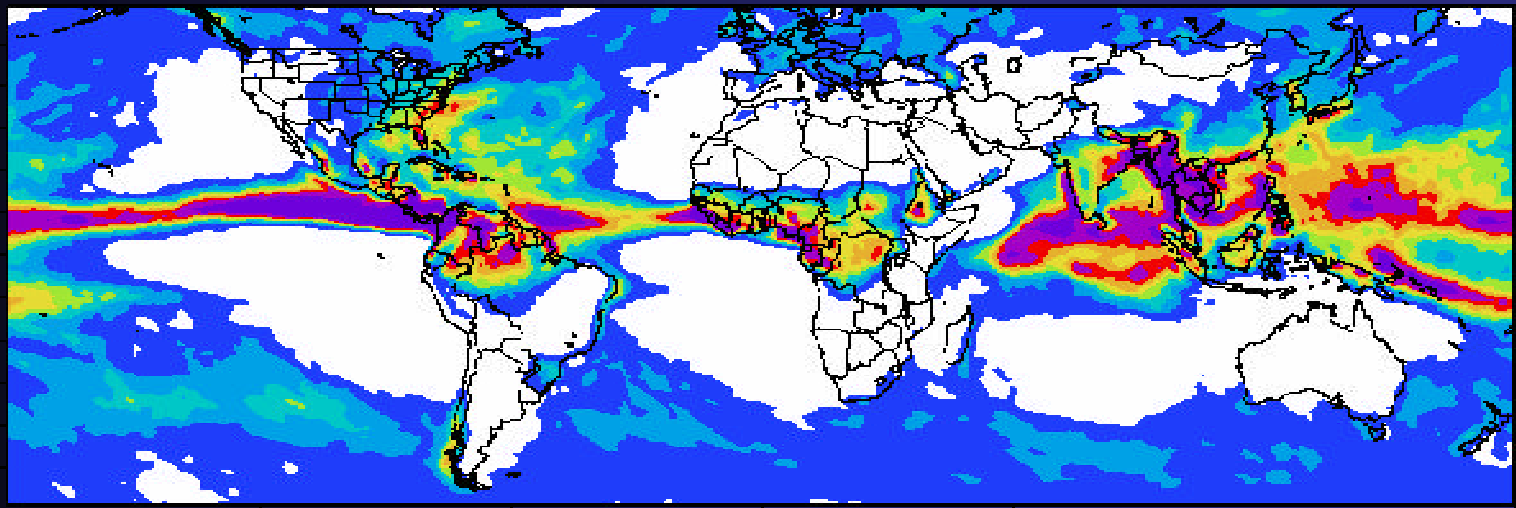
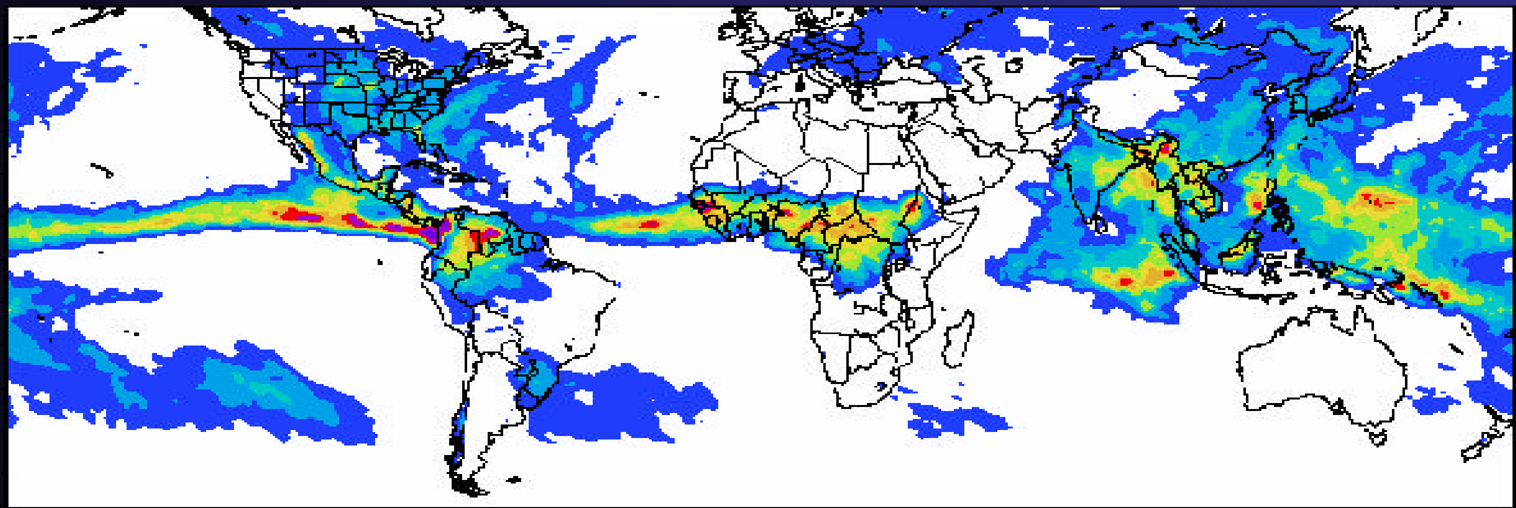
VERIFICATION OF NUMERICAL MODEL FORECASTS OF PRECIPITATION AND SATELLITE-DERIVED RAINFALL ESTIMATES OVER THE TROPICS AND THE MID-LATITUDES

CEM-GCM (day1)



JJAS 2004 (mm/d)

CPC CMORPH



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5th CEOP Implementation Planning Meeting: Paris, 26 February-1 March 2006

Introduction

Why is the verification of Quantitative Precipitation Forecasts (QPFs) important?

