Dealing With Climate Change

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Climate Change Café

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Brattleboro, VT

Outline

- **Science of climate change**
  - **Global and local**
  - **What is happening to Vermont?**
  - **Why is extreme weather increasing?**
- **The transition we face**
  - **Can we stabilize the climate?**
  - **Why is it difficult?**
  - **How long can we adapt?**

Discussion

Earth sustains life

- **Burning fossil fuels is increasing greenhouse gases and melting polar ice**
- **Climate is warming and extreme weather is increasing**
- **Water plays crucial role everywhere**

January 2, 2012: NASA

System Issues

- **Human waste streams are transforming the Earth's climate, and human and natural ecosystems**
- **How will this affect landscape, water supplies, food system and human health?**
- **What strategies and mindset are needed to mitigate, adapt and build resilience in Vermont?**
  - **Is this an efficient way of doing this?**
  - **Can we manage our waste streams better?**
  - **Can I deepen my connection to the Earth?**

Our Present Challenge

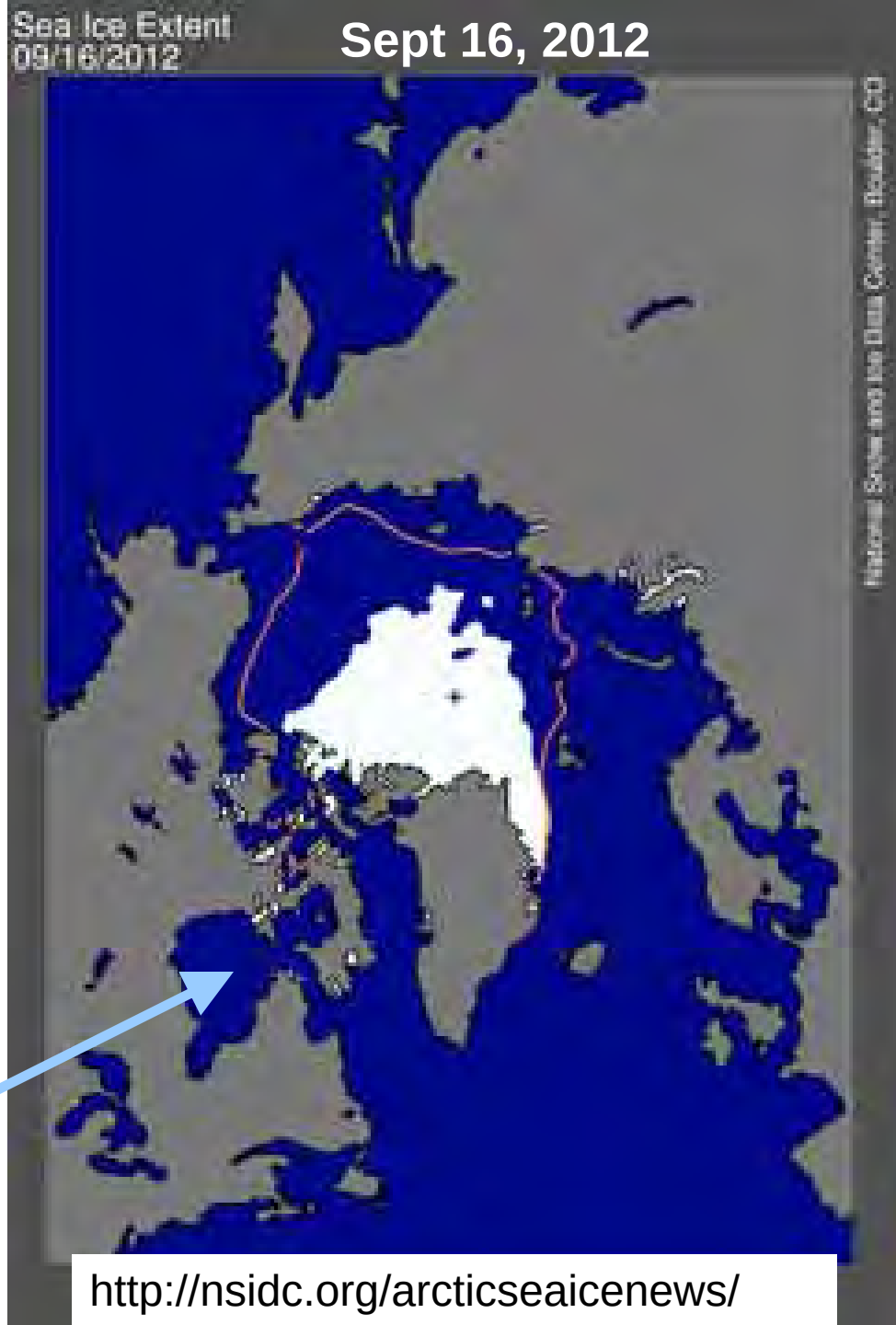
- **How to reintegrate**
  all that we know and understand

  – *given the deep interconnectedness*
  of life & climate on Earth

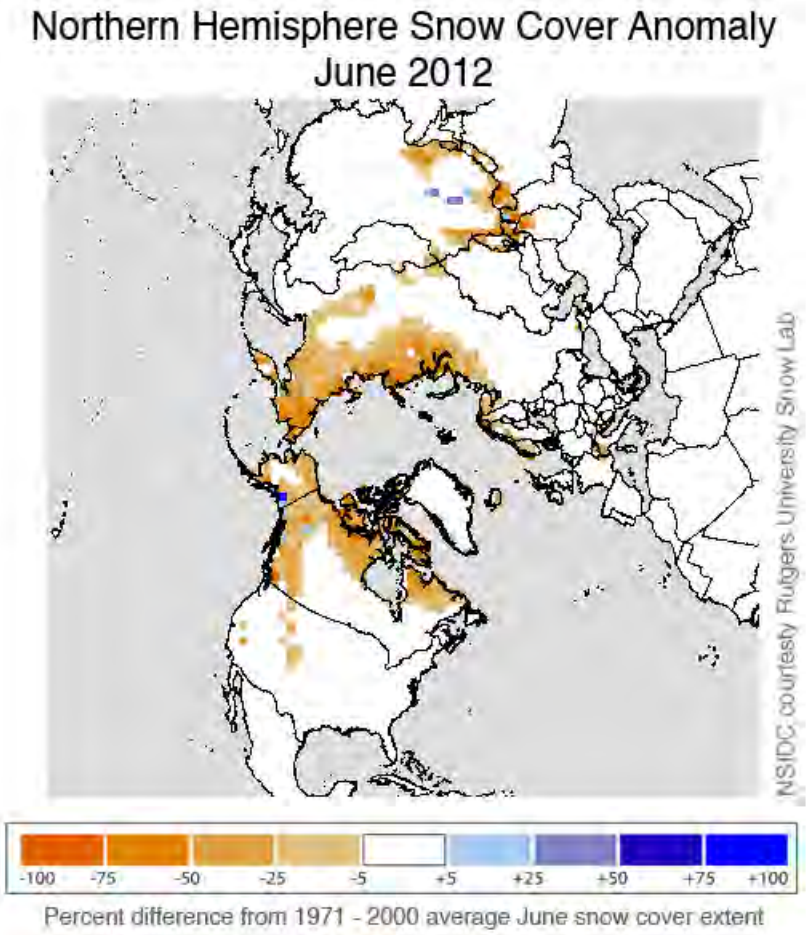
- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

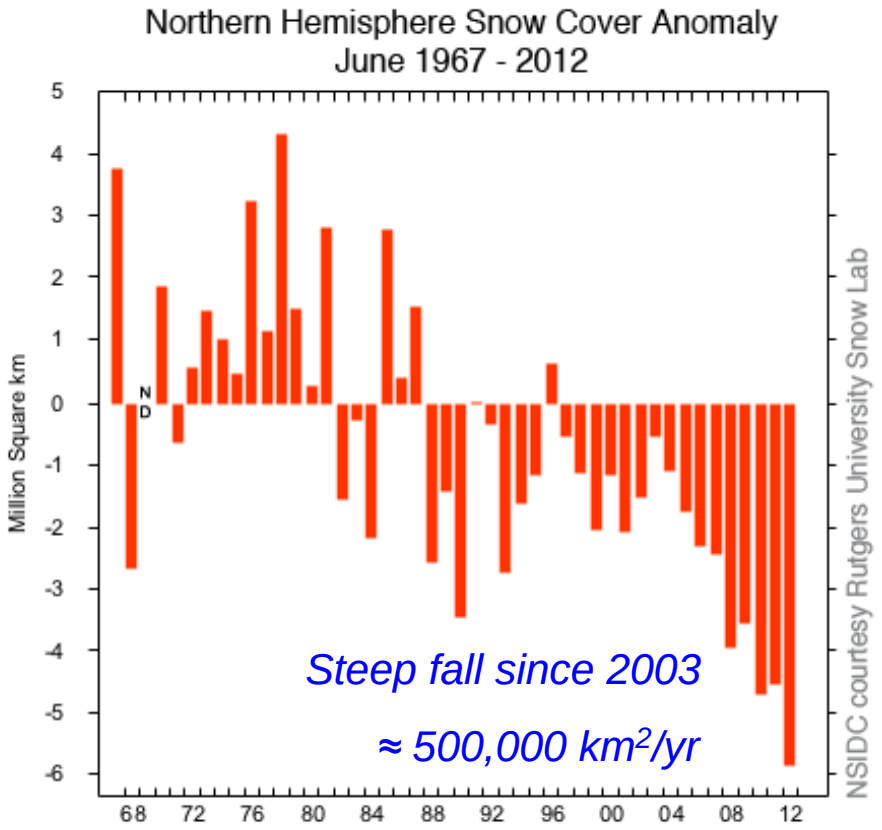
- ***Positive feedbacks:***
- ***Less ice, less reflection of sunlight***
- ***More evaporation, larger vapor greenhouse effect***
- ***Ice thin: most 1-yr-old***

End of Nov. 2011 Hudson Bay was still nearly ice-free



June 2012 snow cover minimum





- **Arctic warming rapidly**
  - **Melting fast**
  - ***Much faster than IPCC models***
- **Northeast winters**
  - ***Same positive feedbacks***

Changes in Vermont

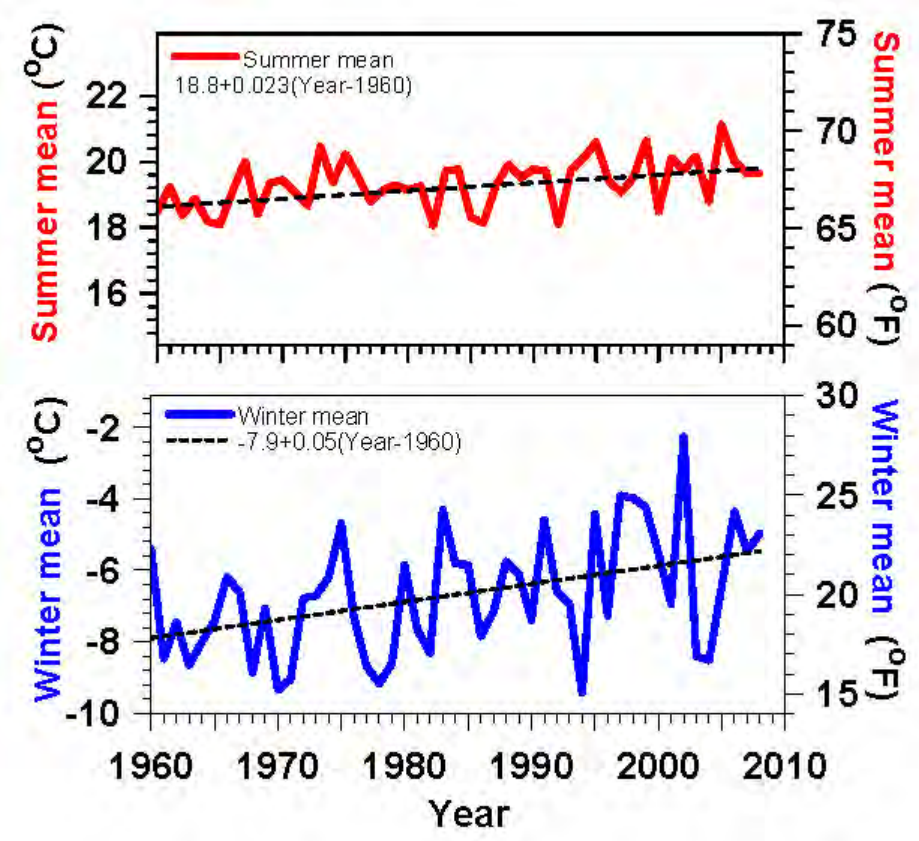
- **PAST 40/50 years** ***(global CO_2 forcing detectible)***
- **Warming twice as fast in winter than summer**
- **Winter minimums increasing even faster**
- **Lakes frozen less by 7 days / decade**
- **Growing season longer by 3-4 days / decade**
- **Spring coming earlier by 2-3 days / decade**

