Estimating aerosol emissions from variational assimilation

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Variational assimilation

$J=(x-x_b)^T \boldsymbol{B}^{-1}(x-x_b)+(y-\mathbf{H}[x])^T \boldsymbol{R}^{-1}(y-\mathbf{H}[x])$

J: Cost function
x: Control vector
x_b: Background vector
y: observation vector
H: Transport model
B,R: Covariance error matrices

We aim to minimize J !

$$x^{n+1} = x^n - \alpha \nabla_x J\left(x^n\right)$$

Adjoint Method

$$\nabla_X J = \mathbf{H}' * \nabla_Y J$$

Computation of the gradient of J

LMDz 3.3.R

DMS, H_2S, DMSO, MSA, SO_2, SO_4 → **Sulfur Chemistry** (Multiple pathways in Gaseous & Aqueous oxidation)

BC (hydrophilic & hydrophobic) → **Ageing of BC**

POM (hydrophilic & hydrophobic) → **Transport**

Sedimentation

SS (10 bins 0.03 – 20 µm) → **Dry Deposition**

DD (2 bins; 0.03 – 0.5 µm, 0.5-10 µm) → **Wet Deposition** (Convective & Large Scale Pp, in-cloud & below-cloud)

→ **AOD** at different λ

(Reddy et al 2005)

