What's new at ECMWF that is relevant to CMMAP

Martin Miller

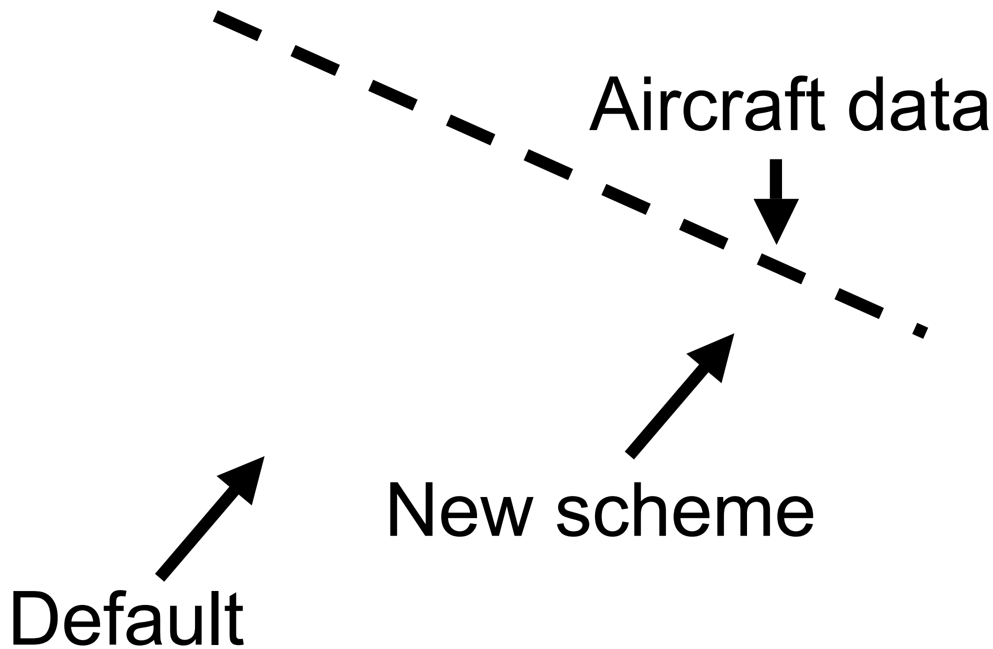
- Parametrization developments including McRad, boundary layer clouds, convection and tropical variability
- The MJO (in monthly forecasting)
- Resolution issues
- ERA-Interim (a new reanalysis)
- Systematic Errors Workshop

(material provided by several colleagues at ECMWF)

Recent or planned changes to the ECMWF physical parametrizations

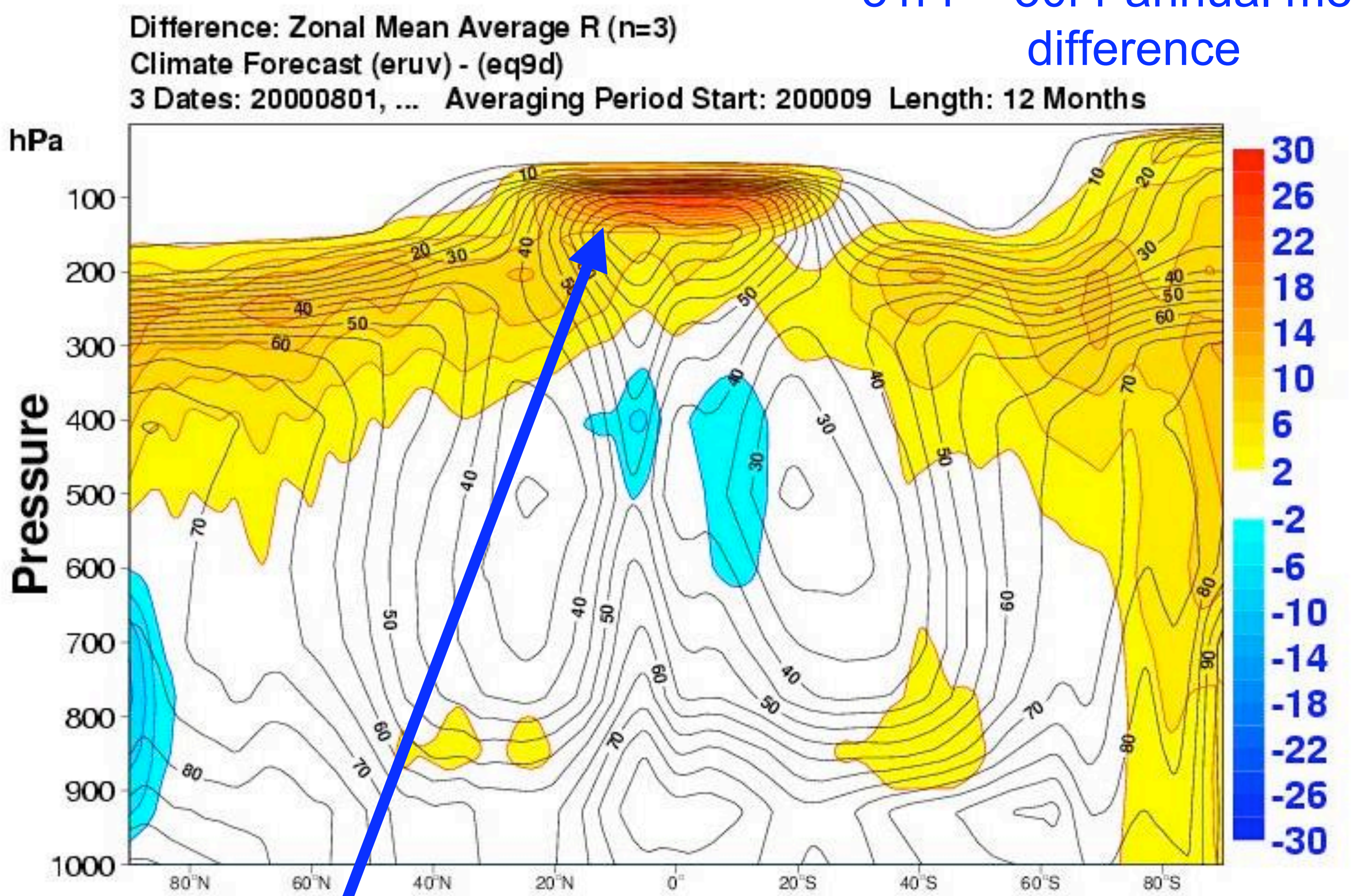
- Improved treatment of ice sedimentation, auto-conversion to snow in cloud scheme and super-saturation with respect to ice
- RRTM-SW + McICA
- MODIS albedo + revised cloud optical properties
- New formulation of convective entrainment
- Variable relaxation timescale for closure
- Reduction in background free atmosphere vertical diffusion

Simple ECMWF scheme: comparison to Mozaic aircraft data (from Gierens et al.)



Impact on relative humidity (RH) climatology

31r1 – 30r1 annual mean difference

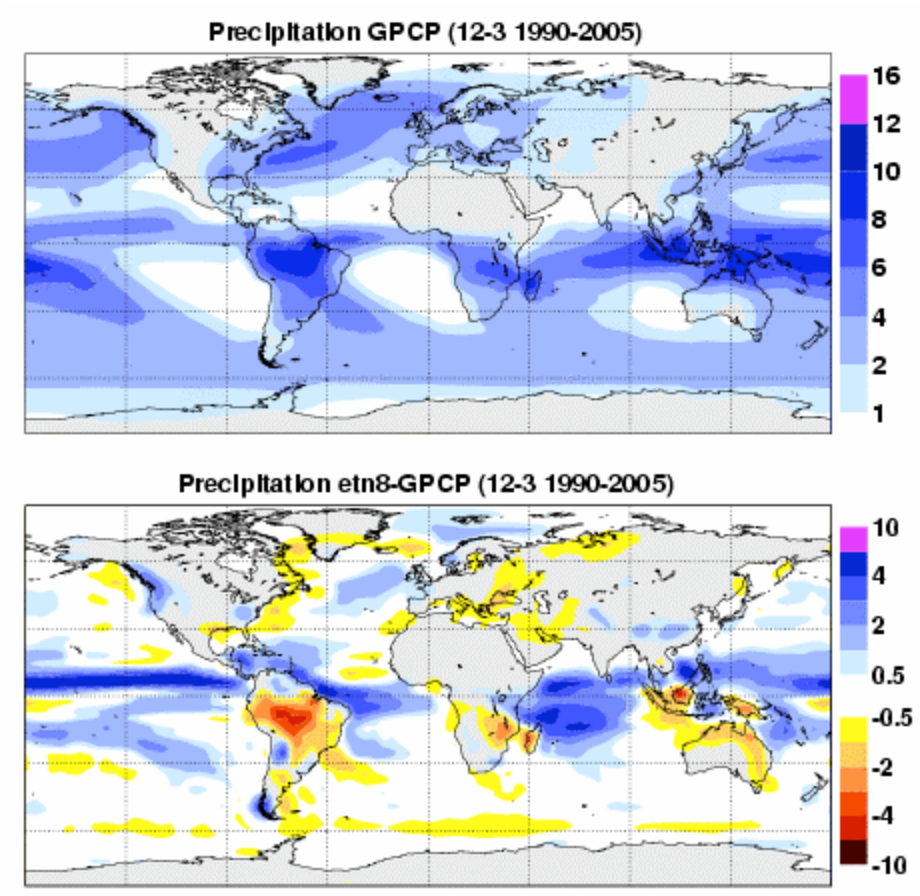


Largest changes in the tropical upper troposphere

Forecast Biases

Precipitation for DJF against GPCP for different cycles: from 15 years of 5 month integrations for 1990-2005.

CY31R1 Sep 2006

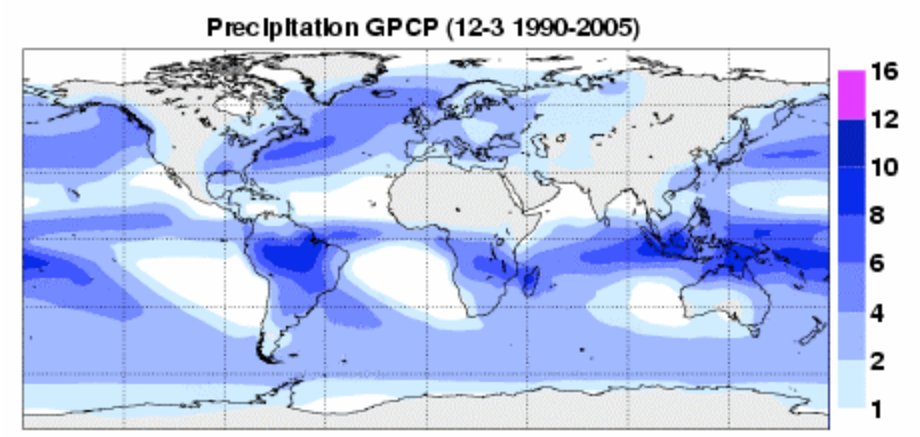


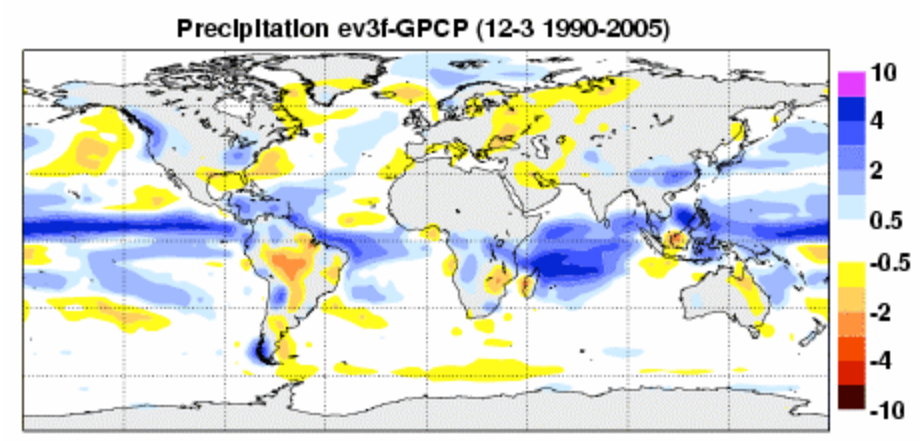
CTRL - GPCP

Forecast Biases

Precipitation for DJF against GPCP for different cycles: from 15 years of 5 month integrations for 1990-2005.

