united nations
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organization

international atomic
energy agency

the
abdus salam
international centre for theoretical physics

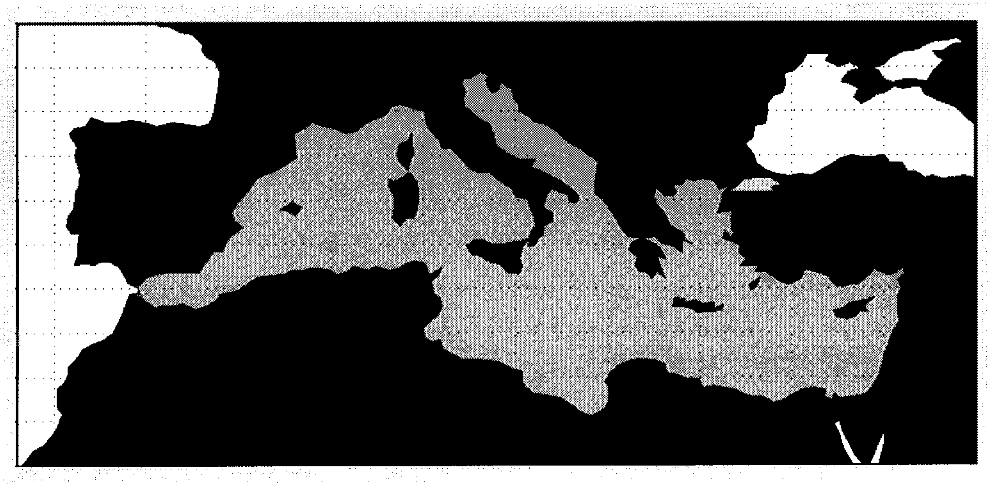
SMR.1303 - 4

Advanced Course:
CLIMATE CHANGE IN THE MEDITERRANEAN REGION
PART I: PHYSICAL ASPECTS
(12 - 16 March 2001)

"Main Climate Driving Forces in the Mediterranean Region"

Manuel DE CASTRO
Universidad Complutense
Dept. Geofisica y Meteorolgia
28040 Madrid
SPAIN

Main climate driving forces in the Mediterranean region

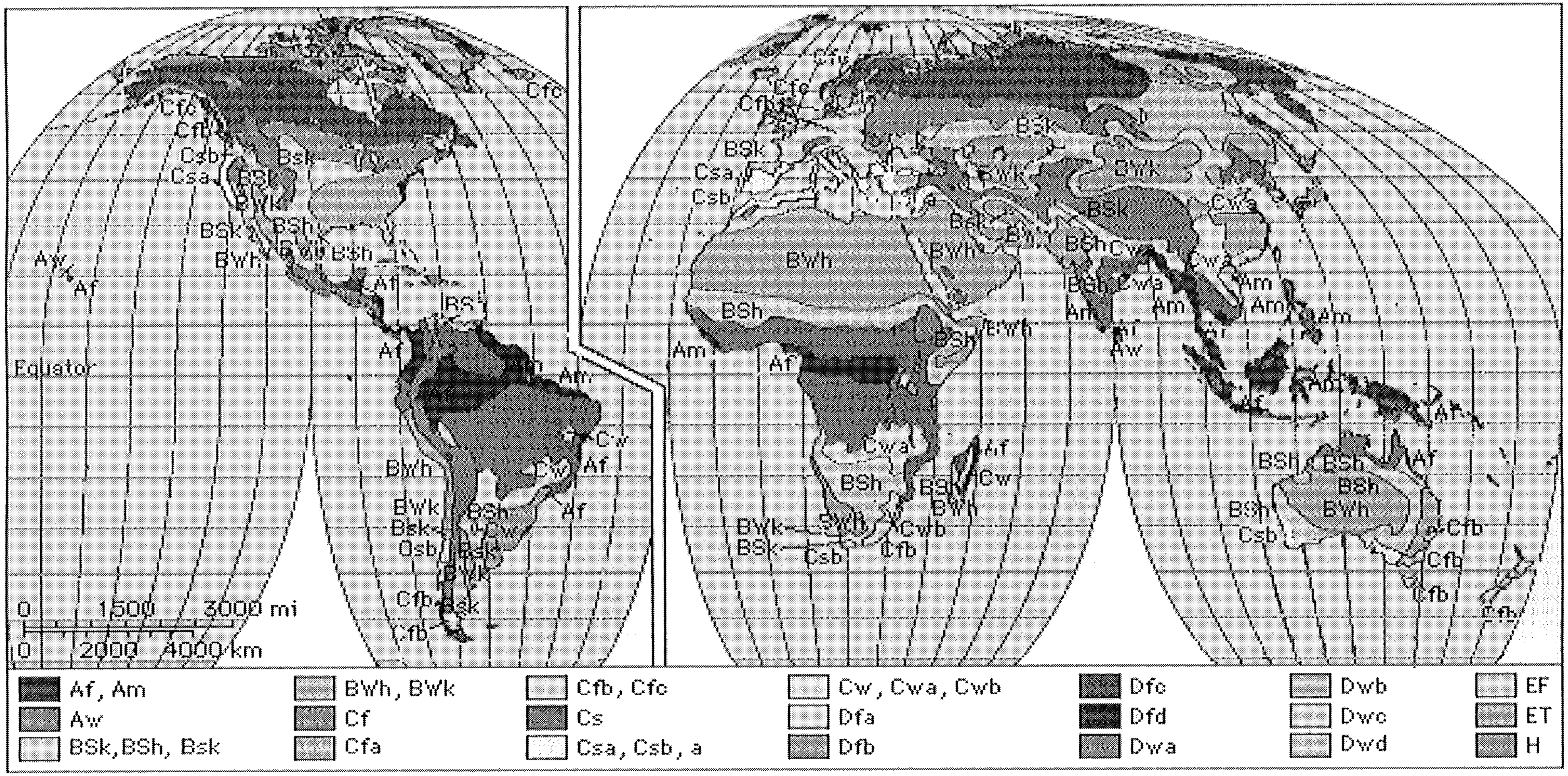


Manuel de Castro
Universidad Complutense
Madrid (Spain)

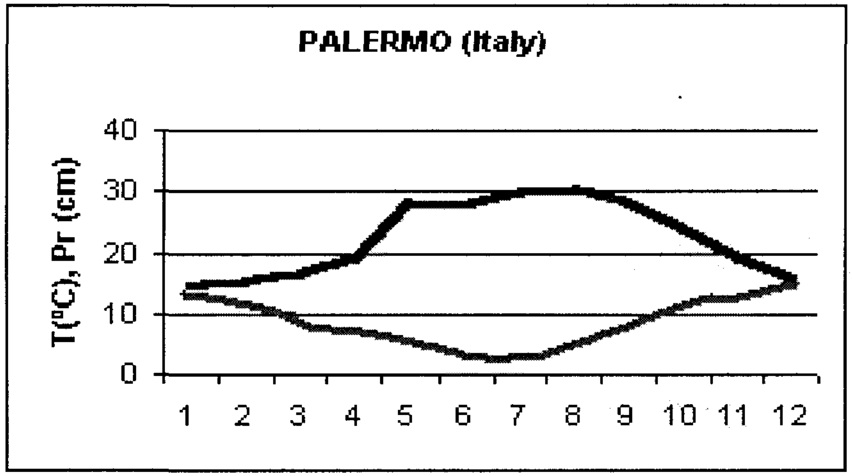
CLIMATIC CONTROLS

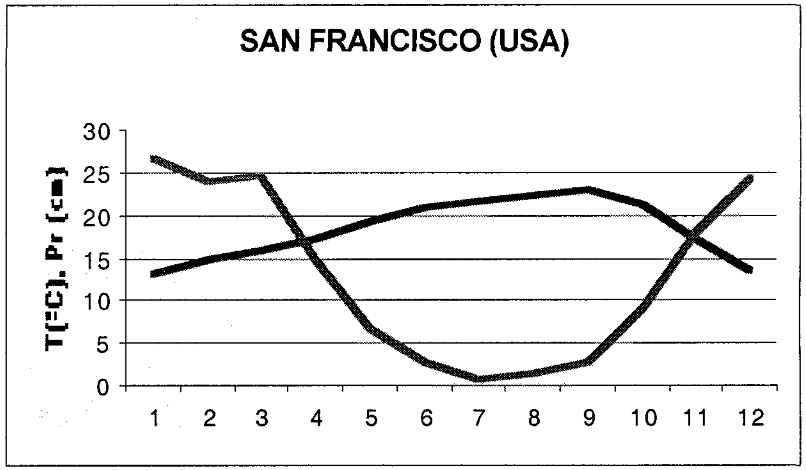
1. Variation with latitude of sunshine intensity
2. Distribution of land and water
3. Ocean currents
4. Prevailing winds
5. Positions of high and low pressure areas
6. Mountain barriers
7. Altitude over sea level

Worldwide distribution of climatic regions after Köppen

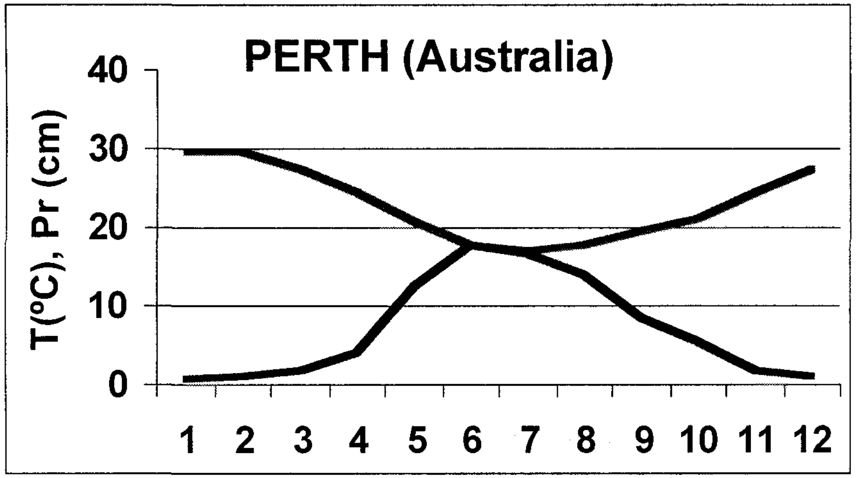


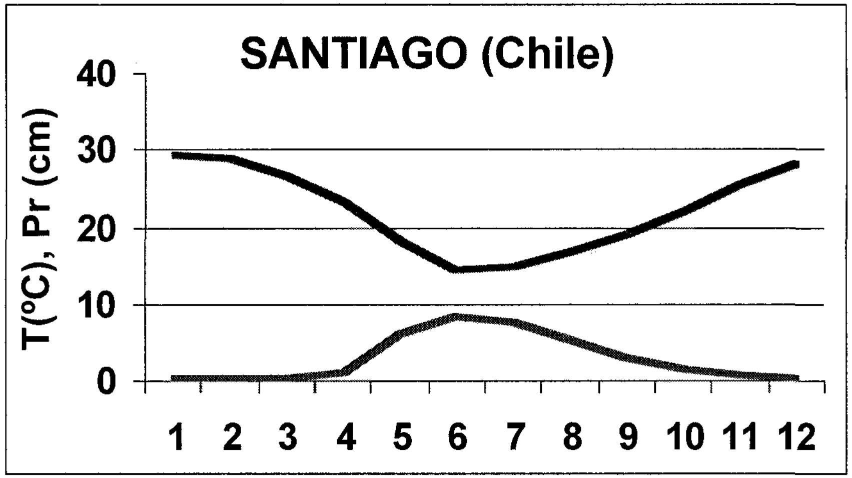
Anual distributions of T and Pr in sites with a mediterranean climate type



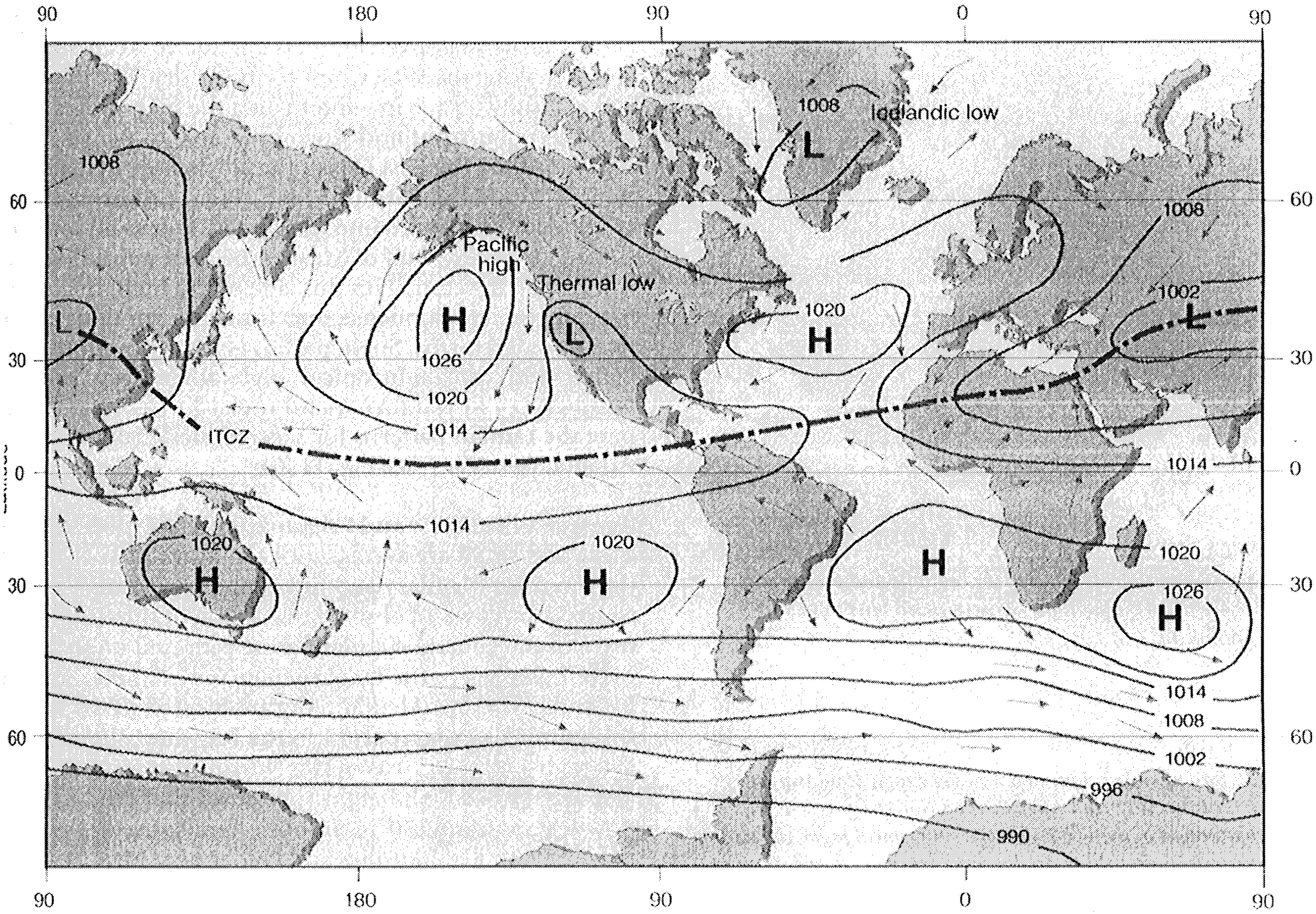


TEMPERATURE (C) PRECIPITATION (cm)

