The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1934-33

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Effect of remote forcings on the winter precipitation of central southwest Asia

GIORGI Filippo

the Abdus Salam International Centre For Theoretical Physics
Earth System Physics Section
Physics of Weather and Climate Group
Strada Costiera 11, P.O. Box 586, 34014 Trieste
ITALY

Strada Costiera 11, 34014 Trieste, Italy - Tel. +39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it, www.ictp.it

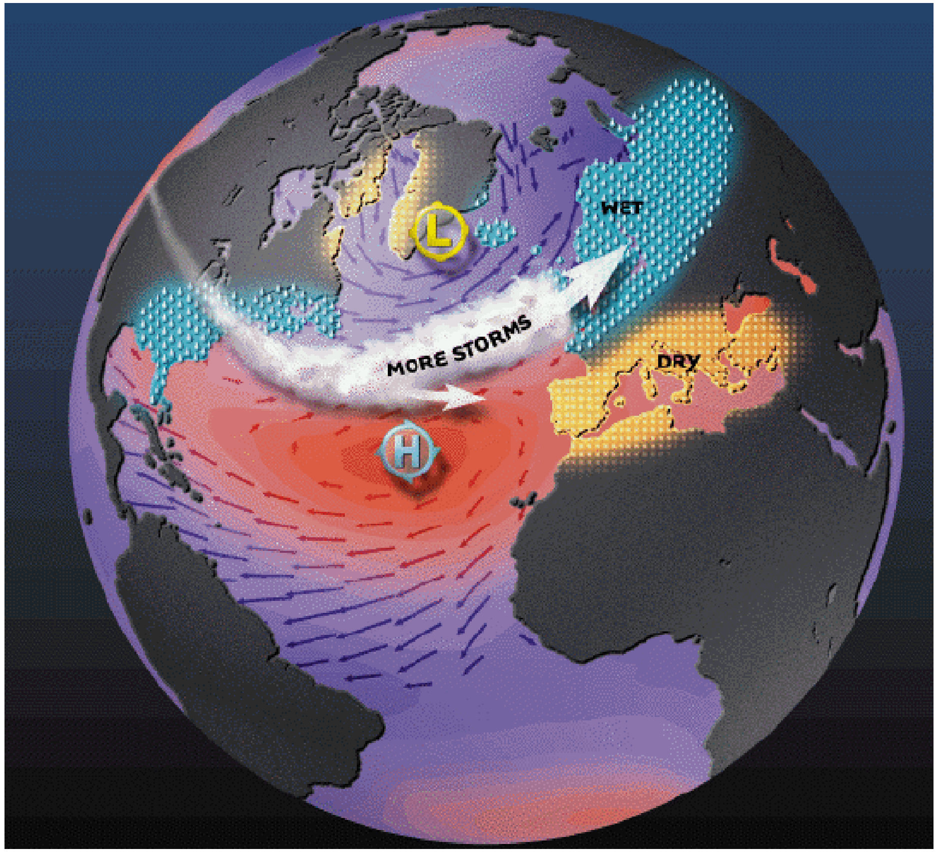
EFFECT OF REMOTE FORCINGS ON THE WINTER PRECIPITATION OF CENTRAL SOUTHWEST ASIA

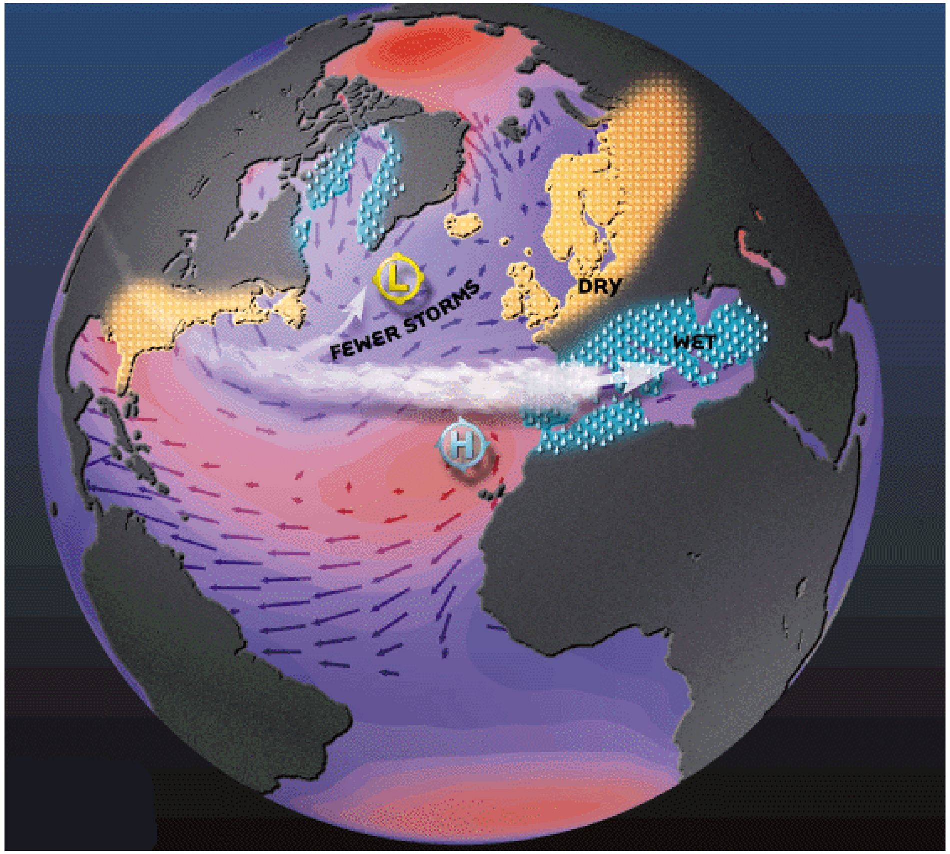
F.S. Syed(1), F. Giorgi(2), J. S. Pal(2), M.P. King(2), Kevin Keay(3)

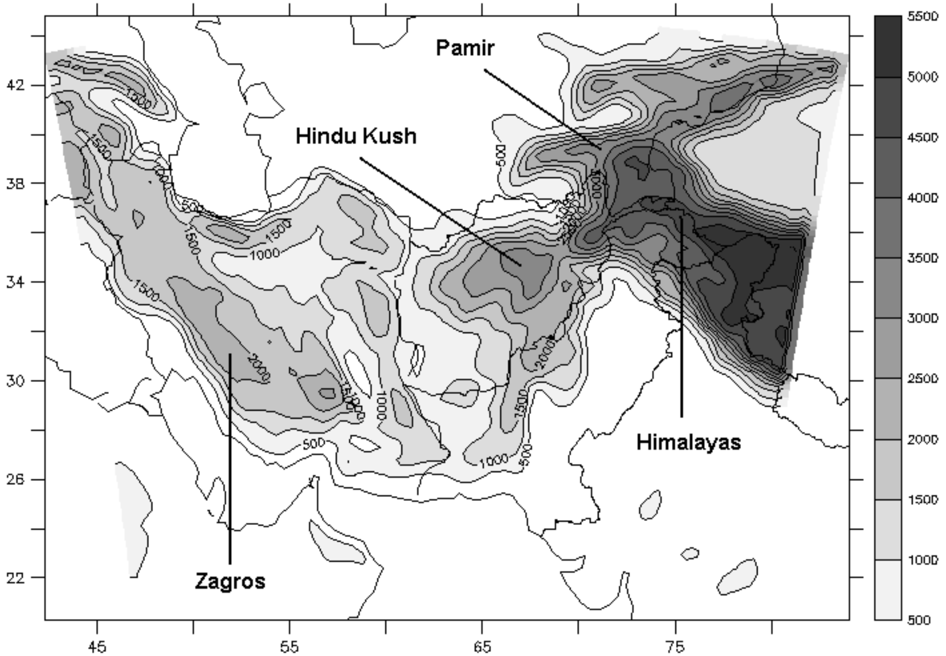
(1) Pakistan Meteorological Department / Global Change Impact Studies Centre, Islamabad, Pakistan
(2) Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
(3) School of Earth Sciences, University of Melbourne, Australia

4th ICTP Workshop on the Theory and Use of Regional Climate Models (March 3, 2008)

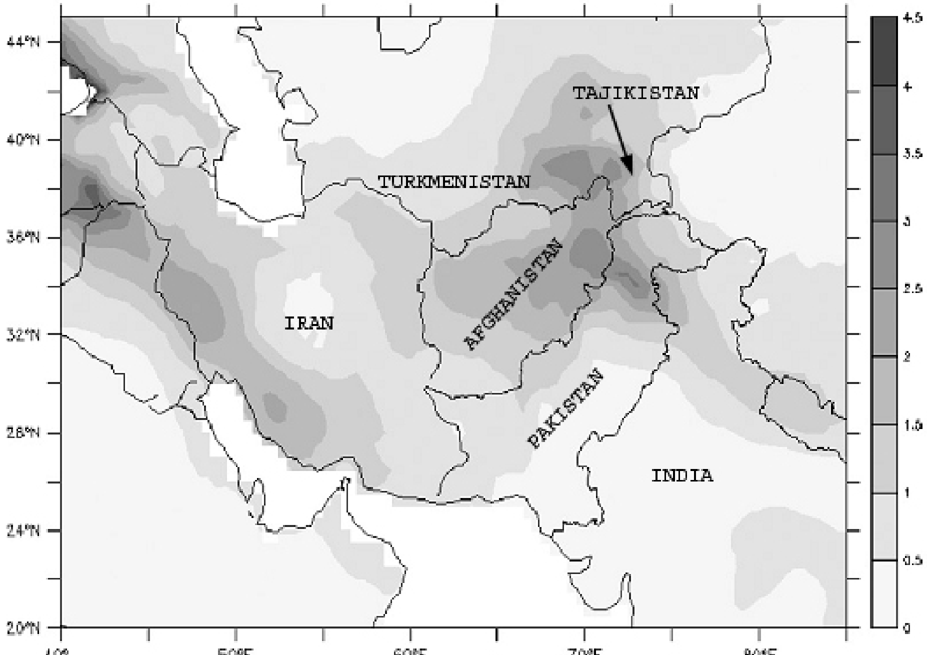
MOTIVATION







a)

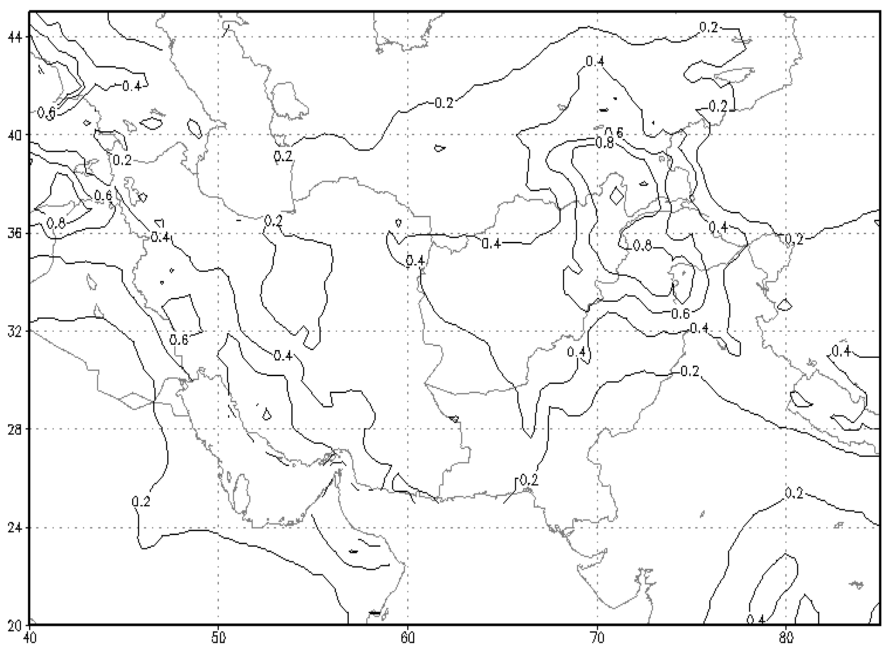


b)

(a) Topography of Central Southwest Asia (m)

(b) Average DJFM precipitation (mm/day) over the CSWA region for the period 1950-2000. CRU

(c) Standard Deviation of seasonal DJFM precipitation for 1950-2000



c)

