Aerosols in LMDz model

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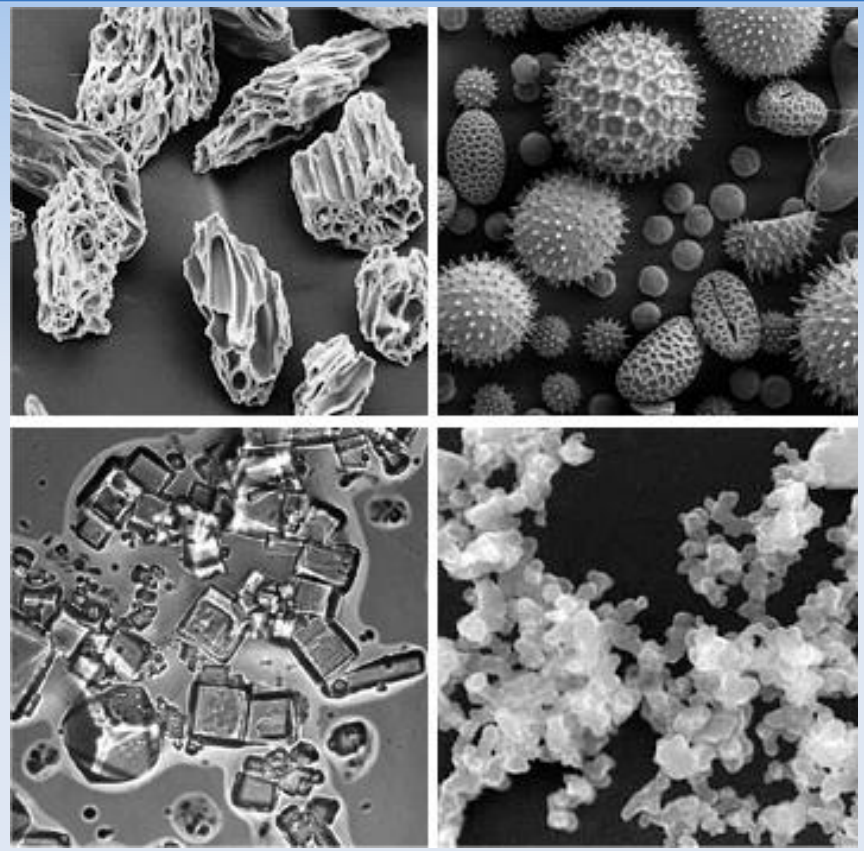
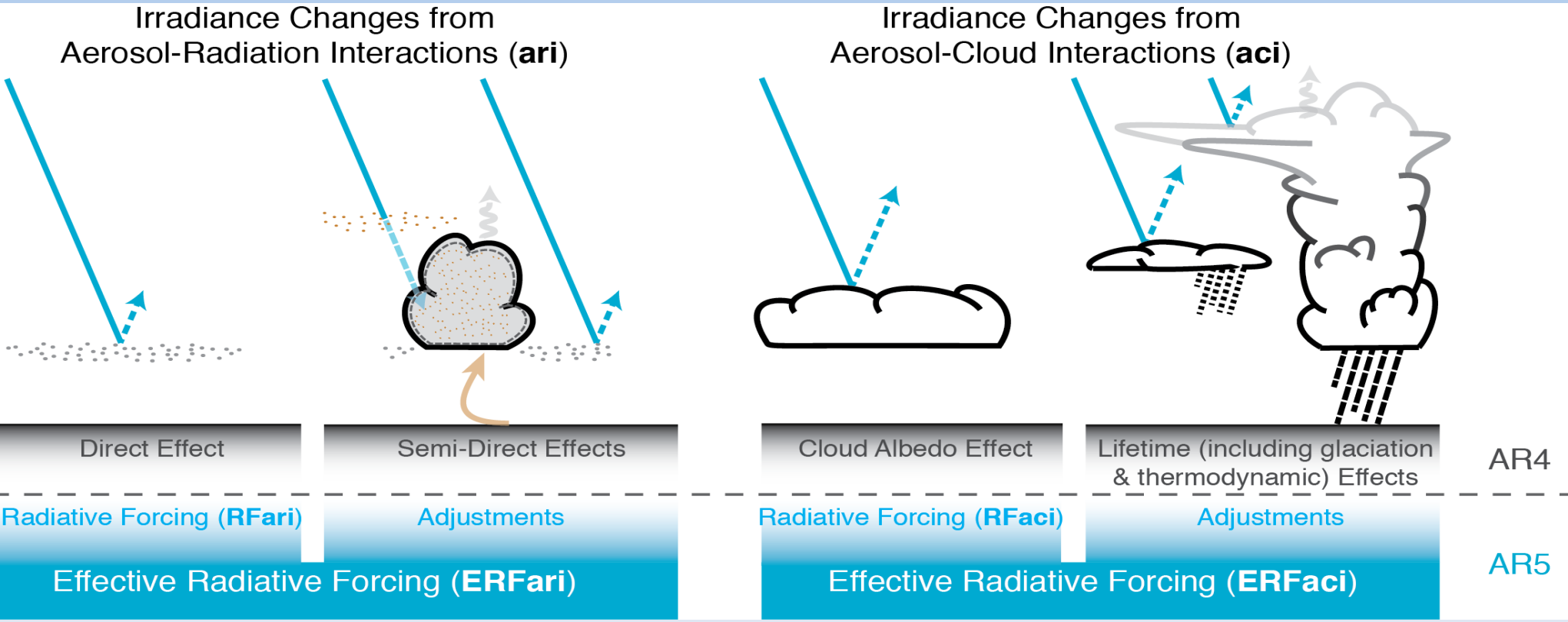
Atmospheric aerosols

Particles in suspension in the atmosphere, with size ranging from a few nm to 100 µm, but particularly important for climate between 0.1 and 10 µm. Both natural and anthropogenic sources. Primary and secondary aerosols.



