GCSS Working Group 4 Model Intercomparison

Procedures for Case 3: Summer 1997 ARM SCM IOP

Steven K. Krueger,[1] Richard T. Cederwall,[2] Shaocheng C. Xie,[2]
and J. John Yio[2]

This file is available from the ARM SCM Case 3 Intercomparison web page[3] and from the GCSS WG4 web page.[4]

1 Introduction

1.1 GCSS strategy

GCSS has the challenging goal of improving the parameterization of cloud related processes in general circulation and numerical weather prediction models through an improved physical understanding of these processes. The focus of GCSS WG4 is precipitating convective cloud systems.

1.2 Description of Case 3

Case 3 is based on the 29-day ARM (Atmospheric Radiation Measurement program) SCM IOP that took place at the Southern Great Plains site in June and July 1997. The Case 3 dataset starts at 2330 UTC on 18 June and ends at 2330 UTC on 17 July.

Our intercomparison study will consist of two phases:

Phase I Evaluate the accuracy of the large-scale forcing for three periods of deep convection during Case 3 by comparing CRM results to observations. Use specified radiative heating profiles to reduce the computational resources required. Submit a limited set of results to expedite the evaluation process. Complete by October 1999 meeting.

Phase II Provide detailed diagnostics to SCM and NWP modelers based on CRM simulations of the "best" of the three periods. The diagnostics will be developed and refined based on discussions at the October 1999 meeting. Complete by October 2000.

[1]University of Utah
[2]Lawrence Livermore National Laboratory
[3]http://www.arm.gov/docs/scm/scmic3/
[4]http://www.met.utah.edu/skrueger/gcss/wg4.html

1.3 Questions addressed with Case 3

[To be added.]

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2 Numerical Experiment Protocol

2.1 General Description for all Models

The descriptions below of vertical grid structure, initial conditions, upper and lower boundary conditions, and large-scale forcing apply to all models, 1D single column models (SCMs) as well as 2D and 3D CRMs. Aspects that apply only to CRMs will follow these descriptions.

Holton's values for some physical constants: $g = 9.81$ m s^{-2}, $R = 287$ J kg^{-1}, $c_p = 1004$ J kg^{-1}, $L = 2.5e6$ J kg^{-1}. If it is convenient for you to use these values, please do so.

2.1.1 Obtaining and reading the files

Profiles of the large-scale temperature ($\bar{T}$), mixing ratio ($\bar{q}$), velocity components ($\bar{u}$, $\bar{v}$, and $\bar{w}$), and the advective tendencies of temperature and mixing ratio ($(\partial\bar{T}/\partial t)_{\text{L.S.}}$ and $(\partial\bar{q}/\partial t)_{\text{L.S.}}$) from the Constrained Variational Analysis (Zhang and Lin 1997) are available from the ARM SCM Case 3 Intercomparison web page (http://www.arm.gov/docs/scm/scmic3/). See Table 1 for a complete list of these multi-layer quantities.

[**New 990721**] Profiles of the radiative heating rate Q_R from the ECMWF model are available from the ARM SCM Case 3 Intercomparison web page.

Time series of the horizontally averaged turbulent surface fluxes of sensible and latent heat, ground temperature (T_g), and surface pressure ($\overline{p}_0$) are available from the ARM SCM Case 3 Intercomparison web page. [**New 990721**] Time series of the skin temperature (T_s) based on the SIROS network of radiometers are available from the ARM SCM Case 3 Intercomparison web page.

2.1.2 Initial conditions

The initial profiles are based on the observed SGP CART areal averages of temperature, water vapor mixing ratio, and horizontal wind velocity. These are provided as functions of pressure at Δp mb intervals from p_{bot} to p_{top} mb. For this case, $\Delta p = 50$ mb, $p_{\text{bot}} = 965$ mb, and $p_{\text{top}} = 115$ mb. The values at p_{bot} represent those of the layer that starts at the surface. The values provided must be interpolated to each model's vertical grid levels. [**New 990721**] The average elevation for the ARM SGP domain is 360 m.

