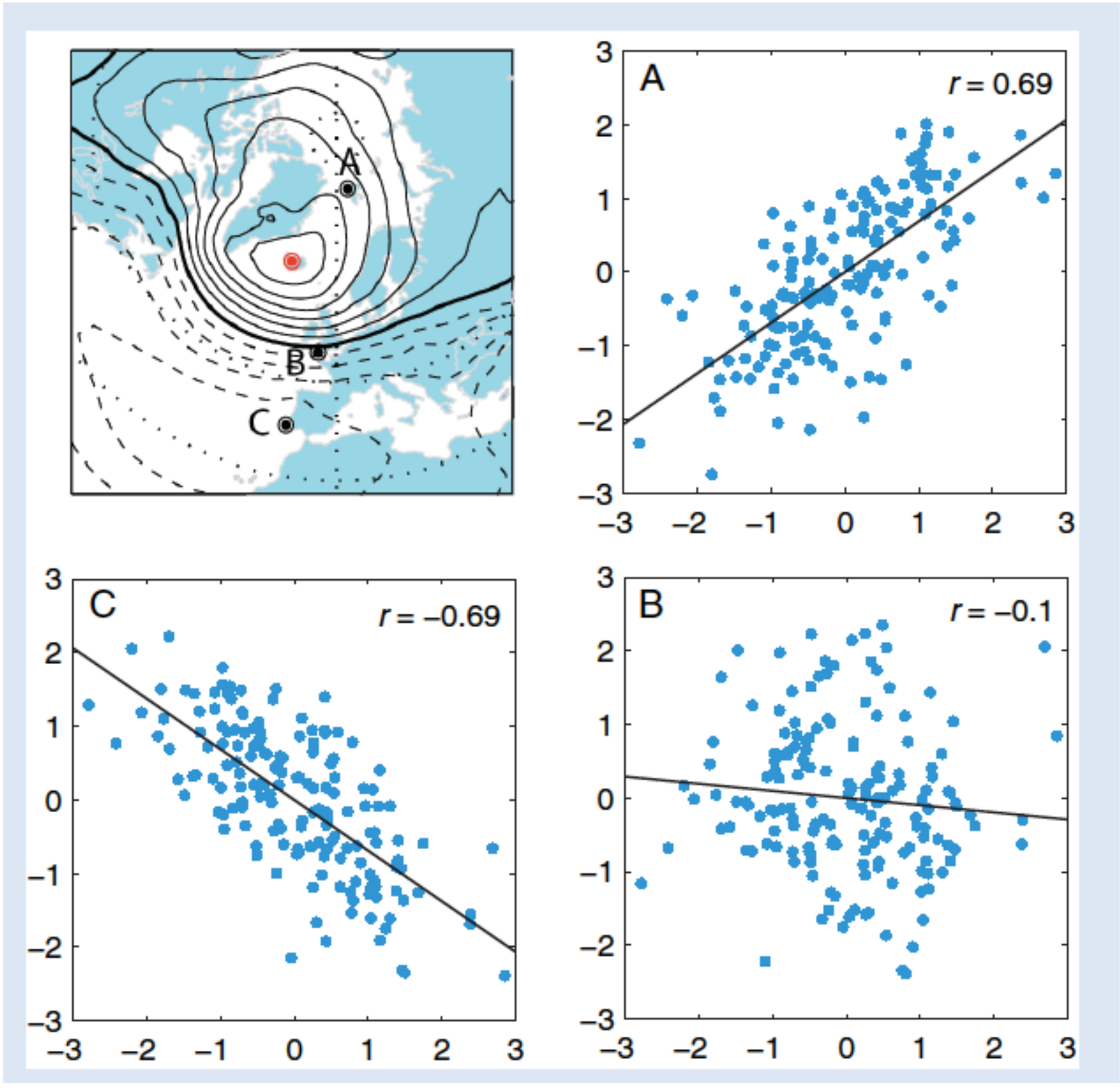
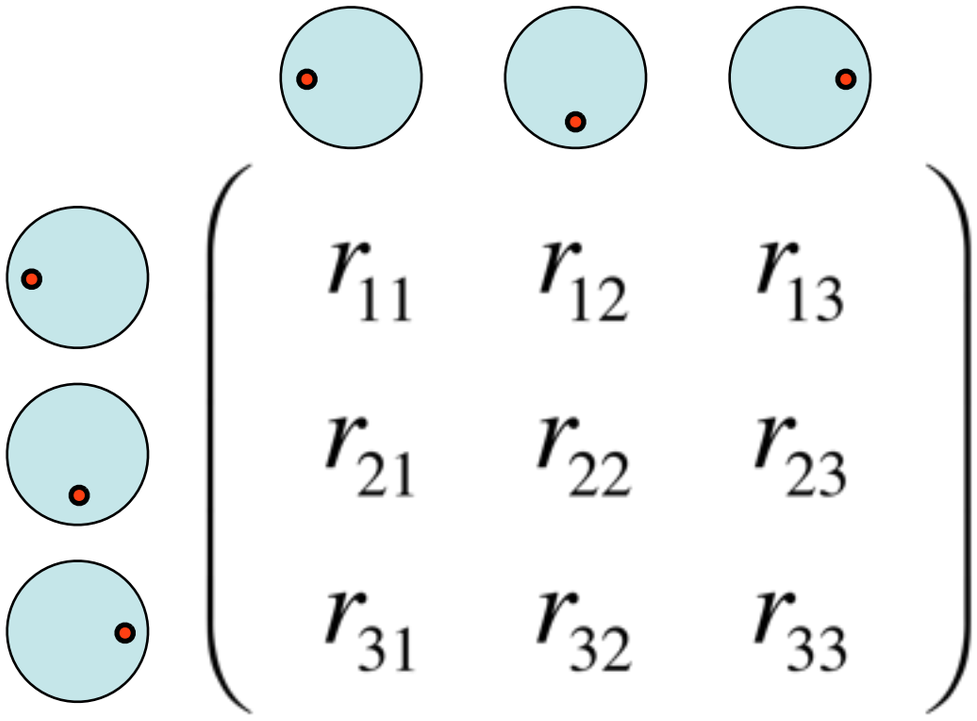
One-point correlation maps: an example



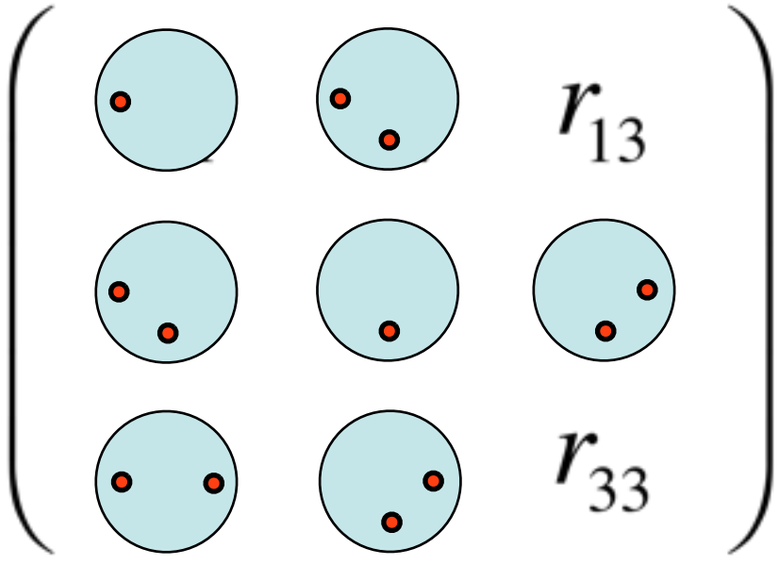
Wallace and Hobbs 2nd edition

The correlation (or covariance) matrix



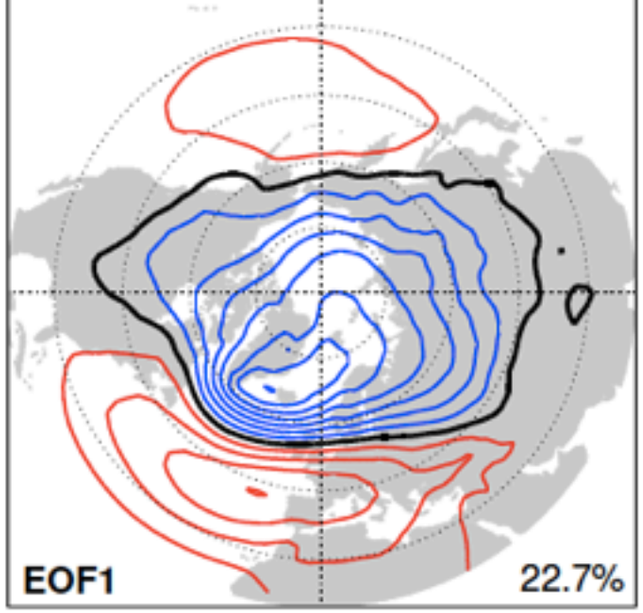
CORRELATION MATRIX
Each row or column is a one-point correlation map.

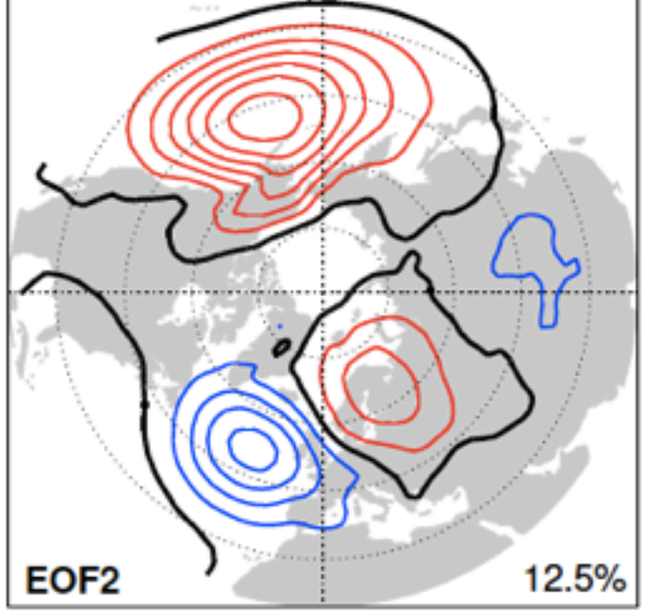
Elements on the diagonal are equal to 1.

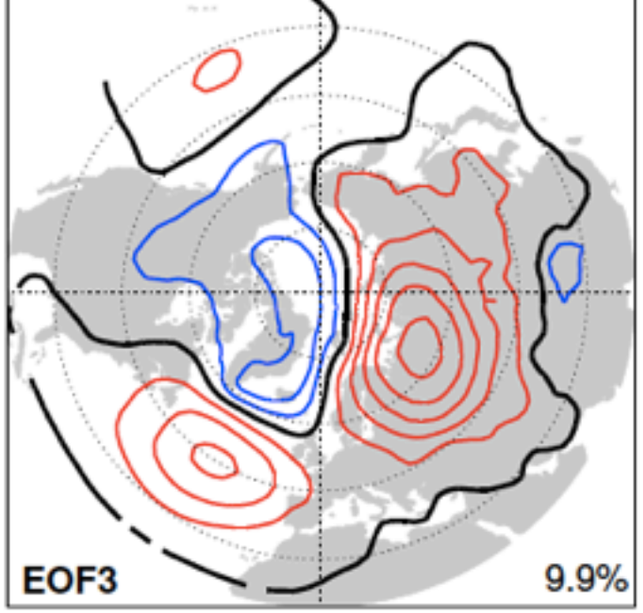


COVARIANCE MATRIX
Each row or column is a one-point covariance map (i.e., a regression map for one grid point).

Elements on the diagonal comprise the variance map.

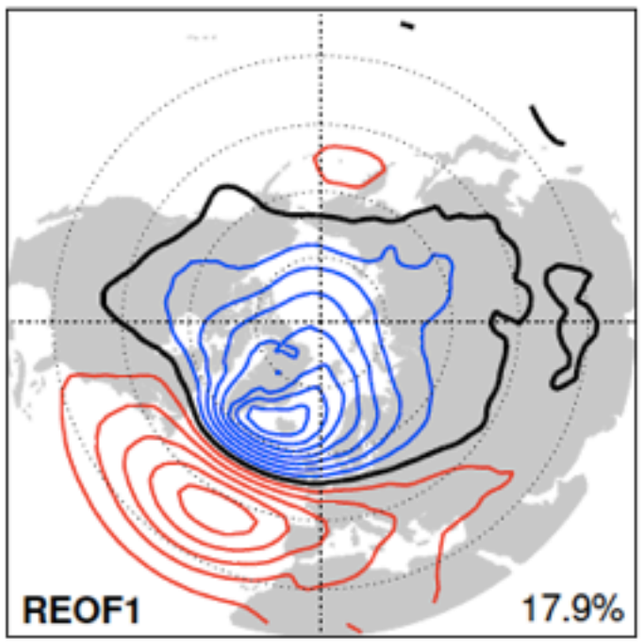


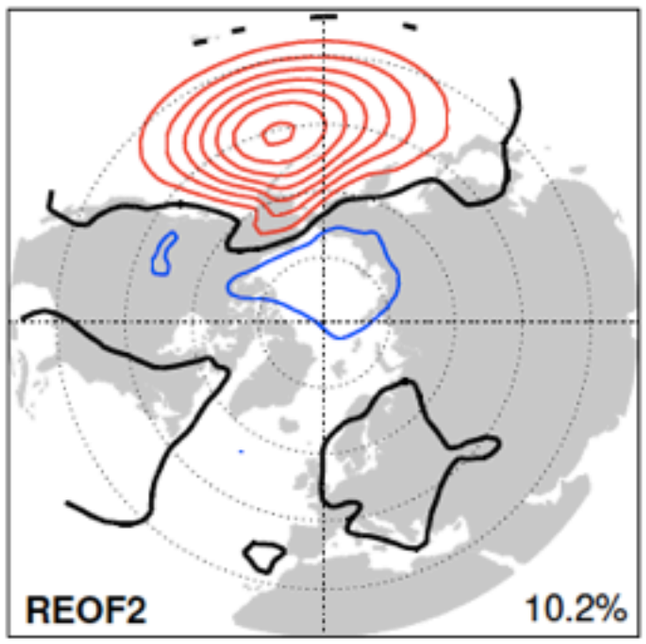


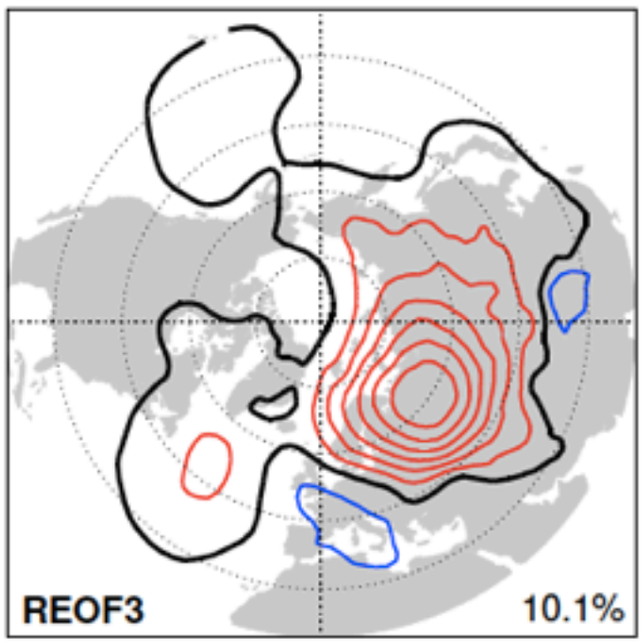


Wintertime SLP

Hemispheric EOFs







Rotated EOFs

Sectoral EOFs

M.S. Thesis
Brian Smoliak

Wintertime SLP

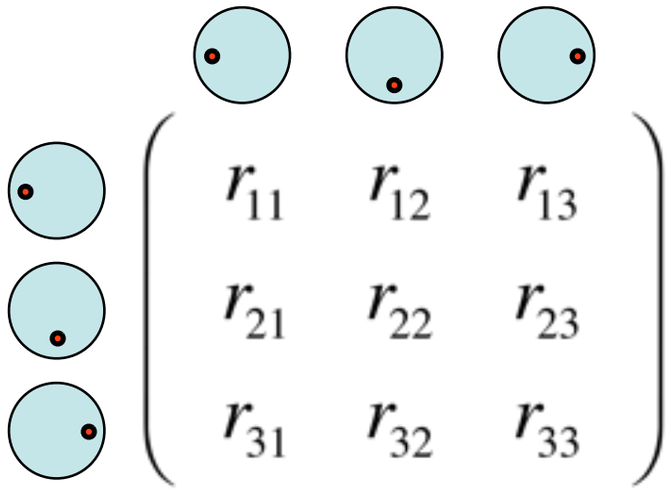
Rotated EOFs

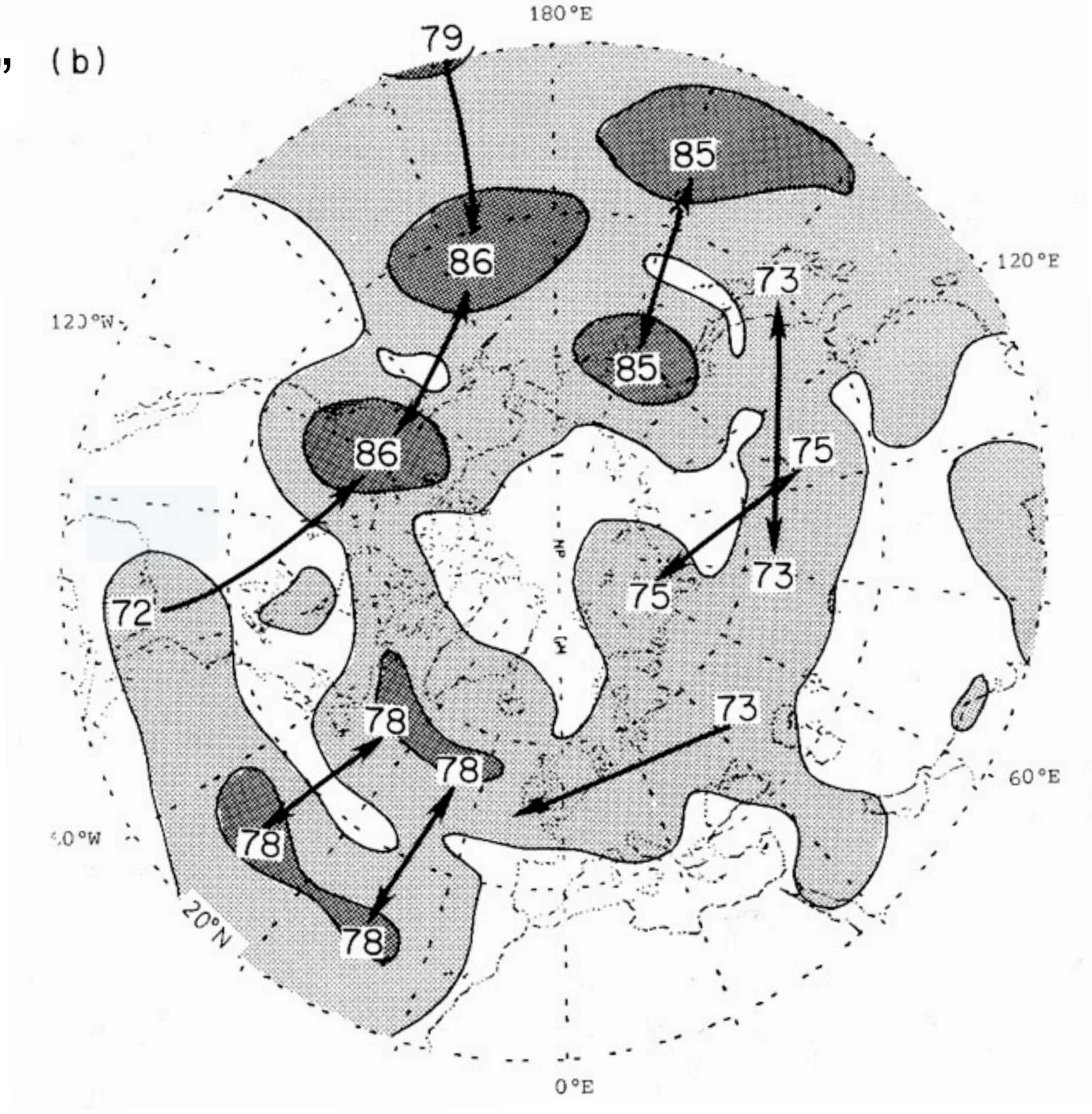
Sectoral EOFs

EOTs

M.S. Thesis
Brian Smoliak

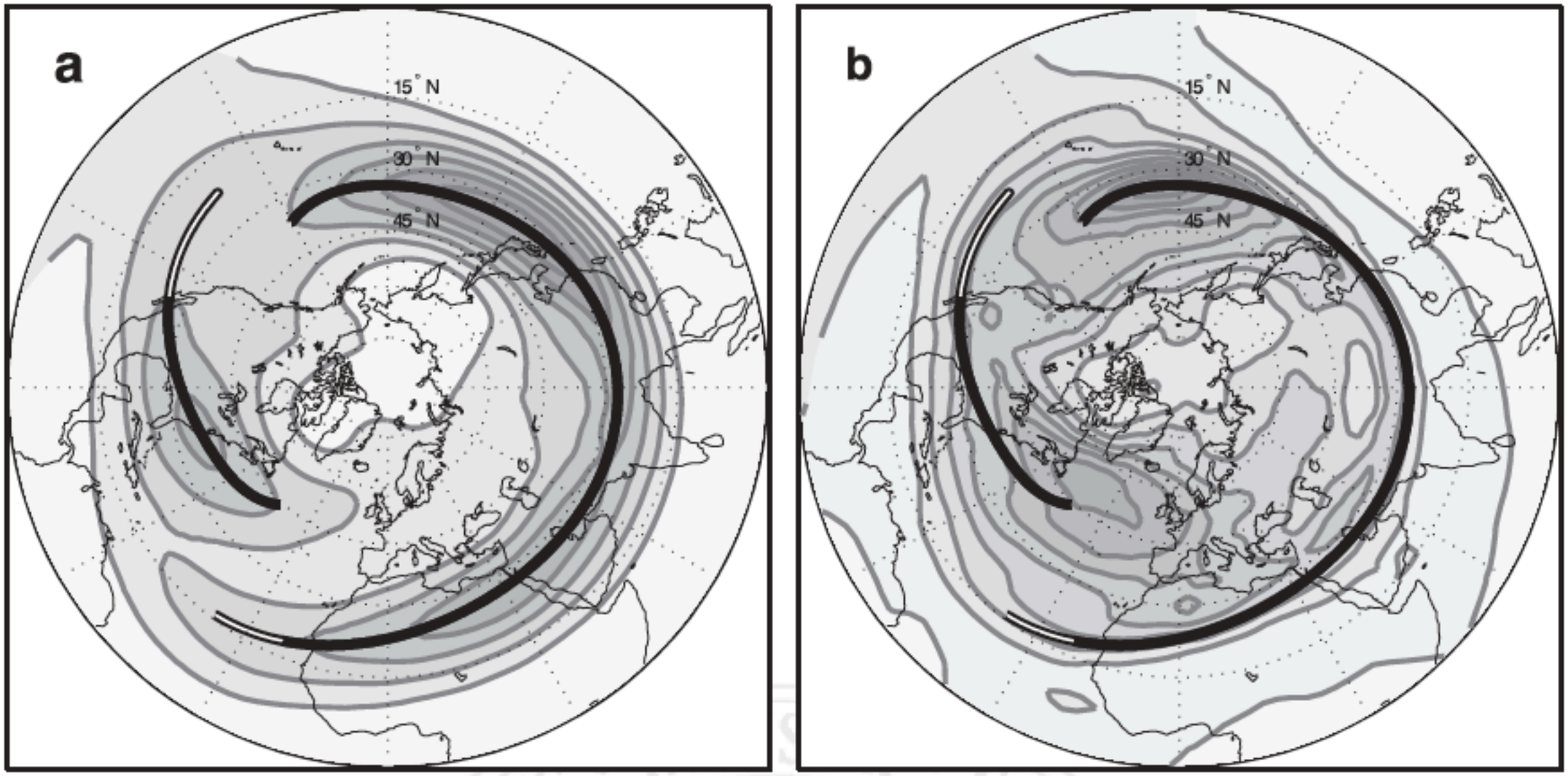
“Teleconnectivity”





wintertime 500 hPa height field

Blackmon et al. (1984a)

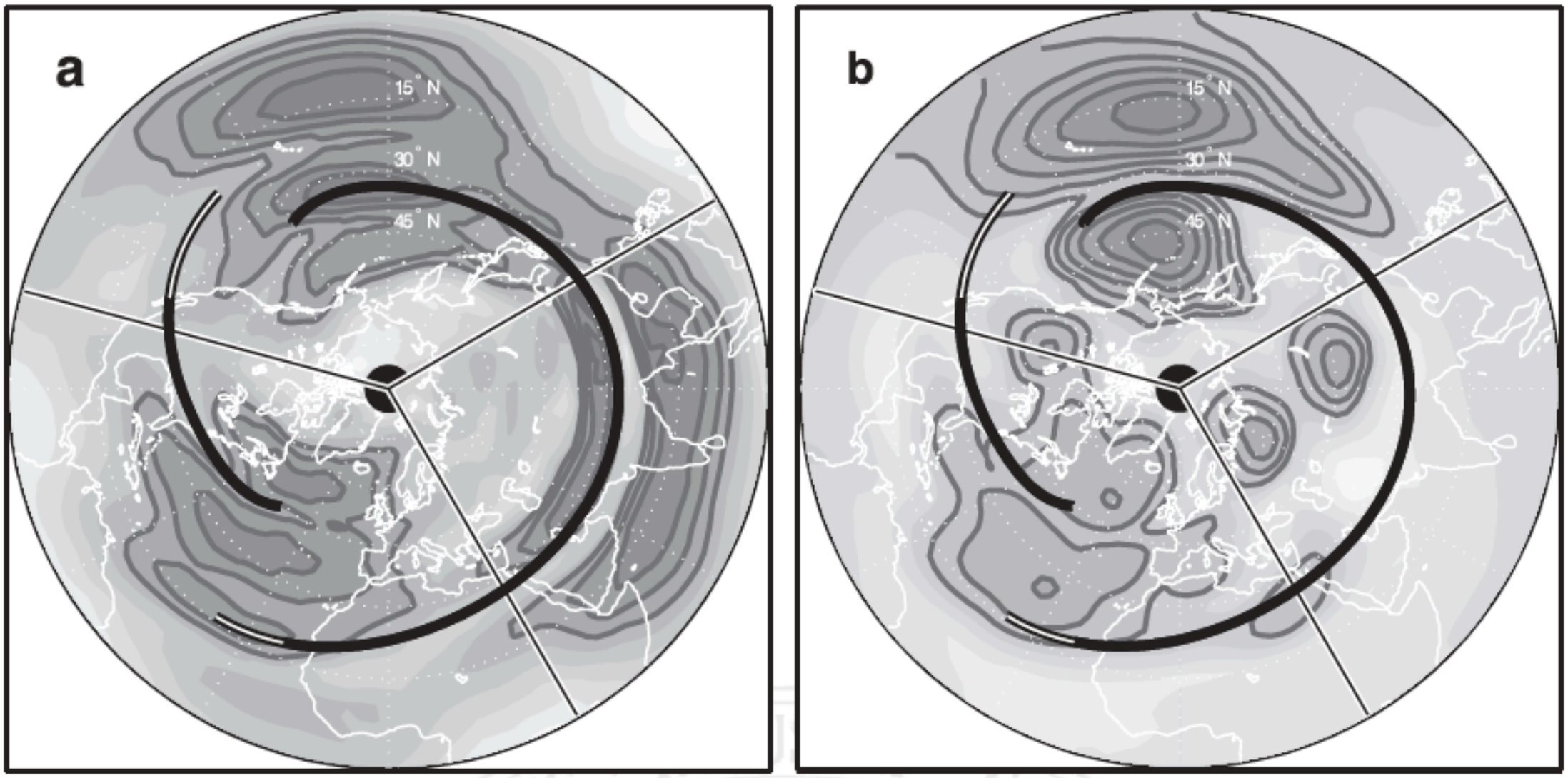


Mean of *u*

Variance of *u*

wintertime daily, unfiltered 300 hPa *u* field

Athanasiadis et al. (1984a)



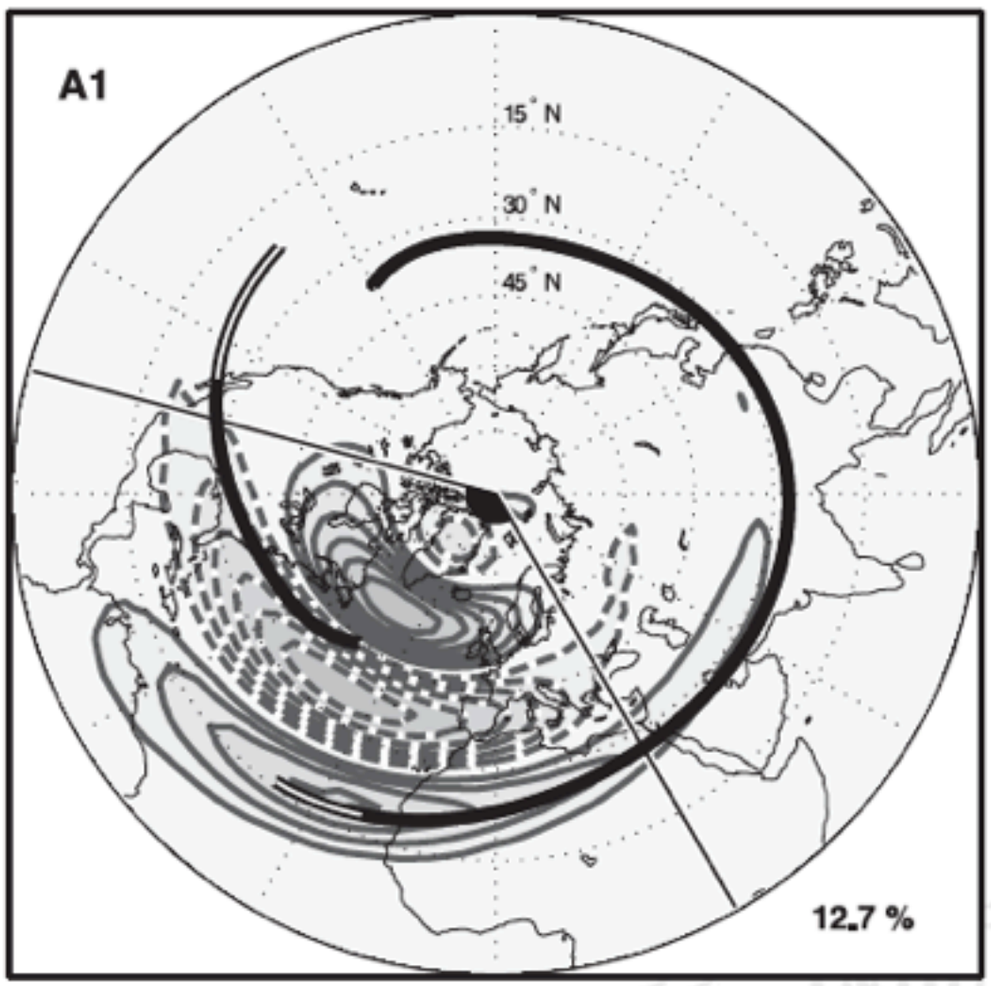
teleconnectivity of u_{300}

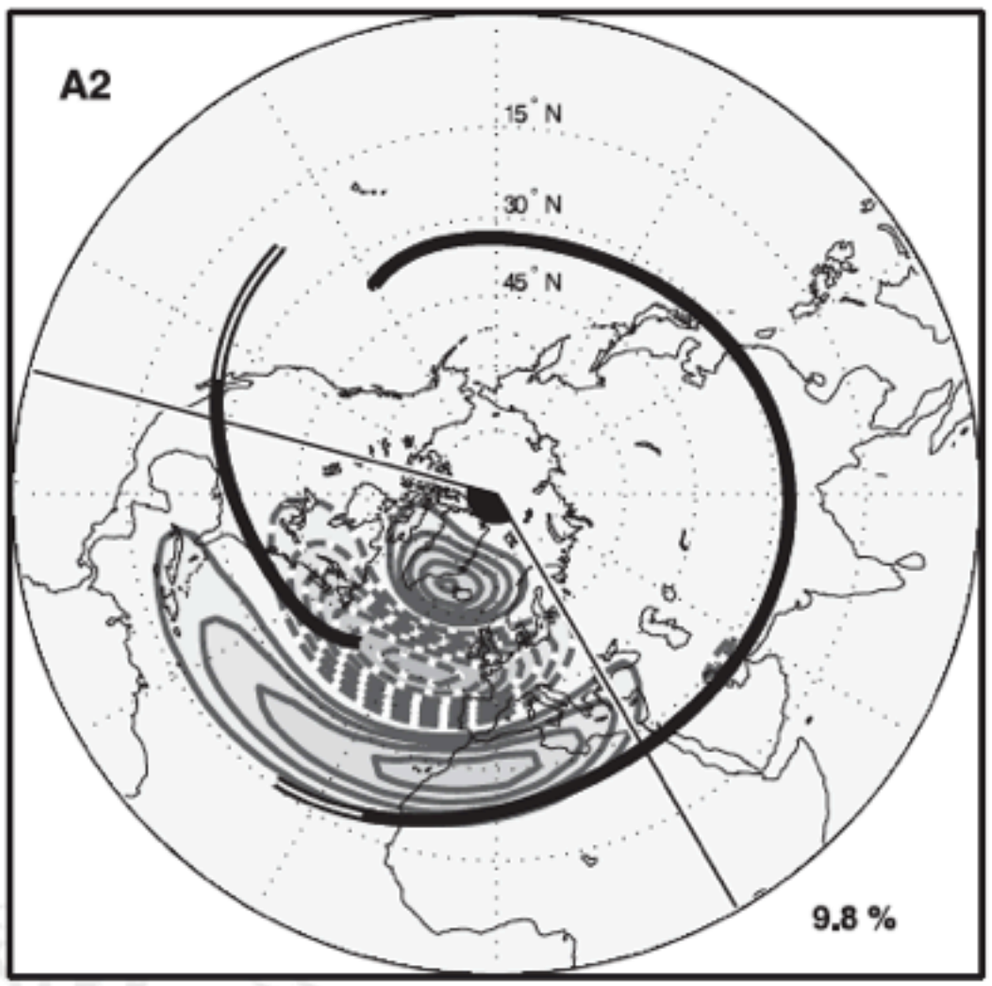
teleconnectivity of Z_{300}

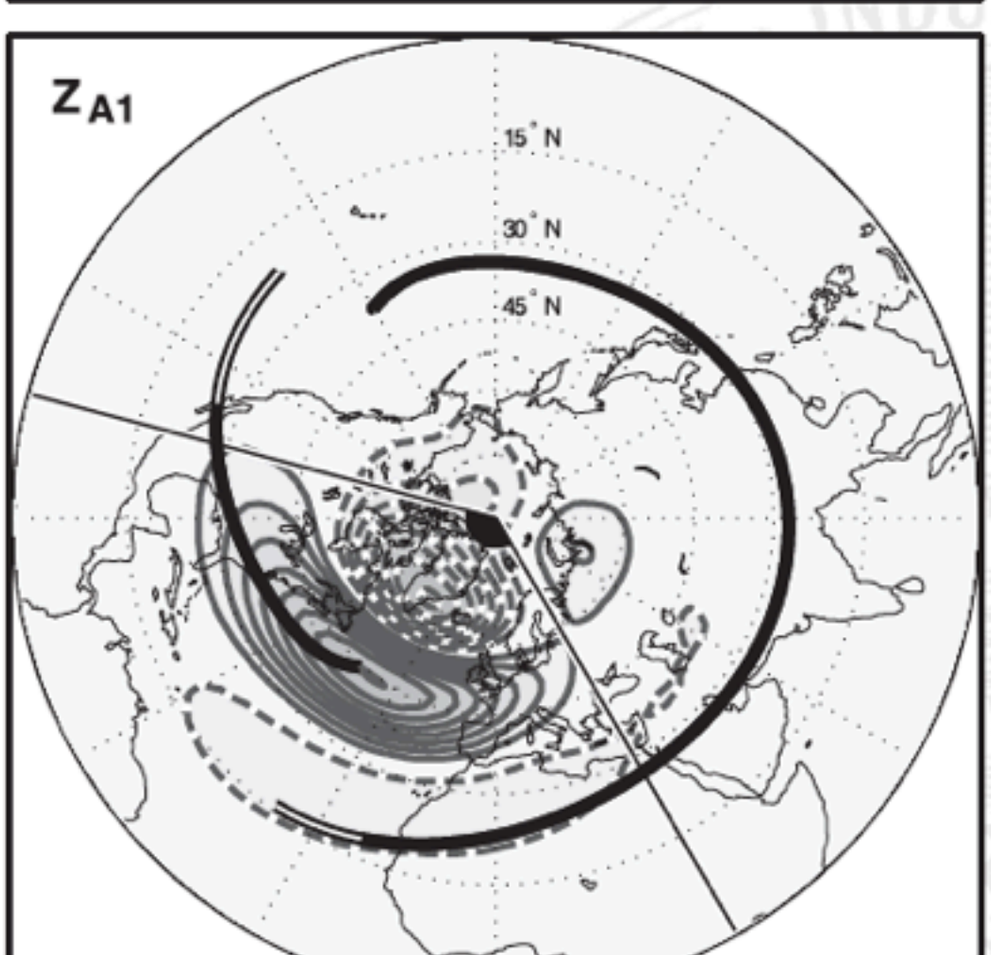
wintertime daily, unfiltered 300 hPa data

