Changes in tropospheric aerosol and reactive gases burdens and concentrations under IPCC-AR5 emission scenarios for 1850-2100

Sophie Szopa

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Cliquez pour modifier le style des sous-titres du masque

Laboratoire des Sciences du Climat et de l'Environnement, FRANCE.

LSCE

07/201

Sciences de l'environnement

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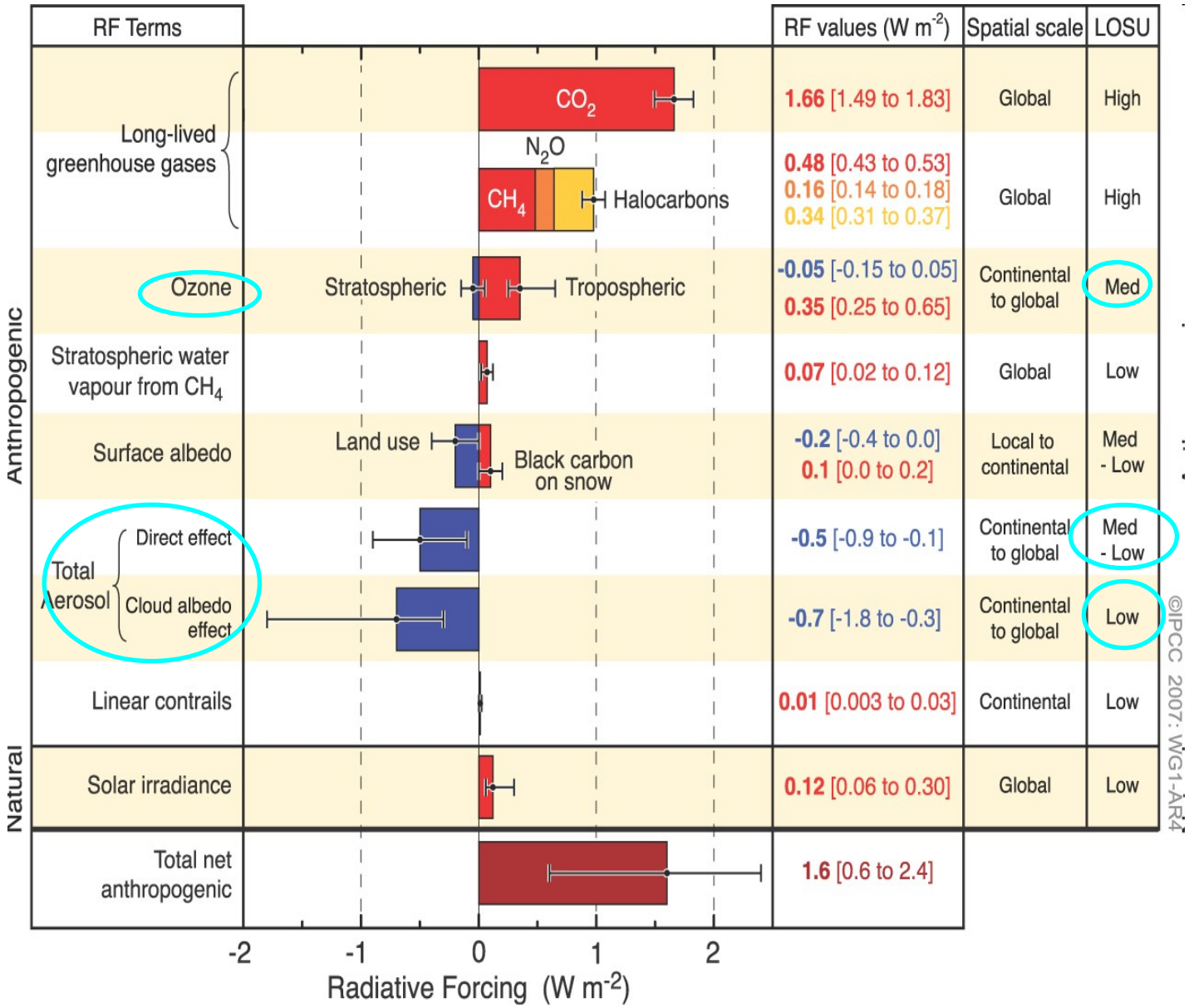
RF Terms
RF values (W m-2)
Spatial scale
LOSU
Anthropogenic
Natural
Long-lived greenhouse gases
CO2
N2O
CH4
Halocarbons
1.66 [1.49 to 1.83]
Global
High
0.48 [0.43 to 0.53]
0.16 [0.14 to 0.18]
0.34 [0.31 to 0.37]
Global
High
Ozone
Stratospheric
Tropospheric
-0.05 [-0.15 to 0.05]
0.35 [0.25 to 0.65]
Continental to global
Med
Stratospheric water vapour from CH4
0.07 [0.02 to 0.12]
Global
Low
Surface albedo
Land use
Black carbon on snow
-0.2 [-0.4 to 0.0]
0.1 [0.0 to 0.2]
Local to continental
Med - Low
Total Aerosol
Direct effect
-0.5 [-0.9 to -0.1]
Continental to global
Med - Low
Cloud albedo effect
-0.7 [-1.8 to -0.3]
Continental to global
Low
Linear contrails
0.01 [0.003 to 0.03]
Continental
Low
Solar irradiance
0.12 [0.06 to 0.30]
Global
Low
Total net anthropogenic
1.6 [0.6 to 2.4]
-2
-1
0
1
2
Radiative Forcing (W m-2)
©IPCC 2007: WG1-AR4

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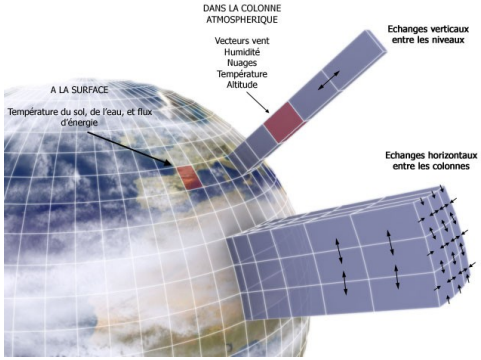
Aim Provide Global 3D concentrations/loads of aerosols & ozone from 1850 to 2100

Usages

Forcing for the french Earth System Models (IPSL-CM5 or CNRM-CM5) for AR5/CMIP5 runs

Boundary conditions for Air Quality Models

AC&C intercomparison project



Inputs

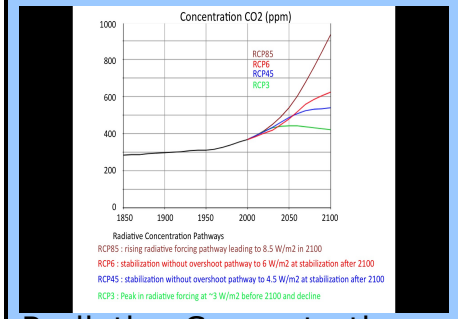
Atmospheric Models

Outputs

Athropogenic emissions for aerosols and tropo O3 precursors (Lamarque et al. 2010 and RCP pathways)

Biogenic emissions (isoprene, terpenes) & Sea salt & Dust kept at the present-day level

Evolution of climate forcing agents :
- Landuse
- SST
- [Long-lived-GHG]



Radiative Concentration Pathways

INCA Chemistry Model
- Natural aerosol emissions
- aerosol transport and
- photochemistry (NMHC/NOx/O3)
- wet and dry deposition ...

General Circulation Model

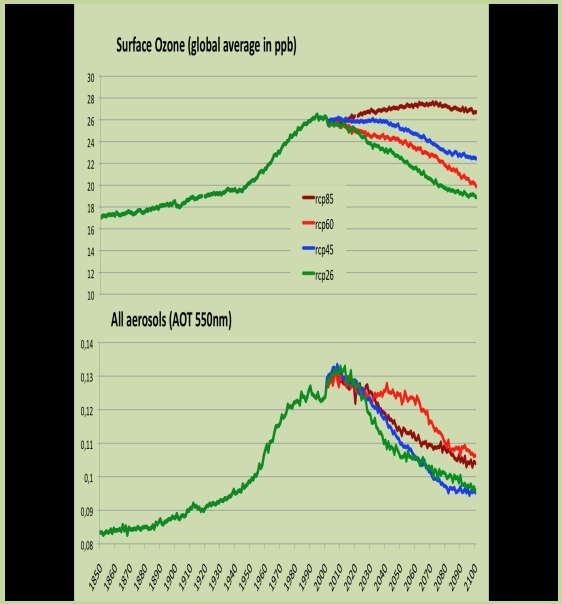
Large scale advection of tracers

LMDz

Resolution: 3.75°x1.9°x19 vertical levels (surf to 35 km)

3D fields: tropospheric ozonechemistry (mineral, sea-salt, BC, OC, sulfur, dust)

Temporal Evolution between 1850 and 2100



Historical period (1850-2000): HADiSST

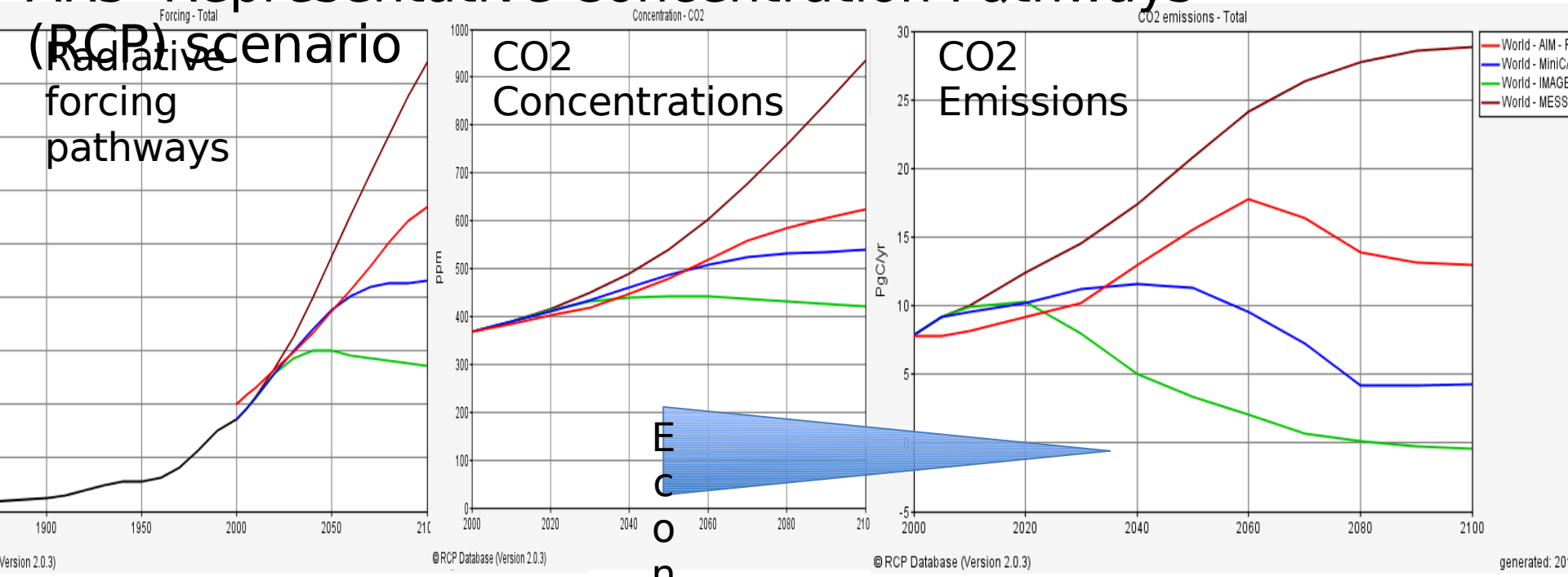
Analogy between AR5 and AR4 scenario, used to apply SST from ESM (IPSL-CM4) runs

AR5	**AR4**
RCP8.5	A2
CP6.0	A1B
RCP4.5	B1
RCP3.6	E1 from ENSEMBLE EU project

CPU time required: ~1 year

Note: Strato O3 computed by LATMOS/IPSL on the CCMVAL basis and

AR5 'Representative Concentration Pathways' (RCP) scenario



	Description[1]	Publication – IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 in 2100.	Riahi et al. (2007) – MESSAGE
RCP6	Stabilization without overshoot pathway to 6 W/m^2 at stabilization after 2100	Fujino et al. (2006) and Hijioka et al. (2008) – AIM
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2 at stabilization after 2100	Clarke et al. (2007) – MiniCAM
RCP3-PD[2]	Peak in radiative forcing at ~ 3 W/m^2 before 2100 and decline	van Vuuren et al. (2006, 2007) – IMAGE

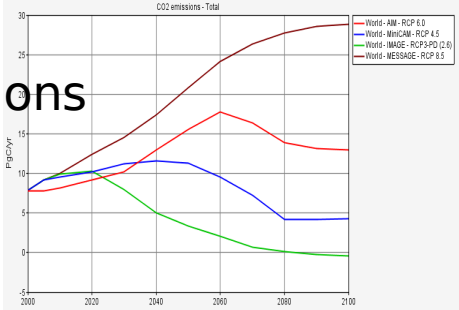
Notes:
[1] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m^2 relative to pre-industrial levels Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents.
[2] PD = peak and decline.

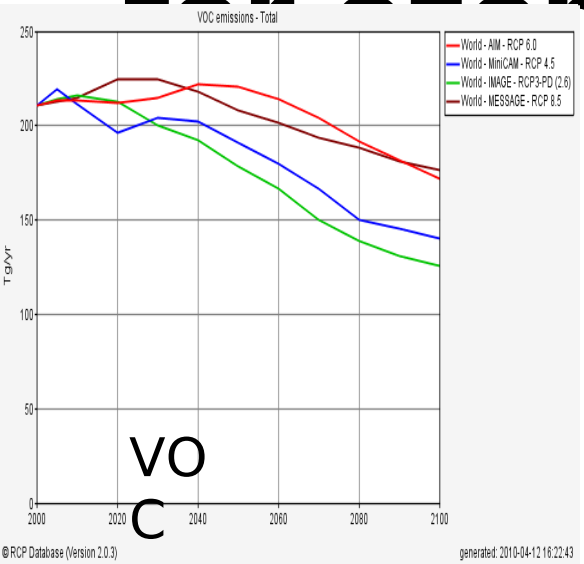
From http://www.iiasa.ac.at/web-apps/tnt/RcpDb/

Ozone troposherique

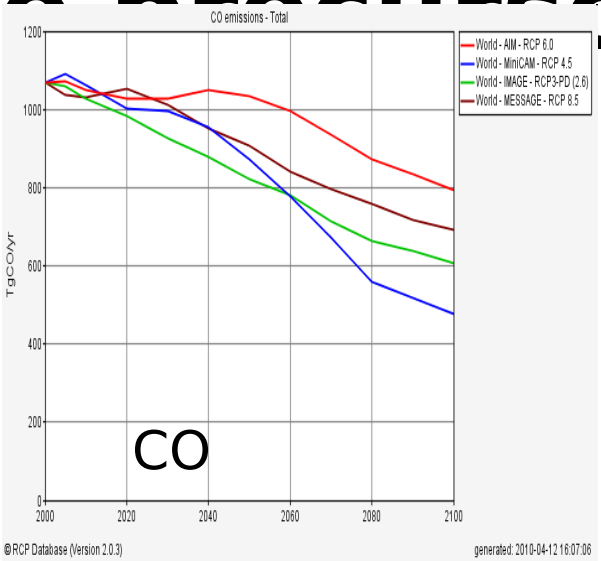
Anthropogenic emissions for ozone precursors

