The dominant patterns of climate variability

John M. Wallace
Department of Atmospheric Sciences
University of Washington

Patterns = Modes

- Do they exist?
- If so, how many? What are they?
- Are they relevant for estuaries research?

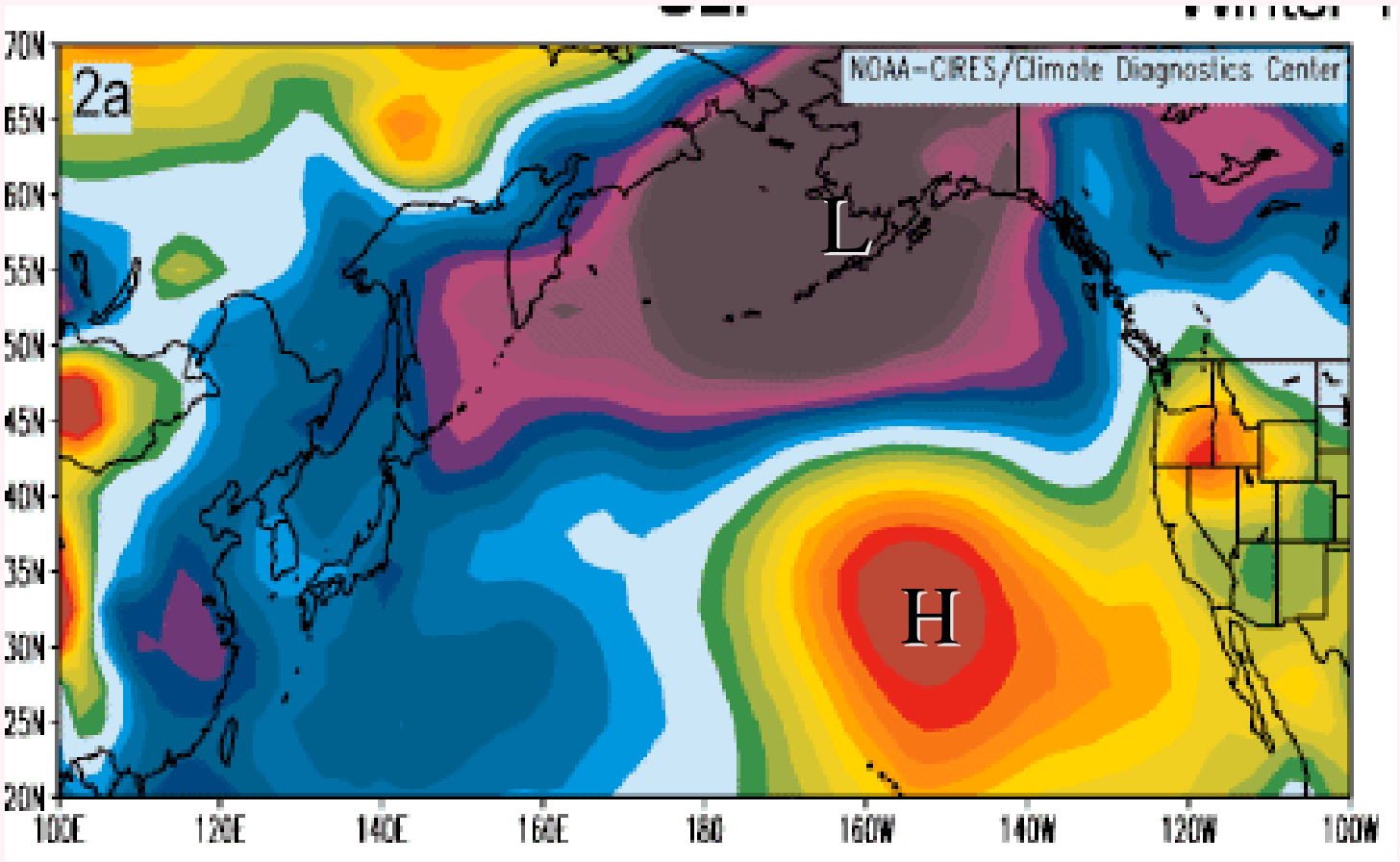
Types of patterns

- observed patterns
- corresponding patterns
- modes (preferred patterns)

Examples of observed patterns

- anomalies

Anomalies: Winter 1999-2003



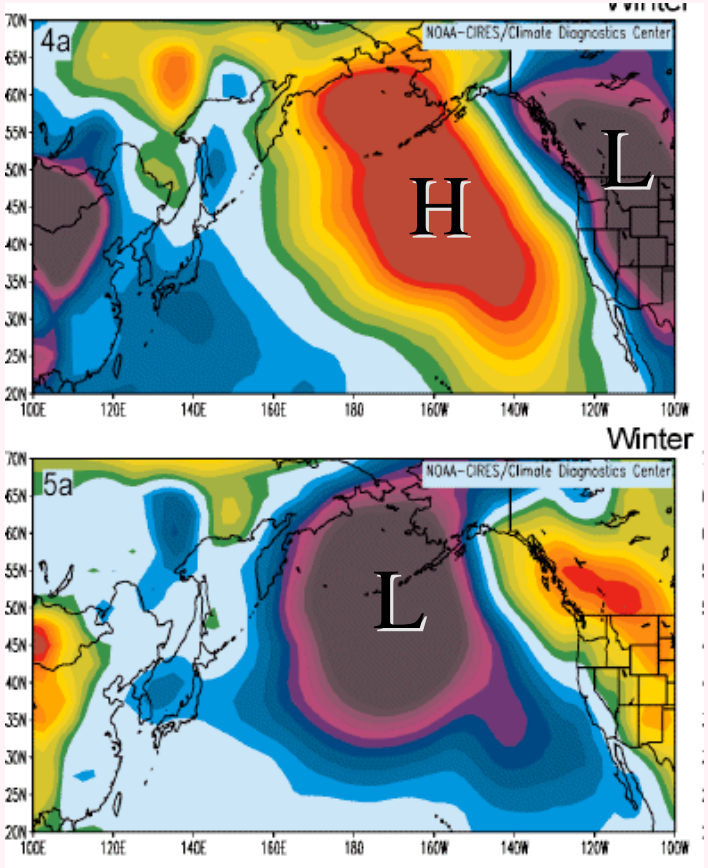
Examples of observed patterns

- “regime shifts”

1976-77 “regime shift”

winter
1972-76

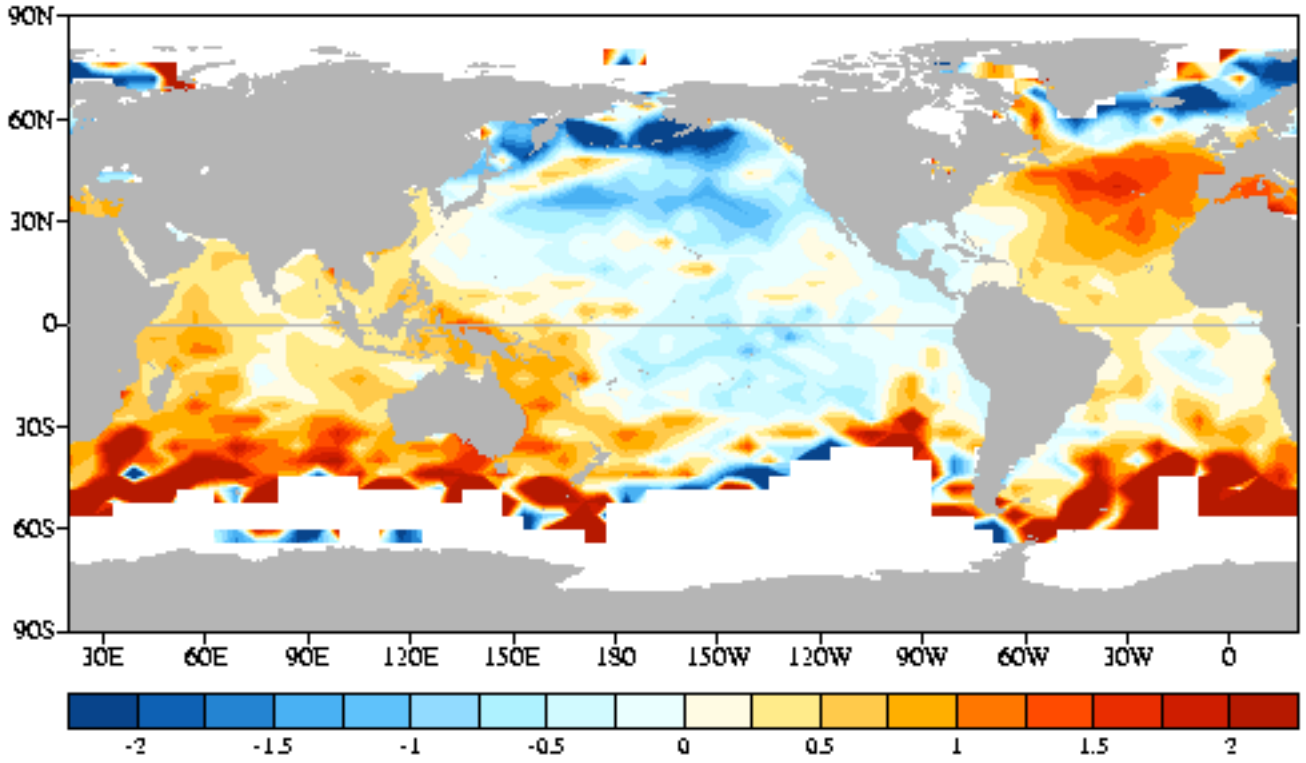
winter
1977-81



Examples of observed patterns

- secular trends

Observed pressure trend (mb / 53-years)



