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Long term changes of precipitation in Greece

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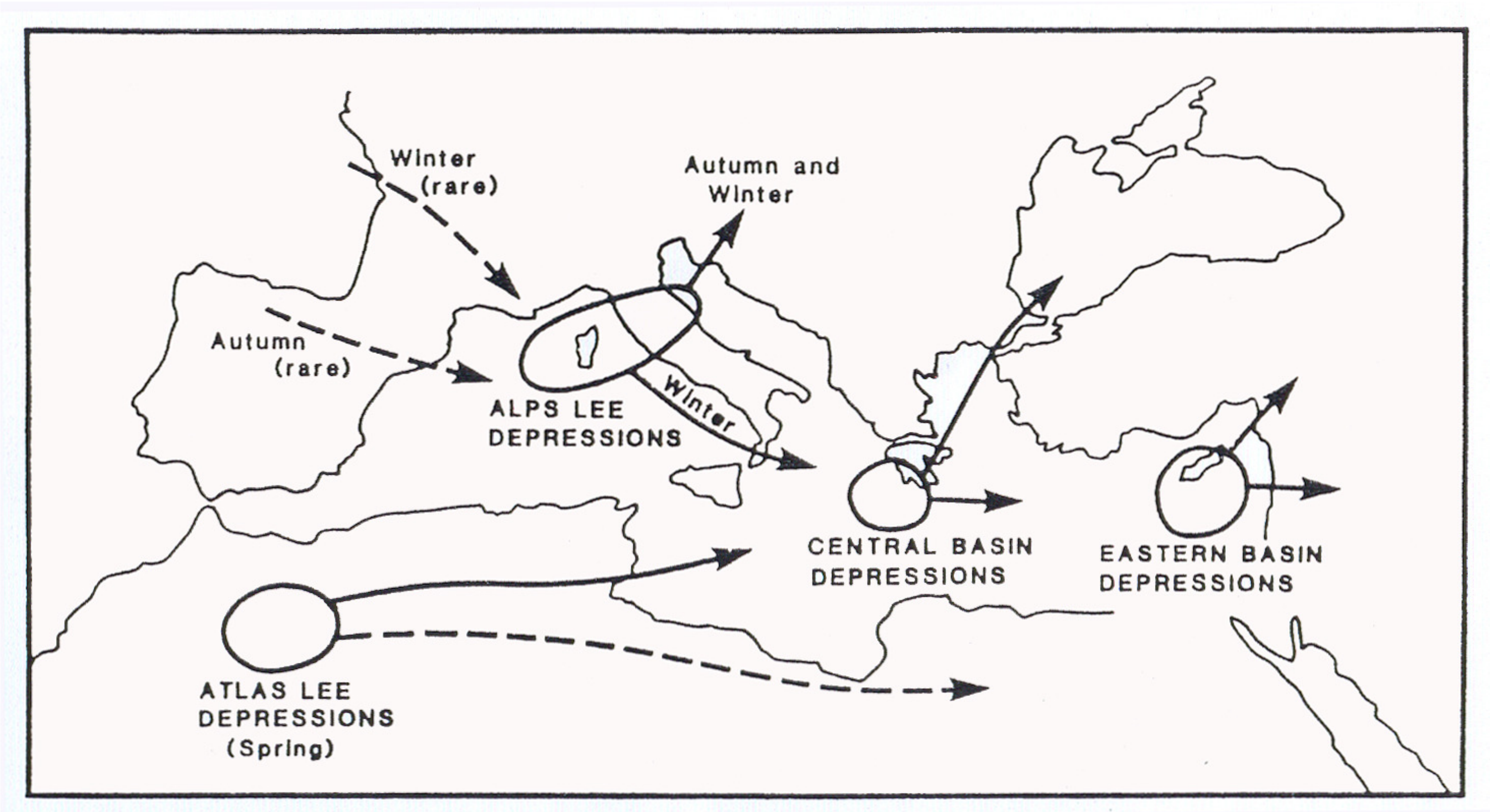
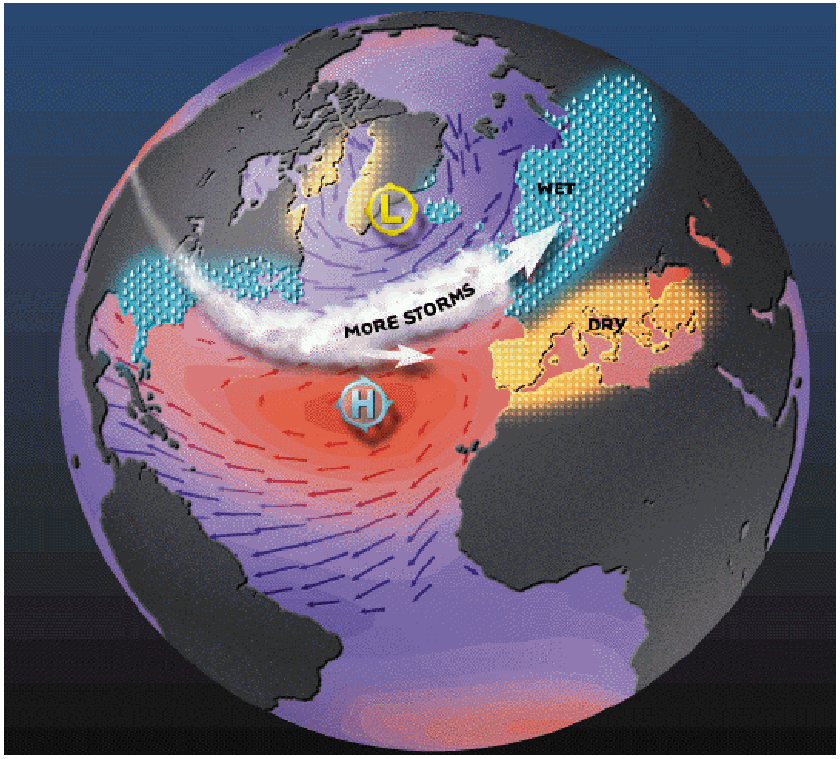
Introduction