CO2 Emissions

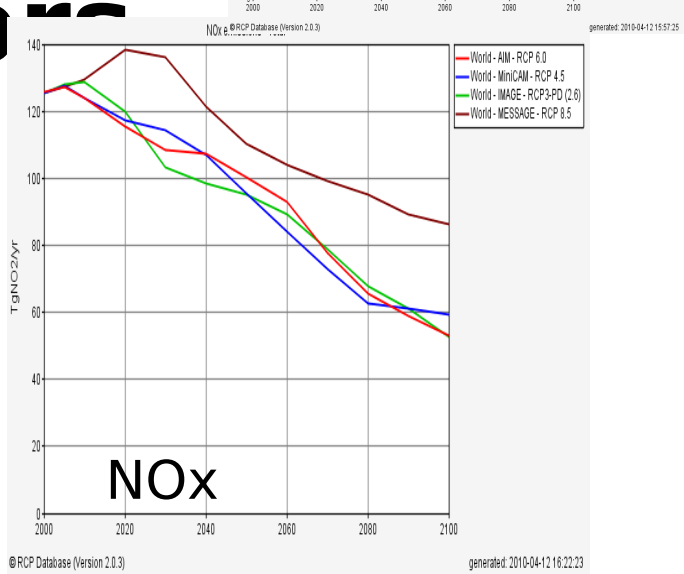




VOC



CO



NOx

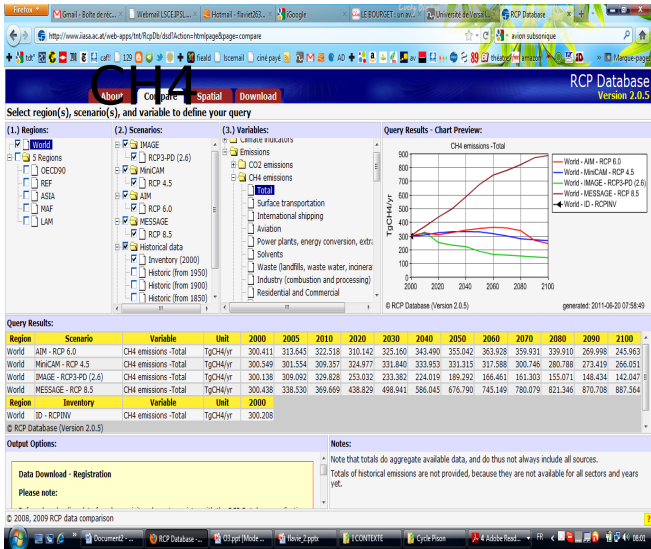
RCP8 5

RCP 6

RCP4 5

RCP 3

CH4



VOC + CO + CH4+ NOx Ozone tropo

 forcage positif

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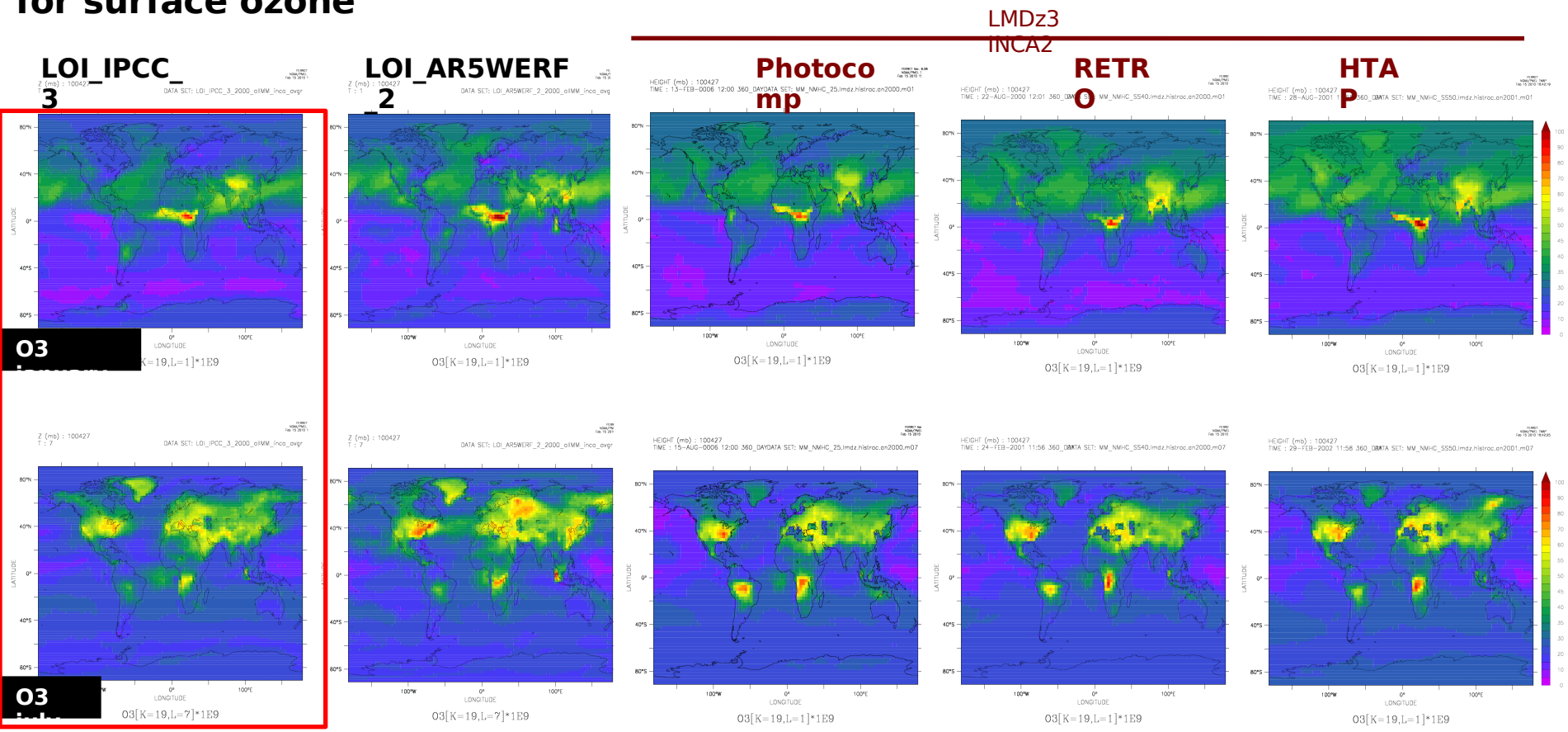
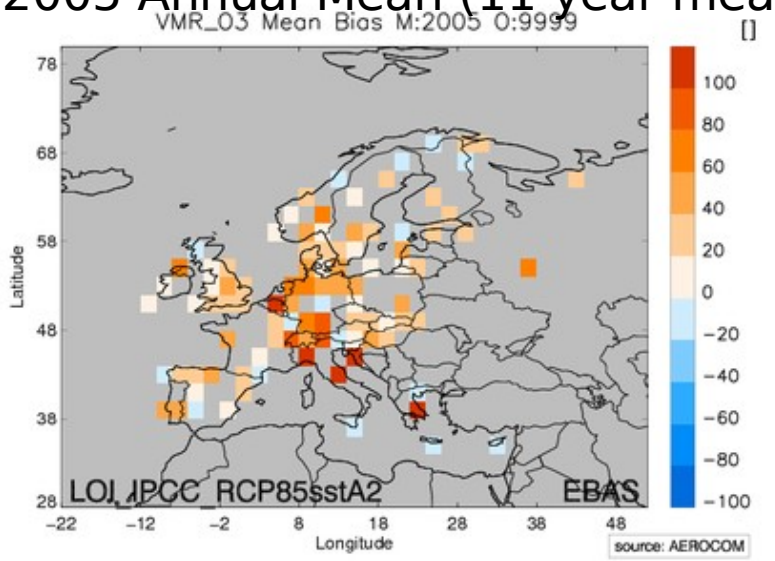
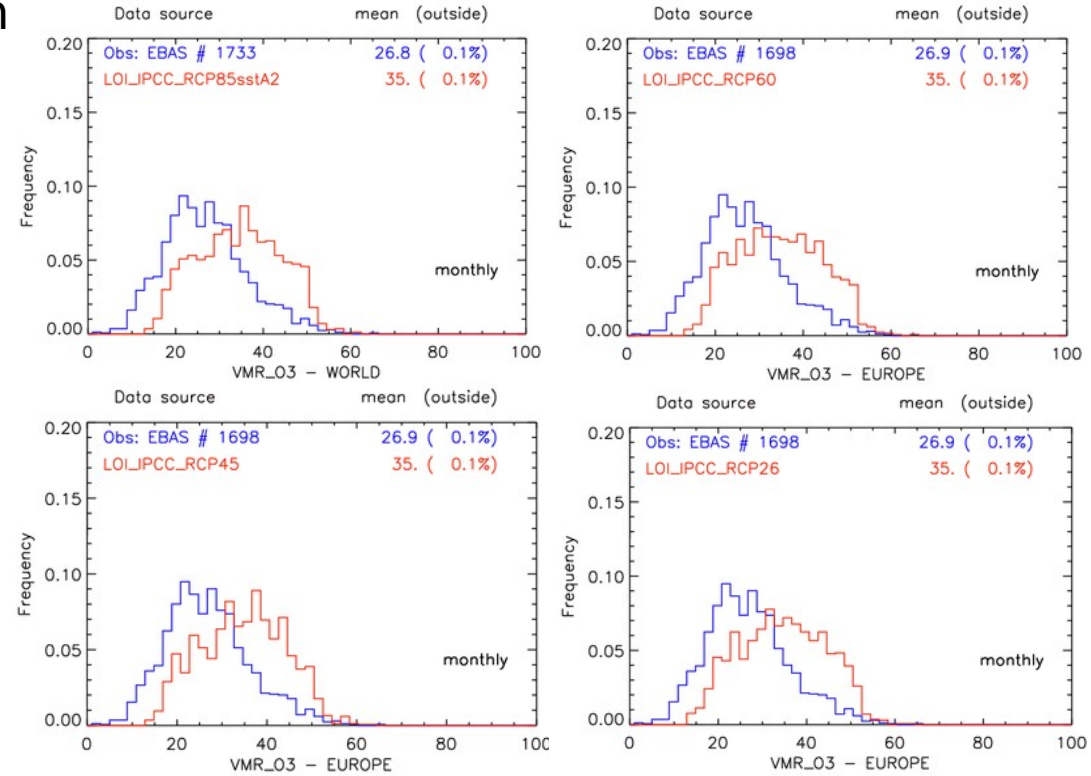
Are the past and present-day concentrations realistic?

Comparisons for the year 2000 with previous runs for surface ozone



Surface ozone bias compared with EBAS data (%)
2005 Annual Mean (11 year mean`





Source AEROCOM/M. Schulz

<u>Work in progress:</u>

Comparison with TES satellites data (Audrey Fortems-Cheiney - LSCE)

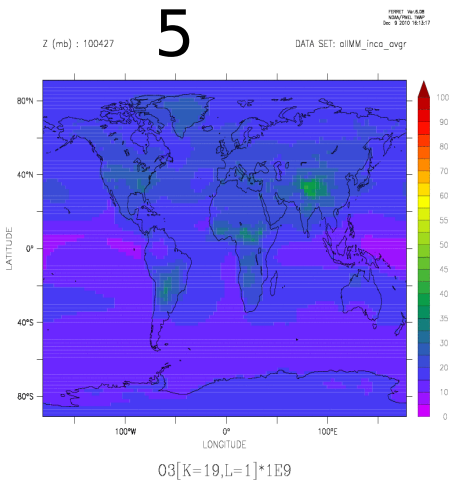
Comparison with a IASI ‘climatology’ being produced by Solène Turquety (LMD)

Evolution of ozone

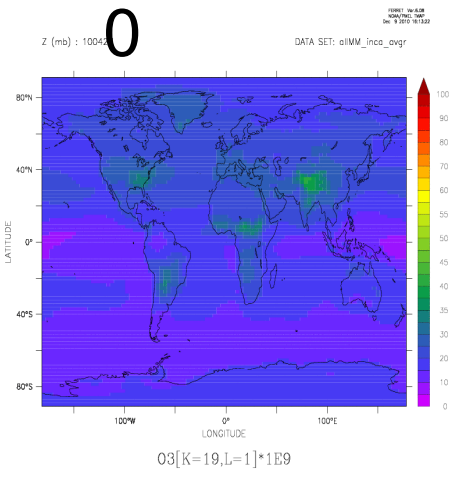
Surface Ozone (11 year mean)

Historical run

1855 1900 1950 1995



O3[K=19,L=1]*1E9



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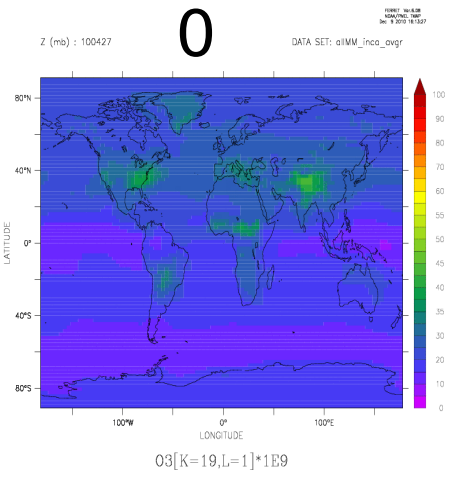
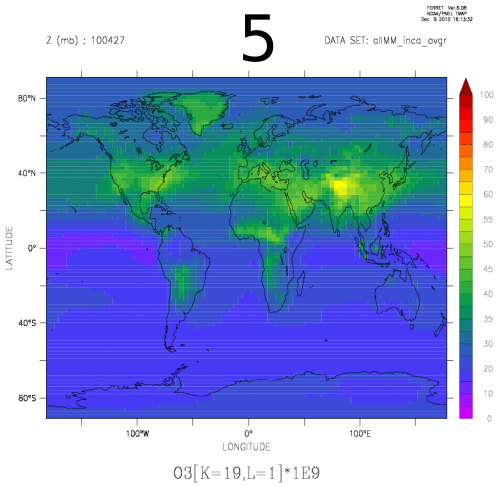


O3[K=19,L=1]*1E9



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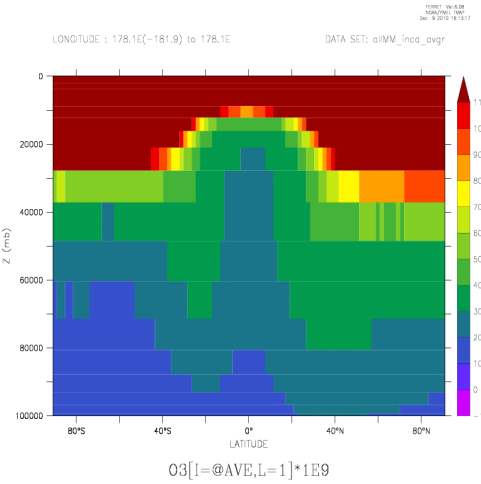
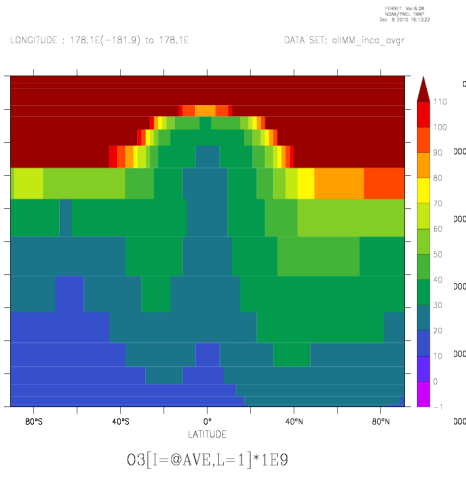


O3[I=@AVE,L=1]*1E9



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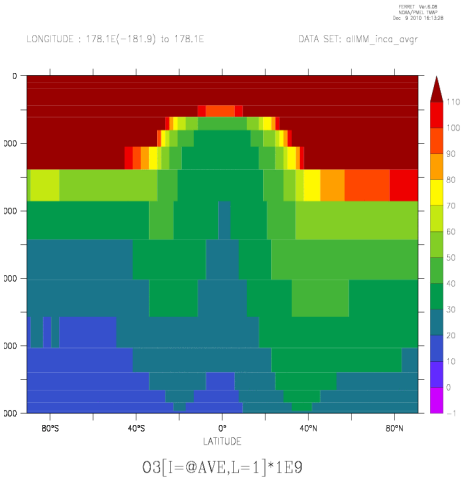

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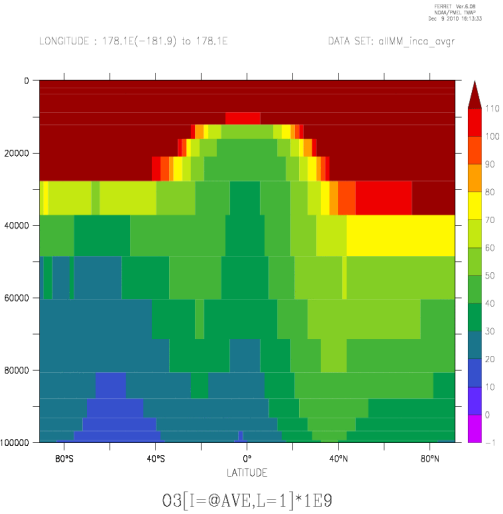