- ✓ ***Precipitation is one of the most difficult weather elements to predict.***
- ✓ ***Many dynamical and physical processes can lead to rain formation.***
- ✓ ***An accurate prediction of rainfall depends on the accurate representation of all these processes in the model , including precipitation parameterization.***
- ✓ ***A good forecast of rainfall over a large domain is indicative of a good forecast overall.***

…because QPFs skill is a measure of “model health”.

Why is the validation of satellite-derived estimates of precipitation important?

- ✓ ***Near real time satellite estimates provide information on rainfall intensity and frequency with high spatial and temporal resolution and over regions that are inaccessible to other observing systems.***

…because these data are very useful for many applications such as flood warning, water resources monitoring, NWP data assimilation, model verification over remote regions and oceans.

Motivation

✓ To study and evaluate the capabilities of a global circulation model in predicting precipitation:

1) on a daily basis,

2) over large domains,

3) when and where important thermal and dynamical processes are involved,

4) during CEOP Phase I,

5) in comparison with satellite derived estimates: an alternative source of rainfall information for verification purposes over complete (sea and land) and/or remote domains.

Standard verification methodology

WGNE (Working Group on Numerical Experimentation): recommendations on a standard verification and intercomparison methodology for QPFs.

Main points:

✓ To verify QPFs both against a) **gridded** observations on a common lat/lon grid (gauge/radar analysis); b) **station** observations.

✓ To use **daily accumulation** as temporal scale.

✓ To **stratify results** by a) lead time, b) season, c) region, d) intensity threshold (1, 2, 5, 10, 20, 50 mm/d).

✓ To report **persistence forecasts** (or climatology) to show the usefulness of the forecast system.

✓ To provide a standard suite of **statistics**.

✓ To provide quantitative estimates of the **uncertainty** of the verification results using 95% confidence intervals.

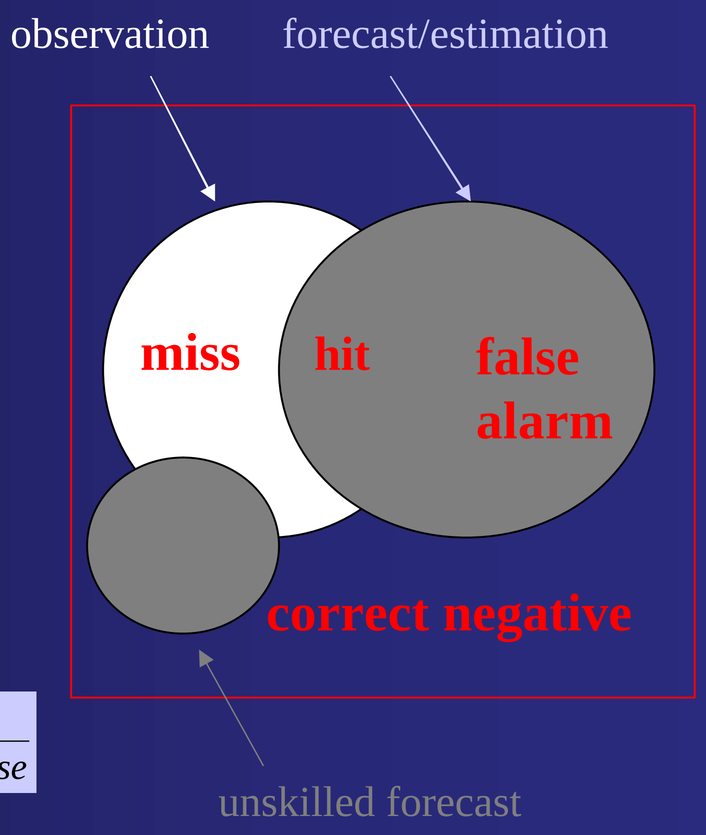
WGNE highly recommended statistics

✓ **Continuous Verification Statistics:** measure the accuracy of predicted or estimated rain **amount.**

• Mean Error (bias), Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Correlation Coefficient.

✓ **Categorical Verification Statistics:** measure the correspondence between the predicted/estimated and observed **occurence** of the events.

• Bias Score, Proportion Correct (PC), Probability of Detection (POD), False Alarm Ratio (FAR), Equitable Threat Score (ETS), Hansen and Kuipers Score (HK).



$$\textbf{BIAS} = \frac{hits + false}{hits + miss}$$

$$\mathrm{PC} = \frac{hits + corr.negative}{total}$$

$$\mathrm{POD} = \frac{hits}{hits + miss}$$

$$\mathrm{FAR} = \frac{false}{hits + false}$$

$$\textbf{ETS} = \frac{hits - hitsR}{miss + false + hits - hitsR}$$

$$\mathrm{HK} = POD - \frac{false}{corr.neg. + false}$$

CEM-GCM and **CMORPH** verification: *data and methods*

CEM-GCM

- Based on the NCEP/ECPC GSM [Roads et al.,1999]
- 1°x1° lat/lon, 28 vertical levels.
- Time step: 20 min.
- SAS cumulus conv., Tiedke (1983) shallow convection.
-OSU LSM (2 layers: 10 and 200 cm) with heterogeneous b. c.
- Initialization: NCEP/GDAS at 12z.
- Forecasts: +12/+90 (output every 6 hours).

India: day1=+42; day2=+66; day3=+90

Europe: day1=+30; day2=+54; day3=+78

CPC CMORPH [Joyce et al., 2004]

- Cloud motion and evolution information derived from IR data to propagate the estimates derived from PMW observations (DMSP 13, 14 & 15 (SSM/I), NOAA 15, 16 & 17 (AMSU-B) and TRMM- TMI).
- 0.5°x0.5° lat/lon, 3-hourly.

