Assimilation of information on Moisture and Diabatic heating from satellite imagery

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Modelling issues for tropics

- Diabatic processes play an important role in determining the circulation in the tropics
- Current NWP models have problems in adequately handling these processes –
  - Sparcity of data
  - Deficiences in parametrisation of physical processes
  - Inability of analysis schemes to include information on diabatic heating
  - Inability to provide initial fields that are dynamically consistent and sensitive to regions of heating and cooling

TLAPS

The Bureau of Meteorology operationally runs a Tropical Limited Area Prediction System, TLAPS

Main features

- **High order numerics**
- **Detailed parameterisation of physical processes**
- **Generalised statistical interpolation analysis**
- **Options for data assimilation and dynamical nudging**
- **Flexibility to run at different resolutions and domains**

TLAPS

TLAPS includes features that are specifically designed for the tropics

- **Use of diabatic heating information inferred from GMS imagery**
- **Use of proxy moisture data inferred from GMS imagery**
- **Use of tropical cyclone bogus data**

Use of GMS-based heating rates

- Puri and Miller (1990) have considered 2 procedures for estimating heating rates
- Both rely on obtaining estimates of rainfall rate R, which essentially is a measure of vertically integrated heating rate

Use of GMS-based heating rates

Method 1

- Vertical profile is specified based on observations of typical profiles in convective situations
- Intensity of heating can then be readily evaluated

However use of same specified profile throughout a domain is unsatisfactory

Use of GMS-based heating rates

Method 2

- Derive heating rate from convective parametrisation used in model
- Use derived rain rate and allow parametrisation to generate heating rate

Shortcomings –

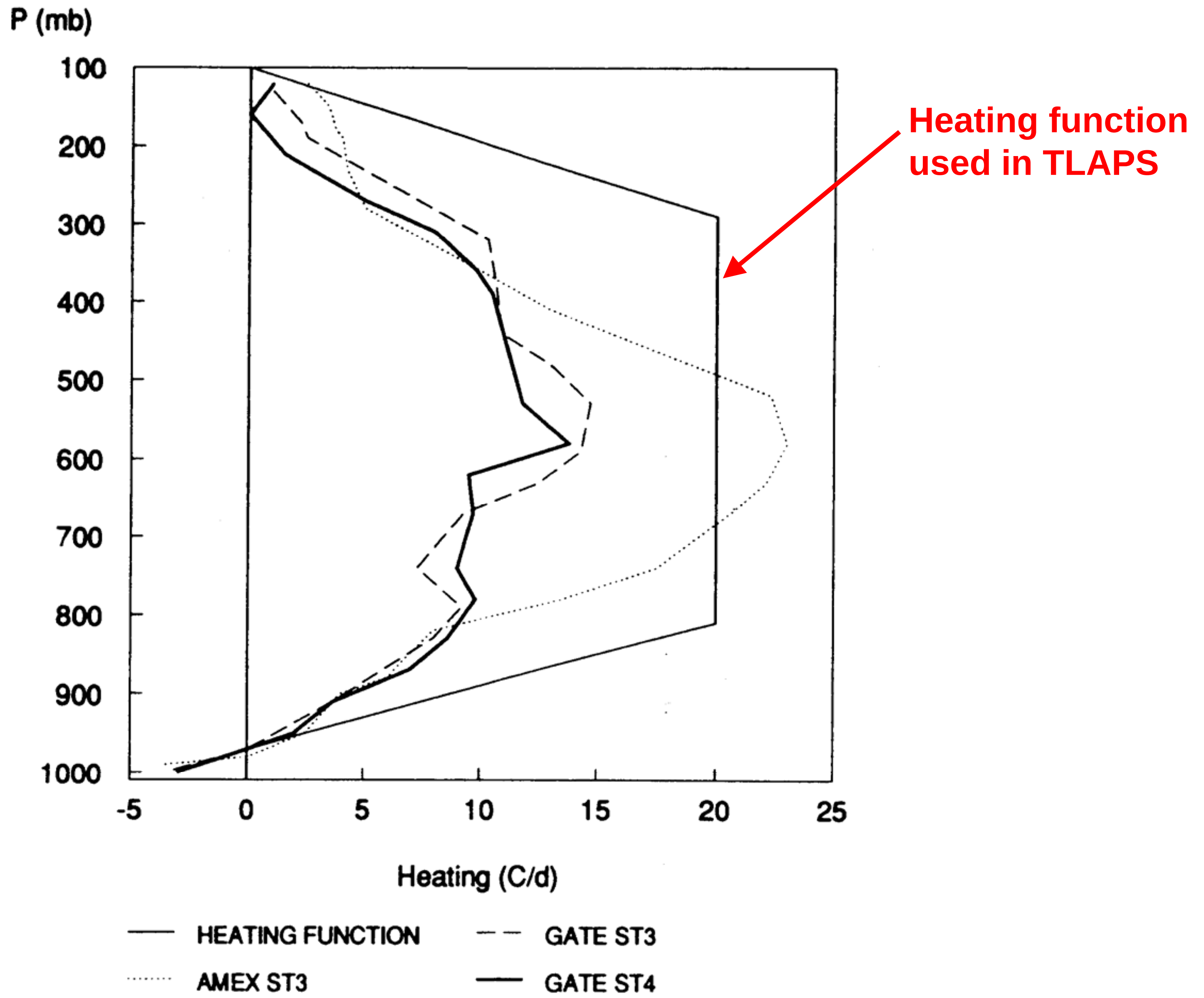
- It is only possible to apply heating rates at points where model diagnoses convection
- Scheme cannot handle situations where observations indicate convection but model does not

Use of GMS-based heating rates

- Another approach to use inferred rainfall rates is through moisture initialisation
- This procedure attempts to adjust the initial moisture field so that the rainfall rate in the early stages of model integrations is close to the observed rate

Use of GMS-based heating rates in TLAPS

- During nudging, the heating from the model convective parametrisation is replaced by a heating profile
- The structure of profile is defined by CTT obtained from GMS cloud imagery
- Triggering occurs if CTT < 273^{o} K
- Comparison between CTT and model temperature profile determines depth of the heating profile (d_{CT})


P (mb)
100
200
300
400
500
600
700
800
900
1000
-5
0
5
10
15
20
25
Heating (C/d)
HEATING FUNCTION
GATE ST3
AMEX ST3
GATE ST4
Heating function
used in TLAPS

Generation of synthetic moisture data (*Mills and Davidson, 1987)*

Premise of moisture retrieval algorithm –

- **A statistical analysis of the equivalent T_{bb} of each pixel (cloud-top T, CTT) in an area co-located with a radiosonde ascent can be used to classify the cloud depth, amount and type in the area**
- **This cloud specification can be related to the dew-point depression profile of the associated radiosonde ascent**

Generation of synthetic moisture data

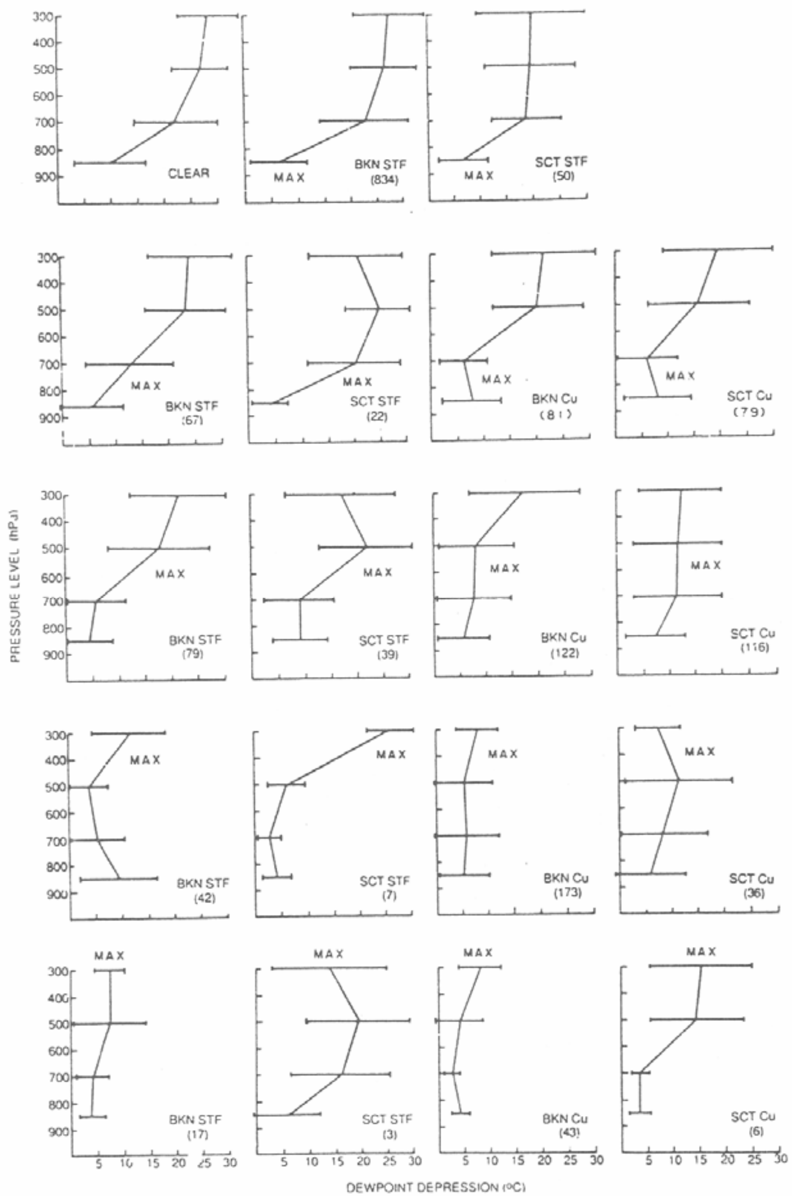
The data were stratified into categories based on 3 priory criteria

- Layer of maximum cloudiness
- Whether cloud amount covered more or less than 50% of area
- Whether major cloud layer was cumuliform or stratiform

Generation of synthetic moisture data

19 categories were assigned:

- Amount (scattered, broken)
- Depth (5 layers)
- Type (cumuliform, stratiform)
- Plus 1 clear category less 2 categories since no cumulus category was assigned below 850 hPa


PRESSURE LEVEL (hPa)
300
400
500
600
700
800
900
CLEAR
MAX
BKN STF
(834)
MAX
SCT STF
(50)
MAX
BKN STF
(67)
MAX
SCT STF
(22)
MAX
BKN Cu
(81)
MAX
SCT Cu
(79)
MAX
BKN STF
(79)
MAX
SCT STF
(39)
MAX
BKN Cu
(122)
MAX
SCT Cu
(116)
MAX
BKN STF
(42)
MAX
SCT STF
(7)
MAX
BKN Cu
(173)
MAX
SCT Cu
(36)
MAX
BKN STF
(17)
MAX
SCT STF
(3)
MAX
BKN Cu
(43)
MAX
SCT Cu
(6)
5 10 15 20 25 30
DEWPOINT DEPRESSION (°C)

