



Global and Local Climate and our Future



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RACC Intern Orientation
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Outline

- **Science of climate change**
 - Global and local
 - What is happening to Vermont?
- **The transition we face**
 - How can we stabilize the climate?
 - What are scientists' responsibilities?

Discussion

January 2, 2012: NASA

Earth's climate sustains life

- Burning fossil fuels is increasing greenhouse gases
- **Climate is warming: ice is melting, extreme weather is increasing**
- Water plays crucial amplifying role
- Planetary modes crucial

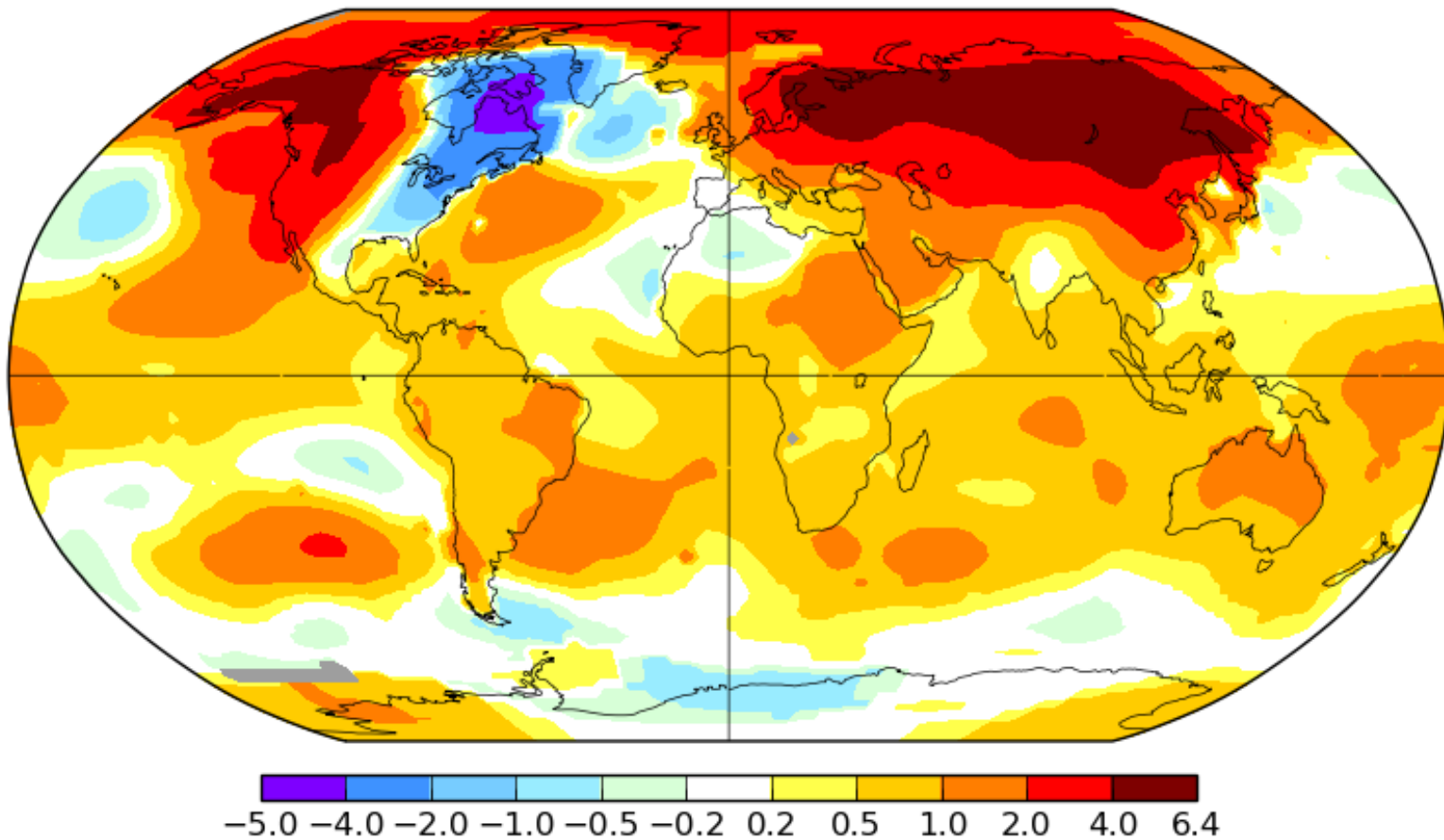


Jan-Feb-Mar 2015

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86

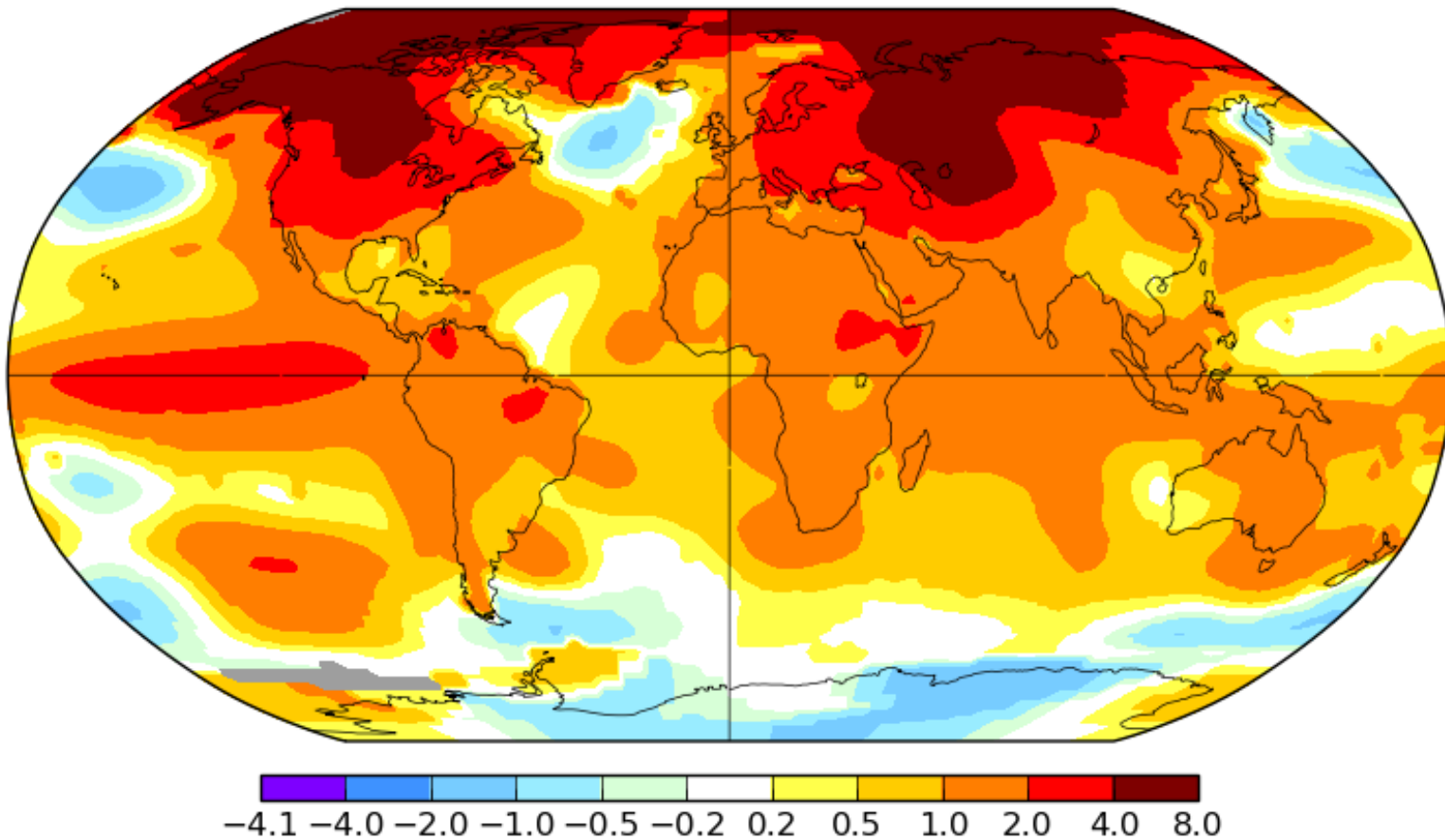


Jan-Feb-Mar 2016

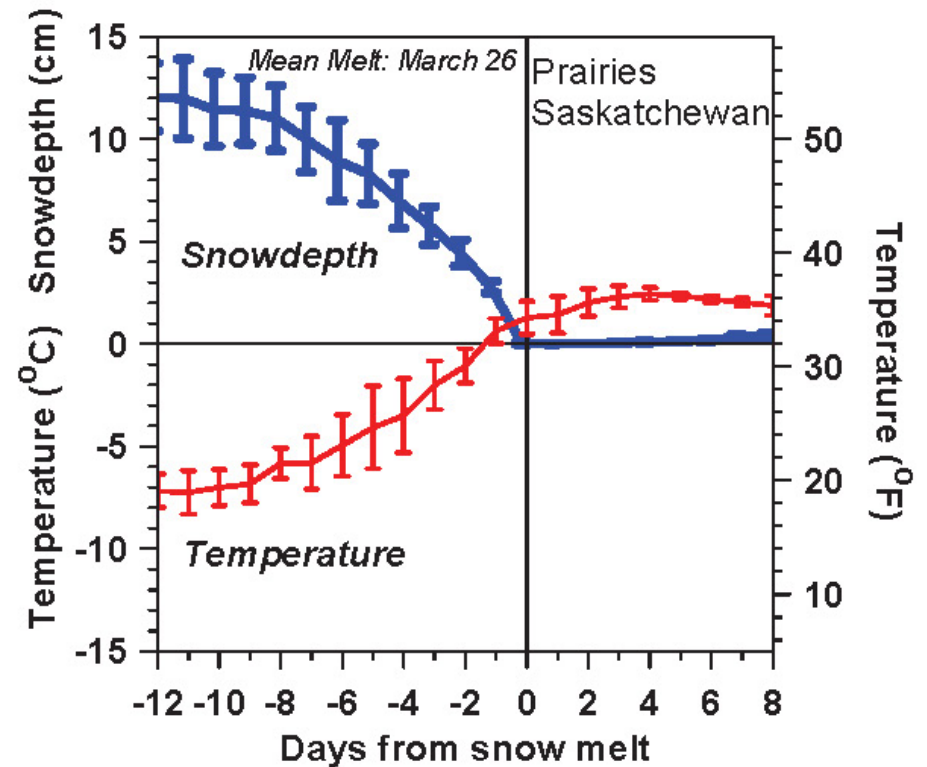
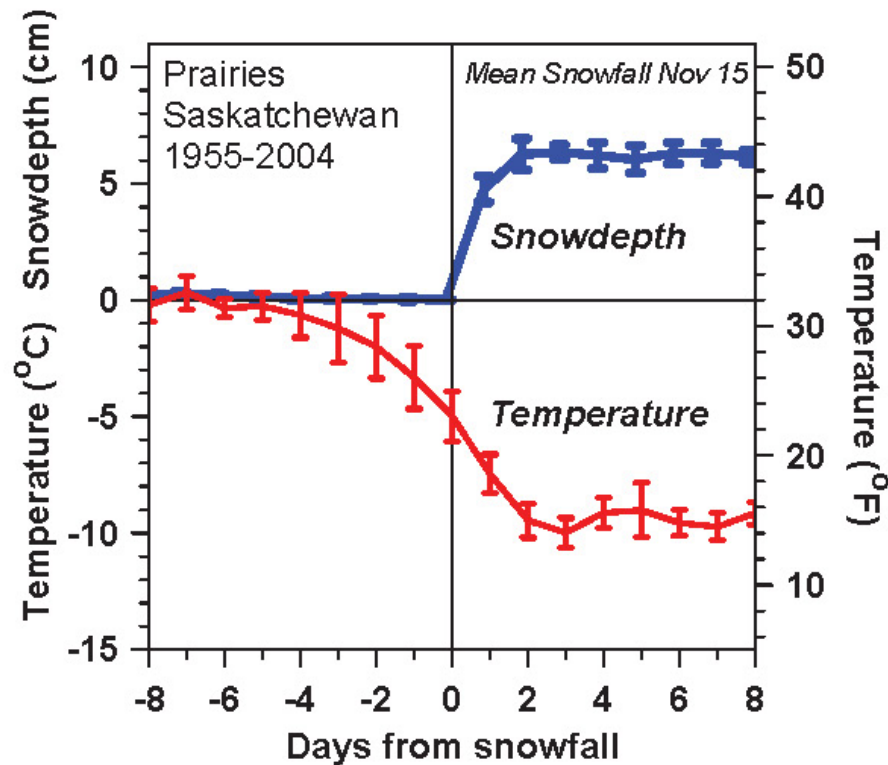
Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24

