

# **Use of Climate Data in Climate Research**

## **A Random Walk Through the MPI**

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Talk presented at the  
Fourth Session  
of the Joint Scientific and Technical Committee  
of the Global Climate Observing System  
in Hamburg, Germany  
September 19 - 22, 1994

# For which Purposes do we Use Observed Data

- **Climate modelling**

- Design of parameterisations
- “Validation” of dynamical climate models\*
- Optimization of dynamical models\*
- Design of numerical experiments\*
- Fit of empirical models\*

- **Climate forecasts**

- Need of initial conditions.
- Need of boundary conditions to spin models up.
- Data assimilation

- **Climate diagnostics**

Identification of

- modes of natural variability,\*
- sensitivities among sub-systems,\*
- external signals.\*

\* Examples will be presented in the talk.

# Validation of climate models

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## atmospheric models

mean state, seasonal cycle  
variability on time  
scales < 1 year

data requirements:  
- global coverage  
- high quality  
- short period

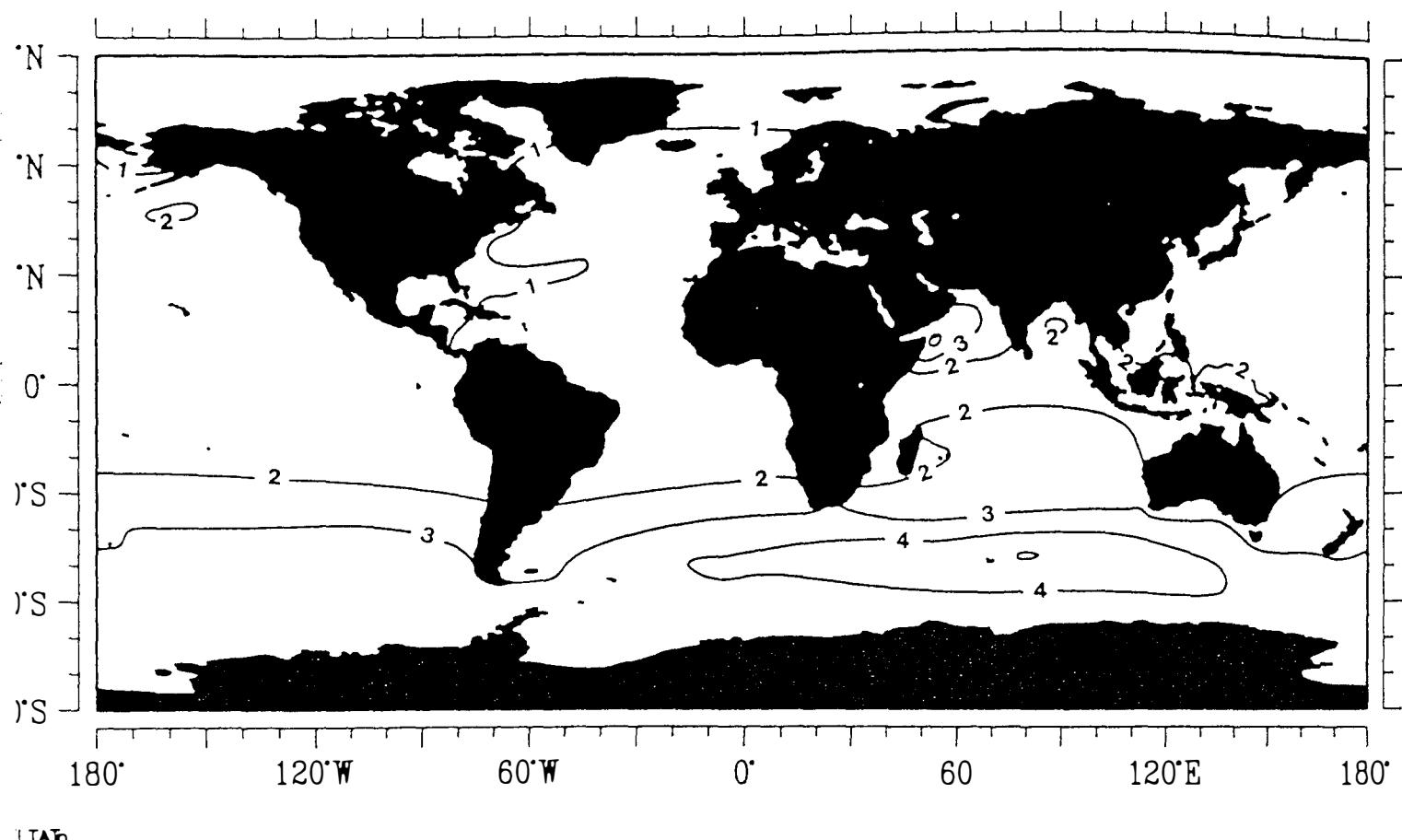
## oceanic models

mean state(s)  
data requirements:  
- global coverage

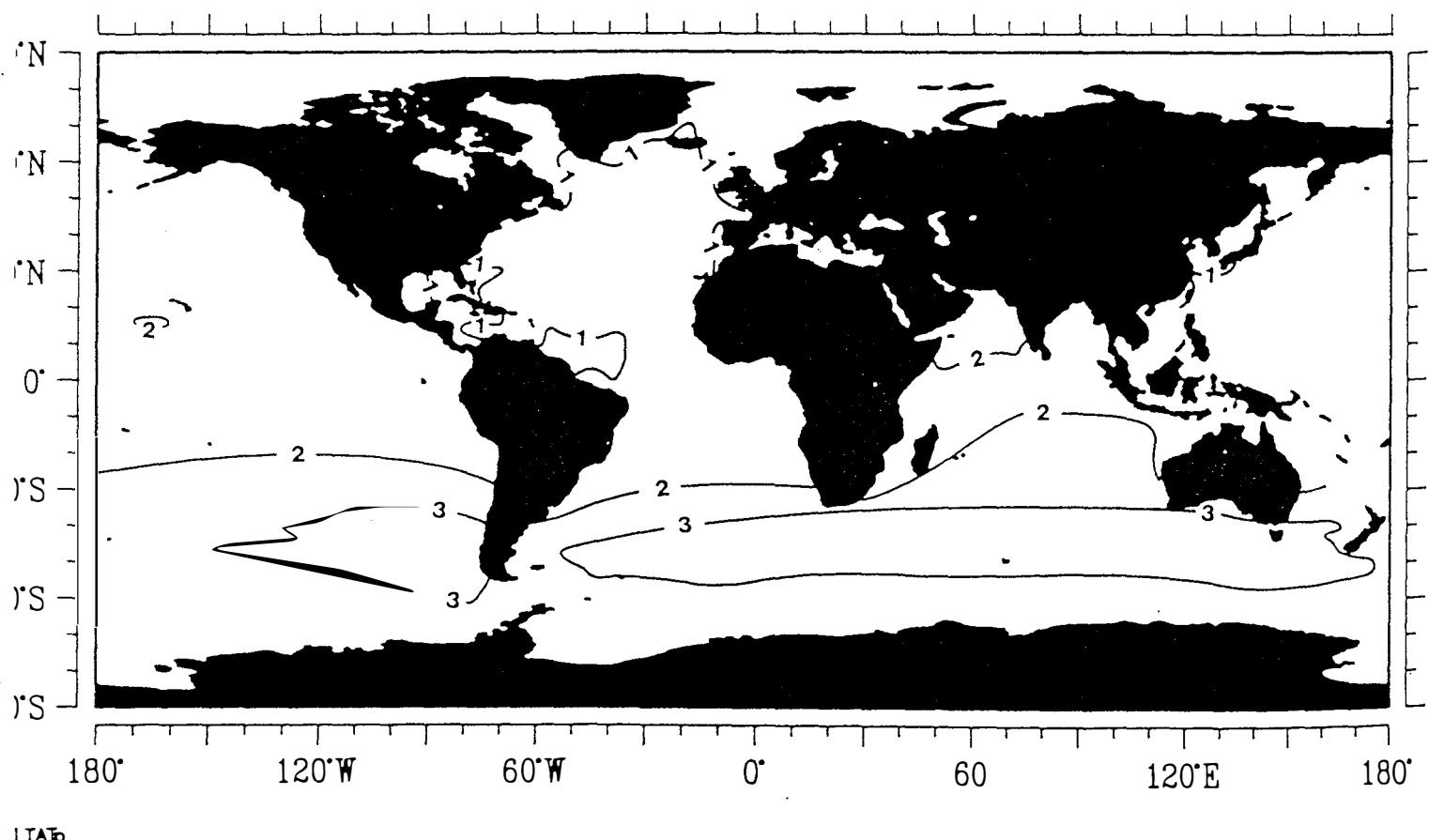
## coupled models

low-frequency variability  
on time scales  $\geq$  10 years

data requirement  
- long records  
- low quality  
- homogeneous



LTATO



LTATO

**Fig. 3a, b.** The July-mean significant wave height  $\bar{H}_s$  (in m). **a** as forecast by ECMWF from analyzed winds (mean over July 1987, 1988, 1989 and 1990); **b** as simulated by the coupled wave-atmosphere model (360-day mean)

DKRZ Hamburg GKSGRAL 7.4

84/07/15

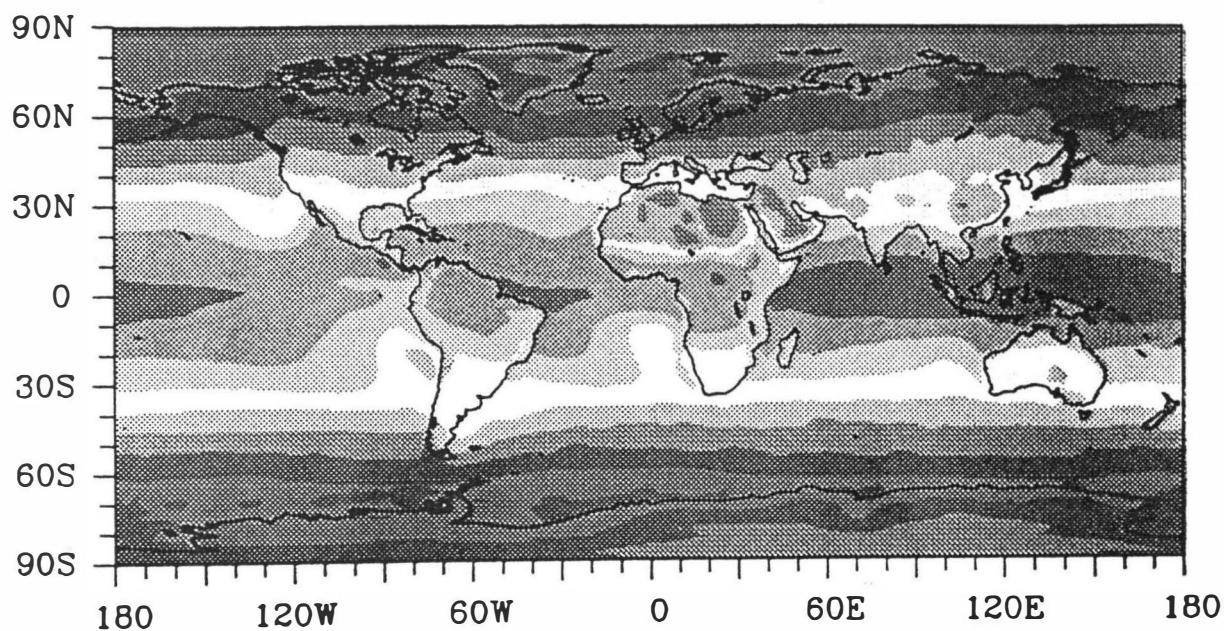
GKSM

m214008

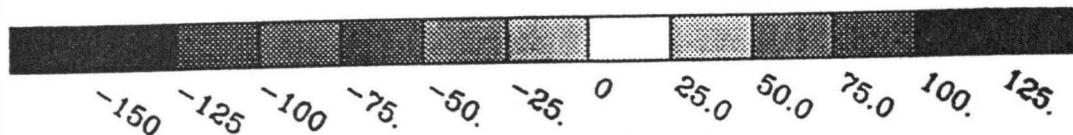
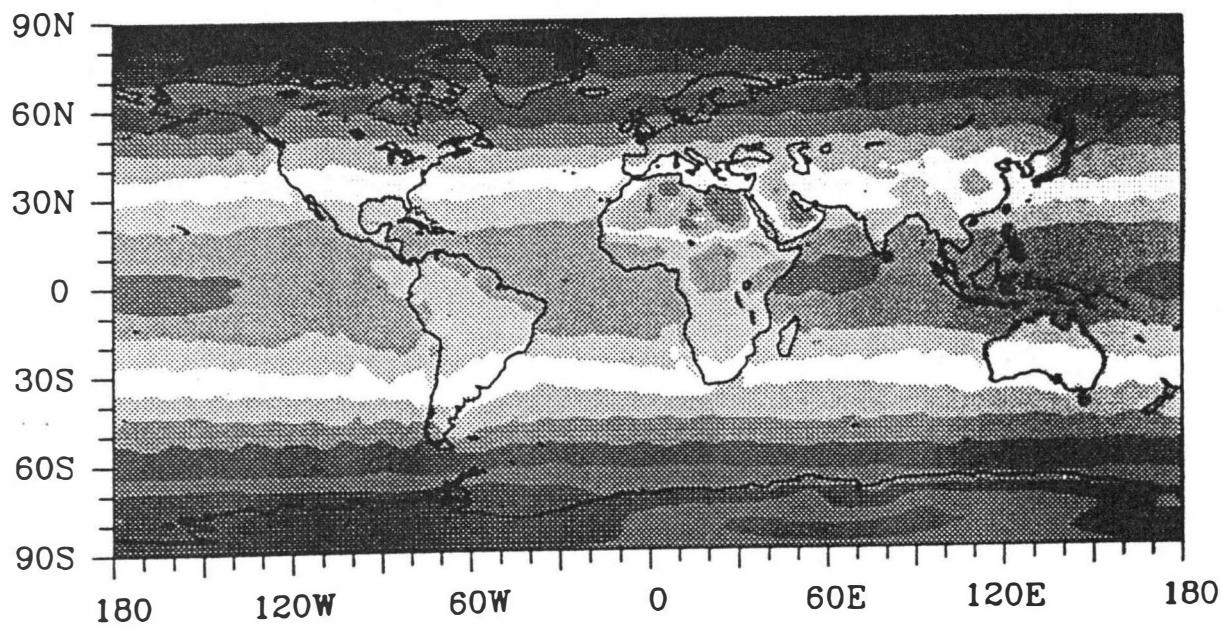
1-Mar-94 14:13:39

