IPCC Standard Output from Coupled Ocean-Atmosphere GCMs

WGCM Climate Simulation Panel[1] with the assistance of PCMDI[2]

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Introduction and format requirements

The following list of standard output for coupled GCMs is intended both to serve the immediate needs of the IPCC and to become a recommended "core set" of variables for CMIP.

Modeling groups contributing output to the IPCC and CMIP database must ensure that it meets rather strict format and metadata requirements. These requirements yield files produced in network Common Data Form (netCDF; see http://www.unidata.ucar.edu/packages/netcdf), which has become the most popular form for exchanging ocean-atmosphere model output. The files will be "self-describing" and the metadata contained in the files will conform with the NetCDF Climate and Forecast (CF) Metadata Conventions (see http://www.cgd.ucar.edu/cms/eaton/cf-metadata). The new CF conventions for netCDF data generalize and extend the Cooperative Ocean / Atmosphere Research Data Service (COARDS) conventions developed in the 1990s. Note that the CF convention establishes standard names for climate and weather variables, which identify the physical quantity. These standard names are given in the tables below. Note that more than one field can be associated with the same standard name because different fields sampled in different ways (e.g., surface air temperature vs. upper air temperature) refer to the same physical quantity. Nevertheless, one can uniquely identify each stored field by considering additional metadata stored in the file (e.g., dimension information). Extended definitions of CF standard names, which basically answer the question "What do you mean precisely by this quantity?", may be found on the Web at http://www.cgd.ucar.edu/cms/eaton/cf-metadata/standard_name.html.

The detailed requirements for CMIP / IPCC contributions are contained in the document http://www-pcmdi.llnl.gov/ipcc/IPCC_output_requirements.htm. This document should be read carefully before preparing contributions. Perhaps the easiest way to meet these requirements is to rewrite your model output through CMOR, a software library available from PCMDI and further described in the next paragraph. Put briefly, the requirements involve metadata, coordinate systems, and file organization. Units and sign conventions of the data must conform to the tables below. Latitude-longitude grids must be rectilinear, i.e., have a unique set of longitudes that applies to all latitudes. Data on non-rectilinear grids (typically occurring for ocean output) must be interpolated to rectilinear grids before transmission to the PCMDI. (In this case, the original "native grid" data, if deemed of sufficient value, may also be provided to the PCMDI.) Vertical coordinates must be depth for ocean variables and pressure for atmosphere variables (with the exception of cloudiness, which as noted below should be provided on model levels). Three-dimensional atmosphere variables must be interpolated to standard pressure levels given below. We also recommend -- but do not require -- that the ocean depth levels match Levitus observations. Finally, we require that submitted files contain only one output variable per file, though they may have many time points per file. This file organization contrasts with the typical model output history files, which contain all variables for a single time step.

To facilitate adherence to these standards, the PCMDI has written (in FORTRAN 90) a standard output code called CMOR (pronounced "see more"; see http://www-pcmdi.llnl.gov/software-portal/cmor). This code structures the data uniformly and writes netCDF files in full compliance with IPCC requirements. Use of CMOR is being encouraged (and in some cases required) by various ongoing model intercomparison projects. The CMOR documentation in pdf format is available at http://www-pcmdi.llnl.gov/software/cmor/cmor_users_guide.pdf, and the source code is available at http://www-pcmdi.llnl.gov/software-portal/cmor/download. For further information, contact taylor13@llnl.gov.

The notes that appear in the following tables are meant to provide precise definitions of the requested fields. Sometimes it may be impossible to satisfy the requests; in these cases, any deviations from the specifications below should be described in the "history" and/or "comment" attributes associated with the variable

Model output overview

The model output fields listed below are identified as either being "highest priority" (tables A1a-A1c, A2-A4, and O1a-O1e) or "lower priority" (tables A1d-A1f, A5, and O1f-O1g). The fields appearing in the "lower priority" tables will in some cases be essential for carrying out analyses of high interest (e.g., the radiative forcing fields are needed to help determine why models have different responses to anthropogenic influences); placement in the "lower priority" table may reflect one or more of the following factors: 1) perceived to be difficult to calculate (or lack of agreement as to calculation method), 2) nominated late, after the "highest priority" tables had been officially released, or 3) generally perceived to be of somewhat less interest than other fields.

Some of the variables in the tables below were required for the original 1997 version of CMIP2 or have been requested for contributions to the CMIP pilot project "20th Century Climate in Coupled Models" (20C3M). Many of the additional fields were requested by AMIP, the atmosphere-only counterpart of CMIP in which ocean surface and sea ice boundary conditions are prescribed to match observations over the late 20th century (see AMIP2 standard output). Suggestions for additions or changes to these tables are welcome and will be considered for future model intercomparison and IPCC exercises.

In most cases, variables that appear in the same table will all be associated with a single climate component (i.e., atmosphere, ocean, land, or sea ice) and will all be a function of the same spatial dimensions. Also the temporal sampling (3-hourly, daily, monthly, or time-independent) and any spatial or temporal averaging will in most cases be the same within each table.

Highest priority output fields

Monthly-mean and time-independent data

Table A1a: **Monthly-mean 2-d atmosphere or land surface data (longitude, latitude, time:month).**

	CF standard_name	**output variable name**	**units**	**notes**
1	air_pressure_at_sea_level	psl	Pa	

2	precipitation_flux	pr	kg m^{-2} s^{-1}	includes both liquid and solid phases.
3	air_temperature	tas	K	near-surface (usually, 2 meter) air temperature; the CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".
4	moisture_content_of_soil_layer	mrsos	kg m^{-2}	water in all phases in the upper 0.1 meters of soil, and averaged over the land portion of the grid cell (i.e., compute by dividing the total mass of water contained in the soil layer of the grid cell by the land area in the grid cell); report as "missing" or 0.0 where the land fraction is 0; the CMOR singleton dimension default value of 0.1 m can be overridden, if absolutely necessary, by redefining axis "depth1".
5	soil_moisture_content	mrso	kg m^{-2}	water in all phases summed over all soil layers, and averaged over the land portion of the grid cell (i.e., compute by dividing the total mass of water contained in the soil layer of the grid cell by the land area in the grid cell); report as "missing" or 0.0 where the land fraction is 0.
6	surface_downward_eastward_stress	tauu	Pa	
7	surface_downward_northward_stress	tauv	Pa	
8	surface_snow_thickness	snd	m	this thickness when multiplied by the average area of the grid cell covered by snow yields the time-mean snow volume. Thus, for time means, compute as the weighted sum of thickness (averaged over the snow-covered portion of the grid cell) divided by the sum of the weights, with the weights equal to the area covered by snow. report as 0.0 in snow-free regions.

