Global Simulation of Aerosol Dynamics and Microphysics

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1. Motivation

- *Simulate sulfate aerosol number concentration and size distribution globally*

- *Interaction of sulfate with non-sulfate aerosols (OC/BC/mineral dust/sea salt)*
  - for sulfate: different lifetime, burden, and size distribution
  - for non-sulfate aerosols: BC/mineral dust from hydrophobic to hydrophilic; cloud scavenging

2. The IMPACT Model

- The global CTM model (IMPACT), driven by the NASA Data Assimilation Office meteoro. data
  - horizontal resolution: 2.5° x 2°
  - vertical resolution: 46 levels, top at 0.1 hPa

- UM Aerosol Module
  - sulfate aerosol (sulfur chemistry)
    - 2 moments: mass & number
    - 2 modes: nuclei (< 0.05 um) & accumulation (>0.05um)

- superposition of lognormal distributions with constant width
- nucleation scheme: Vehkamaki et al. (2002)

- non-sulfate aerosols:
  natural OC, fossil fuel OC/BC, biomass OC/BC
  dust 4 bins & sea salt 4 bins:
  (0.05-0.6,0.6-1.2, 1.2-2.5, 2.5-10 um radius)

- include interactions between sulfate and non-so4 aerosols

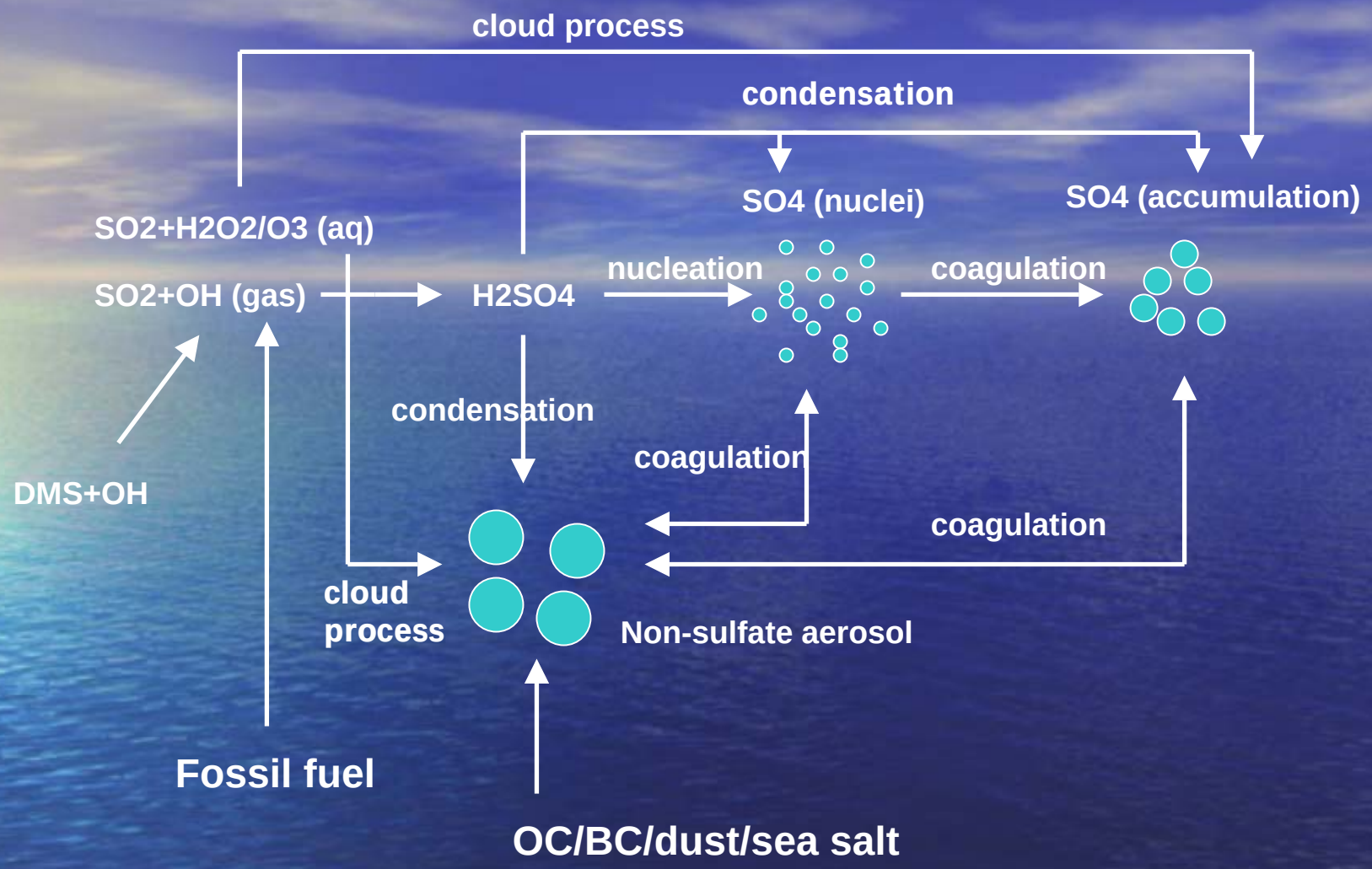


Diagram of aerosol dynamics and microphysics

- ***Surface coating of OC/BC/dust by sulfate molecules***

  - Area coverage of non-sulfate aerosol surface by SO_4 molecules

$$f_{so4bc} = \frac{\pi r_{so4}^2 N_{so4}}{4\pi (r_{so4} + r_{bc})^2}$$

  - pure sphere: S = 27.5 m^2/g, fso4bc = 10 layers
    measured S = 75~400 m^2/g, fso4bc = 0.67-3.6 layer
    ⇨ mass fraction ~13%.

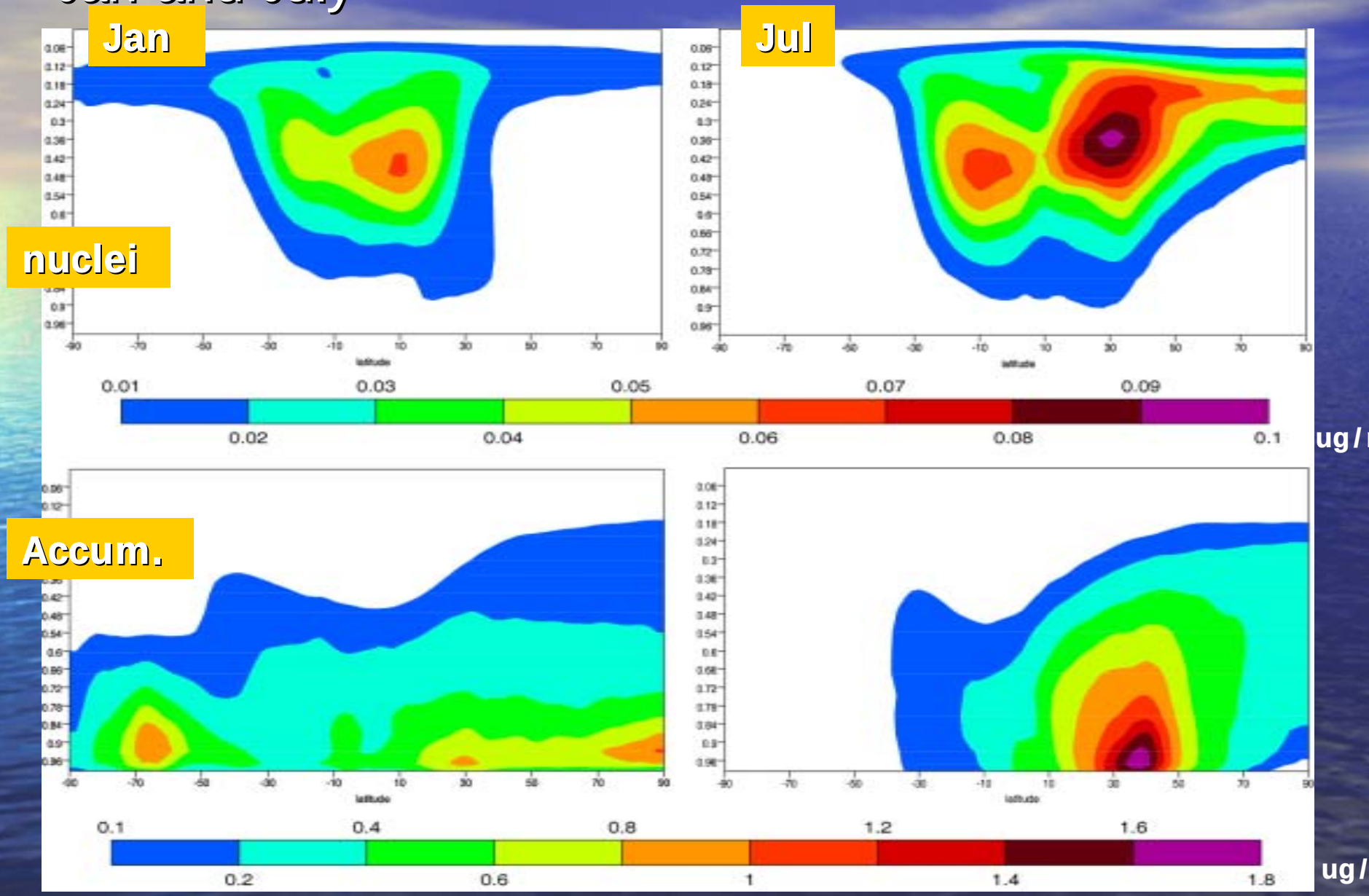
  - Same for mineral dust (fso4d = 10 for pure sphere)

Wyslouzil et al. (1994), Lammel and Novakov (1995) : when the soluble mass fraction is > 10% for the treated BC aerosols, the nucleation ability was the same as for completely soluble (NH4)2SO4 particles