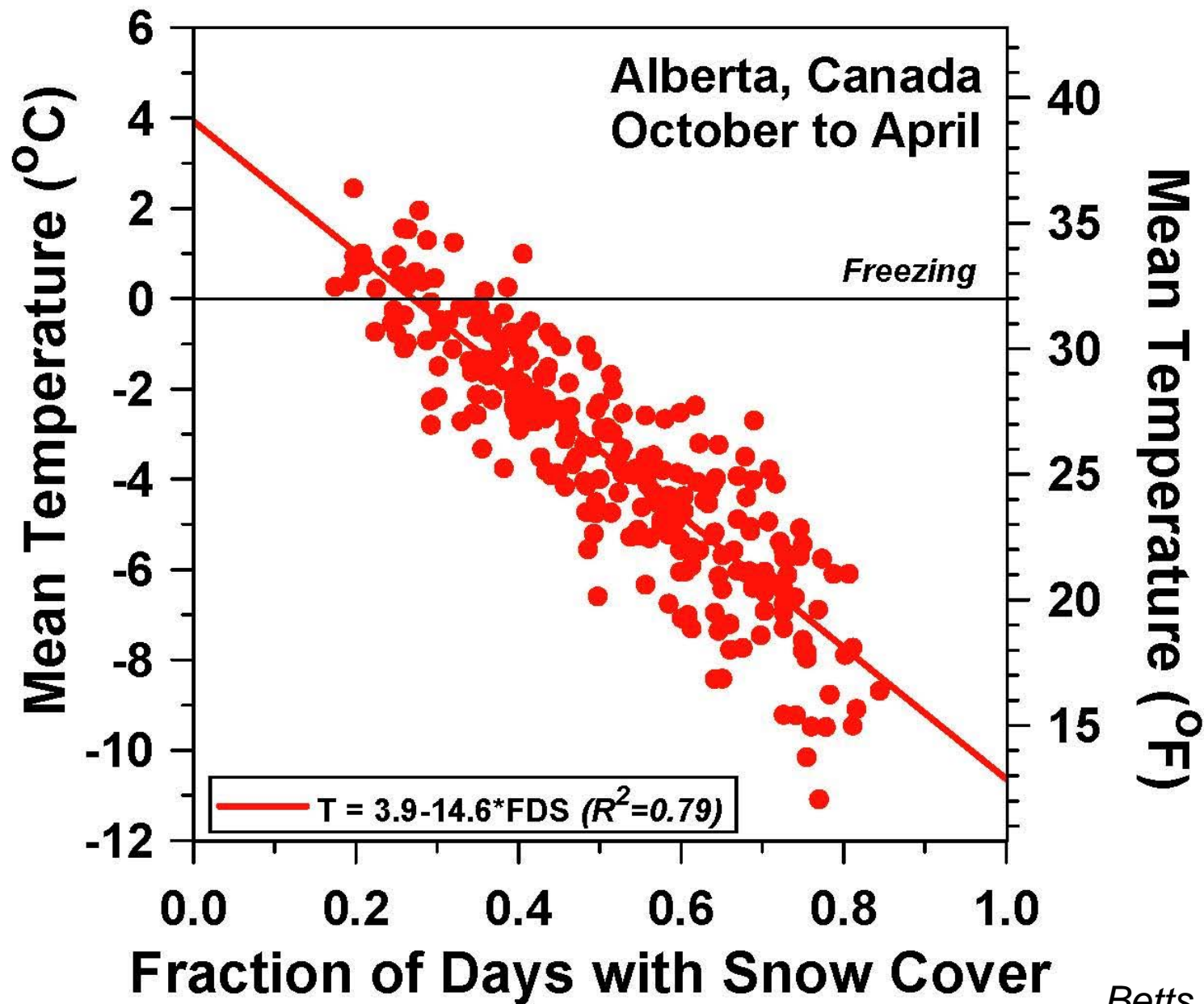


Snowfall and Snowmelt

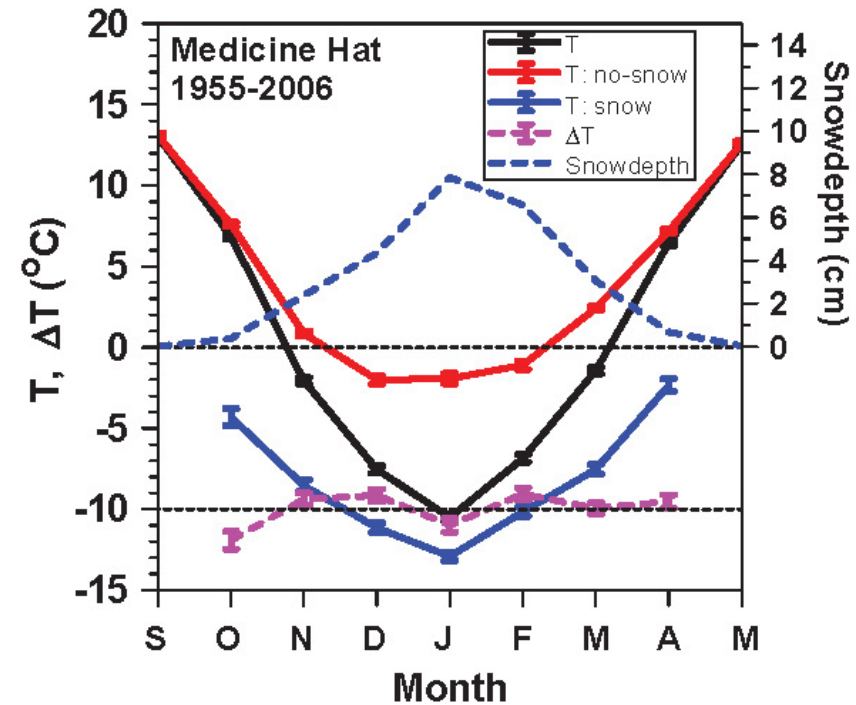
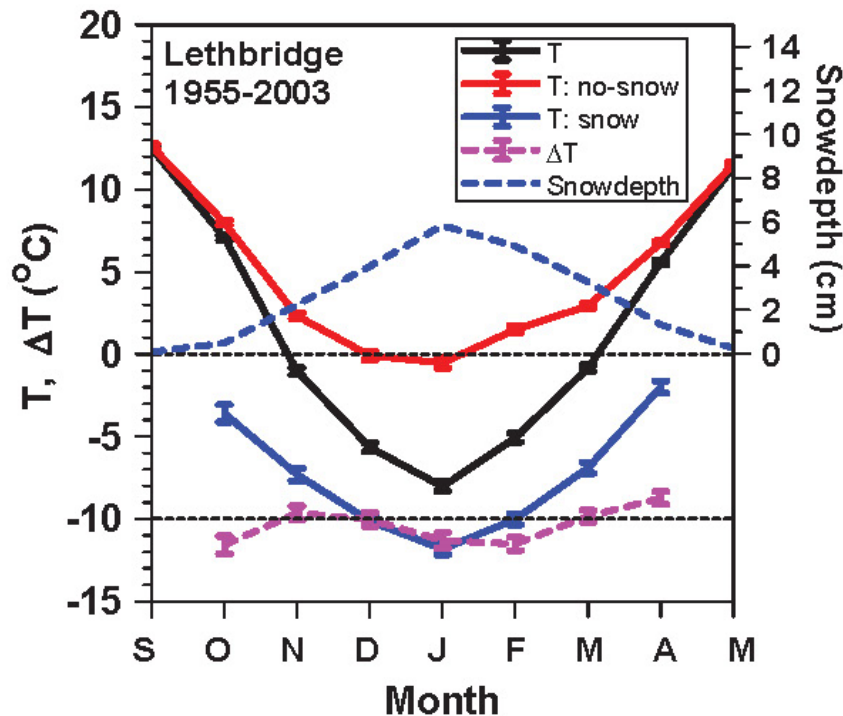


- Temperature falls 18F (10C) with first snowfall
- Reverse change with snowmelt
- *Fast transitions in 'local climate'*
 - *Snow reflects sunlight*
