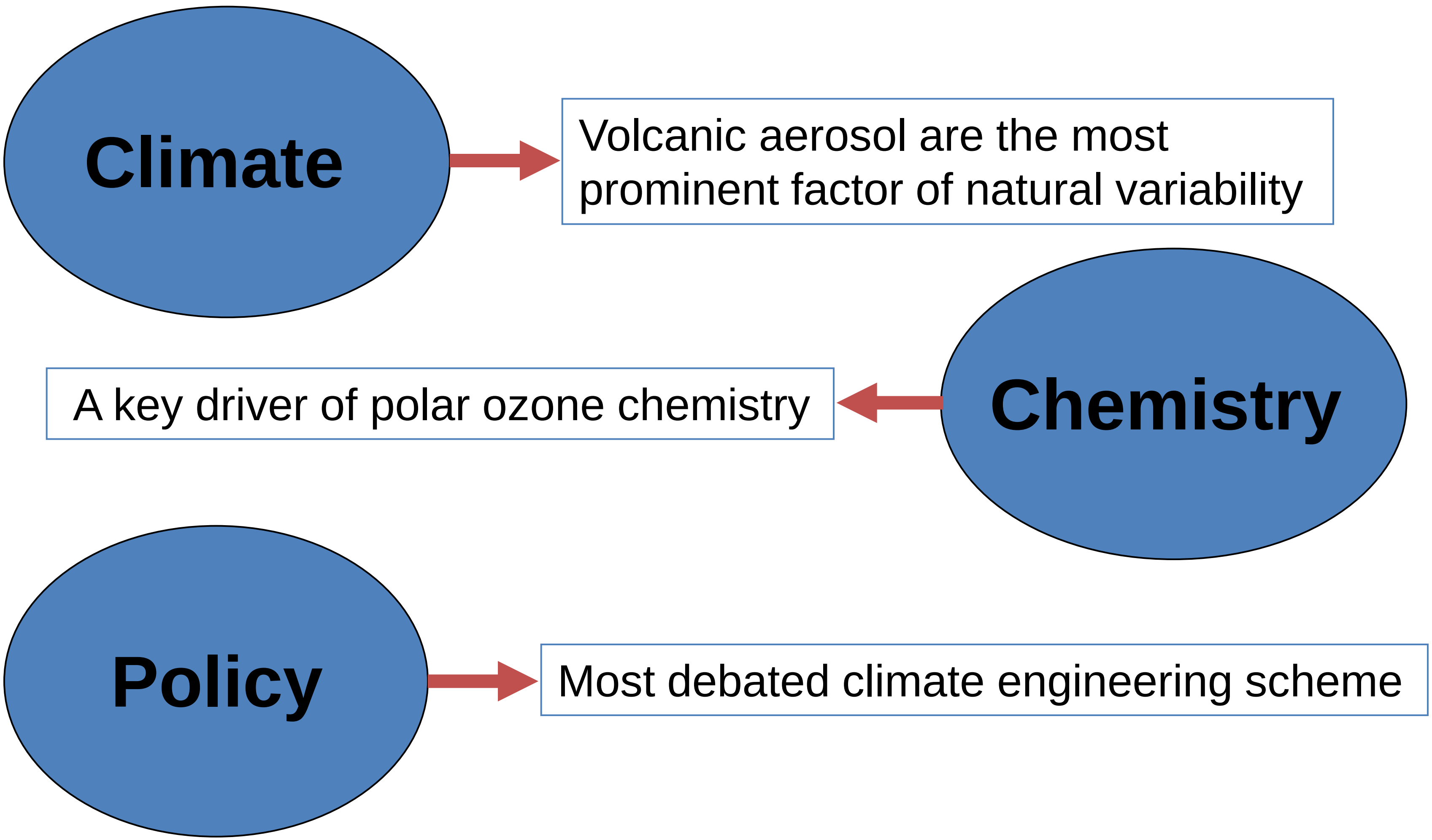
A possible joint WCRP SPARC SSiRC/AeroCom initiative on stratospheric sulfur

