

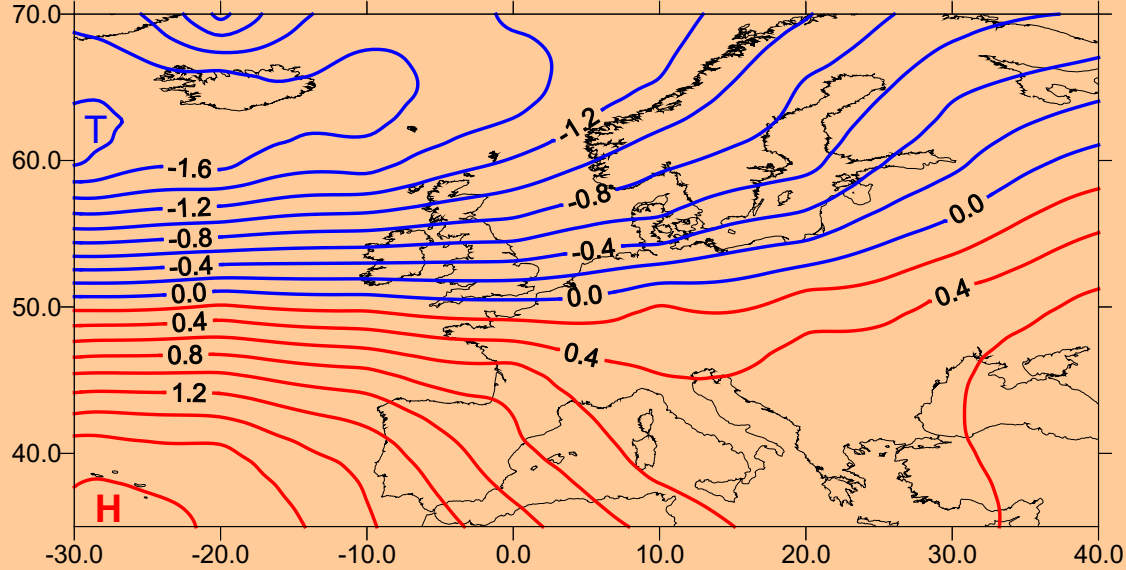
Atmosphärische Zirkulation und Klimawandel

Prof. Dr. Jucundus Jacobeit

**Institut für Geographie
Universität Augsburg**

Mittlere monatliche Luftdruckverteilung im europäischen Raum bei verschiedenen Phasen der Nordatlantischen Oszillation (NAO)

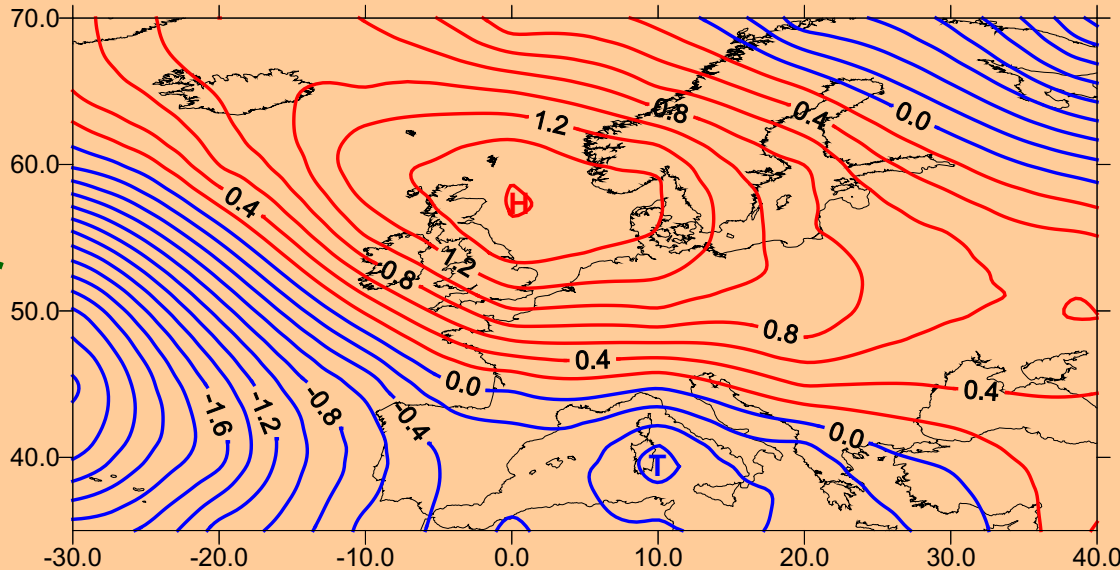
Luftdruckfeld bei positiver Phase der NAO (Beispiel Januar 1984)



Januar
1984

NAO +

Luftdruckfeld bei negativer Phase der NAO (Beispiel Januar 1963)

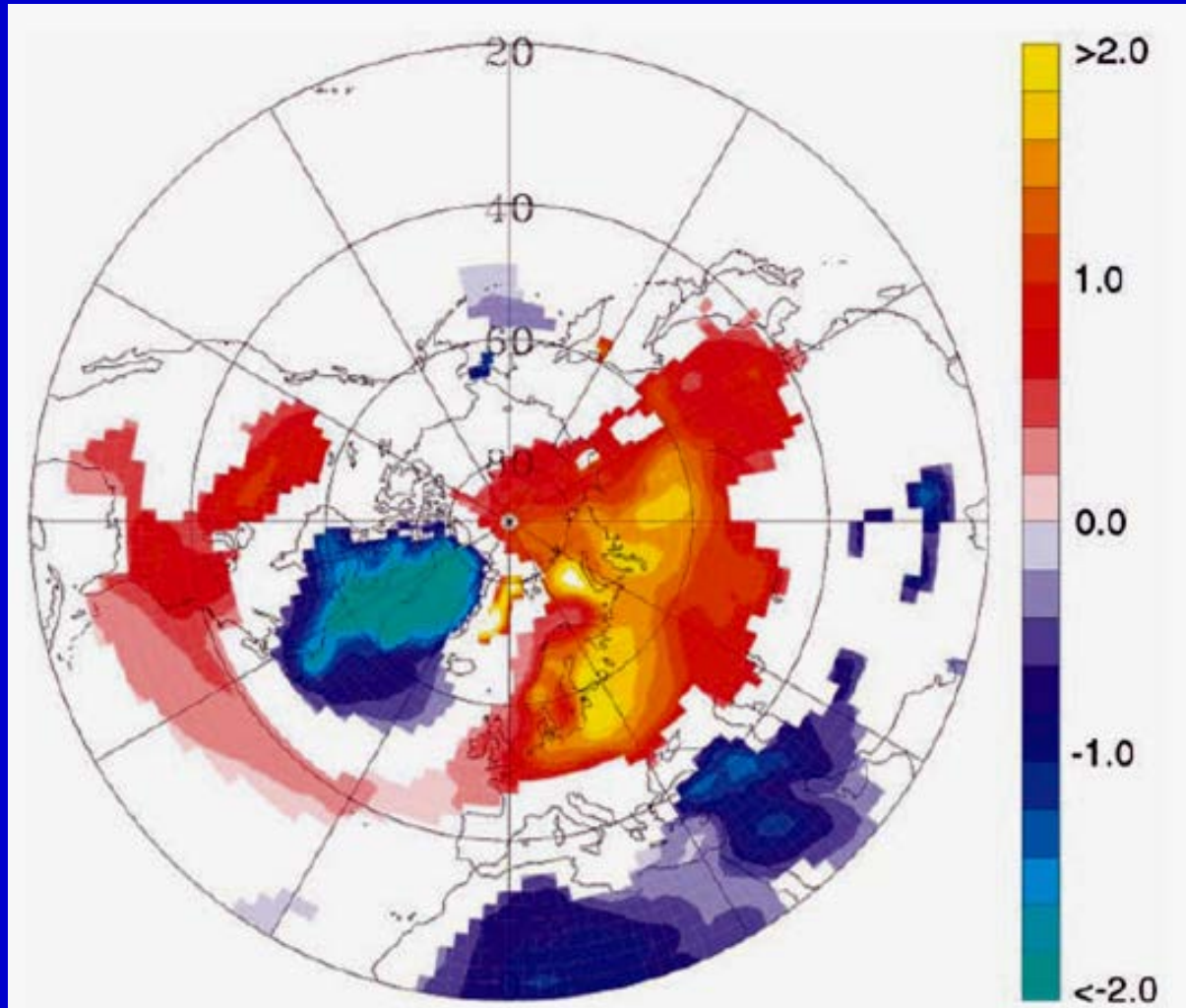


Januar
1963

NAO -

Hupfer & Jacobeit 2003
Nationalatlas BRD

Winterliche Temperaturabweichungen (°C) bei positiver Phase der NAO (> 1 Standardabweichung über mittlerem Index)

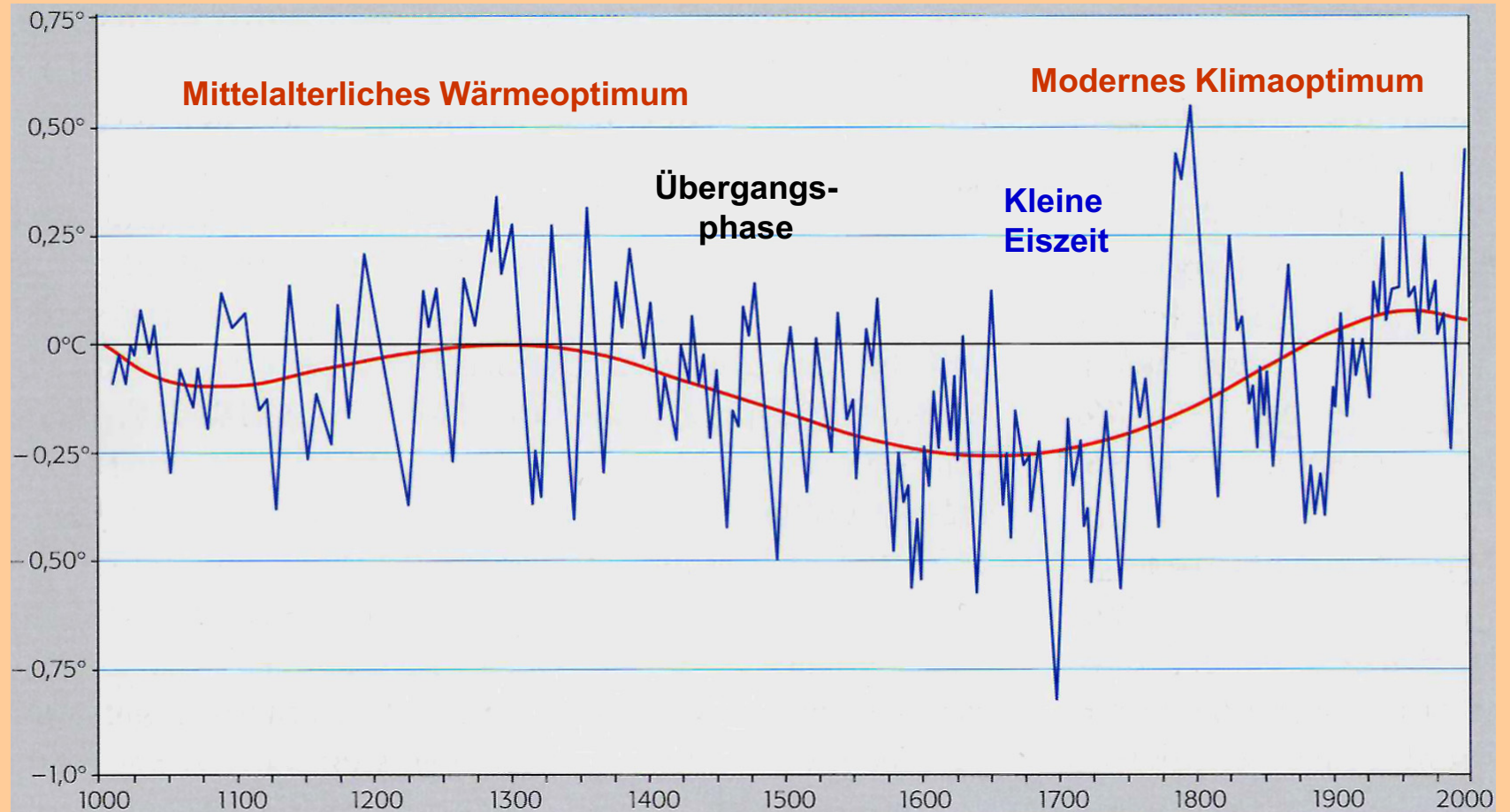


Appenzeller et al. 2000

Atmosphärische Zirkulation im

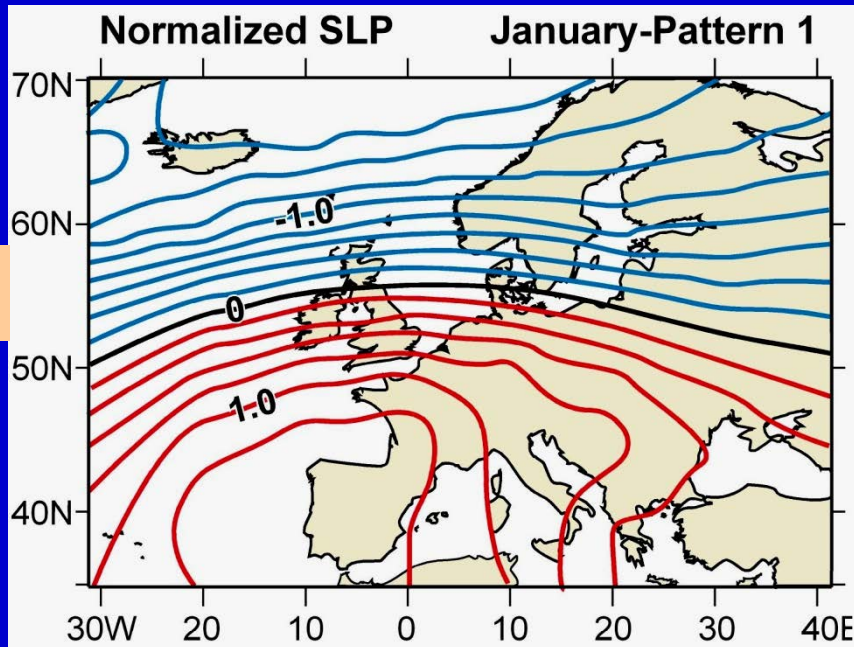
- historischen Klimawandel**
- rezenten Klimawandel**
- künftigen Klimawandel**

Temperaturverlauf in Mitteleuropa in den letzten 1000 Jahren

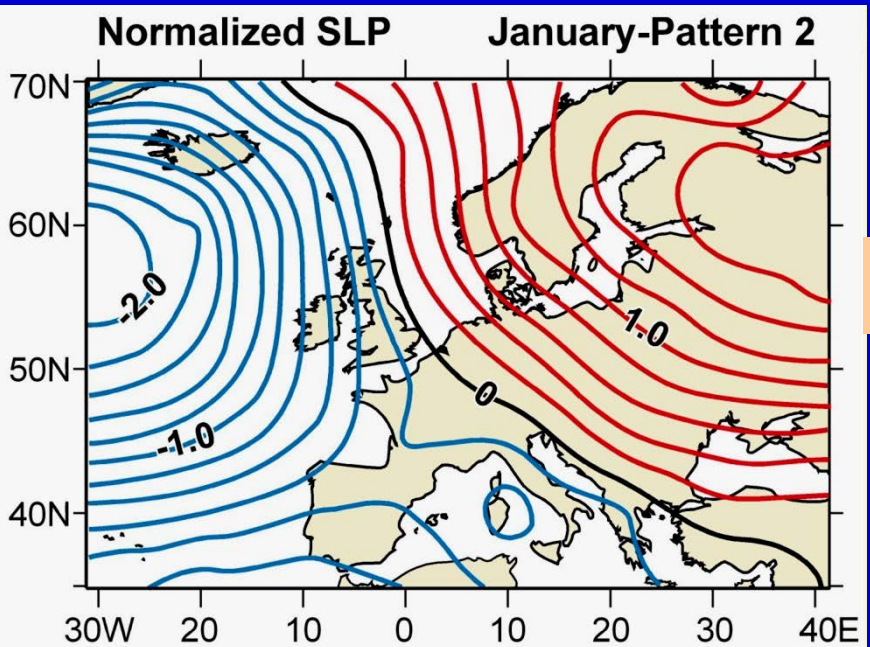


Glaser 2001

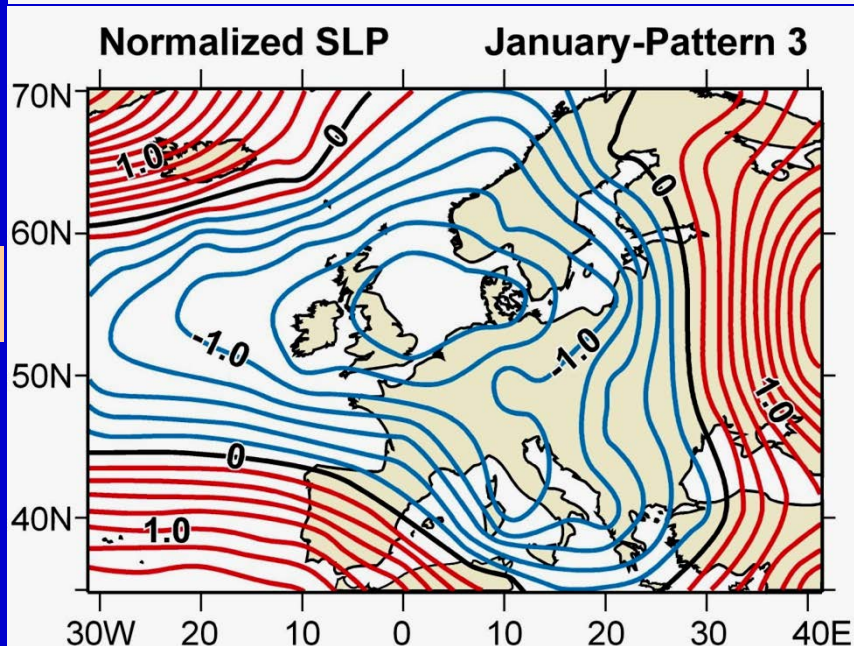
Grundlegende winterliche Zirkulationsmuster im ostatlantisch-europäischen Raum (basierend auf rekonstruierten monatlichen Luftdruckfeldern)



W



RH

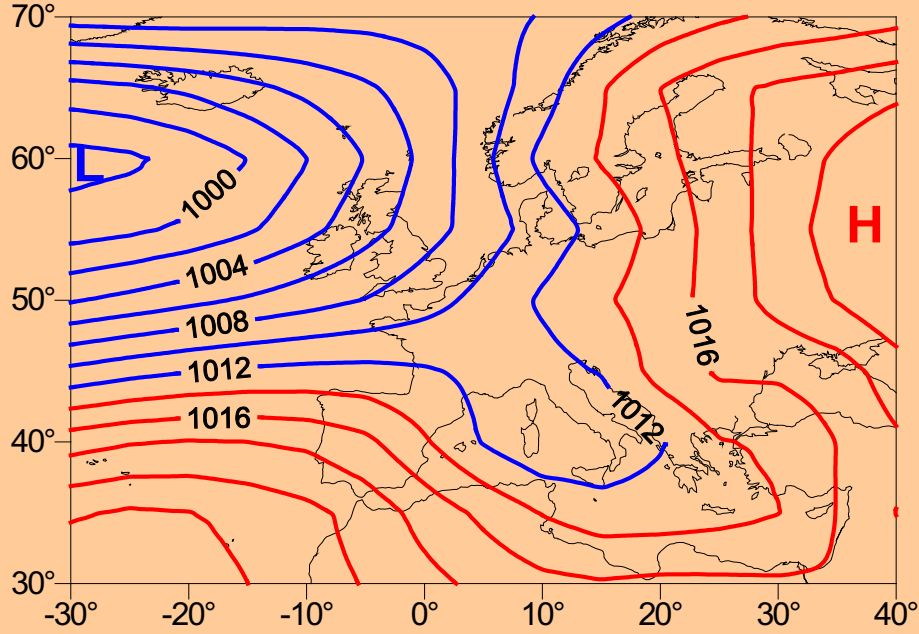
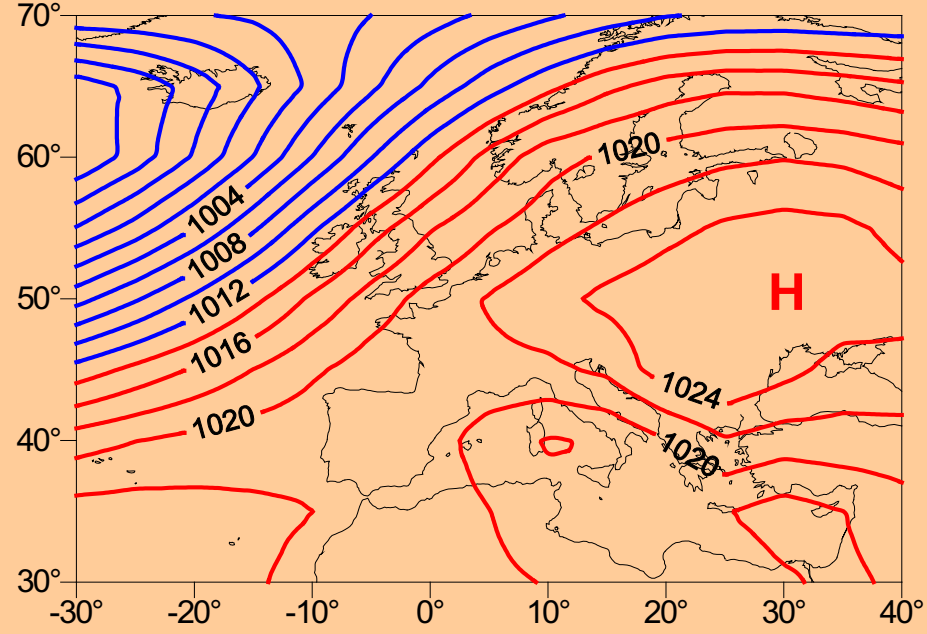
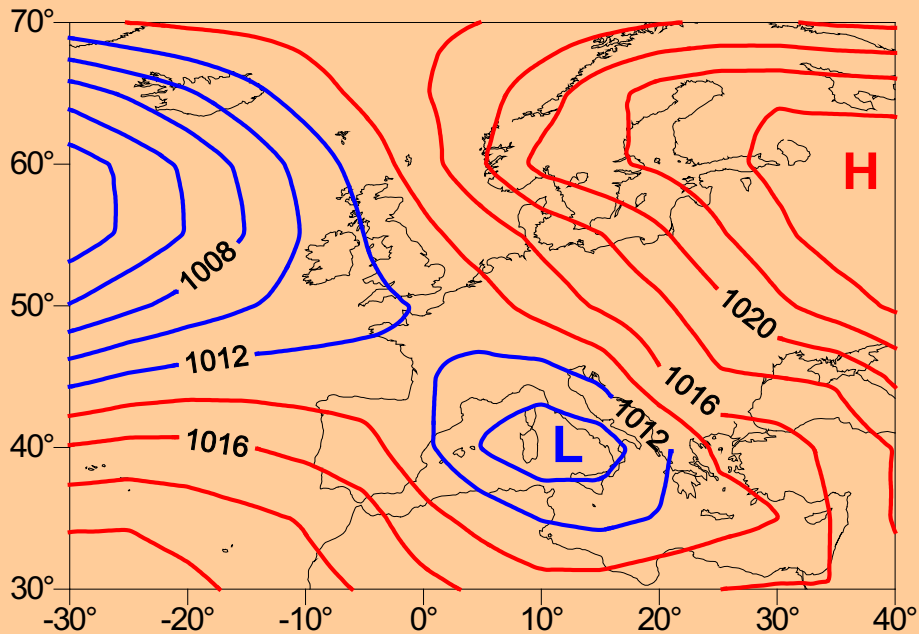
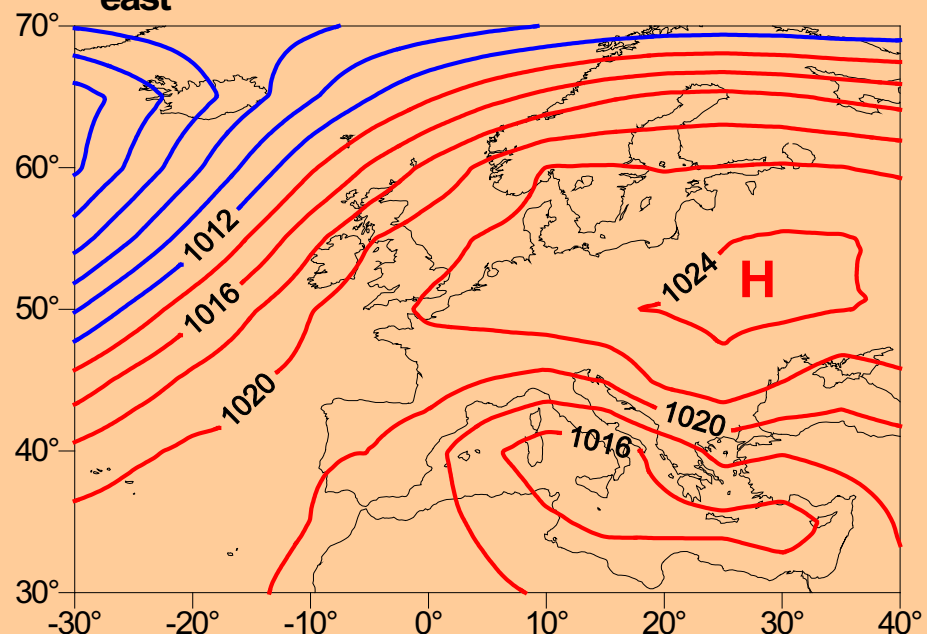