Part I - Observations

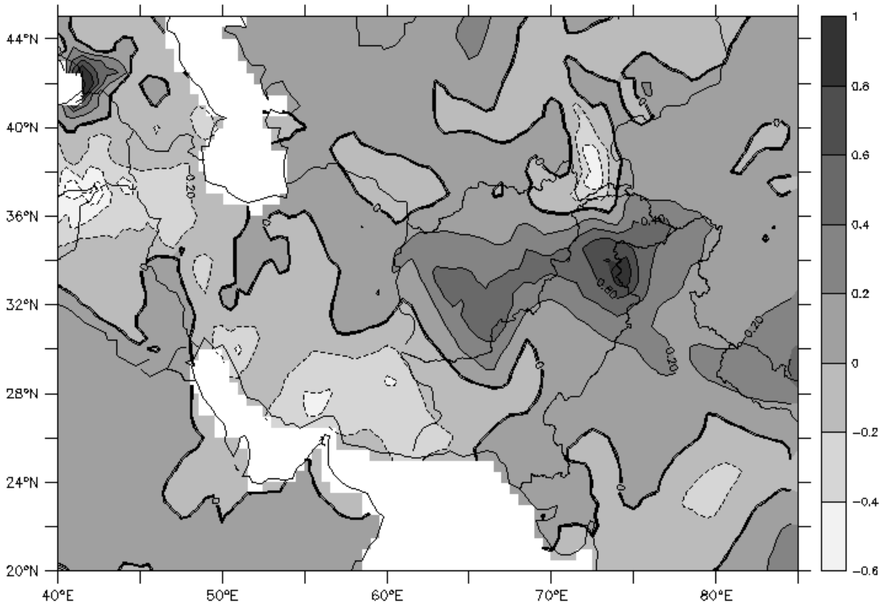
Data

- In this study, the NAO is measured by the winter (DJFM) NAO index (NAOI) of Hurrell (1995). The NAOI is based on the normalized sea level pressure (SLP) difference between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland
- The Southern Oscillation Index (SOI) is one measure of the large-scale fluctuations in air pressure between the western and eastern tropical Pacific (i.e. the state of the Southern Oscillation) during El Niño and La Niña episodes. Traditionally, this index is calculated from the pressure anomaly difference between Tahiti and Darwin, Australia
- The large scale circulation data (SLP, 500 hPa and 200 hPa geopotential heights) used in our analysis are from the National Center for Environmental Prediction / National Center for Atmospheric Research (NCEP/NCAR) reanalysis
- For Meteorological observations over land, we use the Climate Research Unit, CRU TS 2.0 dataset (Mitchell et al., 2003), which includes monthly surface air temperature and precipitation for the period 1901-2000 on a regular global 0.5 degree land surface grid
- Data from 26 meteorological stations distributed throughout Pakistan was obtained from the Central Data Processing Centre, Pakistan Meteorological Department, Karachi, Pakistan. We find generally good consistency between these station data and the CRU data.

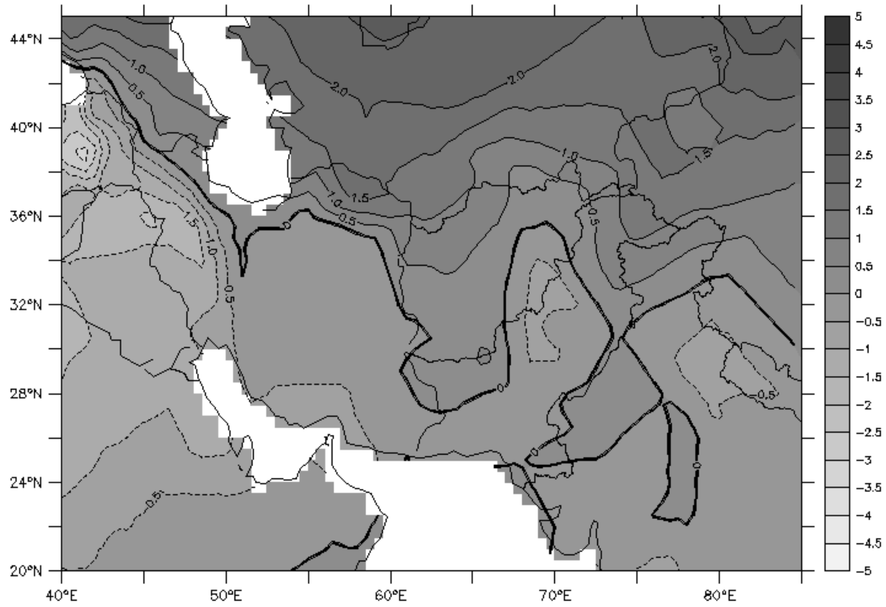
Methods

- A year is considered to be in a positive (negative) NAO phase,when the NAOI is more than one standard deviation above (below) the average NAOI for 1951-2000 for DJFM months. An analogous definition is applied to positive and negative SOI years
- During the 1951-2000 period we found 10 positive NAOI years (1973, 1981, 1983, 1989, 1990, 1992, 1993, 1994, 1995, 2000), 9 negative NAOI years (1955, 1962, 1963, 1964, 1965, 1969, 1977, 1979, 1996), 7 positive SOI years (1956, 1971, 1974, 1976, 1989, 1999, 2000) and 7 negative SOI years (1978, 1983, 1987, 1990, 1992, 1993, 1998)
- The composites are calculated as the difference between the ensemble average of positive NAOI (or SOI) years and that of negative NAOI (or SOI) years.
- Standard Pearson’s correlation coefficients *r* are calculated in the correlation analysis, and a two tailed t-test is used to assess the significance of the Pearson's *r*
- Gamma Distribution is used to calculate mean and standard deviation for the station data as a measure of inter-annual variability
- We also used Singular Value Decomposition (SVD) analysis. The SVD analysis had been found to give robust results compared with other methods for extracting coupled signals

North Atlantic Oscillation Forcing



a)



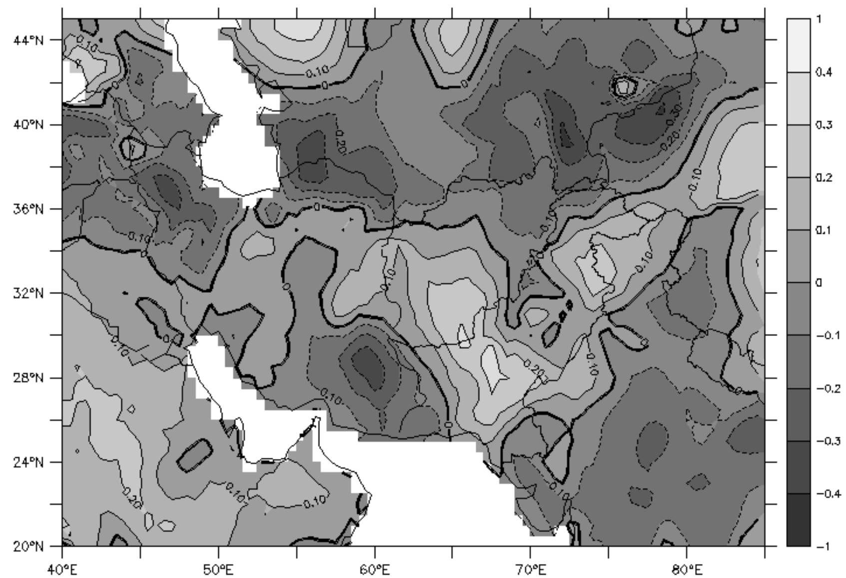
b)

Composite and Correlation Analysis

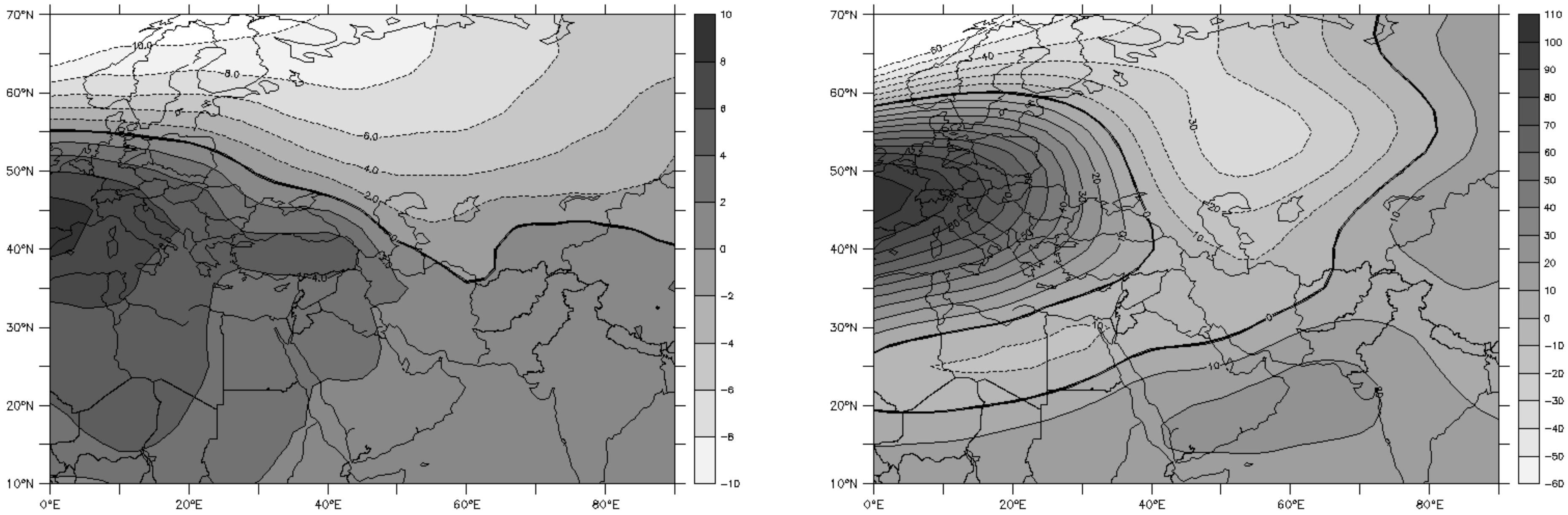
(a) NAO composite of precipitation (mm/day)

(b) NAO composite of surface temperature (ºC)

(c) Correlation Coefficients of NAOI and CSWA Precipitation



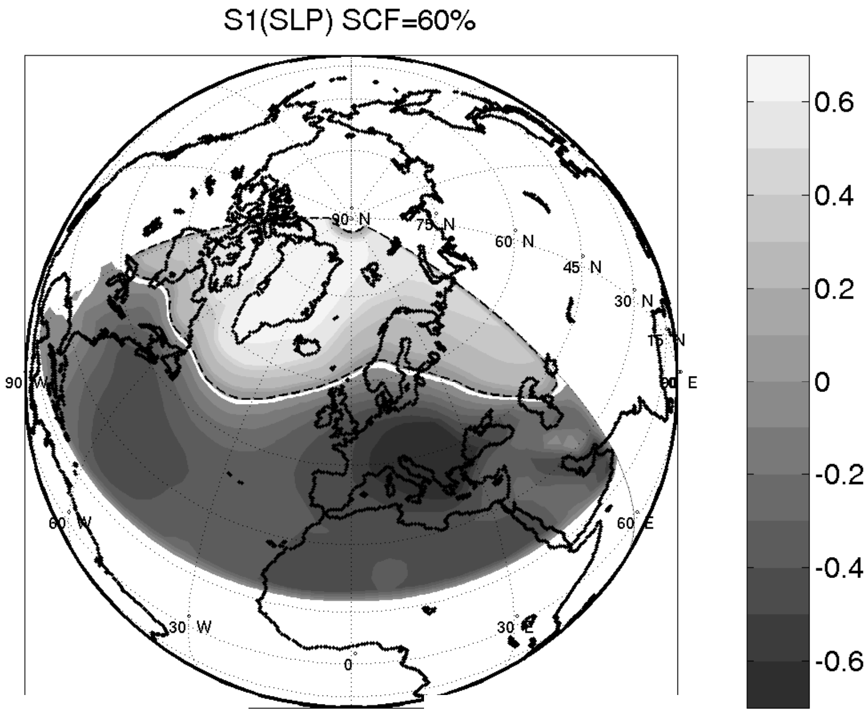
c)



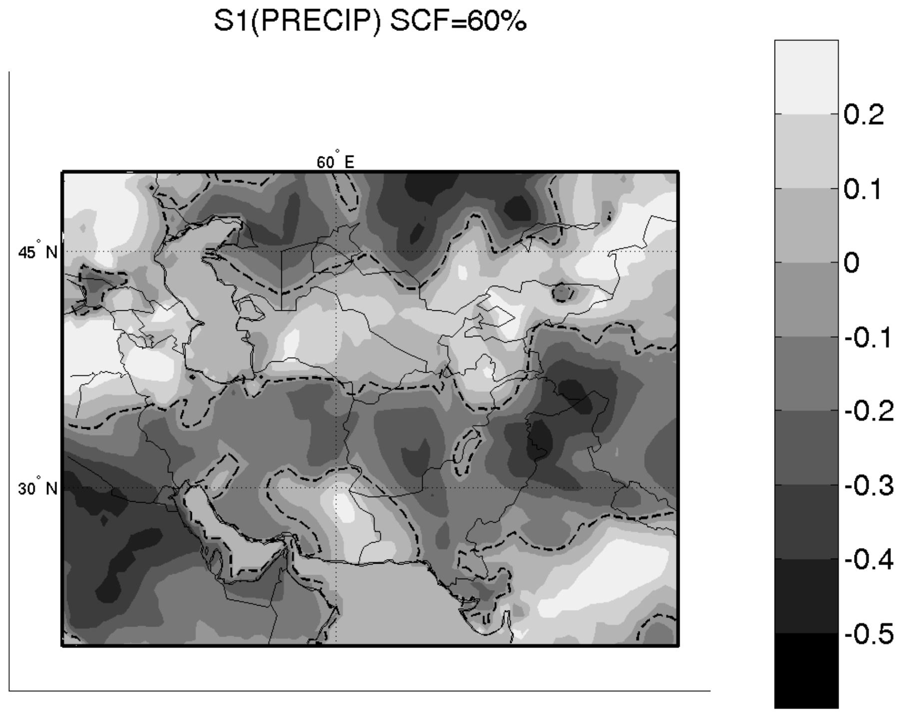
a) b)

