Downscaled Multimodel Superensemble Forecasts of seasonal rains over the Asian Monsoon belt

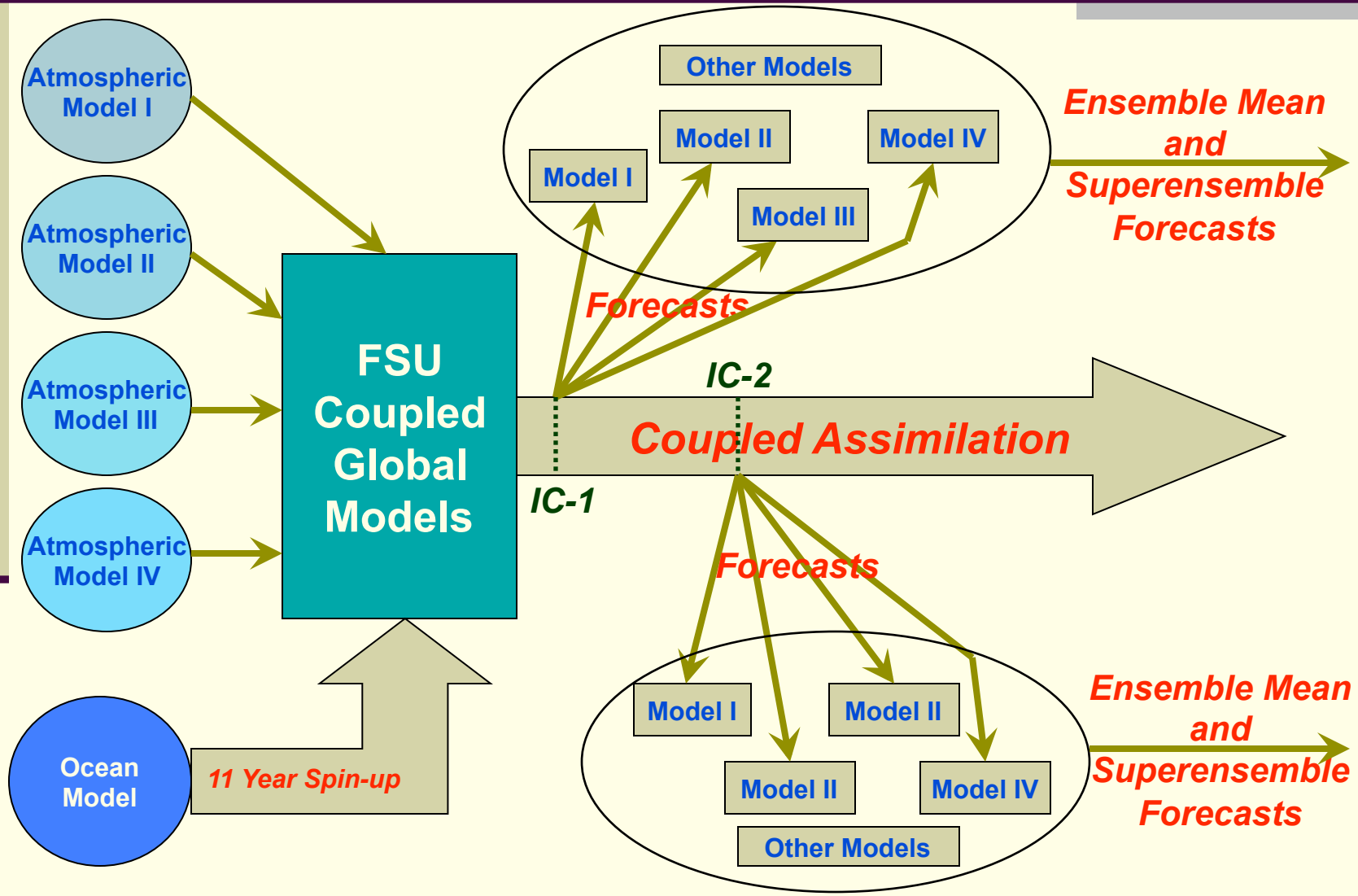
T. N. Krishnamurti

Department of Meteorology, Florida State University, Tallahassee, FL 32306, USA.

Downscale Methodology

1. Coarse resolution precipitation data from 16 coupled climate models (resolution 2.5 degree) were bi-linearly interpolated to 0.5 degree grid to conform with the APHORDITE observations.
2. Regression coefficients a and b were obtained by least square linear fit of the model interpolated precipitation with that of the high resolution observational data sets.
3. A cross-validation technique was adopted in which the year to be forecasted was excluded from the calculations in obtaining the regression coefficients. Coefficients vary in space and for every month of the years.
4. Now, these regression coefficients were applied to the forecast year to obtain downscaled model forecasts for that year.
5. The above steps (1-4) were repeated for each year of the period 1987 to 2001 to obtain downscaled forecasts of individual models.
6. The final outcome of this methodology is precipitation forecast at 0.5 degree grids over the South Asian region from 18 coupled models for forecast on monthly basis.

Coupled Assimilation Methodology



Multimodel Synthetic Ensemble/Superensemble Prediction System

Generating Synthetic Data Using EOF

Training | Forecast

PC | EOF

N - Actual Data Sets $F_i(x,T) = \sum_n F_{i,n}(T)\varphi_{i,n}(x)$

i = model

n = mode

Observed Analysis $O(x,T) = \sum_n P_n(T)\phi_n(x)$

Estimating Consistent Pattern

What is matching spatial pattern in forecast data Fi(x,t), which evolves according to PC time series P(t) of observed data, O(x,t) ?

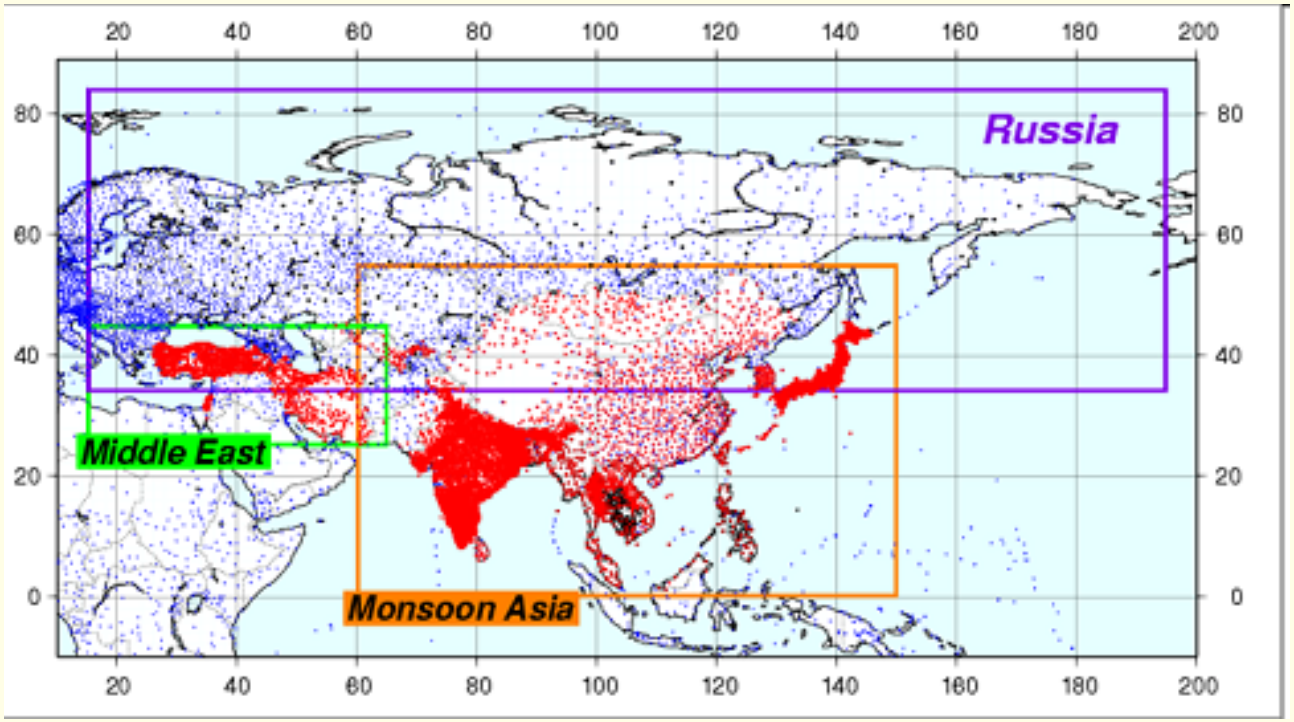
$P(t) = \sum_{n,i} \alpha_{i,n} F_{i,n}(t) + \varepsilon(t)$ → Forecasts

$F_i^{reg}(T) = \sum_n \alpha_{i,n} F_{i,n}(T)$ → Normalized Weights

Obs

N - Synthetic Data Sets $F_i^{syn}(x,T) = \sum_n F_{i,n}^{reg}(T)\phi_n(x)$ → Observation

APHORDITE's Precipitation datasets for Monsoon Asia for 1987-2001



Yatagai, A., P. Xie, and P. Alpert (2008): Development of a daily gridded precipitation data set for the Middle East, Adv. in Geosci., 12, 165-170

Characteristics of the 18 models

Name (Source)	Atmospheric Component			Oceanic Component		
	Model	Resolution	Initial Condition	Model	Resolution	Initial Condition
ANR (FSU)	FSUGSM with Arakawa-Schubert convection and new radiation (band model)	T63L14	ECMWF with Physical Initialization	HOPE global	5° longitude, 0.5-5° latitude, 17 levels	Coupled assimilation relaxed to observed SST
AOR (FSU)	FSUGSM with Arakawa-Schubert convection and old radiation (emissivity/absorptivity based)	T63L14	ECMWF with Physical Initialization	HOPE global	5° longitude, 0.5-5° latitude, 17 levels	Coupled assimilation relaxed to observed SST
KNR (FSU)	FSUGSM with Kuo convection and new radiation (band model)	T63L14	ECMWF with Physical Initialization	HOPE global	5° longitude, 0.5-5° latitude, 17 levels	Coupled assimilation relaxed to observed SST
KOR (FSU)	FSUGSM with Kuo convection and old radiation (emissivity/absorptivity based)	T63L14	ECMWF with Physical Initialization	HOPE global	5° longitude, 0.5-5° latitude, 17 levels	Coupled assimilation relaxed to observed SST
CCM3 (NCAR)	CCM3 atmospheric model	T63L18	ECMWF	SOM	2.4° x 1.2°-2.4°	Coupled assimilation
POAMA1 (Australia)	BMRC Atmospheric Model (BAM3)	R47L17	From latest atmosphere and ocean conditions from GASP	ACOM2	2° x 0.5°-1.5°, 25 levels	From ocean assimilation which was based on optimum interpolation (OI) technique.
CERFACS (France)	ARPEGE	T63L31	ERA40	OPA 8.2	2° x 2°, 31 Levels	Forced by ERA40
ECMWF (Europe)	IFS	T95L40	ERA40	HOPE-E	1.4° x 0.3°-1.4°, 29 levels	Forced by ERA40
INGV (Italy)	ECHAM-4	T42L19	Coupled AMIP type	OPA 8.1	2° x 0.5°-1.5°, 31 levels	Forced by ERA40
LODYC (France)	IFS	T95L40	ERA40	OPA 8.2	2° x 2°, 31 levels	Forced by ERA40
MPI (Germany)	ECHAM-5	T42L19	Coupled run relaxed to observed SST	MPI-OMI	2.5° x 0.5°-2.5°, 23 levels	Coupled run relaxed to observed SST
MetFr (France)	ARPEGE	T63L31	ERA40	OPA 8.0	182 x 152 GP, 31 levels	Forced by ERA40
UKMO (England)	ARPEGE	2.5 x 3.75, 19 levels	ERA40	GloSea OGCM HadCM3 based	1.25° x 0.3°-1.25°, 40 levels	Forced by ERA40

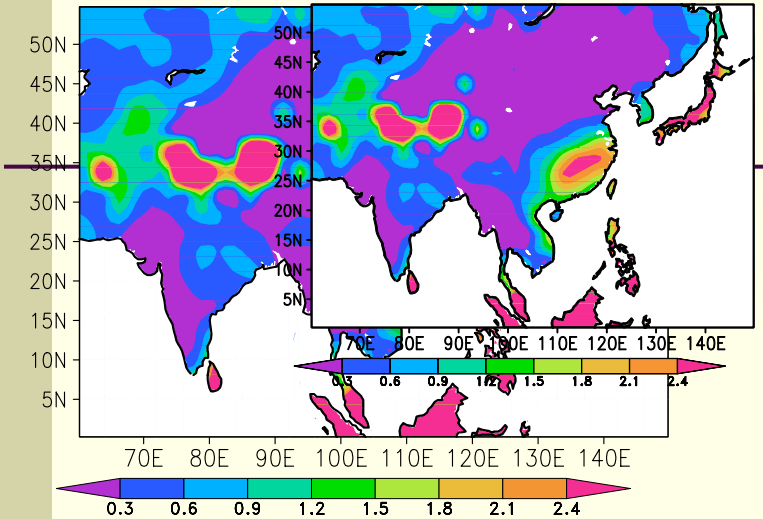
…..continued

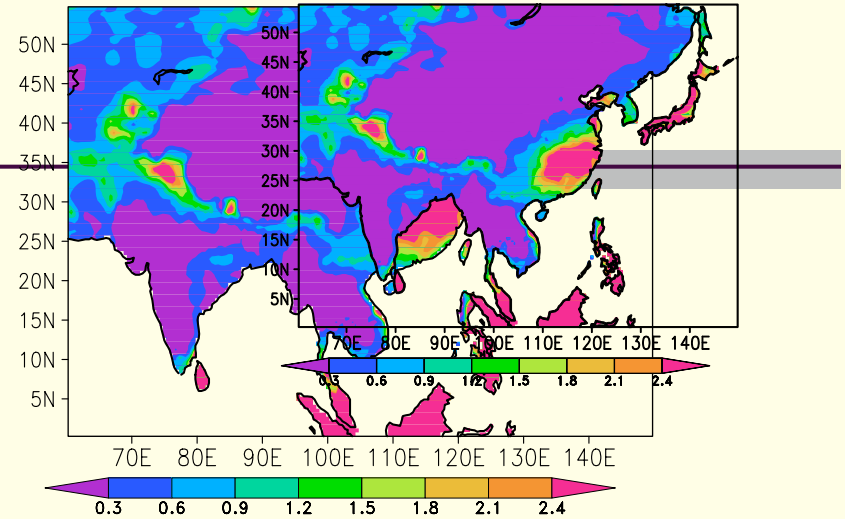
Institute	AGCM	Resolution	OGCM	Resolution	Ensemble Member	Reference
BMRC	BAM v3.0d	T47L17	ACOM2	0.5-1.5° latx 2° lon L25	10	Zhong et al., 2005
FRCGC	ECHAM4	T106 L19	OPA 8.2	2° cos(lat)x2° lon L31	9	Luo *et al*. (2005)
GFDL	AM2.1	2°latx2.5°lon L24	MOM4	1/3°latx1°lon L50♪	10	Delworth et al. (2006)
NASA	NSIPP1	2° latx2.5° lon L34	Poseidon V4	1/3° lat x 5/8° lon L27	3	Vintzileos *et al*. (2005)
NCEP	GFS	T62 L64	MOM3	1/3° lat x 1° lon L40	15	Saha *et al*. (2005)
SNU	SNU	T42 L21	MOM2.2	1/3° lat x 1° lon L32	6	Kug *et al*. (2005)
UH	ECHAM4	T31 L19	UH Ocean	1° lat x 2° lon L2	10	Fu and Wang (2001)

