# Today's Outline

- Day 2 - Tuesday 14/02 **Chemistry/Aerosols**

Morning

- Keynote: Y. Balkanski, *Aerosols and Climate*
- *Student discussions*

Atfternoon

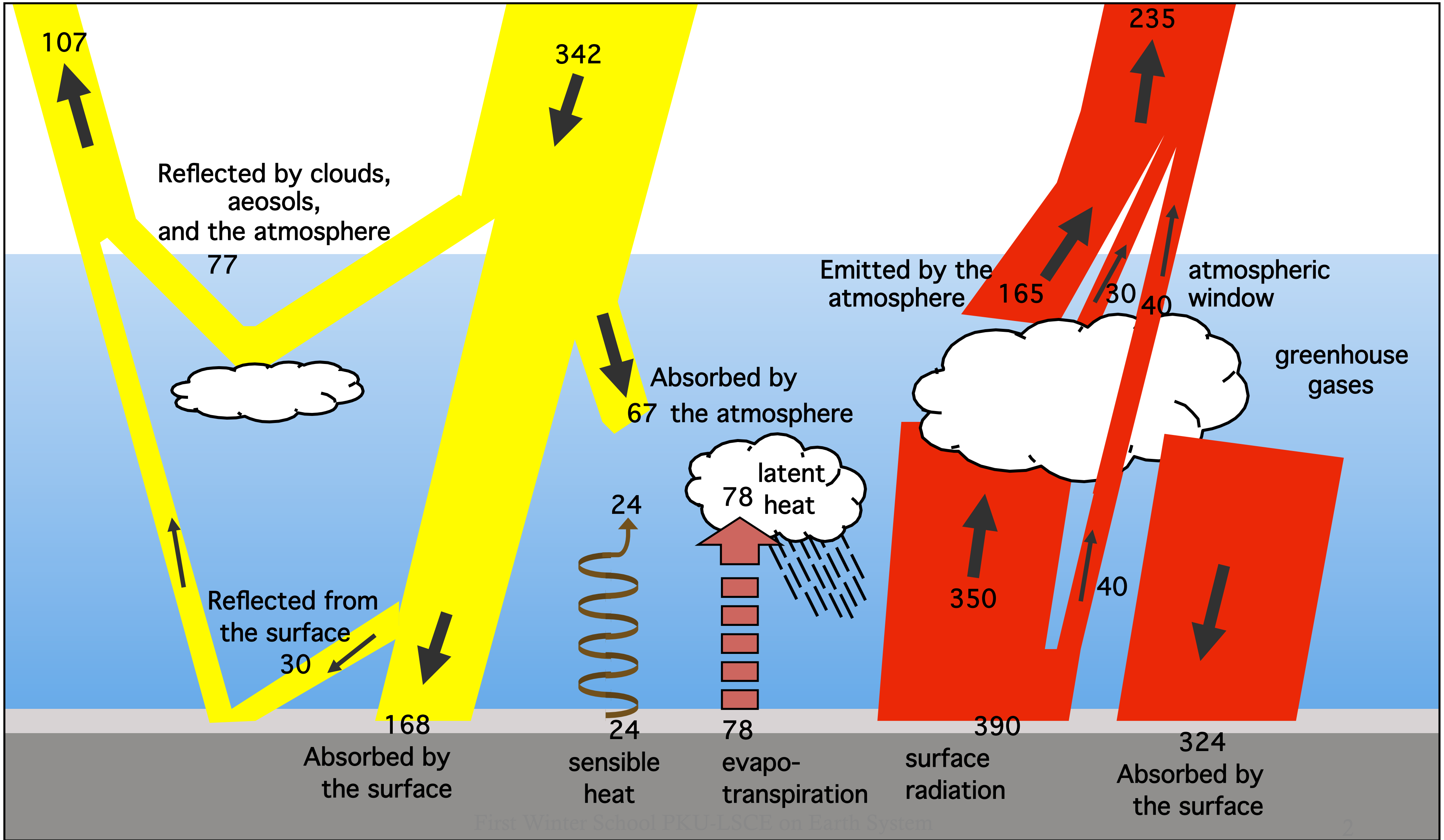
- Course 1: P. Ciais: *Atmospheric Chemistry and the Carbon Cycle*
- Course 2: J. Liu, *Photochemistry Smog and Secondary Aerosol Formation*
- Course 3: F. M. Bréon: *Aerosol and Cloud remote sensing from space*
- Course 4: P. Bousquet*: Interactions between atmospheric chemistry and Climate*