Generation of synthetic moisture data

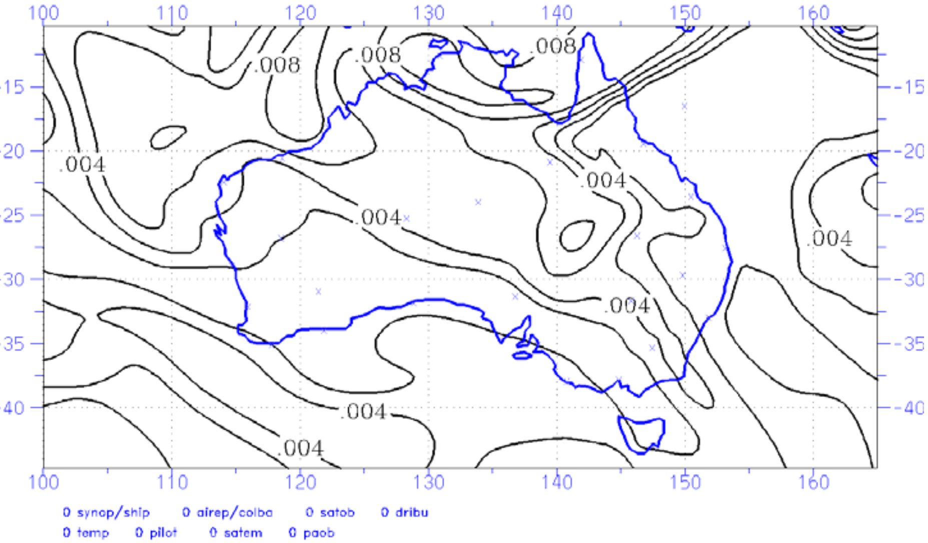
Practical application of scheme involves –

- Ingestion of satellite pixel data
- For 50km radius circle compute mean CTT, fractional pixel count (ie cloud amount), std deviation of CTT of cloudy pixels within layer (type of cloud)
- Assign corresponding cloud category and dew point depression profile at each point
- Recover dewpoint using using current temperature analysis

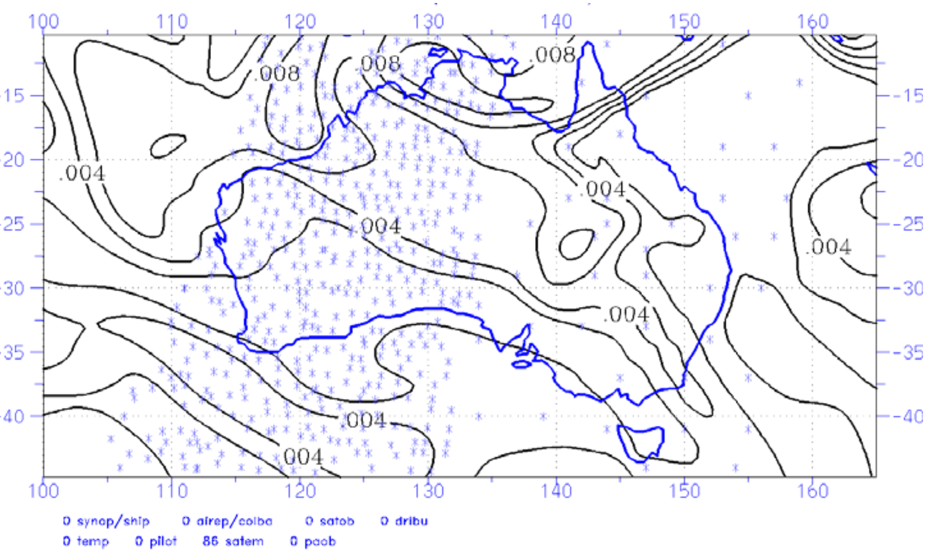
Generation of synthetic moisture data

- Moisture profile data are operationally generated 4 times a day on a 2^{o} x 2^{o} grid
- Generated data are treated as observations

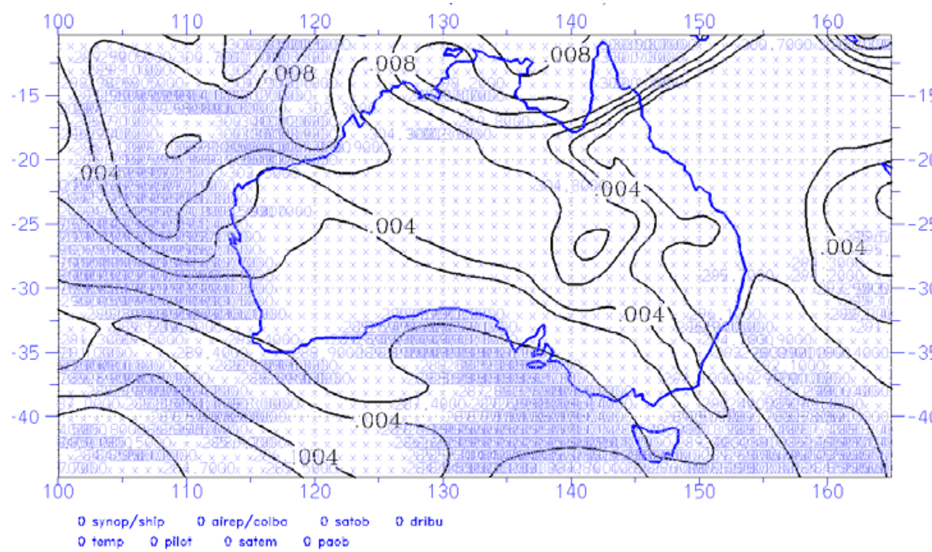
sondes

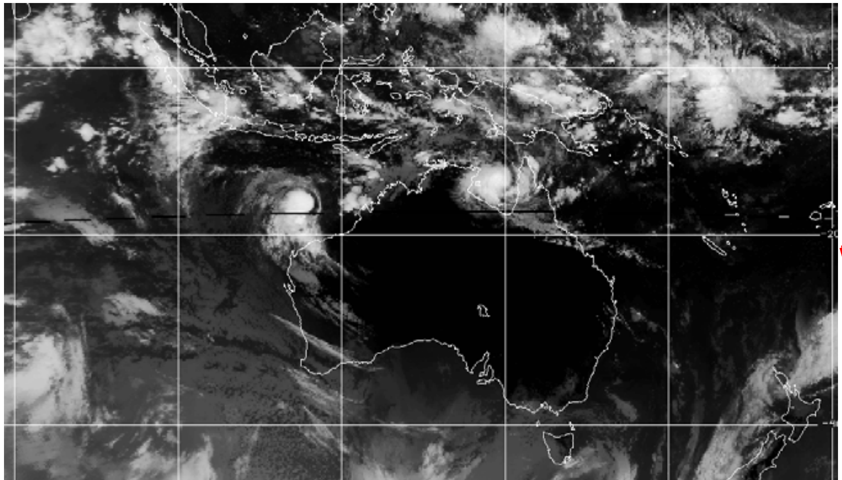


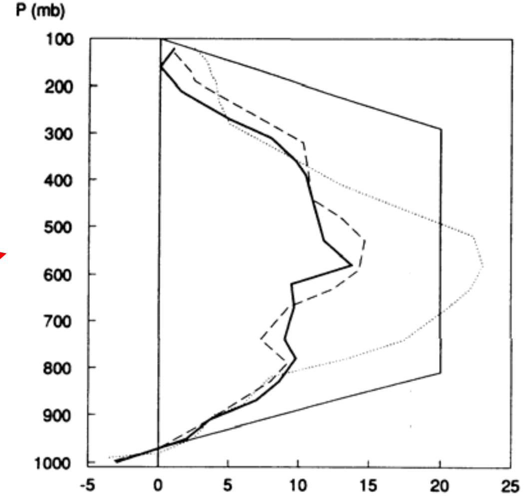
satem



GMS moisture






P (mb)
100
200
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1000
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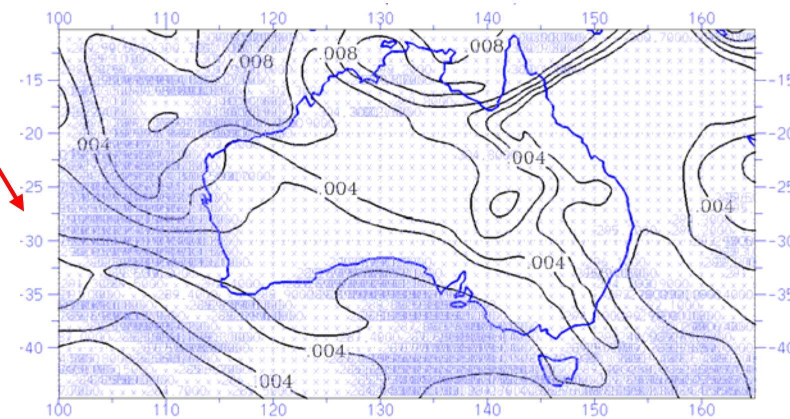
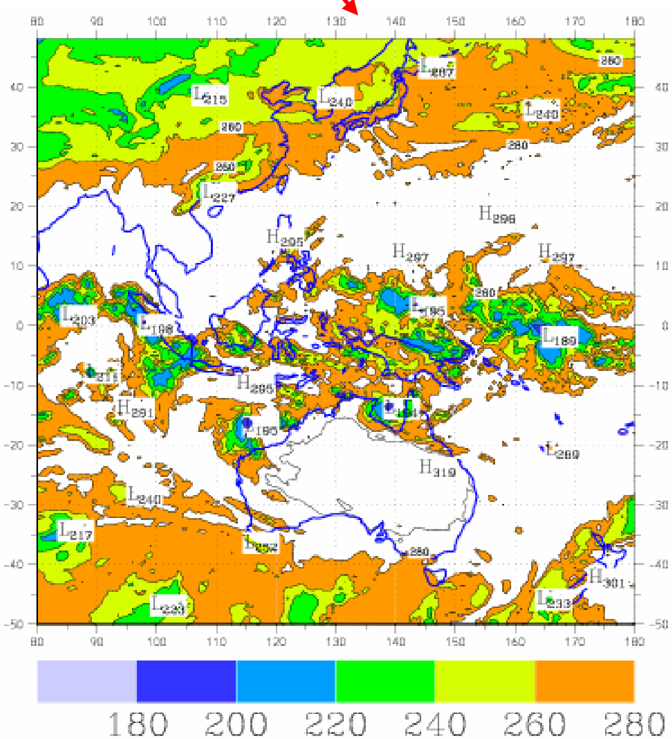
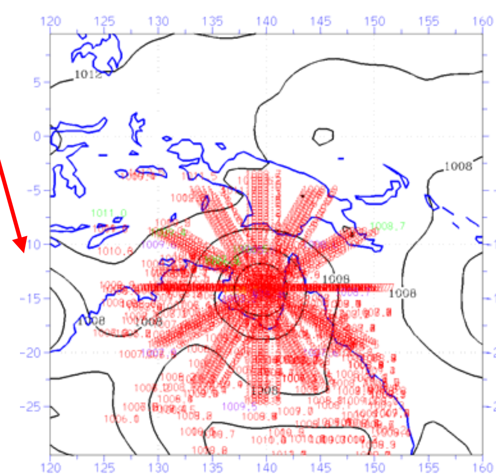
25