(Betts, 2011)

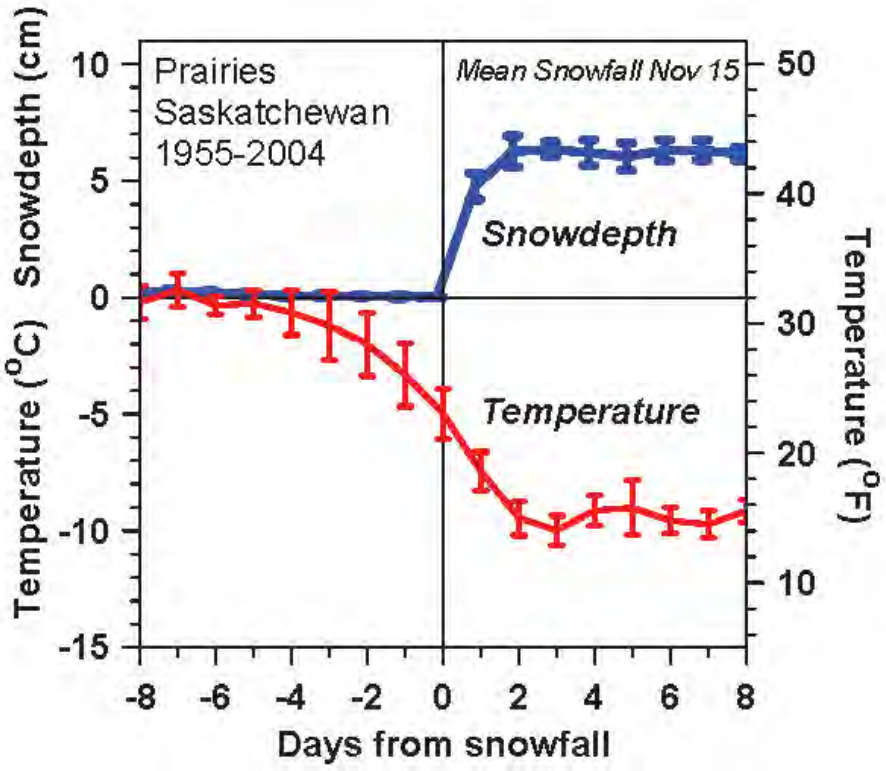
- **Extreme weather increasing**
- ***Evaporation increases with T***
- ***More 'quasi-stationary weather patterns'***

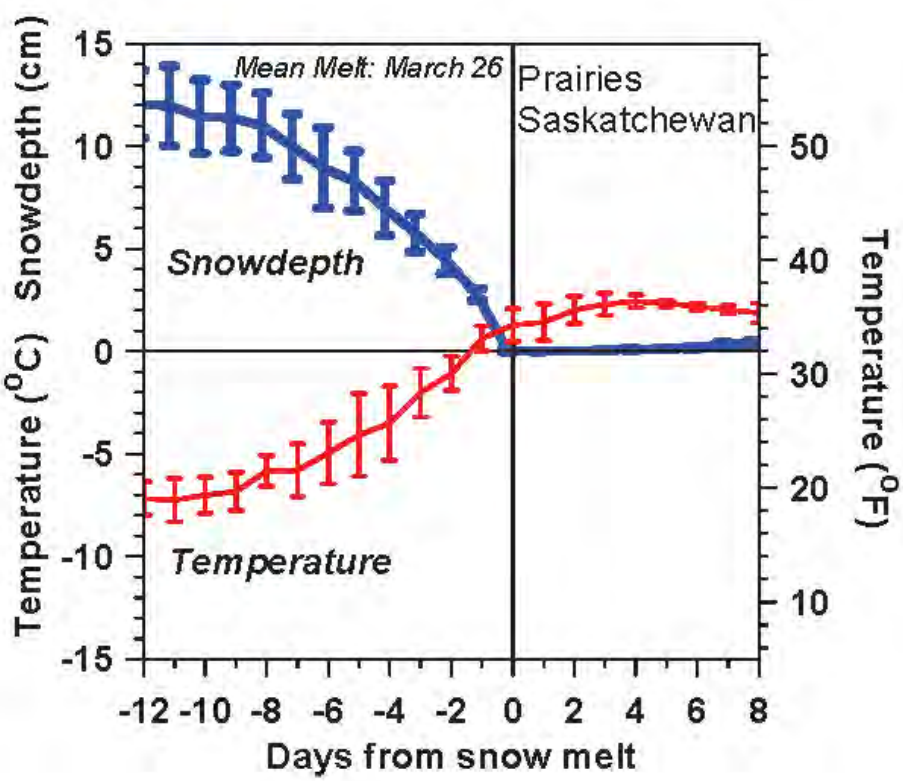
Vermont Temperature Trends 1961-2008

- **Summer +0.4°F / decade**
- **Winter +0.9°F / decade**
- **Larger variability, larger trend**
- ***Less snow (and increased water vapor) drive larger winter warming***



Snowfall and Snowmelt



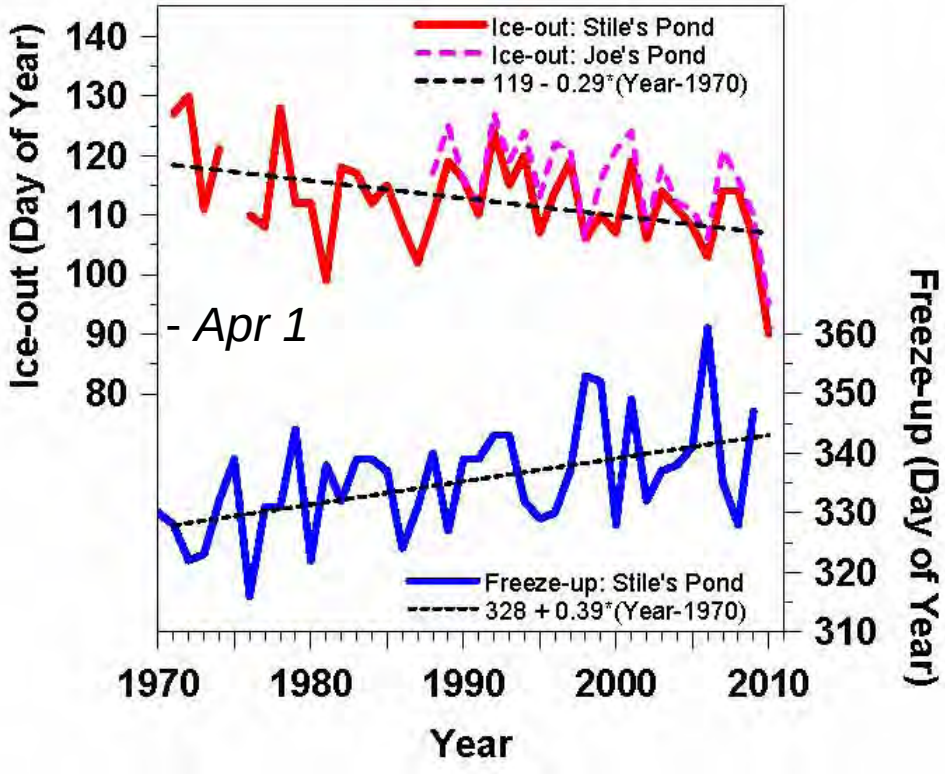


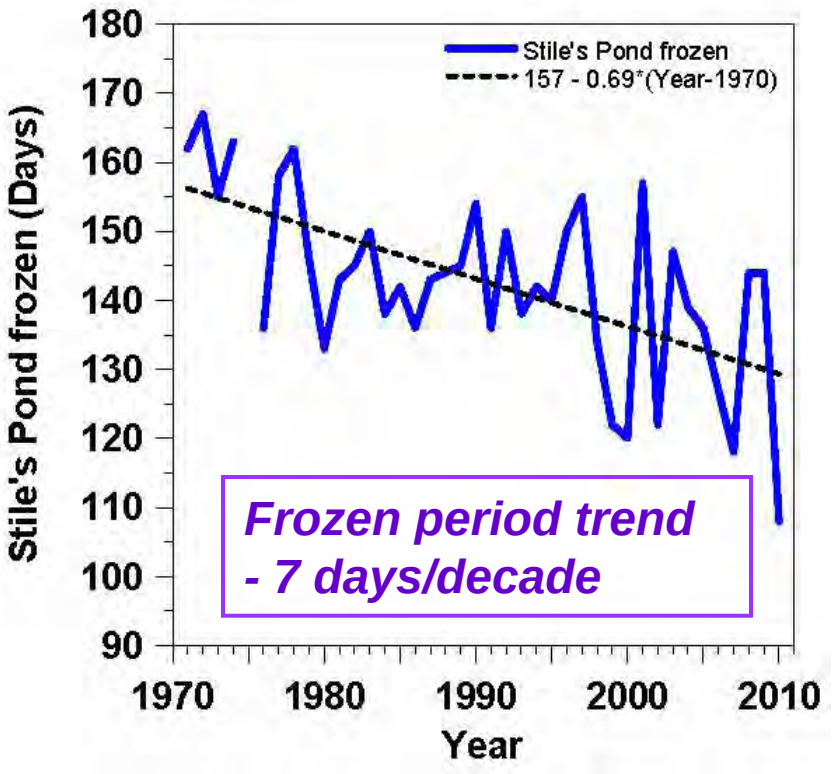
- **Temperature falls 16F (9C) with first snowfall**
- **Similar change with snowmelt**
- ***Snow reflects sunlight; reduces evaporation and water vapor greenhouse – changes 'local climate'***

Betts et al. 2014

Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking Fast

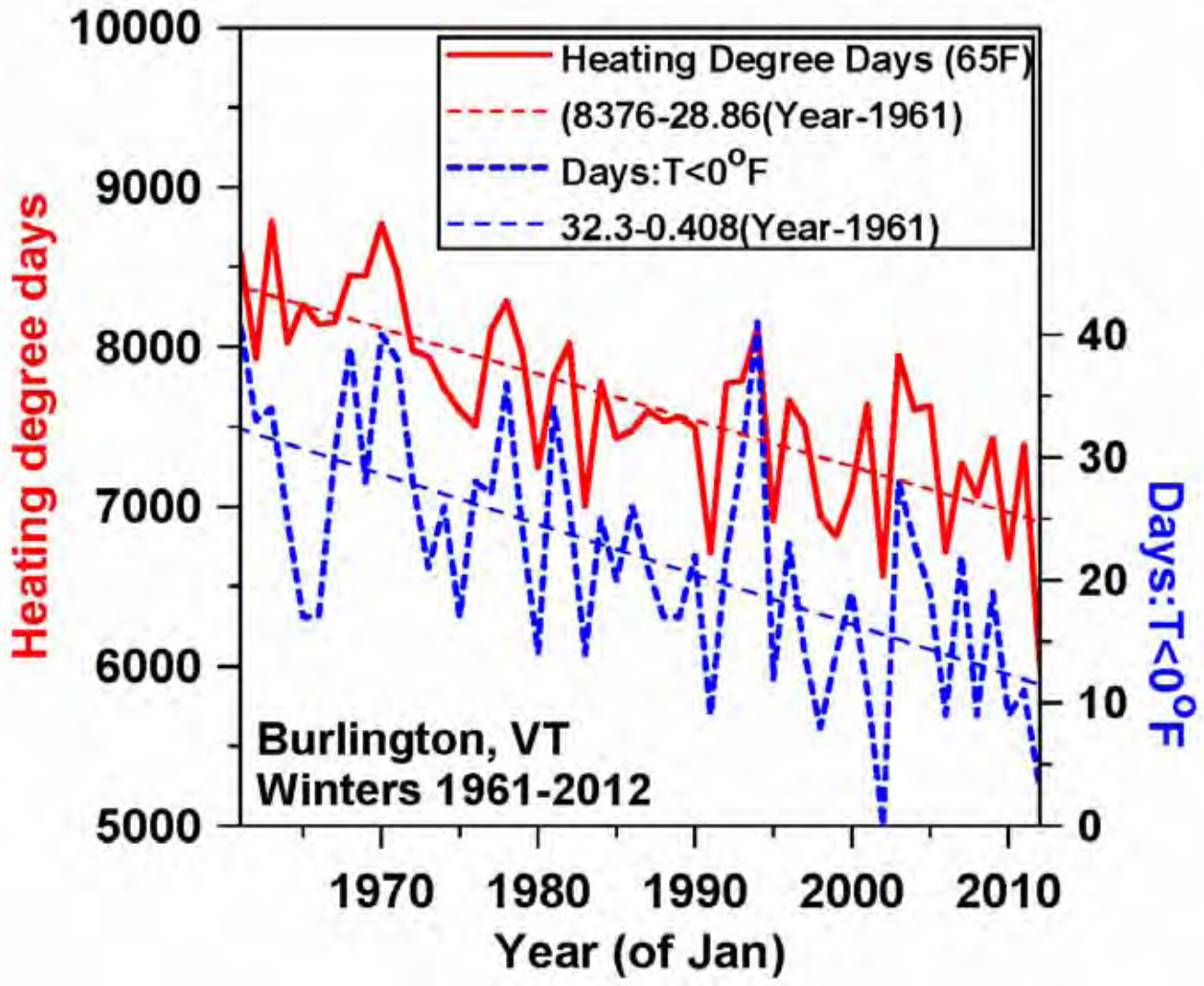




- **Ice-out earlier by 3 days / decade**
- **Freeze-up later by 4 days / decade**
- ***Soil ice probably similar***