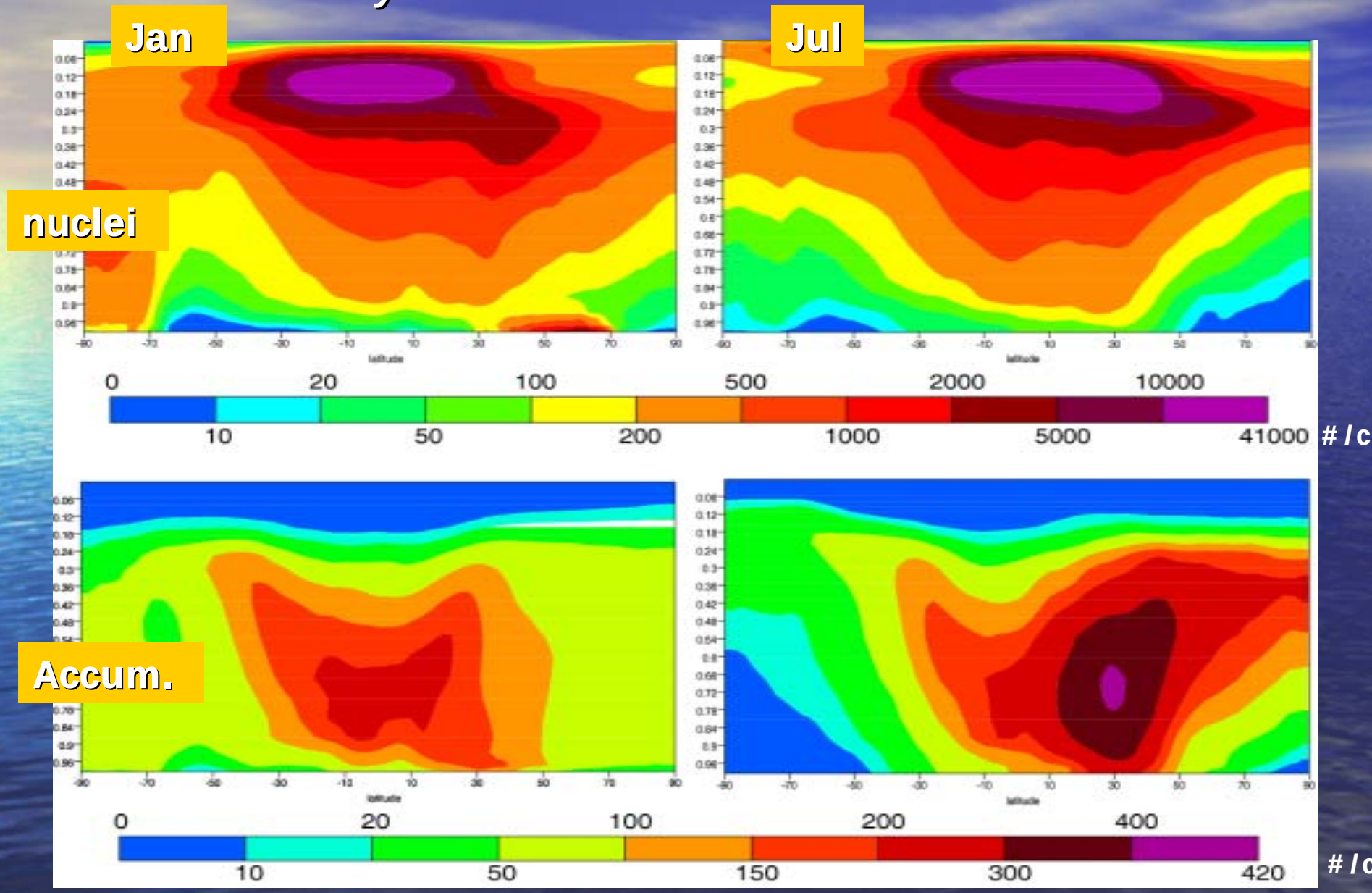
4. Model Results

- Analysis of control run (with non-so4 aerosols, no direct so4 emissions from fossil fuel)
- Interactions between so4 and non-so4 aerosols in the atmosphere
- Impacts of interactions on so4 and non-so4 aerosols.

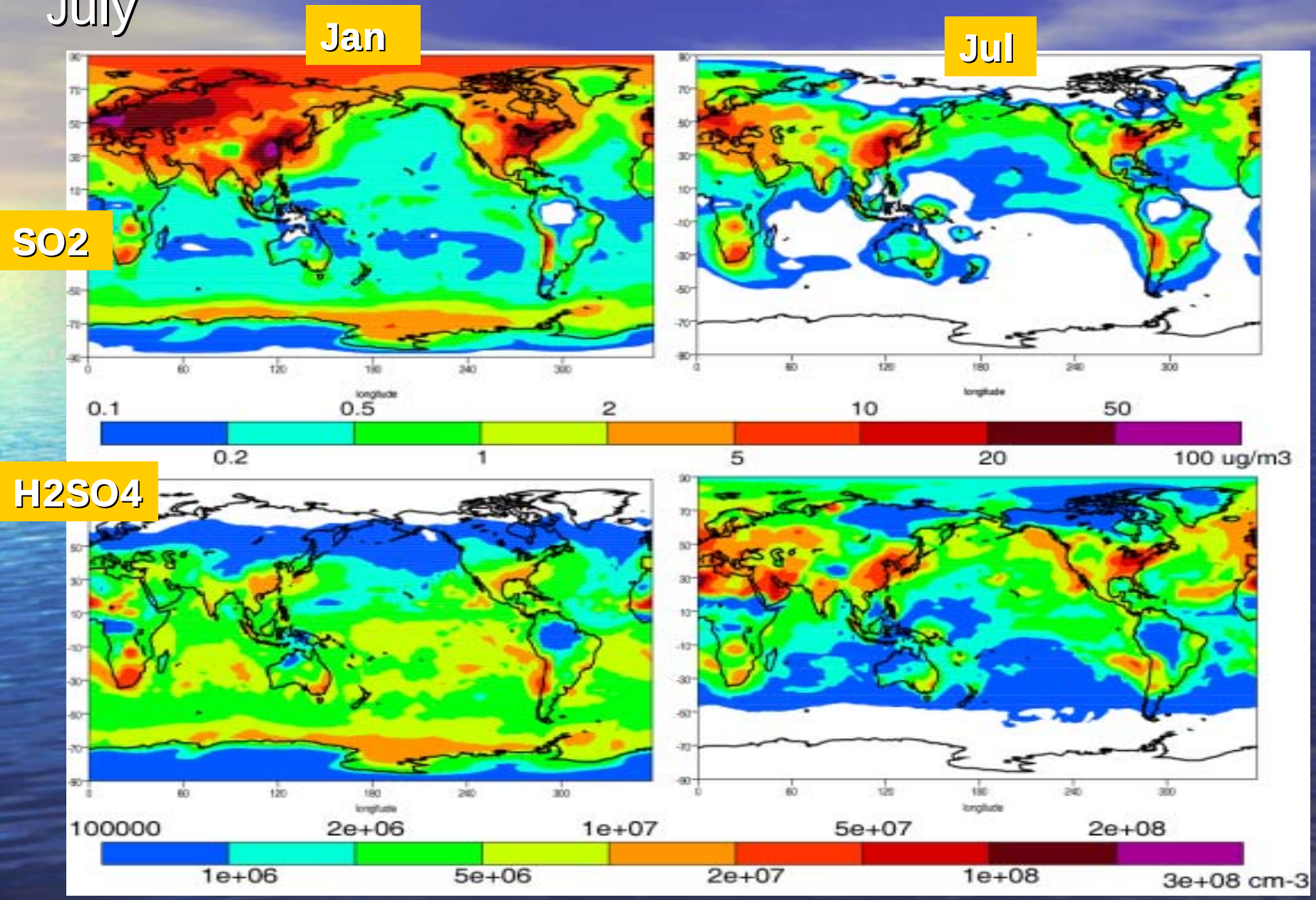
Pure SO4 aerosol mass: nuclei and accu. mode in Jan and July



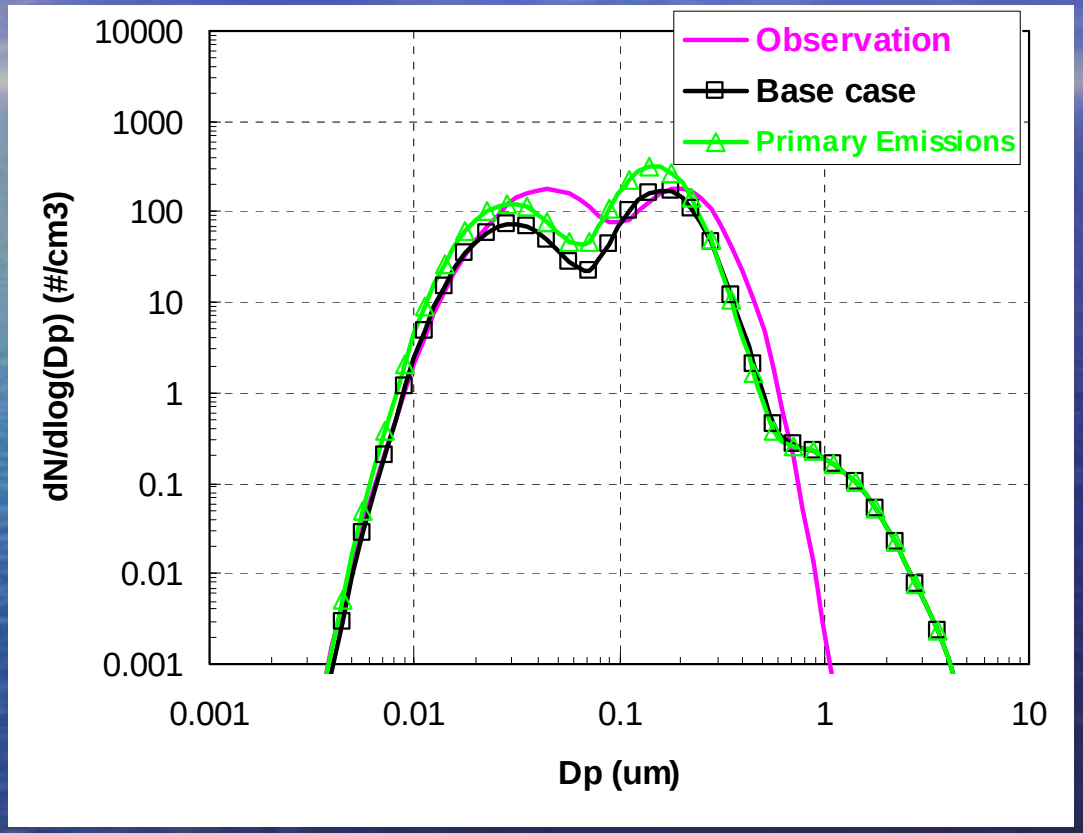
Pure SO4 aerosol number: nuclei and accu. mode in Jan and July



SO2 and H2SO4 (gas) at surface layer in Jan and July

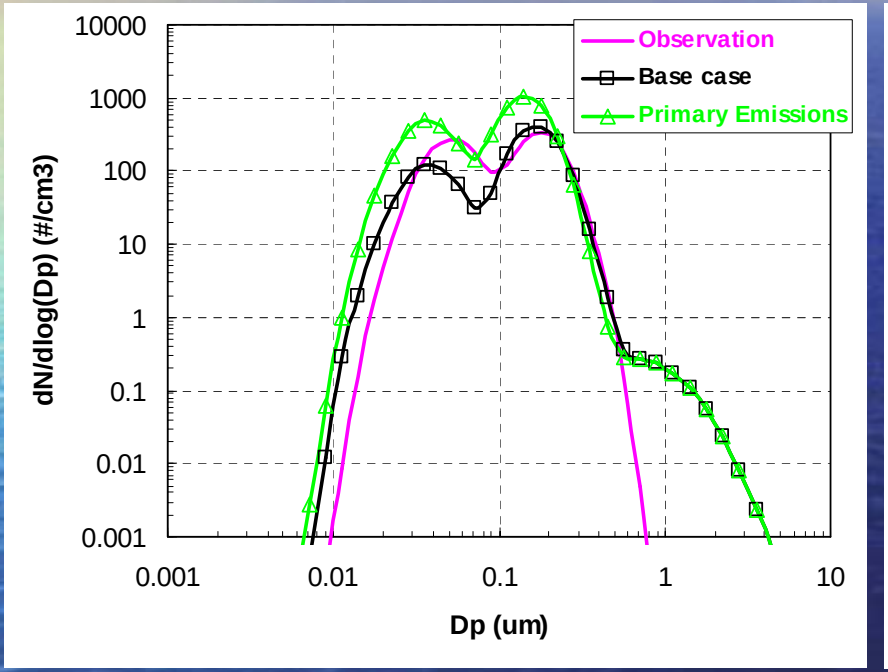


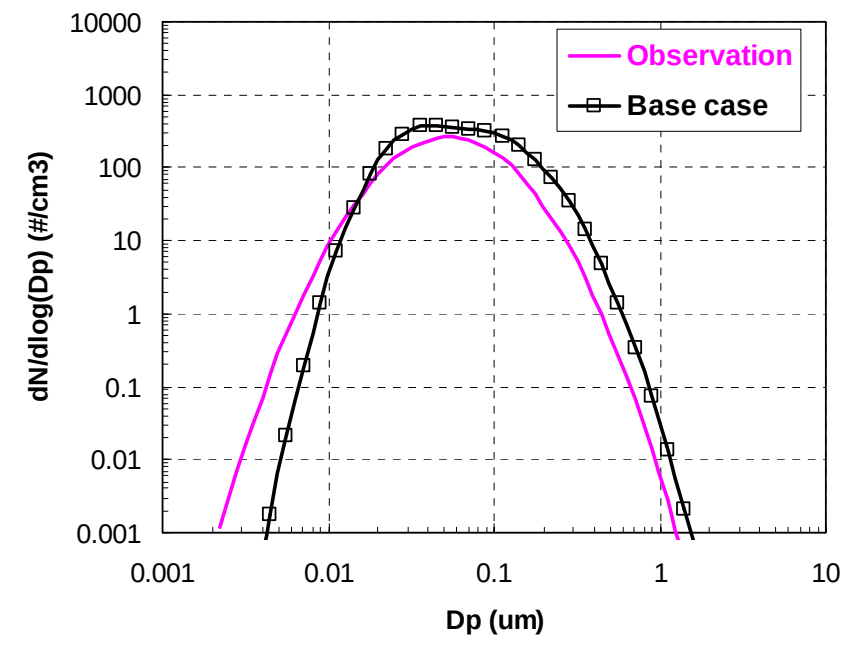
Aerosol Size Distribution: Remote N. Atlantic



