Aerosols in LMDz model

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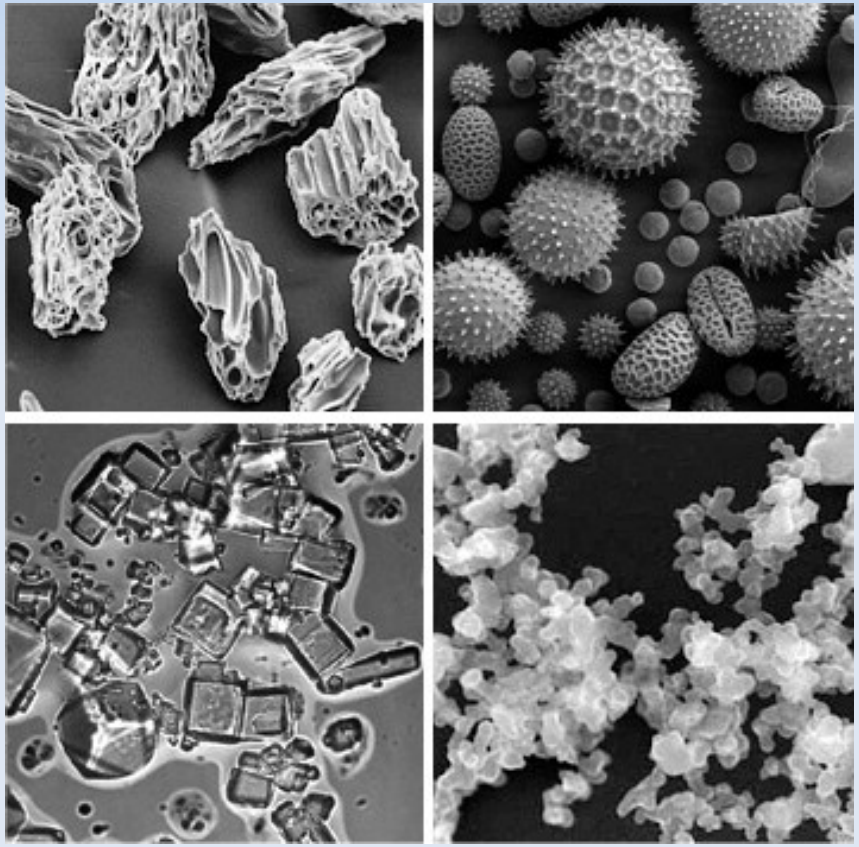
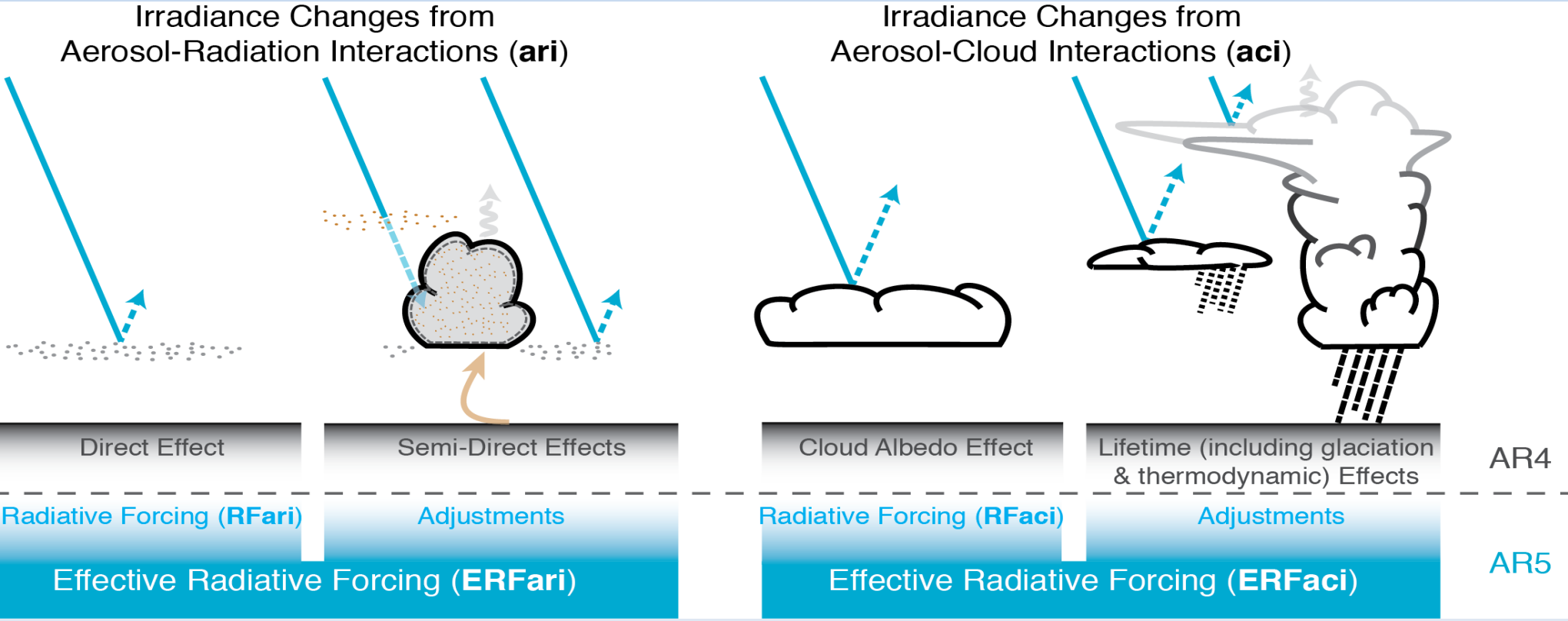
Atmospheric aerosols