Net [W/m<sup>2</sup>] annual mean 1985–1989

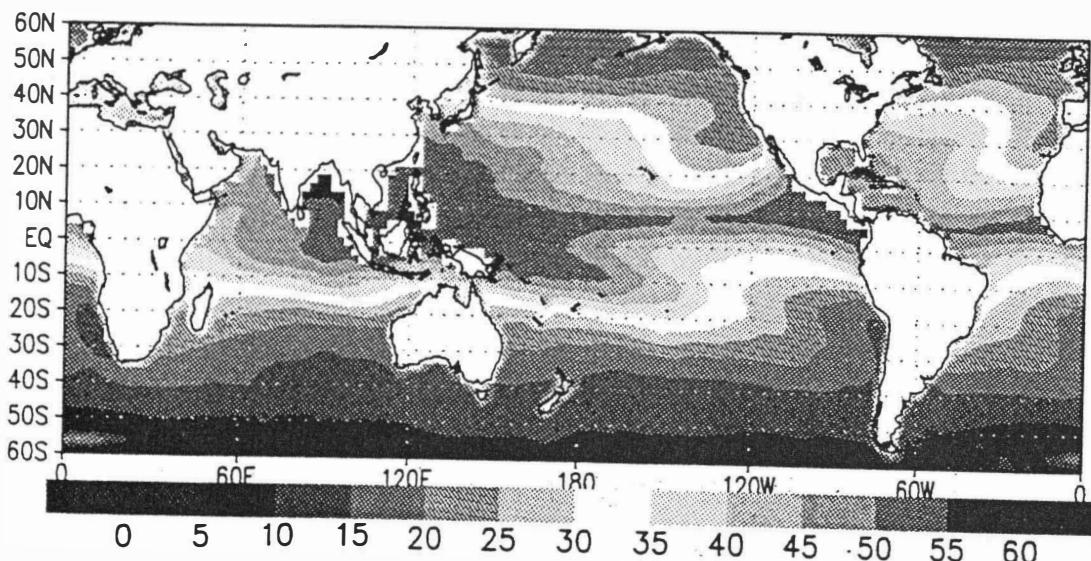
ERBE



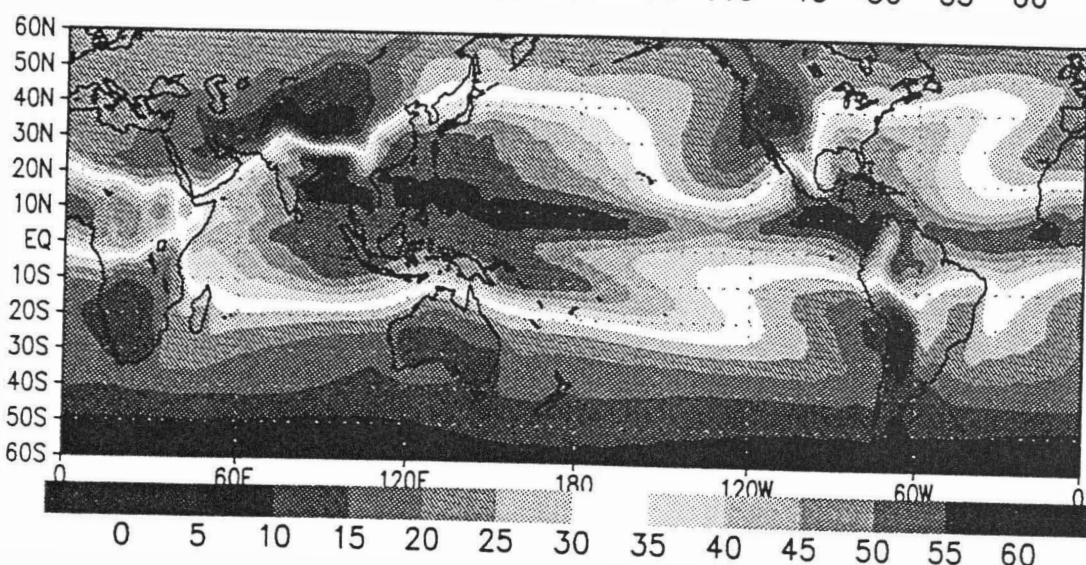
ECHAM



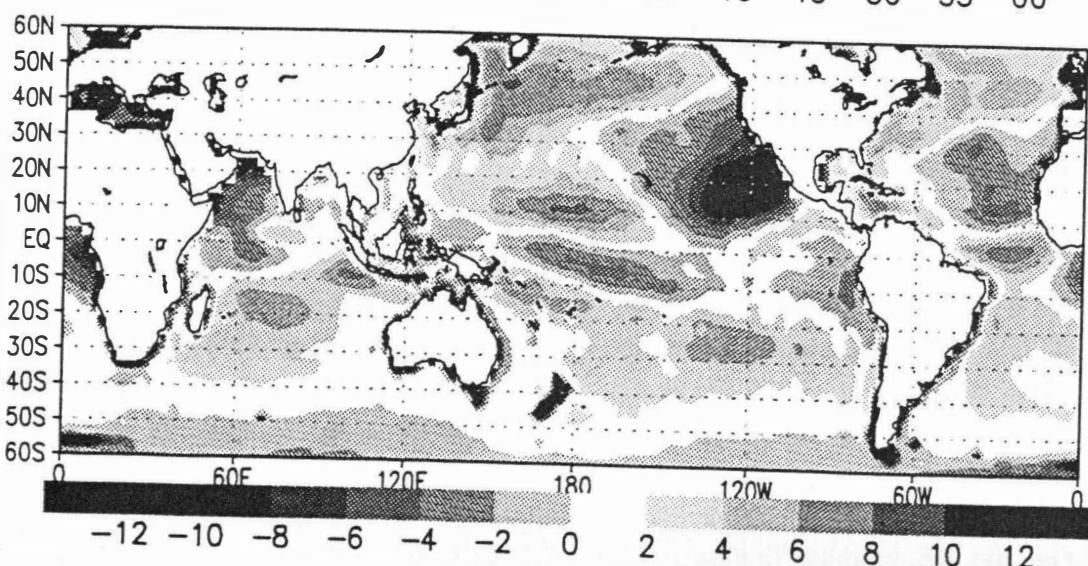
# TPW ( JJA )



SSM1



2255 Fech4

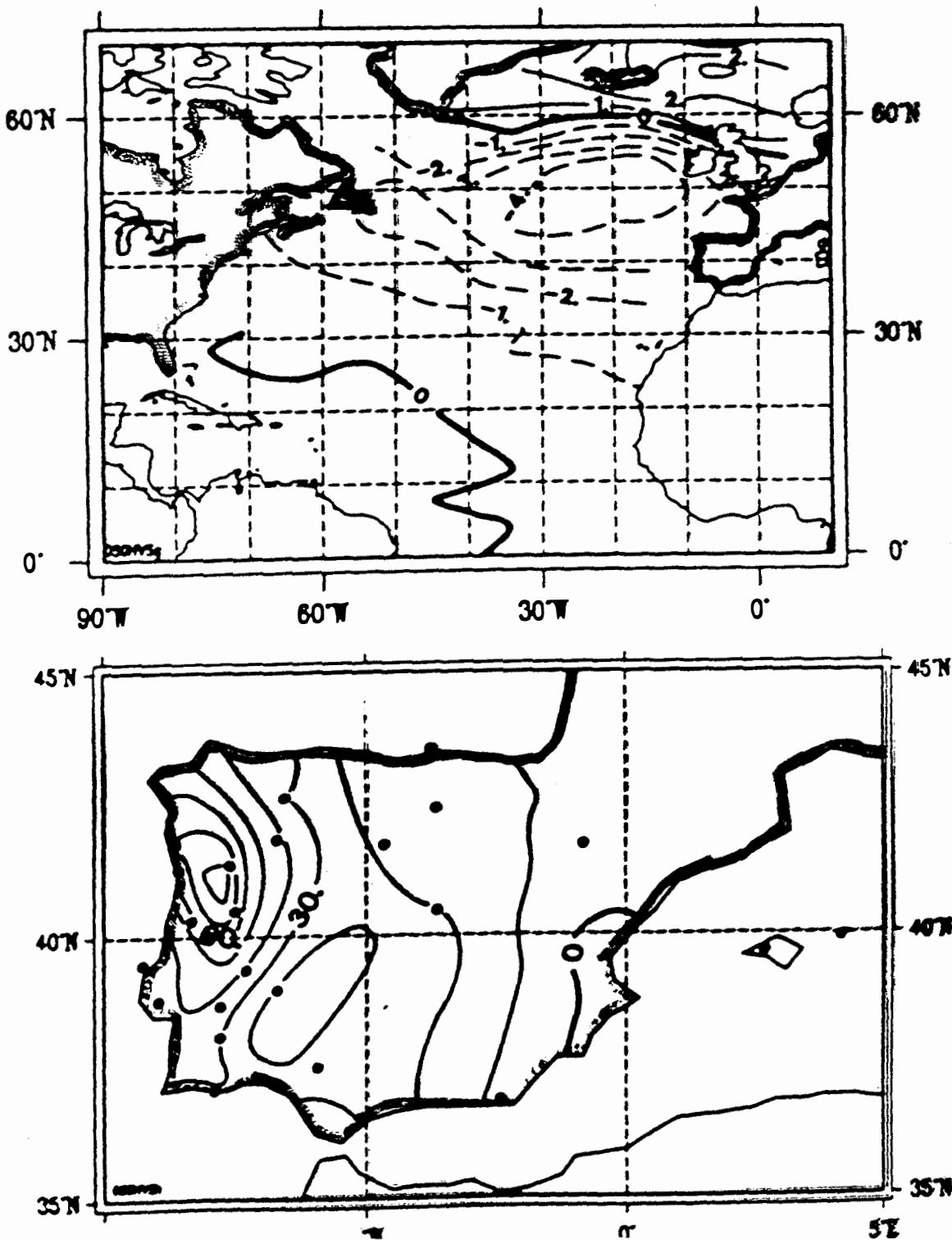


**Figure 3.**

Canonical correlation patterns of observed winter (DJF) Iberian rainfall and simultaneous SLP field in the North Atlantic area. The correlation between the associated time coefficients is 0.75. They explain about 65% and 40% of the respective total variances.

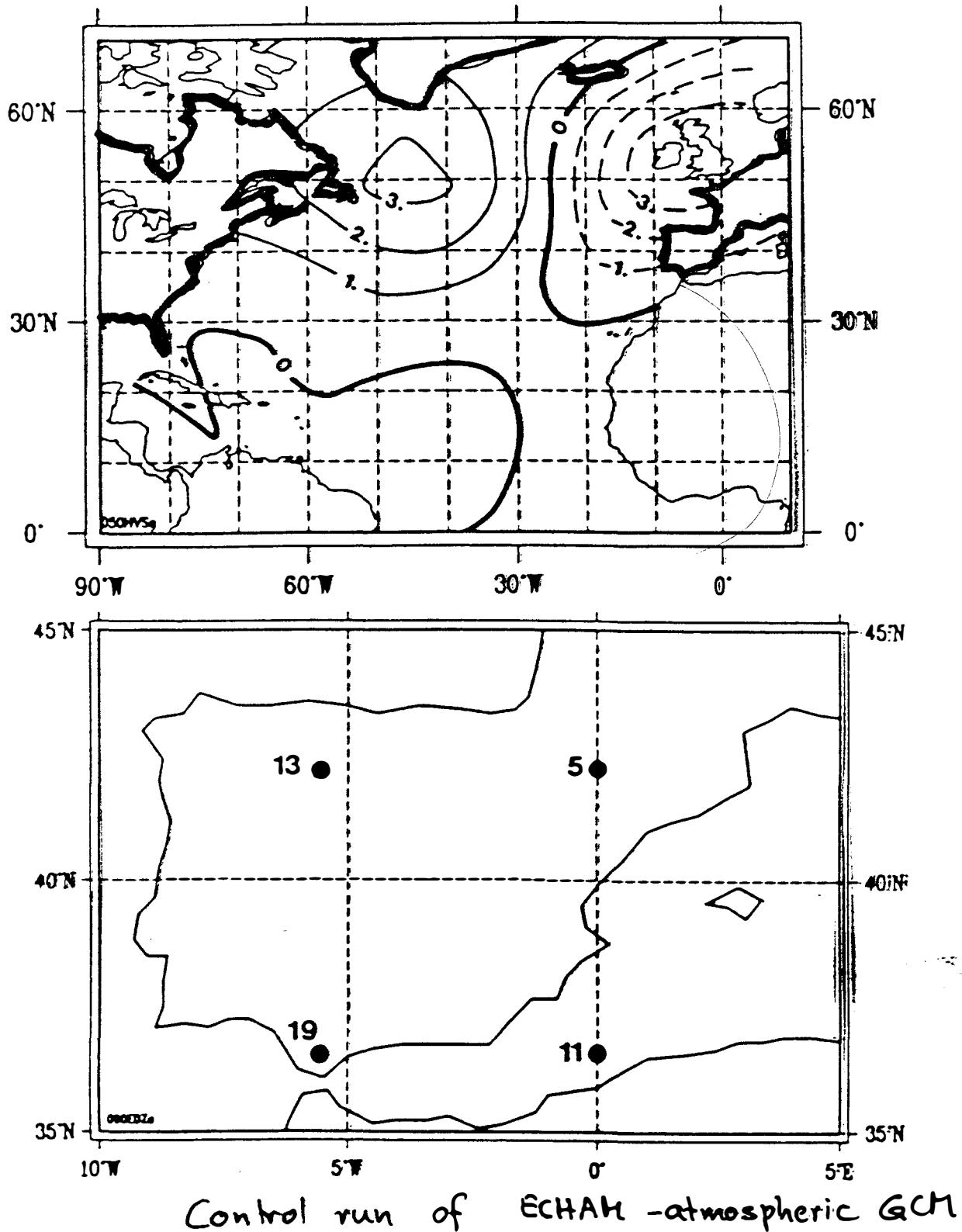
The SLP data are derived from COADS on a  $10^\circ \times 4^\circ$  lat-long grid from 1950 through 1980. The rainfall data comprise 29 stations, the locations of which are marked by dots, from WMSC covering the same period.

(From Zorita et al., 1991)

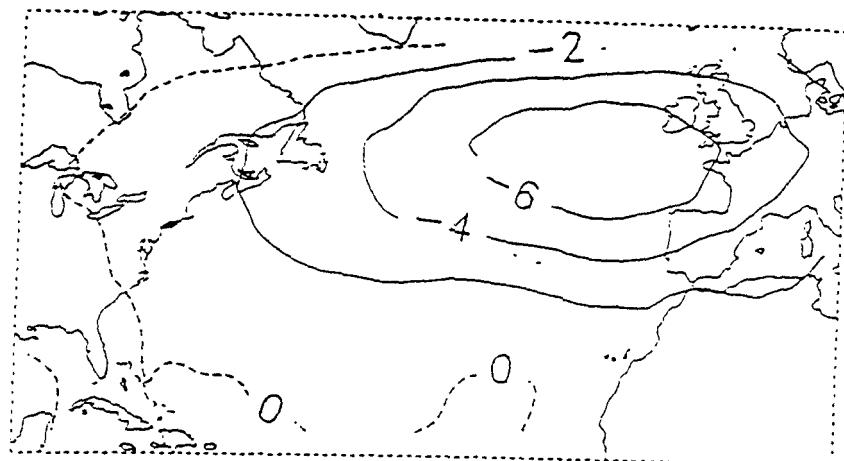


**Figure 8.**

Canonical correlation patterns of winter (DJF) Iberian rainfall (mm/month) and SLP (mb) in the North Atlantic derived from the GCM control run. Correlation between time coefficients is 0.38. The explained variances are 48% and 23%, respectively.