Van Dingenen et al. (1995): September/October, 1992

Aerosol Size Distribution: N.E. Atlantic (Tenerife: 16.5W, 28N; July 1994)



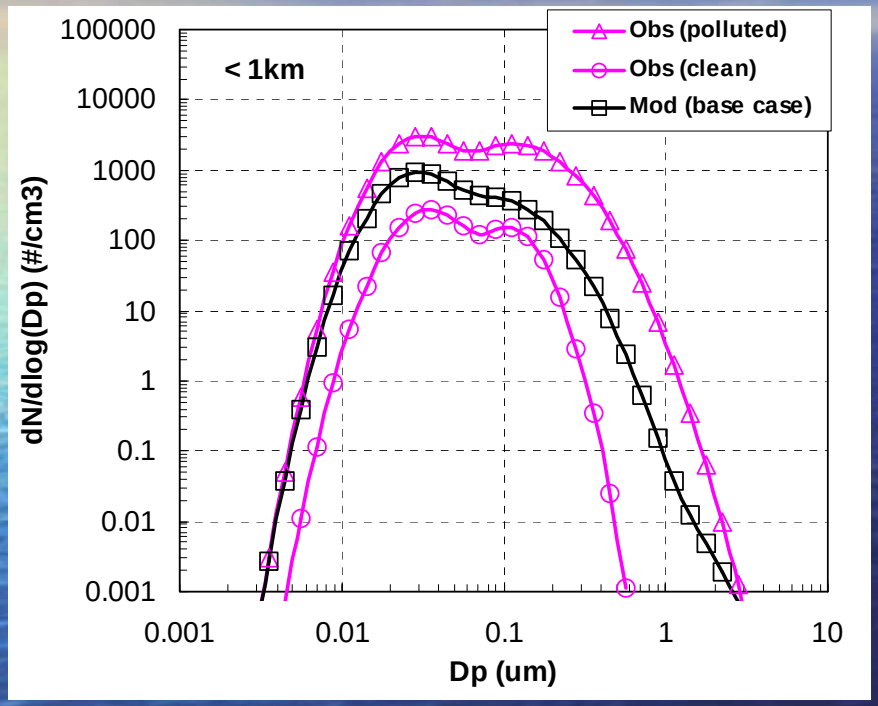


MBL

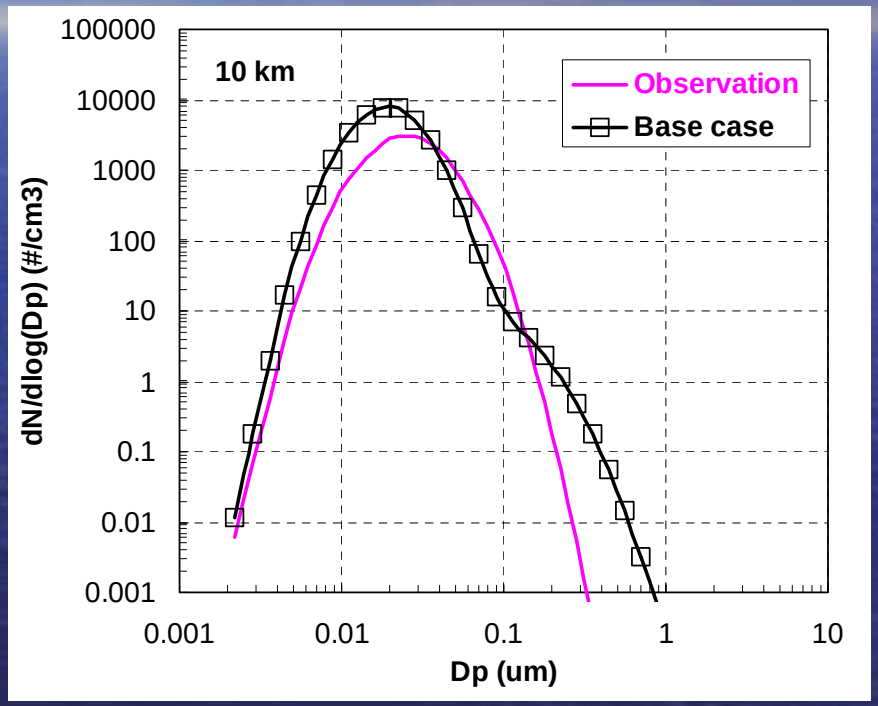
2.3 km

Raes et al. (1997)

Aerosol Size Distribution: southern Florida CRYSTAL-FACE, July 2002



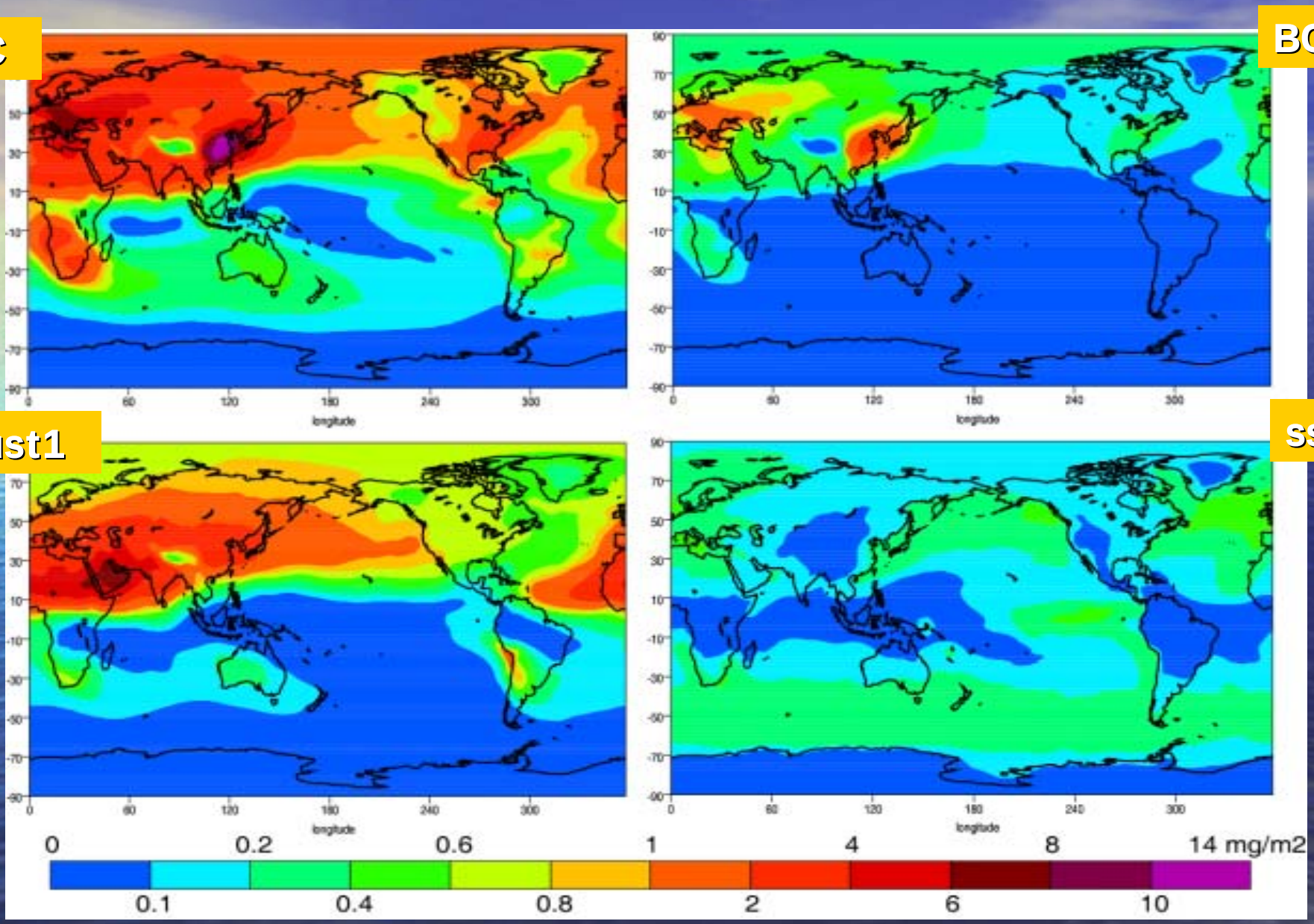
< 1 km



10 km

Fridlind et al. (2004)