CPC DAILY RAIN GAUGE ANALYSIS

- 0.5°x0.5° lat/lon.
- Daily acc. 06z-06z India; 18z-18z Europe.

- All data remapped to a common 1°x1° grid and accumulated to daily values.
- WGNE highly recommended statistics over India (5°-27°N; 70°-90°E) and over Europe (36°-56°N; 10°W-25°E). Land points only.

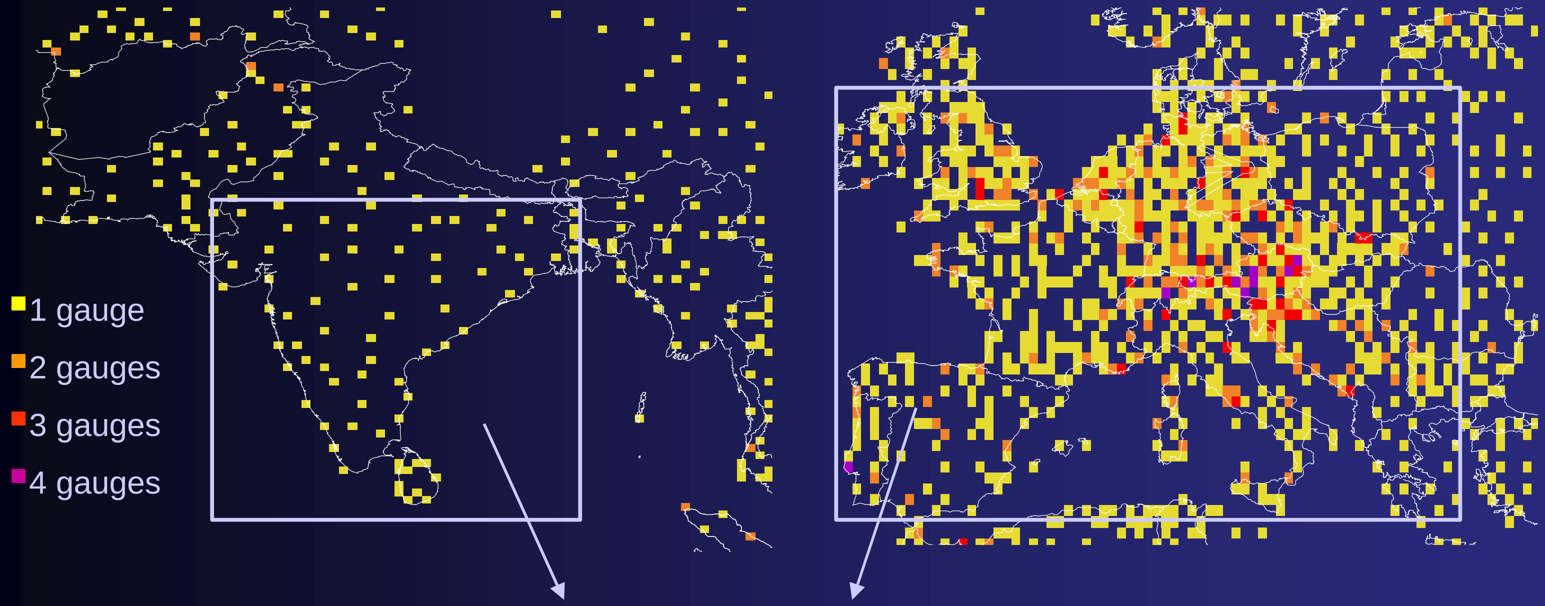
PERIOD: 1 June - 31 December 2004

Reference for verification/validation

✓ The reference data used for verification (the “truth”) contain errors due to smoothing and sampling.

✓ Verification against irregular distributed data (e.g. synop via GTS) can lead to misinterpretation.

✓ Using low-density rain gauges data over Europe the Bias Score increases, while the ETS tends to decrease. (From QPF Conference – Reading -- UK Sept. 2002 – Anna Ghelli)

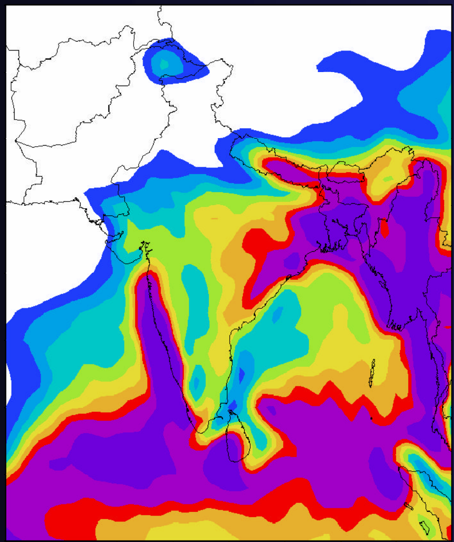


Investigated domains

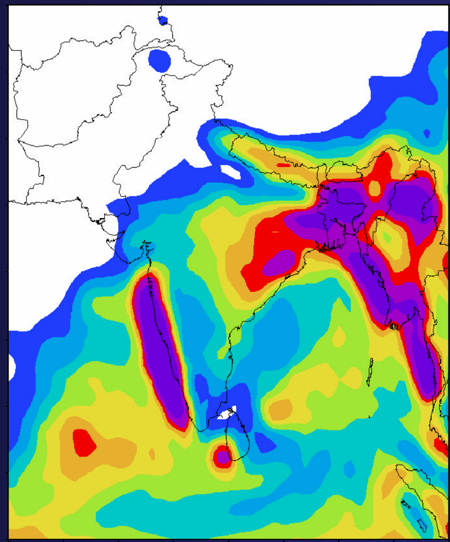
(distribution of gauges for CPC analysis)