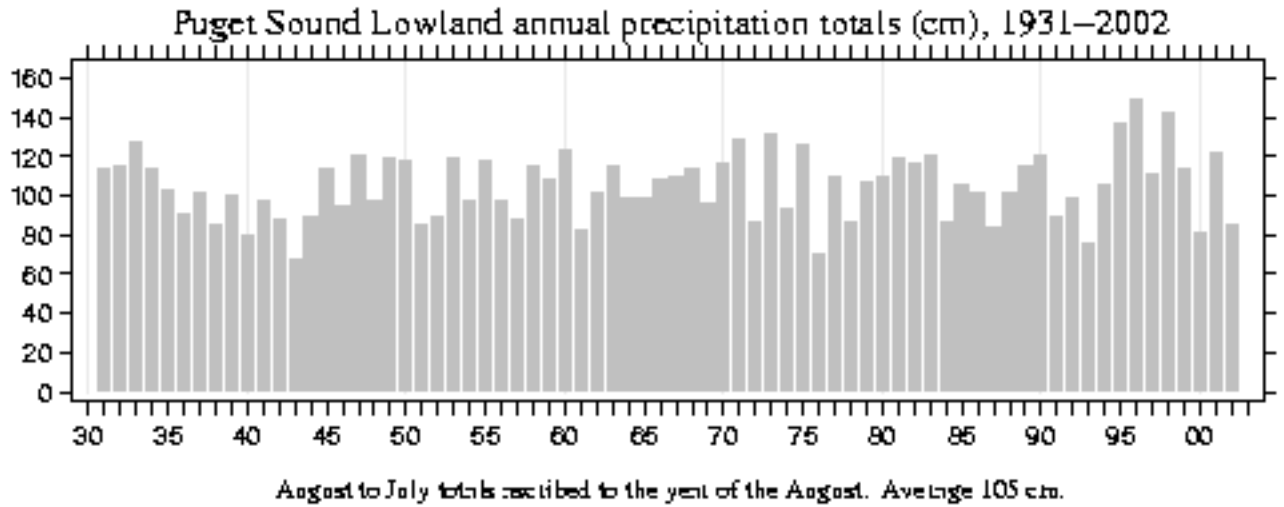
Corresponding patterns

Define reference variable, time frame

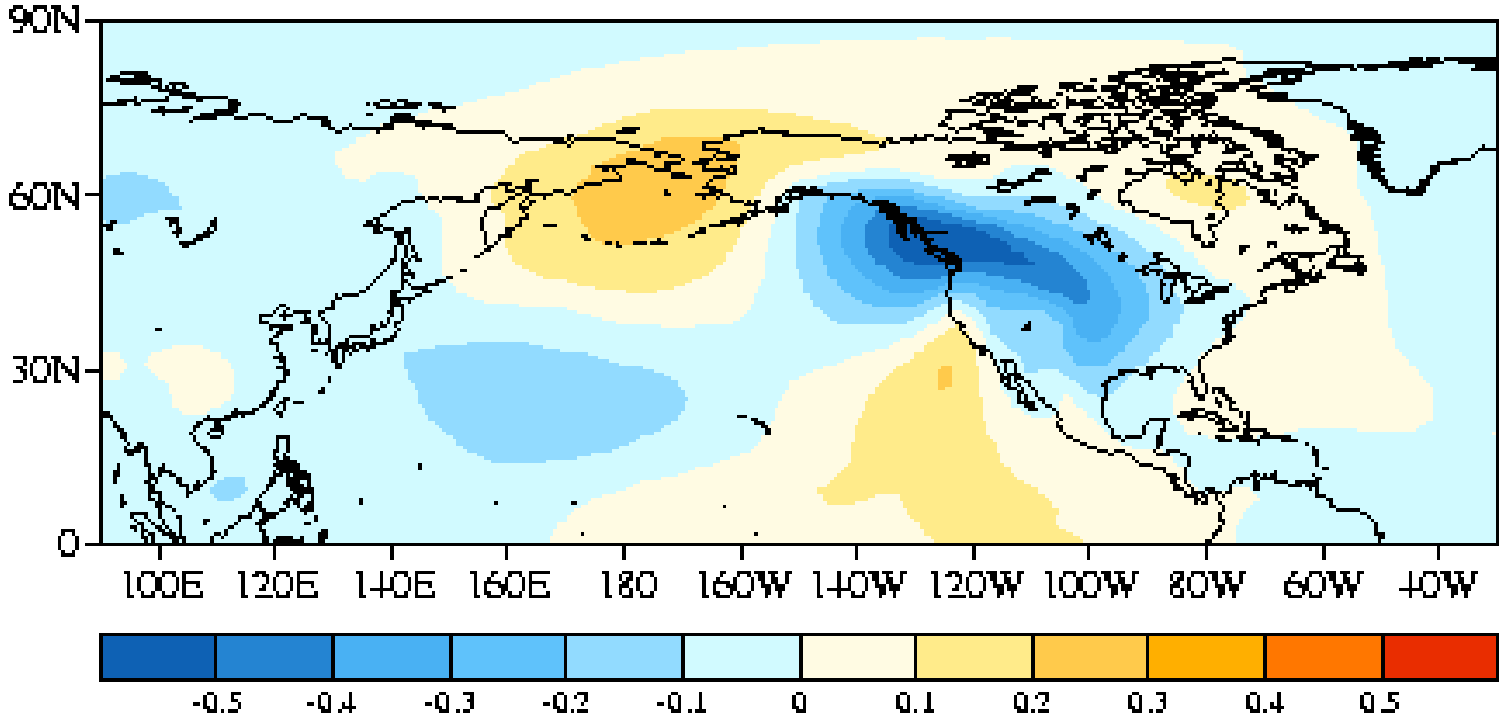
- Composite map
- Composite difference map
- Regression map
- Correlation map

Corresponding patterns: Examples

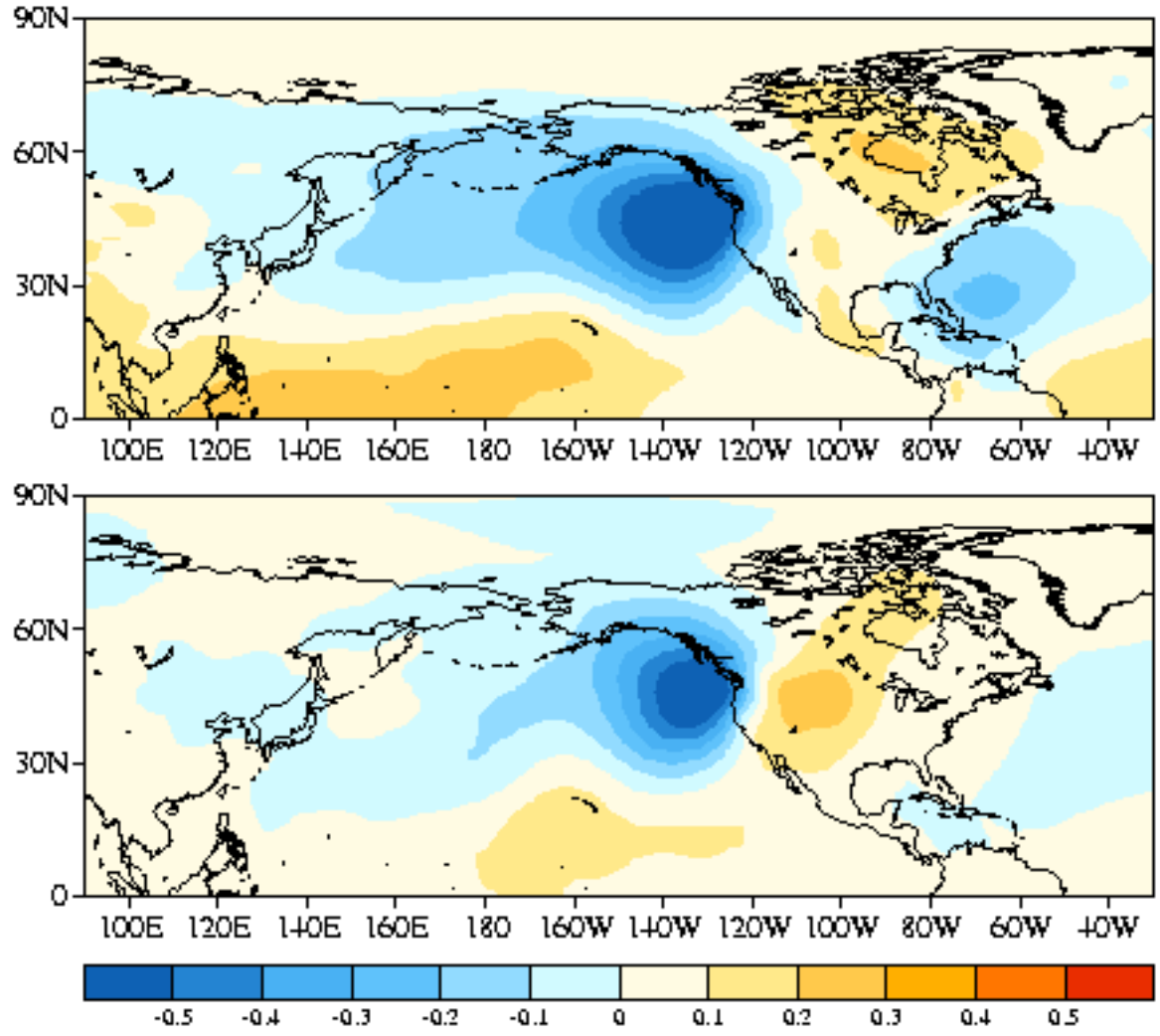
(Puget Sound)