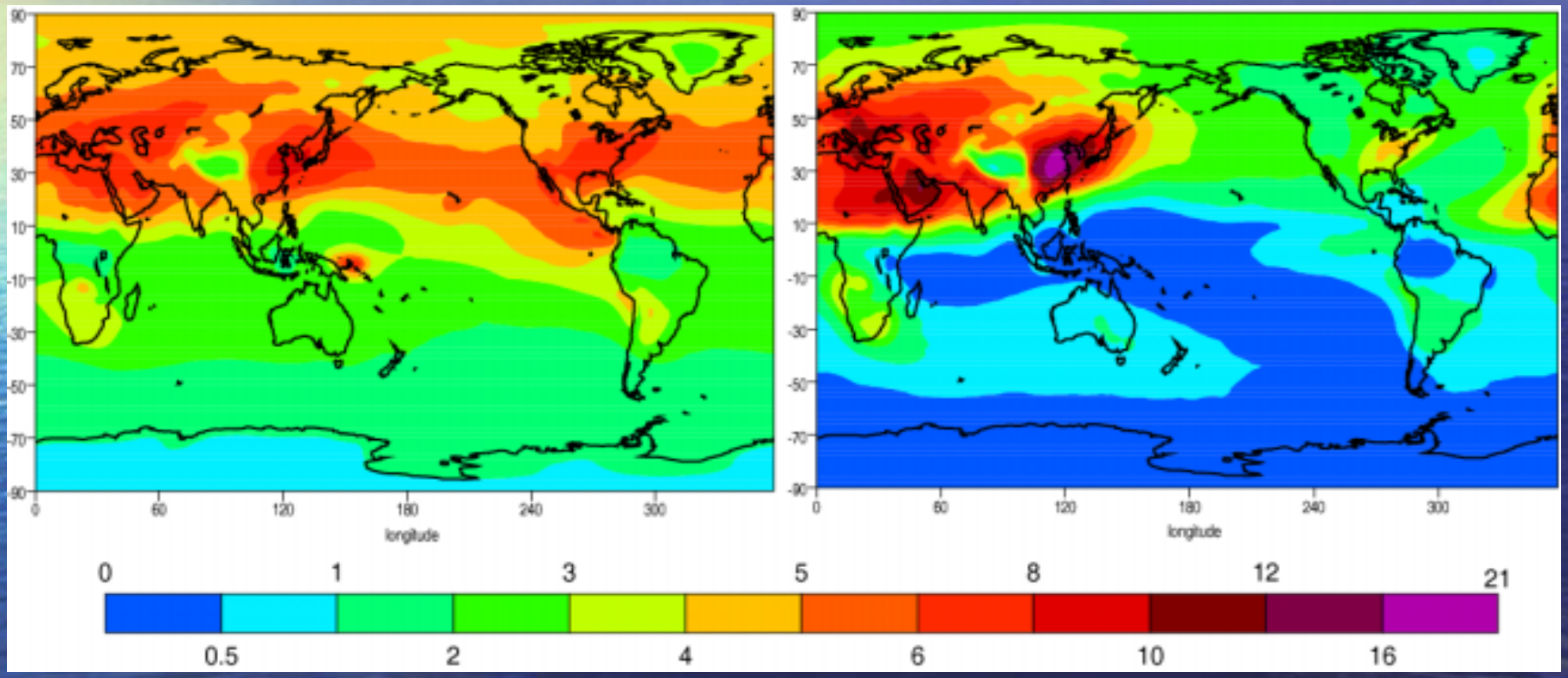
SO4 mass column burden on OC/BC/Dust1/SS1



SO4 mass column burden as pure sulfate versus on non-sulfate aerosols

pure SO4

On non-SO4 aerosols



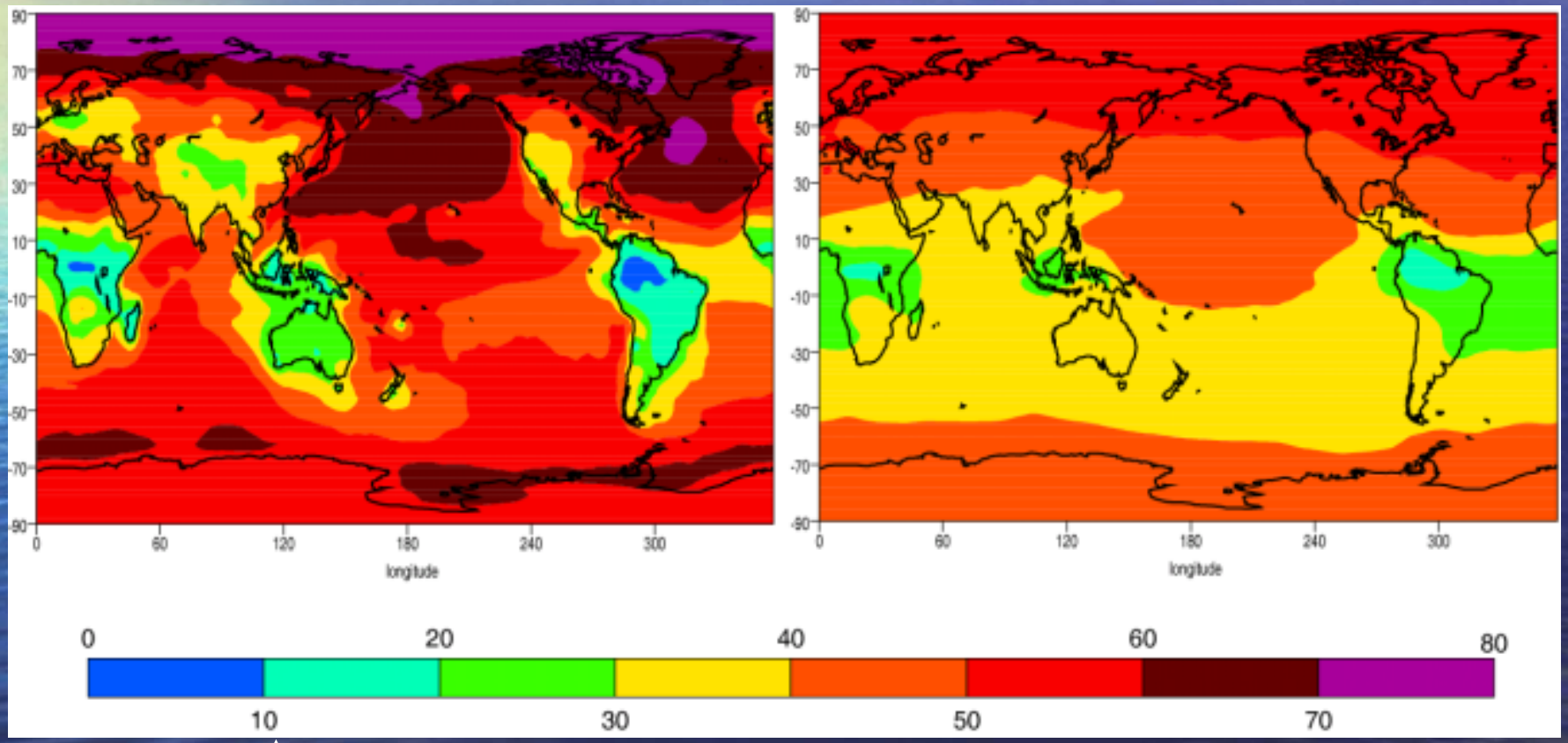
Nuclei: 9%, Accu.: 53%

OC: 18%, BC: 3%, dust: 14%, ss: 3%

Interactions between SO4 and BC/mineral dust

Mass fraction (%) of SO4 on BC

< 900 mb **470-220mb**

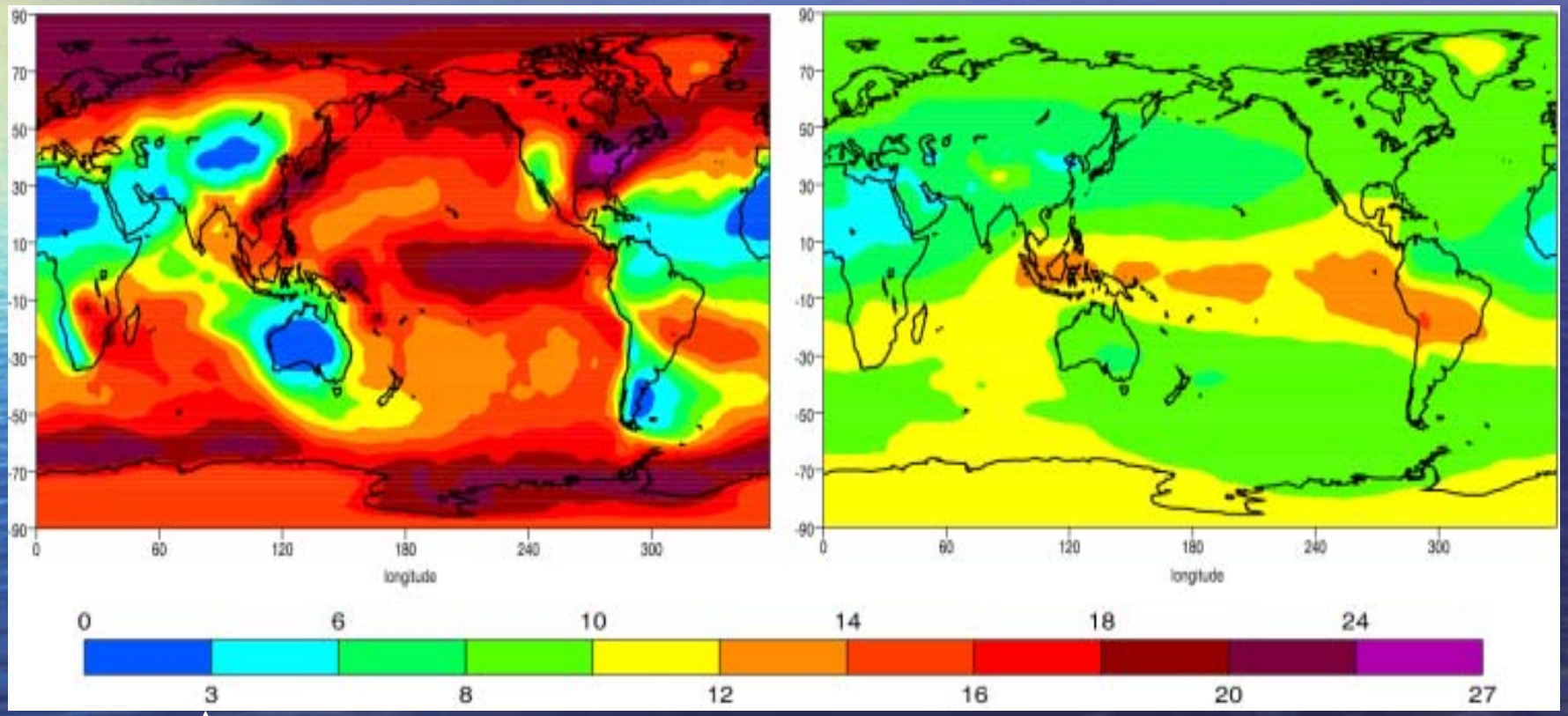


hydrophilic

Mass fraction (%) of SO4 on dust 1 (0.05-0.6 um)

