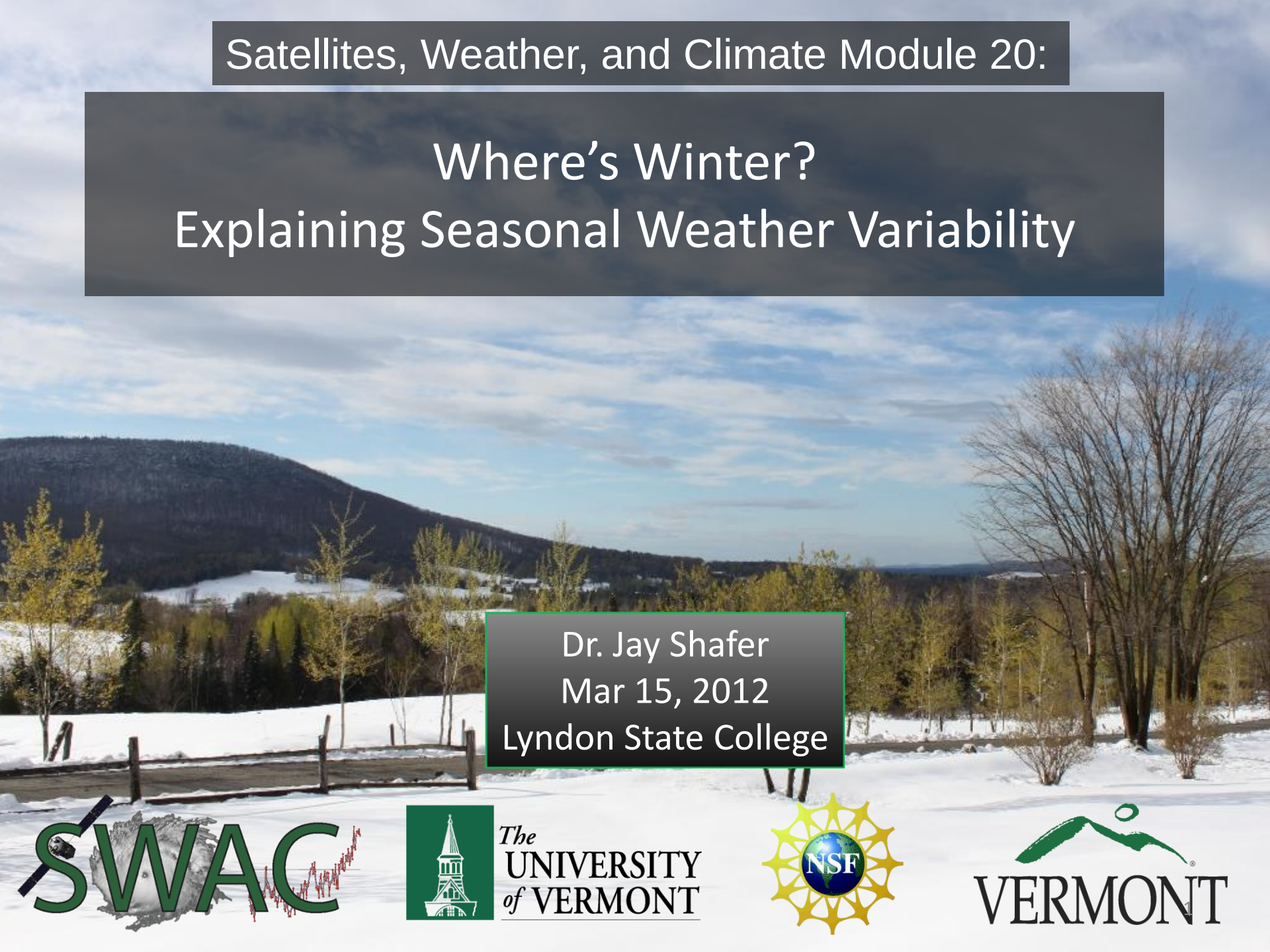
Satellites, Weather, and Climate Module 20:

Where's Winter?
Explaining Seasonal Weather Variability



Dr. Jay Shafer
Mar 15, 2012
Lyndon State College

SWAC

The UNIVERSITY of VERMONT

NSF

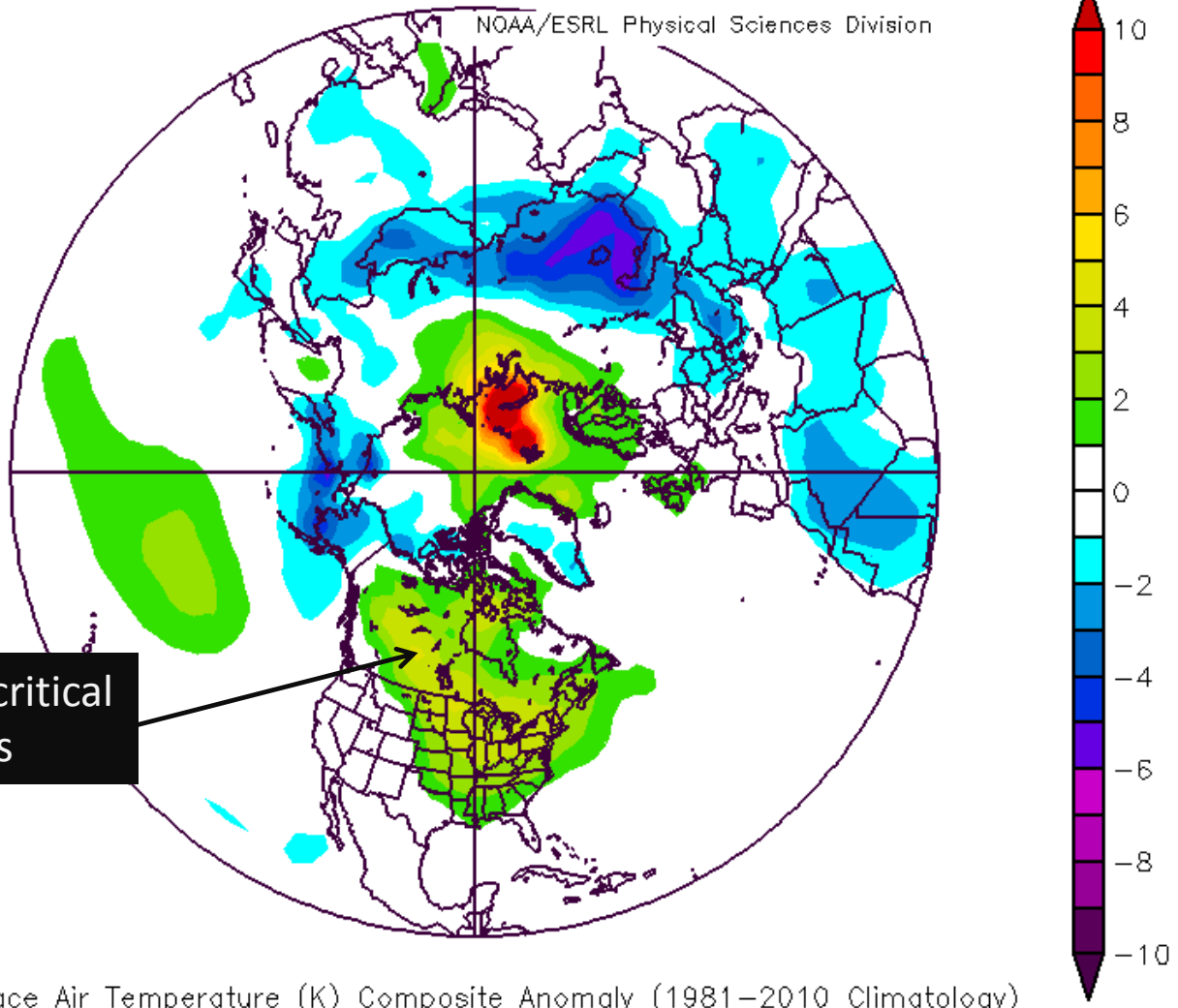
VERMONT

Outline

- Winter 2012 Rankings
- Possible Culprits
  - AO (Arctic Oscillation)
  - ENSO (El Nino Southern Oscillation)
- Climate Change Considerations

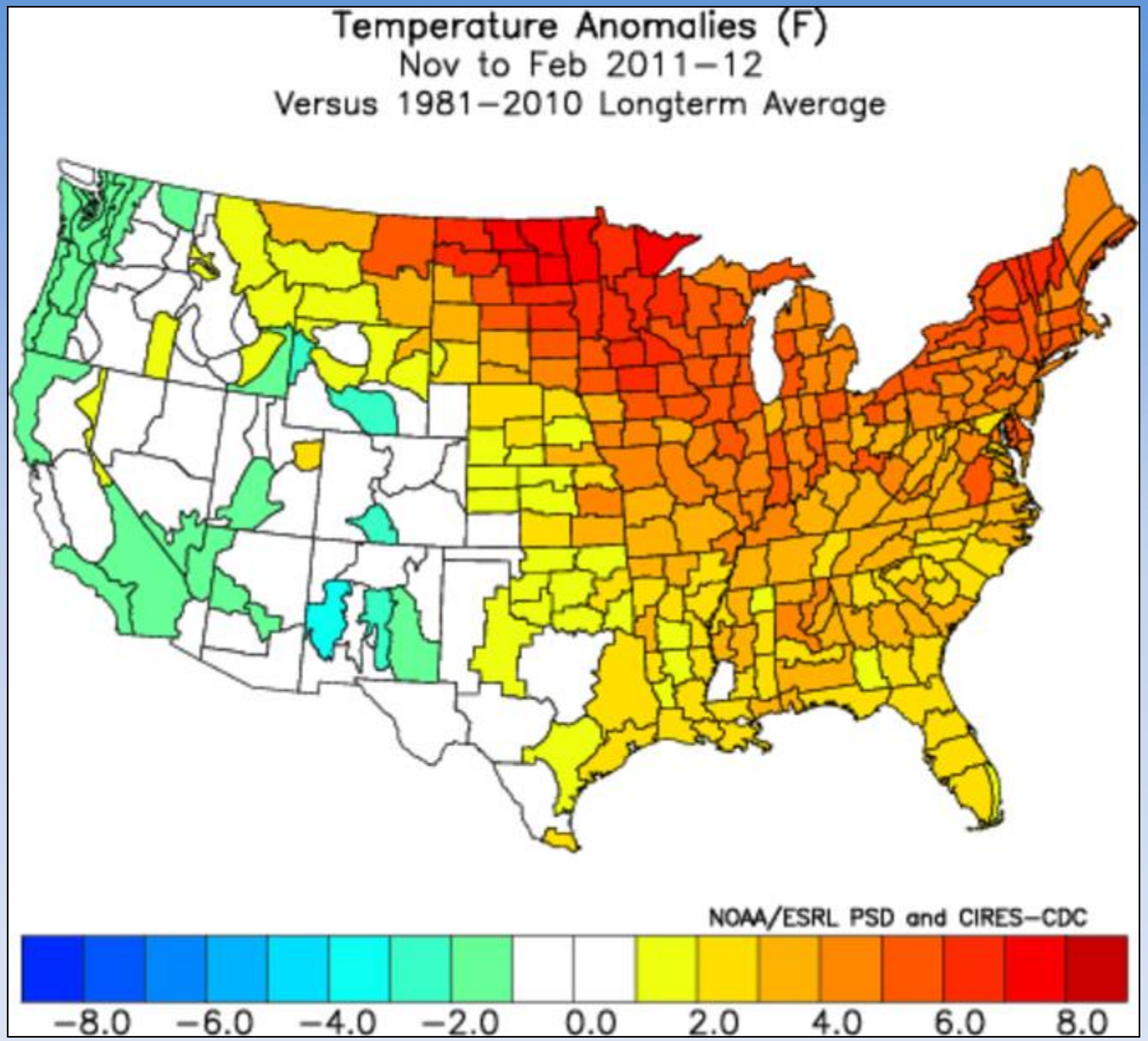
Winter 2011-2012 Stats

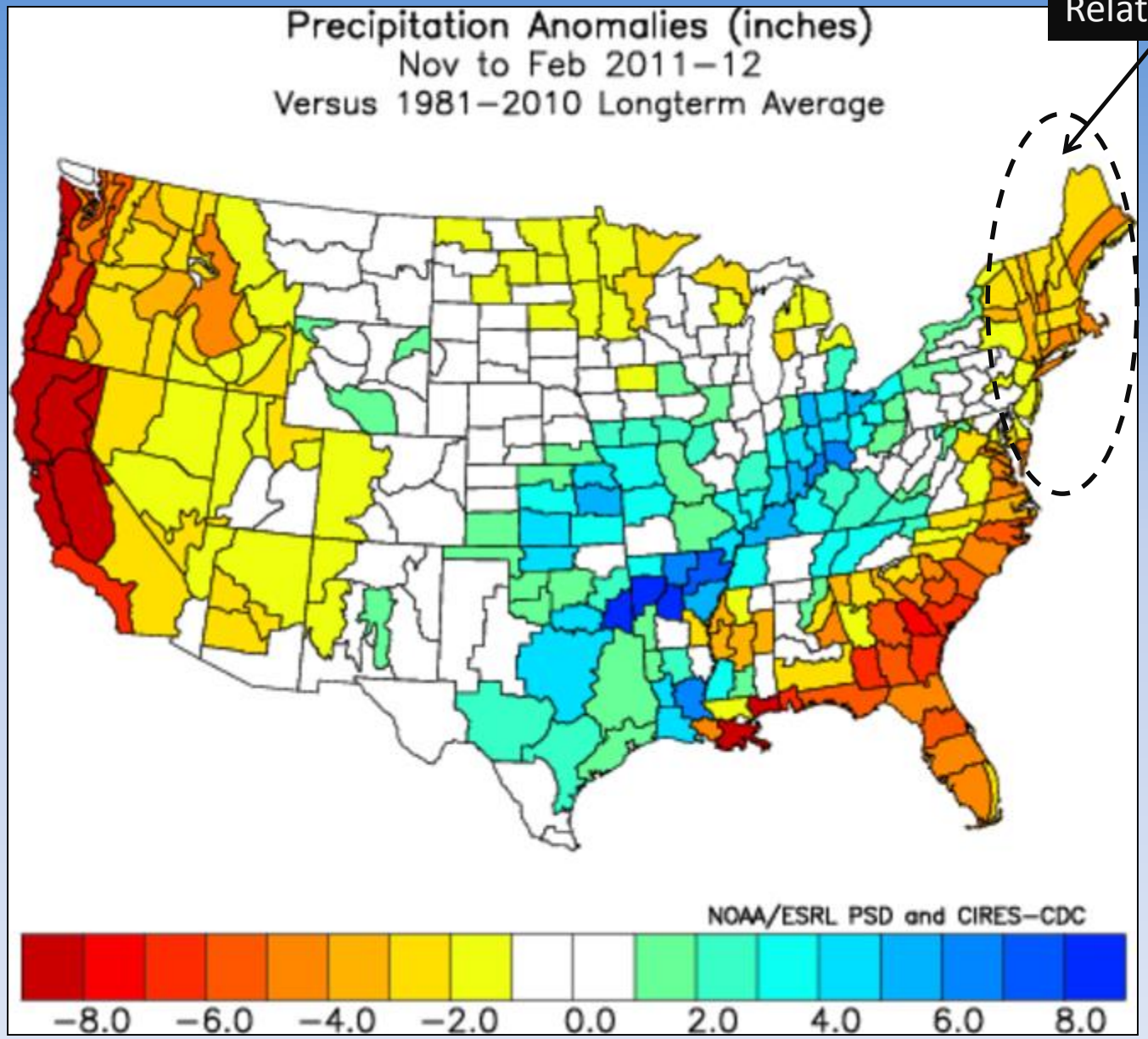
Temperature Anomaly: November to February 2012



Persistent warm over critical cold air source regions

Units: Degrees Celsius


Temperature Anomalies (F)
Nov to Feb 2011–12
Versus 1981–2010 Longterm Average
NOAA/ESRL PSD and CIRES–CDC
−8.0
−6.0
−4.0
−2.0
0.0
2.0
4.0
6.0
8.0


Relatively dry
Precipitation Anomalies (inches)
Nov to Feb 2011–12
Versus 1981–2010 Longterm Average
NOAA/ESRL PSD and CIRES–CDC
−8.0
−6.0
−4.0
−2.0
0.0
2.0
4.0
6.0
8.0

Snowfall Ranks

Mt. Mansfield Oct 1 – Mar 12 Snowfall

1	99.4	1964-1965
2	105.5	1958-1959
3	108.9	1955-1956
4	111.4	1982-1983
5	115.3	1956-1957
6	118.4	1961-1962
7	118.6	2011-2012
8	122.1	1960-1961
9	128.4	1986-1987
10	128.7	1979-1980

Records back to 1954

Burlington Oct 1 – Mar 12 Snowfall

1	28.4	1979-1980
2	30.5	1988-1989
3	37.7	2011-2012
4	40.1	1990-1991
5	40.4	1948-1949
6	40.7	1960-1961
7	41.3	1964-1965
8	42.4	2001-2002
9	42.9	1950-1951
10	47.6	1944-1945

Records back to 1943

Temperature Ranks:
Average Mean Temperature Nov 1- Mar 12

Montpelier

1	29.2	2001-2002
2	28.4	2011-2012
3	28.1	1948-1949
4	27.9	2009-2010
5	27.4	1982-1983
6	27.0	1974-1975
7	26.9	1973-1974
8	26.6	2005-2006
9	26.6	1994-1995
10	26.3	1953-1954

Records back to 1948

Burlington

1	32.4	2001-2002
2	31.9	2011-2012
3	30.1	1948-1949
4	29.9	1982-1983
5	29.4	2009-2010
6	29.0	2005-2006
7	28.9	1994-1995
8	28.9	1990-1991
9	28.5	1953-1954
10	28.5	1952-1953