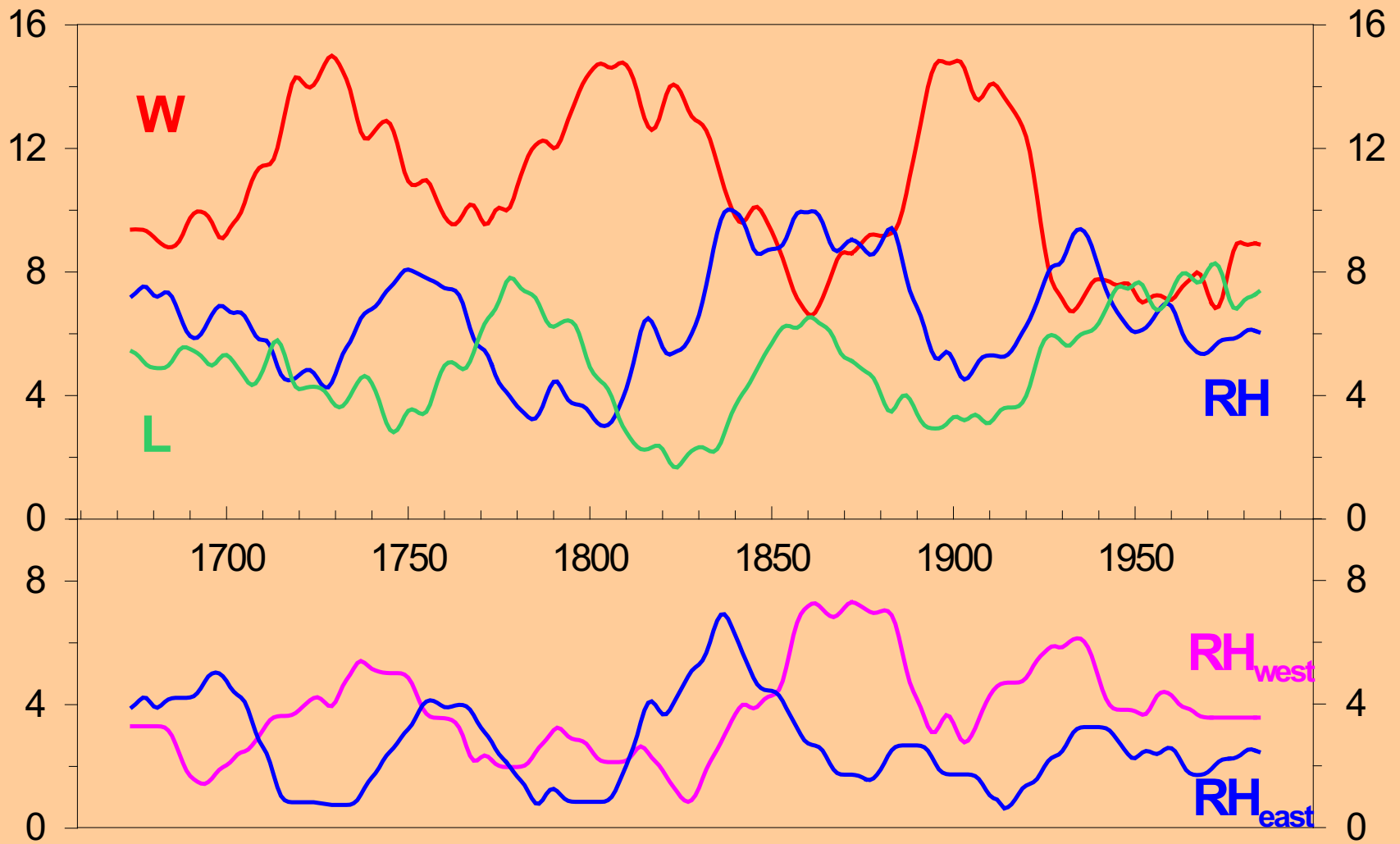
L

W: westliches Strömungsmuster

RH: Russland-Hoch-Muster

L: Ostatlantik-Tief-Muster

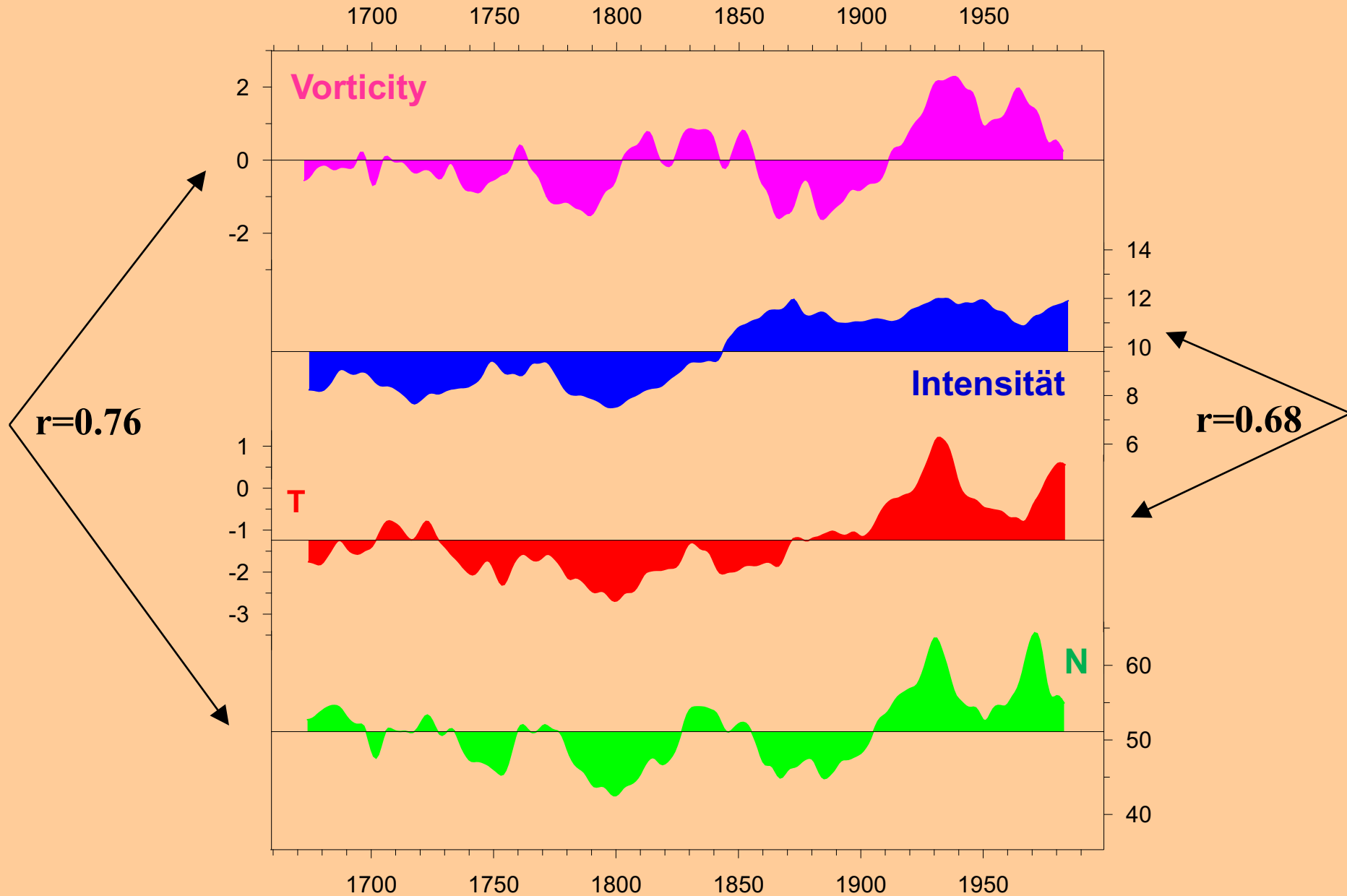
SLP**Mode RH_{west}****Jan****Mode RH_{east}**

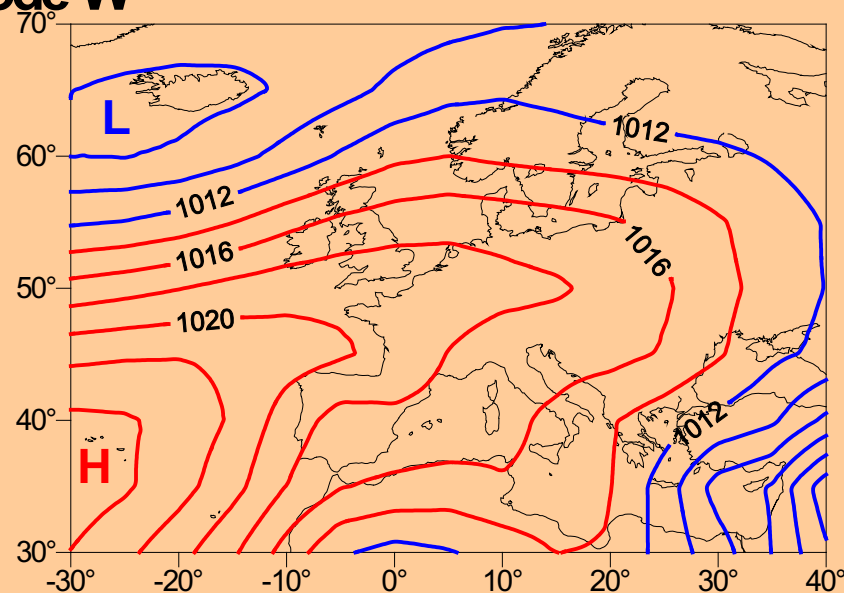
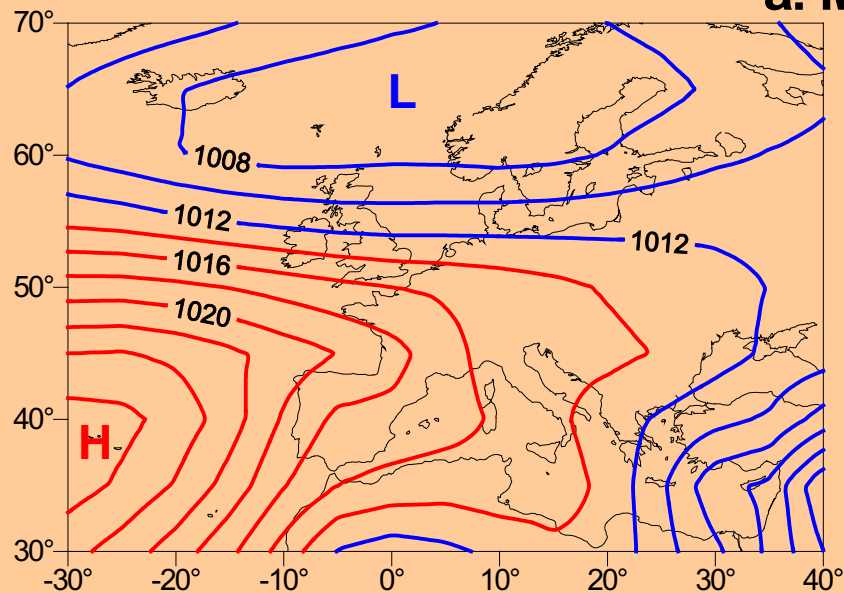
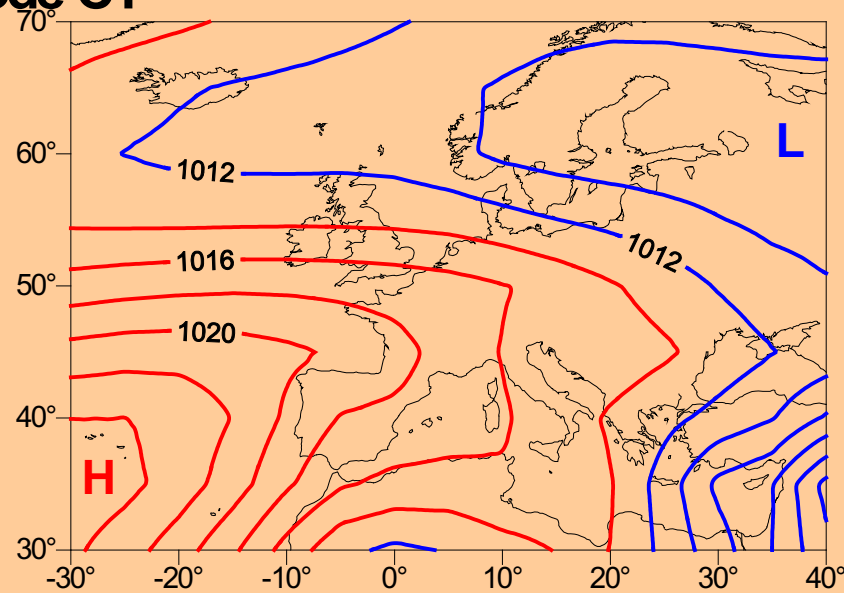
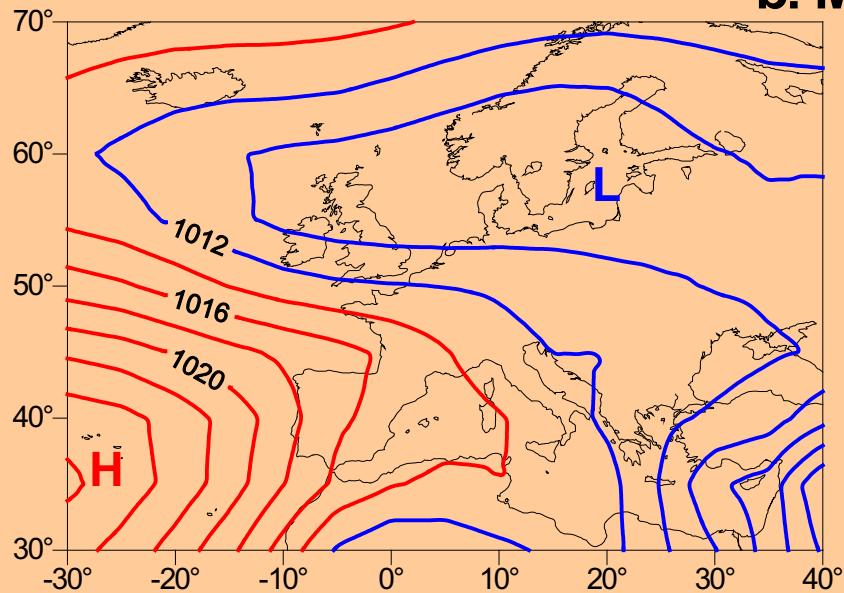


Häufigkeitsschwankungen der Zirkulationsmuster

Januar 1659-1999

Interne Änderungen der winterlichen Westlage seit 1659

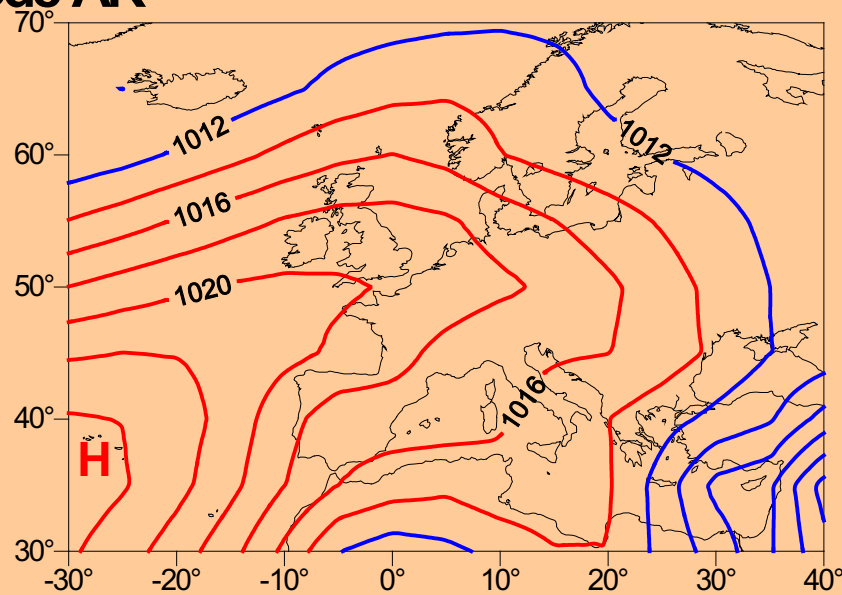
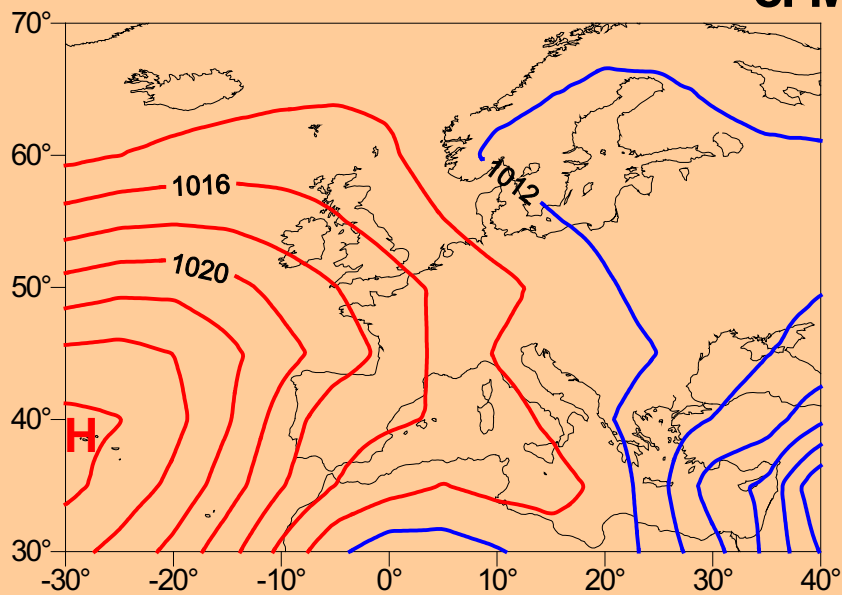


SLP**a: Mode W****Juli****b: Mode CY**

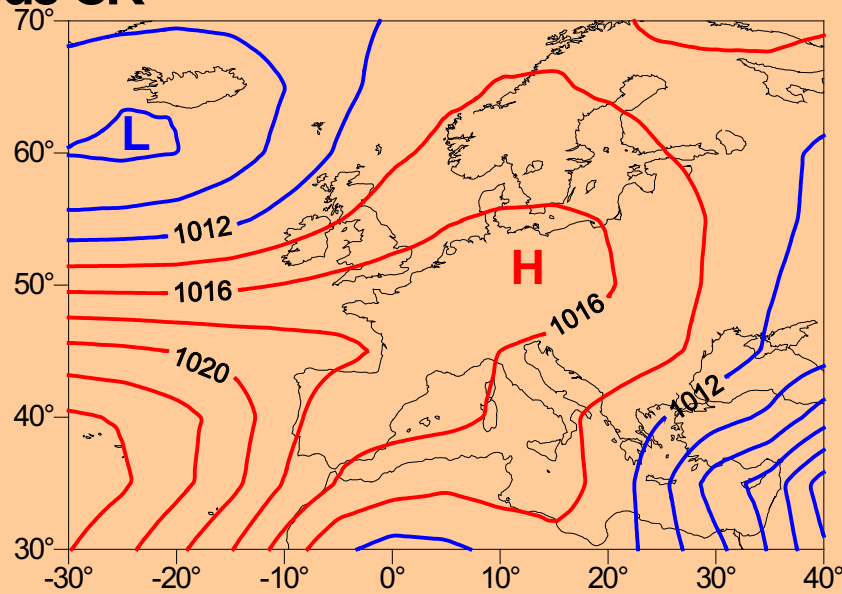
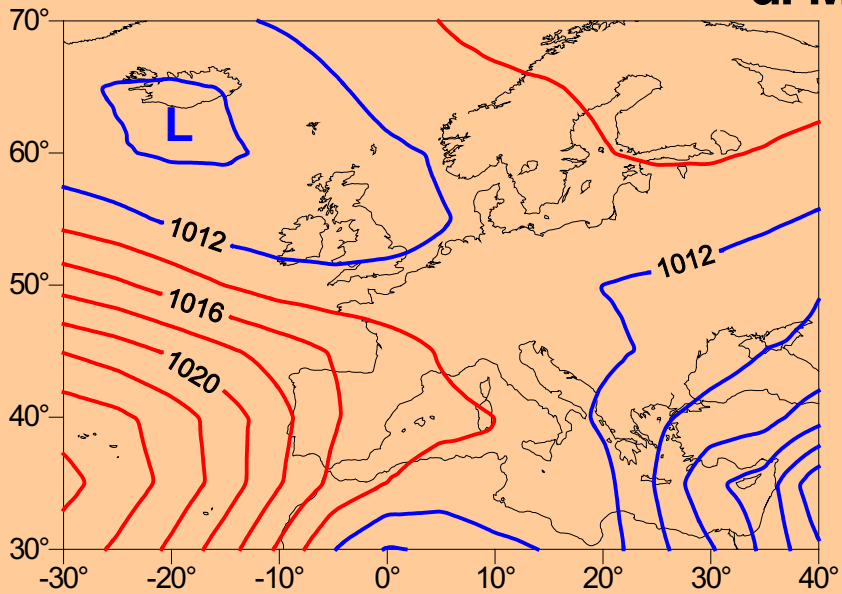
SLP