9	surface_upward_latent_heat_flux	hfls	W m^{-2}	
10	surface_upward_sensible_heat_flux	hfss	W m^{-2}	
11	surface_downwelling_longwave_flux_in_air	rlds	W m^{-2}	
12	surface_upwelling_longwave_flux_in_air	rlus	W m^{-2}	
13	surface_downwelling_shortwave_flux_in_air	rsds	W m^{-2}	
14	surface_upwelling_shortwave_flux_in_air	rsus	W m^{-2}	
15	surface_temperature	ts	K	"skin" temperature (i.e., SST for open ocean)
16	surface_air_pressure	ps	Pa	*not* mean sea-level pressure
17	snowfall_flux	prsn	kg m^{-2} s^{-1}	
18	convective_precipitation_flux	prc	kg m^{-2} s^{-1}	
19	atmosphere_water_vapor_content	prw	kg m^{-2}	vertically integrated through the atmospheric column
20	soil_frozen_water_content	mrfso	kg m^{-2}	summed over all soil layers, and averaged over the land portion of the grid cell (i.e., compute by dividing the total mass of frozen water contained in the soil layer of the grid cell by the land area in the grid cell); report as "missing" or 0.0 where the land fraction is 0.
21	surface_runoff_flux	mrros	kg m^{-2} s^{-1}	compute as the total surface runoff leaving the land portion of the grid cell divided by the land area in the grid cell; report as "missing" or 0.0 where the land fraction is 0.
22	runoff_flux	mrro	kg m^{-2} s^{-1}	compute as the total runoff (including "drainage" through the base of the soil model) leaving the land portion of the grid cell divided by the land area in the grid cell; report as "missing" or 0.0 where the land fraction is 0.

23	surface_snow_amount_where_land	snw	kg m^{-2}	compute as the mass of surface snow on the land portion of the grid cell divided by the land area in the grid cell; report as "missing" or 0.0 where the land fraction is 0; exclude snow on vegetation canopy or on sea ice.
24	surface_snow_area_fraction_where_land	snc	%	fraction of grid cell covered by snow that lies on land; exclude snow that lies on sea ice.
25	surface_snow_melt_flux_where_land	snm	kg m^{-2} s^{-1}	compute as the total surface melt water on the land portion of the grid cell divided by the land area in the grid cell; report as 0.0 for snow-free land regions; report as 0.0 or "missing" where the land fraction is 0.
26	eastward_wind	uas	m s^{-1}	near-surface (usually, 10 meters) eastward component of wind; the CMOR singleton dimension default value of 10 m can be overridden, if absolutely necessary, by redefining axis "height2".
27	northward_wind	vas	m s^{-1}	near-surface (usually, 10 meters) northward component of wind; the CMOR singleton dimension default value of 10 m can be overridden, if absolutely necessary, by redefining axis "height2".
28	specific_humidity	huss	1 (i.e., dimensionless fraction)	near-surface (usually, 2meters) specific humidity; the CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".
29	toa_incoming_shortwave_flux	rsdt	W m^{-2}	incident shortwave at the top of the atmosphere
30	toa_outgoing_shortwave_flux	rsut	W m^{-2}	at the top of the atmosphere
31	toa_outgoing_longwave_flux	rlut	W m^{-2}	at the top of the atmosphere (to be compared with satellite measurements)

32	net_downward_radiative_flux_at_top_of_ atmosphere_model	rtmt	W m^{-2}	i.e., at the top of that portion of the atmosphere where dynamics are explicitly treated by the model.
33	net_downward_shortwave_flux_in_air	rsntp	W m^{-2}	at 200 hPa only; the CMOR singleton dimension default value of 200 hPa can be overridden, if absolutely necessary, by redefining axis "pressure1".
34	net_upward_longwave_flux_in_air	rlntp	W m^{-2}	at 200 hPa only; the CMOR singleton dimension default value of 200 hPa can be overridden, if absolutely necessary, by redefining axis "pressure1".
35	net_downward_shortwave_flux_in_air_ assuming_clear_sky	rsntpcs	W m^{-2}	at 200 hPa only; method "2" is recommended for calculating clear-sky fluxes; the CMOR singleton dimension default value of 200 hPa can be overridden, if absolutely necessary, by redefining axis "pressure1".
36	net_upward_longwave_flux_in_air_ assuming_clear_sky	rlntpcs	W m^{-2}	at 200 hPa only; method "2" is recommended for calculating clear-sky fluxes; the CMOR singleton dimension default value of 200 hPa can be overridden, if absolutely necessary, by redefining axis "pressure1".
37	surface_downwelling_shortwave_flux_in_ air_assuming_clear_sky	rsdscs	W m^{-2}	method "2" is recommended for calculating clear-sky fluxes
38	surface_upwelling_shortwave_flux_in_ air_assuming_clear_sky	rsuscs	W m^{-2}	method "2" is recommended for calculating clear-sky fluxes
39	surface_downwelling_longwave_flux_in_ air_assuming_clear_sky	rldscs	W m^{-2}	method "2" is recommended for calculating clear-sky fluxes
40	toa_outgoing_longwave_flux_assuming_ clear_sky	rlutcs	W m^{-2}	method "2" is recommended for calculating clear-sky fluxes
41	toa_outgoing_shortwave_flux_assuming_ clear_sky	rsutcs	W m^{-2}	method "2" is recommended for calculating clear-sky fluxes

42	cloud_area_fraction	clt	%	for the whole atmospheric column, as seen from the surface or the top of the atmosphere. Include both large-scale and convective cloud.
43	atmosphere_cloud_condensed_water_content	clwvi	kg m^{-2}	include both liquid and ice phases, consider all the mass of condensed water in the column and divide by its area (in the longitude-latitude plane)
44	atmosphere_cloud_ice_content	clivi	kg m^{-2}	consider all the mass of ice-phase water in the column and divide by its area (in the longitude-latitude plane)

