Motivation:

Better constrain aerosol radiative effects
Use an assimilation technique to nudge the fields of optical depth
Describe the difference in the TOA forcing between assimilated and not assimilated fields

Developments:

A coupled GCM/chemical module, the chemistry and the aerosols can be treated interactively

Include this chemical module into the IPSL Earth System Model

GCM-Chemistry coupling: LMDz-INCA
INCA=INteractions between Chemistry and Aerosols

Reference Versions

- ✓ LMDZ.3.3, 96x72x19, Tiedtke's convection
- ✓ Gaseous Chemistry: 90 species, 300 reactions (INCA CH4 et INCA NMHC)
- ✓ Aerosols: 25 species, 15 reactions, spectral scheme (INCA CH4AER)
- ✓ Inverse modelling and assimilation CO_2, CH_4, aerosols
- ✓ Stratospheric version: 96x72x50 (version INCA CH4STRATO)

Emissions

- ✓ Biogenic emissions coupled to the bosphere model ORCHIDEE
- ✓ Biomass burning emissions distributed following ATSR fire counts

Diffusion of INCA

- ✓ Several laboratoires: LSCE, SA, LMDZ, LOA, LGGE
- ✓ Publications INCA: 6 chemistry + 3 aerosols
- ✓ Web site, web interface for results through AEROCOM
- ✓ (we also produce maps of all physical variables and tracer dignostics from the simulations)

INCA Aerosol Module

INCA Aerosol Module

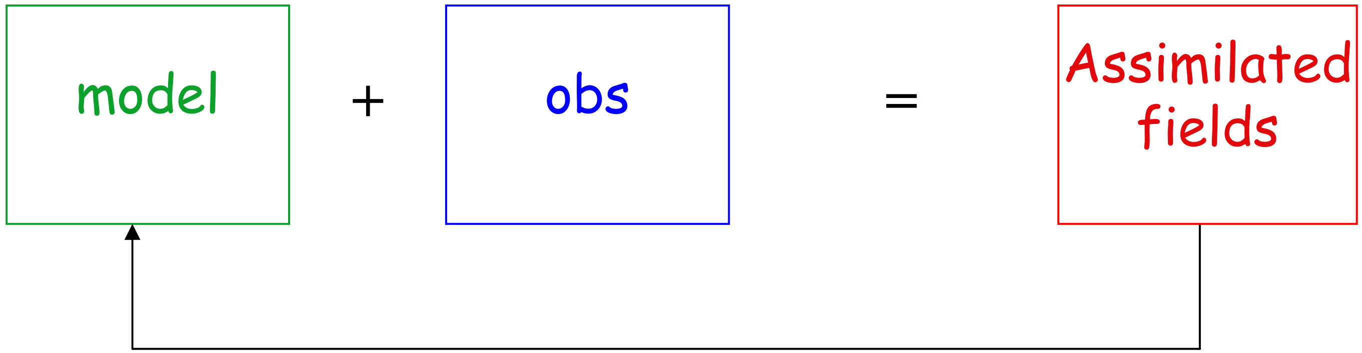
Dust / Sulphate / Black Carbon / Organic Matter / Sea Salt / Nitrate / Ammonium

Modal approach: one **N**(umber) and x **M**(ass) tracer per aerosol mode

	Insoluble Modes		**Soluble Modes**
Coarse	N_{CI} M_D M_{NO3}	⇒	N_{CS} M_{SO4} M_{MSA} M_{SS} M_{NO3} M_{NH4}
			⇑
Accumulation	N_{AI} M_{BC} M_{POM}		N_{AS}, M_{SO4} M_{MSA} M_{BC}, M_{POM}, M_{SS} M_{NO3} M_{NH4}
			⇑
Aitken	$N_{BC/OC}$, M_{BC}, M_{OC}	⇒	N_T, M_{SO4}, M_{BC}, M_{OC}
			⇑
Nucleation			N_{SO4}, M_{SO4}

The Kalman Filter

Each time step :



$$x^b \quad + \quad K(y_0 - Hx^b) \quad = \quad x^a$$

(1st time step : $x^b = x^{model}$ then : $x^b = x^a$)

$$K = BH^t\,(\,HBH^t + O)^{-1}$$

After integration of obs $y_0(t)$:

$B = B_t - B_tH^t\,(HB_tH^t+O)^{-1}HB_t$

⇒ propagation of B

B : error covariance matrix of the background

O : error covariance matrix of the observations

B & O error covariance matrix

for the observations :