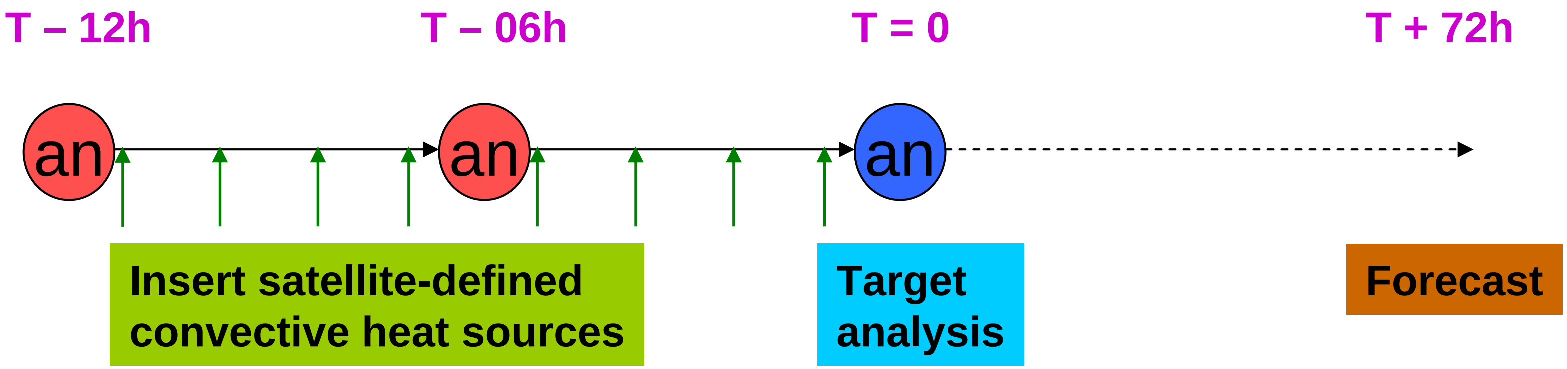

100
110
120
130
140
150
160
.008
.004

CTT


180
200
220
240
260
280

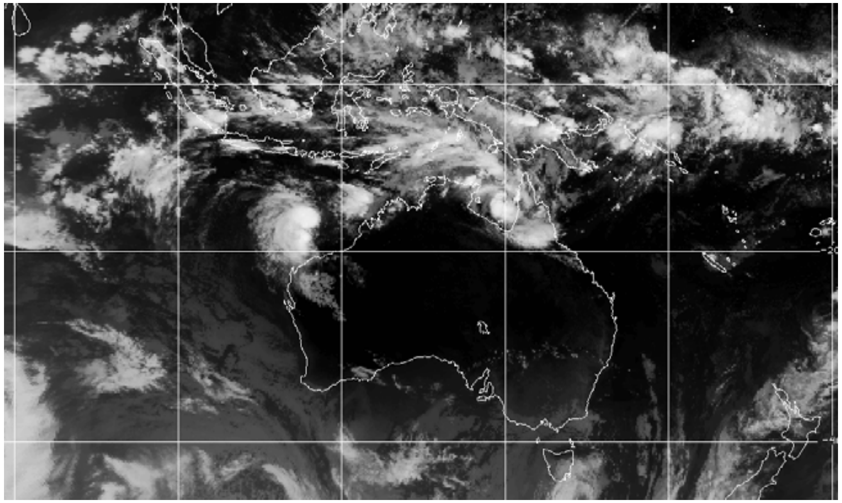

1012
1008

Dynamic nudging scheme used in TLAPS



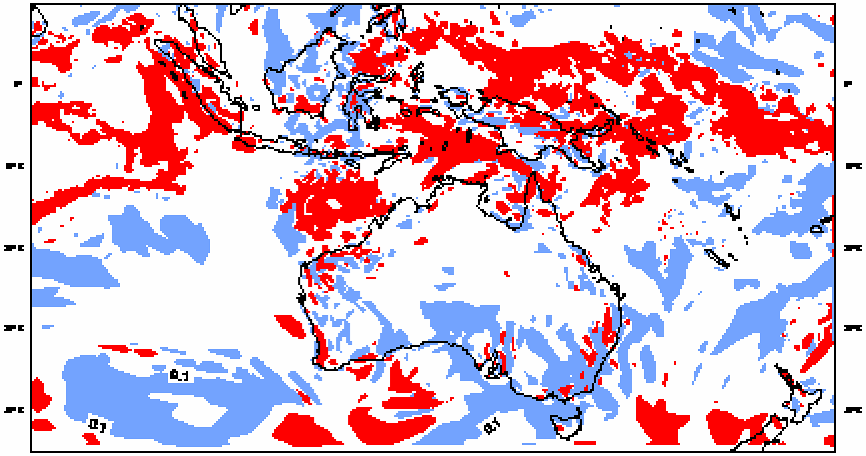
- **Target analysis: reanalysis of all data + TC bogus + satellite data**
- **Nudge to preserve observationally reliable rotational wind component in the target analysis**
- **Replace model heating with satellite defined heat sources updated every 6 hours – forces divergent wind component**