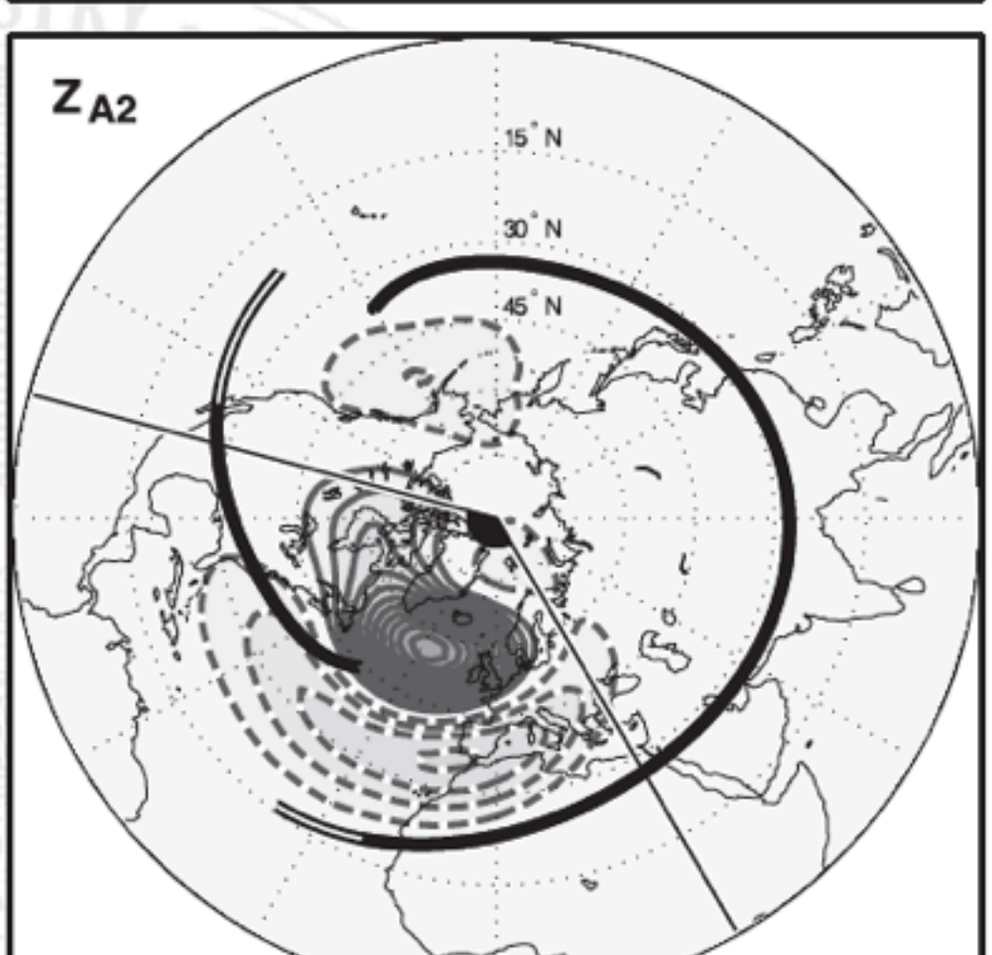
Athanasiadis et al. (1984a)

Leading two Atlantic modes

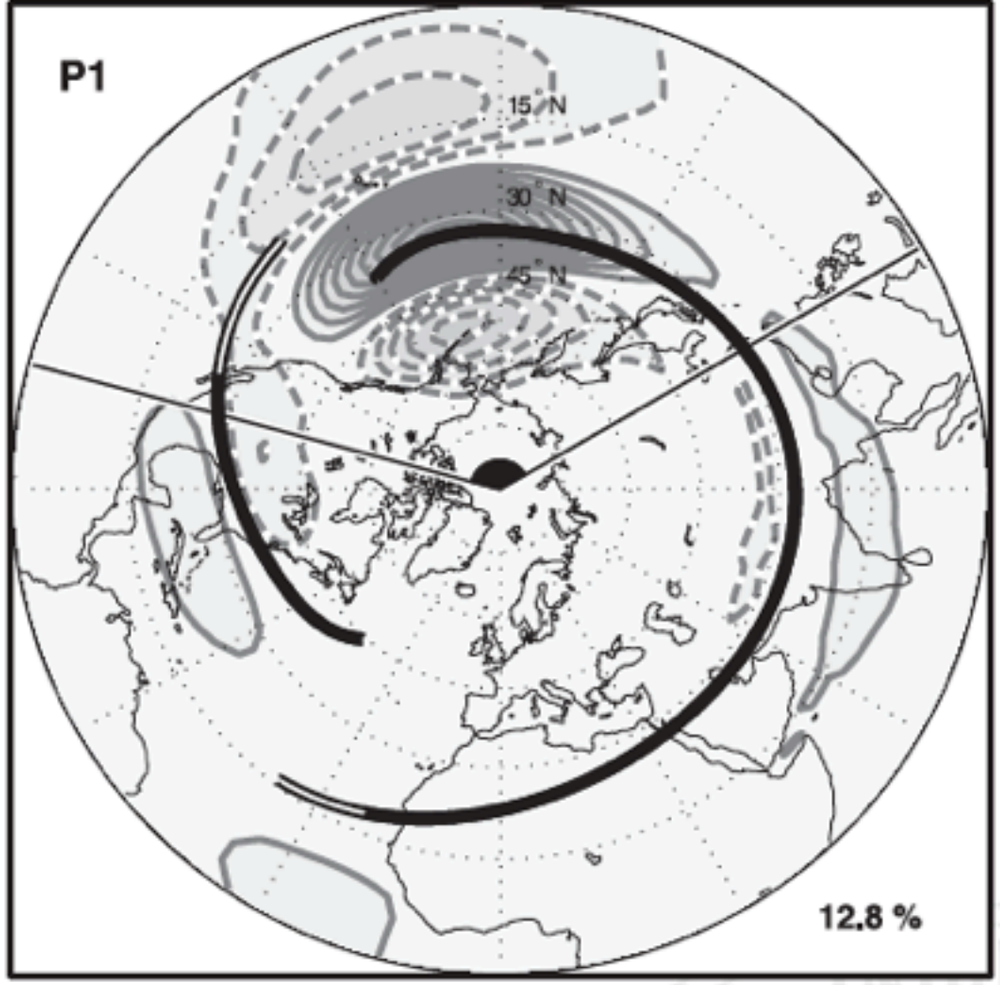


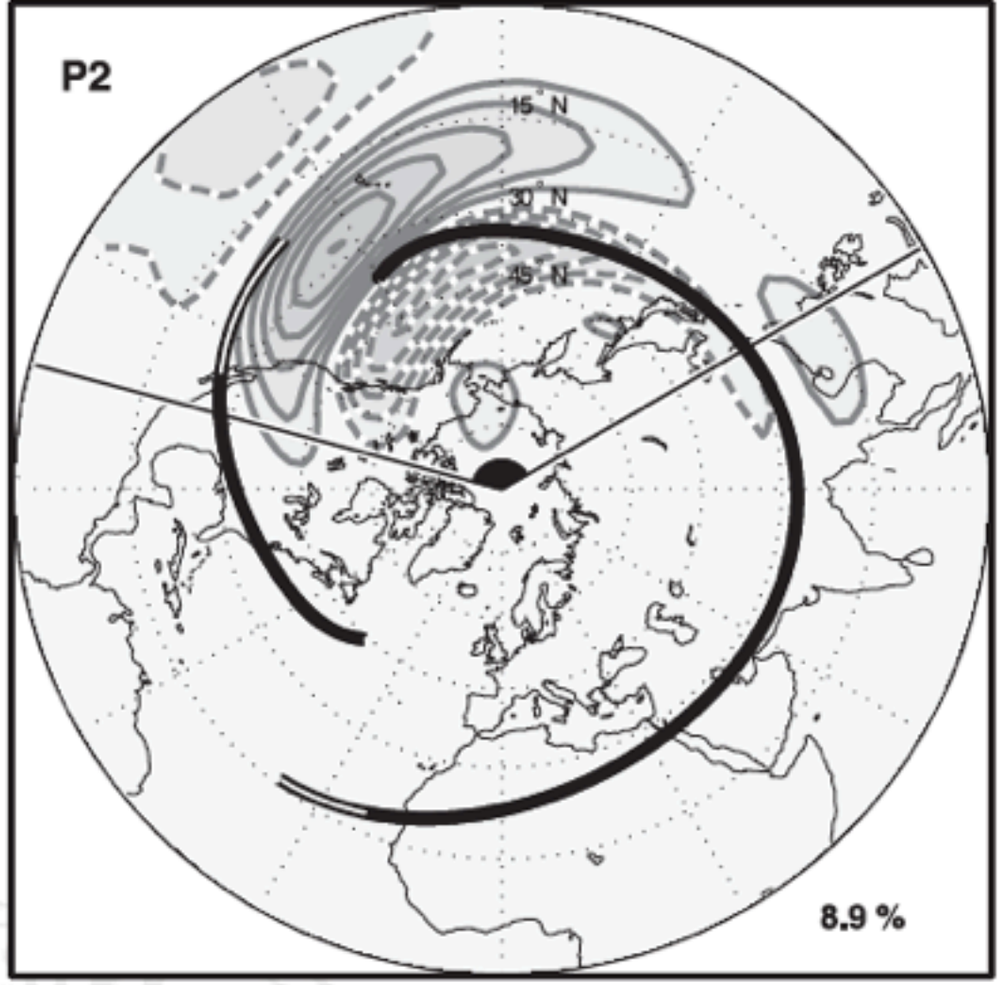


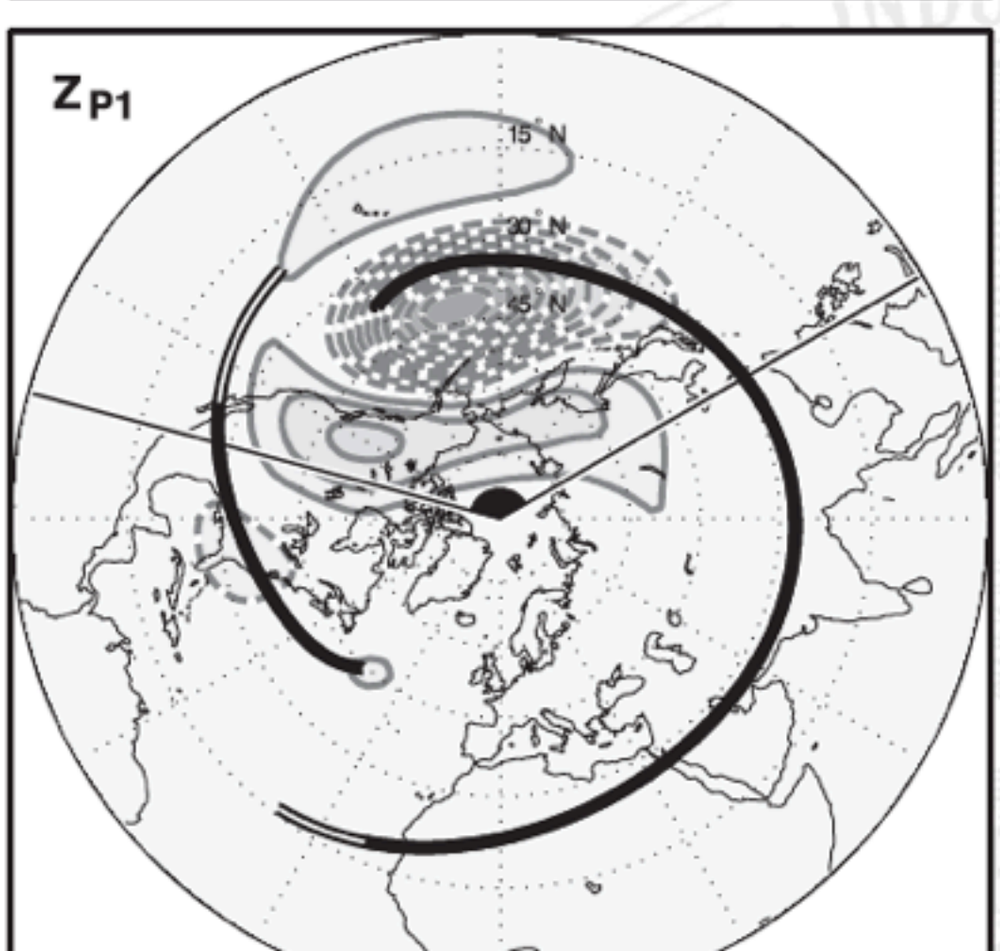


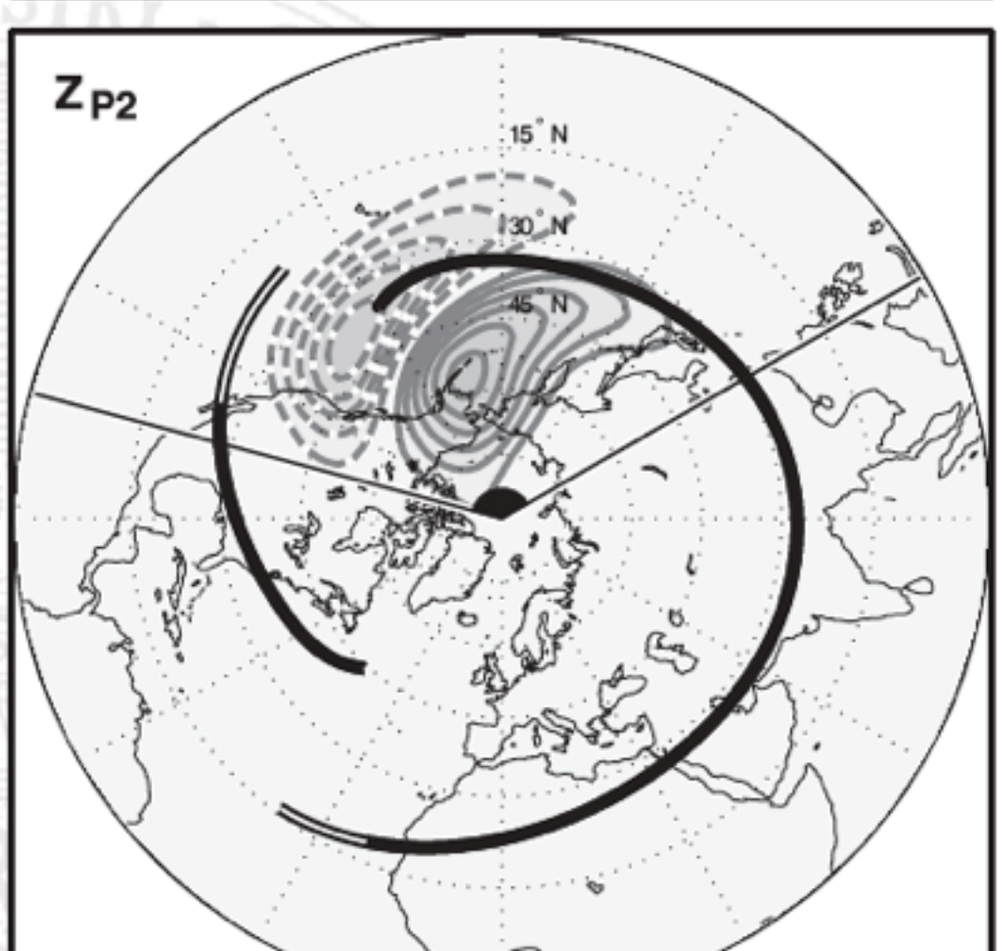


Leading two Pacific modes





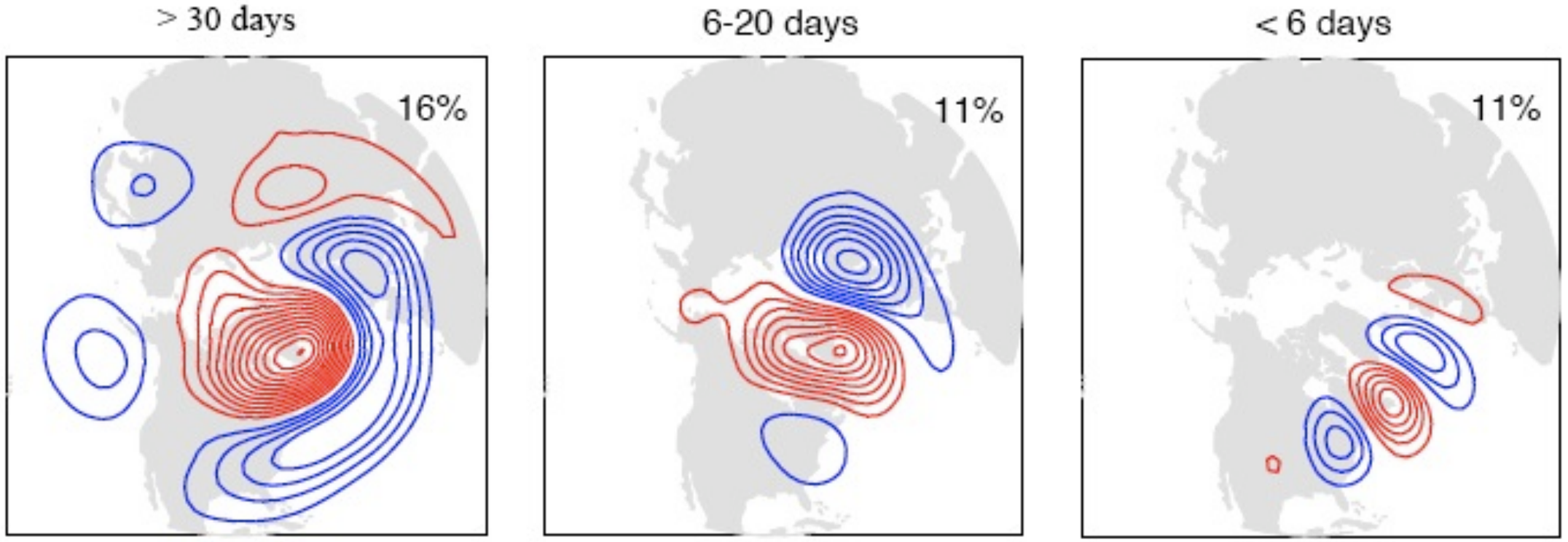




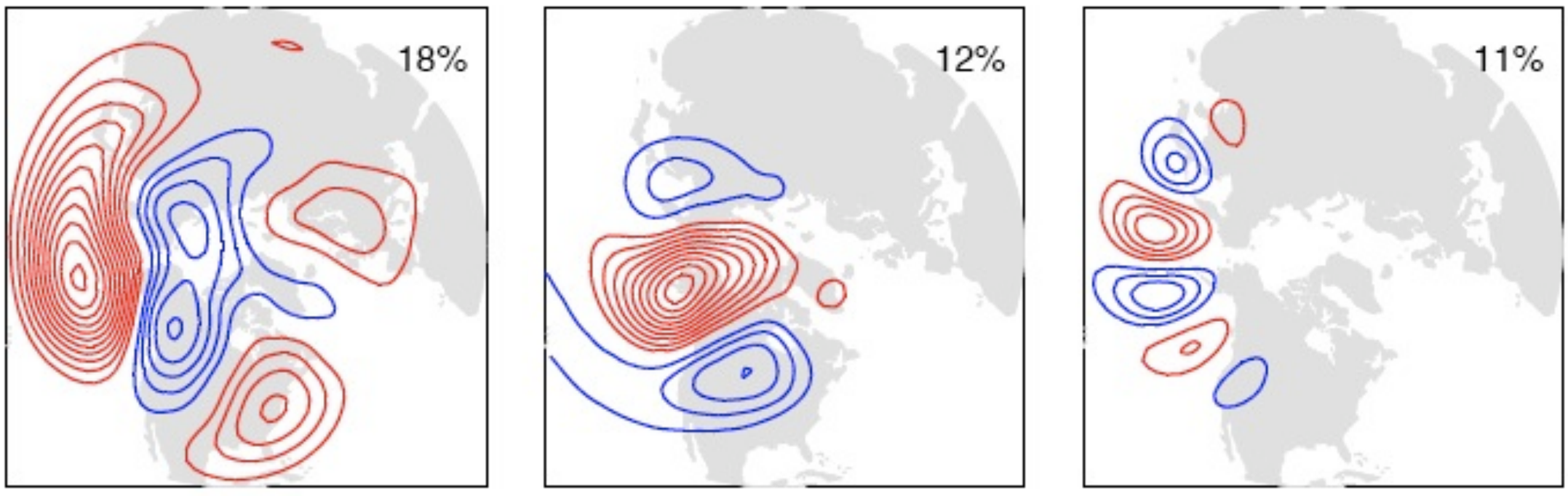
Leading EOFs: wintertime 500 hPa height

ATL 90°W eastward to 90°E
PAC 90°W westward to 90°E

ATL



PAC



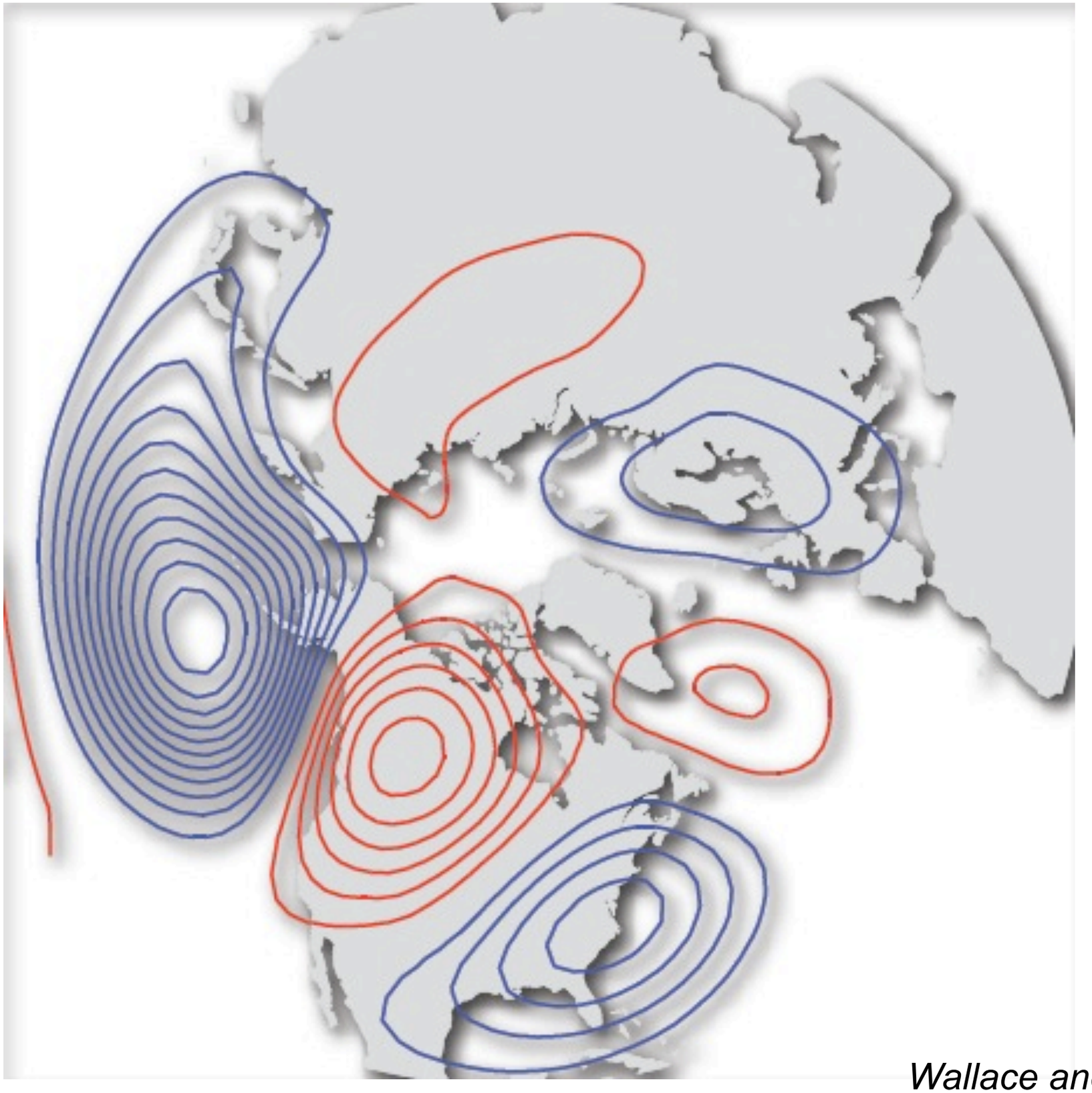
Rennert and Wallace, JAS 2009

Teleconnection patterns

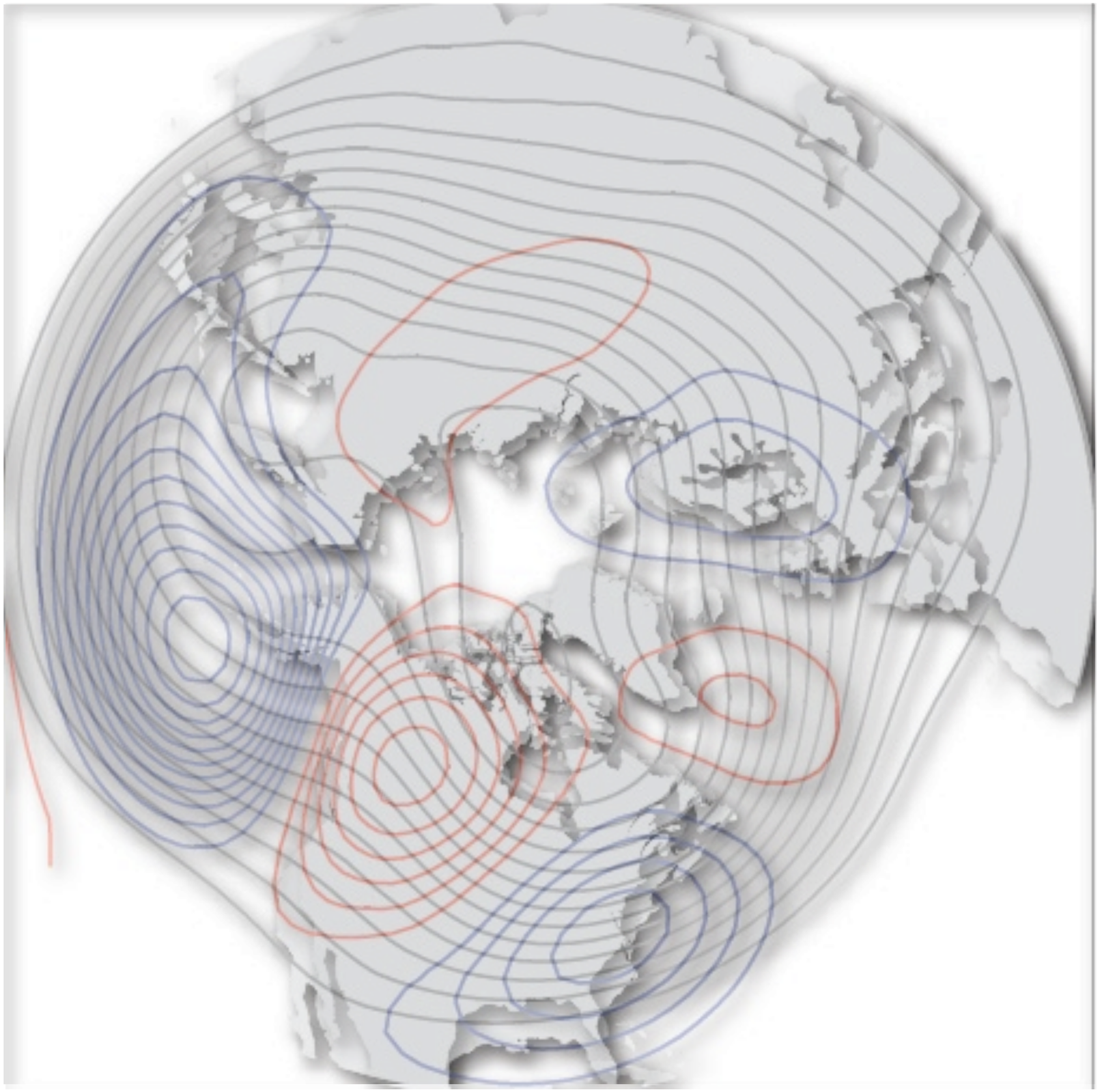
Description

- Geographically fixed anomaly patterns
- Can appear with either sign
- No well defined evolution; no preferred frequency
- Account for large fraction of the temporal variance
- Increasingly prominent as one goes to lower frequencies
- Occur in response to a wide variety of forcings
- Have distinctive formation mechanisms
- Structure depends upon the background flow

Pacific-North American (PNA) Pattern



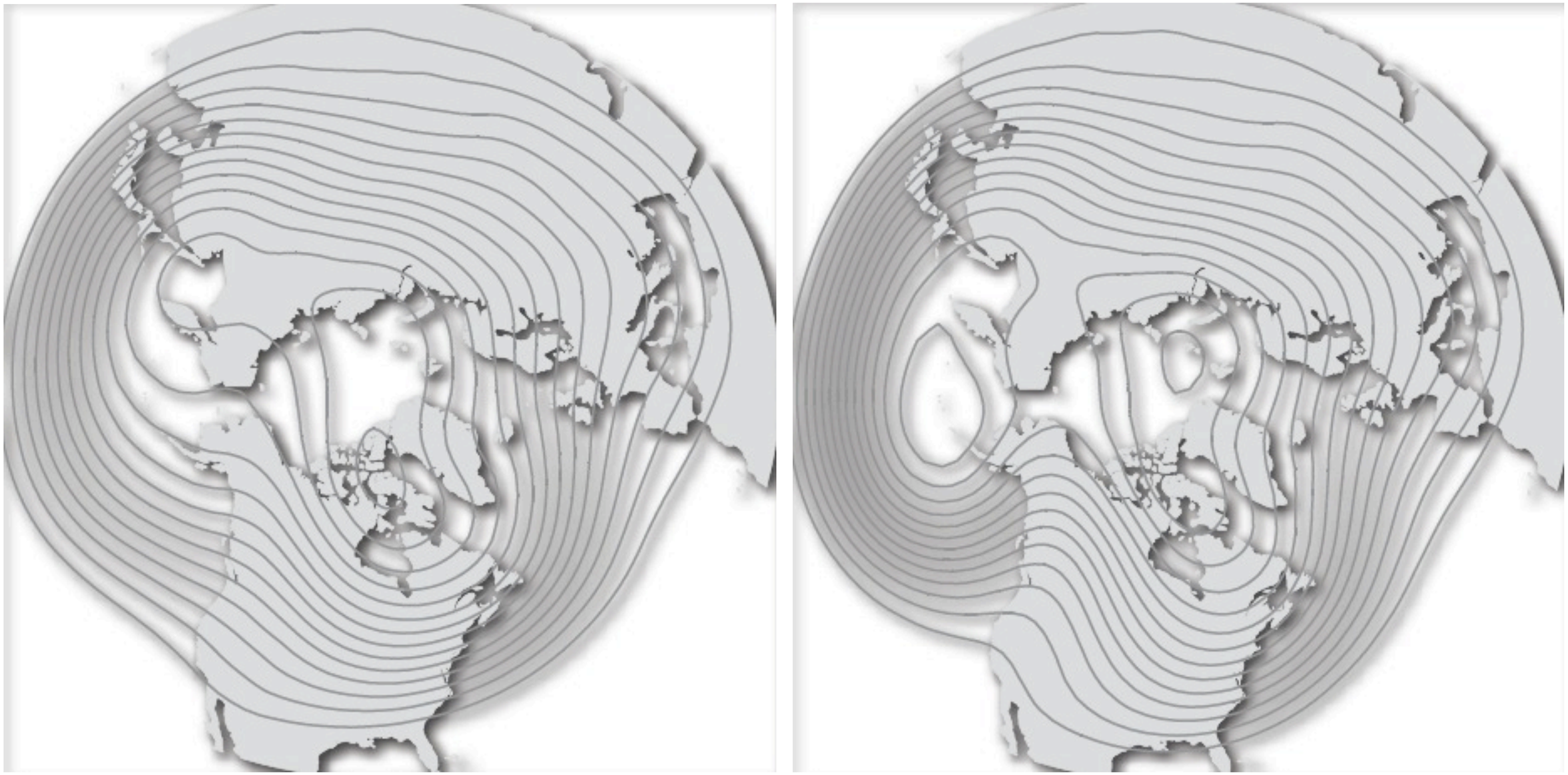
Wallace and Gutzler, JAS 1981
Rennert and Wallace, JAS 2009



PNA pattern superimposed upon climatological-mean 500 hPa field

PNA–

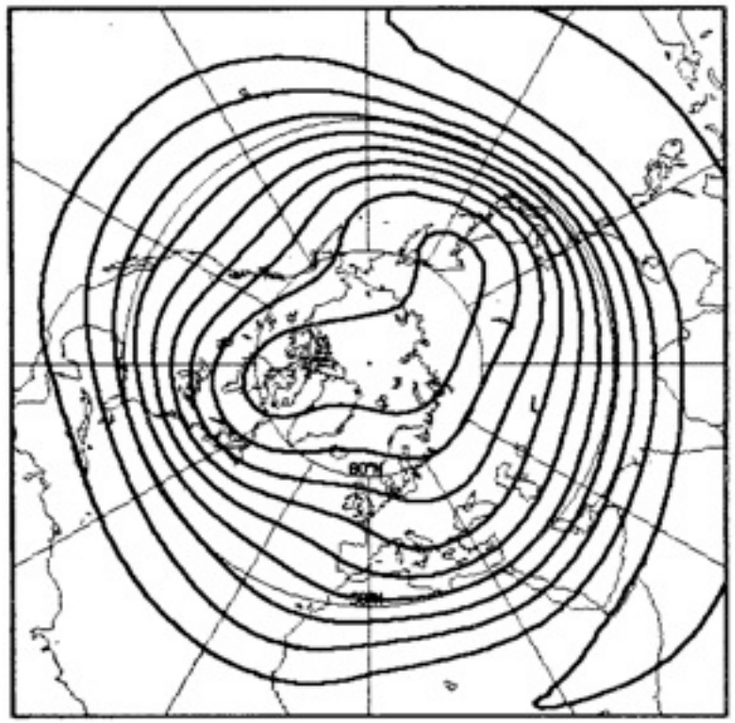
PNA+

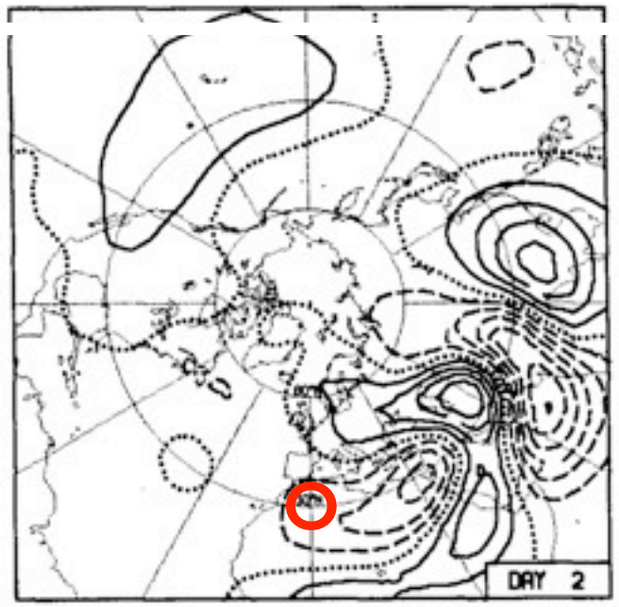


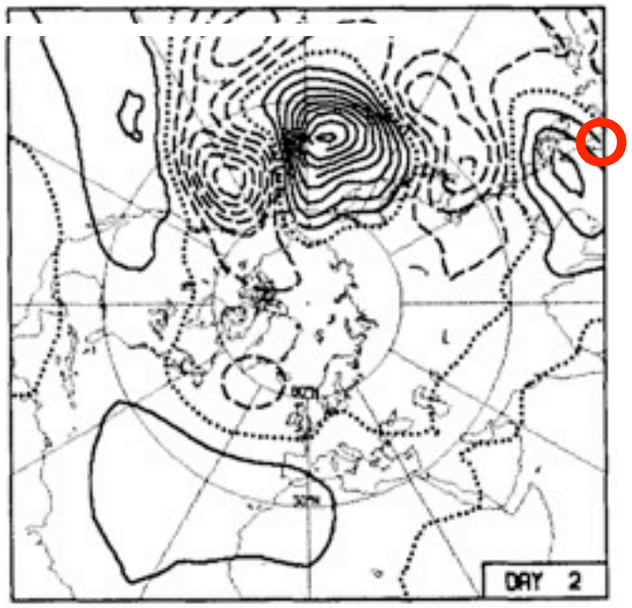
Wintertime 500 hPa height

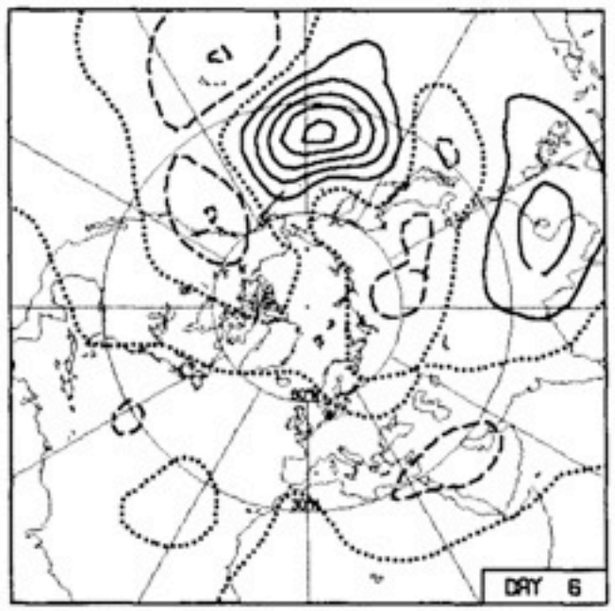
Barotropic instability a forcing mechanism

