Changes in upper troposphere/lower stratosphere aerosol since 1980 in the Goddard Earth Observing System (GEOS-5) model

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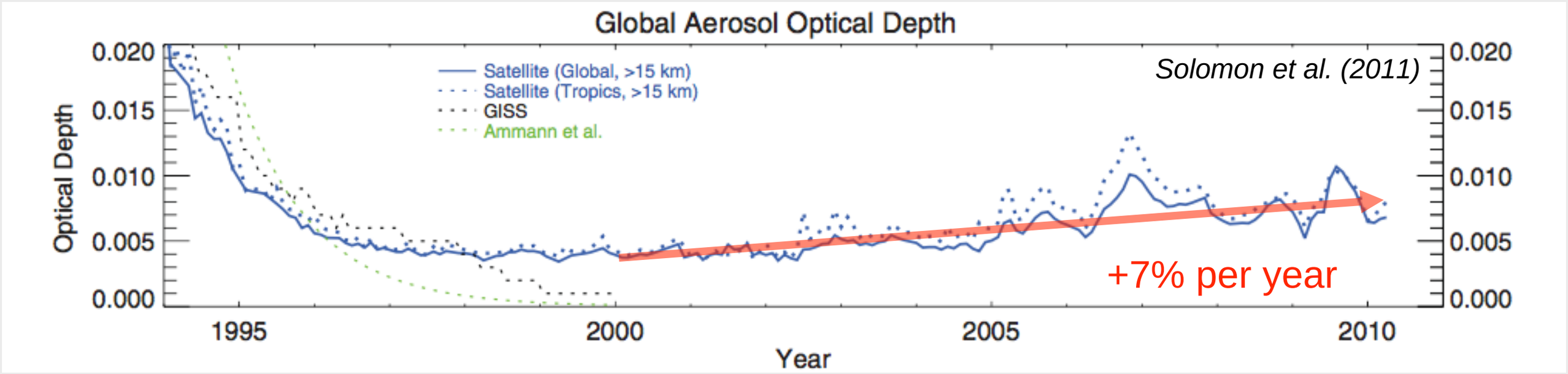
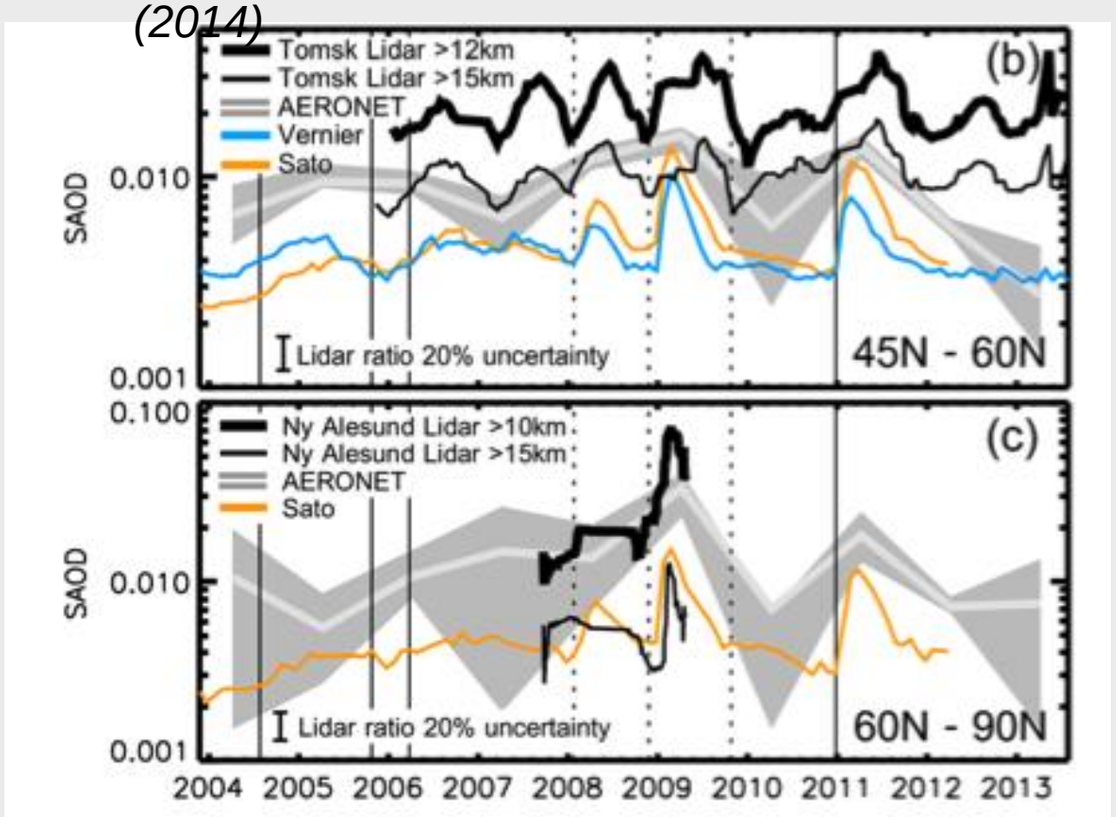
Stratospheric aerosol as a climate forcer



$RF_{2000\text{-}2010}$ from stratospheric aerosol significant with respect to $RF_{2000\text{-}2010}$ from CO_2 (-0.1 W/m^2 Vs +0.28 W/m^2) Solomon et al. 2011

Ridley et al. (2014)



Lidar > 12 km

Lidar > 15 km

AERONET

Satellites-based SAOD datasets underestimate stratospheric aerosol by not including lower stratospheric aerosol (Ridley et al. 2014)

The MERRA2-GMI simulation

- NASA GEOS-5 model simulation driven by the MERRA-2 reanalysis over the 1980-2016 period (continuing into the future as emission data sets become available)
- Horizontal resolution ~0.5°; output available on the MERRA-2 horizontal grid (0.625° x 0.5°)
- MERRA2-GMI includes:
  - ➞ Full stratospheric and tropospheric chemistry from the Global Modeling Initiative (GMI) chemical mechanism
  - ➞ Prognostic aerosol from the GOCART aerosol module (sulfate, dust, sea salt, organic carbon, black carbon, and nitrate)
  - ➞A full suite (over 20) of transport diagnostic tracers
- MERRA2-GMI will soon be available through OpenDAP. Please contact Luke Oman (luke.d.oman@nasa.gov) for access.