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 Offline

Anthropogenic and natural emissions

AP only: Coefficient to reconstruct a natural only aerosol field online

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

LMDz – AP / NP with RRTM
General Circulation Model

Climatologies of natural and anthropogenic aerosol concentrations

LMDz – AP or NP
General Circulation Model

Climatologies of natural and anthropogenic aerosol concentrations

LMDz – NP with RRTM
General Circulation Model

Simple aerosol model with **-dust** compilation option

LMDz – NP with RRTM
General Circulation Model

Sectional stratospheric aerosol model with **–StratAer** compilation option

LMDz – AP / 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

Nature of aerosols

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 but providing the input for klev layers is also acceptable

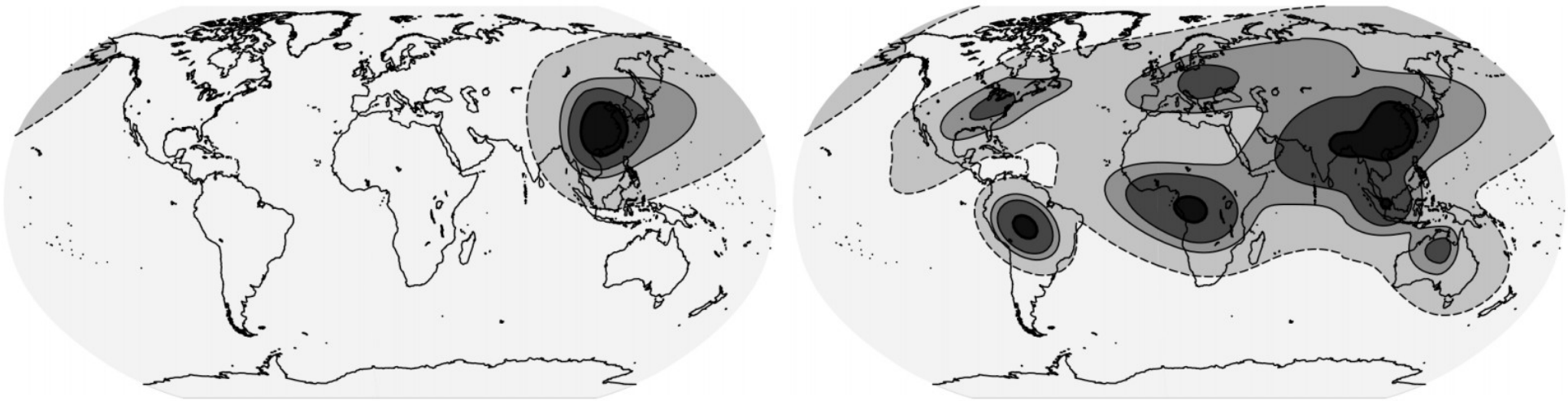
Aerosols: input files (continued)

- 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 (1/3)

- Runtime parameter new_aod (logical):
  to use the most recent parameterization of aerosol optical depth. y is the default value.