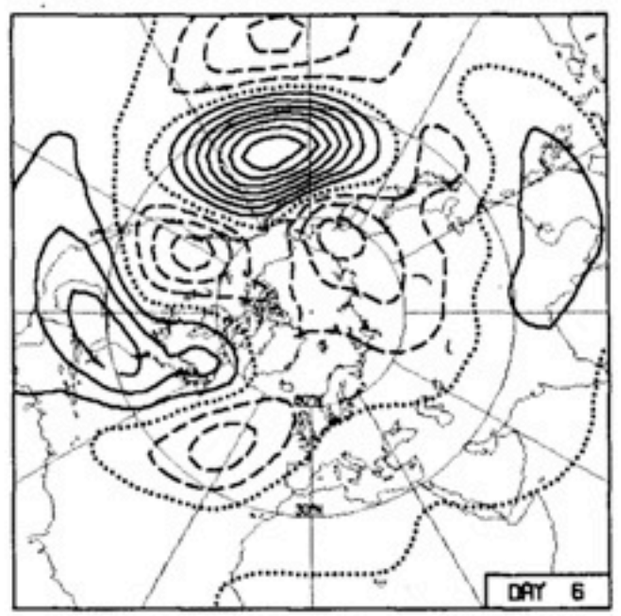
Simmons et al. JAS 1983

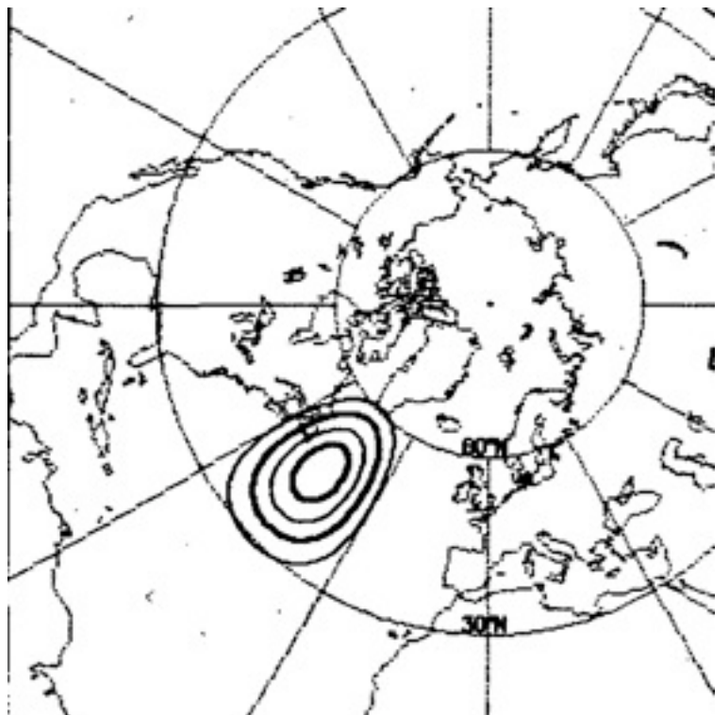


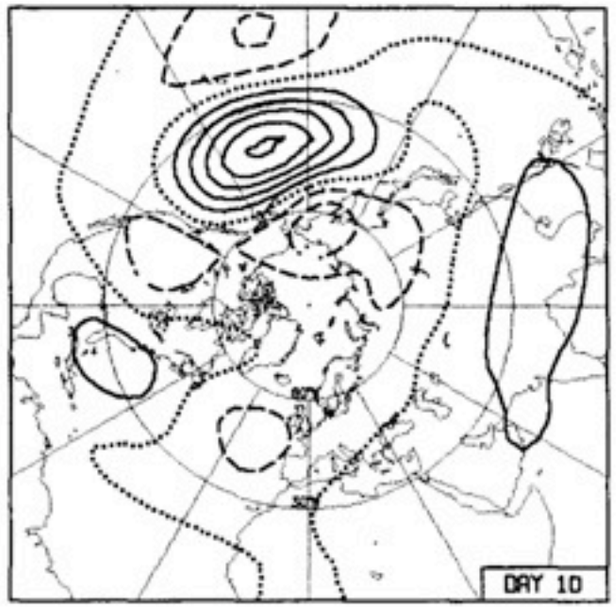


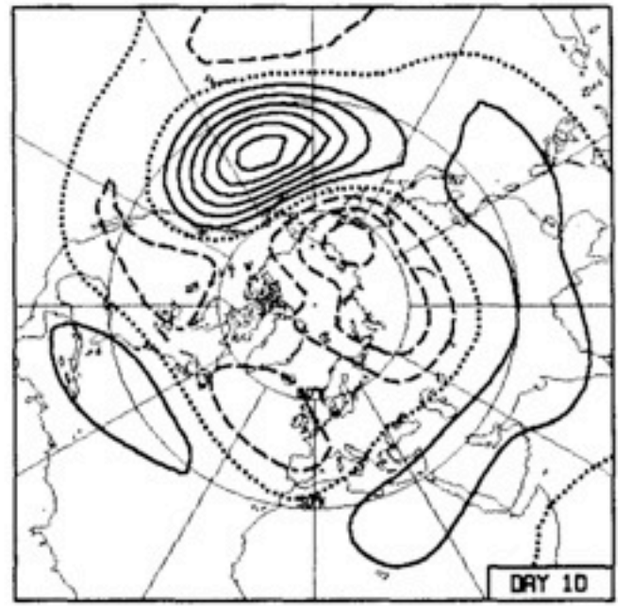


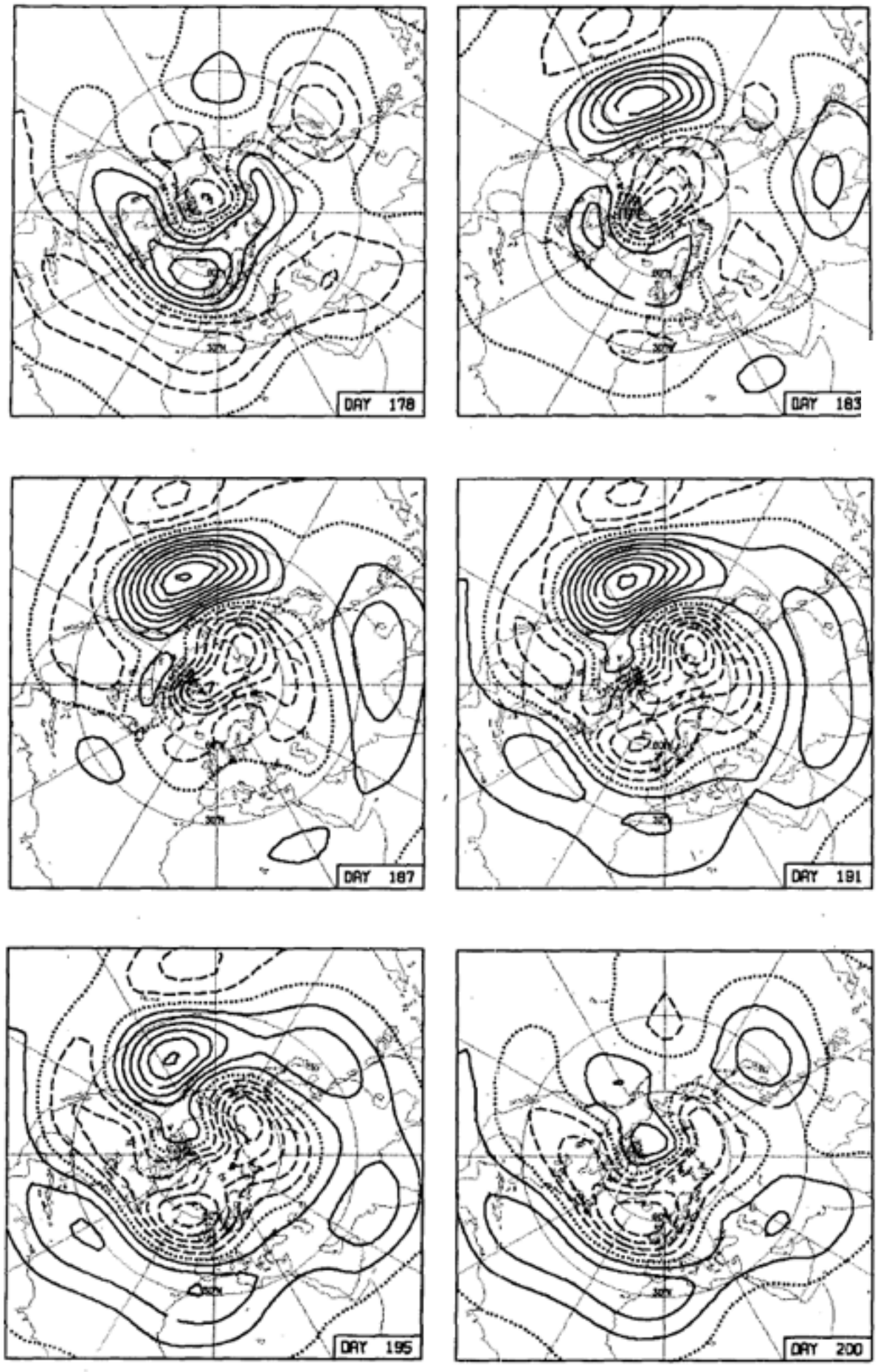






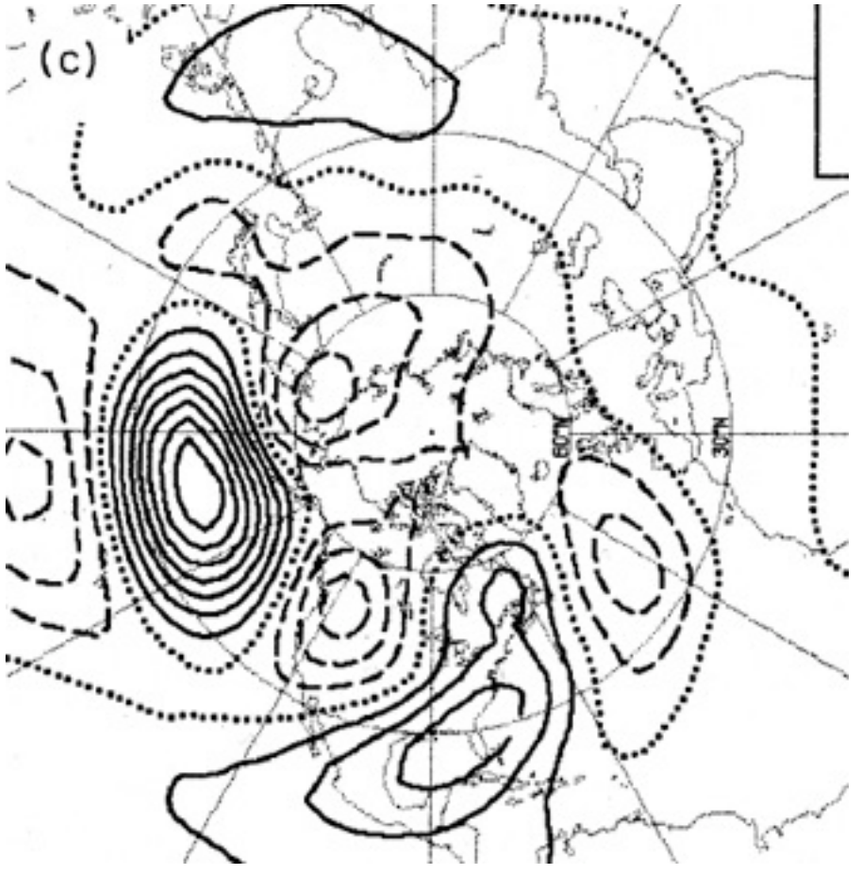




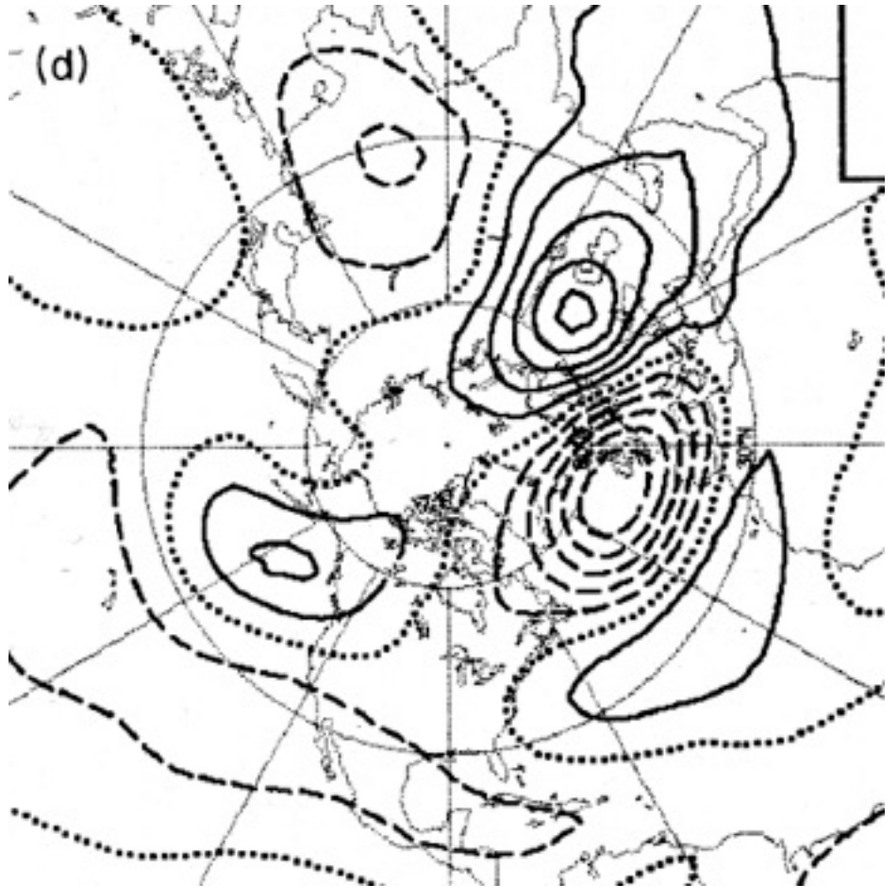


Normal mode structure

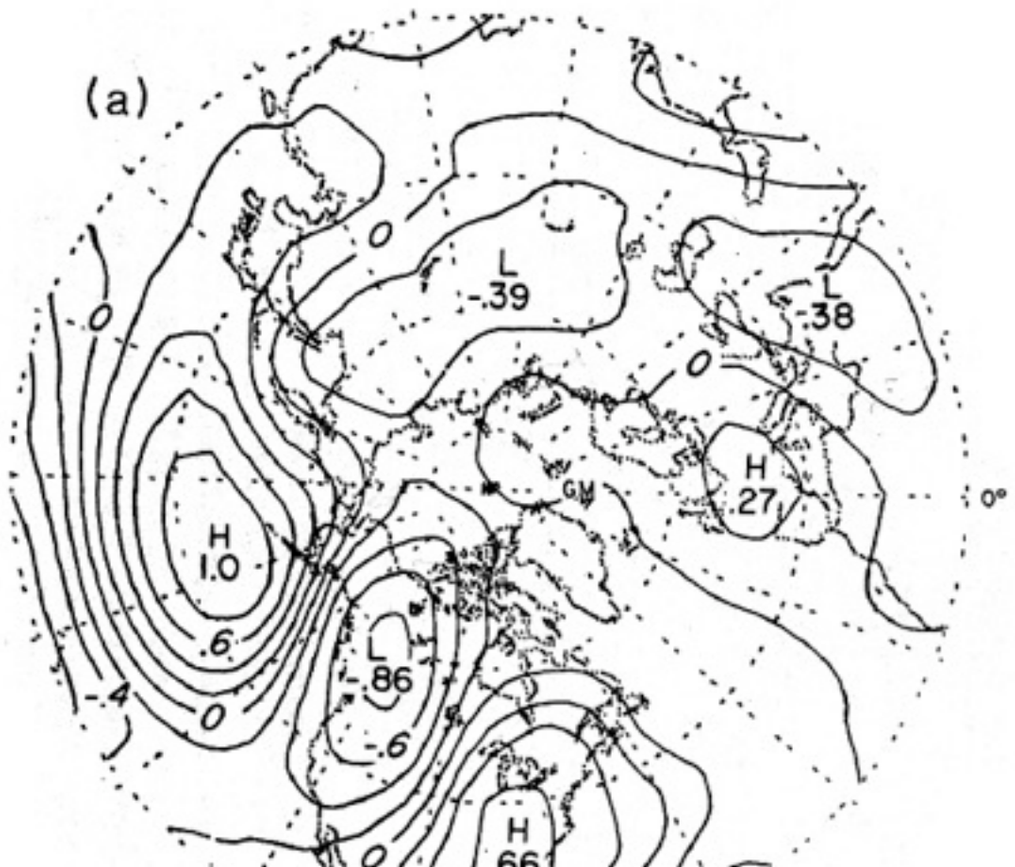
$$e^{\sigma t}[A(\lambda, \theta)\,\sin\omega t + B(\lambda, \theta)\,\cos\omega t],$$