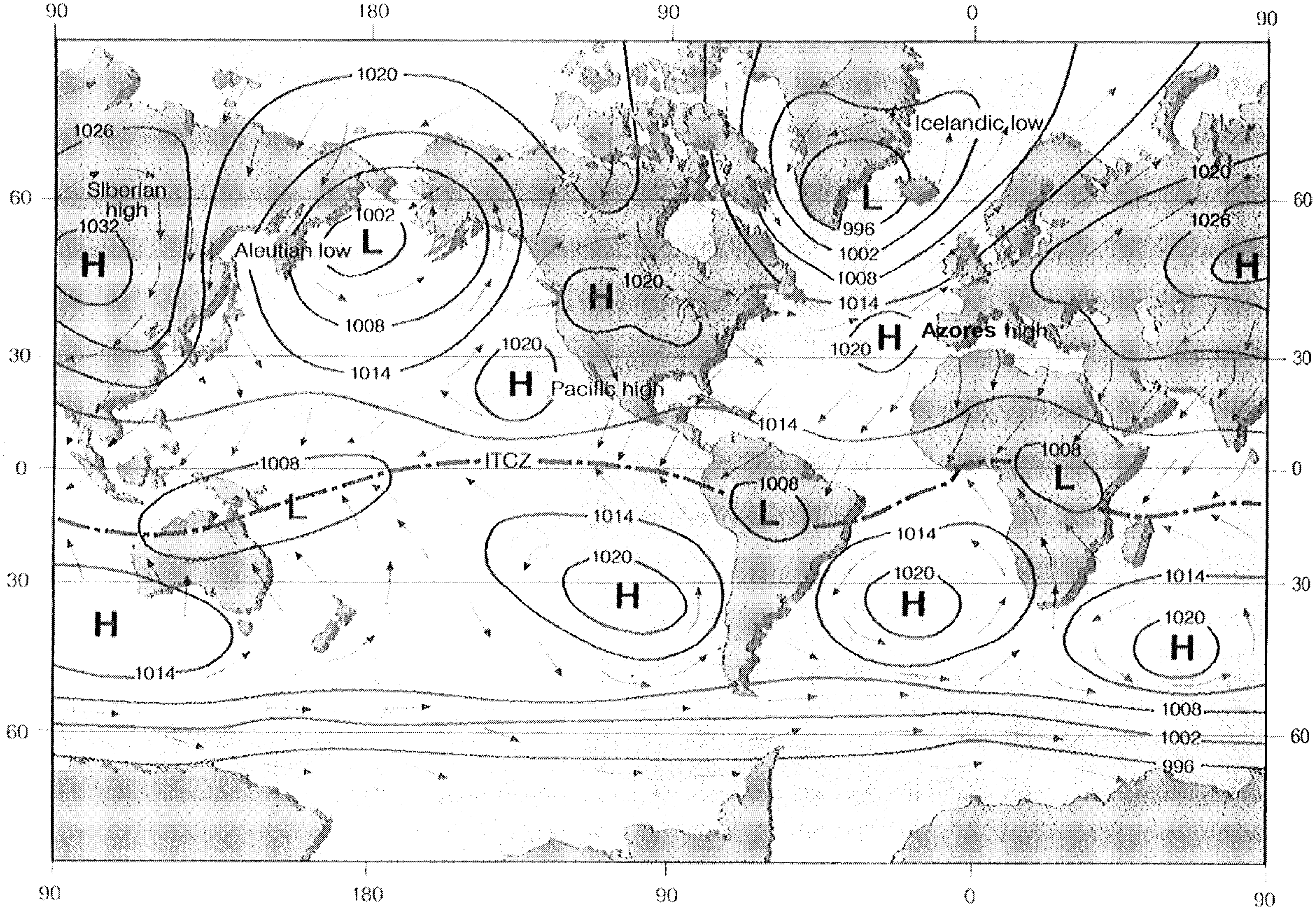




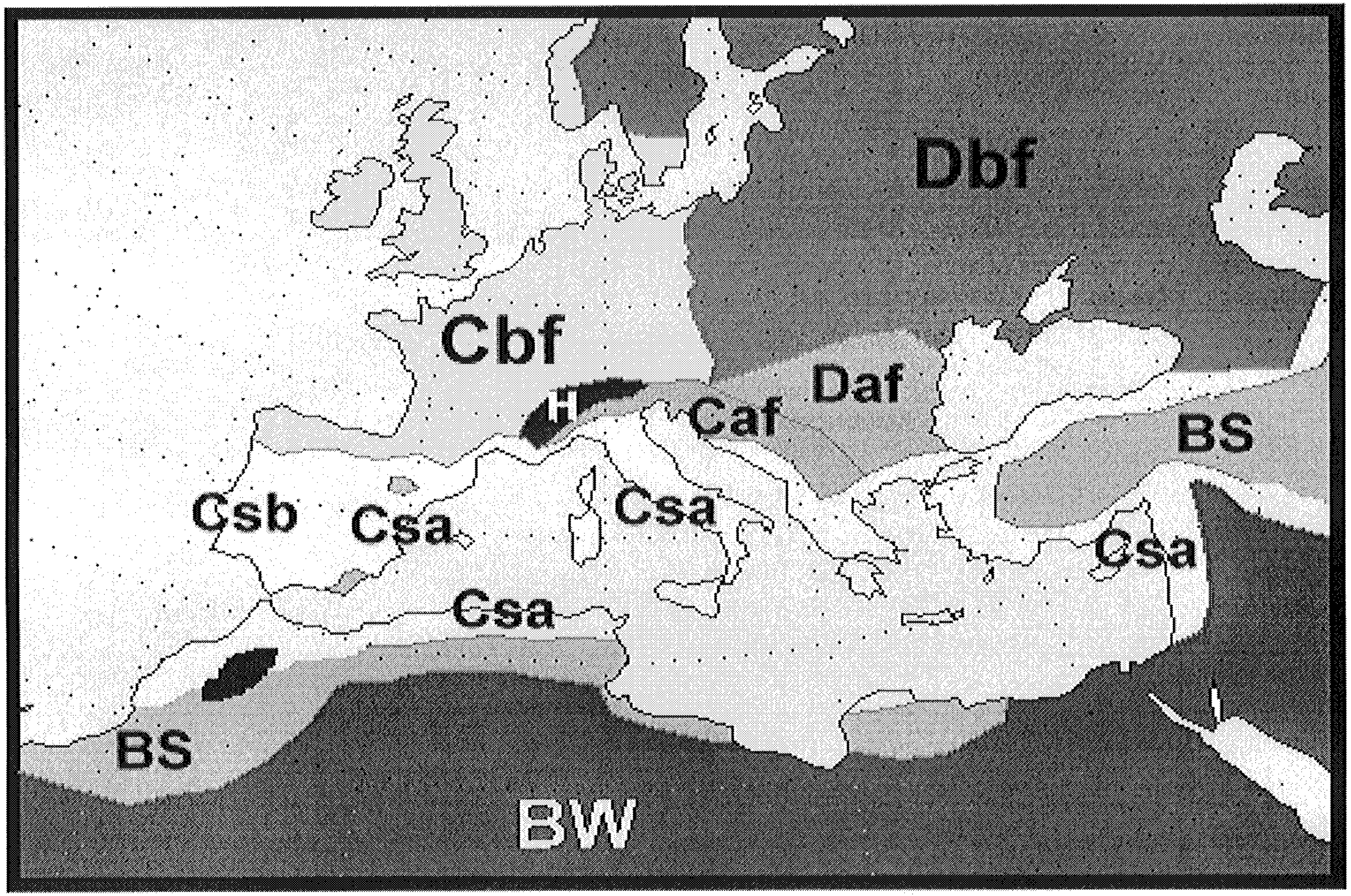
Average mean sea-level pressure in July



Average mean sea-level pressure in January



Köppen's climatic types in the Mediterranean region



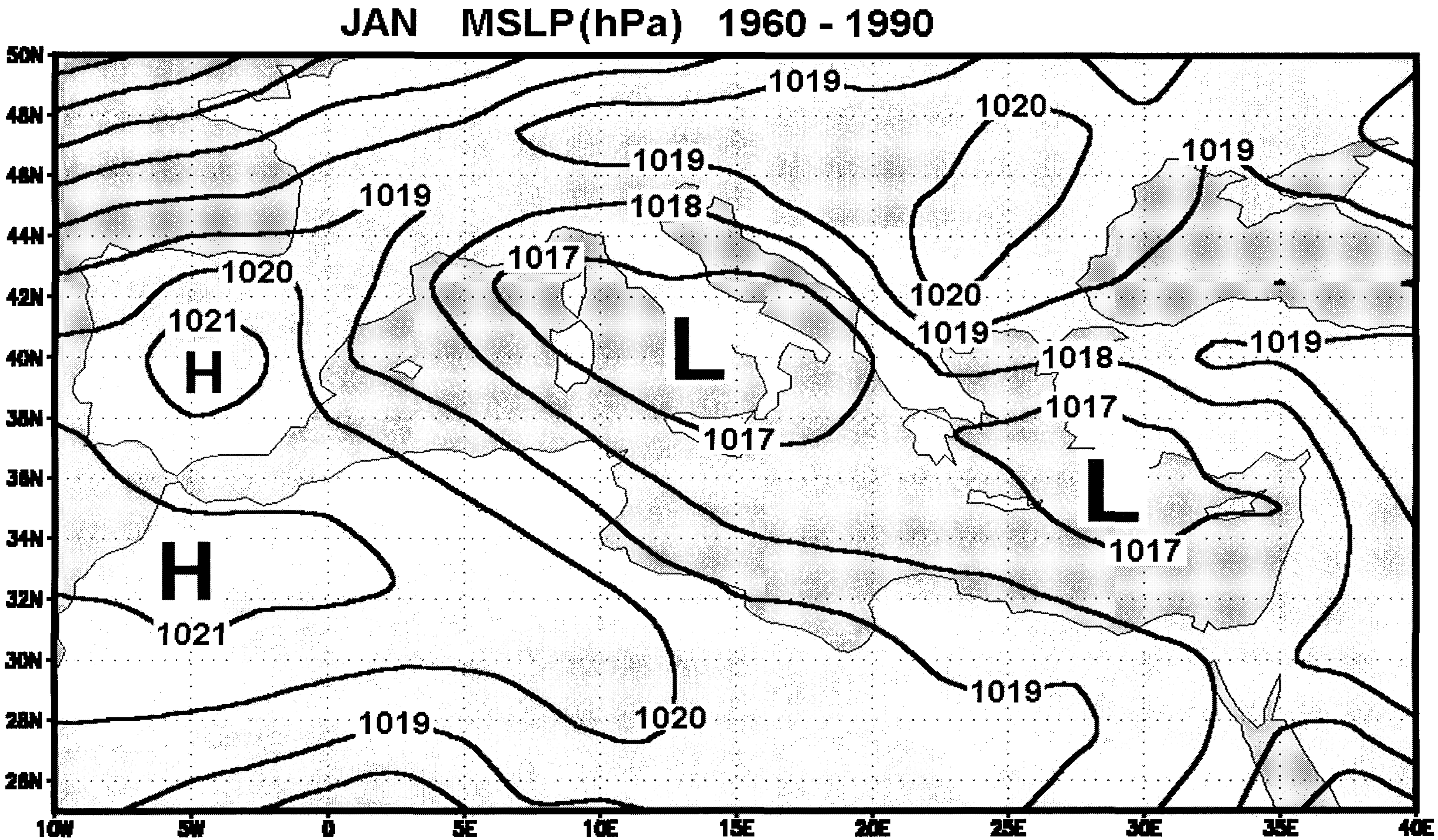
GEOGRAPHICAL FEATURES OF MEDITERRANEAN REGION

- WARM SEA
- OROGRAPHY
- BETWEEN TWO CONTINENTS
- MIDDLE - SUBTROPICAL LATITUDES

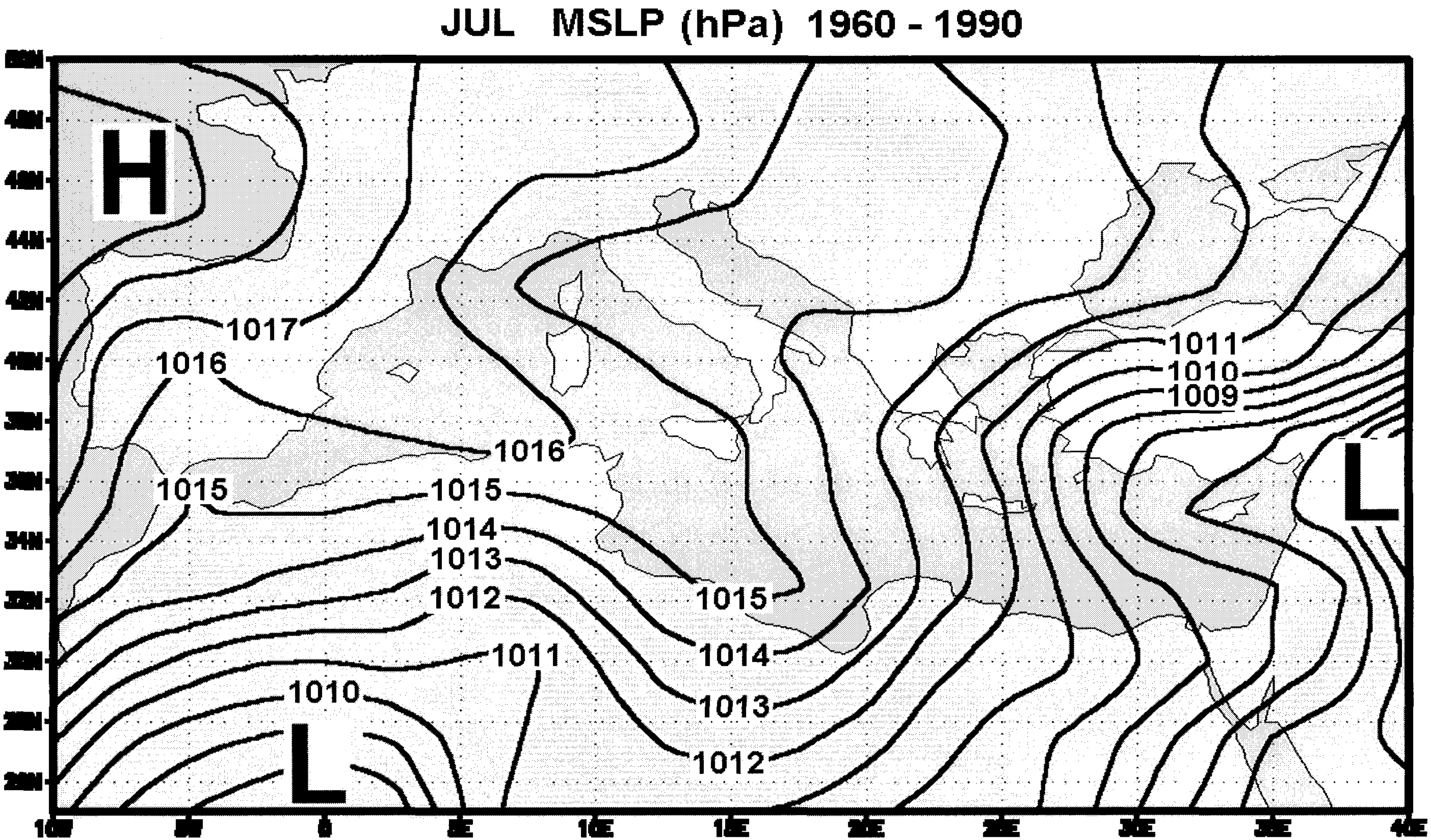
CLIMATE FEATURES

- Surface pressure (mslp)
  - Surface winds
    - Surface temperature (2m)
      - Precipitation

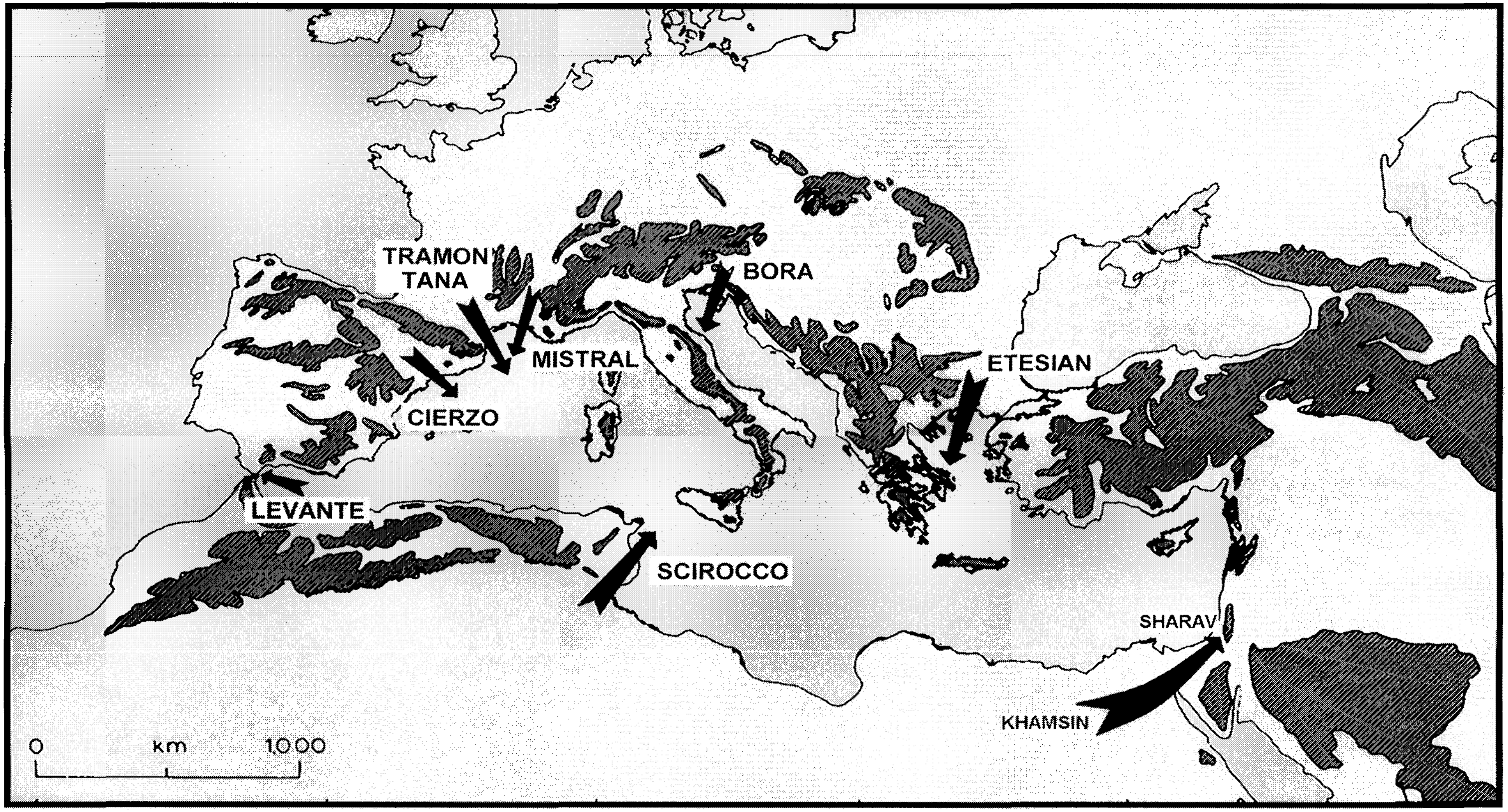
Average msl pressure (hPa) in January



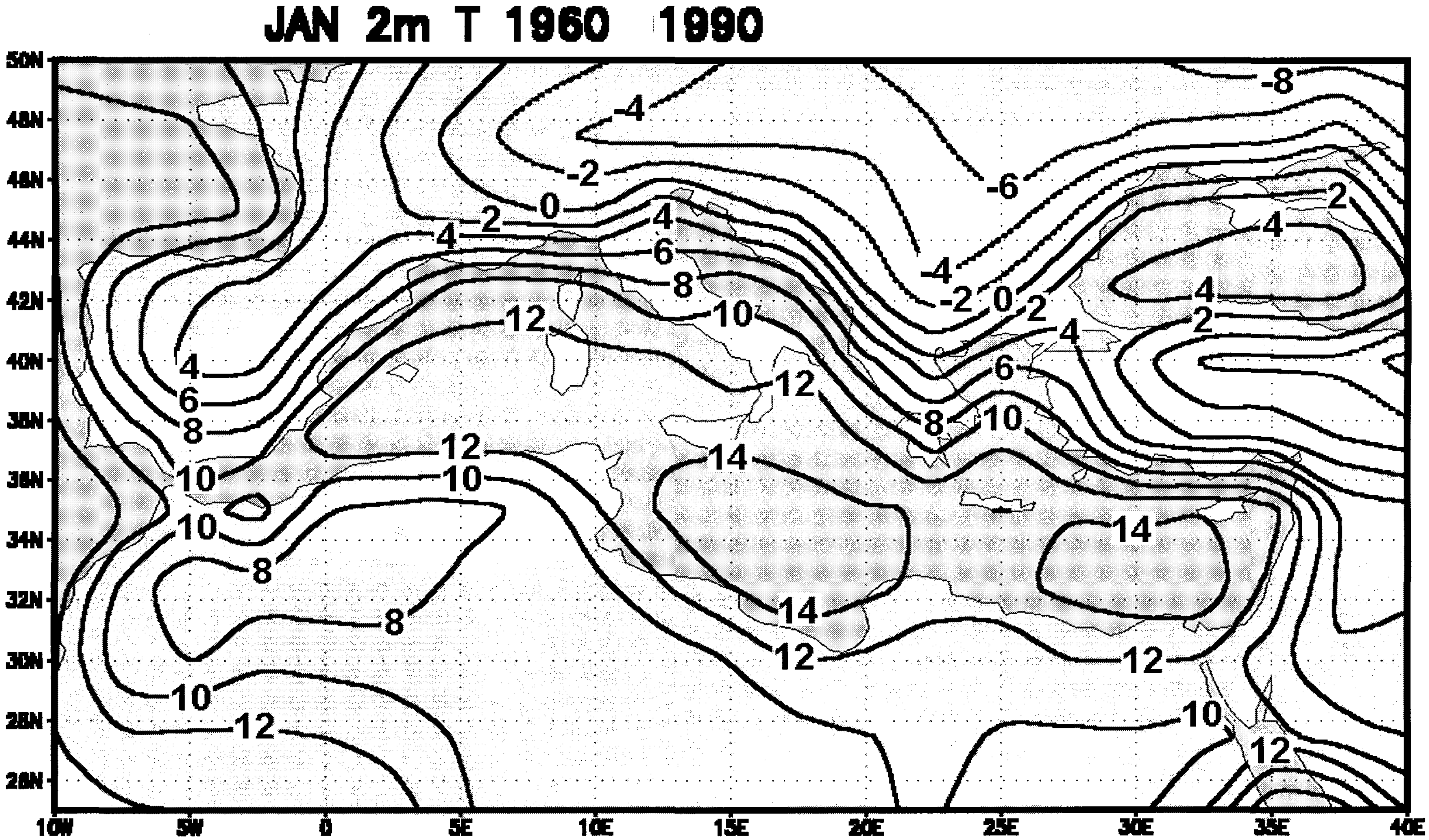
Average msl pressure (hPa) in July



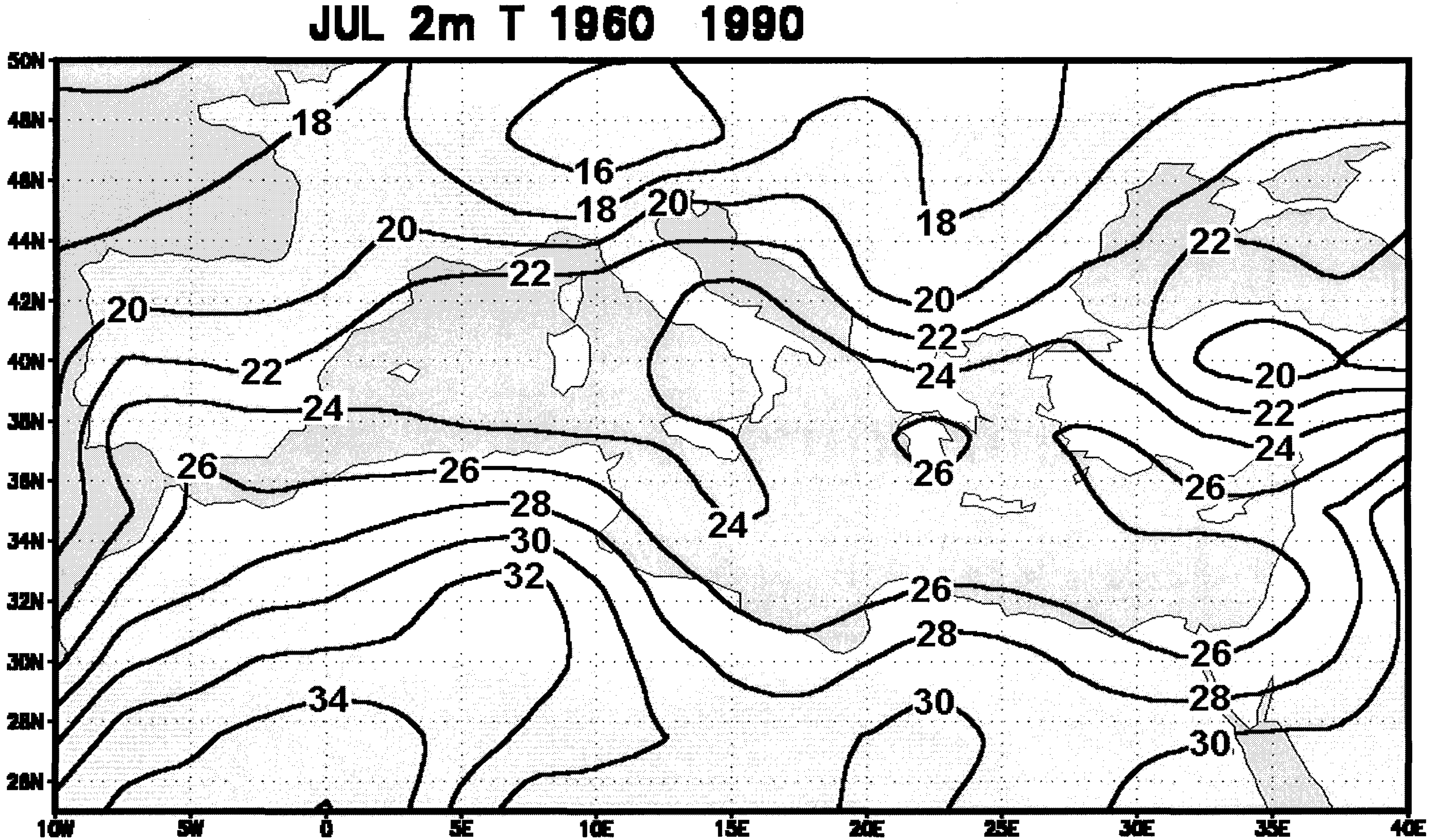
MEDITERRANEAN LOCAL WINDS
originated by orographic pressure perturbations