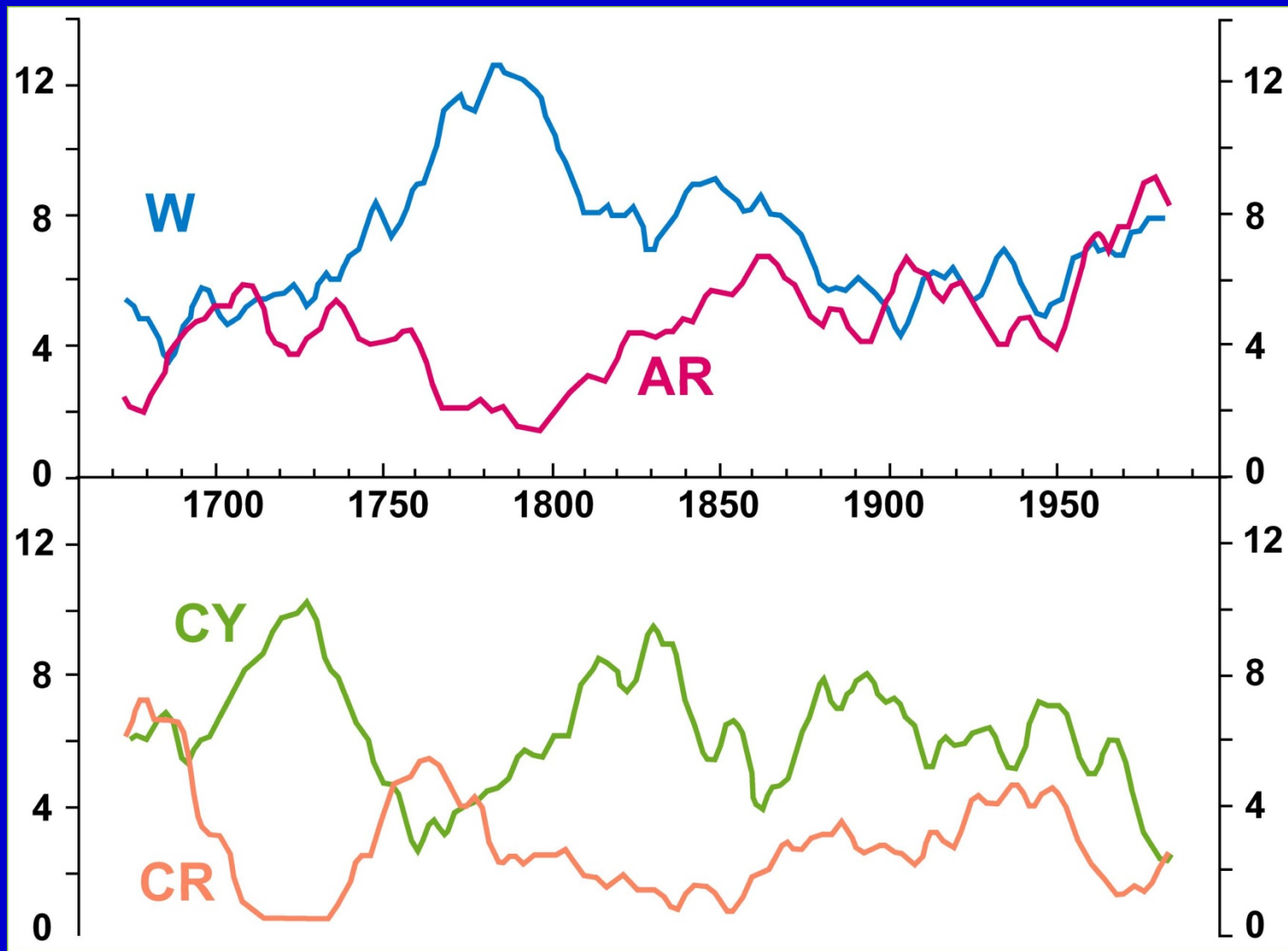
c: Mode AR

Juli



d: Mode CR





W: westl. Strömungsmuster

CY: zyklonales Aktionszentrum

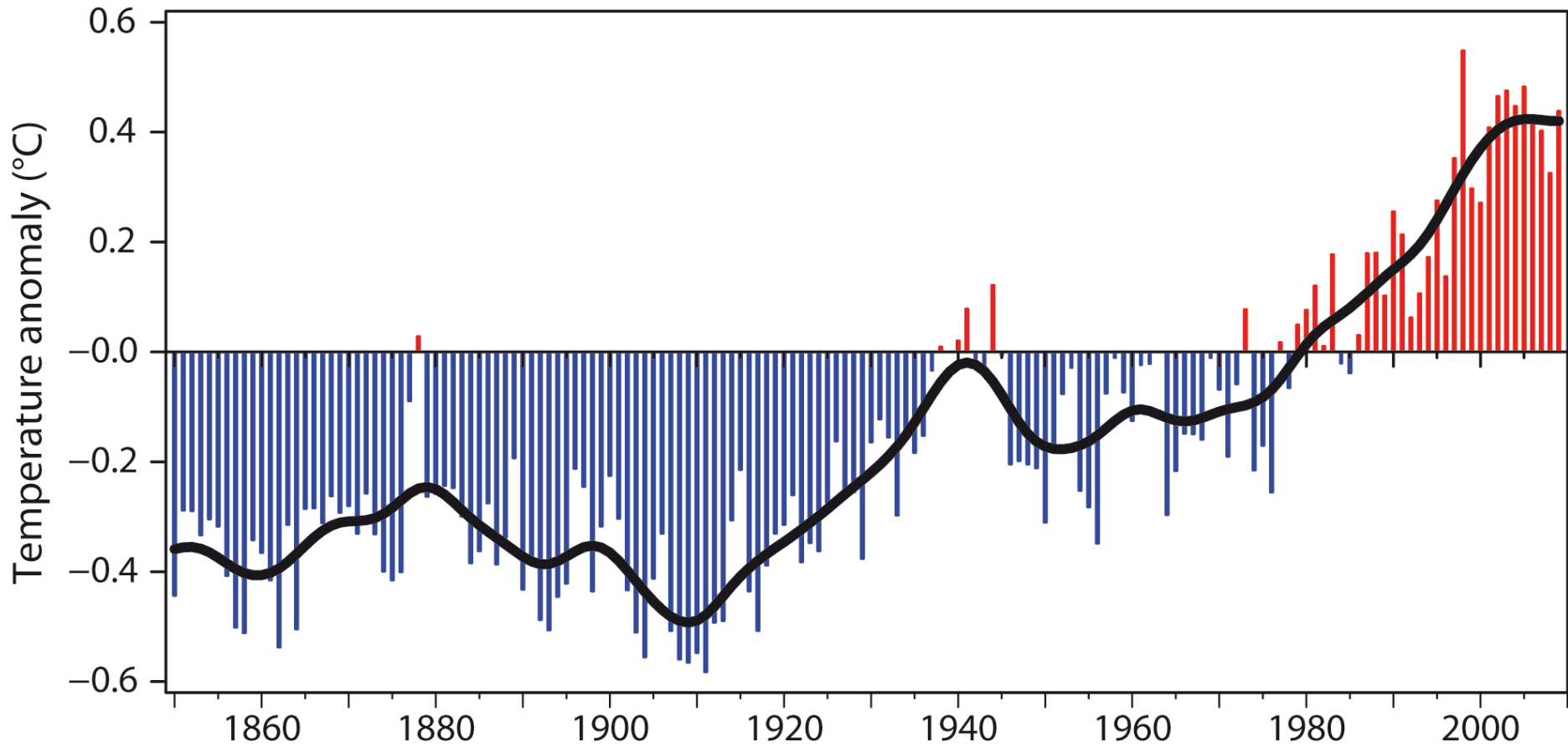
AR: atlantischer Rücken

CR: kontinentaler Rücken

nach-kleineiszeitliche Entwicklung ...

Jahresmittel der globalen Lufttemperatur

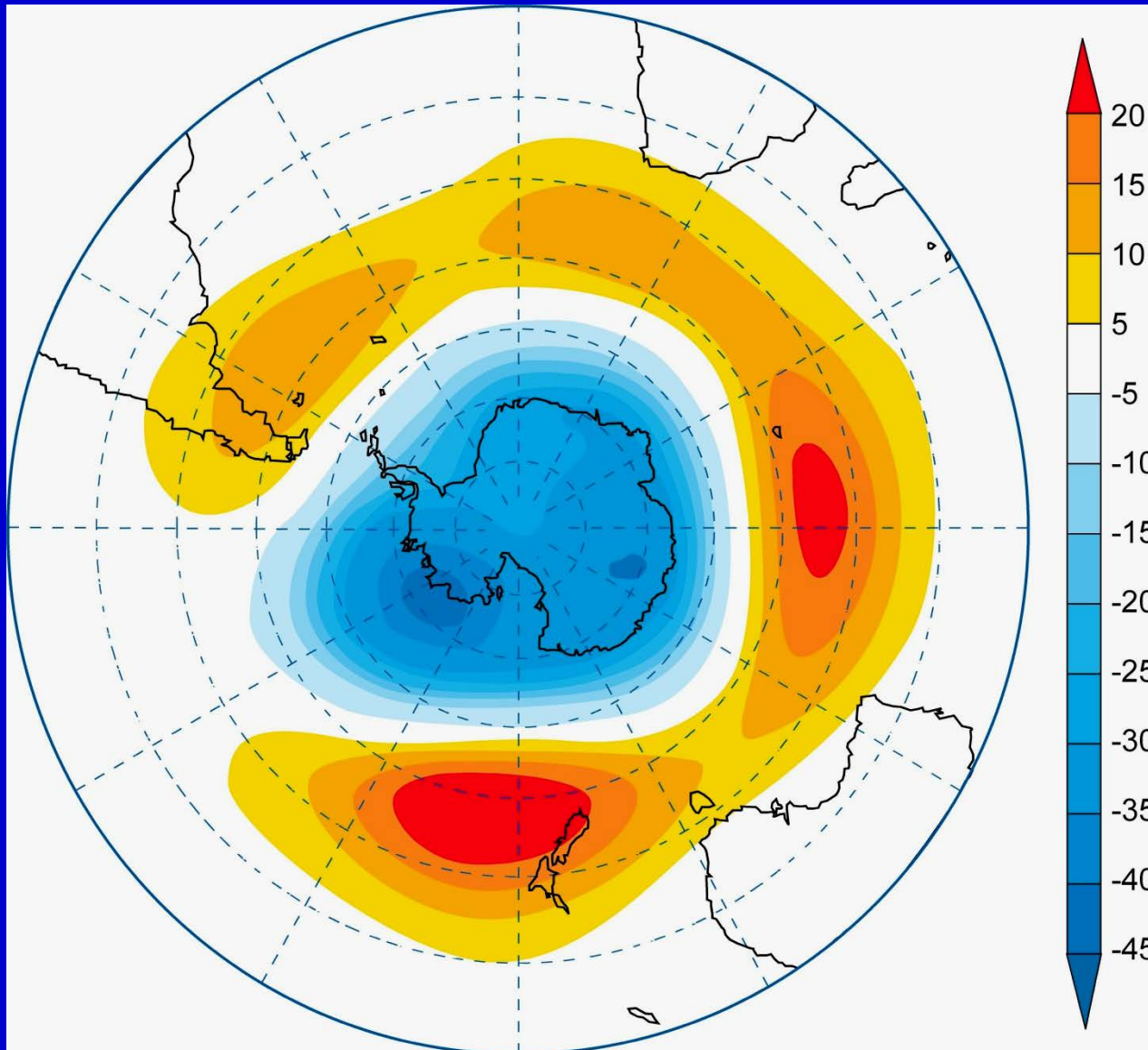
Anomalien bezogen auf das Mittel 1961-1990



Climatic Research Unit

Positive Phase der Antarktischen Oszillation (AAO)

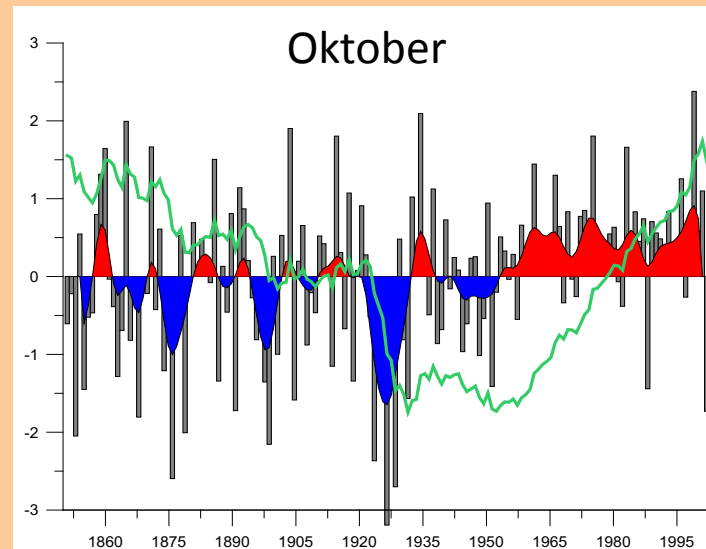
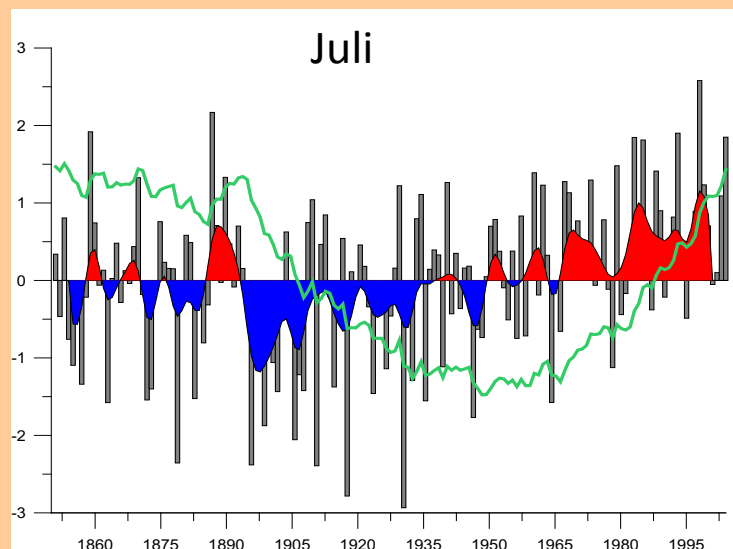
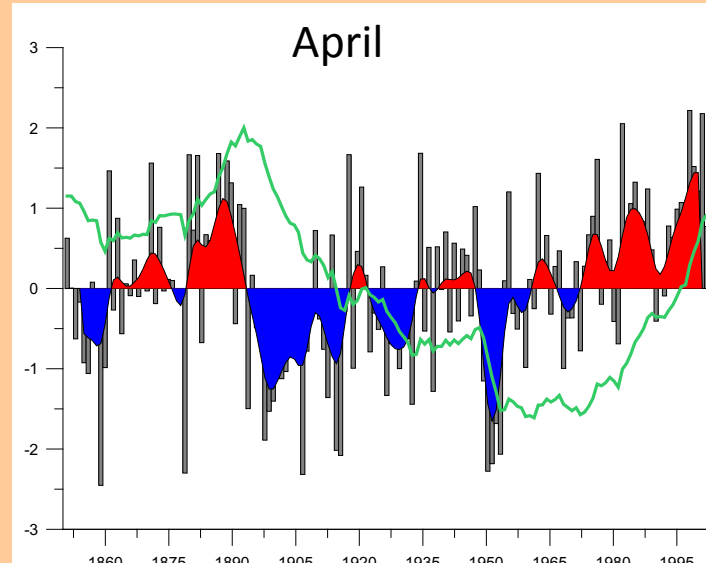
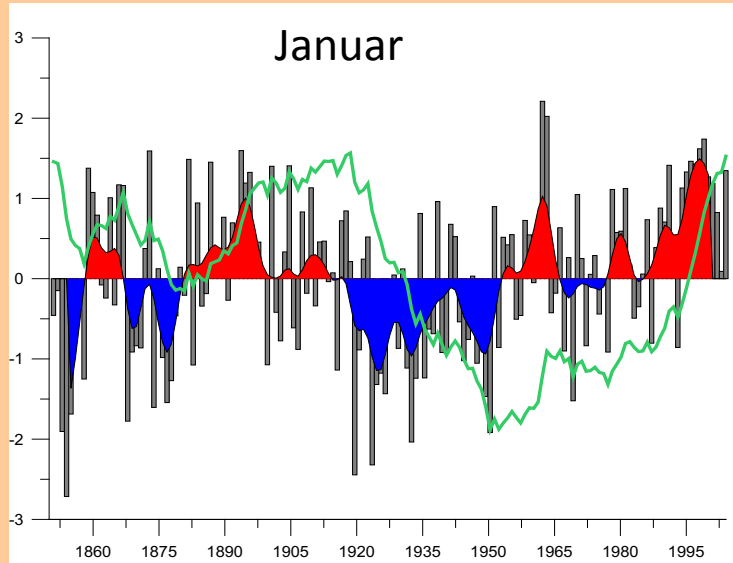
700 hPa Niveau (gpm-Anomalien)



Climate Prediction Center

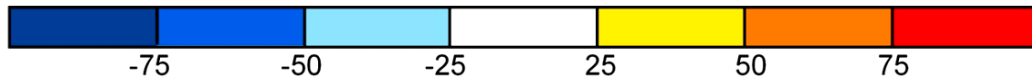
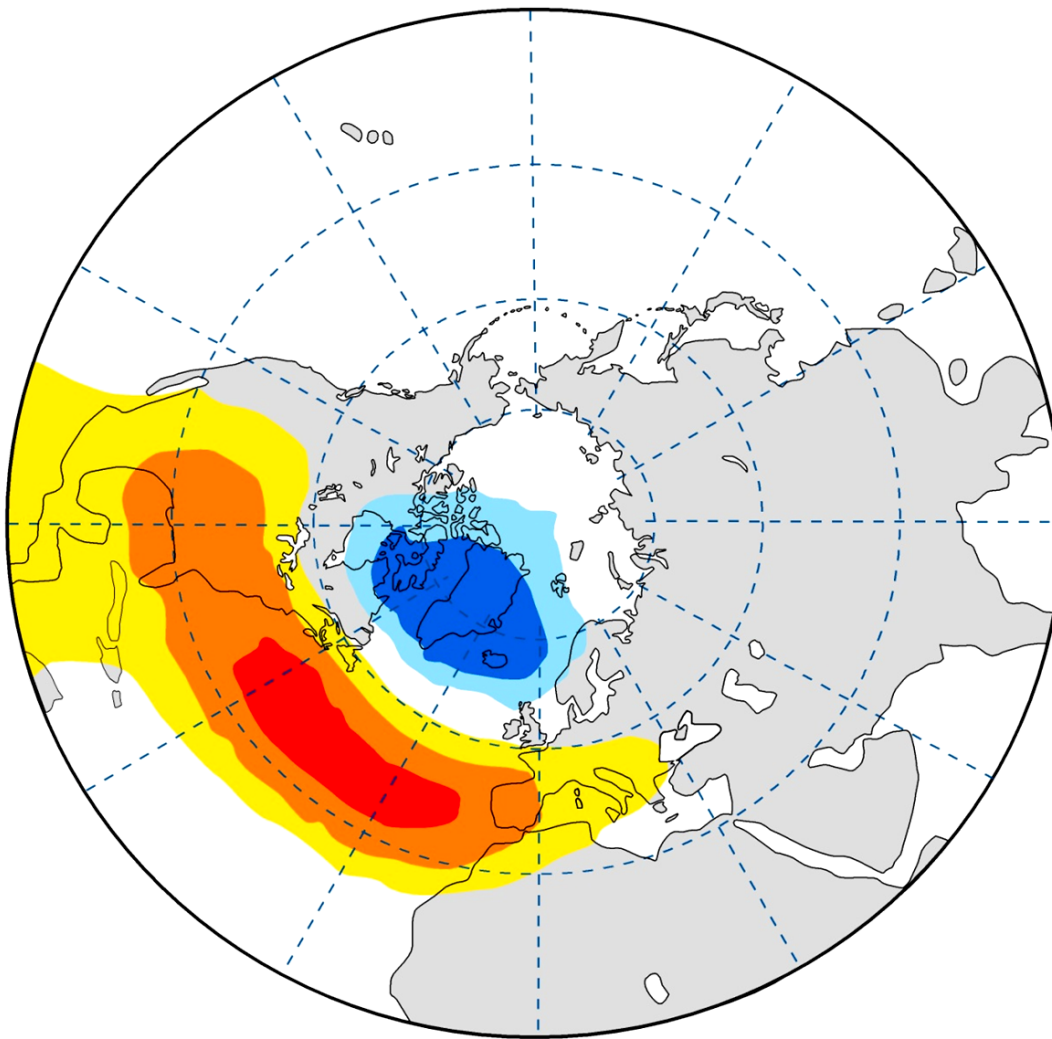
AAO-Index 1850 bis 2004

mit gefilterten Werten (10-jähriger Gauß-Tiefpassfilter, rot/blau)
sowie kumulativen Anomalien (grün)



North Atlantic Oscillation (NAO)