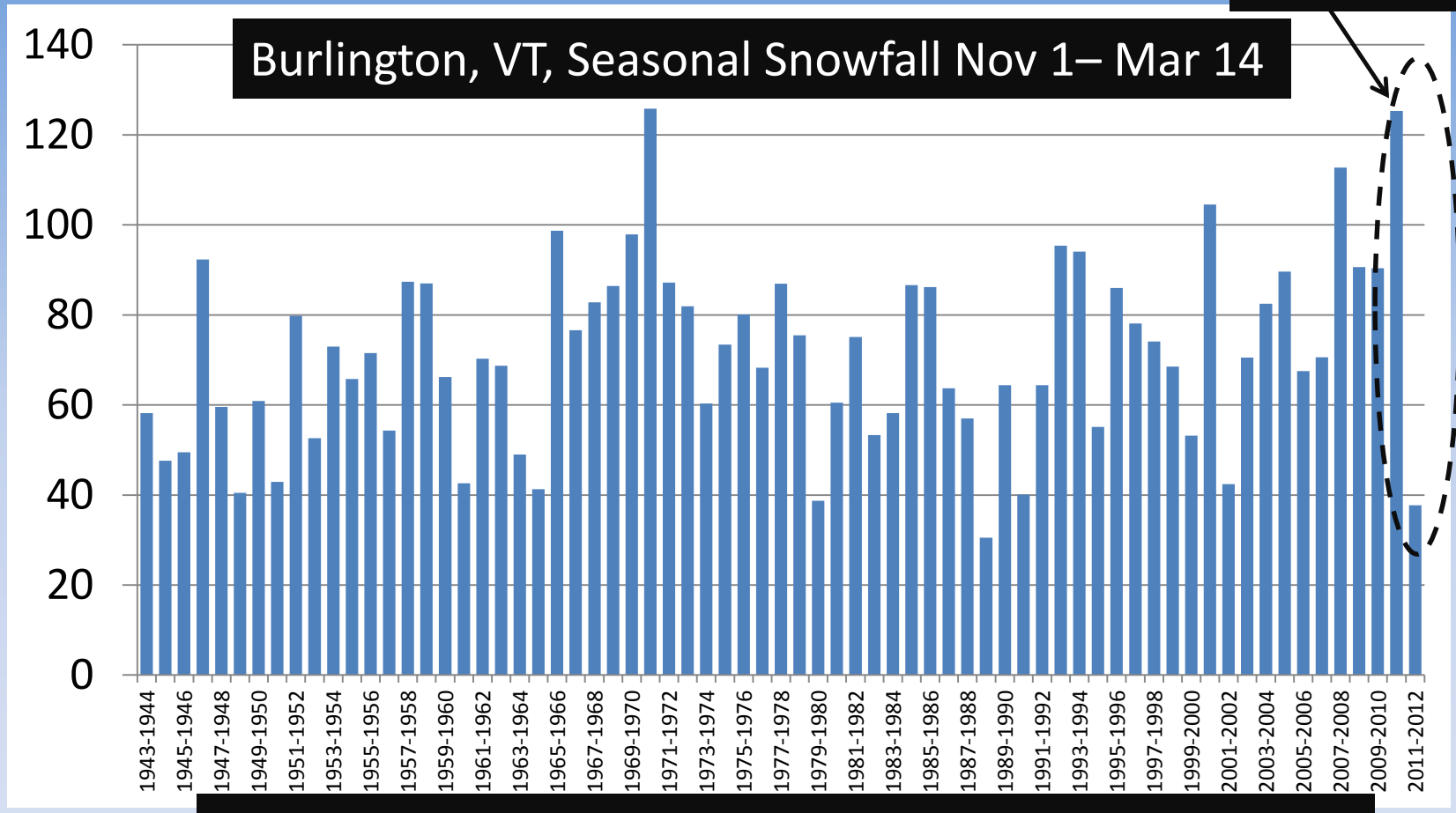
Records back to 1940

St. Johnsbury

1	30.6	2001-2002
2	29.9	1948-1949
3	29.2	1982-1983
4	28.4	1931-1932
5	28.3	2009-2010
6	28.2	1950-1951
7	27.7	2011-2012
8	27.7	1932-1933
9	27.6	1997-1998
10	27.6	2005-2006

Records back to 1894

Seasonal Variability



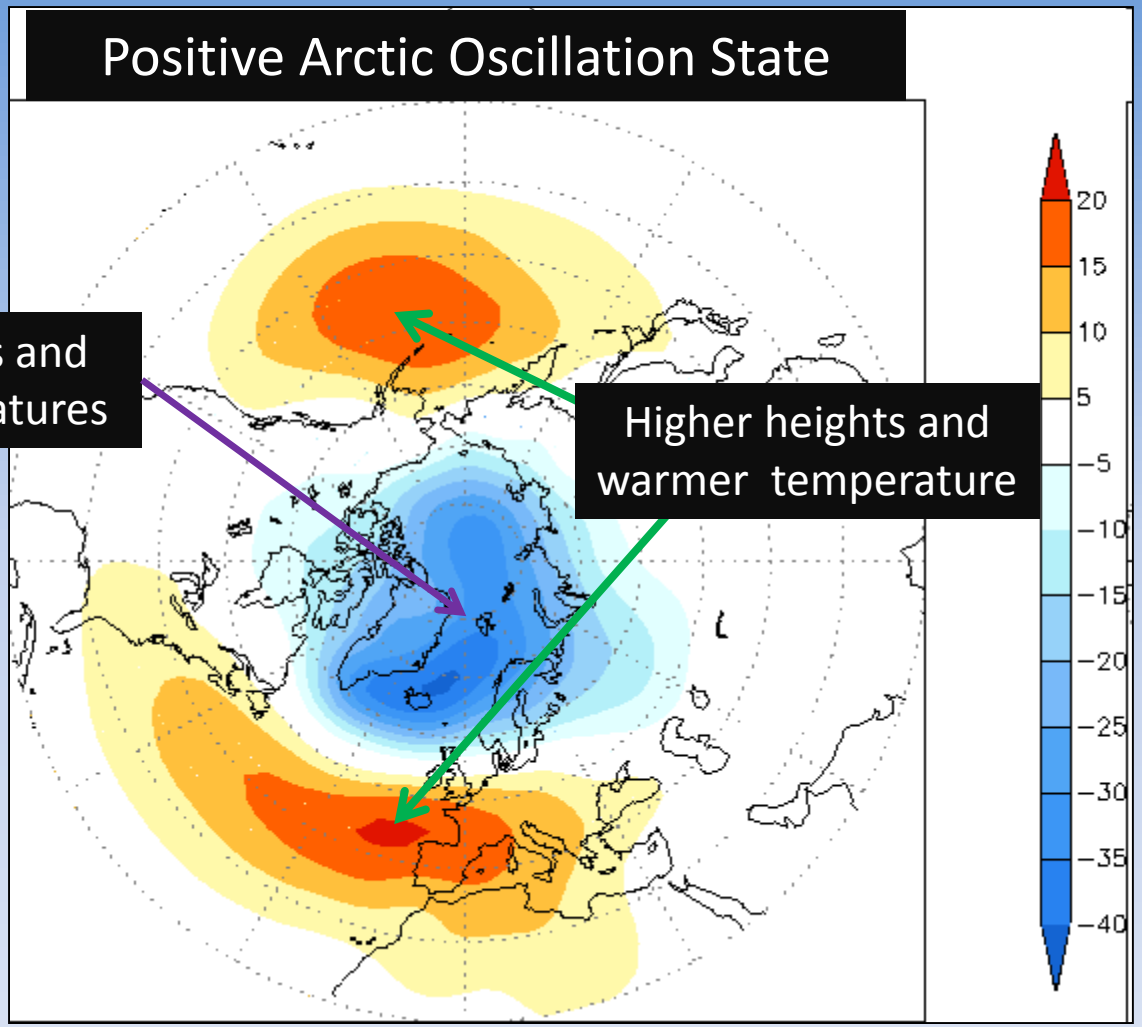
How can one explain year-to-year variations?

Arctic Oscillation

Arctic Oscillation

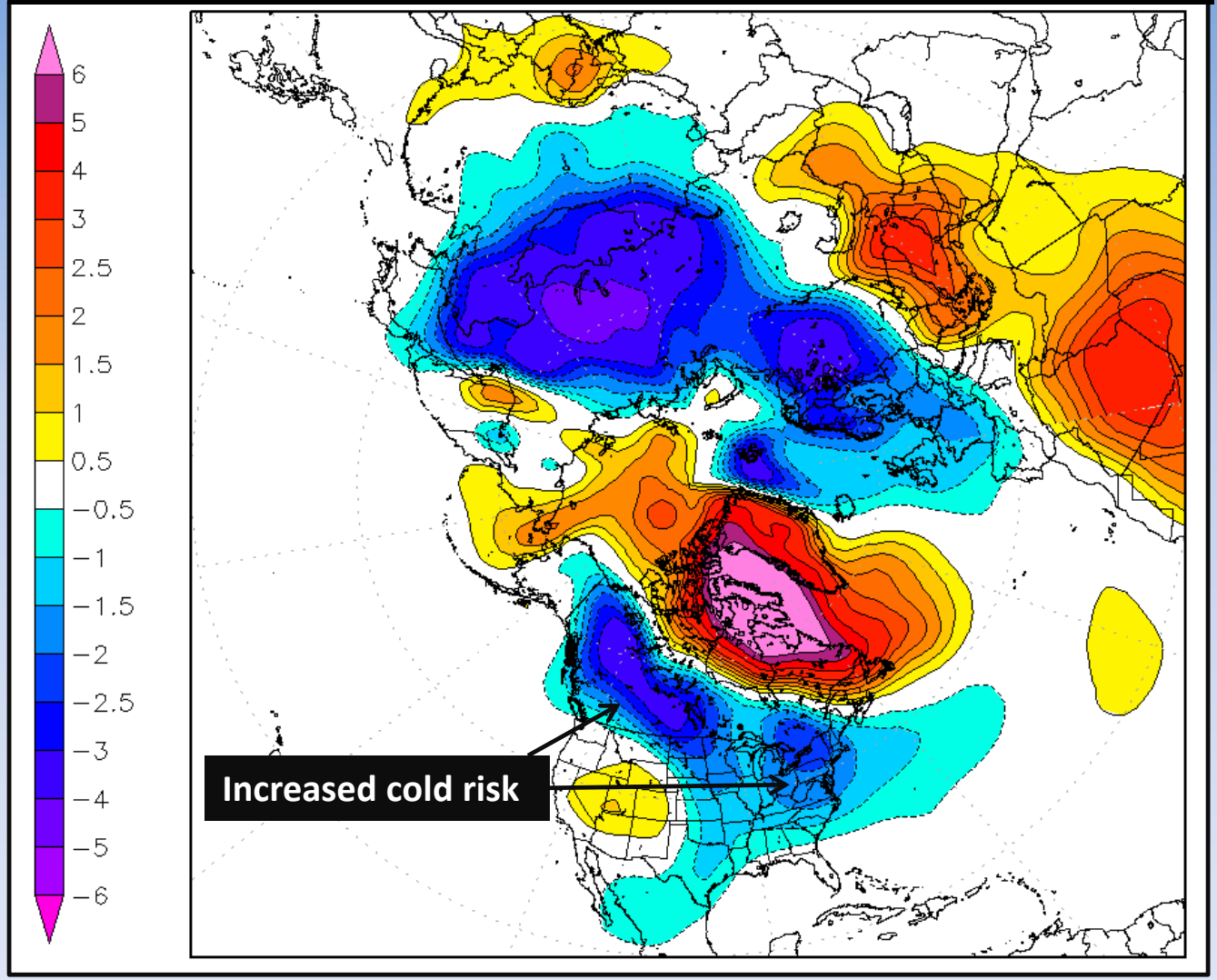
- Describes high latitude pressure pattern oscillations (atmospheric oscillation)
- Derived from principal pattern of variability in low tropospheric (low level) atmospheric pressure patterns
- Most influential during winter season
- Can help to lock in long-lived (weeks to months) patterns that influence seasonal conditions
- Predictable one to two weeks ahead

Anomaly pattern associated with Arctic Oscillation (AO)

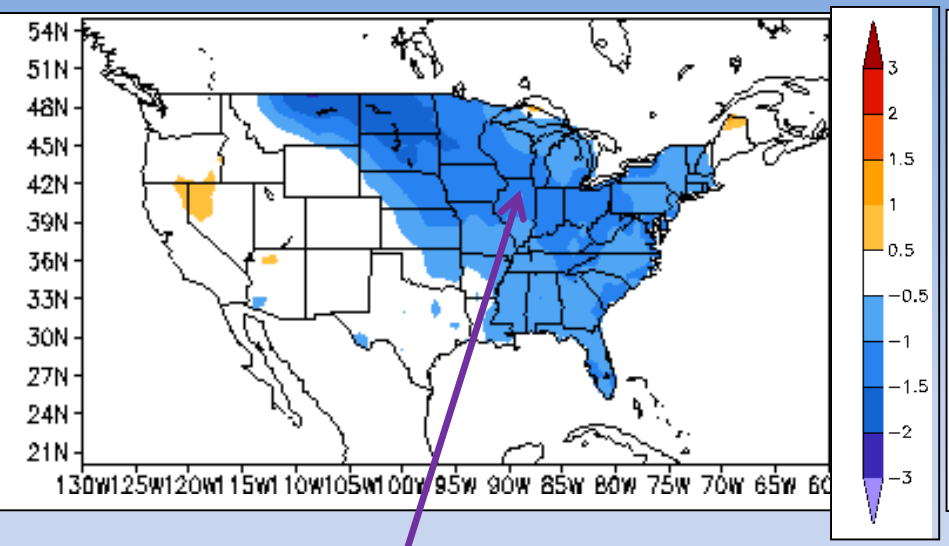


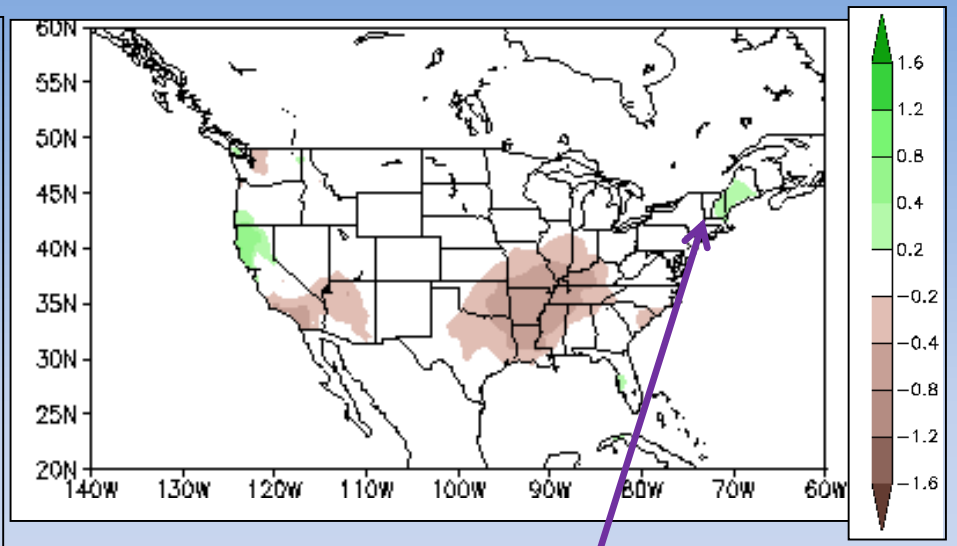
Source: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/loading.html

