UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL ATOMIC ENERGY AGENCY
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR/930 - 29

"Workshop on El Niño, Southern Oscillation and Monsoon"
15 - 26 July 1996

"Monsoon Predictability"

J. SHUKLA
COLA
Calverton, MD
USA

Please note: These are preliminary notes intended for internal distribution only.

Monsoon Predictability

J. Shukla
COLA

18-July-1996
ICTP, Trieste

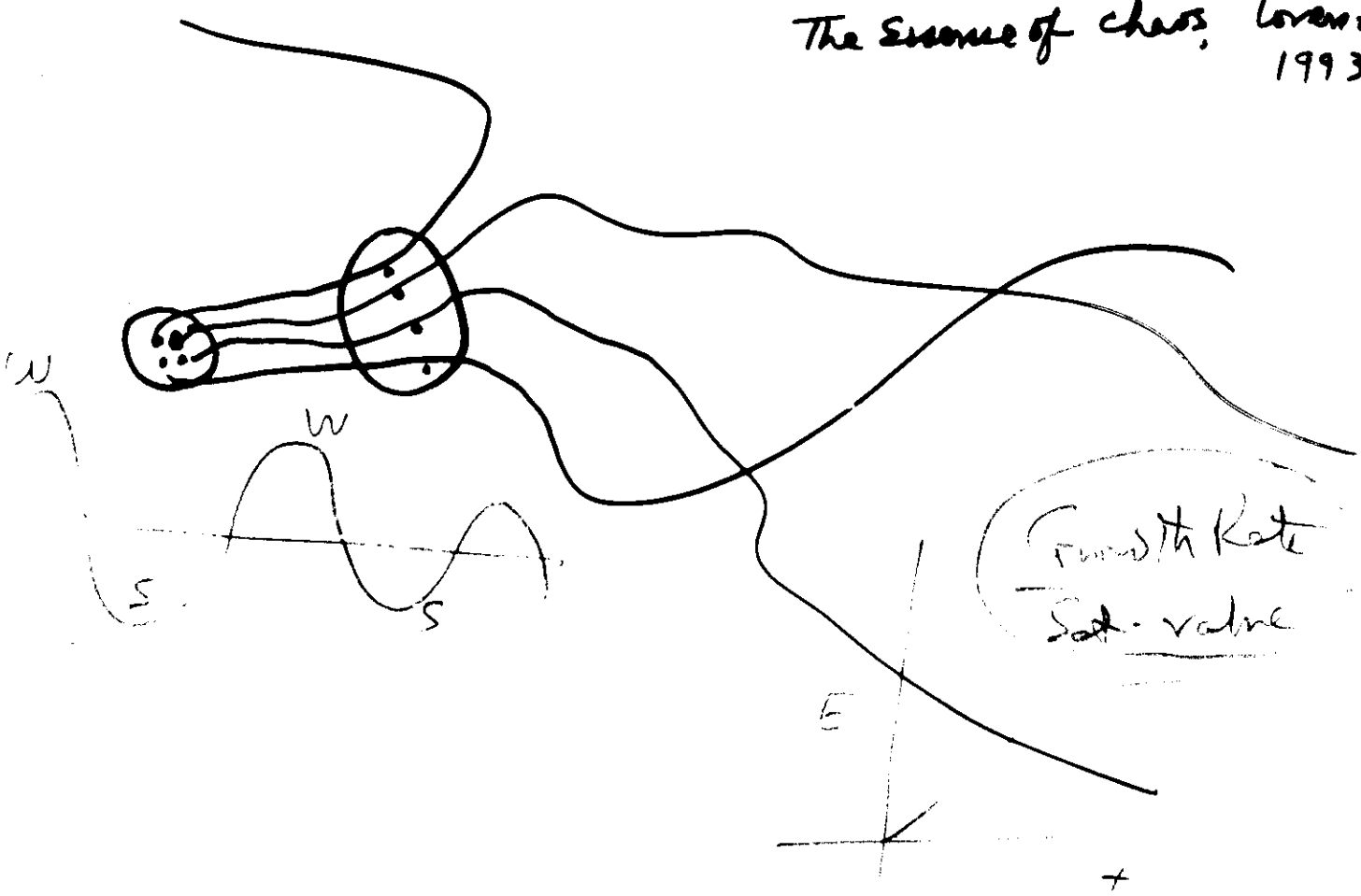
"Predictability" [Chaos, Sensitivity to I.C.

"Prediction" (model output)

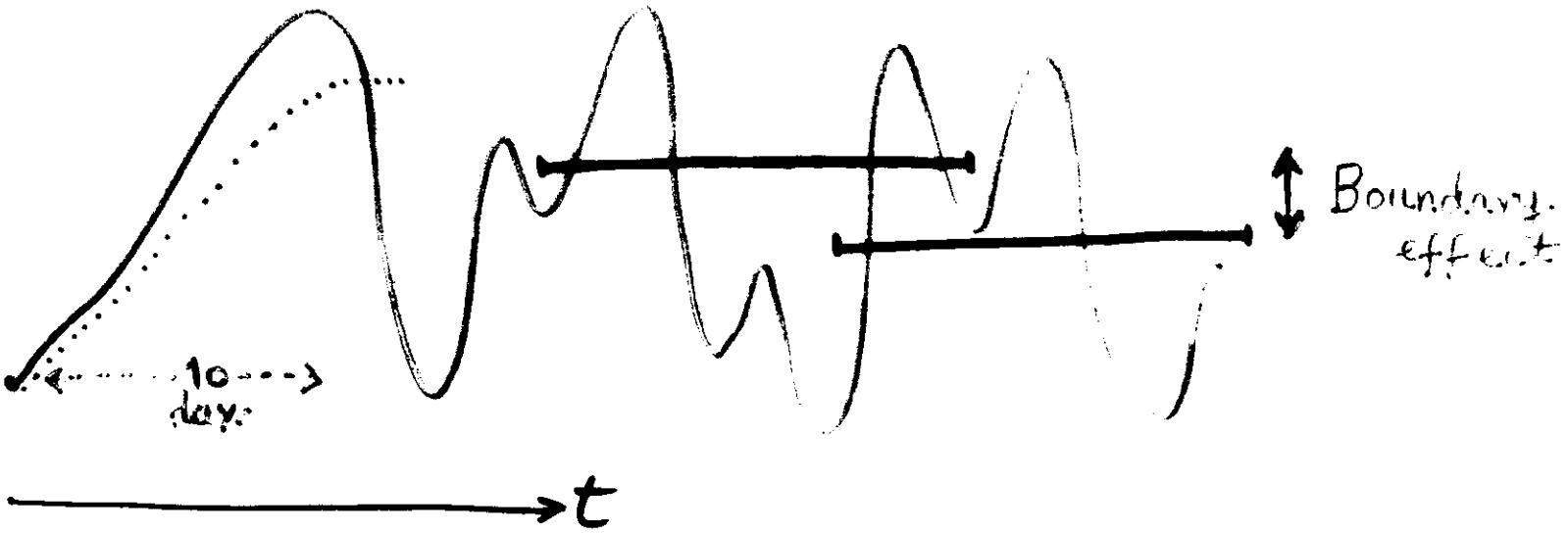
"Forecast" (issued to public)

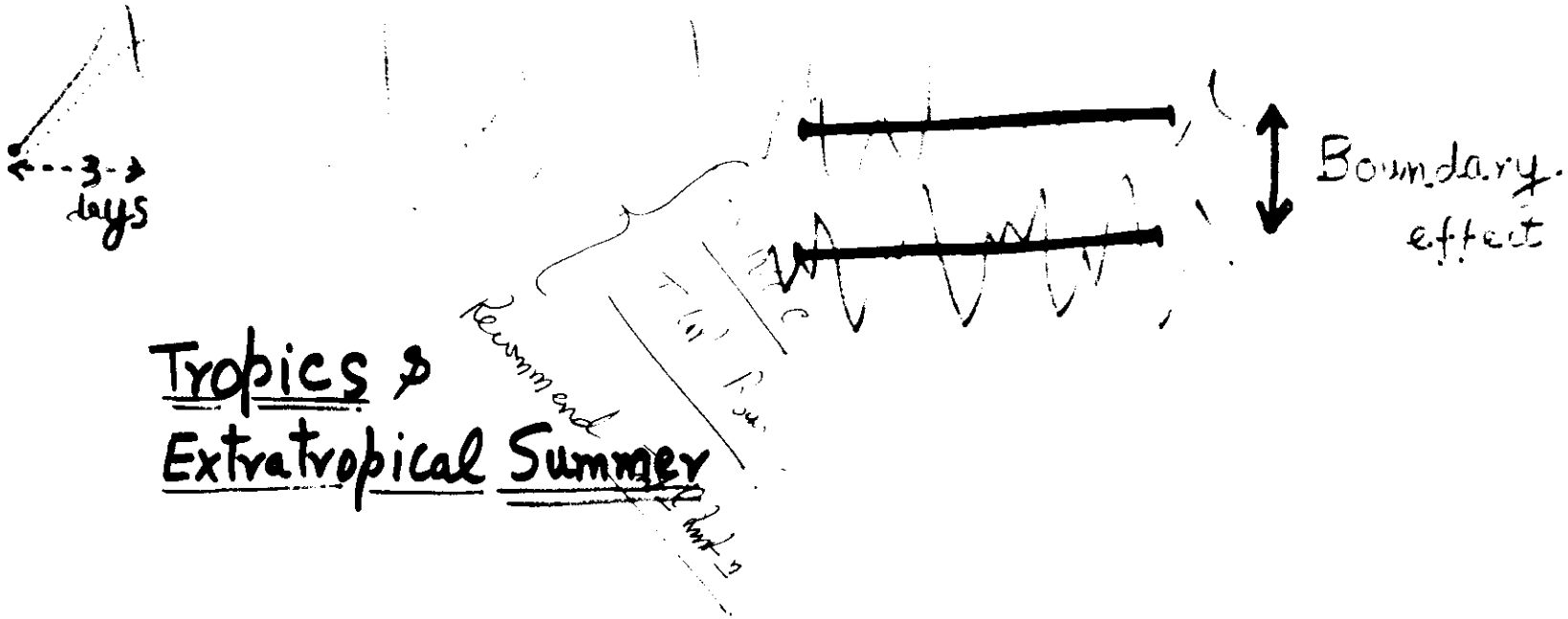
"Chaos": "A system that is sensitively dependent on interior changes in initial conditions."

The Essence of chaos, Lorenz 1993



Extratropical Winter





Tropics & Extratropical Summer

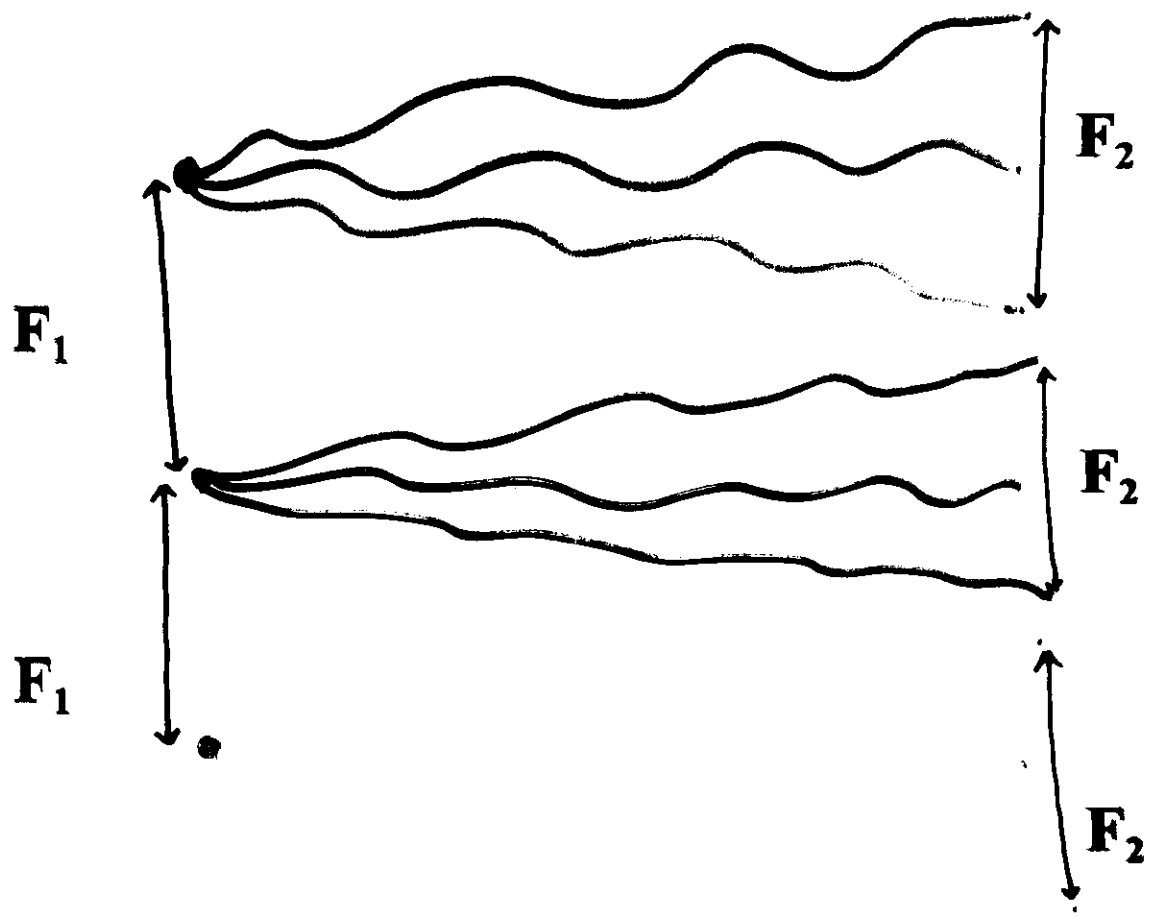
Doubling Time for initial "error"