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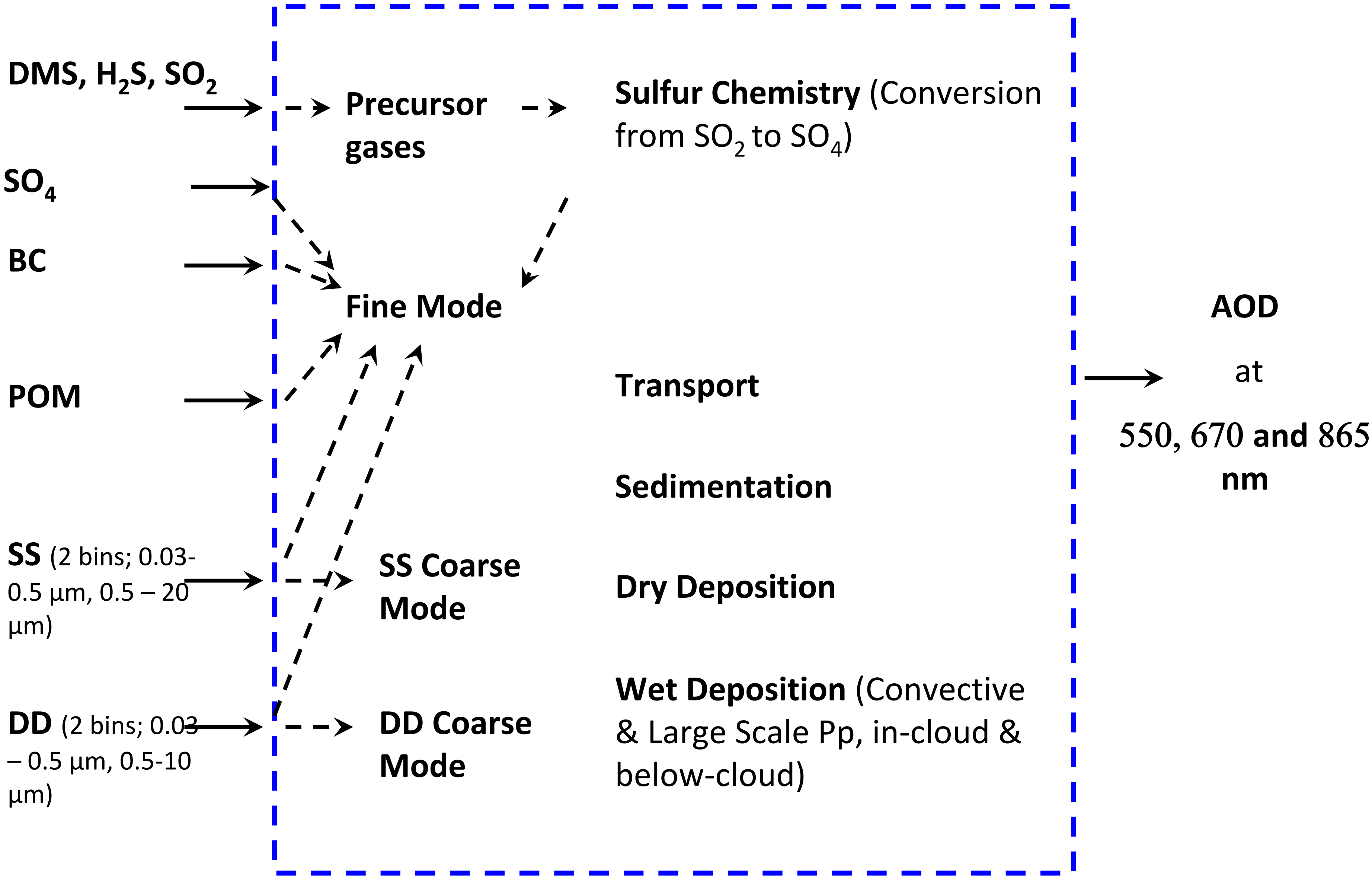
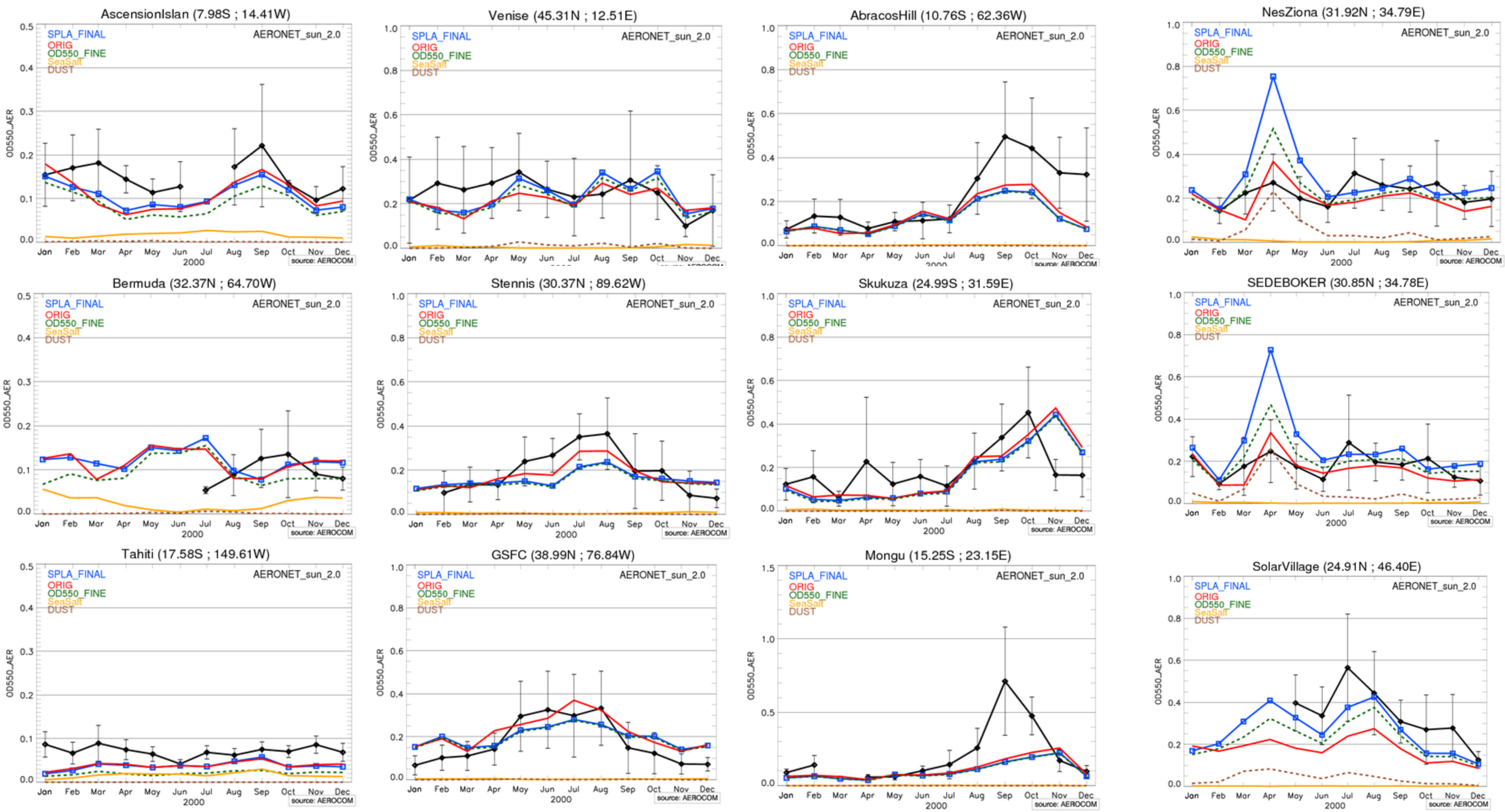
Simplified Aerosol Model (SPLA)



(Huneeus et al., accepted)