# Radiation budget

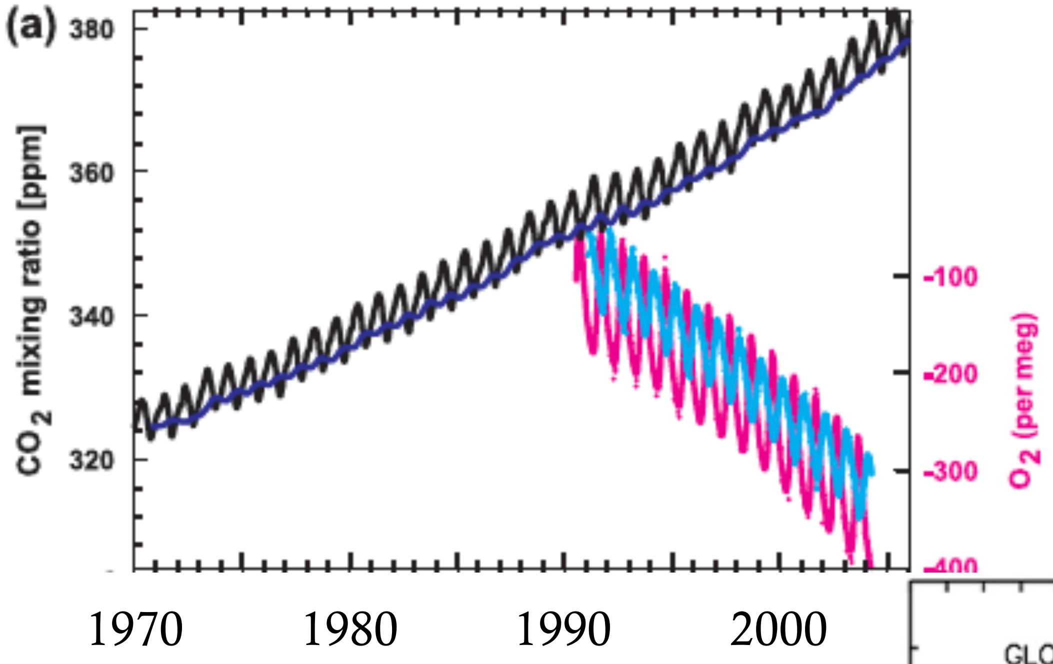
Reflected Solar radiation : 107 W/m²

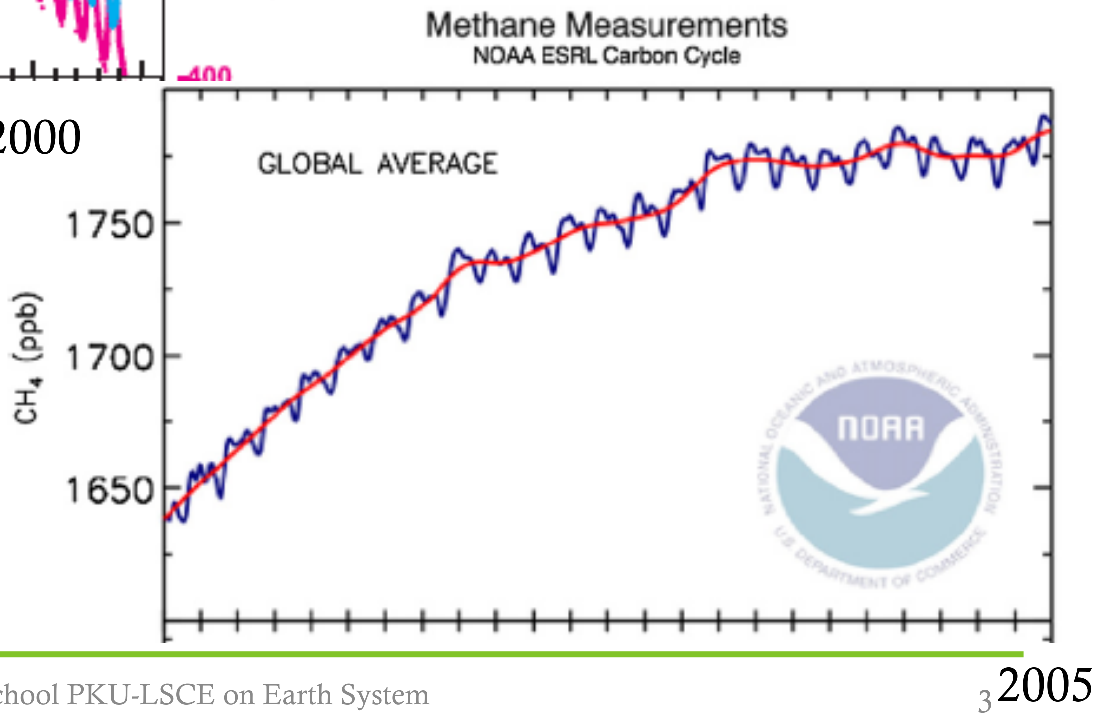
Incident solar radiation : 342 W/m²

Outgoing infrared radiation : 235 W/m²

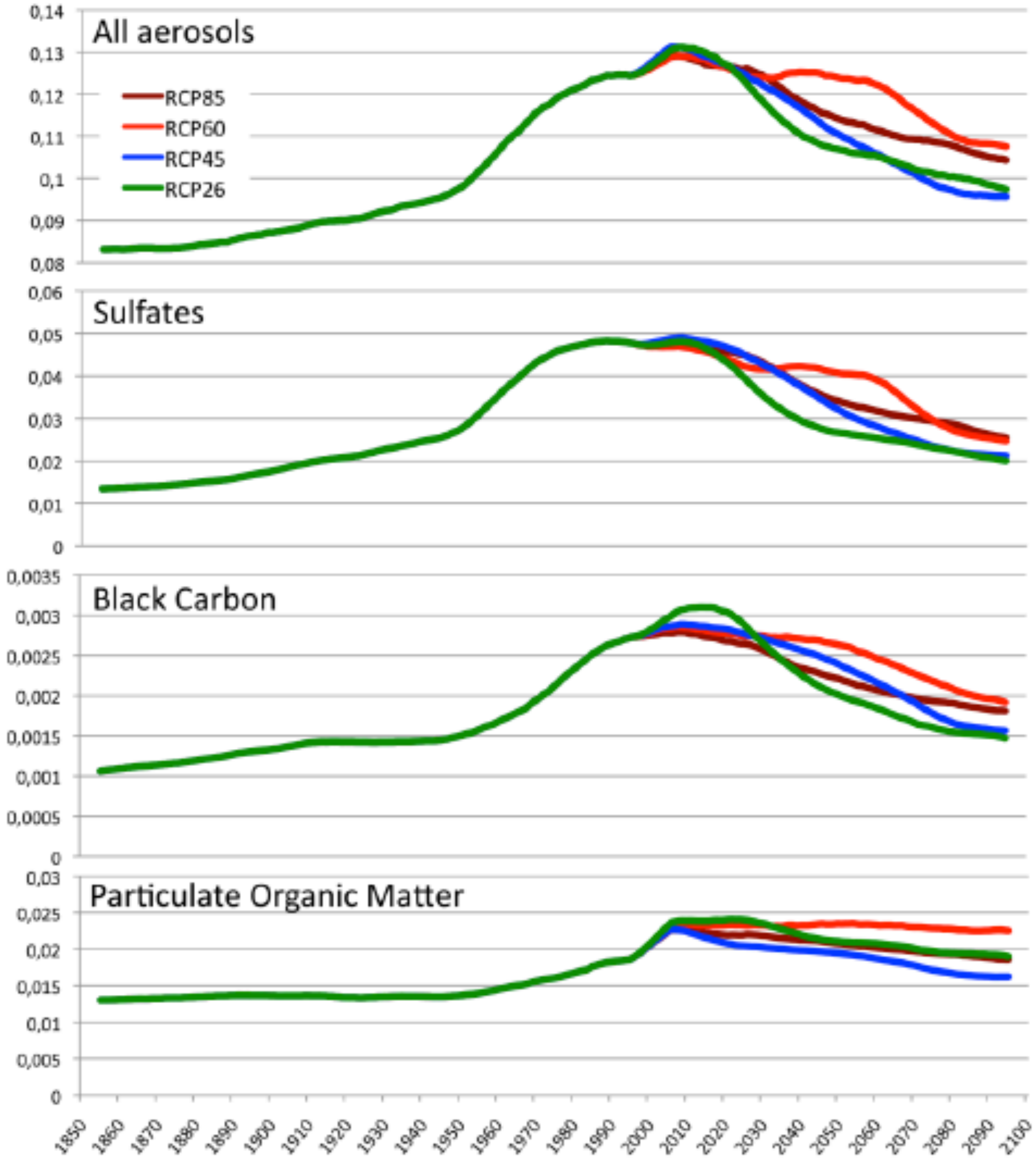


# Greenhouse gases increase in the last 35 years



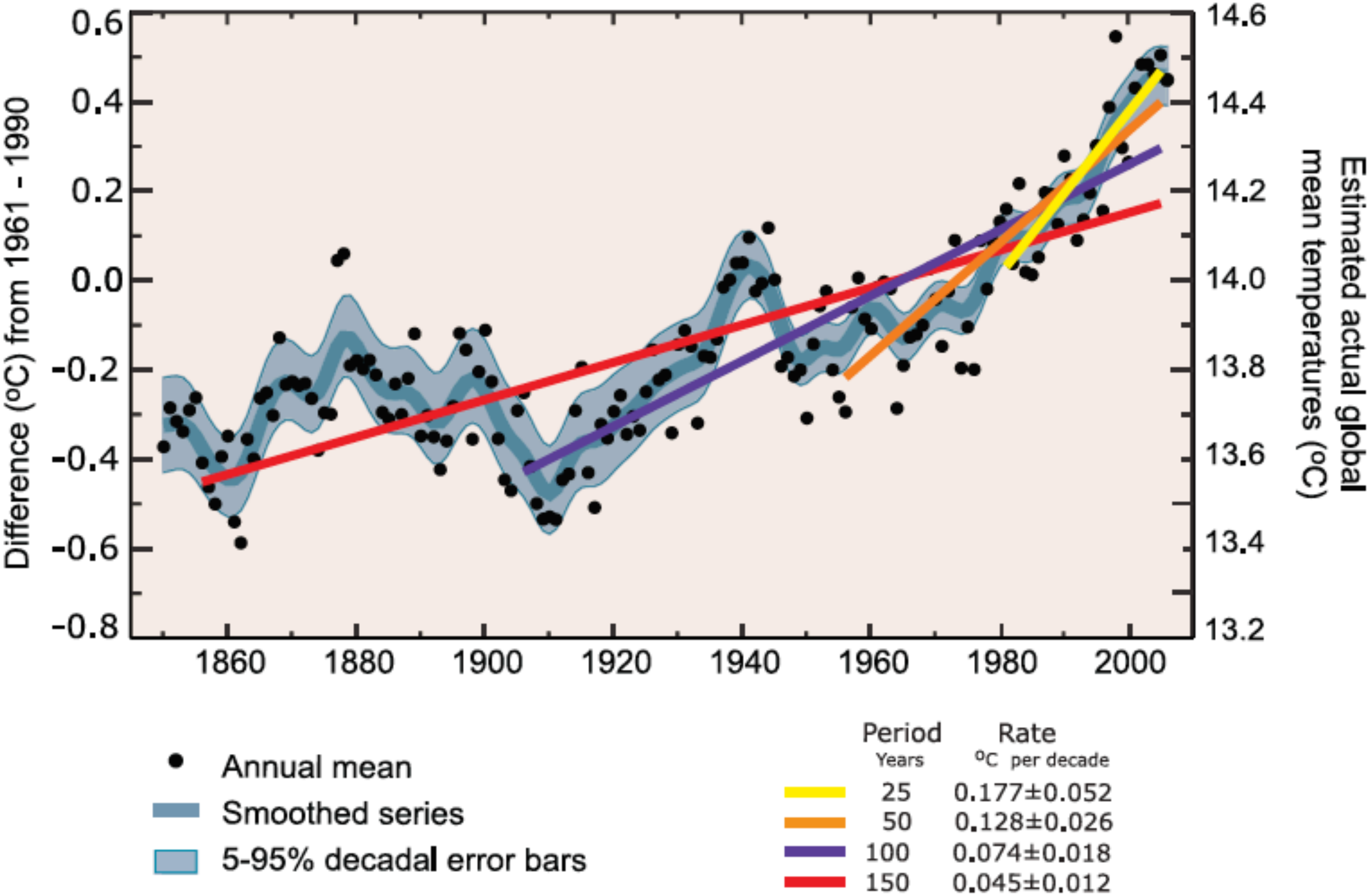



# Simulated increase of aerosol optical depth (1850-2100)

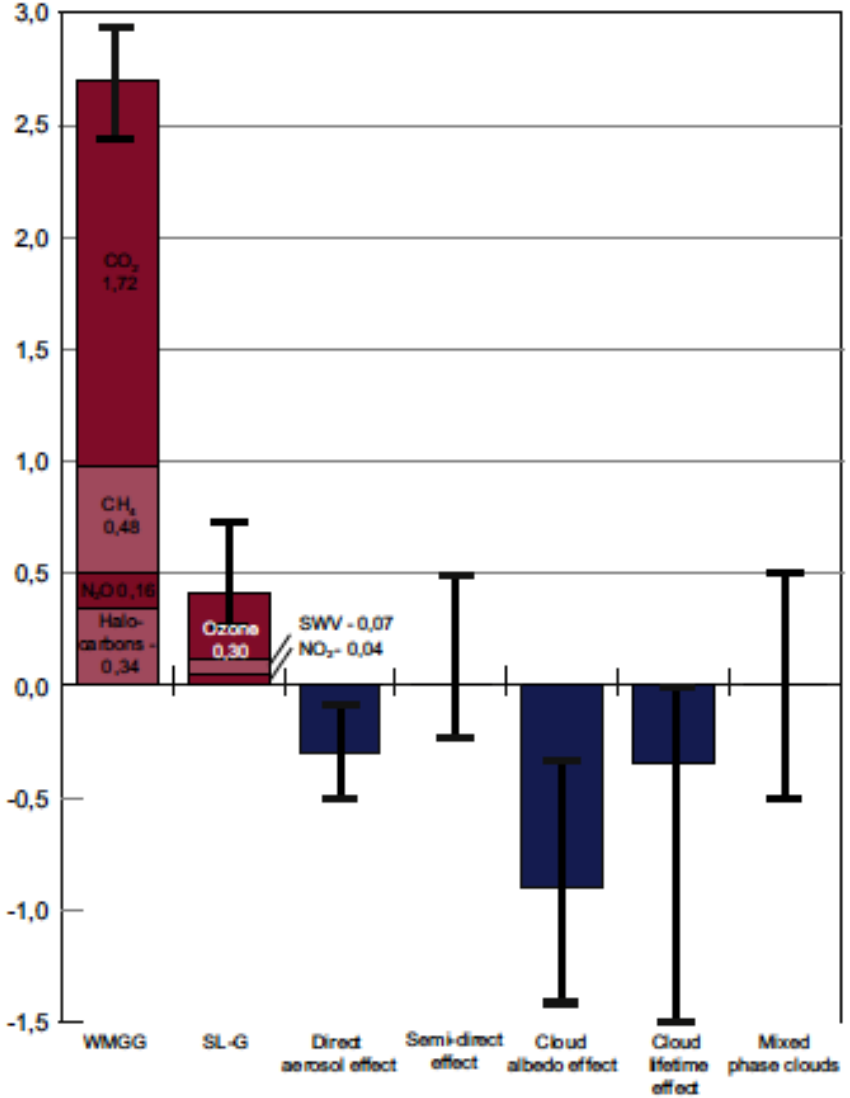



*Szopa et al., (2012)*

# Observed temperature change from 1850

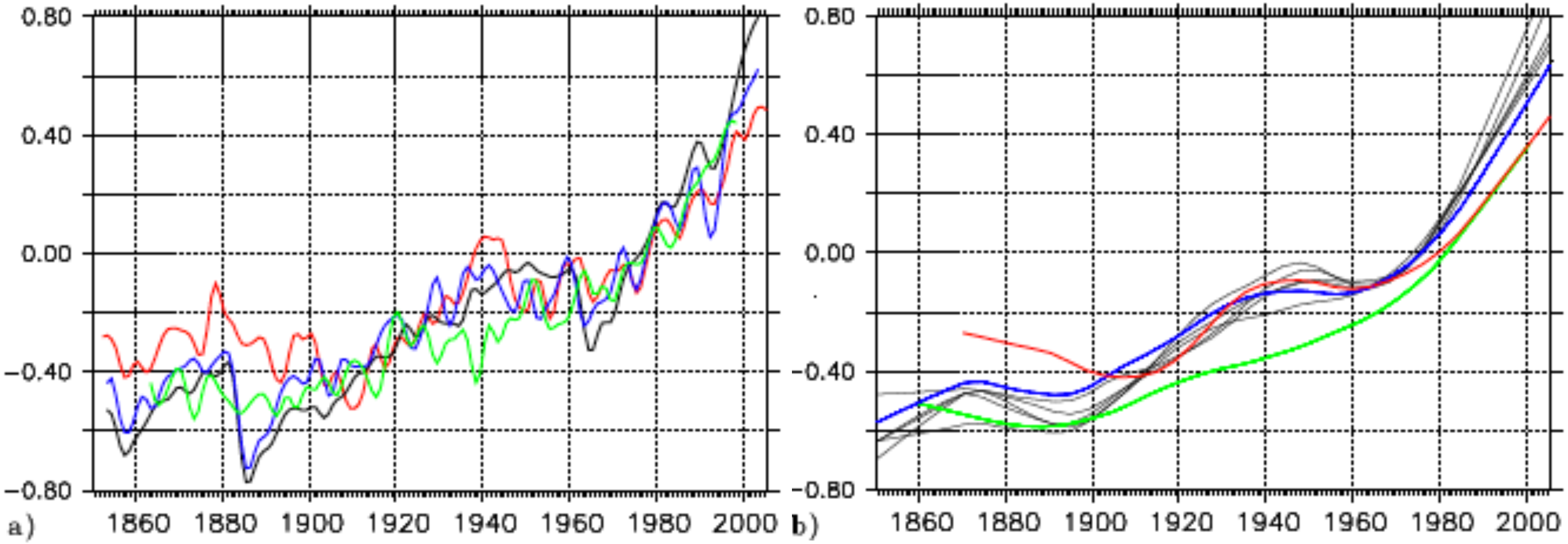


# Different climate forcings



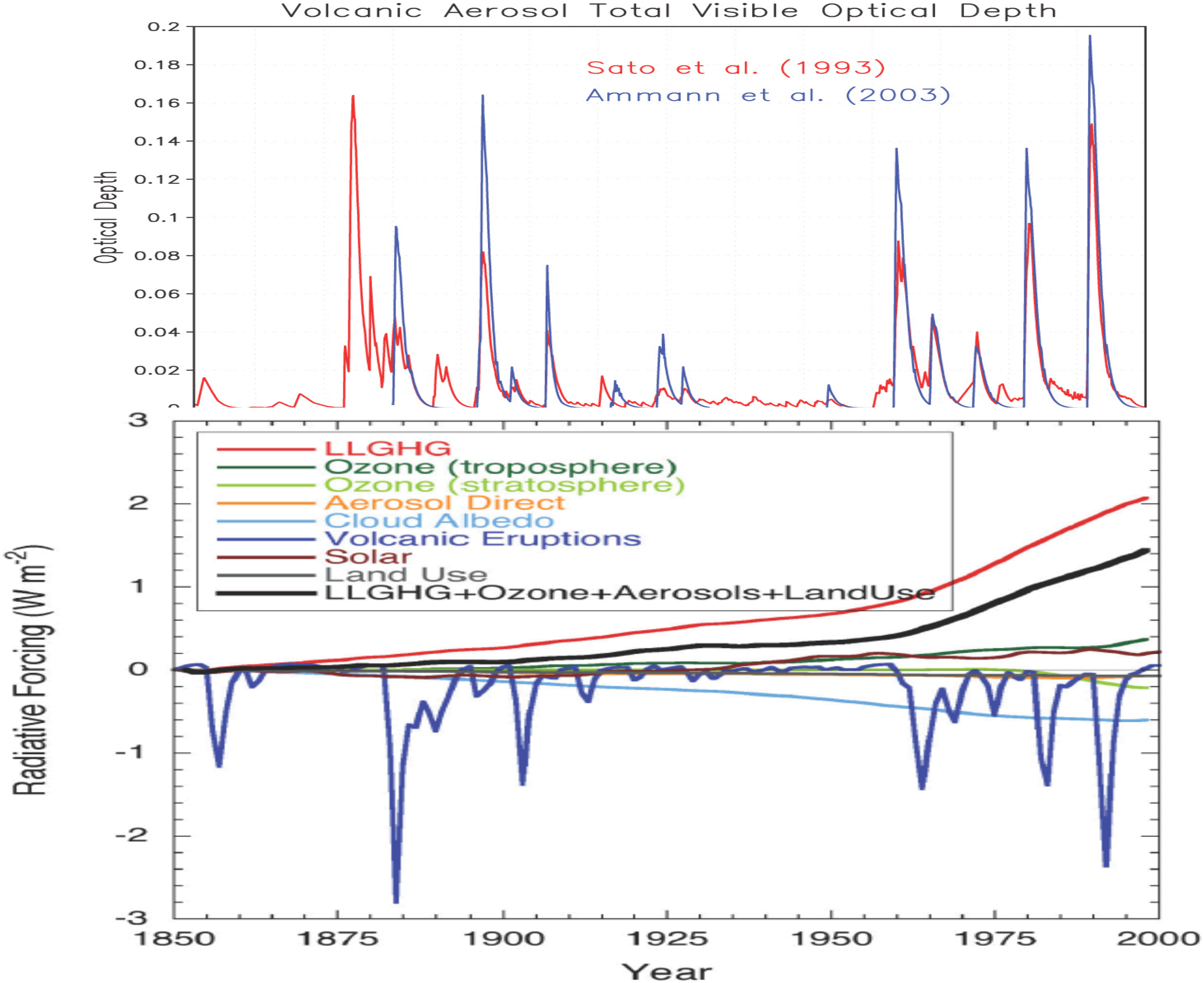
# Comparison of observed and simulated temp. changes relative to the 1961-1990 period

