TWP-ICE Single Column Model case

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1 Introduction

This documentation is the description of the Single Column Model (SCM) intercomparision project run jointly by ARM and GCSS. The intercomparision project will focus on the Tropical Warm Pool - International Cloud Experiment (TWP-ICE), see May *et al.* (2008) for further details. The SCM project will run alongside other intercomparison projects involving Cloud-Resolving Models (CRM), Limited Area Models (LAM) and Numerical Prediction Models (NWP). These intercomparison projects have been designed and developed in parallel so there can be comparison between the projects, in addition to the comparisons between the models in the individual projects.

The SCM intercomparison project outlined here will be fundamentally different from previous SCM intercomparison projects (www.convection.info) in that an ensemble of forcing data sets is provided instead of just a single forcing data set. More details on the derivation of the forcing data set are provided in Section 2. Due to the increased demands of set up and handling the data from an ensemble, only single long simulations are requested (compared to the series of 48hr integrations requested in the TOGA-COARE Case 5) and new diagnostics are not requested.

2 Ensemble SCM forcing data set

2.1 Usefulness of SCM

SCM models are useful for testing parameterisations of numerical models for two main reasons. As SCMs are limited to a single column of the atmosphere they are computationally quick to run and, as the forcing is directly specified, feebacks between atmospheric forcings are removed. (Although, of course, this is also a fundamental limitation of SCM.) It is usual to force SCM with data derived from field campaigns as it is then possible to compare results from the SCM to observations made during the campaign. It is possible, in theory, to identify errors in the parameterisation from errors between the model response and observations.

One of the main limitations of SCMs, and the method by which they are forced, is that errors in the model solution can be attributed to two sources. Firstly, there is error in the parameterisation schemes, which we are most interested in isolating, however, there are also errors introduced in the calculation of the forcing data. This second source of error is undesirable and complicates the process of comparing the model solution to the observations. Are differences between the model solution and the observations due to errors in the model parameterisations or because the forcing data is inconsistent with the observations?

2.2 Deriving an ensemble forcing model data set

Observational data from field campaigns can be used to derive forcing data sets using variational analysis (Zhang and Lin, 1997). This process provides the best estimate of the time evolution of the atmosphere during the field campaign from surface observations, vertical profiles of the atmosphere, satellite observations and numerical model data. The variational analysis process minimises the errors between the observations and is constrained by mass, moisture, heat and momentum. One of the inputs to variational analysis is the mean surface precipitation over the observational domain. It has been shown (Zhang *et al.*, 2001) that the surface precipitation has a large effect on the derived forcing data set, for example the analysed vertical velocity is very sensitive to surface precipitation. The derivation of surface precipitation from radar data is also highly complex and liable to large errors. These errors will have a large effect on the derived forcing data set.

One method that has been used extensively in weather forecast and climate simulations to account for uncertainties in model simulations due to errors in the forcing data is an ensemble technique. A set of equally possible forcing data sets are used (for the time being we are agnostic about the definition of the forcing), in place of a single best estimate of the forcing. The ensemble members represent the uncertainty in the forcing. The spread in the model solutions between the ensemble members give an indication of the uncertainty in the model solution, given the uncertainty in the forcing.

