SETS OF PREDICTOR VARIABLES DERIVED FROM CGCM3.1 T47 AND NCEP/NCAR REANALYSIS

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Please refer this report on CGCM3 predictors using the following reference:

DAI CGCM3 Predictors, 2008: ''Sets of Predictor Variables Derived From CGCM3 T47 and NCEP/NCAR Reanalysis'', version 1.1, April 2008, Montreal, QC, Canada, 15 pp.

Montreal

January 2010

INTRODUCTION

The third version of the Canadian Centre for Climate Modelling and Analysis (CCCma) Coupled Global Climate Model (CGCM3), use the same ocean component as CGCM2 (Flato and Boer, 2001), but it makes use of the substantially updated atmospheric component AGCM3 (Atmospheric Canadian GCM, version 3). The CGCM3 model data is an improvement on previous models, mainly updated through introductions to the atmospheric component, which include : CLASS, a new module for treatment of the land surface processes (Verseghy et al., 1993); new treatment of water vapour transport; and cumulus parameterization. The CGCM3 upper air variables were archived at every 6 hours and defined on a spectral grid (T47) with 31 vertical ETA15 levels (top at ~ 50 km). The surface and near-surface variables are defined at daily scale on a global Gaussian grid of 96 lon. x 48 lat. grid cells (3.75° lon. x ~ 3.75° lat.). Upper level variables, available on standard pressure levels and every 6-hours, have been interpolated onto the Gaussian grid (see Table 1 for the grid-box definition), and then aggregated at daily scale. The diagnostic surface pressure (SP) variable, archived every 6-hours, has also been averaged on a daily basis.

The NCEP/NCAR reanalysis products (e.g., Kalnay et al., 1996; Kistler et al., 2001) have been interpolated onto the CGCM3 grid (Gaussian), and made available for the calibration procedure of statistical downscaling models (e.g., SDSM and ASD, see the downscaling tools section on http://cccsn.ca/), over the current climate period (1961-2001). The NCEP/NCAR reanalyses use a T62 (~ 209 km) global spectral model to consistently collect observational data from a wide variety of observed sources. All the data included are of quality 'A' or 'B', which means that they are influenced directly (to some extent) by observational data. Details of the reanalysis project and this categorization scheme can be found in Kalnay et al. (1996). All NCEP/NCAR data has been averaged on a daily basis from 6 hourly data, before being linearly interpolated to match the CGCM3 data. Where variables are derived, they are computed on the native 2.5° lat. x 2.5° lon. regular grid, and then interpolated. Surface reanalysis variables are originally available on a regular Gaussian grid (Kalnay et al., 1996). Therefore, surface variables (i.e. temperature) are instead interpolated from a native regular Gaussian grid to the CGCM3 regular Gaussian grid. The list of predictors has been chosen according to the data availability and to correspond to the same physical variables issued from the CGCM3 predictors (see Table 2 for the full list of predictors from both CGCM3 and NCEP output variables).

SPATIAL AND TEMPORAL COVERAGE

The CGCM3 T47 historical simulation and future runs together cover the entire period from 1961 to 2100 (1961-2000 and 2001-2100, for current and future time windows, respectively). Datasets for the future period follow two SRES GHG+A scenarios A2 and A1B (both the 4th member CGCM3 model runs). Predictors from both CGCM3.1 T47 and NCEP/NCAR global datasets are available (see Table 1 and Figure 1). Note that due to model constraints, no data exists for boxes where Y=01 and Y=48. Also, due to the dependence of airflow calculations on the Coriolis parameter, boxes where Y=24 or Y=25 (i.e. boxes close to the equator where the Coriolis force tends to zero) contain only a limited predictor set.

Table 1 : Coordinates and box numbering for all continent windows, following the CGCM3 native Gaussian grid. See the global land/sea mask of the CGCM3 model in Figure 1. All boxes outside of these regions cover the ocean surfaces.

