The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

SMR/1849-29

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 - III

K. Puri

Bureau of Meteorology Research Centre
Melbourne, Victoria
Australia

Predictability of Tropical Weather

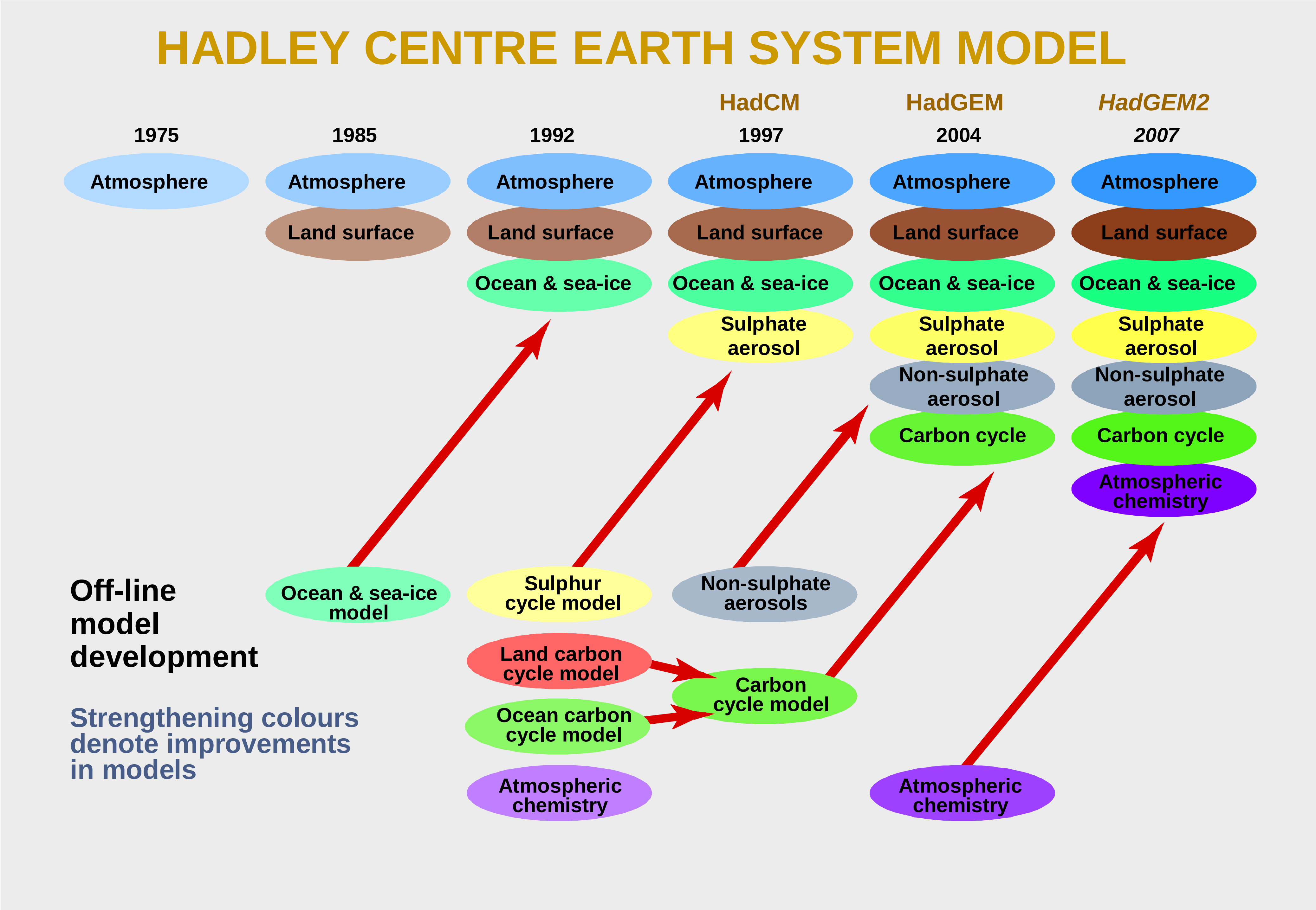
K. Puri

(Thanks to many colleagues)

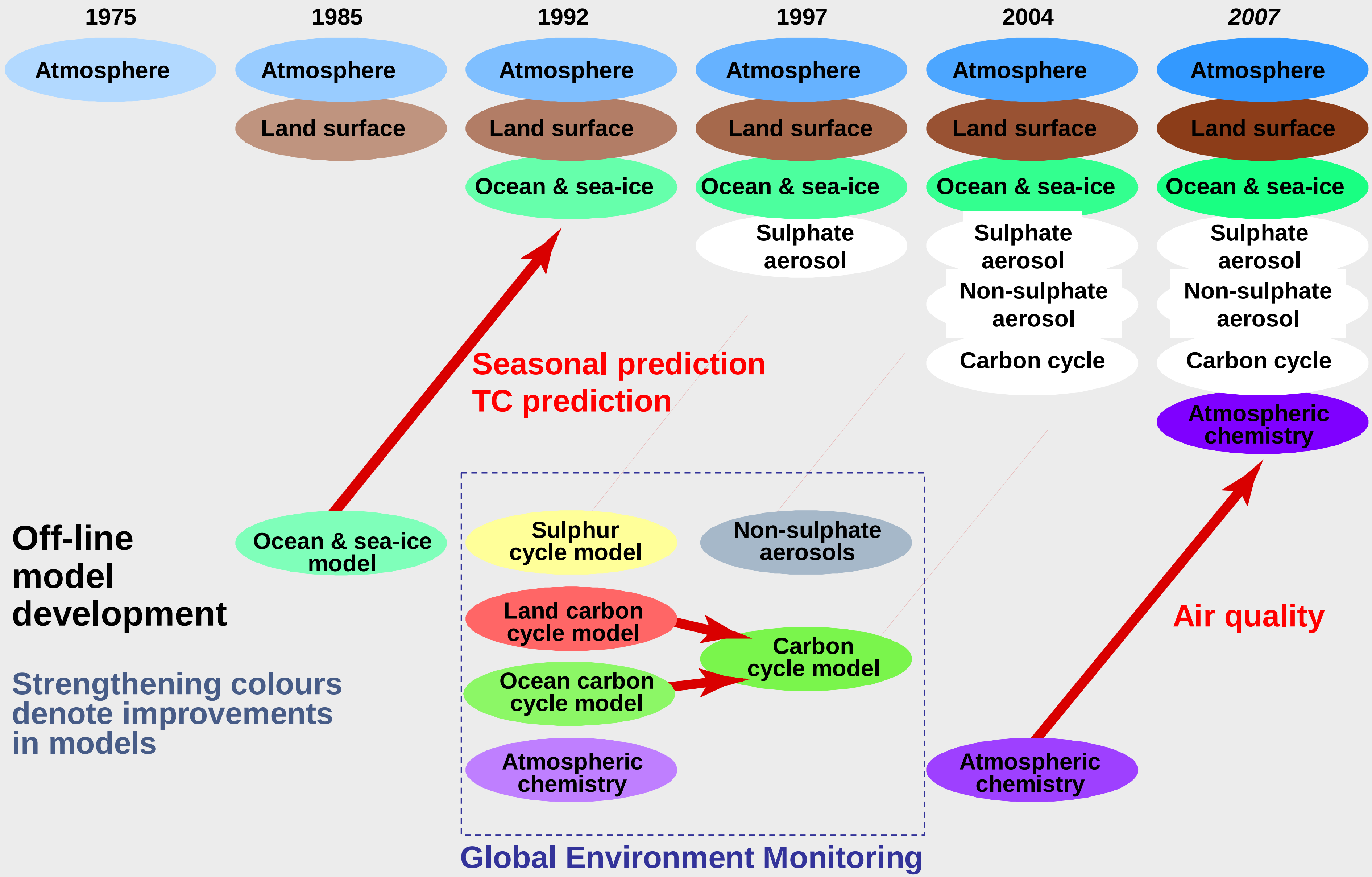
Lecture 3
Outline

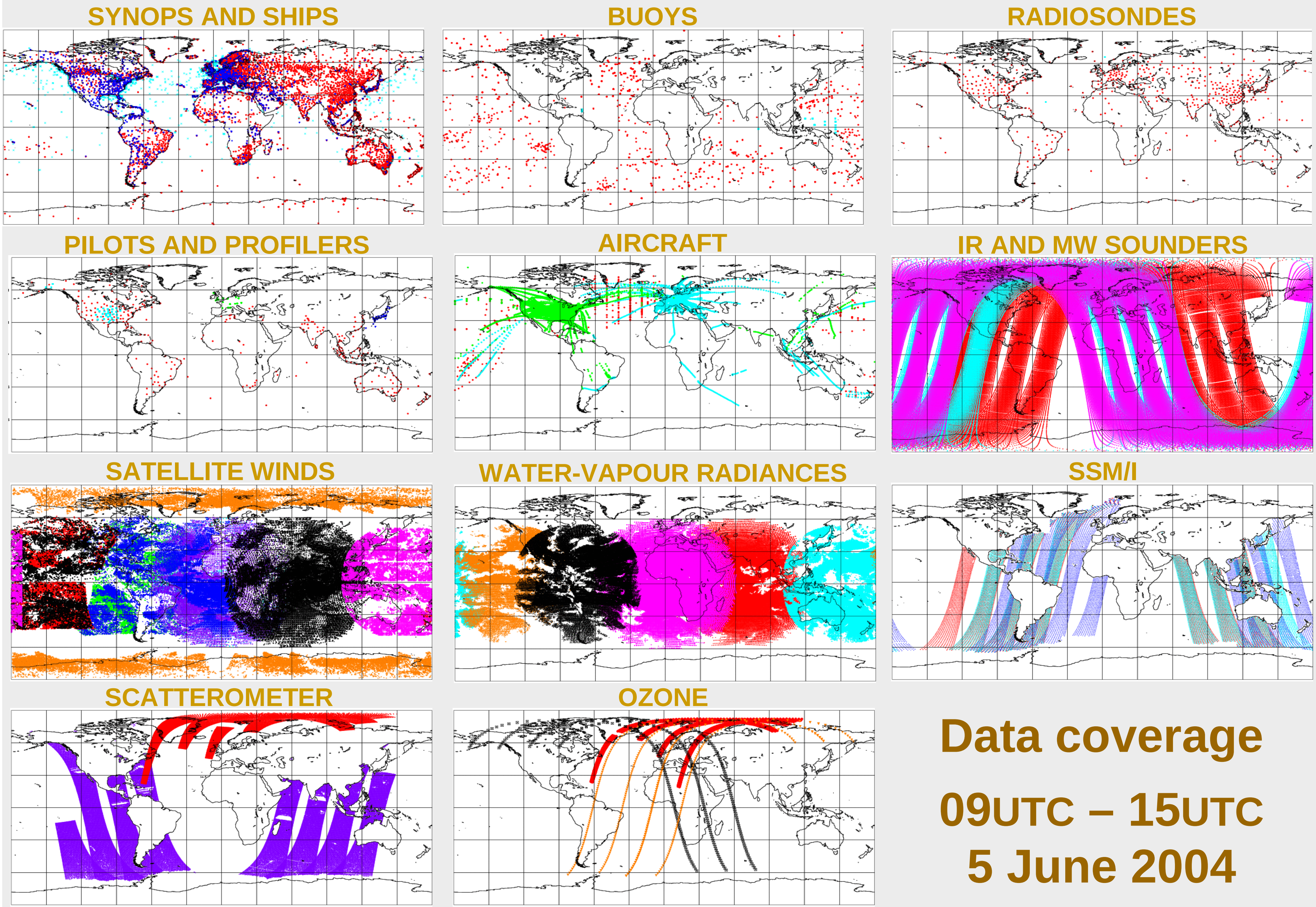
The emphasis is on future trends in:

- **Model development, including resolution and physical parametrisations**
- **Observations, including field experiments, reanalyses**
- **Data assimilation**


HADLEY CENTRE EARTH SYSTEM MODEL
HadCM
HadGEM
HadGEM2
1975
1985
1992
1997
2004
2007
Atmosphere
Land surface
Ocean & sea-ice
Sulphate aerosol
Non-sulphate aerosol
Carbon cycle
Atmospheric chemistry
Off-line model development
Ocean & sea-ice model
Sulphur cycle model
Non-sulphate aerosols
Land carbon cycle model
Ocean carbon cycle model
Carbon cycle model
Atmospheric chemistry
Atmospheric chemistry
Strengthening colours denote improvements in models

NUMERICAL WEATHER PREDICTION MODELS



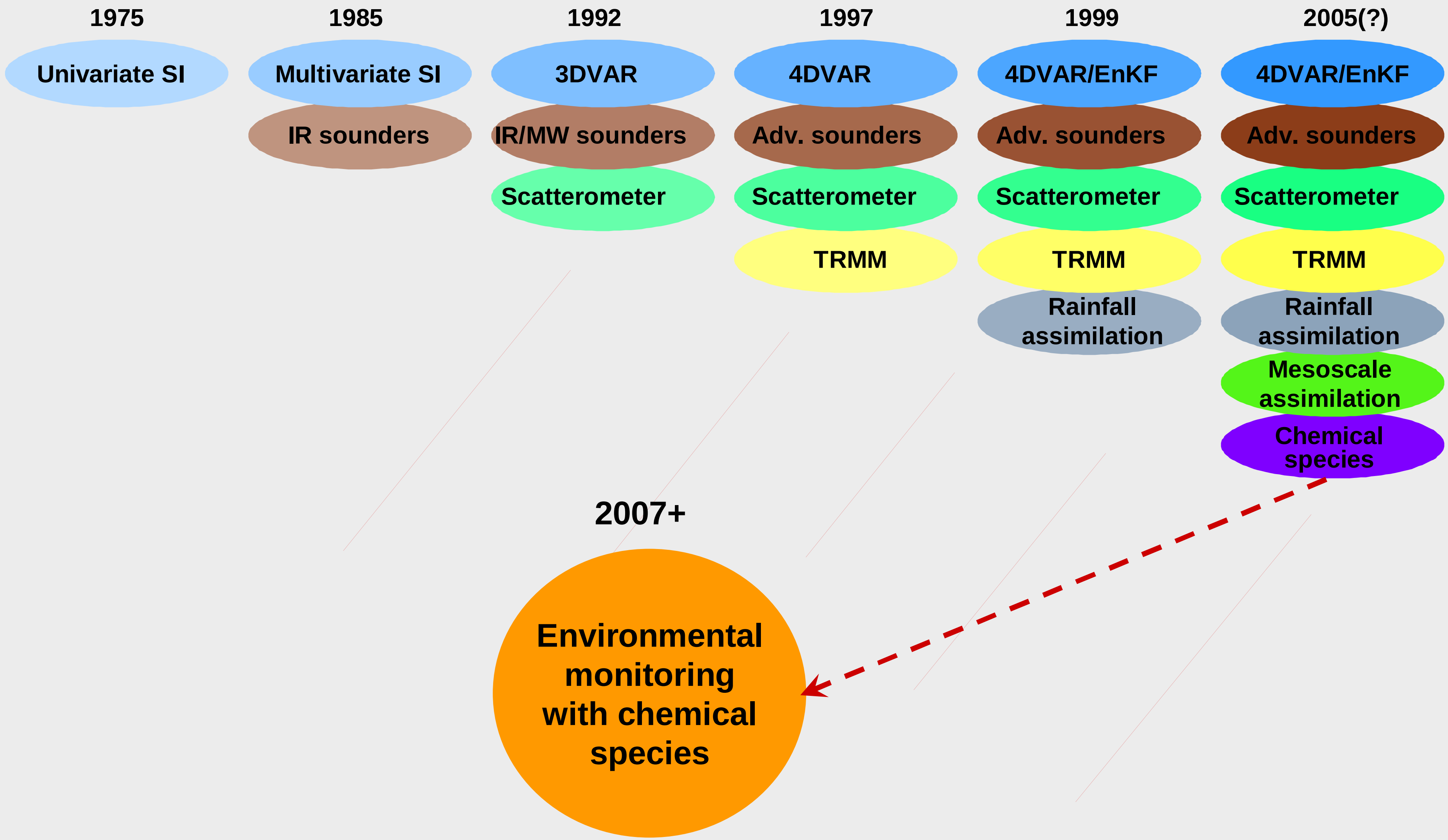


Data coverage

09UTC – 15UTC

5 June 2004

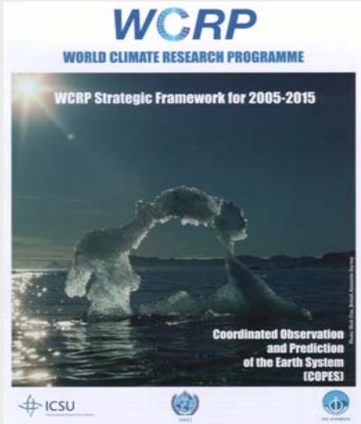
NWP – DATA ASSIMILATION



International strategies

WCRP/COPES

To facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society



THORPEX

Accelerating improvements in the accuracy of one-day to two weeks high-impact weather forecasts for the benefit of society and economy

THORPEX
A GLOBAL ATMOSPHERIC RESEARCH PROGRAMME

Current trends
Models

WGNE List of Operational Global Numerical Weather Prediction Systems (as of January 2007)

Forecast Centre (Country)	Computer (Peak in TFlop/s)	High resolution Model (FC Range in days)	Ensemble Model (FC Range in days)	Type of Data Assimilation
ECMWF (Europe)	IBM p690, 2x68 nodes (20)	T_L799 L91 (10)	T_L399 L62; (10) T_L255 L62 (+5)	4D-Var (T_L255)
Met Office (UK)	NEC SX6, 34 nodes NEC SX8 21 nodes (5)	~40km L50 (6)	~90km L38; M24 (3)	4D-Var (~120km)
Météo France (France)	Fujitsu VPP5000 (1.2)	T_L358 (C2.4) L46 (3)	T_L358(C2.4) L46; M11 (2.5)	4D-Var (T_L149)
DWD (Germany)	IBM p575; 2x52 nodes (2x3.1)	40 km L40 (7)	No global EPS	3D-OI
HMC (Russia)	Itanium 4x4; Xeon 2x4 (0.10; 0.028)	T85 L31 (10); 0.72°x0.9° L28 (10)	No global EPS	3D-OI
NCEP (USA)	IBM pSeries 5 575 (18)	T382 L64 (7.5) T190 L64 (16)	T126 L28; M61 (14/cycle) (16)	3D-Var (T382)
Navy/FNMOC/NRL (USA)	SGI and IBM (800 proc) (3.2)	T239 L30 (6)	T119 L30; M10 (10)	3D-Var
CMC (Canada)	IBM p575, 2X40 nodes (9.6)	~35 km L58 (10)	SEF (T_L149); GEM (1.2°); M16 (16)	Det: 4D-Var (1.5°, 0.9°) EPS: EnKF M96 (1.2°)
CPTEC/INPE (Brazil)	NEC SX6, 12 nodes (0.768)	T126L28, T213 L42; T126L28 Coupled (15, 7,30)	T126 L28; M15 (15)	3D-Var
JMA (Japan)	Hitachi SR11000-K1, 2*80 nodes (21.5)	T_L319 L40 (9)	T_L159L40; M51 (9)	4D-Var (T106)
CMA (China)	IBM p655/p690: 21 (SW1: 0.384)	T213 L31 (10)	T106 L19; M33 (10)	3D-OI
KMA (Korea)	Cray X1E-8/1024-L (18.4)	T426 L40 (10)	T213 L40; M32 (10)	3D-Var
NCMRWF (India)	Cray X1E-64 processor (1.1)	T254 L64 (7)	T80 L18; M8 (7)	3D-Var
BMRC (Australia)	NEC SX6, 28 nodes (1.792)	T_L239 L29 (10)	T_L119 L19; M33 (10)	3D-OI

Current models

Key future developments

- Moves towards higher resolution models
- Improved parametrisation of physical processes
- Advances in data assimilation including assimilation of increased variety of observations particularly satellites
- Field experiments – essential for parametrisation improvements and model evaluation

NWP Centres - *plans and resolution issues*

- **Global model resolutions of 40kms or less**
- **Limited area model forecast resolutions of a few kms**
- **High-resolution NWP models are now almost all non-hydrostatic and can be run at CRM resolution in principle and 'driven' with lateral boundary conditions (eg reanalyses or forecasts)**

  However, at this point they are mostly used well above CRM resolution
- **4D-Var now in use at several centres**
- **Global and LAM EPS now running at 10 Centres at least**
- **Expansion to seasonal (and monthly) forecasts**

Plans for operational global forecasting systems resolutions (from WGNE ‘Overview of plans at NWP Centres with Global Forecasting Systems, Jan 2007’)

Canada	2011	15 km/L80	(35km)
ECMWF	2010	16 km/L91	(~25km)
Germany	2008	20 km/L60	(40km)
Japan	2007	20 km/L60	
UK	2009	25 km/L90	(40km)
USA	2010	20 km/L90	(~50km)

Also

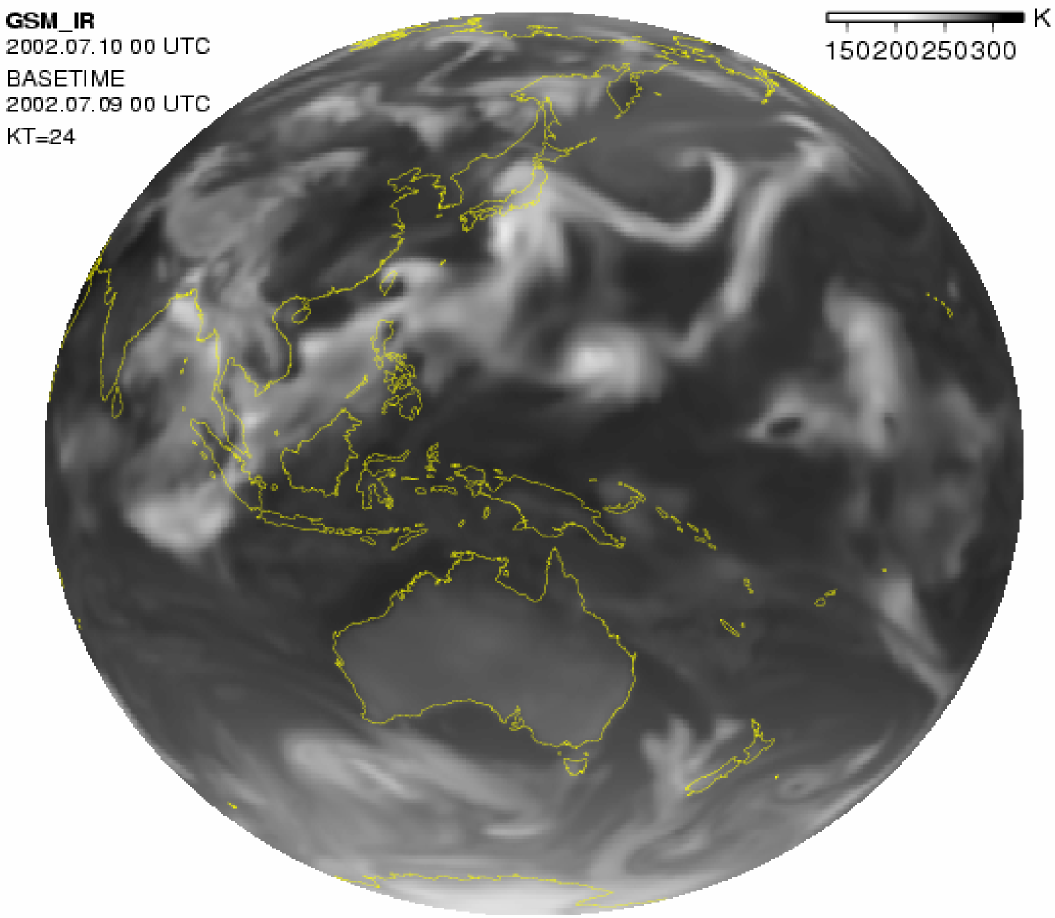
The Earth Simulator has facilitated both global ‘almost cloud resolving’ 3.5 km experiments and some very large domain 1km forecast experiments.

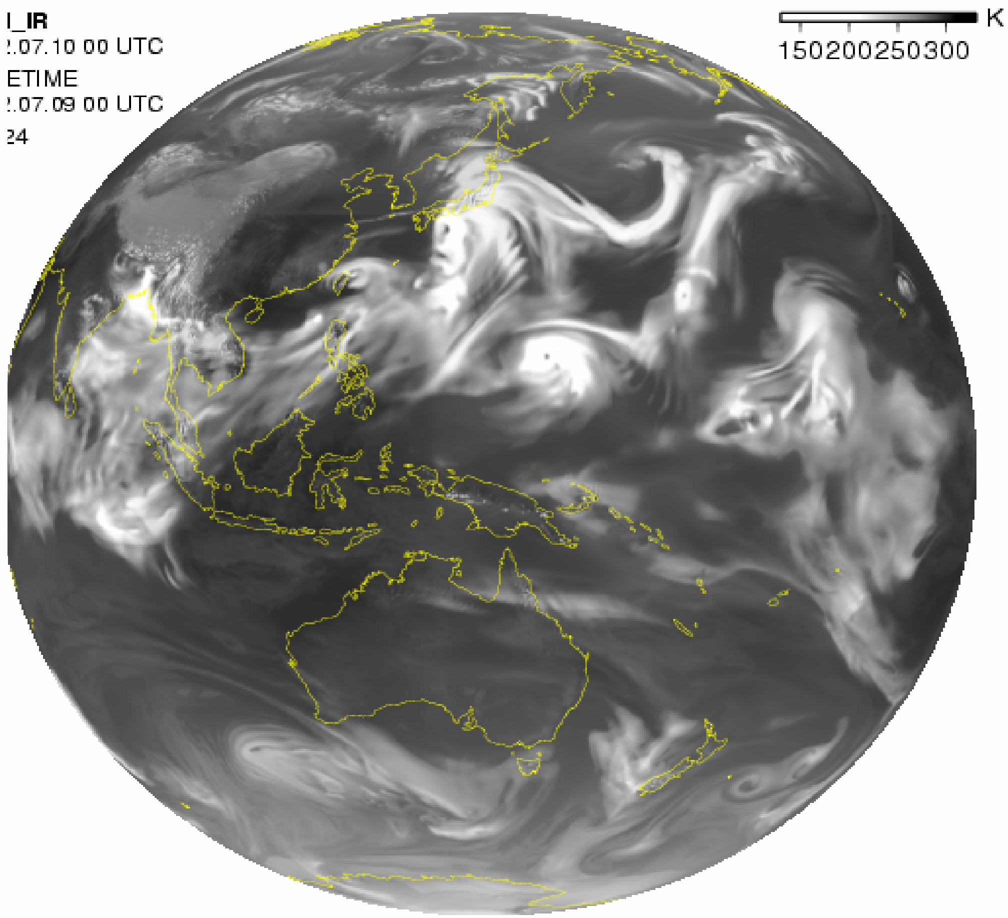
• There are well-developed plans to do similar studies for large-scale tropical convection in the UK and elsewhere.

• The new Science and Technology Centre at Colorado State University (Centre for multi-Scale Modelling of Atmospheric Processes (CMMAP)) will also accelerate progress in the use of CSRMs in global domains.

•Data assimilation at these ‘convective-scale’ resolutions??

High Resolution Global Climate Model





60km-GSM T213L40 2002.7.9.00Z FT=24

20km-GSM TL1023L40 2002.7.9.00Z FT=24

GSM T213 (60km)

FT=24 00UTC 09 July 2003 Initial

GSM TL1023 (20km)

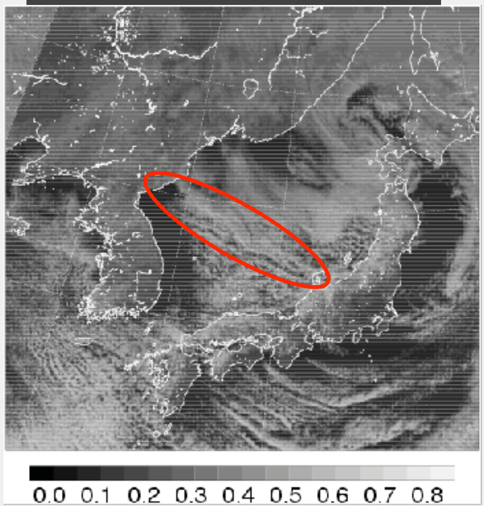
FT=24 00UTC 09 July 2003 Initial

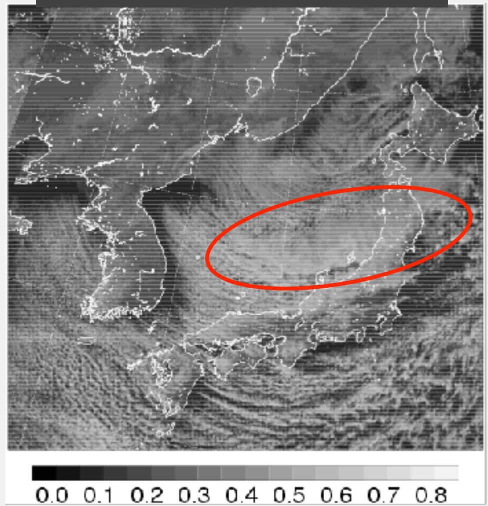
Regional Cloud Resolving Model with 1km Resolution

13JST 28 JAN 2003

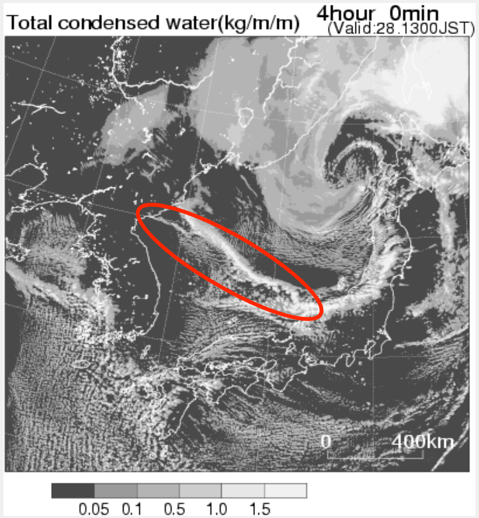
13JST 29 JAN 2003

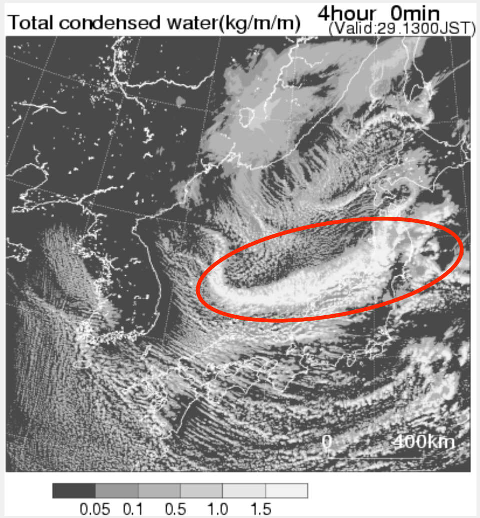
VIS image of satellite obs.



