Are Exceptionally Cold Vermont Winters Returning?

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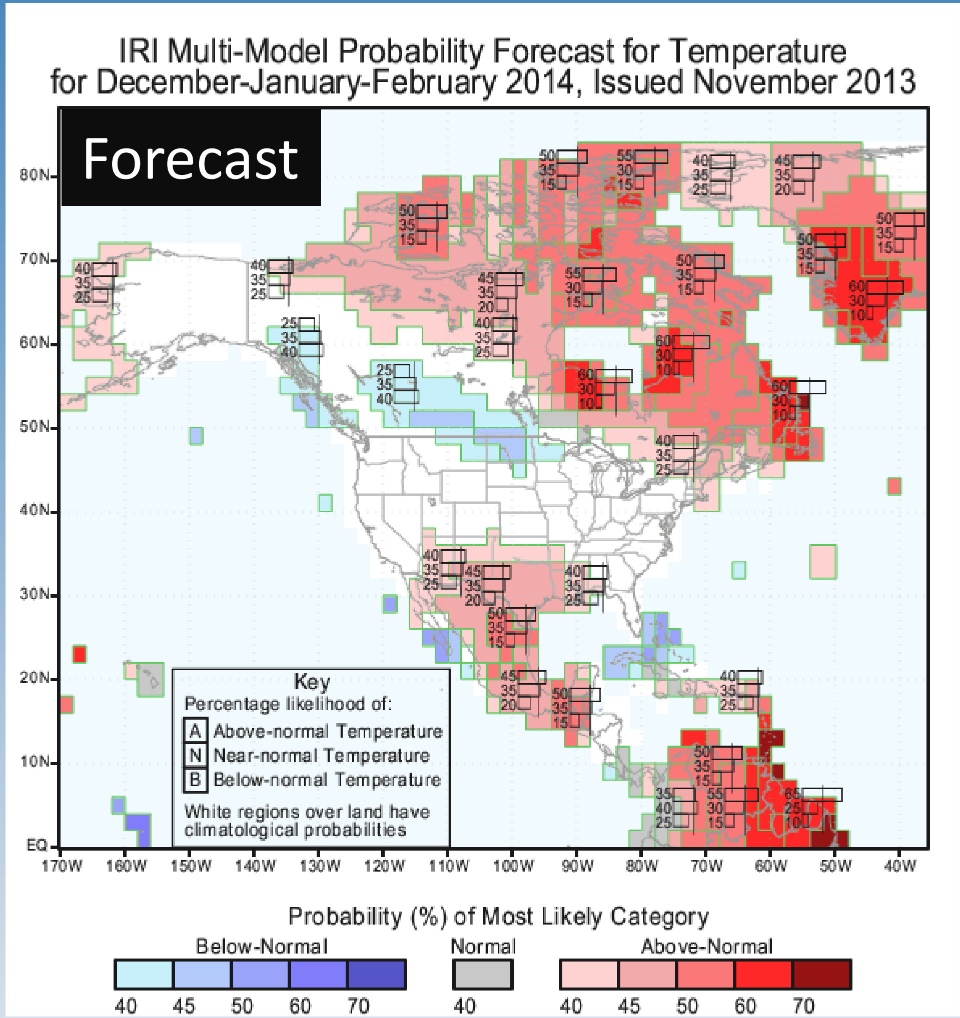
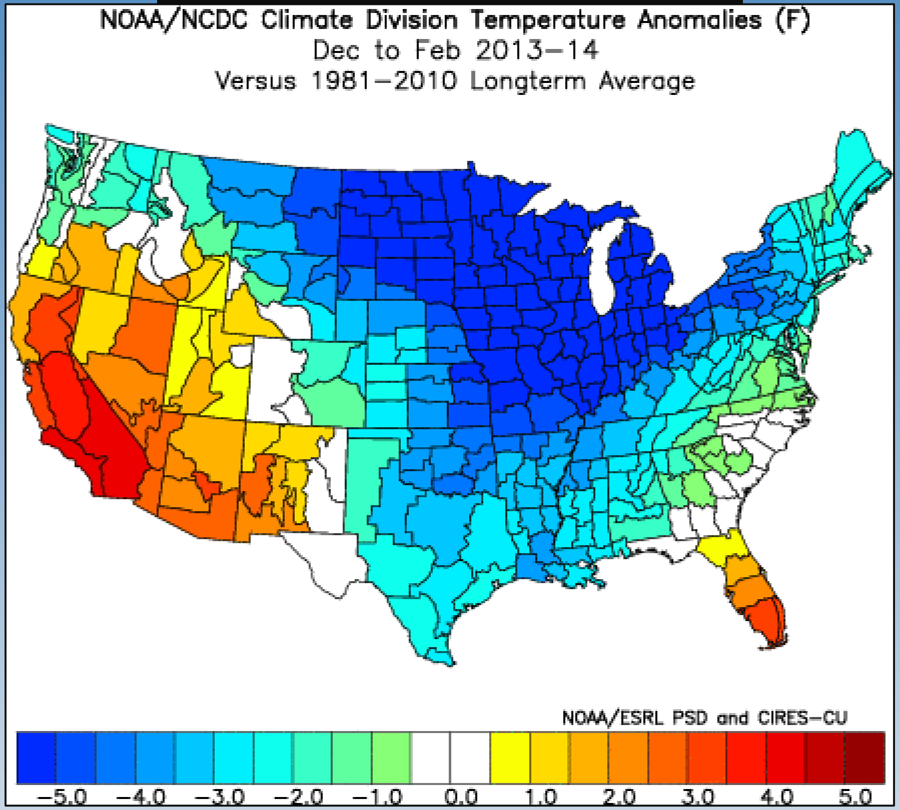
Outline

- What the cold forecast well?
- How cold was it?
- Arctic air characteristics
- Regional climate controls
- Climate trends
- Activity – statistical method to predict seasonal weather

Dynamical Model Forecasts and Verification



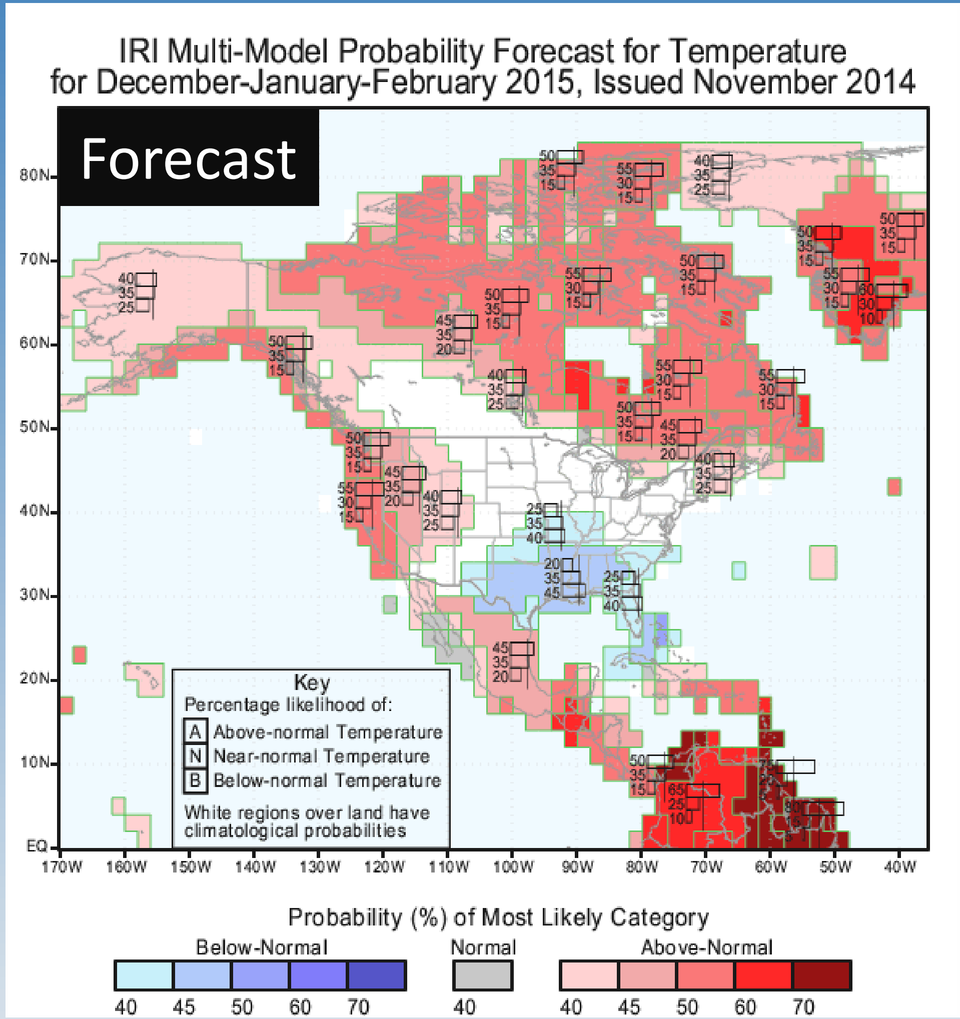
Verification: 2013-14



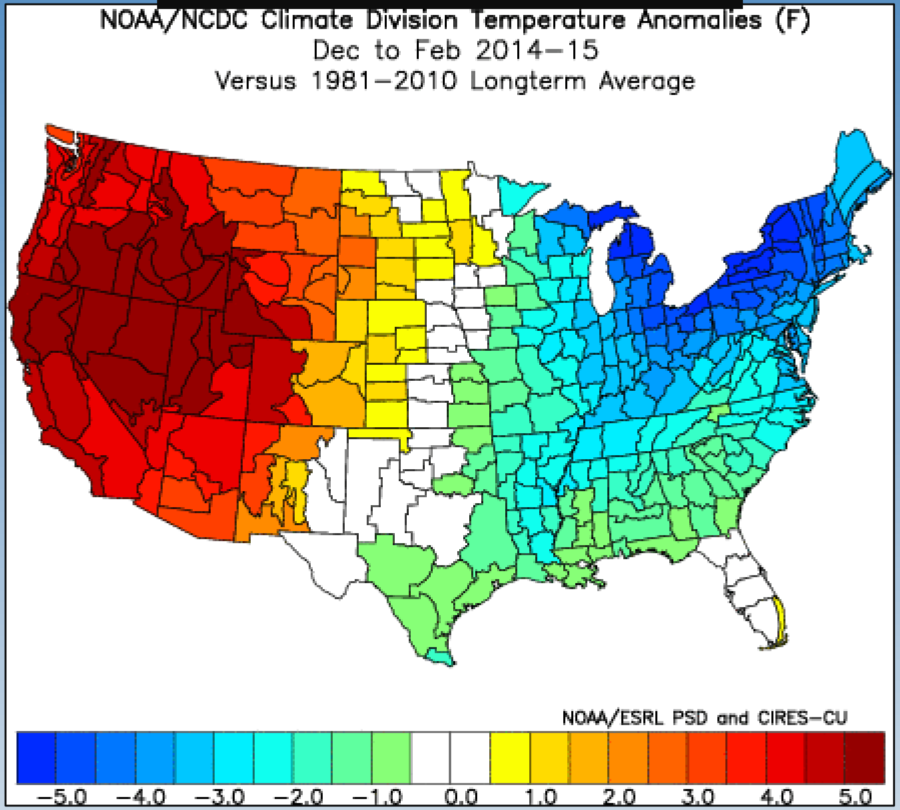
http://www.esrl.noaa.gov/psd/data/usclimdivs/