Window	Latitude	No of _Y	Longitude[1]	No of _X
Africa (af)	38.97°N – 35.26°S	14 – 34	341.25° – 60.00°E	92 – 96 01 – 17
Antarctica (an)	61.23°S – 83.48°S	41 – 47	0.00° – 356.25°E	01 – 96
Asia (as)	79.78°N – 9.28°S	03 – 27	63.75° – 191.25° E	18 – 52
Australia & New Zeland (au)	12.99°S – 46.39°S	28 – 37	112.50° – 180.00°E	31 – 49
Europe (eu)	72.36°N – 42.68°N	05 – 13	348.75° – 52.50°E	94 – 96 01 – 15
North America (na)	83.48°N – 5.57°N	02 – 23	195.00° – 337.50°E	53 – 91
South America (sa)	12.99°N – 57.52°S	28 – 40	270.0° – 326.25°E	73 – 88

[1] All longitude values correspond to 0°-360° in the East direction (i.e., 187.5° is a equivalent to 172.5°W, 187.5°-360°).

Figure 1 : CGCM3 global land/sea mask. Land grid points are in red, while sea grid points are in blue.

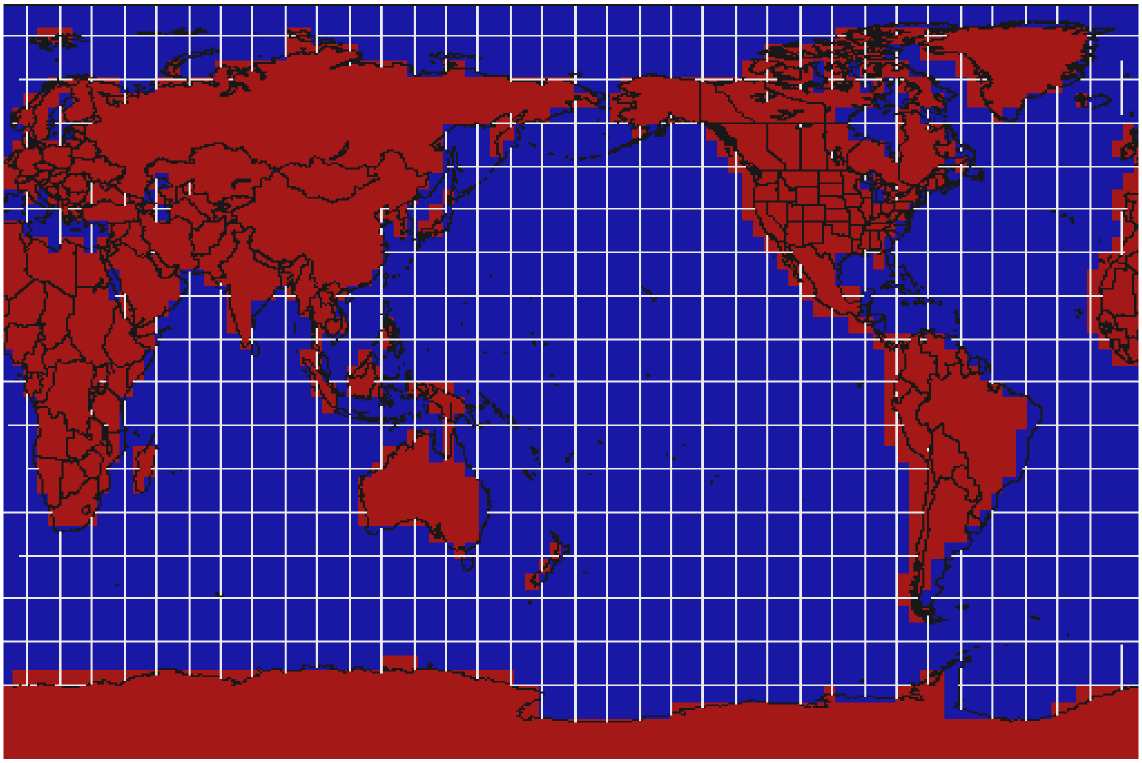

Figure 1.1 : CGCM3 land/sea mask over North America. Land grid points are in green, while sea grid points are in blue.