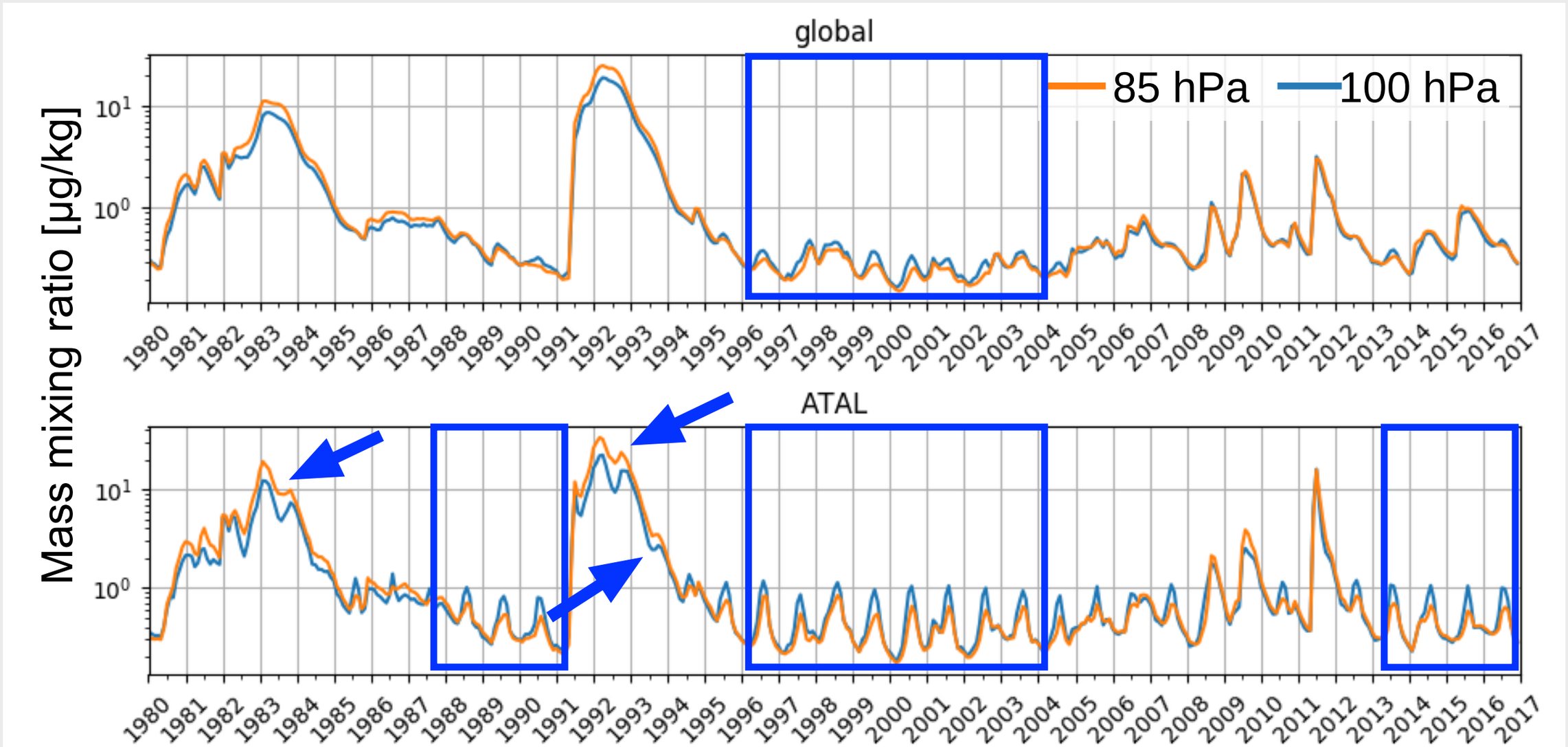
The MERRA2-GMI simulation

Relevant aerosol emissions

- Dust and sea salt: wind driven emissions
- DMS: climatology from Lana et al. (2011)
- Biomass Burning (SO_2, POM, BC, NH_3):
  - 1980-1996: scaled RETROv2
  - 1997-1999: scaled GFEDv3.1
  - 2000 onward: QFED 2.4-r6 (daily emissions)
- Anthropogenic SO_2: EDGARv4.2
- Anthropogenic SO_4, POM, BC, aircraft SO_2: AeroCom Phase II
- Explosive volcanic SO_2: Carn et al. (2015)
- Degassing volcanic SO_2: Andres and Kasgnoc (1998)