O3[I=@AVE,L=1]*1E9

Zonal Mean Ozone (11 year mean)

Evolution of ozone

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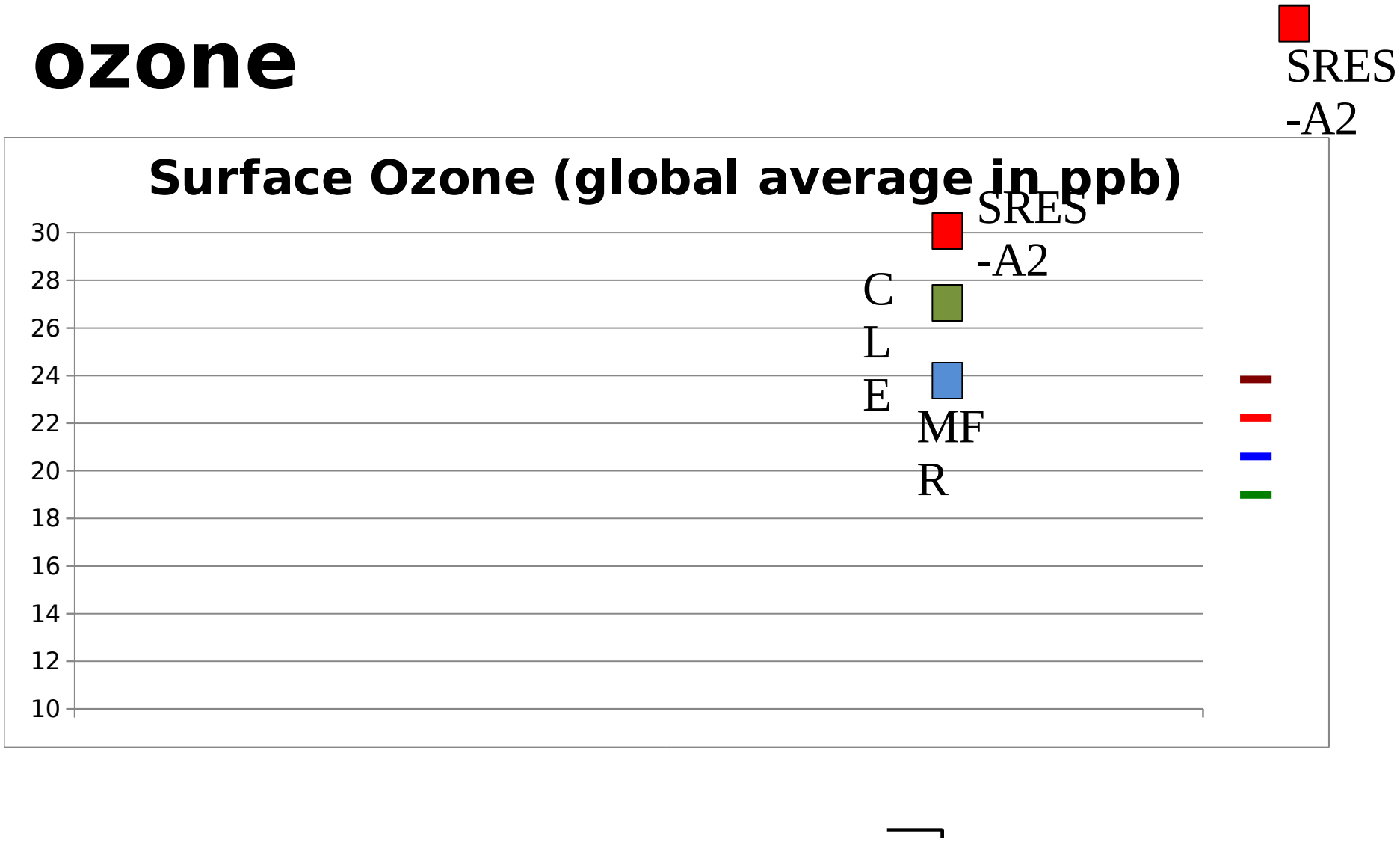
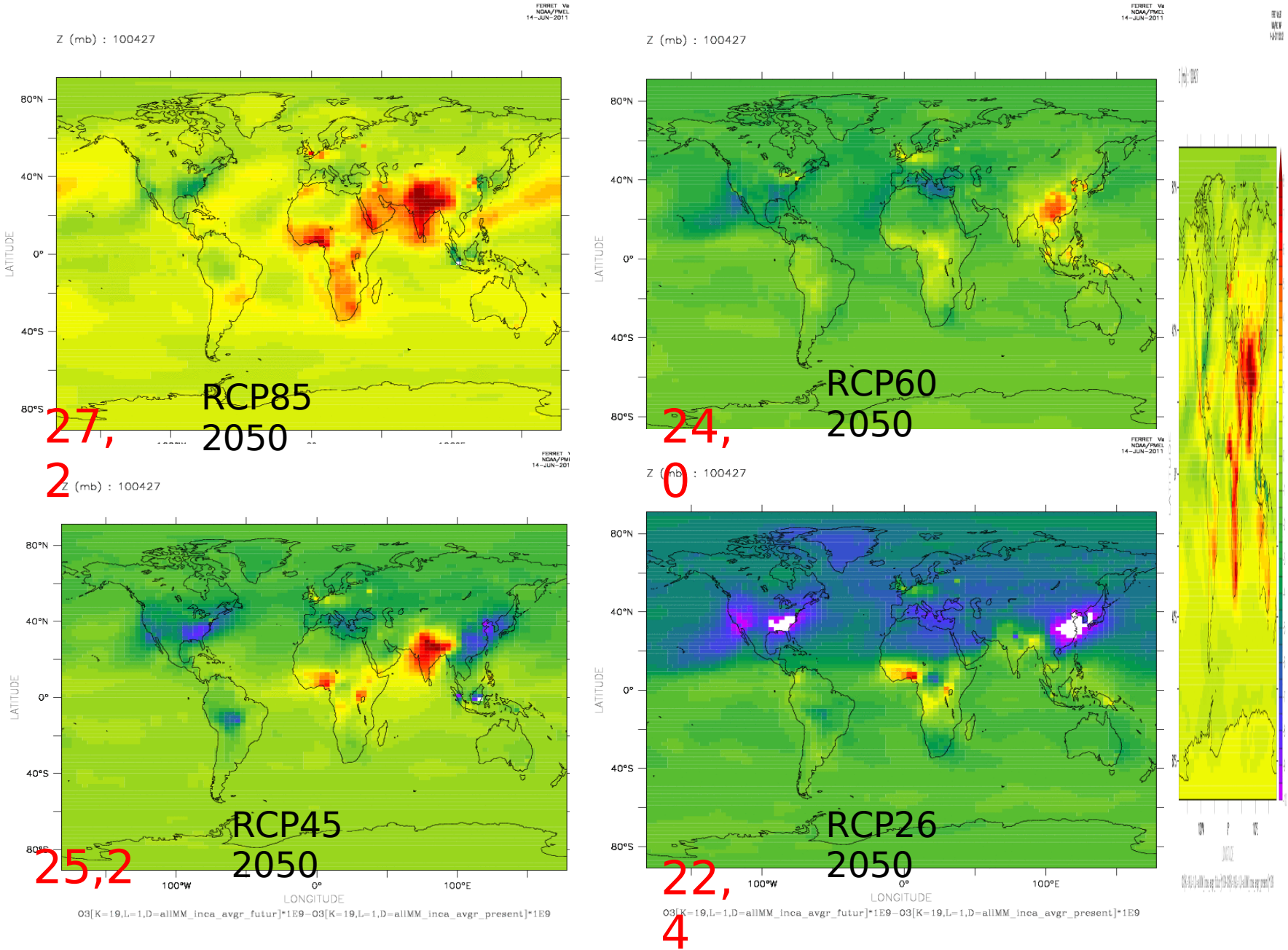
Evolution of ozone

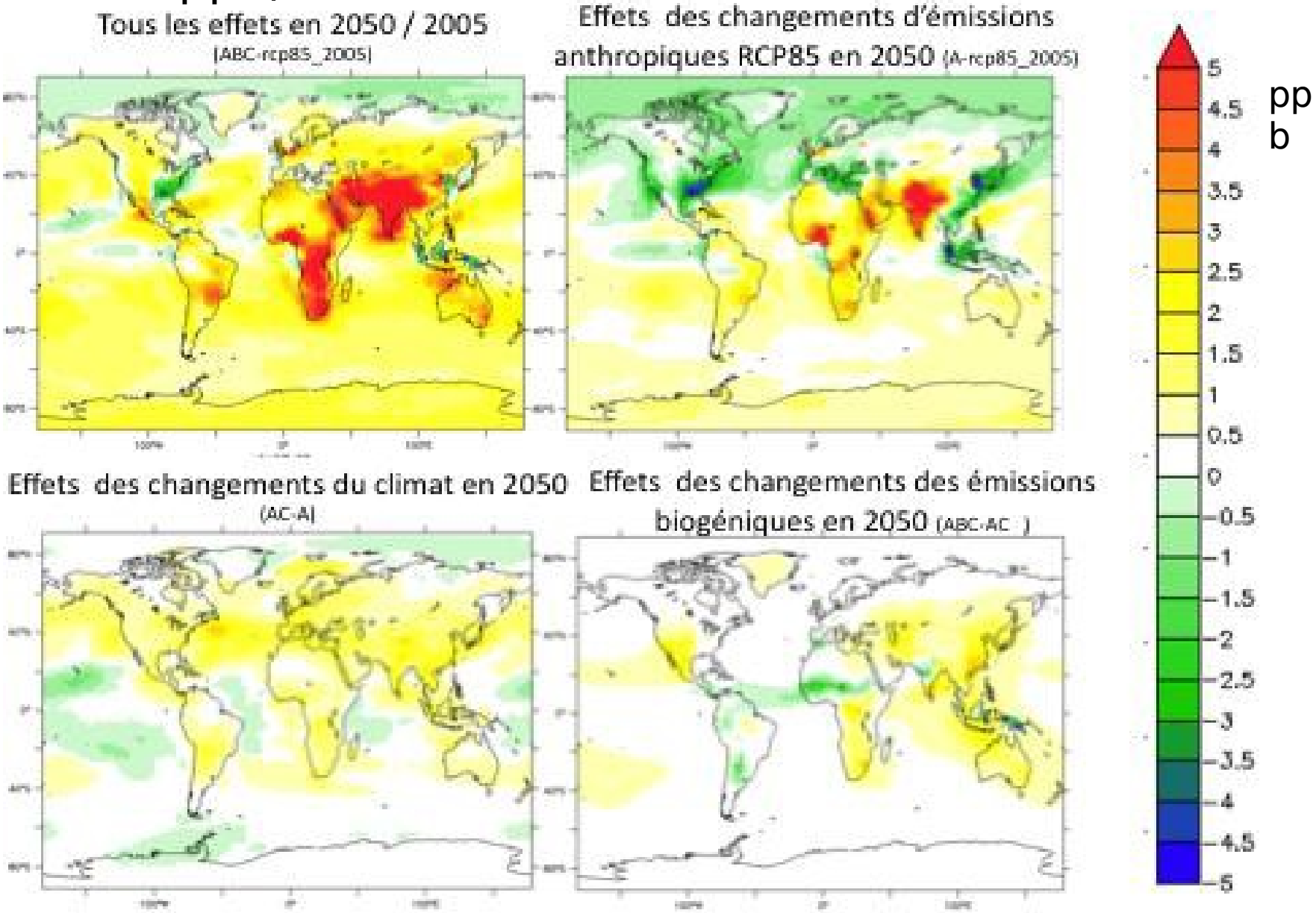


Local Ozone observations gathered by Marenco et al.

Changements d'ozone en % pour les RCP (comparé à 2005) – basés sur des moyennes annuelles sur 11 ans

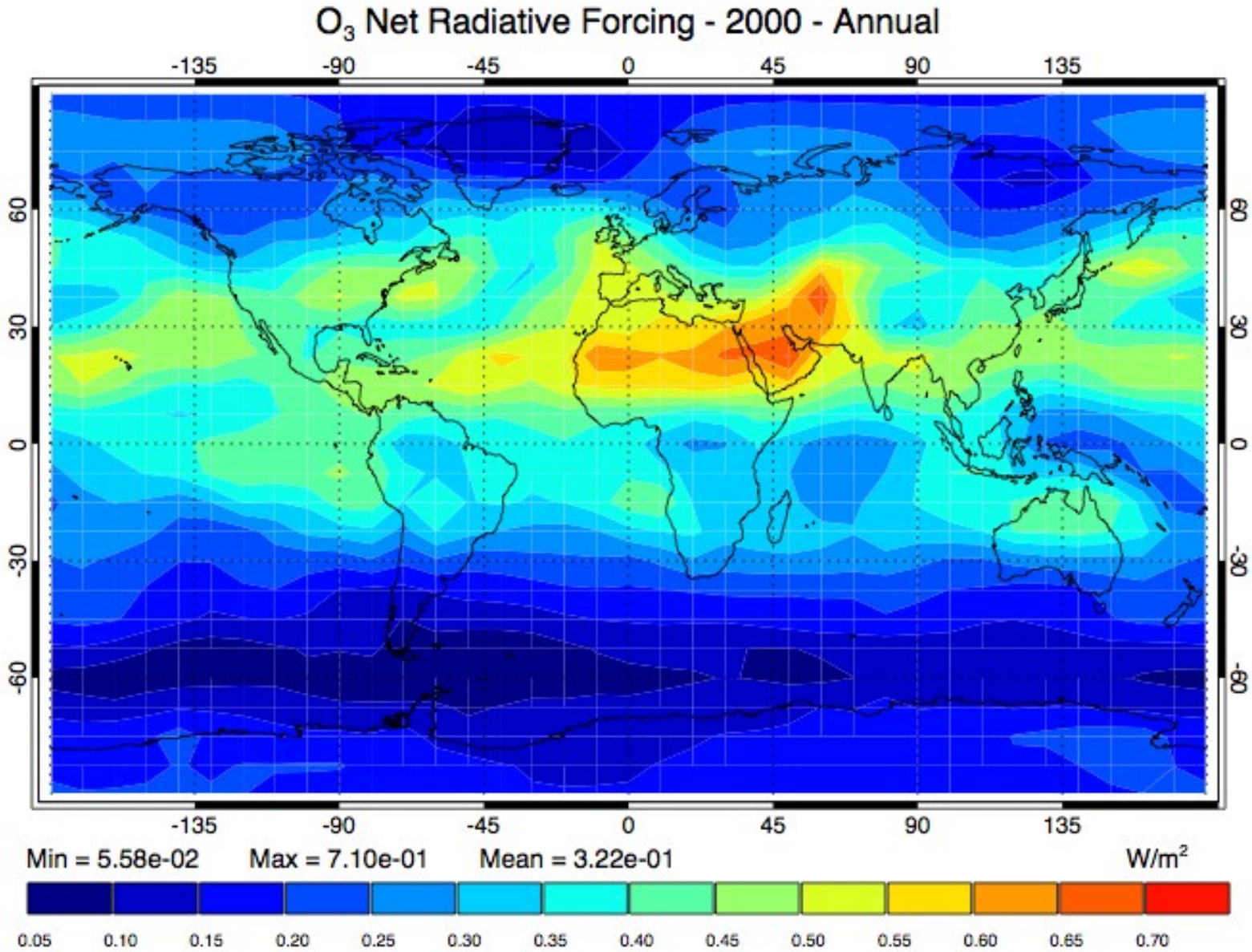


Discrimination des effets (changements d'O3 en ppb)