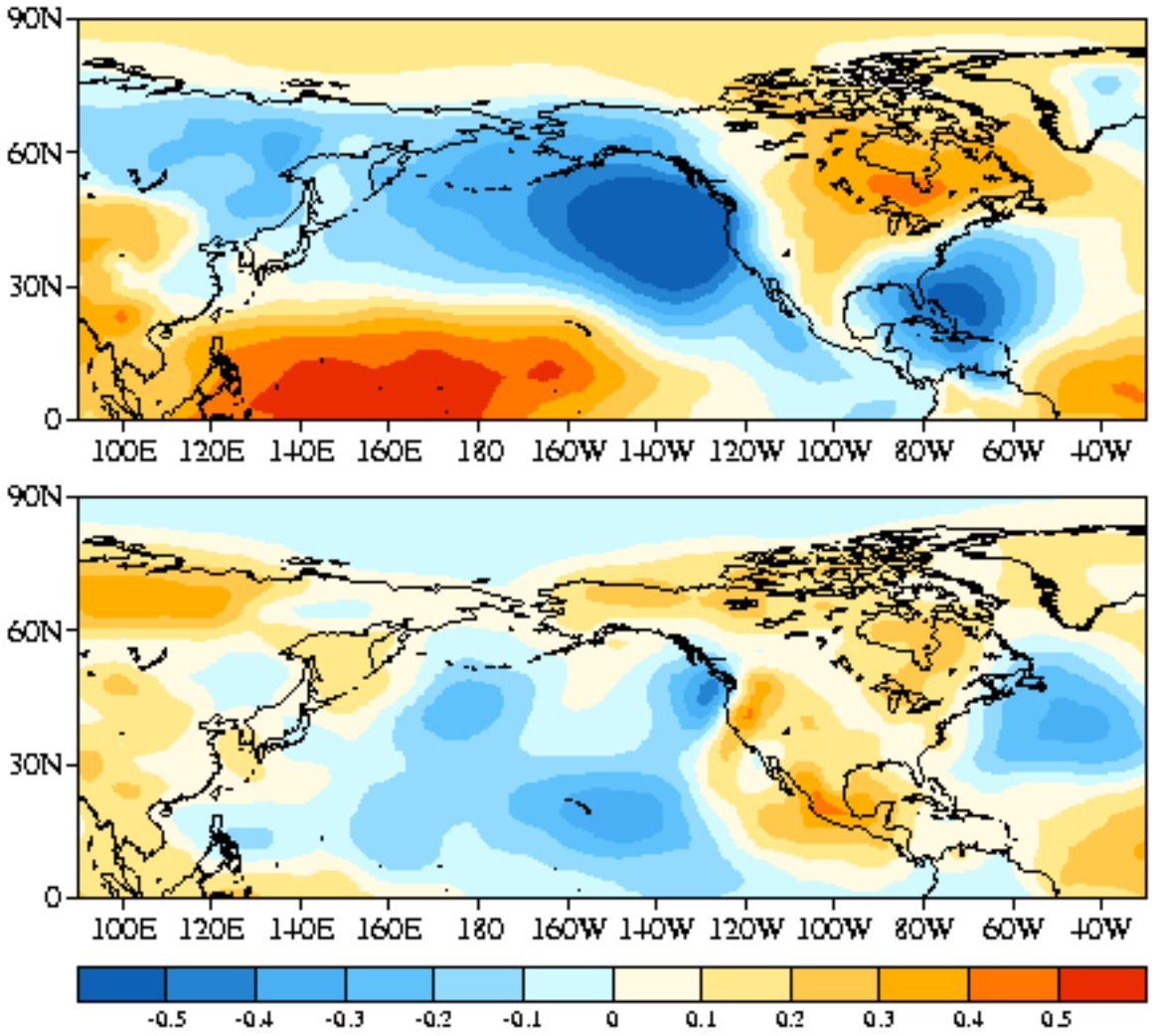
Correlation of pressure and Puget Sound monthly precipitation