India: precipitation rate*(mm/d) – JJAS*

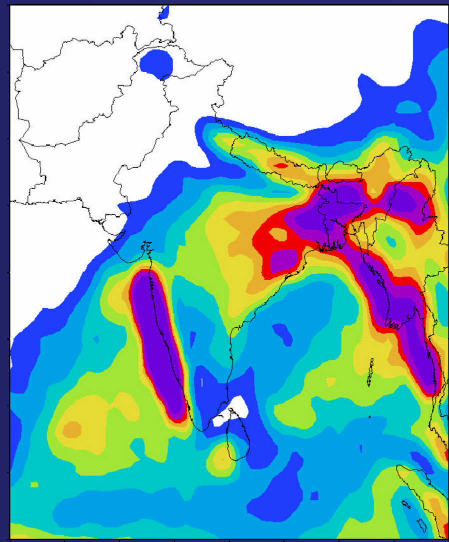
day1



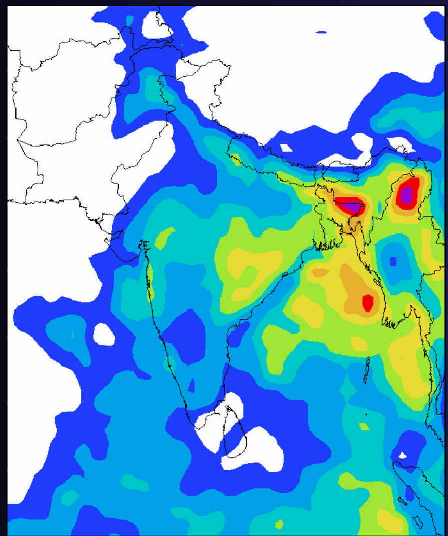
day2



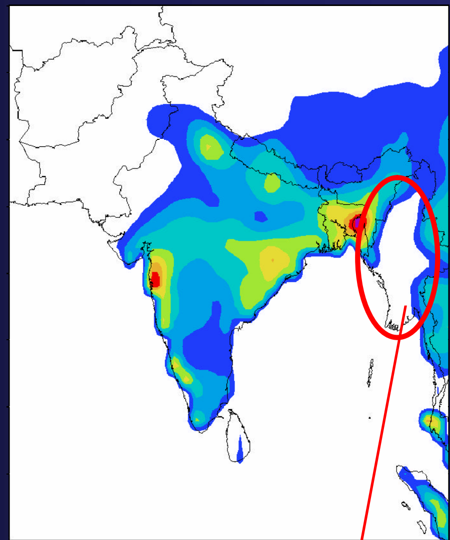
day3



cmorph