According to the Koppen definition, the Mediterranean climate is characterized by winter rainfall which exceeds three times the summer rainfall totals, and indeed over most of the region, summer rainfall is close to zero. This strong winter/summer rainfall contrast is associated with a well pronounced seasonal cycle with summertime warm, dry conditions associated with a strong high-pressure ridge which extends eastwards from the Azores subtropical high to the Mediterranean. The axis of ridge is displaced southward over Egypt by a trough which extends from the Persian Gulf area north-westwards towards Greece and which is associated with the Indian summer monsoon depression. The rainy season begins in October, associated with a change in the mean-wave pattern of the upper westerlies and an upper air flow which is characterized by a trough over Europe. Winter is characterized by cyclonic disturbances and low mean pressure in the Mediterranean, with higher pressure to the east associated with the Siberian high. In March and April, as the main features of the upper flow (e.g. jet streams) begin to move northward from their southernmost winter positions, the rainy season continues until May where the summer dry regime is established.



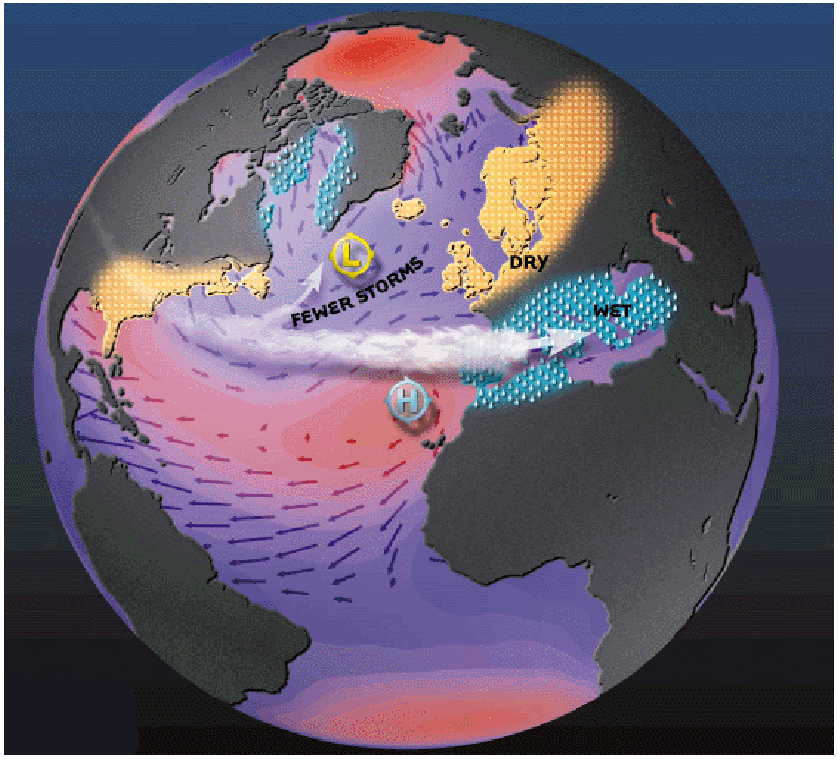
Regions of cyclogenesis and principal cyclone tracks

Positive NAO phase



An enhanced Icelandic low and an enhanced subtropical high result in more and stronger winter storms crossing the Atlantic Ocean on a more northerly track, bringing moist air to the northern Europe

