The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

SMR/1849-27

Conference and School on Predictability of Natural Disasters for our Planet in Danger. A System View; Theory, Models, Data Analysis

25 June - 6 July, 2007

Predictability of Tropical Weather - I

K. Puri

Bureau of Meteorology Research Centre
Melboure, Victoria
Australia

Predictability of Tropical Weather

K. Puri

(Thanks to many colleagues)

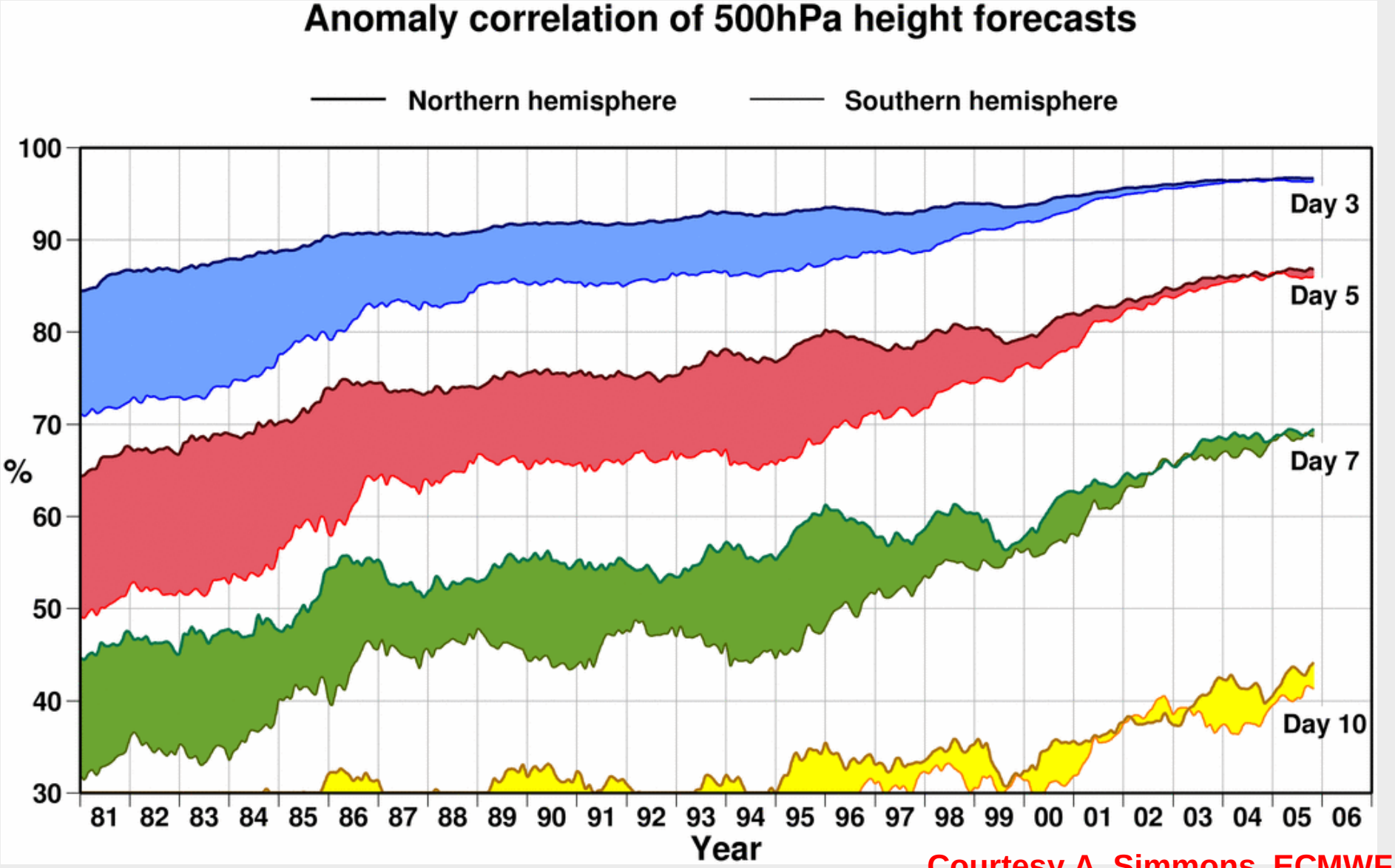
Numerical Weather Prediction

The last few years have seen significant advances in numerical weather prediction

Several factors have contributed to these advances -

- **Increase in model resolution**
- **Improvements in parameterisation of physical processes**
- **Improvement in data assimilation, including better usage of different types of data**
- **Implementation of more accurate and stable numerics**

Convergence of N.Hem and S.Hem Medium Range Forecast skill



Courtesy A. Simmons, ECMWF

Numerical Weather Prediction

'The success of numerical weather prediction represents one of the most significant scientific, technological and societal achievements of the 20th century' – THORPEX International Plan

Despite the notable increase in skill over the past quarter century, there is a necessity for further improvements, particularly, in the accuracy of high-impact weather forecasts and *in the tropics*

Why are the tropics different?

- Small Coriolis force
- Geostrophy and other balances may not be generally applicable – large Rossby number $R_o = U/fL$
- No analytical pressure-wind relationship and sometimes weak coupling between the mass and wind fields – other processes, eg diabatic heating become more important
- Divergent component of wind becomes comparable in magnitude to the rotational component during developing convective events
- Uncertainties in how extra-tropical flows influence tropical flows

➢ These factors lead to significant analysis and prediction issues in the tropics

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

Predictability of tropical weather

Emphasis of lectures is on **short to medium-range prediction**

Lecture 1: Performance in the tropics

Lecture 2: Tropical NWP systems

Lecture 3: Future trends

Acknowledgements:

Thanks to colleagues at BMRC, ECMWF, MetOffice, JMA, NCAR, CSU and others for allowing me to use their material

Lecture 1
Outline

The emphasis is on practical aspects of forecasting in the tropics

- **Present brief experience from an operational centre**
- **Present objective scores to indicate performance of models in the tropics**
- **Present examples to indicate performance of models in the tropics for some key features – tropical cyclones, precipitation, monsoons, MJO**

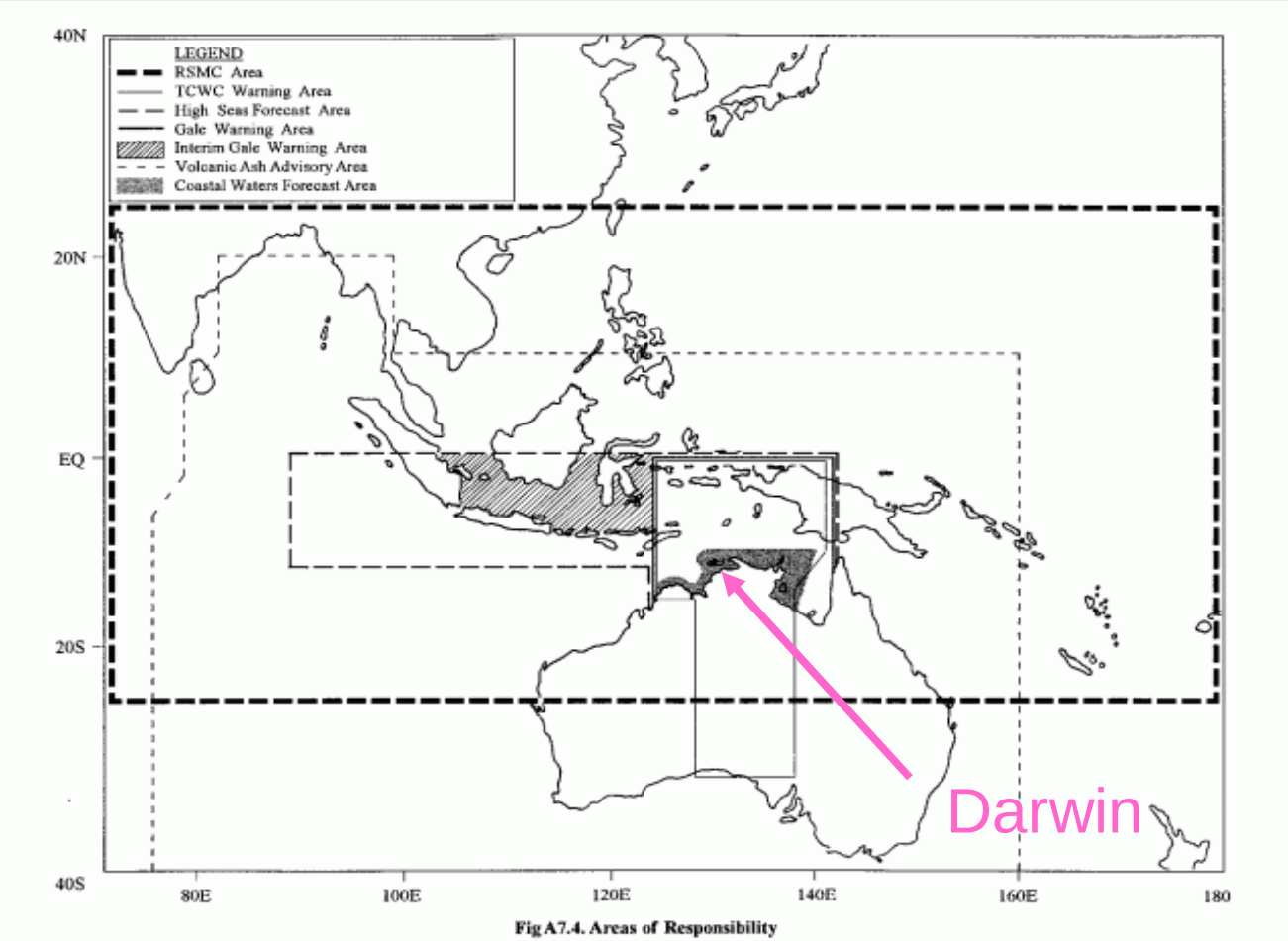
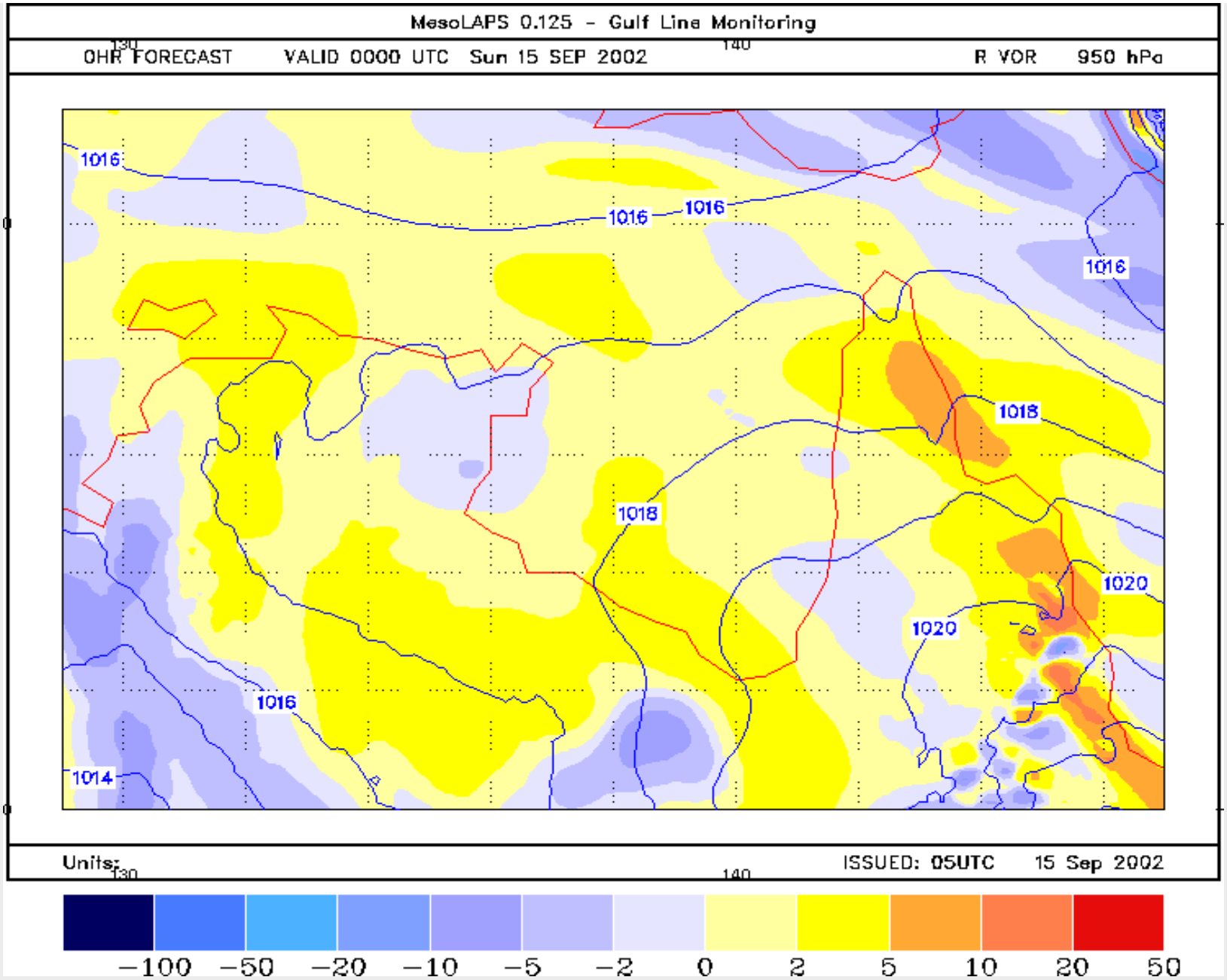


Fig A7.4. Areas of Responsibility

Example from an operational forecasting centre

Darwin Meteorology….. wet/dry seasons
Many varieties of tropical weather
Eg TCs, complex TDs, waves, continental TS, marine TS, NW monsoon streams…



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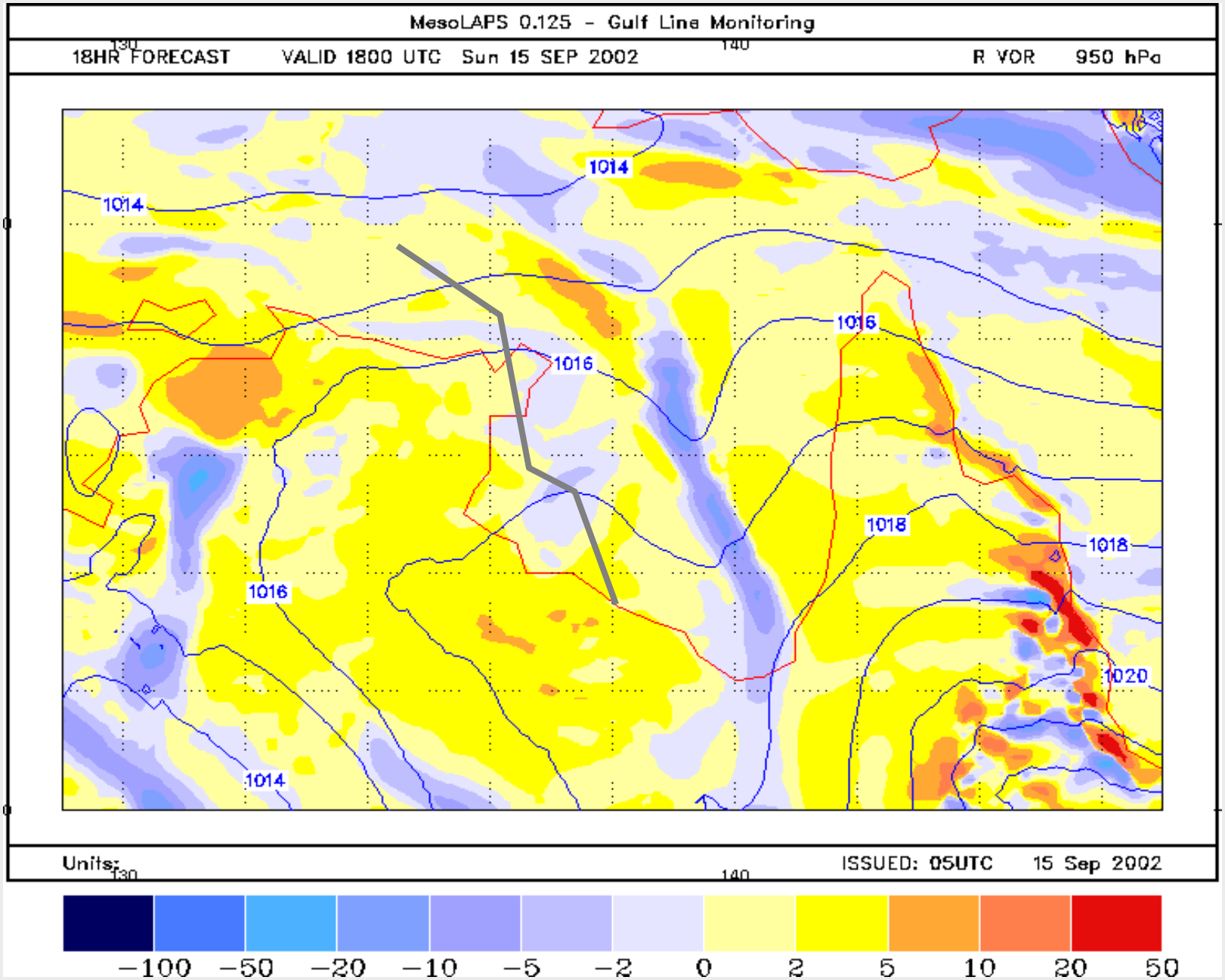

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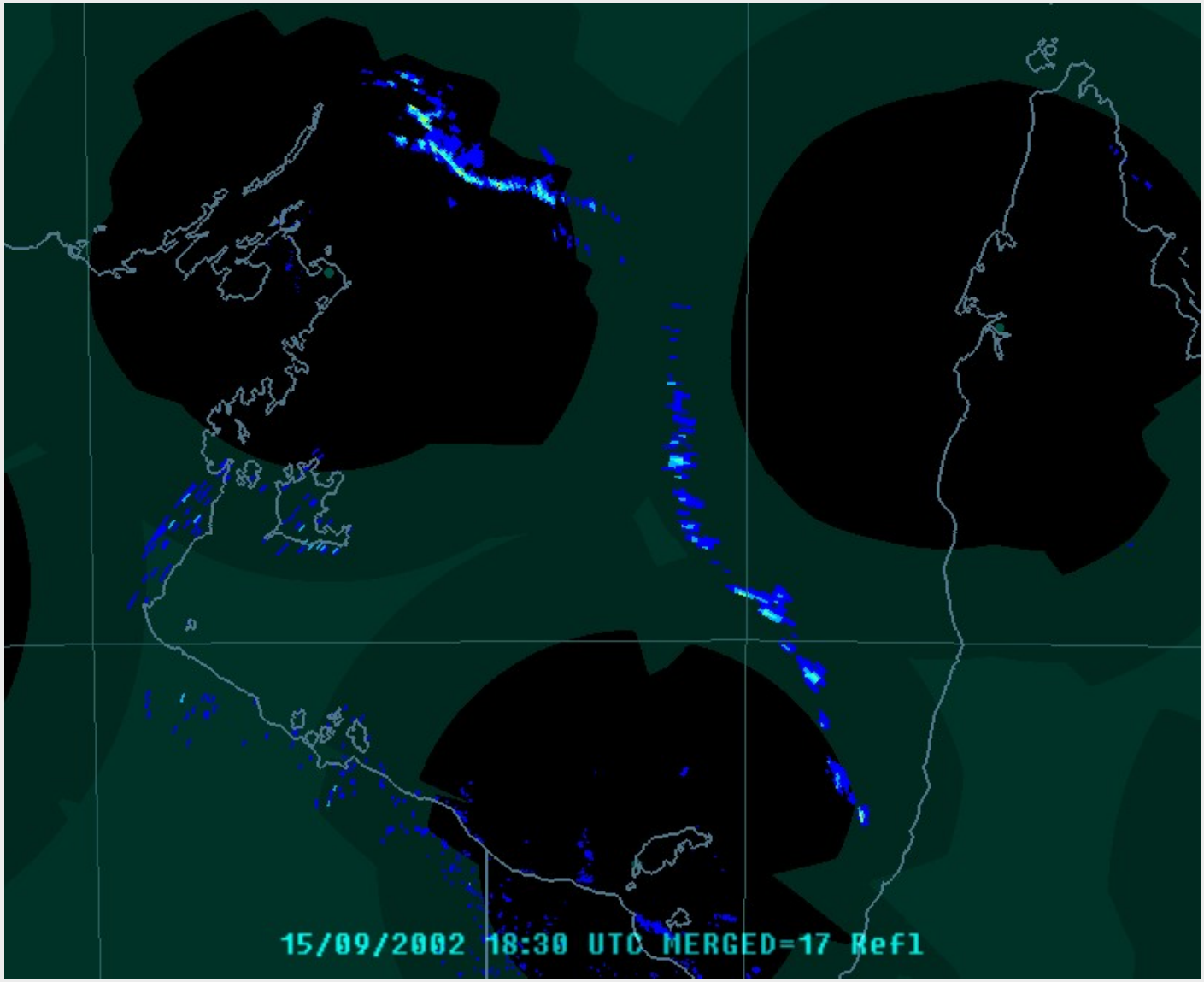
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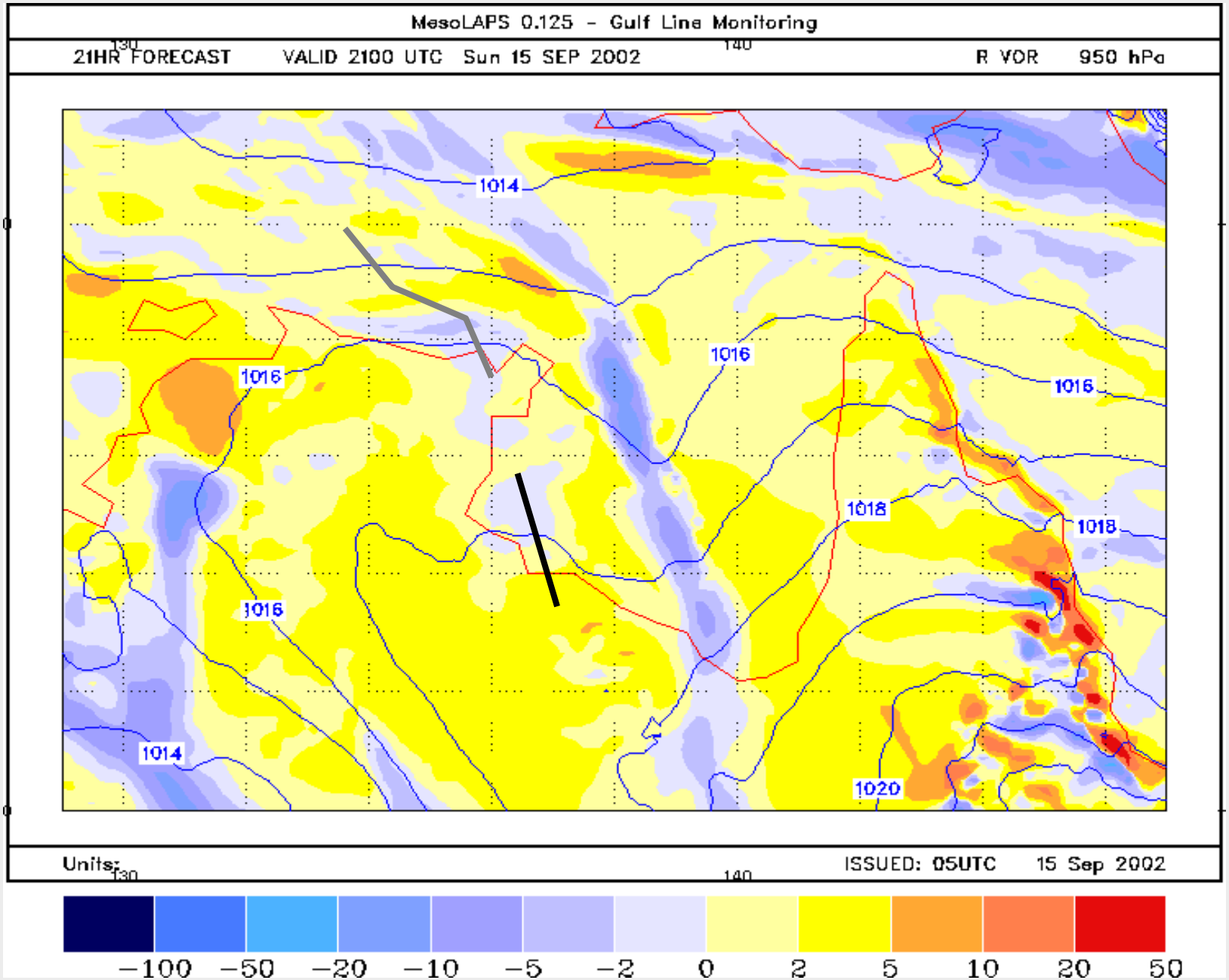

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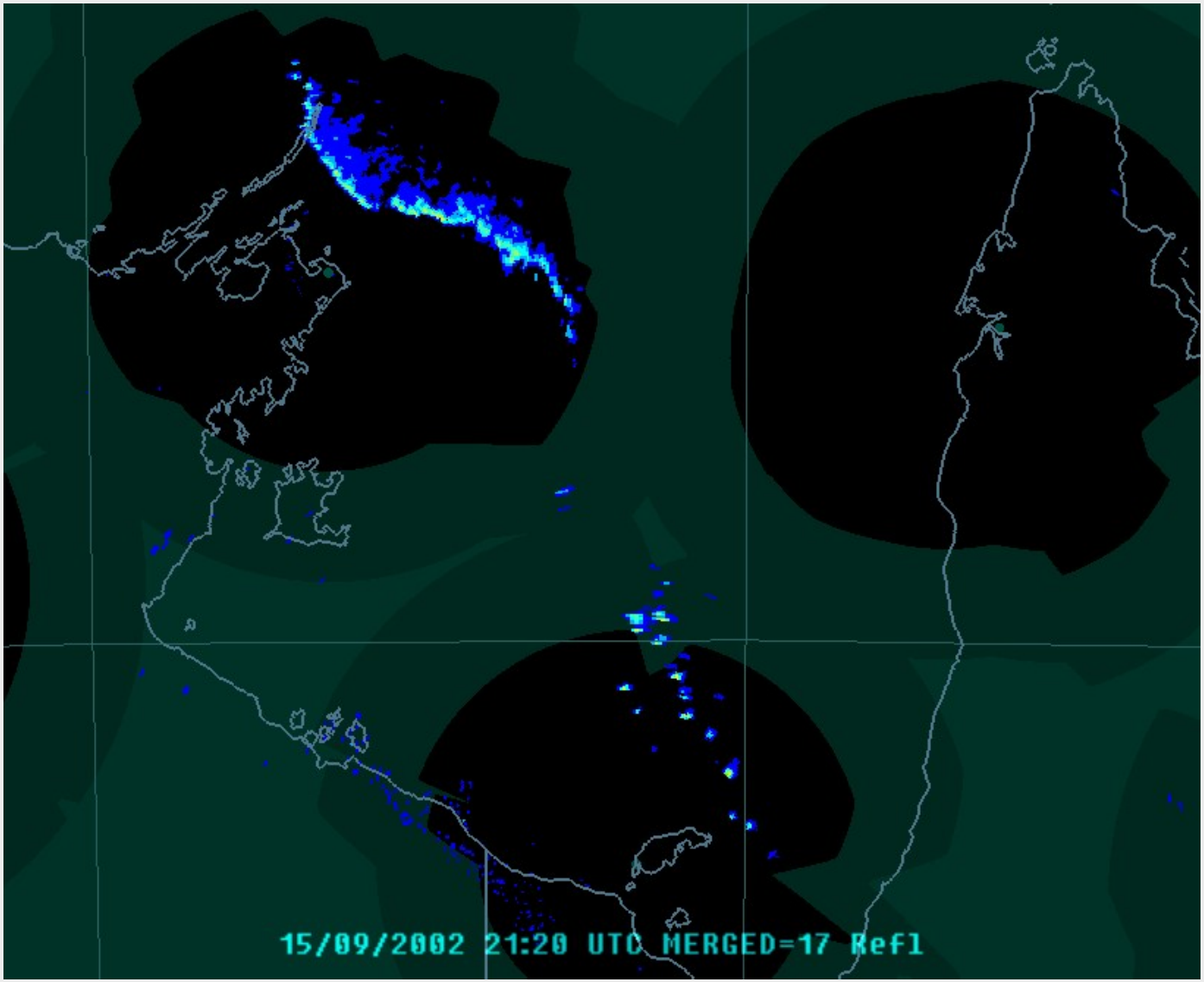
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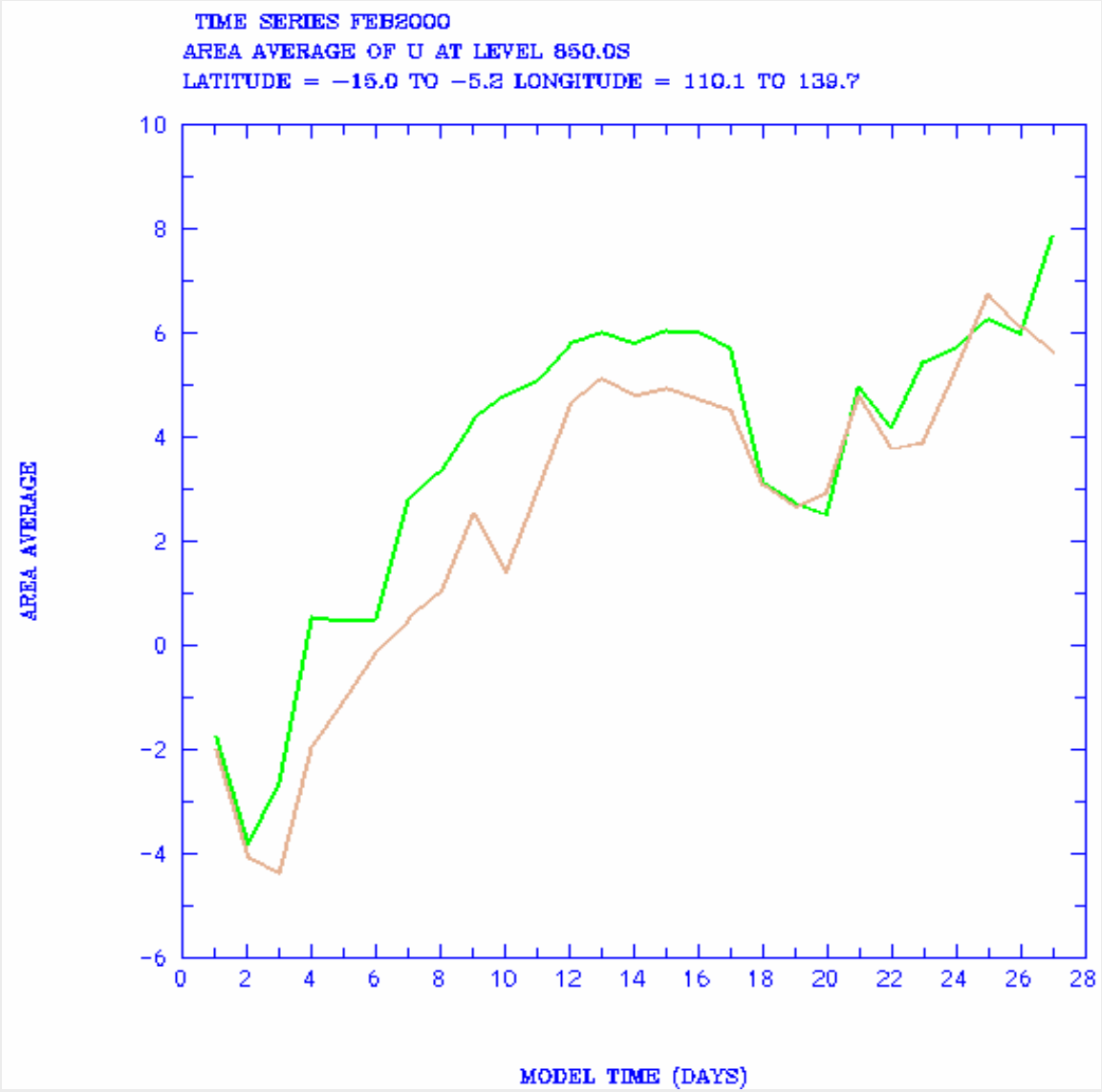
TLAPS forecasting of NW monsoon Feb 2000



__ observed zonal winds

__ 48 hr forecast zonal winds

Not perfect, but useful

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

Forecast Issued 5.00pm Thursday 12 Sep 2002

Darwin

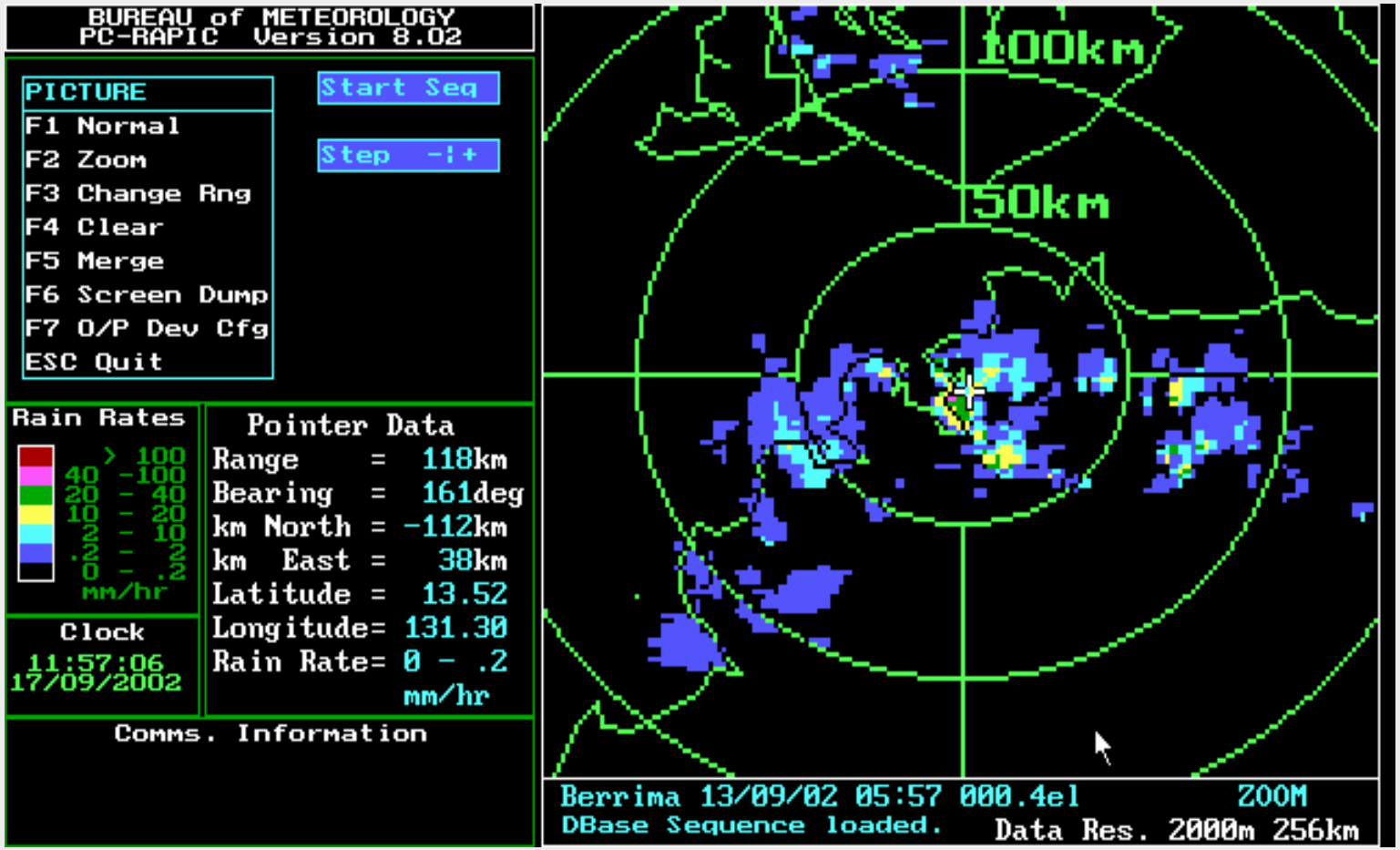
Fine and mostly sunny. Light winds with early afternoon seabreezes.

Forecast Issued 5.00am Friday 13 Sep 2002

Darwin

Fine, cloudy periods with a morning shower in the rural area. Light winds with early afternoon seabreezes.

The Result - Darwin Radar at 3.30pm Friday 13 Sep 2002



50 to 75 mm of rain in greater Darwin area

The Truth?

LETTERS
TO THE EDITOR
Northern Territory News,
PO BOX 1300, Darwin,
Northern Territory, 0801

E-MAIL US AT
NTNMAIL@NTN.NEWSLTD.COM.AU

Name, address and phone number of all writers MUST be supplied for verification

Capricious rain gods

WHO pays the weather bureau?

Haven't these guys learnt that they can't predict the weather in the Northern Territory?

Having lived in the Territory for some time, I have learnt that if the Bureau of Meteorology makes a bold prediction you generally believe the opposite.

Forecaster Graeme King was quoted in Friday's *Northern Territory News* as saying "It's just going to get hotter, without raining for now".

The rest is history.

DJ Thomas
Darwin

Is this forecast failure Uncommon?

Answer: NO

we were unable to correctly forecast the next three occasions of substantial rain in Darwin this wet season

Verification of Severe Storm Warnings for Darwin

	Forecast			Not Forecast		
	99/00	00/01	01/02	99/00	00/01	01/02
Observed – long lived squall line	0	0	0	2	1	1
Observed – other severe thunderstorms	0	0	1	4	9	10
Not Observed	1	0	0			

One correct forecast out of 27 events in 3 years

Are these problems limited to Darwin?