Surface Temperature Anomaly (Deg C)
+5 to +10 days after (–) AO transitions



AO Negative Phase Conditions



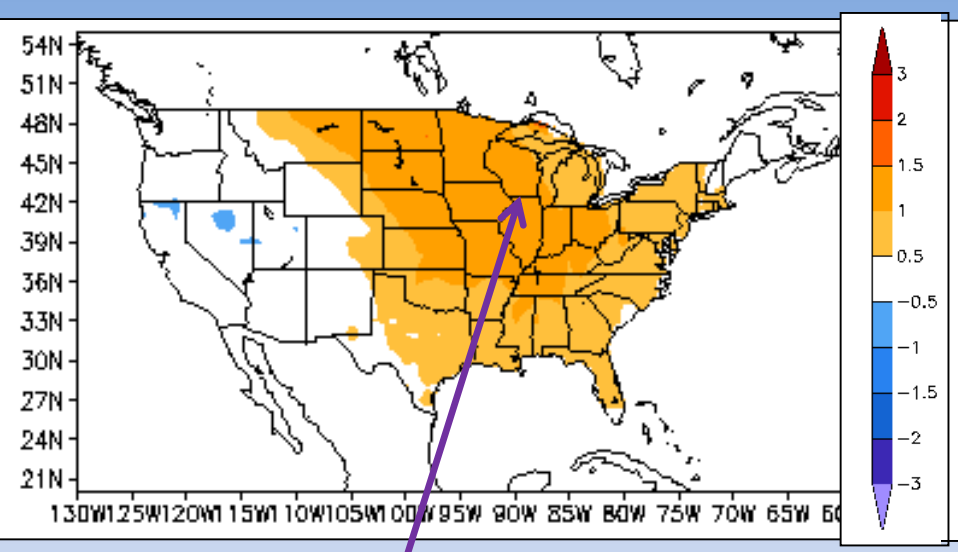


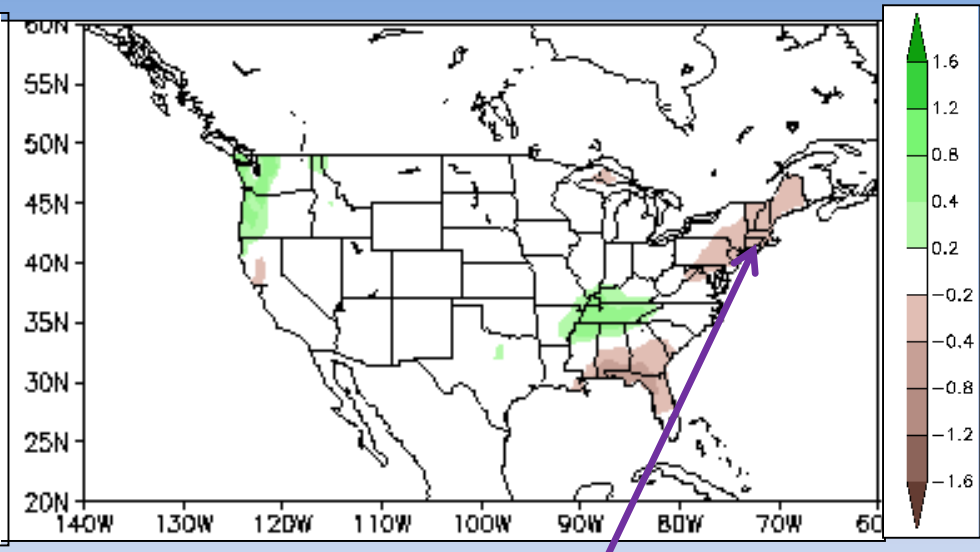
Colder temperatures

Slightly wetter

Source: http://www.cpc.noaa.gov/research_papers/ncep_cpc_atlas/8/table_ao.html

AO Positive Phase Conditions



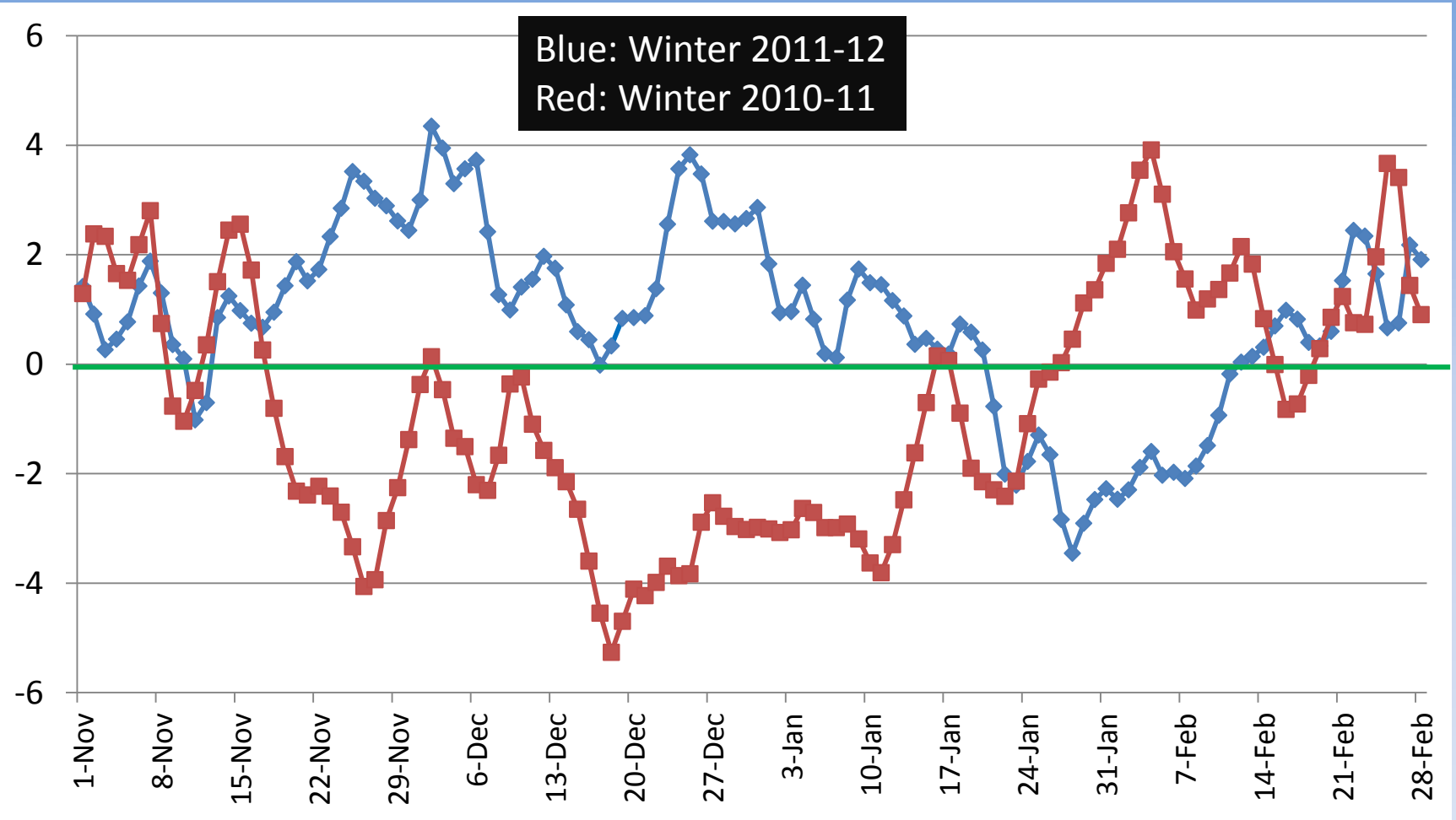


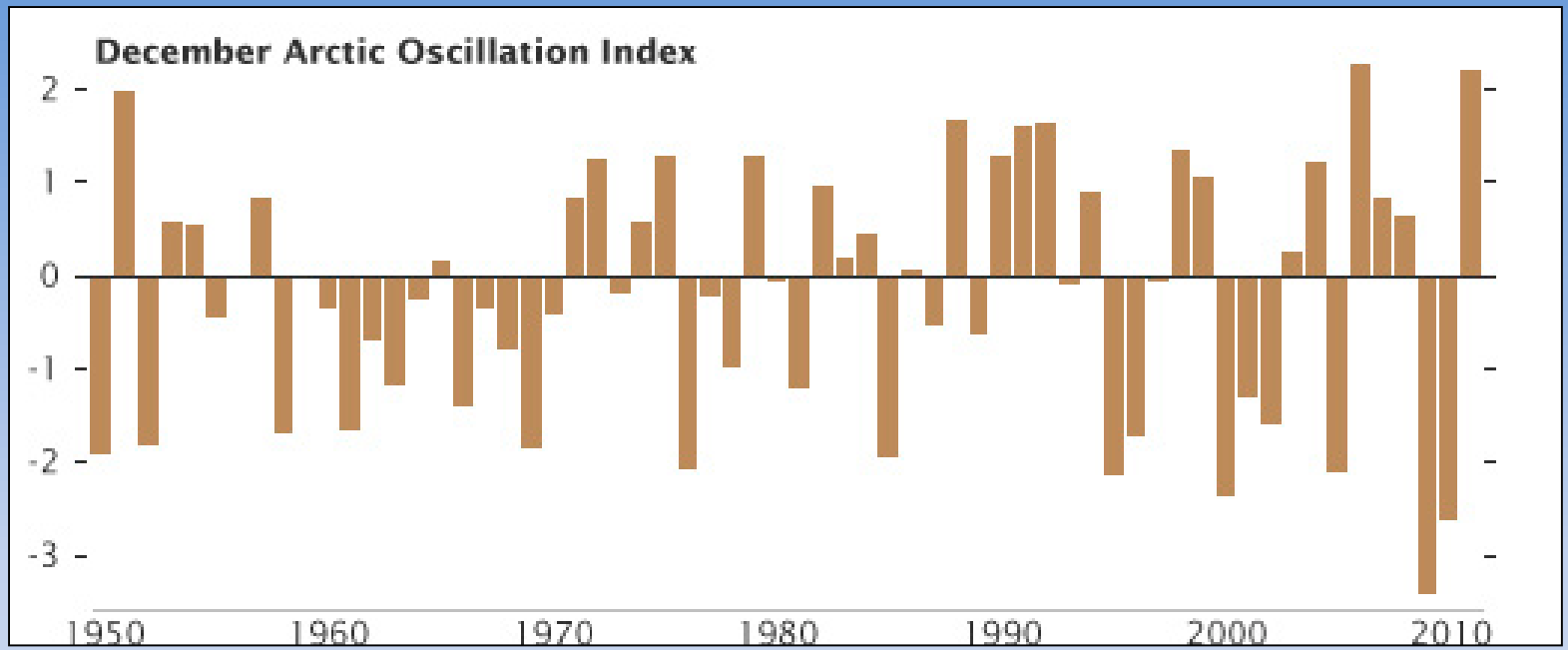
Warmer temperatures

Drier

Source: http://www.cpc.noaa.gov/research_papers/ncep_cpc_atlas/8/table_ao.html

AO Year-to-Year Variability

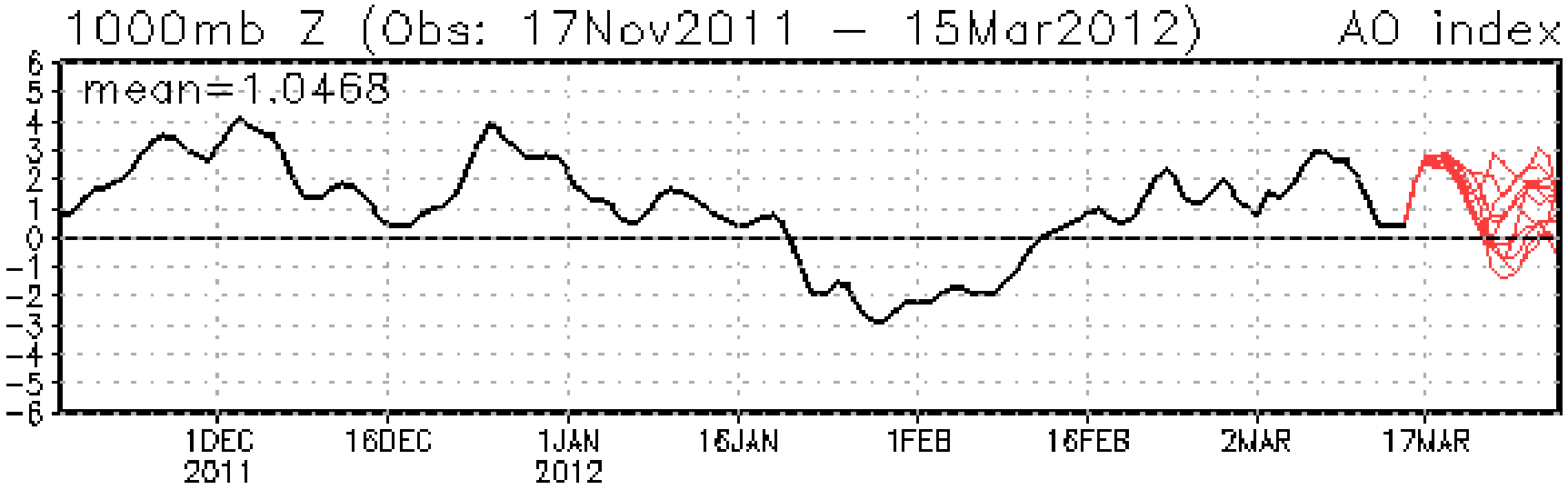




What causes the AO to be positive one December and negative another?
We don't fully understand – it's very complex!

NASA: http://earthobservatory.nasa.gov/IOTD/view.php?id=77076&src=eoa-iotd

Observed AO (solid line) and Forecasts (Red lines)

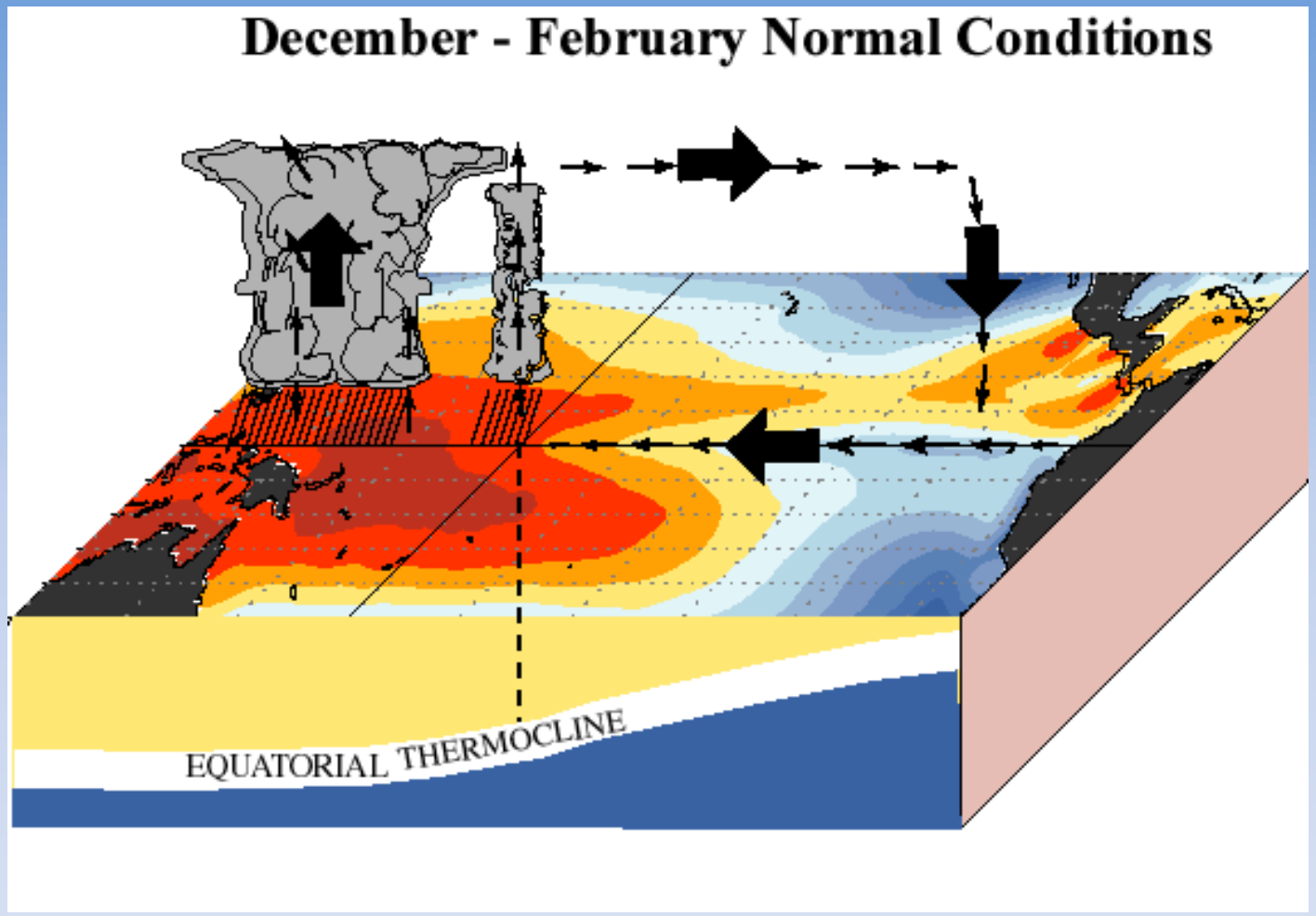


http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao_index_ensm.shtml

ENSO

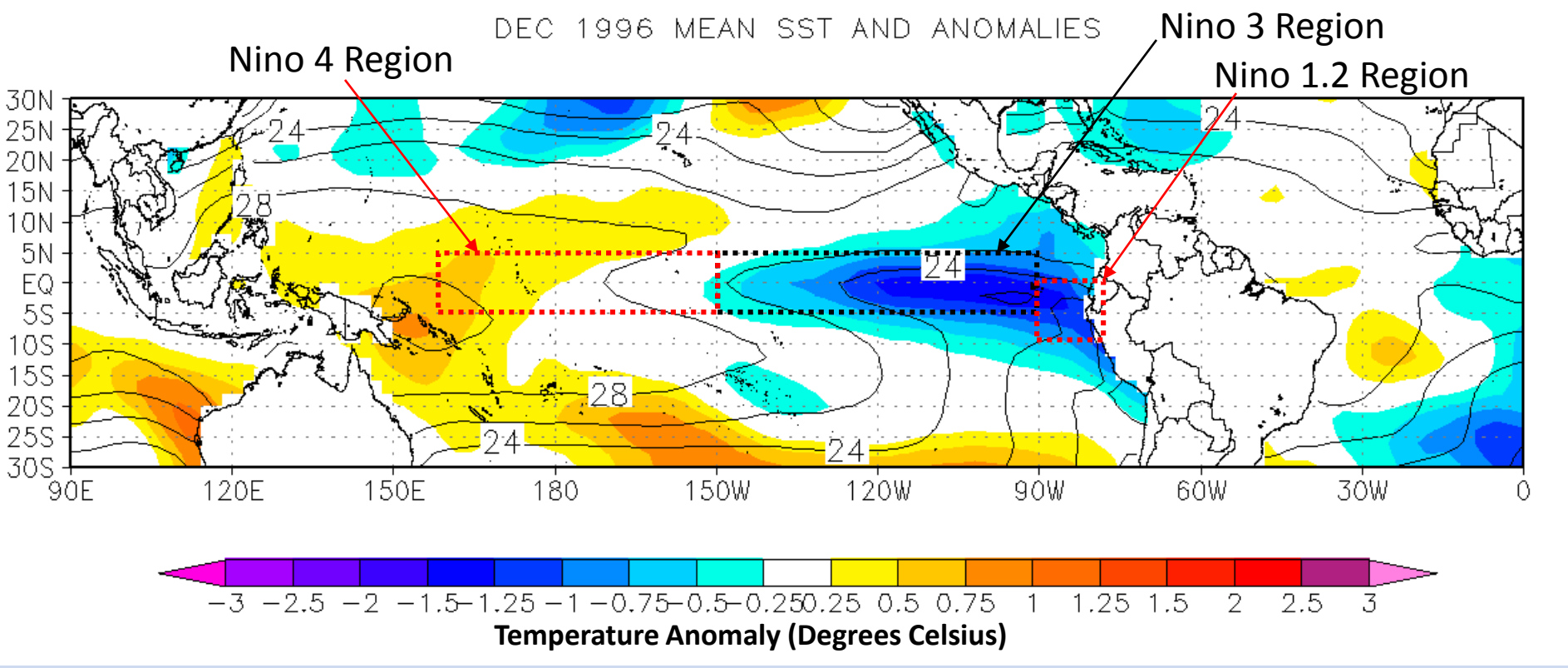
EL Nino – Southern Oscillation

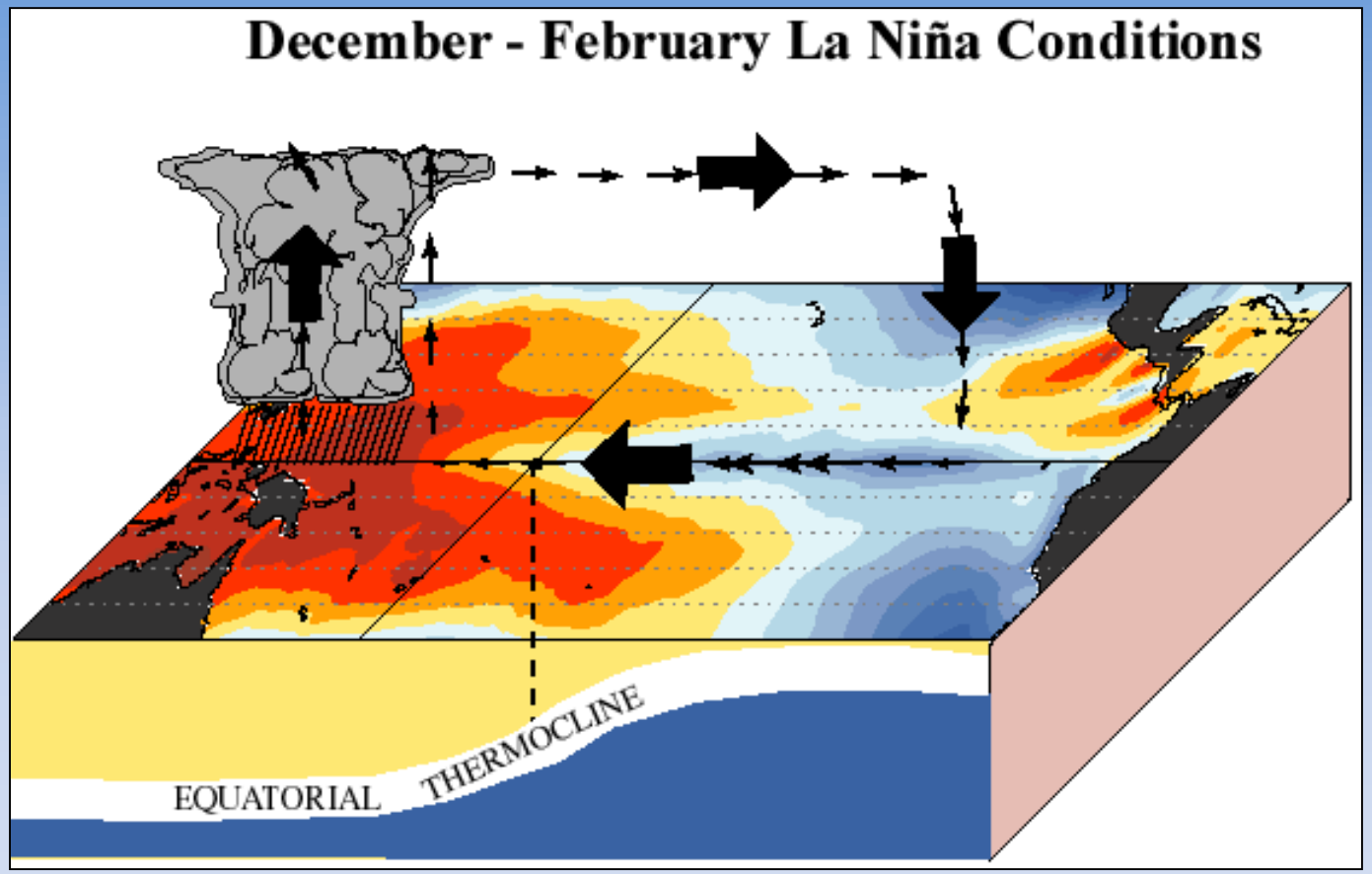
- Oceanic oscillation of equatorial sea surface temperatures (SST) in Pacific Ocean
- Southern Oscillation: refers to atmospheric response to oceanic fluxes of heat and moisture (oceans lead the atmosphere)
- Largest and most significant oscillation of SSTs in the world
- Has significant impacts on global circulation



Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.shtml

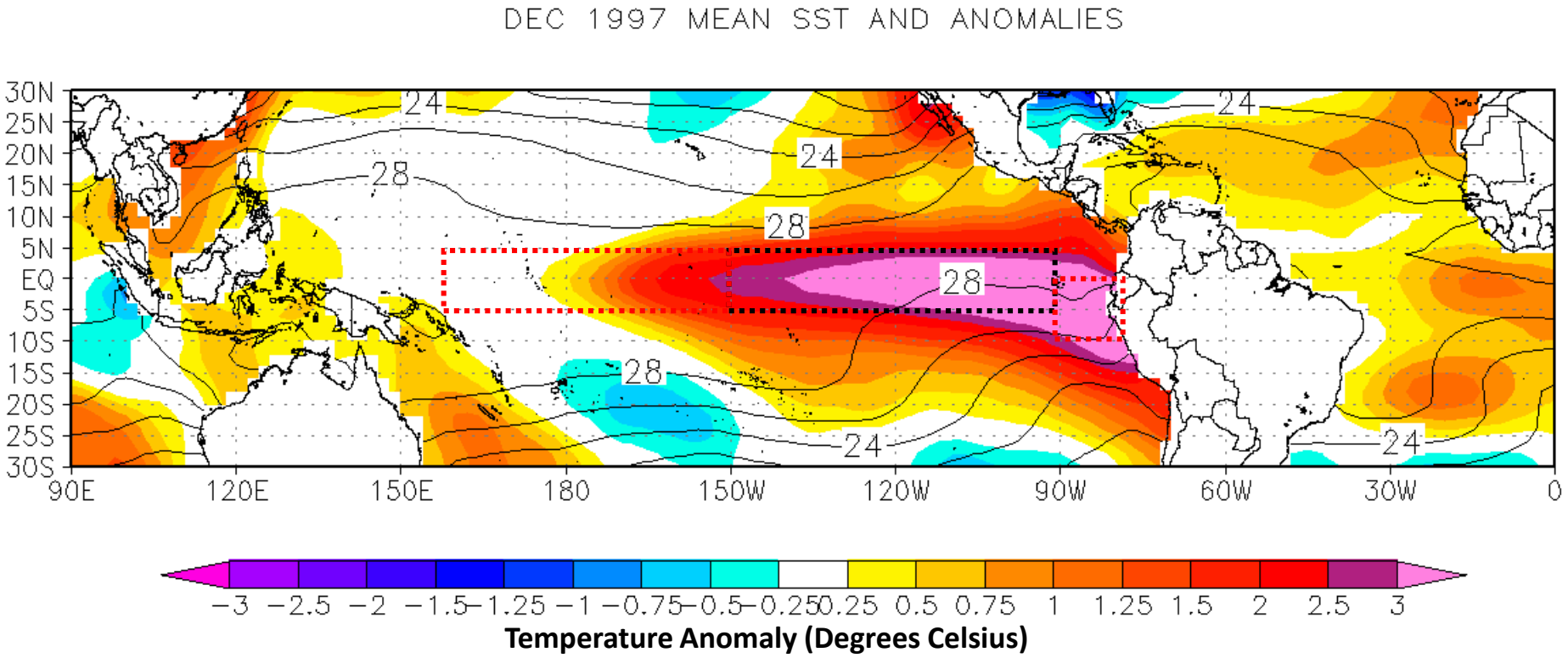
Example La Nina (cold phase) Conditions

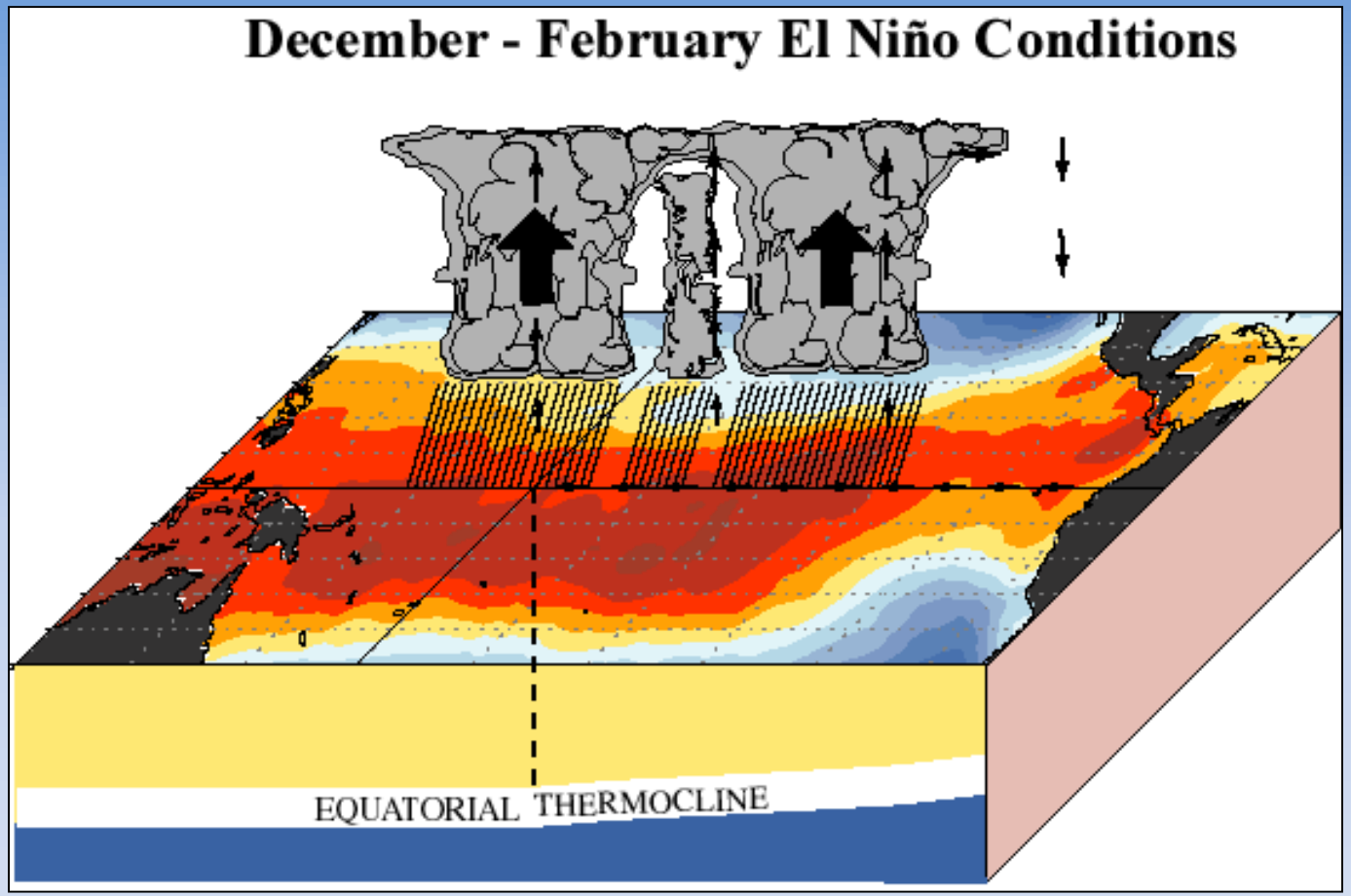




Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.shtml

Example El Nino (warm phase) Conditions

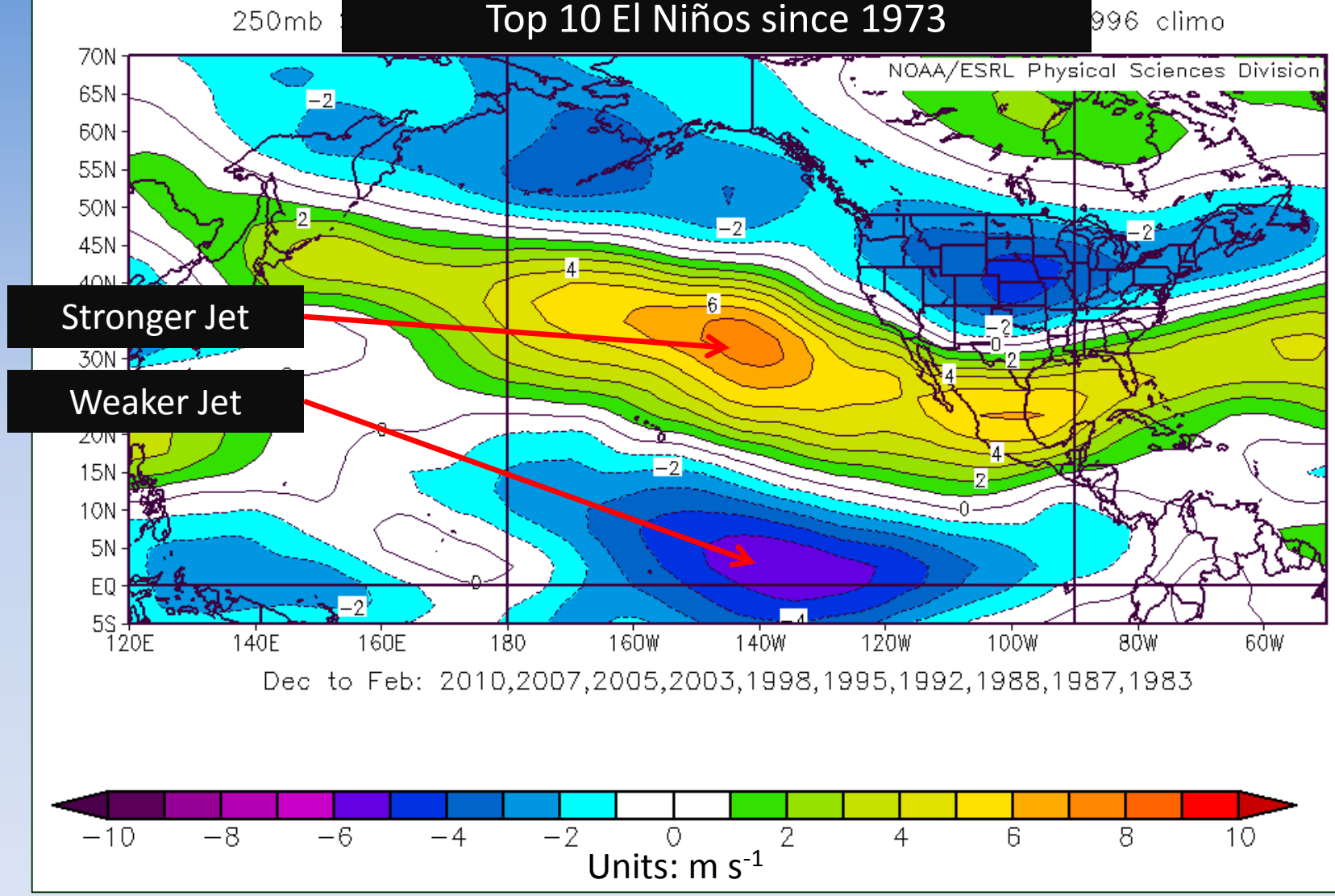




Source: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.shtml

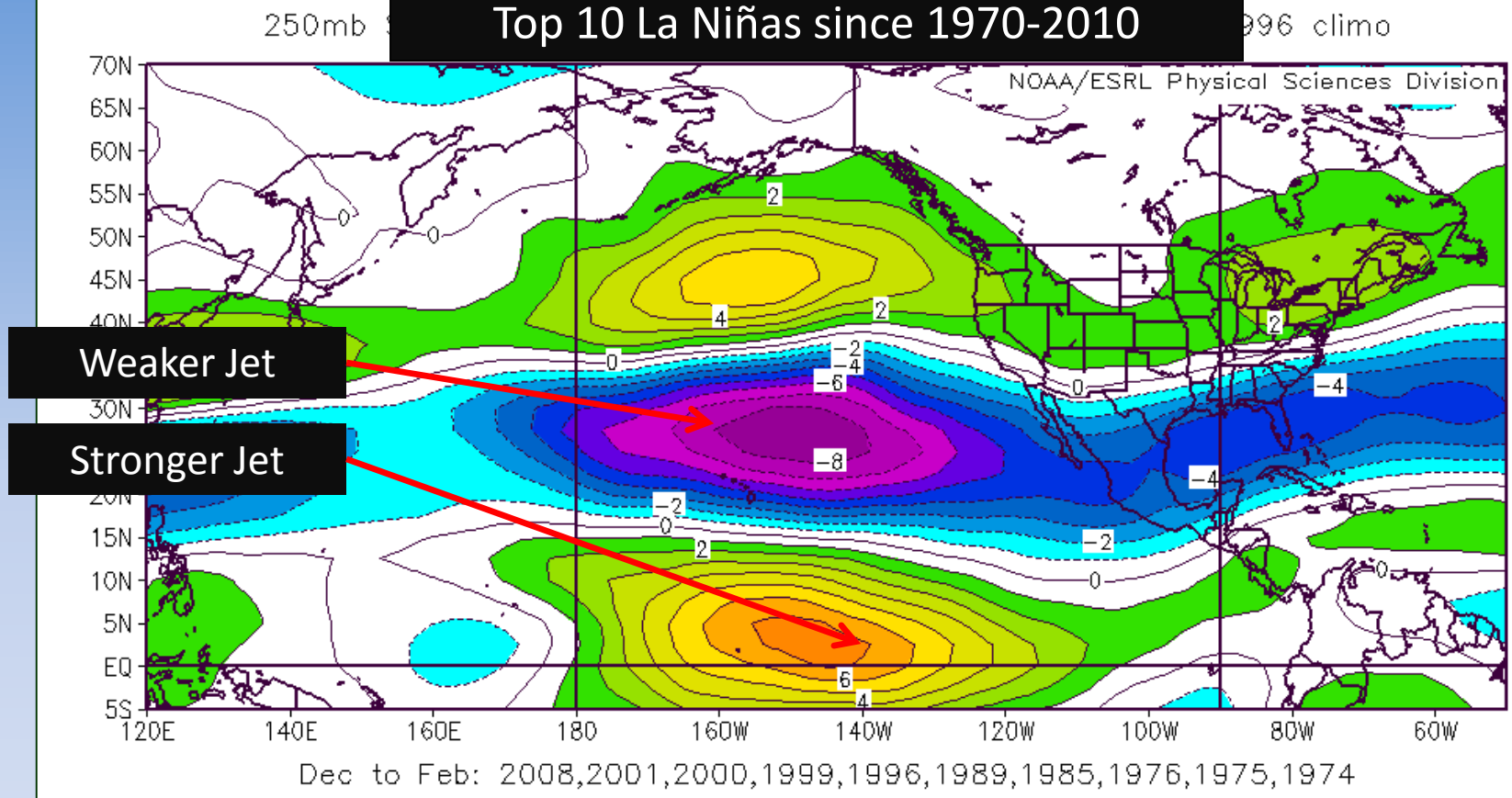
El Nino Winter Jet Stream Wind Anomaly

Top 10 El Niños since 1973



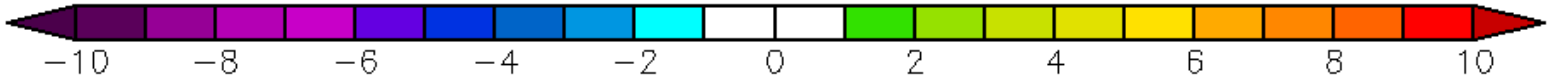
La Nina Winter Jet Stream Wind Anomaly