(a) NAO composite of SLP (hpa)

(b) NAO composite of 500 hPa heights



a)

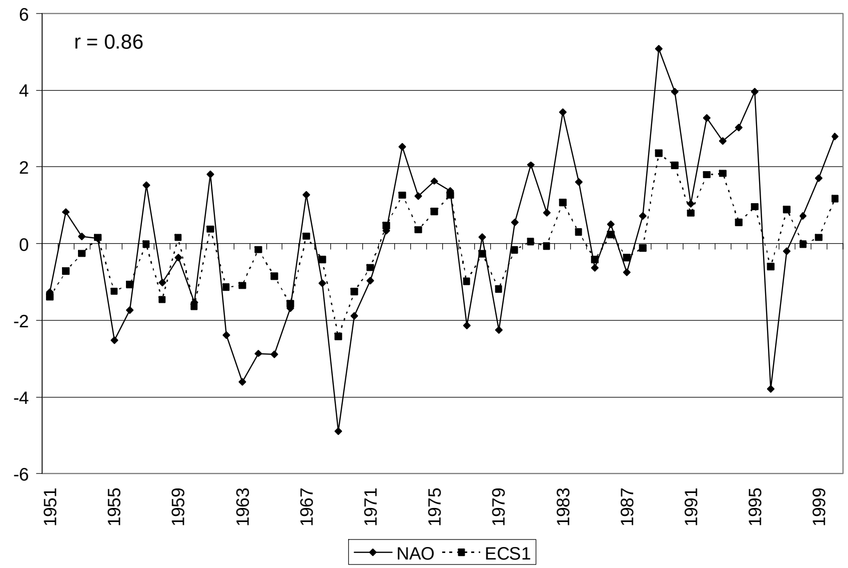


b)

Singular Value Decomposition Analysis

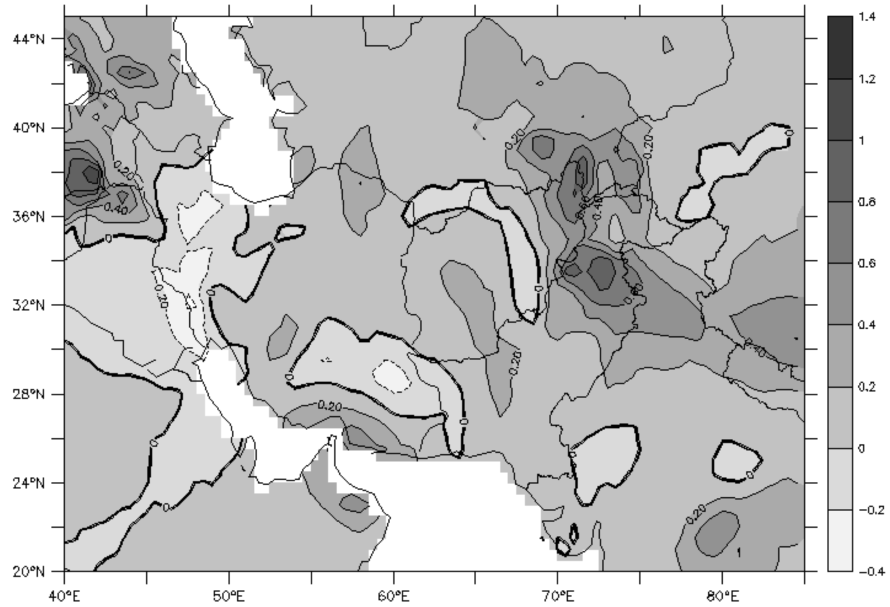
(a) and (b) The leading mode of SVD applied to SLP in the North Atlantic and precipitation over CSWA.

(c) Comparison of expansion coefficients time series (ECS1) from the SLP regions with NAOI

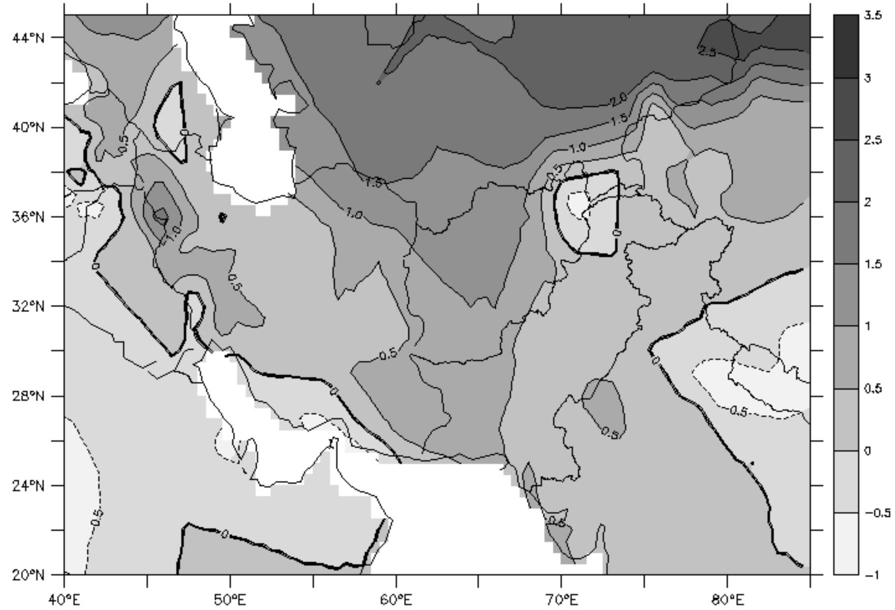


c)

El-Nino Southern Oscillation Forcing



a)



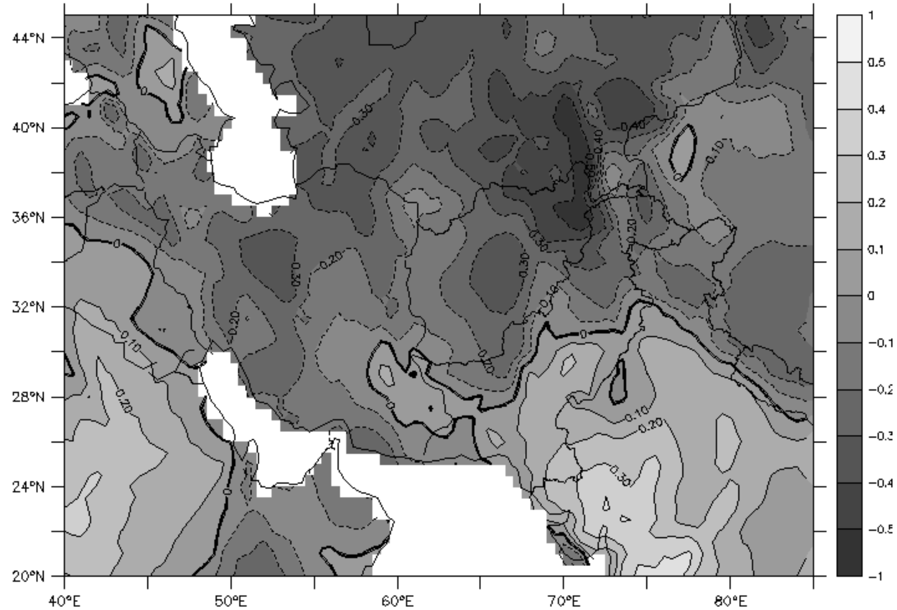
b)

Composite and Correlation Analysis

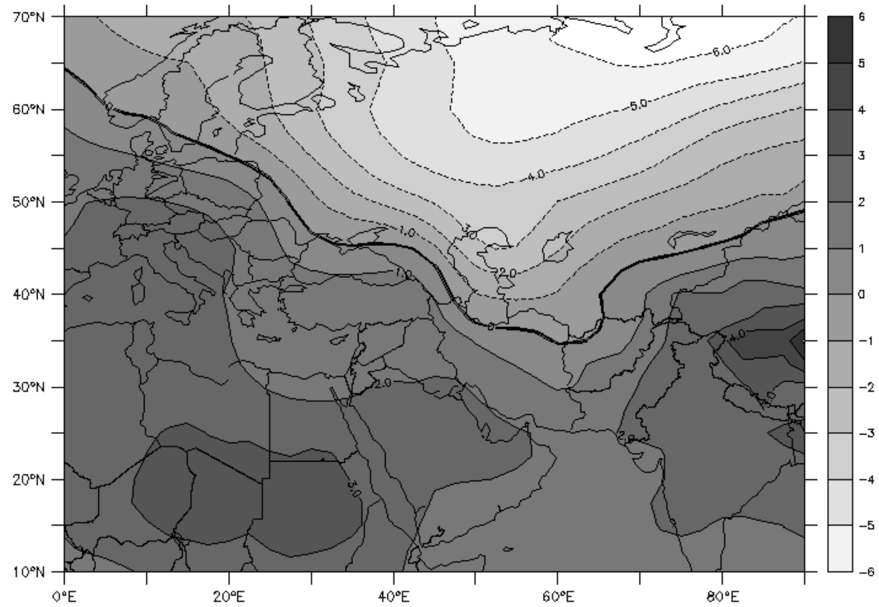
(a) SOI composite of precipitation (mm/day)

(b) SOI composite of surface temperature (ºC)

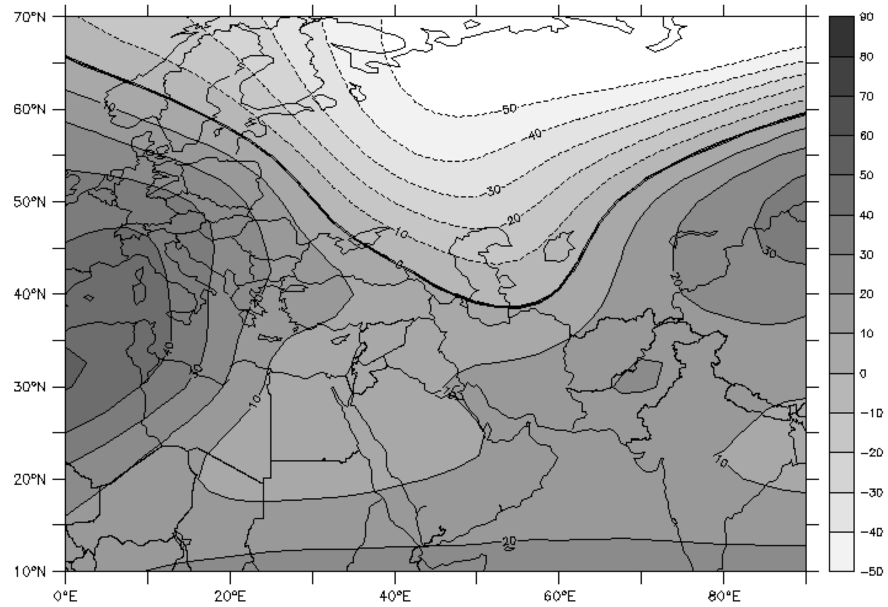
(c) Correlation Coefficients of SOI and CSWA Precipitation



c)



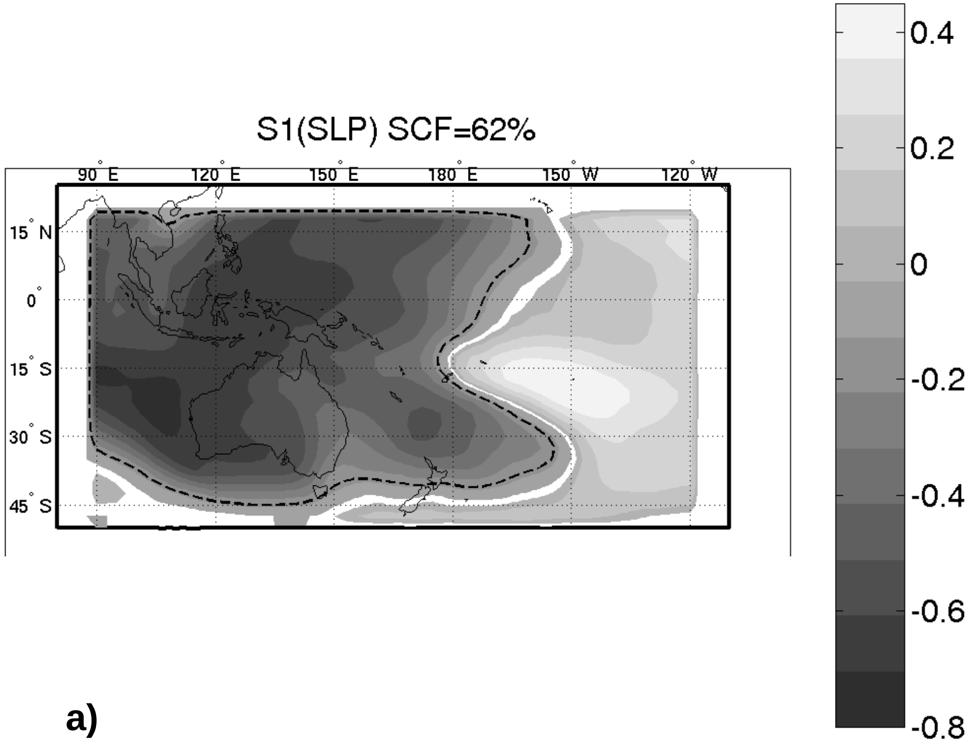
a)