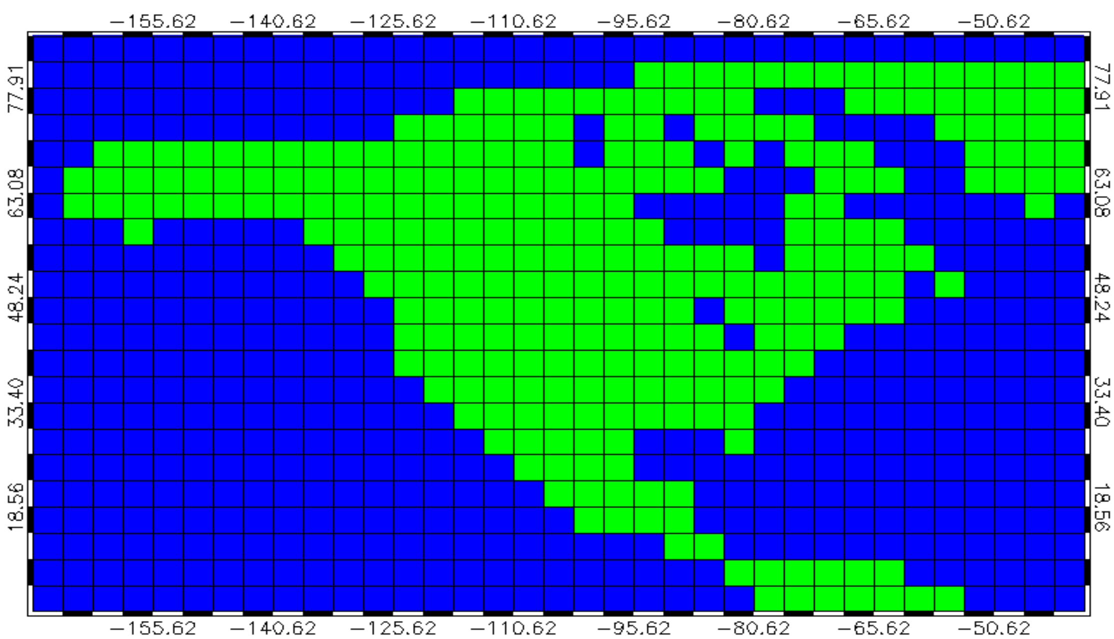

Figure 2 : Value in each grid box or cell corresponds to the value over the center of the cell defined over an area of 3.75° longitude and approx. 3.75° latitude.

NOMENCLATURE OF FILE NAMES

All file names follow the established convention. The first 4 characters display the data type, either ‘ncep’ for NCEP reanalysis data or ‘c3a2’/‘c3a1’ for CGCM3 data. The future climate CGCM3 projection uses different acronyms ‘a2’, or ‘a1’, for data following the SRES A2 and A1B GHG+A emission scenarios. The ‘a2’ acronym is also used for the historical run that follows observed greenhouse gas and aerosol (GHG+A) concentrations (until the end of 2000). The scenarios runs available from CGCM3 correspond to the SRES A2 and A1B GHG+A emission scenarios forcing in the present case (see Nakicenovic et al., 2000). The next 4 characters are given as the name of the relevant variable (e.g. ‘mslp’, for mean sea level pressure), and the final 2 characters display the region under consideration (the global ocean is marked by ‘gl’ while the continental areas follow the acronyms given in Table 1). These file names, and the variables they refer to, are given in Table 2. This table also shows whether variables are directly available from model or reanalysis output, i.e. are ‘Prognostic’ (P), or must be calculated from such variables, i.e. are ‘Diagnostic’ (D). If variables are listed as D*, it means that they are available as model or reanalysis output, but also as a result of post-processing within the model or reanalysis, and are calculated from one or more other output variables. For NCEP variables, this means that they are category ‘B’ quality (Kalnay et al., 1996), i.e., these variables are partly derived from observed values.