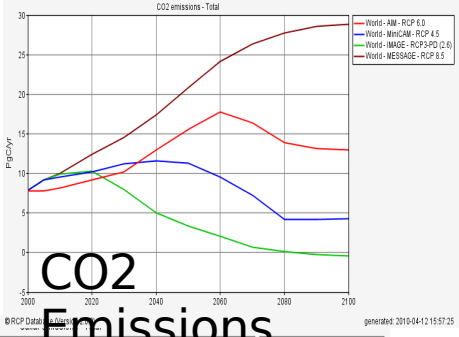
Ozone Radiative forcing

0.32 W/m2
[0.35 dans l'AR4]

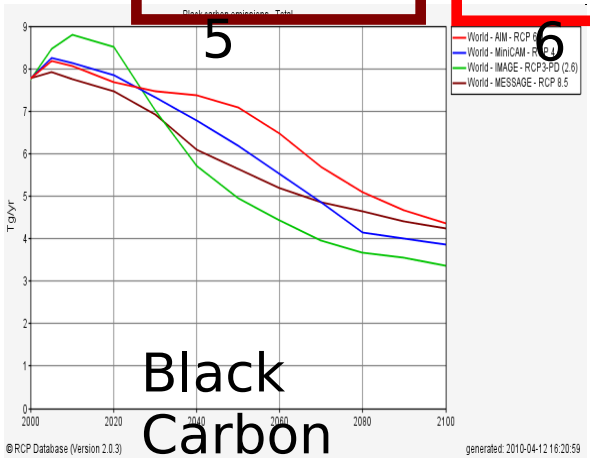


Aerosols

Anthropogenic emissions for aerosols

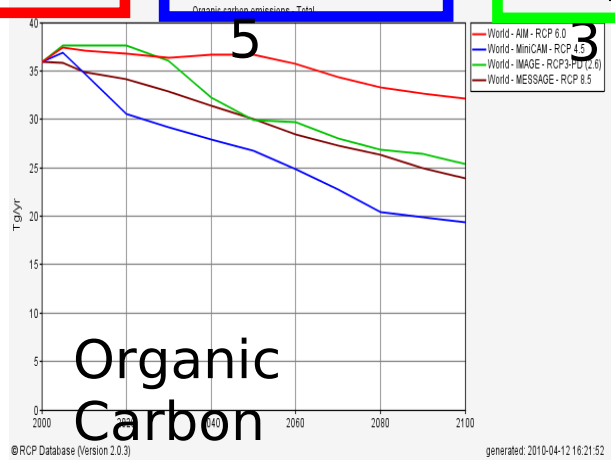


RCP8 5

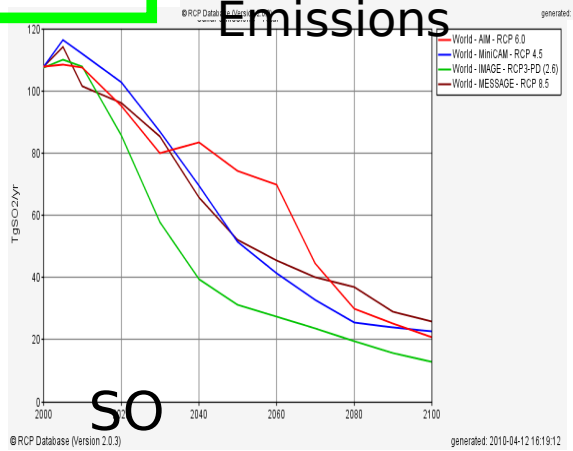


RCP 6

RCP4 5



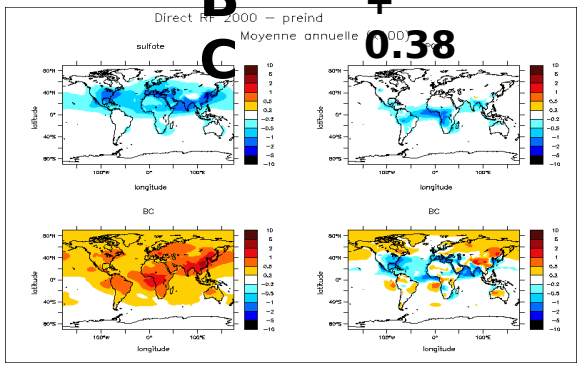
RCP 3



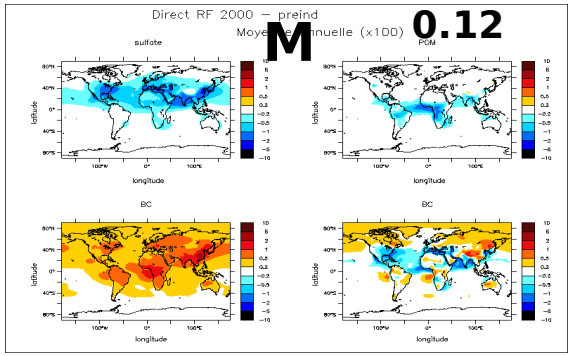
Direct Effect distribution

Radiative Forcing (W/m²)

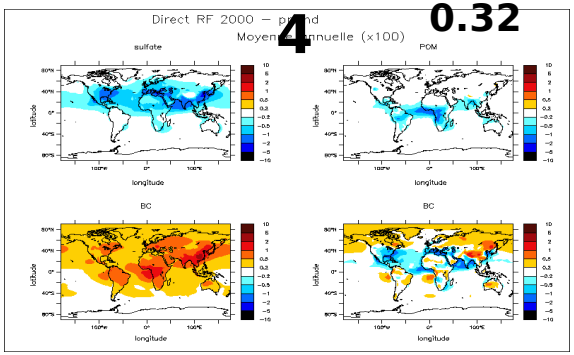
B C +0.38

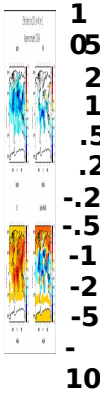


PO M -0.12



SO 4 -0.32





These C. Déandreis 2008

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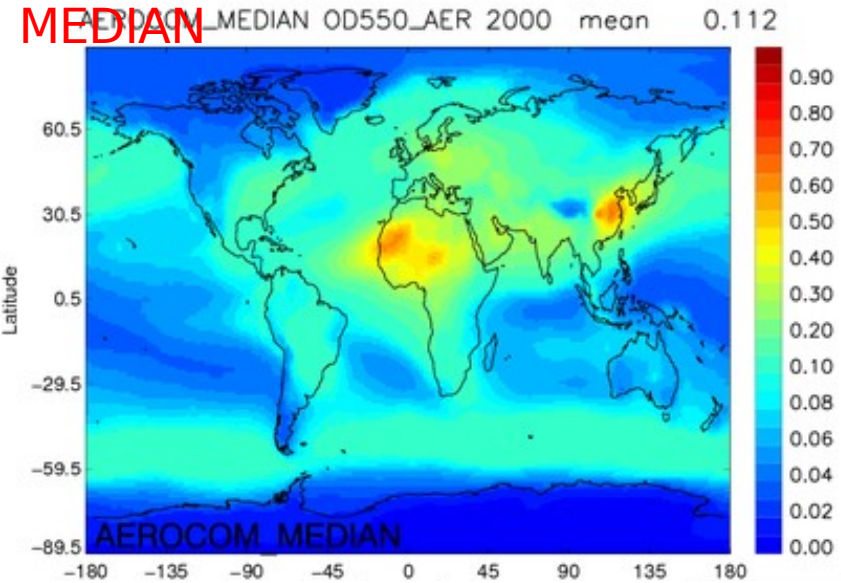
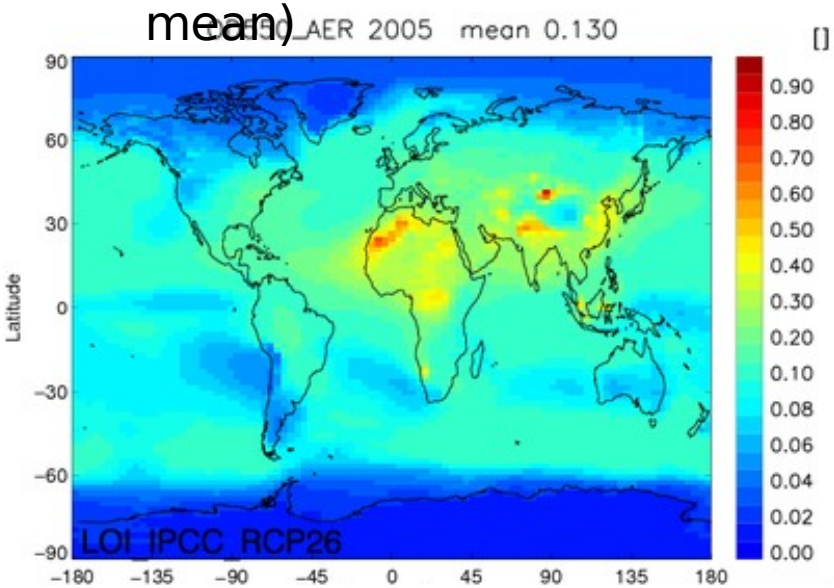
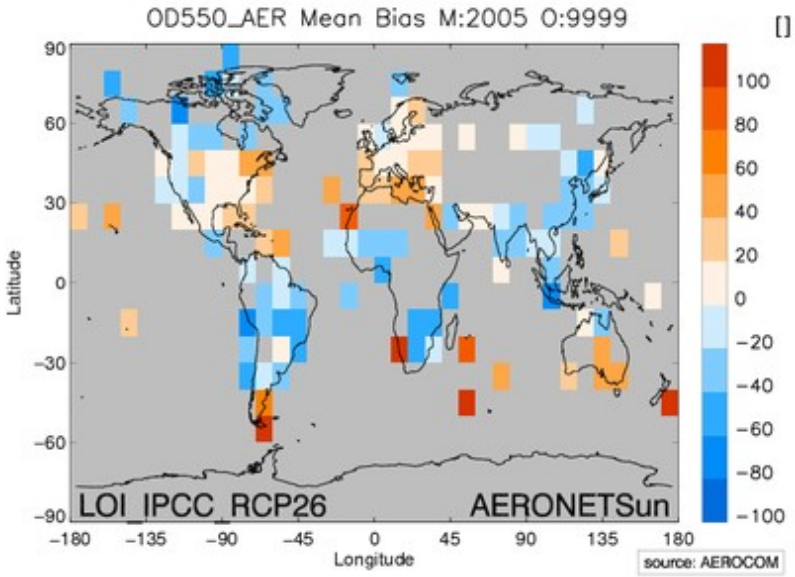
Aerosols

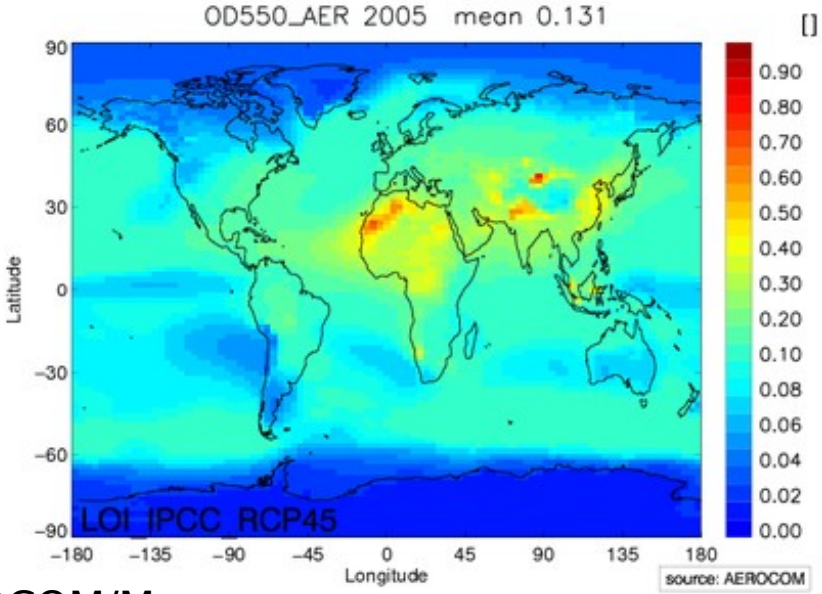
AEROCOM MEDIAN

RCP26 – 2005 (11 year mean)



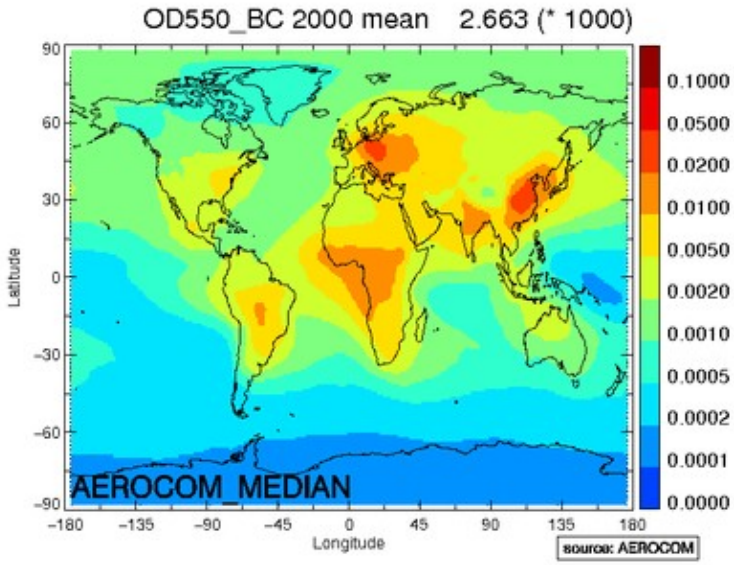


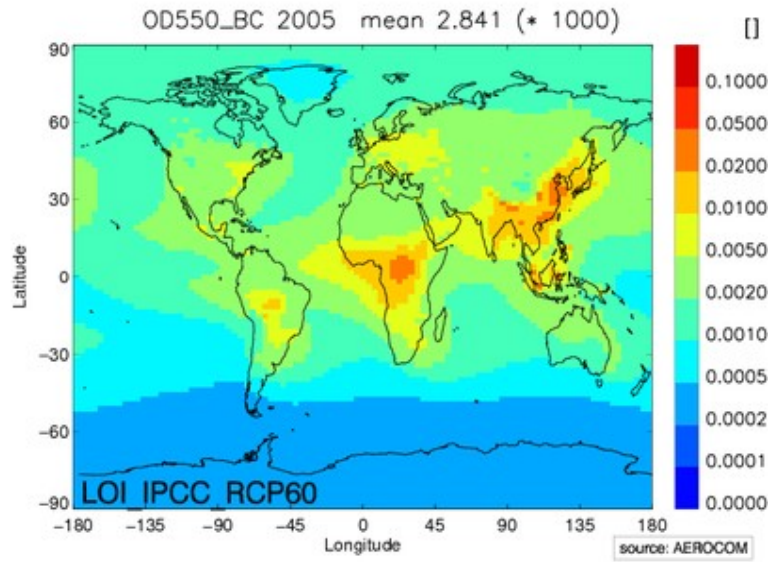




Source AEROCOM/M.

