Nonlinear (paleo)climatology: Studying polar climate with self-organizing maps

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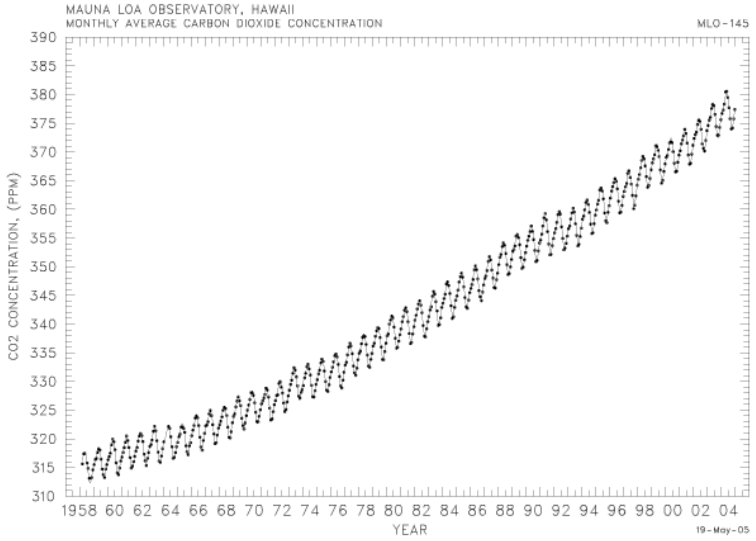
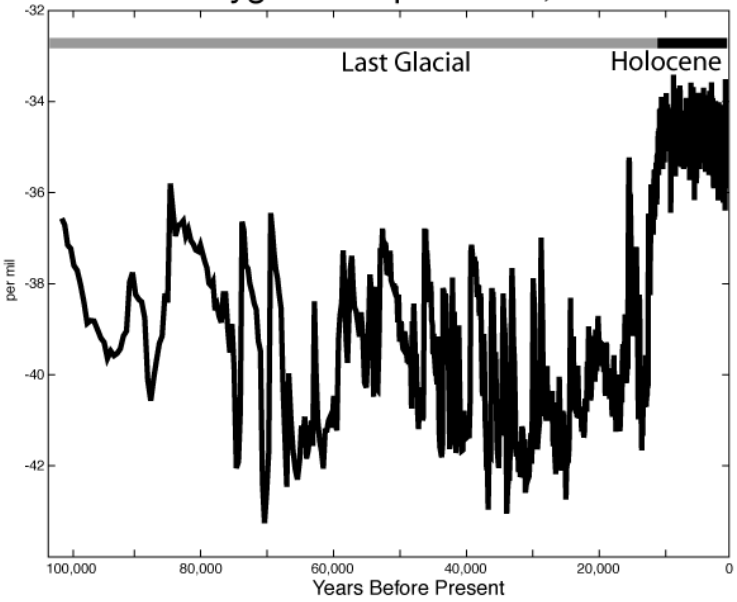
Motivation

Mauna Loa Carbon Dioxide Record 1957-2004

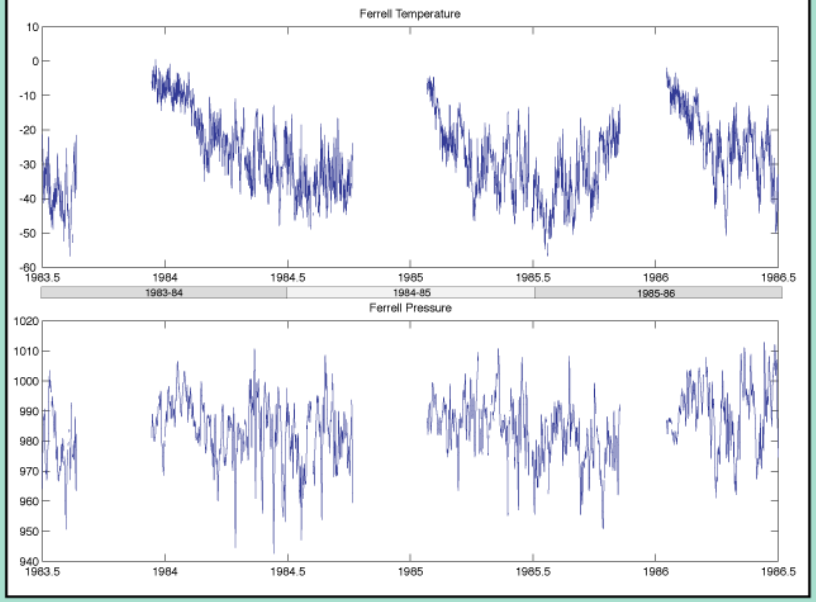


http://cdiac.ornl.gov/trends/co2/sio-mlo.htm

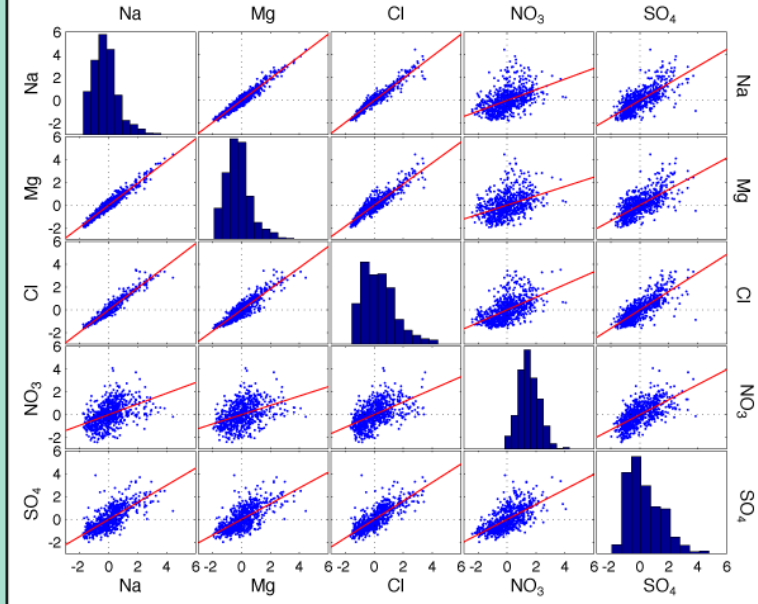
GISP2 Oxygen Isotopes - 100,000 Years

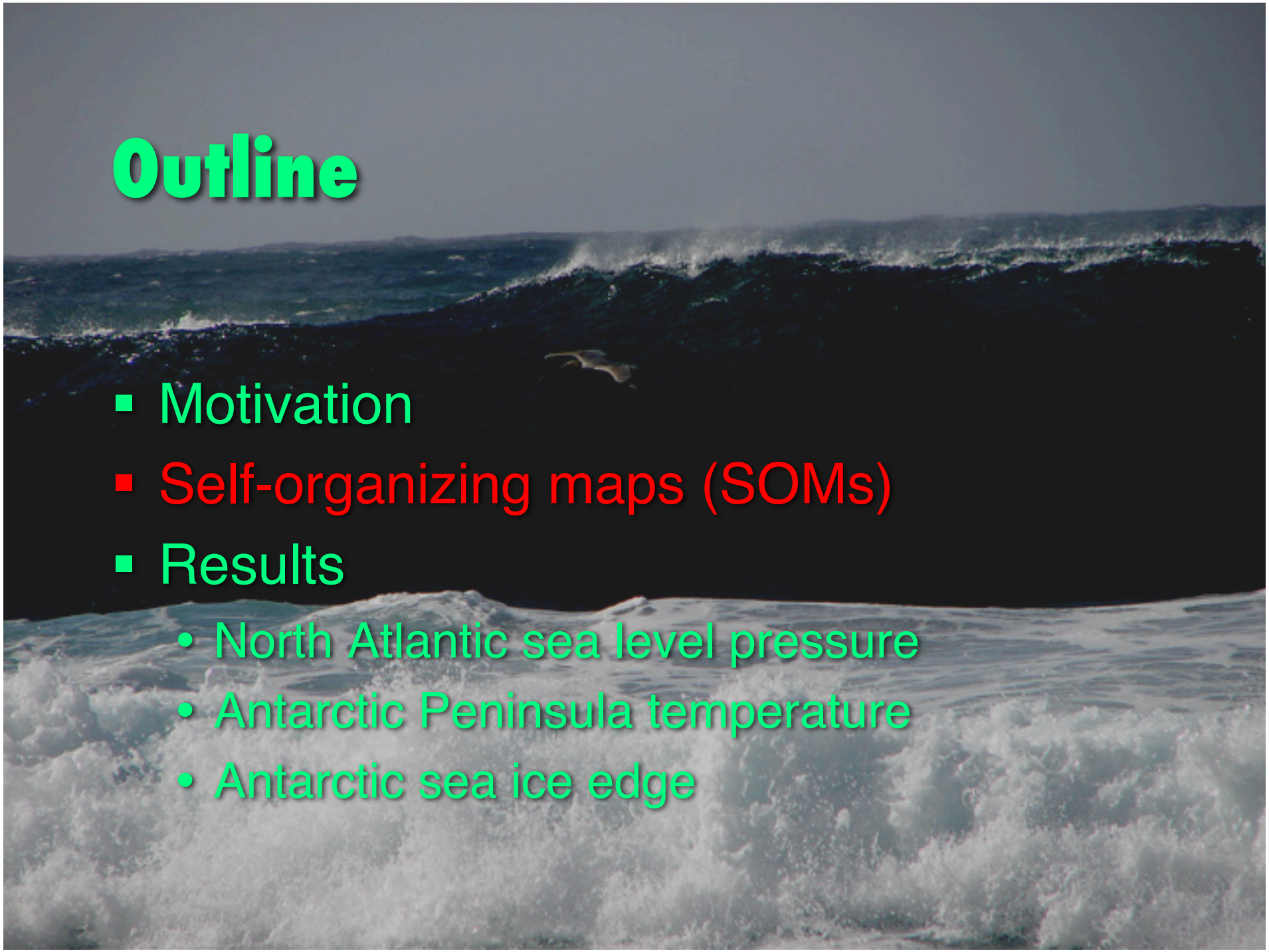


Three Years at an Antarctic Automatic Weather Station



Some Antarctic Ice Core Chemistry





Outline

- Motivation
- Self-organizing maps (SOMs)
- Results
  - North Atlantic sea level pressure
  - Antarctic Peninsula temperature
  - Antarctic sea ice edge