CMAP

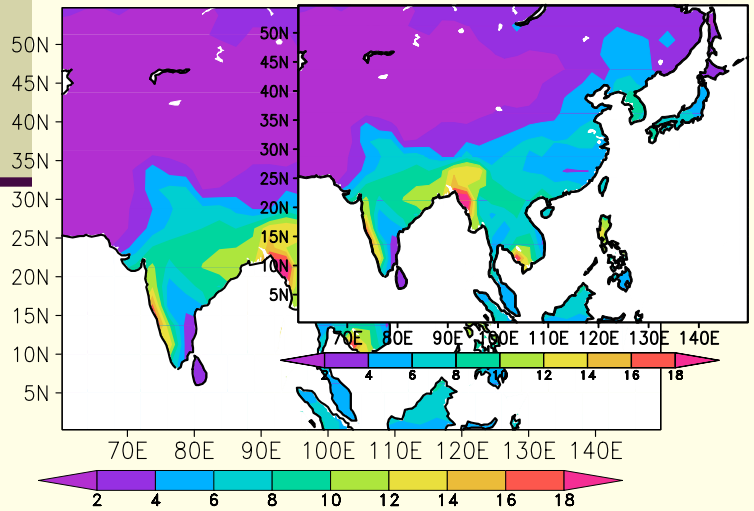
Precipitation Climatology - January

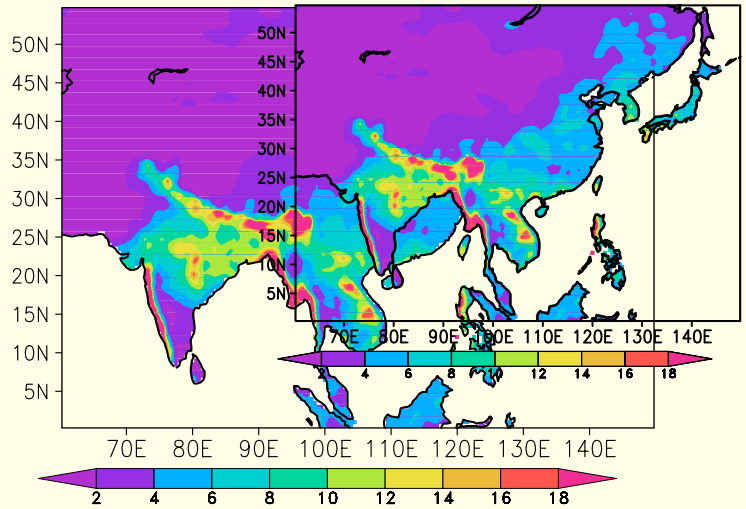
APHRODITE



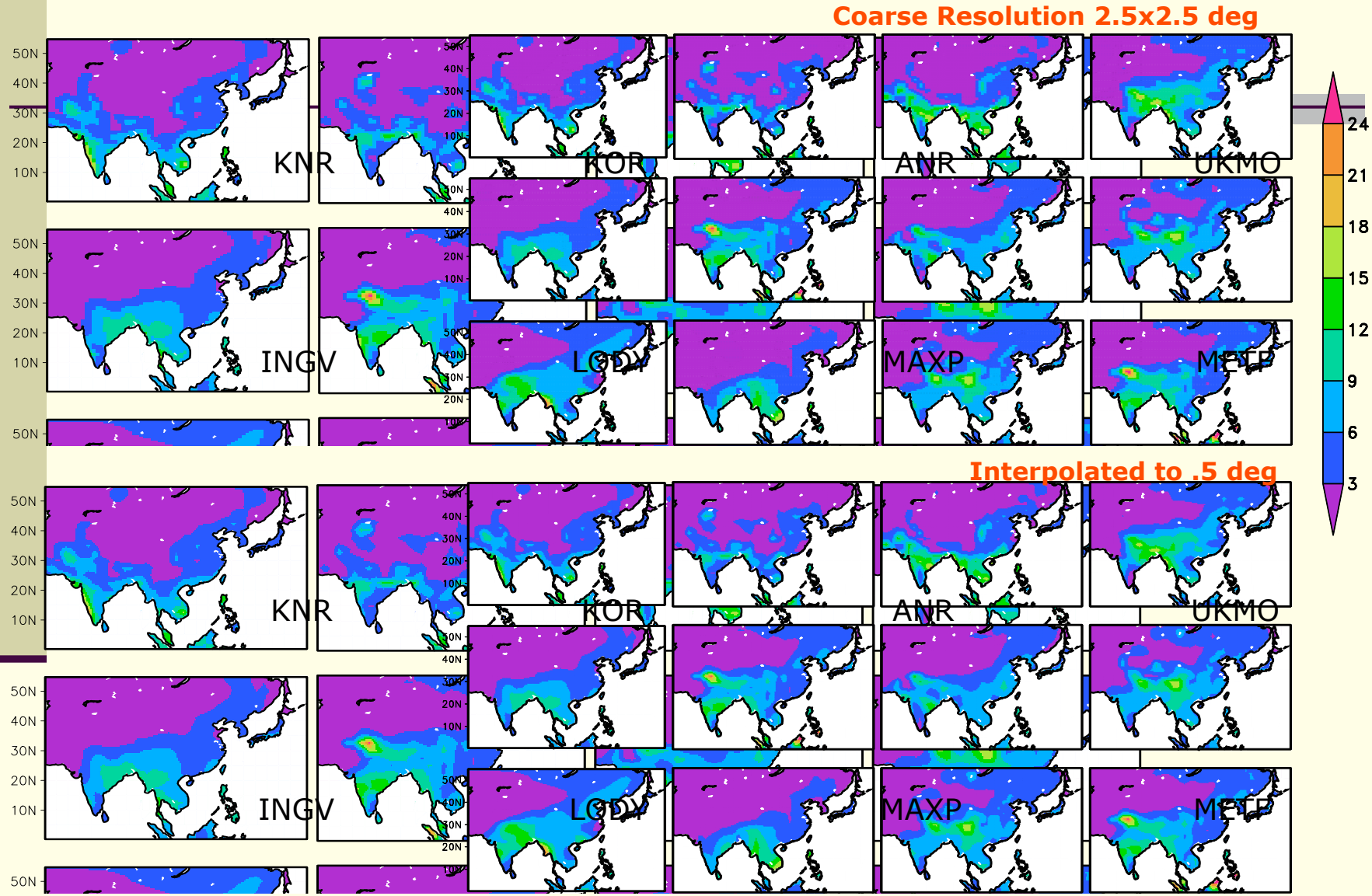


Precipitation Climatology - July

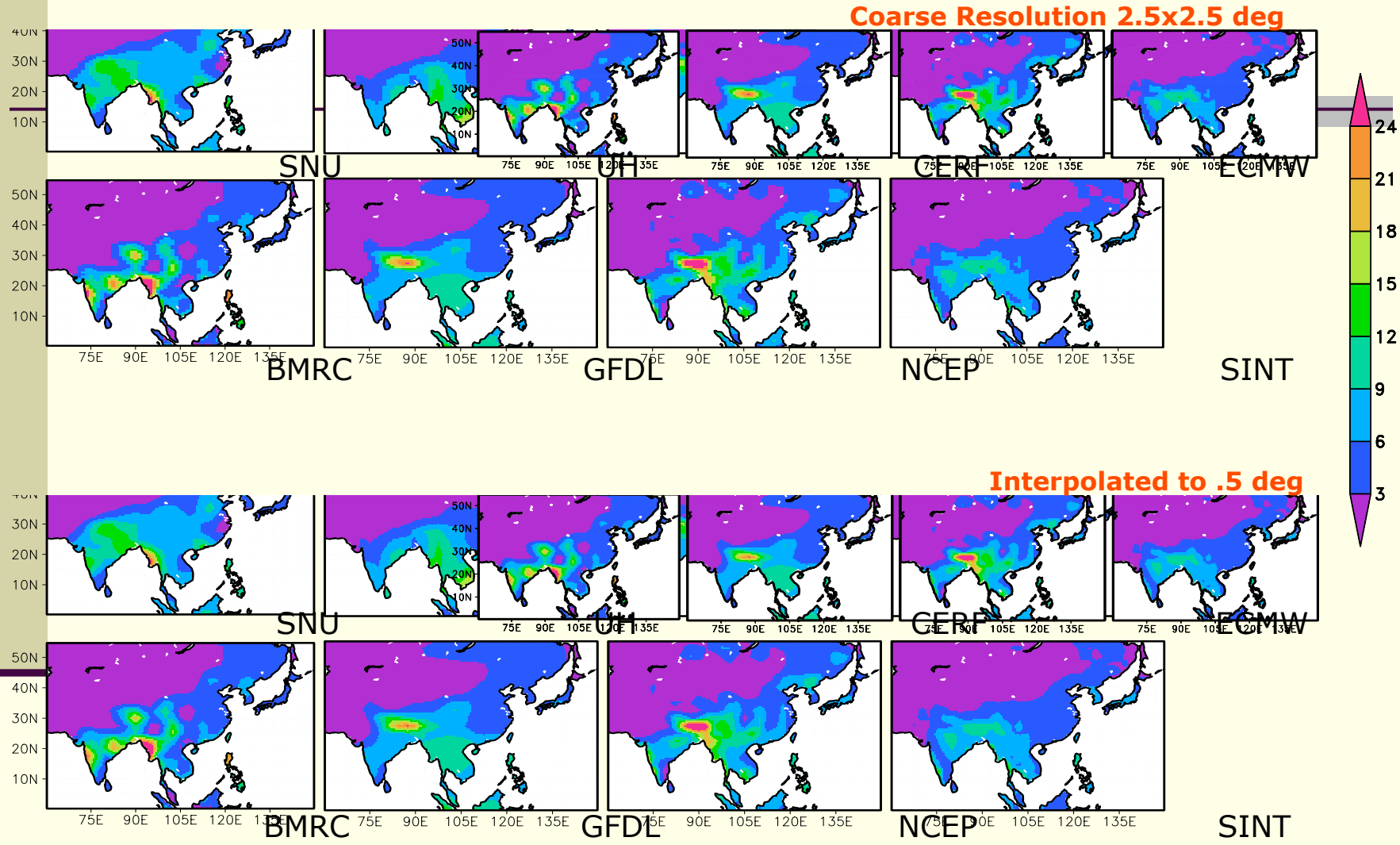




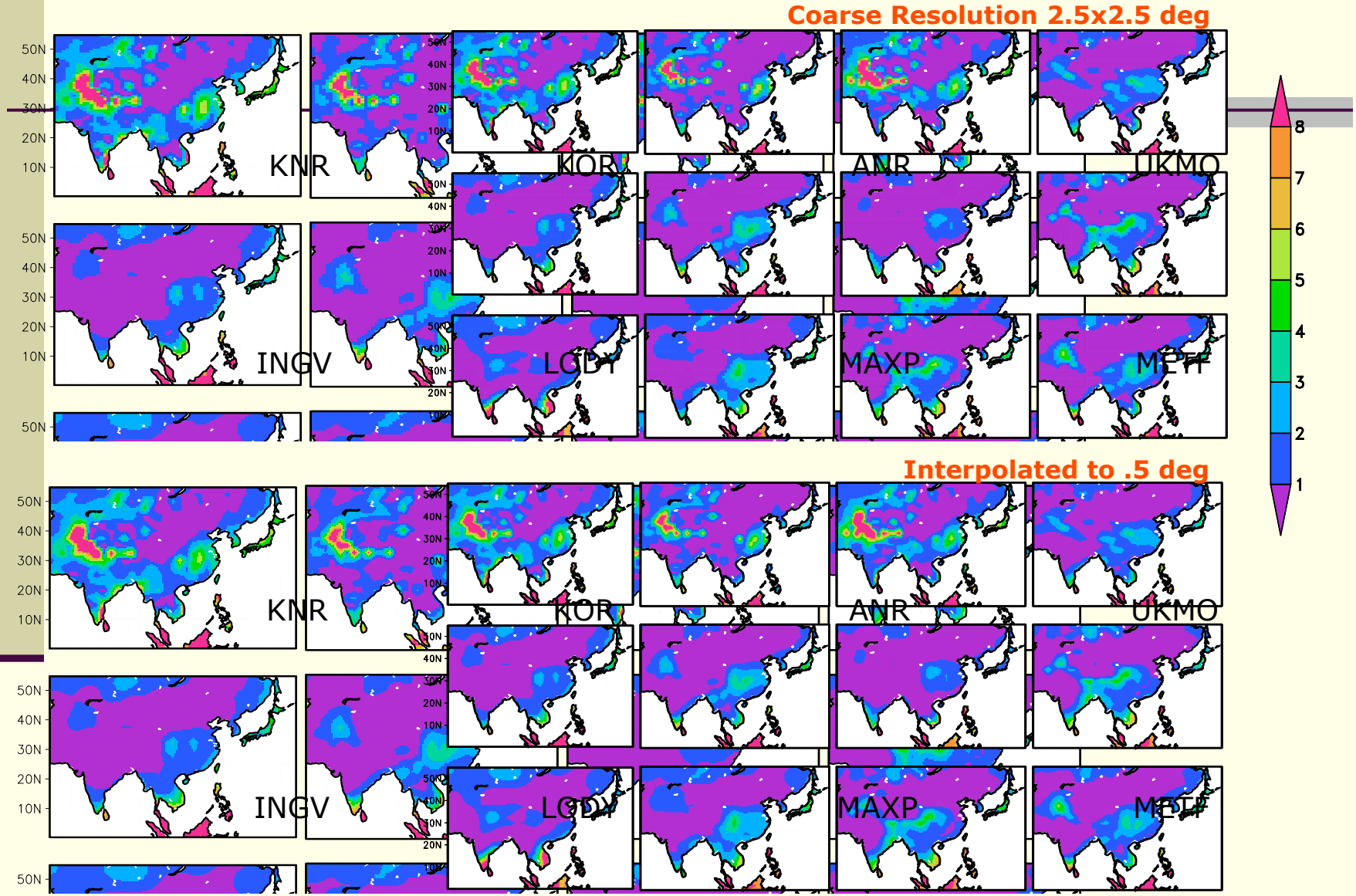
Precipitation climatology, July 1987-2001



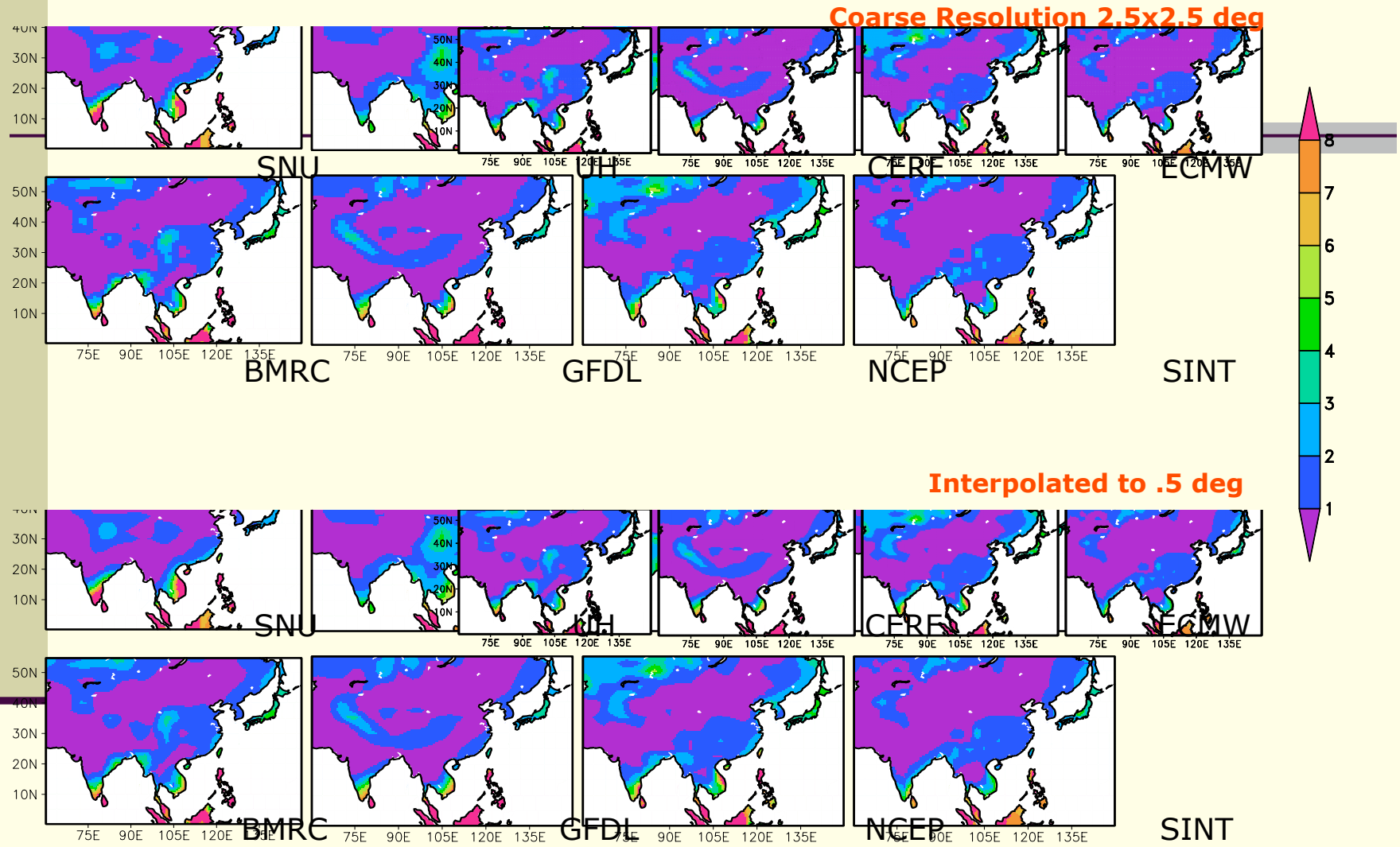
Precipitation climatology, July 1987-2001