Correlation of pressure and north-south wind: monthly and daily

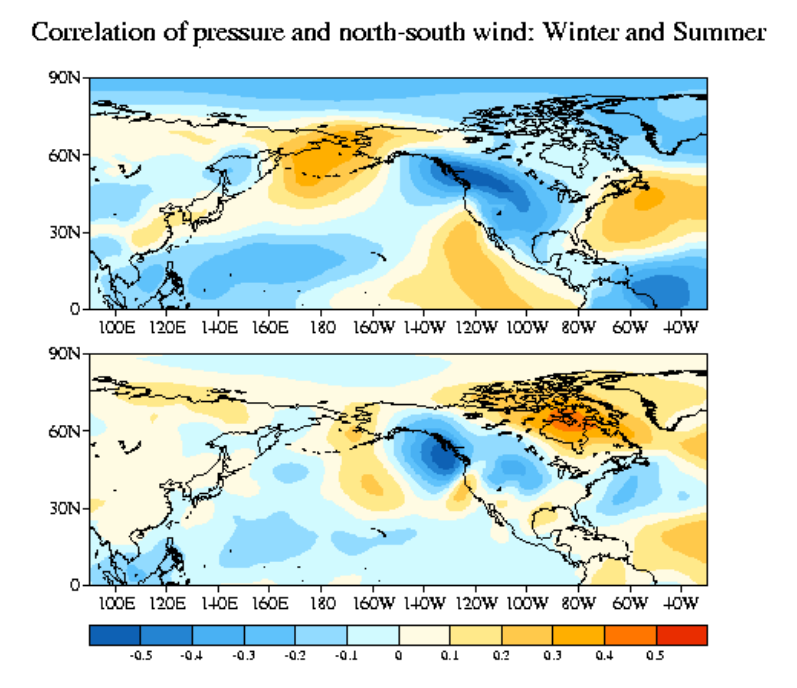


Correlation of pressure and north-south wind: Winter and Summer



Corresponding patterns
Things to consider

- Statistical significance
- Explained variance
- Physical consistency

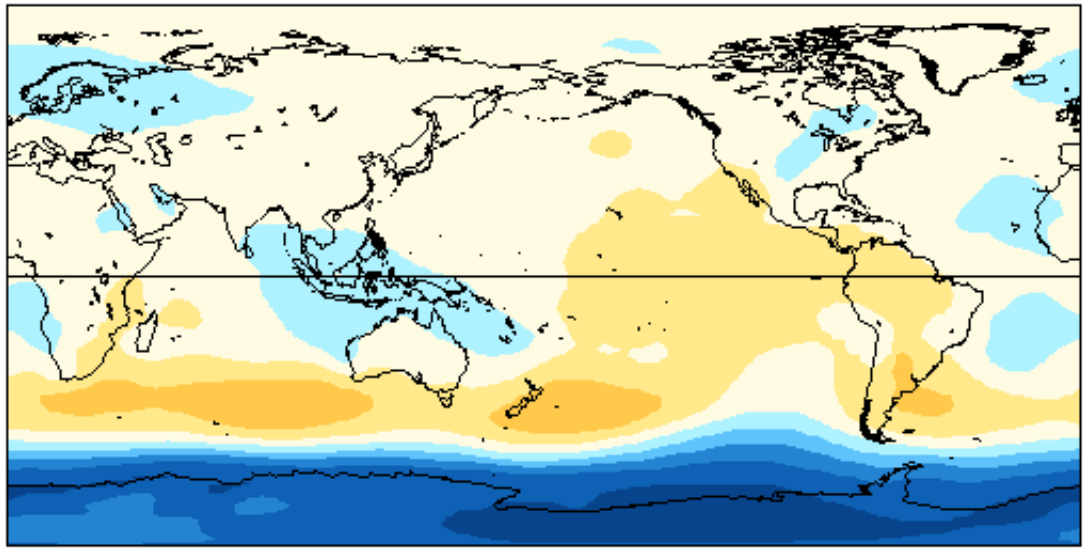


Modes

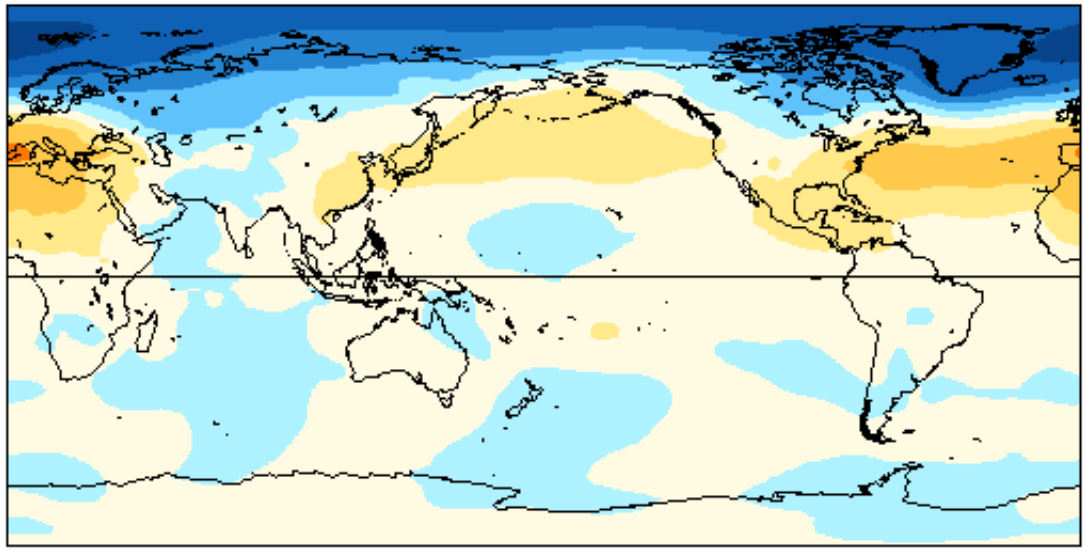
EOF's of global SLP
Monthly: all calendar months
1979-2002

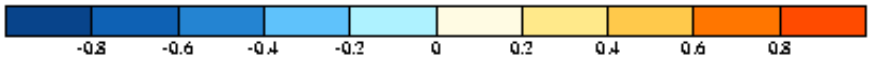
(Courtesy of Todd Mitchell, JISAO)

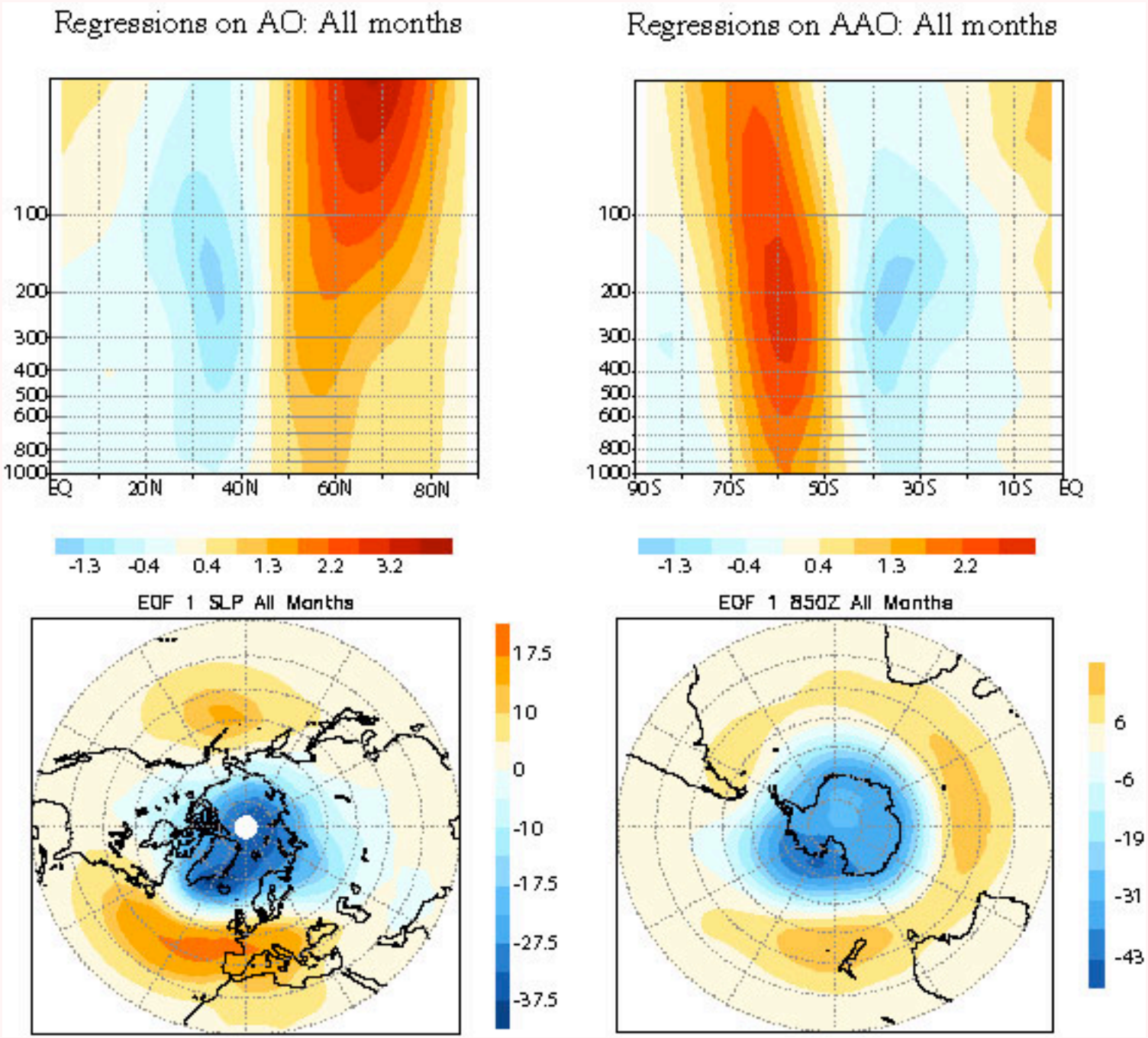
Southern Annular Mode (EOF1, Antarctic Oscillation (AAO))



Northern Annular Mode (EOF2, Arctic Oscillation (AO))

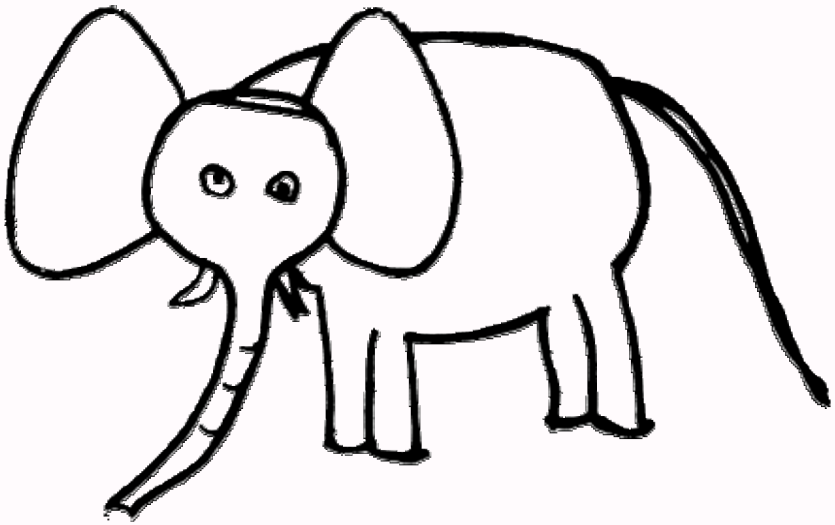





Regressions on AO: All months
100
200
300
400
500
600
800
1000
EQ
20N
40N
60N
80N
-1.3
-0.4
0.4
1.3
2.2
3.2
EOF 1 SLP All Months
17.5
10
0
-10
-17.5
-27.5
-37.5
Regressions on AAO: All months
100
200
300
400
500
600
800
1000
90S
70S
50S
30S
10S
EQ
-1.3
-0.4
0.4
1.3
2.2
EOF 1 850Z All Months
6
-6
-19
-31
-43