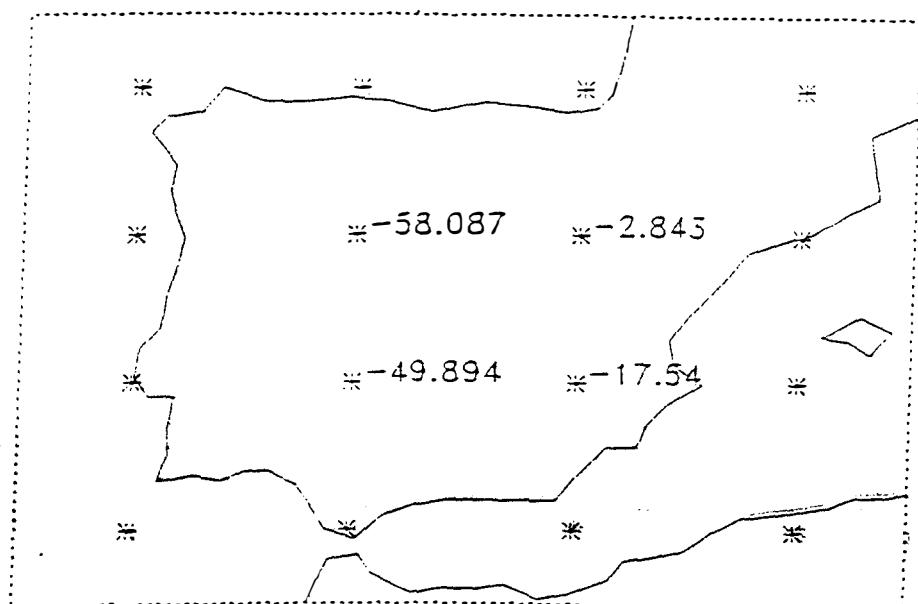


(a) MSLP



Variance explained = 51.9%

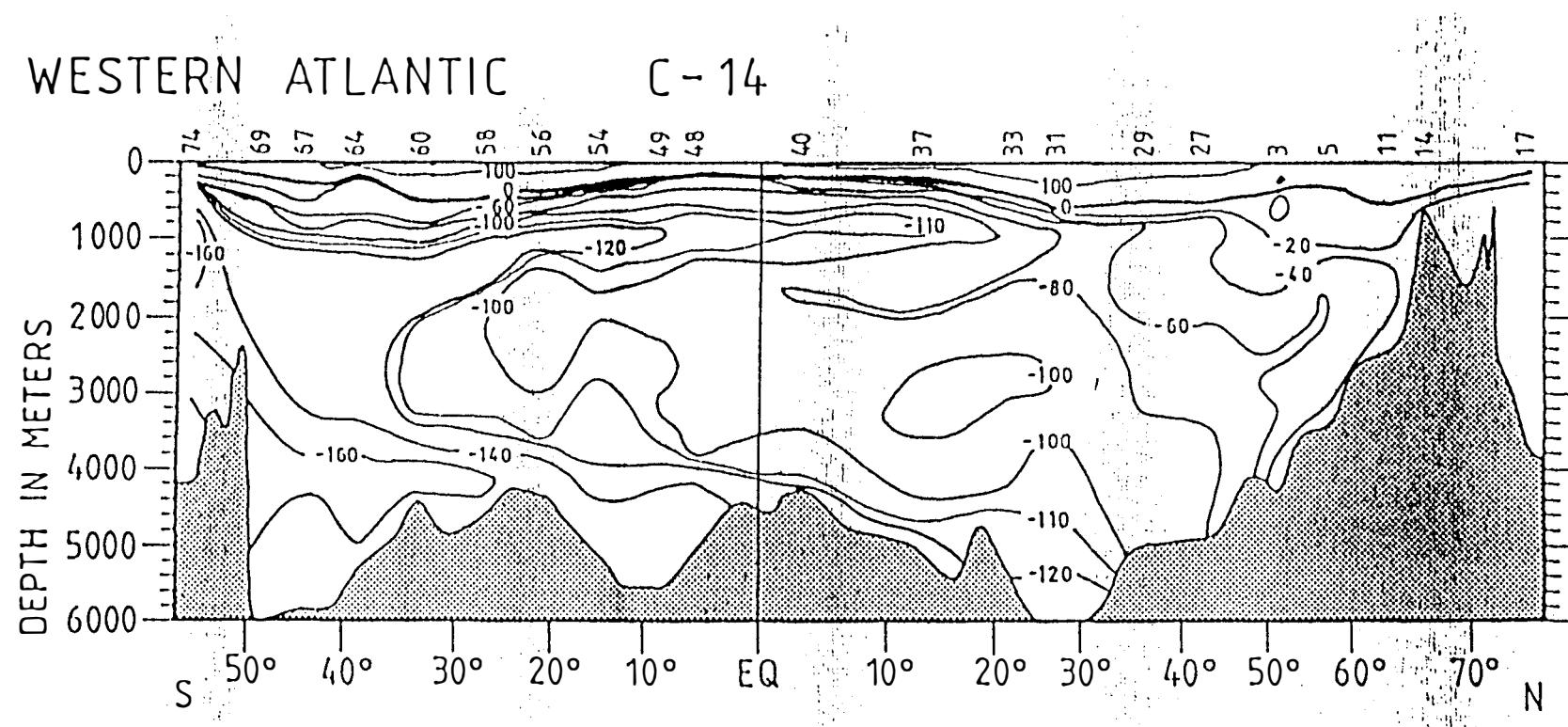
(b) Precipitation



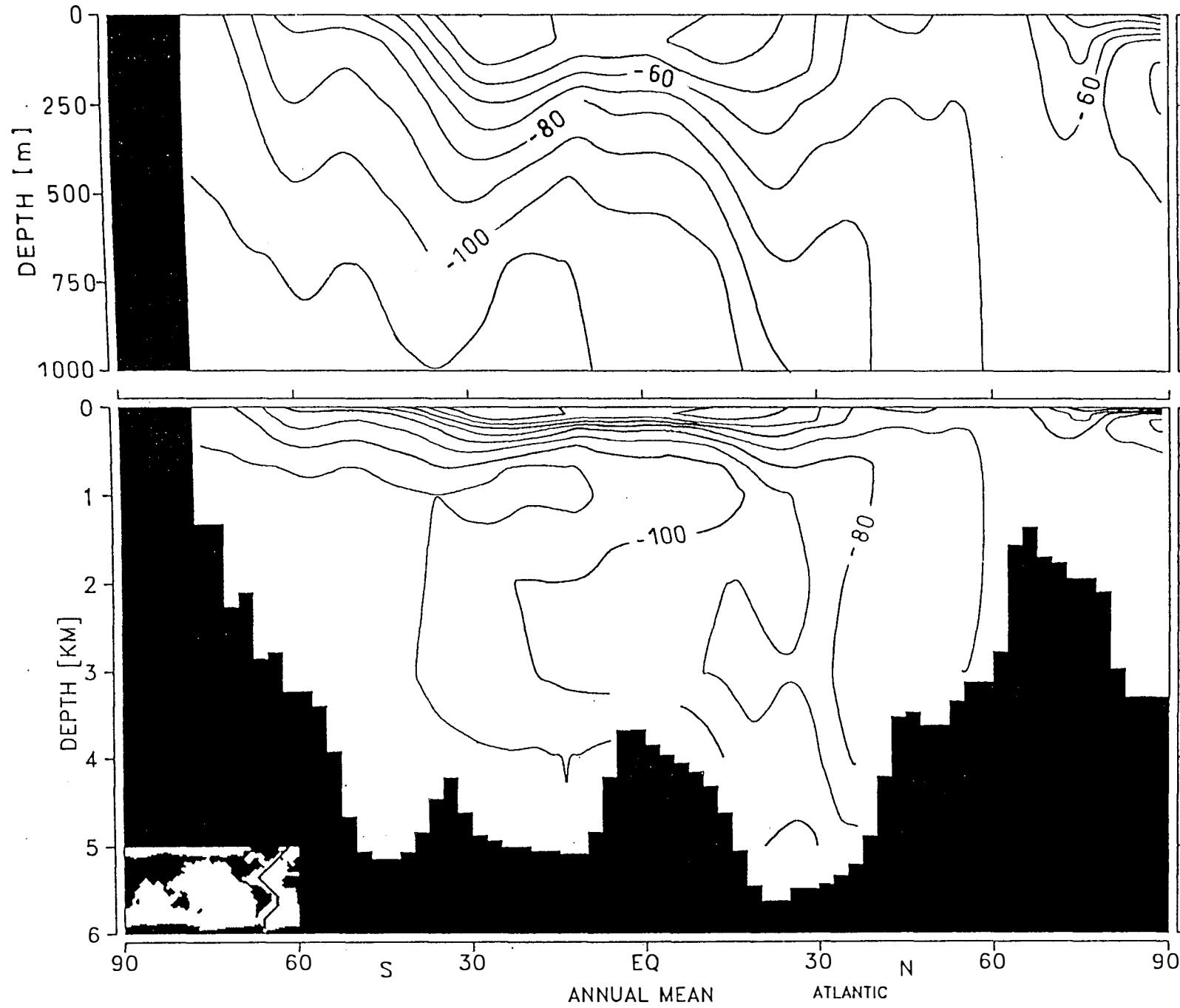
Variance explained : 77.6%

Figure 9. (a) MSLP and (b) precipitation patterns (arbitrary units) obtained by Canonical Correlation Analysis between simulated monthly-mean MSLP and Iberian precipitation

WESTERN ATLANTIC C - 14

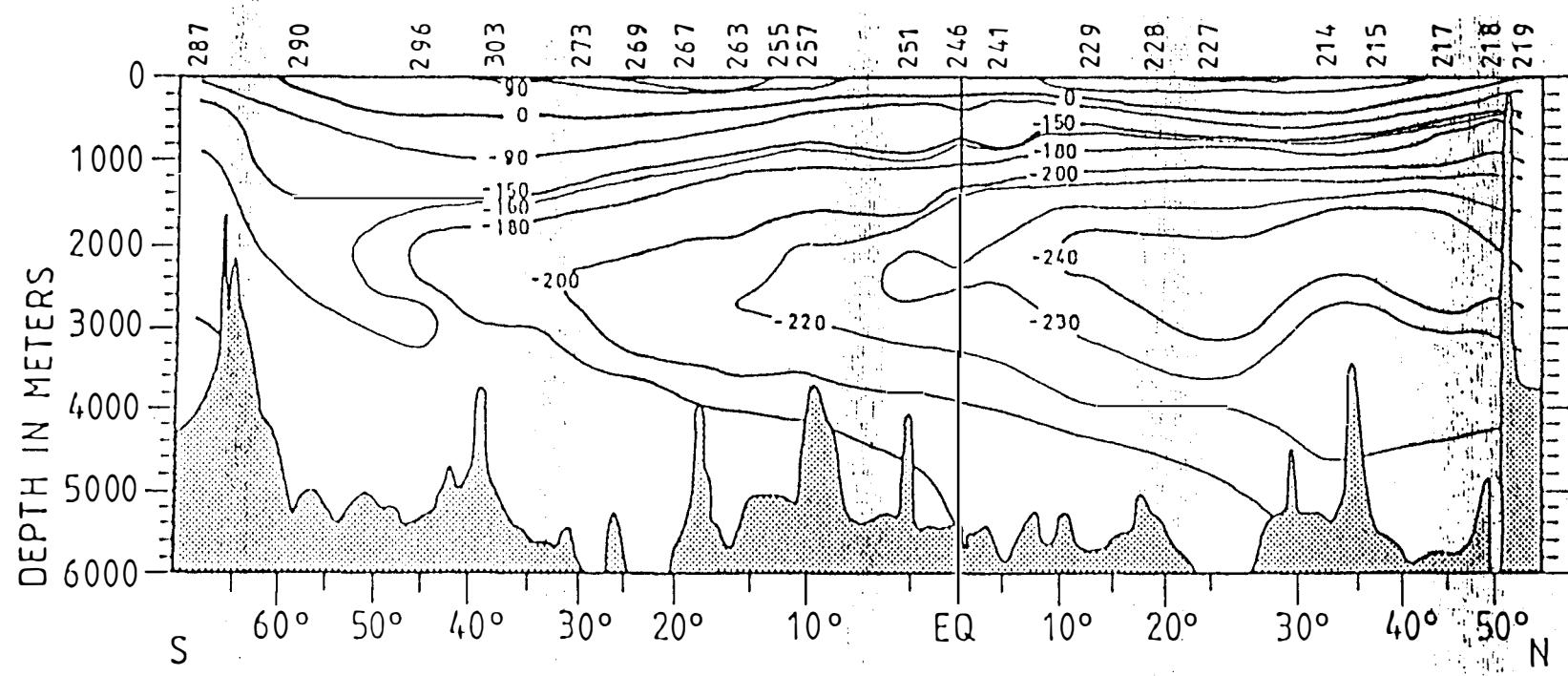


C-14 (QUICK) 7.5M/Y

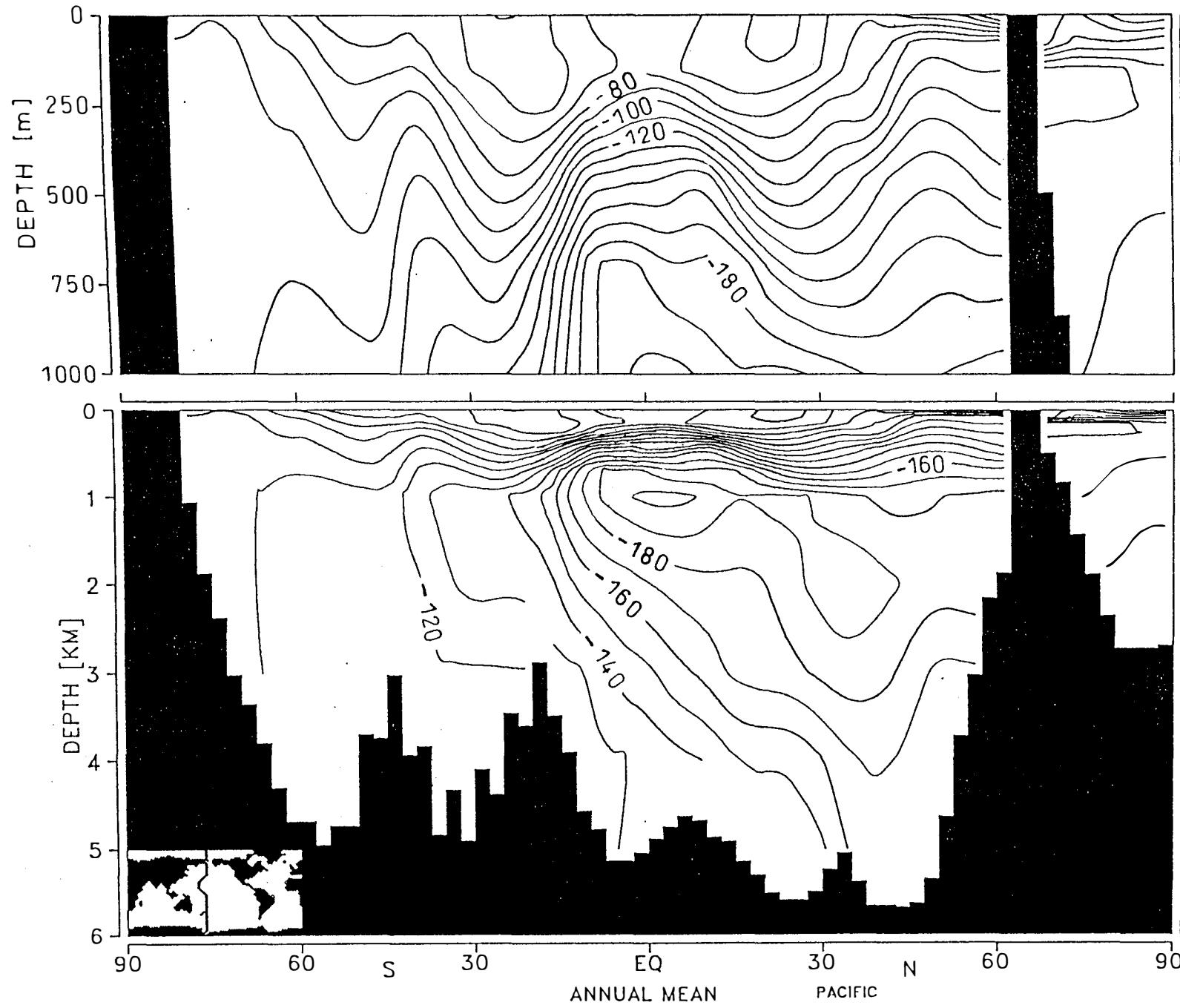


## WESTERN PACIFIC

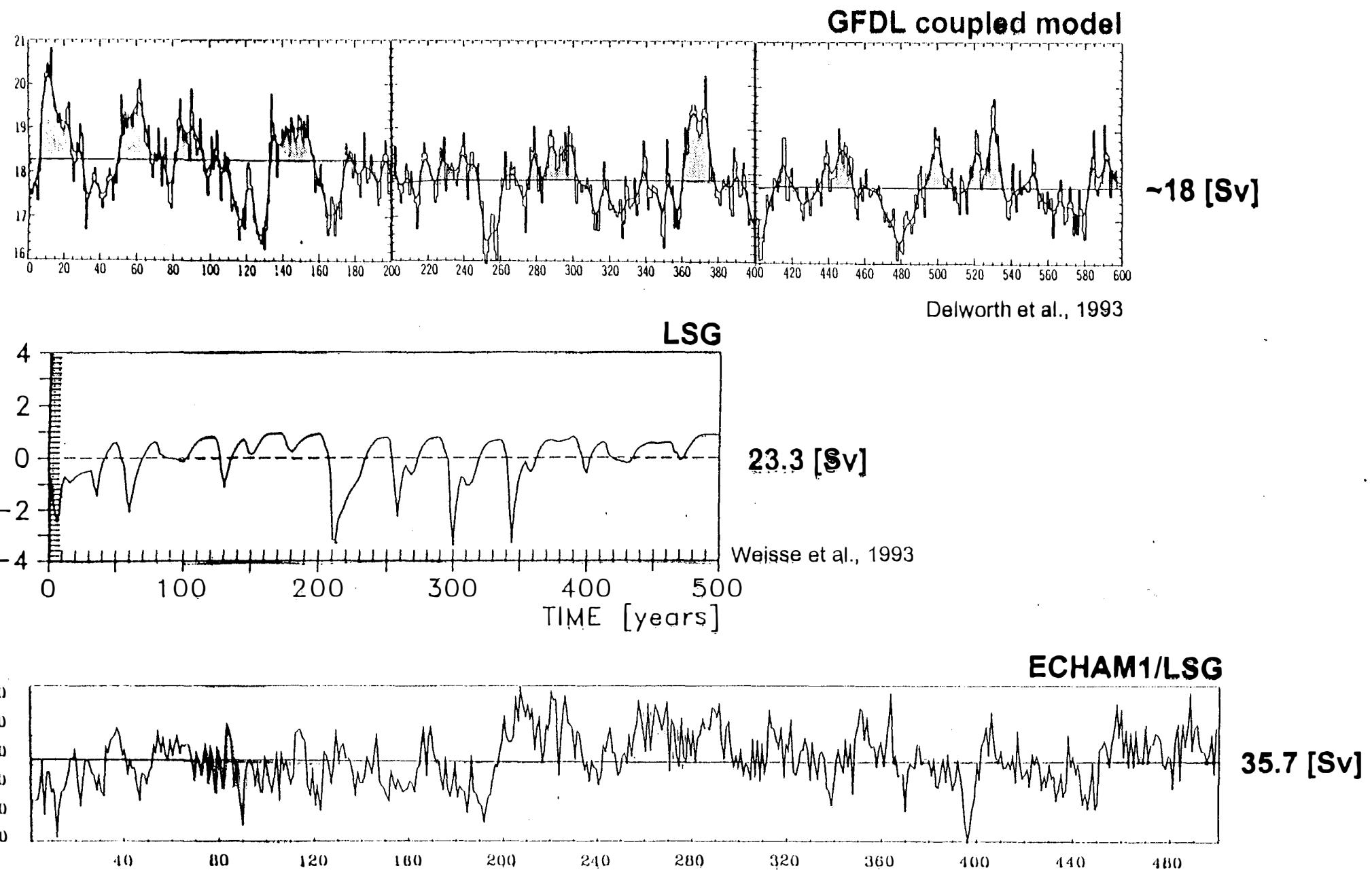
C - 14



C-14 (QUICK) 7.5M/Y

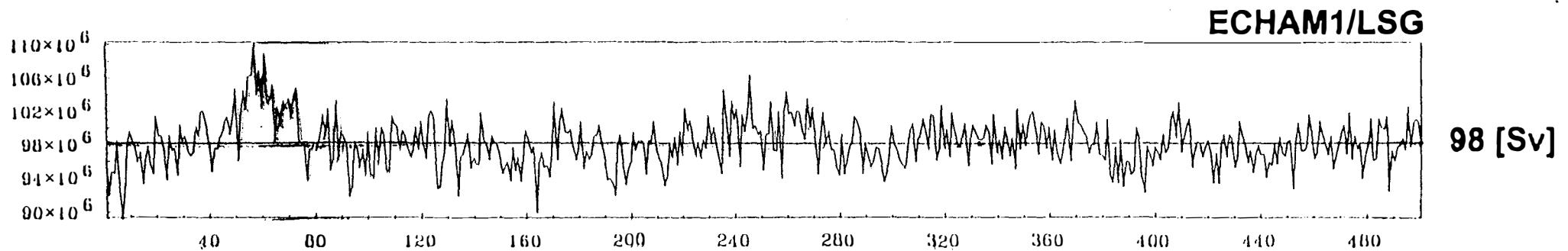
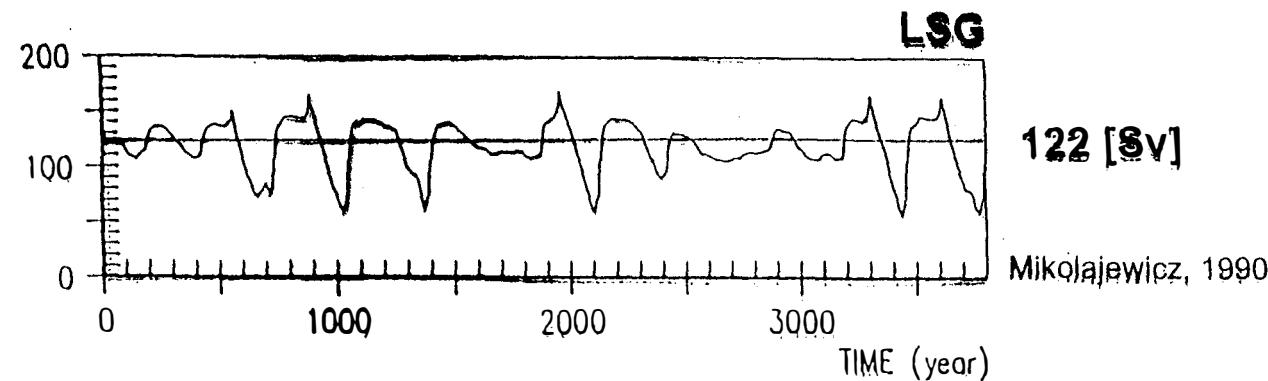