Heating Degree Days and Days below 0°F (Burlington)

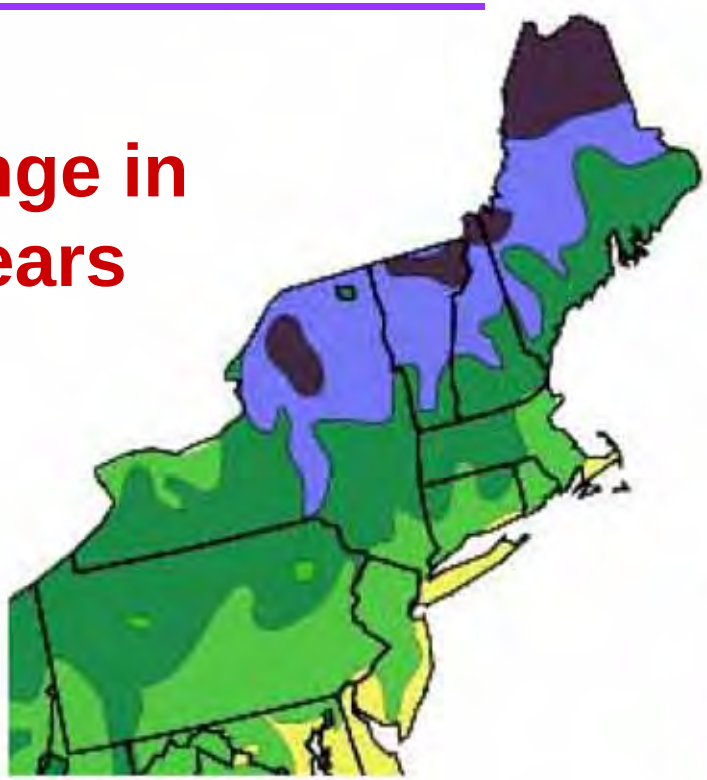
- **Heating degree days *falling 290/decade***
- **T_{min}<0°F *falling 4 days /decade***



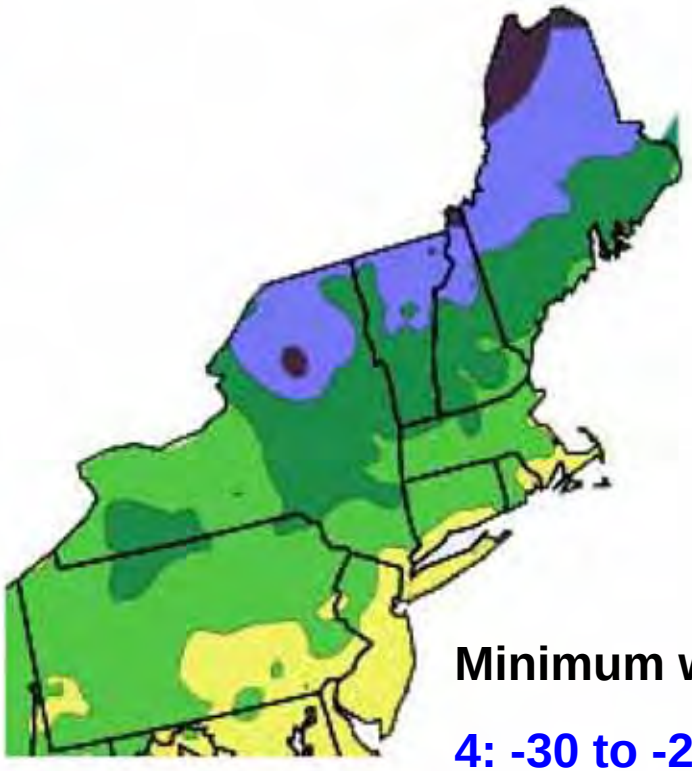
Winter Hardiness Zones

– ***winter cold extremes***

Change in 16 years



1990



2006

Minimum winter T

4: -30 to -20°F

5: -20 to -10°F

6: -10 to 0°F

Zone

2 3 4 5 6 7 8 9 10

USDA Hardiness Zones

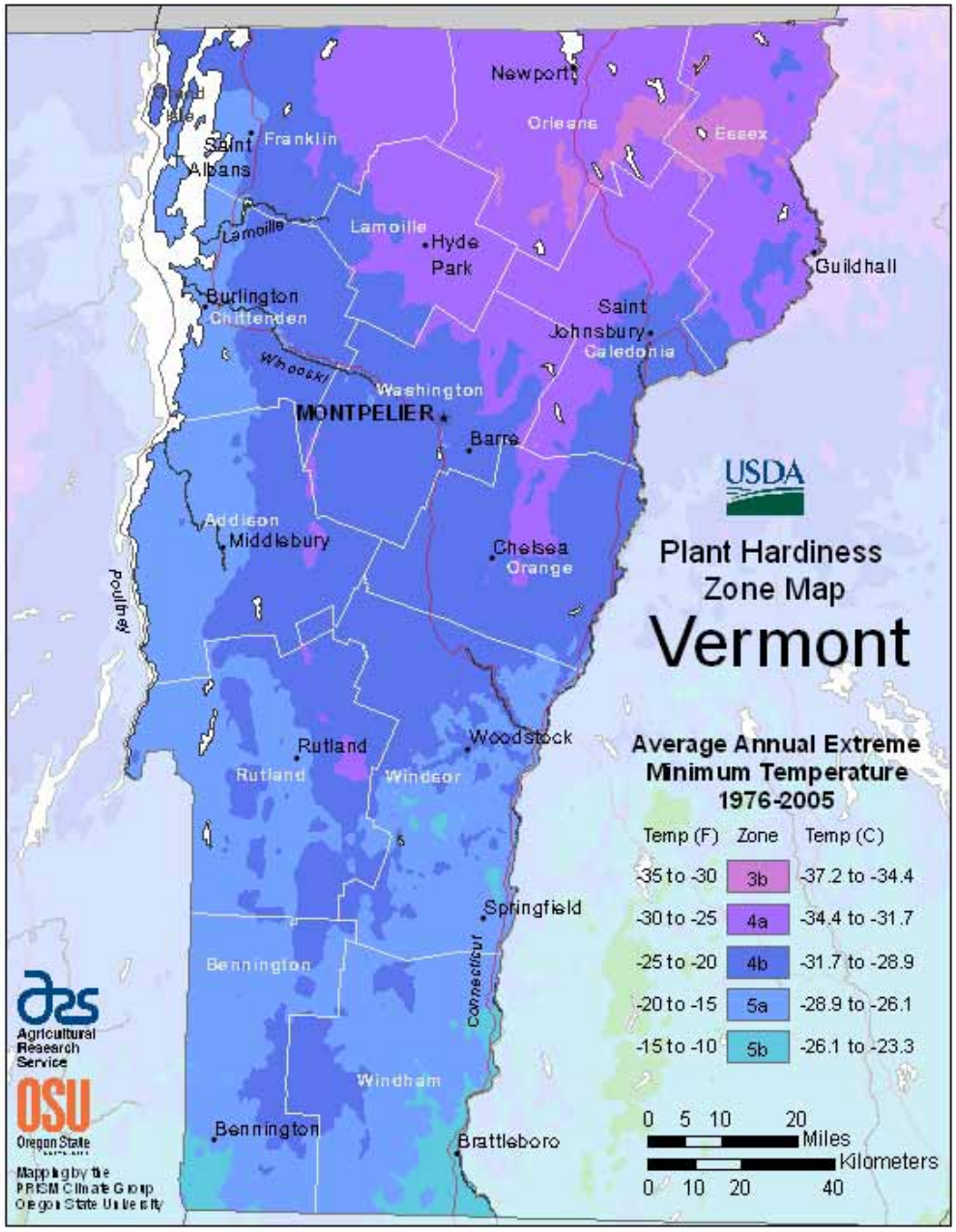
Detailed Map *(most recent)*

- **VT Hardiness Zone Map 1976-2005**
  - **mean 1990**
  - **South now zone 6**

- **Half-zone in 16 yrs = 3.1°F/ decade**
  - ***triple the rise-rate of winter mean T***
  - ***3 zones/century***

- ***http://planthardiness.ars.usda.gov/PHZMWeb/***

(Krakauer, Adv. Meteor. 2012)



Bennington & Brattleboro are becoming zone 6 *(T_{min} > -10F)*

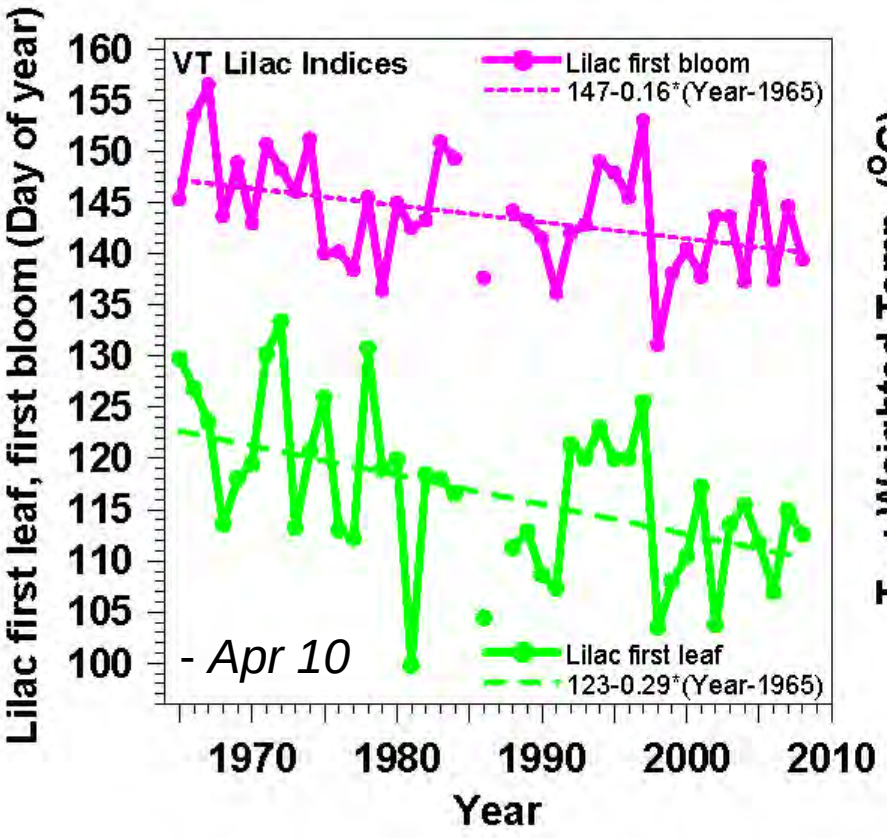
- **Hardy peaches: 2012**
- **More pests survive winter**
- **What is this?**