< 900 mb

470-220 mb

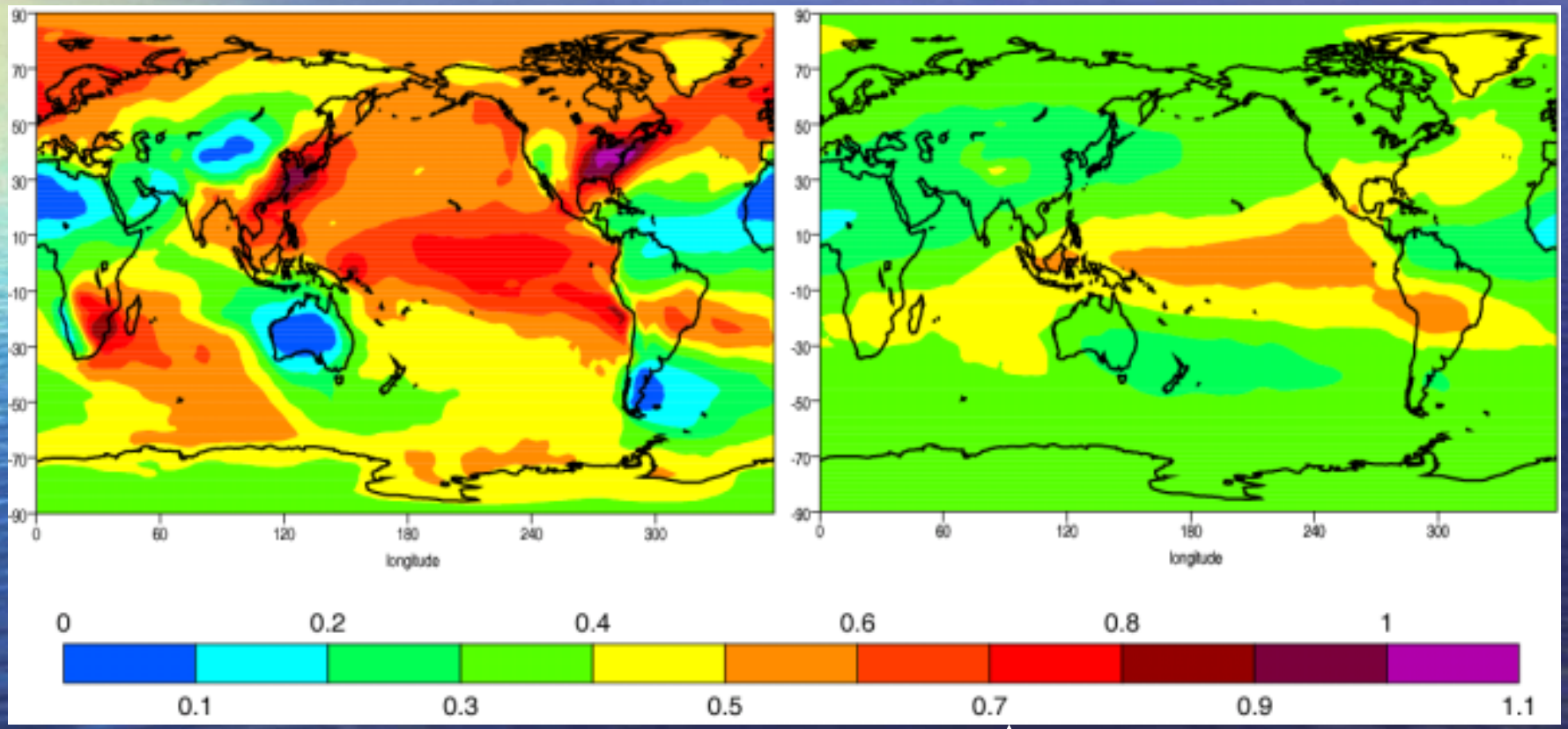


hydrophilic

Mass fraction (%) of SO4 on dust 2 (0.6-1.2 um)

< 900 mb

470-220 mb



hydrophilic

- Impact of interactions on SO4/BC/dust

<u>Comparison to another IMAPCT model run</u>

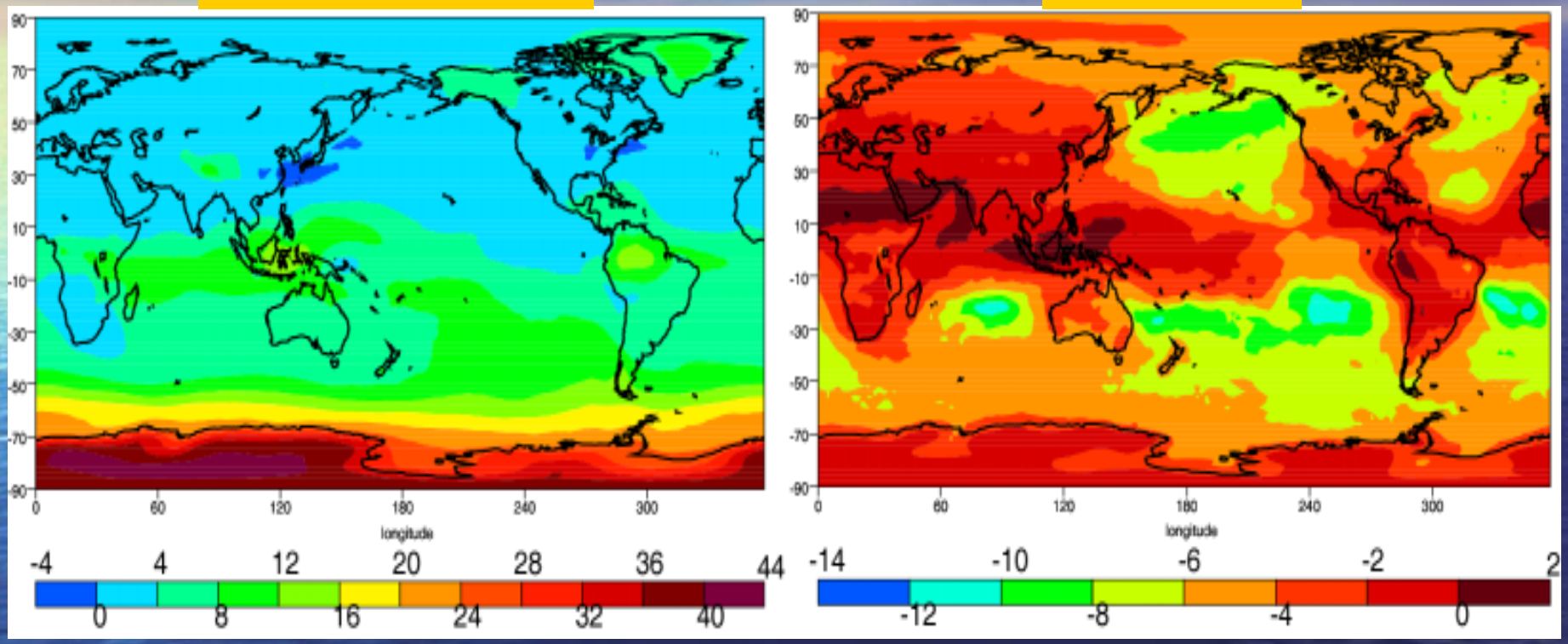
- with same meteorology & emission sources
- predicted only SO4 mass (no aerosol nucleation)
- no interactions between SO4 and non-so4 aerosols
- cloud scavenging efficiency for BC=0.4, for dust=1.0
- relative difference RD (%):

$$RD = \frac{RUN_{\text{int}} - RUN_{no-\text{int}}}{RUN_{no-\text{int}}} \times 100$$

RD (%) of SO4 column burden and SO4 concentration below 900 mb

column burden

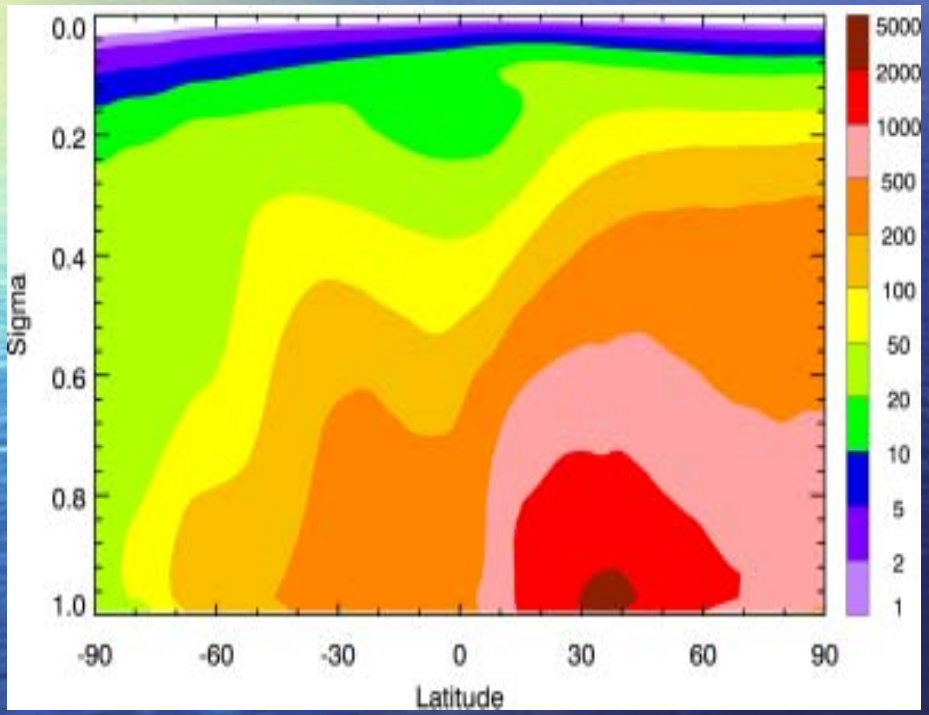
< 900 mb



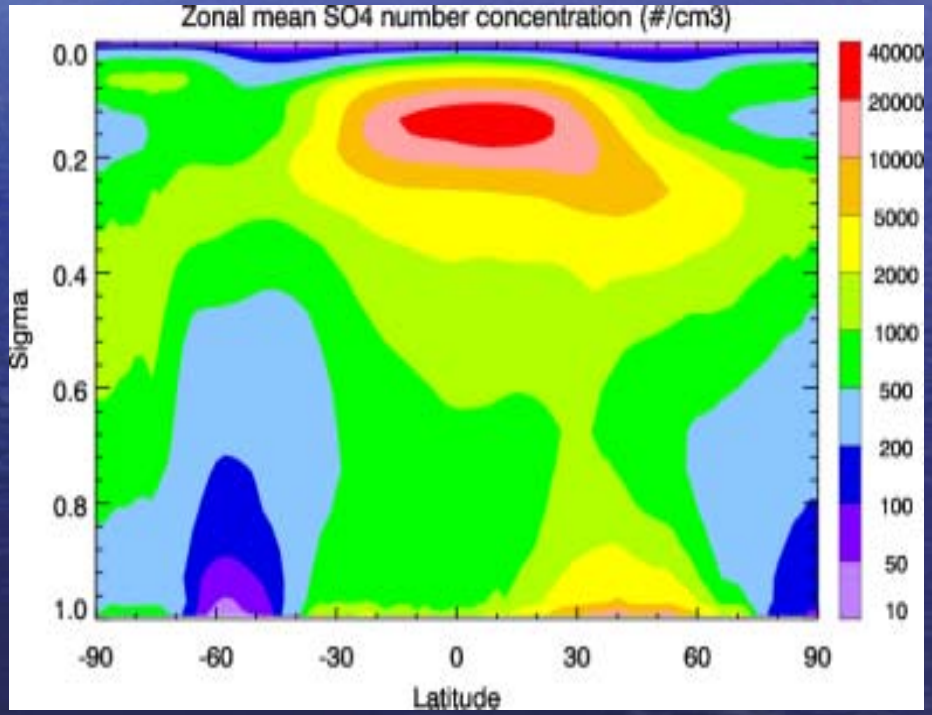
Total SO4 burden increases 3%

How SO4 aerosol number change with new aerosol module?