# Intensity of the Index of the Meridional Overturning in the North Atlantic

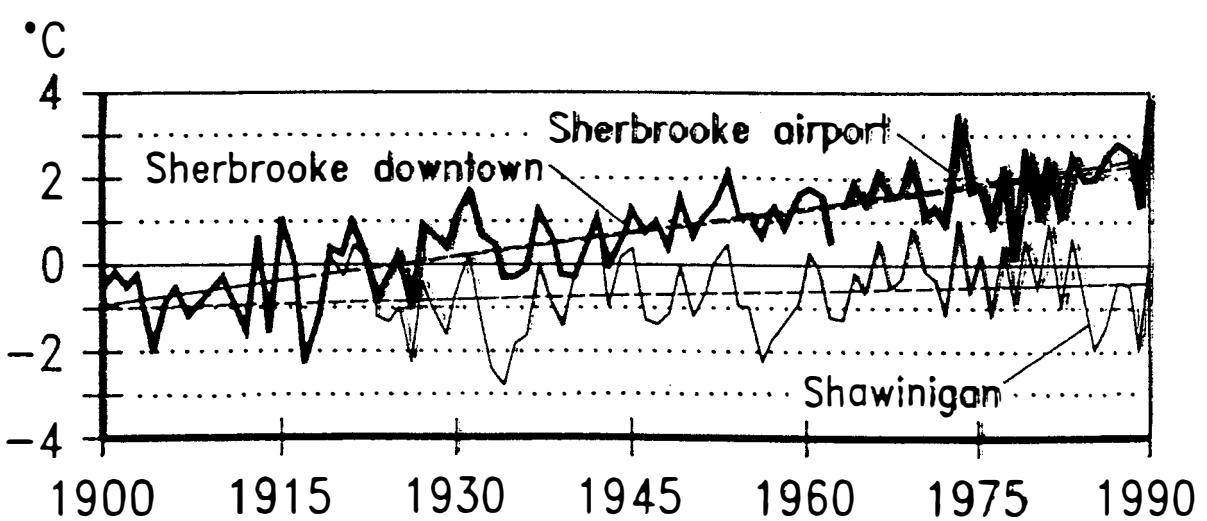
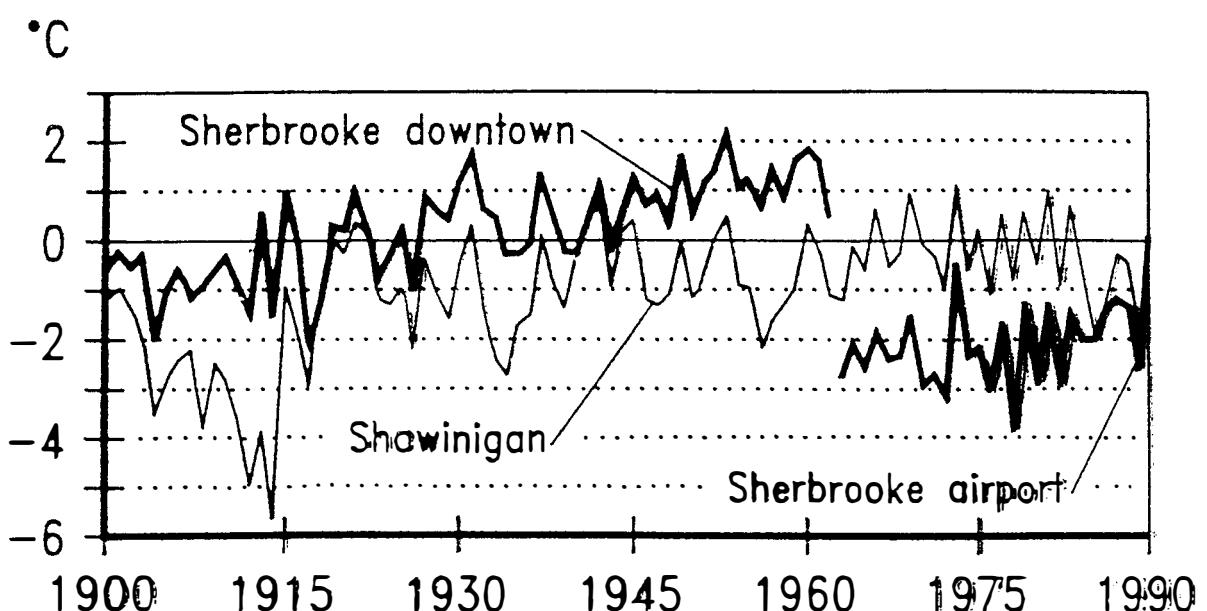


from J. von Storch (1994)

## Intensity of the Masstransport through the Drake Passage



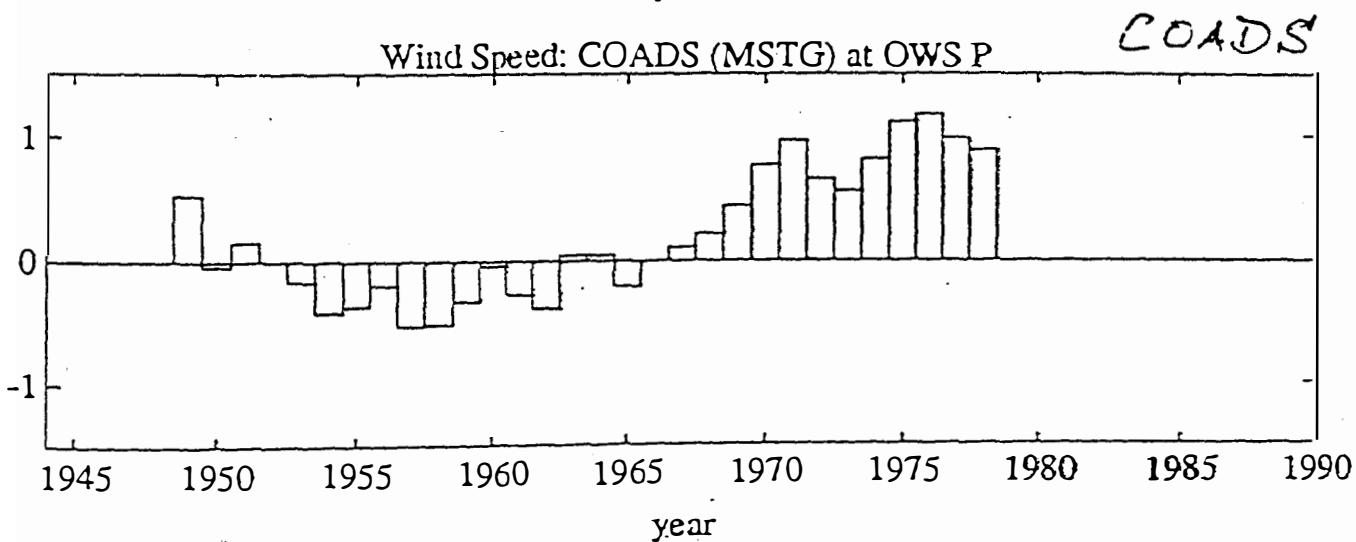
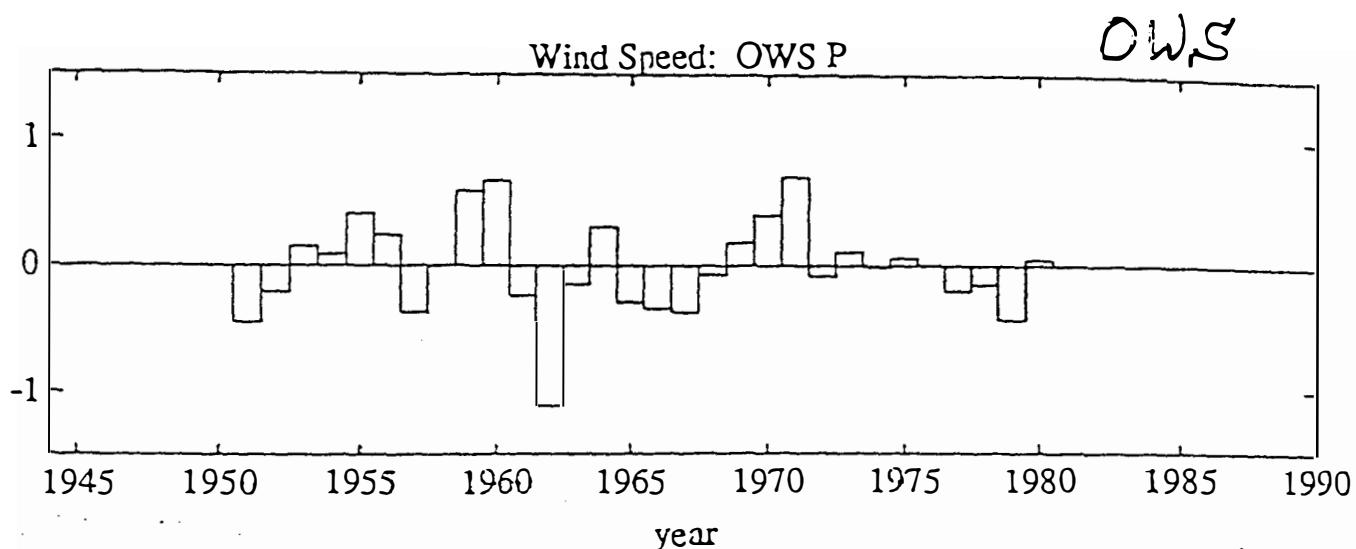
from J. von Storch (1994)



122HVSb

30

OWS P



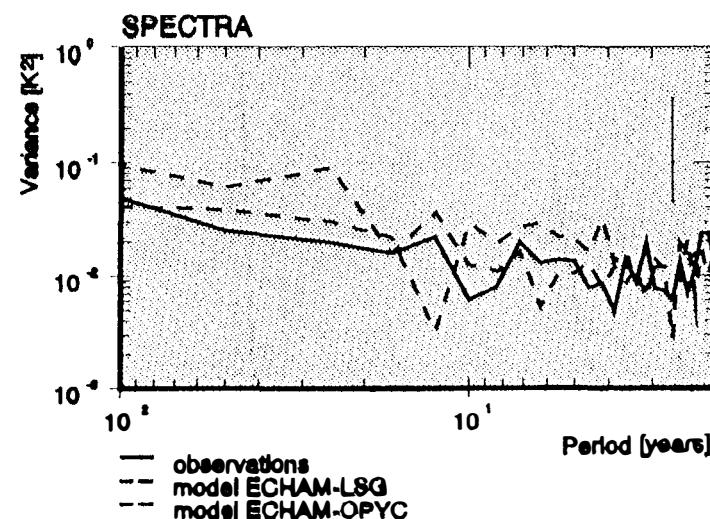
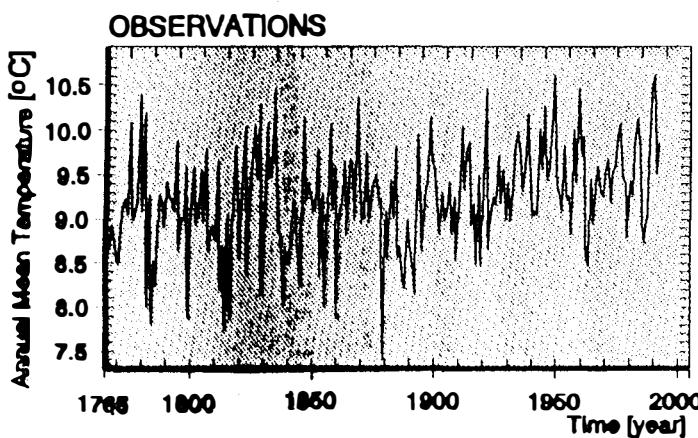
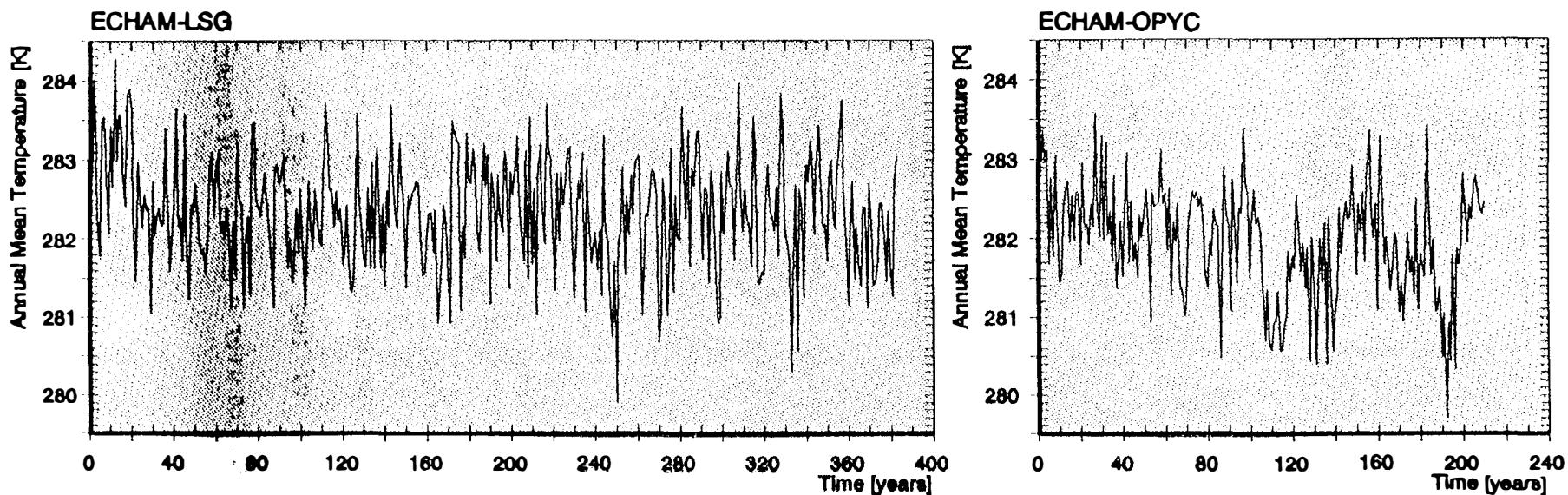
OWS :  $b = -0.02 \text{ ms}^{-1}/10y$        $R = -0.07$