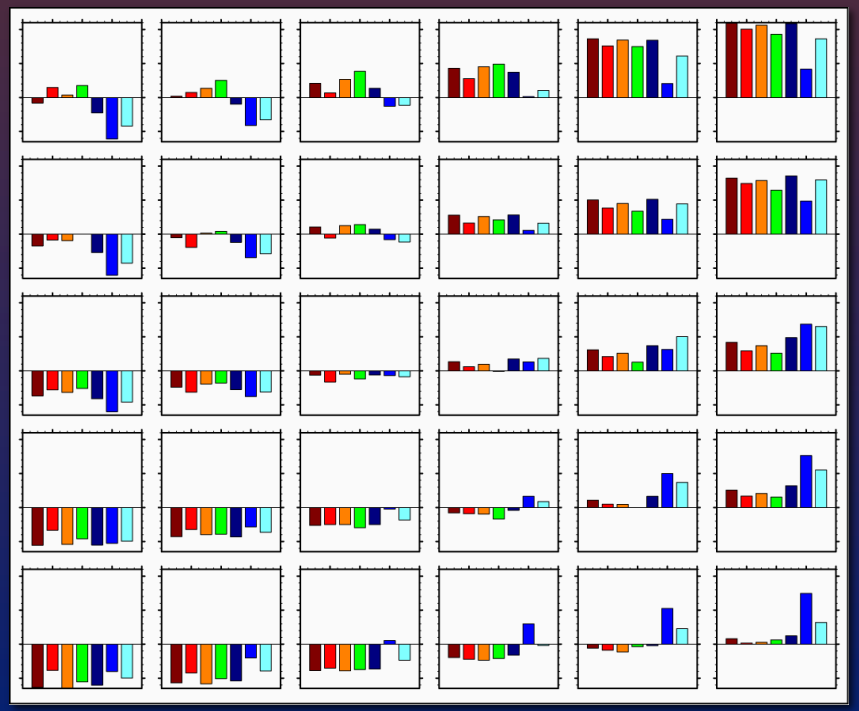
Self-organizing Maps (SOMs)

1) Concise summary of data variability expressed as a user-defined number of generalized patterns

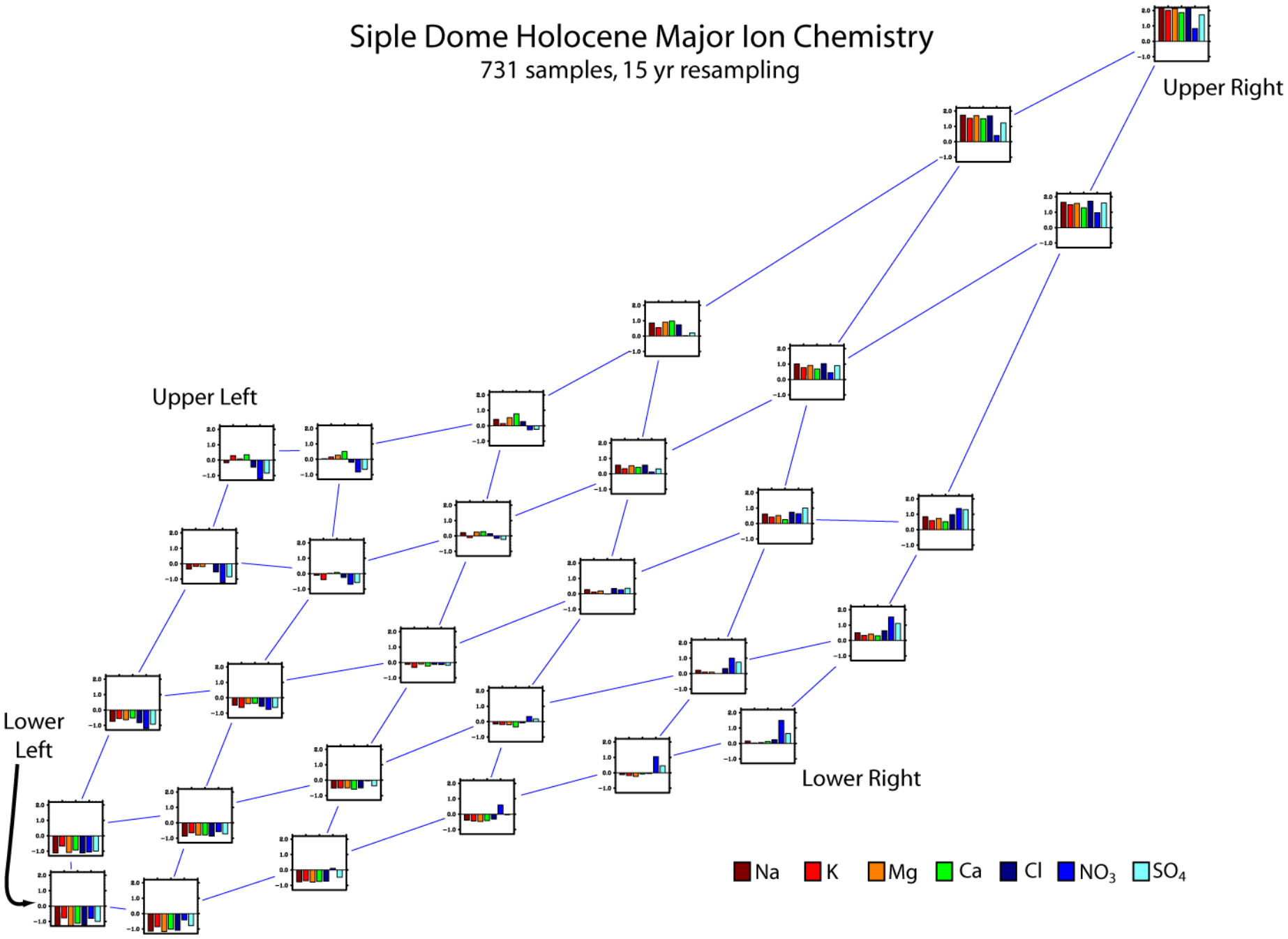
Patterns arranged in a grid by their relative similarity

Opposite corners are often end members

A projection (mapping) from the multidimensional input space to the 2-D pattern space



Holocene ice core chemistry


Siple Dome Holocene Major Ion Chemistry
731 samples, 15 yr resampling
Upper Left
Upper Right
Lower Left
Lower Right
Na
K
Mg
Ca
Cl
NO3
SO4

Self-organizing Maps (SOMs)

2) Also used for classifying multivariate data and studying its temporal behavior

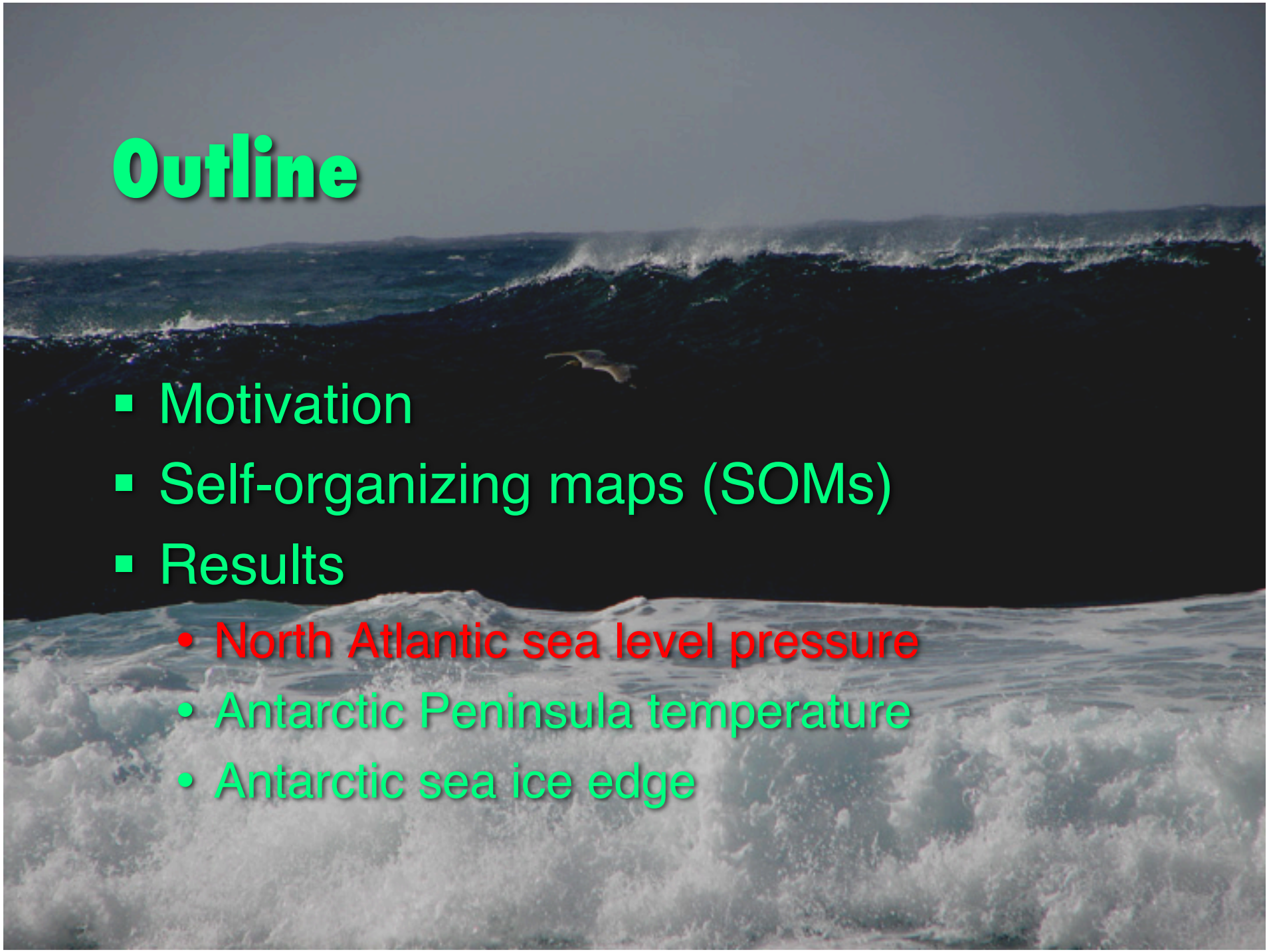
Each input record matches one pattern most closely