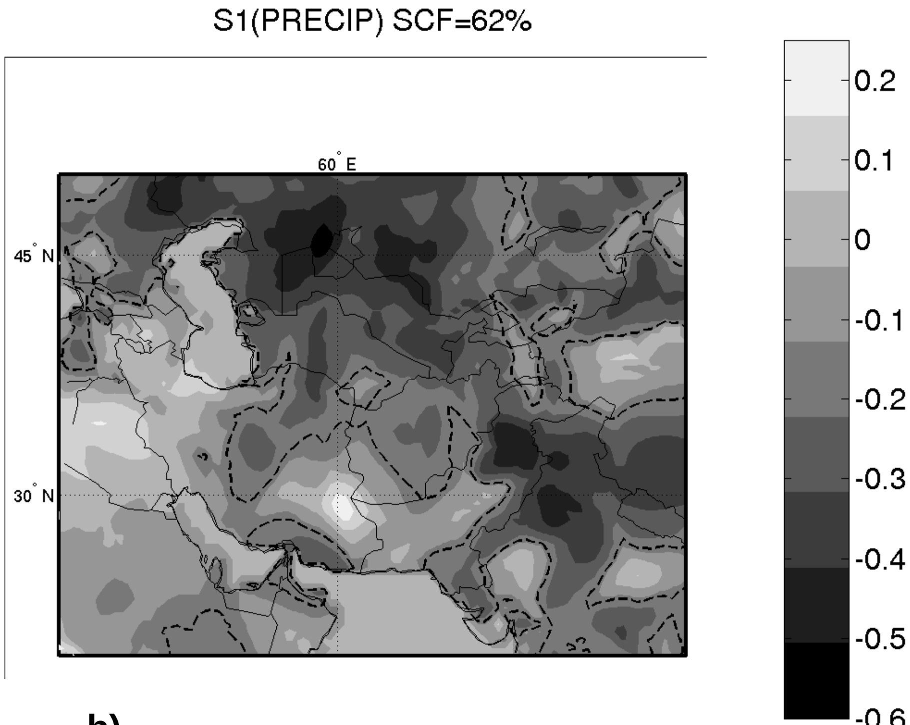
b)

(a) SOI composite of SLP (hpa)

(b) SOI composite of 500 hpa heights



a)

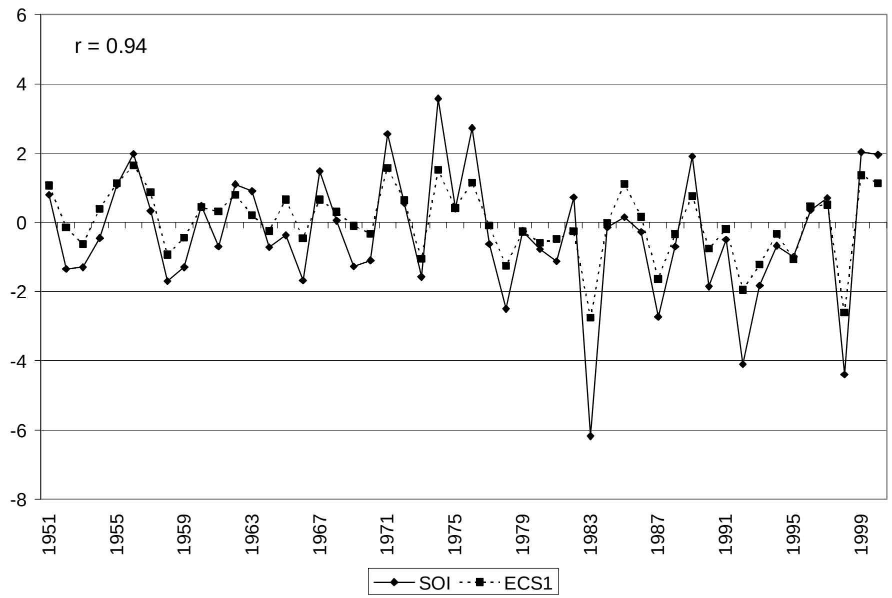


b)

Singular Value Decomposition Analysis

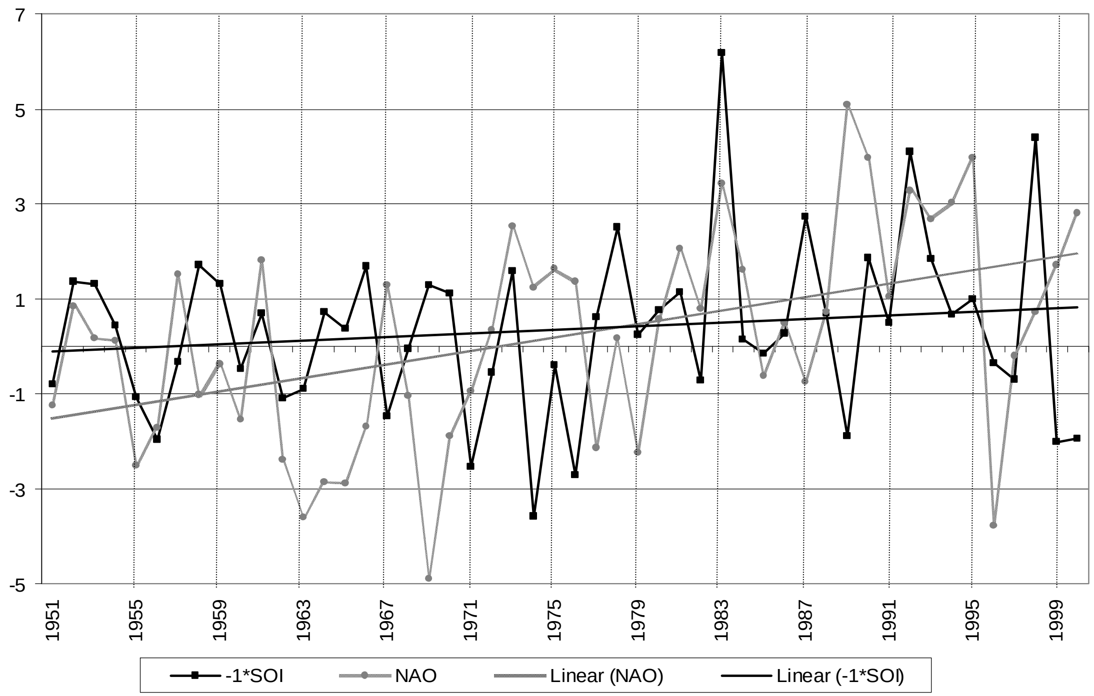
(a) and (b) The leading mode of SVD applied to SLP in the western Pacific and precipitation in CSWA.

(c) Comparison of expansion coefficients time series (ECS1) from the SLP regions with SOI



c)

The time series of NAOI and -1* SOI and their respective linear tends from 1951 to 2000



The time series of average winter precipitation (mm/month) of 17 stations over Pakistan and CRU precipitation (mm/day) over the region (28-40 N; 60-80 E)

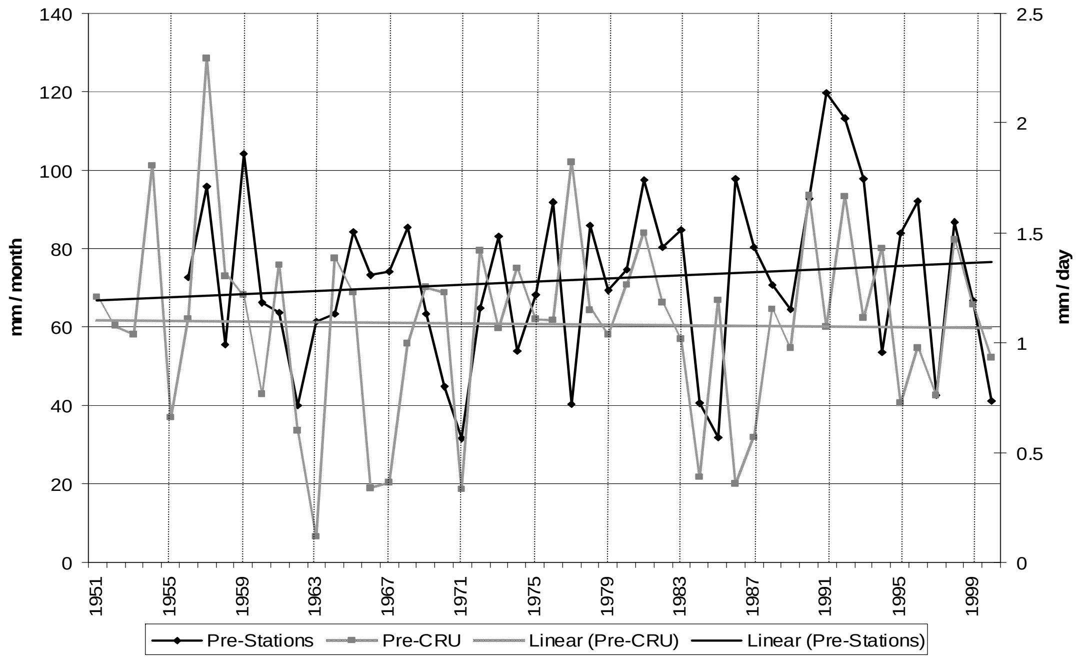


Table I:

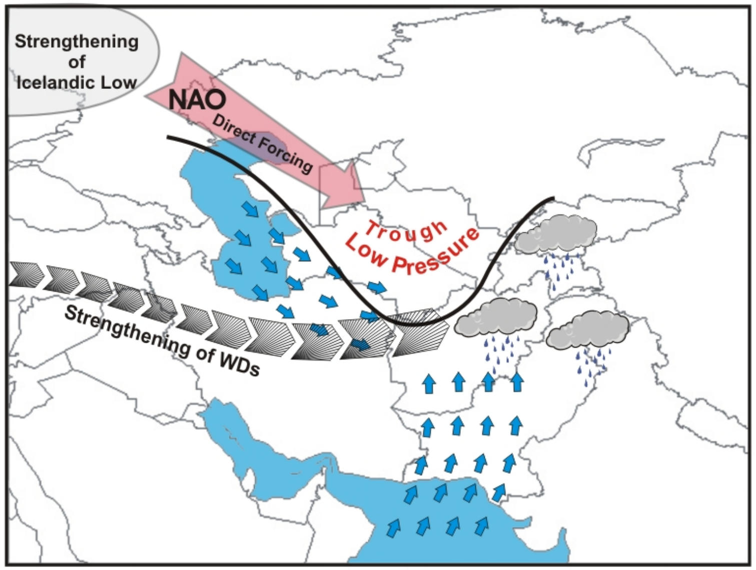
Table of Meteorological Stations of Pakistan with Latitude, Longitude, Elevation, Mean (1961-90) DJFM precipitation, Standard Deviation, NAOI / SOI Correlation with winter precipitation and composites, arranged in descending order with respect to Latitude