Categorization of aerosol effects



Boucher et al., AR5, Chapter 7, Clouds and Aerosols

Aerosols in LMDz

Online

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

LMDZ5-AP → libIGCM IPSL-CM5A2-INCA

LMDZ6-NP → libIGCM IPSL-CM6A-INCA

Simple aerosol model with **-dust** compilation option → LMDZ6 – NP with RRTM General Circulation Model

Sectional stratospheric aerosol model with – **StratAer** compilation option → LMD6 – NP with RRTM General Circulation Model → libIGCM CM6.1.11 IPSL-CM6A-INCA

Offline

Climatologies of natural and anthropogenic aerosol concentrations

LMDZ6 – NP with RRTM General Circulation Model

Aerosols: running w or w/o INCA

- LMDZ with INCA: runtime parameter in config.def, aerosol_couple = y, requires libIGCM environment

version with interactive aerosols, management of radiative transfer is somewhat different to that of LMDZ without INCA in AP (old physics) but same in NP + RRTM (new physics) except for a few things

- LMDZ without INCA: runtime parameter in config.def, aerosol_couple = n

Available aerosol types

Runtime parameter in config.def flag_aerosol (int):

- 0: no tropospheric aerosol
- 1: sulfate
- 2: black carbon
- 3: particulate organic matter
- 4: marine salts
- 5: dust
- 6: all tropospheric aerosols
  - including nitrate in RRTM in CMIP6 climatologies
- 7: anthropogenic aerosols from MACv2SP
  - aerosol plume model from MPI Hamburg

Aerosols: input files

- If 0 < flag_aerosol <= 6:
  gcm.e reads aerosol data from two files **aerosols.nat.nc** and may need a second file **aerosols1980.nc** depending on the value of
- runtime parameter aer_type (char) in config.def:
  - **preind**: pre-industrial aerosols ✹ **aerosols.nat.nc** only
  - **actuel**: use a climatology of natural + anthropogenic aerosols

    ✹ **aerosols.nat.nc** + **aerosols1980.nc** (fixed name, meaningless)
  - **annuel**: **aerosols.nat.nc** + **aerosolsYYYY.nc**
    where YYYY is the current year in the model simulation

Aerosols: input files (continued)

- Input files should contain concentrations of aerosols of all the desired types (according to flag_aerosol) with nitrates being optional
- Input files should already be horizontally regridded to the LMDZ grid
- For LMDZ5 as used in AR5 runs, the input is for 19 layers and regridded online to the klev layers of the model. For LMDZ6 as used in AR6 runs, the input is for 79 layers. But providing the input on a different vertical grid is OK.

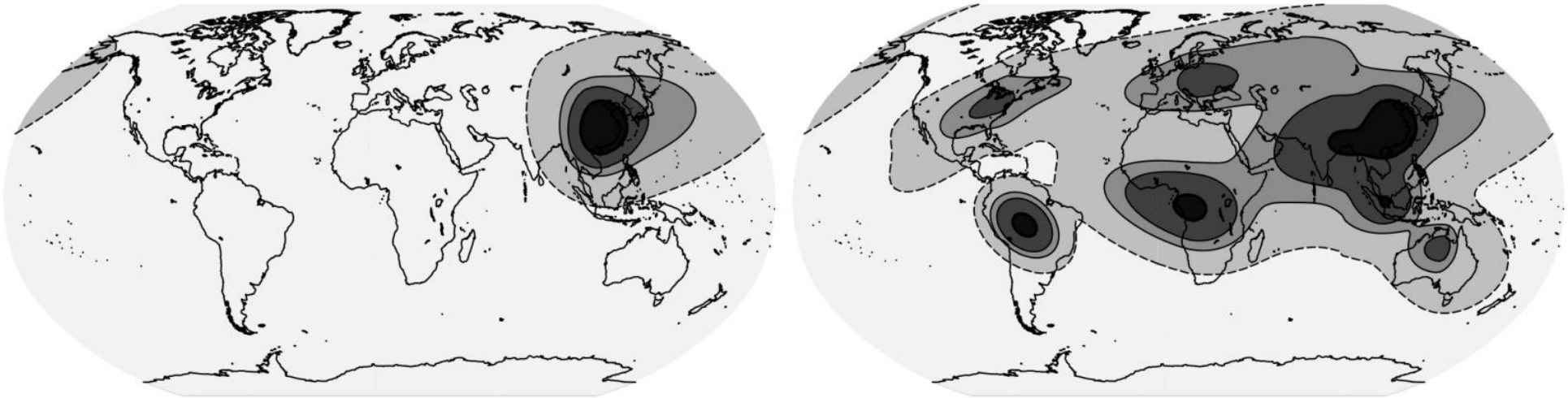
Aerosols: input files (continued)