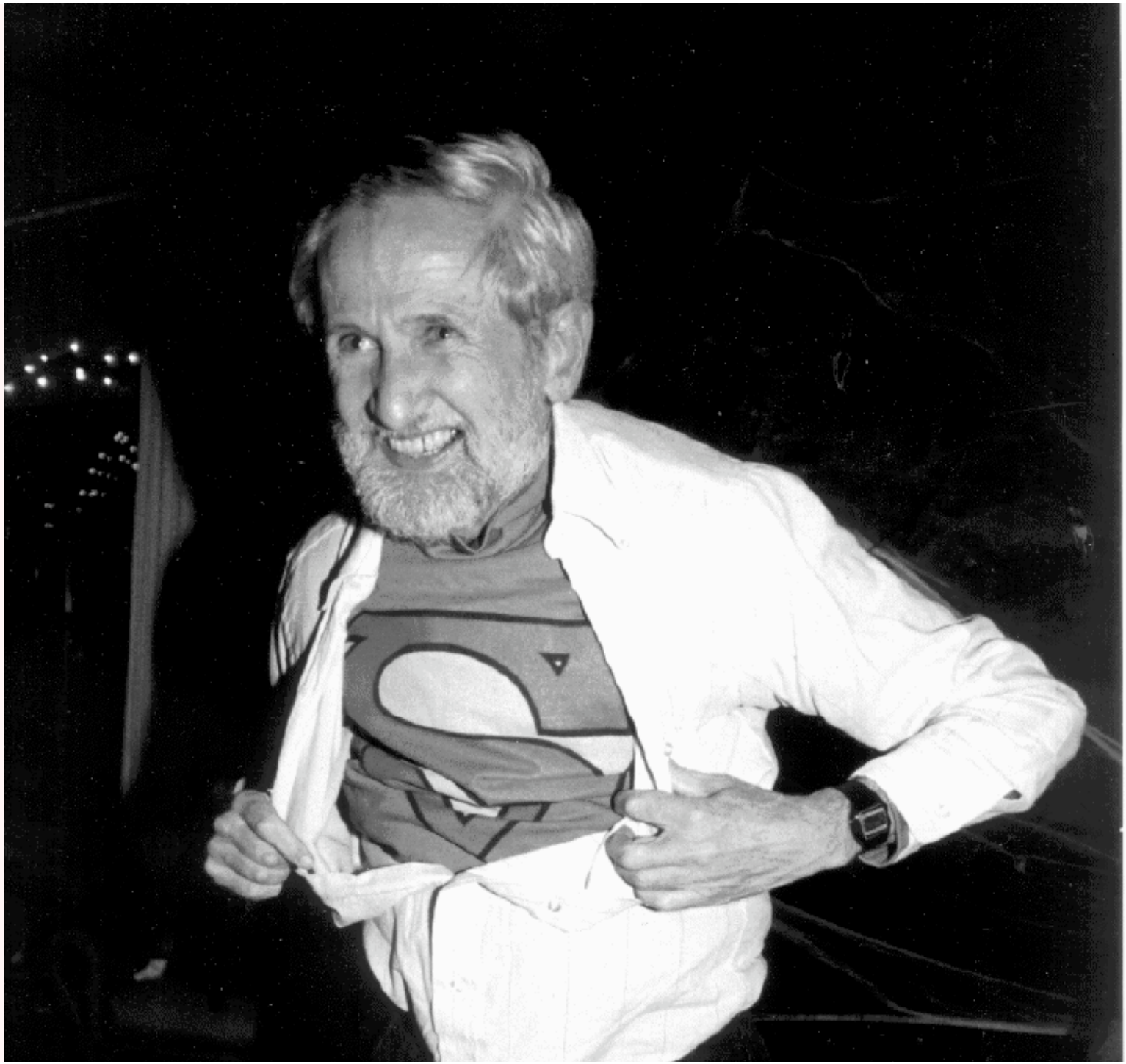
Notes:
#19 Leading EOF's of extratropical NH and SH SLP (courtesy of Dave Thompson)
Note the similarity between the global EOF's and the hemispheric EOF's
#21 The NAO refers to the "North Atlantic Oscillation", a name coined by British meteorologist Sir Gilbert Walker in the 1920's. Zonal index cycle was a term coined bu C.-G. Rossby and Jerome Namias during the 1940's (they were apparently unaware of Walker's work). AO denotes "Arctic Oscillation" used by Dave Thompson and me in our first paper on this phenomenon. In subsequent papers we've used the term "Northern Hemisphere annular mode (NAM).
#22 The NAM is to the NAO what Superman is to Clark Kent.
#24 The Pacific / North American (PNA) pattern is defined on the basis of Northern hemisphere wintertime upper air data (Wallace and Gutzler, Mon. Wea. Rev., 1981).
#25 "G" refers to the leading EOF of tropical Pacific (20N-20S) SST presented in #26); CTI refers to the "Cold Tongue Index", Equatorial Pacific SST averaged from 6N to 6 S and from 90-180 W. SOI refers to the Southern Oscillation Index defined as Tahiti minus Darwin SLP (both standardized).
#30 and following: // is shorthand for "looks like".
#31 The observed changes (O), whatever they happen to be, are relevant to explaining the corresponding changes observed in the estuary only if O//C.
#35 The upper right panel is the pattern of surface air temperature anomalies observed in association with the positive polarity of the annular mode (low pressure over the polar cap). The other panels are corresponding patterns for surface air temperature at gridpoints as indicated. The signs for the Labrador and Turkey gridpoints have been reversed. Note the similarity between the patterns. Had we chosen gridpoints that lie on the nodes of the NAM we would not have recovered this pattern.

North Atlantic Oscillation

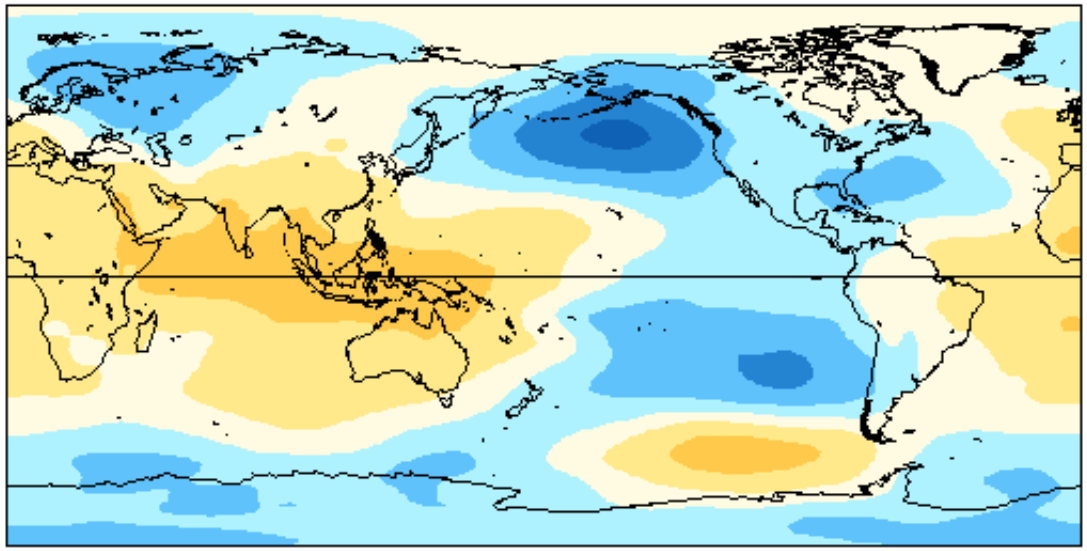


Zonal Index Cycle

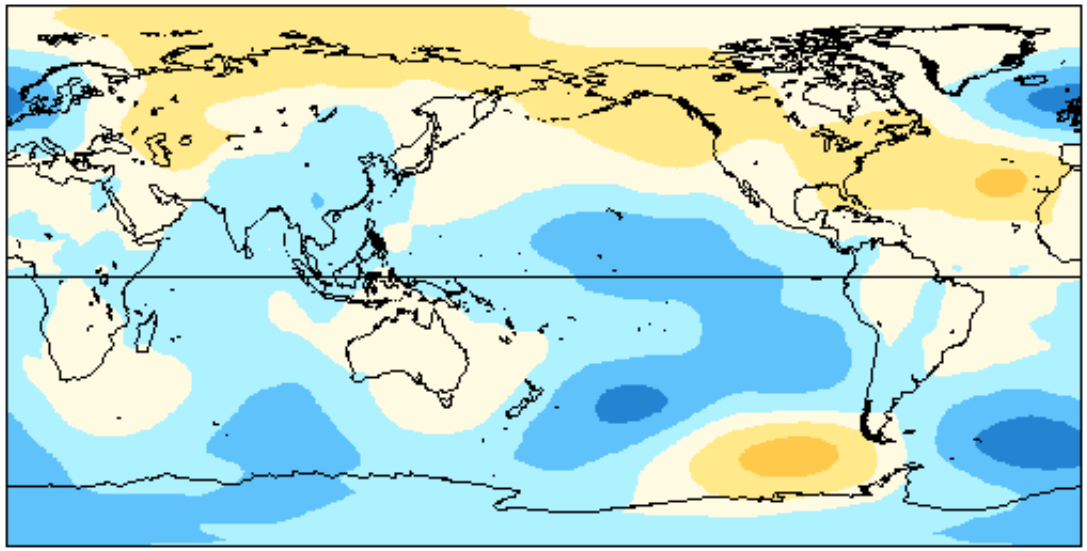
Arctic Oscillation

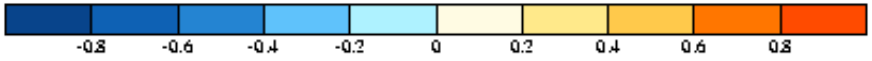


Southern Oscillation (EOF3)