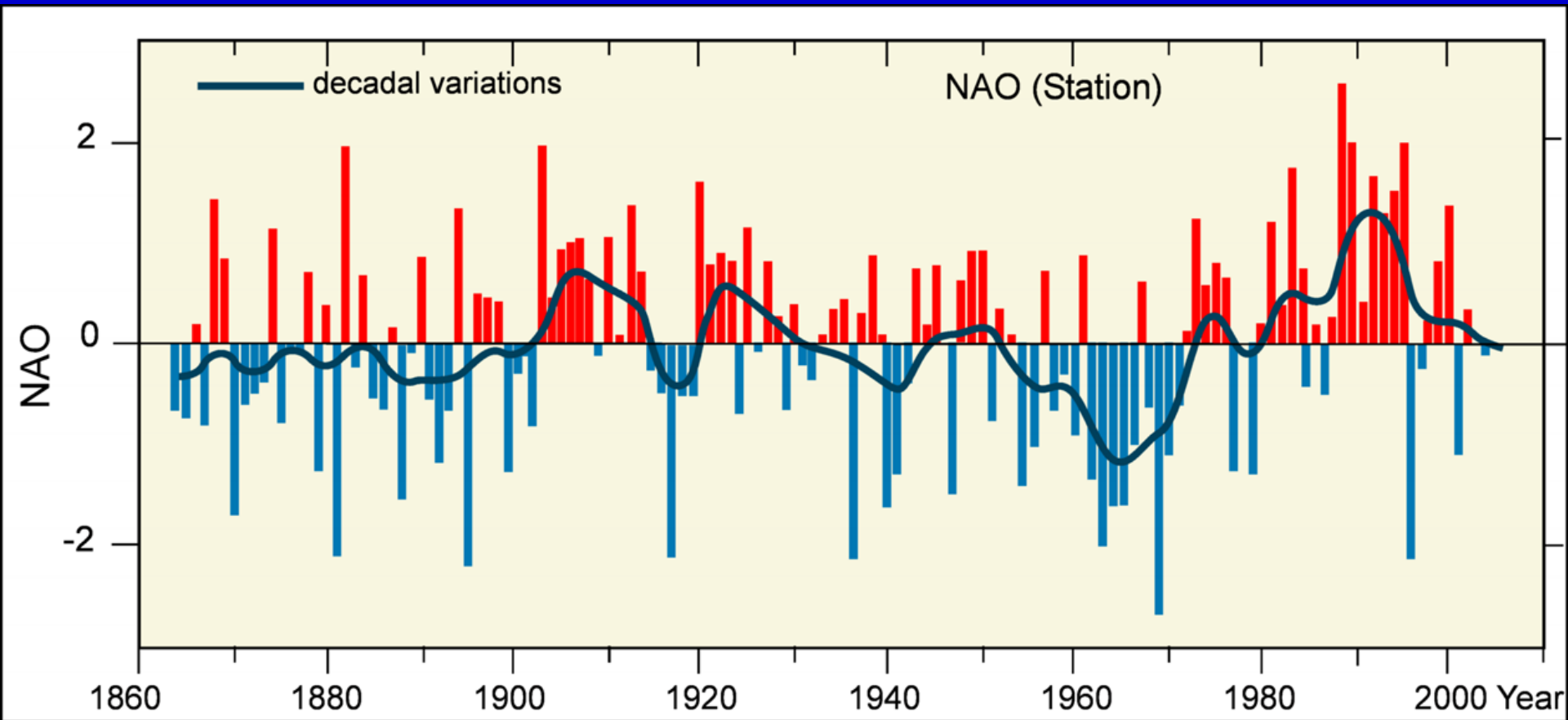
January



Positive Phase der Nordatlantischen Oszillation (NAO)

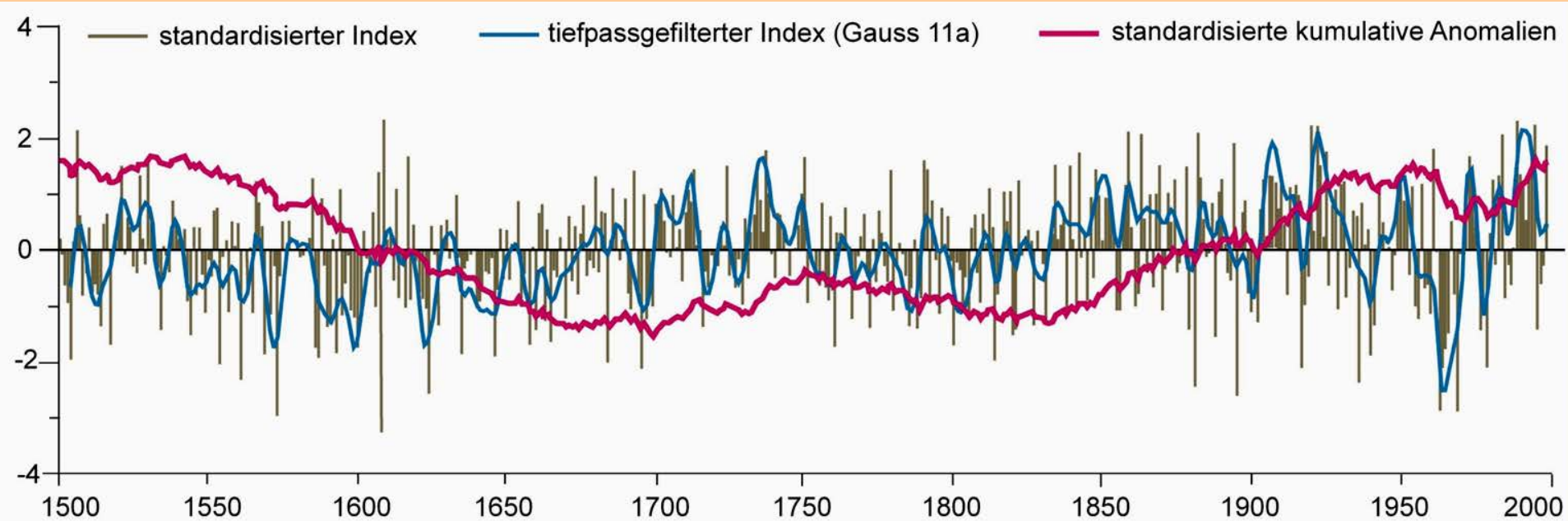
500 hPa Niveau (gpm-Anomalien)

Climate Prediction Center



The December to March North Atlantic Oscillation Index
Hurrell et al. 2003

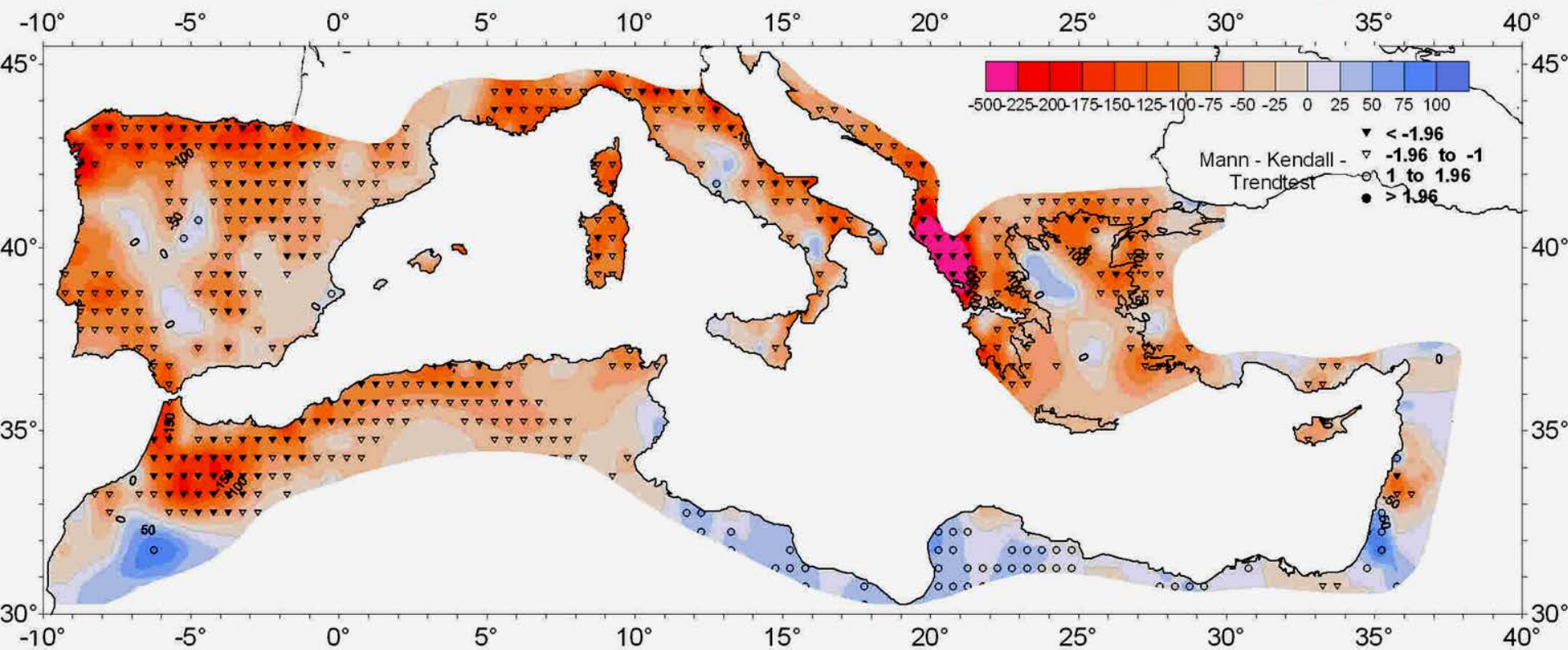
NAO-Index Winter 1500-1999



basierend auf den Luftdruck-Rekonstruktionen von Luterbacher et al. (2002)

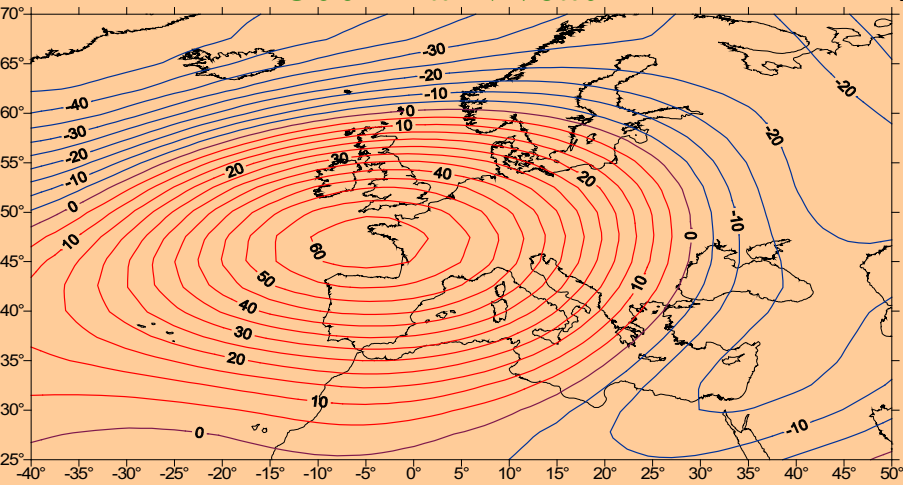
Linear Trends of Winter Rainfall

Winter (ONDJFM) 1951-2000



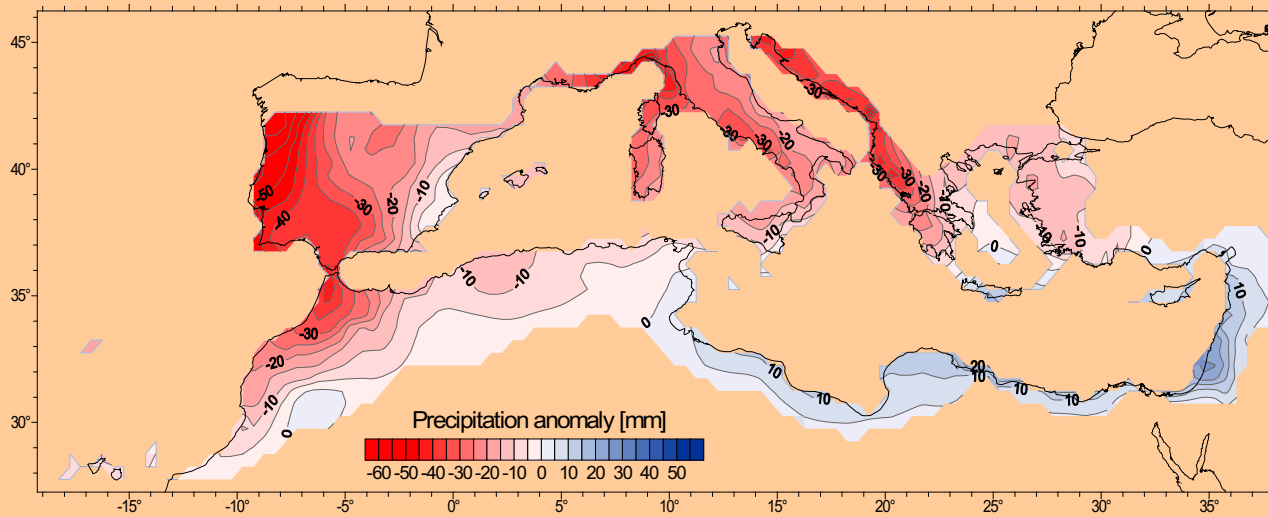
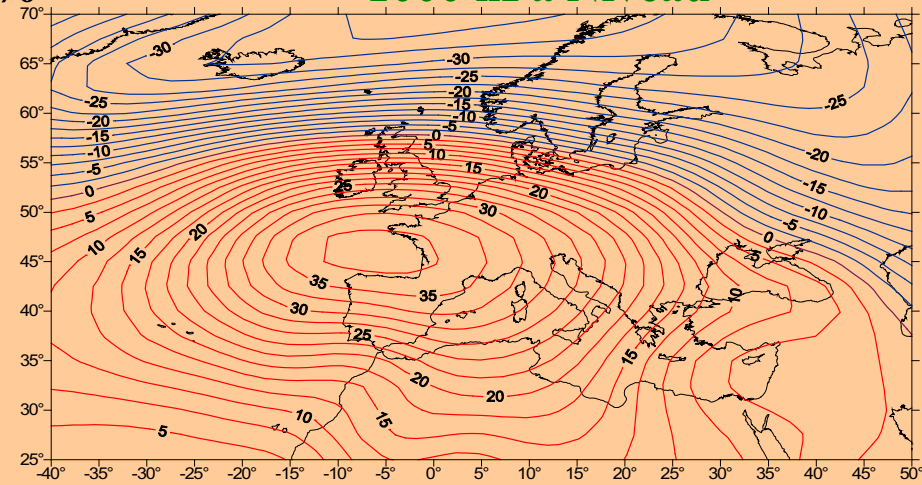
Jacobeit et al. 2007

500 hPa Niveau



20.1%

1000 hPa Niveau



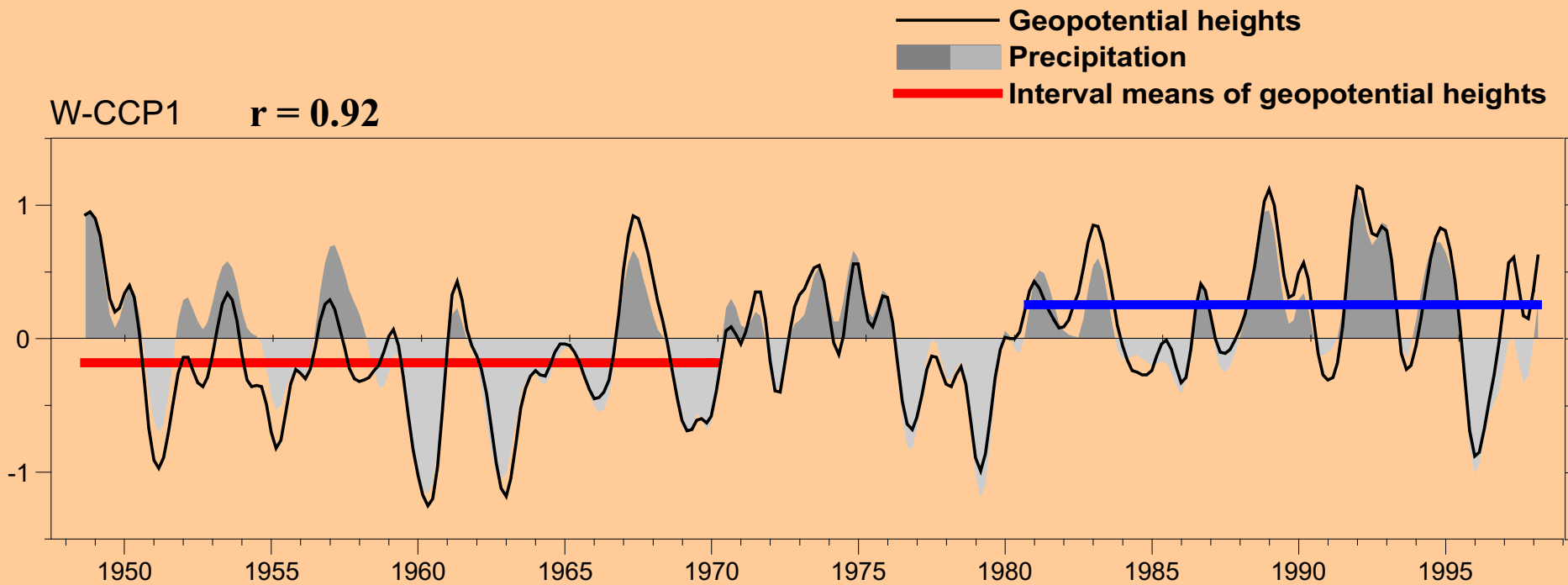
Niederschlag

30.4%

$r = 0.72$
mit NAO

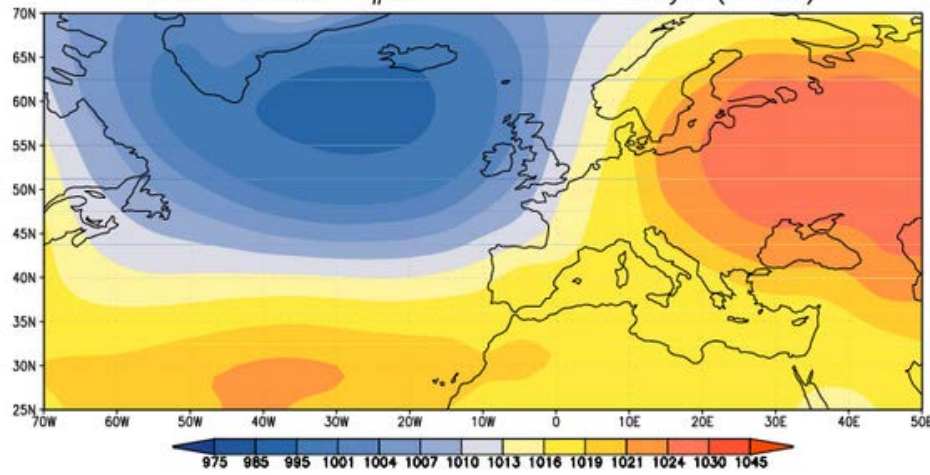
Mediterrane Oszillation (MO)

Düneloh & Jacobeit 2003



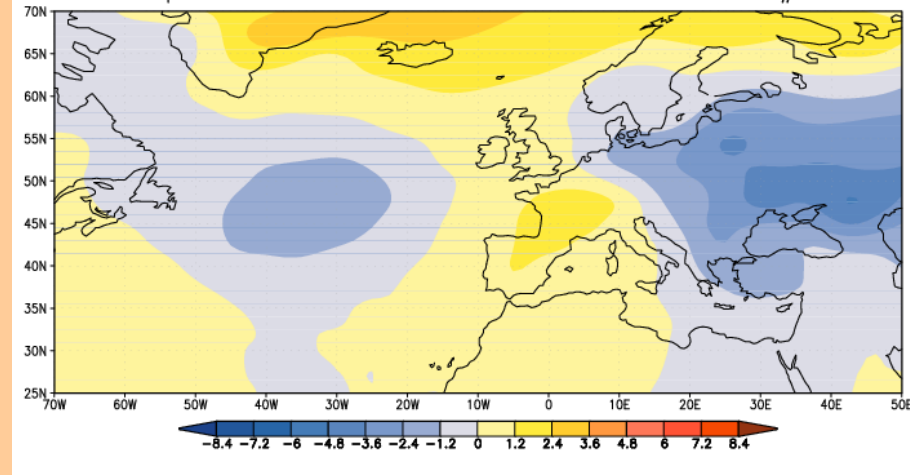
**Geglättete Zeitkoeffizienten des
Mediterranen Oszillations-Musters **im Winter****

Cluster centroid #06 1477 days (=11%)

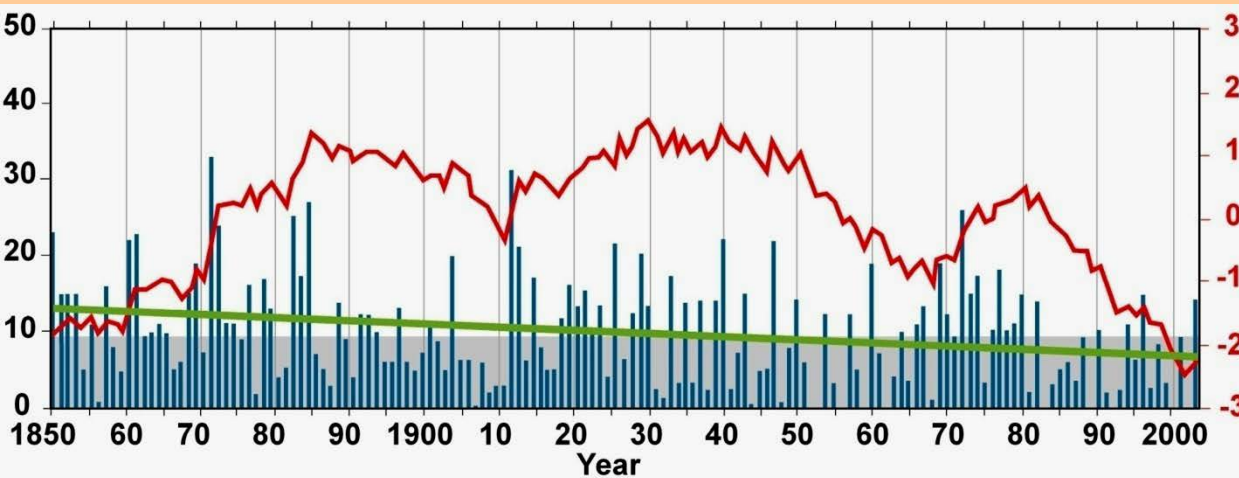


SLP (hPa) centroid pattern

Temperature anomalies 1948-2003 DJF cluster #06



Associated mean temperature anomalies [K] 1948-2003

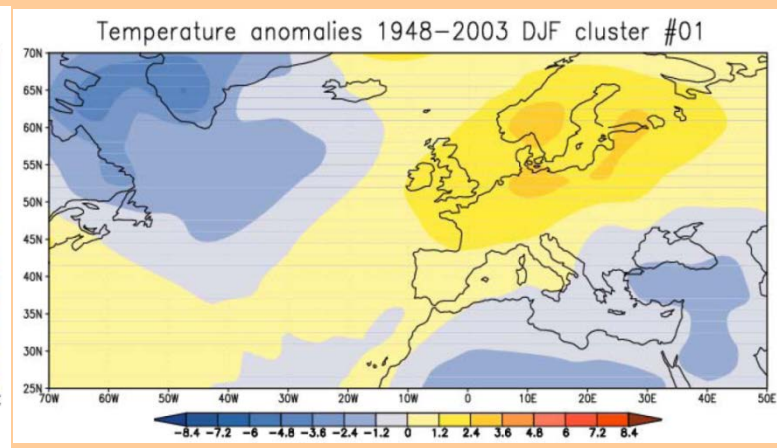
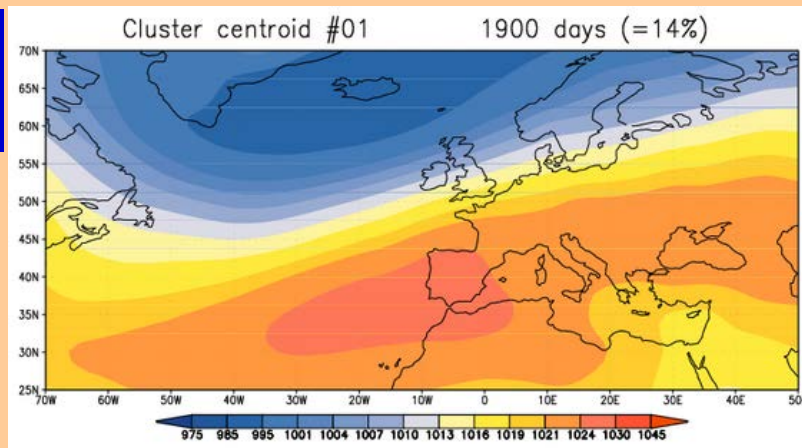


significant trend (95% level)