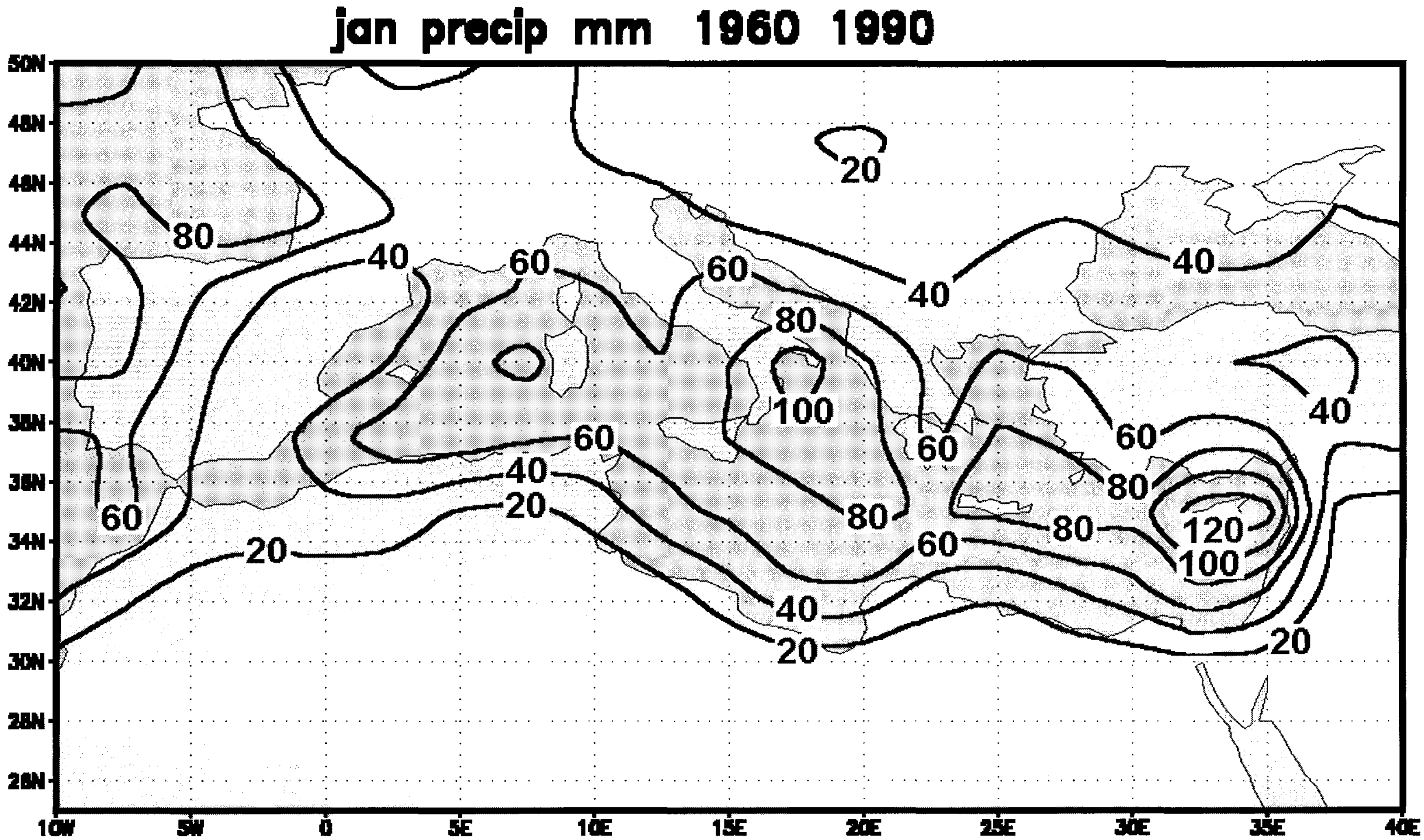
Average surface temperature in January



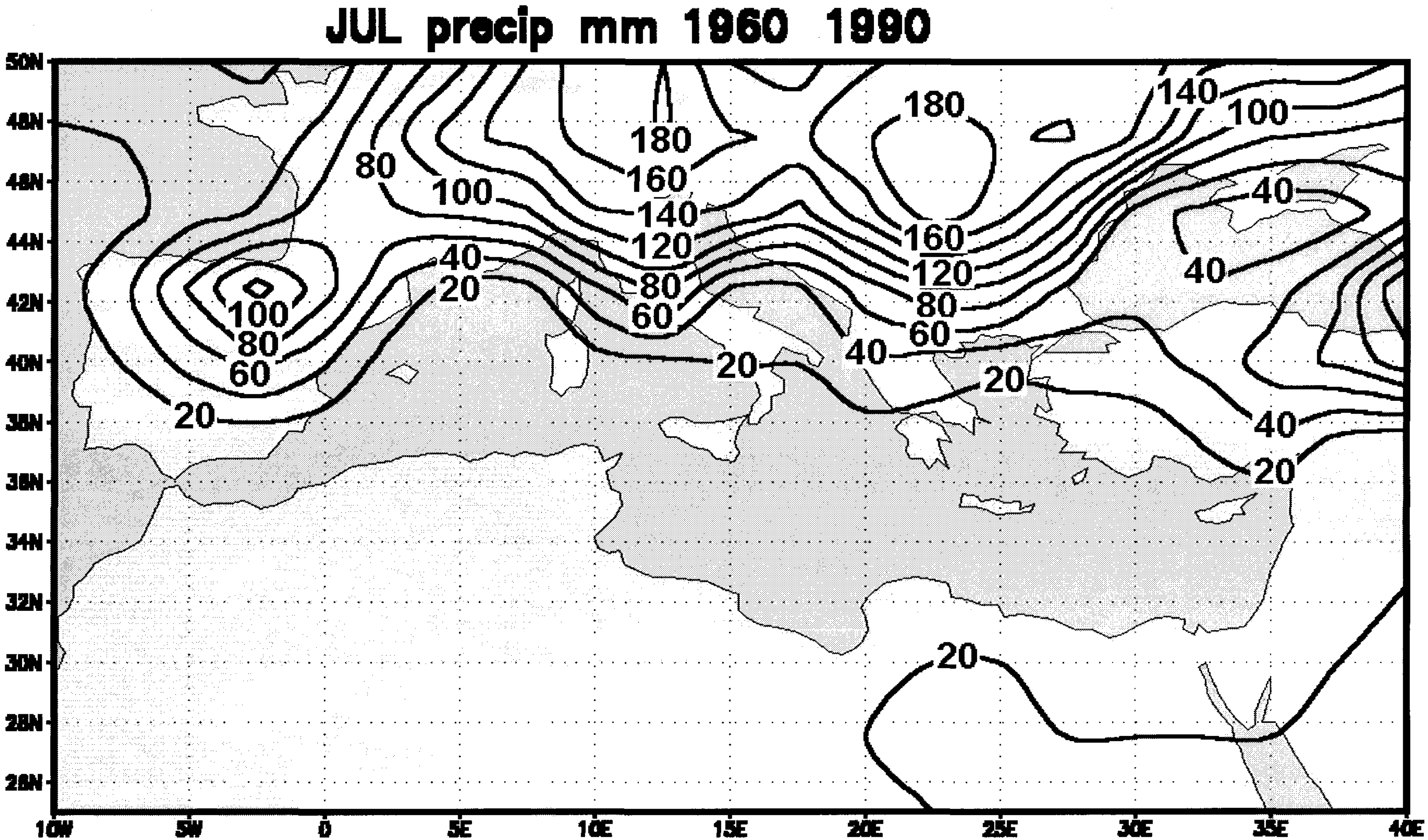
Average surface temperature in July



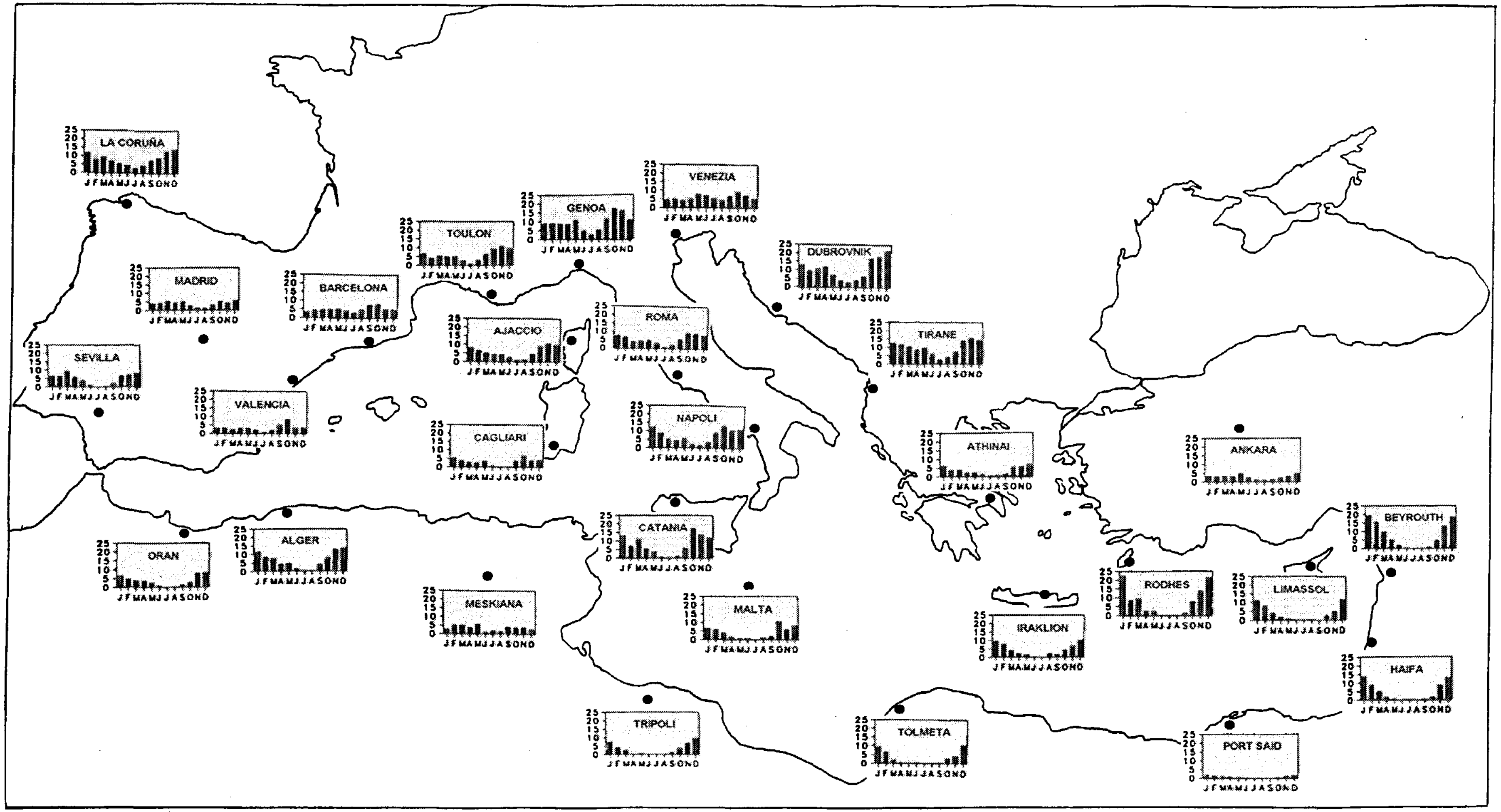
Average precipitation (mm) in January



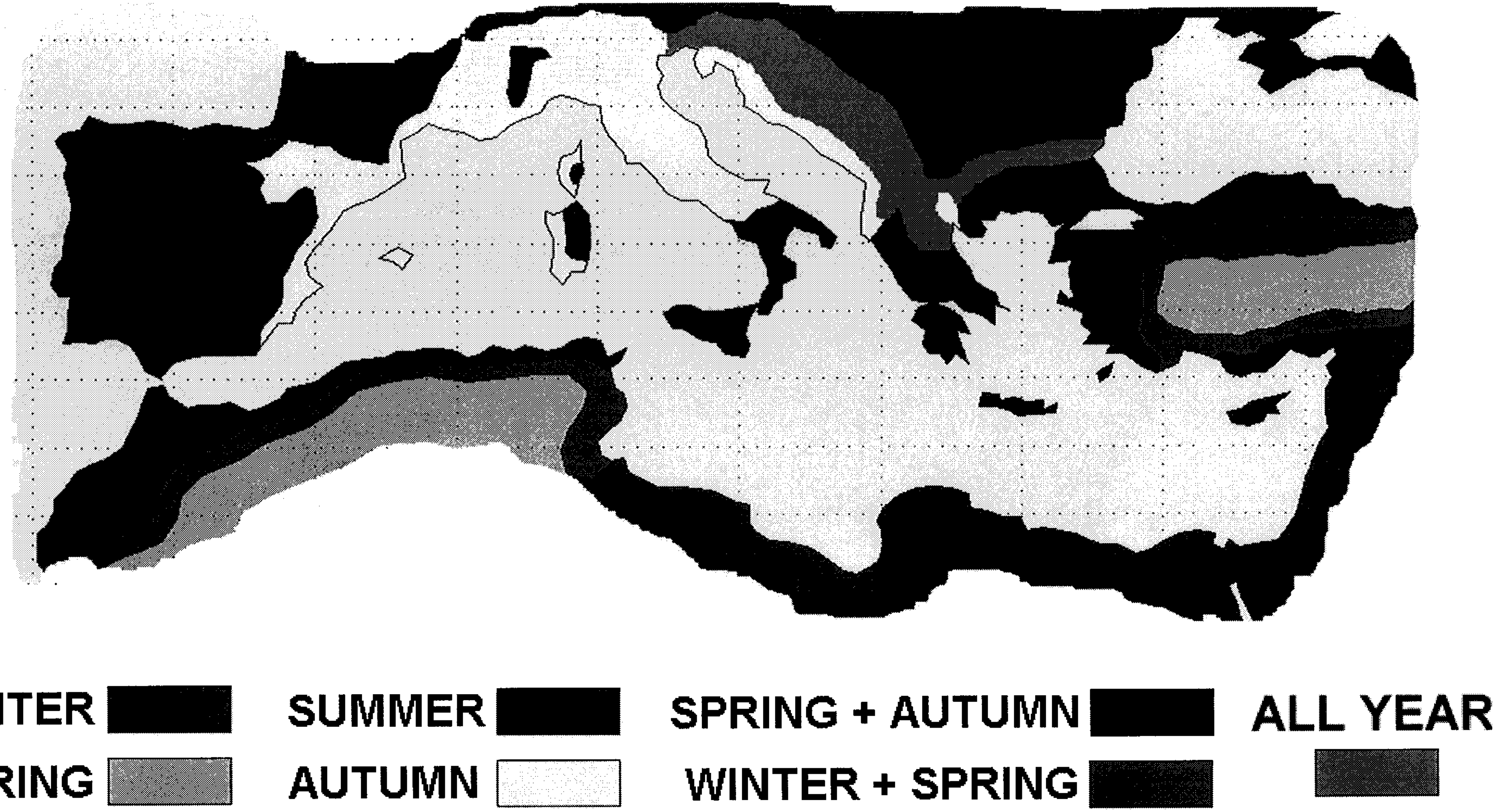
Average precipitation (mm) in July



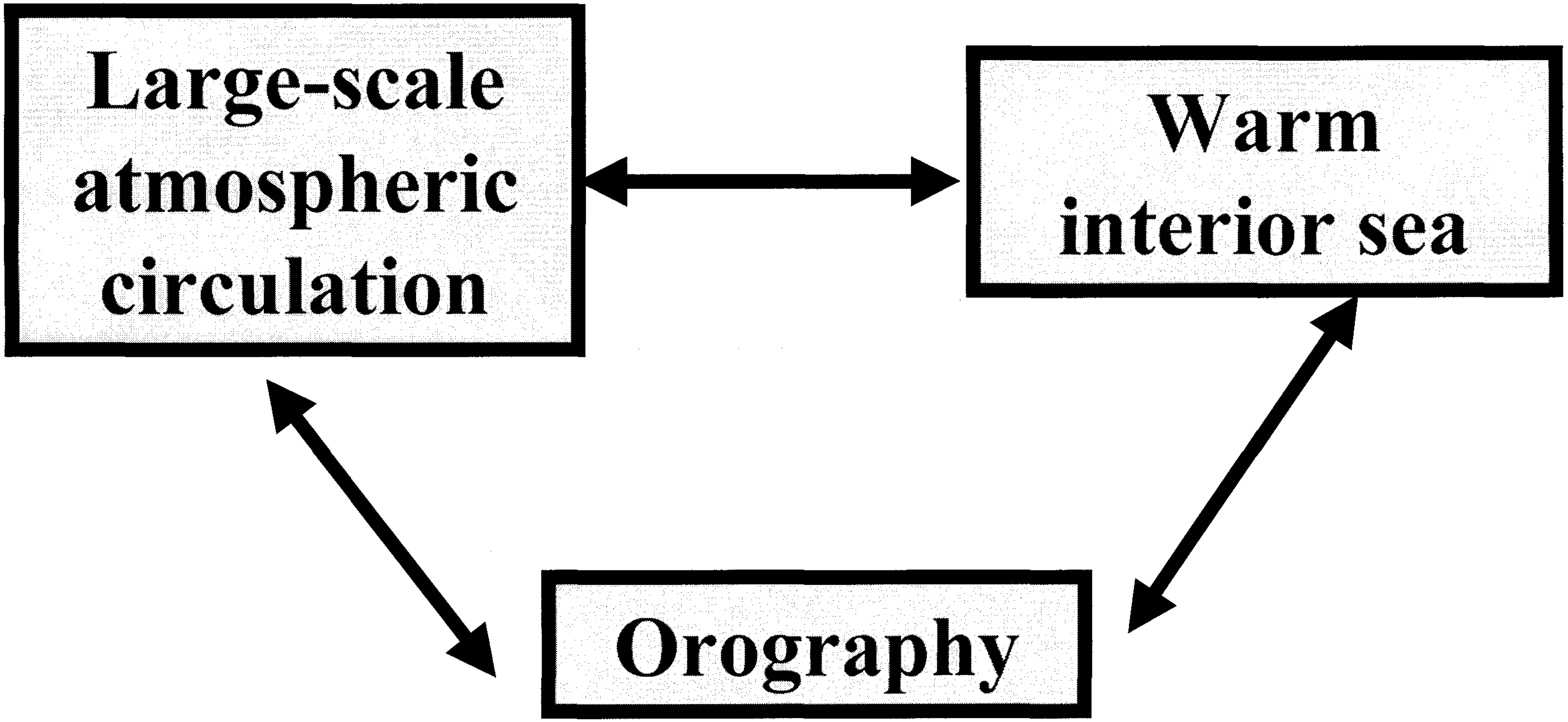
Annual distributions of precipitation



PRECIPITATION SEASONALITY



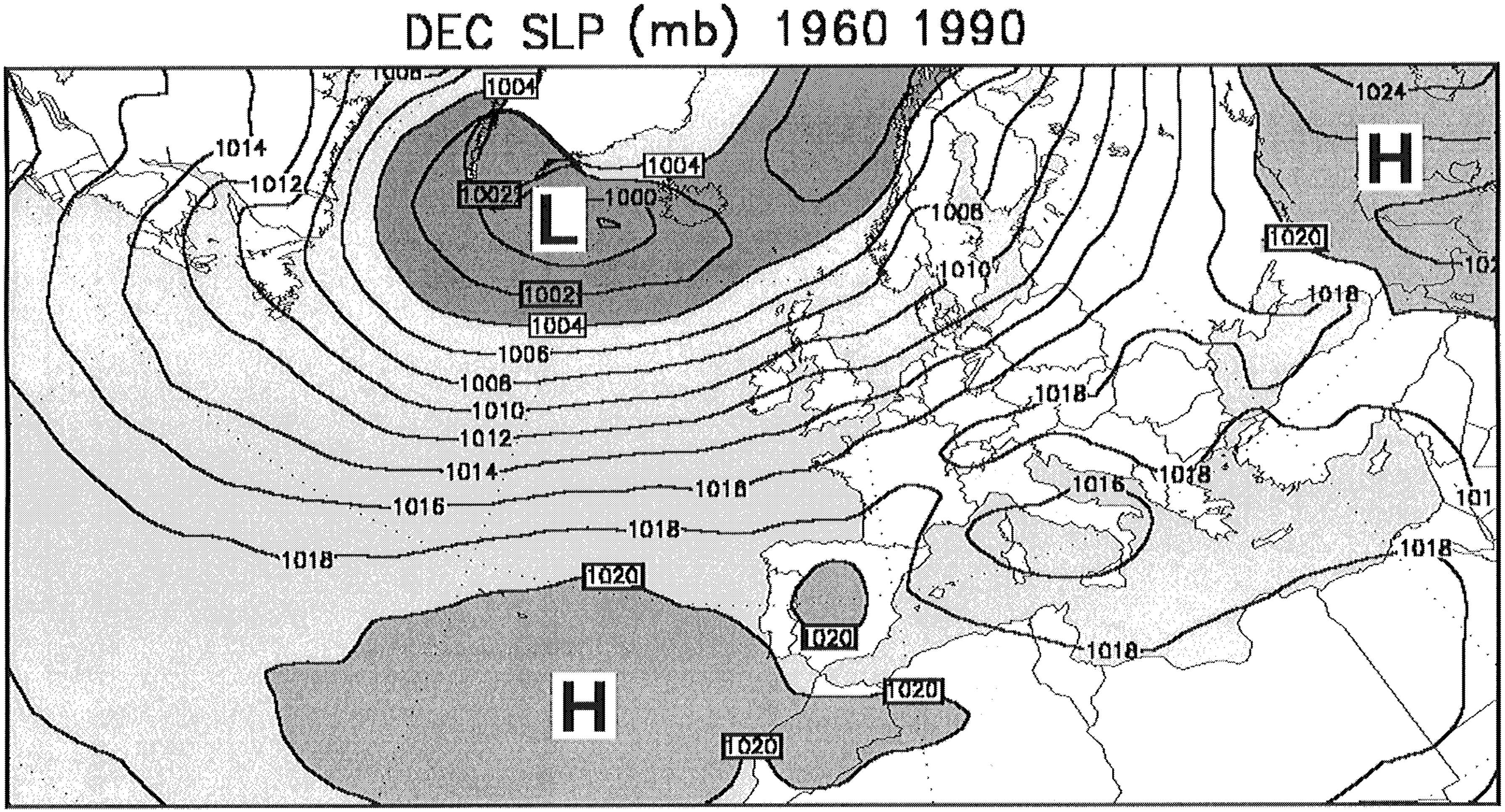
PRINCIPAL FORCINGS INFLUENCING THE MEDITERRANEAN REGION CLIMATE



Relative influence ? → Effects of anomalies

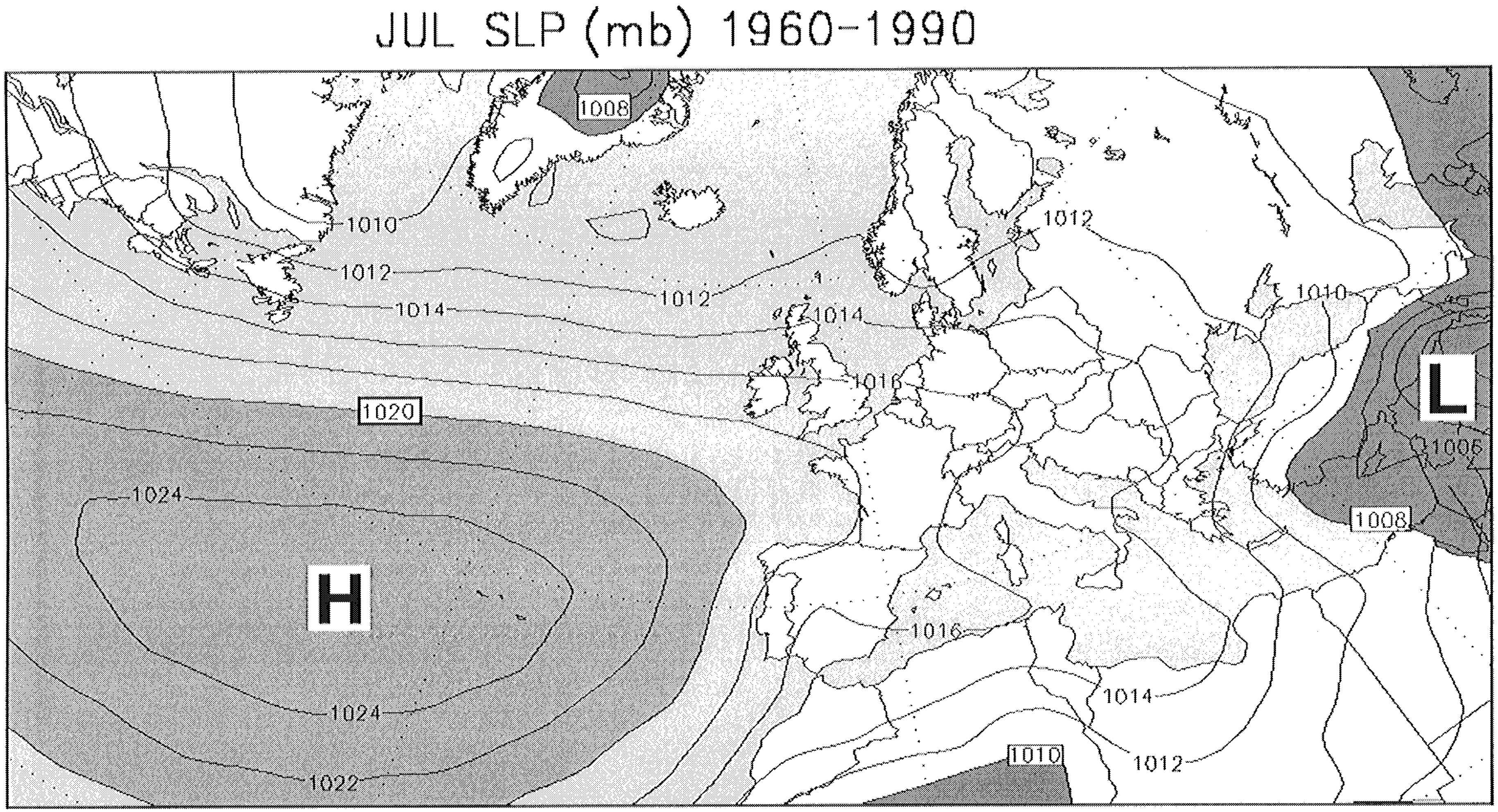
Large-scale surface atmospheric circulation