NB: Content and Framework of each Grid Box

Each grid box (see Figure 2) represents a mesh surrounding the corresponding model grid points given in Tables 4.1 and 4.2. The dimensions of each grid box are defined here by approx. 3.75° lat. x 3.75° lon. (Gaussian grid). Each grid box (i.e. z ipped file) contents 4 sub-directories where the 25 predictors are included (as given in Table 2) namely:

1. NCEP_1961-2003 : NCEP predictors interpolated onto the CGCM3 Gaussian grid covering the period 1961-2003.
2. CGCM3A2_1961_2000 : CGCM3 predictors covering the period 1961-2000 (i.e. using the historical GHG and aerosol concentration).
3. CGCM3A2_2001_2100 : CGCM3 predictors covering the future period 2001-2100 following the SRES A2 scenario (see Nakicenovic et al., 2000).
4. CGCM3A1B_2001_2100 : CGCM3 predictors covering the future period 2001-2100 following the SRES A1B scenario (see Nakicenovic et al., 2000).

METHODOLOGY

Where Table 2 details a variable as diagnostic (D), the means of calculation are summarised in Table 3, with specific equations for CGCM3 and NCEP/NCAR variables given in Appendix A. The place of these calculations within the means of production is also summarised in Figure 3, below. The table 4.1 and 4.2 present the Box numbering for the CGCM3.1 Gaussian grid (same as for CGCM2), i.e. latitude corresponding to Y and longitude corresponding to X as given in Table 1.

Except for wind direction (THETA), all values (*x*), for both the historical and future periods, with respect to native Reanalysis or CGCM, have been normalised with respect to the means (μ) and standard deviations (σ) of the 1961-1990 reference period using the following expression :

$$n_i = \frac{(x_i - \mu_{1961-1990})}{\sigma_{1961-1990}} \quad (1)$$

Figure 3 : Visual representation of the method by which predictors are produced for both CGCM3 and NCEP variables. Boxes between horizontal full lines blue lines show the post processing detailed in this document.