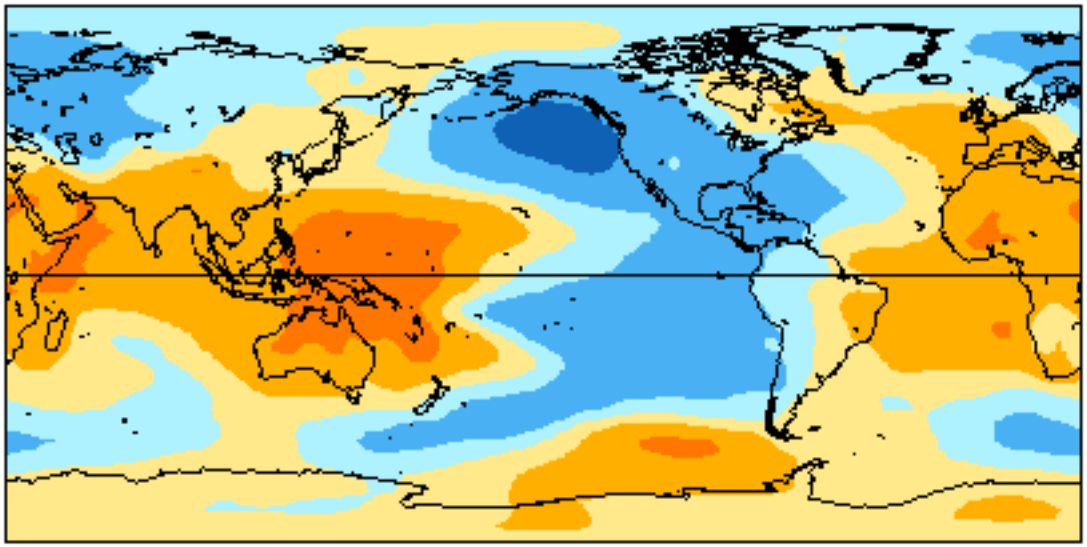


EOF4

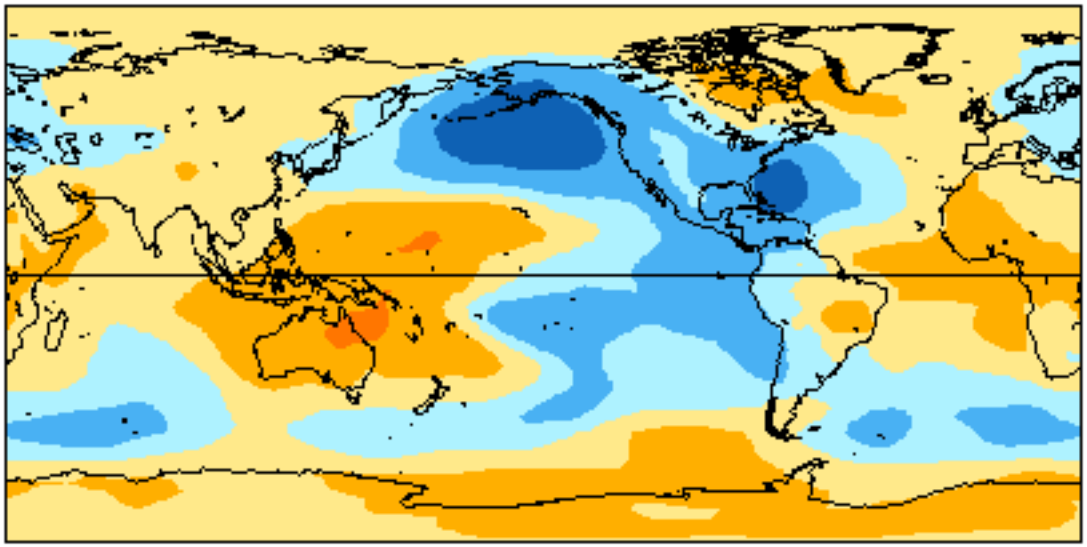




Correlation of DJFM PC3 and PNA with pressure (1950-2002)