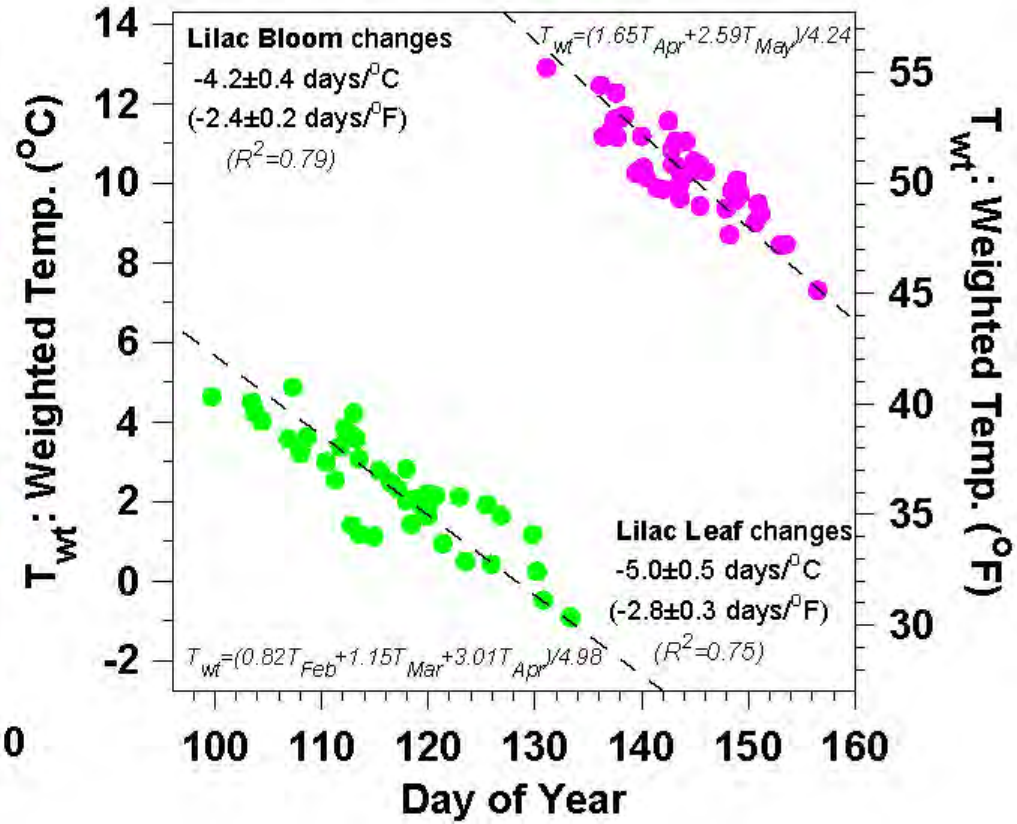
Bennington & Brattleboro are becoming zone 6

- **Hardy peaches: 2012**
- **More pests survive winter**
- **What is this?**

- **Avocado**
  - **Didn’t survive frost**
  - **2100 survive in CT**
  - **Our forests?**

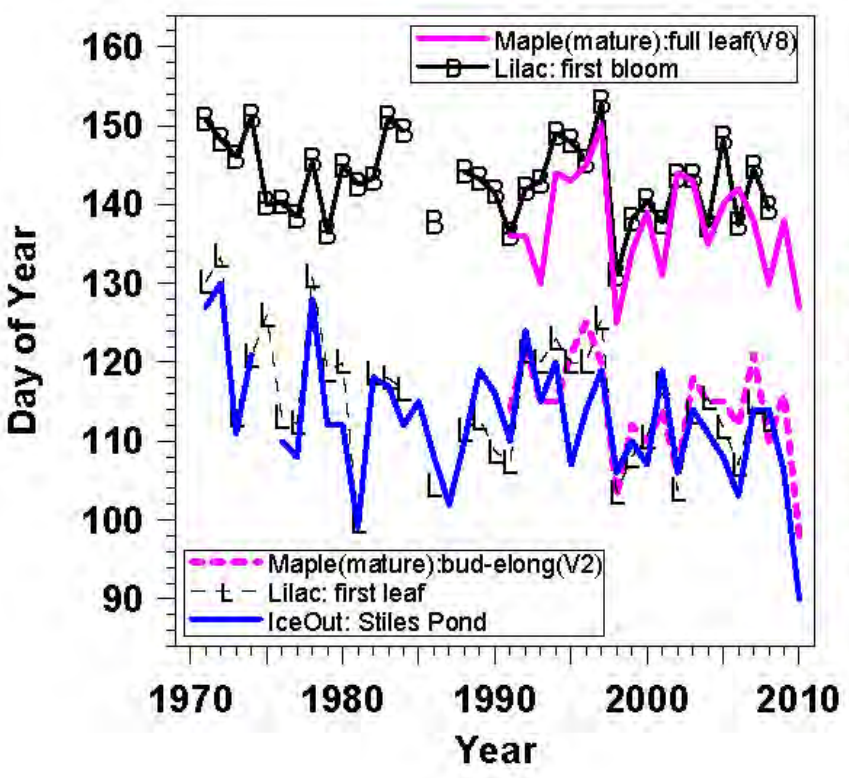
Lilac Leaf and Bloom

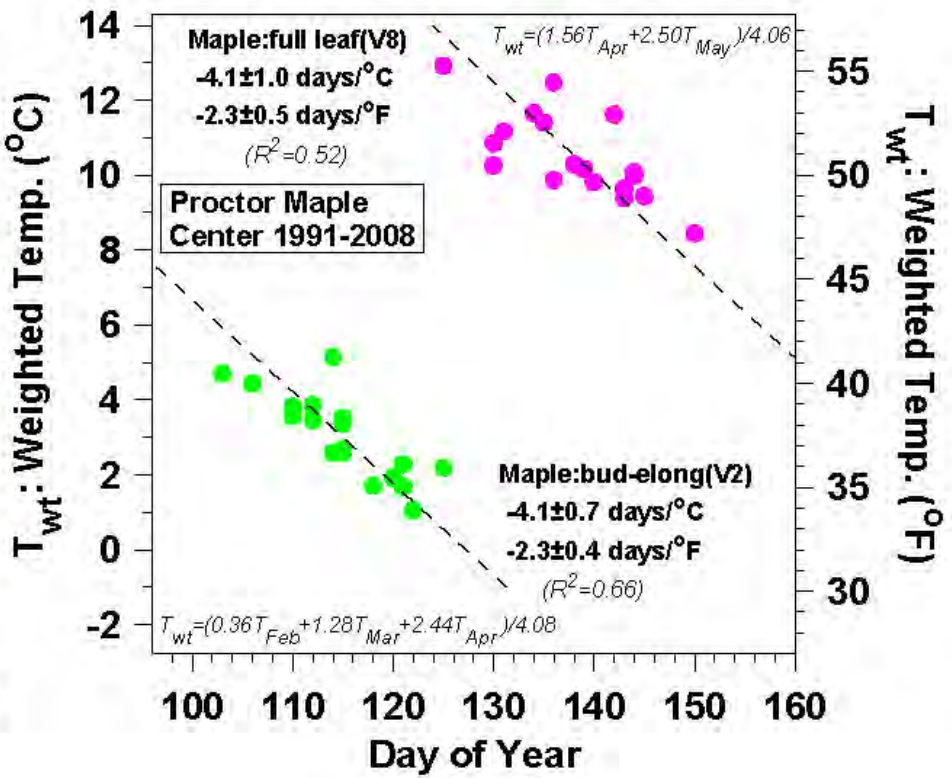




- **Leaf-out -2.9 days/decade; Bloom -1.6 days/decade**
- ***Large year-to-year variation related to temperature: 2.5 days/ °F***

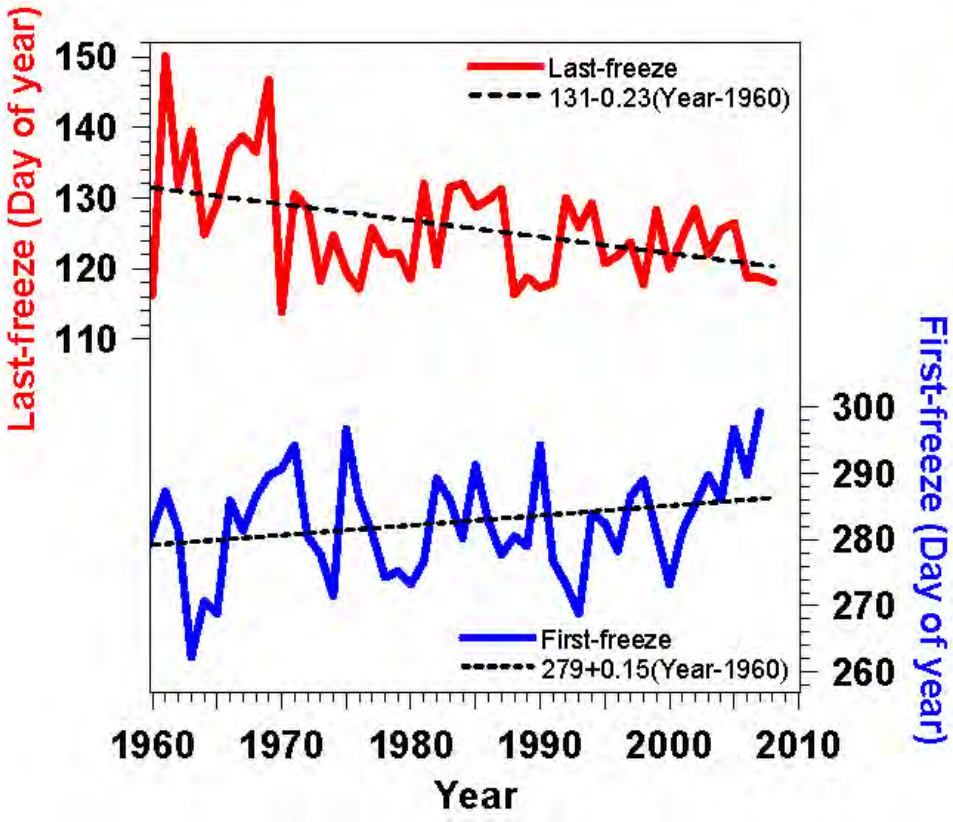
Maples and Lilacs in spring

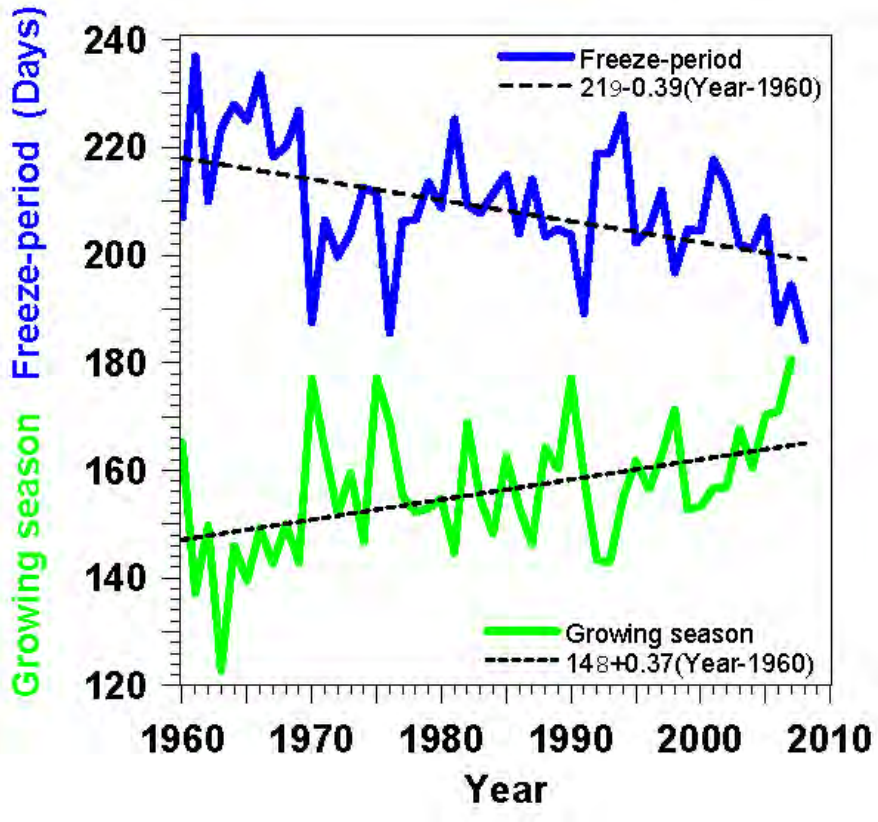




- **Maple bud elongation mirrors lilac leaf**
- **Maple leaf-out mirrors lilac bloom**