To obtain values for model levels below p_{bot} by interpolation, one may assume that $\bar{\theta}$, $\bar{q}$, $\bar{u}$, and $\bar{v}$ at the surface are equal to their values at p_{bot}, and that $(\partial\bar{T}/\partial t)_{\text{L.S.}}$, and $(\partial\bar{q}/\partial t)_{\text{L.S.}}$ are equal to zero at the surface. These assumptions are reasonable only when

the surface layer is unstably stratified. Other assumptions should be used when the surface layer is stably stratified.

To obtain values for model levels above $p_{\rm top}$ by interpolation, the simplest approach is to assume that $\bar{T}$, $\bar{q}$, $\bar{u}$, and $\bar{v}$ at 20 km are equal to their values at $p_{\rm top}$ mb, and that $\bar{\omega}$, $(\partial\bar{T}/\partial t)_{\rm L.S.}$, and $(\partial\bar{q}/\partial t)_{\rm L.S.}$ are equal to zero at 20 km.

2.1.3 Lower boundary conditions

The lower boundary is a land surface. The time-varying, site-wide averages of the surface sensible and latent heat fluxes as measured by the ARM Energy Balance Bowen Ratio (EBBR) stations are available from the ARM SCM Case 3 Intercomparison web page. In addition, the site-wide average surface pressure, the site-wide average ground temperature (T_g) measured at the EBBR stations, and the site-wide average skin temperature (T_s) measured at the SIROS stations are provided. These values must be interpolated to obtain values at each time step.

The "ground temperature" is actually the average 0-5 cm soil temperature measured by the EBBR. It may not be suitable for calculating the turbulent surface fluxes.

2.1.4 Radiative heating rate

The profile of the radiative heating rate Q_R may be specified for some simulations. In this case, obtain the time-varying profiles from the ARM SCM Case 3 Intercomparison web page.

Radiative transfer calculations may require temperature, water vapor mixing ratio, and ozone mixing ratio profiles above 20 km. The "standard mid-latitude summer atmosphere" profiles are available for this purpose, and can be found on the ARM SCM Case 3 Intercomparison web page under SCM Supporting Data Sets.

The site-wide average skin temperature (not the "ground temperature") should be used for calculating the upwelling IR radiative flux at the surface. Other radiative properties of the land surface include albedo (specifed, perhaps as a function of solar zenith angle and wavelength) and emissivity (specified). Each model will use its own specifications of these properties.

Radiative transfer calculations require the *solar constant* and the *solar zenith angle* (or its cosine). Due to the variation of the earth-sun distance d from its mean value d_m, the solar "constant" S usually differs from its mean value of $S_m = 1365$ W/m^2. The ratio $r = d/d_m$ is given by

$$r = 1 + a_0 \sin\left((2\pi/365.25)(n_d - 365.25/4)\right),$$

where $a_0 = 0.0167381$ and n_d is the number of days since January 4, 1958. This formula comes from the American Ephemeris and Nautical Almanac, United States Naval Observatory (1956).

You may use the Fortran subroutine listed below (solar_99.f, which will be available via the ARM SCM Intercomparison web page) to calculate the cosine of the solar zenith

angle. The central facility of the SGP CART is located at latitude 36° 36′ N, longitude 97° 29′ W.

```
      subroutine solar (month,day, hour, min, sec, lat, lon,
     $ cosine_zenith_angle )
c     revised July 1999
      real min, month, lat, lon
c
c     lat = latitude (degrees N, < 0 for degrees S)
c     lon = longitude (degrees E, < 0 for degrees W)
c     time coordinate is UTC
c     month = month of year (1-12)
c     day = day of month (1-31)
c     hour = hour of day (0-23)
c
      pi   = 3.141593
      dechr = hour + min / 60.0 + sec / 3600.0
      decday = day + dechr / 24.
      sin_lat = sin(pi/180.*lat)
      cos_lat = cos(pi/180.*lat)
      decmonth = month + day/30.
      sun_azim = 2.*pi*(decday + lon/360.) ! radians
      sun_lat = (pi*23./180.)*cos((decmonth - 6.75)*pi/6.) ! radians
      cosine_zenith_angle =
     $ max(-cos(sun_lat)*cos(sun_azim)*cos_lat+sin(sun_lat)*sin_lat,0.)
c
      return
      end
```

