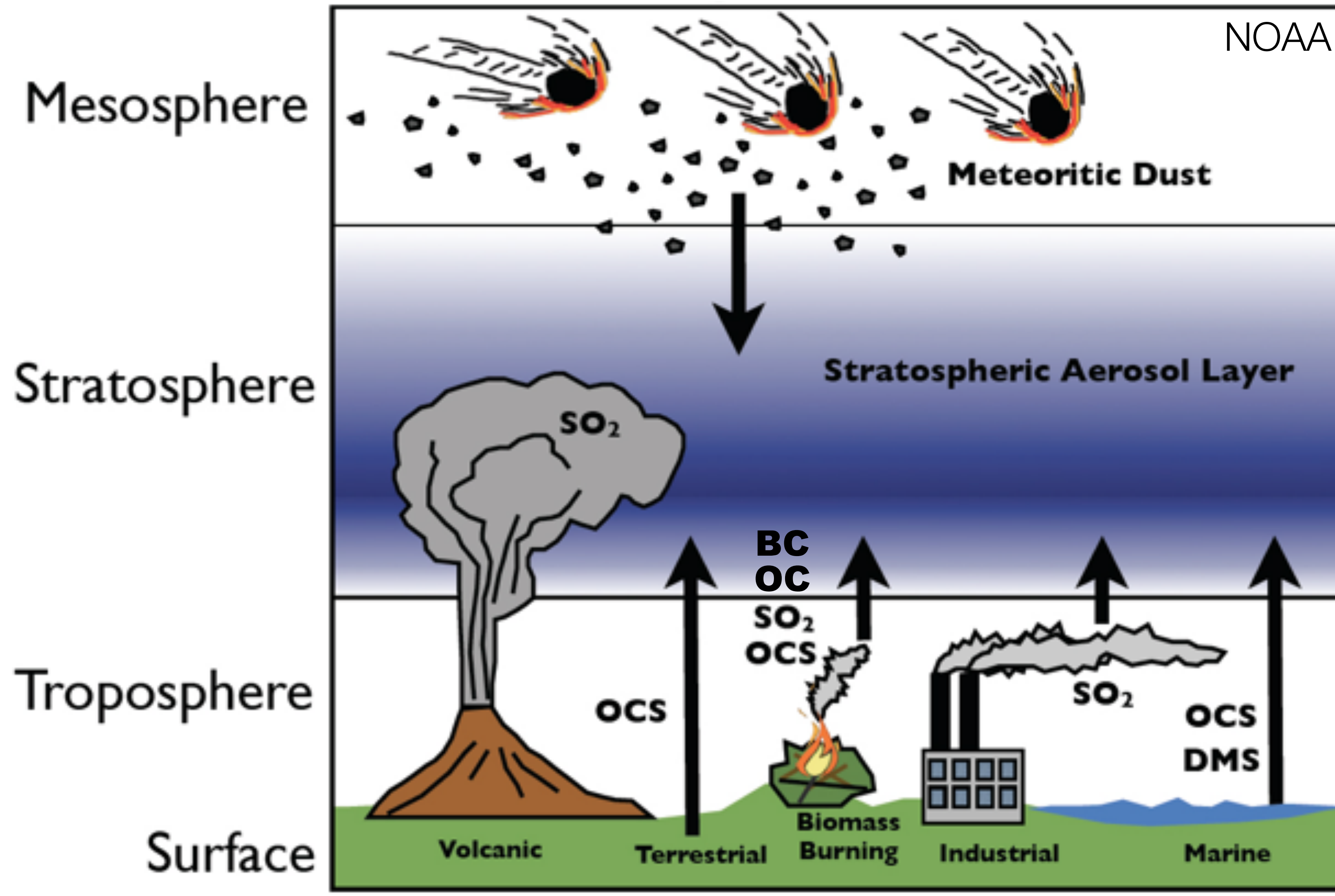
Composition and sources of aerosol in the upper troposphere/lower stratosphere

Valentina Aquila[1,2]
Peter Colarco[2], Anton Darmenov[3], Mian Chin[2]

[1]GESTAR/Johns Hopkins University, Baltimore, MD
[2]Laboratory for Atmospheric Chemistry and Dynamics, NASA GSFC, Greenbelt, MD
[3]Global Modeling Assimilation Office, NASA GSFC, Greenbelt, MD

Sources of aerosol in the UTLS



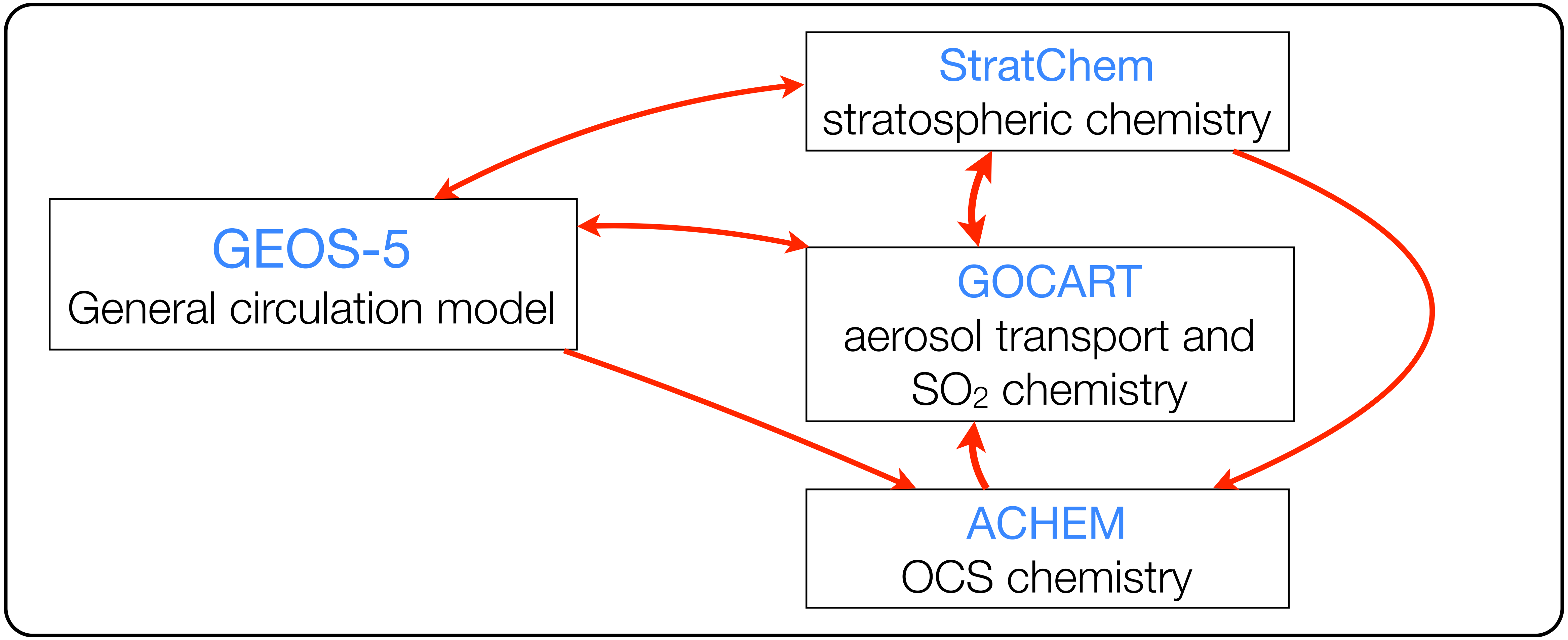
Natural Sources

- Volcanic eruptions emit SO2, which transform into sulfate aerosol
- Biomass burning emits mainly Black Carbon (BC) and Organic Carbon (OC)
- Biogenic OCS (~75%) transform into sulfate aerosol in the stratosphere