WINTER



Large-scale surface atmospheric circulation

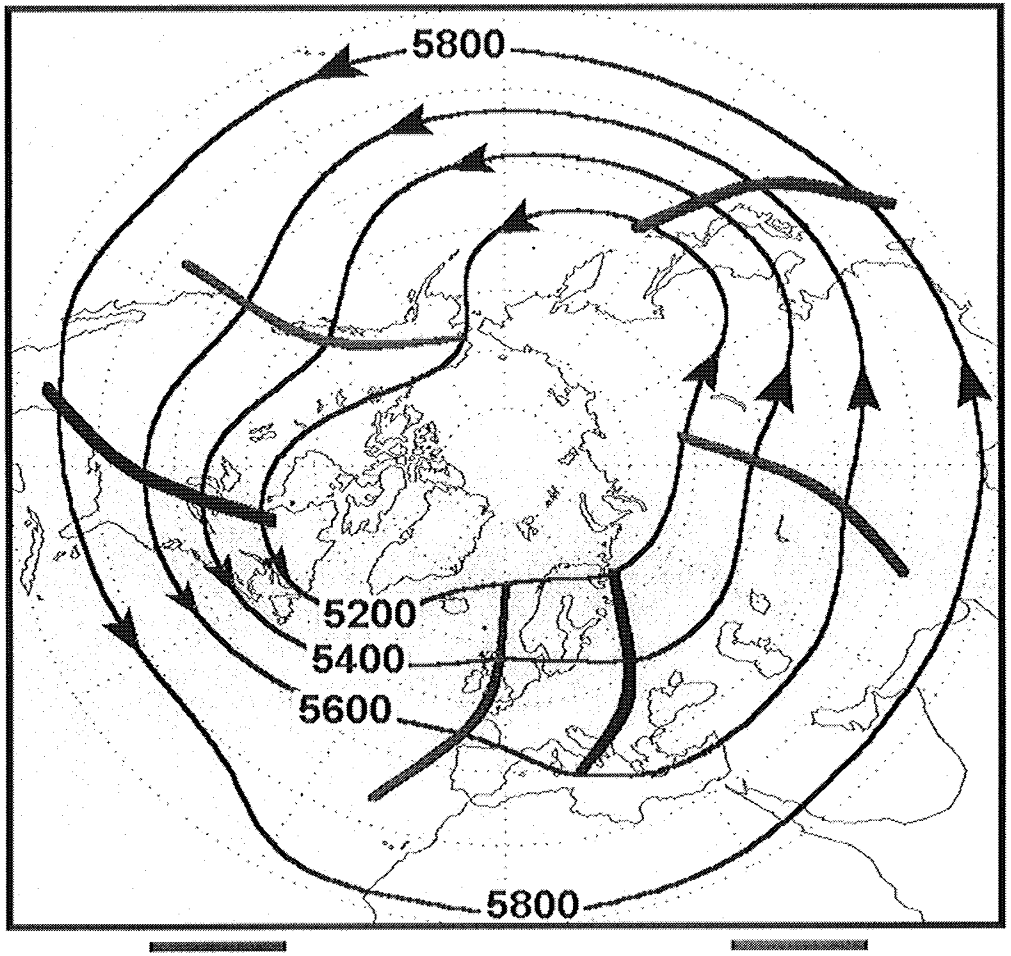
SUMMER



Large-scale upper- air circulations

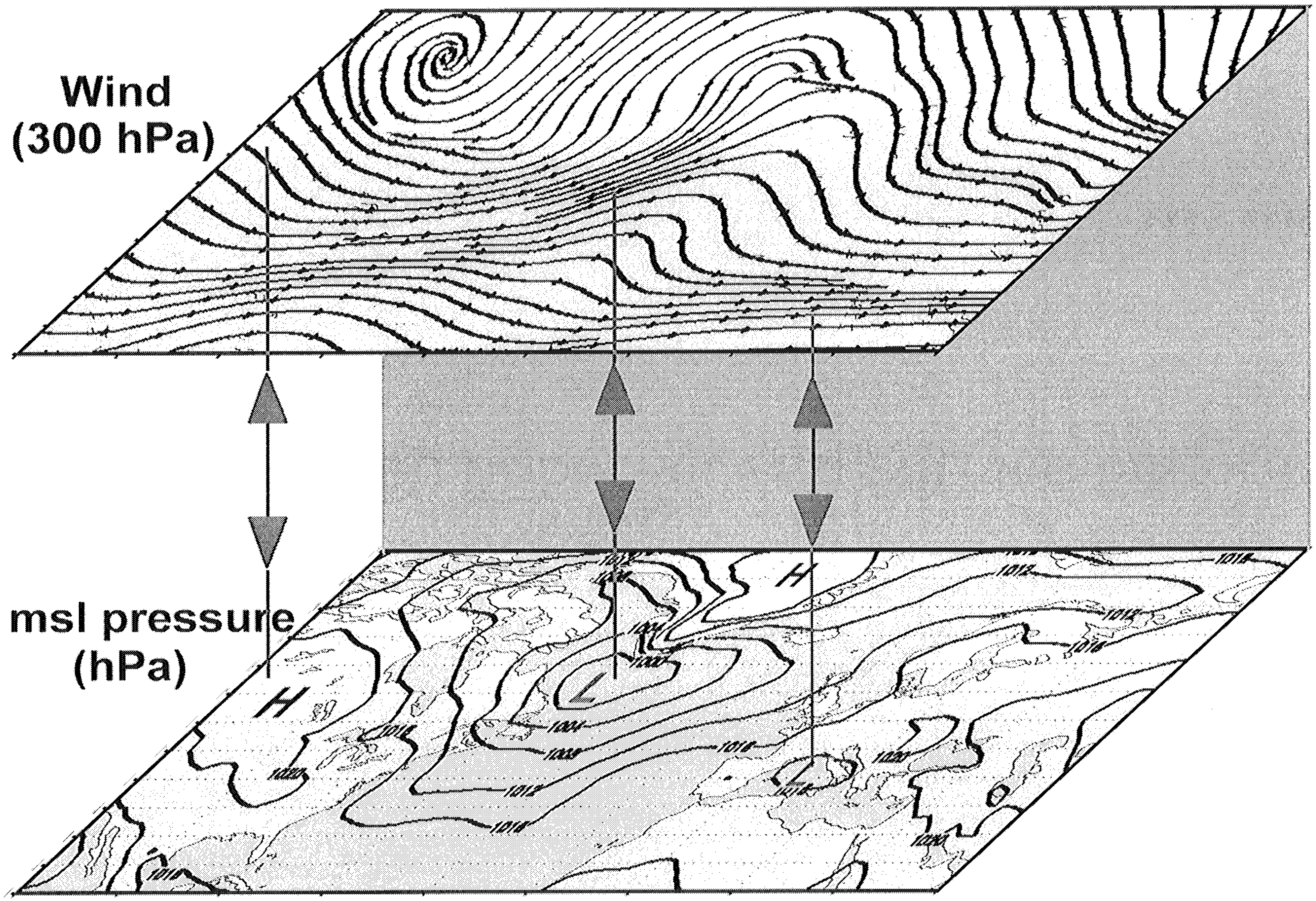
WINTER

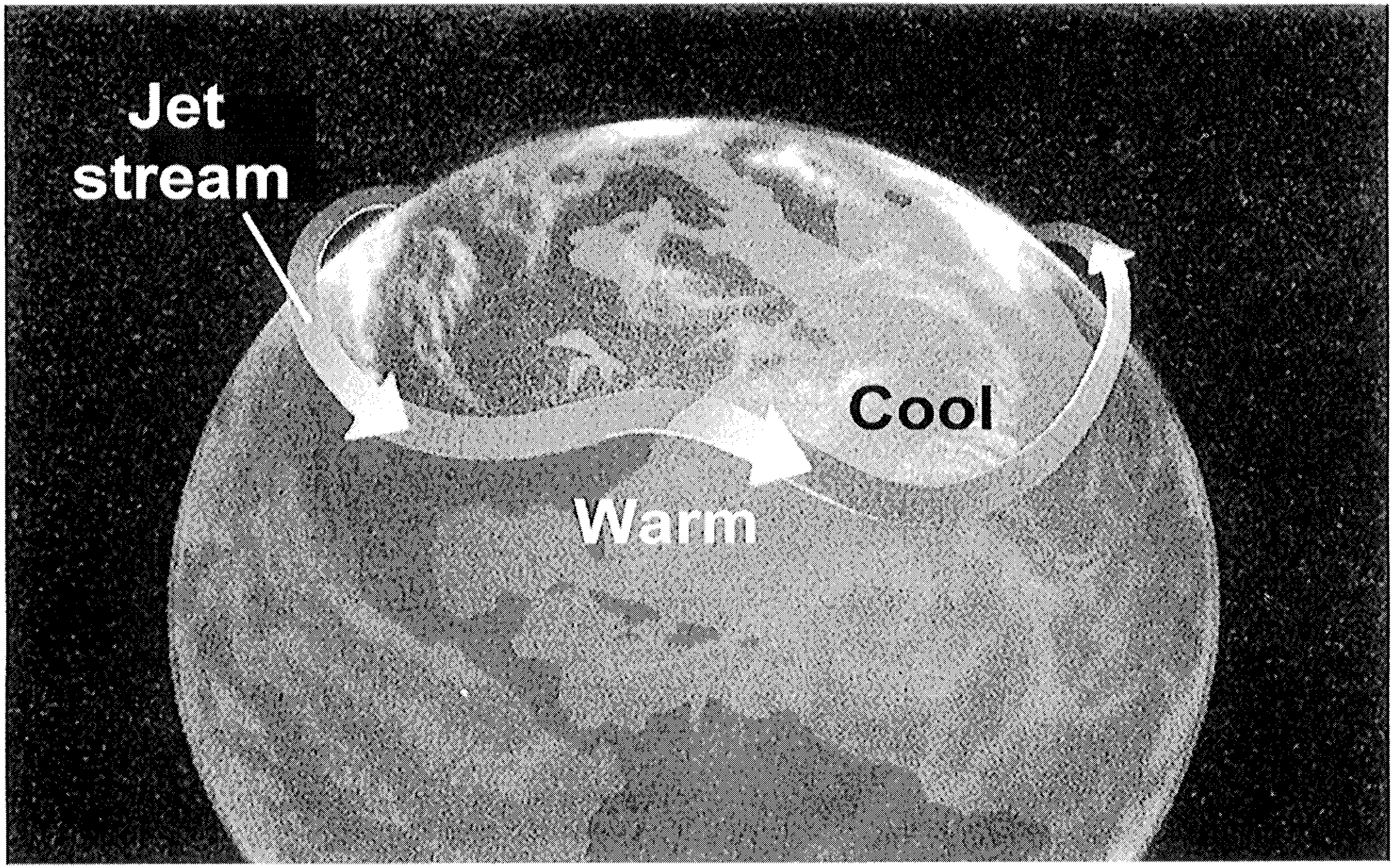
Z 500 hPa (January average)



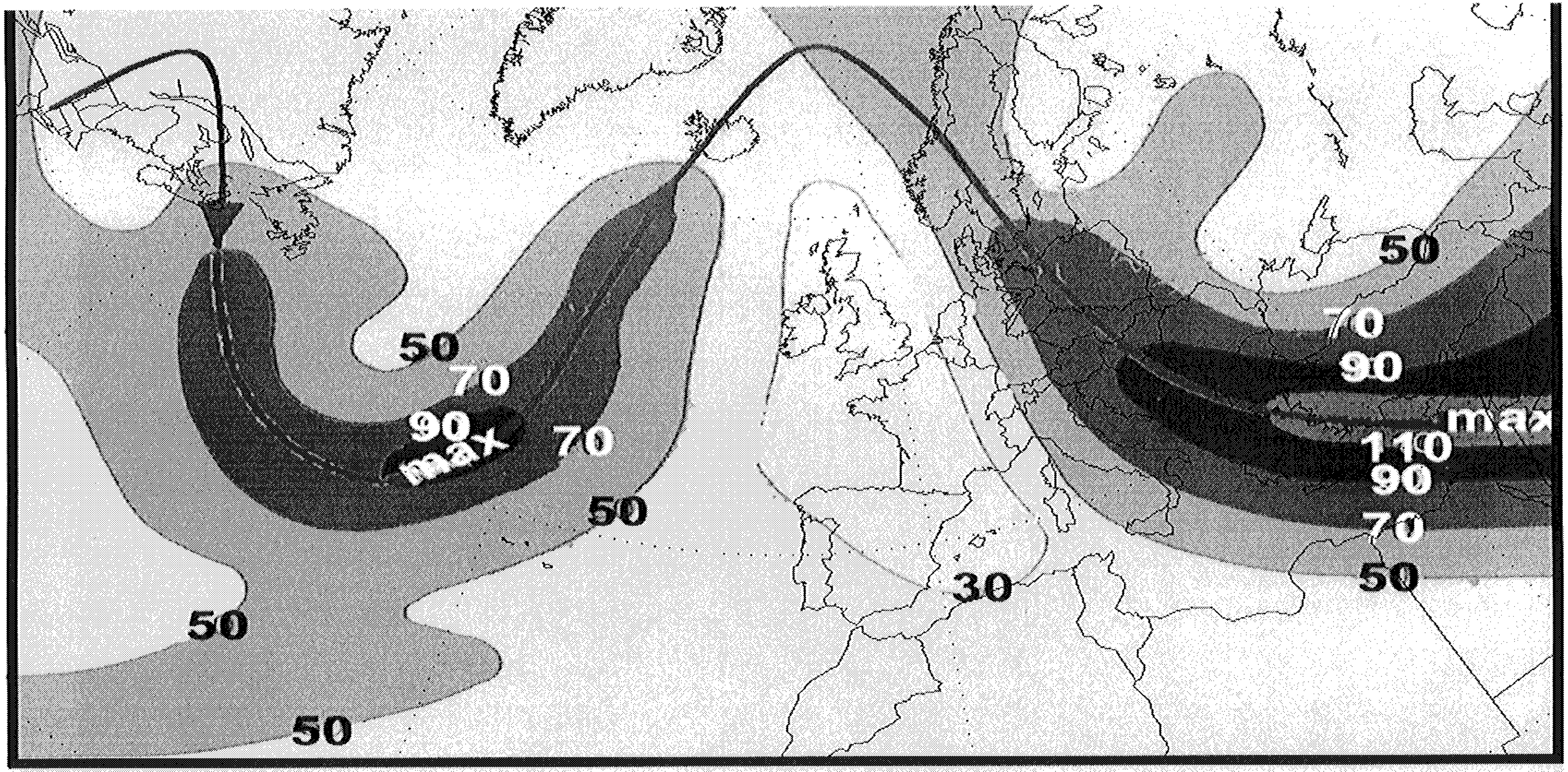
stationary troughs stationary ridges

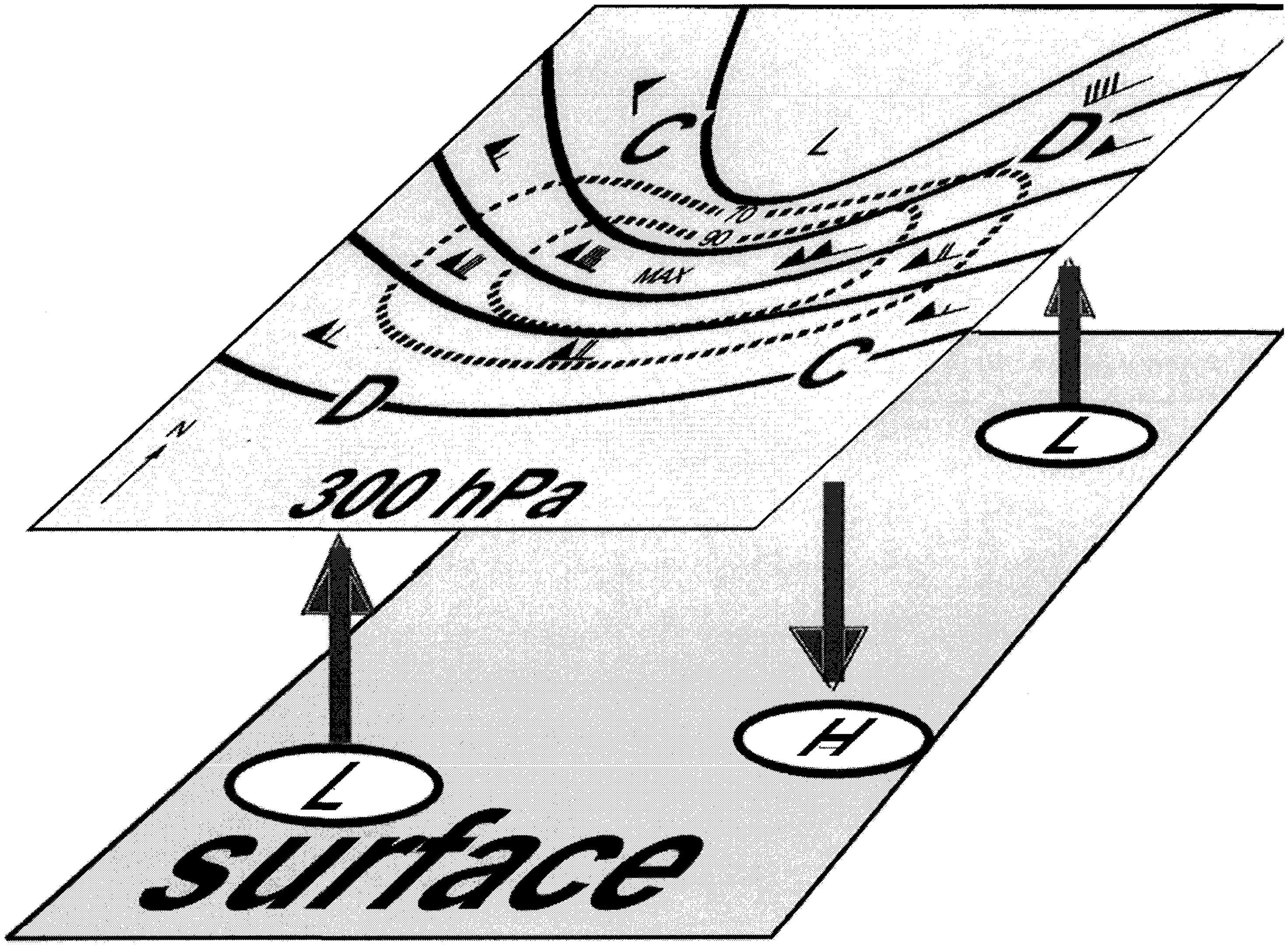
Connection between upper-air and surface patterns




Jet
stream
Cool
Warm

<u>Jet streaks</u> : maxima of upper-air jet stream

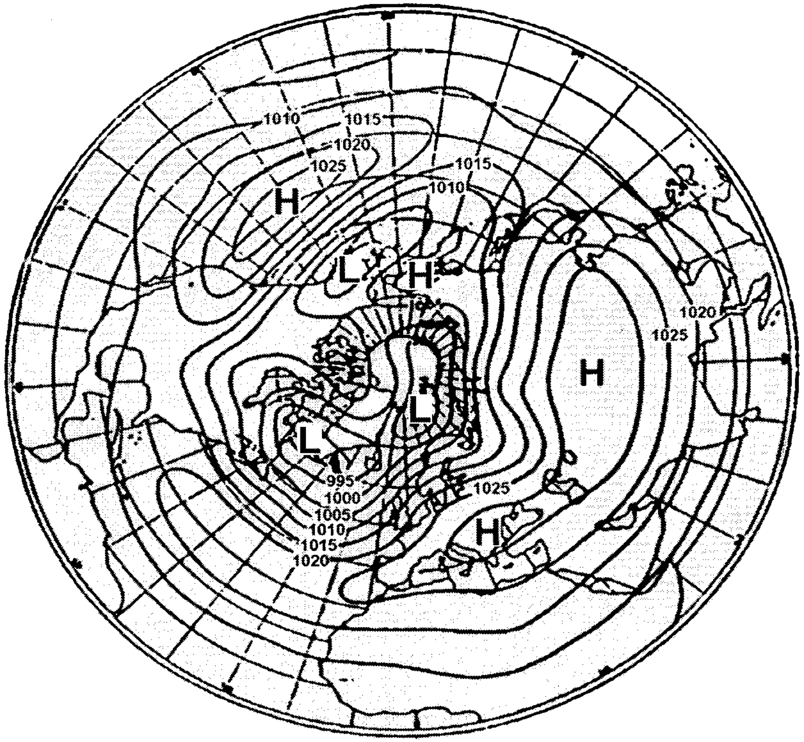




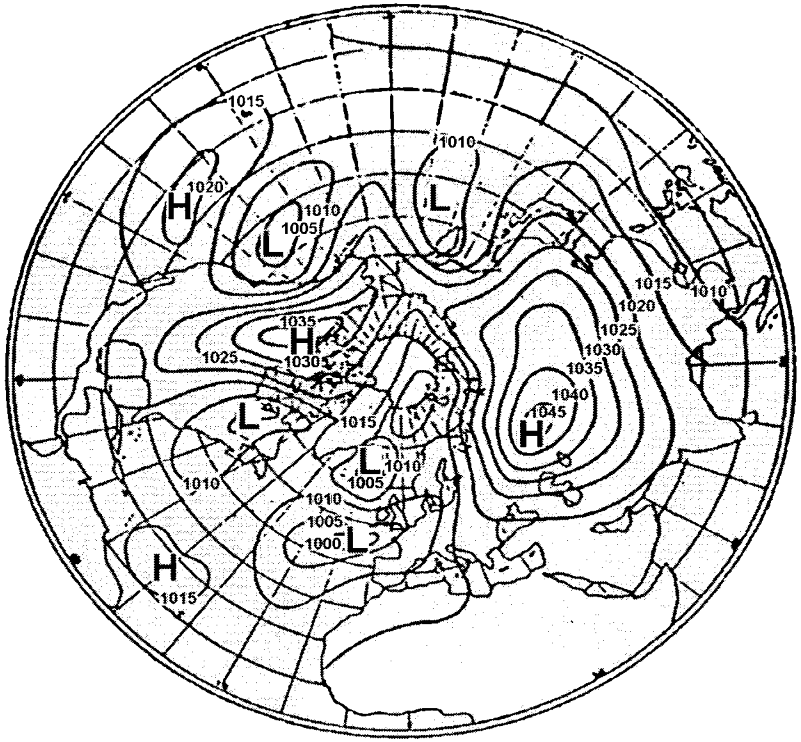
C
L
D
70
90
MAX
C
D
N
300 hPa
L
H
L
surface

Periodic oscillations of troughs and ridge intensities and locations

ZONAL INDEX



Zonal index
(13 hPa)



Zonal index
(- 3 hPa)

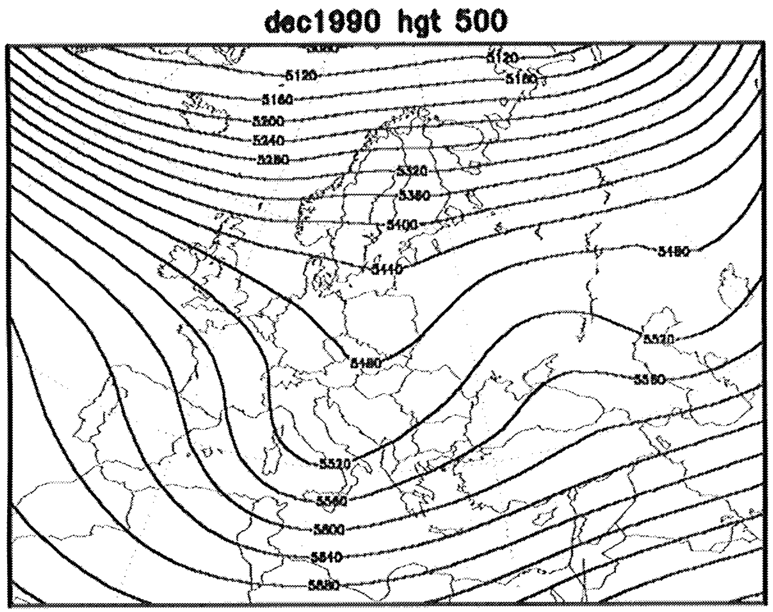
Spatially averaged mslp difference between 35° and 55° lat circles

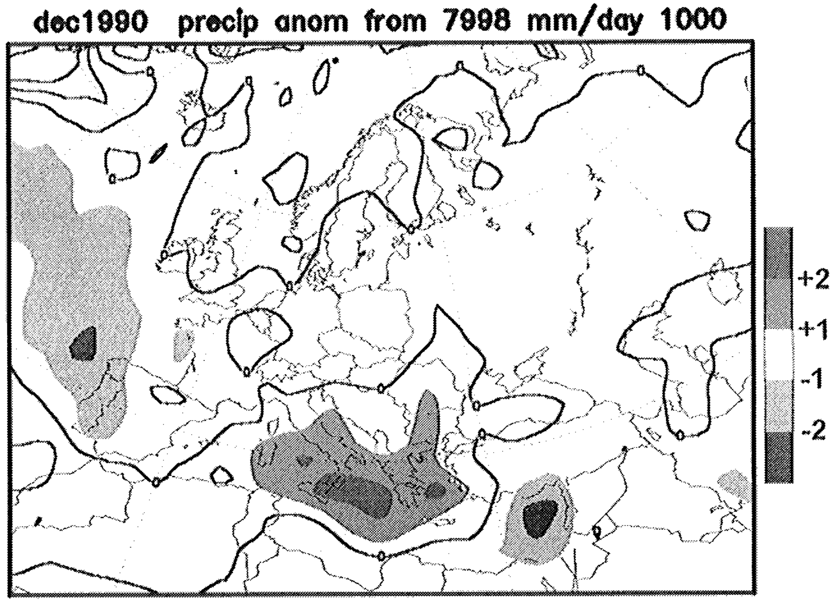
LARGE-SCALE ATMOSPHERIC CIRCULATION PATTERNS

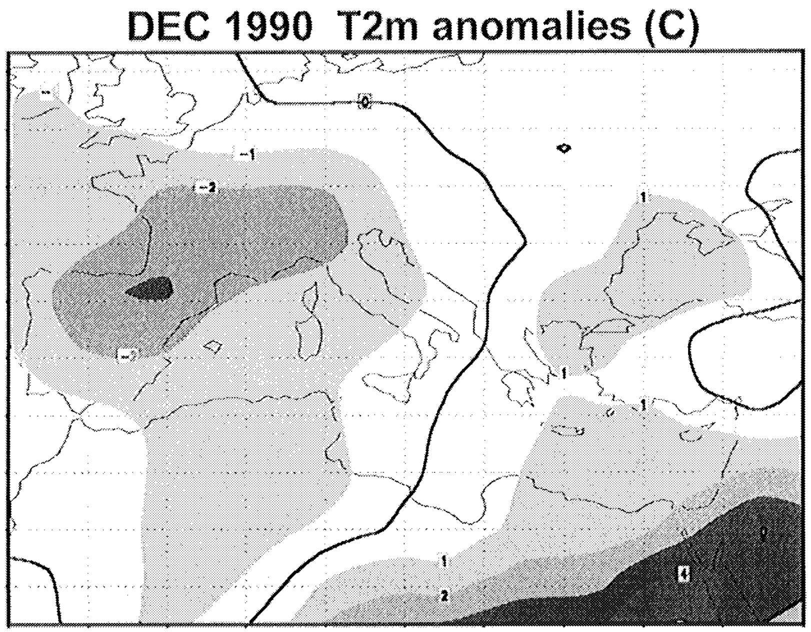
↓

CLIMATE FEATURES IN THE MEDITERRANEAN REGION

Corte-Real et al. (1995). Int. Jour. Clim.