Table A1b: **Time-independent 2-d land surface data (longitude, latitude).**

	CF standard_name	**output variable name**	**units**	**notes**
1	surface_altitude	orog	m	height above the geoid; as defined here, "the geoid" is a surface of constant geopotential that, if the ocean were at rest, would coincide with mean sea level. Under this definition, the geoid changes as the mean volume of the ocean changes (e.g., due to glacial melt, or global warming of the ocean). Report here the height above the present-day geoid. Over ocean, report as 0.0
2	land_area_fraction	sftlf	%	
3	land_ice_area_fraction	sftgif	%	fraction of grid cell occupied by "permanent" ice (i.e., glaciers).
4	soil_moisture_content_at_ field_capacity	mrsofc	kg m^{-2}	divide the total water holding capacity of all the soil in the grid cell by the land area in the grid cell; report as "missing" or 0.0 outside land areas.

Table A1c: **Monthly-mean 3-d atmosphere data (longitude, latitude, pressure, time:month).** Except for cloud area fraction, this data must be provided on pressure levels, including at least the following standard levels:1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 hPa.

	CF standard_name	**output variable name**	**units**	**notes**
1	cloud_area_fraction_in_atmosphere_layer	cl	%	unlike all other fields in this table, the cloud fraction should be reported for each model layer (not interpolated to standard pressures). Include both large-scale and convective cloud.
2	air_temperature	ta	K	
3	eastward_wind	ua	$m\ s^{-1}$	
4	northward_wind	va	$m\ s^{-1}$	
5	specific_humidity	hus	1 (i.e., dimensionless fraction)	
6	lagrangian_tendency_of_air_pressure	wap	$Pa\ s^{-1}$	commonly referred to as "omega", this represents the vertical component of velocity in pressure coordinates (positive down)
7	geopotential_height	zg	m	
8	relative_humidity	hur	%	
9	mole_fraction_of_o3_in_air	tro3	1e-9 (i.e., ppbv)	if climatologically specified, report only for 1 year.

Table O1a: **Monthly-mean 1-d ocean data (latitude, region, time:month).** Zonal mean over all oceans and also zonal mean for individual ocean basins (Atlantic, Indian, and Pacific basins: divide roughly at 20E and 120E).

	CF standard_name	output variable name	units	notes
1	northward_ocean_heat_transport	hfogo	W	transport by all ocean-related processes, both explicitly simulated and parameterized (e.g., any contribution from the 'bolus velocity' in the Gent-McWilliams parameterization), including sea water and sea ice contributions.

Table O1b: **Monthly-mean 2-d ocean data (latitude, depth, region, time:month).** Zonal mean over all oceans and also zonal mean for individual ocean basins (Atlantic, Indian, and Pacific basins: divide roughly at 20E and 120E). Data must be provided on depth levels. We recommend that these match the 33 standard levels of Levitus observations: 0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750, 2000, 2500, 3000, 3500, 4000, 4500, 5000, and 5500 meters.

	CF standard_name	output variable name	units	notes
1	ocean_meridional_overturning_streamfunction	stfmmc	$m^3 s^{-1}$	Note that the units do not include mass. This should include only the explicitly calculated, purely advective component and should exclude contributions of the 'bolus velocity' that arise, for example, in the Gent-McWilliams parameterization.

Table O1c: **Monthly-mean 0-d or 2-d ocean or sea ice data (longitude, latitude, time:month).**

	CF standard_name	output variable name	units	notes
1	sea_surface_height_above_geoid	zos	m	this height, when multiplied by the area fraction of the grid cell covered by ocean (or sea ice), yields the volume of sea water above the geoid. As defined here, "the geoid" is a surface of constant geopotential that, if the ocean were at rest, would coincide with mean sea level. Under this definition, the geoid changes as the mean volume of the ocean changes (e.g., due to glacial melt, or global warming of the ocean). Report zos as "missing" over grid cells that are entirely land. There are a couple of acceptable options for reporting this field: 1) if the geoid is defined to relate to the instantaneous volume of the ocean, the global mean of zos will always be zero, and 2) if the geoid is defined relative to a time-mean sea level over some period, then the global mean of zos will be time-dependent. In either case a global mean time-series of sea level should also be reported as described in the next two table entries immediately below. In general IPCC analysis of global mean sea level changes will not rely on zos. It is recommended that in reporting zos, the atmospheric "inverted barometer" effect be omitted, since it can be easily calculated from the reported mean sea level pressure field. The "comment" attribute associated with zos should indicate whether or not the atmospheric "inverted barometer" influence on zos has been included. Additionally, it should be noted in the "comment" attribute whether zos is obtained directly, as in a free-surface model, or has been derived, for example, from geostrophy using diagnosed velocities at some level or from geostrophy relative to an assumed level of quiescence.

2	global_average_thermosteric_ sea_level_change	zostoga	m	a function only of time, zostoga is the contribution to change in global mean sea level, relative to some fixed distance from the center of the earth, due only to thermal structure changes. The fixed reference height should be invariant across all IPCC simulations by a model. In a rigid-lid model this quantity can be calculated by using a reference 3D salinity field to compute density as the 3D temperature field evolves. If only the total sea level change (due to thermosteric changes, water flux input from land/glaciers/atmosphere, and salinity influences on density) is available, omit zostoga, and report only zosga (see next table entry below). Please note in the "comment" attribute any assumptions or methodological details related to calculation of this time-series.
3	global_average_sea_level_change	zosga	m	a function only of time, zosga is the total change in global mean sea level, relative to some fixed distance from the center of the earth, due to thermosteric changes, water flux input from land/glaciers/atmosphere, and salinity influences on density. If the model cannot be trusted to provide estimates of the water flux input from land/glaciers, there is no need to report zosga (since salinity influences are of secondary importance and the thermosteric contribution is reported by zostoga). Note that to good approximation the difference between zostoga and zosga yields the global mean change in sea level due to water budget imbalances (presumably, resulting largely from changes in glacial mass). Please note in the "comment" attribute any assumptions or methodological details related to calculation of this time-series.
4	sea_surface_temperature	tos	K	this may differ from "surface temperature" in regions of sea ice.
5	sea_ice_area_fraction	sic	%	fraction of grid cell covered by sea ice.
6	sea_ice_thickness	sit	m	this thickness, when multiplied by the average area of the grid cell covered by sea ice, yields the time-mean sea ice volume. Thus, for time means, compute as the weighted sum of thickness (averaged over the sea ice-covered portion of the grid cell) divided by the sum of the weights, with the weights equal to the area covered by sea-ice; Report as 0.0 in regions free of sea ice.
7	eastward_sea_ice_velocity	usi	$m\ s^{-1}$	report as "missing" in regions free of sea ice.