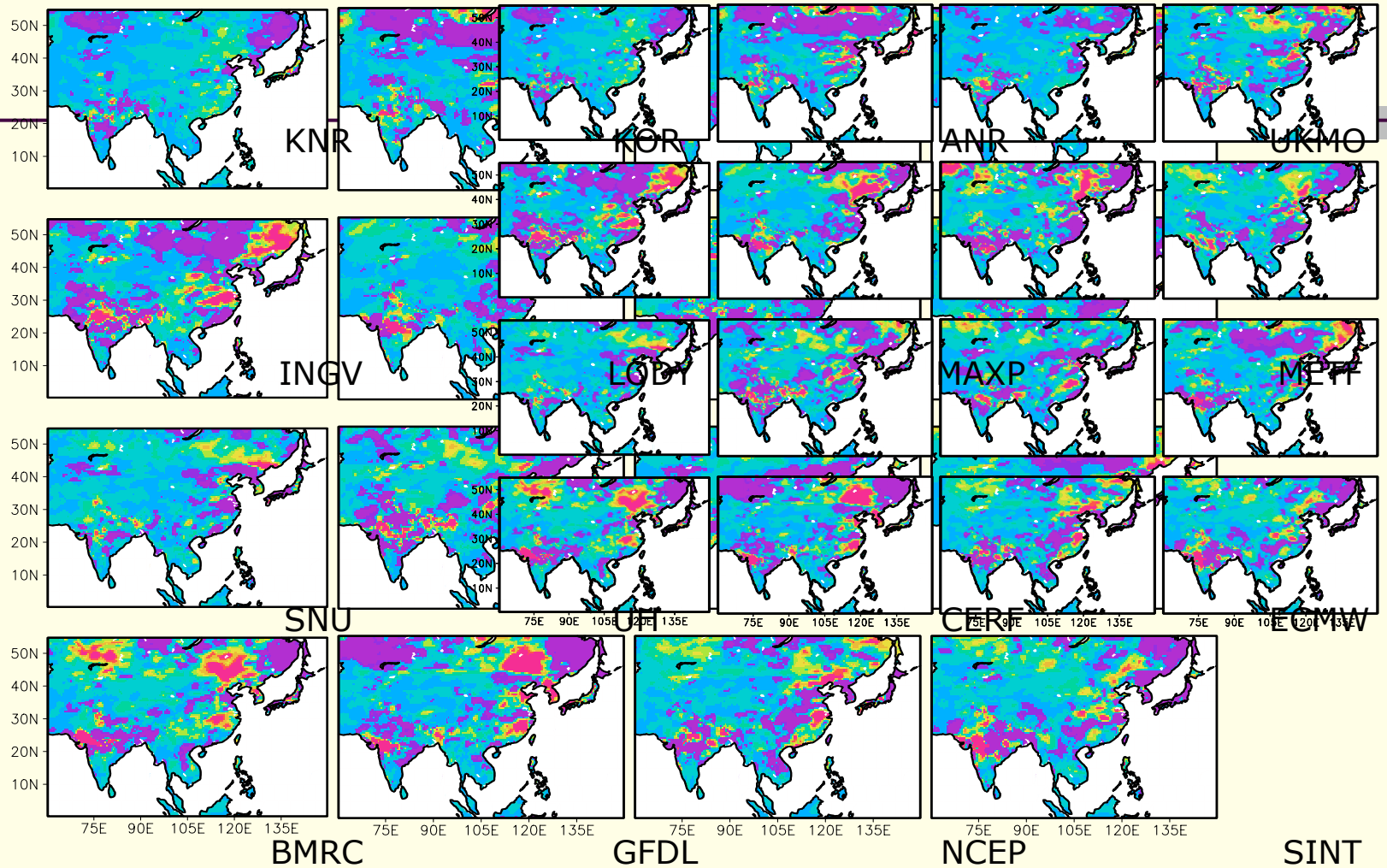
Precipitation climatology, December 1987-2001



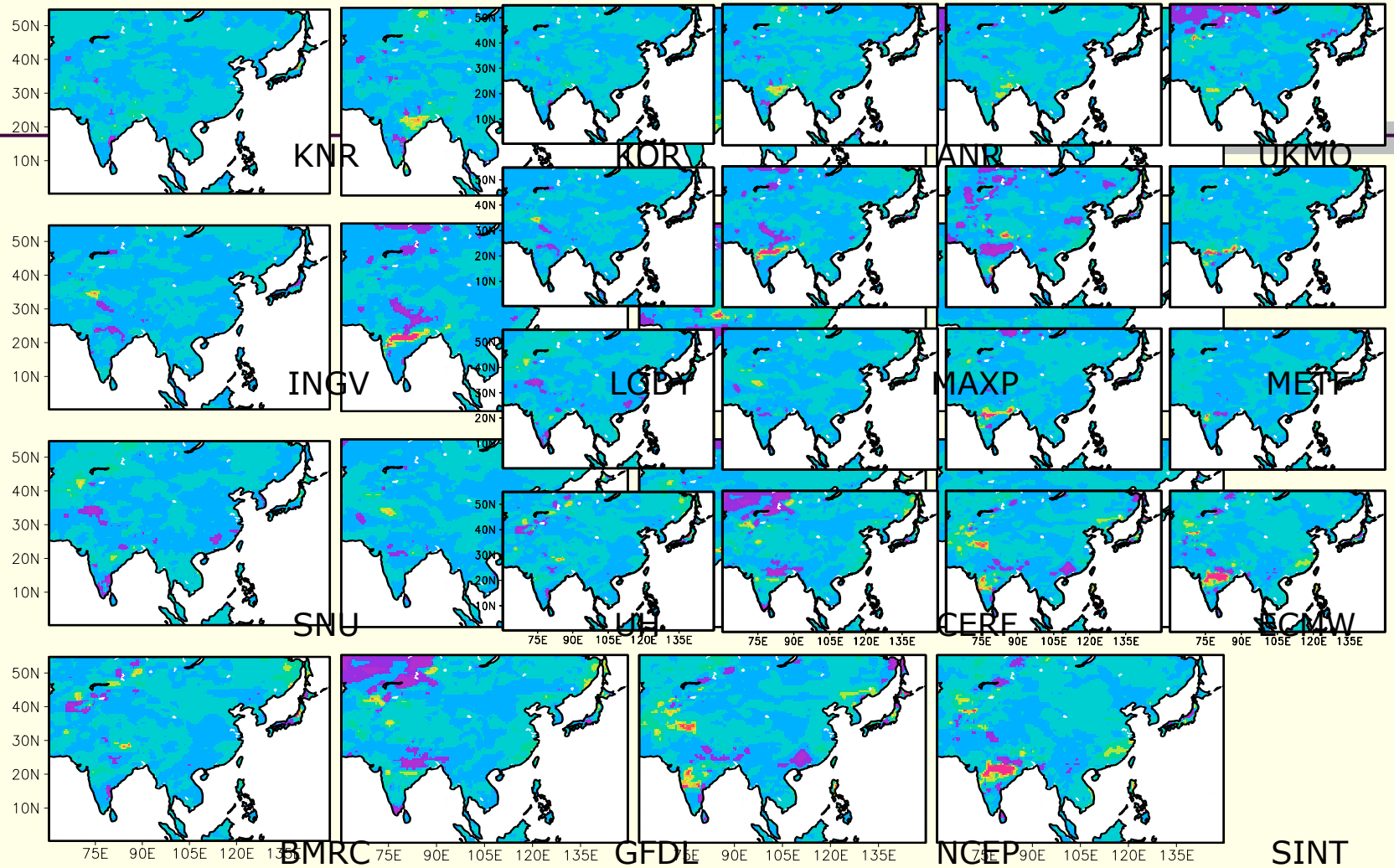
Precipitation climatology, December 1987-2001



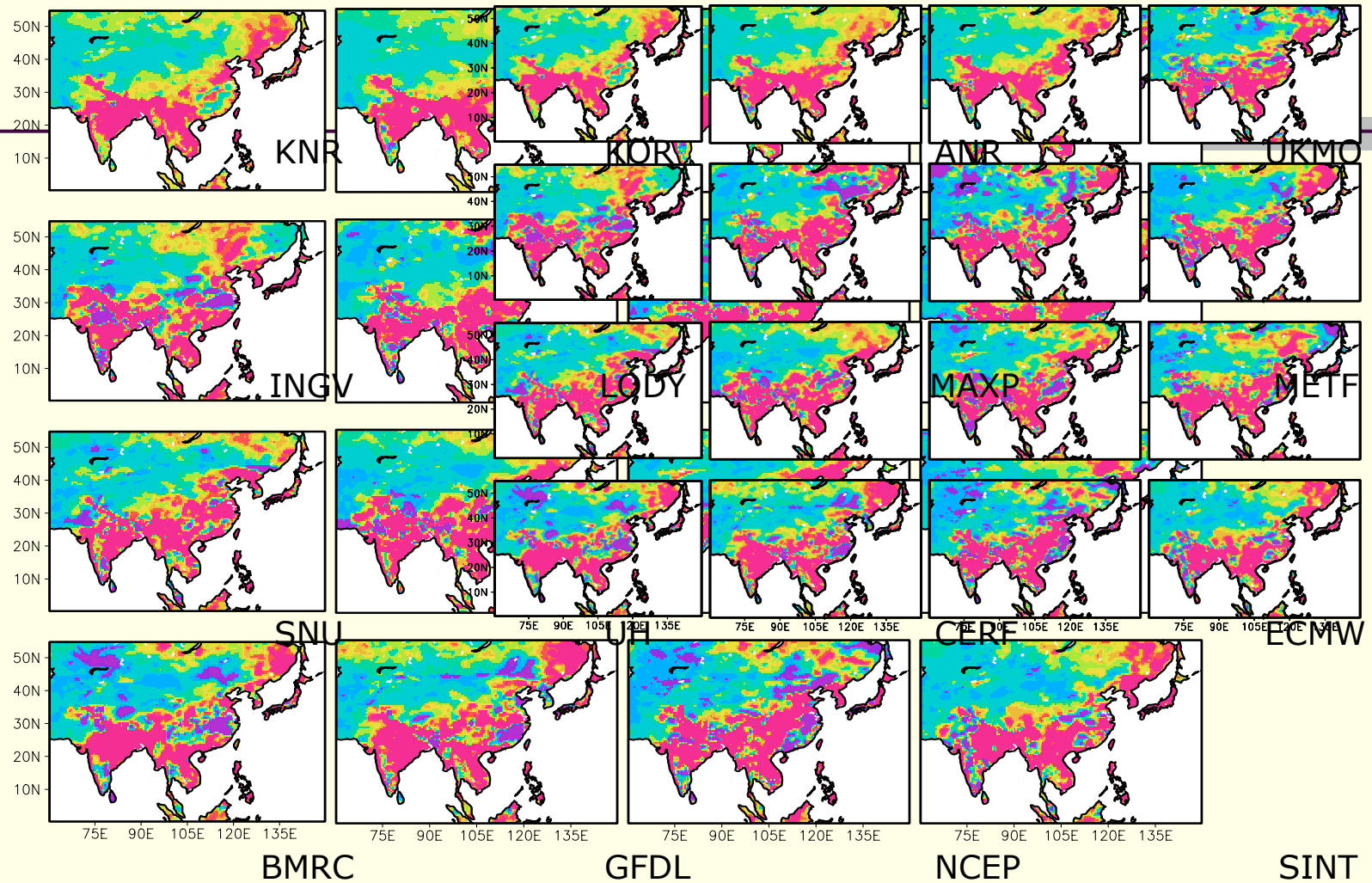
Spatial Distribution of Regression Coefficients- 'a' SLOPE, for July



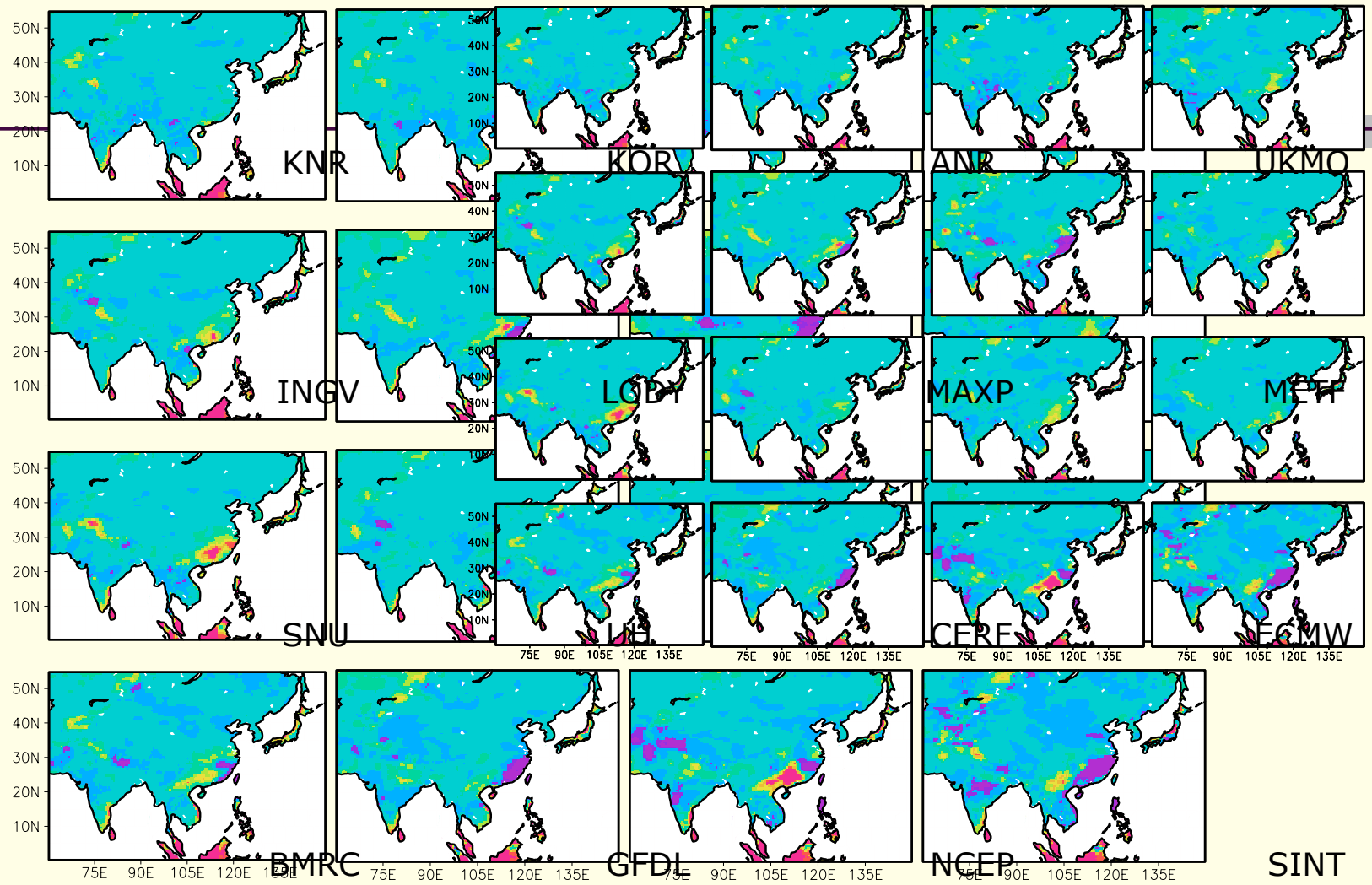
Spatial Distribution of Regression Coefficients- 'a' SLOPE, for December