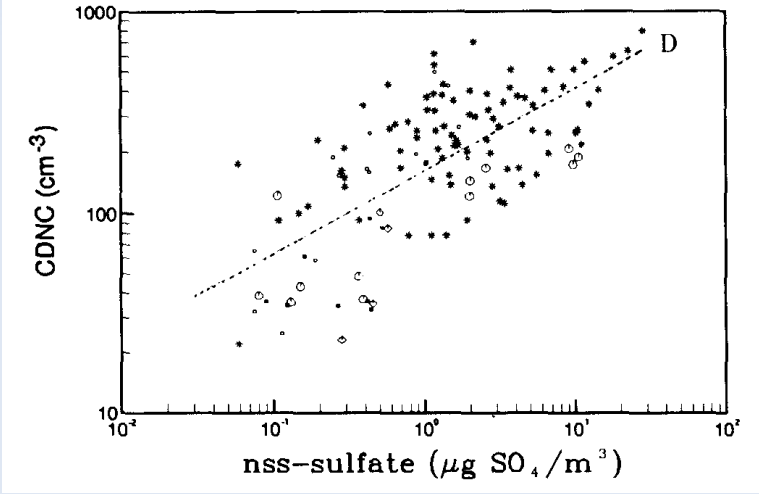
  Note: new_aod = n can only be used with flag_aerosol = 1 (sulfate aerosols only). Obsolete.

Aerosols for expert users (2/3)

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)

Now uses mass of all soluble species

Aerosols for expert users (3/3)

- 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)
  - Set the variable aerosolfeedback_active to .false. in routine sw_aeroAR4.F90 (no RRTM) or rrtm/recmwf_aero.F90 (RRTM) and recompile
  - Or 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)

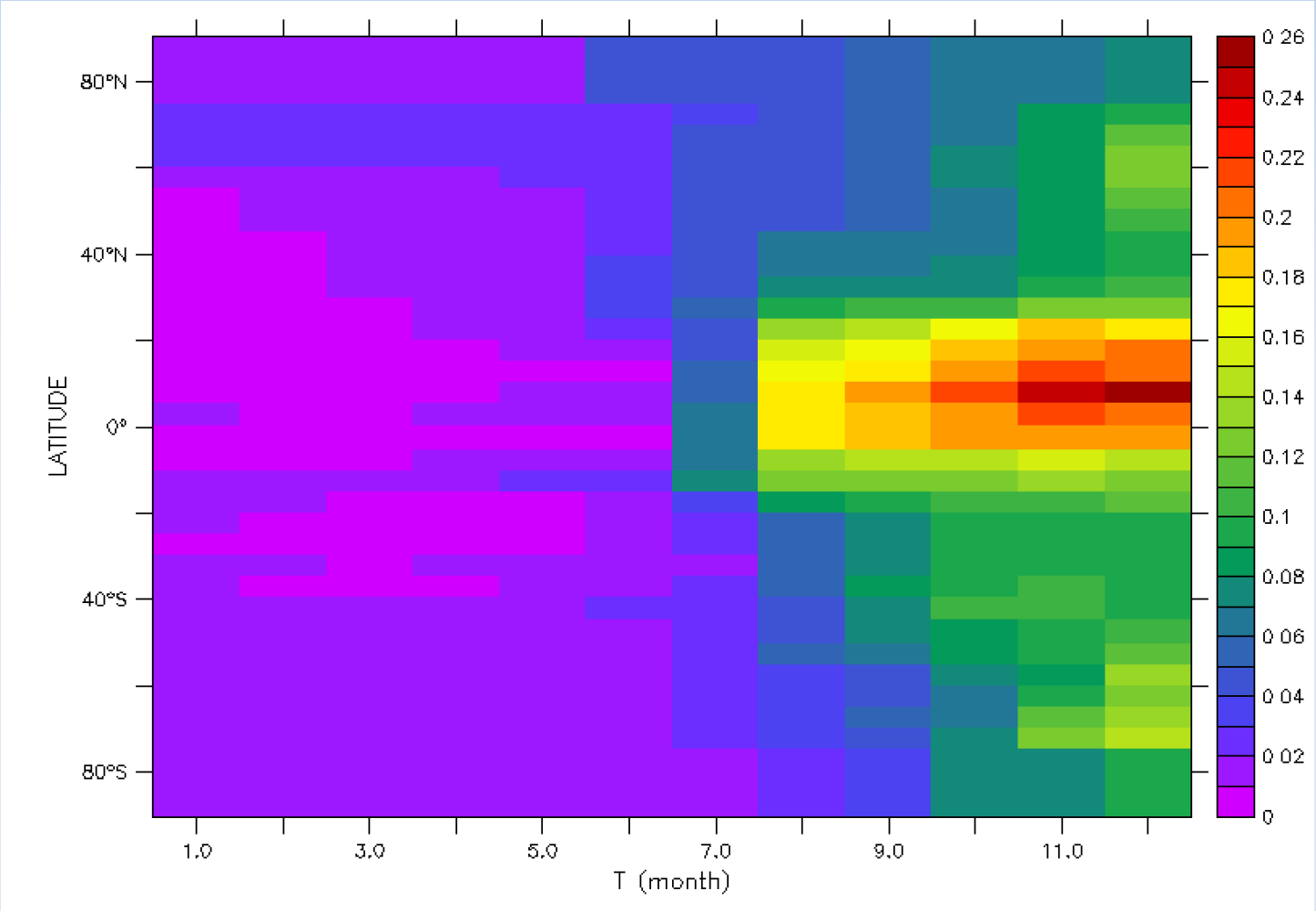
Stratospheric aerosols (CMIP6)