http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

Dynamical Model Forecasts and Verification



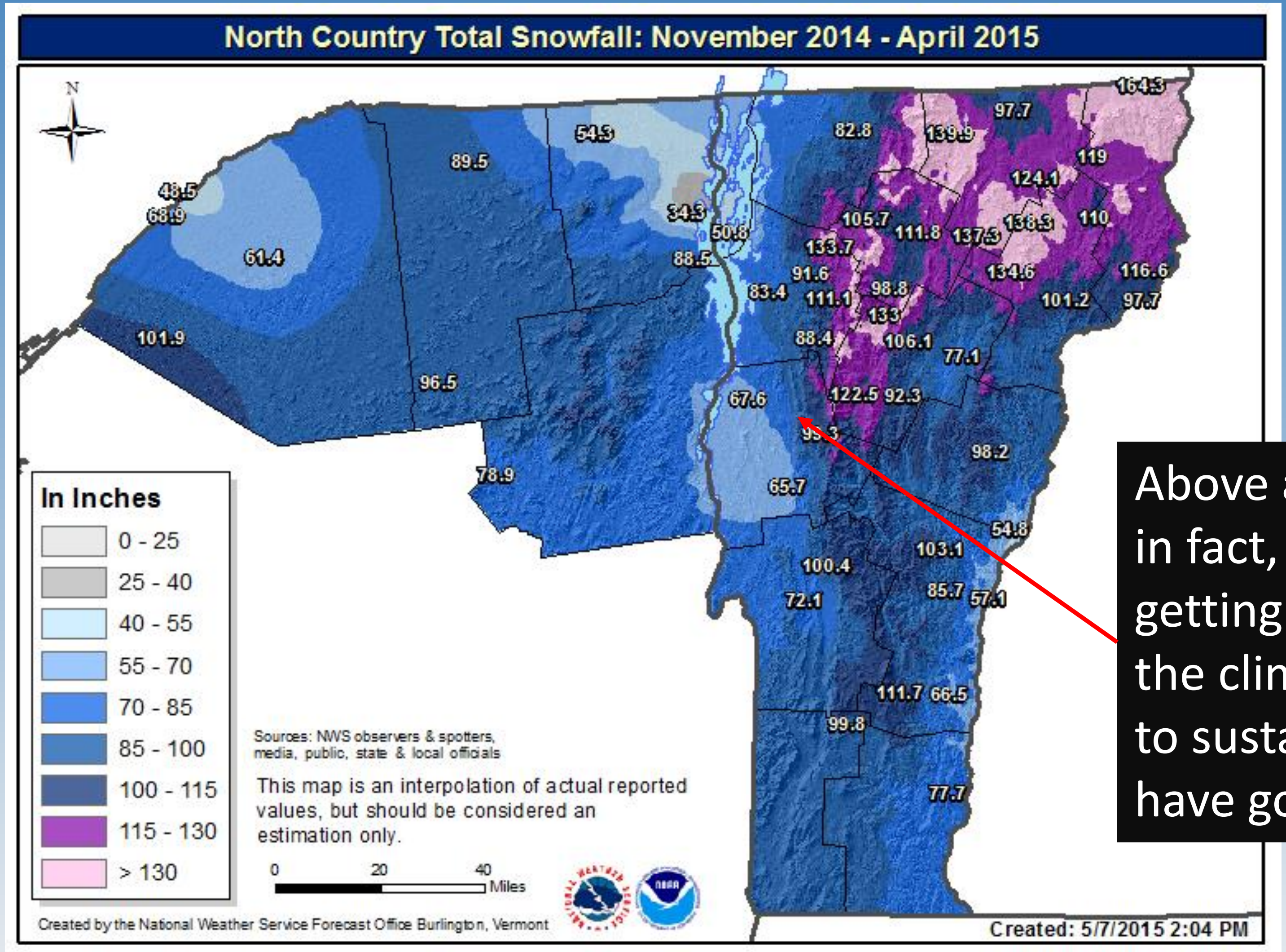
Verification: 2014-15



http://www.esrl.noaa.gov/psd/data/usclimdivs/

http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

Seasonal Snowfall 2014-15

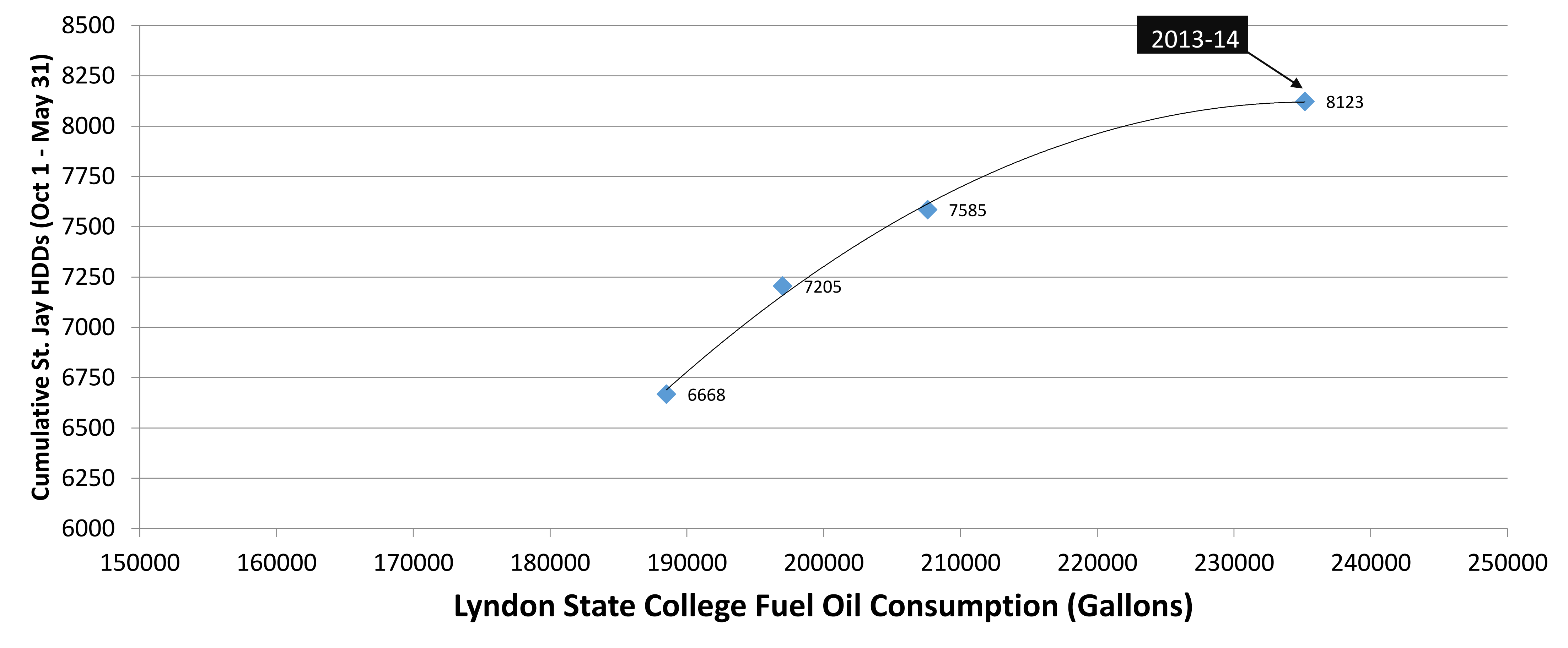


Above average snowfall
in fact, winters are
getting wetter, and
the climate is cold enough
to sustain snow, so winters
have gotten snowier

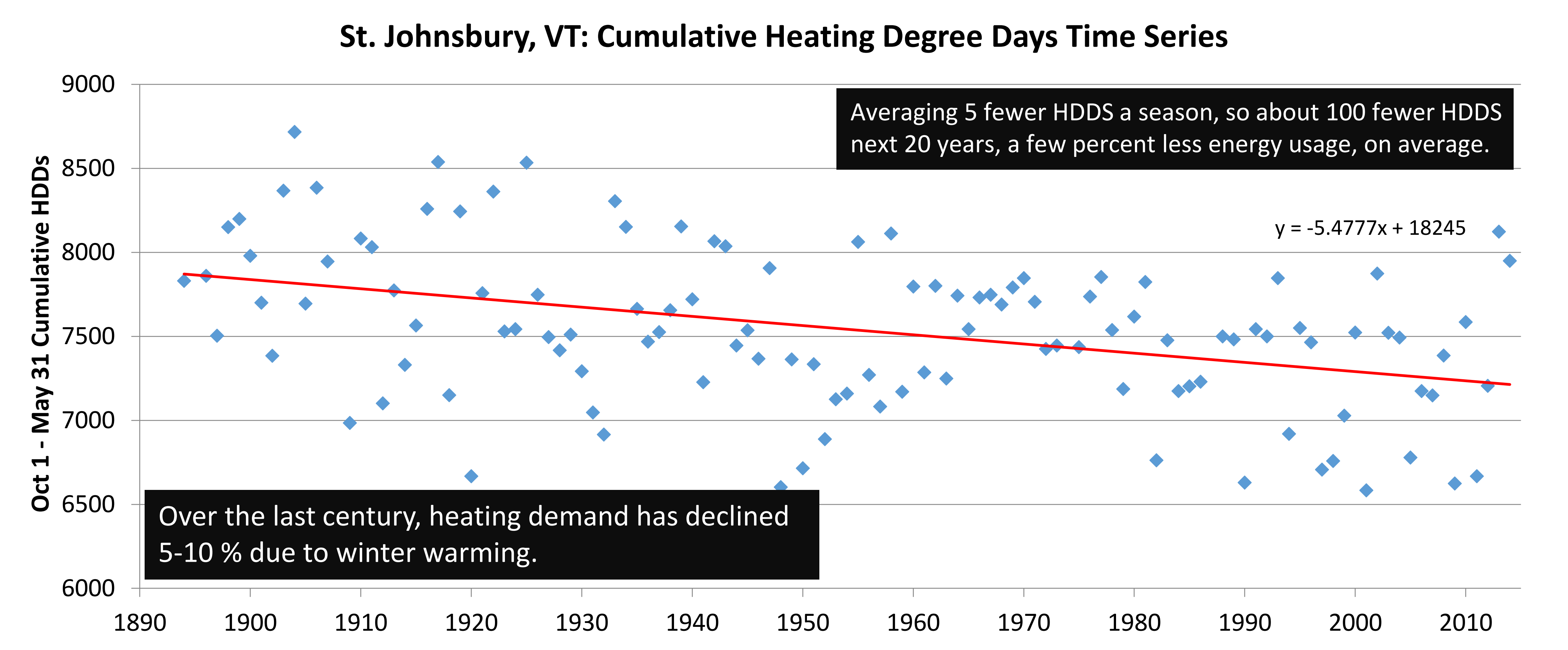
Heating Degree Days

- HDD = 65 deg F - (daily avg temperature)
- For example, high = 40, low = 20, daily avg temperature = 30
- 65-30 = 35 HDDs
- HDDs correlate well with energy use