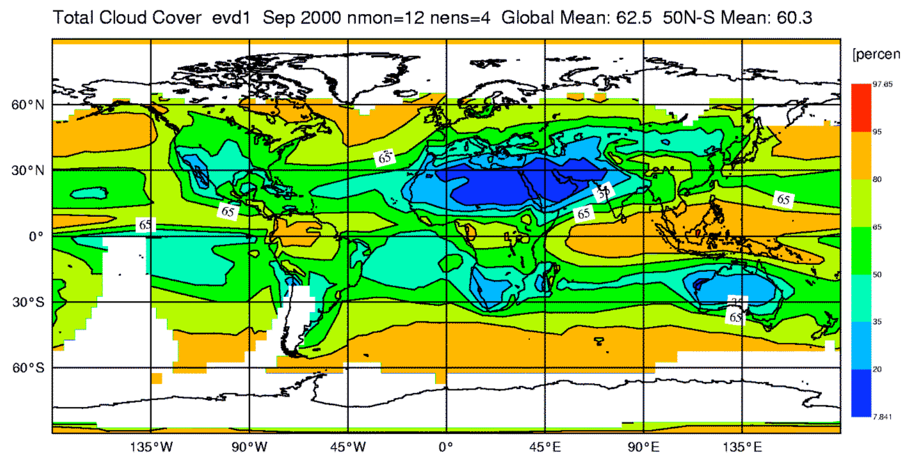
CY32R2 June 2007



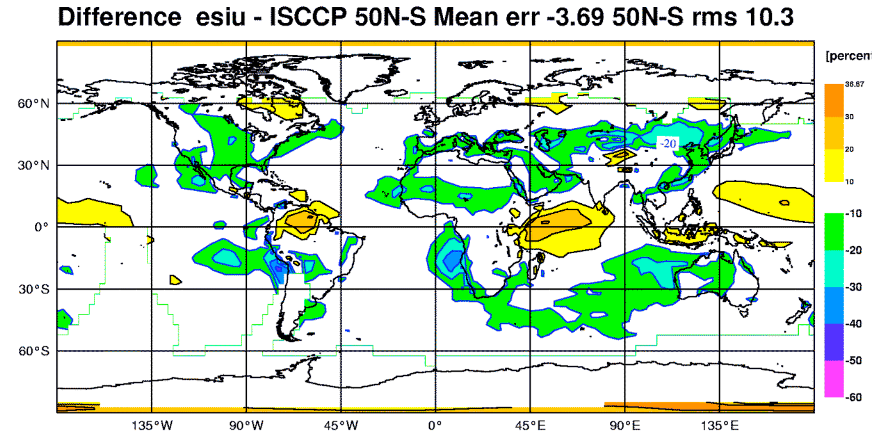


Cloud cover against ISCCP D2

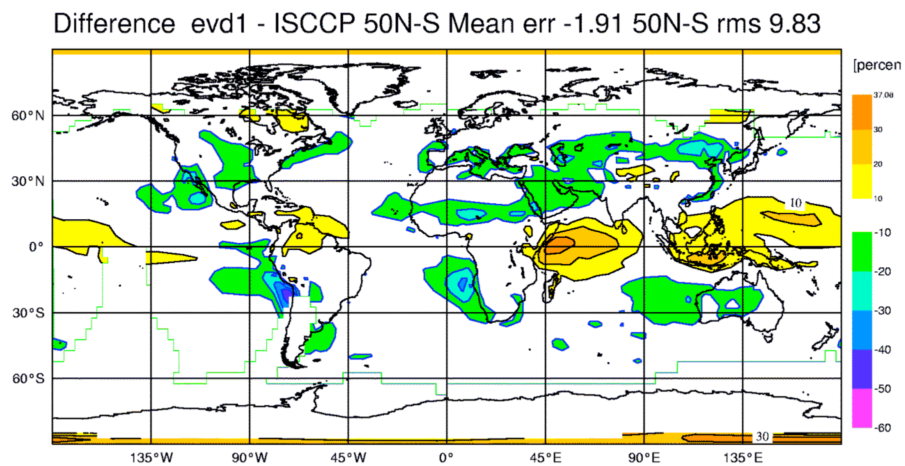
ISCCP obs



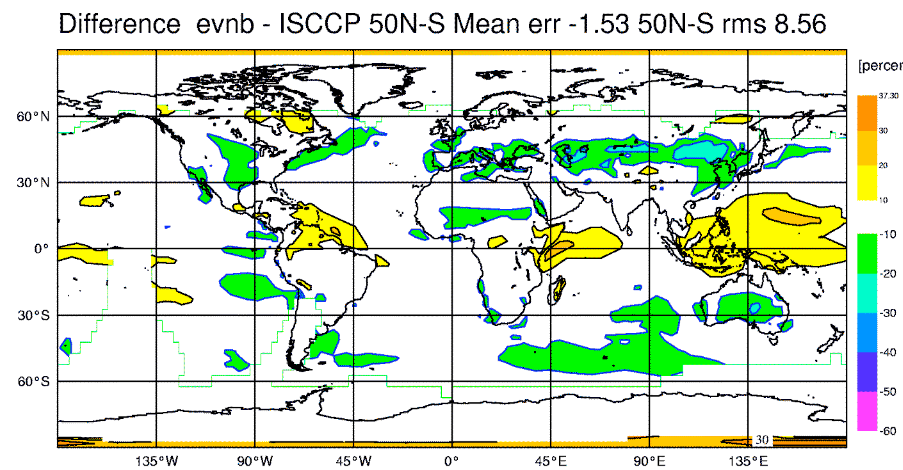
CY31R1 - obs



CY32R2 - obs



CY32R3 - obs

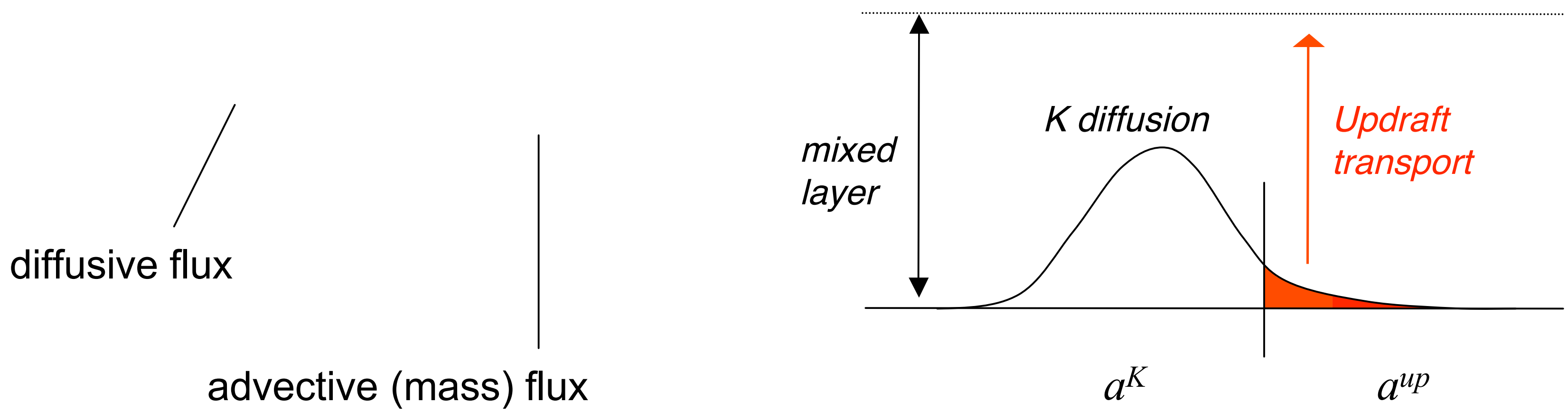


Enhancing model complexity

I. The Eddy Diffusivity Mass Flux (EDMF) framework

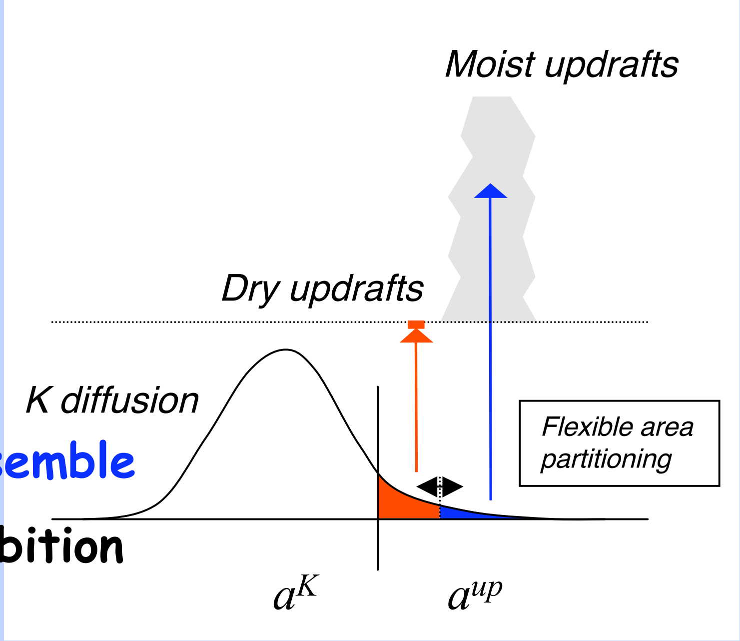
For turbulent transport in well-mixed layers

Siebesma et al. (JAS, 2007)



EDMF already represents dry and stratocumulus convection in the current operational ECMWF forecast model

II. A proposed set of modifications



Enables EDMF to also represent shallow cumulus

(replacing the current shallow cumulus scheme)

* increased number of resolved updrafts
* flexible area partitioning of the updraft ensemble
  -> determined by moist convective inhibition
* flexible updraft entrainment

* flexible vertical structure of cumulus mass flux
* top-entrainment efficiency closure at shallow cumulus inversion
  Wyant et al. (JAS, 1997)
* a bimodal statistical cloud scheme within the PBL