NWP models: ~ 2 days
Day to day weather prediction

Coupled Ocean-Atmosphere model: ~ : 5 months
~ : 15

Predictability of Seasonal Averages:

(Influence of Boundary Conditions)



$$\textit{Predictability} \propto \frac{F_1}{F_2}$$

Observed IC and global SST; Climatological snow//soil wetness/sea ice

ANALYSIS OF VARIANCE

	Year 1 j = 1	Year 2 j = 2	Year 3 j=3	Year 4... j=4	Year J j=J
IC1, i=1	μ_{11}	μ_{21}	μ_{31}	μ_{41}	μ_{j1}
IC2, i=2	μ_{12}	μ_{22}	μ_{32}	μ_{42}	μ_{j2}
IC3, i=3	μ_{13}	μ_{23}	μ_{33}	μ_{43}	μ_{j3}
. . .	. . .	. . .	. . .	. . .	. . .
ICn, i=n	μ_{1n}	μ_{2n}	μ_{3n}	μ_{4n}	μ_{jn}

$$F = \frac{\textit{Variance among different years (B.C. forced variance)}}{\textit{Variance among different (I.C.) (Internal variance)}}$$

$$F(\nu_1,\nu_2) = \frac{\sum_j \frac{(\sum_i \mu_{ji})^2}{n_j} - \frac{(\sum_j \sum_i \mu_{ji})^2}{N}}{\sum_j \sum_i \mu_{ji}^2 - \sum_j \frac{(\sum_i \mu_{ji})^2}{n_j}} \frac{(N-J)}{(J-1)}$$

$$N = n \times J;\ \nu_1 = J-1;\ \nu_2 = N - J$$

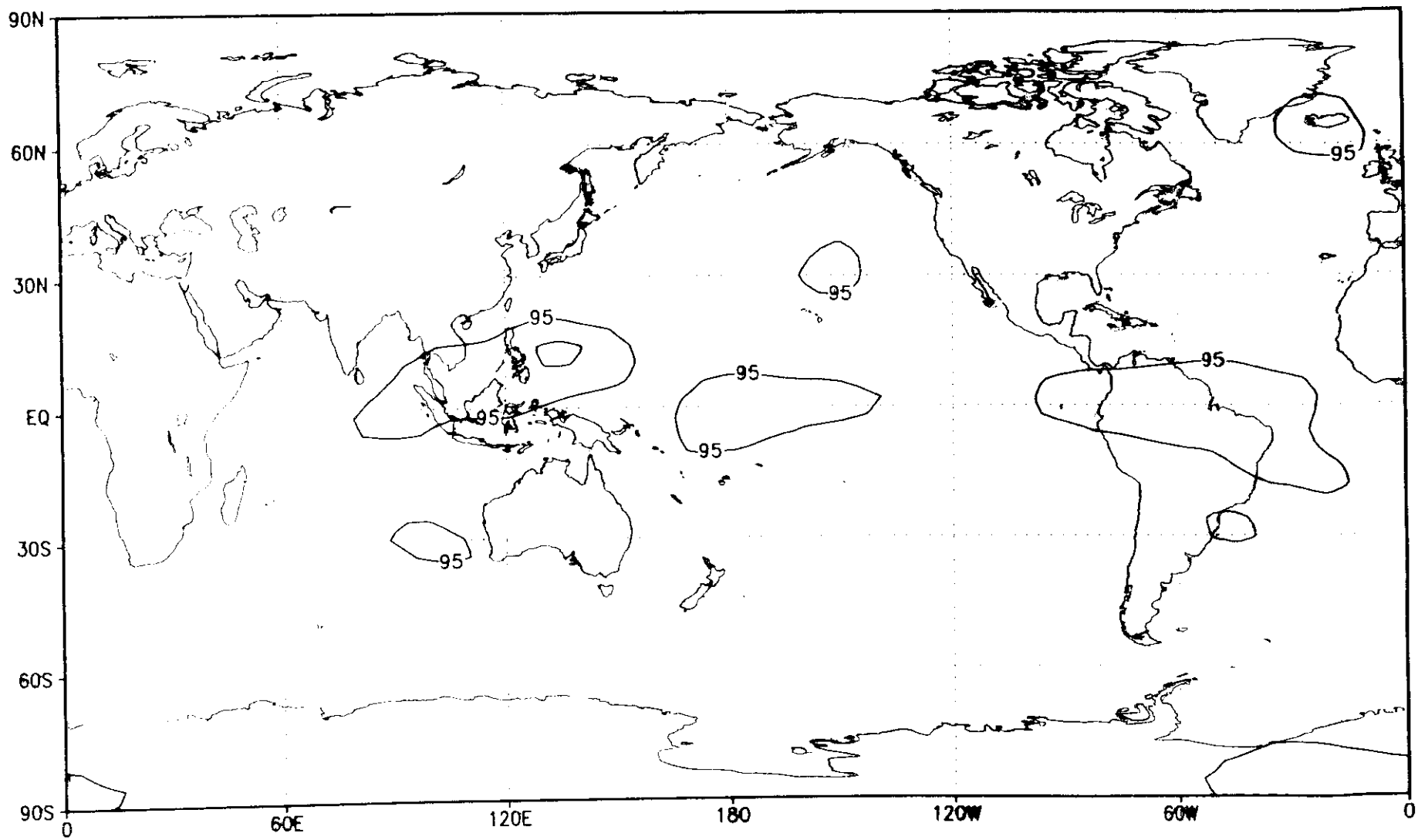
Experimental Design

	j=1	j=2	j=3	j=4	j=5
1 June (i=1)	1986	1987	1988	1989	1990
2 June (i=2)	"	"	"	"	"
3 June (i=3)	"	"	"	"	"

15 × 90 day runs : obs. SST

15 × 90 day runs : Clim. SST

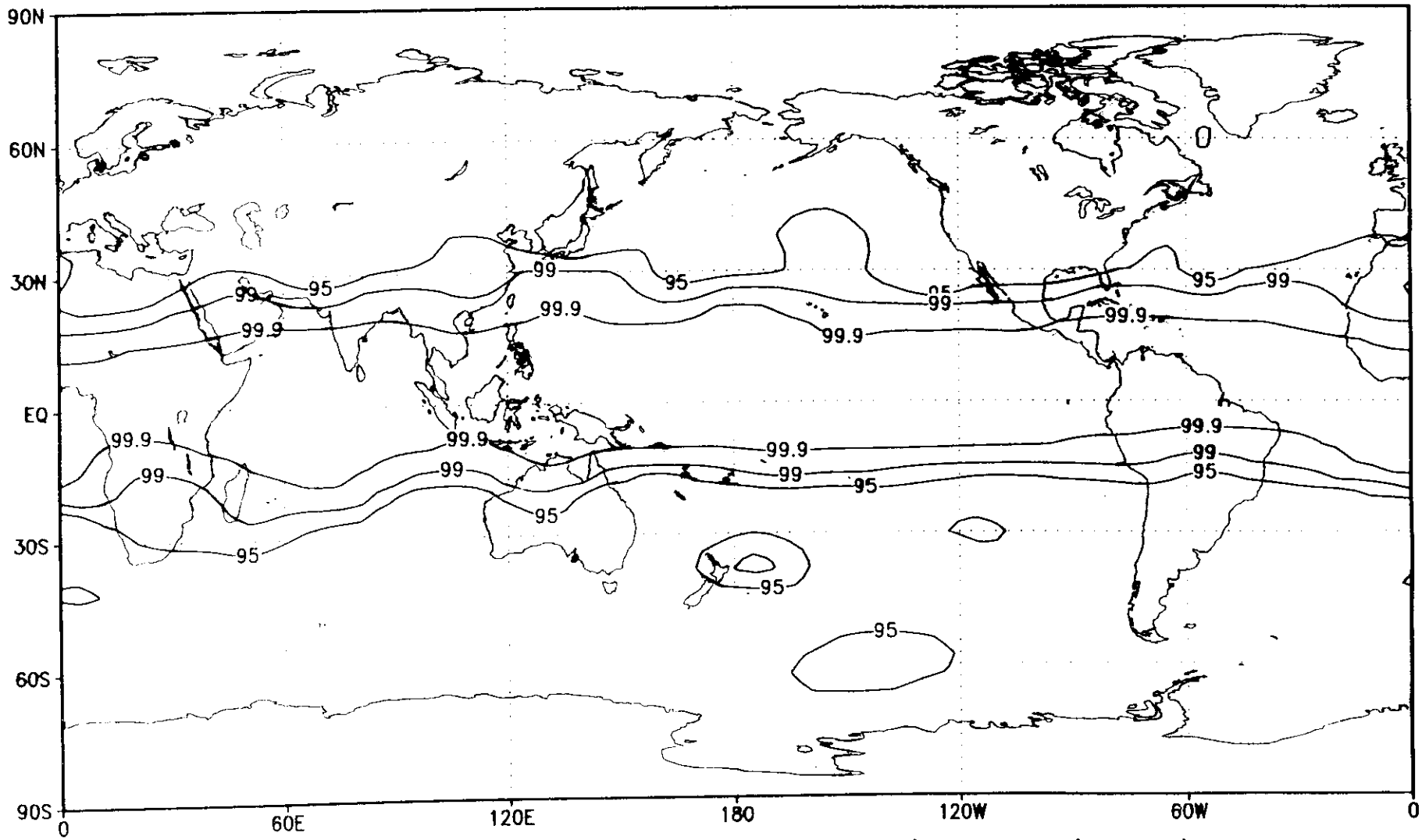
F probability from 300 mb height for days 1–90
3 runs each for 5 summers using climatological SST



contours = 95% (5.96) 99% (14.55) 99.9% (48.05)

GrADS: COLA/IGES

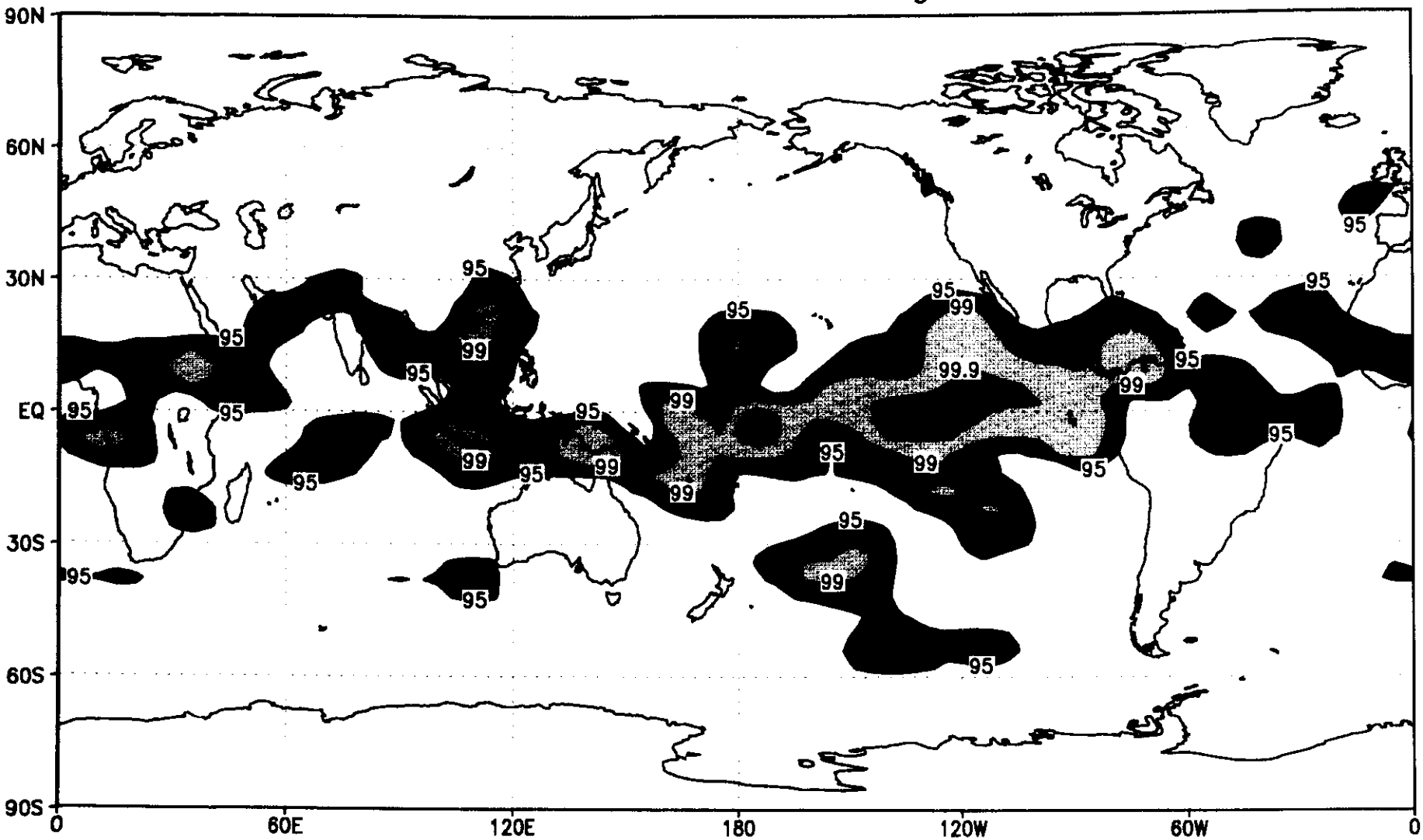
F probability from 300 mb height for days 1–90
3 runs each for 5 summers using observed SST



contours = 95% (5.96) 99% (14.55) 99.9% (48.05)