COADS :  $b = +0.52 \text{ ms}^{-1}/10y$        $R = +3.70$

$S_m = 0.59$ ,  $n = 358$

HJ | semer

# VARIABILITY IN A SINGLE-POINT TIMESERIES (CENTRAL ENGLAND)



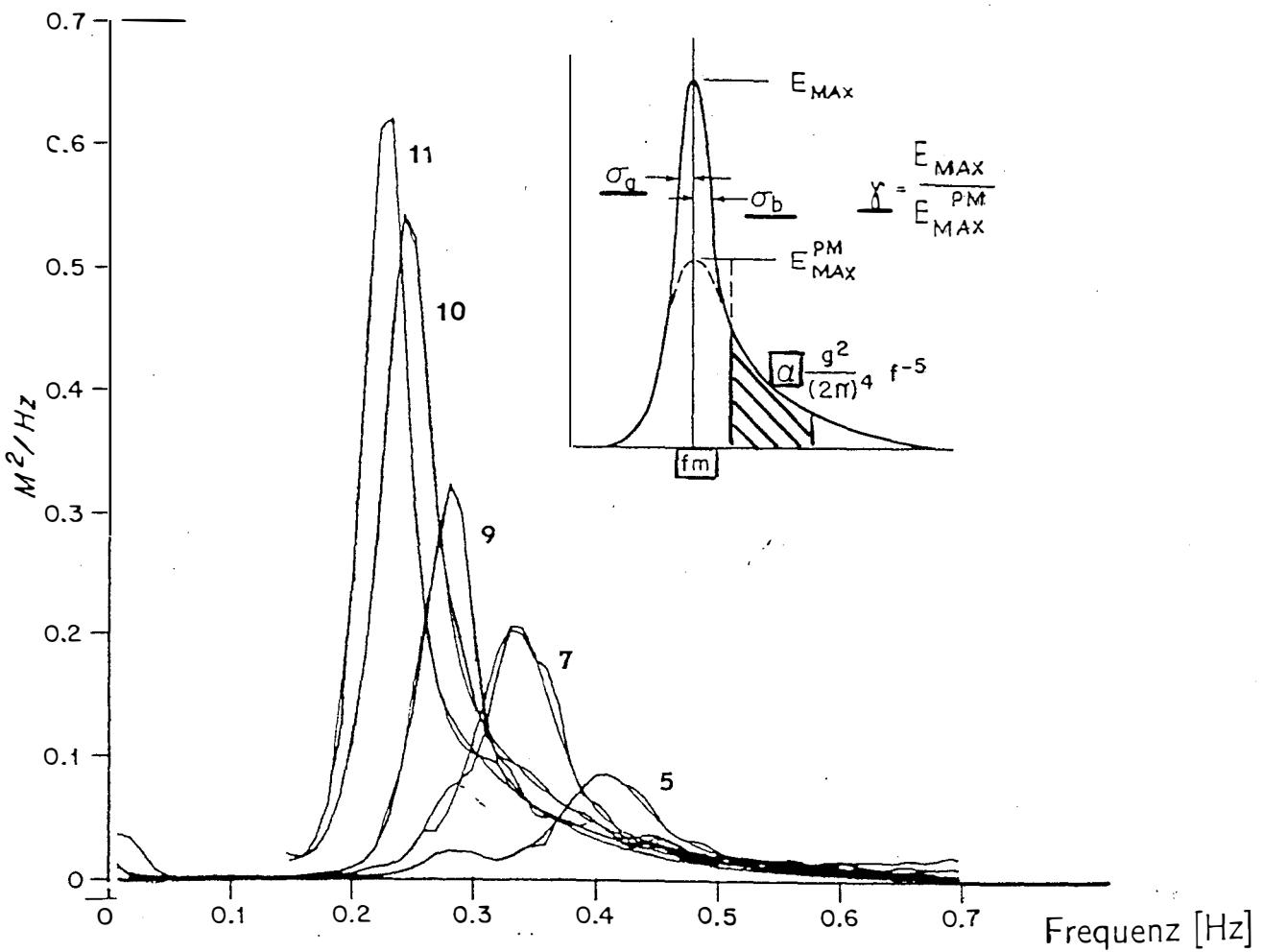
G18GCHf  
Gohl Hegerl

# **Improvement / Optimization of Climate Models**

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## Modellphysik Eigenschaften und Grundgleichung des Seegangs

ein dimensionales Spektrum  $F(\vec{k}; \vec{x}, t)$  beschreibt den Seegangszustand  
 $(\vec{x}, t)$ : Ort und Zeit;  $\vec{k}$ : Wellenzahlvektor mit  $k = |\vec{k}| = \frac{2\pi}{\lambda}$ , Dispersionsrelation  $\omega = \sqrt{gk}$ )



zeitliche und räumliche Entwicklung des Spektrums:

Energiebilanzgleichung (Hasselmann (1960))

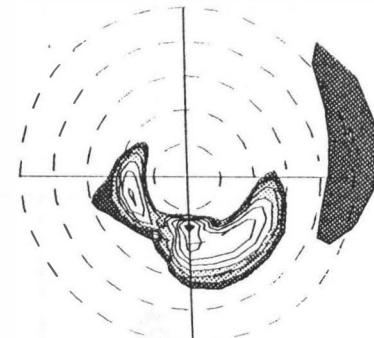
$$\frac{D}{Dt} F = \frac{\partial F}{\partial t} + \vec{c}_{gr} \vec{\nabla} F = S_{\text{tot}} = S_{\text{in}} + S_{\text{ds}} + S_{\text{nl}} + \dots ; \quad S = S(\vec{k}; F(\{\vec{k}_i\}_{i \in I}))$$

$\vec{v} = \vec{\nabla}_k \omega(k) = \frac{1}{2} \vec{c}_{ph}$ : Gruppengeschwindigkeit ( $c_{ph} = \frac{\omega}{k} = \frac{g}{\omega}$ : Phasengeschwindigkeit)

# X Atlantic 93-01-30 corrWAM 1.it

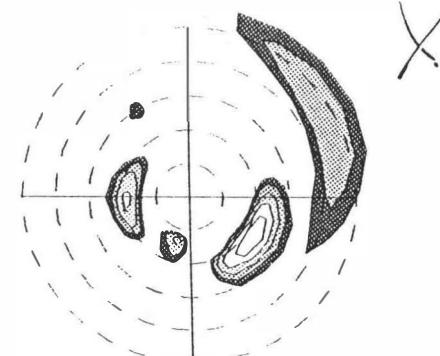
Time: 93- 1-30 11:36  
 Long.: -35.00 Lat.: -56.00  
 U\*: 8.56 m/s 0. Deg

Time: 93- 1-30 11:36  
 Long.: -34.00 Lat.: -54.00  
 U\*: 8.48 m/s 0. Deg



Hs: 2.24 M  
 MEAN  
 -Frg.: 0.11 Hz  
 -Dir.: 168. Deg

PEAK  
 -Max.: 5.78  
 -Frg.: 0.07 Hz  
 -Dir.: 180. Deg

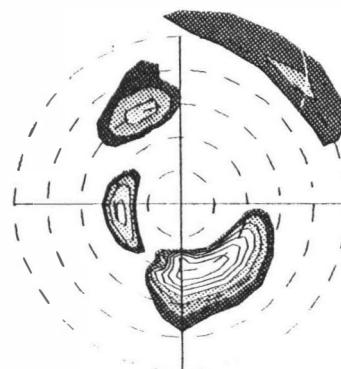


Hs: 1.58 M  
 MEAN  
 -Frg.: 0.13 Hz  
 -Dir.: 99. Deg

PEAK  
 -Max.: 1.43  
 -Frg.: 0.11 Hz  
 -Dir.: 120. Deg

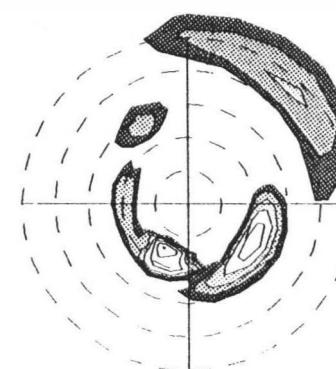
Time: 93- 1-30 11:36  
 Long.: -33.00 Lat.: -53.00  
 U\*: 8.39 m/s 0. Deg

Time: 93- 1-30 11:36  
 Long.: -32.00 Lat.: -51.00  
 U\*: 10.33 m/s 0. Deg



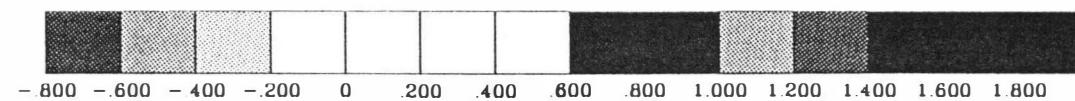
Hs: 2.14 M  
 MEAN  
 -Frg.: 0.12 Hz  
 -Dir.: 158. Deg

PEAK  
 -Max.: 3.88  
 -Frg.: 0.10 Hz  
 -Dir.: 185. Deg

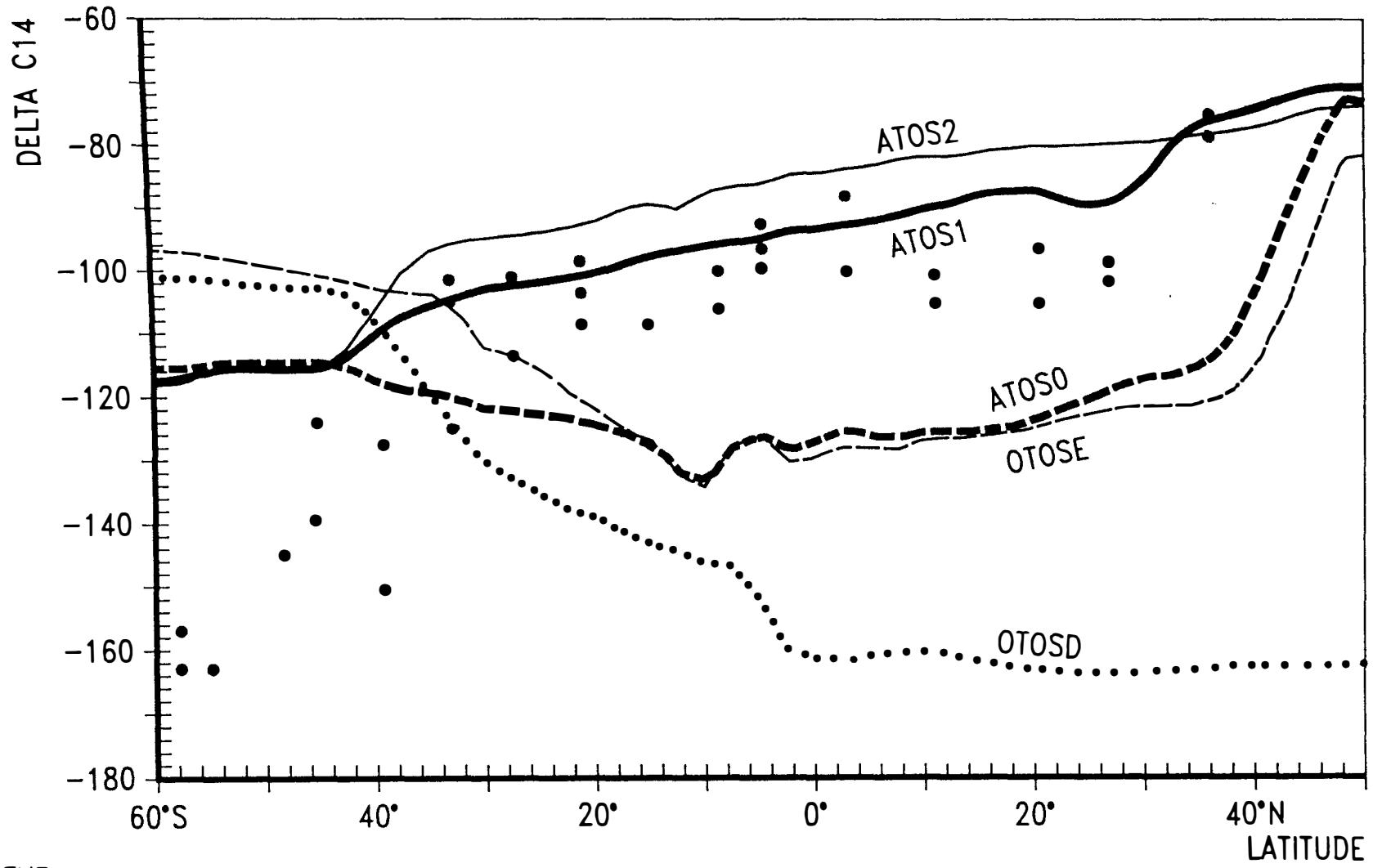


Hs: 1.83 M  
 MEAN  
 -Frg.: 0.13 Hz  
 -Dir.: 132. Deg

PEAK  
 -Max.: 2.64  
 -Frg.: 0.07 Hz  
 -Dir.: 210. Deg



Isolines in logarithmic scale - circles in frequency steps of 0.05 Hz



022EMRa

# Sensitivity Experiments with Climate Models

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atmospheric models

effect of anomalous SST

Example: June 1988

oceanic models

anomalous heating/mixing

Example: North Pacific

1950-80

coupled models

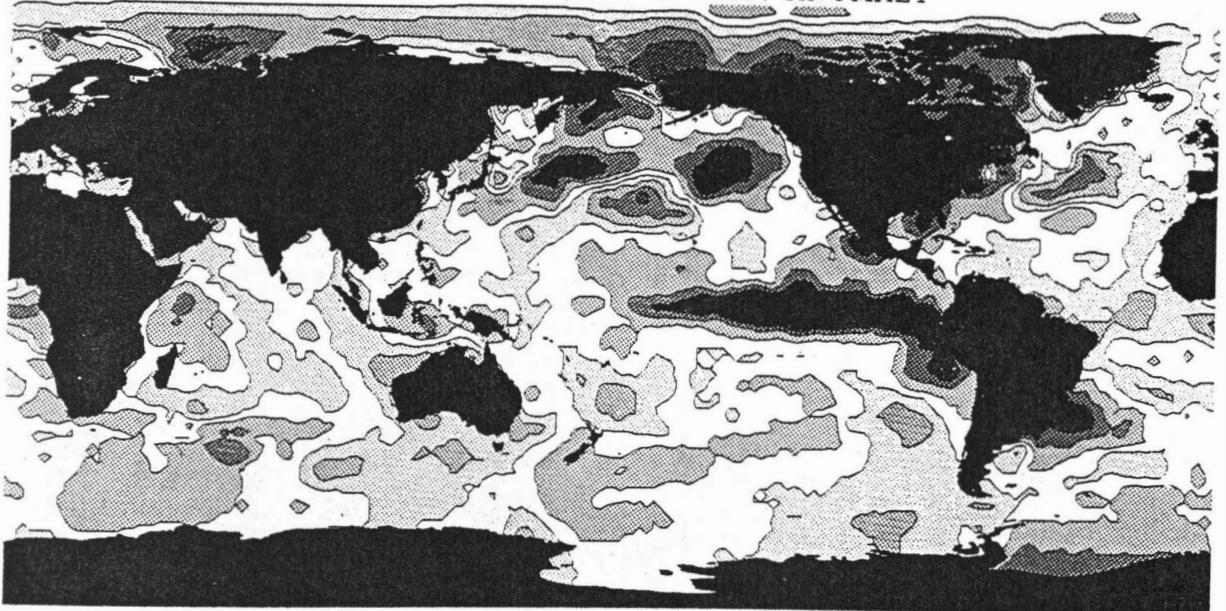
effect of anomalous

radiative forcing

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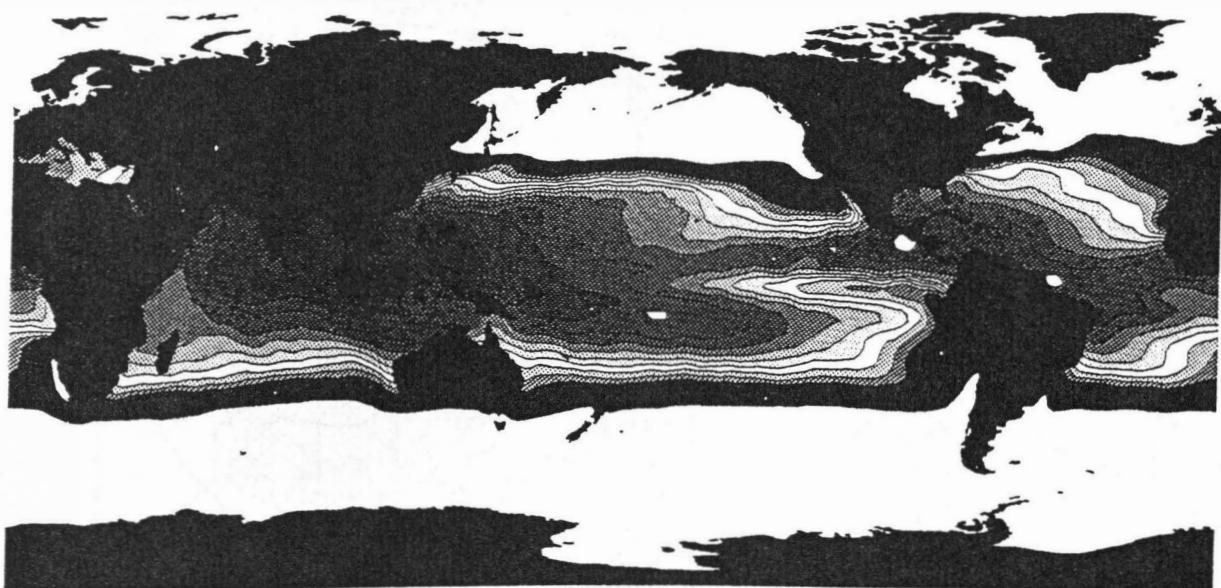
36