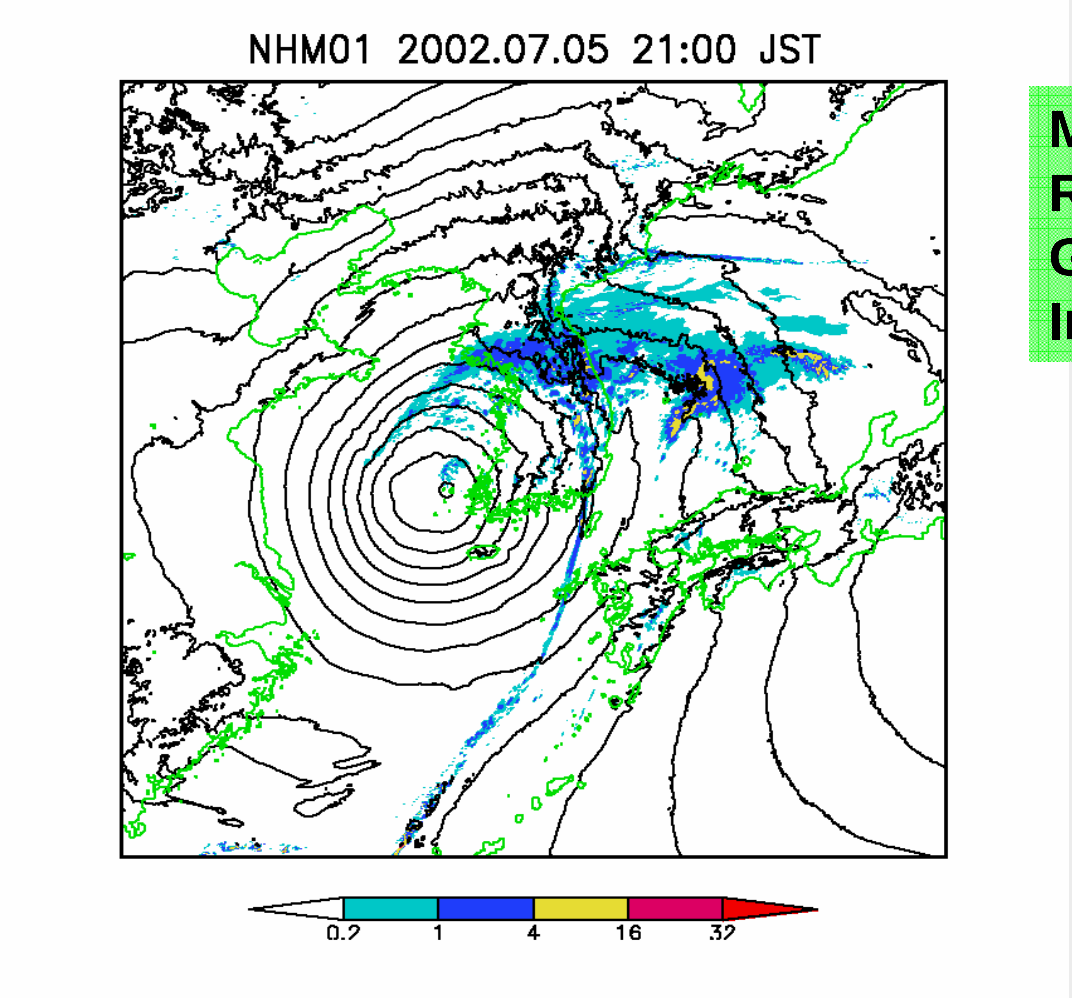


Simulation with 1km CRM





Regional Cloud Resolving Model with 1km Resolution - Typhoon T0205 -



Model: JMA-NHM
Resolution: 1km
Grid size: 2000 x 2000 x 38
Initial time: 18UTC 04 JUL 2002

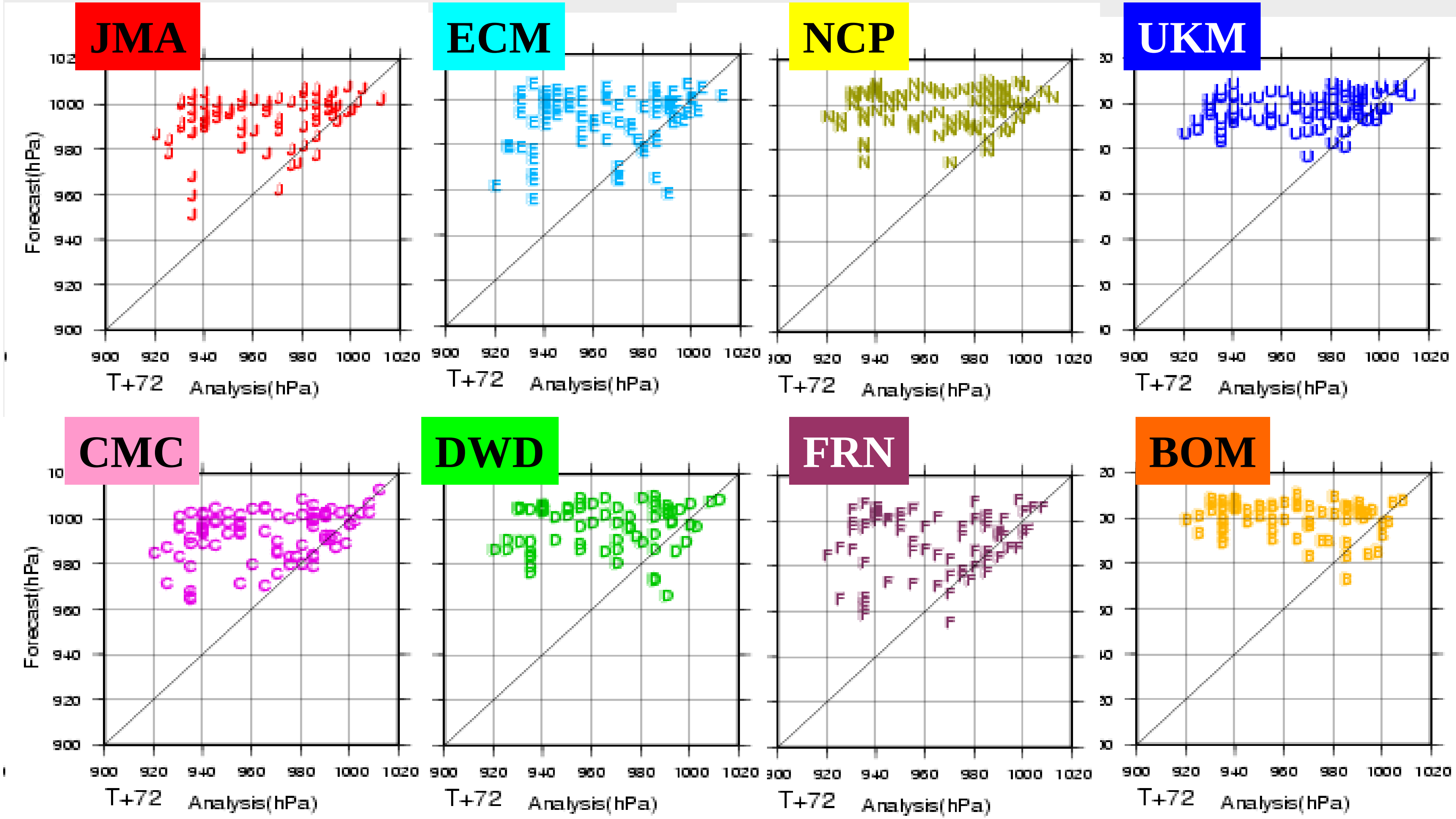
Some recent developments
TC prediction

With increasing resolutions and developments in data assimilation relevant for the tropics, increasing attention is being placed on TC genesis and intensity

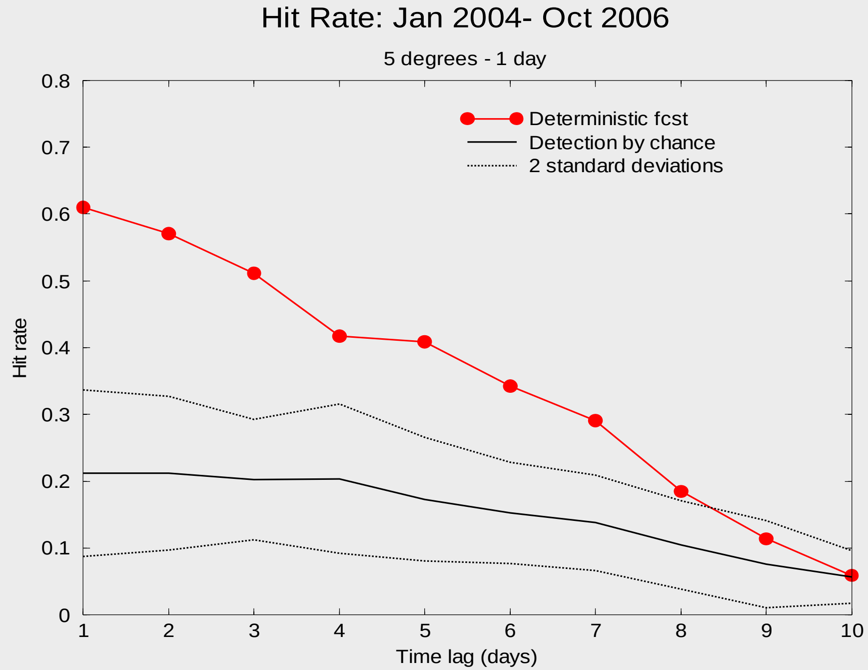
TC Intensity Verification

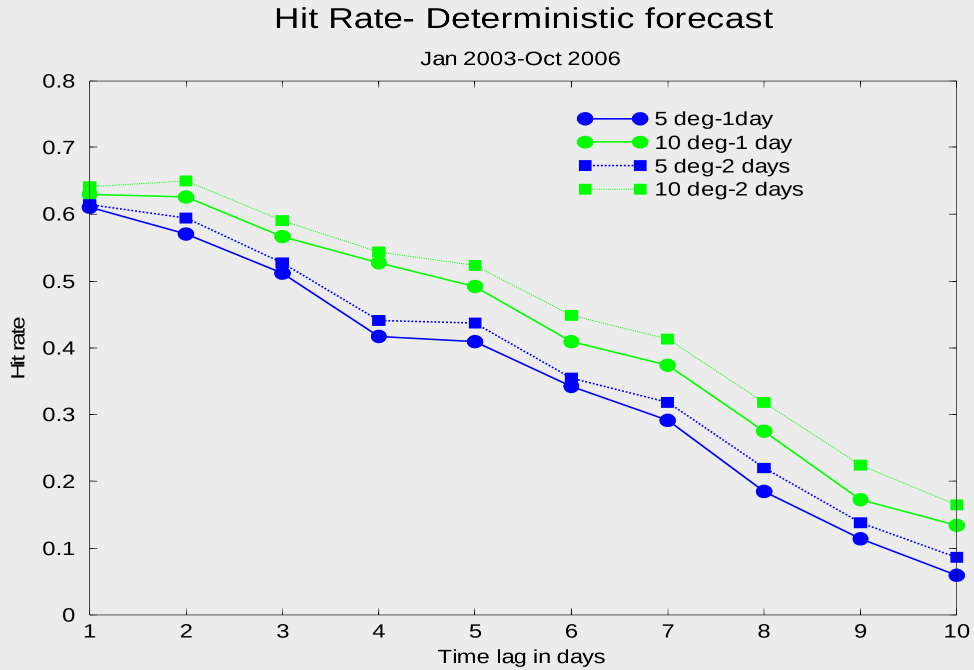
- western North Pacific area -

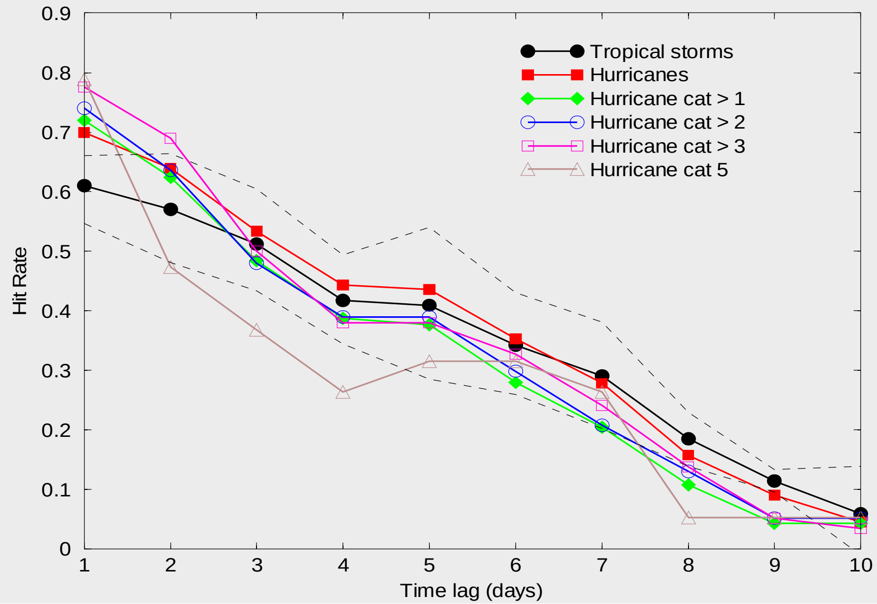
T+72

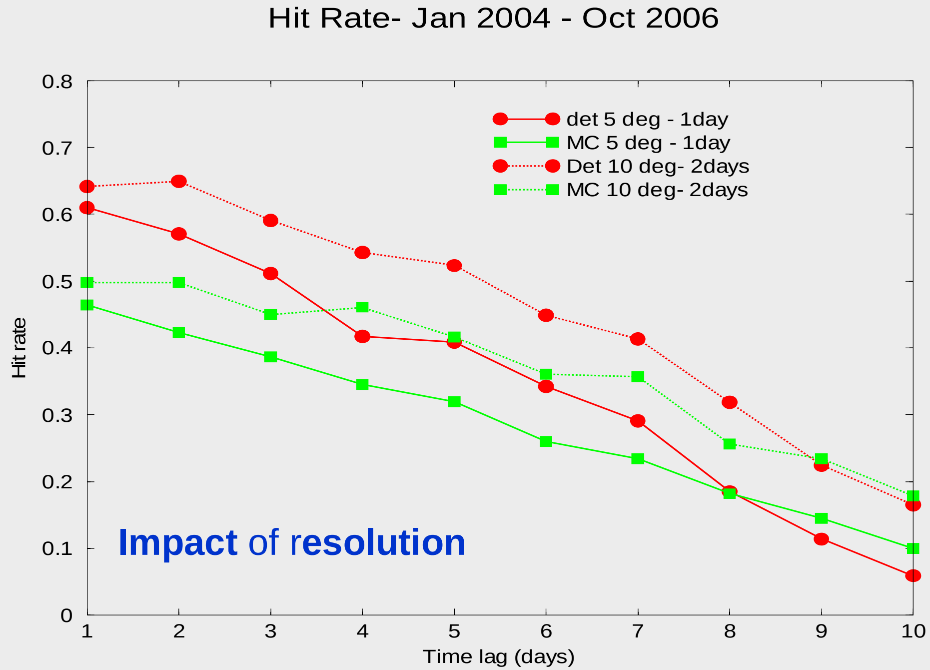


Tropical storm genesis – ECMWF model

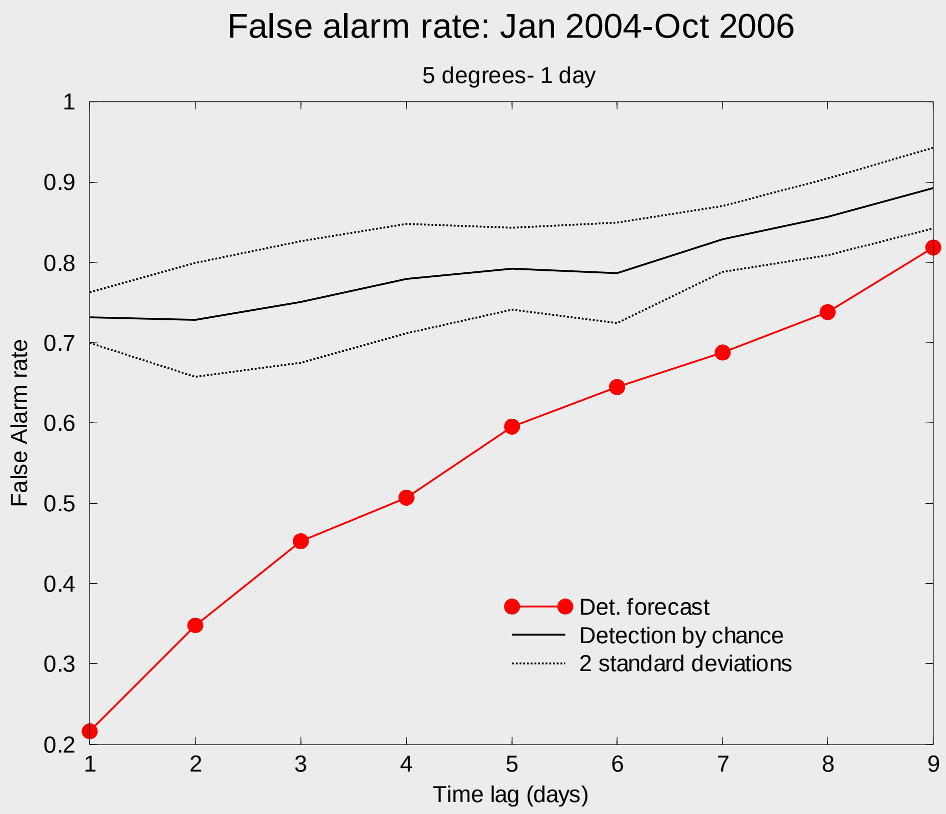


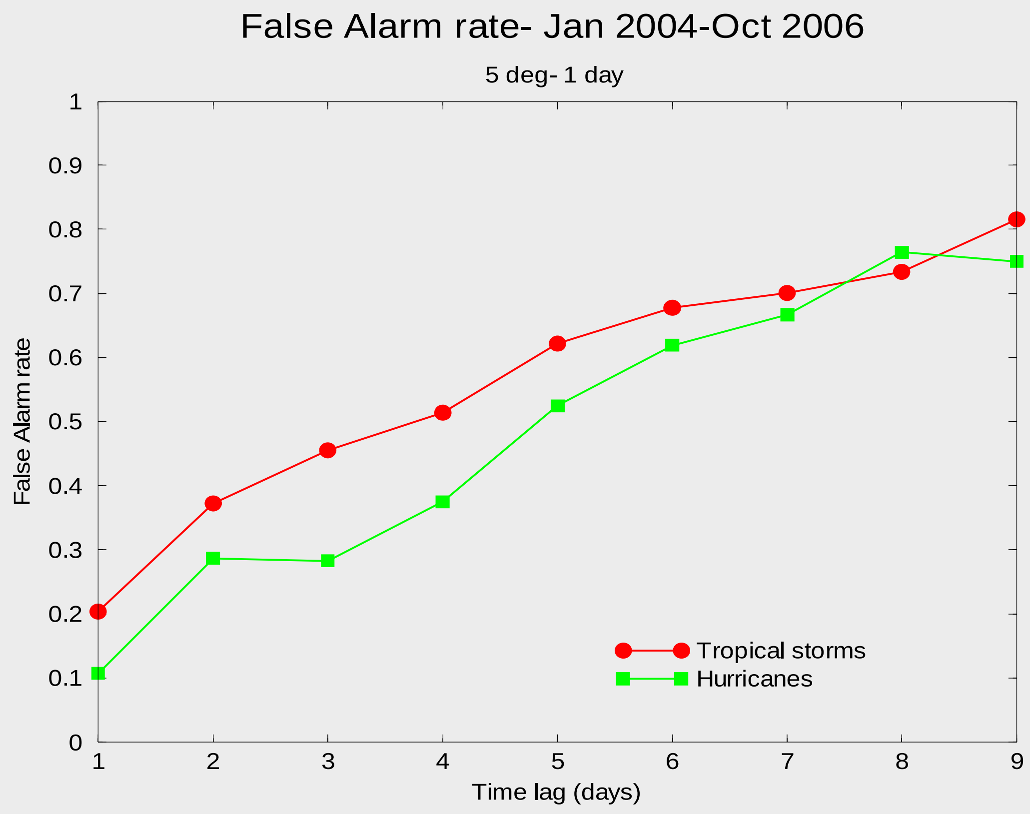






Tropical storm genesis

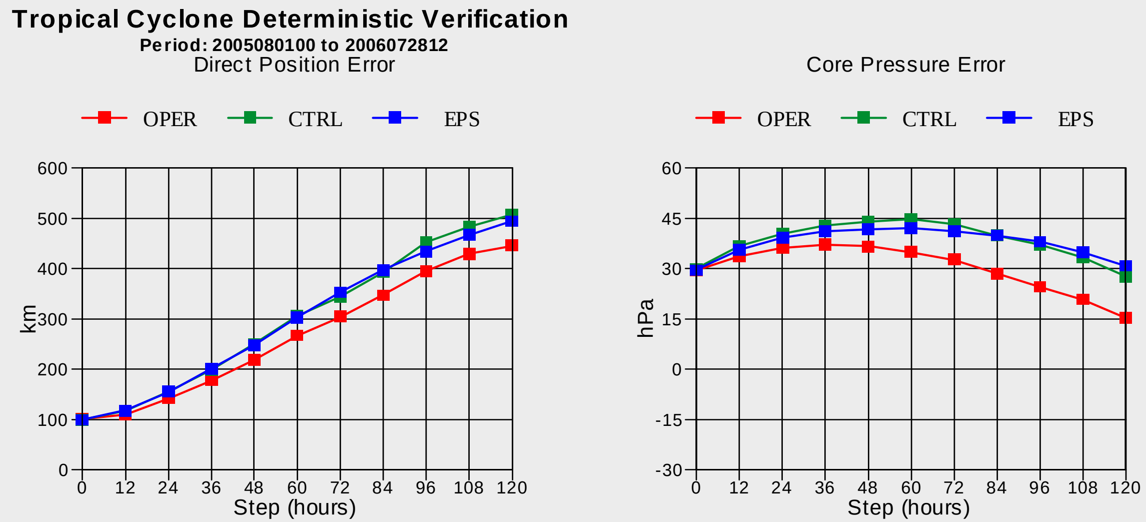




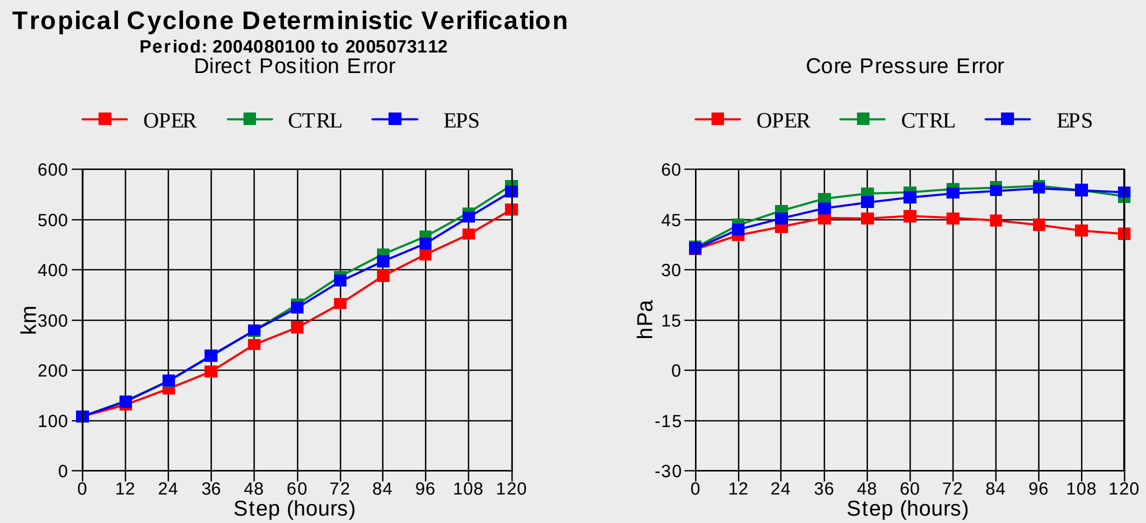
ECMWF model

Tropical cyclone verification

2005-2006



2004-2005



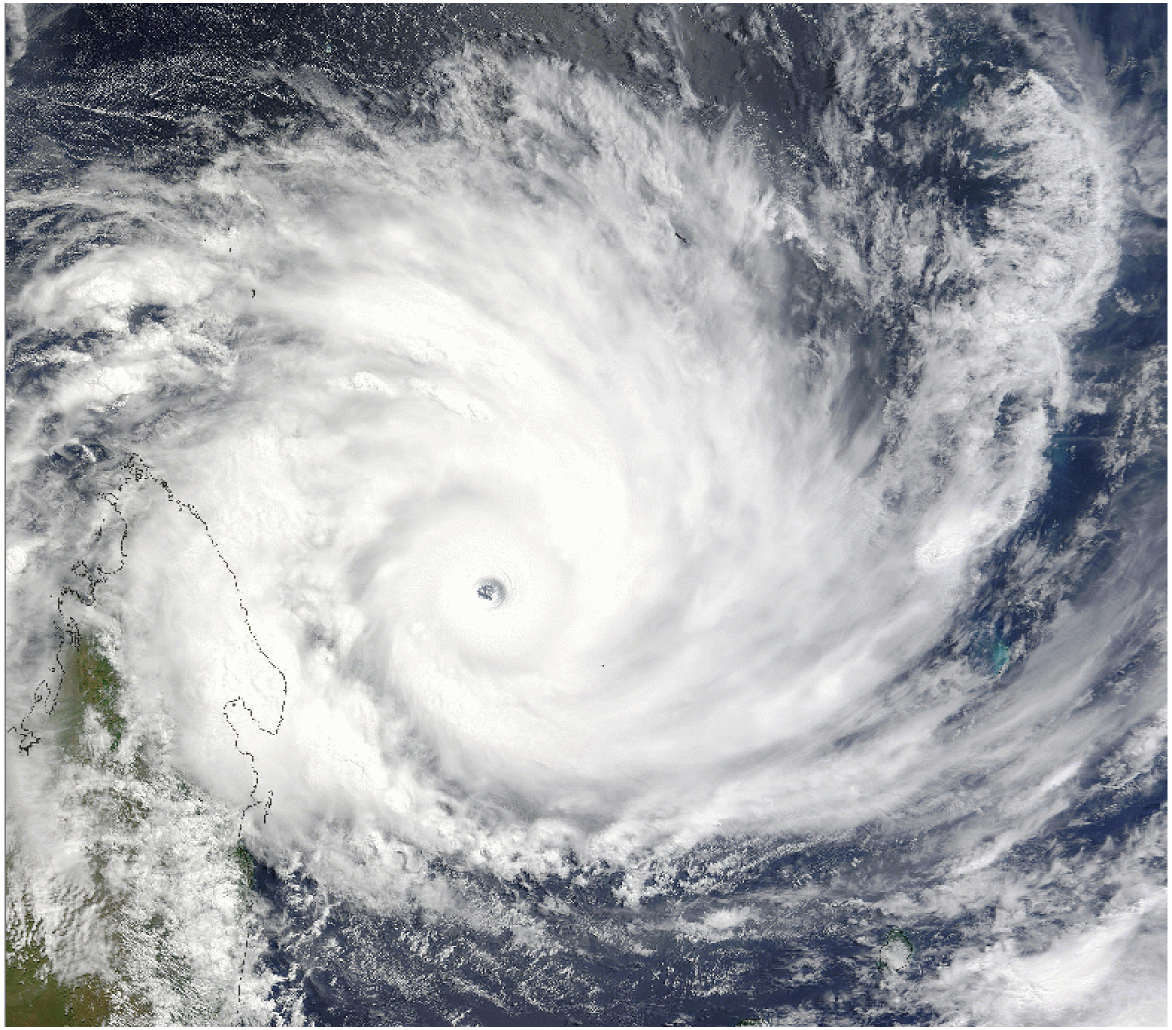
ECMWF model

Cyclogenesis

- TCs generated by the model in the forecast
- Not currently objectively verified
- Subjective assessment indicates considerable skill
  - TC Gafilo
  - TCs Nancy and Olaf

Tropical Cyclone Gafilo

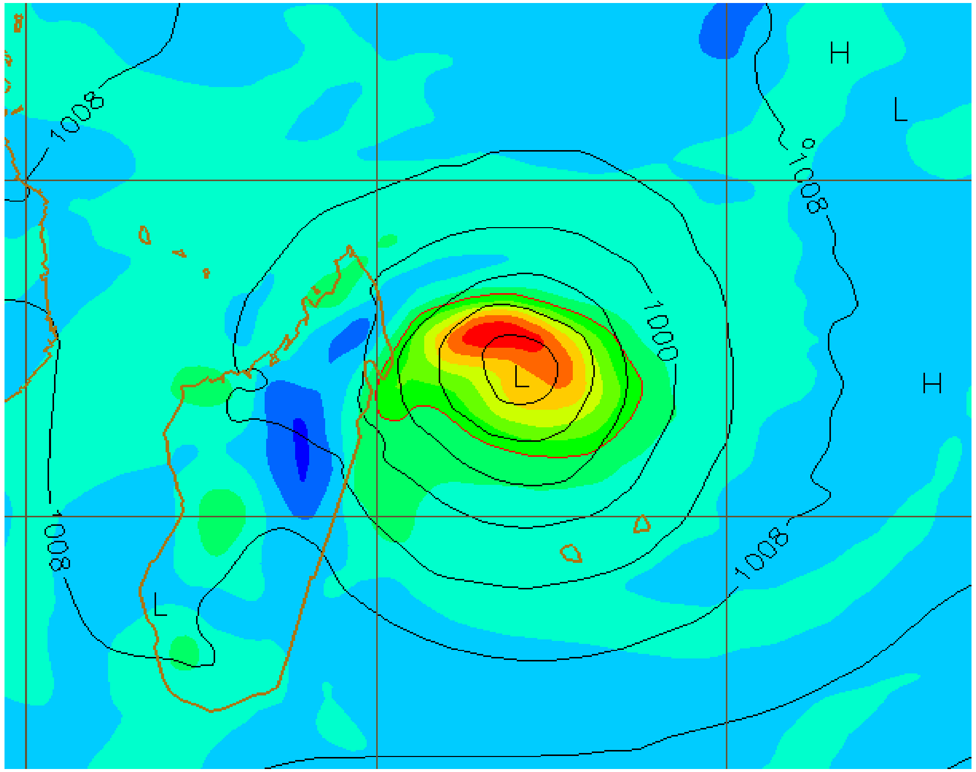
Cyclone Gafilo
satellite image
06.03.2004
(estimated 140 knots
sustained winds)

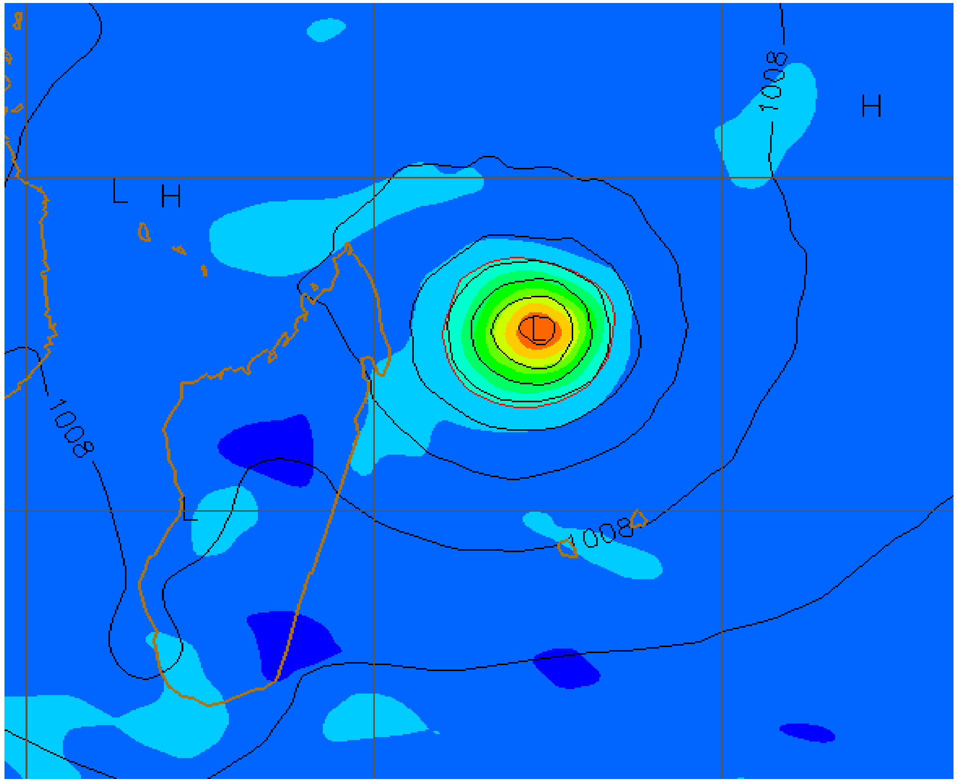


Tropical Cyclone Gafilo

5 day forecast
DT 00Z 01.03.2004
(a day before formation)