Answer: NO

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 depressions
- 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

SUMMARY

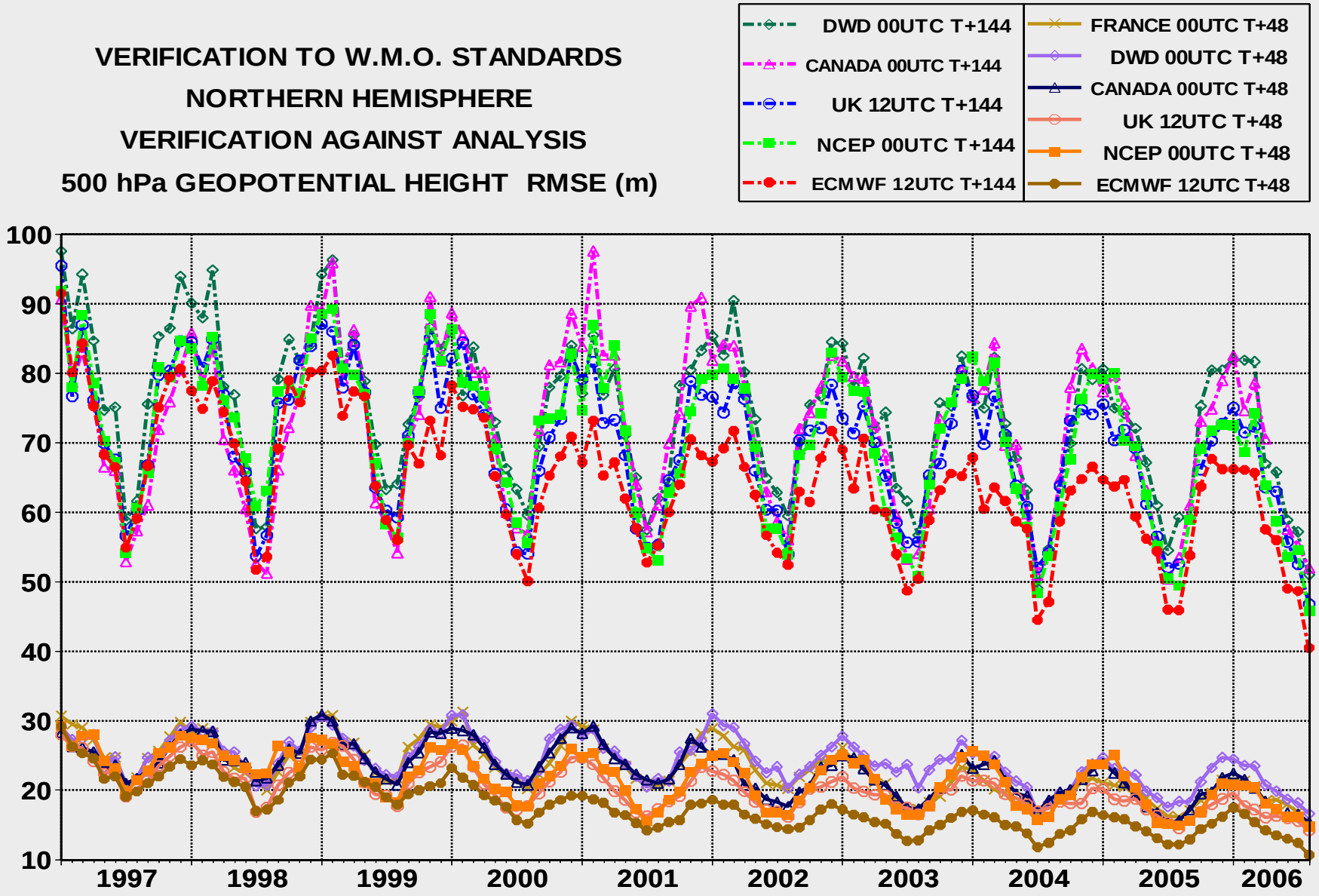
- Forecasting in the tropics has no credibility??
- Need systematic study of tropical NWP output
- Transfer of knowledge gained from these studies to forecasters
- Need more researchers living and working in the tropics

Gross scores

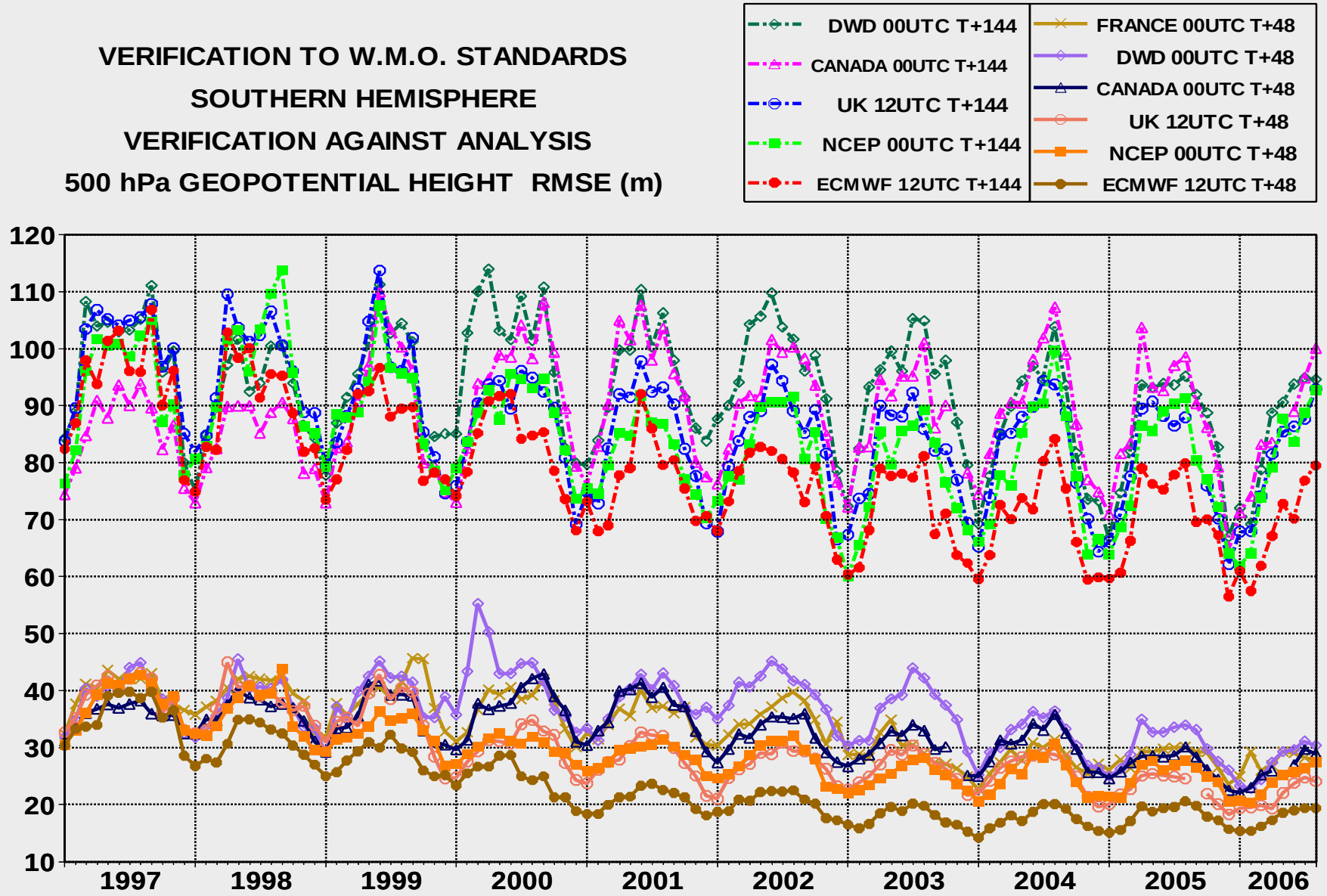
Performance of global operational forecast models

- The WCRP/CAS Working Group on Numerical Experimentation (WGNE) routinely reviews the skill of daily forecasts from a number of operational centres
- This long-term record of consistent verification **(to WMO Standards)** provides a very useful indication of improvements and deficiencies in the various models

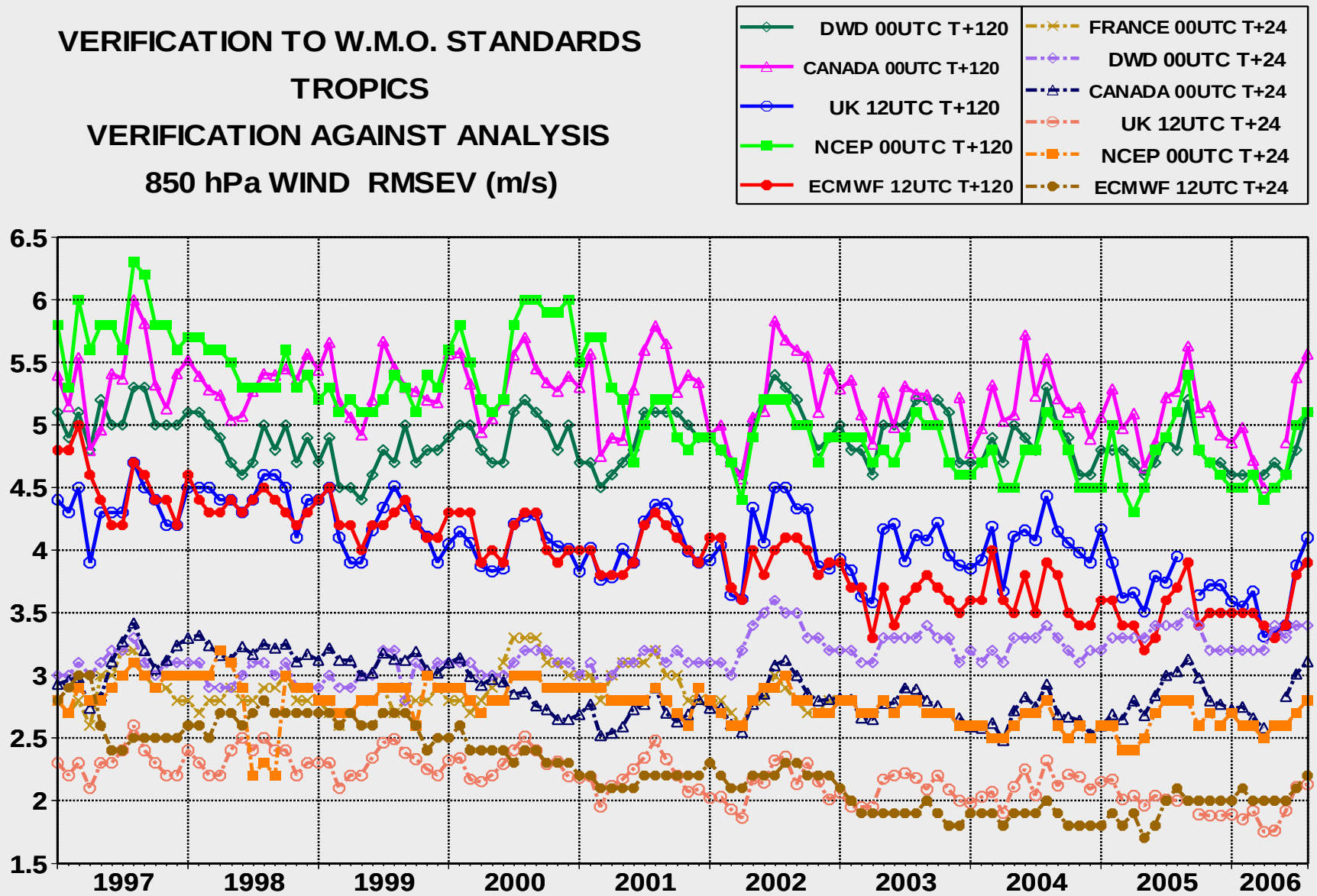
Time series Z500 N Hemisphere



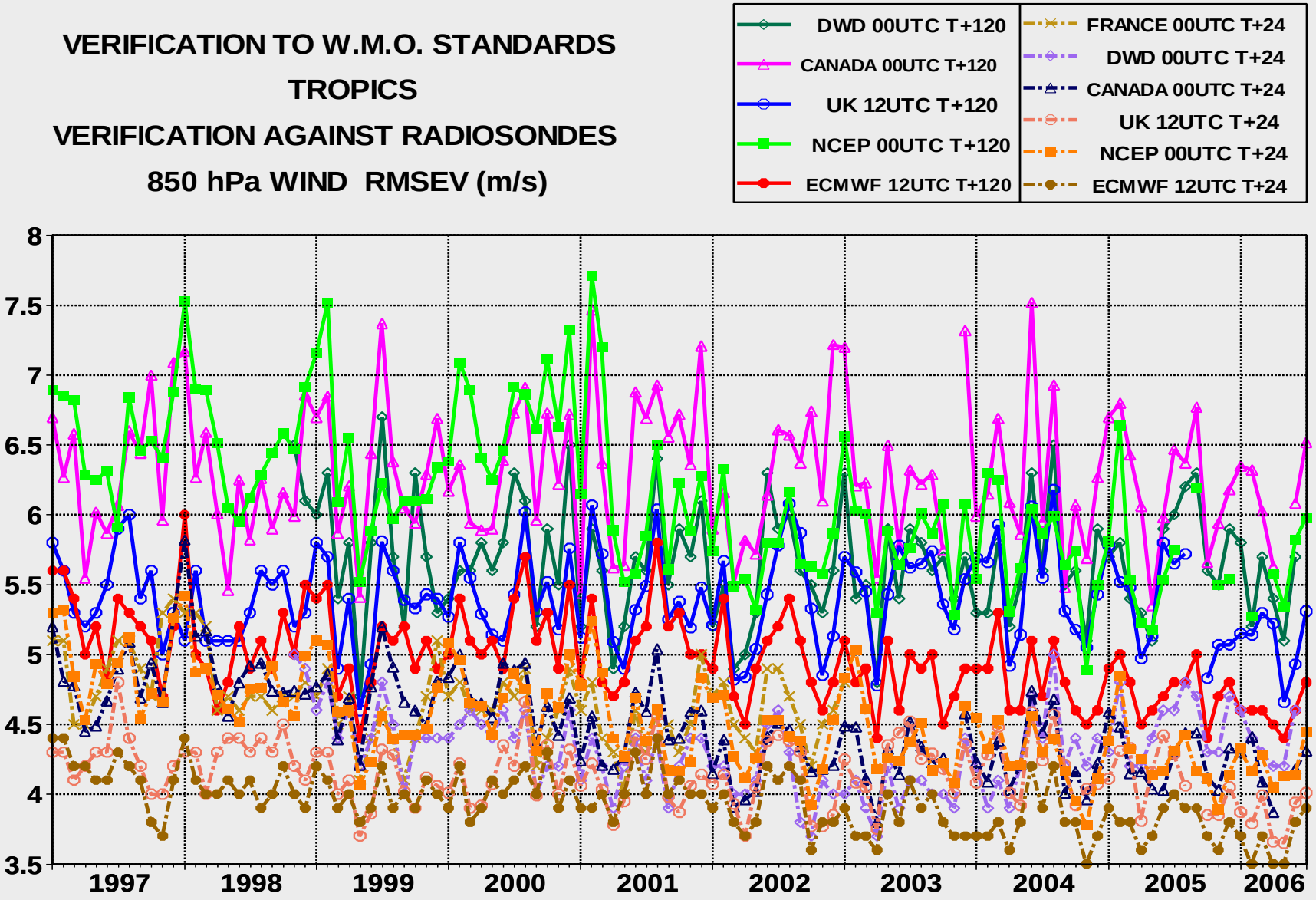
Time series Z500 S Hemisphere



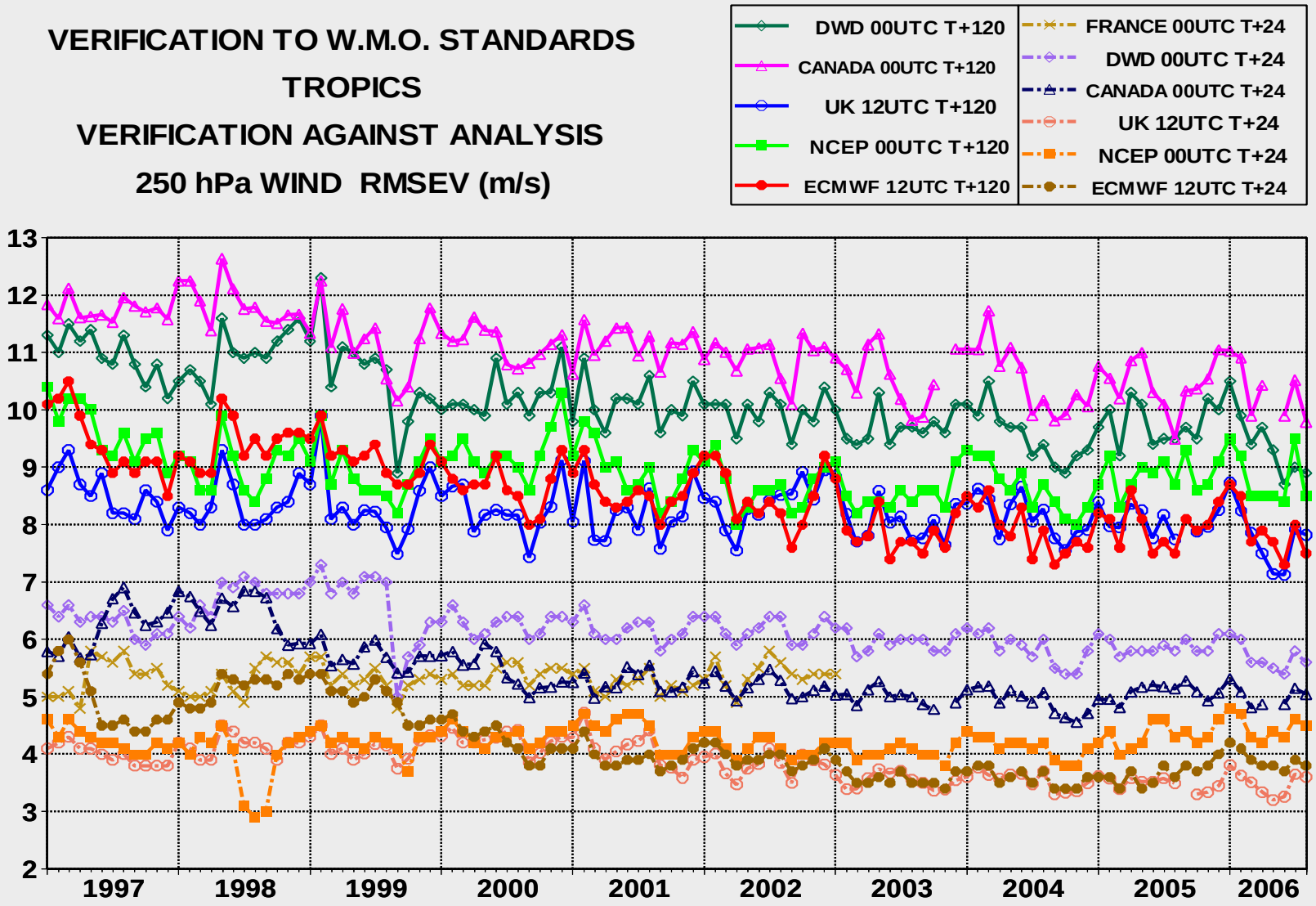
Time series VW 850 tropics



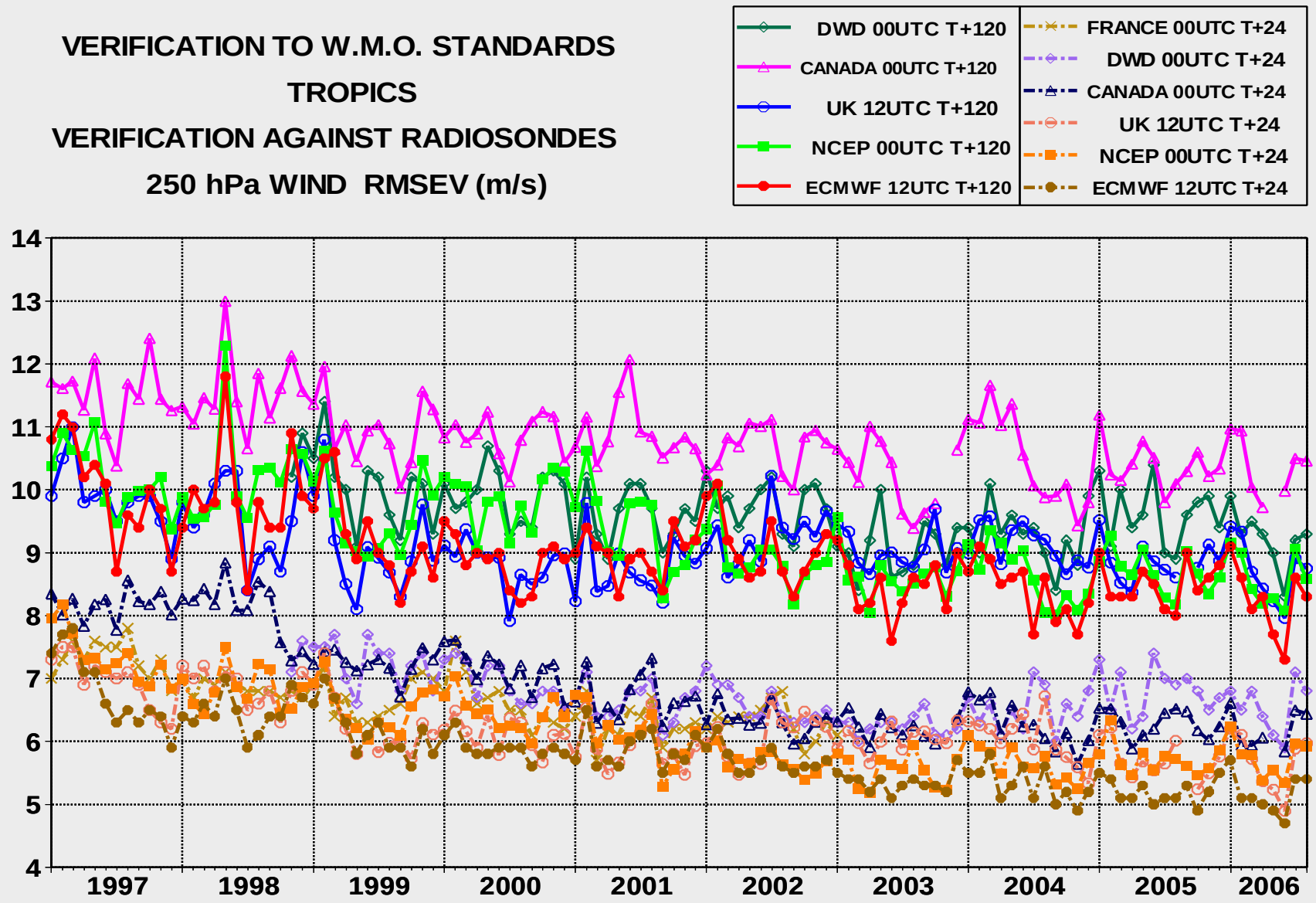
Time series VW 850 tropics (v observations)



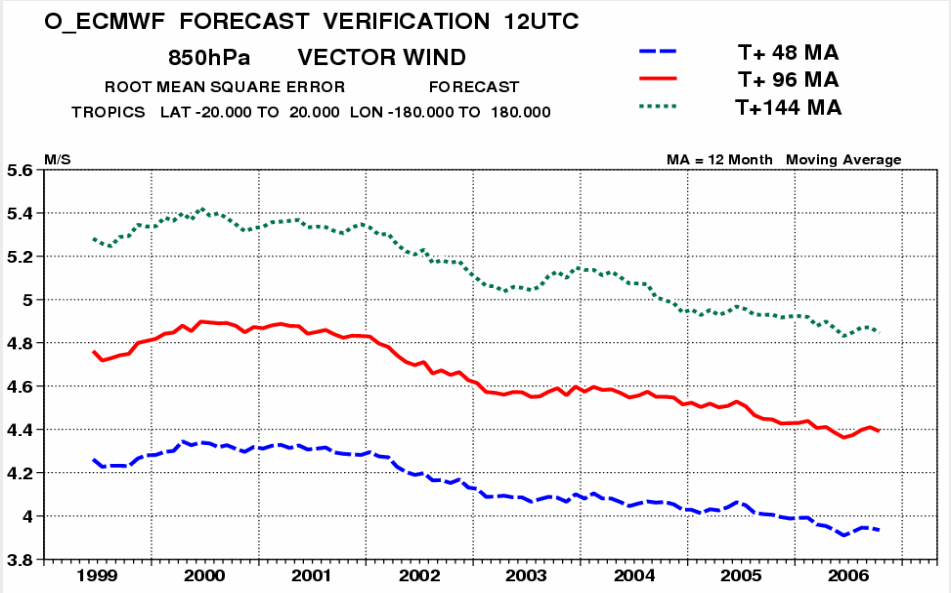
Time series VW 250 tropics

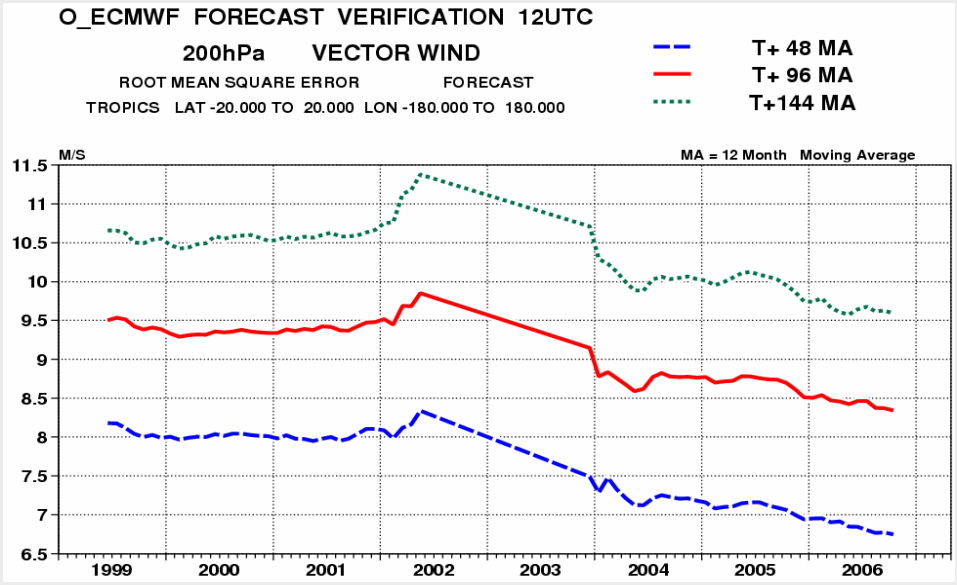


Time series VW 250 tropics (v observations)

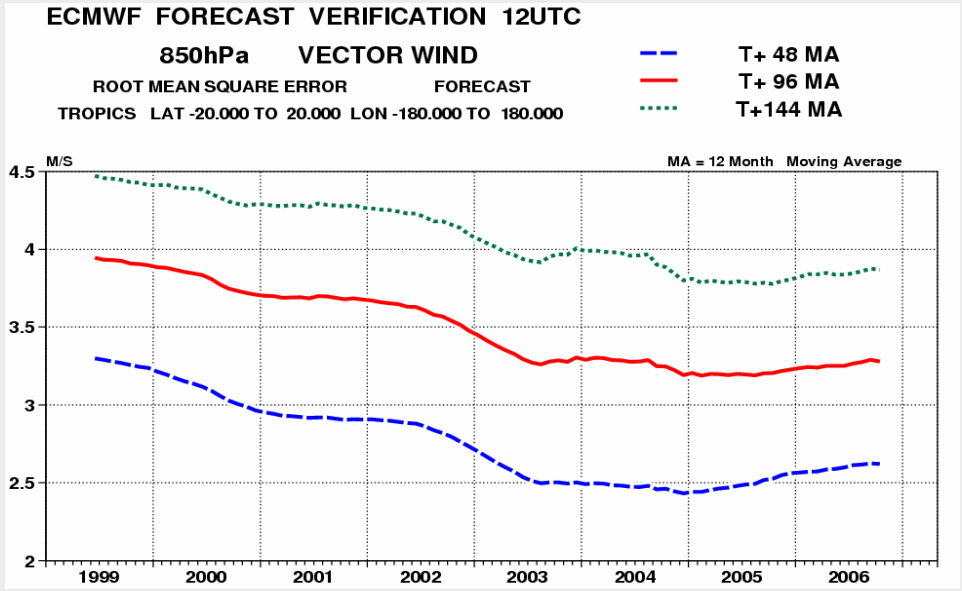


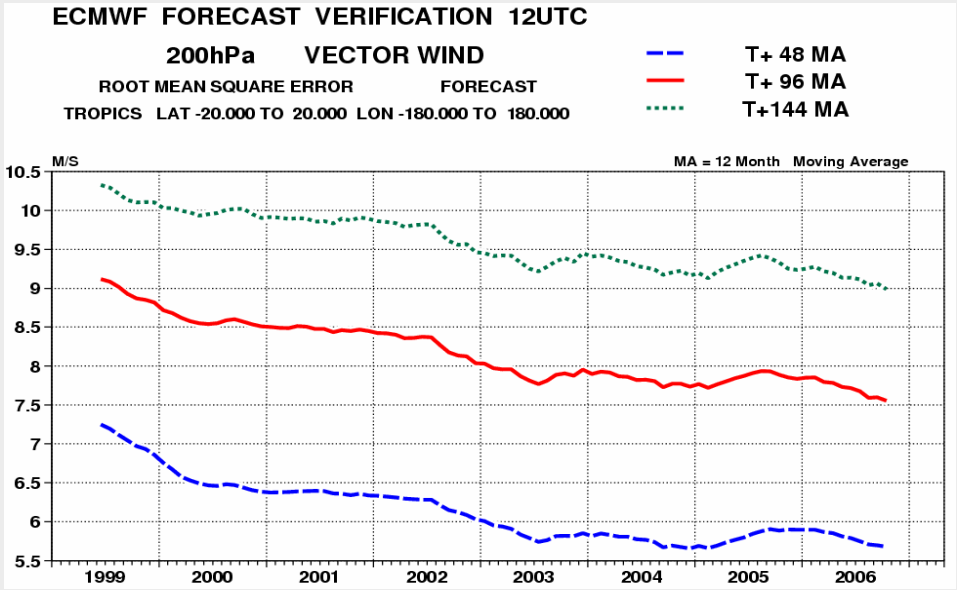
Verifications against radiosondes





Verifications against analyses





~2-day improvement in 8 years

ECMWF system

Precipitation prediction

Quantitative Precipitation Forecasts over Australia from Operational NWP Models

Results for 2005-06

Beth Ebert

BMRC

WGNE annual meeting, 2006

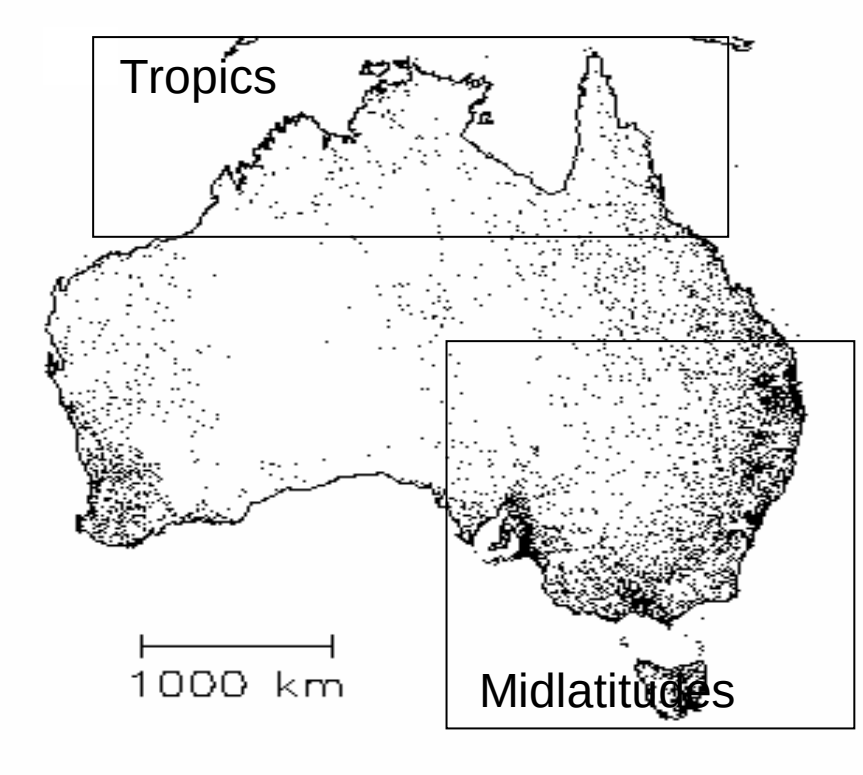
Operational model forecasts

Operational Center	Start Year
Australia (global and regional)	1997
Canada	2000
ECMWF	1997
Germany	1997
Japan	1997
United Kingdom	1997
United States	1997

Additional forecasts

Forecast	Description
AVG	Ensemble mean
PM	Probability matched ensemble mean: 1. Derive ensemble mean QPF 2. Transform rain rates to match the probability distribution of the ensemble of QPF
Persistence	Previous day's observed rain

Verifying data



0.25° resolution objective analysis, averaged onto:

- 1° grid (continuing previous years verification)
- 0.5° grid (following recommendations)

Selected verification scores

Bias and equitable threat scores

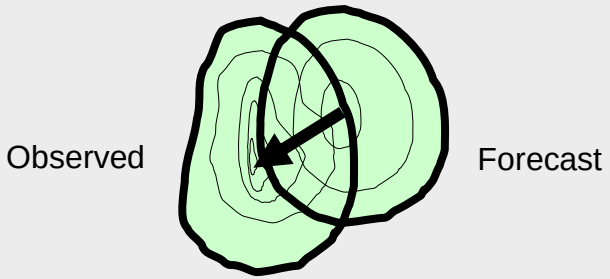
$$BIAS = \frac{hits + false\ alarms}{hits + misses}$$

$$ETS = \frac{hits - hits_{random}}{hits + misses + false\ alarms - hits_{random}}$$

Thresholds of 1 mm/day (~ all rain) and 20 mm/day (heavy rain)

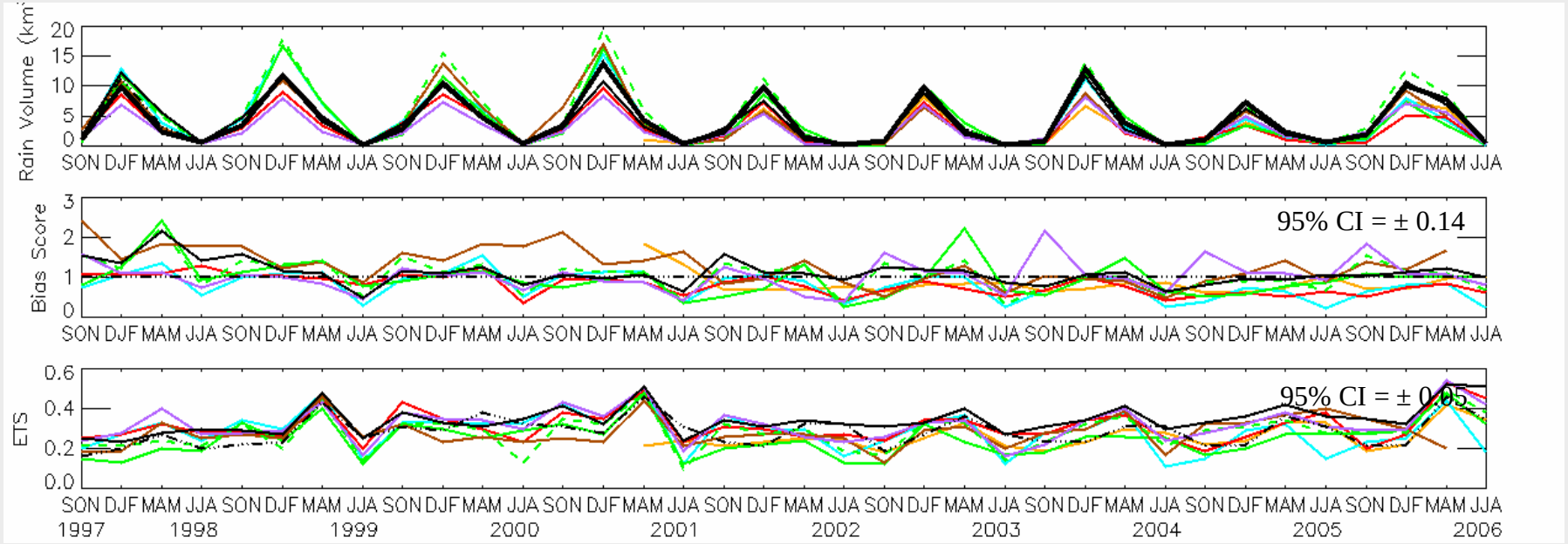
Location error

Determined using pattern matching of contiguous rain areas (CRAs)

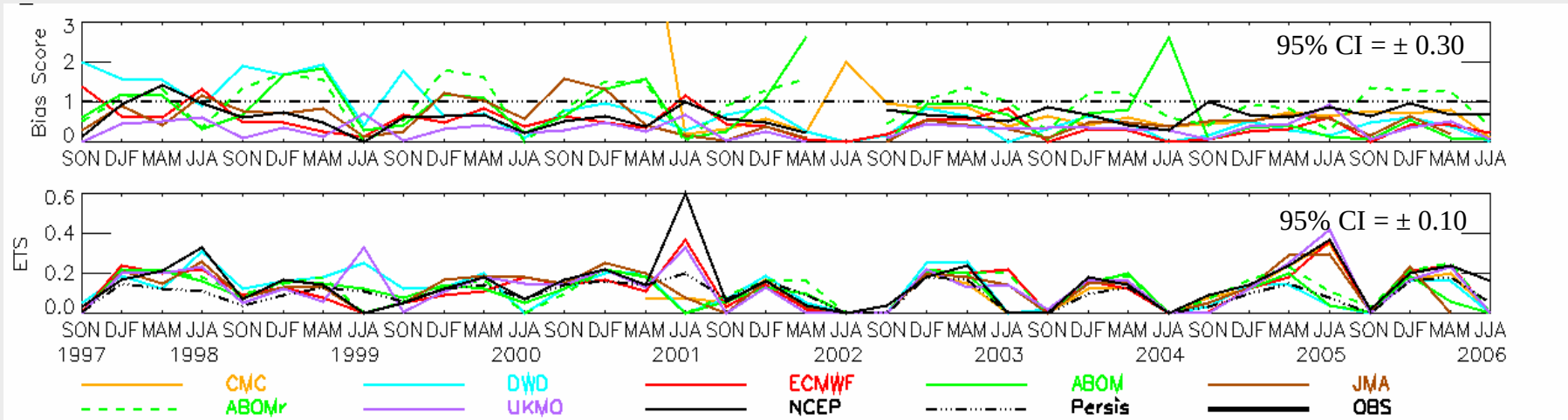


Results for tropical Australia

24 h forecasts, rain ≥ 1 mm/day, 1° resolution

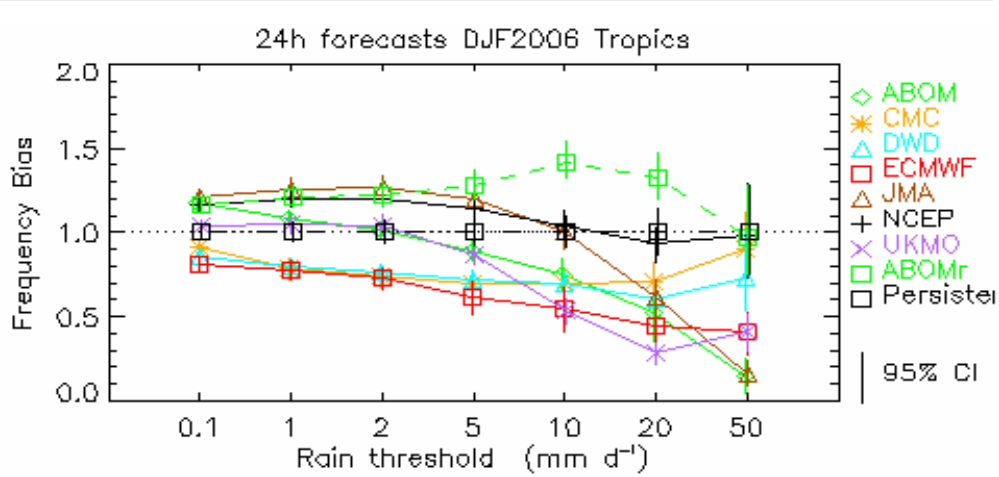


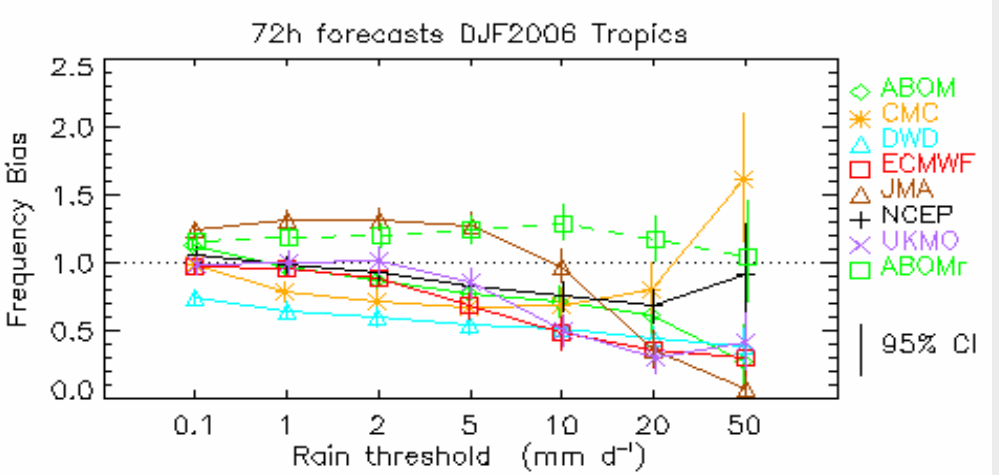
24 h forecasts, rain ≥ 20 mm/day, 1° resolution