First and Last Frosts Changing





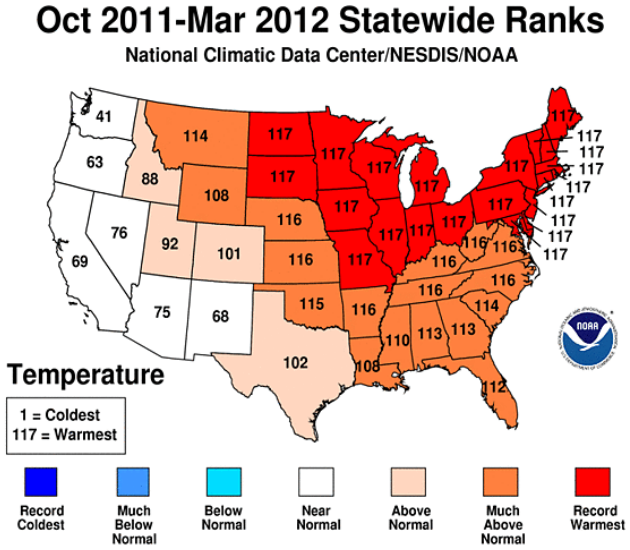
- **Growing season for frost-sensitive plants increasing 3.7 days / decade**
- ***Important for agriculture; local food supply***

January 2, 2012

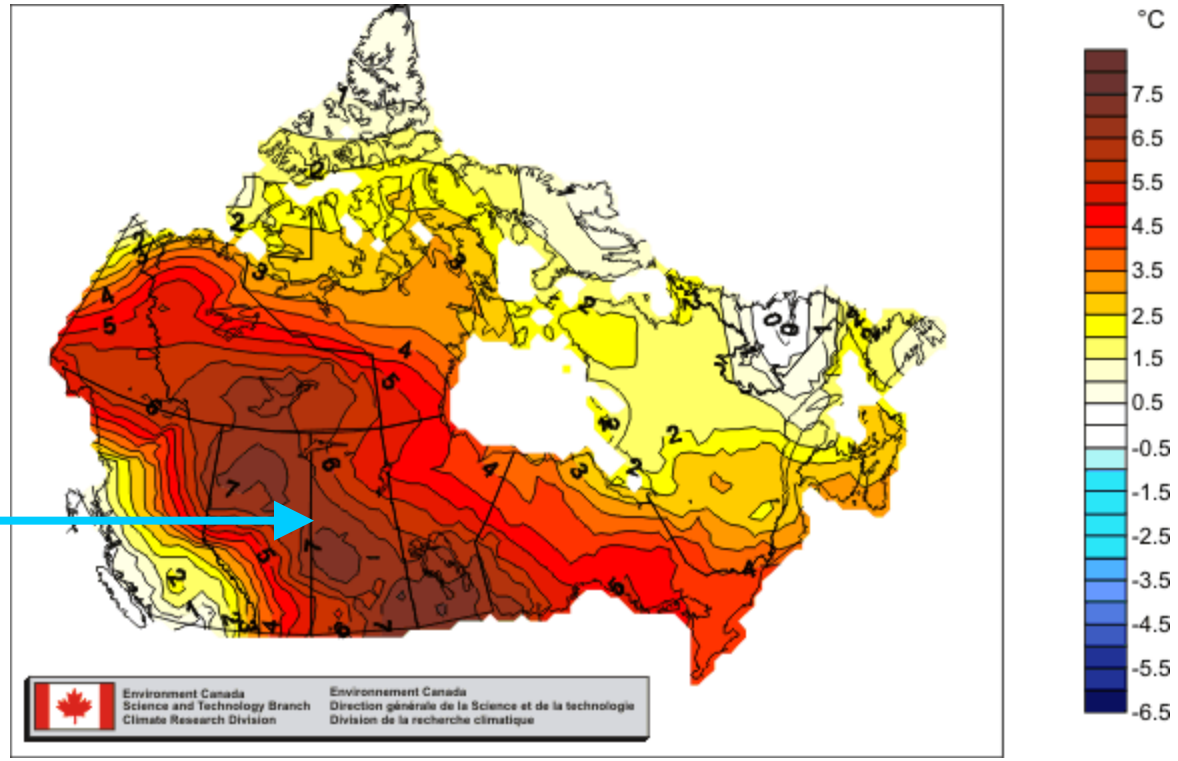
March 11, 2012

October 2011– March 2012

- **Warmest 6 months on record**
- **My garden frozen only 67 days**
- **No permanent snow cover west of Green Mountains**
- **Contrast snowy winters**
  - **2010-11; 2013-14**



Across the border: Canada



+12ºF

- **Winter 2011-12: Far above "normal"**
  - **Canada's winters also warming 0.9ºF/decade**
- ***Climate doesn't see the border!***

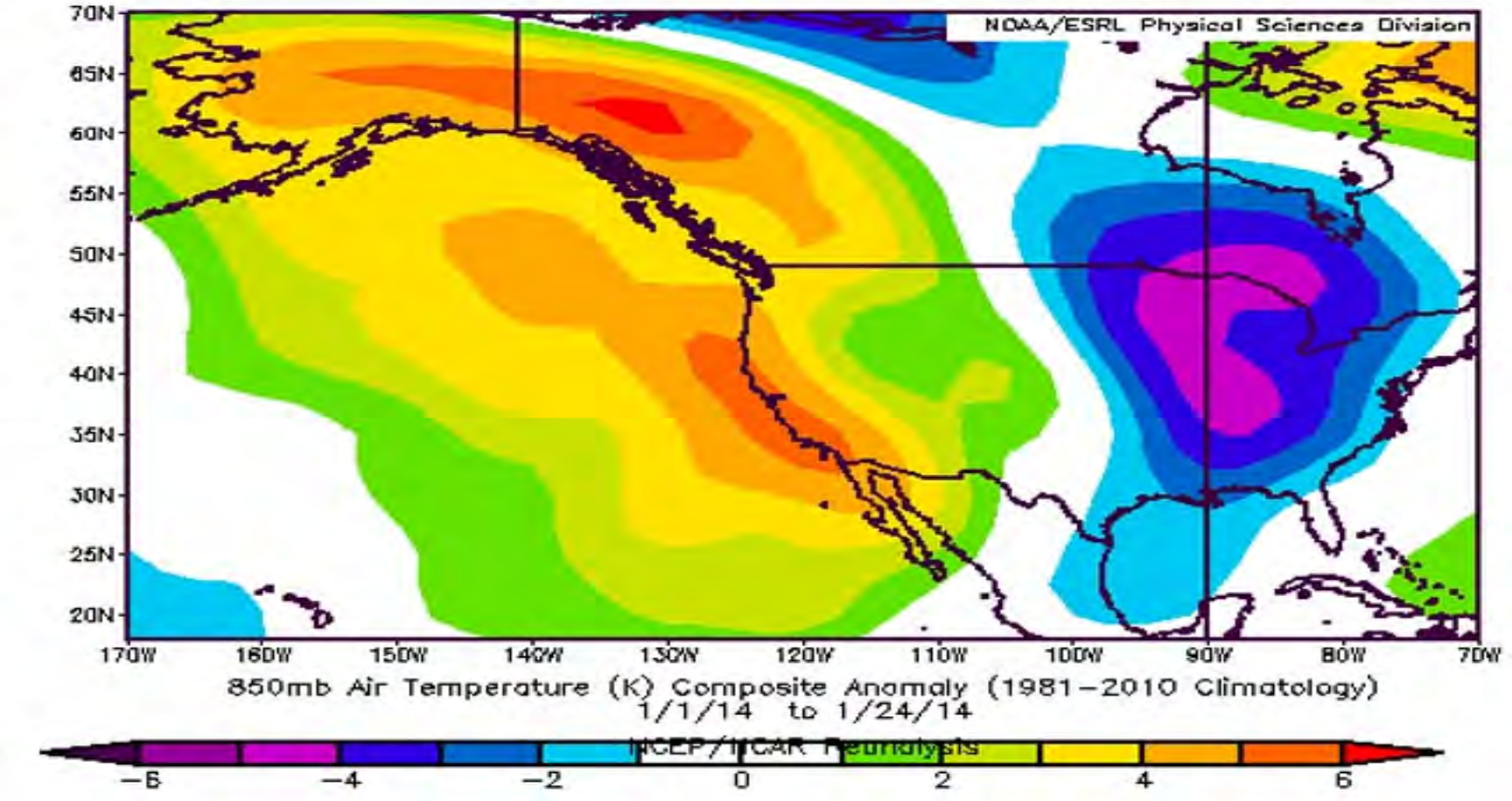
December 21, 2012

January 15, 2013

Winter 2012-13

- Dec 25: Ground froze hard
- Dec 27-28: Foot of snow
  - Air temperatures plunged but ground thawed under snow
- Jan 12-14: 45-50F: Snow melted
- Jan 15: Time to dig again..
- Followed by freeze-up.. Melt
- Final Melt - March 11

Jan. 1-24, 2014
850mb Temperature Anomaly

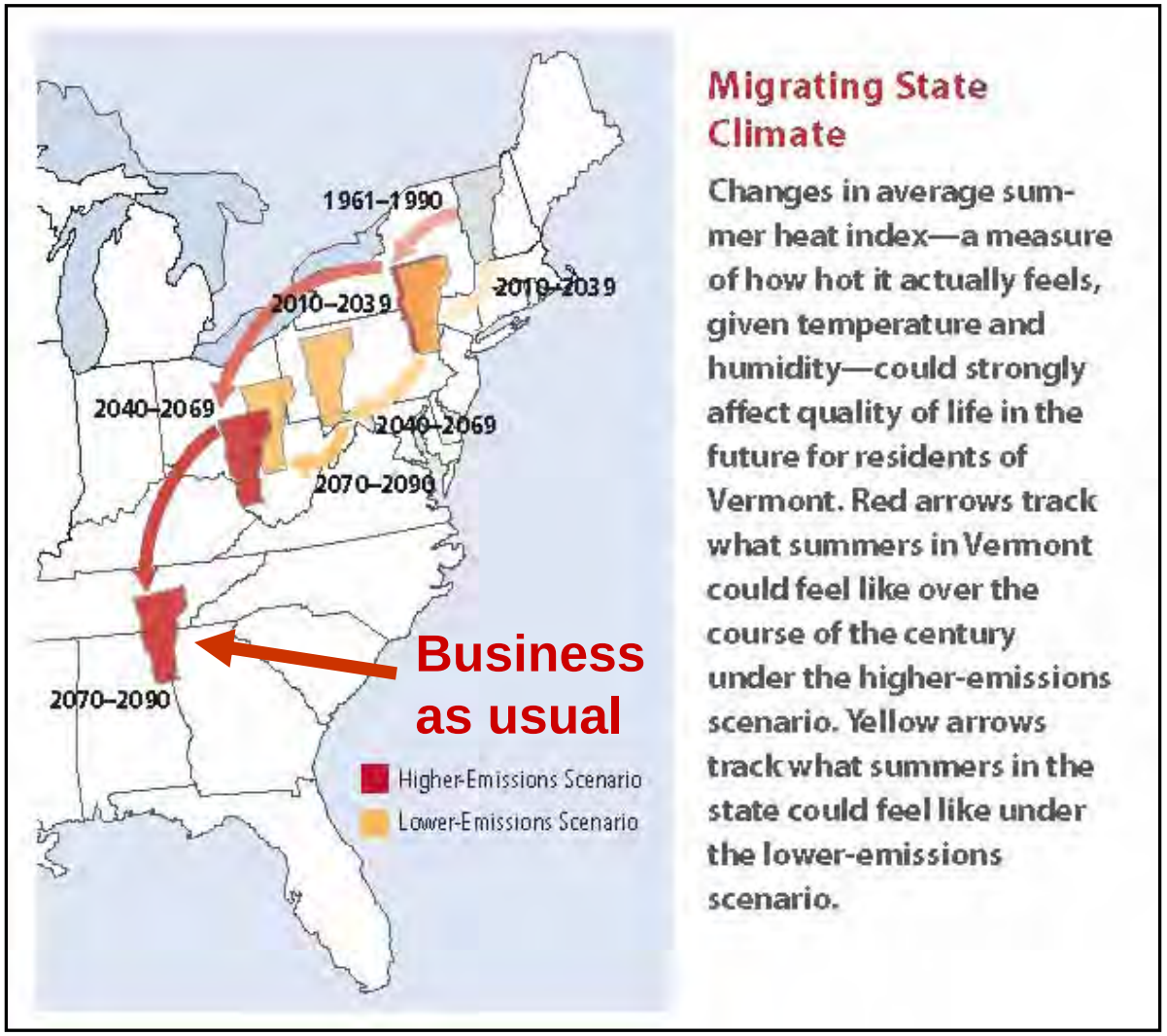


Extremes increasing across whole hemisphere: stationary patterns

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



NECIA, 2007

Why Is More Carbon Dioxide in the Air a Problem?

