Rough draft for BMRC Technical Report:

The BMRC Contribution to CEOPS

Lawrie Rikus
Bureau of Meteorology Research Centre,
Model Development Group.
l.rikus@bom.gov.au

Abstract:

This paper describes the files contributed by BMRC to the Coordinated Enhanced Observing Period (CEOP).

The BMRC and CEOP.

Description of ceops etc MOLTS versus grid output, description of timing etc

The Bureau's operational global model.

The Bureau's current[1] operational medium range prediction model is a global spectral model with a horizontal resolution of T_L239 and 29 vertical (sigma) levels. Assimilation is performed with data inserts every 6 hours using optimal interpolation (Seaman et al 1995, Bourke et al 1995).

The model's prognostic variables are surface pressure, temperature, water vapour mixing ratio, vorticity and divergence.

The vertical diffusion uses a stability dependent Louis type scheme (Louis 1979) which is applied for sigma levels greater than 0.5 and any unstable layers.

The surface moisture is modelled by an interactive scheme which uses a fixed bucket with uniform capacity and source terms due to precipitation and snowmelt. Soil temperature is computed from an energy balance at the surface using the heat storage in two layers underpinned by a climatologically defined deep soil layer.

The land albedo is from climatology (Hummel and Reck 1979), and the sea surface temperatures are specified by a weekly updated operational Bureau analysis scheme. The surface turbulent eddy fluxes of heat, moisture and momentum are parameterized with a Monin-Obhukov scheme with stability dependent coefficients determined as suggested by Loius (1979).

Radiative transfer is parameterized by a two-band Lacis-Hansen (1974) scheme for shortwave and a Fels-Schwarzkopf (1975, 1991) scheme for the longwave. There are no aerosols or trace gases included.

The convection scheme is a slightly modified version of the original mass flux Tiedke scheme (1989) coupled to a large scale condensation scheme which instantaneously rains out relative humidities above a set threshold.

The large scale cloud is diagnosed from the relative humidity with additional stability dependent low cloud and is restricted to 3 non-contiguous layers. Cloud condensate content is a diagnostic parameterization using temperature as the predictor (Deschamps et al 1997). The ice/water identification is also a function of temperature.

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[1] as at 1 August 2003

Definition of the fields.

The CEOP organising committee suggested a list of variables for the MOLTS output. These are given in Appendix A. The definitions for the variables and any extra steps required to define them from the model's standard fields are described below under the appropriate headings from the table in the appendix.

Top of the atmosphere processes

The top of the atmosphere irradiances are calculated directly by the radiative transfer parameterization and require no additional processing.

Atmospheric variables

Temperature (T), surface pressure (P_S) , the wind components (U,V), geopotential (gZ) and pressure velocity (ω) are standard model fields and require no additional processing. The model's humidity variable is mixing ratio (r) and is converted to specific humidity (q) for output via, $q=r/(1+r)$, where r is the model mixing ratio in kg/kg and q is the specific humidity.

The sigma layer mean kinetic energy at level i in the model is defined by,

$$KE=\frac{P_s}{g}\int_{\Delta\sigma_i}(U^2+V^2)\,d\sigma=\frac{P_s}{g}(U_i^2+V_i^2)$$

The sigma layer mean potential energy at level i in the model is defined by,

$$PE=\frac{P_s}{g}\int_{\Delta\sigma_i}(gZ+C_pT)\,d\sigma=\frac{P_s}{g}(gZ_i+C_pT_i)$$

Cloud water (water + ice) is defined by the model as a diagnostic dependent on the cloud layer temperature (Deschamps et al 1997) and is carried as a mixing ratio in the model. This is output directly.

Atmospheric Processes 3D

The sigma layer mean convective latent heating rate at level i in the model is given by,

$$\Delta T_{con}=\frac{P_s}{g}\int_{\Delta\sigma}C_p\left(\frac{dT}{dt}\right)_{con}d\sigma=\frac{P_s}{g}C_p\left(\frac{dT_i}{dt}\right)_{con}$$

where $\left(\frac{dT_i}{dt}\right)_{con}$ is diagnosed directly in the model's convection parameterization scheme.

The sigma layer mean stable latent heating rate at level i in the model is given by,

$$\Delta T_{str}=\frac{P_s}{g}\int_{\Delta\sigma}C_p\left(\frac{dT}{dt}\right)_{str}d\sigma=\frac{P_s}{g}C_p\left(\frac{dT_i}{dt}\right)_{str}$$

where $\left(\frac{dT_i}{dt}\right)_{str}$ is diagnosed directly in the model's large scale condensation scheme.

The sigma layer mean convective moistening rate at level i in the model is given by,

$$\Delta q_{con}=\frac{P_s}{g}\int_{\Delta\sigma}\left(\frac{dq}{dt}\right)_{con}d\sigma=\frac{P_s}{g}\left(\frac{dq_i}{dt}\right)_{con}$$

where $\left(\frac{dq_i}{dt}\right)_{con}$ is diagnosed directly in the model's convection parameterization scheme.