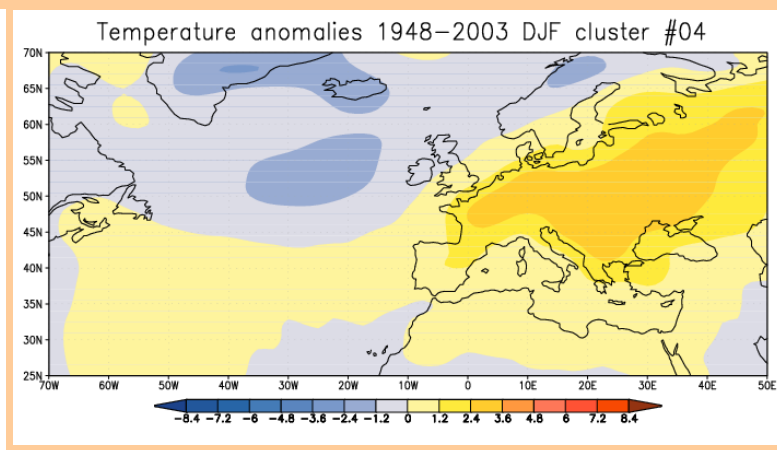
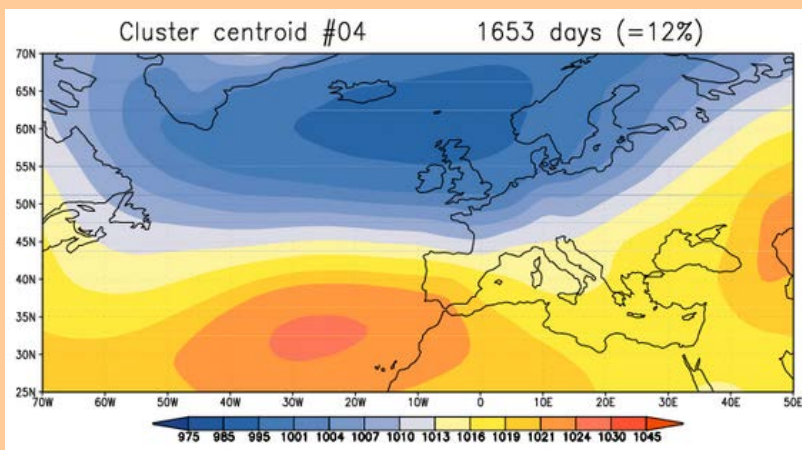
- seasonal cluster frequency (SCF)
- normalised cumulative anomalies of SCF
- linear trend of SCF

**Winter (DJF)
1850-2003**

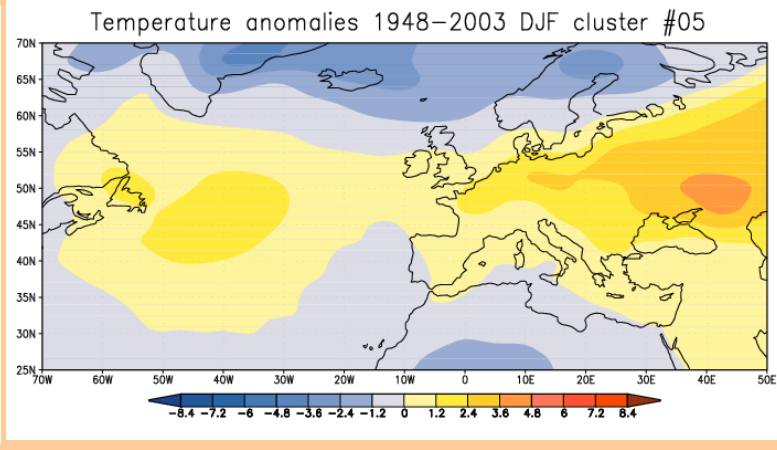
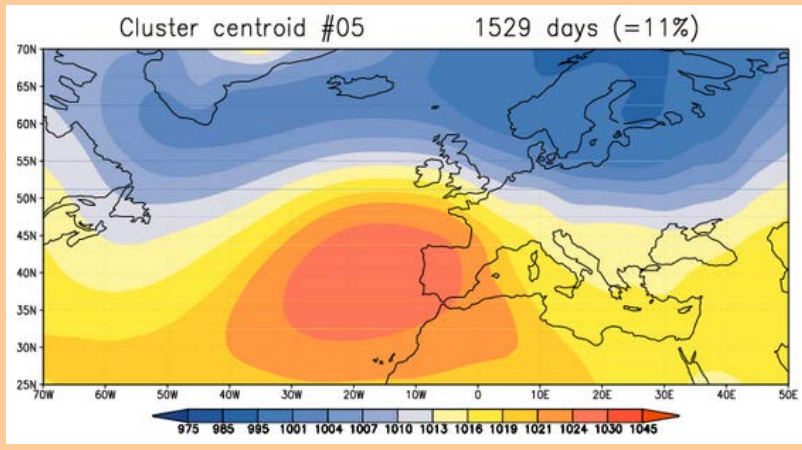
Cluster 1



Cluster 4

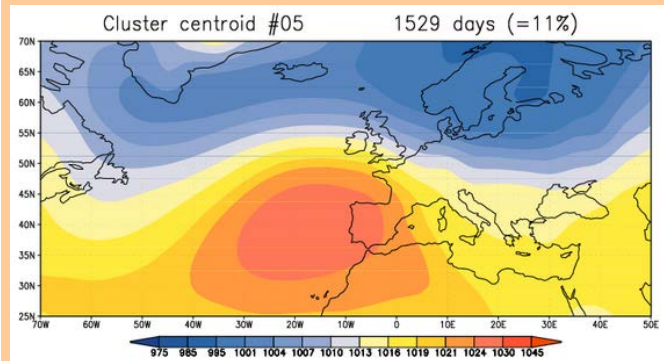
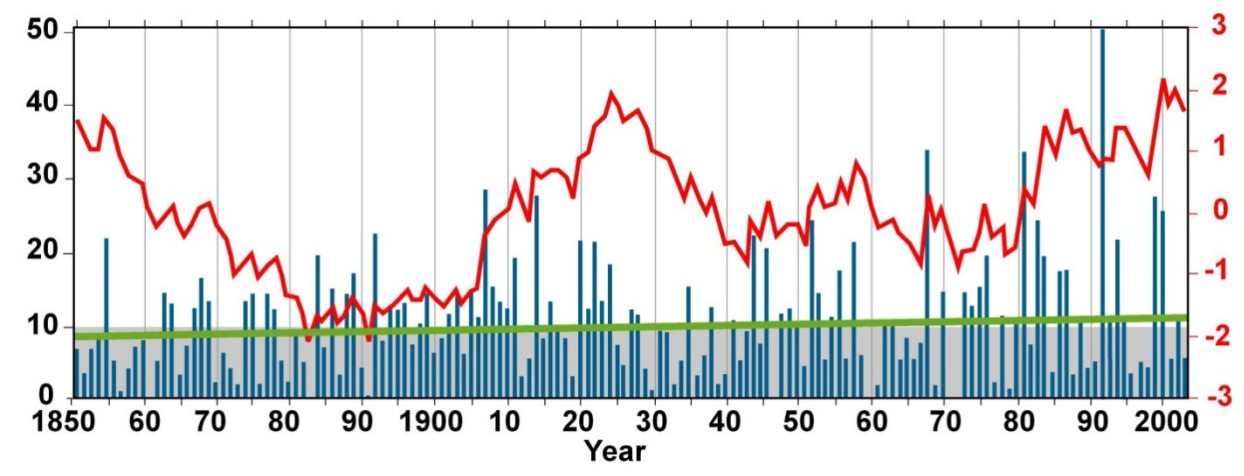
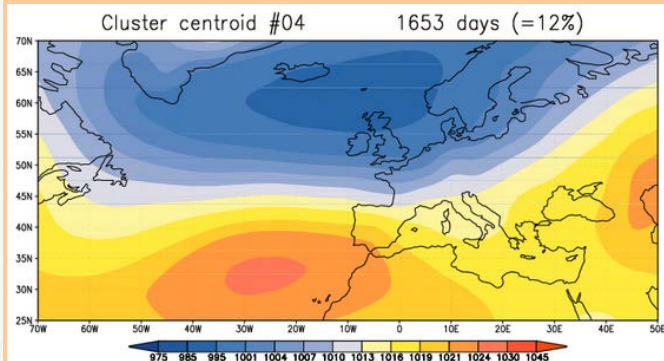
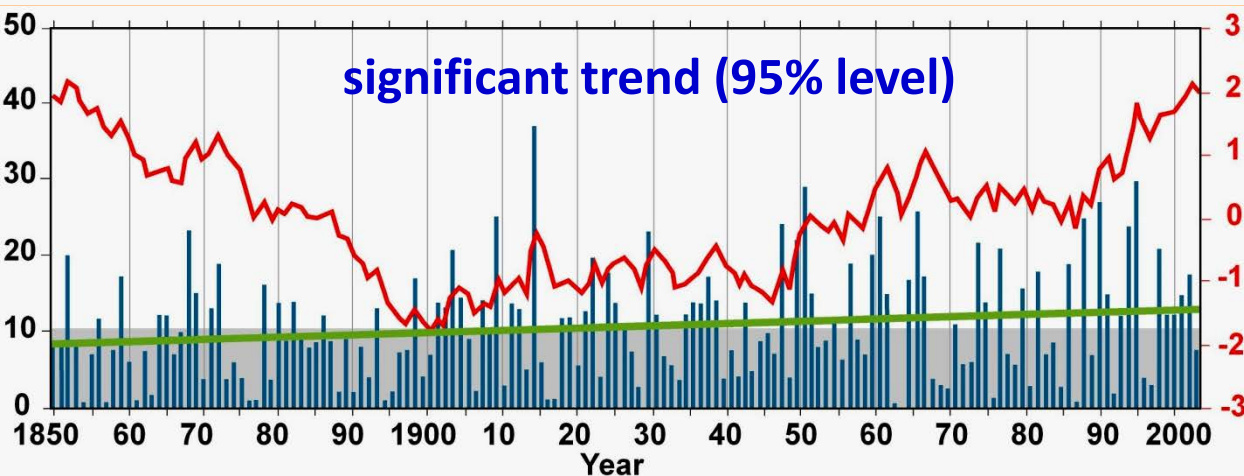
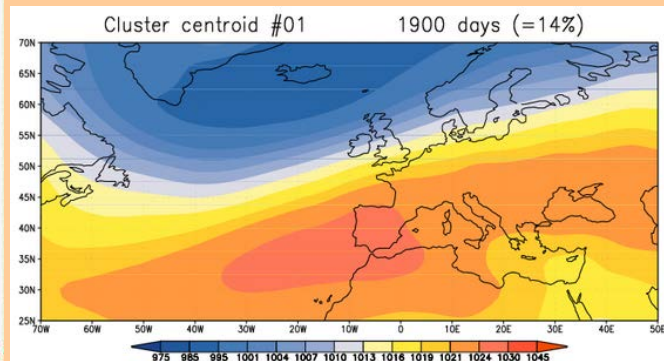
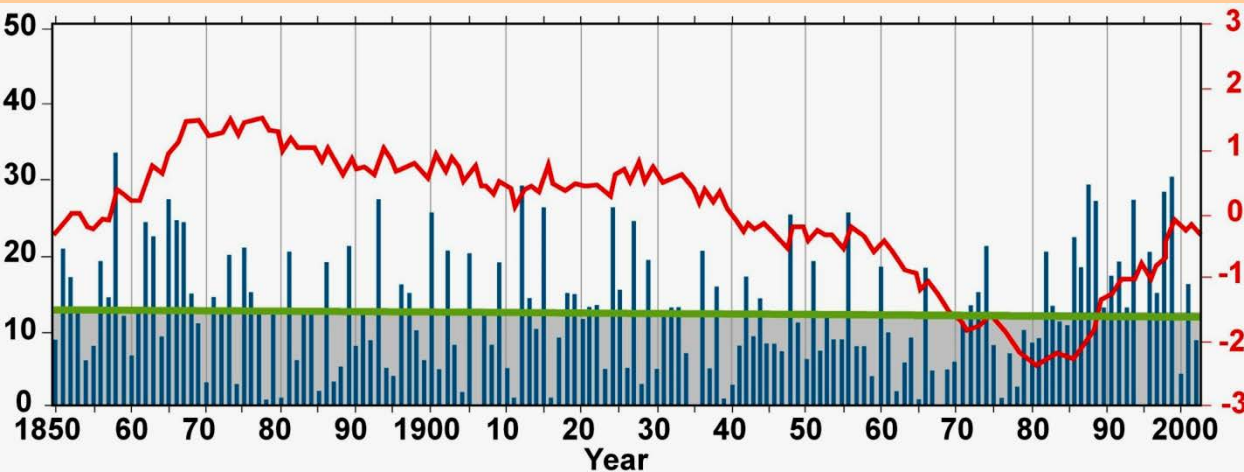


Cluster 5



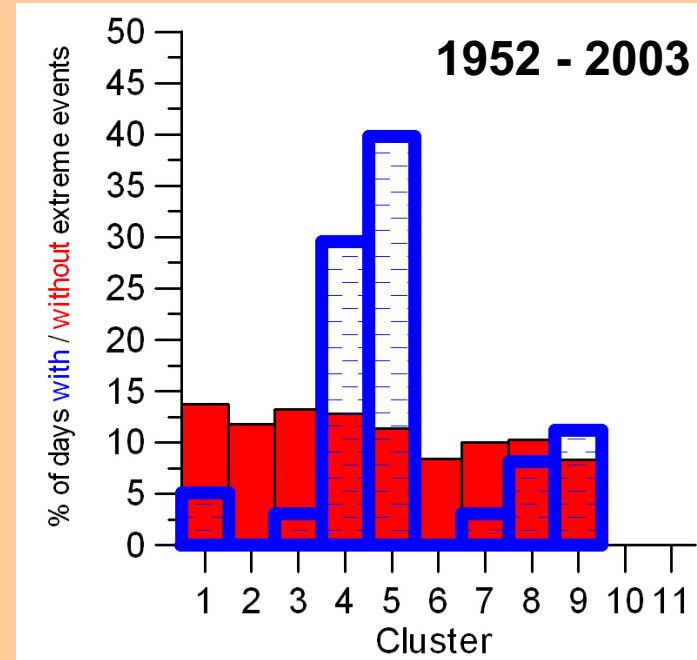
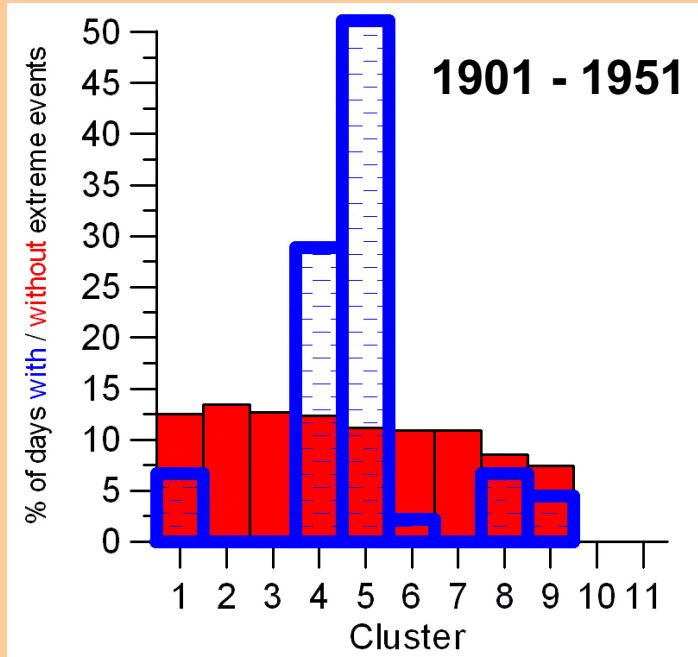
SLP (hPa) centroid pattern

Associated mean temp. anomalies [K]



% of extreme/normal days for each SLP Cluster

DJF extreme precipitation



nach Jones & Lister (2009)

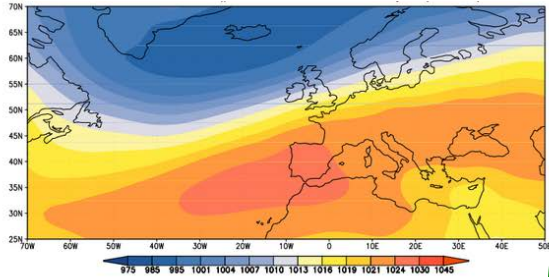
haben sich im Laufe des 20. Jahrhunderts
winterliche Zirkulationsmuster in ihren Eigenschaften wie folgt verändert:

8 von 9 → wärmer

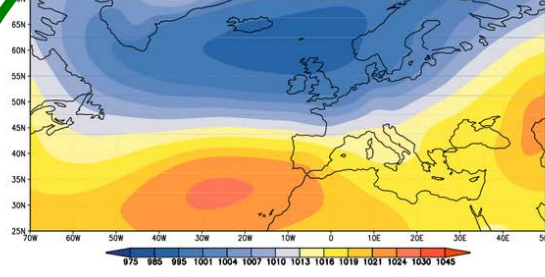
2 von 9 → feuchter

2 von 9 → trockener

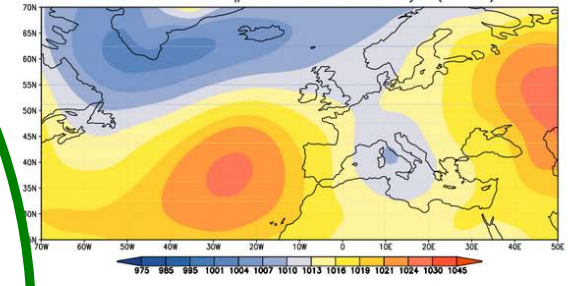
Cluster centroid #01 1900 days (=14%)



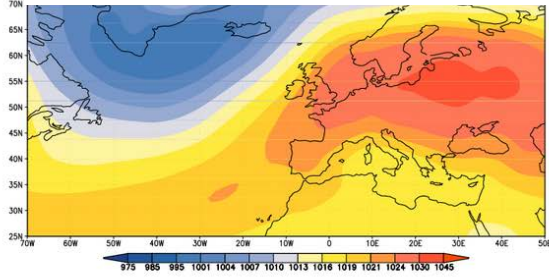
Cluster centroid #04 1653 days (=12%)



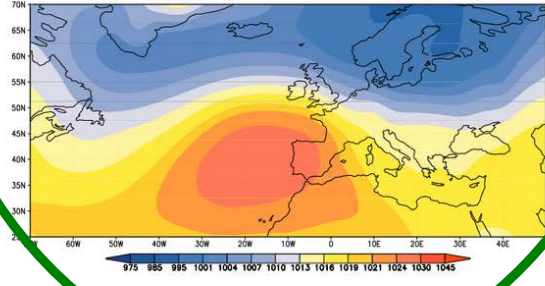
Cluster centroid #07 1415 days (=10%)



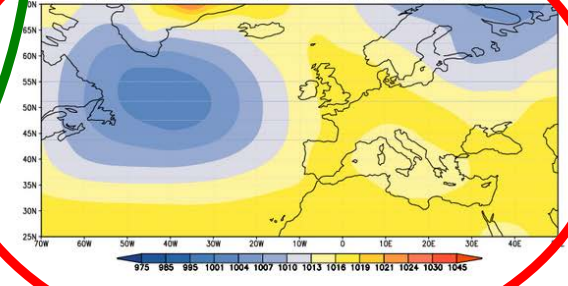
Cluster centroid #02 1762 days (=13%)



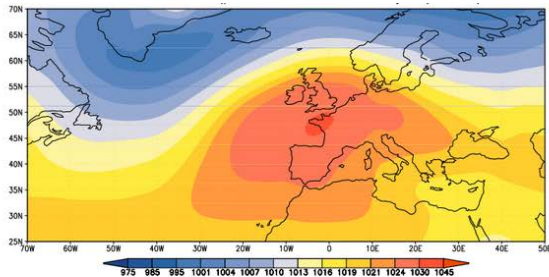
Cluster centroid #05 1529 days (=11%)



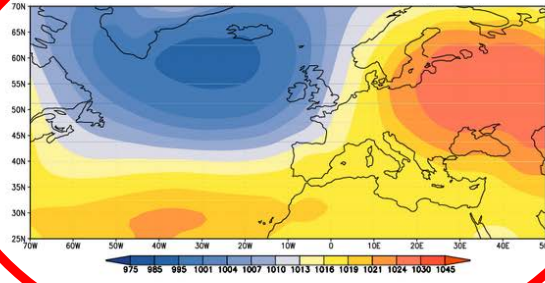
Cluster centroid #08 1348 days (=10%)



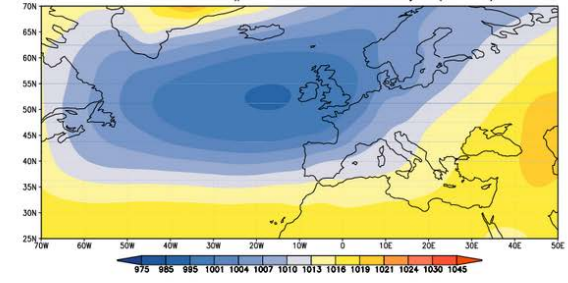
Cluster centroid #03 1728 days (=12%)

