AEROCOM Indirect effect
Protocol for pilot experiments

Johannes Quaas, 17 December 2007

Project description
See AeroCom Indirect effect working group wiki: http://wiki.esipfed.org/index.php/Indirect_forcing

Contact
Please do not hesitate to contact me for any remarks or questions
Johannes Quaas
phone +49 40 41173 179
E-mail johannes.quaas@zmaw.de

Data submission deadline
Submission of results by 30 April 2008

Simulation setup
Simulation start 1 October 1999
Forcing by AMIP2 sea surface temperature and sea-ice extent
Greenhouse gas concentrations for year 2000
Aerosol direct, semi-direct, and indirect effects taken into account.

simulation PD (present-day): year 2000 AEROCOM aerosol emissions
simulation PI (pre-industrial): pre-industrial AEROCOM aerosol emissions (year 2000 GHG concentration)

option (a) (recommended if possible)
nudged to ECMWF re-analysis wind and temperature fields (1 year simulations for each, PD and PI)

option (b)
free run (5 years simulations for each, PD and PI)

Diagnostics
Data is to be collected at the AEROCOM server.
Data in NetCDF format
All data are 3-dimensional ( lon x lat x time )
(optional ISCCP-simulator output 5-dimensional ( lon x lat x time x COD x PTOP ). For the ISCCP simulator please refer to http://gcss-dime.giss.nasa.gov/simulator.html.)

In addition to the diagnostics below, it is highly recommended to store the AEROCOM standard and forcing diagnostics, so that the simulations can be analysed for the direct forcing as well, and future more in-depth analyses are possible.

(1) For evaluation with satellite data
1 year (year 2000) of daily data from the PD run, taken at the overpass time of the Aqua Train satellite constellation (about 13.30 p.m. local time) (or, alternatively, at an arbitrary instant, 13.30 UTC).
<table>
<thead>
<tr>
<th>name</th>
<th>long_name</th>
<th>units</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>od550, atmosphere_optical_thickness_due_to_aerosol</td>
<td>-</td>
<td>Aerosol optical depth (@ 550 nm)</td>
</tr>
<tr>
<td>2</td>
<td>cdr, liquid_cloud-top_droplet_effective_radius</td>
<td>m</td>
<td>Droplet effective radius at top of liquid water clouds</td>
</tr>
<tr>
<td>3</td>
<td>cdnc, liquid_cloud_droplet_number_concentration</td>
<td>m$^{-3}$</td>
<td>Droplet number concentration in top layer of liquid water clouds</td>
</tr>
<tr>
<td>4</td>
<td>tcc, cloud_area_fraction</td>
<td>-</td>
<td>Fractional cover by all clouds</td>
</tr>
<tr>
<td>5</td>
<td>lcc, liquid_cloud_area_fraction</td>
<td>-</td>
<td>Fractional cover by liquid water clouds</td>
</tr>
<tr>
<td>6</td>
<td>lwp, atmosphere_cloud_ice_content</td>
<td>kg m$^{-2}$</td>
<td>In-cloud liquid water path for liquid water clouds</td>
</tr>
<tr>
<td>7</td>
<td>albs, planetary_albedo</td>
<td>-</td>
<td>TOA broadband SW planetary albedo, all-sky</td>
</tr>
<tr>
<td>8</td>
<td>rst, toa_net_downward_shortwave_flux</td>
<td>W m$^{-2}$</td>
<td>Net TOA downward SW flux, all-sky</td>
</tr>
<tr>
<td>9</td>
<td>rstcs, toa_net_downward_shortwave_flux_assuming_clear_sky</td>
<td>W m$^{-2}$</td>
<td>Net TOA downward SW flux, clear-sky</td>
</tr>
<tr>
<td>10</td>
<td>rlt, toa_net_downward_longwave_flux</td>
<td>W m$^{-2}$</td>
<td>Net TOA downward LW flux, all-sky</td>
</tr>
<tr>
<td>11</td>
<td>rlts, toa_net_downward_longwave_flux_assuming_clear_sky</td>
<td>W m$^{-2}$</td>
<td>Net TOA downward LW flux, clear-sky</td>
</tr>
<tr>
<td>12</td>
<td>ttop, air_temperature_at_cloud_top</td>
<td>K</td>
<td>Temperature at top of clouds</td>
</tr>
<tr>
<td>13</td>
<td>lts, lower_tropospheric_stability</td>
<td>K</td>
<td>Difference in potential temperature between 700 hPa and 1000 hPa</td>
</tr>
<tr>
<td>14</td>
<td>iwp, atmosphere_cloud_ice_content</td>
<td>kg m$^{-2}$</td>
<td>In-cloud ice water path for ice clouds</td>
</tr>
<tr>
<td>15</td>
<td>icr, cloud-top_ice_crystal_effective_radius</td>
<td>m</td>
<td>Effective radius of crystals at top of ice clouds</td>
</tr>
<tr>
<td>16</td>
<td>icc, ice_cloud_area_fraction</td>
<td>-</td>
<td>Fractional cover by ice clouds</td>
</tr>
<tr>
<td>17</td>
<td>cod, atmosphere_optical_thickness_due_to_clouds</td>
<td>-</td>
<td>In-cloud optical depth</td>
</tr>
<tr>
<td>18</td>
<td>ccn, cloud_condensation_nuclei</td>
<td>m$^{-3}$</td>
<td>Cloud condensation nuclei number concentration for liquid water clouds where activation corresponding to CDR and CDNC occurs (cloud base or top-layer of liquid water clouds)</td>
</tr>
<tr>
<td>19</td>
<td>isccp, isccp_cloud_area_fraction</td>
<td>-</td>
<td>Joint histogram of the fractional cover by clouds for 49 bins of cloud optical thickness and cloud top pressure</td>
</tr>
<tr>
<td>20</td>
<td>hfls, surface_upward_latent_heat_flux</td>
<td>W m$^{-2}$</td>
<td>Surface latent heat flux</td>
</tr>
<tr>
<td>21</td>
<td>hfs, surface_upward_sensible_heat_flux</td>
<td>W m$^{-2}$</td>
<td>Surface sensible heat flux</td>
</tr>
<tr>
<td>22</td>
<td>rls, surface_net_downward_longwave_flux_in_air</td>
<td>W m$^{-2}$</td>
<td>Net surface LW downward flux</td>
</tr>
<tr>
<td>23</td>
<td>rss, surface_net_downward_shortwave_flux</td>
<td>W m$^{-2}$</td>
<td>Net surface SW downward flux</td>
</tr>
<tr>
<td>24</td>
<td>rds, surface_downwelling_shortwave_flux_in_air</td>
<td>W m$^{-2}$</td>
<td>Surface SW downward flux (in order to estimate the model's 'true' surface albedo)</td>
</tr>
</tbody>
</table>
(2) For forcing estimates
as (1), but monthly-mean fields for both PD and PI simulations
if option (a): for year 2000
if option (b): for five years (one average seasonal cycle)