GrADS: COLA/IGES

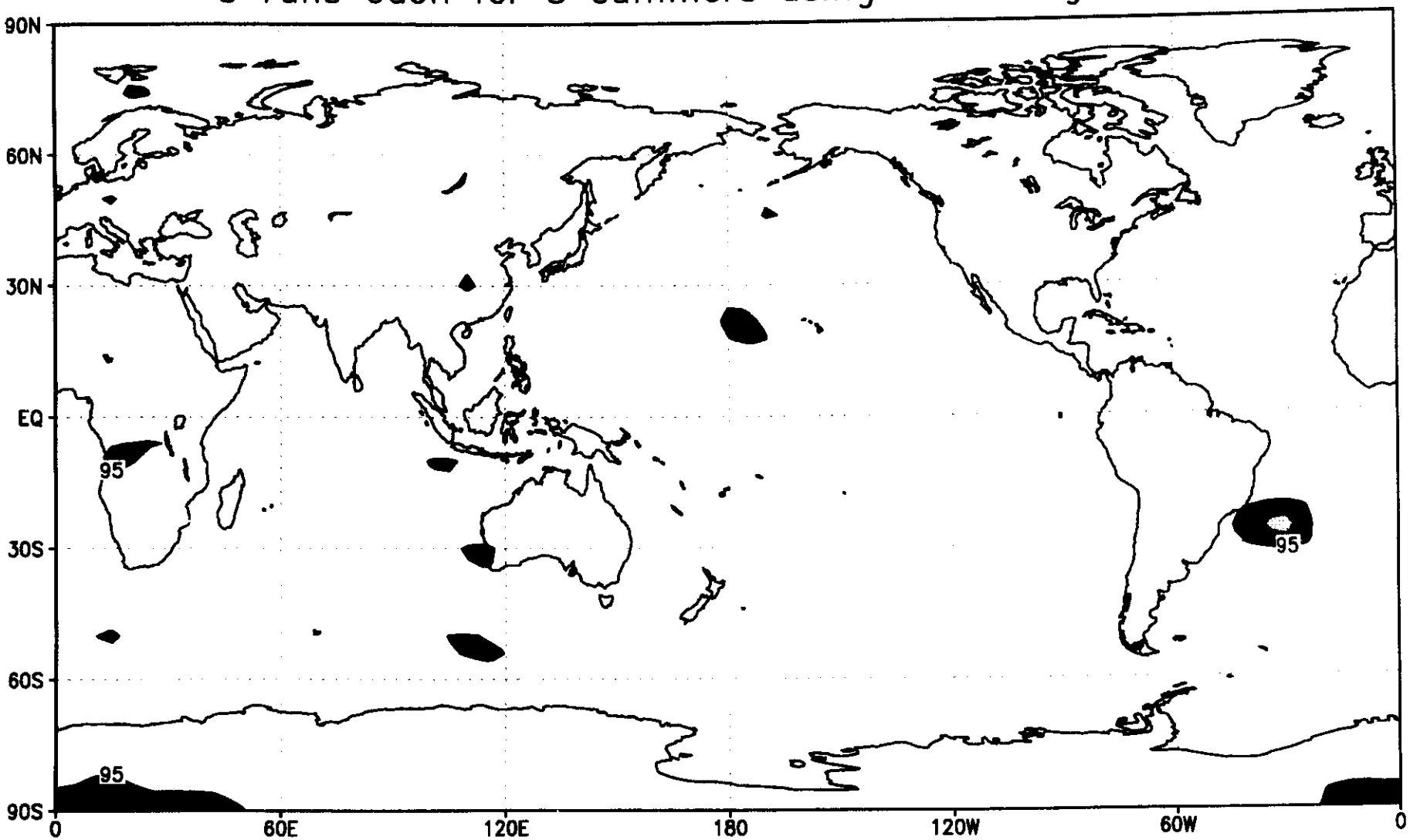
f probability for days 1–90 for Total precip.
3 runs each for 5 summers using observed SST



levels = 95% (5.91) 99% (14.37) 99.9% (47.41)

GrADS: COLA/IGES

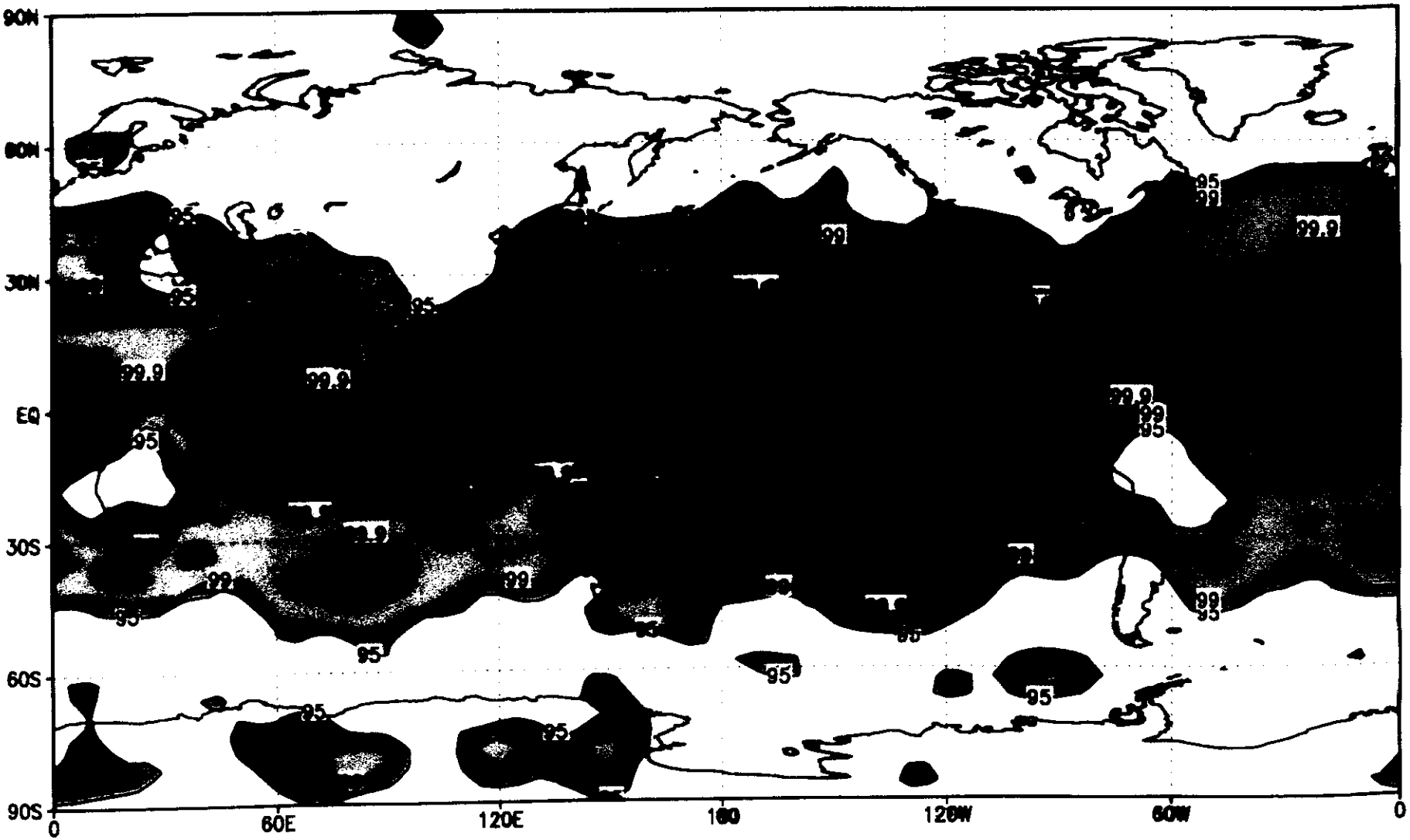
f probability for days 1–90 for Total precip.
3 runs each for 5 summers using climatological SST



levels = 95% (5.91) 99% (14.37) 99.9% (47.41)