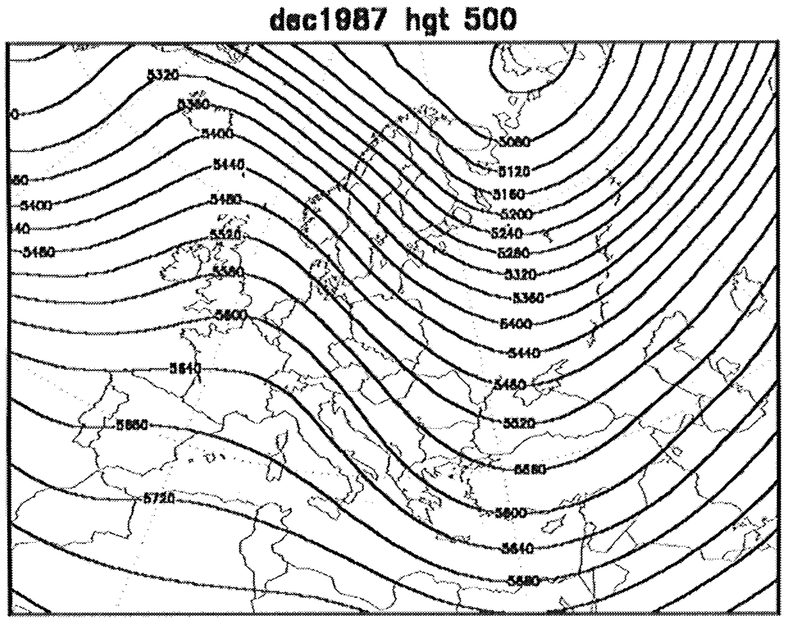


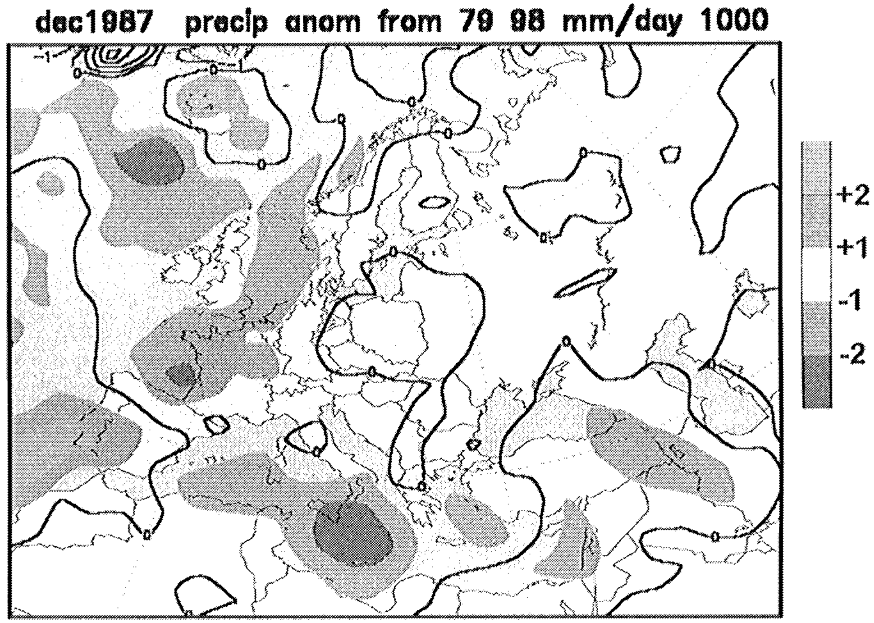


Deep trough over central Mediterranean

↓

T, pr anomalies

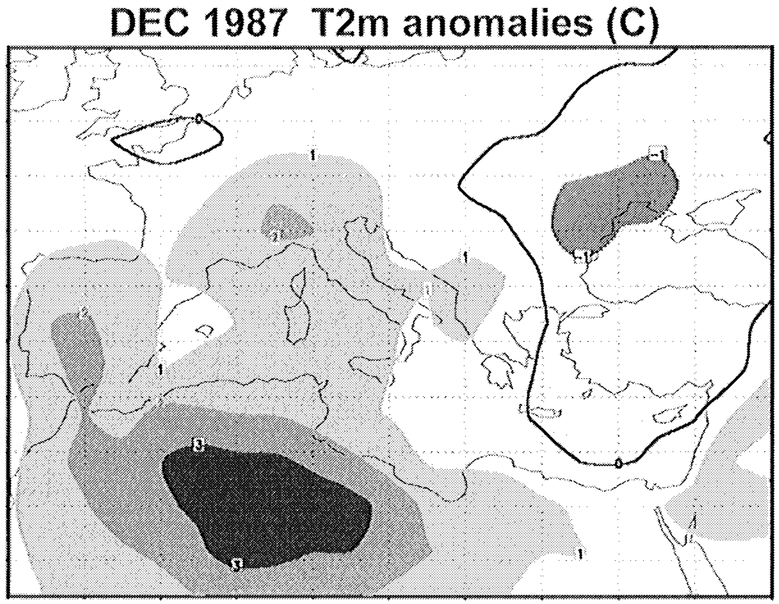




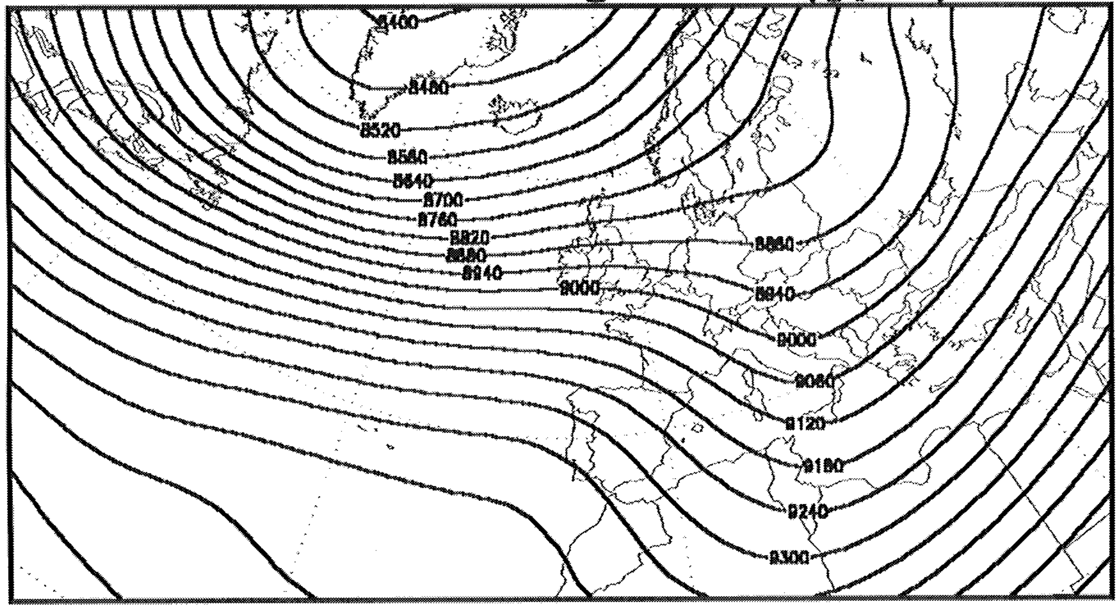
Ridge over western Europe

↓

T, pr anomalies



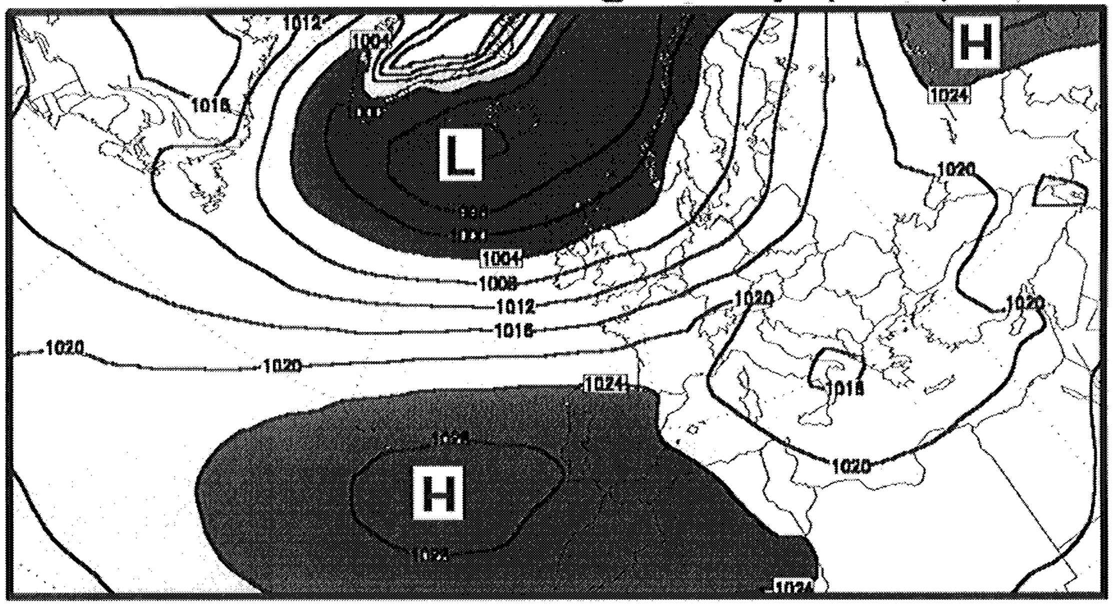
JAN 1995 average Z300 (gpm)



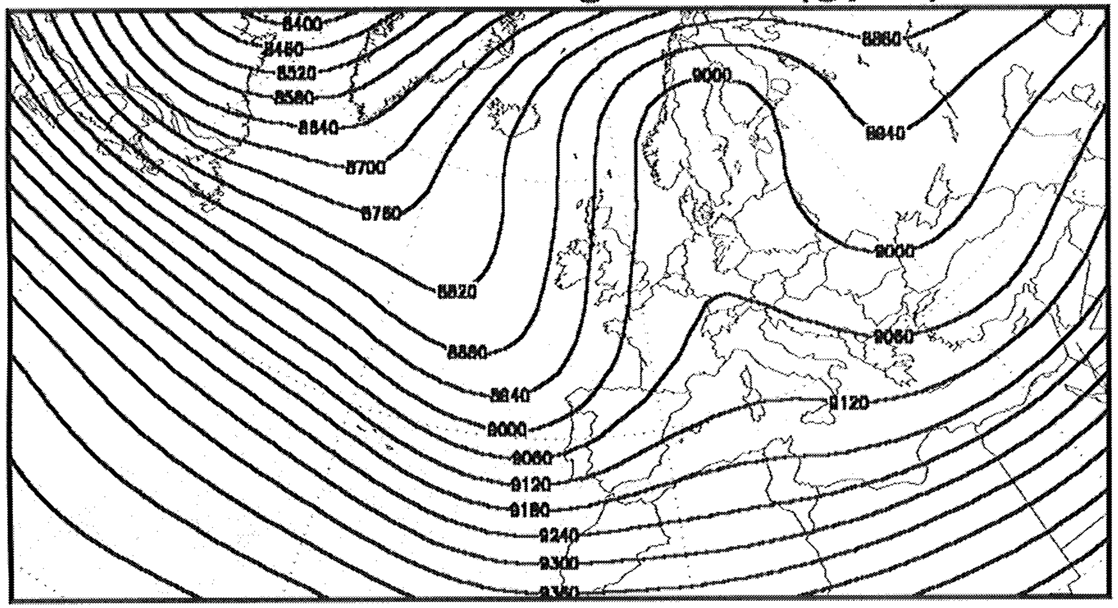
Upper-air high zonal index over the Atlantic sector

JAN 1995 average mslp (hPa)

Surface pattern



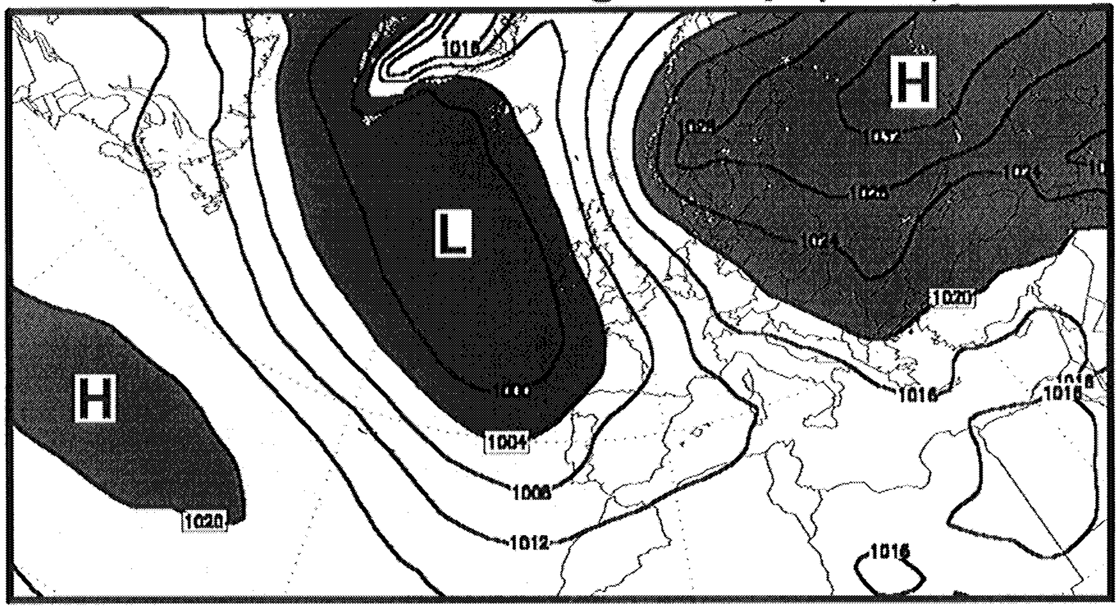
JAN 1996 average Z300 (gpm)



Low zonal index over the Atlantic sector

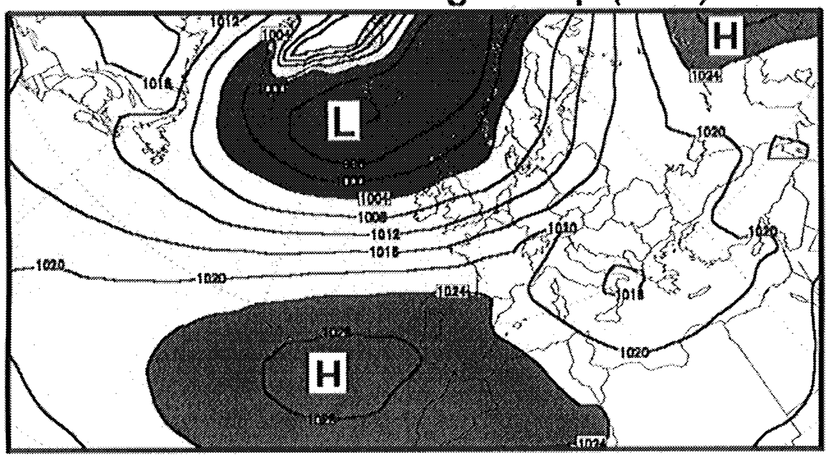
JAN 1996 average mslp (hPa)

Surface pattern



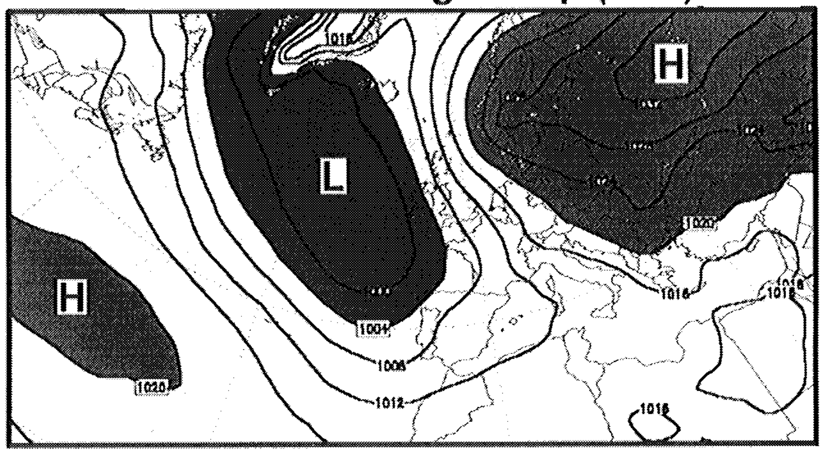
NAO (North Atlantic Oscillation)

JAN 1995 average mslp (hPa)



Positive NAO index phase

JAN 1996 average mslp (hPa)



Negative NAO index phase

What is the NAO ?

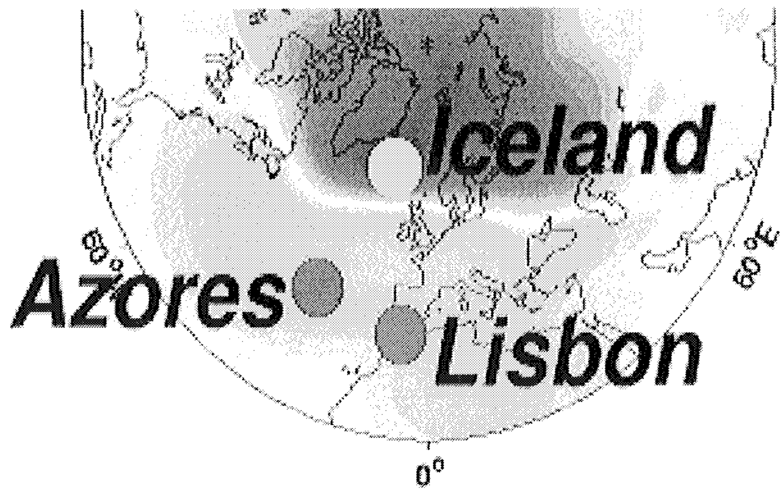
The first mode of climate variability affecting western Europe and Mediterranean regions

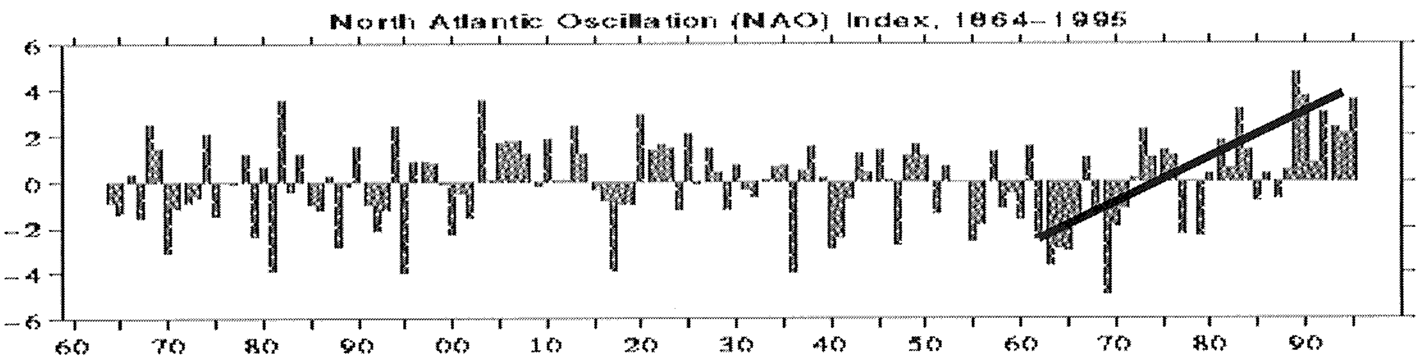
NAO

A see-saw of surface pressure anomalies between polar and sub-tropical latitudes in the North Atlantic

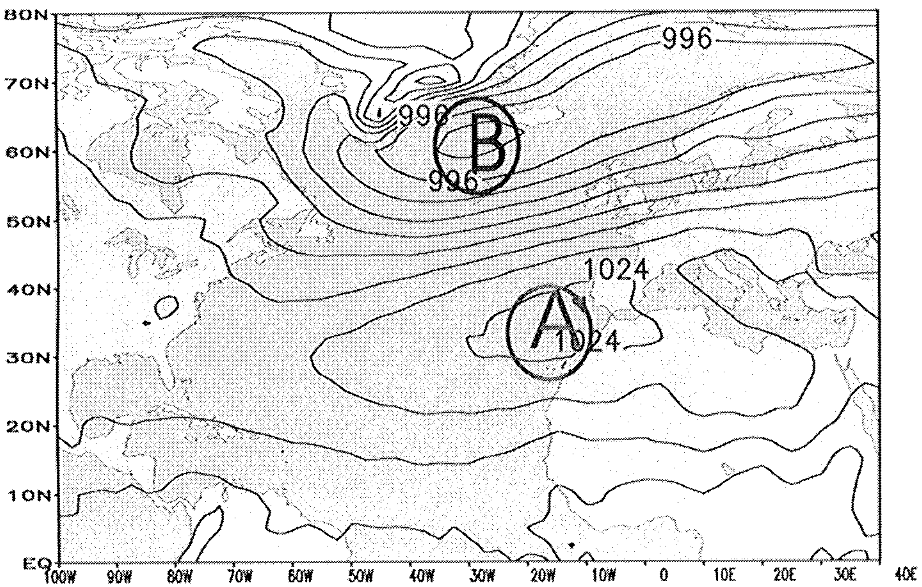
NAO Index

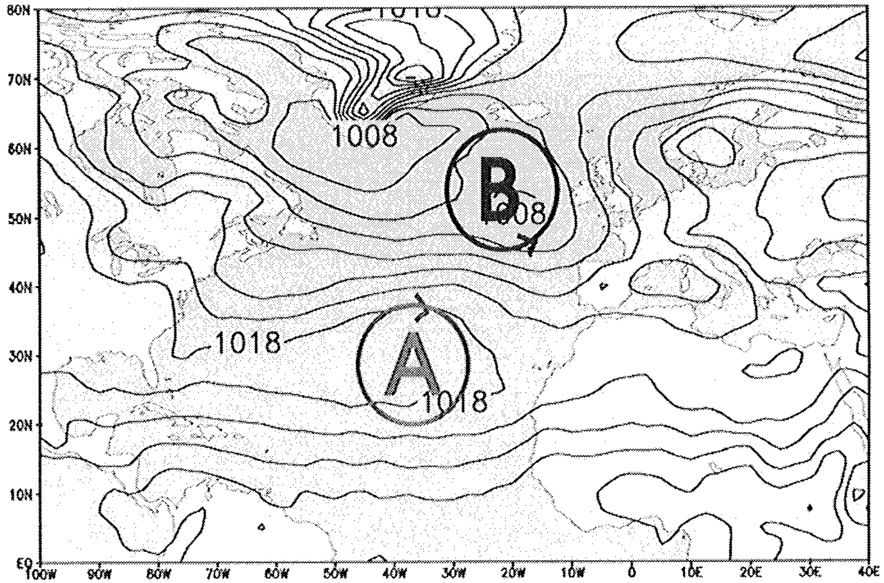
Winter average between the subtropical high (Azores) and the subpolar low (Iceland)