Top 10 La Niñas since 1970-2010



Weaker Jet

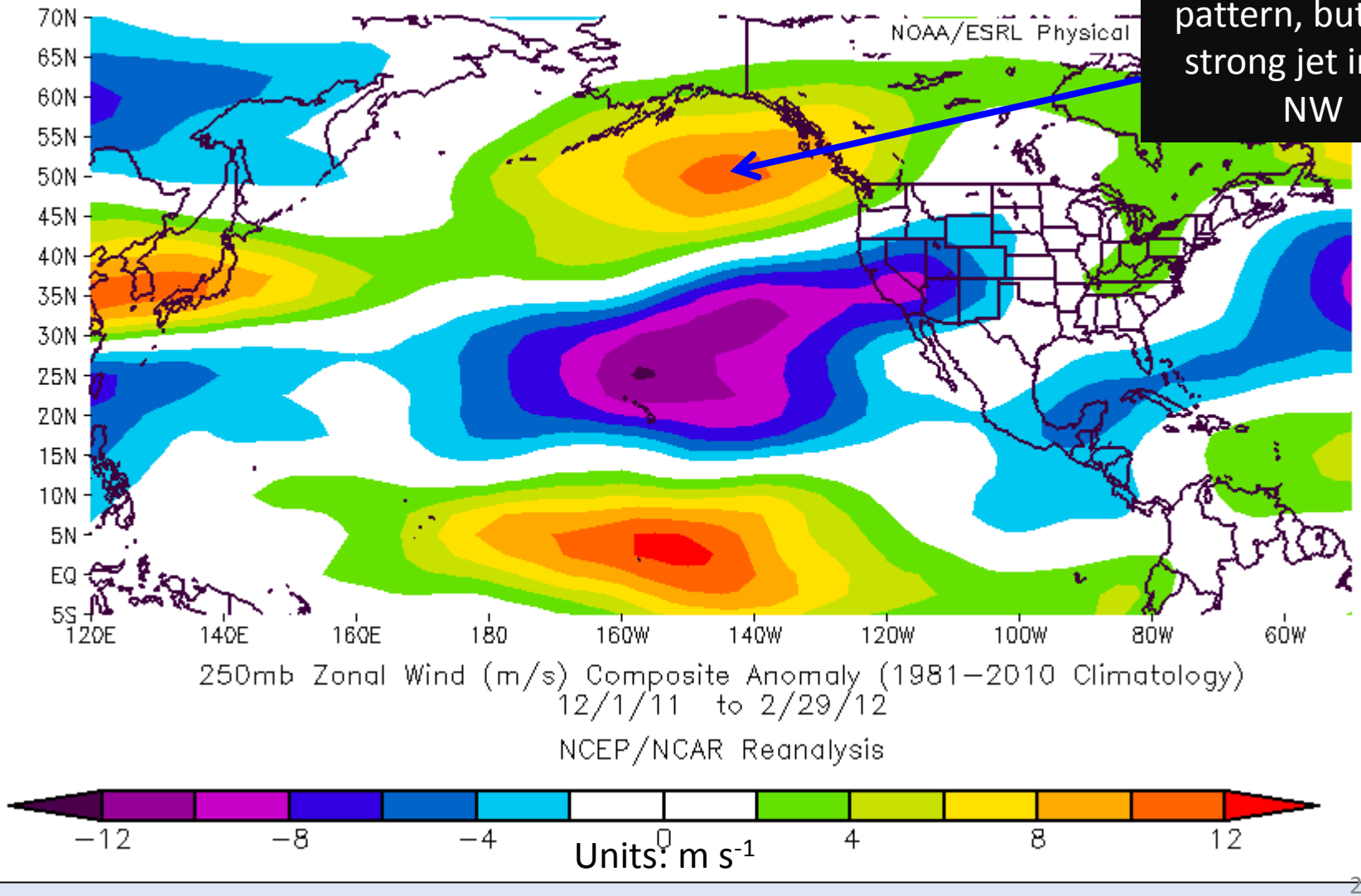
Stronger Jet



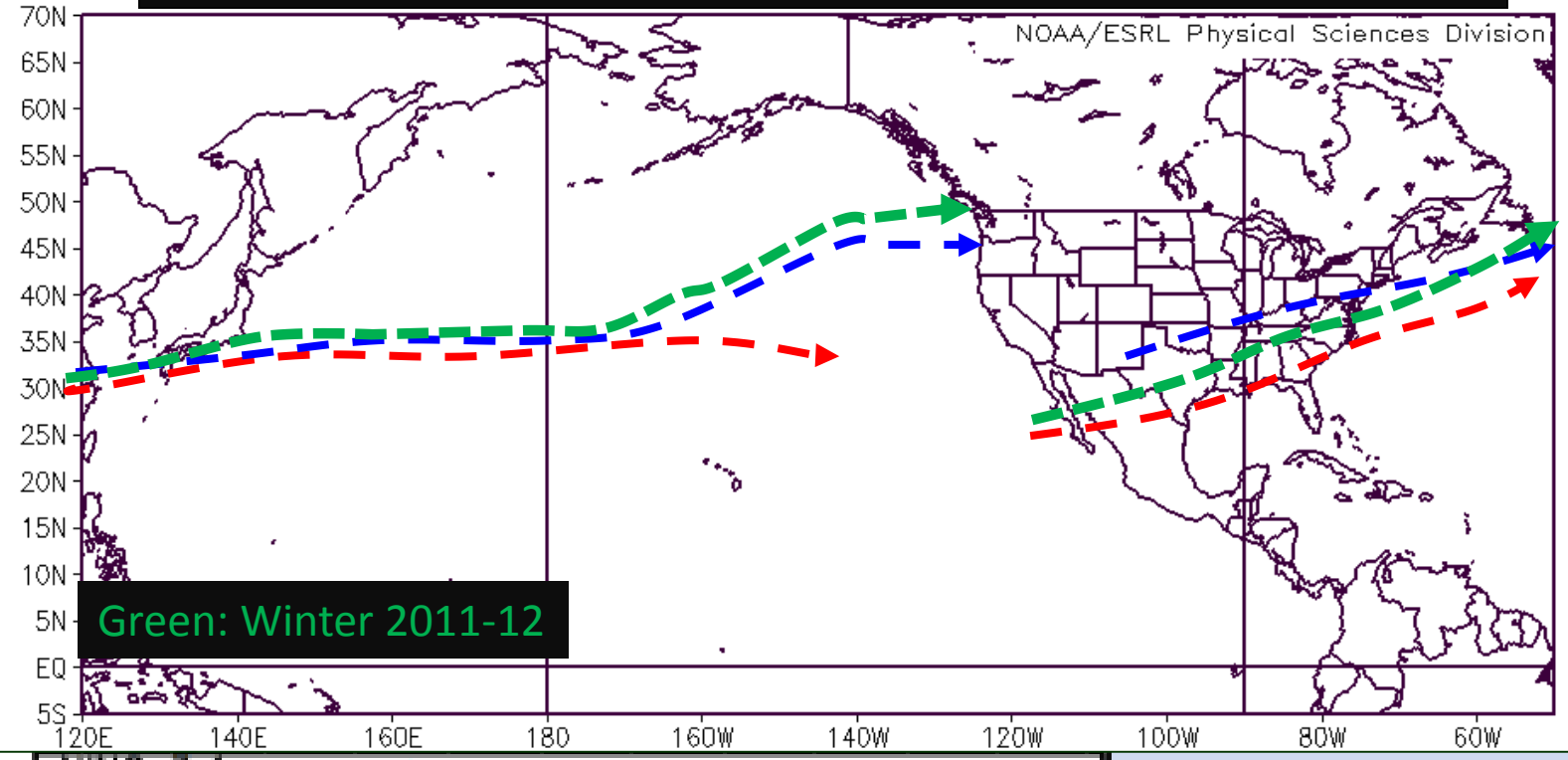
Units: m s^{-1}

Winter 2011-12 Jet Stream Speed Anomaly

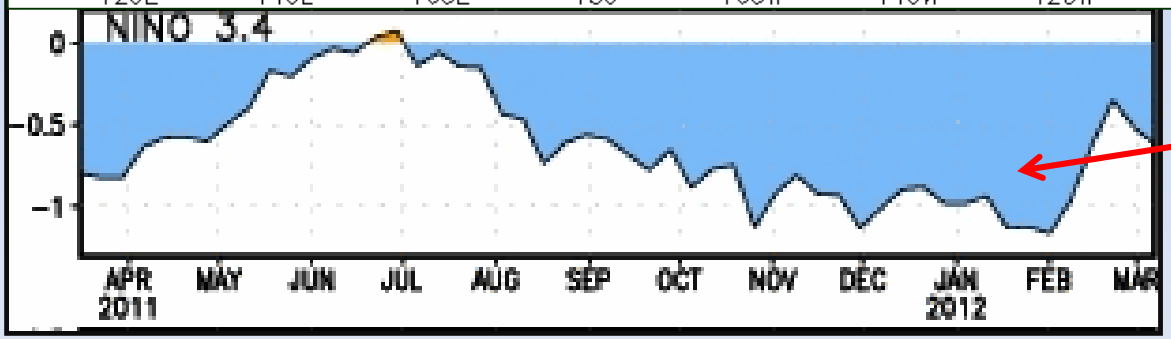
Typical La Nina pattern, but note strong jet in Pac NW



Winter Mean Jet Stream Positions
Red: Strong El Nino: Blue Strong La Nina

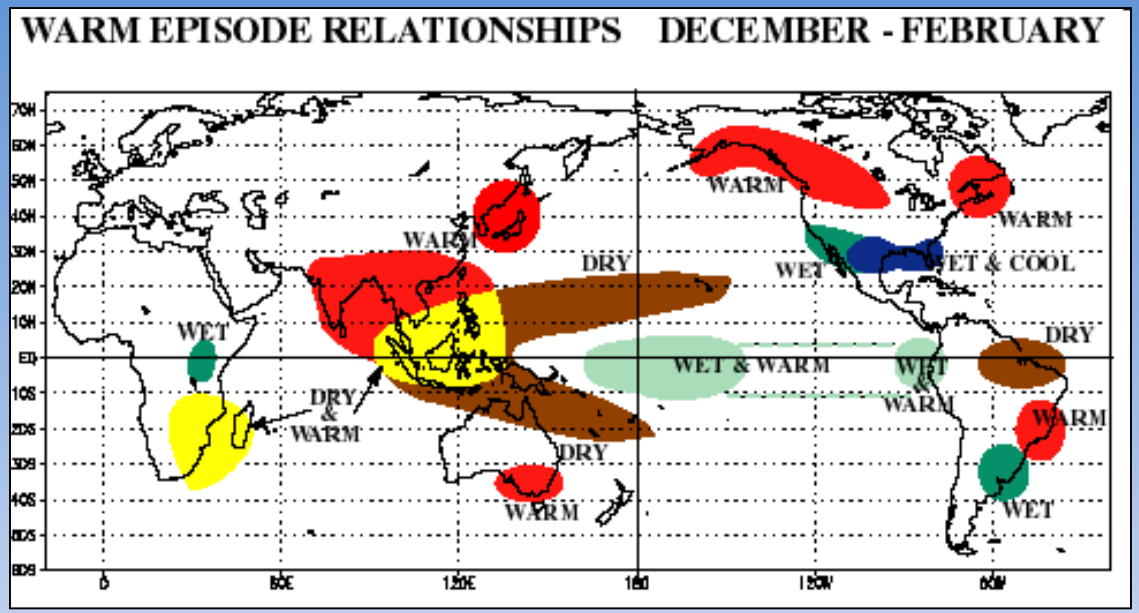


Green: Winter 2011-12

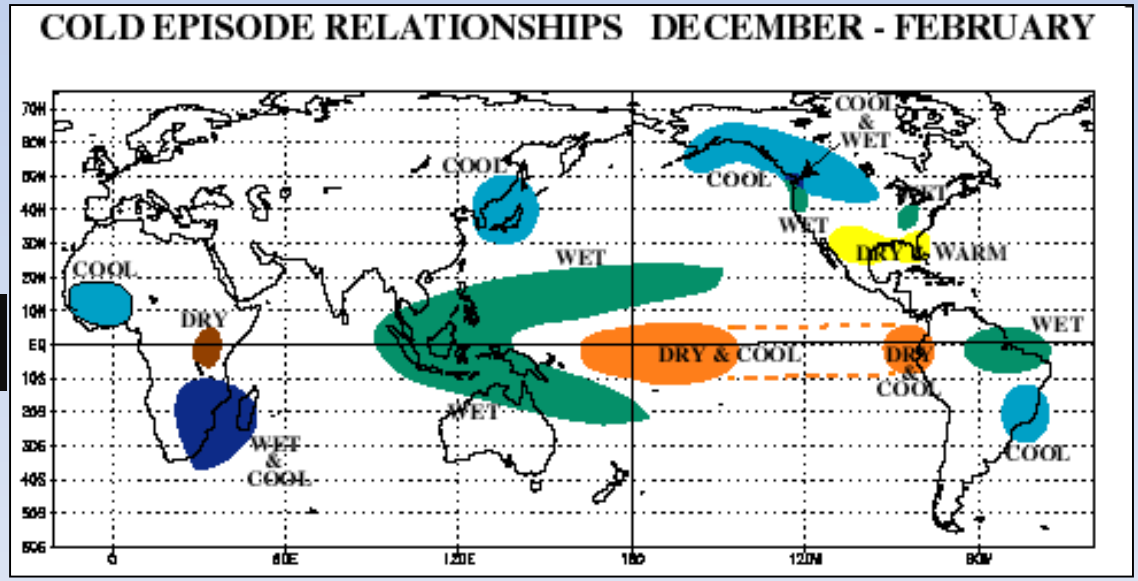


La Nina this winter.

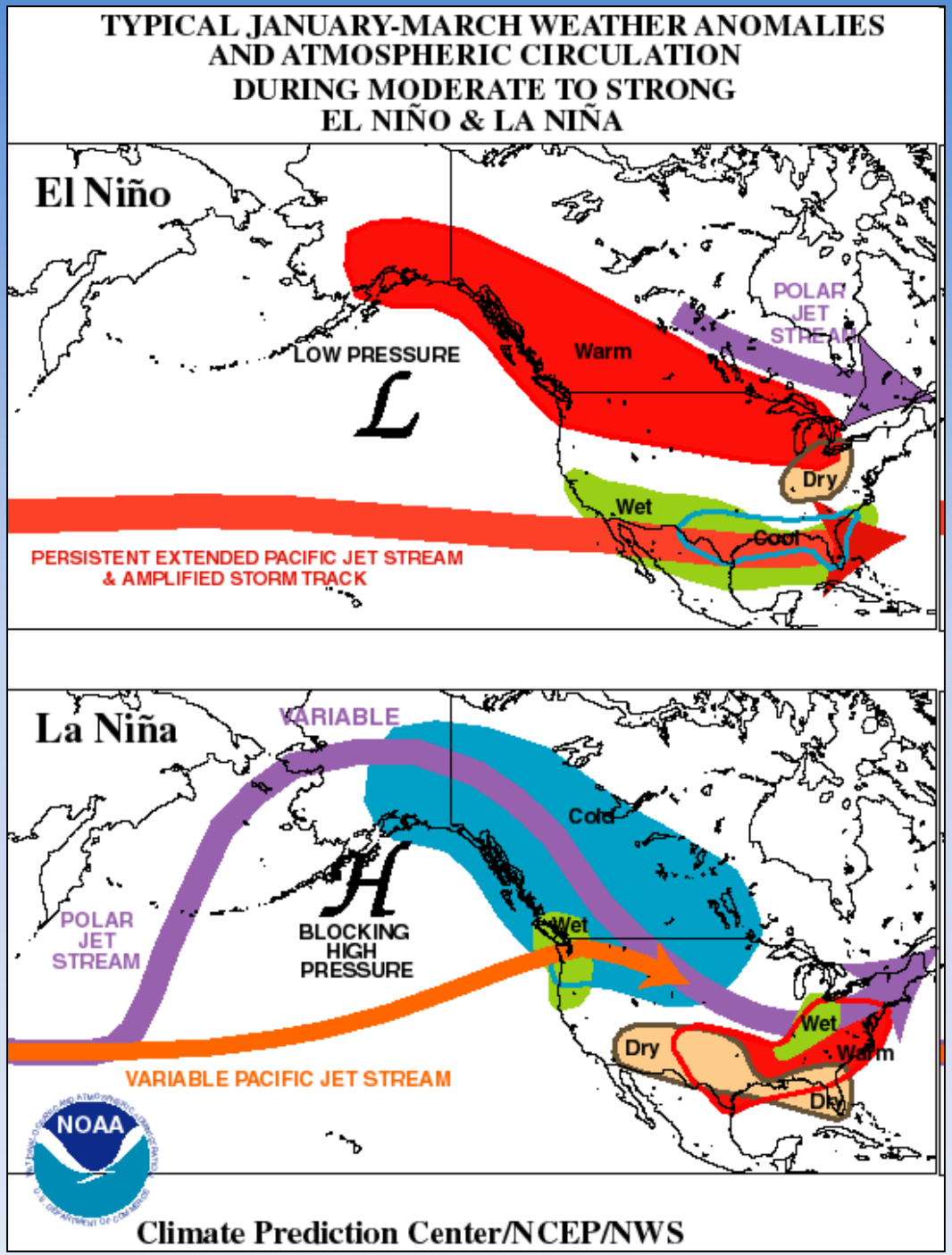
El Nino:



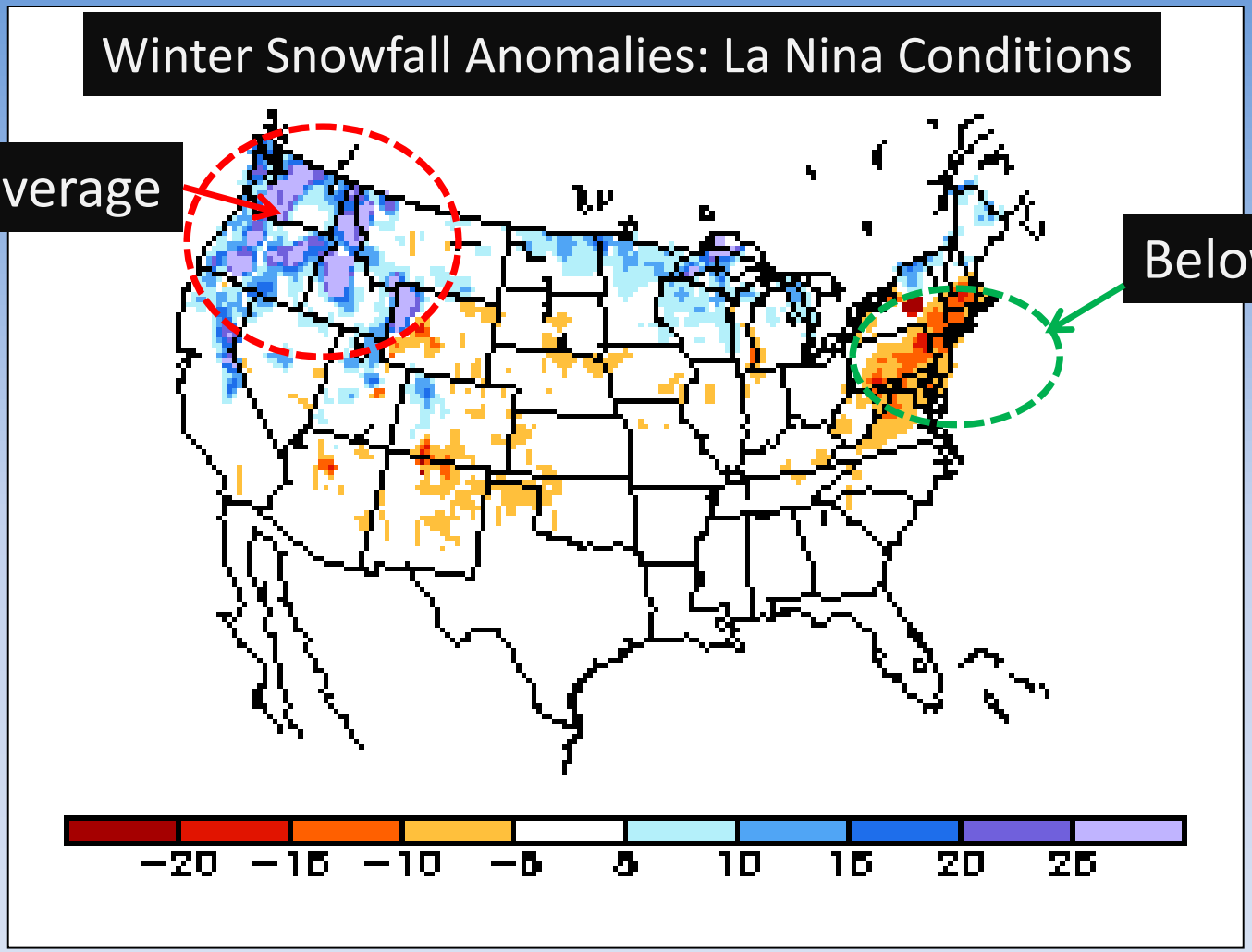
La Nina:



Source: NOAA - http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml#GLOBALimpacts

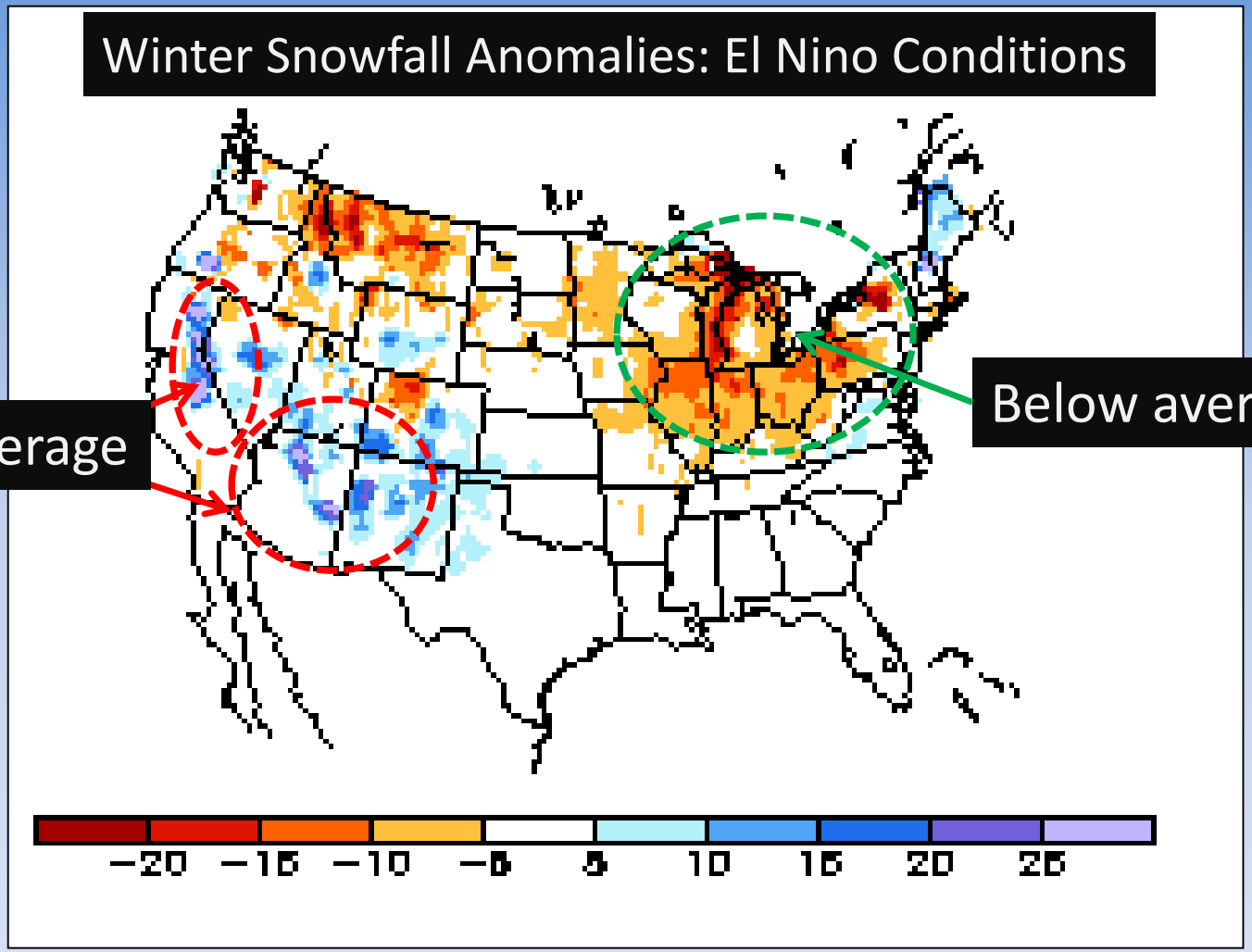

TYPICAL JANUARY-MARCH WEATHER ANOMALIES
AND ATMOSPHERIC CIRCULATION
DURING MODERATE TO STRONG
EL NIÑO & LA NIÑA
El Niño
LOW PRESSURE
L
Warm
POLAR
JET
STREAM
Dry
Wet
Cool
PERSISTENT EXTENDED PACIFIC JET STREAM
& AMPLIFIED STORM TRACK
La Niña
VARIABLE
Cold
H
POLAR
JET
STREAM
BLOCKING
HIGH
PRESSURE
Wet
Wet
Dry
Warm
Dry
VARIABLE PACIFIC JET STREAM
NOAA
Climate Prediction Center/NCEP/NWS

Winter Snowfall Anomalies: La Nina Conditions



NOAA: http://www.cpc.noaa.gov/products/analysis_monitoring/lanina/us_impacts/ustp_impacts.shtml#NVC

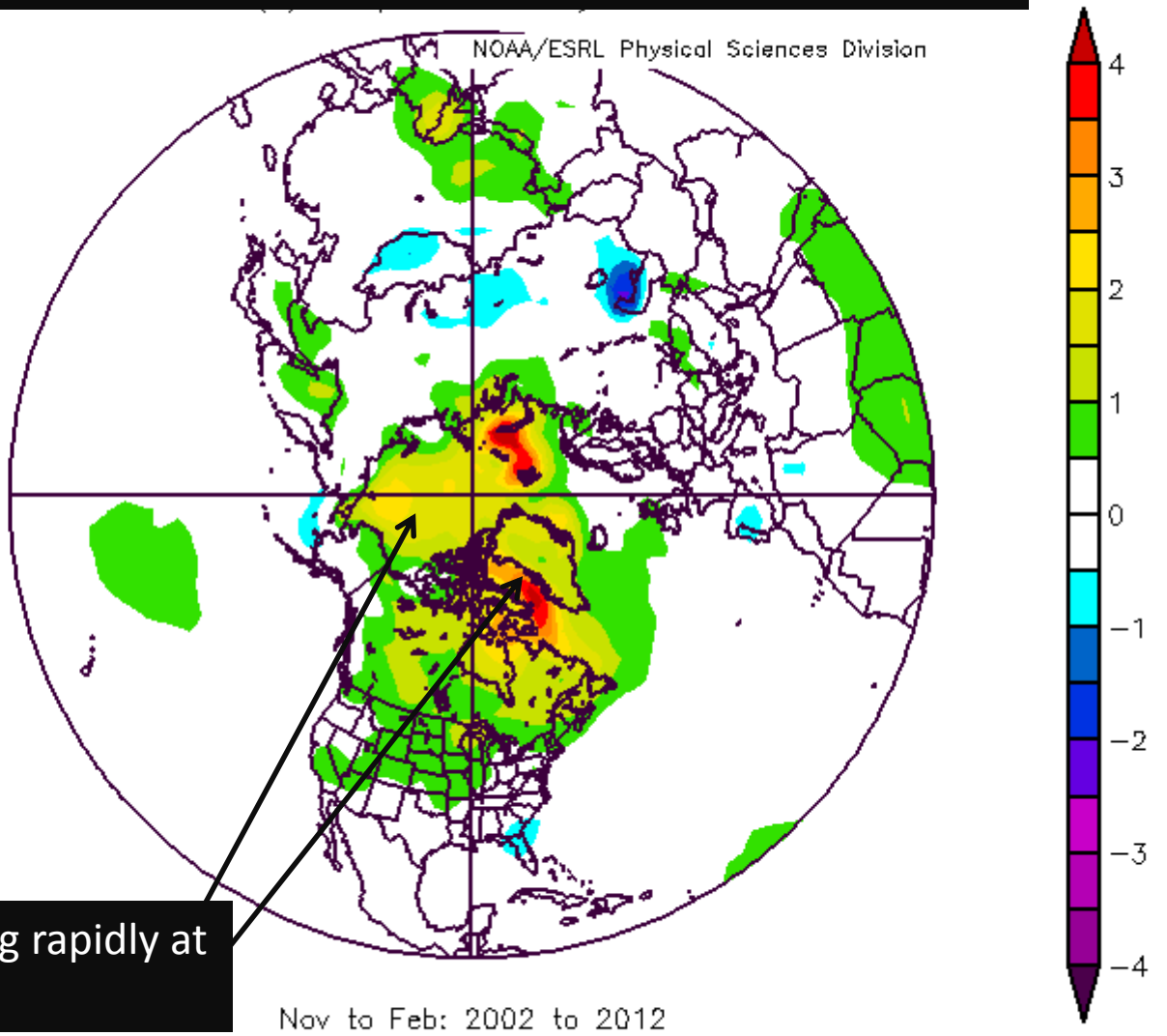
Winter Snowfall Anomalies: El Nino Conditions



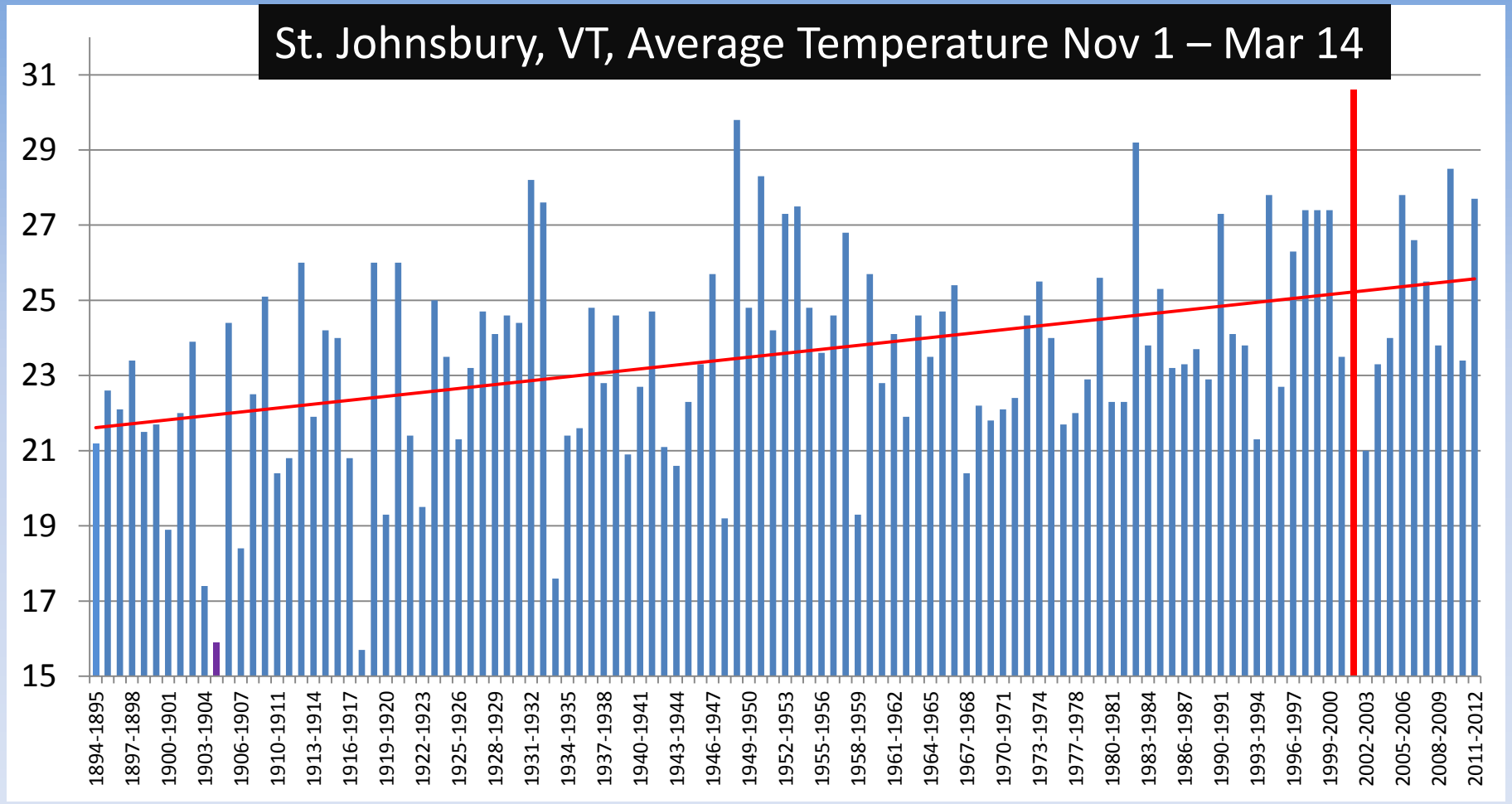
NOAA: http://www.cpc.noaa.gov/products/analysis_monitoring/lanina/us_impacts/ustp_impacts.shtml#NVC

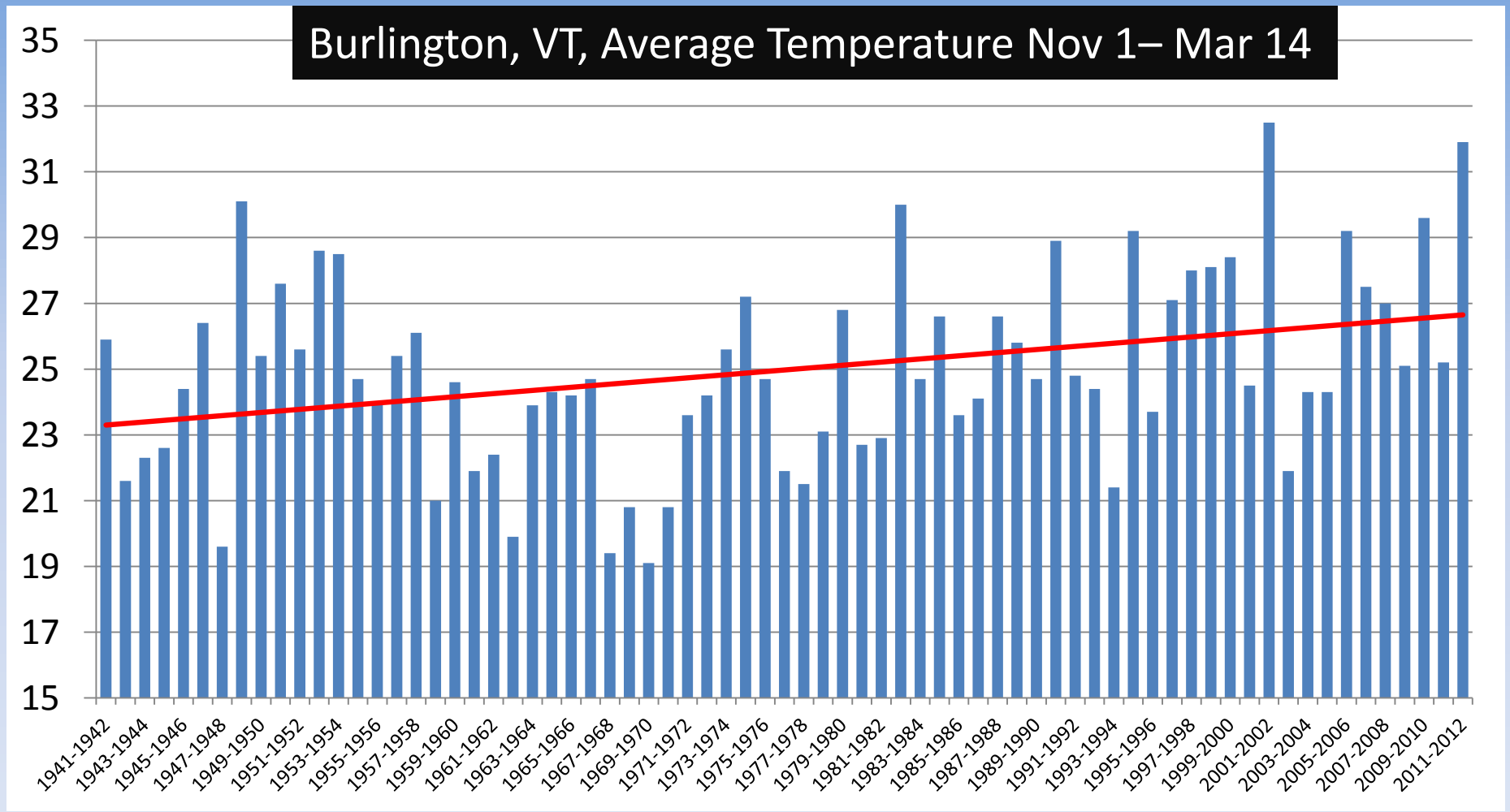
Climate Change Signals

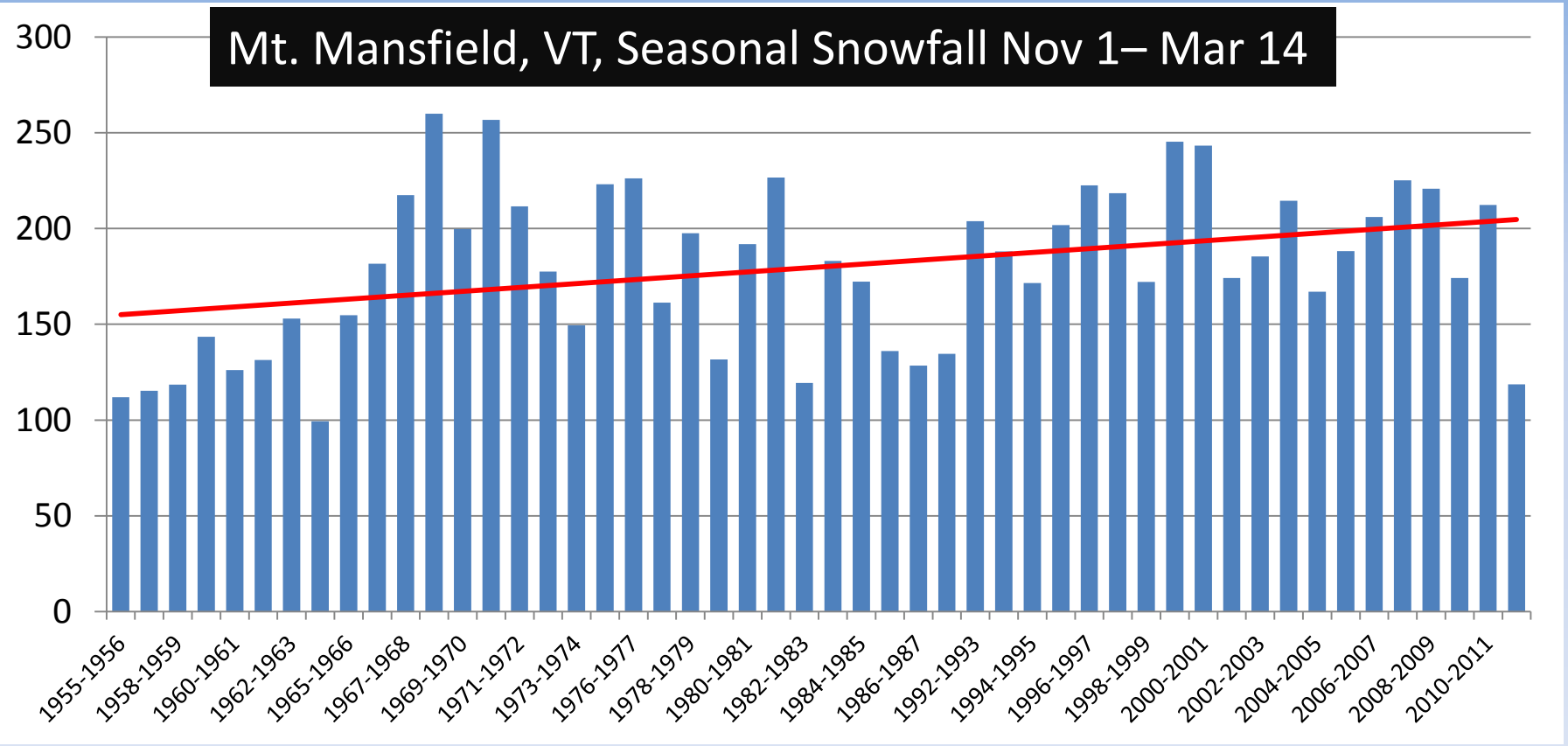
Winter Air Temperature Anomalies Last 10 Years