2.1.5 Large-scale forcing

The large-scale forcing terms in the CRM governing equations include the large-scale horizontal pressure gradient force, the large-scale advective tendencies of horizontal momentum, potential temperature, water vapor mixing ratio, and hydrometeor mixing ratios. The CRM domains and SCM horizontal grid sizes are considered to be small compared to large-scale disturbances. In this case, the large-scale forcing will be approximately uniform over the model domains. For this reason, the large-scale forcing terms are defined to be functions of height and time only. The available large-scale forcing terms are based on observations averaged over the SGP CART region (about 365 km by 300 km).

The large-scale advective tendencies for temperature T and water vapor mixing ratio q are are formally defined (on isobaric surfaces) as

$$\left(\frac{\partial \bar{T}}{\partial t}\right)_{\text{L.S.}} \equiv -\bar{\mathbf{v}} \cdot \nabla \bar{T} - \bar{\omega}\frac{\partial \bar{T}}{\partial p} + \frac{\bar{\omega}}{c_p}\alpha$$

Table 1: Multi-layer quantities provided.

Fortran variable	physical quantity
`Temp`	$\bar{T}$
`Water_Vapor_Mixing_Ratio`	$\bar{q}$
`u_wind`	$\bar{u}$
`v_wind`	$\bar{v}$
`omega`	$\bar{\omega} \equiv d\bar{p}/dt$
`Wind_Divergence`	$\nabla \cdot \bar{\mathbf{v}}$
`Horizontal_Temp_Advec`	$-\bar{\mathbf{v}} \cdot \nabla \bar{T}$
`Vertical_T_Advec`	$-\bar{\omega}\, \partial \bar{T}/\partial p$
`Horizontal_q_Advec`	$-\bar{\mathbf{v}} \cdot \nabla \bar{q}$
`Vertical_q_Advec`	$-\bar{\omega}\, \partial \bar{q}/\partial p$
`s(Dry_Static_Energy/Cp)`	$\bar{s}/c_p \equiv \bar{T} + g\bar{z}/c_p$
`Horizontal_s_Advec`	$-\bar{\mathbf{v}} \cdot \nabla \bar{s}/c_p$
`Vertical_s_Advec`	$-\bar{\omega}/c_p\, \partial \bar{s}/\partial p$
`ds/dt`	$d\bar{s}/dt$
`DT/dt`	$d\bar{T}/dt$
`dq/dt`	$d\bar{q}/dt$
`Q1`	Q_1
`Q2`	Q_2

and

$$\left(\frac{\partial \bar{q}}{\partial t}\right)_{\text{L.S.}} \equiv -\bar{\mathbf{v}} \cdot \nabla \bar{q} - \bar{\omega} \frac{\partial \bar{q}}{\partial p},$$

where ∇ is the horizontal del operator on an isobaric surface.

The "multi-layer" file available from the ARM SCM Case 3 Intercomparison web page includes the quantities listed in Table 1. All quantities are defined on *isobaric* surfaces. These values must be interpolated in height to the model's grid and in time to obtain values at each time step.