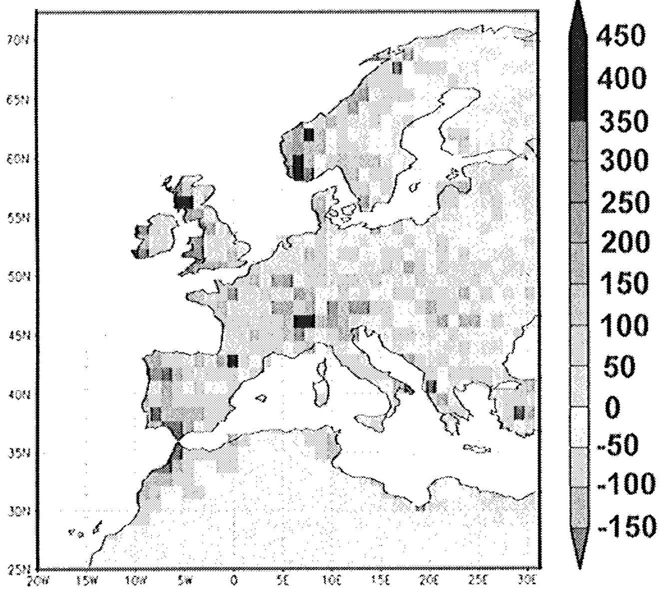


Impacts of NAO in the Mediterranean climate

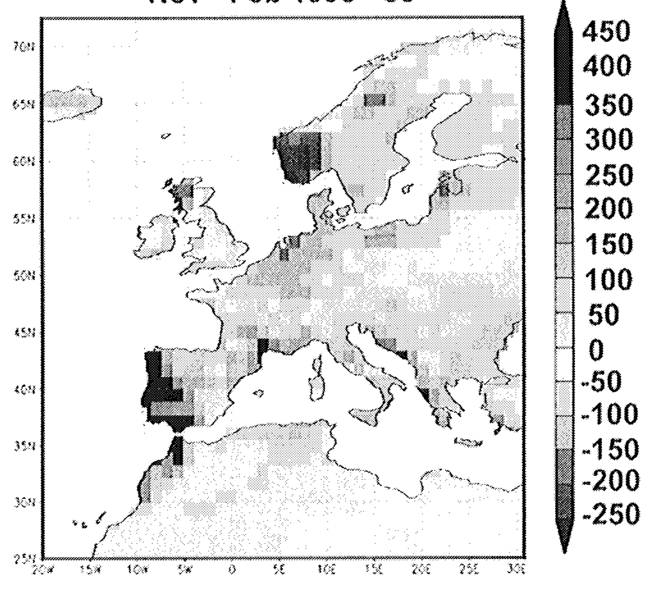




Nov - Feb 1994 - 95

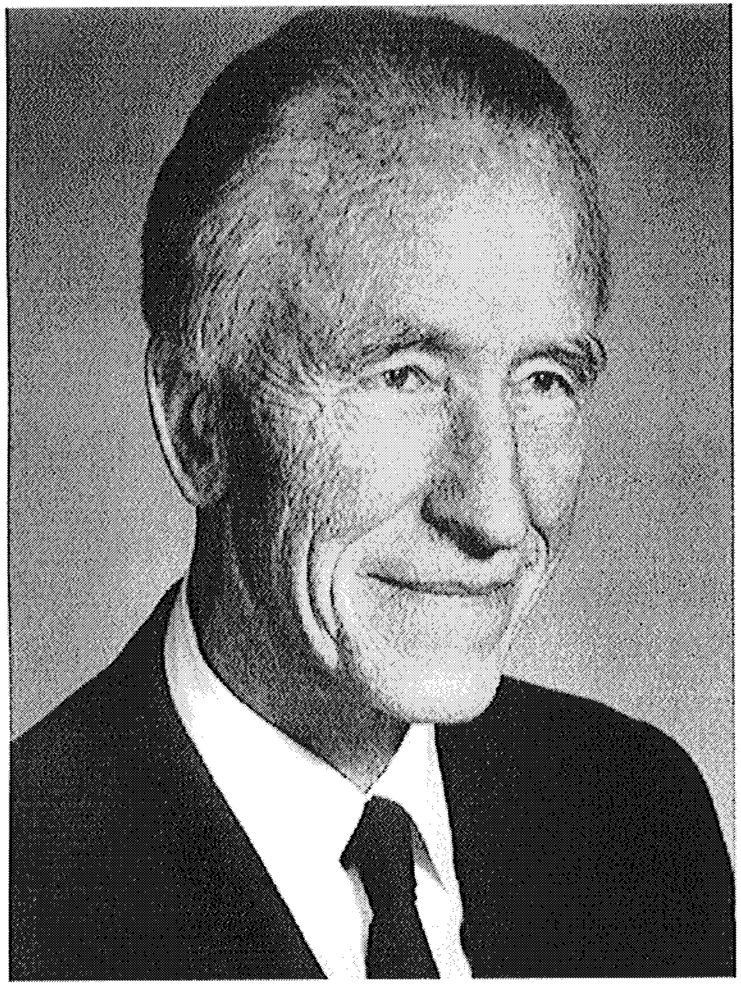


Nov - Feb 1995 - 96

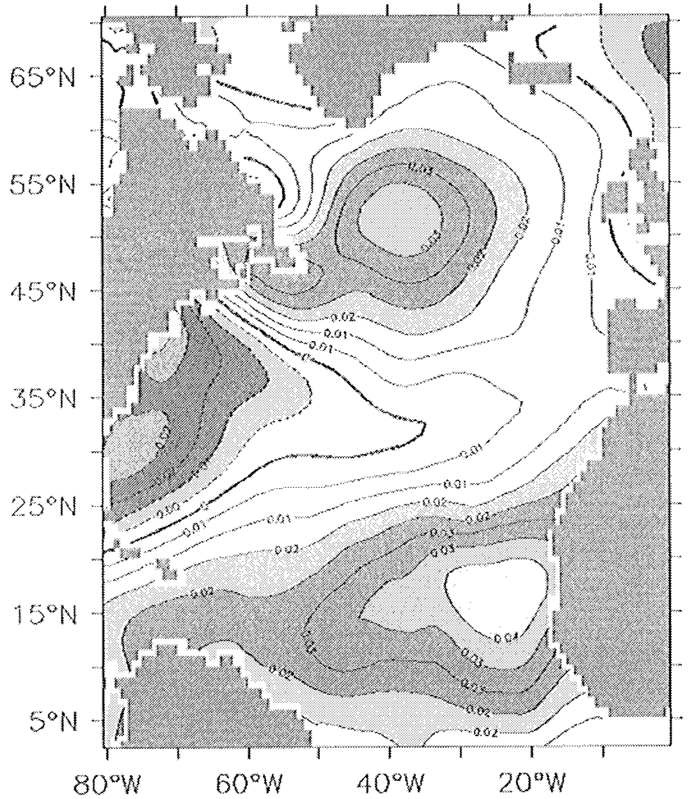


North Atlantic SST connection with NAO

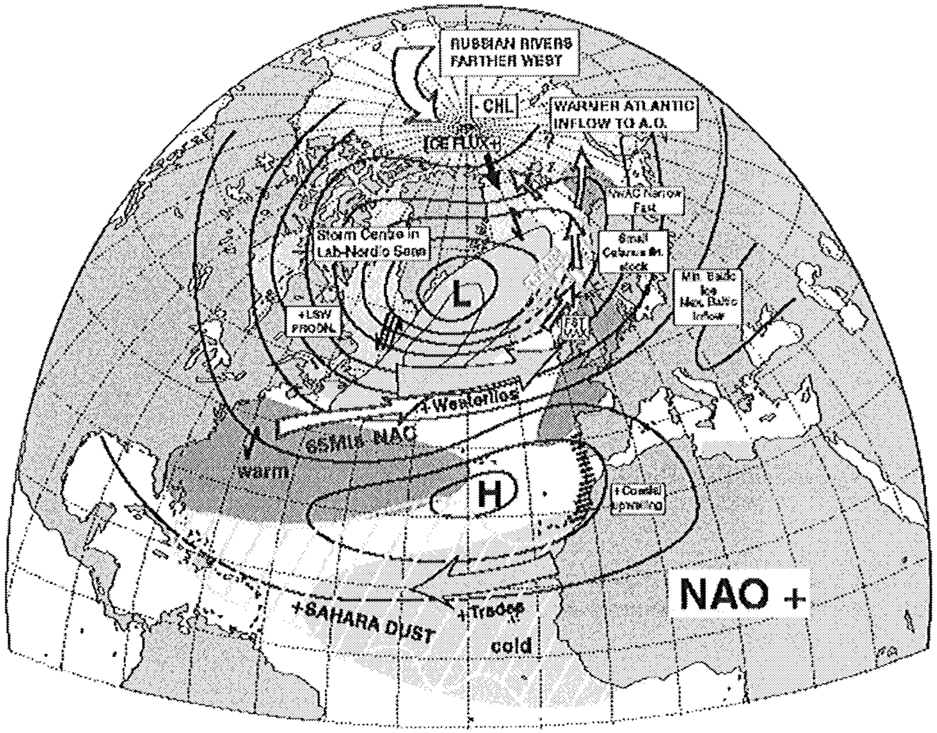
Jacob Aaal Bonnevie Bjerknes
1897-1975



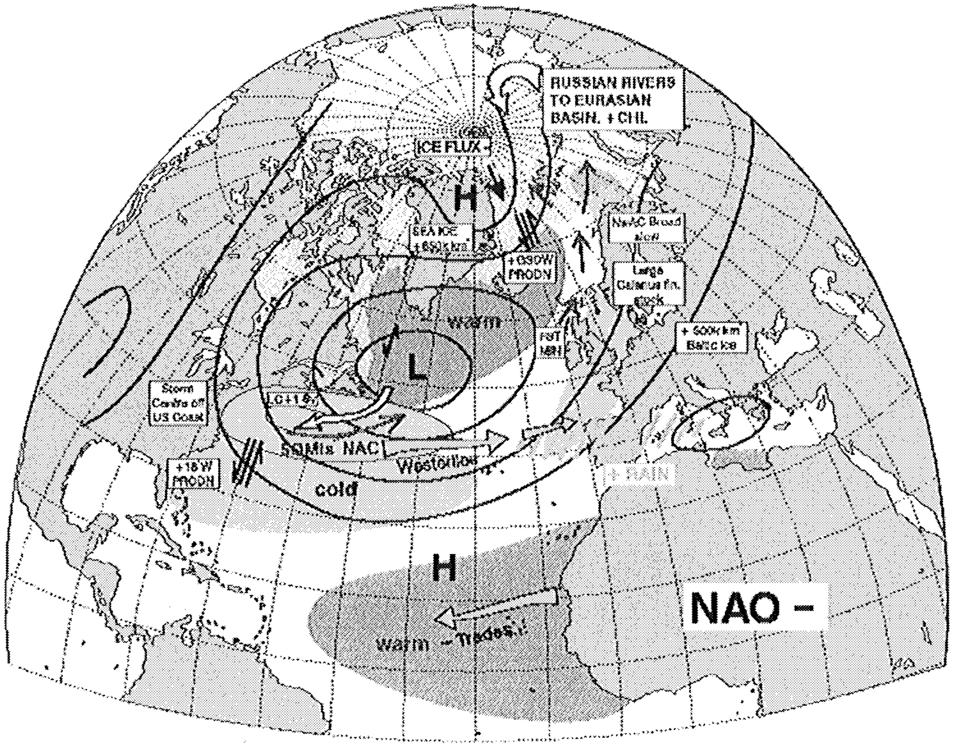
NAO related tripole
in sea surface temperatures



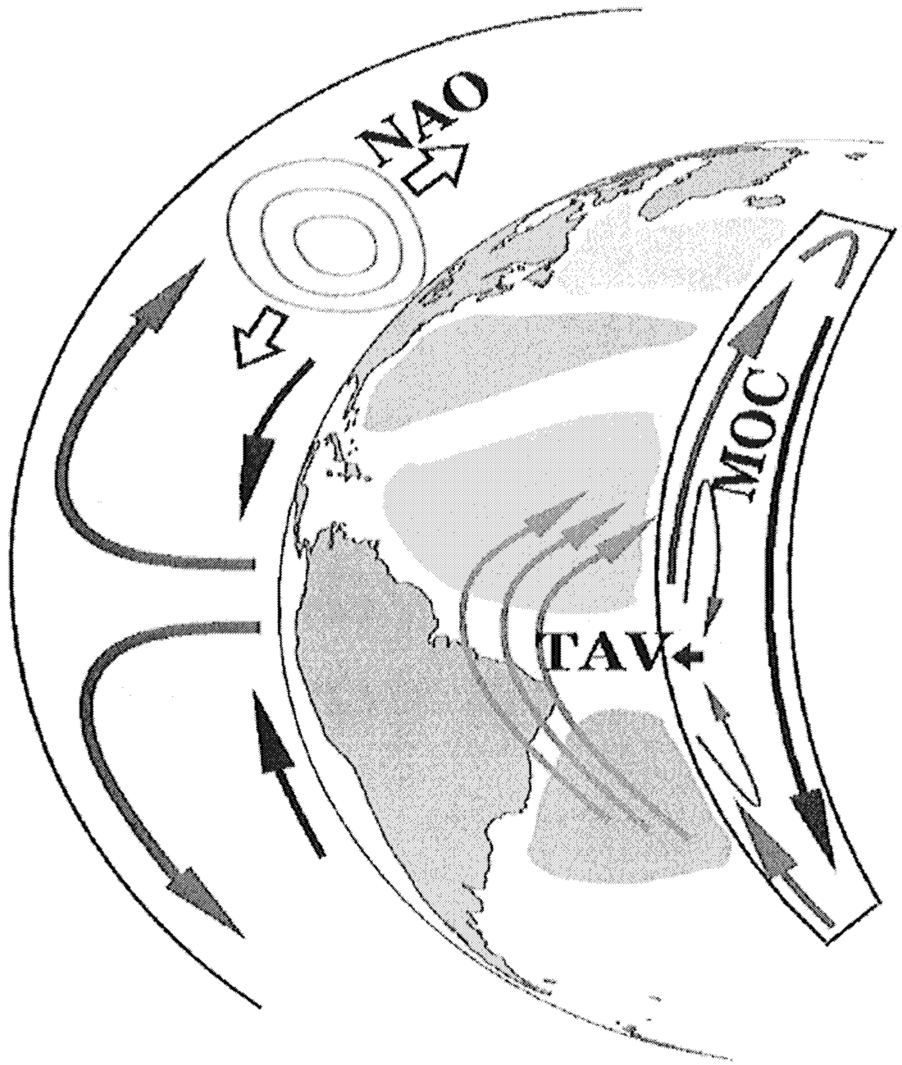
The positive NAO index phase



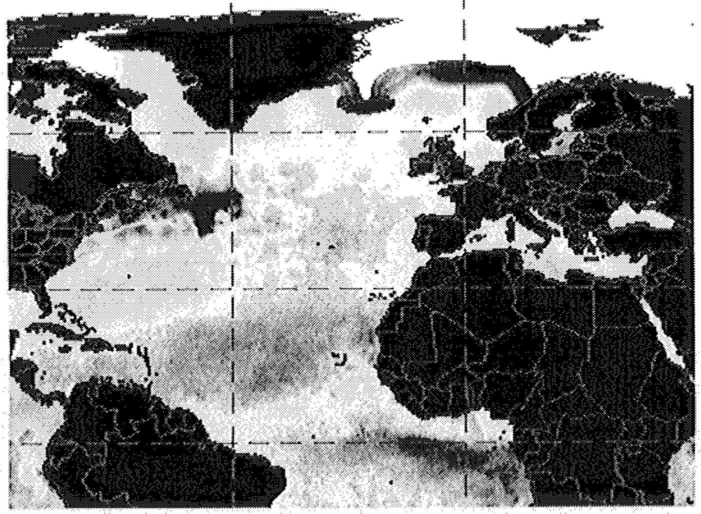
The negative NAO index phase



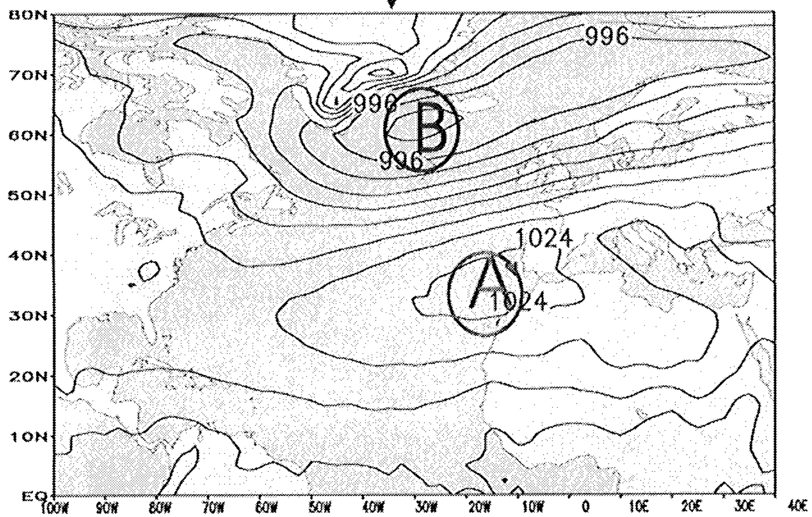
NAO forced by SST anomalies ?



SST anomalies for June 1994

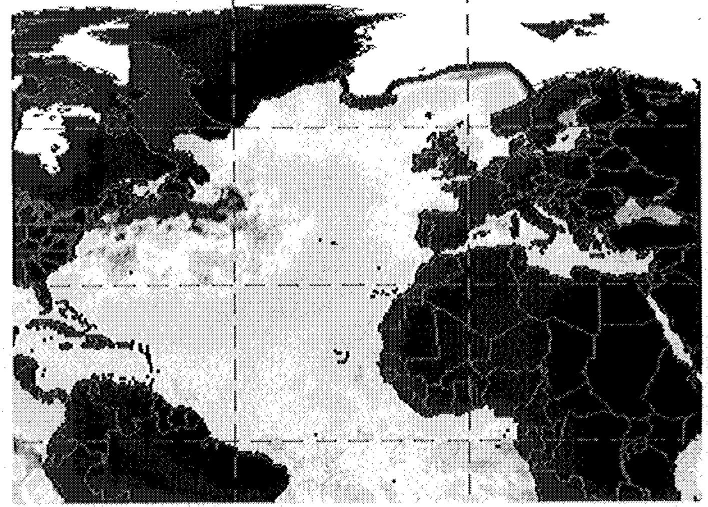


?



Positive NAO (Nov-Feb 1994-95)

SST anomalies for June 1995



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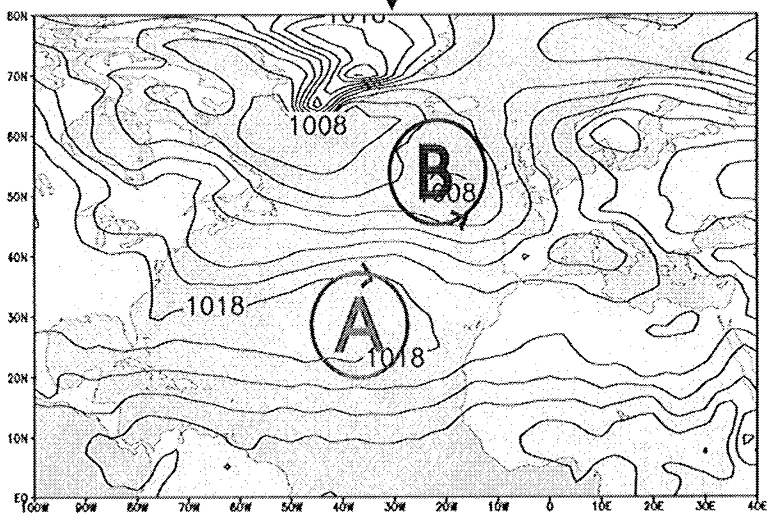


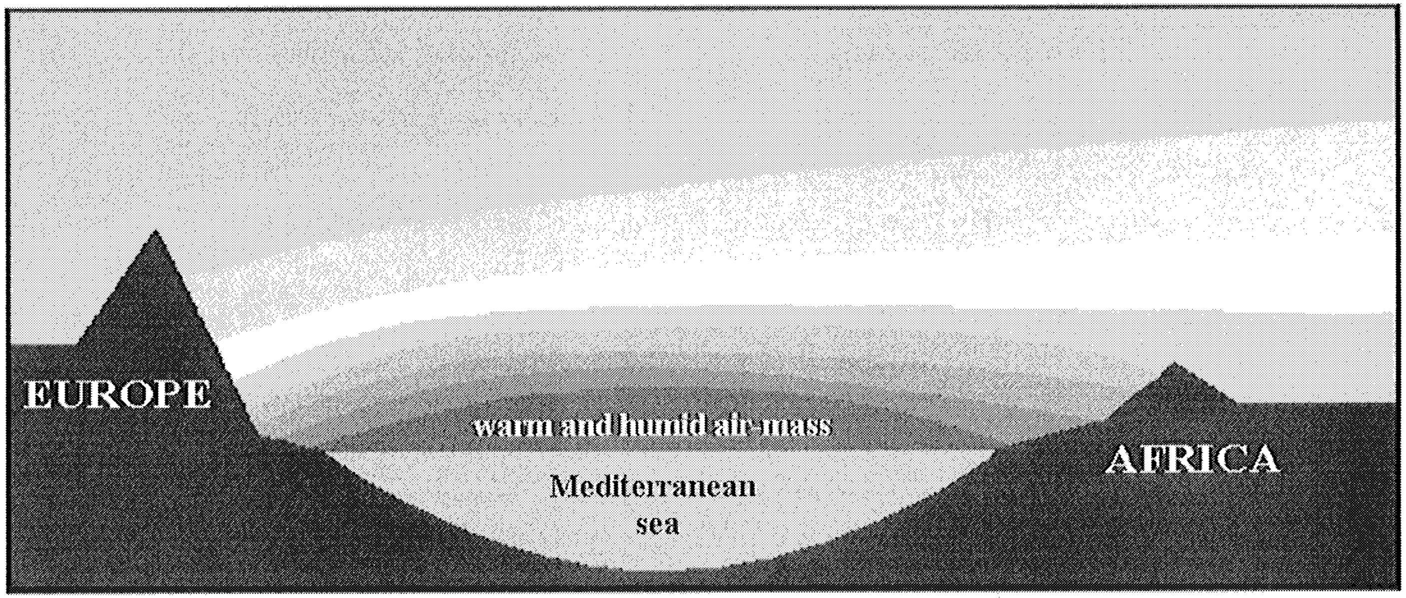
Negative NAO (Nov-Feb 1995-96)