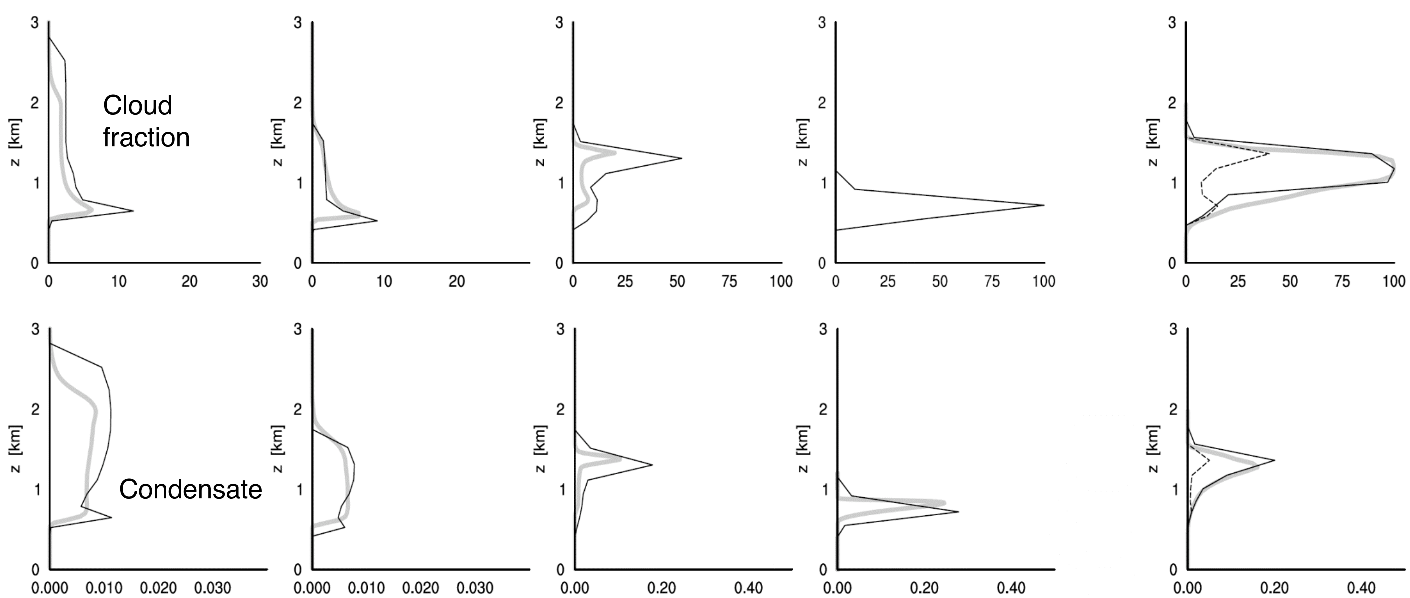
SCM
LES

Evaluation for as many prototype LES/CRM cases as possible

θ_l

q_{sat}

q_t



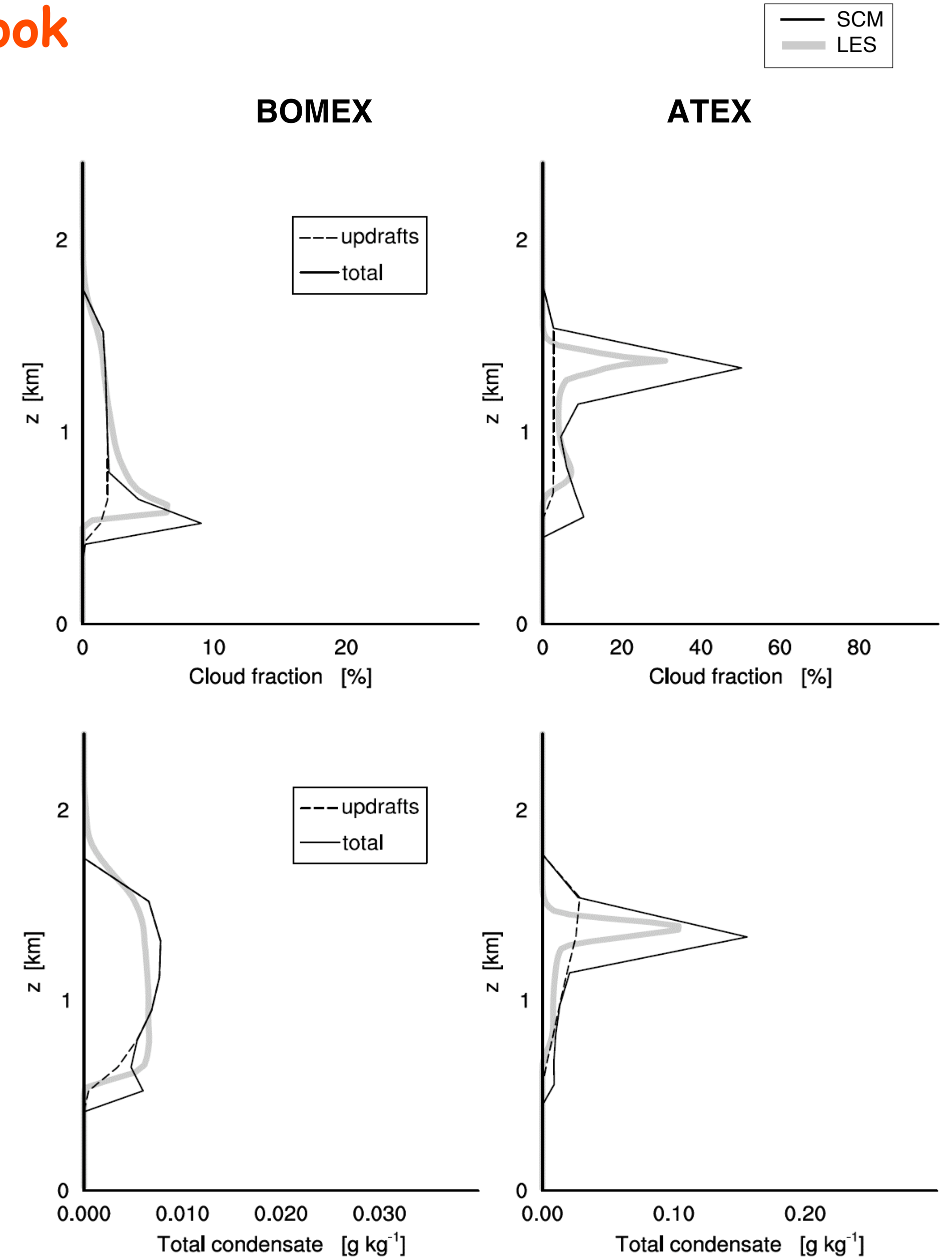
EDMF bimodal clouds: a closer look

The advective PDF captures convective (updraft) clouds, while the diffusive PDF picks up the more passive clouds

Strong PBL inversions automatically create capping "outflow" clouds, due to:

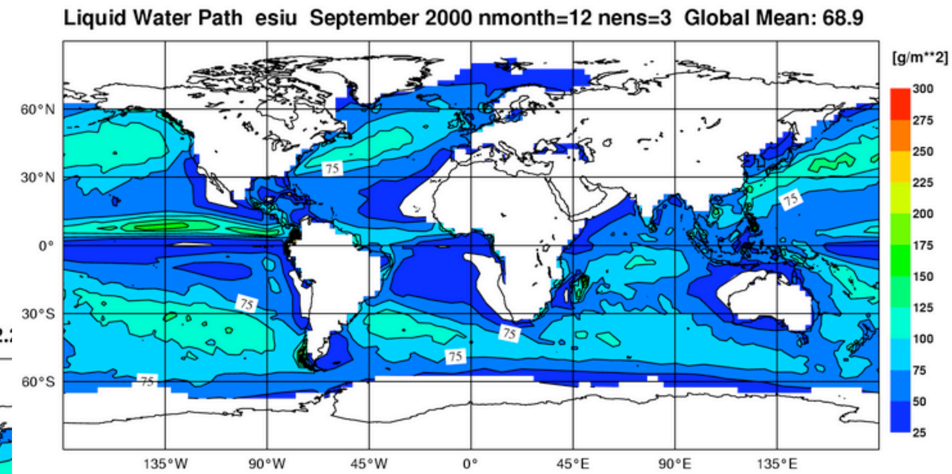
- Adaptive structure of cloud layer mass flux

- Cumulus top-entrainment efficiency closure

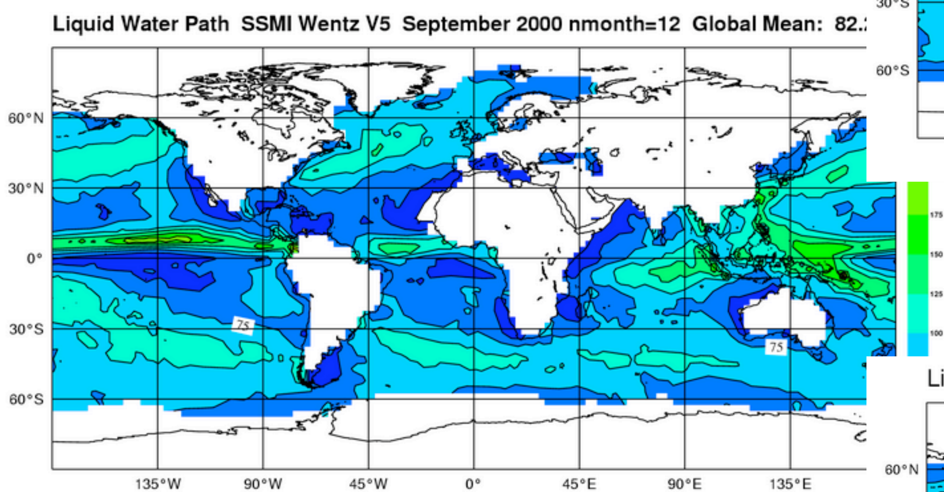


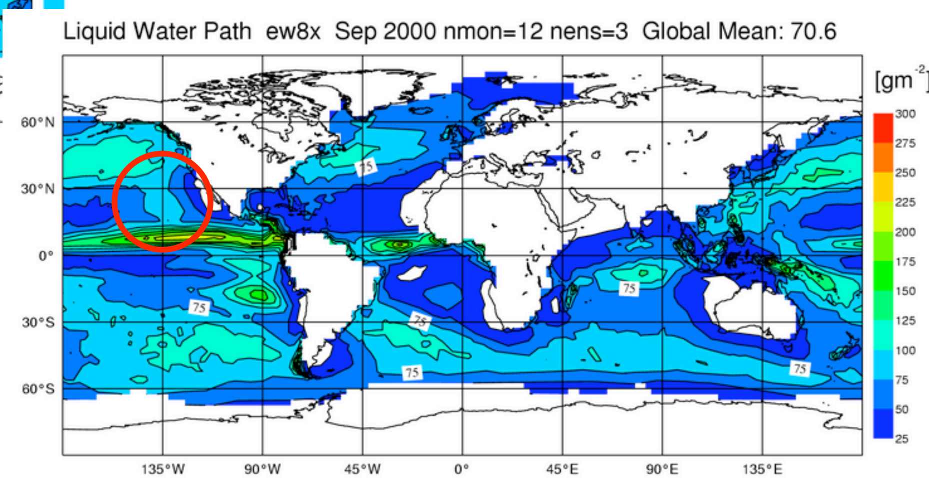
Stratocumulus -> shallow cumulus transition “bridges” are more pronounced

Old



Observed Liquid water path

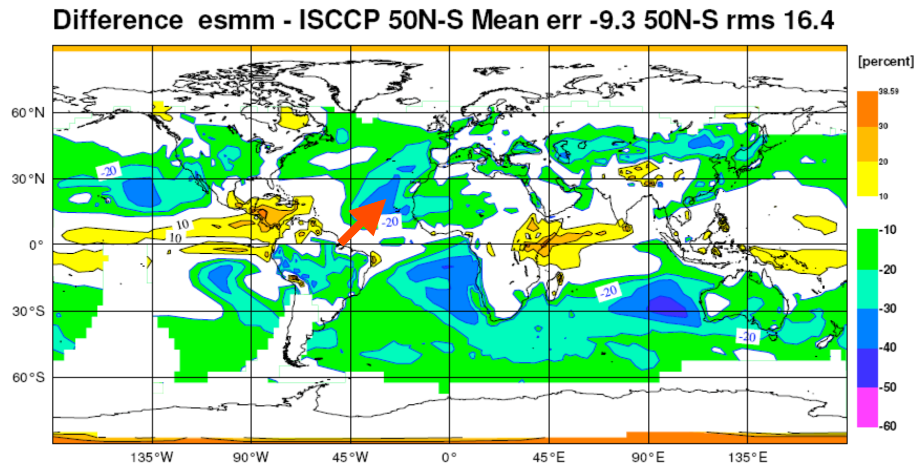


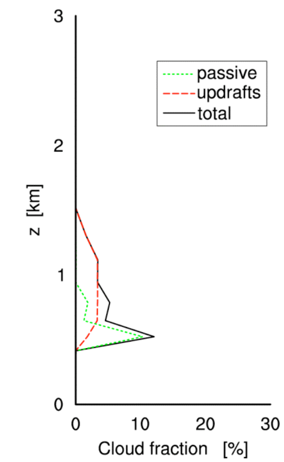


New

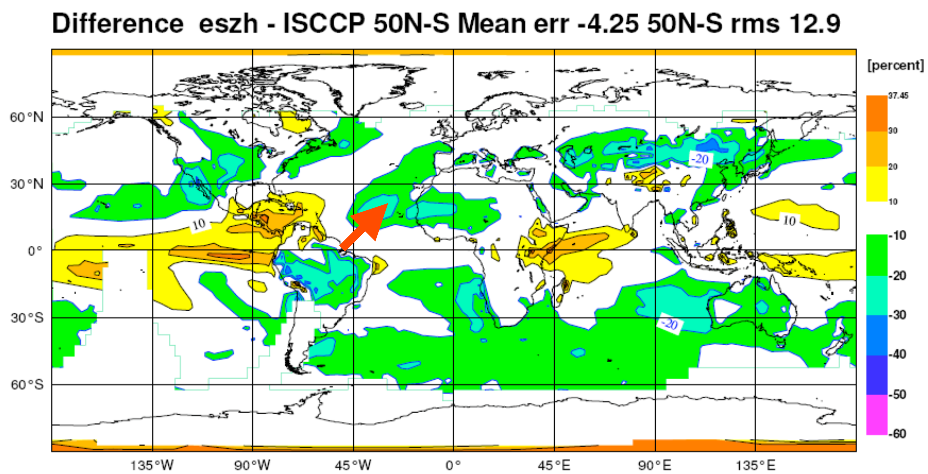
Impacts of the new entrainment efficiency closure for shallow cumulus