An ensemble forcing data set has been derived for the TWP-ICE field campaign which account for the uncertainties in the radar-derived rainfall estimates. Christian Jakob and collaborators (publication to follow) have been working on a project that estimates the error in the radar-derived rainfall estimates from a comparison with rain gauge data and used this to estimate to calculate N rainfall scenarios (currently N=100). Each of these scenarios is a percentile of a distribution that encompasses the full range of the errors in deriving the radar-derived rainfall and each scenario is possible given the uncertainties in the radar-derived rainfall. Figure 1 shows the ensemble timeseries of the domain-mean surface precipitation. It can be seen that there is a large spread in possible surface precipitation, particularly apparent 23-24 Jan 2006. These N scenarios are then processed separately using the variational analysis (all other observations are unchanged and are the same for each N scenario) to produce 100 separate forcings that are all equally possible given the uncertainty in rainfall estimate. The higher (lower) the percentile corresponds to stronger (weaker) surface precipitation. Figure 2 shows the vertical velocity profile averaged over both the active (20-25 January 2006) and suppressed (26-31 January 2006) monsoon periods. It can be seen the stronger rainfall (higher percentiles) is associated with stronger vertical motion. In the active monsoon there is always strong upward vertical motion, although the ensemble members with weaker rainfall have weaker vertical motion. During the suppressed monsoon the ensemble members with strong rainfall have upward vertical motion at all levels. The lower percentiles, with weaker rainfall, have upward motion at lower levels (below 4km) but downward motion above. In addition to the ensemble members, Figures 1 and 2 also show the results from the standard best estimate for vertical velocity, as it would have been applied in earlier intercomparison studies. As is evident the best estimate results are close, but not identical, to the 50^{th} percentile of the ensemble forcing.

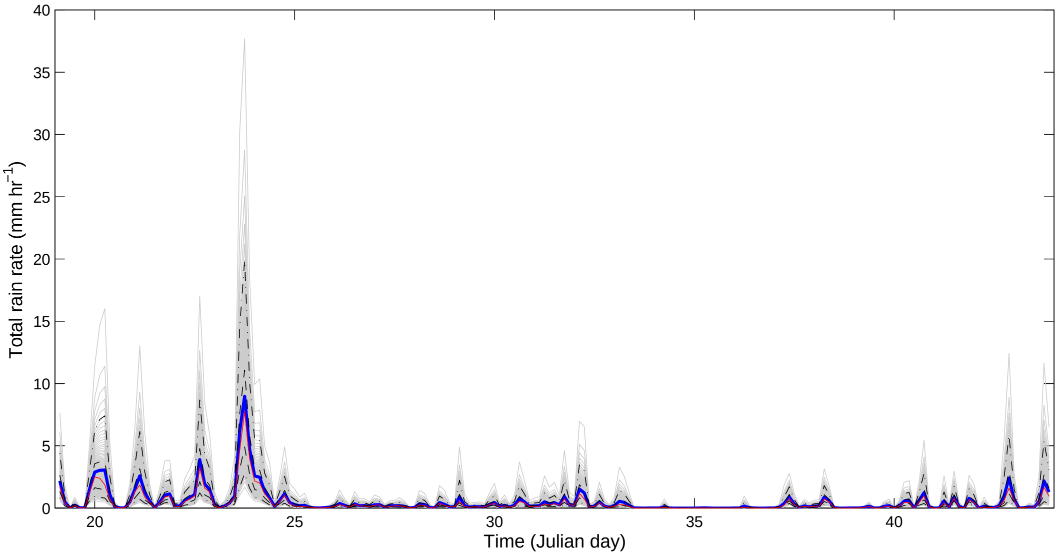
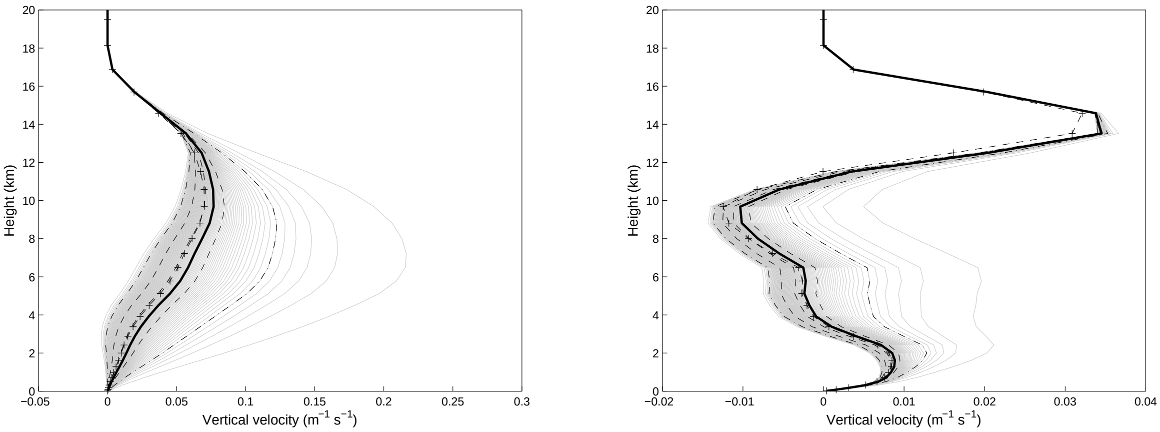