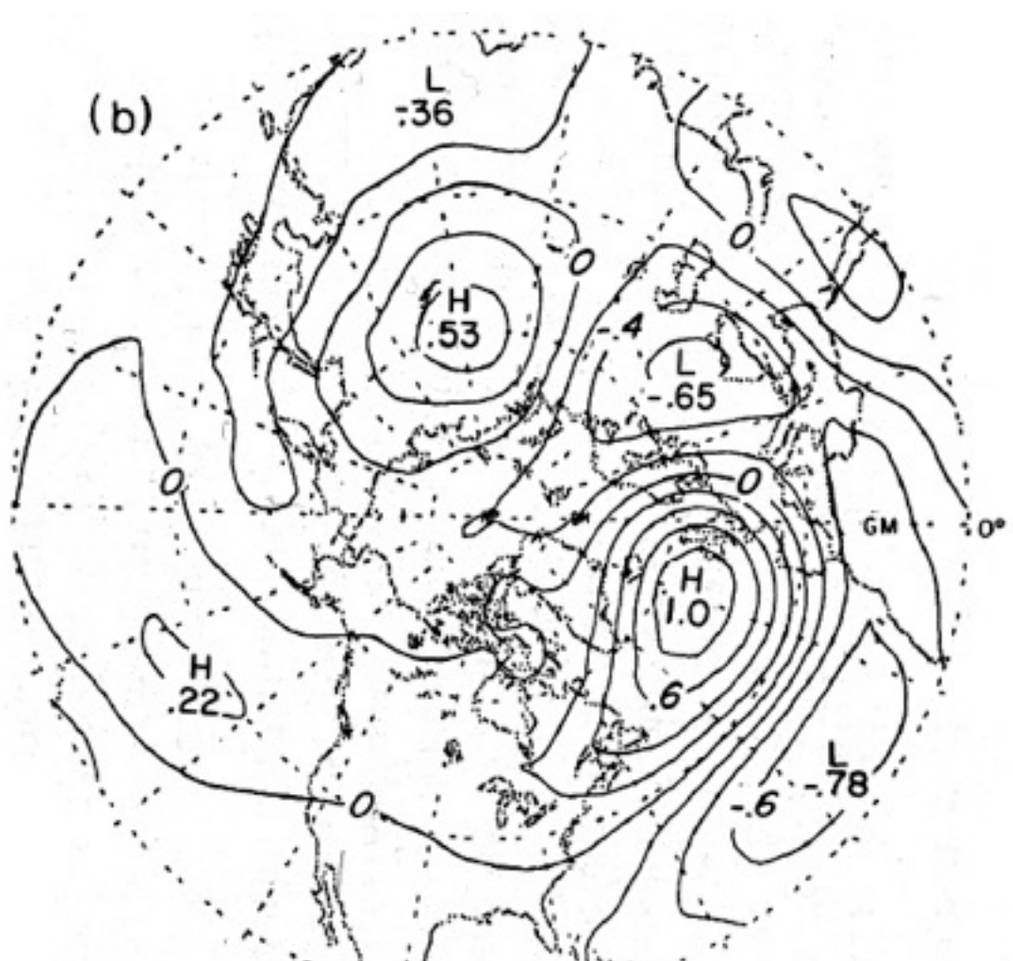
Model



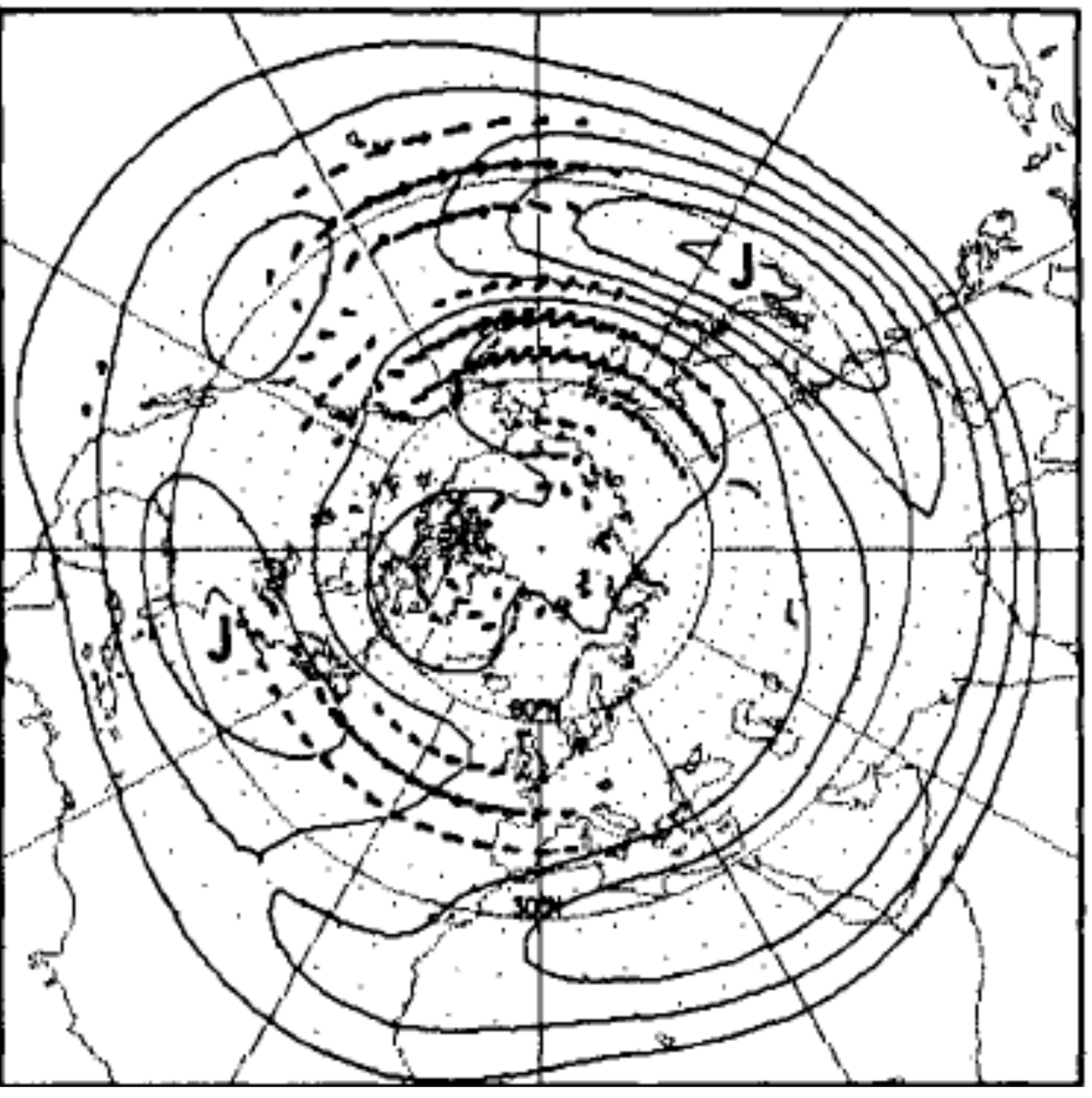
Selected snapshots from nonlinear runs



Obs

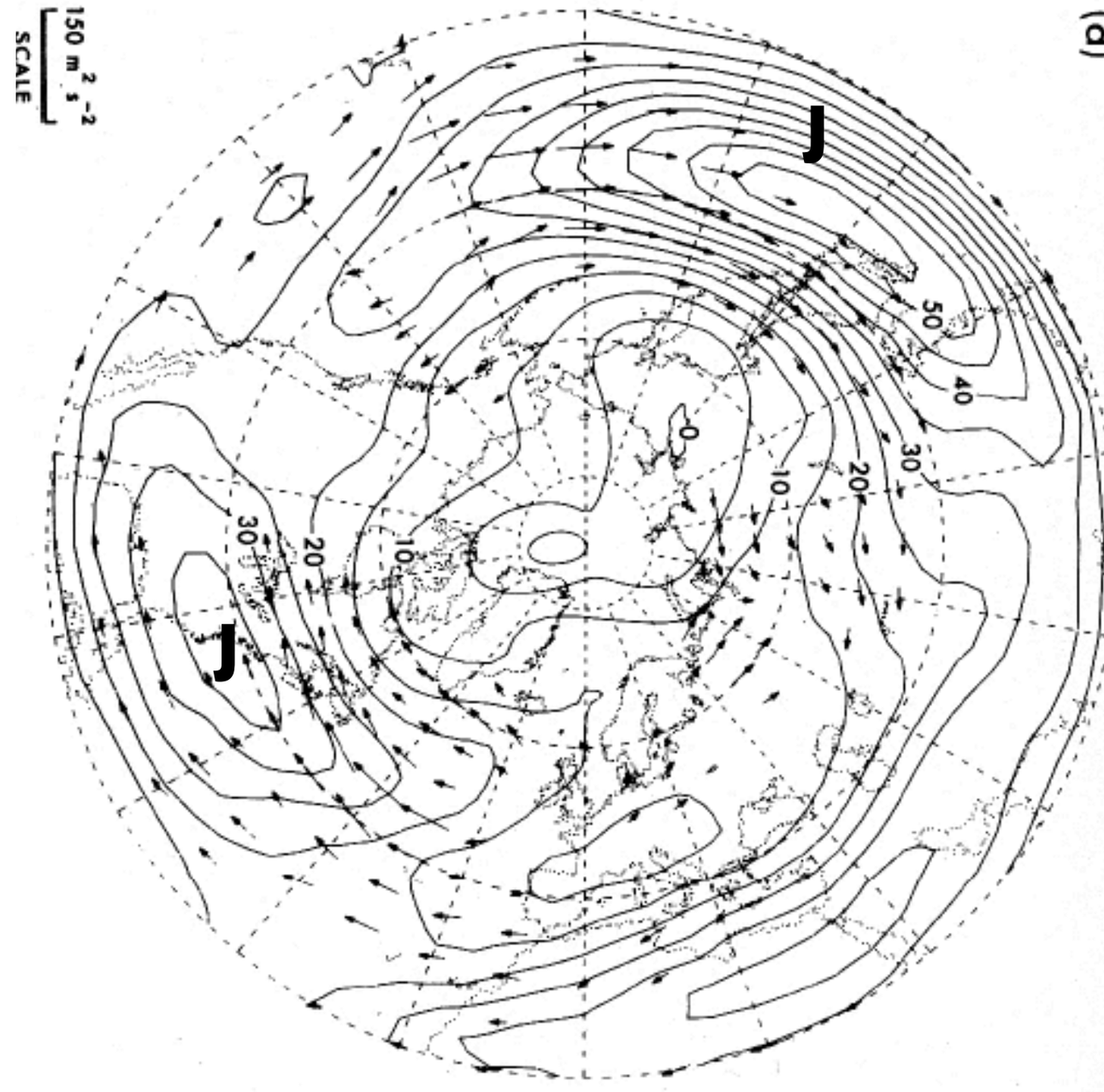


E-vectors



Barotropic model: leading mode

Simmons et al. JAS 1983

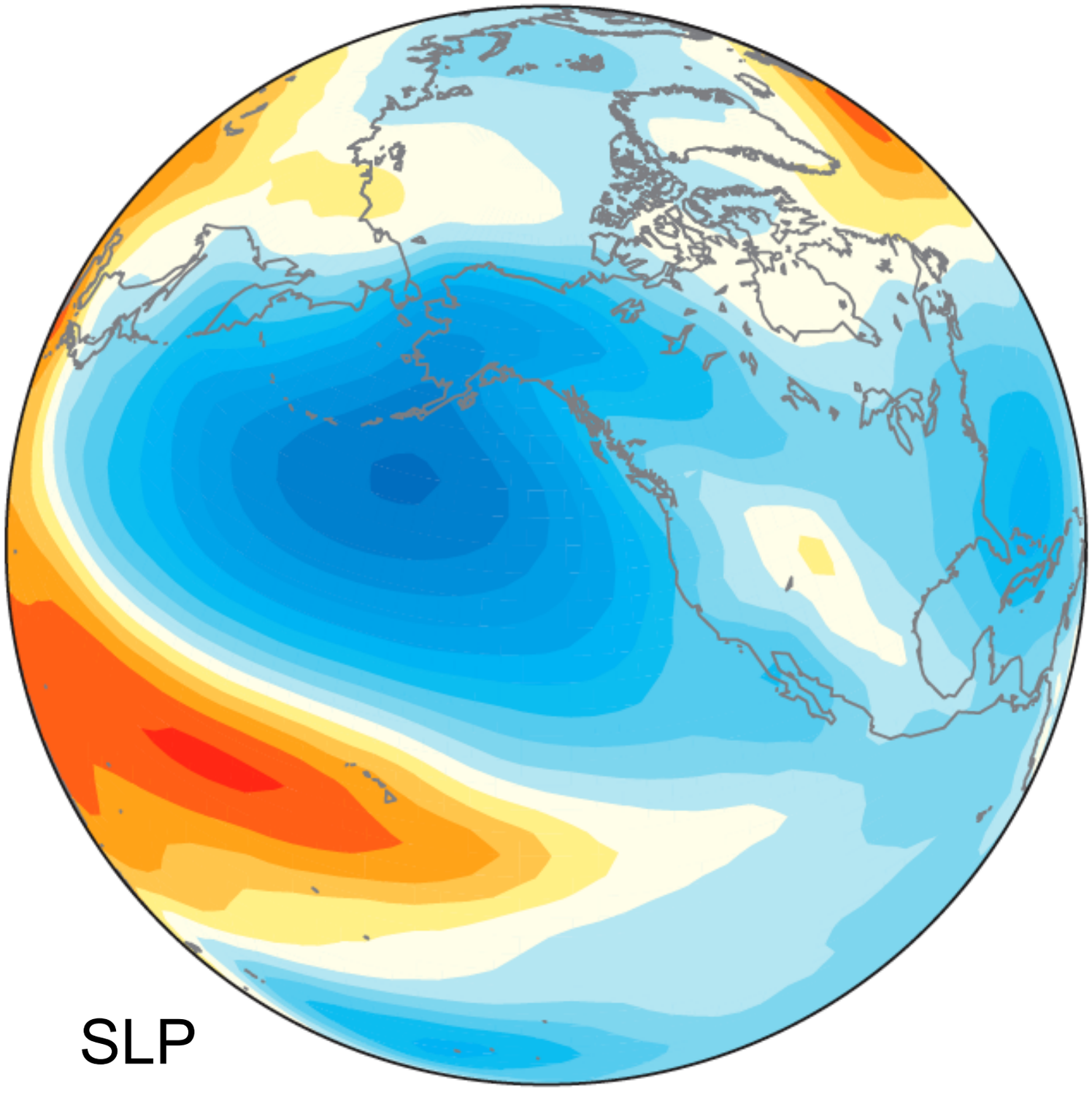


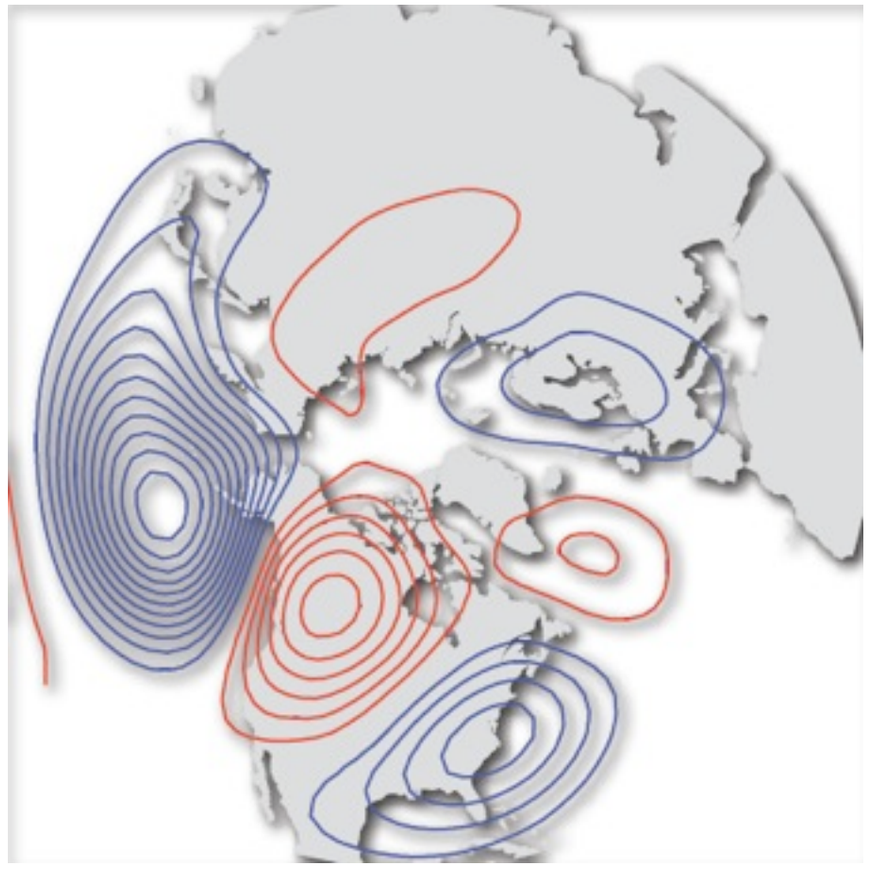
Observations

Wallace and Lau, 1985

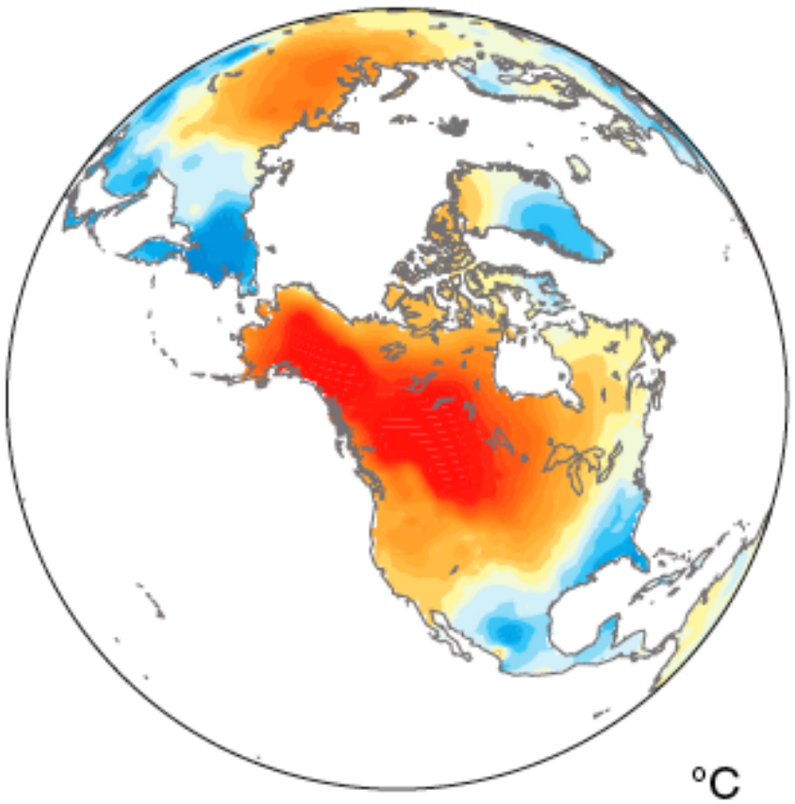
Climate impacts

PNA pattern





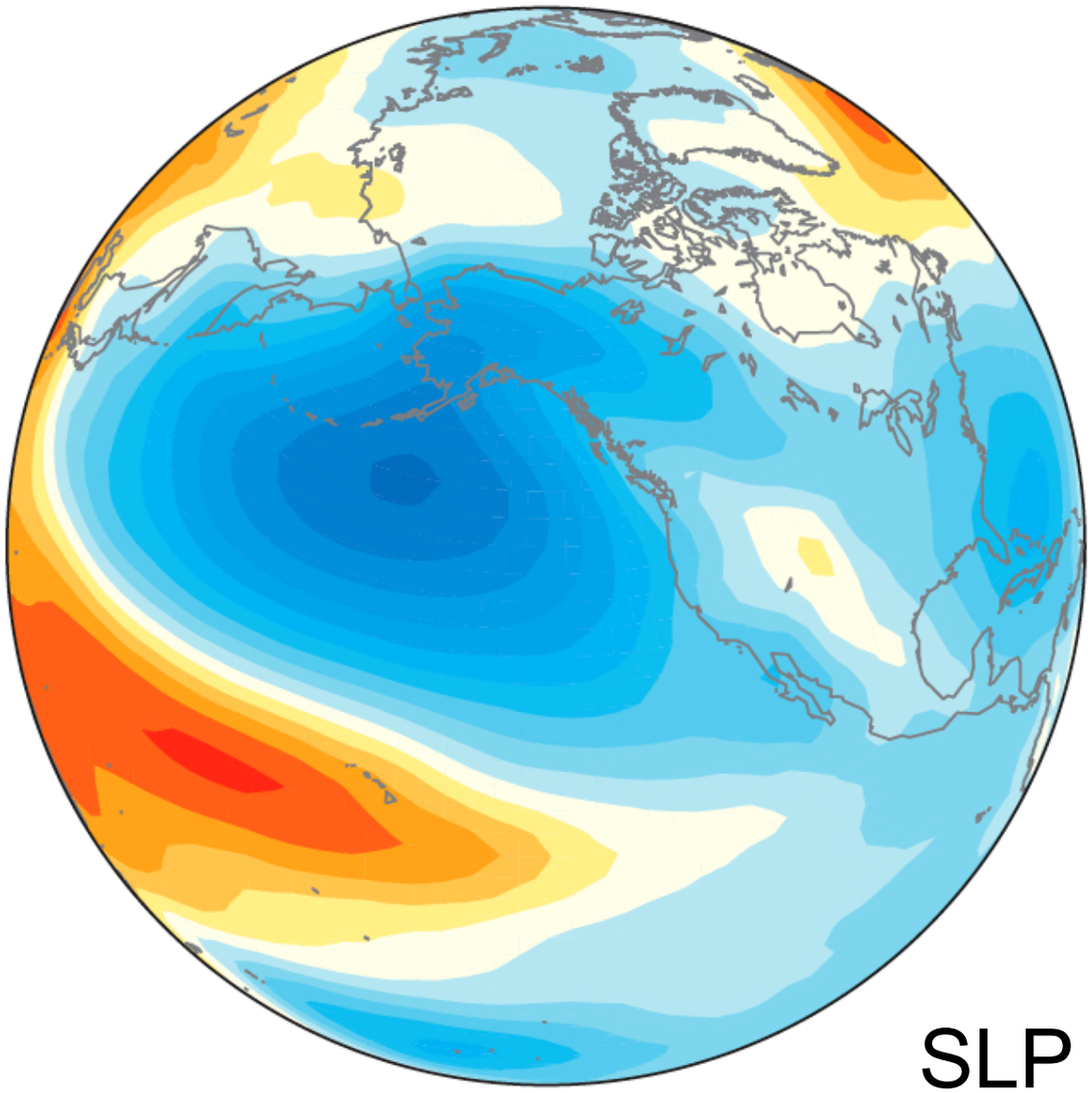
500 hPa height



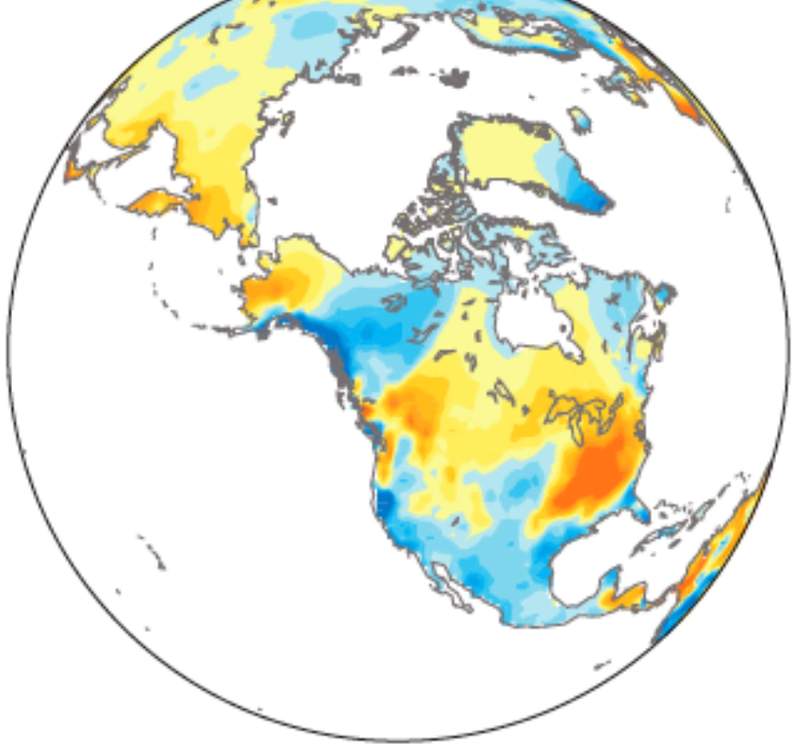
°C

−2.0 −1.0 0 1.0 2.0

SAT



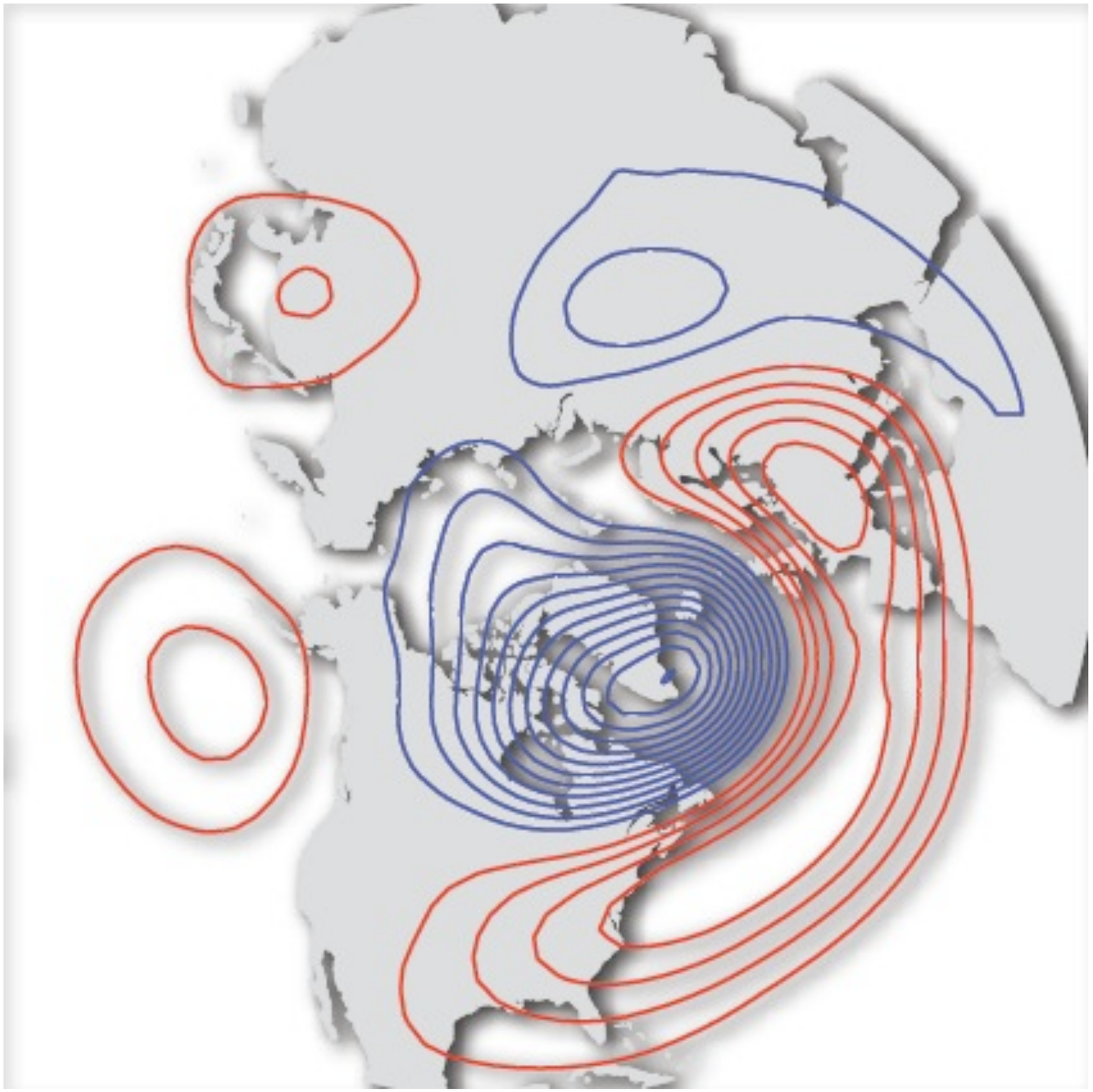
SLP



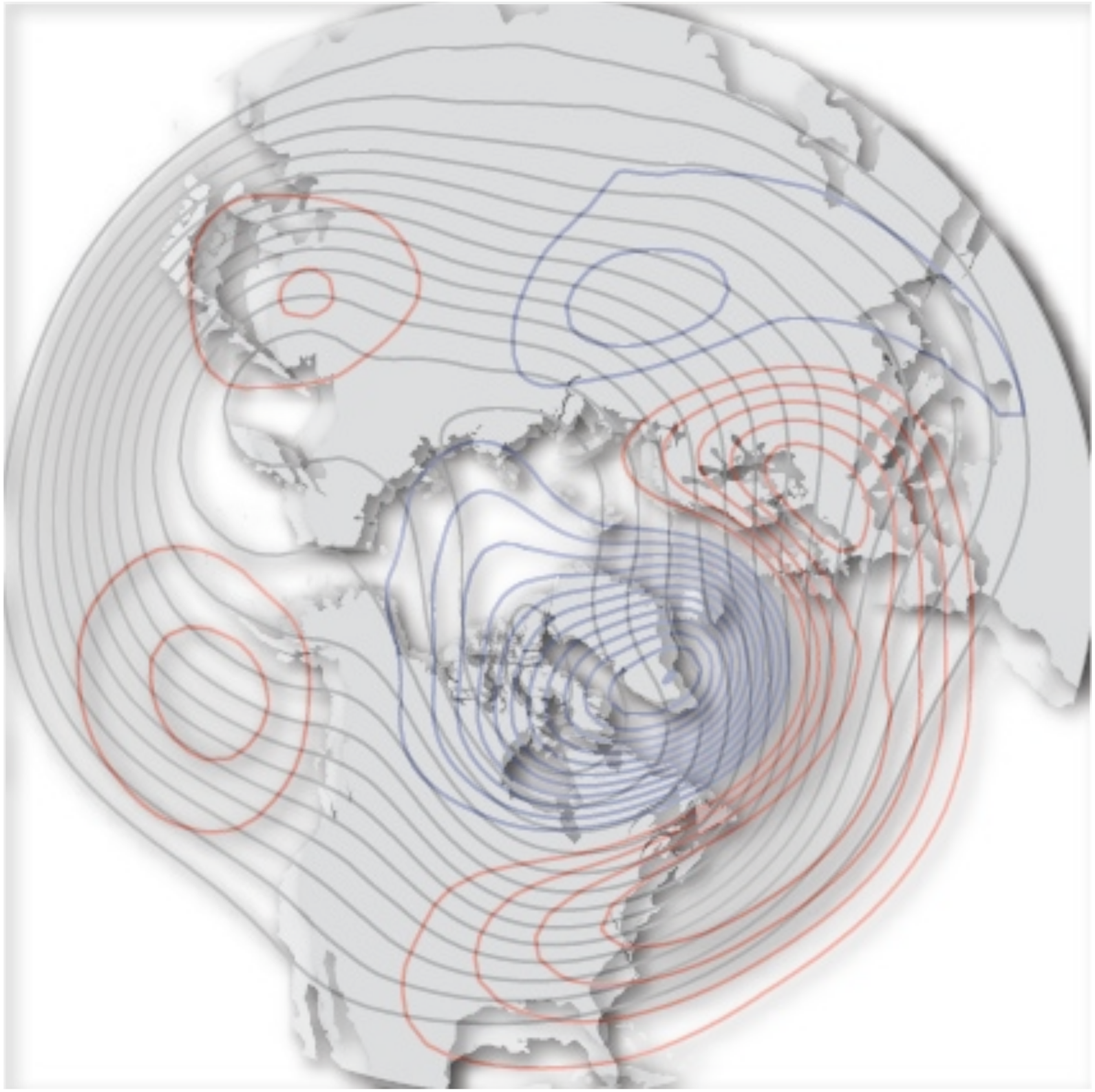
−1.0 −0.5 0 0.5 1.0

rainfall

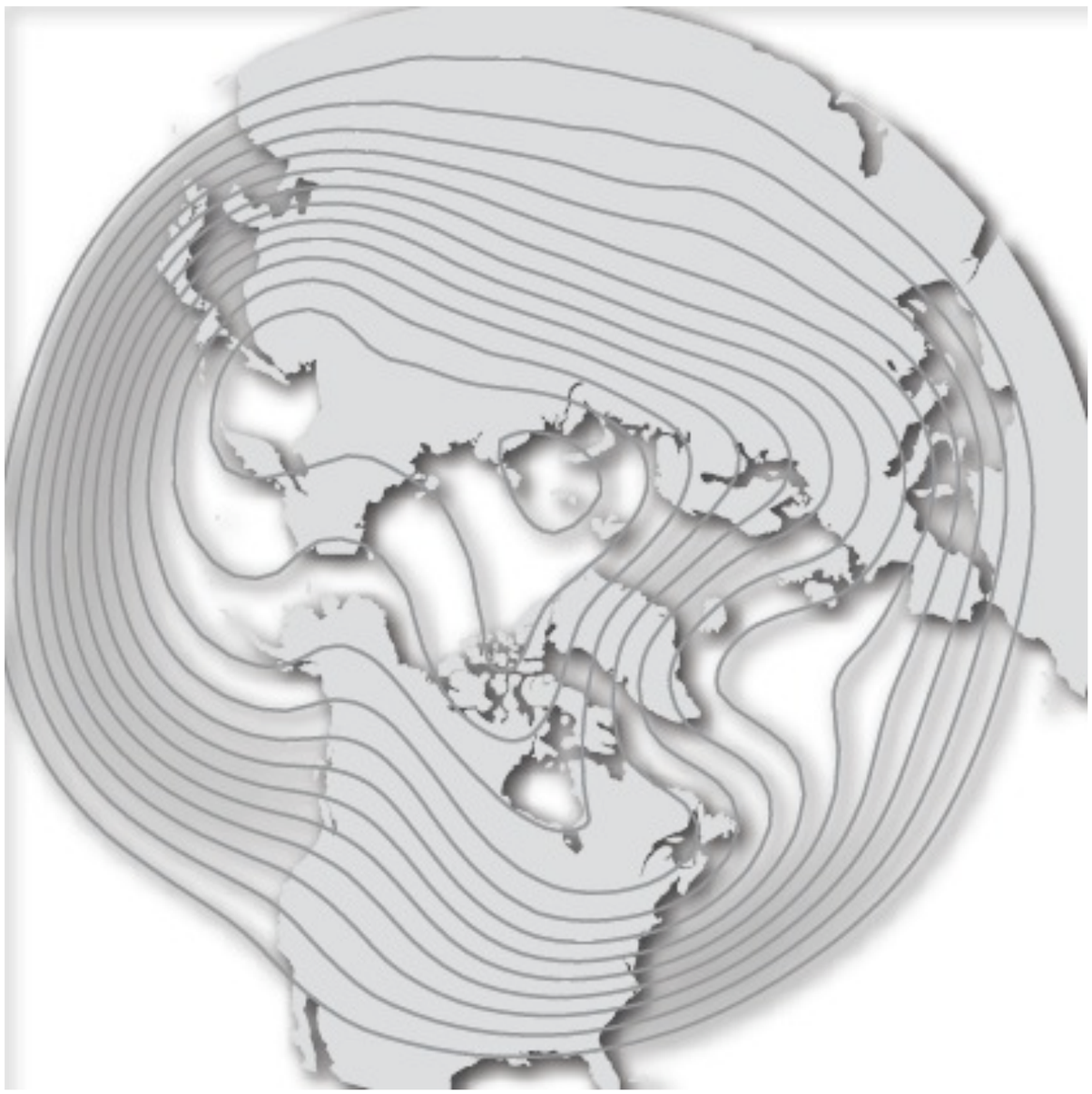
North Atlantic Oscillation (NAO)



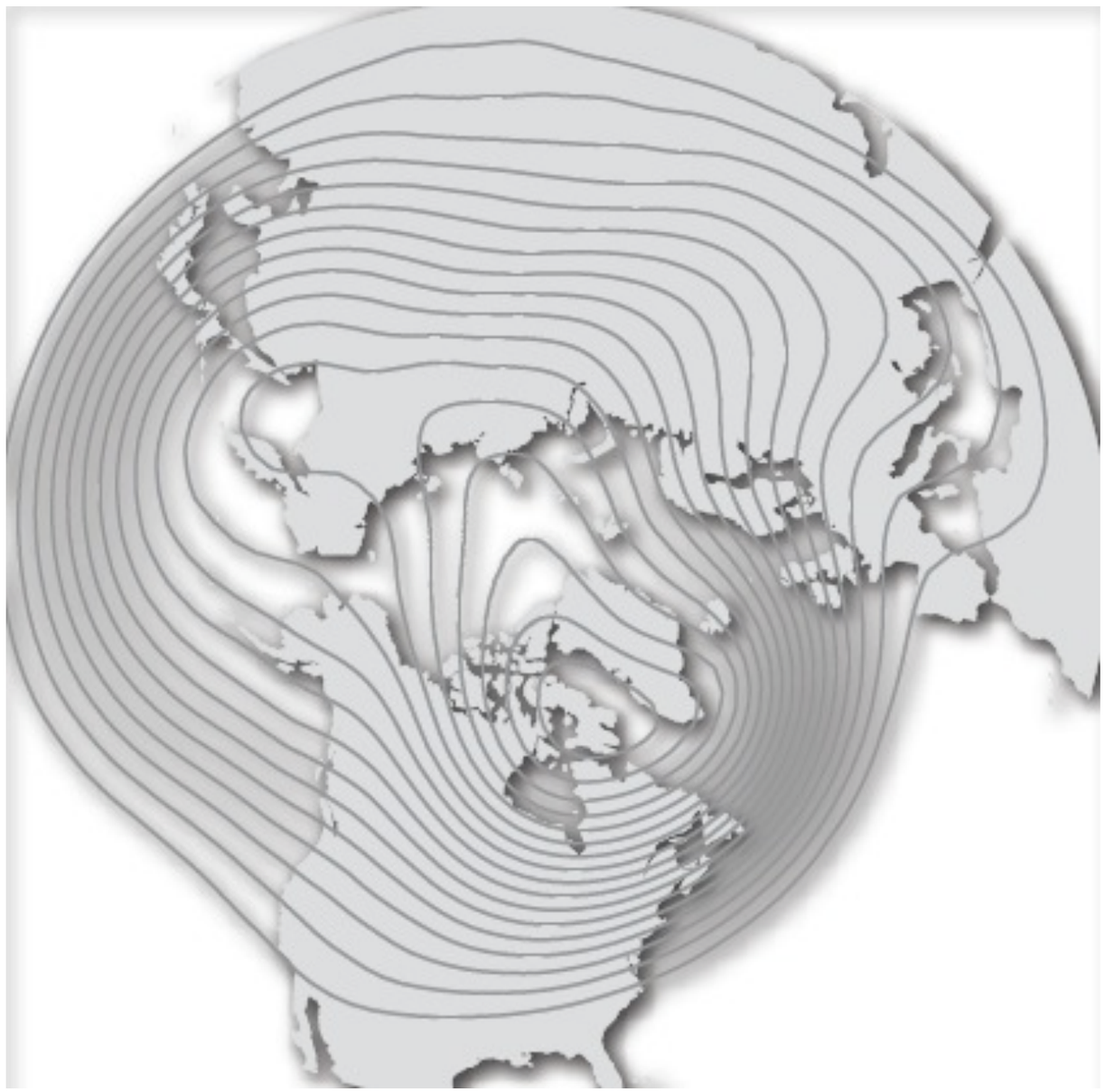
NAO



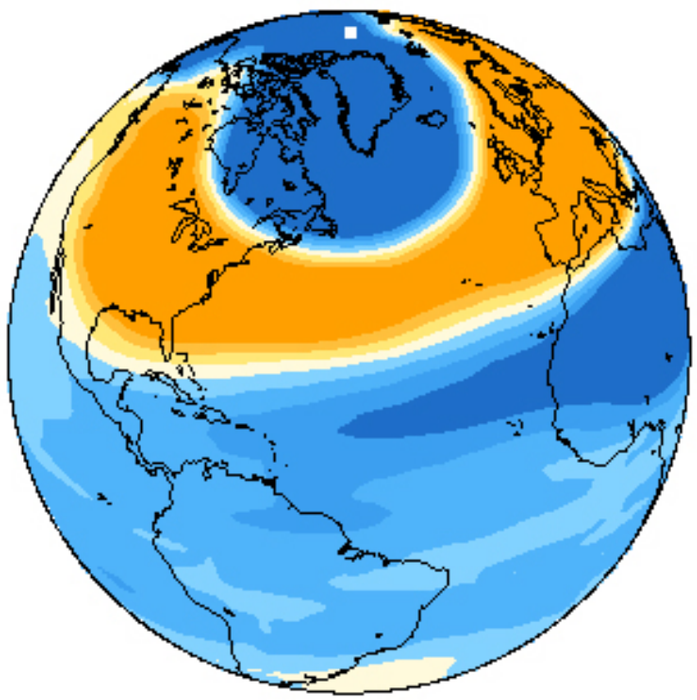
NAO–

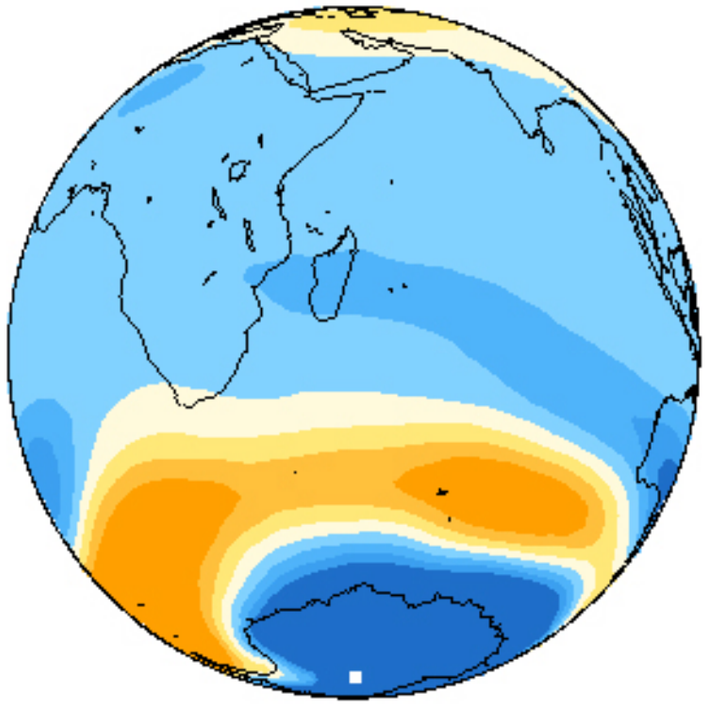


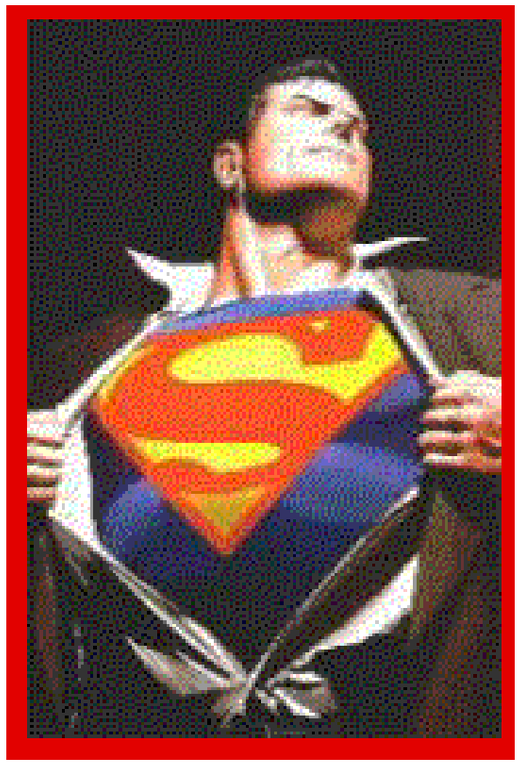
NAO+



The Great AO/NAO Debate

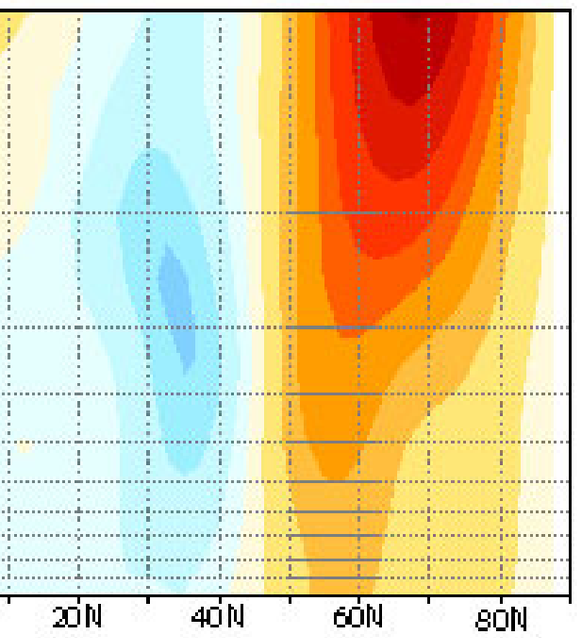


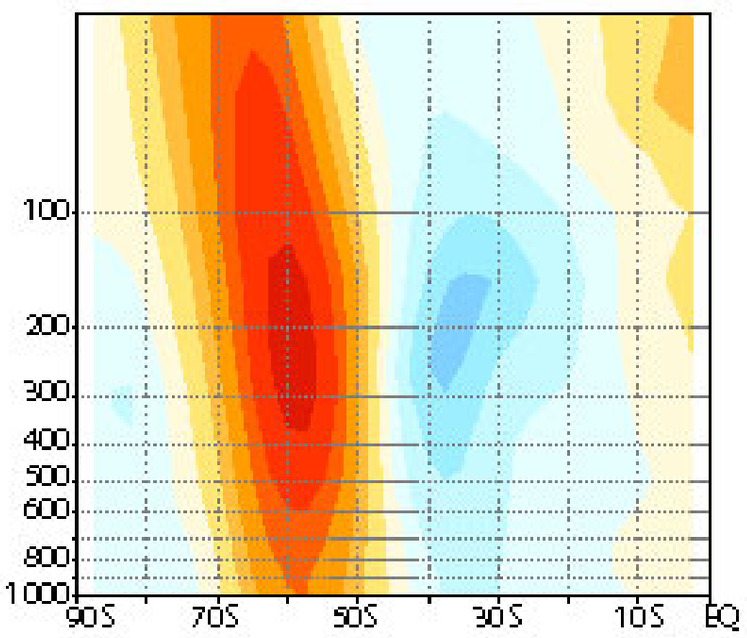


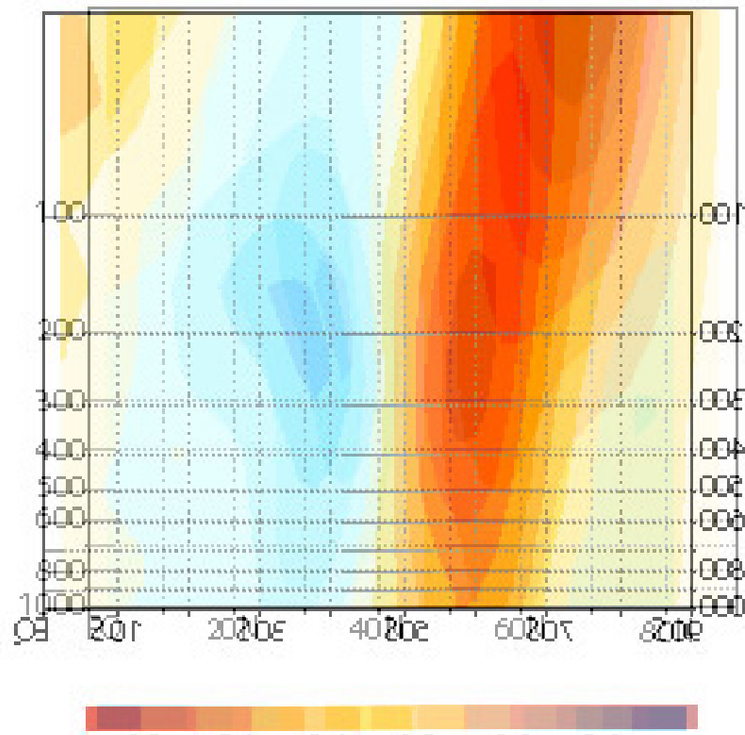


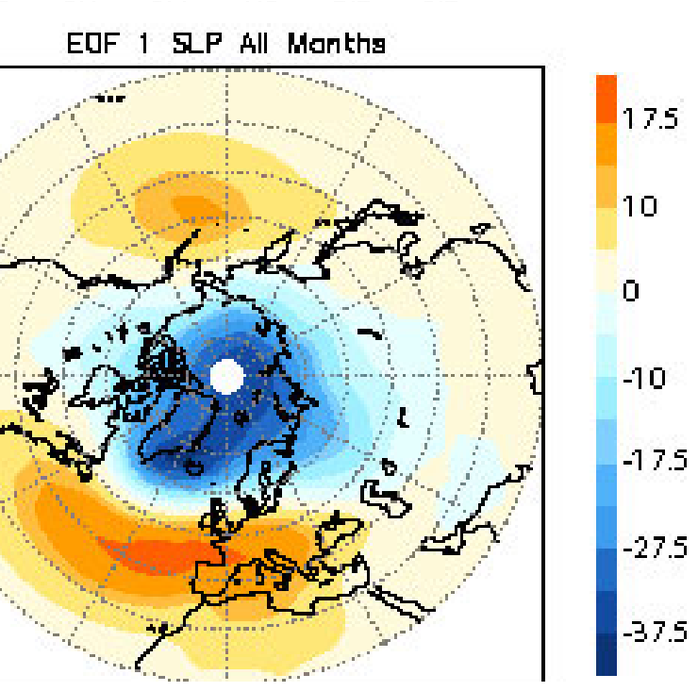
Wallace QJRMS 2000
Ambaum, Hoskins and Stephenson, JCL 2001
Wallace and Thompson JCL 2001

Structure of the AO/AAO

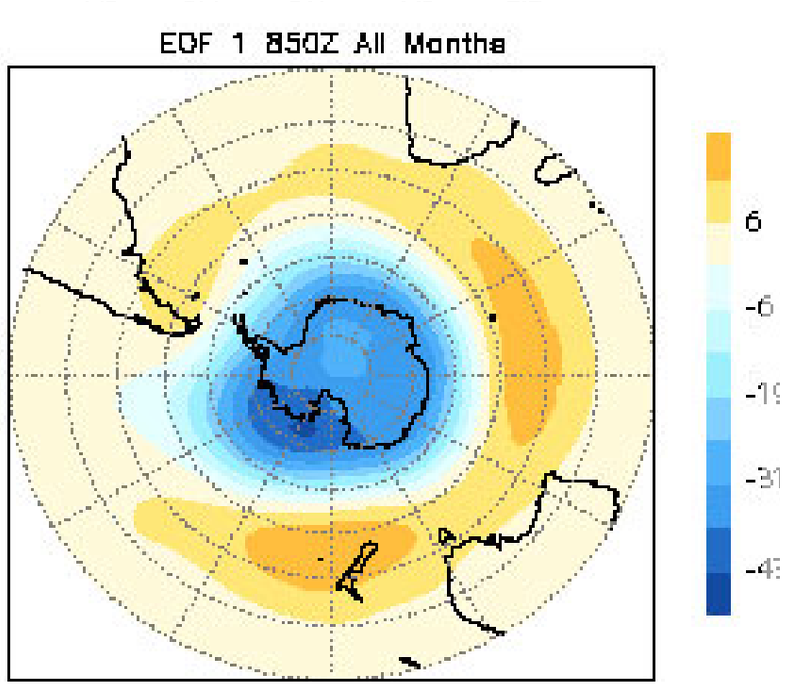




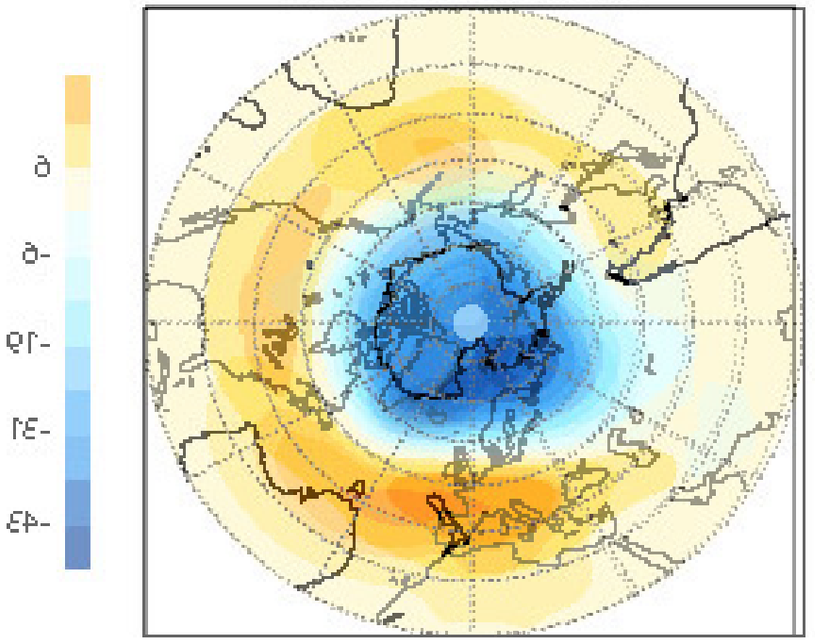




NAM

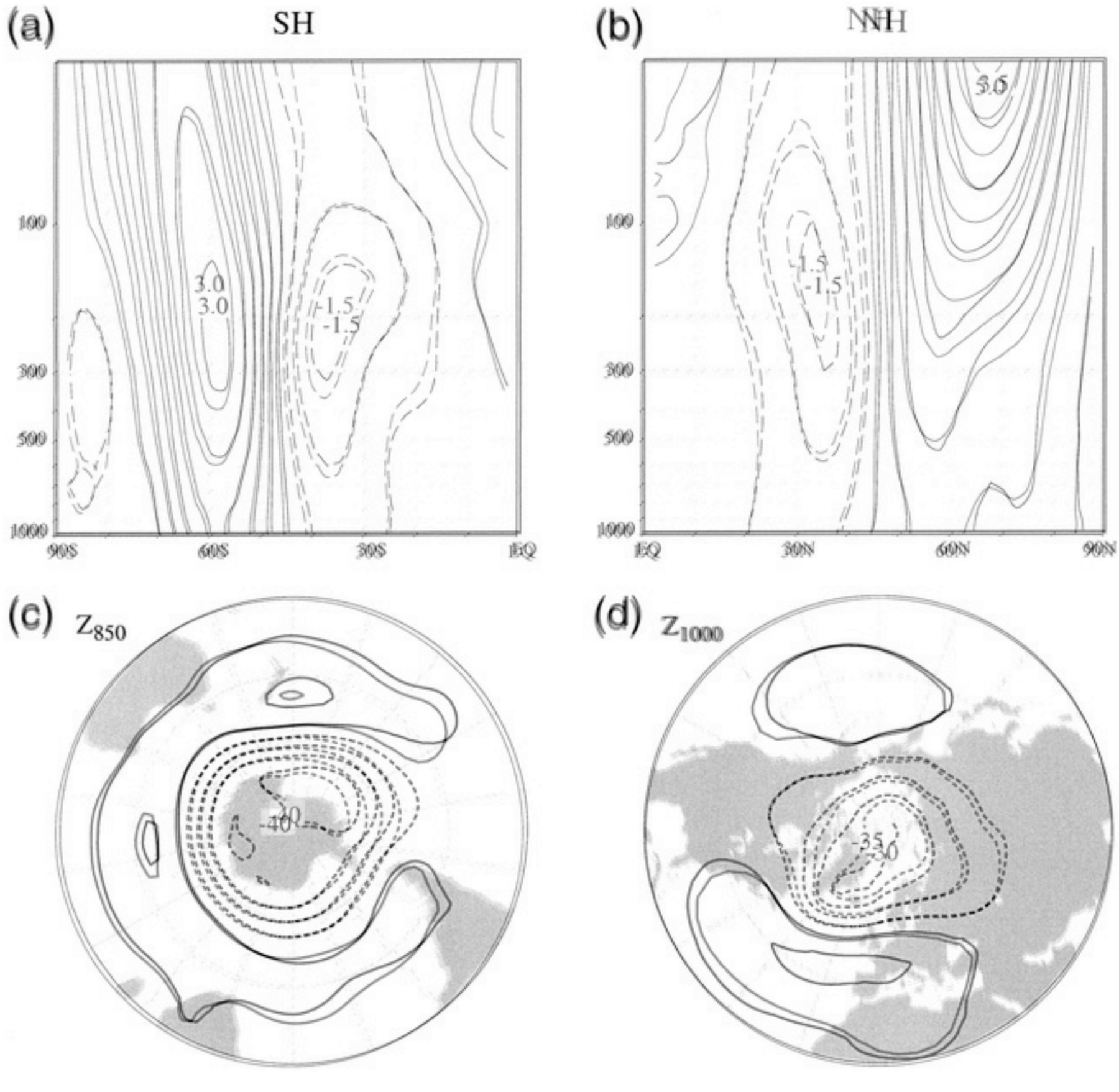


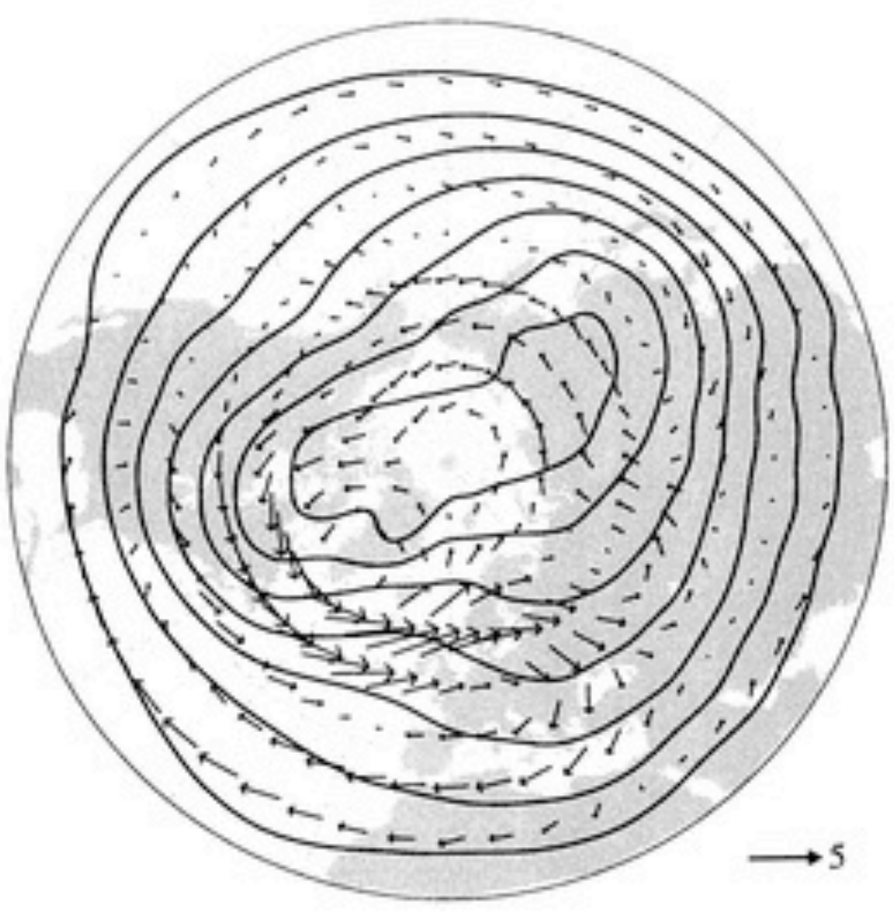
SAM



“AM”

