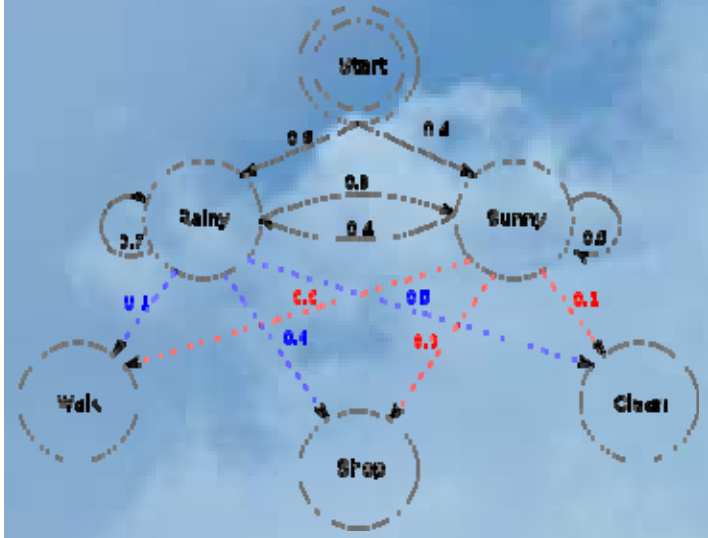
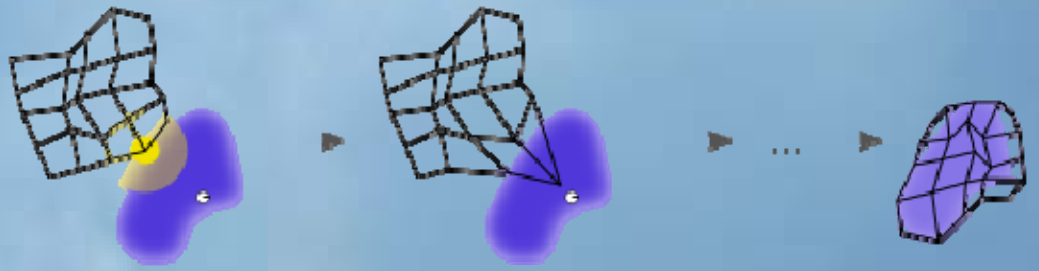
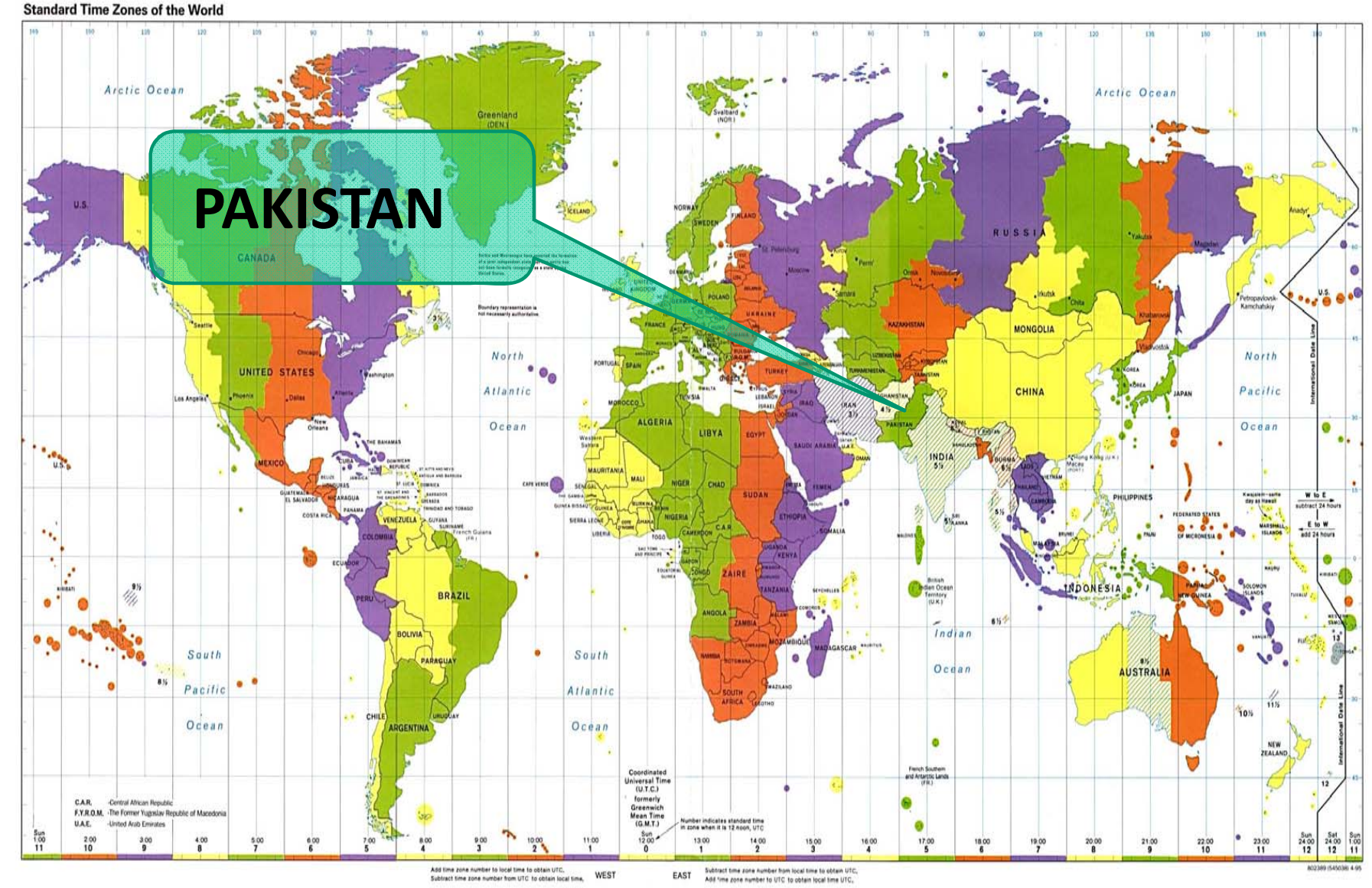
- **Seasonal (JJAS) Rainfall Distribution over the core monsoon region of Pakistan (32° - 35° N & 72° - 75° E); using APHRODITE and Station Data**

- **Propagation of mid-latitude features (westerlies) into the subcontinent using clustering analysis**





1) Mr. Muhammad Latif
2) Dr. K.P. Harikrishnan
3) Dr. Suneet Dwivedi
4) Dr. Alok Sagar Gautam


Standard Time Zones of the World
PAKISTAN
Arctic Ocean
Greenland (DEN.)
Svalbard (NOR.)
U.S.
CANADA
ICELAND
NORWAY
SWEDEN
FINLAND
RUSSIA
UNITED STATES
MEXICO
CHINA
MONGOLIA
INDIA
JAPAN
PHILIPPINES
INDONESIA
AUSTRALIA
NEW ZEALAND
BRAZIL
ARGENTINA
CHILE
BOLIVIA
PARAGUAY
PERU
COLOMBIA
VENEZUELA
ECUADOR
ALGERIA
LIBYA
EGYPT
SUDAN
ETHIOPIA
SOMALIA
KENYA
ZAIRE
TANZANIA
ANGOLA
ZAMBIA
MOZAMBIQUE
MADAGASCAR
SOUTH AFRICA
NIGERIA
NIGER
CHAD
MALI
MAURITANIA
MOROCCO
TURKEY
IRAN
IRAQ
SAUDI ARABIA
PAKISTAN
AFGHANISTAN
KAZAKHSTAN
UKRAINE
POLAND
FRANCE
SPAIN
PORTUGAL
ITALY
GERMANY
North Atlantic Ocean
South Atlantic Ocean
North Pacific Ocean
South Pacific Ocean
Indian Ocean
International Date Line
Coordinated Universal Time (U.T.C.) formerly Greenwich Mean Time (G.M.T.)
C.A.R. -Central African Republic
F.Y.R.O.M. -The Former Yugoslav Republic of Macedonia
U.A.E. -United Arab Emirates
WEST
EAST