Records matching the same pattern have it in common

Basis for frequency, transition and trajectory maps

11	6	5	4	2	5
1	5	2	3	2	4
4	5	5	3	5	5
4	6	3	4	3	5
9	5	5	3	6	5

A Frequency Map



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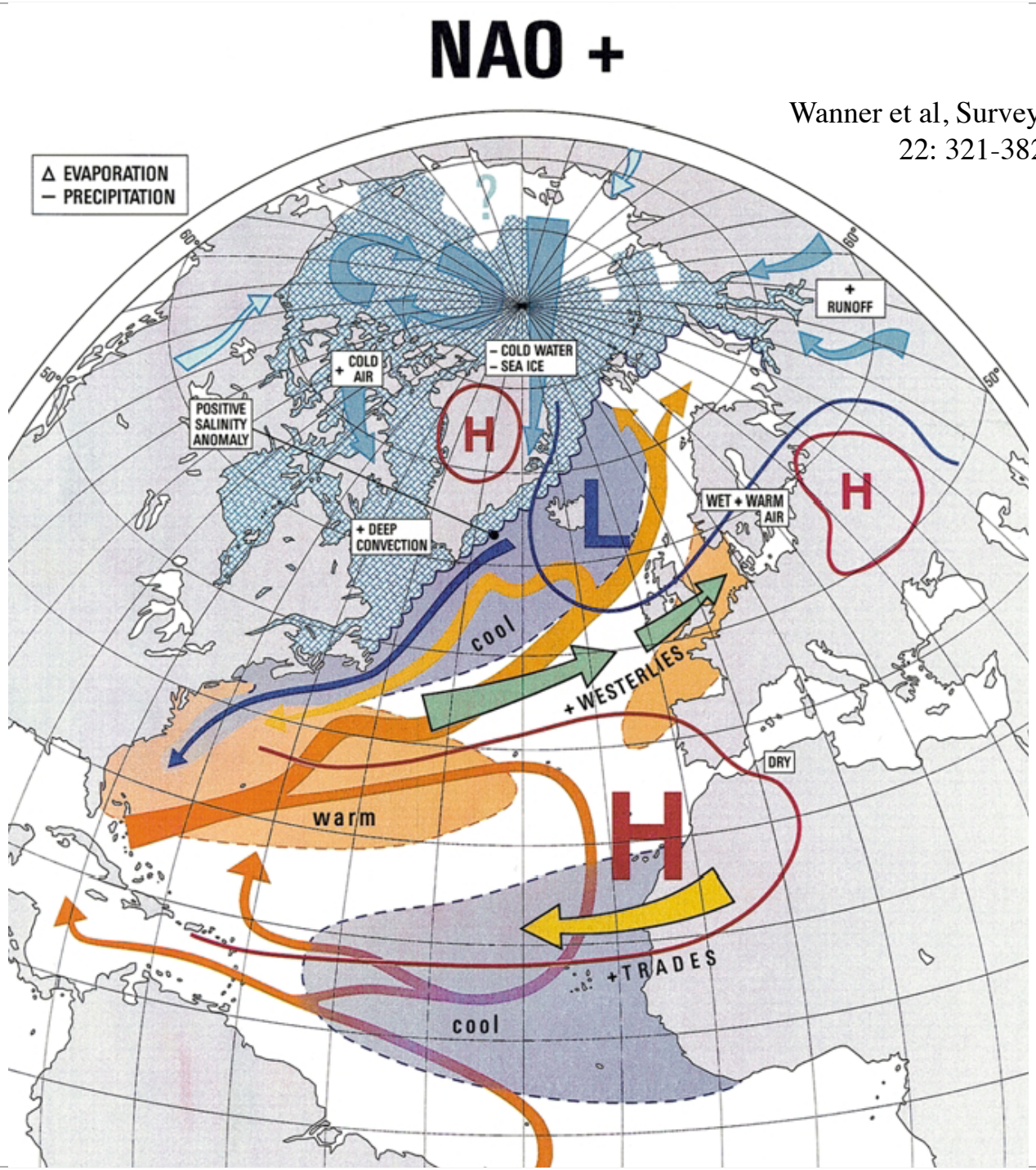
NAO +