8	northward_sea_ice_velocity	vsi	$m\ s^{-1}$	report as "missing" in regions free of sea ice.
9	water_flux_into_ocean	wfo	$kg\ m^{-2}\ s^{-1}$	precipitation minus evaporation, plus runoff, melting of sea ice and any water flux correction calculated considering only the ocean-portion of each grid cell
10	ocean_barotropic_streamfunction	stfbarot	$m^3\ s^{-1}$	units do not include mass.
11	heat_flux_correction_where_ocean	hfcorr	$W\ m^{-2}$	if applicable, should be positive down (i.e., added to ocean); the total flux correction entering the ocean portion of the grid cell should be divided by the ocean area in the grid cell (in this context, ocean includes sea ice); report only for a single year and a single run, assuming this field is the same from year to year and for all runs.
12	water_flux_correction_where_ocean	wfcorr	$kg\ m^{-2}\ s^{-1}$	if applicable, should be positive down (i.e., added to ocean); the total flux correction entering the ocean portion of the grid cell should be divided by the ocean area in the grid cell (in this context, ocean includes sea ice); report only for a single year and a single run, assuming this field is the same from year to year and for all runs.
13	eastward_momentum_flux_ correction_where_ocean	tauucorr	Pa	if applicable, should be positive down (i.e., added to ocean); the total flux correction entering the ocean portion of the grid cell should be divided by the ocean area in the grid cell (in this context, ocean includes sea ice); report only for a single year and a single run, assuming this field is the same from year to year and for all runs.
14	northward_momentum_flux_ correction_where_ocean	tauvcorr	Pa	if applicable, should be positive down (i.e., added to ocean); the total flux correction entering the ocean portion of the grid cell should be divided by the ocean area in the grid cell (in this context, ocean includes sea ice); report only for a single year and a single run, assuming this field is the same from year to year and for all runs.

***Table O1d:* Time-independent 2-d ocean data (longitude, latitude).**

	CF standard_name	output variable name	units	notes
1	sea_floor_depth_below_geoid	zobt	m	this height, when multiplied by the area fraction of the grid cell covered by ocean (or sea ice), yields the volume of water below the geoid. As defined here, "the geoid" is a surface of constant geopotential that, if the ocean were at rest, would coincide with mean sea level. Under this definition, the geoid changes as the mean volume of the ocean changes (e.g., due to glacial melt, or global warming of the ocean). Report here the sea floor depth for present day.
2	prescribed_heat_flux_into_slab_ocean	qflux	W m^{-2}	the so-called q-flux added to slab ocean cell, which is meant to account for convergence (or divergence) of heat by the ocean circulation. It should be computed as the total qflux energy added to the ocean-portion of the grid cell divided by the ocean area in the grid cell; report as "missing" or 0.0 where the ocean fraction is 0. Report only for slab ocean experiments.

***Table O1e:* Monthly-mean 3-d ocean data (longitude, latitude, depth, time:month).** Data must be provided on depth levels. We recommend that these match the 33 standard levels of Levitus observations: 0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750, 2000, 2500, 3000, 3500, 4000, 4500, 5000, and 5500 meters. For the 3-d ocean fields, it is likely that storage space constraints will limit relatively quick access to output from only a single member of each ensemble, so in prioritizing your processing, consider initially sending PCMDI the 3-d ocean output from only 1 member of the ensemble.

	CF standard_name	output variable name	units	notes
1	sea_water_salinity	so	1e-3 (i.e., ppt)	The unit of salinity is PSU (expressed here as parts per thousand).
2	sea_water_potential_temperature	thetao	K	assume reference height is sea level
3	sea_water_potential_density	rhopoto	kg m^{-3}	assume reference height is sea level
4	eastward_sea_water_velocity	uo	m s^{-1}	

5	northward_sea_water_velocity	vo	m s^{-1}	
6	upward_sea_water_velocity	wo	m s^{-1}	

Daily-mean data

Table A2a: Daily-mean 2-d atmosphere data (longitude, latitude, time:day). It is recommended that the daily means be computed for intervals beginning at 0 Z and ending the following midnight at 0Z. Except for the temperature (mean, min., and max.) and precipitation fields, the following daily-mean data should be provided for just one ensemble member per scenario. Also report data only for the years specified in the table at the end of this document.

	CF standard_name	**output variable name**	**units**	**notes**
1	air_pressure_at_sea_level	psl	Pa	
2	precipitation_flux	pr	kg m^{-2} s^{-1}	includes both liquid and solid phases.
3	air_temperature	tasmin	K	daily-minimum near-surface (usually, 2 meter) air temperature. Consistent with the CF-conventions, the cell_methods attribute should specify "time: minimum" (automatically done by CMOR); The CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".
4	air_temperature	tasmax	K	daily-maximum near-surface (usually, 2 meter) air temperature. Consistent with the CF-conventions, the cell_methods attribute should specify "time: maximum" (automatically done by CMOR). The CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".
5	air_temperature	tas	K	daily-mean near-surface (usually, 2 meter) air temperature; The CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".