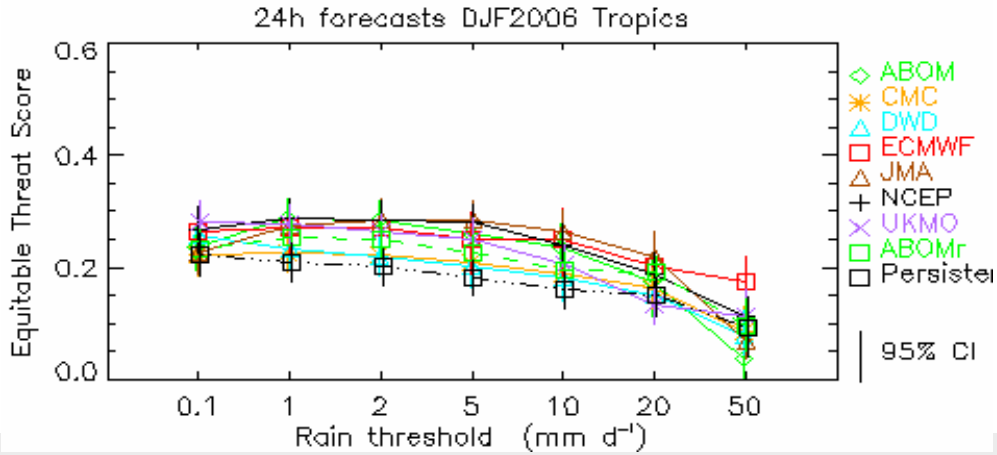


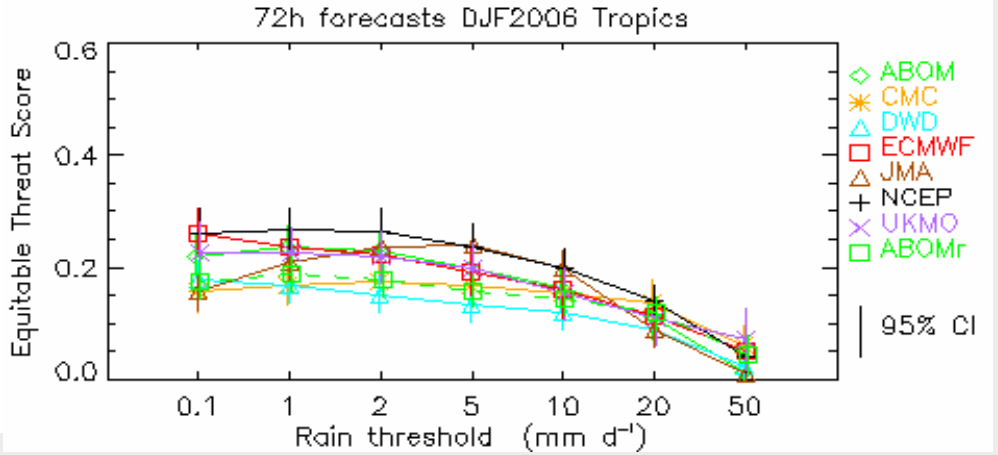
Results for tropical Australia

Summer 2005-2006, 0.5° resolution



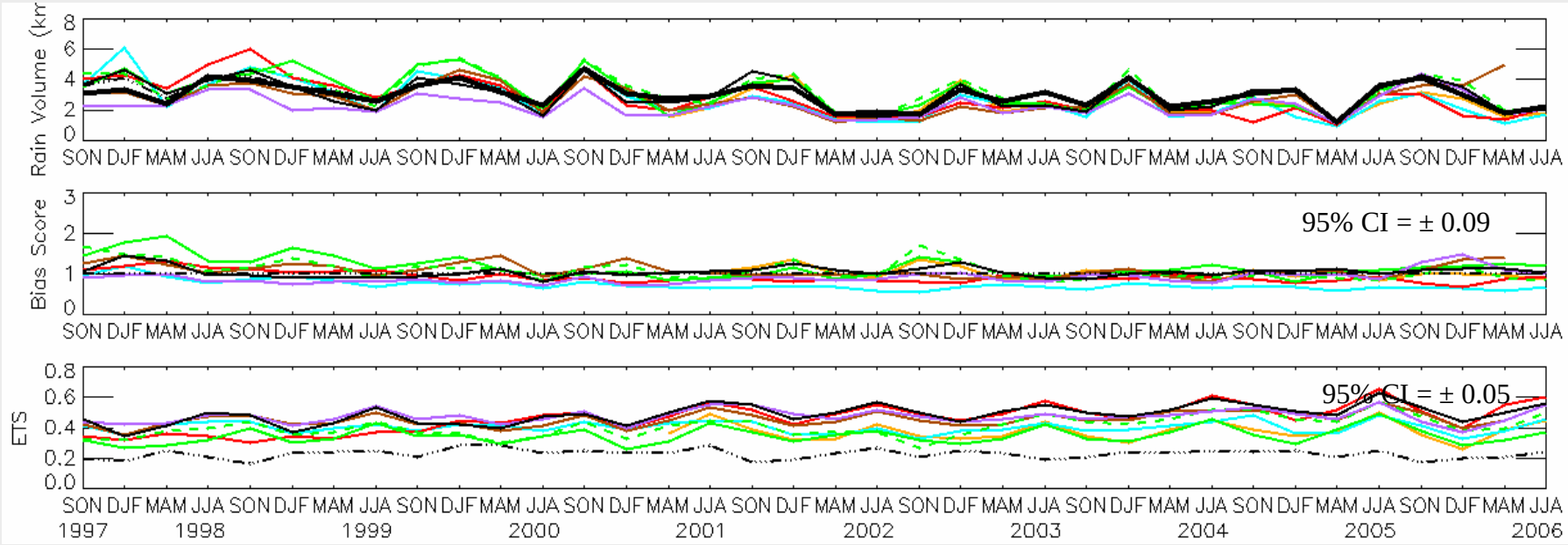




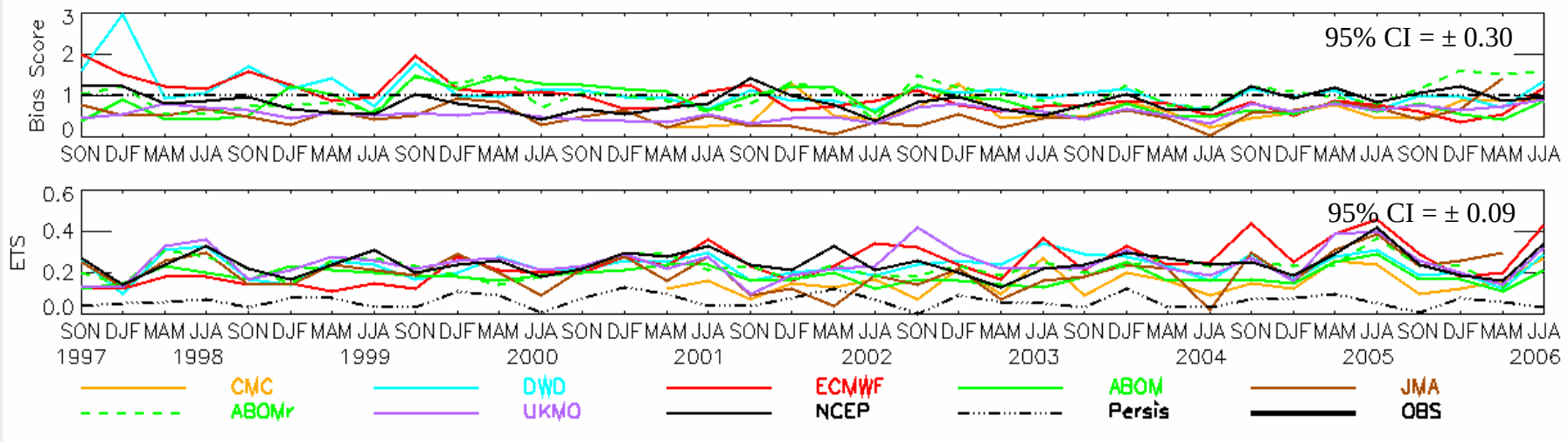


Results for mid-latitude Australia

24 h forecasts, rain ≥ 1 mm/day, 1° resolution

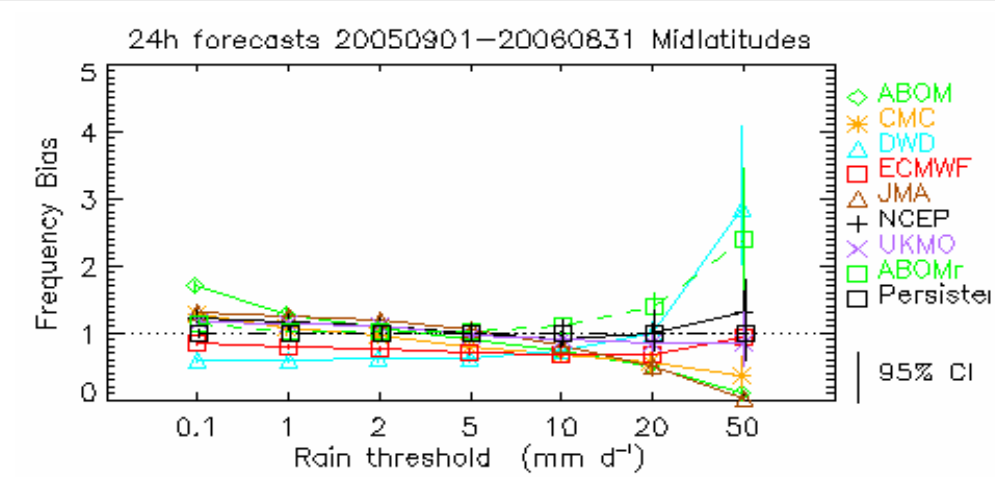


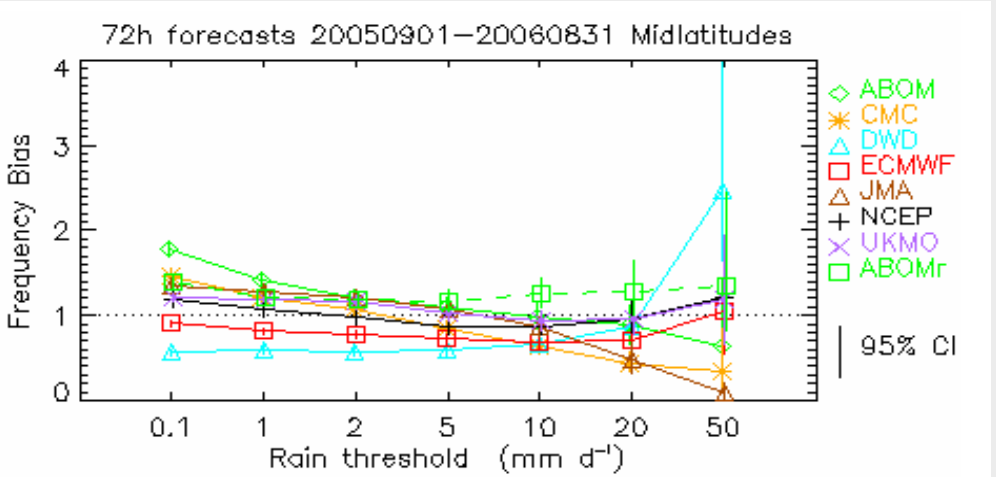
24 h forecasts, rain ≥ 20 mm/day, 1° resolution

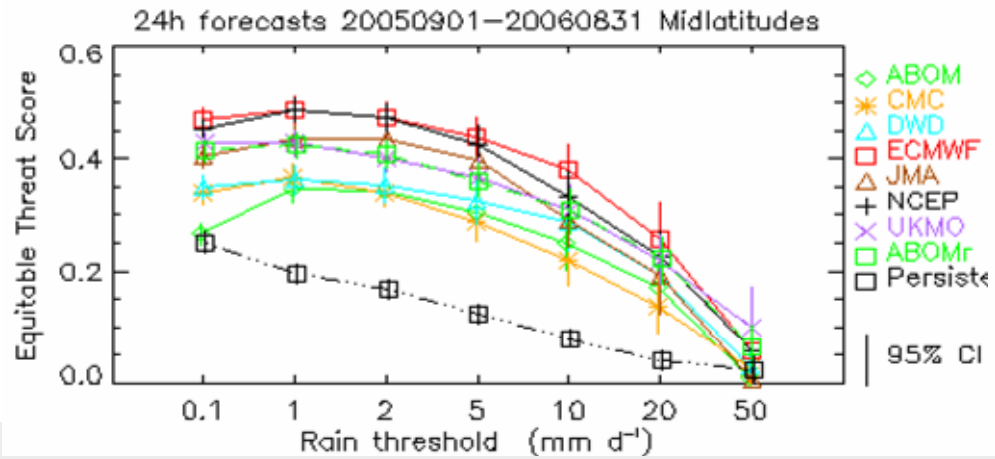


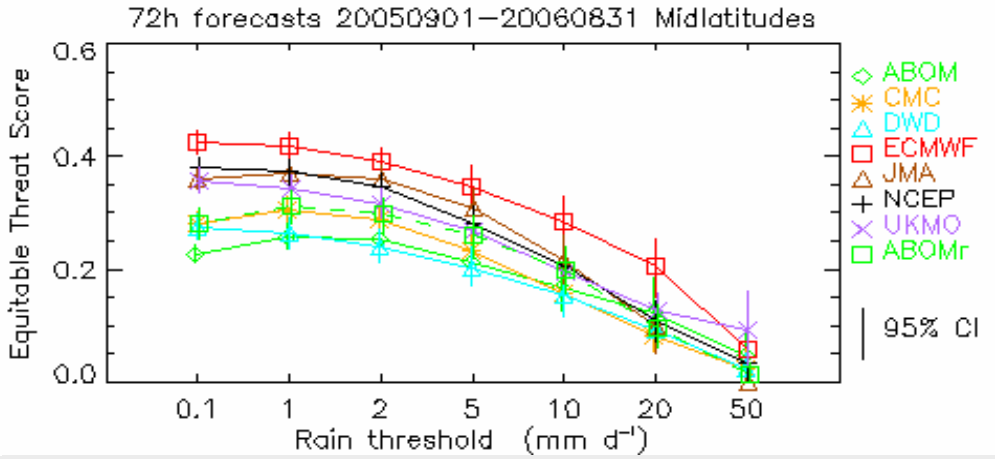
Results for mid-latitude Australia

September 2005 – August 2006, 0.5° resolution



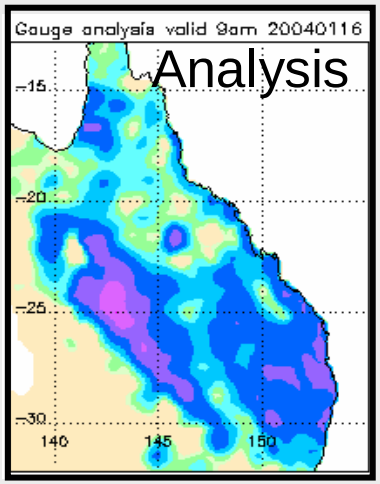


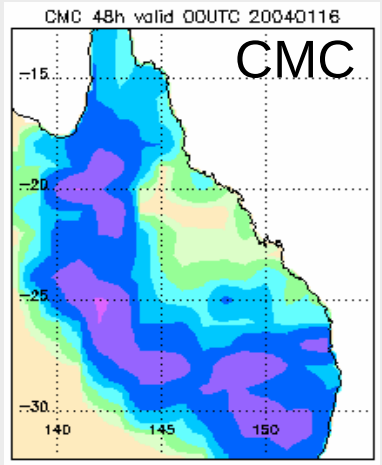


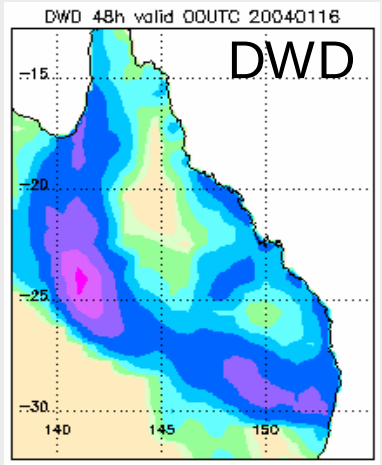


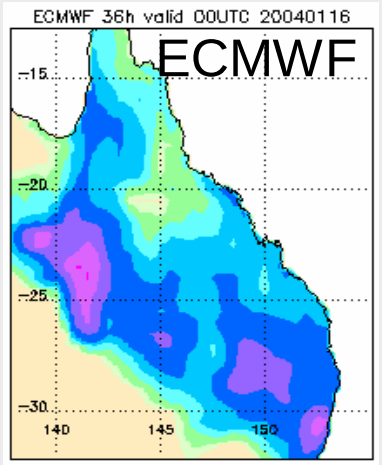
Flooding rains in central Queensland

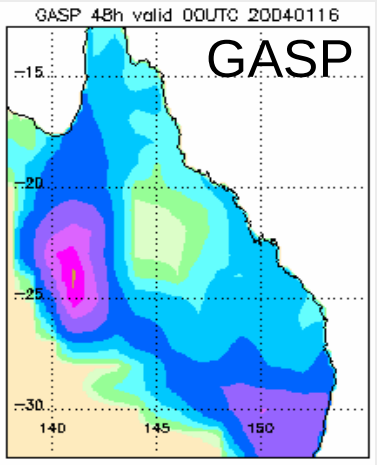
48 h fcsts
15 Feb 2004

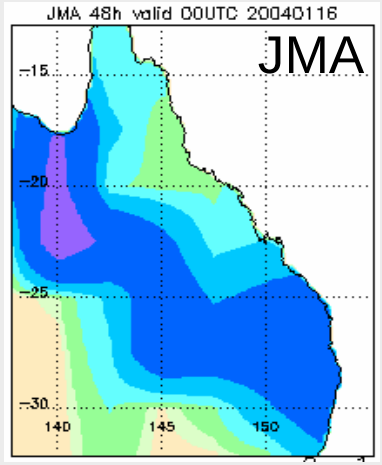


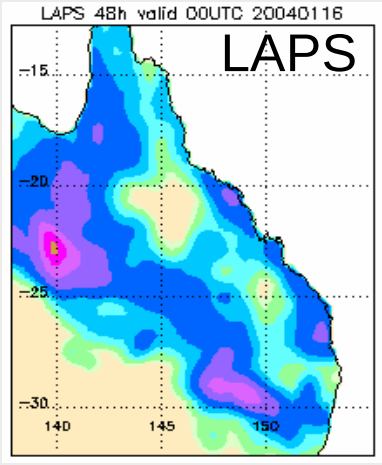


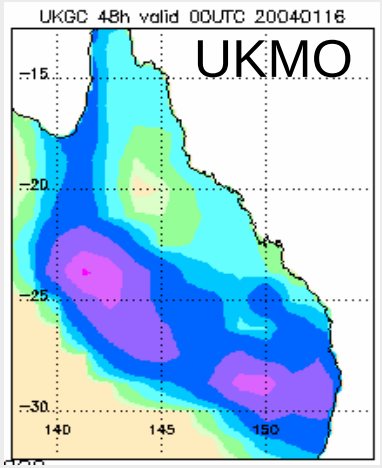


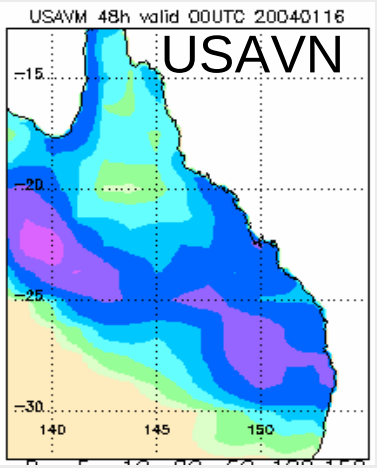










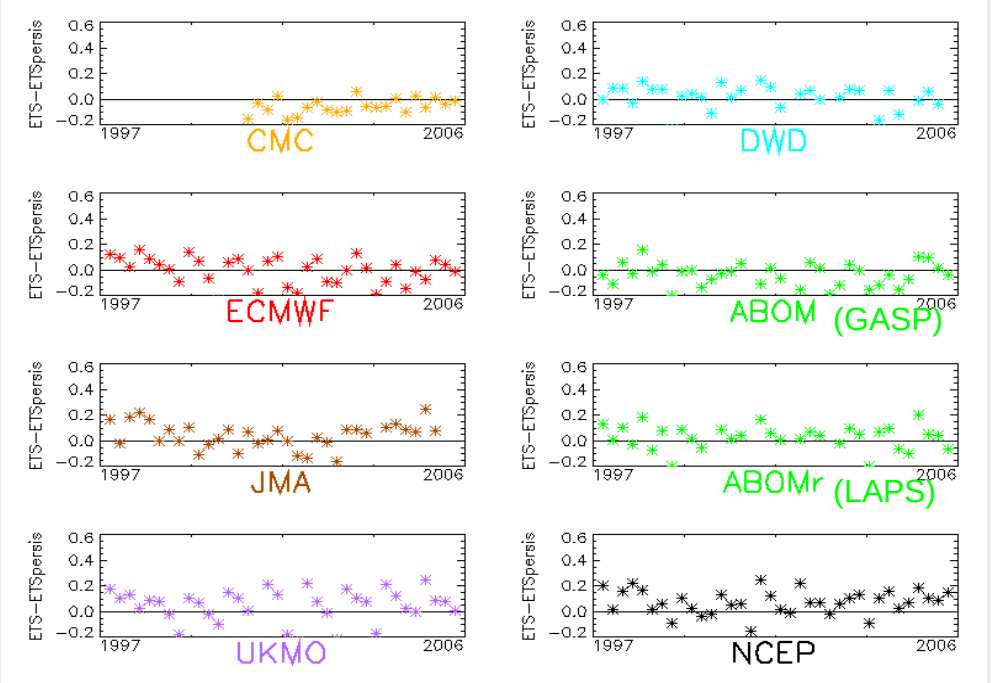


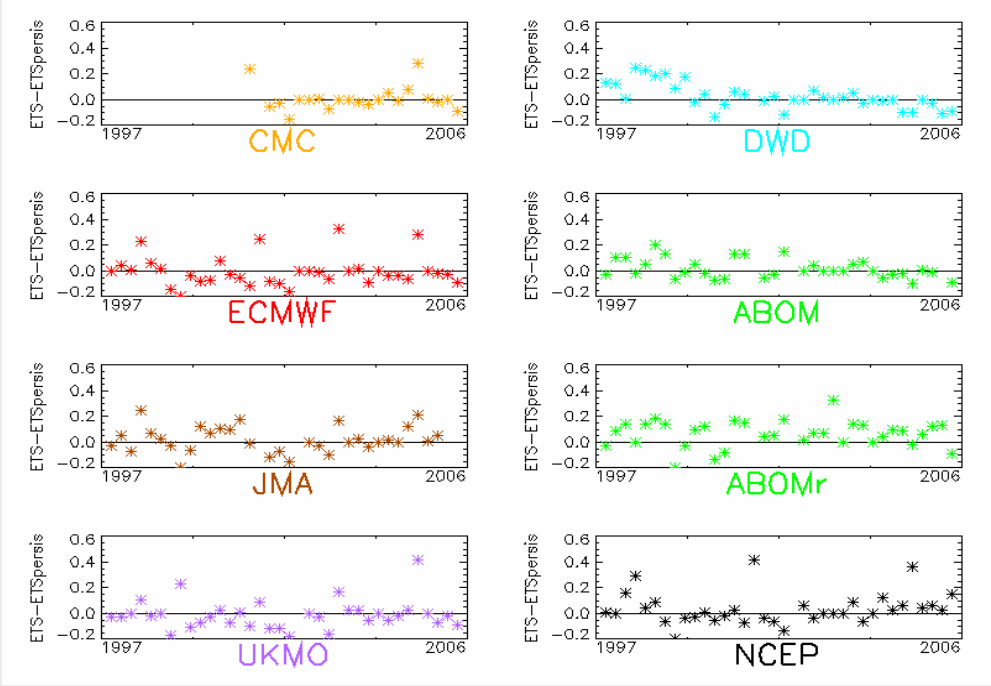
E. Ebert

Are model QPFs improving with time?

ETS_{model}-$ETS_{persistence}$ crudely accounts for "easier" weather

Seasonal values for tropical Australia
24 h forecasts, Sept 1997 - Aug 2006, 1° resolution





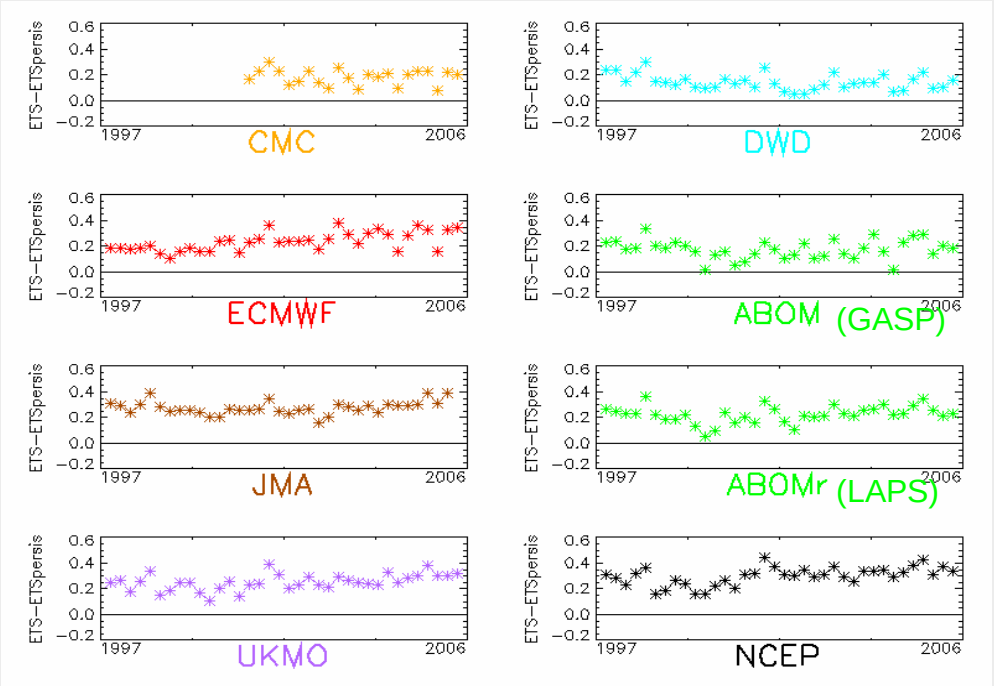
Rain ≥ 1 mm/day

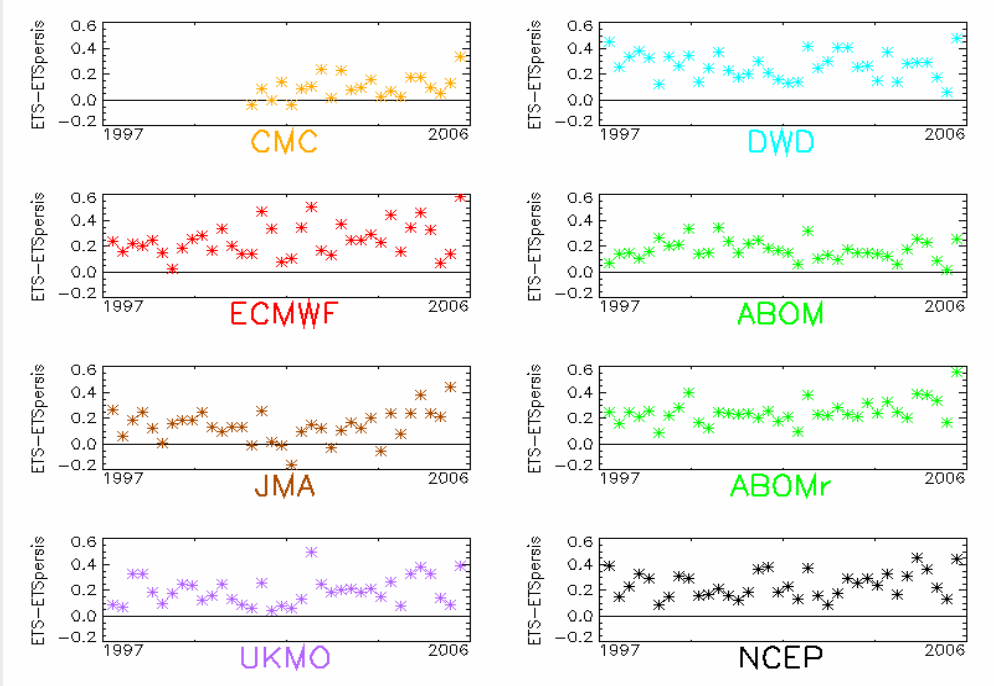
Rain ≥ 20 mm/day

Are model QPFs improving with time?

ETS_{model}-$ETS_{persistence}$ crudely accounts for "easier" weather

Seasonal values for mid-latitude Australia
24 h forecasts, Sept 1997 - Aug 2006, 1° resolution





Rain ≥ 1 mm/day

Rain ≥ 20 mm/day

Tropical cyclones

WGNE Intercomparison of Tropical Cyclone Track Forecast 2005

22nd session of CAS/WGNE, 25-27 October 2006, Boulder, Colorado, USA

Prepared by
Takuya Komori,
Munehiko Yamaguchi and Ryota Sakai
(NPD/JMA)

NWP Centers Data List

NWP Centers	*Participate Year*	*Bogus Data*	*Horizontal Res. of provided data*	*Model Res. as of 2005*
BoM	2003	Not used	0.75°x 0.75°	TL239L29 =>TL239L33
CMC	1994	Not used	1.0°x 1.0°	0.9°x 0.9°L28
DWD	2000	Not used	0.5°x 0.5°	40km L40
ECMWF	1991	Not used	0.5°x 0.5°	TL511 L60
JMA	1991	Used in WNP area	1.25°x 1.25°	TL319 L40
METEO FRANCE*1	2004	Used*2	0.5°x 0.5°	**TL358(C2.4)L41**
NCEP	2003	Used in the rare cases*3	1.0°x 1.0°	T254 L64 => T382 L64
UKMO	1991	Used	0.8333°x 0.5555° => 0.5625°x 0.375° (from 13th Dec. 2005)	0.8333°x 0.5555°L38 => 0.5625°x 0.375°L50

***1 METEO FRANCE data is up to T+72hr, others are at least up to T+120hr.**

***2 except for south Pacific and North Indian ocean**

***3 when the storm is not found in the first guess**

Verification Methods

- **Forecast Error (km)**

  The distance between the best track position and the forecast position

- **Detection Rate (%)**

Detection Rate (*t*) = A / B (*t*; forecast time)

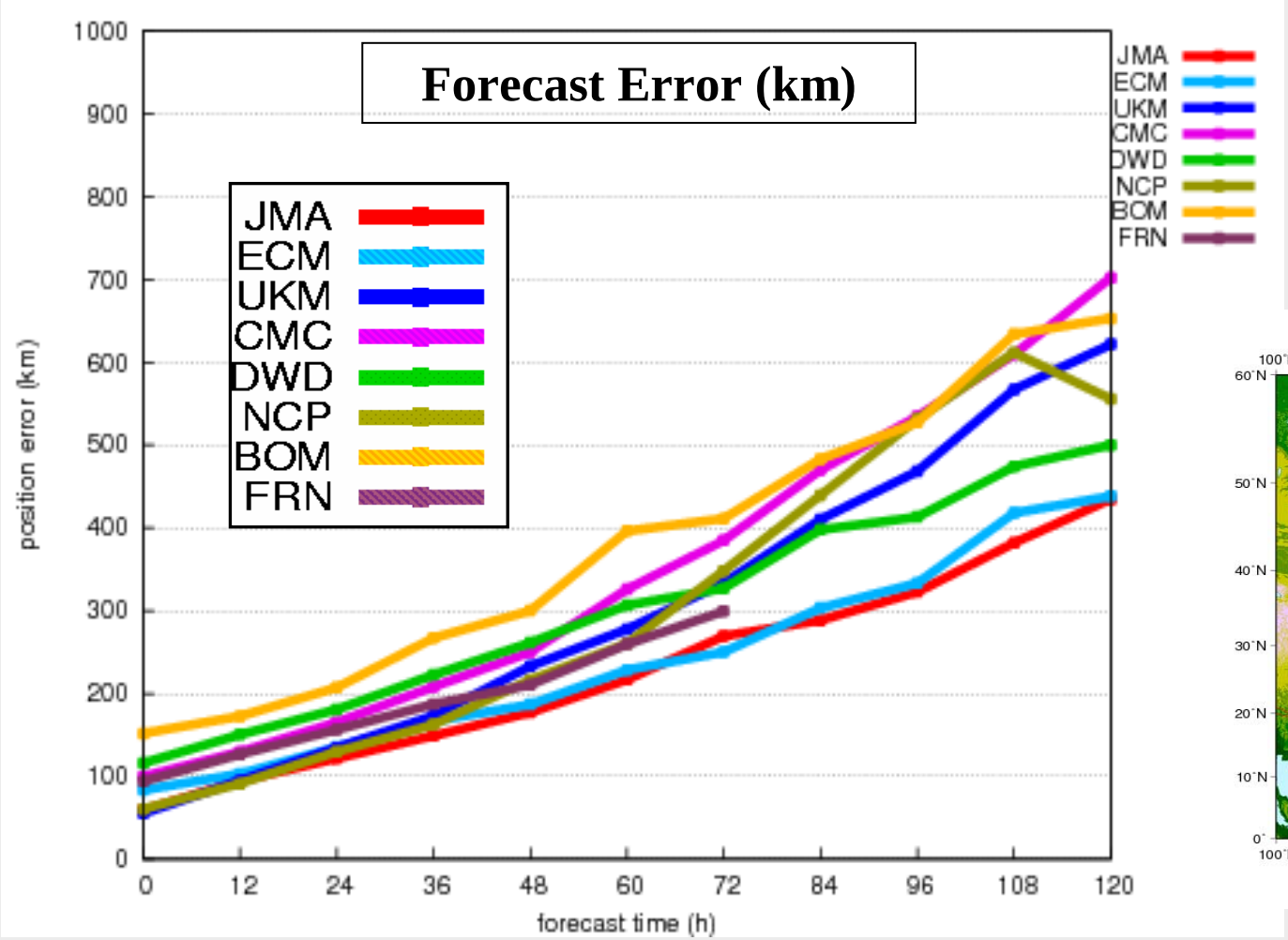
A: The number of initial times as a TC is analyzed at forecast time *t* and a NWP model tracks the TC at forecast time *t*.

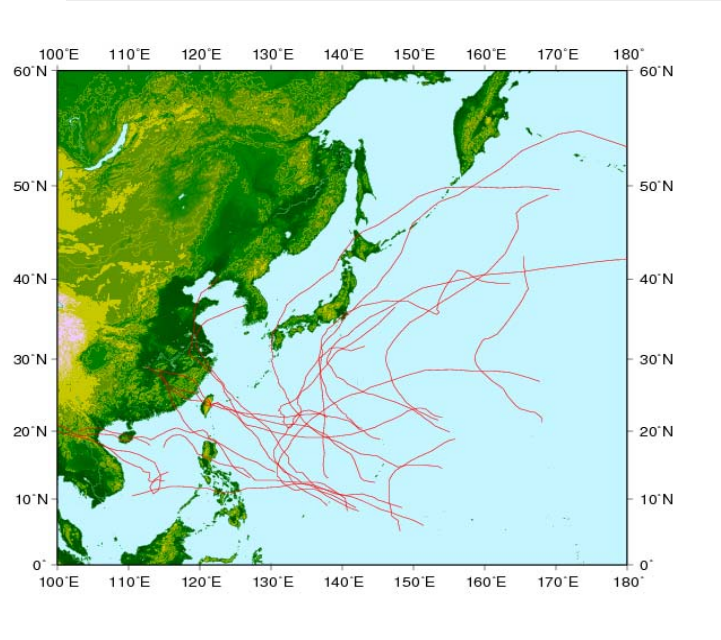
B: The number of initial times as a TC is analyzed at forecast time *t*.

Verification using both methods is important for inhomogeneous sample.