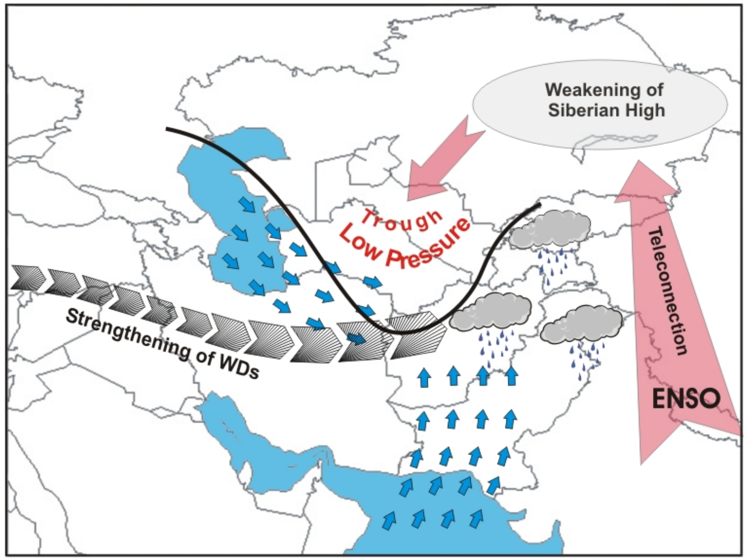
Station	Lat. (N)	Long. (E)	Elev. (m)	Ave. (mm/day)	S.D	NAO		SOI	
						Corr.	Comp. (mm/day)	Corr.	Comp. (mm/day)
Gilgit	35º 55´	74º 20´	1460	0.23	0.15	-0.12	-0.04	-0.04	-0.05
Drosh	35º 34´	71º 47´	1465	2.37	0.83	+0.02	0.45	-0.27*	0.46
Astore	35º 22´	74º 54´	2168	1.69	0.66	+0.15	0.39	-0.28*	0.33
Skardu	35º 18´	75º 41´	2210	0.87	0.61	+0.22	0.34	-0.15	0.26
Muzaffarabad	34º 22´	73º 29´	702	3.98	1.40	+0.25	1.16	-0.23	1.46
Garhi Dupatta	34º 13´	73º 37´	813	4.41	1.49	-0.05	-0.10	-0.37**	1.99
Kakul	34º 11´	73º 15´	1309	3.14	0.91	+0.18	0.55	-0.33*	1.17
Risalpur	34º 04´	71º 59´	315	1.70	0.76	+0.15	0.45	-0.38**	0.97
Peshawar	34º 01´	71º 35´	360	1.45	0.69	+0.19	0.43	-0.45**	1.12
Murree	33º 55´	73º 23´	2168	4.09	1.97	+0.42**	2.12	-0.35**	2.42
Parachinar	33º 52´	70º 05´	1729	2.65	1.15	+0.01	0.02	-0.13	0.83
Islamabad	33º 37´	73º 06´	508	2.13	0.80	+0.24	0.62	-0.28*	0.58
Kotli	33º 31´	73º 54´	615	2.87	1.18	+0.33*	1.19	-0.28*	1.11
Jhelum	32º 56´	73º 43´	234	1.58	0.85	+0.29*	0.69	-0.31*	1.19
D. I. Khan	31º 49´	70º 55´	174	0.65	0.33	+0.15	0.19	-0.27*	0.32
Lahore	31º 31´	74º 24´	216	0.85	0.51	+0.42**	0.38	-0.33*	0.63
Faisalabad	31º 26´	73º 06´	184	0.51	0.36	+0.08	0.03	-0.09	0.27
Zhob	31º 21´	69º 28´	1407	0.89	0.44	+0.09	0.10	+0.03	-0.11
Quetta	30º 15´	66º 53´	1601	1.53	0.79	+0.27*	0.53	-0.12	0.63
Bahawalpur	29º 24´	71º 47´	117	0.26	0.21	-0.06	-0.01	-0.21	0.14

* Significant at 95% confidence level

** Significant at 99% confidence level

PROPOSED MECHANISM





Part II – Modeling and Tracking Cyclones

Model and Tracking Scheme

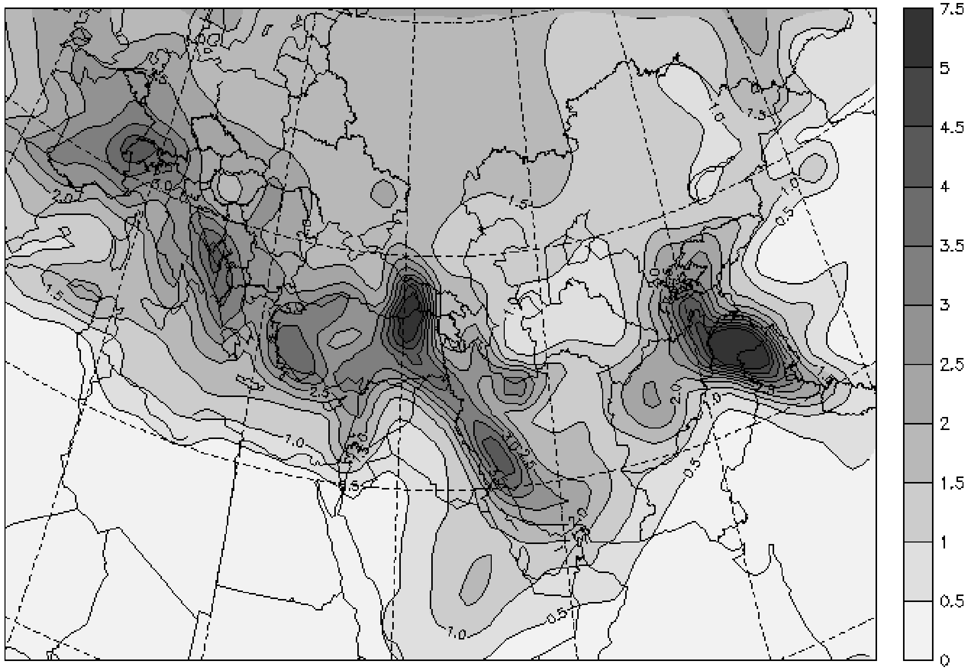
- The numerical experiments are carried out using the ICTP regional climate modeling system in its latest version RegCM3. This version is documented by Pal et al. (2007). It is an augmented version of the model of Giorgi et al., (1993a and 1993b).

- The model was integrated for 4.5 month-long simulations beginning on November 15 and ending on March 31. The first 15 days of these simulations are discarded from the analysis to allow for model spin up, so that the analysis period is DJFM simulations, from 1958 to 2000. The model domain encompass the entire Euro-CSWA region (approximately -5 to 90° E and 10 to 65° N) at a horizontal grid spacing of 70 km.

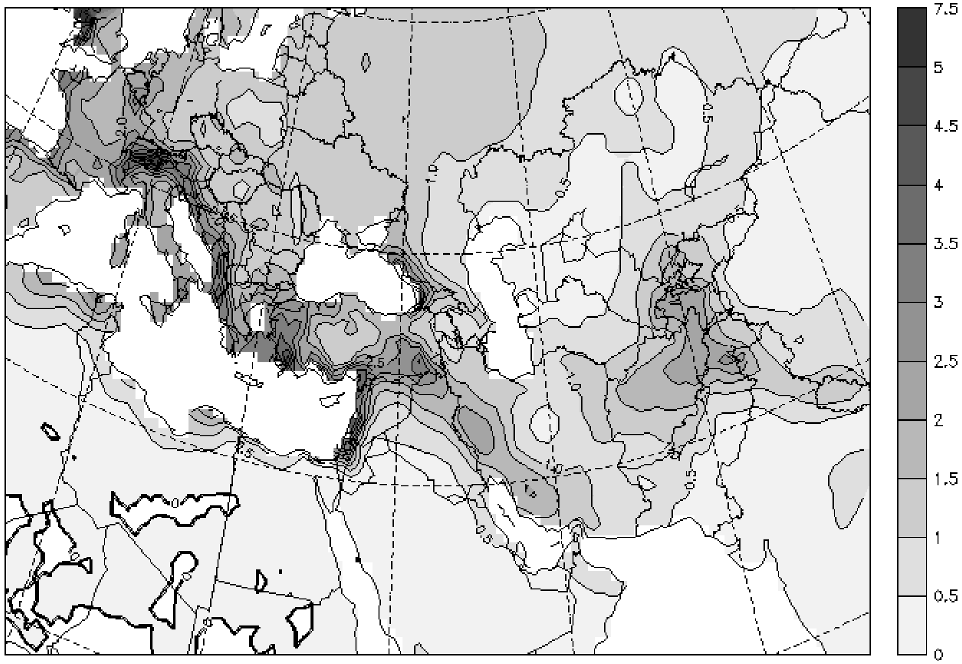
- Cyclone 'finding' and 'tracking' scheme developed by Murray and Simmonds (1991) and refined by Simmonds and coworkers (Simmonds et al., 1999; Simmonds and Murray, 1999) is used in the analysis.

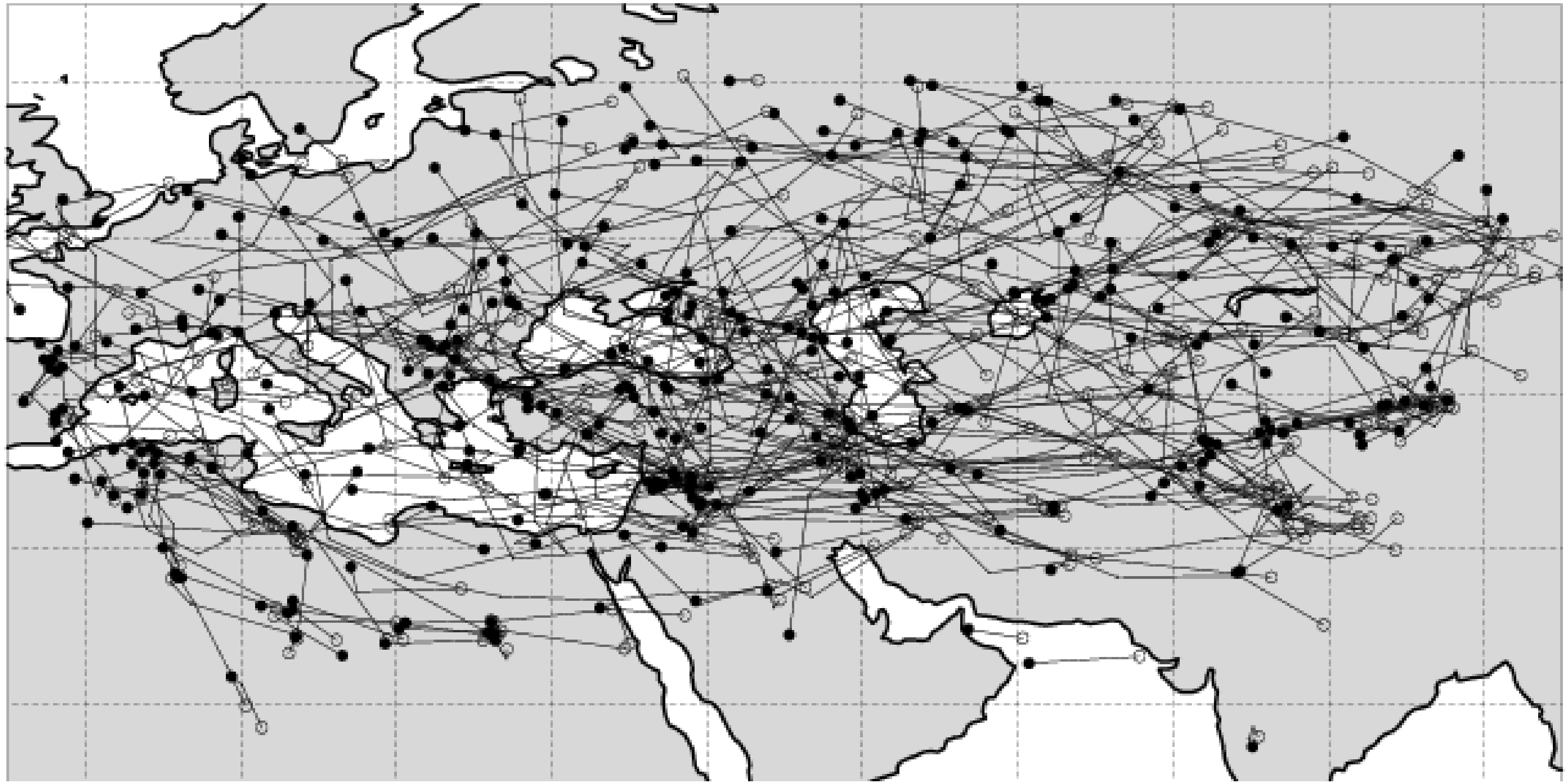
- Different cyclone statistics have been defined by Murray and Simmonds (1991). 'cyclone density' is the mean number of cyclones per analysis to be found in the prescribed reference area. "cyclogenesis" and "cyclolysis" refer to the formation and the disappearance of a cyclone, respectively, per reference area per day. Another quantity the scheme produces is the 'net velocity', i.e. the average speed and direction with which the cyclone centers move at a given point. Finally, the terms "intensity", "depth" and "radius" of a cyclone refer to particular characteristics of a cyclonic structure (Simmonds and Keay, 2000a)

RegCM3 - Simulated
climatology (1961-2000)
of DJFM precipitation
(mm/day)