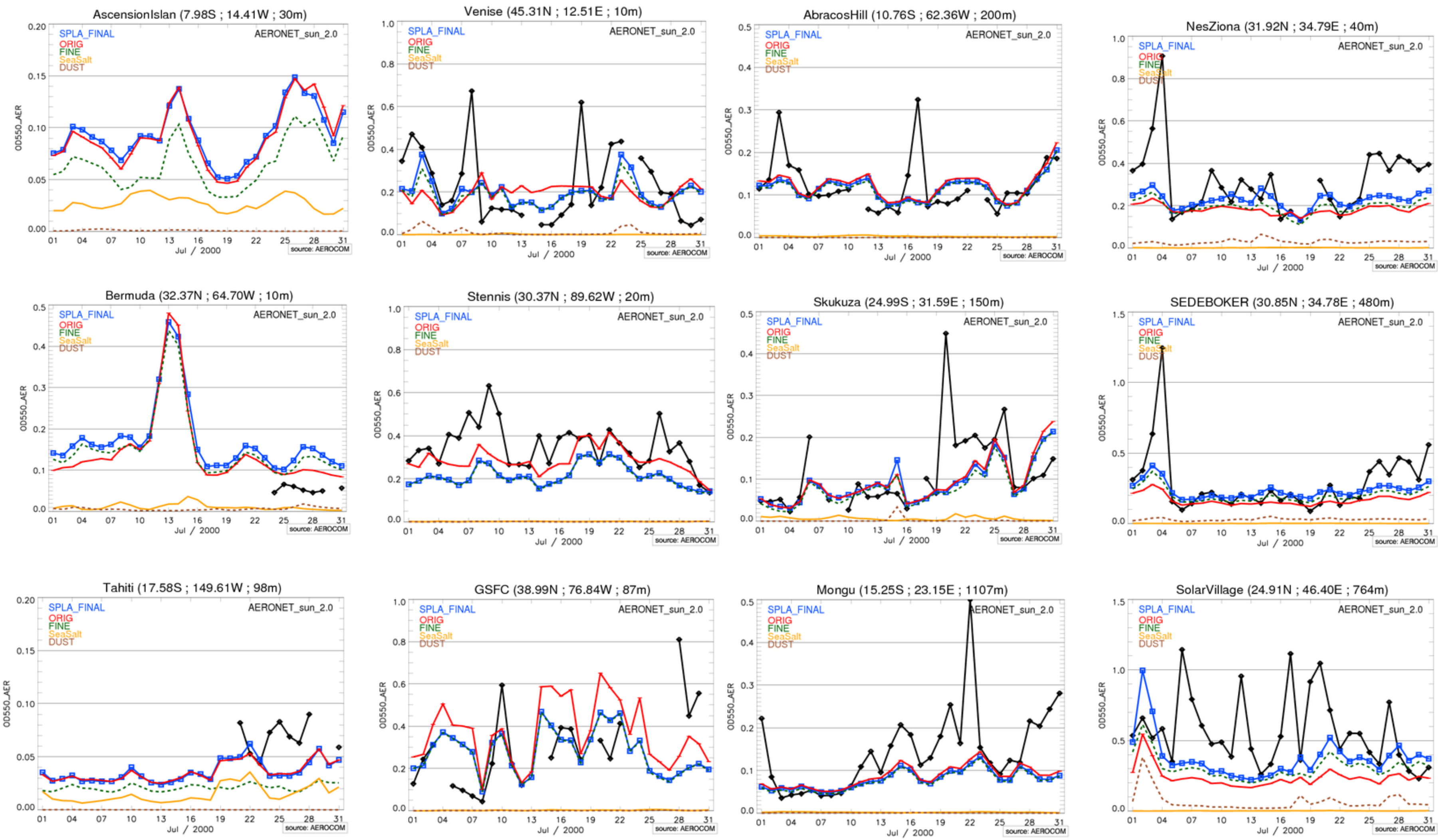
Validation of SPLA (seasonal variability)

Sea Salt Sites | Fossil Fuel Sites | Biomass Burning Sites | Desert Dust Sites



Validation of SPLA (daily variability)

Sea Salt Sites	Fossil Fuel Sites	Biomass Burning Sites	Desert Dust Sites



Control Vector

Emission parameters defined by region :

- Sulfur Emissions (6)
- Biomass Burning (6)
- Combustion of fossil fuels (6)
- Sea salt fine & coarse (Global, 2)
- Desert dust fine & coarse (2x10)
- Conversion from sulfur to sulfate (5)