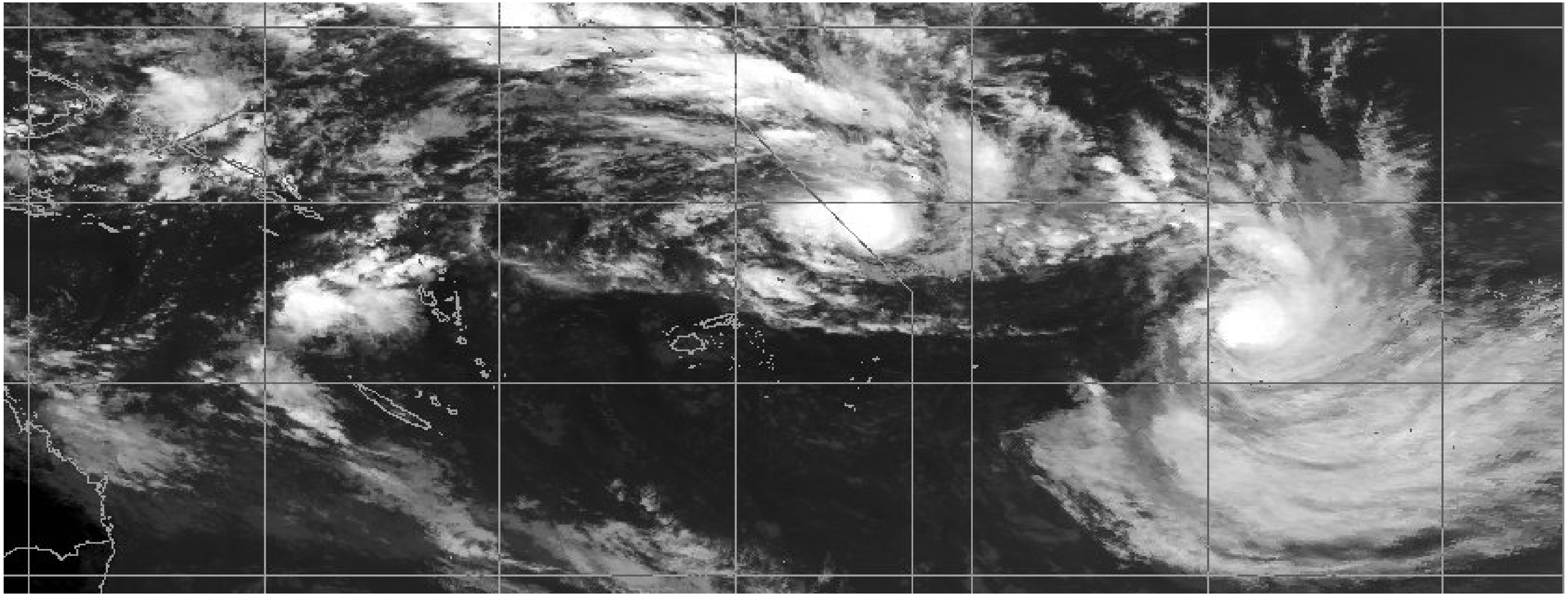
Verifying analysis
DT 00Z 06.03.2004



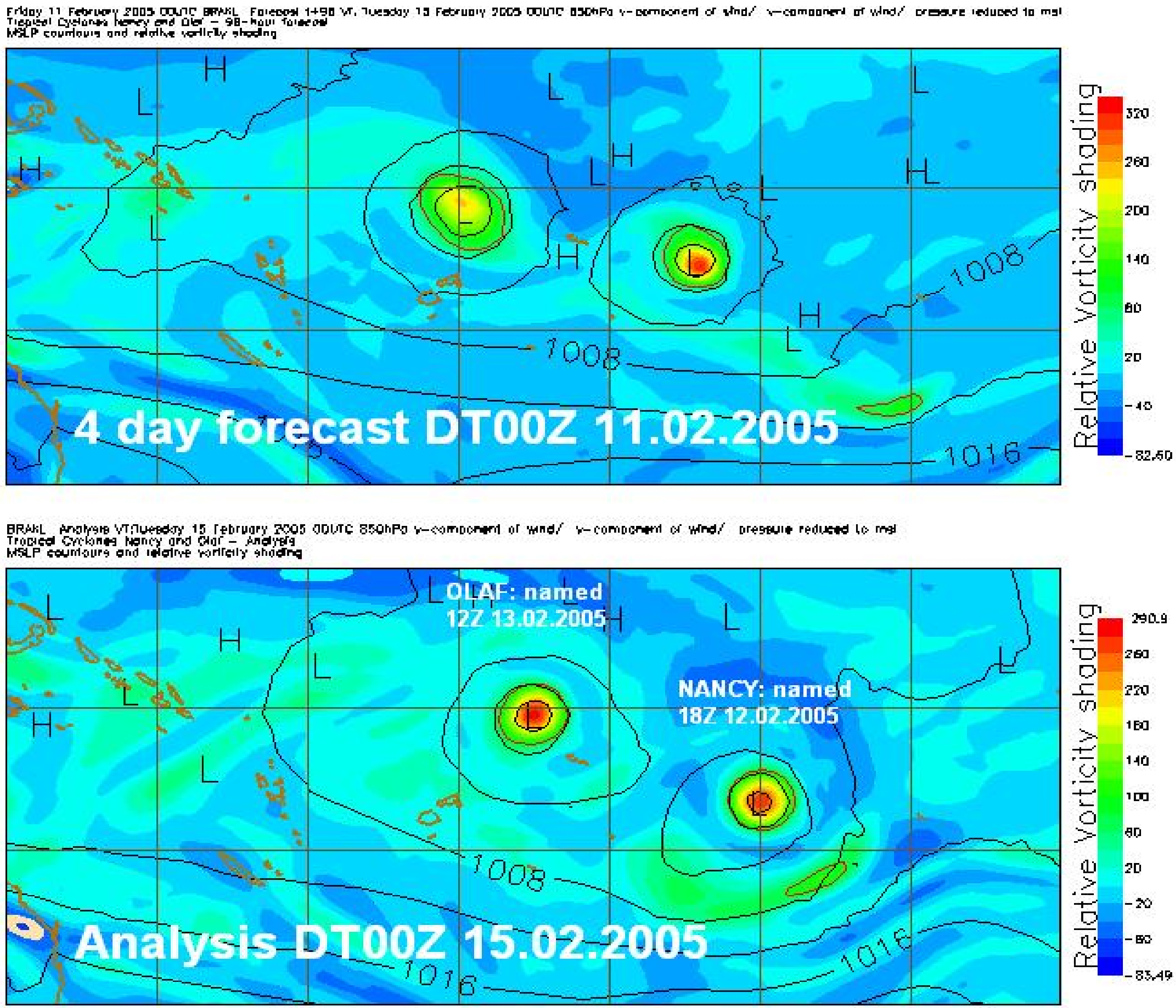


Tropical Cyclones Nancy and Olaf satellite image 15.02.2005

(Nancy: 100 knots, Olaf: 120 knots)



Tropical Cyclones Nancy and Olaf

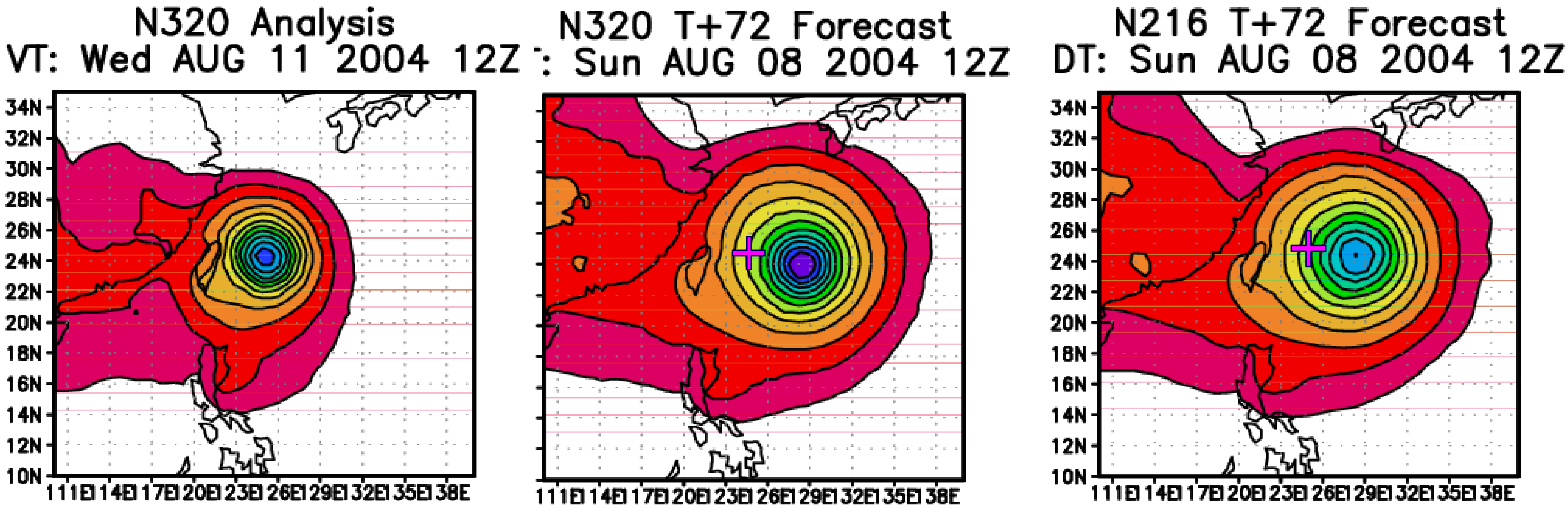


Impact of Enhanced Horizontal Resolution on TC's

Tropical Cyclone Rananim - 11 Aug 2004

Met Office

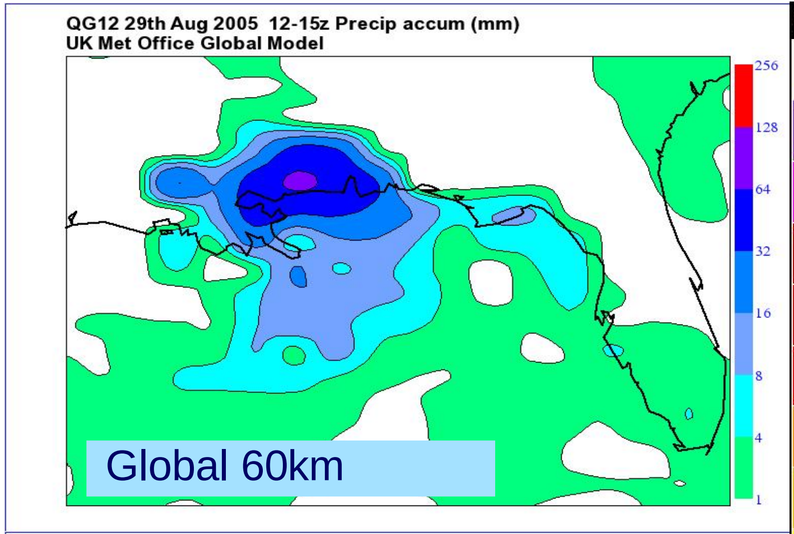
New resolution 40km | Old resolution 60km

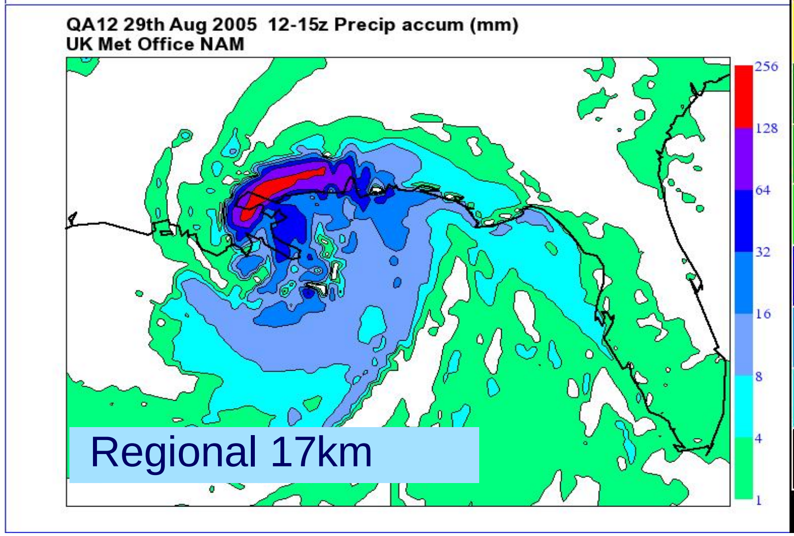


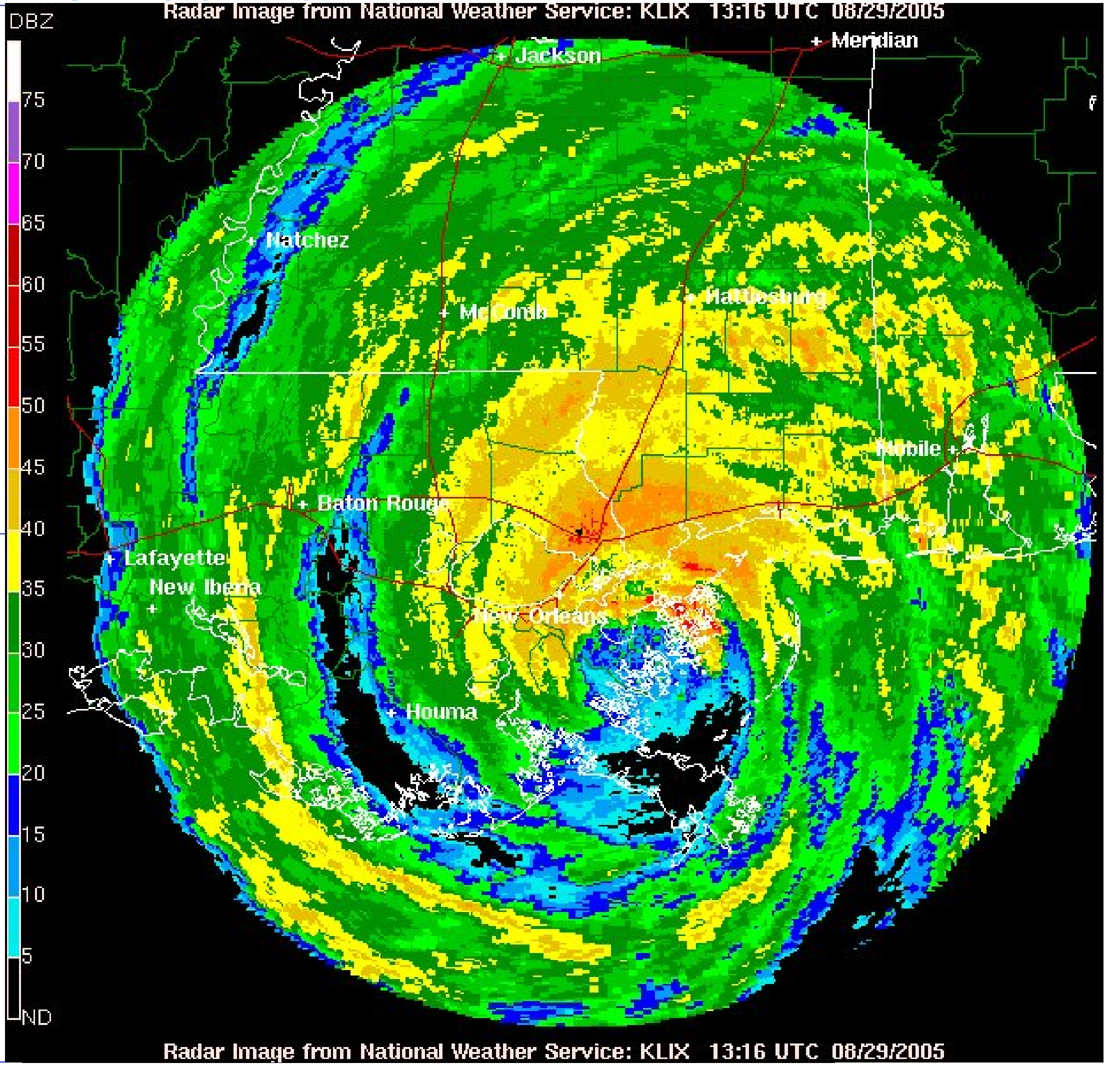
N320 TC's systematically deeper, but no change in track error

Hurricane Katrina – Impact of Resolution

Hurricane Katrina







TC Genesis and intensity

With increasing resolutions and improvements in the physics, models are starting to show some skill in both TC genesis and intensity prediction

Some recent developments
MJO, monsoon prediction

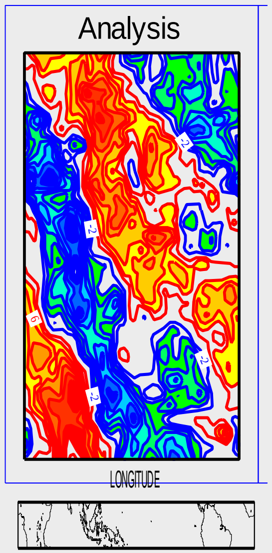
- **Improvements in physical parametrisations and data assimilation**

ECMWF model changes

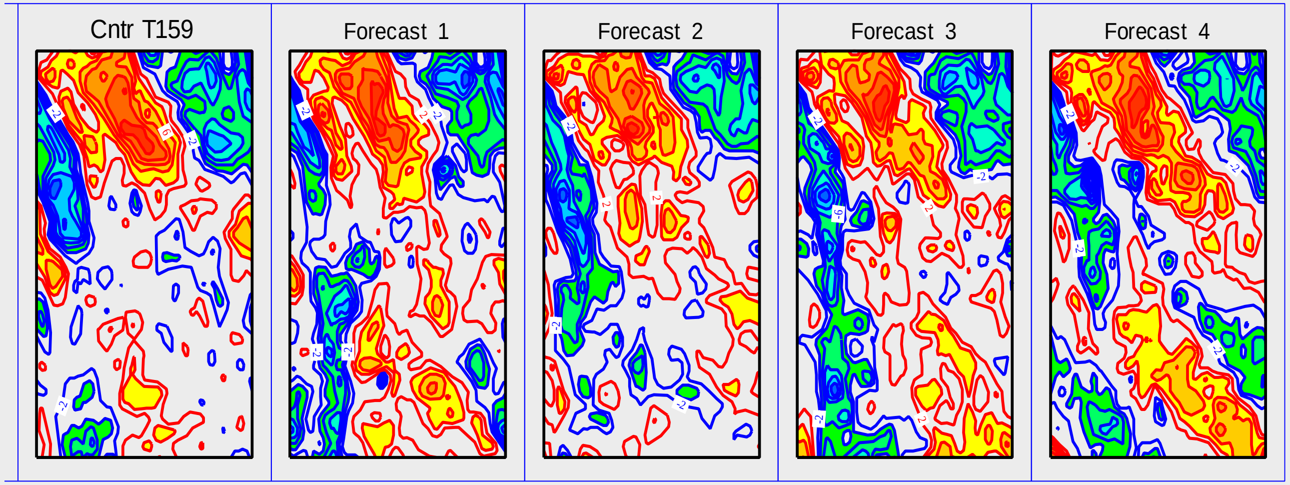
- Revisions to the cloud scheme, including treatment of ice supersaturation and new numerics
- Implicit computation of convective transports
- Introduction of turbulent orographic form drag scheme and revision to sub-grid scale orographic drag scheme
- Gust fix for orography and stochastic physics
- Reduction of ocean surface relative humidity from 100% to 98% (due to salinity effects)
- Revised assimilation of rain-affected radiances
- Variational bias correction of satellite radiances
- Thinning of low level AMDAR data (mainly affects Japanese AMDAR network)

Madden-Julian oscillation
Forecast starting on 31 December 1992

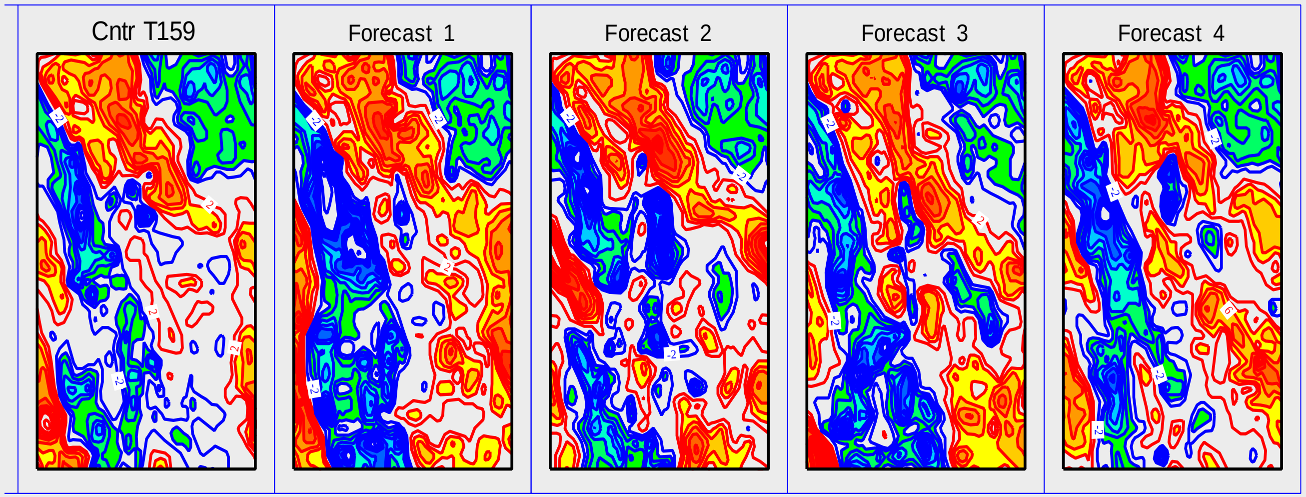
Analysis



CY29R1



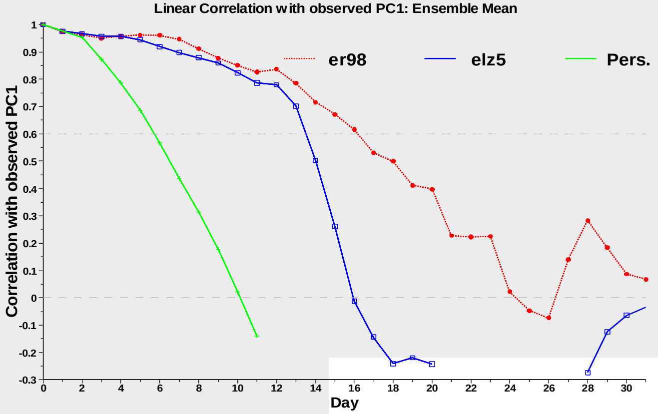
CY30R2



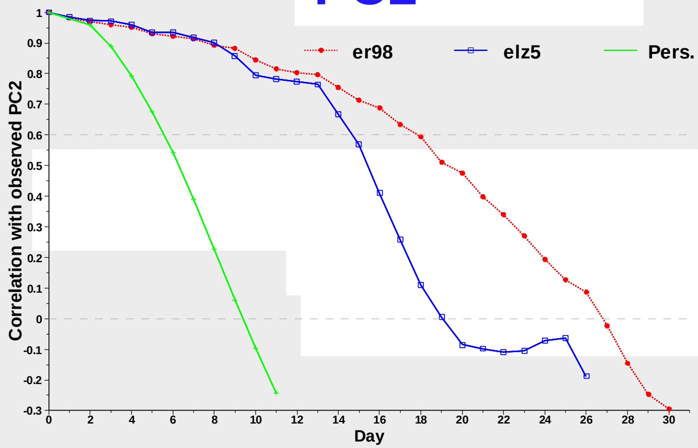
ECMWF model

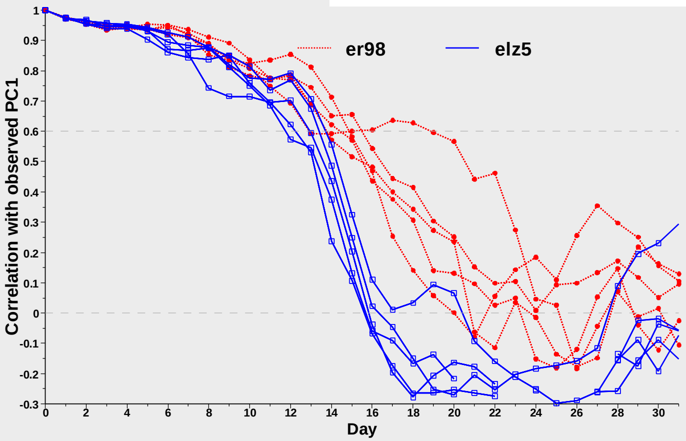
MJO EOF analysis

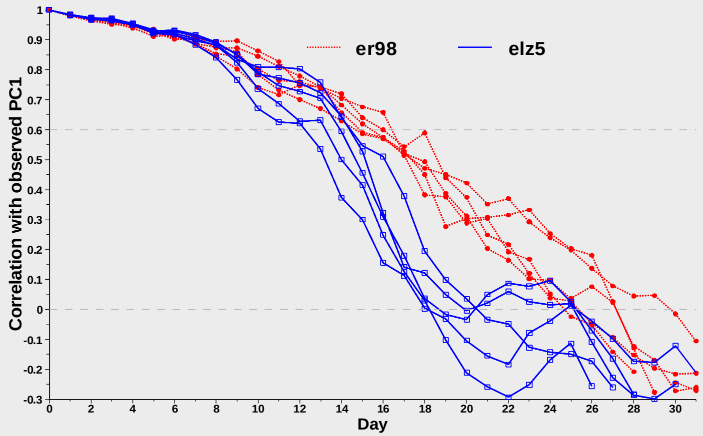
PC1



PC2







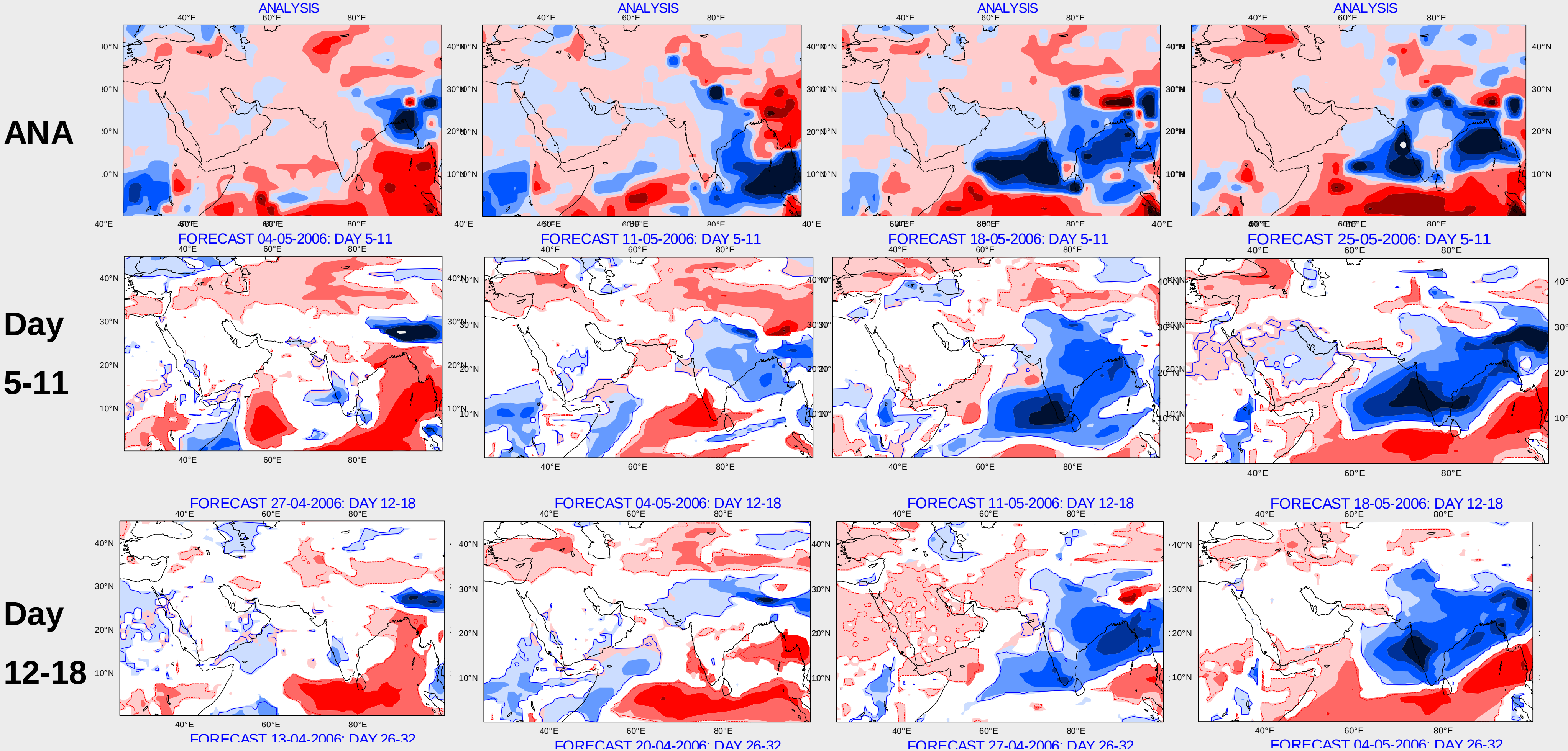
30R2 29R1

ECMWF model

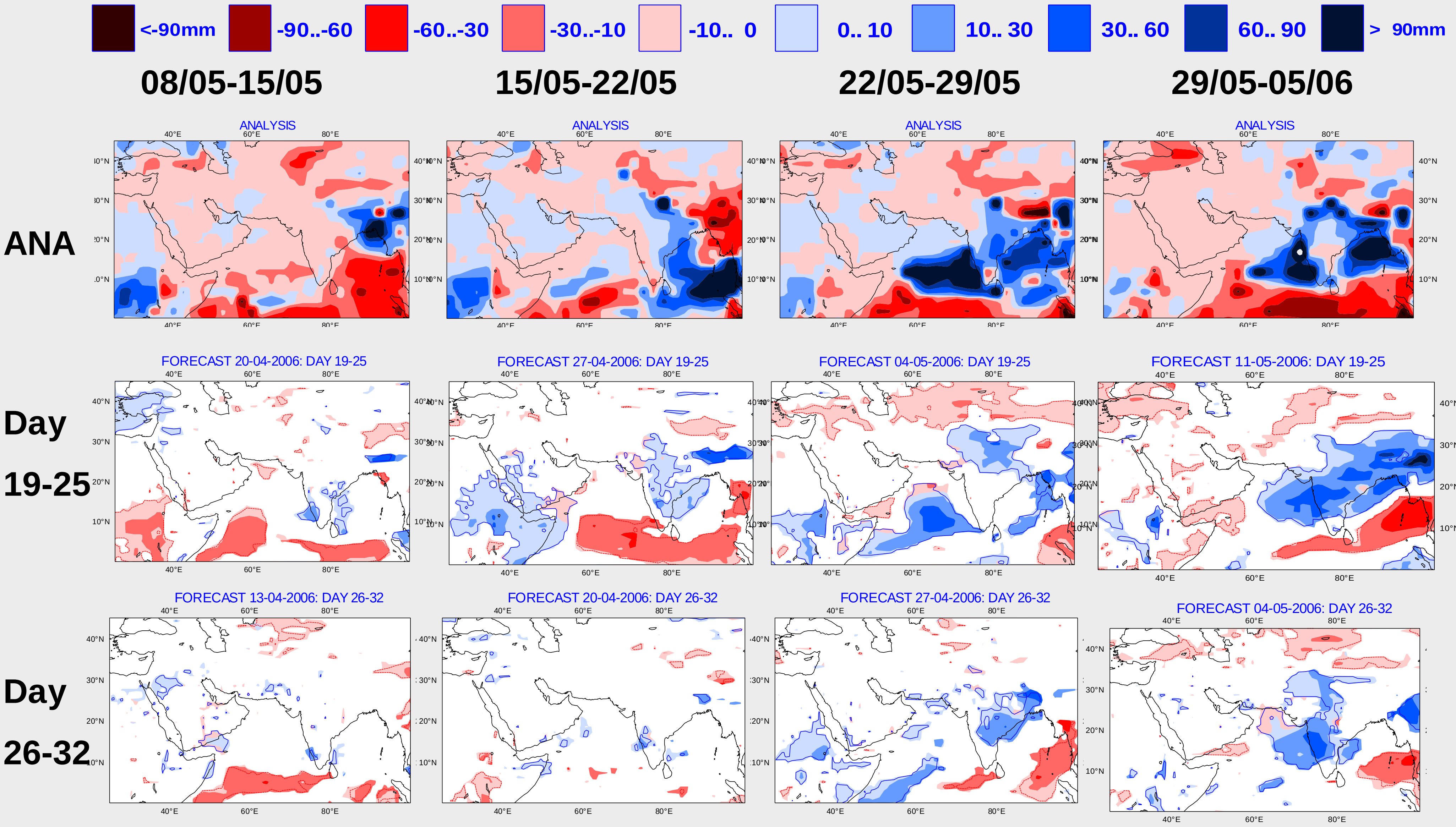
Precipitation over India (ECMWF)

<-90mm | -90..-60 | -60..-30 | -30..-10 | -10.. 0 | 0.. 10 | 10.. 30 | 30.. 60 | 60.. 90 | > 90mm

08/05-15/05 **15/05-22/05** **22/05-29/05** **29/05-05/06**



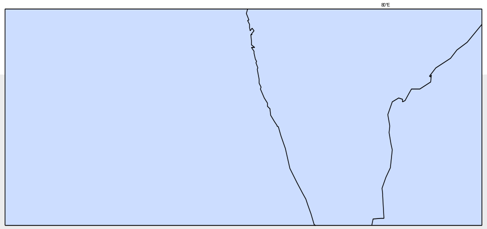
Precipitation over India (ECMWF)



Indian monsoon

Probability of precipitation in the upper tercile

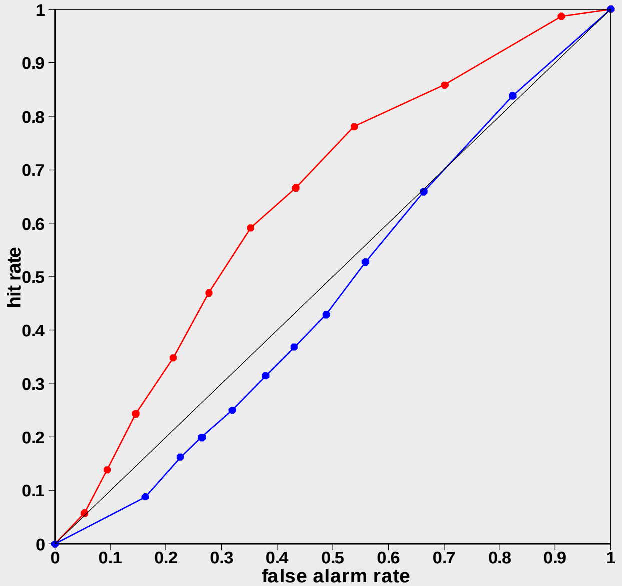
27 real-time cases covering the period May-June-July-August 2002, 2003, 2004 , 2005