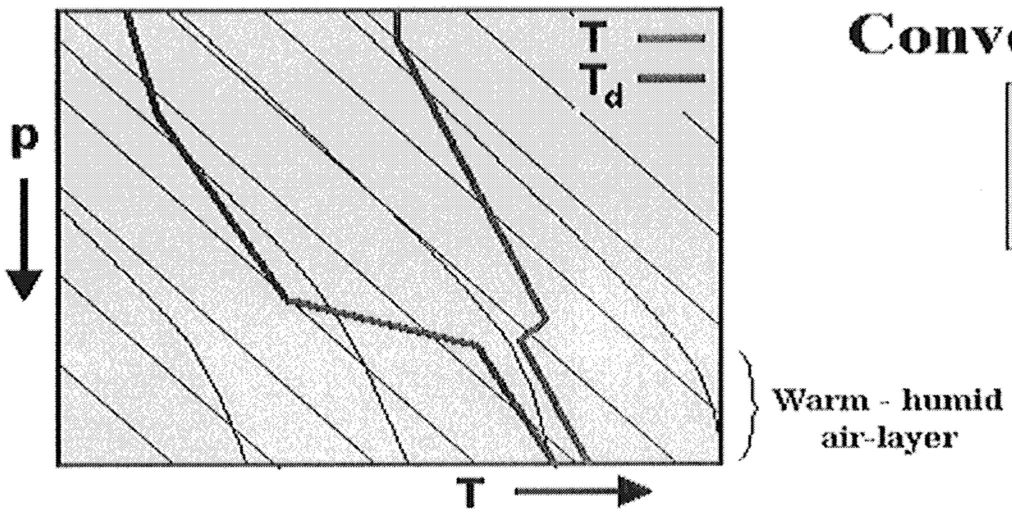
OROGRAPHICAL PRIMARY EFFECTS ON MEDITERRANEAN CLIMATE

a) formation of a particular air mass

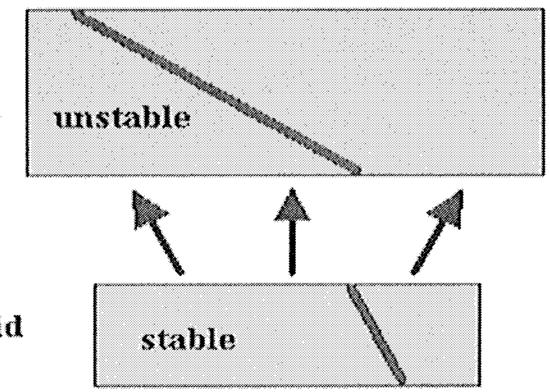
b) genesis of lee depressions

The formation of a Mediterranean air-mass

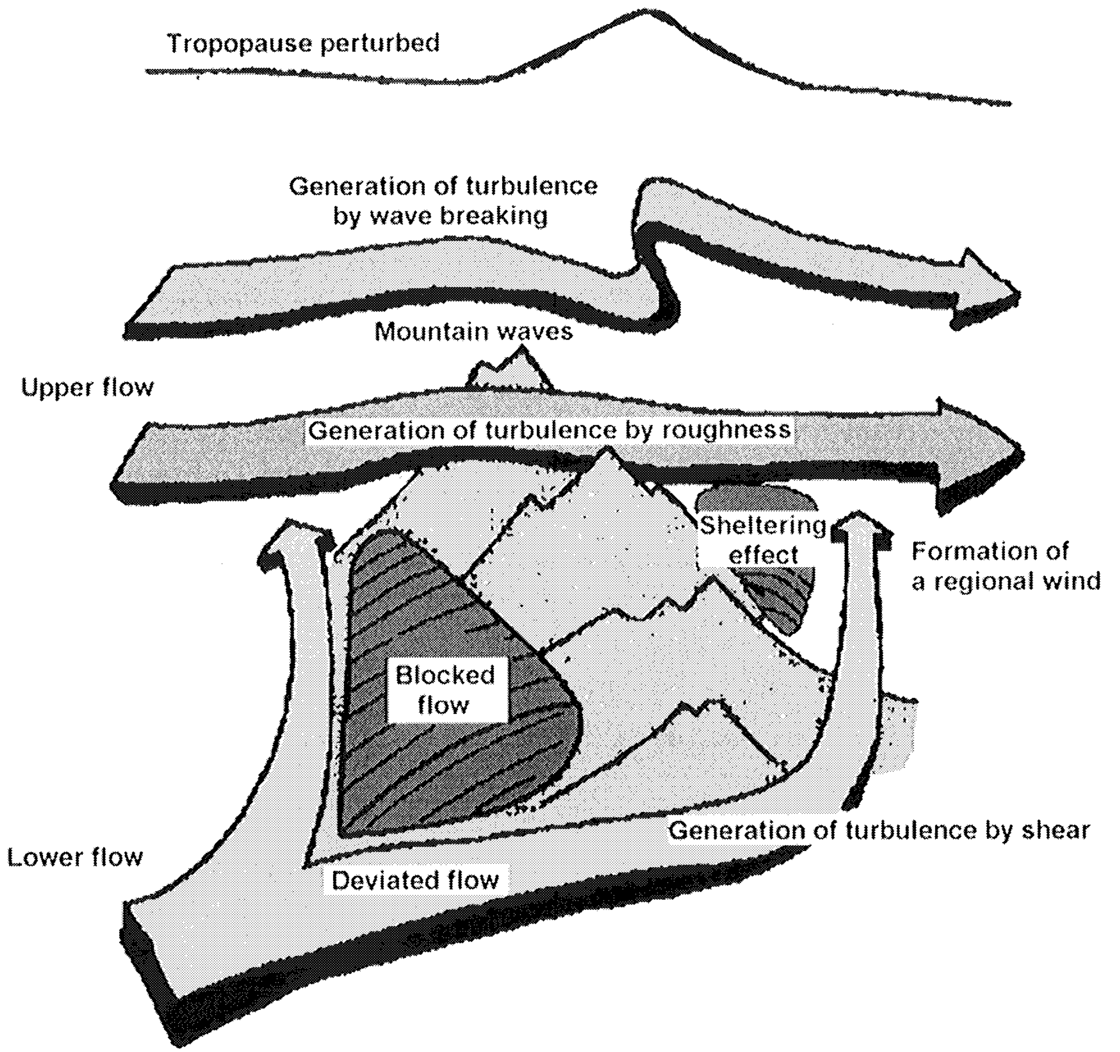




Convective instability



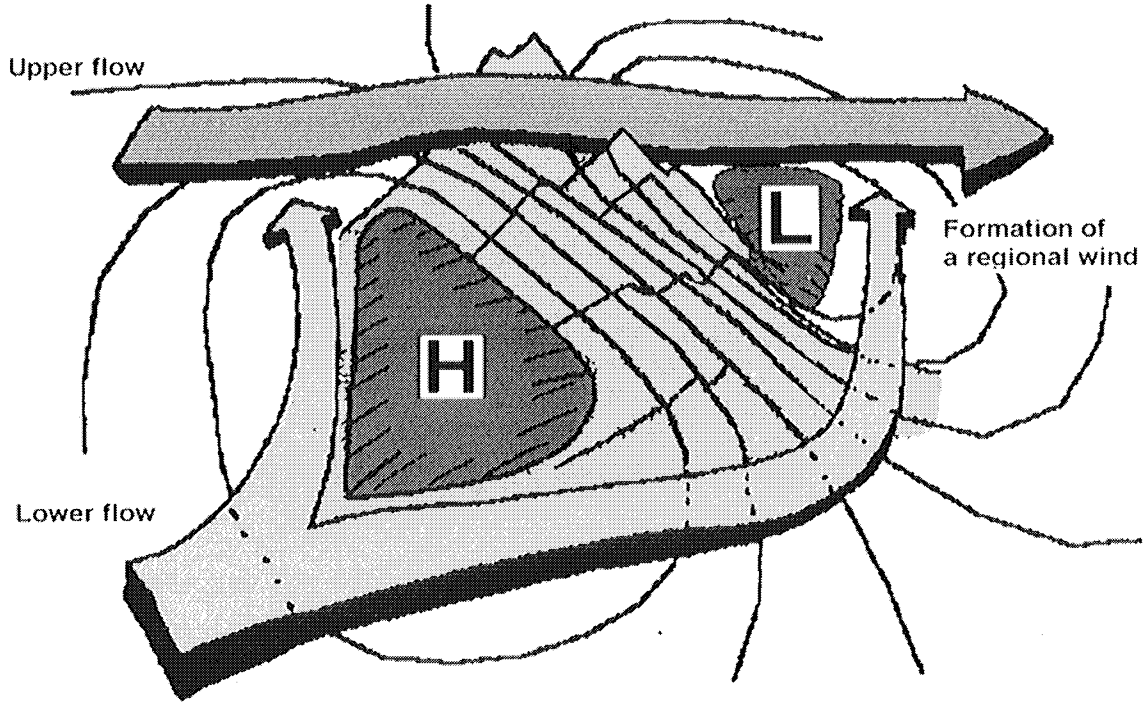
Orographical air-flow deviation



Dipole pressure structure induced by the orography

L = Lee low

H = Windward high

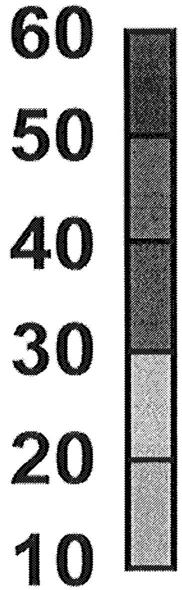


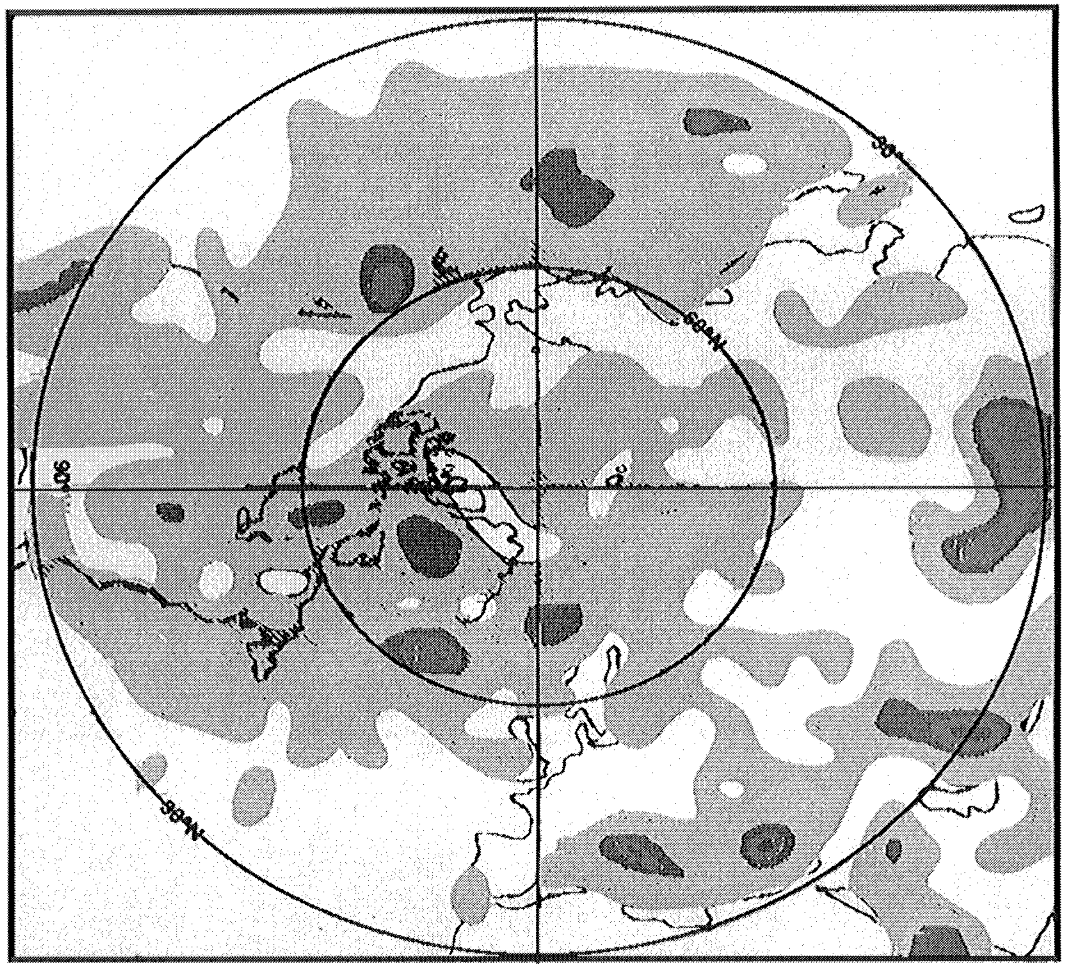
MEDITERRANEAN CYCLONES

How much frequent are they in winter ?

Number of surface cyclones per 400 x 400 km^2

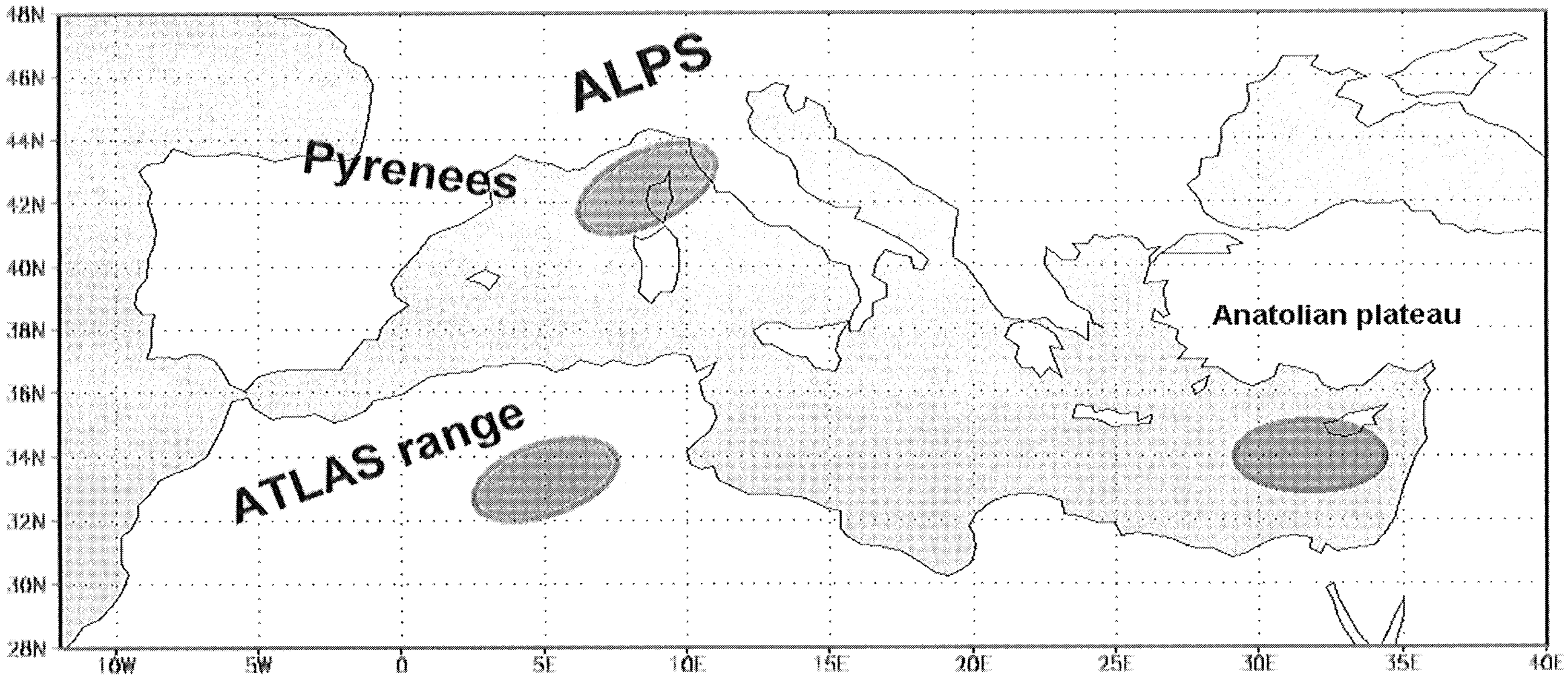
(DJF 1980-84)



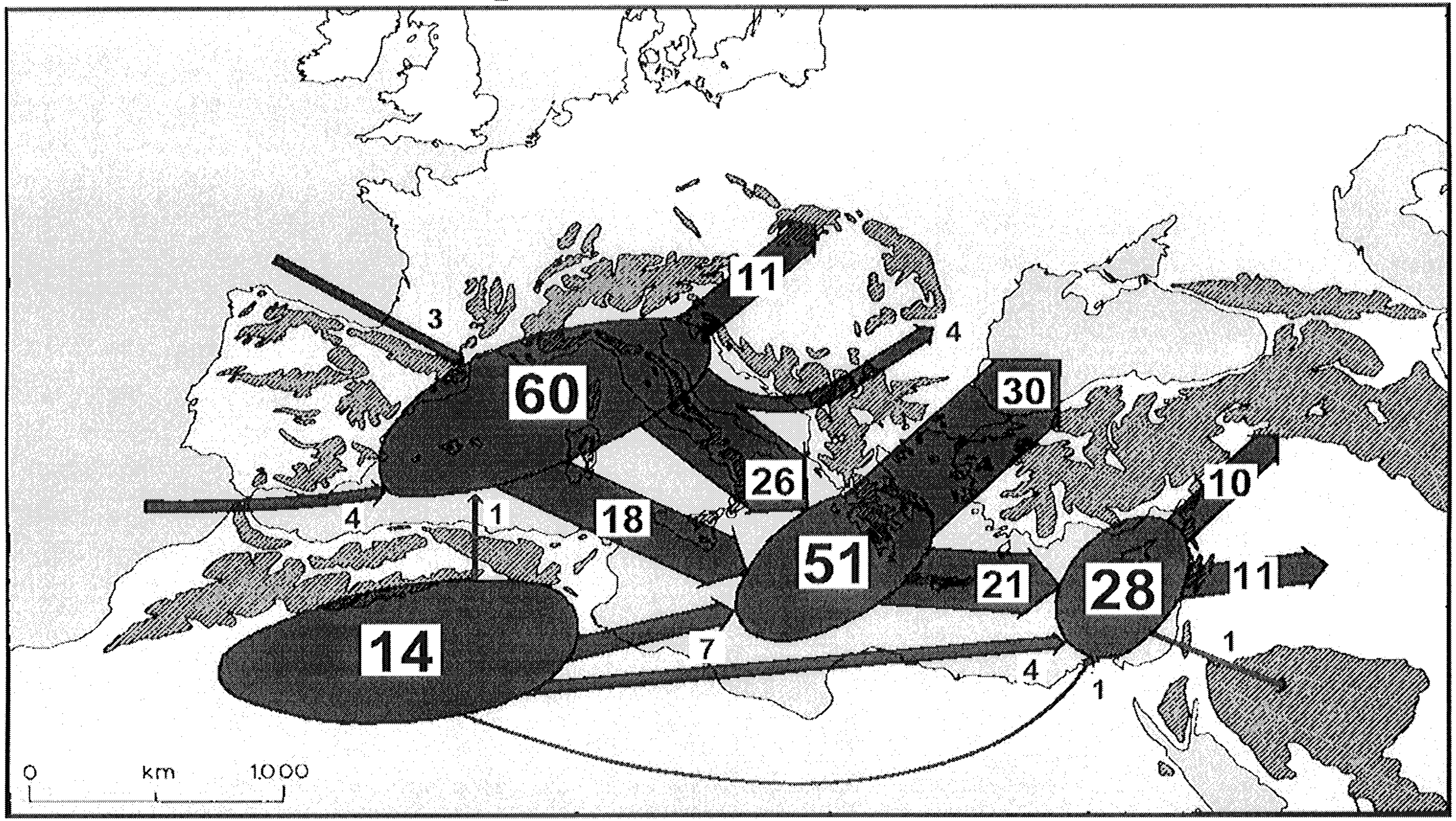


ECMWF analysis

Preferential cyclogenetical zones



TRACKS OF MEDITERRANEAN DEPRESSIONS
(average annual frequencies %)