Aerosols (by sources)





Black Carbon

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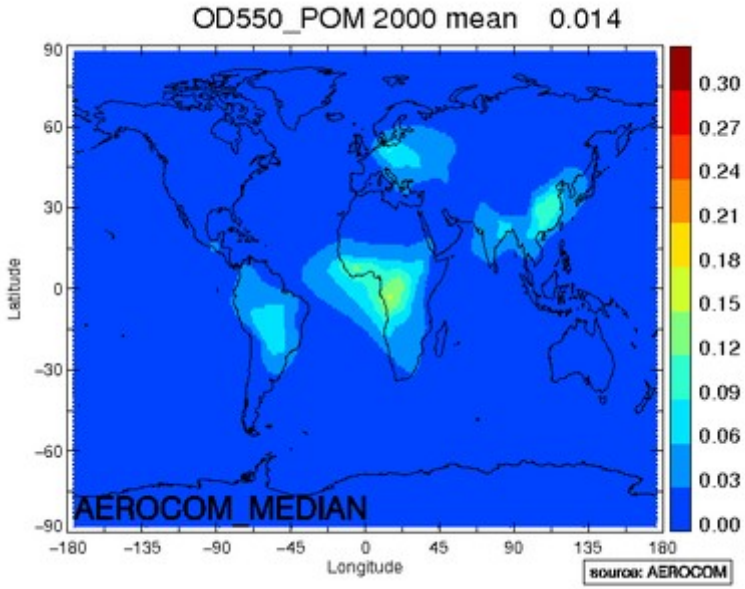
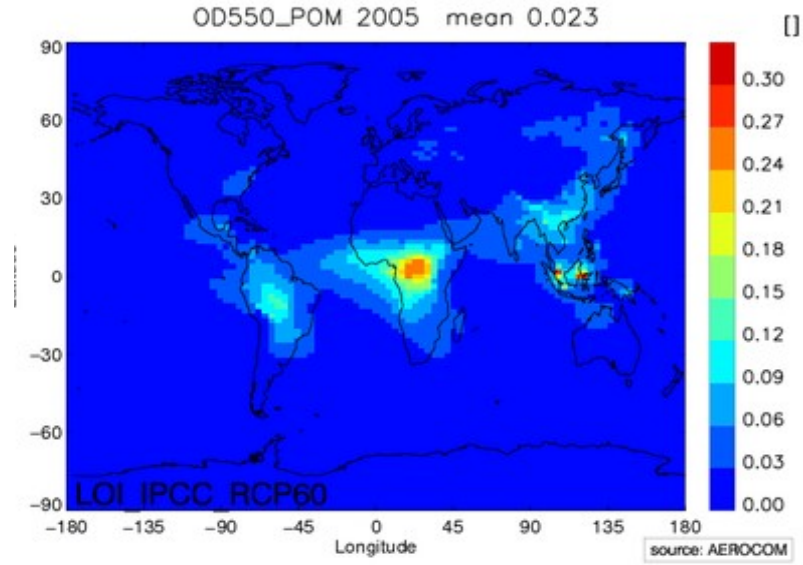
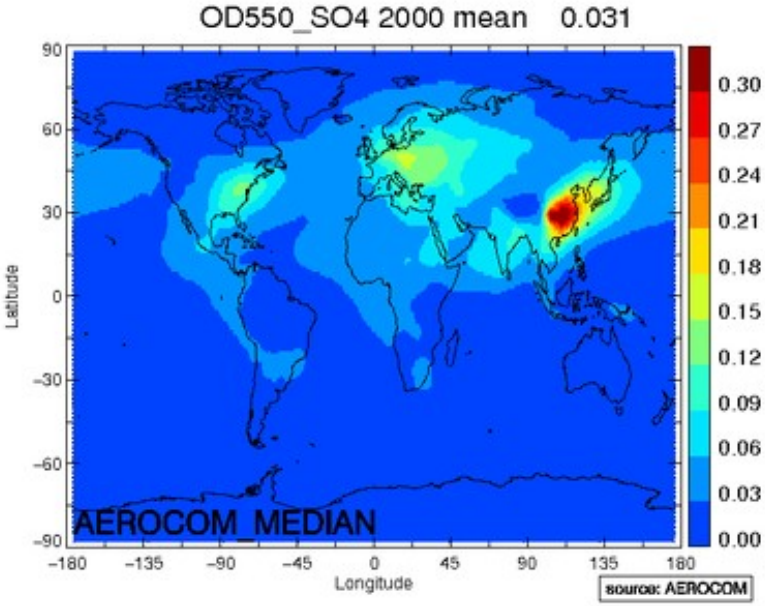
Source AEROCOM/M.

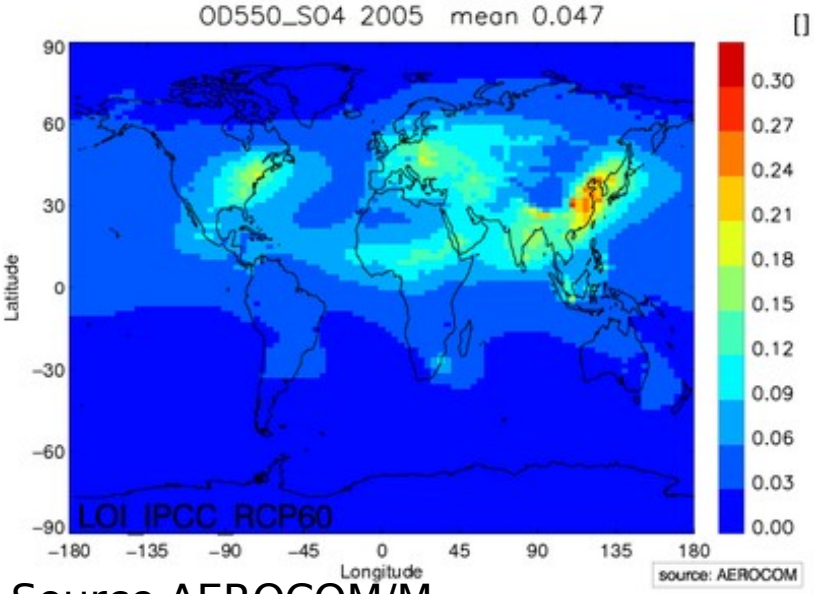
Aerosols (by sources)





Particulate Organic Matter

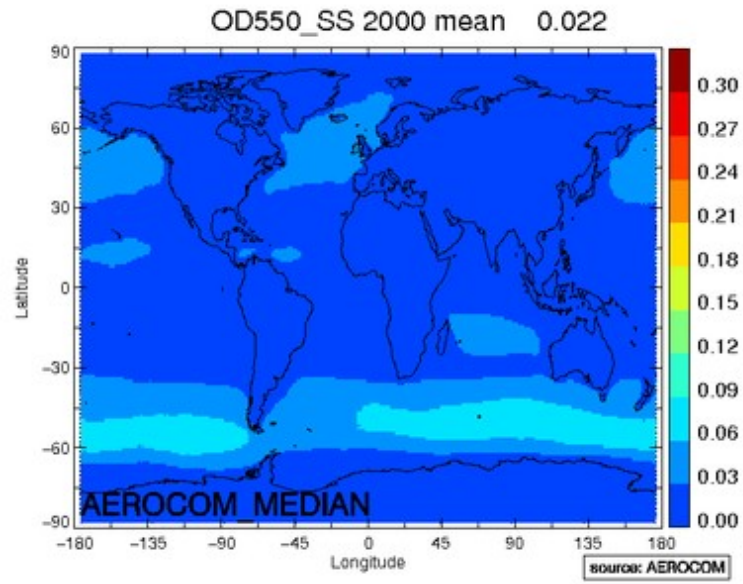


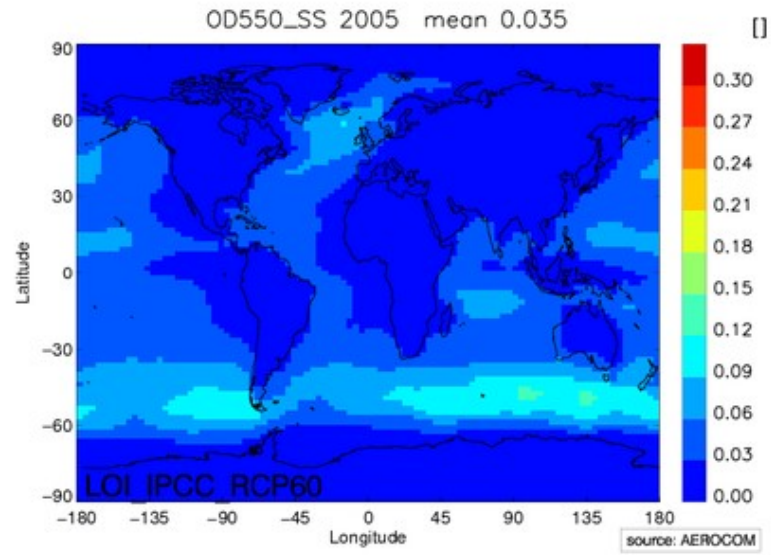


Sulfates

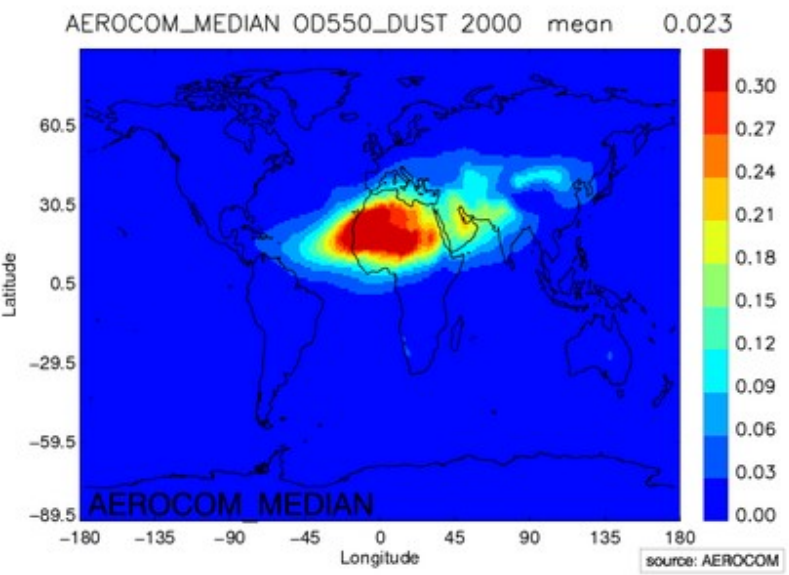
Source AEROCOM/M.

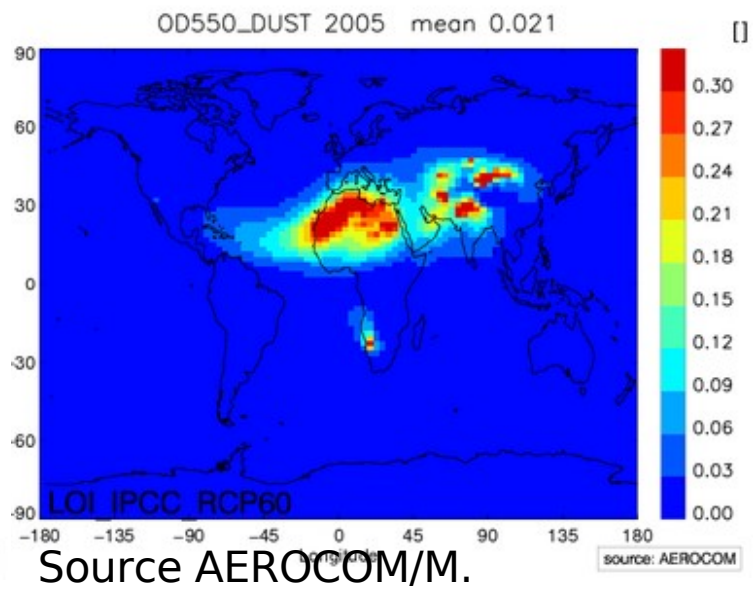
Aerosols (by sources)





Sea salt



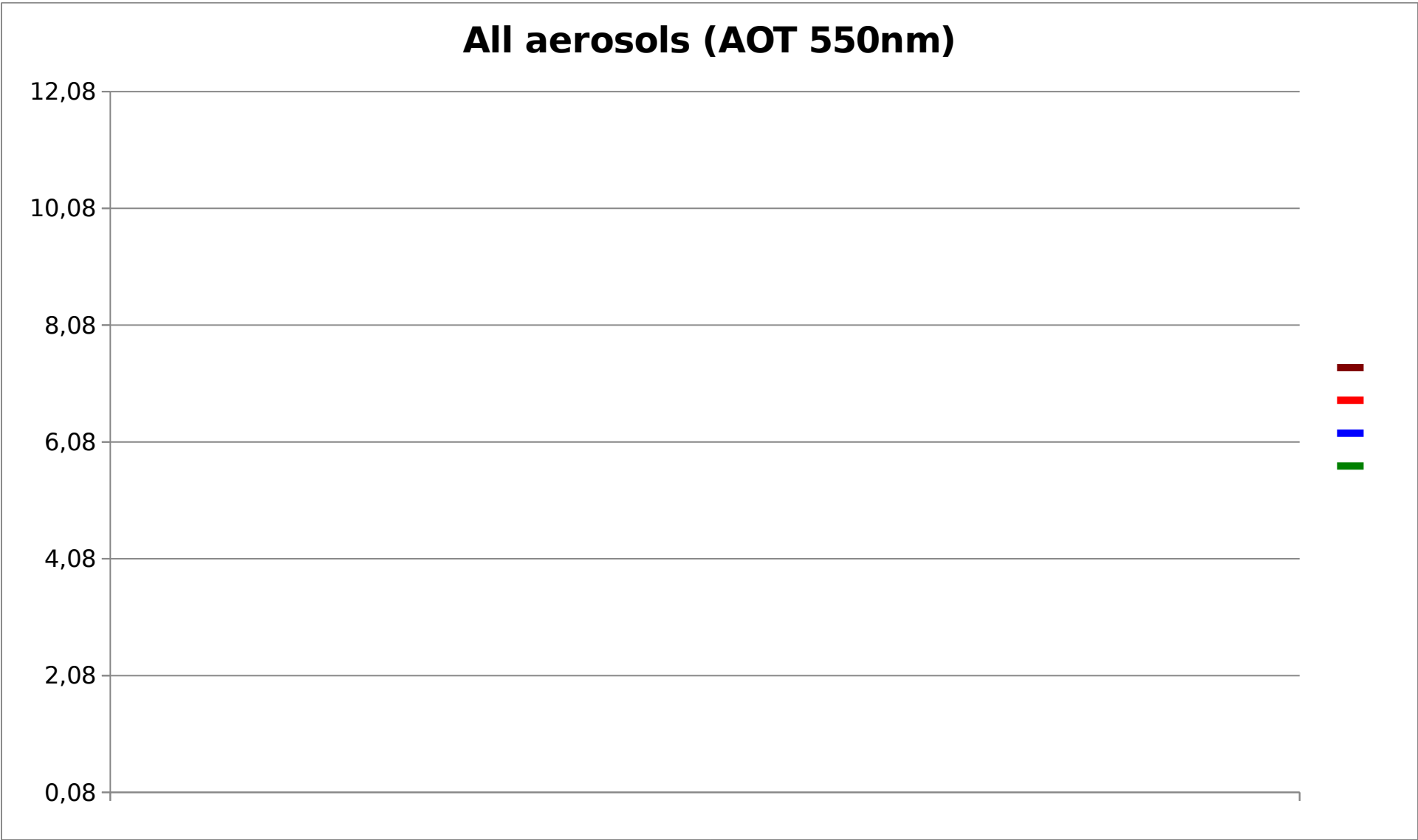


Dust

Source AEROCOM/M.