*Dufresne et al., 2012*

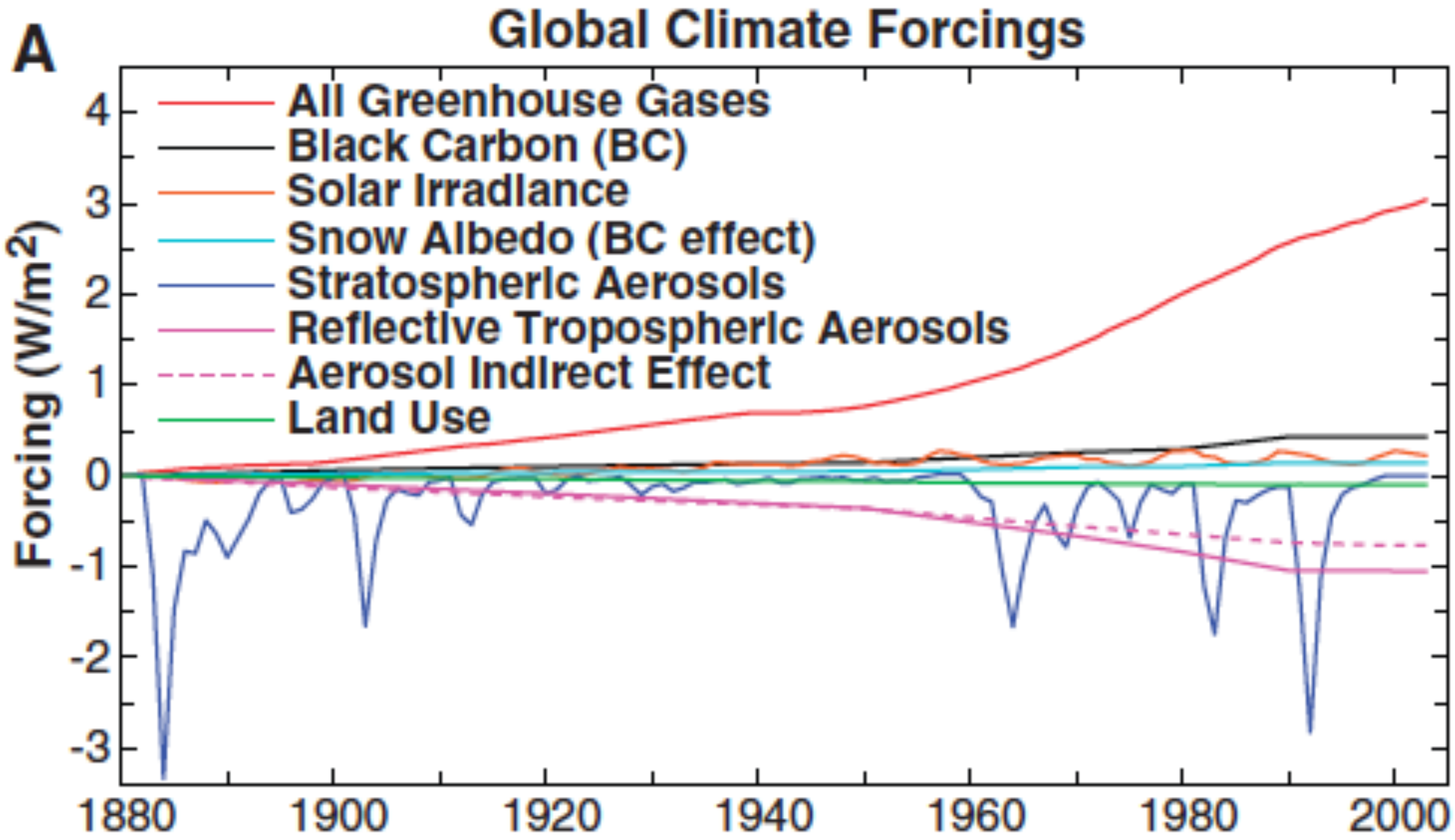



------ Observations Hadcrut3v dataset
------ Low resolution IPSLCM5 (96x95)
------ High resolution IPSLCM5 (144x142)
------ IPSLCM4

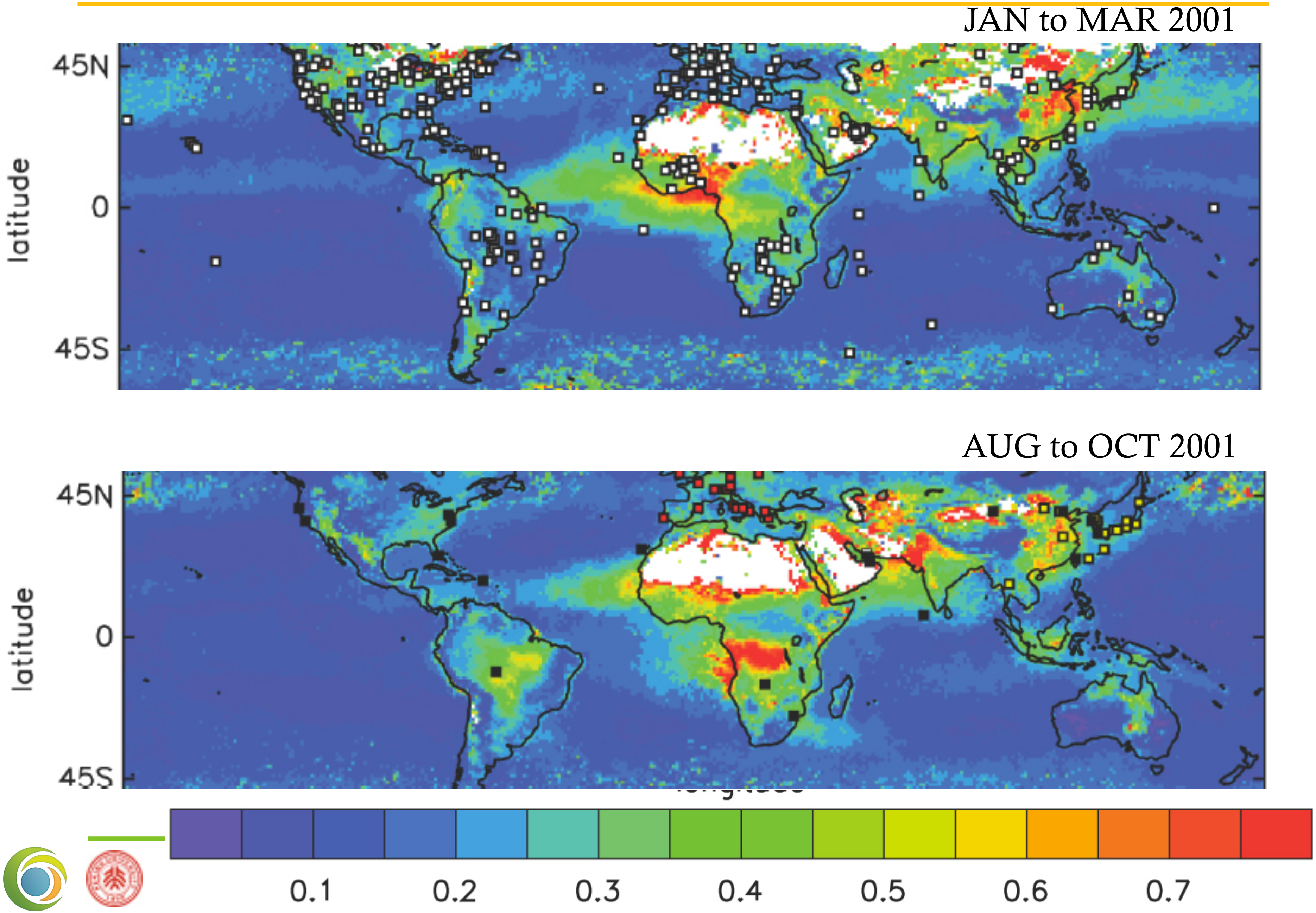
# Volcanoes and climate



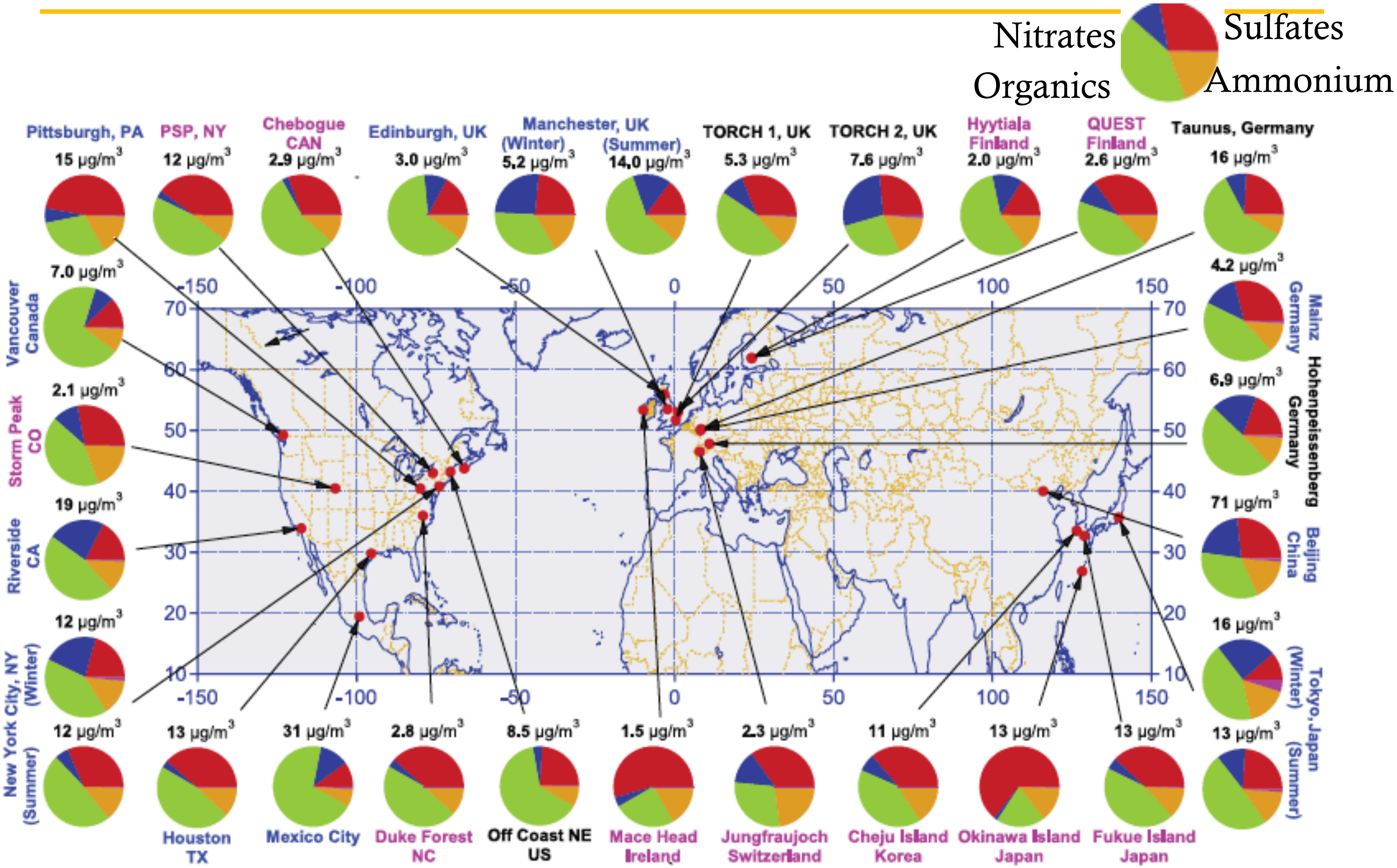
# Different climate forcings and their relative strength



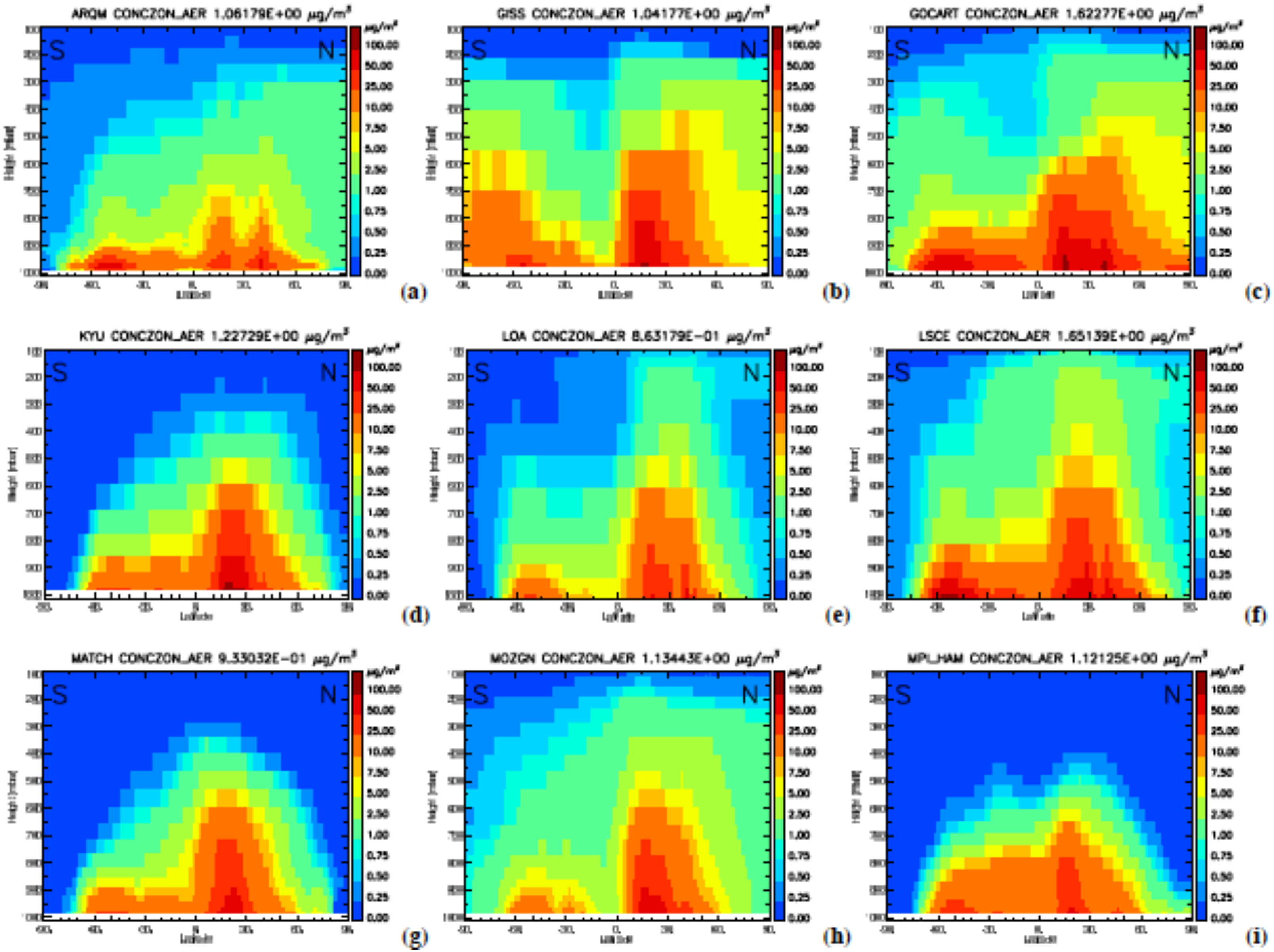
# Total aerosol Optical Depth as seen from MODIS retrieval