6	surface_upward_latent_heat_flux	hfls	W m^{-2}	
7	surface_upward_sensible_heat_flux	hfss	W m^{-2}	
8	surface_downwelling_longwave_flux_in_air	rlds	W m^{-2}	
9	surface_upwelling_longwave_flux_in_air	rlus	W m^{-2}	
10	surface_downwelling_shortwave_flux_in_air	rsds	W m^{-2}	
11	surface_upwelling_shortwave_flux_in_air	rsus	W m^{-2}	
12	eastward_wind	uas	m s^{-1}	near-surface (usually, 10 meters) eastward component of wind. The CMOR singleton dimension default value of 10 m can be overridden, if absolutely necessary, by redefining axis "height2".
13	northward_wind	vas	m s^{-1}	near-surface (usually, 10 meters) northward component of wind. The CMOR singleton dimension default value of 10 m can be overridden, if absolutely necessary, by redefining axis "height2".
14	toa_outgoing_longwave_flux	rlut	W m^{-2}	at the top of the atmosphere (to be compared with satellite measurements)

Table A2b: Daily-mean 3-d atmosphere data (longitude, latitude, pressure, time:day). It is recommended that the daily means be computed for intervals beginning at 0 Z and ending the following midnight at 0Z. This data should be provided for just one ensemble member per scenario, and for only the years specified in the table at the end of this document. Also this data must be provided on pressure levels, including at least the following subset of standard levels:1000, 925, 850, 700, 600, 500, 400, 300, 200 hPa.

	CF standard_name	**output variable name**	**units**	**notes**
1	air_temperature	ta	K	
2	eastward_wind	ua	m s^{-1}	
3	northward_wind	va	m s^{-1}	
4	specific_humidity	hus	1 (i.e., dimensionless fraction)	

3-hourly data

***Table A3:* 3-bourly 2-d atmosphere data (longitude, latitude, time:3hour at 0, 3, 6, 9, 12, 15, 18, 21 Z).** The data should be provided for just one ensemble member per scenario, and for the years specified in the table at the end of this document. 3-hourly precipitation should be an average over the 3-hour intervals, 0-3Z, 3-6Z, ... 21-24Z; all other 3-hourly data should be instantaneous "snapshots" at 0, 3, 6, ... 21Z.

	CF standard_name	output variable name	units	notes
1	air_pressure_at_sea_level	psl	Pa	
2	precipitation_flux	pr	kg m^{-2} s^{-1}	includes both liquid and solid phases.
3	air_temperature	tas	K	near-surface (usually, 2 meter) air temperature (CMOR singleton dimension table entry is "height1").
4	surface_upward_latent_heat_flux	hfls	W m^{-2}	
5	surface_upward_sensible_heat_flux	hfss	W m^{-2}	
6	surface_downwelling_longwave_flux_in_air	rlds	W m^{-2}	
7	surface_upwelling_longwave_flux_in_air	rlus	W m^{-2}	
8	surface_downwelling_shortwave_flux_in_air	rsds	W m^{-2}	
9	surface_upwelling_shortwave_flux_in_air	rsus	W m^{-2}	

Extremes indices

The following ten "extremes indices" are described in Frich, P, Alexander LV, Della-Marta P, Gleason B, Haylock M, Klein Tank AMG, Peterson T, 2002: Observed coherent changes in climate extremes during the second half of the twentieth century, *Climate Research 19*: 193-212. Frich et al. describe these as "derived data in the form of annual indicator time series" and present them (as derived from observations) as a function of longitude, latitude, and year. See http://www.cru.uea.ac.uk/cru/projects/stardex for sample computer code and documentation.

Table A4: **Extremes indices (longitude, latitude, time:year) from Frich et al. (their Table 1).**

	output variable name	**units**	**notes**
1	fd	days	Total number of frost days (days with absolute minimum temperature < 0 deg C)
2	etr	K	Intra-annual extreme temperature range: difference between the highest temperature of any given calendar year (T_h) and the lowest temperature of the same calendar year (T_l)
3	gsl	days	Growing season length: period between when T_{day} > 5 deg C for > 5 d and T_{day} < 5 deg C for > 5 d
4	hwdi	days	Heat wave duration index: maximum period > 5 consecutive days with T_{max} > 5 deg C above the 1961-1990 daily T_{max} normal
5	tn90	%	Fraction (expressed as a percentage) of time T_{min} > 90th percentile of daily minimum temperature, where percentiles are for the 1961-1990 base period.
6	r10	days	No. of days with precipitation greater than or equal to 10 mm d^{-1}
7	cdd	days	Maximum number of consecutive dry days (R_{day} < 1 mm)
8	r5d	kg m^{-2}	Maximum 5 d precipitation total
9	sdii	kg m^{-2} s^{-1}	Simple daily intensity index: annual total / number of R_{day} greater than or equal to 1 mm d^{-1}
10	r95t	%	Fraction (expressed as a percentage) of annual total precipitation due to events exceeding the 1961-1990 95th percentile

Lower priority output fields

ISCCP simulator output

Cloud-related output that matches the quantities observed by the International Satellite Cloud Climatology Project. This output is produced by the ISCCP simulator code and which usually must be run in the climate model, not as a post-processing step. See the Cloud Forcing Model Intercomparison Web site (http://www.cfmip.net) for details of the ISCCP simulator -- where to get code, settings for climate models, etc.

Table A1d: Monthly-mean ISCCP simulator data (longitude, latitude, pressure2, tau, time). Data should be sampled no less frequently than every 15 hours. The ISCCP cloud layers refer to the following ranges (hPa): 800 and higher, 800-680, 680-560, 560-440, 440-310, 310-180, and 180-0. The ISCCP optical depth (tau) categories refer to the following ranges: 0-0.3, 0.3-1.3, 1.3-3.6, 3.6-9.4, 9.4-23, 23-60, and >60. The preferred time periods and experiments for which this data will be collected have not be agreed upon yet, but discussions are underway. Anyone having an opinion about this is invited to participate in the discussion.

CF standard_name	output variable name	units	notes
isccp_cloud_area_fraction	clisccp	1 (i.e., dimensionless fraction)	as seen from above, mean fraction of grid column occupied by cloud of optical depths and heights specified by the tau and pressure intervals given above; for each longitude and latitude grid column, the ISCCP simulator output comprises a 7x7 (pressure x tau) matrix of values matching those of the satellite. With CMOR, use "pressure2" to define the vertical coordinates for this variable.