Anthropogenic sources

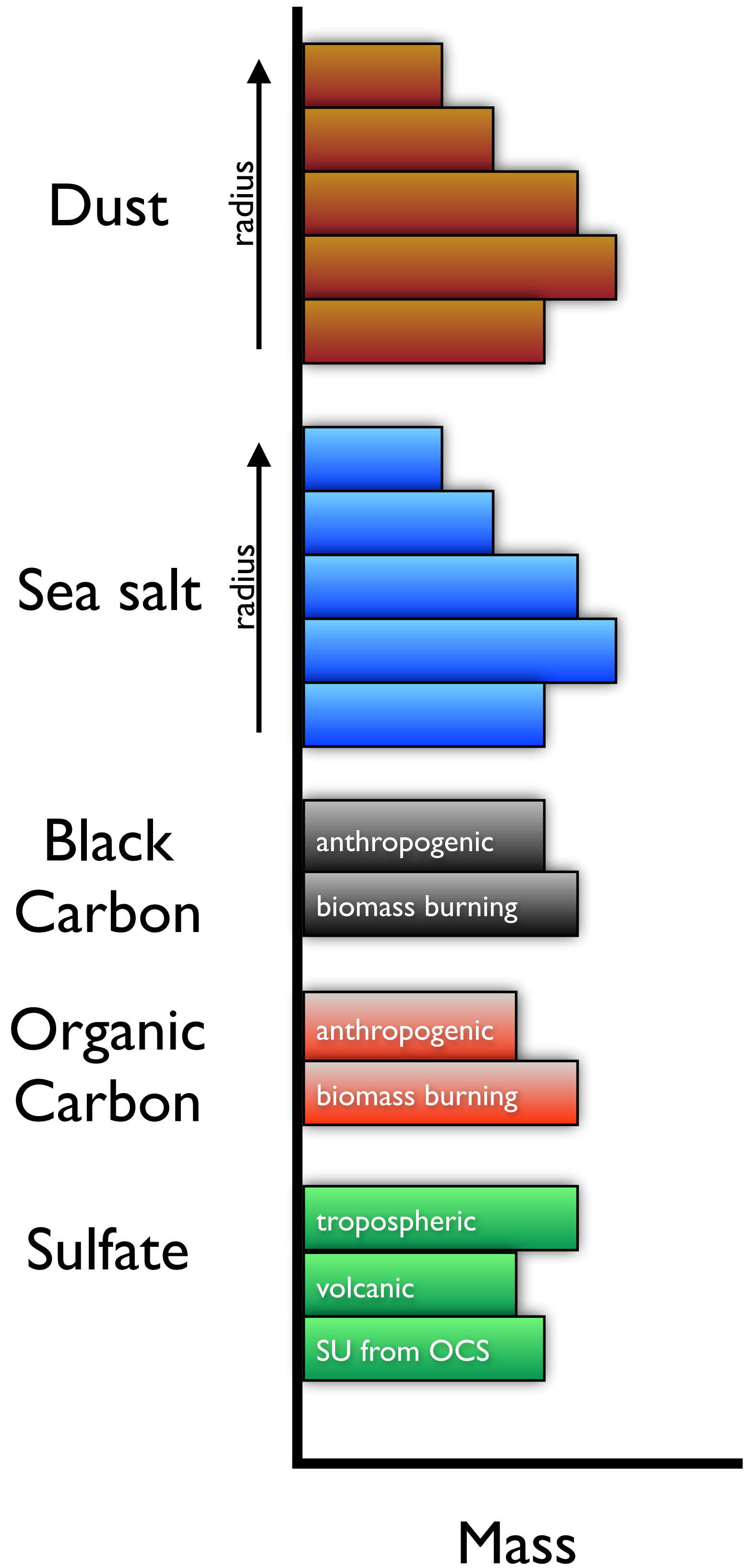
- Industrial emissions
- Anthropogenic OCS (~25%)

The GEOS-5 Chemistry Climate Model



- Radiatively interactive water vapor, O_3, O_2, CO_2, clouds, aerosols and most trace gases.
- OCS photolysis, OCS+O, OCS+OH to generate SO_2, which GOCART transforms into sulfate aerosol
- Includes all tropospheric emissions of aerosol (EDGAR and QFED), and volcanic eruptions simulated as injection of SO_2 (Carn et al., GRL 2015; TOMS+OMI+OMPS)
- Simulations driven by MERRA meteorology (replay) from Jan 2001 to Dec 2014

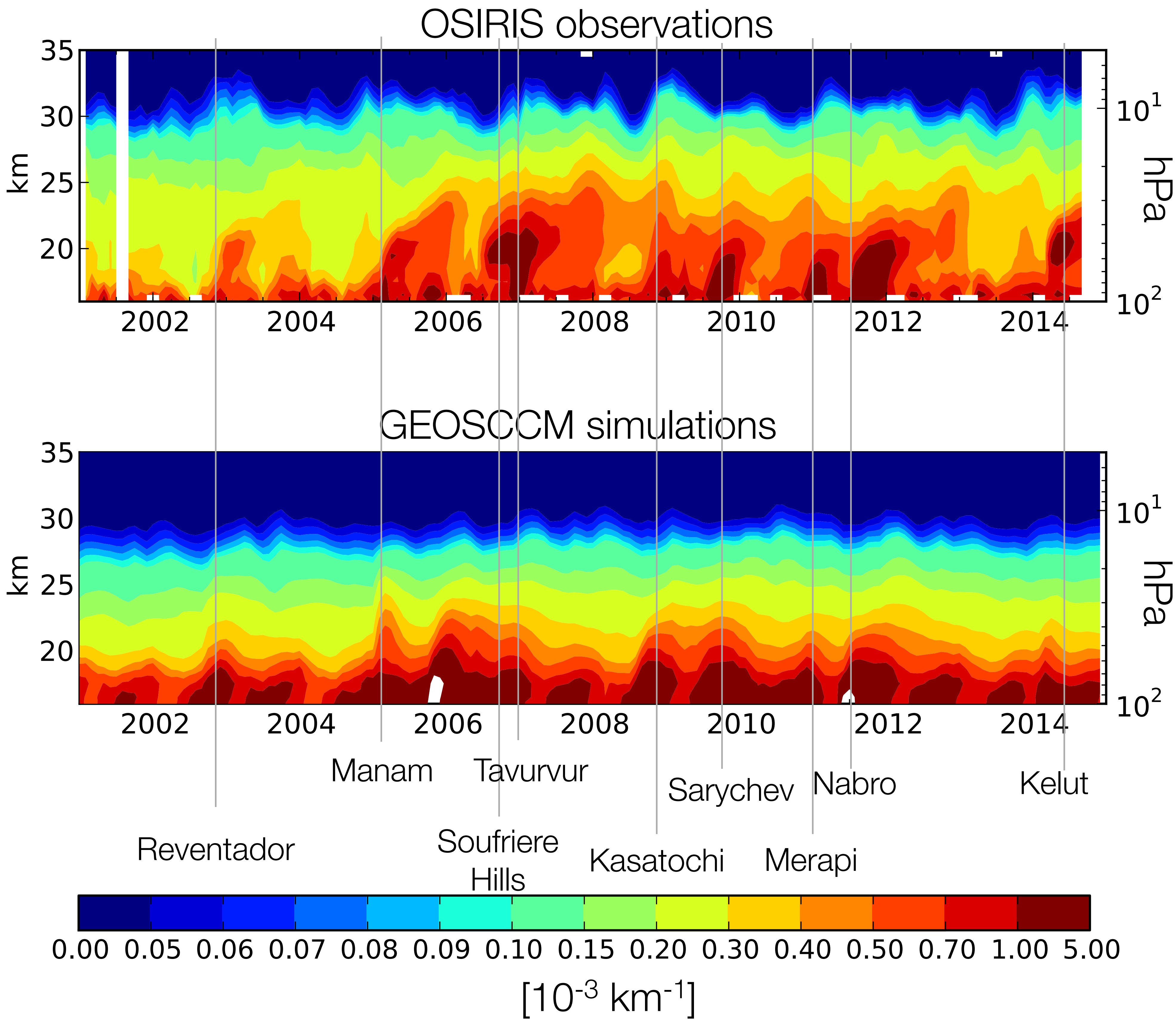
The GOCART aerosol module



Goddard Chemistry, Aerosol, Radiation, and Transport Model

- Tracks the mass and size of dust and sea salt aerosol
- Tracks the mass of BC, OC, volcanic sulfate, and tropospheric sulfate aerosol. Their radius is prescribed.
- Separately tracking:
  - Volcanic sulfate, tropospheric sulfate, and sulfate from OCS
  - BC/OC from anthropogenic emissions and from biomass burning
- Aerosol optical properties and settling velocity depend on the species and on the assumed radius.

Tropical aerosol extinction (30°S-30°N)