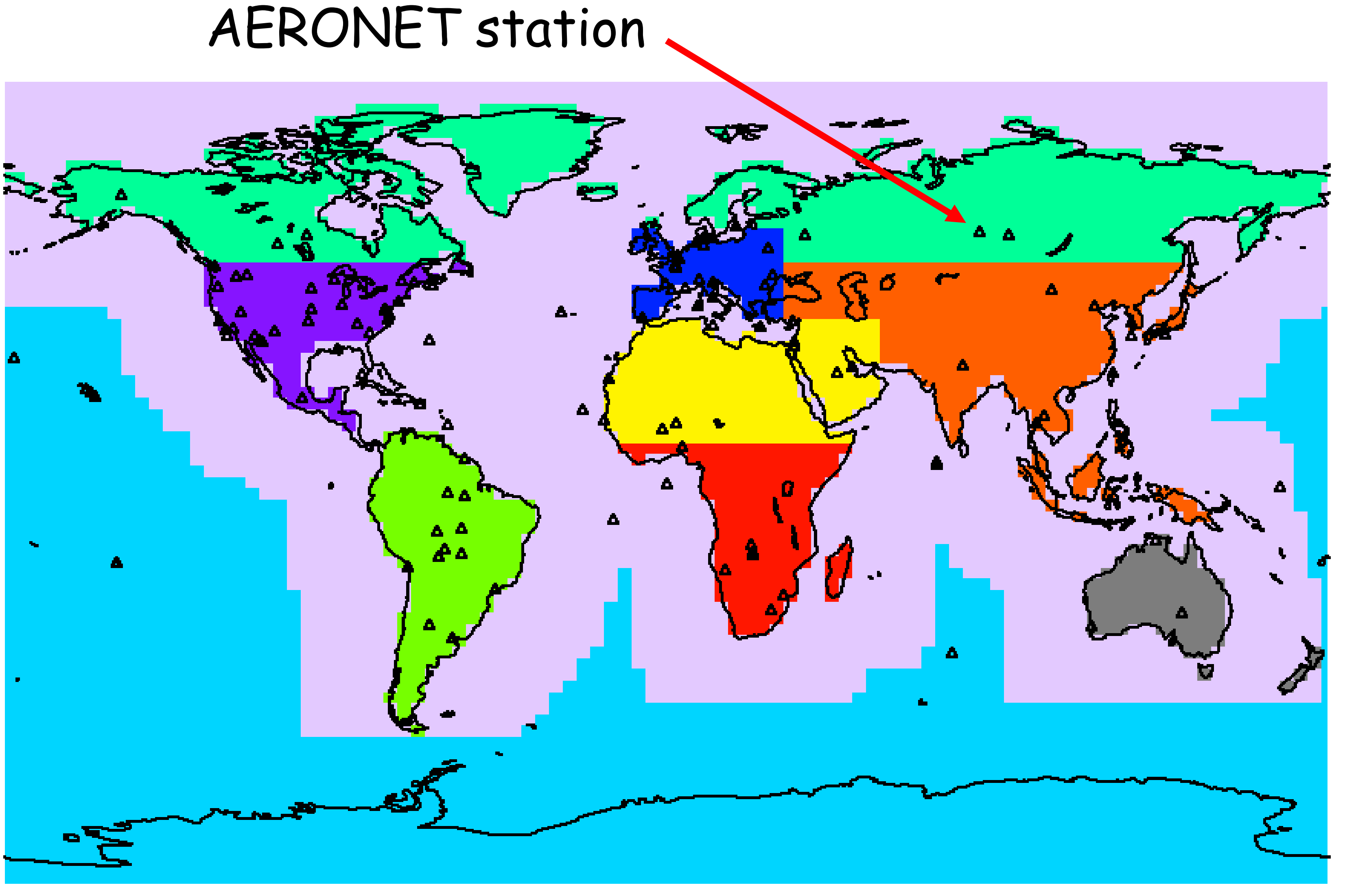
$$O = \sigma_O I \quad \text{avec} \quad \sigma_O = \varepsilon_0 + f_0 \tau_0$$

for the a priori :

$$B = \sigma_B I \quad \text{avec} \quad \sigma_B = \varepsilon_m + f_m \tau_m$$

- ε_0, f_0, ε_m, f_m depend on the region
- Both are determined following exactly the same method, from comparisons to AERONET data

To characterise O & B ...