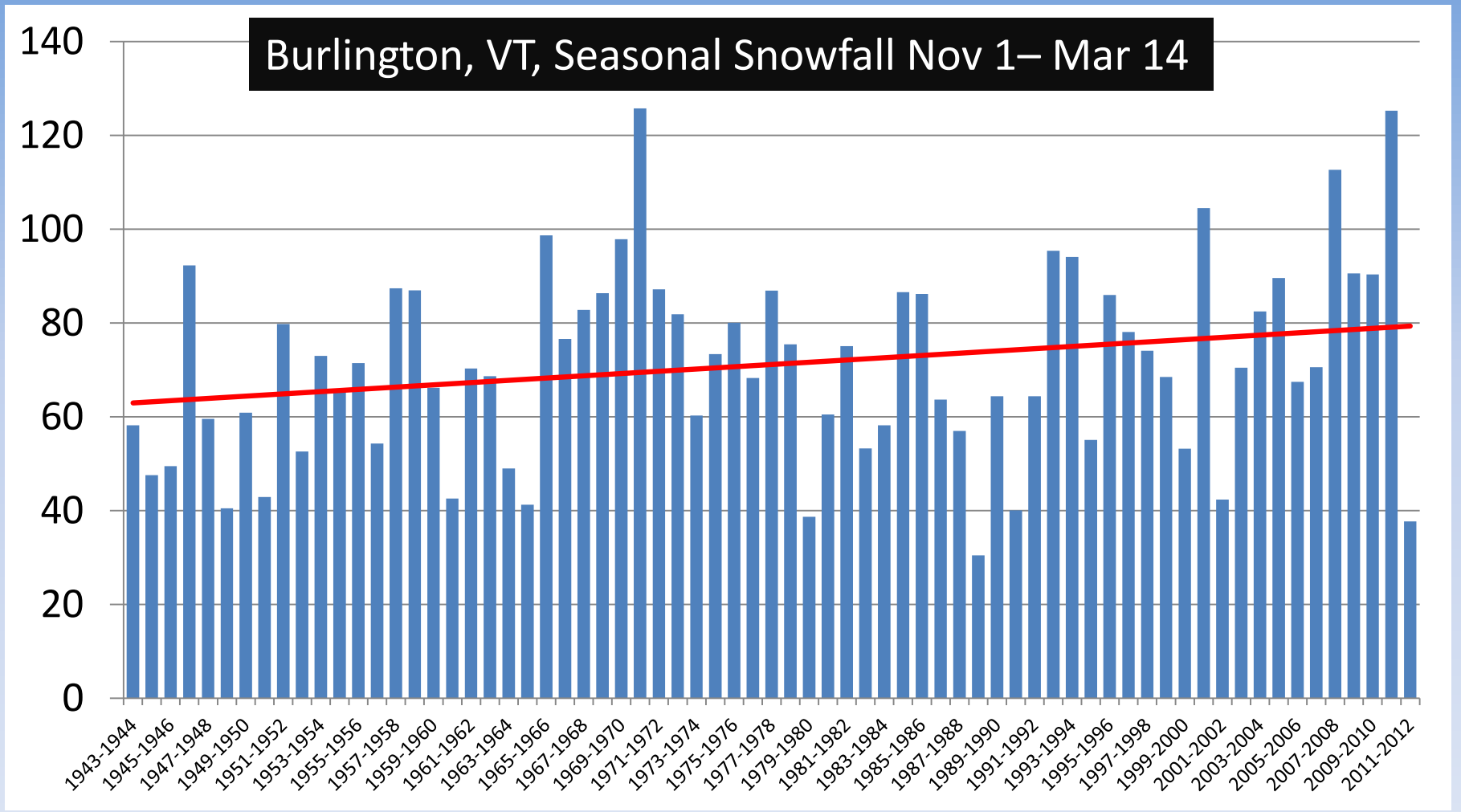


Warming is occurring rapidly at high latitudes.


St. Johnsbury, VT, Average Temperature Nov 1 – Mar 14
31
29
27
25
23
21
19
17
15
1894-1895
1897-1898
1900-1901
1903-1904
1906-1907
1910-1911
1913-1914
1916-1917
1919-1920
1922-1923
1925-1926
1928-1929
1931-1932
1934-1935
1937-1938
1940-1941
1943-1944
1946-1947
1949-1950
1952-1953
1955-1956
1958-1959
1961-1962
1964-1965
1967-1968
1970-1971
1973-1974
1977-1978
1980-1981
1983-1984
1986-1987
1990-1991
1993-1994
1996-1997
1999-2000
2002-2003
2005-2006
2008-2009
2011-2012


Burlington, VT, Average Temperature Nov 1– Mar 14
35
33
31
29
27
25
23
21
19
17
15
1941-1942
1943-1944
1945-1946
1947-1948
1949-1950
1951-1952
1953-1954
1955-1956
1957-1958
1959-1960
1961-1962
1963-1964
1965-1966
1967-1968
1969-1970
1971-1972
1973-1974
1975-1976
1977-1978
1979-1980
1981-1982
1983-1984
1985-1986
1987-1988
1989-1990
1991-1992
1993-1994
1995-1996
1997-1998
1999-2000
2001-2002
2003-2004
2005-2006
2007-2008
2009-2010
2011-2012


Mt. Mansfield, VT, Seasonal Snowfall Nov 1– Mar 14
300
250
200
150
100
50
0
1955-1956
1958-1959
1960-1961
1962-1963
1965-1966
1967-1968
1969-1970
1971-1972
1973-1974
1976-1977
1978-1979
1980-1981
1982-1983
1984-1985
1986-1987
1992-1993
1994-1995
1996-1997
1998-1999
2000-2001
2002-2003
2004-2005
2006-2007
2008-2009
2010-2011


Burlington, VT, Seasonal Snowfall Nov 1– Mar 14
140
120
100
80
60
40
20
0
1943-1944
1945-1946
1947-1948
1949-1950
1951-1952
1953-1954
1955-1956
1957-1958
1959-1960
1961-1962
1963-1964
1965-1966
1967-1968
1969-1970
1971-1972
1973-1974
1975-1976
1977-1978
1979-1980
1981-1982
1983-1984
1985-1986
1987-1988
1989-1990
1991-1992
1993-1994
1995-1996
1997-1998
1999-2000
2001-2002
2003-2004
2005-2006
2007-2008
2009-2010
2011-2012

Betts 2011

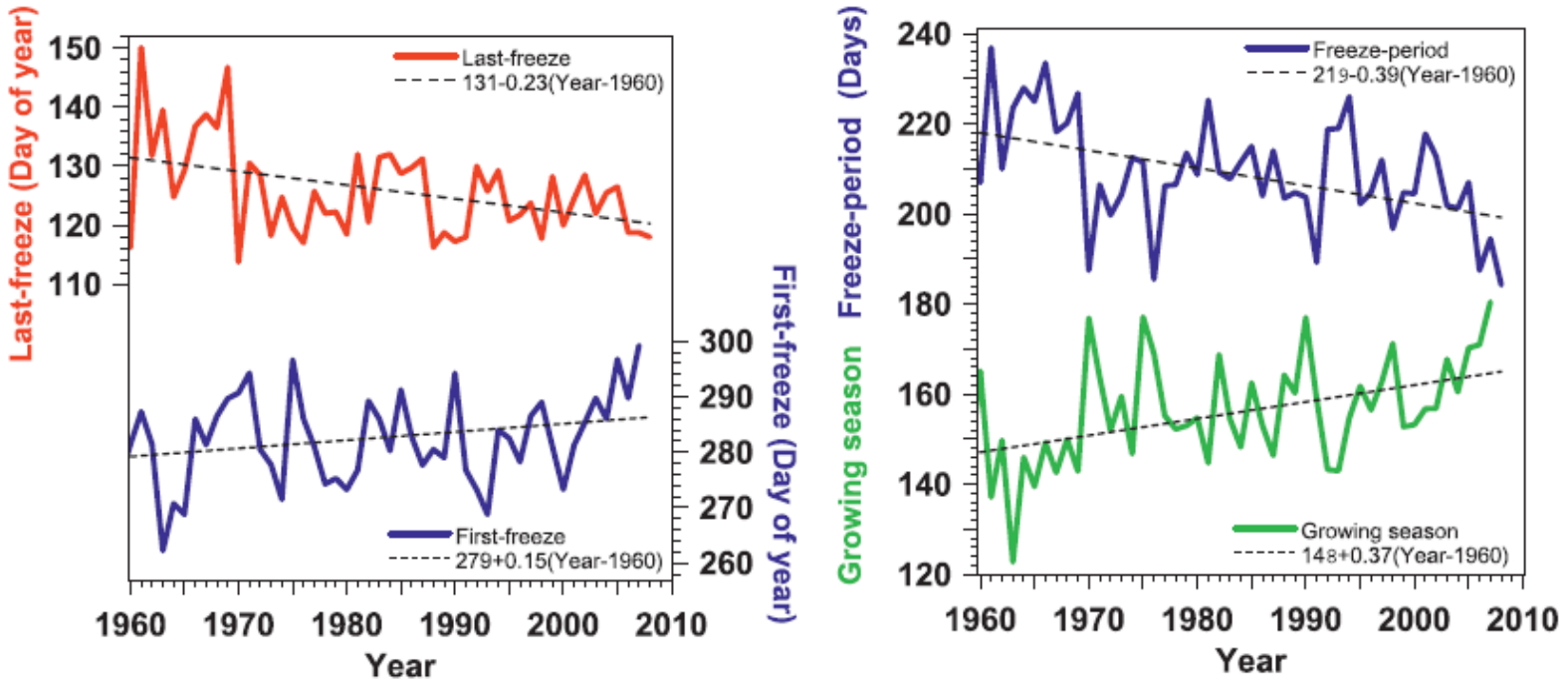


FIG. 3. (left) Last spring freeze and first autumn frost and (right) length of freeze period and growing season (data from Schwartz et al. 2006).

http://journals.ametsoc.org/doi/full/10.1175/2011WCAS1096.1?prevSearch=[Contrib%3A+alan+betts]&searchHistoryKey=

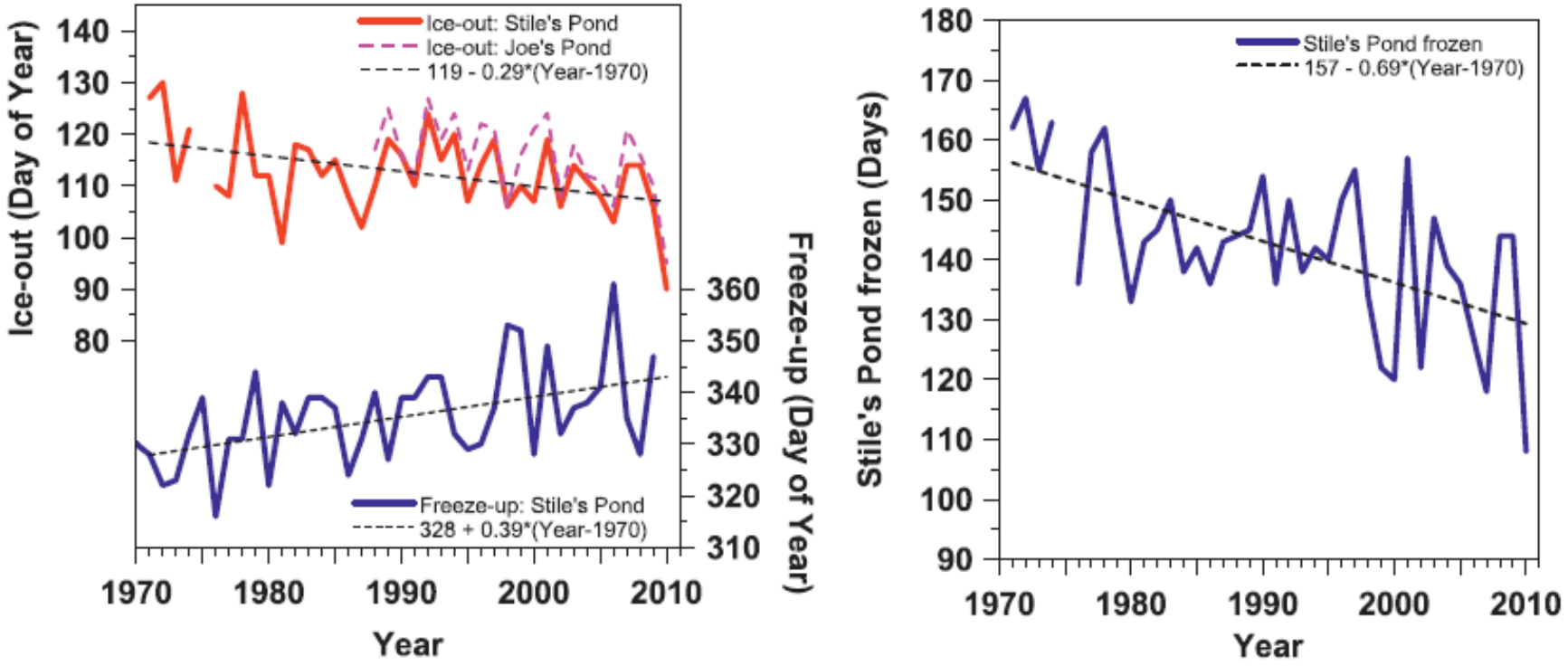


FIG. 4. (left) Freeze-up and ice-out days for Stile's Pond and ice-out for Joe's Pond and (right) winter frozen period for Stile's Pond. (Ice-out in 1975 is missing.)

Betts 2011

Activity

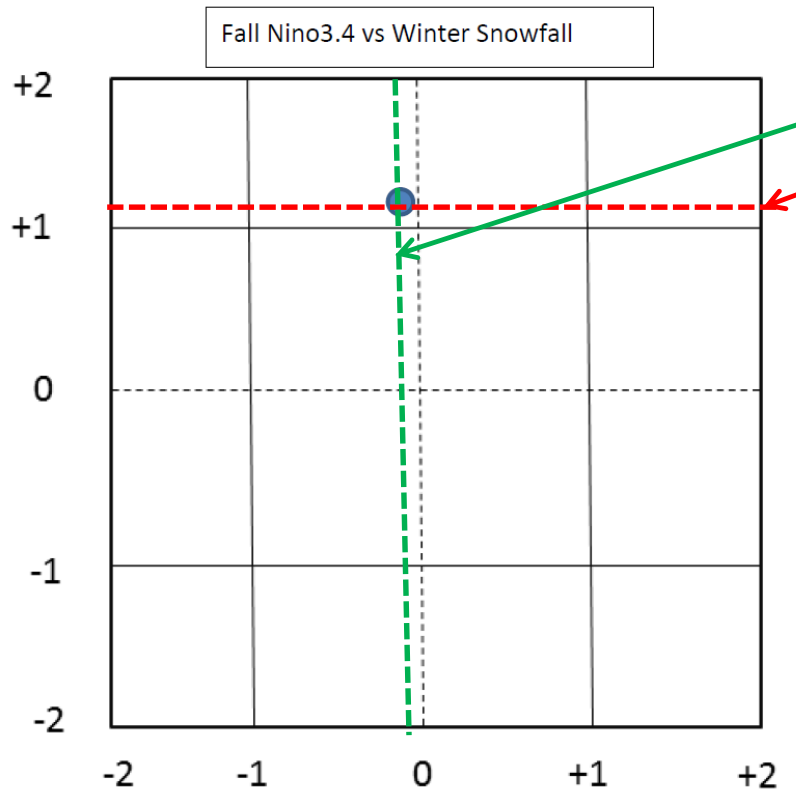
For this activity, we will investigate the prior 20 winters and the relationship between fall ENSO conditions with the following winter's snowfall and temperature at Burlington, VT. All data are shown in normalized space, or as standard deviations from average. A zero score means the data is the same as the average, whereas negative values are below average and positive above average.

	Fall Nino3.4	Winter Snowfall	Winter Temperature
1992	-0.1	1.2	-0.2
1993	0.4	1.1	-1.2
1994	1.0	-0.8	1.4
1995	-0.6	0.7	-0.4
1996	-0.2	0.3	0.7
1997	2.6	0.1	1.0
1998	-1.1	-0.1	1.1
1999	-1.1	-0.9	1.2
2000	-0.5	1.6	-0.2
2001	0.0	-1.4	2.5
2002	1.4	0.0	-1.0
2003	0.6	0.5	-0.2
2004	0.9	0.9	-0.2
2005	-0.1	-0.2	1.4
2006	1.0	0.0	0.9
2007	-1.0	2.0	0.7
2008	0.0	0.9	0.0
2009	1.2	0.9	1.6
2010	-1.4	2.6	0.1
2011	-0.7	-1.6	2.3

1. Produce a graph of Nino3.4, which is a measure of the ENSO state, and the following winter's snowfall. Data for 1992 is plotted to help get you started; Nino3.4 in both instances is on x-axis.