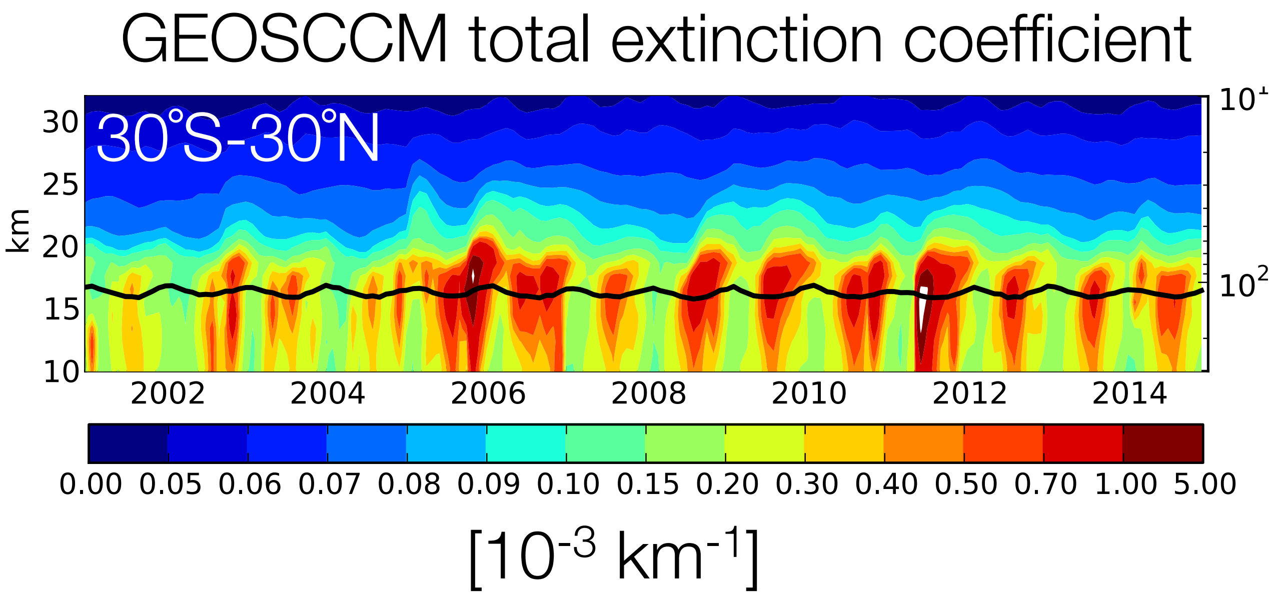


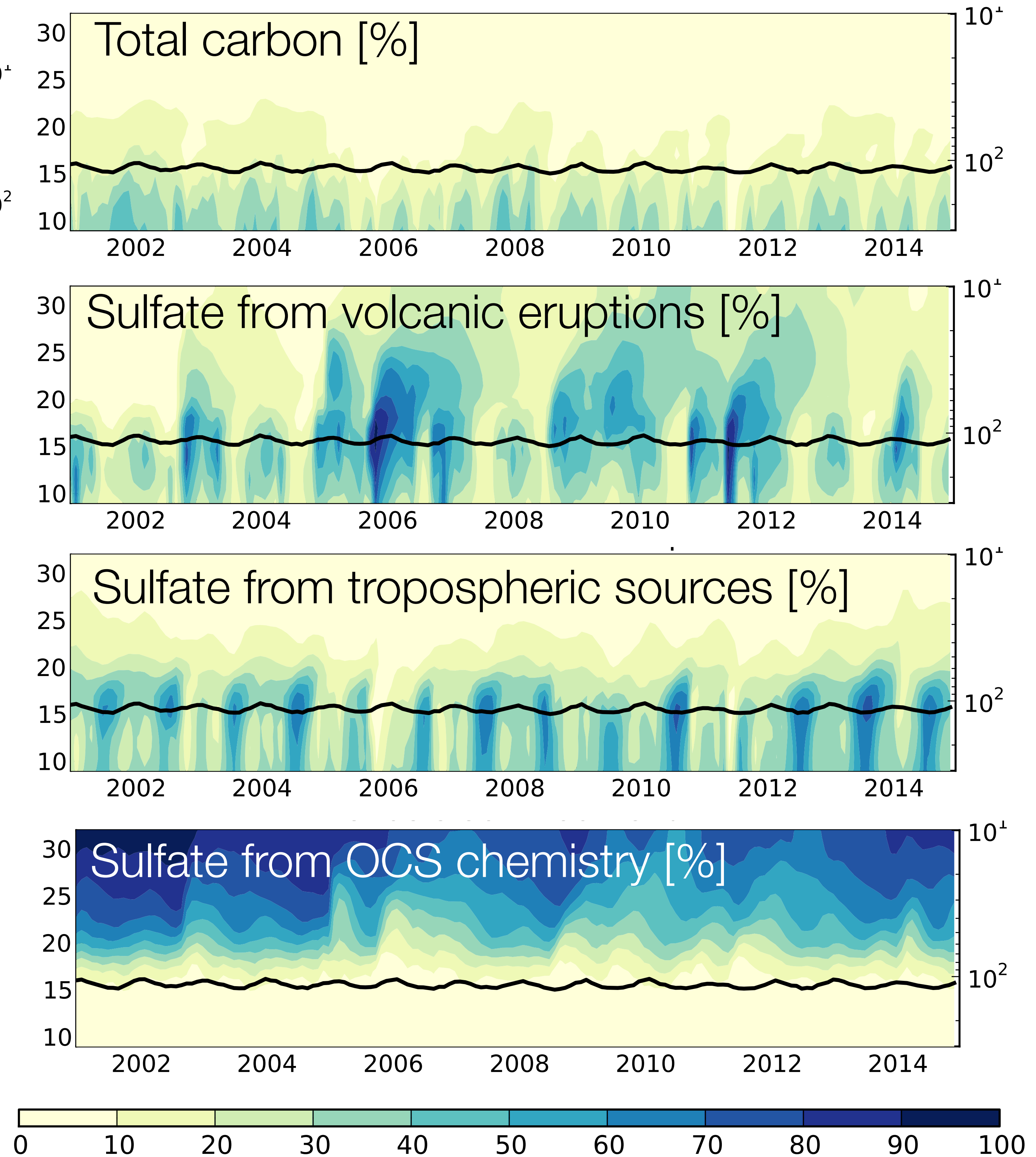
Clear influence of volcanic eruptions for during the whole period.

Seasonal contributions to the aerosol extinction from the troposphere.

OSIRIS data by L. Reiger

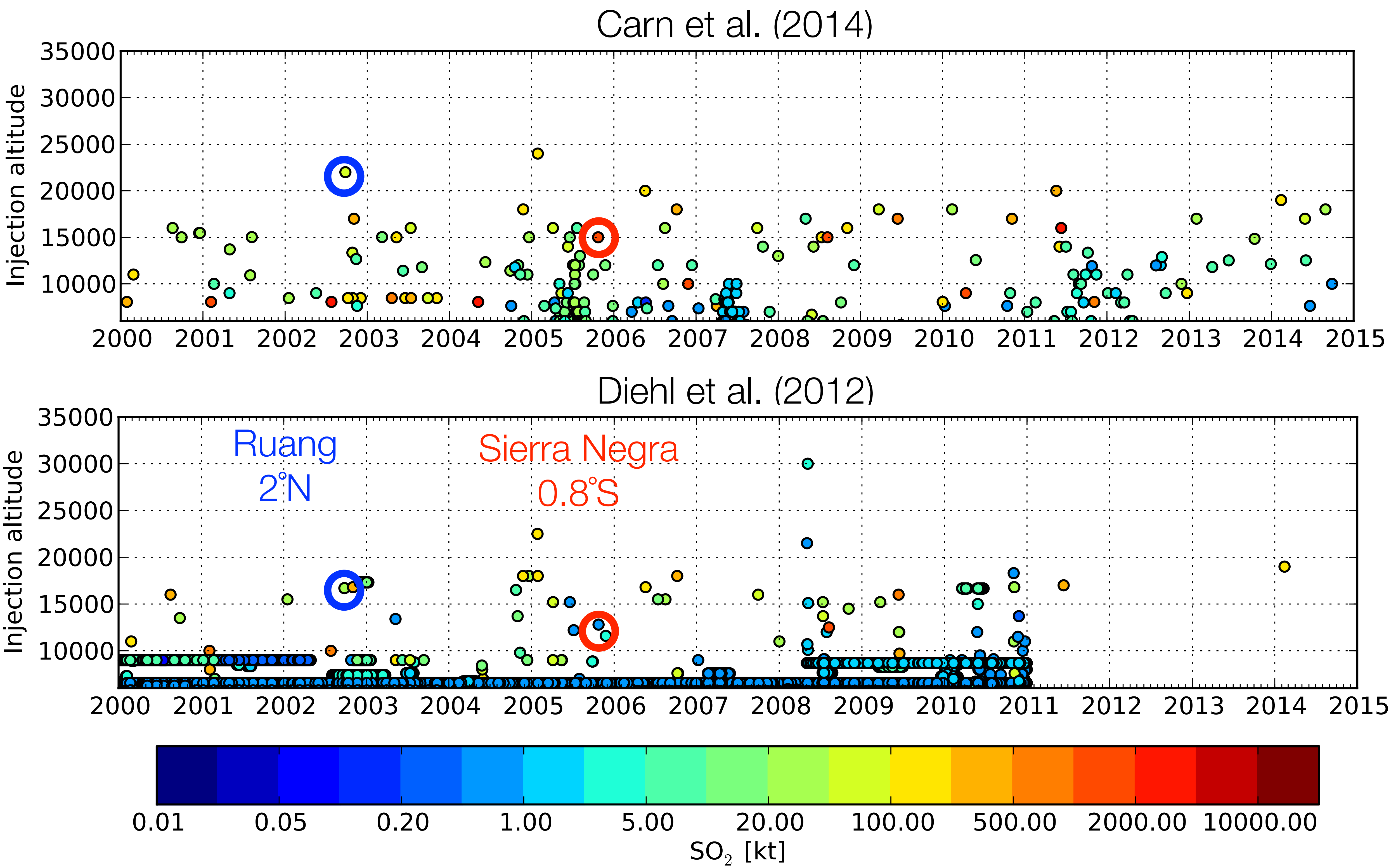
What makes up the total extinction in the tropics?