Within each region, the same error statistics are used

	σ_g	mmr	r_m	r_e
CI	2.00	1.170	0.277	0.921
CS	2.00	1.831	0.433	1.439
SS	2.00	5.010	1.185	3.939
AI	1.59	0.113	0.059	0.101
AS	1.59	0.190	0.100	0.171

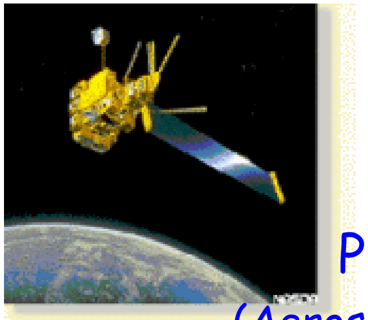
	σ^*(m^2/g)	ρ (g/cm3)
Dust	0.78	2.65
BC	4.9 (7.5)	1.55 (1.0)
SS	0.59	2.2
POM	1.7	1.5
SO4		1.7

Properties are given for the dry aerosol

σ_g : geometric standard deviation
mmr : mass median radius (μm)
r_m : modal radius (μm)
r_e : effective radius (μm)

The POLDER mission

Pol D E R



POLDER-1 : Nov 96 to Jun 97

POLDER-2 : Apr 03 to Oct 03

(On ADEOS)

POLDER AOT

(Aerosol Optical Thickness)

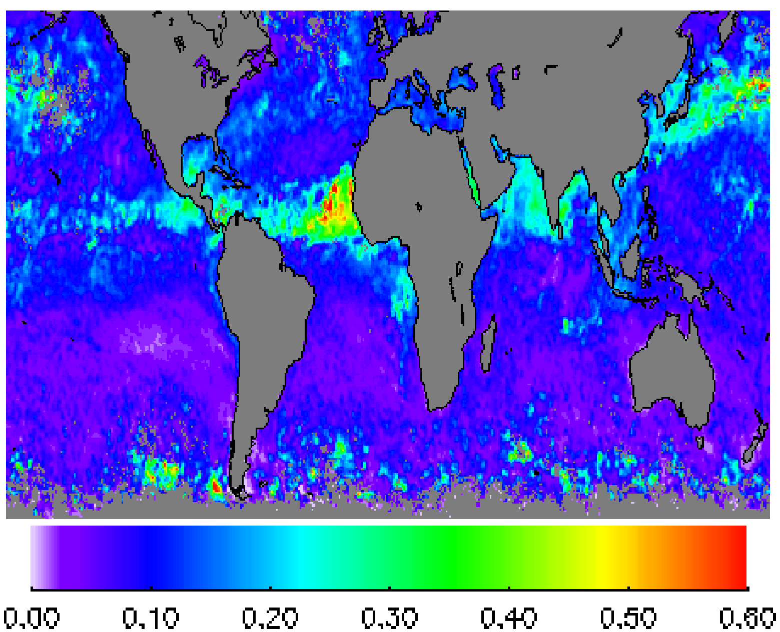
Classical method - Over ocean only

AOT $\propto$ aerosols load

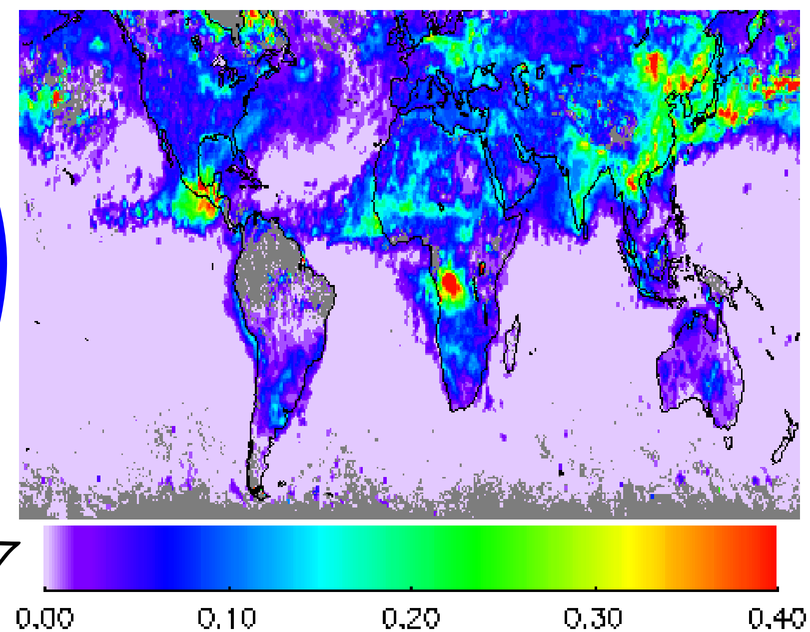
POLDER AI (Aerosol Index)