Regressions on the $\overline{z}$ PC1




5

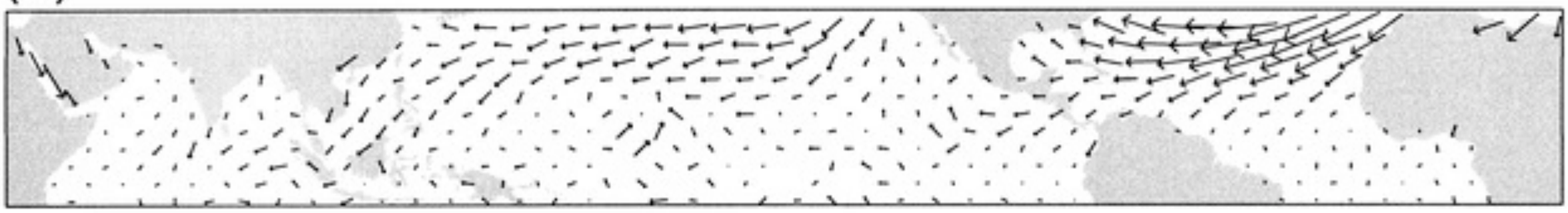

T. Adv.
0.5
-0.9


Z_{500}-Z_{1000}
30
-50

Surface wind regressed on the annular modes

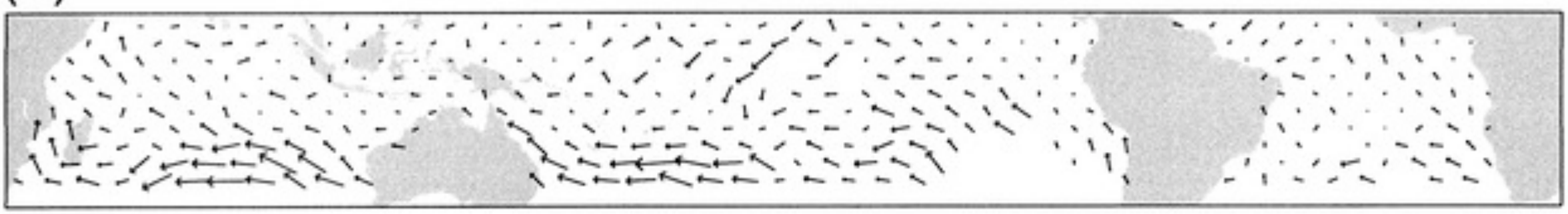
(a)

NH annular mode

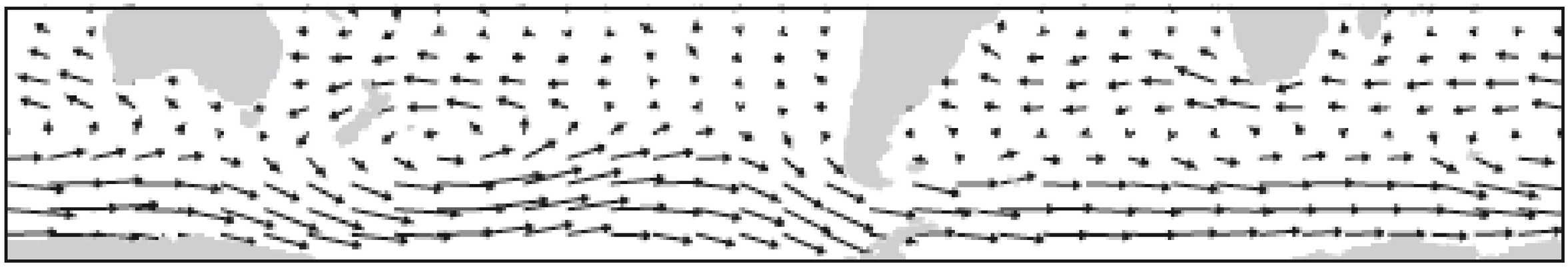


(b)

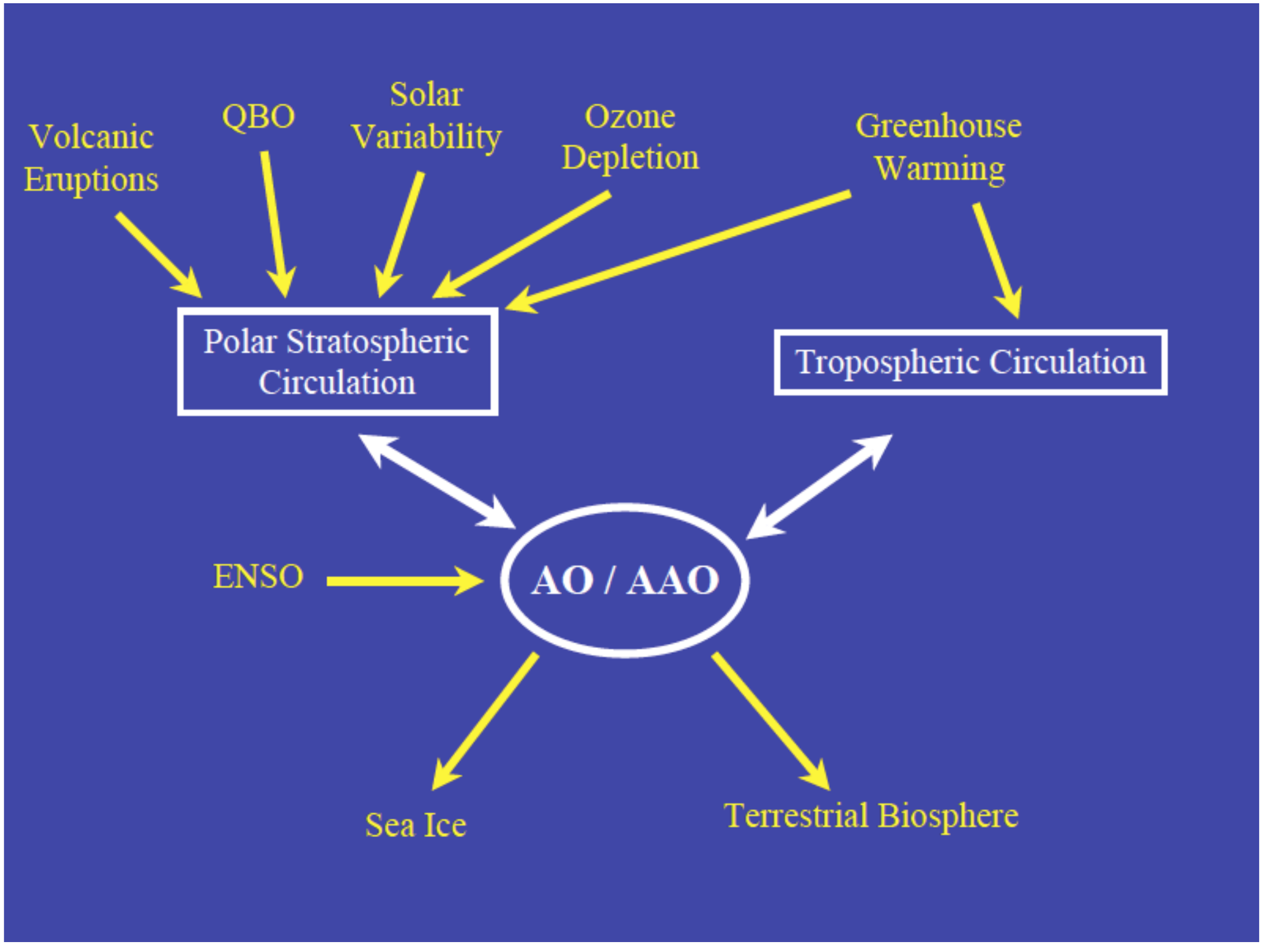
SH annular mode



1

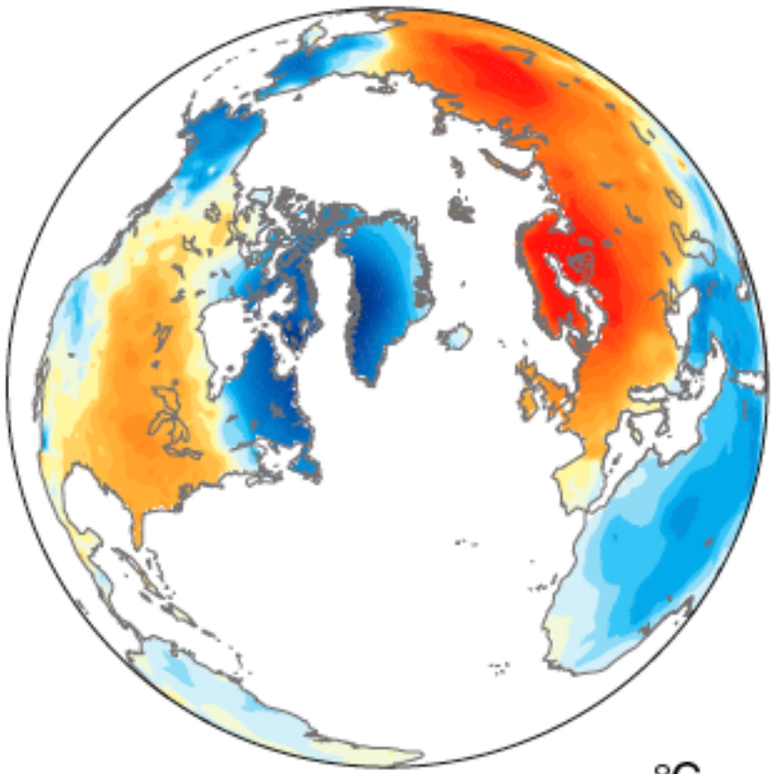


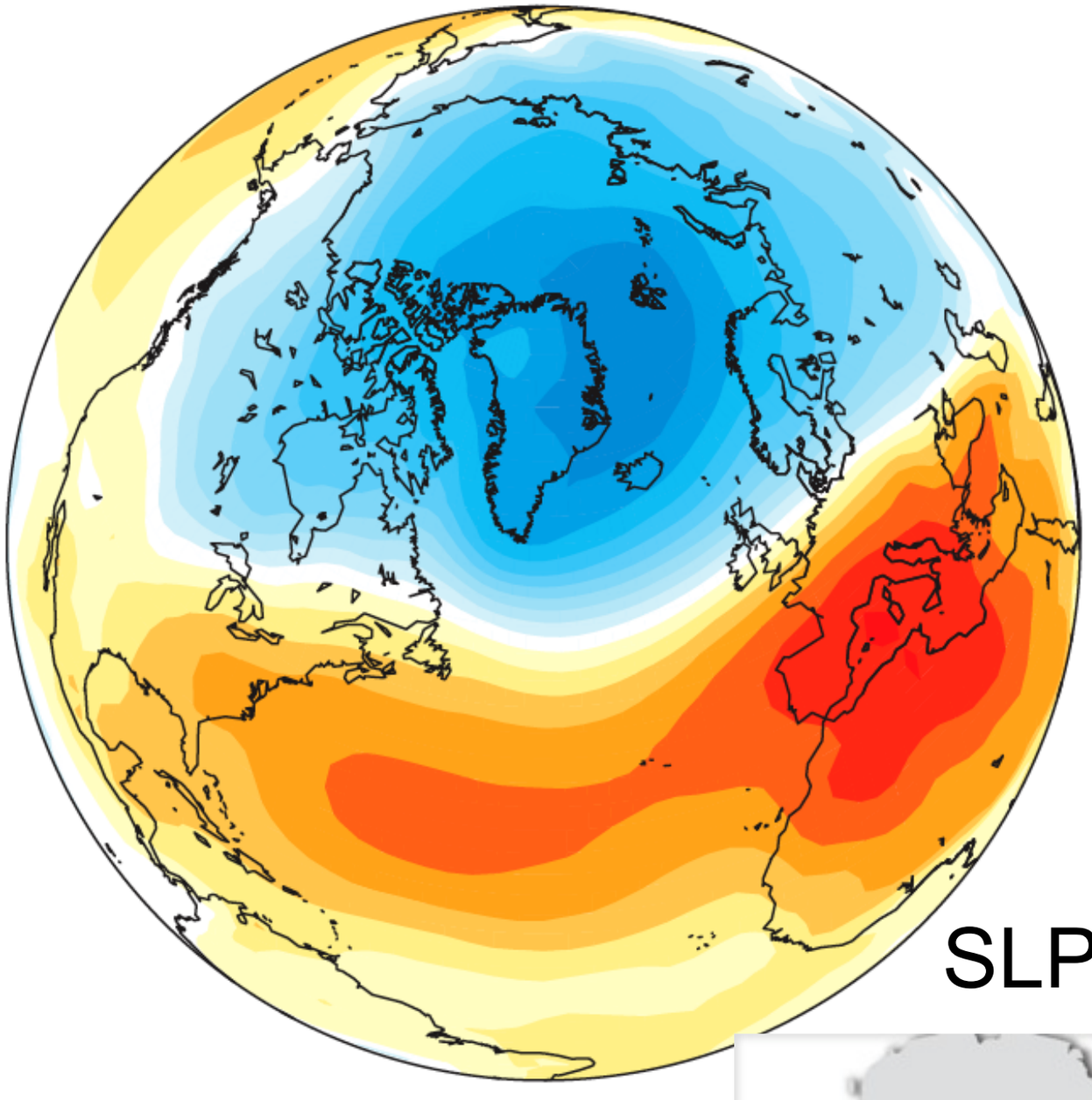
3


Volcanic Eruptions
QBO
Solar Variability
Ozone Depletion
Greenhouse Warming
Polar Stratospheric Circulation
Tropospheric Circulation
ENSO
AO / AAO
Sea Ice
Terrestrial Biosphere

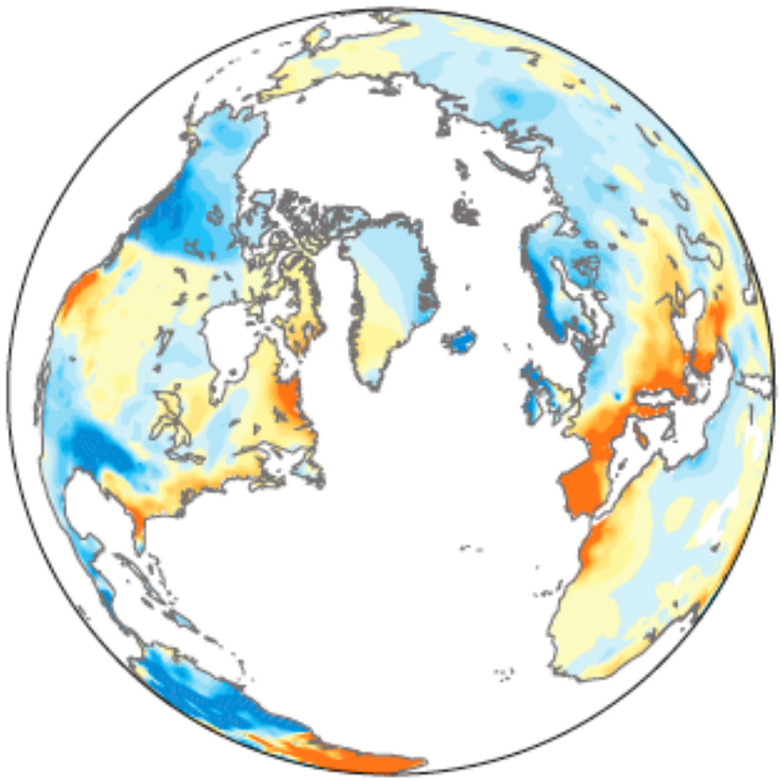
NAO / AO / NAM

SAT

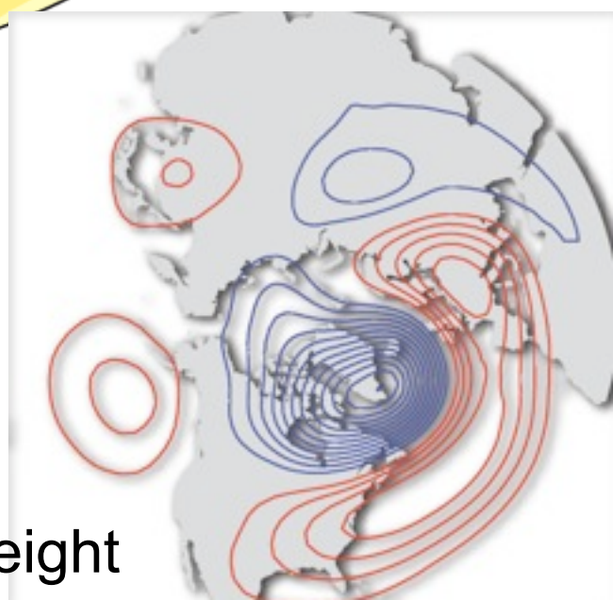




SLP

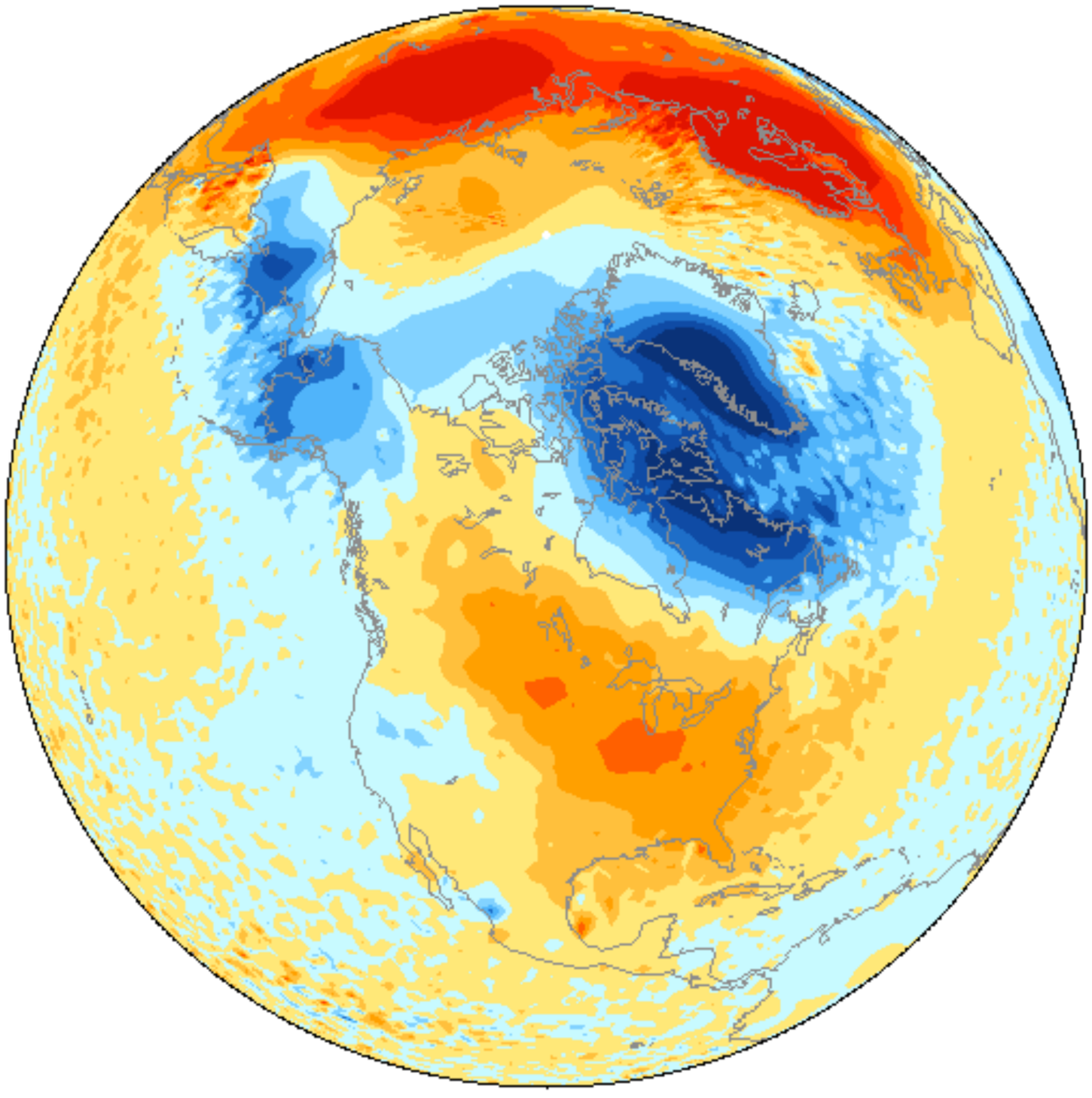


rainfall



500 hPa height

AO surface temperature anomalies (C) 1979-97



-1.5 -1.2 -0.9 -0.6 -0.3 0 0.3 0.6 0.9 1.2 1.5

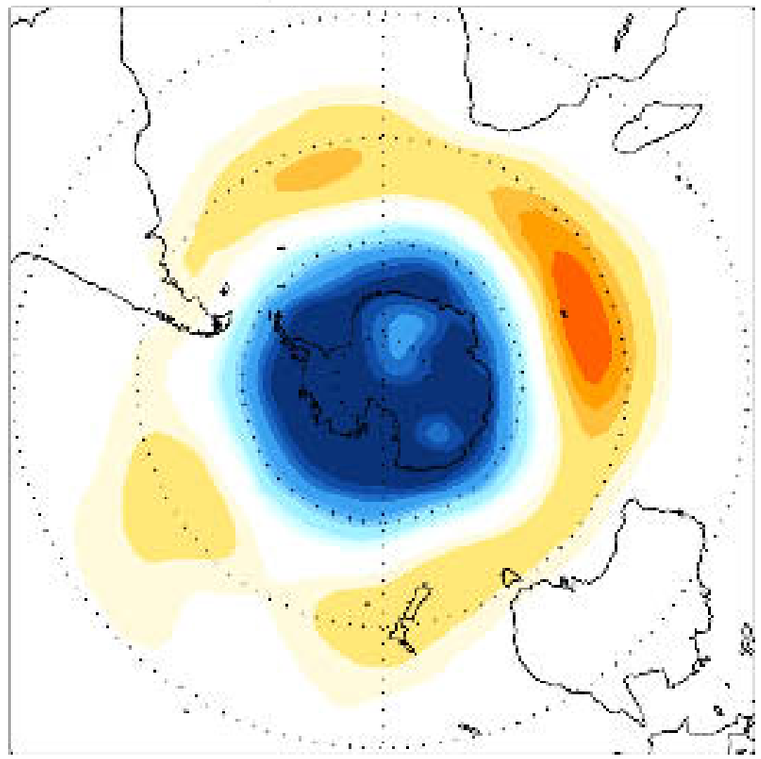
Jet stream configuration

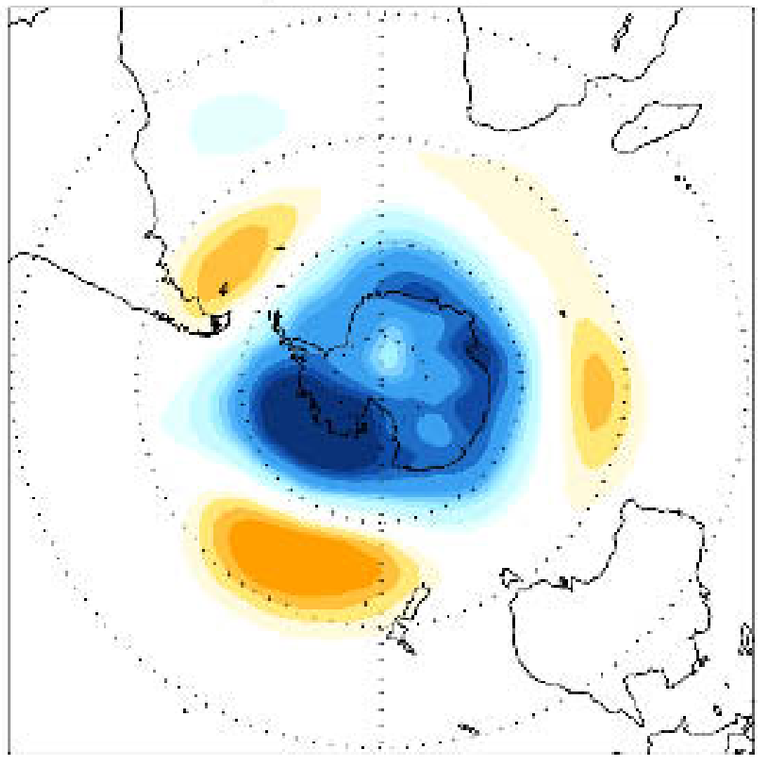
Positive Phase

Negative Phase

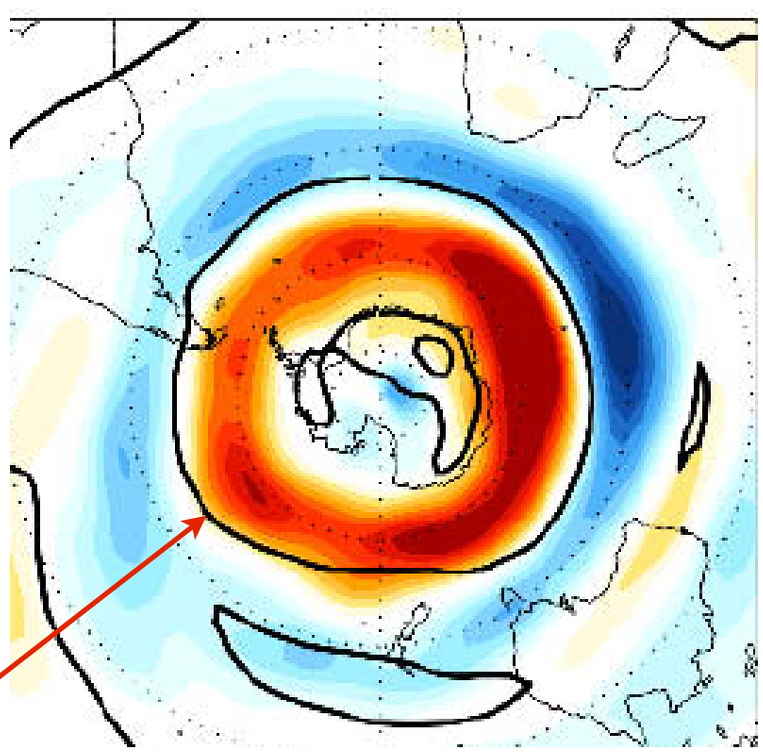
a) Dec–Jan

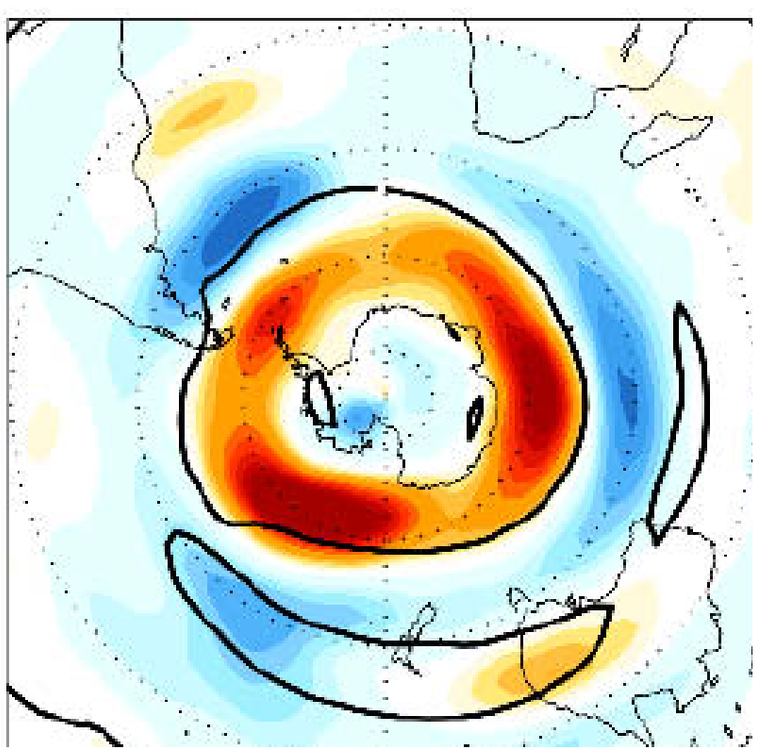
b) Mar–Apr





Z_{850}
EOF 1



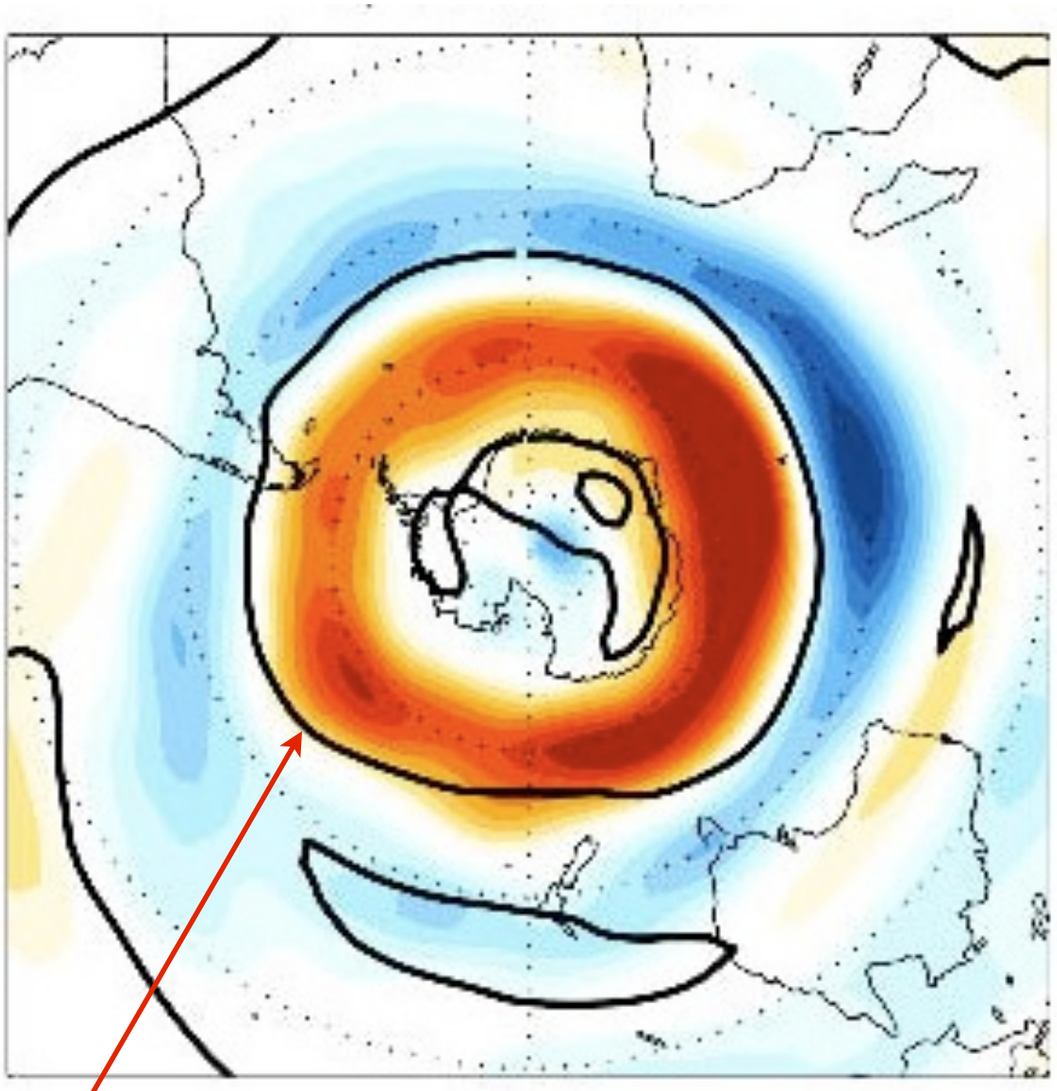


u 300

climatological-mean jet position

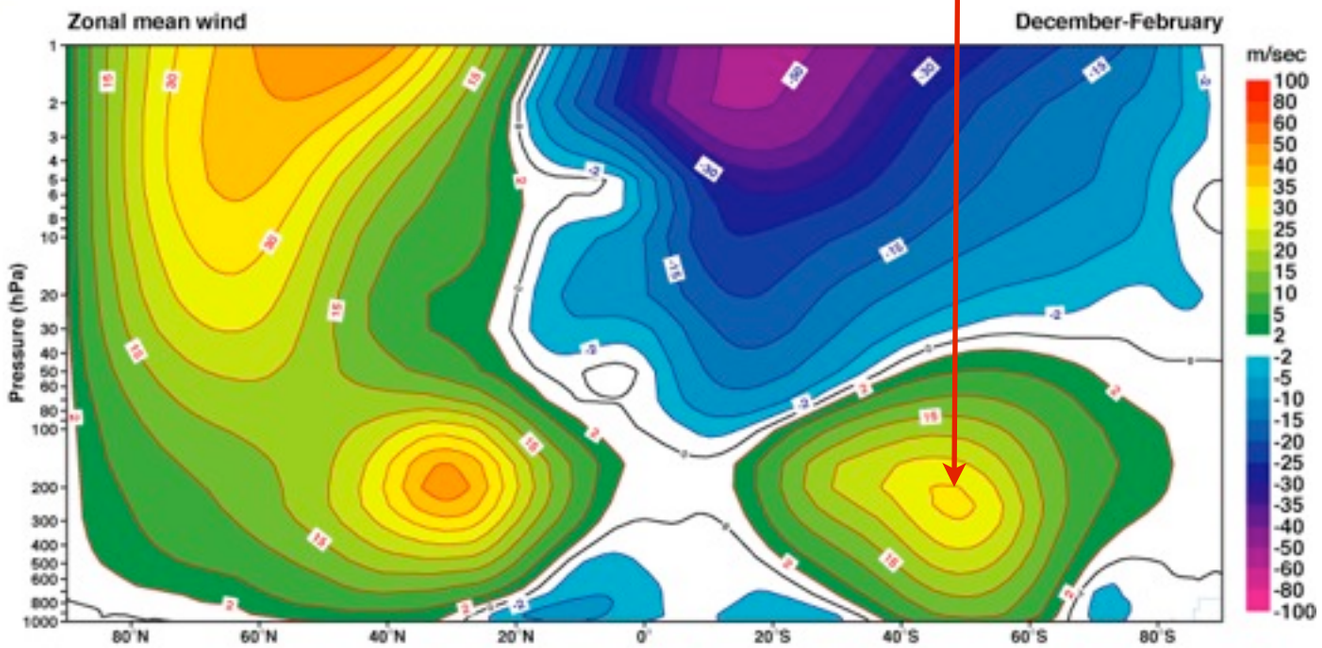
Codron 2005

DJ SAM *u*



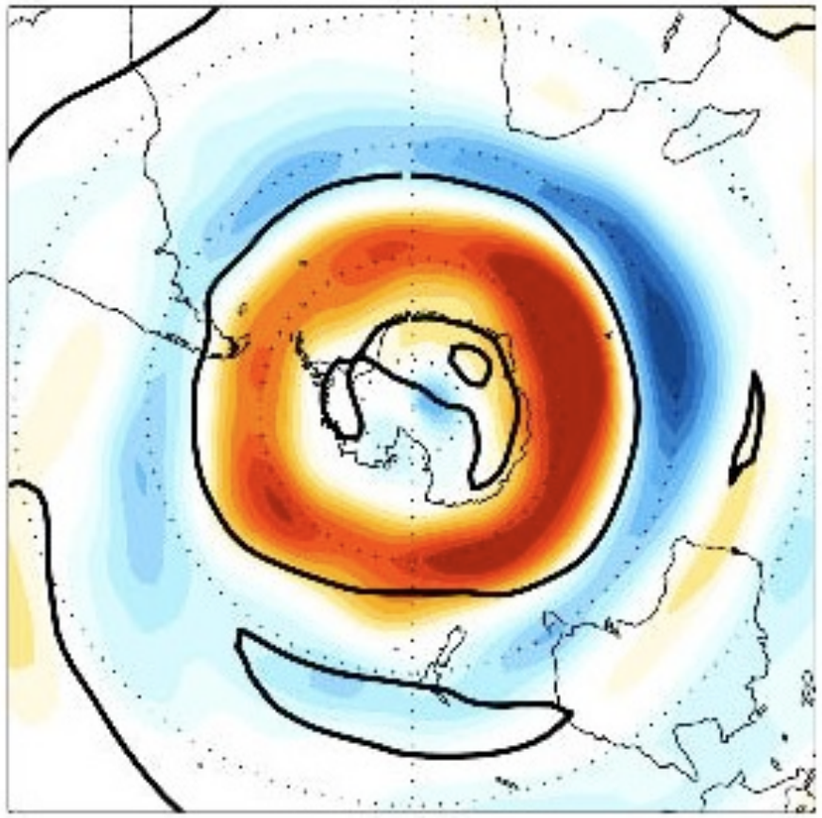
climatological-mean jet position

climatological-mean jet position



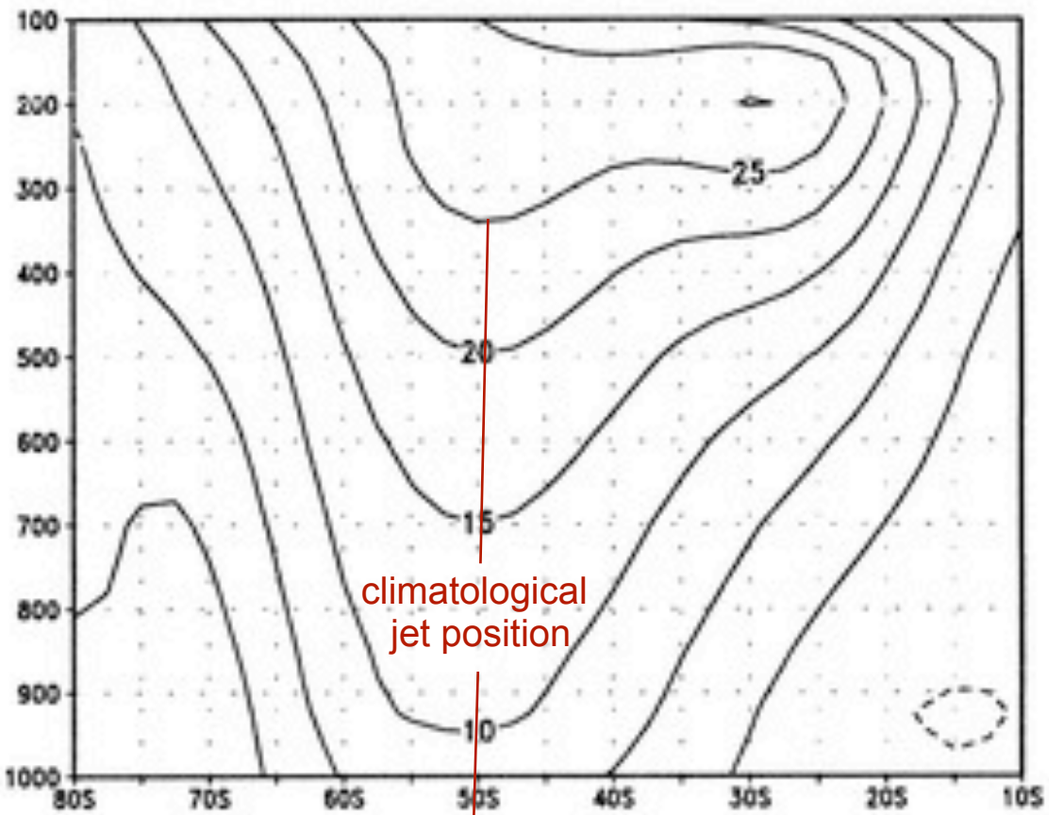
Codron 2005

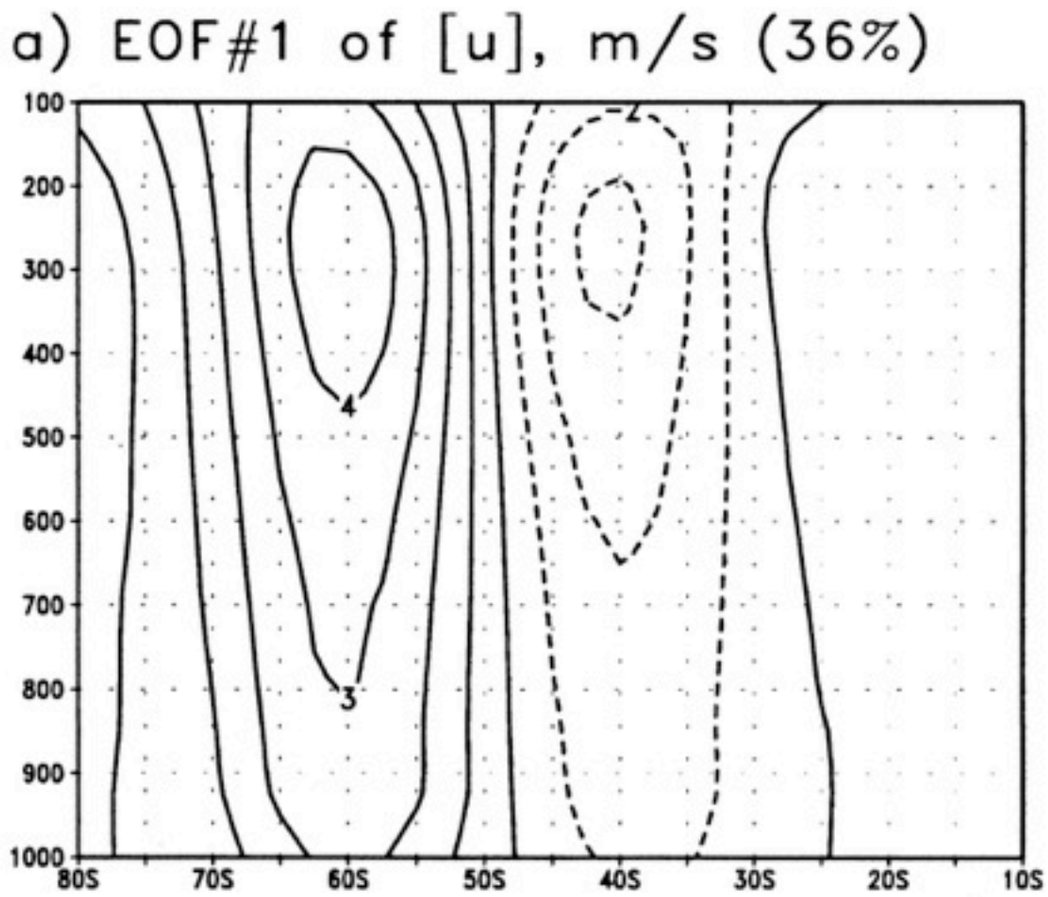
Lorenz and Hartmann (2001)