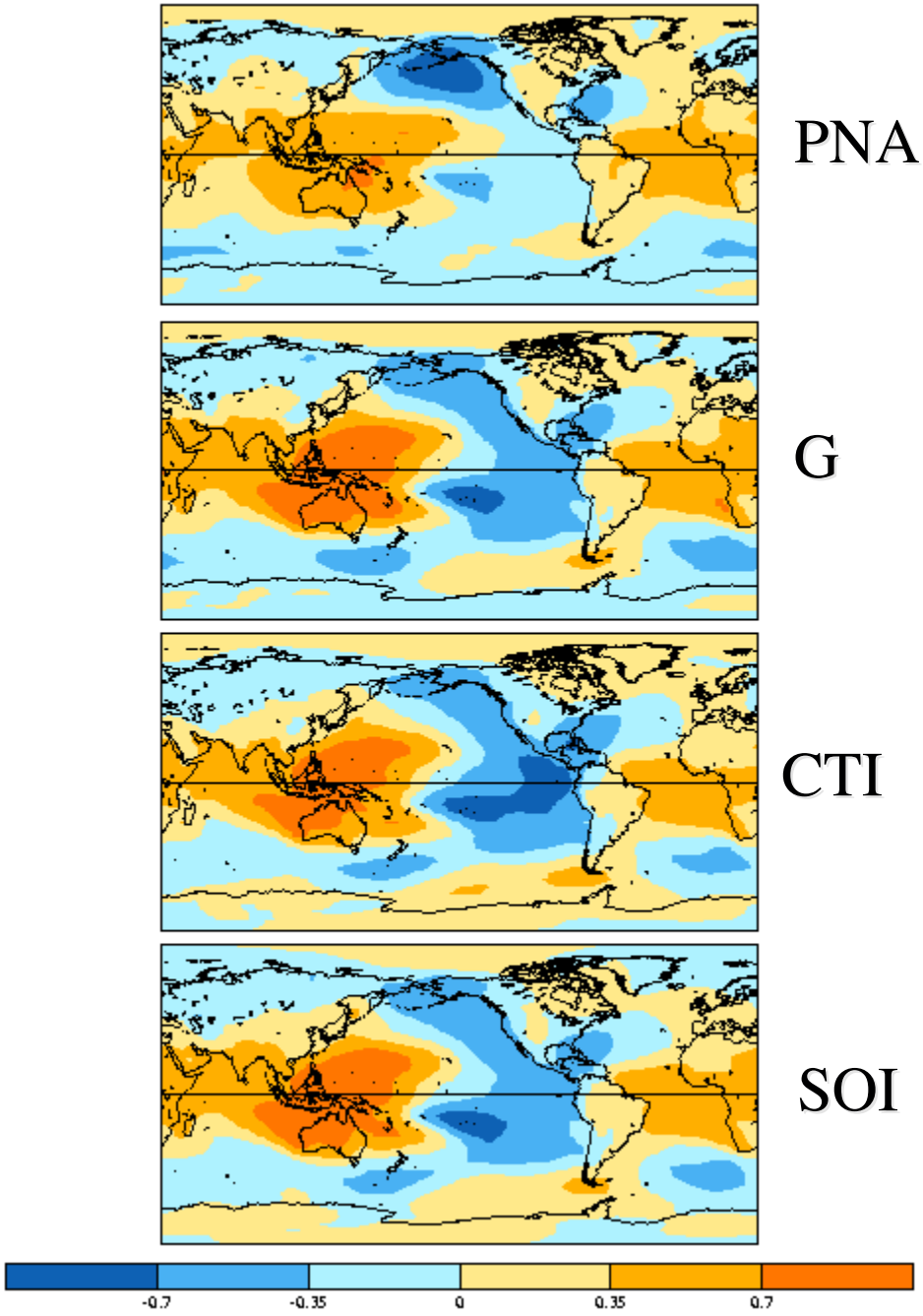


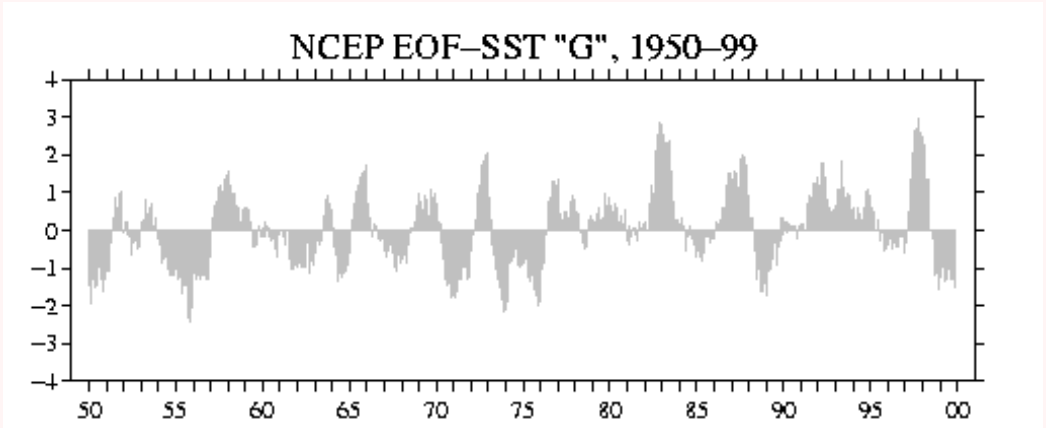
PC3

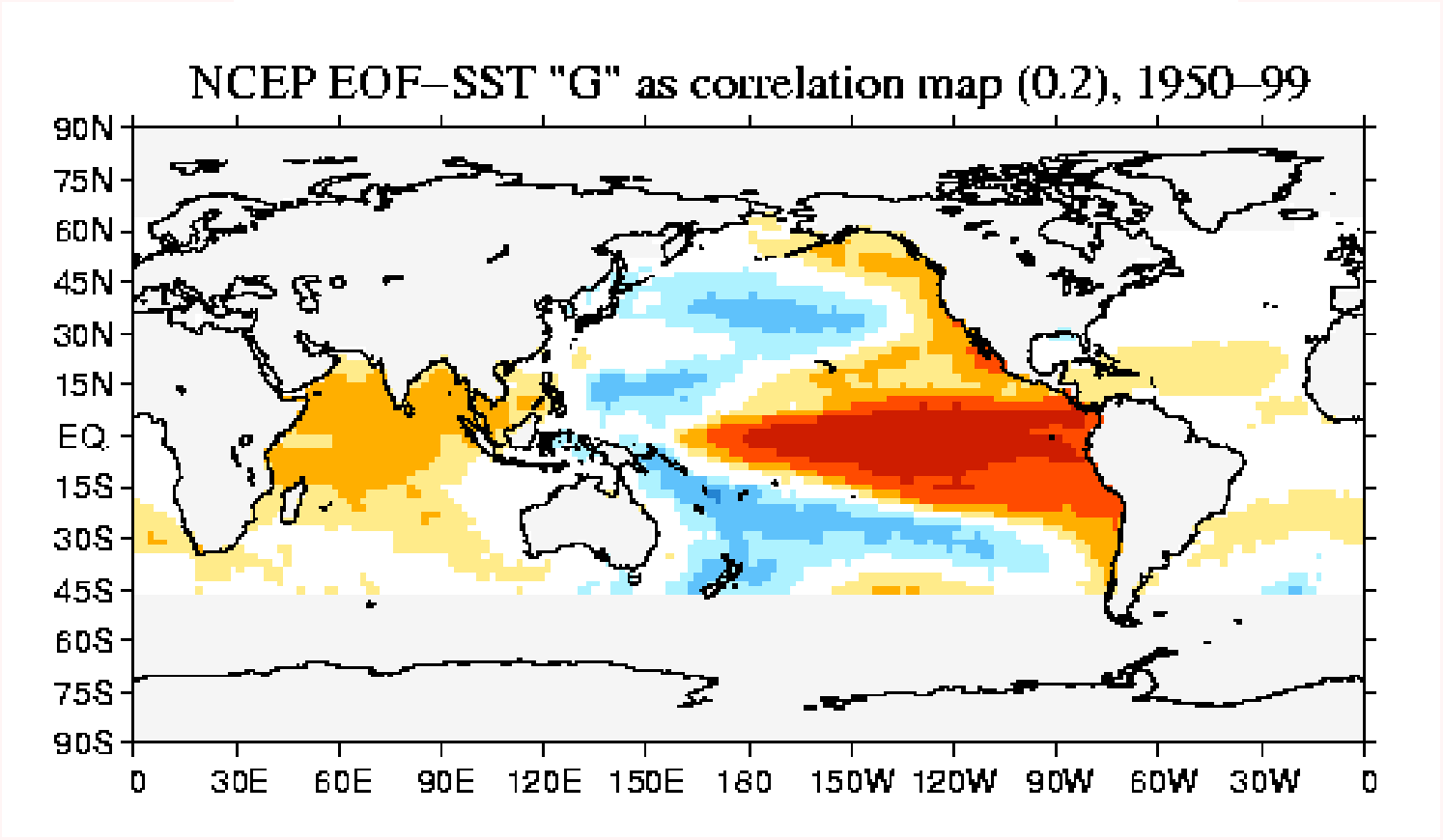


PNA

Correlation of DJFM PNA, "G", CTI, & SOI with pressure (1950-2002)

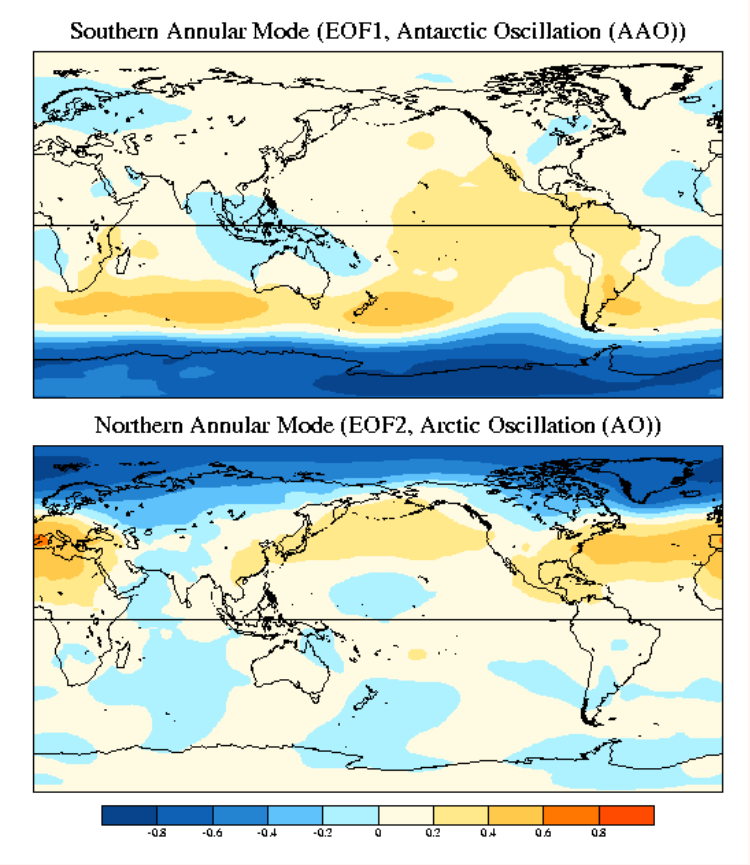



NCEP EOF–SST "G", 1950–99
+4
3
2
1
0
–1
–2
–3
–4
50
55
60
65
70
75
80
85
90
95
00


NCEP EOF–SST "G" as correlation map (0.2), 1950–99
90N
75N
60N
45N
30N
15N
EQ
15S
30S
45S
60S
75S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0

Modes: Things to consider

- Explained variance
- Domain dependence
- Dynamical mechanism
- Temporal behavior