Originality : polarization - over ocean and land

AI $\propto$ aerosols load in the fine mode

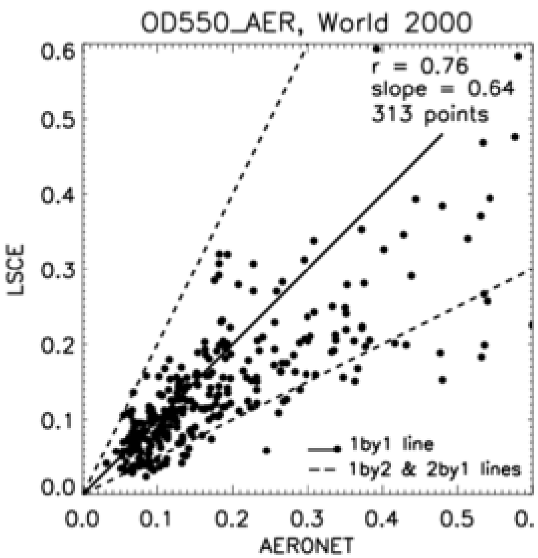


May 1997

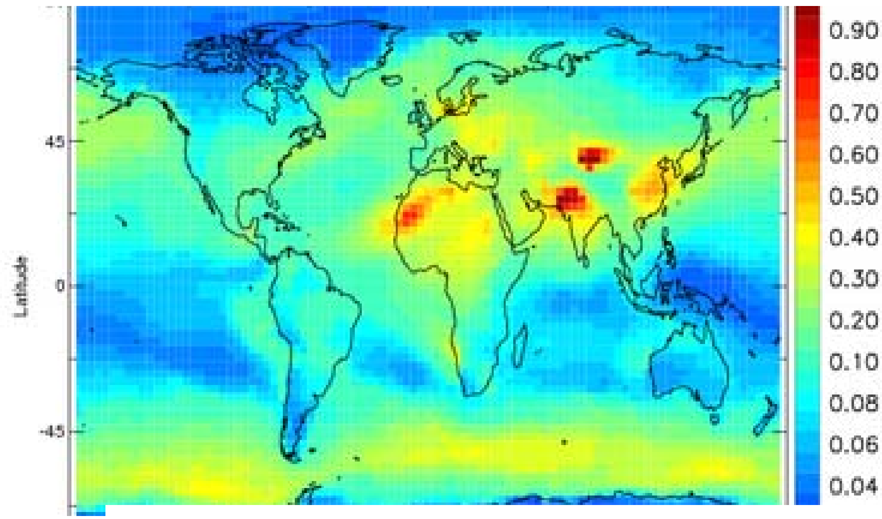


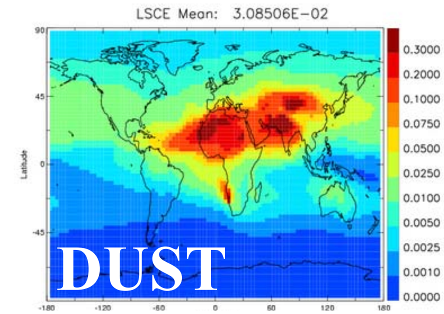
Validation / Evaluation

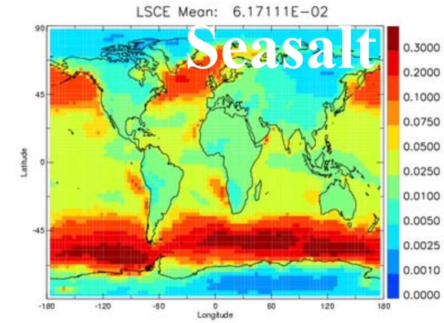
Aerosol optical depth at 550nm