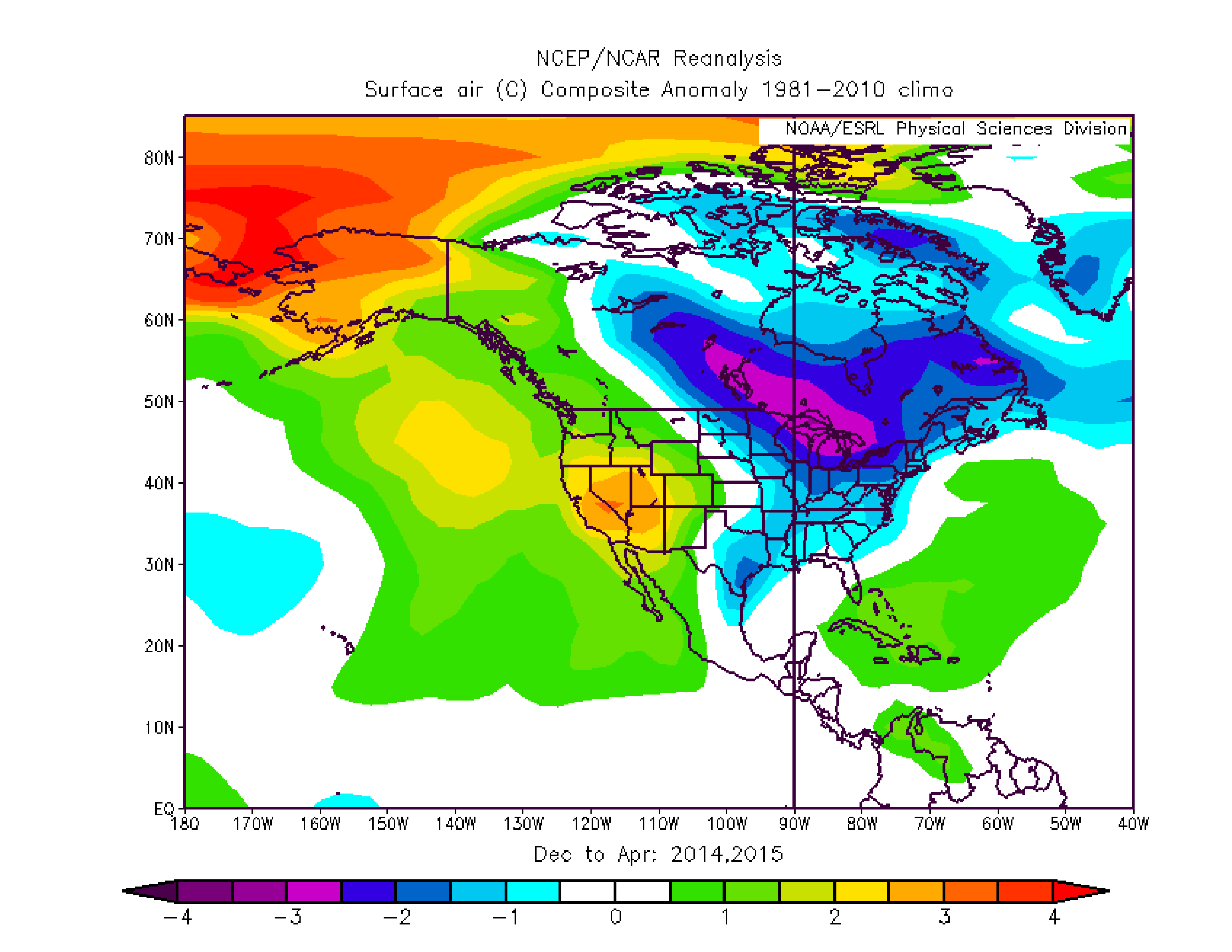
Energy Use vs HDDs



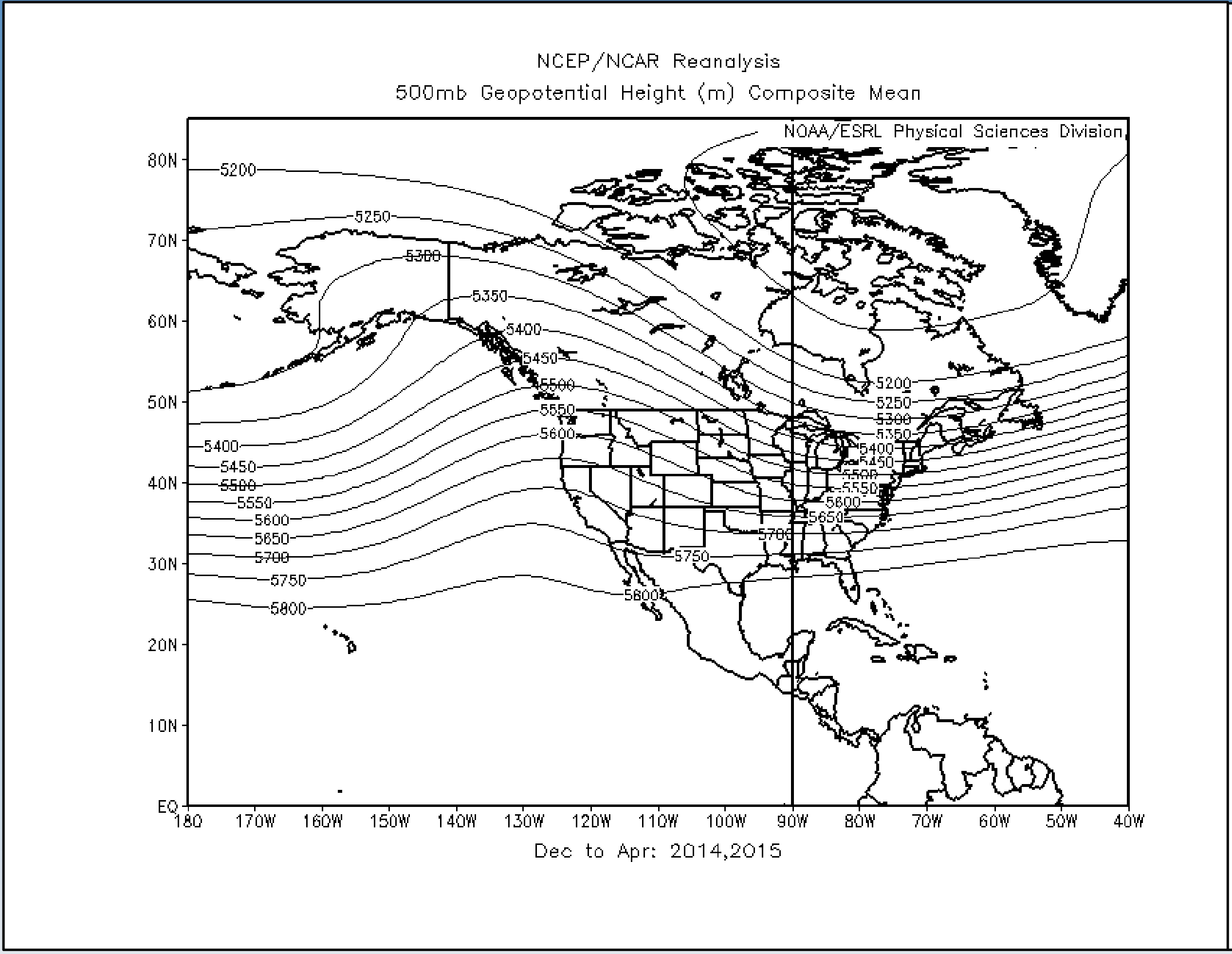
Heating Degree Day Trends

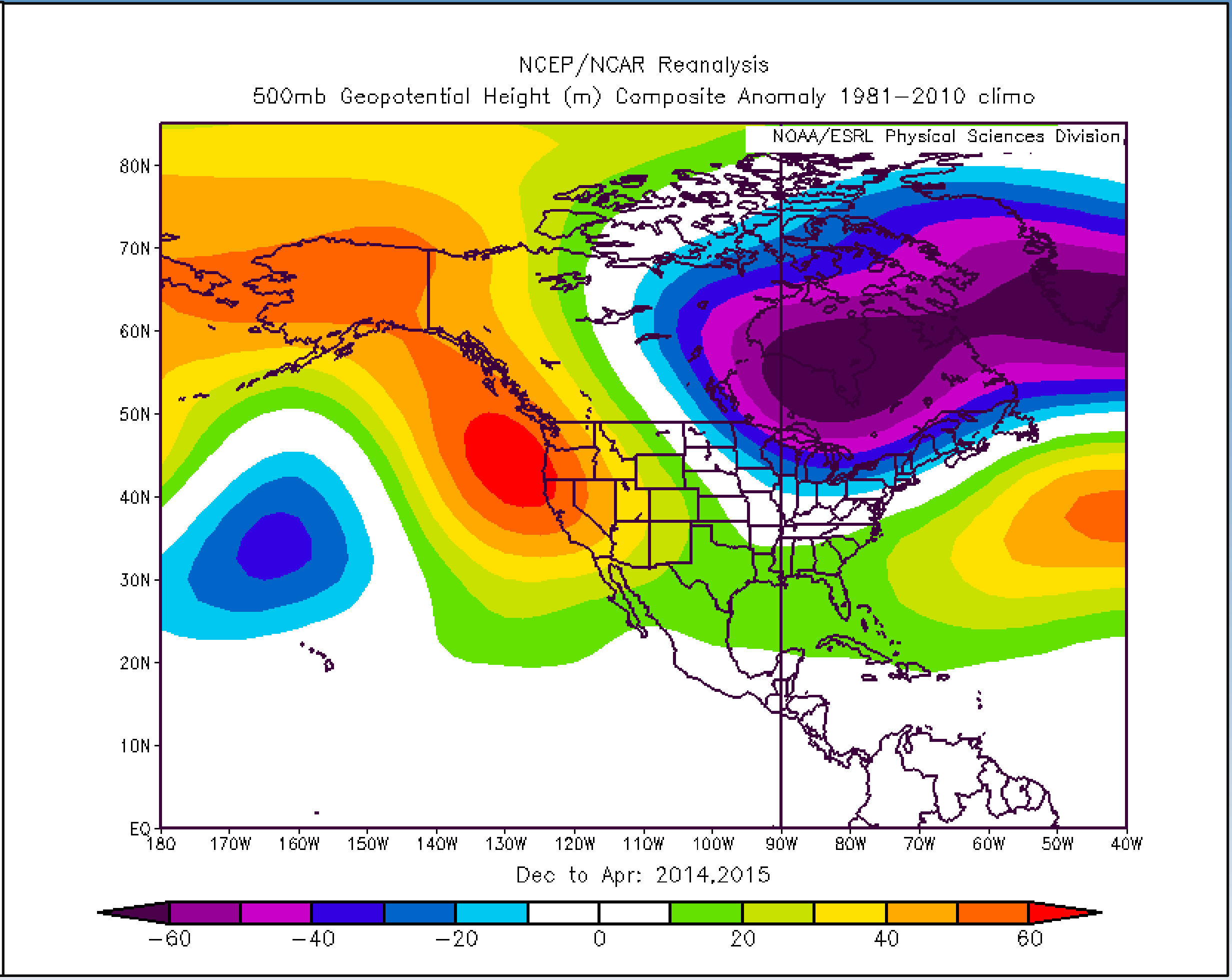


Why were these last two winters so cold?