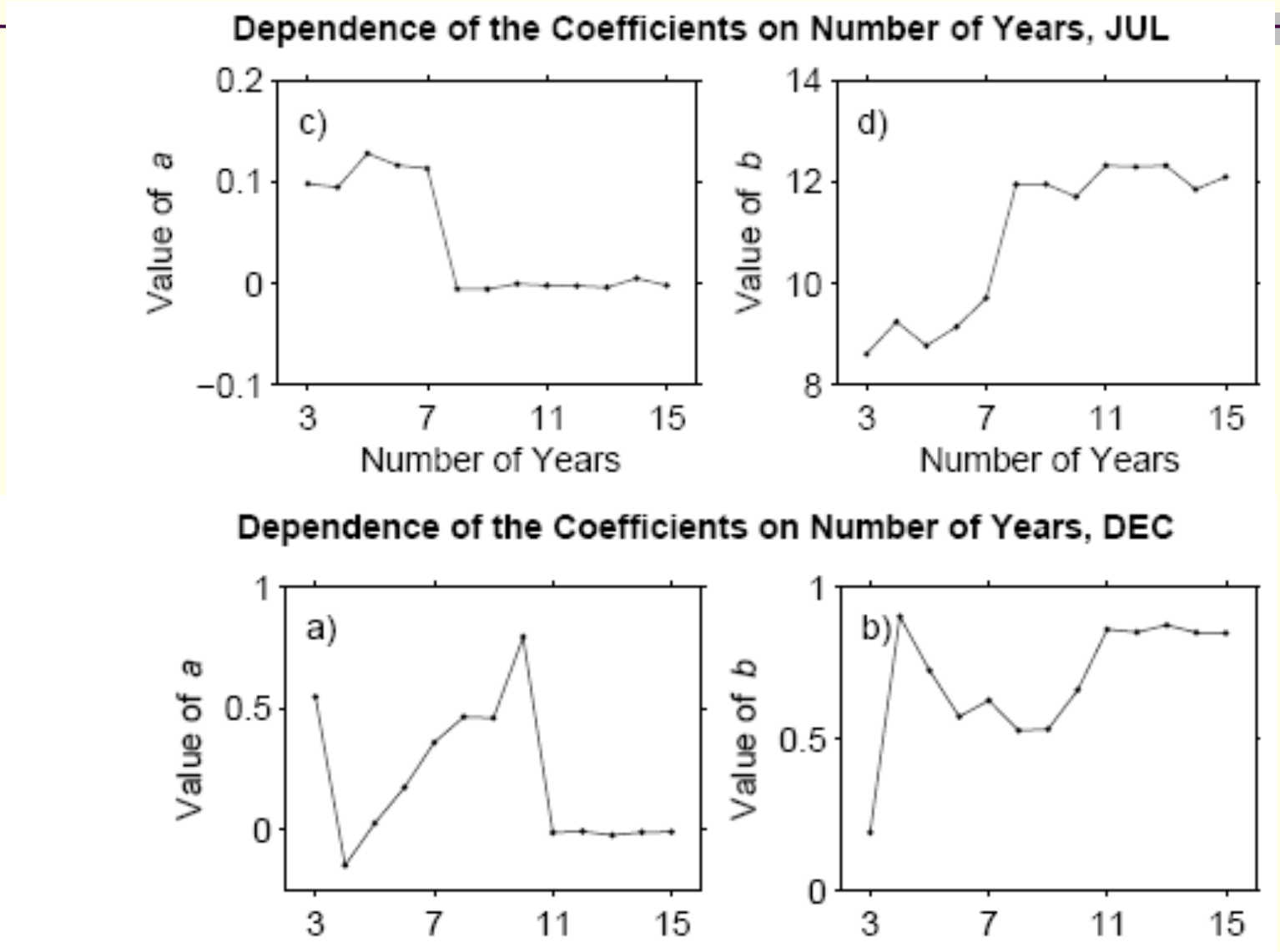
Spatial Distribution of Regression Coefficients- 'b' INTERCEPT, for July



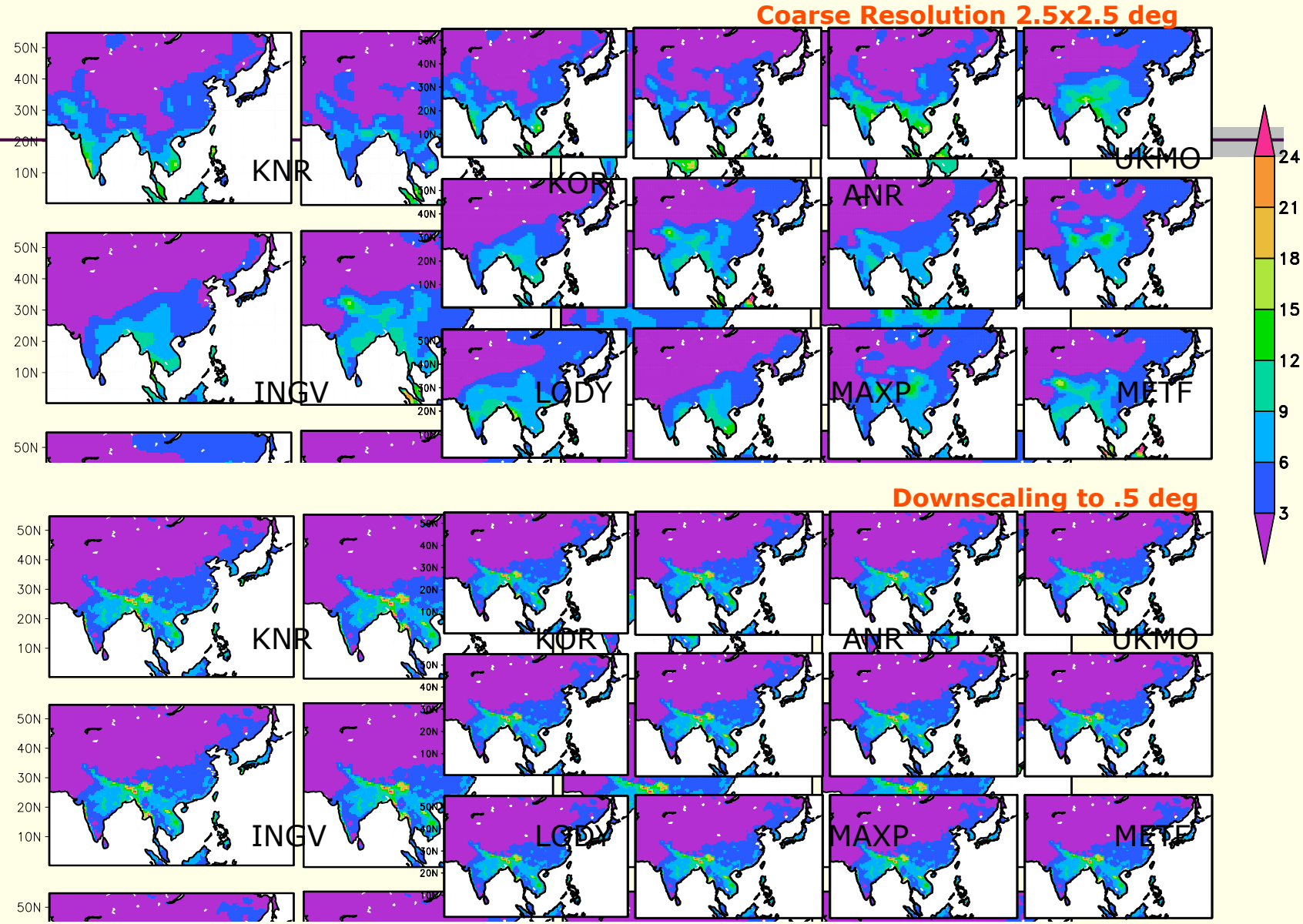
Spatial Distribution of Regression Coefficients- 'b' INTERCEPT, for December



Dependence of downscaling coefficients (a & b) on the number of years in the training period, from FSU Coupled models forecasts at 75.5°E, 13.5°N. The values of the regression coefficients get stable when more than 10 years of data is used in training.

