sinks of stratospheric background aerosol, assessment of sulfate aerosol load under volcanically quiescent conditions
Transient Strat Aerosol [MITAR]	*R. Hommel; A. Schmidt, M. Chin; R. Neely; C. Brühl*	Evaluate models over the period 1998-2012 with different emission data sets **Understand drivers and mechanisms for observed stratospheric aerosol increase since 2000**
Historic Eruption SO_2 Emission Assessment [HErSEA]	*G. Mann, S. Dhomse, M. Mills, J. Sheng*	Assess how injected SO2 for historical eruptions perturbs stratospheric aerosol properties and radiative forcings in different complexity global strat-aerosol models, **Link emission uncertainties to forcing uncertainties**
Pinatubo Emulation in Multiple Models [PoEMS]	*L. Lee G. Mann; V. Aquila; M. Toohey*	Intercompare Pinatubo perturbation to strat-aerosol properties with full uncertainty analysis over PPE run by each model. **Quantify sensitivity of simulated Pinatubo ERF**

Interactive stratospheric aerosol model intercomparison:

(ISA-MIP) (co-chairs: *Claudia Timreck, Graham Mann*)

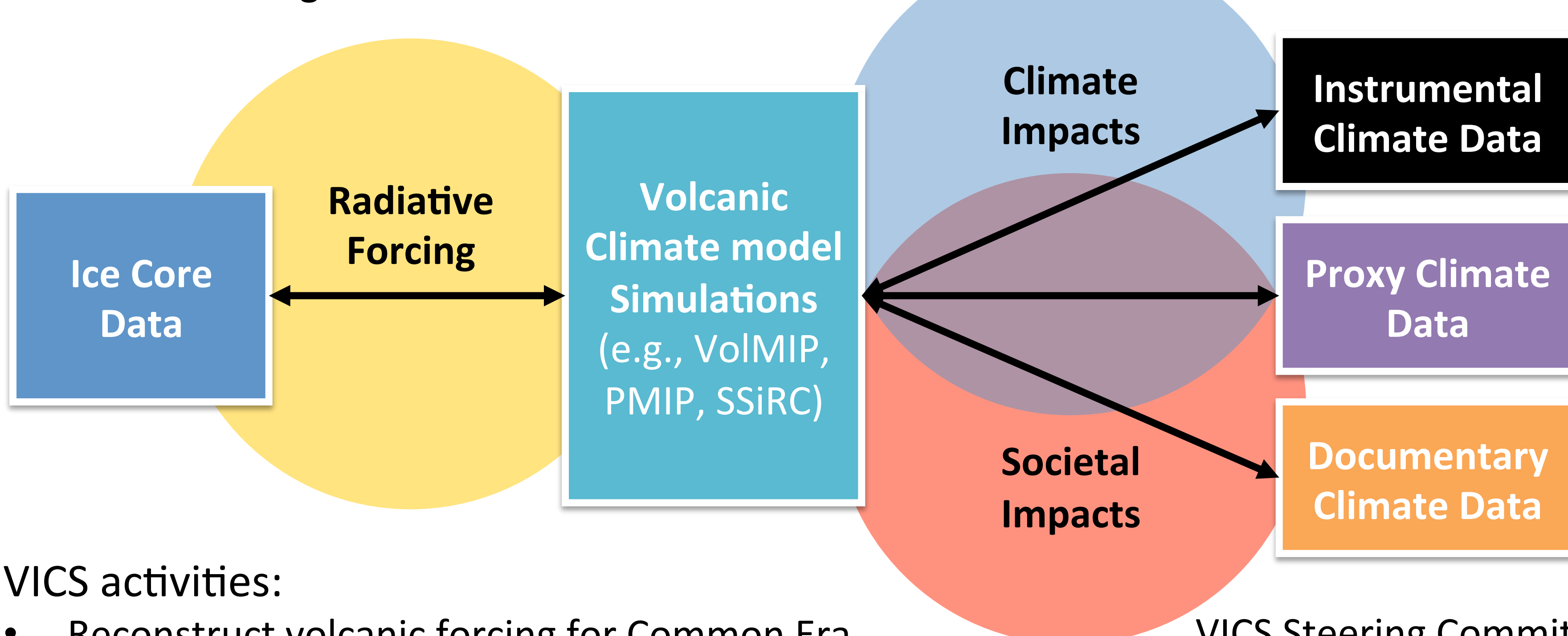


Coordinated experiments to intercompare simulated stratospheric aerosol properties, assess volcanic SO_2 emissions & quantify uncertainty in predicted volcanic forcings