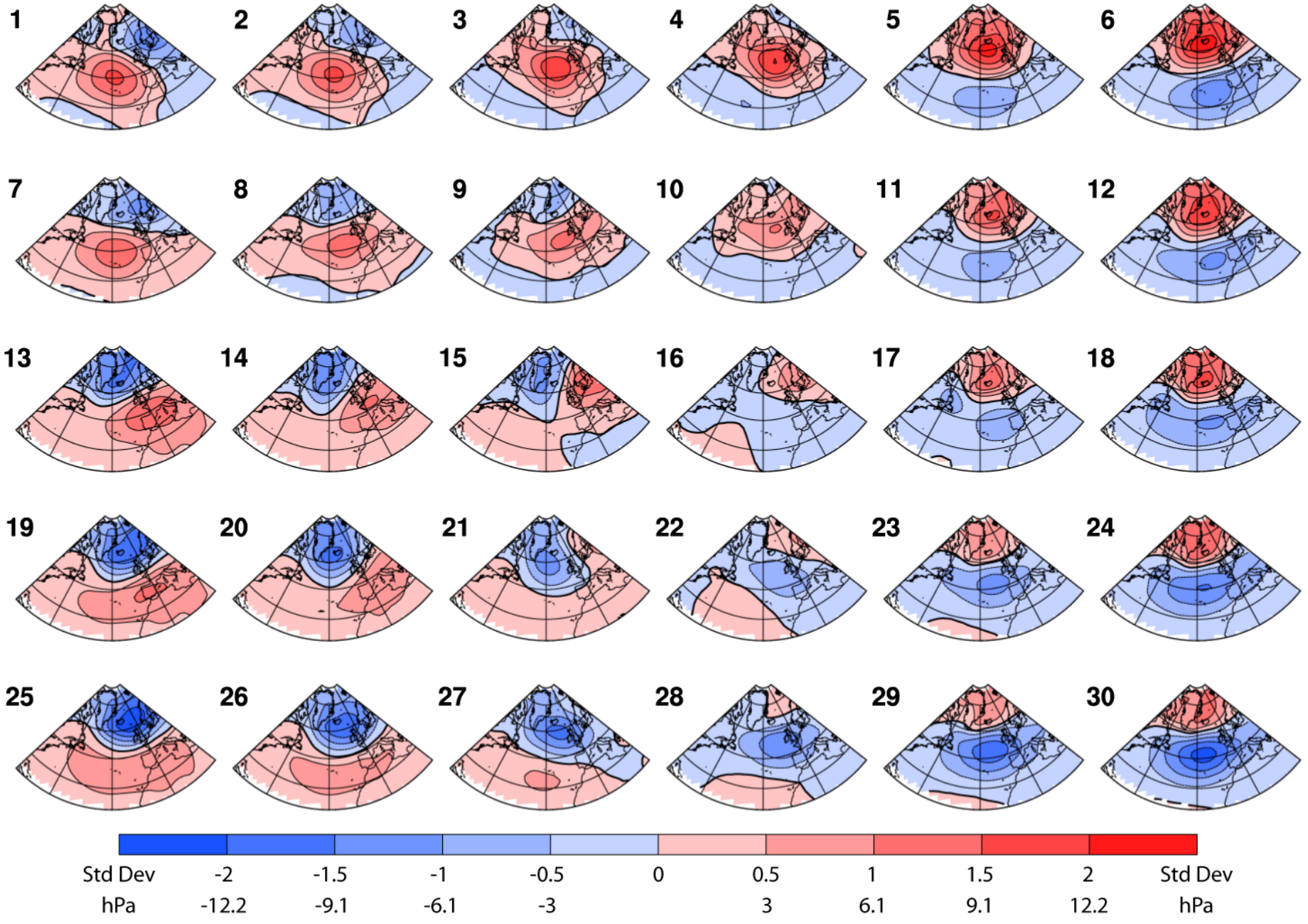


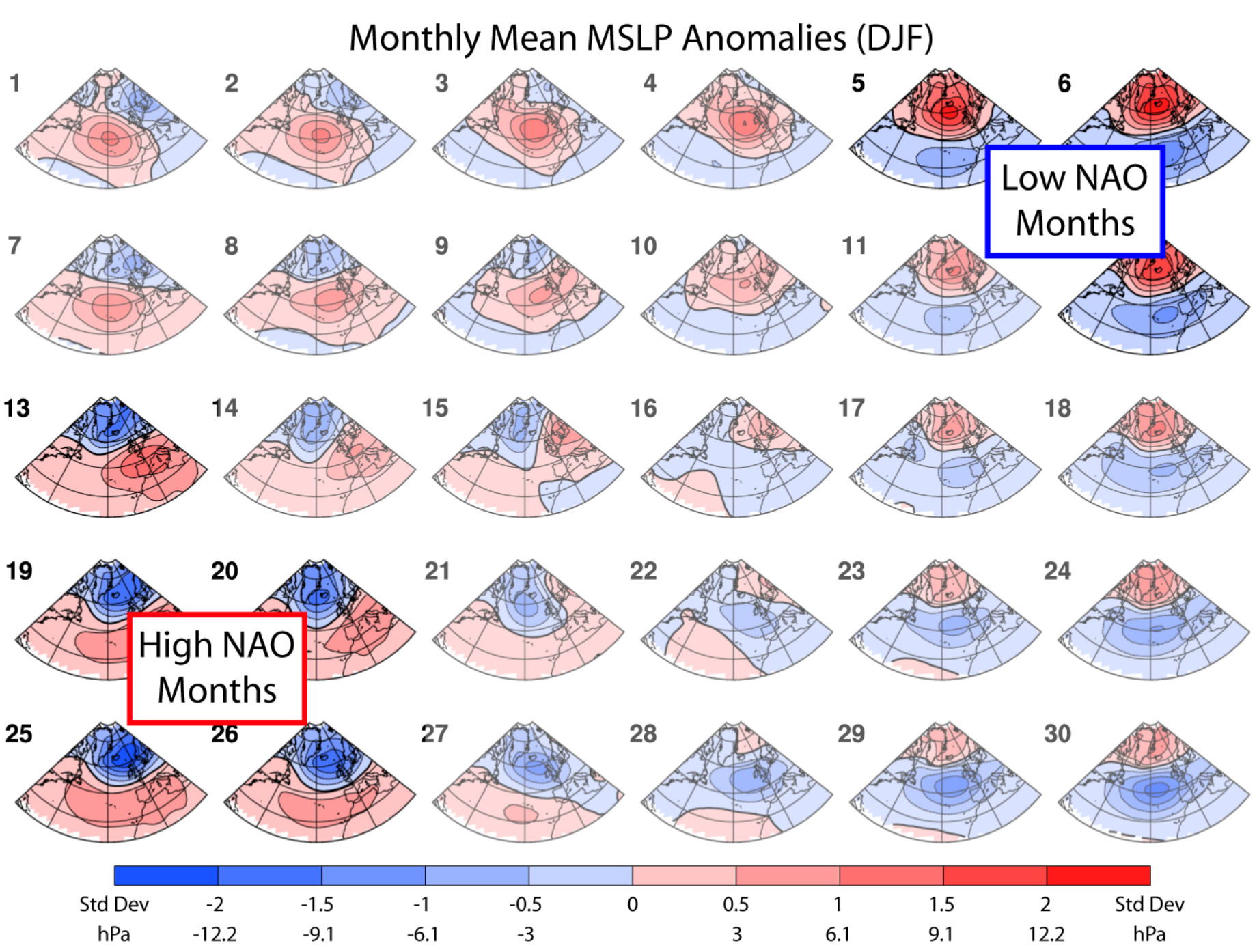
Wanner et al, Surveys in Geophysics, 22: 321-382, 2001.

North Atlantic Atmosphere

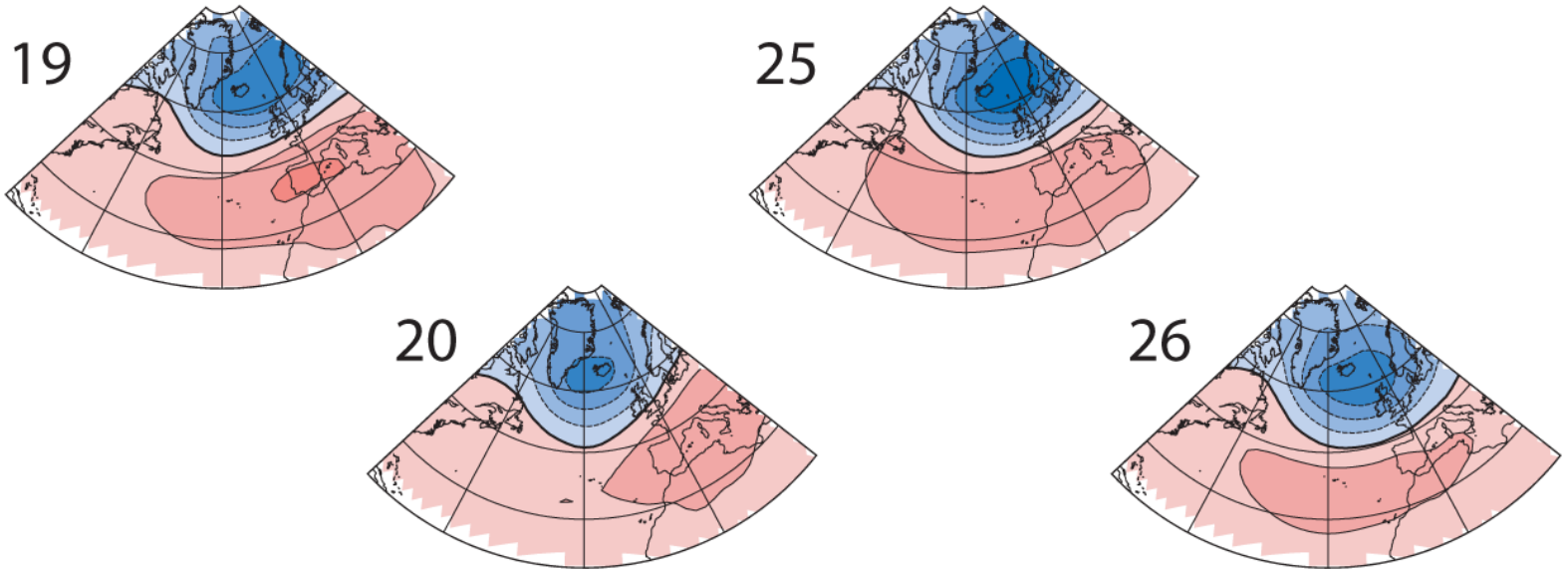
- Focus on NAO (North Atlantic Oscillation)
- Dec-Jan-Feb monthly data, 1957-2001
  - ECMWF 45 yr reanalysis (ERA-40)
  - 20-85° N, 80° W - 25° E
  - Anomalies from 1971-2000 baseline
- Monthly mean, standard deviation for MSLP, T-2m, $(U, V, Z)_{500}$

Monthly Mean MSLP Anomalies (DJF)

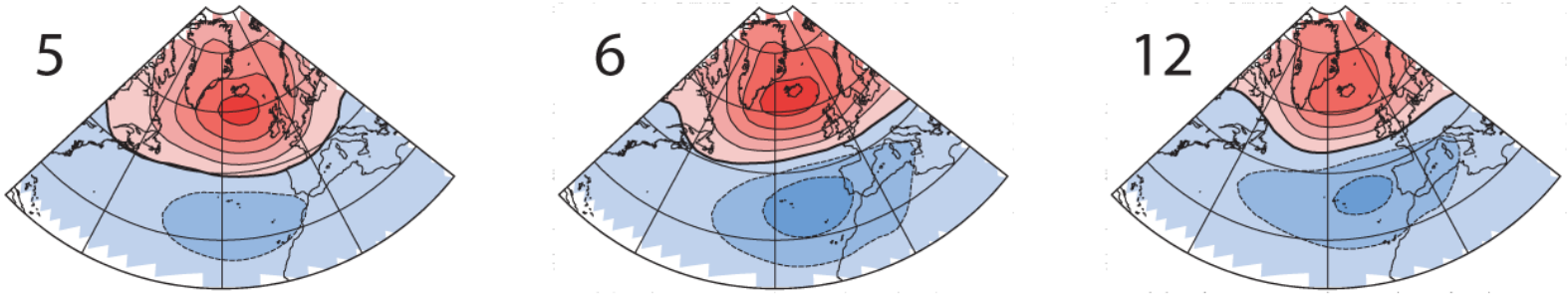



Monthly Mean MSLP Anomalies (DJF)
1
2
3
4
5
6
Low NAO Months
7
8
9
10
11
13
14
15
16
17
18
19
20
High NAO Months
21
22
23
24
25
26
27
28
29
30
Std Dev -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 Std Dev
hPa -12.2 -9.1 -6.1 -3 3 6.1 9.1 12.2 hPa