 - *Reduces evaporation and water vapor greenhouse*

More snow cover - Colder temperatures



Impact of Snow on Climate

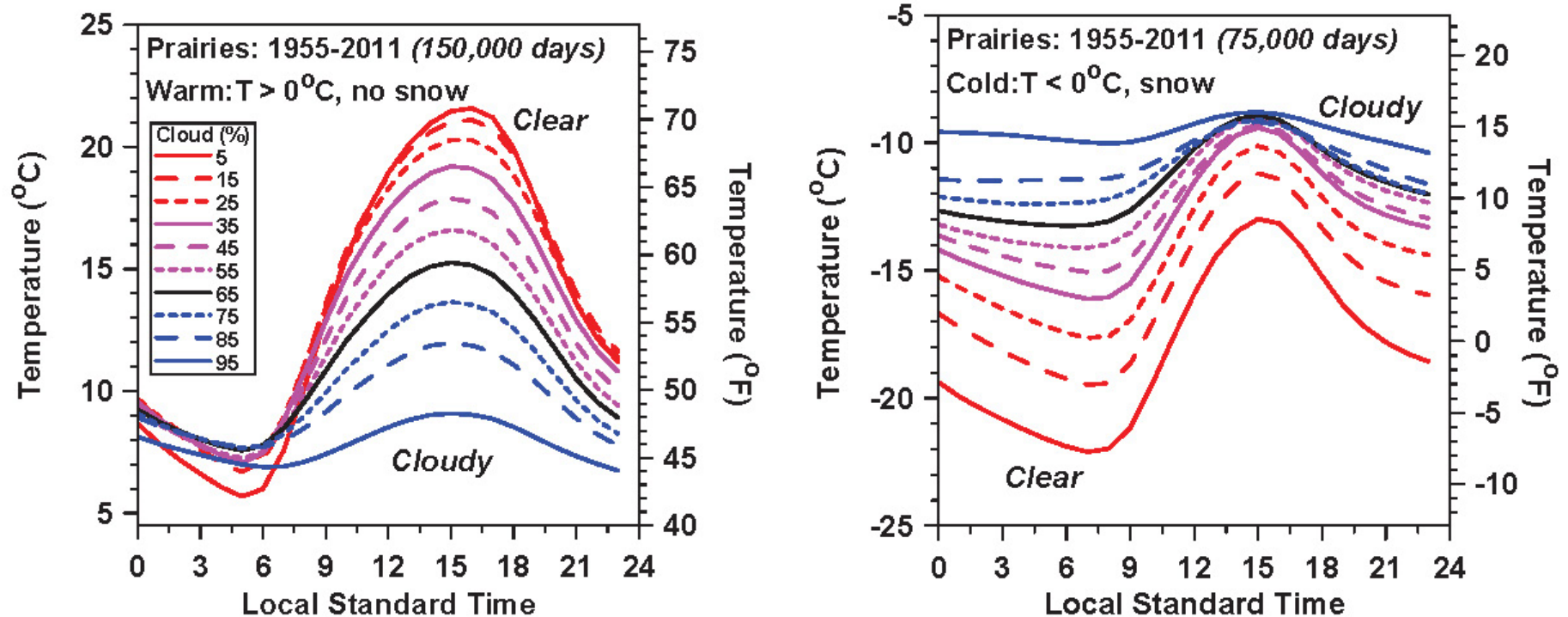


Separate mean climatology into days
with no-snow and snowdepth >0

$$\Delta T = T:\text{no-snow} - T:\text{snow} = -10.2(\pm 1.1)^{\circ}\text{C}$$

Betts et al. (2016)