- **The air is transparent to sunlight, which warms the Earth**
- **But some gases in the air trap the Earth's heat , reradiate down, and keep the Earth warm (30^{o}C)**
- **These are "Greenhouse gases"- water vapor, carbon dioxide, ozone, methane (H_2O, CO_2, O_3, CH_4, CFCs..)**
- **CO_2 is rising fast: by itself only a small effect**

But as CO_2 Increases, Strong Water Cycle Feedbacks

- **Earth warms, and evaporation and water vapor in the air increases and this triples the warming**
- **As Earth warms, snow and ice decrease, so less sunlight is reflected, so winters and the Arctic are warming faster**
- **Doubling CO_2 will warm Earth about 5°F**
  - **Much more in the North, over land, in winter**
  - **Climate change we are seeing in Vermont will continue**

Increasing CO_2 is long-lived driver

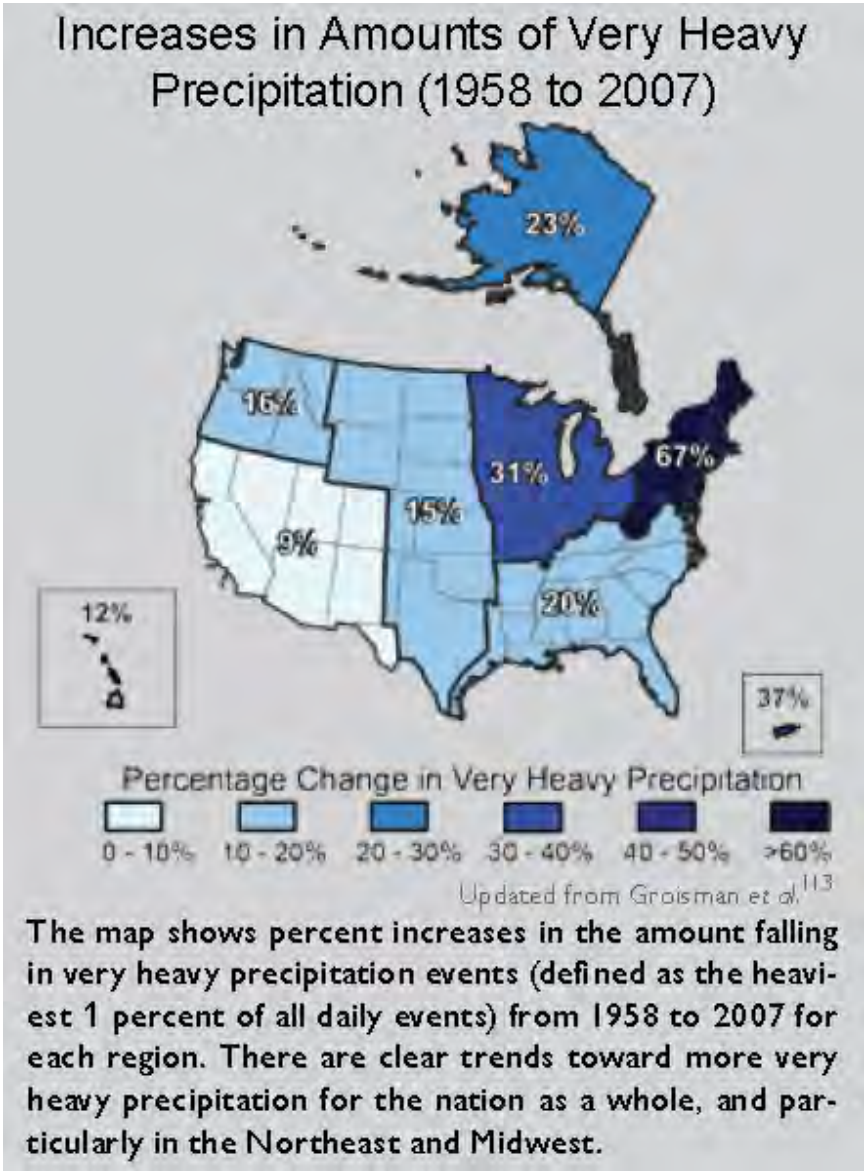
Water: *Strong Feed-backs Amplify*

- **GHGs up → Oceans, land warmer → Evaporation up**
- **Water Vapor up**
  - **WV infrared greenhouse up**
    - **Approx triples climate warming of planet**
    - **Locally reduces night-time cooling**
      - **Winter T_{min} increase: less severe winters**
      - **Longer growing season between frosts**
  - **Latent heat release in storms up**
    - **Increases precipitation rates**
      - **Increases precipitation extremes**
    - **Increases wind-speeds and storm damage**
    - **Increases snowfall from coastal storms in winter**
- **Snow and ice down, less sunlight reflected**
    - **Warmer Arctic in summer**
    - **Warmer northern winters**
  - **Less ice-cover: more evaporation**
  - **More lake-effect snowstorms**

Very Heavy Precipitation Is Increasing

(USGCRP, 2009)

- **Precipitation Extremes**
- **Most of the observed increase in precipitation during the last 50 years has come from the increasing frequency and intensity of heavy downpours.**
- **67% increase in Northeast**
- ***Nine out of ten recent summers have been 'wet'***



The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

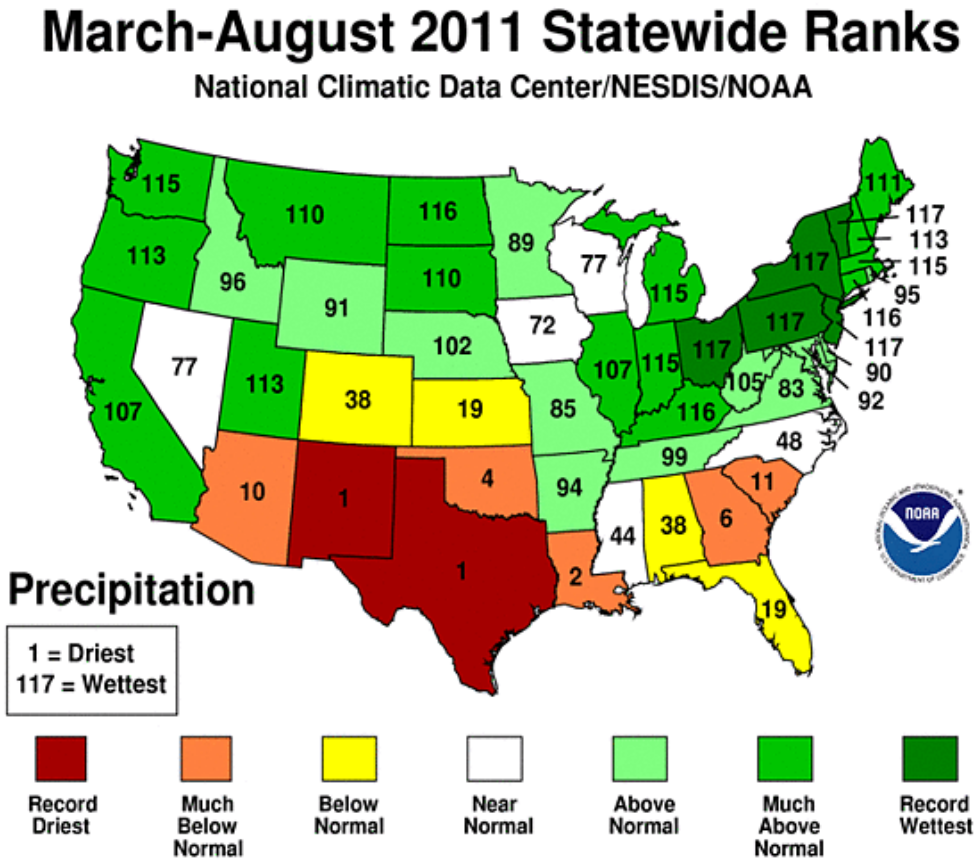
Extreme Weather (precip.)

- **Precip. is condensation of atmospheric water vapor - larger latent heat release drives storms**
- ***Saturation vapor pressure at cloud-base increases steeply with temperature (4%/ºF)***

- **Quasi-stationary large-scale flow means longer rain events in low-pressure convergent regions, and longer droughts in high-pressure divergent regions**
- ***As climate changes, quasi-stationary large-scale modes appear to be more frequent***
  - ***Cause may be Arctic warming: needs more study***

2011 Floods: VT and NY

- **Record spring flood: Lake Champlain**
- **Record flood with tropical storm Irene**

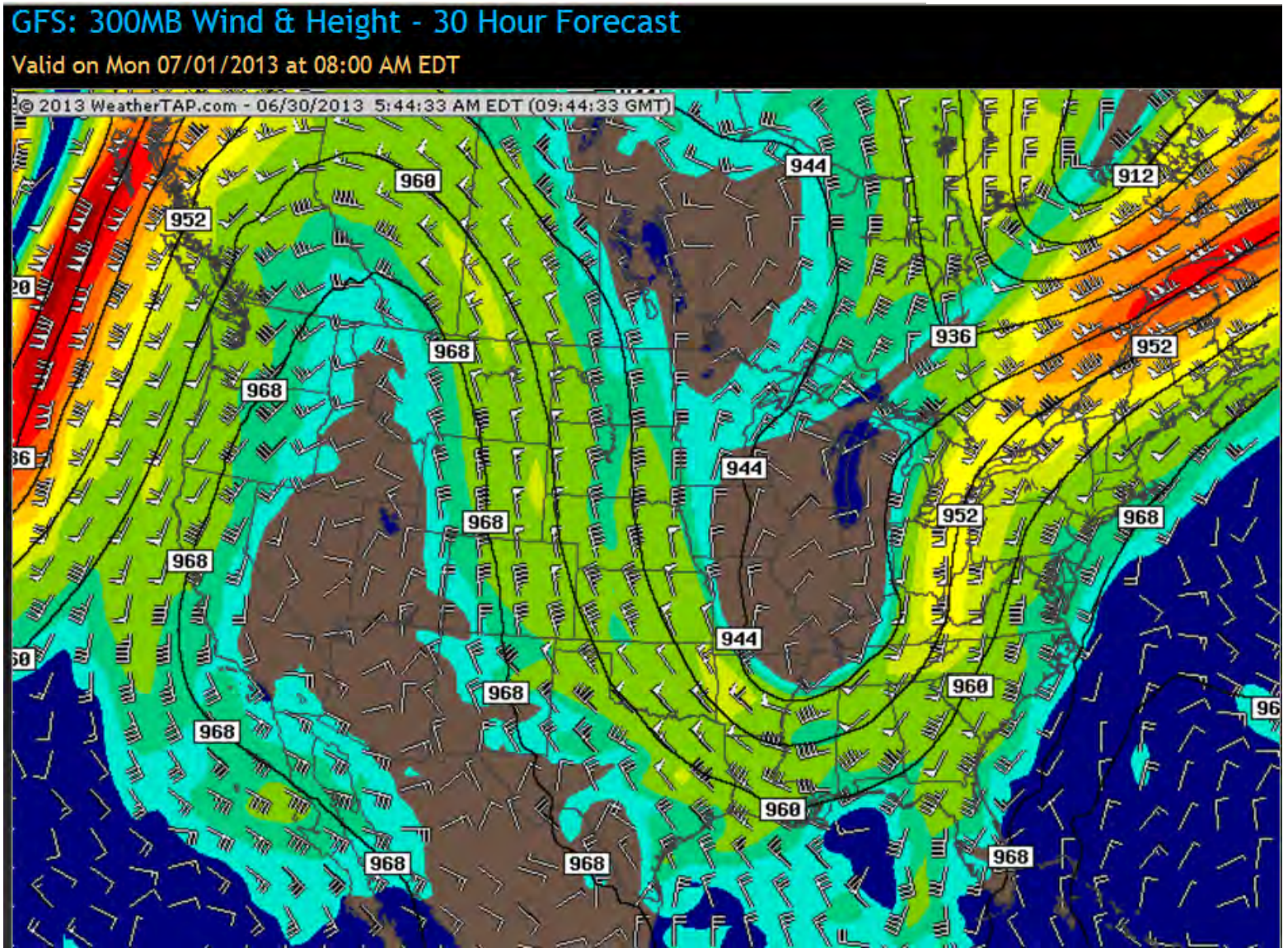


March-August, 2011

- **Record wet : OH to VT**
- **Record drought: TX & NM**
- **'Quasi-stationary' pattern**