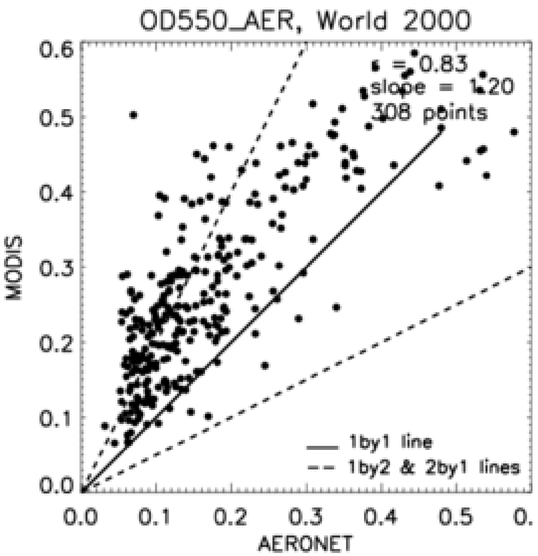
LMDzT-INCA-AER

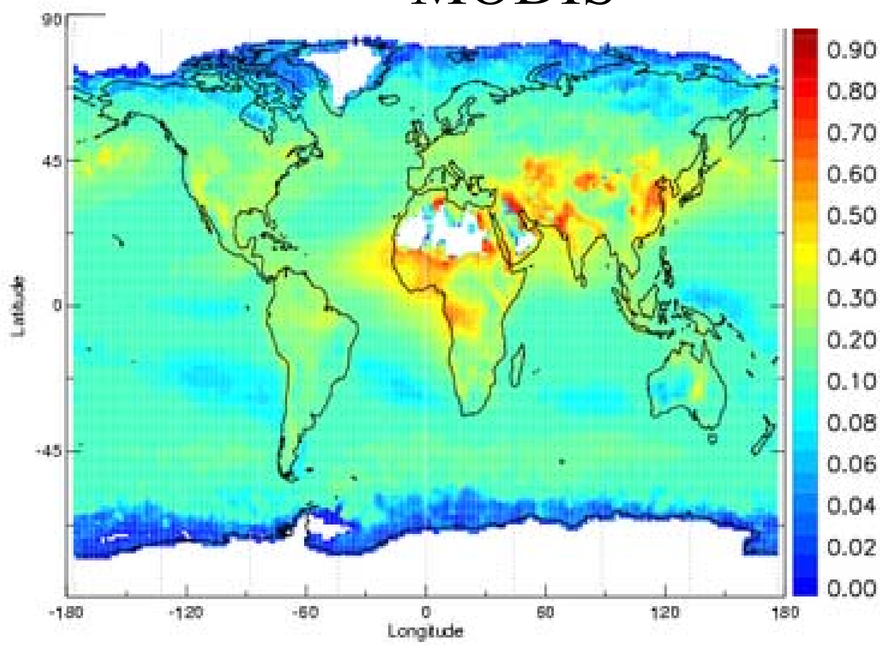


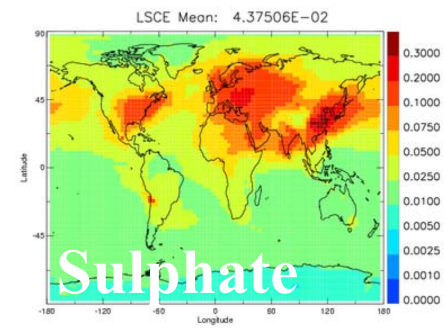


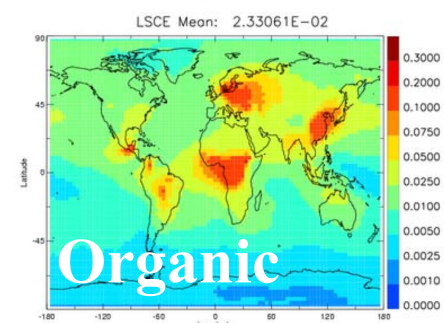


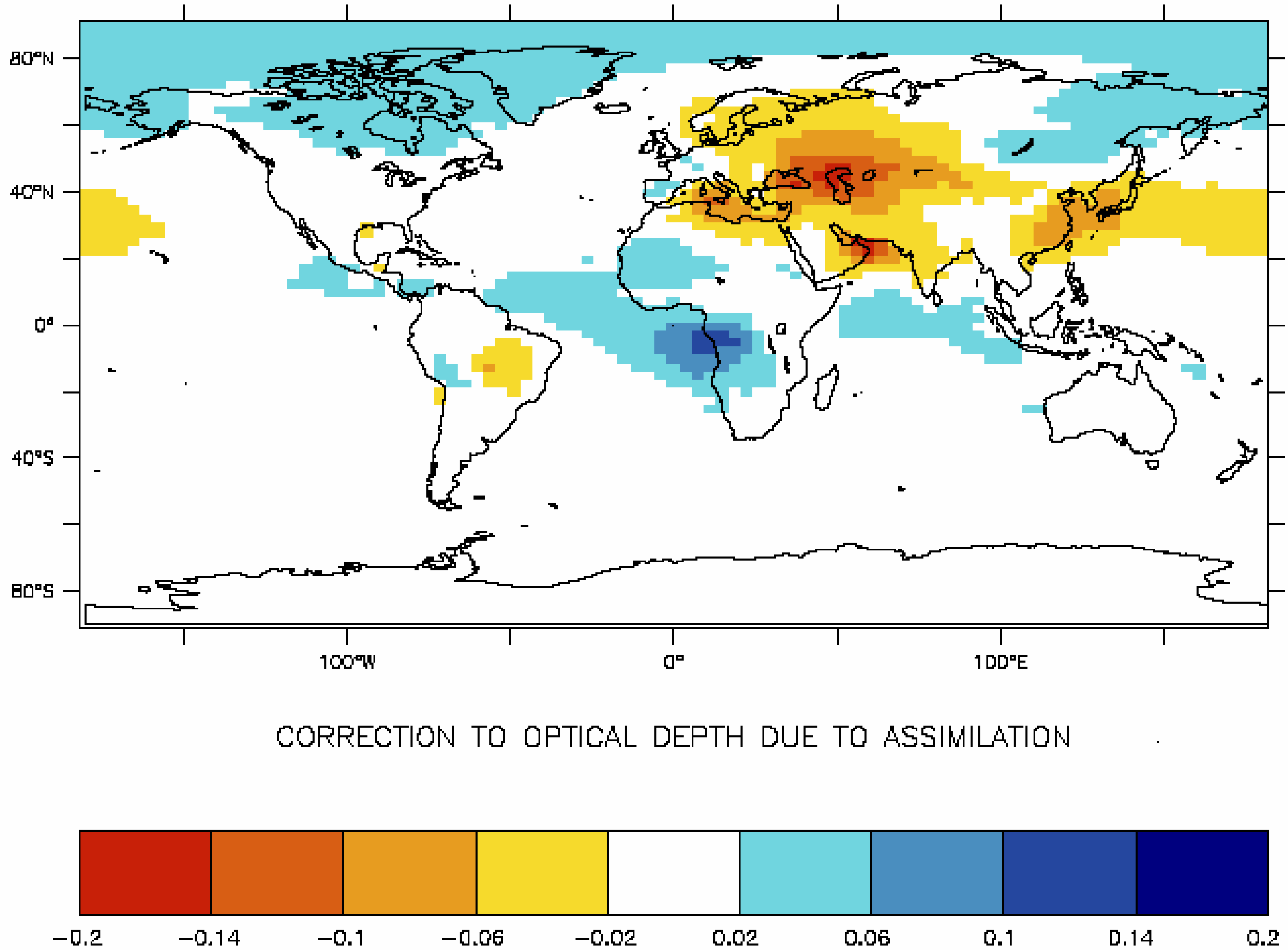
MODIS





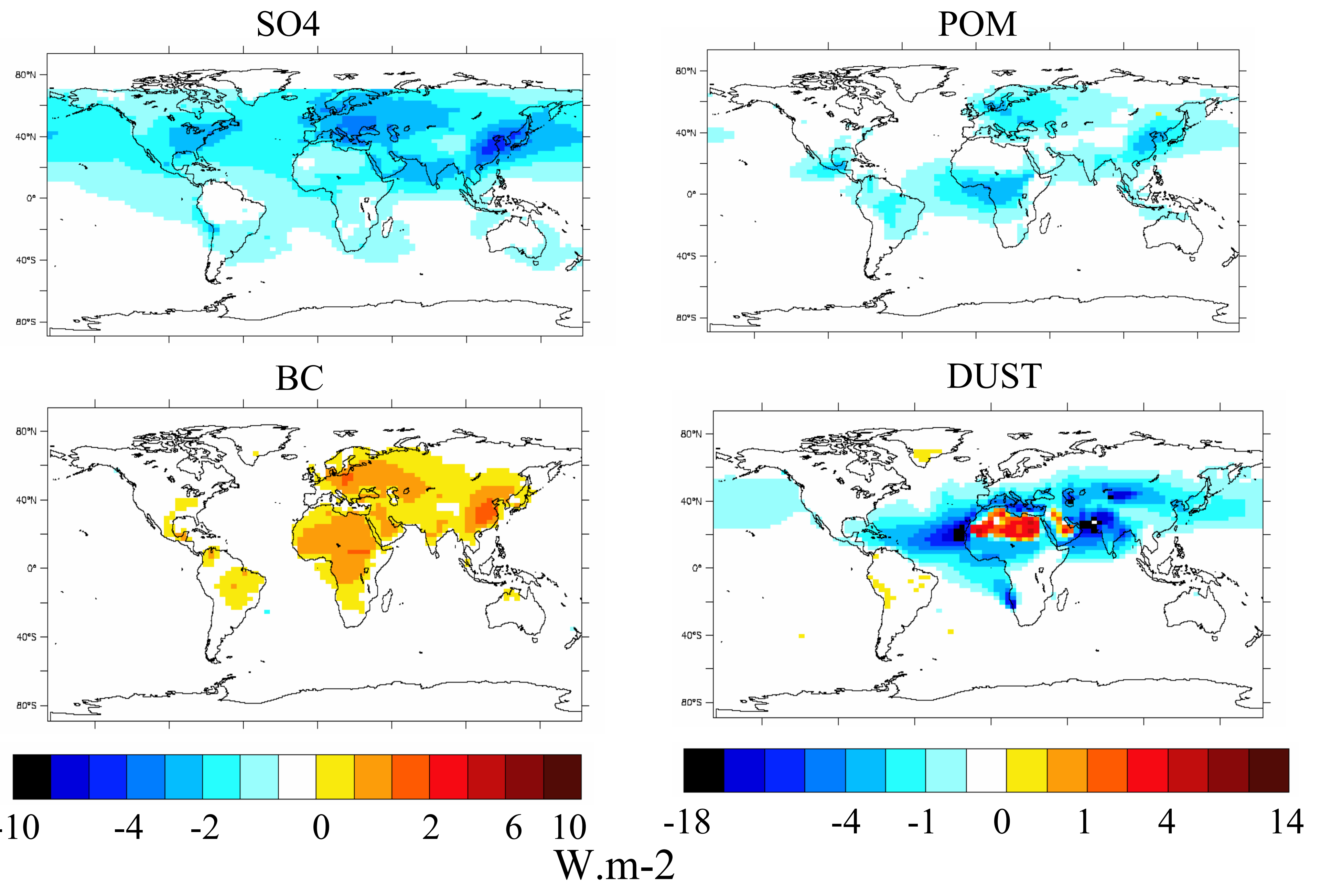


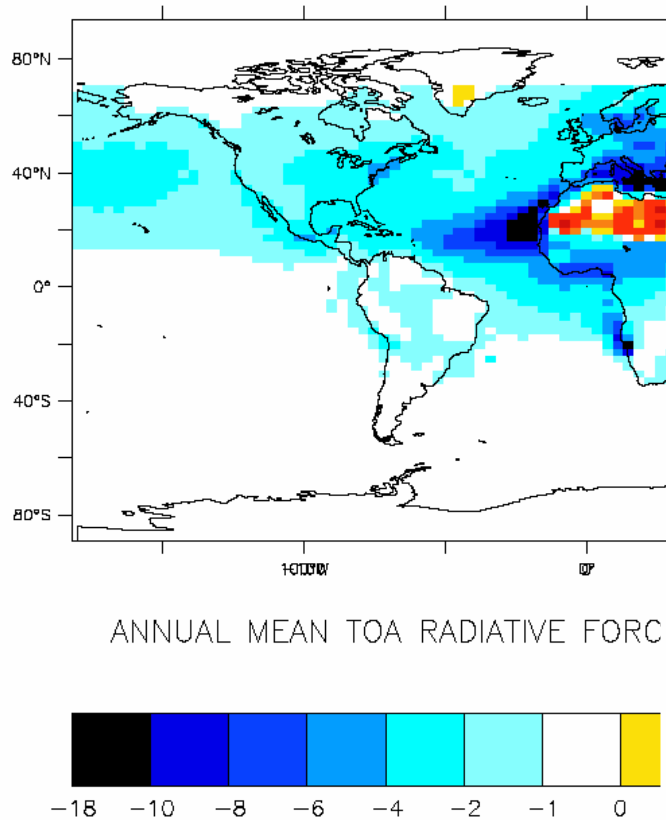