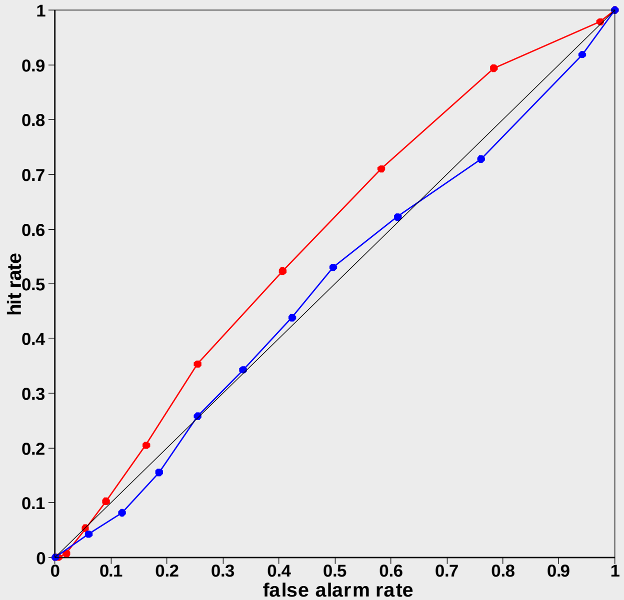
Monthly Forecast

Persistence of the probabilities of the previous week

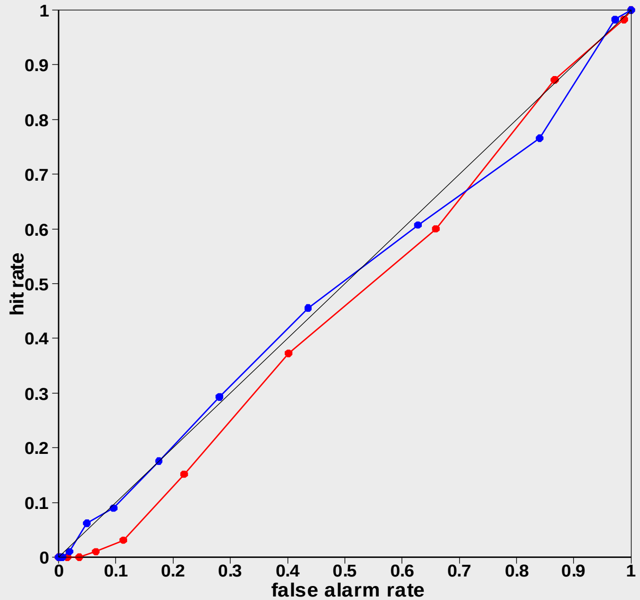
DAY 12-18
ROC score: 0.64 0.49



DAY 19-25
ROC score: 0.58 0.49



DAY 26-32
ROC score: 0.46 0.48



Physical Parametrization Changes

Model Cycle G39 - Parallel Suite 10

•Convection

- •Adaptive detrainment (A. Maidens, S. Derbyshire)
- •Revisions to mid-level convection (M. Willett)

•Boundary Layer

- •Marine BL changes (J. Edwards)
- •Non-gradient stress (A. Brown)
- •Sharp tailed stability functions over Sea (R. Beare)

- •Correction to decoupled diagnosis (A. Lock)
- •Correction to CU diagnosis (in MES) (J. Edwards)
- •Correction to prevent entrainment in stable BL's (A. Lock)

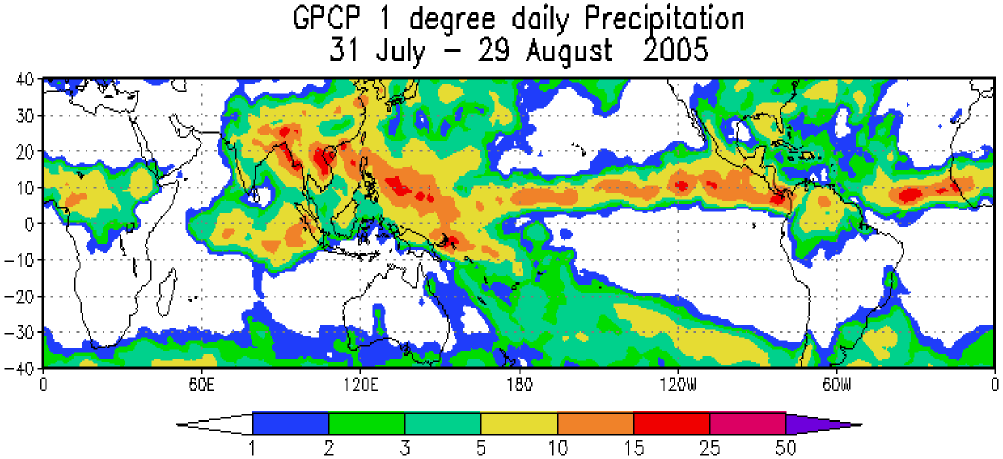
•Valley cooling problem

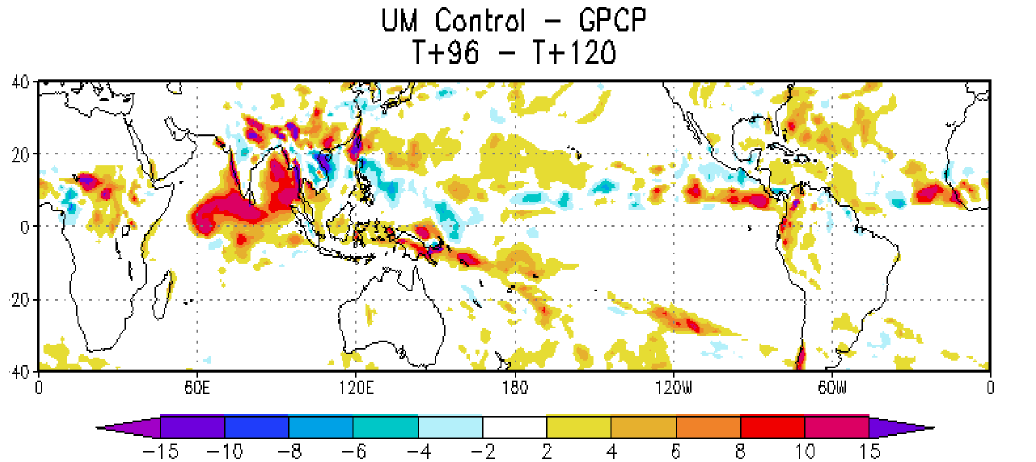
- •Intelligent limiter

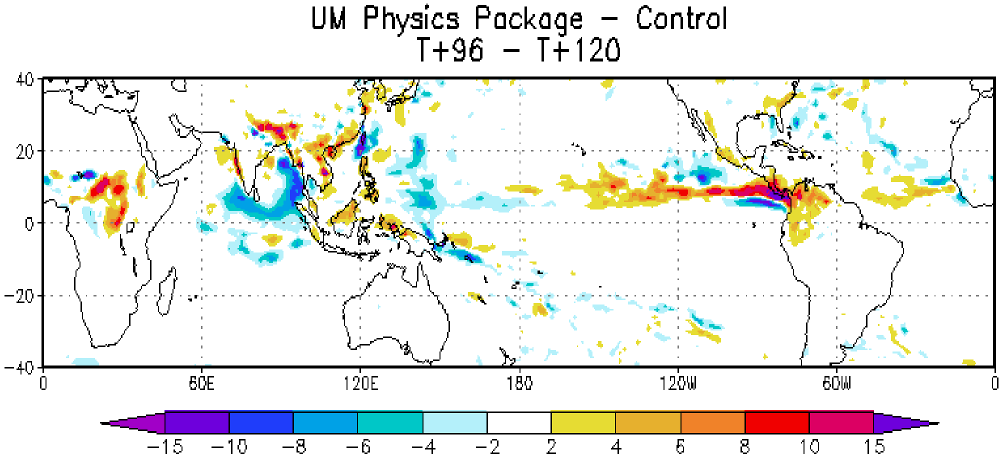
•Upper level diffusion (already operational)

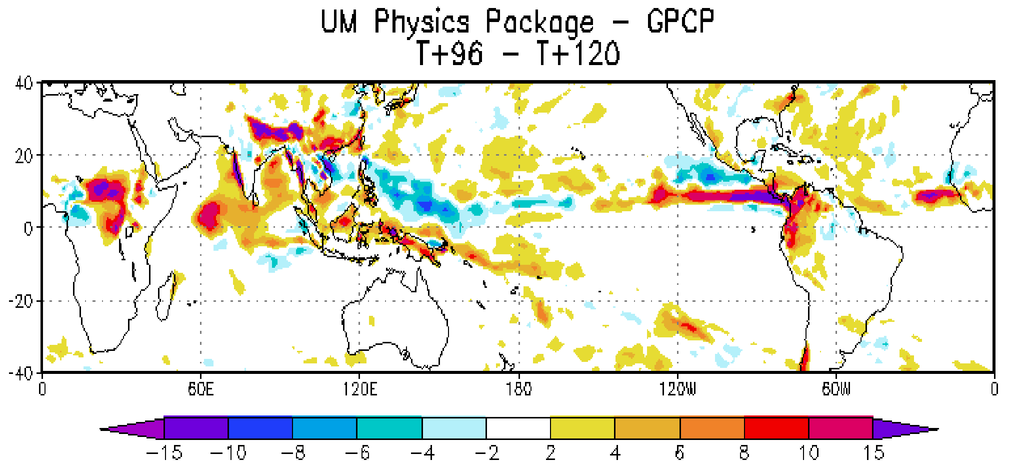
Impact of New Physics (adaptive detrainment….)

MetOffice Model Cycle G39









New directions in cloud parametrisation

The new Science and Technology Centre at Colorado State University - Centre for multi-Scale Modelling of Atmospheric Processes (CMMAP)

CMMAP's Research Goals

A. Create radically new models that take advantage of petascale computers to produce dramatically improved simulations of the interactions of clouds with the global circulation of the atmosphere.

B. Identify, analyze, and understand the strengths and weaknesses of the new models using a variety of state-of-the-art observational datasets, derived from in situ observing systems, as well as both ground-based and satellite-borne remote sensors.

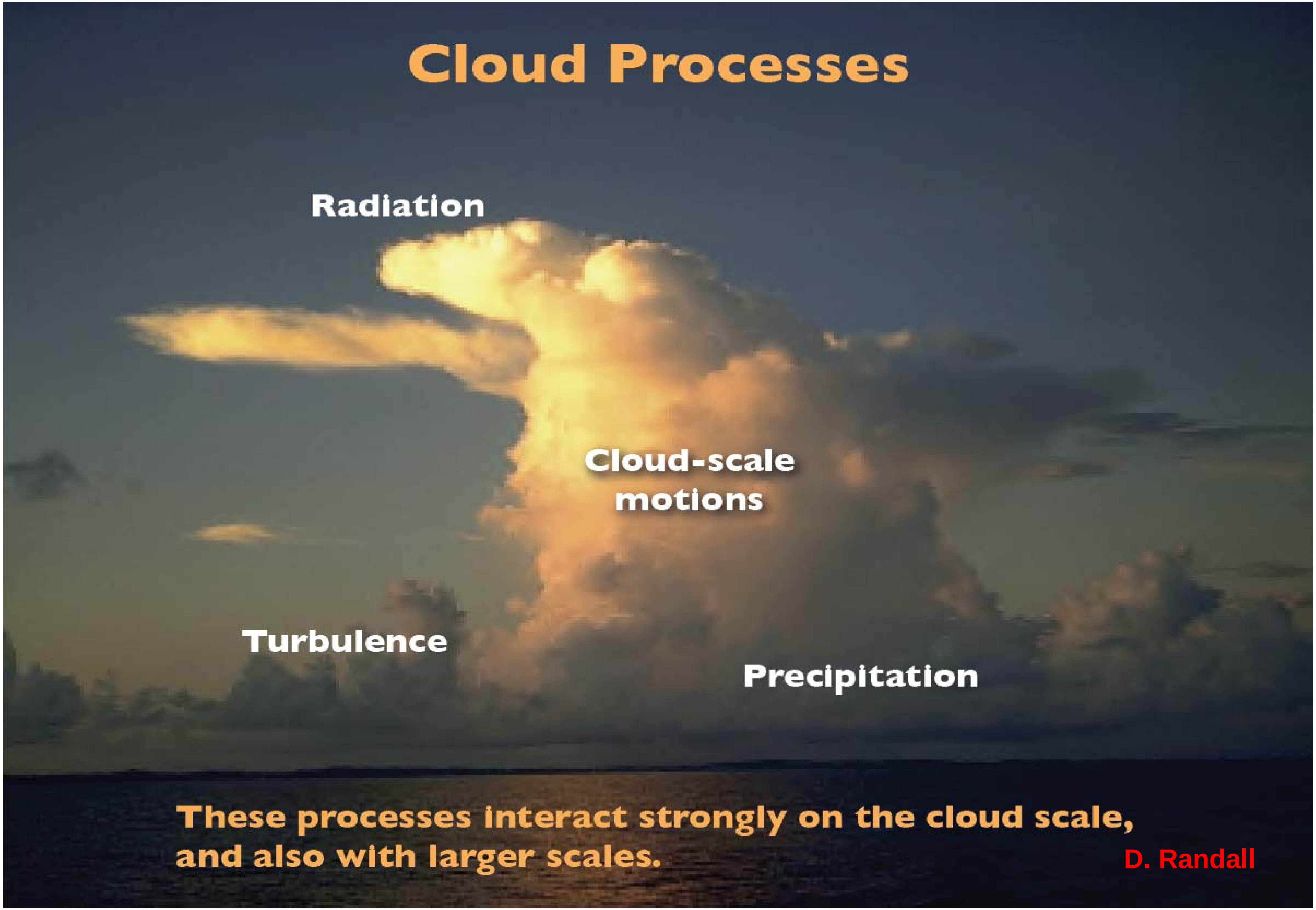
C. Apply the new models to develop an improved understanding of the role of clouds in the Earth system.

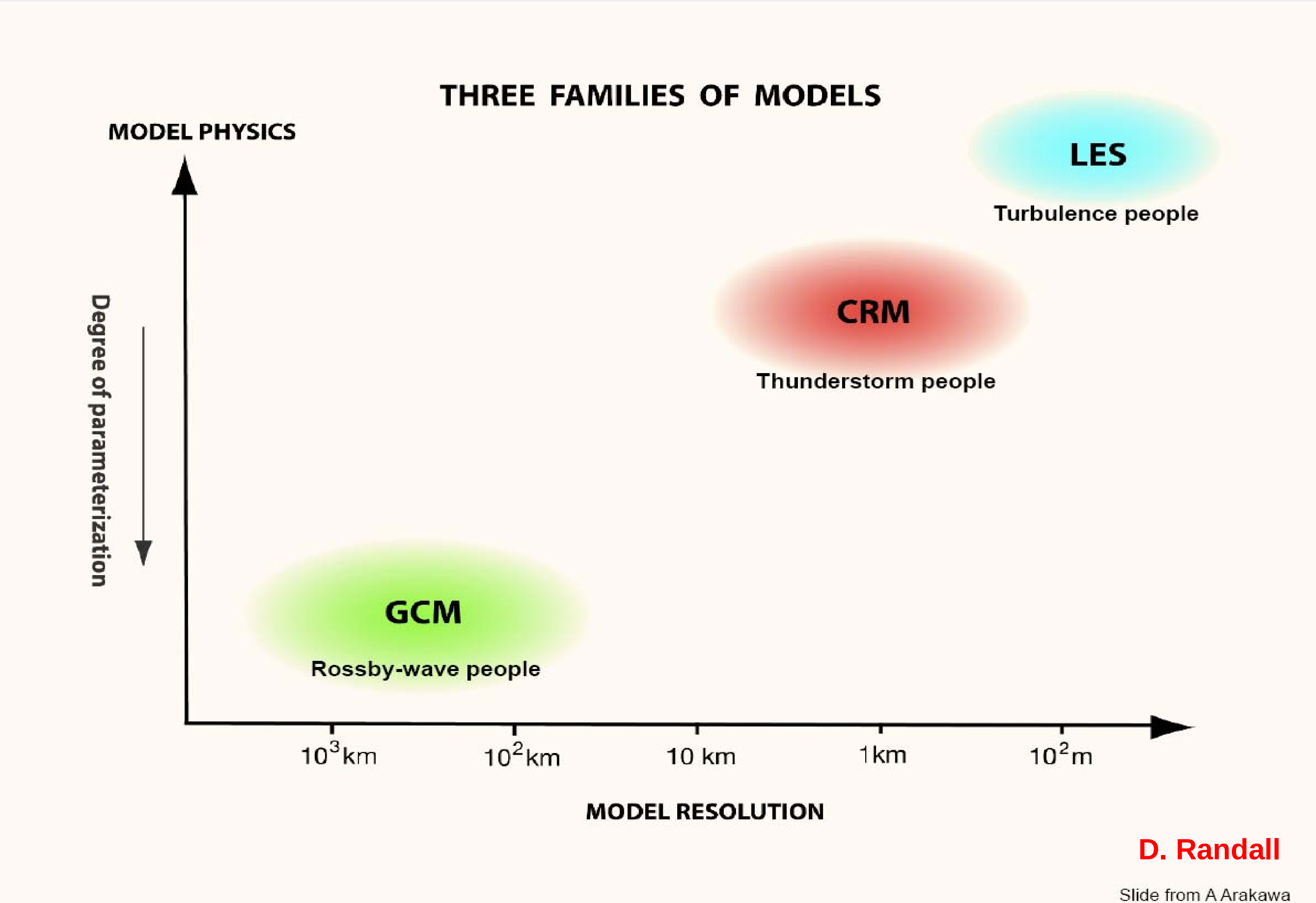
Clouds Are Central to the Earth Sciences

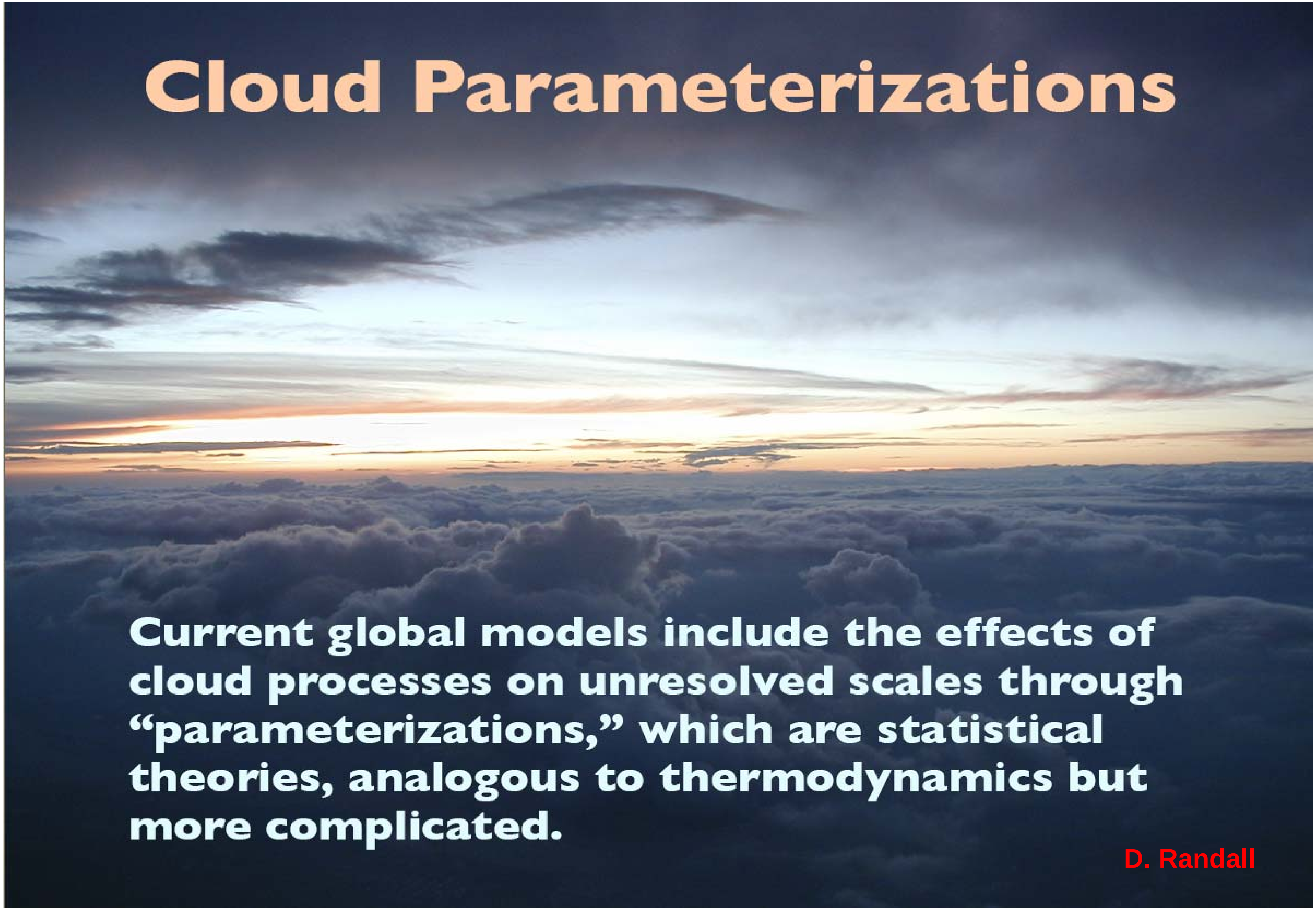
- Climate change
- Weather prediction
- The water cycle
- Global chemical cycles
- The biosphere

We are being held back in all of these areas by an inability to simulate the global distribution of clouds and their effects on the Earth system.

D. Randall


Cloud Processes
Radiation
Cloud-scale motions
Turbulence
Precipitation
These processes interact strongly on the cloud scale, and also with larger scales.
D. Randall


THREE FAMILIES OF MODELS
MODEL PHYSICS
Degree of parameterization
LES
Turbulence people
CRM
Thunderstorm people
GCM
Rossby-wave people
10³km
10²km
10 km
1km
10²m
MODEL RESOLUTION
D. Randall
Slide from A Arakawa


Cloud Parameterizations
Current global models include the effects of cloud processes on unresolved scales through "parameterizations," which are statistical theories, analogous to thermodynamics but more complicated.
D. Randall

Multiple Scales

Cloud-scale processses
Well understood

→

Meso-scale statistics
Poorly understood

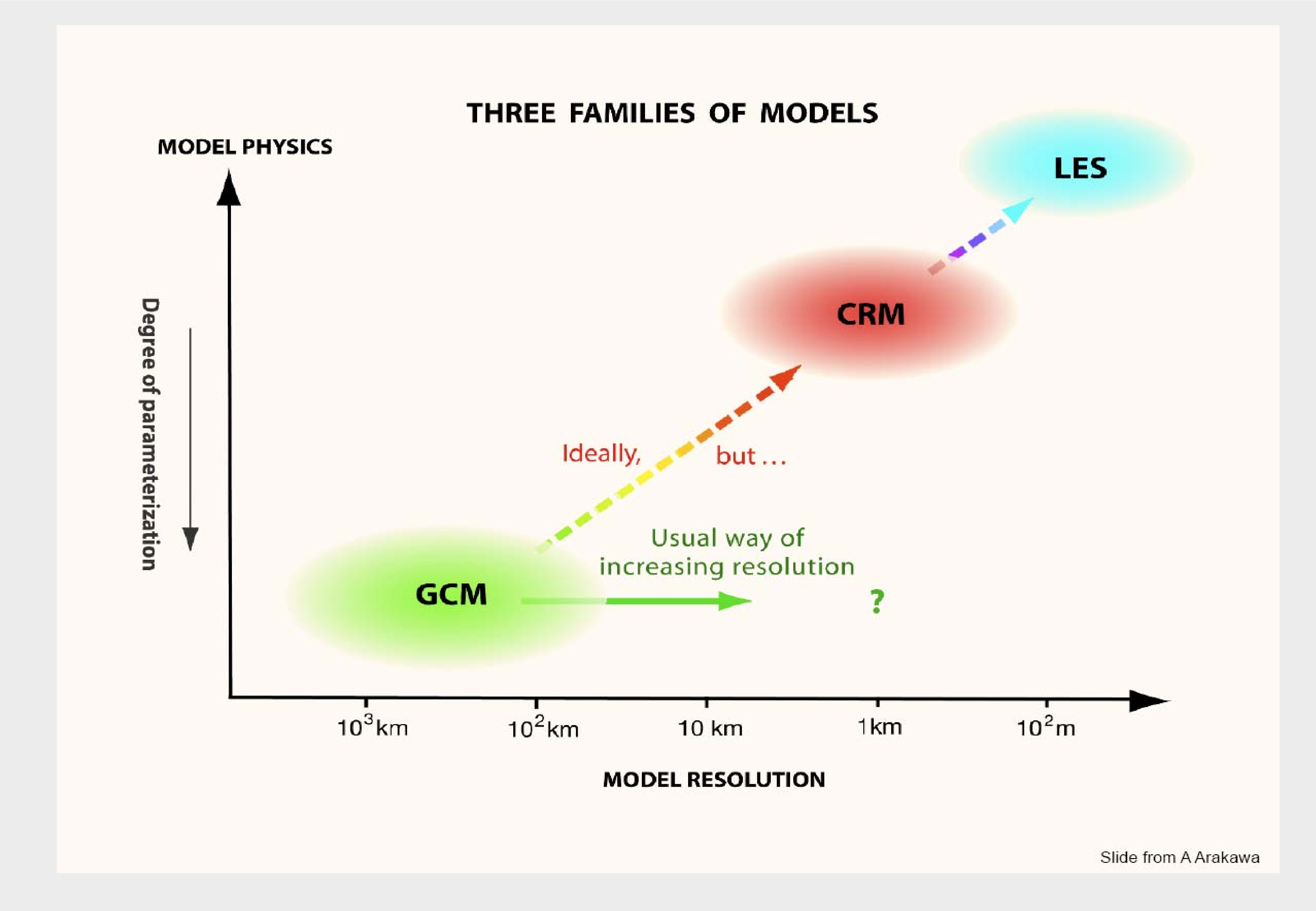
→

Global scale

This is where parameterization comes in.

D. Randall


At very high resolution, a realistic model should grow individual clouds.
A model that uses cloud parameterizations can't do this.
Therefore, global models have to be reformulated when run at high resolution.
D. Randall


THREE FAMILIES OF MODELS
MODEL PHYSICS
Degree of parameterization
LES
CRM
Ideally,
but ...
Usual way of
increasing resolution
GCM
?
10^3km
10^2km
10 km
1km
10^2m
MODEL RESOLUTION
Slide from A Arakawa

Multiple Scales

Cloud-scale processses
Well understood

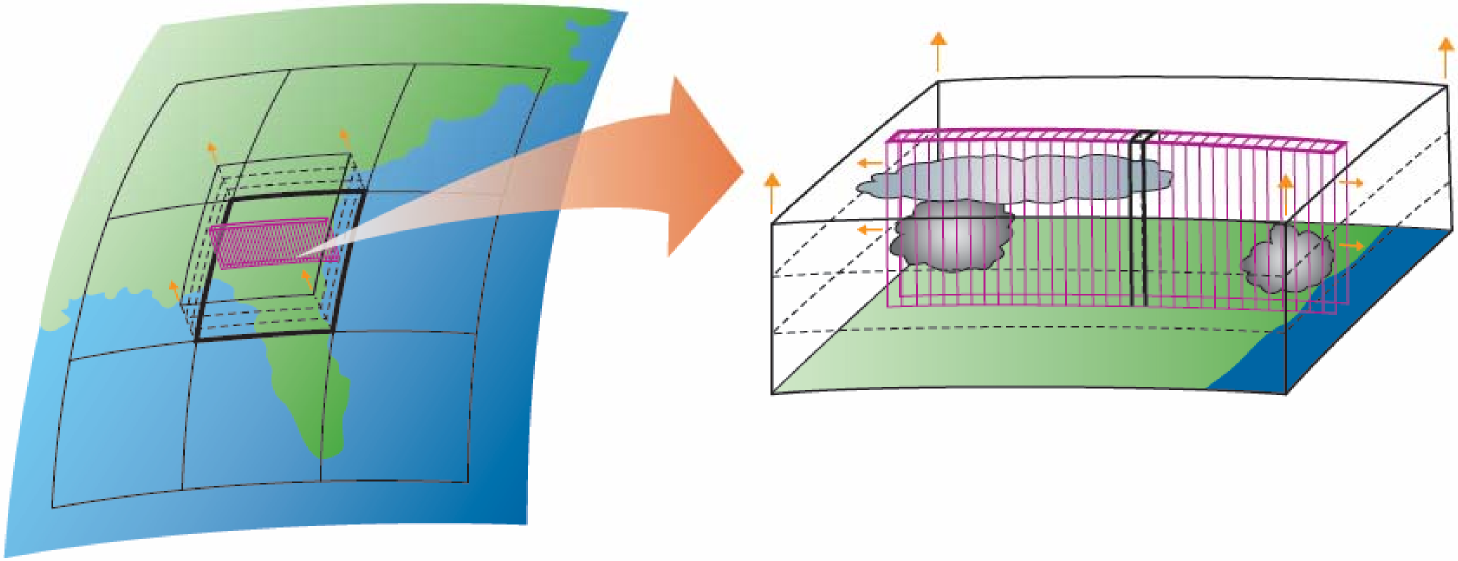
Global scale

Good news: We now have very powerful computers.

Not quite powerful enough, though...

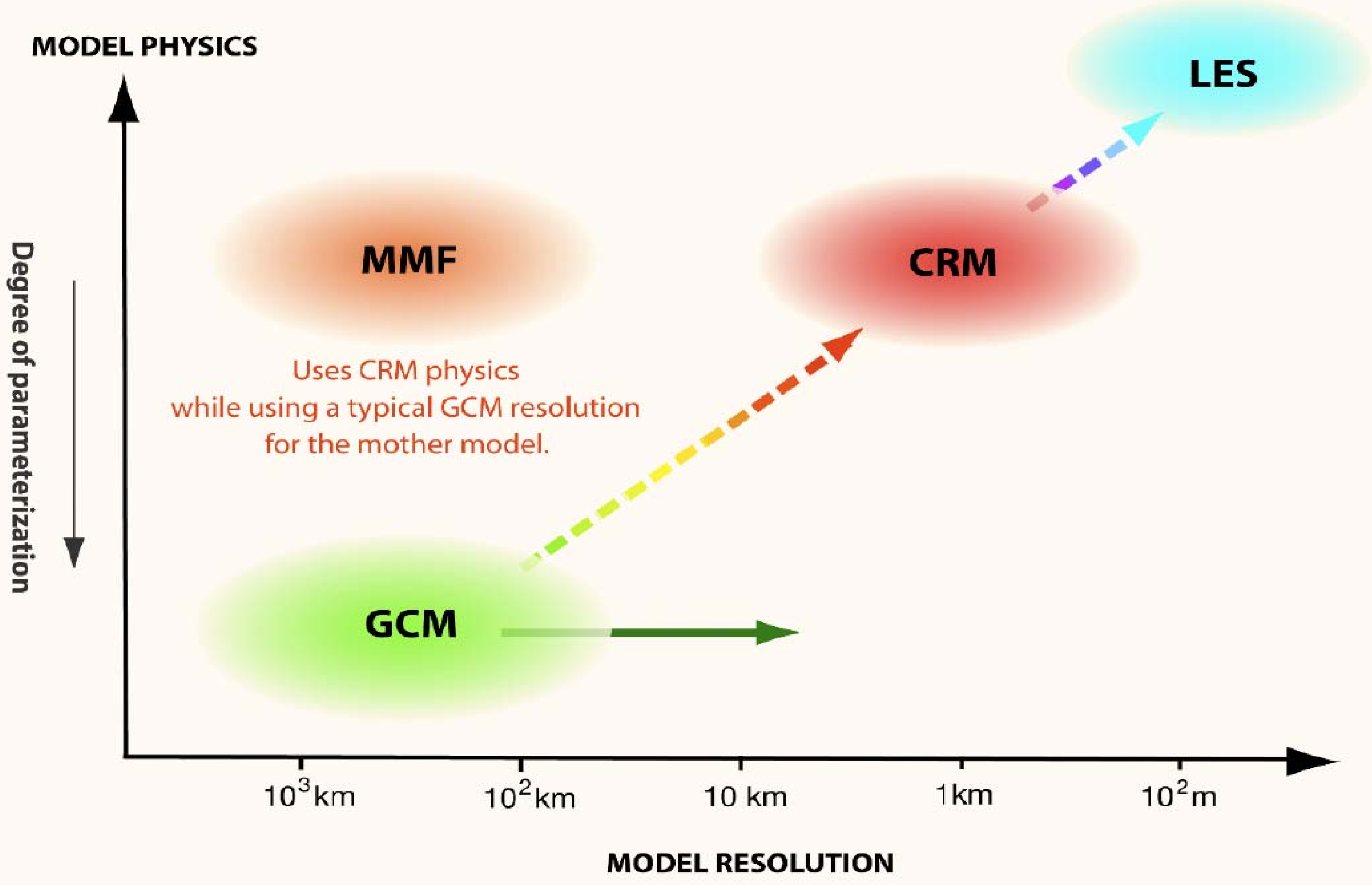
D. Randall

Super-Parameterization:
A Multiscale Modeling Framework



This idea was proposed and first tested by Wojciech Grabowski.