Clouds, Snow and Climate



- **Above freezing:** Clouds reflect sunlight
 - Less cloud, much warmer in afternoon
- **Below freezing:** Clouds are greenhouse
 - Snow reflects sun
 - Less cloud, temperatures fall at night, very cold at sunrise

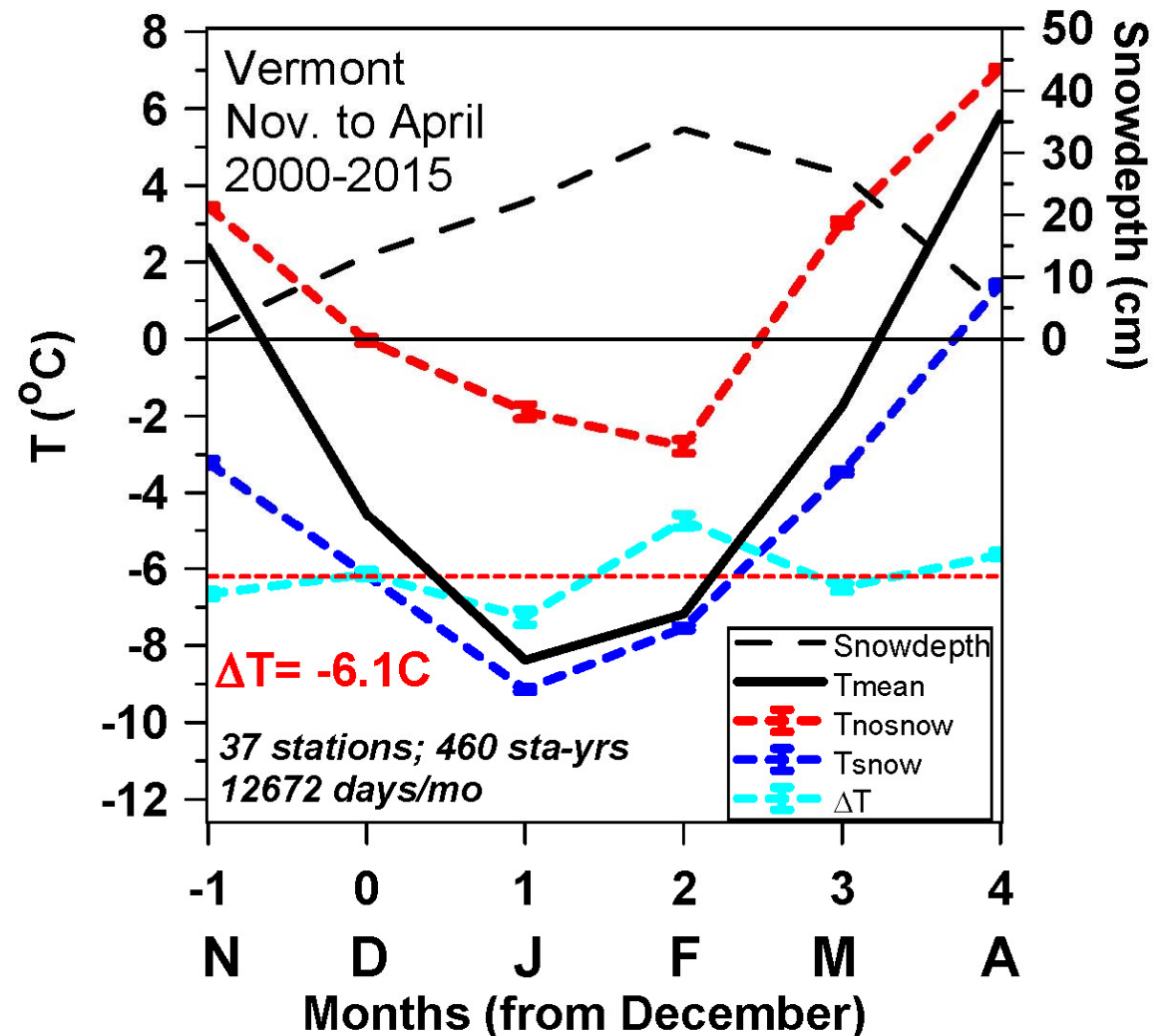
Climatological Impact of Snow: Vermont