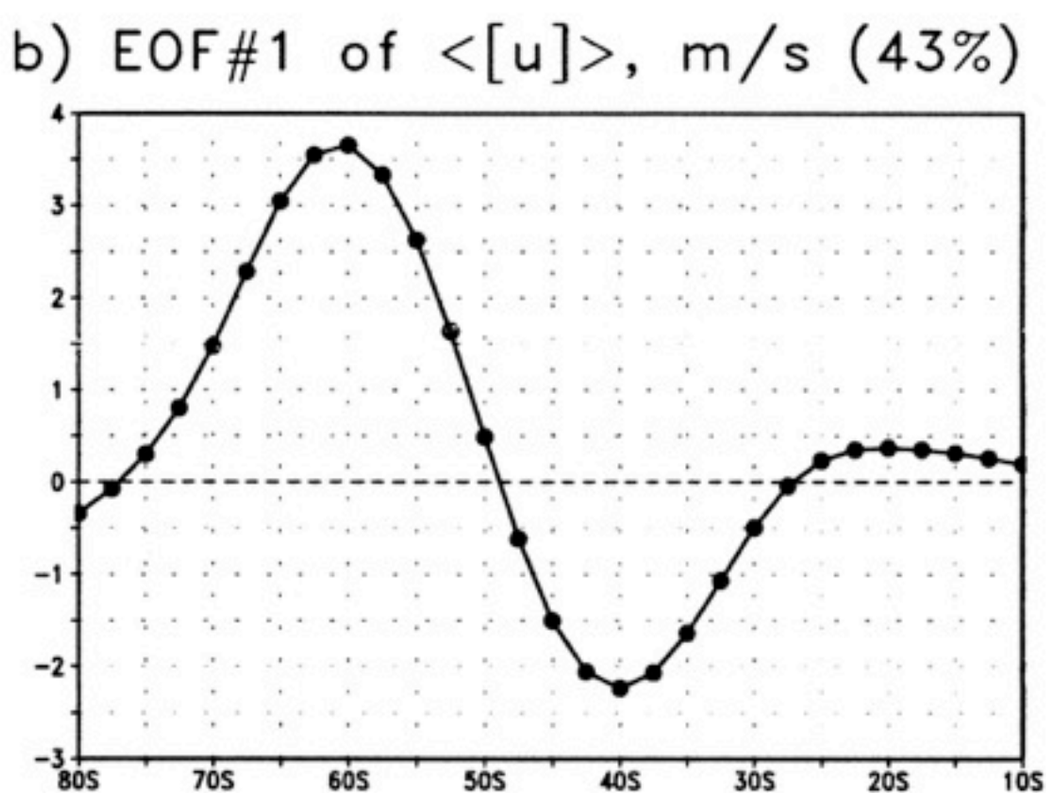


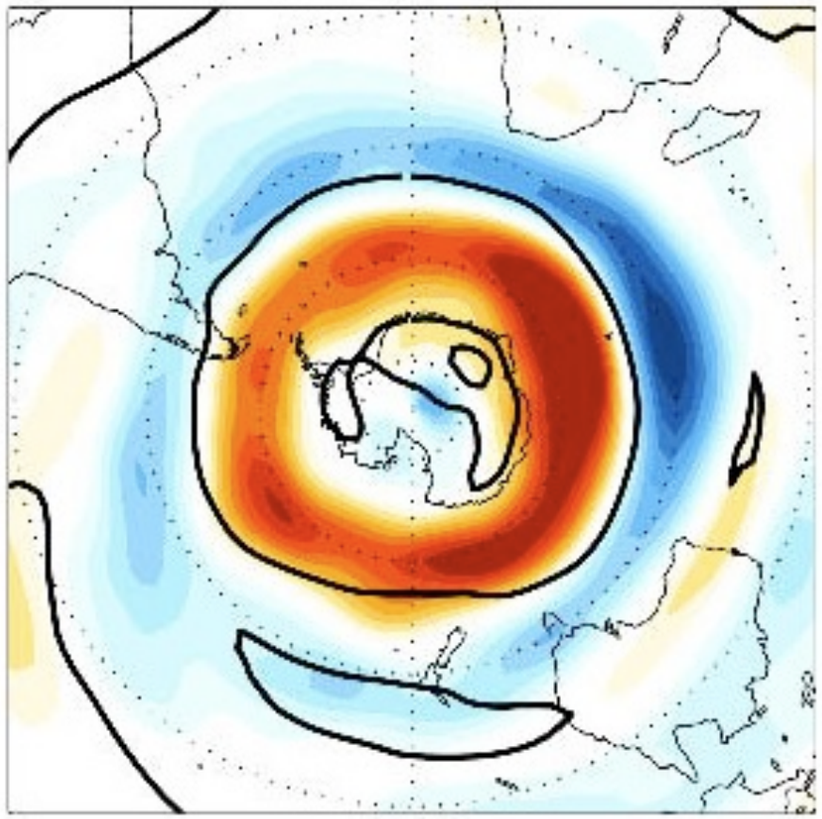
annual mean zonal wind

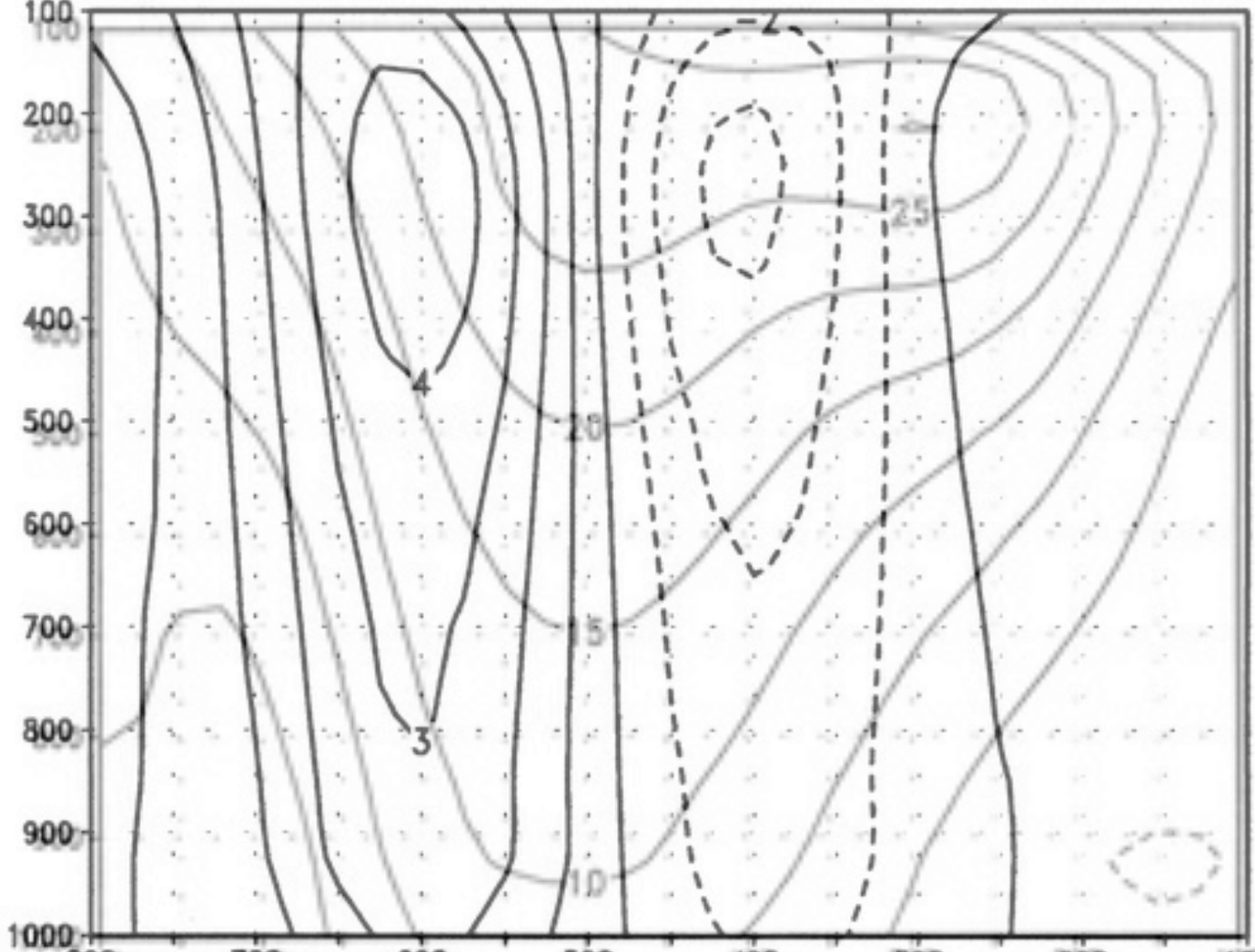
a) [u], m/s



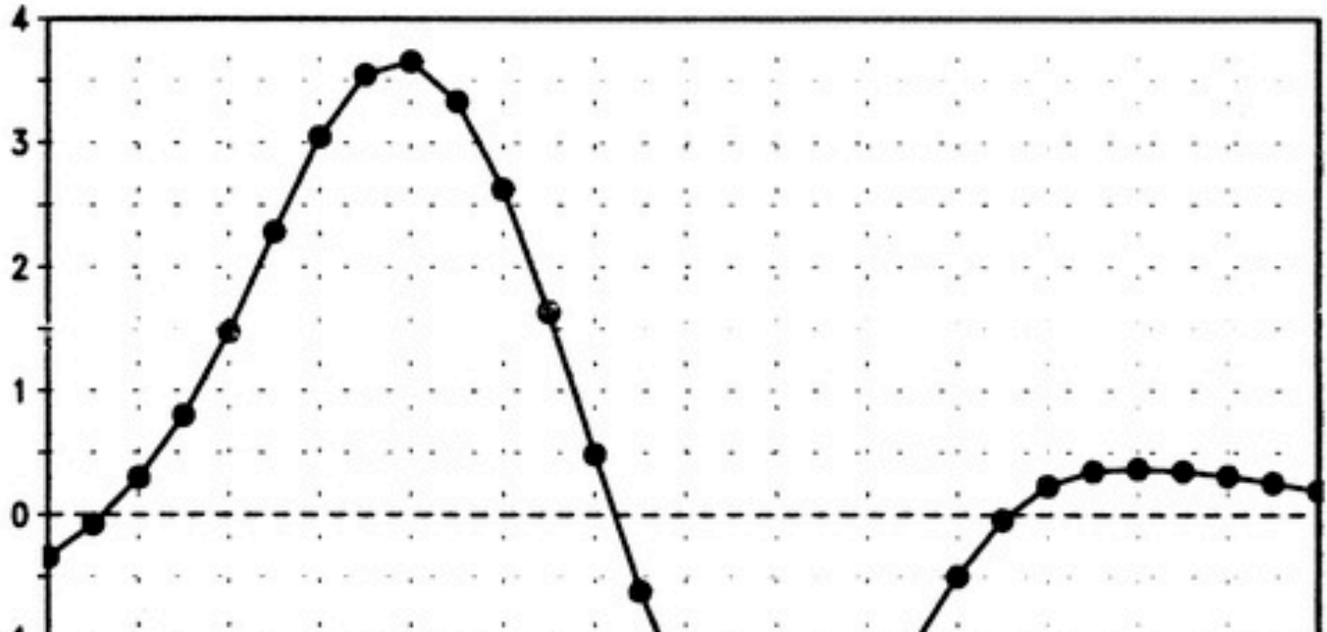






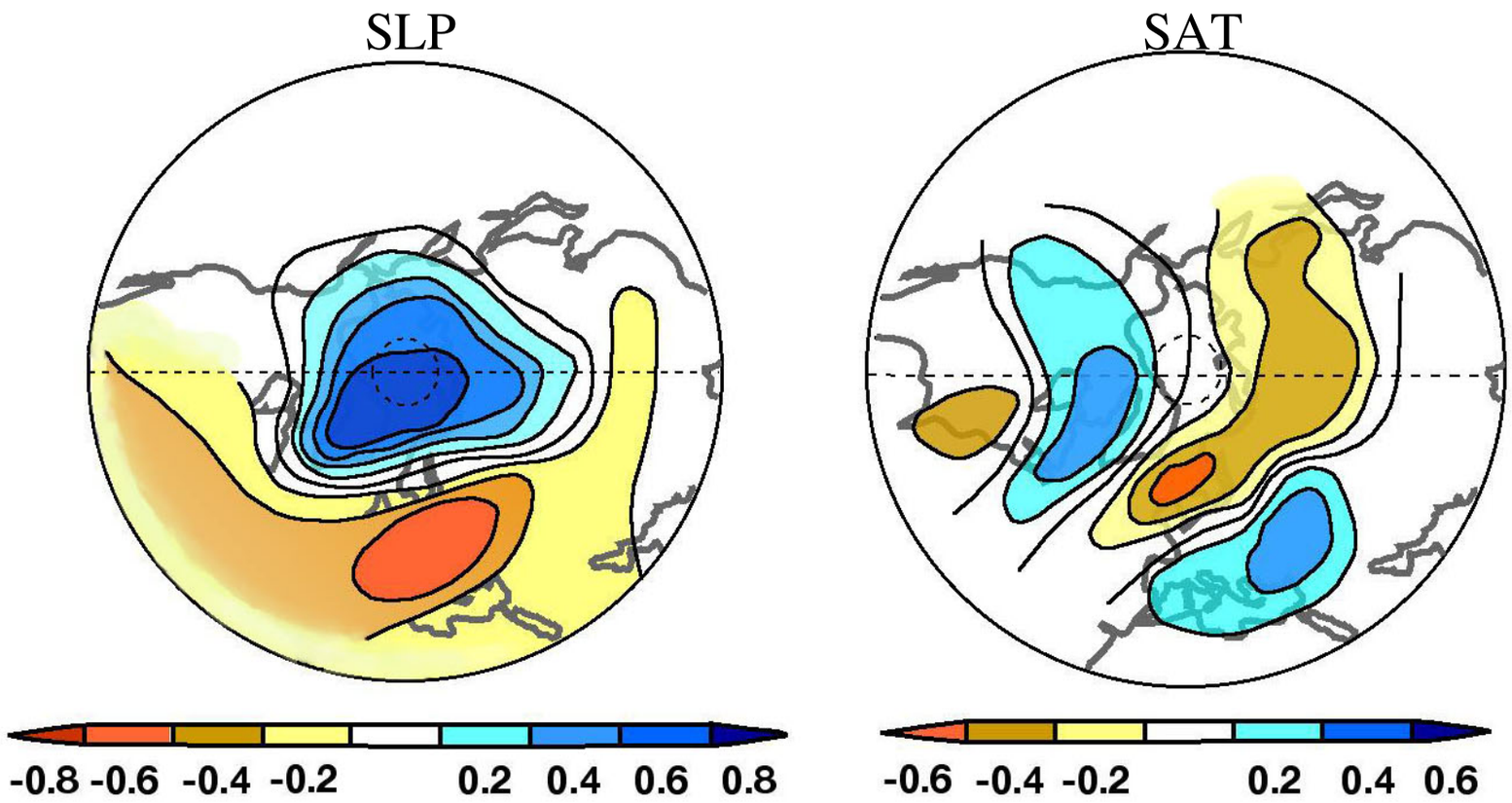


b) EOF#1 of <[u]>, m/s (43%)

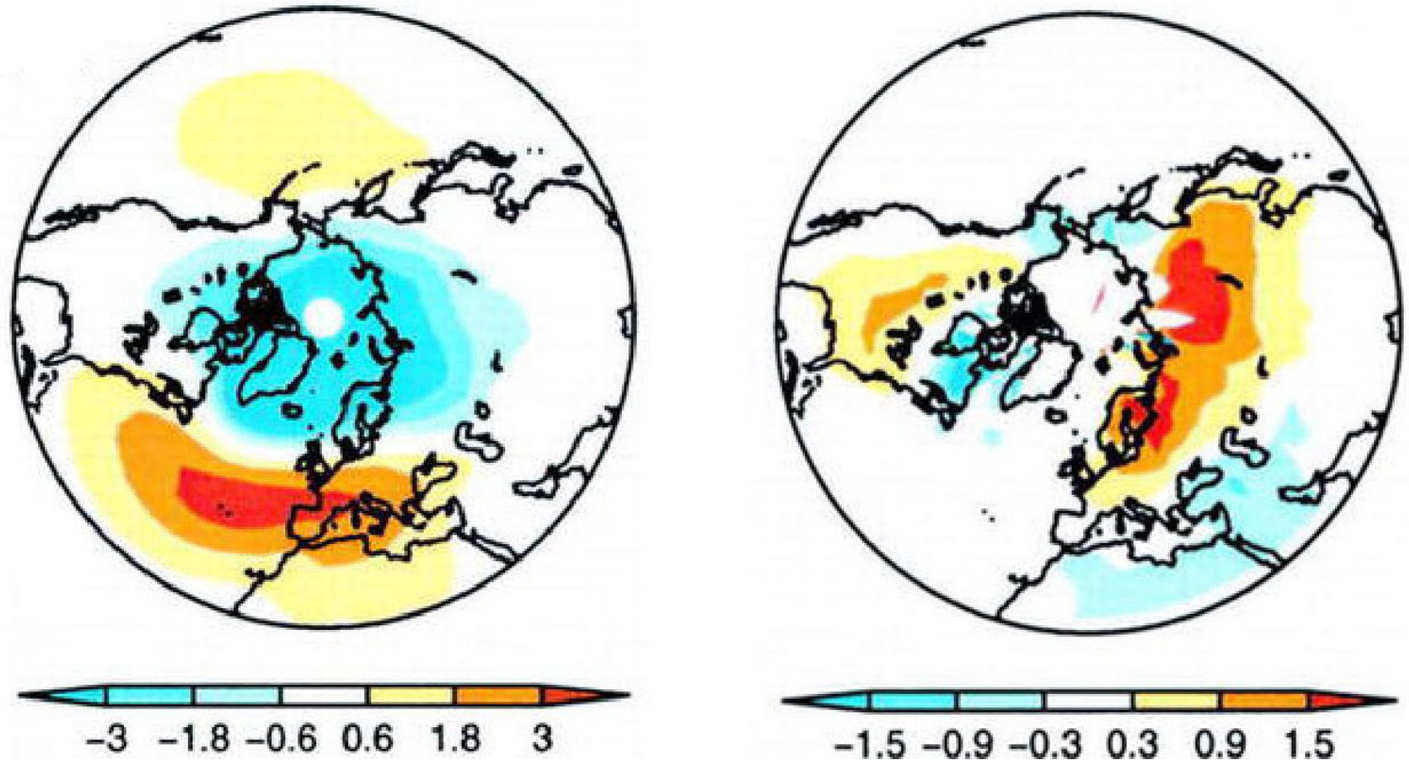


Historical Perspective

Exner (1913)



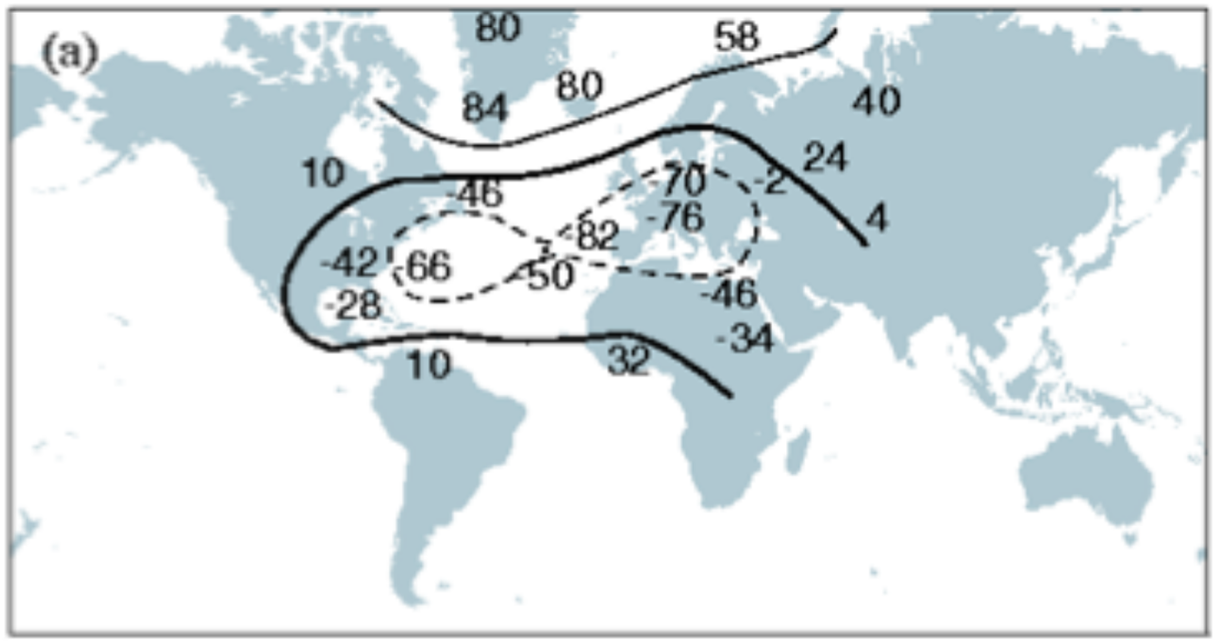
modern

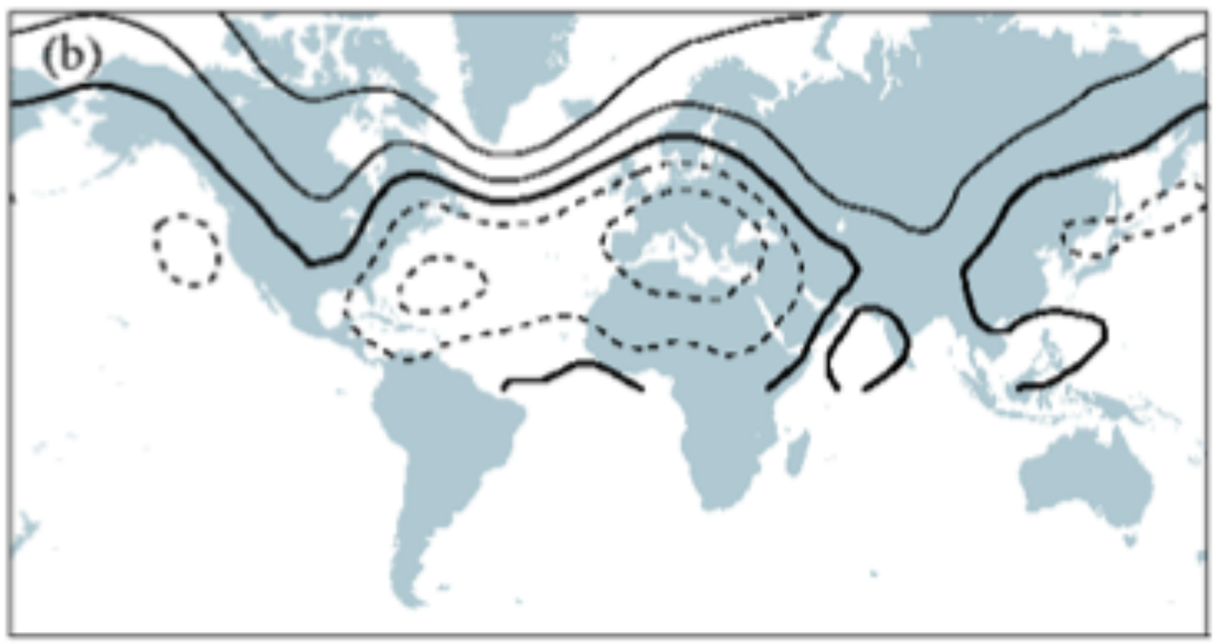


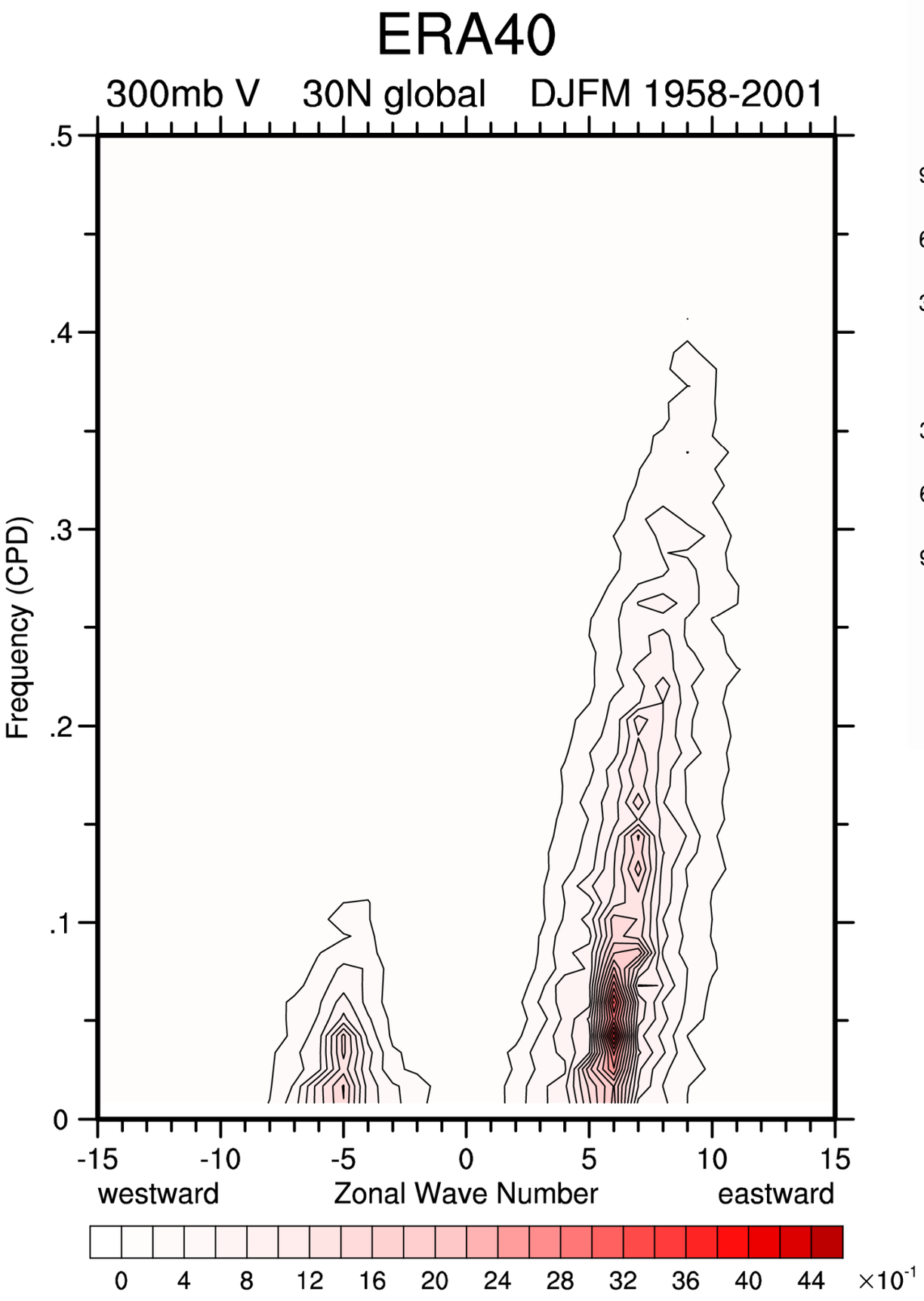
Courtesy of Kevin Wood

NAO

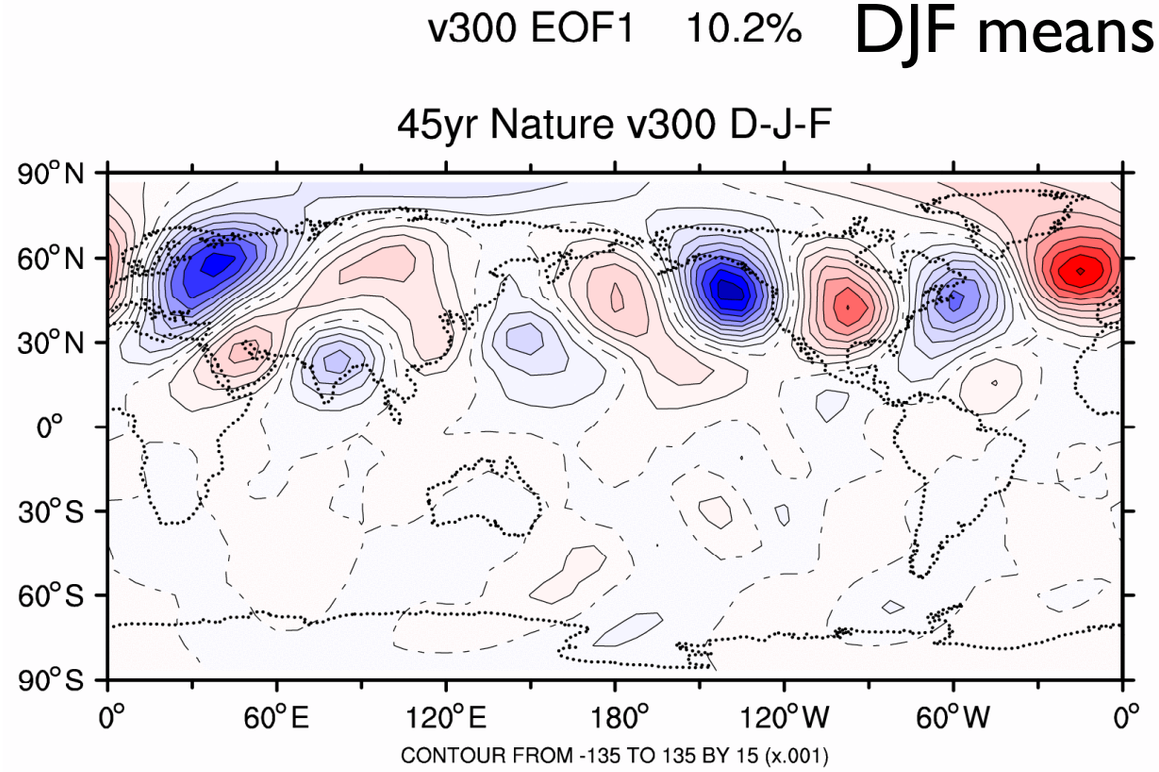
Walker and Bliss
(1932)

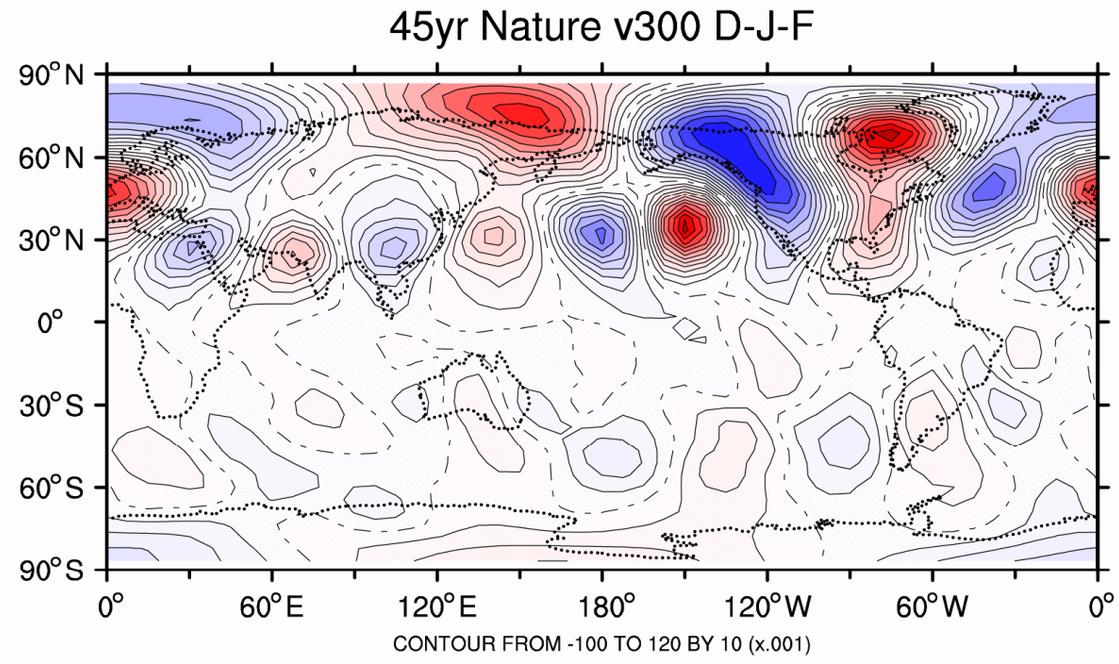






Circumglobal, zonal wavenumber 5



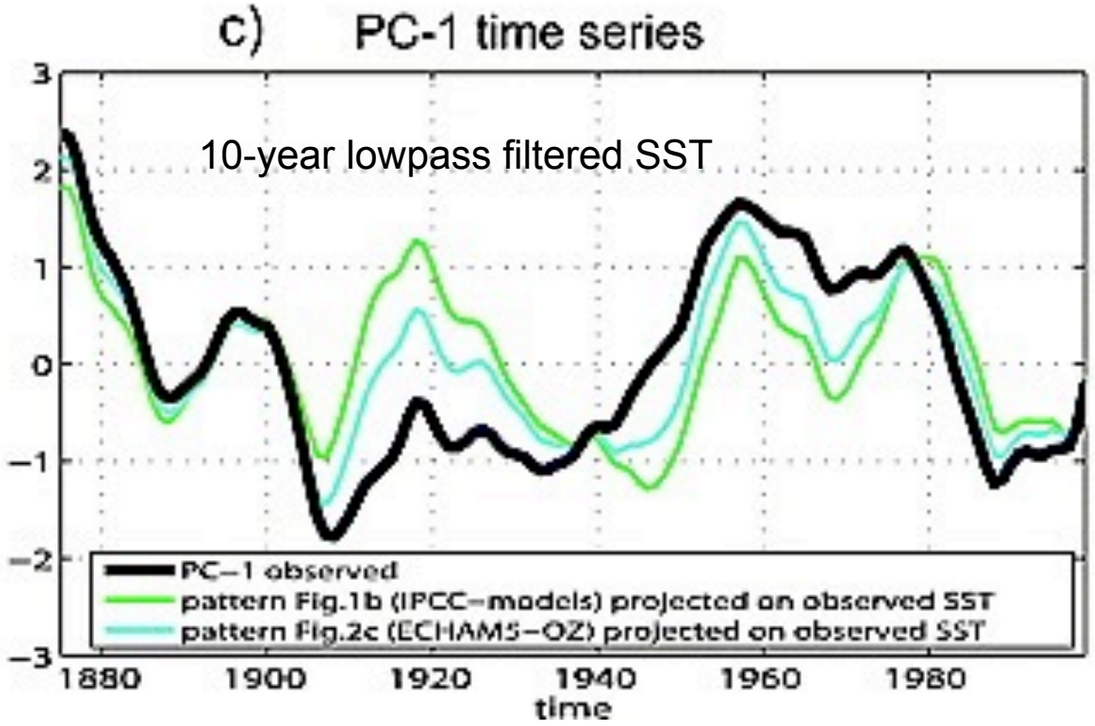


Branstator JCL 2002

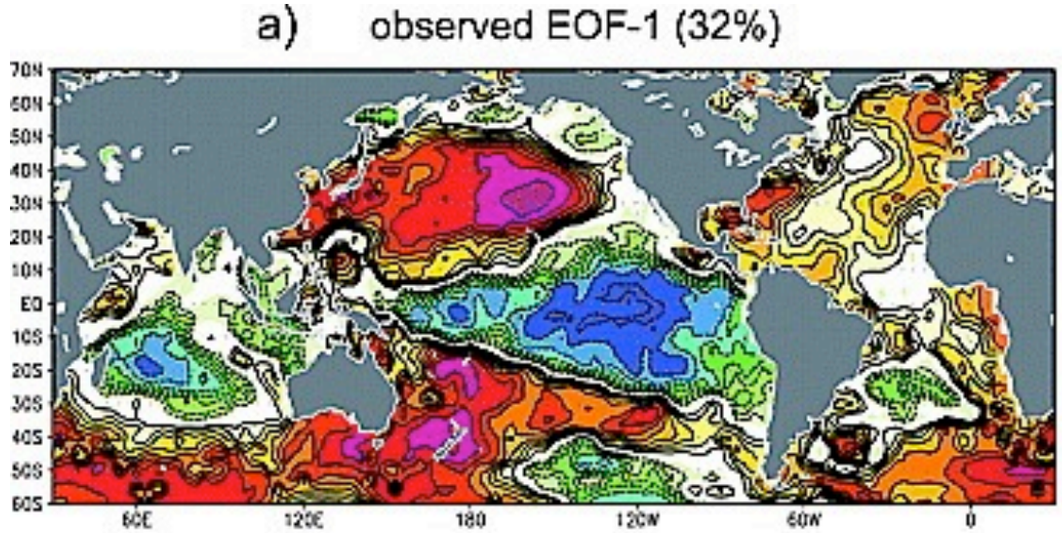
Teleconnection patterns

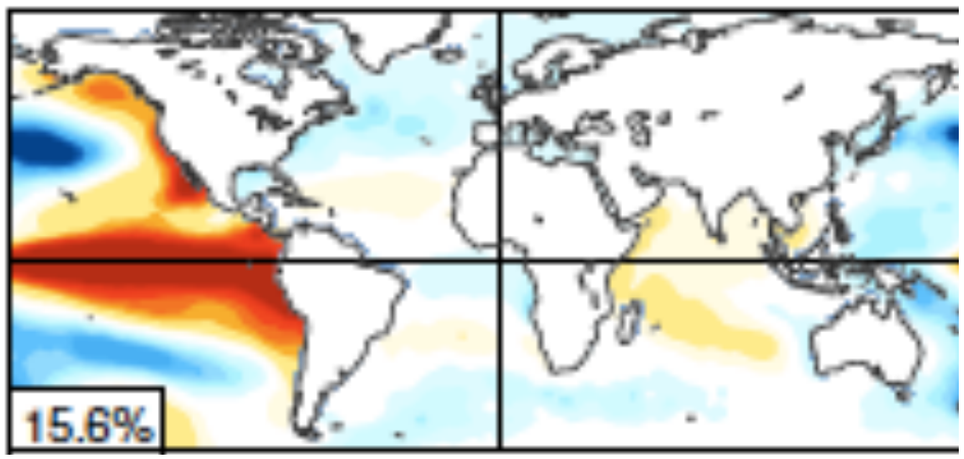
Why are they important?