D. Randall



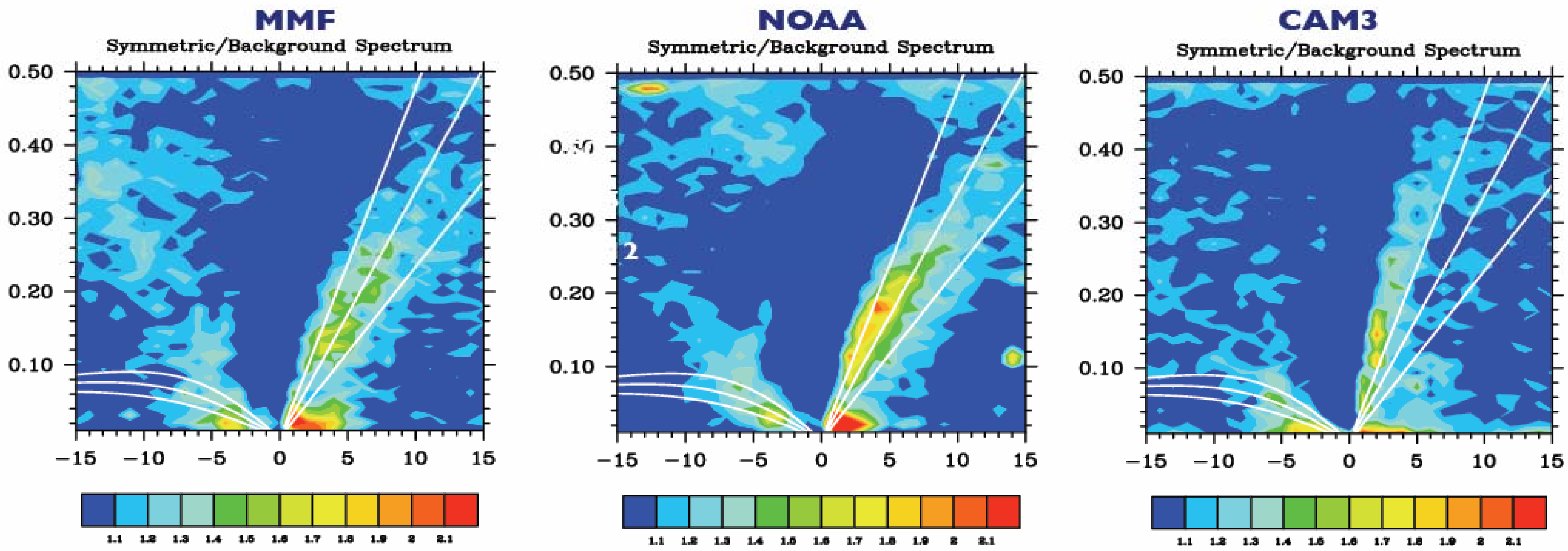
Slide from A Arakawa

Trade-offs

Local physics (Cloud-resolving model)	Statistical physics (Parameterization)
Well understood	Partially/imperfectly understood
Simple	Complicated
Computationally expensive	Computationally cheap

D. Randall

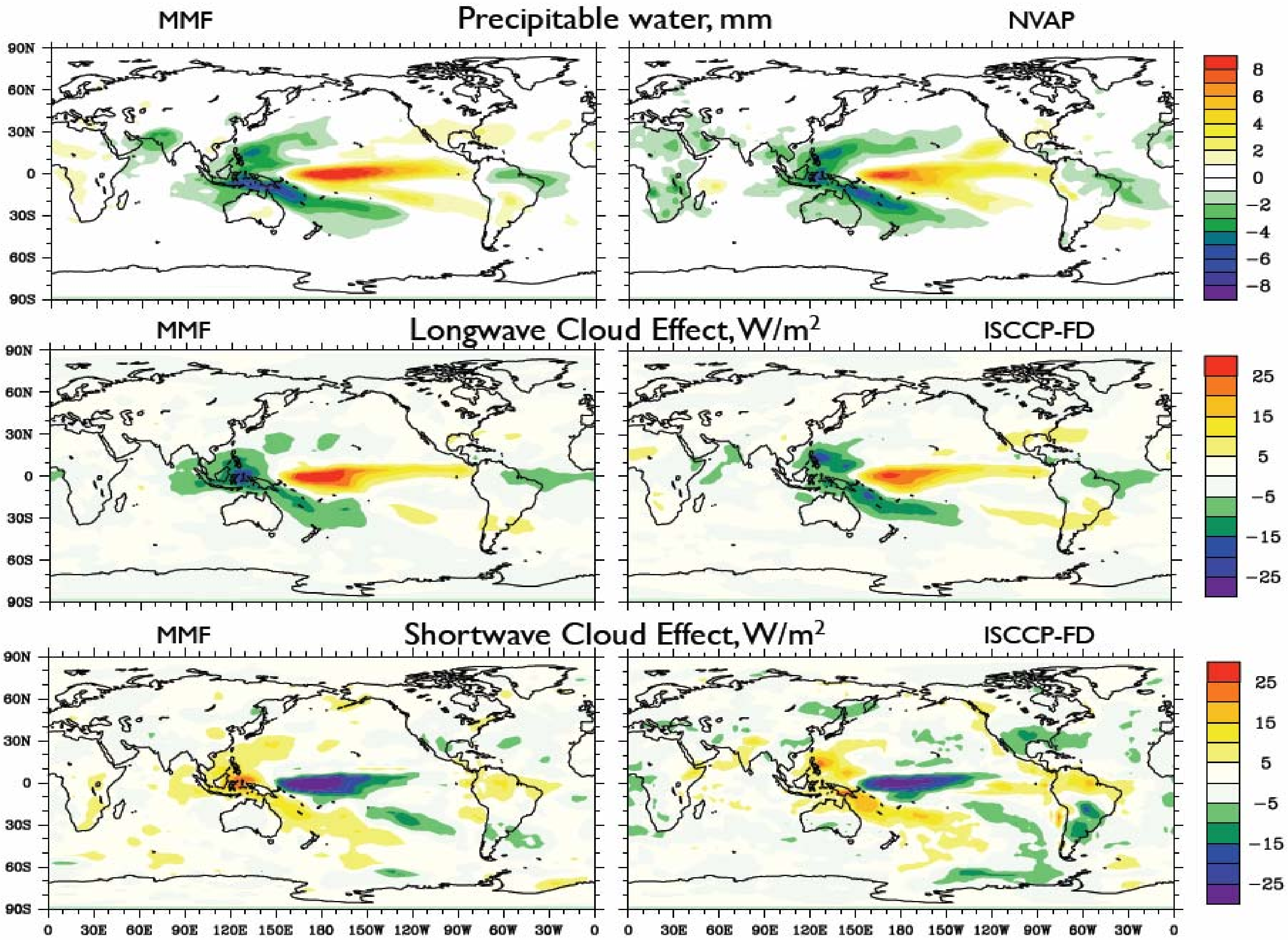
An analysis of wave activity along the Equator



Outgoing Longwave Radiation

D. Randall

El Nino - La Nina Anomalies



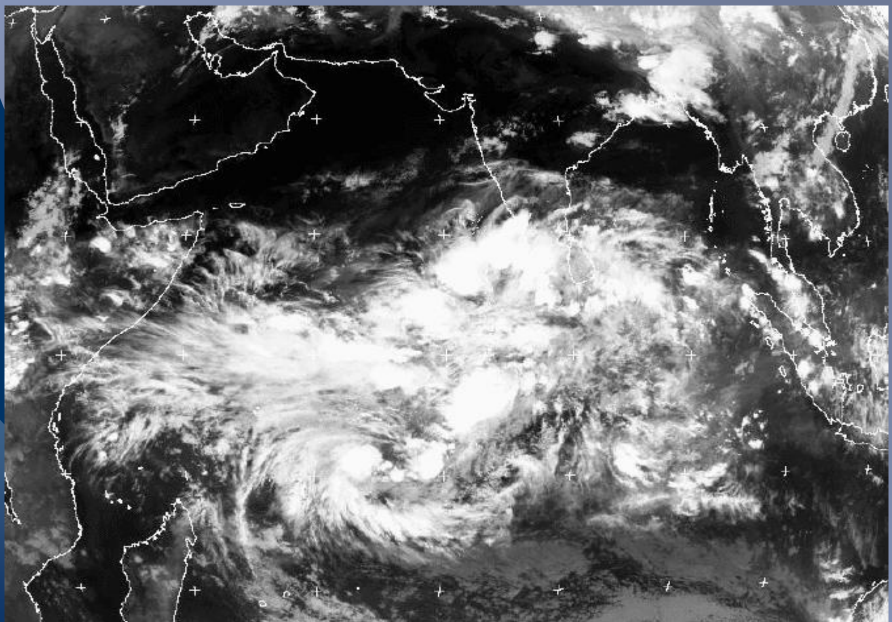
D. Randall

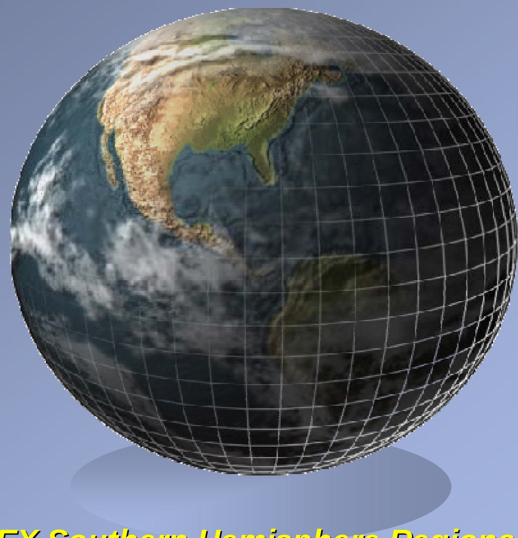
Current trends
Observations and analyses

Year of Tropical Convection (YOTC)

Mitch Moncrieff, NCAR

Acknowledgement -- Duane Waliser, JPL





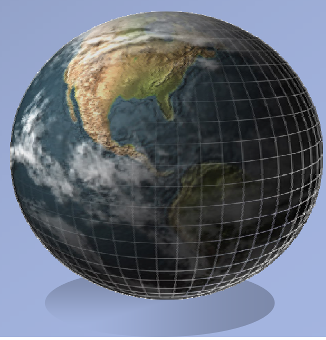
***Workshop of the THORPEX Southern Hemisphere Regional Committee*, BMRC, Melbourne, Australia, 28-31 May 2007**

Origin of YOTC ... A recommendation of THORPEX-WCRP Workshop at the ICTP, Trieste, Italy, March 2006

(Moncrieff et al. 2007, *WMO Bulletin*, in press)

"Develop an internationally coordinated 'virtual computational-observational laboratory' to … provide the infrastructure to exploit observations, operational prediction, and high-resolution simulations of tropical convection, its two-way interaction with extra-tropical weather & climate, and socio-economic impacts and their assessment."

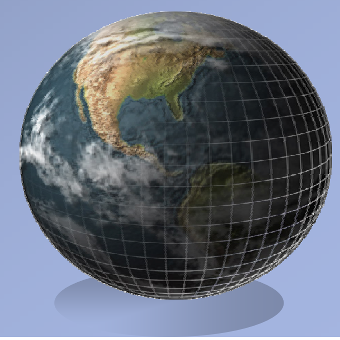
… including a strong research component



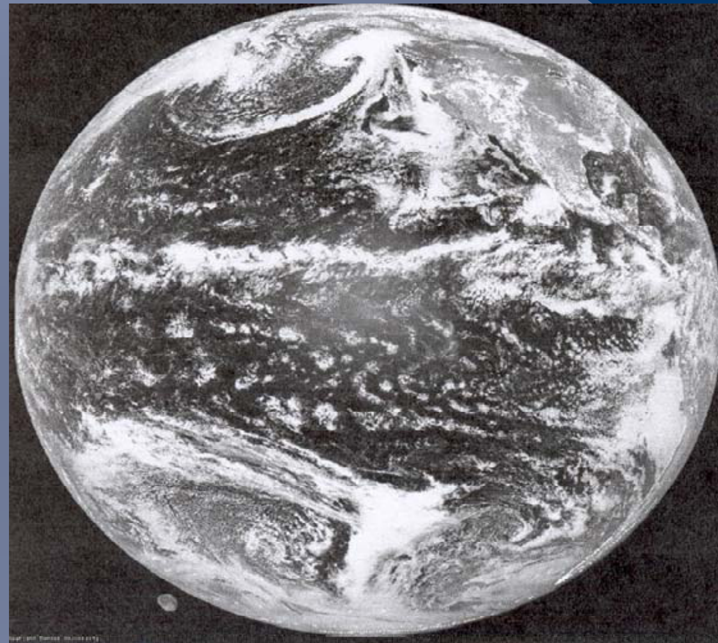
Strategic objective

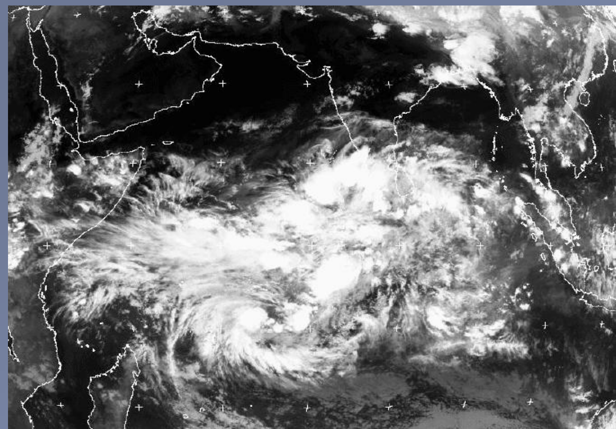
Integrate numerical simulations and observations at timescales pertinent to the intersection of weather and climate ~ days through subseasonal

… hence, improve physical knowledge and convective parameterization



Convective organization

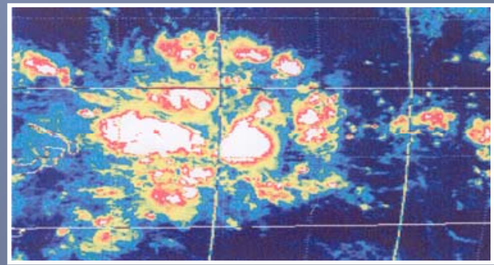




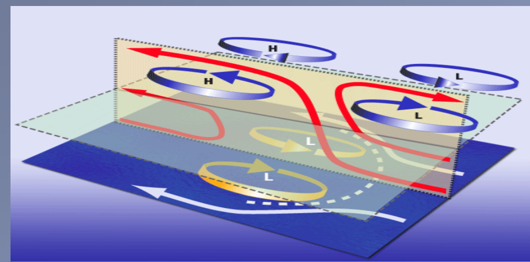
…but organization is not represented in parameterizations

Basic science questions

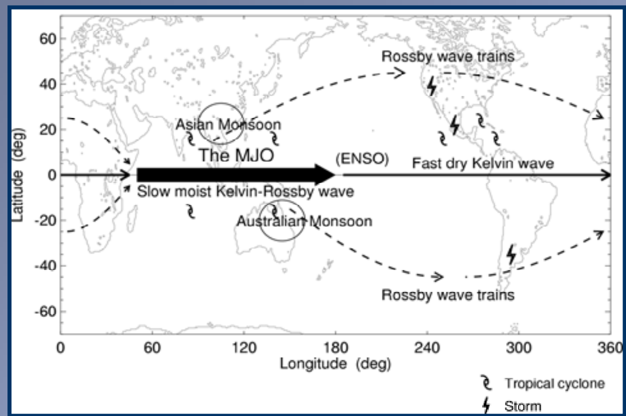
- How is **organized convection** influenced by, and how does it **feedback to**, the **large-scale circulation**?
- How do **large-scale dynamics, synoptic scales,** and **mesoscale convective organization** interact?
- How does large-scale **tropical convection** generate planetary waves and communicate with the **extra-tropics**?



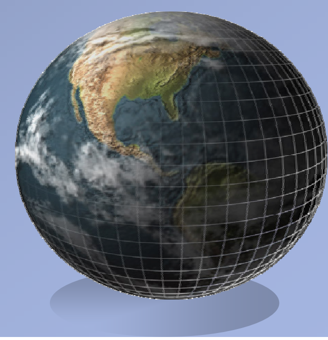
Supercluster: a powerful hierarchy of convective organization



Mesoscale – Supercluster interaction (Moncrieff 2004)

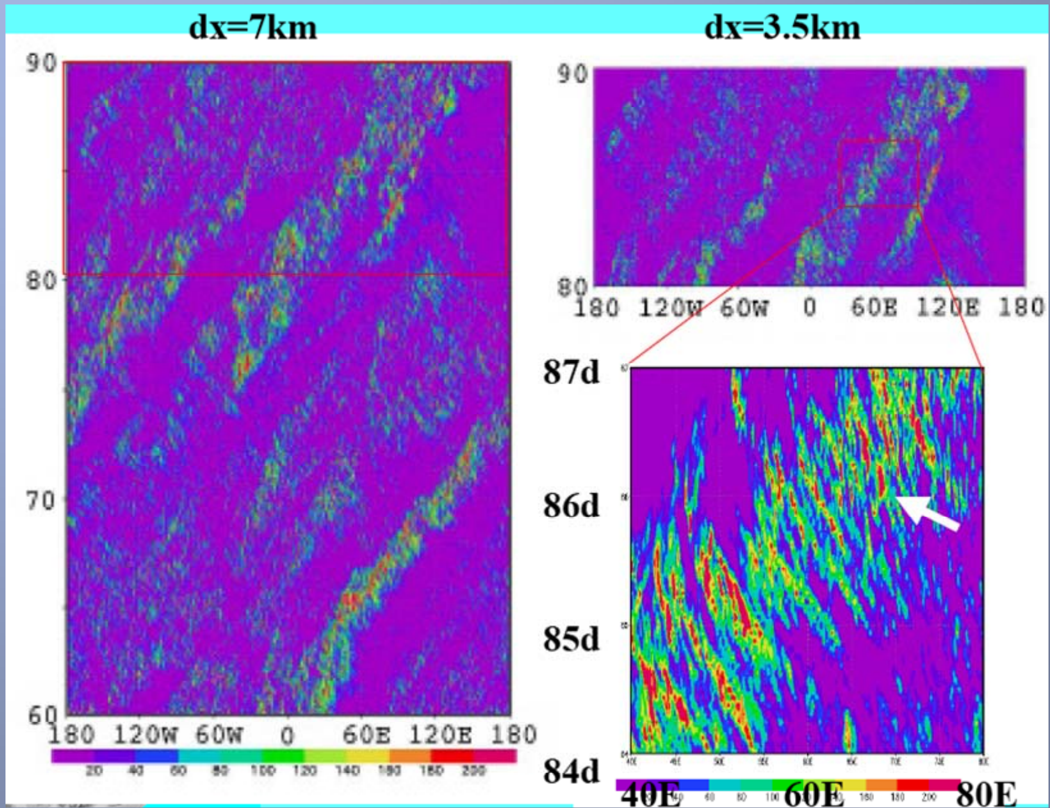


Global effects of organized tropical convection
J .Lin et al. (2006)



Advances in modeling infrastructure

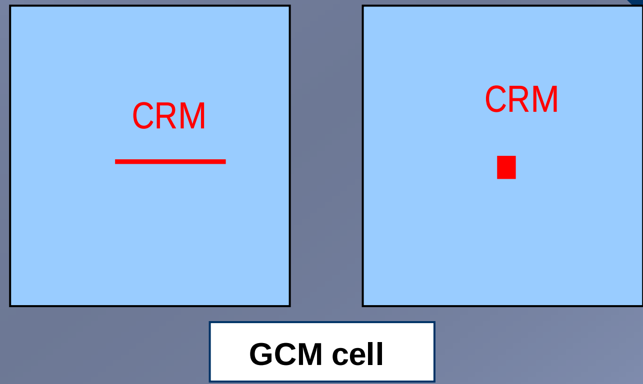
Global CRM



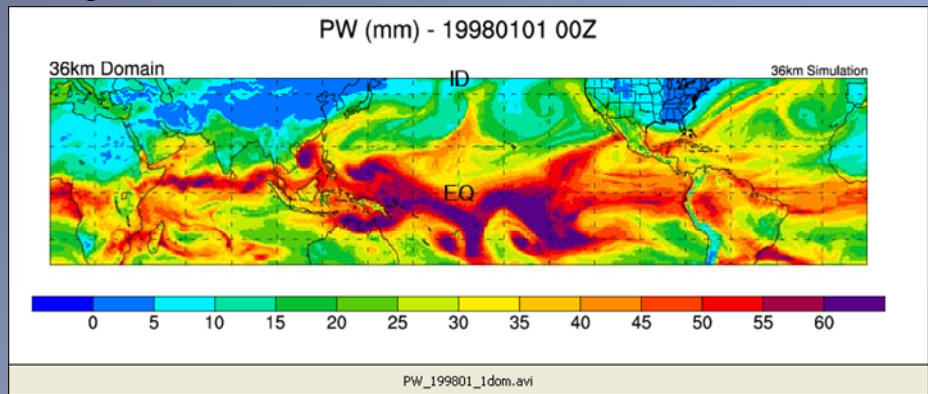
Courtesy: Satoh, Frontier Research Center for Global Change

Superparameterized models

(NCAR, CSU, LLNL, GSFC & PNNL)



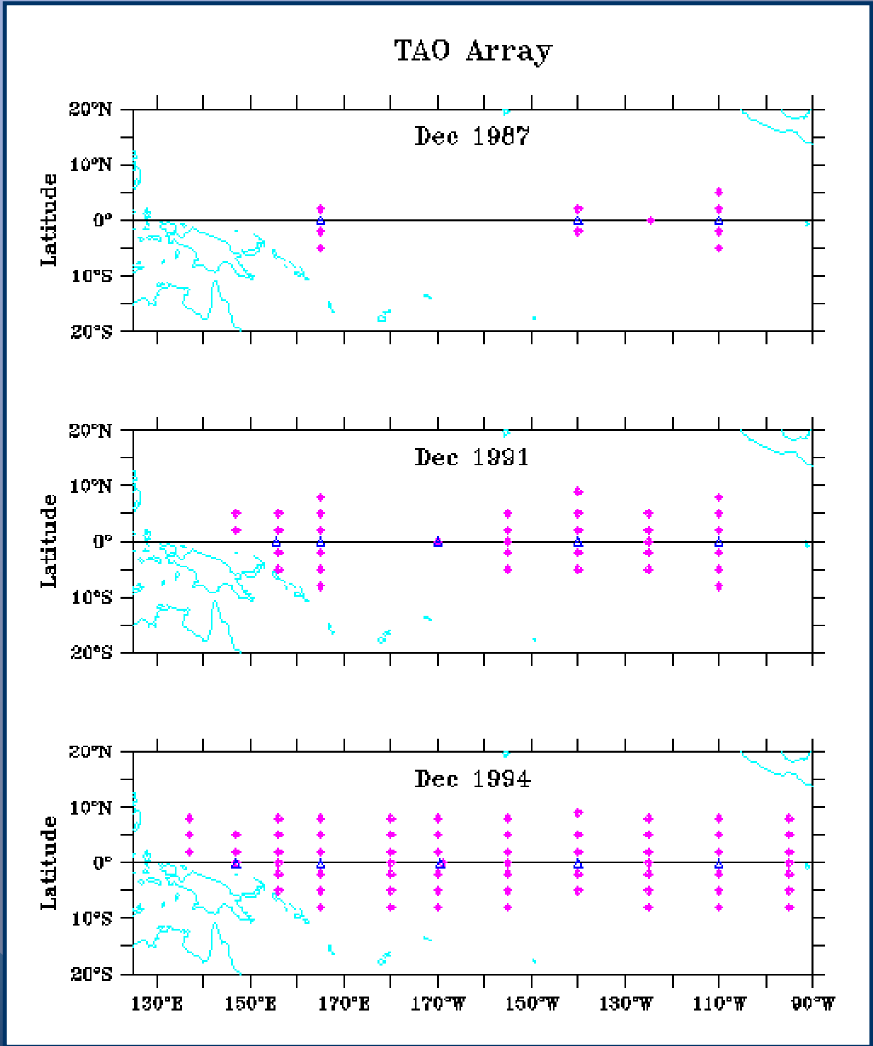
New generation of numerical models

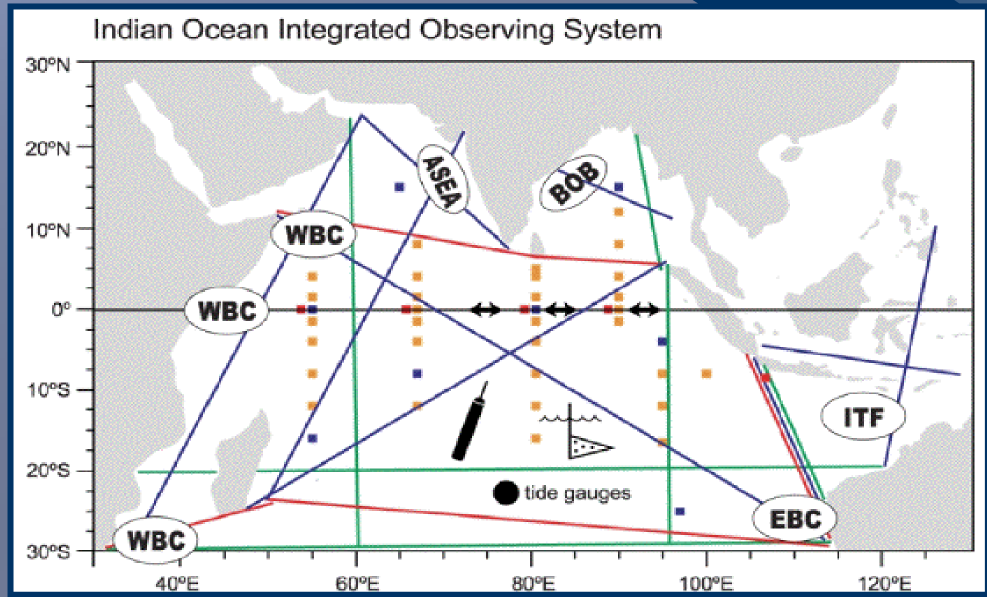


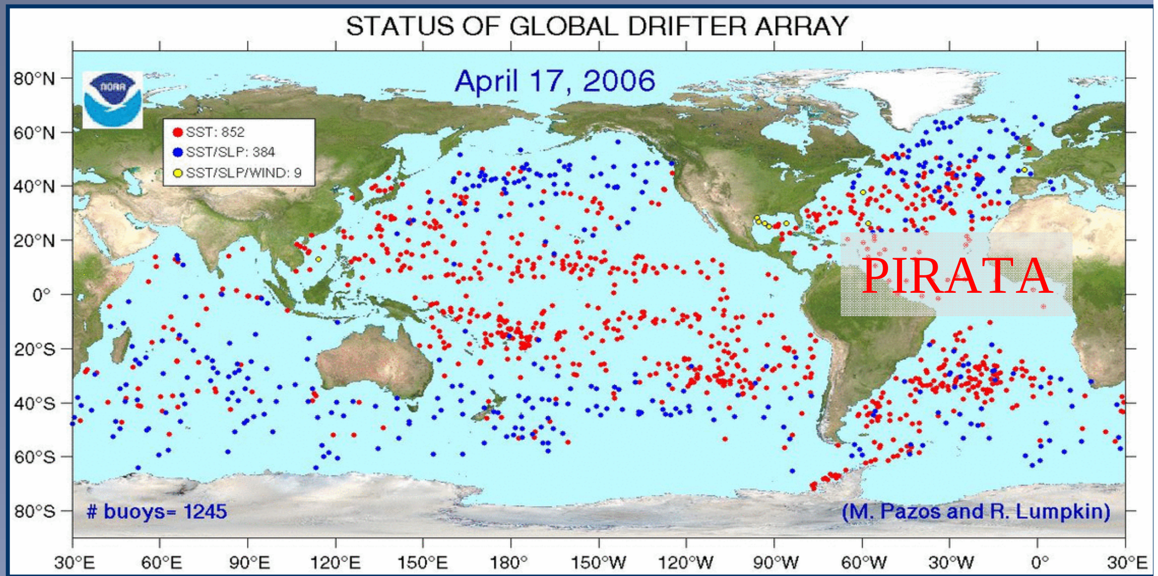
NCAR's Nested Regional Climate Model

Advances in measurement infrastructure

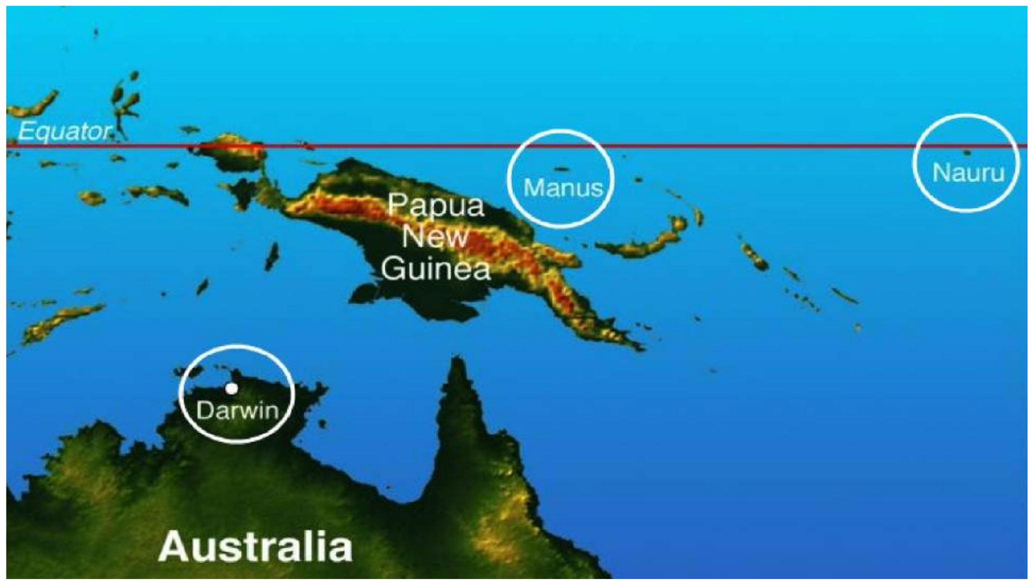
Towards a Global Observing System (GOOS)





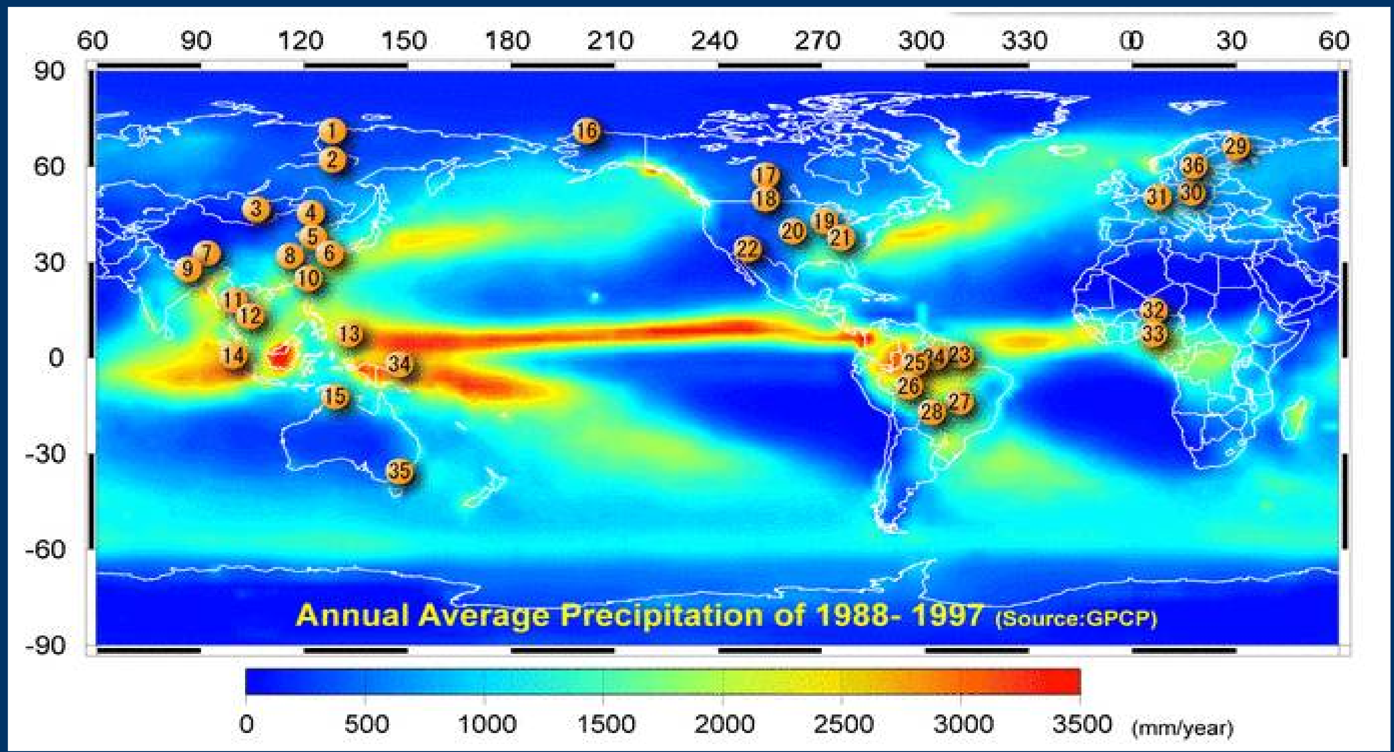


Enhanced In-situ Observation Programs



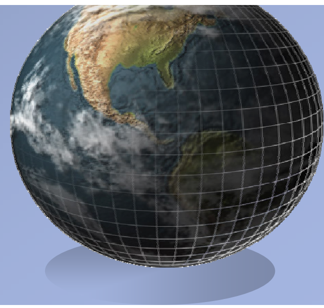
ARM TWP

GEWEX/CEOP



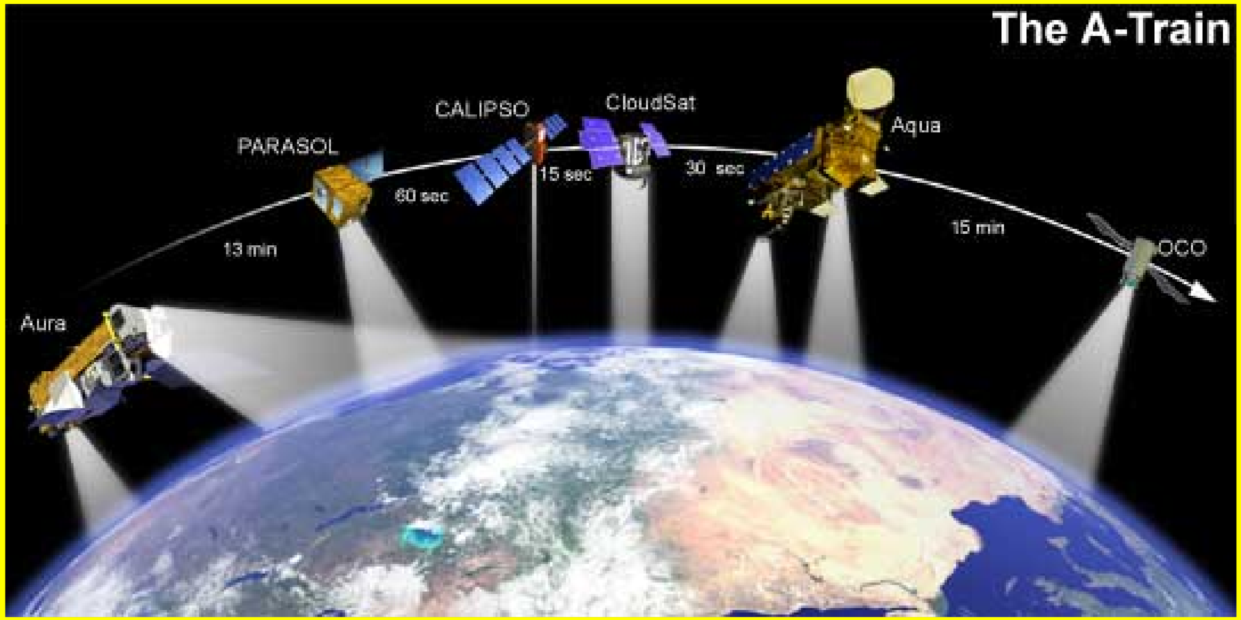
Coordinated Enhanced Observing Period (CEOP)

2-year data set of in-situ, satellite and model data for the period 2003-200 to support research objectives in climate prediction and monsoon system studies.