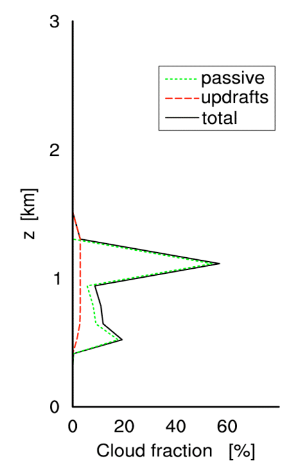
Without





With



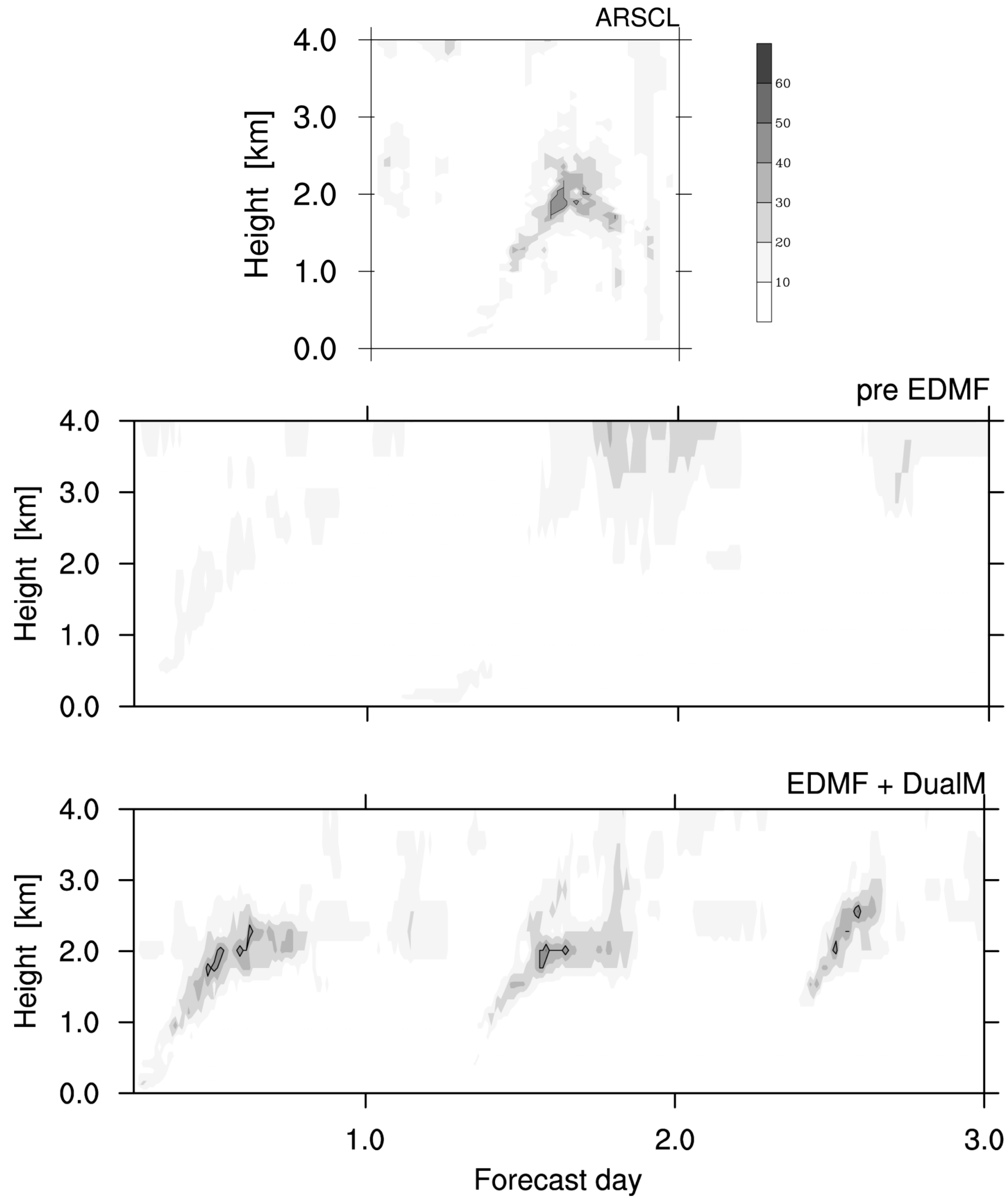


1D results carry over to 3D simulations!

Impacts on IFS forecasts: evaluation at ARM SGP

Frequency of occurrence [%] of low level cumulus clouds in July 2003

Actively Remote Sensed Cloud Algorithm
(ARSCL, Clothiaux et al., 2000)



Further reading…

Neggers, R. A. J., M. Köhler and A. C. M. Beljaars, 2007:
A dual mass flux scheme for boundary layer convection.
Part I: Transport

Neggers, R. A. J., 2007:
A dual mass flux scheme for boundary layer convection.
Part II: Clouds

ECMWF ARM Report series

Available at *http://www.ecmwf.int/publications/*

ECMWF

Convection changes to operational massflux scheme

New formulation of convective entrainment:

Previously linked to moisture convergence

– Now more dependent on the relative dryness of the environment

New formulation of relaxation timescale used in massflux closure:

Previously only varied with horizontal resolution – Now a variable that is dependent on the convective turnover timescale i.e. variable in both space and time also

Impact of these changes is large including a major increase in tropical variability

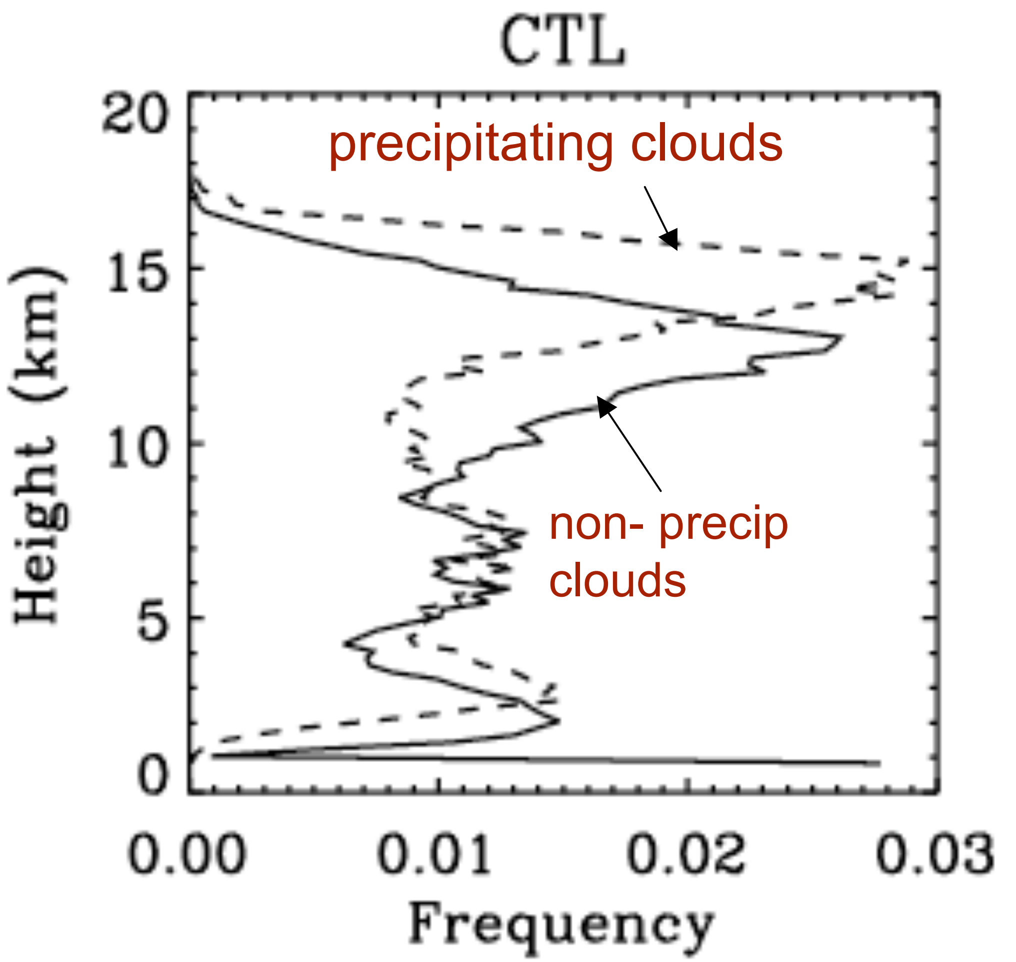
Composite vertical profile for west pac, JJA

Minimum cloud top heights distributions (CloudSat)

Of note:

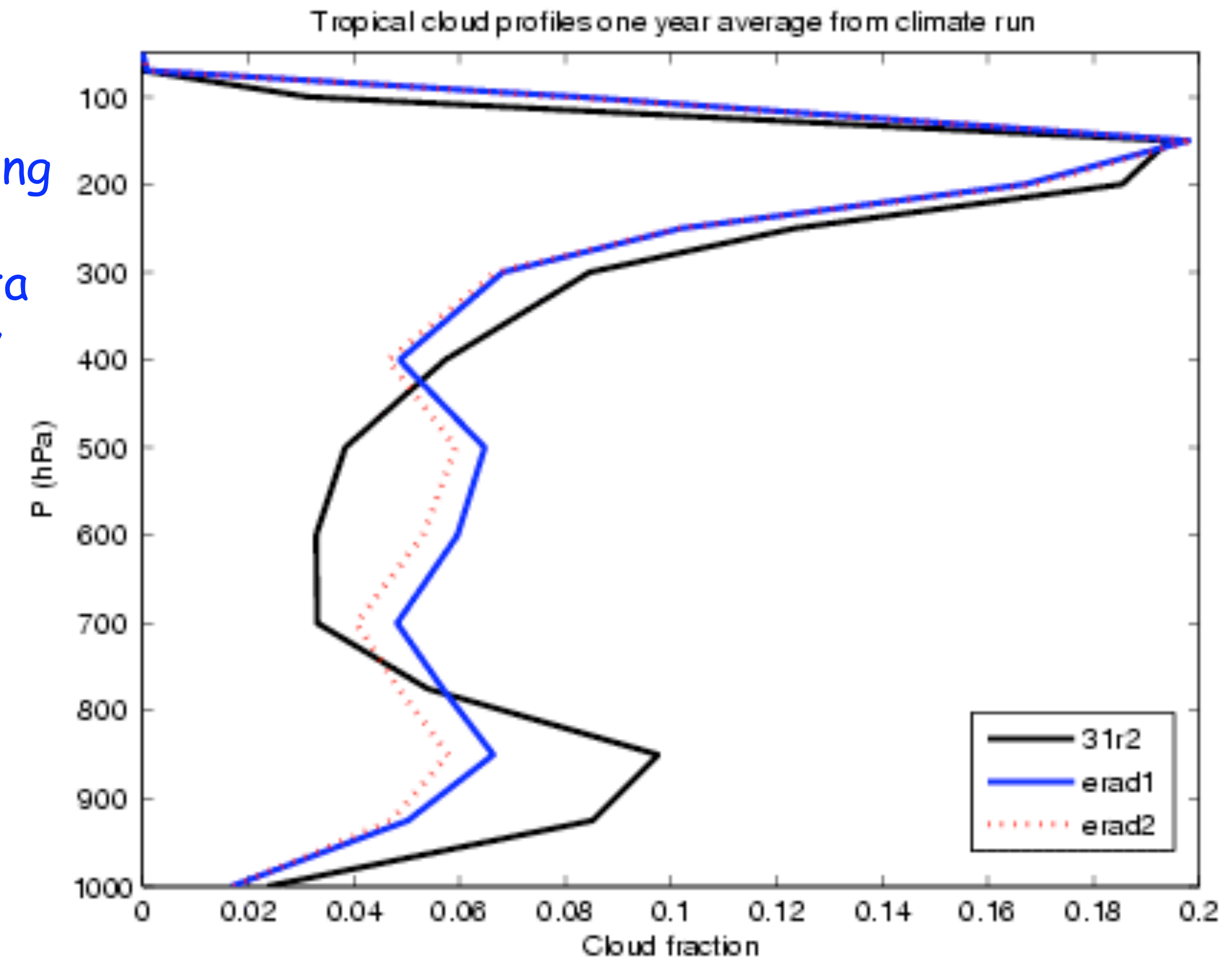
•Trimodality (quadra-modal) heights

• precipitating clouds are deeper than non precipitating clouds



Average tropical cloud profiles

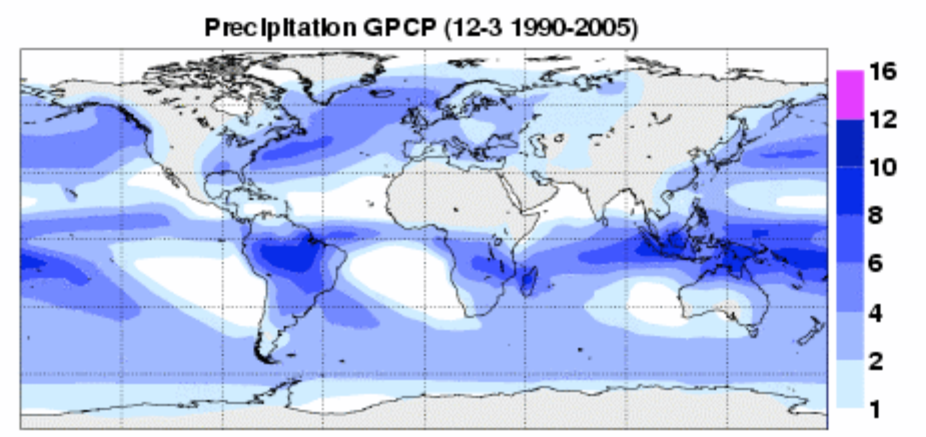
In the Tropics now a tri-modal cloud distribution becomes apparent, with a strong increase in mid-level clouds. CloudSat data will be used to verify these results.

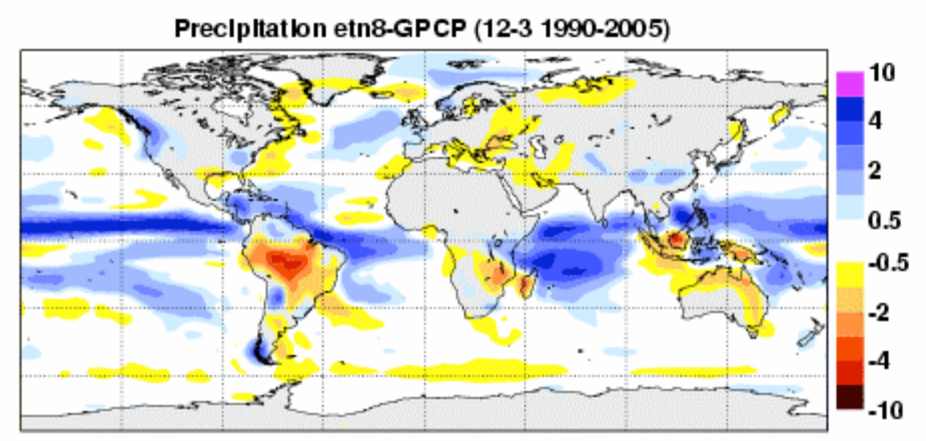


Forecast Biases and Convection

Precipitation for DJF against GPCP for different cycles: from 15 year 5 months integrations for 1990-2005.