Note that

$$-\frac{\bar{\omega}}{c_p} \frac{\partial \bar{s}}{\partial p} = -\bar{\omega} \frac{\partial \bar{T}}{\partial p} + \frac{\bar{\omega}}{c_p} \alpha,$$

where $s \equiv c_p T + gz$. We recommend that one obtain the large-scale advective tendency for temperature using

$$\left(\frac{\partial \bar{T}}{\partial t}\right)_{\text{L.S.}} = -\bar{\mathbf{v}} \cdot \nabla \bar{T} - \frac{\bar{\omega}}{c_p} \frac{\partial \bar{s}}{\partial p}.$$

To obtain the large-scale advective tendency for potential temperature, use

$$\left(\frac{\partial \bar{\theta}}{\partial t}\right)_{\text{L.S.}} = \left(\frac{p_0}{\bar{p}}\right)^{R/c_p} \left(\frac{\partial \bar{T}}{\partial t}\right)_{\text{L.S.}},$$

where $p_0 = 1000$ mb.

Unfortunately, observations of the advective tendencies for hydrometeors are not available. This may have a significant impact on the simulation of upper tropospheric stratiform clouds.

The large-scale forcing term in the horizontal momentum equation (the pressure gradient force) is difficult to accurately measure. One alternative that has been successfully used is to replace this term with a nudging term of the following form:

$$\left(\frac{d\bar{\mathbf{v}}}{dt}\right)_{\text{L.S.}} = -\frac{\bar{\mathbf{v}} - \bar{\mathbf{v}}_{\text{obs}}}{\tau},$$

where $\bar{\mathbf{v}}$ is the predicted large-scale horizontal velocity, $\bar{\mathbf{v}}_{\text{obs}}$ is the observed large-scale horizontal velocity (which varies with height and time), and τ is the specified adjustment time scale (1 to 2 hours). Ideally, this approach will maintain the horizontally-averaged winds in the simulation close to the observed large-scale winds, but will have little impact on the cloud or mesoscale circulations. The "multi-layer" file available from the ARM SCM Case 3 Intercomparison web page includes the observed large-scale horizontal velocity components. These values must be interpolated in height to the model's grid and in time to obtain values at each time step.

The Coriolis force may be neglected because the the momentum nudging term represents both it, the large-scale pressure gradient force, and the large-scale advective tendencies of horizontal momentum.

2.2 Multidimensional (CRM) Aspects

2.2.1 Domain size

In order to simulate MCSs and to average out the "noise" produced by MCSs in the large-scale statistics, a large horizontal domain is needed. A large domain is also necessary to be consistent with the density of observations. Ideally, the simulation would cover a region about 500 km across. This is not a problem for 2D CRMs, but for 3D CRMs, the domain will be less extensive and the horizontal grid size will be larger.

2.2.2 Vertical grid structure

When submitting results with height as the vertical coordinate, define zero height as mean sea level. [**New 990721**] The average elevation for the ARM SGP domain is 360 m above mean sea level.

The following vertical grid structure is recommended for CRMs. SCMs may use other grids. The domain depth will be at least 20 km. The vertical grid size nearest the surface will be 100 m, stretching gradually to 500 m at 6 km, and remaining constant at 500 m from 6 km to 20 km. The grid level heights (in meters) between 0 and 6 km where the vertical velocity is defined are

$$z_k = (c_1 + c_2 z'_k) z'_k \text{ for } k\text{=0,20}$$

where $z'_k = k\Delta z'$, $c_1 = 0.2982456142$, $c_2 = 1.169590643 \times 10^{-4}$, and $\Delta z' = 300$ m. The grid level heights between 0 and 6 km where the horizontal velocity and pressure are defined when using a staggered grid are

$$z_k = (c_1 + c_2 z'_k) z'_k \text{ for } k\text{=}1,20$$

where $z'_k = (k - 0.5)\Delta z'$. The grid level heights between 6 and 20 km where the vertical velocity is defined are

$$z_k = (k - 20)\Delta z + 6000 \text{ for } k\text{=}21,50$$

where $\Delta z = 500$ m. The grid level heights between 6 and 20 km where the horizontal velocity and pressure are defined are

$$z_k = (k - 20.5)\Delta z + 6000 \text{ for } k\text{=}21,50.$$

2.2.3 Convection initiation

The initial conditions will be horizontally uniform. Convection will be initiated by introducing small random perturbations in the temperature field (0.5 K maximum magnitude) in the subcloud layer for the first hour or so. It may be necessary to introduce such perturbations during the entire simulation in order to trigger convection after undisturbed periods.