Separate mean climatology into days with no-snow and with snow

Difference $\Delta T = -6.1(\pm 0.7)^{\circ}\text{C}$

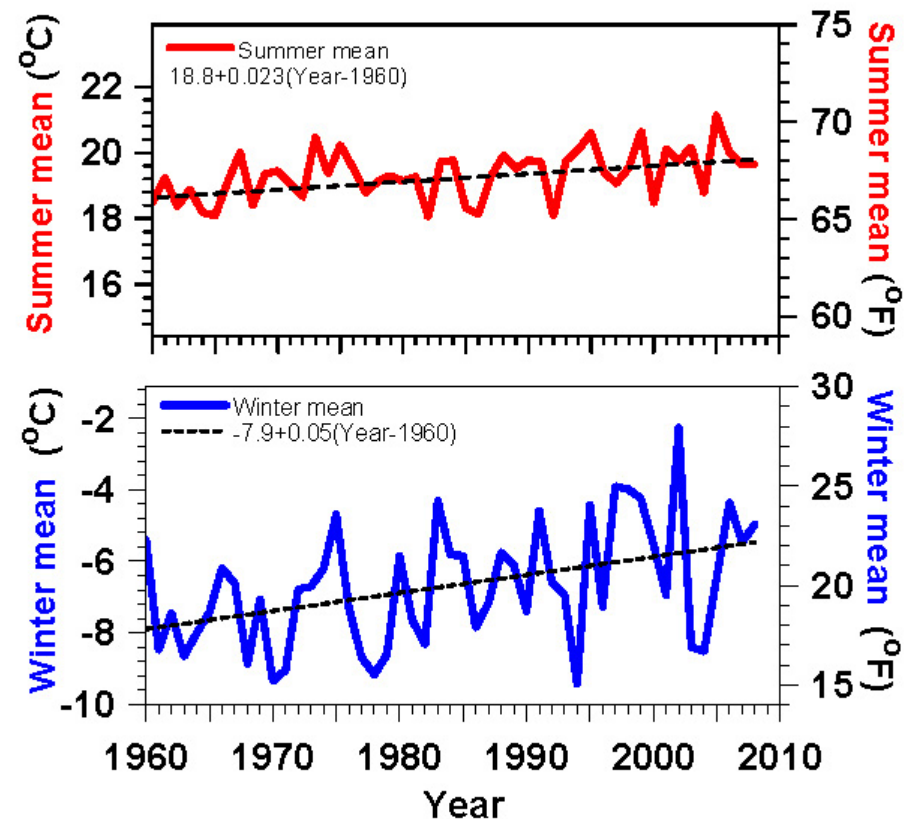
$= -11 (\pm 1.3)^{\circ}\text{F}$

*Less than Prairies:
Vermont has more forest*



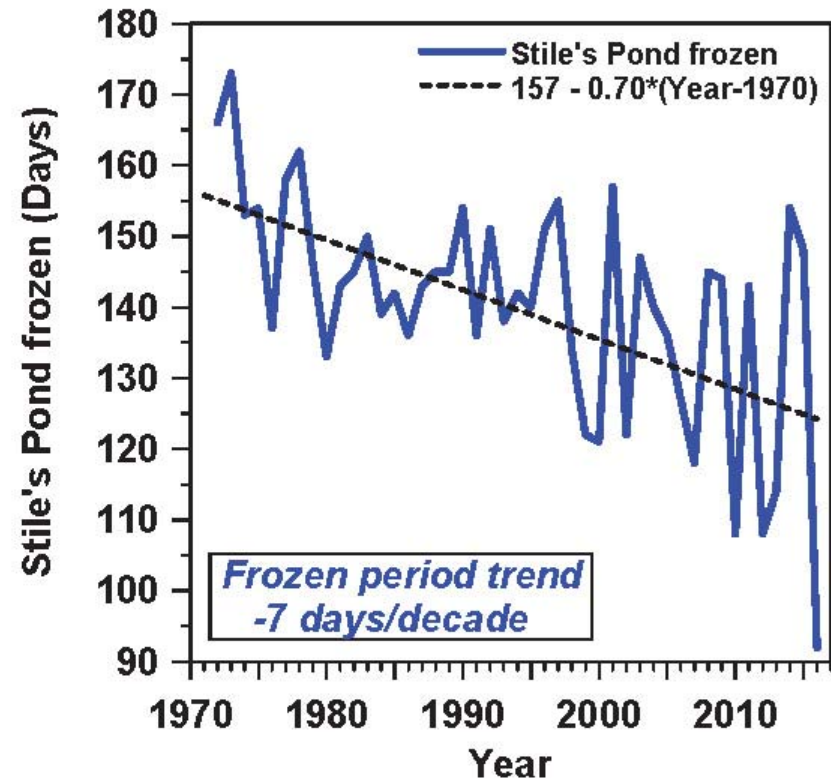
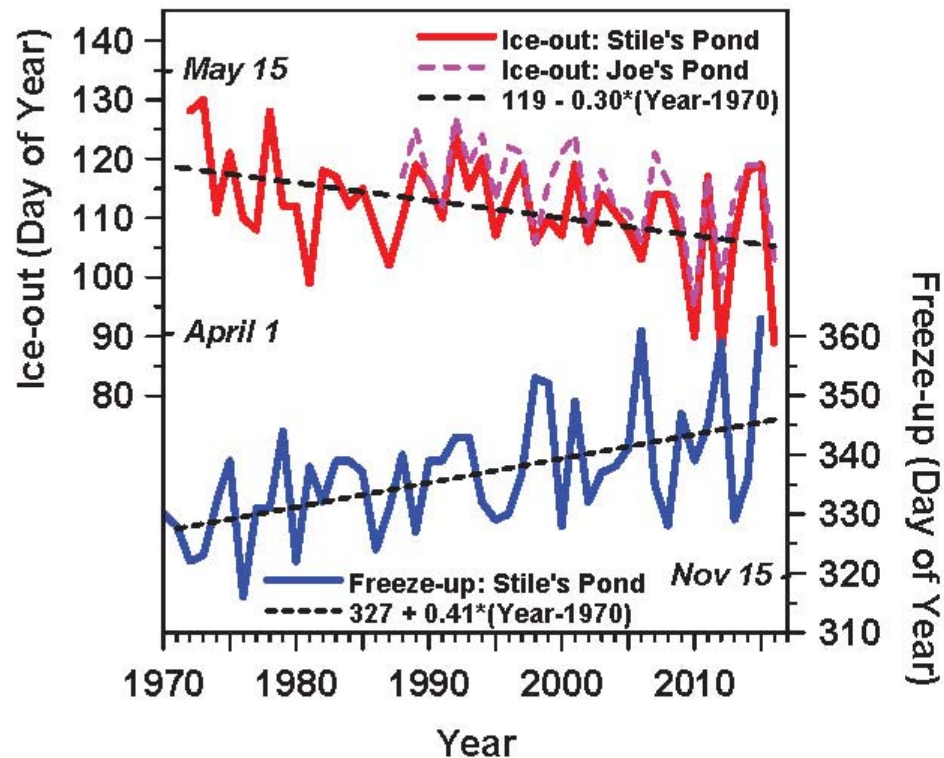
Vermont Temperature Trends 1961-2008