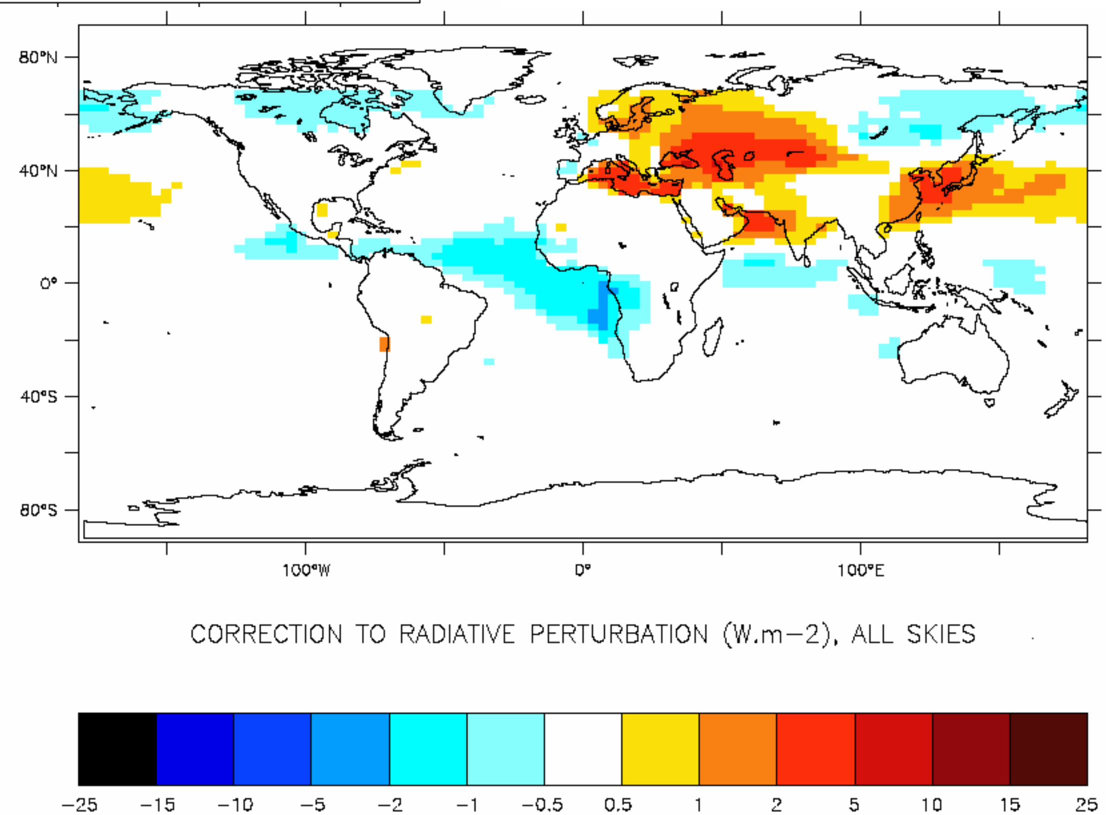


80°N
40°N
0°
40°S
80°S
100°W
0°
100°E
CORRECTION TO OPTICAL DEPTH DUE TO ASSIMILATION
−0.2
−0.14
−0.1
−0.06
−0.02
0.02
0.06
0.1
0.14
0.2

Direct Radiative Forcing by component




80°N
40°N
0°
40°S
80°S
100°W
0°
ANNUAL MEAN TOA RADIATIVE FORC
−18 −10 −8 −6 −4 −2 −1 0


80°N
40°N
0°
40°S
80°S
100°W
0°
100°E
CORRECTION TO RADIATIVE PERTURBATION (W.m−2), ALL SKIES
−25 −15 −10 −5 −2 −1 −0.5 0.5 1 2 5 10 15 25

Uncertainties

Model

- ✓ Treating internal mixtures
- ✓ Coherence between satellite resolution, model resolution and point measurements from AERONET
- ✓ Large range in the water content associated with the aerosol (hygroscopicity of seasalt at high RH is an issue).
- ✓ Evaluate model vs measured size distributions (issues of dataset strategies)

Future Developments

- ✓ Inclusion of chemistry module in the Coupled Model (atm-ocean-seaice)
- ✓ Include the information from the LW radiative forcing
- ✓ Role of aerosol in current climate (GEMS project)