Example:

550 nm AOD

CMIP6 data

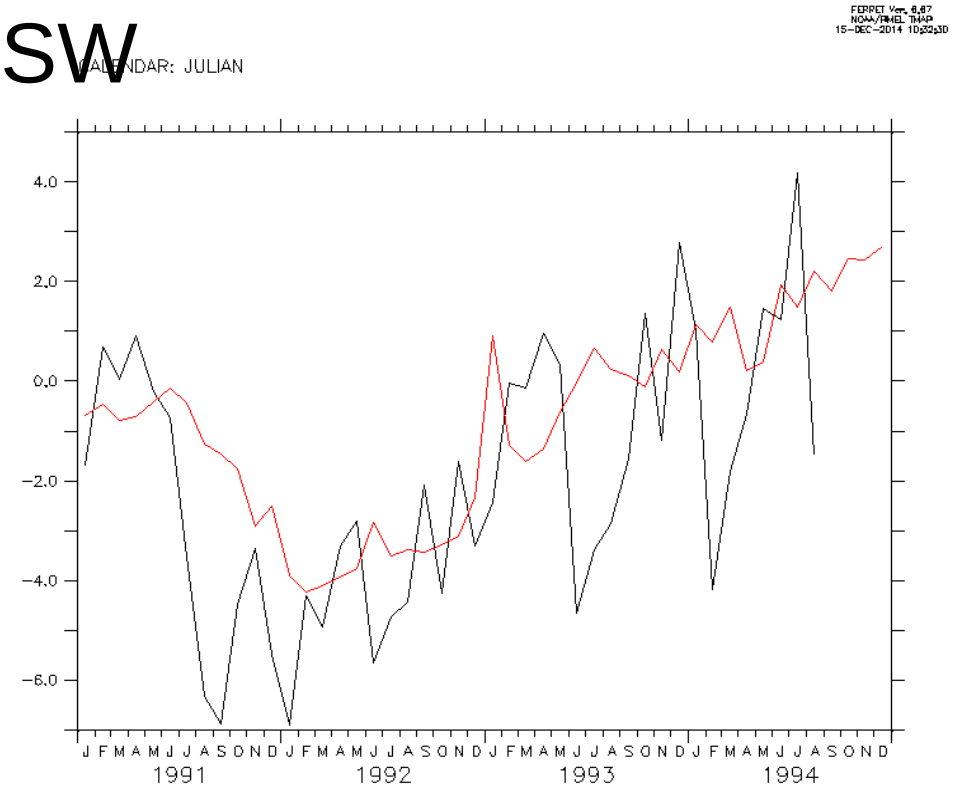
Year 1991



Stratospheric aerosols: Pinatubo

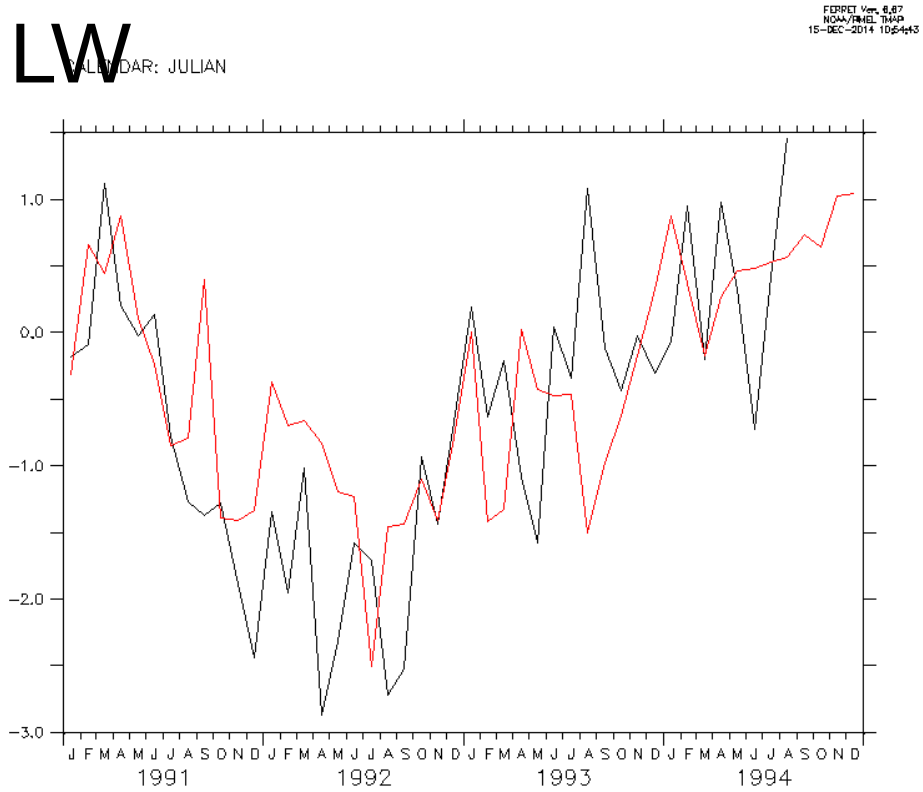