Weather Systems of Pakistan

Monsoon Weather Systems
(Jun – Sep)

65%
Annual Rainfall

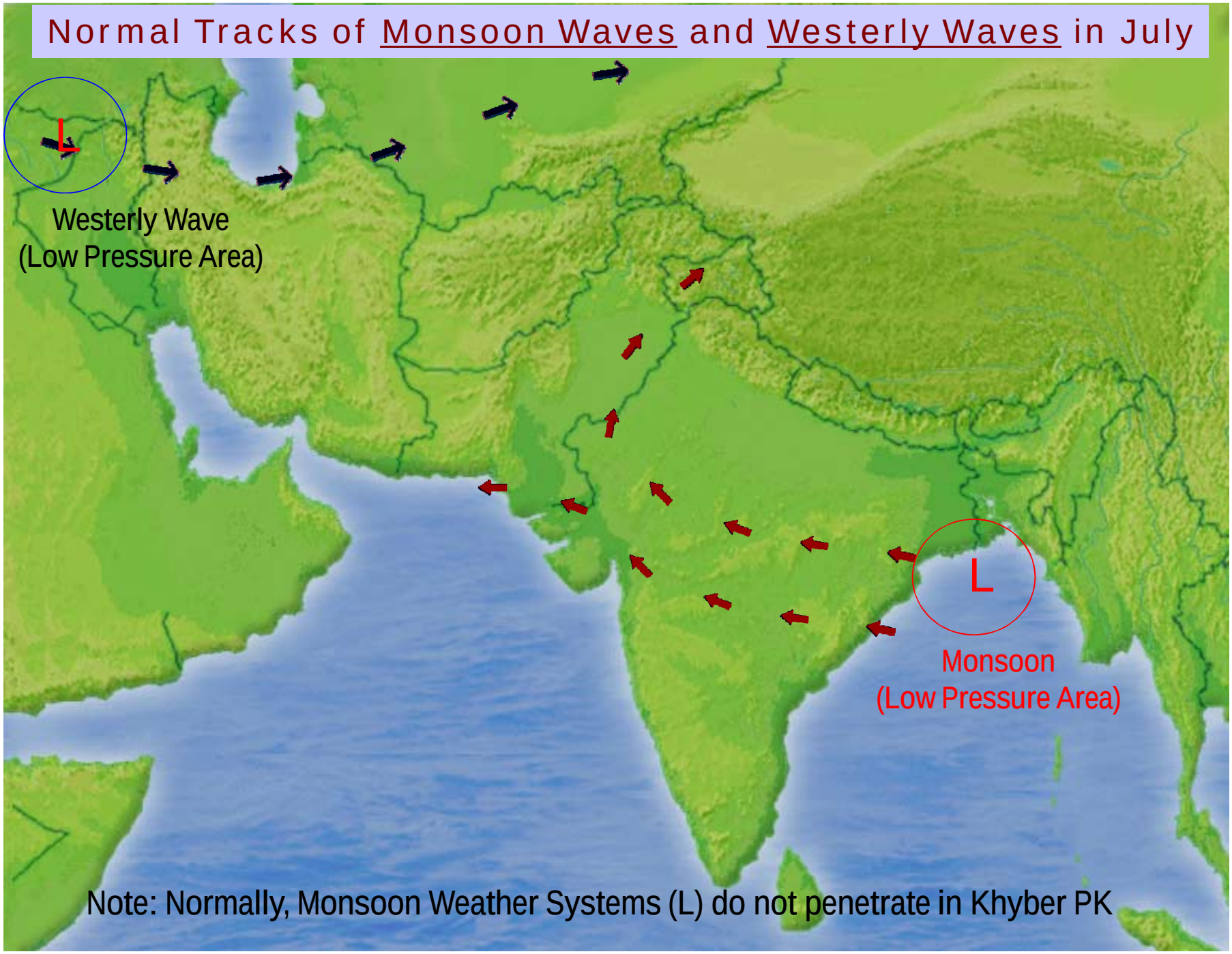
Western Disturbances (Mid Latitude Weather Systems)
(Dec – Mar)