The sigma layer mean stable moistening rate at level *i* in the model is given by,

$$\Delta q_{str} = \frac{P_s}{g}\int_{\Delta\sigma}\left(\frac{dq}{dt}\right)_{str} d\sigma = \frac{P_s}{g}\left(\frac{dq_i}{dt}\right)_{str}$$

where $\left(\frac{dq_i}{dt}\right)_{str}$ is diagnosed directly in the model's large scale condensation scheme.

The sigma layer mean short-wave heating rate at level *i* in the model is given by,

$$\Delta T_{SW} = \frac{P_s}{g}\int_{\Delta\sigma} C_p\left(\frac{dT}{dt}\right)_{SW} d\sigma = \frac{P_s}{g} C_p\left(\frac{dT_i}{dt}\right)_{SW}$$

where $\left(\frac{dT_i}{dt}\right)_{SW}$ is calculated directly in the model's Lacis-Hansen short-wave scheme.

The sigma layer mean long-wave heating rate at level *i* in the model is given by,

$$\Delta T_{LW} = \frac{P_s}{g}\int_{\Delta\sigma} C_p\left(\frac{dT}{dt}\right)_{LW} d\sigma = \frac{P_s}{g} C_p\left(\frac{dT_i}{dt}\right)_{LW}$$

where $\left(\frac{dT_i}{dt}\right)_{LW}$ is calculated directly in the model's Fels-Schwarzkopf long-wave scheme.

Note that the long-wave heating is predominately negative and the short-wave heating is positive so that the total radiative heating rate is just the sum of the two.

The layer mean horizontal moisture flux at level *i* in the model is given by,

$$\vec{F}_q(i) = \frac{P_s}{g}\int_{\Delta\sigma} \vec{v} q \, d\sigma = \frac{P_s}{g}\vec{v}_i q_i$$

The layer mean horizontal dry energy flux at level *i* in the model is given by,

$$\vec{F}_E(i) = \frac{P_s}{g}\int_{\Delta\sigma} \vec{v}(KE+PE) d\sigma = \frac{P_s}{g}\vec{v}_i (KE+PE)_i$$

The layer mean horizontal mass flux at level *i* in the model is given by,

$$\vec{F}_m(i) = \frac{P_s}{g}\int_{\Delta\sigma} \vec{v} \, d\sigma = \frac{P_s}{g}\vec{v}_i$$

To obtain layer mean vertical fluxes the hydrostatic approximation is applied to the pressure velocity ω to obtain a vertical velocity at each level,

$$w_i = \frac{-\omega_i}{\rho_i g}$$

Then the layer mean moisture vertical flux is,

$$F_q^v(i) = \frac{P_s}{g} \int_{\Delta\sigma} w\, q\, d\sigma = \frac{P_s}{g} w_i q_i$$

The layer mean dry energy vertical flux is,

$$F_E^v(i) = \frac{P_s}{g} \int_{\Delta\sigma} w(KE + PE)\, d\sigma = \frac{P_s}{g} w_i (KE + PE)_i$$

The layer mean mass vertical flux is,

$$F_m^v(i) = \frac{P_s}{g} \int_{\Delta\sigma} w\, d\sigma = \frac{P_s}{g} w_i$$

Local time tendencies are calculated at each timestep as the current value – the value from the previous time step. They are layer mean values.

Vertically Integrated Atmospheric Variables

The vertical integral of water vapor is given by,

$$PW = \frac{P_s}{g} \int_0^1 q\, d\sigma$$

The vertical integral of kinetic energy in the model is defined by,

$$KE = \frac{P_s}{g} \int_0^1 (U^2 + V^2)\, d\sigma$$

The vertical integral of potential energy in the model is defined by,

$$PE = \frac{P_s}{g} \int_0^1 (gZ + C_p T)\, d\sigma$$

The vertical integral of total dry energy is just the sum $KE + PE$.

The vertical integral of total cloud water in the model is defined by,

$$TCW = \frac{P_s}{g} \int_0^1 (r_{ice}^{cld} + r_{water}^{cld})\, d\sigma$$

Note that there is no account taken of cloud overlap or layer cloud fraction in this calculation.

The model doesn't currently include aerosols.