- If flag_aerosol = 7: 

  - requires **aerosols.nat.nc**
  - requires **aerosols1980.nc = aerosols.nat.nc** (fudge)
  - requires input file **MACv2.0-SP_v1.nc**

    => does not depend on resolution
  - module **mo_simple_plumes.F90** and routine **macv2sp.F90** add a set of anthropogenic plumes on top of the natural aerosol
  - function of (month, year) but 1850 <= year <= 2017

Aerosols: flag_aerosol=7



550 nm AOD with 0.005, 0.05, 0.1 and 0.3 contour levels

Plumes can be selected / deselected if needed

From Stevens et al. (GMD, 10, 433–452, 2017)

Aerosols: direct and indirect effects

- Runtime parameters ok_ade and ok_aie (logical) in config.def to activate direct and indirect effects of anthropogenic aerosols
- If ok_ade = n then direct effect of natural aerosols only (and no anthropogenic aerosols)
- If ok_aie = n then indirect effect of natural aerosols only (and no anthropogenic aerosols)

Aerosols: direct and indirect effects

- You can choose ok_ade and ok_aie independently
- flag_aerosol must be ≥ 1 if ok_ade or ok_aie is y
- If ok_ade or ok_aie is y and forcing diagnostics are requested (e.g. topswad, solswad, topswai and solswai, ...) then double radiation calls w/ and w/o anthropogenic aerosols are automatically called
- Note that for online aerosols (i.e. INCA) in LMDZ-NP topswai and solswai diagnostics are meaningless

Aerosols for expert users (1/2)

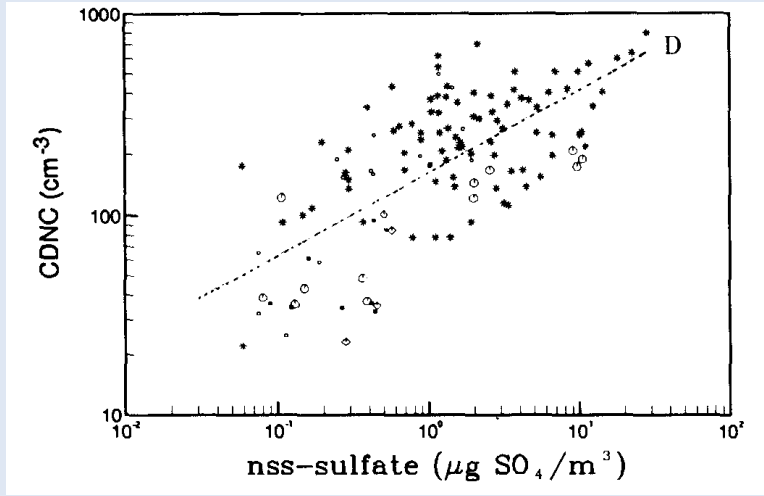
Runtime parameters in config.def in case ok_aie = y

ok_cdnc = y
bl95_b0 = 1.7
bl95_b1 = 0.2
(recommended values)

$$CDNC = 10^{\,b0 + b1 \log(m\ SO4)}$$

Link cloud droplet number concentration to aerosol mass concentration (Boucher and Lohmann, Tellus, 1995)

B0=1.3 and uses mass of all soluble species



Aerosols for expert users (2/2)