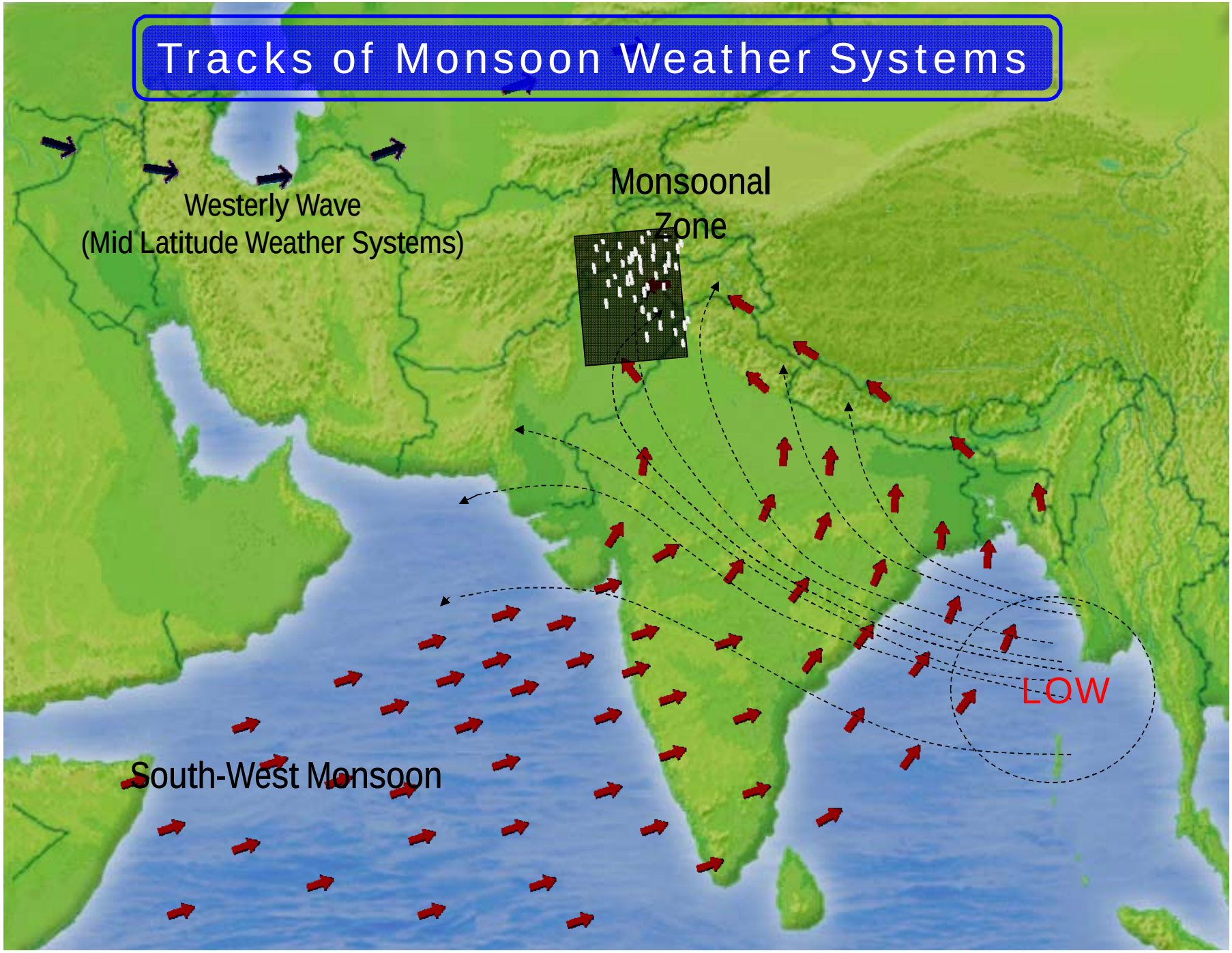
25%
Annual Rainfall

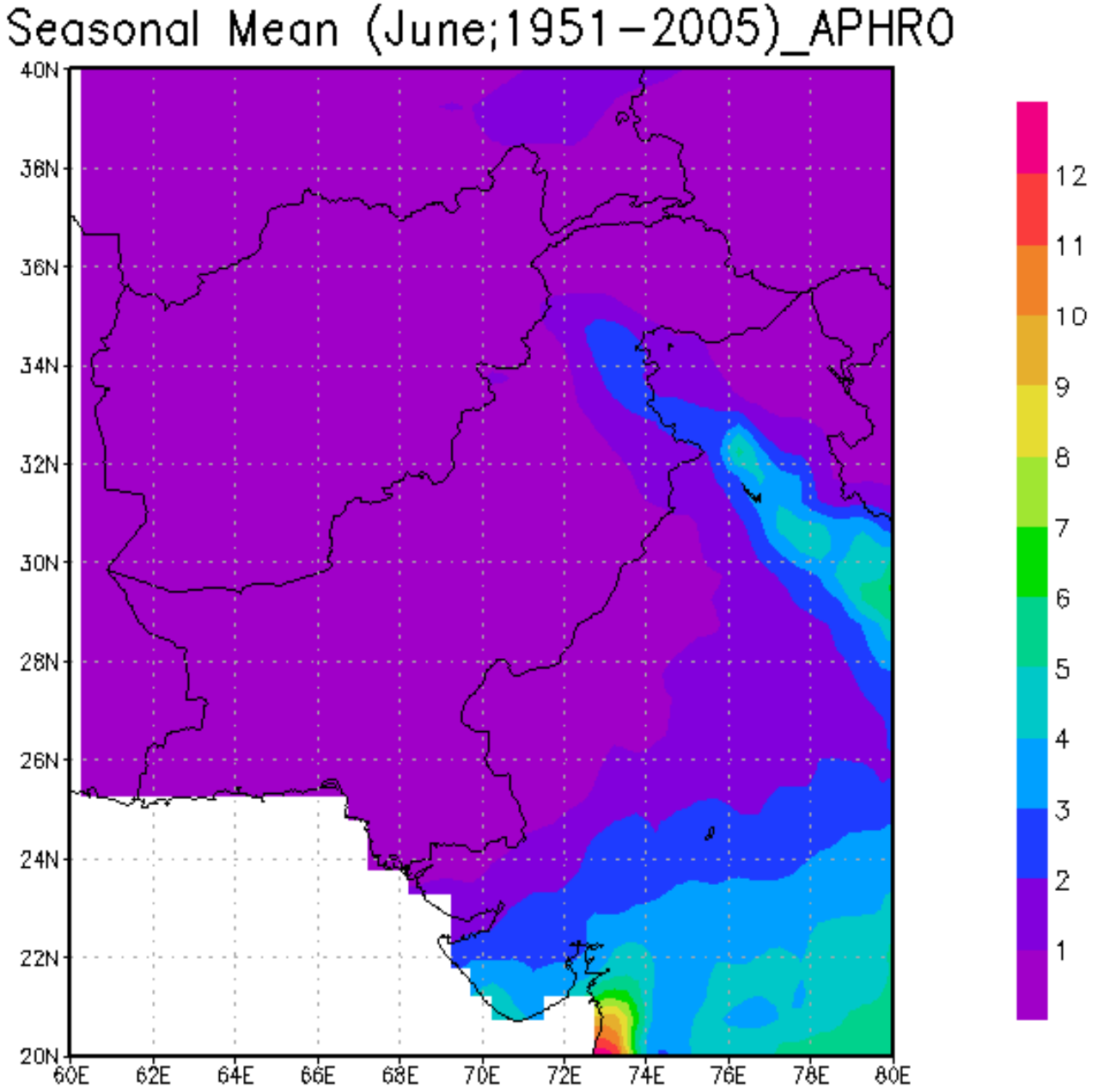
Pre & Post Monsoon Weather Systems (Tropical Storms)
(May-Jun-Sep-Oct)