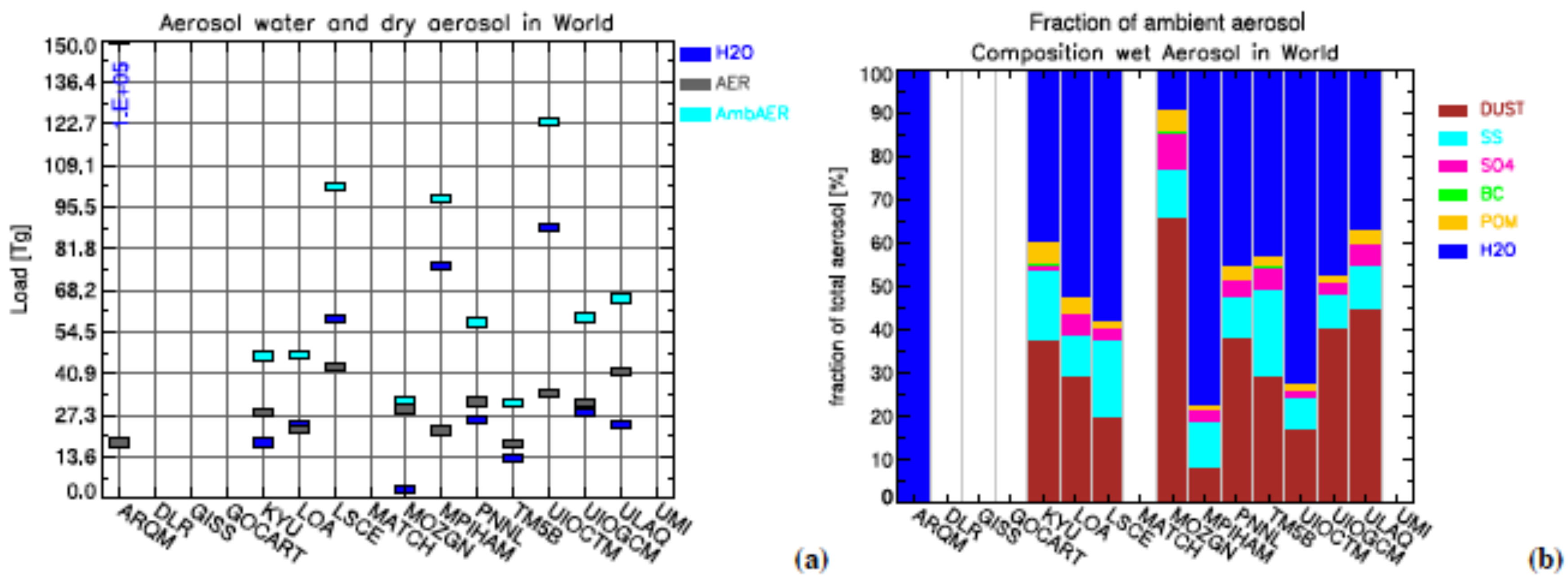
# Importance of organic aerosols (Zhang et al., 2007)



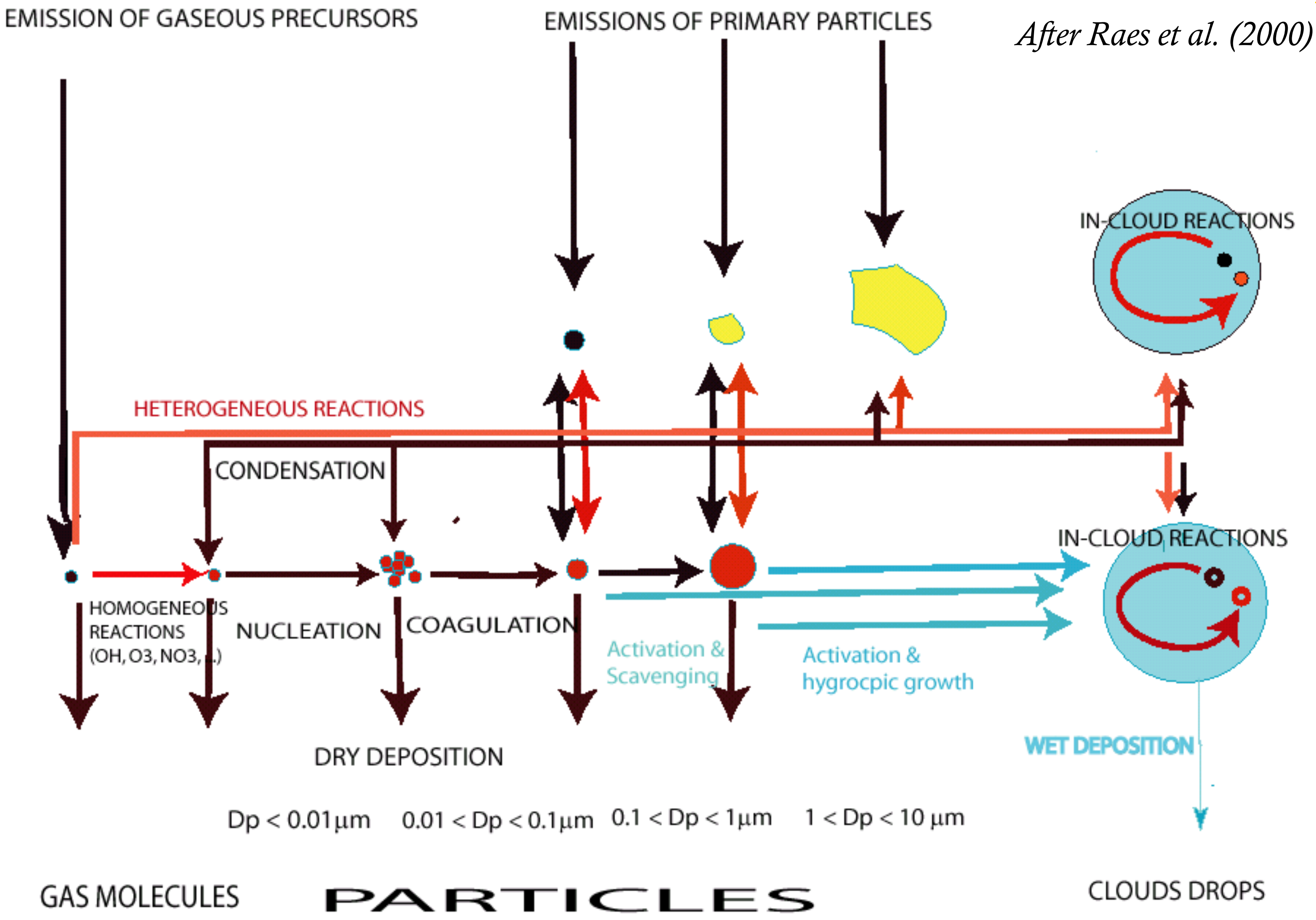
# Differences in simulated zonal aerosol distributions



# Importance and uncertainty of water associated with the aerosol



# Processes for aerosol formation and loss



# Representation of the aerosol in the INCA model

**INCA Aerosol Tracer Overview**

**Dust / Sulphate / Black Carbon / Organic Matter / Sea Salt / Nitrate / Ammonium**

One **N**(umber) and several **M**(ass) tracer per aerosol mode

| | **Insoluble Modes** | | **Soluble Modes** |
|---|---|---|---|
| ***Super coarse*** | | | $N_{SS}$ $M_{SS}$ |
| ***Coarse*** | $N_{CI}$ $M_{D}$ $M_{NO3}$ | $\Rightarrow$ | $N_{CS}$ $M_{SO4}$ $M_{MSA}$ $M_{SS}$ $M_{NO3}$ $M_{NH4}$ |
| | | | $\Uparrow$ |
| ***Accumulation*** | $N_{AI}$ $M_{BC}$ $M_{POM}$ | $\Rightarrow$ | $N_{AS}$, $M_{SO4}$ $M_{MSA}$ $M_{BC}$, $M_{POM}$, $M_{SS}$ $M_{NO3}$ $M_{NH4}$ |

# What are optical parameters?

## Optical Parameters to Compute the Aerosol Direct Forcing

✓ Light can be either scattered or absorbed. Both processes lead to extinction.

We define 3 parameters in order to compute the Aerosol Direct Forcing:

1/ Aerosol Optical Depth (*AOD*) often noted $\tau$

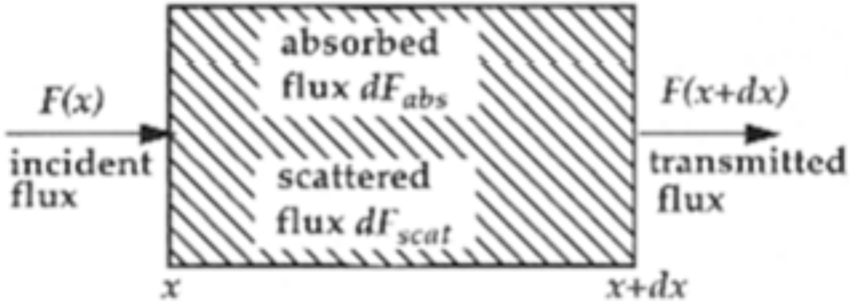
2/ The *asymmetry parameter* (or the phase function) $\beta$

3/ The *single scattering albedo* often noted $\omega_0$

AOD is a measure of the integrated vertical column of aerosol present,

Asymmetry parameter gives information on the ratio of backward to forward light scattering,

The single scattering albedo measures how absorbing a particle is




$$F(x+dx) = F(x) - dF_{abs} - dF_{scat}$$

$$dF_{abs} = n\,\sigma_{abs}\,F(x)\,dx$$

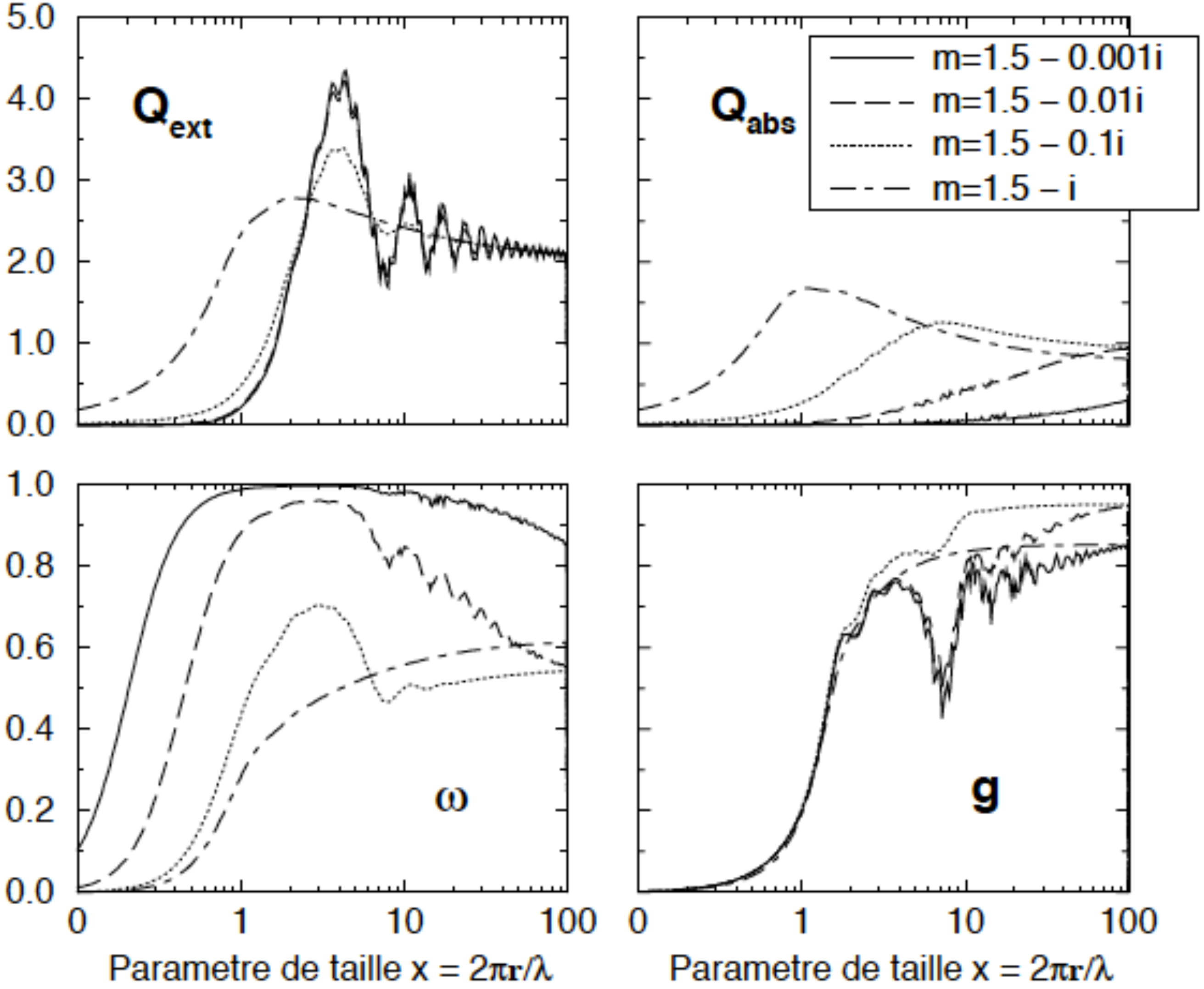
$$dF_{scat} = n\,\sigma_{scat}\,F(x)\,dx$$

$\sigma_{abs} = Q_{abst}\,\sigma$

and, $\sigma_{scat} = Q_{scat}\,\sigma$

$Q_{scat}$ is the scattering coefficient

Where $\sigma$ is the cross-section of the particle, $\sigma = \Pi . r_{eff}^2$



Q ext
Q abs
m=1.5 – 0.001i
m=1.5 – 0.01i
m=1.5 – 0.1i
m=1.5 – i
ω
g
5.0
4.0
3.0
2.0
1.0
0.0
0.8
0.6
0.4
0.2
0
1
10
100
Parametre de taille x = 2πr/λ
Parametre de taille x = 2πr/λ