Observations (ERBE) vs Model

SW



observed anomaly in reflected SW vs. tops

LW

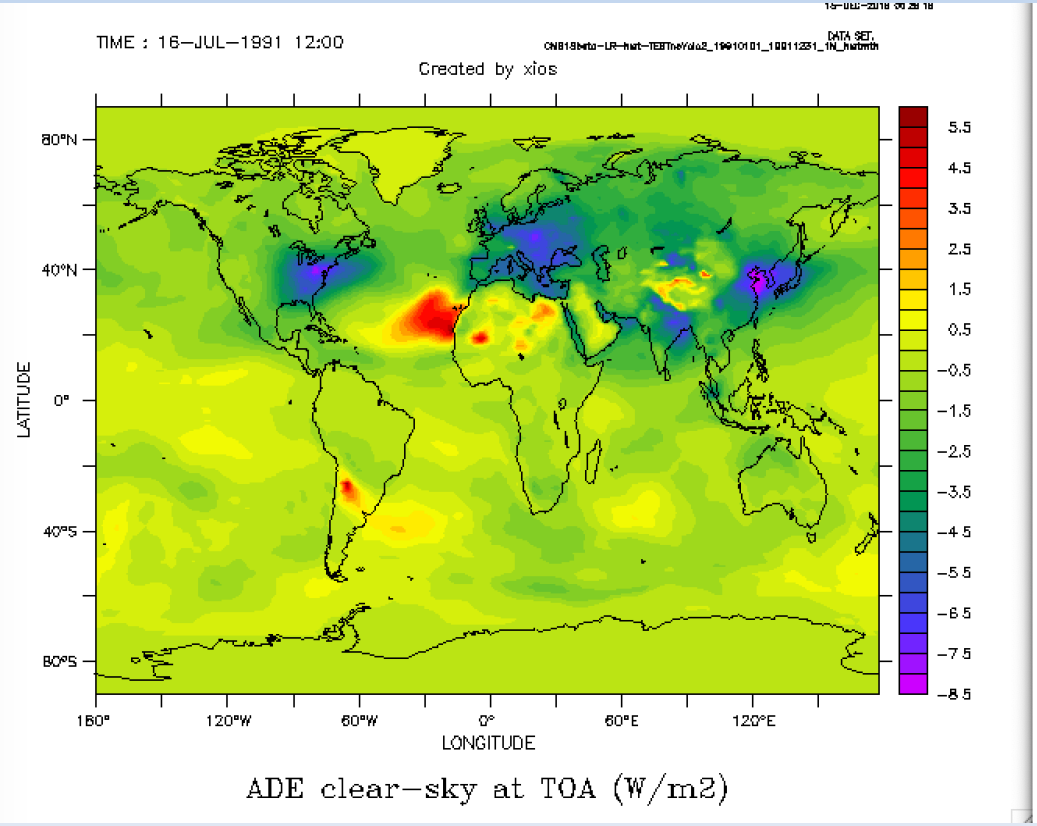