Vertically integrated processes

The vertical integral of convective latent heating rate is given by,

$$\Delta T_{con} = \frac{P_s}{g}\int_0^1 C_p\left(\frac{dT}{dt}\right)_{con} d\sigma$$

The vertical integral of stable latent heating rate is given by,

$$\Delta T_{str} = \frac{P_s}{g}\int_0^1 C_p\left(\frac{dT}{dt}\right)_{str} d\sigma$$

The vertical integral of convective moistening rate is given by,

$$\Delta q_{con} = \frac{P_s}{g}\int_0^1 \left(\frac{dq}{dt}\right)_{con} d\sigma$$

The vertical integral of stable moistening rate is given by,

$$\Delta q_{str} = \frac{P_s}{g}\int_0^1 \left(\frac{dq}{dt}\right)_{str} d\sigma$$

The vertical integral of the horizontal moisture fluxes is given by,

$$\vec{F}_q = \frac{P_s}{g}\int_0^1 \vec{v} q \, d\sigma$$

The vertical integral of the horizontal dry energy fluxes is given by,

$$\vec{F}_E = \frac{P_s}{g}\int_0^1 \vec{v}(KE+PE) d\sigma$$

Physical Constants

The physical constants used in the calculations are given below,

c_{pd} = 1004.64 J/kg/K

c_{pv} = 1850 J/kg/K

M_d = 28.97 kg/(kg-mol)

M_v = 18.016 kg/(kg-mol)

R_d = 287.04 J/kg/K

R_v = 461 J/kg/K

$\varepsilon = M_v/M_d = 0.622$

$$R-R_d(1+(\frac{R_v}{R_d}-1)q)-R_d(1+0.608q)$$

$$c_p-c_{pd}\lceil 1+(\frac{c_{pv}}{c_{pd}}-1)q^{\cdot}-c_{pd}(1+0.84)$$

Description of the data files.

The data is supplied in the form of NetCDF files (http://www.unidata.ucar.edu/packages/netcdf/index.html).

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Appendix A.

MODEL OUTPUT VARIABLES REQUESTED BY CEOP

(as per document Appendix A 28 Mar 2003)

Output frequency:

1) During assimilation.

MOLTS at all CEOP sites preferably at hourly resolution or better.

2) During forecast.

MOLTS at all CEOP sites preferably at hourly resolution or better.
36 hour forecast started from 12UTC (only the 12-36 hour period is going to be used).

	Top of Atmosphere Processes	**Units**		**NetCDF Name**
1	shortwave downward flux (positive)	W/m^2	A	sw_toa_dwn
2	shortwave upward flux (positive)	W/m^2	A	sw_toa_up
3	longwave upward flux (positive)	W/m^2	A	lw_toa_up

	Atmospheric Variables	**Units**		**NetCDF Name**
1	temperature	K	I	air_temp
2	pressure	Pa	I	pressure
3	moisture	kg/kg	I	spec_hum
4	zonal wind	m/s	I	zonal_wnd
5	meridional wind	m/s	I	merid_wnd
6	geopotential (gZ)	m^2/s^2	I	geo_height
7	pressure velocity	Pa/s	I	omega
8	kinetic+potential energy (KE+gZ+CpT)	J/m^2	I	dry_energy
9	kinetic energy + enthalpy (CpT+KE)	J/m^2	I	ke_enth
10	cloud water	kg/kg	I	totl_cld_water

	Atmospheric Processes 3D	Units		**NetCDF Name**
1	convective latent heating rate	W/m^2	A	condel_t
2	stable latent heating rate	W/m^2	A	stratdel_t
3	convective moistening rate	$kg/(m^2s)$	A	condel_q
4	stable moistening rate	$kg/(m^2s)$	A	stratdel_q
5	turbulent moistening rate	$kg/(m^2s)$	A	---------------------
6	turbulent heating rate	W/m^2	A	---------------------
7	short-wave heating rate	W/m^2	A	heat_sw
8	long-wave heating rate	W/m^2	A	heat_lw
9	moisture zonal flux	kg/(ms)	A	znl_q_flx
10	moisture meridional flux	kg/(ms)	A	mer_q_flx
11	moisture vertical flux	kg/(ms)	A	ver_q_flx
12	moisture flux divergence	$kg/(m^2s)$	A	---------------------

	Atmospheric Processes 3D	Units		**NetCDF Name**
13	energy (CpT+gZ+KE) zonal flux	W/m	A	znl_e_flux
14	energy (CpT+gZ+KE) meridional flux	W/m	A	mer_e_flx
15	energy (CpT+gZ+KE) vertical flux	W/m	A	ver_e_flx
16	energy flux divergence	W/m^2	A	---------------------
17	total mass zonal flux	kg/(ms)	A	znl_mass_flx
18	total mass meridional flux	kg/(ms)	A	mer_mass_flx
19	total mass vertical flux	kg/(ms)	A	ver_mass_flx
20	mass flux divergence	kg/(ms)	A	---------------------
21	local time tendency of total energy	W/m^2	A	lcl_e_tend
22	local time tendency of temperature	K/s	A	lcl_t_tend
23	local time tendency of moisture	kg/(m^{2}s)	A	lcl_q_tend
24	Local time tendency of mass	kg/(m^{2}s)	A	---------------------