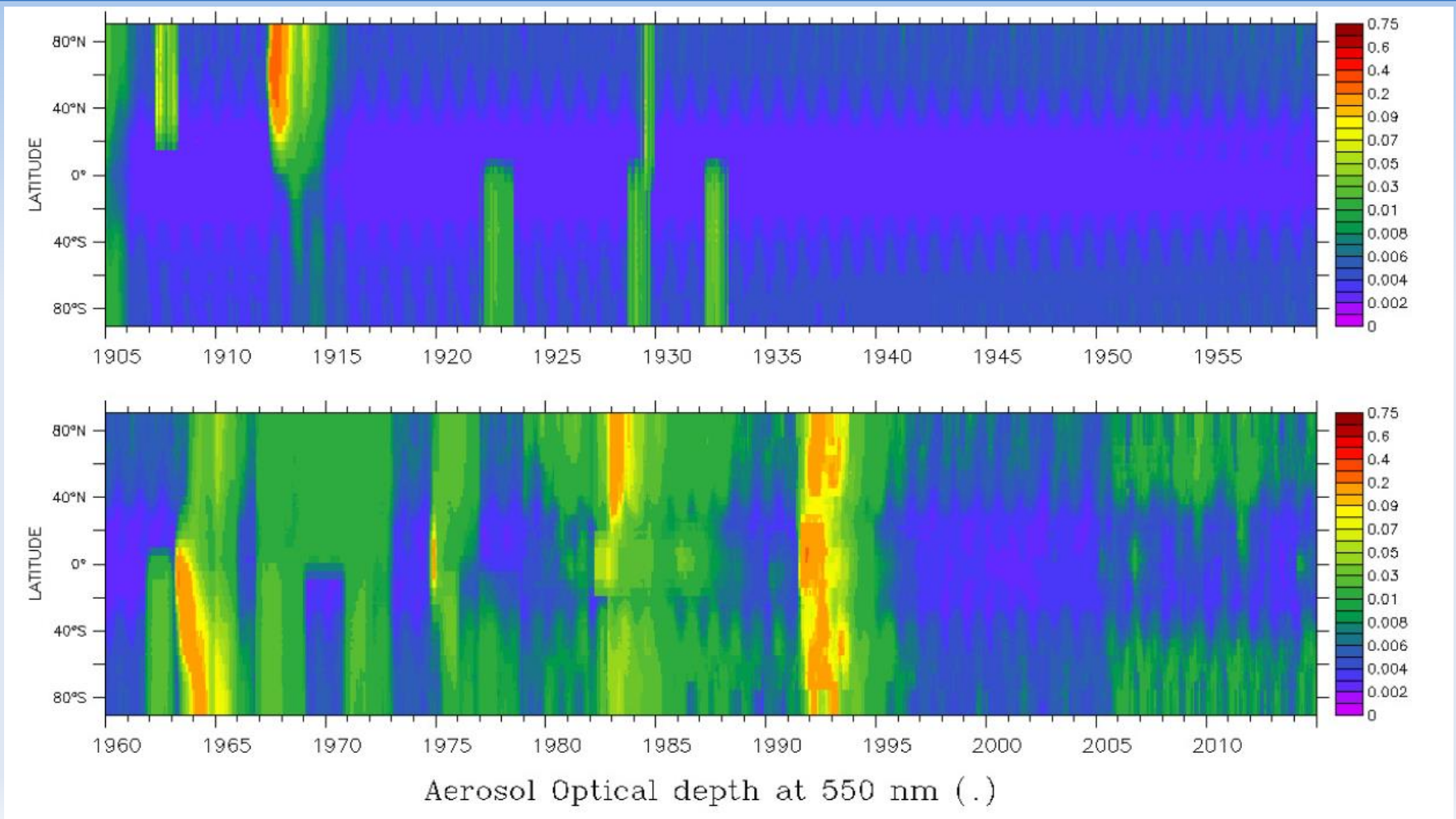
- If you want to compute at each time step the direct or indirect effect that aerosols would have, but not let those effects impact the simulation (e.g. to get the same meteorology with different RF estimates)
  - Choose flag_aer_feedback = y at runtime
  - Choose flag_aerosol > 0 at runtime
  - Choose ok_ade = y or ok_aie = y at runtime 

Stratospheric aerosols

- flag_aerosol_strat= 0 (none), 1 (Sato) or 2 (CMIP6)