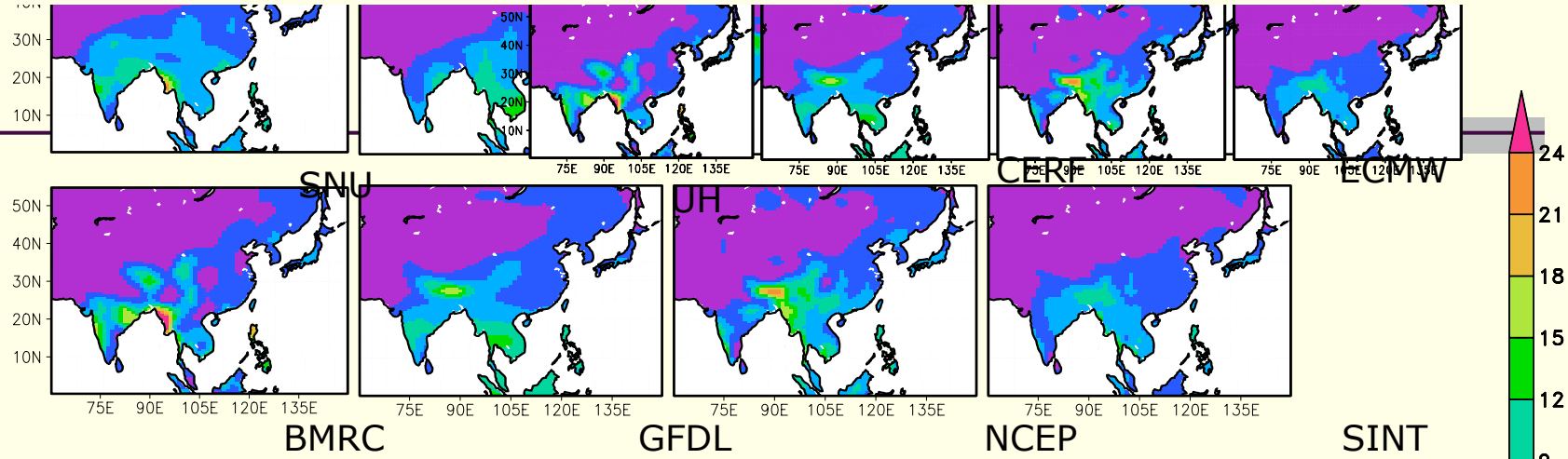


Precipitation climatology, JJAS 1987-2001

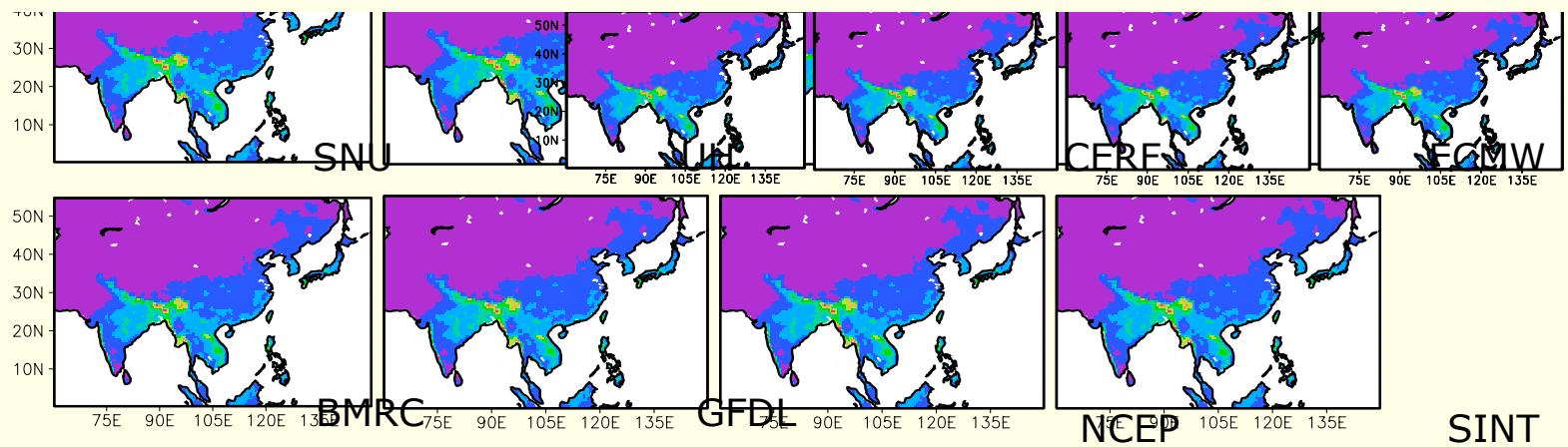


Precipitation climatology, JJAS 1987-2001

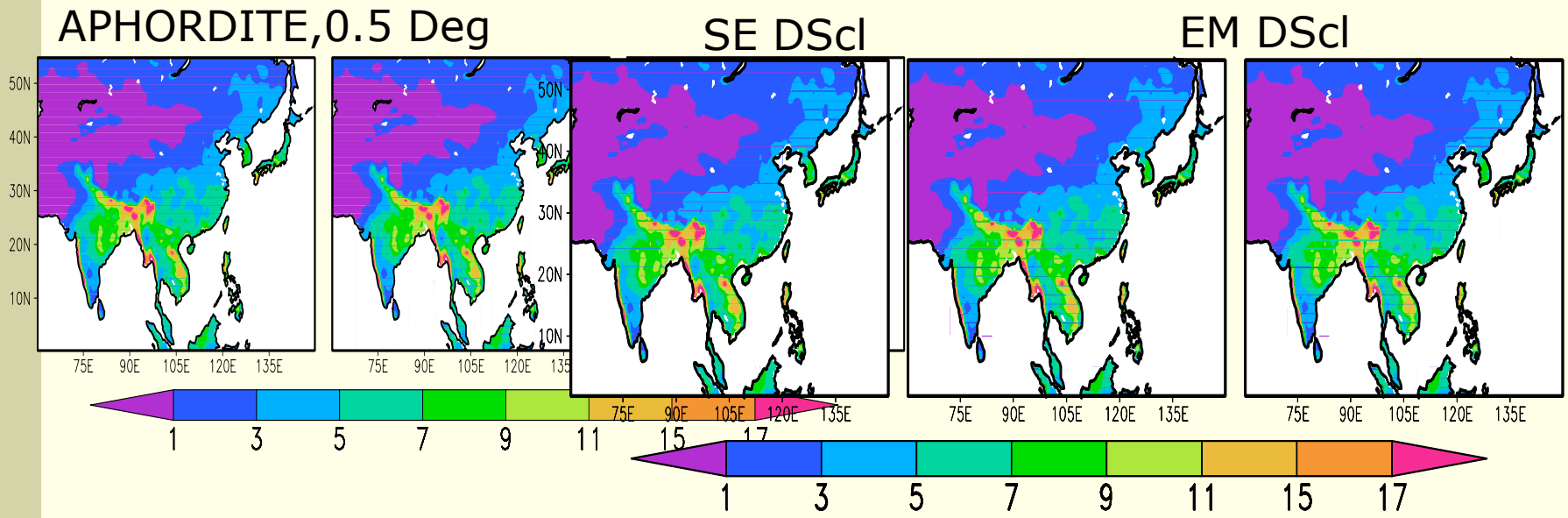
Coarse Resolution 2.5x2.5 deg



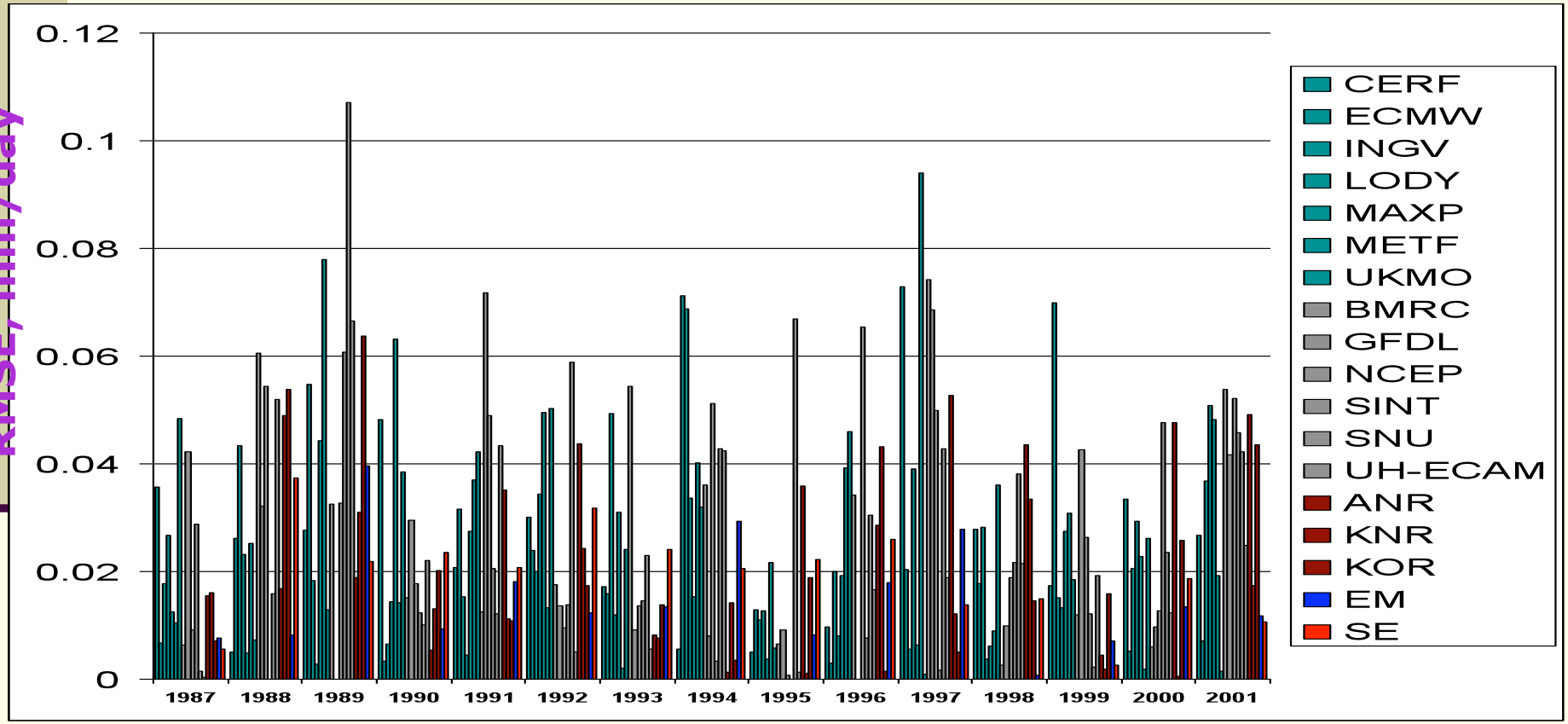
Downscaling to .5 deg



Precipitation climatology, JJAS 1987-2001 – Downscaling

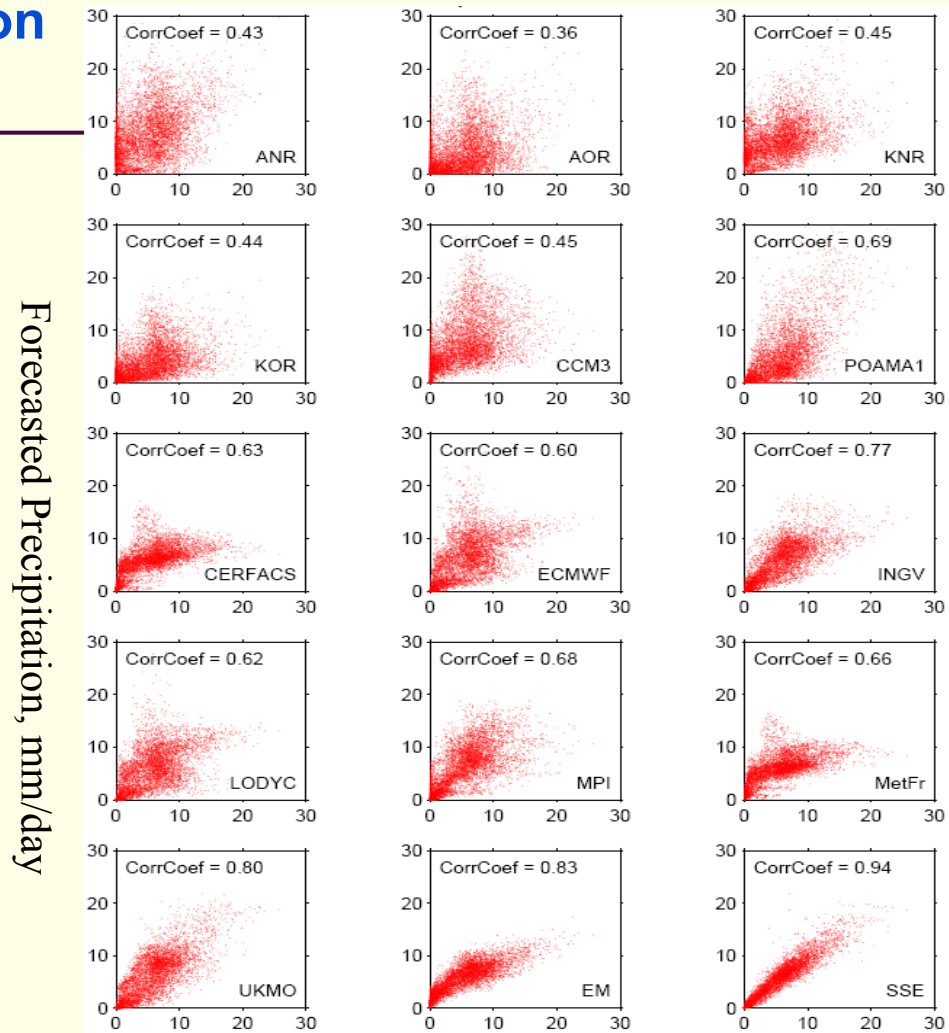


Seasonal forecast skills of precipitation over the South Asian monsoon region (69.25°–149.75°E;0.25°S–54.75°N) during June-August of 1987–2001: RMS errors



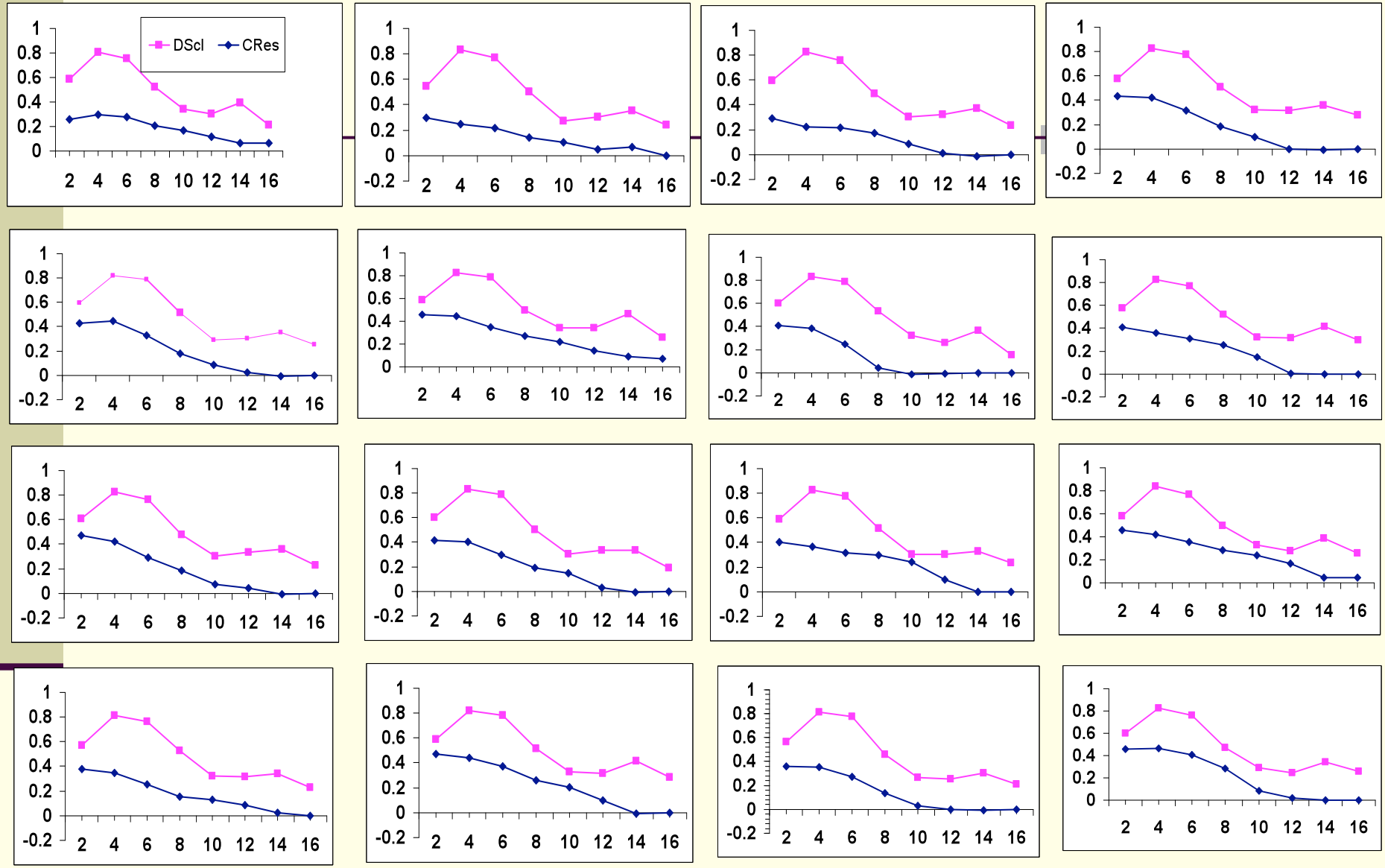
Observed vs. Forecasts of Precipitation, June-August 1989-2001, South Asian Monsoon Region

- ❑ CERFACS and MetFr used similar models for their Atmospheric (ARPEGE) and Oceanic (OPA) components.
- ❑ UKMO, which used HadAM3 atmospheric model and GloSea ocean model, showed higher skill compared to CERFACS and MetFr.
- ❑ ECMWF and LODYC used IFS model as their atmospheric component.
- ❑ Two different versions of ECHAM were used by INGV and MPI as their atmospheric model.



➢ It appears that models with same atmospheric component show similar pattern in precipitation forecast over this region.

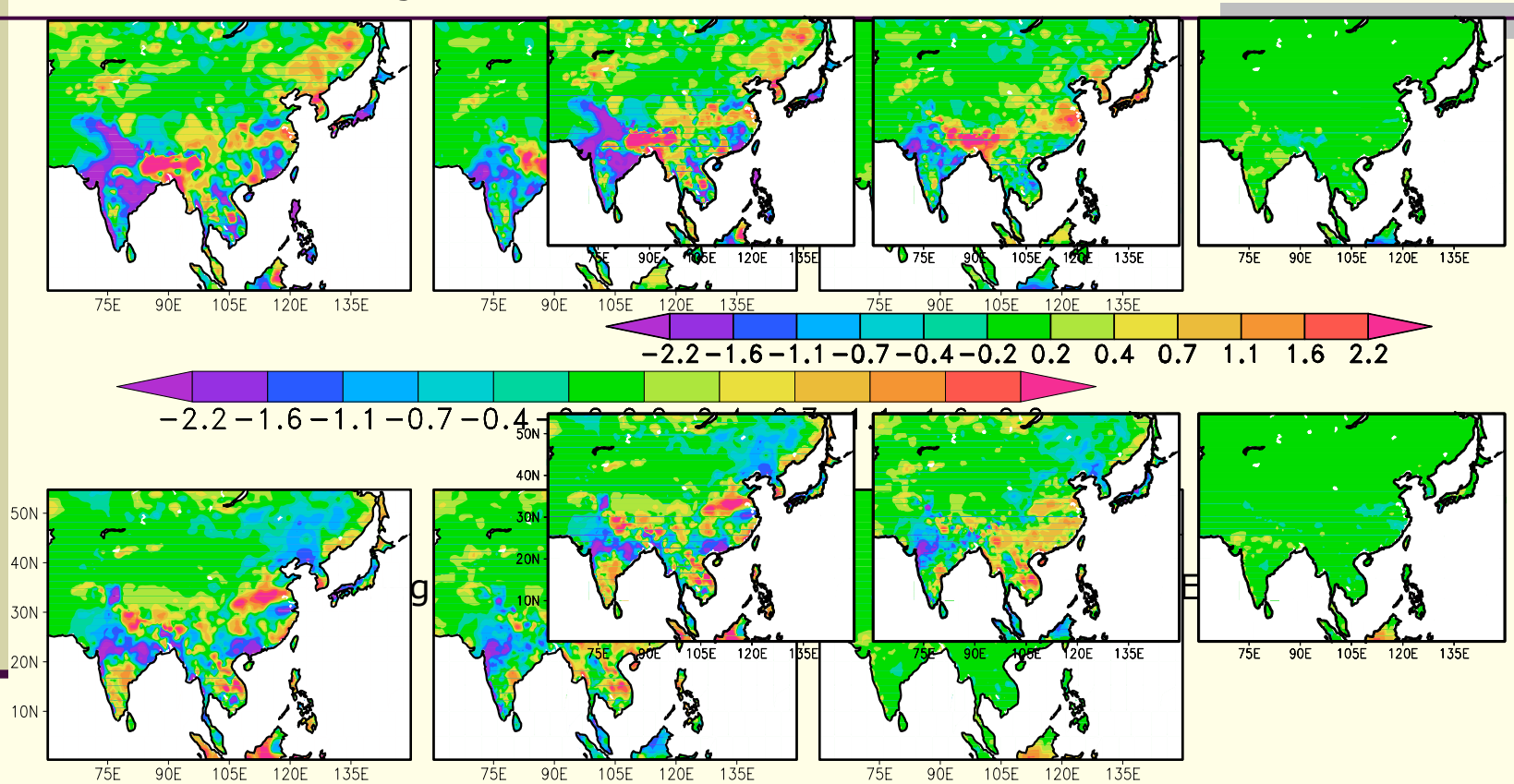
Equitable Threat Score of precipitation over Monsoon Asia (JJAS)



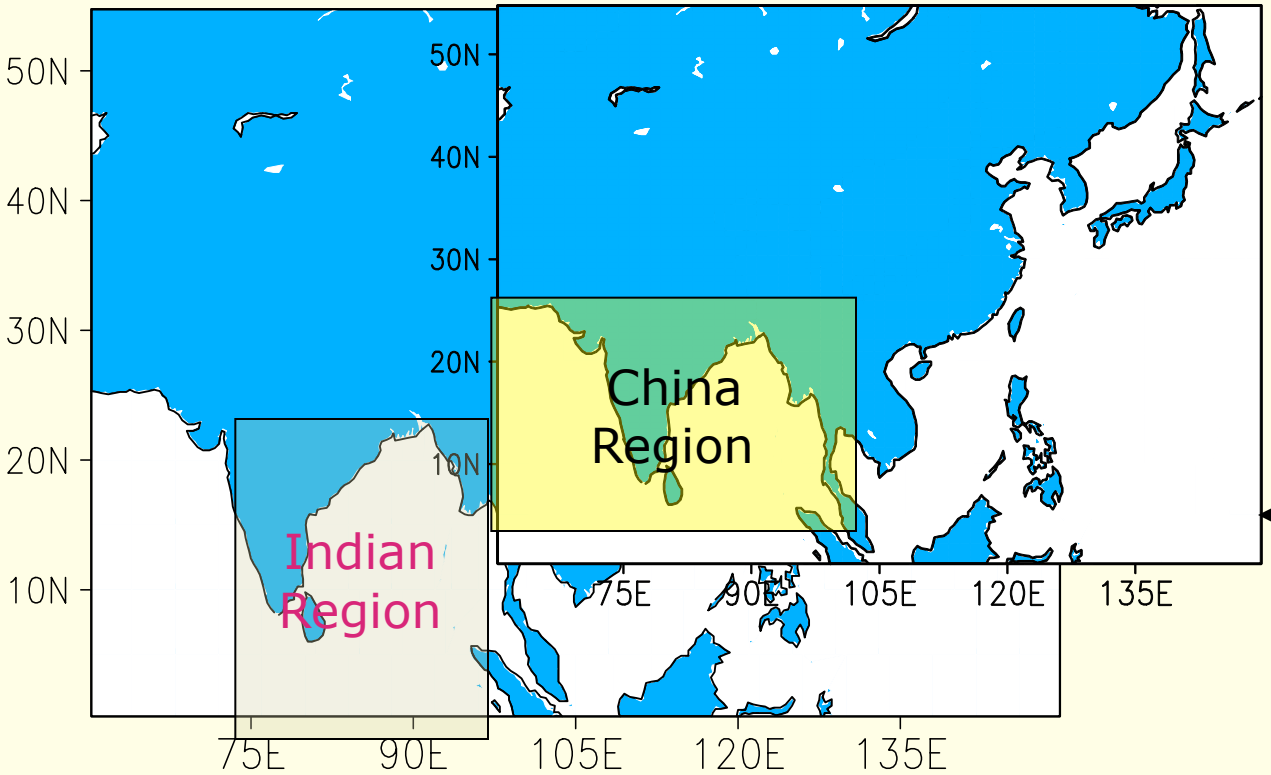
For the period 1987-2001 before and after downscaling