Jet Stream Patterns Slowing Down and Amplifying, Giving More Extreme Weather

(Francis and Vavrus, 2012)



Blocking Pattern - Unique track

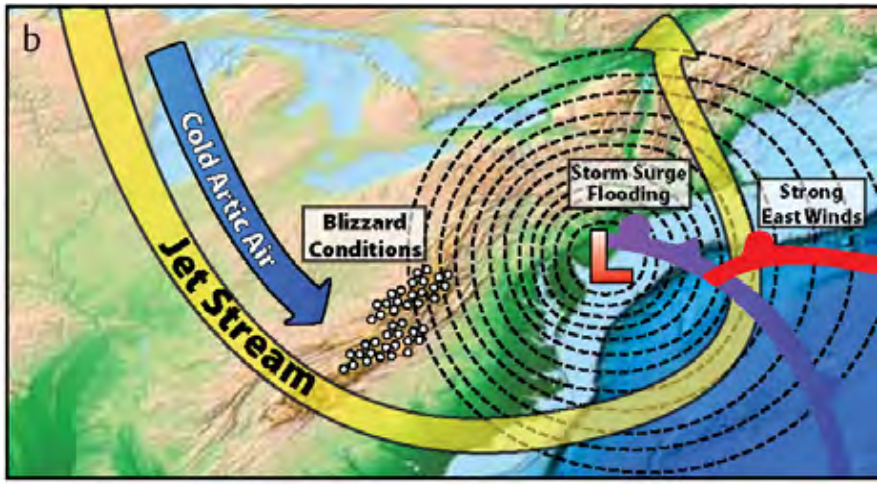
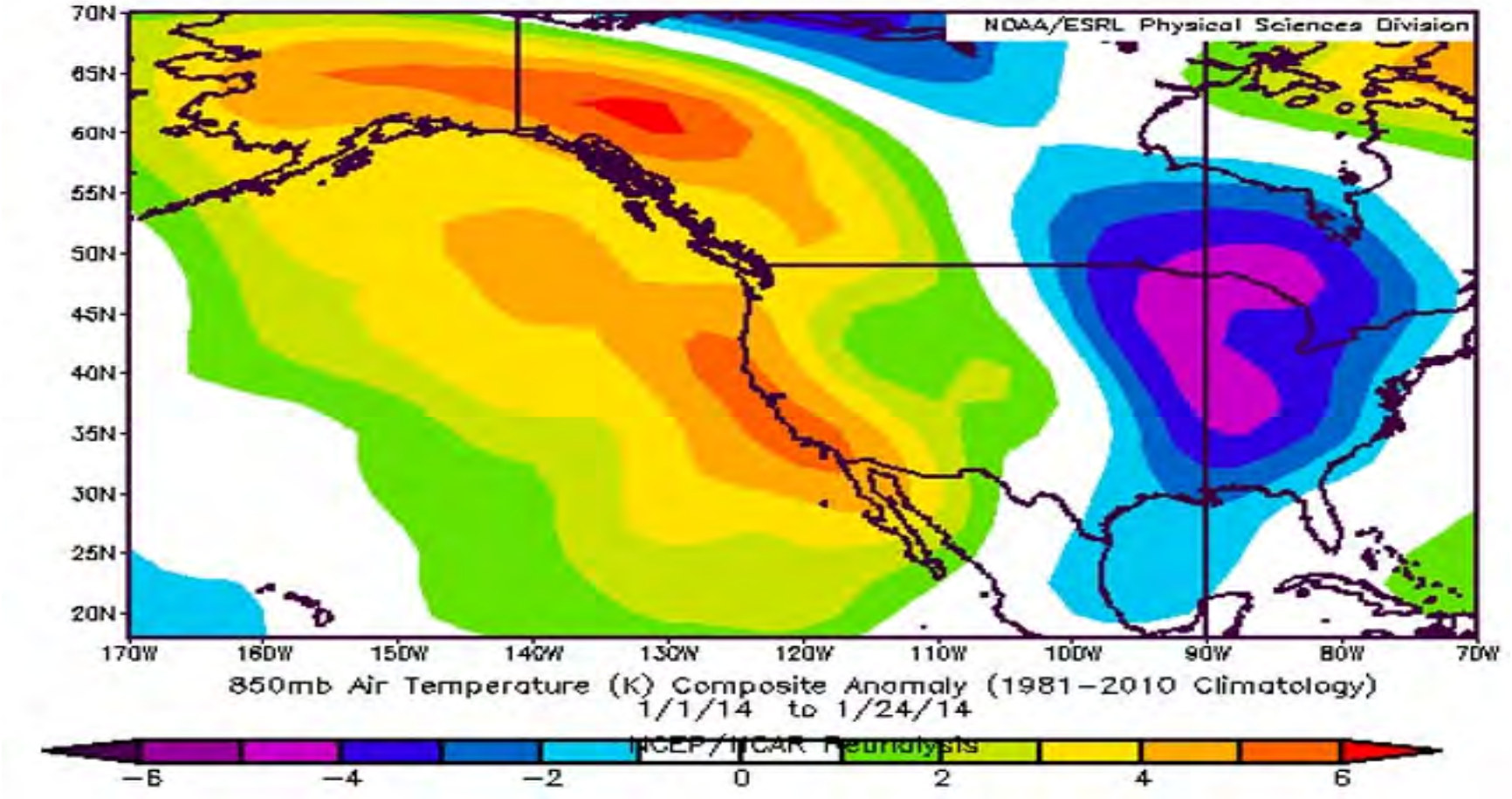


Figure 1. (a) Atmospheric conditions during Hurricane Sandy's transit along the eastern seaboard of the United States, including the invasion of cold Arctic air into the middle latitudes of North America and the high-pressure blocking pattern in the northwest Atlantic. (b) After the convergence of tropical and extra-tropical storm systems, the hybrid Superstorm Sandy made landfall in New Jersey and New York, bringing strong winds, storm surge, and flooding to areas near the coast and blizzard conditions to Appalachia.

- **High amplitude jet-stream + blocking pattern + strong cyclone + hurricane winds + full moon high tide = record storm surge + disaster**

[Greene et al., Oceanography, 2013]

Jan. 1-24, 2014
850mb Temperature Anomaly



Extremes increasing across whole hemisphere: stationary patterns

Extreme floods in UK; record warm in SE Europe

What Lies Ahead?

- **Accelerating change, increasing extremes**
- **Increasing adaptation and rebuilding costs**
- **Environmental damage that will transform or destroy ecosystems- locally and globally**

- **Freely dumping waste streams from society into atmosphere, streams, lakes and oceans is unsustainable – long term costs now exceed $1000 trillion**

- ***Will need fossil carbon tax (a "waste" tax) to incentivize mitigation and pay for the long-term adaptation and health costs***

Can We Stop "Dangerous Climate Change"?

(UNFCCC 1992)

- **Yes: Quickly stabilize atmospheric CO_2**
- ***This means an 80% drop in CO_2 emissions!***
- **This is very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **Our "lifestyle" has become dependent on fossil fuels**

‘Managing’ Our Relation to the Earth System

- **Our technology and our waste-streams are having large local and global impacts on the natural world and must be carefully managed — *because we are dependent on the natural ecosystems***
- **We need new ‘rules’ because**
  - **Our numbers and industrial output are so large**
  - **Maximizing consumption and profit have led to present predicament**

A Path Towards ‘Sustainability’

- **Minimize the lifetime of human waste products in the Earth system and eliminate waste with critical biosphere interactions**
- **Maximize recycling and re-manufacturing to minimize waste-streams and the use of non-renewable raw materials**
- **Maximize the efficiency with which our society uses energy (and fresh water)**
- **Maximize the use of renewable resources**
- ***Relocalize to re-establish responsibility and control***

Efficiency Comes First

- **We need to double or triple our energy efficiency because…**
  - **We cannot replace current fossil fuel use with biofuels & renewable energy**
  - **Oil and gas reserves are limited, but coal & oil shale reserves are enough to push CO_2 above 1,000 ppm—and in time melt icecaps**
    - ***Back to the Carboniferous era climate?***
    - **Will we pay to "sequester" CO_2 (put it back in the earth)?**

Why Is It Difficult for Us?

- **The "American dream" is crumbling**
  - **"Economic growth" based on fossil fuels, debt, and consumerism is unsustainable — and a disaster for the planet!**
- **Individual "rights" and the needs of humanity must be balanced against the needs of the earth's ecosystem**
- **We don't know how to guide and manage technology —so the result is tremendous successes and catastrophic failures**

Why Is It Difficult for Us?

- **Fossil fuels reserves are worth $20-30T**
  - **Regulating emissions of CO_2 is an "unfair cost" to the "free market"**
- **Real Earth system issues being ignored**
- ***Our politics are facing collapse***
  - ***Disconnected from the real world***
  - ***Local Transition efforts are critical***

Surely Technology Can Save Us?

- **Critical for transition but real issue is**

- **Our world of technology is having a global impact on the natural world, which is alive, complex and beyond our 'control'**
- **So technology must be carefully managed — particularly our waste-streams — because we are dependent on the natural world**
  - **But this is challenging with our ideology**

Technology can be Useful

Trucks or lightweight Trikes!

30 mph Danish electric tricycle:

with 150 mile range

Food Issues

- **Milder winters and longer growing season in Northeast**
  - **Over-winter more crops**
  - **Increasing variability of weather**
  - **Increasing precipitation extremes**
  - **Flood-plain and soil water management**
  - **Possible increase in summer pests**
- **Increasing drought in southern, central and western US**
  - **Critical fresh water issues world-wide**
  - **Many pumped aquifers near exhausted**
  - ***Localize Vermont food system***

Simple Suggestions

- **Reeducation of society and its 'systems'**
  - **The transition we face is huge**
  - **What will raise awareness/change paradigm?**
  - **How can we better manage our relation to Earth?**
- **Understand water and landscape**
  - **Limit phosphorus loads on streams/lakes**
  - **Fresh water supply not critical in VT, but is elsewhere**
- **Examine all waste-streams**
  - **Aim to recycle/remanufacture everything**
  - **Fully cost all waste streams**
- **Relocalize food system**
  - **Compost all organic waste**
- **Default energy use should be 'OFF'**
  - **Maximize energy efficiency: housing, transport, power**
  - **Add and monitor renewable power**
- **Reconnect with natural world**
  - **Fundamental if we are to accept transition**

Attitude Matters

(Hope versus Despair)

- **People ask "Why are you so hopeful?"**
- **This is a deeper question than understanding and responding to climate change**
  - **For human beings, hope expands our vision, hope connects us to each other and deepens our sense of communion**
  - **Hope opens doors and frees us to be creative and work joyfully with each other and with the Earth**
  - **Hope is a spiritual connection**

- ***Despair closes us off from the real world of possibilities into a dark and isolated world***

What Do We Need?