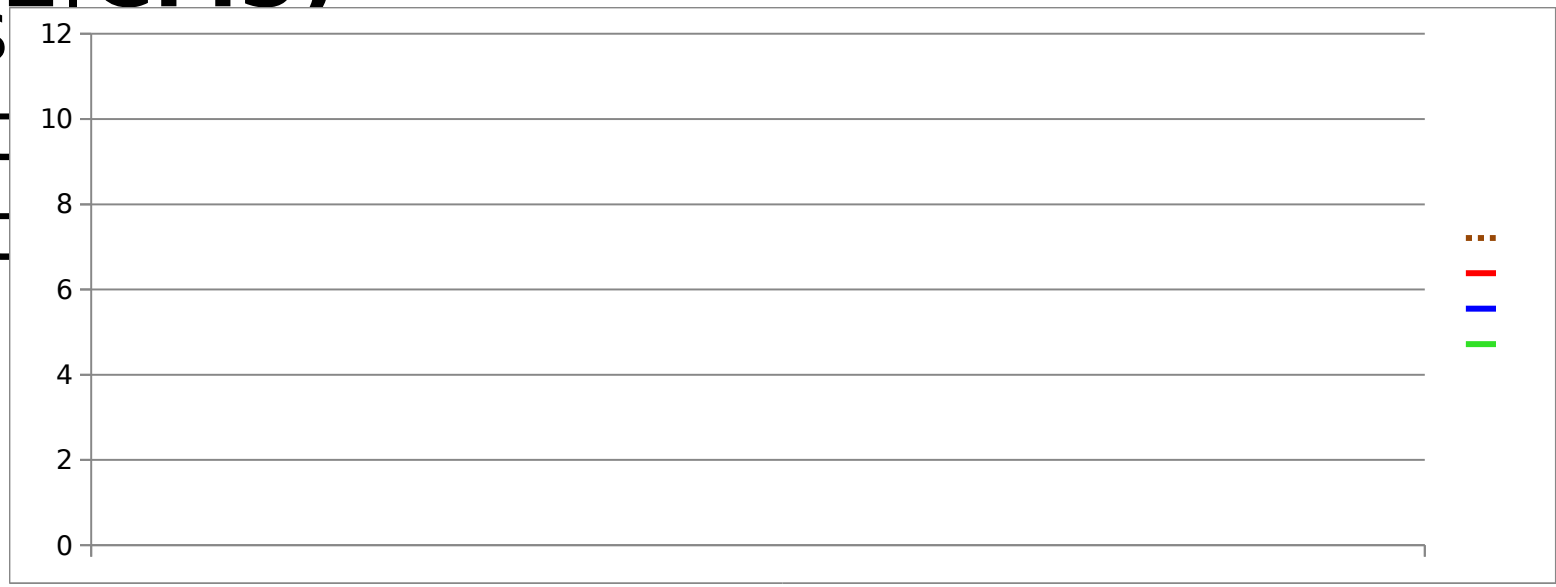
Evolution of aerosols

Aerosol Optical Depth at 550 nm (11 year mean)

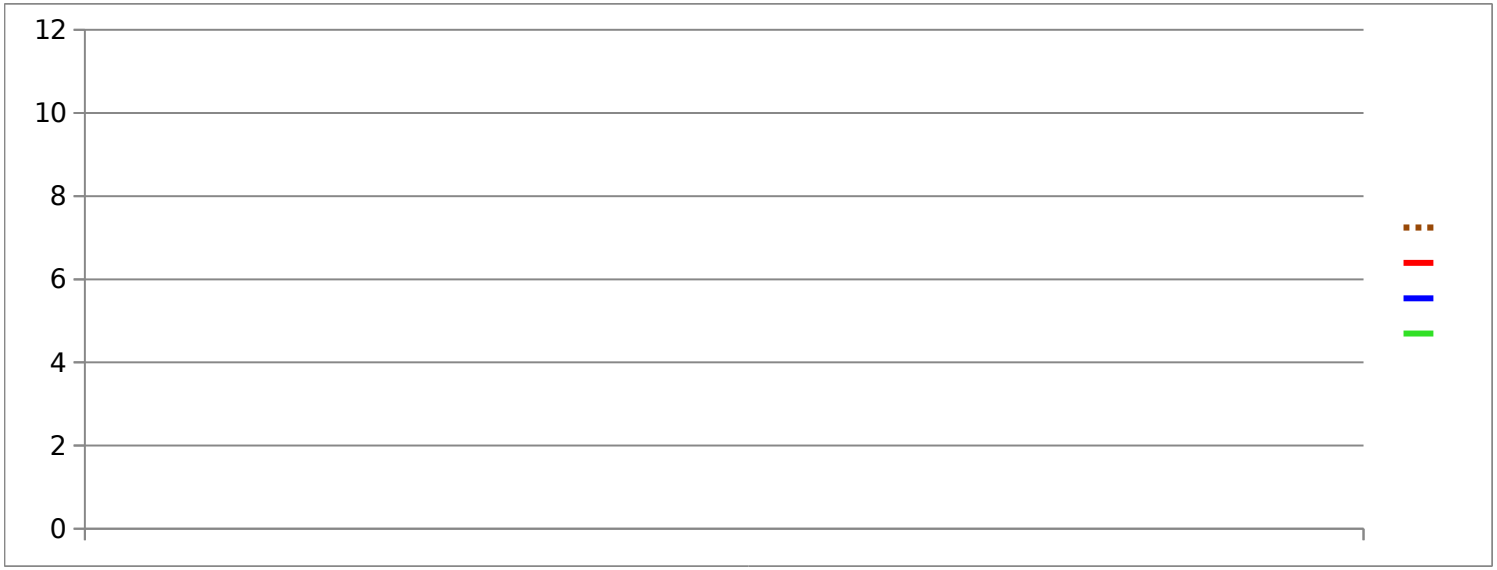


Aerosol Radiative Forcing (simulated by IPSL-CM5)

Aeros
direct
effect



Aeros
ol
indire
ct
effect



Changes in tropospheric aerosol and reactive gases burdens and concentrations under IPCC-AR5 emission scenarios for 1850-2100 – Szopa et al.

A. **Intro**

B. **Methodology**

Dans le modèle du système Terre de l'IPSL

Set-up des simulations LMDzINCA

C. Evolution des concentrations d'ozone et d'aérosols dans ces simulations (et de quelques variables de climat, Tglobale, precip ???)

D. Réalisme des concentrations simulées pour le présent

E. Réalisme des tendances entre <u>préindustrielle</u> et présent, Discussion de la pertinence des niveaux préindustriels

F. Quantification de la Variabilité interannuelle de ces espèces et discussion sur le lissage différences entre champs 3D mensuels sur 19 niveaux en sortie d'INCA et valeurs lissées sur 11 ans et interpolés sur 39 niveau dans ESM => quel impact. (et au cnrm ?)

G. Forcages Radiatifs induits par l'ozone tropo et les aérosols de cette climatologie + forcage O3 strato

Conclusion

07/07/2011

Perspectives

ANALYSIS (on going)

- Assess the realism of the simulations (use of the AEROCOM database)
- Compute the radiative forcing for all species in a coherent framework
- Investigate separate effects of different type of aerosols for 2050 (Y. Balkanski)
- Paper in *Climate Dynamics* Special Issue focusing on IPSL-CM5 set-up and preliminary analysis

NEW SIMULATIONS (on going)

- Compute the future projections (at least 2050's and 2090's) with CMIP5 climate projections
- Re-run the historical simulation with correct POM
- Impact on Air Quality (regionalization with WRF and CHIMERE) over Europe
- Perform Earth system model simulations with interactive aerosols
- Fully couple biogenic emissions and chemistry

TECHNICAL PROCESSING (to be done)

- CMORisation of the outputs and upload on accmip database

Objectif : calculer la distribution et l'évolution des gaz à effet de serre réactifs et des aérosols

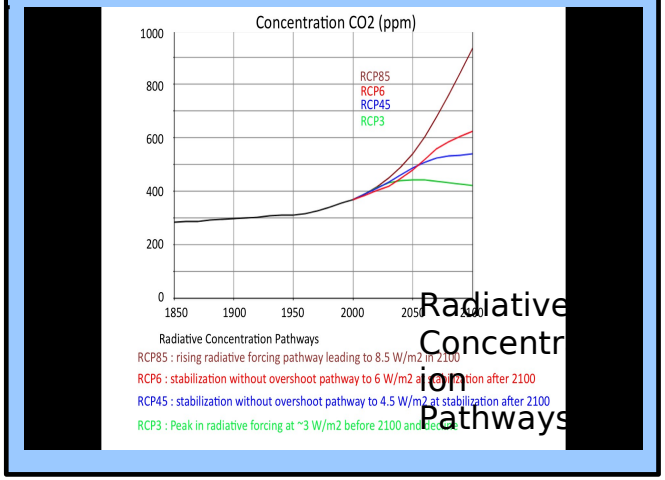
Pourquoi forcages chimie-aérosols des simulations systèmes Terre
IPSL et Météo-France
Comment ? modèle
LMDz-INCA

Entrées

Emissions anthropiques d'aérosols et précurseurs de l'ozone troposphérique

CH4, CO, NOx, 20 Composés Organiques

Evolution des forcages climatiques :
- Occupation des surfaces continentales
- Températures océaniques
- Concentrations GHG à longue durée de vie



Radiative Concentration Pathways

Modèles Atmosphériques

INCA Modèle de Chimie
- émissions naturelles d'aérosols marins et désertiques
- photochimie
- dépot sec et humide …

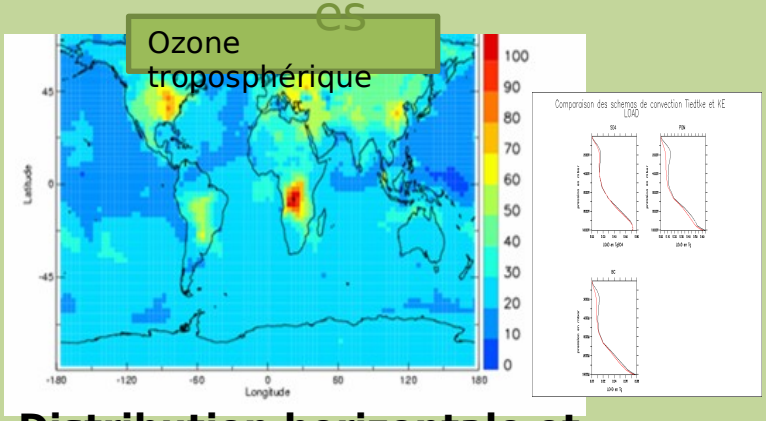
Modèle de Circulation Générale

Transport

LMDz

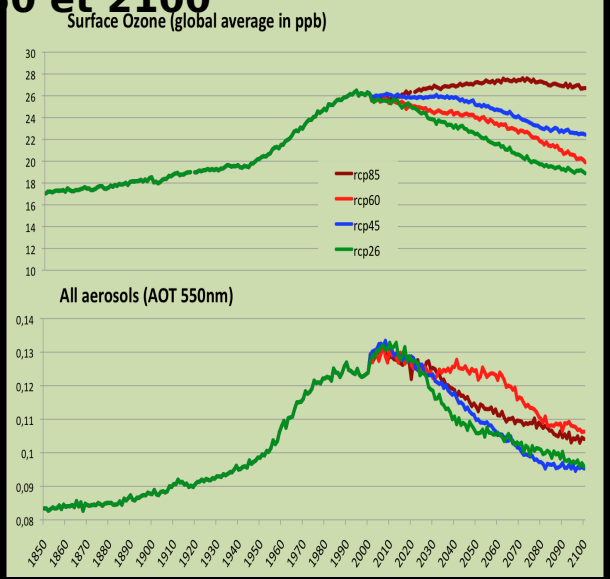
CPU time required: ~1 year

Sorties



Distribution horizontale et verticale : ozone troposphérique, aérosols suie, organiques, sulfatés, poussières désertiques, sels marins

Evolution temporelle entre 2000 et 2100



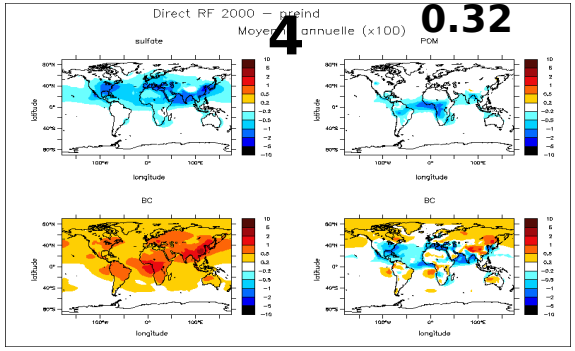
Aerosol Radiative Forcing

irect Effect distribution

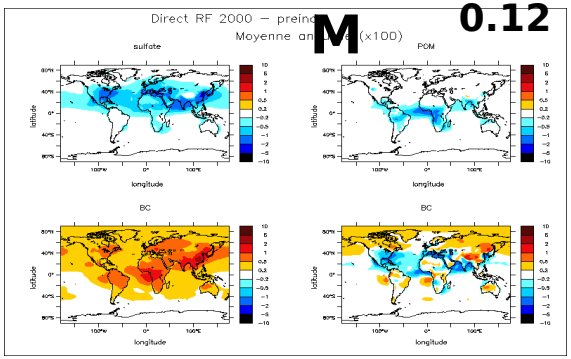
- ü Industrial region (SO4 et BC)
- ü Biomass burning regions (POM et BC)

adiative Forcing (W/m²)

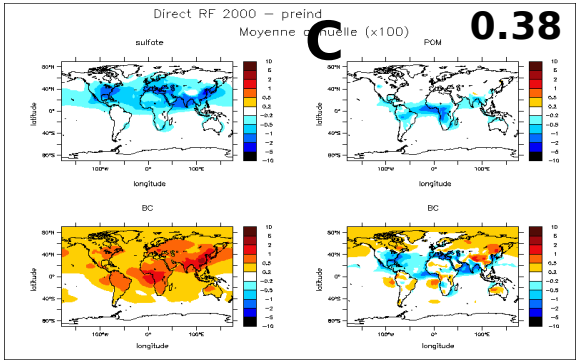
SO4 - 0.32

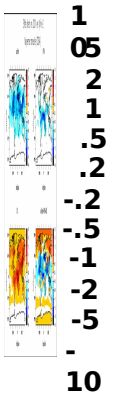


POM - 0.12

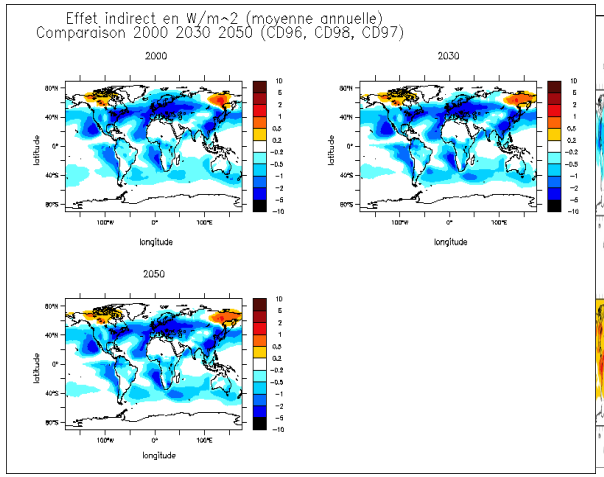


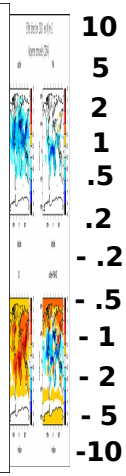
BC + 0.38





st Indirect Effect distribution





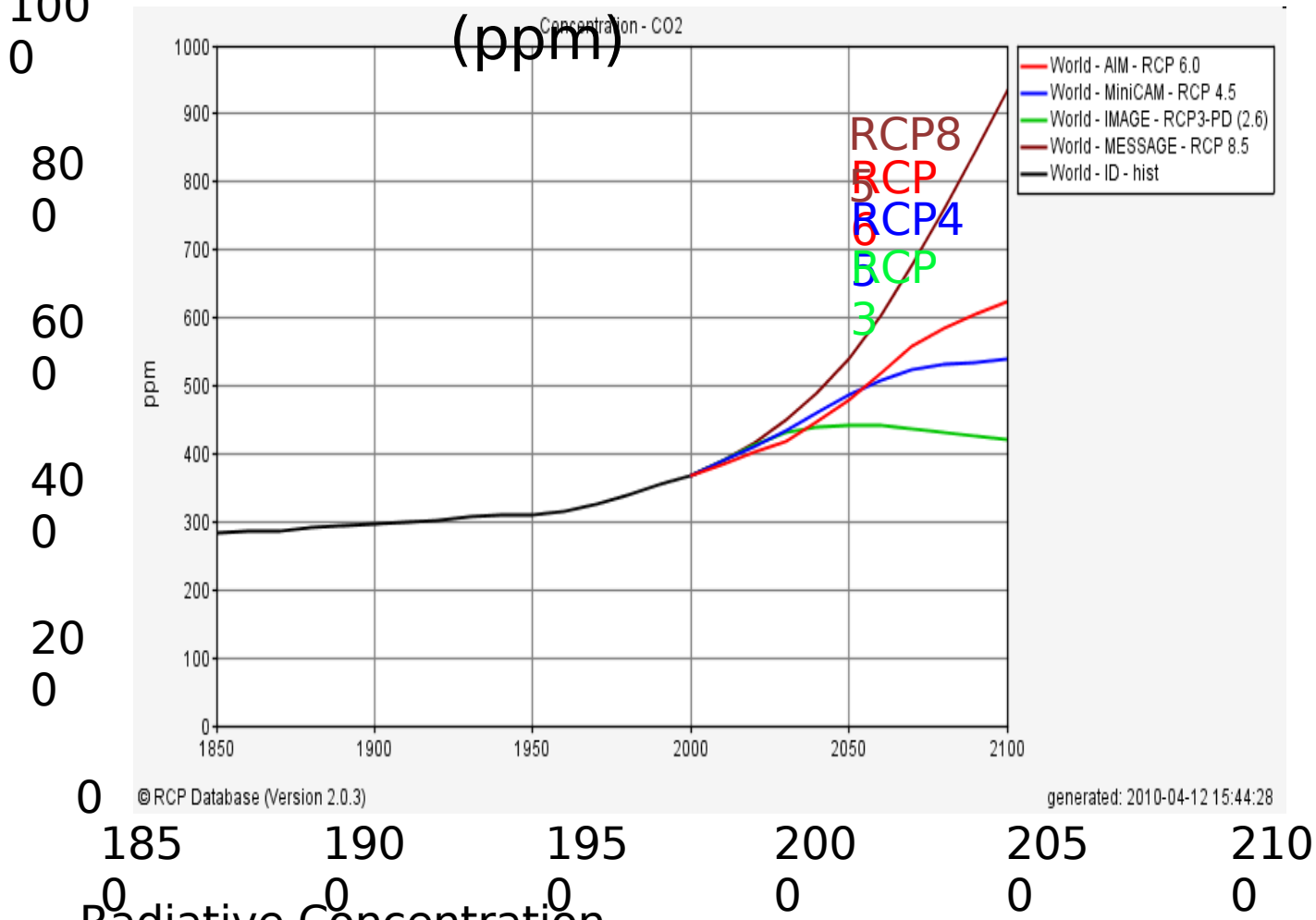
80 °N
40 °N
0 °
40° S
80° S
100°W
0°
100°E