20050205 12Z

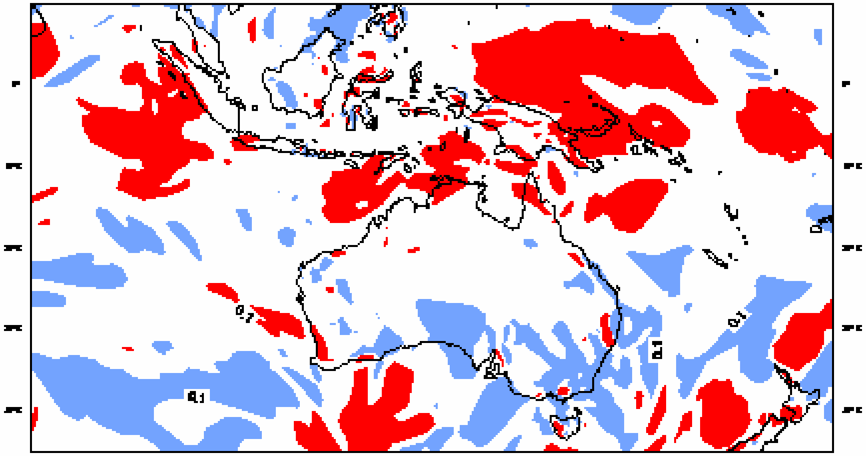


Omega analyses, 500hPa

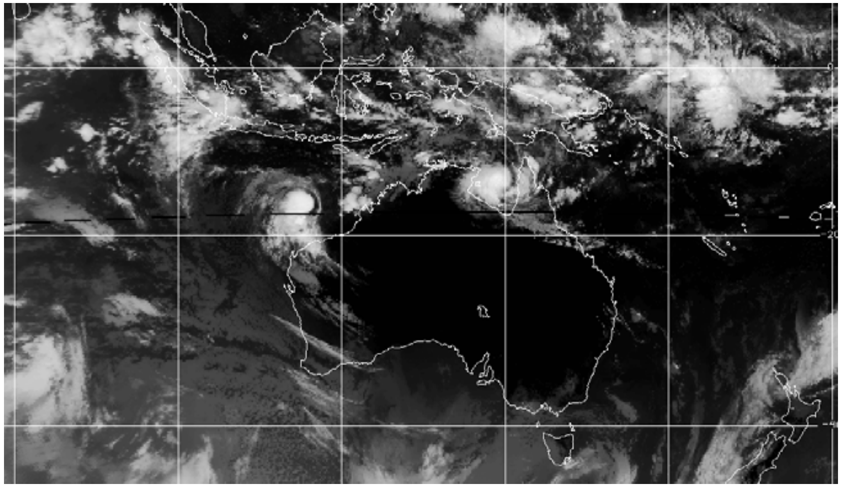
With gms



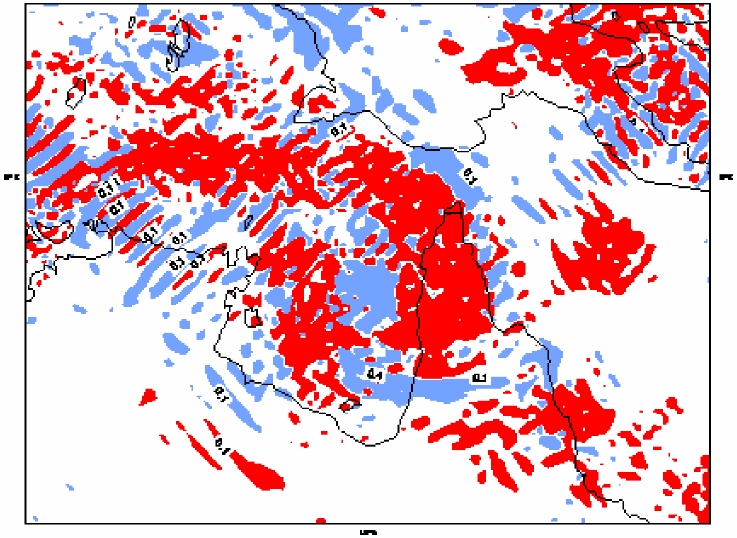
No gms



20050206 00Z

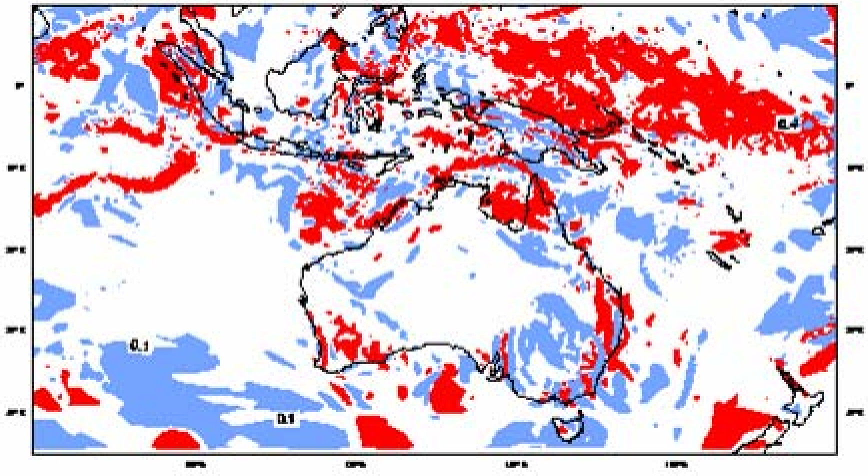


TCLAPS, With gms

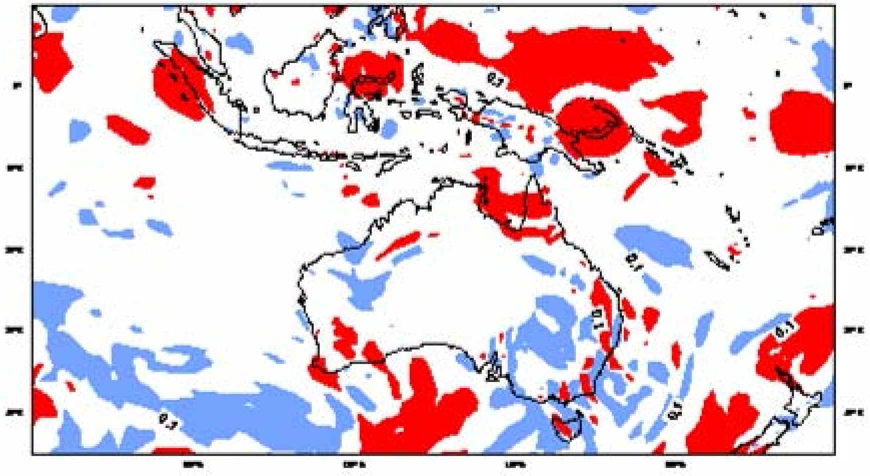


Omega analyses, 500hPa

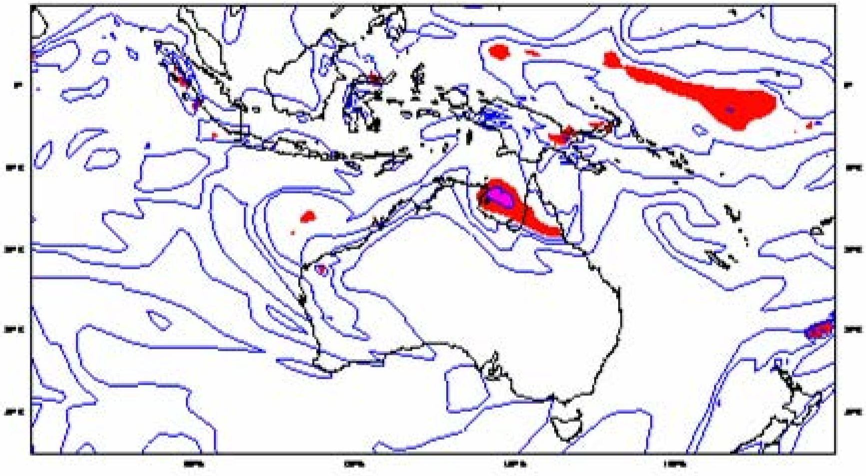
With gms



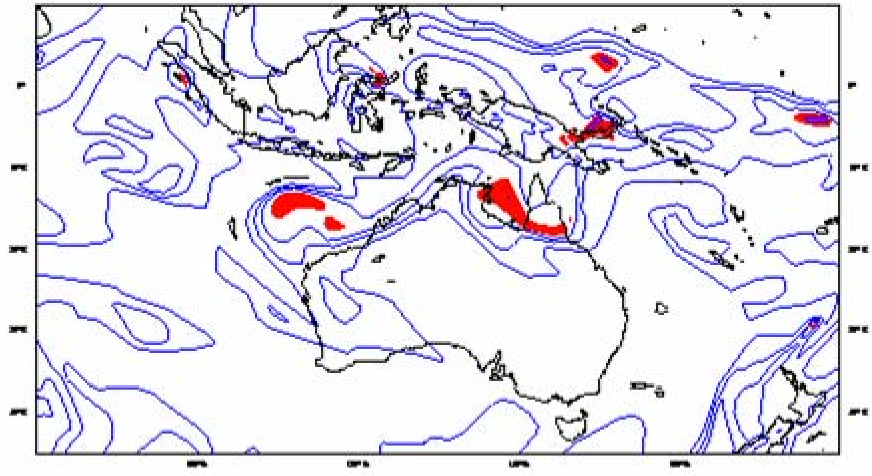
No gms



With gms 20050206 00Z

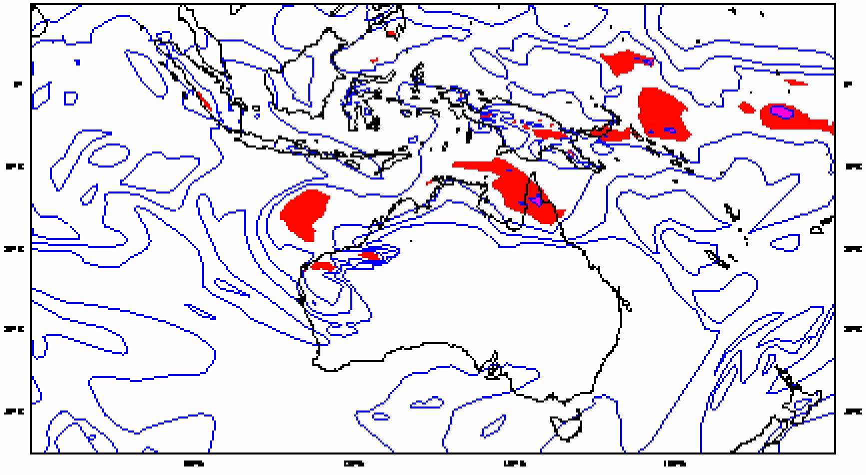


No gms 20050206 00Z

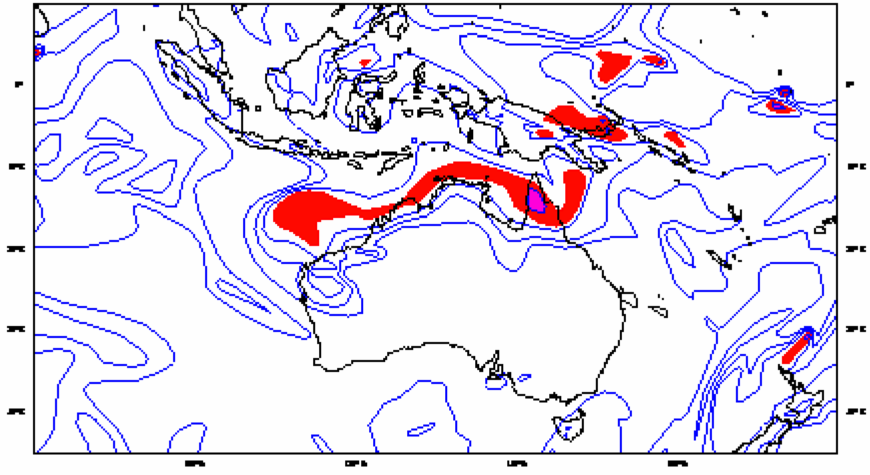


Mixing ratio analyses, 500hPa

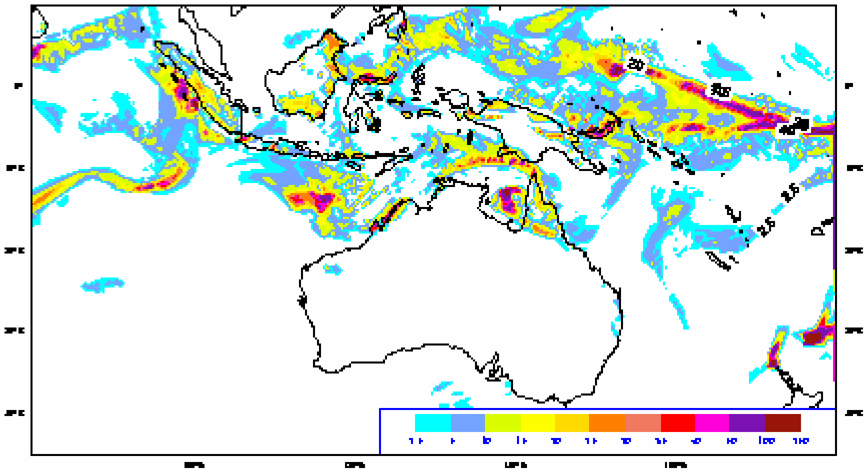
With gms 20050205 12Z



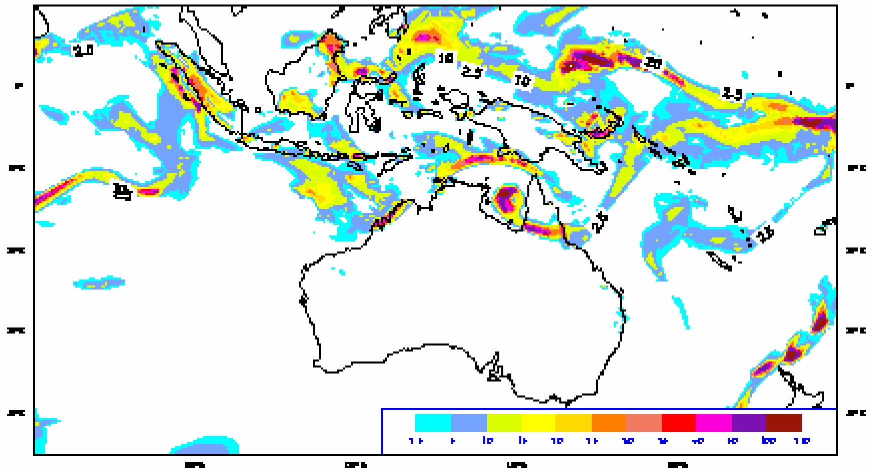
No gms 20050205 12Z



With gms 20050206 00Z

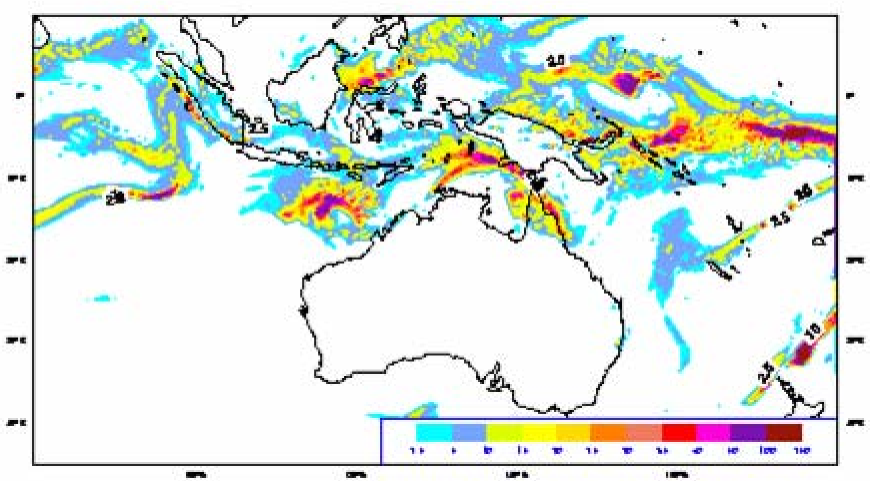


No gms 20050206 00Z

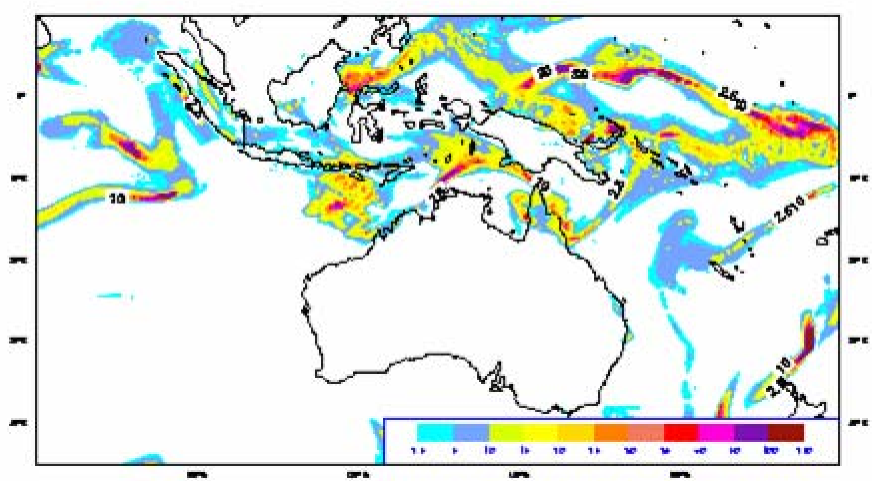


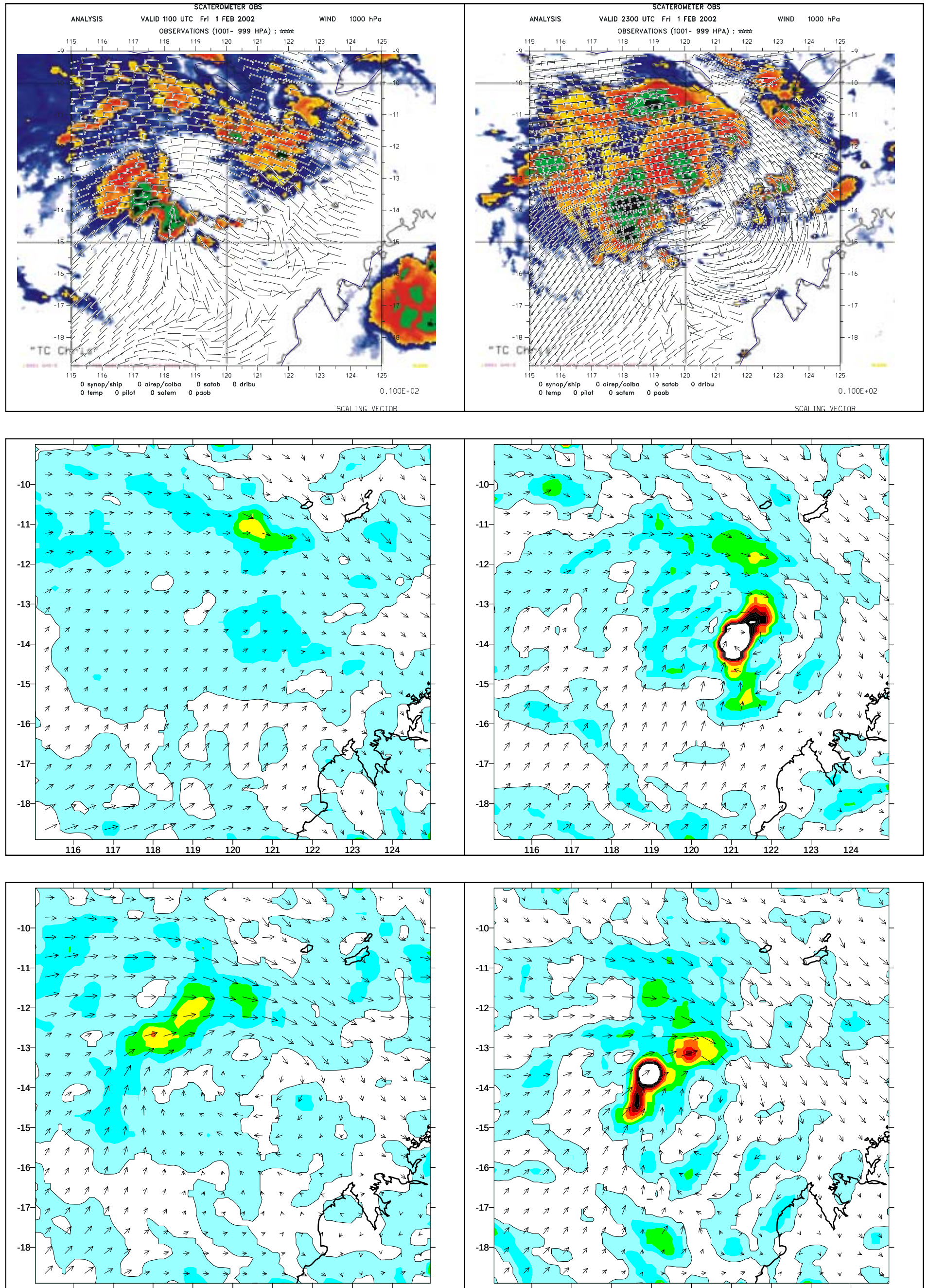
12 hour precipitation forecasts

With gms 20050205 12Z



No gms 20050205 12Z





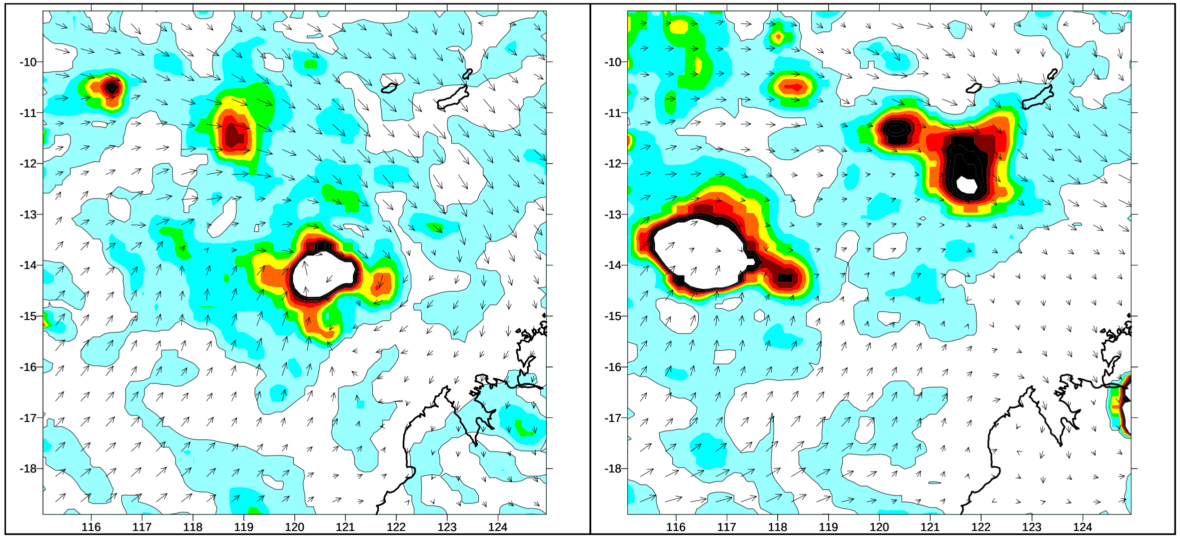