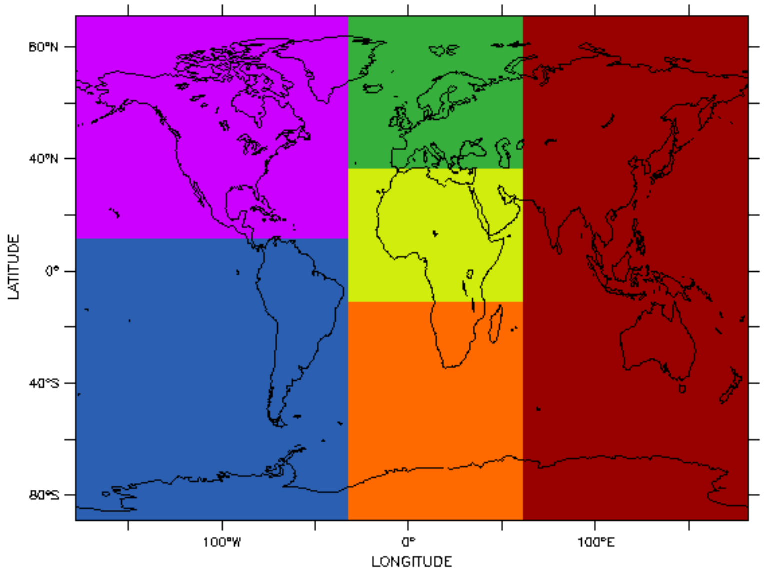
« Observations » vector

Daily means of :

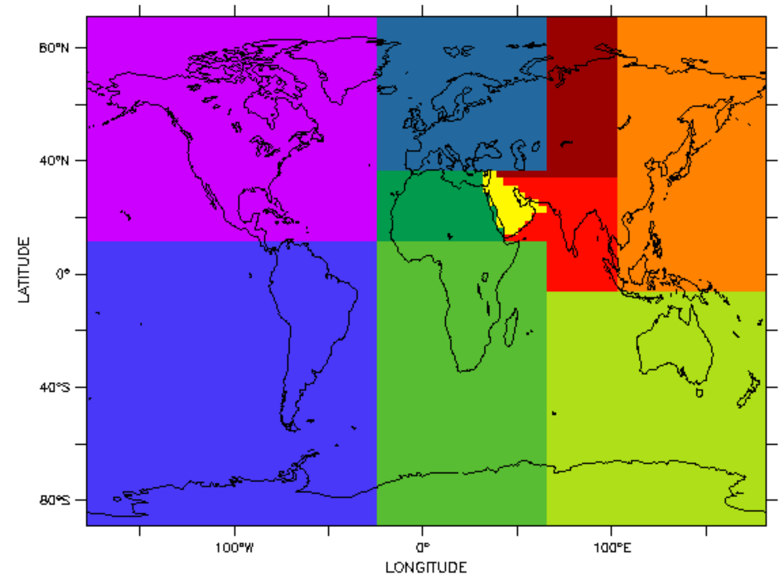
- MODIS total optical depth at 550 nm
- MODIS fine mode optical depth at 550 nm

Emission Regions

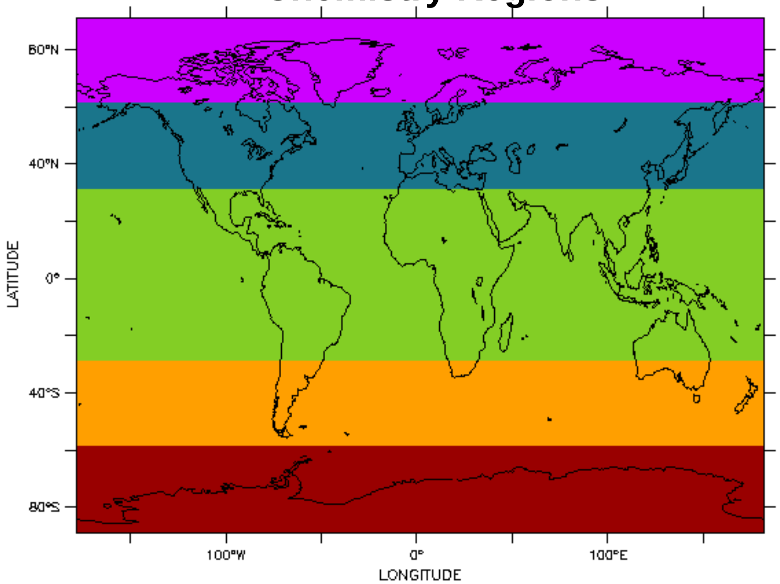
Fossil Fuel, Biomass Burning & Industrial Regions



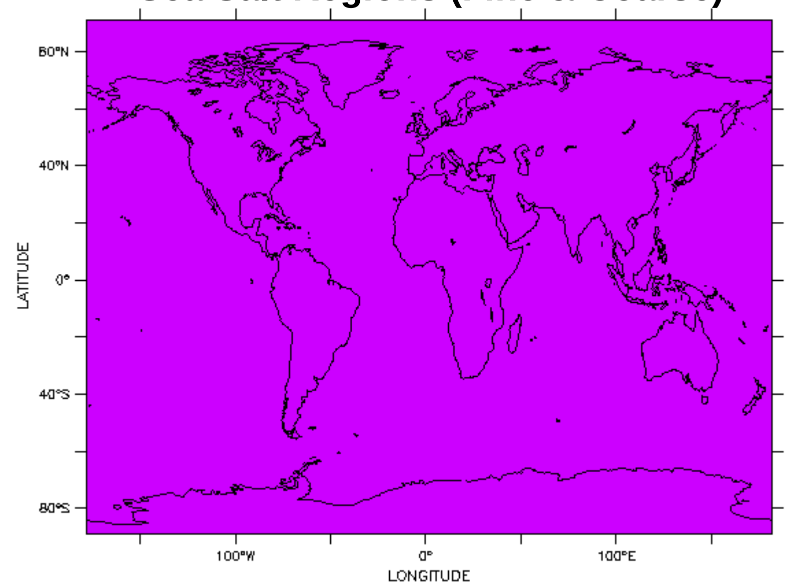
Dust Regions (Fine & Coarse)