Figure 1: Timeseries of ensemble of surface precipitation for ensemble forcing for TWP-ICE. The light grey lines show all ensemble members with the ensemble mean in blue. The red line is the best estimate surface precipitation (this is the standard ARM surface precipitation estimate). The dashed lines are the 25th and 75th percentiles with the dash-dot line being the 5th and 95th percentiles.



(a) Active monsoon

(b) Suppressed monsoon

Figure 2: Vertical profiles of vertical velocity for ensemble forcing for TWP-ICE averaged over a) the active monsoon (20 Jan 2006 0000Z - 25 Jan 2006 0000Z) and b) the supressed monsoon (26 Jan 2006 0000Z - 31 Jan 2006 0000Z). The light grey lines show all ensemble members with the ensemble mean as a heavy line. The dashed lines are the 25th, 50th and 75th percentiles with the dash-dot line being the 5th and 95th percentiles. The best estimate vertical velocity is the dash-plus line (this is the standard ARM vertical velocity estimate).

3 Case description

In this section the SCM test case will be described. Firstly in Section 3.1 the time periods for the forcing data provided will be detailed, then in Section 3.2 the data required to simulate the test case will be specified. This will outline from where the data should be downloaded and what you should expect to find in the data. Section 3.3 will described how the data should be used to force the SCMs for this test case,

3.1 Time period

The TWP-ICE intensive observation period (IOP) was from 20 January 2006 through to 13 February 2006 and ARM has derived a forcing data set from 0300Z 17 January 2006 to 2100Z 12 February 2006. This is the forcing data set the is being used in the CRM intercomparison project, although the CRMs will only simulate 17 Jan - 3 Feb. The ensemble forcing data set is available from 0300Z 19 January 2006 to 2100Z 12 February 2006. (The additional data in the standard ARM forcing data set from the 17 Jan - 20 Jan is to allow the CRMs to spin up.)

At the start of the IOP the Darwin region experienced monsoon conditions. Between 23 - 24 Jan a mesoscale convective system passed through the domain and then the domain was affected by suppressed monsoon conditions. There were then clear conditions from 3 - 5 Feb with little rain followed by monsoon break conditions to the end of the IOP. Full details of the meteorological conditions can be found in May *et al.* (2008).

The SCM intercomparison will consist of a continuous simulation of the full TWP-ICE period. Whilst the CRM simulations will focus on the active and break monsoon periods from 17 Jan - 3 Feb, SCMs are comparatively computationally cheap to run and can simulate the full TWP-ICE IOP. It is possible that in final analysis we will restrict our analysis to a similar period as the CRM intercomparison, however, there may be interesting results from the ensemble SCM simulations of the break period that we can not pre-empt. As the CRM and LAM intercomparison project will not be able to run for the whole period, SCM simulations of the entire IOP will be the only way to investigate model responses at all times.

3.2 Data provided

Both the best estimate forcing data set and ensemble forcing data set are required to simulate this test case. These are provided in two locations.

3.2.1 Best estimate forcing data set

The standard ARM forcing data set (as used in the CRM test case) is provided here: http://science.arm.gov/wg/cpm/scm/scmic6/forcing_data.html, follow the links. The standard forcing data set at 25mb vertical resolution should be downloaded. The ARM archive is password protected but a password can be requested by clicking ’Create Account’ at this website: http://iop.archive.arm.gov/cgi-bin/account-maint?/arm-iop/. This data constitutes the best estimate for the ensemble as shown in Figures 1 and 2.