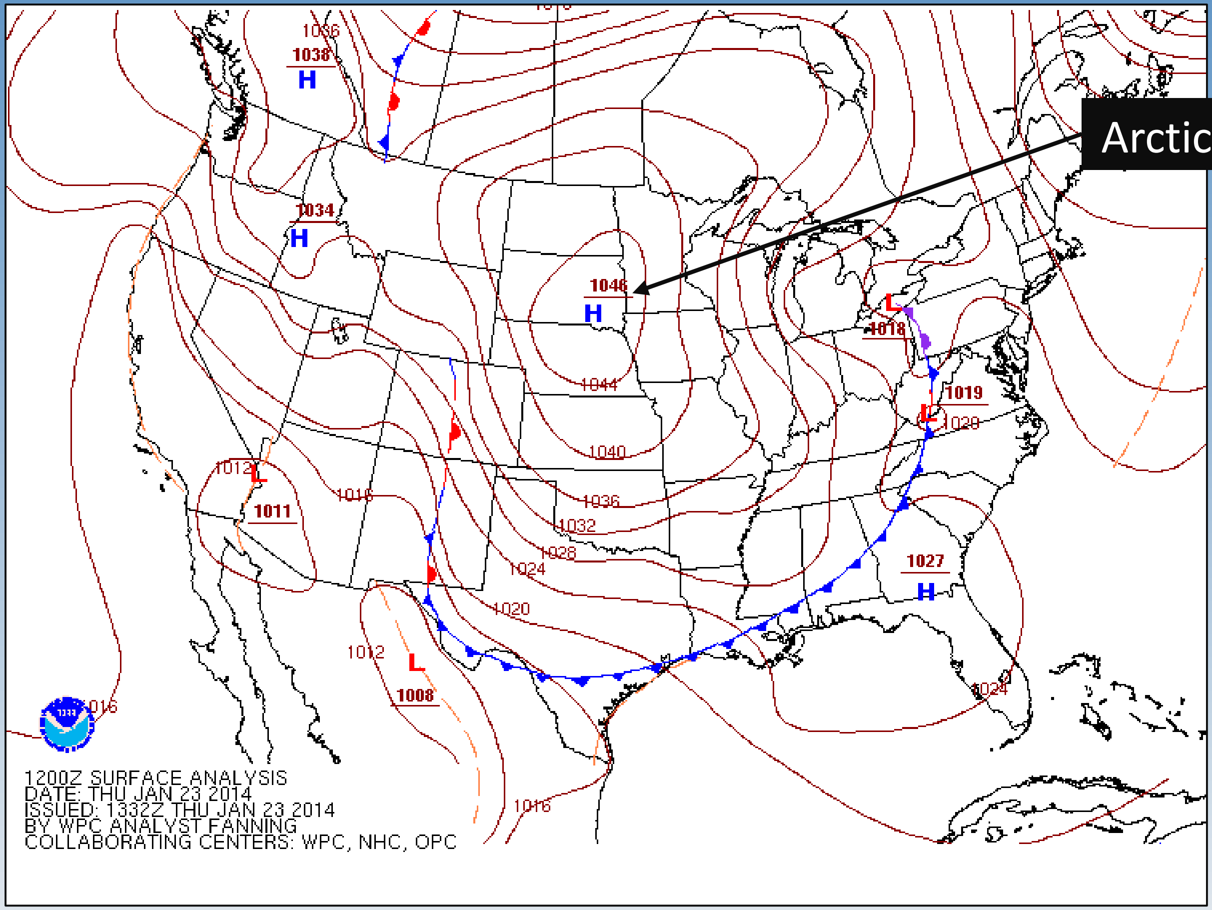
North American Circulation Pattern

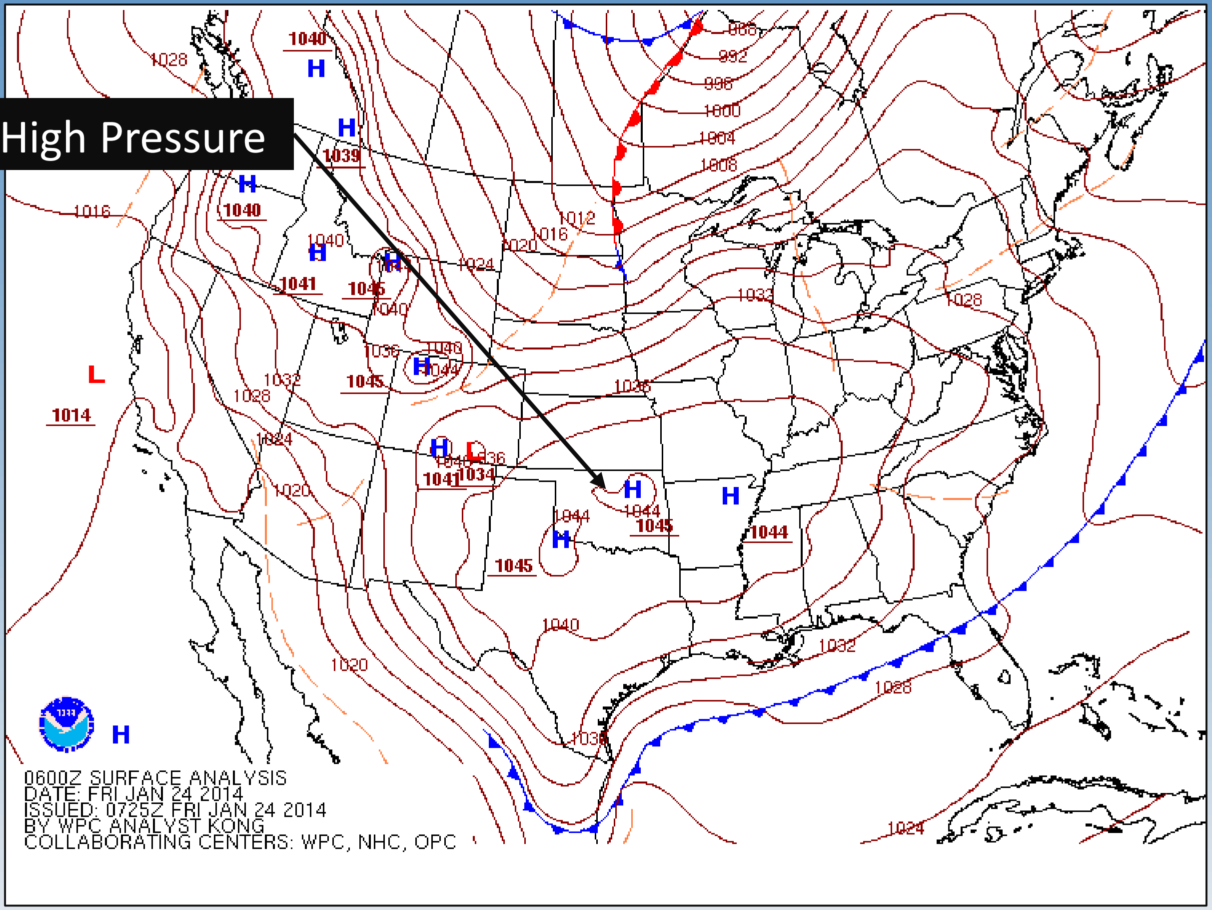




Arctic Air Mass Example – January 23, 2104

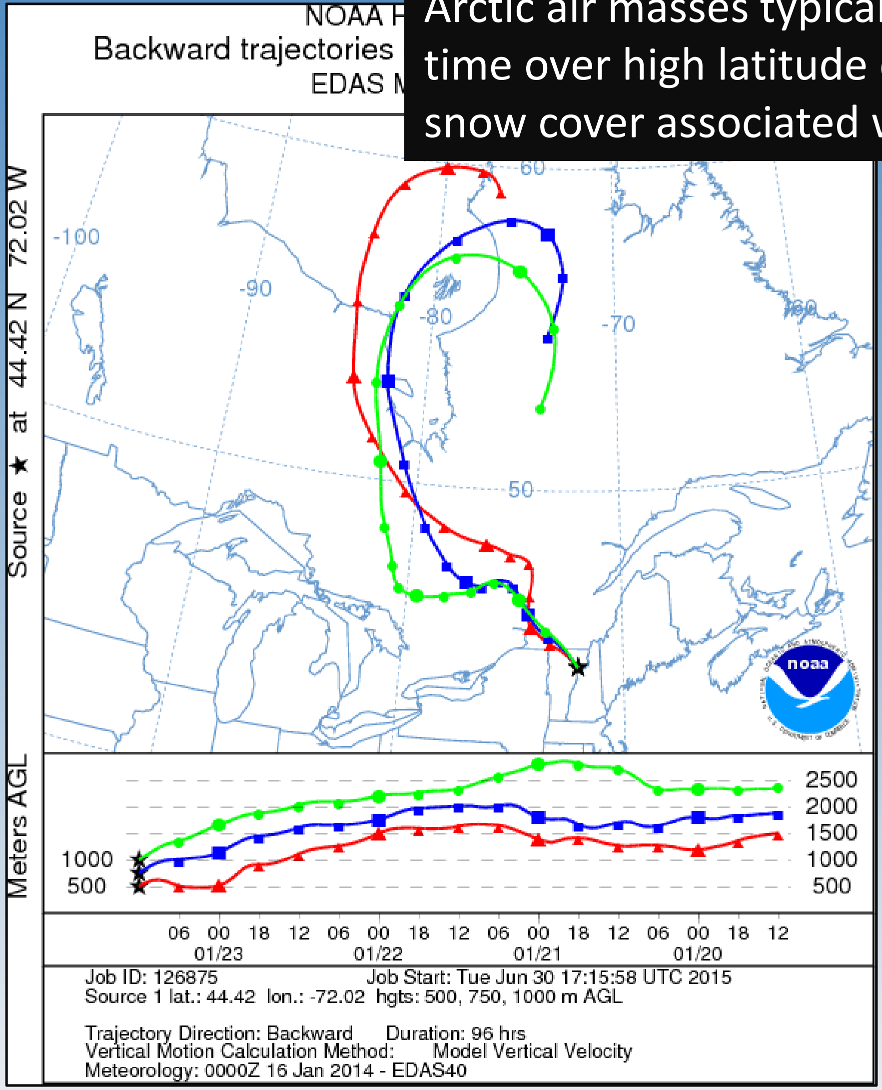
Arctic High Pressure

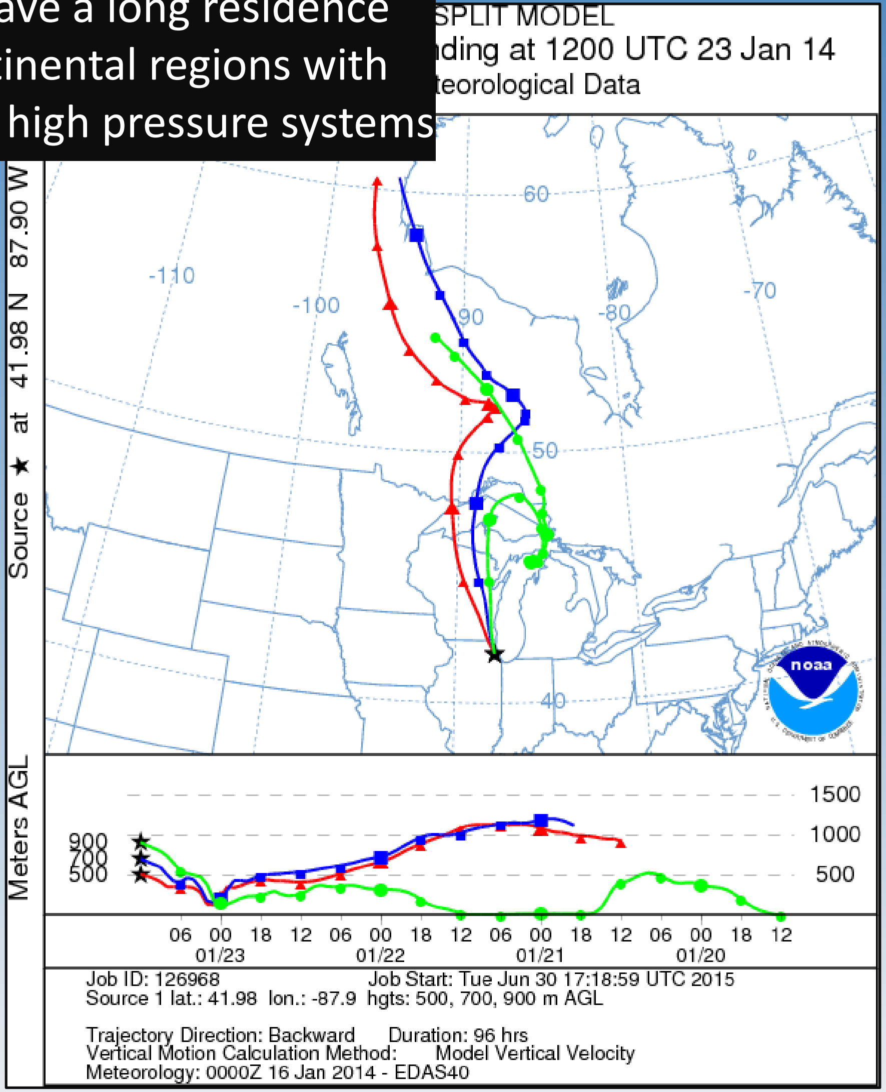




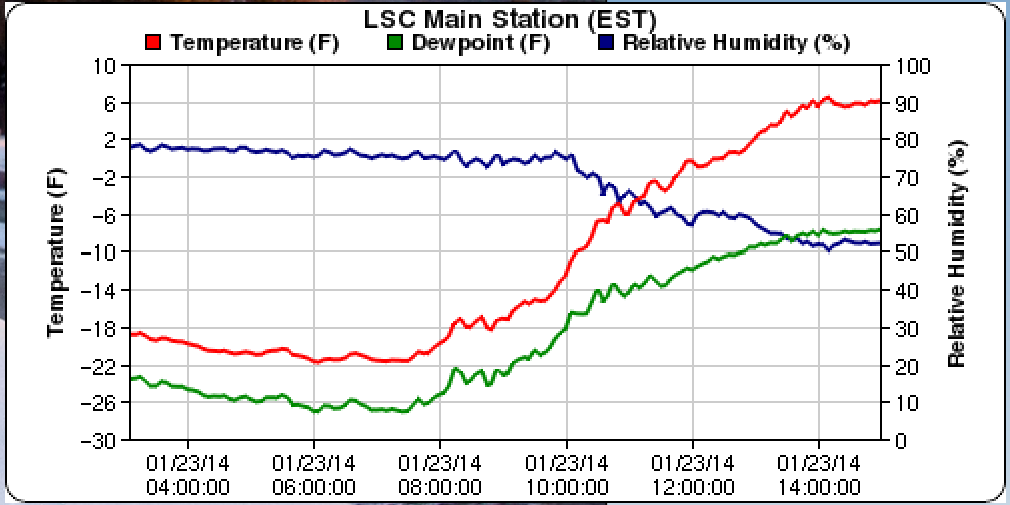
Where did the arctic air originate?

Arctic air masses typically have a long residence time over high latitude continental regions with snow cover associated with high pressure systems





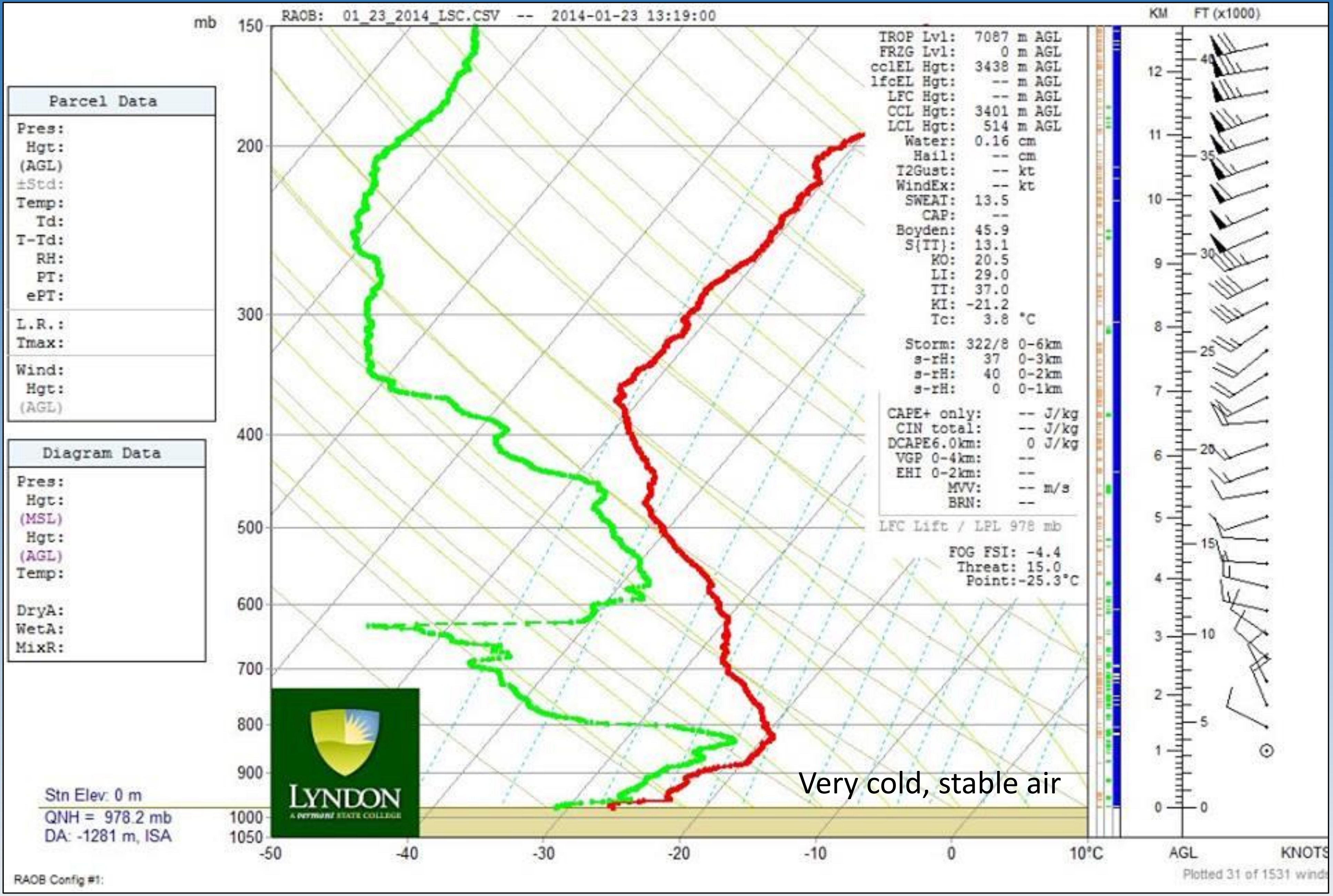
Sampling arctic air at Lyndon State



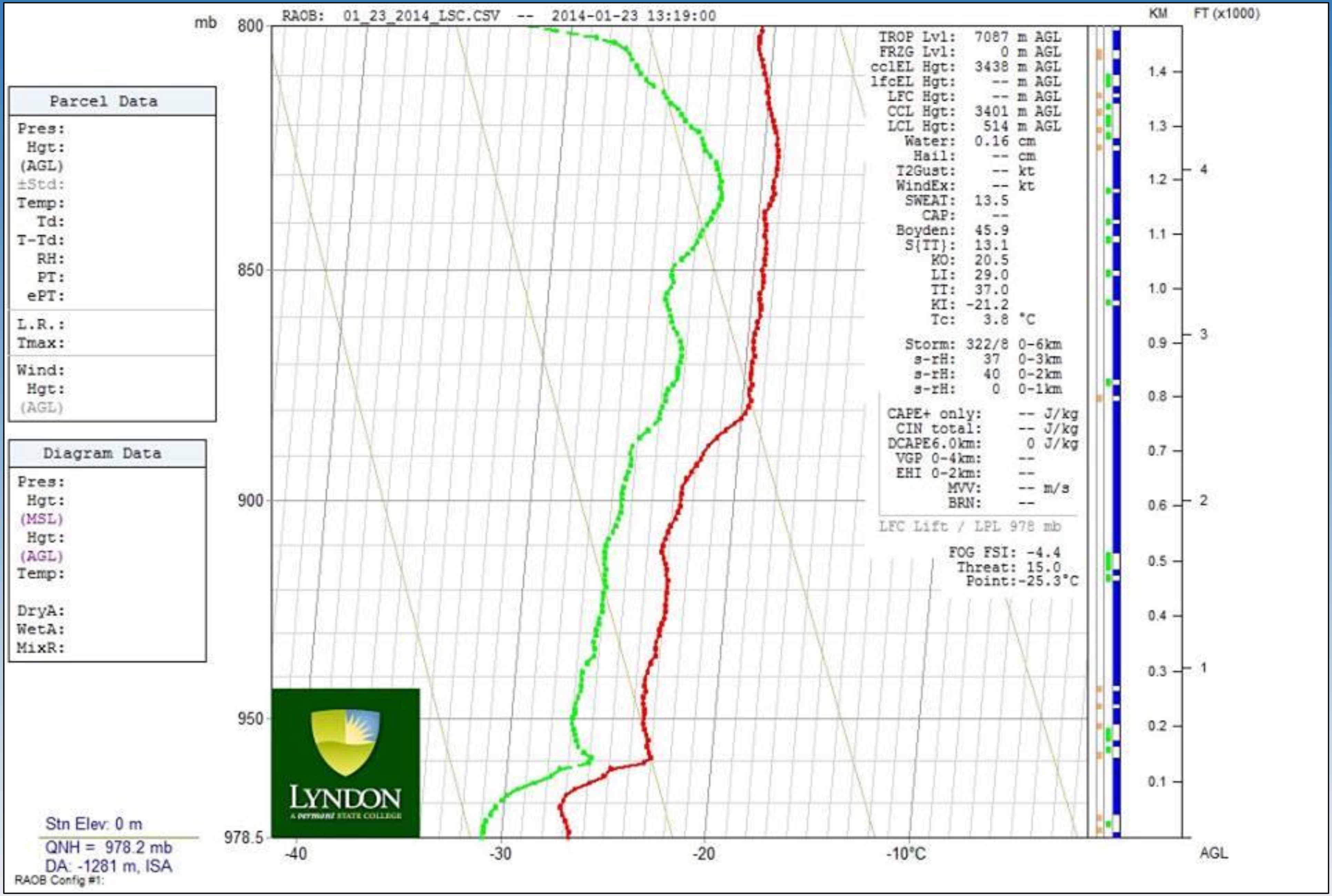

ASPEN 30
8.5 x 11

Arctic Air Mass Characteristics

- Dry (typically sunny)
- Very cold (less than -30 deg C)
- Stable (difficult to get precipitation/clouds to form)
- Isothermal low-level air mass (coldest air mass at the surface)