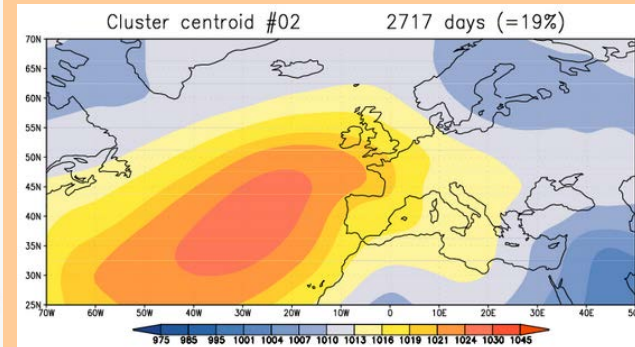
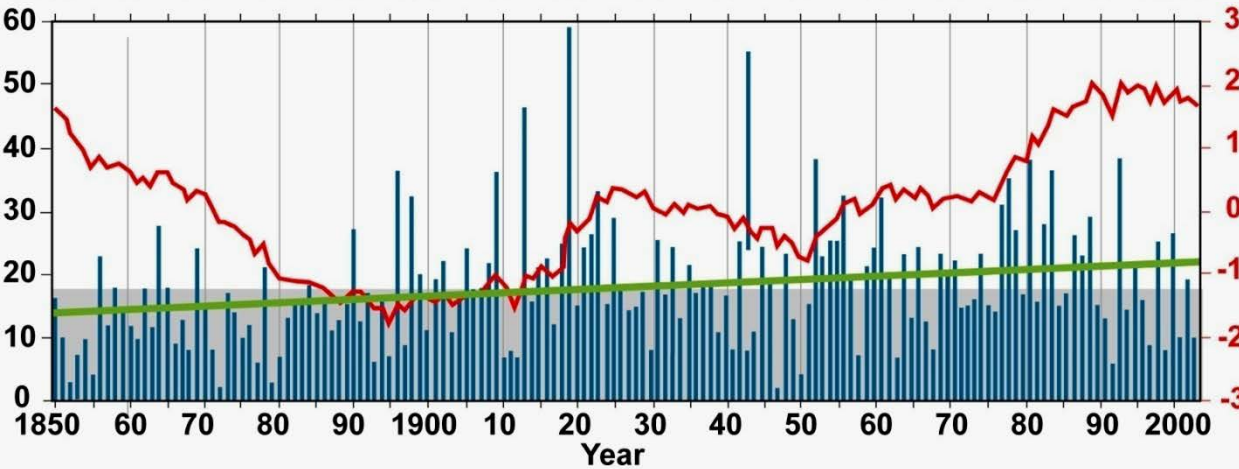
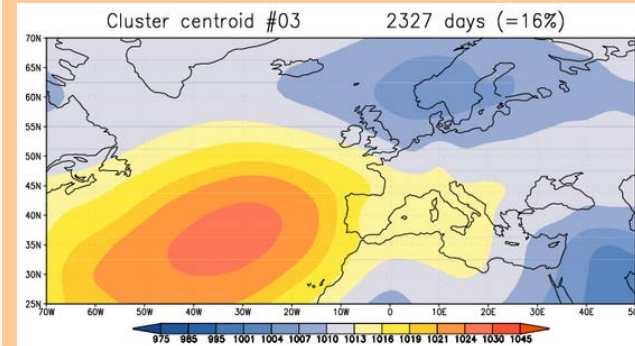
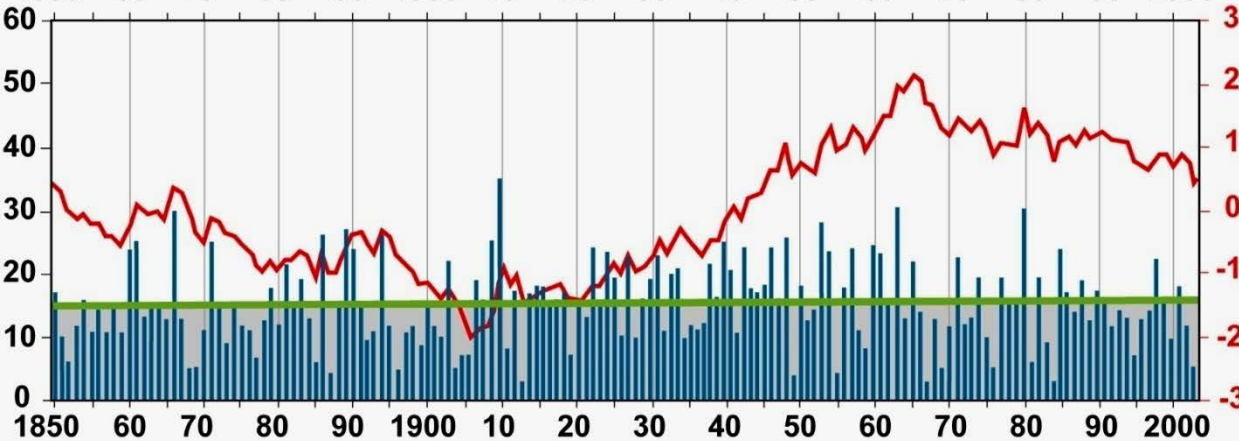
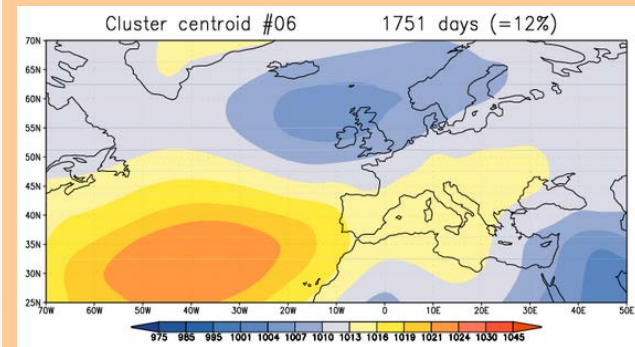
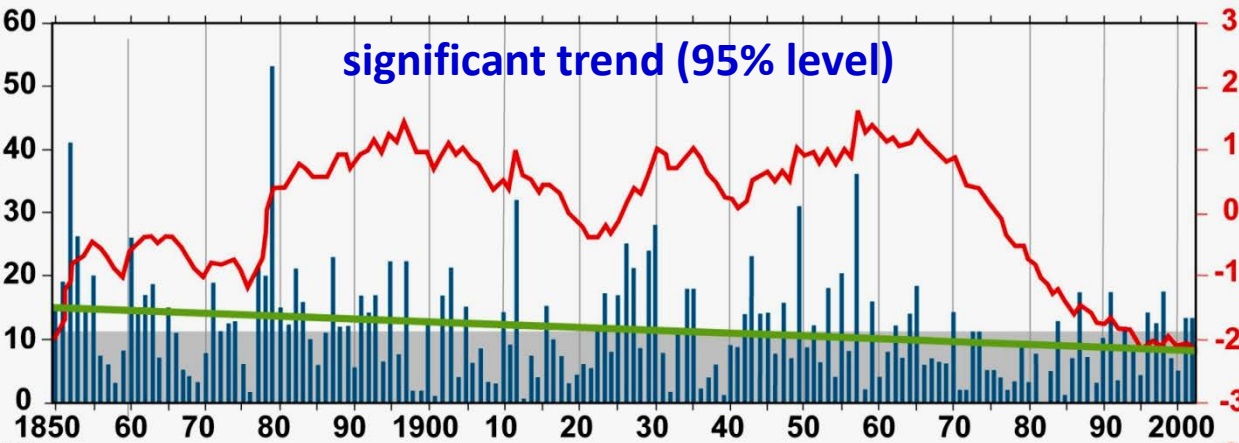


Cluster centroid #06 1728 days (=11%)



Cluster centroid #09 1085 days (=8%)

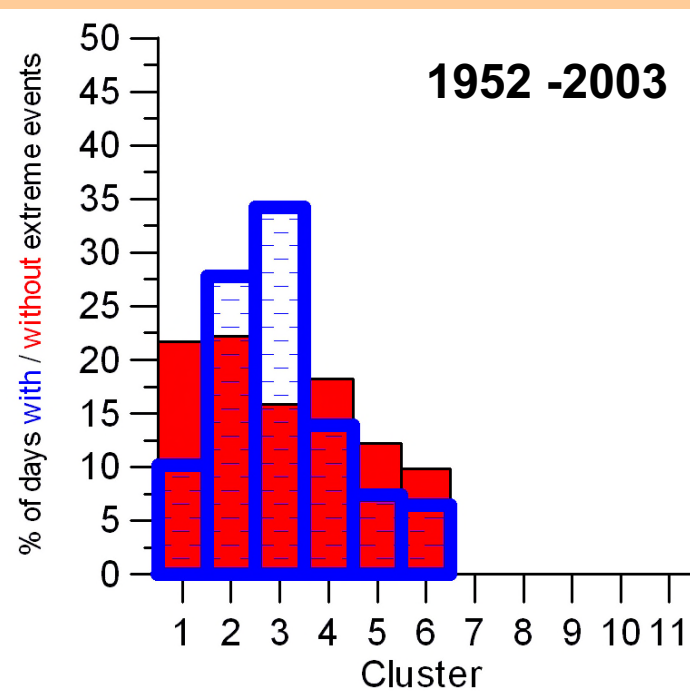
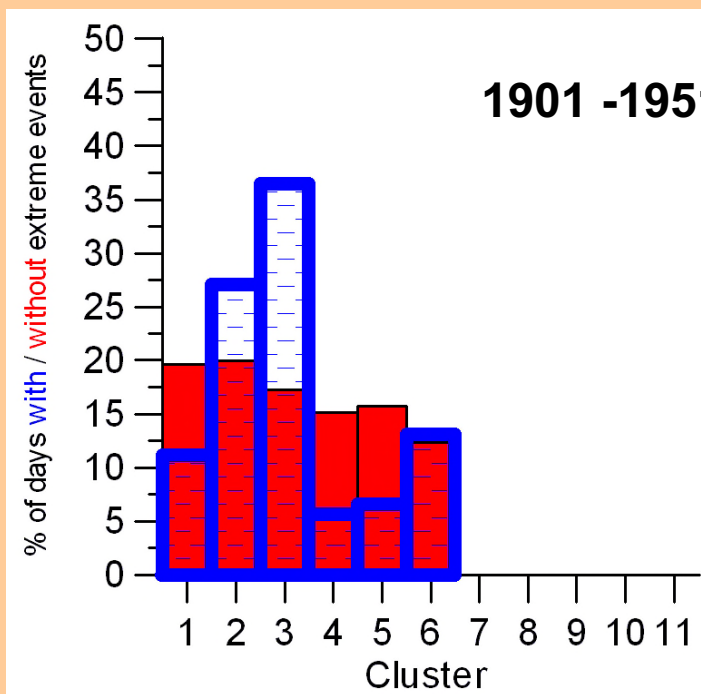




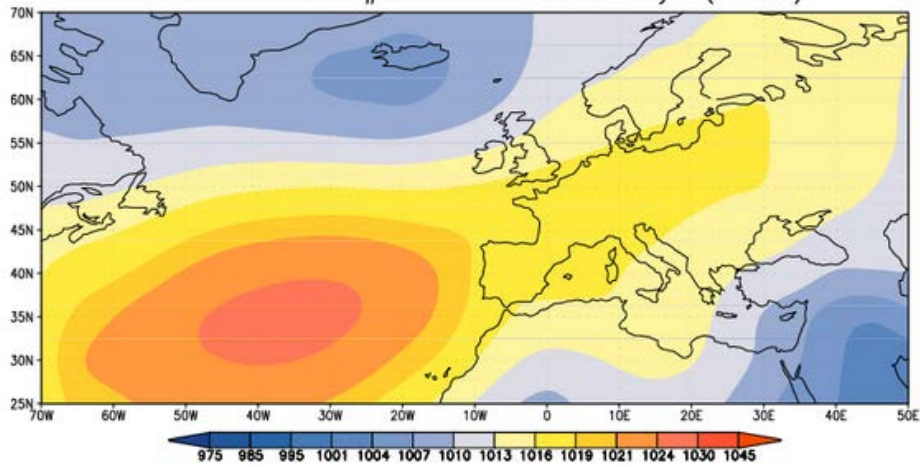
Summer (JJA) 1850-2003

% of extreme/normal days for each SLP Cluster

JJA extreme precipitation

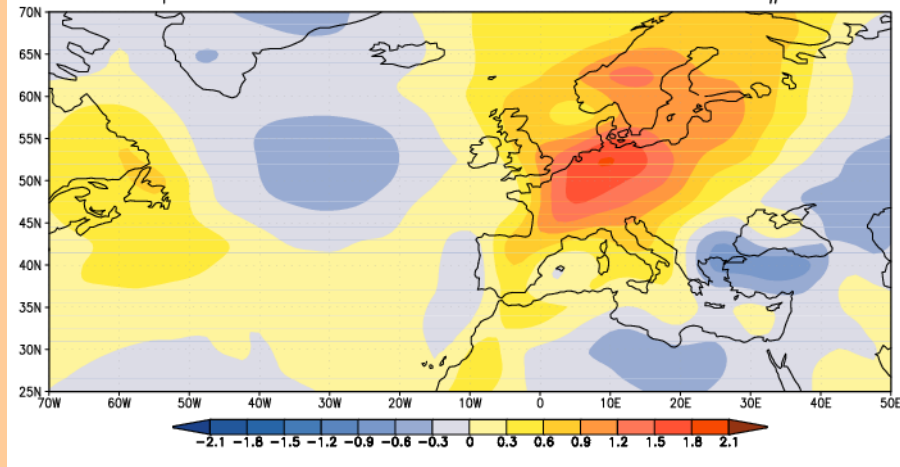


Cluster centroid #01 2879 days (=20%)

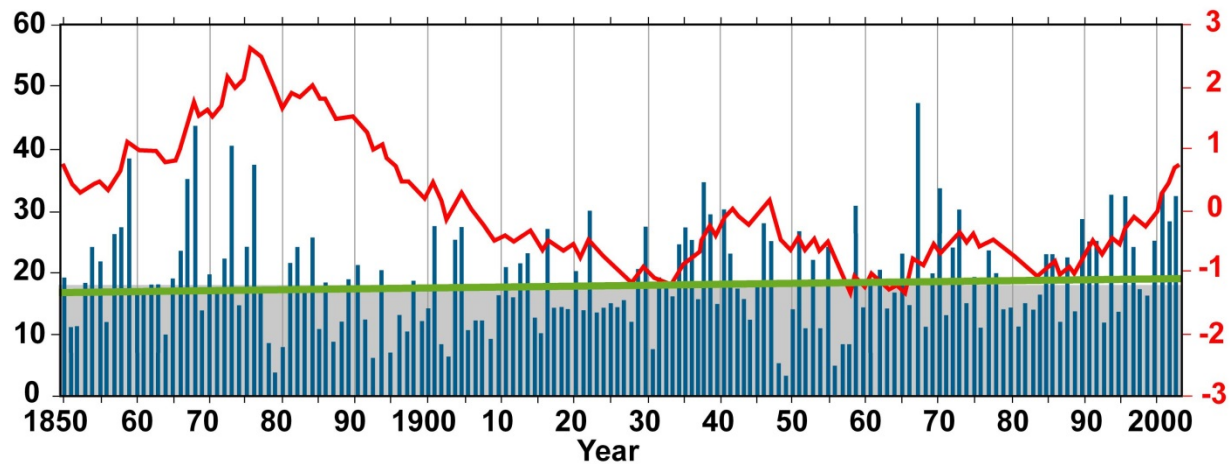


SLP (hPa) centroid pattern

Temperature anomalies 1948-2003 JJA cluster #01

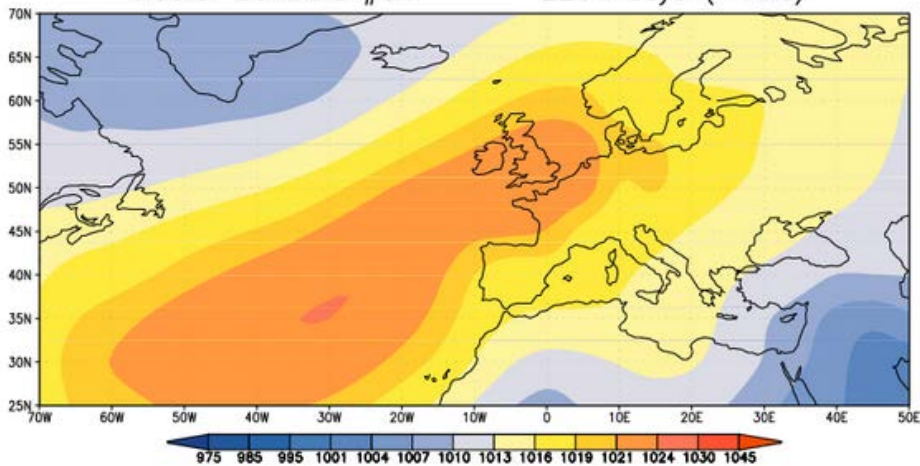


Associated mean temperature anomalies [K] 1948-2003



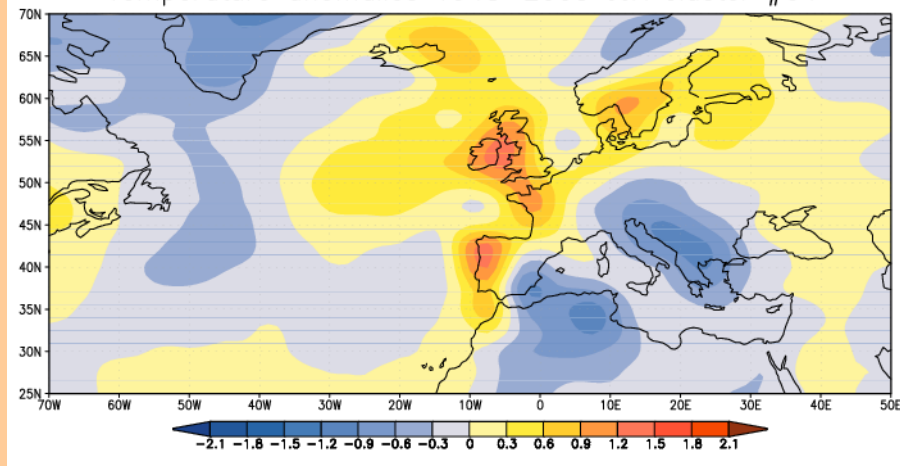
- seasonal cluster frequency (SCF)
- normalised cumulative anomalies of SCF
- linear trend of SCF

Cluster centroid #04 2264 days (=16%)

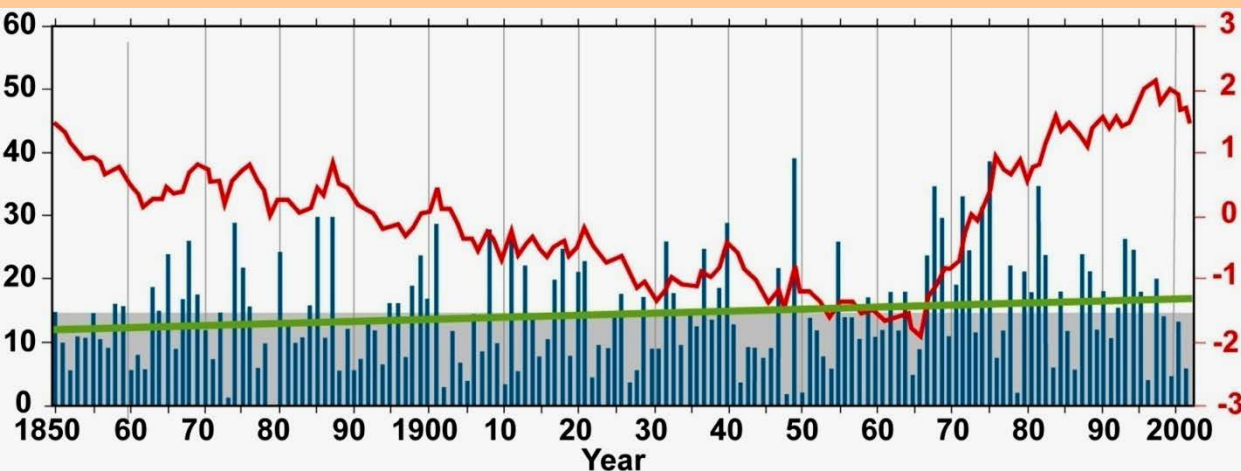


SLP (hPa) centroid pattern

Temperature anomalies 1948-2003 JJA cluster #04



Associated mean temperature anomalies [K] 1948-2003



- seasonal cluster frequency (SCF)
- normalised cumulative anomalies of SCF
- linear trend of SCF

nach Jones & Lister (2009)

haben sich im Laufe des 20. Jahrhunderts

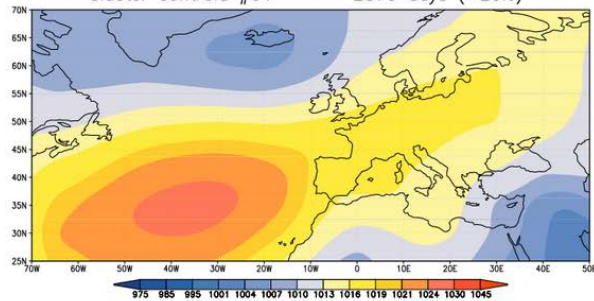
sommerliche Zirkulationsmuster in ihren Eigenschaften wie folgt verändert:

3 von 6 → wärmer

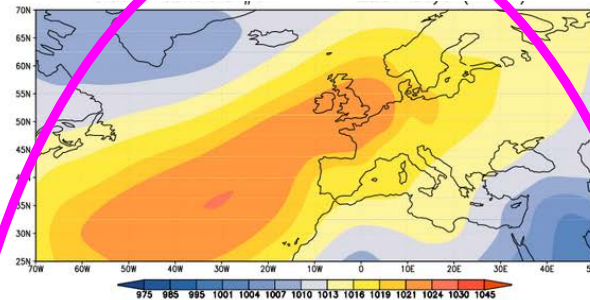
1 von 6 → feuchter

1 von 6 → trockener

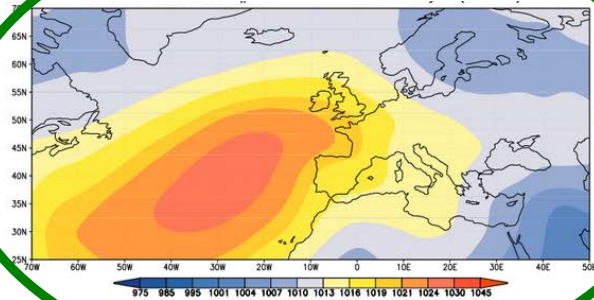
Cluster centroid #01 2879 days (=20%)



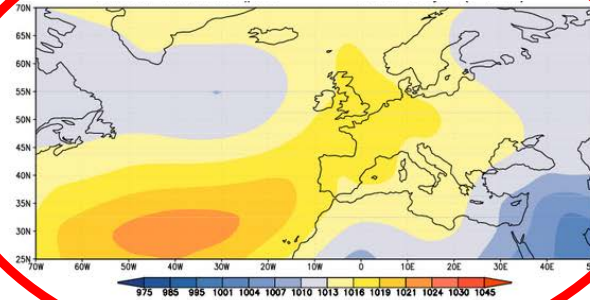
Cluster centroid #04 2264 days (=16%)



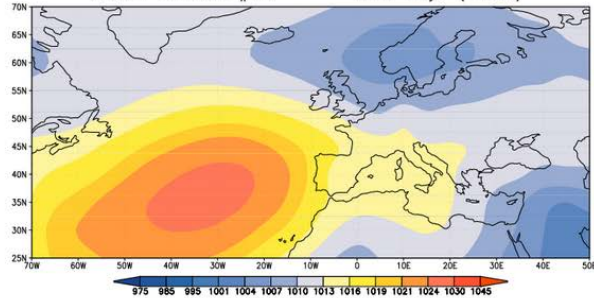
Cluster centroid #02 2717 days (=19%)



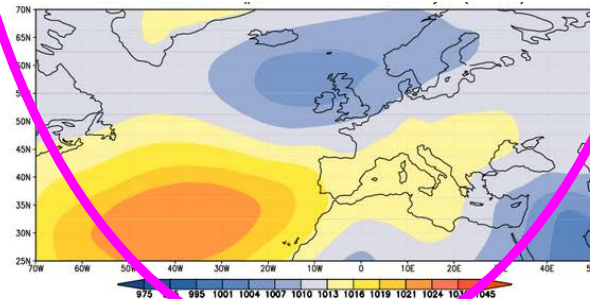
Cluster centroid #05 2230 days (=16%)