Radiative forcing

To enable an analysis of feedbacks, which explain differences in model sensitivity, the WGCM urges groups to calculate, if at all practical, the clear-sky and all-sky shortwave and longwave radiative forcing. These four fields should be a function of longitude latitude and time (monthly sampling). No standard method for calculating radiative forcing has been agreed on by the WGCM, but one good option would be to follow the method suggested in Appendix A of a letter from the IPCC co-chairs (see http://www-pcmdi.llnl.gov/ipcc/Appendix_A.php). The highest priority (and easiest) calculation of this kind is to calculate monthly-mean values of radiative forcing for doubled CO_2.

Calculation of clear-sky radiative forcing as well as all-sky forcing will make it possible to estimate the importance of cloud feedbacks in the 1% / year CO2 simulations and the 2xCO2 equilibrium simulations (assuming the radiative forcing scales with the logarithm of CO2 concentration). The evolution of forcing fields for any and all other climate change agents are also welcome. A rough priority for forcing calculations follows:

1. CO2 doubling (*Please provide this at the very least!*)
2. Total forcing (from all anthropogenic influences) for SRES A1b, B1, and A2 (reported at least at the end of the simulation, and as frequently as necessary to characterize, approximately, the forcing changes throughout the experiment.
3. CO2 quadrupling(to check that logarithmic scaling holds).
4. Total anthropogenic forcing for the historical run (sampled every 10 years or more frequently)
5. Total natural forcing (if any) for the historical run (sampled as frequently as necessary)
6. Forcing due to individual constituents (e.g., volcanic aerosols, anthropogenic aerosols, individual greenhouse gases) for the historical run.
7. Forcing due to individual constituents for the experiments listed in 2.

Table A5: **Monthly-mean 2-d radiative forcing data (longitude, latitude, time).** For the following output fields choose the variable name corresponding to the method you used to calculate radiative forcing and replace the "?" suffix with one of the following abbreviations for different forcing agents: g (all greenhouse gases), co2 (carbon dioxide only), s (total sulfate aerosol), sd (direct effect only of sulfate aersol), si (indirect effect only of sulfate aerosols), bc ("black carbon"), o (ozone), to (tropospheric ozone only), so (stratospheric ozone only), l (vegetation and other land surface changes), a (all anthropogenic factors, inclusive), v (volcanic aerosols), sun (solar constant changes), or n (all natural factors, inclusive). Use the term that is most specific (e.g., if the only anthropogenic effect included in the model simulation is an increase in carbon dioxide, use "co2", not "a" or "g"). A complete example is: rsftoaa_a.

	CF standard_name	**output variable name**	**units**	**notes**
1	toa_adjusted_shortwave_forcing tropopause_adjusted_shortwave_forcing toa_instantaneous_shortwave_forcing tropopause_instantaneous_shortwave_forcing	rsftoaa_? rsftropa_? rsftoai_? rsftropi_?	$W m^{-2}$	all-sky conditions, defined to be positive down. Choose appropriate variable, and indicate in the "comment" attribute (associated with the variable) any particulars (e.g., 200 hPa taken as approximate tropopause). For tropopause, CMOR will by default record a singleton dimension value of 200 hPa. To override this value redefine pressure1.

2	toa_adjusted_longwave_forcing tropopause_adjusted_longwave_forcing toa_instantaneous_longwave_forcing tropopause_instantaneous_longwave_forcing	rlftoaa_? rlftropa_? rlftoai_? rlftropi_?	$W\ m^{-2}$	all-sky conditions, defined to be positive down. Choose appropriate variable, and indicate in the "comment" attribute (associated with the variable) any particulars (e.g., 200 hPa taken as approximate tropopause). For tropopause, CMOR will by default record a singleton dimension value of 200 hPa. To override this value redefine pressure1.
3	toa_adjusted_shortwave_forcing_assuming_clear_sky tropopause_adjusted_shortwave_forcing_assuming_clear_sky toa_instantaneous_shortwave_forcing_assuming_clear_sky tropopause_instantaneous_shortwave_forcing_assuming_clear_sky	rsftoaacs_? rsftropacs_? rsftoaics_? rsftropics_?	$W\ m^{-2}$	clear-sky calculation, defined to be positive down. Choose appropriate variable, and indicate in the "comment" attribute (associated with the variable) any particulars (e.g., 200 hPa taken as approximate tropopause). For tropopause, CMOR will by default record a singleton dimension value of 200 hPa. To override this value redefine pressure1.
4	toa_adjusted_longwave_forcing_assuming_clear_sky tropopause_adjusted_longwave_forcing_assuming_clear_sky toa_instantaneous_longwave_forcing_assuming_clear_sky tropopause_instantaneous_longwave_forcing_assuming_clear_sky	rlftoaacs_? rlftropacs_? rlftoaics_? rlftropics_?	$W\ m^{-2}$	clear-sky calculation, defined to be positive down. Choose appropriate variable, and indicate in the "comment" attribute (associated with the variable) any particulars (e.g., 200 hPa taken as approximate tropopause). For tropopause, CMOR will by default record a singleton dimension value of 200 hPa. To override this value redefine pressure1.

Sulfate aerosol data

Provide both the column integrated 2-D fields and the 3-D fields on the following pressure levels: 1004, 983, 953, 910, 848, 765, 663, 546, 425, 318, 238, 183, 140, 103, 72, 47, 27, 13, and 4 hPa.

Table A1e: **Monthly-mean 2-d and 3-d sulfate aerosol fields.**

	CF standard_name	output variable name	units	notes
1	mass_concentration_of_sulfate_aerosol_in_air	trsul	1e-9 kg m^{-3}	3-d field (longitude, latitude, pressure3, time)
2	atmosphere_content_of_sulfate_aerosol	trsult	1e-6 kg m^{-2}	2-d field, vertically integrated through atmospheric column (longitude, latitude, time)

Additional Monthly-mean fields

Table O1f: **Monthly-mean 1-d and 2-d ocean fields.**

	CF standard_name	output variable name	units	notes
1	ocean_mixed_layer_thickness	zmlo	m	mixed layer depth; (longitude, latitude, time). No agreement has been reached as to the precise definition of the mixed layer depth, so this field may be of limited value.
2	northward_ocean_heat_transport_due_to_diffusion	htovdiff	W	vertically integrated northward heat transport by unresolved processes, summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time); include specifically contributions of the 'bolus velocity' that arise, for example, in the Gent-McWilliams parameterization.