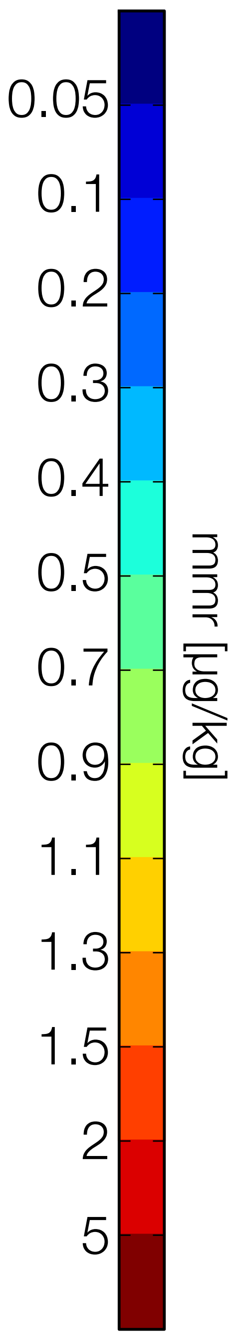
- The dominant contribution to the total extinction is sulfate
- Carbon (OC+BC) contributes up to 50% in the UT and up to 20% in the LS
- Above 20km, sulfate from OCS chemistry is the dominant sources, but absolute extinction values are low
- If there is a large volcanic eruption, volcanic sulfate is the overwhelming source of extinction in the UTLS

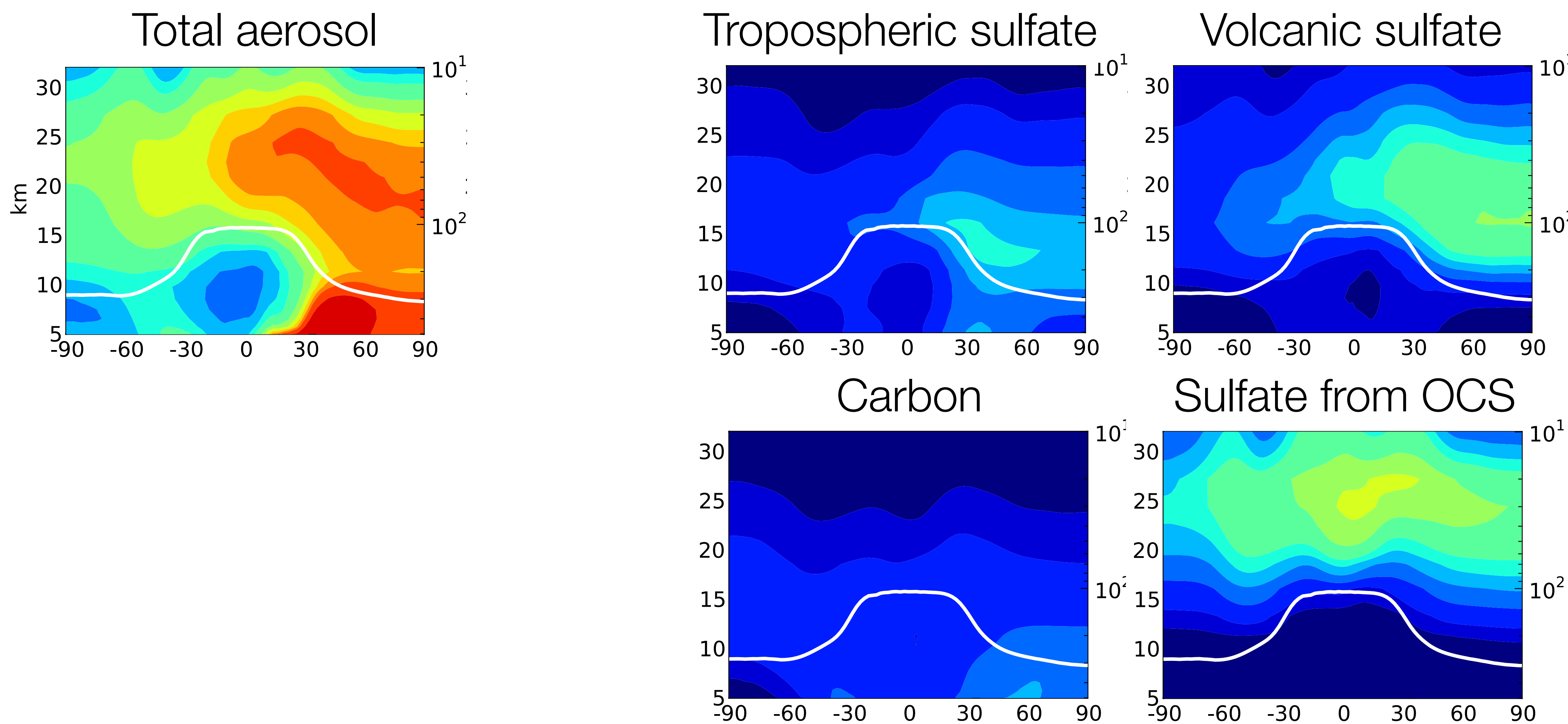
Volcanic databases



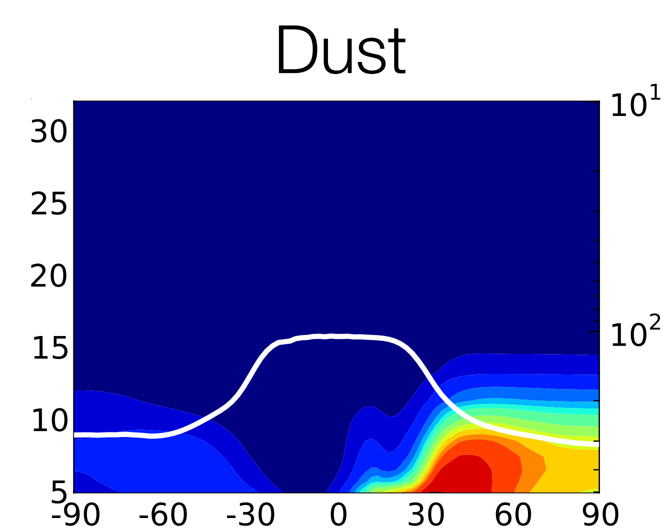
Different databases treat some major eruptions differently, and this impacts strongly the result of the simulations.

Mass mixing ratio of aerosol

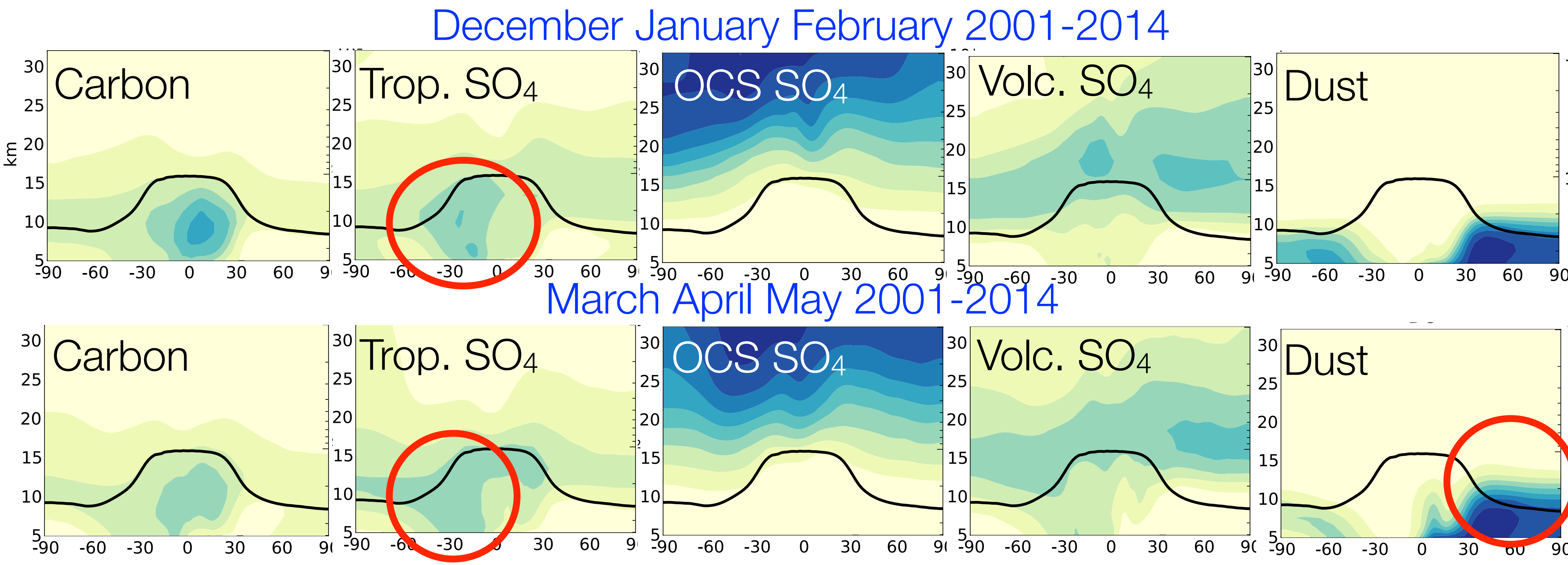


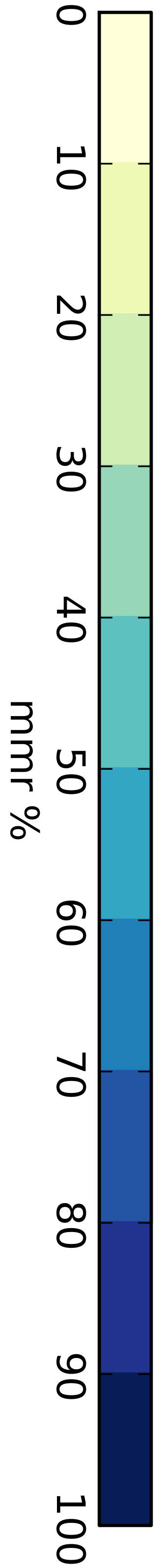


- Asymmetric distribution of aerosol, related to the asymmetric distribution of sources
    - Only 18 eruptions south of 20°S in 2000-2015
    - Most aerosol sources in the northern hemisphere
- Tropical lower stratosphere: mainly volcanic sulfate
- NH UTLS: contributions of carbonaceous aerosol, dust, and sulfate from tropospheric sources