CTT + QuickSCAT data

No CTT
No QuickSCAT

With QuickSCAT

Low level wind

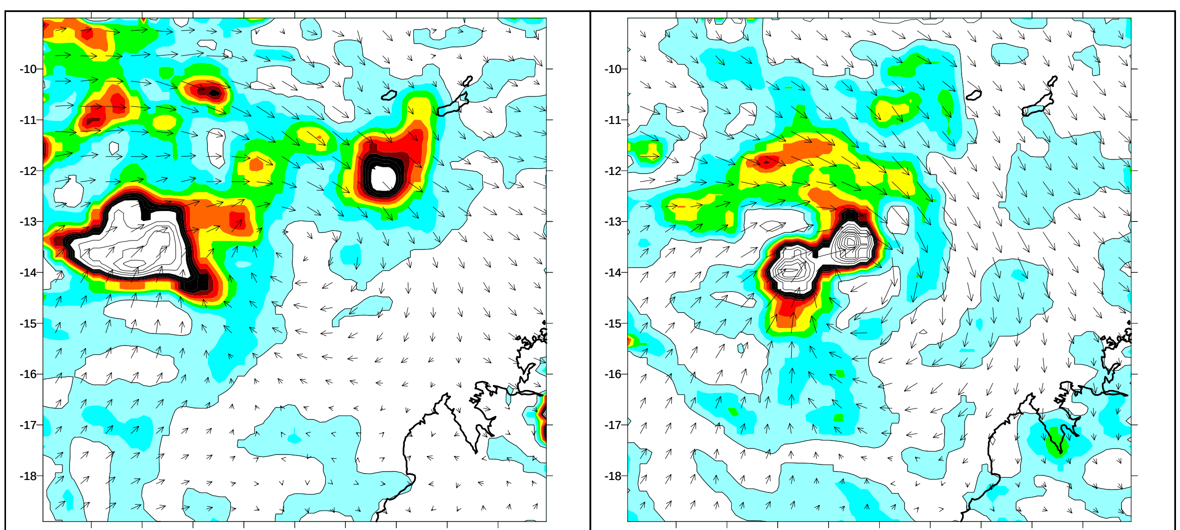
Vertical motion



With CTT

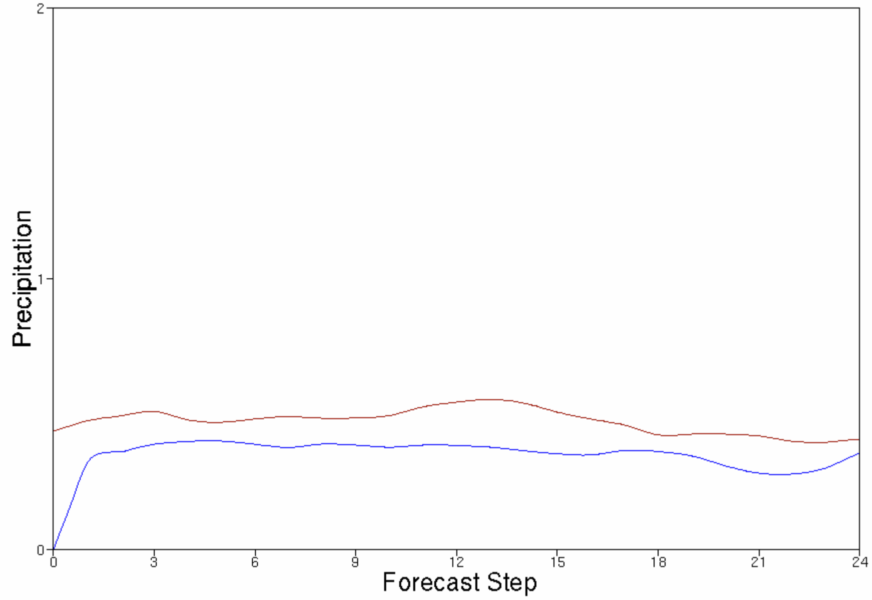
Low level wind

Vertical motion



With CTT
and QuickSCAT

20050204 00Z

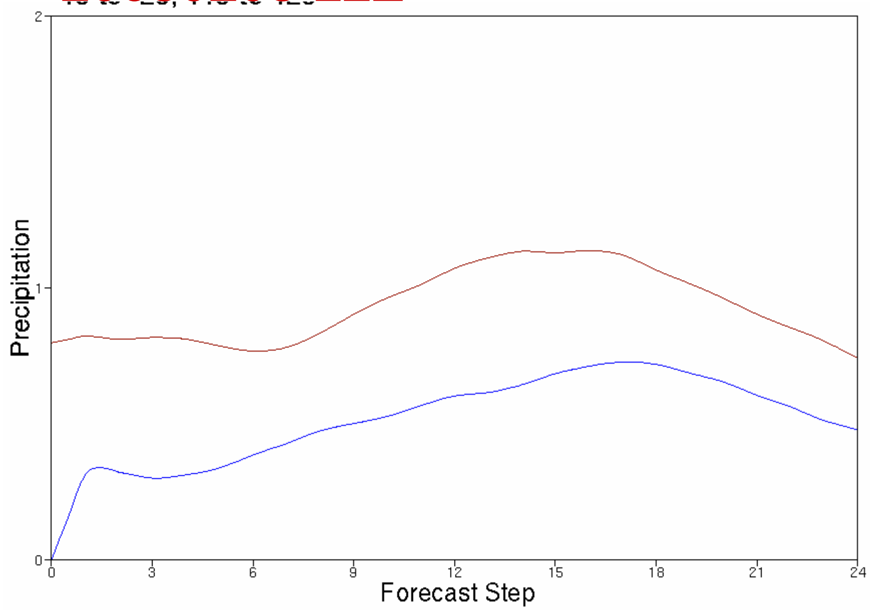


Area average
10S-20S; 110E-120E

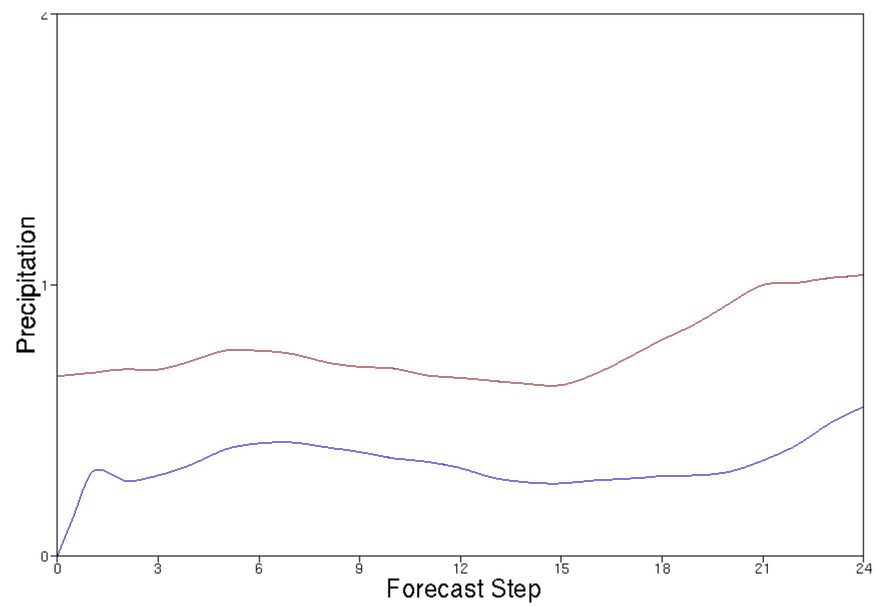
With gms

No gms

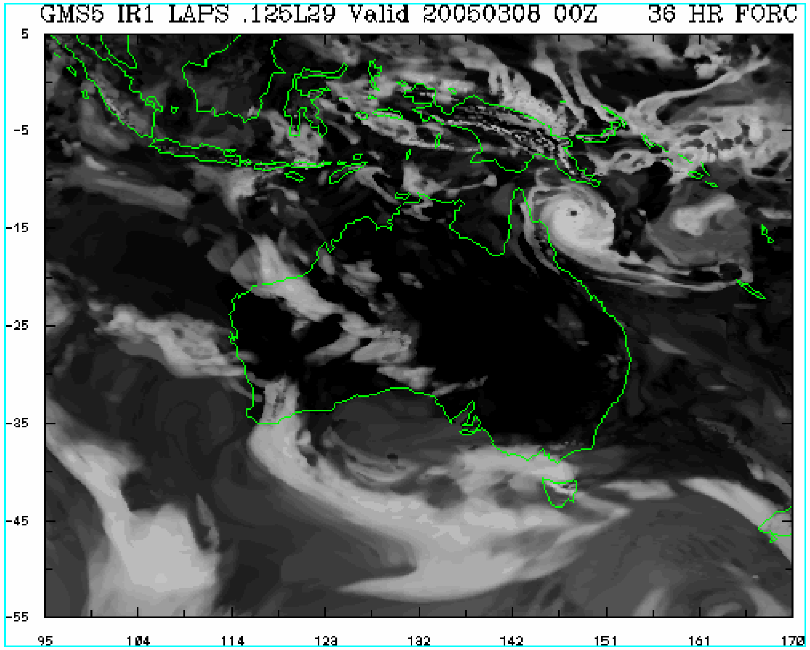
20050205 12Z



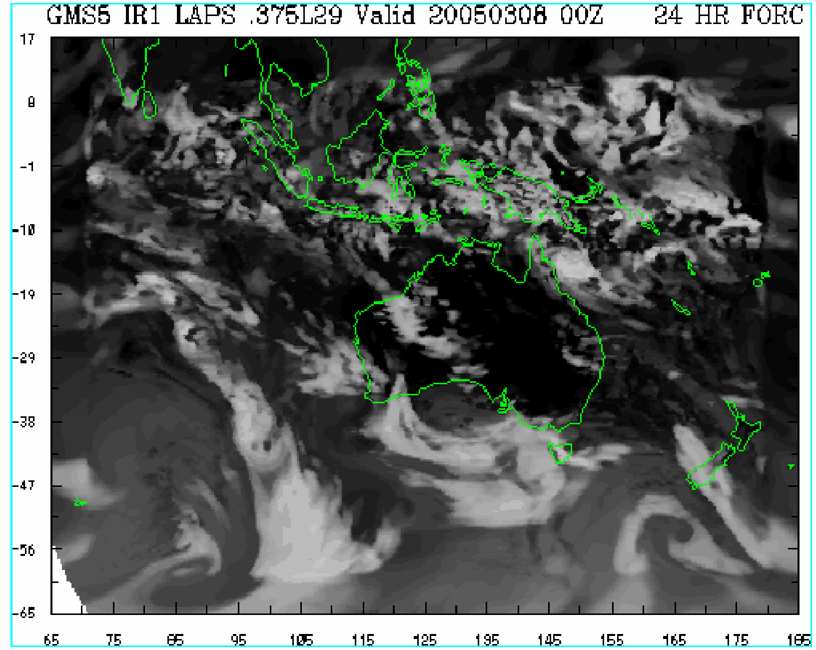
20050206 00Z



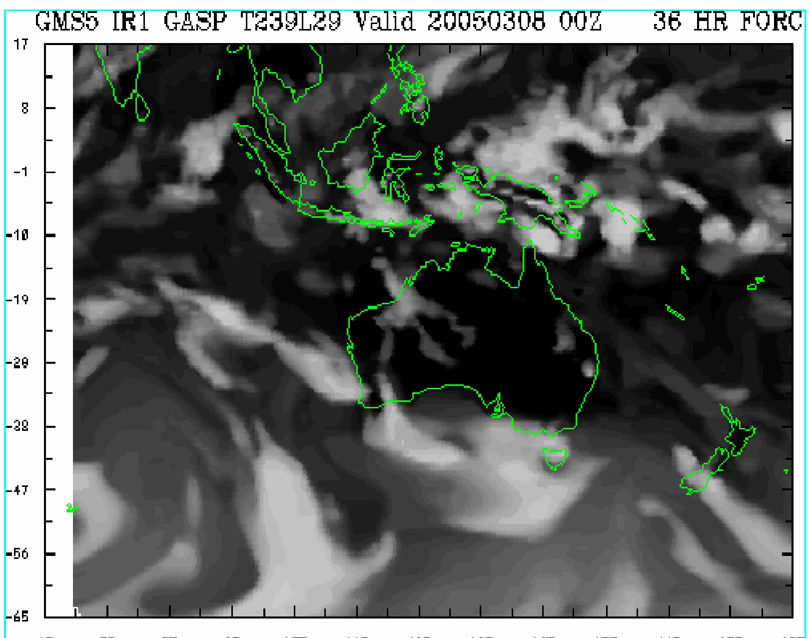
Loop for Mlaps .125



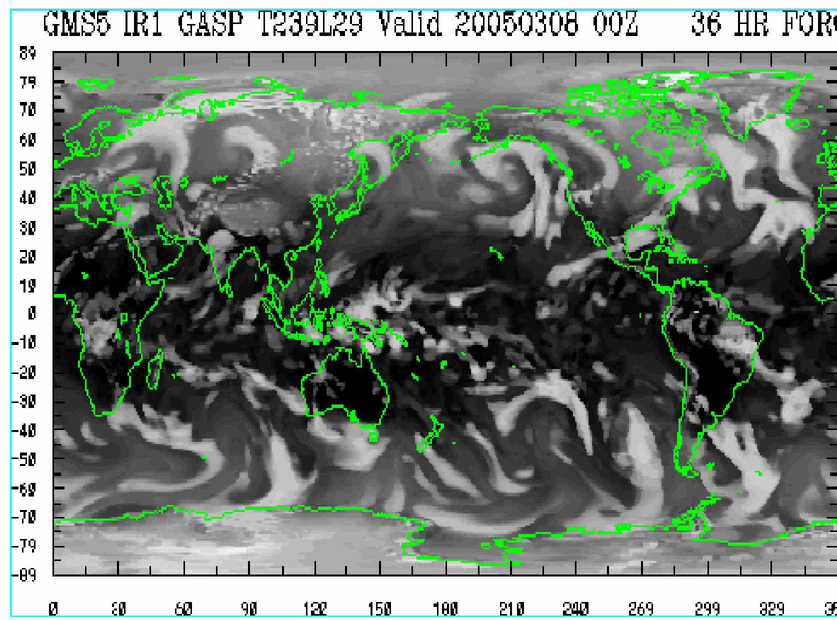
Loop for Laps .375



Loop for T239 Gasp on Laps Domain



Loop for T239 Gasp



Concluding remarks

Predictability of the Tropical Atmosphere (Shukla, 1981)

- The theoretical upper limit of deterministic predictability for low latitudes is shorter than for middle latitudes
- Most of day-to-day fluctuations in the tropics are determined by the growth and decay of condensation driven instabilities for which the amplitudes equilibrate rapidly
- It takes only a few days for an initial error to grow to a magnitude comparable to the climatological variance

Predictability of the Tropical Atmosphere (Shukla, 1981)

- Variability of time averages in low latitudes is largely influenced by the slowly varying boundary conditions of SST and soil moisture
- Since synoptic instabilities are not strong enough to change drastically the large scale flow, there is larger potential for predictability of monthly and seasonal means in low latitudes

International Workshop on the Dynamics and Forecasting of Tropical Weather Systems

(IWDFTWS) - Darwin -January 2001

Topics for workshops

- Synoptic scale tropical waves
- Regional NWP
- Forecasting convection
- Life cycles of monsoon depress
- Utility of potential vorticity in the tropics
- Subtropical/tropical interactions
- Role of topography
- Limits of predictability
- Probability forecasting methods based on models and /or archived radar data

How useful is NWP in the Tropics?