A Set of Positive NAO Patterns

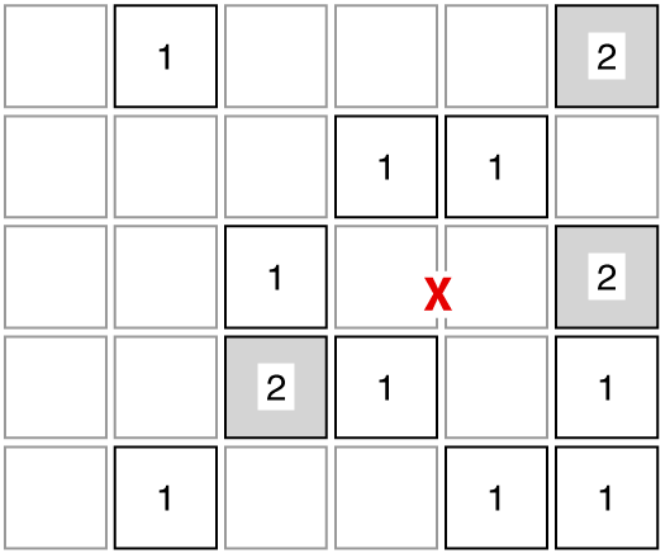


A Set of Negative NAO Patterns

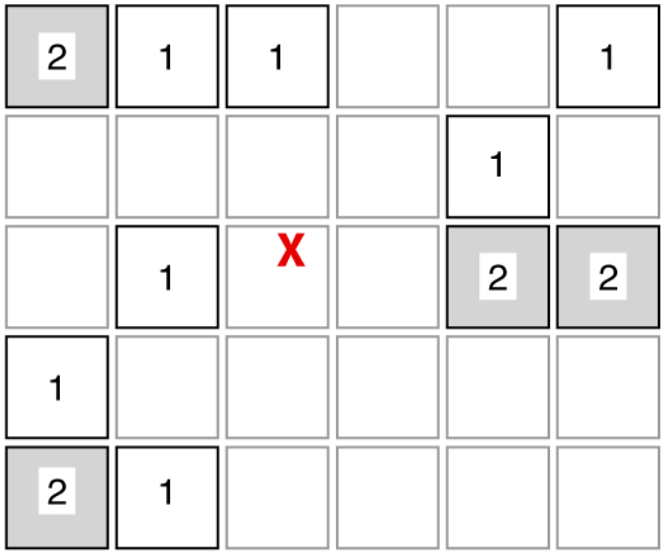


January Patterns Over Time

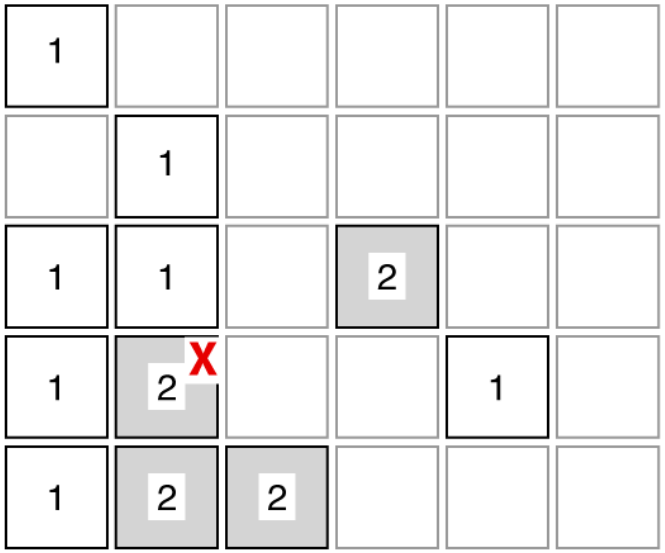
1957 - 1972



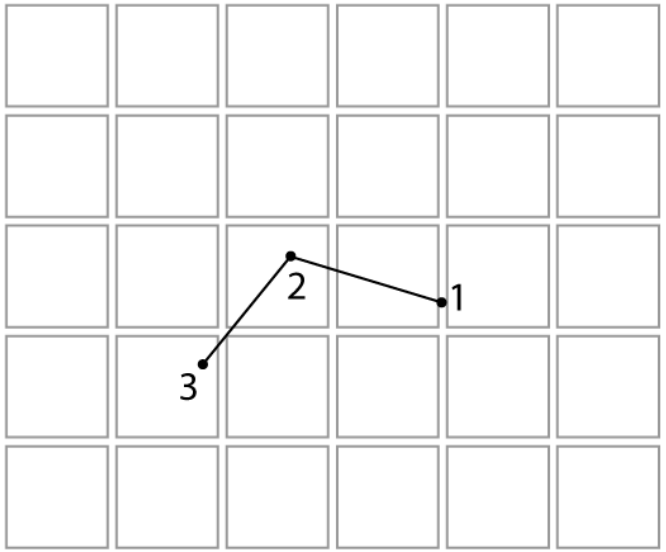
1972 - 1987

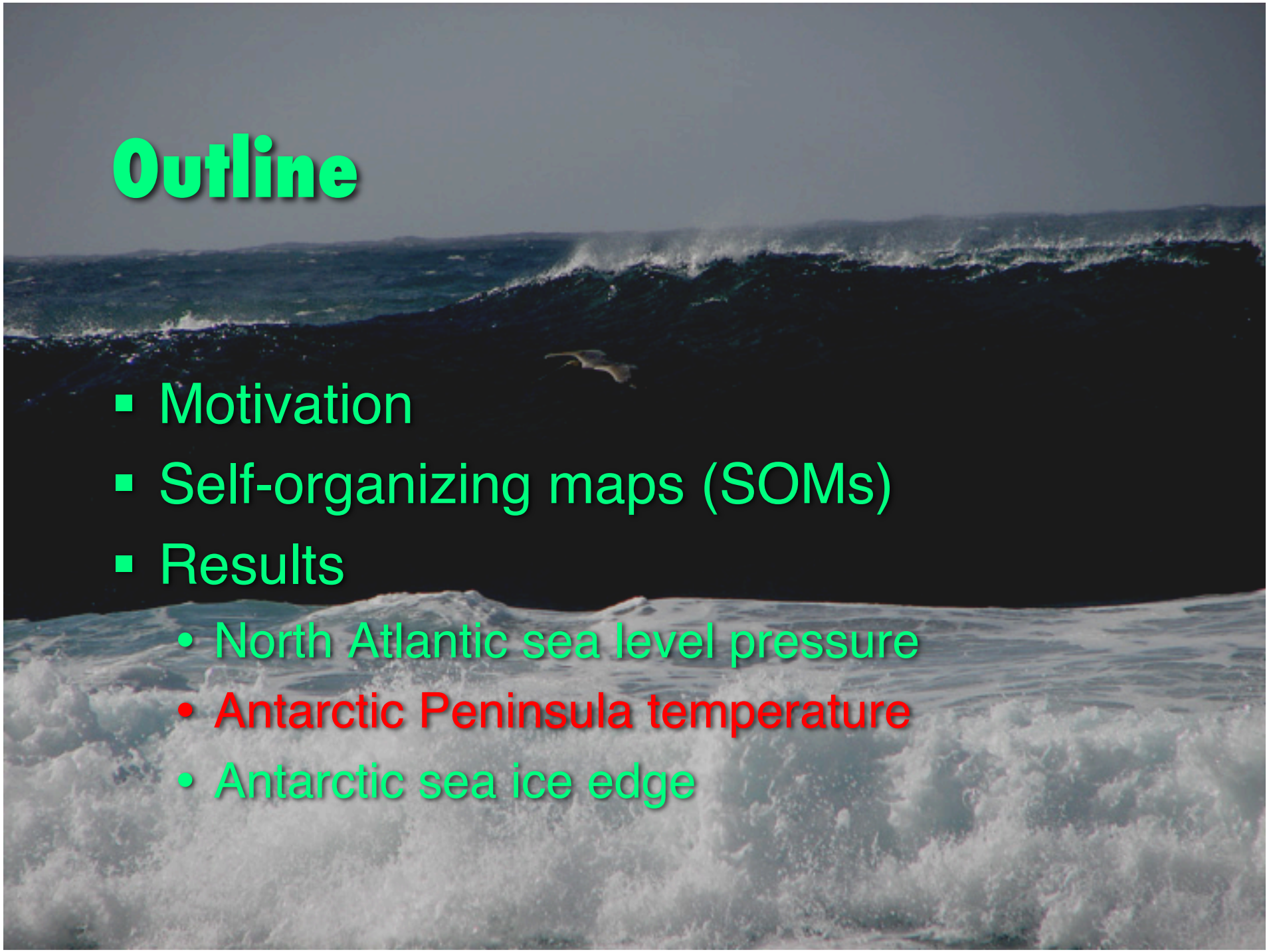


1987 - 2002



Trajectory of Mean





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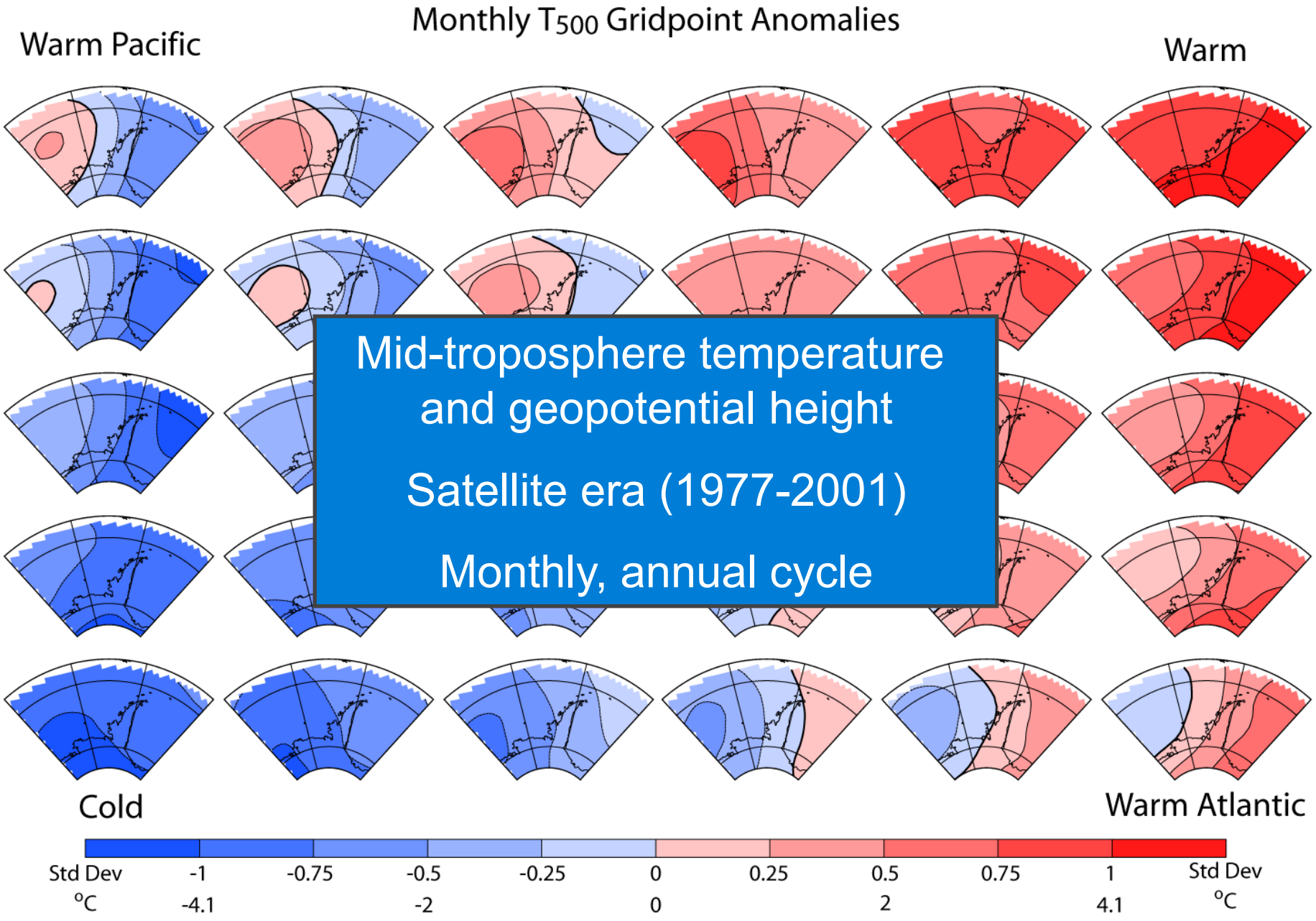
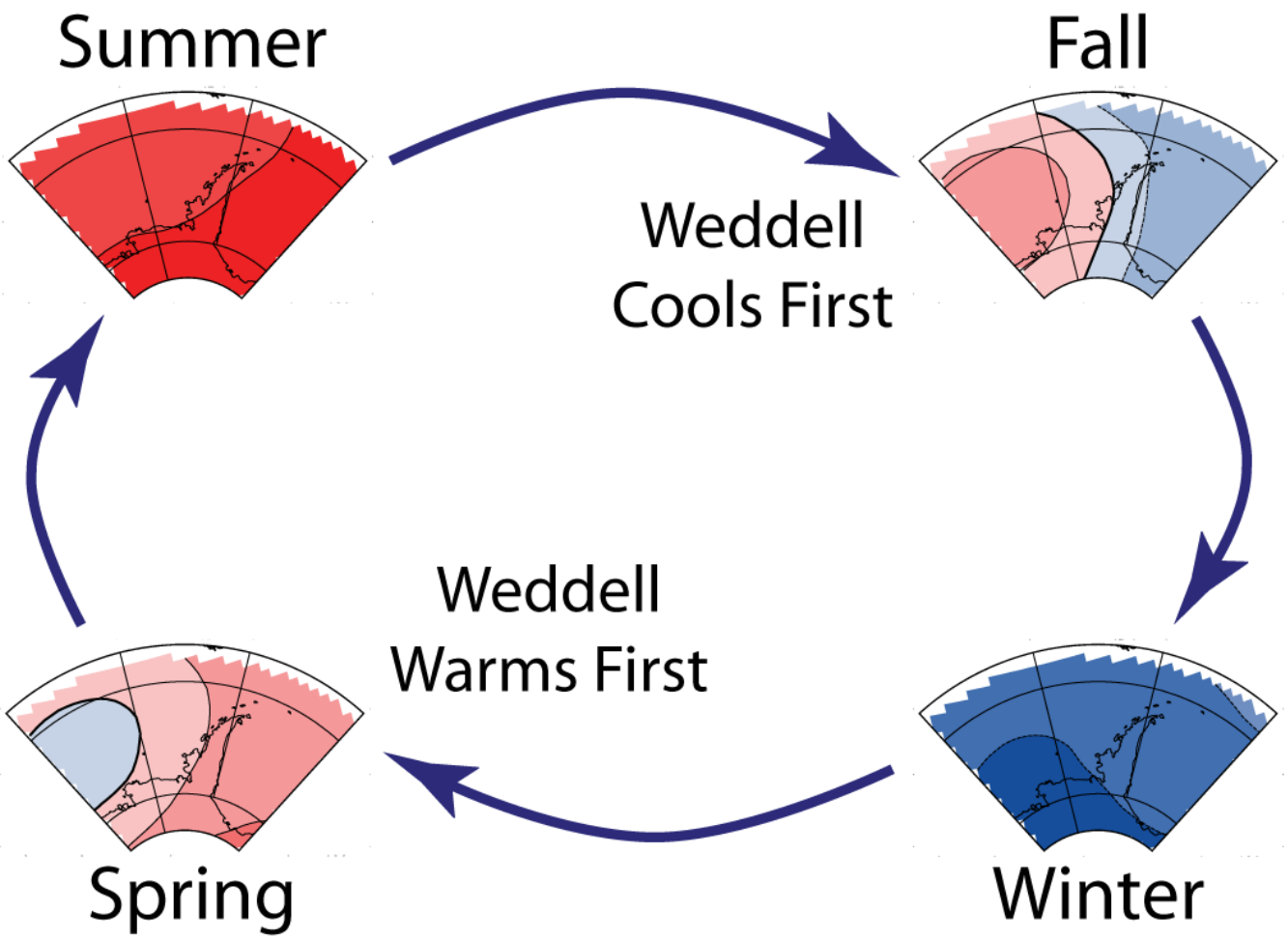