2.2.4 Boundary conditions

The lateral boundary condition will be cyclic. This is consistent with imposing horizontally-uniform large-scale forcing. It is also convenient for budget studies.

Ideally, the upper boundary at 20 km should not reflect upward-propagating gravity wave energy. However, the particular approach used will be up to each modeler. Additional (sponge) layers may be added above 20 km (to perhaps 40 km) to absorb gravity wave energy.

The Case 3 time-averaged area-mean surface pressure is 968.7 mb. The standard deviation of the area-mean surface pressure is 3.2 mb. The time-averaged value of the surface pressure can probably be used in place of the time-varying values without significant error. For simulations that span a shorter period than the entire Case 3 period, use the time average for the simulation period.

When the horizontally averaged turbulent surface fluxes are specified as a boundary condition, it is not necessary to constrain the local (grid-point) fluxes to be equal to the horizontal average. However, when deep convection is occurring, spatial variability of surface fluxes appears to have little effect on the bulk properties of convection (C. Doran, personal communication, 1999). Therefore, it is recommended that the local (grid-point) fluxes be set equal to the horizontal average.

2.3 Numerical simulations for Phase I

Three subcases (A, B, C) are described below. They are identical except for the time period covered. For all subcases, *specify the turbulent surface fluxes* using the time series available from the ARM SCM Case 3 Intercomparison web page.

[**New 990721**] For each subcase, *specify the radiative heating rate profiles,* Q_R, using the following form:

$$Q_R(p,t) = Q_{R\mathrm{EC}}(p,t_d) \times f(t),$$

where p is pressure, t is time, t_d is the time-of-day relative to 0000 UTC, $Q_{R\mathrm{EC}}$ is the ECMWF model *diurnally averaged composite profile for the subcase*, and f is a time-dependent factor for each subcase that guarantees that the specified radiative heating rates are the same as those used in the variational analysis when vertically integrated. The quantities $Q_{R\mathrm{EC}}(p,t_d)$ and $f(t)$ for each subcase are available from the ARM SCM Case 3 Intercomparison web page.

For all CRM simulations, orient the x-coordinate east-west so it increases toward the east, and use a horizontal grid size of 2 km or less. For all 2D CRM simulations, orient the domain east-west and use a domain size of about 500 km.

2.3.1 Subcase A

[**New 990721**] This is a 4-day simulation starting at 2330 UTC 26 June 1997.

2.3.2 Subcase B

[**New 990721**] This is a 5-day simulation starting at 2330 UTC 7 July 1997.

2.3.3 Subcase C

[**New 990721**] This is a 5-day simulation starting at 2330 UTC 12 July 1997.

3 Results to Submit

The results to be submitted will consist of *large-scale* quantities unless otherwise noted. Large-scale is defined as both a space and time average. The space average is the horizontal average over the entire domain. The time average is the average over a 3-hour period, and should be based on "observations" taken frequently enough to avoid aliasing due to cloud-scale and mesoscale variability. Some quantities, such as surface rainfall, should be accumulated every time step. Unless noted otherwise, time averages should be obtained from observations taken no less often than every 15 or 20 minutes.

The large-scale quantities to be submitted will consist of time series and profiles at 3-hourly intervals. The time series will be largely based on quantities provided in more detail in the profiles, so the latter will be described first.

An overbar indicates a large-scale average. Unless explicitly defined as a large-scale quantity, a variable without a bar is a grid-scale average (i.e., a grid-point value). A grid-scale average may also be denoted by angle brackets. A grid-scale departure from the large-scale average is indicated by a single prime, so that $a' = \bar{a} - a$. A subgrid-scale departure from the grid-scale average is indicated by a double prime.