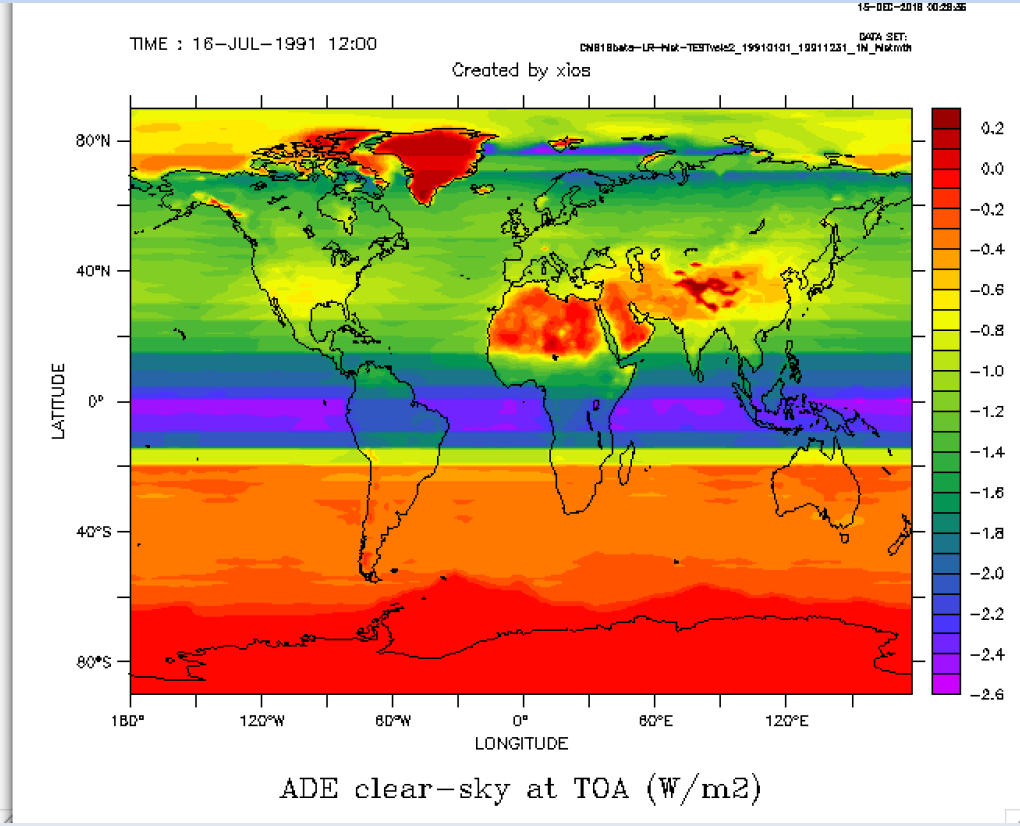
observed anomaly in emitted LW vs. topl

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
- Only in LMD6.0.15 branch for now