- They provide a focus for studies of low frequency atmospheric dynamical processes
- They account for a disproportionate share of the low frequency variance, especially on very long time scales
  Dommenget and Latif GRL 2008
- Response to a variety of forcings projects strongly on them
- Their indices are convenient for characterizing low frequency variability in observations and models
- Their signatures are sometimes evident in time series of climate impacts

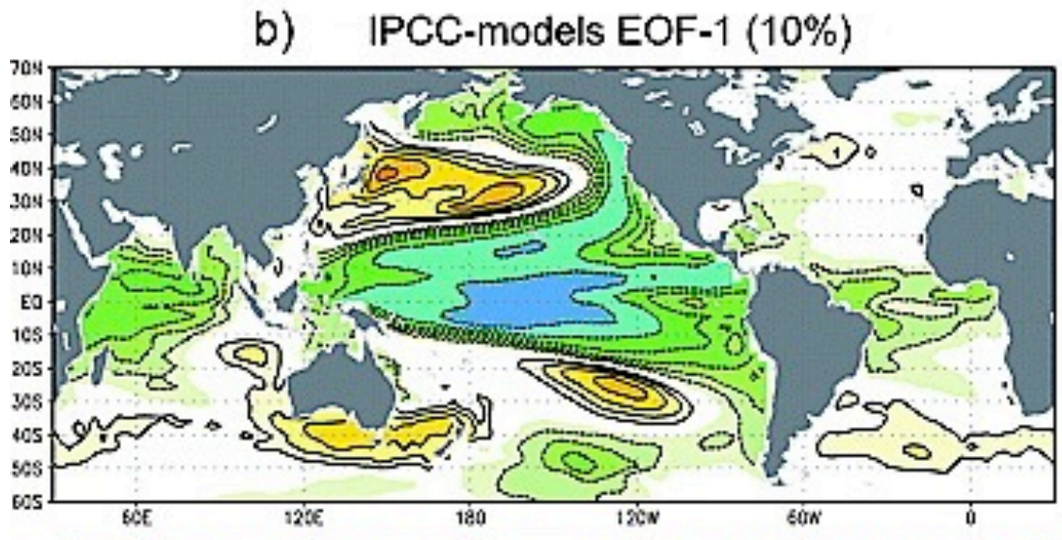


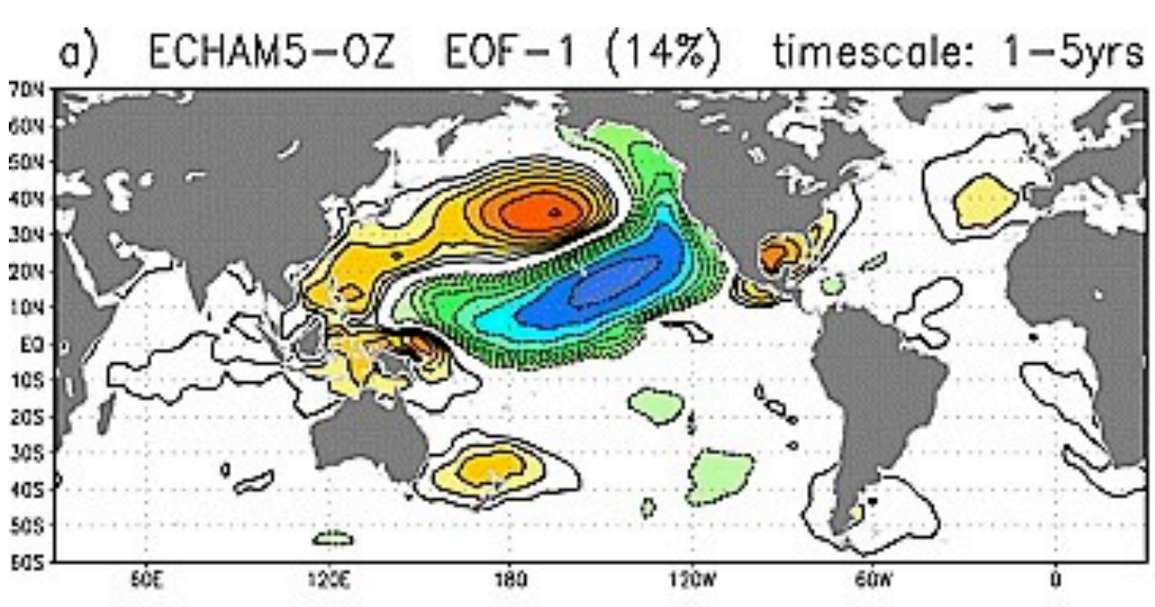
- *Dommenget and Latif GRL 2008*

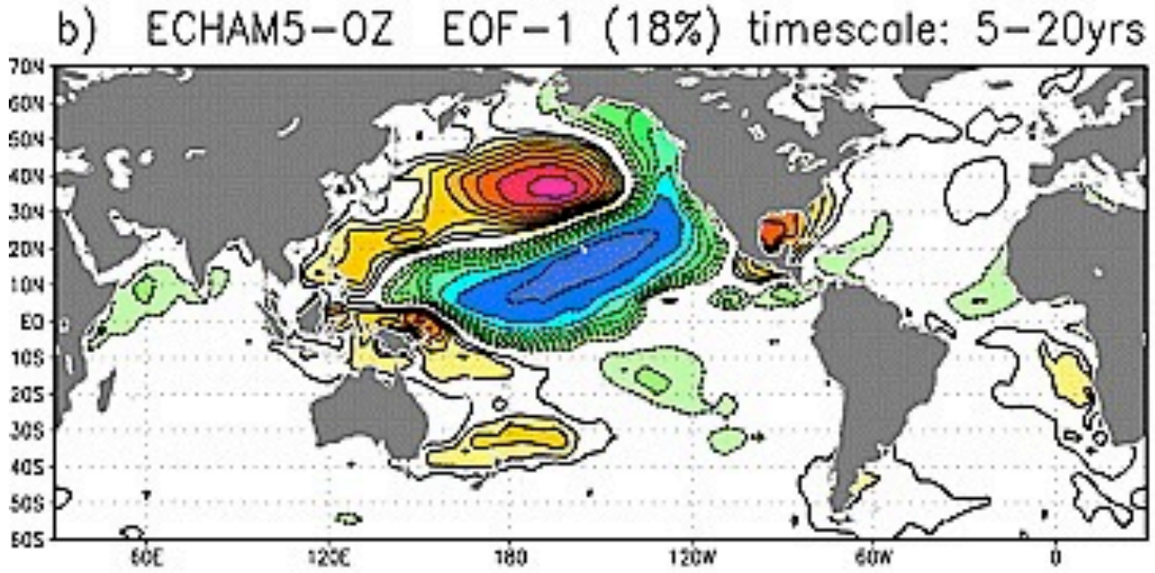


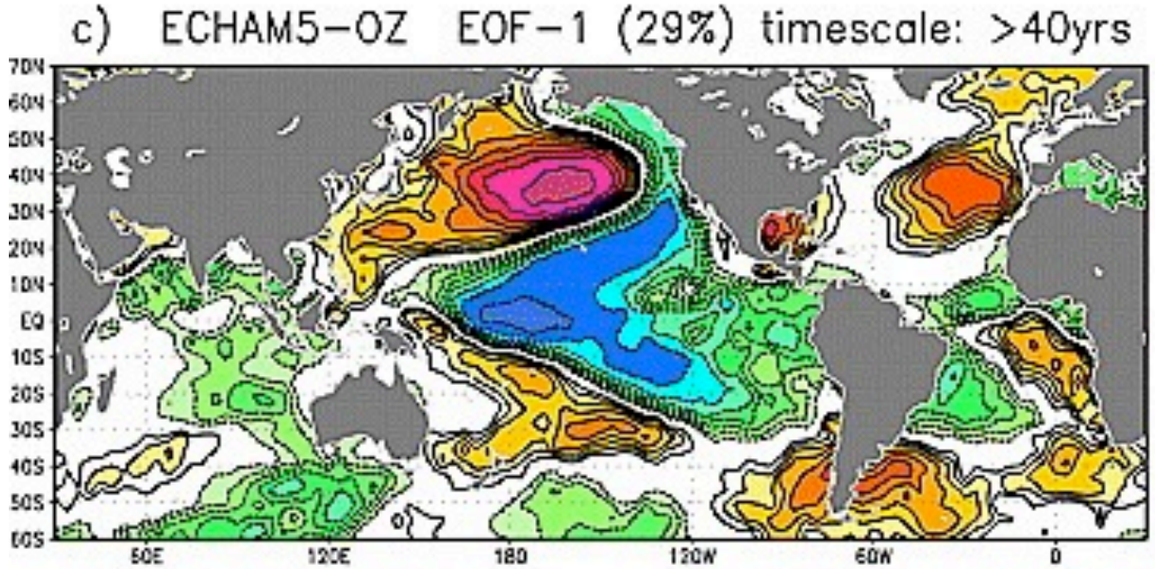


unfiltered monthly SST: *Brian Smoliak*









from an extended run with atmosphere coupled to a passive ocean mixed layer

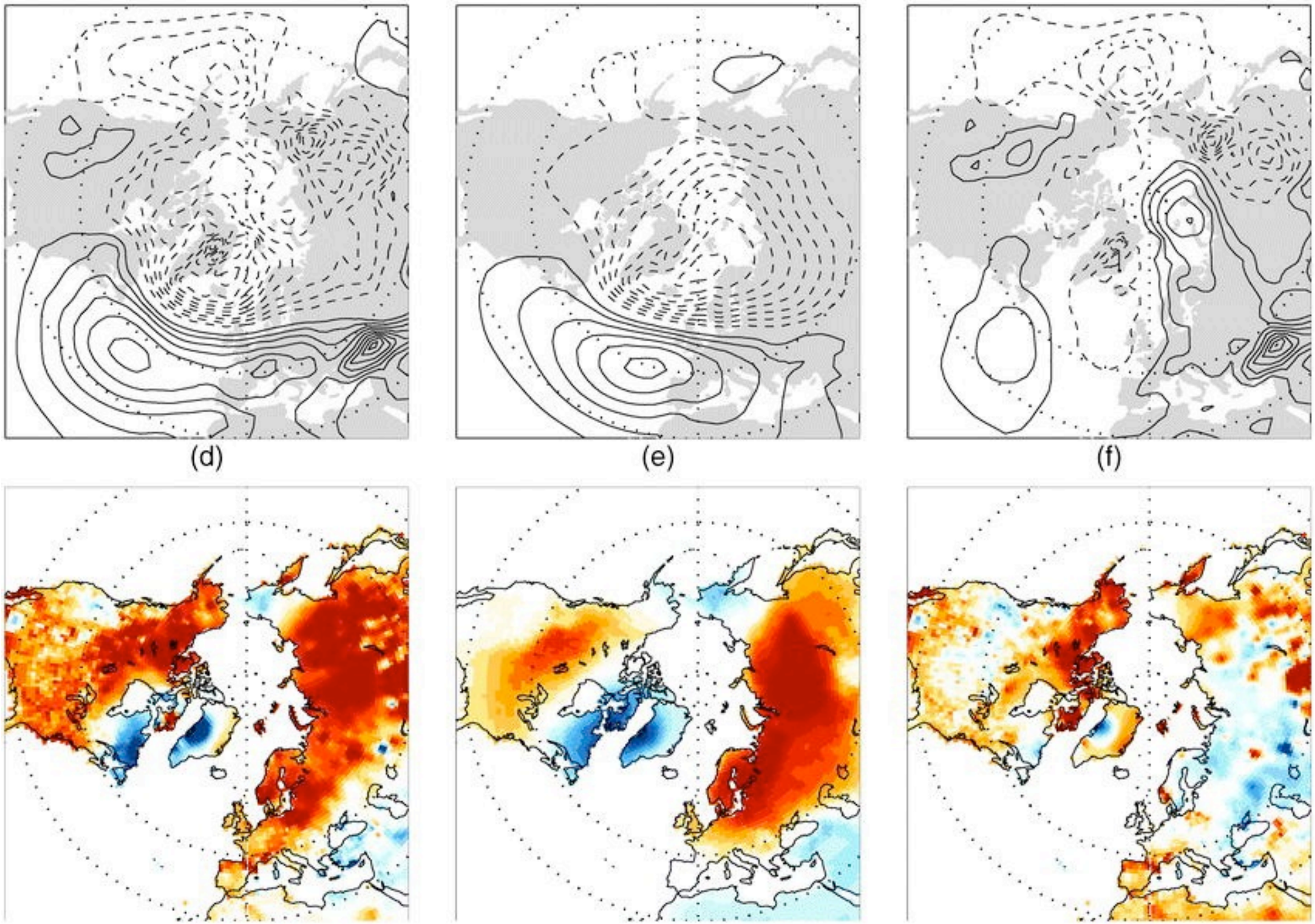
- *Dommenget and Latif GRL 2008*

Winter Trends 1958-1999

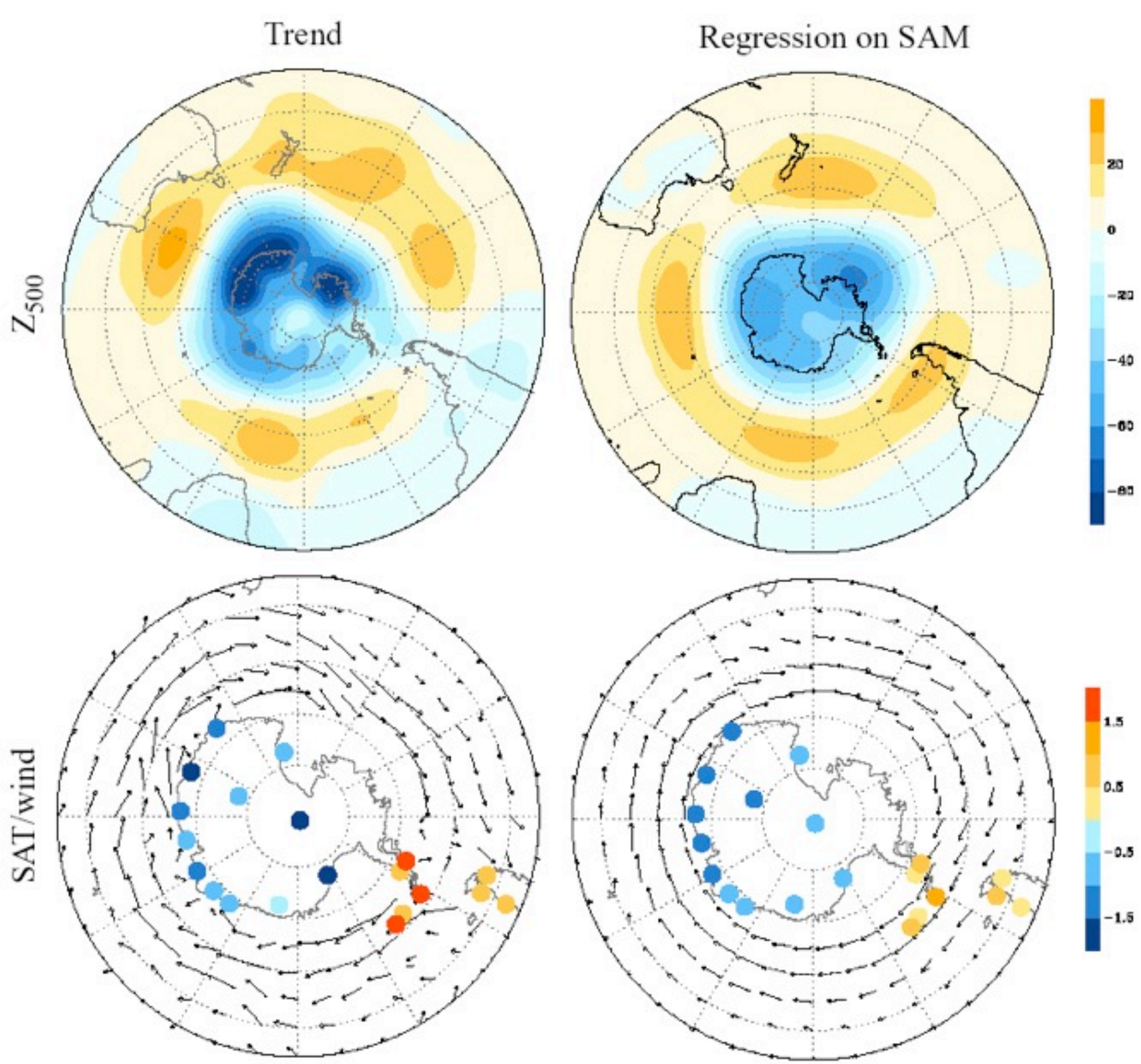
Total

AO / PNA Component

Residual



Quadrelli and Wallace JCL 2004a

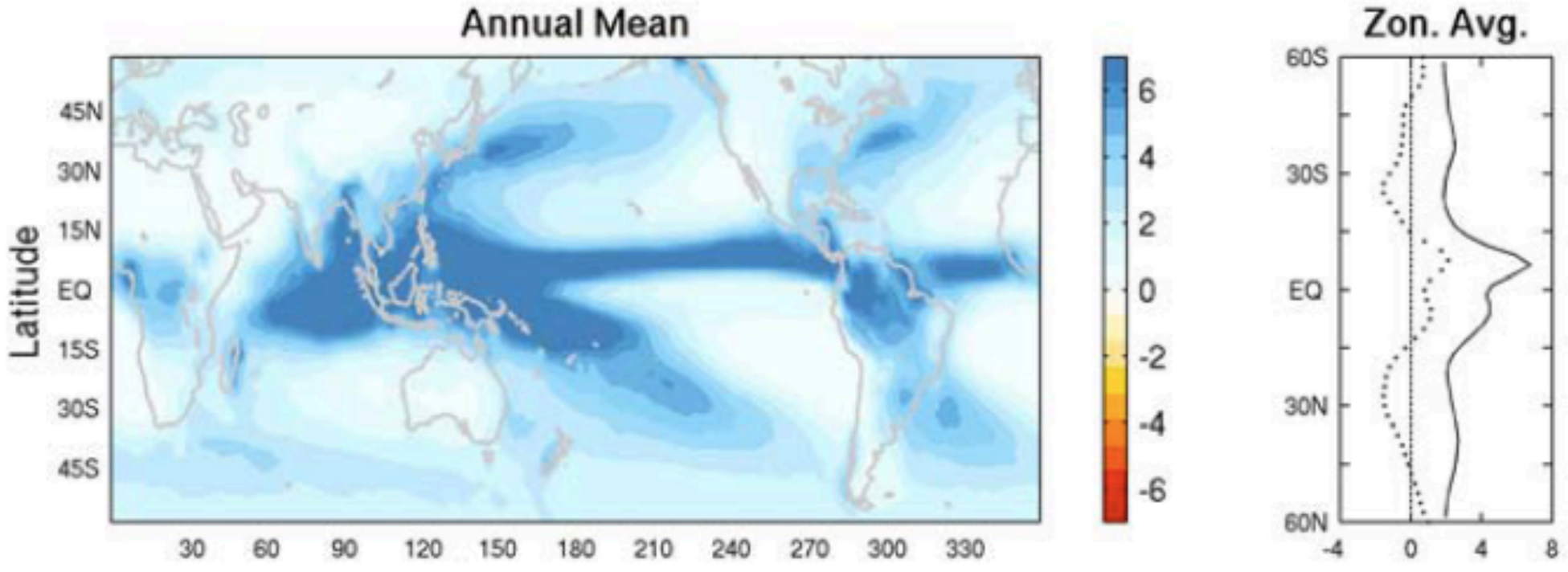


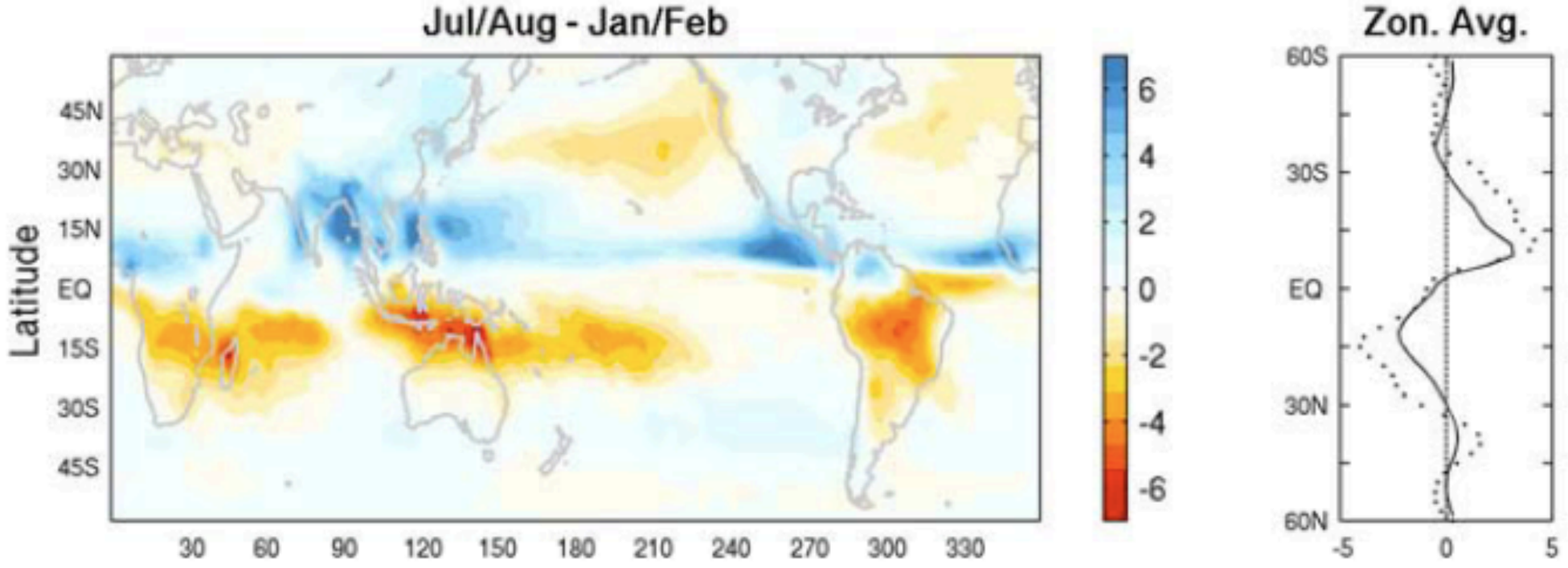
December-May 1979-2000

Thompson and Solomon
Science (2002)

Tropical teleconnection patterns

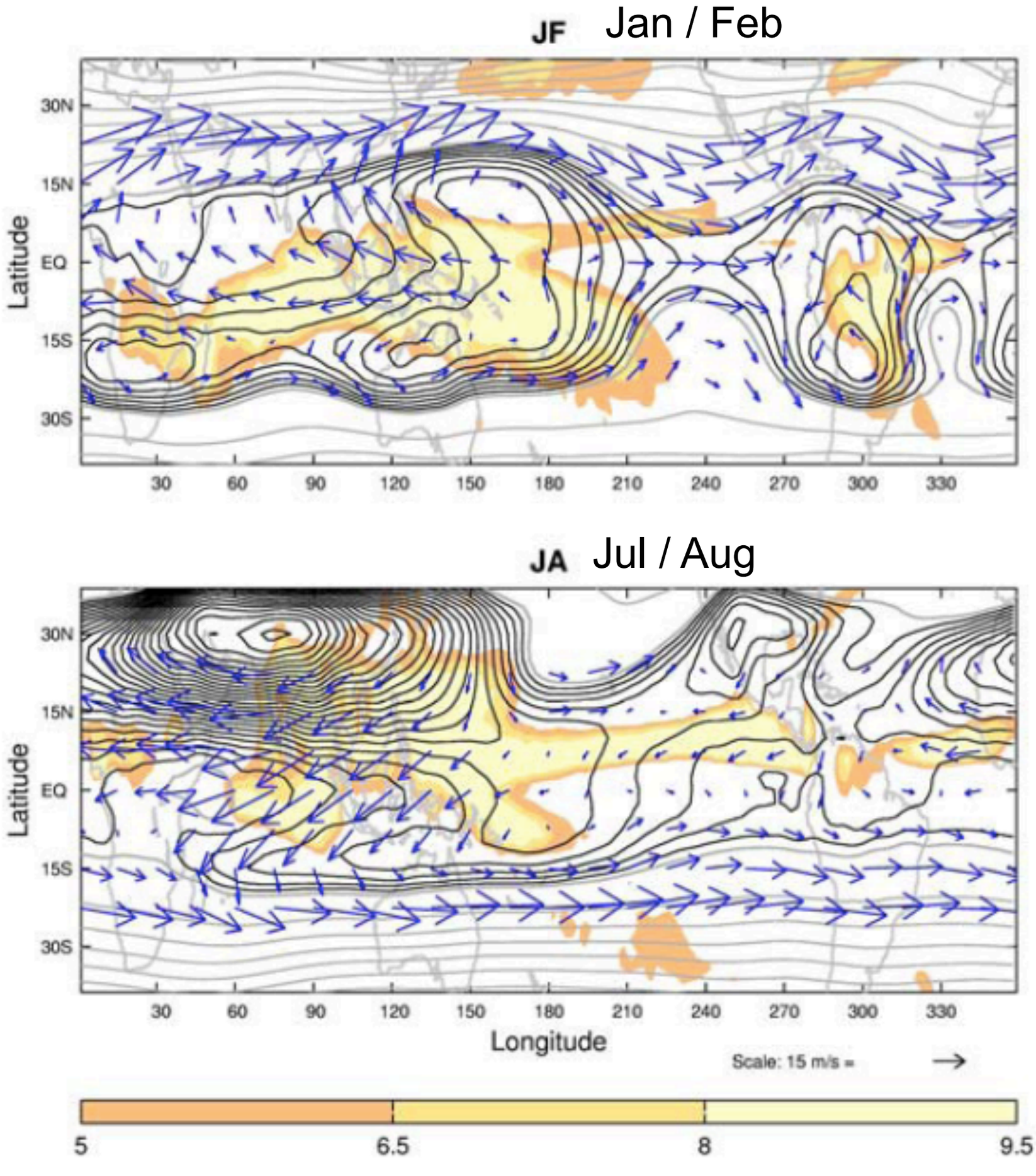
First a bit about the seasonally-varying background state