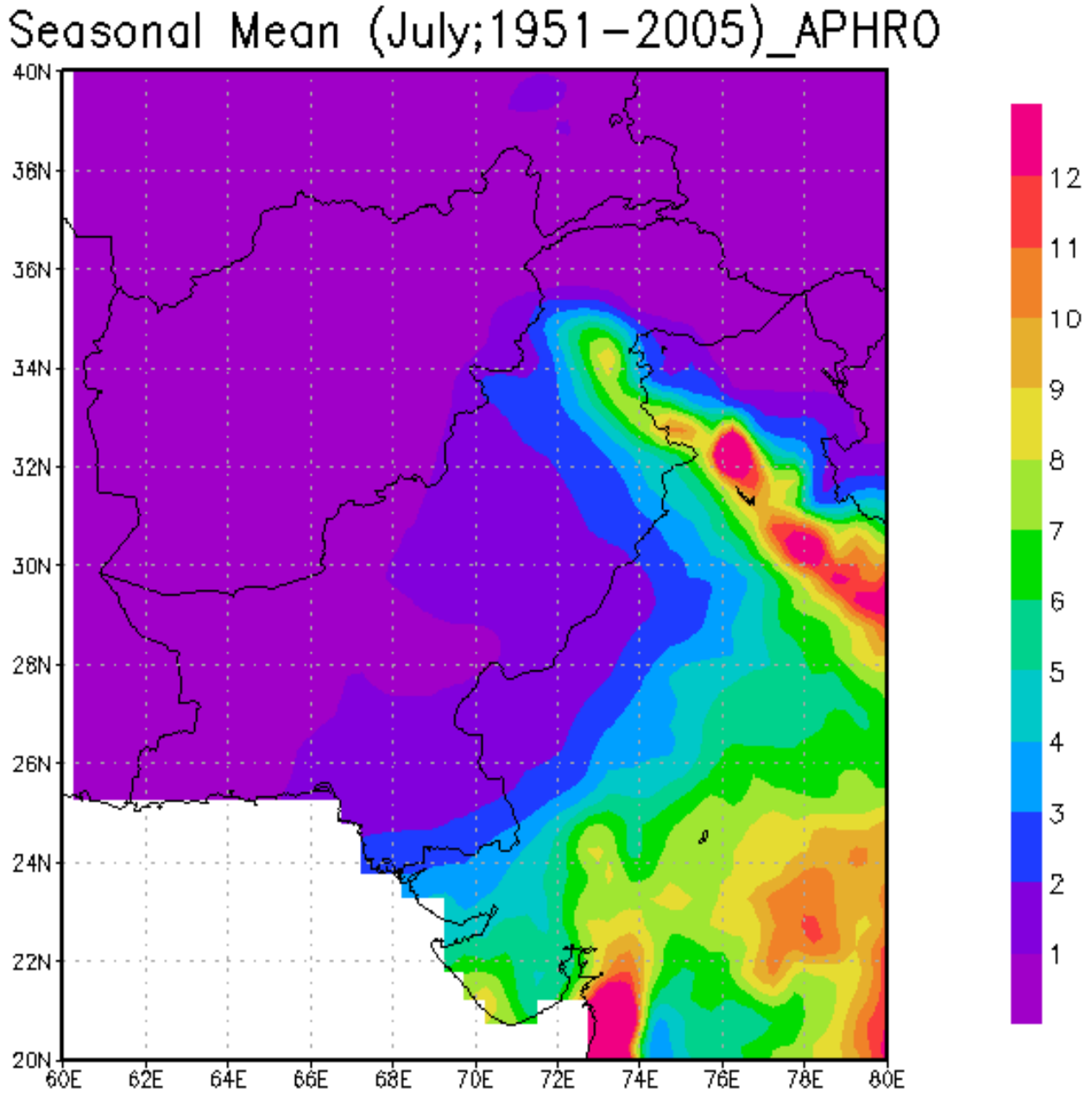
Extreme
Events

Normal Tracks of Monsoon Waves and Westerly Waves in July




Tracks of Monsoon Weather Systems
Westerly Wave
(Mid Latitude Weather Systems)
Monsoonal
Zone
LOW
South-West Monsoon


Seasonal Mean (June;1951-2005)_APHRO
40N
36N
36N
34N
32N
30N
28N
26N
24N
22N
20N
60E
62E
64E
66E
68E
70E
72E
74E
76E
78E
80E
12
11
10
9
8
7
6
5
4
3
2
1


Seasonal Mean (July;1951-2005)_APHRO
40N
36N
36N
34N
32N
30N
28N
26N
24N
22N
20N
60E
62E
64E
66E
68E
70E
72E
74E
76E
78E
80E
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8
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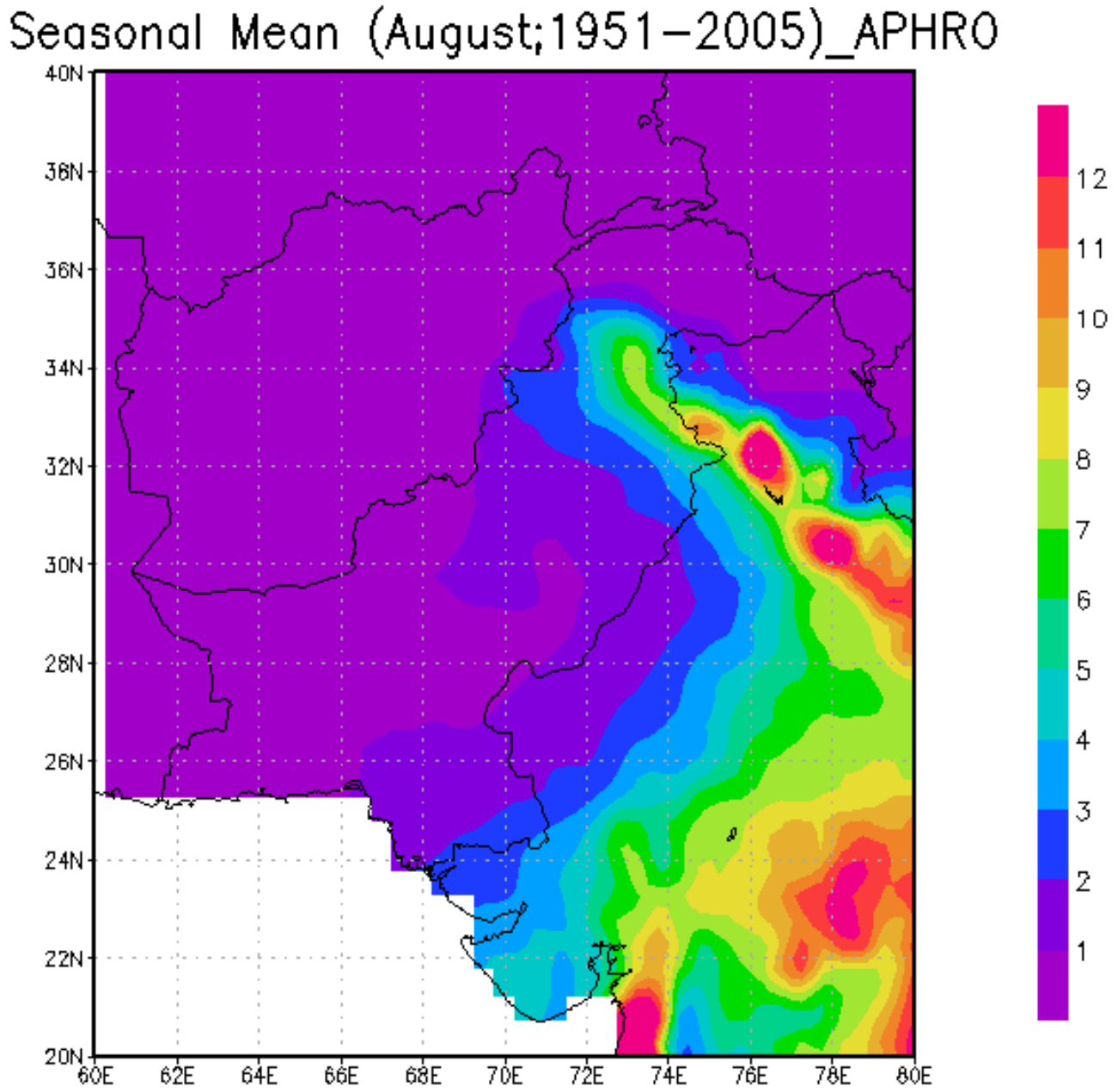
6
5
4
3
2
1


Seasonal Mean (August;1951–2005)_APHRO
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34N
32N
30N
28N
26N
24N
22N
20N
60E
62E
64E
66E
68E
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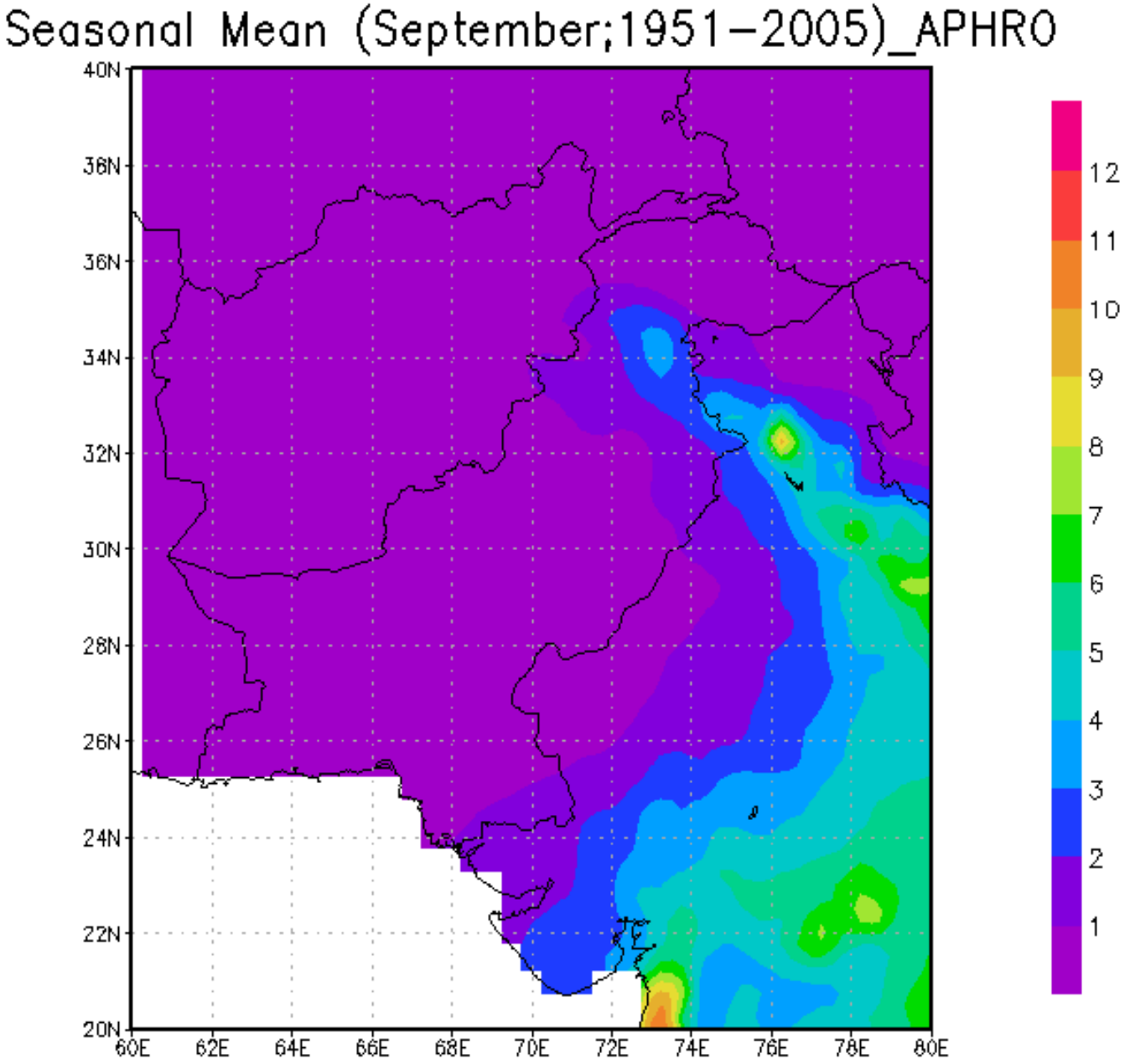
4
3
2
1