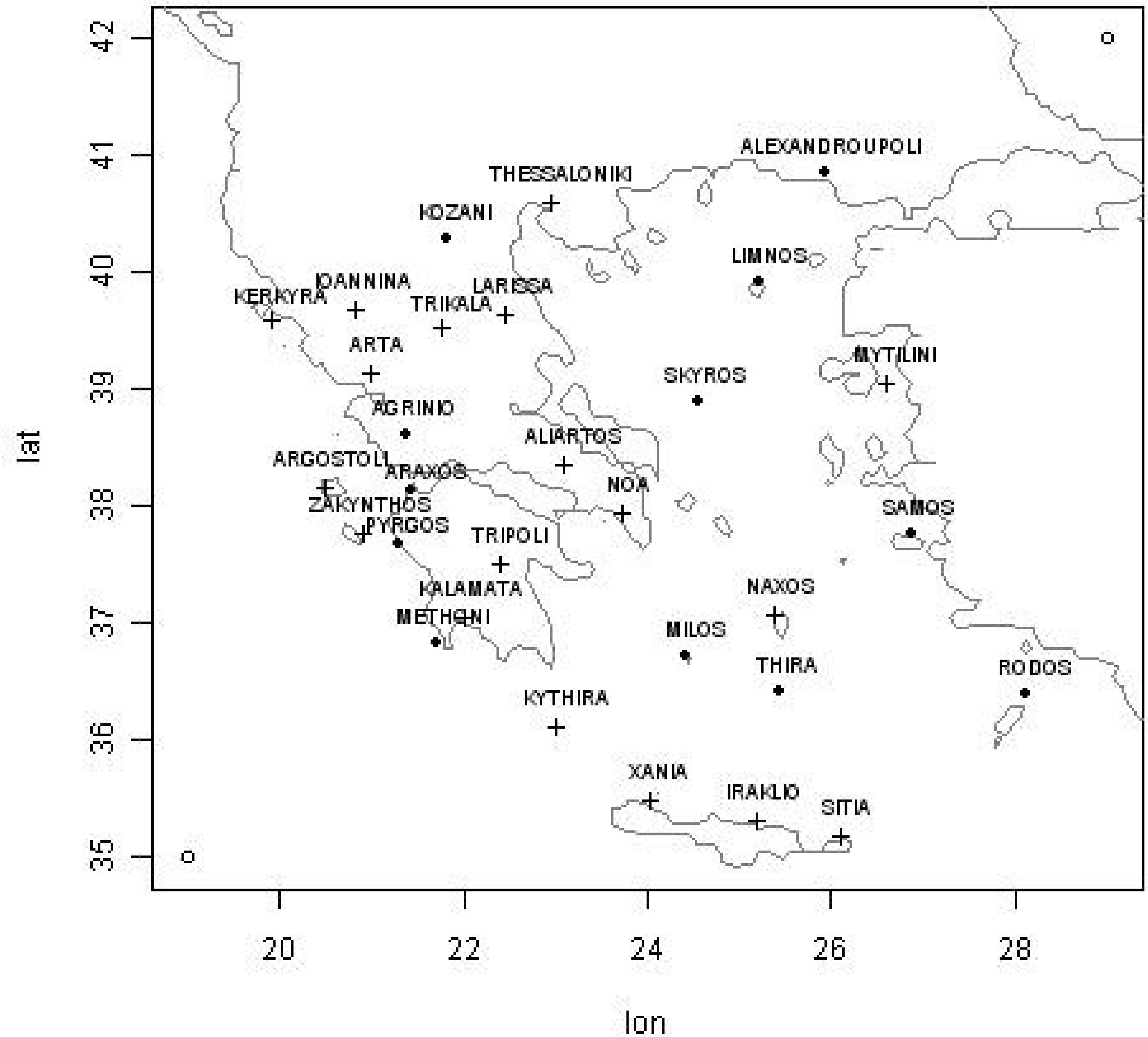
Negative NAO phase



A weak Icelandic low and a weak subtropical high result in fewer and weaker winter storms crossing on a more west-east pathway, bringing moist air into the Mediterranean

Correlation with NAO index
Precipitation (mm/day)
Global Precipitation Climatology Project
data 1980-2009

Lisbon	-0.67
Madrid	-0.74
Valencia	-0.29
Toulouse	-0.31
Marseille	-0.60
Nice	-0.60
Genoa	-0.66
Milan	-0.11
Rome	-0.49
Trieste	-0.25
Naples	-0.49
Malta	-0.45
Bari	-0.39
Ioannina	-0.62
Naxos	-0.64
Antalya	-0.42
Nicosia	-0.18
Adana	-0.21



+ records since 1900

• records since 1950

Stations with recovered precipitation data in Greece

11 stations in W. Greece
9 stations in E. Greece
9 stations in E. Aegean

Table of Stations with recovered precipitation data in Greece

W. Greece

1. Kerkyra	1887-1940, 1947-2007
2. Ioannina	1915-1940, 1951-2001
3. Arta	1899-1941, 1957-2001
4. Argostoli	1899-1930, 1937-1940, 1951-2003
5. Agrinio	1951-2001
6. Araxos	1951-2001
7. Zakynthos	1901-2008
8. Pyrgos	1951-1998
9. Methoni	1951-2008
10. Kalamata	1894-1940, 1950-2008
11. Hania	1915-1940, 1947-2004

E. Greece

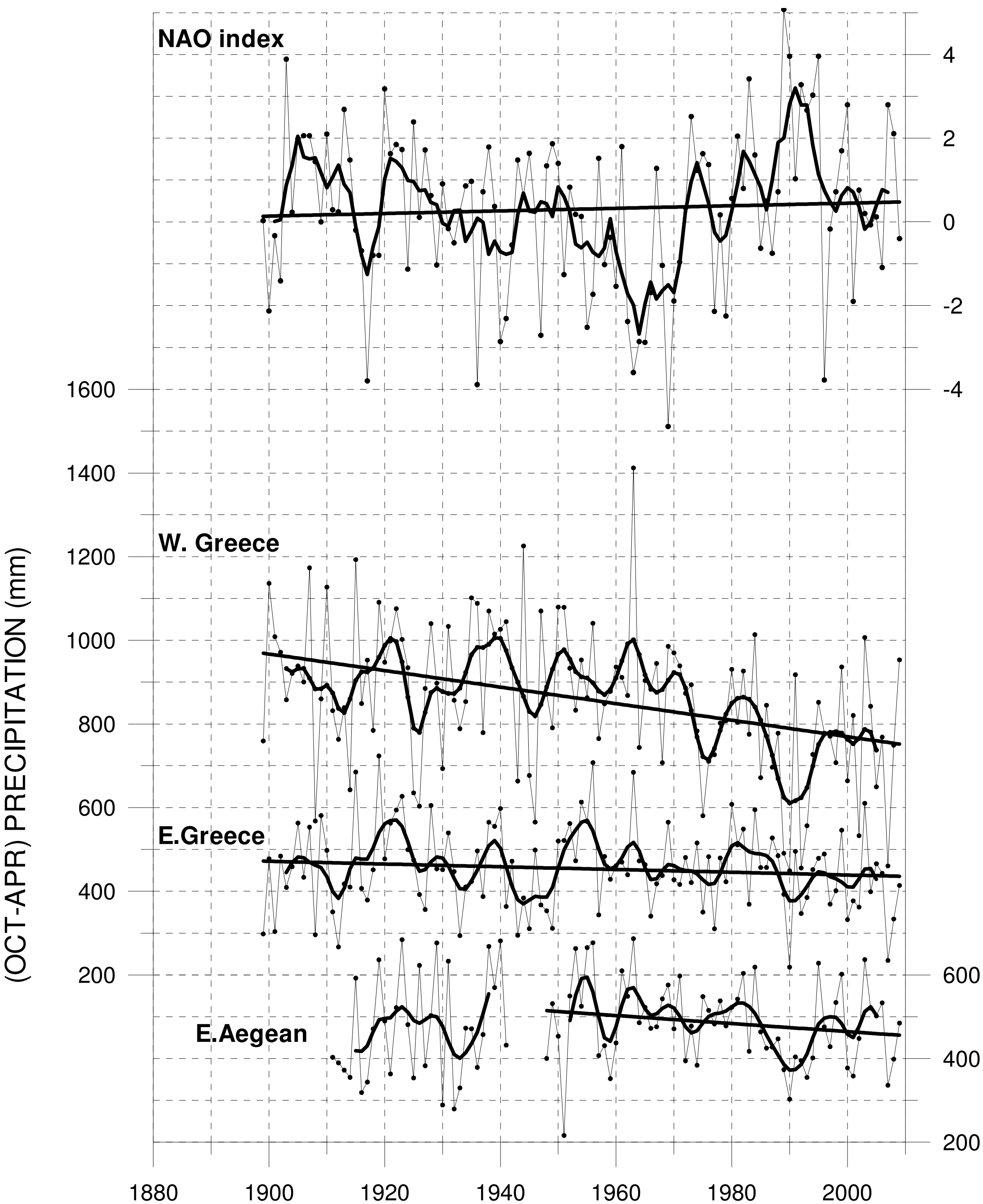
1. Kozani	1951-2001
2. Thessaloniki	1915-2008
3. Larissa	1898-2008
4. Skyros	1951-2008
5. Aliartos	1907-1997
6. Athens	1891-2008
7. Tripolis	1898-1940, 1949-2008
8. Milos	1951-2008
9. Kythira	1899-1940, 1949-2008