3.2.2 Ensemble forcing data set

The ensemble forcing data and additional files can be downloaded from: http://users.monash.edu.au/ ladavies/gcss.html and clicking on the link under the heading 'Ensemble forcing data'. The downloaded ensemble forcing data is the zipped and tarred file Final_ensemble280108.tar.gz. The forcing data has exactly same format as the data provided on the ARM site, the standard vertical resolution (25mb) data. The data starts at 03Z 19 Jan 2006 (compared to 03Z 17 Jan 2006 for standard ARM data) but finishes at the same time, 21Z 12 Feb 2006. (Details of the time period to simulate are given in Section 3.3)

When uncompressed Final_ensemble280108.tar.gz produces a folder Final_ensemble280108 with 100 sub-folders. These folders, ensmem00....ensem99, contain the forcing for the 100 ensemble members. Within each of the 100 folders are two ASCII data files twpice_pXX_layer.dat and twpice_pXX_surface.dat where XX is a number indicating the ensemble member. These are identical to the equivalent surface and layer data files for the best estimate. In addition, in each folder there is a netcdf file of the forcing data twpice_pXX.cdf. This file is identical to the equivalent netcdf file for the best estimate.

In Final_ensemble280108 there are additional files that will be used in setting up the simulation. The file CRM_ozone.txt is the ozone profile derived from the observations and which is being used in the CRM study. It should also be adopted here. There is also the file McCProfiles.dat which contains the standard McClatchy atmospheric profiles for a tropical atmosphere. It has data for geopotential height, pressure, temperature, specific humidity and ozone. These profiles should be used in the initial conditions of temperature, moisture and ozone above the available forcing data. These two additional files are ASCII text files. More details are given in Section 3.3.

3.3 Forcing method

Consistent with the CRM intercomparison, and due to the mixed surface types within the TWP-ICE domain, the simulations will assume an ocean surface. We would like you to set up your model in your usual, preferred configuration, however, we would like to specify that you run with the following for the baseline simulations:

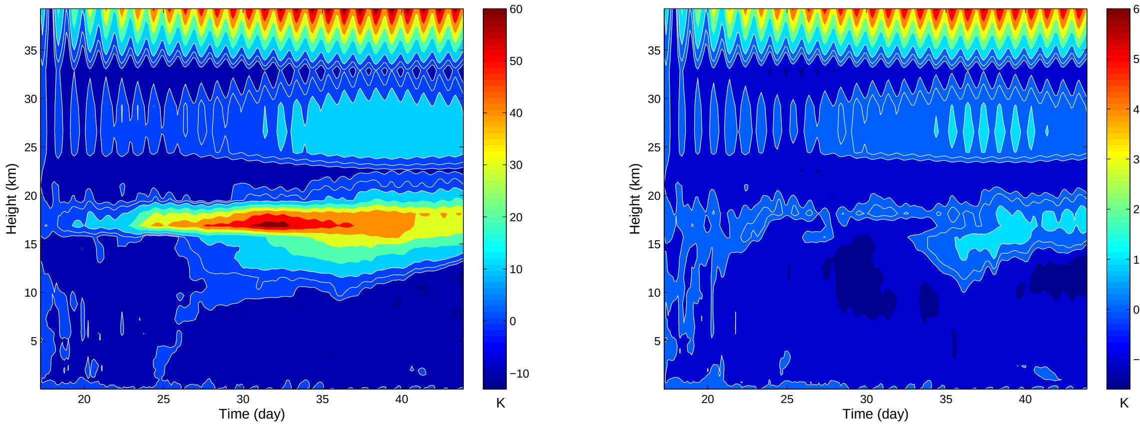
- Fixed time-invariant SST = 29 °C. Interactive surface fluxes should calculated in the boundary layer scheme.

- Simulations initialised with observed temperature and moisture profiles at 0300Z 19 Jan 2006. (Note: this is the start of the forcing data for the ensemble but 2 days after the start of the best estimate forcing data.) The McClatchy atmospheric profiles should be adopted above the observed profiles (i.e. above 40 mb).