Seasonal Mean (September;1951-2005)_APHRO
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36N
34N
32N
30N
28N
26N
24N
22N
20N
60E
62E
64E
66E
68E
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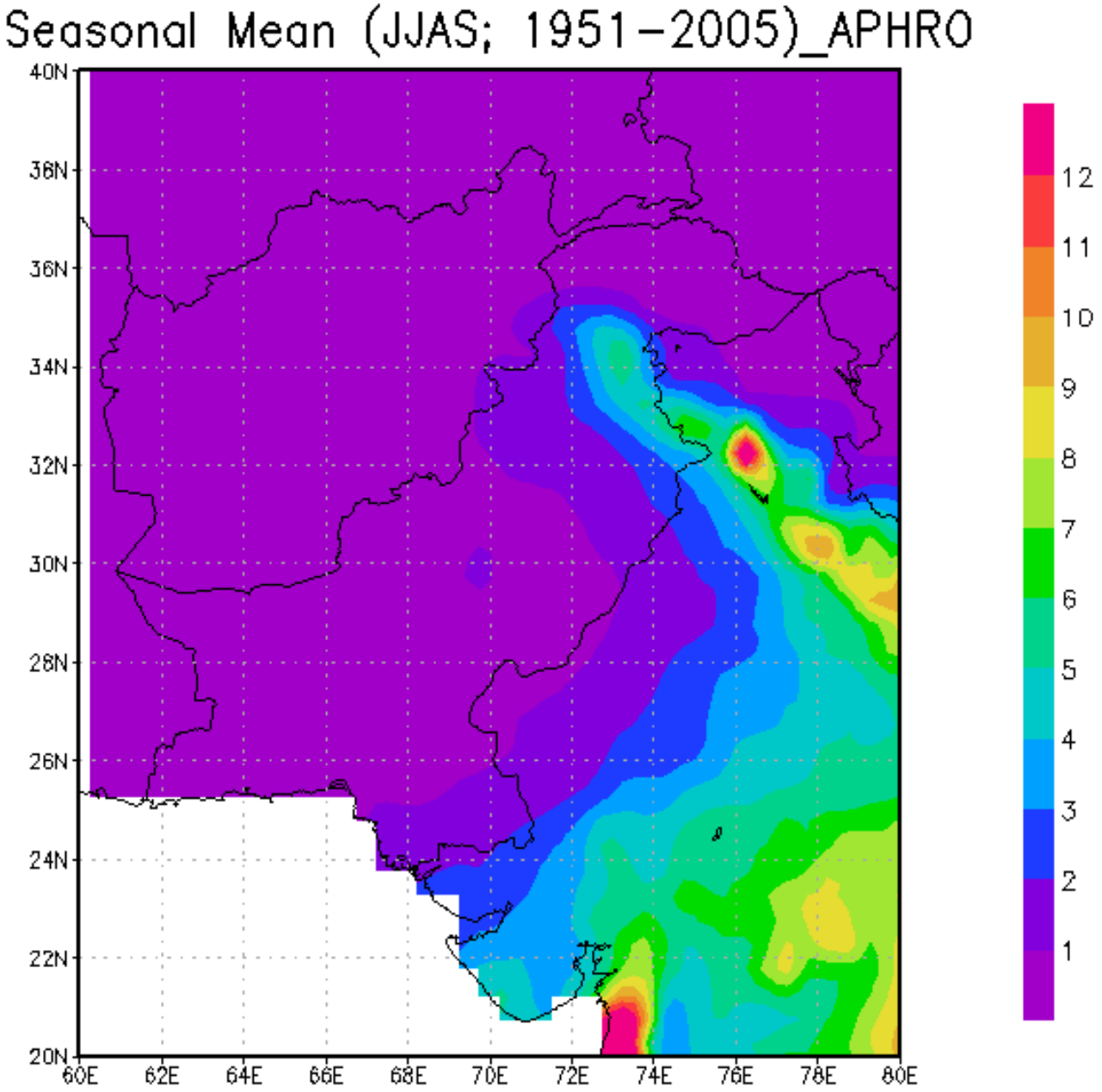
4
3
2
1