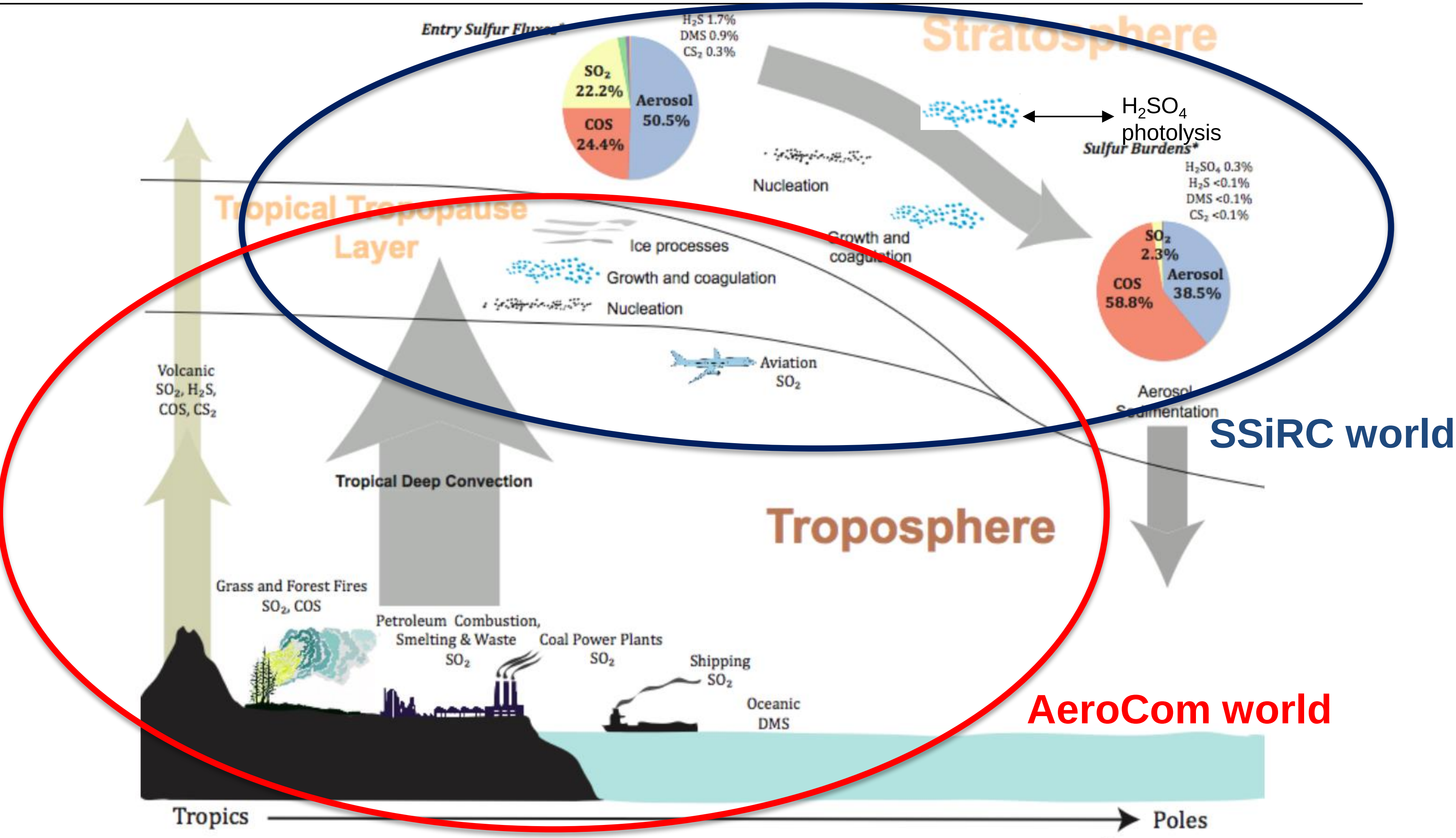
Claudia Timmreck
and the SSiRC team

AeroCom workshop,
Hamburg, 23. 9. 2013

Stratospheric Sulfur and Climate



The stratospheric sulfur cycle



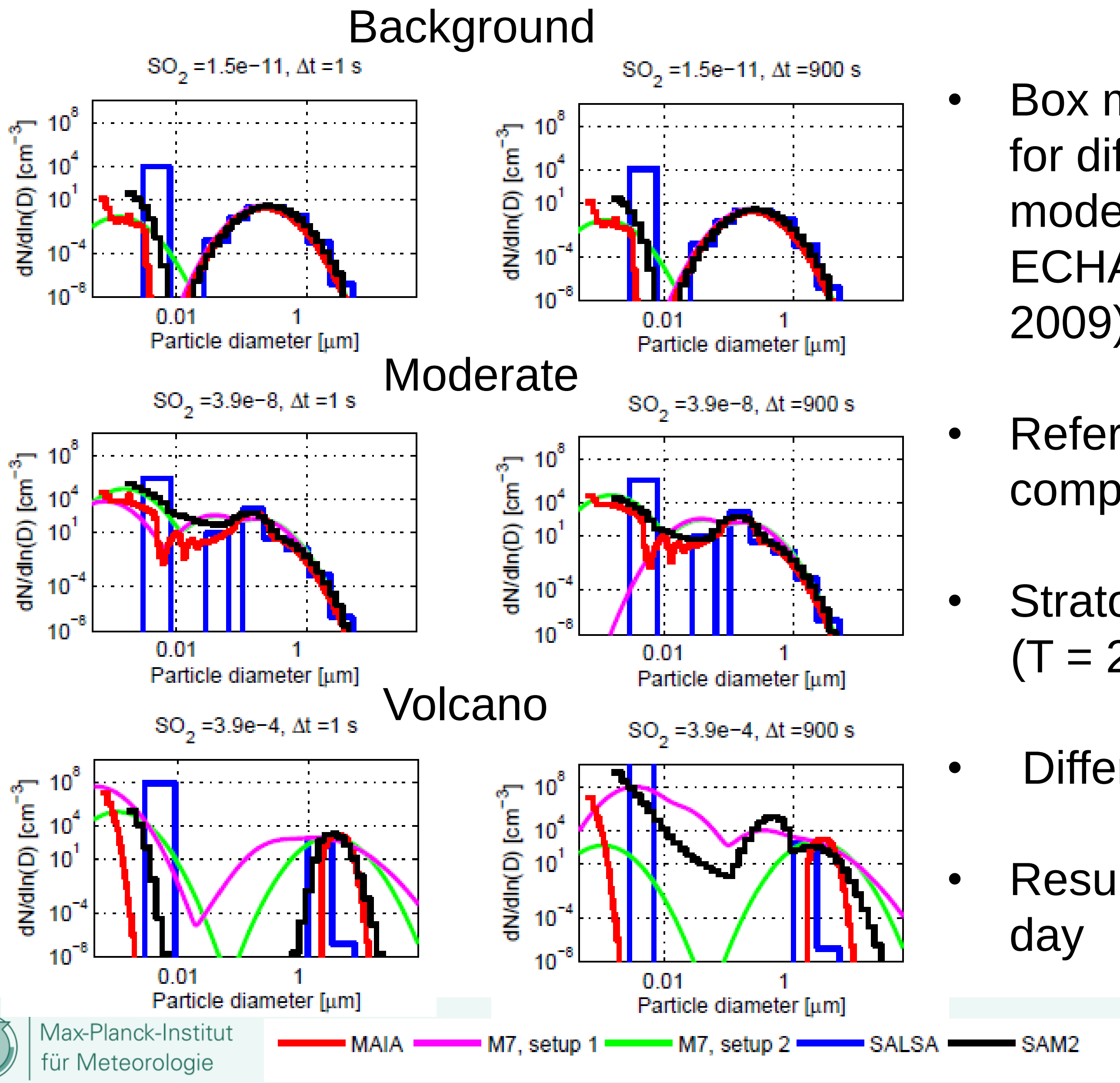
* Sulfur fluxes and burdens from AER model (SPARC report). The total annual flux of sulfur to the stratosphere is 128.9×10^9 g. This is balanced almost exclusively by polar aerosol removal via sedimentation. The total stratospheric burden of sulfur is 485.9×10^9 g of sulfur.