Verification of western North Pacific area

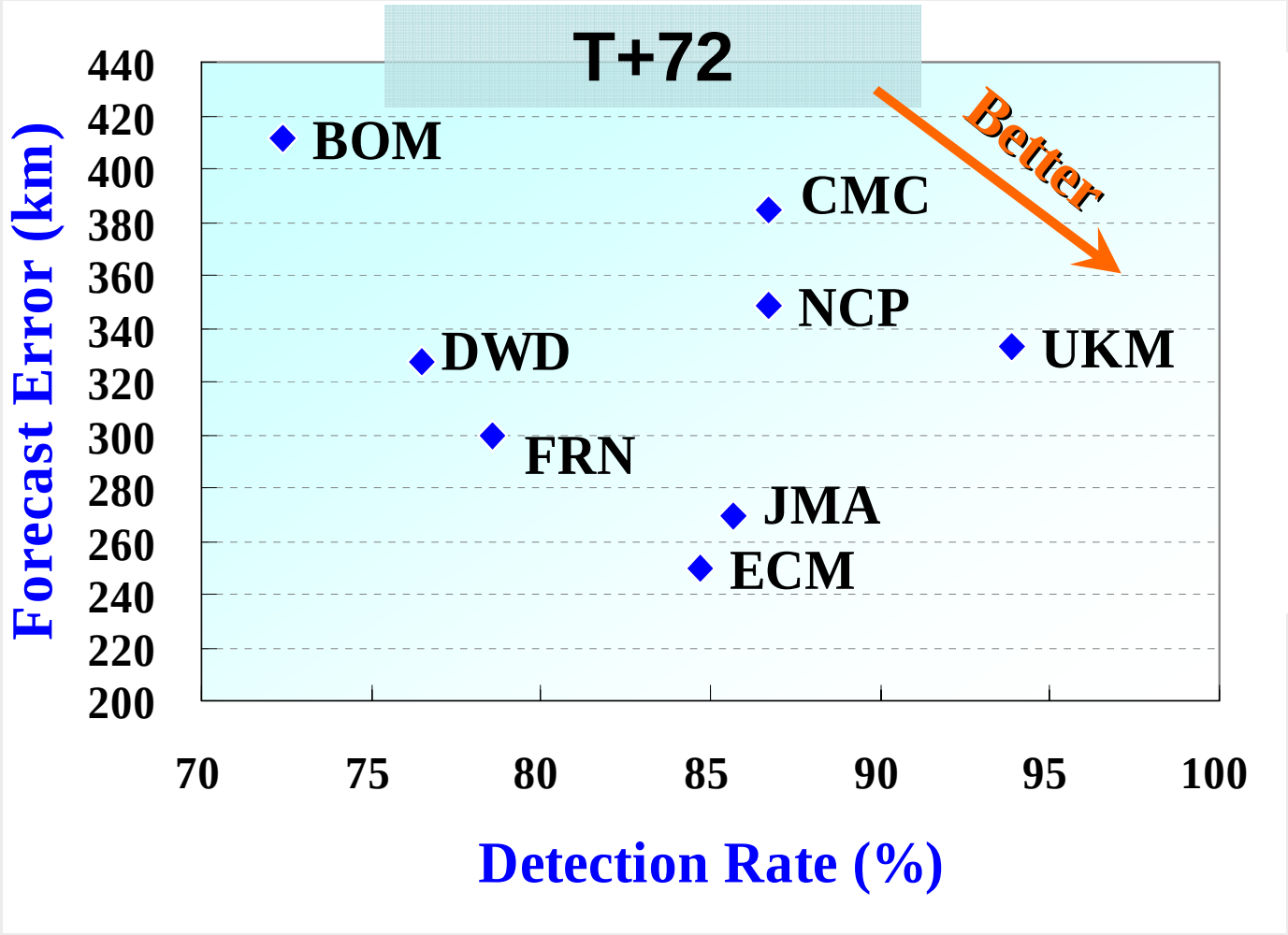
- 23 TC cases in 2005 -

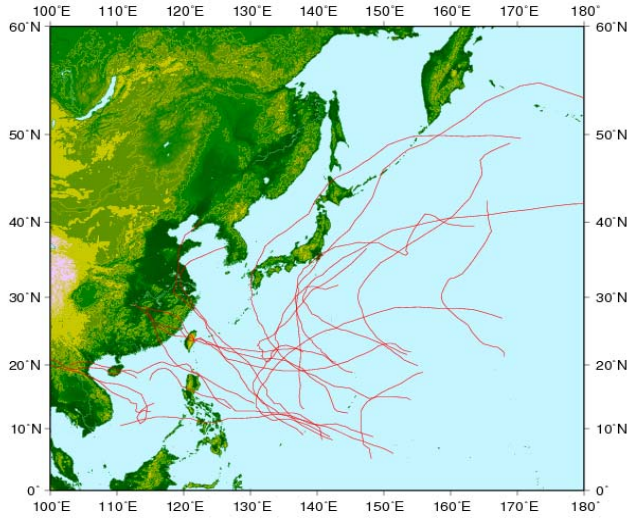




Verification of western North Pacific area

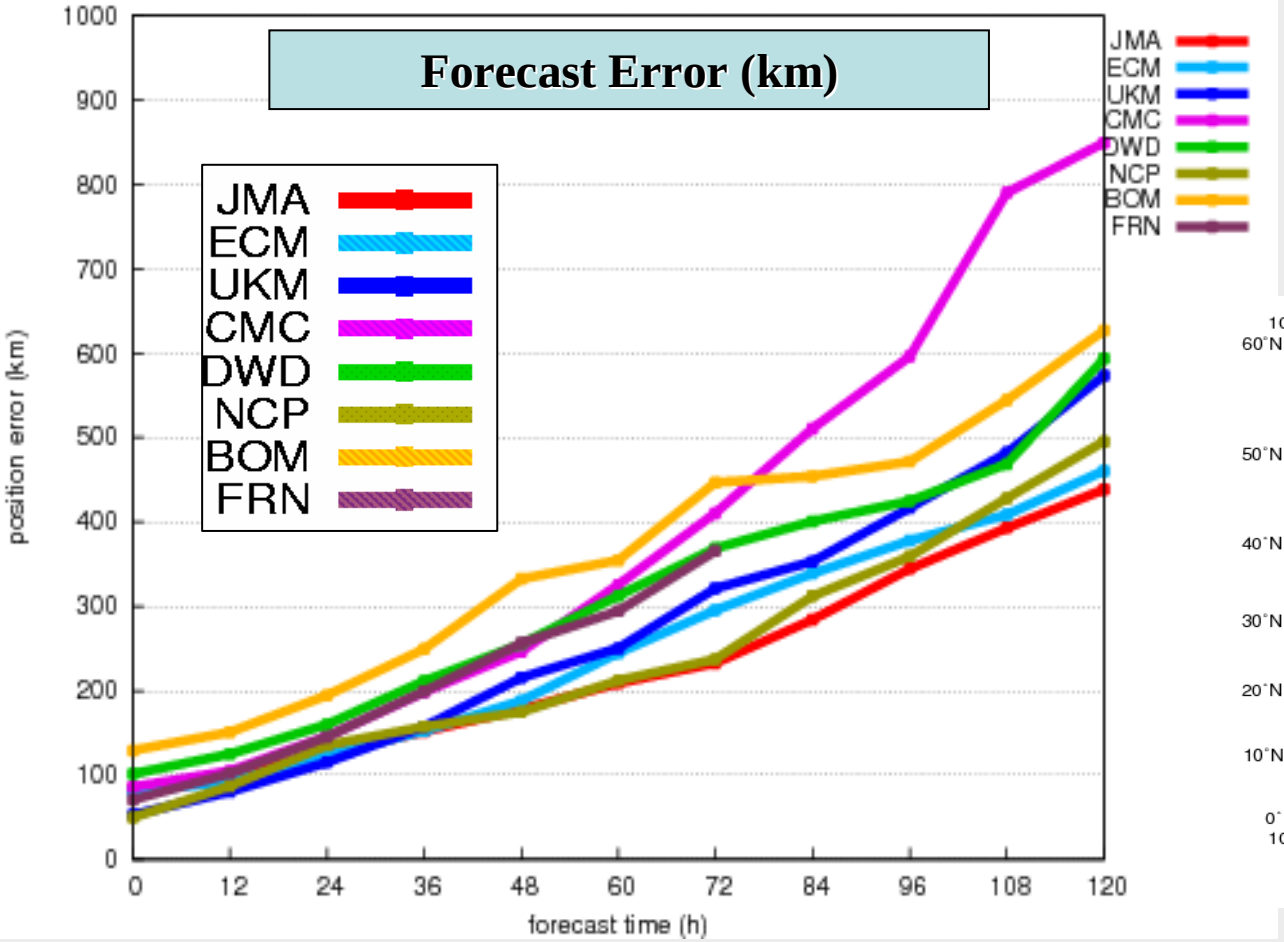
- 23 TC cases in 2005 -

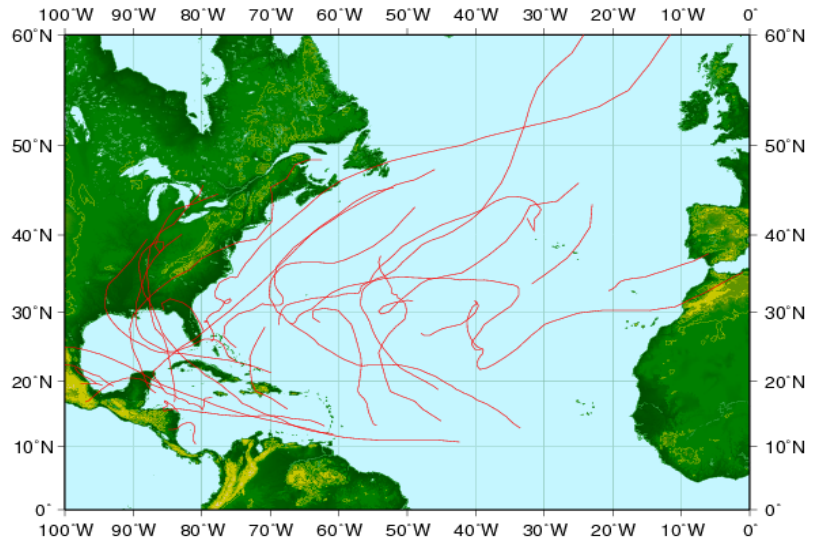




Verification of North Atlantic area

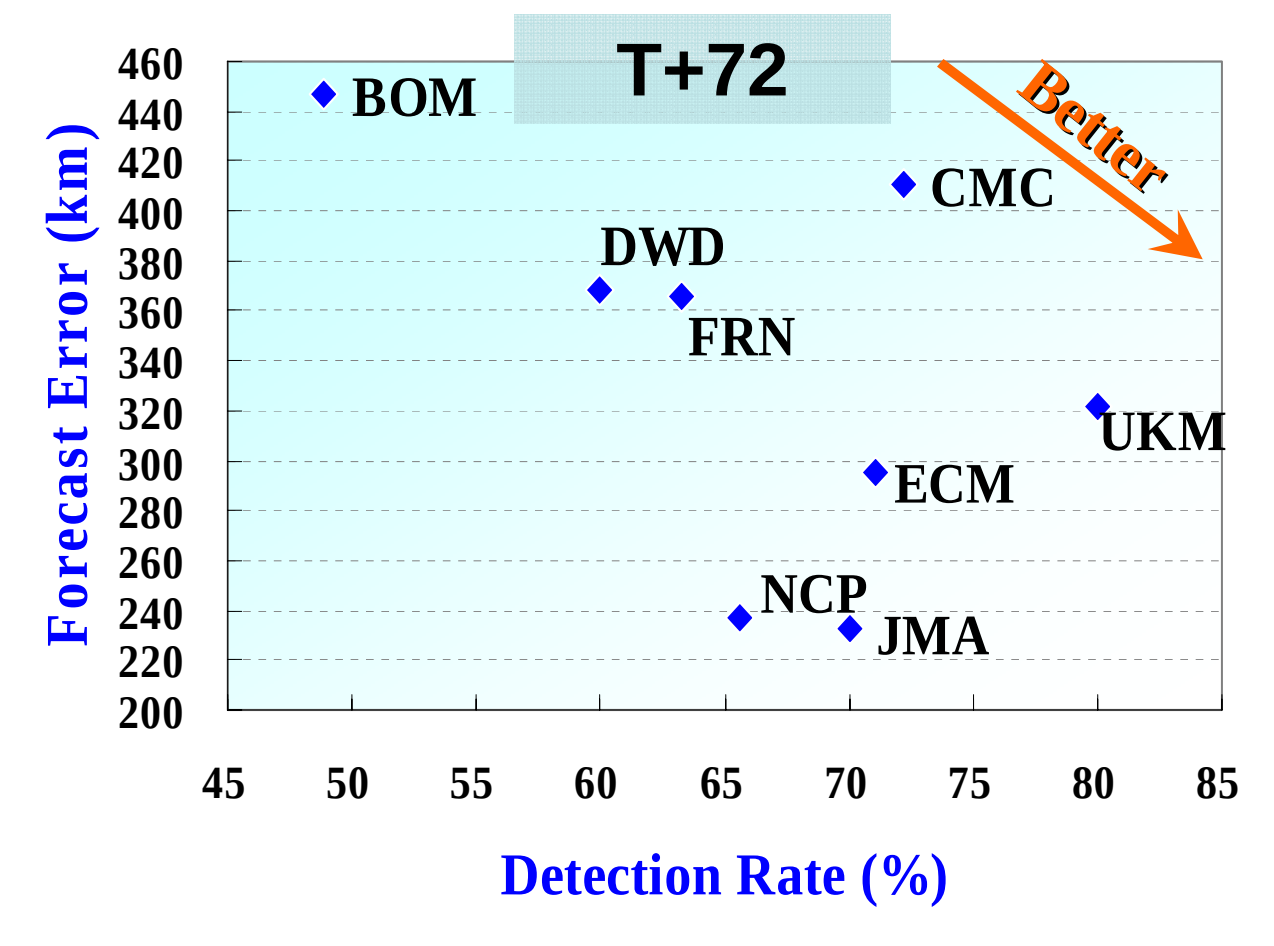
- 28 TC cases in 2005 -

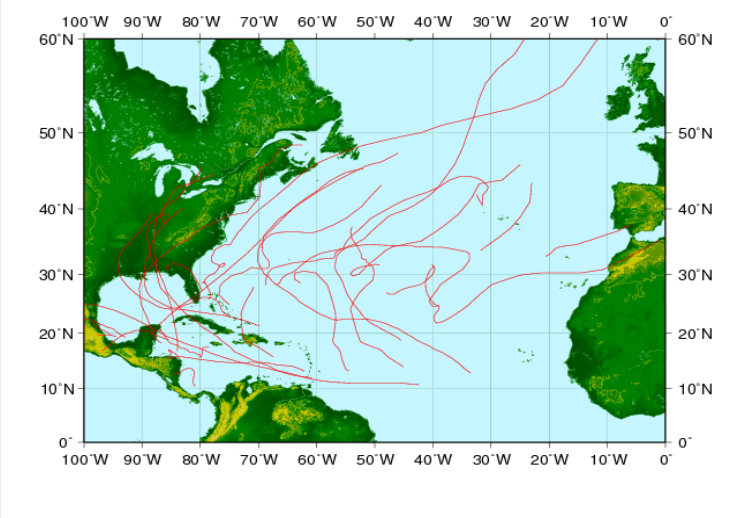




Verification of North Atlantic area

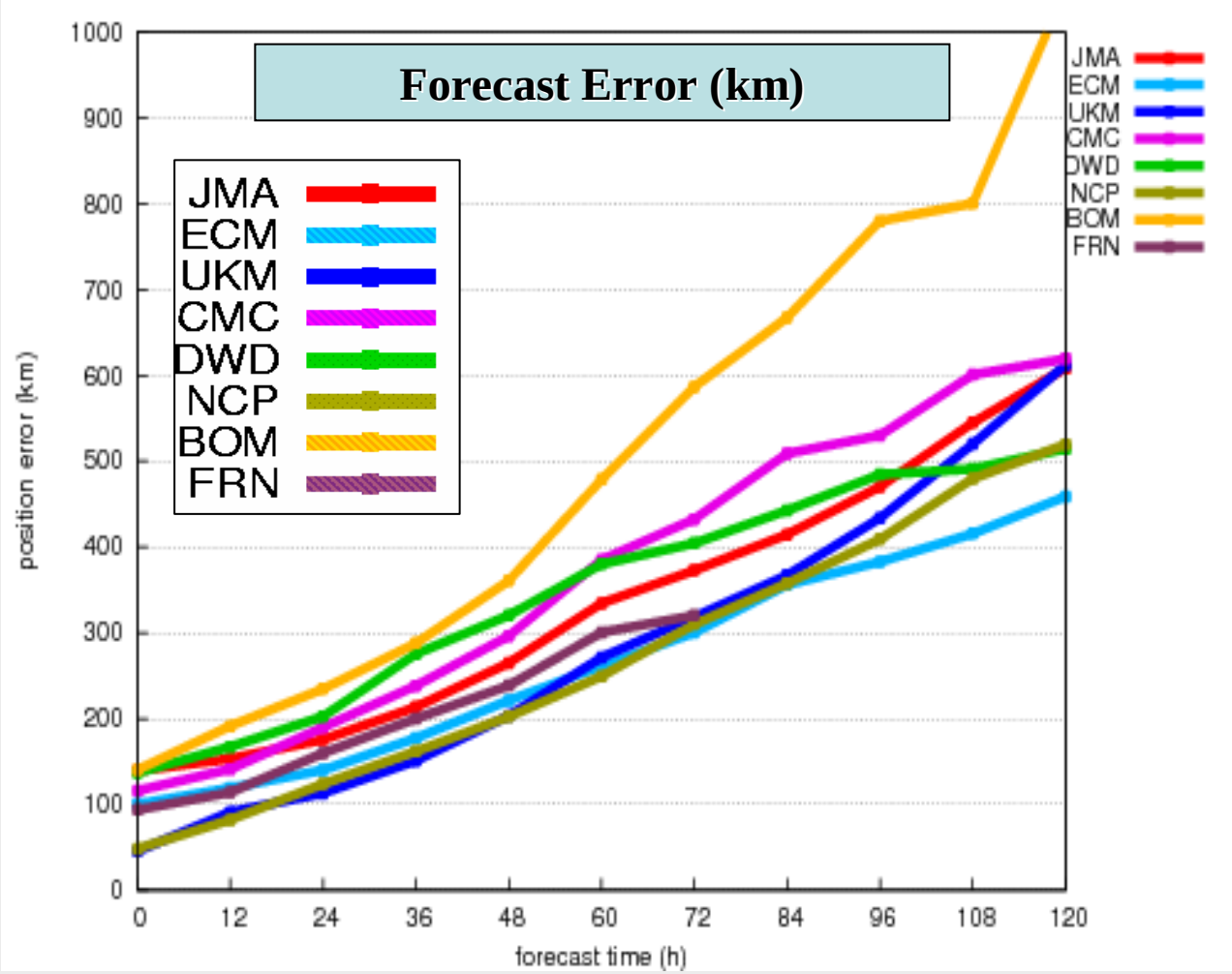
- 28 TC cases in 2005 -

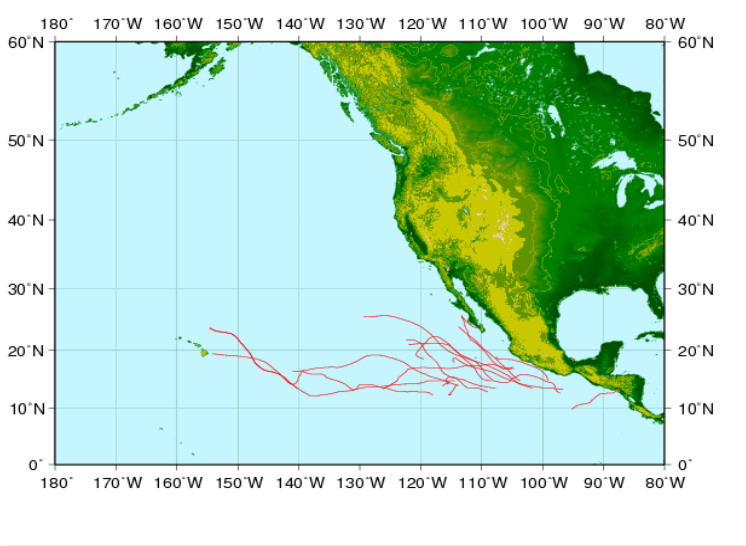




Verification of eastern North Pacific area

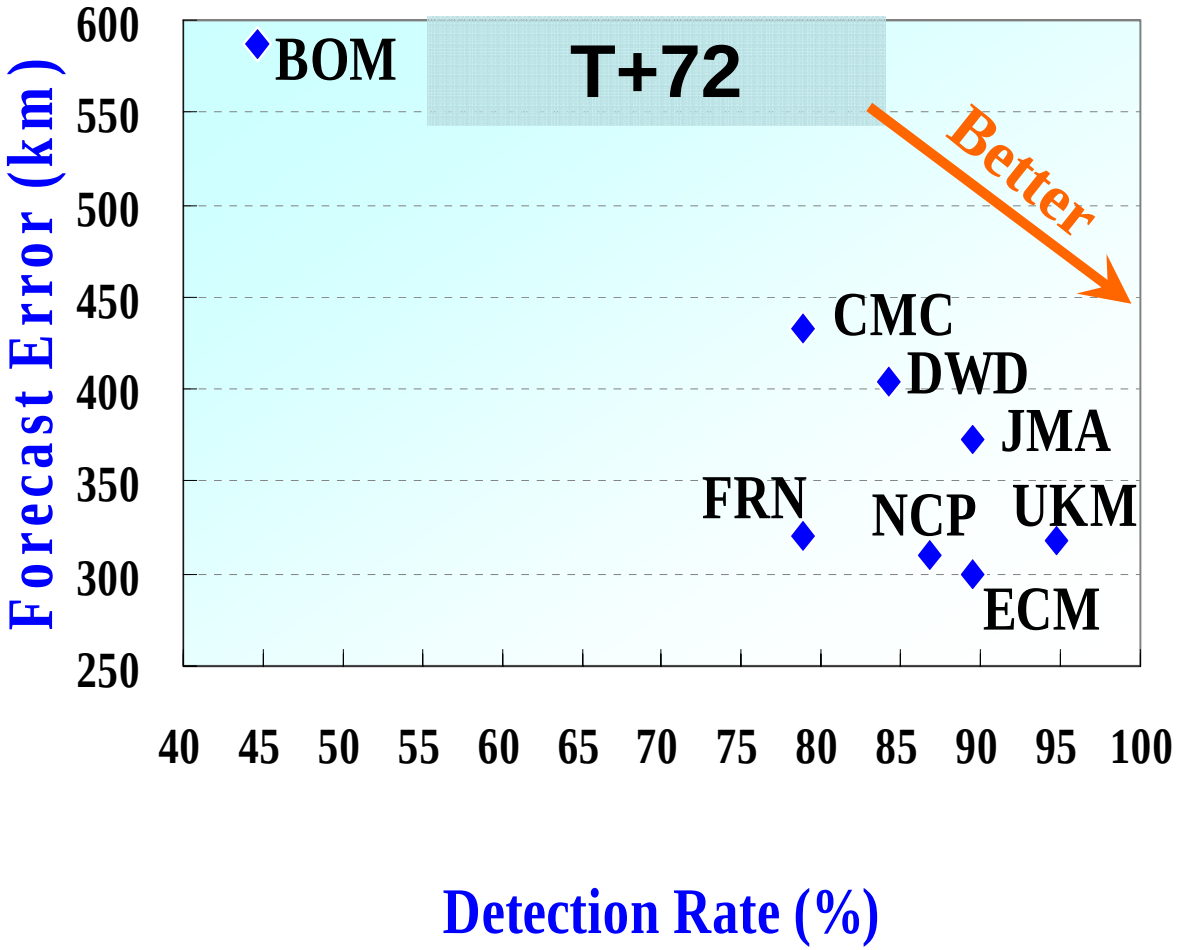
- 15 TC cases in 2005 -

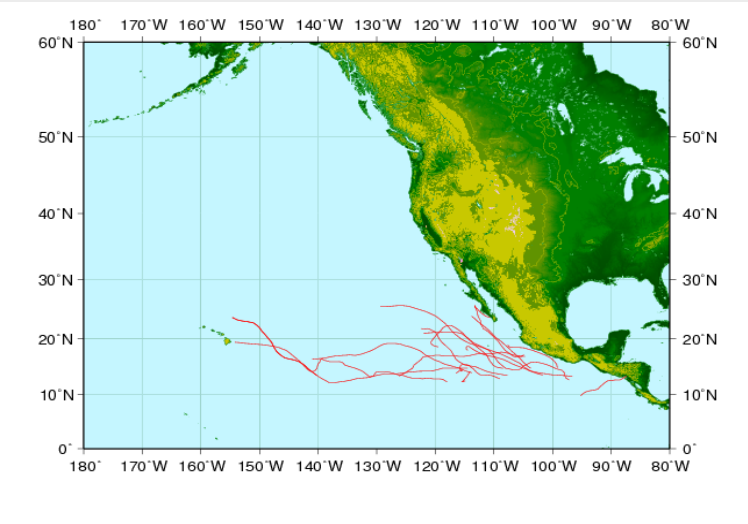




Verification of eastern North Pacific area

- 15 TC cases in 2005 -





3. Forecast Lead Time Estimate :

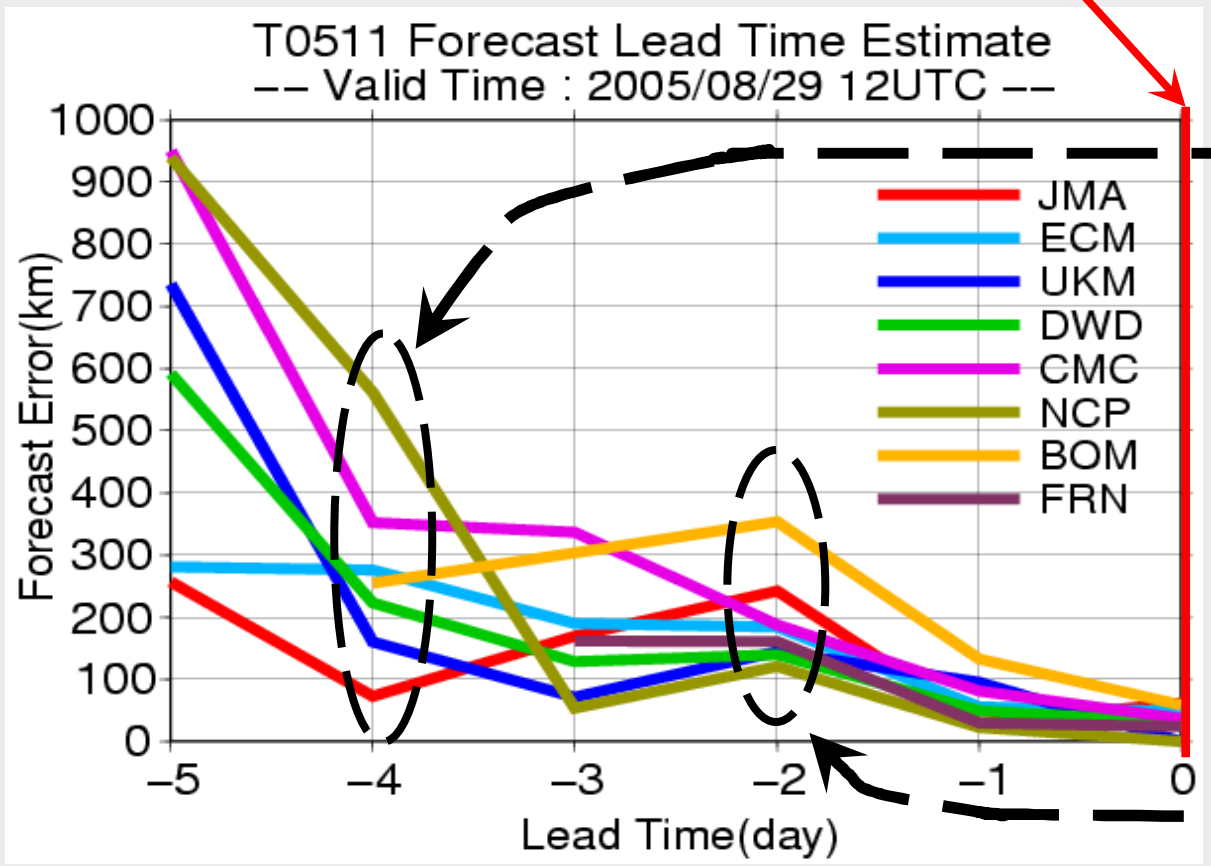
KATRINA & *RITA*

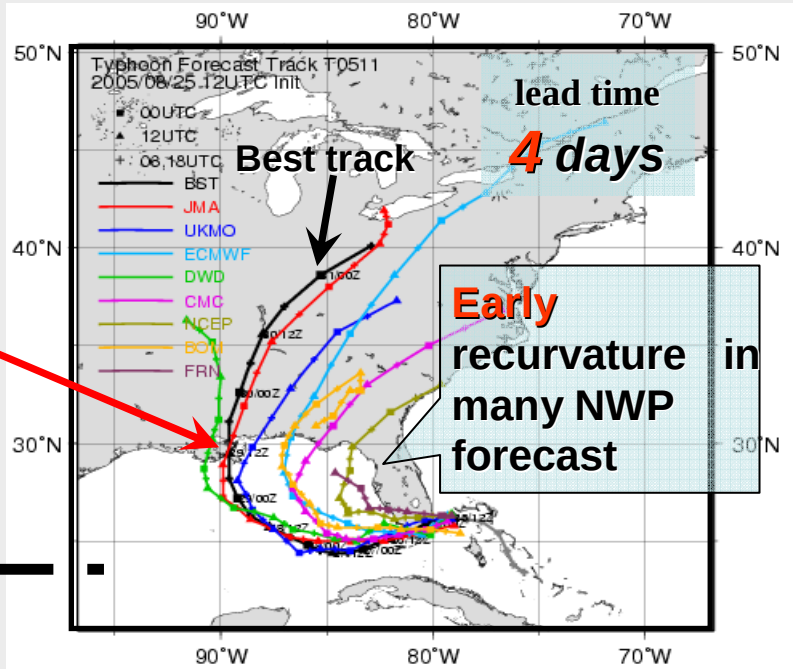
Forecast Lead Time Estimate :

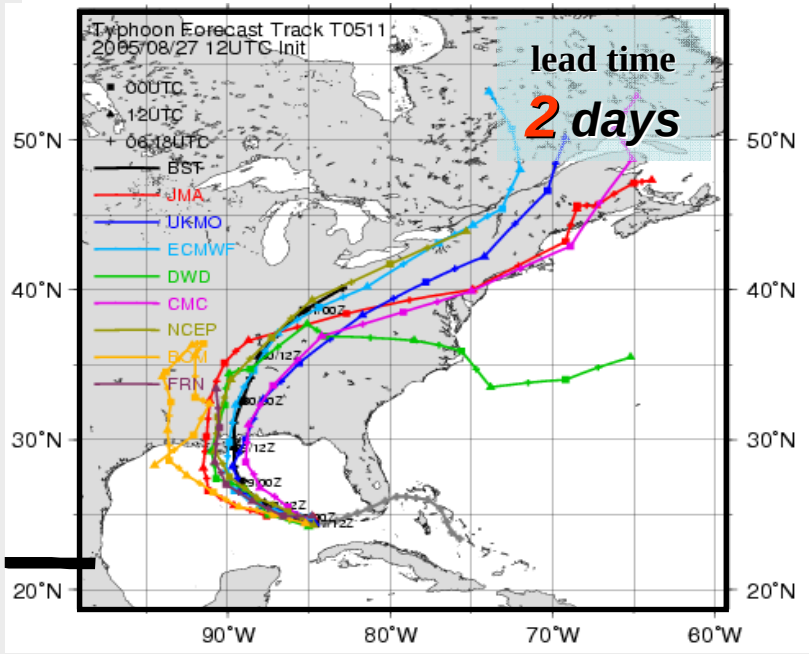
KATRINA(T0511)

- North Atlantic area -

The Time of Landfall





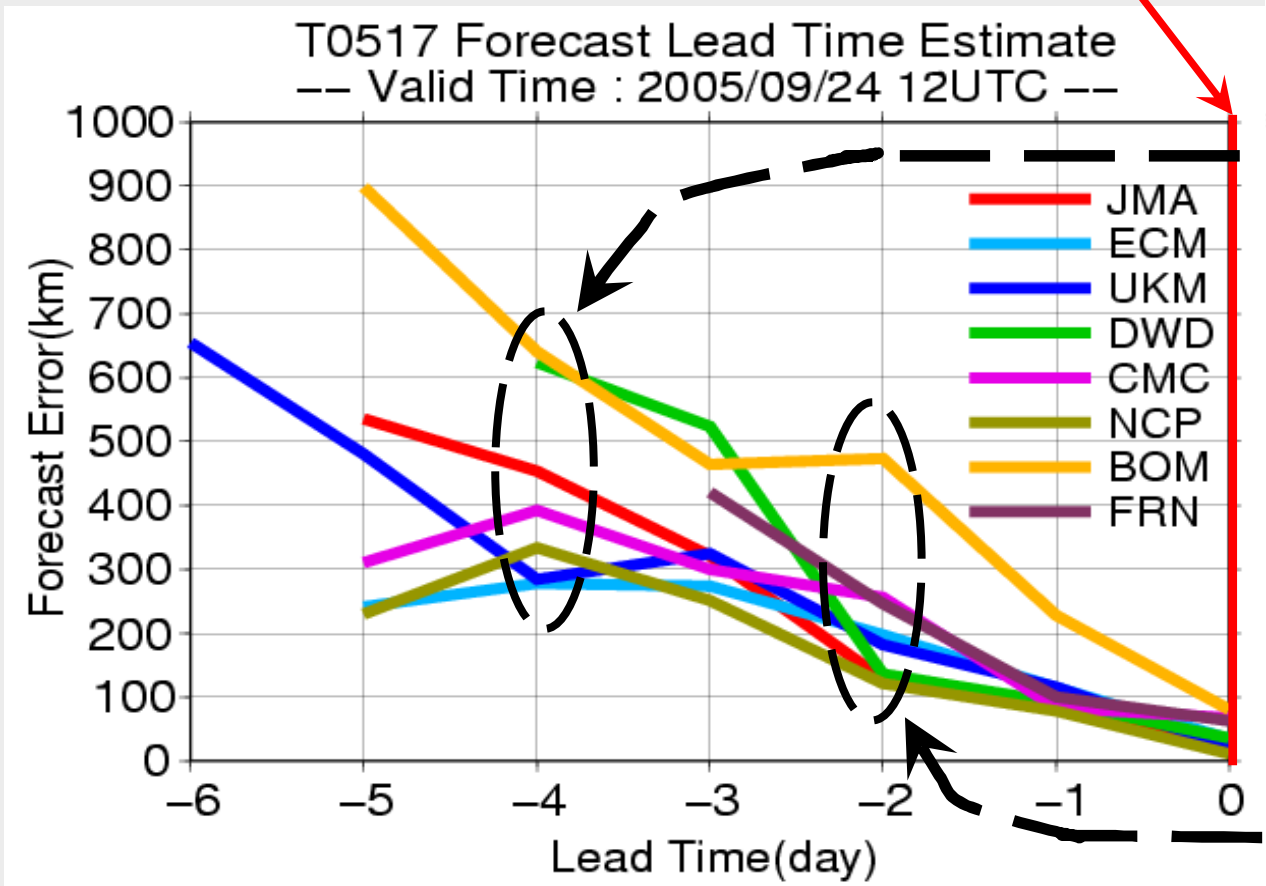


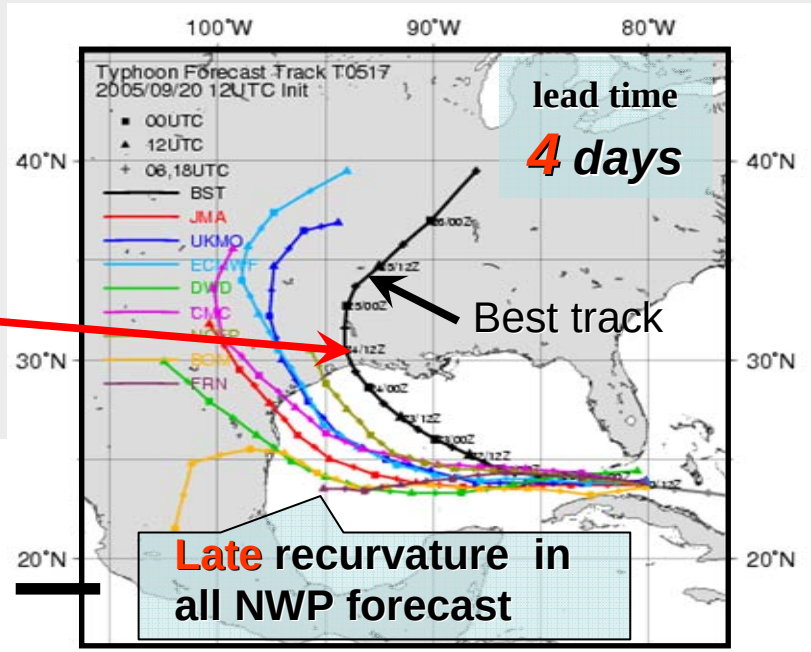
Forecast Lead Time Estimate :

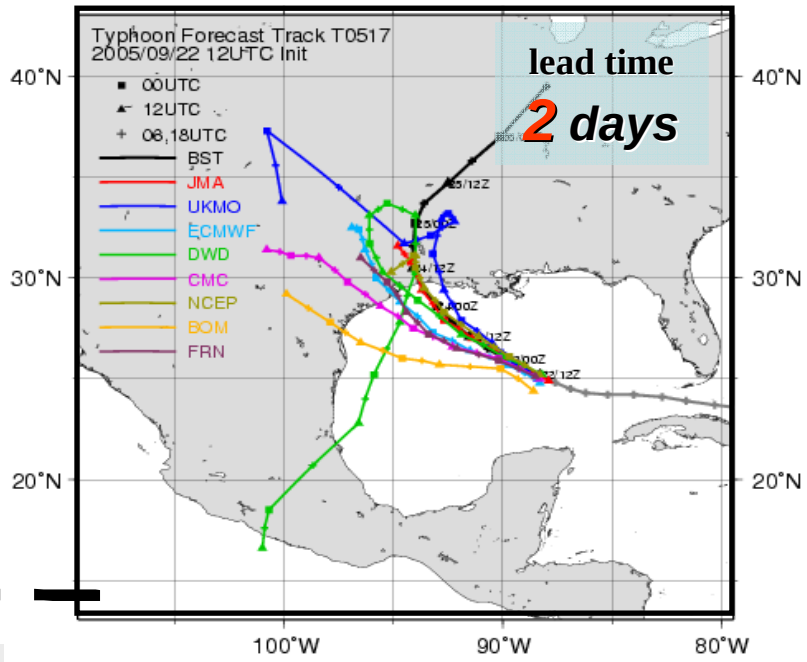
RITA(T0517)