GrADS: COLA/IGES

F probability for total precipitation
JJAS from 9 runs over 13 years



levels = 95 (2.4) 99 (3.5) 99.9 (5.6) %

GrADS: COLA/IGES

Influence of Land Surface on weather and Climate

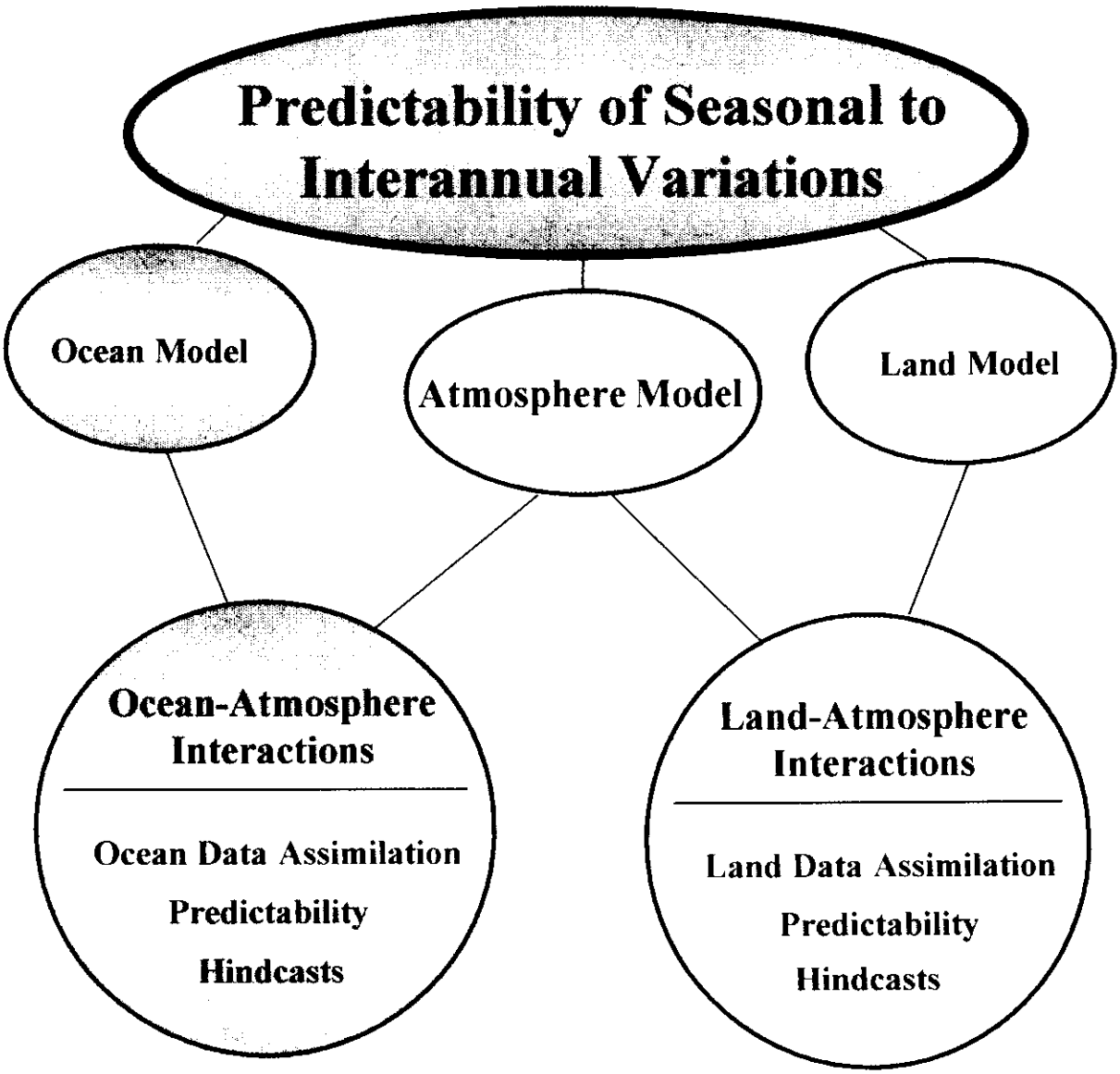
J. Shukla
COLA

{ Biasutti
Dirmeyer
Fennessy
Marx
Xue, Zeng }

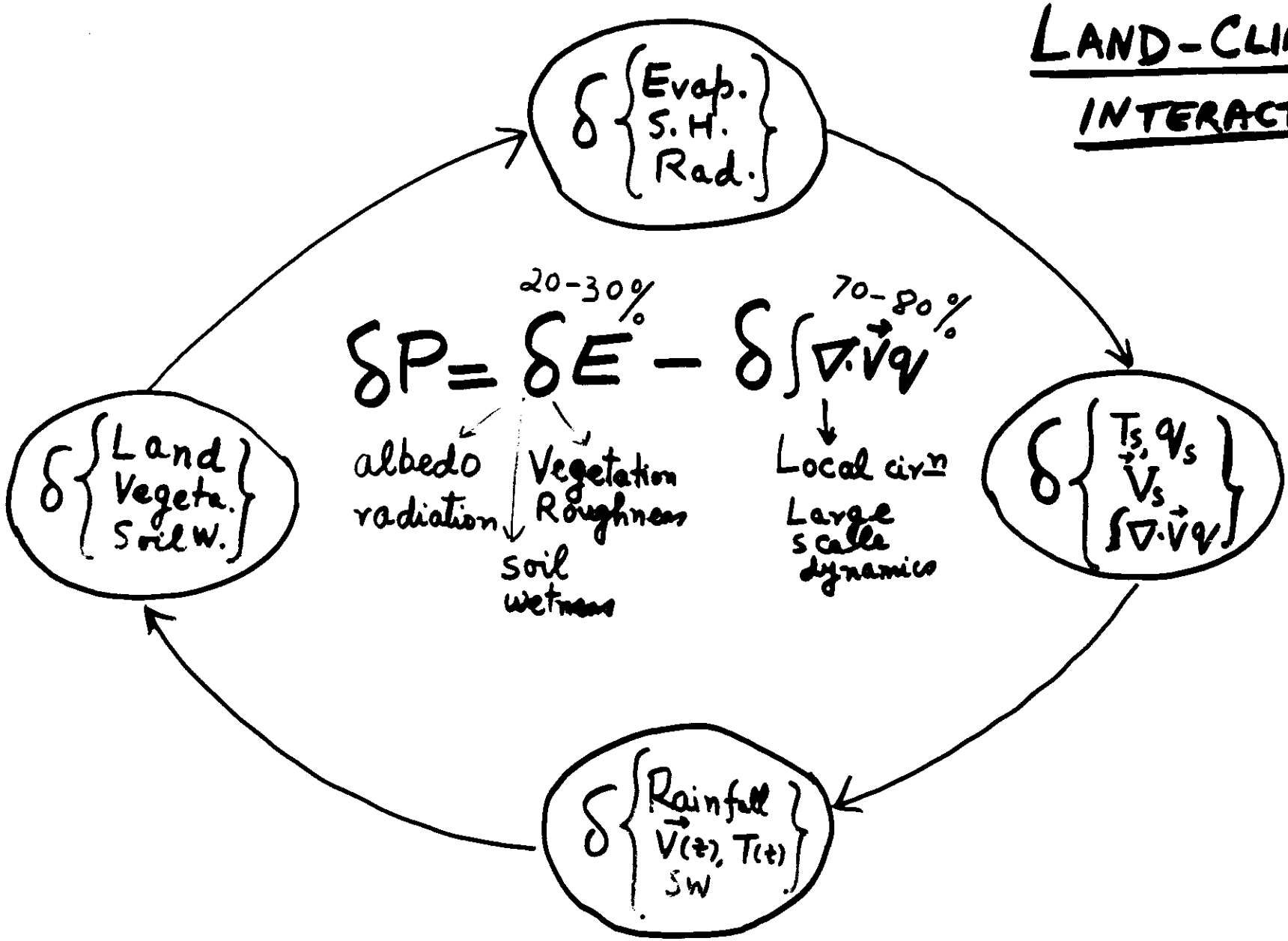
(Snow → Bamzai)

Roles of Internal Dynamics, Atmosphere-Ocean, and Atmosphere-Land Interaction in Generating Interannual Variability

J. Shukla
L. Marx
M. Biasutti


Predictability of Seasonal to Interannual Variations
Ocean Model
Atmosphere Model
Land Model
Ocean-Atmosphere Interactions
Ocean Data Assimilation
Predictability
Hindcasts
Land-Atmosphere Interactions
Land Data Assimilation
Predictability
Hindcasts
• Land model
• Soil wetness
• Vegetation

LAND-CLIMATE INTERACTION



MECHANISMS OF INTERANNUAL VARIABILITY:
ROLES OF INTERNAL DYNAMICS AND ATMOSPHERE-OCEAN-LAND INTERACTIONS

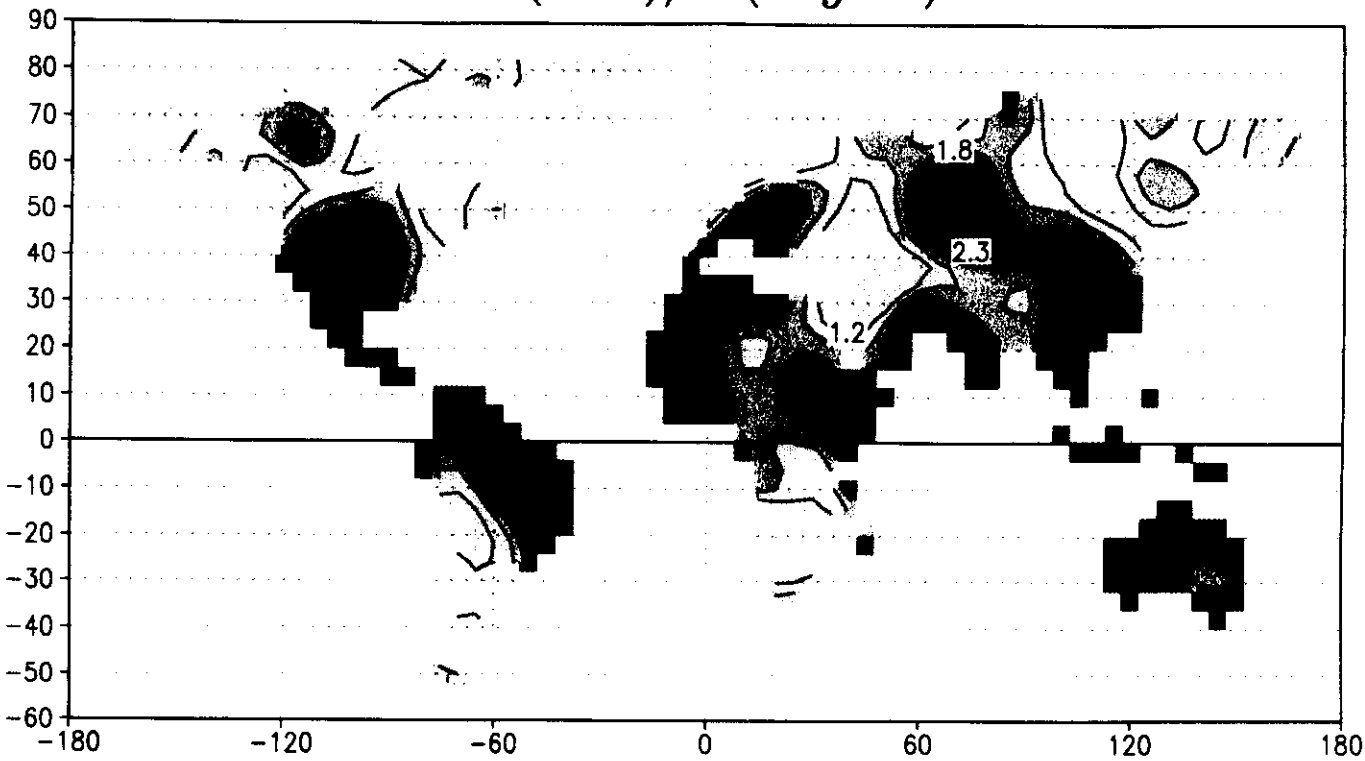
1. Internal Dynamics: (AMEAN)	• Nonlinear advections; transients; diurnal cycle • Cloud - radiation - H_20 interaction • Mountains - land - ocean distribution • Fixed annual mean sun, 0_3, SST, Sea Ice, Snow, Albedo, Vegetation, Soil Moisture
2. Annual Cycle: (ACYCLE)	AMEAN + Climatological Annual Cycle of SST, Sea Ice, Snow, Soil Wetness
3. Interactive Land, Fixed Climatological SST (CSST)	AMEAN + Climatological Annual Cycle of SST, Sea Ice; Interactive Land-Atmosphere
4. Observed SST, Fixed Climatological Land (CLAND)	AMEAN + Climatological Annual Cycle of Land (Snow, Soil Wetness); observed SST
5. Interactive Land-Atmosphere-Ocean (Actual Climate)	AMEAN + Annual Cycle + Interactive Land-Atmosphere + Observed SST and Sea Ice

Model Integrations

COLA AGCM (T30, L18)

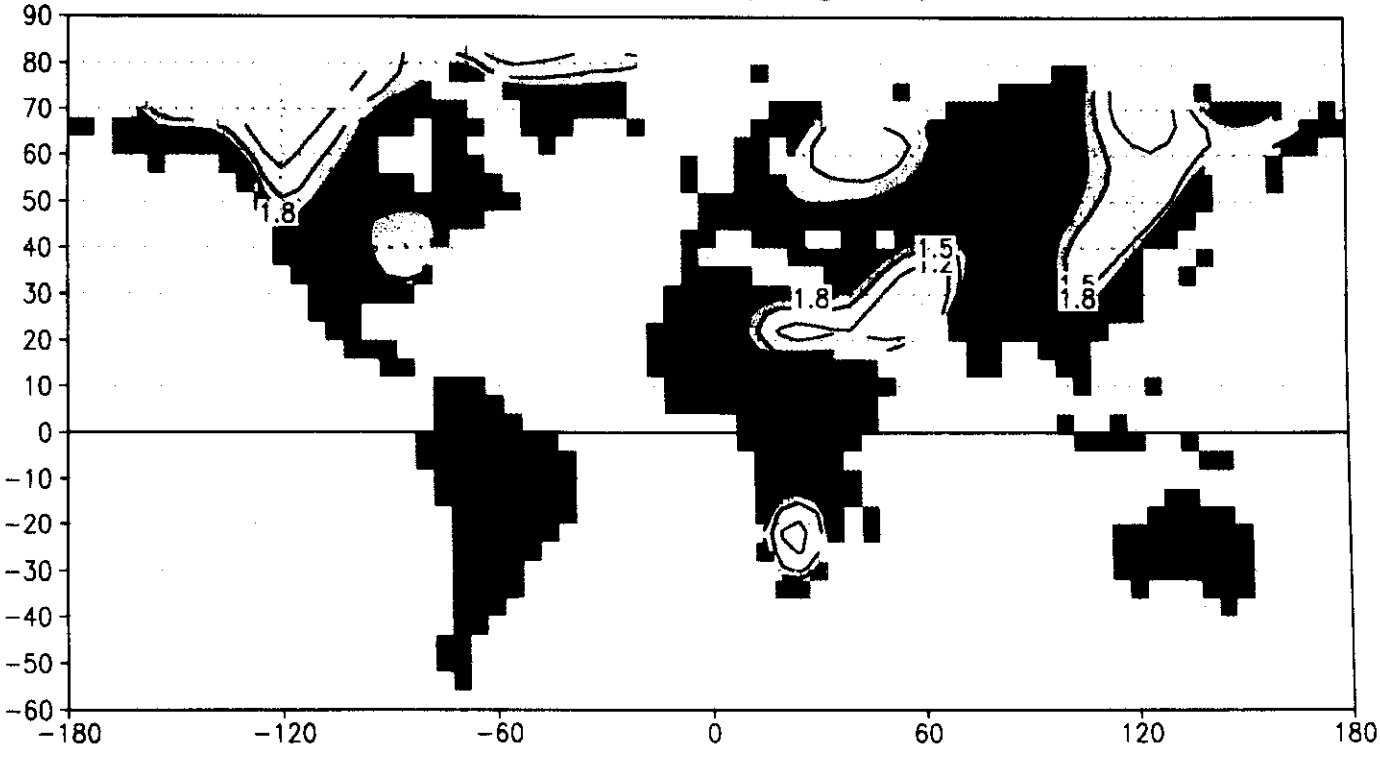
OSST:	**44 years (1948-1992)**
CSST:	**50 years**
CLAND:	**30 years**
ACYCLE:	**30 years**
AMEAN:	**10 years**