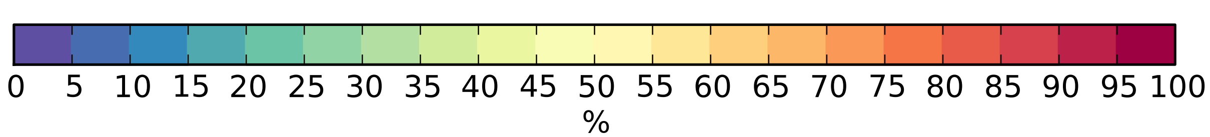


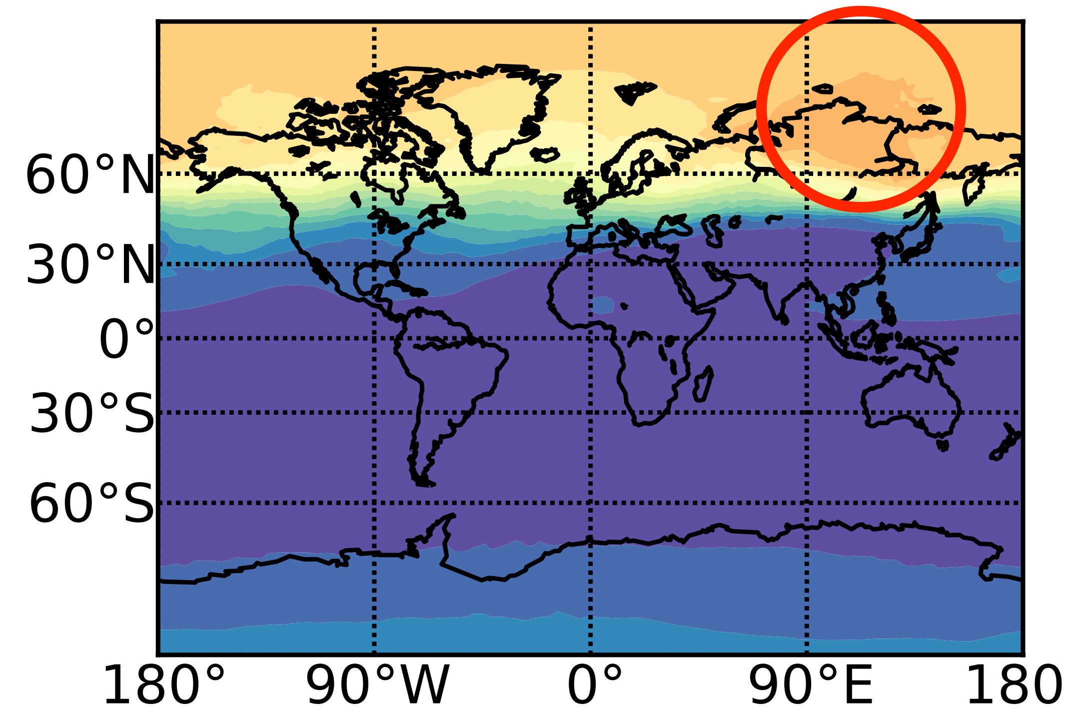
The vertical transport of aerosol





60-65% of dust in the stratospheric aerosol column





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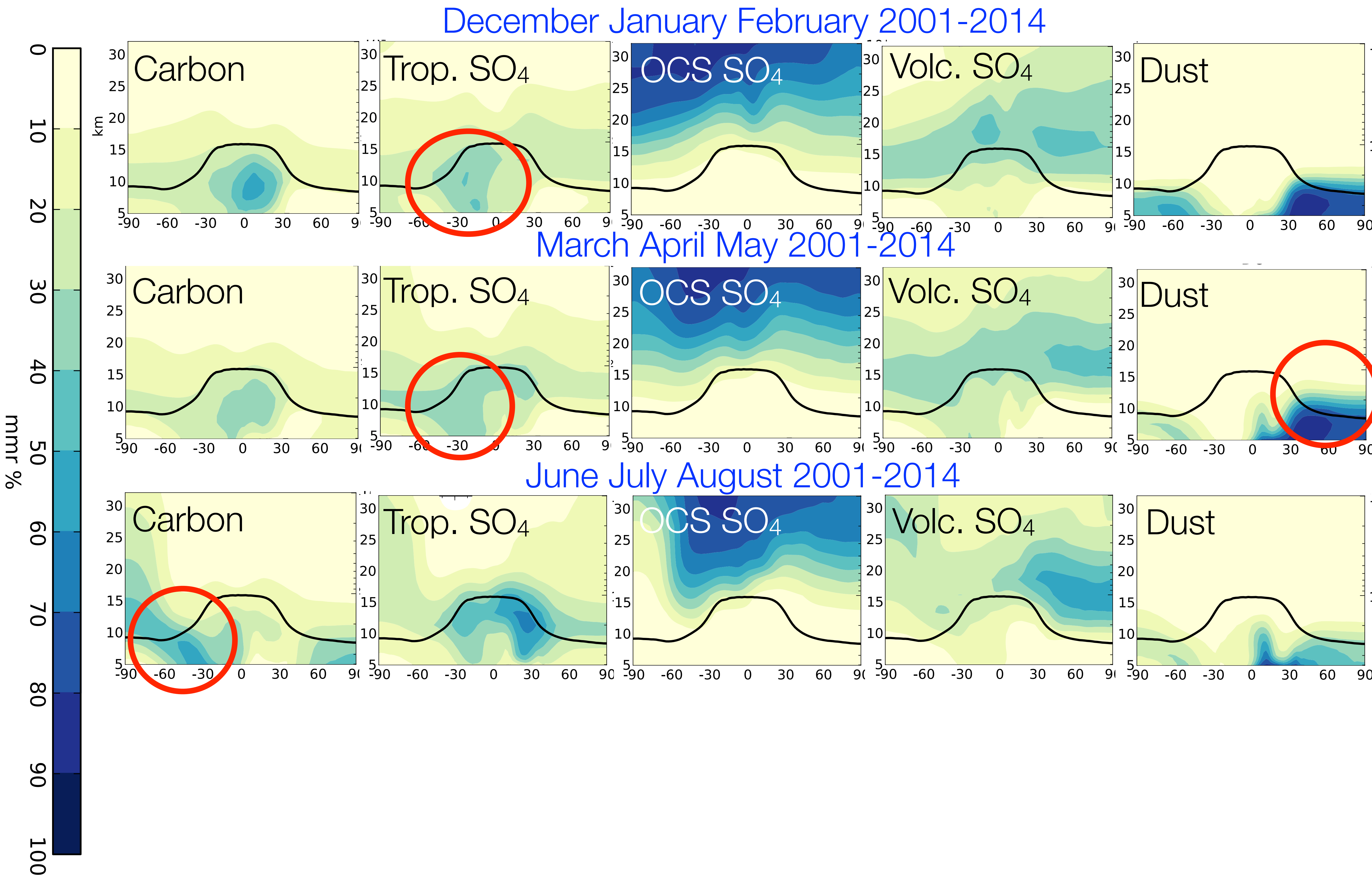