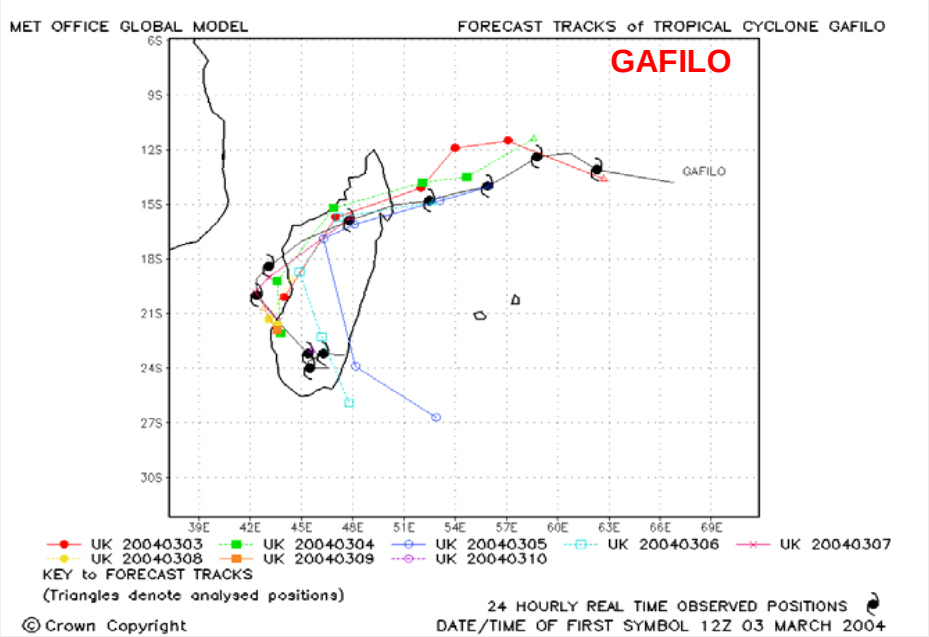
- North Atlantic area -

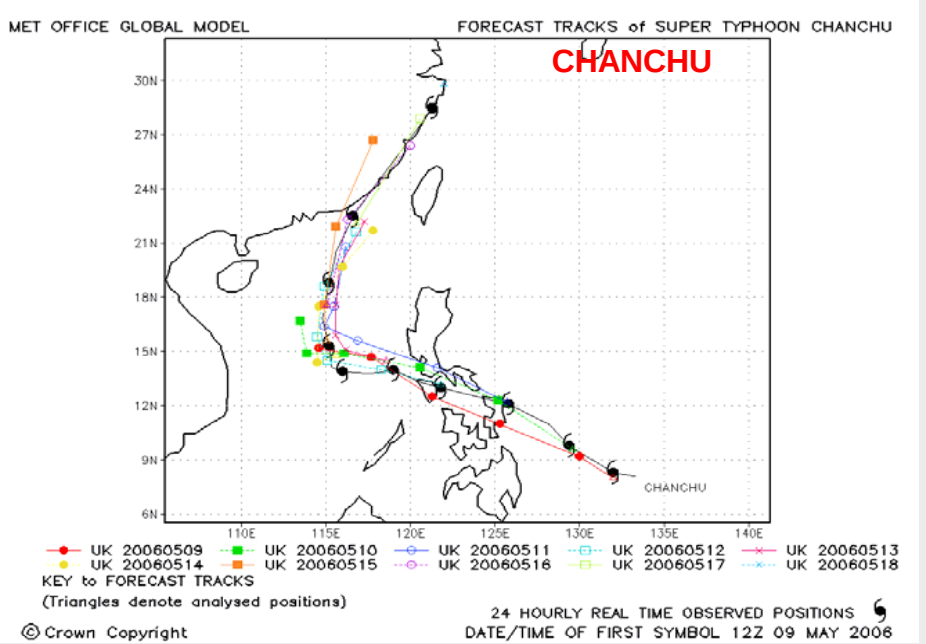
The Time of Landfall

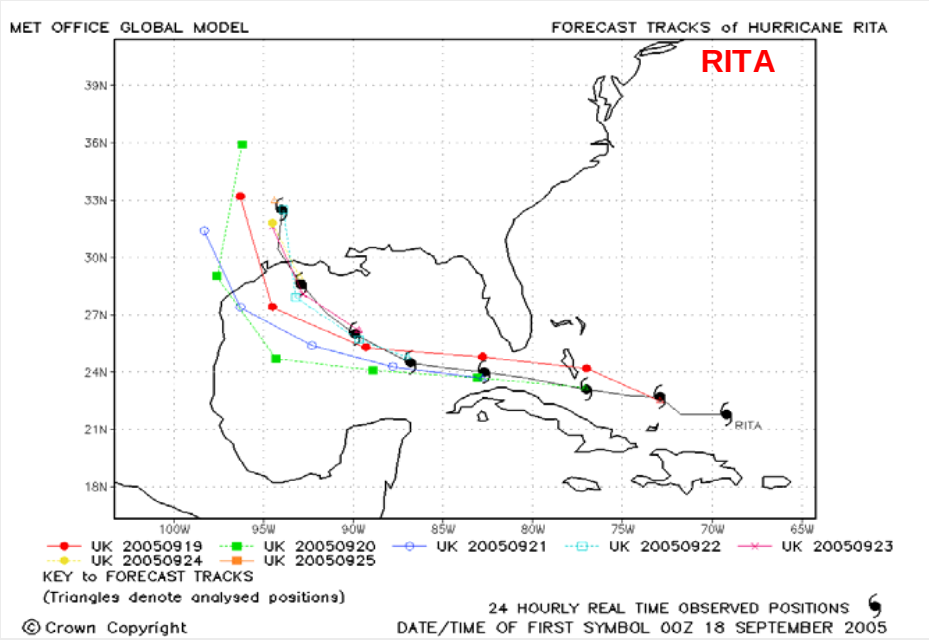


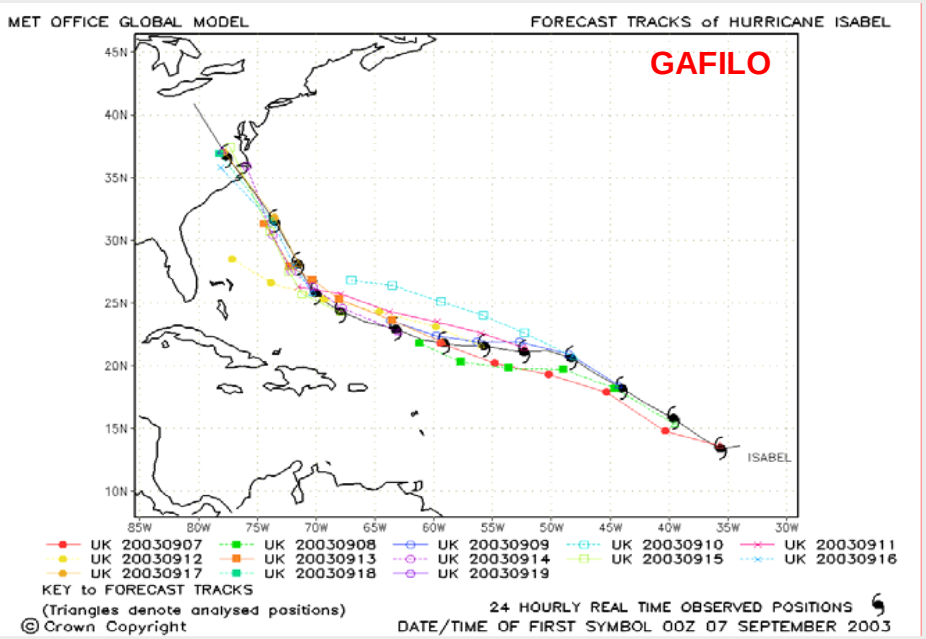










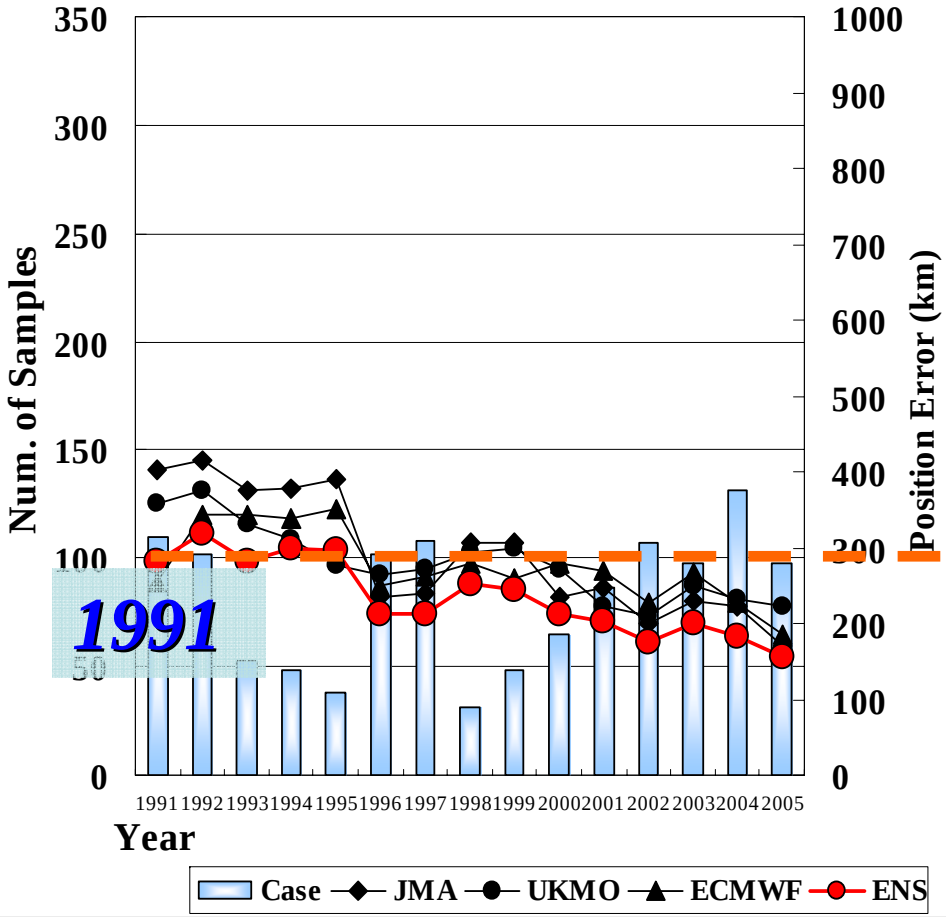


Example from MetOffice operational global model

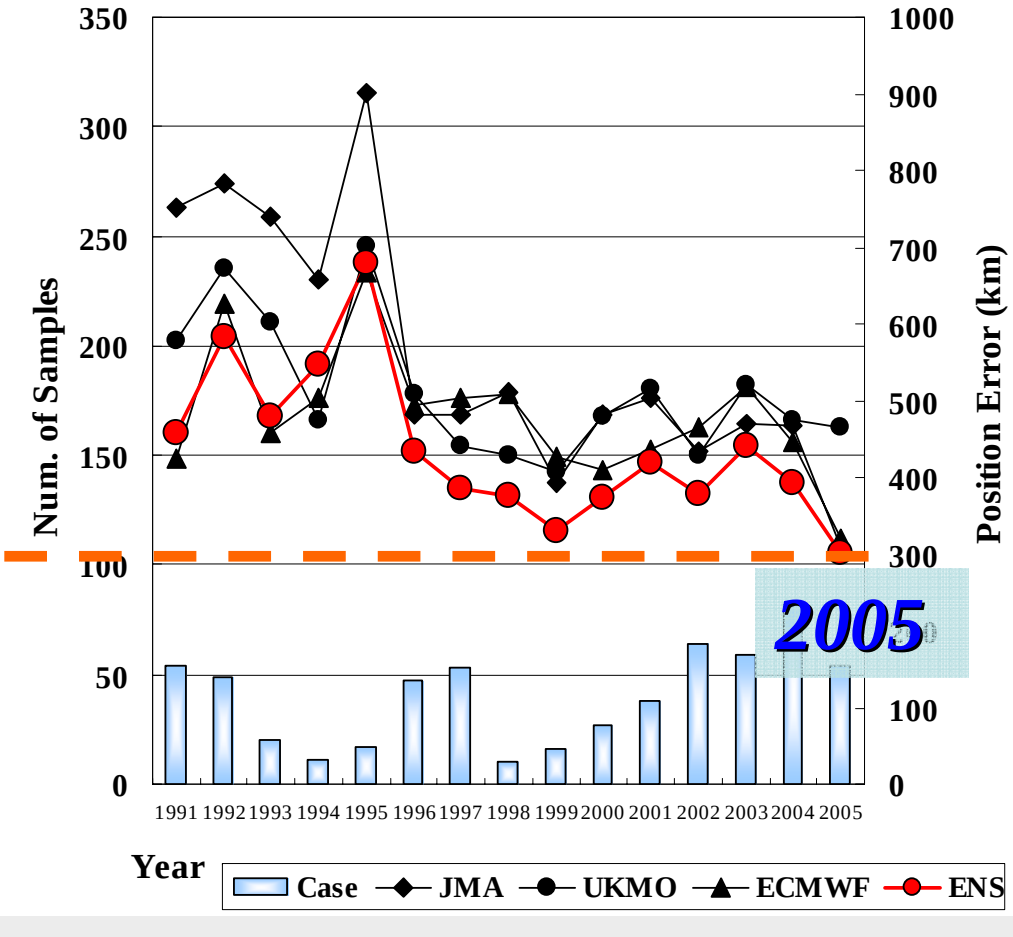
3 NWP Multi-Model Ensemble (JMA, ECMWF, UKMO)

- western North Pacific area -

2days Forecast



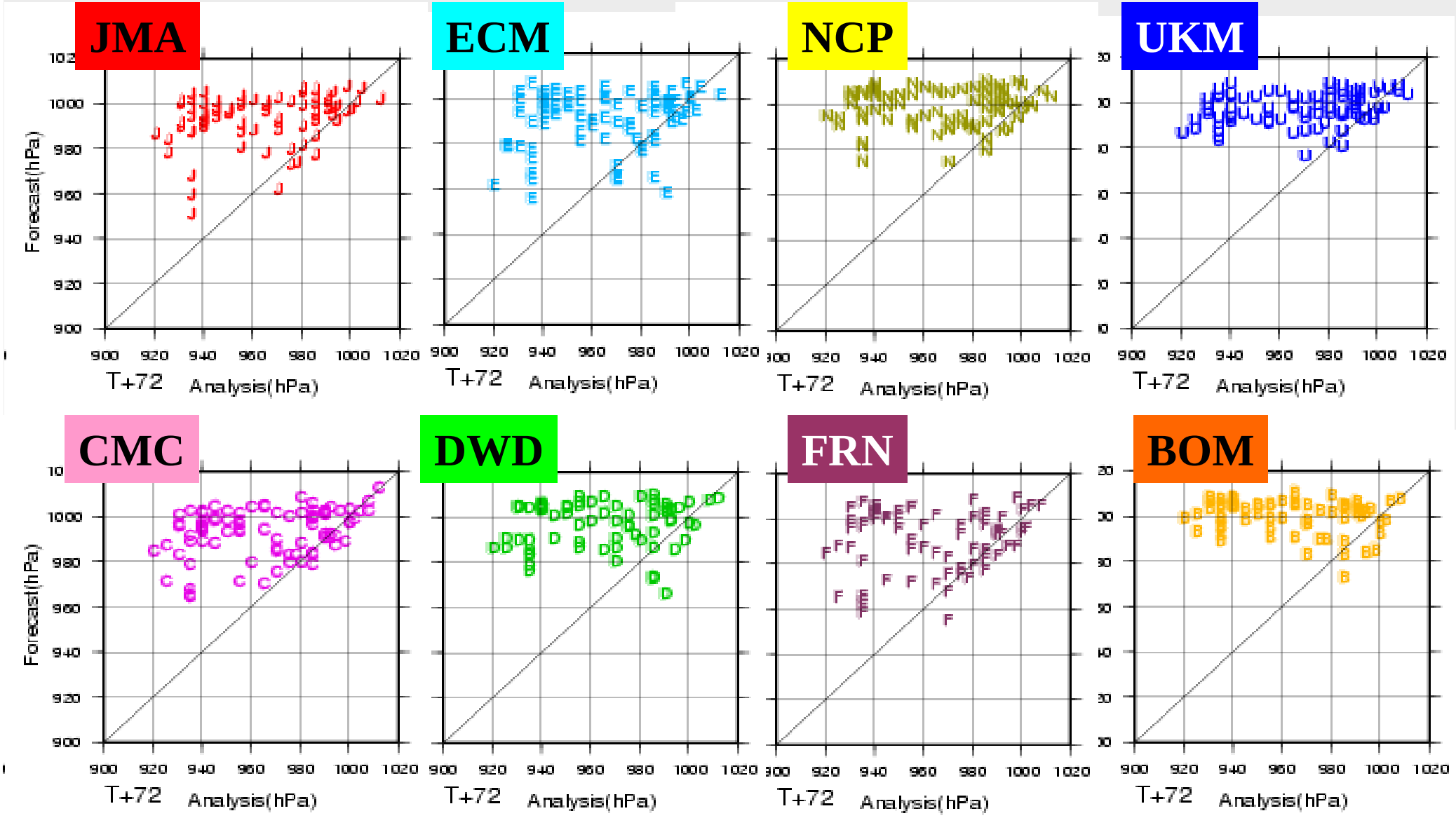
4days Forecast



TC Intensity Verification

- western North Pacific area -

T+72

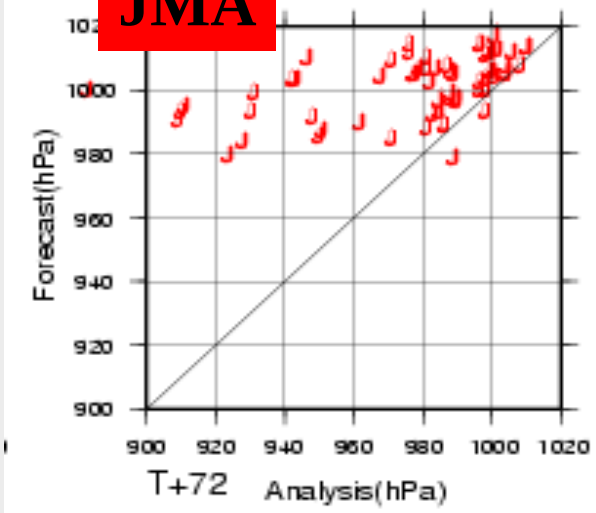


TC Intensity Verification

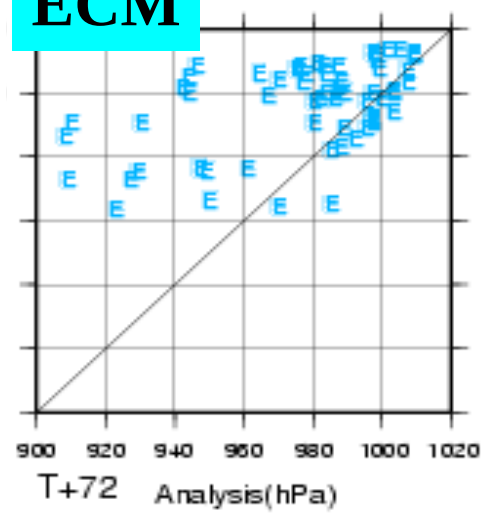
- North Atlantic area -

T+72

JMA



ECM



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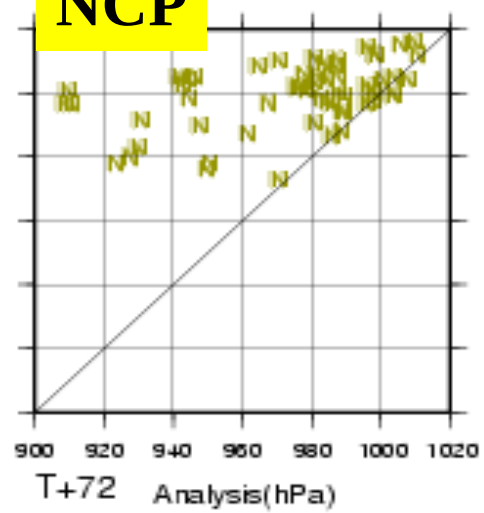
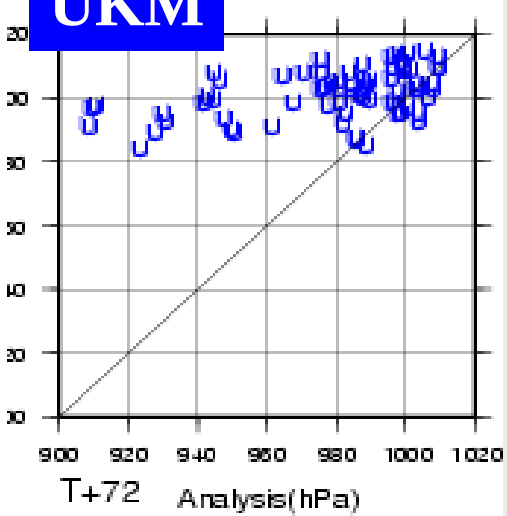
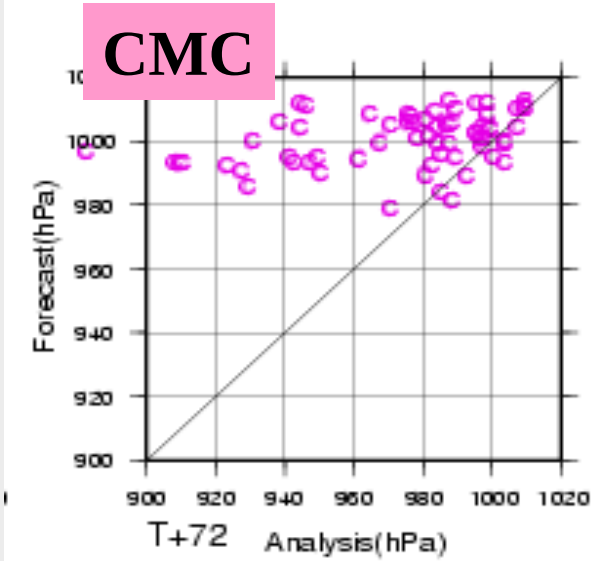


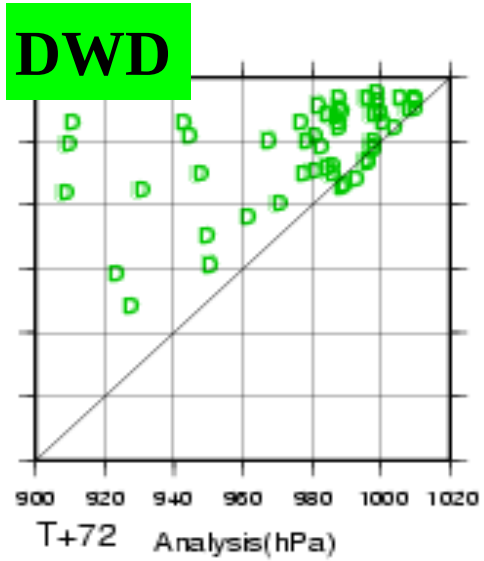
UKM



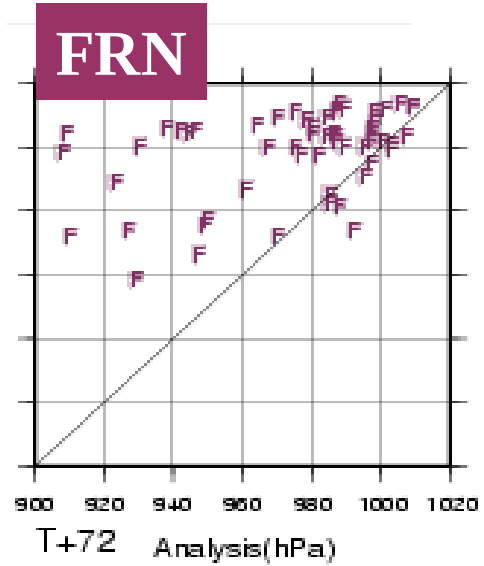
CMC



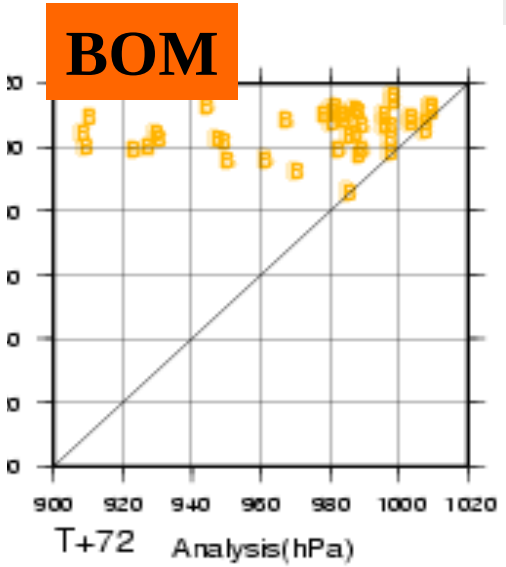
DWD



FRN

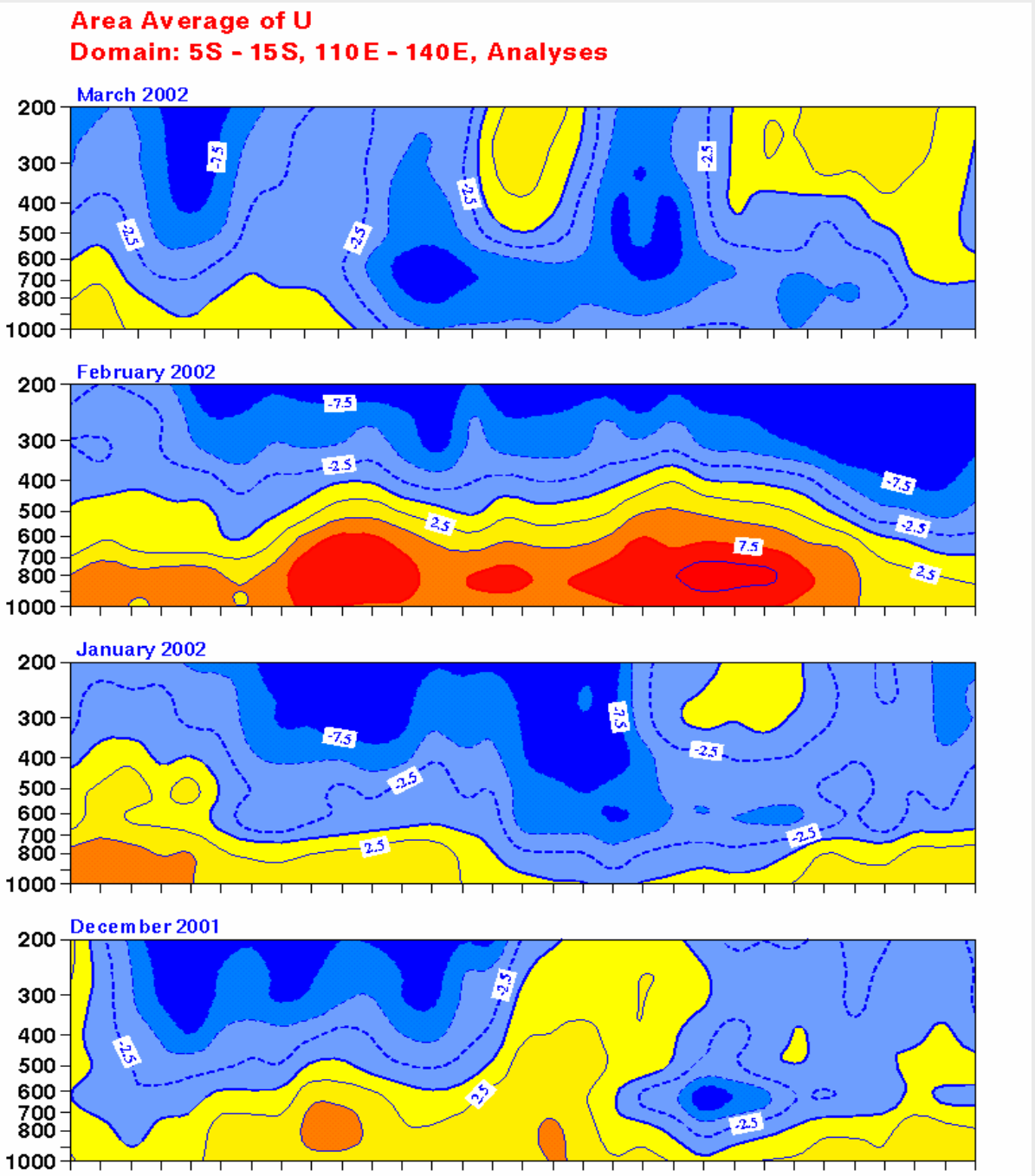


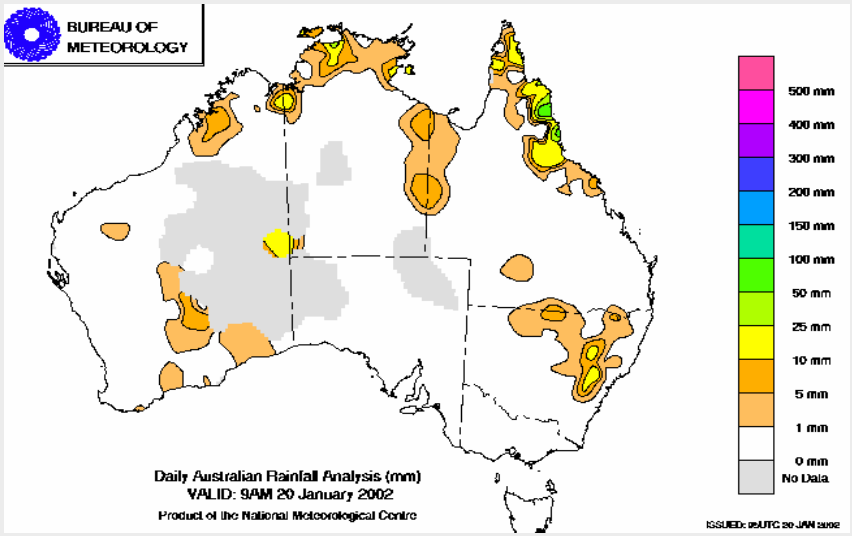
BOM

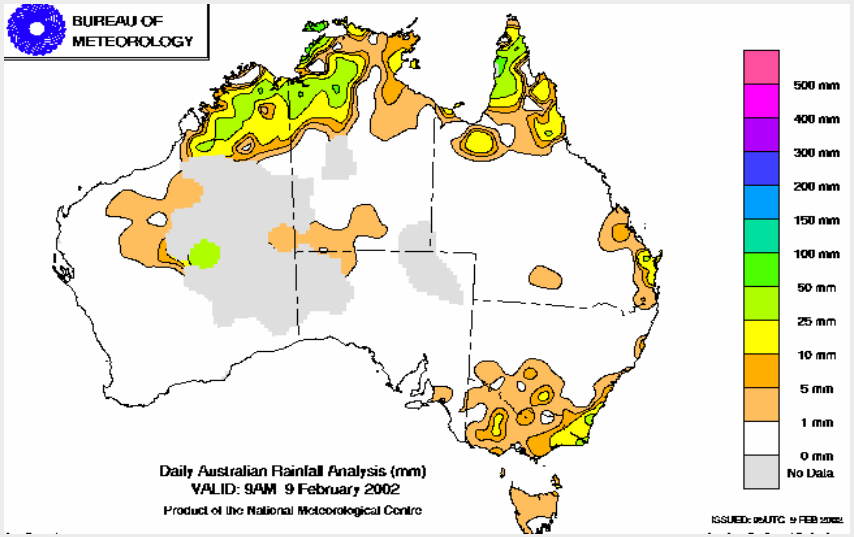


Monsoon Prediction

- The monsoon season over northern Australia usually occurs from December to March
- Onset is rapid and is marked by low level easterlies changing to westerlies and is accompanied by heavy rainfall
- Monsoon season is marked by active and break periods
- The active periods are associated by passage of MJO waves


Area Average of U
Domain: 5S - 15S, 110E - 140E, Analyses
March 2002
February 2002
January 2002
December 2001
200
300
400
500
600
700
800
1000
-7.5
-2.5
2.5
7.5


BUREAU OF METEOROLOGY
500 mm
400 mm
300 mm
200 mm
150 mm
100 mm
50 mm
25 mm
10 mm
5 mm
1 mm
0 mm
No Data
Daily Australian Rainfall Analysis (mm)
VALID: 9AM 20 January 2002
Product of the National Meteorological Centre


BUREAU OF METEOROLOGY
500 mm
400 mm
300 mm
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0 mm
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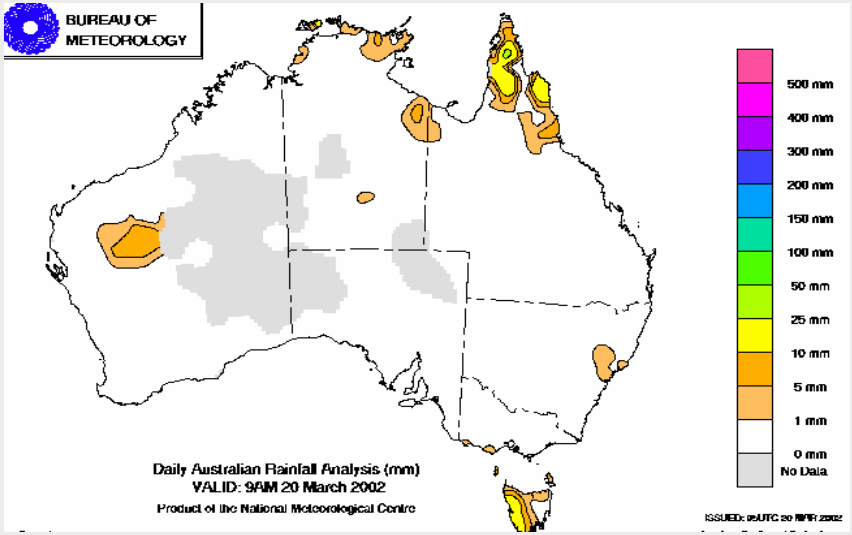
Daily Australian Rainfall Analysis (mm)
VALID: 9AM 9 February 2002
Product of the National Meteorological Centre


BUREAU OF METEOROLOGY
500 mm
400 mm
300 mm
200 mm
150 mm
100 mm
50 mm
25 mm
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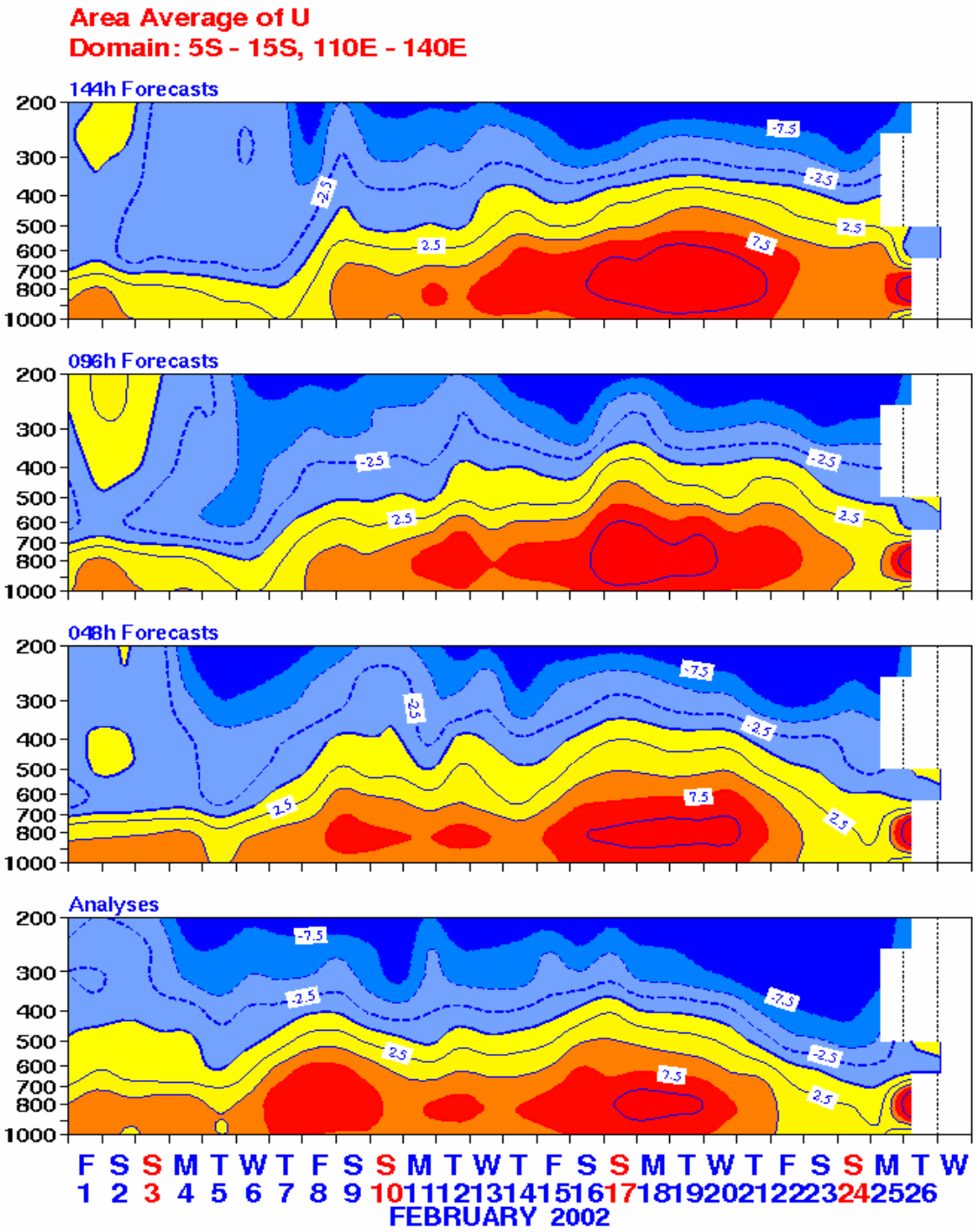
No Data
Daily Australian Rainfall Analysis (mm)
VALID: 9AM 20 March 2002
Product of the National Meteorological Centre

Bureau's operational global model 2001-2002 monsoon



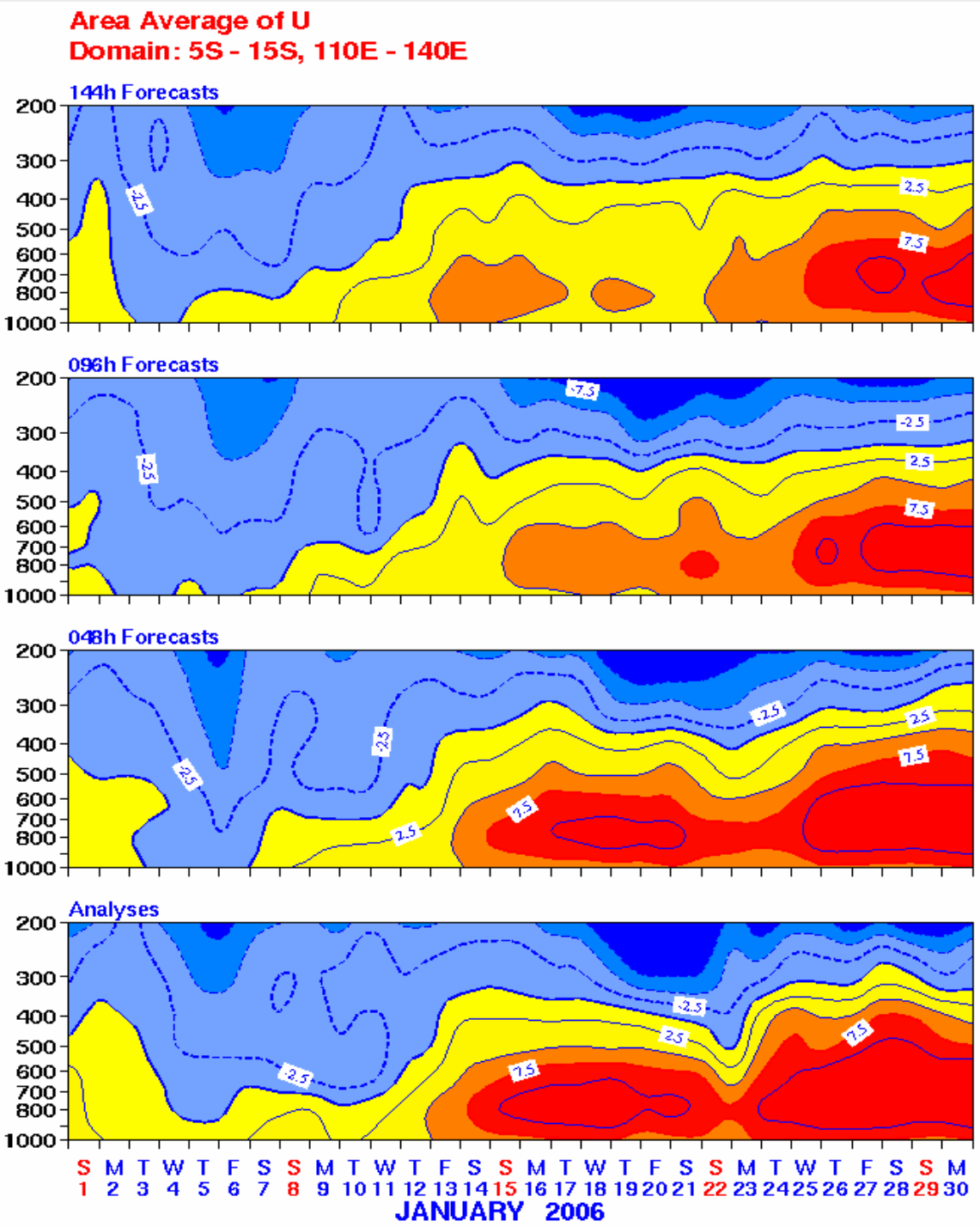
144h

96h

48h

Analyses

Bureau's operational global model 2005-2006 monsoon



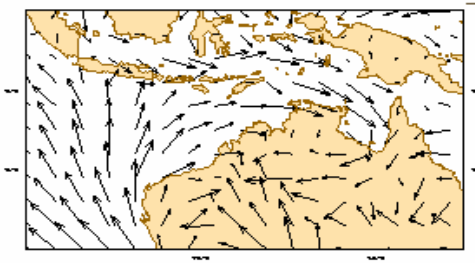
144h

96h

48h

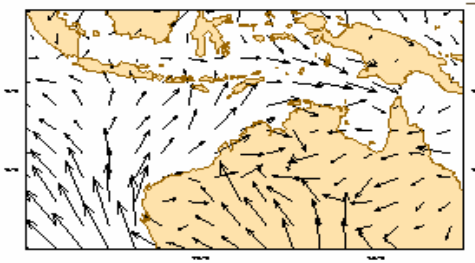
Analyses

EC w10m: 20060113 1200Z AN

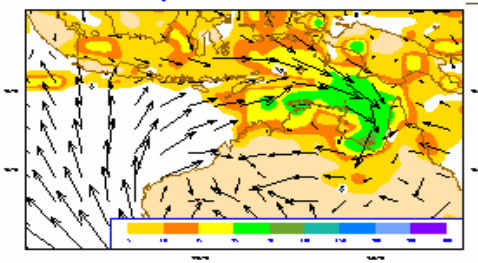


2005-2006 monsoon
ECMWF model

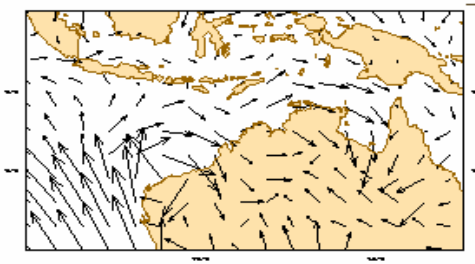
EC w10m: 20060111 1200Z AN



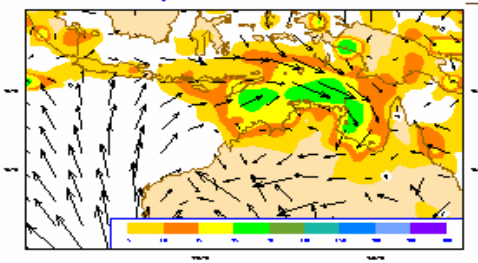
EC w10m, tp: 20060111 1200Z + 48h



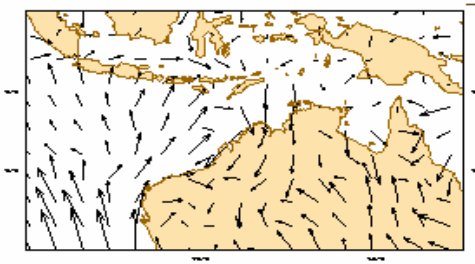
EC w10m: 20060109 1200Z AN



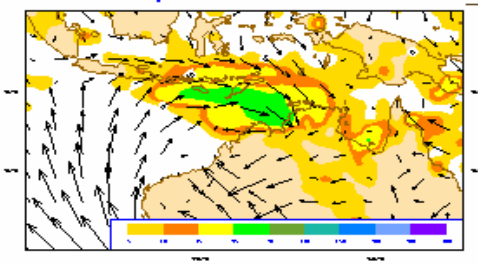
EC w10m, tp: 20060109 1200Z + 96h



EC w10m: 20060107 1200Z AN



EC w10m, tp: 20060107 1200Z + 144h



2005-2006 monsoon
Bureau model

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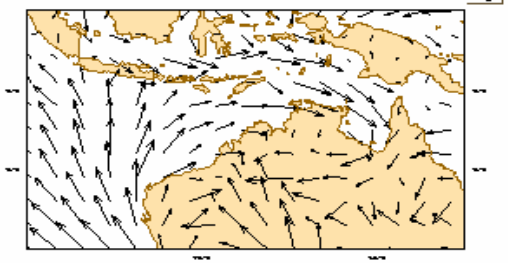
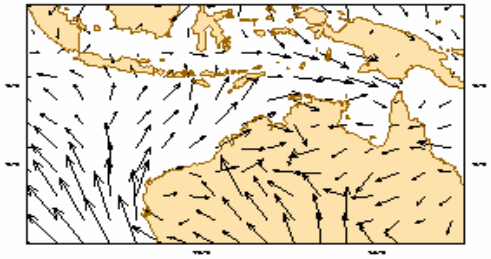
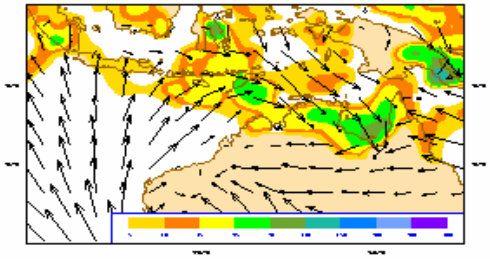