Very cold, stable air


RAOB: 01_23_2014_LSC.CSV -- 2014-01-23 13:19:00
mb
800
850
900
950
978.5
-40
-30
-20
-10°C
Parcel Data
Pres:
Hgt:
(AGL)
±Std:
Temp:
Td:
T-Td:
RH:
PT:
ePT:
L.R.:
Tmax:
Wind:
Hgt:
(AGL)
Diagram Data
Pres:
Hgt:
(MSL)
Hgt:
(AGL)
Temp:
DryA:
WetA:
MixR:
Stn Elev: 0 m
QNH = 978.2 mb
DA: -1281 m, ISA
RAOB Config #1:
TROP Lvl: 7087 m AGL
FRZG Lvl: 0 m AGL
cclEL Hgt: 3438 m AGL
lfcEL Hgt: -- m AGL
LFC Hgt: -- m AGL
CCL Hgt: 3401 m AGL
LCL Hgt: 514 m AGL
Water: 0.16 cm
Hail: -- cm
T2Gust: -- kt
WindEx: -- kt
SWEAT: 13.5
CAP: --
Boyden: 45.9
S{TT}: 13.1
KO: 20.5
LI: 29.0
TT: 37.0
KI: -21.2
Tc: 3.8 °C
Storm: 322/8 0-6km
s-rH: 37 0-3km
s-rH: 40 0-2km
s-rH: 0 0-1km
CAPE+ only: -- J/kg
CIN total: -- J/kg
DCAPE6.0km: 0 J/kg
VGP 0-4km: --
EHI 0-2km: --
MVV: -- m/s
BRN: --
LFC Lift / LPL 978 mb
FOG FSI: -4.4
Threat: 15.0
Point: -25.3°C
KM
FT (x1000)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
4
3
2
1
AGL
LYNDON
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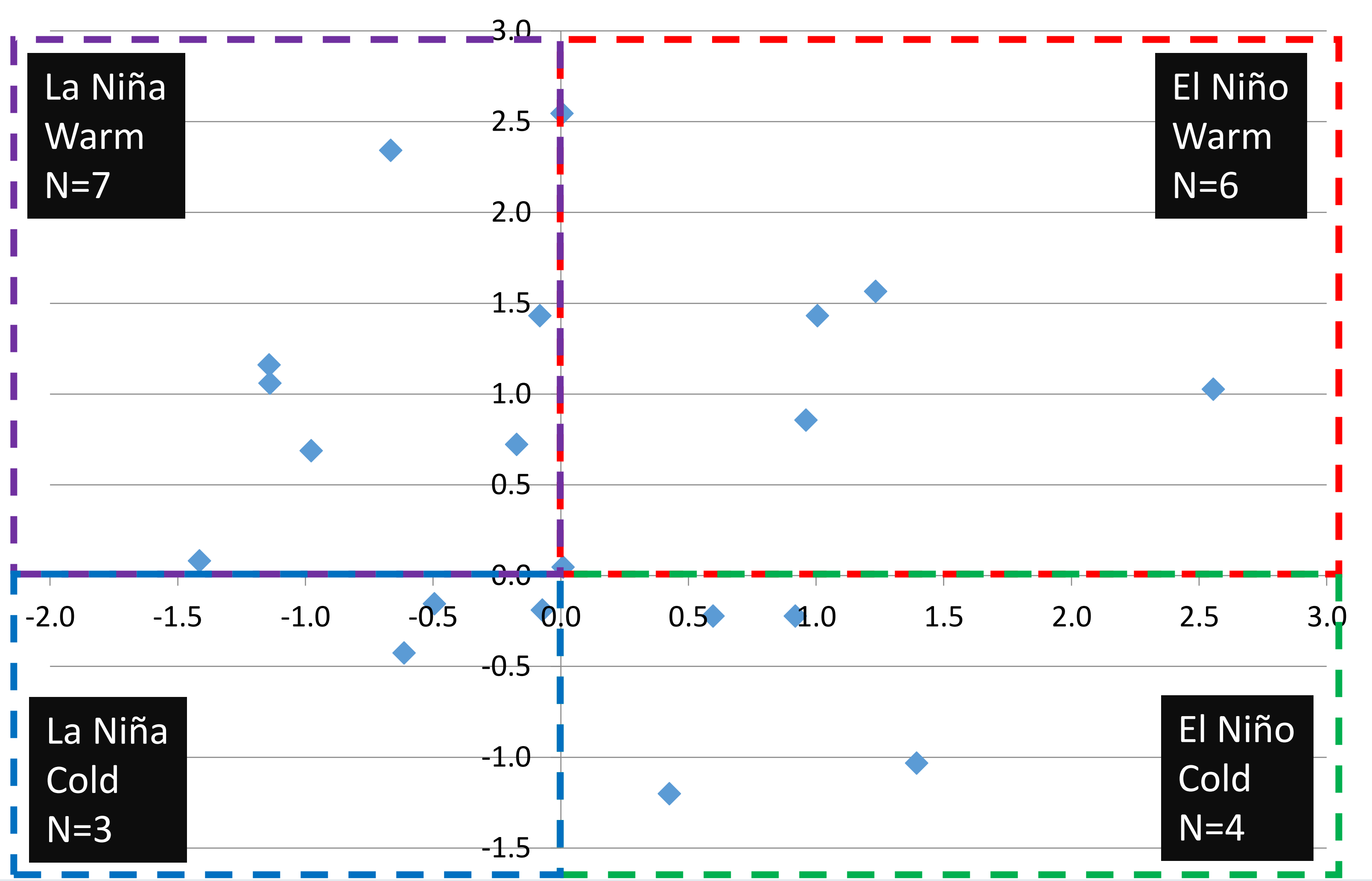
Seasonal Controls of Winter Weather Variability

El Niño/La Niña (Nino3.4) vs. Burlington Winter Temperatures



El Niño/La Niña (ENSO) Conclusions

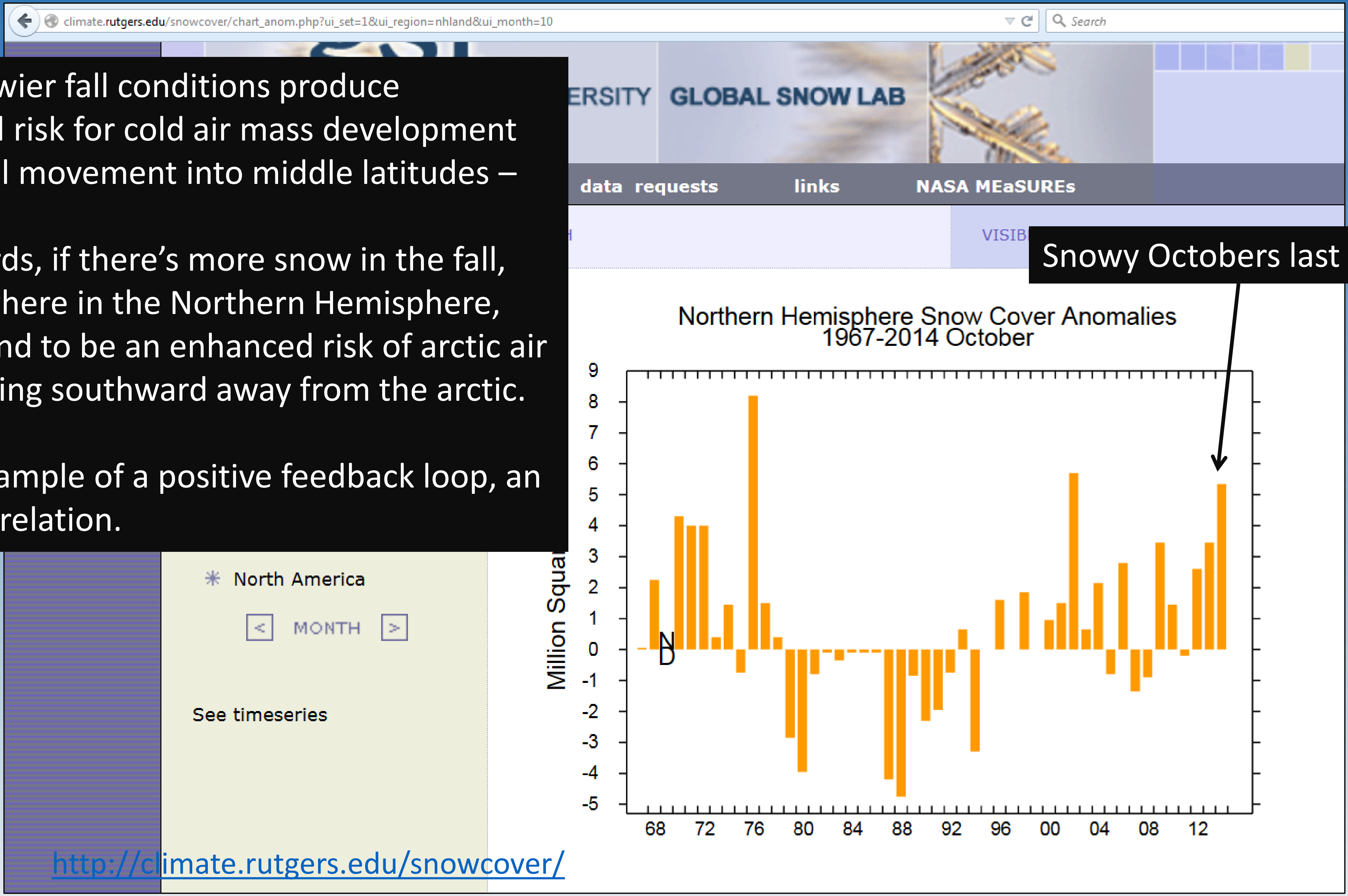
- ENSO does not explain the variability
- Other factors are at play, complex interactions of tropics and high latitudes
- Other areas of the US have significant winter ENSO relationships, but not the Northeast US
- ENSO has little to no effect on winter conditions in the Northeast US

Snow Cover – Land Surface Feedbacks

Theory: snowier fall conditions produce an increased risk for cold air mass development and eventual movement into middle latitudes –

In other words, if there's more snow in the fall, then somewhere in the Northern Hemisphere, there is bound to be an enhanced risk of arctic air masses moving southward away from the arctic.

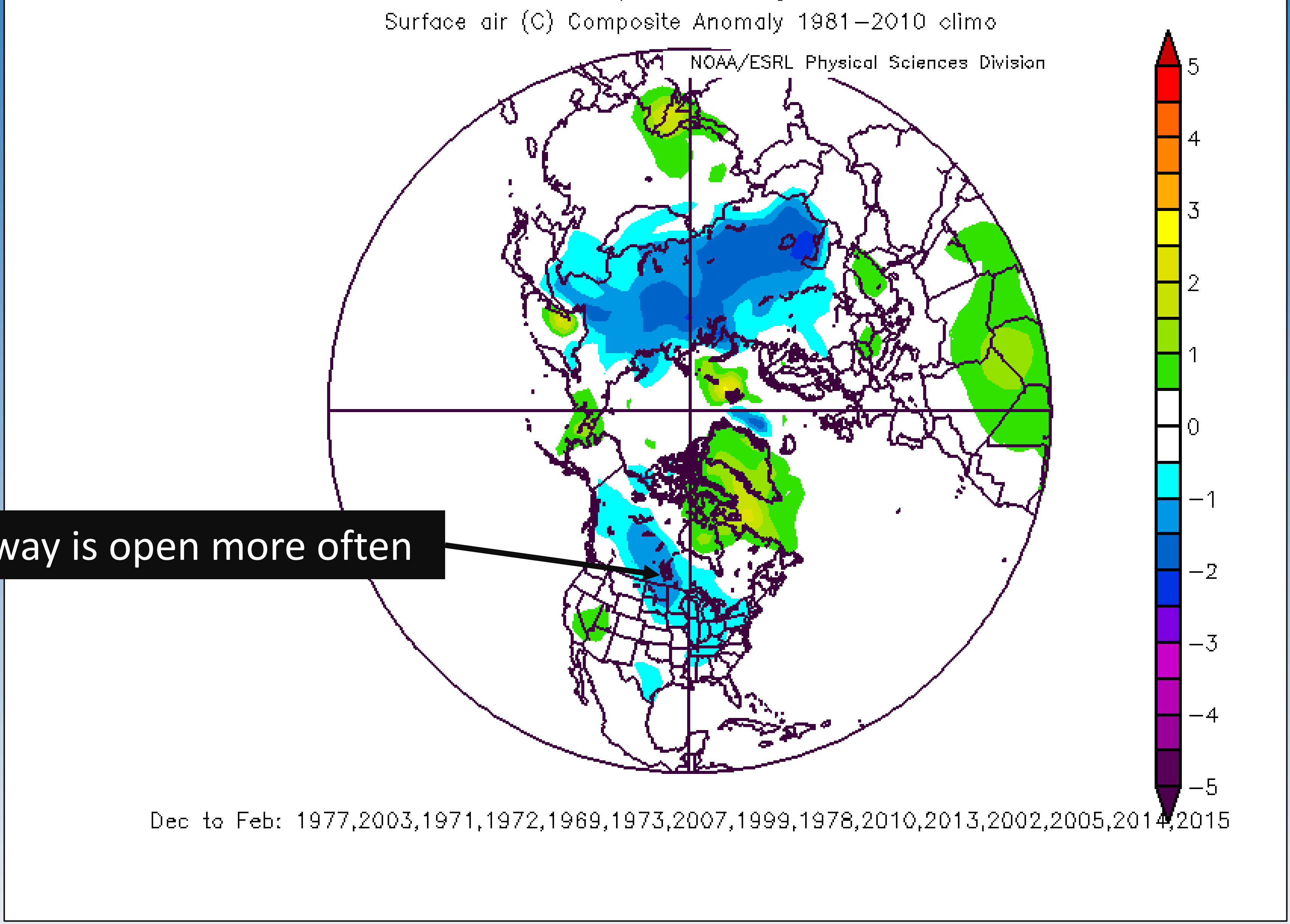
This is an example of a positive feedback loop, an negative correlation.