(F) JJAS precipitation (25 pt ave.)
$\sigma^2(osst)/\sigma^2(acycle)$



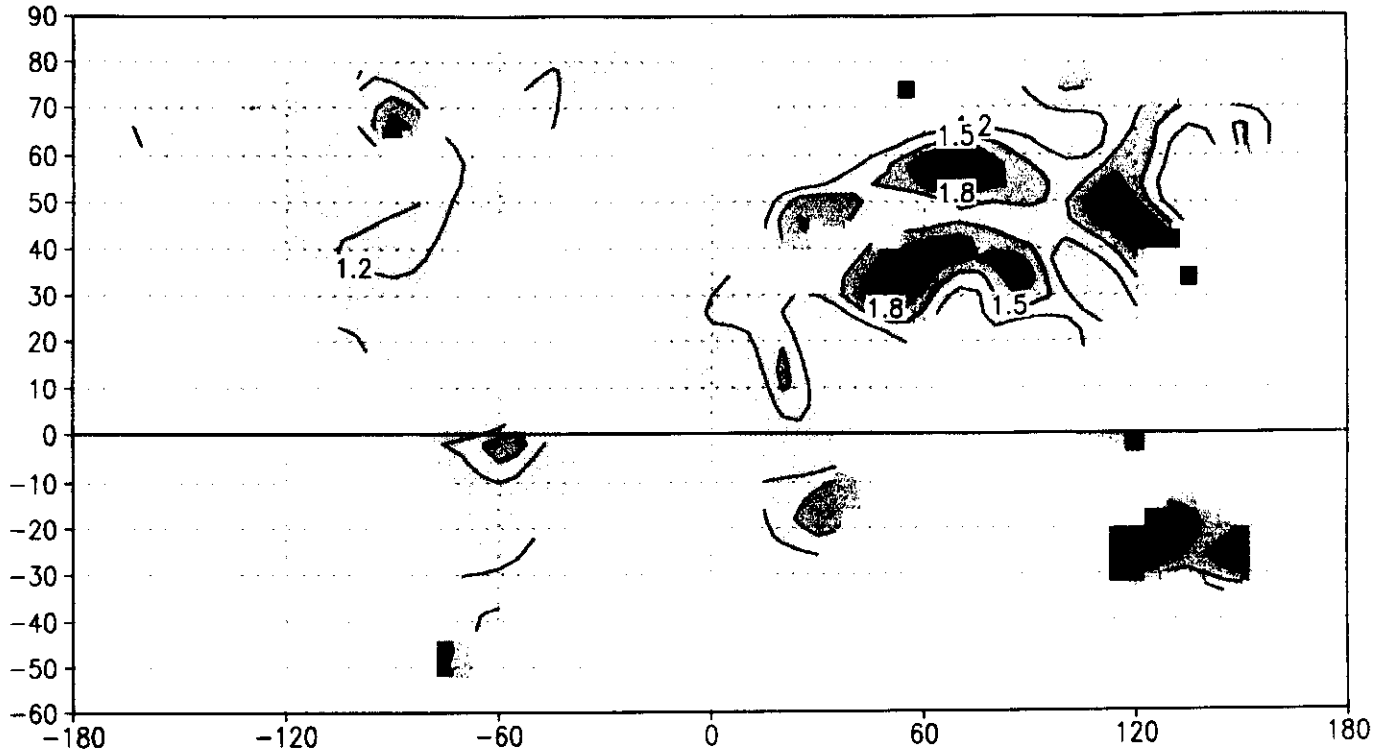
Contouring at levels 1.2 1.5 1.8 (95% sig.) 2.3 (99% sig.)

(F) JJAS temp.canopy sp. (25 pt ave.)
$\sigma^2(osst)/\sigma^2(acycle)$



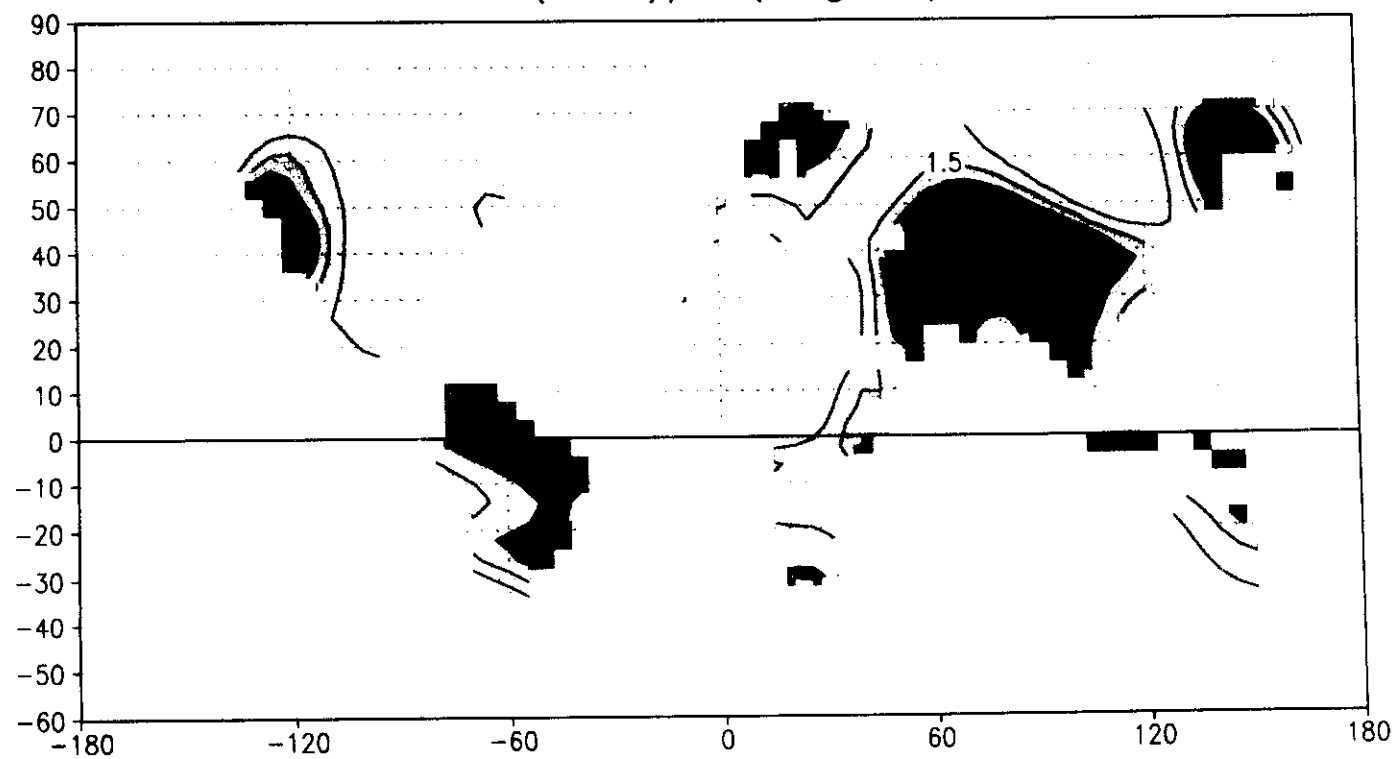
Contouring at levels 1.2 1.5 1.8 (95% sig.) 2.3 (99% sig.)

(F) MAM precipitation (25 pt ave.)
$\sigma^2(csst)/\sigma^2(acycle)$



Contouring at levels 1.2 1.5 1.8 (95% sig.) 2.3 (99% sig.)

(F) MAM temp.canopy sp. (25 pt ave.)
$\sigma^2(csst)/\sigma^2(acycle)$



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(F) JJAS precipitation (25 pt ave.)
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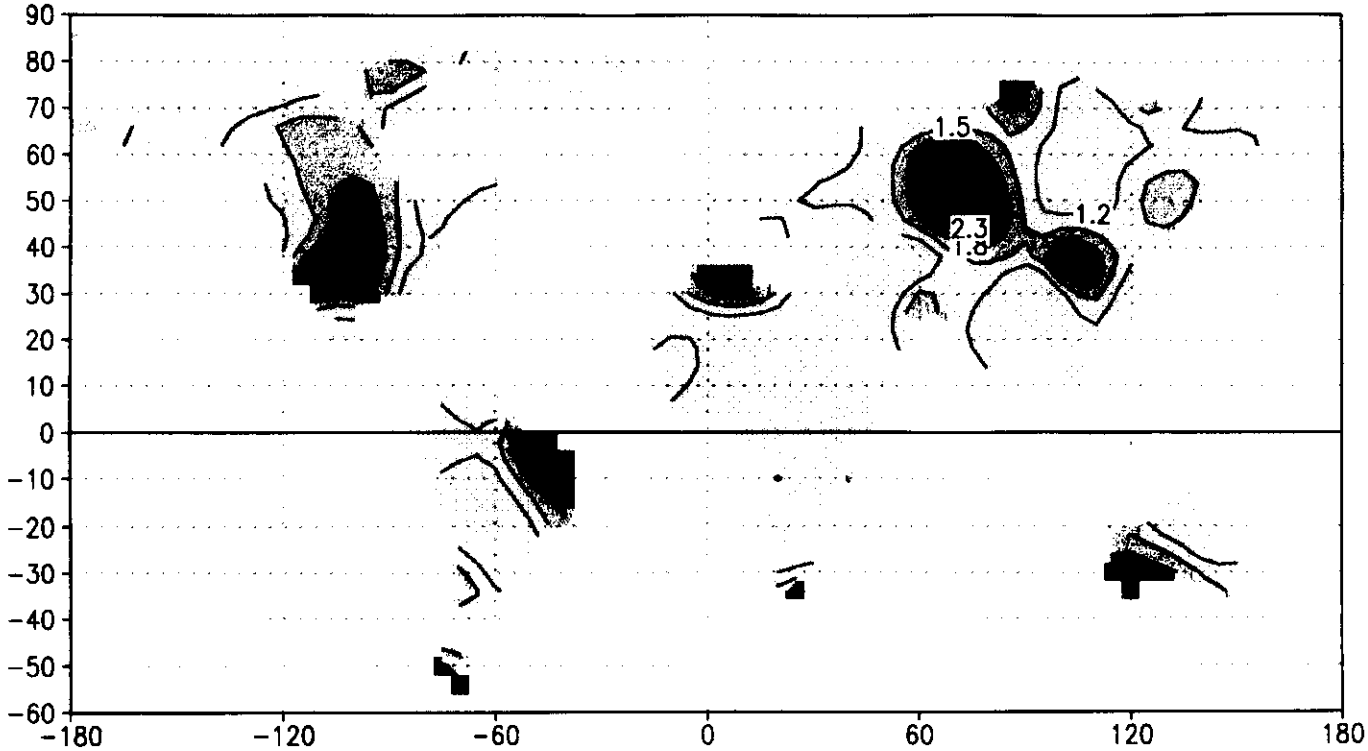

Contouring at levels 1.2 1.5 1.8 (95% sig.) 2.3 (99% sig.)