# *Which strategy to reduce uncertainty in aerosol radiative forcing?*

*Change in albedo due to aerosols*

$$\Delta\alpha_p = [T_a^2(1-A_c)][2(1-R_s)^2\bar{\beta}f_b M\alpha_s f(RH) - 4R_s M\alpha_s f(RH)((1-\omega_0)/\omega_0)]$$

cloud fraction

surface albedo

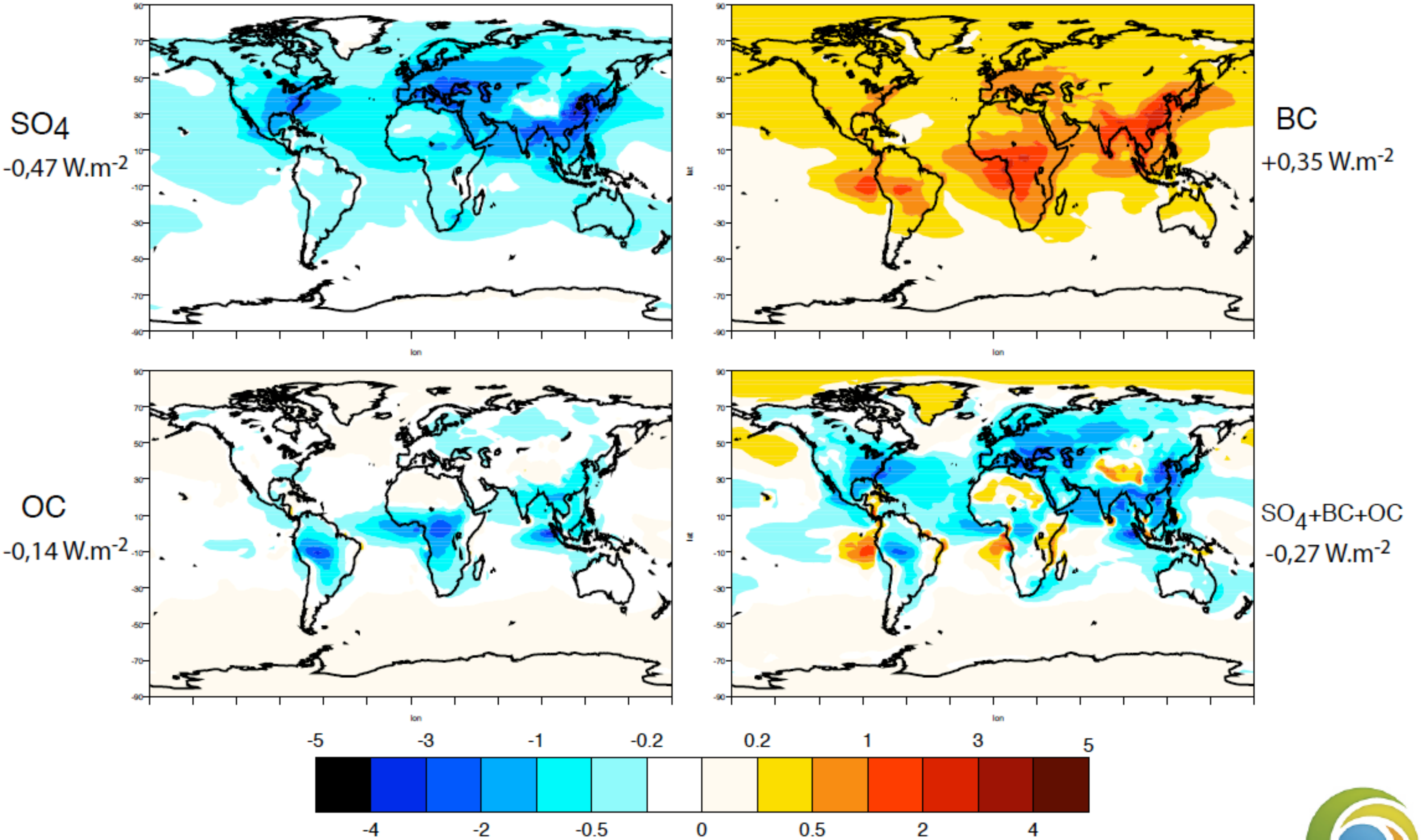
upscatter fraction
+f(RH) for upscatter

burden

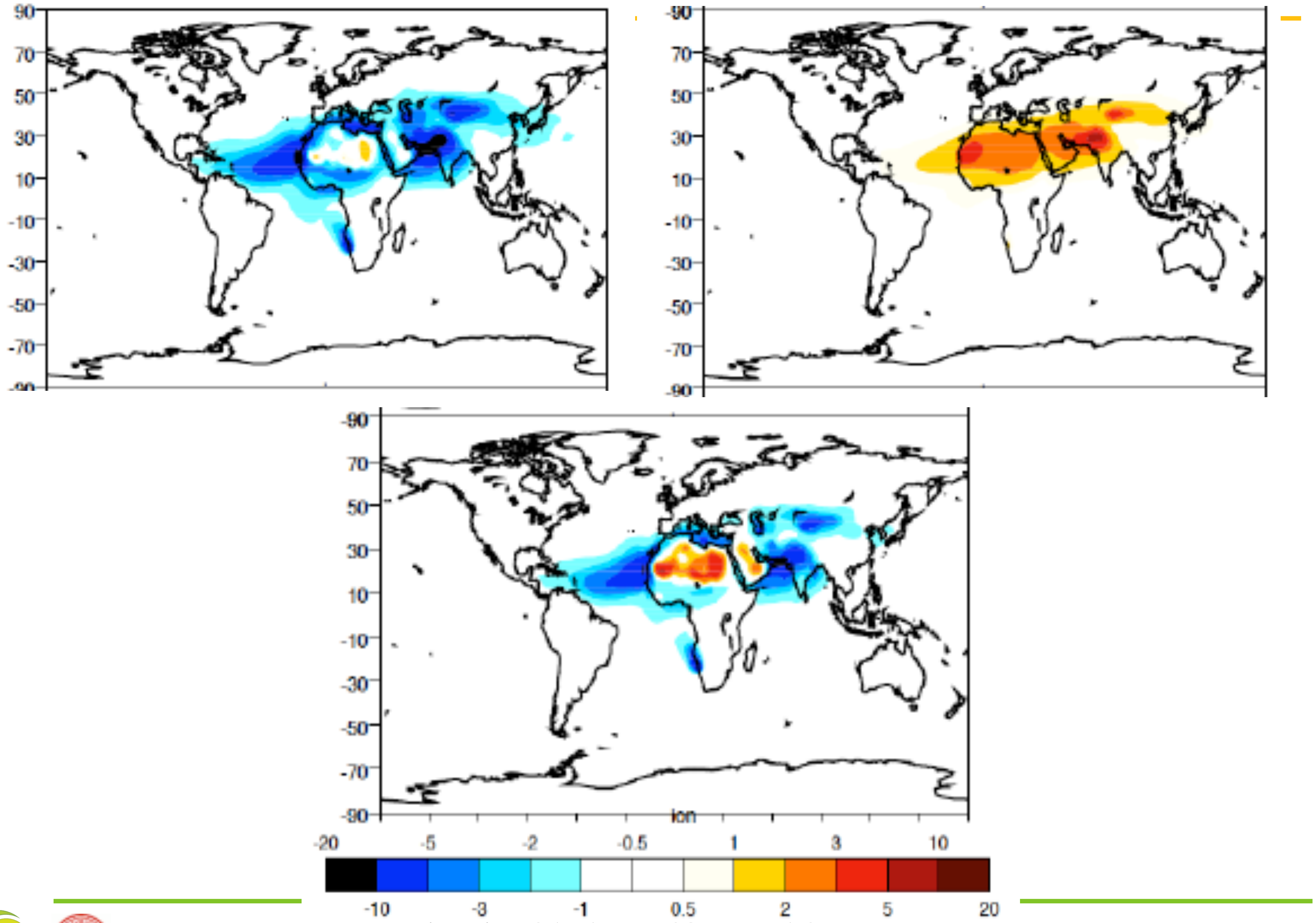
mass extinction coefficient
hygroscopic growth factor mec

« absorption coefficient »

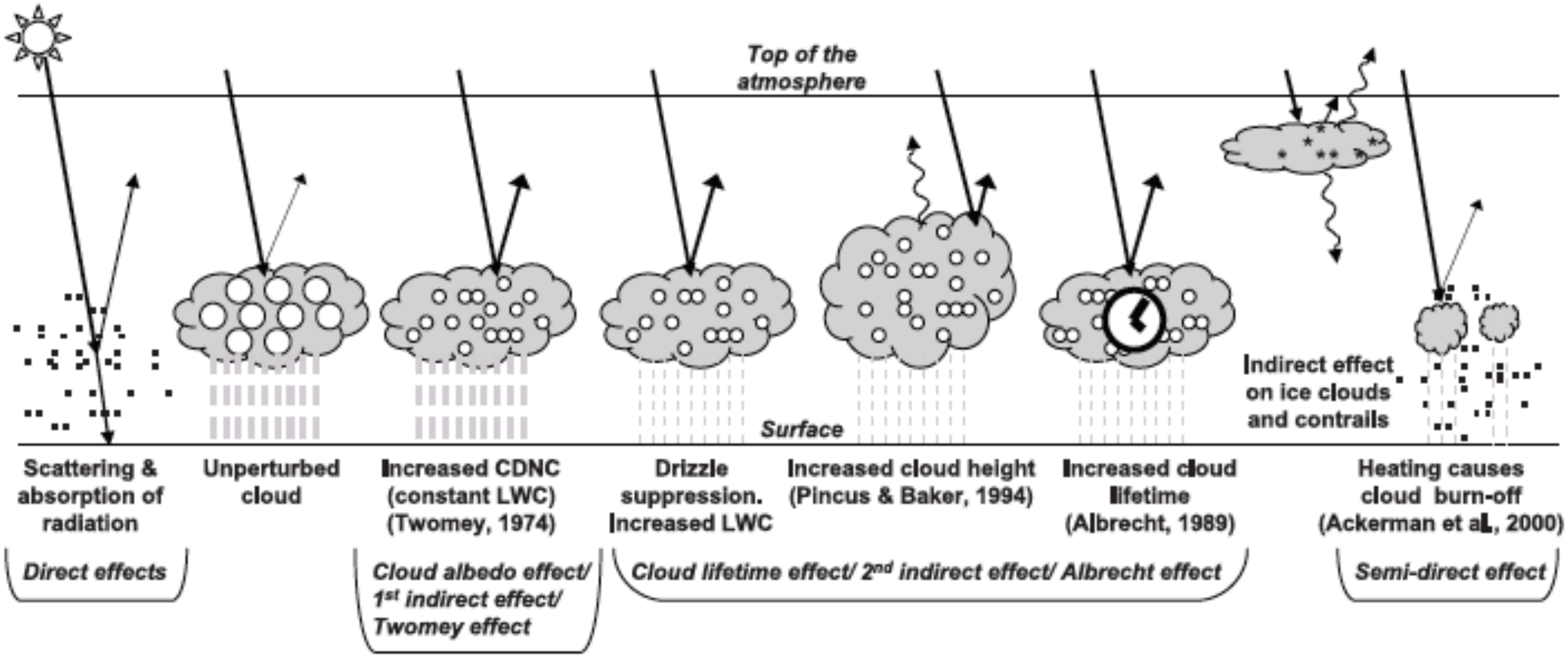
# Radiative Forcings from the ESM IPSLCM5a



# Radiative pertubation from mineral dust



# Aerosol effects on radiation and clouds

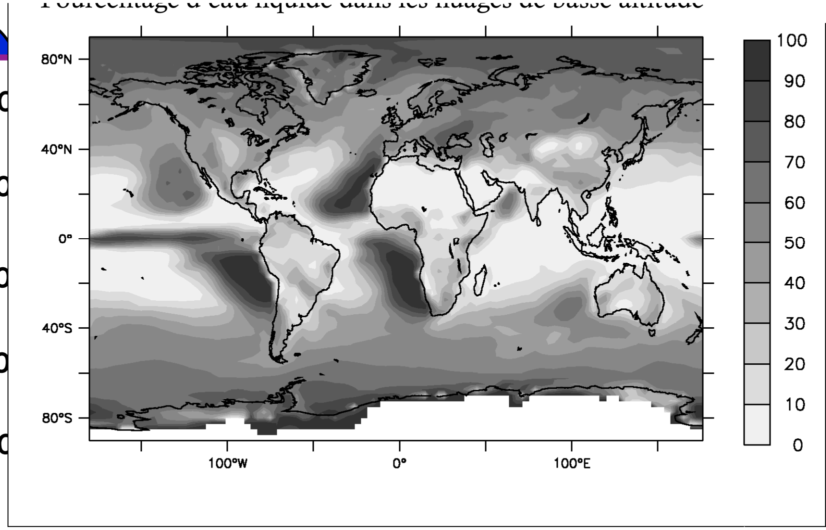


# Ship Tracks seen from space (from Durkee et al., 2000)

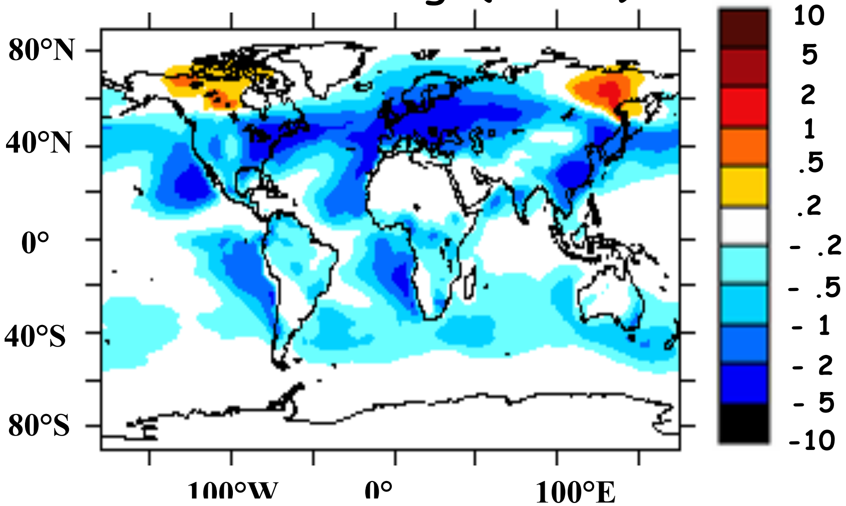
# Aerosol first indirect effect

*Deandreis et al., (2012)*

Pourcentage of liquid water in low-level clouds

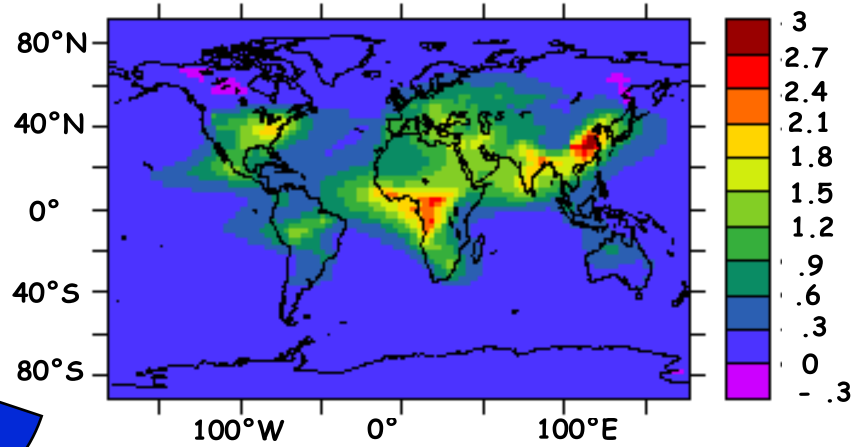



Radiative Forcing (W/m²)