CY31R1 Sep 2006

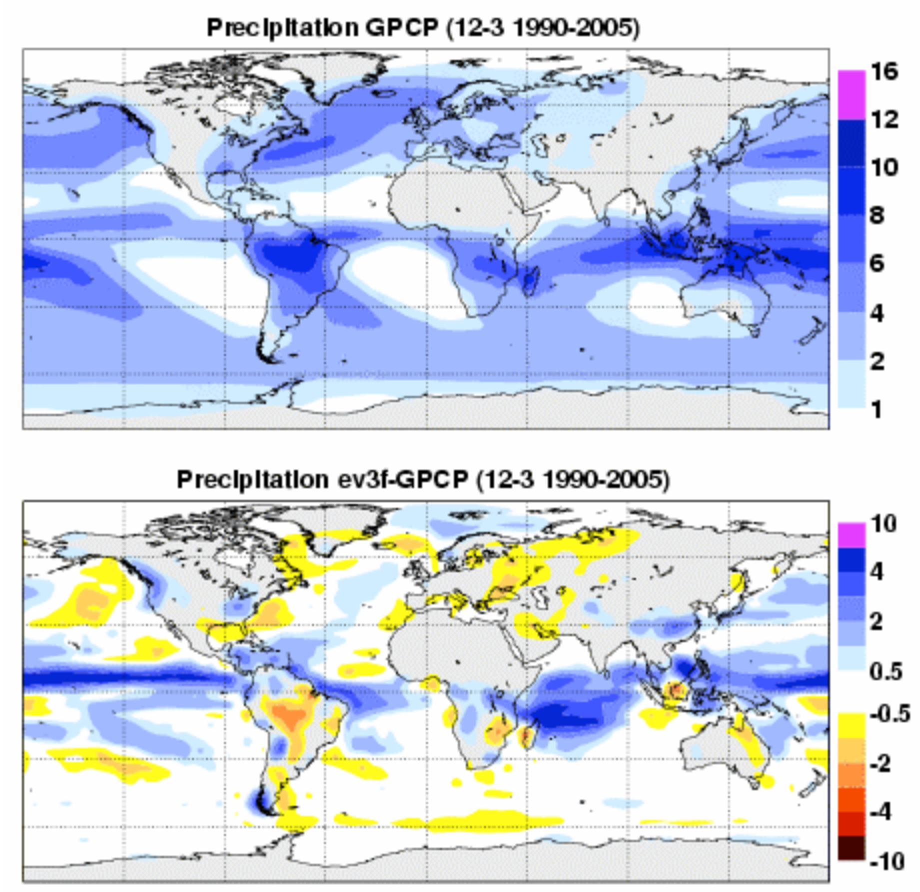




Forecast Biases and Convection

Precipitation for DJF against GPCP for different cycles: from 15 year 5 months integrations for 1990-2005.

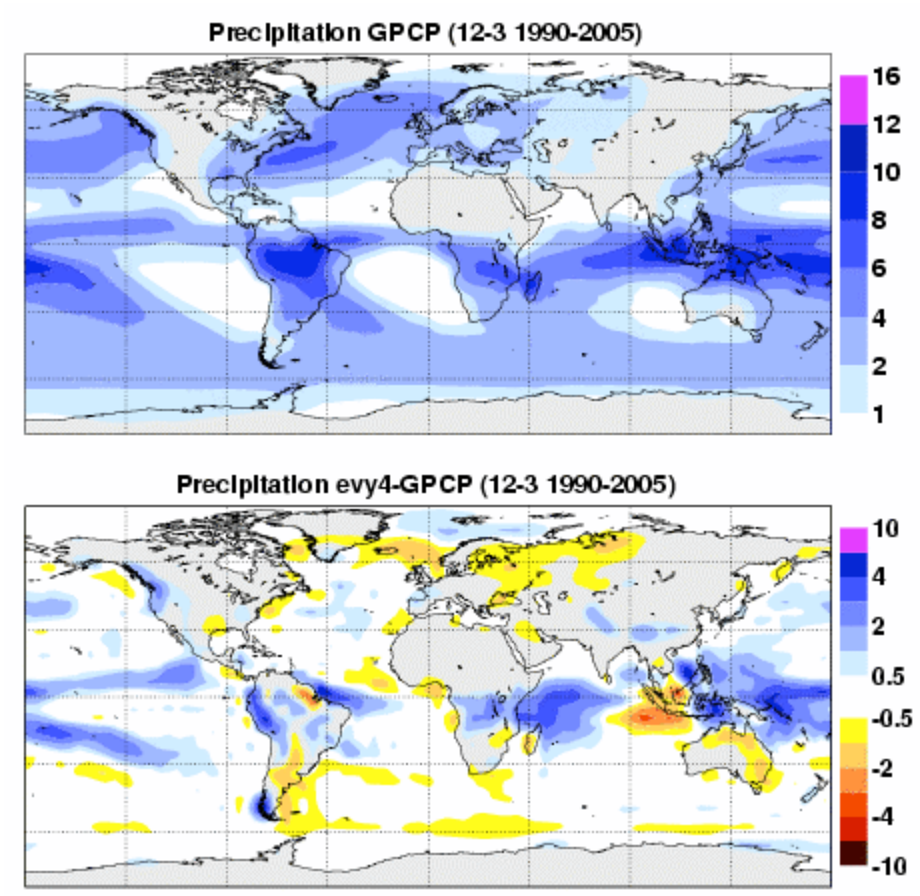
CY32R2 June 2007



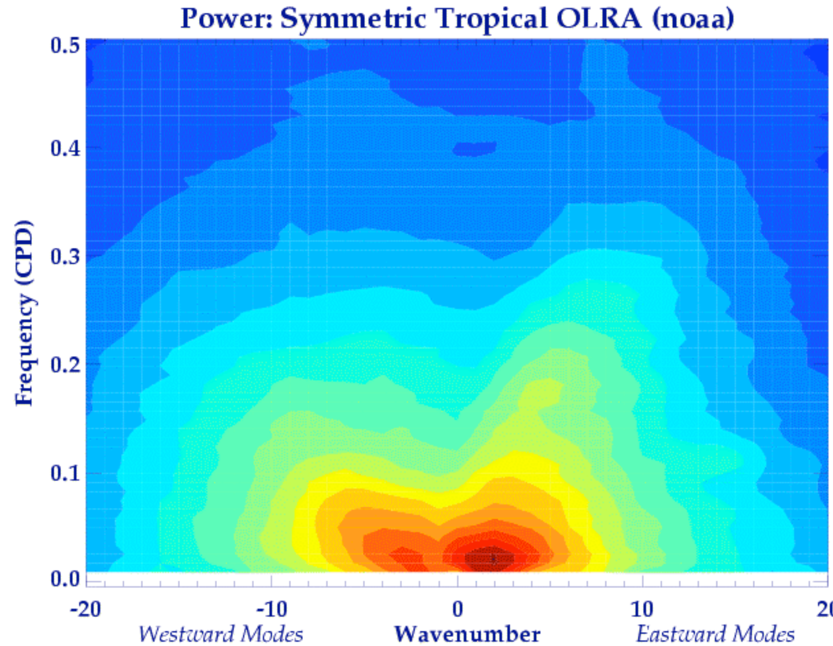
Forecast Biases and Convection

Precipitation for DJF against GPCP for different cycles: from 15 year 5 months integrations for 1990-2005.

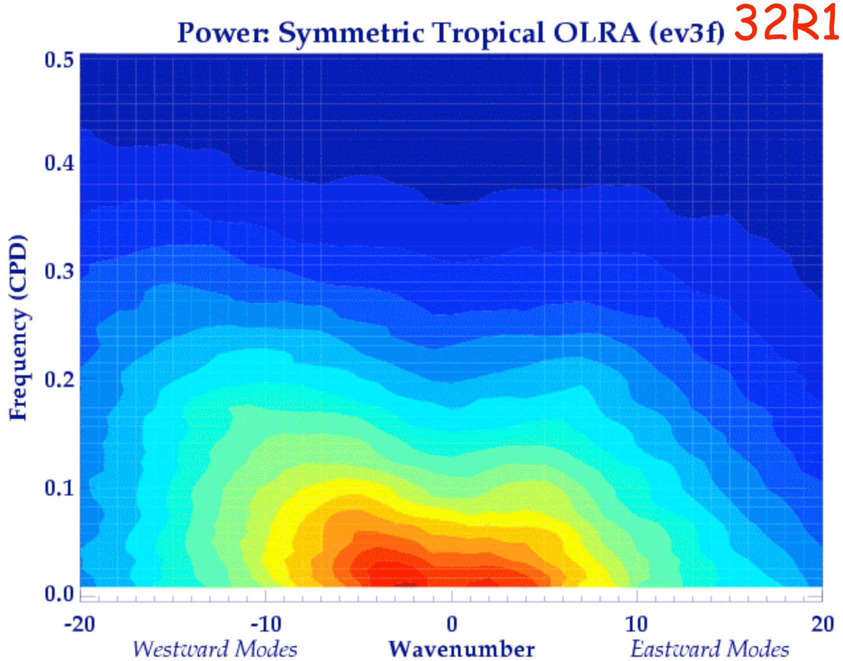
CY32R3 Sep 2007 ?



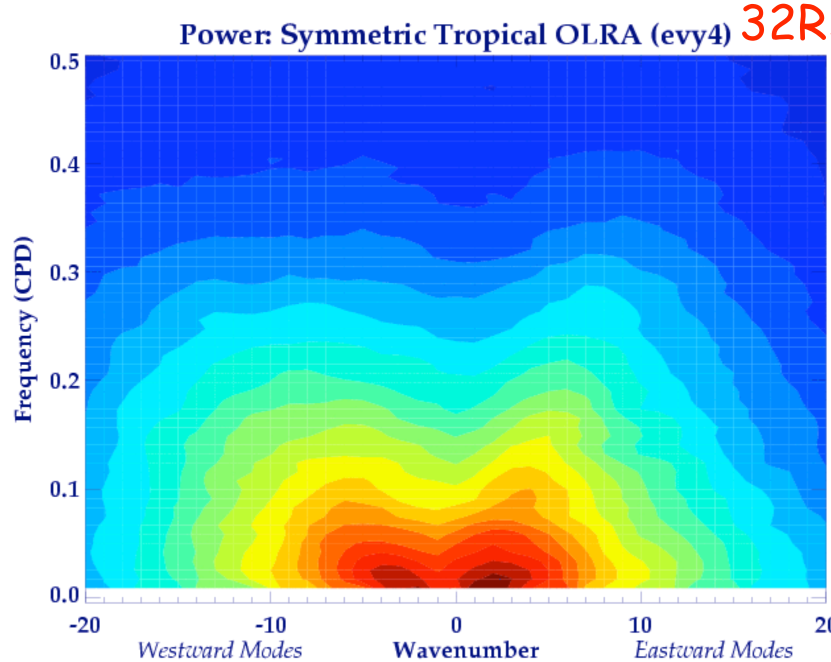
Tropical variability in wave-number frequency space of OLR (DJFM)



Obs (NOAA)



32R1



32R3

Tropical variability: OLRA (JJA)