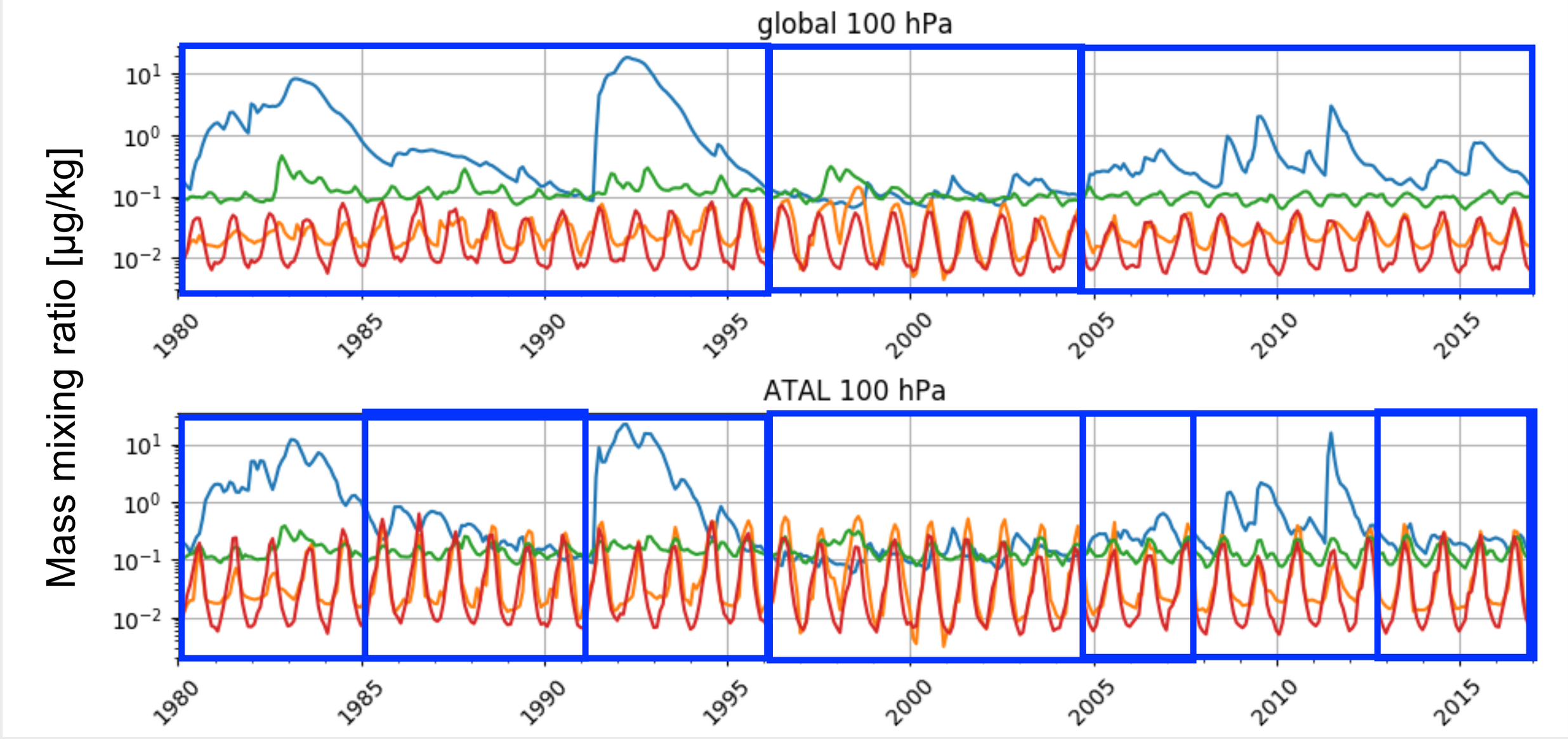
See Randles et al. (2016) for additional details

UTLS aerosol in MERRA2-GMI



- MERRA2-GMI simulates the enhancement in aerosol associated with the ATAL.
- The enhancement is also visible in the global mean during years with low volcanic activity.
- After major eruptions, ATAL appears in MERRA2-GMI as cleaning up the UTLS.

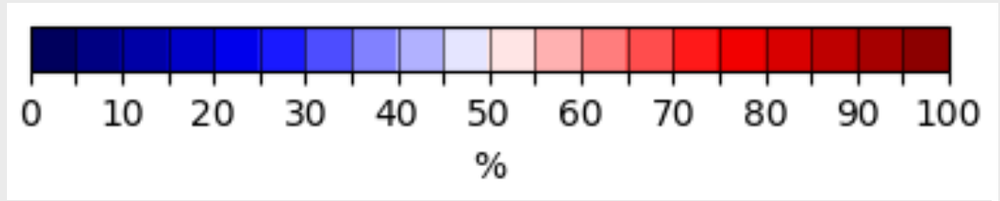
Aerosol composition in the UTLS



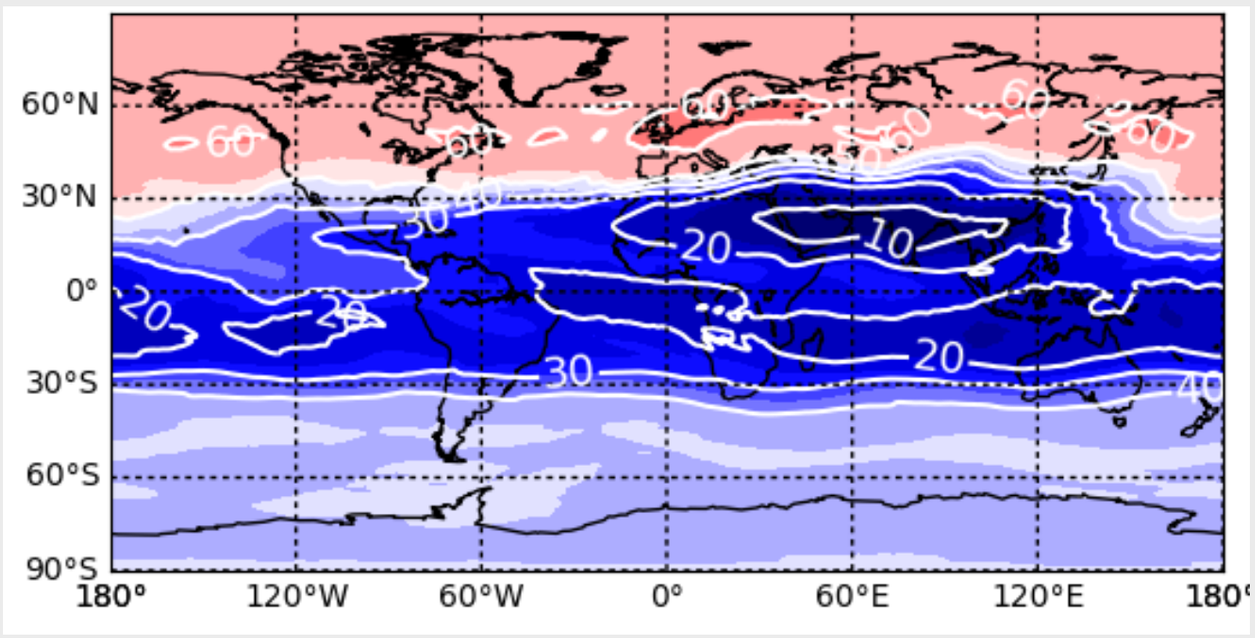
- Years with mid- to high volcanic perturbation: globally, sulfate is the major species.
- Years with low volcanic perturbation: globally, carbon is as abundant as sulfate.
- ATAL: sulfate, dust, nitrate, and carbon mixing ratios are comparable