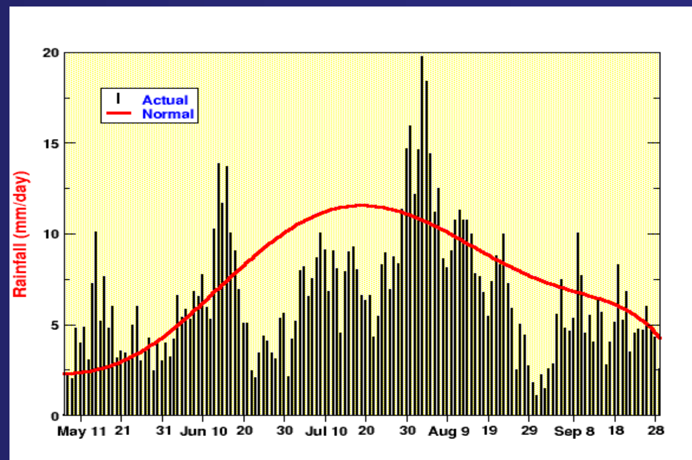
gauge analysis



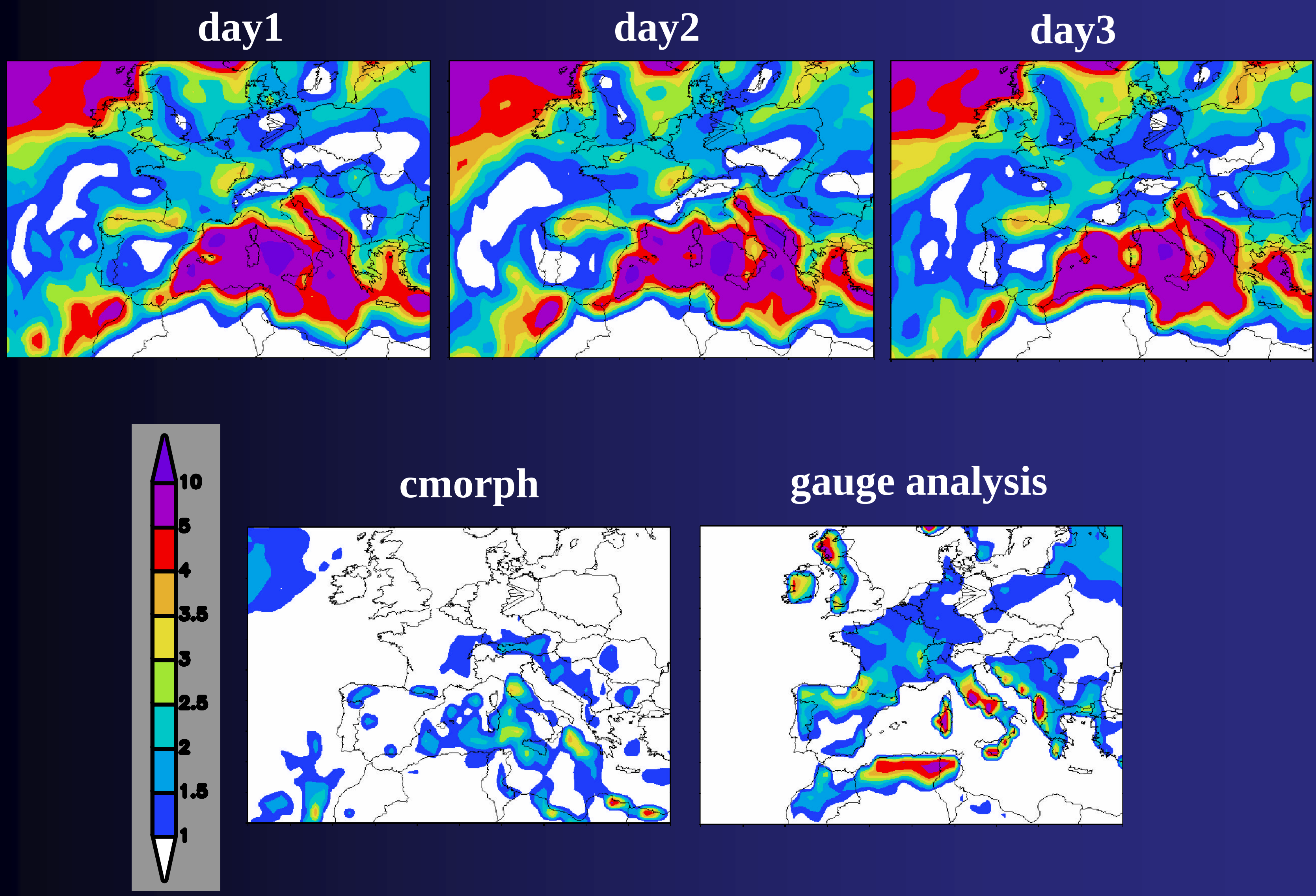
data not available

All-India Rainfall 2004

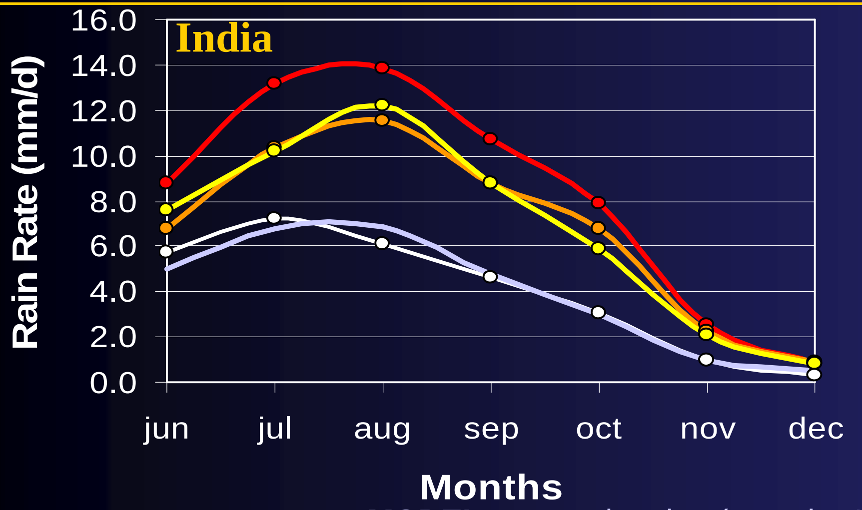
(Indian Institute of Tropical Meteorology)