3	northward_ocean_heat_transport_due_to_gyre	htovgyre	W	vertically integrated northward heat transport by gyre circulation (including heat advection by sea ice), summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time); exclude contributions of the 'bolus velocity' that arise, for example, in the Gent-McWilliams parameterization.
4	northward_ocean_heat_transport_due_to_overturning	htovovrt	W	vertically integrated northward heat transport by overturning circulation, summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time); exclude contributions of the 'bolus velocity' that arise, for example, in the Gent-McWilliams parameterization.
5	northward_ocean_salt_transport_due_to_diffusion	sltovdiff	kg s^{-1}	vertically integrated northward salt transport by unresolved processes, summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time)
6	northward_ocean_salt_transport_due_to_gyre	sltovgyre	kg s^{-1}	vertically integrated northward salt transport by gyre circulation (including salt advection by sea ice), summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time)
7	northward_ocean_salt_transport_due_to_overturning	sltovovrt	kg s^{-1}	vertically integrated northward salt transport by overturning circulation, summed over longitude for each of 3 basins (Atlantic, Indian, Pacific) and global ocean; (latitude, region, time)

***Table O1g:* Monthly-mean 2-d sea ice fields (longitude, latitude, time:month).**

	CF standard_name	output variable name	units	notes
1	water_evaporation_flux_where_sea_ice	sbl	kg m^{-2} s^{-1}	Compute the average rate that water mass evaporates (or sublimates) from the sea ice surface (i.e., kg/s) divided by the average area of the grid cell covered by sea ice. This quantity multiplied both by the average area covered by sea ice and by the length of the month should yield the total mass of water evaporated (or sublimated) from the sea ice. Report as 0.0 in regions free of sea ice.
2	upward_sea_ice_basal_heat_flux	hfsib	W m^{-2}	Compute the average rate that heat flows up at the base of the sea ice (i.e., Watts) divided by the average area of the grid cell covered by sea ice. This quantity multiplied both by the average area covered by sea ice and by the length of the month should yield the total energy flowing into the ice from below. Report as 0.0 in regions free of sea ice.
3	downward_sea_ice_basal_salt_flux	sltfsib	kg m^{-2} s^{-1}	Compute the average rate that salt mass flows down at the base of the sea ice (i.e., kg/s) divided by the average area of the grid cell covered by sea ice. This quantity multiplied both by the average area covered by sea ice and by the length of the month should yield the total salt mass flowing into the ocean at the base of the sea ice. Report as 0.0 in regions free of sea ice.

Table A1f: **Monthly-mean surface fields, and prescribed land surface characteristics.**

	CF standard_name	output variable name	units	notes
1	precipitation_flux_onto_canopy	prveg	kg m^{-2} s^{-1}	As a function of longitude, latitude, and time, report the precipitation flux intercepted by vegetation canopy (if present in model), averaged over only the land portion of the grid cell; report as "missing" or 0.0 where the land fraction is 0;
2	water_evaporation_flux_from_canopy	evspsblveg	kg m^{-2} s^{-1}	As a function of longitude, latitude, and time, report the canopy evaporation+sublimation (if present in model), averaged only over the land portion of the grid cell; report as "missing" or 0.0 where the land fraction is 0;
3	atmosphere_boundary_layer_thickness	zmla	m	As a function of longitude, latitude, and time, report the height of the atmospheric boundary layer (if defined in model); No agreement has been reached as to the precise definition of this quantity, so this field may be of limited value.
4	root_depth	rootd	m	As a function of longitude and latitude, report the maximum soil depth reachable by plant roots, i.e., the maximum soil depth from which they can extract moisture (if defined in model); report as "missing" or 0.0 where the land fraction is 0;
5	air_temperature	tasmin	K	monthly mean of the daily-minimum near-surface (usually, 2 meter) air temperature. Consistent with the CF-conventions, the cell_methods attribute should specify "time: minimum within days time: mean over days" (automatically done by CMOR); The CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".
6	air_temperature	tasmax	K	monthly mean of the daily-maximum near-surface (usually, 2 meter) air temperature. Consistent with the CF-conventions, the cell_methods

				attribute should specify "time: maximum within days time: mean over days" (automatically done by CMOR); The CMOR singleton dimension default value of 2 m can be overridden, if absolutely necessary, by redefining axis "height1".

Coordinate dimensions.

In the tables given above, variables are a function of various coordinate variables, which are stored in the netCDF files with the following names and units:

Table of Coordinate Dimensions.

	CF standard_name	output coordinate variable name	CMOR table "entry" I.D.	units	default value of scalar dimension	notes
1	longitude	lon	longitude	degrees_east		
2	latitude	lat	latitude	degrees_north		
3	time	time	time	days_since_??		where ?? should be specified in the form year-month-day (e.g., days_since_1800-1-1).
4	time	time	time1	days_since_??		used for 3-hourly "snapshot" fields in Table A3, where the cell_bounds attribute should be omitted for the time dimension.
5	air_pressure	plev	pressure	Pa		used for all fields that are a function of pressure except those listed in the next 3 rows below.

6	air_pressure	plev	pressure1	Pa	20000.	used by some near-tropopause radiation fluxes (Table A1a, entries 33-36), and some radiative forcing fields (Table A5, entries 1-4)
7	air_pressure	plev	pressure2	Pa		used by clisccp in Table A1d
8	air_pressure	plev	pressure3	Pa		used by trsul in Table A1e
9	height	height	height1	m	2.	used by tas, huss, tasmin and tasmax in Tables A1a, A2a, and A3.
10	height	height	height2	m	10.	used by uas and vas in Tables A1a and A2a.
11	depth	depth	depth1	m	0.05	used by mrsos in Table A1a; bounds for this scalar dimension should be 0.0 and 0.1 m.
12	cloud_optical_depth	tau	tau	1		used by clisccp in Table A1d
13	atmosphere_sigma_coordinate	lev	standard_sigma	1 (dimensionless)		one choice of dimensionless vertical coordinate needed for cl field (cloud fraction). The following parameters (specified by the CF-standard) are also needed to fully describe this coordinate: ptop, sigma, and ps.
14	atmosphere_hybrid_sigma_ pressure_coordinate	lev	standard_hybrid_sigma	1 (dimensionless)		one choice of dimensionless vertical coordinate needed for cl field (cloud fraction). The following parameters (specified by the CF-standard) are also needed to fully describe this coordinate: p0, a, b, and ps.
15	atmosphere_hybrid_sigma_ pressure_coordinate	lev	alternate_hybrid_sigma	1 (dimensionless)		one choice of dimensionless vertical coordinate needed for cl