(F) JJAS temp.canopy sp. (25 pt ave.)
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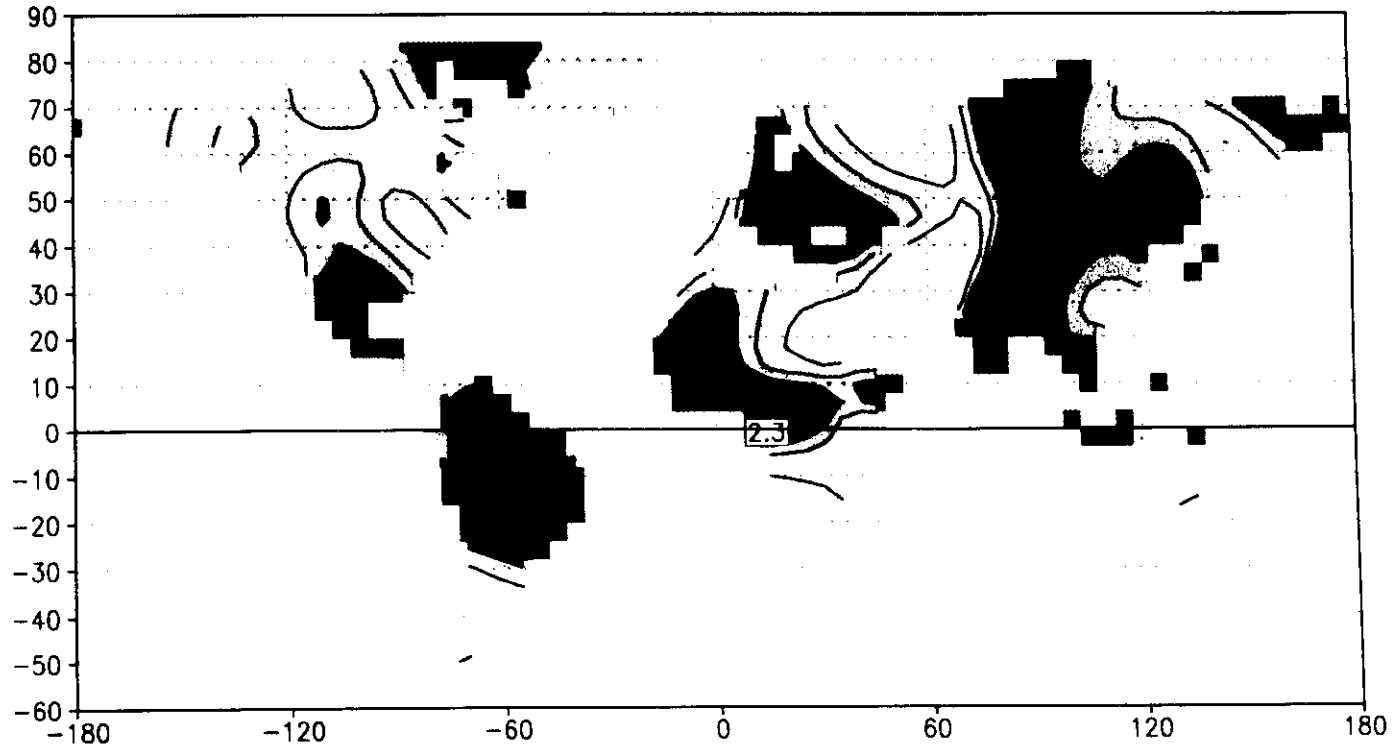
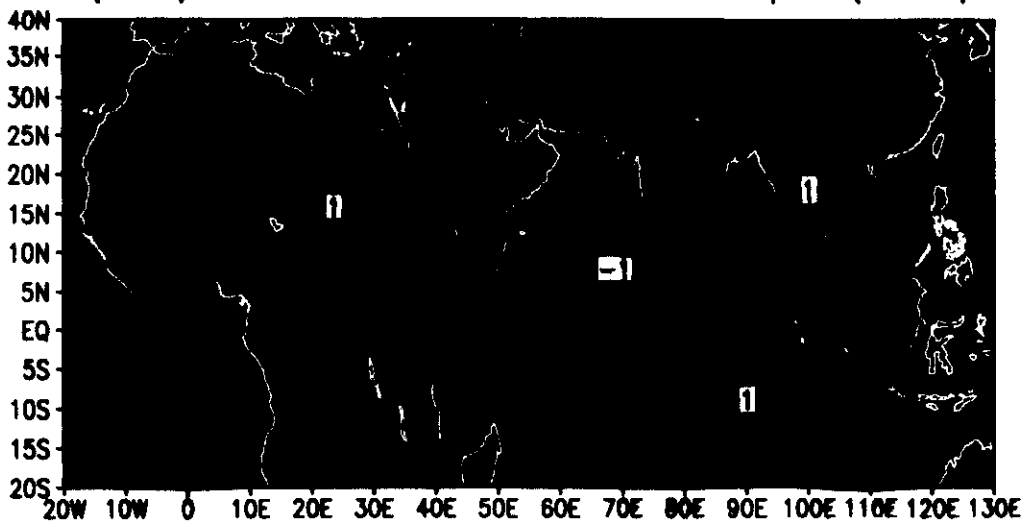
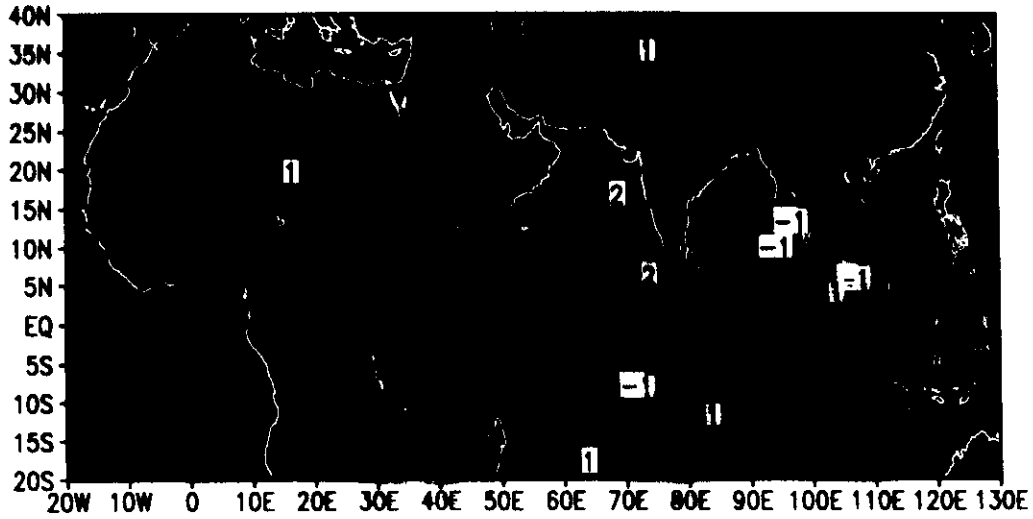


Contouring at levels 1.2 1.5 1.8 (95% sig.) 2.3 (99% sig.)

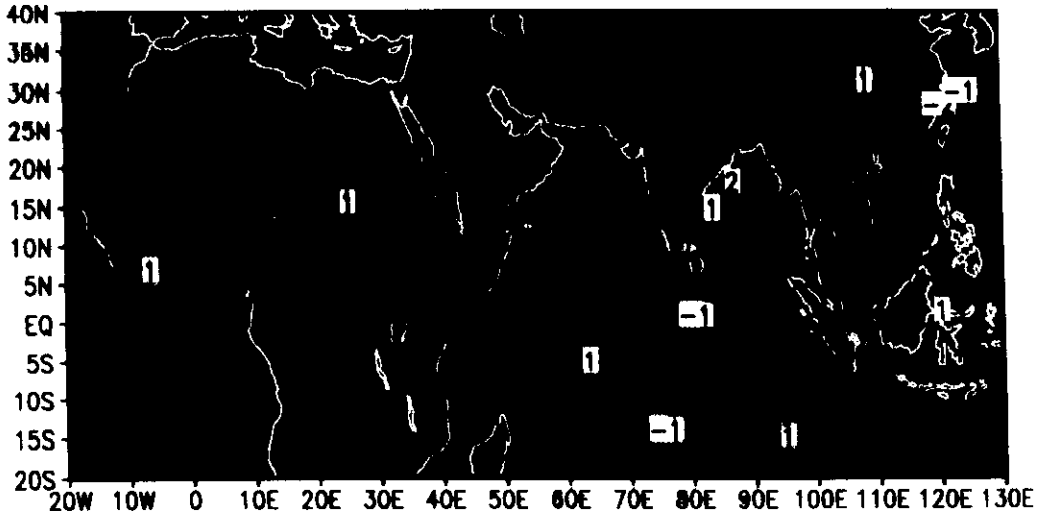
COLA (old) JJA 88–87 Precip. (mm/day)



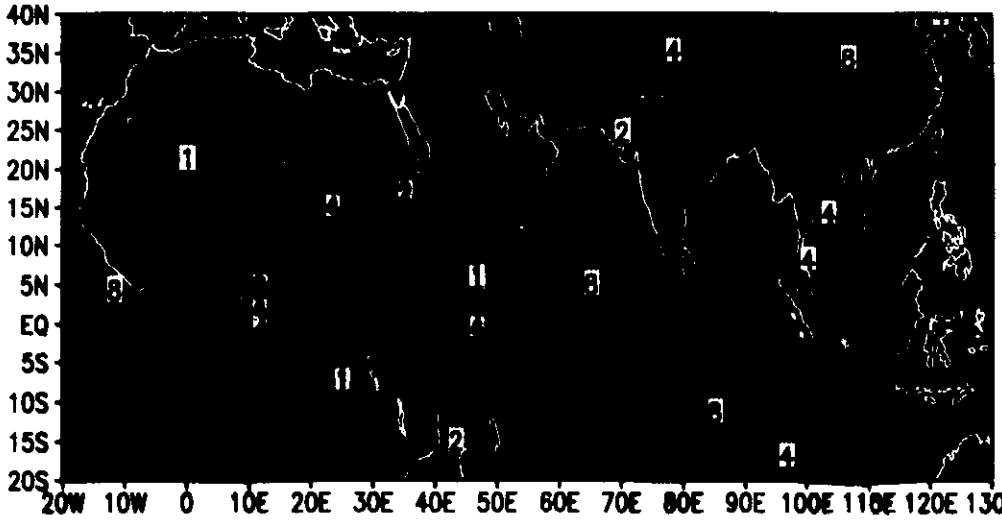
GPCP/MSU JJA 88–87 Precip. (mm/day)



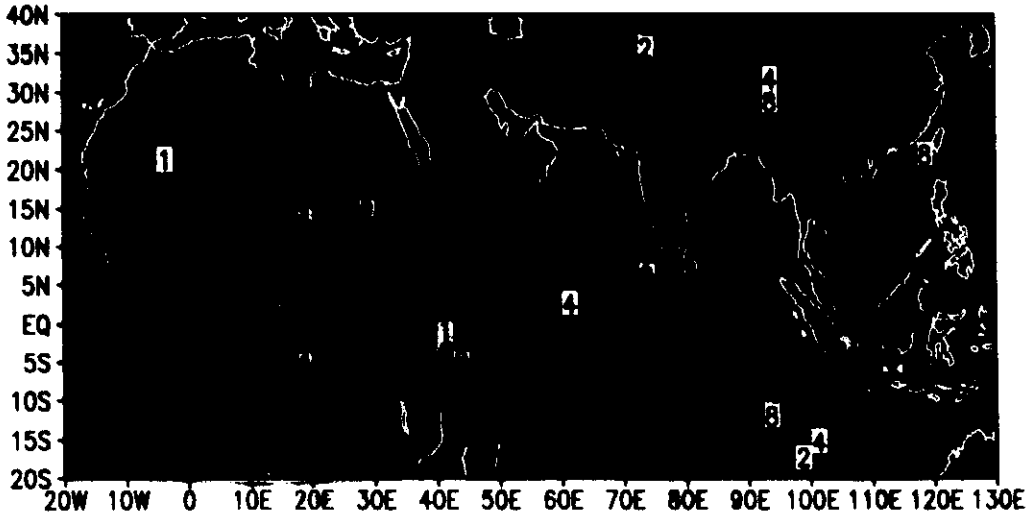
COLA (new) JJA 88–87 Precip. (mm/day)



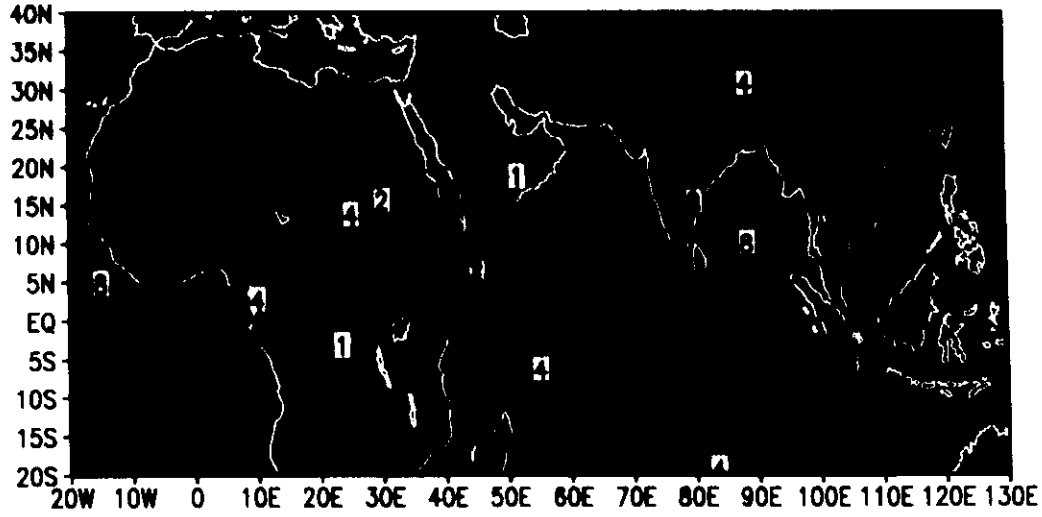
COLA (old) JJA 88 Precip. (mm/day)