Global Mean= - 0.46 W/m²

IPCC AR4: - 0.7 [-1.8 to -0.3] W/m²

07/07/2011

Concentration CO2 (ppm)



1000
800
600
400
200
0

1850 1900 1950 2000 2050 2100

Radiative Concentration Pathways

RCP85 : rising radiative forcing pathway leading to 8.5 W/m2 in 2100

RCP6 : stabilization without overshoot pathway to 6 W/m2 at stabilization a 2100

RCP45 : stabilization without overshoot pathway to 4.5 W/m2 at stabilizatio after 2100

RCP3 : Peak in radiative forcing at ~3 W/m2 before 2100 and decline

Forcing data

Atmospheric Models

Aim

Usages

Sea Surface Temperature + long lived [GHG] from AR4 (by analogy with AR5-rcp)

LMDz General Circulation Model

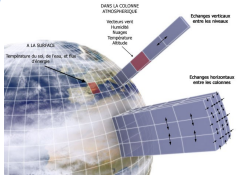
Transport, T, H2O

Anthropogenic and biomass burning emissions for AR5 (RCP)

INCA Chemistry Model

Global 3D concentrations/loads of aerosols & ozone from 1850 to 2100

Forcing for Earth System Models (IPSL-CM5 or CNRM-CM5) for AR5/CMIP5 runs

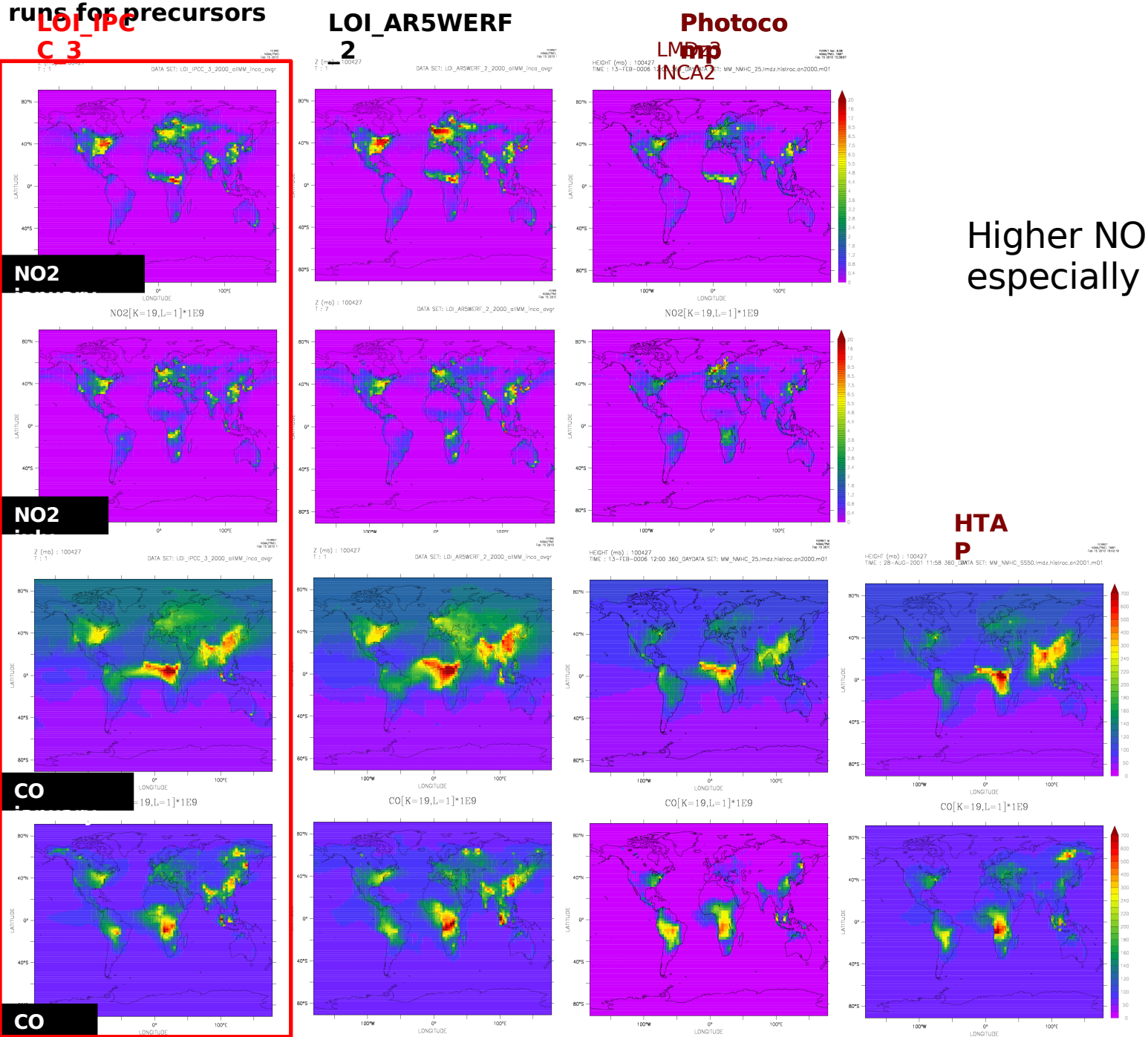


Boundary conditions for Air Quality Models

AC&C intercomparison project

07/07/2011

Comparisons for the year 2000 with previous runs for precursors



Higher NO2, especially in winter

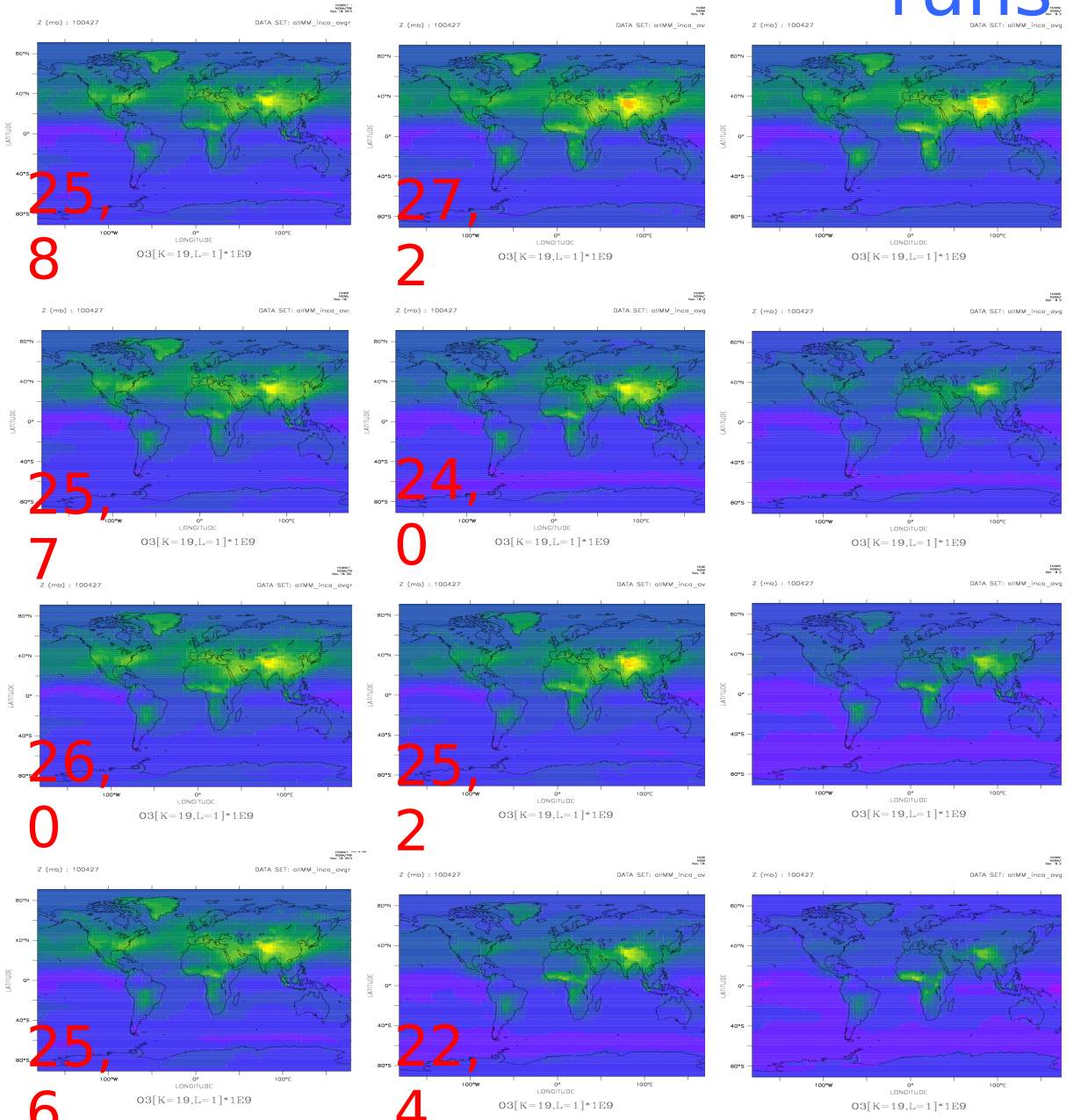
Higher CO, especially in winter

Evolution of surface ozone

RCP runs

2015 2050 2095 2095

ppb

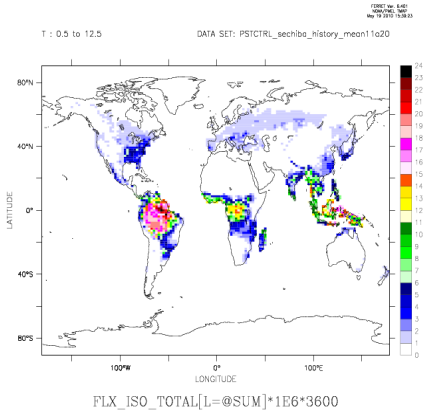


Biogenic emissions

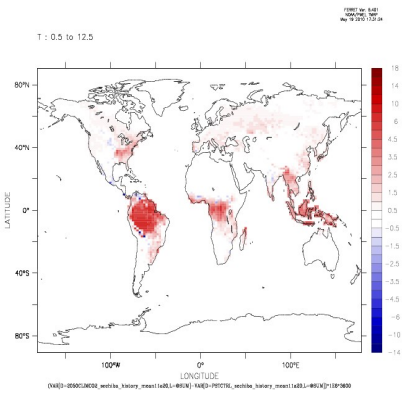
Natural emissions are not provided neither for the historical nor for RCP projections. NOx emitted by soils, biogenic VOC as well as secondary organic , dust or sea salt are kept to the present day values. Lightning NOx are interactively computed depending on the meteorology.

For isoprene, this choice was motivated by experiments conducted in parallel with the ORCHIDEE vegetation model to assess future change in emissions considering climate change, CO2 fertilization on vegetation , landuse change as well as an effect recently parameterized based on chamber studies (by Possell et al. 2005 and Wilkinson et al. 2009) : the **CO2 inhibition effect** directly acting on **plant isoprene emission capacity**.

Present day Control

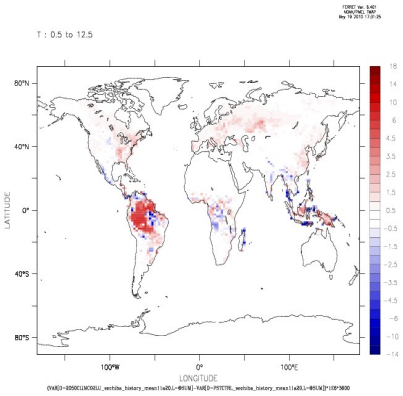


2050 CLIMATE + CO2 fertilization



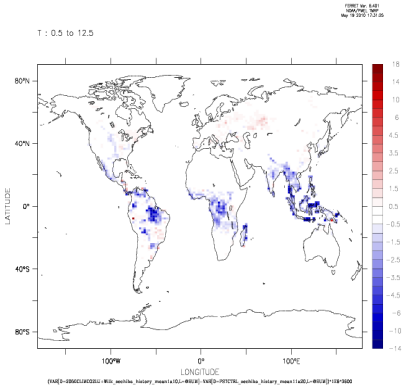
+33%

2050 CLIMATE + CO2 fertilization + landuse change (CLIMCO2LU)



+16%

2050 CLIMCO2LU + Wilkinson CO2 inhibition effect



-10%

Difference to present day control

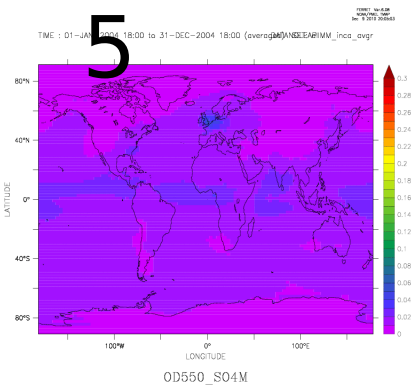
- **In the 2050s, global isoprene emissions increase by 33% when changes in climate and atmospheric CO2 concentration only are considered. Land-use change slightly counteracts this effect but an increase in emission by 16% is still calculated.**
- **When CO2 inhibition is taken into account, our estimates show a 10% (Wilkinson approach) decrease in global annual isoprene emissions compared to the present-day scenario.**

ORCHIDEE emissions computed by J.