Example: topswad0 diagnostic





ok_volc = n (default)

ok_volc = y

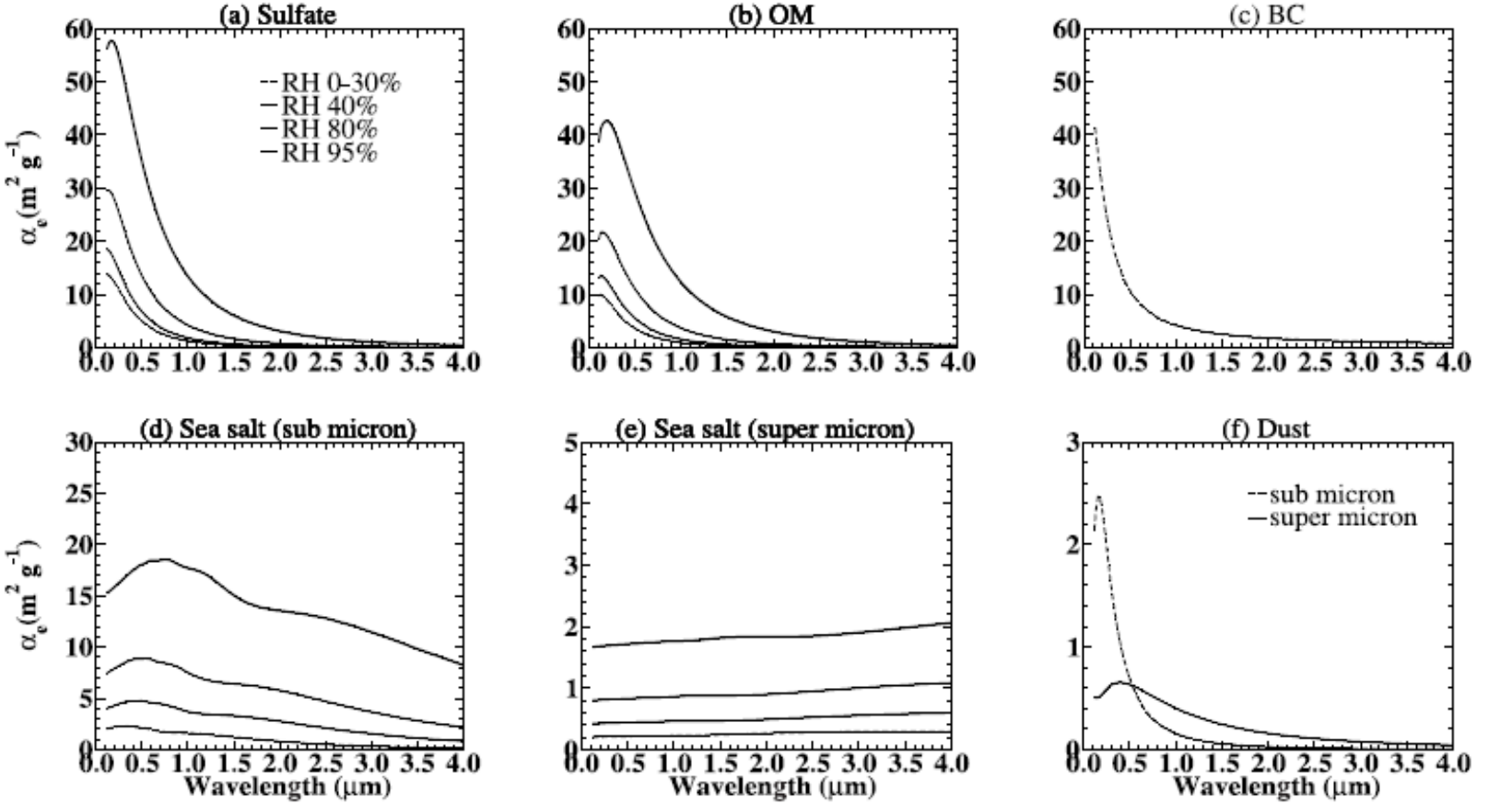
RRTM (-rrtm true)

- 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 under libIGCM environment