Definitely useful especially if well defined synoptic systems, BUT……the connection to the actual weather, especially rainfall, is still unsure

Concluding remarks

- Significant progress has been made in TC track prediction.

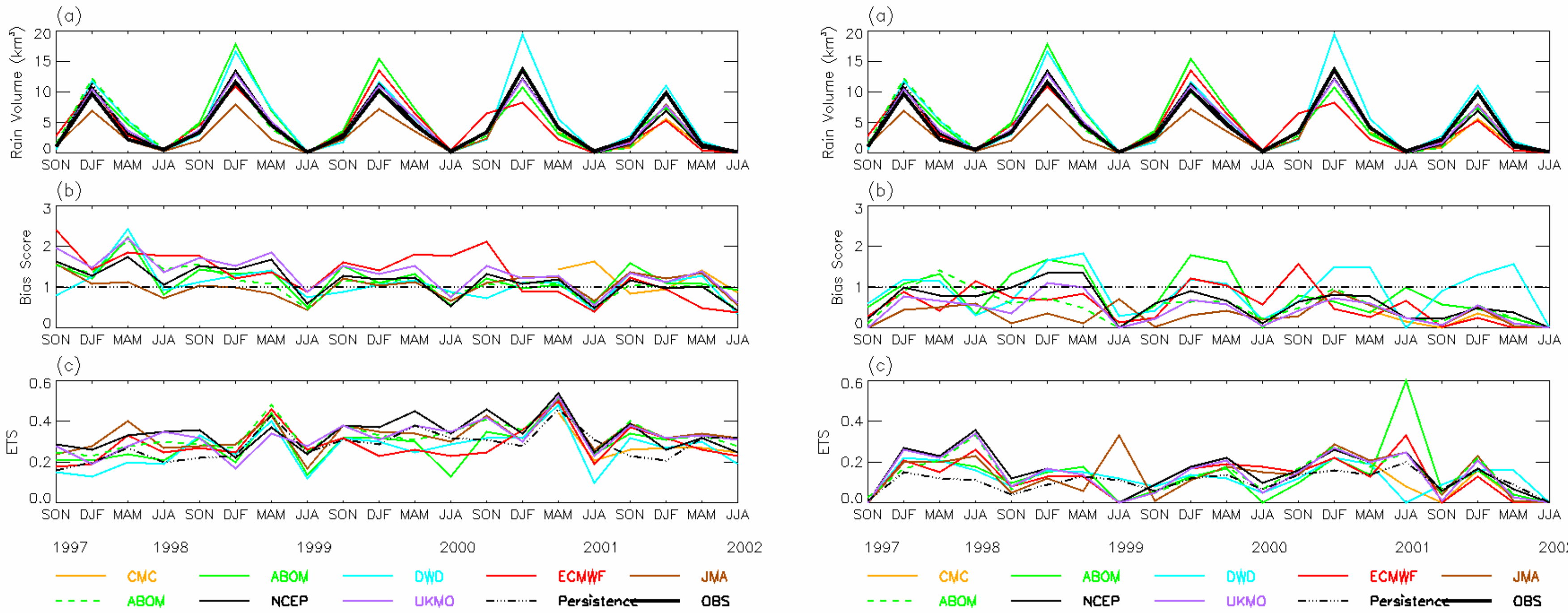
  Ensemble prediction has enhanced this progress

However

- Little progress has been made in rainfall prediction
- Prediction of monsoon onset remains a problem, although there has been slow progress

24 h forecasts for tropical Australia

Rain > 1mm/day **Rain > 20mm/day**



Concluding remarks

- Till recently analysis of moisture has not been taken seriously
- Current satellite sensors and future missions will provide reliable and good coverage of moisture and precipitation
- Operational Centres have or will soon start assimilating rainfall data using improved analysis methods (eg 4DVAR) - this has potential to provide significant improvements in tropical NWP, and in particular rainfall prediction