Snowy Octobers last two years

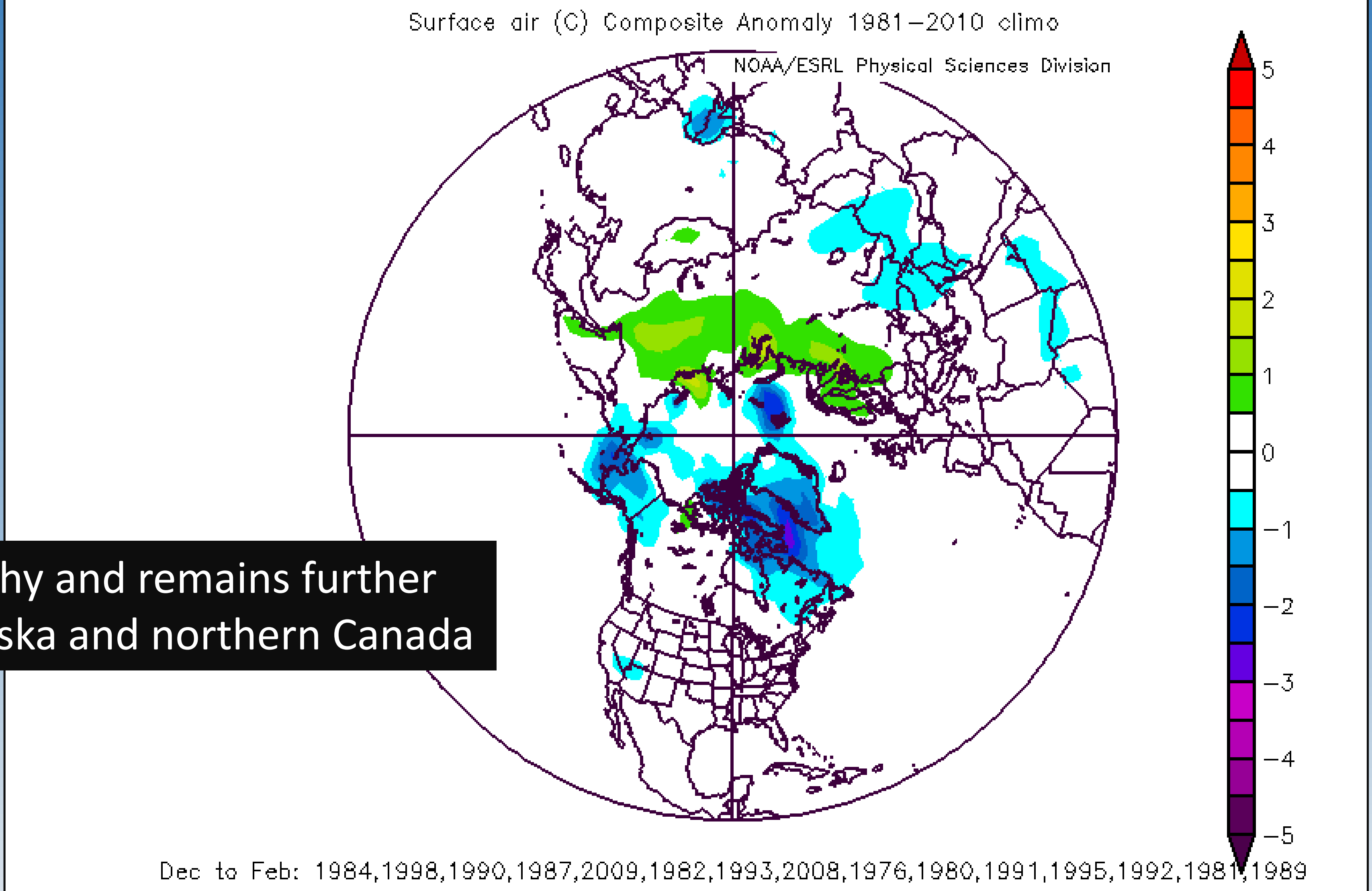
http://climate.rutgers.edu/snowcover/

Winters following high October Eurasian Snow Cover



Arctic air pathway is open more often

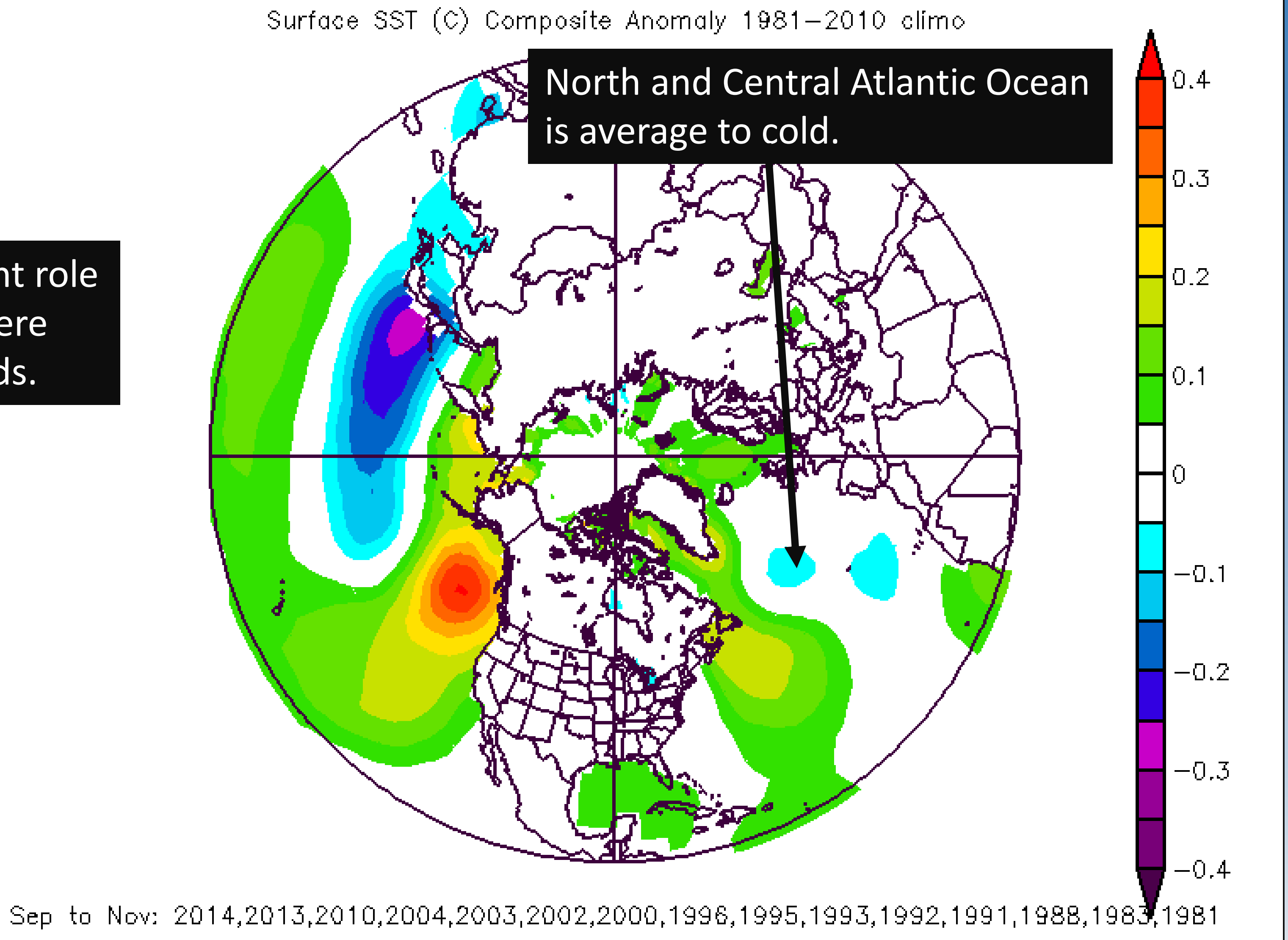
Winters following low October Eurasian Snow Cover



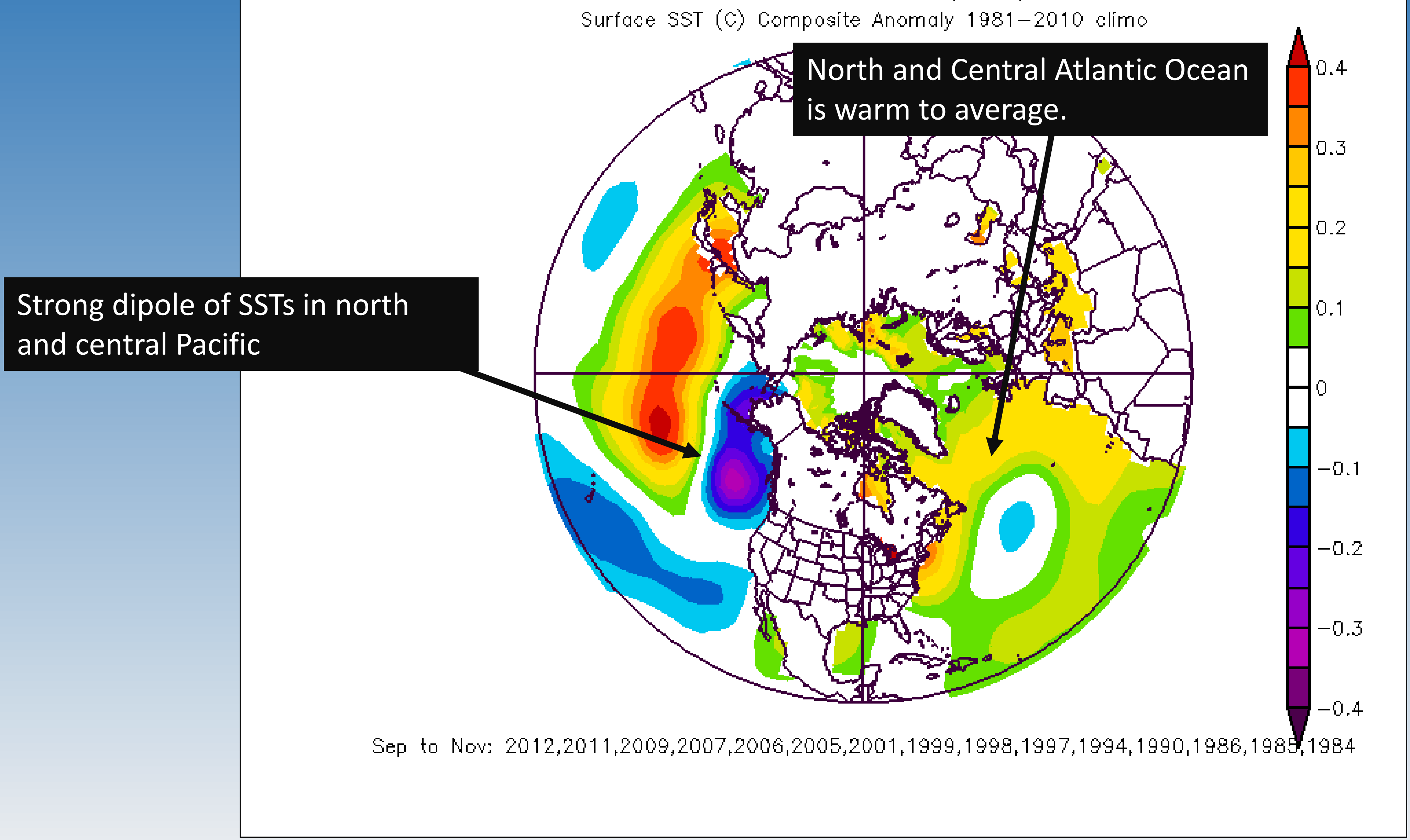
Cold air is shy and remains further north – Alaska and northern Canada

Fall Sea-Surface Temperature Anomalies Preceding Cold Winters

Oceans play a significant role in forcing the atmosphere over longer time periods.