The definitions of "cloud top height," "cloud top temperature," "clear" and "cloudy" columns, "rainy" columns, "echo top height" and "convective" and "stratiform" columns, follow the lists.

It is nearly certain that there will be revisions and additions to this list, both before and after the intercomparison workshop. To allow for such reprocessing, please save the following 2D or 3D CRM fields at all grid points every 15 or 20 minutes: temperature or potential temperature (T or θ), all water substance mixing ratios (q, q_c, q_i, q_r, q_s, q_g), the velocity components (u, v, w) and the downwelling and upwelling infrared and solar radiative fluxes (F^-_{LW}, F^+_{LW}, F^-_{SW}, and F^+_{SW}).

Instructions on how to submit the files containing the quantities described below are available from the ARM SCM Case 3 Intercomparison web page.

3.1 Description of quantities for Phase I

For Phase I, please submit the following set of results.

- **Profiles**

  Submit the results for each quantity listed below as a separate ASCII file in the special file format described in the section after the definitions. Include the time at the midpoint of the averaging interval $\bar{t}$ (calendar days, F8.3) and the height z (km, F7.3) as the x and y coordinates. *Calendar days* is the number of days since 0000 UTC 31 December. Thus the calendar day at midday on 3 January is 3.5.

  [**New 990721**] Name each file as follows: *simulation*.p*item.model_acronym*. Each simulation is labeled with the subcase (e.g., A, B, or C) and model type (1=1D SCM, 2=2D CRM, 3=3D CRM). For example, the file name "a2.p1.UU_CRM" indicates simulation=a2, profile item=1 (temperature), and model=UU_CRM. The model acronym should have at most 13 characters (shorter is better), and the underscore character should be used in lieu of the period or slash if needed. To reduce the file sizes, suggested formats for each quantity are included in the descriptions below using Fortran notation.

  If you do not plan to submit a file, please supply an empty file in its place with the same name but with the suffix '.no_submitted' added. Or, alternatively (though less machine decipherable) you may submit a file named README to list the files not submitted.

  The profile item numbers used for GCSS WG 4 Case 2 are retained for convenience. There are no changes from Case 2 in the definitions for these items. However, items 0 and 30 are new.

  0. Pressure at the temperature levels, $\overline{p}$ (mb) (F7.1)
  1. Temperature, $\overline{T}$ (K) (F7.2)
  2. Water vapor mixing ratio, $\overline{q}$ (g/kg) (F7.3)
  3. Relative humidity, R (unitless) (F6.3): $R = \bar{q}/q^*(\bar{T}, \bar{p})$, where $q^*(T, p)$ is the saturation mixing ratio over water.
  4. Cloud water (suspended liquid water) mixing ratio, $\overline{q_c}$ (g/kg) (F7.4)
  5. Cloud ice (suspended ice) mixing ratio, $\overline{q_i}$ (g/kg) (F7.4)
  6. Rain (falling liquid water) mixing ratio, $\overline{q_r}$ (g/kg) (F7.4)
  7. Snow (slow-falling ice) mixing ratio, $\overline{q_s}$ (g/kg) (F7.4)
  8. Graupel (fast-falling ice) mixing ratio, $\overline{q_g}$ (g/kg) (F7.4)
  9. Cloud fraction, $\bar{\sigma}$ (unitless) (F6.3): At each grid point, $\sigma = 1$ if $q_c + q_i > 0.01q^*(\bar{T}, \bar{p})$; otherwise, $\sigma = 0$.

23. Updraft cloud mass flux, M_u (kg m^{-2} s^{-1}) (F7.4):

$$M_u = \frac{\bar{\rho} \sum_j \sigma w^+}{\sum_j},$$

where j is the grid point column index, σ is the cloud fraction (defined previously), $w^+ = w$ if $w > 0$, otherwise, $w^+ = 0$.