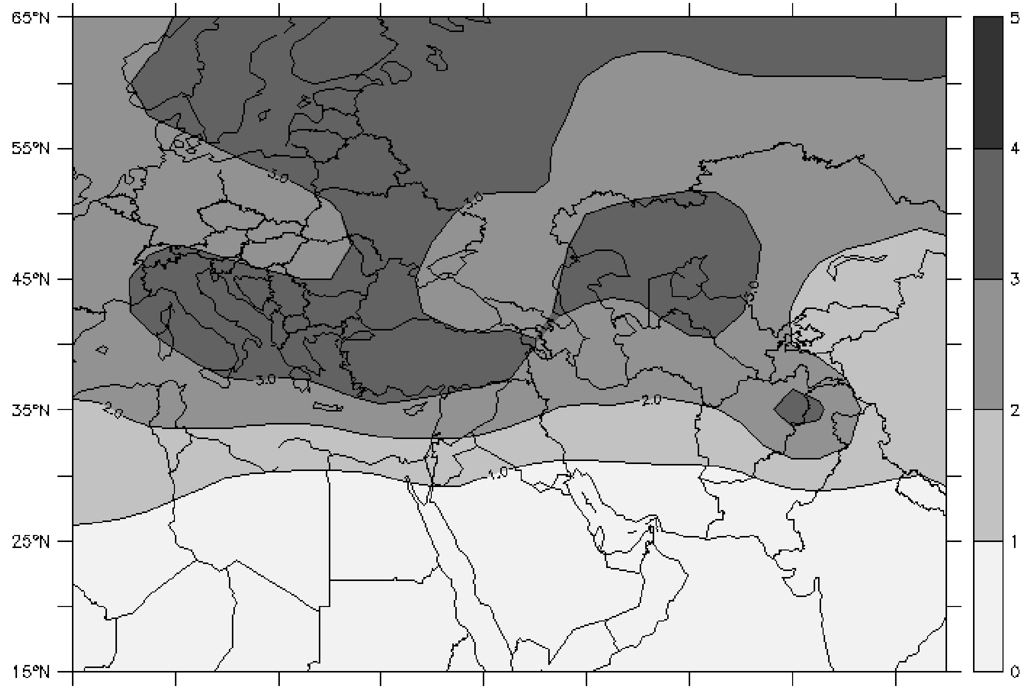
CRU - Observed
climatology (1961-2000) of
DJFM precipitation
(mm/day)



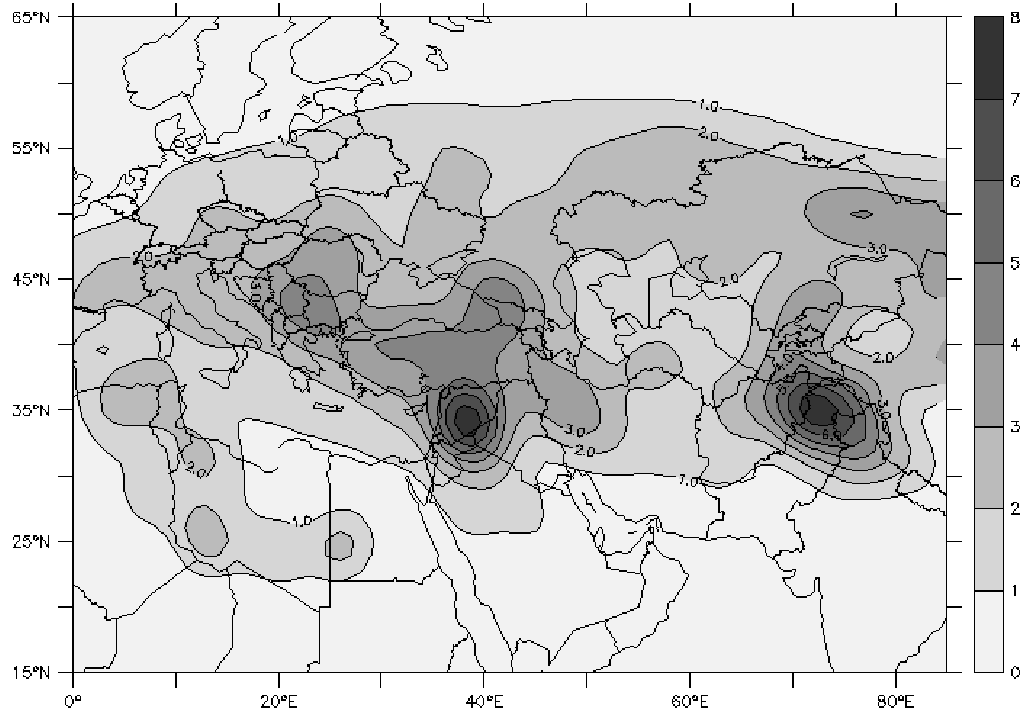


Tracks of storms lasting at least 2 days, DJFM (1991-93). Solid circles represent locations of cyclogenesis and hollow circles represent locations of cyclolysis.

ERA40 storm climatology (1961-2000): System density (Deg.Lat. Sq)



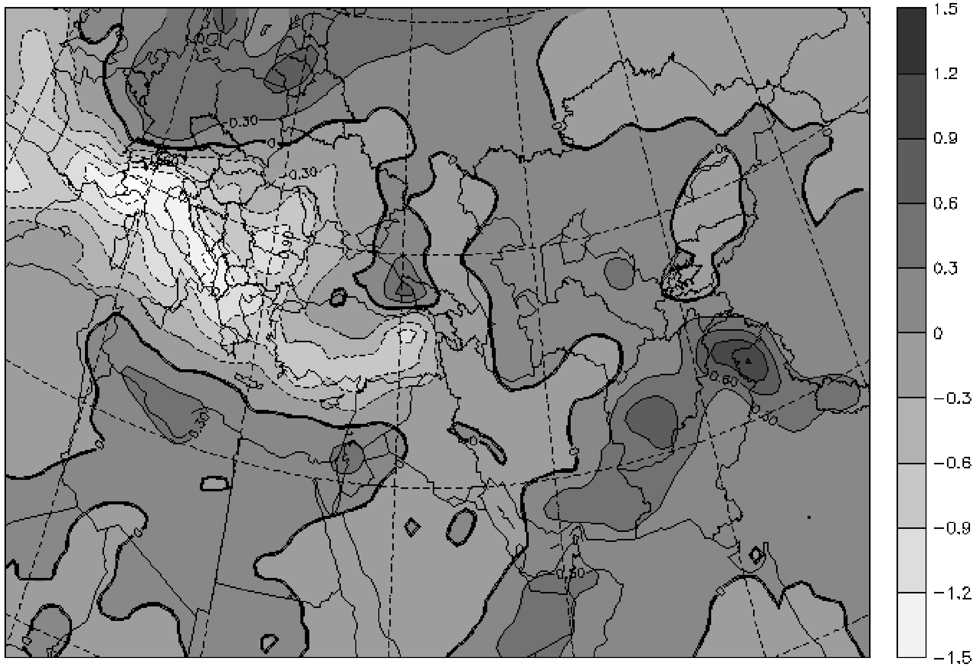
RegCM3-Simulated storm climatology (1961-2000): System density (Deg.Lat. Sq)



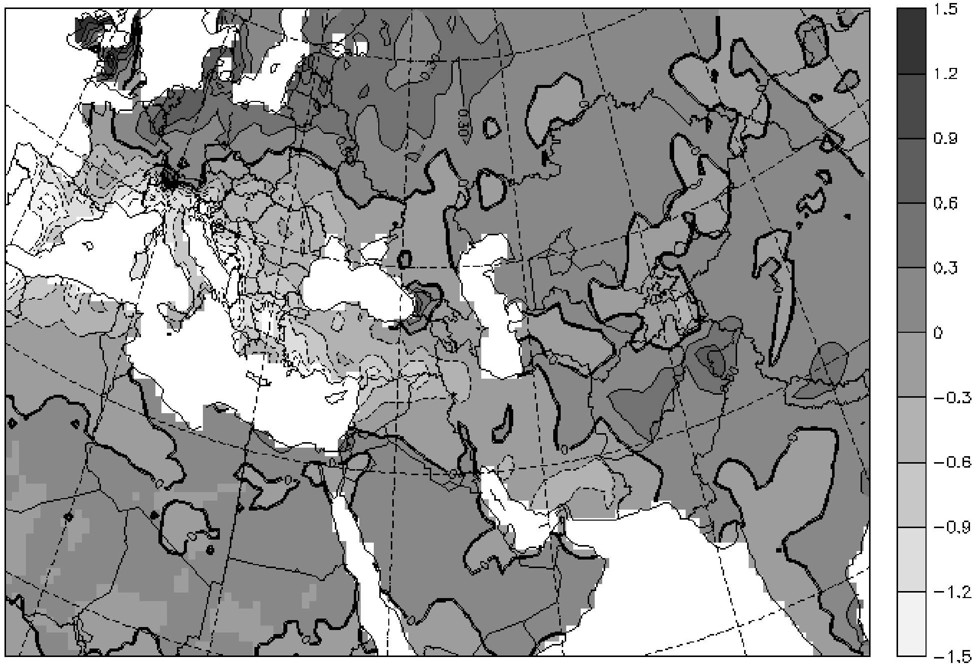
North Atlantic Oscillation Forcing

NAO precipitation composite (mm/day).

Simulated - RegCM3

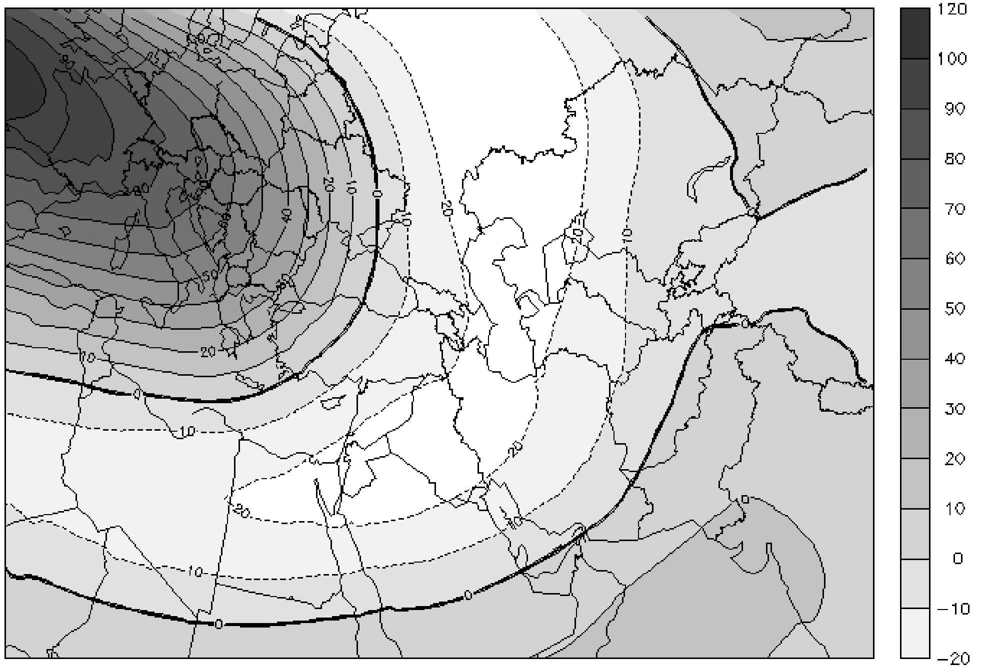


Observed - CRU

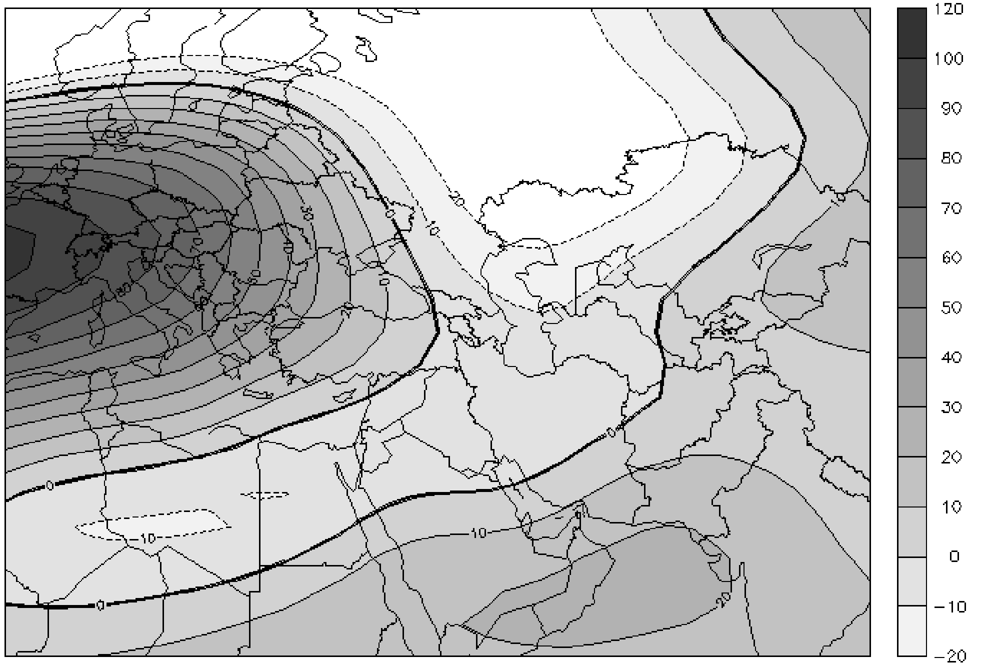


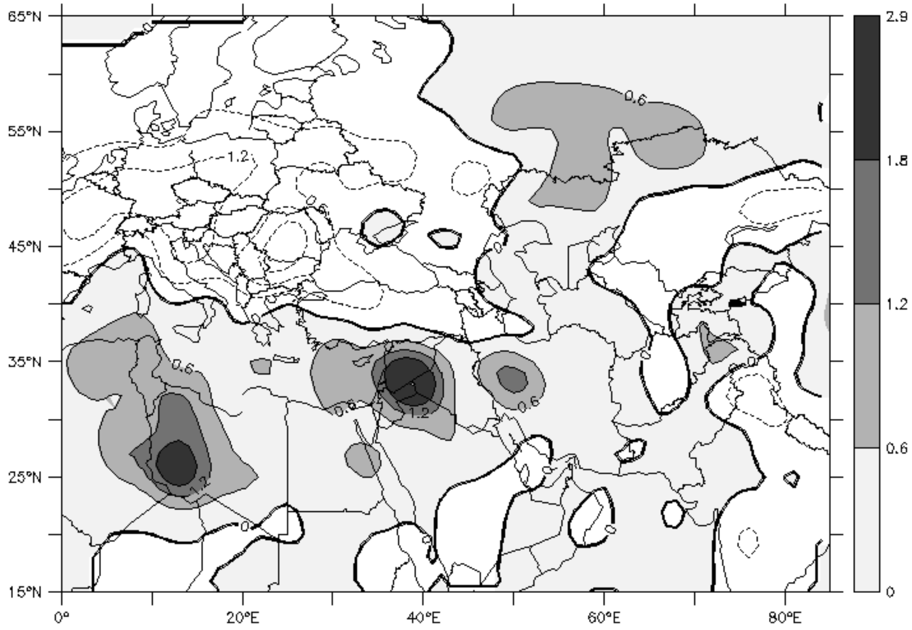
NAO 500 hPa height composite (gpm)