	Vertically Integrated Atmos. Variables	**Units**		**NetCDF Name**
1	total moisture (precipitable water)	kg/m^2	I	total_wv
2	total dry energy (CpT+KE+gZ)	J/m^2	I	vint_dry_energy
3	Total cloud water	kg/m^2	I	vint_totl_water
4	surface pressure	Pa	I	sfc_pres
5	total aerosol	kg/m^2	I	---------------------

	Vertically integrated processes	Units		**NetCDF Name**
1	convective latent heating rate	W/m^2	A	vint_con_dt
2	stable latent heating rate	W/m^2	A	vint_str_dt
3	convective moistening rate	kg/(m^{2}s)	A	vint_con_dq
4	stable moistening rate	kg/(m^{2}s)	A	vint_str_dq
5	total precipitation	kg/(m^{2}s)	A	prec
6	precipitation (snow)	kg/(m^{2}s)	A	snowfall
7	moisture zonal flux	kg/(ms)	A	vint_znl_q_flx
8	moisture meridional flux	kg/(ms)	A	vint_mer_q_flx
9	moisture flux divergence	kg/(m^{2}s)	A	---------------------
10	total energy flux divergence	W/m^2	A	---------------------
11	mass flux divergence	kg/(ms)	A	---------------------
12	Local time tendency of total mass	kg/(m^{2}s)	A	vint_lcl_m_ten
13	local time tendency of total energy	W/m^2	A	vint_lcl_e_ten
14	local time tendency of moisture	kg/(m^{2}s)	A	vint_lcl_q_ten

	Surface Variables	**Units**		**NetCDF Name**
1	skin temperature	K	I	skin_temp
2	2-meter temperature	K	I	temp_1.5m
3	2-meter specific humidity	kg/kg	I	rh2o_1.5m
4	u-component at 10 m	m/s	I	u10
5	v_component at 10 m	m/s	I	v10
6	potential temperature at 10 m	K	I	potnl_t10m
7	specific humidity at 10 m	kg/kg	I	mixr_10m
8	soil moisture	m	I	sfc_mois
9	snow water equivalent	m	I	eqv_depth_snow
10	Snow depth	m	I	
11	vegetation water	kg/m^2	I	---------------------
12	planetary boundary layer height	m	I	pbl_ht

	Surface Processes	**Units**		**NetCDF Name**
1	shortwave downward flux (positive)	W/m^2	A	sw_sfc_irr
2	shortwave upward flux (positive)	W/m^2	A	sw_sfc_up
3	longwave downward flux (positive)	W/m^2	A	lw_sfc_irr
4	longwave upward flux (positive)	W/m^2	A	lw_sfc_up
5	sensible heating	W/m^2	A	sfc_sens
6	latent heating	W/m^2	A	sfc_latent
7	evaporation (positive)	kg/(m^{2}s)	A	evap
8	snow + frozen ground to soil water	W/m^2	A	totl_melt
9	snow + frozen ground to soil water	kg/(m^{2}s)	A	---------------------
10	surface runoff	kg/(m^{2}s)	A	sfc_runoff
11	baseflow runoff	kg/(m^{2}s)	A	---------------------
12	total ground heating	W/m^2	A	totl_grnd_heat
13	local skin temperature tendency	K/s	A	---------------------
14	local soil moisture tendency	kg/(m^{2}s)	A	---------------------
15	local snow water equivalent tendency	kg/(m^{2}s)	A	---------------------

	Subsurface Variables	**Units**		**NetCDF Name**
1	soil moisture	%	I	---------------------
2	temperature	K	I	soil_temp

	Subsurface Processes	**Units**		**NetCDF Name**
1	infiltration rate	kg/m^{2}s		---------------------
2	local soil moisture tendency	kg/m^{2}s		---------------------

3	local temperature tendency	kg/m^{2}s		---------------------

	Bottom of Subsurface Variables	**Units**		**NetCDF Name**
1	temperature	K	I	---------------------

	Bottom of Subsurface Processes	**Units**		**NetCDF Name**
1	ground heat flux	W/m^2	A	grnd_heat_flx

	Miscellaneous	**Units**		**NetCDF Name**
1	Precipitation type 1rain or 2snow	1,2	I	---------------------
2	elevation	m	C	elevation
3	Surface albedo	%	I	albedo
4	Land/sea/ice mask 0(land)or1(sea)or(2) ice	0,1,2	I	lsi_mask
5	Total cloud cover	%	I	totl_cloud
6	Surface exchange coefficient	m/s	I	---------------------
7	roughness length	m	I	roughness
8	Vegetation cover	%	I	---------------------
9	Water table (wells)	m	I	---------------------
10	streamflow	m^3/s	I	---------------------
11	Stream discharge	m^3/s	I	---------------------
12	Reservoir storage	m	I	---------------------