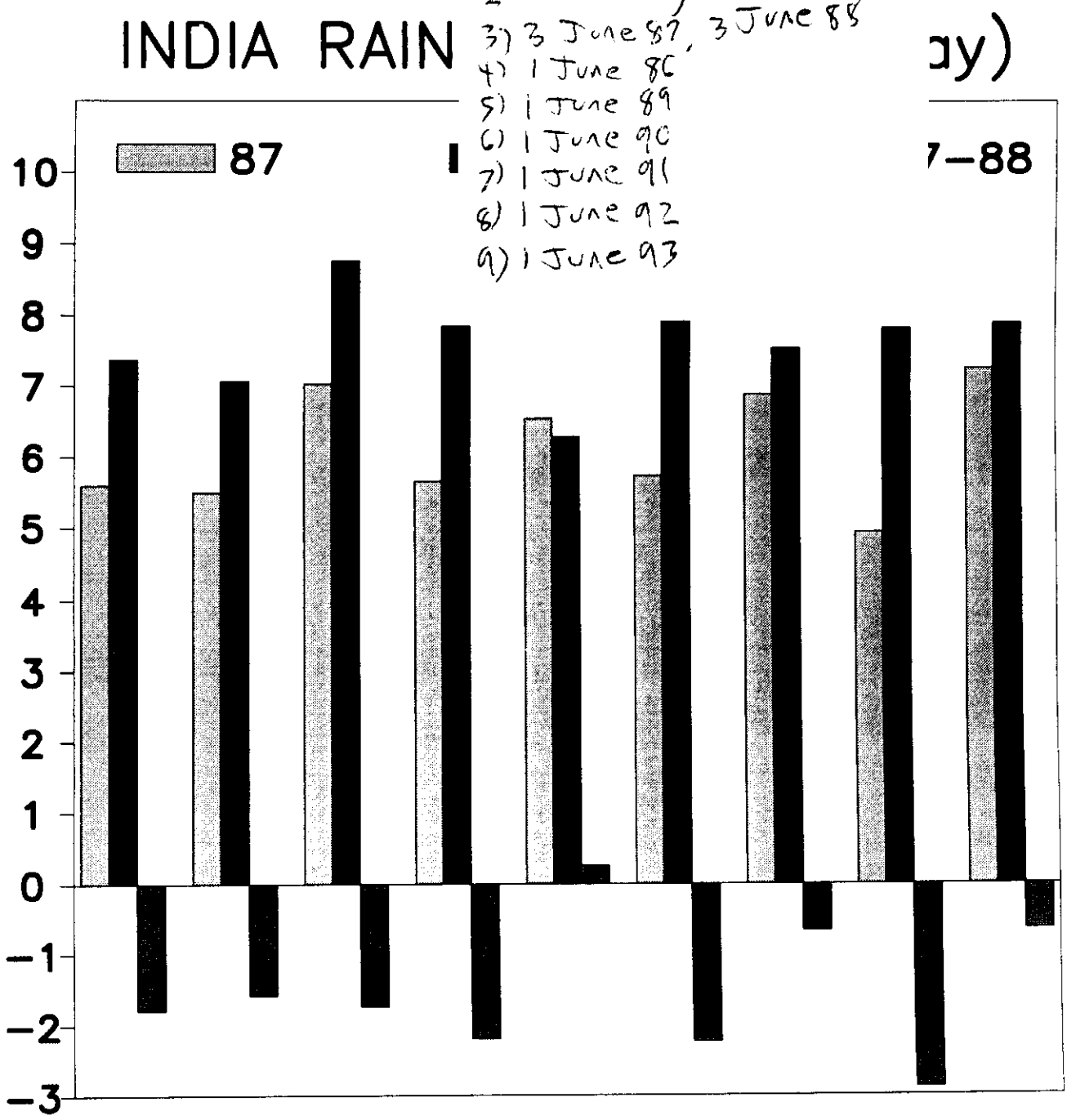
GPCP/MSU JJA 88 Precip. (mm/day)



COLA (new) JJA 88 Precip. (mm/day)

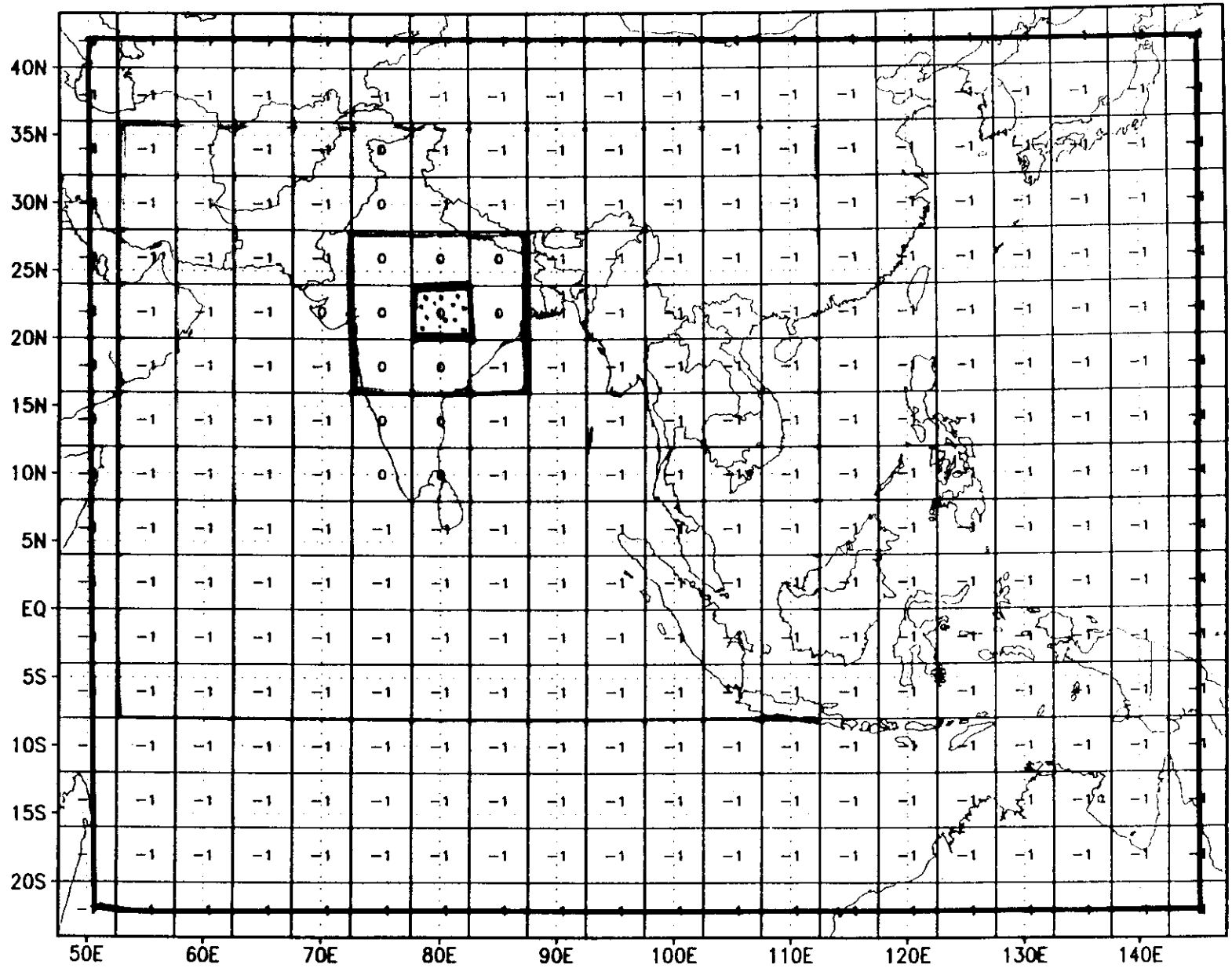


From Left to Right 9 pairs:
1) 1 June 87, 1 June 88
2) 2 June 87, 2 June 88
3) 3 June 87, 3 June 88
4) 1 June 86
5) 1 June 89
6) 1 June 90
7) 1 June 91
8) 1 June 92
9) 1 June 93