JUNE 1988 GLOBAL SST. 2\*2 LAT/LONG GRID. ANOMALY

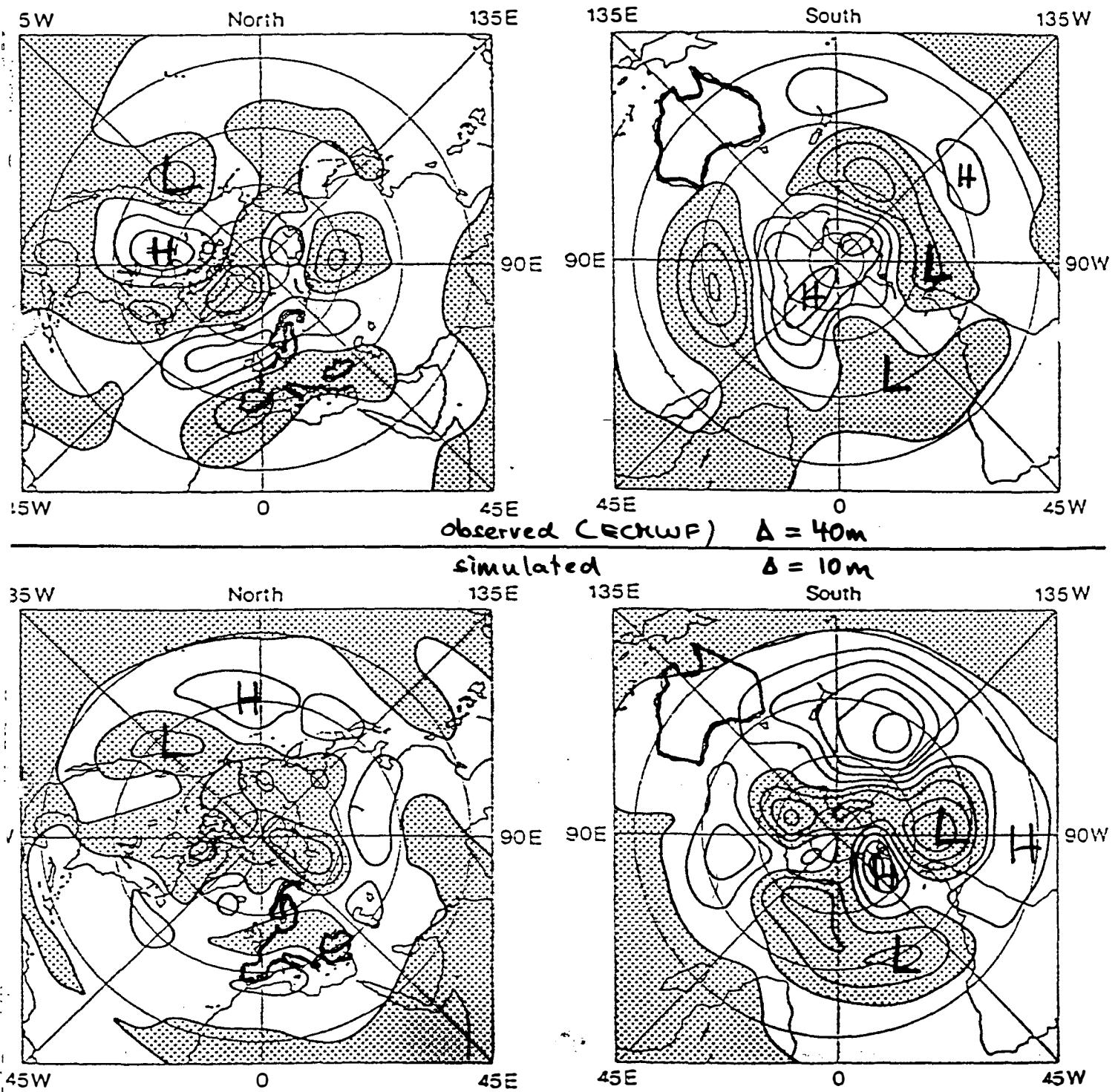


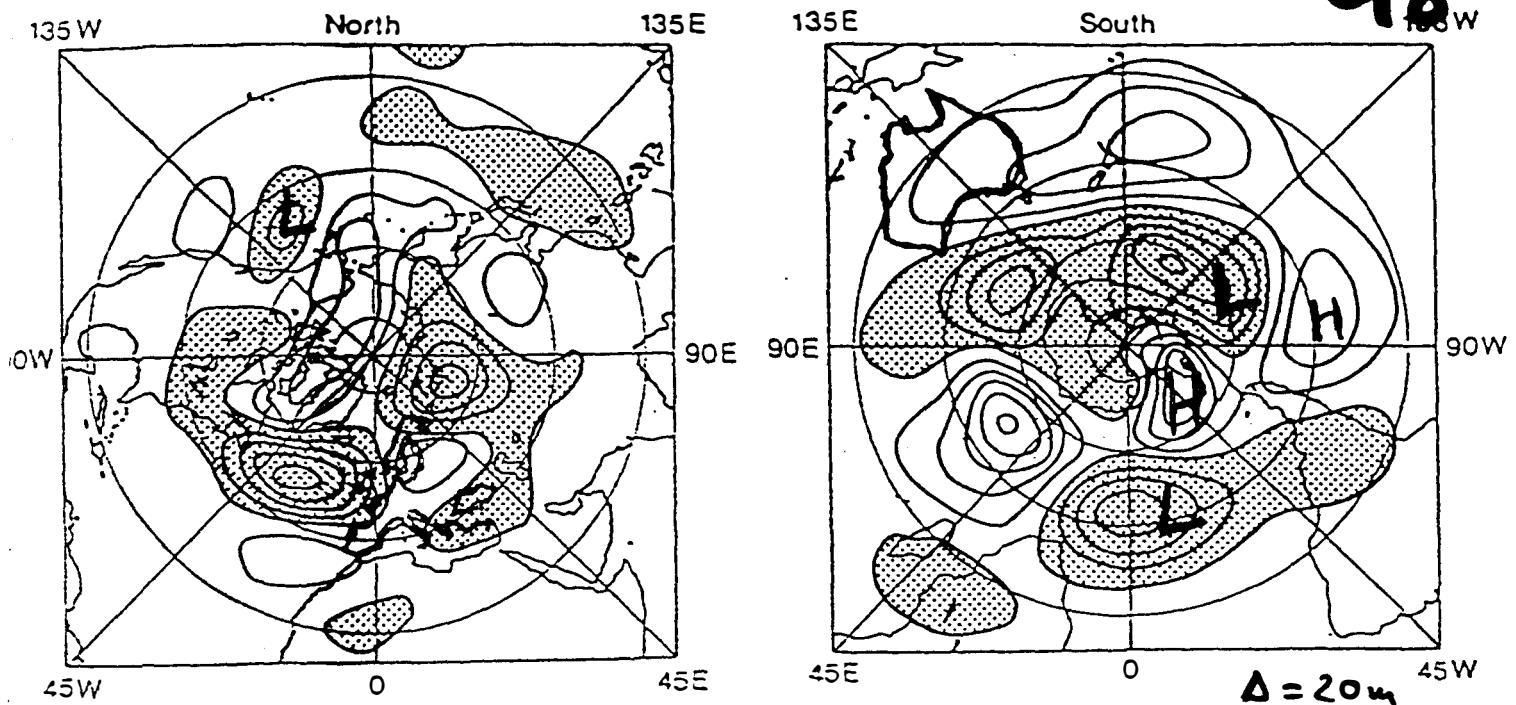
-3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 DEG

JUNE 1988 GLOBAL SST. 2\*2 LAT/LONG GRID



16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0 30.0 DEG



18  
100W

Result of two "T42" realizations  
of "June-88"  $Z_{500}$ .

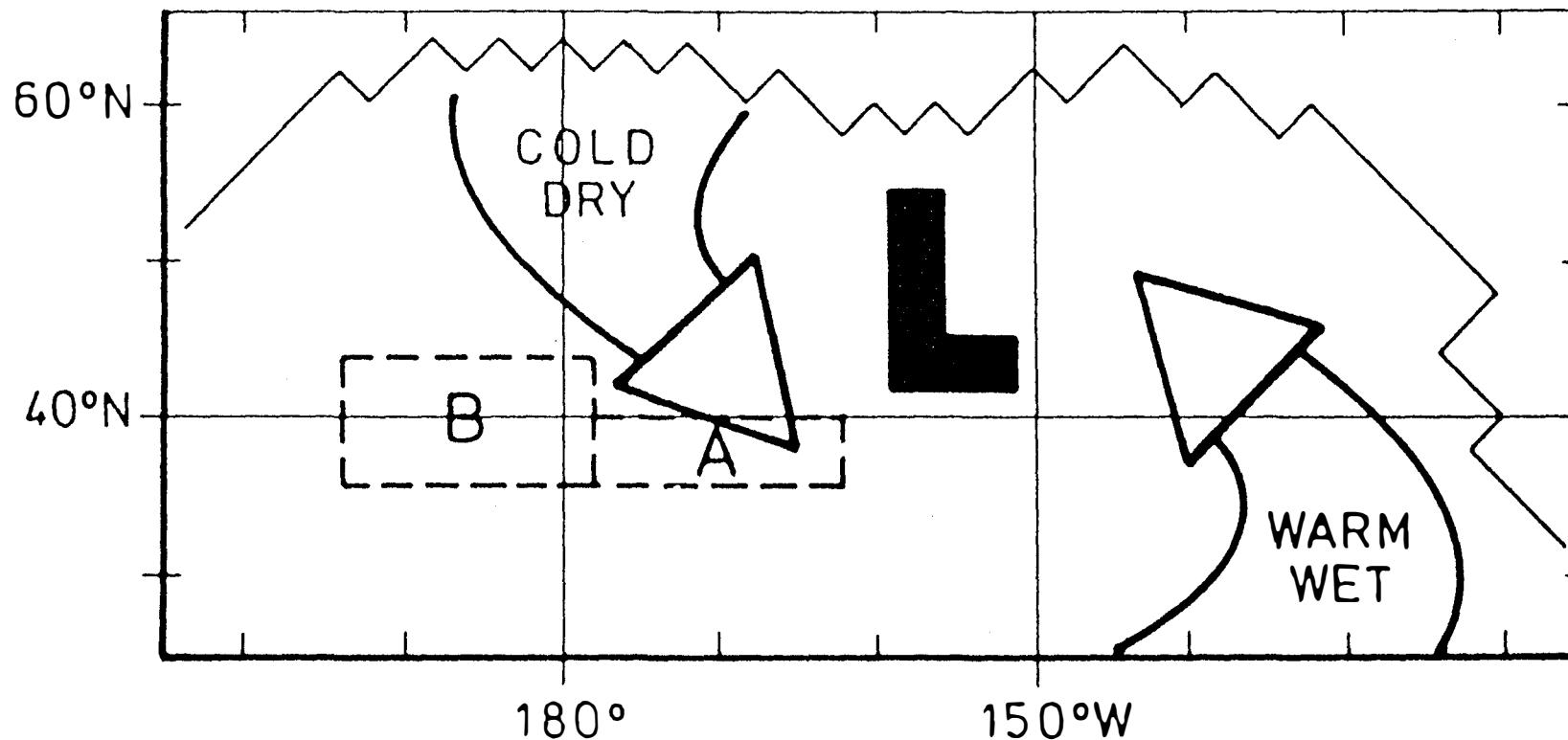


Fig. 1. Schematic map of the anomalous wintertime flow during a warm SO event (after a 700 mb height composite given by Van Loon and Rogers, 1981). Time series of observed and simulated *SST* anomalies averaged in area *A* and *B* are shown in the third part of the fourth section.

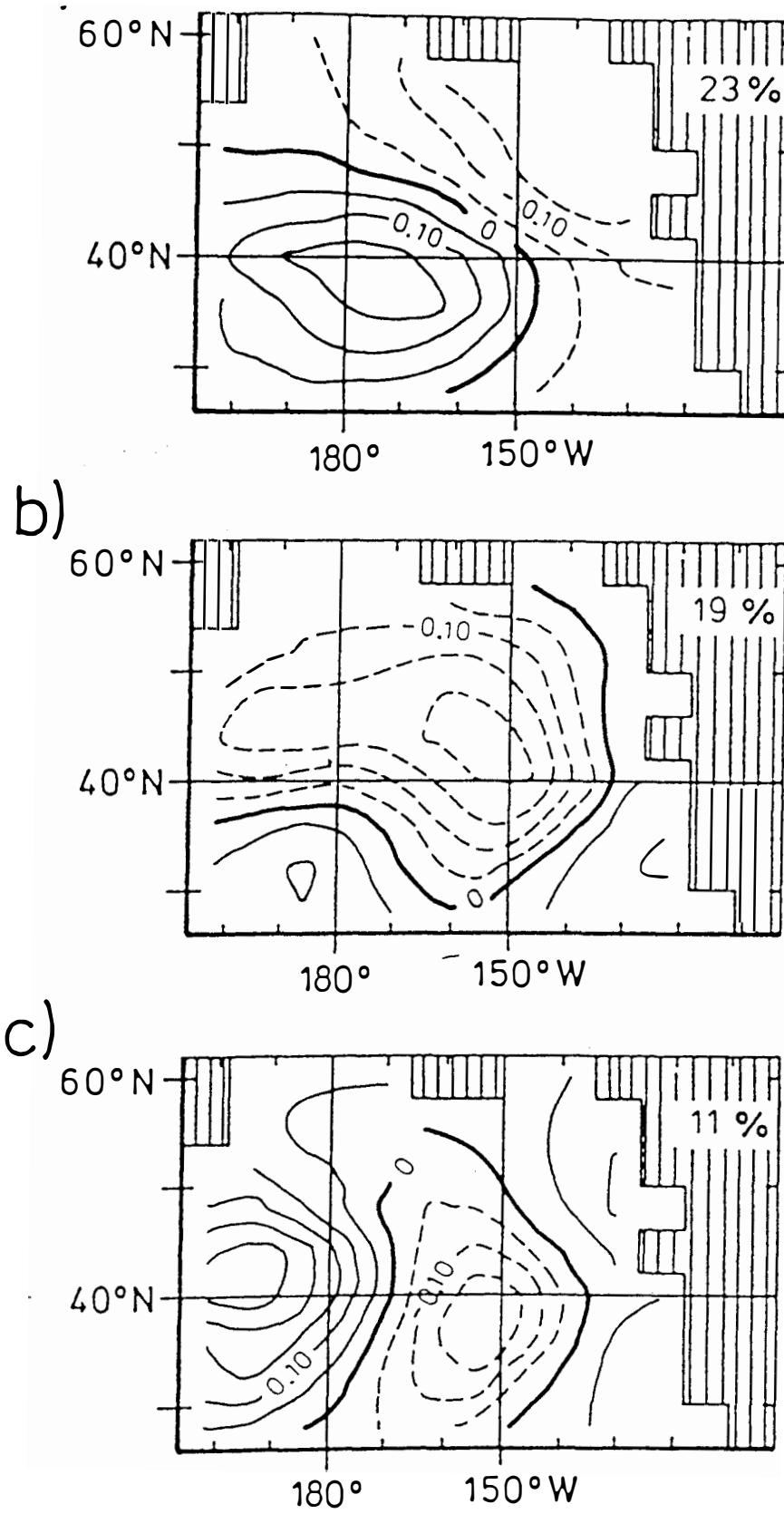


Fig. 4. EOF analysis of the observed *SST* anomalies derived from 1950–1979 COADS (360 months). (a) first EOF, explained variance: 23%. (b) second EOF, explained variance: 19%. (c) third EOF, explained variance: 11%.

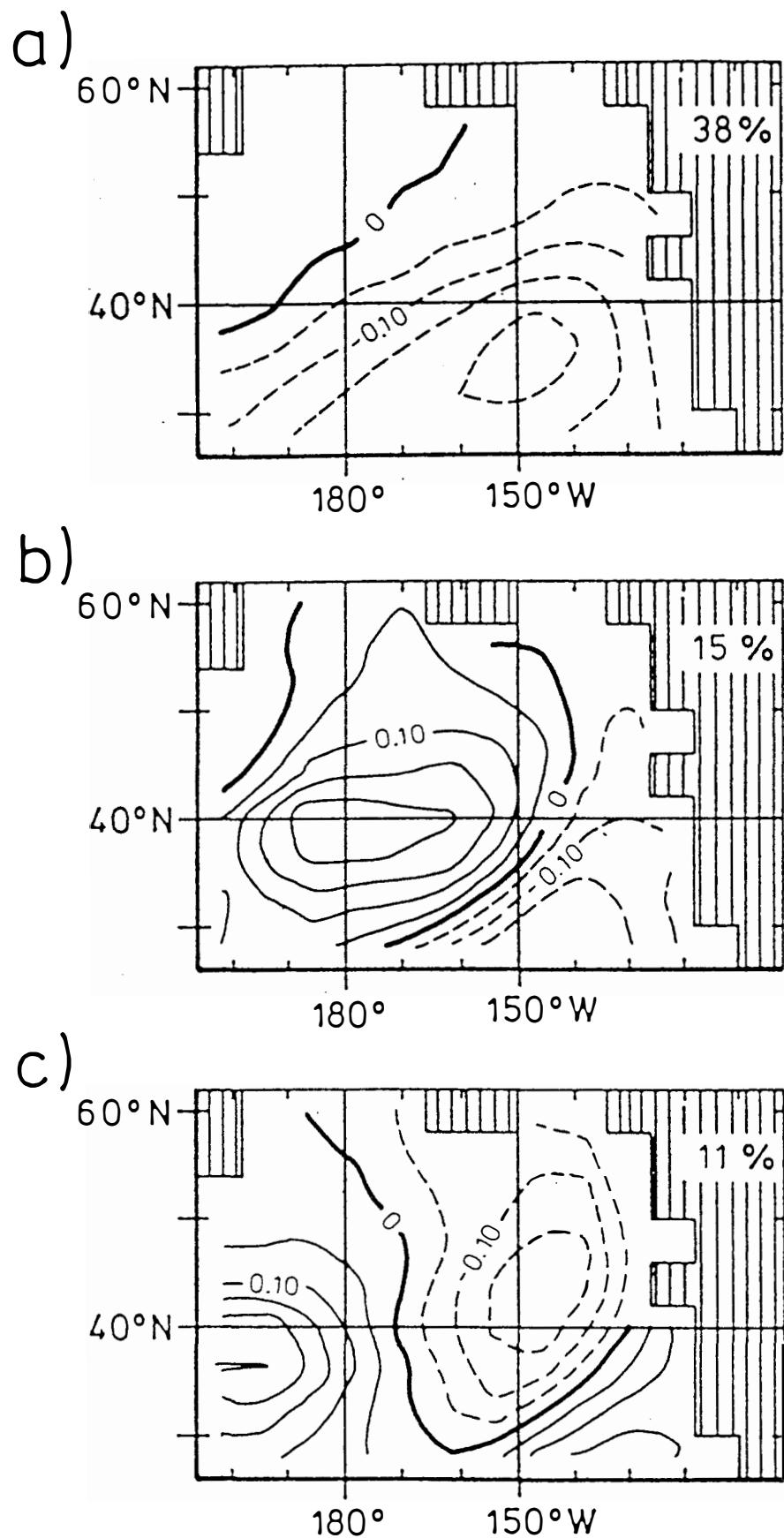


Fig. 7. EOF analysis of the *SST* anomalies simulated in experiment II (anomalous heat fluxes derived from the temperature advection model) based on 360 monthly means. (a) first EOF, explained variance: 38%. (b) second EOF, explained variance: 15%. (c) third EOF, explained variance: 11%.