Global Mean = - 0.46 W/m²

IPCC AR4: - 0.7 [-1.8 to -0.3 ] W/m²

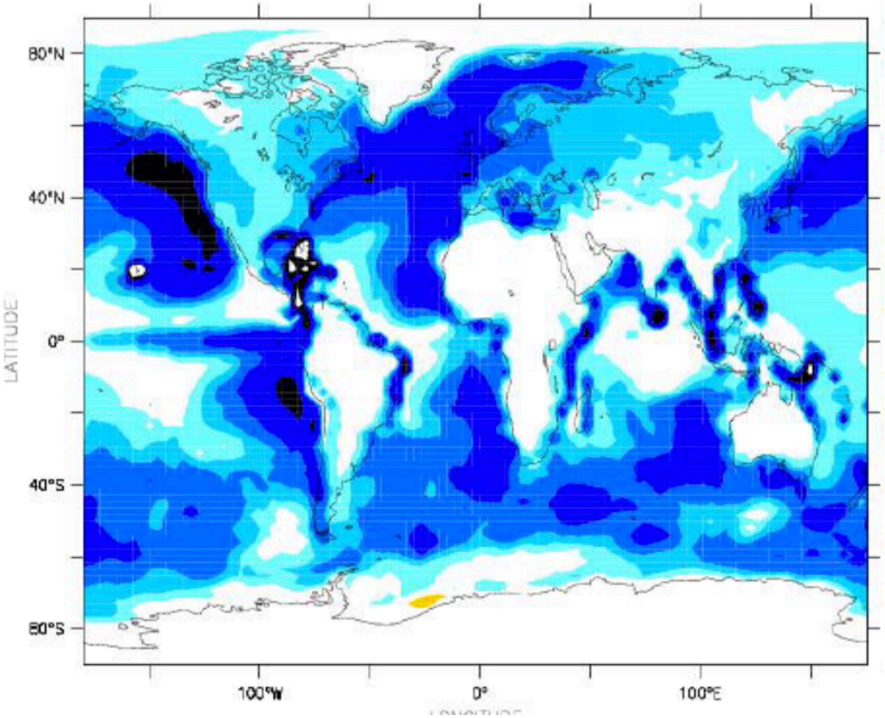



Difference in aerosol concentrations
2000 -1750 ($\mu g/m^3$)

*The indirect effect is sensitive to pre-industrial conditions in particular to background volcanic aerosols*

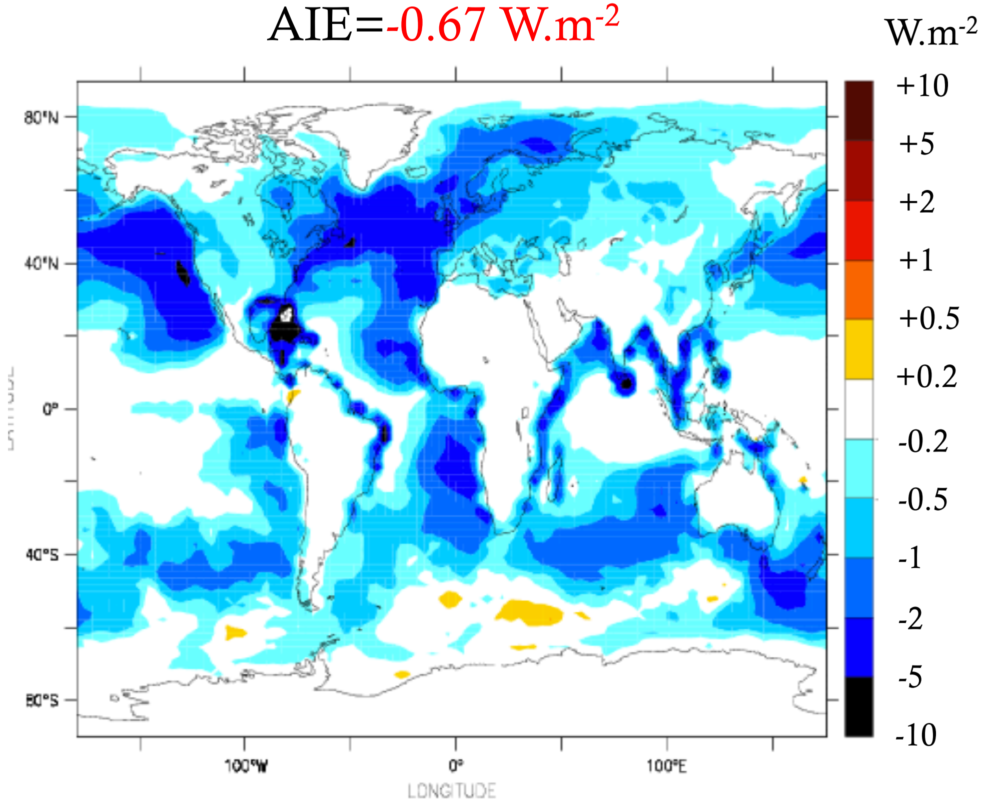
Case 1: No SO2 emission from volcanoes:

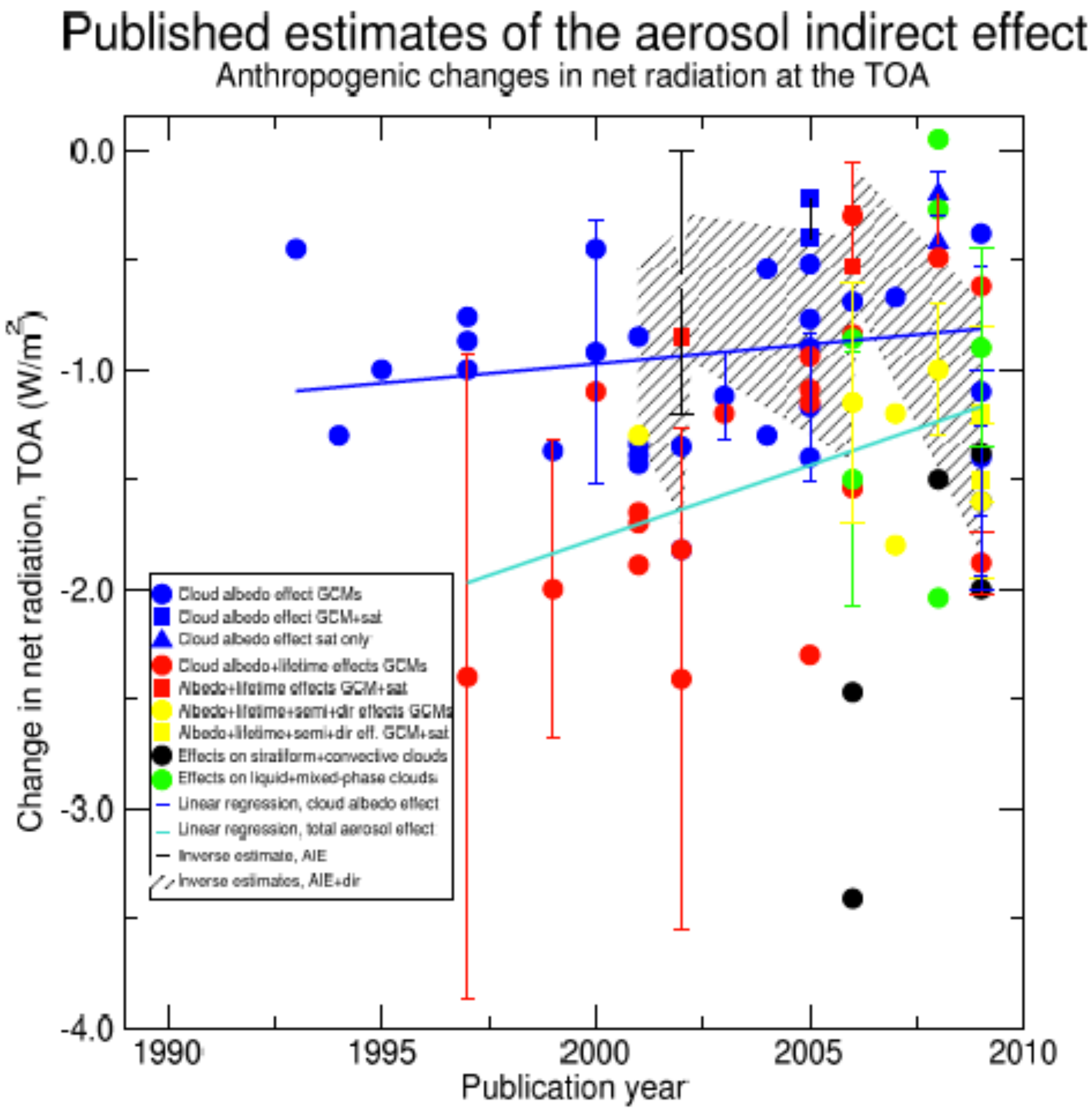
AIE=-1.18 W.m$^{-2}$



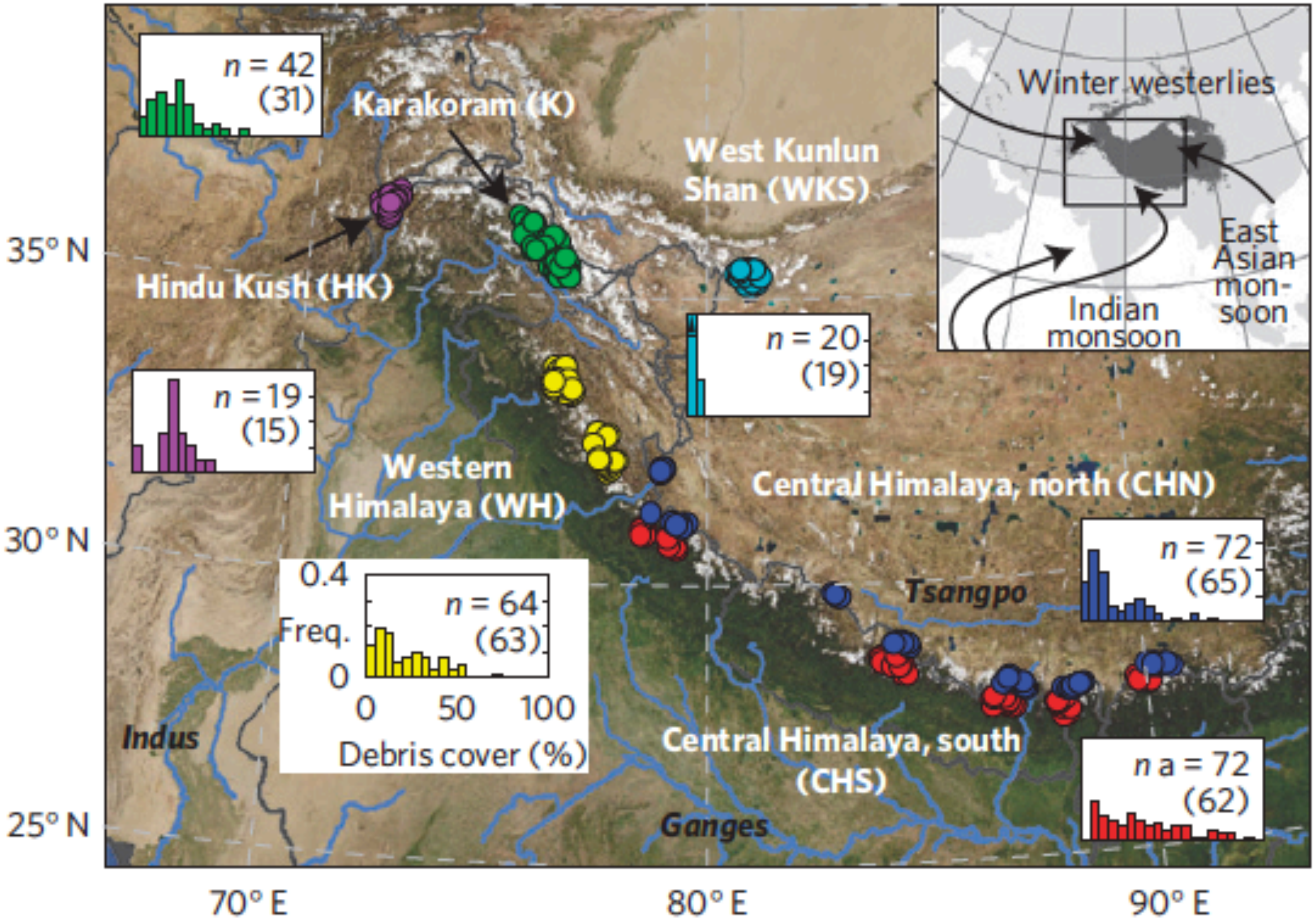

Case 2: $SO_2$ from volcanoes = 29 Tg $SO_2$/an (*Dentener et al., 2006*)

AIE=-0.67 W.m$^{-2}$




Published estimates of the aerosol indirect effect
Anthropogenic changes in net radiation at the TOA
Change in net radiation, TOA (W/m2)
0.0
-1.0
-2.0
-3.0
-4.0
1990
1995
2000
2005
2010
Publication year
Cloud albedo effect GCMs
Cloud albedo effect GCM+sat
Cloud albedo effect sat only
Cloud albedo+lifetime effects GCMs
Albedo+lifetime effects GCM+sat
Albedo+lifetime+semi+dir effects GCMs
Albedo+lifetime+semi+dir eff. GCM+sat
Effects on stratiform+convective clouds
Effects on liquid+mixed-phase clouds
Linear regression, cloud albedo effect
Linear regression, total aerosol effect
Inverse estimate, AIE
Inverse estimates, AIE+dir