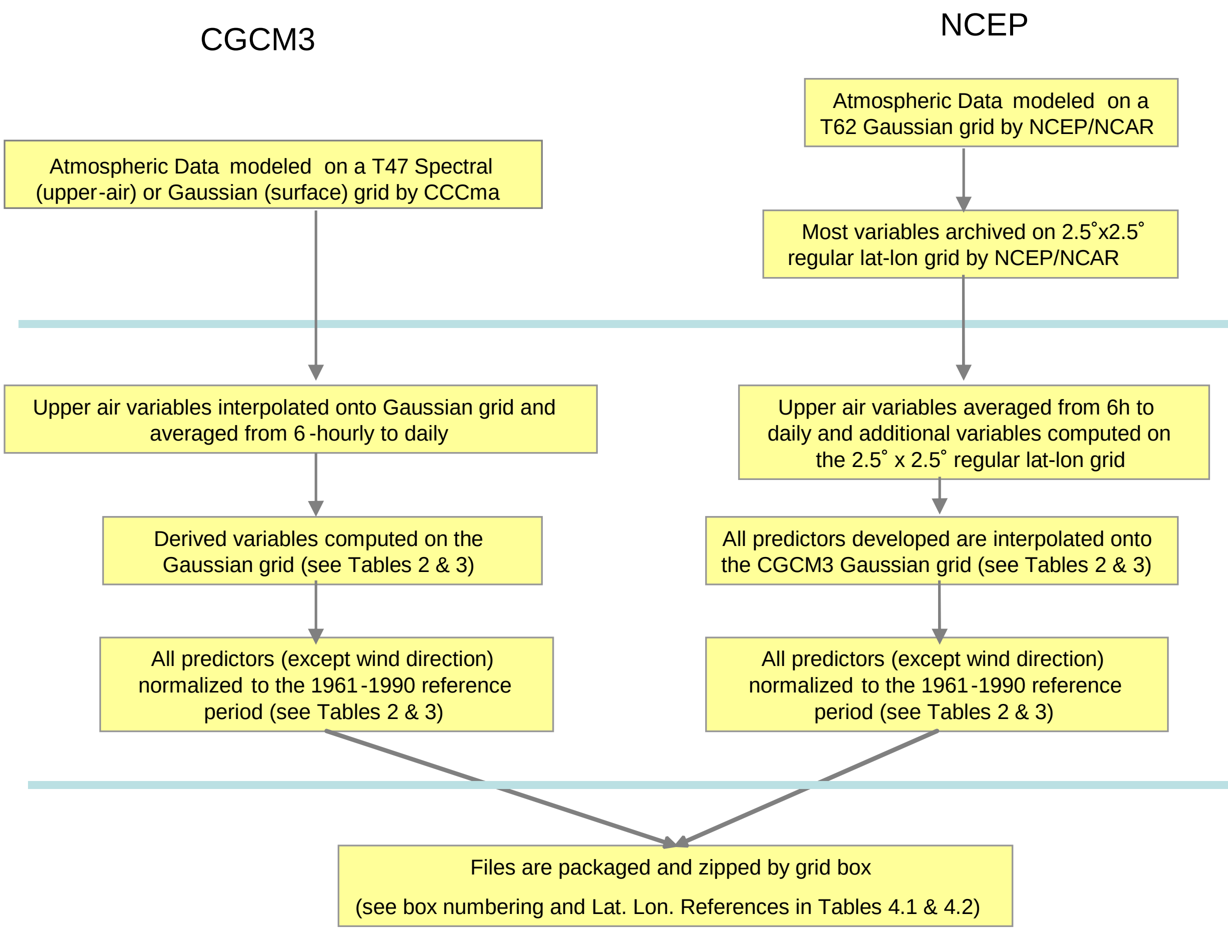

Table 2 : Nomenclature of file names for CGCM3.1 and NCEP/NCAR predictors. Given for the SRES A2 scenario only[***]. (U, V, F, DIV, VORT) are considered as geostrophic (g) as they are computed from pressure gradients using the geostrophic approximation (see Appendix A).

No	CGCM3.1 T47	TYPE (CGCM3)	NCEP/NCAR	TYPE (NCEP)	PREDICTOR VARIABLE
1	c3a2mslpgl.dat	D	ncepmslpgl.dat	P	Mean sea level pressure
2	c3a2p__fgl.dat	D**	ncepp__fgl.dat	D_g	1000hPa Wind Speed
3	c3a2p__ugl.dat	D*	ncepp__ugl.dat	D_g	1000hPa U-component
4	c3a2p__vgl.dat	D*	ncepp__vgl.dat	D_g	1000hPa V-component
5	c3a2p__zgl.dat	D*	ncepp__zgl.dat	D_g	1000hPa Vorticity
6	c3a2p_thgl.dat	D**	ncepp_thgl.dat	D_g	1000hPa Wind Direction
7	c3a2p_zhgl.dat	D*	ncepp_zhgl.dat	D_g	1000hPa Divergence
8	c3a2p5_fgl.dat	D**	ncepp5_fgl.dat	D_g	500hPa Wind Speed
9	c3a2p5_ugl.dat	D*	ncepp5_ugl.dat	D_g	500hPa U-component
10	c3a2p5_vgl.dat	D*	ncepp5_vgl.dat	D_g	500hPa V-component
11	c3a2p5_zgl.dat	D*	ncepp5_zgl.dat	D_g	500hPa Vorticity
12	c3a2p500gl.dat	D	ncepp500gl.dat	P	500hPa Geopotential
13	c3a2p5thgl.dat	D**	ncepp5thgl.dat	D_g	500hPa Wind Direction
14	c3a2p5zhgl.dat	D*	ncepp5zhgl.dat	D_g	500hPa Divergence
15	c3a2p8_fgl.dat	D**	ncepp8_fgl.dat	D_g	850hPa Wind Speed
16	c3a2p8_ugl.dat	D*	ncepp8_ugl.dat	D_g	850hPa U-component
17	c3a2p8_vgl.dat	D*	ncepp8_vgl.dat	D_g	850hPa V-component
18	c3a2p8_zgl.dat	D*	ncepp8_zgl.dat	D_g	850hPa Vorticity
19	c3a2p850gl.dat	D	ncepp850gl.dat	P	850hPa Geopotential
20	c3a2p8thgl.dat	D**	ncepp8thgl.dat	D_g	850hPa Wind Direction
21	c3a2p8zhgl.dat	D*	ncepp8zhgl.dat	D_g	850hPa Divergence
22	c3a2s500gl.dat	D	ncep s500gl.dat	D*	500hPa Specific Humidity
23	c3a2s850gl.dat	D	nceps850gl.dat	D*	850hPa Specific Humidity
24	c3a2shumgl.dat	D	ncepshumgl.dat	D*	1000hPa Specific Humidity
25	c3a2tempgl.dat	D*	nceptempgl.dat	D*	Temperature at 2m