Cluster centroid #03 2327 days (=16%)



Cluster centroid #06 1751 days (=12%)

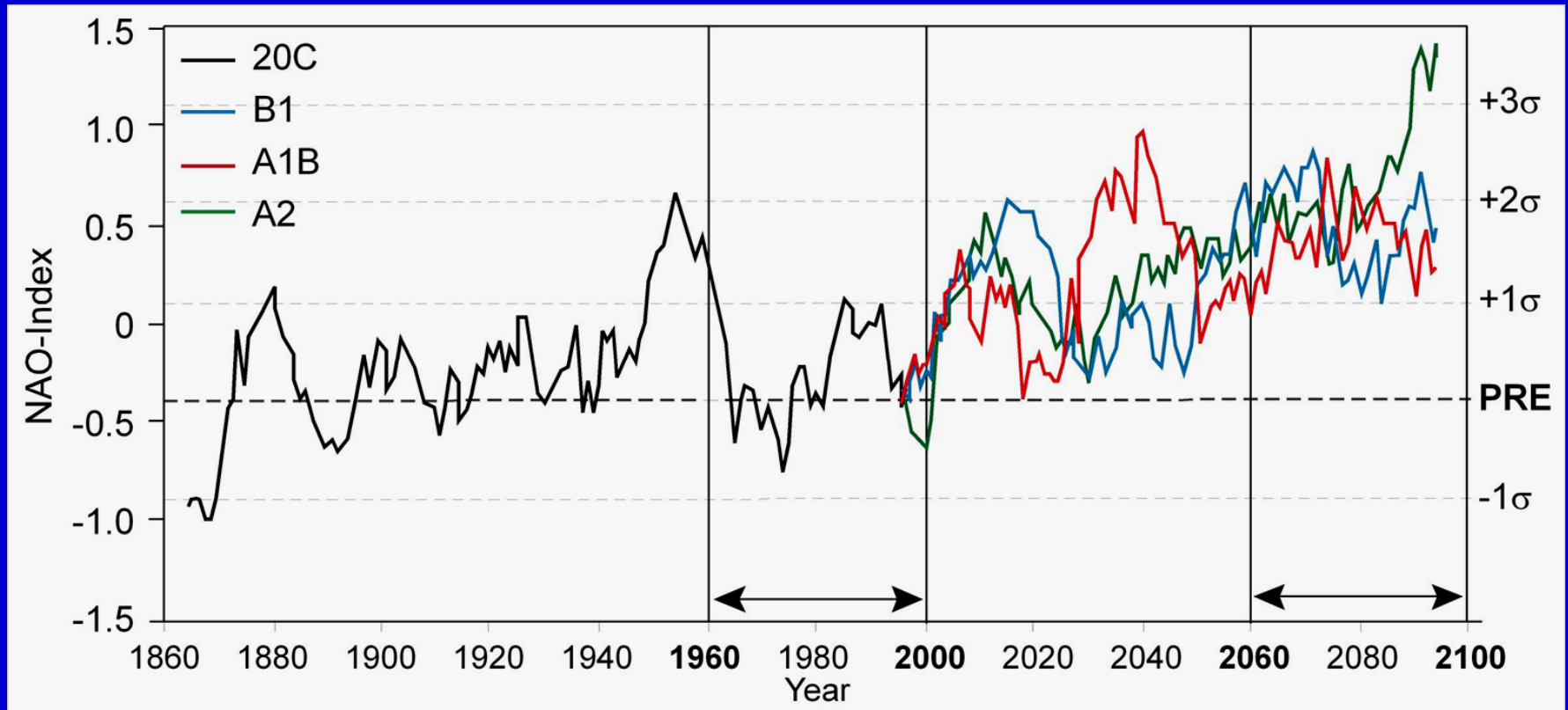


zukünftige Entwicklung ...

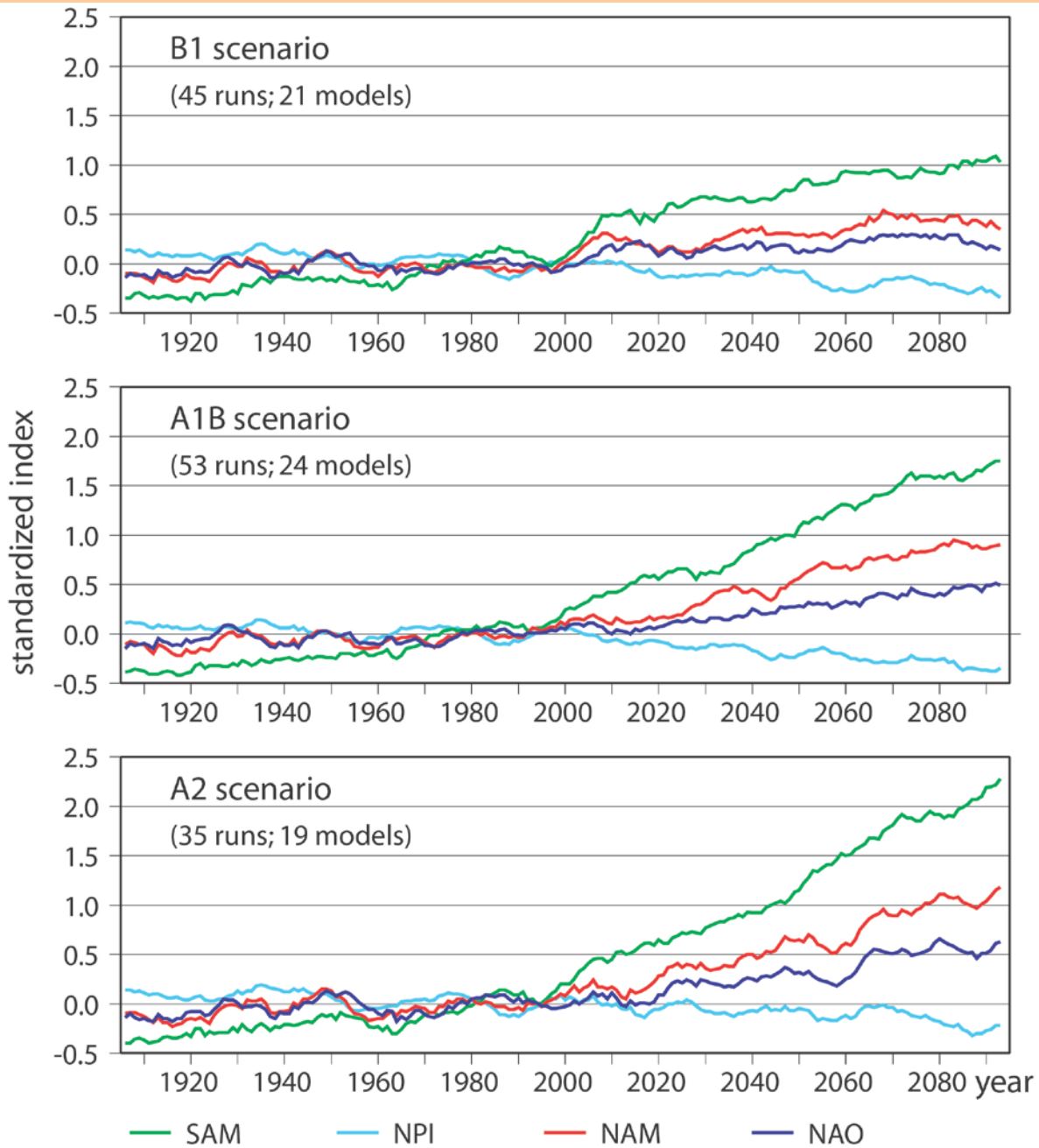
NAO-Index 1860-2100

Ensemblemittel aus ECHAM5-OM1-Simulationen
für die IPCC-Szenarien B1, A1B und A2

normalisierte Bodenluftdruckdifferenz zwischen den Gebieten
(0° - 40°W, 35° - 50°N) und (0° - 40°W, 55° - 70°N),
11-jährige gleitende Mittel



Projections of the 11-year low-pass filtered multi-model mean time series for the large-scale circulation modes SAM, NPI, NAM, NAO for emission scenarios B1, A1B, and A2



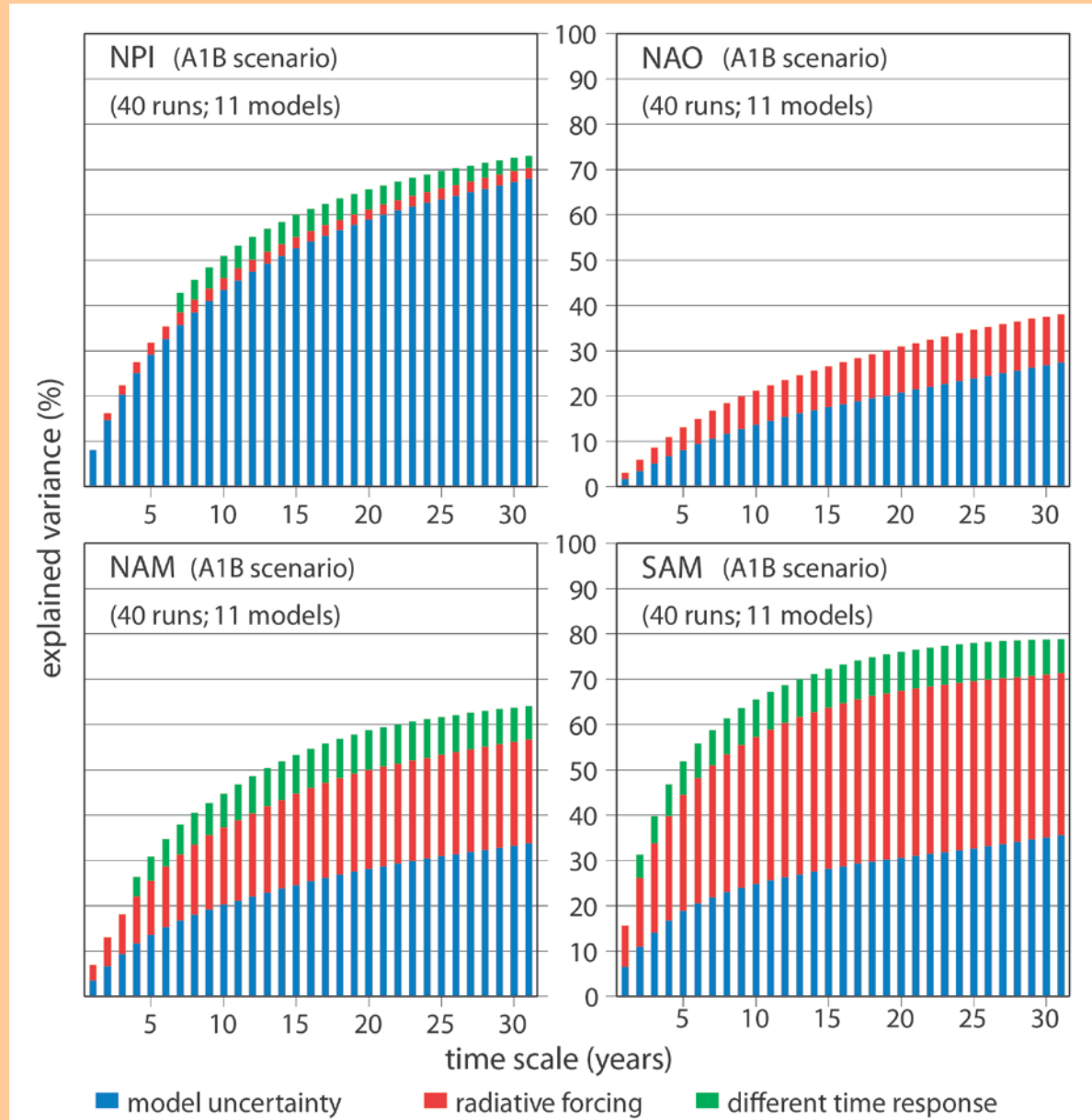
Portion of variance related to
model uncertainty

anthropogenic radiative
forcing (scenario A1B)

differences in the time response
during the 1970–2098 period

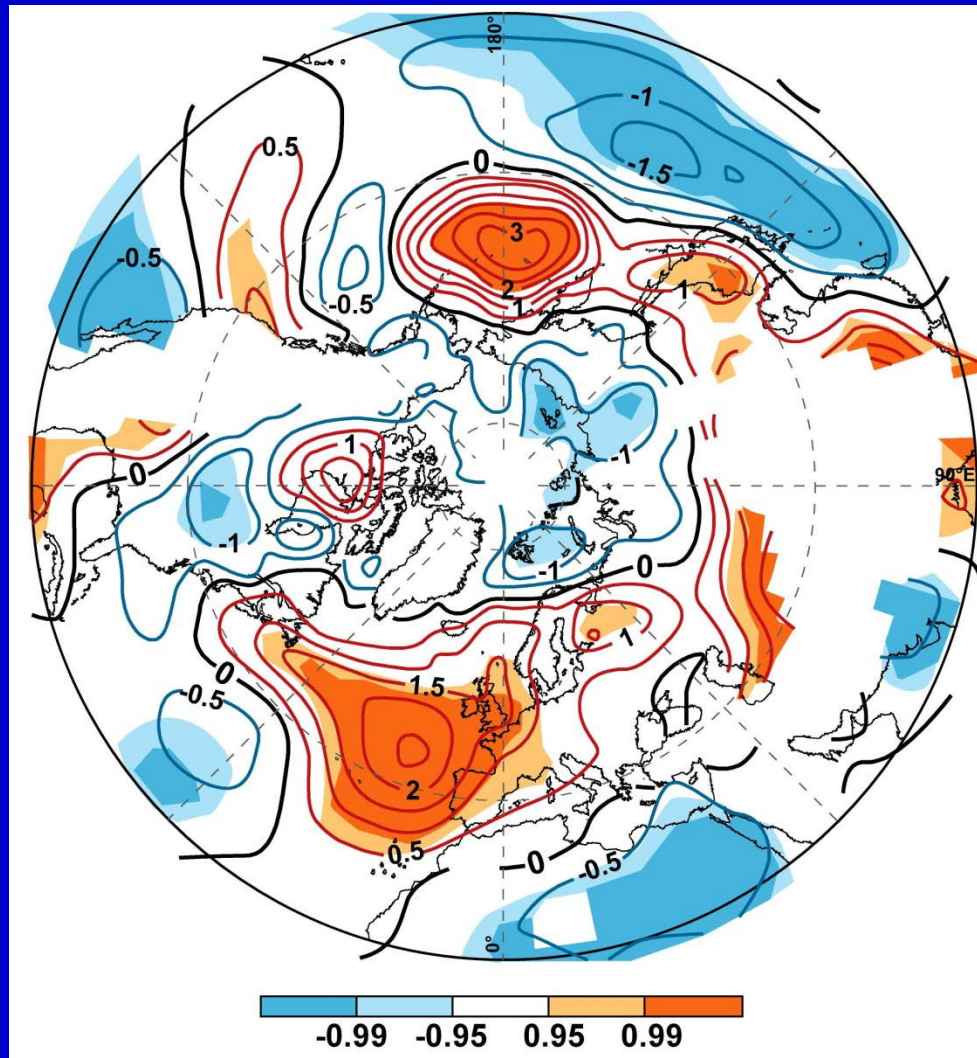
internal variability
(complementary percentage
up to 100%)

for the circulation modes
NPI, NAO, NAM, SAM

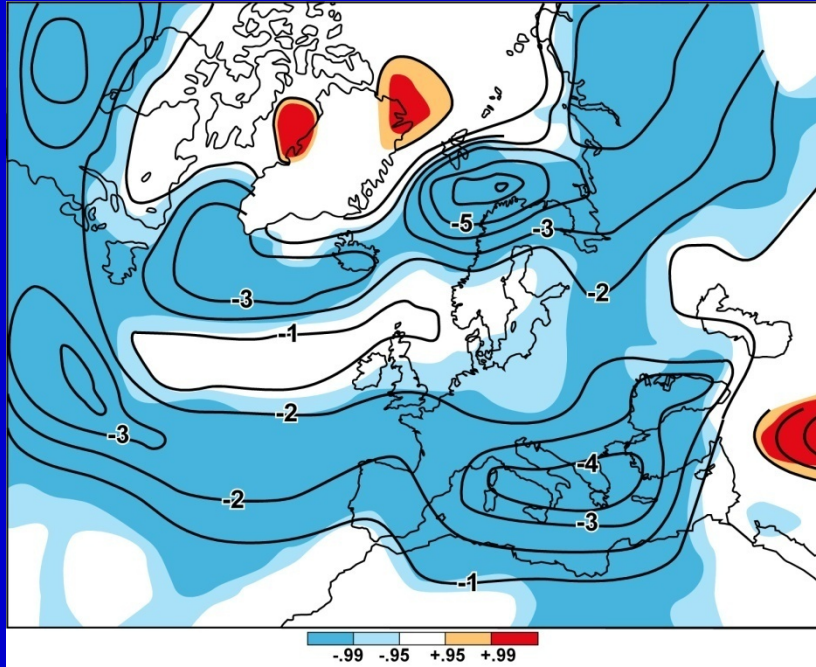


Difference in baroclinic wave activity (MSLP, 1/10 hPa) between 2080-2100 (A1B scenario) and 1960-2000

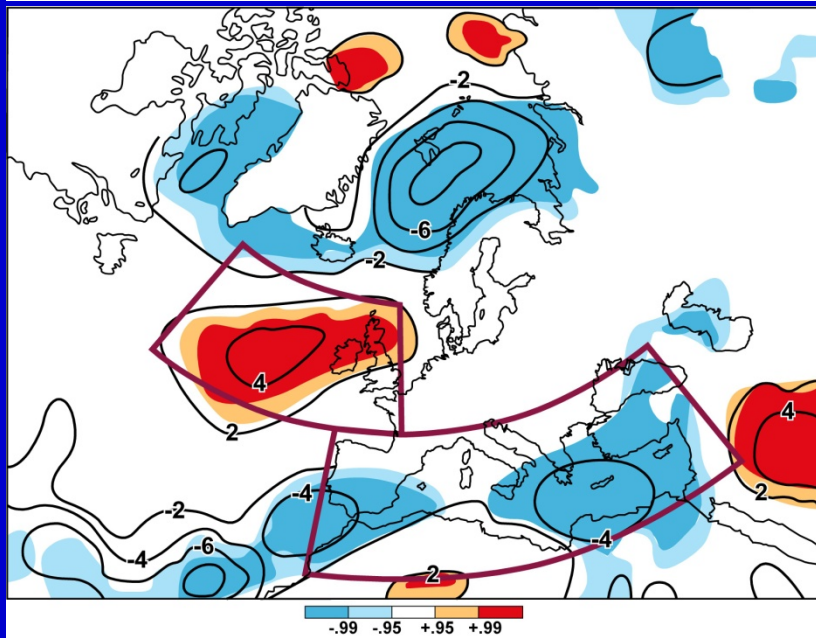
Values over high ground (>1000 m MSL) are omitted



**Cyclone track statistics ECHAM5 ensemble averages,
A1B scenario, 2060-2100 minus 1960-2000**

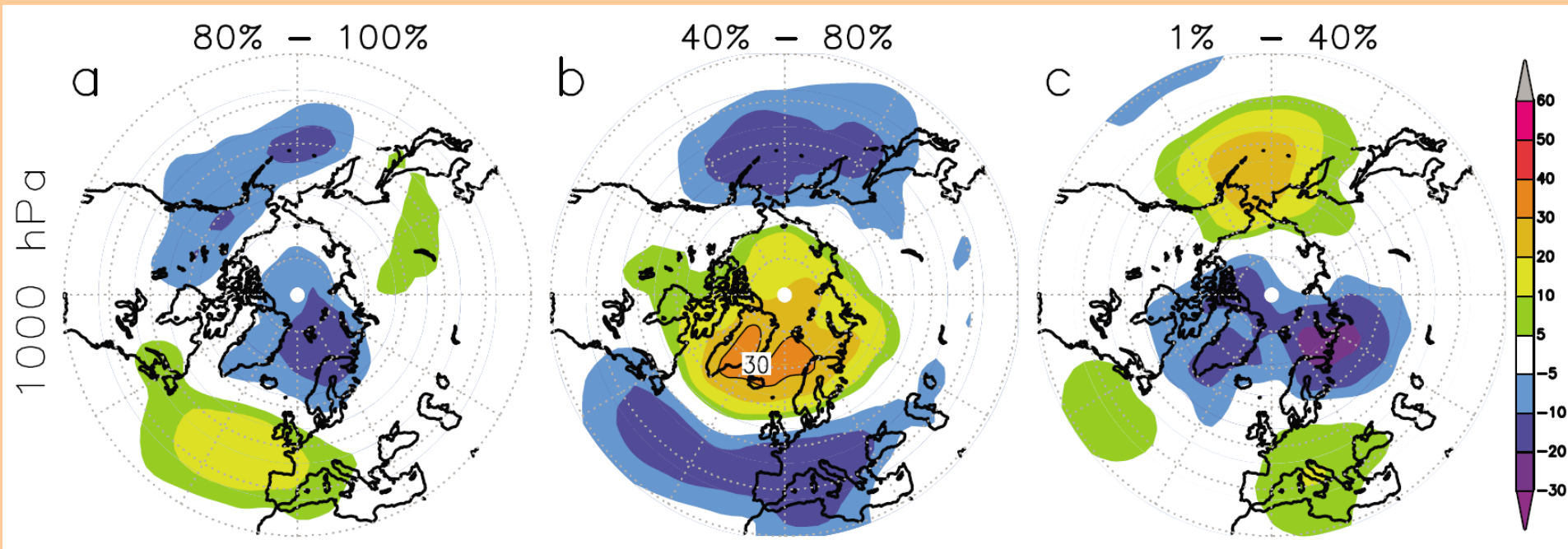


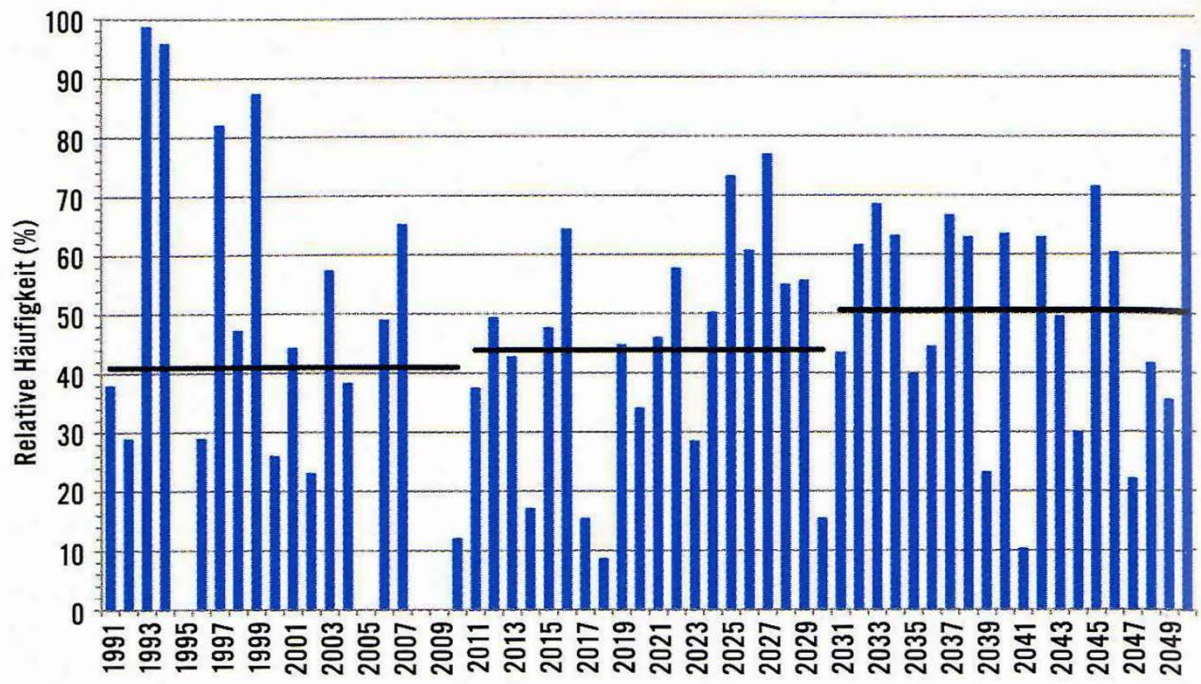
**cyclone track density
(cyclone days/winter)**