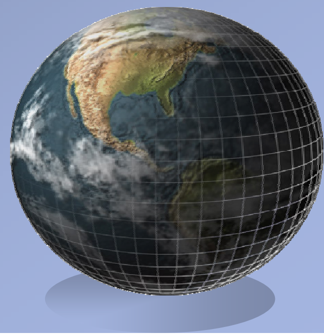
EOS-era of satellite observations: moist physics

Considering where we were 10-15 years ago…



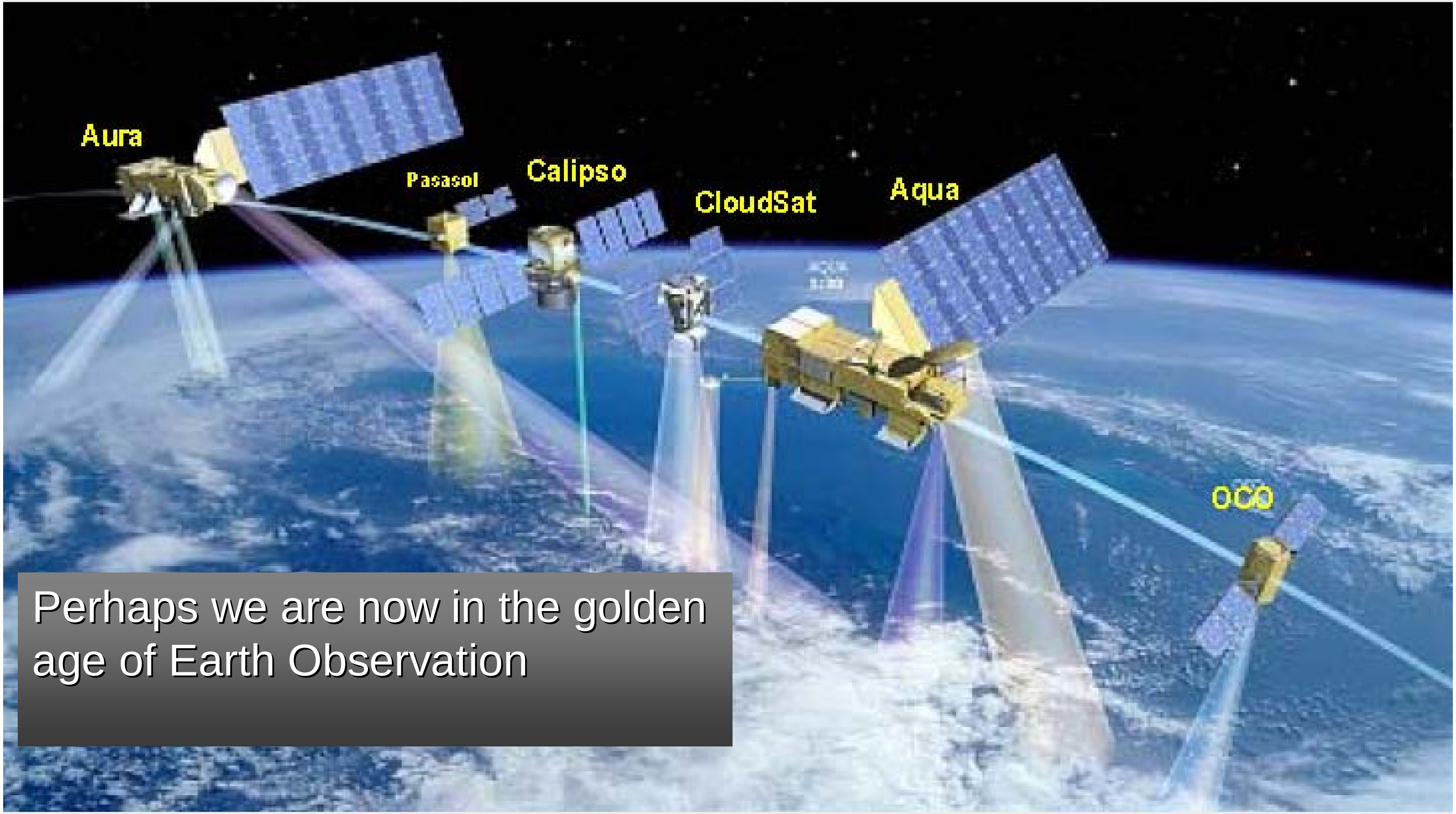
QuickScat: ocean surface winds
TRMM: precipitation
TMI: sea surface temperature w/clouds
AIRS: temperature and water vapor profiles
CloudSat: cloud profiles
CALIPSO: aerosol/optically thin cloud profiles
AMSRE: ocean precip, water vapor, liquid water
Aqua: cloud properties/mapping
MLS: upper tropospheric water vapor, cloud ice, temperature
CERES: TOA and surface radiative fluxes
MODIS: cloud characteristics, ocean color, land characteristics
AURA platform: atmospheric composition/chemistry
MISR: aerosol and cloud structure

Tropical Soundings:
AIRS: ~100,000/day
CloudSat:~90,000/day
TOGA COARE: 120-day IOP ~ 6000 soundings

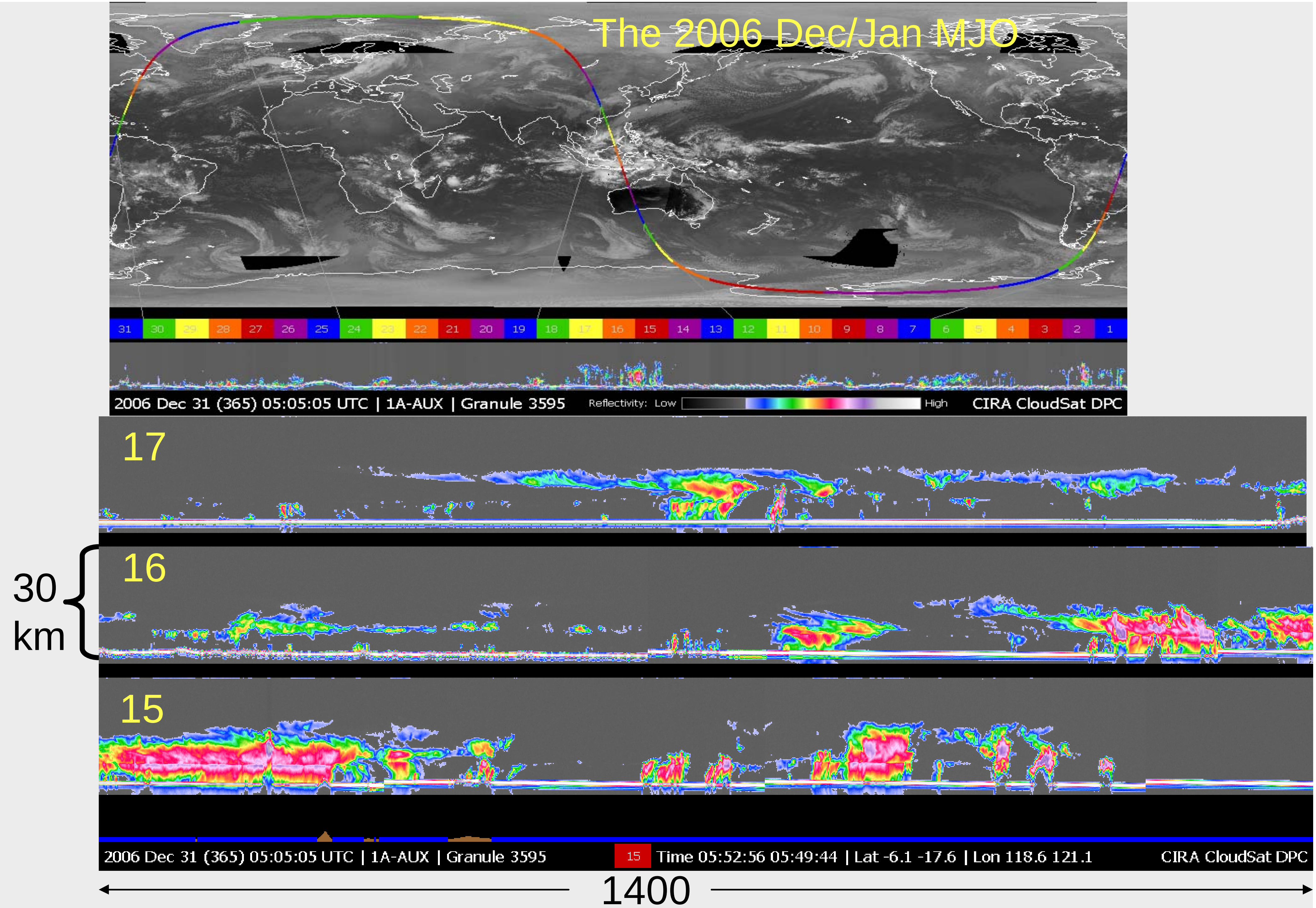


YOTC Summary

- Excellent prospect for quantifying global effects of tropical convection and its organization
- An integrative approach: observations, numerical modeling, dynamical interpretation
- Convective parameterization needed for global NWP and climate models for foreseeable future
- Explicit approach (i.e., CRM) a powerful tool



Opportunity for Year of Tropical Convection

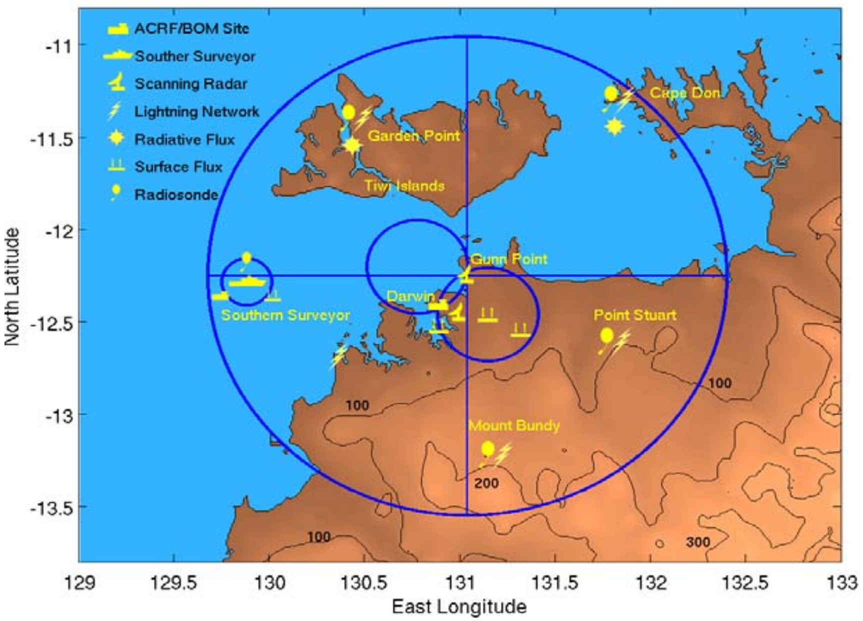


The 2006 Dec/Jan MJO
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
2006 Dec 31 (365) 05:05:05 UTC | 1A-AUX | Granule 3595
Reflectivity: Low High
CIRA CloudSat DPC
17
16
15
30 km
2006 Dec 31 (365) 05:05:05 UTC | 1A-AUX | Granule 3595
15
Time 05:52:56 05:49:44 | Lat -6.1 -17.6 | Lon 118.6 121.1
CIRA CloudSat DPC
1400

What was TWP-ICE?

- **Tropical Warm Pool International Cloud Experiment - 21 Jan - 13 Feb 2006, Darwin – Collected one of the most comprehensive tropical data sets ever**
- **Aims:**
  - Study monsoon convection and resulting cloud fields and the two-way interaction with the large-scale environment they are embedded in
  - Provide data sets for physical parametrization development - both forcing and verification
  - Relation between cloud properties with convection properties, age and aerosol
  - Validation of remote sensing of cloud properties

TWP-ICE setup



- Extensive ground-based network – long record of obs
  - >1000 three-hourly radiosondes at 5 sites
  - Ship
  - radars, lidars, radiometers, lightning...
- 5 research aircraft
- >150 participants

Thermodynamics
Microphysics
Remote sensing
Aerosols
Chemistry

ERA-Interim: A new ECMWF Reanalysis

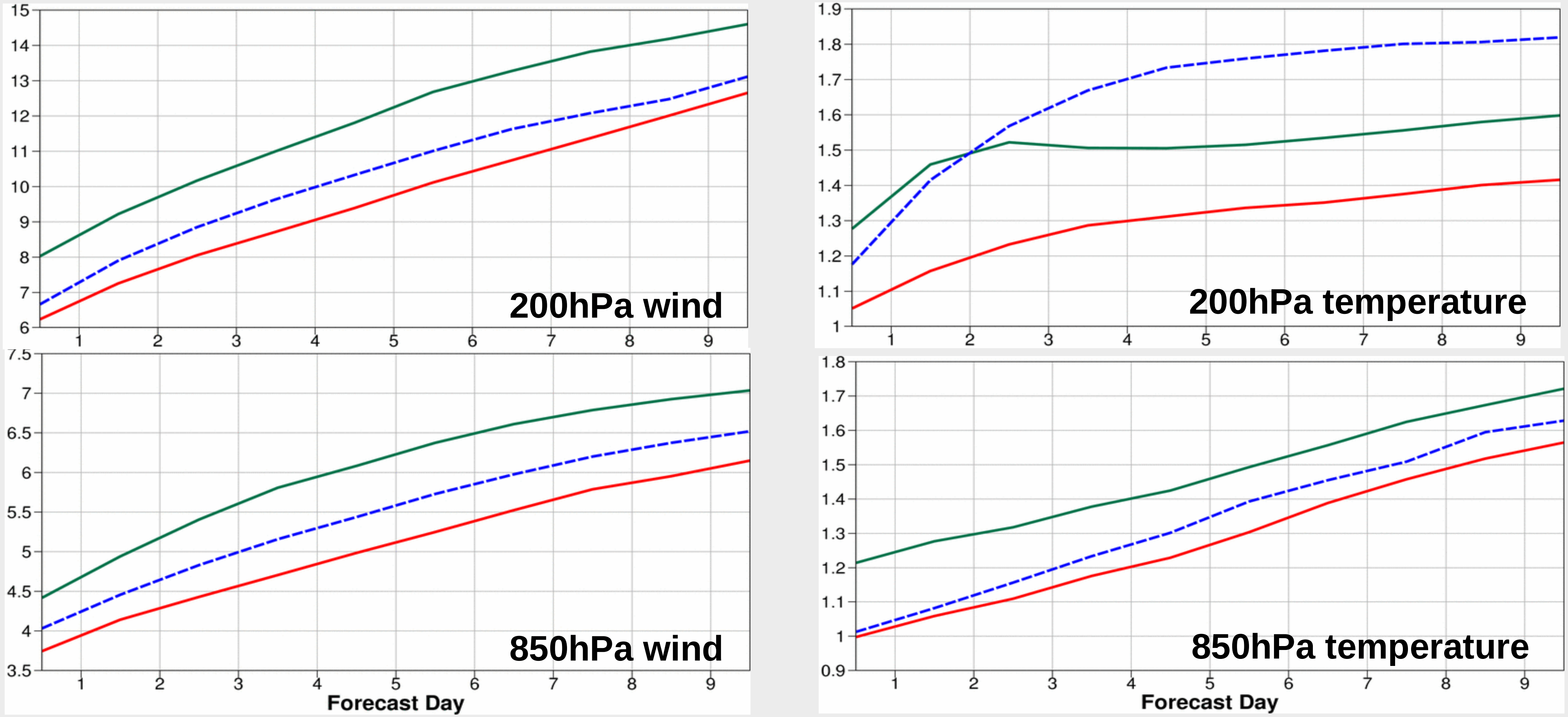
Sakari Uppala, Dick Dee, Shinya Kobayashi[1],
Adrian Simmons and colleagues

- From 1989 onwards, to be continued in near real time
- T255 L60 (ERA-40: T159 L60)
- 12h 4D-Var (ERA-40: 6h 3D-Var)
- Cycle of forecasting-system libraries operational at ECMWF since 12 September 2006 (ERA-40: ~ system operational in 2H 2001)

[1] On leave from Japan Meteorological Agency

Improvement in tropical forecasts

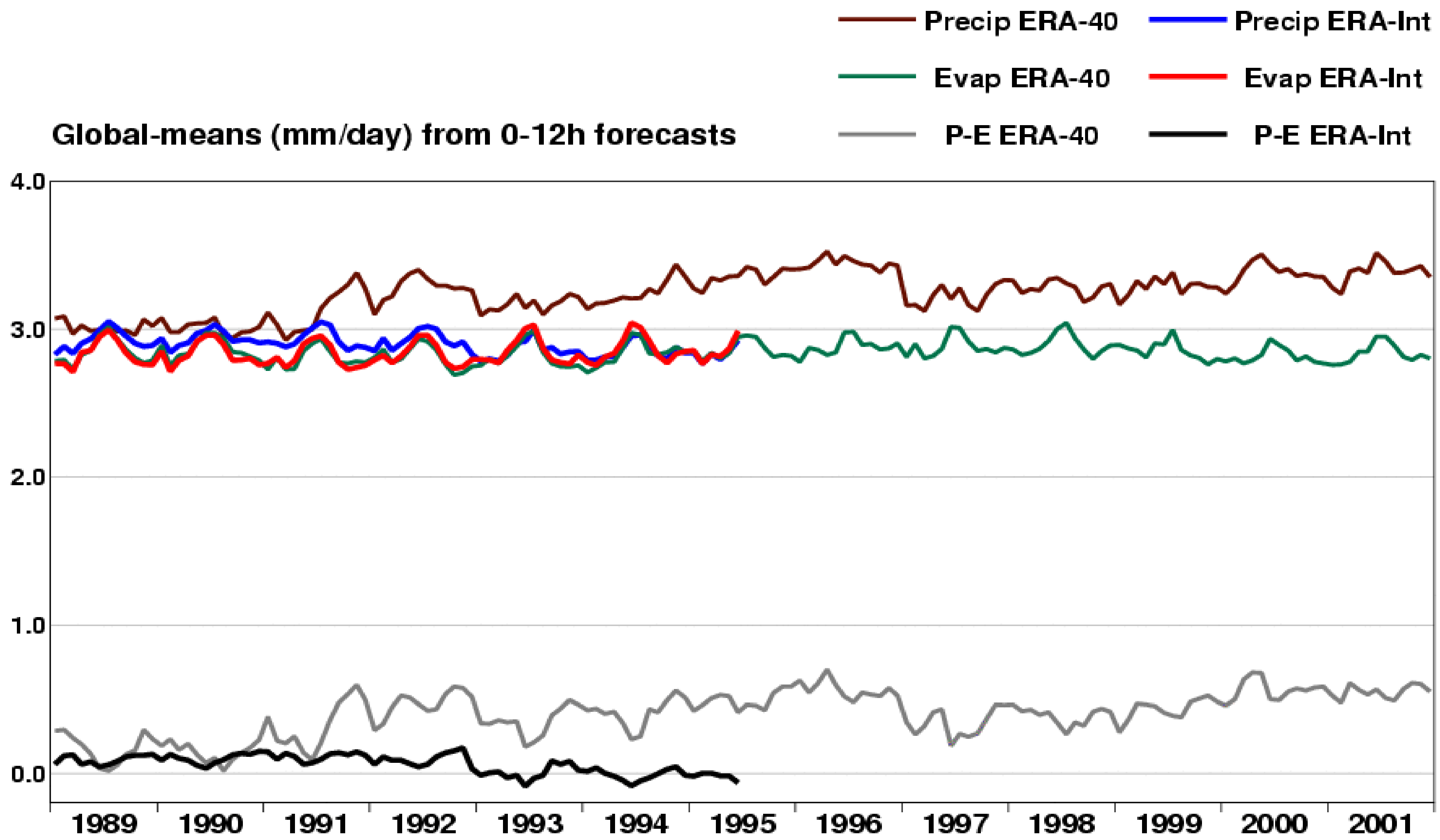
Root-mean-square error of tropical wind and temperature forecasts



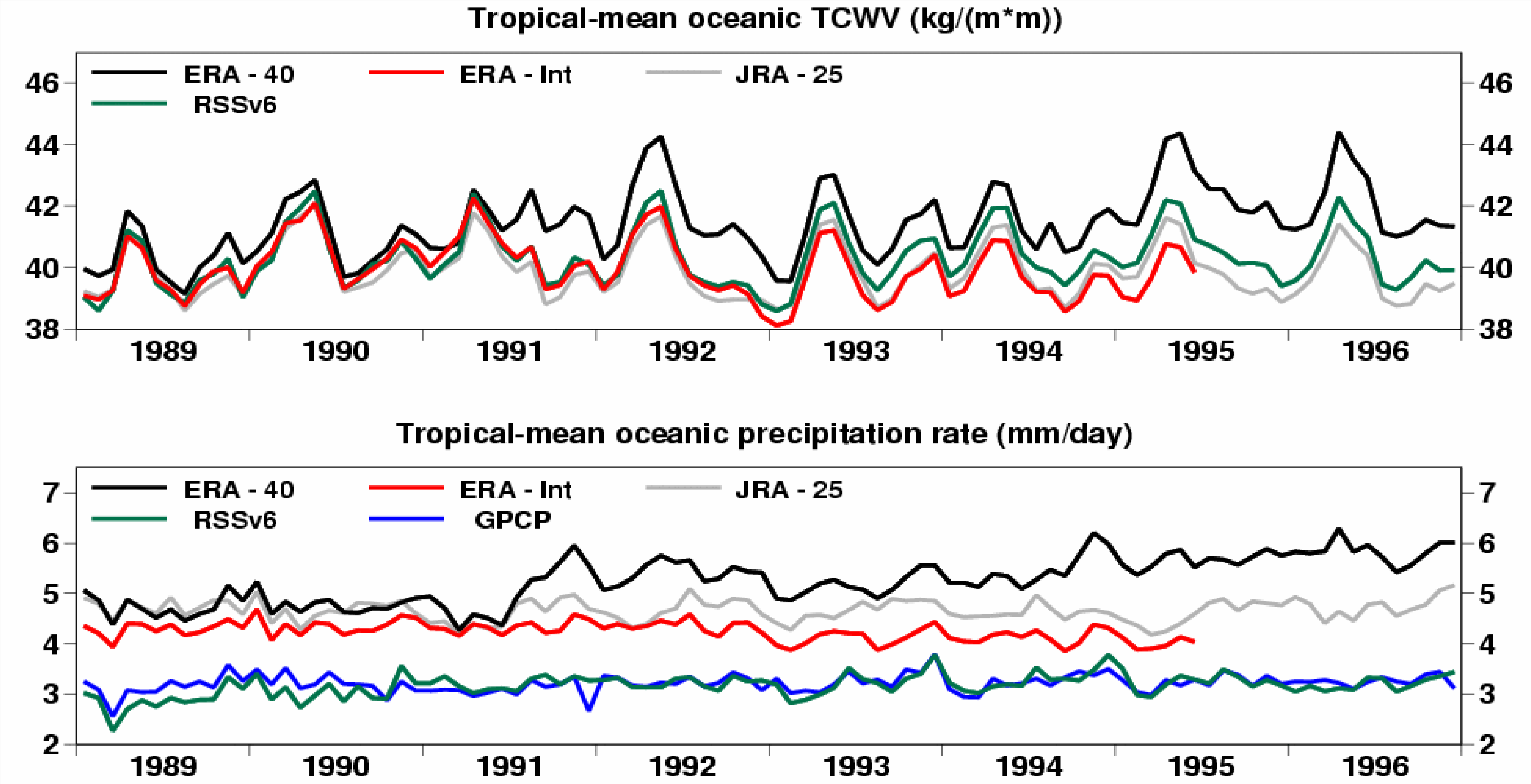
Operations 1989 **ERA-40 1989** **ERA-Interim 1989**

Forecasts from 12UTC, each verified against 00UTC radiosondes

Improvement in global hydrological balance



Improvement in humidity/rainfall over tropical oceans



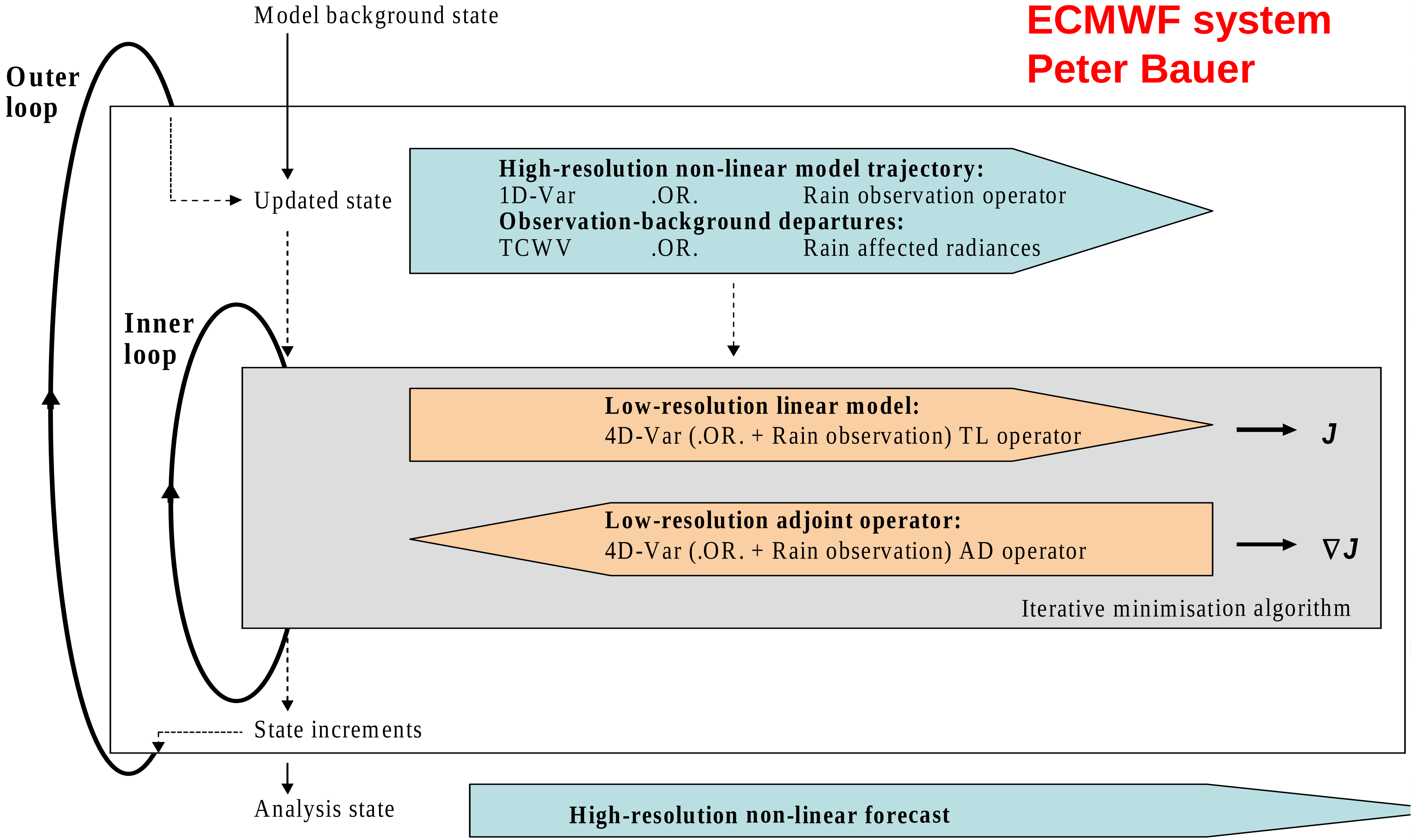
Assimilation of rainfall data

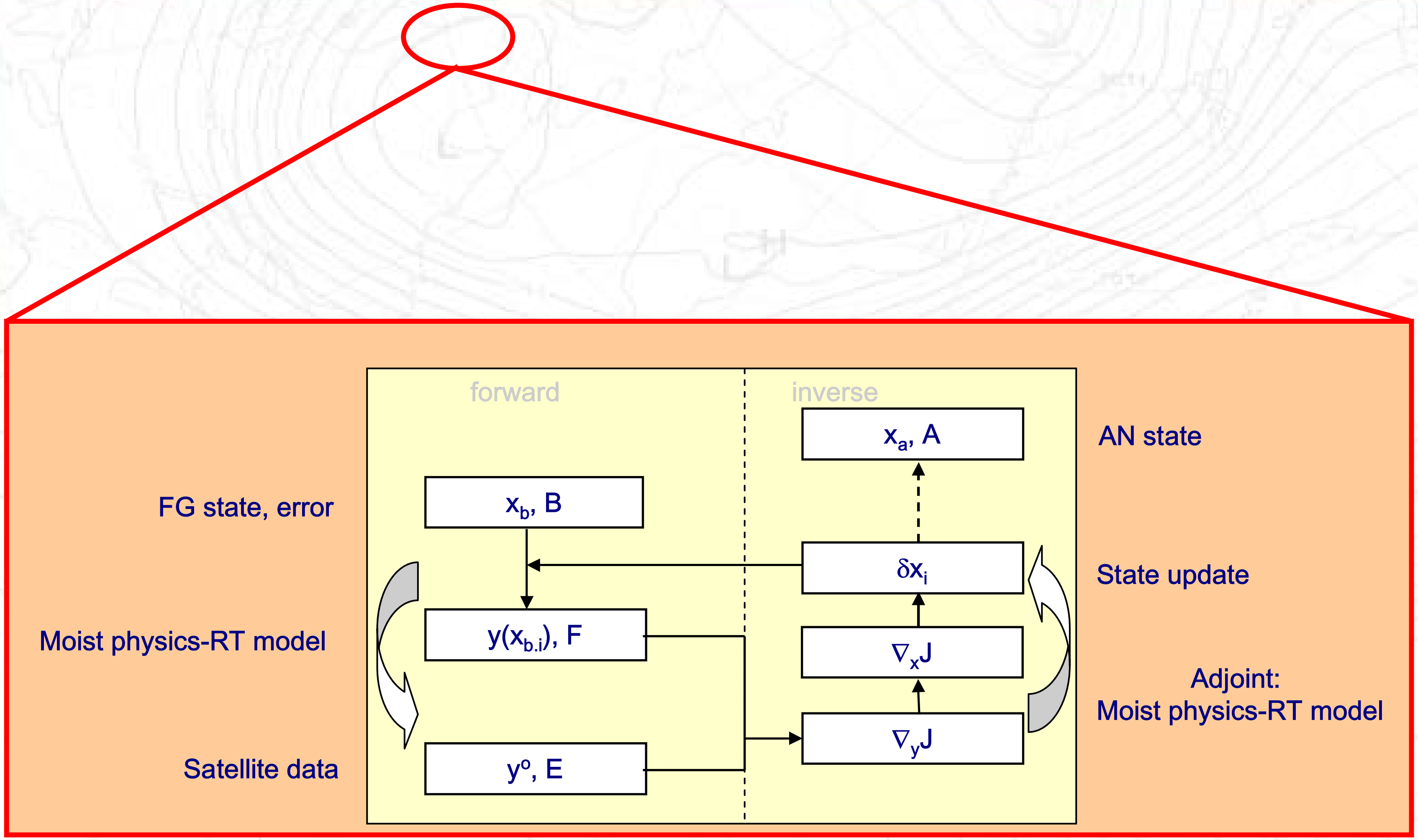
Assimilation of rainfall data

- 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 started (or will soon start) **assimilating rainfall data** - this has potential to provide significant improvements in tropical NWP, and in particular **rainfall prediction**