E. Aegean

1. Alexandroup	1951-2008
2. Limnos	1951-2008
3. Mytilini	1915-1931, 1936-40, 1952-2008
4. Samos	1951-2008
5. Naxos	1897-1940, 1955-2008
6. Thira	1961-1999
7. Hraklio	1910-1942, 1948-2008
8. Sitia	1915-1926, 1930-1943, 1947-2001
9. Rodos	1951-2008

11 stations in W. Greece
9 stations in E. Greece
9 stations in E. Aegean

Correlation between precipitation in Greece and NAO



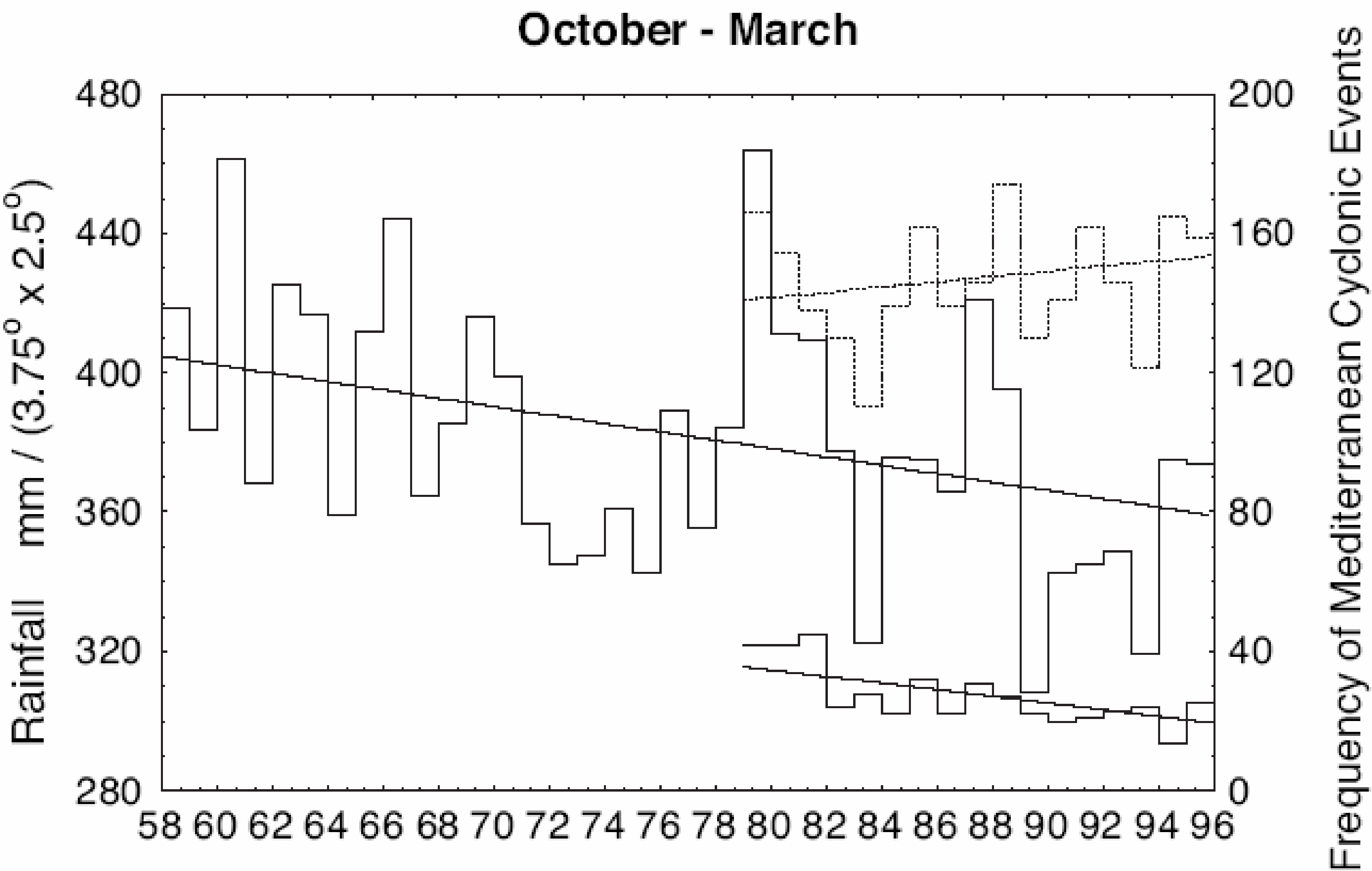
r = -0.38 (>99% conf. level)

r = -0.21 (95% conf. level)