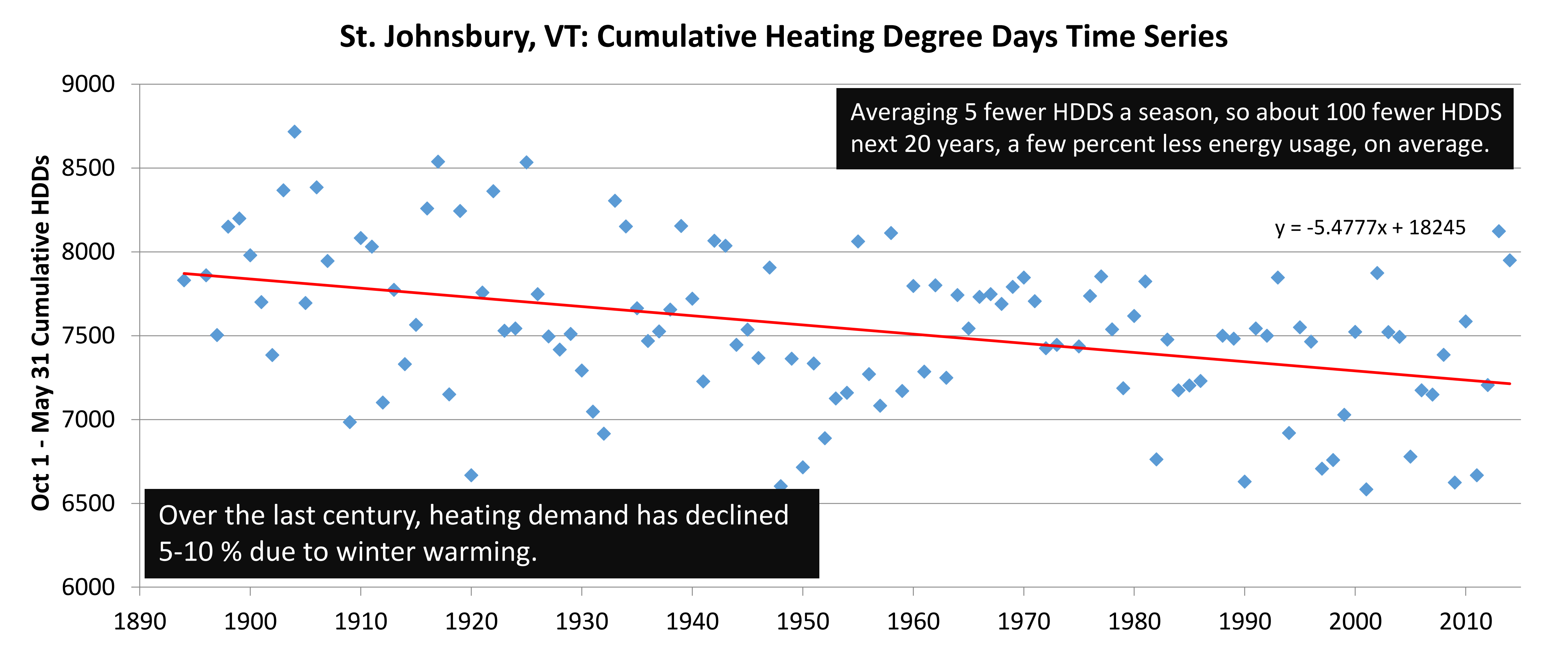
Fall Sea-Surface Temperature Anomalies Preceding Cold Winters



Arctic Oscillation

Vermont Climatic Changes

Heating Degree Day Trend – Temperature Trend



Betts 2011

APRIL 2011 BETTS

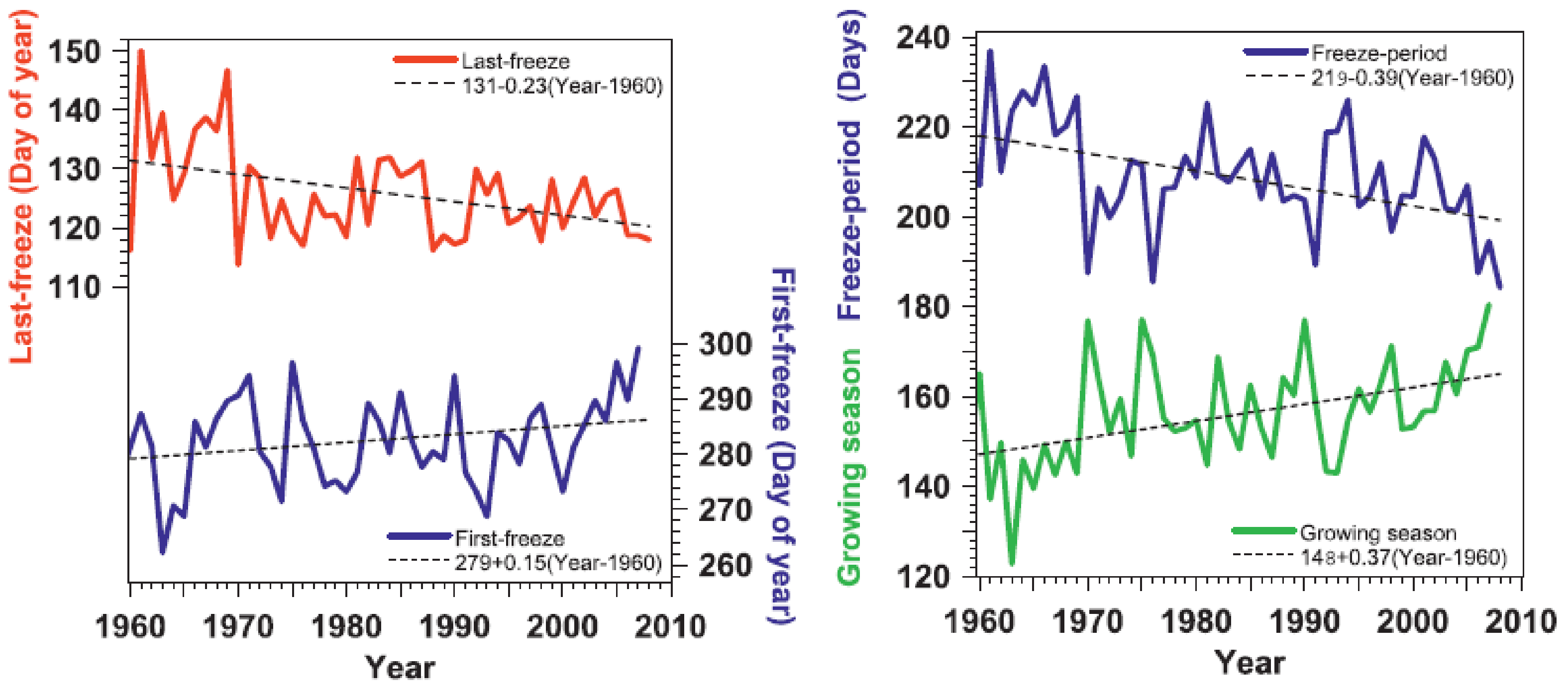


FIG. 3. (left) Last spring freeze and first autumn frost and (right) length of freeze period and growing season (data from Schwartz et al. 2006).

Winters are getting shorter and the growing season is increasing.

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

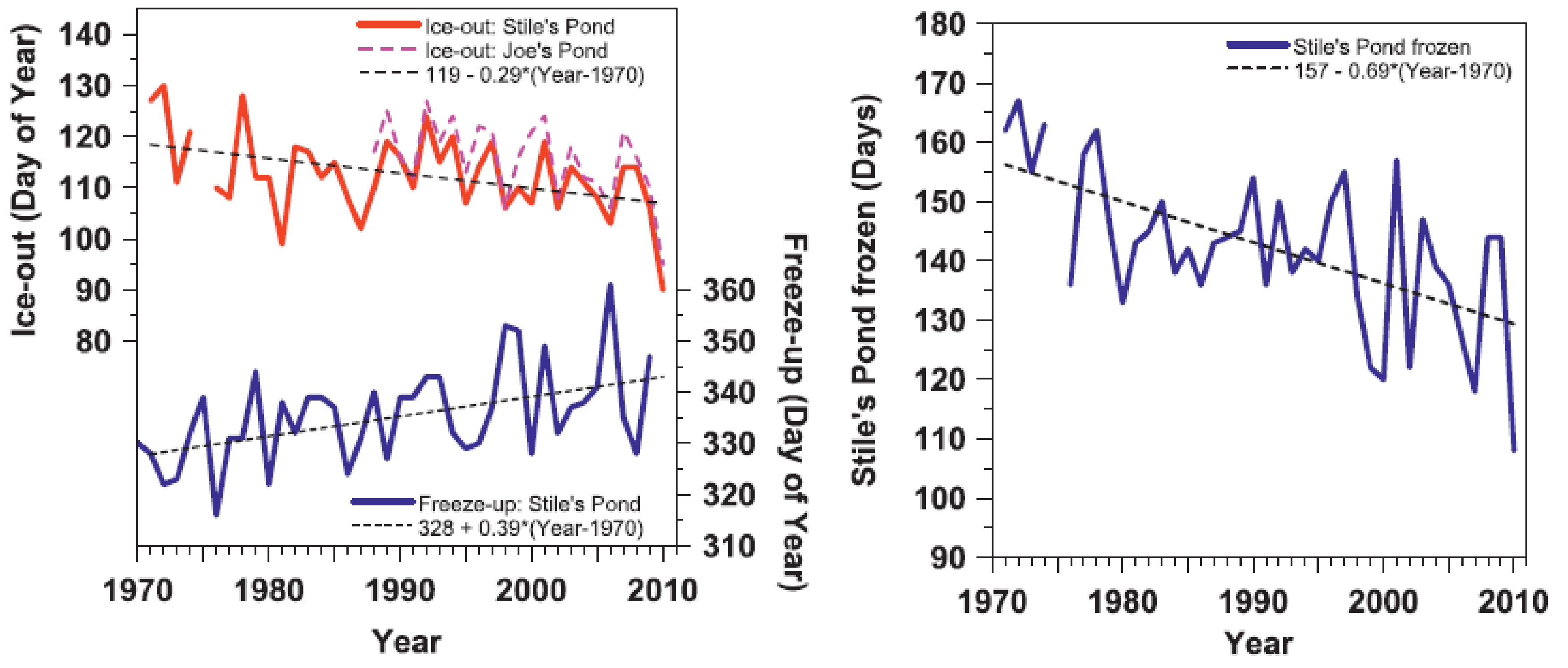


FIG. 4. (left) Freeze-up and ice-out days for Stile's Pond and ice-out for Joe's Pond and (right) winter frozen period for Stile's Pond. (Ice-out in 1975 is missing.)

Betts 2011

Winters are getting shorter through other proxies.

Seasonal Forecasting

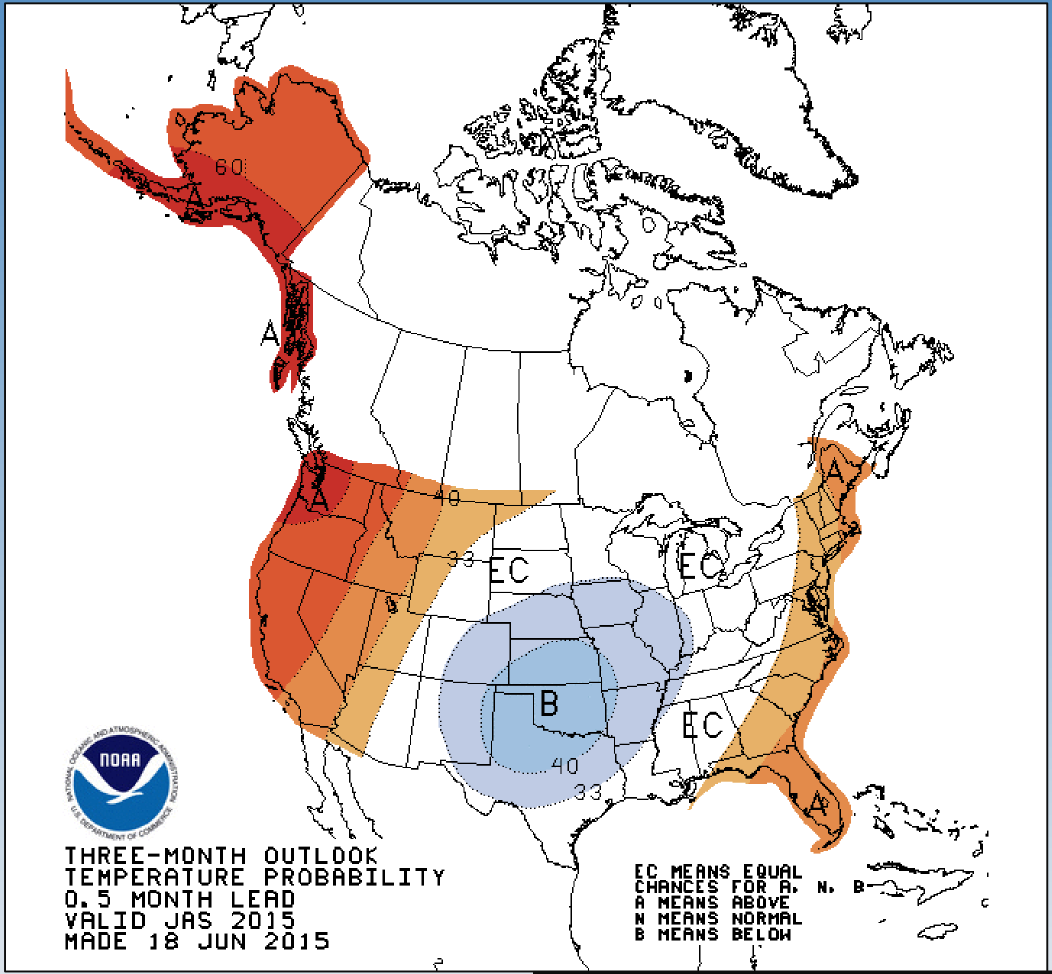
Statistical Prediction Methods

- Relate numerical index values of oceanic temperature patterns (or whatever variable you choose) to the following winter's temperature and precipitation
- For example, you could look at the ENSO state, which represents El Niño/La Niña, the largest oceanic oscillation on monthly to yearly time scales
- We will relate the Arctic Oscillation to show how this is related to winter temperatures