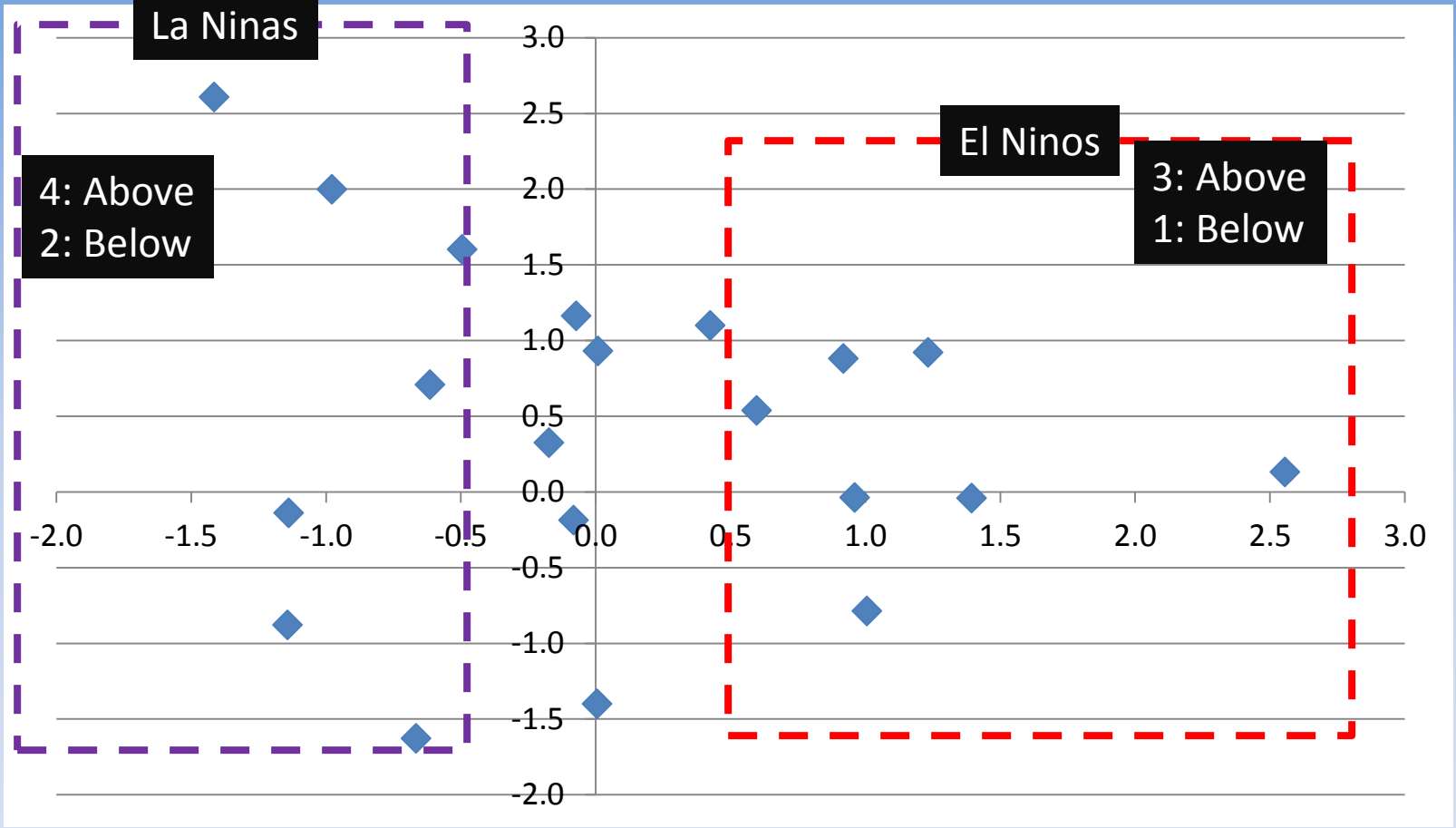
2. Produce a graph of Nino3.4, which is a measure of the ENSO state, and the following winter's temperature. Data for 1992 is plotted to help get you started.

3. We will discuss how much, if any, of the year-to-year variability might be attributed to El Nino/La Nina.

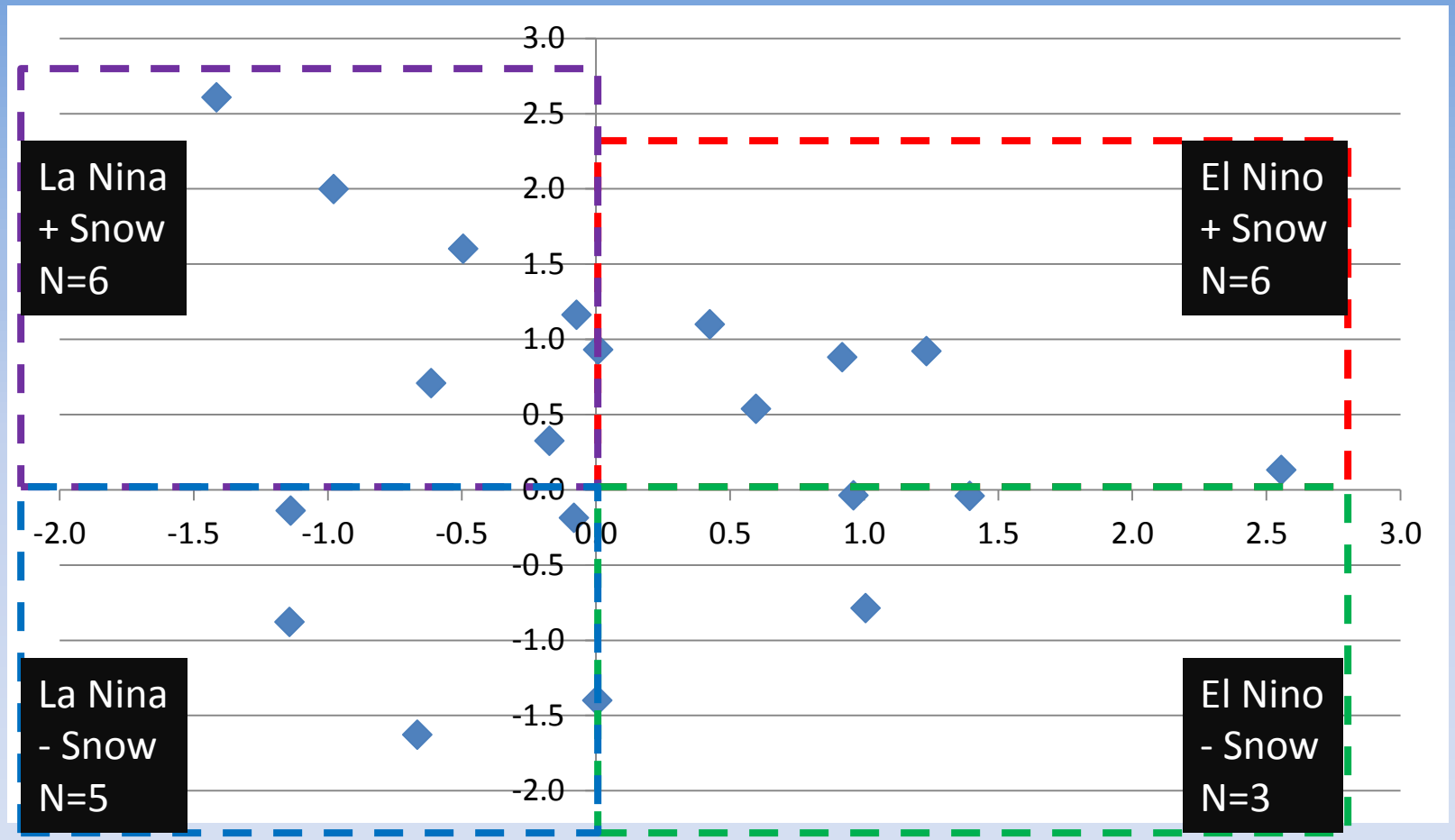


	Fall Nino3.4	Winter Snowfall	Winter Temperature
1992	-0.1	1.2	-0.2
1993	0.4	1.1	-1.2
1994	1.0	-0.8	1.4
1995	-0.6	0.7	-0.4
1996	-0.2	0.3	0.7
1997	2.6	0.1	1.0
1998	-1.1	-0.1	1.1
1999	-1.1	-0.9	1.2
2000	-0.5	1.6	-0.2
2001	0.0	-1.4	2.5
2002	1.4	0.0	-1.0
2003	0.6	0.5	-0.2
2004	0.9	0.9	-0.2
2005	-0.1	-0.2	1.4
2006	1.0	0.0	0.9
2007	-1.0	2.0	0.7
2008	0.0	0.9	0.0
2009	1.2	0.9	1.6
2010	-1.4	2.6	0.1
2011	-0.7	-1.6	2.3

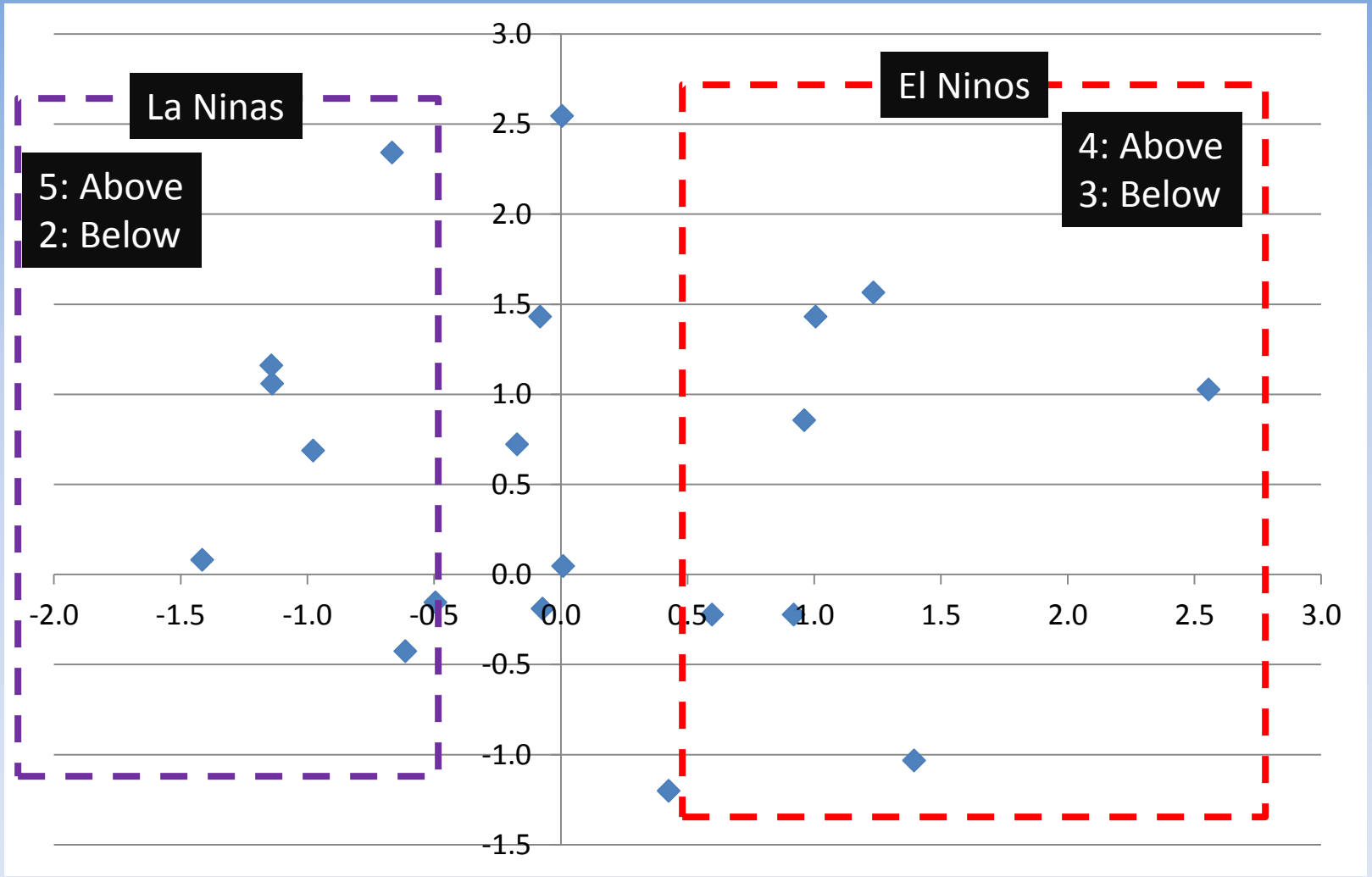
Nino3.4 vs Burlington Winter Snowfall



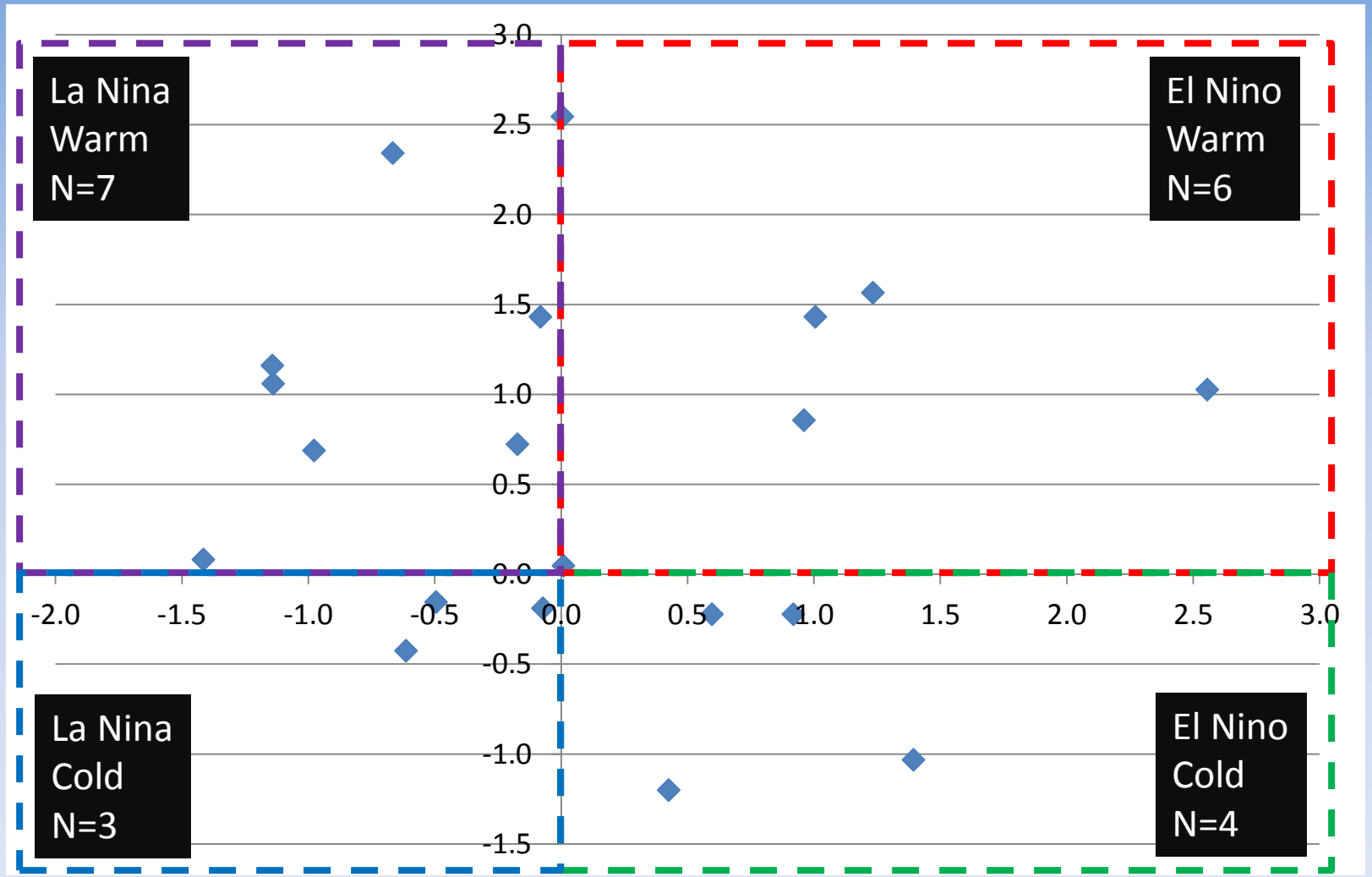
Nino3.4 vs Burlington Winter Snowfall



Nino3.4 vs. Burlington Winter Temperatures



Nino3.4 vs. Burlington Winter Temperatures



ENSO Conclusions

- A lot of spread, ENSO does not explain much of the variability
- Other factors must be at play, complex interactions of tropics and high latitudes
- Slight tendency for snowier winters to be associated with La Ninas (top 3 winters were La Nina winters), however this year is an exception

Post Assessment Questions

1. How warm was this winter?
   a. Exceptionally warm (top 10%)
   b. Warm (top 25%)
   c. Near average
   d. Below average (cold) – lower 25%
   e. Very cold – (coldest 10%)

2. How much snow fell this winter?
   a. Epic (top 10%)
   b. Above average (top 25%)
   c. Near average
   d. Below average (lower 25%)
   e. Well below average (lowest 10%)

3. How much snow fell last winter (2010-11)?
   a. Epic (top 10%)
   b. Above average (top 25%)
   c. Near average
   d. Below average (lower 25%)
   e. Well below average (lowest 10%)

4. How are Vermont winters changing?
   a. Becoming warmer and snowier
   b. Becoming colder and snowier
   c. Becoming warmer and less snowy
   d. Becoming colder and less snowy
   e. There has been little change to temperatures and snowfall

5. Name three principle drivers of long-range (months to seasons) weather patterns?

a. Arctic Oscillation

b. Pacific Jet Stream Patterns

c. ENSO

6. Define El Nino or La Nina.

El Nino: Warm or positive phase of ENSO featuring well above average sea-surface
temperatures in the equatorial central and eastern Pacific Ocean.
La Nina: Cold or negative phase of ENSO featuring well below average sea-surface
temperatures in the equatorial central and eastern Pacific Ocean.

7. The following best describes the Arctic Oscillation.

a. An Oscillation of sea-ice coverage, with a maximum extent in March and minimum in September

b. An Oscillation of upper-level atmospheric winds , contributing to extreme air temperature patterns over the Northern Hemisphere

c. An Oscillation of low-level atmospheric winds , contributing to extreme air temperature patterns over the Northern Hemisphere

d. An Oscillation of stratospheric ozone contributing to large temperature variations in the Northern Hemisphere