24. Downdraft cloud mass flux, M_d (kg m^{-2} s^{-1}) (F7.4): $M_d = M_{ds} + M_{du}$, where M_{ds} and M_{du} are the saturated and unsaturated downdraft cloud mass fluxes:

$$M_{ds} = \frac{\bar{\rho} \sum_j \sigma w^-}{\sum_j}$$

and

$$M_{du} = \frac{\bar{\rho} \sum_j \sigma_p w^-}{\sum_j}.$$

Here, $w^- = |w|$ if $w < 0$, otherwise, $w^- = 0$. Also, $\sigma_p = 1$ if $\sigma = 0$ *and* $q_r + q_s + q_g > P$, with $P = 0.1$ g/kg; otherwise, $\sigma_p = 0$.

30. Hydrometeor fraction, $\bar{\sigma_h}$ (unitless) (F6.3): At each grid point, $\sigma_h = 1$ if $\sigma = 1$, or if $q_r + q_s + q_g > E = 10^{-3}$ g/kg; otherwise, $\sigma_h = 0$.

- **Time series**

Submit the results for each group of quantities listed below as a separate ASCII file. [**New 990721**] Name each file as follows: *simulation*.t*group.model_acronym*. For example, the file name "a2.t1.UU_CRM" indicates simulation=a2, time series group=1, and model=UU_CRM. The model acronym should have at most 13 characters (shorter is better), and the underscore character should be used in lieu of the period or slash if needed.

If you do not plan to submit a file, please supply an empty file in its place with the same name but with the suffix '.not_submitted' added. Or, alternatively (though less machine decipherable) you may submit a file named README to list the files not submitted.

Please include as the first line of each file a line of up to 80 characters that includes a comment identifier (#k), the filename, and, optionally, any further distinguishing characteristics. Follow this with the results; use one line for each time. This is an example of the file format:

```
#k a2.t1.UU_CRM 2D baseline run
```
... (results for all group 1 quantities at the first time) ...
.
.
.

... (results for all group 1 quantities at the last time) ...

Suggested formats for each quantity are included in the descriptions below using Fortran notation. So that each line includes no more than 80 characters (necessary for e-mail transmission), simply write each line using the suggested formats. For example, the format for each line for group 1 is (F8.3,F6.1,2F6.3,F6.2,2E10.3,3F7.2).

If the files are transmitted via ftp, all that is required is that the results for each time are contained within one record (a line ending with a carriage return) of any length, and that each quantity (including the first) be preceded by at least one space. The format can be fixed point or E- (exponential) format.

[New 990721] *If the values for a quantity are not available, assign each of them a value of -8888., or the value of a negative constant with '8' in all decimal positions that does not overflow the format used.*

Group 1:

1. Time of mid-point of averaging interval, $\bar{t}$ (calendar days, F8.3)
2. TOA upwelling infrared radiative flux (OLR), $\overline{(F^+_{LW})_T}$ (W/m^2) (F6.1)
3. Cloud amount, $\overline{A_{\rm cld}}$ (unitless) (F6.3): Fraction of columns which are "cloudy."
4. Cold cloud top area, $\overline{A^{\rm cold}_{\rm cld}}$ (unitless) (F6.3): Fraction of columns for which the "cloud top temperature" is less than 245 K.
5. Precipitable water, $\overline{\rm PW}$ (kg/m^2) (F6.2): PW $= \int_0^{z_T} \bar{\rho} q \, dz$, where z_T is the model top height.
6. Cloud liquid water path, $\overline{\rm LWP}$ (kg/m^2) (E10.3): LWP $= \int_0^{z_T} \bar{\rho} q_c \, dz$.
7. Cloud ice path, $\overline{\rm IWP}$ (kg/m^2) (E10.3): IWP $= \int_0^{z_T} \bar{\rho} q_i \, dz$.
8. Surface rainfall rate, $\bar{P}$ (mm/day) (F7.2): Calculate from the surface rain accumulated over every time step.
9. Convective surface rainfall rate, $\overline{P_c}$ (mm/day) (F7.2): The contribution to $\bar{P}$ from the "convective" columns.
10. Stratiform surface rainfall rate, $\overline{P_s}$ (mm/day) (F7.2): The contribution to $\bar{P}$ from the "stratiform" columns.

