

Operational Upgrade of TCLAPS to 51 Levels

12 August 2008

Introduction

The operational Tropical Cyclone Limited Area Prediction System, known as TCLAPS, was upgraded from a 29 to a 51 vertical-level version by Darwin Region Specialised Meteorological Centre (RSMC) on Wed 11 June 2008. The upgraded system; along with the upgraded Australian Region Limited Area Prediction System (LAPS_PT375) and Tropical eXtended region Limited Area Prediction System (TXLAPS_PT375) were developed by BMRC's (now CAWCR) Data Assimilation and the Model Development Groups; led by Dr Bill Bourke and Dr Kamal Puri respectively. Drs Noel Davidson and Kevin Tory of CAWCR undertook the scientific development of L51 TCLAPS; while final development and testing were completed by Robin Bowen (CAWCR) in late 2007.

From late December 2007 to March 2008 Joan Fernon of Darwin RSMC ran parallel trials comparing results of the old L29 TCLAPS to the upgraded L51 TCLAPS. Objective verification obtained from this trial shows mixed results with no major differences in skill between the two systems.

System Description

Analysis and Prediction Operations Bulletin No. 51 of January 2000 was the last bulletin issued for a TCLAPS system. This bulletin described 19 level TCLAPS, being the operational system prior to L29 TCLAPS. There are major differences from the 19 level system compared with the L51 system. L51 TCLAPS uses L61 TXLAPS_PT375 as the large-scale environment (LSE), while the older versions ran their own LSE. The L61 TXLAPS_PT375 system is described in Analysis and Prediction Operations Bulletin No. 72. Both these operations bulletins can be found under http://www.bom.gov.au/nmoc/bulletins/nmc_bulletin.shtml

TCLAPS 00UTC and 12UTC runs are triggered by the existence of one or more tropical cyclones within the L61 TXLAPS_PT375 domain. The domain for each of these runs is centred on the tropical cyclone, with up to 3 domains available (for 3 tropical cyclones). If there are two or less tropical cyclones for a given run time then a default domain centred on the Northern Territory will also run. For each domain five high-resolution analyses are performed every six hours from T-24 to T-0. With first guess fields being derived from the L60 GASP analyses and forecasts; and TXLAPS analyses implanted into the first guess fields at T-12, T-6 and T-0 hours. Additionally pre-existing tropical cyclone circulations are removed from the first guess fields and replaced by idealised vortices. The forecast model is run from T-24 to T+72. For the first 24 hours boundary conditions are provided by the TCLAPS analyses and diabatic nudging is used to insert synthetic heating/moisture profiles into the model at 6 hourly intervals in observed cloudy regions. Thereafter the boundary conditions are derived from L61 TXLAPS_PT375. Further details can be found in Davidson and Puri (1992).

Please refer to Table 1 for details of the L51 and L29 TCLAPS systems. Further details can be found in Davidson and Weber (2000).

	L51 TCLAPS	L29 TCLAPS
LSE: Domain	48.75°N-45.0°S, 60.0°E-142.5°W <i>L61 TXLAPS_PT375</i>	57.5°N-55.0°S, 70.0°E-162.5°W
LSE: Horizontal grid size	0.375°	0.75°
High resolution domains	Variable 30°x30°, TC centred, up to 3 per run	Variable 27°x27°, TC centred, up to 3 per run
Horizontal grid size	0.10 (300x300 latitude-longitude grid)	0.15 (180x180 latitude-longitude grid)
Vertical resolution (analysis and prognosis) <i>See Table 2 for levels and approximate heights.</i>	51 sigma levels, top level at ~ 10 hPa	29 sigma levels, top level at ~ 50 hPa
Topography:	derived from a 0.1° resolution data set, coast corrected	Derived from a 0.1° resolution data set, coast corrected
Soil Moisture Analysis:	daily 0.25°x 0.25° (Pescod scheme)	same
Sea Surface Temperature Analysis:	Global Weekly 1° (generated in NMOC Melbourne)	same
MTSAT CTT data	2 hourly 0.5°x 0.5°	same
Bogused heating/moisture profile	6 hourly 1°x 1°	same
Data insertion frequency	at T-24, T-18, T-12, T-6 and T-0	same
Data cut off	Approximately 3hrs 50min after 00UTC and 12UTC.	same
Manual intervention	TC bogus observations	same
Observational data used	synop, ship, buoy, paob, sonde, rawin, aireps, metar, amv, qscat	synop, ship, buoy, paob, sonde, rawin, aireps, metar, amv, qscat, atovs
Initialisation	digital filtering technique	same
Diabatic Nudging	24 hours	same
Timestep	dynamics: 10 seconds; physics: 90 seconds	dynamics: 40 seconds; physics: 360 seconds
First Guess <i>Only consider HR domains for L29 TCLAPS</i>	T-24 and T-18: L60 GASP analyses T-12 to T-0: L61 TXLAPS analyses implanted in L60 GASP prognoses	T-24 and T-18: L33 GASP analyses T-12 to T-0: LSE L29 TCLAPS analyses implanted in L33 GASP prognoses
Lateral Boundary Conditions <i>Only consider HR domains for L29 TCLAPS</i>	T-24 and T-0: TCLAPS analyses T+3 to T+72: L61 TXLAPS prognoses	T-24 and T-0: TCLAPS HR analyses T+3 to T+72: L29 TCLAPS LSE prognoses
Output:	6 hourly analyses. 72 hour forecast from 00 UTC and 12 UTC daily	same