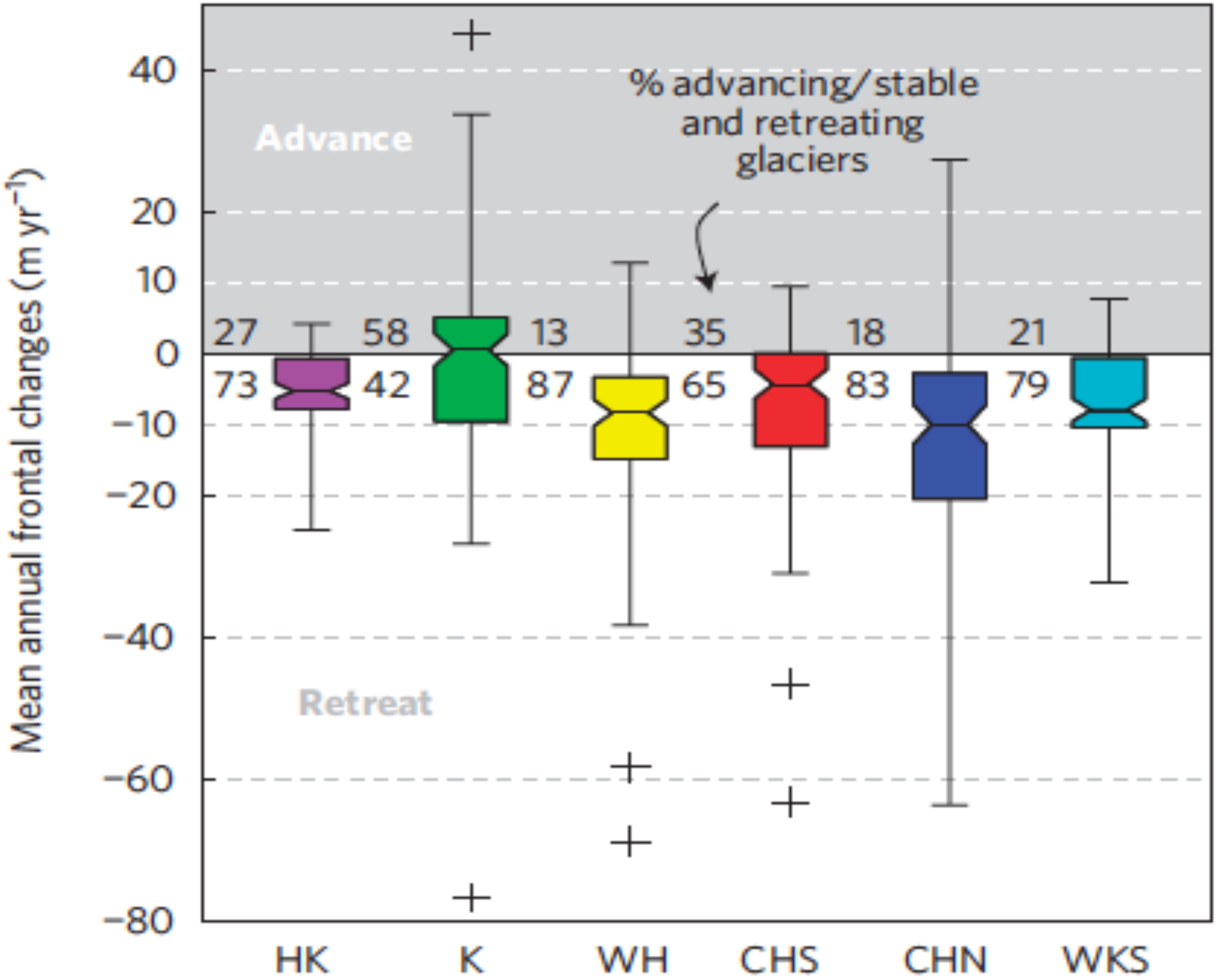
# Glaciers retreat from 2000 to 2008 (1/2)




*Scherler et al., 2011*

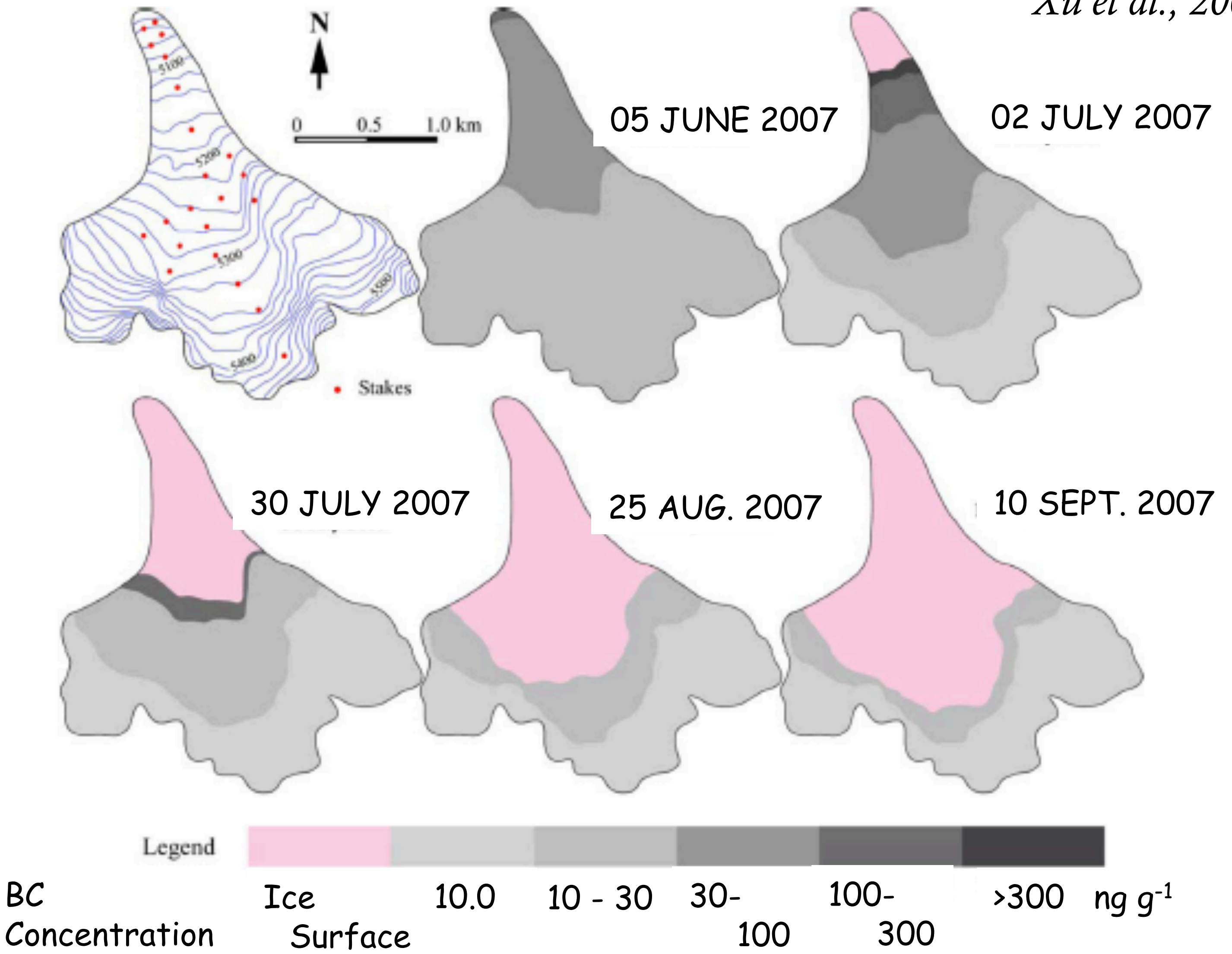
# Glaciers retreat between 2000 and 2008 (2/2)

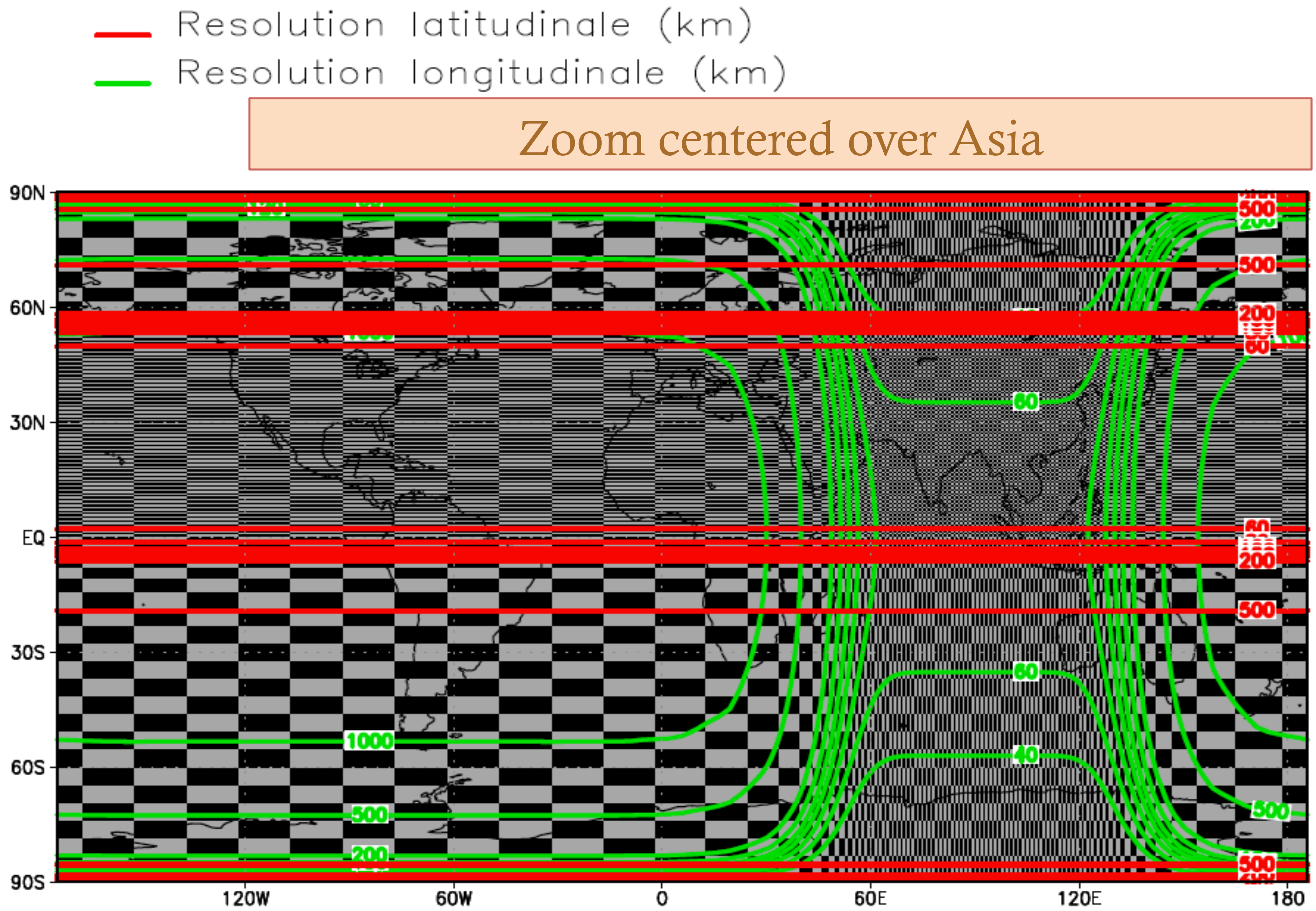
*Scherler et al., 2011*



# Black carbon measurements over a glacier

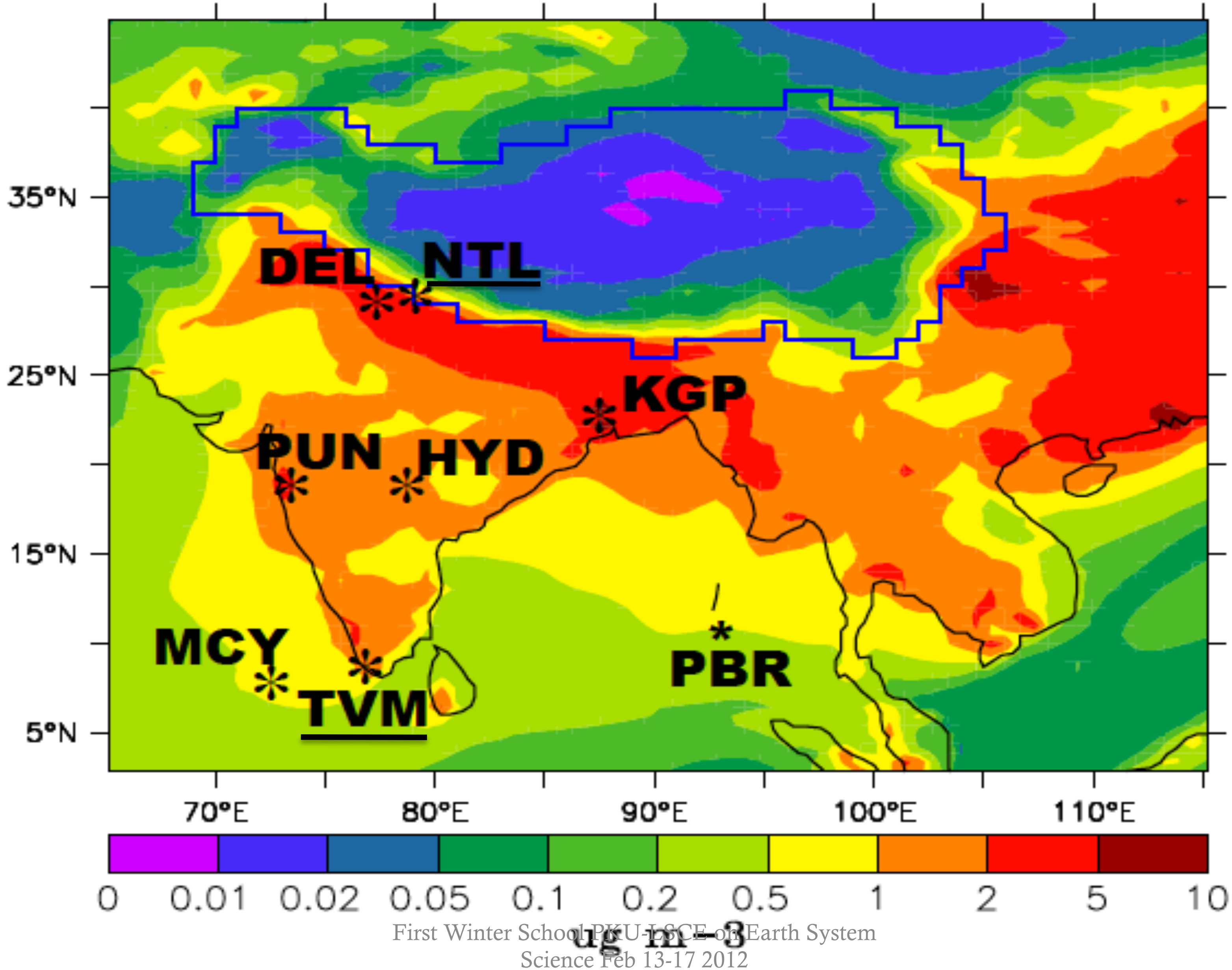
*Xu et al., 2009*





Resolution latitudinale (km)
Resolution longitudinale (km)
Zoom centered over Asia
90N
60N
30N
EQ
30S
60S
90S
120W
60W
0
60E
120E
180
500
200
60
40
1000