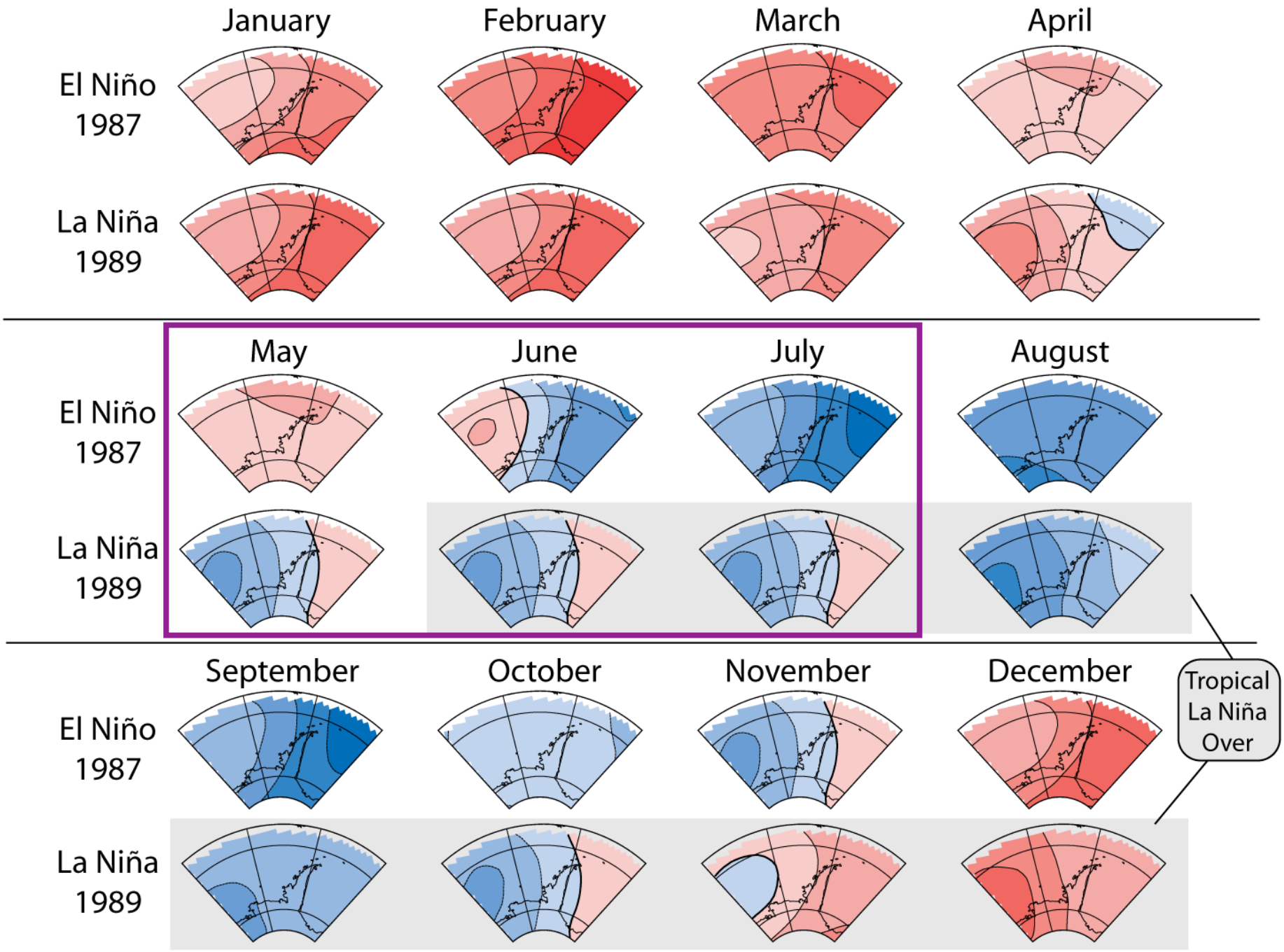

Monthly T_{500} Gridpoint Anomalies
Warm Pacific
Warm
Mid-troposphere temperature and geopotential height
Satellite era (1977-2001)
Monthly, annual cycle
Cold
Warm Atlantic
Std Dev °C
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
Std Dev °C
-4.1
-2
0
2
4.1

Cartoon of the Annual Cycle in T_{500}




January
February
March
April
El Niño 1987
La Niña 1989
May
June
July
August
El Niño 1987
La Niña 1989
September
October
November
December
El Niño 1987
La Niña 1989
Tropical La Niña Over