						field (cloud fraction). The following parameters (specified by the CF-standard) are also needed to fully describe this coordinate: p0, ap, b, and ps.
16	atmosphere_hybrid_ height_coordinate	lev	hybrid_height	1 (dimensionless)		one choice of dimensionless vertical coordinate needed for cl field (cloud fraction). The following parameters (specified by the CF-standard) are also needed to fully describe this coordinate: a, b, and orog.
17	depth	depth	depth	m		for some ocean fields
18		region	region	none		this coordinate is a simple index. A variable named geo_region must also be stored with the four values: "atlantic_ocean", "indian_ocean", "pacific_ocean", and "global_ocean".

Experiments and time periods for which data should be submitted:

A figure summarizing the reporting periods is available at http://www-pcmdi.llnl.gov/ipcc/output_periods.pdf, but more precise information is provided below. The following table indicates for each IPCC simulation the years for which output should be submitted to the PCMDI archive. All time intervals should be interpreted as extending from the beginning of the first year indicated through the end of the last year indicated. For example, years 1961-2000 means 0Z 1-1-1961 through 0Z 1-1-2001.

Table of Experiments.

	Experiment Name	**Monthly Data and Yearly Data (Extreme Indices)** (submit for each member of ensemble)	**Daily Data** (temperature and precipitation data should be submitted for each member of ensemble, but all other fields should be submitted for only a single ensemble member)	**3-Hourly Data** (submit for a single ensemble member)	**Notes**
1	pre-industrial control experiment	> 100 years (~500 years)	40 years that can best be compared to years 1961-2000 (i.e., through the end of year 2000) of the 20C3M expt.	last year of reported daily data (i.e., corresponding to year 2000 of the 20C3M expt.)	control for experiments 3-7 and for some models also the control for experiments 8-9. There will be no anthropogenic or natural forcing in this control. The control experiment should be long enough to extend to the furthest point in time reached by the end of the perturbation experiments (which presumably branch from it). Thus the control should allow us to subtract any residual, unforced drift from all perturbation simulations.

2	present-day control experiment	> 100 years (~300 years)	last 20 years	last year	for most models this experiment is not needed, but for some it is the control for experiments 8-9. There will be no natural forcing and anthropogenic influences will be set at present-day level. The control experiment should be long enough to extend to the furthest point in time reached by the end of the perturbation experiments (which branch from it). Thus the control should allow us to subtract any residual, unforced drift from the perturbation simulations.
3	climate of the 20th Century experiment (20C3M)	~1850 - present	1961 - 2000 (i.e., through the end of year 2000)	1991-2000 (i.e., through the end of year 2000)	should initialize from a point early enough in the pre-industrial control run to ensure that the end of all the perturbed runs branching from the end of this 20C3M run end before the end of the control. This will enable us to subtract any residual drift in the control from all runs that will be compared to it.
4	committed climate change experiment	present - 2100	2046-2065, 2081 - 2100	2050, 2100	should take the end of the 20C3M run as its initial condition.
5	SRES A2 experiment	present - 2100	2046 - 2065, 2081 - 2100	2050, 2100	should take the end of the 20C3M run as its initial condition.
6	720 ppm stabilization experiment (SRES A1B)	present - 2300 (present - 2200)	2046 - 2065, 2081-2100, 2181-2200, 2281-2300	2050, 2100, 2150, 2200, 2300	Impose SRES A1B conditions and initialize with conditions from the end of the 20C3M simulation and run to 2100, after which hold concentrations fixed and continue run to 2200. One member of the ensemble should be extended for an additional 100 years (to 2300), continuing to hold concentrations fixed.

7	550 ppm stabilization experiment (SRES B1)	present - 2300 (present - 2200)	2046 - 2065, 2081-2100, 2181-2200, 2281-2300	2050, 2100, 2150, 2200, 2300	Impose SRES B1 conditions and initialize with conditions from the end of the 20C3M simulation and run to 2100, after which hold concentrations fixed and continue run to 2200. One member of the ensemble should be extended for an additional 100 years (to 2300), continuing to hold concentrations fixed.
8	1%/year CO2 increase experiment (to doubling)	~70 years to doubling + an additional 150 years	20 years centered on time of doubling + last 20 years	at doubling and 150 years after doubling	Hold CO2 fixed after reaching doubled concentration. This run should be initialized from a point either within a present-day control run or a pre-industrial control run. Make sure that the initial time is early enough in the control run to subtract out any residual (unforced) drift that might occur over the 220 years of this experiment.
9	1%/year CO2 increase experiment (to quadrupling)	~140 years to quadrupling + an additional 150 years	20 years centered on time of quadrupling + last 20 years	at quadrupling and 150 years after quadrupling	Hold CO2 fixed after reaching quadrupled concentration. This run should be initialized from a point either within a pre-industrial control run or a present-day control run. Make sure that the initial time is early enough in the control run to subtract out any residual (unforced) drift that might occur over the 290 years of this experiment.
10	slab ocean control experiment	~100 years??	last 20 years	last year	slab ocean control for experiment 11. Be sure to run long enough to reach a true equilibrium state and to produce stable statistics (at least 20 years beyond equilibrium).

11	2xCO2 equilibrium experiment	~100 years??	last 20 years	last year	slab ocean experiment with an instantaneous doubling. There is interest in the transient response to the instantaneous doubling, so please report all years and be sure to run long enough to reach a true equilibrium state and to produce stable statistics (at least 20 years beyond equilibrium).
12	AMIP simulation	1979 - present	all years	2000	atmospheric component should be identical to that used in the above experiments