32R1

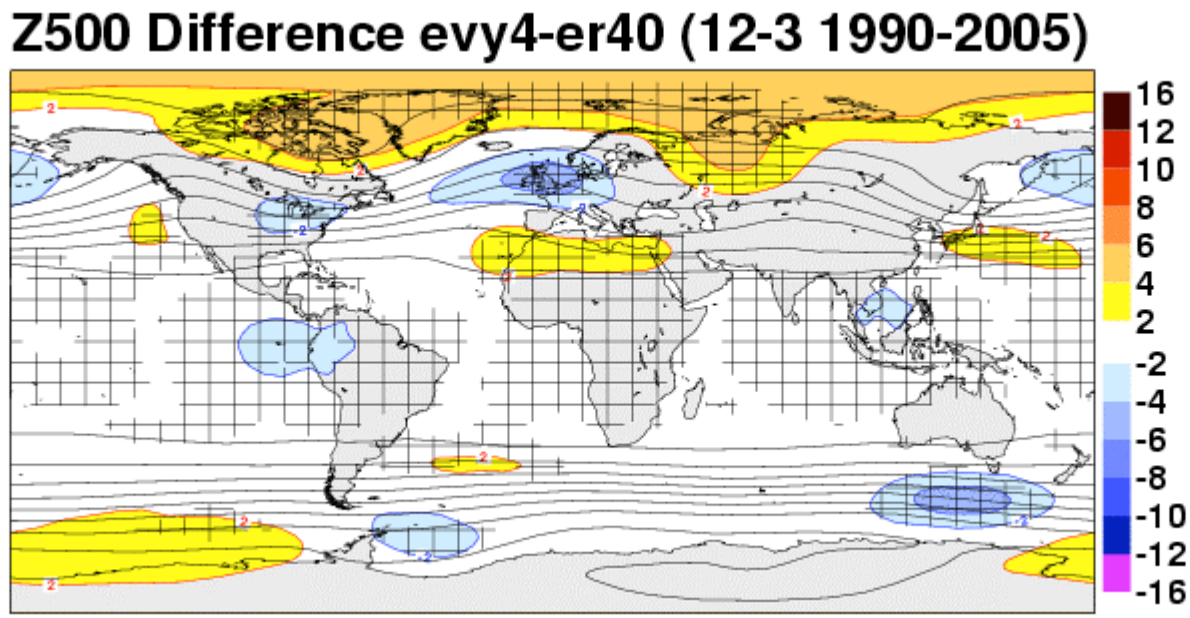
32R3

Forecast Biases and Convection

As previously for precipitation but for the 500 hPa Geopotential against ERA40

Hatched areas denote statistically significant differences

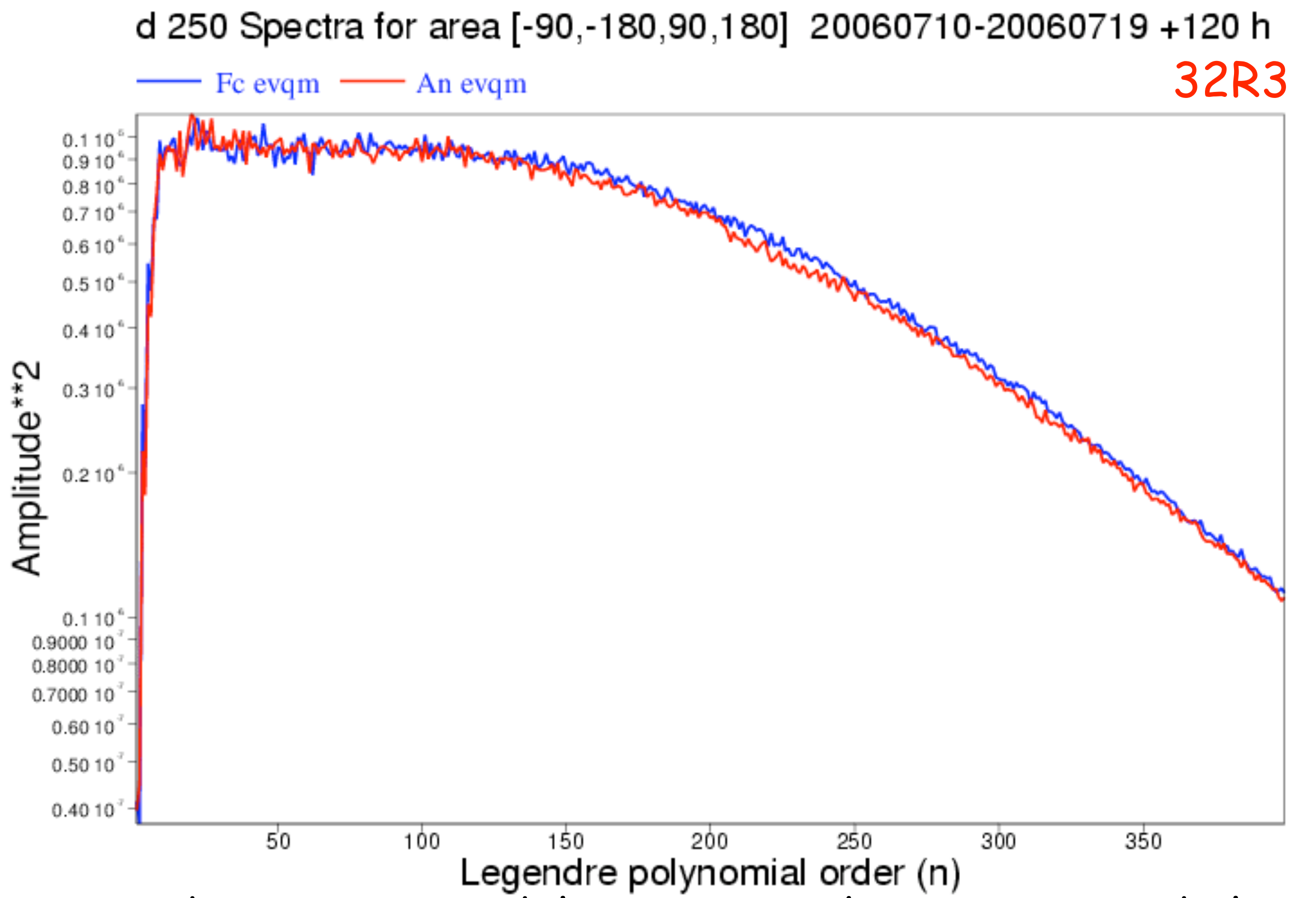
CY32R3e Sep 2007 ?



The impact of improved Tropics e.g. over Indian Ocean – Indonesia including tropical variability such as MJO projects on the North East Pacific errors

Blocking Frequency (DJFM)   Black=ERA40, Red=control, blue=new physics

Model activity and Divergence Spectra T799 at d+5 versus own Analysis



The IFS features a decrease in model activity in the synoptic and planetary scales (global wavenumbers 1-100) with forecast time. This is also evident from the power spectra of divergence at 250 hPa at day 5 against own analysis. However, in 32R3 this decrease is no longer evident.

Total Precipitable Water (DJFM)

New physics

Control

New - control

Parametrization development

- Still much mileage!

- Large improvements and sensitivities shown raise the question as to whether MMF approach shows similar? i.e. more diagnostics of the sort shown briefly here would be good. Tropical variability, blocking frequency, upper trop humidity, tri-modal clouds etc.

- MMF can/should provide more input to conventional parametrization development

- Recent progress with parametrization of shallow cumulus, stratocumulus and transitions relevant to MMF also

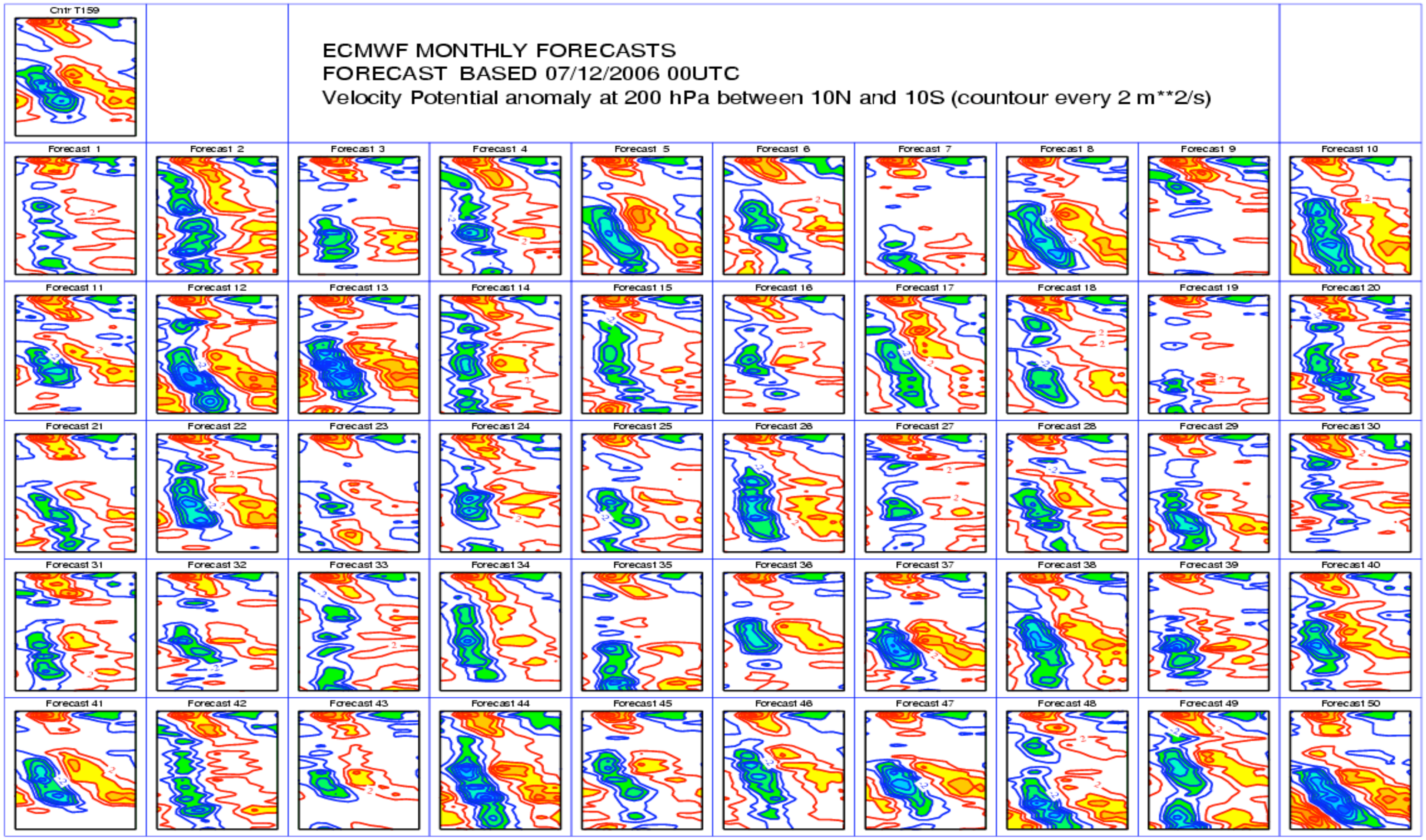
Prediction of the Madden Julian Oscillation (MJO)

Monthly Forecast starting on 7 December 2006

analyses

Prediction of the Madden Julian Oscillation (MJO)

Monthly Forecast starting on 7 December 2006



Benefits of a coupled system: skill in predicting MJO

Prediction of the Madden Julian oscillation: anomaly correlation between the PC1 and PC2 time series predicted by the monthly forecasting system at different time ranges from 45 cases one day apart and the time series computed from the analysis. Cycle 30R2.

VAREPS **Coupled** **Pers. SSTs** **Ocean ML**

MJO experiments- CY31R1

Control (coupled)

Coupled+slab

Ocean Mixed-layer

6. Impact of initial conditions: skill in predicting MJO

Prediction of the Madden Julian oscillation: anomaly correlation between the PC1 and PC2 time series predicted by the monthly forecasting system at different time ranges from 45 cases one day apart and the time series computed from the analysis.

ERA40 **ERA15**

6. Impact of model physics: skill in predicting MJO

Prediction of the Madden Julian oscillation: anomaly correlation between the PC1 and PC2 time series predicted by the monthly forecasting system at different time ranges from 45 cases one day apart and the time series computed from the analysis.

CY28R3 **CY29R1** **CY31R1**

NWP : resolution issues

- 'Deep convection permitting' fc systems e.g. gridlengths of a few kms
- But…resolution is more like 6-8 gridlengths
- So what are models resolving? It certainly is not individual convective clouds
- Encouraging results probably come from either :

  better resolution of macrostructures such as downdraught outflows (cold-pools etc) and other mesoscale forcing processes?

  or that the physical tendencies project better onto resolved dynamics?