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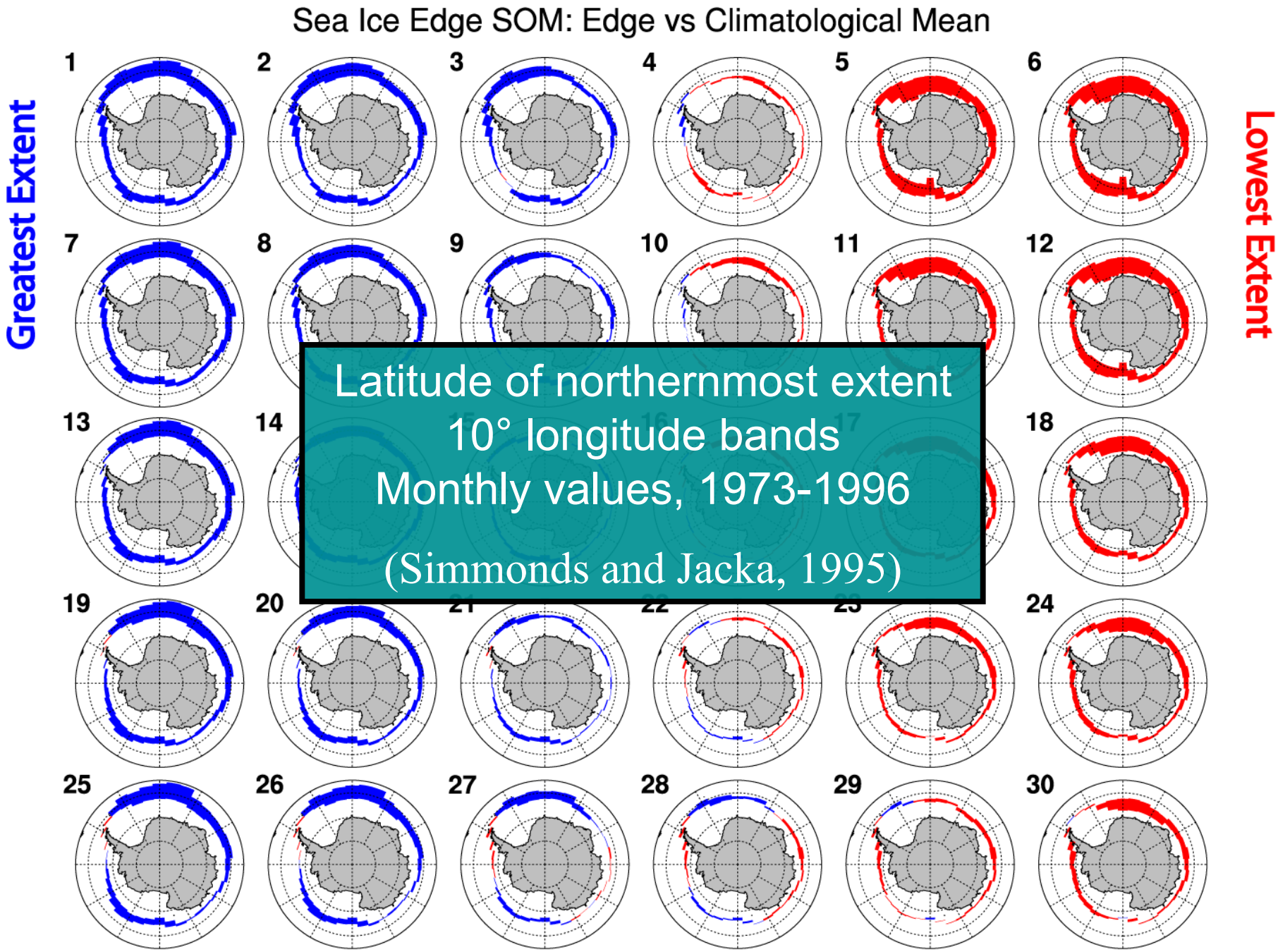
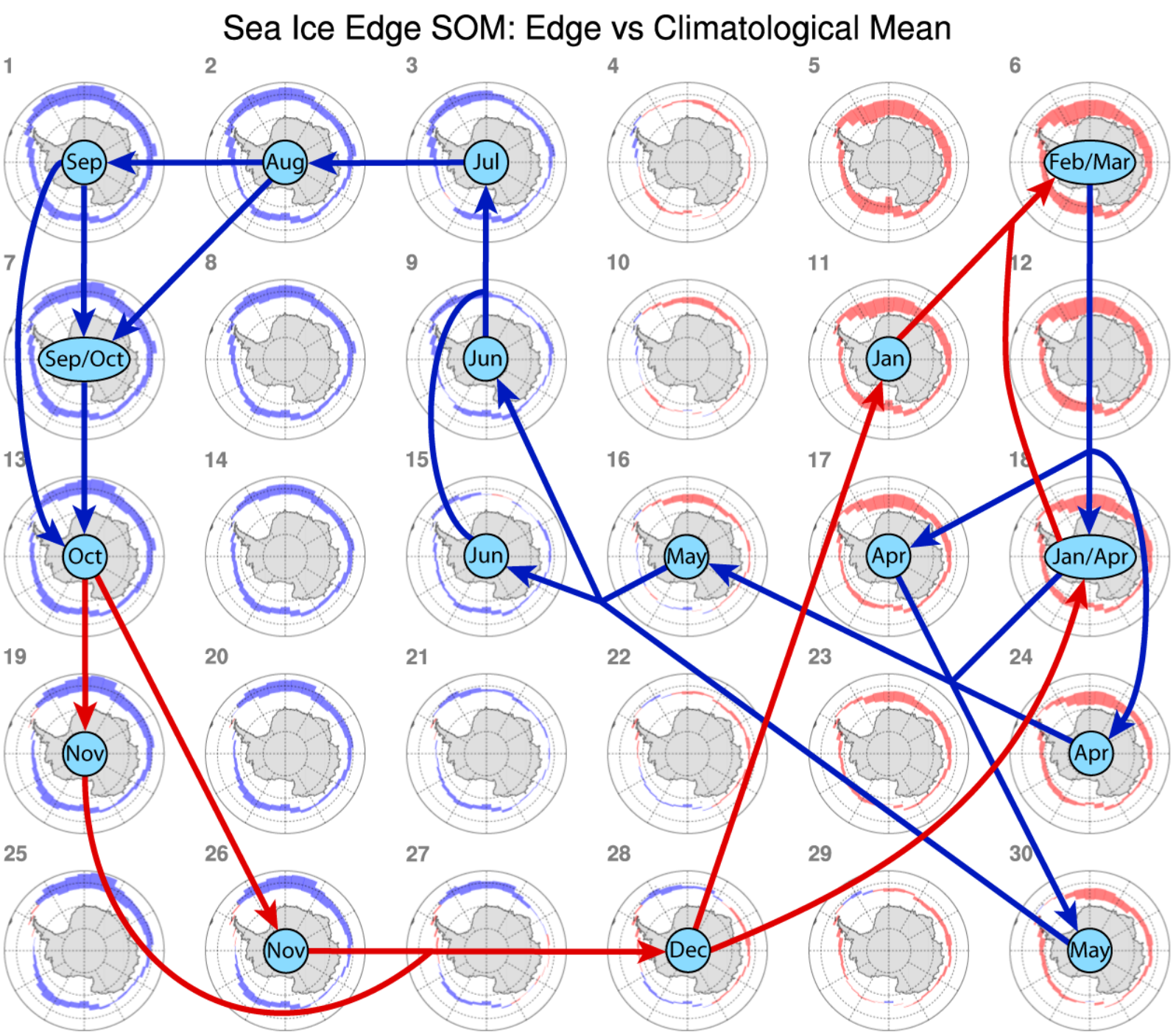
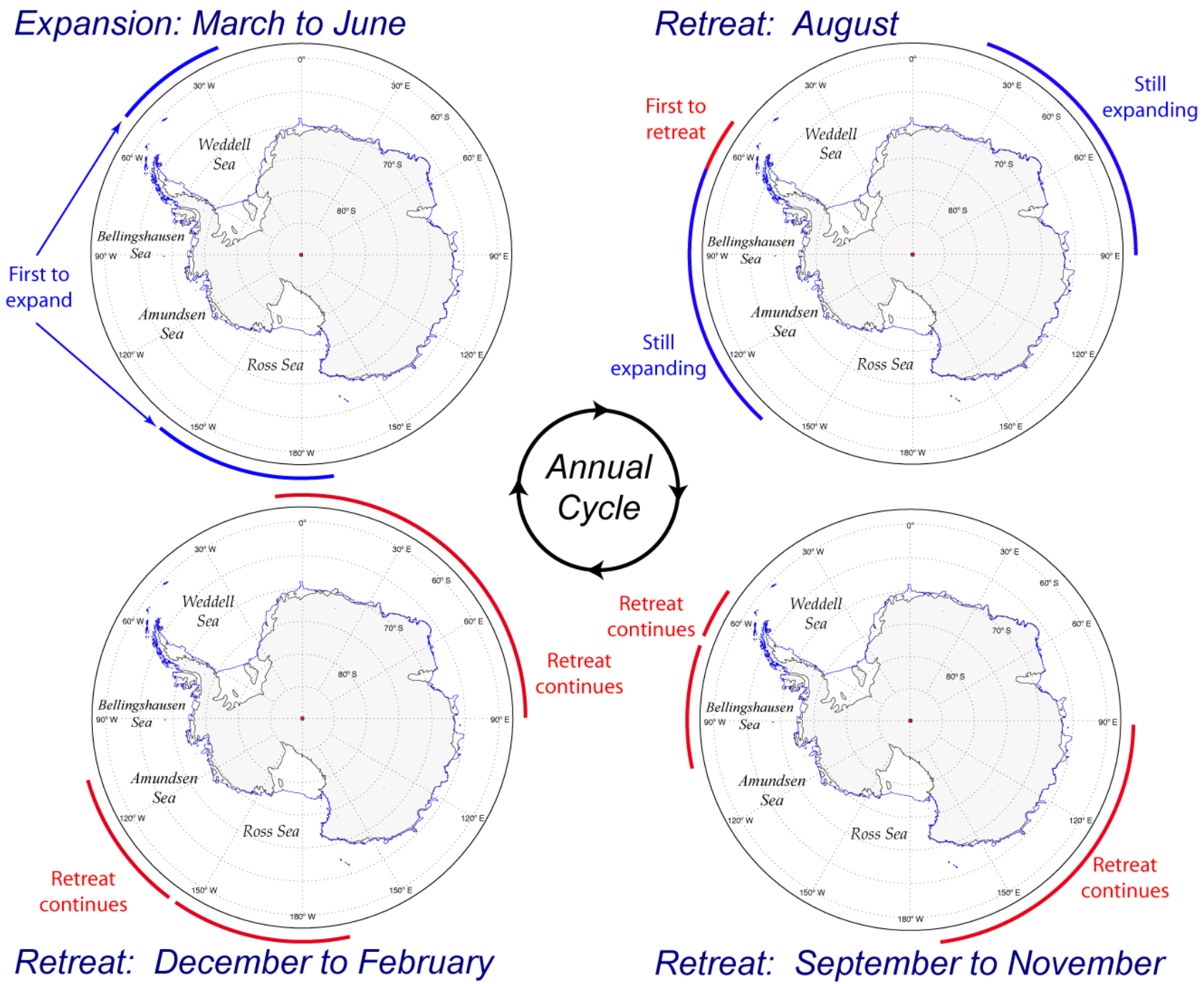