- gcm.e reads 2D (latitude-height) aerosol data with monthly timestep
- Input data are available over period 1750 to 2010 (Sato) or 2014 (CMIP6)
- A routine exists to prepare input files to various resolutions http://forge.ipsl.jussieu.fr/igcmg/svn/TOOLS/CMIP6_FORCING/AER_STRAT/

- Direct effect in SW (old radiation + RRTM) and in the LW (RRTM only, dependent on aerosol size)

CMIP6 stratospheric aerosols



Lurton et al., JAMES, submitted, 2019

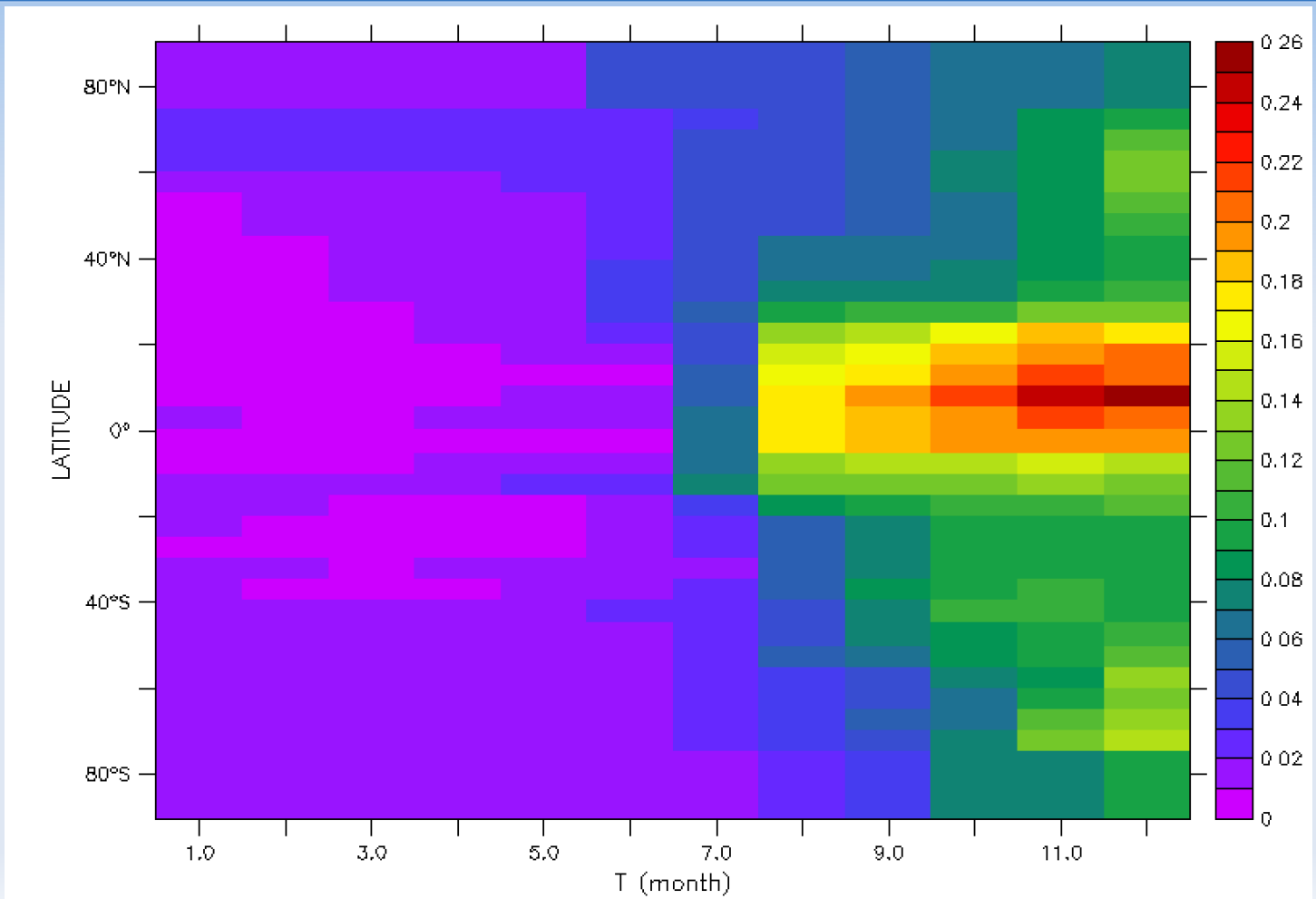
CMIP6 stratospheric aerosols (zoom)