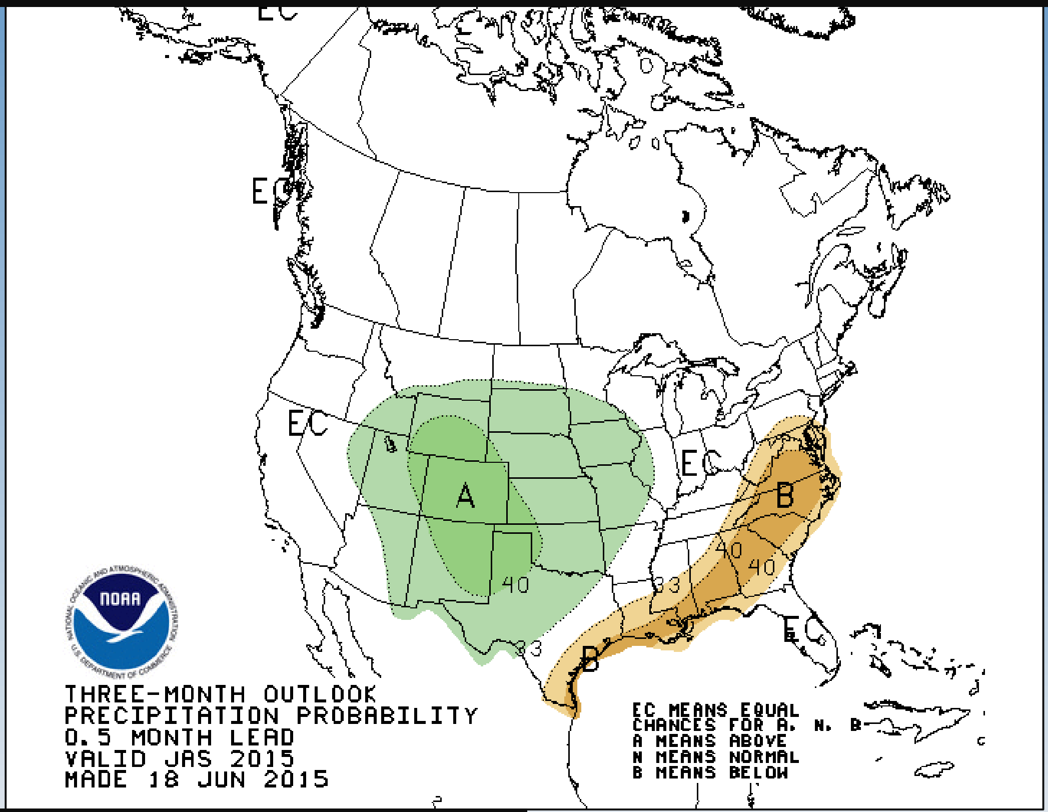
Statistical Methods: Fall Snow Cover

- Siberian snowfall during October has an effect on winter temperature patterns over the Northern Hemisphere.
- There is well documented literature on the topic physically connecting the two – as mentioned earlier
  - Enhanced fall snow cover enhances the Hemispheric cold air reservoir and creates a greater potential for winter cold in the mid and high latitudes
  - Complex interaction involving stratosphere and troposphere, but it has been physically described – still need “weather” events to move cold air south

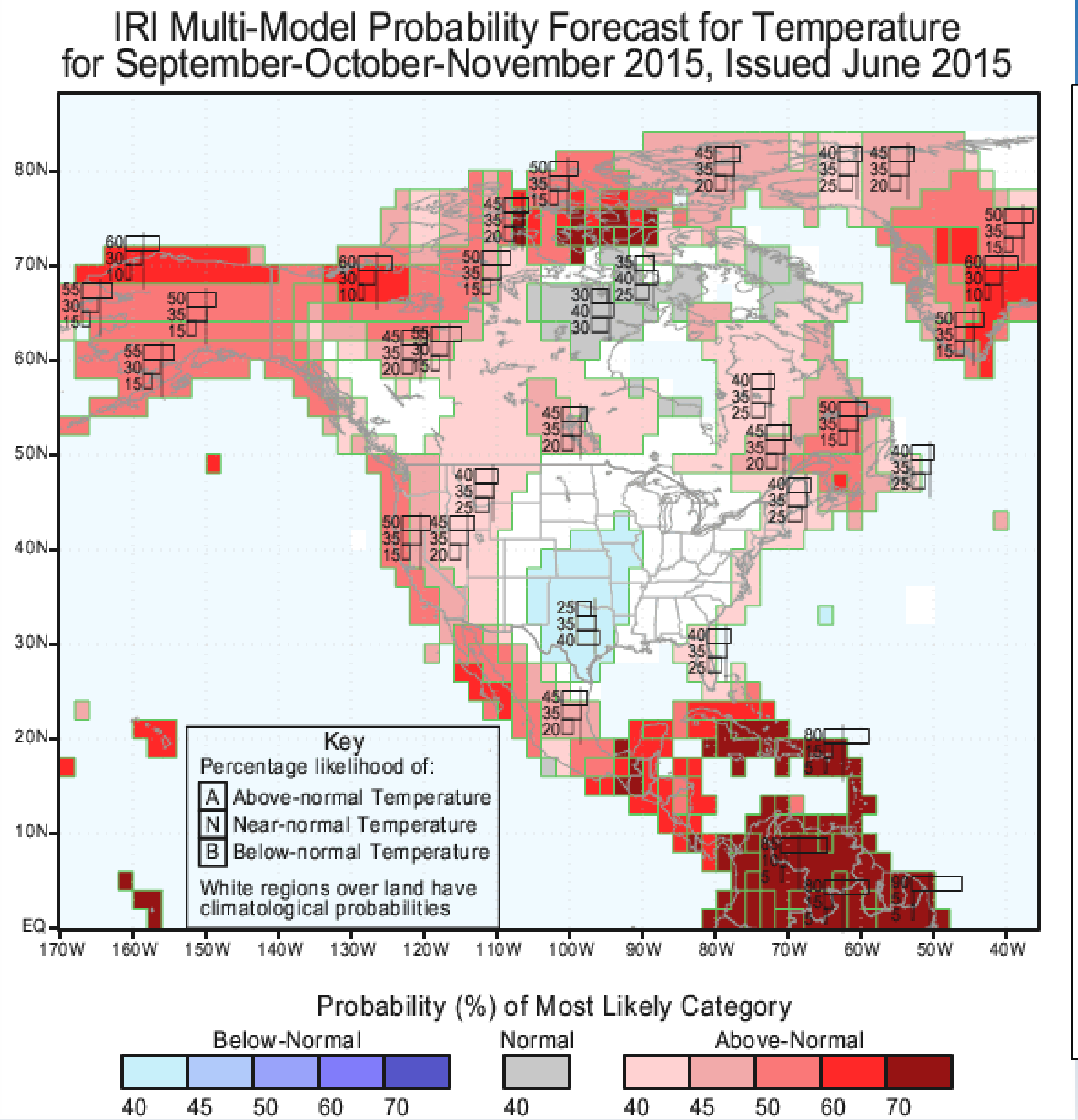
Climate Prediction Center Forecasts



Precipitation forecasting is much more difficult than temperature forecasting.

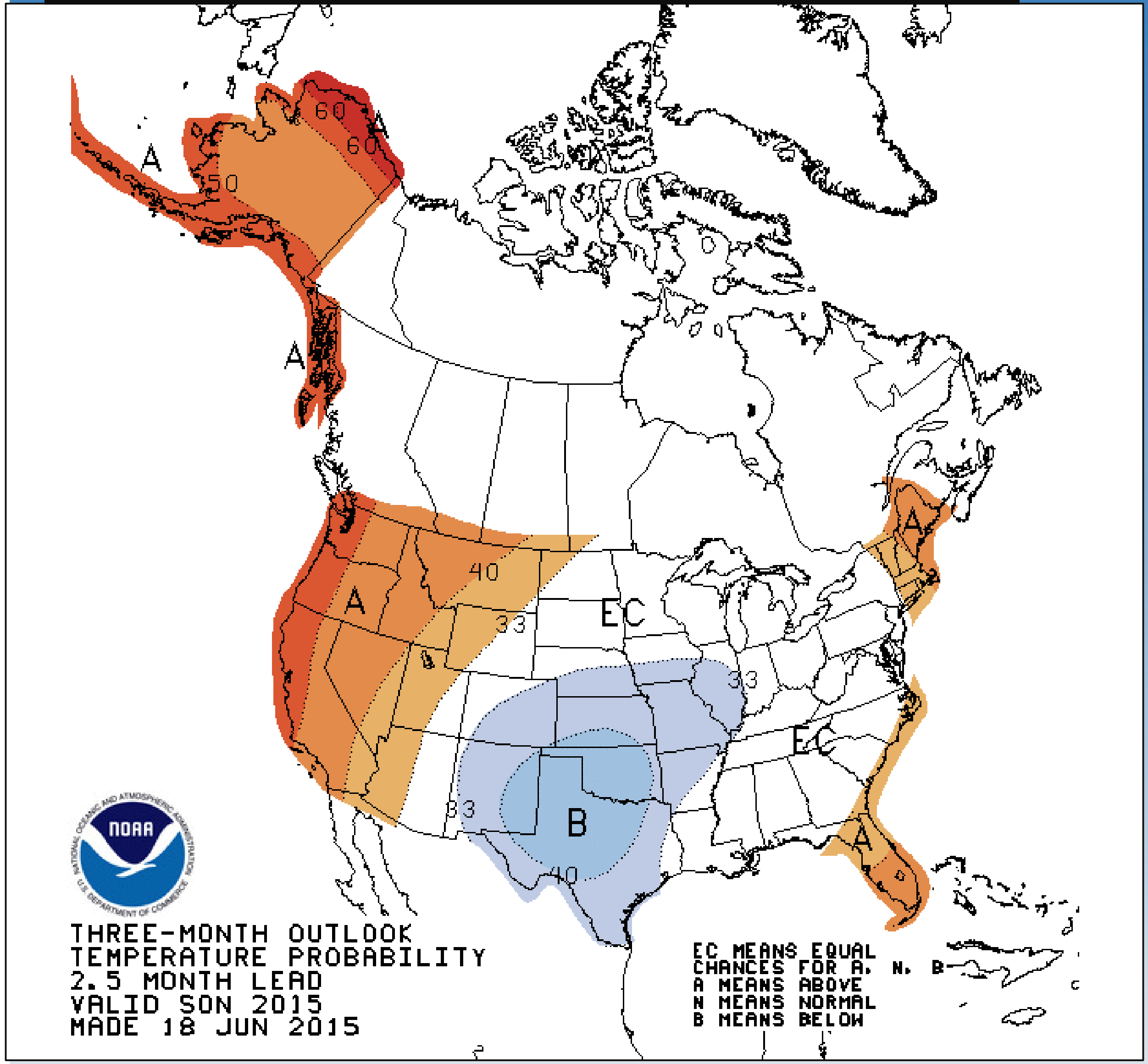


July, August, September Outlook



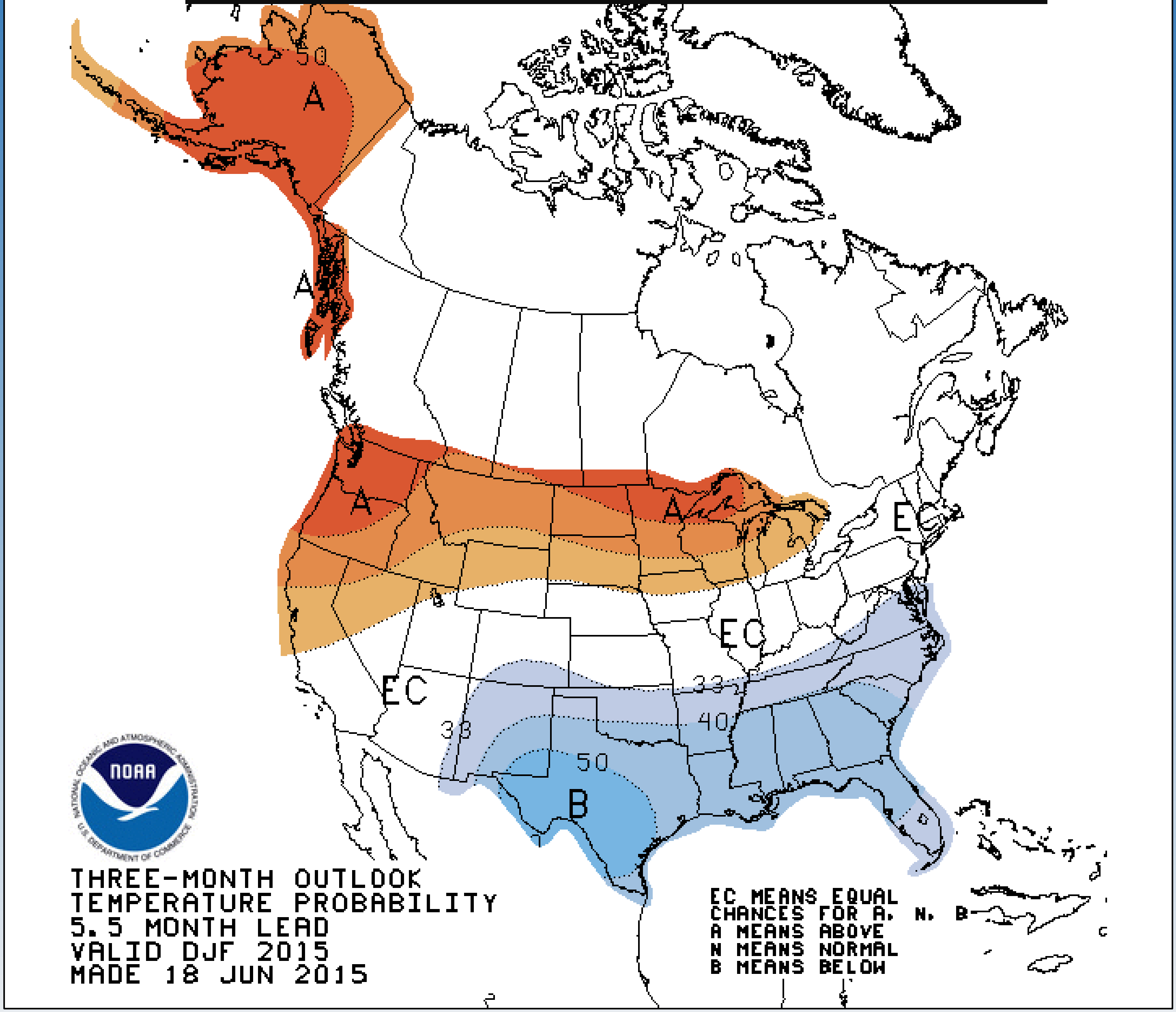
http://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

Fall (Sept – Nov) Outlook



http://www.cpc.ncep.noaa.gov/products/predictions/long_range/seasonal.php?lead=3

Winter (Dec– Feb) Outlook



Conclusions

- Are cold winters returning?
  - No, not for the long haul
  - However, natural variability will continue to produce cold spells and occasional prolonged cold weather like the last two winters
- Climate models struggle with seasonal forecasting and processes as snow cover-land surface feedbacks
- Vermont winters are getting shorter (especially with their late arrival), but they can have intense stretches as they have in the past
- The next ten winters will probably be like the last ten winters

Activity

- Correlate Arctic Oscillation state with season cumulative HDDs
- Hypothesis: Arctic Oscillation phase during winter has an effect on Vermont seasonal temperatures
- Excel sheet is available at: https://drive.google.com/file/d/0B3NtxLJnOImFRUxHQU9qMnNJazg/view?usp=sharing