- The observed ozone profile where possible but the McClatchy ozone profile above.

- Full interactive radiation with a diurnal cycle. The domain is centred on 12.425^oS, 130.891^oE.

• Horizontal advective tendencies for temperature and moisture only. The vertical terms should be calculated by the model. (Specifically we do not want total advective forcing to be used - horizontal + vertical terms, with an adiabatic term added to the temperature forcing. This was the forcing method for the TOGA-COARE SCM intercomparison project.) We experimented with both methods of forcing a SCM. The results in Figure 3 show the effect of the forcing method. When a total forcing was prescribed (Figure 3a) there was a warm temperature bias above 15 km which results from the forcing. As the model can not freely evolve vertical advection associated with this warming and a very large temperature bias grows with time. When just the horizontal terms are prescribed (Figure 3b) the model develops vertical advection and a temperature bias is reduced.



(a) Total forcing prescribed

(b) Horizontal terms only

Figure 3: Comparison of θ bias (modelled θ - observed θ) for a simulation of the ARM forcing data (best estimate) when a) the total forcing is prescribed (horizontal + vertical terms) and b) with only the horizontal terms are prescribed and the vertical terms calculated by the model using an upstream approximation. White contours are at 4 and 10 °C.

• Relaxation of horizontal winds to observed profiles with τ = 2 hr.

• There is no nudging of the temperature and moisture fields. These should be free to respond to the forcing.

It would also be greatly appreciated if you could perform simulations of all 100 ensemble members and the best estimate, however, if that is not possible for whatever reason, the key simulations to perform are the 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles and the best estimate simulation.

Participants are free to perform additional experiments with alternative model set ups beyond the specified configuration.

We would also be very interested in CRM simulations of the ensemble. These could be performed in 2D to ease computational constraints. In particular, we would like to have some simulations of the best estimate, standard ARM data, using this method of forcing to enable comparison between CRMs and SCMs.

4 Objectives

Forcing a SCM with an ensemble forcing data set provides an additional way to investigate the characteristics of a parameterisations in GCM. Hume and Jakob (2007) showed that there were different responses to the ensemble in different SCM models (representing to different numerical models) and showed that ensemble forecasts were more skilful than a single forecast (they derived the ensemble using a different method). This intercomparison project will provide an opportunity to extend these methods of model evaluation. As this is the first time an ensemble forcing data set has been proposed for an intercomparison project the final investigations and conclusions will be somewhat determined by the nature of the results. The following questions will provide a starting point, however, for the analysis of the model results.

- What are the sensitivities of the different models? How do the different model sensitivities vary in time?

- How does the spread of the ensemble compare between the models?

- How does the ensemble mean solution compare to the best estimate solution?

- Can we identify particular times when models are most sensitive to the forcing? From our knowledge of the model physics can we establish why?

- How sensitive are the cloud characteristics to the forcing?

- Which variables show the greatest sensitivity to the forcing?

- How do the SCM ensemble simulations compare to the CRM simulations?

- For the different models would a probabilistic forecast represent an improvement over a single forecast?

5 Description of quantities for SCM integrations

The diagnostics for SCM simulations will not be more extensive than for the last intercomparison project. The focus of the project being the behaviour of the ensemble for key model diagnostics. It is requested that timestep by timestep outputs are submitted for the diagnostics in Tables 1-3. A single netcdf file is requested for the diagnostics in each of the tables. Each netcdf file should be named in the following form: profiles.*model*_pXX.nc, timeseries.*model*_pXX.nc and budgets.*model*_pXX.nc, where *model* is a short acronym for the model and XX is the ensemble member. Data should conform to Climate and Forecast Metadata Conventions.

Details of submission will be provided on the ARM CMWG TWP-ICE intercomparison webpages and http://users.monash.edu.au/ ladavies/gcss.html.

If you have access to an ISCCP simulator and can produce ISCCP diagnostics, then these diagnostics can be provided in a separate netcdf file.

Please submit as many of the diagnostics as possible, however, if some diagnostics are missing omit them from the diagnostic file to save disk space (i.e. do not have diagnostics that are all missing values).