- But parametrization of PBL including shallow convection, and (obviously) cloud microphysics still essential

RESOLUTION – (Current situation)

- For a variety of reasons climate simulations are almost universally run at 'inadequate' resolutions
- Sensitivity of systematic errors to resolution
- Wrong statistics of extra-tropical cyclones
- Air-sea interaction, hydrology, etc

Mean Z500 Error (DJFM)

T_L95-ERA40

T_L159-ERA40

T_L255-ERA40

T_L511-ERA40

Synoptic Activity: V_{rot} @ 700hPa (JJAS)

ERA40

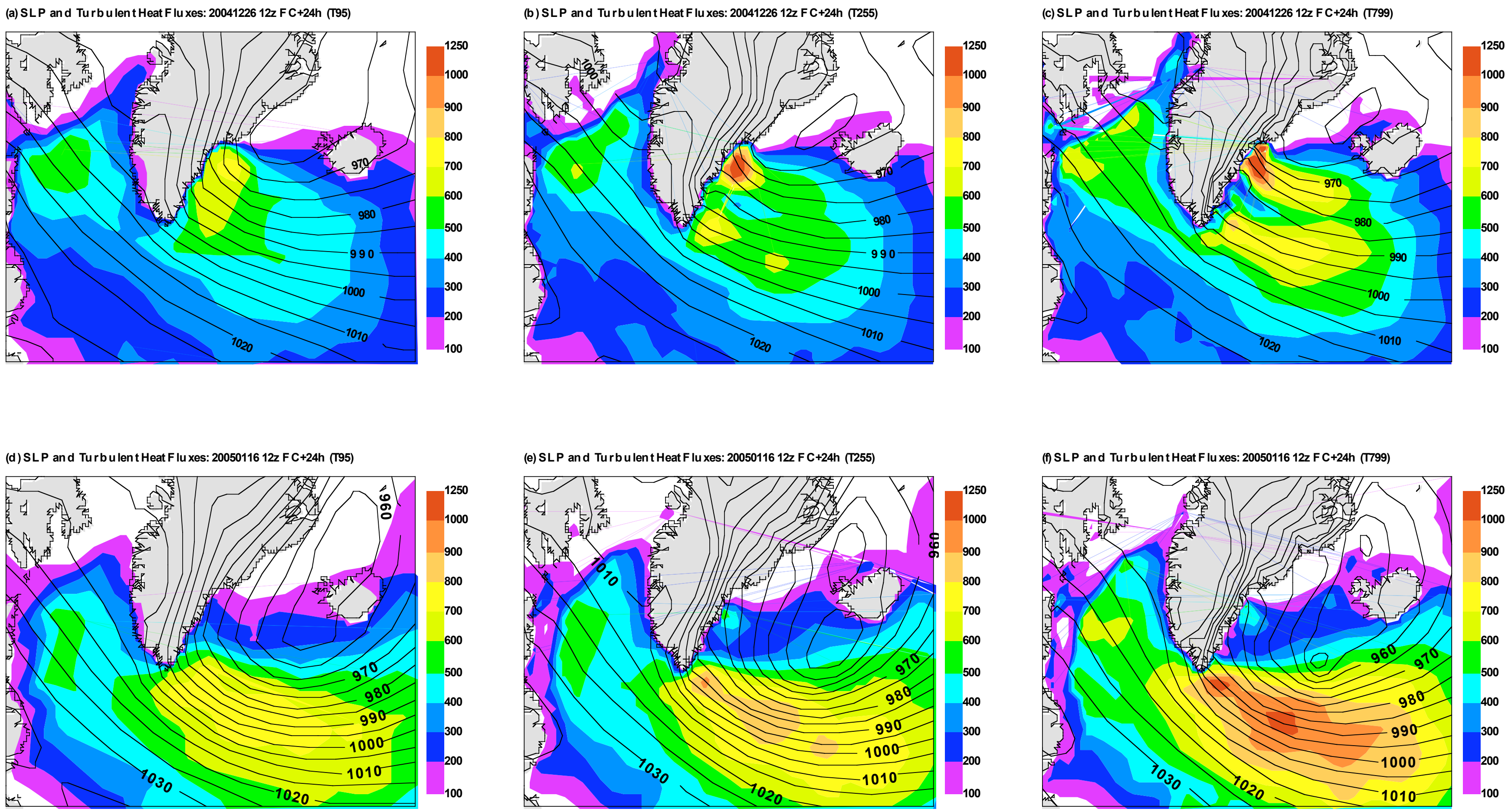
T_L95-ERA40

T_L511-ERA40

T_L511-T_L95

D+1 FC: MSLP and Surface Heat Fluxes

T_L95L60 | T_L255L60 | T_L511L60



Jung and Rhines, JAS

Remarks

- Resolution challenges for parametrizations
- Importance of capturing –5/3 part of KE spectrum?
- Still major problems with the diurnal cycle
- Still major large-scale problems in Tropics e.g. MJO, monsoons

- Growing application of NWP techniques for climate model development

- Not yet practical to run climate (change) experiments at 1km or so. Always a fundamental need for 10-100 km simulations not least because of ensemble requirements and demands of geo/bio-complexity

- Inadequate climate model (inc. ocean) resolution:
  E.g. systematic errors, extra-tropical cyclones, air-sea interaction etc

- Good set of climate model metrics needed (in progress)