Global modes

- NAM / AO / NAO
- SAM /AAO / HLM
- PNA / ENSO / PDO

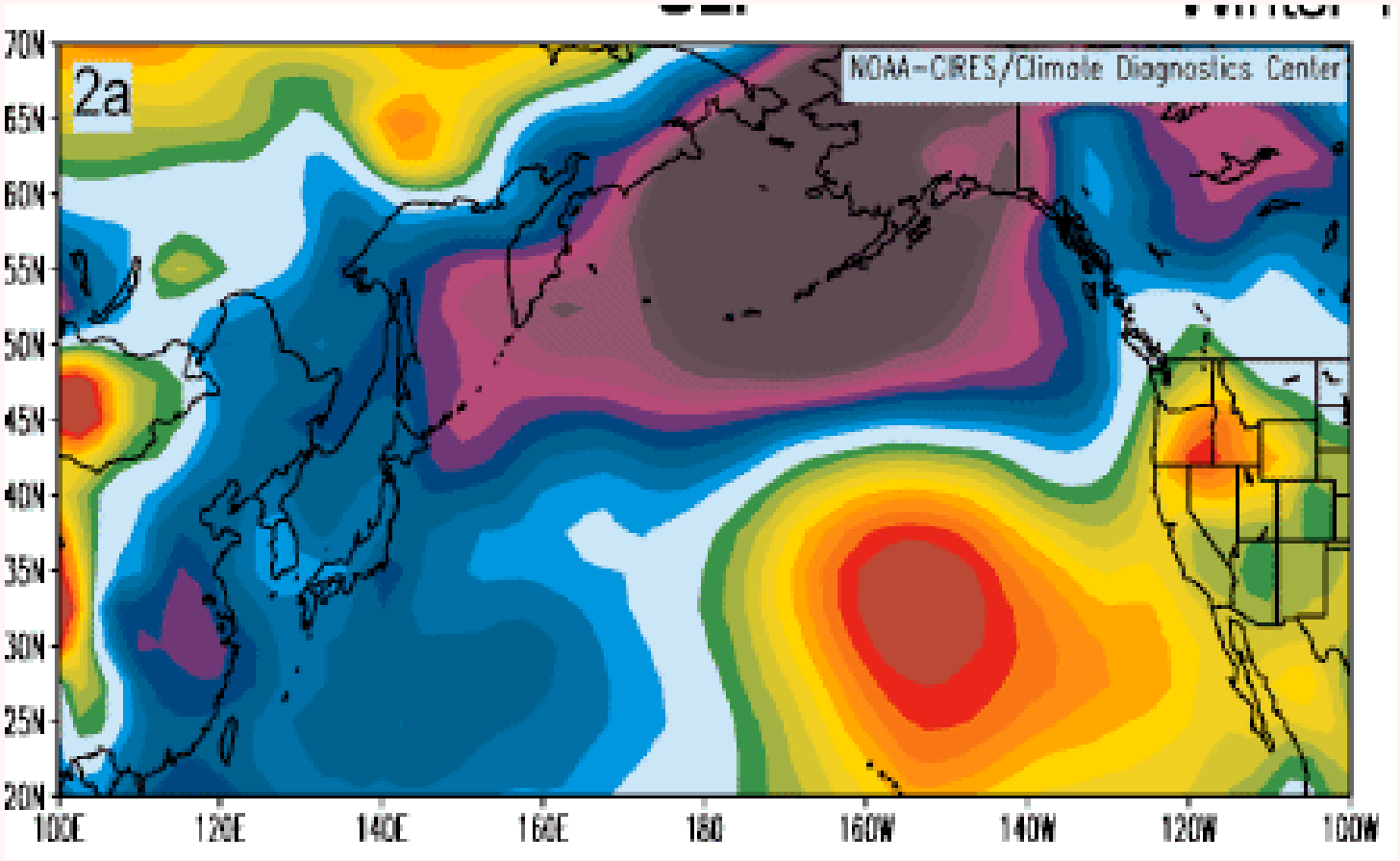
Types of patterns

- observed patterns O
- corresponding patterns C
- preferred patterns (modes) M

Relationships between patterns

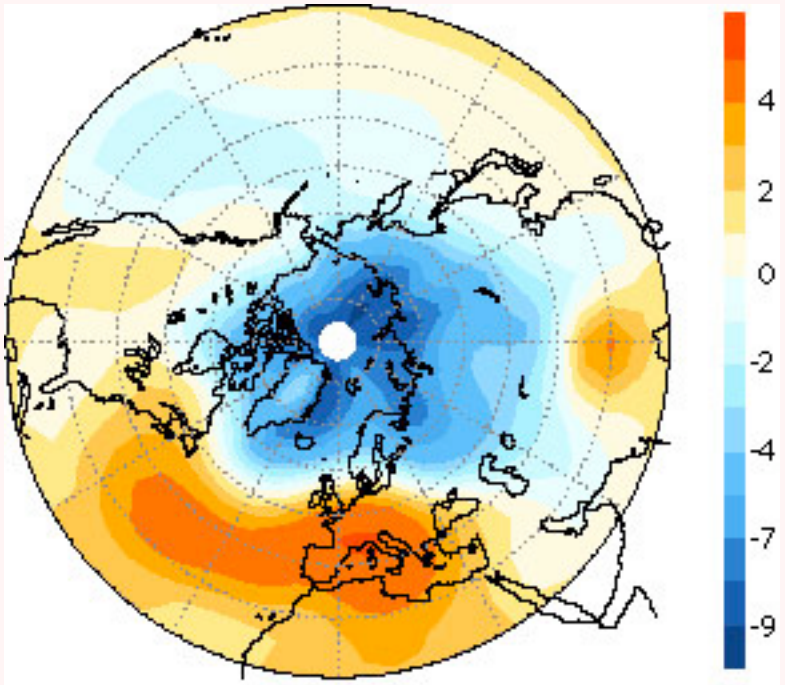
- **O // C**
- O // M
- C // M
- O // C // M

Winter 1999-2003

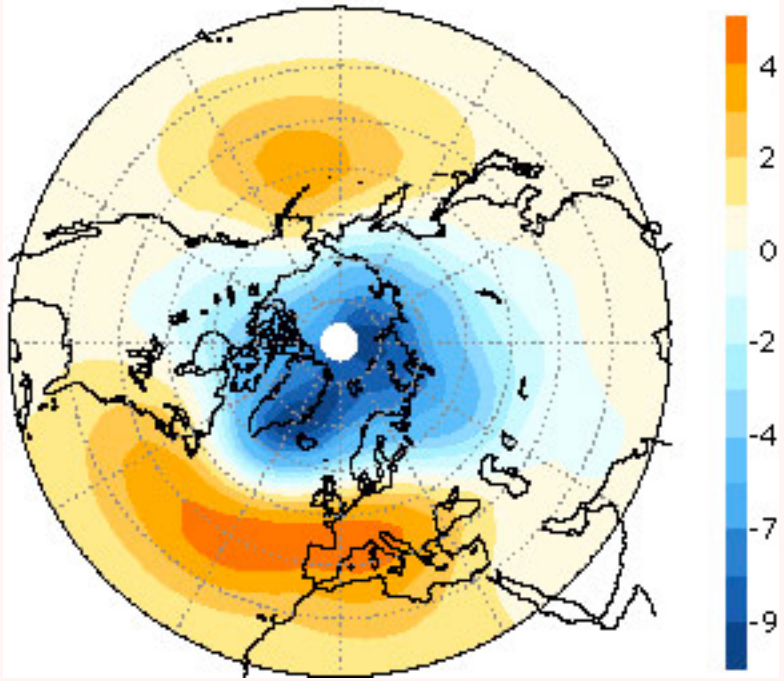


Relationships between patterns

- O // C
- **O // M**
- C // M
- O // C // M



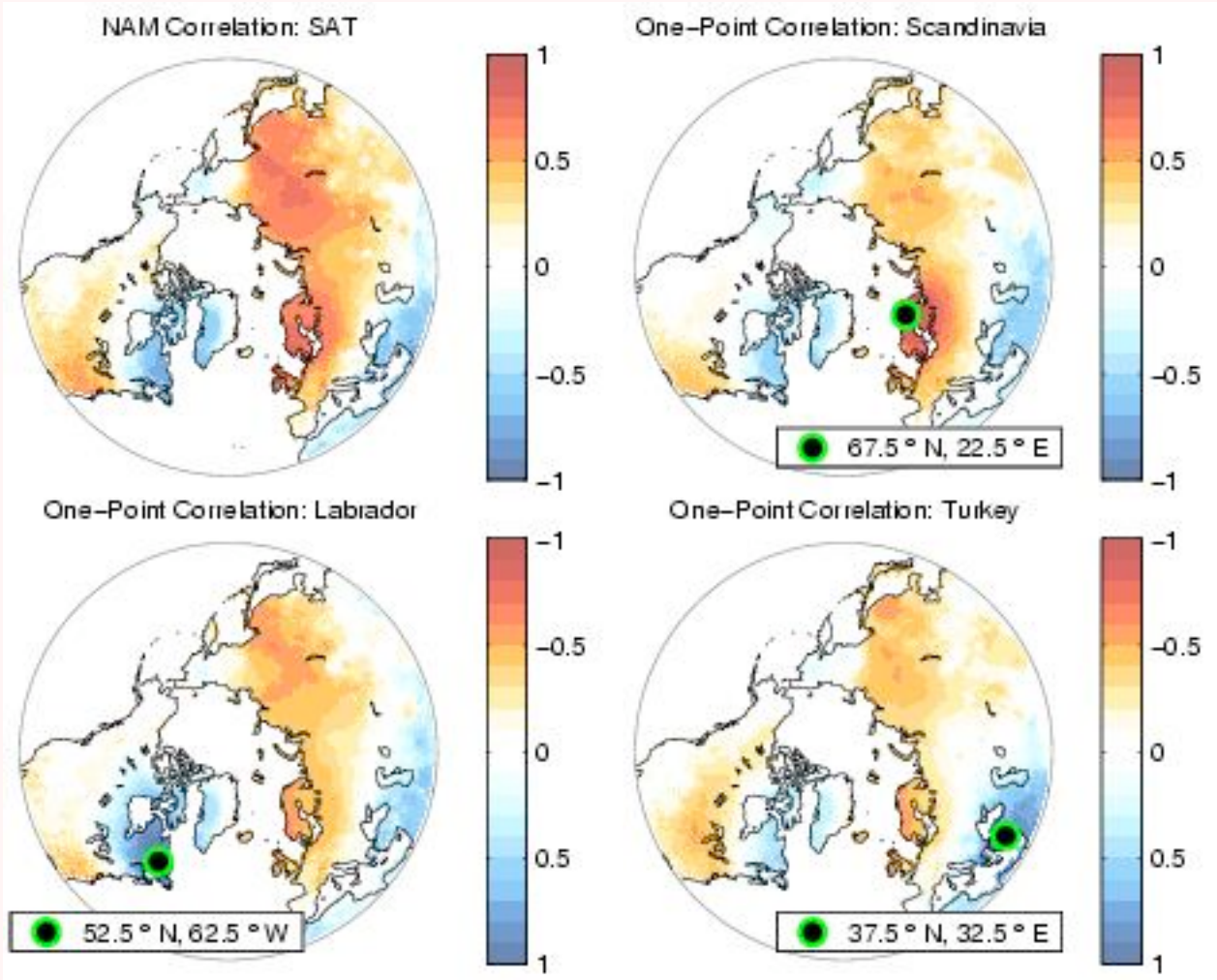
Annular Mode



Trend

Relationships between patterns

- O // C
- O // M
- **C // M**
- O // C // M


NAM Correlation: SAT
One–Point Correlation: Scandinavia
67.5 ° N, 22.5 ° E
One–Point Correlation: Labrador
52.5 ° N, 62.5 ° W
One–Point Correlation: Turkey
37.5 ° N, 32.5 ° E
1
0.5
0
−0.5
−1

Relationships between patterns

- O // C
- O // M
- C // M
- **O // C // M**

Global Modes of variability

- Do they exist? Yes
- If so, how many? What are they?

  Annular modes, Pacific mode
- Are they relevant for estuaries research?

  Yes, when C // M