Chemistry Regions



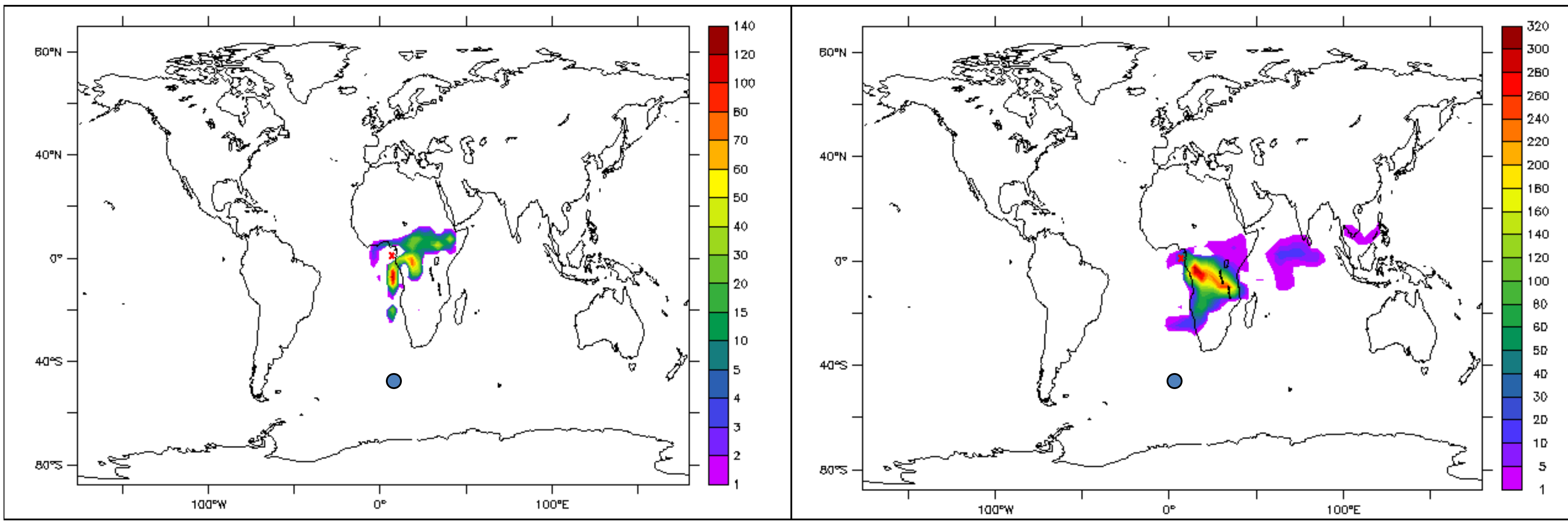
Sea Salt Regions (Fine & Coarse)



Adjoint of SPLA□ ⟹ Automatic differentiation

TAPENADE

Adjoint : Perturbations in the input with respect to perturbations in the output□