Example:

550 nm AOD

CMIP6 data

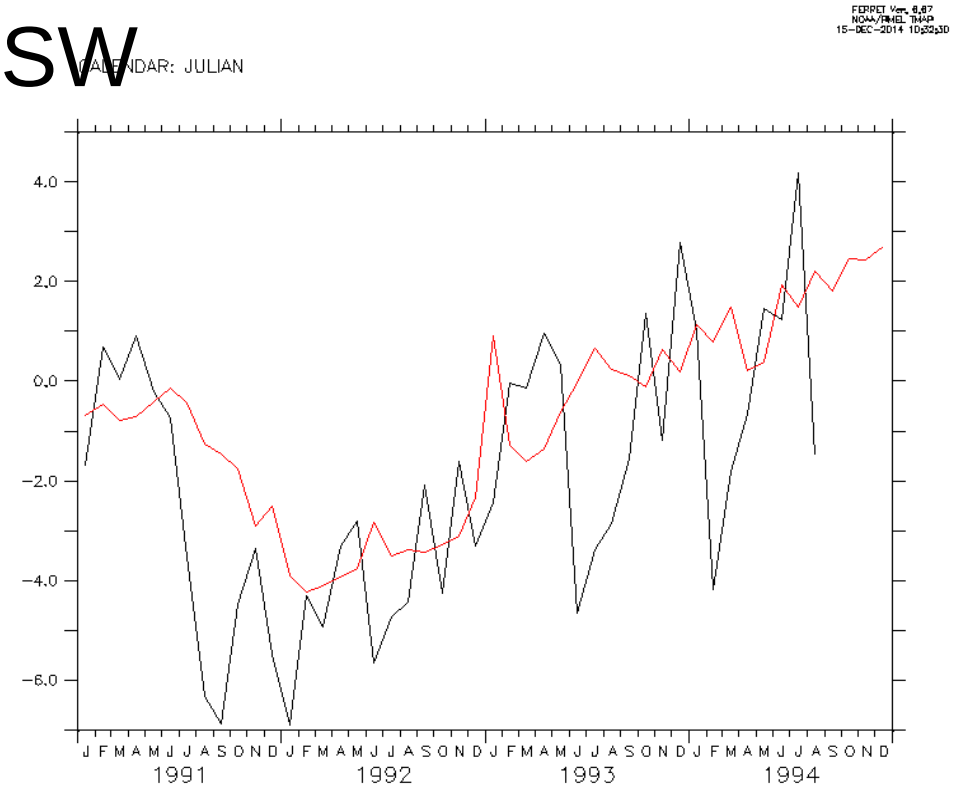
Year 1991



Stratospheric aerosols: Pinatubo

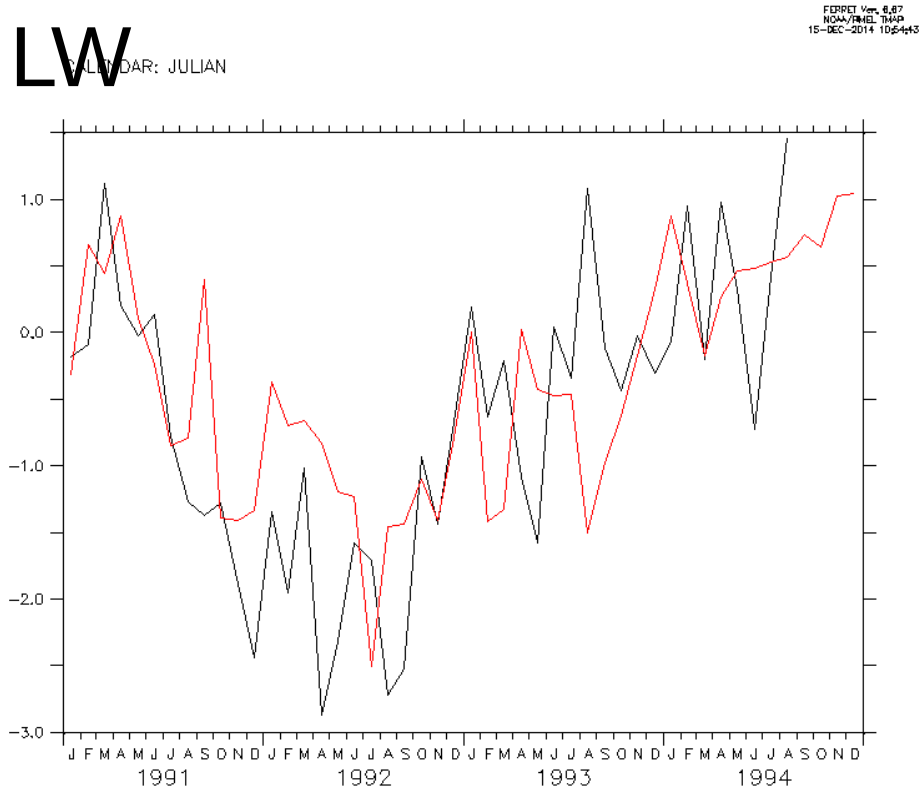
Observations (ERBE) vs Model

SW



observed anomaly in reflected SW vs. tops

LW

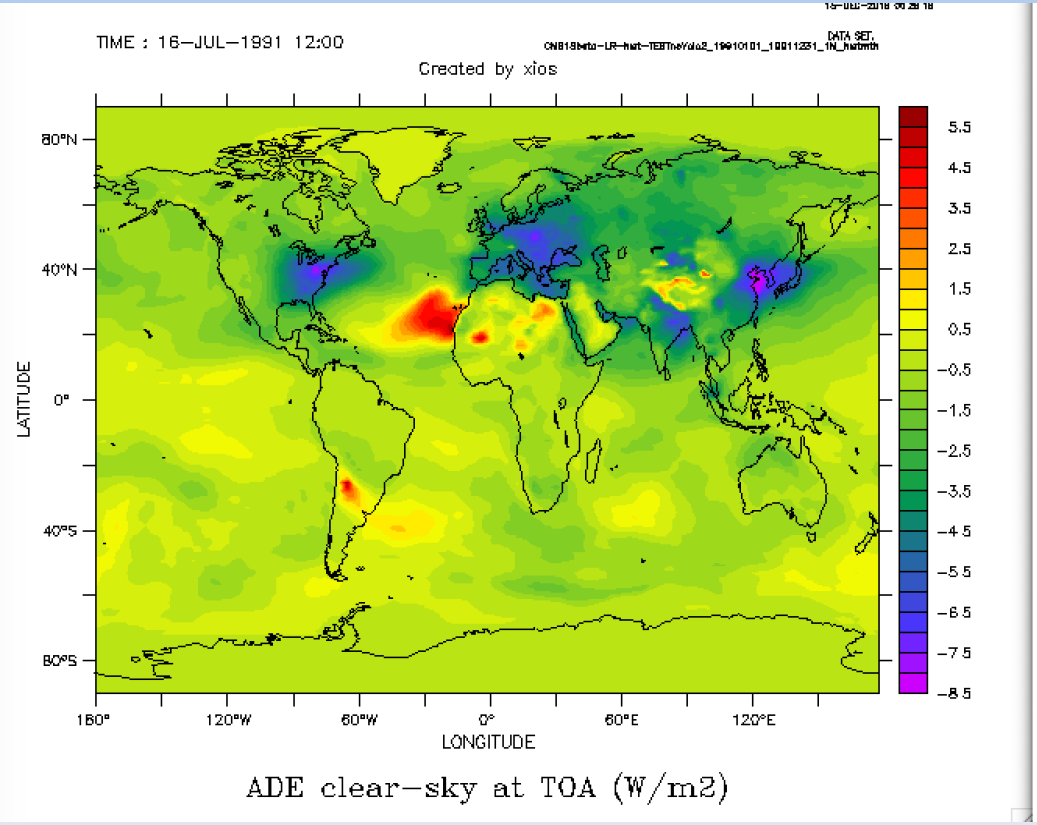


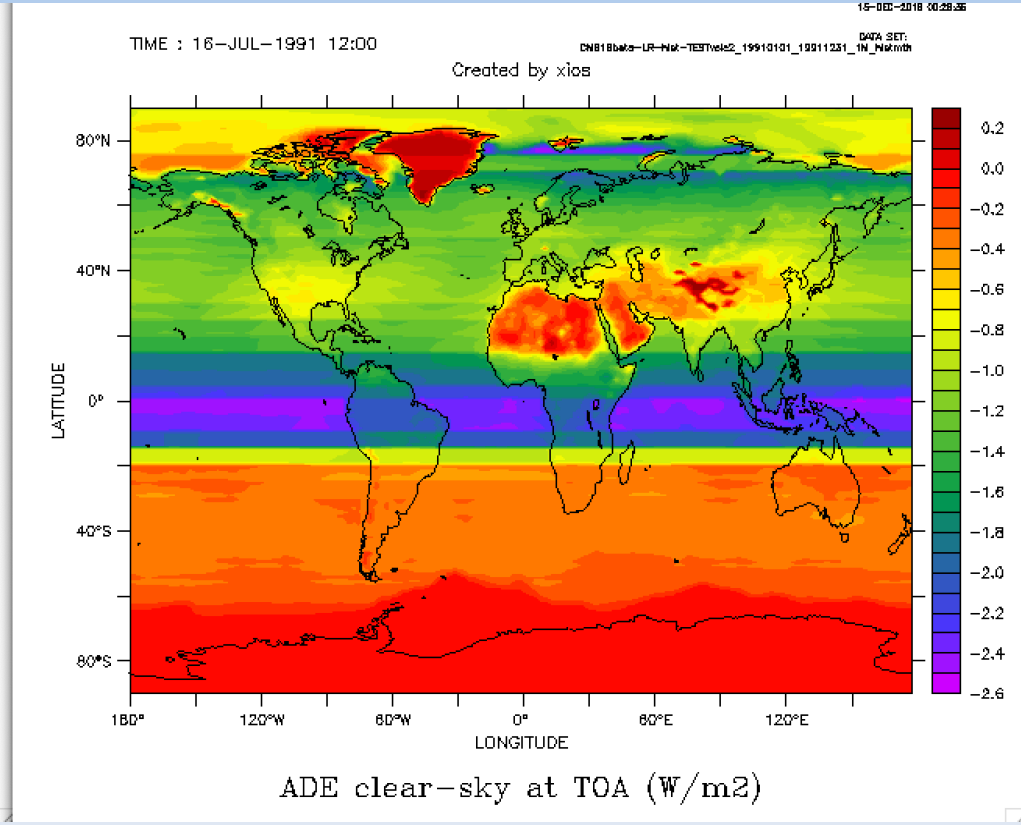
observed anomaly in emitted LW vs. topl

Stratospheric aerosols

- Runtime parameter ok_volc (logical)
- If ok_volc = y and ok_ade = y
- The model uses double radiation calls to diagnose the radiative effects and heating rates of stratospheric aerosols instead of that of anthropogenic aerosols