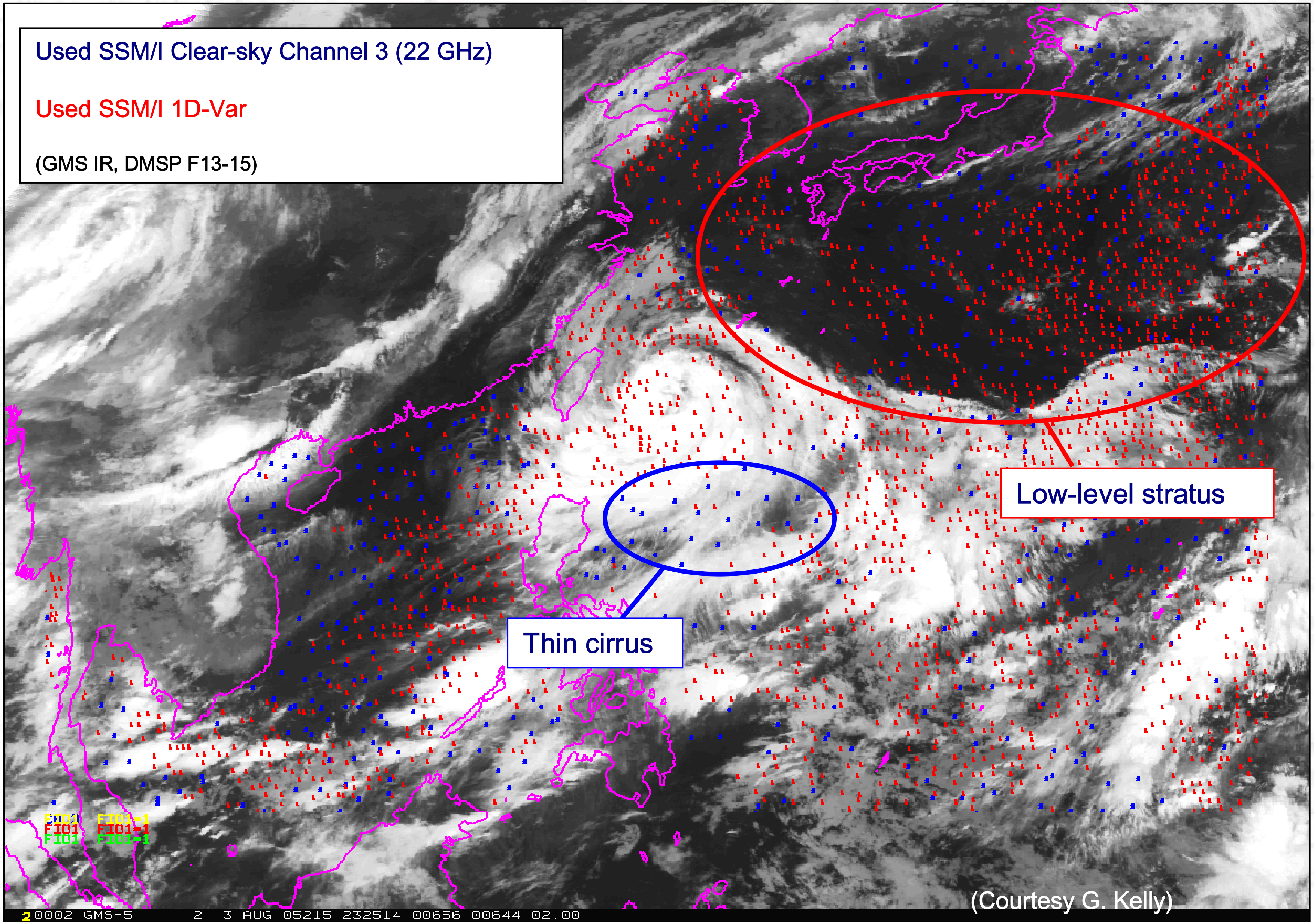
(1D+) 4D-Var Assimilation

ECMWF system
Peter Bauer

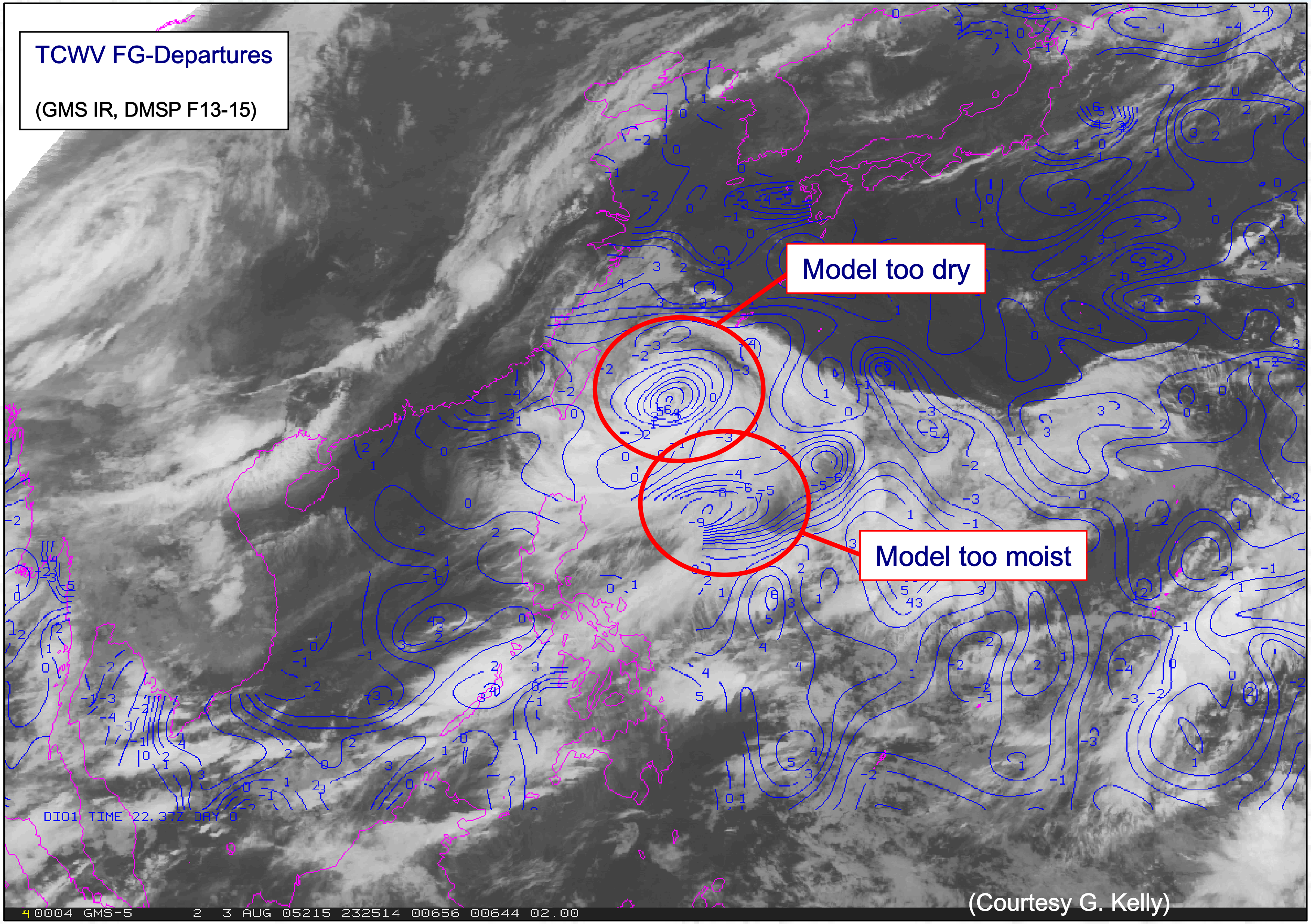



forward
inverse
AN state
x_a, A
FG state, error
x_b, B
δx_i
State update
Moist physics-RT model
$y(x_{b,i})$, F
$\nabla_x J$
Adjoint:
Moist physics-RT model
$\nabla_y J$
Satellite data
y^o, E

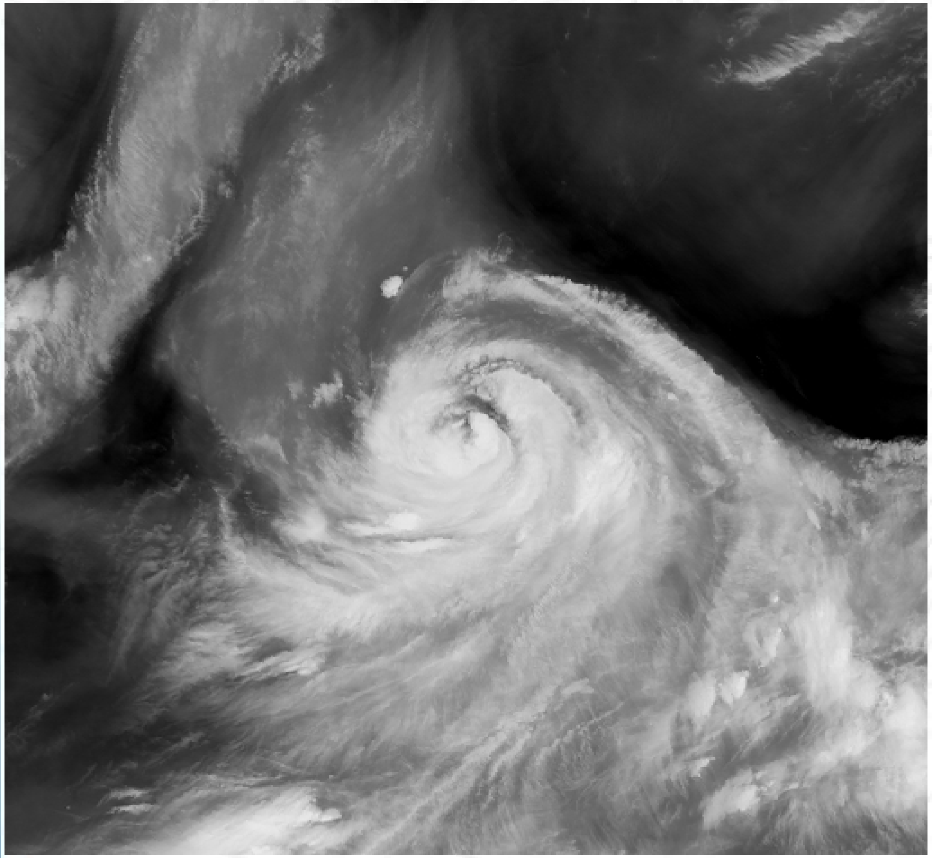
Typhoon *Matsa* (04/08/2005 00 UTC)



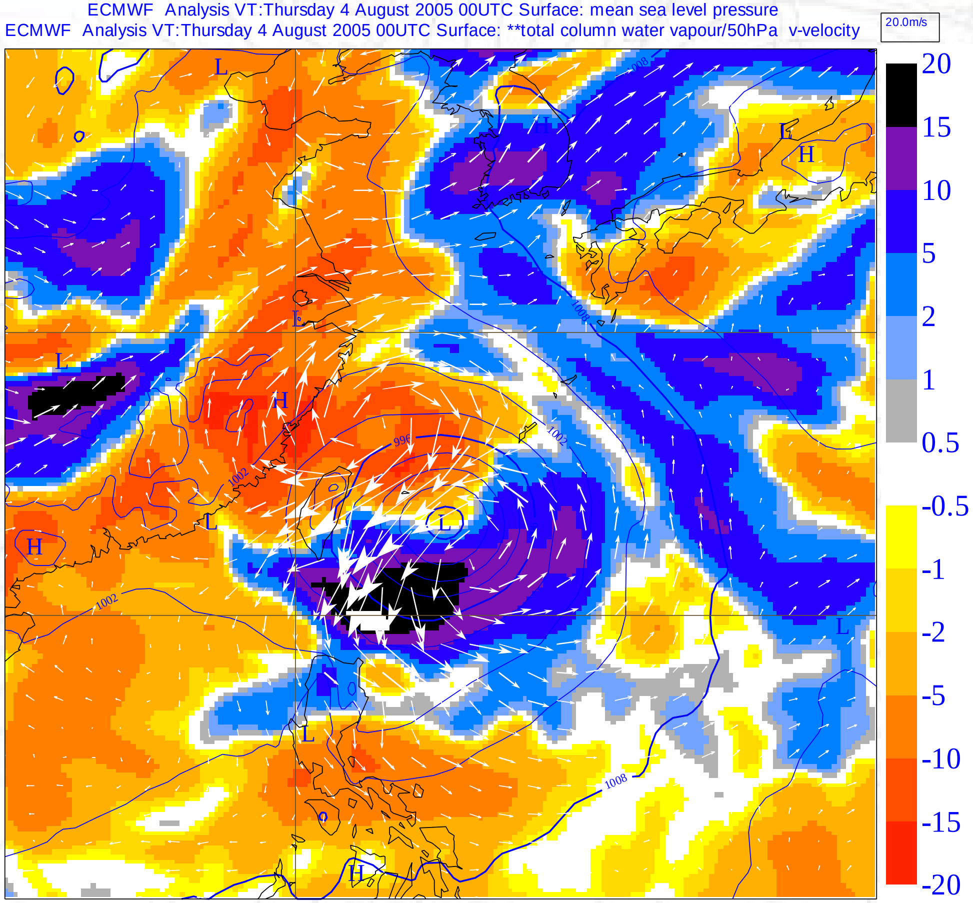
Typhoon *Matsa* (04/08/2005 00 UTC)



Typhoon *Matsa* (04/08/2005 00 UTC)



MTSAT Infrared image of typhoon MATSA approaching Taiwanese and Chinese coast on August 4, 2005, 00 UTC.



4D-Var moisture increments with rain assimilation (colors in %), 900 hPa wind increments (white arrows), surface pressure (isolines).

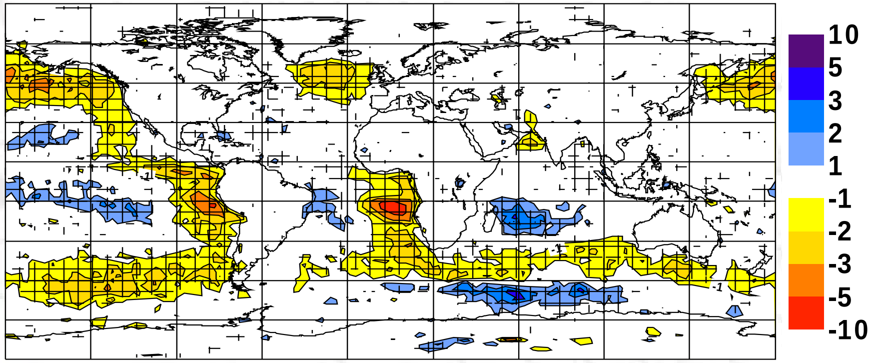
Peter Bauer

Mean TCWV Analysis/Forecast Difference 08-10/2004

Rain – No Rain

Analysis

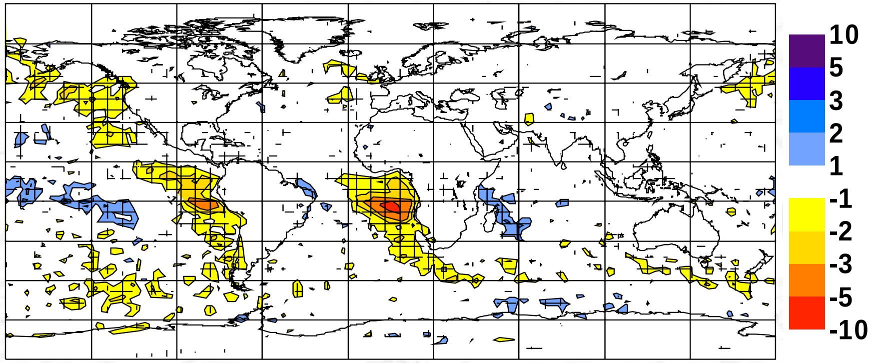
a) Analysis 00 UTC (20040801-20041031)



[kg m^{-2}]

Day 2 (48h)

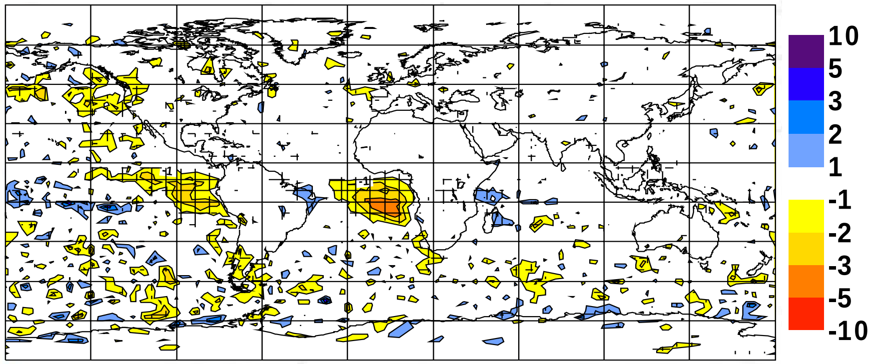
b) Forecast Day +1 (20040801-20041031)



[kg m^{-2}]

Day 3 (72h)

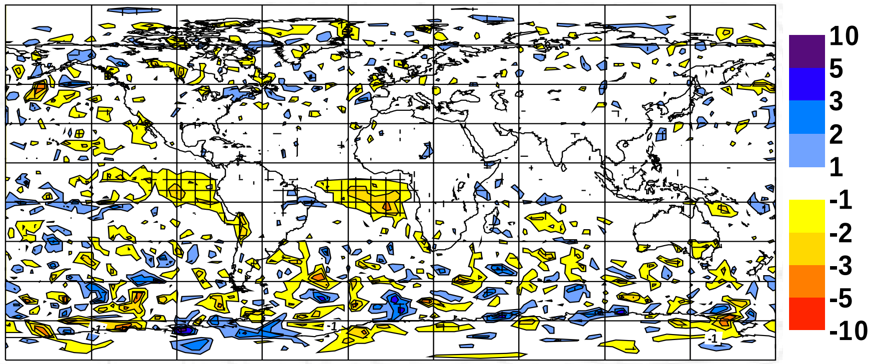
c) Forecast Day +2 (20040801-20041031)



[kg m^{-2}]

Day 5 (120h)

d) Forecast Day +3 (20040801-20041031)



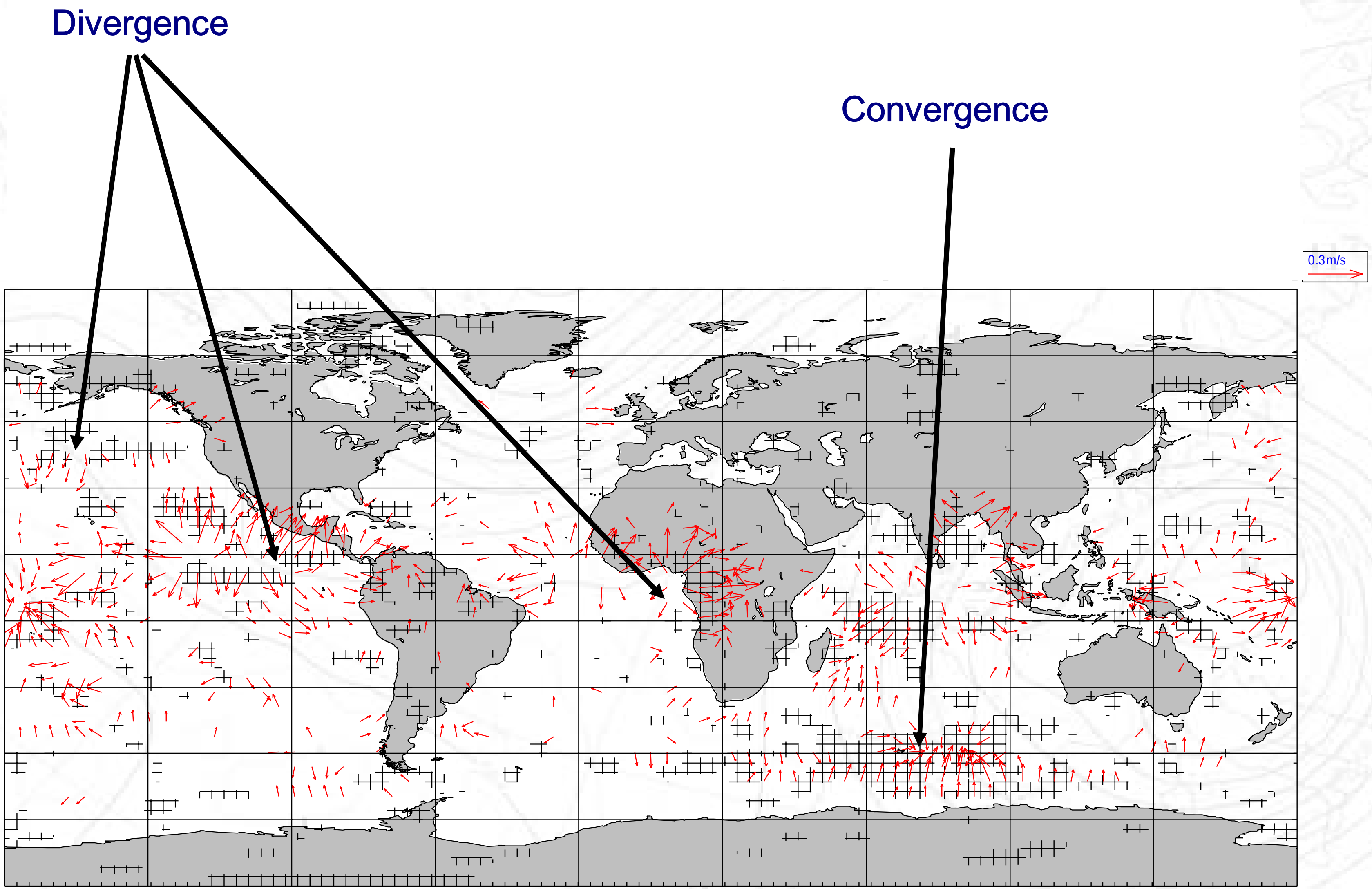
[kg m^{-2}]

(Courtesy T. Jung)

Mean 850 hPa Divergent Wind Analysis Difference 08-10/2004

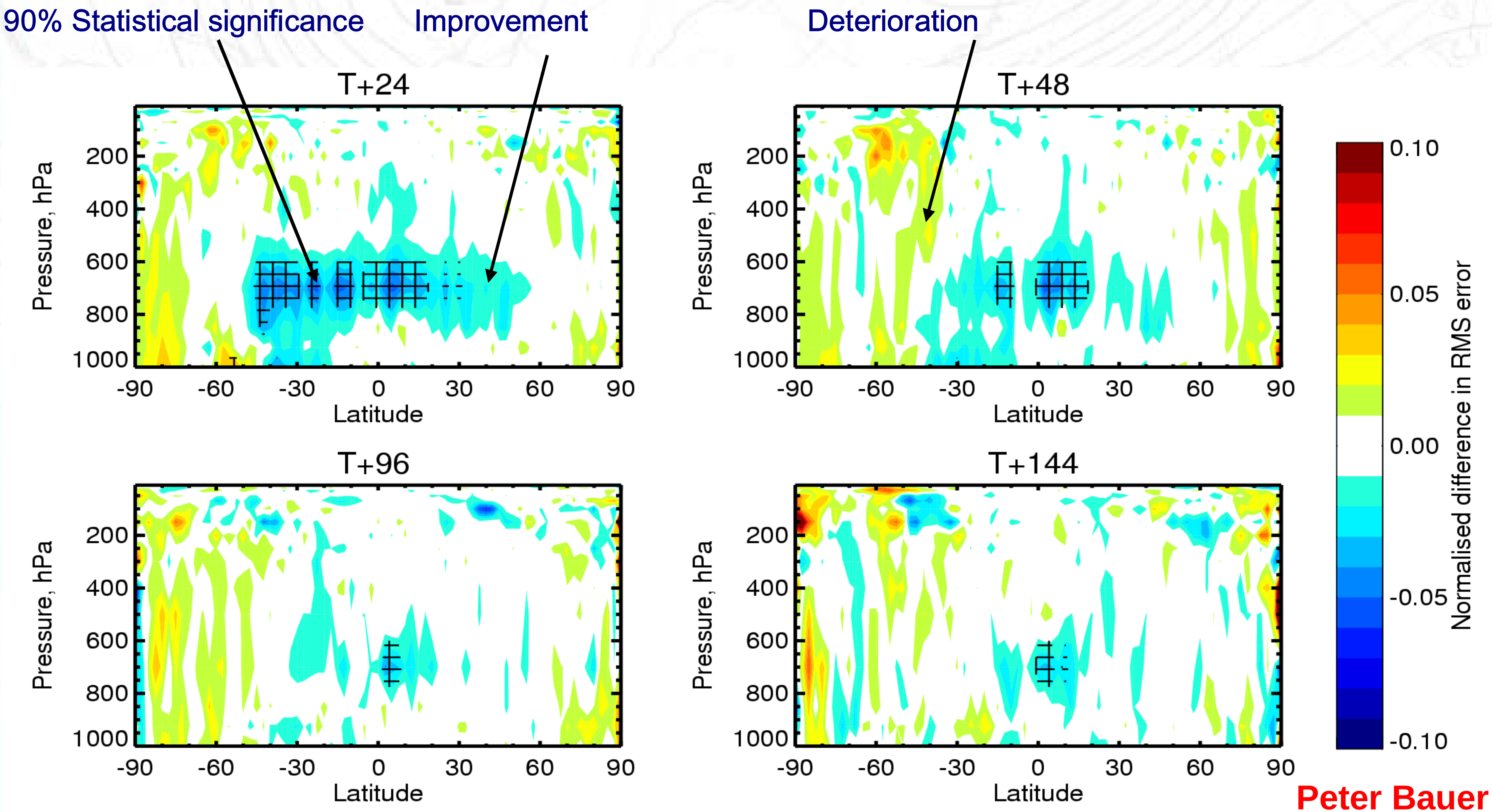
Rain – No Rain

(Courtesy T. Jung)



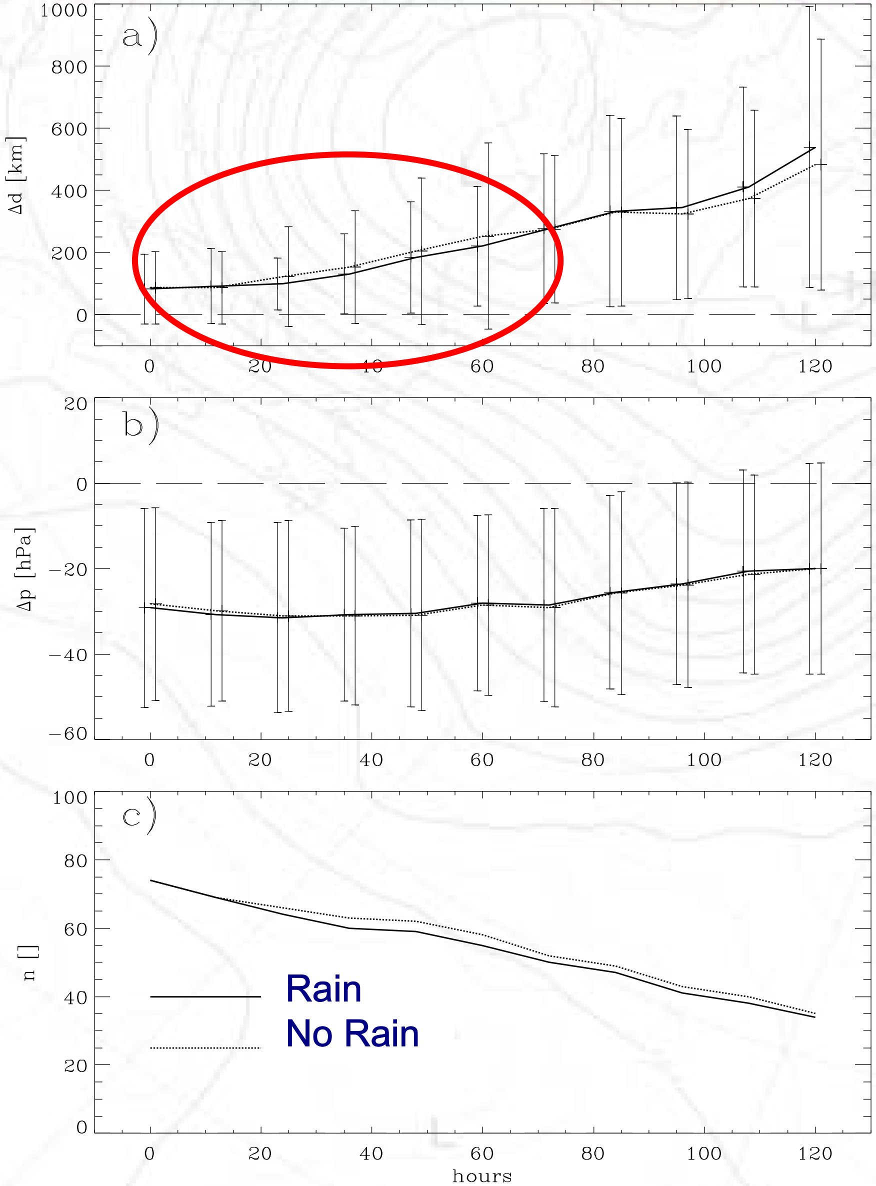
Mean Relative Humidity Forecast Score Difference 08-10/2004

Improvements in RMS forecast errors between “Rain” and “No Rain” experiments



Peter Bauer

Tropical Cyclone Verification: 08-09/2004



Cyclone centre location error [km]

→ reduction in error standard deviation

Cyclone centre pressure error [hPa]

→ neutral

Sample size []

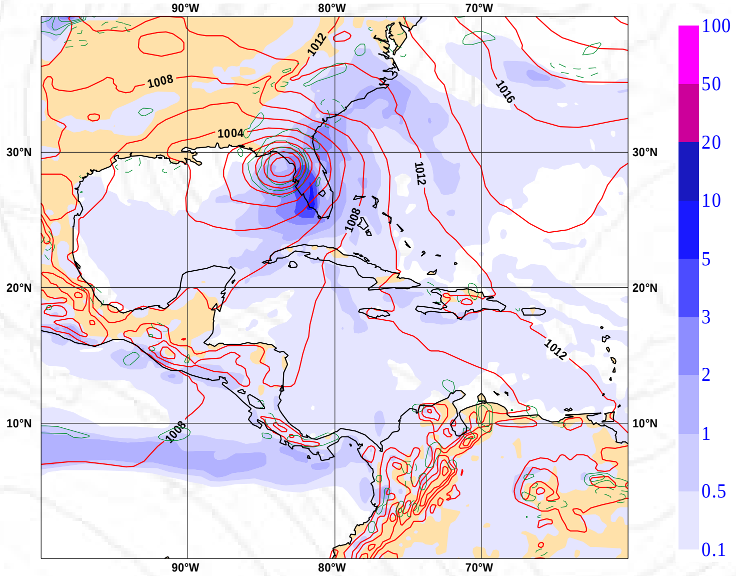
Peter Bauer

TC *Katrina* Forecast 20050825 00 UTC + 96 Hours

35[TH] Session ECMWF Scientific Advisory Committee, 2-4/10/2006
Special topic paper: *Assimilation of cloud- and rain-affected radiances*