cyclone intensity

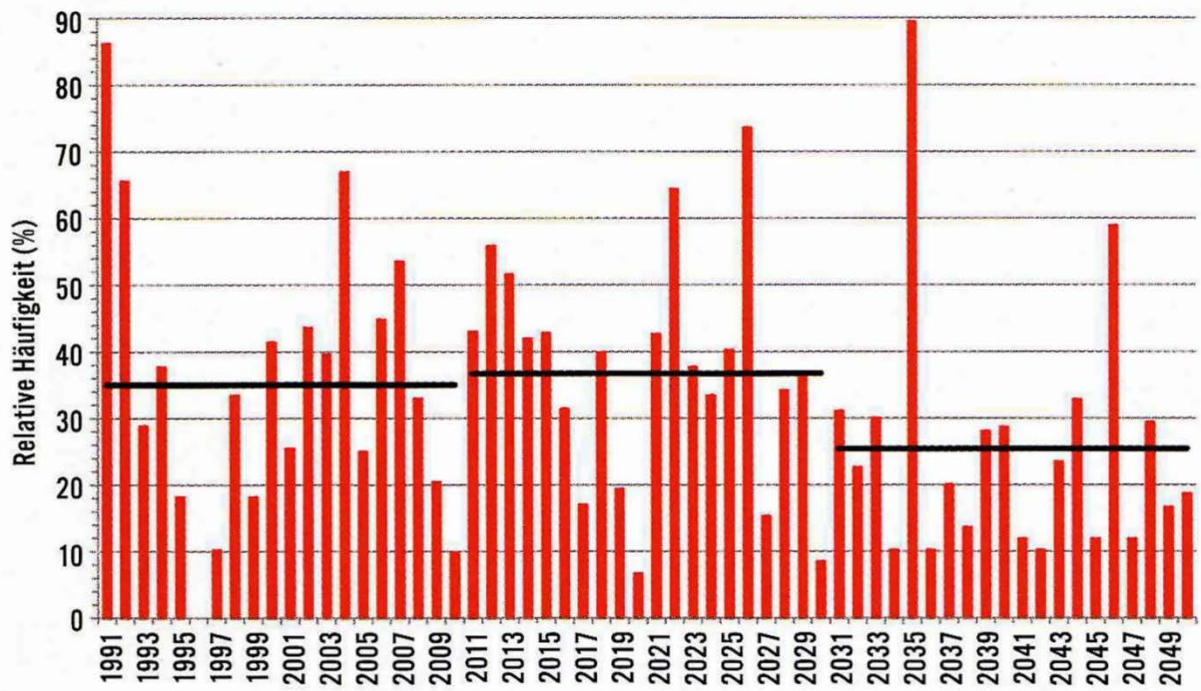
Änderung der geopotentiellen Höhen (gpm) im 1000 hPa Niveau als Reaktion auf Übergänge des Meereises in der Barents-Kara-See von 100%-80%, 80%-40% und 40%-1% (Februar, Echam5-Simulation)



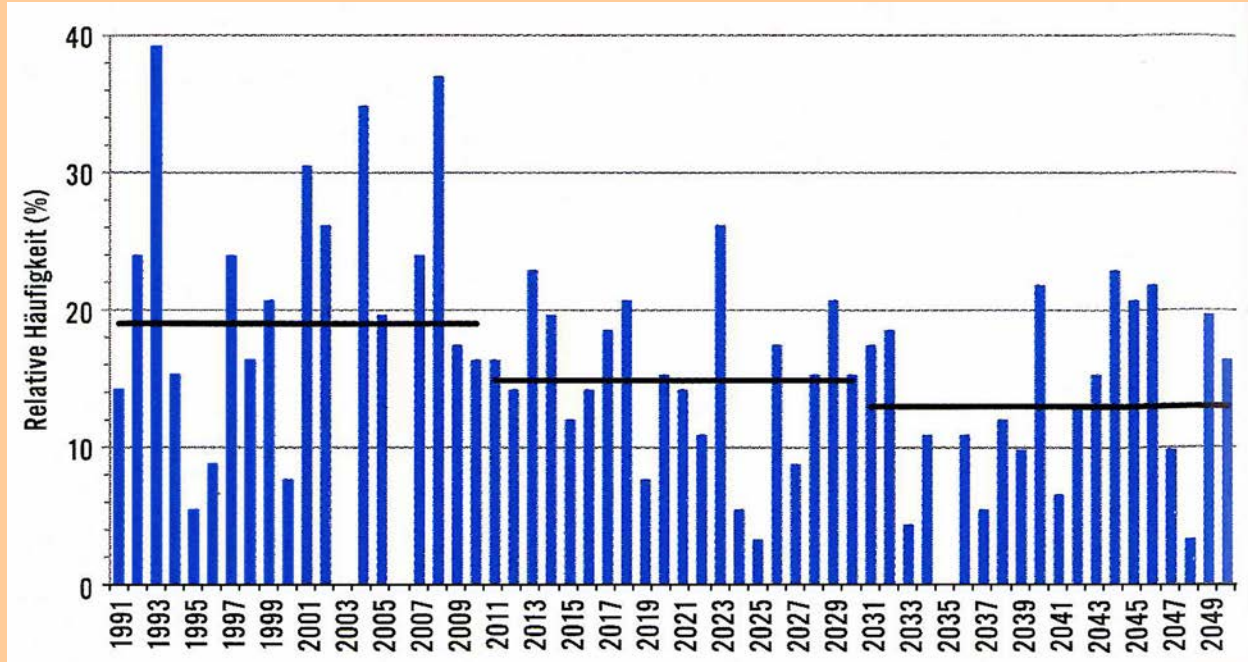


Wz: West zyklonal

**Auftrittshäufigkeit von
Großwetterlagen zwischen
1991 und 2050, Winter**

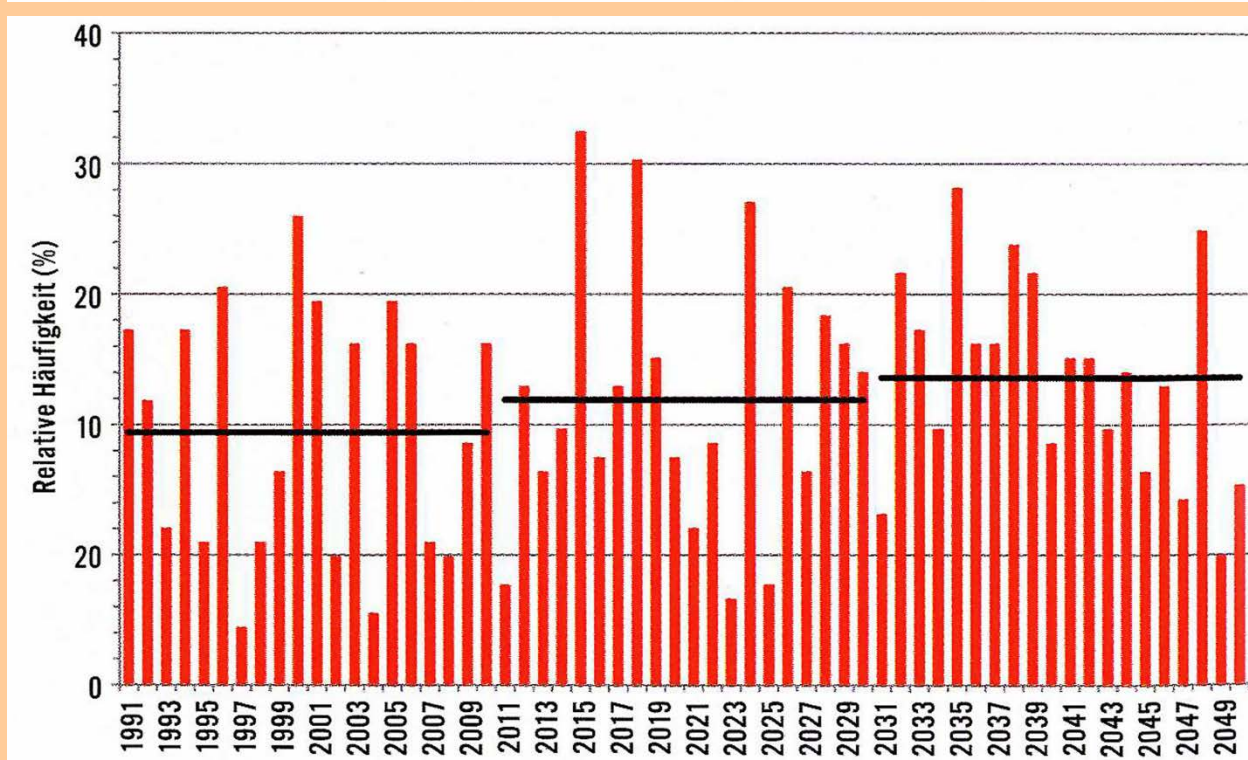


HM: Hoch Mitteleuropa
und
BM: Hochdruckbrücke
Mitteleuropa



Wz: West zyklonal

Auftrittshäufigkeit von
Großwetterlagen zwischen
1991 und 2050, Sommer



HM: Hoch Mitteleuropa
und
BM: Hochdruckbrücke
Mitteleuropa

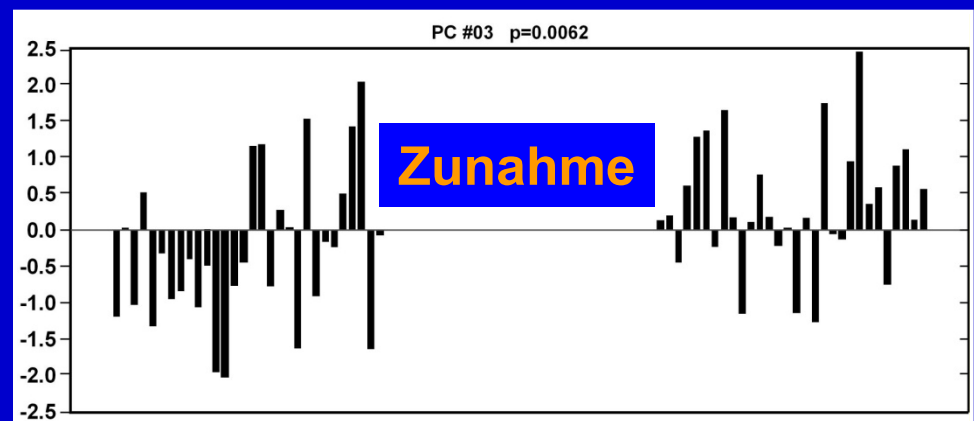
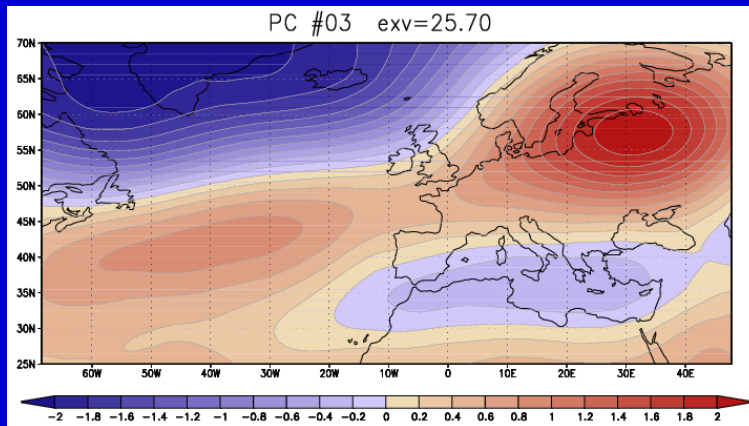
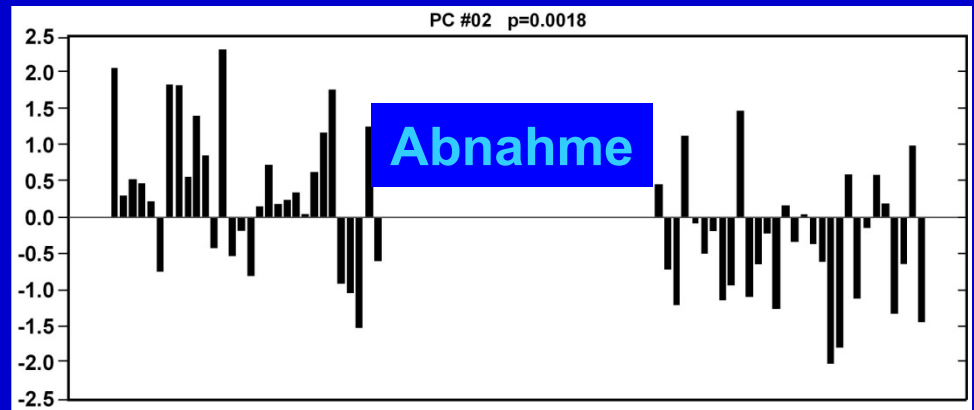
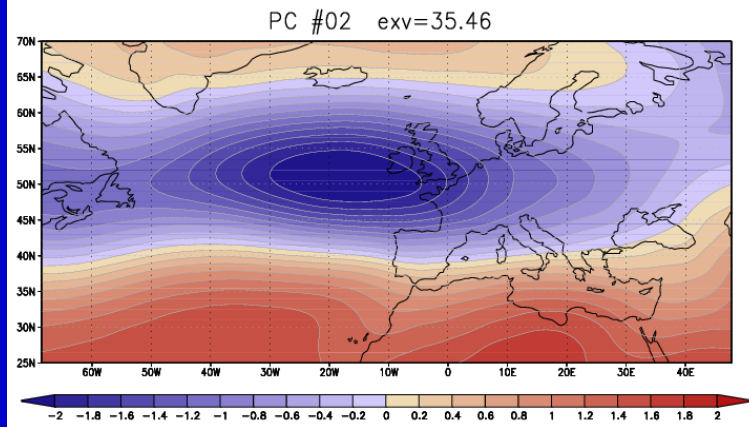
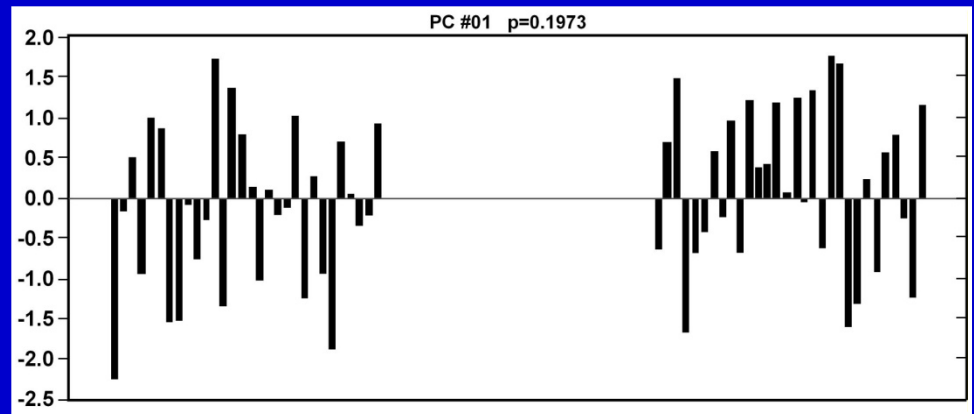
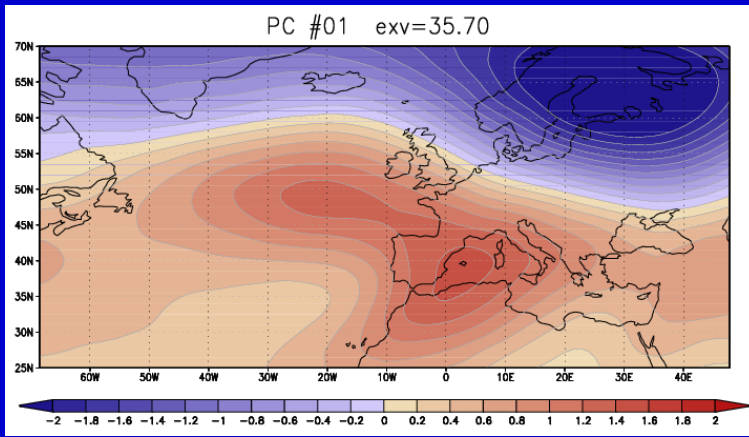
Veränderungen grundlegender Zirkulationsmuster:

**Vergleich ihrer Zeitkoeffizienten
zwischen erstem und letztem Jahrzehnt im 21. Jahrhundert**

**unter Verwendung von Output des britischen
Klimamodells HadCM3 (Szenario A1B)**

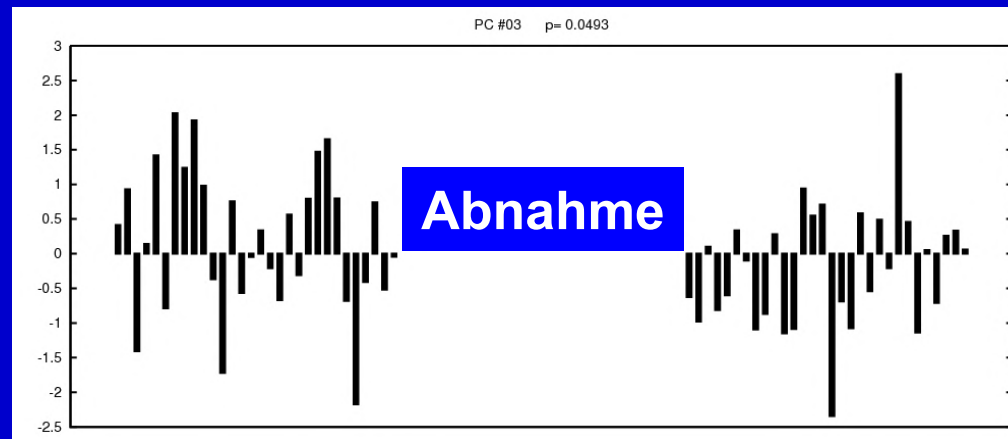
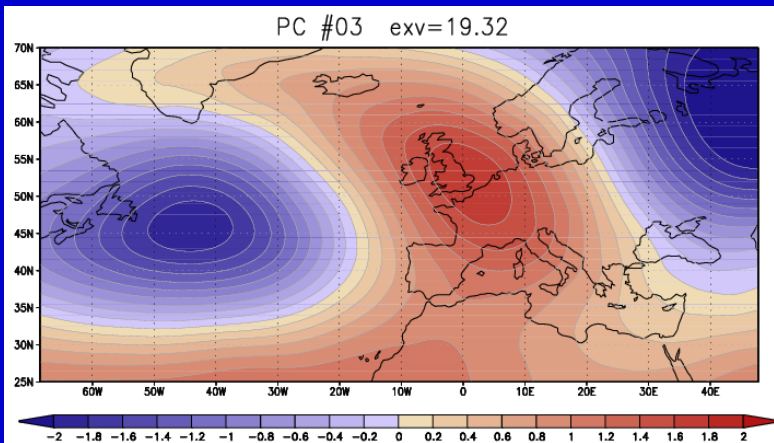
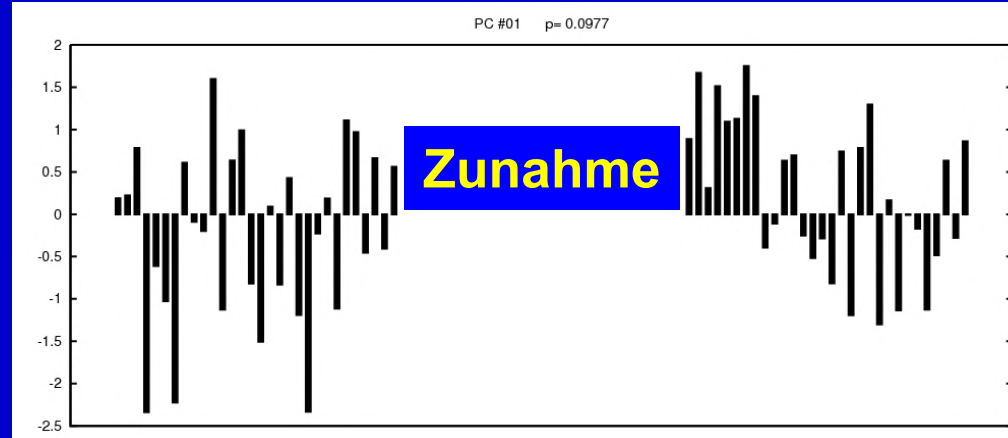
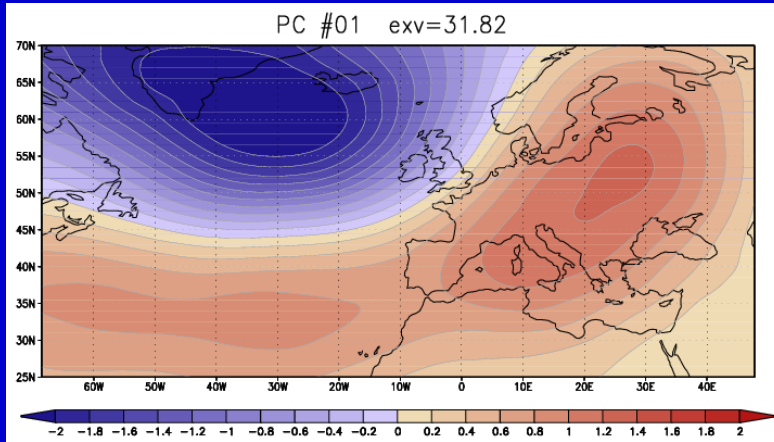
Zirkulationsmuster (500 hPa) Sommer

2001-2010 Zeitkoeffizient 2091-2100



Zirkulationsmuster (500 hPa) Winter

2001-2010 Zeitkoeffizient 2091-2100



**mutmaßliche Zirkulationsänderungen in Europa
bei fortschreitender globaler Erwärmung:**

im Winter häufiger NAO + und seltener NAO –

**im Sommer häufiger antizyklonale und
seltener zyklonale Wetterlagen**

Atmosphärische Zirkulation und Klimawandel

Prof. Dr. Jucundus Jacobeit

**Institut für Geographie
Universität Augsburg**