Profiles		
Variable	Unit	Description
t	h	time (hours since 0000Z 20 Jan 2006)
p	Pa	pressure
h	m	height
T	K	temperature
theta	K	potential temperature
rho	$kg\ m^{-3}$	reference density of air
w	$m\ s^{-1}$	vertical velocity
q_v	$kg\ kg^{-1}$	water vapour mixing ratio
RH	(unitless)	q/q^* where q^* is the saturation mixing ratio over water
q_c	$kg\ kg^{-1}$	cloud water mixing ratio (suspended liquid water)
q_i	$kg\ kg^{-1}$	cloud ice mixing ratio (suspended ice)
q_r	$kg\ kg^{-1}$	rain mixing ratio (falling liquid water)
CF	(unitless)	cloud fraction
q_h	(unitless)	total hydrometeor fraction
Q_1	$K\ day^{-1}$	apparent heat source, see equation 1
Q_2	$K\ day^{-1}$	apparent moisture source, see equation 2
dT_{LS}	$K\ day^{-1}$	large scale temperature forcing on model grid
dqv_{LS}	$kg\ kg^{-1}\ day^{-1}$	large scale temperature forcing on model grid
M_{cu}	$kg\ m^{-2}\ s^{-1}$	convective updraft mass flux
M_{cd}	$kg\ m^{-2}\ s^{-1}$	convective downdraft mass flux
CC	(unitless)	convective cloud fraction
Cq_c	$kg\ kg^{-1}$	convective cloud water mixing ratio (suspended liquid water)
Cq_i	$kg\ kg^{-1}$	convective cloud ice mixing ratio (suspended ice)
LSC	(unitless)	large-scale cloud fraction
LSq_c	$kg\ kg^{-1}$	large-scale cloud water mixing ratio (suspended liquid water)
LSq_i	$kg\ kg^{-1}$	large-scale cloud ice mixing ratio (suspended ice)
TQ_{sw}	$K\ day^{-1}$	total sky shortwave radiative heating rate
CSQ_{sw}	$K\ day^{-1}$	clear sky shortwave radiative heating rate
TQ_{lw}	$K\ day^{-1}$	total sky longwave radiative heating rate
CSQ_{lw}	$K\ day^{-1}$	clear sky longwave radiative heating rate

Table 1: Profile diagnostics requested for the SCM TWP-ICE intercomparison. All data should conform to Climate and Forecast Metadata Conventions. Where the convention differs from what is here, the convention is probably right, but please notify me (laura.davies@sci.monash.edu.au) so I can update the documentation.

$$\overline{Q}_1 = \left(\frac{\overline{p}}{p_0}\right)^{R/c_p} \left[\frac{\partial\,\overline{\theta}}{\partial t} - \left.\frac{\partial\,\overline{\theta}}{\partial t}\right|_{LS}\right] - \overline{Q}_R, \qquad (1)$$

where $\left.\frac{\partial\overline{\theta}}{\partial t}\right|_{LS}$ is the large-scale forcing term which is specified from the observations

$$\overline{Q}_2 = \left[\frac{\partial \overline{q}}{\partial t} - \left. \frac{\partial \overline{q}}{\partial t} \right|_{LS} \right], \tag{2}$$

where $\left.\frac{\partial \overline{q}}{\partial t}\right|_{LS}$ is the large-scale forcing term which is specified from the observations.