Relative aerosol composition [mmr] in the UTLS

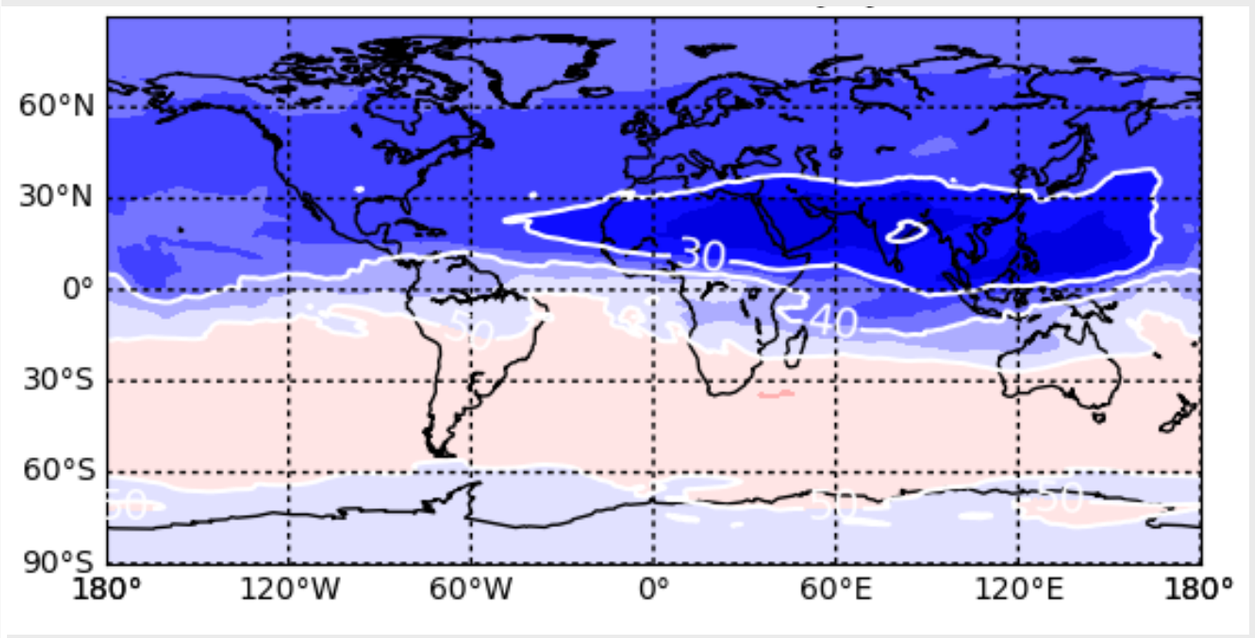
100 hPa - July 2000 (**low** volcanic perturbation)