Precipitation Anomaly from Observation, SE and EM, JJAS

APHORDITE, .5 Deg, 1987 SE, 1987 EM, 1987



Three Regions of Study Including Monsoon Asia



Indian Region

(70-90E; 8-28N)

China Region

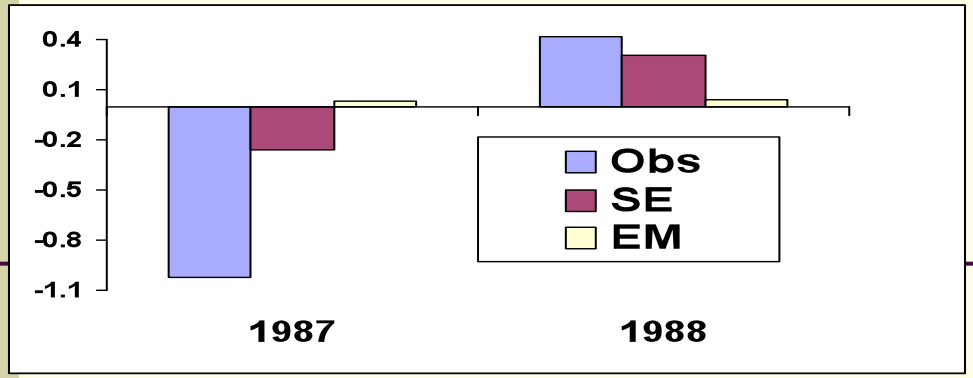
(90-120E;20-35N)

Monsoon Asia

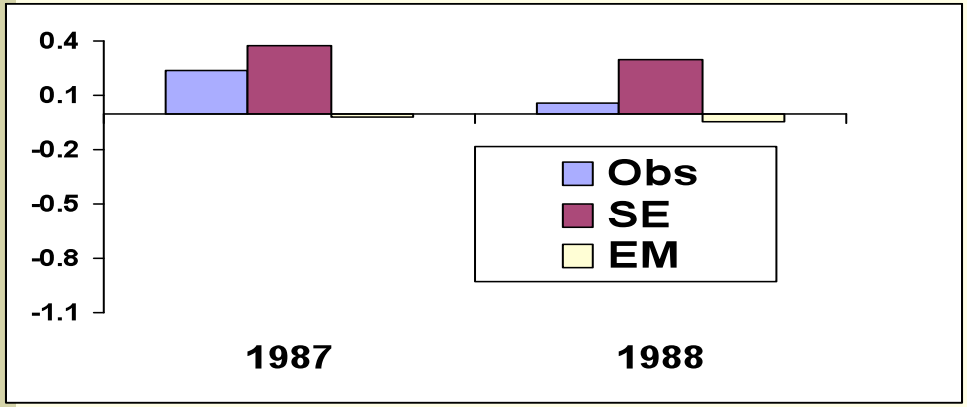
(61-149E; 1-54N)

Precipitation Anomaly JJAS

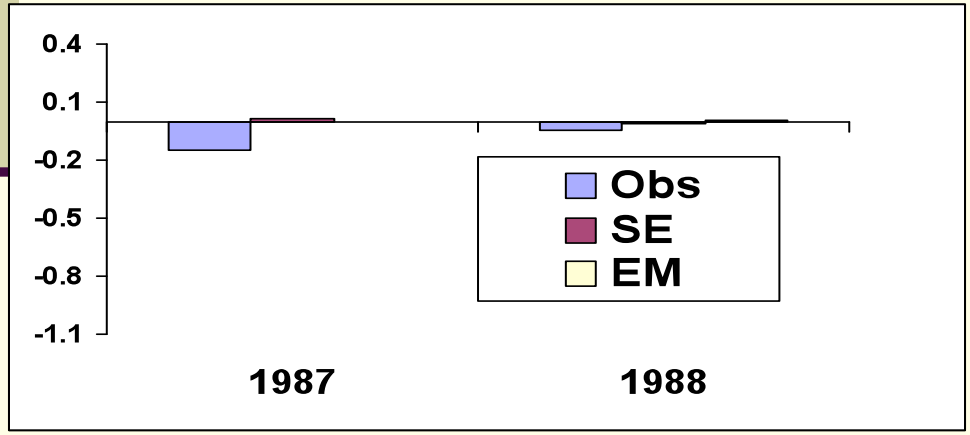
Rainfall, mm/day



Indian Region

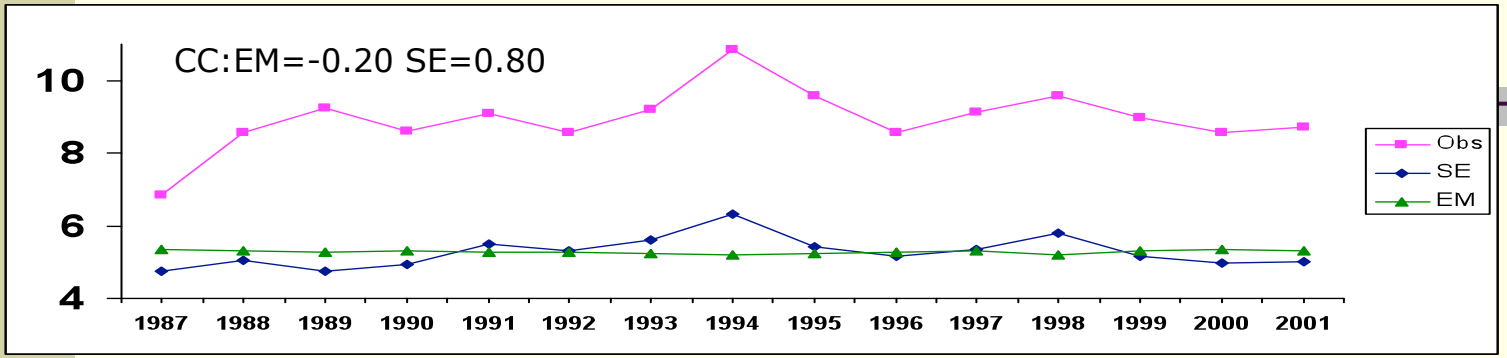


China Region

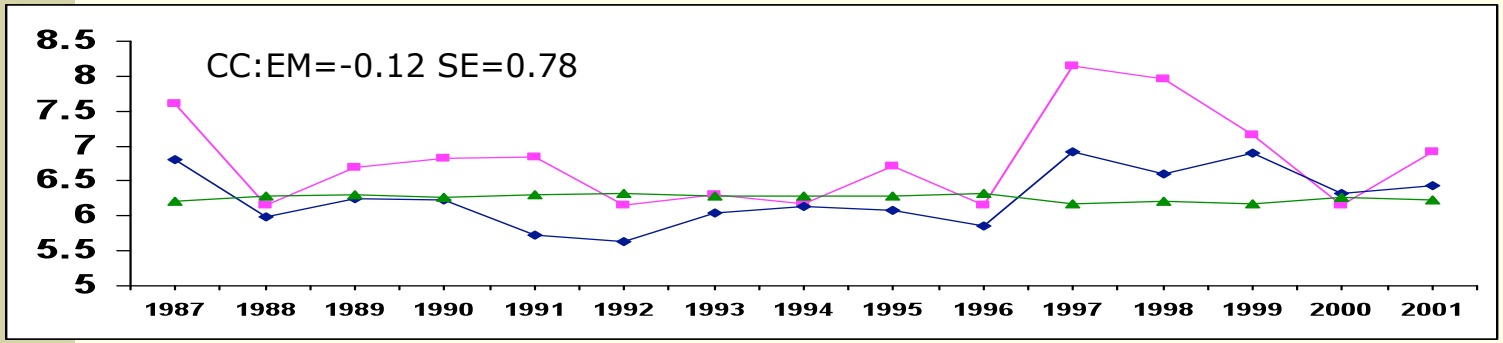


Monsoon Asia

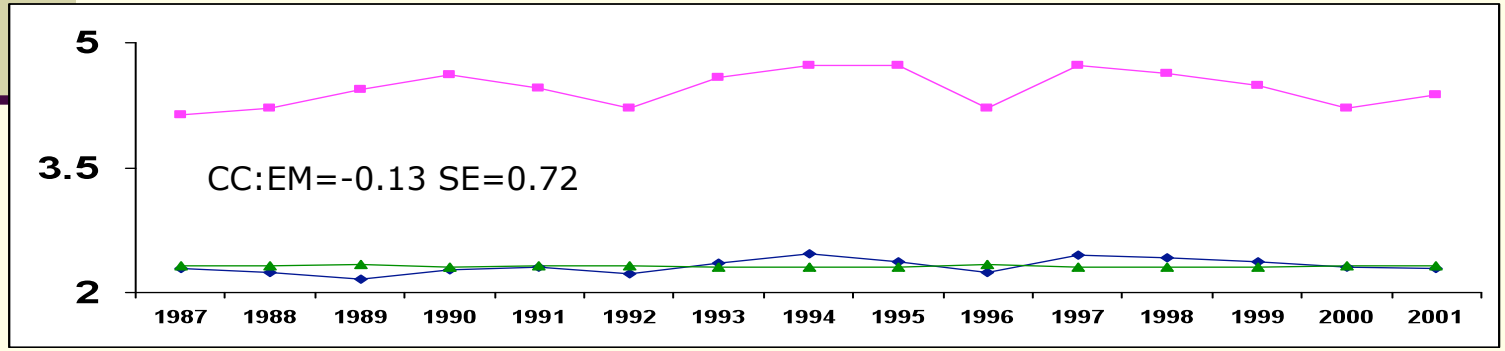
Precipitation over various regions of Monsoon Asia



India(70-90 E; 8-28N)



China(90-120 E;20-35N)



Monsoon Asia (61-149E; 1-54N)

Probabilistic forecasting

$$b = \underbrace{\sum_{i=1}^{I} p(y_i)(y_i - \overline{o}_i)^2}_{\text{reliability}} - \underbrace{\sum_{i=1}^{I} p(y_i)(\overline{o}_i - \overline{o})^2}_{\text{resolution}} + \underbrace{\overline{o}(1 - \overline{o})}_{\text{uncertainty}}$$

$$= b_{\text{rel}} - b_{\text{res}} + b_{\text{unc}},$$

where $\overline{o} = (1/n)\Sigma_{k=1}^{n} o(k)$ is the unconditional mean frequency of occurrence of the event .

One of the most widely used methods for verification of probability forecasts is the Brier skill score.

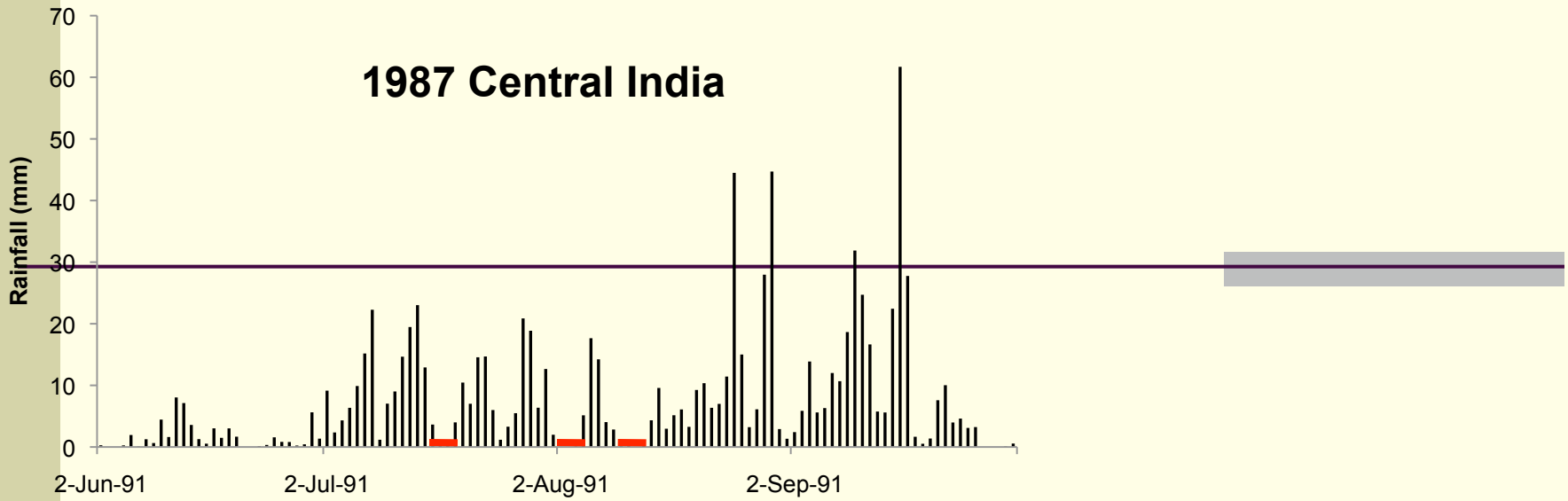
Following Wilks (1995), the Brier score is then defined as

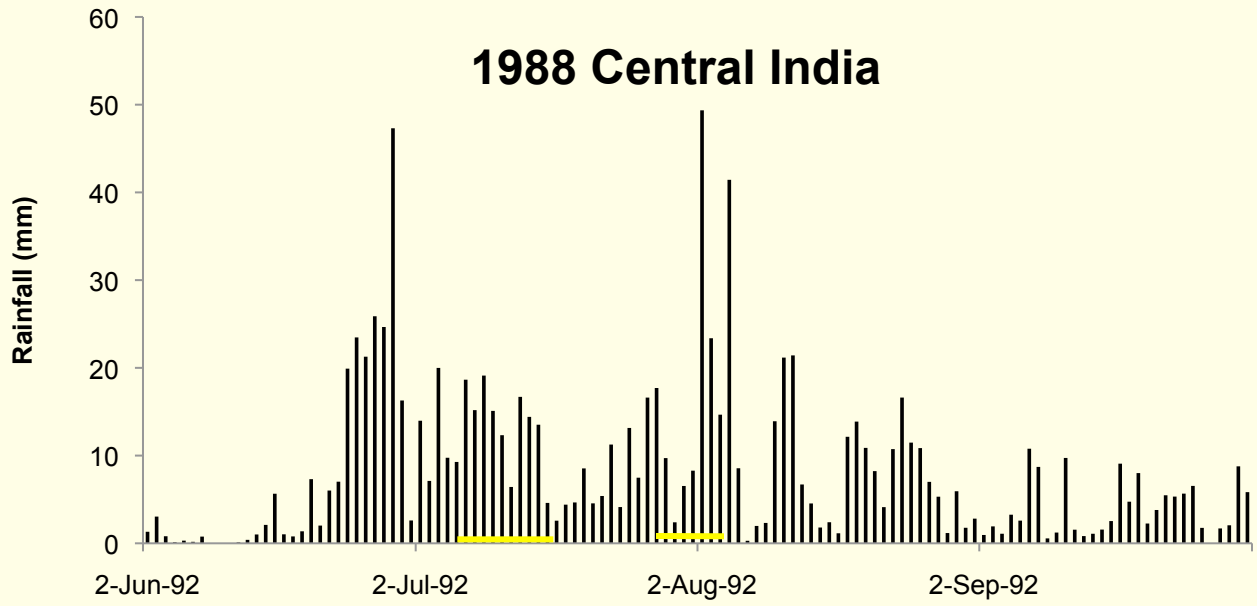
$$b = \frac{1}{n} \sum_{k=1}^{n} [f(k) - o(k)]^2,$$