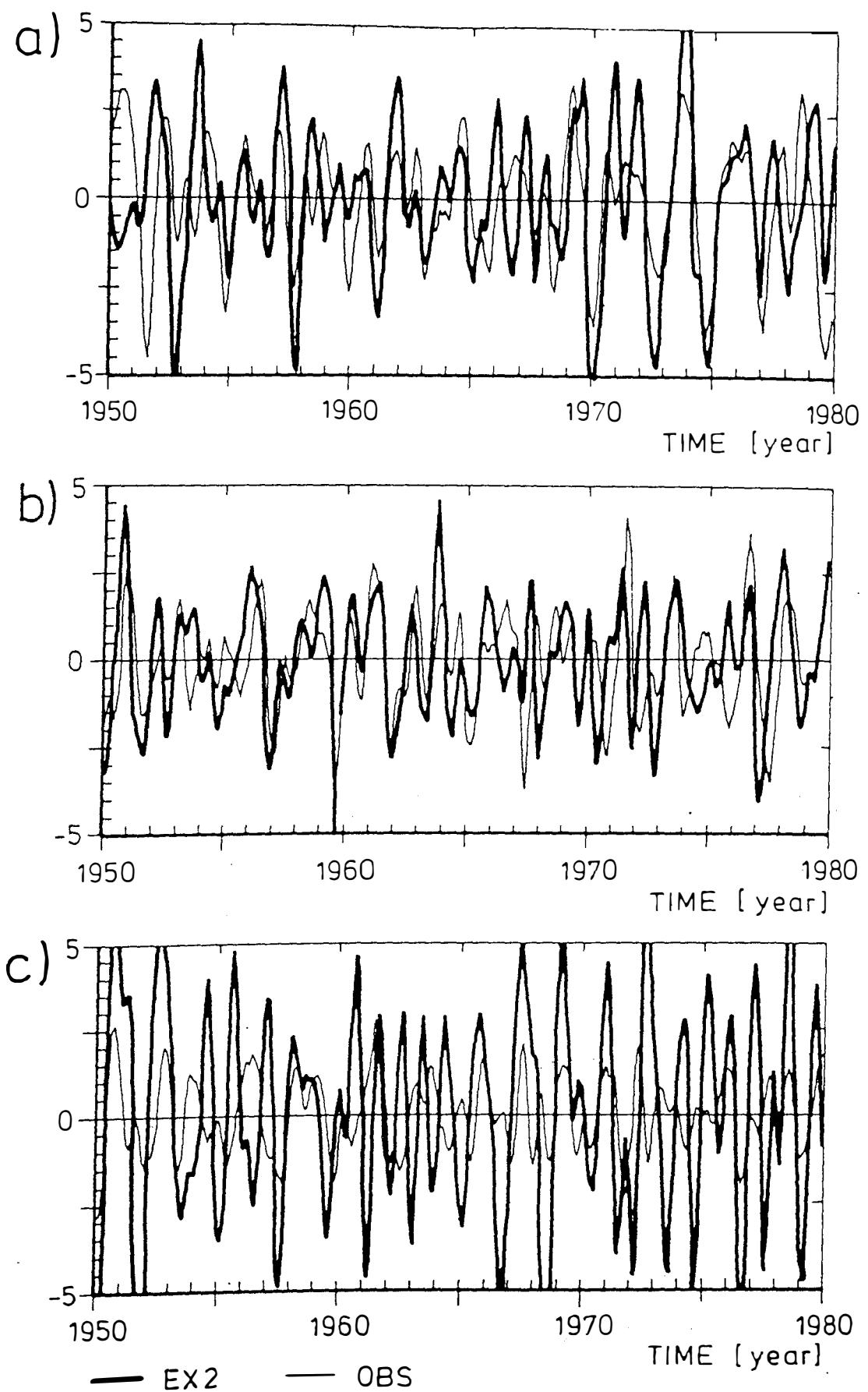
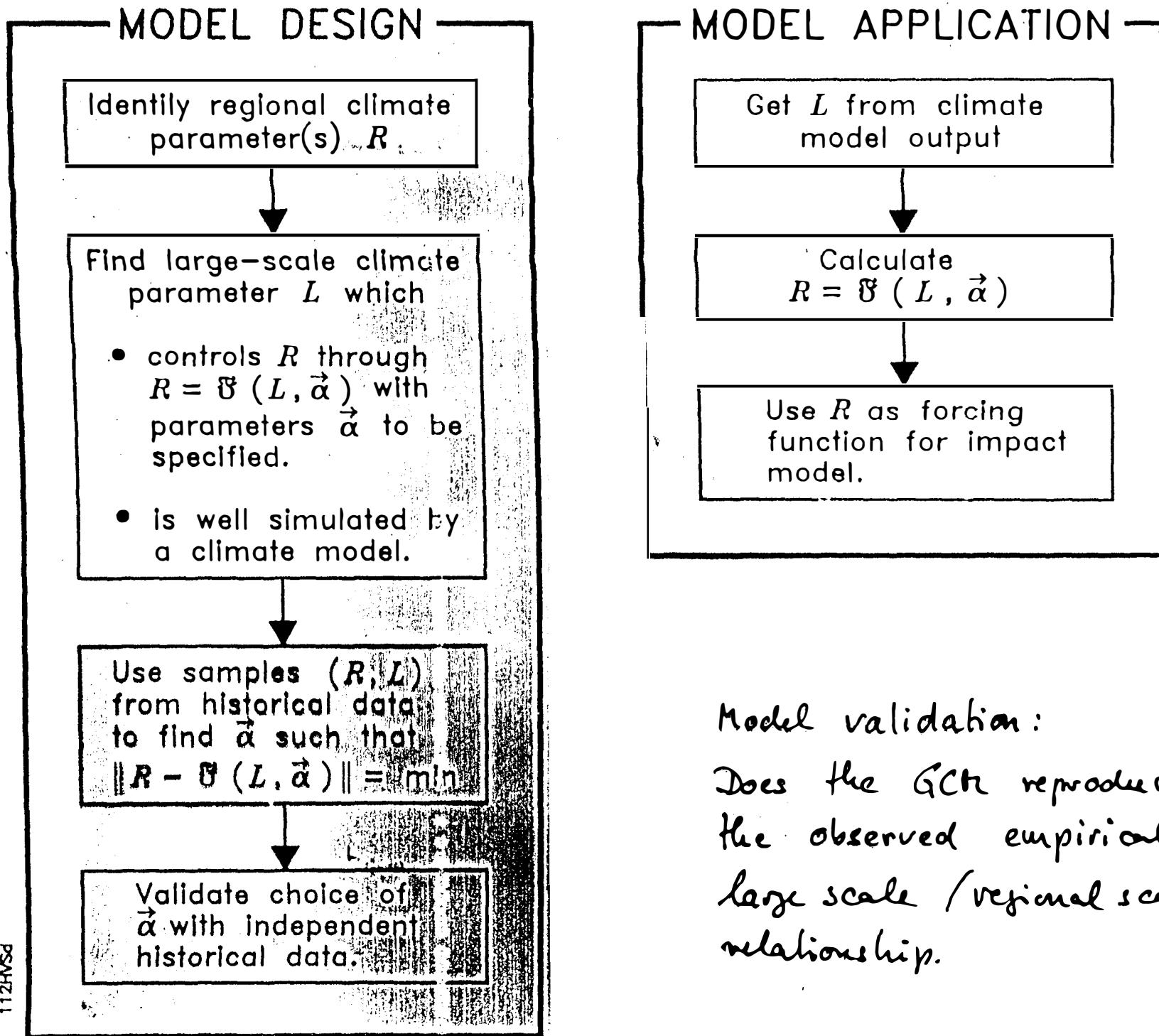


Fig. 8. Coefficient time series of the first three observed (continuous line) and experiment II (heavy line) EOF. The data are smoothed by a 5-months running mean filter. (a) first observed EOF, second simulated EOF. (b) second observed EOF, third simulated EOF. (c) third observed EOF, first simulated EOF.

# Empirical Models

- For some applications general circulation models can not be used directly because of limited computational resources.
- Climate Models return useful information only for spatial scales which are larger than a few grid sizes. Information required by most “users” (regional oceanographers, geographers, ecologists ...) concern spatial scales of the order of tens to few hundredths of kilometers.  
“Statistical Downscaling” is a wholesale option to satisfy this demand by postprocessing climate model output with such procedures.
- Climate models can neither be run often nor be expressed as an invertible function which relates forcing and climate state. Such functions are needed for “Global Environment and Society” models.  
Statistical climate models, which summarize the experience gathered in the observational record or in the output of a dynamical climate model, can be used in such cases.

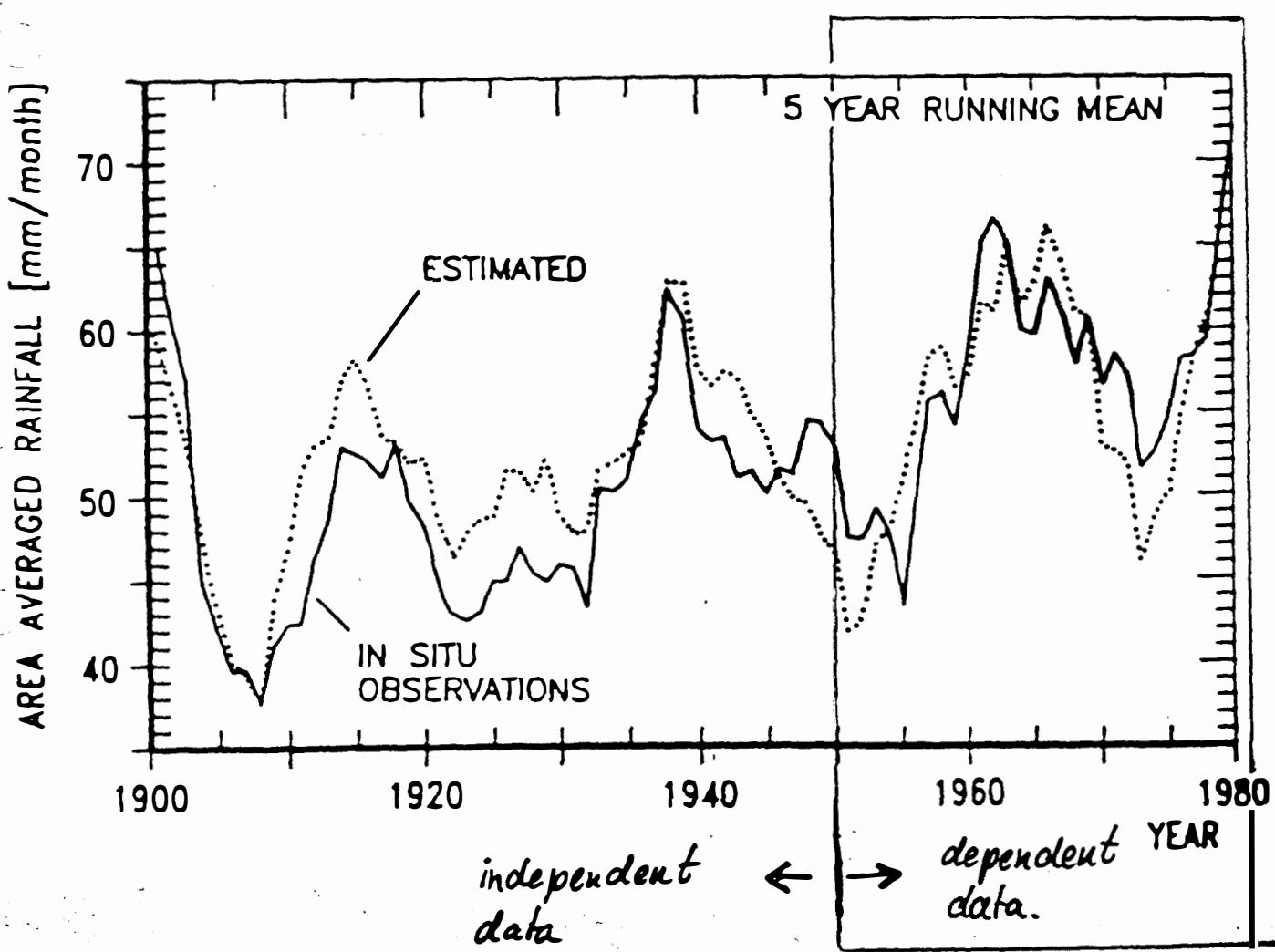


Model validation:

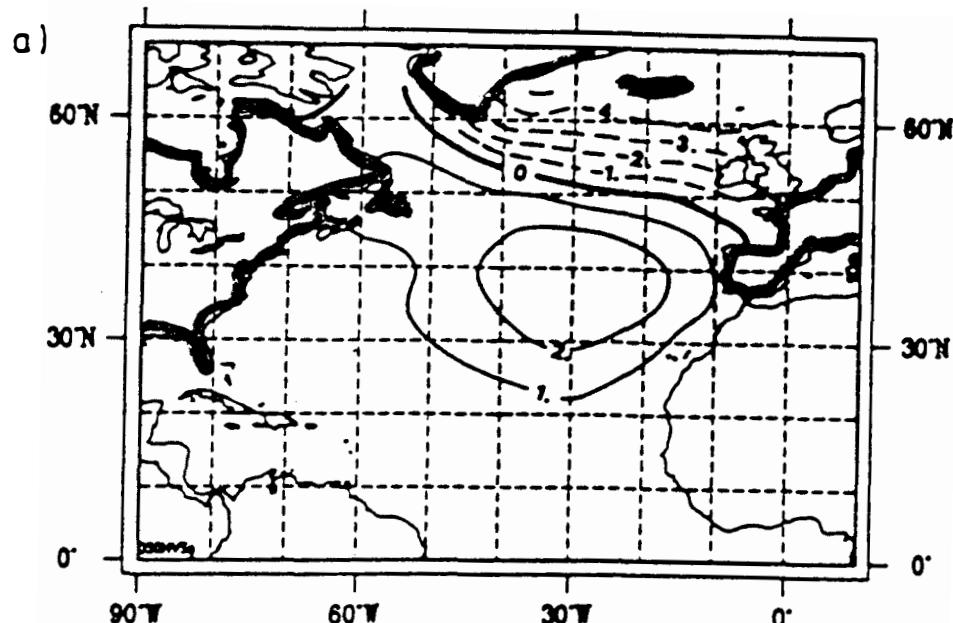
Does the GCM reproduce the observed empirical large scale / regional scale relationships.