Precipitation

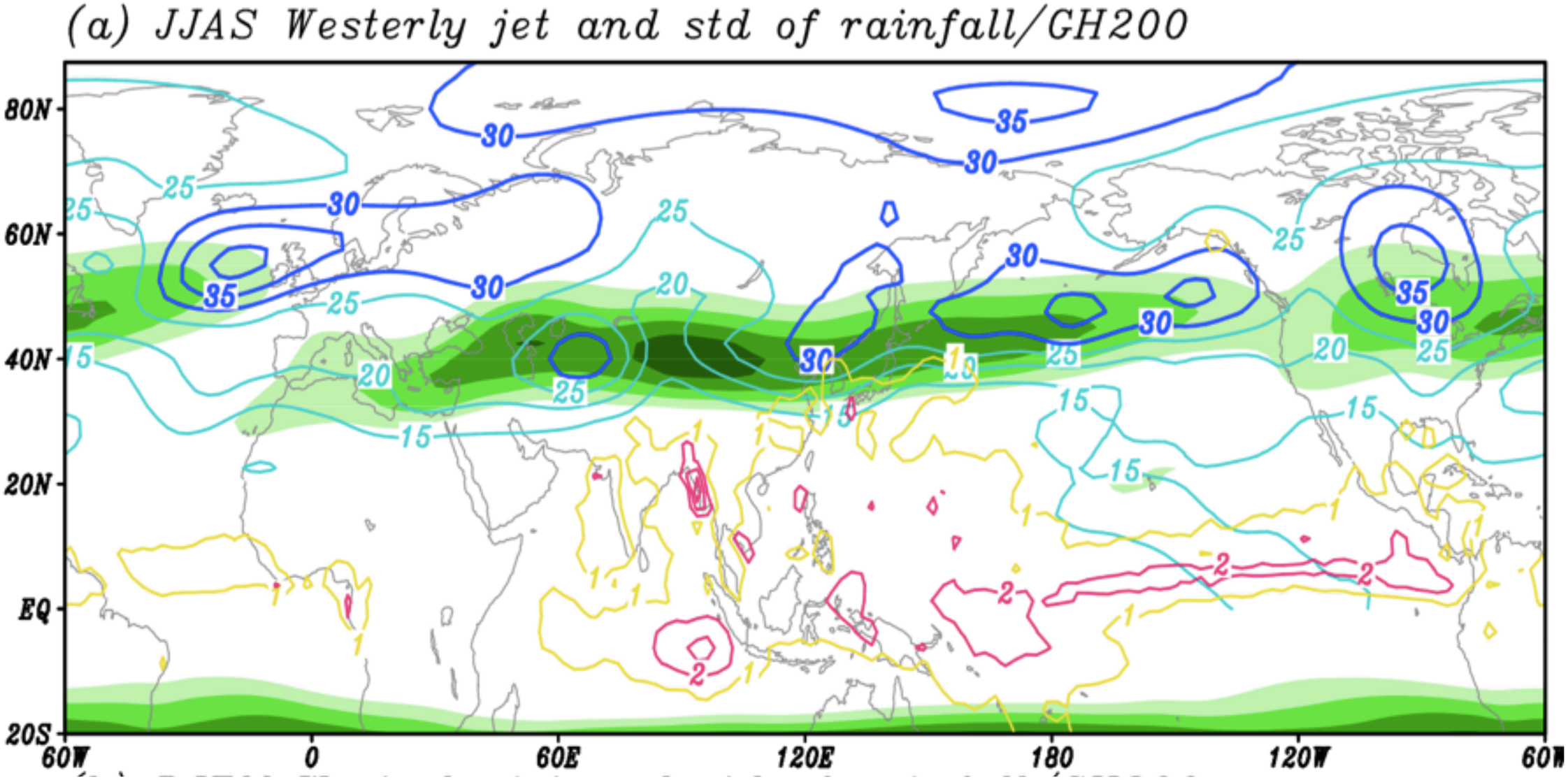
Ioana Dima PhD thesis



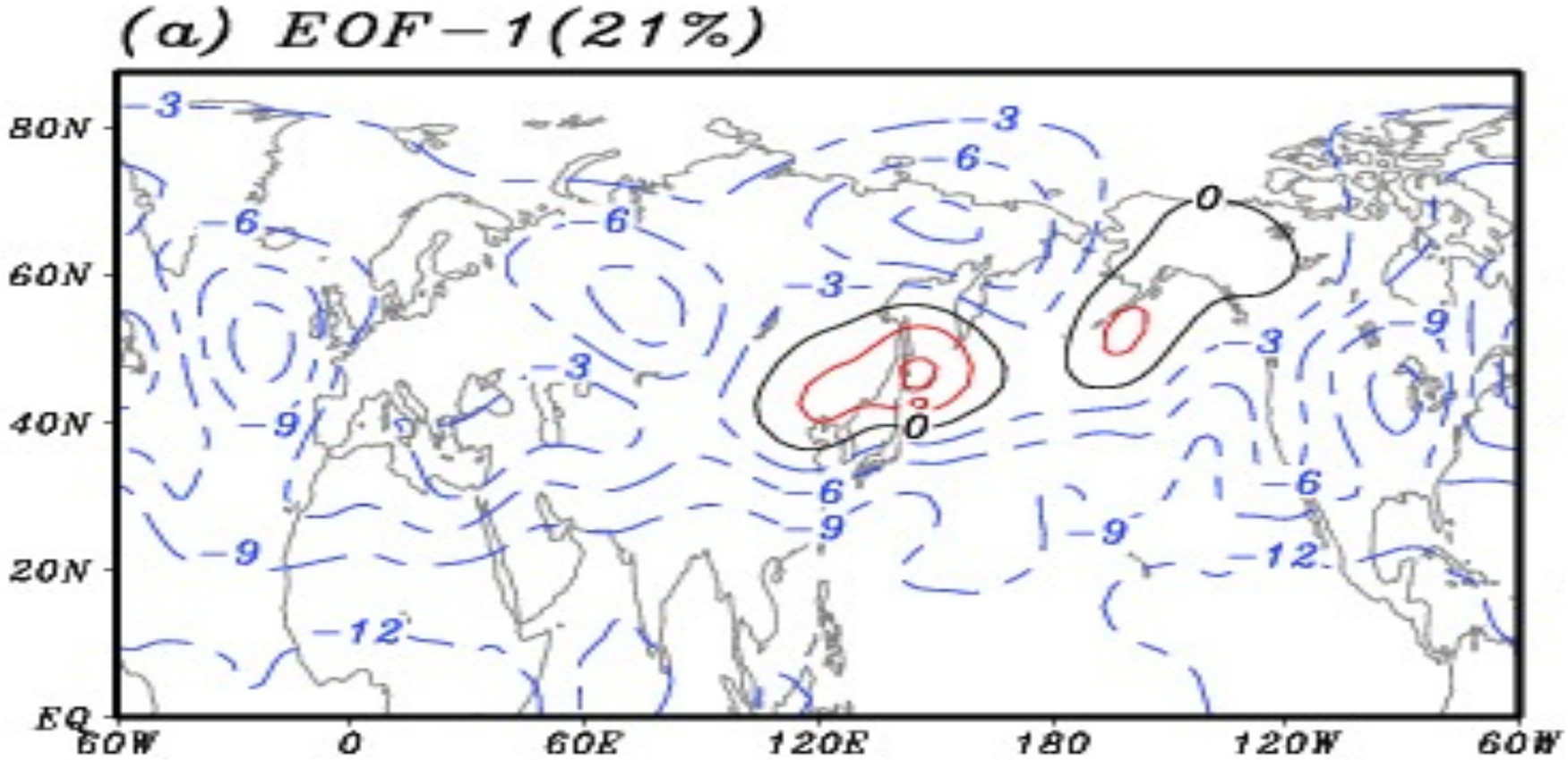
150 hPa wind and geopotential height

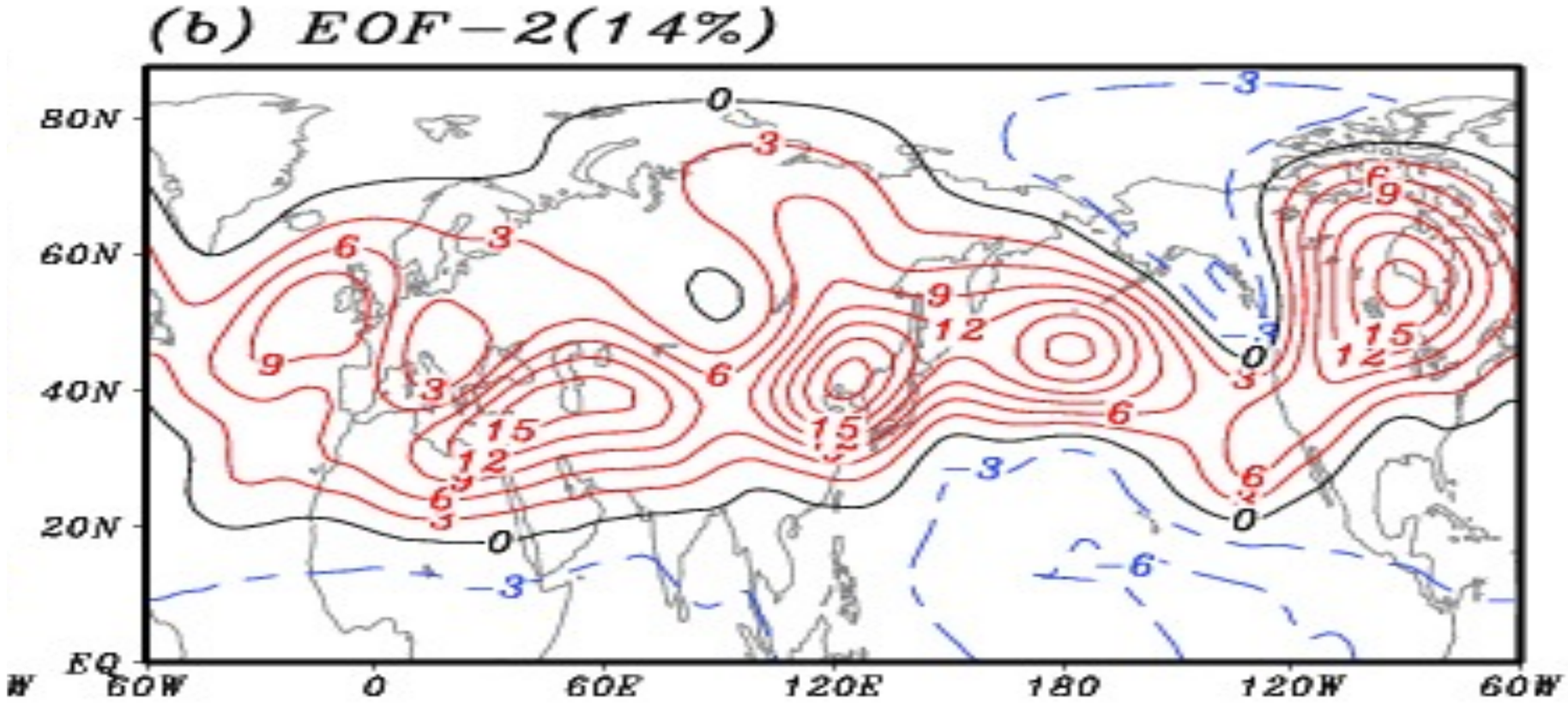
Ioana Dima PhD thesis

JJAS Climatology



Qinghua Ding et al. JCL in review





Z200

JJAS seasonal means

1948-2005

Ding et al. JCL in review

MCA Domains

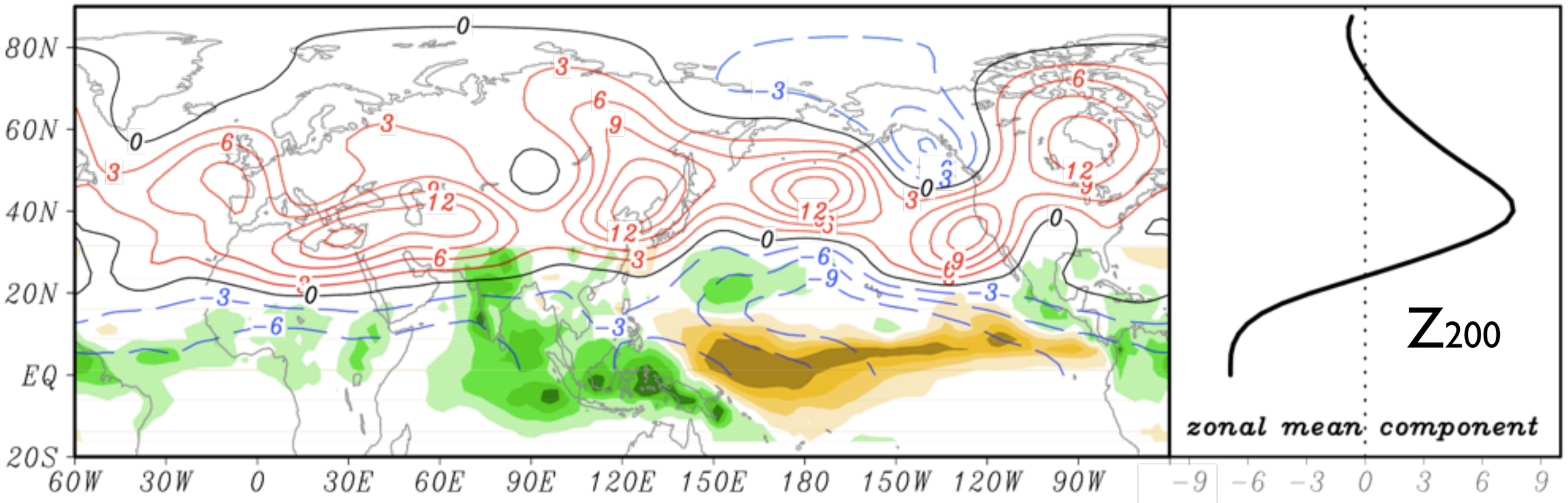
Extratropical Z200

eq. to 90°N

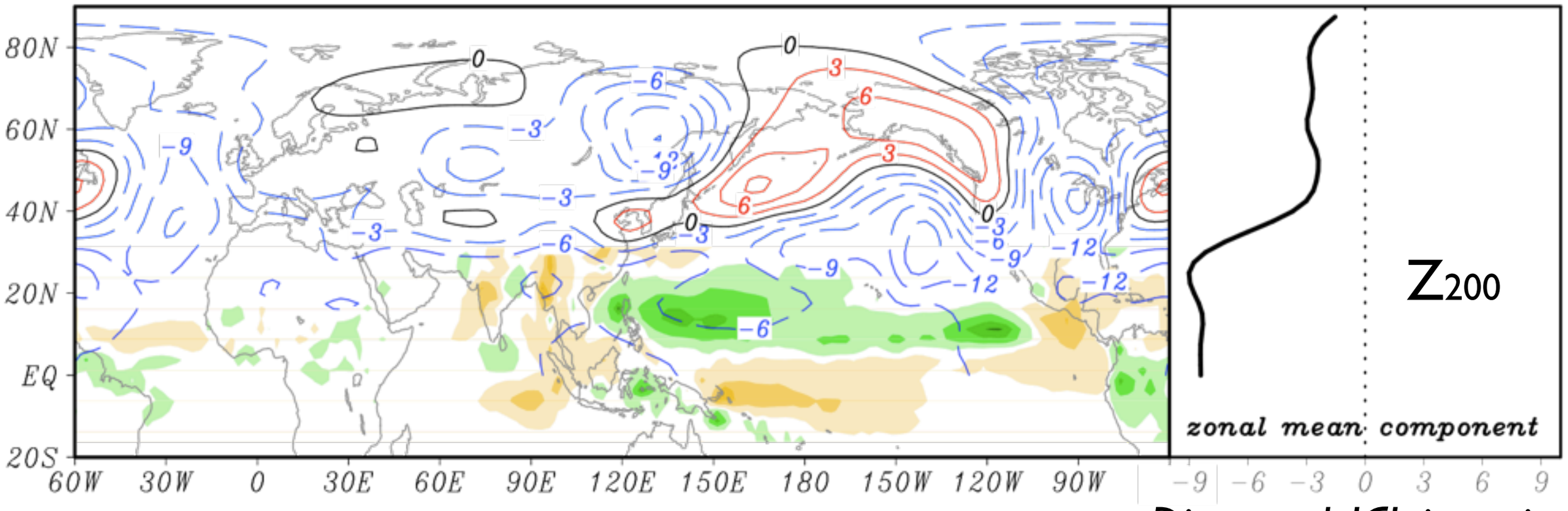
Tropical Rainfall

15°S – 30°N

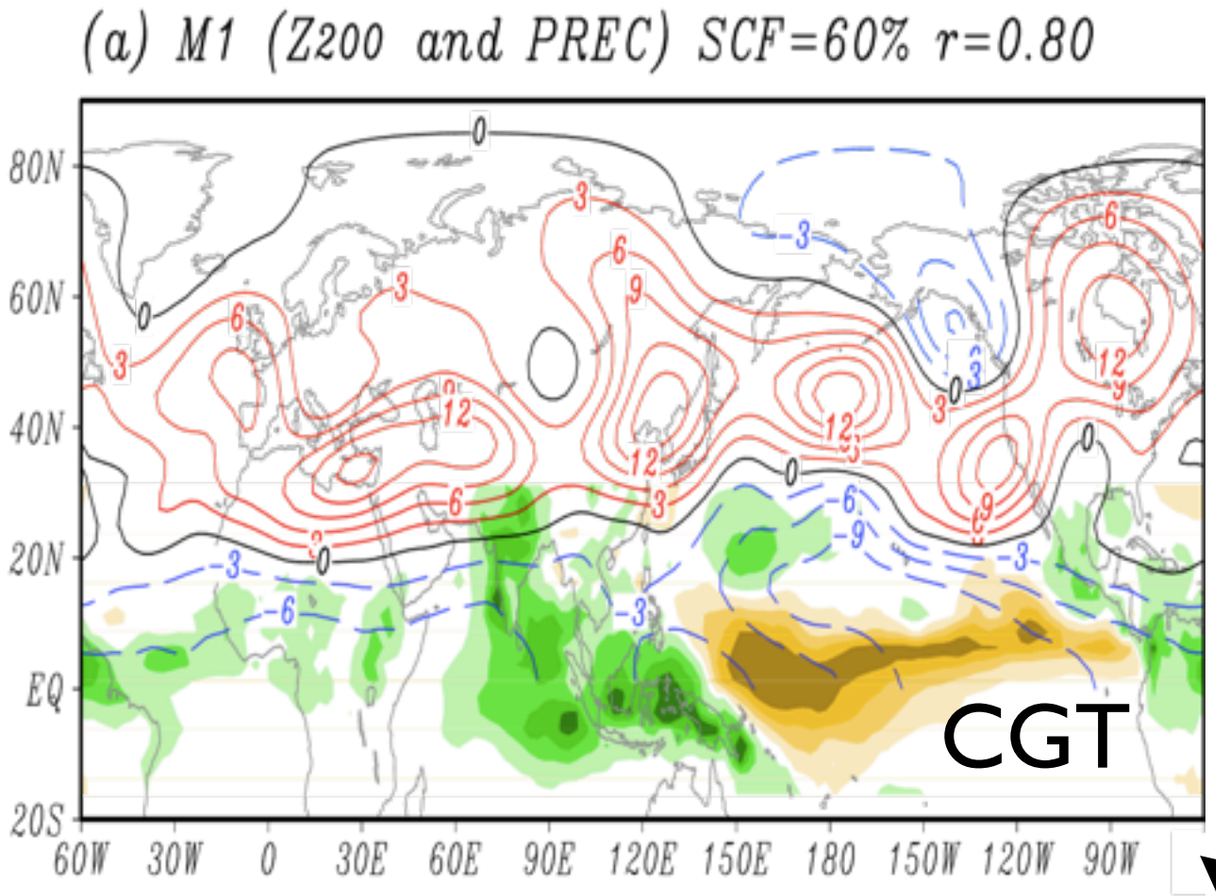
(a) M1 (Z200 and PREC) SCF=60% r=0.80

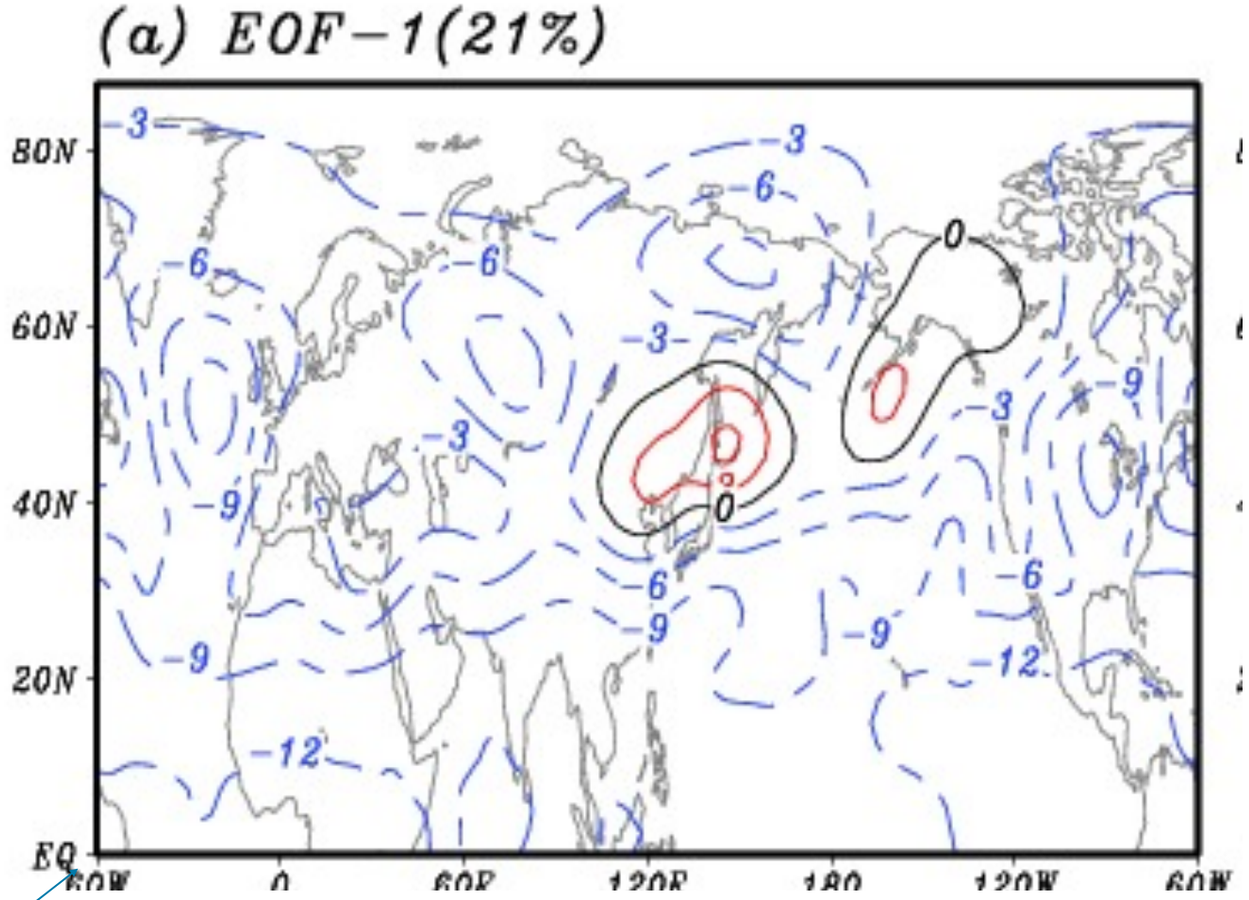


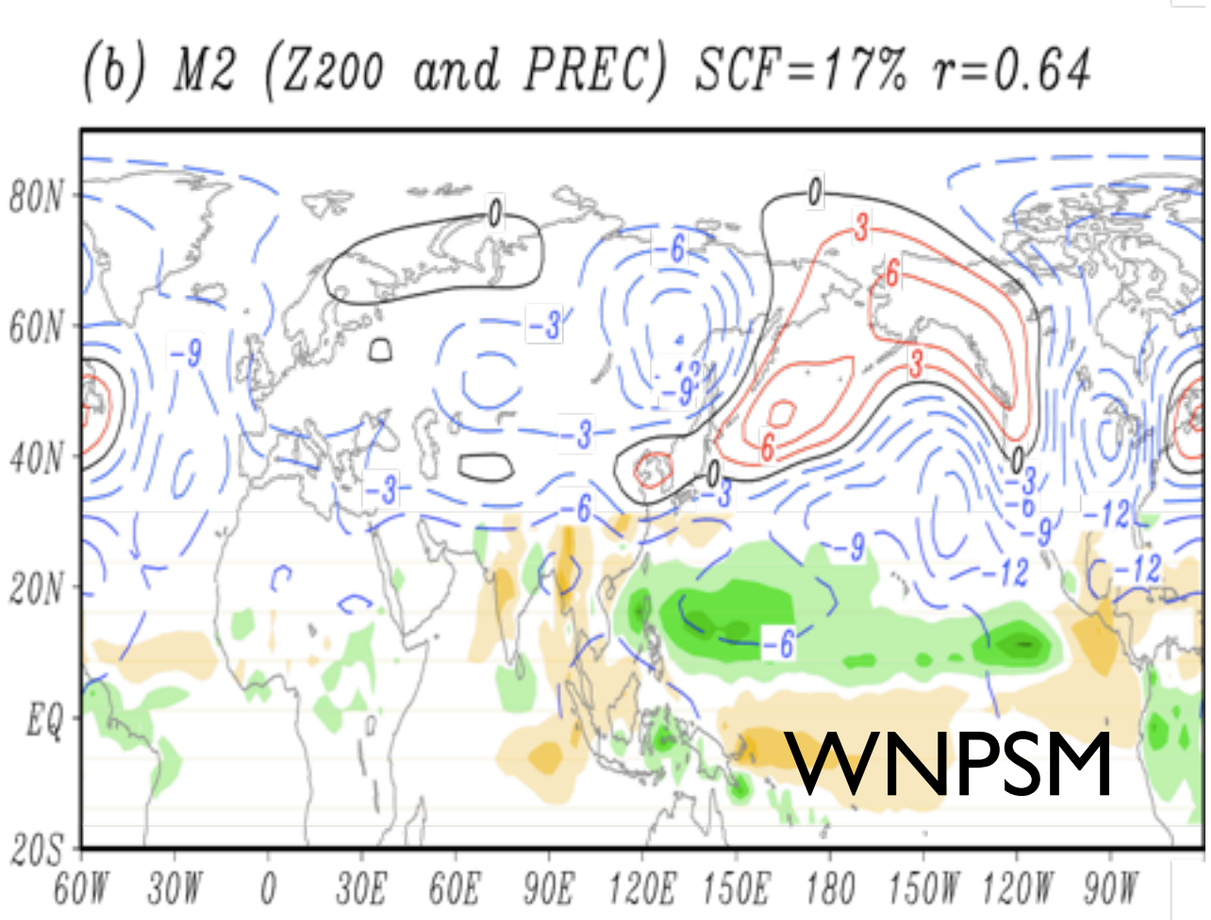
(b) M2 (Z200 and PREC) SCF=17% r=0.64

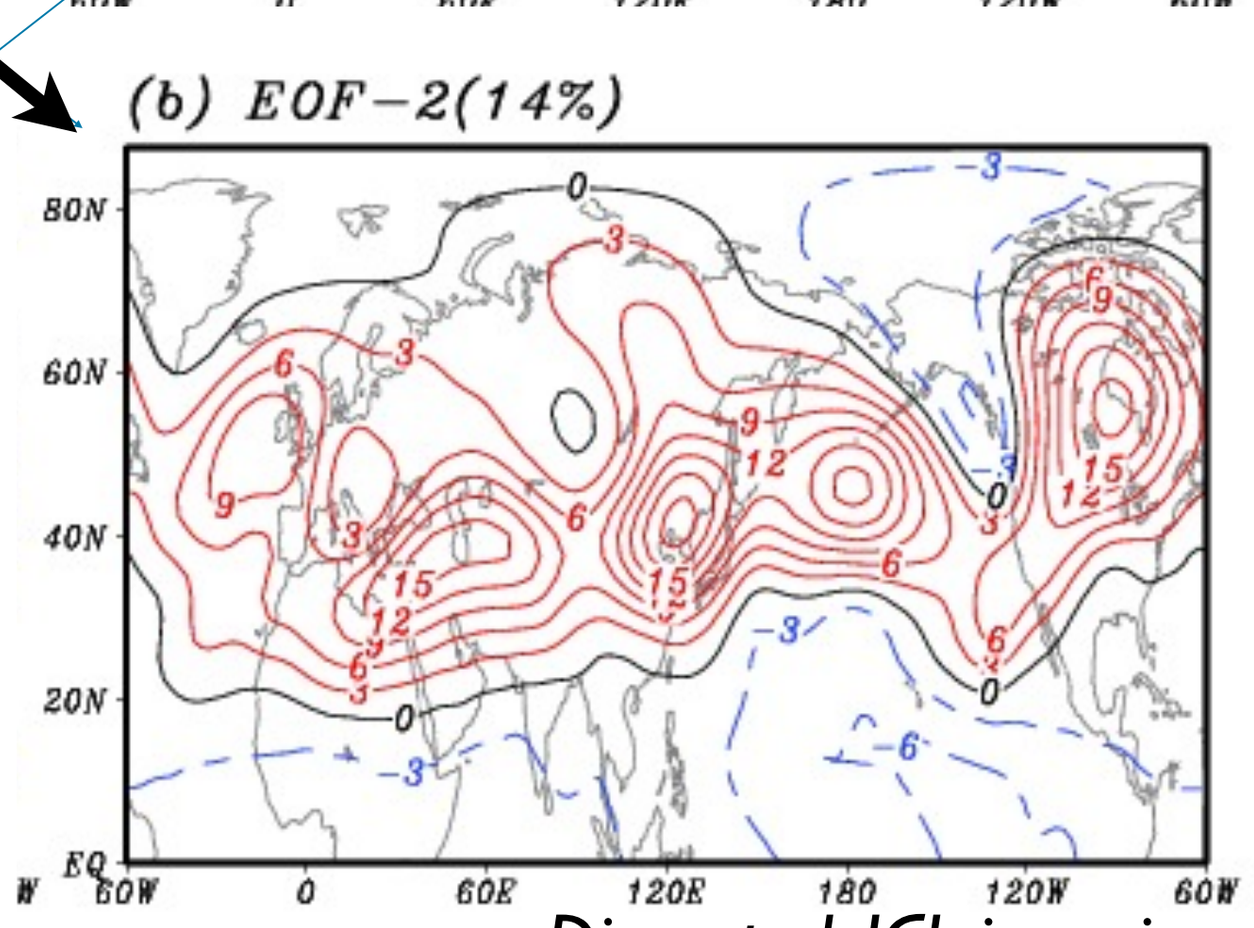


Ding et al. JCL in review









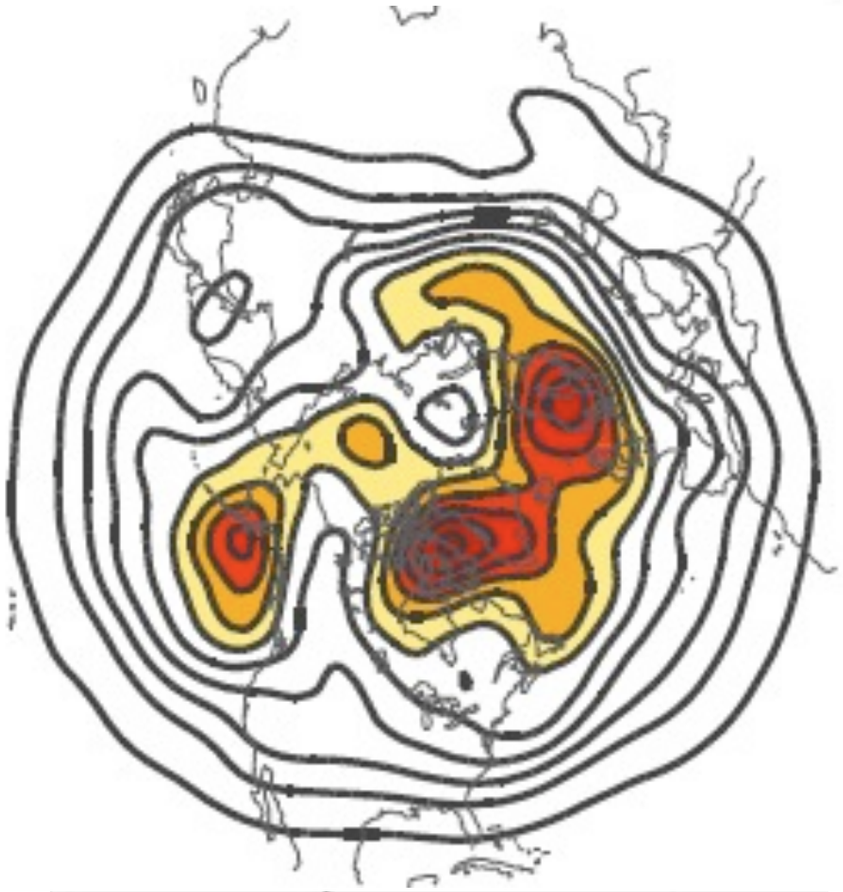
Ding et al. JCL in review

Cross-frequency coupling

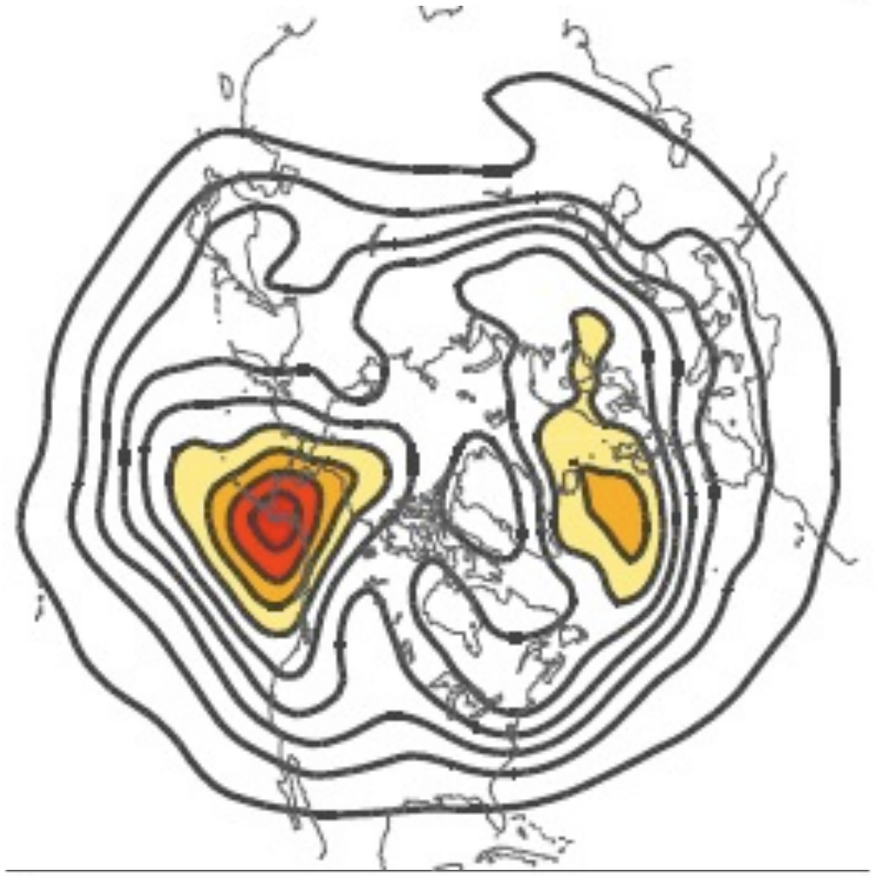
- Background flow influences amplitude and structure of low frequency variability

- High frequency variability feeds back on (reinforces) the background flow

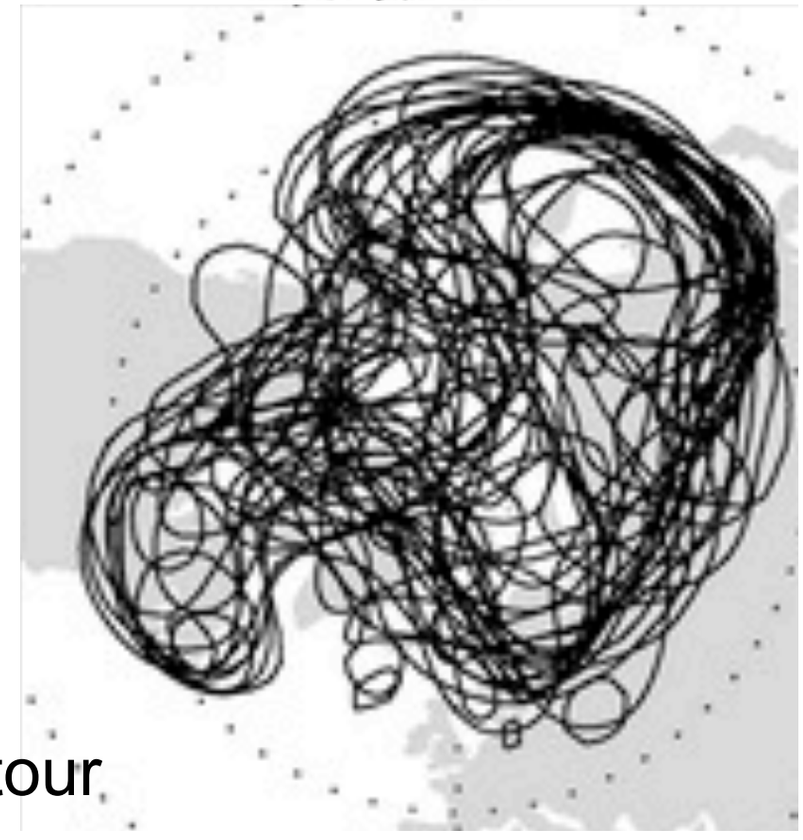
NAO$^-$



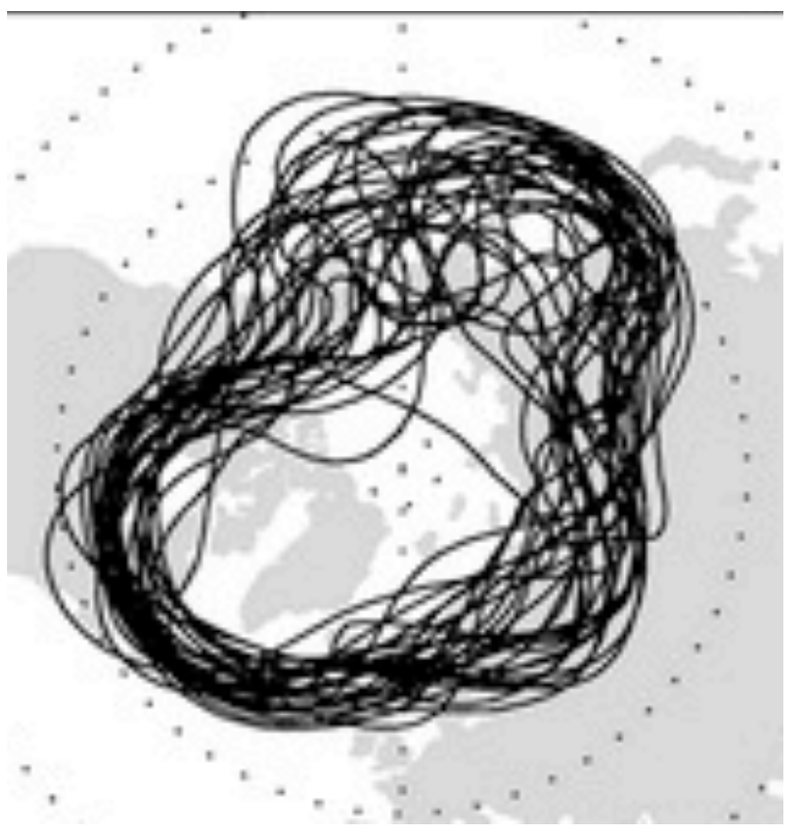
NAO$^+$



Variance



522 m contour

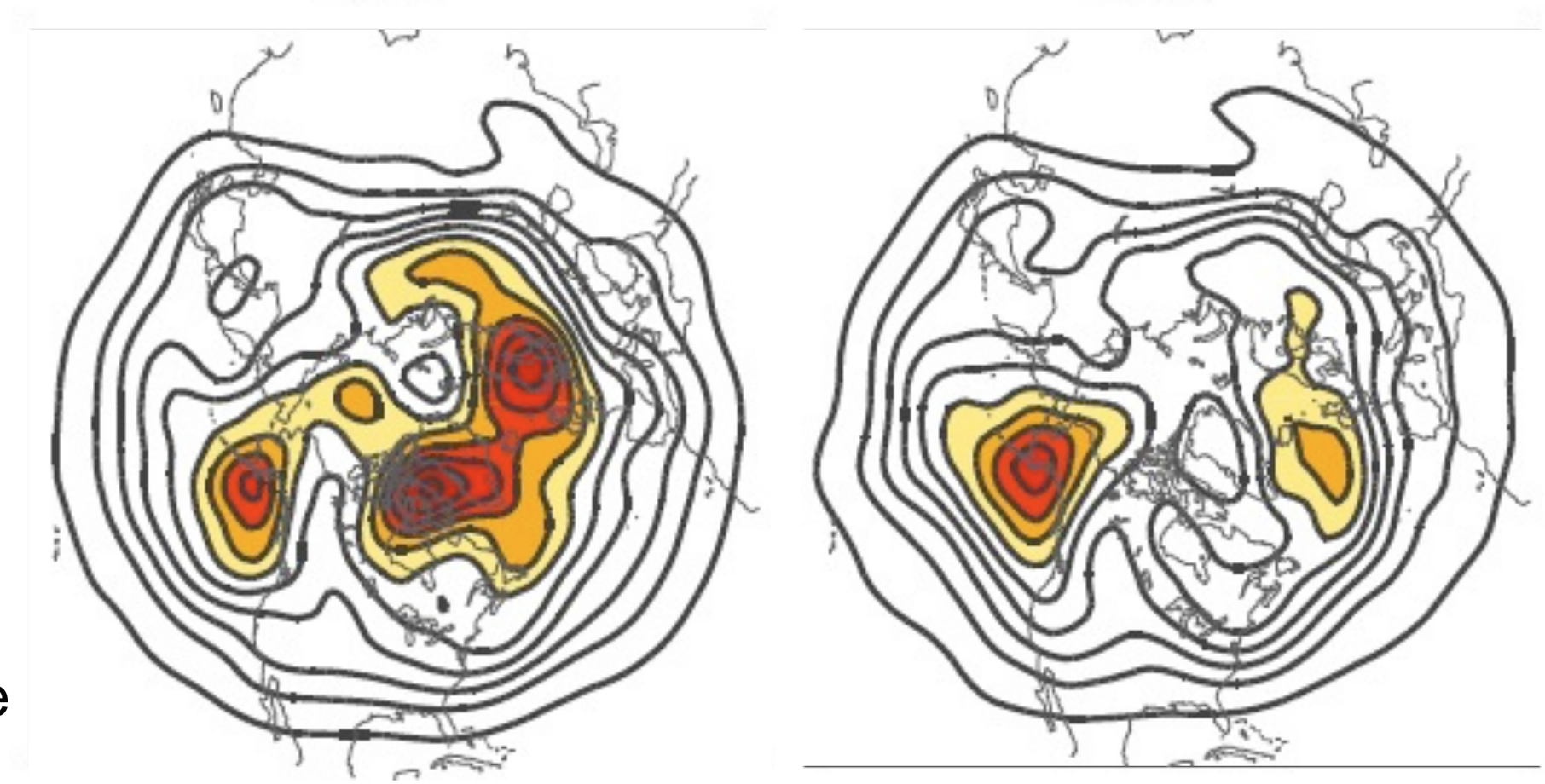


Quadrelli and Wallace JCL 2004b

6-20 d

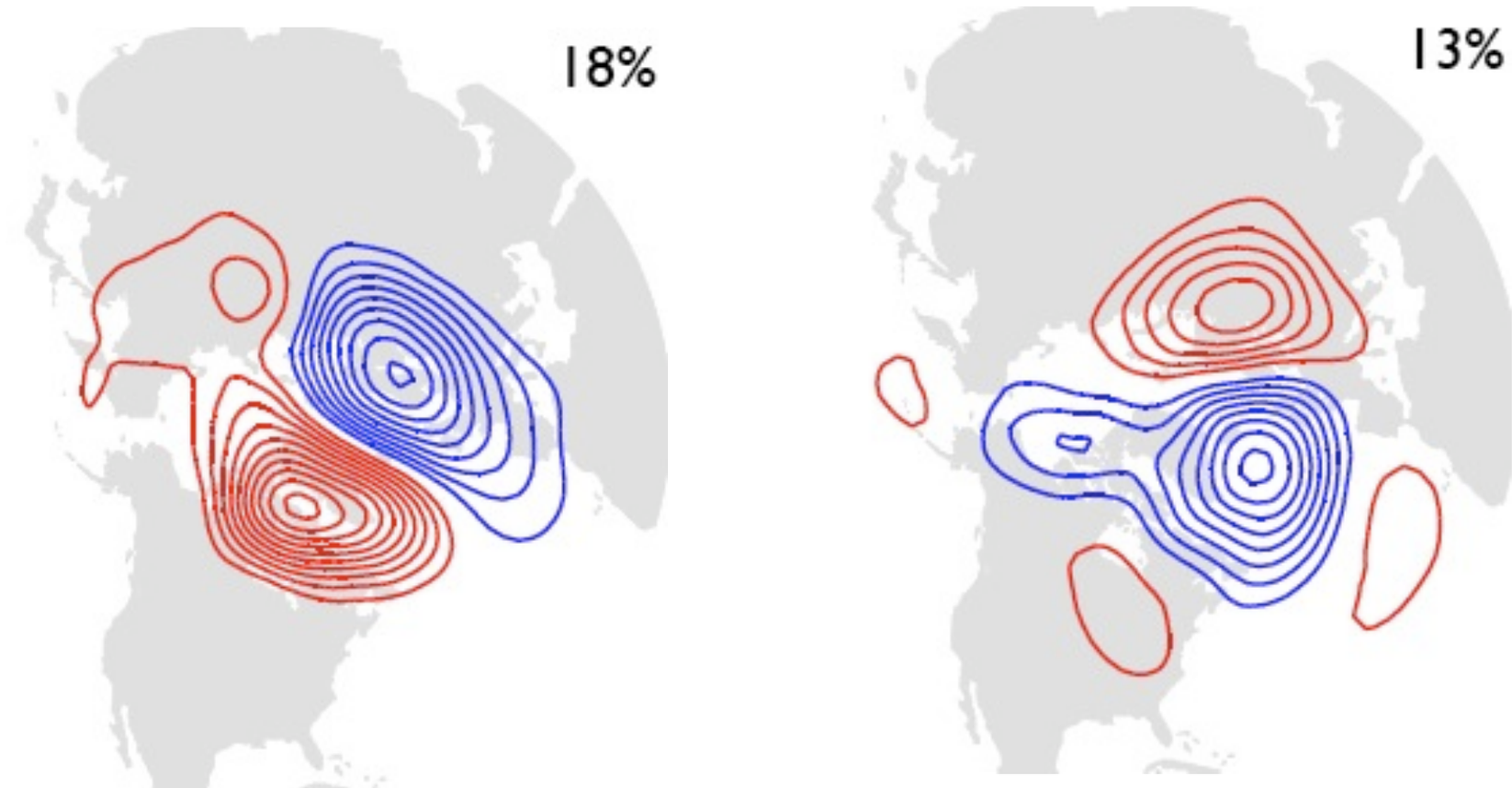
NAO$^-$

NAO$^+$



Variance

EOF 1



MCA Leading mode