ASAP2006, Schofield 2011

Three flavors

- **Stratospheric background aerosol**
  - Natural sources, transport TTL (ca 0.1 Tg S/yr).
  - Interannual and seasonal variability
  - Reff: 0.15 - 0.2µm, AOD: 0.002 - 0.003
- **Volcanic aerosol**
  - Point source strong S injection, over hours (days)
  - Short life time, large temporal and spatial variability emission from several Tg up to 1000 Tg
  - Reff: 0.5-1.1 µm, peak AOD: 0.15 (Pinatubo) -> 4 (Toba)
- **Climate engineering aerosol**
  - Constant source 1 to 5 Tg S/yr
  - Reff::0.2-0.4 µm, AOD: 0.05 - 0.1

Box model studies

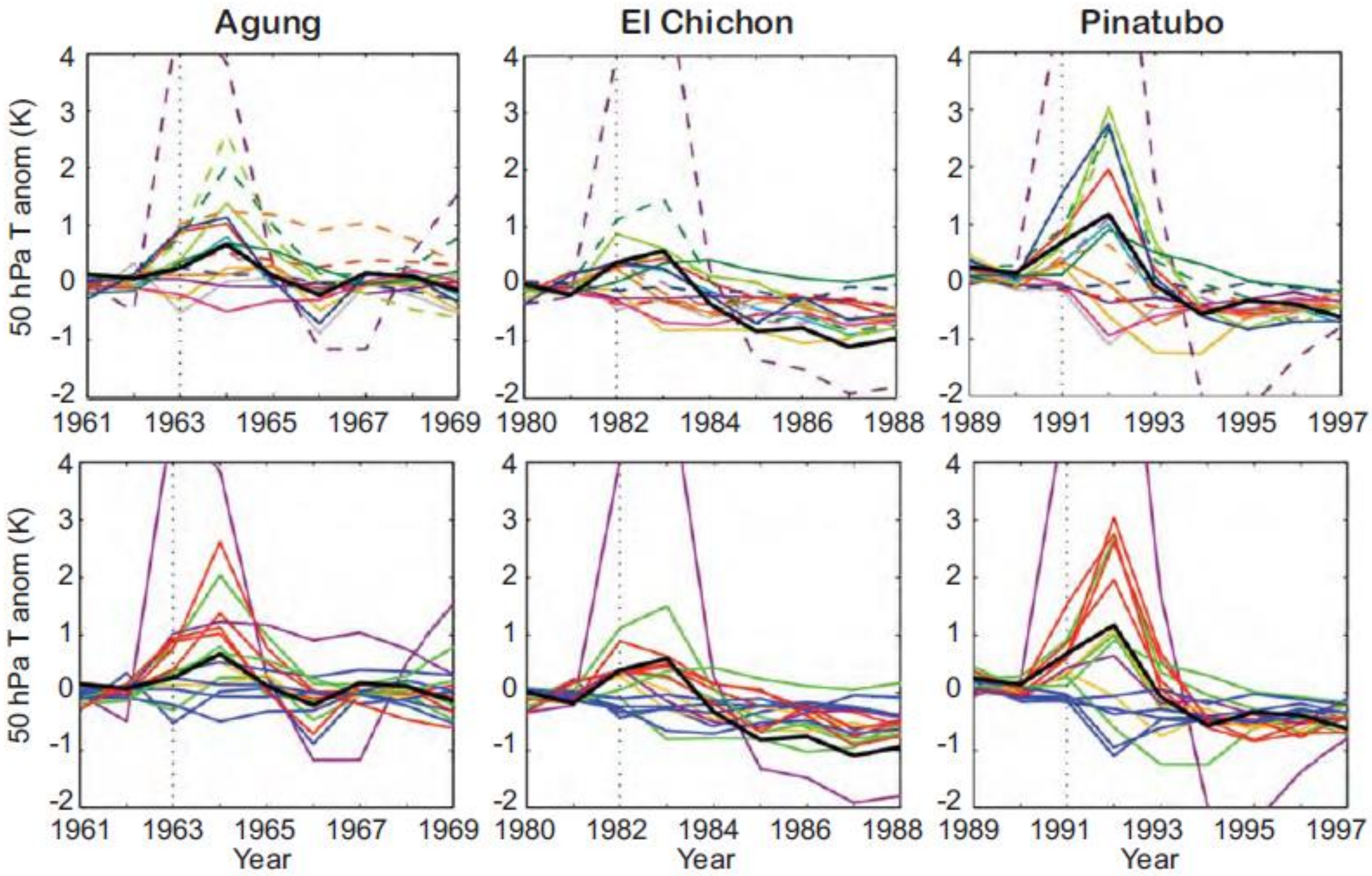


- Box model intercomparison for different microphysical models in the framework of ECHAM5 (Kokkola et al, 2009)
- Reference model MAIA, a complex bin box-model
- Stratospheric conditions (T = 214.8 K, P = 30 hPa
- Different time steps
- Results at noon of the 10th day

Kokkola et al., 2009

Temperature anomalies in CCMs

after large volcanic eruptions



Top: Results color-coded by model.

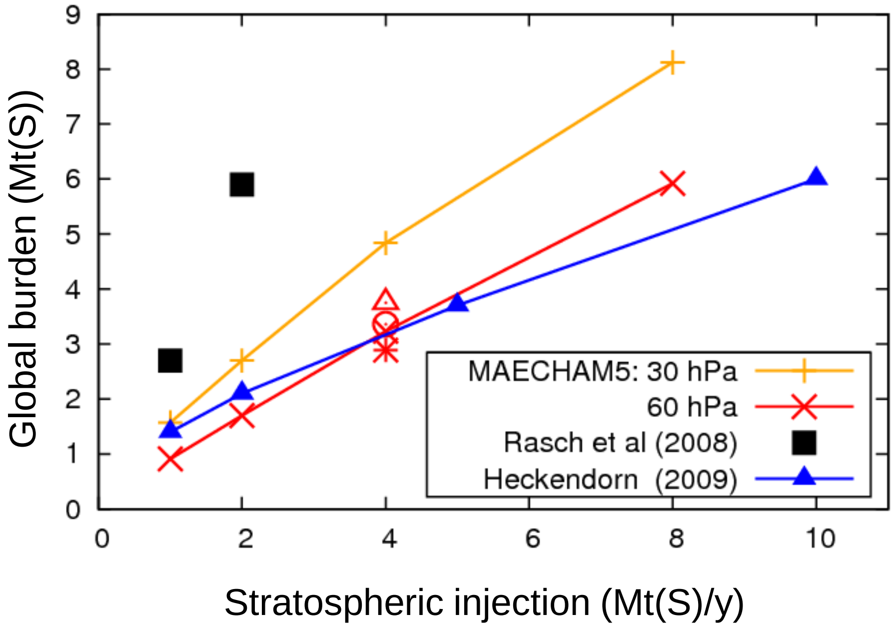
Bottom: Results color coded by type of volcanic heating parameterization used