- So we need honest, truthful, smart pathways forward
  - That will not frighten people into paralysis
  - That will spread hope, not anger or despair
  - That sidestep ideological barriers with new language
  - That develop adaptive governance
    - The US Constitution gives no rights to the Earth
  - That respect Earth system processes & limits

The Future Is Not Our Past

- **Collectively, we create the future, so we need to plan for a transition to a sustainable society**
- **Face the future with an attitude of**

“Bold Humility”

(Frances Moore Lappé: RAFFL, Rutland, 2007)

- **Efficient society with renewable technologies**
- **Balance community solutions and government interventions**
- **Ask**
  - **Is this an efficient and sustainable way of doing this?**
  - **Do I have a deep understanding and connection to Earth?**

Discussion

Background material:

http://alanbetts.com/

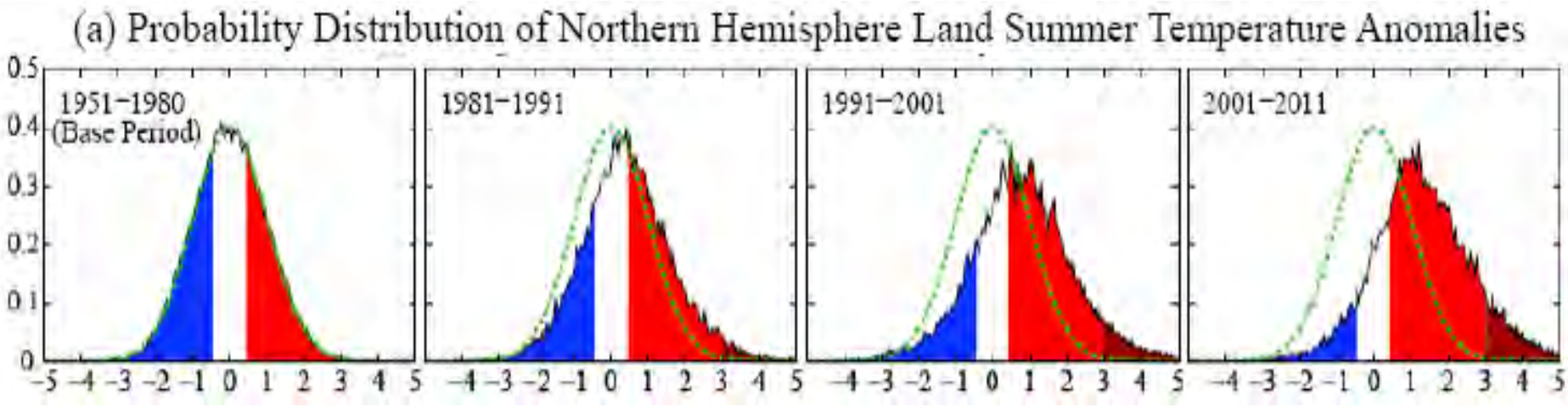
- ***Vermont Climate Change Indicators***
- ***Seasonal Climate Transitions in New England***
- ***Extreme Weather and Climate Change***

http://www.anr.state.vt.us/anr/climatechange/Adaptation.html

Health Issues

- **Higher temperature extremes**
  - **Offset by wet summers in Northeast**
- **Winter survival of pests**
  - **Blacklegged Tick (Deer Tick):** A warming climate, combined with the spread of the invasive shrub Barberry, has allowed this pest to expand its range to the entirety of Vermont. This invasive is responsible for the spread of Lyme disease throughout New England.
- **Mosquito-borne diseases – EEE/West Nile**
  - **Increased summer breeding:** ***nine out of ten recent summers have had well-above 'average' rainfall***

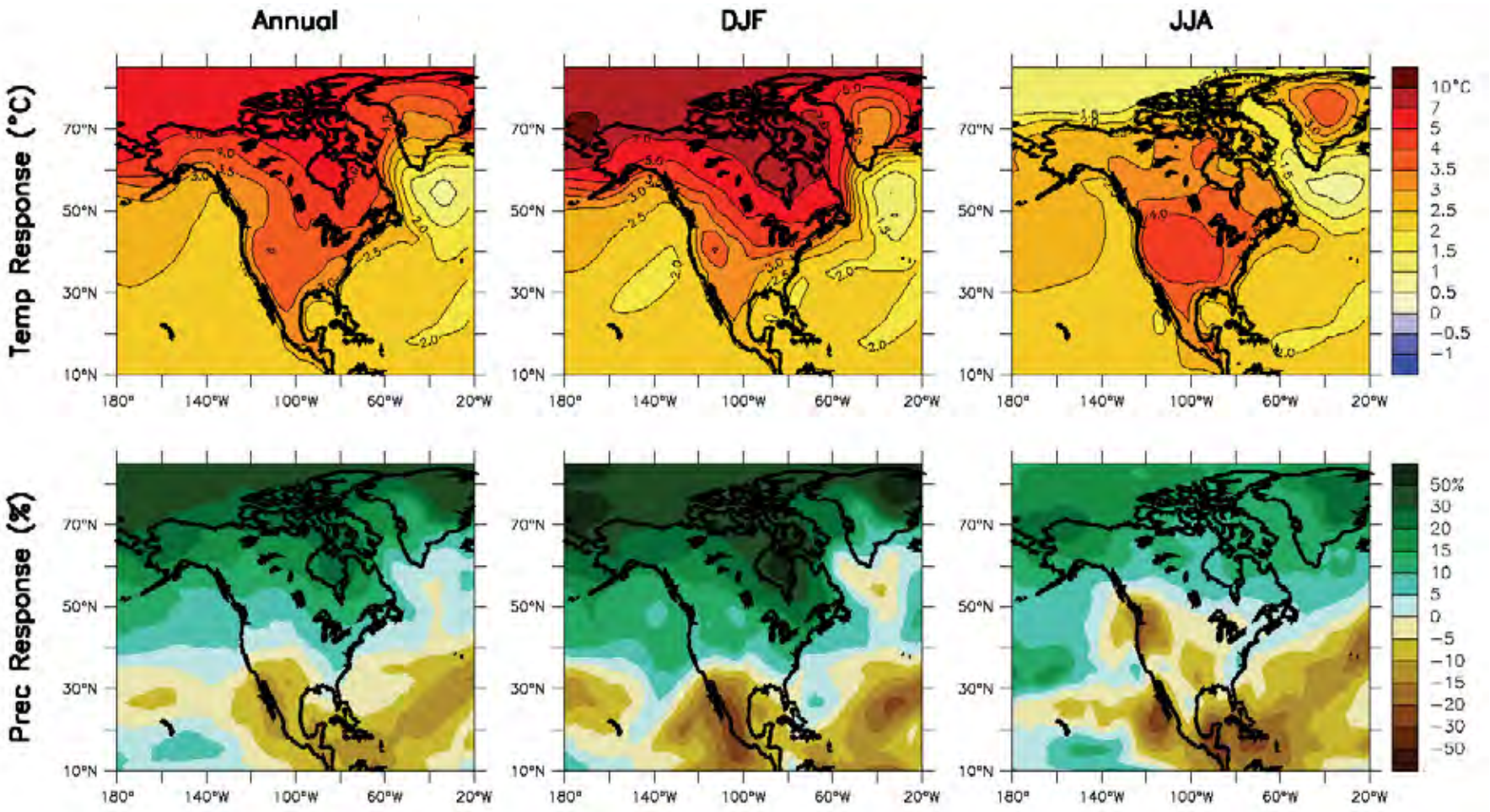
Increasing Positive Temperature Extremes is "Global Warming"



(Hansen, 2012)

- **Frequency of occurrence (vertical axis) of local June-July-August temperature anomalies for Northern Hemisphere land in units of local standard deviation (horizontal axis). The normal (gaussian) distribution bell curve is shown in green.**
- **Large increase in anomalies > +3σ *is* global warming**
  - ***Baseline 0.15% has increased to 10% in 45 years***

North American Changes: T, Precip.



- Temperature and precipitation changes over North America from an average of 21 AOGCM projections for A1B (high emission) scenarios.
- Top row: Annual mean, winter (DJF) and summer (JJA) temperature change between 1980 to 1999 and 2080 to 2099. **[NE winter: +4.5C, +8F]**
- Bottom row: for fractional change in precipitation. **[NE winter: +25%]**

2011 Classic Flood Situations

- **Spring flood: heavy rain and warm weather, melting large snowpack from 2010 winter**
  - **70F (4/11) and 80F(5/27) + heavy rain**
  - **record April, May rainfall: 3X at BTV**
  - **Severe floods on Winooski and Adirondack rivers**
  - **Lake Champlain record flood stage of 103ft**
- **Irene flood: tropical storm moved up east of Green Mountains and Catskills**
  - **dumped 6-8 ins rain on wet soils**
  - **Extreme flooding**
  - **(Floyd on 9/17/1999 had similar rain - but with dry soils there was less flooding)**

Summer "stormflow" increasing

Most >50%

Lent (2010) USGS, Me

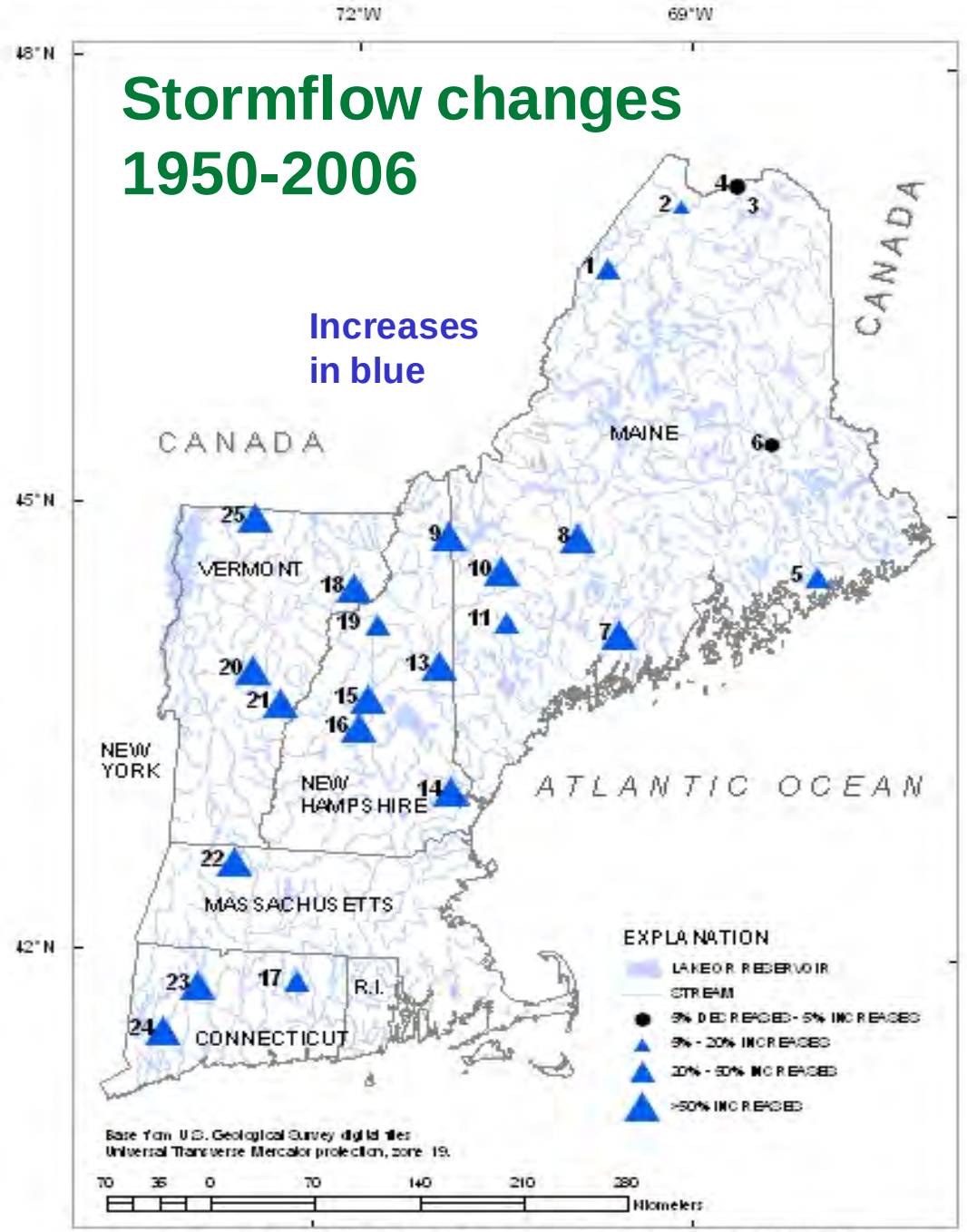


Figure 4. Geographic distribution of summer stormflow trends, 1950-2006.