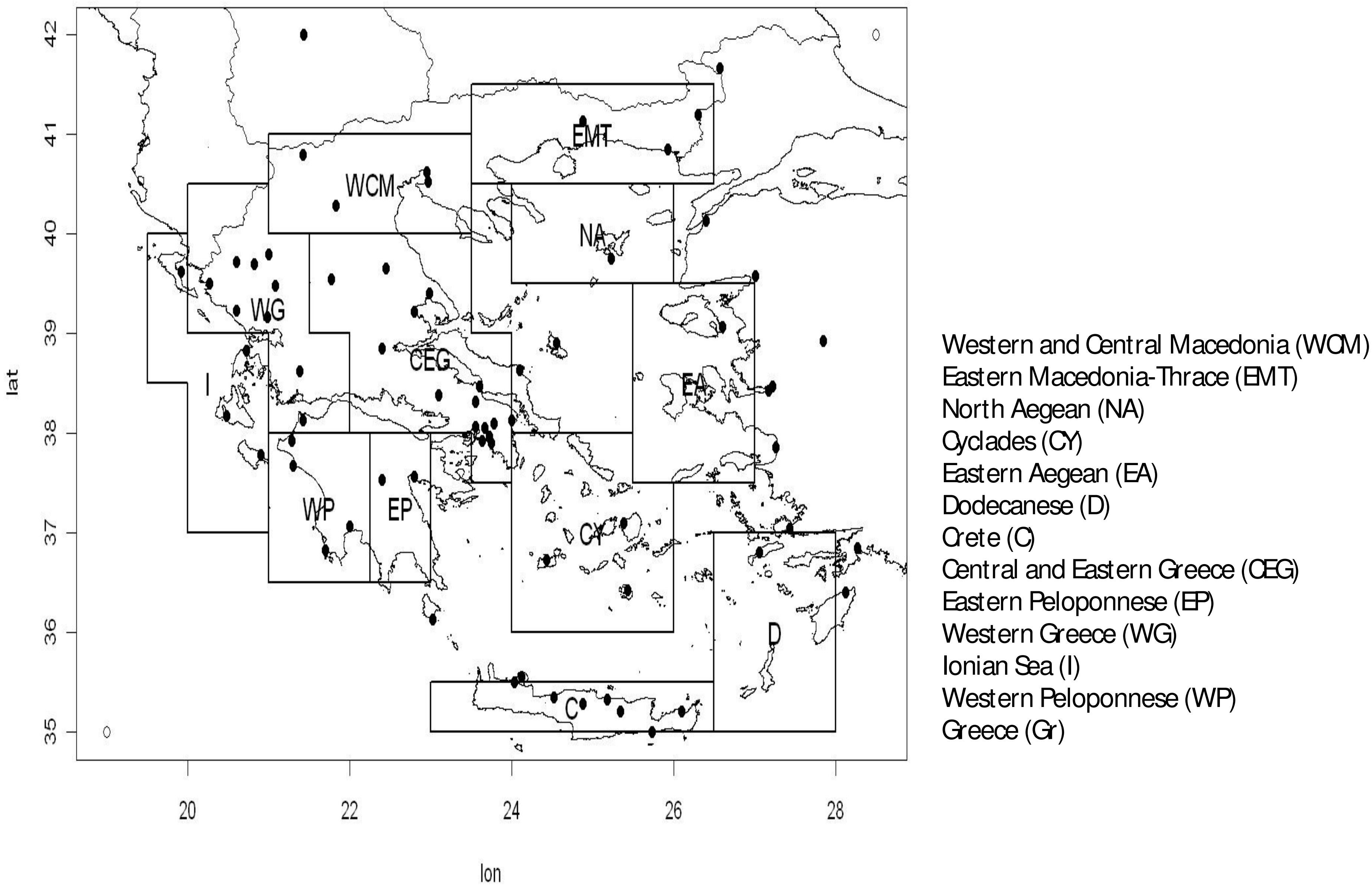
r = -0.19 (90% conf. level)