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



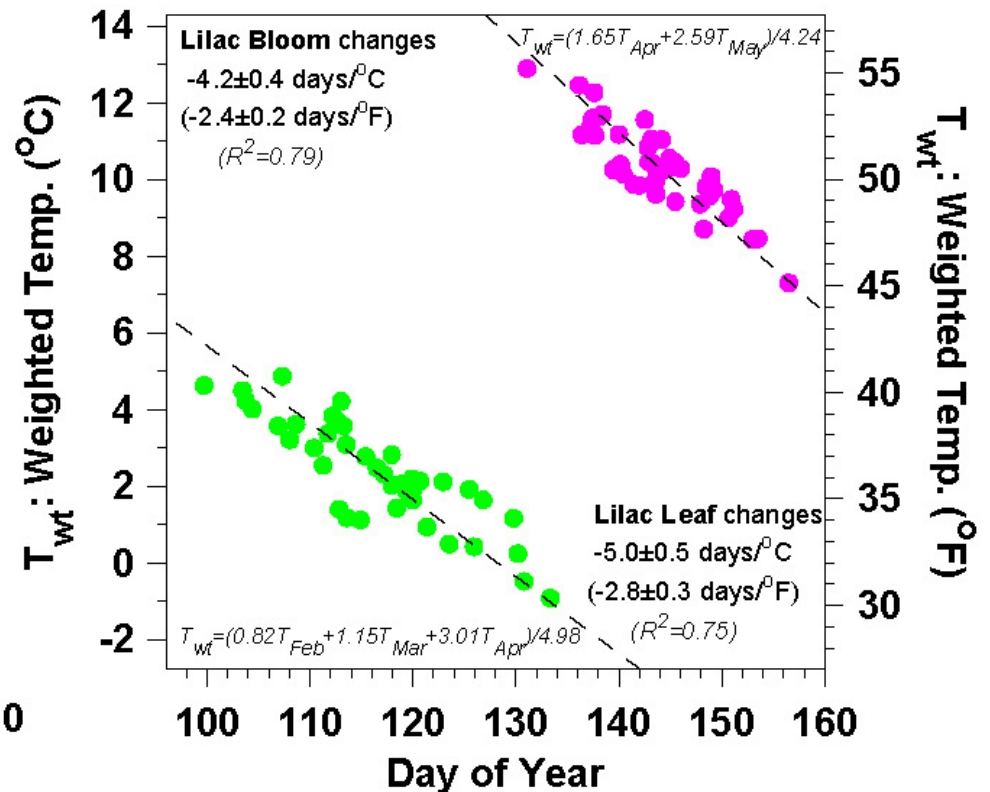
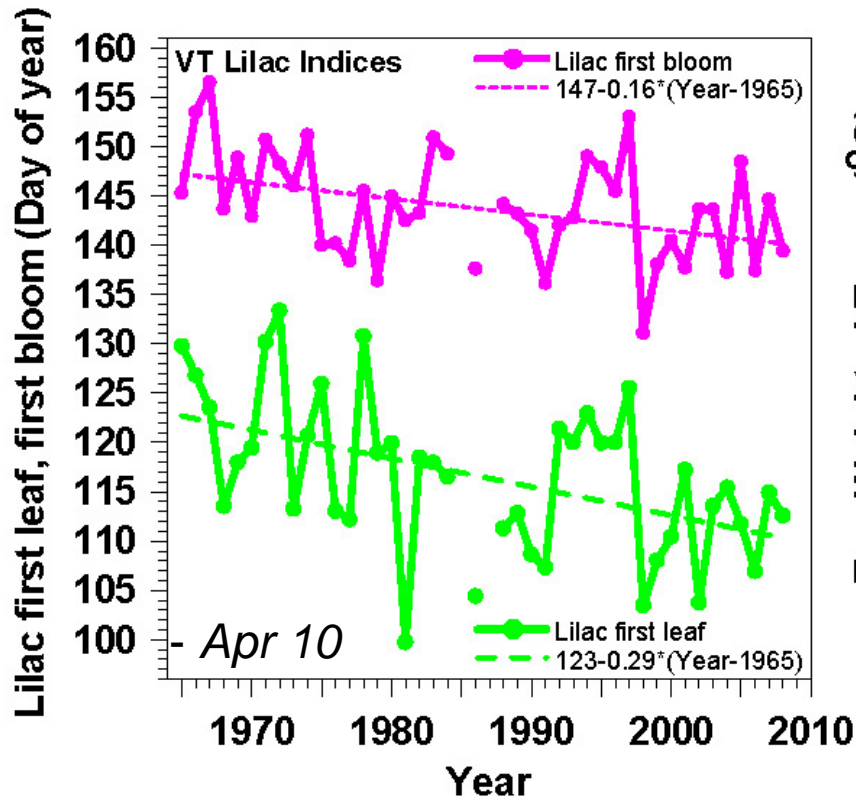
Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking: variability large



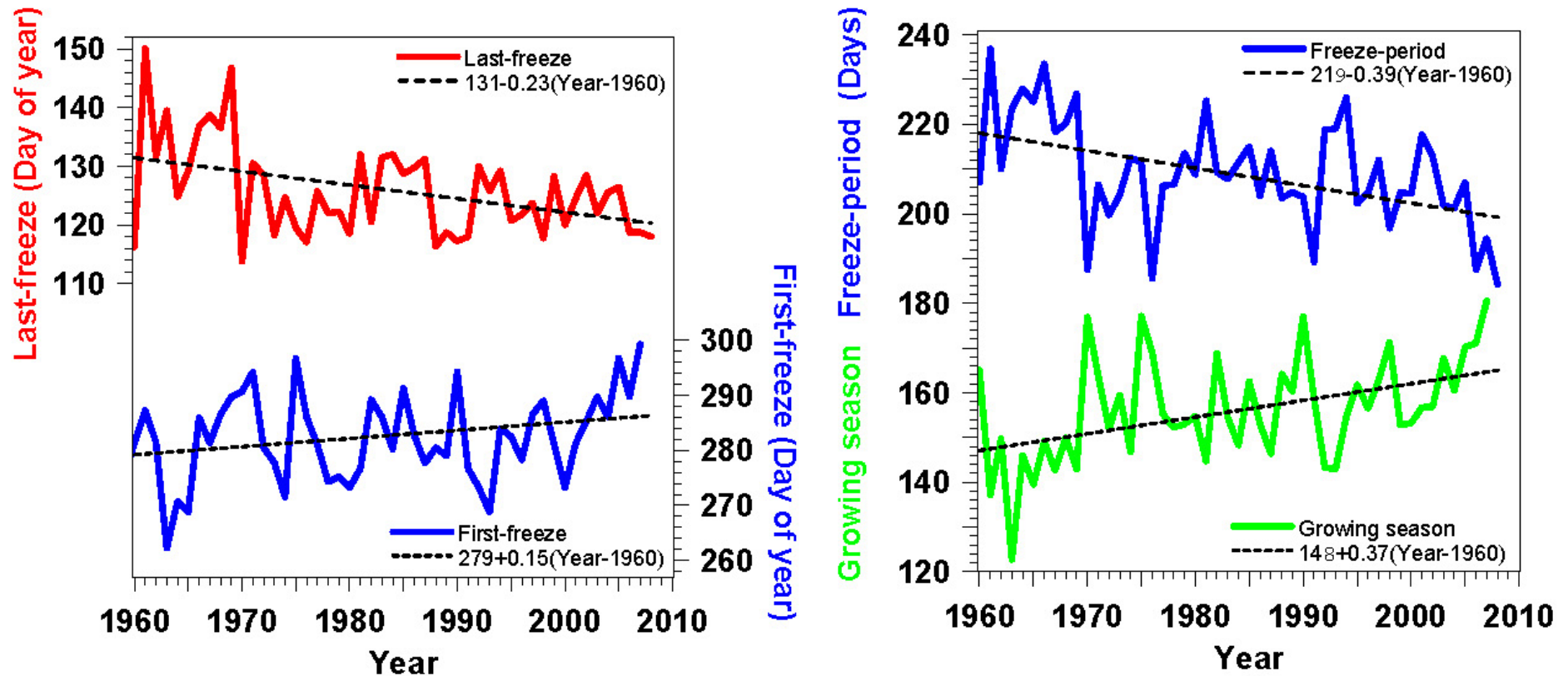
- Ice-out earlier **by 3 days / decade**
- Freeze-up later **by 4 days / decade**
- Lake frozen trend **- 7 days/decade**