[***] c3a1[variable][window].dat files are also available for the SRES A1B emission scenario, as well as [window] 'gl' for global ocean or other land areas not defined in Table 1, 'na' for North America (see Figure 1.1) or 'as' for Asia or 'eu' for Europe, etc. (see Table 1) for both A2 and A1B scenarios.
[**] Computed from U and V wind components (see note below).
[*] Computed from the horizontal Geopotential gradient at corresponding level (see Appendix A).

Table 3 : Description of predictor variables.

PREDICTOR	UNIT	CGCM3.1 T47	NCEP/NCAR
Temperature at 2m (TEMP)	°C	Result of post-processing at CCCma (i.e. interpolated at 2m from the lowest model level)	Result of post-processing at NCEP/NCAR
Specific humidity at 2m (SQ)	kg/kg		
Mean sea level pressure (MSLP)	Pa	Calculated from ln(Surface Pressure), TEMP, and Surface Geopotential, and then while archived at 6-hours daily averaged	
Specific humidity (SHUM)	kg/kg	Calculated from the model's humidity variable	Calculated from the reanalysis' (relative) humidity variable
Geopotential (PHI)	m	Calculated from ln(Surface Pressure), TEMP and SHUM	Result of post-processing at NCEP/NCAR
Vorticity (VORT)	s^{-1}	Geostrophic, calculated from geopotential gradients (see Appendix A)	Geostrophic, calculated from geopotential gradients (see Appendix A)
Divergence (DIV)	s^{-1}		
Zonal wind component (U)	m/s		
Meridional wind component (V)	m/s		
Wind speed (F)	m/s	Calculated from U and V wind components (see Appendix A)	Calculated from U and V wind components (see Appendix A)
Wind direction (THETA)	degrees from N		

Table 4.1 : Box numbering for CGCM3.1 Gaussian grid[2] : latitude corresponding to _Y.

No of _Y	Latitude	No of _Y	Latitude
1	87.16°N	**25**	1.86°S
2	83.48°N	**26**	5.57°S
3	79.78°N	**27**	9.28°S
4	76.07°N	**28**	12.99°S
5	72.36°N	**29**	16.70°S
6	68.65°N	**30**	20.41°S
7	64.94°N	**31**	24.12°S
8	61.23°N	**32**	27.83°S
9	57.52°N	**33**	31.54°S
10	53.81°N	**34**	35.26°S
11	50.10°N	**35**	38.97°S
12	46.39°N	**36**	42.68°S
13	42.68°N	**37**	46.39°S
14	38.97°N	**38**	50.10°S
15	35.26°N	**39**	53.81°S
16	31.54°N	**40**	57.52°S
17	27.83°N	**41**	61.23°S
18	24.12°N	**42**	64.94°S
19	20.41°N	**43**	68.65°S
20	16.70°N	**44**	72.36°S
21	12.99°N	**45**	76.07°S
22	9.28°N	**46**	79.78°S
23	5.57°N	**47**	83.48°S
24	1.86°N	**48**	87.16°S

[2] Same as for CGCM2

Table 4.2 : Box numbering for CGCM3.1 Gaussian grid[3] : longitude corresponding to _X.