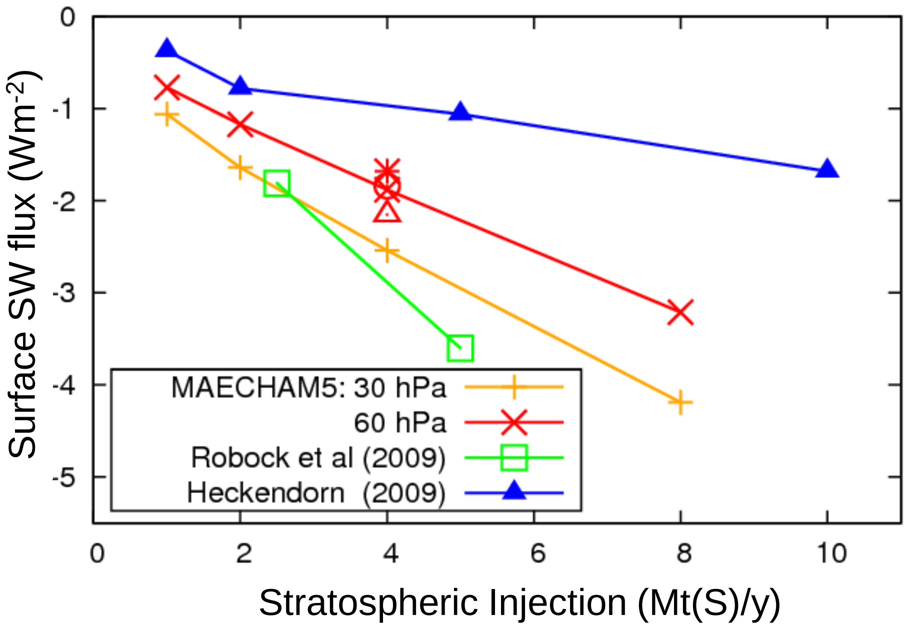
ERA-40 50 hPa temperature anomalies in black