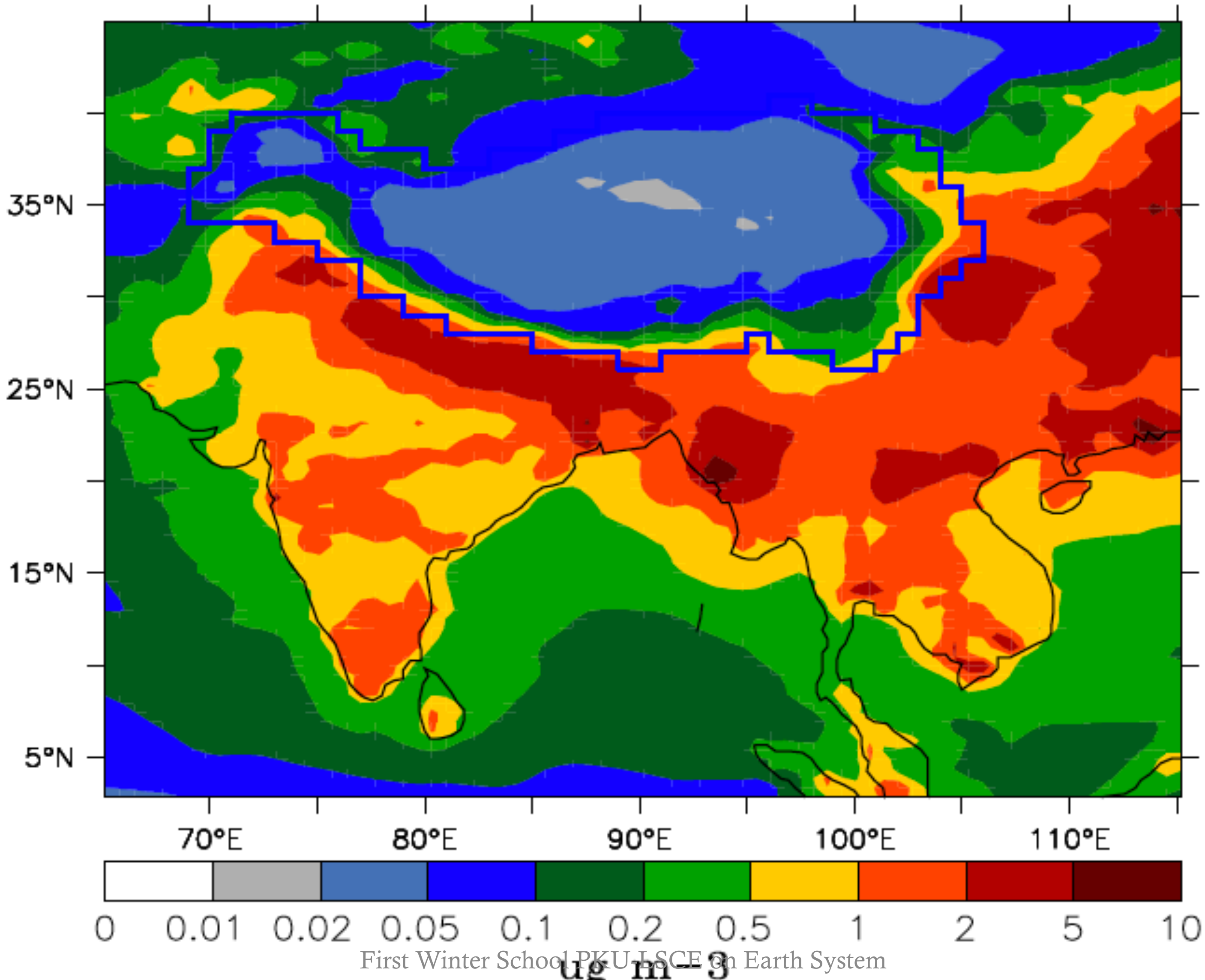
# Mean JAN-FEB BC surface concentrations (µg.m-3)



# Comparison of mean JAN-FEB surface concentrations

| Location | Observation Jan–Feb | Zoom LMDz-INCA | Scaled to 2006 |
| --- | --- | --- | --- |
| Minicoy | 0.47 | 0.36 | 0.47 |
| Trivandrum | 5.2–5.7 | 1.2 | 1.56 |
| Port Blair | 2.6 | 0.37 | 0.48 |
| Hyderabad | 21–25 | 0.86 | 1.12 |
| Pune | 6.4–7.3 | 1.15 | 1.50 |
| Kharagpur | 7.5–8.3 | 2.78 | 3.61 |
| Delhi | 19–27 | 3.28 | 4.26 |
| Nainital | 0.67–1.87 | 1.44 | 1.87 |

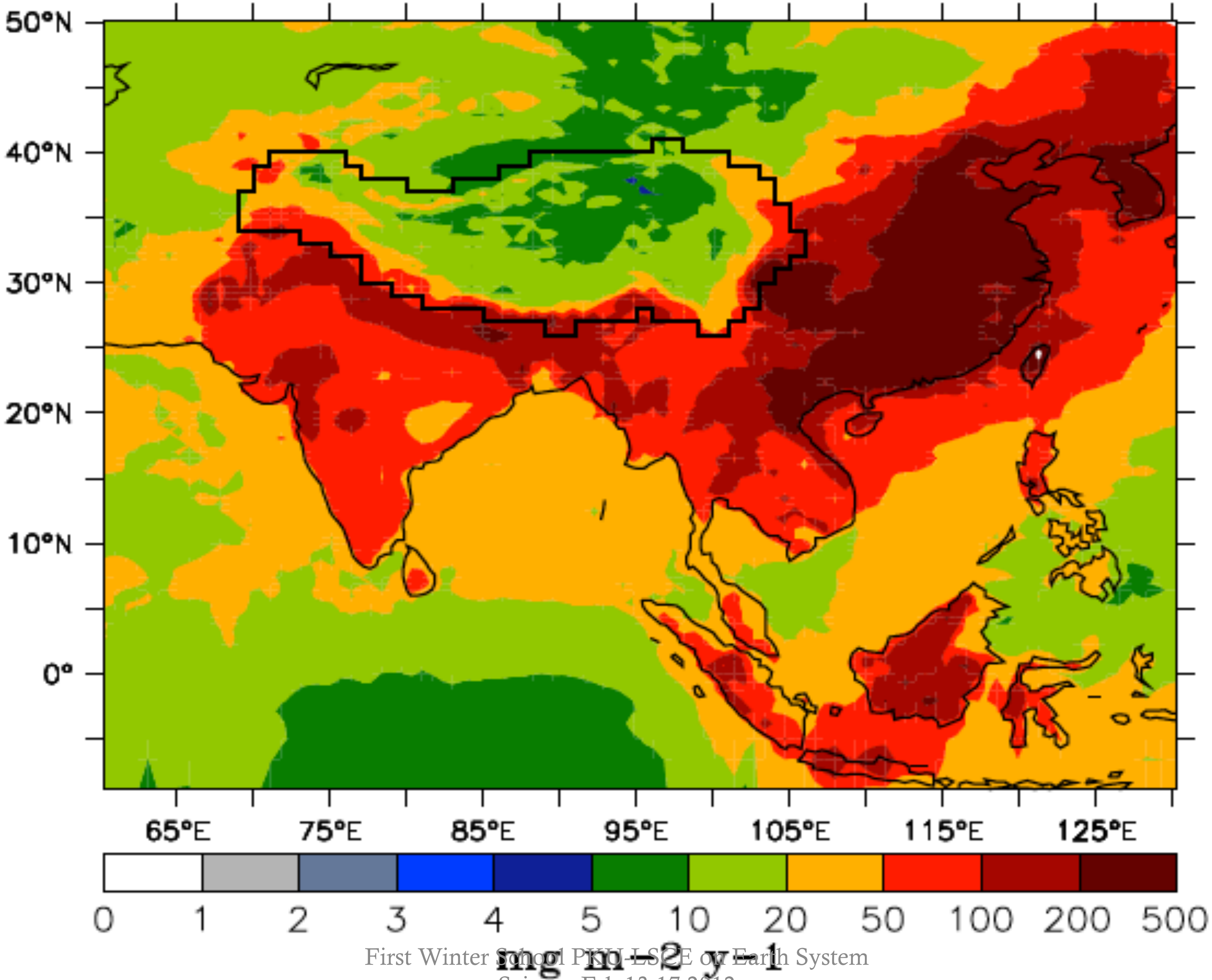
# Mean March-April-May surface concentrations (μg.m-3)



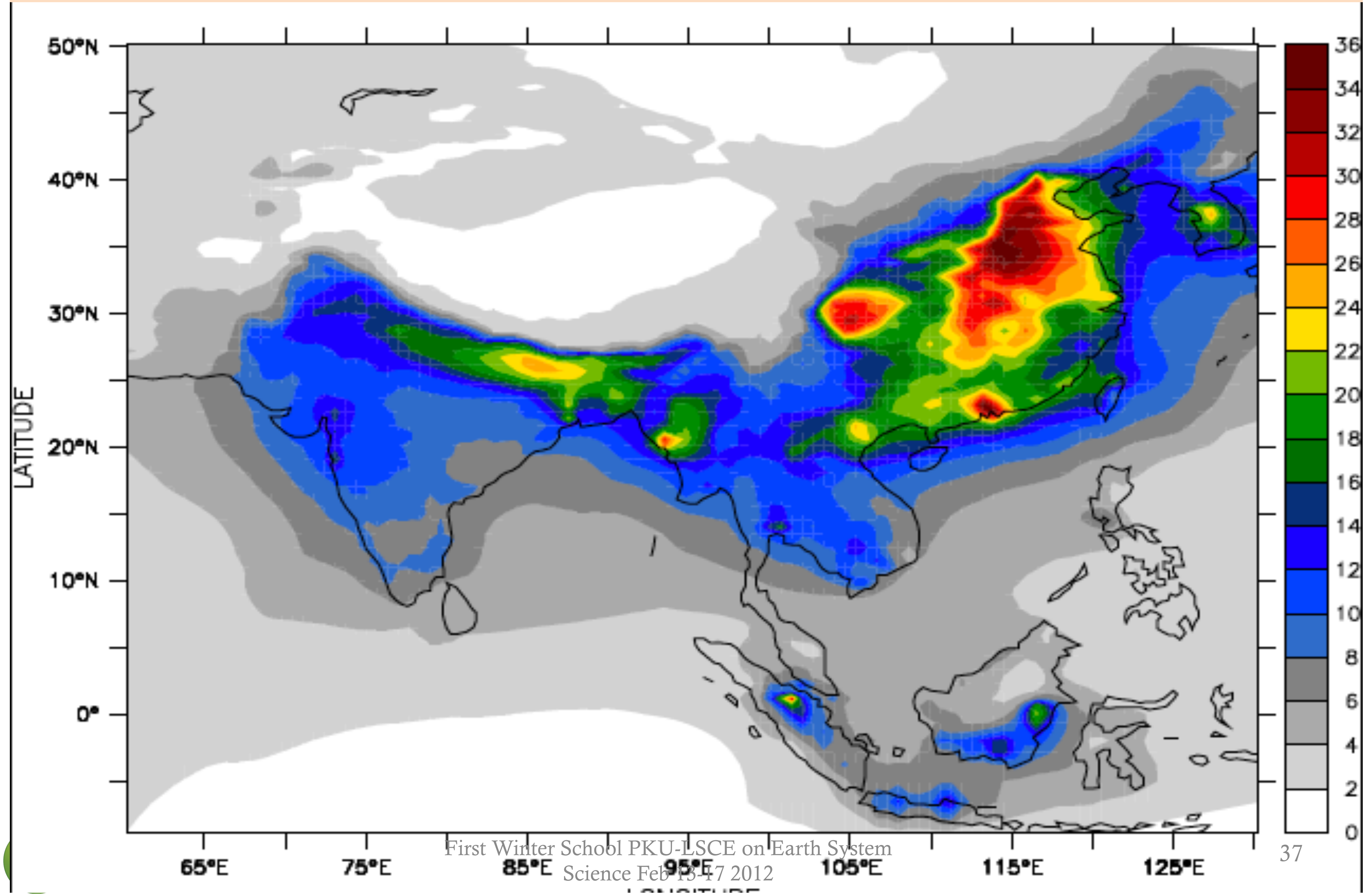
# Comparison of Mean surface during Pre-Monson Season (Mar-Apr-May)

| Location | Observation Mar–May | Zoom LMDz-INCA | Scaled to 2006 |
|---|---|---|---|
| Minicoy | 0.06–0.22 | 0.11 | 0.14 |
| Trivandrum | 1.8-3.0 | 0.82 | 1.07 |
| Port Blair | 2.7–6.9 | 0.12 | 0.16 |
| Hyderabad | 12–15 | 0.70 | 0.91 |
| Pune | 2.2–4.5 | 0.86 | 1.12 |
| Kharagpur | 2.7–6.9 | 1.67 | 2.17 |
| Delhi | 8–12 | 3.18 | 4.13 |
| Nainital | 1.3–1.6 | 1.16 | 1.51 |

# Total Deposition of Black Carbon (mg m-2 y-1)



# Yearly Mean Optical Depth of Black Carbon (X1000)



# Yearly Mean SW Black Carbon Radiative Forcing