NEC SX-6 supercomputer resources:	
Analysis	elapsed time: 10 min (real), 2hr 20 min (virtual) number of processors: 14 (over 2 nodes), memory: 44 GB per node
96 hour prognosis:	elapsed time: 1hr 2 min (real), 14 hr 28 min (virtual) number of processors: 14 (over 2 nodes), memory: 4 GB per node

Table 1: Configurations of L51 and L29 TCLAPS, and supercomputer resources used to run L51 TCLAPS

Data Analysis Changes

L51 TCLAPS does not directly assimilate any satellite sounding data. Firstly L51 TCLAPS can not use the Advanced ATOVS Processing Package (AAPP) radiance data. Secondly the older poorer quality NESDIS-supplied radiances, which had been assimilated into L29 TCLAPS, are not assimilated. This optimises the influence of the improved AAPP data, which has already been assimilated into the L60 GASP and L61 TXLAPS_PT375 analyses, from which the first guess files are derived.

For more detailed discussion of the new AAPP data please refer to Analysis and Prediction Operations Bulletin No. 72.

Model Changes

Forecast model changes with this upgrade include:

- use of L61 TXLAPS_PT375 for boundary conditions from T-0 to T+72;
- use of d2.1 dynamics and BAM 5.0.05 physics. This provides MPI (message passing interface) capability for multi-node running on the NEC sx6 supercomputer and also includes a new single level "slv" output file with more fields than current "slvfld" file;
- use of 51 vertical sigma levels (described below);
- use of a new climate program with improved coast-line matching;
- multi-node running on two sx6 supercomputer nodes for faster turn around.

Equivalent L29 level number	L29 Sigma level value	L29 Approx. height (m)	L51 level number	L51 Sigma level value	L51 Approx. height (m)
-	-	-	51	0.0098	31100
-	-	-	50	0.0145	28600
-	-	-	49	0.0207	26200
-	-	-	48	0.0284	24200
-	-	-	47	0.0375	22400
~ 29	0.05	20500	46	0.048	20800
-	-	-	45	0.0594	19600
~ 28	0.07	18360	44	0.0715	18300
-	-	-	43	0.0845	17250
~ 27	0.10	16100	42	0.099	16250
-	-	-	41	0.115	15300
-	-	-	40	0.133	14400
~ 26	0.15	13520	39	0.1535	13500
~ 25	0.175	12550	38	0.176	12600
24	0.200	11700	37	0.200	11700
23	0.225	11000	36	0.225	11000
22	0.250	10300	35	0.250	10300
21	0.275	9650	34	0.275	9650
20	0.300	9070	33	0.300	9070
-	-	-	32	0.325	8530
19	0.350	8030	31	0.350	8030
-	-	-	30	0.375	7550
18	0.400	7090	29	0.400	7090
-	-	-	28	0.425	6660
17	0.450	6250	27	0.450	6250
-	-	-	26	0.475	5850
16	0.500	5480	25	0.500	5480
-	-	-	24	0.525	5110
-	-	-	23	0.550	4770
-	-	-	22	0.575	4430
15	0.600	4100	21	0.600	4100
-	-	-	20	0.625	3790
-	-	-	19	0.650	3490
-	-	-	18	0.675	3190
14	0.700	2910	17	0.700	2910
-	-	-	16	0.725	2630
13	0.75	2360	15	0.750	2360
-	-	-	14	0.775	2100
12	0.800	1840	13	0.800	1840
-	-	-	12	0.825	1590
11	0.850	1350	11	0.850	1350
10	0.875	1110	10	0.875	1110
9	0.900	880	9	0.900	880
8	0.925	650	8	0.925	650
7	0.950	430	7	0.950	430
~ 6	0.9625	320	6	0.972	240
~ 5	0.9750	210	5	0.9841	135
~ 4	0.9875	106	4	0.9911	75
~ 3	0.9943	48	3	0.9950	42
2	0.9974	22	2	0.9974	22
1	0.9988	10	1	0.9988	10