Volcanic Impacts on Climate and Society (VICS)

PAGES PAST GLOBAL CHANGES

A PAGES Working Group to foster interdisciplinary activities towards better understanding of the impacts of volcanic forcing on climate and societies



VICS activities:

- Reconstruct volcanic forcing for Common Era (phase 1, 2016-2018) and Holocene (phase 2, 2019-2022)
- Annual workshops
- Special issue(s)/review paper(s)

<u>VICS Steering Committee</u>

- Matthew Toohey
- Michael Sigl
- Francis Ludlow
- Allegra LeGrande
- Kevin Anchukaitis

Contact: Matthew Toohey (mtoohey@geomar.de)

The IPCC-AR5 report states (WG1, Ch. 8):

"Volcanic eruptions […] are the dominant natural cause of externally forced climate change on the annual and multi-decadal time scales […]"

"The RF [radiative forcing] of volcanic aerosols is well understood"

	Evidence	Agreement	Confidence Level	Basis for Uncertainty Estimates (more certain / less certain)	Change in Under-standing Since AR4
Volcanic aerosol	Robust	Medium	*High*	Observations of recent volcanic eruptions/Reconstructions of past eruptions	Elevated owing to improved understanding

Table 8.5 from Myhre et al., 2013 | **Confidence levels for the forcing estimates**

"The volcanic RF has a **very irregular temporal pattern** and for certain years has a strongly negative RF"

"Although the effects of volcanic eruptions on climate are largest in the 2 years following a large stratospheric injection […] there is **new work indicating extended volcanic impacts** via long-term memory in the ocean heat content and sea level […]"