Old

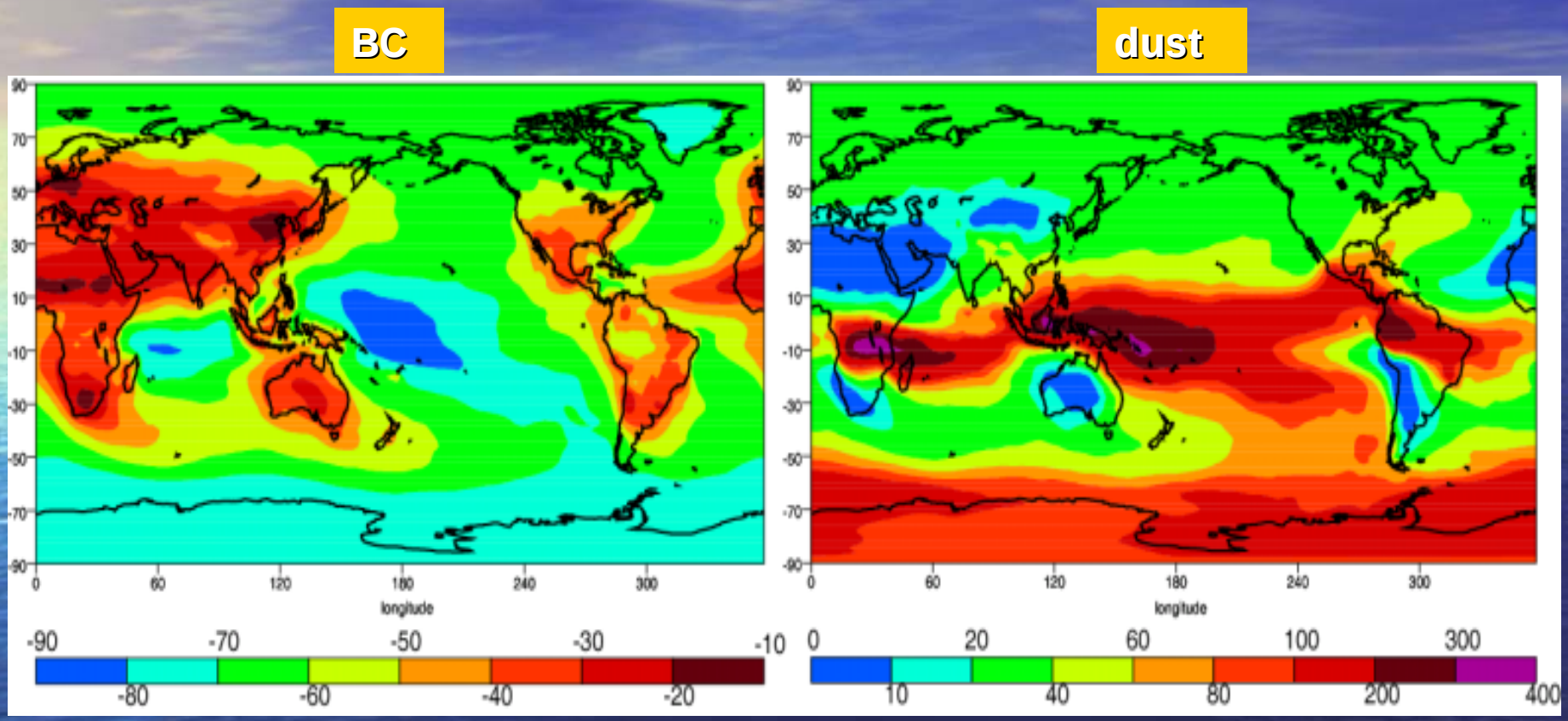


New



Zonal mean pure sulfate concentration (#/cm^3)

RD (%) of BC and dust column burden



Total BC burden reduces

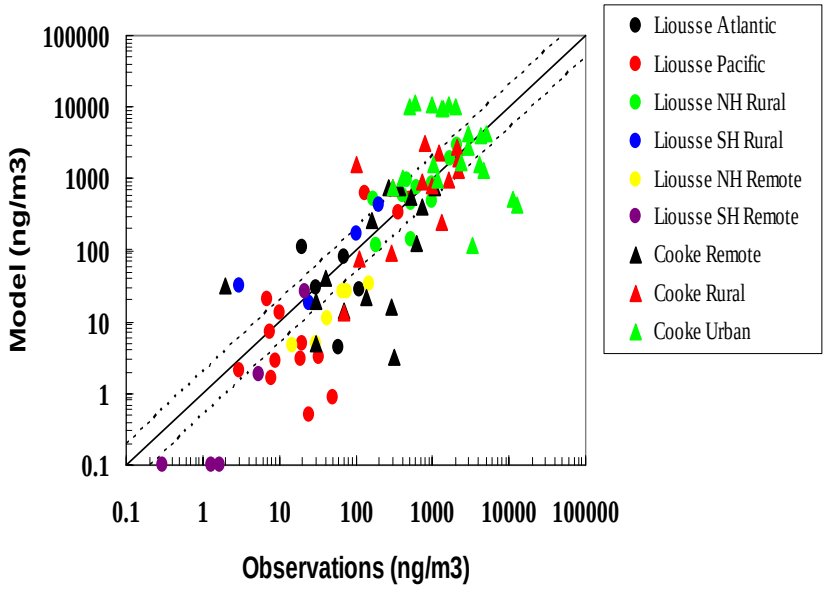
30~40%

Total dust burden increases

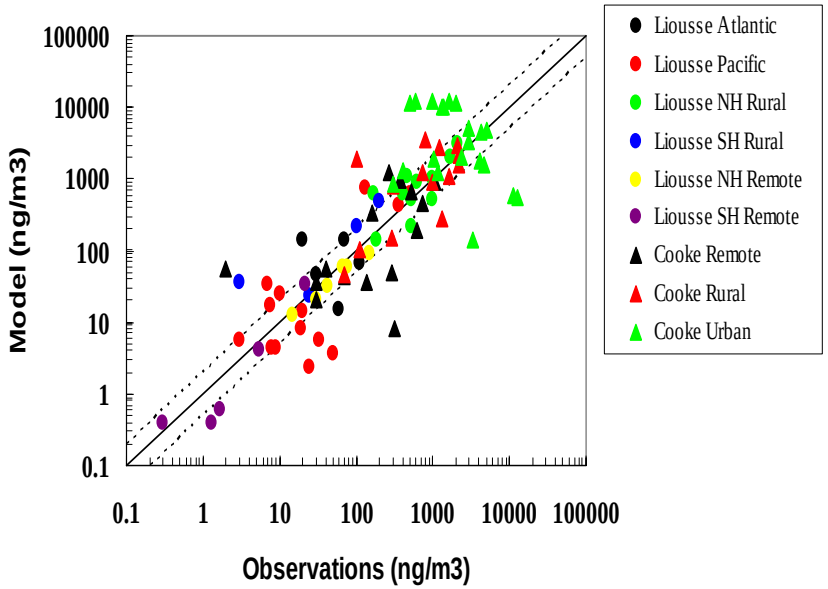
~12%

Comparison of modeled BC with observations at surface

with interactions



without interactions



Average bias: 0.39 ug/m3

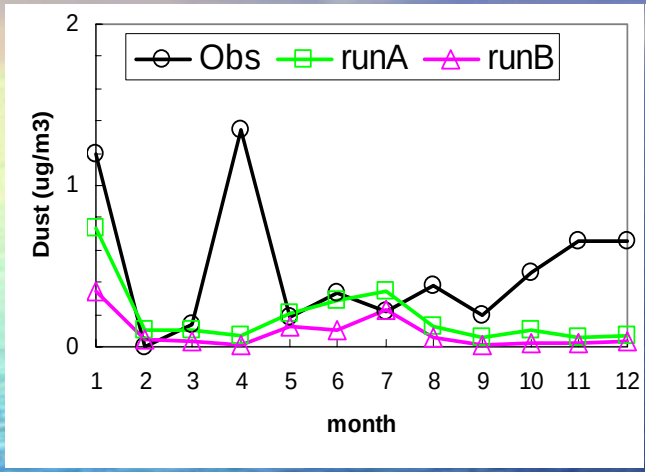
Relative bias: 113 %

Average bias: 0.55 ug/m3

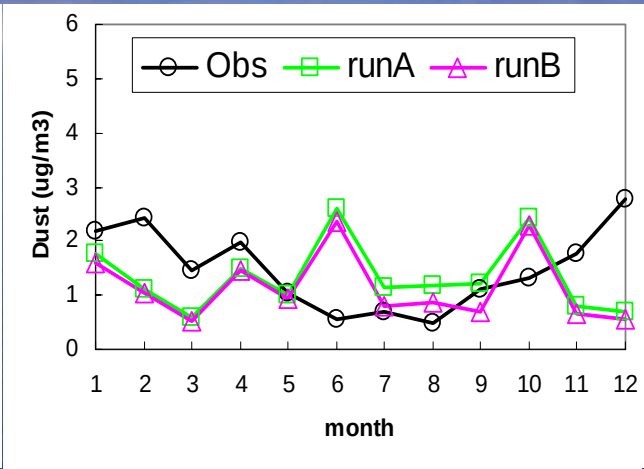
Relative bias: 167 %

Comparison of modeled dust with observations at surface

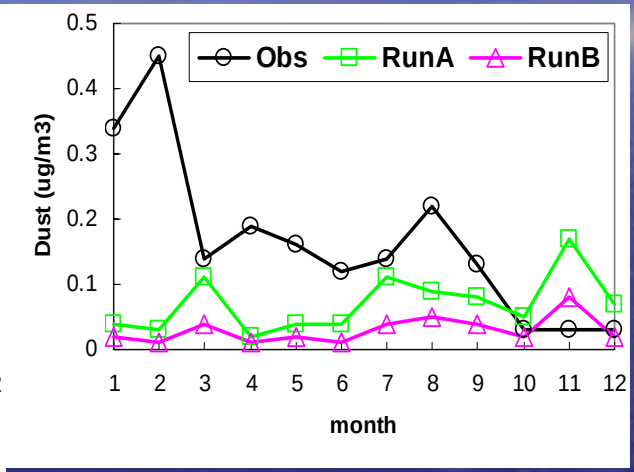
MARSH-KING GEORGE ISLAND
(62.2S,58.3W)



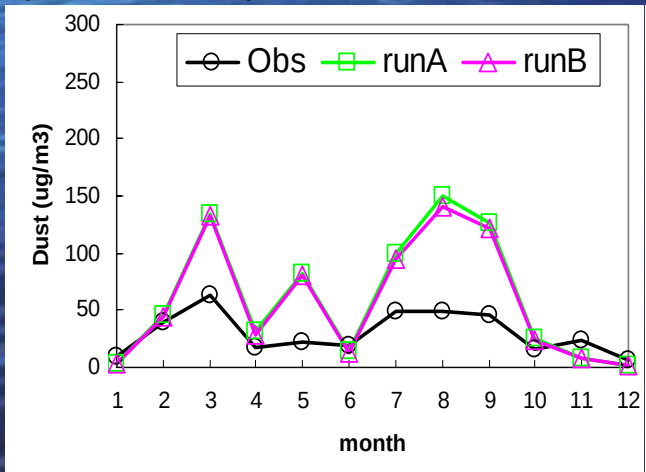
CAPE GRIM - TASMANIA
(40.7S,144.7E)



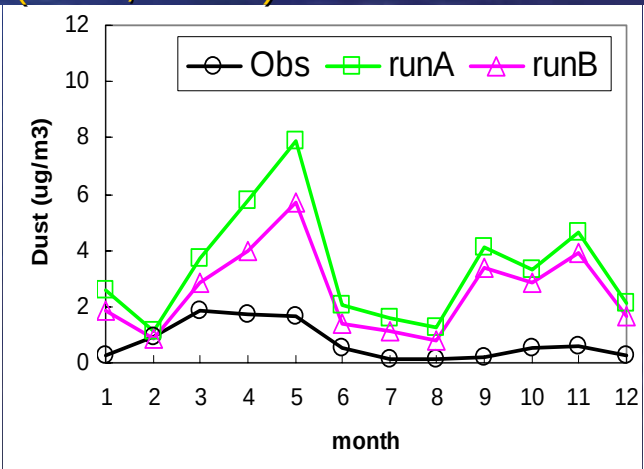
AMERICAN SAMOA
(14.3S,170.6W)