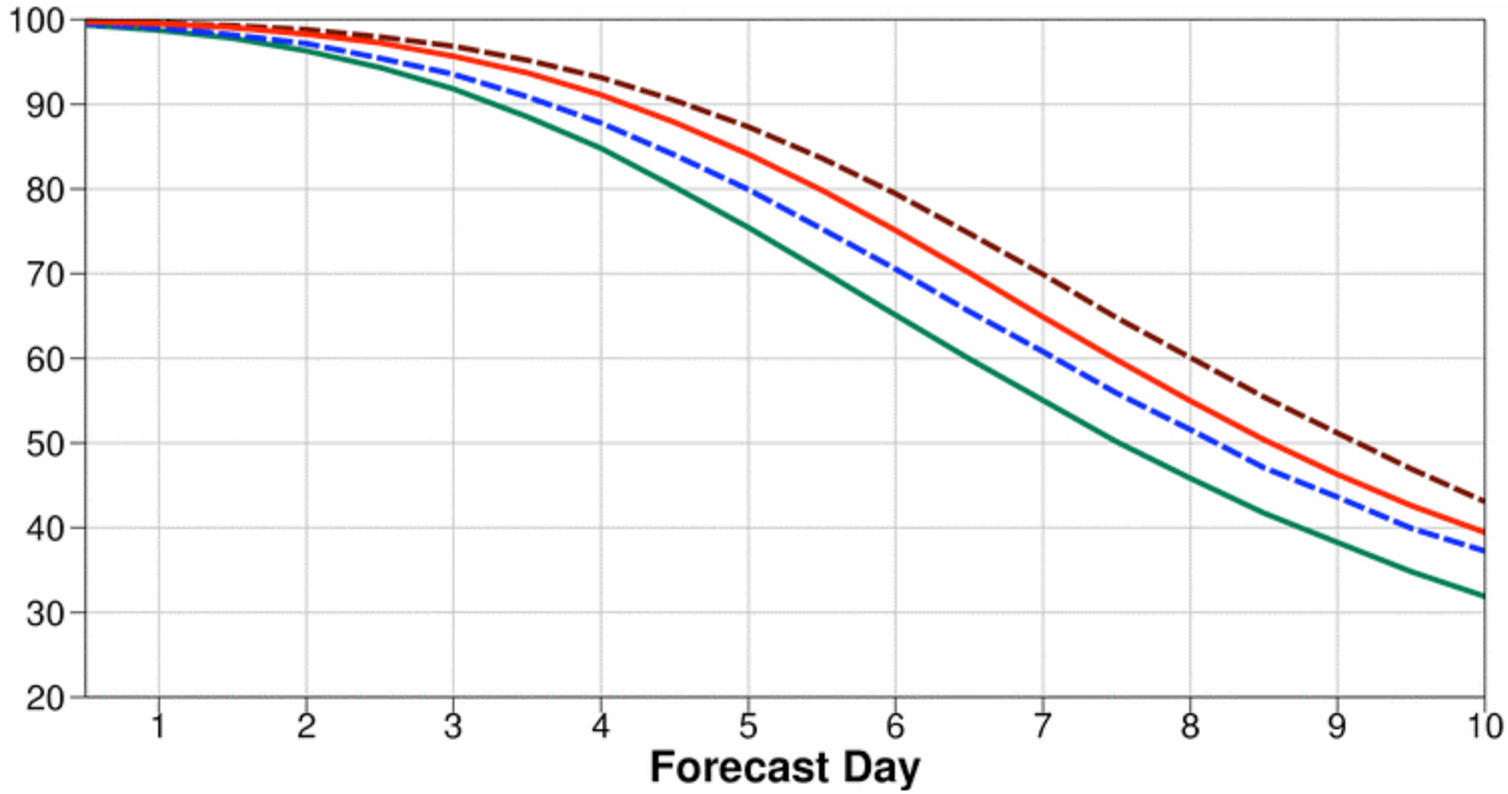
ERA-Interim: A new ECMWF Reanalysis

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

Anomaly correlation of 500hPa height forecasts for northern hemisphere

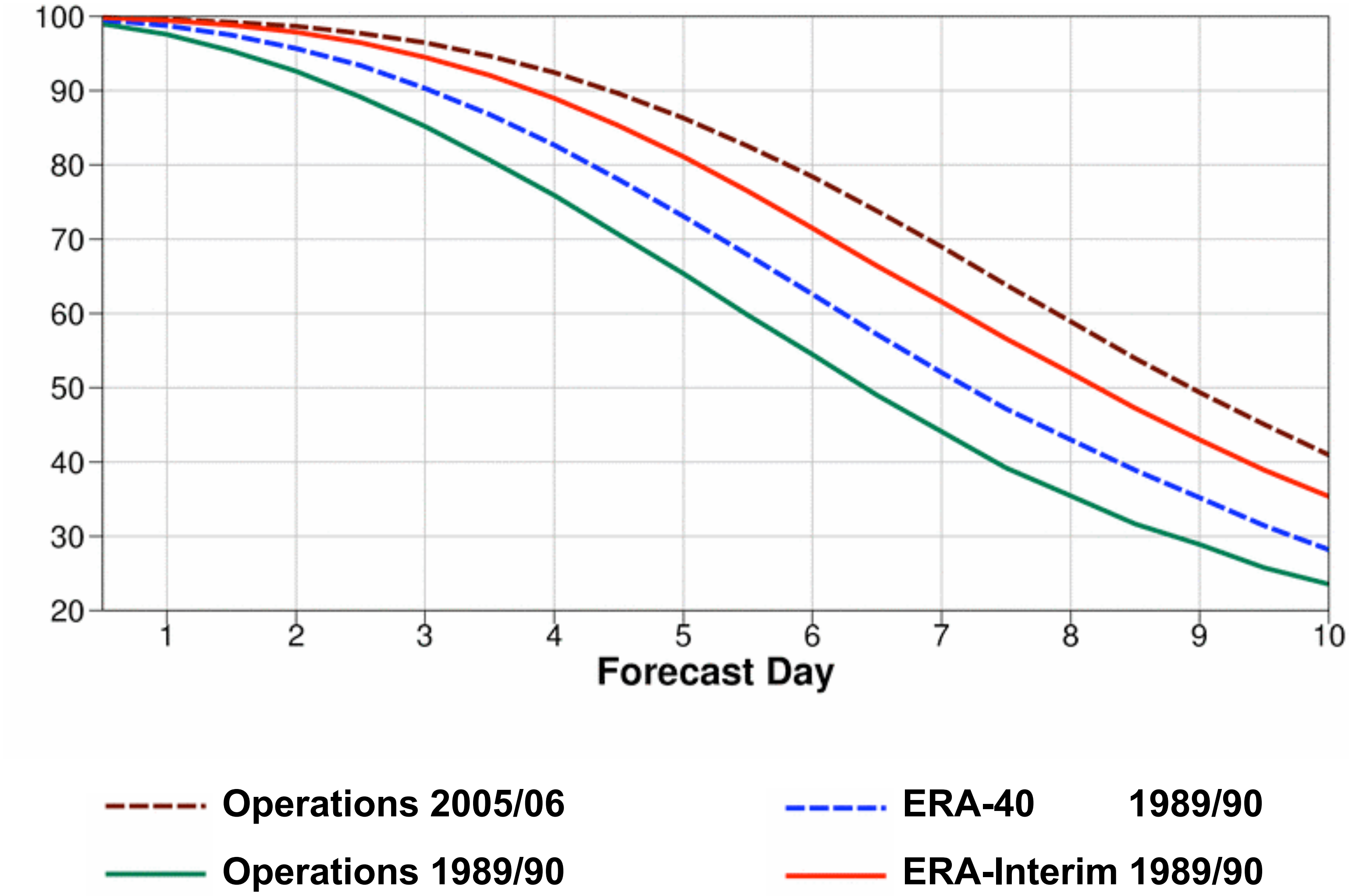


Operations 2005/06 — ERA-40 1989/90

Operations 1989/90 — ERA-Interim 1989/90

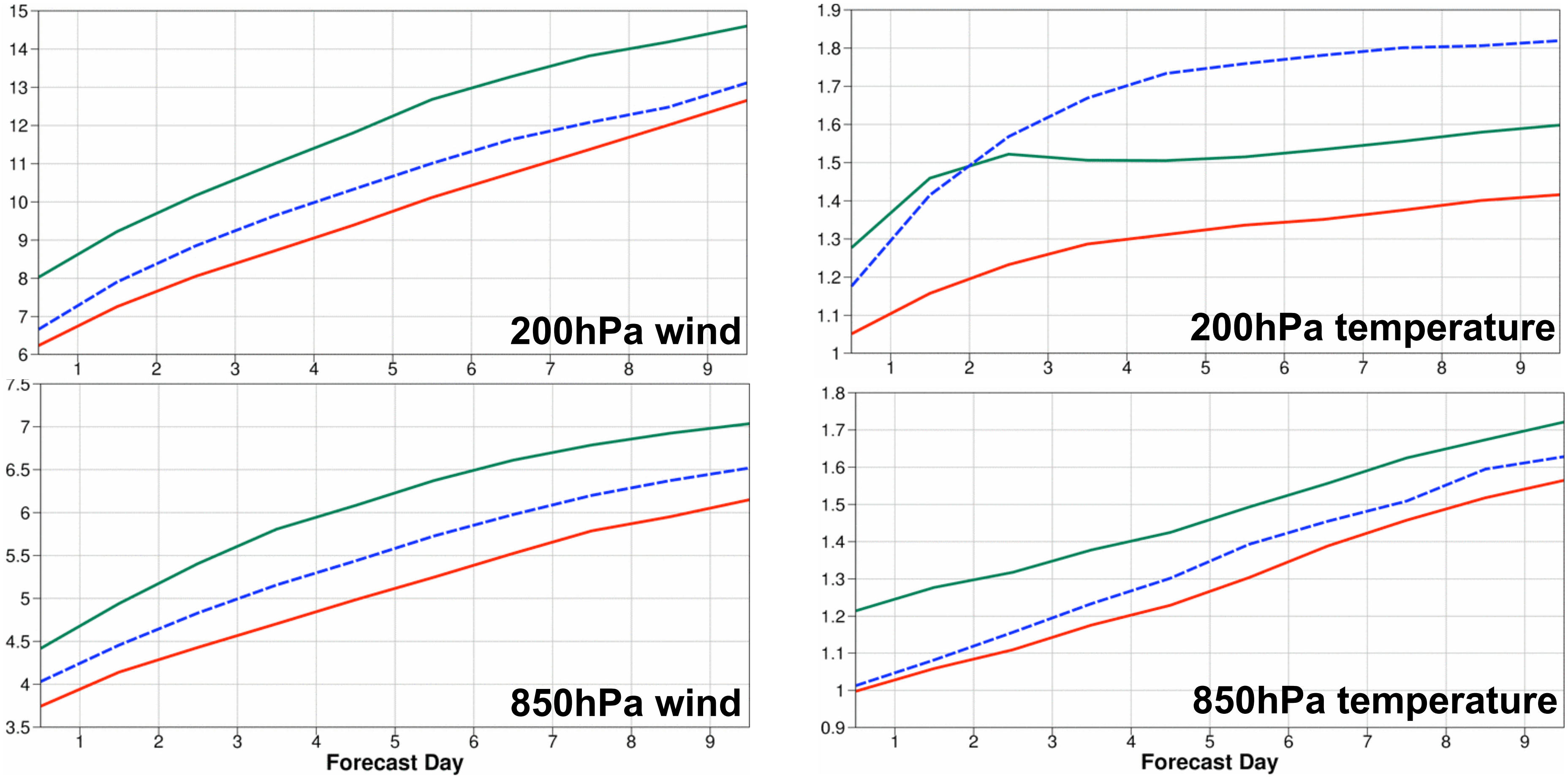
Forecasts from 12UTC, each verified against its own analysis

Anomaly correlation of 500hPa height forecasts for southern hemisphere



Forecasts from 12UTC, each verified against its own analysis

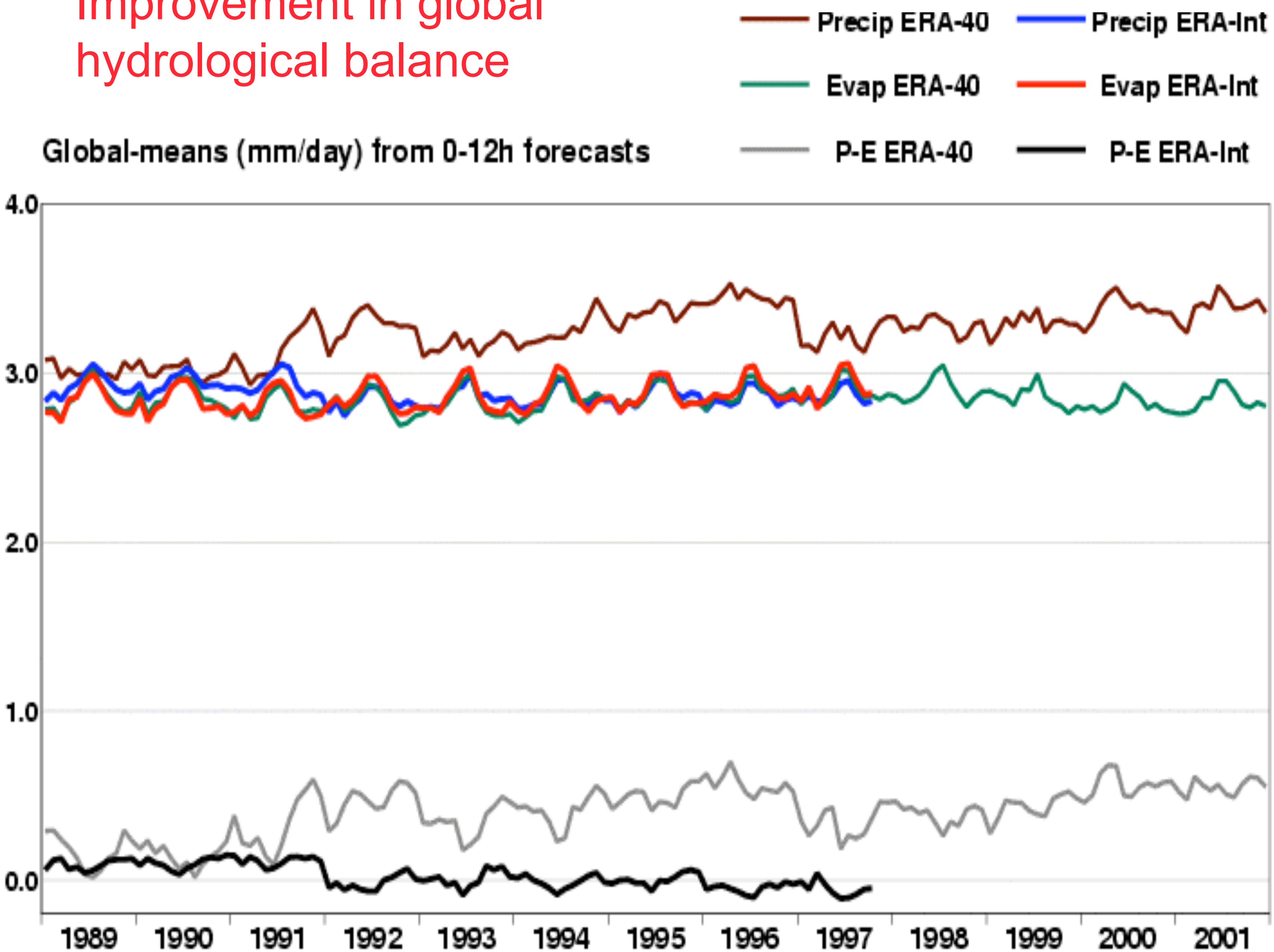
Root-mean-square error of tropical wind and temperature forecasts



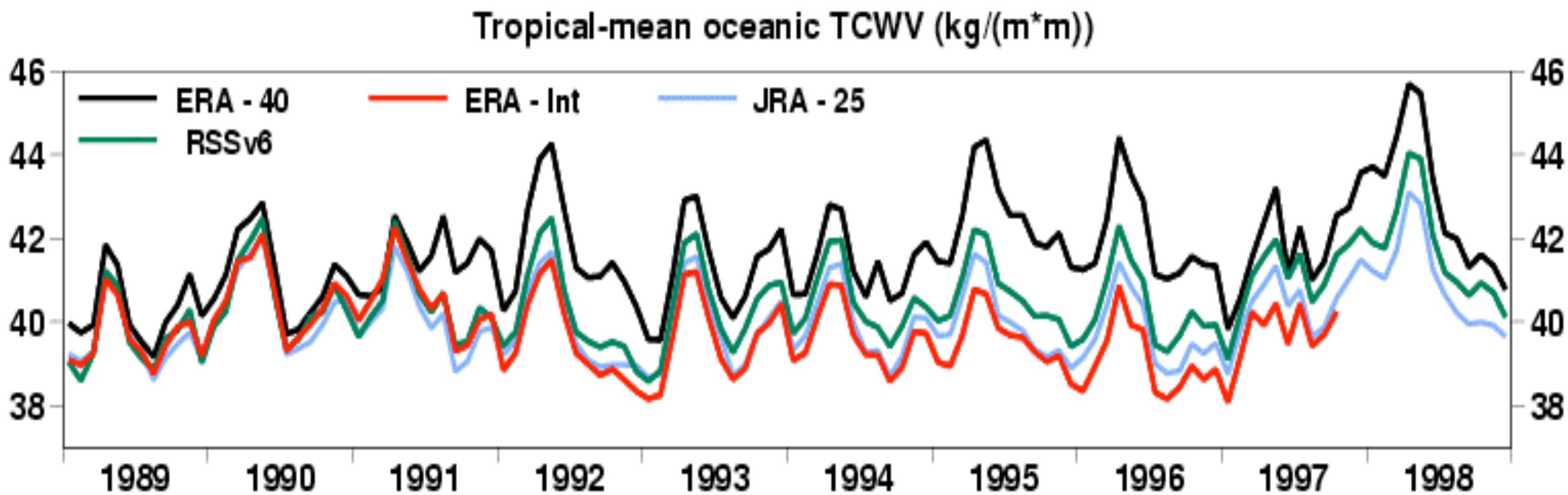
Operations 1989 — **ERA-40 1989** — **ERA-Interim 1989**

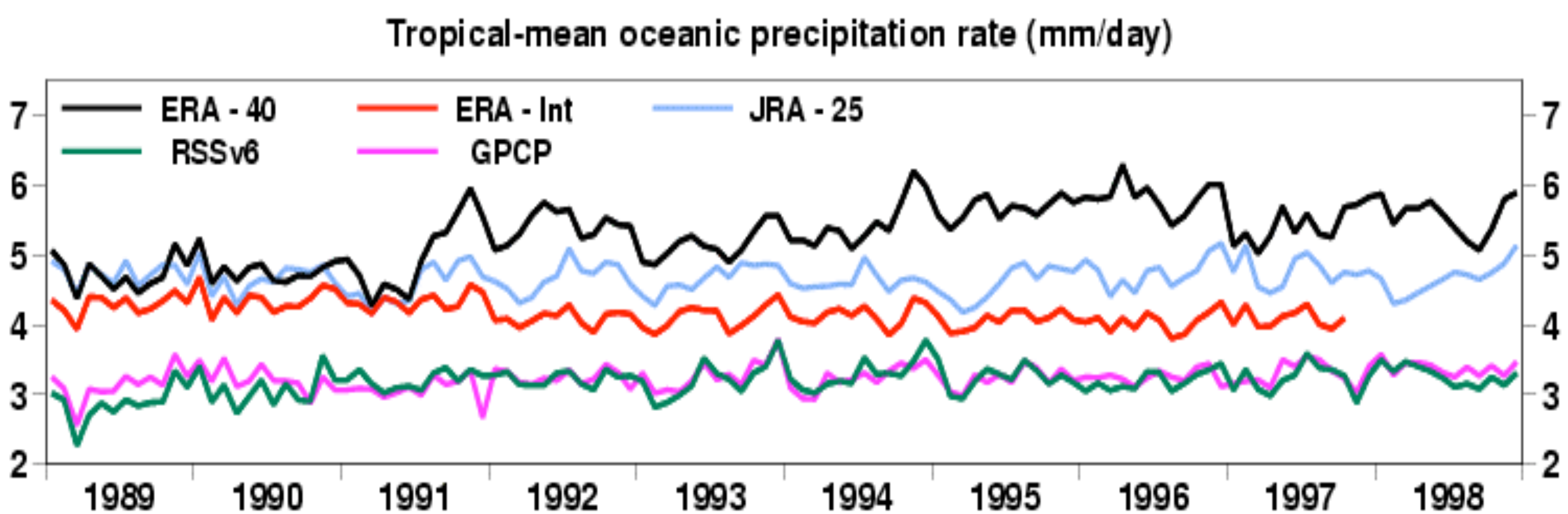
Forecasts from 12UTC, each verified against 00UTC radiosondes

Improvement in global hydrological balance



Improvement in humidity/rainfall over tropical oceans





ERA-Interim: A new ECMWF Reanalysis

- Now completing 10 years. (Data soon through ECMWF data services)
- When it reaches 2001/2 at the end of this year then all data will be freely available via a server at full resolution (subject to confirmation)
- It will reach real-time later in 2008 as a 20-year dataset and continue on.

Workshop on Systematic Errors – SUMMARY (1)

- **Importance of metrics**
- **The importance of short-range forecasts from NWP analyses**
- **The value of running suitably initialized coupled models in forecast mode over seasonal timescales**
- **Accurate representation of the diurnal cycle (a hard problem)**
- **Persistent errors (limited understanding) eg MJO, monsoons (inc. onset/breaks)**
- **Striking examples of benefits of substantially increased resolution (but does not 'solve' everything!)**

Workshop on Systematic Errors – SUMMARY (2)

- **Cloud feedbacks (low-clouds)**
- **Great opportunities due to 'Golden Age' of satellite data (A-Train etc)**
- **Complexity versus basic physical realism (self-defeating?)**
- **Work on systematic error reduction must be done at high resolution (otherwise tuning for wrong reasons!)**
- **Need major increases in computing power but with balanced investment in manpower (modelling is unattractive?)**