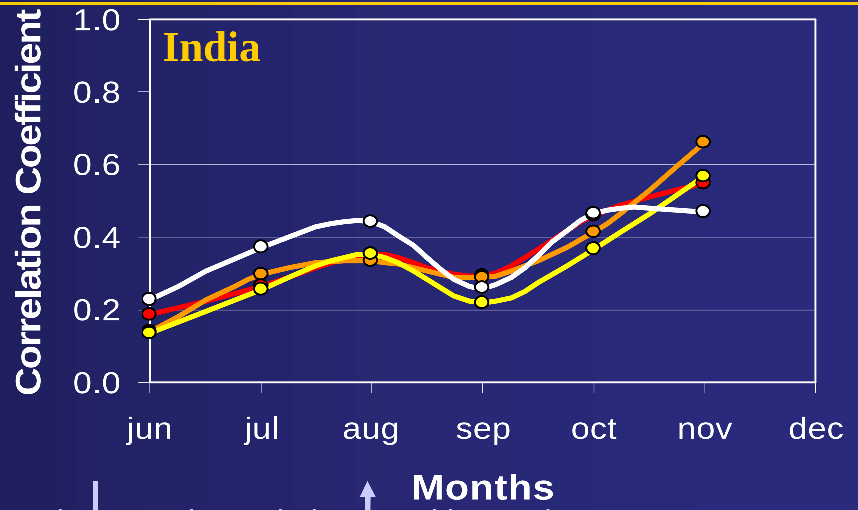


Europe: precipitation rate*(mm/d)* - *December*



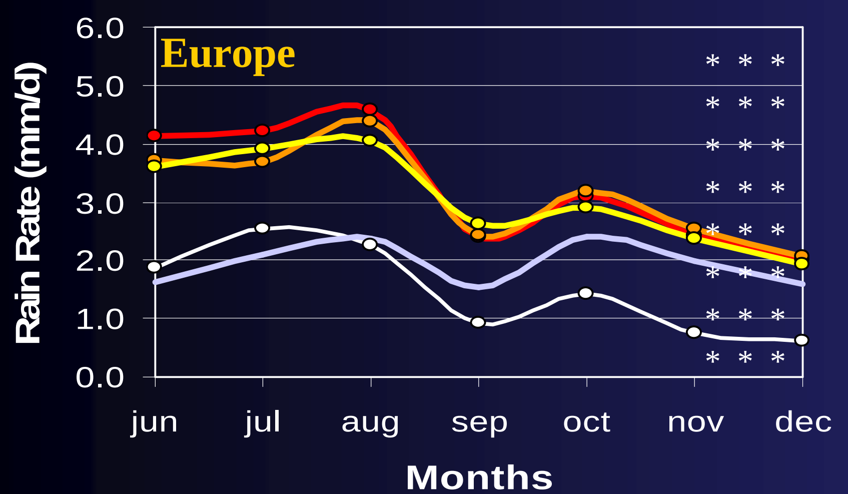
Time Series

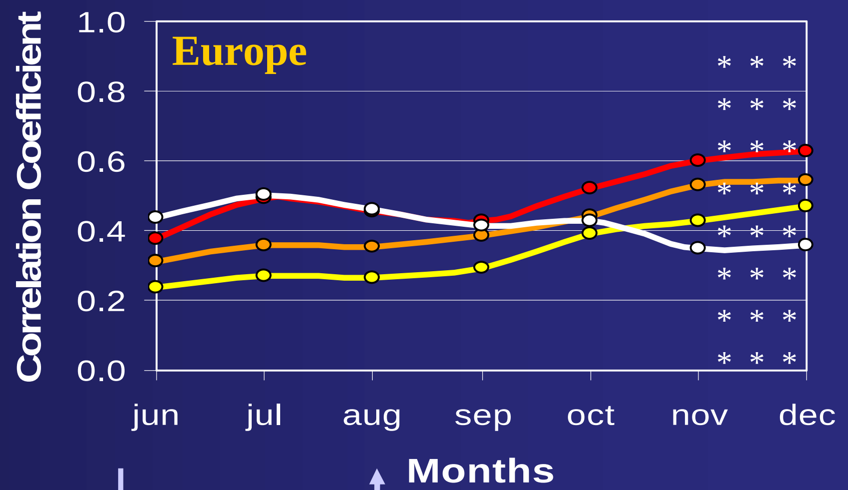




MODEL: overestimation (esp. day1, summer) ↓ and correlation ↑ with months.

CMORPH: good estimated amount. Correlation ↑ with months.



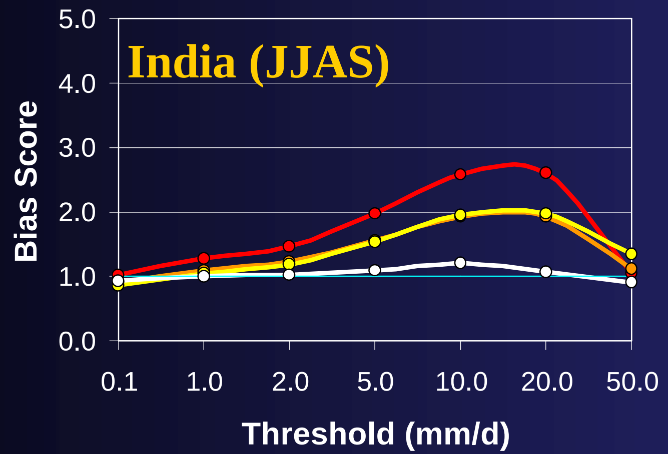


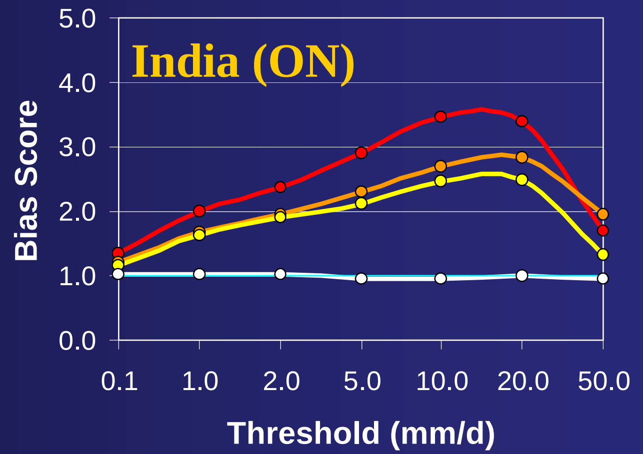
MODEL: overestimation (esp. day1 in summer) ↓ and correlation ↑ with months.

CMORPH: good in summer, then underestimation ↑ and correlation ↓ with months.