- Runtime parameter flag_volc_surfstrat (0, 1, 2) Decouples surface cooling and stratospheric heating. Only in LMD6.0.15 branch for now.

Example: topswad0 diagnostic





ok_volc = n (default)

ok_volc = y

AOD in LMDZ6 *historical* runs

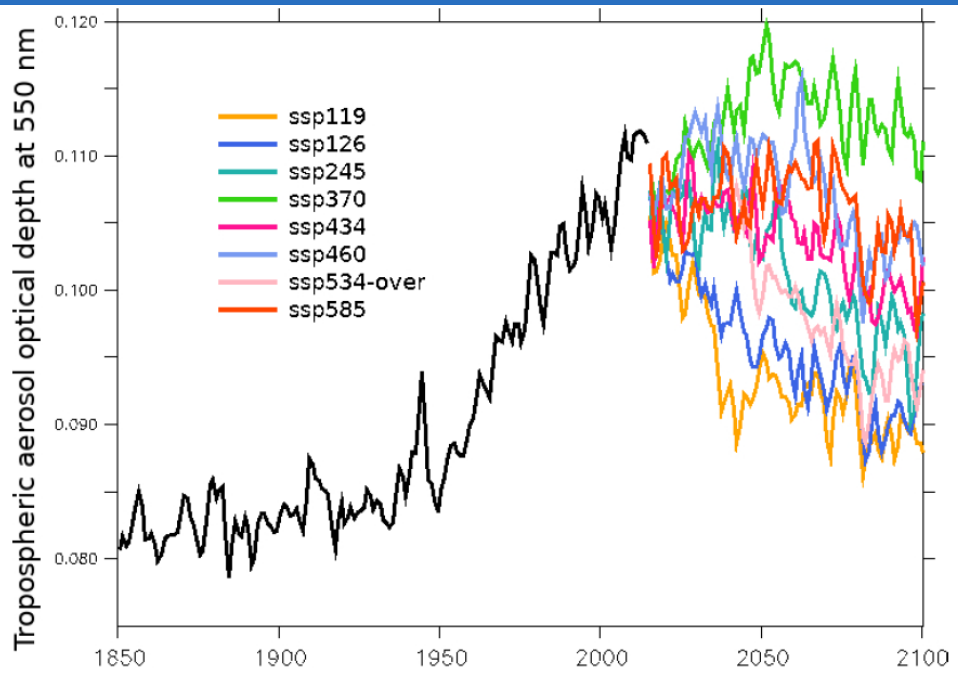


Figure 11. Annual and global mean of the tropospheric aerosol optical depth at 550 nm (unitless) as diagnosed in IPSL-CM6A-LR in the *r1 historical* (black line) and eight different *r1 scenario* experiments (color lines). The running mean entails a gap at the historical/scenario junction.