Table 2: Comparison of model sigma (P/P_s) levels and approximate corresponding heights used in TCLAPS for new L51 and old L29 model configurations. A grey background indicates modified/non-matching levels

Model Performance

Objective Assessment

Darwin RSMC conducted parallel trials of the L29 and L51 versions of TCLAPS from December 2007 to March 2008. Eight southern hemisphere tropical cyclones were used in the verification. Verification results are summarized in Table 3. The number of forecasts which are used to calculate the mean error values are given in the table. The forecast central pressure and positions were verified against values in tropical cyclone advices generated by the Darwin RSMC.

The results are mixed with a slight degradation in the mean track error from 6hrs to 60hrs, and small improvements at higher forecast times. There is little difference in the mean central pressure or the mean absolute central pressure.

Forecast time hrs after run time	No. Forecasts	Means Track Error (nm)		Mean Central Pressure Error (hPa)		Mean Absolute Central Pressure Error (hPa)	
		L29	L51	L29	L51	L29	L51
0	76	7.5	7.4	0.0	0.0	0.0	0.0
6	76	28.8	32.6	0.1	0.1	5.3	5.3
12	76	48.7	56.6	-0.3	-0.3	9.6	9.6
18	70	58.3	77.0	-0.5	-0.5	12.9	12.8
24	68	76.4	98.6	-0.7	-0.7	16.4	16.3
30	62	96.7	115.5	-2.0	-2.0	18.1	18.1
36	59	116.8	133.1	-2.0	-2.0	20.6	20.9
42	55	137.2	155.9	-3.4	-3.4	20.6	20.6
48	52	158.3	170.9	-3.1	-3.2	22.4	22.8
54	48	183.6	190.3	-3.8	-3.8	22.3	22.3
60	45	203.3	208.4	-3.8	-3.9	22.6	23.1
66	39	222.9	219.4	-3.5	-3.3	23.1	23.6
72	36	242.2	233.2	-2.9	-2.7	23.5	24.0

Table 3: Mean Track Errors, Mean Central Pressure Errors and Mean Absolute Central Pressure Errors L29 versus L51 of TCLAPS

Total Period: Late December 2007 – March 2007 2008 using both 00 and 12 UTC runs

Verifying Against: Darwin RSMC generated bogus files

Improvement: An improvement is indicated by blue colouring in the L51 column. While a degradation is indicated by red colouring.

Product Availability

MODEL HISTORY FILES:

The subsidiary “slvfld” single-level history files have been superseded by a new “slv” single-level file which contains an increased number of surface fields, including time-averaged fields in addition to the existing instantaneous fields. Users should note that the names of most of the fields contained within the new “slv” netcdf files will be slightly different from the names used within the old “slvfld” files.

EXTERNALLY AVAILABLE PRODUCTS:

Type	Product Identifier	GTS Header where applicable
Track files	IDYTC800.hr<NN>.txt	FXXT<MM> ADRM
Charts	IDYTC100.<TYPE>hr<NN>.gif	

where

- <NN> : the domain number of the run ie 01, 02 or 03 (there are up to 3 runs for a given run time)
- <MM> : 02, 03 or 04
- <TYPE> : MSLP, 850, 200

INTERNAL PRODUCT AVAILABILITY DETAILS – please refer to Appendix.

Future Developments

NWP modelling in the Bureau will move to systems based on the Australian Community Climate Earth System Simulator (ACCESS), a joint initiative led by the Bureau of Meteorology and CSIRO in cooperation with the university community of Australia. The initial version of ACCESS is based largely around the UKMO Unified Model assimilation and prediction code. Initial system configurations will be based on the current domain/resolutions. Operational use of ACCESS-based models is expected to commence in 2009.