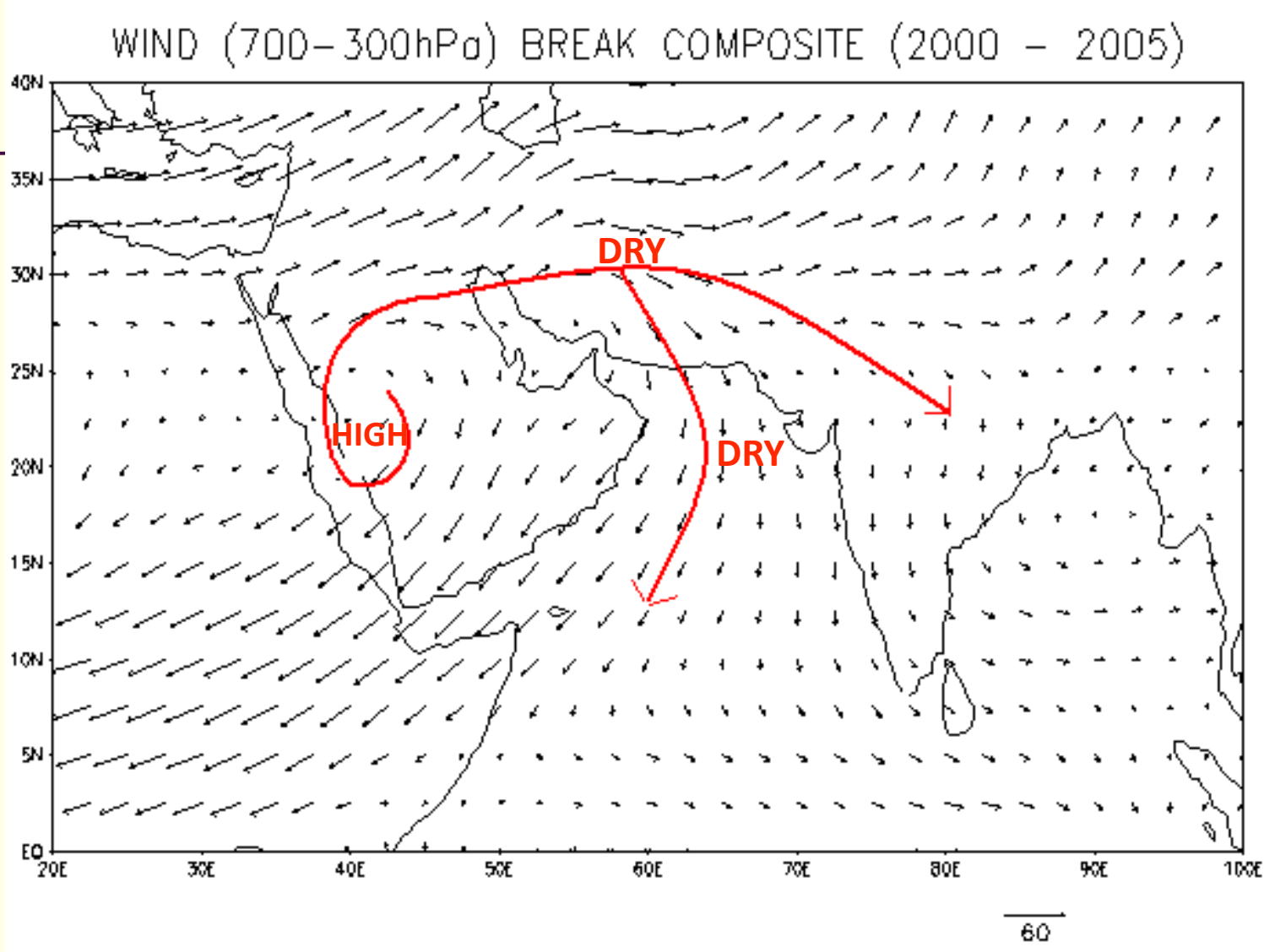
Where k=forecast-observation pairs, n = total numbers of such pairs

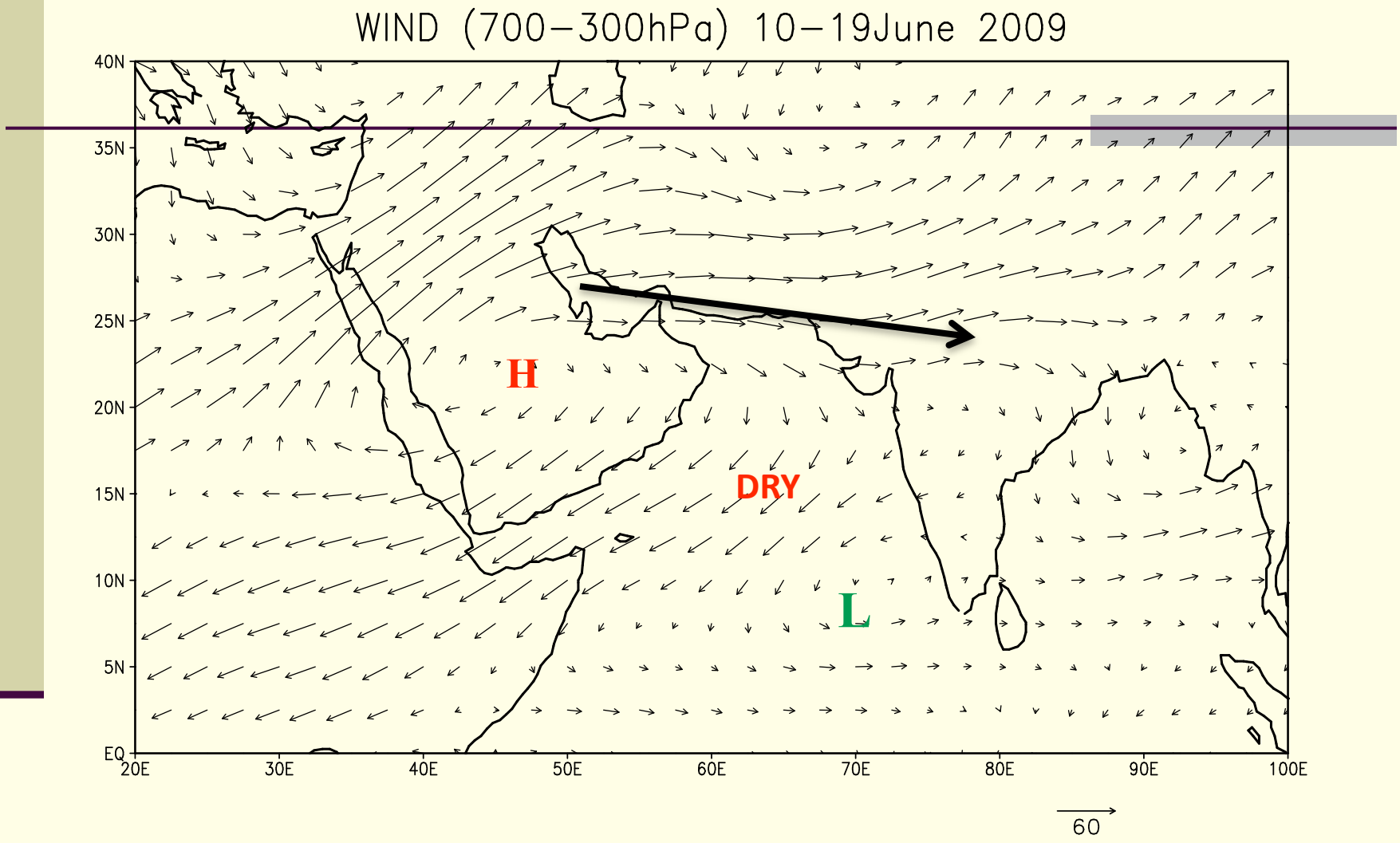
Stefanova, L., and T.N. Krishnamurti, 2002: Interpretation of Seasonal Climate Forecast Using Brier Skill Score, The Florida State University Superensemble, and the AMIP-I Dataset. *J. Climate*, **15**, 537–544.

Predicting DRY Spells of Monsoon with a suite of coupled models

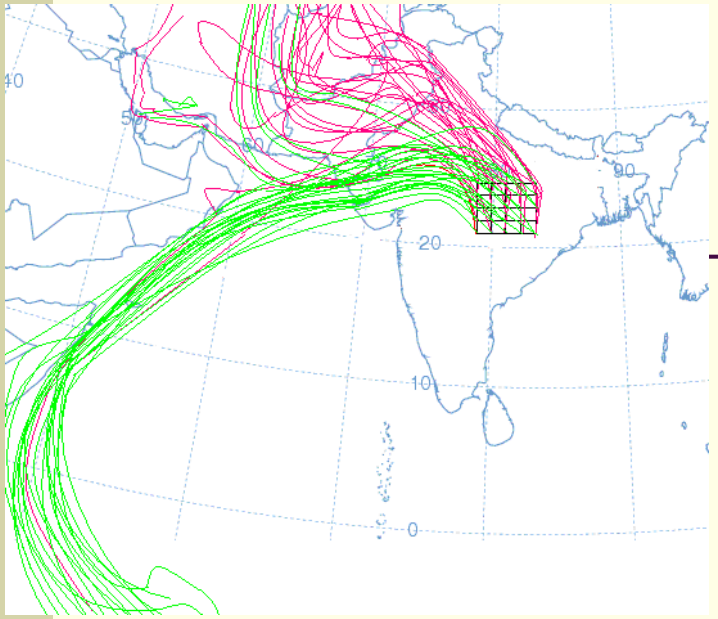

1987 Central India
Rainfall (mm)
70
60
50
40
30
20
10
0
2-Jun-91
2-Jul-91
2-Aug-91
2-Sep-91


1988 Central India
Rainfall (mm)
60
50
40
30
20
10
0
2-Jun-92
2-Jul-92
2-Aug-92
2-Sep-92


WIND (700-300hPa) BREAK COMPOSITE (2000 - 2005)
DRY
HIGH
DRY
40N
35N
30N
25N
20N
15N
10N
5N
EQ
20E
30E
40E
50E
60E
70E
80E
90E
100E
60

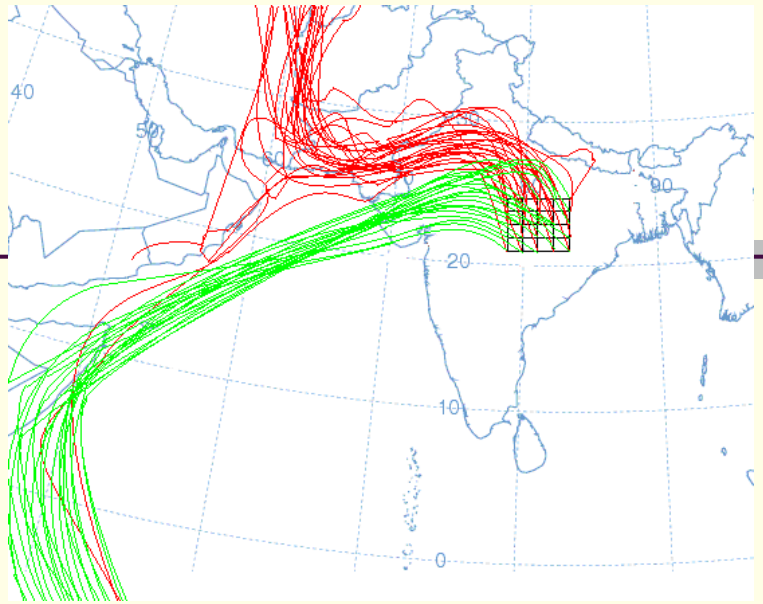

WIND (700–300hPa) 10–19June 2009
40N
35N
30N
25N
20N
15N
10N
5N
EQ
20E
30E
40E
50E
60E
70E
80E
90E
100E
H
DRY
L
60

10 Days back Trajectories, ending on 8th Aug 2000

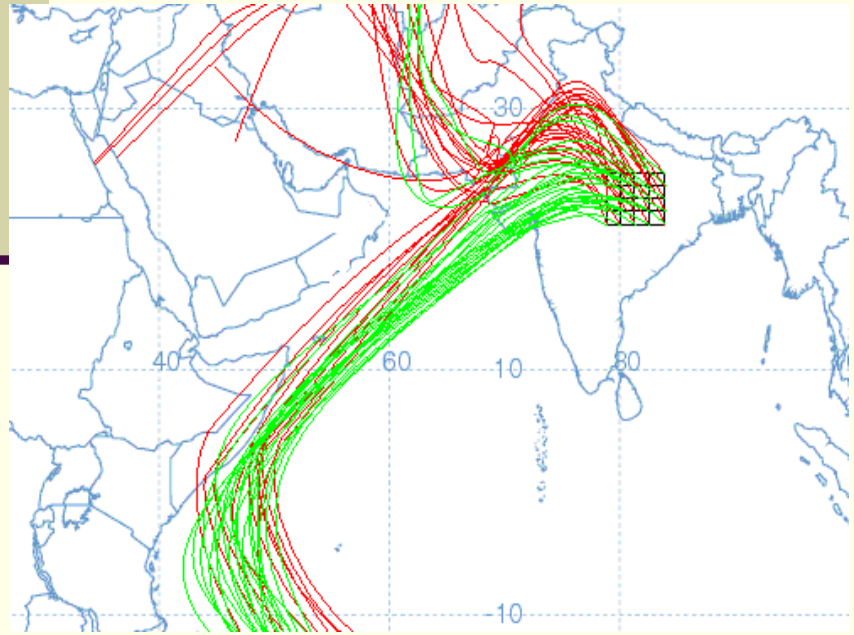


BREAK

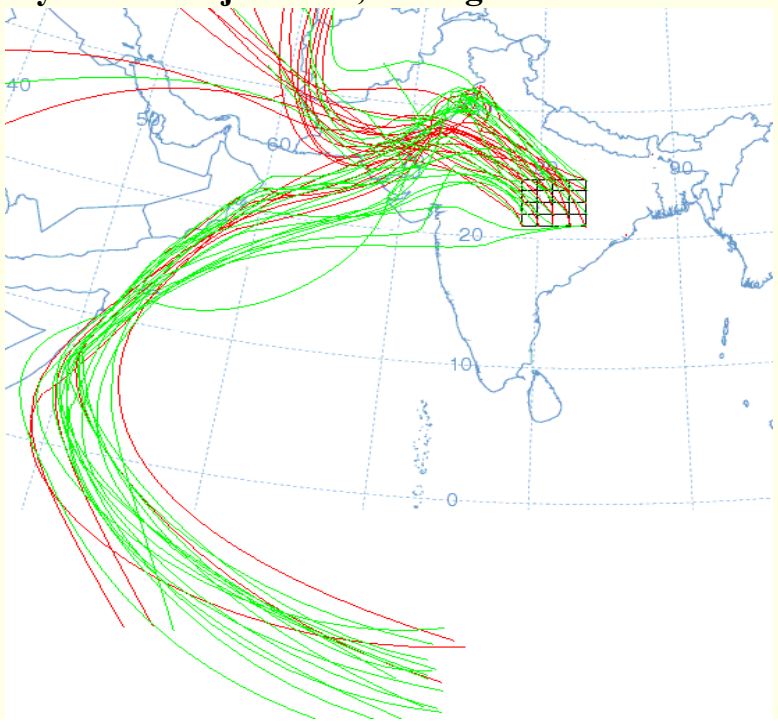
10 Days back Trajectories, ending on 30h Aug 2001