Lurton et al., JAMES, submitted, 2019

Aerosol IRF & ERF in LMDZ6

Forcing	IRF	ERF - fixed SST
Aerosol-radiation interactions	–0.38	N.A.
Aerosol-cloud interactions	–0.34	N.A.
Aerosol total effect	–0.73	–0.62±0.024

Table 2. Values of IRF and ERF for LMDZOR-INCA aerosols, for the year 2014, from fixed SST experiments. All forcing estimates are in $\mathrm{W\,m^{-2}}$. ERF was calculated over 100-year time series, i.e., over the last 25 years of each 30-year member, on 4-member ensembles for each experiment. N.A.: not available. The ERF is not corrected for land surface temperature change.

Lurton et al., JAMES, submitted, 2019

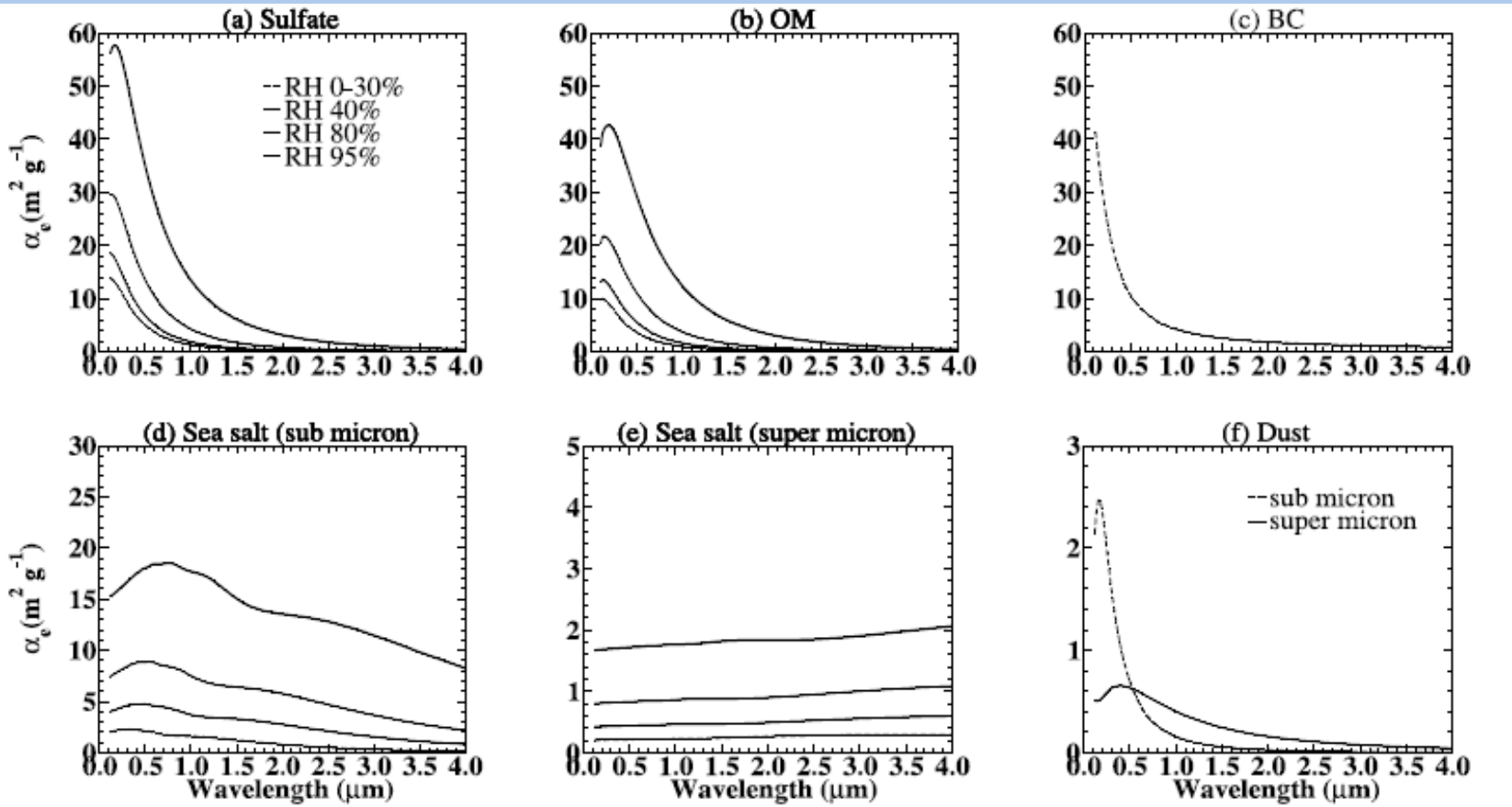
RRTM (-rrtm true)

- Tropospheric and stratospheric aerosols are available in RRTM, but only for the 2 and 6 SW wavebands case (NSW=2 or 6)
- Revised optical properties with routines available

  http://forge.ipsl.jussieu.fr/igcmg/svn/TOOLS/CMIP6_FORCING/AER_OPTICS/

- Reunified routine for offline (LMDZ) and online (INCA) aerosols
- LW properties for dust, forthcoming for the rest

Aerosol optical properties



Example only f(RH,λ)

INCA aerosol in LMDZ-NP

- Reunified aerosol optical properties routine for offline (LMDZ) and online (INCA) aerosols
- Takes into account mixing by boundary layer, thermals and convection (with or without simultaneous scavenging)
- Requires interactive natural sources of aerosols
- Still being improved for AerChemMIP but have been used to prepare CMIP6 aerosol climatologies
- Runs IPSL-CM6 v6.1.11 with libIGCM software