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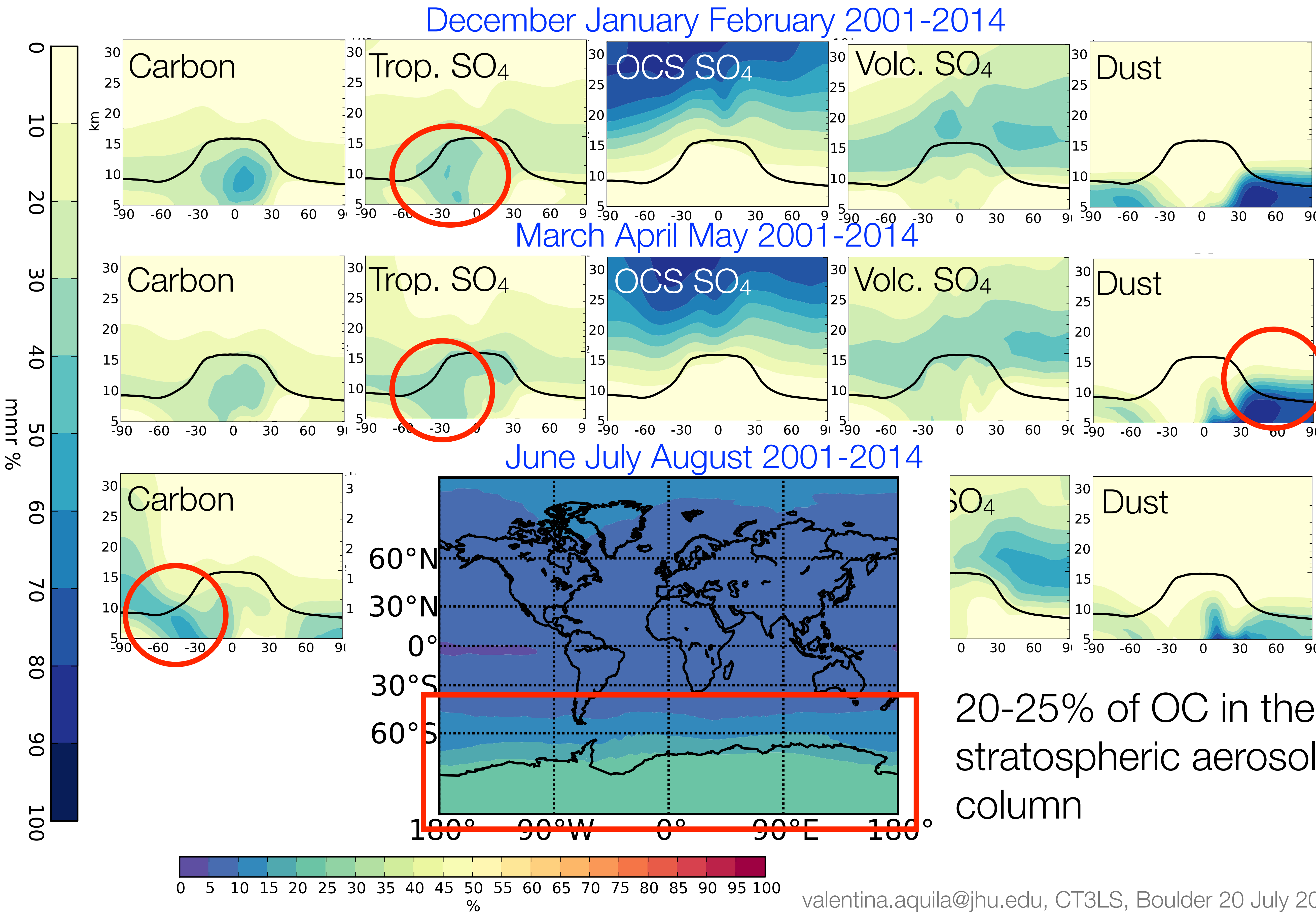
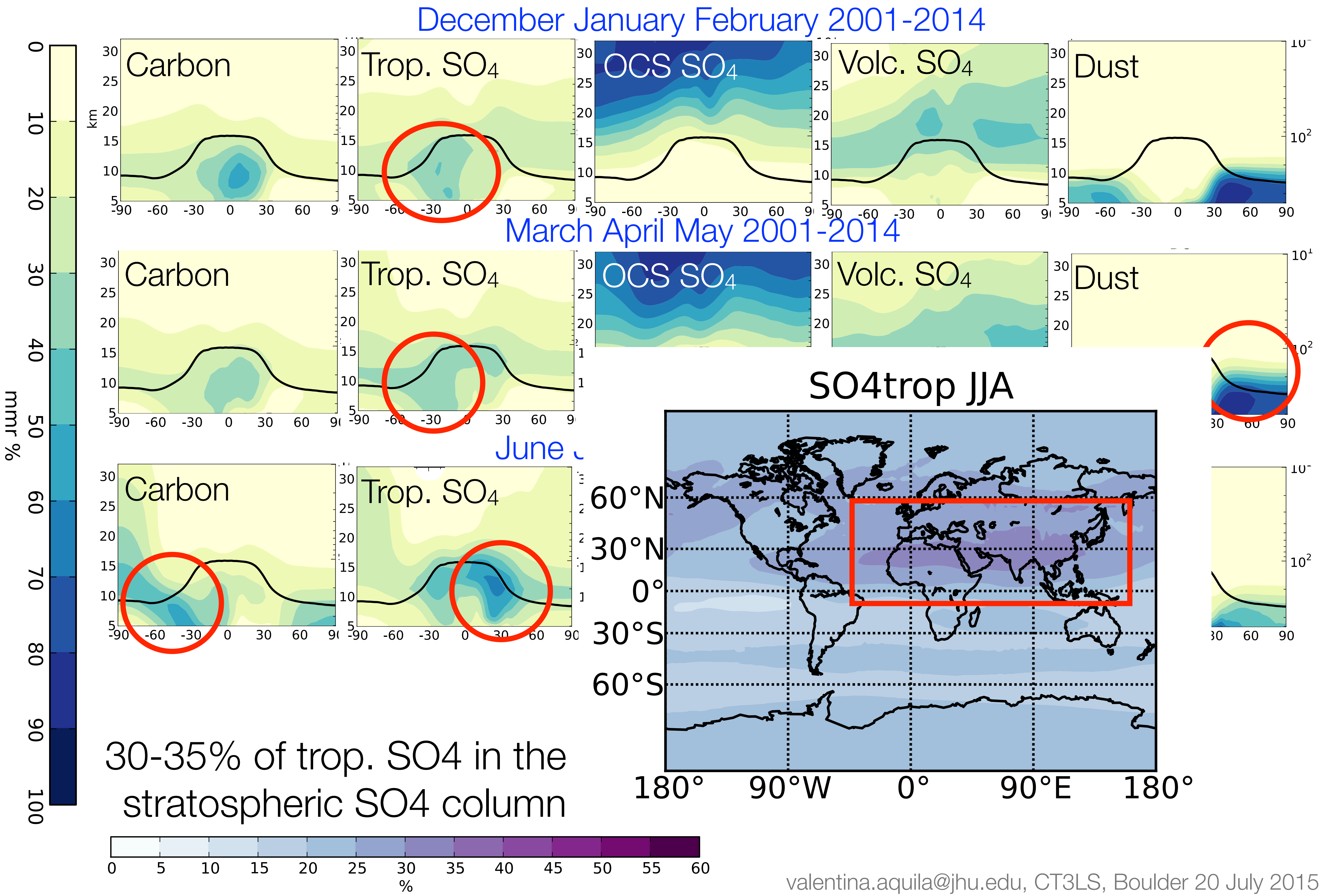


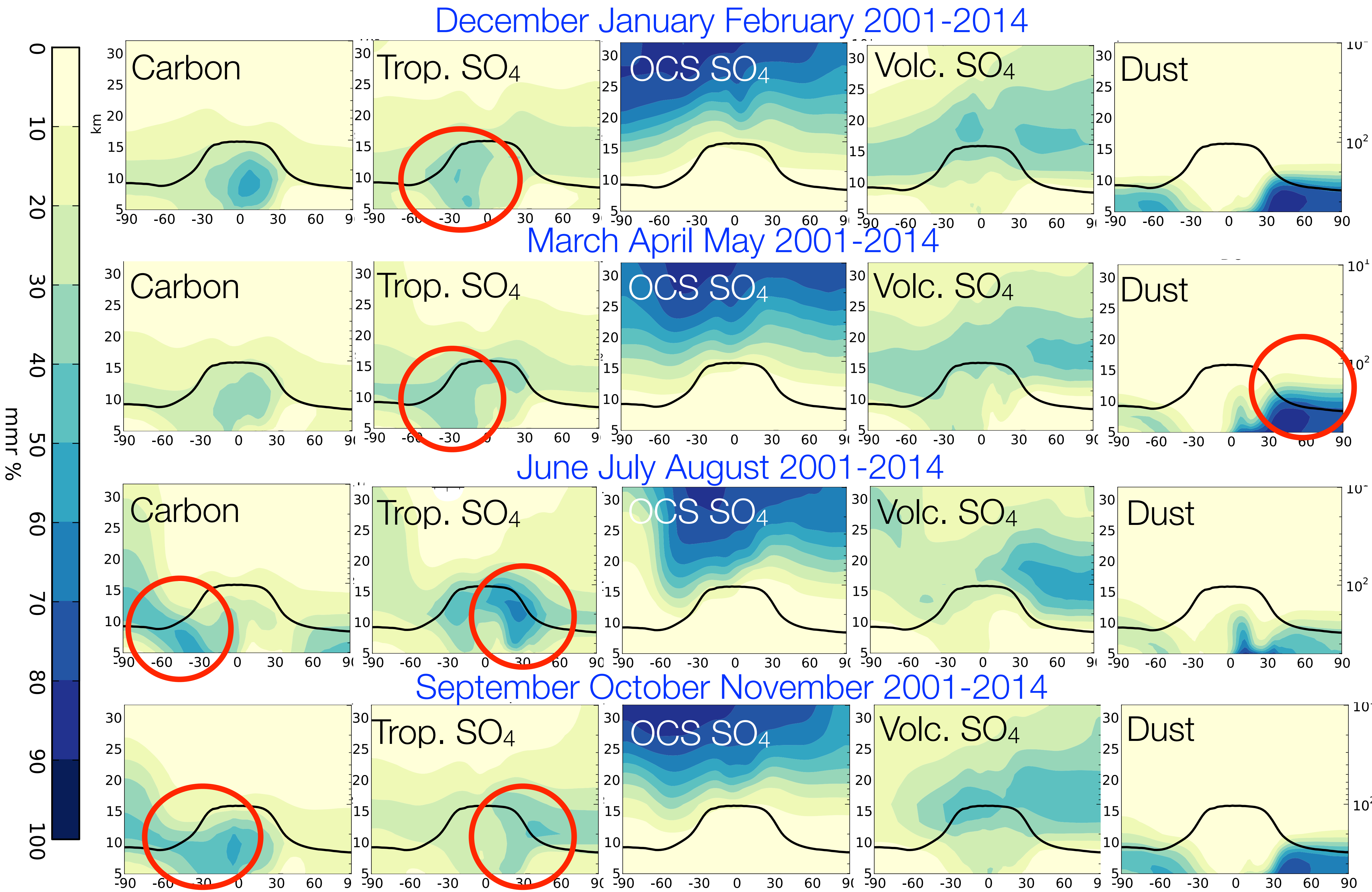
20-25% of OC in the stratospheric aerosol column