Simulated - RegCM3

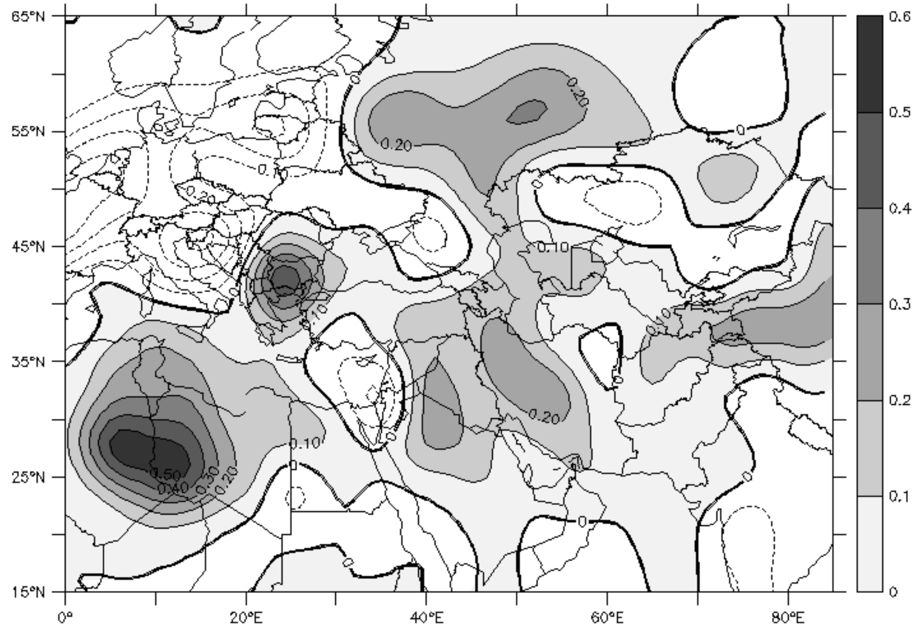


Observed - NCEP





a)



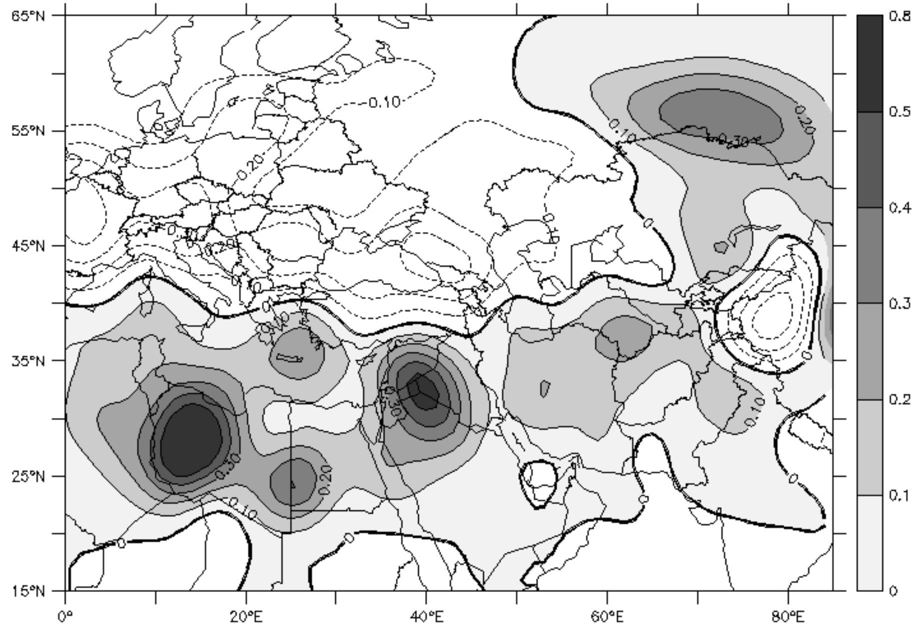
b)

Simulated – RegCM3 NAO storm composite:

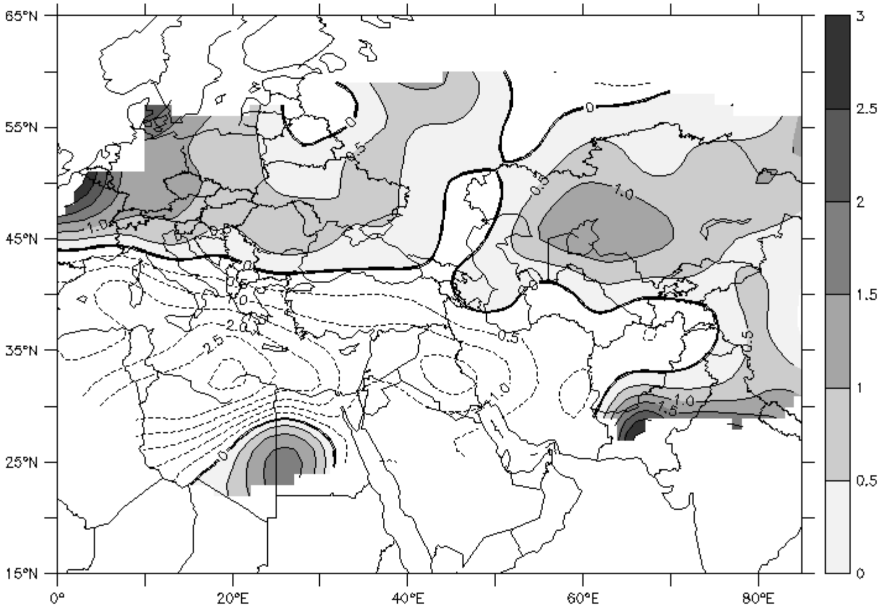
(a) System density (/Deg.Lat. sq);

(b) Cyclogenesis (1000 DLSQ/day);

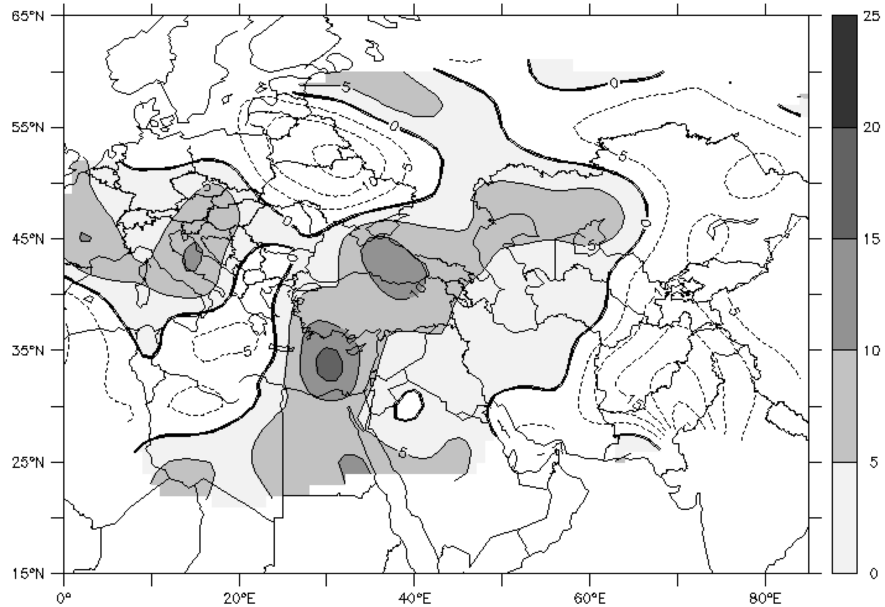
(c) Cyclolysis (1000 DLSQ/day).



c)



a)



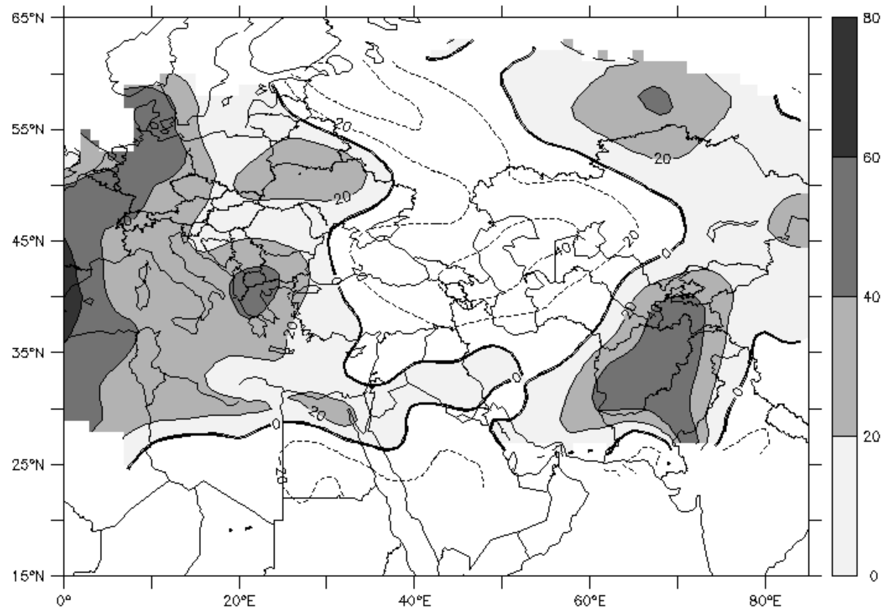
b)

Simulated – RegCM3 NAO storm composite:

(a) Net velocity (m/s);

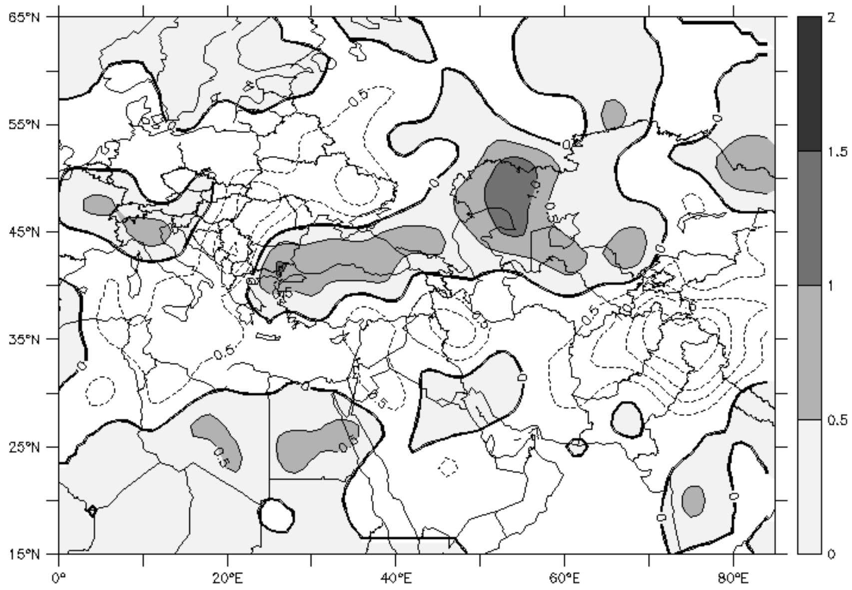
(b) Depth (gpm);

(c) Central heights (gpm).