Table of correlations between precipitation and NAO

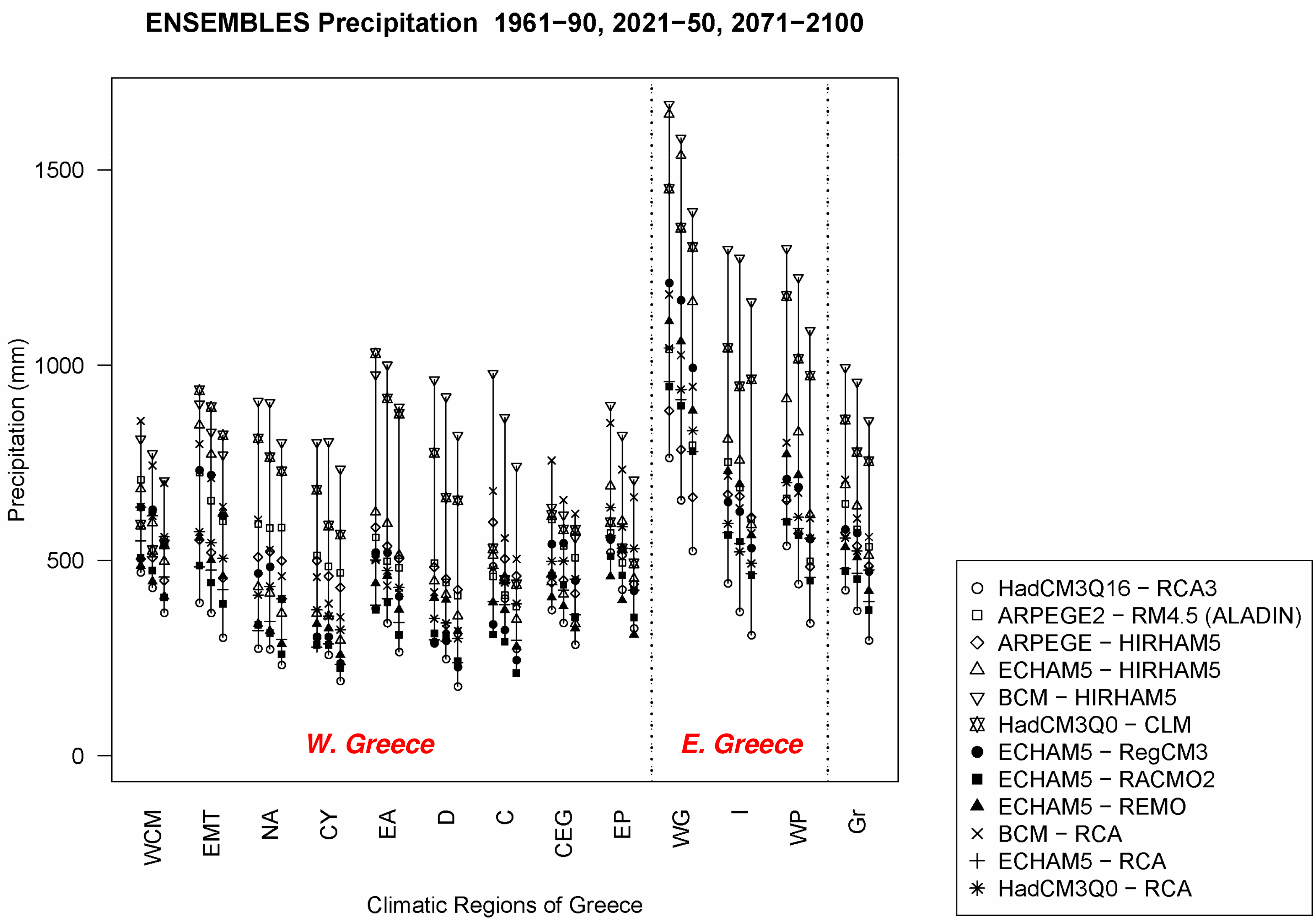
	Stations	Correlation with NAO	Nobs	Confidence level
W. Greece	Kerkyra	-0.43	115	>99%
	Ioannina	-0.46	77	>99%
	Arta	-0.38	86	>99%
	Argostoli	-0.33	92	99%
	Agrinio	-0.28	50	95%
	Araxos	-0.36	50	99%
	Zakynthos	-0.19	108	95%
	Kalamata	-0.01	106	–
	Hania	-0.11	79	–
E. Greece	Thessaloniki	-0.30	92	99%
	Larissa	-0.14	112	–
	Aliartos	-0.08	90	–
	Athens	-0.11	118	–
	Tripolis	-0.30	101	99%
	Kythira	-0.13	95	–
E. Aegean	Alexandroupoli	-0.28	58	95%
	Limnos	-0.13	58	–
	Mytilini	-0.19	80	90%
	Samos	-0.29	58	95%
	Naxos	-0.06	98	–
	Iraklio	-0.16	92	–
	Sitia	0.01	78	–
	W. Greece	**-0.37**	**116**	**>99%**
	E. Greece	**-0.21**	**118**	**95%**
	E. Aegean	**-0.19**	**94**	**90%**