No of _X	Longitude	No of _X	Longitude	No of _X	Longitude	No of _X	Longitude
1	0	**25**	90	**49**	180	**73**	270
2	3.75	**26**	93.75	**50**	183.75	**74**	273.75
3	7.5	**27**	97.5	**51**	187.5	**75**	277.5
4	11.25	**28**	101.25	**52**	191.25	**76**	281.25
5	15	**29**	105	**53**	195	**77**	285
6	18.75	**30**	108.75	**54**	198.75	**78**	288.75
7	22.5	**31**	112.5	**55**	202.5	**79**	292.5
8	26.25	**32**	116.25	**56**	206.25	**80**	296.25
9	30	**33**	120	**57**	210	**81**	300
10	33.75	**34**	123.75	**58**	213.75	**82**	303.75
11	37.5	**35**	127.5	**59**	217.5	**83**	307.5
12	41.25	**36**	131.25	**60**	221.25	**84**	311.25
13	45	**37**	135	**61**	225	**85**	315
14	48.75	**38**	138.75	**62**	228.75	**86**	318.75
15	52.5	**39**	142.5	**63**	232.5	**87**	322.5
16	56.25	**40**	146.25	**64**	236.25	**88**	326.25
17	60	**41**	150	**65**	240	**89**	330
18	63.75	**42**	153.75	**66**	243.75	**90**	333.75
19	67.5	**43**	157.5	**67**	247.5	**91**	337.5
20	71.25	**44**	161.25	**68**	251.25	**92**	341.25
21	75	**45**	165	**69**	255	**93**	345
22	78.75	**46**	168.75	**70**	258.75	**94**	348.75
23	82.5	**47**	172.5	**71**	262.5	**95**	352.5
24	86.25	**48**	176.25	**72**	266.25	**96**	356.25

[3] Same as for CGCM2

APPENDIX A

EQUATIONS USED FOR DIAGNOSTIC VARIABLES OF CGCM3.1 AND NCEP/NCAR REANALYSIS GIVEN IN TABLE 2

CGCM3.1 T47

The following steps are used to compute, and derive the predictor variables from the CGCM3.1 T47 raw atmospheric variables, i.e. using upper air variables from the spectral fields at different ETA15 vertical levels, and the surface fields available on the regular Gaussian grid (97x48 pts).

Geopotential (PHI) as a diagnostic variable from CGCM3.1 T47 datasets :

$$PHI(l) = PHI(l-1) + R(l) \cdot TEMP(l) \cdot c3 \tag{A.1}$$

where l is the corresponding vertical hybrid level, $R(l) = 176 \cdot SHUM(l) + 287$ is a gas constant, $TEMP(l)$ is a temperature field, and $c3$≠const. is a model level top coefficient.

CGCM3 and NCEP/NCAR air flow predictor variables

The air flow predictor variables (Wind, Divergence and Vorticity) from CGCM3 raw data are all derived from the Geopotential fields available on the Global Gaussian grid (97x48 points) at the standard pressure levels. The following steps are used to compute or derive the wind, divergence and vorticity at different pressure levels (see Table 2) :

- From the geopotential field (Φ), interpolated on the regular Gaussian global grid (3.75° Lon x ~ 3.75° Lat), and on the standard pressure levels, and in using the geostrophic approximation, the geostrophic wind is computed using the following equation :

$$\begin{cases} u_g = -\dfrac{1}{2\Omega R}\dfrac{1}{\sin\varphi}\dfrac{\partial\Phi}{\partial\varphi} \\ v_g = -\dfrac{1}{2\Omega R}\dfrac{1}{\sin\varphi\cos\varphi}\dfrac{\partial\Phi}{\partial\lambda} \end{cases}, \tag{A.2}$$

where u and v are the zonal and meridional components of the wind, respectively, $\Phi = g \cdot Z$ is geopotential, ***R*** is radius of Earth ($R_{EQ} = 6378.3880 km$, $R_{EQ} = 6356.9119 km$) :

$$R(\varphi) = \sqrt{\frac{{R_{EQ}}^2 - {R_{Pol}}^2}{(\frac{R_{EQ}}{R_{Pol}} \cdot \tan(\varphi))^2 + 1} + {R_{Pol}}^2} \tag{A.3}$$