SPARC CCMVAL, 2009

Climate engineering

Stratospheric sulfur injection and its dependence on different model approaches

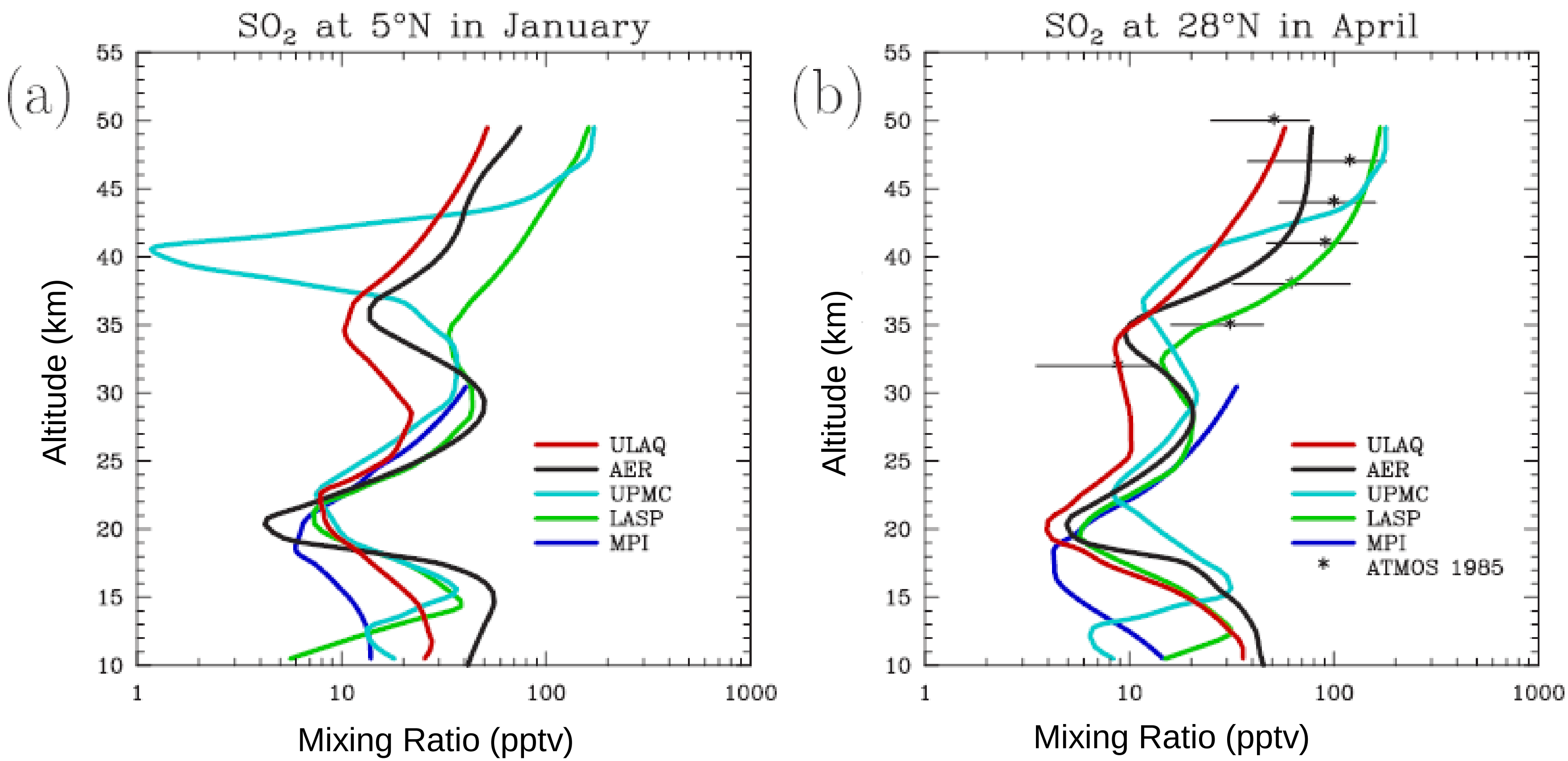




Substantial differences in aerosol burden /forcing for same SO_2 emission

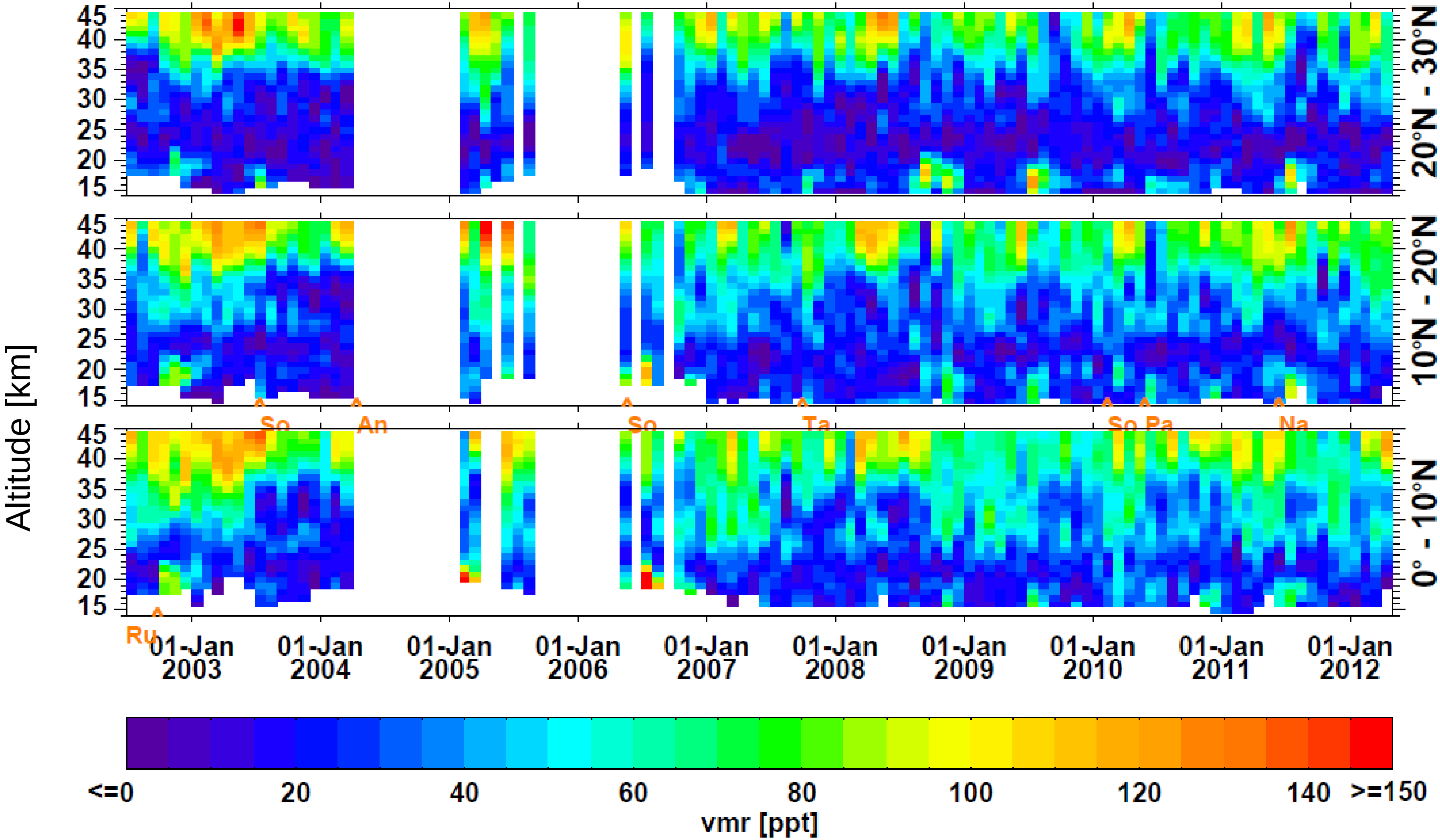
Niemeier et al., 2011

Precursor gas SO_2 background state



In the past only sparse observational data about non volcanic SO_2 available, but

MIPAS SO_2 (vmr) measurements



the situation changed

Hoepfner et al., 2013

A model and data intercomparison on stratospheric sulfur aerosol I

1. Diverse observational data records are now available / will be available soon (longer records, new measurements on the horizon).

2. For more realistic climate simulations an interactive stratospheric aerosol layer in IPCC models is needed

3. Increasing knowledge about:
   - TTL processes
   - Variability of the stratospheric background layer
   - Impact on Volcanoes on the Earth System

4. We need to be prepared :
   - for the next big volcano.
   - for the challenges our community will face from the need to assess proposed climate engineering schemes.

A model and data intercomparison on stratospheric sulfur aerosol II

Three types of experiments are suggested:

1. Background state

2. Volcano studies

3. Climate engineering case

The background state

- 10 year climatology + possible additional case studies in comparison with big measurement campaigns (e.g. StratoClim in the vicinity of the Asian monsoon)