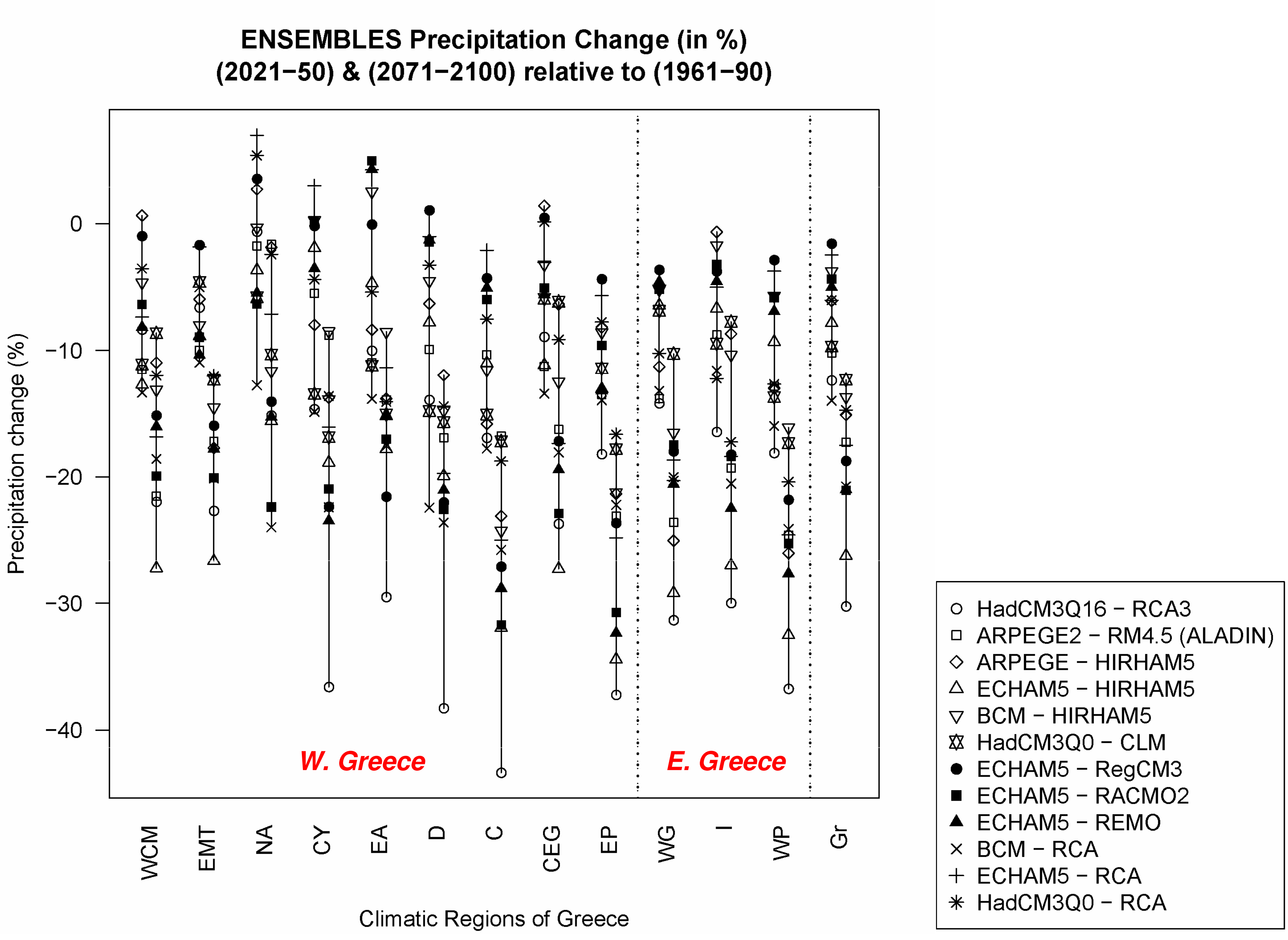


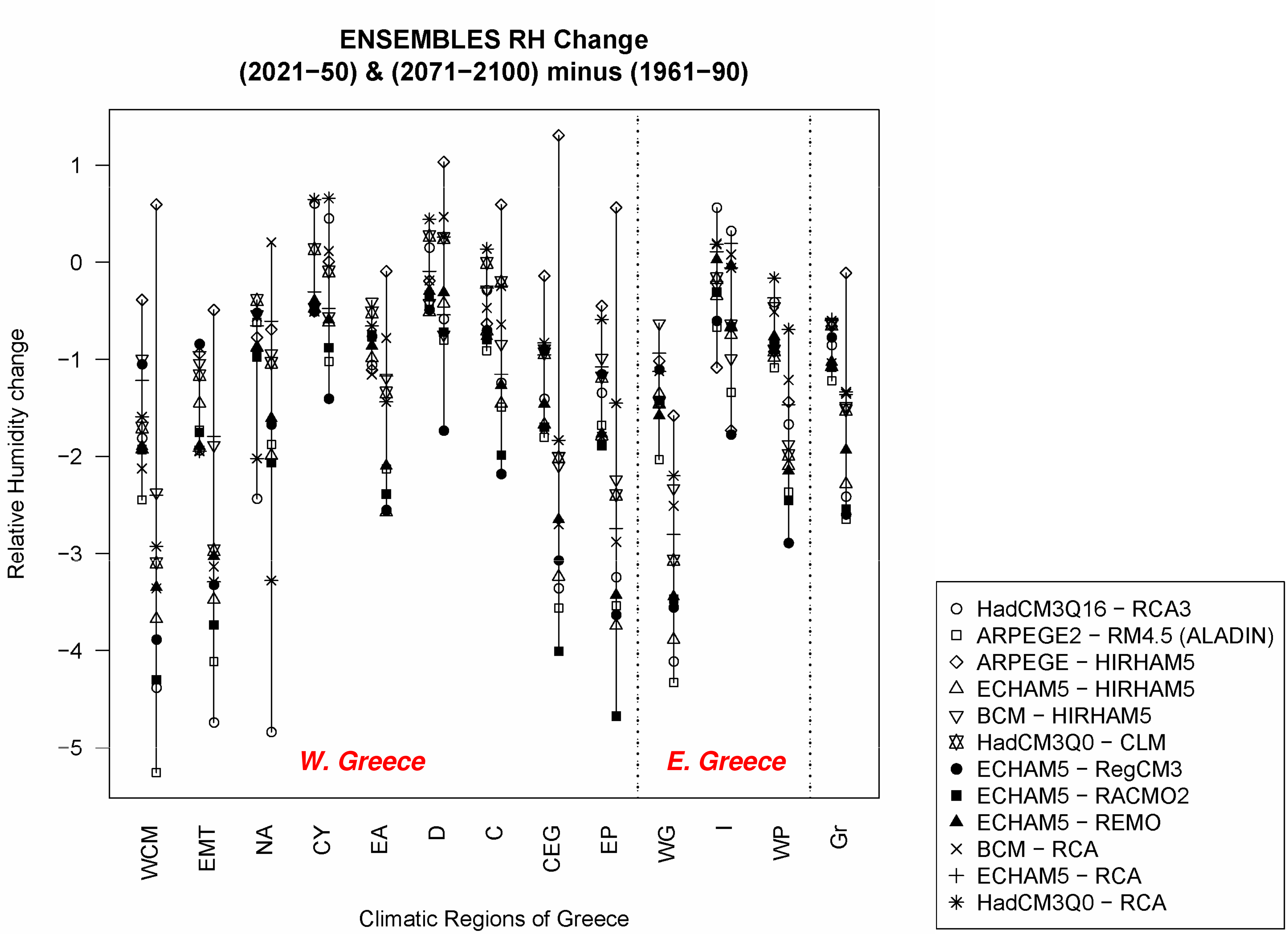
Time series, and respective linear trends, of the total amount of precipitation in the Northern Mediterranean basin (bold curve, left axis), the total occurrence of intense Mediterranean cyclones (light curve, right axis), and of non intense cyclones (dotted curve, right axis) for the October to March period (from Trigo et al., 2000).