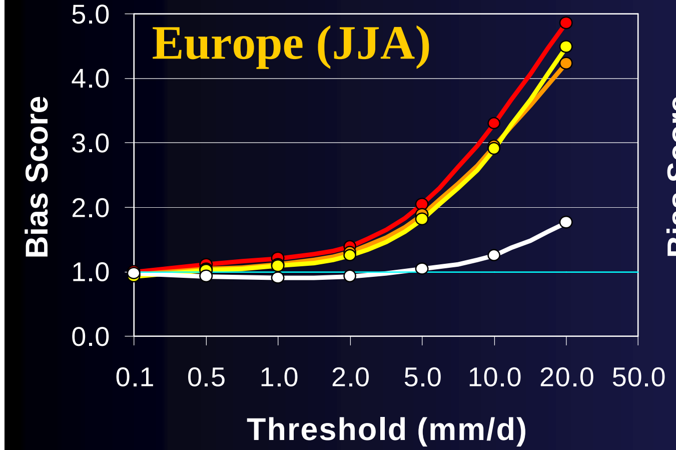
- day1 - day2 - day3 - cmorph - gauge

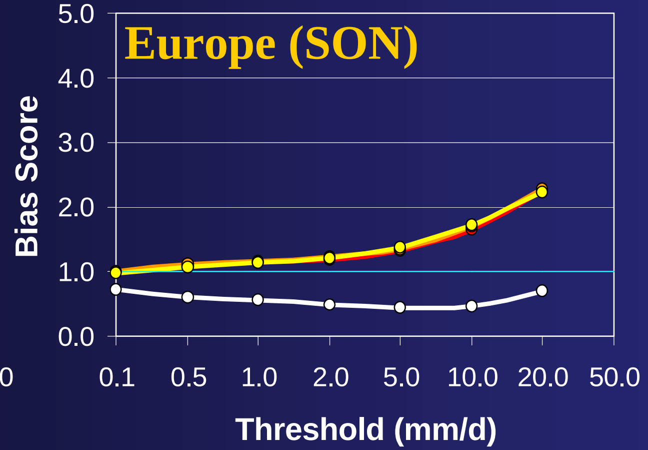
Categorical Statistics (increasing threshold) – BIAS SCORE

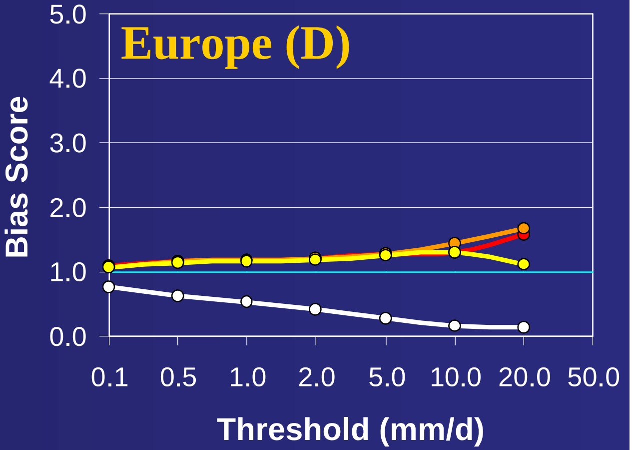




MODEL: strongest overprediction at day1, with moderate precipitation. **CMORPH**: perfect system.





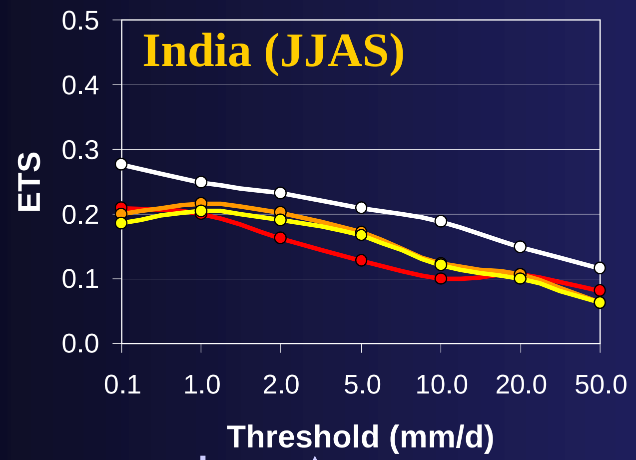


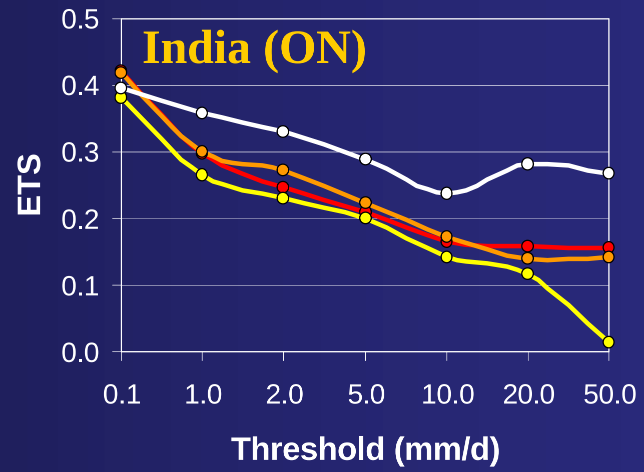
MODEL: strongest overprediction at day1 in summer, with heaviest precipitation.

CMORPH: light overestimation with heaviest summer precipitation, strong underestimation in winter

- day1 - day2 - day3 - cmorph

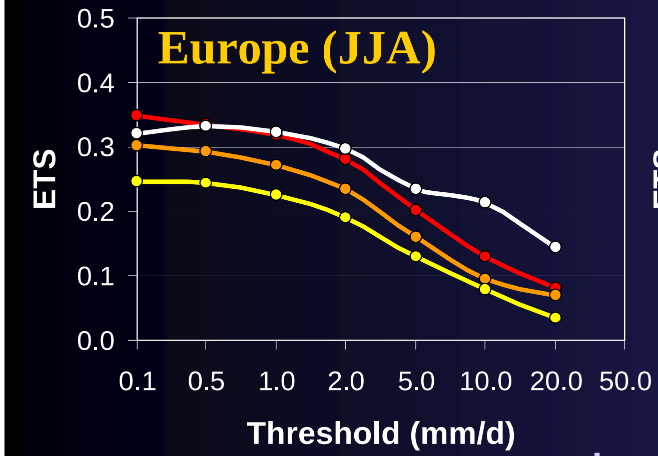
Categorical Statistics (increasing threshold) - ETS