Timeseries		
Variable	Unit	Description
t	h	time (hours since 0000Z 20 Jan 2006)
SST	K	sea surface temperature
F_s	$W\ m^{-2}$	surface turbulent flux of sensible heat
F_q	$W\ m^{-2}$	surface turbulent flux of latent heat
dTF_{sw0}	$W\ m^{-2}$	total surface downwelling shortwave radiative flux
dTF_{lw0}	$W\ m^{-2}$	total surface downwelling longwave radiative flux
uTF_{sw0}	$W\ m^{-2}$	total surface upwelling shortwave radiative flux
uTF_{lw0}	$W\ m^{-2}$	total surface upwelling longwave radiative flux
dTF_{swT}	$W\ m^{-2}$	total TOA downwelling shortwave radiative flux
dTF_{lwT}	$W\ m^{-2}$	total TOA downwelling longwave radiative flux
uTF_{swT}	$W\ m^{-2}$	total TOA upwelling shortwave radiative flux
uTF_{lwT}	$W\ m^{-2}$	total TOA upwelling longwave radiative flux
$dCSF_{sw0}$	$W\ m^{-2}$	clear sky surface downwelling shortwave radiative flux
$dCSF_{lw0}$	$W\ m^{-2}$	clear sky surface downwelling longwave radiative flux
$uCSF_{sw0}$	$W\ m^{-2}$	clear sky surface upwelling shortwave radiative flux
$uCSF_{lw0}$	$W\ m^{-2}$	clear sky surface upwelling longwave radiative flux
$dCSF_{swT}$	$W\ m^{-2}$	clear sky TOA downwelling shortwave radiative flux
$dCSF_{lwT}$	$W\ m^{-2}$	clear sky TOA downwelling longwave radiative flux
$uCSF_{swT}$	$W\ m^{-2}$	clear sky TOA upwelling shortwave radiative flux
$uCSF_{lwT}$	$W\ m^{-2}$	clear sky TOA upwelling longwave radiative flux
ppt	$kg\ m^{-2}\ s^{-1}$	surface preciptiation
$conv_{ppt}$	$kg\ m^{-2}\ s^{-1}$	convective preciptiation
ls_{ppt}	$kg\ m^{-2}\ s^{-1}$	large-scale preciptiation
PW	$kg\ m^{-2}$	precipitable water
LWP	$kg\ m^{-2}$	cloud liquid water path
IWP	$kg\ m^{-2}$	ice water path

Table 2: Timeseries diagnostics requested for the SCM TWP-ICE intercomparison. All data should conform to Climate and Forecast Metadata Conventions. Where the convention differs from what is here, the convention is probably right, but please notify me (laura.davies@sci.monash.edu.au) so I can update the documentation.

6 Time plan and planned outcomes

6.1 Deadline

The project should tie-up with the CRM project (despite the late start!) so final results are requested by 1 July 2009. Earlier results and provisional results are also accepted.

Budget terms		
Variable	Unit	Description
t	h	time (hours since 0000Z 20 Jan 2006)
p	Pa	mean air pressure
h	m	height
$Dtheta_{conv}$	$K\ day^{-1}$	rate of change of θ due to convection
Dqv_{conv}	$kg\ kg^{-1}\ day^{-1}$	rate of change of q_v due to convection
$Dtheta_{BL}$	$K\ day^{-1}$	rate of change of θ due to boundary layer
Dqv_{BL}	$kg\ kg^{-1}\ day^{-1}$	rate of change of q_v due to boundary layer
$Dtheta_{LS}$	$K\ day^{-1}$	rate of change of θ due to large-scale rain and clouds
Dqv_{LS}	$kg\ kg^{-1}\ day^{-1}$	rate of change of q_v due to large-scale rain and clouds

Table 3: Budget term diagnostics requested for the SCM TWP-ICE intercomparison. All data should conform to Climate and Forecast Metadata Conventions. Where the convention differs from what is here, the convention is probably right, but please notify me (laura.davies@sci.monash.edu.au) so I can update the documentation.

6.2 Publications

It is expected that several papers will be possible from this intercomparison project. Although the exact nature of the papers will depend on the final results we receive, we envisage at least a paper comparing the SCM model results and other contrasting SCM and CRM results. Submitted results will be included in these papers and participants included as co-authors.

7 Enquires

The planning and documentation for this project have been as rigourous and explicit as possible, however, all eventualities can not be accounted for, particularly as providing an ensemble forcing data set is in new direction for ARM/GCSS intercomparison projects. If you have any questions please contact me, laura.davies@sci.monash.edu.au. Your time and input into this project, which looks like being an exciting SCM intercomparison project is much appreciated!

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