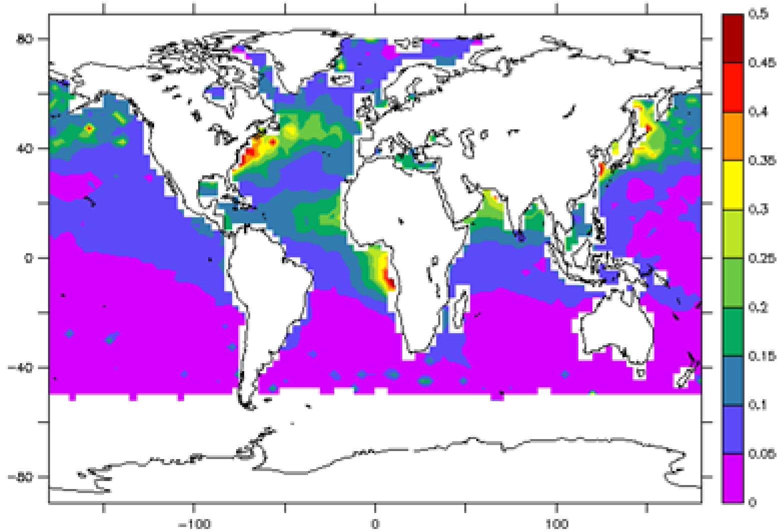


- 2 days - 5 days

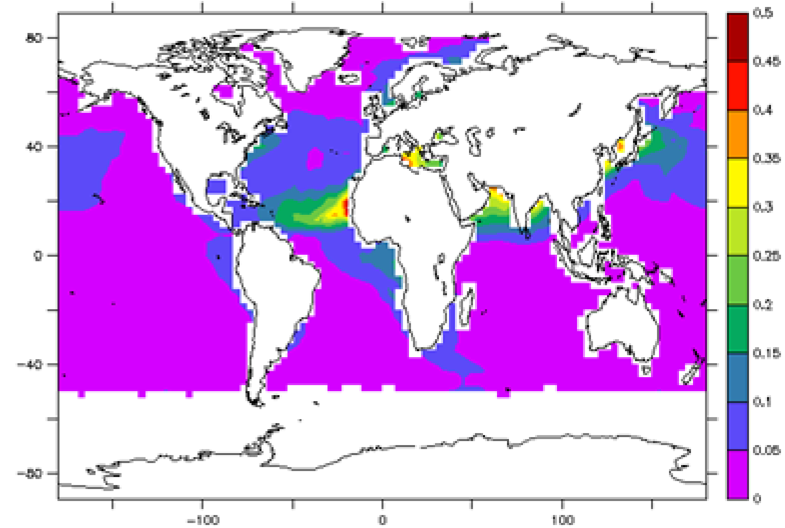
SPLA & Adjoint ⟹ Global assimilation system used in estimation of gaseous emissions (Chevallier et al., 2005)