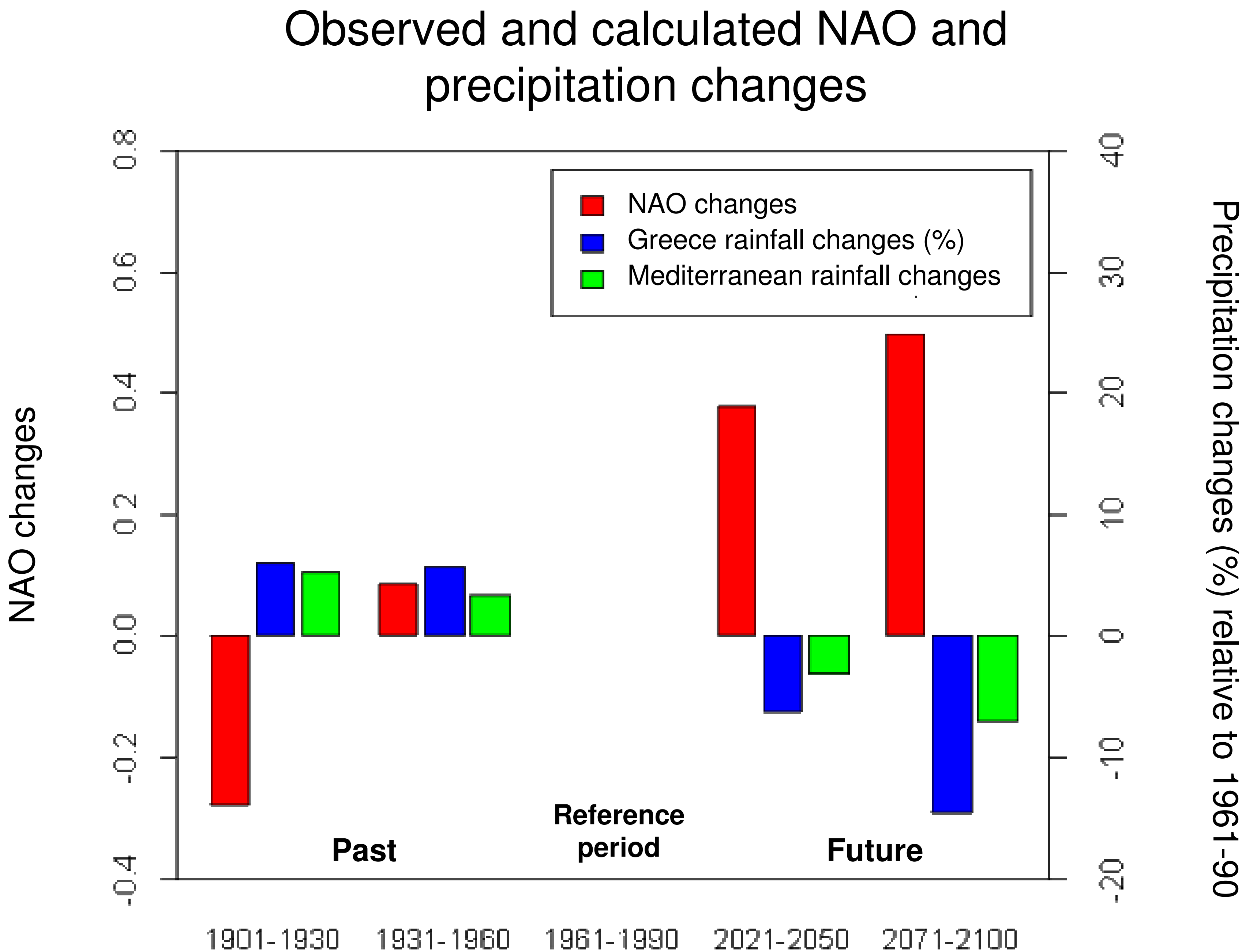


lat
lon
42
41
40
39
38
37
36
35
20
22
24
26
28
WCM
EMT
NA
WG
CEG
I
EA
WP
EP
CY
D
C
Western and Central Macedonia (WCM)
Eastern Macedonia-Thrace (EMT)
North Aegean (NA)
Cyclades (CY)
Eastern Aegean (EA)
Dodecanese (D)
Crete (C)
Central and Eastern Greece (CEG)
Eastern Peloponnese (EP)
Western Greece (WG)
Ionian Sea (I)
Western Peloponnese (WP)
Greece (Gr)


ENSEMBLES Precipitation 1961−90, 2021−50, 2071−2100
Precipitation (mm)
1500
1000
500
0
W. Greece
E. Greece
WCM
EMT
NA
CY
EA
D
C
CEG
EP
WG
I
WP
Gr
Climatic Regions of Greece
HadCM3Q16 − RCA3
ARPEGE2 − RM4.5 (ALADIN)
ARPEGE − HIRHAM5
ECHAM5 − HIRHAM5
BCM − HIRHAM5
HadCM3Q0 − CLM
ECHAM5 − RegCM3
ECHAM5 − RACMO2
ECHAM5 − REMO
BCM − RCA
ECHAM5 − RCA
HadCM3Q0 − RCA


ENSEMBLES Precipitation Change (in %)
(2021−50) & (2071−2100) relative to (1961−90)
Precipitation change (%)
0
−10
−20
−30
−40
W. Greece
E. Greece
WCM
EMT
NA
CY
EA
D
C
CEG
EP
WG
I
WP
Gr
Climatic Regions of Greece
HadCM3Q16 − RCA3
ARPEGE2 − RM4.5 (ALADIN)
ARPEGE − HIRHAM5
ECHAM5 − HIRHAM5
BCM − HIRHAM5
HadCM3Q0 − CLM
ECHAM5 − RegCM3
ECHAM5 − RACMO2
ECHAM5 − REMO
BCM − RCA
ECHAM5 − RCA
HadCM3Q0 − RCA


ENSEMBLES RH Change
(2021−50) & (2071−2100) minus (1961−90)
Relative Humidity change
1
0
−1
−2
−3
−4
−5
W. Greece
E. Greece
WCM
EMT
NA
CY
EA
D
C
CEG
EP
WG
I
WP
Gr
Climatic Regions of Greece
HadCM3Q16 − RCA3
ARPEGE2 − RM4.5 (ALADIN)
ARPEGE − HIRHAM5
ECHAM5 − HIRHAM5
BCM − HIRHAM5
HadCM3Q0 − CLM
ECHAM5 − RegCM3
ECHAM5 − RACMO2
ECHAM5 − REMO
BCM − RCA
ECHAM5 − RCA
HadCM3Q0 − RCA



Observed and calculated NAO and precipitation changes
NAO changes
Greece rainfall changes (%)
Mediterranean rainfall changes
NAO changes
Precipitation changes (%) relative to 1961-90
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
40
30
20
10
0
-10
-20
Past
Reference period
Future
1901-1930
1931-1960
1961-1990
2021-2050
2071-2100

Conclusions

- The longest precipitation series in Greece show generally negative trends in the past one hundred years or so.

- There is indication that in western Greece, which is on the lee side of the mountains, the interannual variability of precipitation is significantly correlated both interannually and in the long term with the variability of NAO.

- An ENSEMBLE of models show the negative trends in precipitation to continue through the 21st century and a number of GCMs show a continuation of positive trends of NAO in the coming decades.