Convergence of N.Hem and S.Hem Medium Range Forecast skill 1981 – 1995

Anomaly correlation of 500hPa height Forecasts

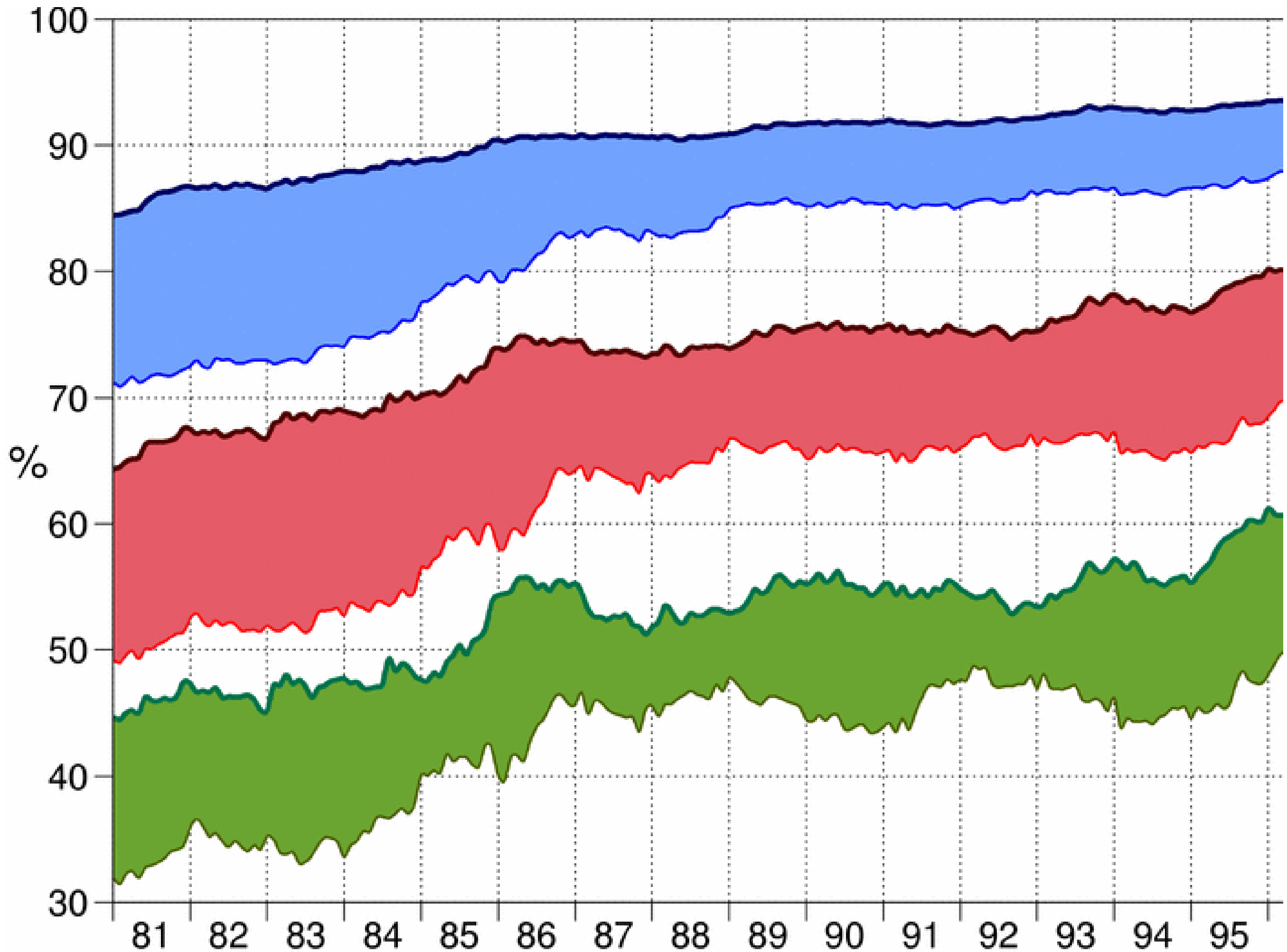
NH

SH

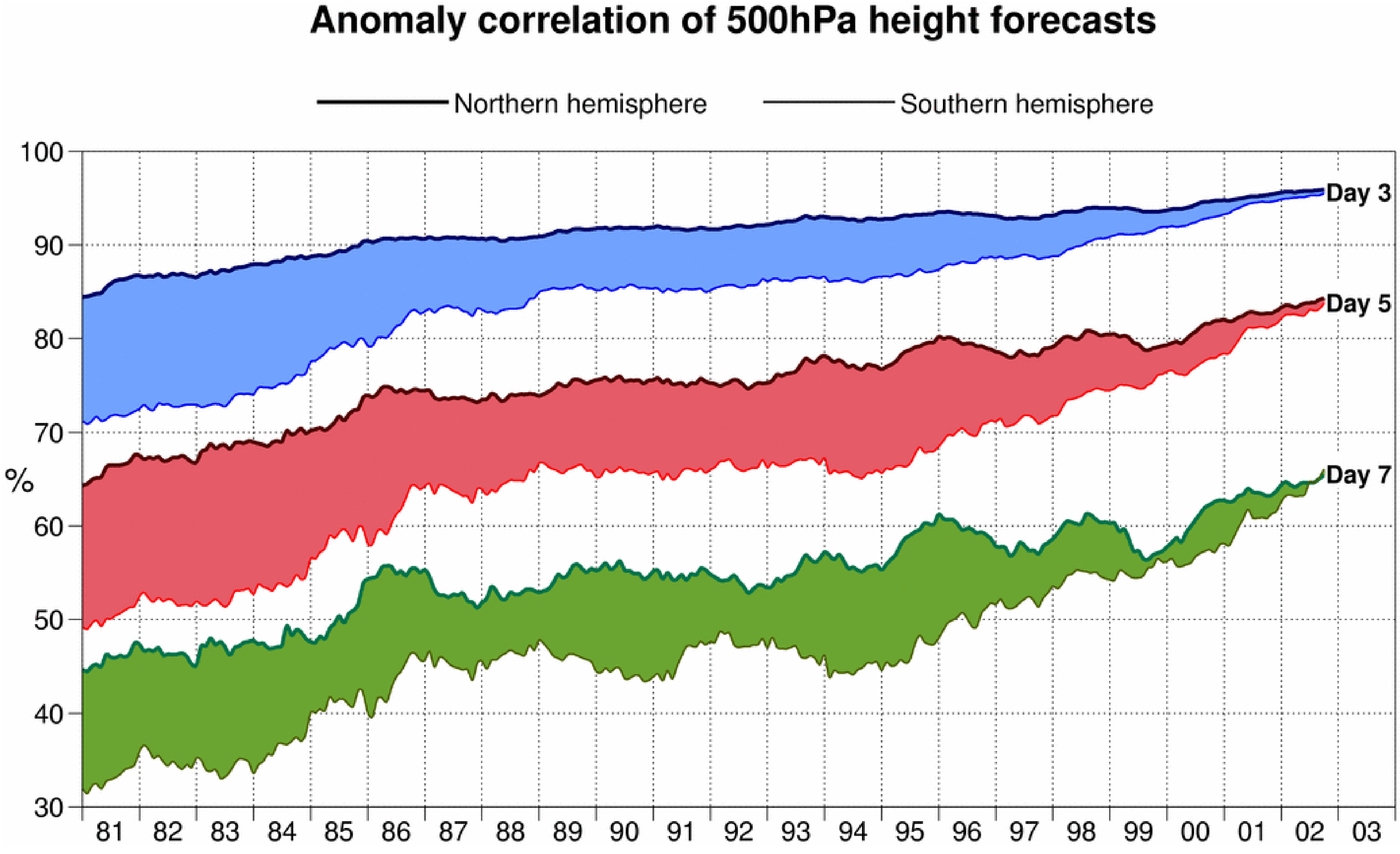
Day 3

Day 5

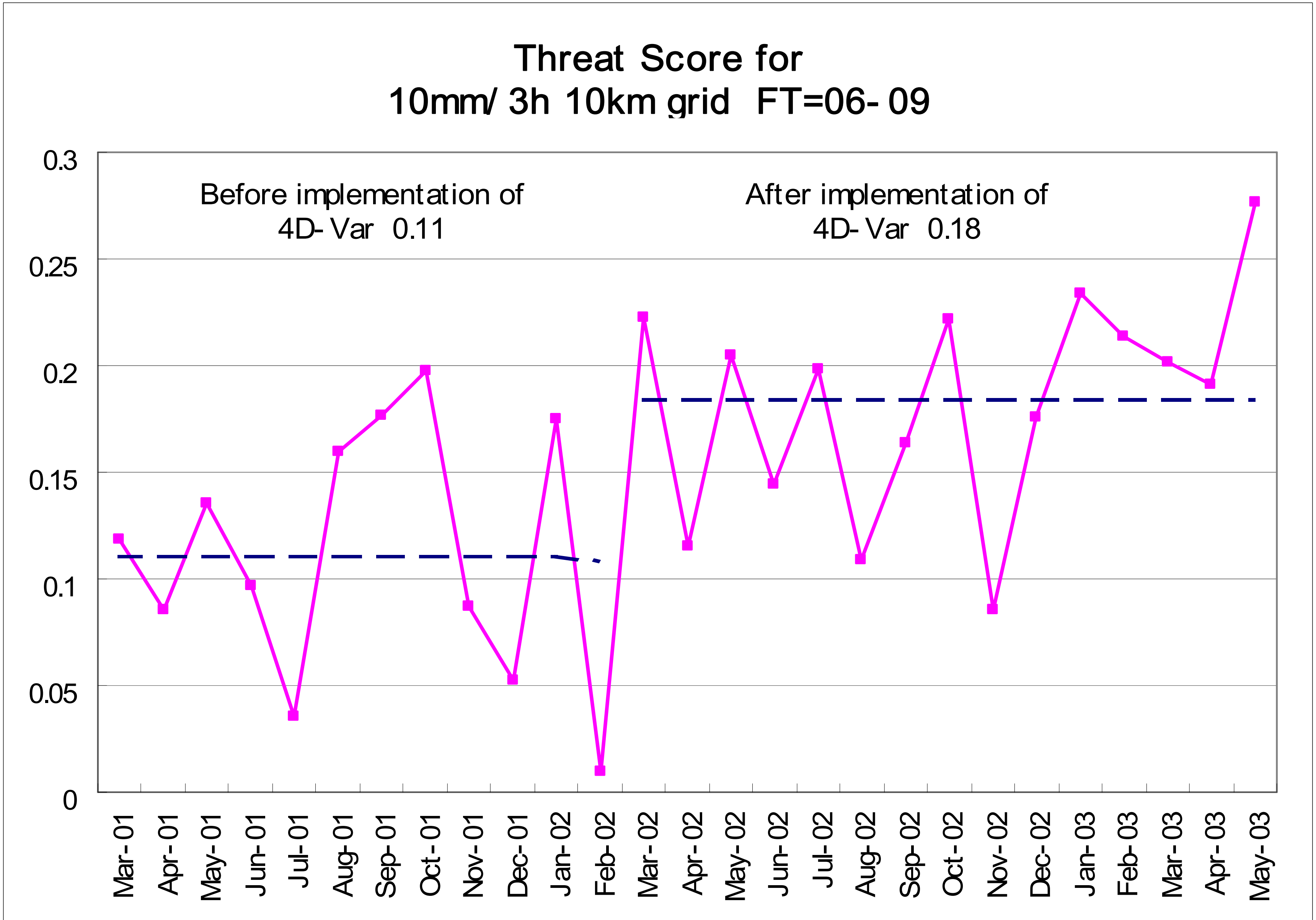
Day 7

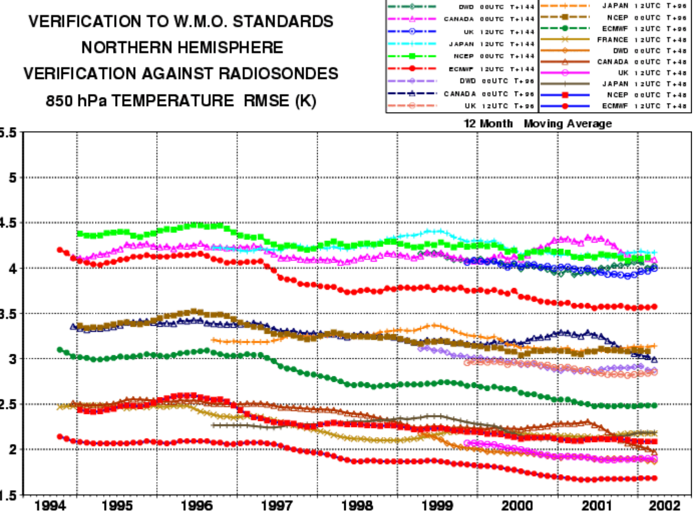


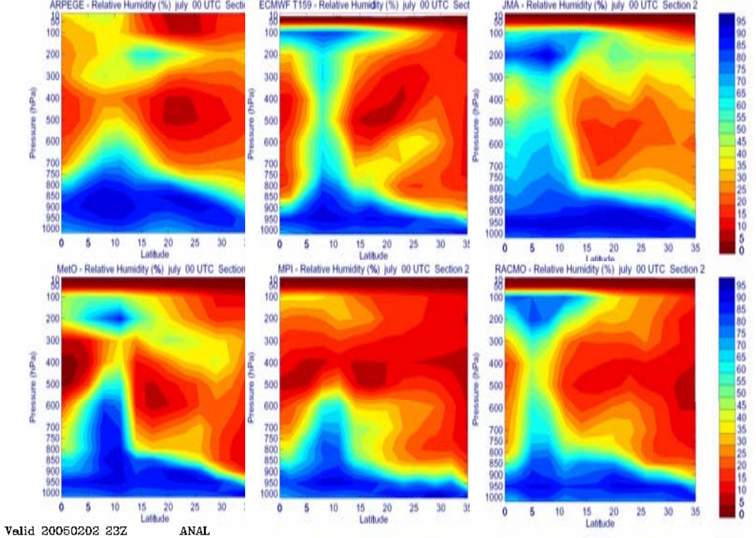
Convergence of N.Hem and S.Hem Medium Range Forecast skill 1981 – 2003



Performance of MSM improved

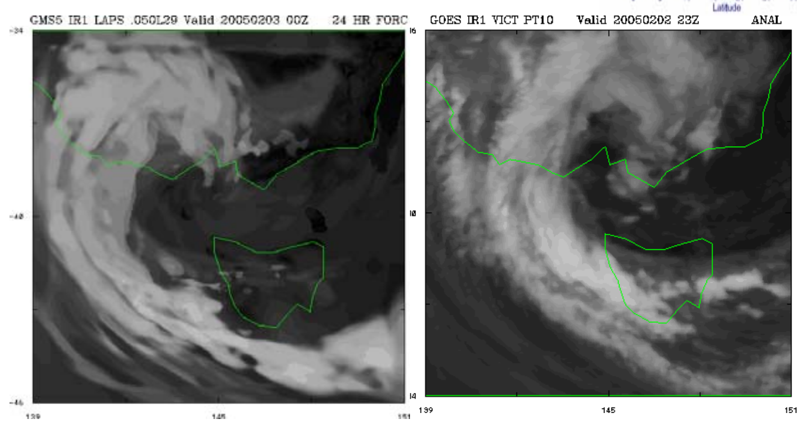


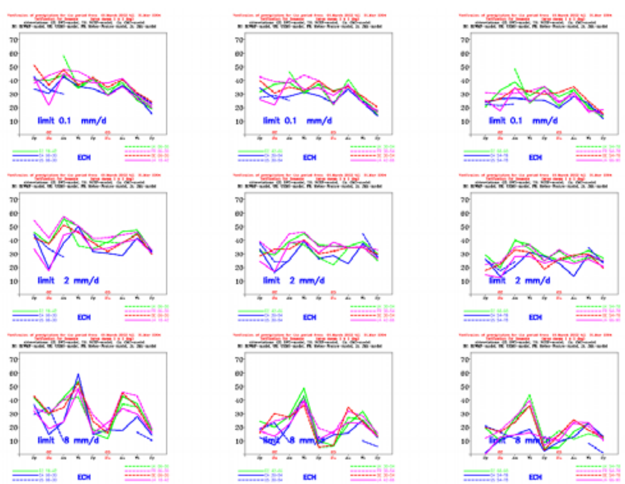




rms error

clouds





precipitation

TC tracks