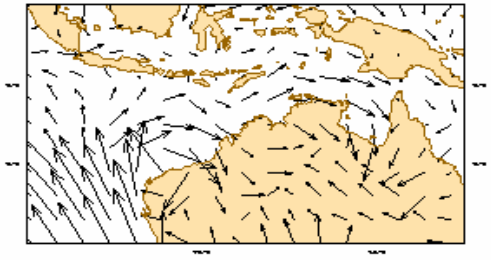
EC w10m: 20060111 1200Z AN



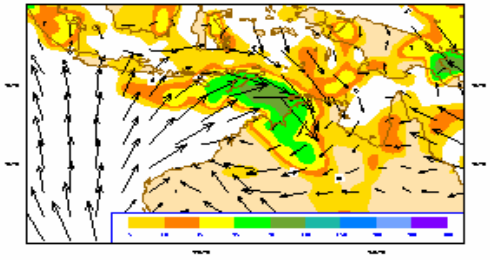
GASP w10m, tp: 20060111 1200Z + 48h



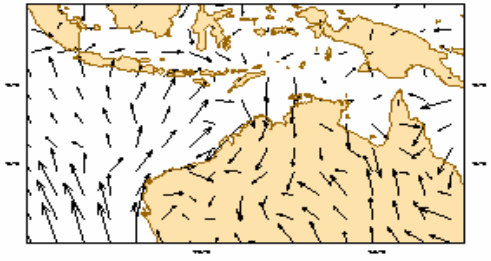
EC w10m: 20060109 1200Z AN



GASP w10m, tp: 20060109 1200Z + 96h



EC w10m: 20060107 1200Z AN



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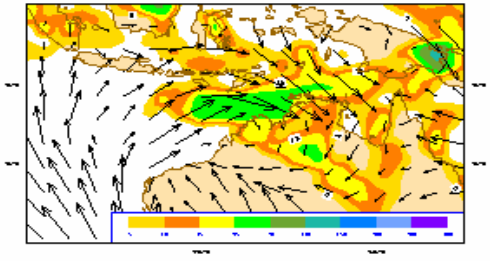
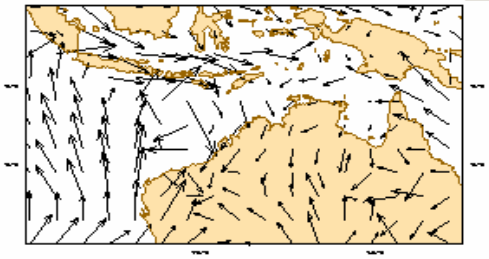
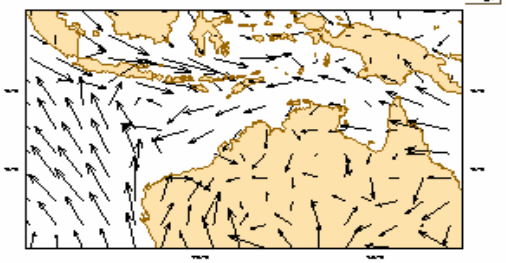


EC w10m: 20070101 1200Z AN

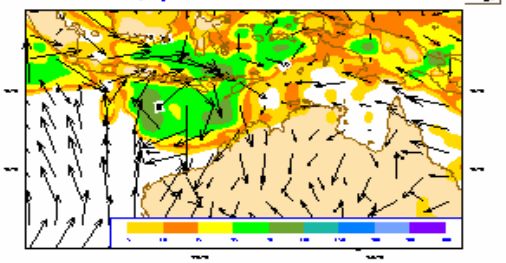


2006-2007 monsoon
ECMWF model

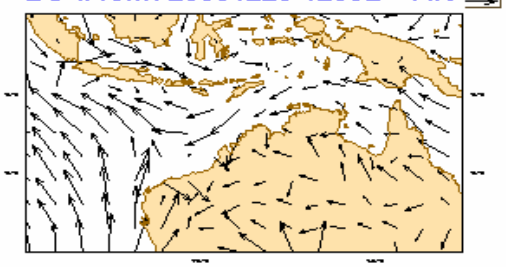
EC w10m: 20061230 1200Z AN



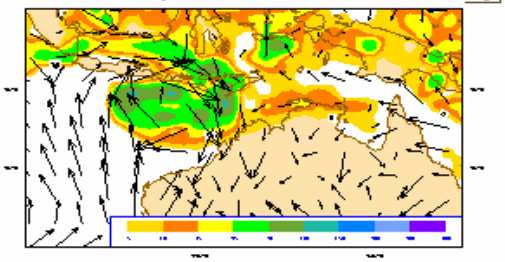
EC w10m, tp: 20061230 1200Z + 48h



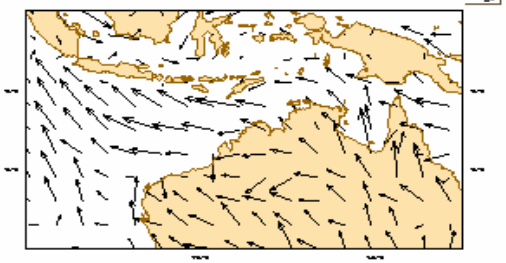
EC w10m: 20061228 1200Z AN



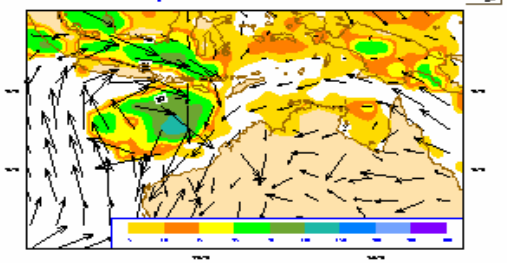
EC w10m, tp: 20061228 1200Z + 96h



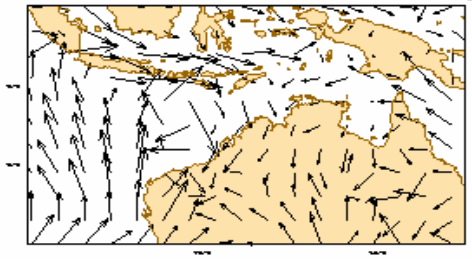
EC w10m: 20061226 1200Z AN



EC w10m, tp: 20061226 1200Z + 144h

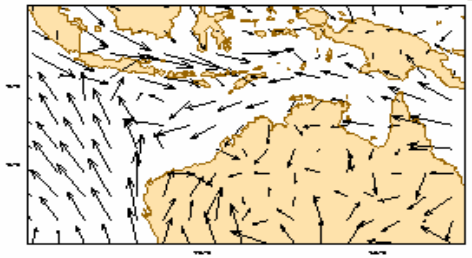


EC w10m: 20070101 1200Z AN

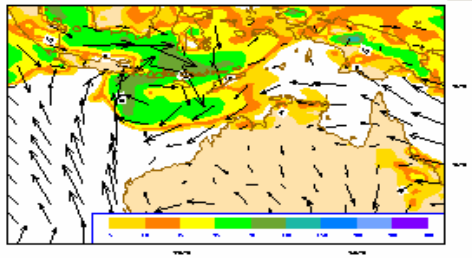


2006-2007 monsoon
MetOffice model

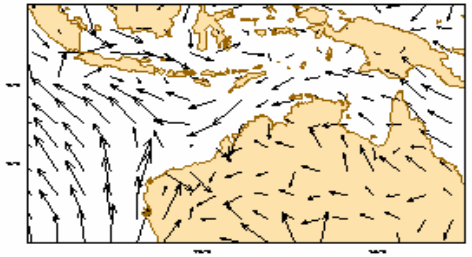
EC w10m: 20061230 1200Z AN



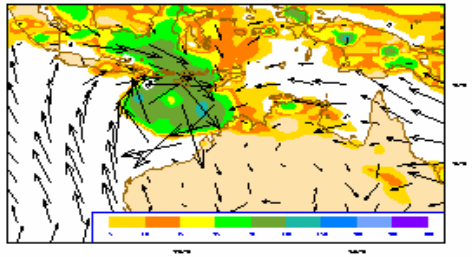
UM w10m, tp: 20061230 0Z + 48h



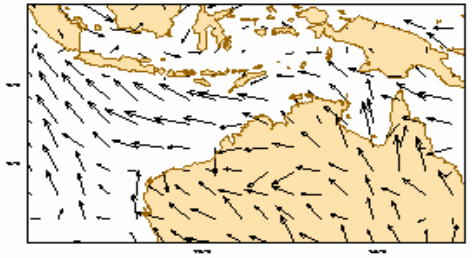
EC w10m: 20061228 1200Z AN



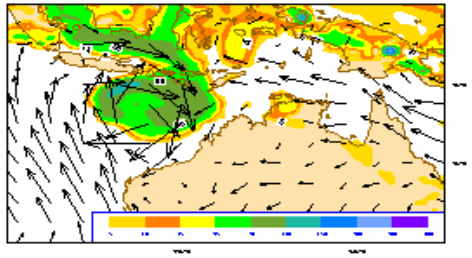
UM w10m, tp: 20061228 0Z + 96h



EC w10m: 20061226 1200Z AN



UM w10m, tp: 20061226 0Z + 144h



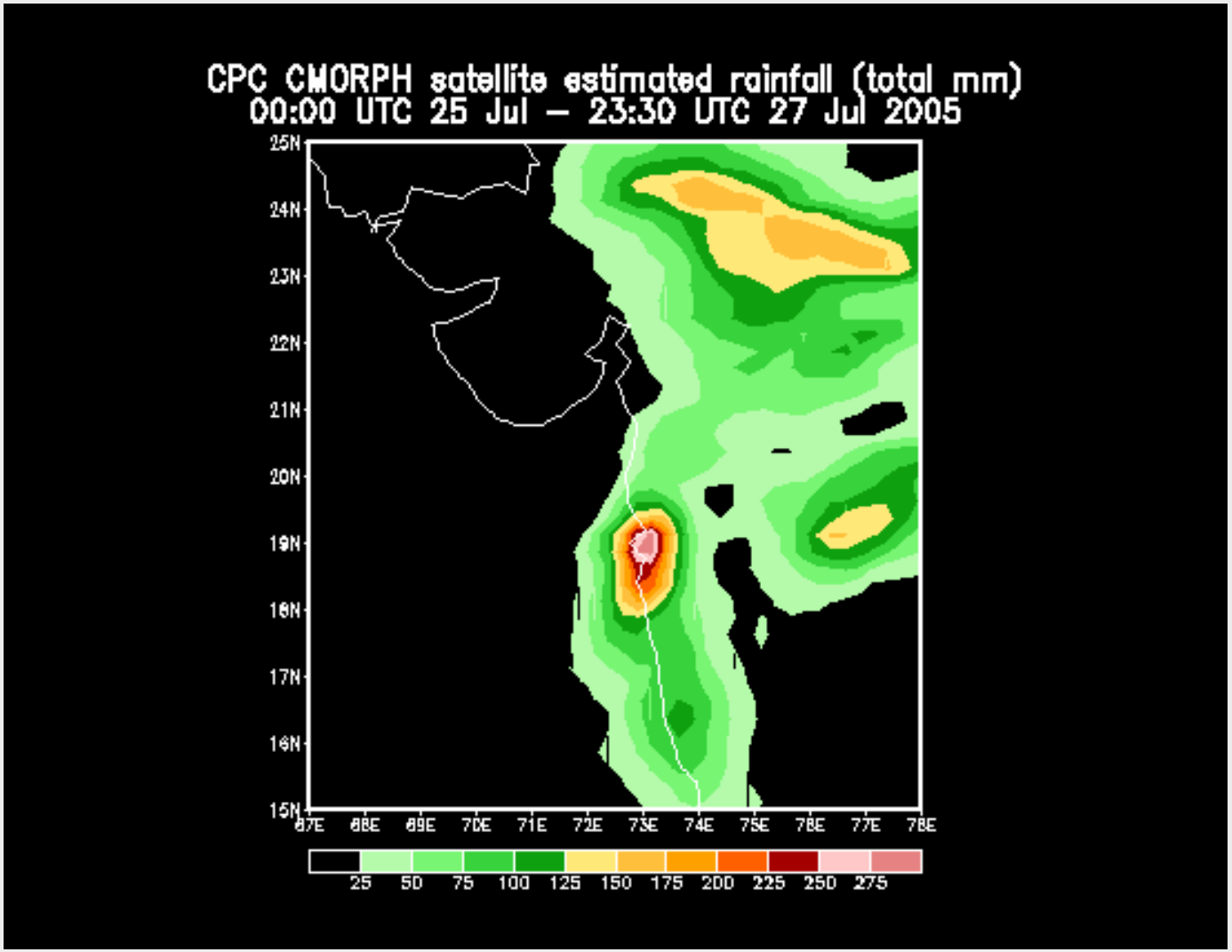
July/August 2005 – Flooding in India

24.7- 5.8 Flooding in India (1.150 fatalities)

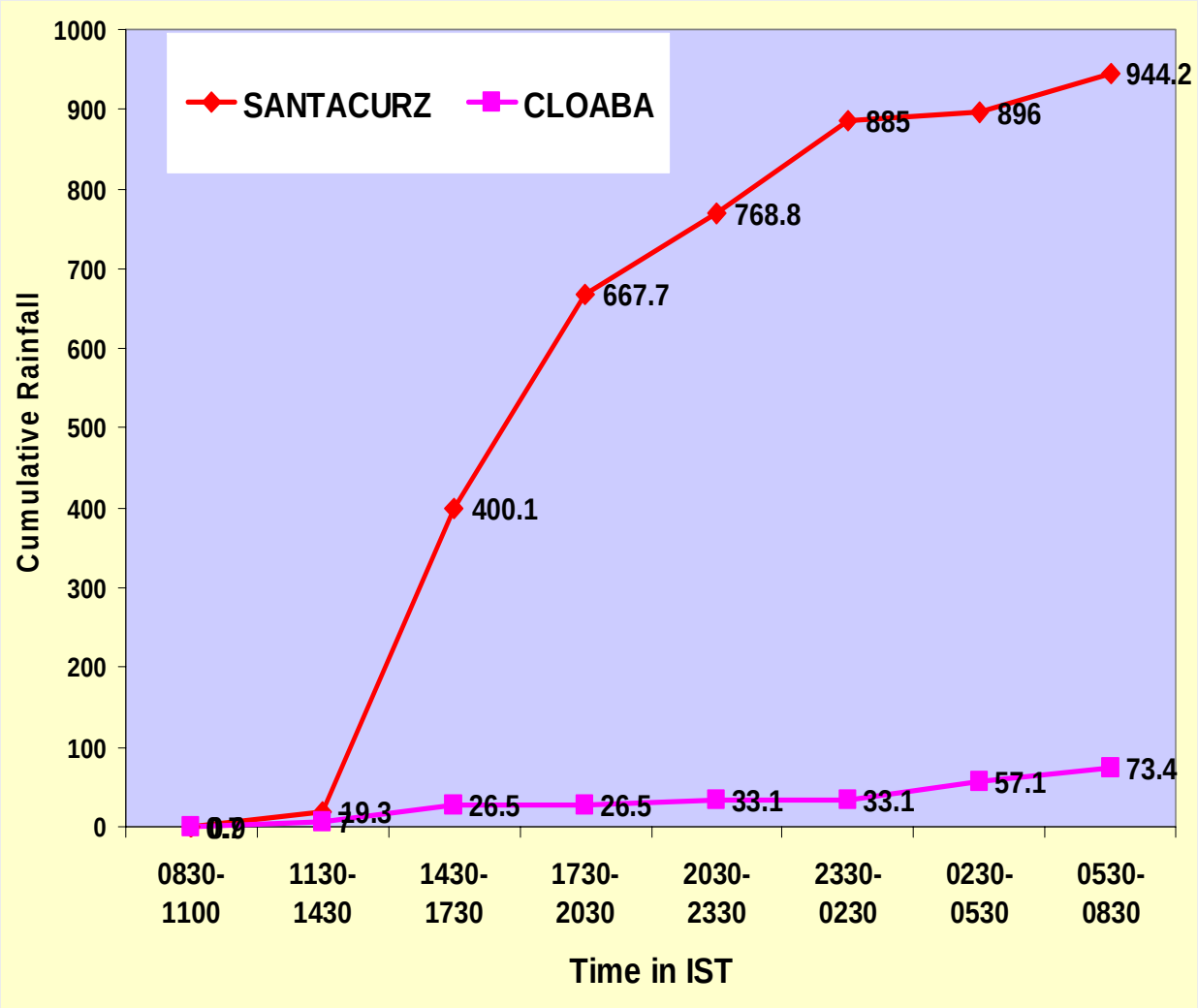
Economic losses (US$ m): 5.000

Insured losses (US$ m): 750

Satellite estimate rainfall

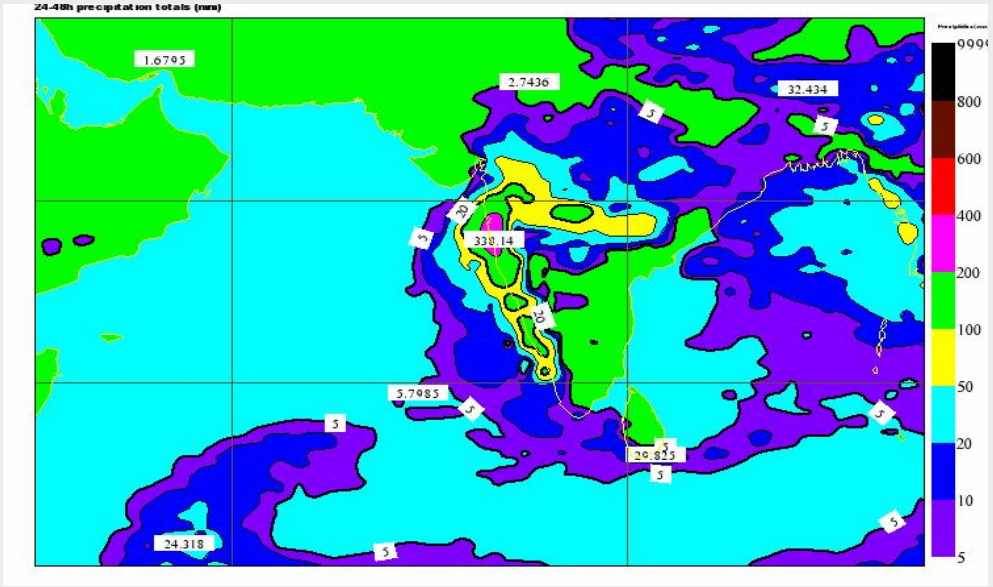


Time series of observed rainfall on 26 July

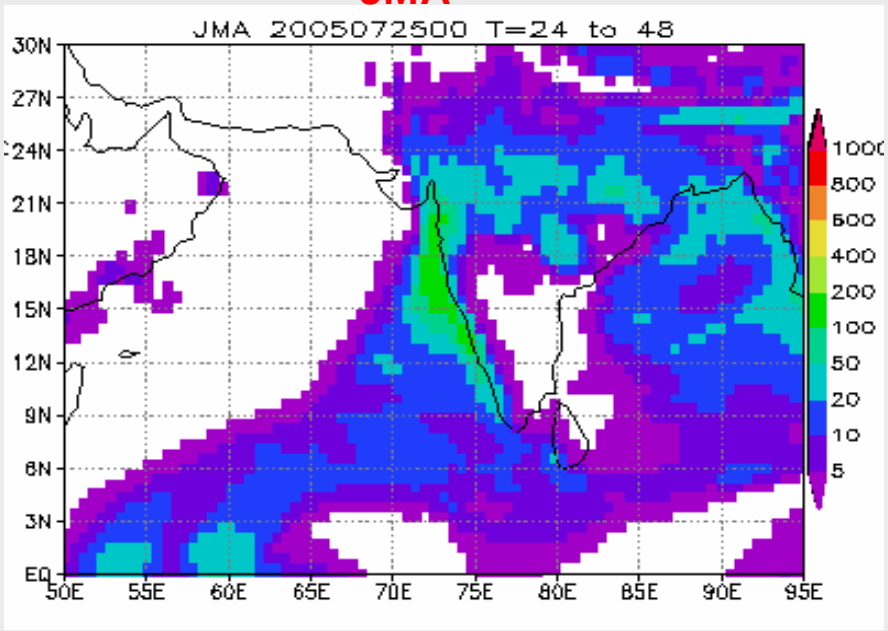


D2

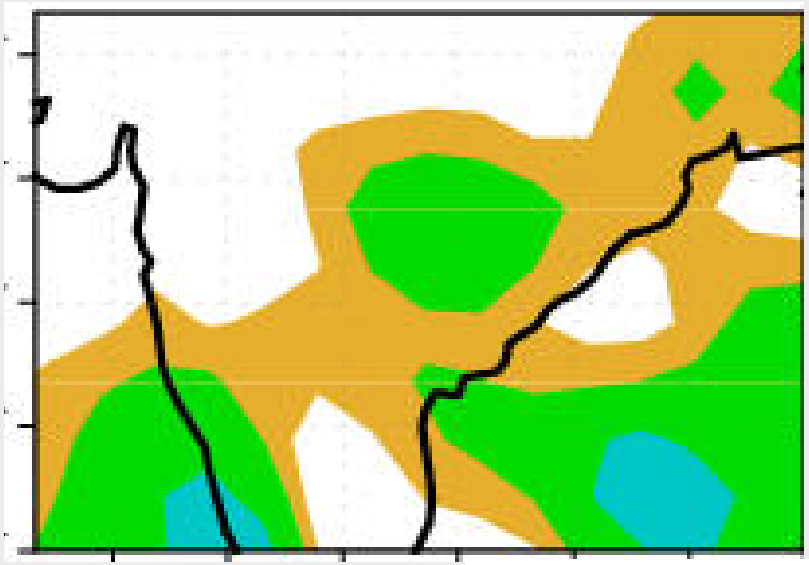
Met Office



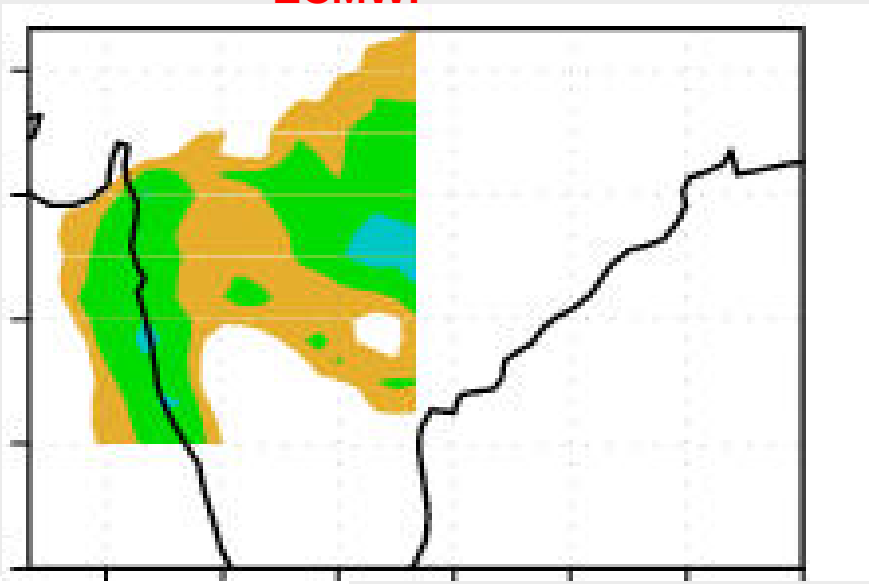
JMA

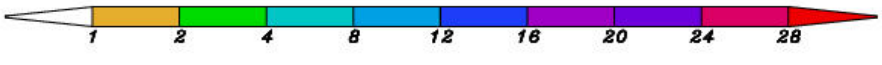


NCMRWF



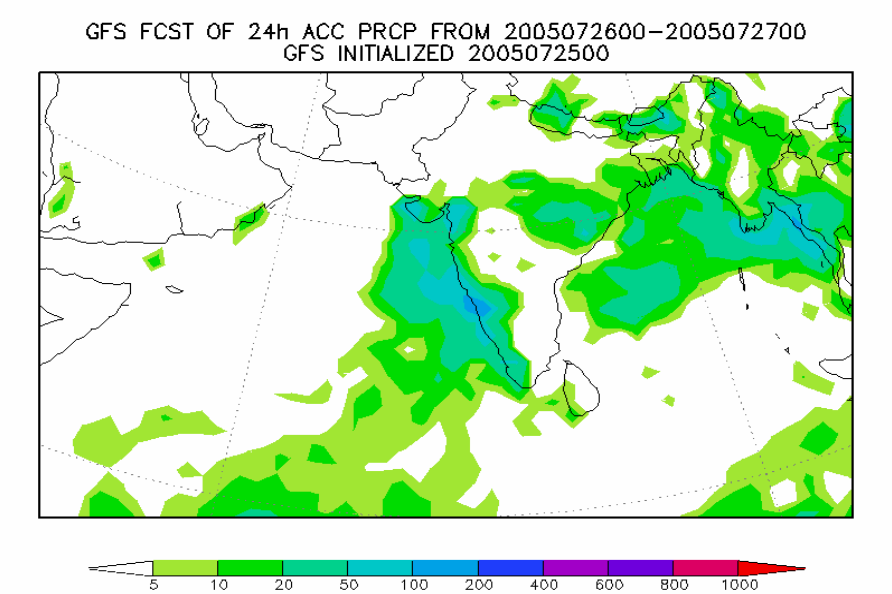
ECMWF



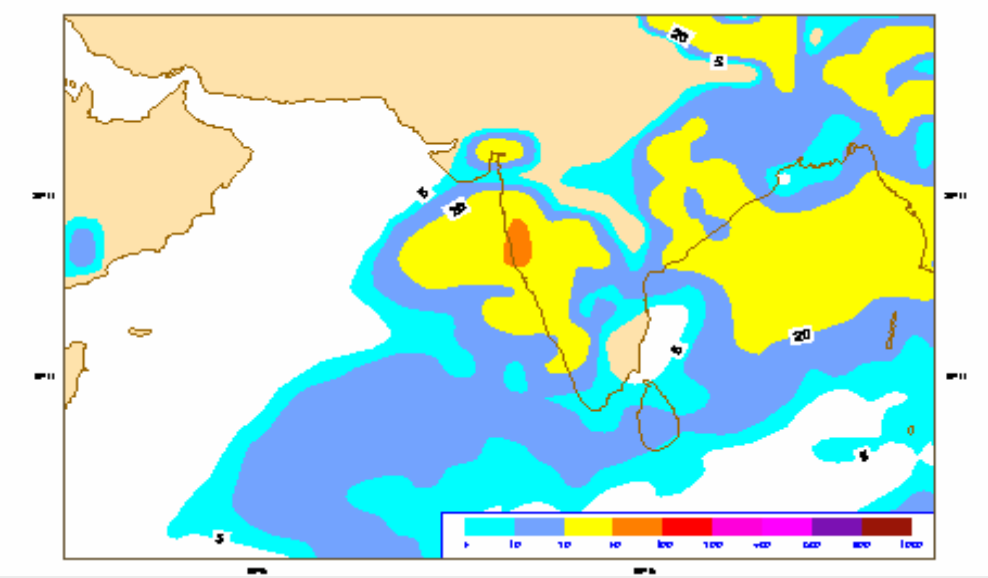


D2

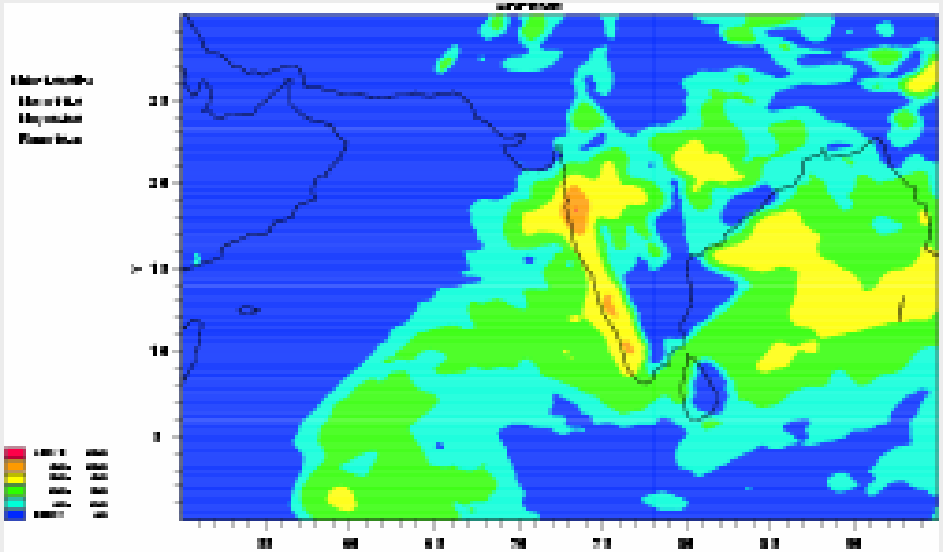
NCEP



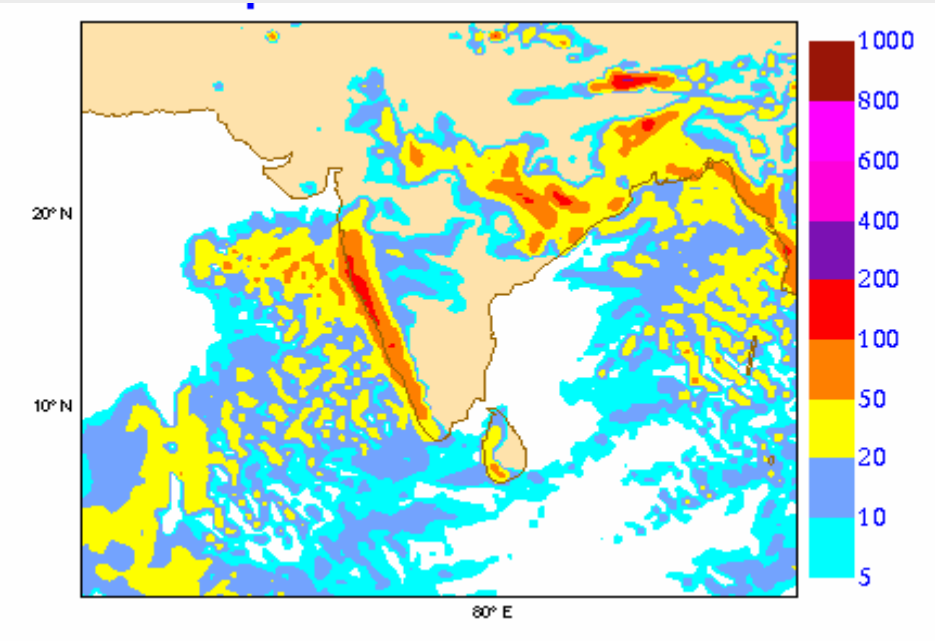
BoM Global



Meteo-France

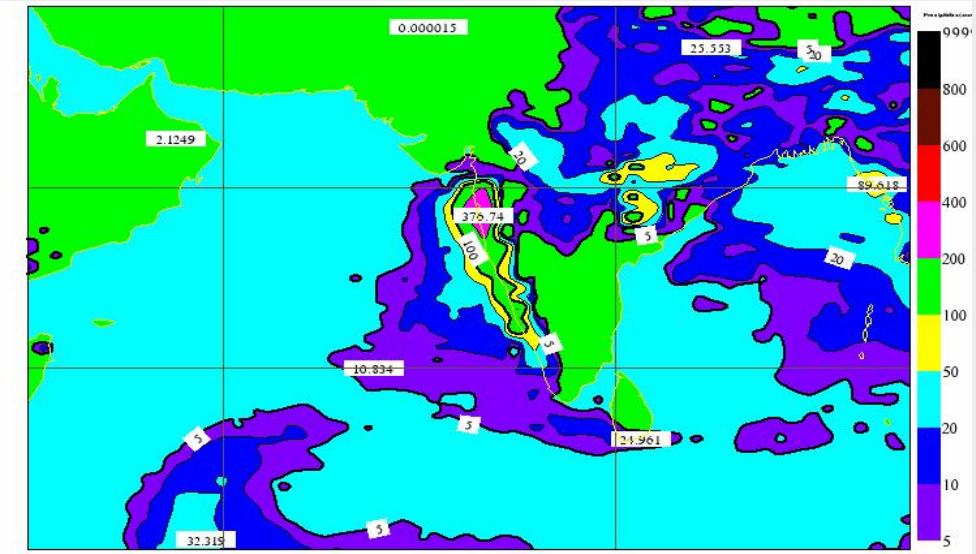


BoM TLAPS

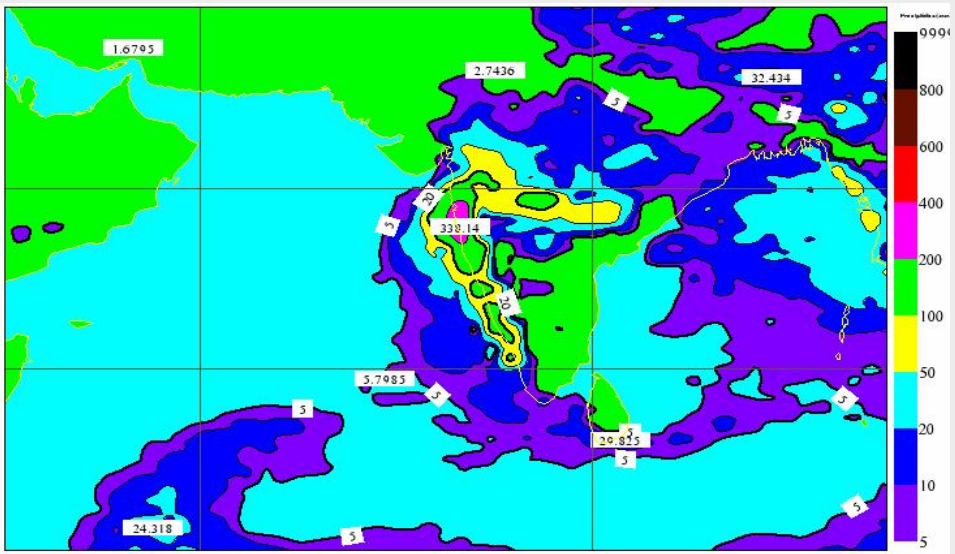


Met Office global model forecasts

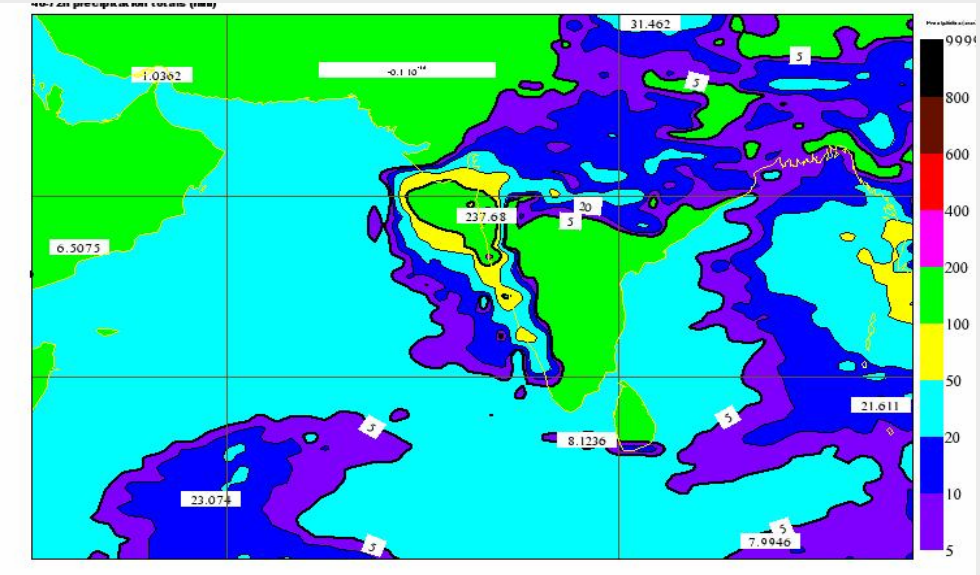
D1



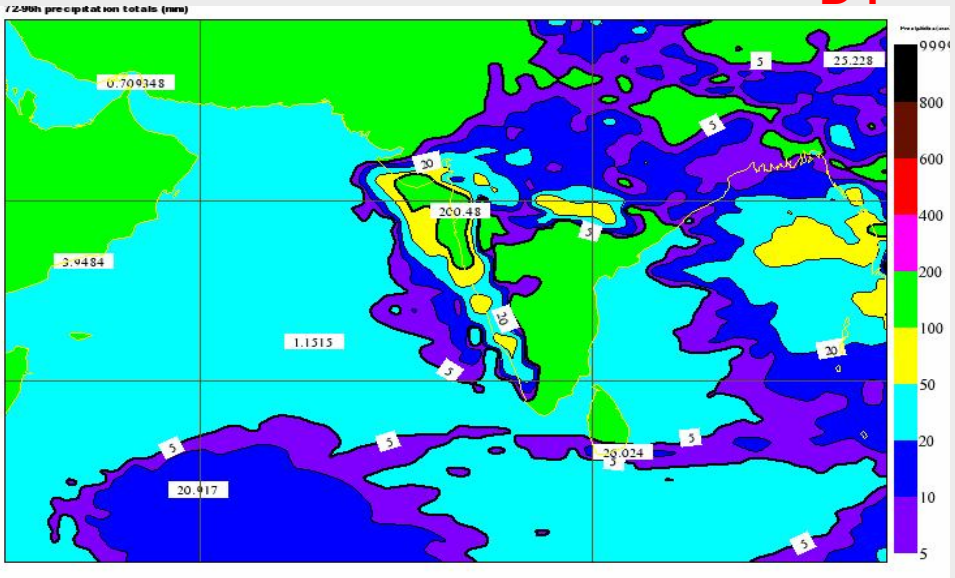
D2



D3



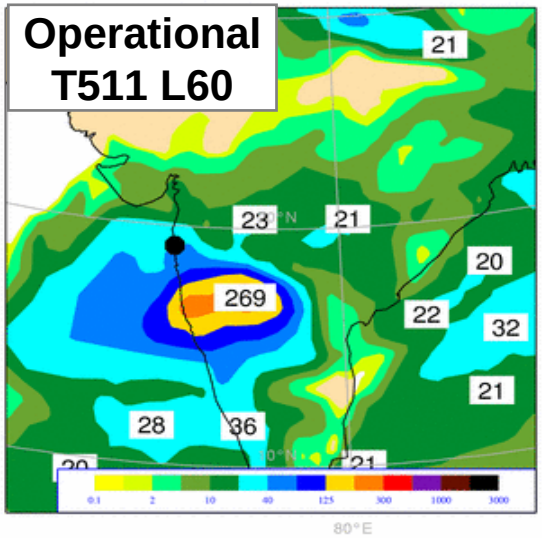
D4



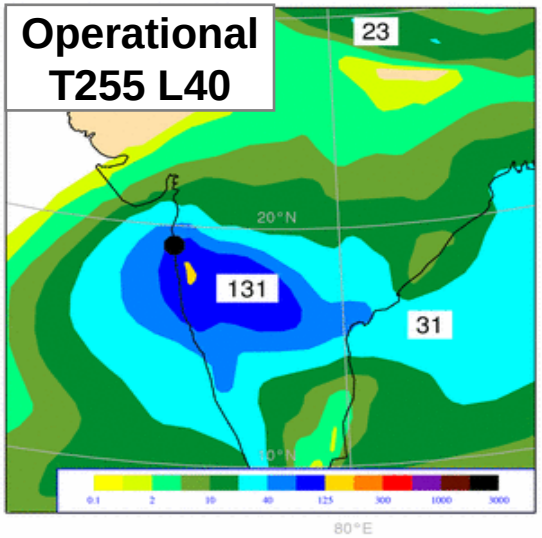
Extreme rainfall over Mumbai: D+5 to D+6

precip forecast (O-suite & E-suite) of deterministic & EPS mean, and probabilities to exceed 200
Forecast is based on Thursday 21 Jul 2005 0UTC
event accumulated from +120h to +144h