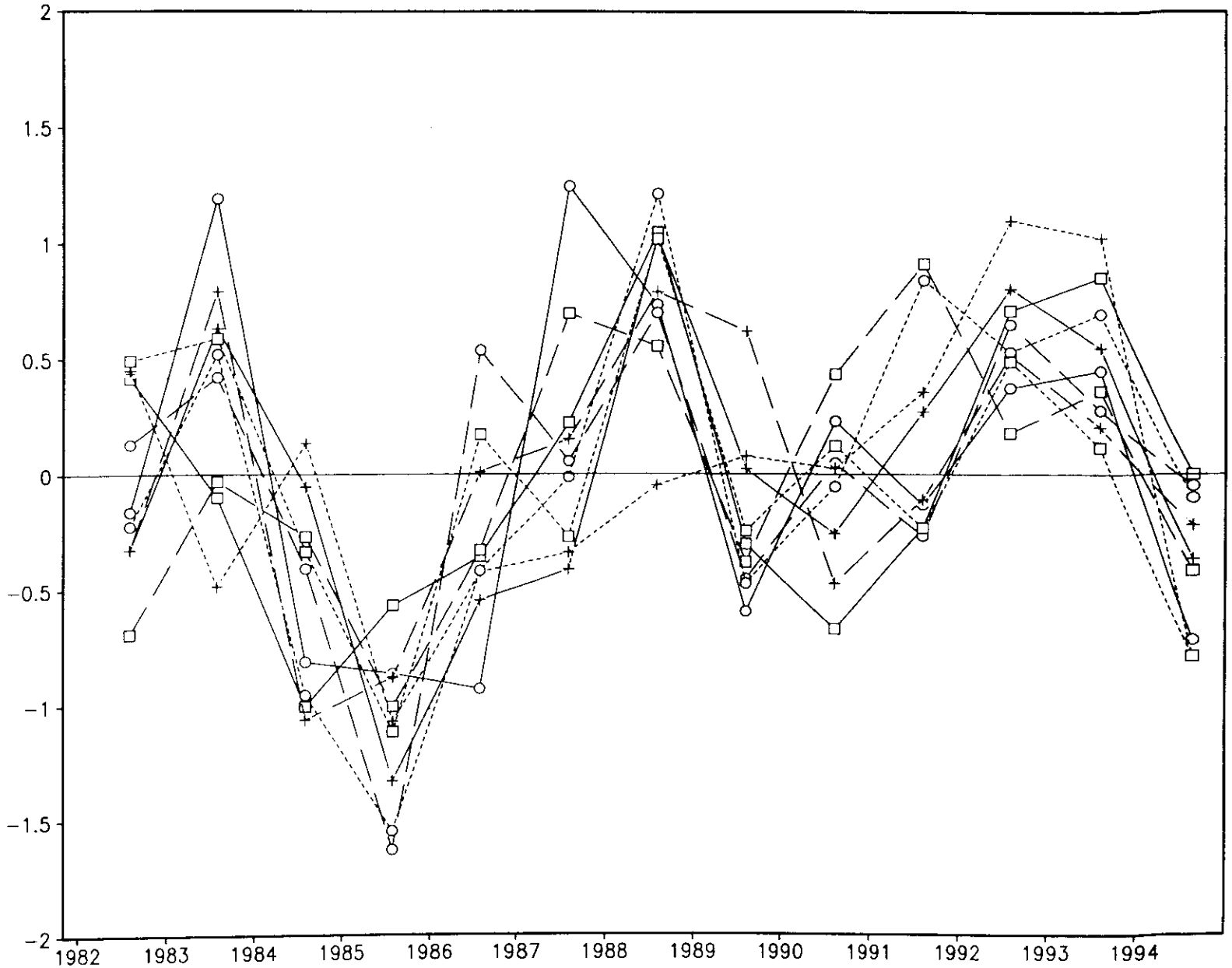


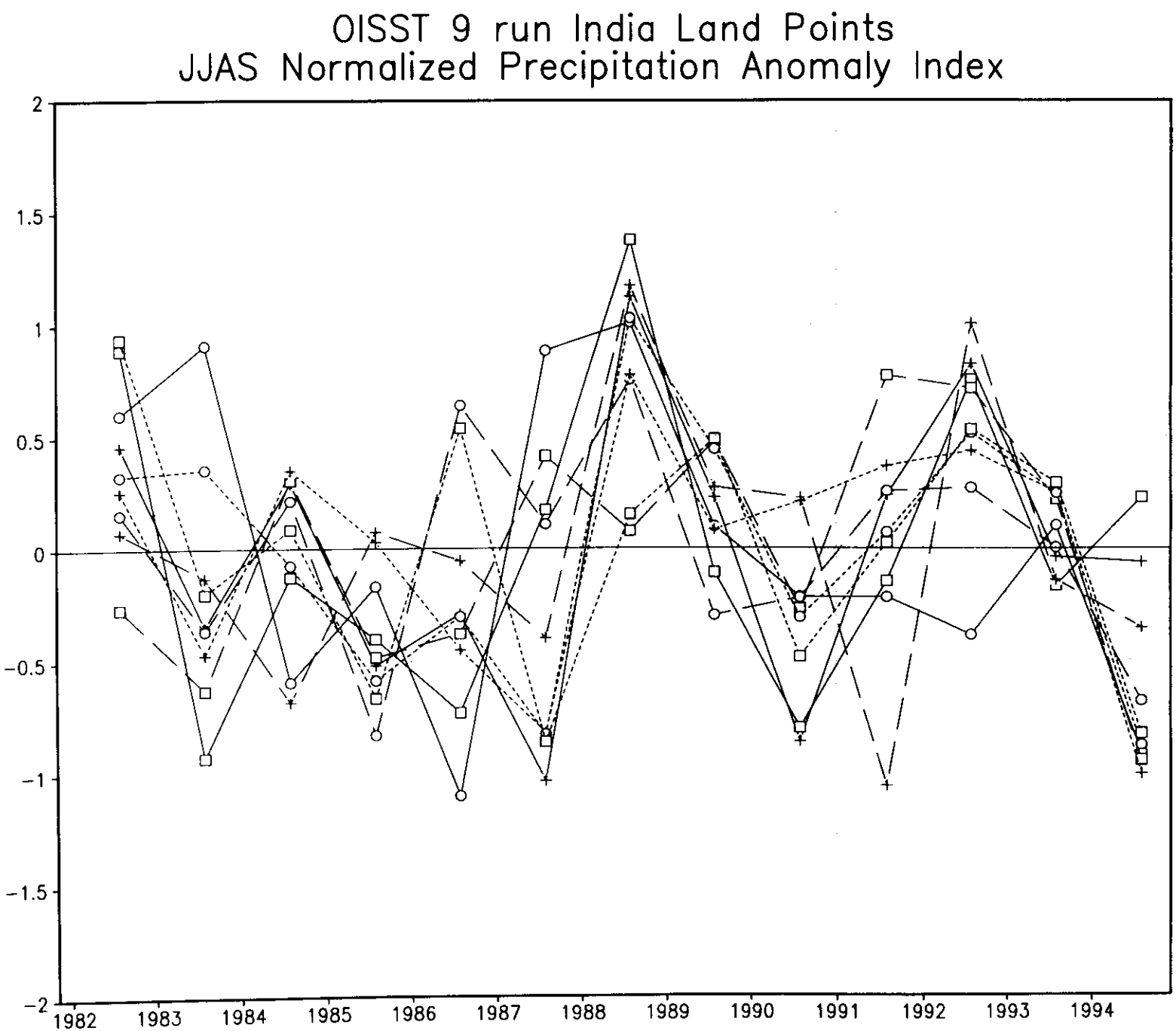
COLA GCM June–July–August mean rainfall area averaged over 15N–30N, 70E–90E, simulated using 1987 and 1988 SST and 9 different atmospheric initial conditions.

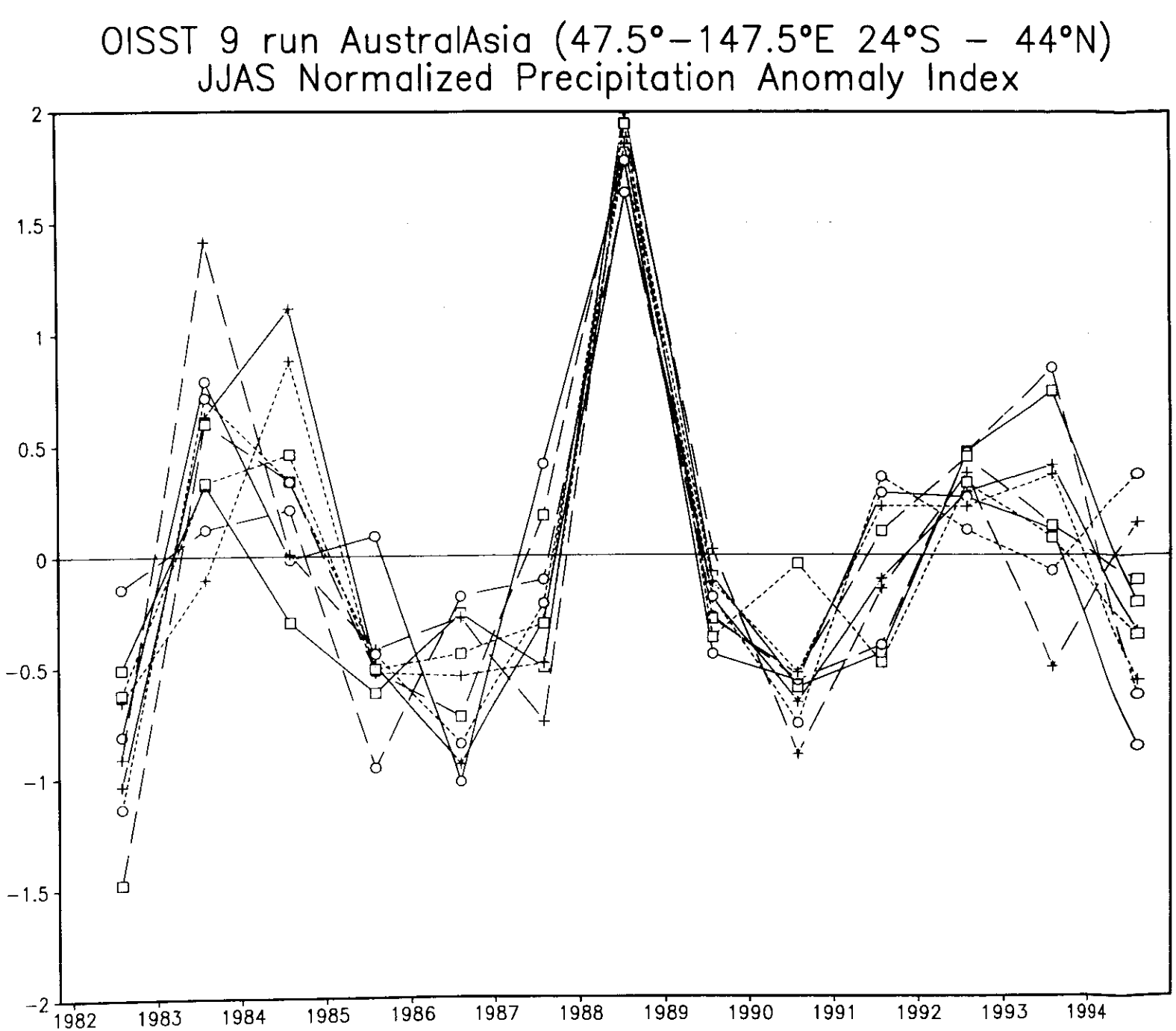
AustralAsia Monsoon Map

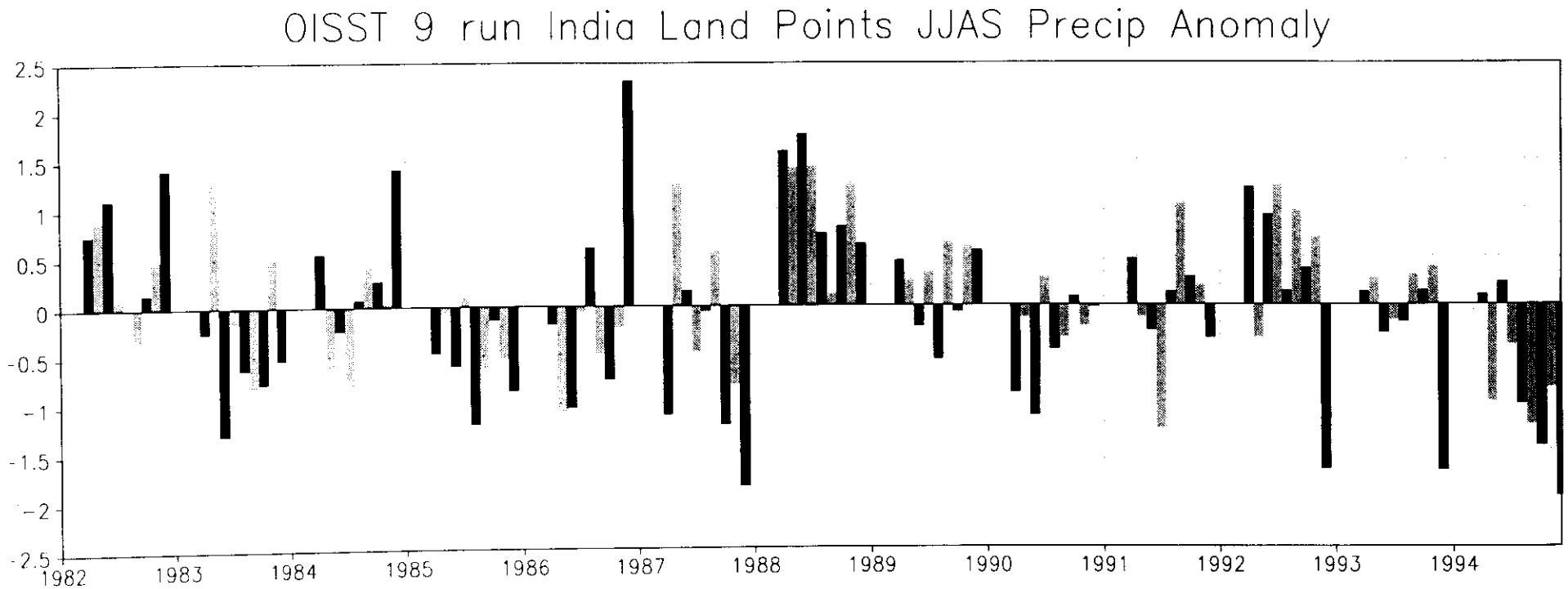


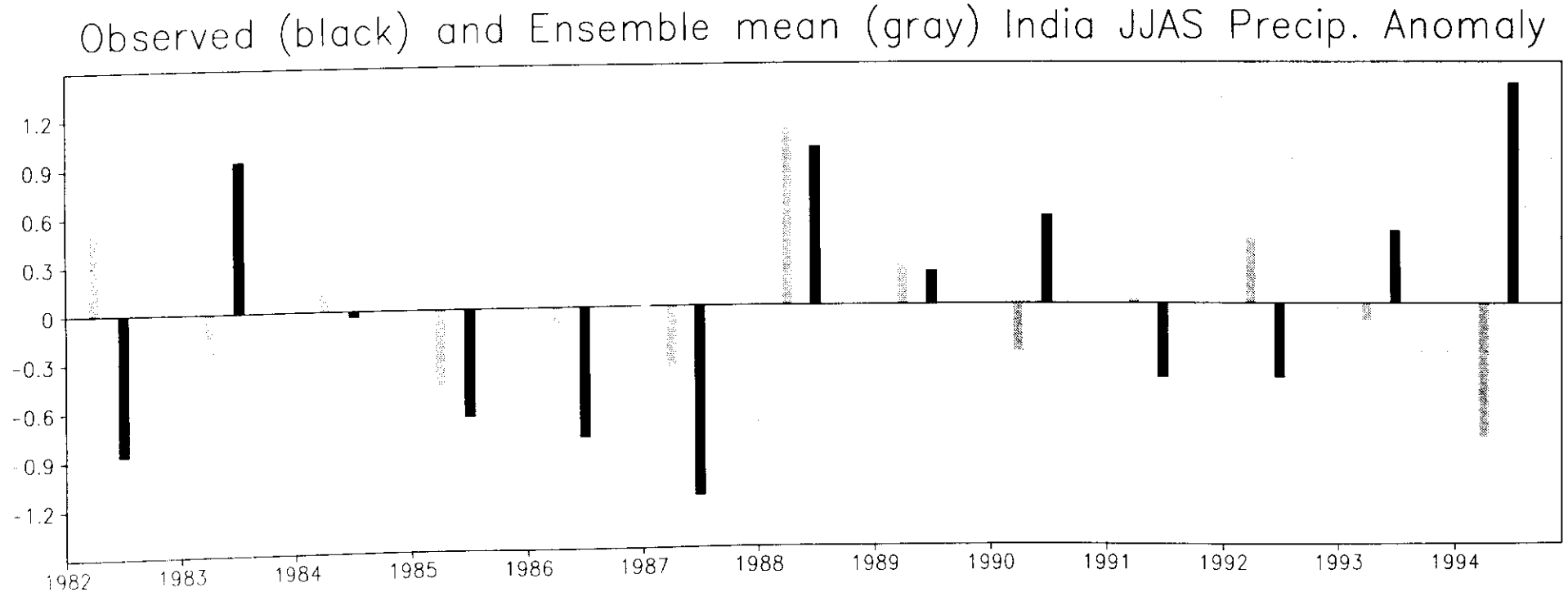
GrADS: COLA/IGES


OISST 9 run India+SE Asia (52.5°–112.5°E 8°S – 36°N)
JJAS Normalized Precipitation Anomaly Index
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994


OISST 9 run India Land Points
JJAS Normalized Precipitation Anomaly Index
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994


OISST 9 run AustralAsia (47.5°–147.5°E 24°S – 44°N)
JJAS Normalized Precipitation Anomaly Index
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994


OISST 9 run India Land Points JJAS Precip Anomaly
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994


Observed (black) and Ensemble mean (gray) India JJAS Precip. Anomaly
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-1.2
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994

Monsoon Predictability Paradox

- **Apparent lack of sensitivity to I.C.**
- **Significant changes due to B.C.**
- **High Predictability (dynamical)**
- **"Bad" dynamical forecasts**
- **"Apparently" good statistical forecasts**