References

Davidson, N.E. and Puri, K.: "Tropical prediction using dynamical nudging, satellite-defined convective heat sources and cyclone bogus.", *Mon.Wea.Rev.*, 120., 1992

Davidson, N.E. and Weber, H.C.: "The BMRC High Resolution Tropical Cyclone Prediction System: TC-LAPS.", *Mon.Wea.Rev.*, 128(5), 2000

Tingwell, C.I.W., M. Chattopadhyay, W.P. Bourke, B. Harris, J.D. Kepert, P.J. Steinle, C. Vincent, 2007: "Assimilation of Level-1D ATOVS Radiances in Australian Regional and Mesoscale Data Assimilation and Prediction Systems". To be submitted to *Australian Meteorological Magazine*.

Glossary

1DVAR	1-Dimensional Variational Analysis
AAPP	Advanced ATOVS Processing Package
ACCESS	Australian Community Climate Earth System Simulator
AMV	Atmospheric Motion Vectors
ATOVS	Advanced TIROS Operational Vertical Sounder
BMRC	Bureau of Meteorology Research Centre
CAWCR	Centre for Australian Weather and Climate Research (formerly BMRC)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GASP	Global Assimilation and Prediction
LAPS	Limited Area Prediction System
LSE	Large-Scale Environment
McIDAS	Man-computer Interactive Data Access System
METAR	Meteorological Aerodrome Report
MPI	Message Passing Interface
NESDIS	National Environmental Satellite, Data, and Information Service
NMOC	National Meteorological and Oceanographic Centre
RSMC	Region Specialised Meteorological Centre
TXLAPS	Tropical eXtended region Limited Area Prediction System
TCLAPS	Tropical Cyclone Limited Area Prediction System
UKMO	United Kingdom Met Office

APPENDIX: Product Availability (for internal Bureau information)

REAL-TIME DATABASE (rtdb):

Sigma and pressure level data from TCLAPS are written to the real time database (rtdb) during each model run. Forecast fields out to +72 hours are available at 3 hourly intervals. The database currently holds TCLAPS data for up to 8 model runs.

At the present time, none of the additional new fields available from the new “slv” single-level model history files have been added to the database – selected fields may be added upon request from the Regional Forecast Centres, subject to database capacity limitations.

McIDAS:

L51 TCLAPS is available through McIDAS using ADDE access to the real-time database rtdb.

WEB:

<http://web.bom.gov.au/nob/nmoc/products/tclaps/>

Tropical cyclone forecast tracks are available from this page. SAM TAPE ARCHIVES:

Data from TCLAPS will continue to be archived on SAM-FS with similar name formats as before, with minor changes as noted below:

Observational boxfiles:	/samnmc/tcmodel/box/yyyy/tropbox.tclaps10.mmdd.hh.nP.TC_NAME.ieceeq
Boundary files:	/samnmc/tcmodel/anal/yyyy/tropprep.tclaps375.mmdd.hh.ncM.nc
Climate files:	/samnmc/tcmodel/climate/yyyy/climate.tclaps10.mmdd.hh.n1.TC_NAME.nc
Output boxfiles:	/samnmc/tcmodel/box/yyyy/tropbox.tclaps10.box1_qc_N.mmdd.hh.TC_NAME.ieceeq
Analysis output:	/samnmc/tcmodel/anal/yyyy/tropanal.tclaps10.mmdd.hh.nN.TC_NAME.nc
Model output:	
Sigma level data	/samnmc/tcmodel/prog/yyyy/tropprog.tclaps10.mmdd.hh.0ii.nN.TC_NAME.nc (3-hourly)
Single level data	/samnmc/tcmodel/prog/yyyy/tropprog.tclaps10.mmdd.hh.slv0ii.nN.TC_NAME.nc /samnmc/tcmodel/prog/yyyy/tropprog.tclaps10slv.mmdd.hh.nN.TC_NAME.nc
Radiation field data	/samnmc/tcmodel/prog/yyyy/tropprog.tclaps10.mmdd.hh.rad0ii.nN.TC_NAME.nc
Track files	/samnmc/tcmodel/tracks/yyyy/trop_fctrk.tclaps10.mmdd.hh.TC_NAME.asc

Variables in the names above are:

yyyy 4 digit year, i.e. 2008

mmdd 4 digit month and day, i.e. 1030 is 30th October

hh 2 digit hour of model/analysis run, either 06, 12, 18 or 00

ii 2 digit hour of model output, 00 to 72

M 1 or 2 digit integer counter (1 to 17) for six-hourly boundary files

N N=1,2, 3,4 or 5 for the assimilation cycle

P P=1,2 - 1 for assim cycle 2 & 3, 2 for assim cycle 1