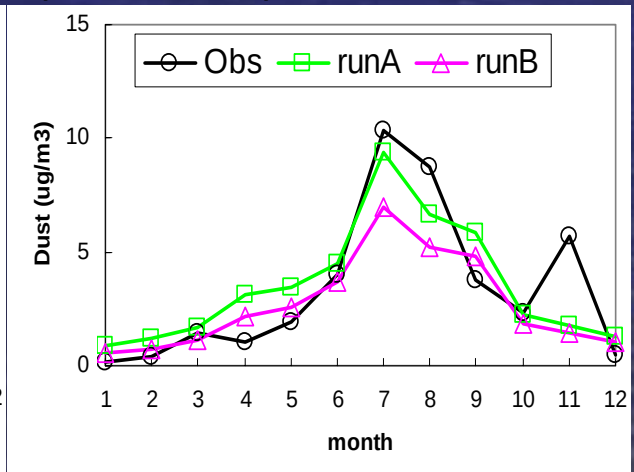
IZAÑA TENERIFE
(28.3N,16.5W)



MIDWAY ISLAND
(28.2N,177.4W)



BERMUDA WEST & EAST
(32.3N,64.9W)

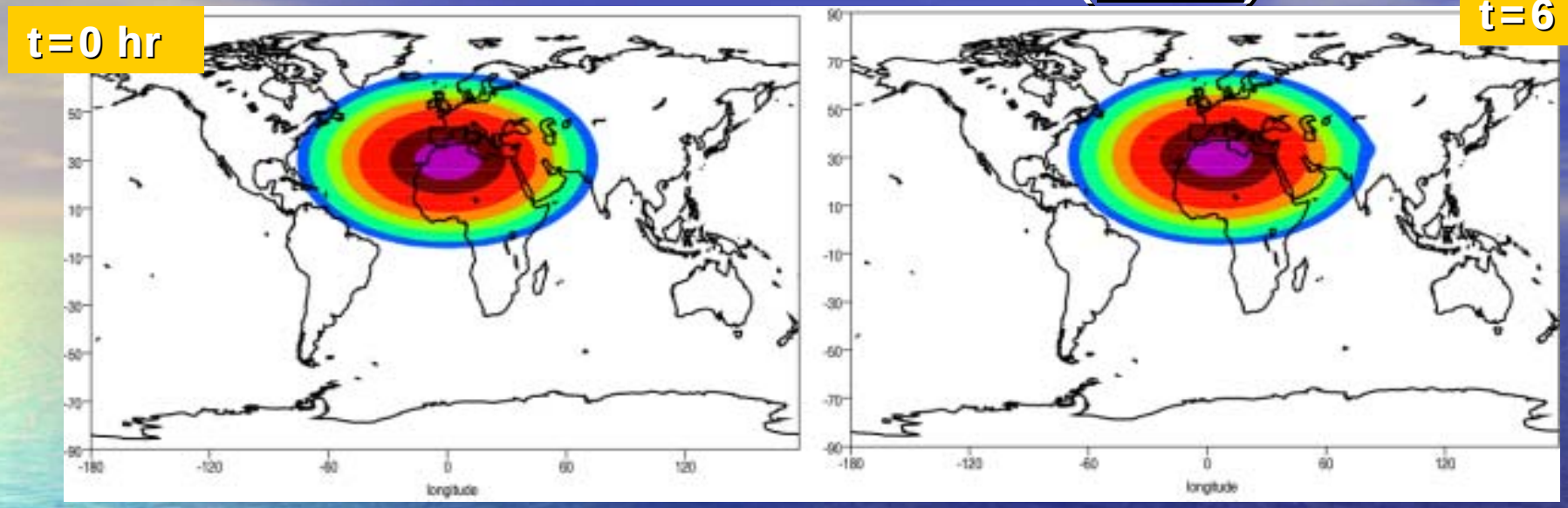


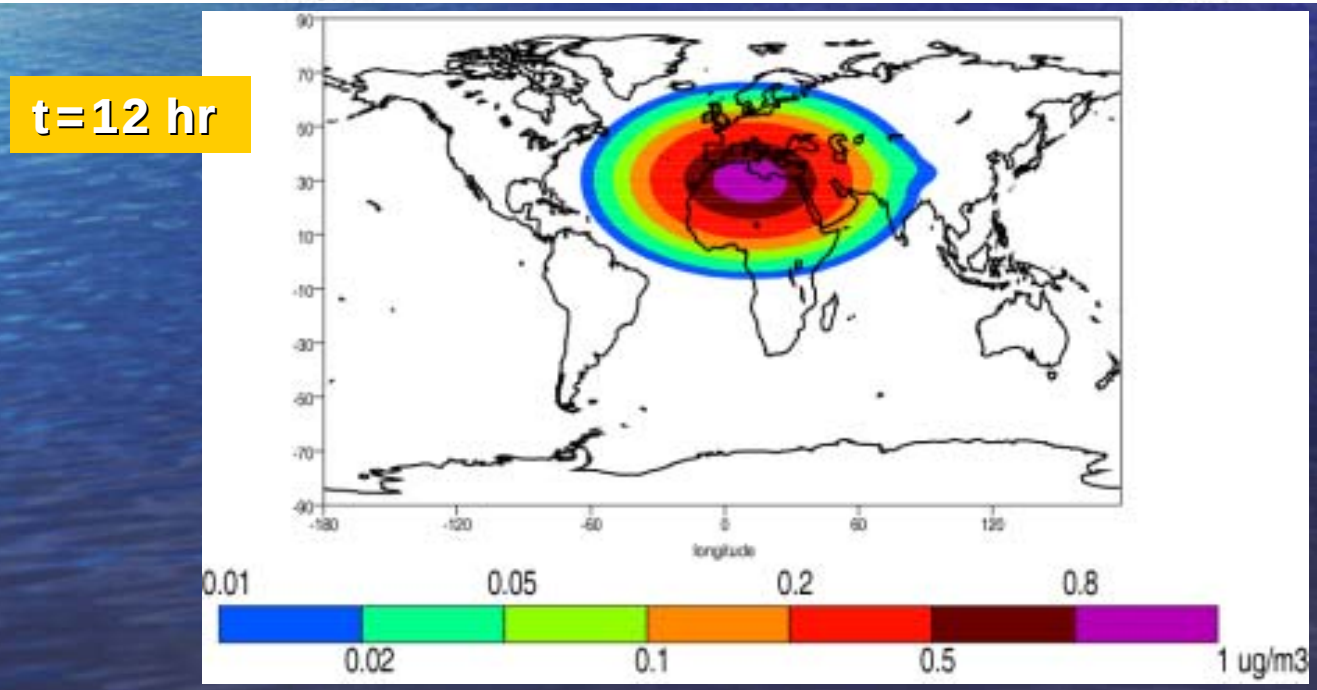
5. Conclusions

- Large amount of SO4 on non-sulfate aerosol. In small sizes of dust (submicron);

- Interactions between BC/dust with SO4 important to SO4/BC/dust burden and concentrations.

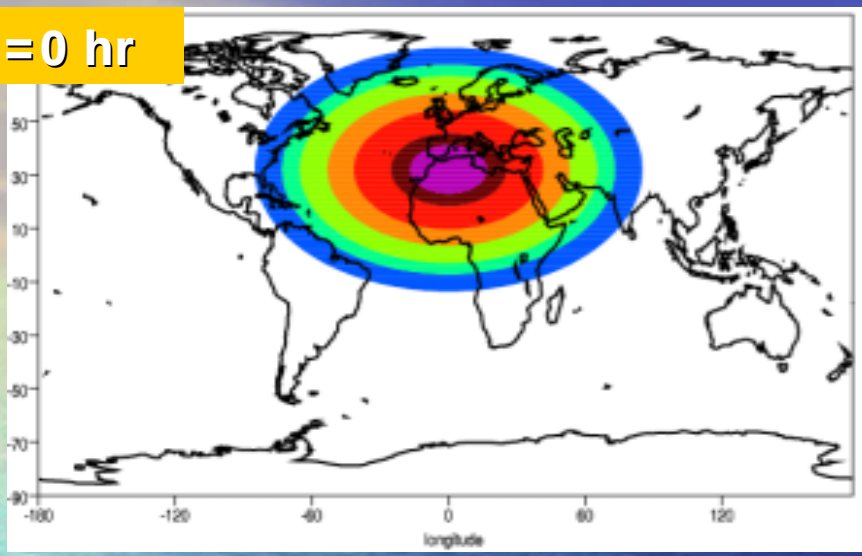
Mass and number conservation test (mass)



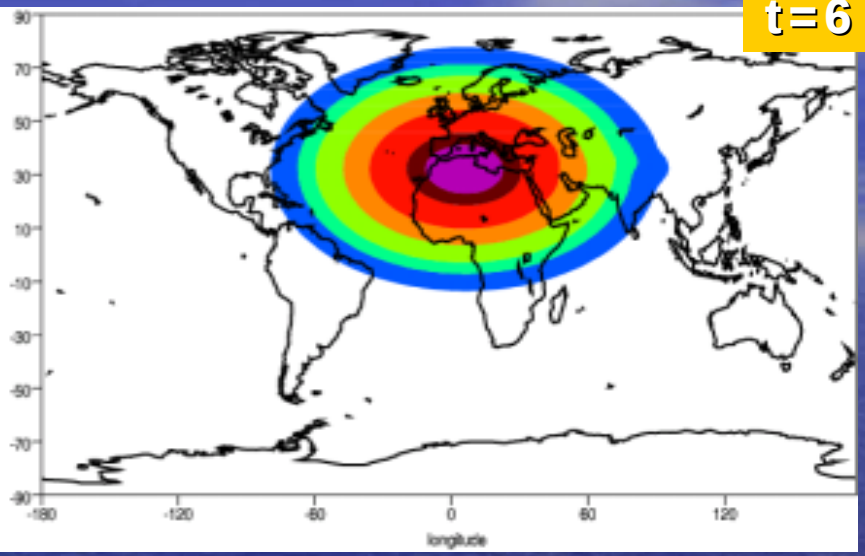


Mass and number conservation test (number)