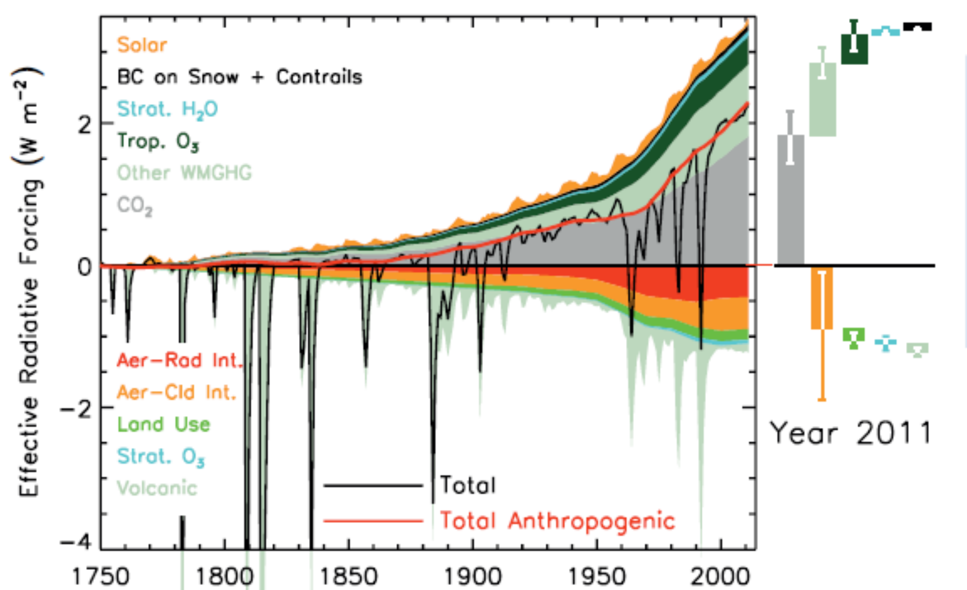
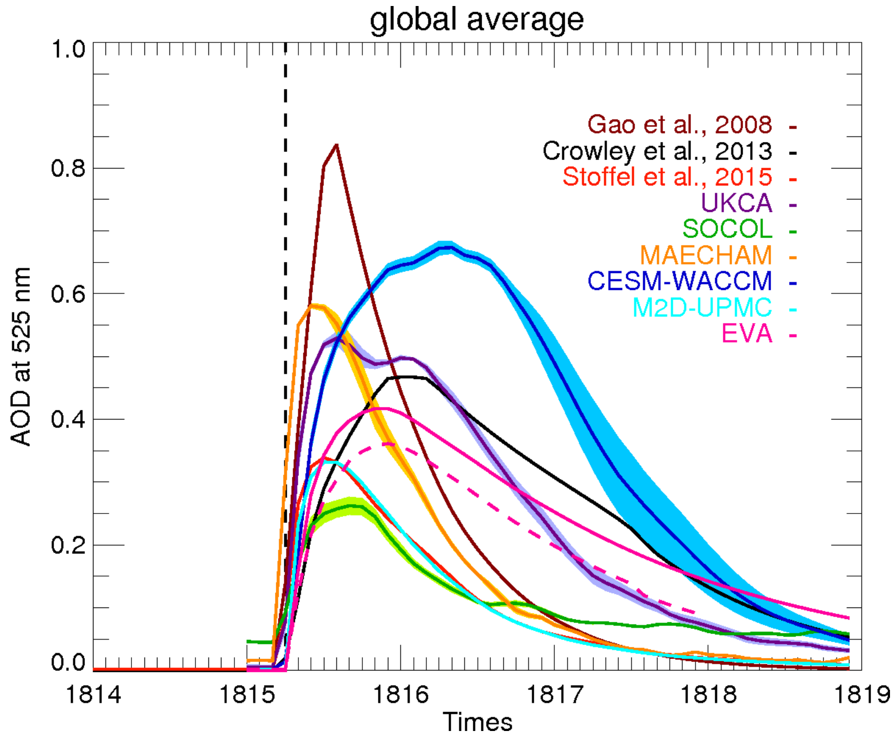
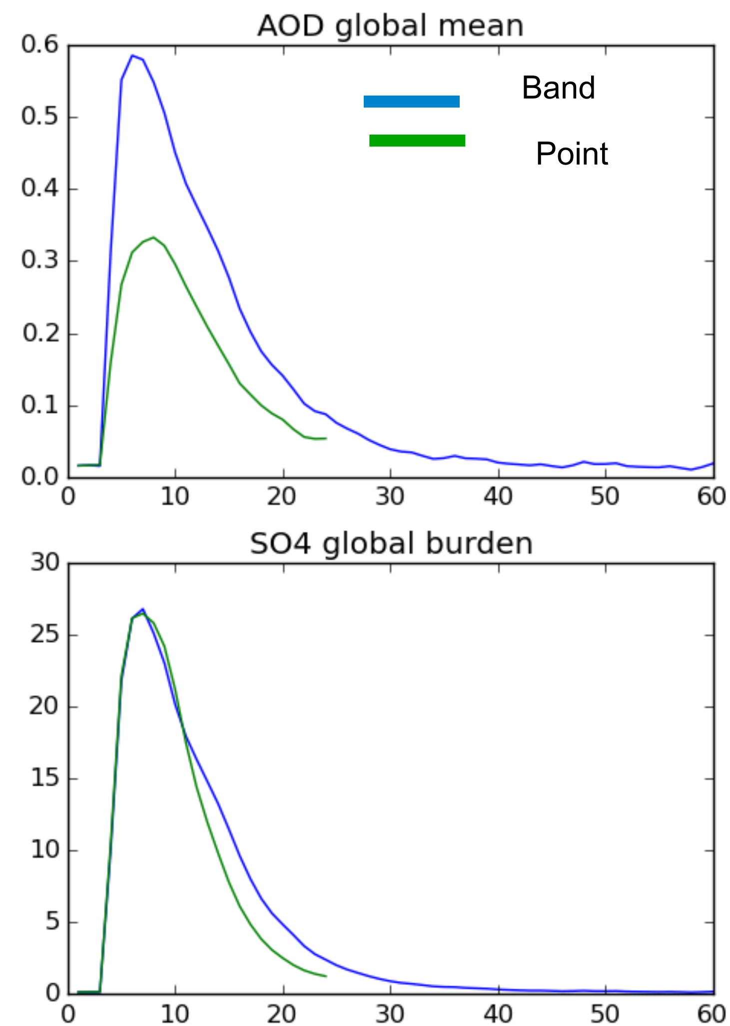


Figure 8.18 from Myhre et al., 2013 | **Time evolution for anthropogenic and natural forcing mechanisms**

Well-defined volcanic forcing for VolLongEQ



MAECHAM5 HAM Results



Understanding the differences between the global aerosol model results, aerosol size play an important role -> **ISA-MIP**