Inversion

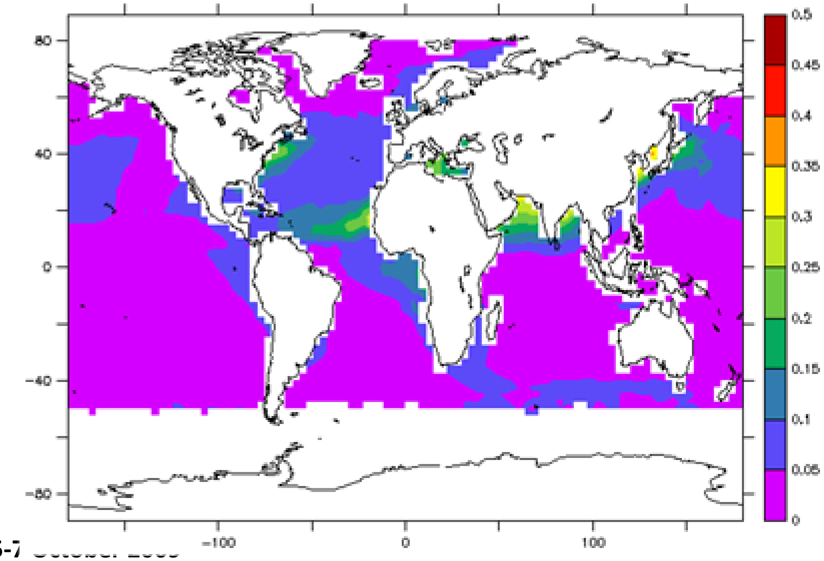
Observations



A priori



Analysis

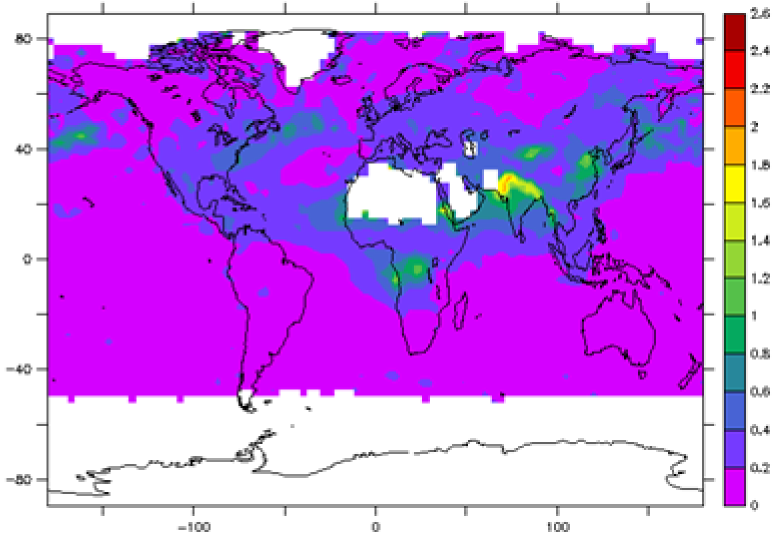


Fine mode AOD

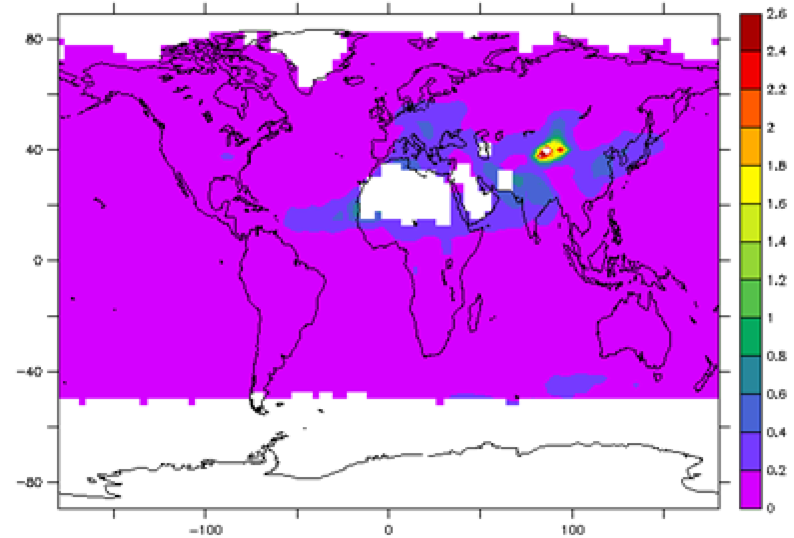
5 Iterations

Inversion

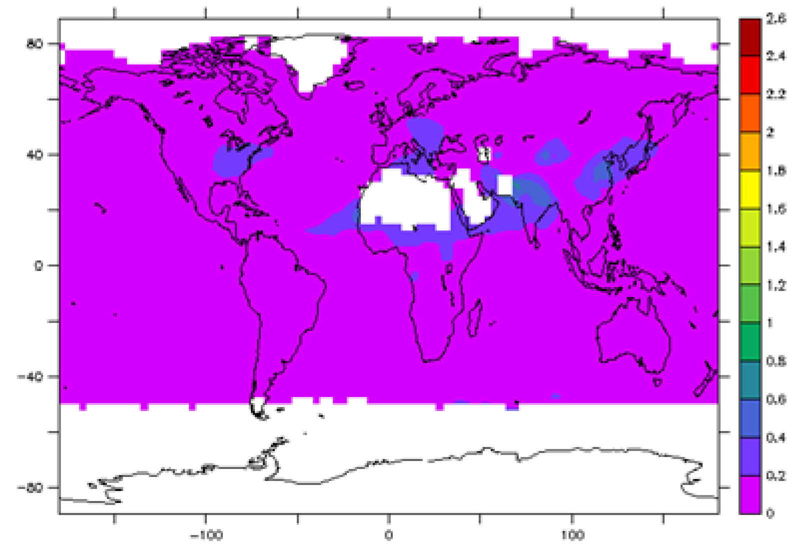
Observations



A priori



Analysis

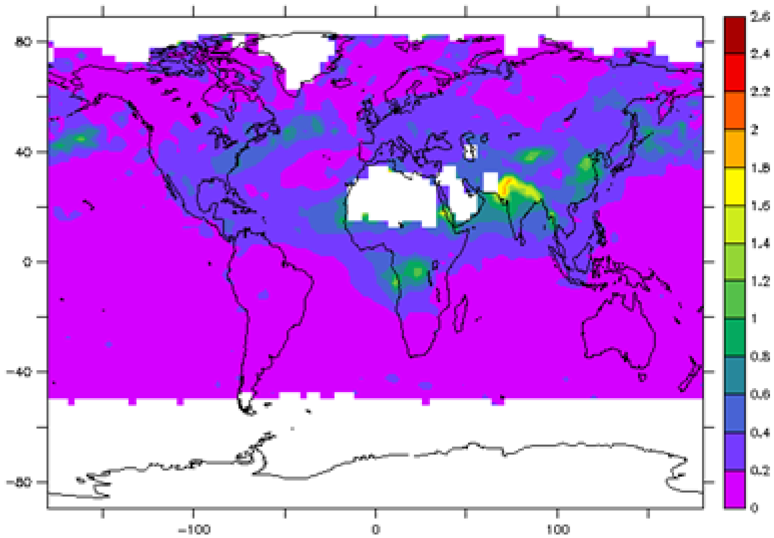


Total AOD

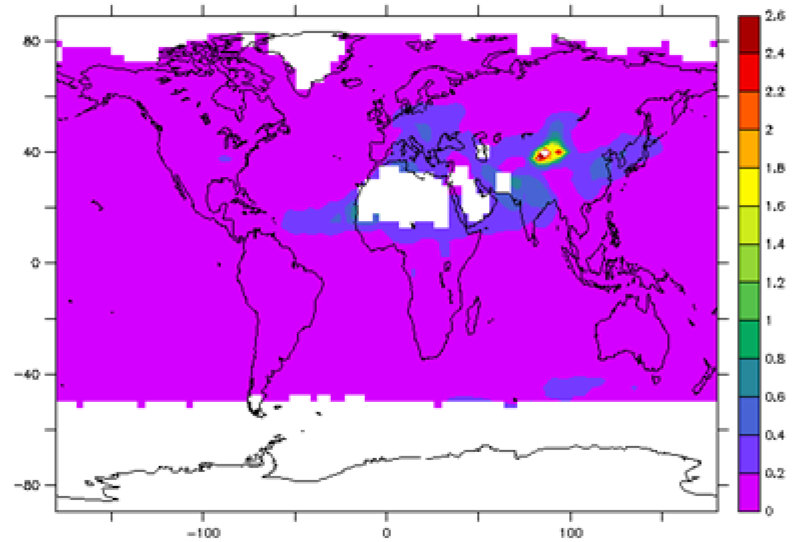
5 Iterations

Inversion - Total AOD

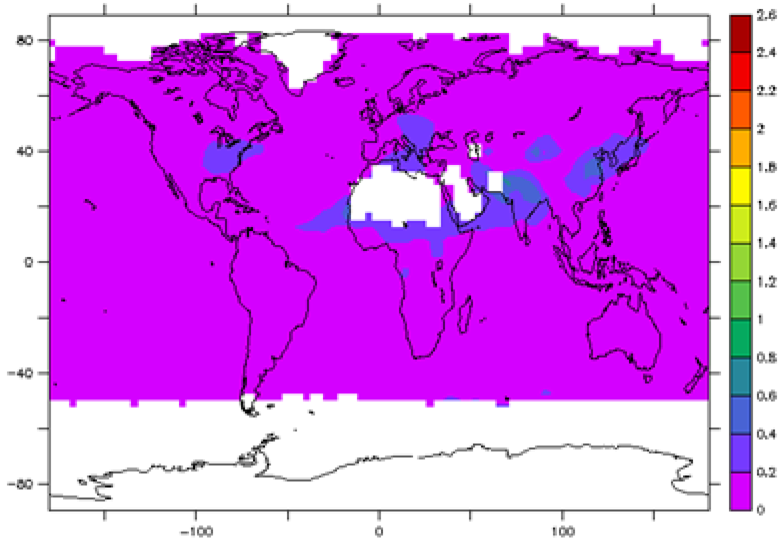
Observations



A priori

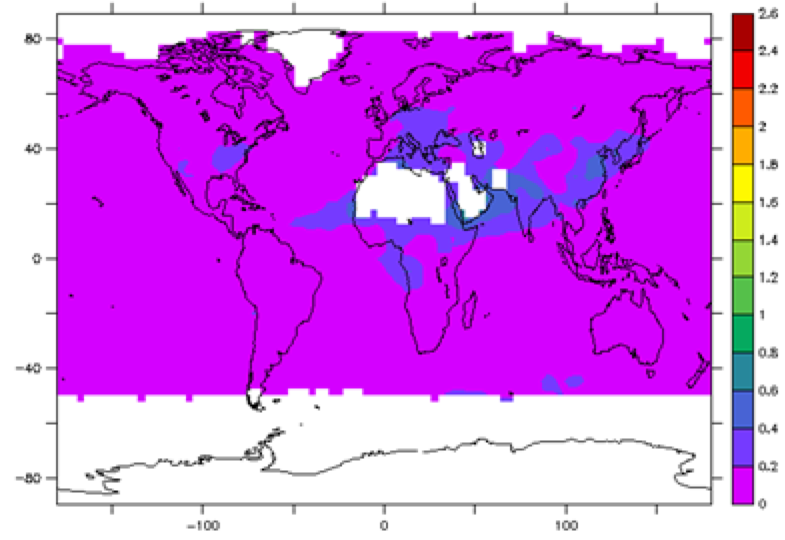


Analysis



5 Iterations

Analysis



40 Iterations

Direct Model

$$E_{species} = \sum_i S_i \times E^i_{orig}$$ i= Aerosol species

Adjoint Model

$$S_i^* = S_i^* + E^i_{orig} \times E^*_{species}$$

⇨ **Definition of background error covariance matrix**

$$J = (x - x_b)^T \boldsymbol{B}^{-1} (x - x_b) + (y - \mathbf{H}[x])^T \boldsymbol{R}^{-1} (y - \mathbf{H}[x])$$

Conclusions

- Derivation of a simplified model groupes 24 original species into 4
- Simplified model reproduces LMDz in monthly variability and is within the variability of AERONET
- More dificulties in reproducing the AERONET daily variability
- Introduced in global assimilation system
- Assimetry in the inversion

Dust Intercomparison

- Definition of stations is now observation based
- Separating between dusty days and days with dust in mixture

$\alpha < 0.4$ Natural Aerosols

Angstrom Exponent ˜ □□ α □̃ı□̣Mixture

$\alpha > 1.2$ Anthropogenic Aerosols

- Next step Paper