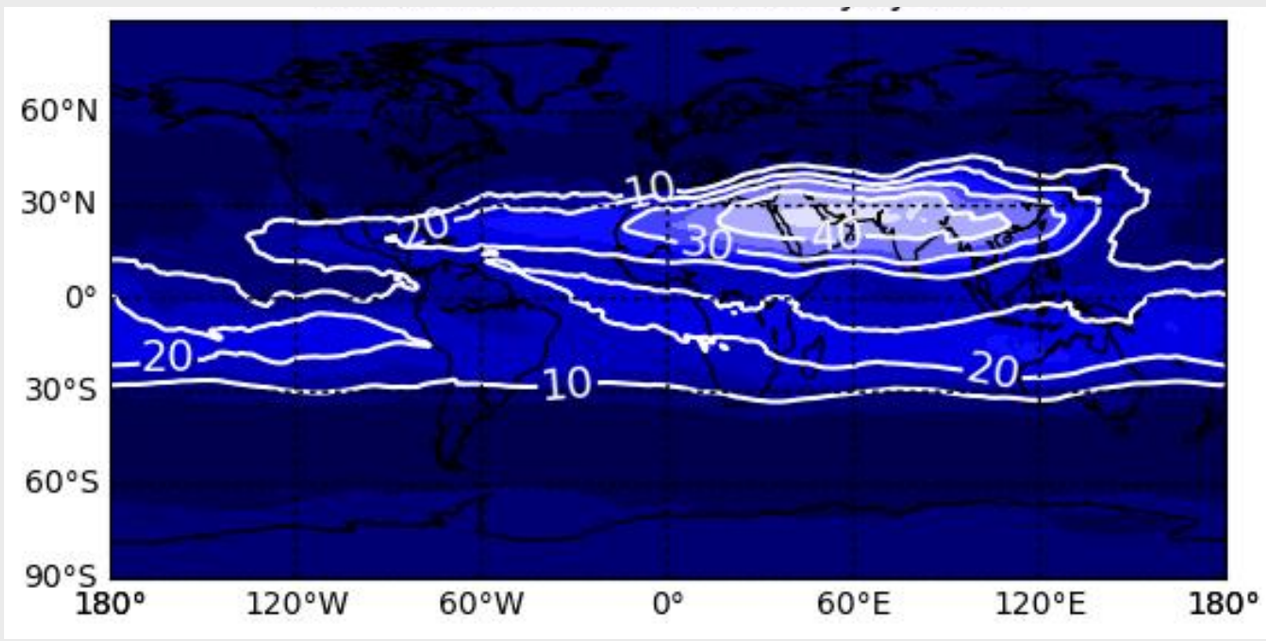
Sulfate



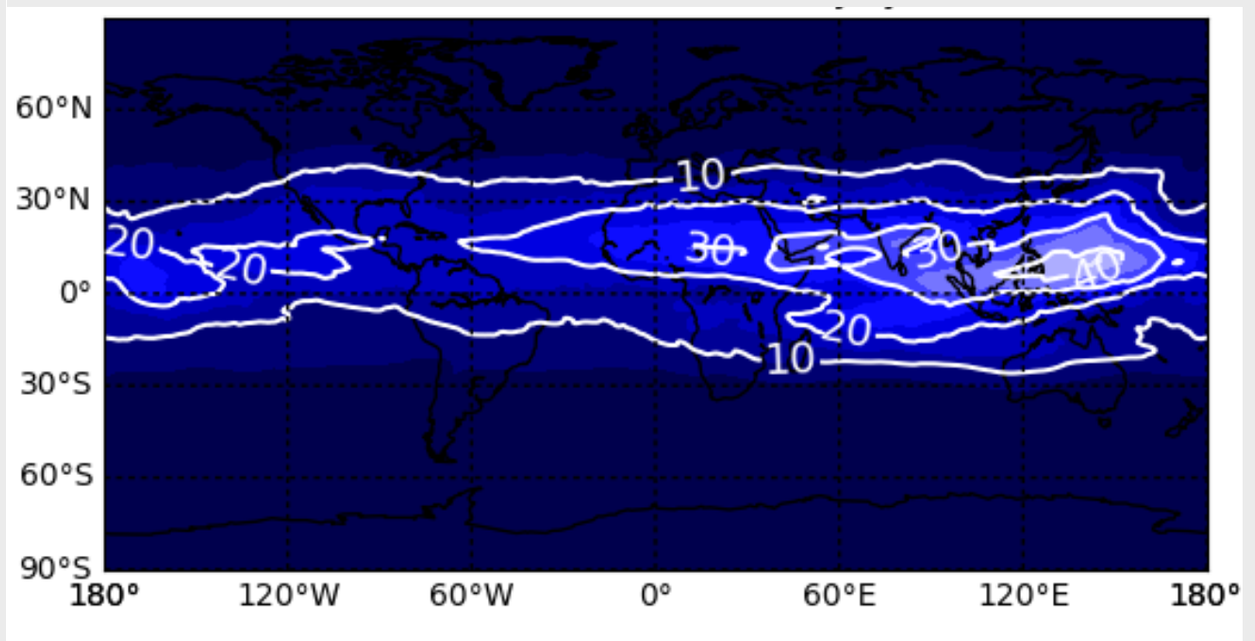
Carbon



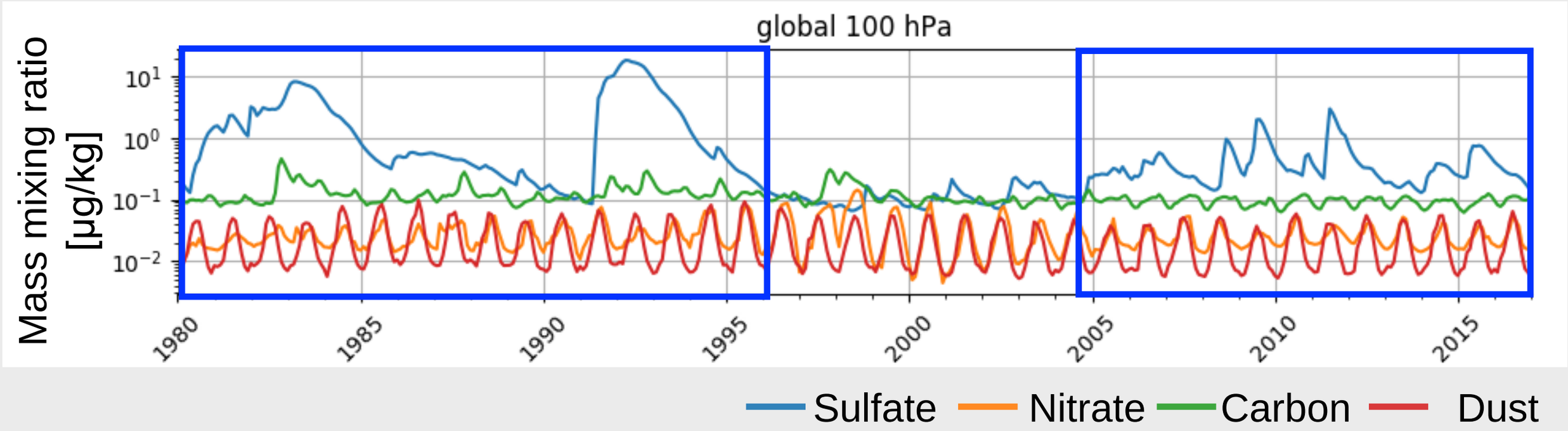
Nitrate



Dust



What are“background” conditions?

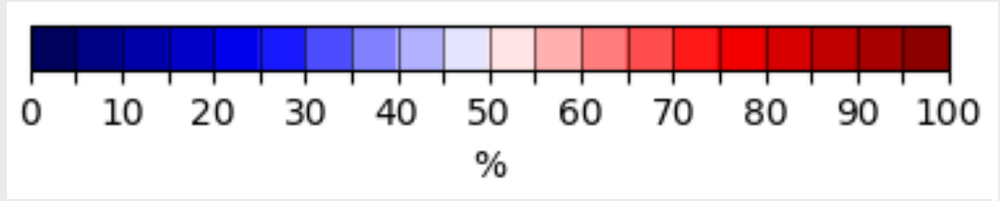


28 of the past 37 years had a mid- to high volcanic perturbation:

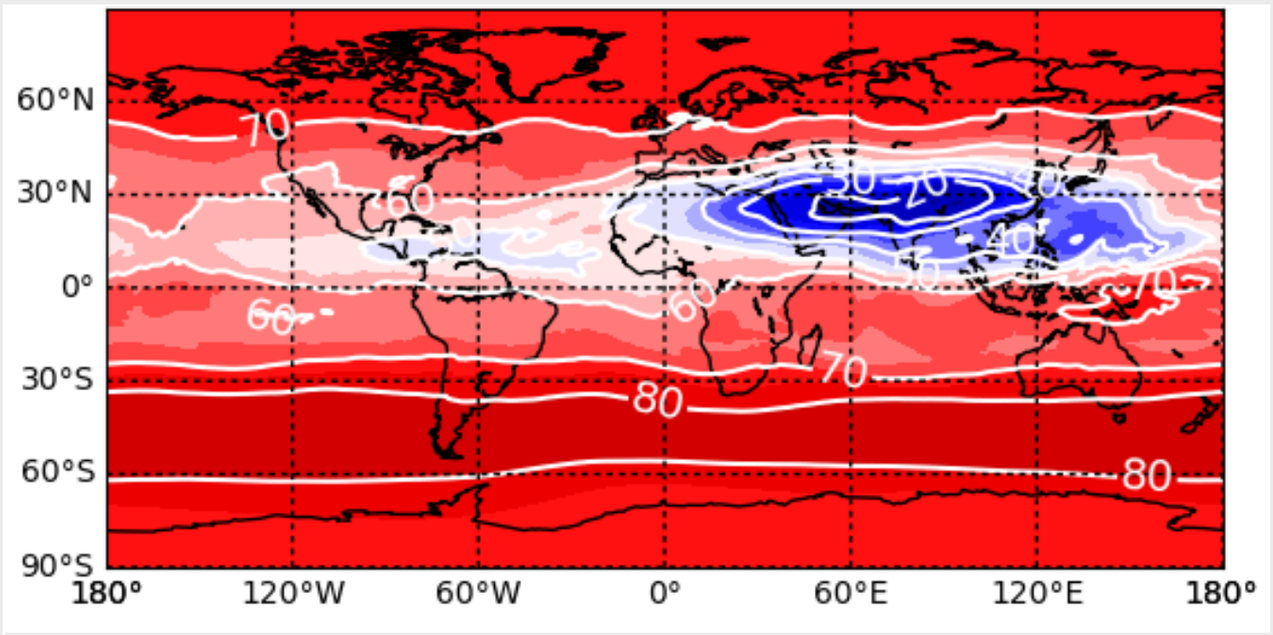
should that be the background condition?

Relative aerosol composition [mmr] in the UTLS

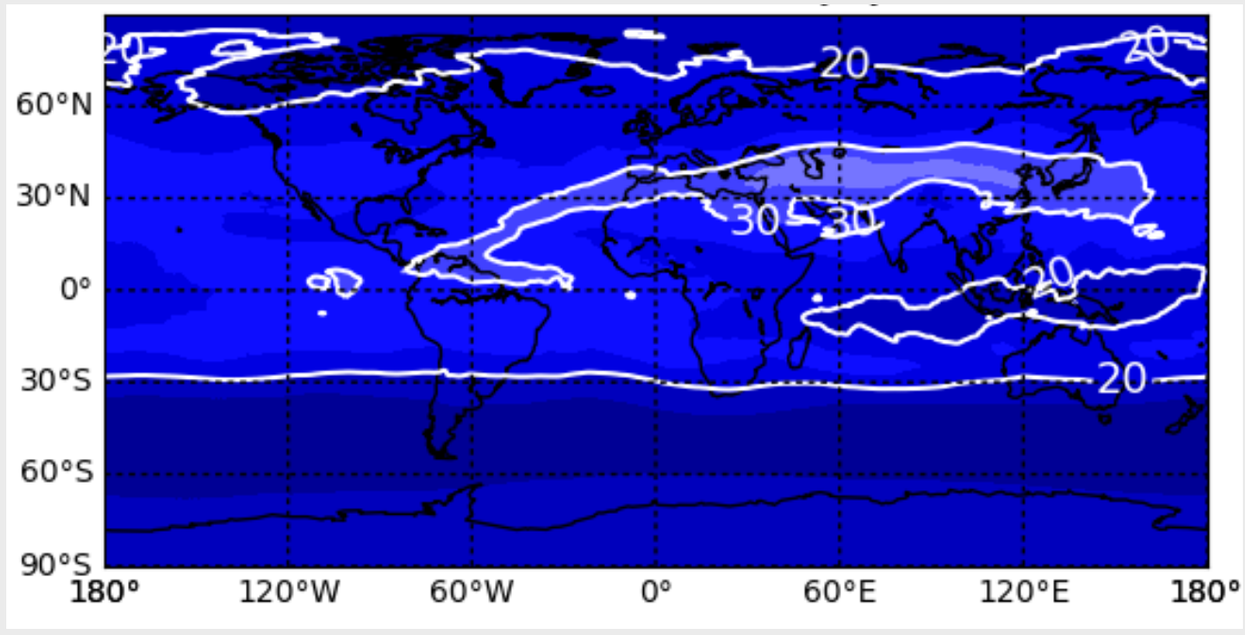
100 hPa - July 2006 (**mid** volcanic perturbation)