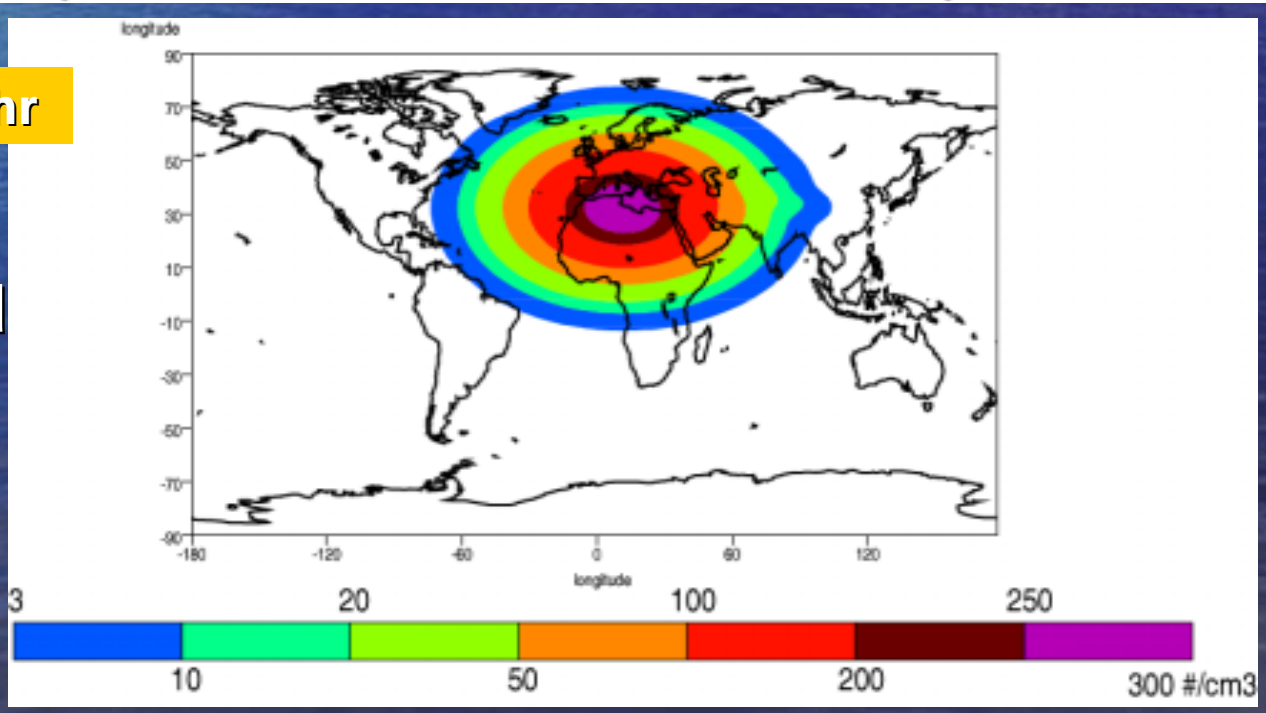
t=0 hr



t=6 hr



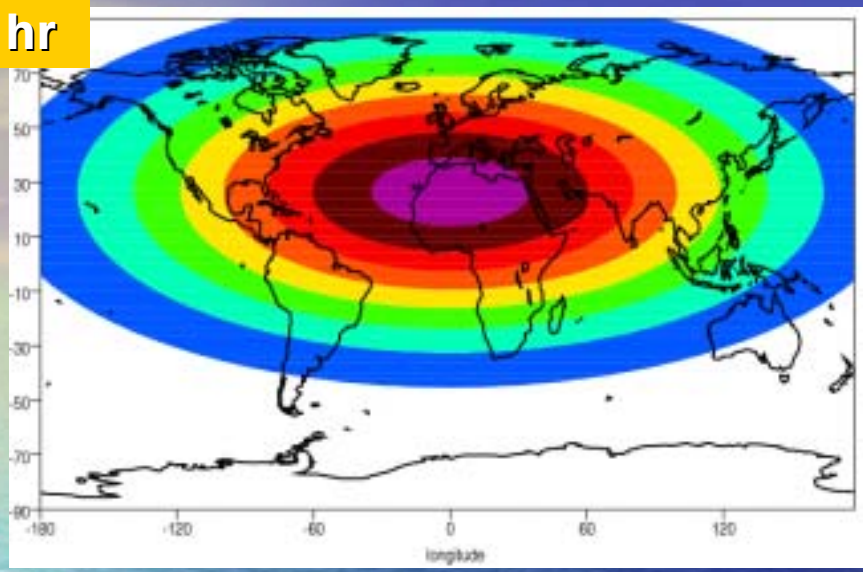
t=12 hr



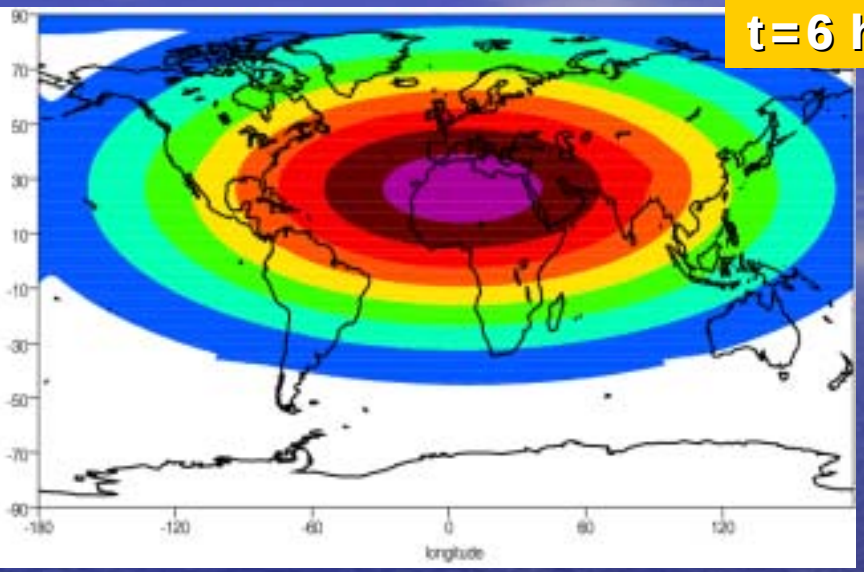
With idealized u=30 m/s

Mass and number conservation test (radius)

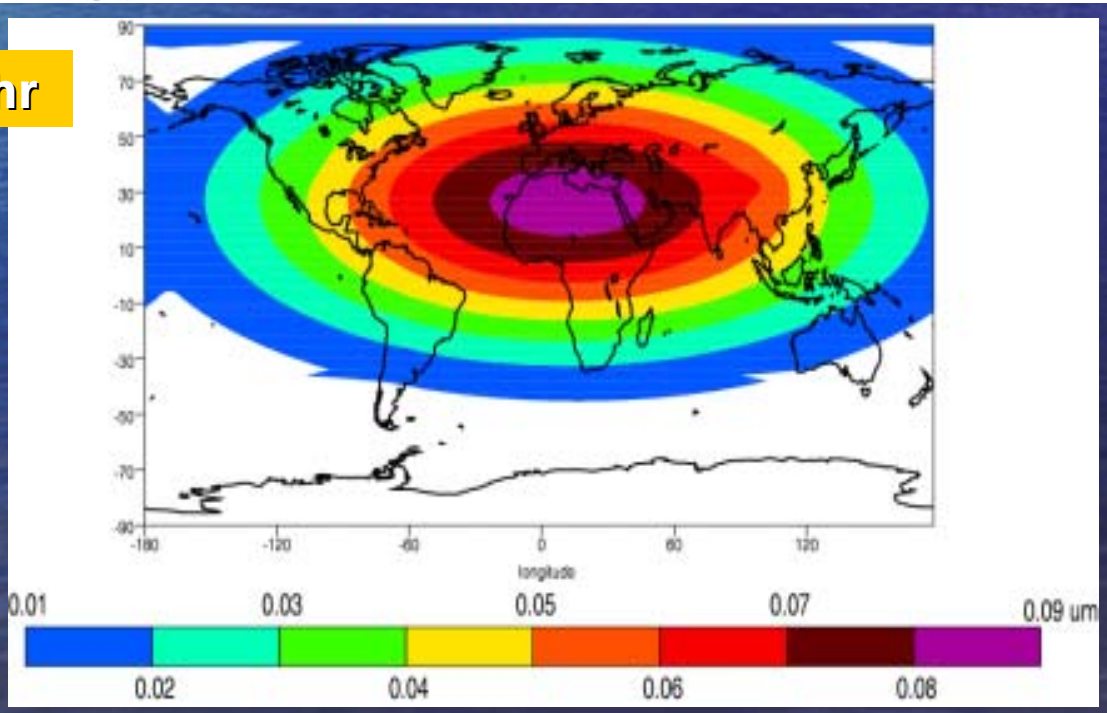
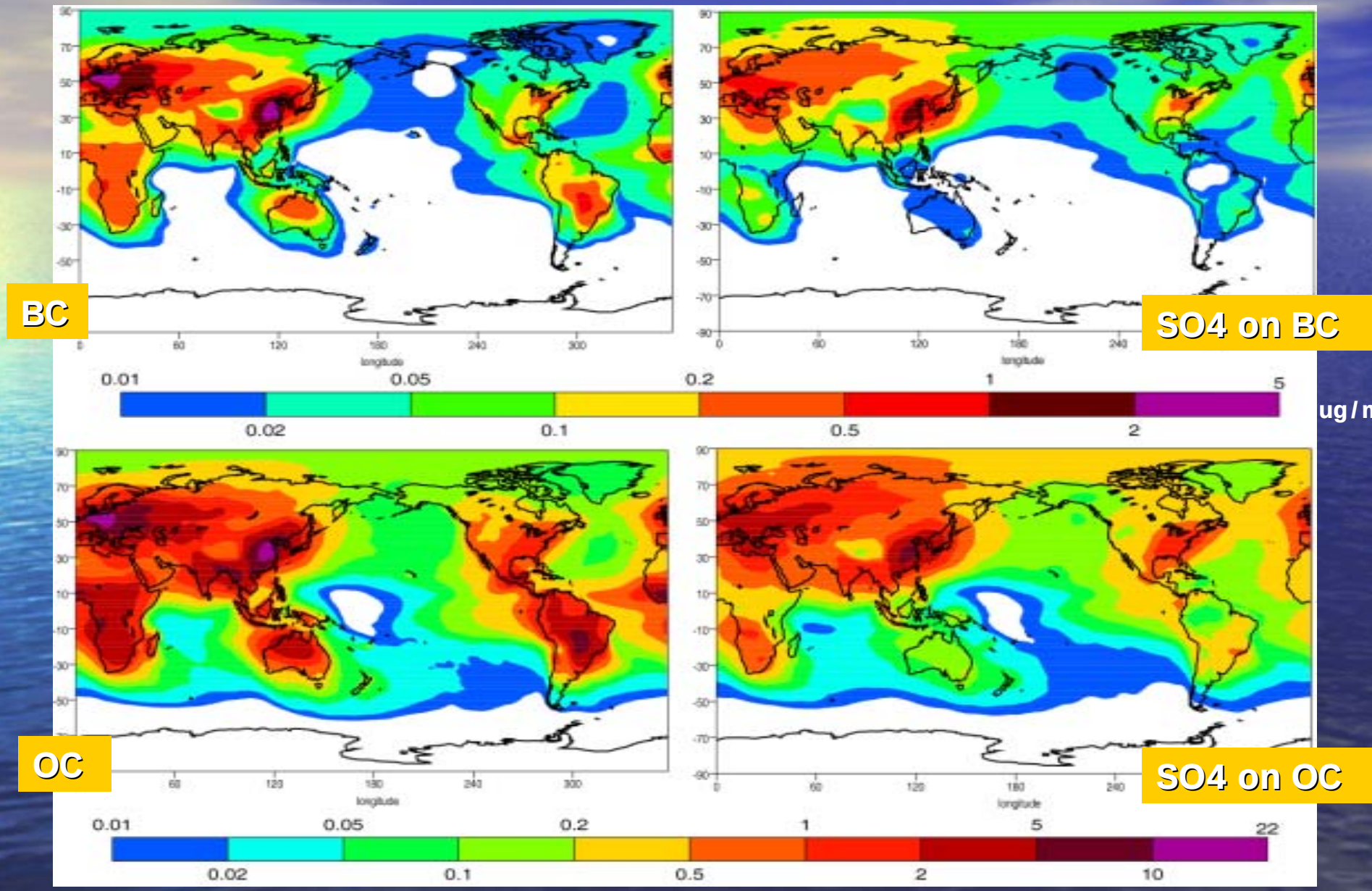
t=0 hr



t=6 hr



t=12 hr



SO4 on OC/BC versus OC/BC below 900 mb