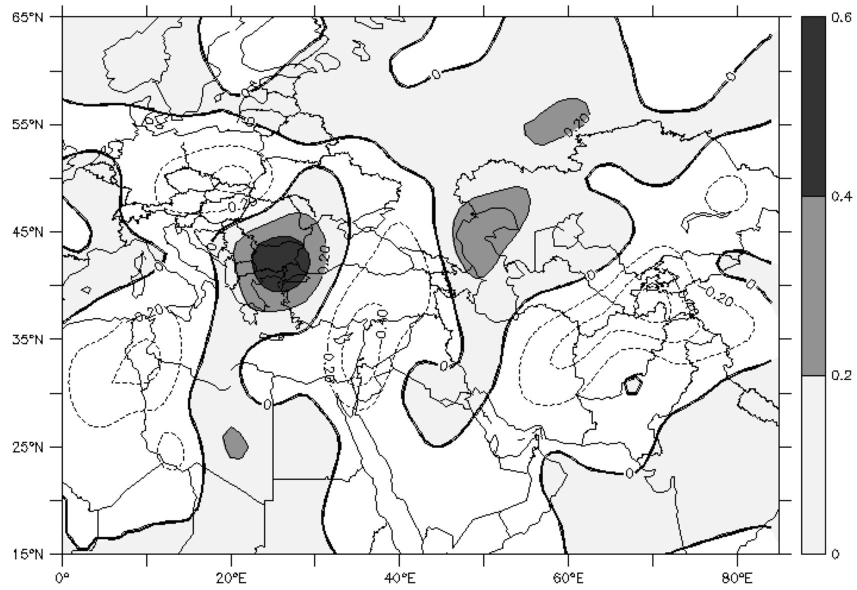


c)

El-Nino Southern Oscillation Forcing



a)



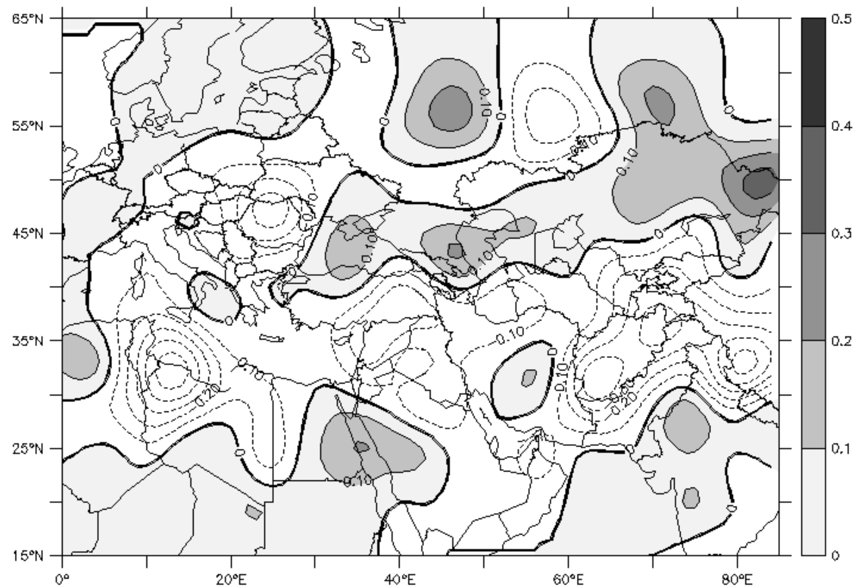
b)

Simulated – RegCM3 ENSO storm composite:

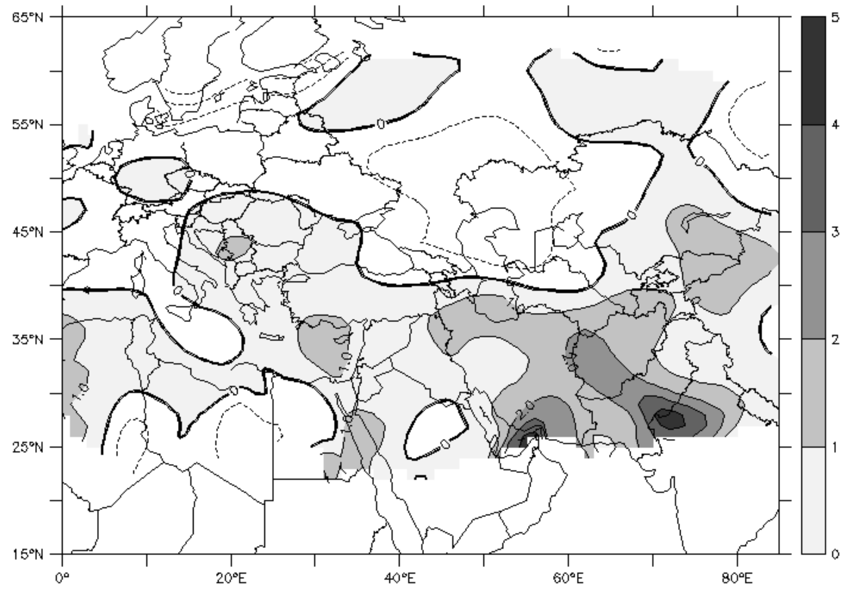
(a) System density (/Deg.Lat. sq);

(b) Cyclogenesis (1000 DLSQ/day);

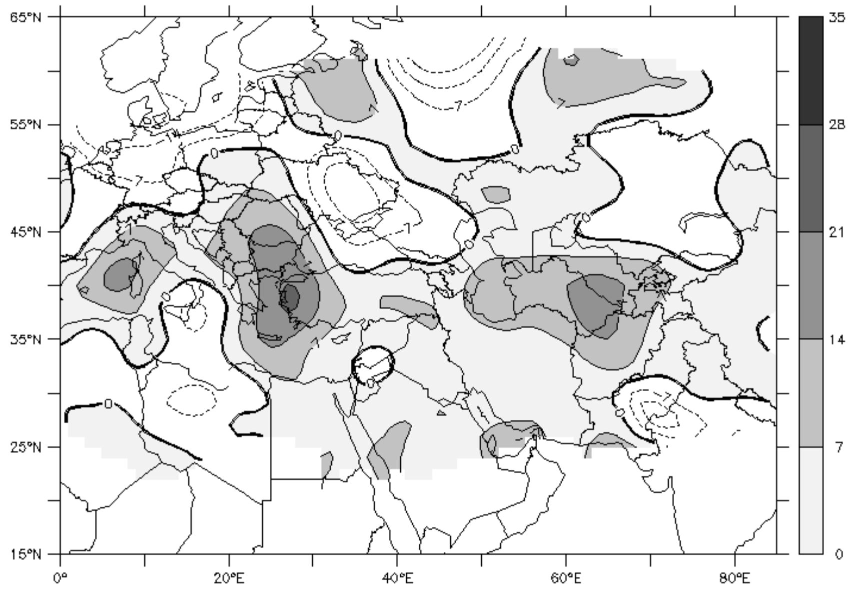
(c) Cyclolysis (1000 DLSQ/day).



c)



a)



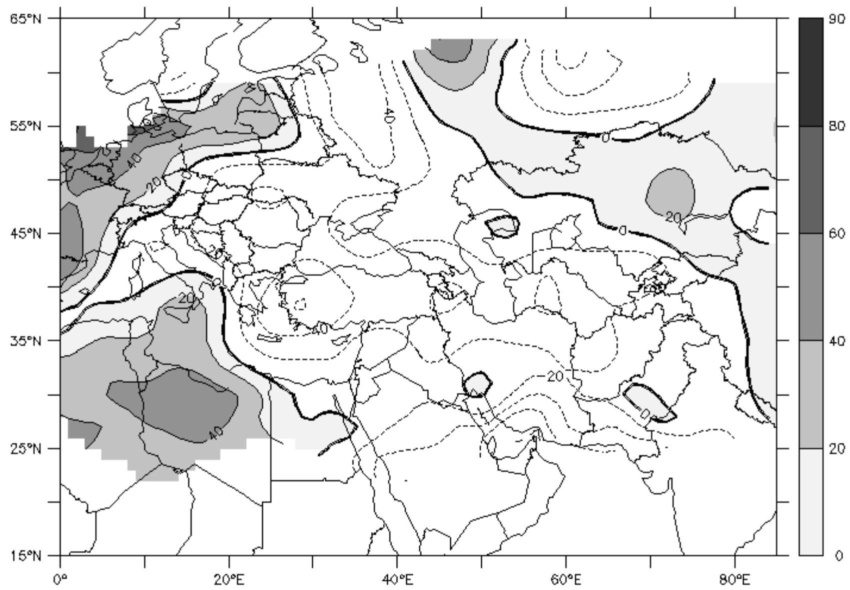
b)

Simulated – RegCM3 ENSO storm composite:

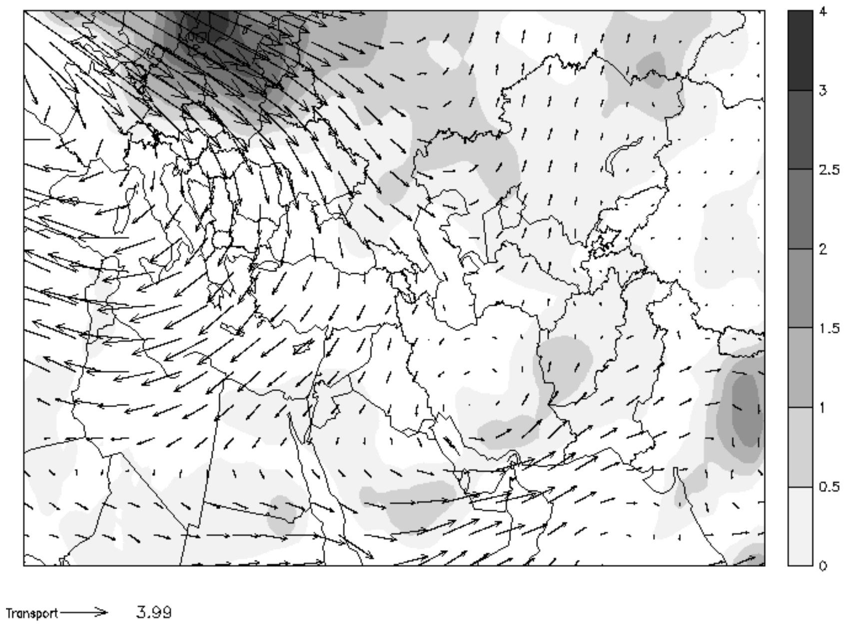
(a) Net velocity (m/s);

(b) Depth (gpm);

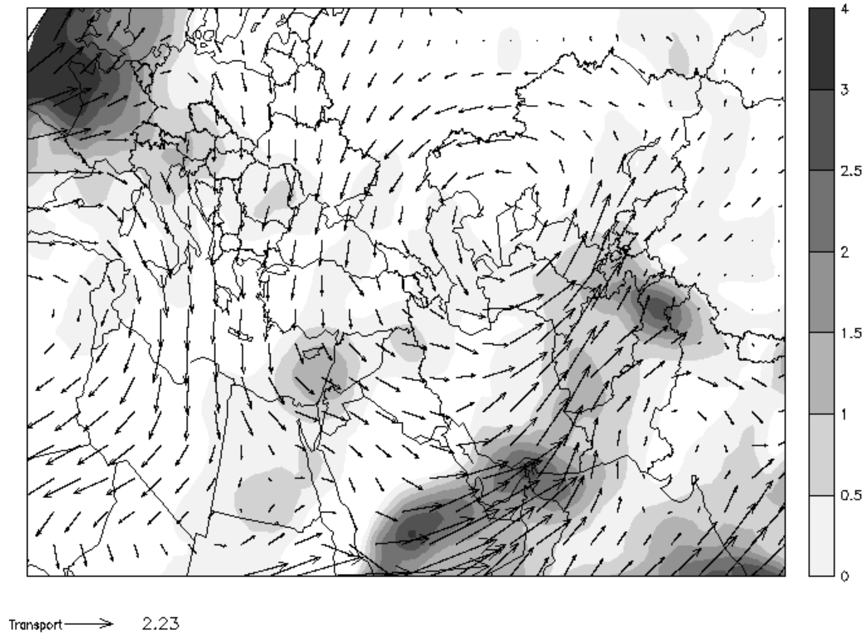
(c) Central heights (gpm).



c)



NAO



ENSO

Composite of vertically integrated (1000-500 hPa) moisture convergence (mm/day) and moisture transport (m/s)

SUMMARY AND CONCLUSIONS

- Both the NAO and ENSO have a substantial influence on the CSWA climate, particularly in the region of Northern Pakistan, Afghanistan and Kazhakistan.
- NAO and ENSO precipitation signal over the CSWA region is mostly associated with an intensification of western disturbances originating in the eastern Mediterranean and Middle East regions and moving eastward across CSWA. This intensification is associated with the effect of an enhanced SLP and 500 hPa trough which develops over the region during these NAO and ENSO phases
- Model driven at the lateral boundaries by meteorological fields from the ERA40 reanalysis was able to reproduce well the climatology of temperature, precipitation and storms over CSWA
- In the positive phase of the NAO and (to a lesser extent) the warm phase of ENSO, the composite of vertically integrated moisture convergence from 1000 hPa to 500 hPa indicates that the transport of extra moisture from the Mediterranean, Caspian Sea and Arabian Sea contribute to the observed precipitation signals.
- The substantial forcing of CSWA winter precipitation by both the NAO and ENSO provides encouraging indications towards the development of predictive tools for winter CSWA precipitation.