The vertical transport of aerosol

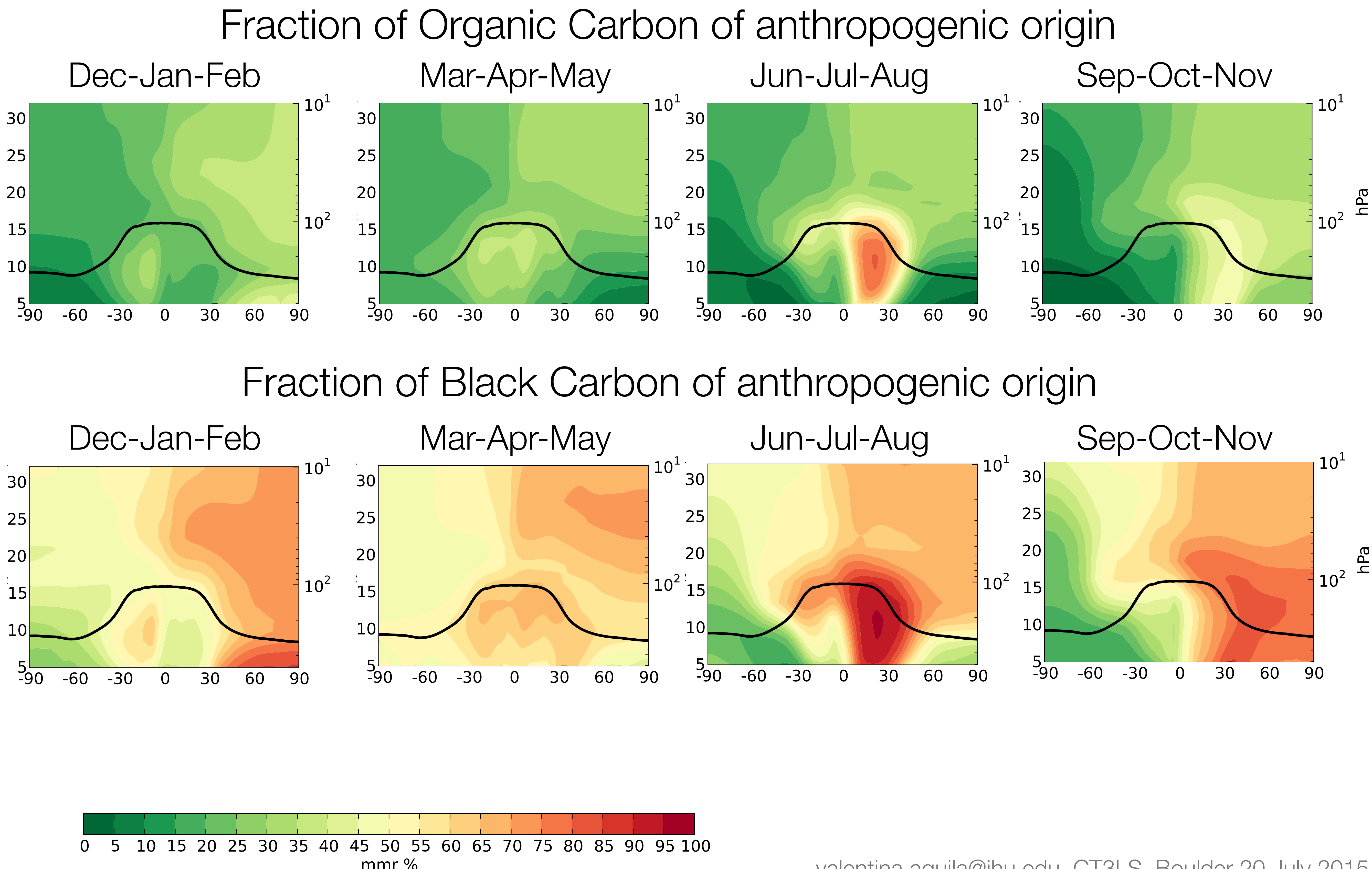


30-35% of trop. SO4 in the stratospheric SO4 column

The vertical transport of aerosol

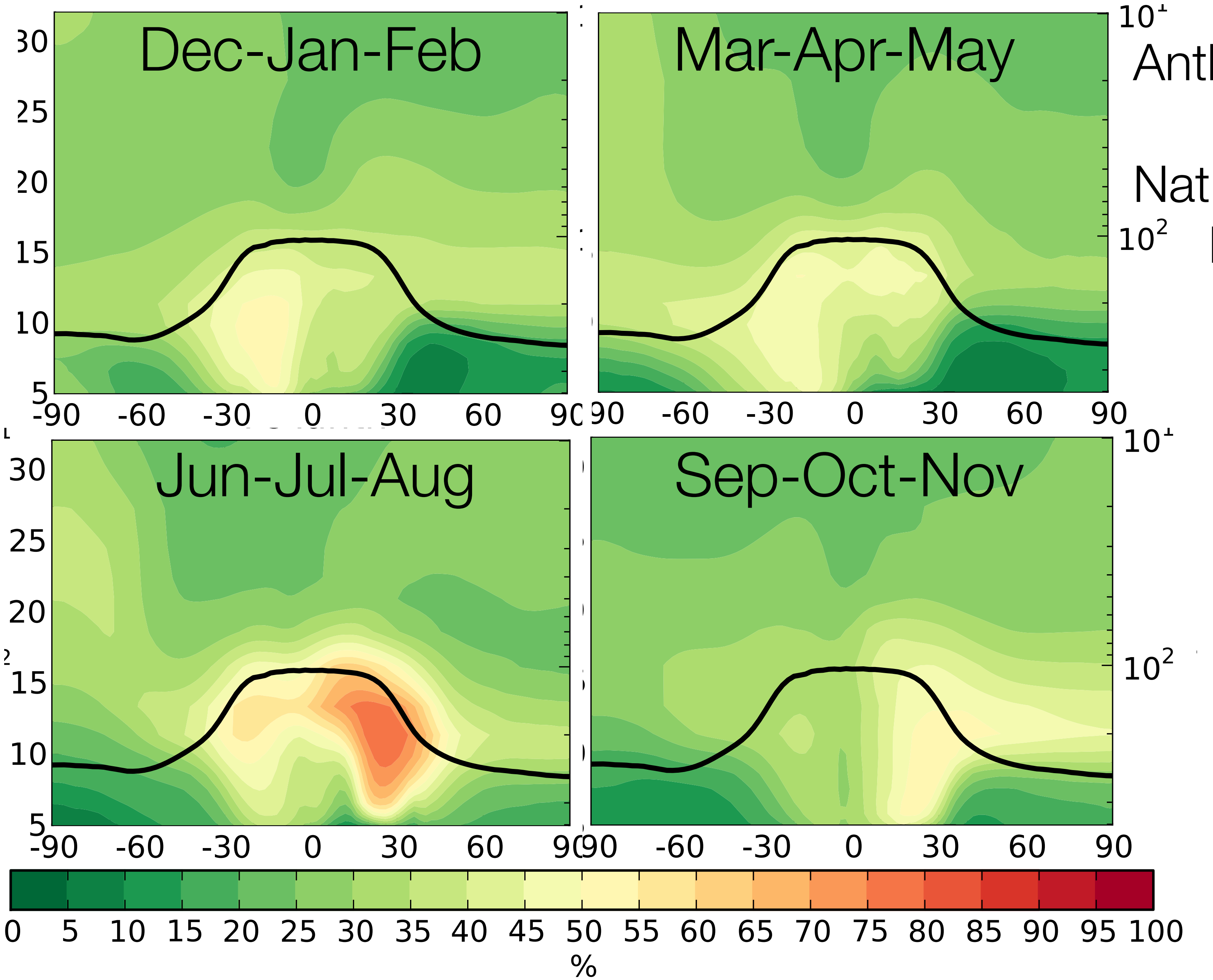


Anthropogenic and natural sources of carbon



Anthropogenic and natural aerosol

Fraction of aerosol of anthropogenic origin



Anthropogenic = trop. SO_4 + 0.25 SO_4^{OCS} + anthro. BC+anthro. OC

Natural = volcanic SO_4 + 75% SO_4^{OCS} + bb BC+ bb OC

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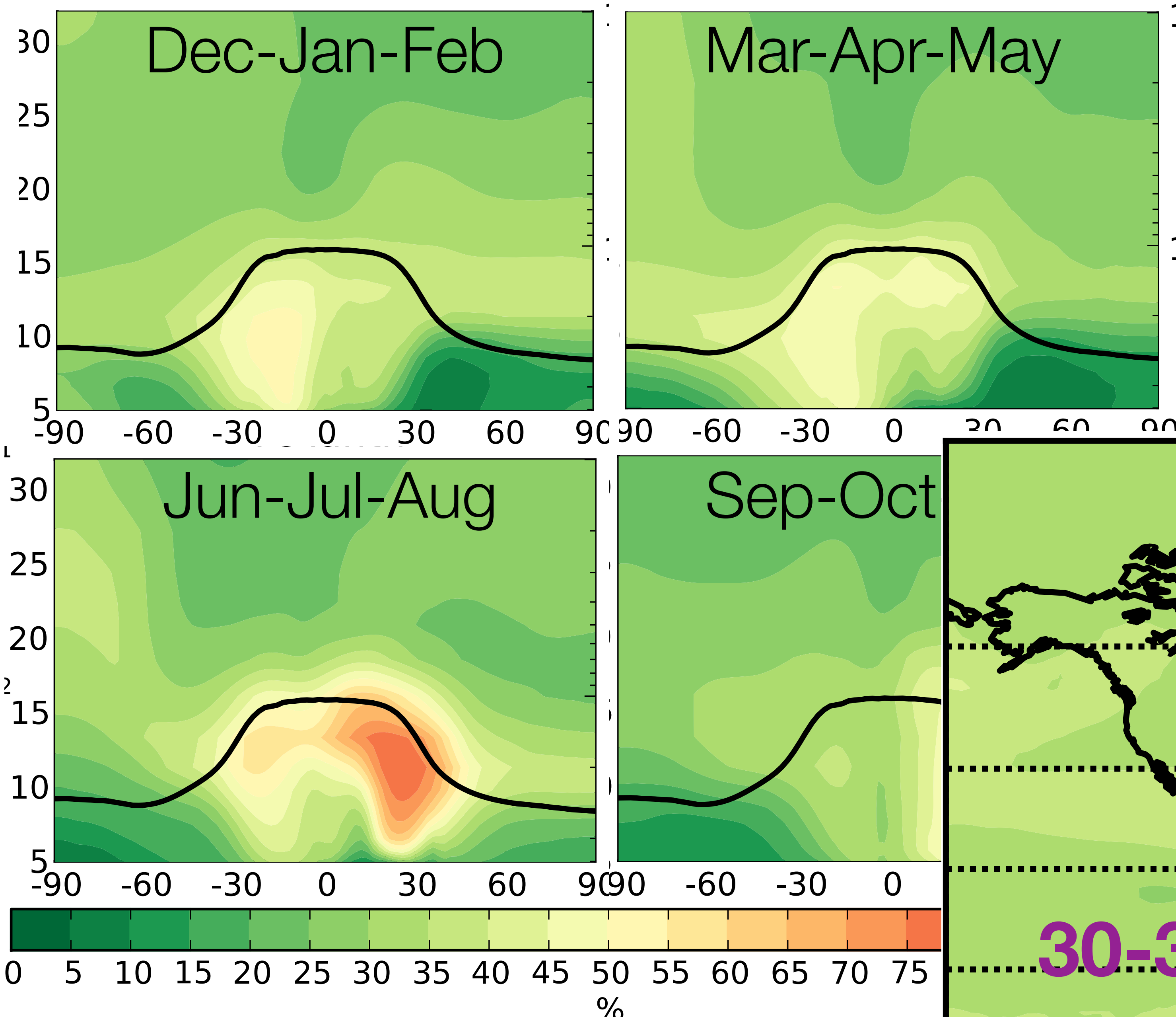

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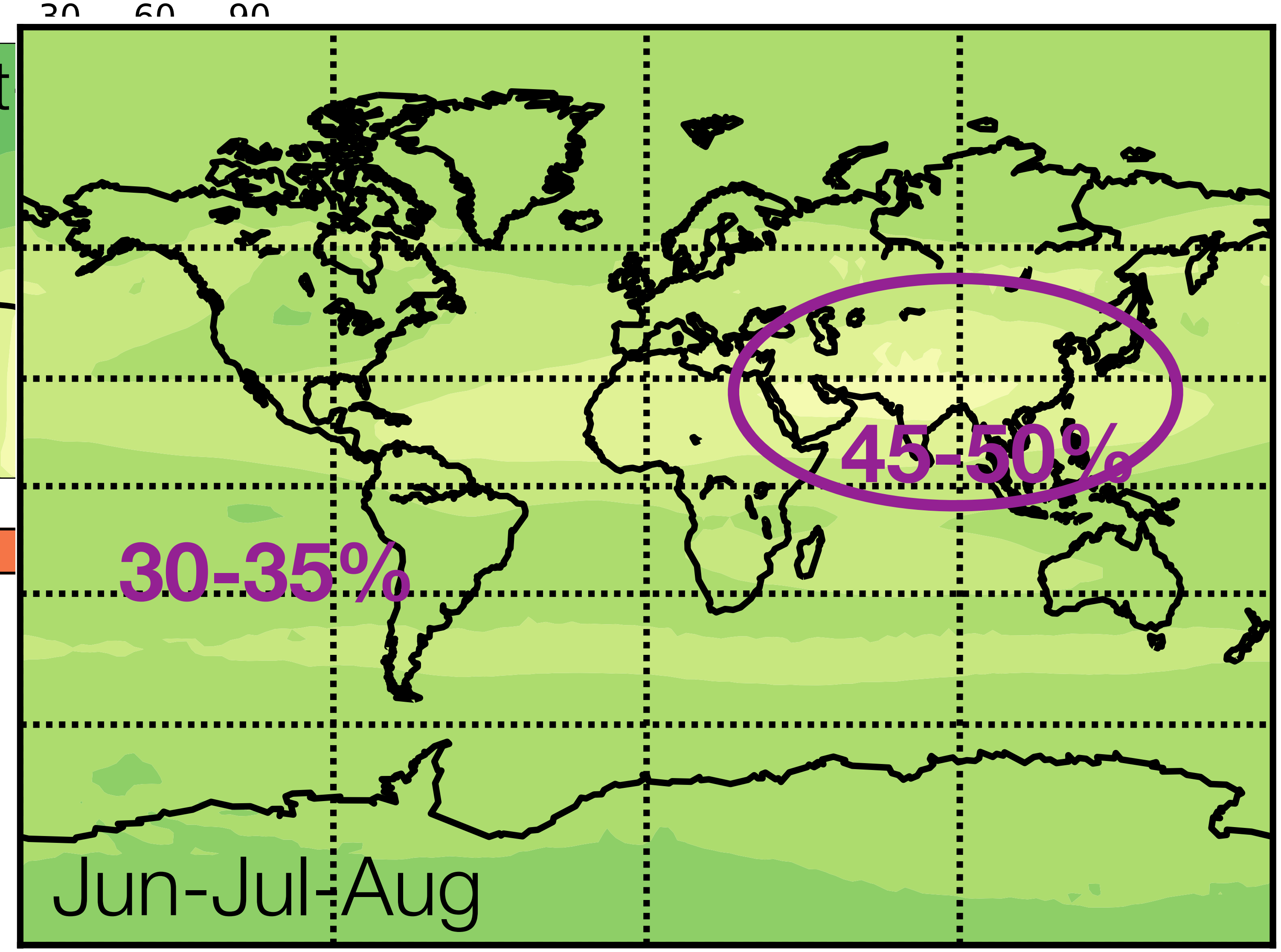

Summary

- Most aerosol in the UTLS is sulfate from volcanic eruptions and tropospheric sources
- The volcanic database is fundamental to simulate correctly the aerosol in the UTLS
- Carbon constitutes up to 20% of the aerosol in the tropical LS is carbon, and up to 40% in the extratropical LS
- GEOS-5 simulates strong injections of dust in the LS at northern high latitudes in MAM
- Tropospheric aerosol is injected in the UTLS in DJF in the SH and in JJA in the NH via the monsoon circulation.
- About 35% of the aerosols in the UTLS is of anthropogenic origin. During JJA up to 80% of aerosol in the UTLS between 15°N and 30°N is anthropogenic.