Seasonal Mean (JJAS; 1951-2005)_APHRO
40N
36N
36N
34N
32N
30N
28N
26N
24N
22N
20N
60E
62E
64E
66E
68E
70E
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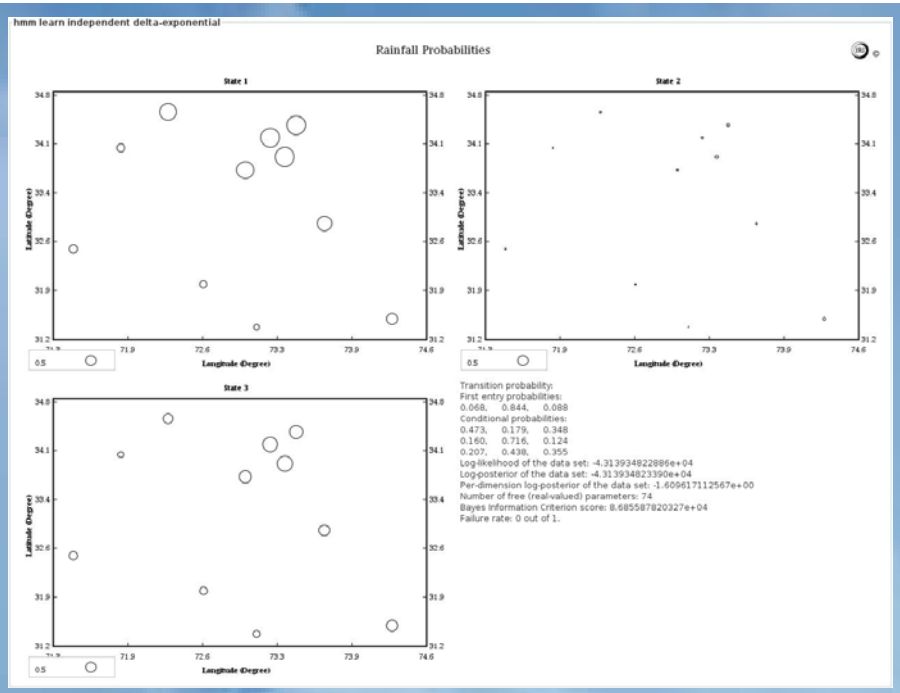
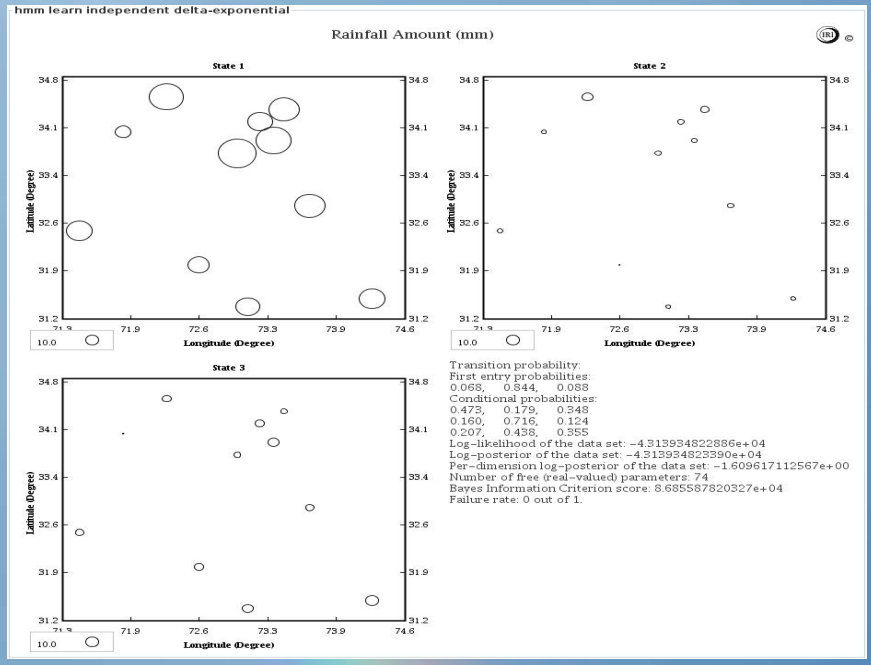
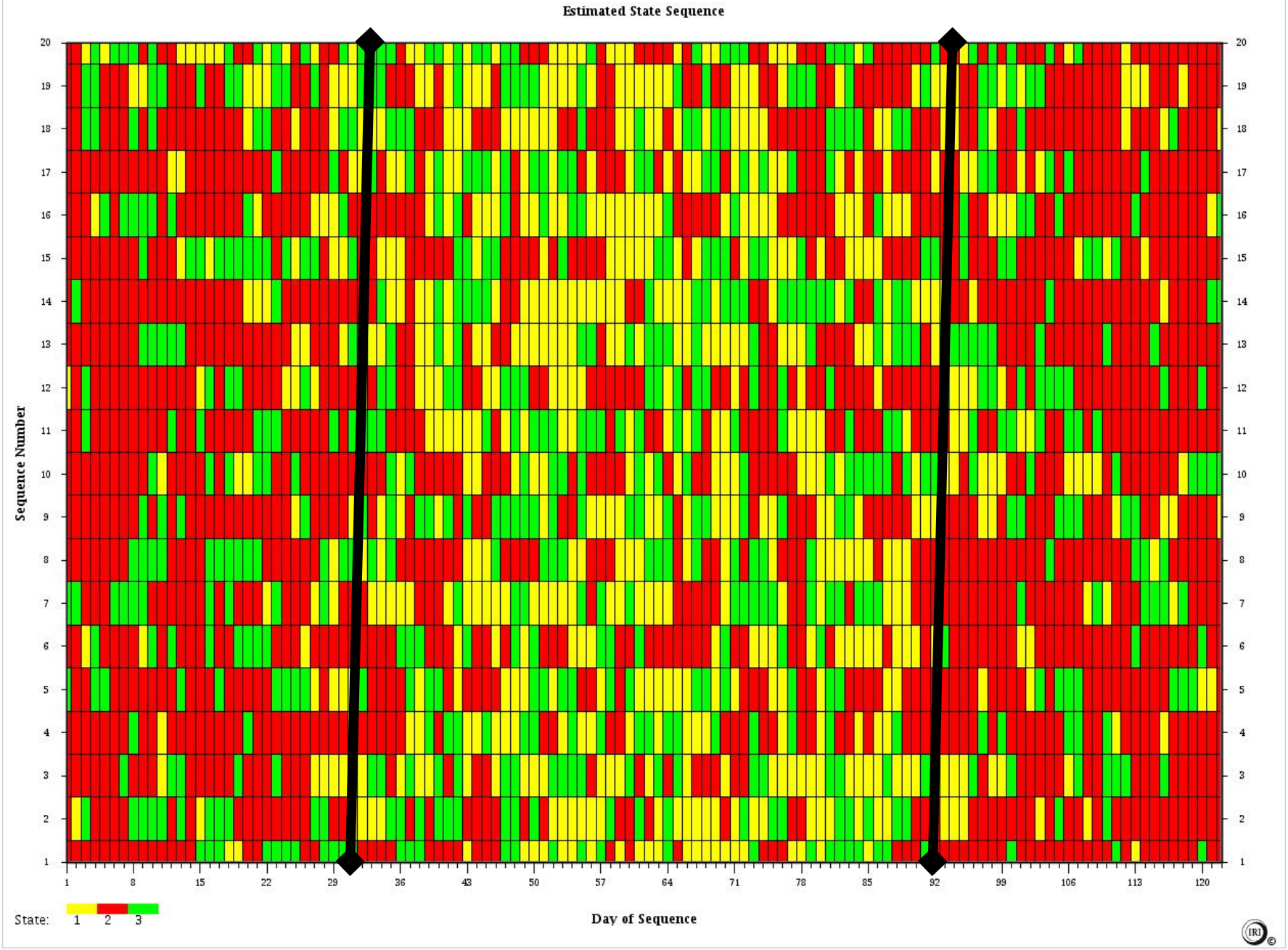
1

What HMM shows?