- From the geostrophic wind computed with equation (A.1) or pressure gradients, the divergence term (see further details in Choux, 2005) is calculated from the following equation :

$$\nabla \cdot \vec{V_g} = -\frac{1}{2\Omega R^2}\left[\frac{1}{\sin\varphi\cos\varphi}\frac{\partial^2\Phi}{\partial\lambda\partial\varphi} + \frac{1}{\cos^2\varphi}\frac{\partial\Phi}{\partial\lambda} - \frac{\partial}{\partial\varphi}\left(\frac{1}{\cos\varphi\sin\varphi}\frac{\partial\Phi}{\partial\lambda}\right)\right] \tag{A.4}$$

$$\zeta_g = \frac{1}{2\Omega R^2}\left(\frac{1}{\sin\varphi}\frac{\partial^2\Phi}{\partial\lambda\partial\varphi}\right) + \frac{\partial}{\partial\varphi}\left(\frac{1}{\cos^2\varphi\sin\varphi}\frac{\partial\Phi}{\partial\lambda}\right) + \frac{1}{\cos\varphi}\frac{\partial\Phi}{\partial\varphi} \tag{A.5}$$

Table A.2 : Wind direction (calculated from U and V components) in degrees, 0° pointing in North, 90° pointing East, 180° pointing South and 2 70° pointing West.

Condition of U, V values	Applied equation for Wind Direction (in degrees from the North)
U ≥ 0 & V ≥ 0	α
U ≥ 0 & V < 0	$90.0° + \beta$
U < 0 & V < 0	$180.0° + \alpha$
U < 0 & V ≥ 0	$270.0° + \beta$

$$\alpha = \frac{A\tan(\frac{|U|}{|V|})}{\pi}180.0° \ , \qquad \beta = \frac{A\tan(\frac{|V|}{|U|})}{\pi}180.0°$$

$$\pi = 3{,}1415926535\ \ 86$$

Table A.1 : List of CGCM3.1 T47 variables directly available and those derived, and/or interpolated.

OUTPUT	Grid, resolution, frequency of output	INPUT	Grid, resolution, frequency of input
Humidity : **Specific** (SHUM) and **Relative** (RHUM)	Gaussian grid (97x48 pts)	**Model humidity** (ES), **Temperature** (TEMP) and **Surface Pressure** (LNSP)	Spectral grid T47
	Standard pressure levels		ETA15 vert levels
	daily		6 hours
Geopotential (PHI)	Gaussian grid (97x48 pts)	**Orography** (PHIS), **Temperature** (TEMP), **Surface Pressure** (LNSP), and **RGASM**[2]	Spectral grid T47
	Standard pressure levels		ETA15 vert levels
	daily		6 hours
Mean Sea Level Pressure (PNM)	Gaussian grid (97x48 pts)	**Orography** (PHIS), **Temperature** (TEMP), and **Surface Pressure** (LNSP)	Spectral grid T47
	Standard pressure levels		-
	daily		6 hours
Temperature (TEMP)	Gaussian grid (97x48 pts)	**Temperature** (TEMP) **[**and for gsaplt : **Orography** (PHIS), and **Surface Pressure** (LNSP)**]**	Spectral grid T47
	Standard pressure levels		ETA15 vert levels
	daily		6 hours
Temperature at 2m (ST)	Gaussian grid (97x48 pts)	**Temperature** at 2m (ST)	Gaussian grid (97x48 pts)
	surface		surface
	daily		daily
	K		°C
Accumulated Precipitation (PCP)	Gaussian grid (97x48 pts)	**Accumulated Precipitation** (PCP)	Gaussian grid (97x48 pts)
	surface		surface
	daily		daily
Specific humidity at 2m (SQ)	Gaussian grid (97x48 pts)	**Specific humidity at 2m** (SQ)	Gaussian grid (97x48 pts)
	surface		surface
	daily		daily

[2] $Rgas = 176 \cdot SHUM + 287$

ACRONYMS

ACRONYM	DESCRIPTION
CGCM3	Third generation of the Canadian coupled Global Climate Model. For further information about the CGCM3 model (see http://www.cccma.ec.gc.ca)
CLASS	Canadian Land Surface Scheme (see http://www.cccma.ec.gc.ca/models/gcm3.shtml)
NCEP/NCAR	National Center for Environmental Prediction/ National Center for Atmospheric Research (see http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml)
SRES	Special Report on Emissions Scenarios projections (i.e. A2 and A1B only in the present case, see Nakicenovic et al., 2000, and/or Barrow et al., 2004)

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