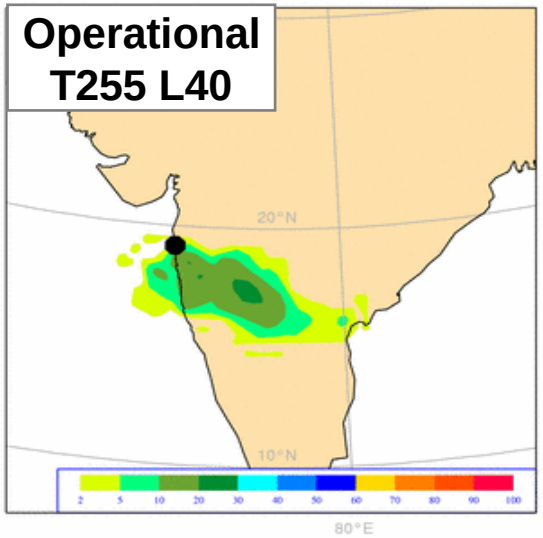
Deterministic, expver: 1



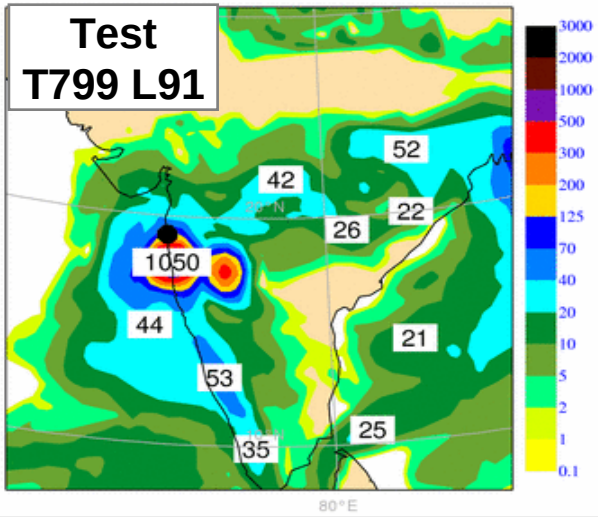
EPS mean, expver: 1



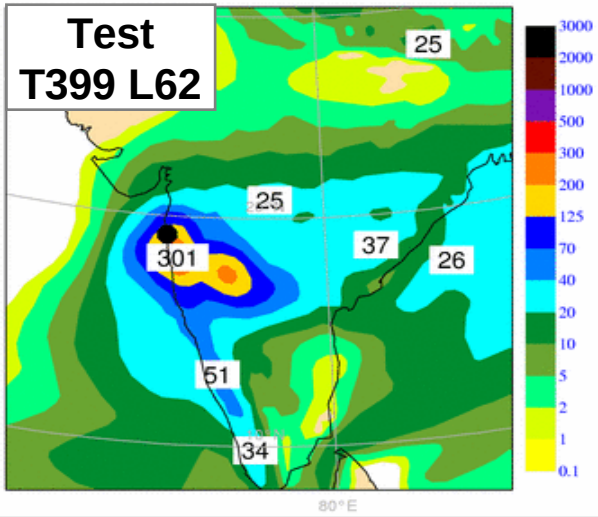
EPS prob. to exceed 200, expver: 1



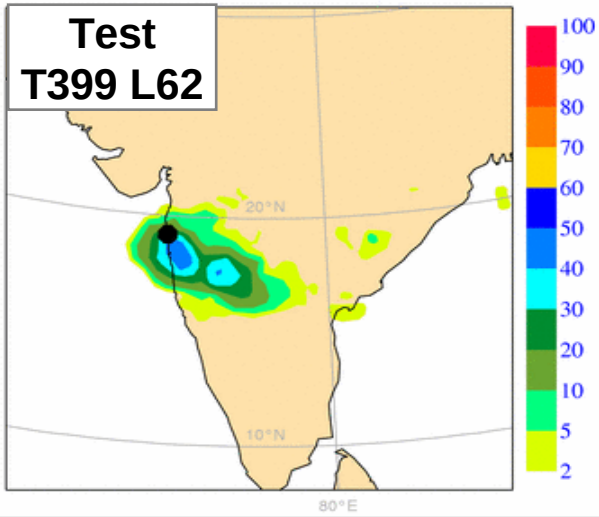
Deterministic, expver: 28



EPS mean, expver: 28



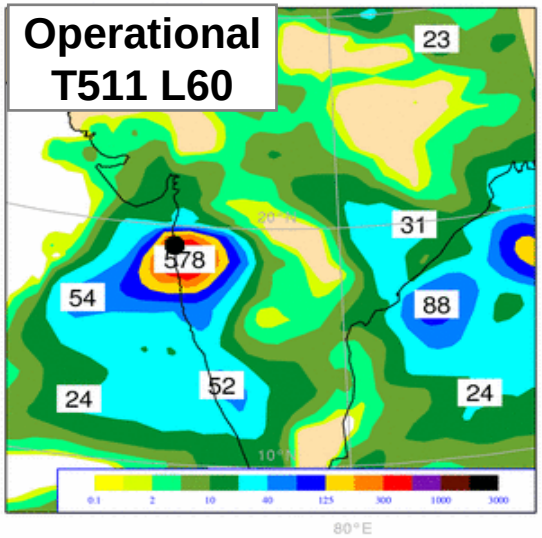
EPS prob to exceed 200, expver: 28



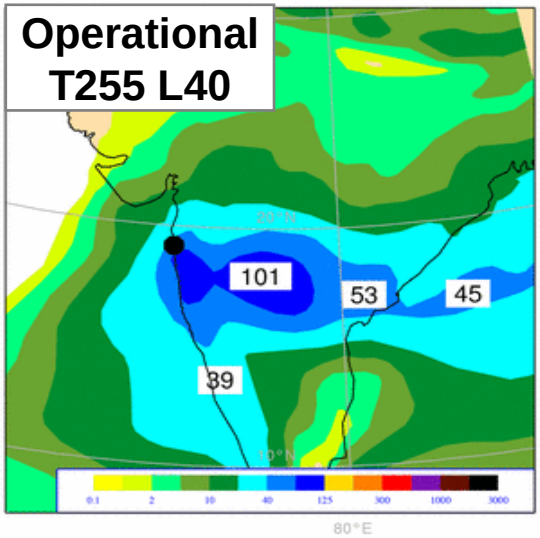
Extreme rainfall over Mumbai: D+8 to D+9

precip forecast (O-suite & E-suite) of deterministic & EPS mean, and probabilities to exceed 200
Forecast is based on Monday 18 Jul 2005 0UTC
event accumulated from +192h to +216h

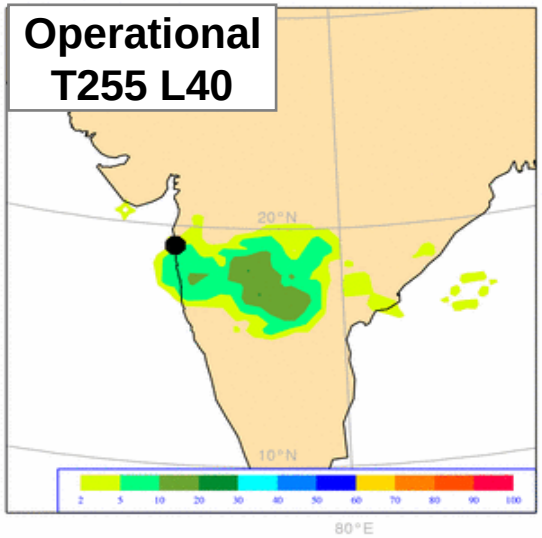
Deterministic, expver: 1



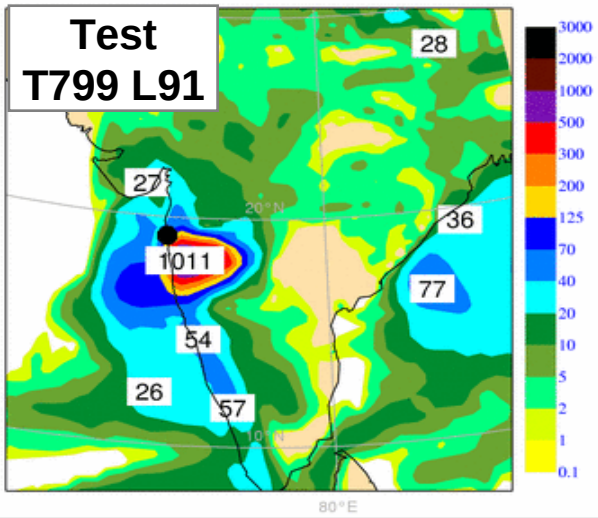
EPS mean, expver: 1



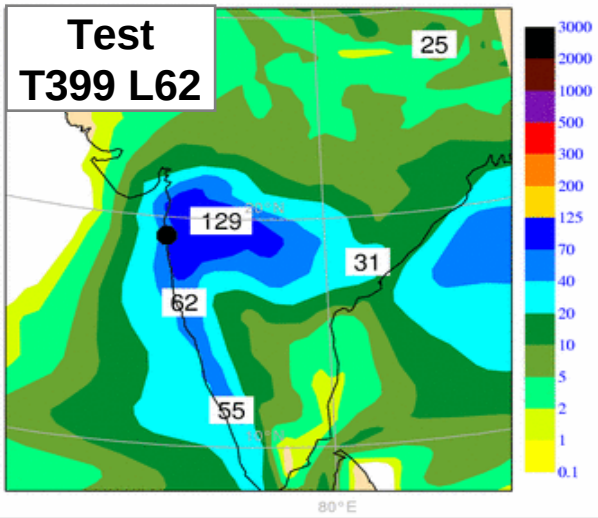
EPS prob. to exceed 200, expver: 1



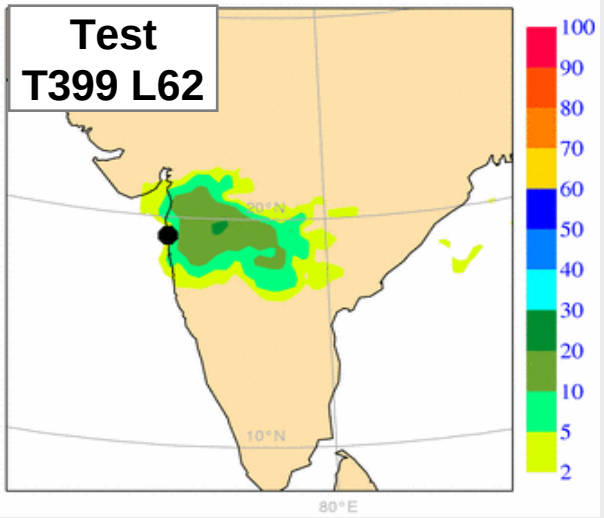
Deterministic, expver: 28



EPS mean, expver: 28



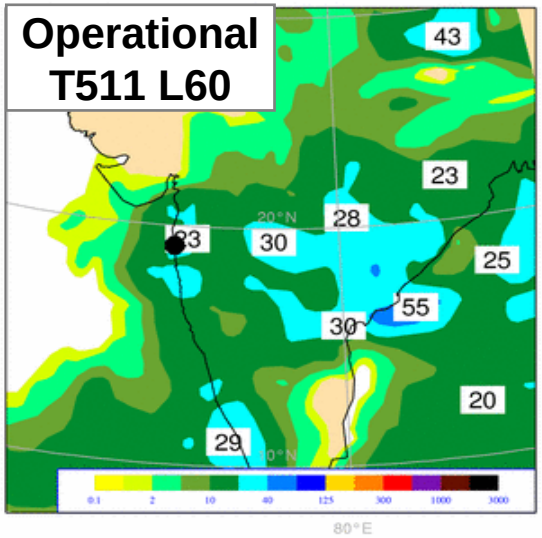
EPS prob to exceed 200, expver: 28



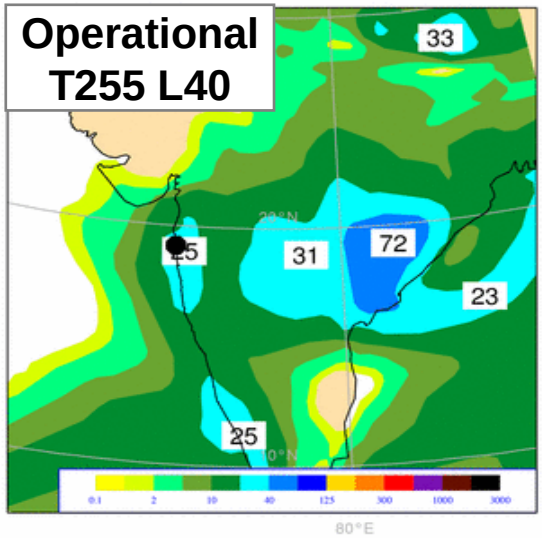
Extreme rainfall over Mumbai: D+1 to D+2

precip forecast (O-suite & E-suite) of deterministic & EPS mean, and probabilities to exceed 200
Forecast is based on Monday 25 Jul 2005 0UTC
event accumulated from +24h to +48h

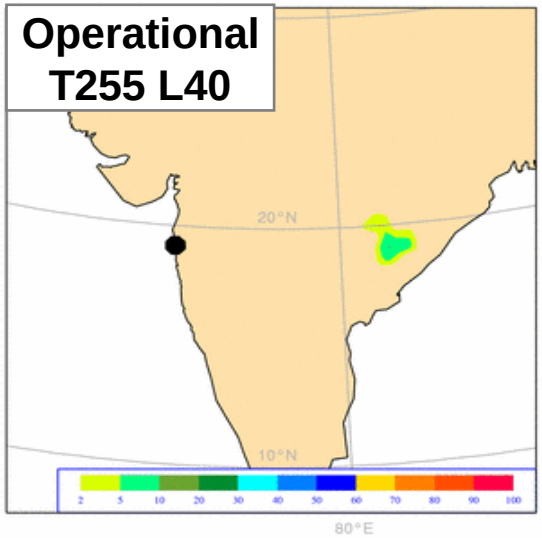
Deterministic, expver: 1



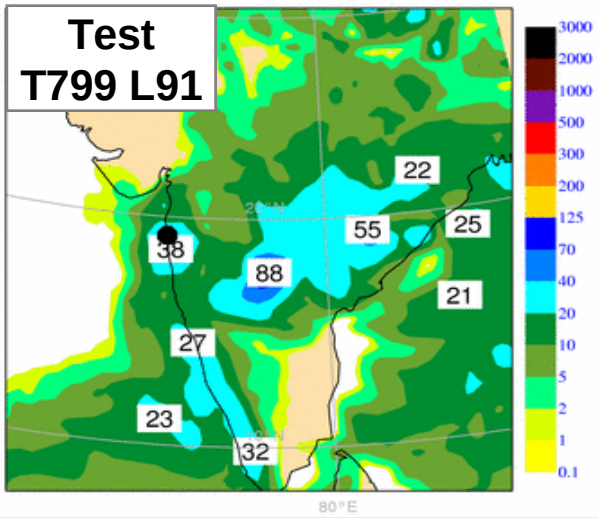
EPS mean, expver: 1



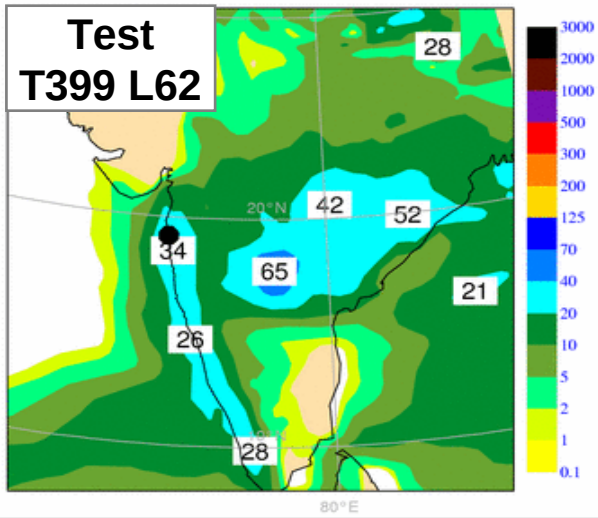
EPS prob. to exceed 200, expver: 1



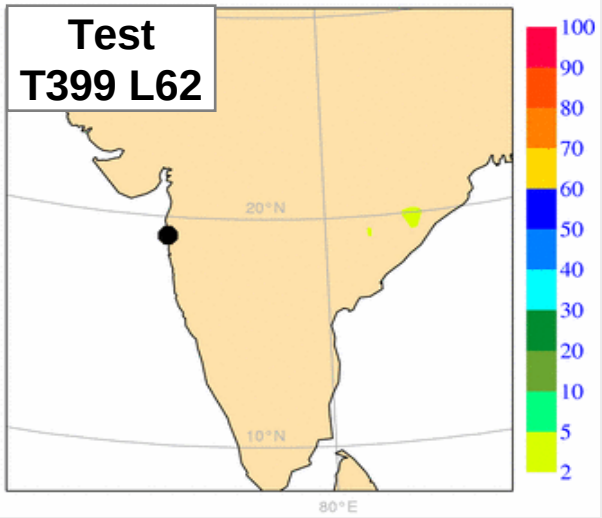
Deterministic, expver: 28



EPS mean, expver: 28



EPS prob to exceed 200, expver: 28



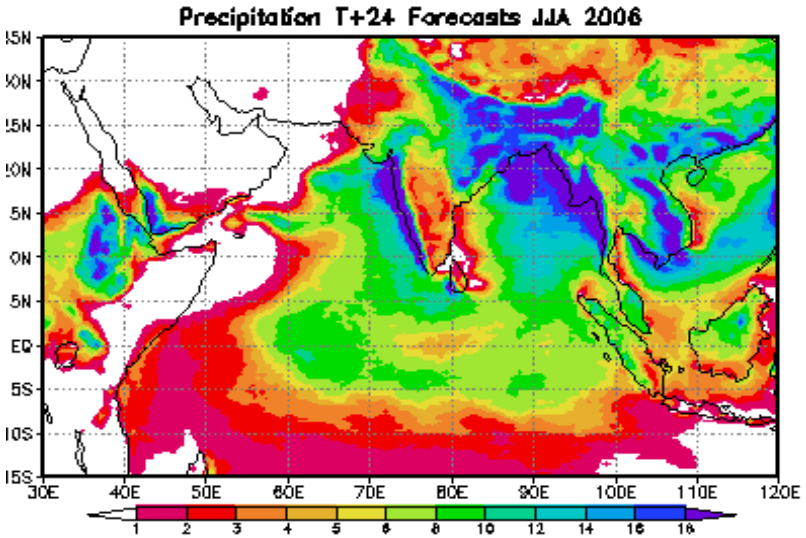
Indian Monsoon JJA 2006 Precipitation

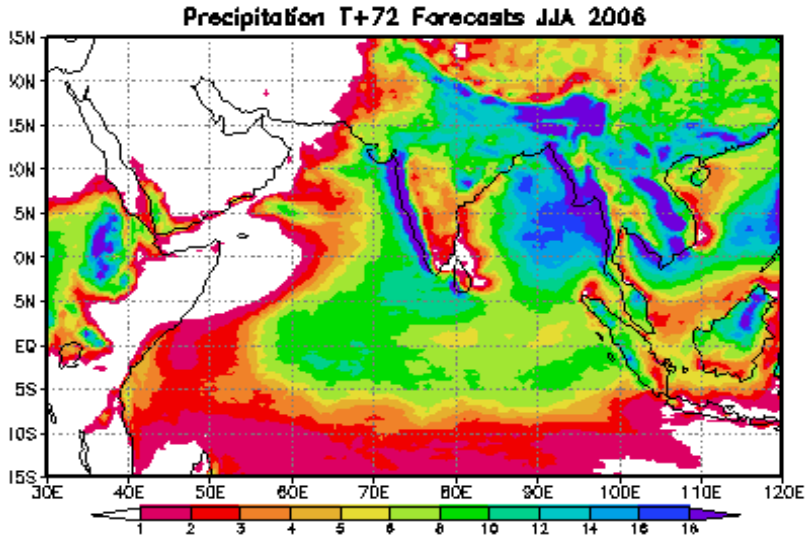
Model Precipitation increases in Central Indian Ocean

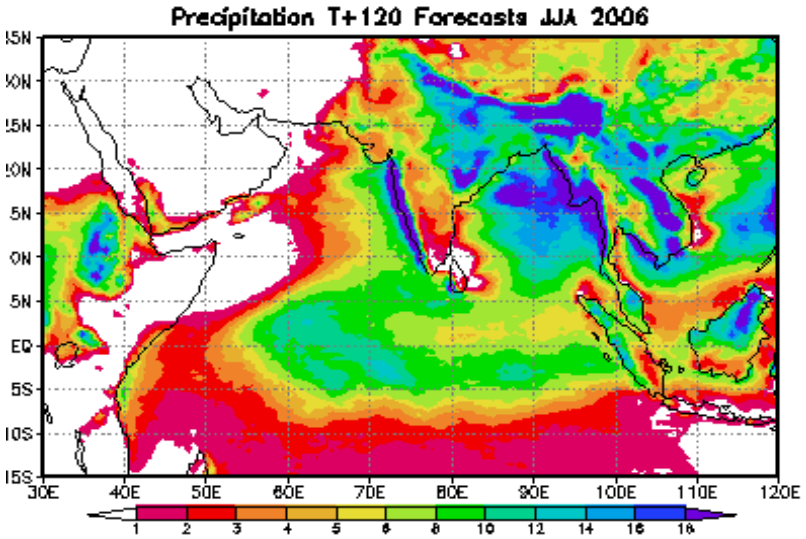
and

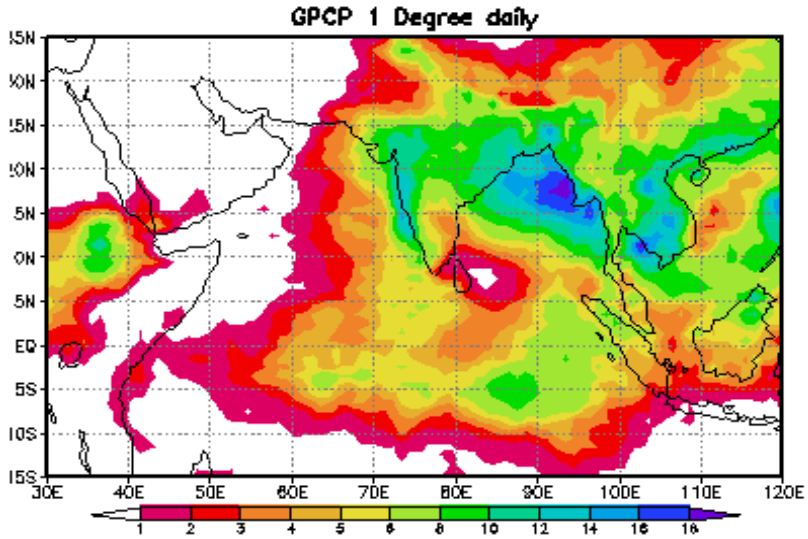
decreases over Indian Subcontinent

Compared to GPCP







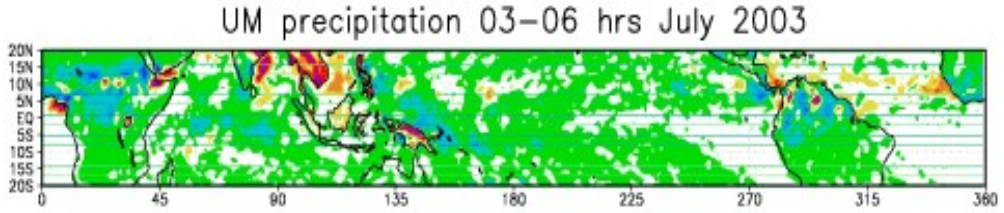


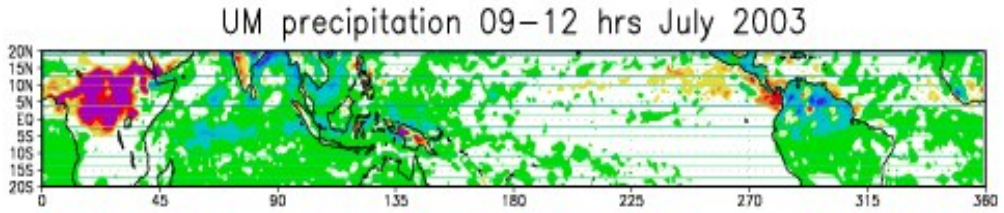
Diurnal Cycle Model vs TRMM

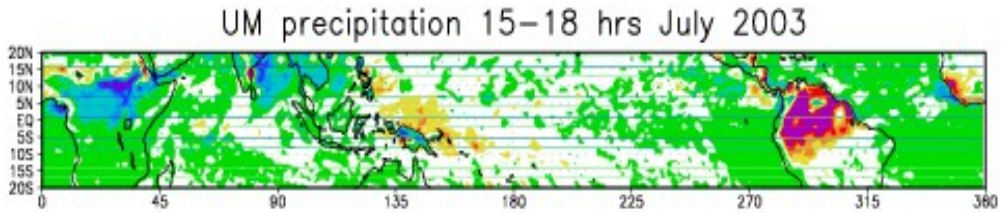
Deviation from daily mean (mm/day)

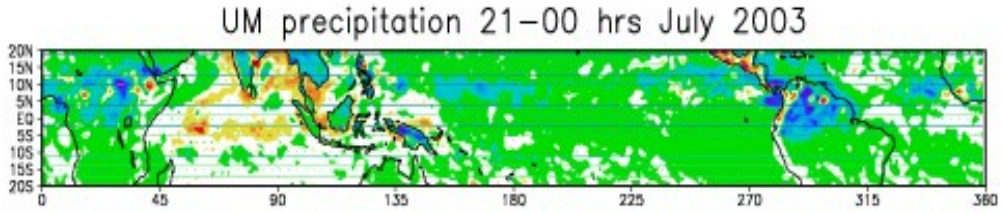
Model precip over land – Peaks at Midday

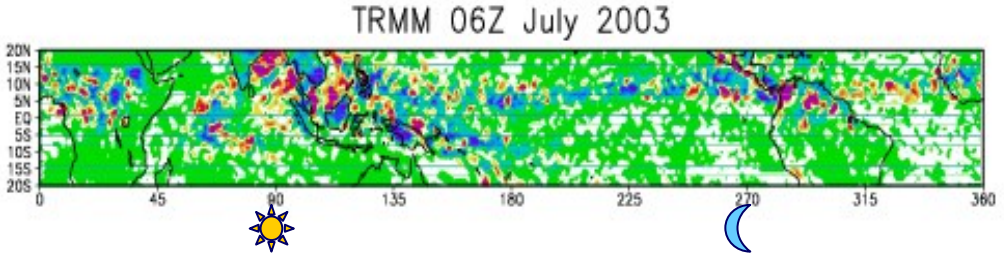
OBS precip over land – Peaks late afternoon & evening

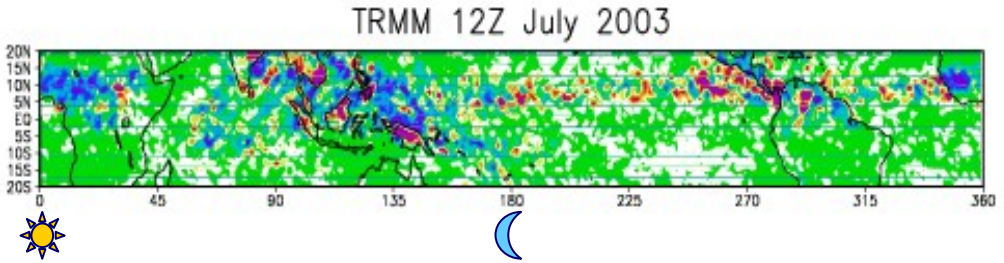


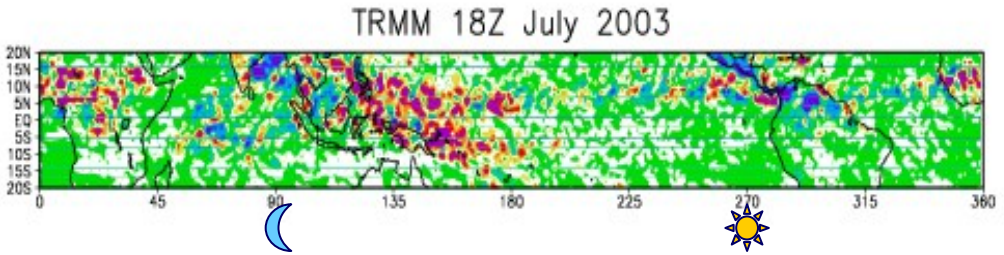


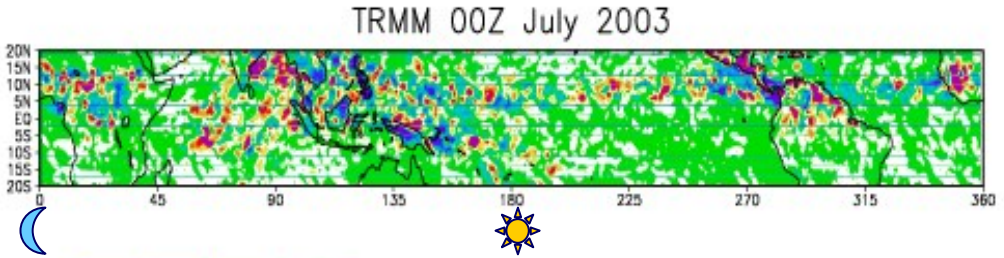




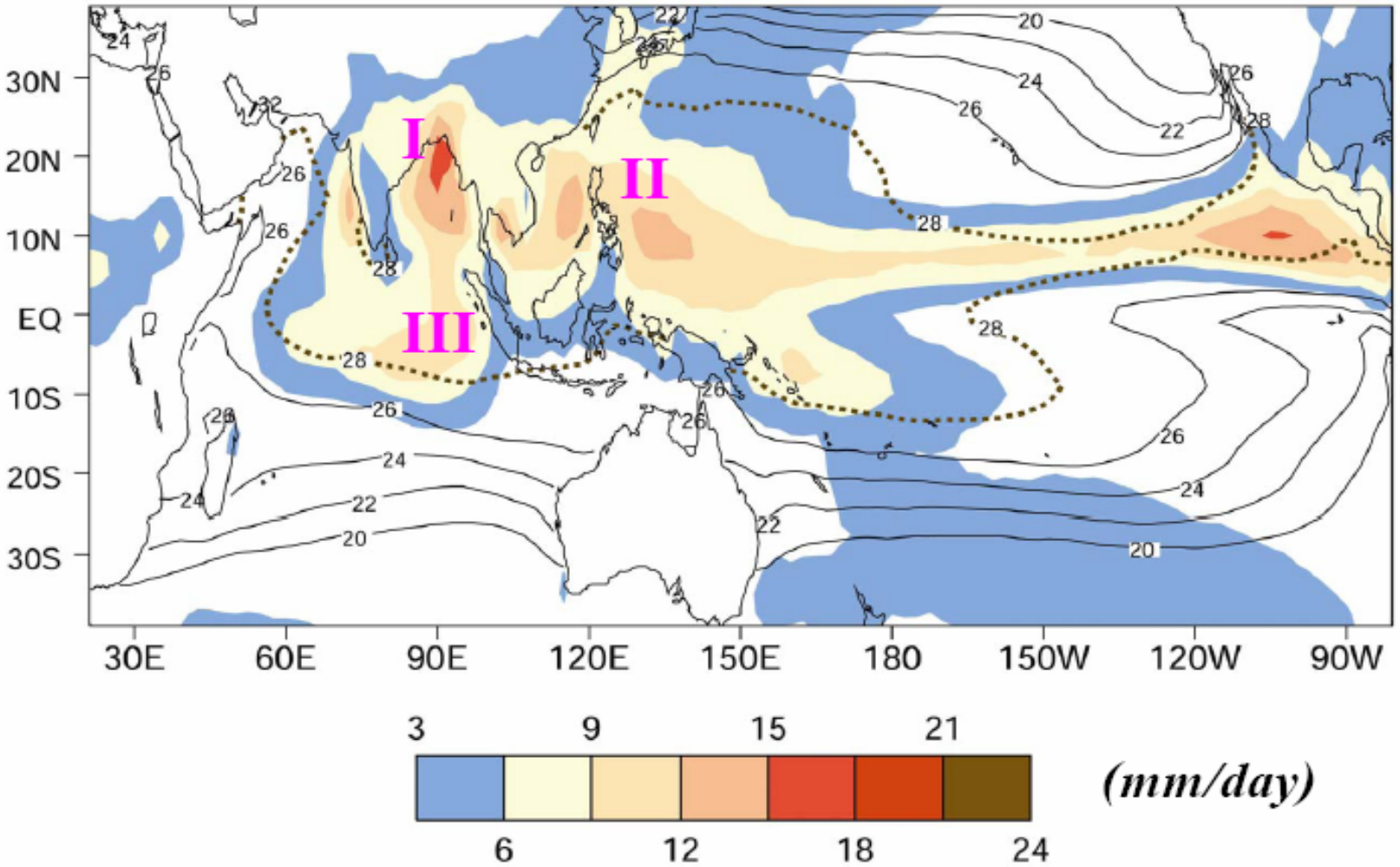






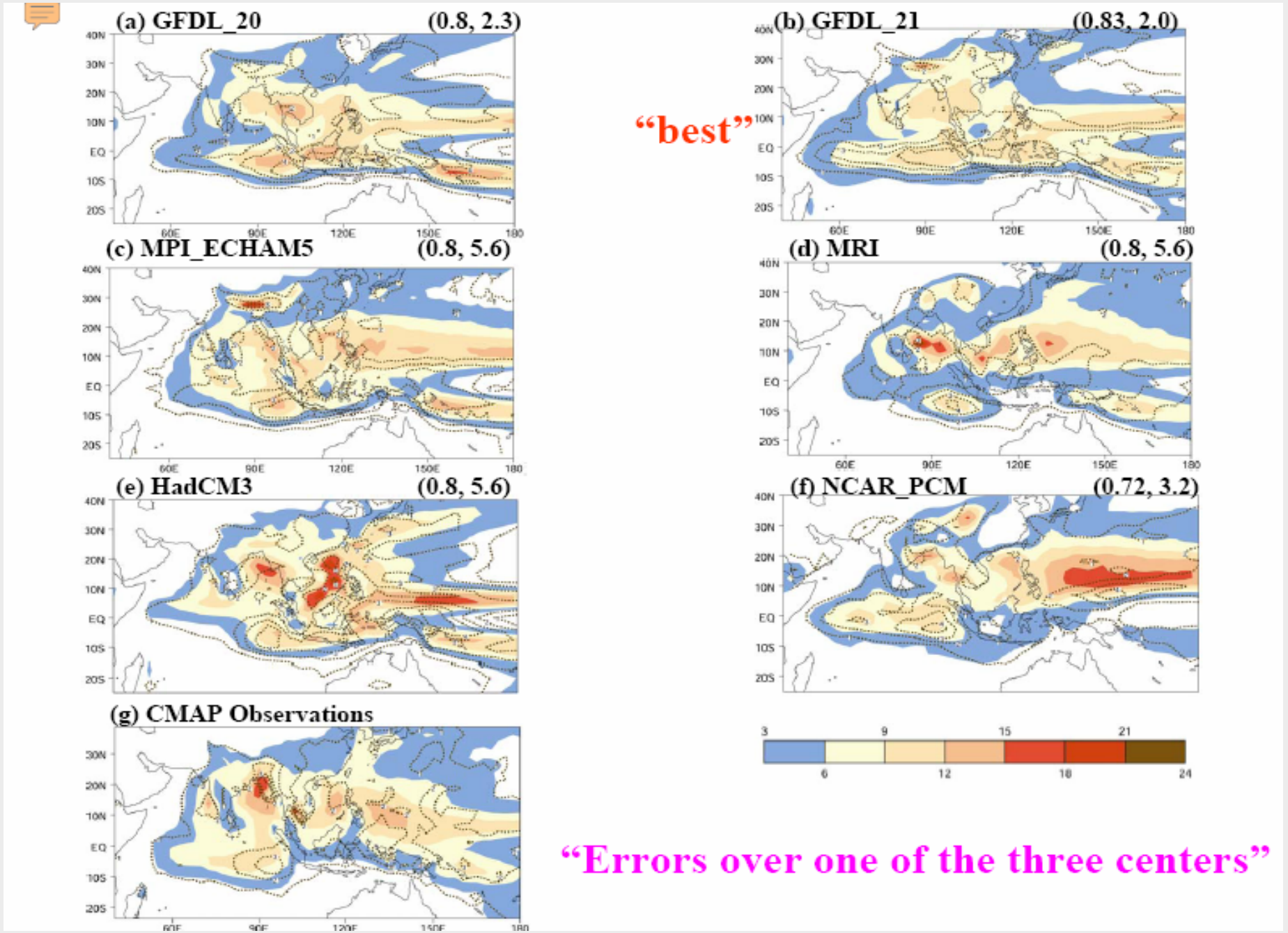


JJAS – Precipitation and SST Climatology



"Three regional heat sources"

Annamalai et al.

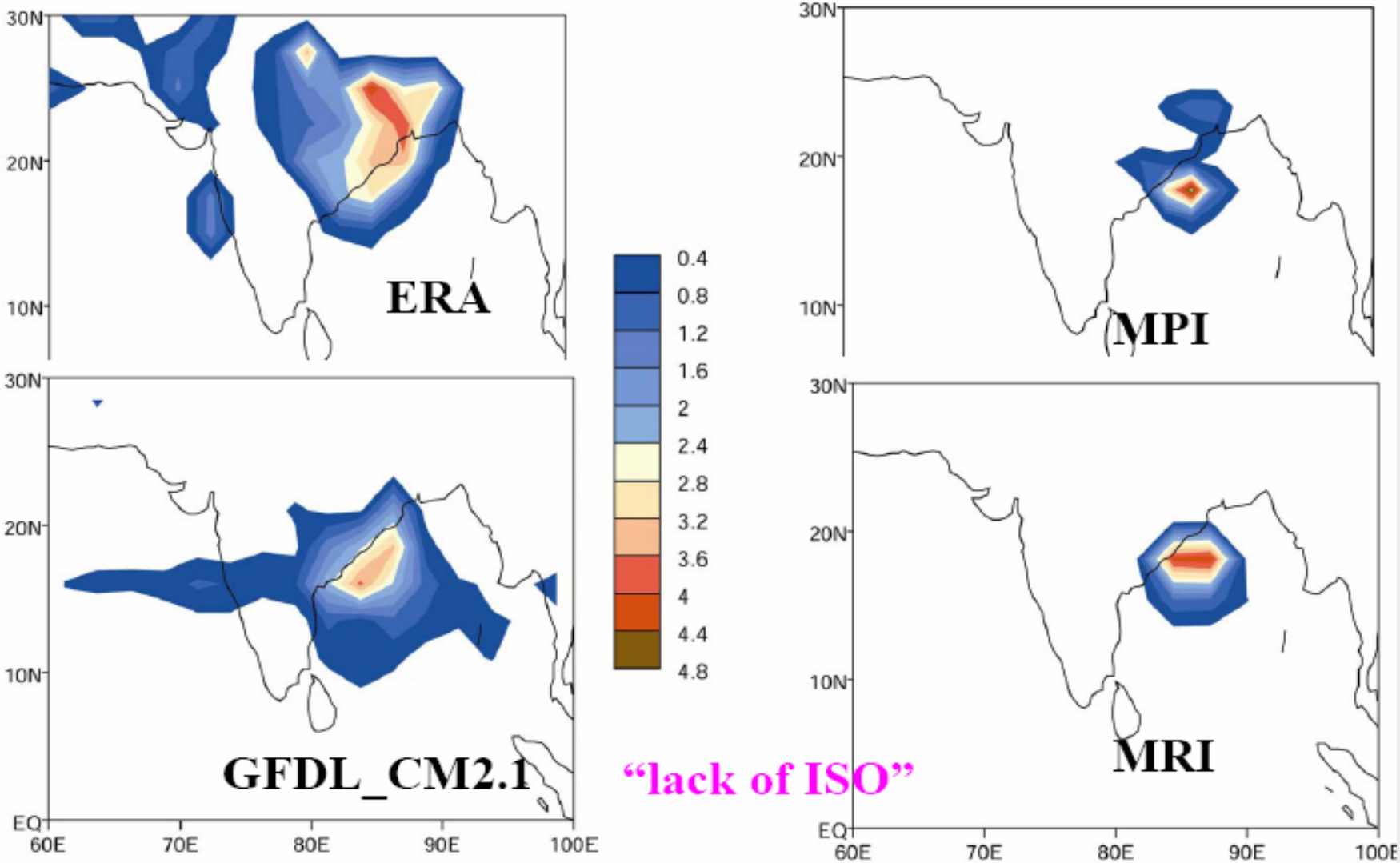


"best"

"Errors over one of the three centers"

Annamalai et al.