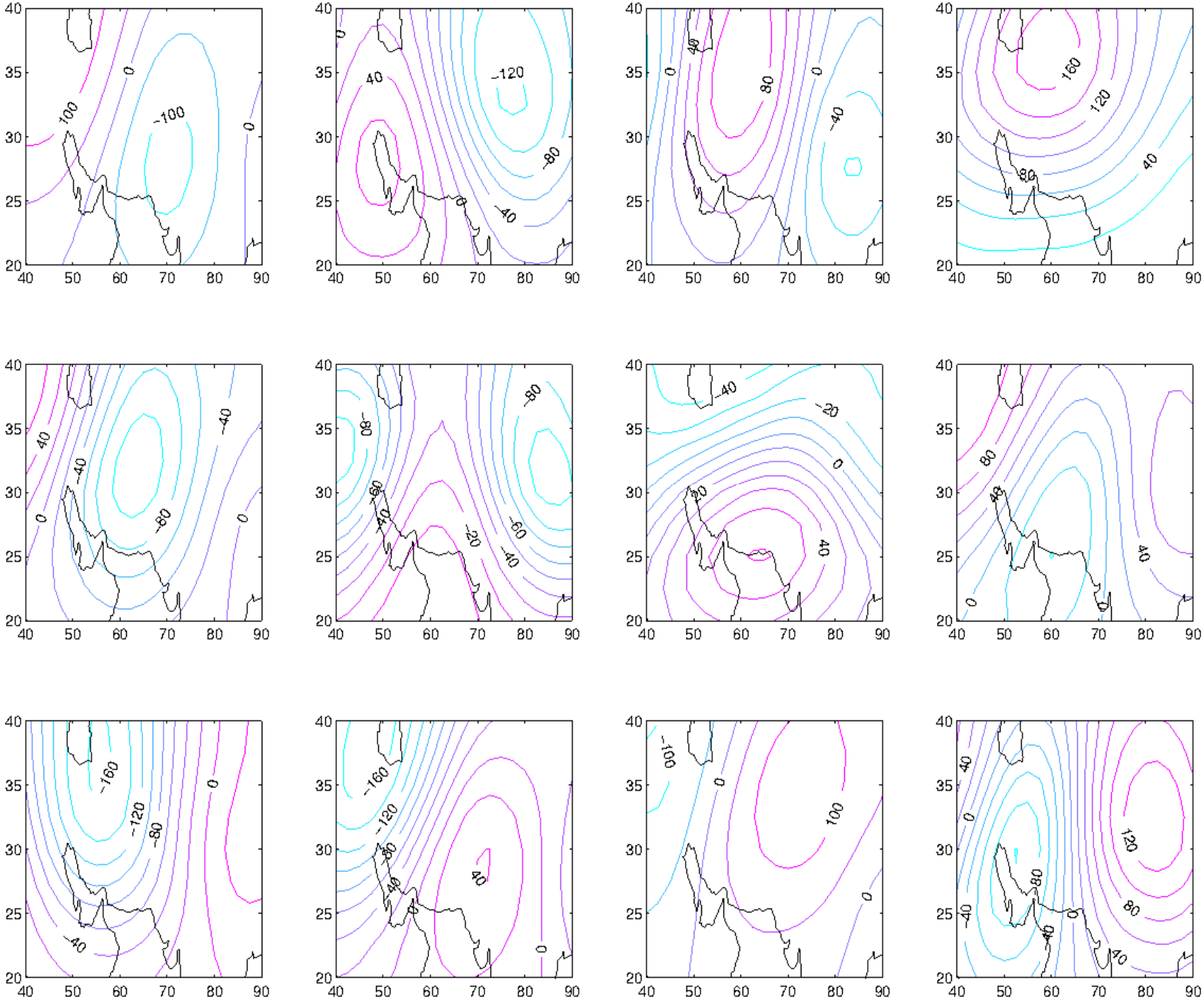




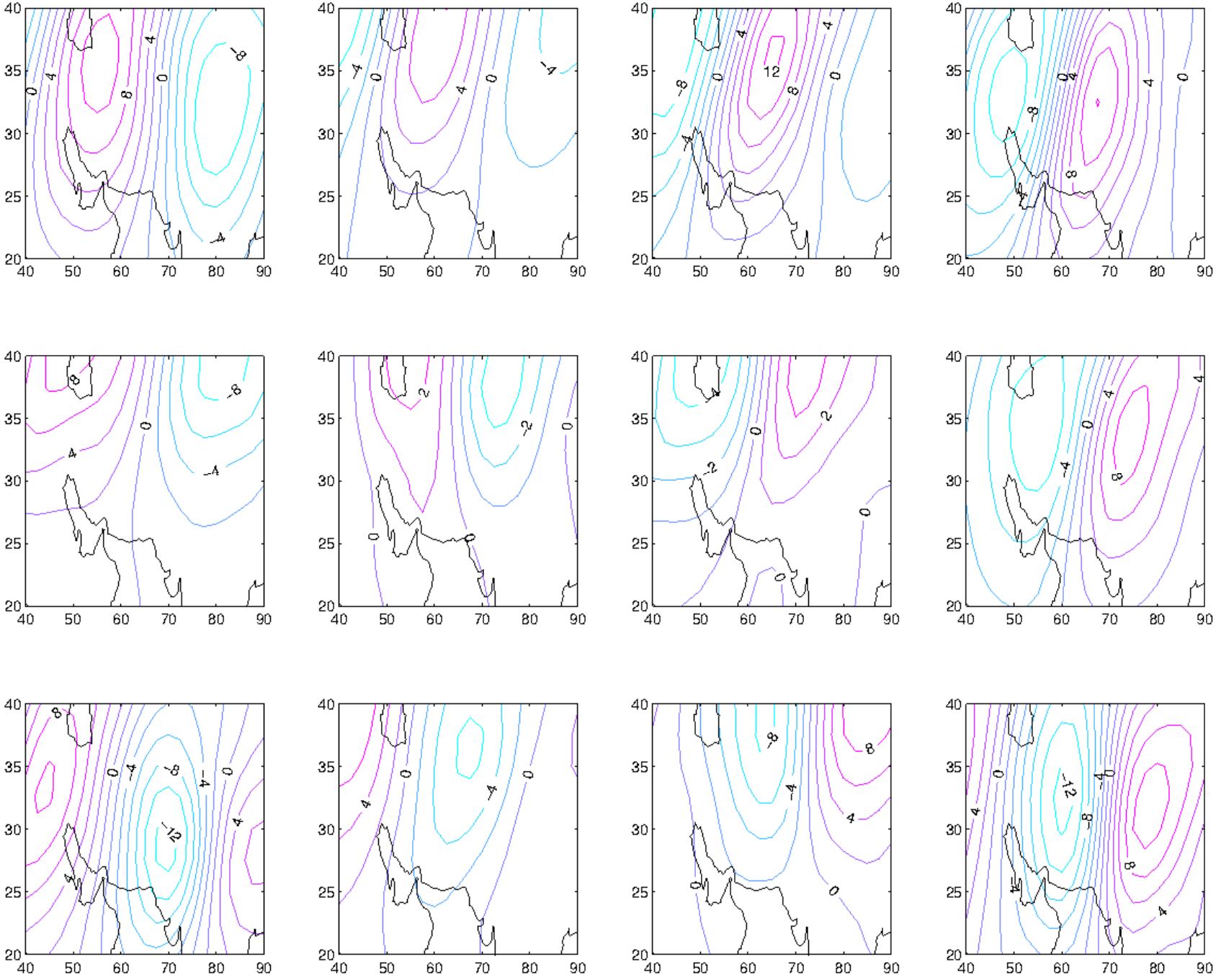
hmm viterbi independent delta-exponential