“Satellite simulator”

(1) Sampling of cloud-top quantities

The idea is to use the cloud overlap assumption (maximum, random, or maximum-random) to estimate which
part of the cloud in a layer can be seen from above.

Note: For the CCN, whether to sample it in the same way as CDNC, or use a similar approach (going from
bottom up) to sample it at cloud base depends on your parameterization of the activation.

let i=1,2,...,nx be the index for the horizontal grid-points
let k=1,2,...,nz be the index for the vertical levels, with 1 being the uppermost level, and nz the surface level

naming convention for the 3D input fields:
iovl is the flag to select the overlap hypothesis
cod3d(nx,nz) cloud optical thickness
f3d(nx,nz) cloud fraction
t3d(nx,nz) temperature
phase3d(nx,nz) cloud thermodynamic phase (0: entire cloud consists of ice, 1: entire cloud consists of liquid
water, between 0 and 1: mixed-phase)
cdr3d(nx,nz) cloud droplet effective radius
icr3d(nx,nz) ice crystal effective radius
cdnc3d(nx,nz) cloud droplet number concentration

thres_cld = 0.001
thres_cod = 0.3
tcc(:) = 0
icc(:) = 0
loc(:) = 0
ttop(:) = 0
cdr(:) = 0
icr(:) = 0
cdnc(:) = 0

DO i=1,nx
  DO k=2,nz ! assumption: uppermost layer is cloud-free (k=1)
    IF ( cod3d(i,k) > thres_cod and f3d(i,k) > thres_cld ) THEN ! visible, not-too-small cloud
      flag_max is needed since the vertical integration for maximum overlap is different from the
two others: for maximum, tcc is the actual cloud cover in the level, for the two others, the actual
cloud cover is 1 - tcc
      ! ftmp is total cloud cover seen from above down to the current level
      ! tcc is ftmp from the level just above
      ! ftmp  tcc is thus the additional cloud fraction seen from above in this level
      IF ( iovl = maximum ) THEN
        flag_max = -1.
        ftmp(i) = MAX( tcc(i), f3d(i,k) ) ! maximum overlap
      ELSEIF ( iovl = random ) THEN
        flag_max = 1.
        ftmp(i) = tcc(i) * ( 1 - MAX( f3d(i,k), f3d(i,k-1) ) ) / &
          ( 1 - MIN( f3d(i,k), 1 - thres_cld ) ) ! maximum-random overlap
      ELSEIF ( iovl = maximum-random ) THEN
        flag_max = 1.
        ftmp(i) = tcc(i) * ( 1 - MAX( f3d(i,k), f3d(i,k-1) ) ) / &
          ( 1 - MIN( f3d(i,k), 1 - thres_cld ) ) ! maximum-random overlap
      ENDIF
    ENDIF
  ENDDO
END
ttop(i) = ttop(i) + t3d(i,k) * ( tcc(i) - ftmp(i) )*flag_max