Feature density of monsoon depressions



"lack of ISO"

"In models, depressions are concentrated over the ocean" – The mean monsoon trough is located "southwards" in the models

Annamalai et al.

MJO

The Madden Julian Oscillation, the Java floods of January/February 2002, and other extremes in weekly rainfall.

Matthew Wheeler

m.wheeler@bom.gov.au

Indonesian floods of January/February 2002

Media attention:

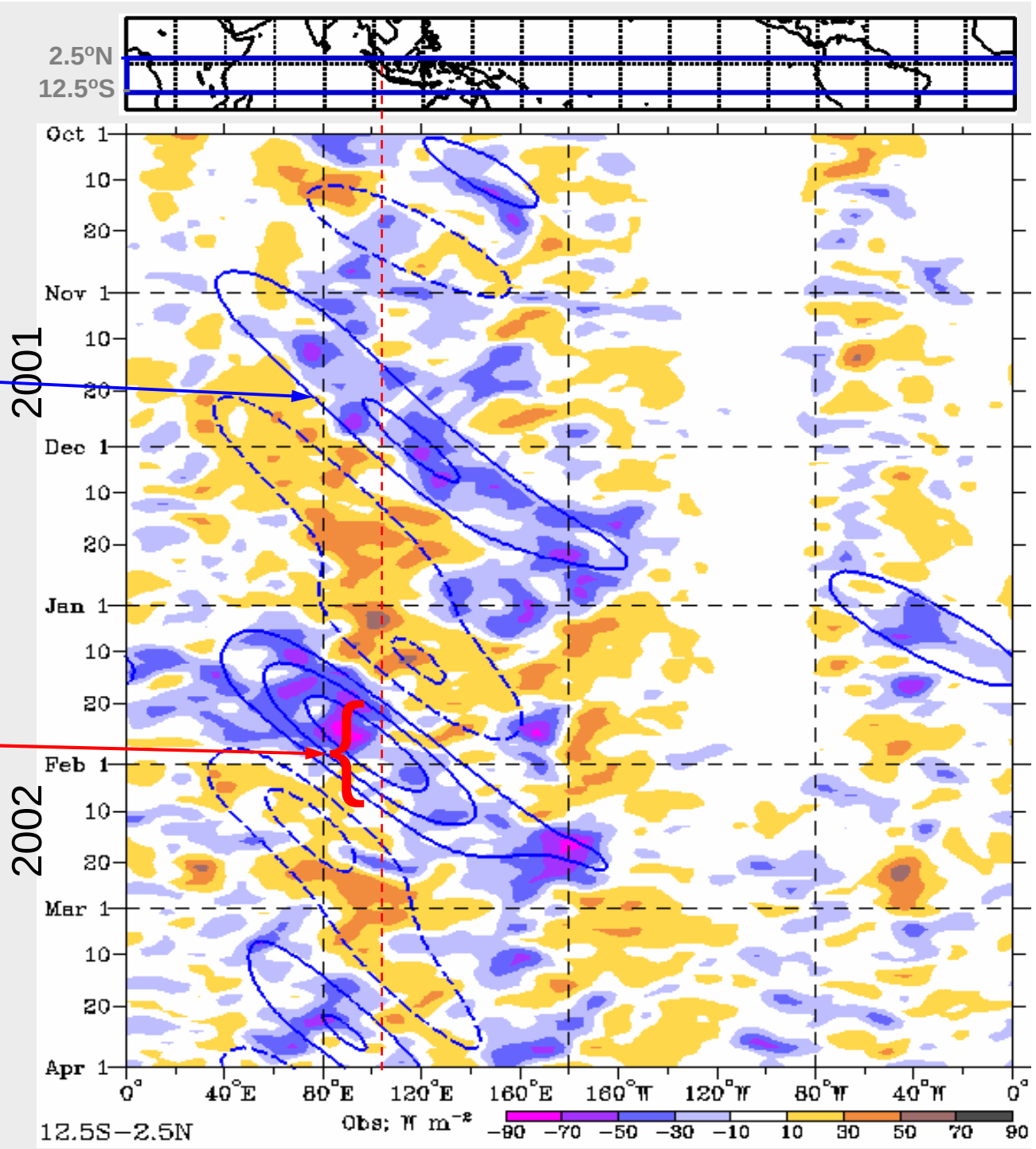
29 Jan, *Jakarta Post*. "Jakarta floods worsen"
1 Feb, *Reuters*. "Heavy rains and floods bring more misery to Jakarta"
6 Feb, *People's Daily*. "Premier Zhu offers condolences to flood-hit Indonesian people"
6 Feb, *Reuters*. "Jakarta floods ease but criticism gets louder"
13 Feb, *WSWS*. "At least 50 dead as floods inundate much of Jakarta"

- 1/4 of surface of Jakarta was under water
- 60 deaths in Jakarta. 90 elsewhere.
- 360,000 temporarily homeless.
- 18,000 suffered from diarrhea

OLR Anomalies for the MJO

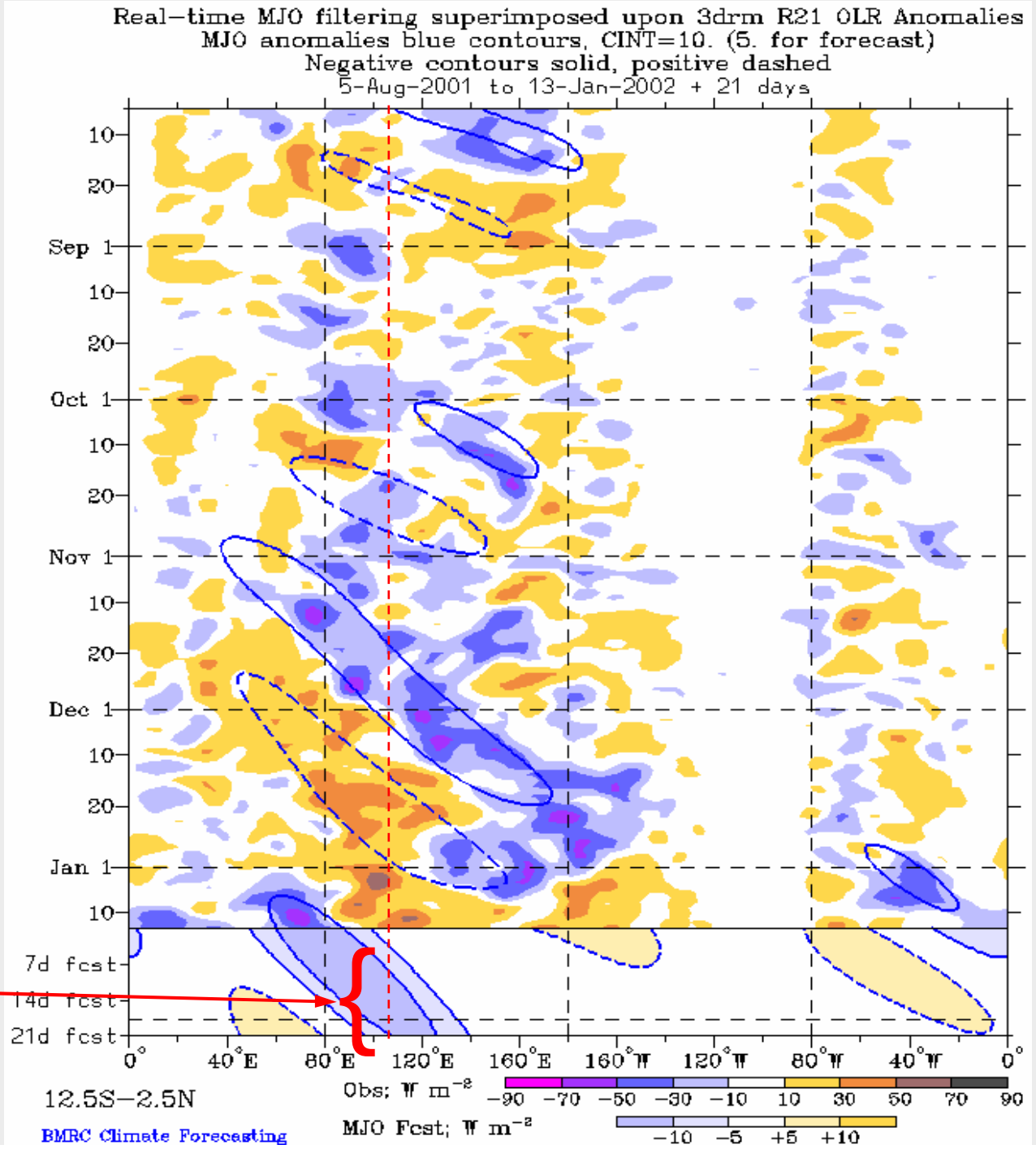
Eastward wavenumbers 1-5,
Periods 30-96 days

Jakarta floods



Forecasting the OLR anomalies of the MJO

Example for Indonesian flooding event using technique of Wheeler and Weickmann (2001)



Jakarta floods

MJO Prediction: Maps from 13th Jan

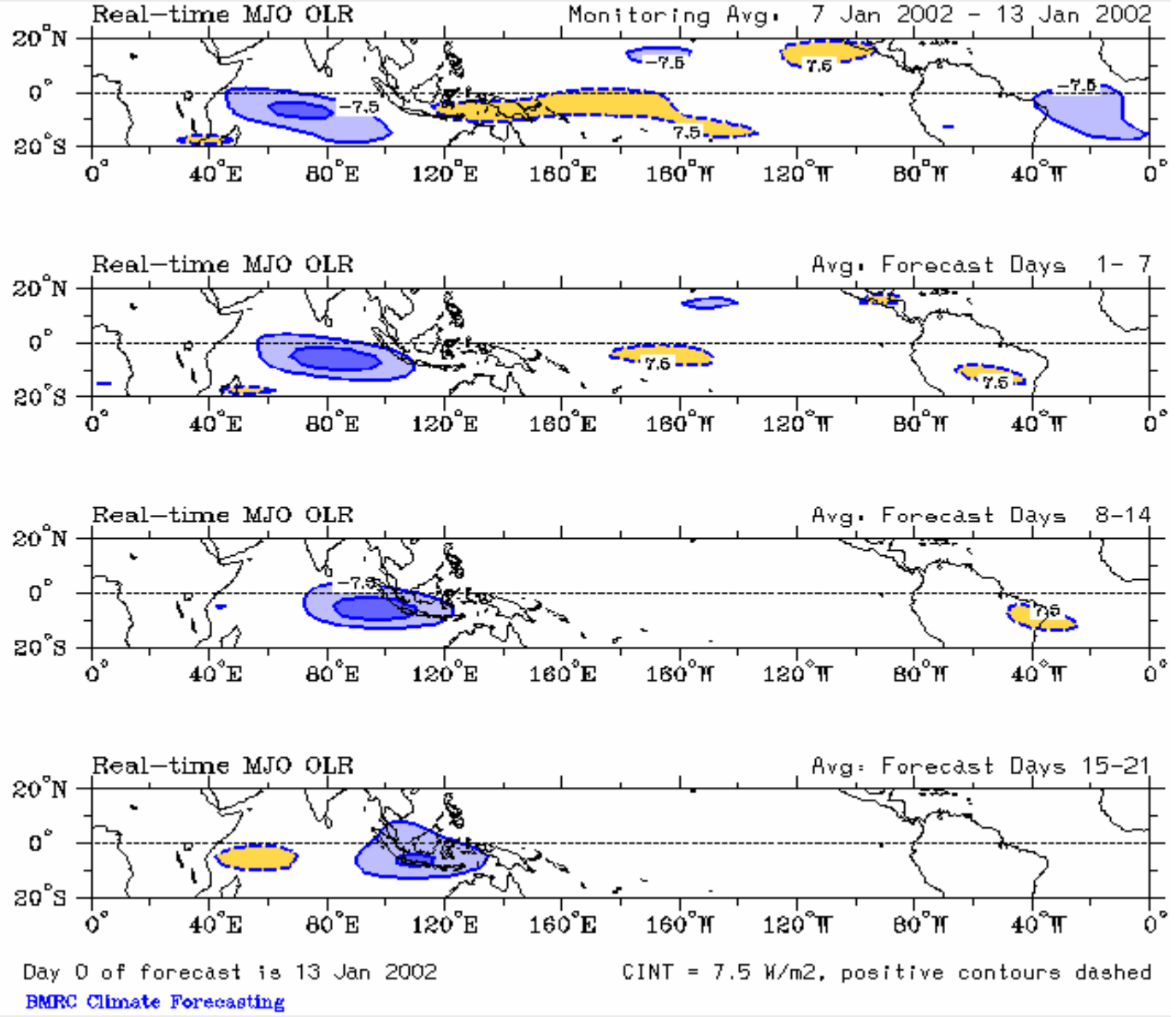
“Initial Condition”
7 - 13 JAN

Week 1 forecast
14 - 20 JAN

Week 2 forecast
21 - 27 JAN

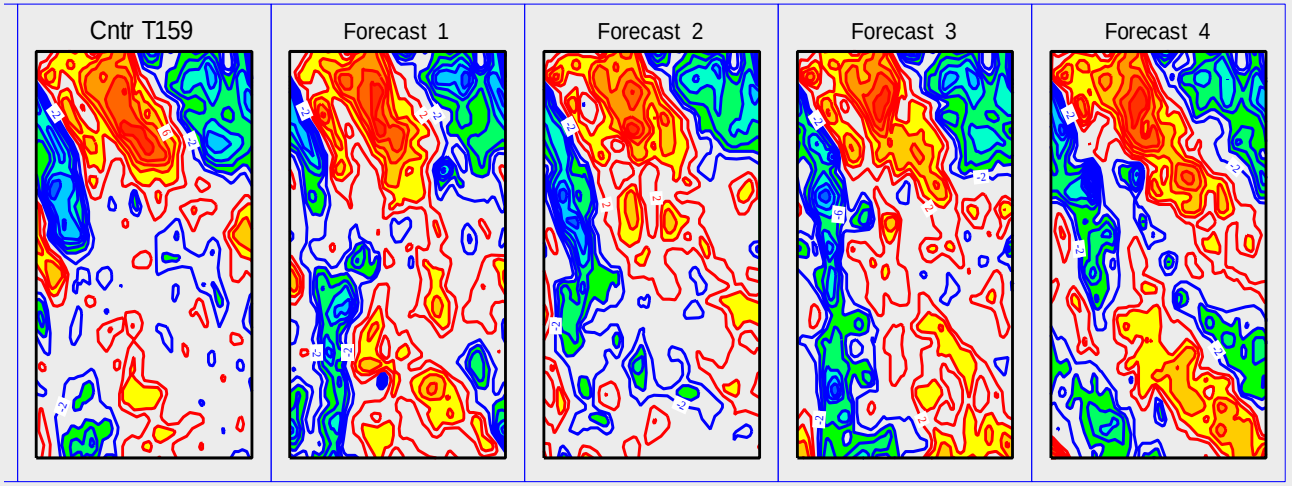
Flood

Week 3 forecast
28 JAN - 3 FEB

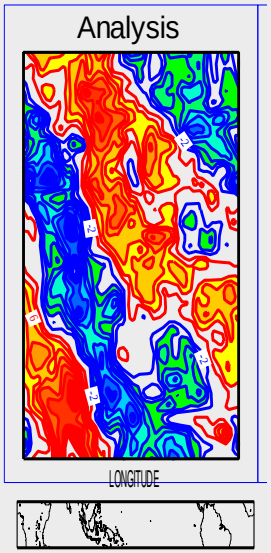


Madden-Julian oscillation
Forecast starting on 31 December 1992

CY29R1



Analysis

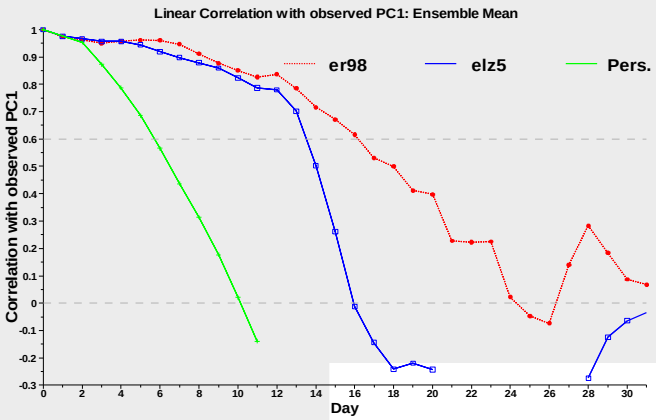


ECMWF operational global model

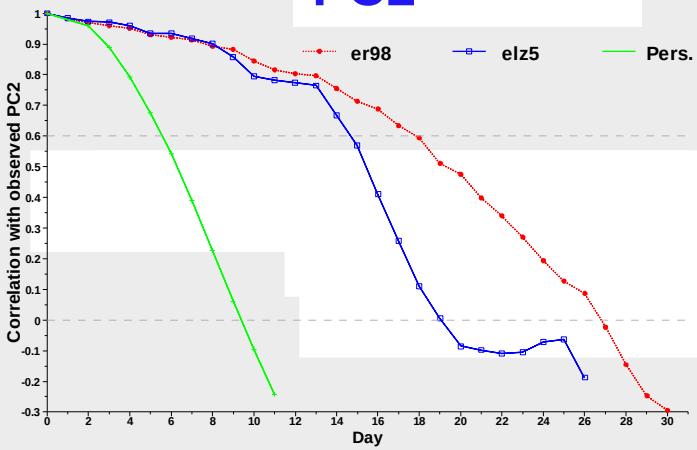
**** Model is unable to maintain the MJO**

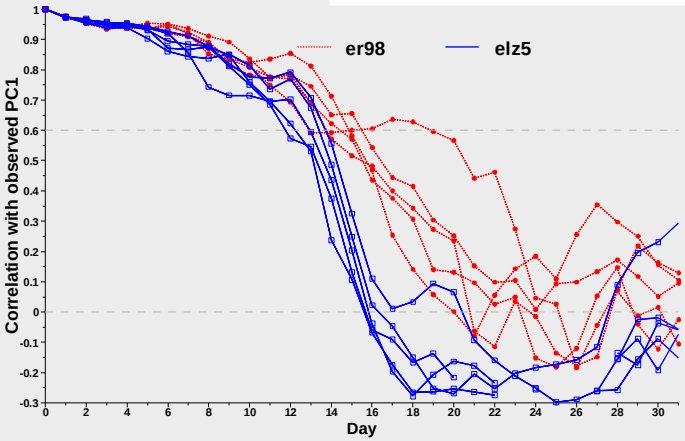
MJO EOF analysis

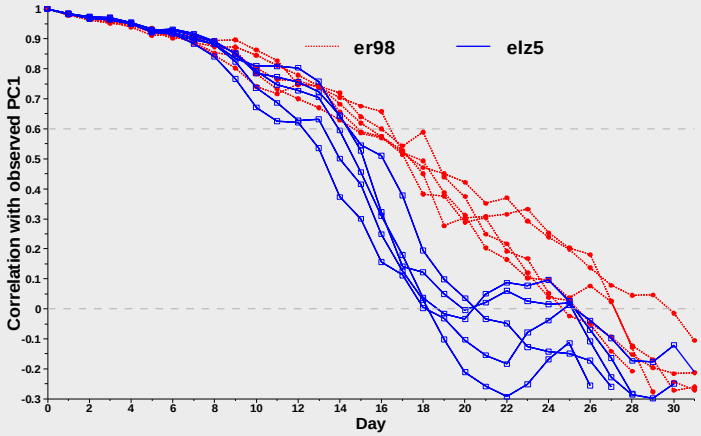
PC1



PC2

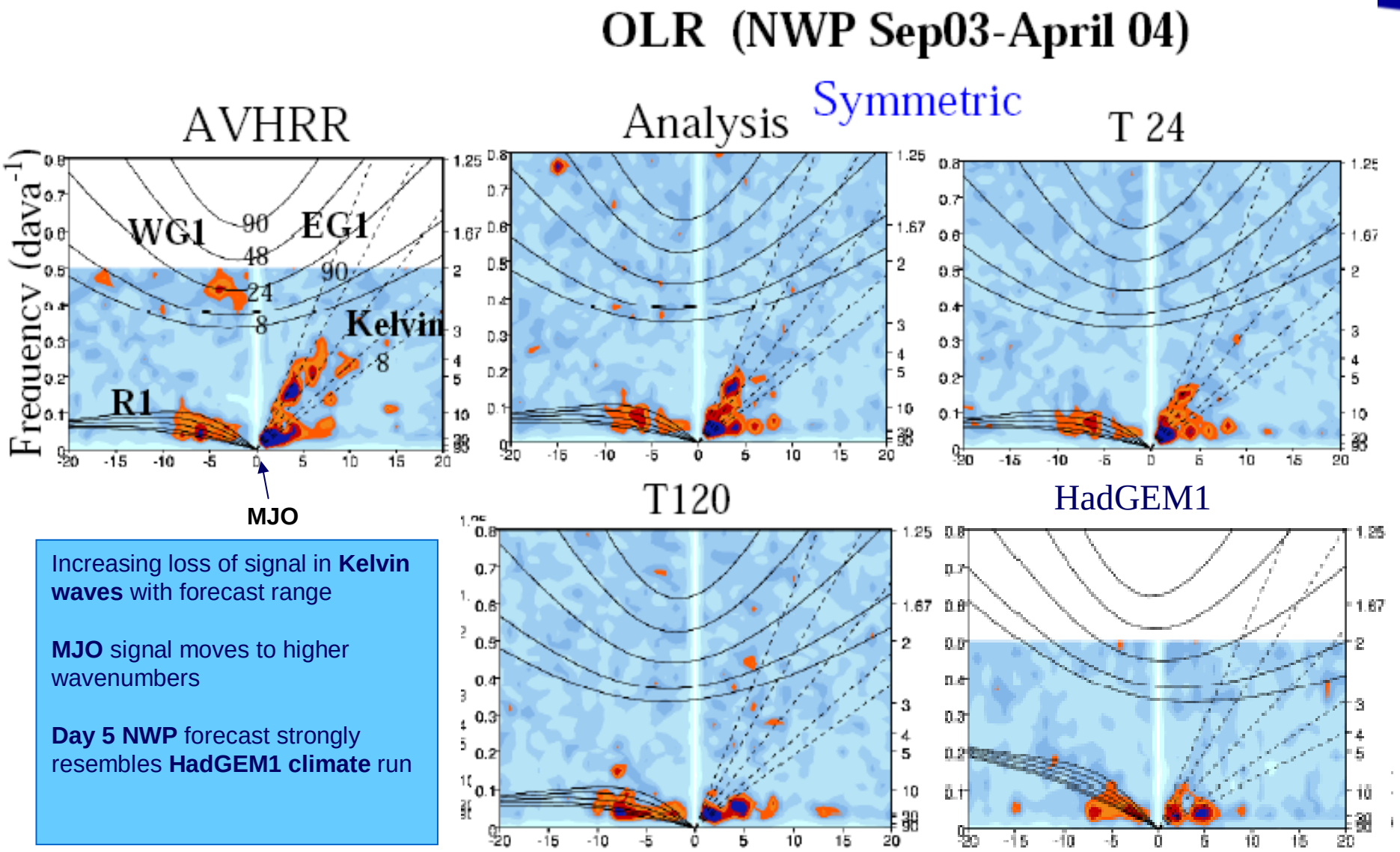






30R2 — **29R1**

WaveNo-Freq Spectra of Equatorial Waves



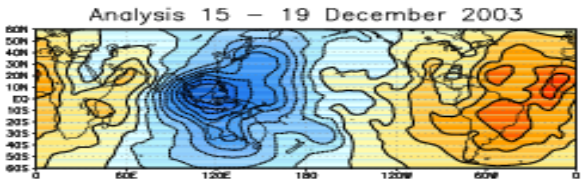
Increasing loss of signal in **Kelvin waves** with forecast range

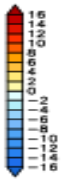
MJO signal moves to higher wavenumbers

Day 5 NWP forecast strongly resembles **HadGEM1 climate** run

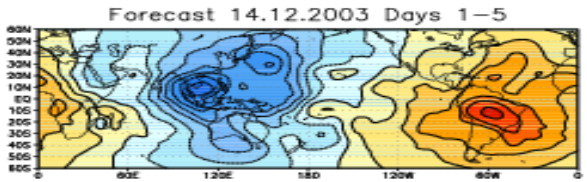
Courtesy G.Yang & P.Inness Walker Centre, Reading University

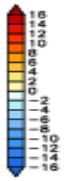
MJO Event : 15 Dec 2003 – 18 Jan 2004

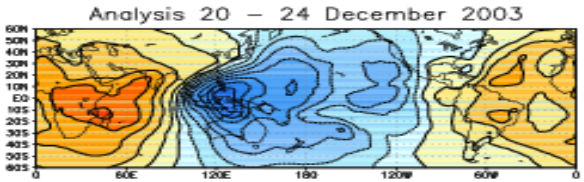




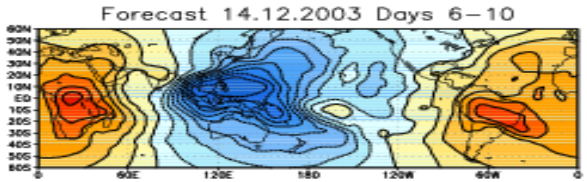
D1-5

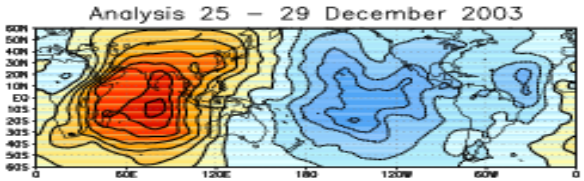




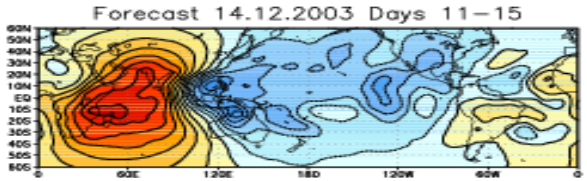


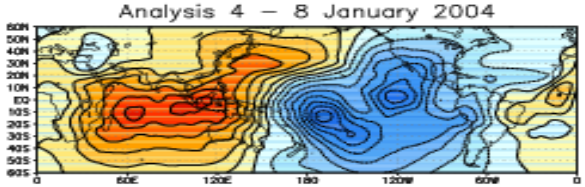
D6-10



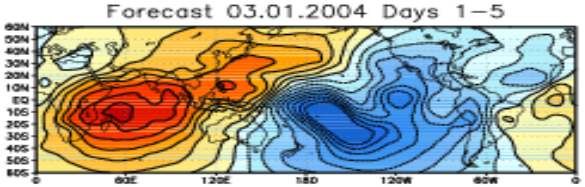


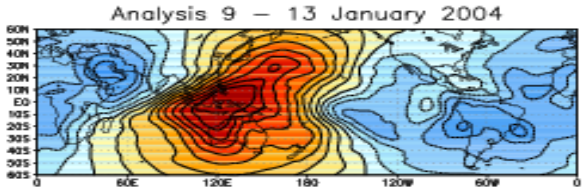
D11-15



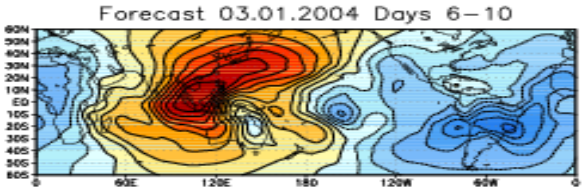


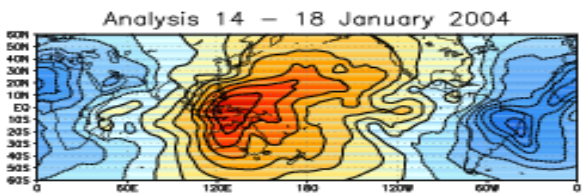
D1-5



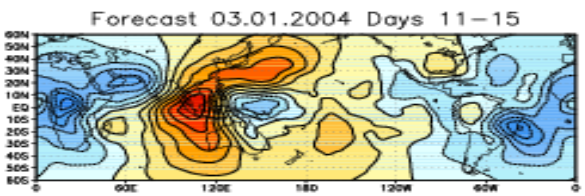


D6-10





D11-15



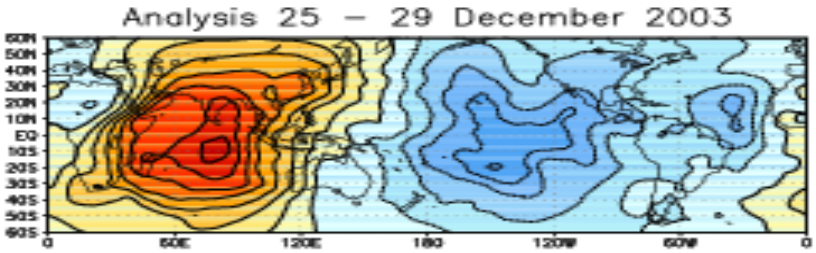
150 hPa velocity potential Anomaly

Red = Suppressed Convection

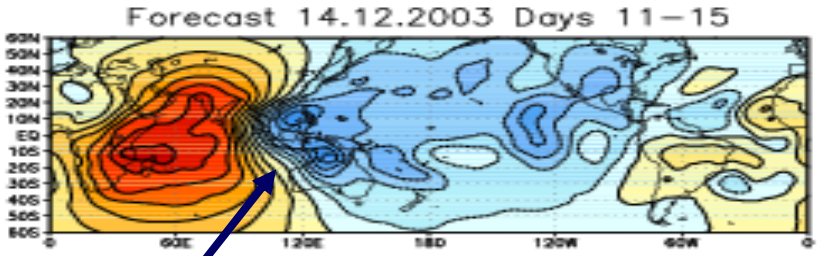
Blue= Enhanced Convection

MJO Event : 15 Dec 2003 – 18 Jan 2004

Analysis

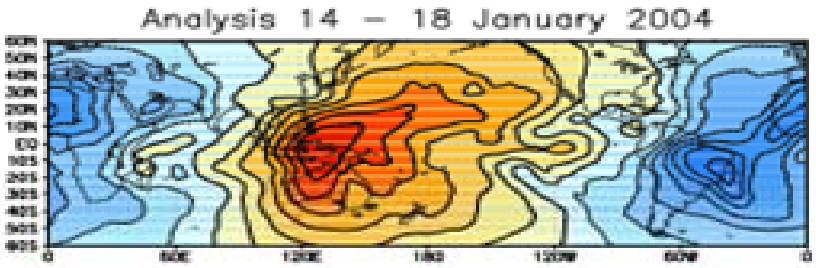


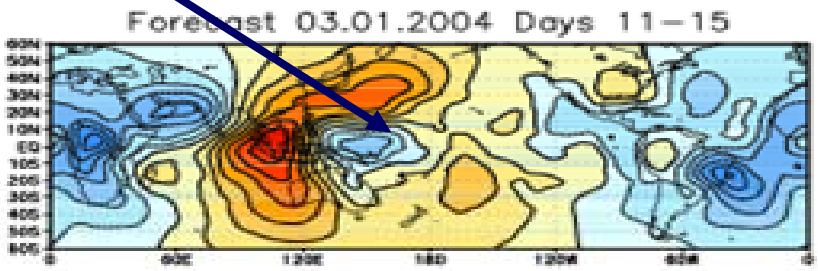
Forecast



150 hPa velocity potential Anomaly

Model Has problems maintaining MJO mode over the Maritime Continent at longer forecast ranges (days 11-15)



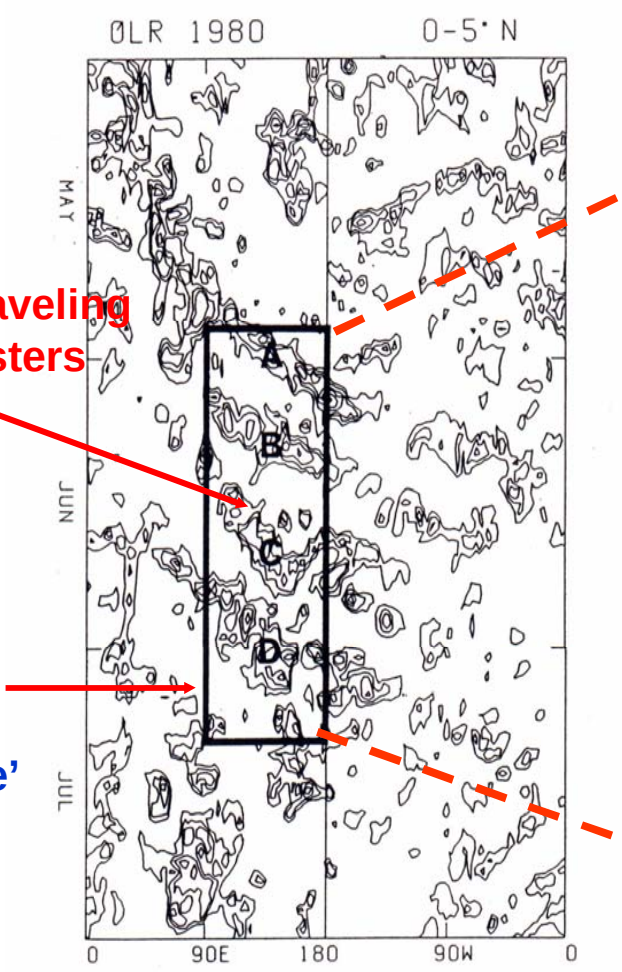


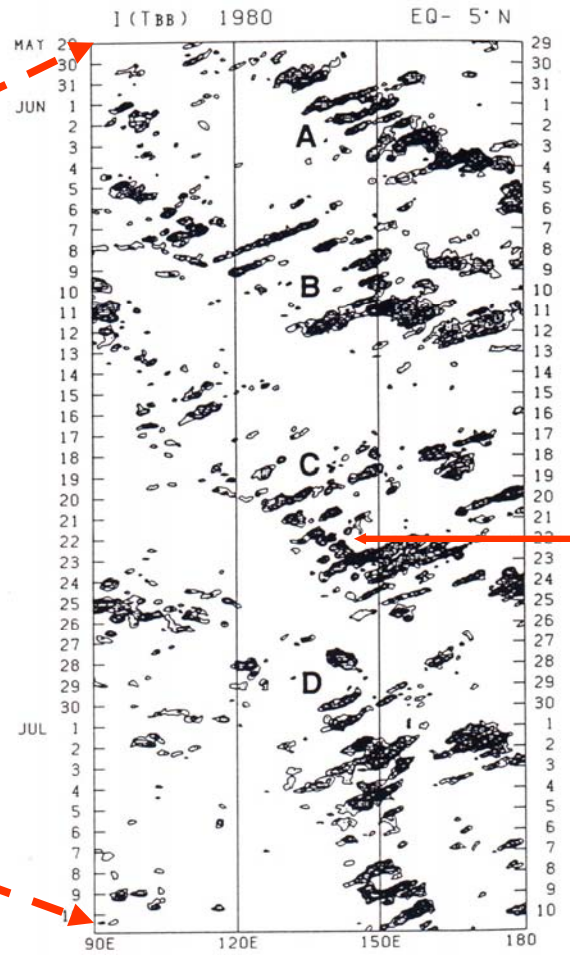
Hierarchical convective organization in the MJO

MJO active envelope

Eastward-traveling superclusters

Eastward-traveling MJO 'active envelope'





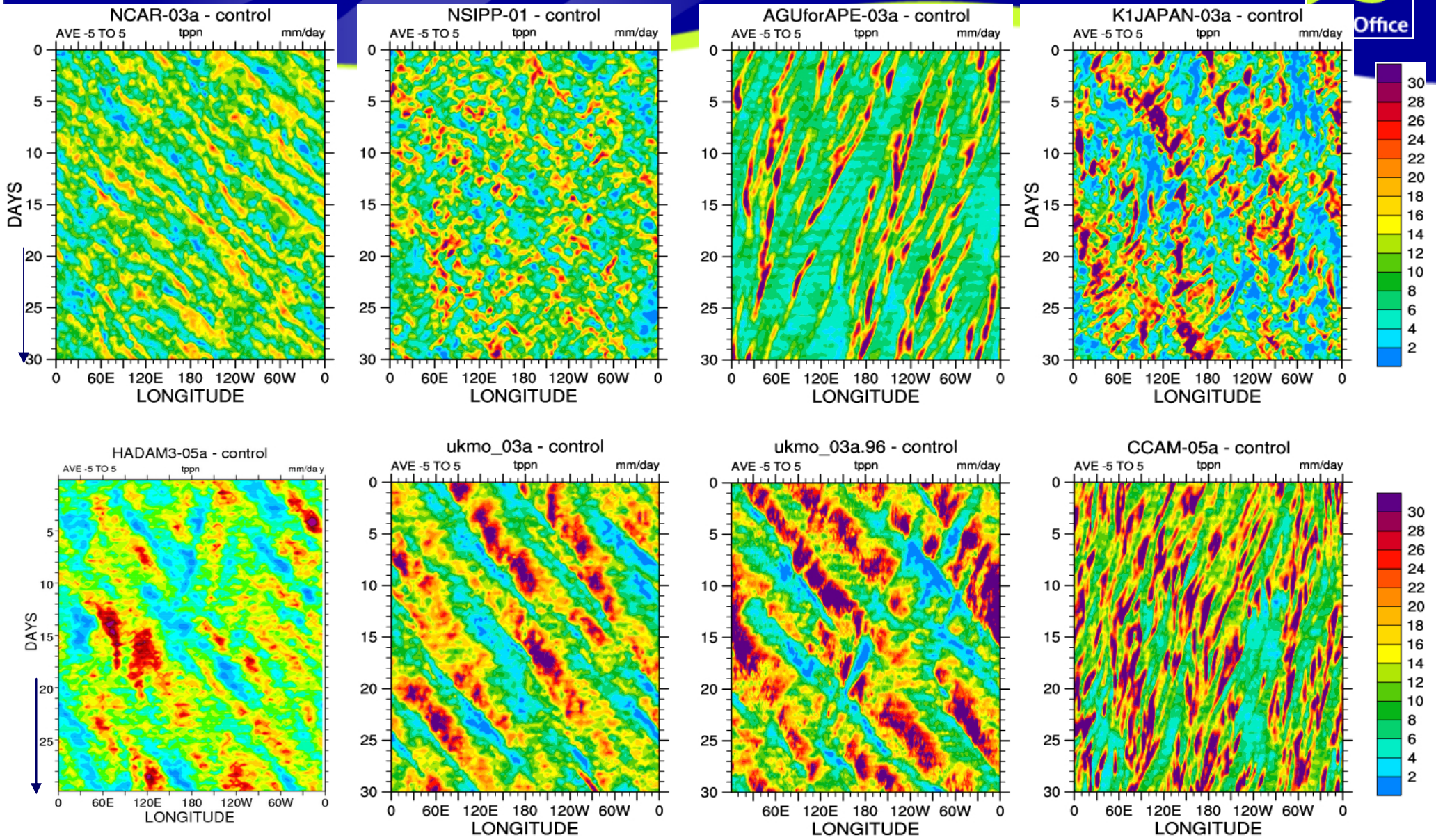
Westward-traveling mesoscale convective systems (MCS) within the envelope

5N-5S averaged OLR - Nakazawa (1988)

Tropical precipitation in aquaplanet models

APE Aqua-Planet Experiment Project

Office



Courtesy David Williamson

average 5ºN-5ºS

http://www-pcmdi.llnl.gov/projects/amip/ape

Conclusions

- **Progress has been made in prediction of synoptic features as shown by objective scores - ~2-day improvement in 8 years**
- **Significant progress has been made in TC track prediction**

  Large underestimation of TC intensity forecasts – resolution(?)

Conclusions

However

- **Little progress has been made in rainfall prediction over the past 10 or so years – however models are able to capture some high rainfall cases**
- **Prediction of aspects of monsoon onset remains a problem**
- **Models have problems maintaining the MJO**
- **Models have problems in correctly simulating the diurnal cycle**