**Figure 5.**

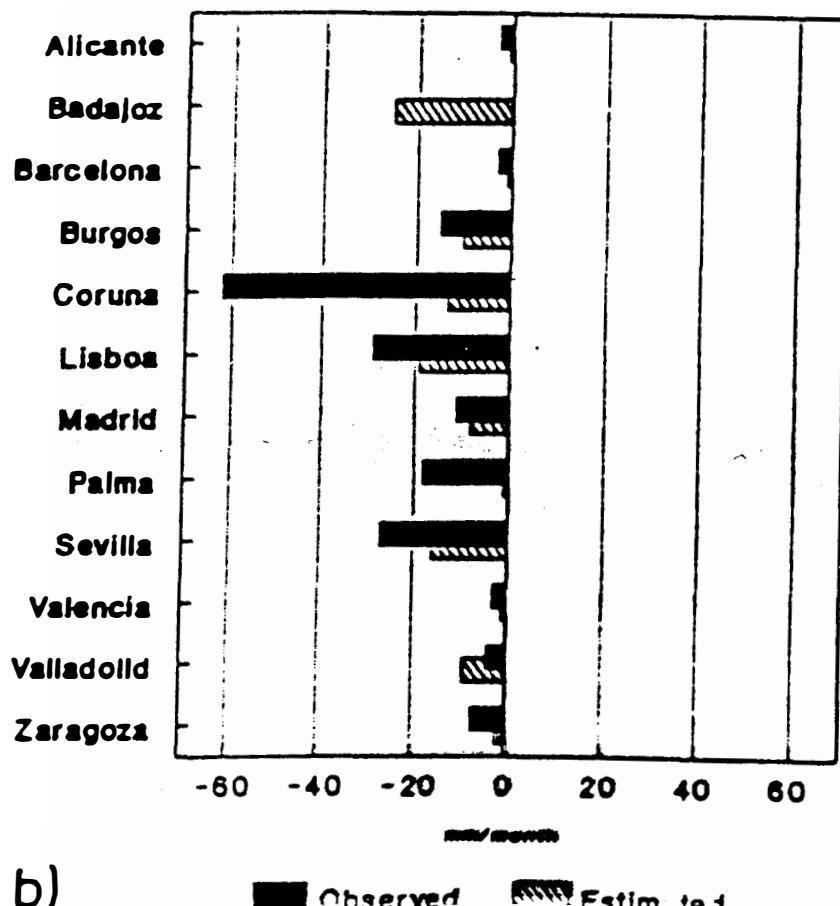
Five-year-running mean time series of area-averaged winter (DJF) mean rainfall (mm/month) as derived from station data and as derived indirectly from the state of the North Atlantic SLP field. Because of the lack of data in the WMSC data-set in the early part of the century, nor the WMSC stations but those with a complete record 1900-1980 in the Universidad Complutense station data set have been used.



- a) Observed winter mean SLP difference (mb), derived from NCAR data  
 b) Winter precipitation differences (mm/month) at the 12 stations contained in both the Complutense data-set and in the WMSC data-set. Solid: in-situ observations. Hatched: rainfall difference estimated from the SLP difference shown in a).



## Decadal DJF rainfall differences 1904-13 vs. 1951-60

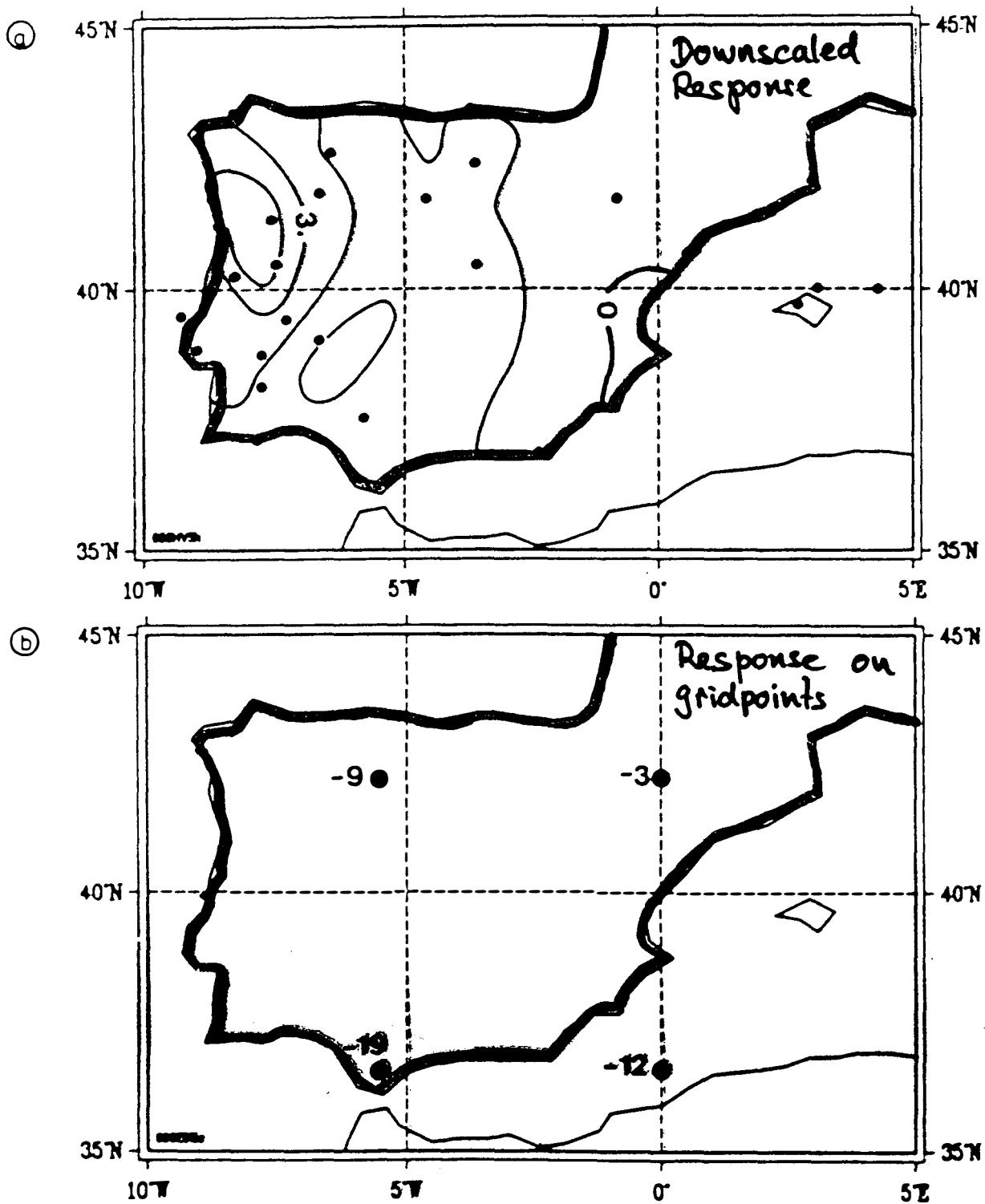


**Figure 9.**

Regional change of winter Iberian rainfall (mm/month) in the "2xCO<sub>2</sub>"-experiment.

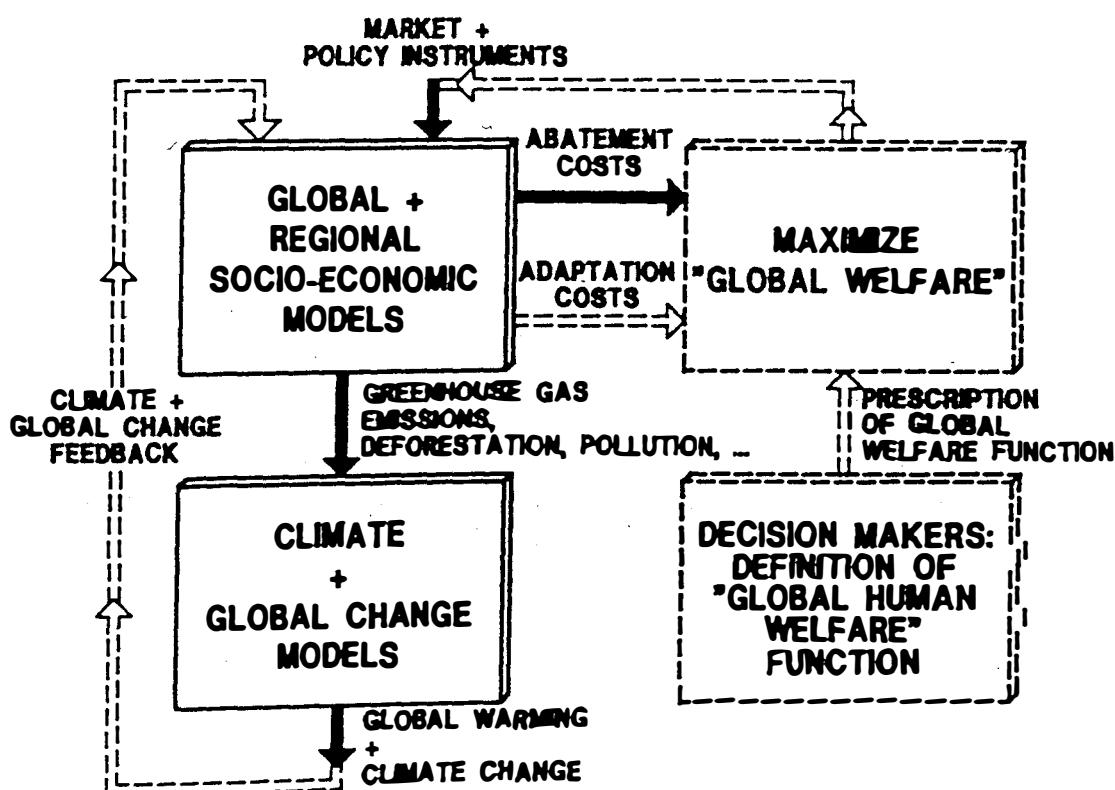
(a) Directly simulated by the GCM.

(b) Indirectly derived from the simulated change of the North Atlantic SLP field.



2. CO<sub>2</sub> climate change experiment  
with MPI coupled climate model.

## GLOBAL ENVIRONMENT AND SOCIETY (GES) MODEL



092HVSe

- after Hasselmann (1990)
- simple version implemented by Tahvonen et al. (1993)

OPTIMAL  $E^*(t)$

**ECONOMIC MODEL**

$$A(t) = a \left[ 1 - E(t)/E_b(t) \right]^2$$

$$D(t) = d\dot{T}(t)$$

$$A(t)$$

$$D(t)$$

**MAXIMIZE INTEGRATED WELFARE**

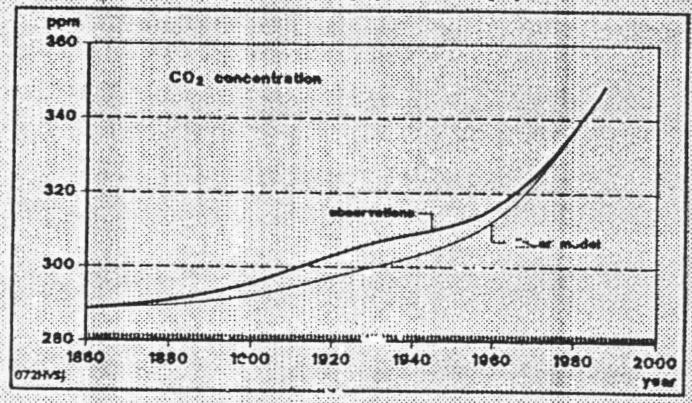
$$\max_{E(t)} \int_0^{100} [U_0 - A(t) - D(t)] e^{(r-\delta)t} dt$$

$$T(t)$$

$$E(t)$$

**CARBON CYCLE MODEL**

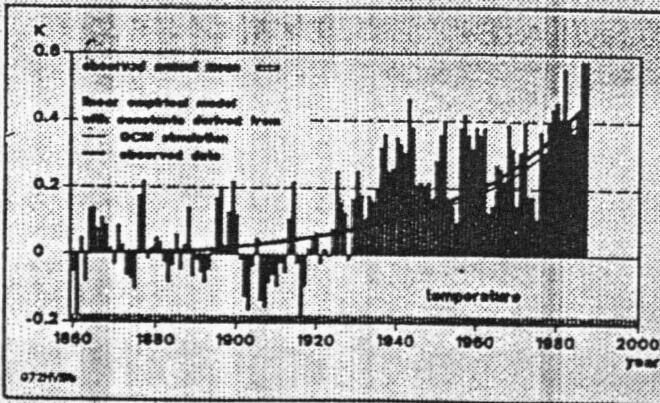
$$\dot{C}(t) = \beta E(t) - \sigma C(t)$$



$$C(t)$$

**CLIMATE MODEL**

$$\dot{T}(t) = \mu C(t) - \alpha T(t)$$



**DECISION MAKERS**

**BLACK STRATEGY**

$$d \neq 0$$

$$T(100) < \infty$$

$$C(100) < \infty$$

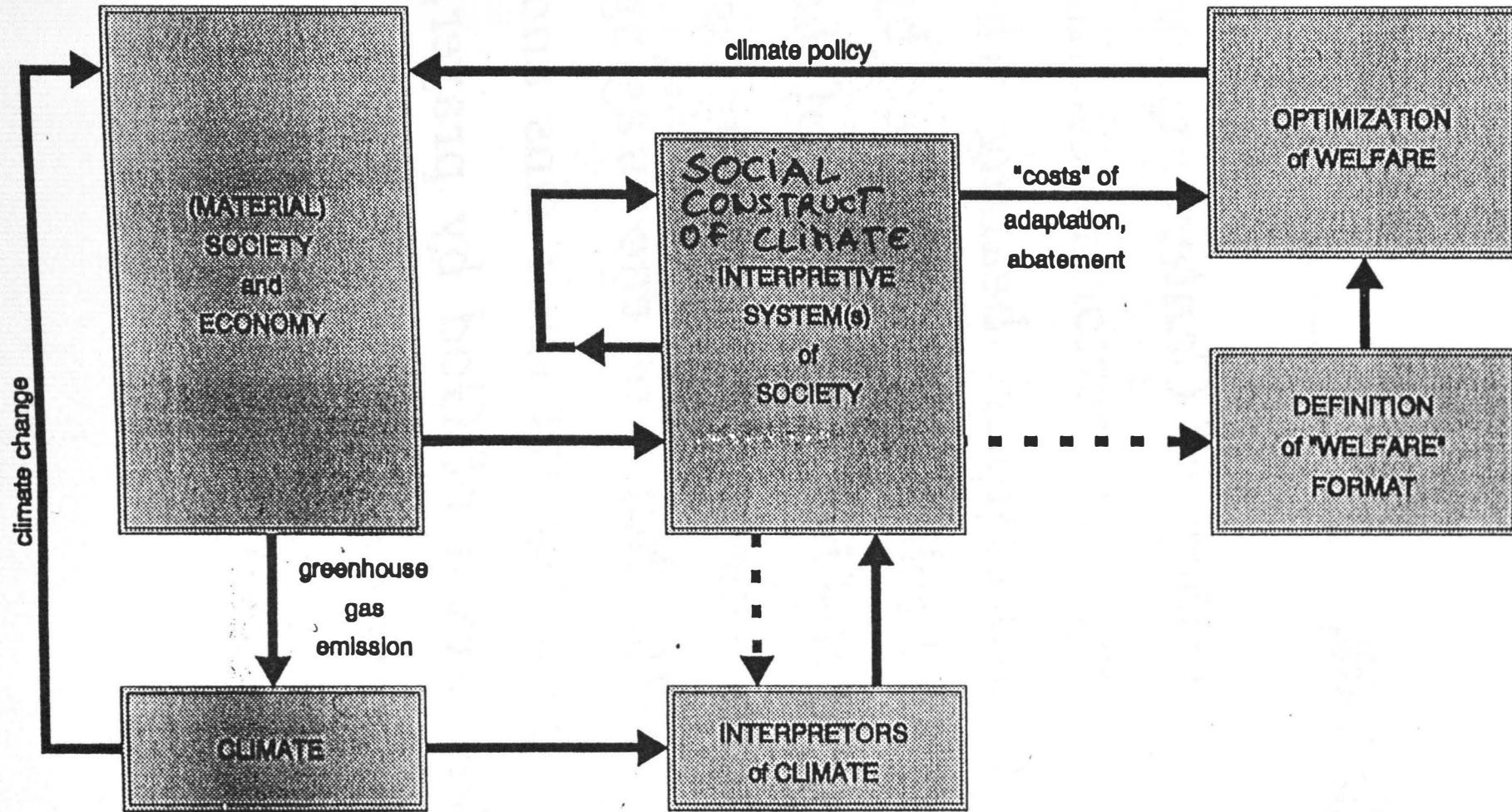
**RED STRATEGY**

$$d = 0$$

$$T(100) < \hat{T}$$

$$C(100) < \hat{C}$$

$$\hat{T} = \frac{\mu}{\alpha} \hat{C}$$



Case 1 : England 1315 - 1317

Rainy summers have severely reduced  
the harvest .... 10% of the population  
left dead ...

... the climate policy

“... the archbishop of Canterbury ordered the clergy to perform solemn, barefooted processions bearing the Sacrament and relics, accompanied by the ringing of the bells, chanting of the litany, and the celebration of the mass. This was in the hope of encouraging the people to atone for their sins and appease the wrath of God by prayer, fasting, alms giving, and other charitable work.”

was successful.

3. juni 84

**POLITIKEN**

## Tegn på klimaændringer

Miljøorganisationen Greenpeace har udsendt en rapport med beskrivelse af 500 ekstreme vejrhændelser – orkaner, rekordtemperaturer, tørke og lignende – fra de seneste tre år. De ekstreme begivenheder er taget til i antal i de senere år og tolkes af Greenpeace som de første tegn på klimaændringer som følge af drivhusseffekten. Rapporten 'Den tidsindstillede klimabombe', der i går blev overrakt til miljøminister Svend Auken (S), vil blive opdateret hver halve år. (Pol)

## Søvand til grundvand

De første forsøg med at danne nyt, rent grundvand ved at pumpe vand op af den plundrede Søvand ved det sive ned

**Is Global Warming**

...

**mainly  
an environmental  
or  
a social problem?**