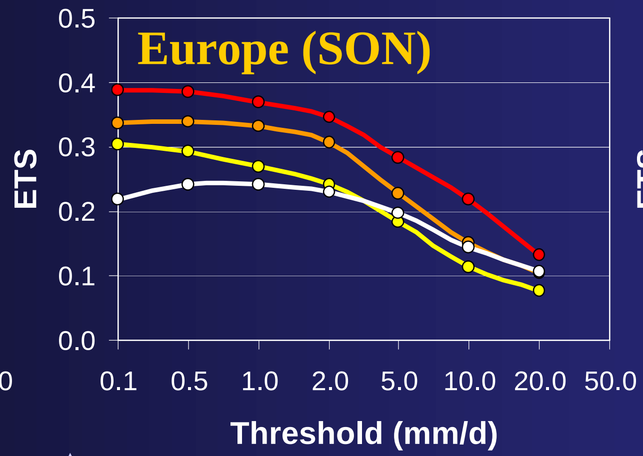


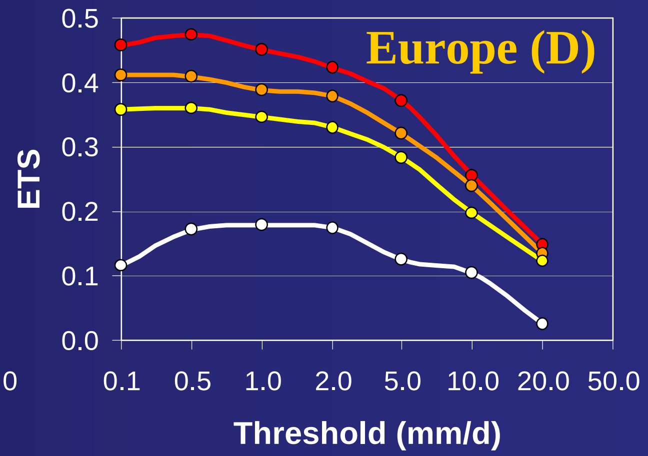


MODEL: the ability ↓ with ↑ amounts, with the monsoon rains, NOT with forecast lead-time.

CMORPH: same. Outperformes the model.







MODEL: the ability ↓ with ↑ amounts, in summer, with forecast lead-time.

CMORPH: shows problems approaching winter, outperformes the model during summer.

- day1 - day2 - day3 - cmorph

SUMMARY AND CONCLUSIONS

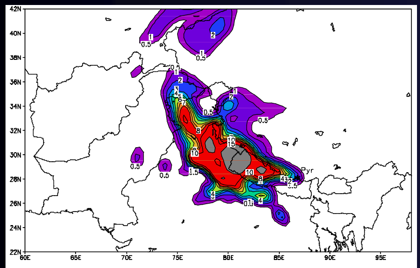
- ✓ **CEM-GCM overestimated precipitation,** especially 1) over the tropics, 2) during mid-latitude summer.
- ✓ **CEM-GCM overpredicted the frequency of all rain events**, particularly those exceeding 10-20 mm/d, especially 1) over the tropics, 2) dramatically during mid-latitude summer.
- ✓ **In the tropics and during mid-latitude summer, the overprediction was greater at day1** than at day2 and day3 (“spin-up” problems?).
- ✓ **The more the rain amount increased, the more the model’s ability dicreased**, due to the increasing amount of false alarms and to the greater difficulty in correctly predict the location of the heaviest rain.
- ✓ **Day1, Day2 and Day3** were increasingly less skillful over mid-latitudes, more similar to each other over the tropics.
- ✓ **CEM-GCM performed well when large-scale synoptic systems prevailed, showed problems with convective precipitation.**
- ✓ **CMORPH showed a complementary behavior:** best agreement with the gauge analysis when convective rainfall prevailed, worst performance when “stratiform” precipitation and snow occured.

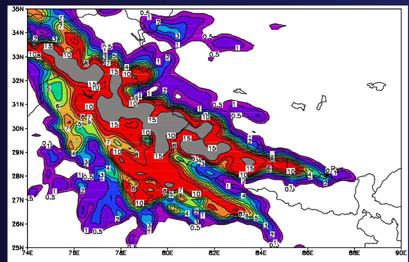
The model outperformed CMORPH over mid-latitudes during Fall and December 2004

FUTURE WORKS

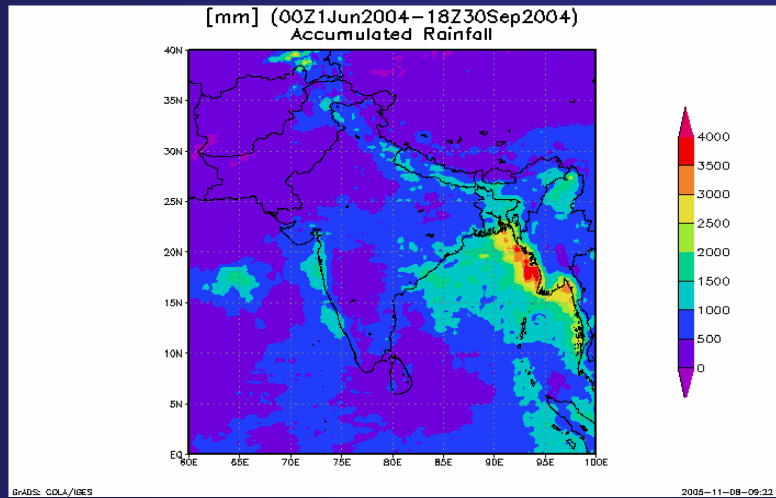
✓ To continue and to develop the global model verification effort over different large domains and seasons (at least 1 year, complete recommendations by WGNE).

✓ To assess the accuracy and skill of different regional models over Europe and the Indian Monsoon regions.





CEM-RSMs : winter (2002/2003) snow storms



TRMM: monsoon 2004

✓ To intercompare and evaluate multi-scale daily and sub-daily model simulations by means of CEOP integrated database, a highly valuable source of data for model verification.

THANK YOU!

A special thanks to Massimo Bollasina