- AEROCOM II Diagnostics Table + additional variables e.g. particle number concentration, surface area density

- Validation of model results:
  - aerosol precursor gases with MIPAS ENVISAT (2002 - 2012), aircraft measurements
  - aerosol extinction with SAGE/CALIPSO, OMI lidar….
  - Particle concentration with balloon measurements, CARIBIC flights (UTLS)
  - - …

Volcanic studies

Two case studies with a well defined emission scenario based on observations:

1. **Pinatubo** (as reference case largest tropical volcanic eruption, several satellite data and in situ measurements are available)

2. **Nabro** (largest strat. input since Pinatubo, many satellite data available (CALIPSO; OSIRIS,OMI, ENVISAT), actual in the focus due to uncertainties in the emission height could be used also a tracer study for transport through Asian Monsoon

The climate engineering case

- Most difficult one to set up due to lack of observations and many possible scenarios
- Probably one or two core experiments and additional case studies with a well defined emission scenario:
  - Tropical injection either latitude belt or box:
  - Continuous injection or pulses
  - Emission strength of 2 to 8 Tg/S
  - Injection height: 60 hPa (70-50hPa)

Suggested time line

Time	Tasks
September 2013	Discussion and predefinition of experiments at AeroCom workshop
October 2013	Refinement of experiments at SSiRC workshop
December 2013	Release of protocol
January 2014	Start of experiments
Summer 2014 (?)	Data submission deadline