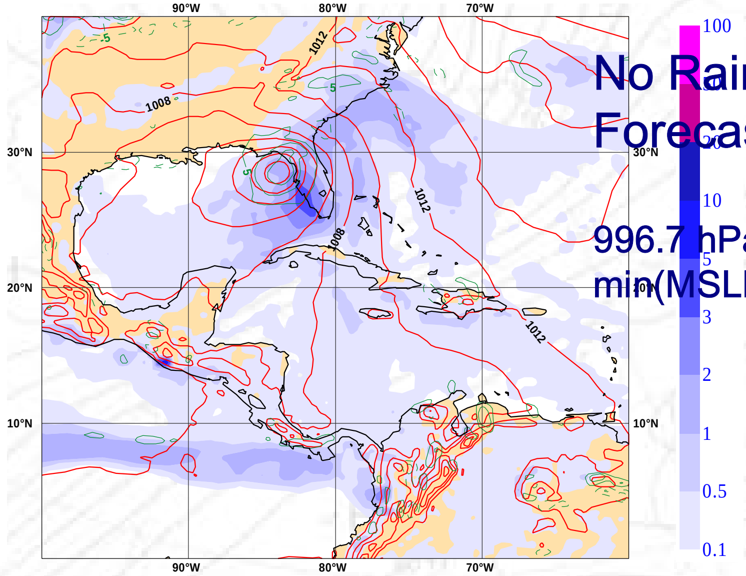
Rain Forecast

992.2 hPa min(MSLP)



No Rain Forecast

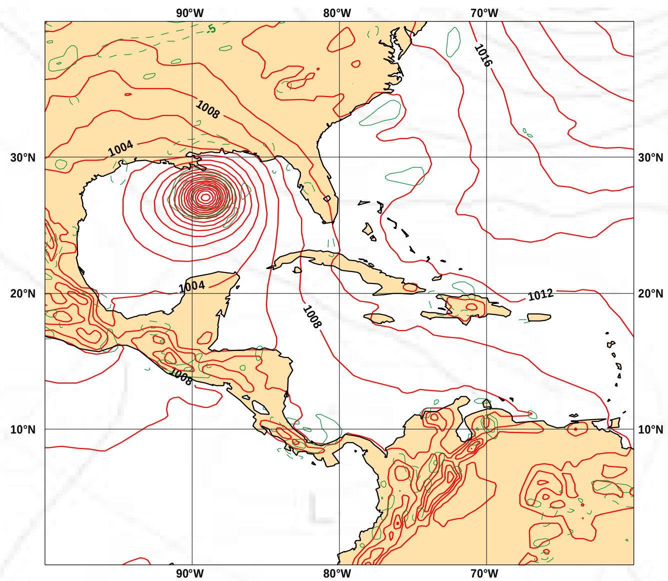
996.7 hPa min(MSLP)

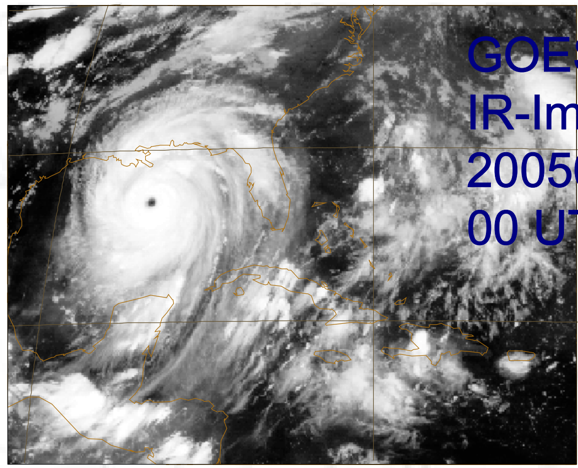


[mm]

Analysis

966.5 hPa min(MSLP)





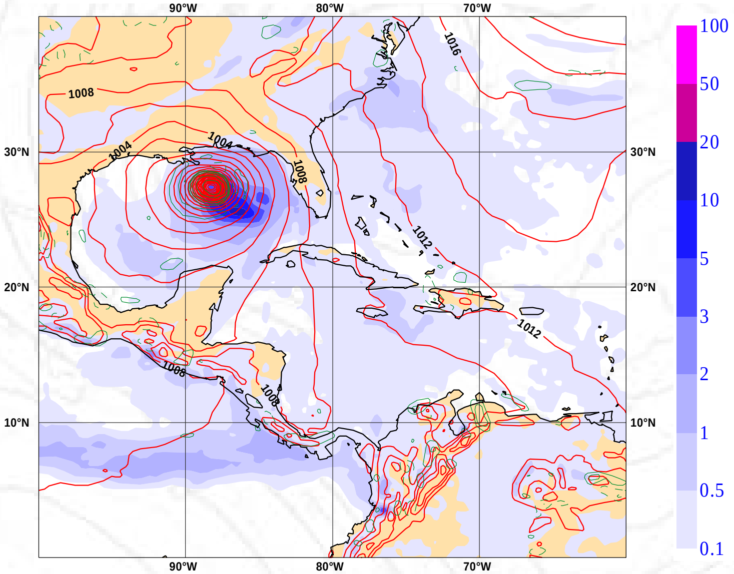
GOES-12 IR-Imagery 20050829 00 UTC

Peter Bauer

TC *Katrina* Forecast 20050826 00 UTC + 72 Hours

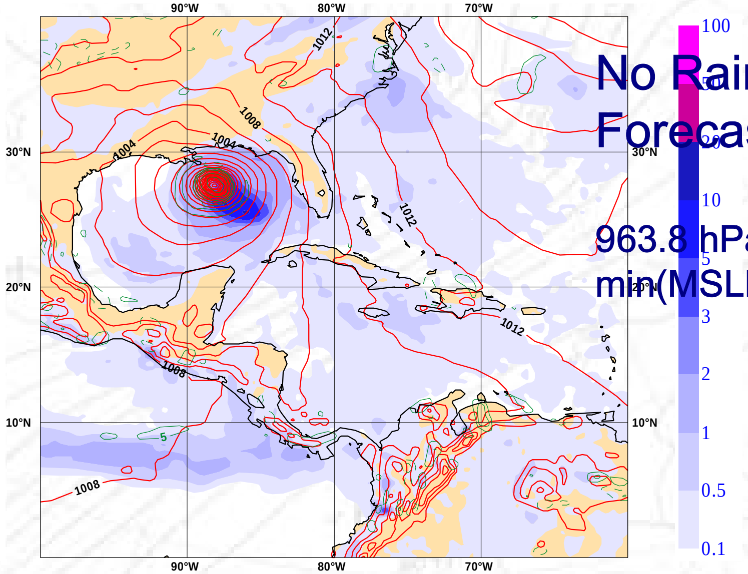
Rain Forecast

962.1 hPa min(MSLP)



No Rain Forecast

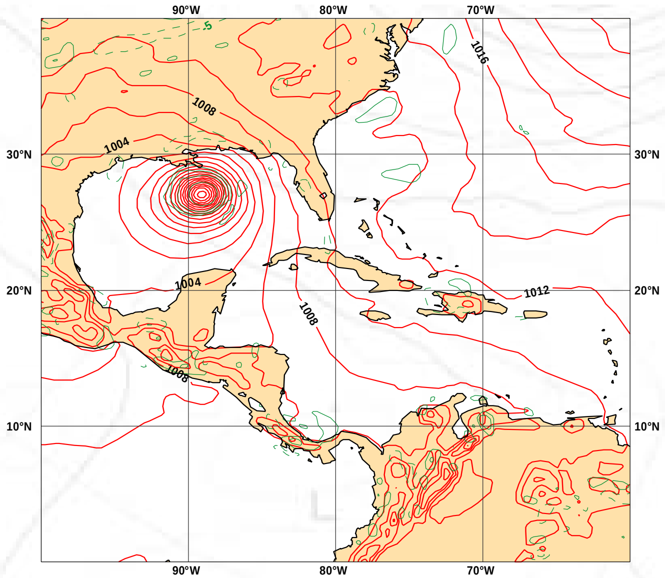
963.8 hPa min(MSLP)

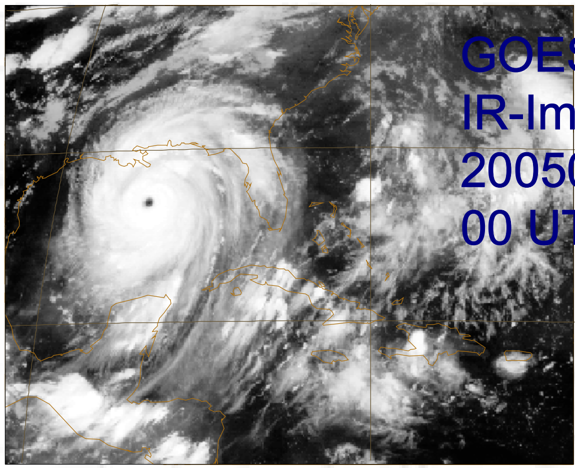


[mm]

Analysis

966.5 hPa min(MSLP)





GOES-12 IR-Imagery 20050829 00 UTC

Peter Bauer

TC *Katrina* Dropsonde Departure Statistics: 20050823-20050830

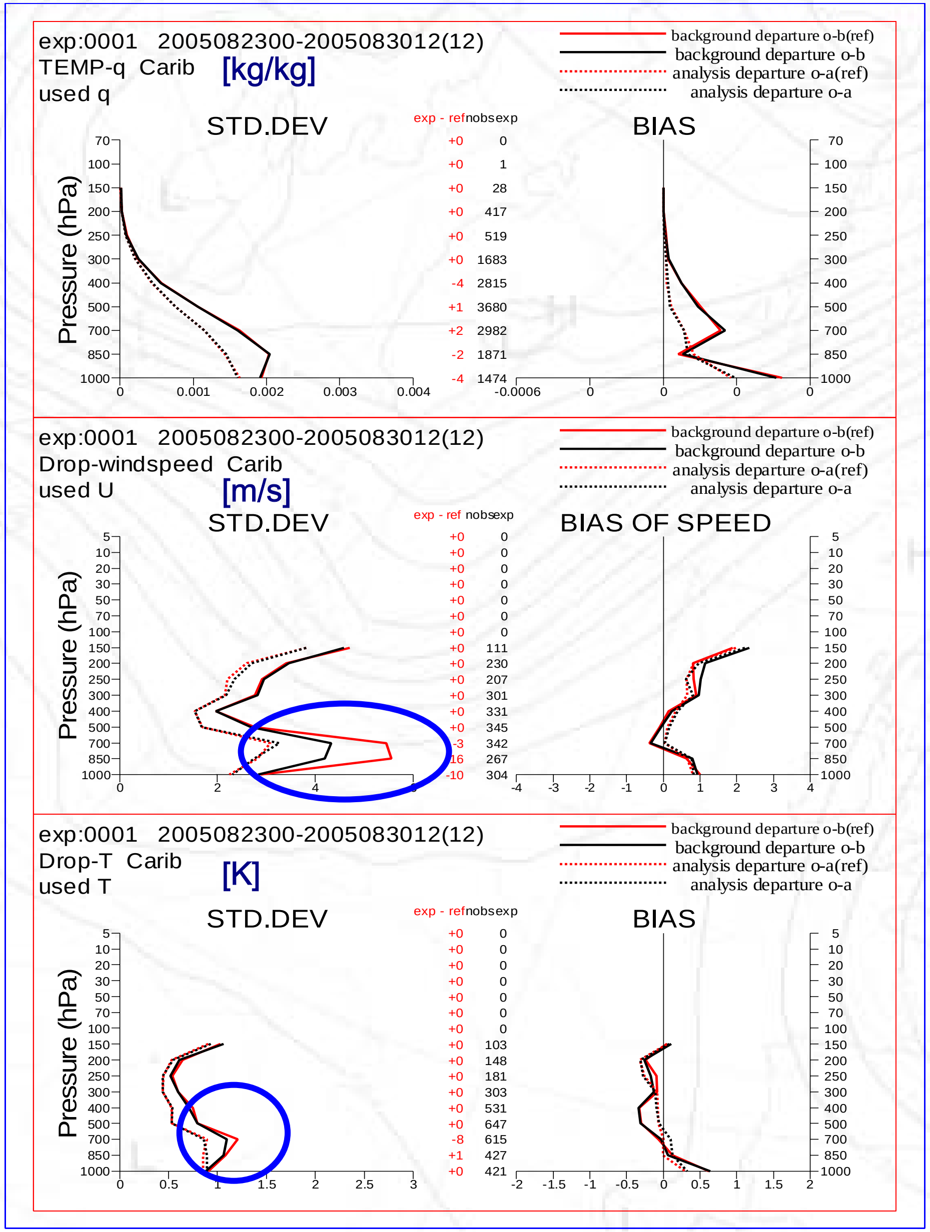
35[TH] Session ECMWF Scientific Advisory Committee, 2-4/10/2006
Special topic paper: *Assimilation of cloud- and rain-affected radiances*

Radiosonde:
Specific humidity

Dropsonde:
Windspeed

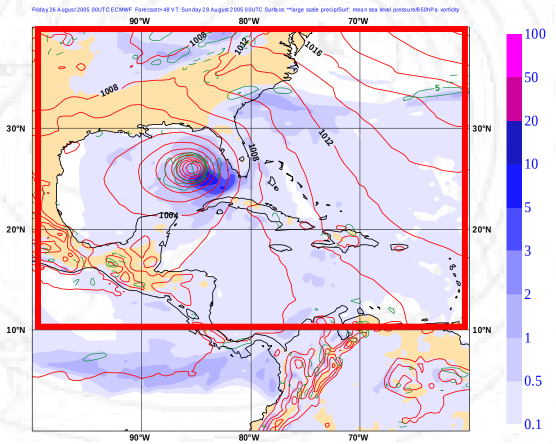
Dropsonde:
Temperature

Peter Bauer



Rain
No Rain

Area:



Assimilation of rainfall data

- It is still early days in the attempts to assimilate rainfall data
- Initial results are encouraging

THORPEX Interactive Grand Global Ensemble (TIGGE) - current status

http://tigge.ecmwf.int/

Australian Government
Bureau of Meteorology

E. Ebert

TIGGE

THORPEX

THORPEX is a WMO/WWRP programme aimed at accelerating improvements in the accuracy of one-day to two weeks high-impact weather forecasts for the benefit of society and economy

TIGGE Objectives

- TIGGE is a multi-model, multi-analysis and multinational ensemble prediction system,
- Assemble and archive ensemble analyses and forecasts from operational Centres so that they are readily available to facilitate research on the design of best configuration of multi-model/multi-analysis ensemble forecast system,
- TIGGE prototype forecast systems, resulting from this research, would be used to produce experimental real-time forecasts.

TIGGE Objectives

- Enhanced international collaboration on ensemble prediction,
- New methods of calibrating and combining ensembles,
- Deeper understanding of the contribution of observation, initial and model uncertainties to forecast error,
- Test feasibility of interactive ensemble system responding dynamically to changing uncertainty (including use for adaptive observing, variable ensemble size, on-demand regional ensembles),
- Exploit new technology for grid computing and high-speed data transfer,
- TIGGE Prediction Centre(s) to produce ensemble-based predictions of high-impact weather, wherever it occurs, on all predictable time ranges,
- Prototype Global Interactive Forecasting System.

TIGGE plan

- Phase 1 – development of ensemble database to facilitate research, central archives at ECMWF, NCAR, CMA — 2005
- Phase 2 –distributed data system offering fast real time access using unified software — 2010
- GIFS – Global Interactive Forecast System available to anyone in real time, incorporates THORPEX benefits — 2012

Phase 1 – data providers

Status as of May 2007:

- **ECMWF**: nominal except 3 missing fields
- **UKMO**: nominal except 3 missing fields
- **JMA**: nominal except 10 missing fields, will move from http to LDM soon
- **NCEP**: all specific humidity fields missing plus some single level fields missing, but this should be solved by Sept 2007 (subject to funding)
- **CMA**: nominal except n missing fields
- **KMA**: on-going transmission tests
- **Canada**: on-going transmission tests, production expected mid-June for the essential data and all fields by end 2007
- **BMRC**: undergoing transmission tests
- **Meteo-France**: transmission tests should start in May
- **CPTEC**: on-going work on GRIB2, transmission tests with LDM

Phase 1 – ensemble data

Surface fields

Mean sea level pressure
Surface pressure
10m U-velocity
10m V-velocity
Surface air temperature
Surface air dewpoint temperature
Surface air max temperature
Surface air min temperature
Total precipitation (liquid+frozen)
Snow fall
Snow depth
Total cloud cover
Total column water
Surface latent heat flux
Surface sensible heat flux
Surface solar radiation
Surface thermal radiation
Sunshine duration
CAPE
Soil moisture
Soil temperature
Skin temperature
Outgoing LW radiation
Convective inhibition
Orography
Land-sea mask

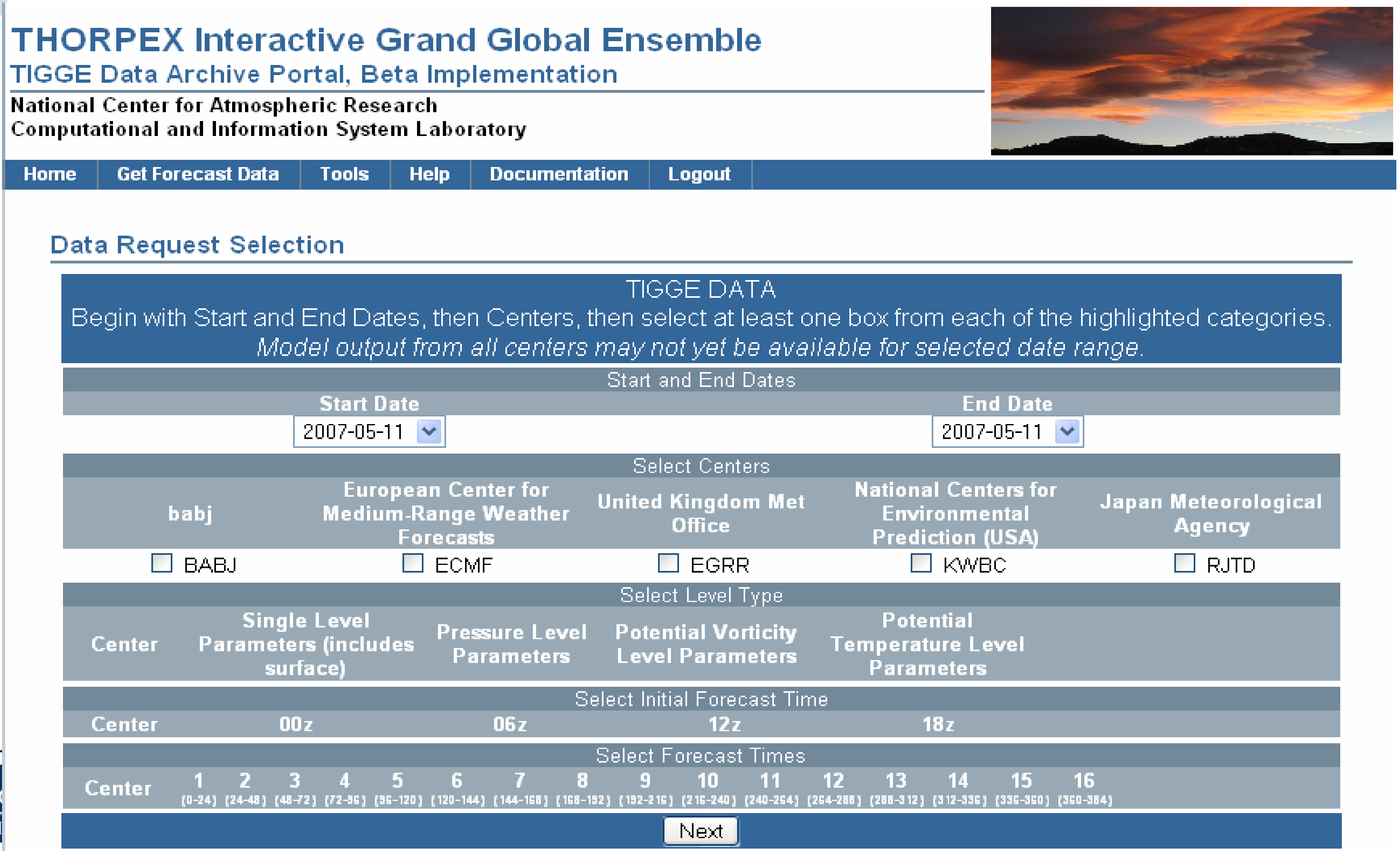
Upper fields - 1000, 925, 850, 700, 500, 300, 250, 200 hPa

Temperature
Geopotential
U-velocity
V-velocity
Specific humidity

Potential vorticity at theta=320K
Potential temperature at PV=2 PVU
U-velocity at PV=2 PVU
V-velocity at PV=2 PVU

TIGGE data portals

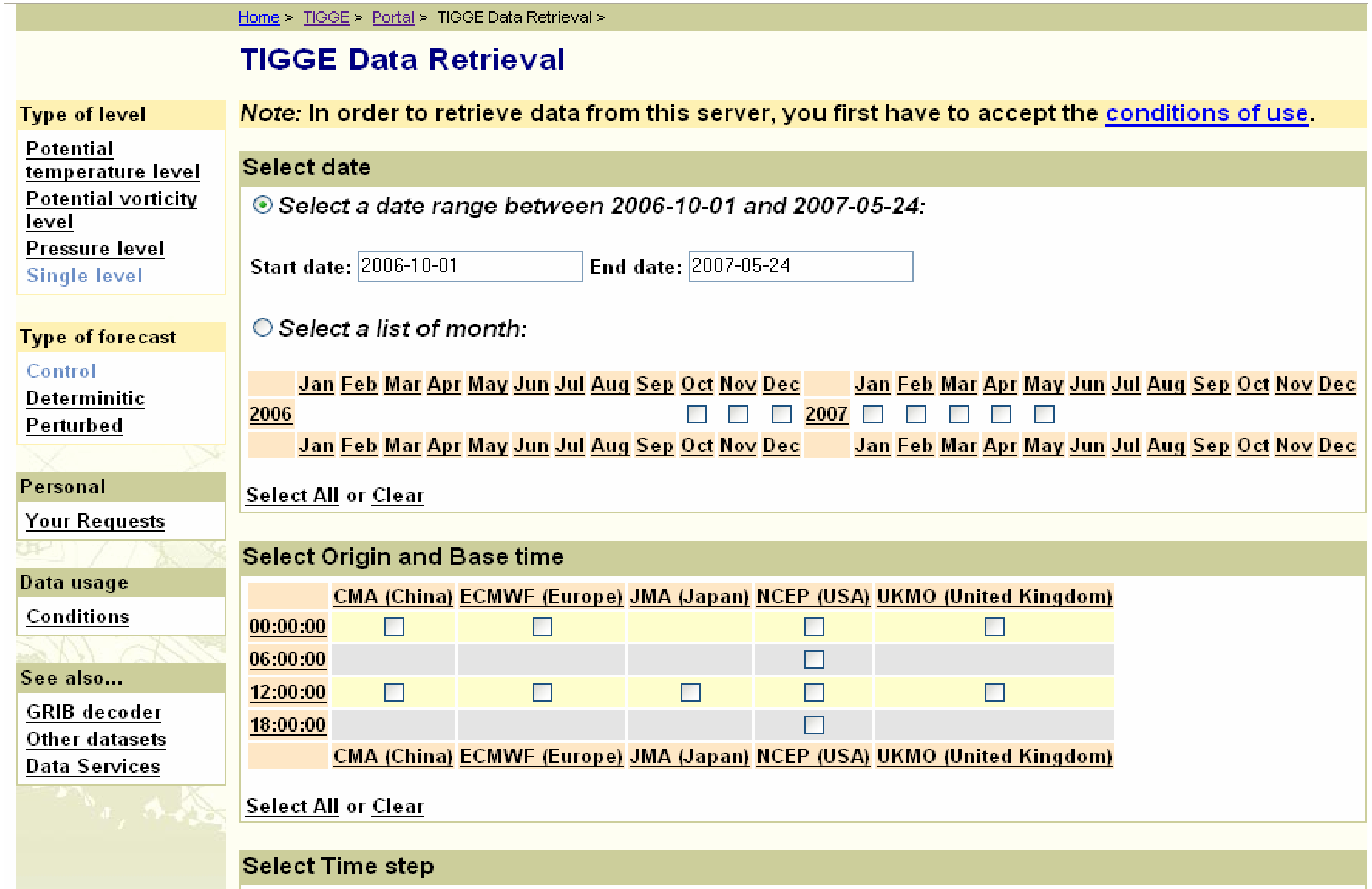
NCAR



Australian Government
Bureau of Meteorology

TIGGE data portals

ECMWF



TIGGE activities

- Limited area modeling (LAM)
- Verification system development
- Support for Beijing 2008 RDP and other demonstration projects (T-Parc, E-TREC, 2010 Olympics, SWFDP in SE Africa)
- Planning for Phase 2 (distributed data with fast real-time access) and GIFS
- User workshop in 2008

TIGGE – limitations for application to the tropics

As noted in lecture 2:

- Most operational global ensemble systems have been designed for the extra-tropics
- Therefore use of TIGGE data for tropical applications will have serious limitations

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

Concluding Remarks 1

- There has been progress in tropical NWP – both global and regional, deterministic and probabilistic, e.g. severe weather such as TCs
- Still major problems with precipitation
- Still major problems with the diurnal cycle
- Still major problems with MJO, monsoons

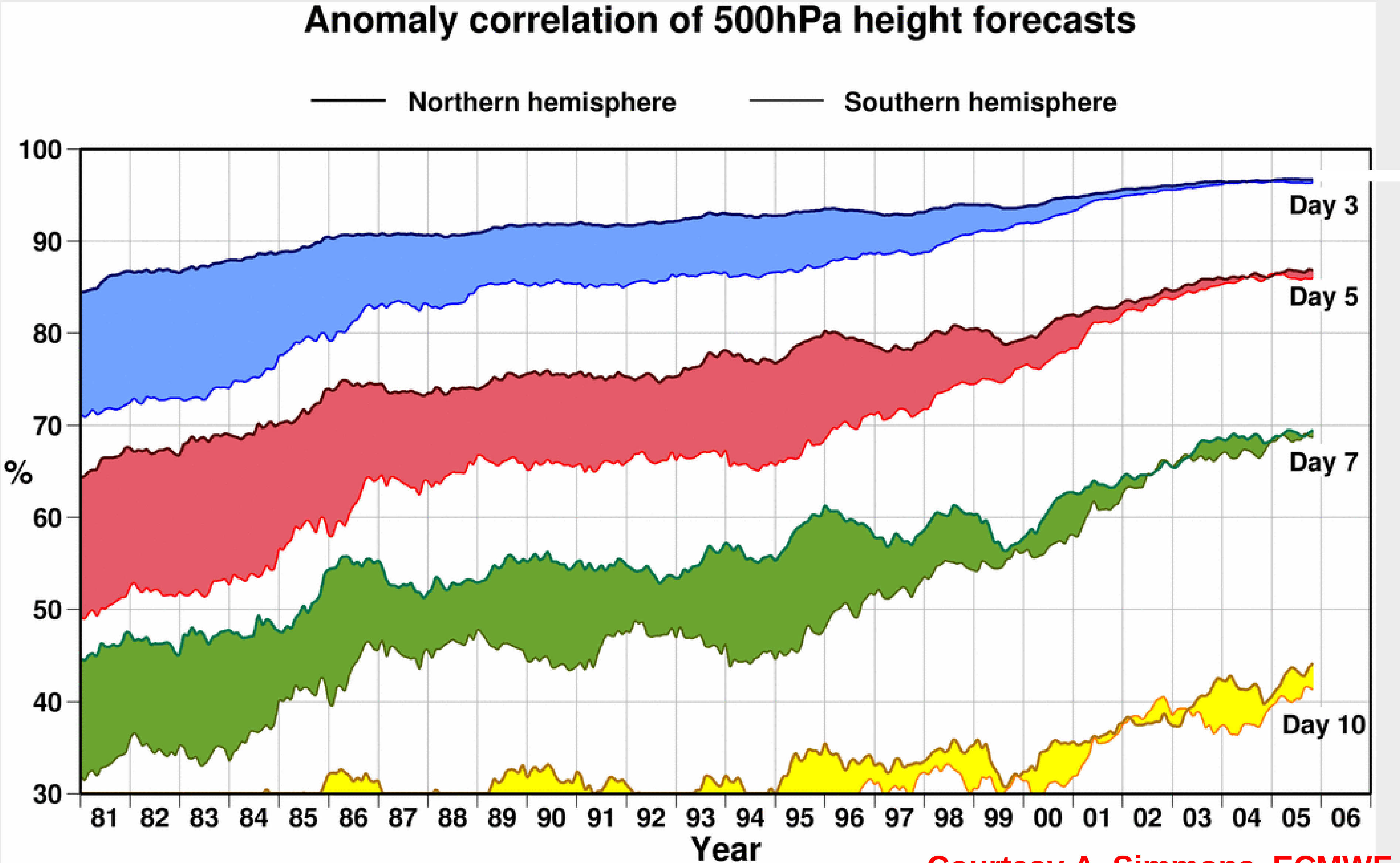
Concluding Remarks 1

- Opportunities from new satellite observations (YOTC)
- Improved assimilation schemes; assimilation of rainfall data
- Resolution challenges for parametrizations – important for tropics
- Verification challenges of very high resolution models

Predictability of the Tropical Atmosphere (Shukla, 1981)??

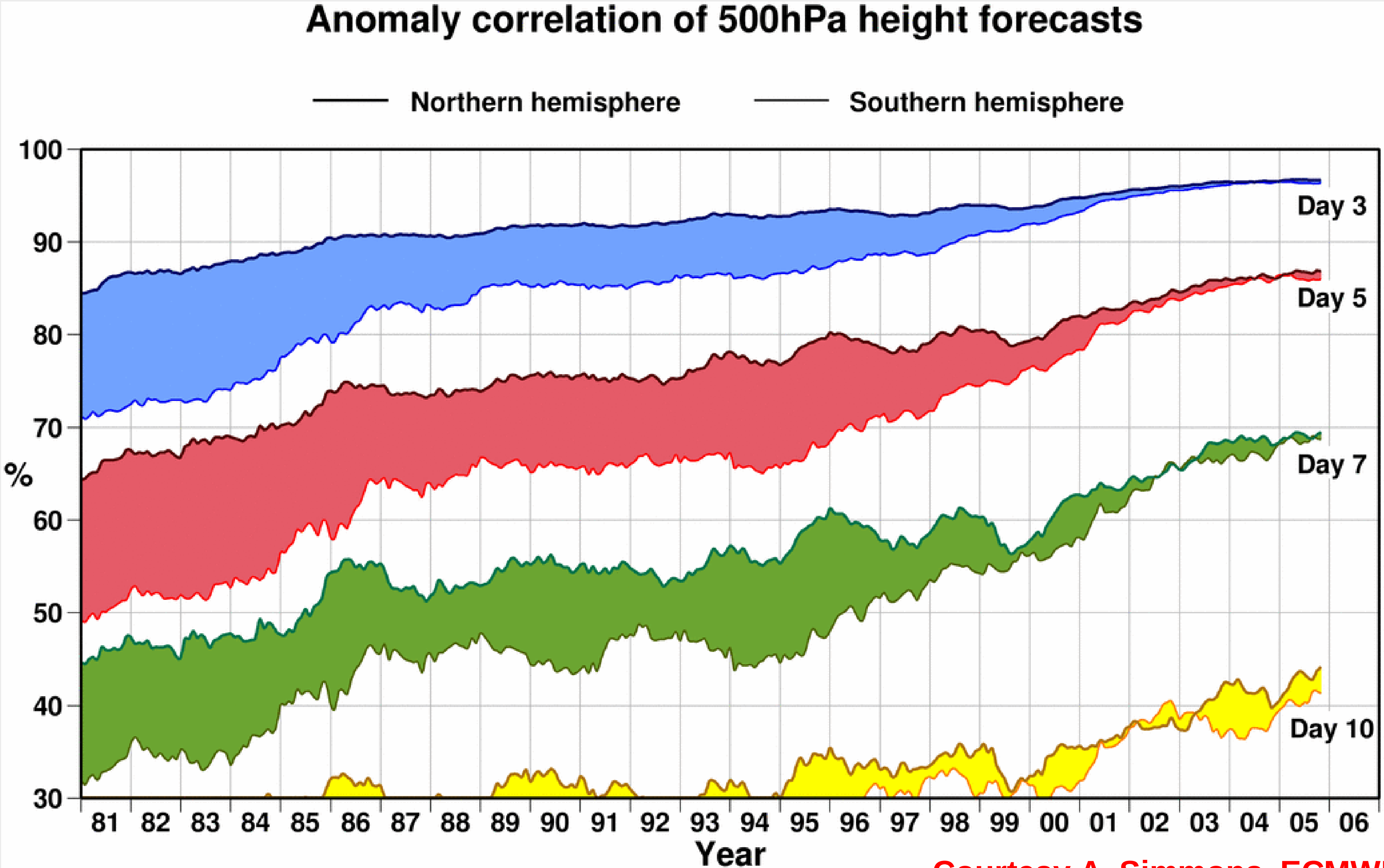
There is clearly cause for some optimism based on:

- Progress has been made in the last few years
- New developments
  - model improvements (resolution and parametrisations)
  - new sources of data particularly satellite data
  - improved methods of assimilating data
  - field experiments will aid parametrisation improvements



Courtesy A. Simmons, ECMWF

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



Courtesy A. Simmons, ECMWF