Sea Ice Edge SOM: Edge vs Climatological Mean
Greatest Extent
Lowest Extent
1
2
3
4
5
6
7
8
9
10
11
12
13
14
18
19
20
24
25
26
27
28
29
30
Latitude of northernmost extent
10° longitude bands
Monthly values, 1973-1996
(Simmonds and Jacka, 1995)


Sea Ice Edge SOM: Edge vs Climatological Mean
1
2
3
4
5
6
Sep
Aug
Jul
Feb/Mar
7
8
9
10
11
12
Sep/Oct
Jun
Jan
13
14
15
16
17
18
Oct
Jun
May
Apr
Jan/Apr
19
20
21
22
23
24
Nov
Apr
25
26
27
28
29
30
Nov
Dec
May


Expansion: March to June
First to expand
Retreat: August
First to retreat
Still expanding
Still expanding
Annual Cycle
Retreat continues
Retreat continues
Retreat continues
Retreat continues
Retreat: December to February
Retreat: September to November
Weddell Sea
Bellingshausen Sea
Amundsen Sea
Ross Sea

Satellite Clouds

- New project with the AMRC
- Attempting to “mine” the AMRC satellite composite database for climate info
- Stay tuned for results next year…

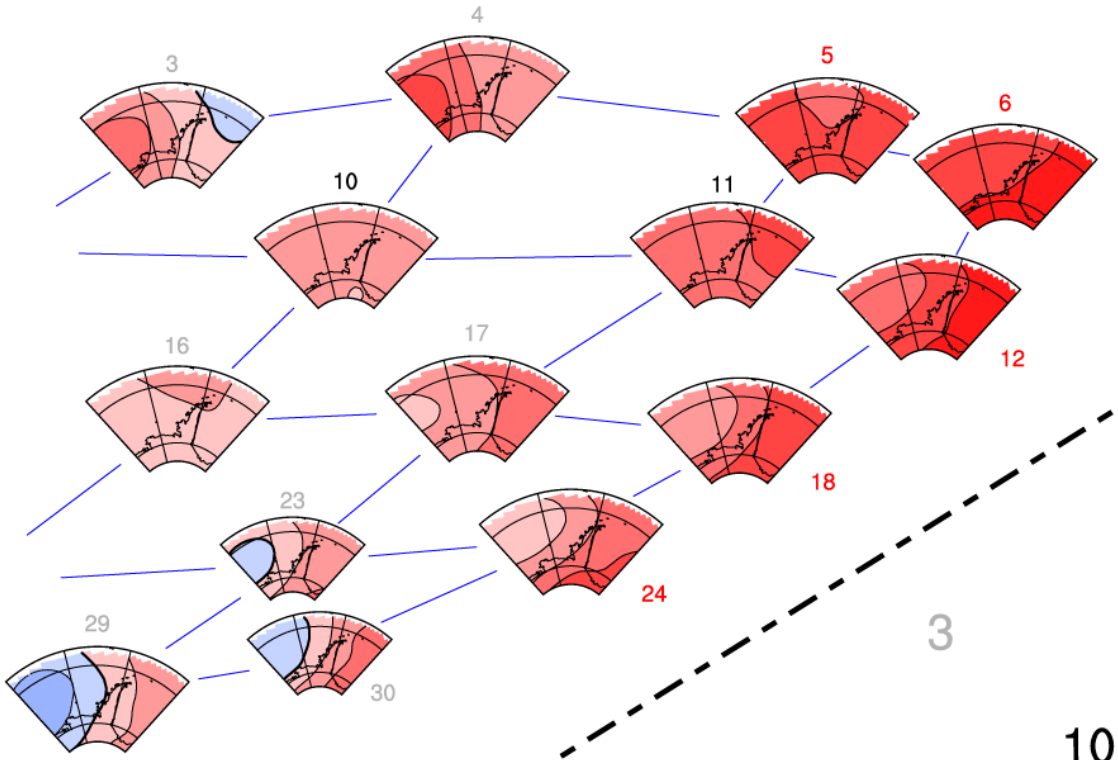
Summary

- Self-organizing maps provide a new, alternative method for studying climate variability and are an exciting new tool for analyzing complex datasets
- SOMs readily identify asymmetric aspects of the NAO and other facets of North Atlantic variability
- SOMs provide potentially new insights into the annual cycles of Antarctic sea ice, the climate of the Antarctic Peninsula
- Continuing work with these datasets and others should bring further useful insights/results

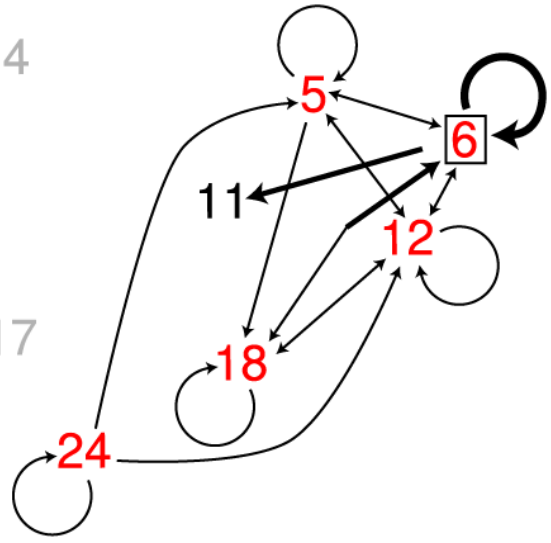
Antarctic Peninsula

- Focus on last 25 years (1977-2001) monthly ERA-40 to avoid the lack of data issues of the pre-satellite-era
- Mid-troposphere temperature (T_{500})
- Other variables processed but not as fully analyzed

Most Frequent Patterns and One-Month Transitions for January T_{500}

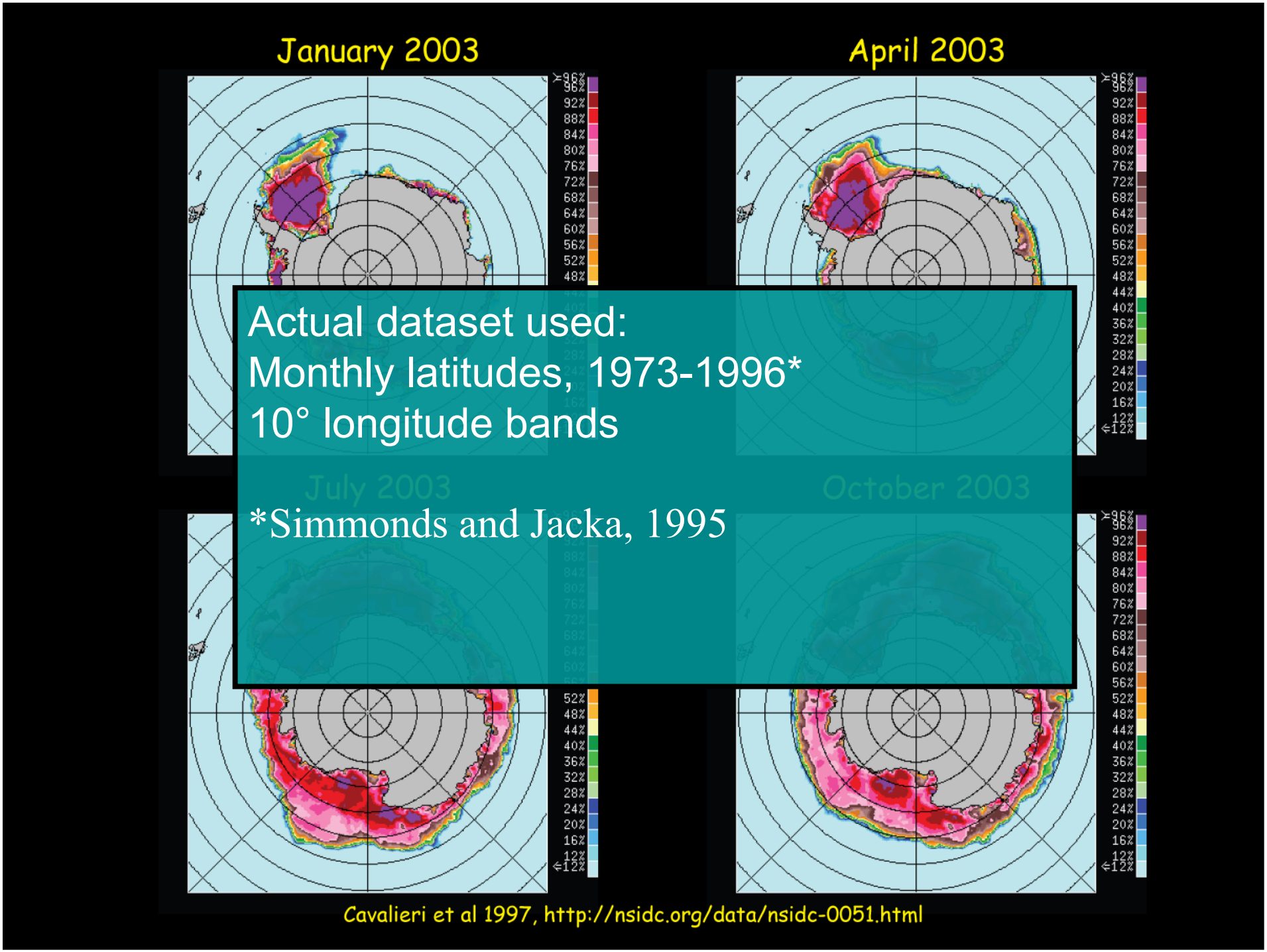


Node	Frequency Count
5	4
6	8
10	1
11	1
12	4
18	4
24	3
	25



Transitions
- one
- two
- three

Occurrence
- 6 most frequent
- 5 frequent (> 10%)
- 10 infrequent
- 28 does not occur


January 2003
April 2003
July 2003
October 2003
Actual dataset used:
Monthly latitudes, 1973-1996*
10° longitude bands
*Simmonds and Jacka, 1995
Cavalieri et al 1997, http://nsidc.org/data/nsidc-0051.html