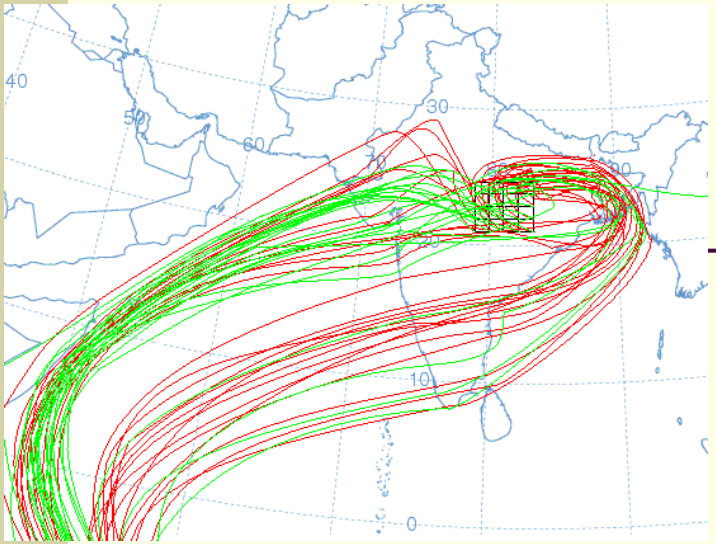
10 Days back Trajectories, ending on 14th Aug 2005



10 Days back Trajectories, ending on 20th Jun 2009

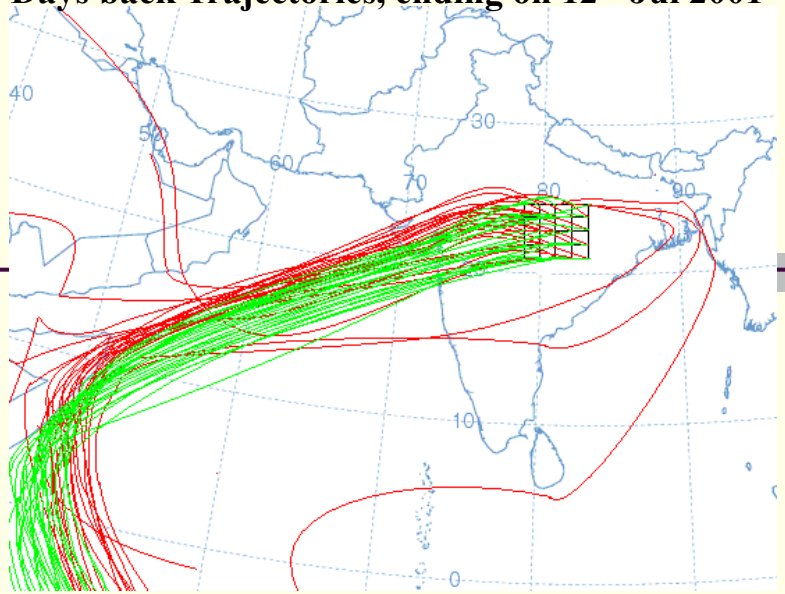


10 Days back Trajectories, ending on 19th Jul 2000

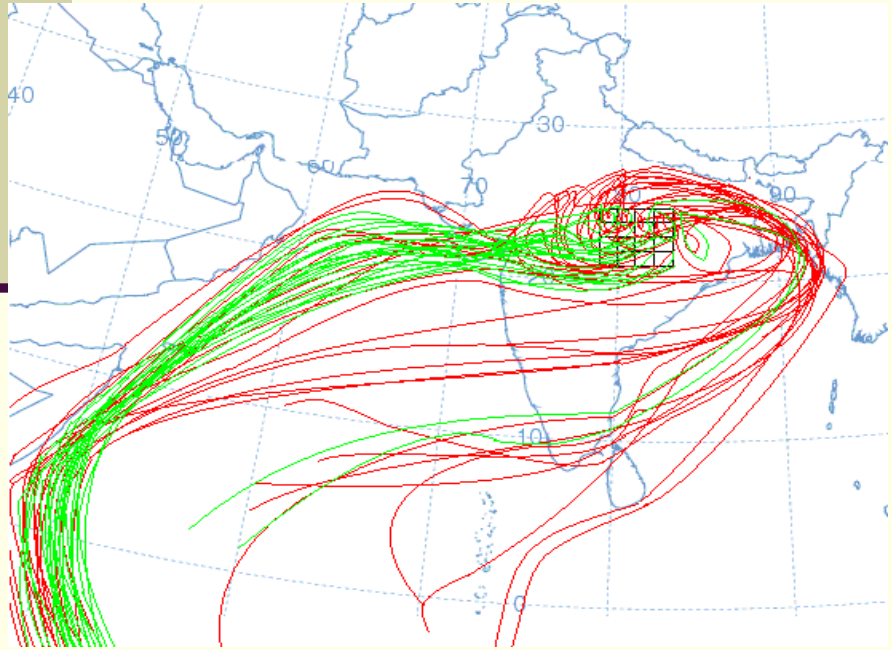


ACTIVE

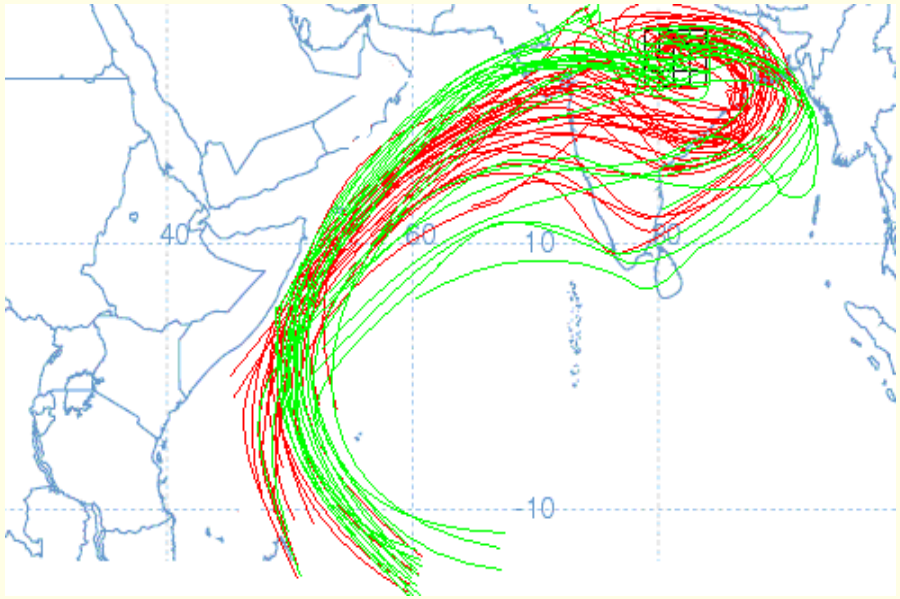
10 Days back Trajectories, ending on 12th Jul 2001



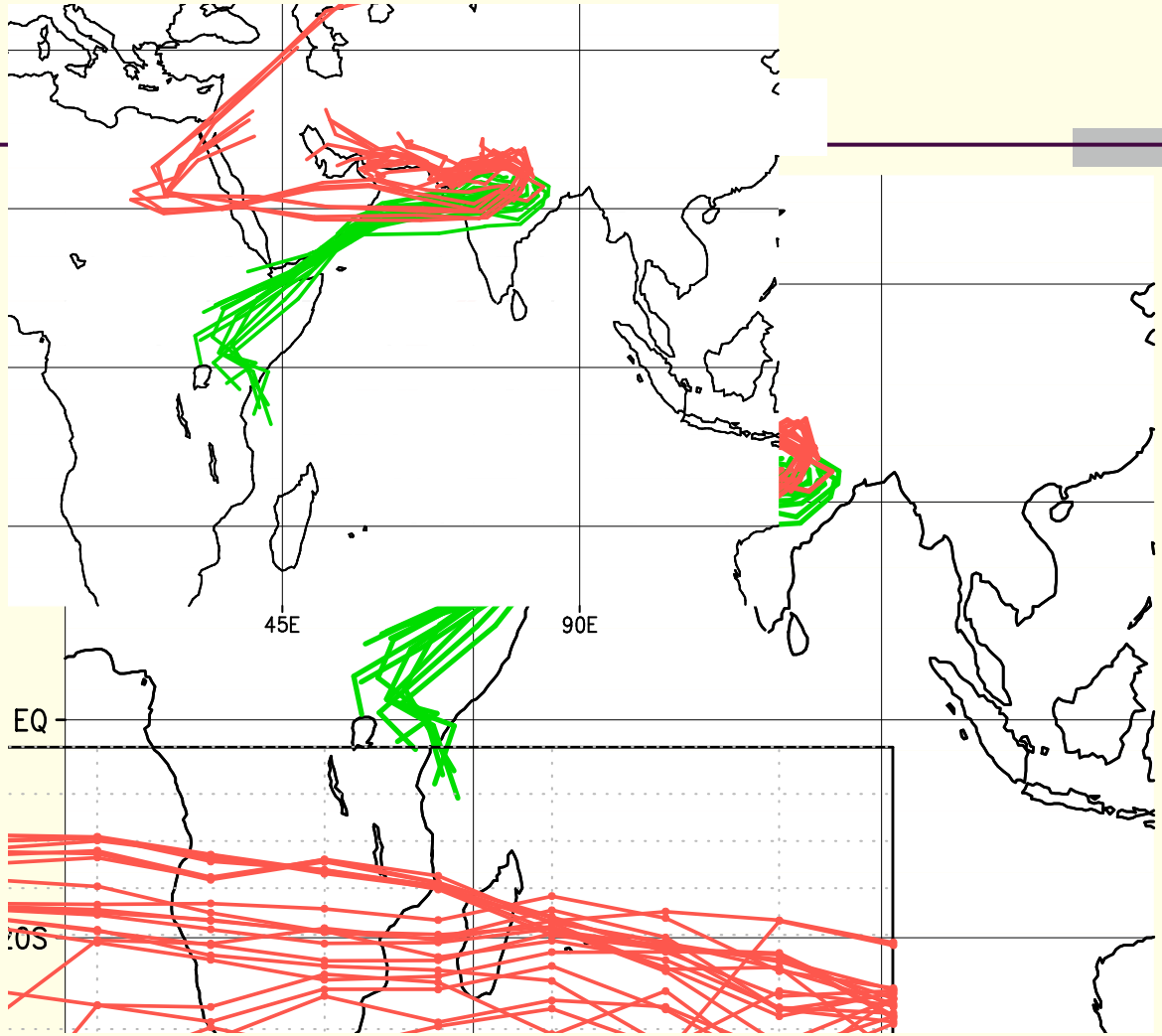
10 Days back Trajectories, ending on 1st Aug 2005



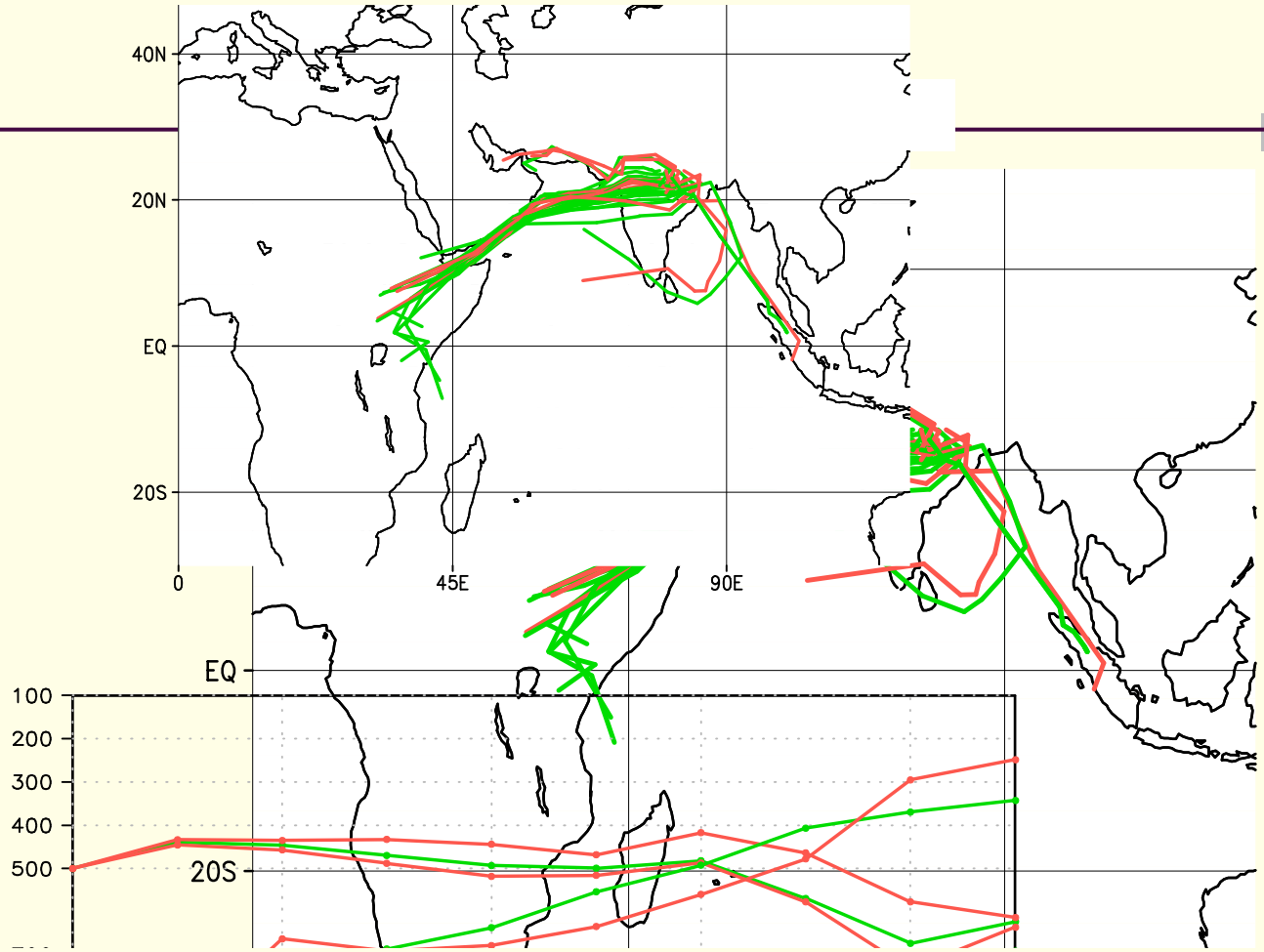
10 Days back Trajectories, ending on 31st Aug 2004



10 Days back Trajectories, ending on 2nd Aug 1987 - BREAK



10 Days back Trajectories, ending on 27th July 1988 - ACTIVE



Summary

- Examining the performance of the various coupled models for the Monsoon Asia, we found none of model's forecast match with observations on the basis of year to year forecast over Monsoon Asia. For a particular year or region some performs better than others.

- TALKING OF STRATEGIES FURTHER WORK ON THE DESIGN OF THE SUPERENSEMBLE CAN BE DONE IN AREAS SPECIFICALLY TAILORED TOWARDS INCREASING THE EQUITABLE THREAT SCORES FOR drought and flood regions of the Monsoon Asia.

- BETTER THAN THE BEST MODEL DOES NOT IMPLY USEFULNESS OF A SUPERENSEMBLE FORECAST FOR ALL LEVELS OF ITS USAGE. ONE MUST CONTINUE TO CHIP AWAY AT SINGLE MODELS AND KEEP MAKING THEM BETTER, AS THEY IMPROVE SO DOES THE SUPERENSEMBLE.

...continue

- **Our major findings are that the use of the downscaled multimodel superensembles provides better forecasts in terms of rms errors, , anomaly correlations and the equitable threat scores compared to all member models , the ensemble mean, the bias removed ensemble mean for the monsoon region.**

- **We have found from an examination of 30 years of reanalysis data sets that most dry spells of the Indian Monsoon are preceded by the occurrence of a blocking high over west Asia. This feature results in the advection into central India of very dry air from the upper troposphere of the Arabian desert regions. The clouds over central India do receive moisture from the Arabian sea and the Bay of Bengal, but these clouds seem to erode from the intrusion of the dry air. Some of these blocking patterns over west Asia last several weeks and contribute to lasting dry spells over India. There are many antecedents to the formation of the West Asian block that moves the question of the dry spells over India to the rain belts of west Africa, the local Hadley cell there and the influence of the equatorial Atlantic SST anomalies. Some of these features have been simulated in our seasonal coupled forecasts of the monsoon using the multimodel superensemble.**

THANK
YOU!