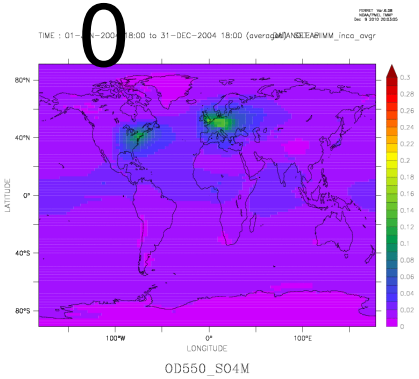
Sulfate Aerosols

Historical run

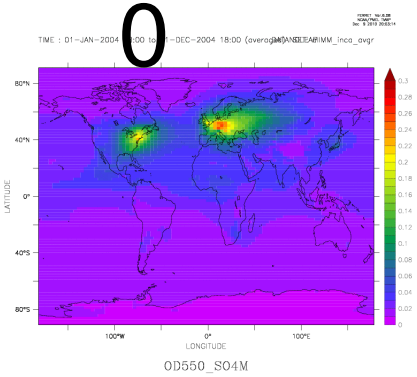
1855



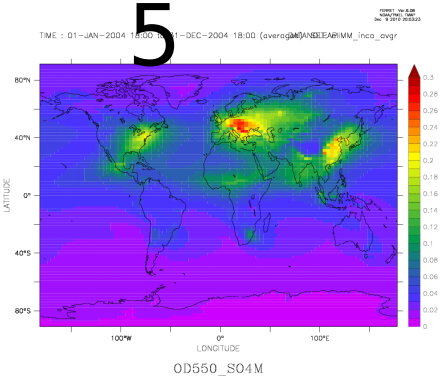
1900



1950



1995



Sulfate Aerosol

2005

2050

2095

Optical depth 550nm

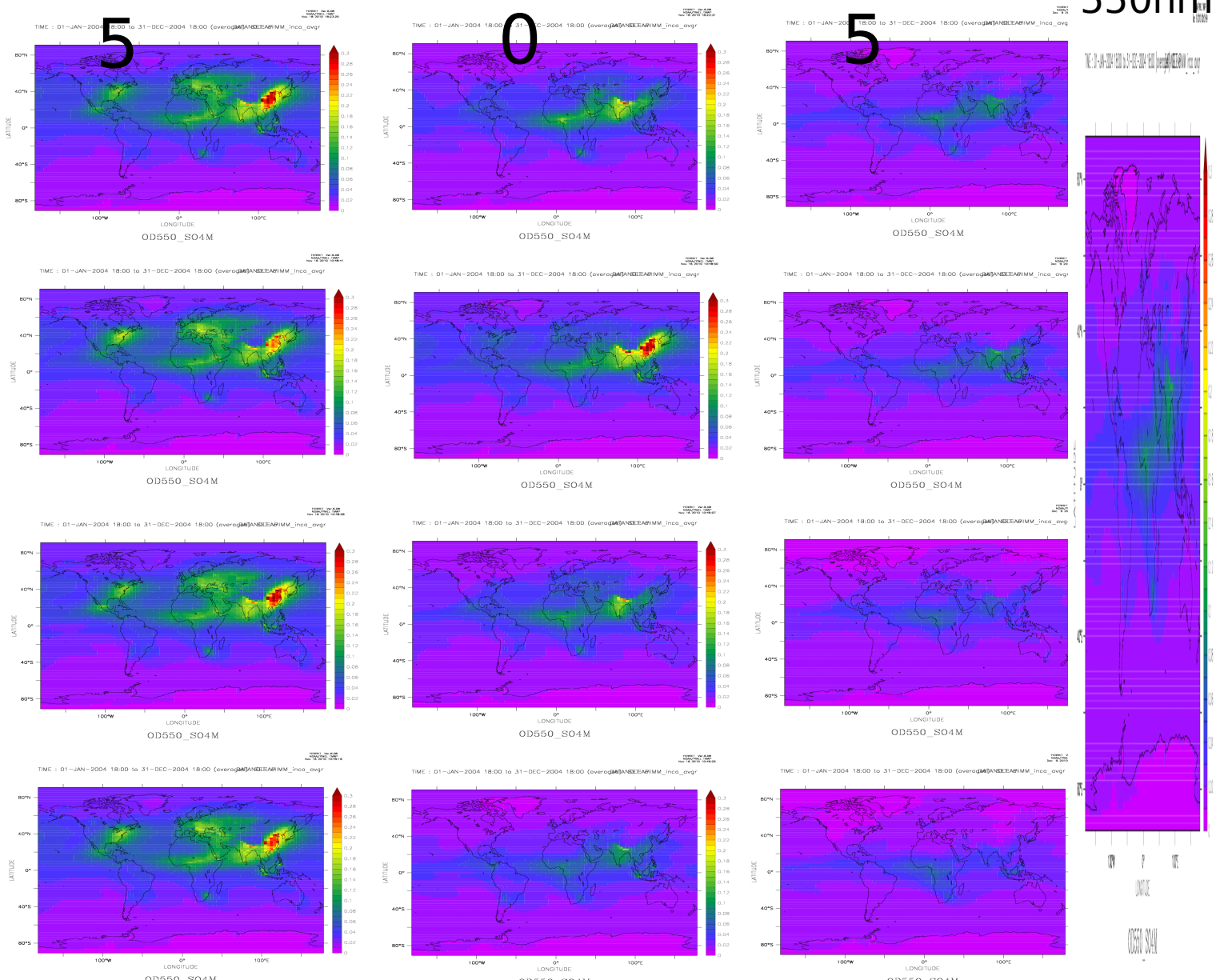
RCP 85

RCP6 0

RCP4 5

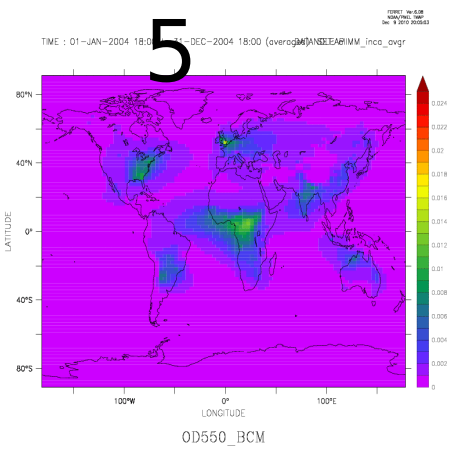
RCP2 6

0

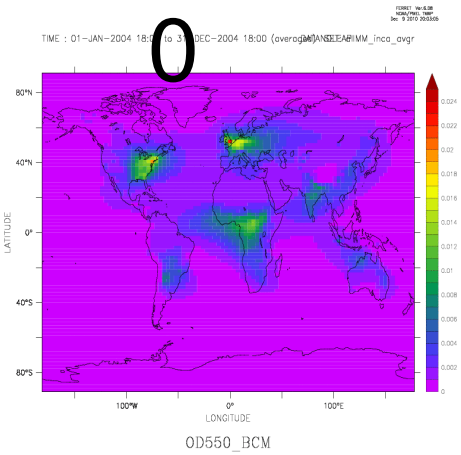


Black Carbon

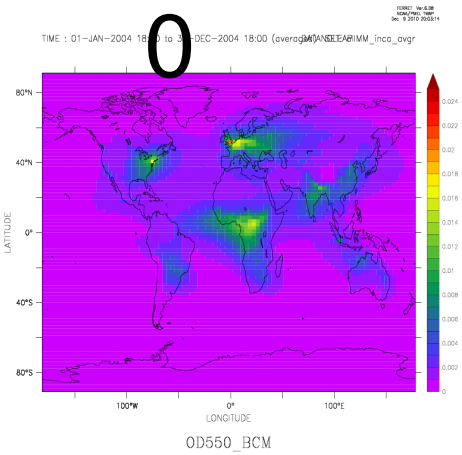
1855



1900



1950



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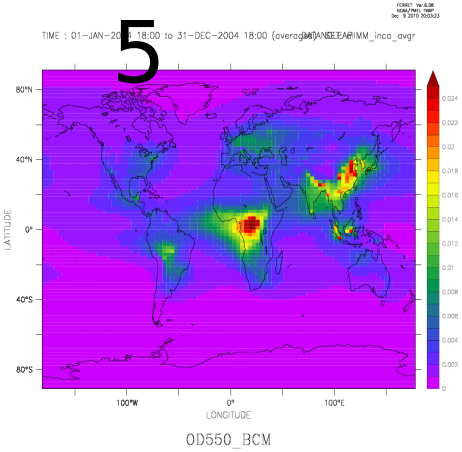


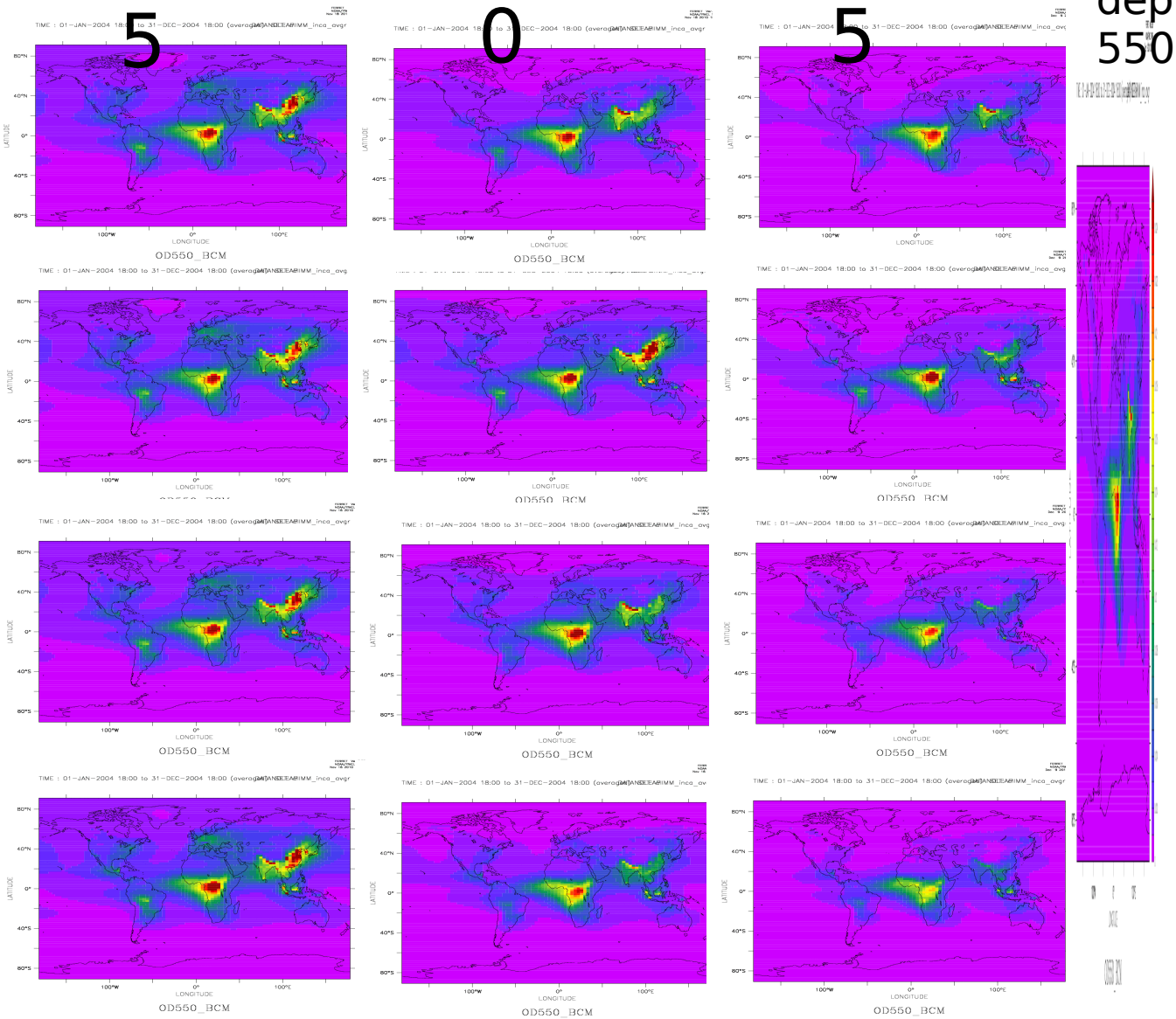
Black Carbon

2005

2050

2095

Optical depth 550nm



RCP85

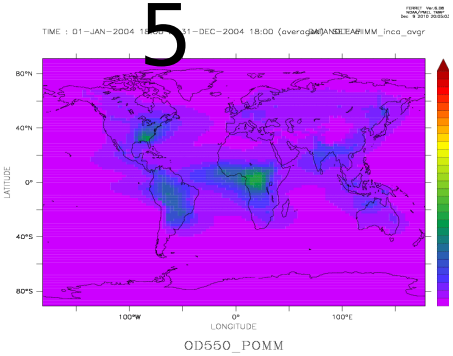
RCP60

RCP45

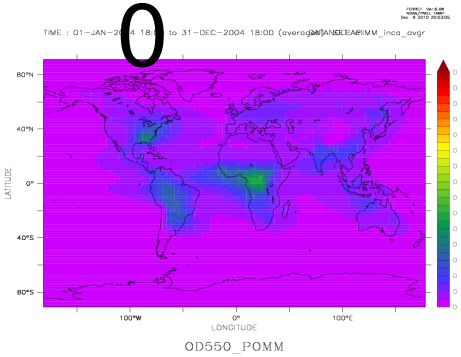
RCP26

Organic Carbon

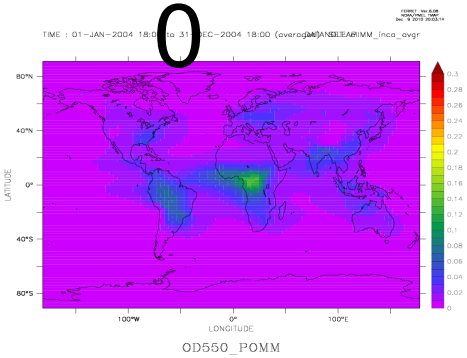
1855



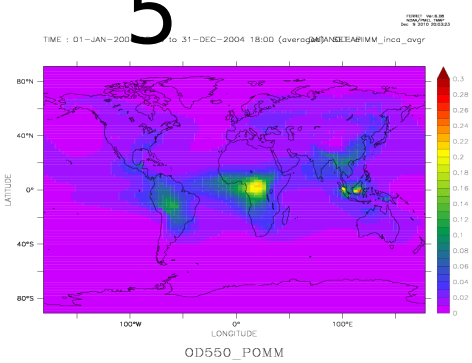
1900



1950



1995



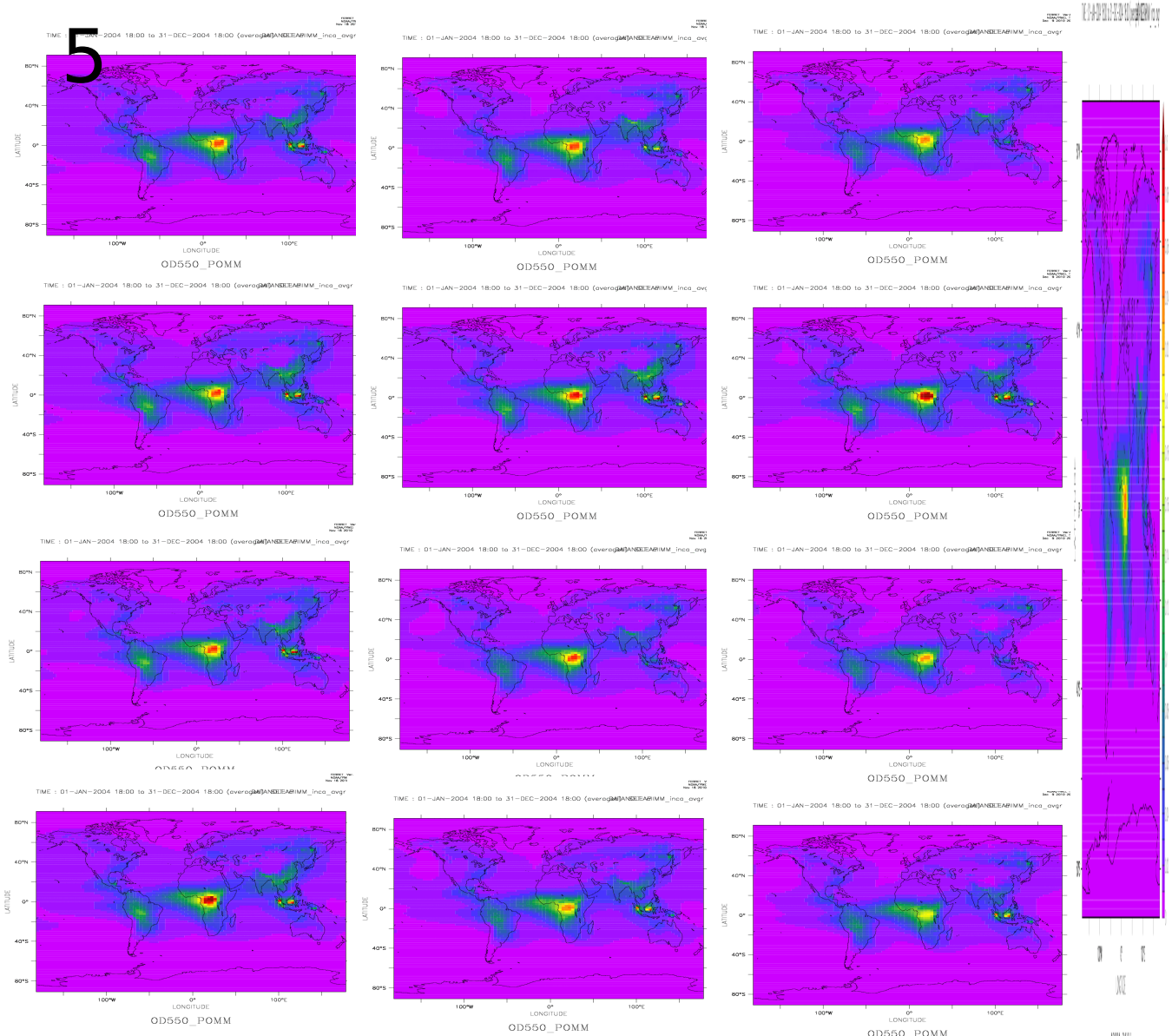
Organic Carbon

2005

205

209

Optical depth 550nm



RCP 85

RCP6 0

RCP4 5

RCP2 6