! ice clouds
icr(i) = icr(i) + icr3d(i,k) * ( 1  phase3d(i,k) ) * ( tcc(i) - ftmp(i) )*flag_max
icc(i) = icc(i) + ( 1   phase3d(i,k) ) * ( tcc(i) - ftmp(i) )*flag_max

! liquid water clouds
cdr(i) = cdr(i) + cdr3d(i,j) * phase3d(i,k) * ( tcc(i)   ftmp(i) )*flag_max
cdnc(i) = cdnc(i) + cdnc3d(i,j) * phase3d(i,k) * ( tcc(i)   ftmp(i) )*flag_max
lcc(i) = lcc(i) + phase3d(i,k) * ( tcc(i) - ftmp(i) )*flag_max

tcc(i) = ftmp(i)
ENDIF ! is there a visible, not-too-small cloud?
ENDDO ! loop over k

IF ( iovl = random OR iovl = maximum-random ) THEN
tcc(i) = 1. - tcc(i)
ENDIF
ENDDO ! loop over I

(2) Sampling of the satellite-overpass-time

To sample the overpass time of the satellite (13.30 h local time), the idea is to create a mask (satmask) indicating whether or not at the grid-box the local time is 13.30 h ± ½ model-timestep. Then, all output fields are weighted with this mask (field * satmask), and in the output, the diurnal mean is taken. The physical fields at 13.30 h local time are obtained in post-processing by dividing each field by the mask (field / satmask).

So, the diurnal mean of satmask must be stored as well!

naming convention for the input variables:
utctime current time of the day in UTC in seconds
time_step_len length of model time-step
lon(nx) longitude in degrees from 0 to 360°
sat_mask(:) = 0
overpasstime = 48600 ! 13.30 p.m. local time

DO i=1,nx
  localtime(i) = utctime + 240 * lon ! for each degree of longitude east, 4 min earlier local time
  IF ( localtime(i) > 86400 ) THEN ! this is still the previous day
    localtime(i) = localtime(i) - 86400
  ENDIF

  ! Select 10.30 a.m. ± dt/2
  IF ( ABS( localtime(i) - overpasstime ) <= time_step_len/2 )
    sat_mask(i) = 1
  ENDIF

  ! Weight the output fields with this mask
  aod(i) = aodd(i) * sat_mask(i)
cdr(i) = cdr(i) * sat_mask(i)
cdnc(i) = cdnc(i) * sat_mask(i)
tcc(i) = tcc(i) * sat_mask(i)
lcc(i) = lcc(i) * sat_mask(i)
lwp(i) = lwp(i) * sat_mask(i)
albs(i) = albs(i) * sat_mask(i)
ssw(i) = ssw(i) * sat_mask(i)
sswclr(i) = sswclr(i) * sat_mask(i)
slw(i) = slw(i) * sat_mask(i)
slwclr(i) = slwclr(i) * sat_mask(i)
ttop(i) = ttop(i) * sat_mask(i)
lts(i) = lts(i) * sat_mask(i)
lwp(i) = lwp(i) * sat_mask(i)
icr(i) = icr(i) * sat_mask(i)
icc(i) = icc(i) * sat_mask(i)
cod(i) = cod(i) * sat_mask(i)
ccn(i) = ccn(i) * sat_mask(i)

ENDDO
In the diurnal-mean output files, the actual in-cloud fields are derived by
\[ cdr' = \frac{cdr}{lcc} \]
\[ cdnc' = \frac{cdnc}{lcc} \]
\[ lwp' = \frac{lwp}{lcc} \]
\[ ttop' = \frac{ttop}{tcc} \]
\[ iwp' = \frac{iwp}{icc} \]
\[ icr' = \frac{icr}{icc} \]

For all other fields, the actual values are derived by
\[ aod' = \frac{aod}{sat\_mask} \]
etc.

**Potential participants** as of December 2007

Yi Ming, GFDL (GFDL GCM)
Yves Balkanski, LSCE (LMDZ-INCA)
Ulrike Lohmann, ETH (ECHAM5 with convection microphysics)
Philip Stier, Univ Oxford (ECHAM5, HadGEM)
Leon Rotstayn, CSIRO (CSIRO GCM, subject to clarification)
Andrew Gettelman, NCAR (CCM)
Toshi Takemura, Univ Kyoto (SPRINTARS)
Surabi Menon, LBL (GISS GCM)
Jon-Egill Kristjánsson, Univ Oslo (CCM-Oslo)
Trude Storelmo, ETH (ECEarth)
Thanos Nenes, Georgia Tech (GMI)
Nicolas Bellouin, Met Office (HadGEM)