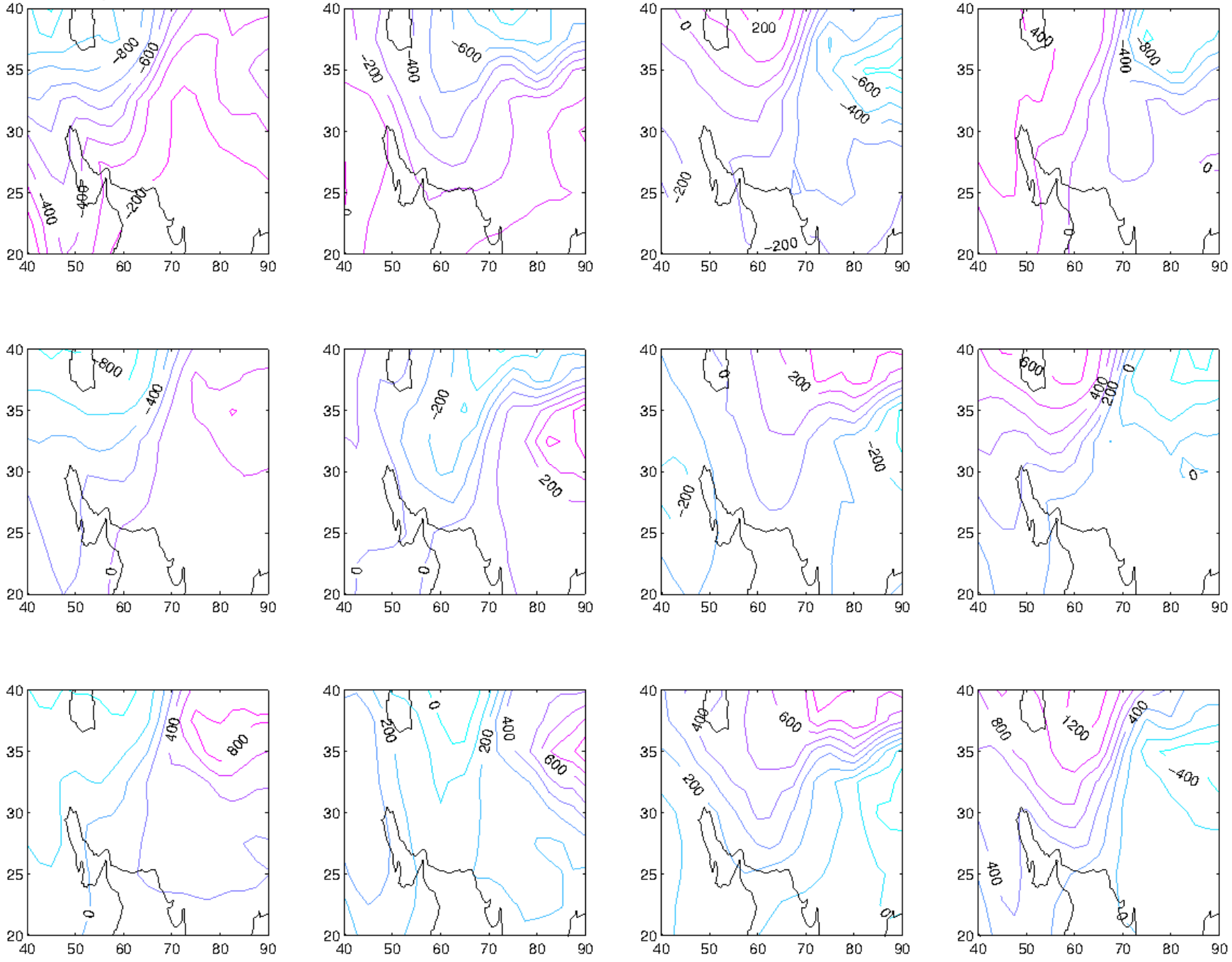
Geopotential Height SOM, 3 Anomaly Patterns, 1990 2011 20 40 40 90 300 300



Vwind SOM, 3 Anomaly Patterns, 1990 2011 20 40 40 90 300 300



SLP SOM, 3 Anomaly Patterns, 1990 2011 20 40 40 90



Transition Probability Matrix

Geopotential Height at 300 hPa

CN	1	2	3	4	5	6	7	8	9	10	11	12
1	0.58	0.10	0.18	0.02	0.03	0.03	0.02	0.04	0.01	0	0	0
2	0.07	0.50	0.08	0	0.03	0.21	0.10	0.01	0	0	0.01	0
3	0.01	0.05	0.45	0.06	0.02	0.08	0.11	0.04	0	0.03	0.14	0.01
4	0.01	0	0.09	0.73	0	0	0.01	0.06	0	0	0.07	0.01
5	0.14	0.11	0.02	0.01	0.50	0.12	0.03	0.05	0.02	0.01	0	0
6	0.01	0.05	0.02	0	0.11	0.48	0.06	0.01	0.08	0.15	0.02	0.02
7	0.01	0.10	0.07	0	0.05	0.03	0.56	0.05	0.01	0.04	0.03	0.02
8	0.13	0.02	0.10	0.07	0.03	0.01	0.03	0.54	0.01	0	0.02	0.04
9	0	0	0.01	0	0.19	0.10	0.02	0.02	0.56	0.08	0	0.03
10	0	0	0.01	0	0.03	0.04	0.13	0	0.18	0.47	0.07	0.08
11	0	0	0.04	0.03	0.01	0	0.12	0.03	0.01	0.03	0.54	0.18
12	0	0.01	0.01	0.04	0.04	0	0.03	0.23	0.04	0.01	0.04	0.55

V wind at 300 hPa

CN	1	2	3	4	5	6	7	8	9	10	11	12
1	0.51	0.19	0.09	0.01	0.09	0.03	0.04	0	0	0.03	0	0.01
2	0.04	0.38	0.2	0	0.06	0.12	0.18	0.01	0.01	0.02	0	0
3	0.02	0.09	0.49	0.14	0	0.03	0.19	0.04	0	0	0	0
4	0	0	0.04	0.46	0.01	0.03	0.08	0.33	0	0.03	0.03	0.01
5	0.11	0.08	0	0	0.6	0.08	0.02	0	0.04	0.07	0	0
6	0.02	0.17	0.01	0	0.08	0.37	0.19	0	0	0.13	0.02	0
7	0	0.03	0.04	0.05	0.01	0.13	0.37	0.13	0	0.09	0.13	0.02
8	0	0.01	0.01	0.05	0	0.06	0.12	0.49	0	0.06	0.09	0.11
9	0.12	0.05	0.03	0	0.1	0.05	0.01	0	0.56	0.06	0.01	0
10	0	0.03	0	0	0.15	0.17	0.03	0	0.1	0.43	0.07	0.01
11	0	0.01	0.01	0	0	0.09	0.14	0.05	0.01	0.13	0.49	0.07
12	0	0	0	0	0	0.03	0.06	0.1	0.08	0.02	0.19	0.52

Sea Level Presssure

CN	1	2	3	4	5	6	7	8	9	10	11	12
1	0.47	0.28	0.05	0.01	0.12	0.04	0.01	0.01	0	0	0	0
2	0.11	0.37	0.13	0.21	0.03	0.11	0.01	0.01	0	0	0	0
3	0.13	0.04	0.45	0.03	0.03	0.02	0.24	0.06	0	0	0	0.01
4	0.02	0.03	0.13	0.33	0	0.05	0.10	0.16	0	0.01	0.02	0.16
5	0.05	0.10	0.01	0.01	0.43	0.28	0.03	0.03	0.05	0.02	0	0.01
6	0.02	0.08	0.05	0.11	0.06	0.34	0.04	0.19	0.02	0.06	0.01	0
7	0.07	0.03	0.07	0.02	0.14	0.10	0.34	0.06	0.11	0.04	0.04	0
8	0	0.01	0.05	0.04	0	0.06	0.19	0.37	0.01	0.04	0.11	0.11
9	0.01	0	0	0.01	0.22	0.12	0.04	0.02	0.43	0.14	0.02	0
10	0	0.01	0	0.03	0.02	0.08	0.05	0.12	0.13	0.45	0.07	0.04
11	0	0	0.01	0	0.01	0	0.16	0.08	0.23	0.12	0.35	0.04
12	0	0	0.02	0.02	0	0	0.09	0.02	0.01	0.02	0.27	0.56

What we learnt?

- There is a lot of year to year variation in the onset dates
- Most of the rainfall over Pakistan occurs during July-August
- SOM maps clearly show propagation of winter monsoon (westerlies) during DJF season
- The transition of movement from one cluster to another is quantified during the season
- Both the methods may be used alternatively for sake of confirming our analysis.

Thank You