3.2 Definitions

The definition for "cloud top height" has been changed since Case 2.

- The "cloud top height," z_c, is the height where the top-downward integrated cloud water path equals $C = 0.01$ kg/m^2.[5] I.e., z_c satisfies

$$\int_{z_c}^{z_T} \bar{\rho}(q_c + q_i) \, dz = C.$$

[5] For Case 2, we used $C = 0.02$ kg/m^2.

$$\text{If} \int_0^{z_T} \bar{\rho}(q_c + q_i)\, dz < C \text{ then } z_c = 0.$$

- The "cloud top temperature," T_B, is the temperature at "cloud top height."
- In a "cloudy" column, the "cloud top height" is greater than the surface height.
- If a column is not "cloudy", it is "clear."
- In a "rainy" column, the rain mixing ratio (q_r) is greater than $E = 10^{-3}$ g/kg at the first model level above the surface. This is approximately equivalent to defining a "rainy" column as one in which the radar reflectivity factor Z exceeds 0.1 (dBZ exceeds -10) or the rainfall rate exceeds 0.01 mm/hr.
- "Convective" column: Use a published algorithm of your choice to define.
- "Stratiform" column: All "rainy" ($P > 0.01$ mm/hr) columns not classified as convective are "stratiform" columns.

3.3 Special file format

This ASCII text file format represents a 2D array $f(x, y)$with x and y coordinates. Such files should be in the format shown below.

```
# filename  simulation_description  variable_description  comments
ny nx
f_max f_min
y(1) y(2)   . . . y(ny)
x(1) x(2)   . . . x(nx)
f(x(1),y(1))  f(x(2),y(1)) . . . f(x(nx),y(1)) f(x(1),y(2)) . . .
f(x(1),y(nx))  f(x(2),y(nx)) . . . f(x(nx),y(nx))
```

The file may consist of lines (records) of any convenient length. The first line is a comment. Values for the numbers may be integers, floating point, or exponential format, separated by spaces, tabs, or end-of-lines. Maximum and minimum values define the range of f. Simply enter 0 for these; they will be reset after all the files are received.

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4 Model Description

In order to compare results from different models, workshop participants are asked to complete the following description relevant for simulations performed for the intercomparison. This description will help to build up the workshop report at the final stage.

- Scientist name
  Affiliation
  Address
  Email address
  Fax Number
- Model type (1D, 2D, 3D)
- [**New 990721**] Model acronym (used in file names of submitted files).
- Numerical Domain
  Domain size in x-direction:
  Domain size in y-direction:
  Domain size in z-direction:
  Number of grid points in x-direction:
  Number of grid points in y-direction:
  Number of grid points in z-direction:
  Grid size in x-direction:
  Grid size in y-direction:
  Grid size in z-direction (if stretched please specify):
- Time step
- Numerical Technique
  Numerical method (finite-difference, spectral, etc.):
  Advection scheme and its order of accuracy:
  Time scheme and its order of accuracy:
  Dynamical equations (elastic, anelastic, etc.):
  Numerical diffusion (type, order, magnitude of coefficient)
  Upper boundary condition (Sponge layer, specification, ...):
  Other information
- Physical Parameterizations:
  Surface flux parameterization for heat, moisture, momentum:
  Longwave radiation parameterization:
  Shortwave radiation parameterization:
  How were radiative fluxes above the computational domain handled?

Microphysical (2D/3D models) or cloud/convective (1D model) parameterization: type, number of hydrometeor classes, ...

Turbulence closure scheme (turbulence closure type, variables predicted and diagnosed by the turbulence closure, closure for turbulent length scale, ...)

Other information

- Documentation: Please provide references that more fully describe your model, if available.