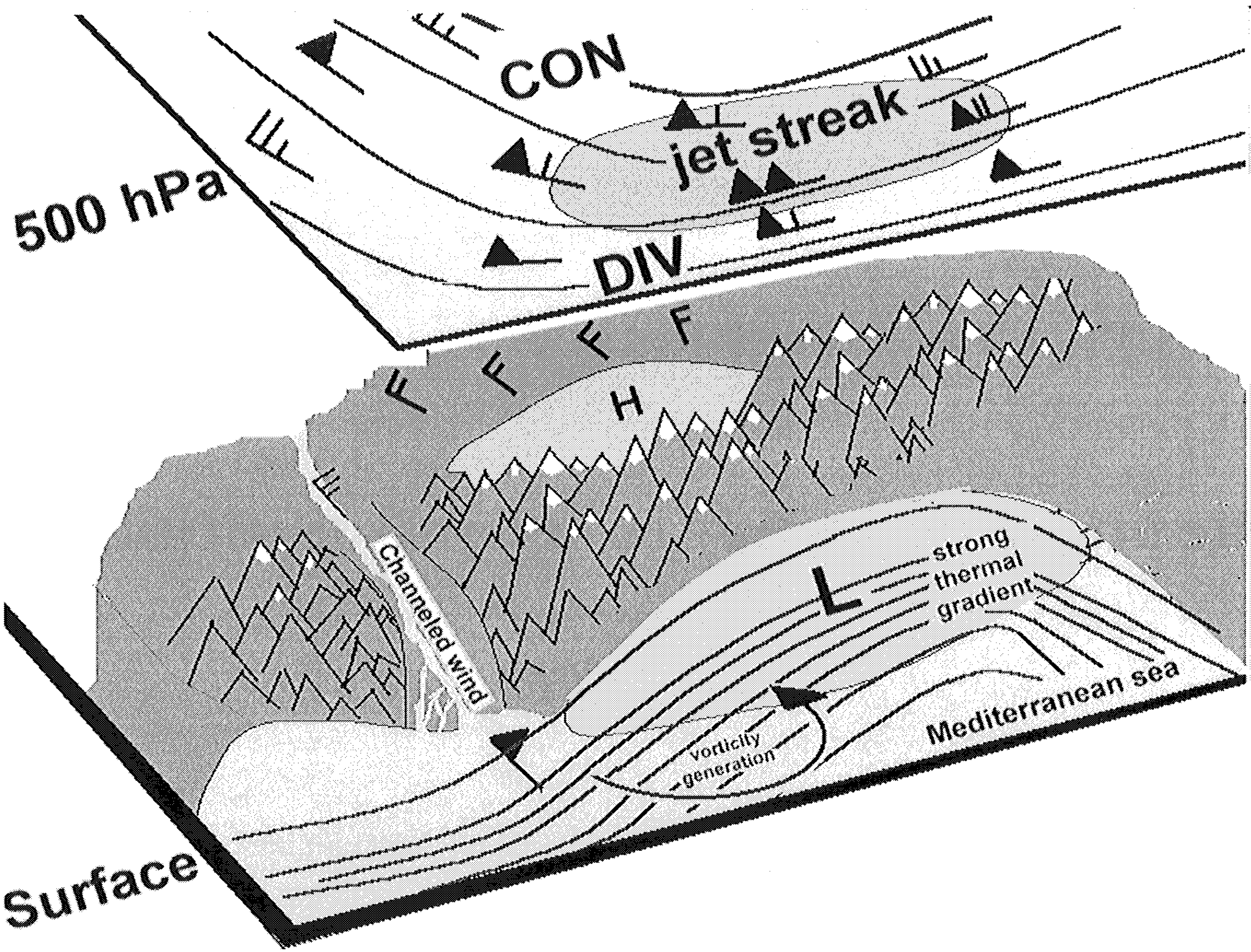
FACTORS CONTRIBUTING TO THE MEDITERRANEAN CYCLOGENESIS

a) The presence of a baroclinic zone

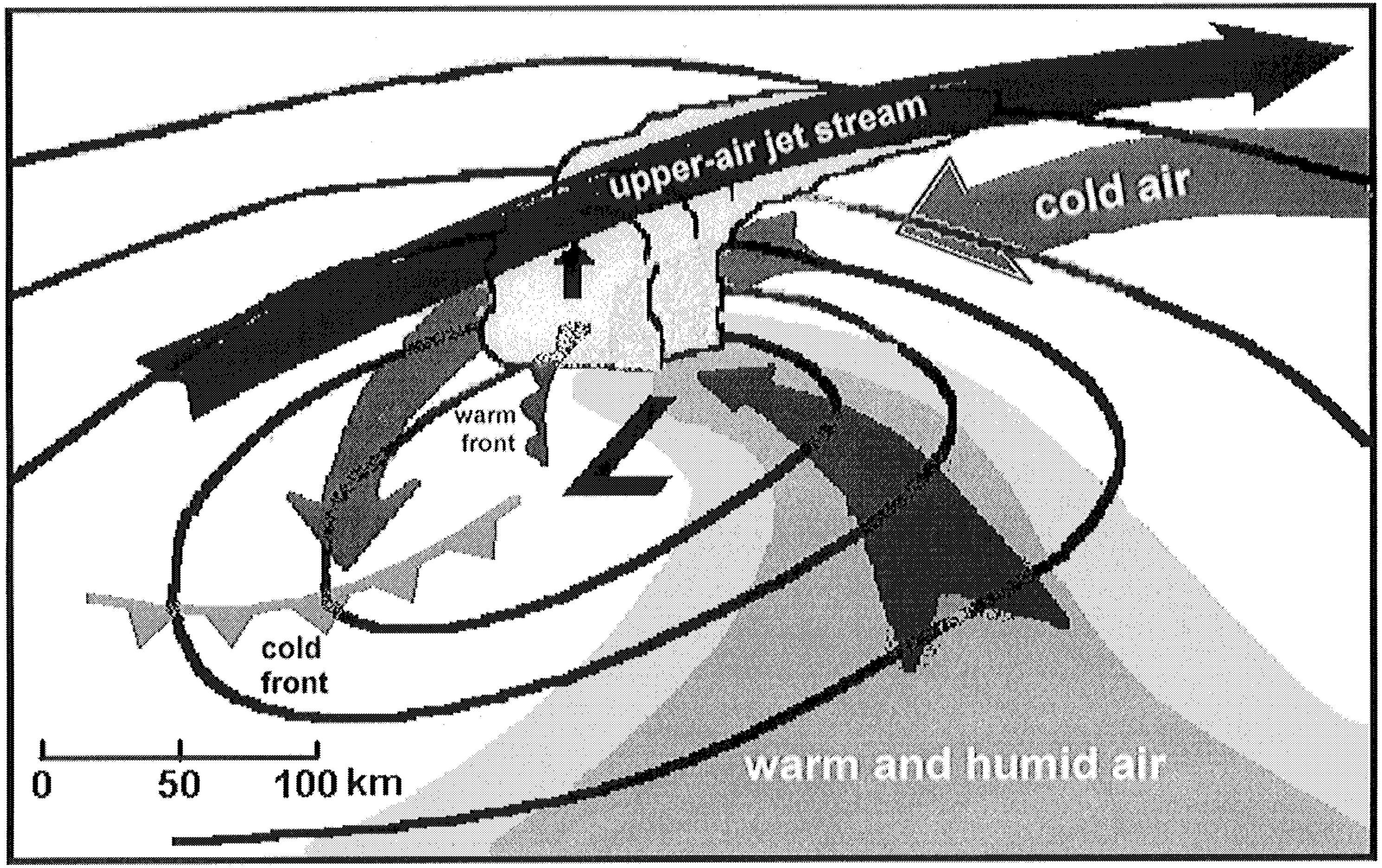
b) Lee effects in a strong air stream

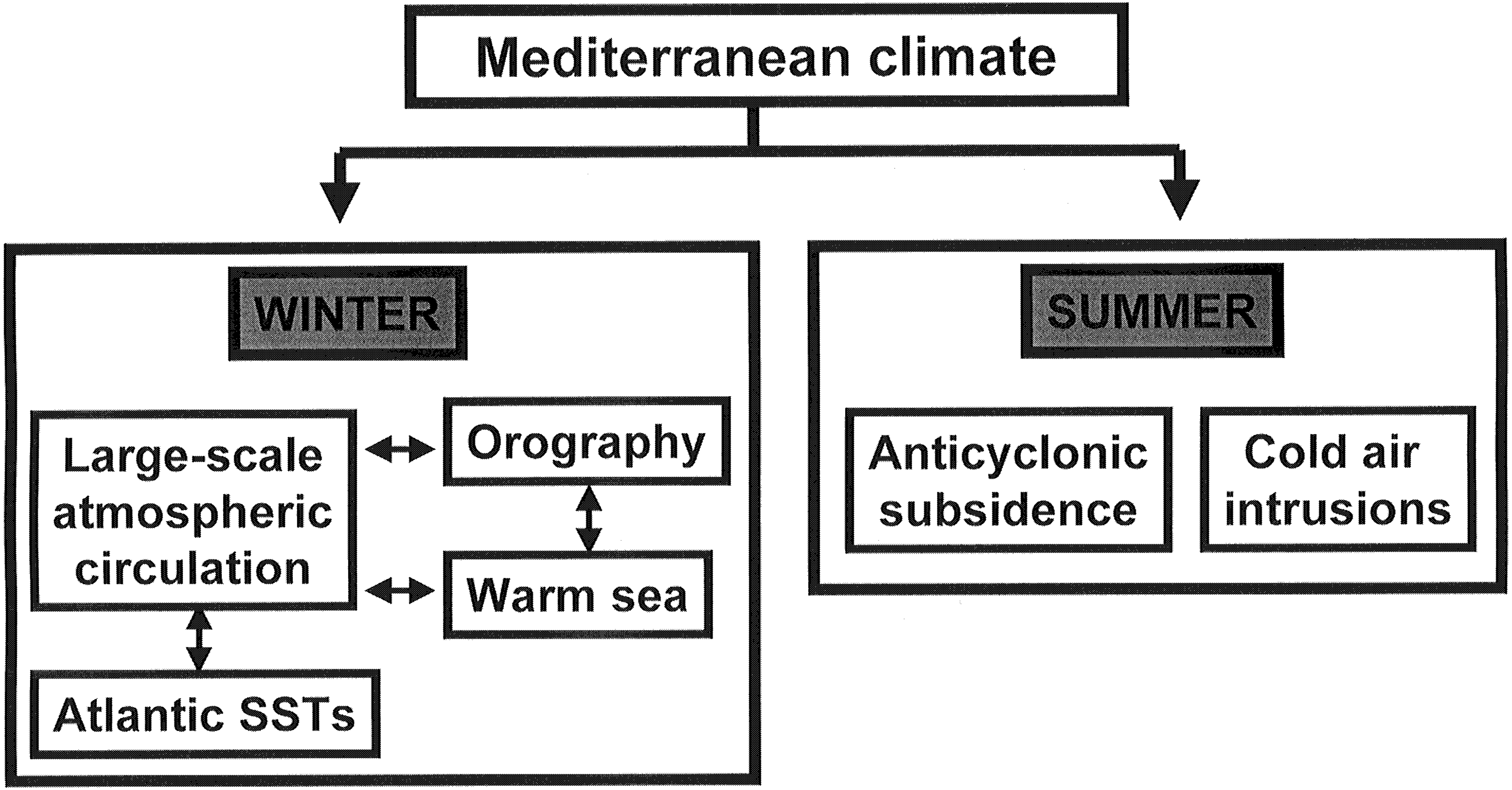
c) Convective instability in the air mass

Conceptual model of lee cyclogenesis



Conceptual model of convective systems responsible for torrential rains in the Mediterranean

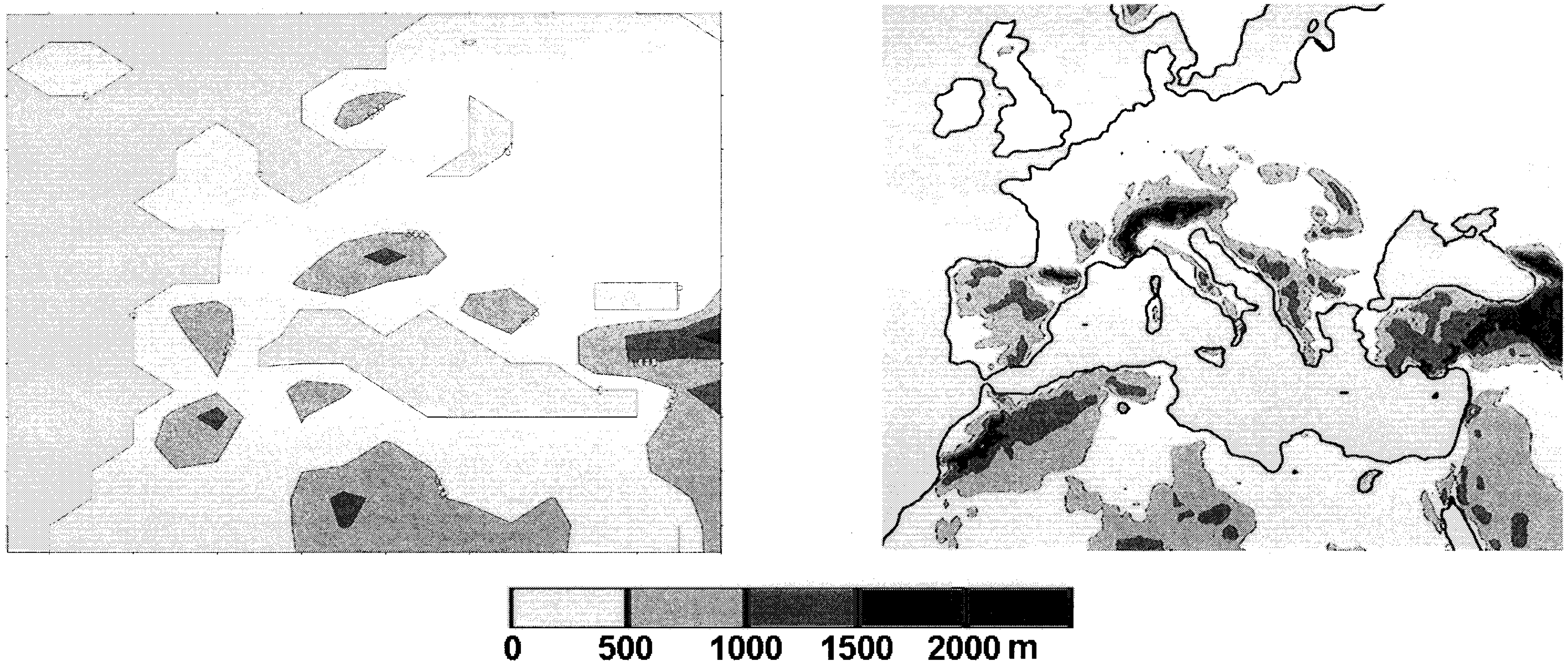




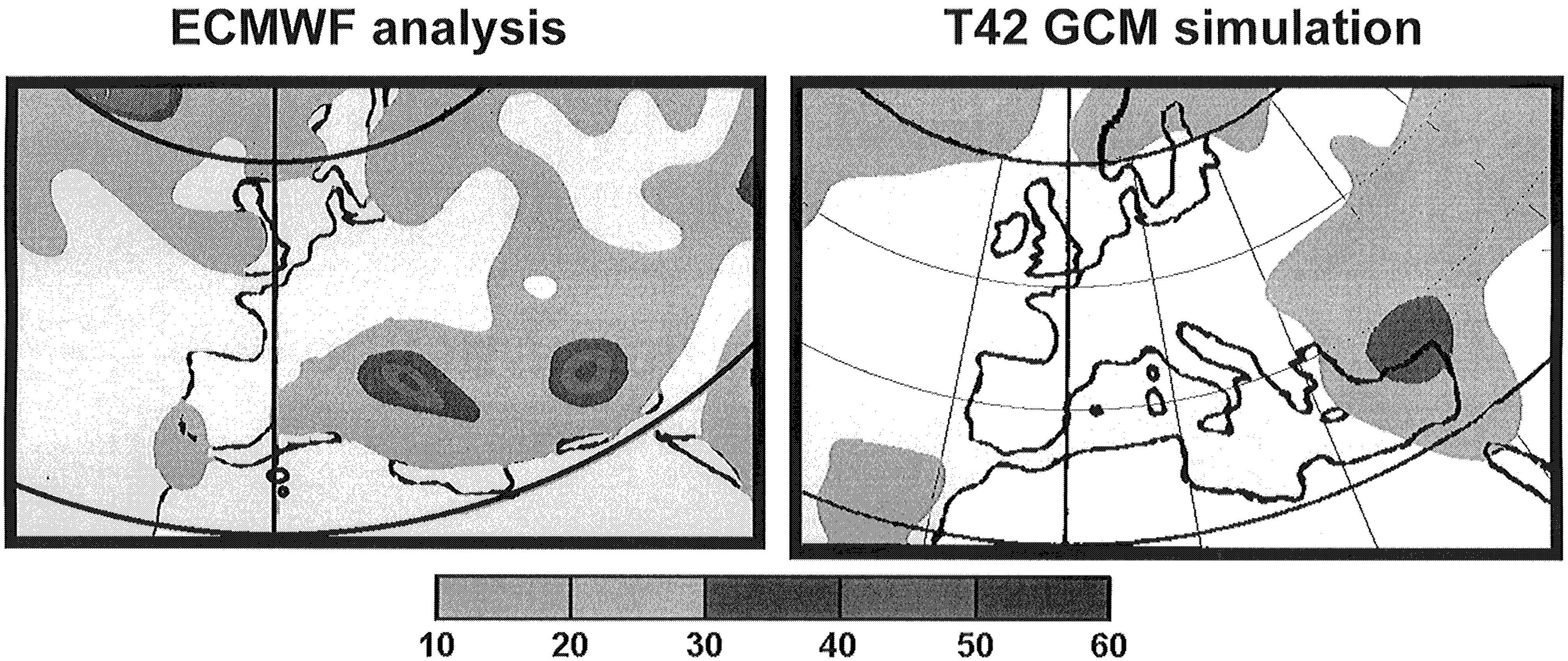
Are current GCMs able to simulate the Mediterranean climate ?

Land-mask and orography of a T42 GCM

Actual orography



Mediterranean cyclogenesis is not modeled properly



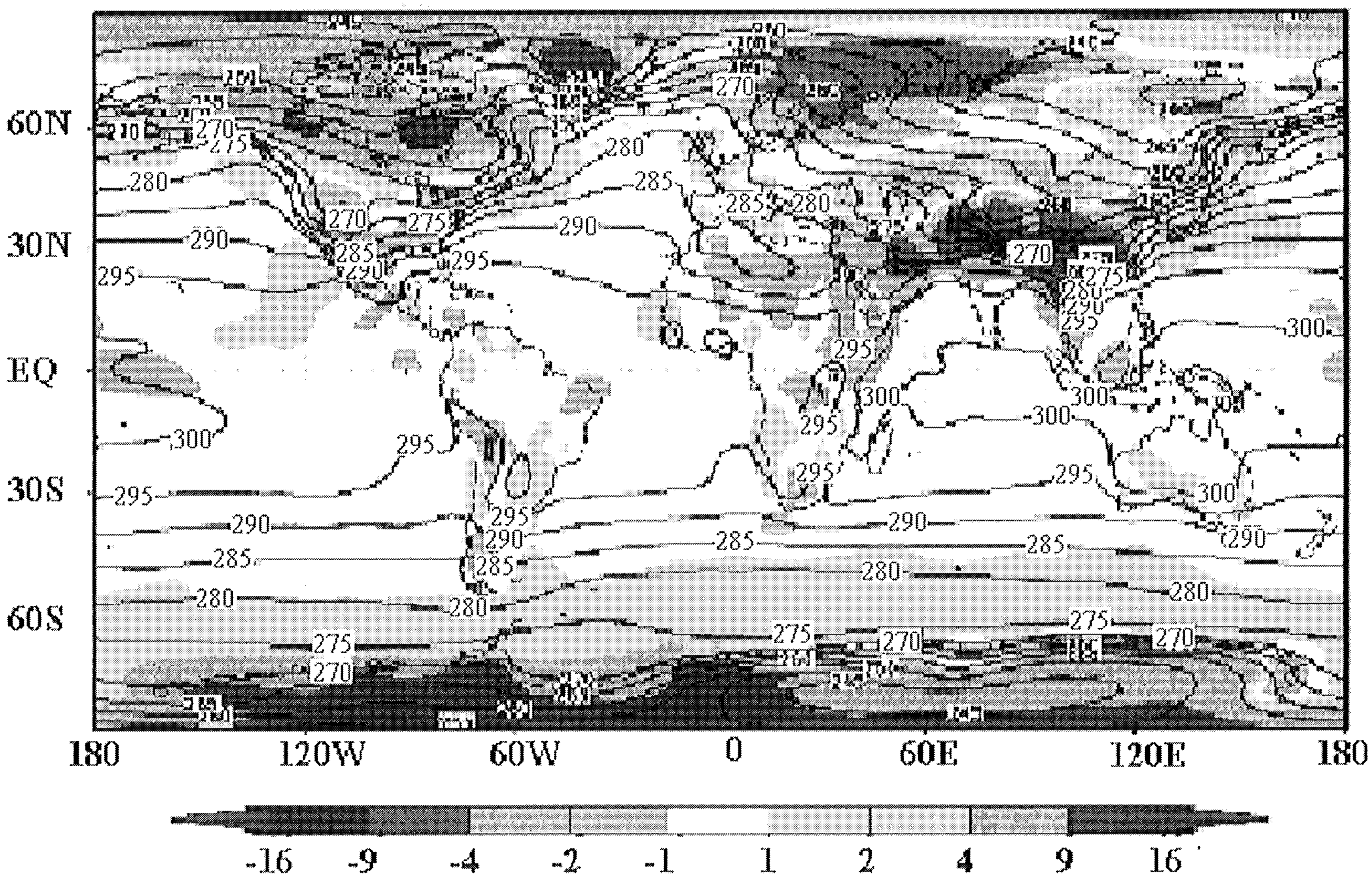
Number of surface cyclones per 400 x 400 km^2 (DJF 1980-84)

Mesoscale convective systems are too small-sized to be reproduced by low resolution models

Atmosphere - ocean connection related to NAO is poorly simulated by AOCGCMs

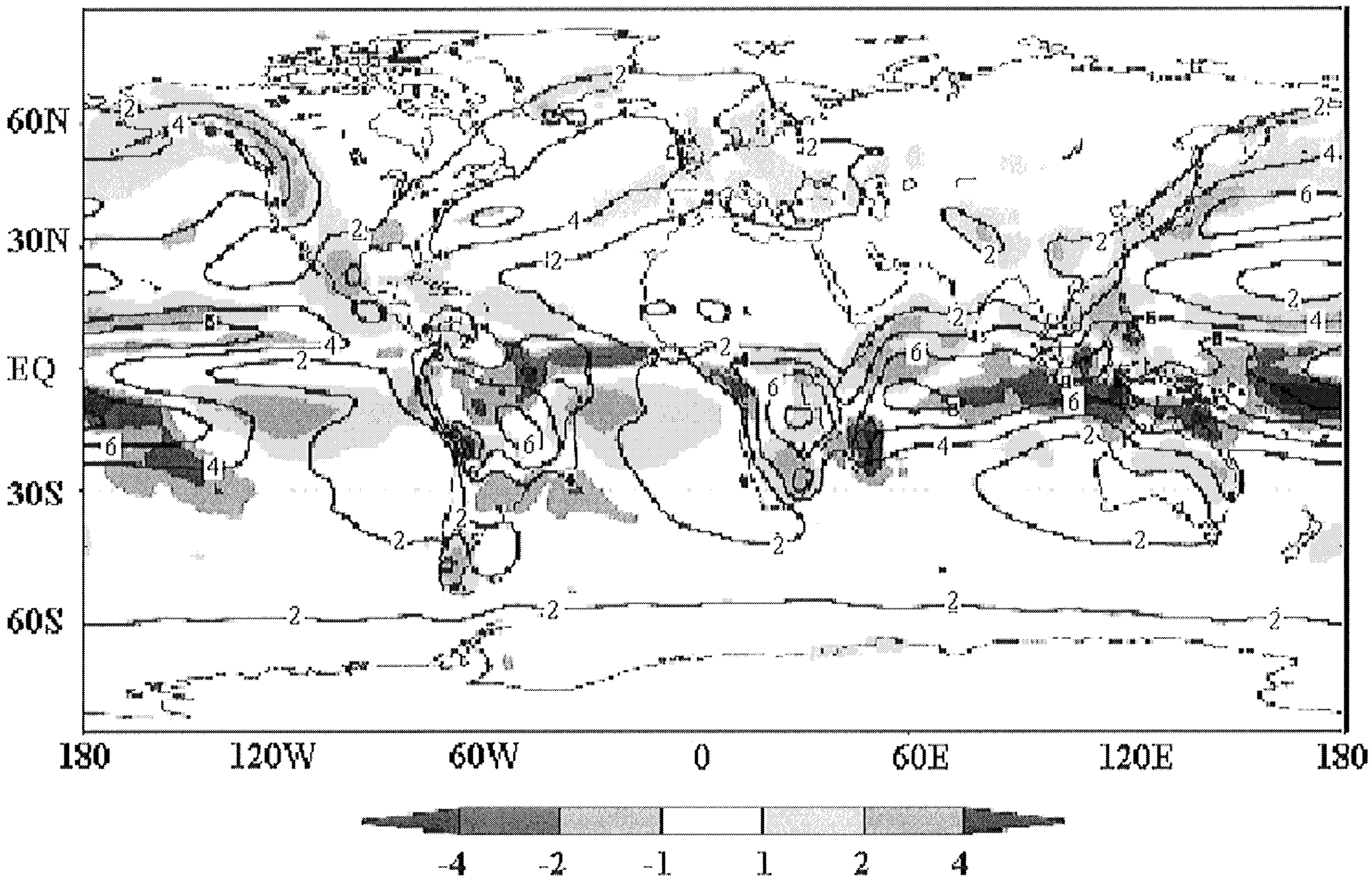
CURRENT CLIMATE SIMULATIONS

Surface air temperature (DJF)
Model mean (contoured) mean minus observed (shaded)



CURRENT CLIMATE SIMULATIONS

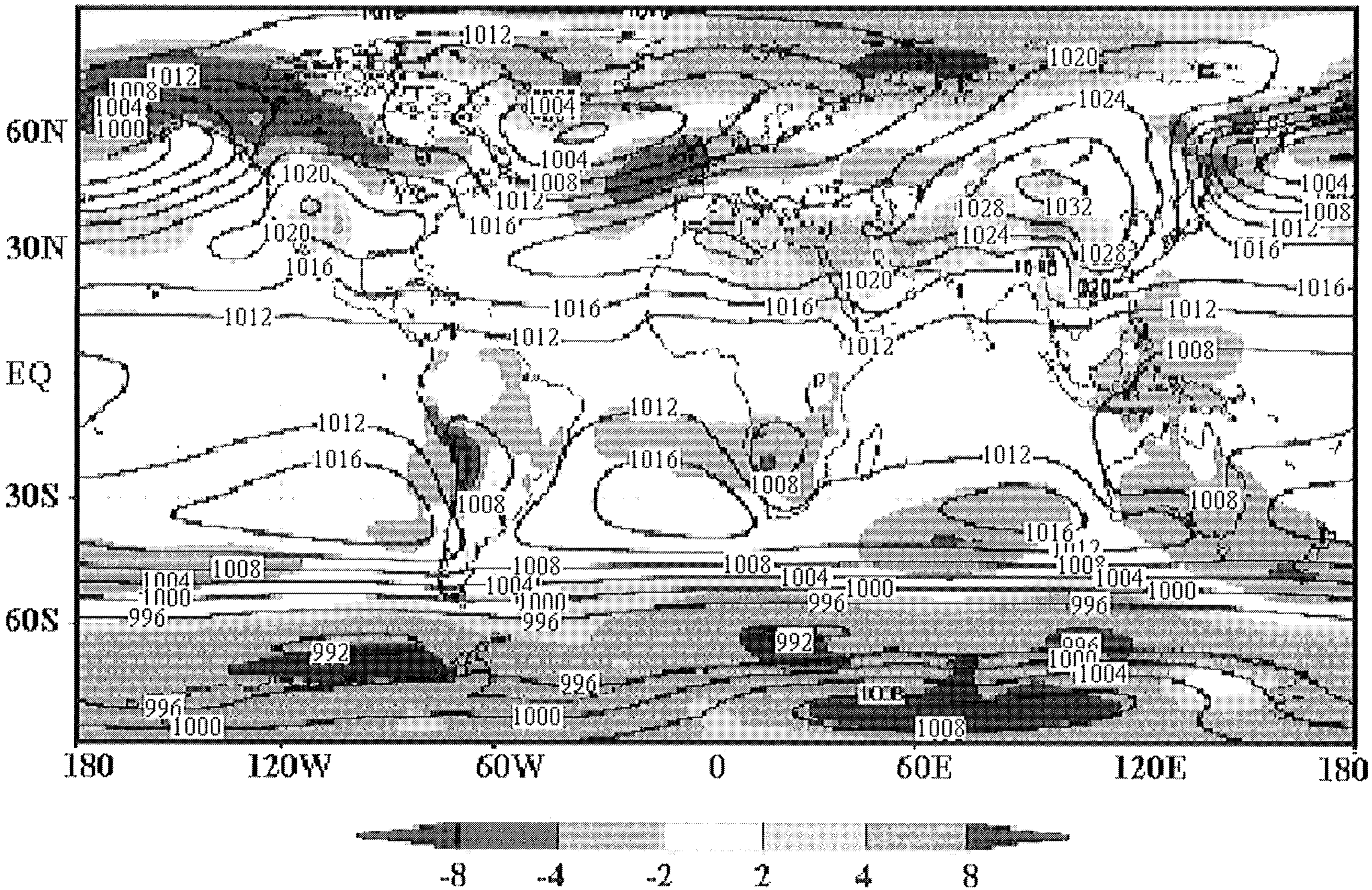
Precipitation (DJF)
Model mean (contoured) mean minus observed (shaded)



CURRENT CLIMATE SIMULATIONS

MSL pressure (DJF)

Model mean (contoured) mean minus observed (shaded)



CONCLUSIONS

- Diverse climate sub-types in the Mediterranean region ("meso-climates")
- Winter climate much more complex than summer
- "Normal" climate features determined by average large-scale atmospheric circulation and geographical characteristics
- Synergetic effects lead to Mediterranean meso-climates
- Climate variability mostly (?) driven by large-scale atmospheric circulation anomalies (Atlantic ocean ?)
- Impact of global change on the Mediterranean meso-climates : <u>many uncertainties still</u>

RECOMMENDED READING

Mediterranean climate:

H.M.S.O., Meteorological Office, 1962: Weather in the Mediterranean, Pub. 391, Vol. 1, General Meteorology, London

Large-scale circulation vs. Mediterranean climate:

Corte-Real, J. et al, 1995: Large-scale circulation regimes and surface climatic anomalies over the Mediterranean. Int. Jour. Clim., 15, 1135-1150.

Mediterranean cyclogenesis:

Radinovic, D., 1987: Mediterranean cyclones and their influence on the weather and climate, WMO, PSMP Rep. Ser. num. 24.

Pichler, H., Steinacker, R., Lanzinger, A., 1990: Cyclogenesis induced by the Alps. Meteorol. Atmos. Phys., 43, 21-29.

Convective systems in the Mediterranean:

Conte, M., 1986: The meteorological bomb in the Mediterranean: a synoptic climatology, WMO/TD No 128, App. 4, 17-31.

The North Atlantic Oscillation:

Hurrell, J.W., 1995: Decadal trends in the North Atlantic Oscillation and relationships to regional temperature and precipitation. *Science* 269, 676-679.

http://www.met.rdg.ac.uk/cag/NAO/index.html