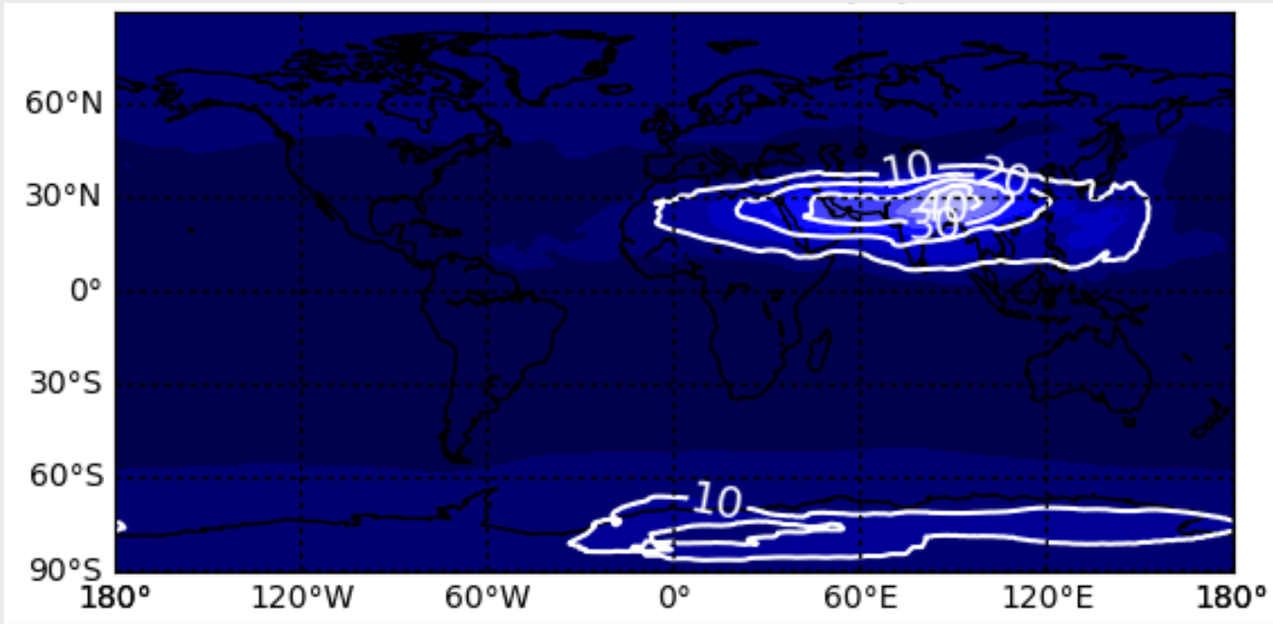
Sulfate



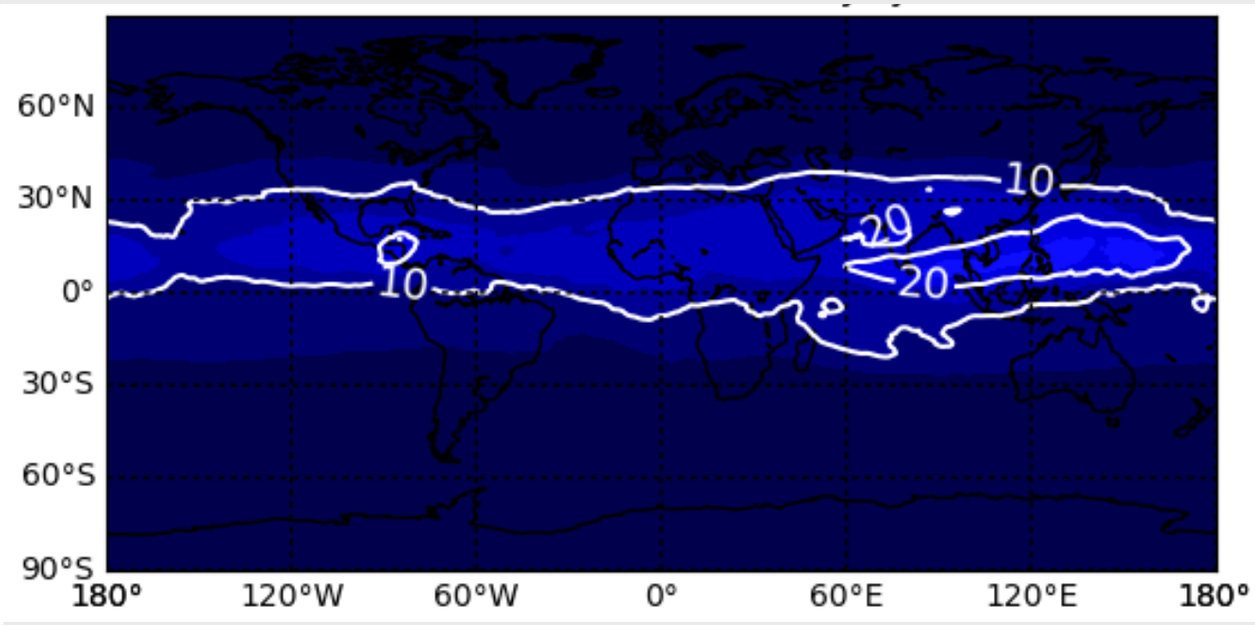
Carbon



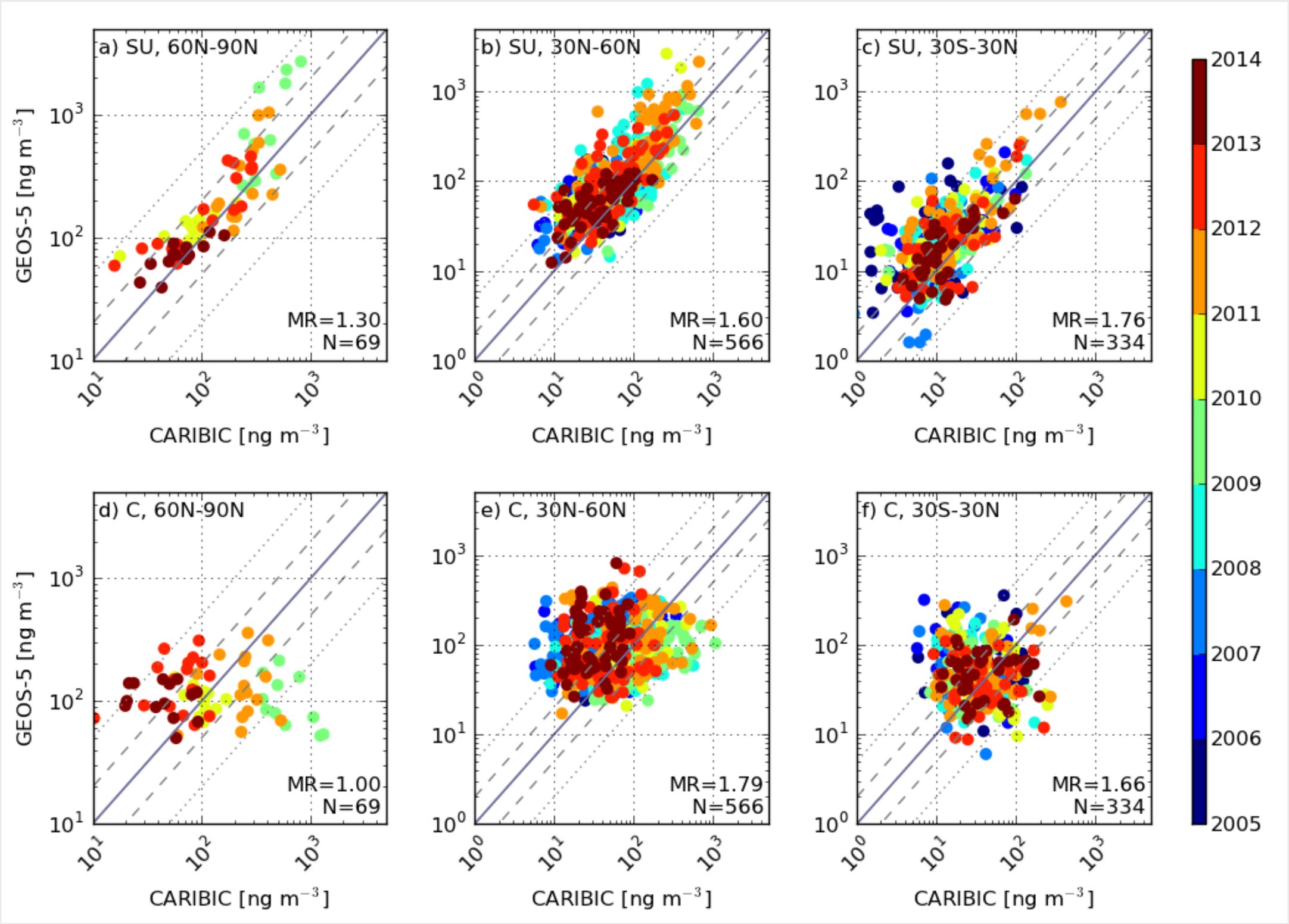
Nitrate



Dust



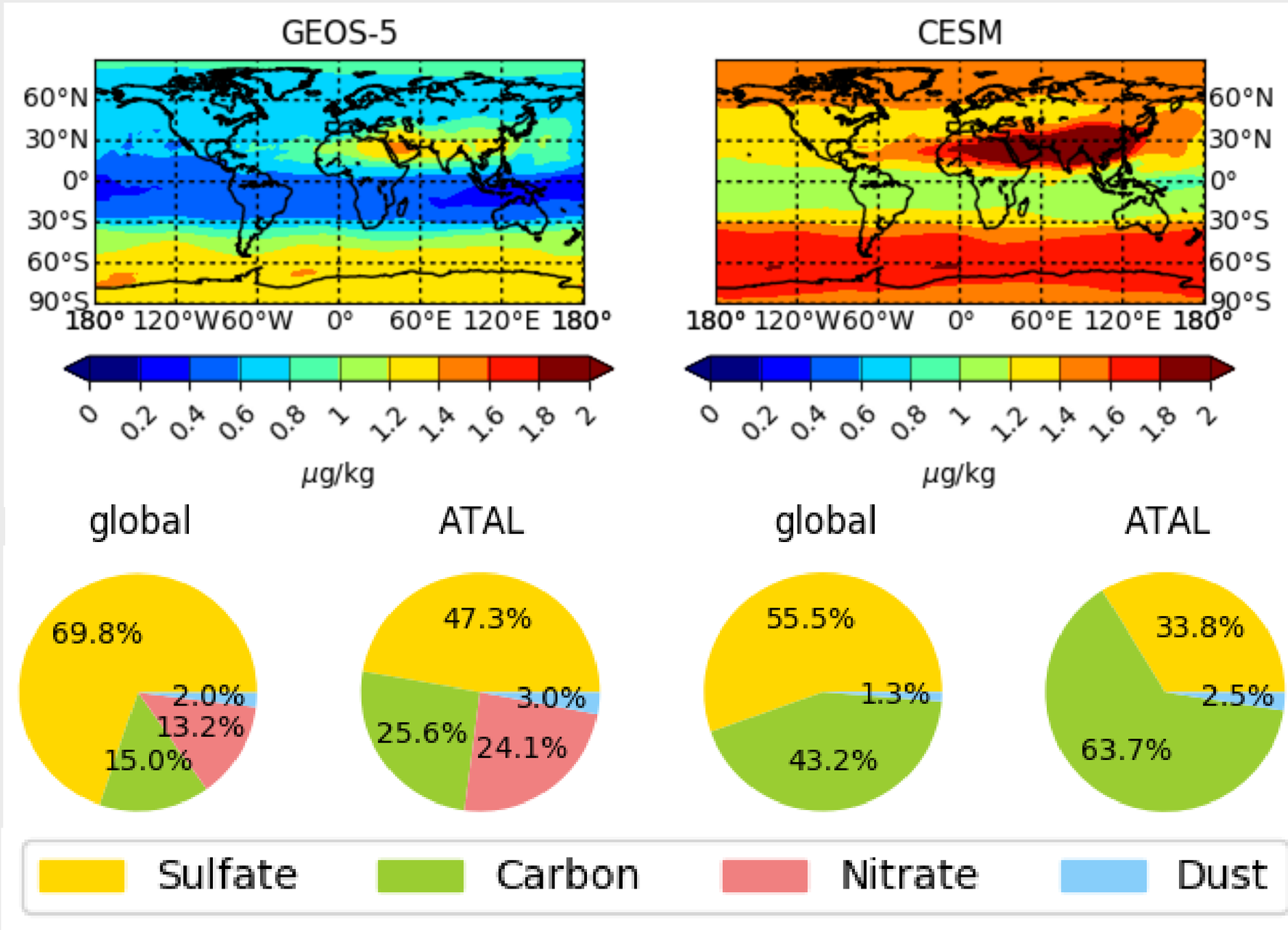
Evaluation with CARIBIC (mostly ~300 hPa)



Uncertainties in modeling UTLS aerosol

Mass mixing ratio [µg/kg]
100 hPa, August 2016

CESM simulations by Pengfei Yu



Many model uncertainties!

Species representations, scavenging of aerosol, convective upwelling, emissions (e.g. biomass burning), pyroCb injections, …

Summary

In the MERRA2-GMI, sulfate is not always the dominant aerosol species in the UTLS. We can identify two regimes:

1. Years with low volcanic perturbation (1995-2005):
   - carbon and sulfate are equally abundant globally in the UTLS during the whole year;
   - nitrate and dust are seasonally relevant on the global scale;
   - the main component of the ATAL is nitrate.
2. Years with moderate to high volcanic perturbation (1980-1995; 2005-present):
   - sulfate is globally the major component of UTLS aerosol;
   - in the ATAL, carbon, nitrate, and dust are also relevant.

Lastly, is “low volcanic perturbation” actually the real background state?