Lilac Leaf and Bloom



- Leaf-out -2.9 days/decade; Bloom -1.6 days/decade
- Year-to-year variation coupled to temperature
 - 4 to 5 days/ °C: (No-snow – Snow) winter = 6*5 ≈ 30 days!

First and Last Frosts Changing



- Growing season for frost-sensitive plants increasing **3.7 days / decade**
- A help for growing “local food”



January 2, 2012



March 11, 2012



October 2011– March 2012

- **Warmest 6 months on record**
- **My garden frozen only 67 days**

• **January 15, 2013**



February 5, 2016

(Digging in Feb. first time ever)

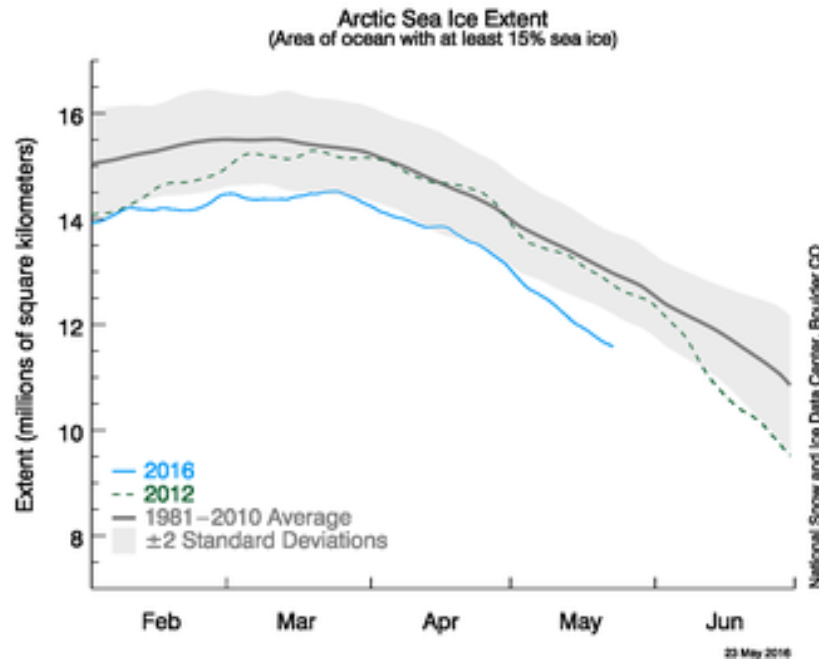


- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

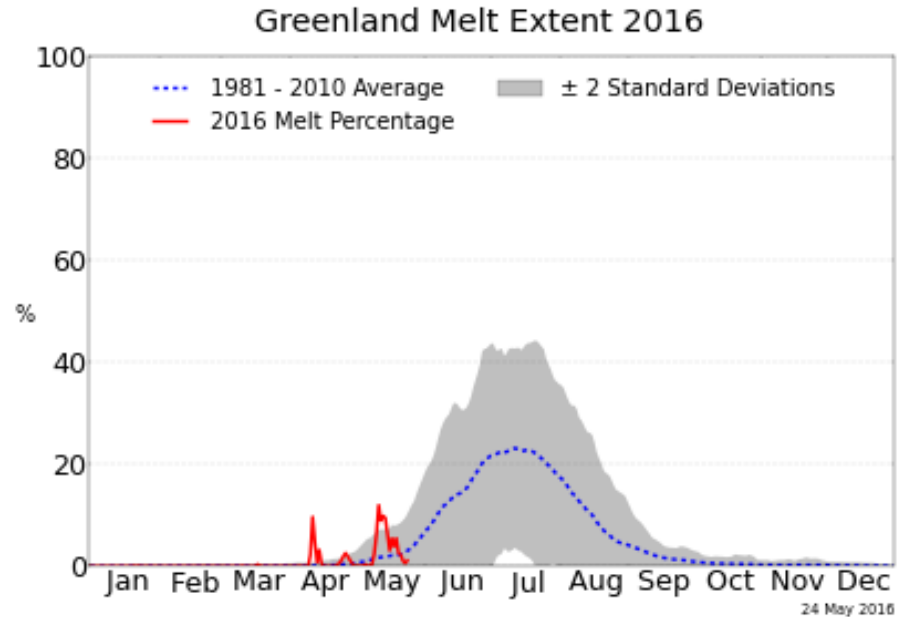
- Positive feedbacks:
- *Less ice, less reflection of sunlight*
- *More evaporation, larger vapor greenhouse effect*
- Same feedbacks as in our winters



Arctic Sea-Ice: Greenland Melt



<http://nsidc.org/arcticseaicenews/>

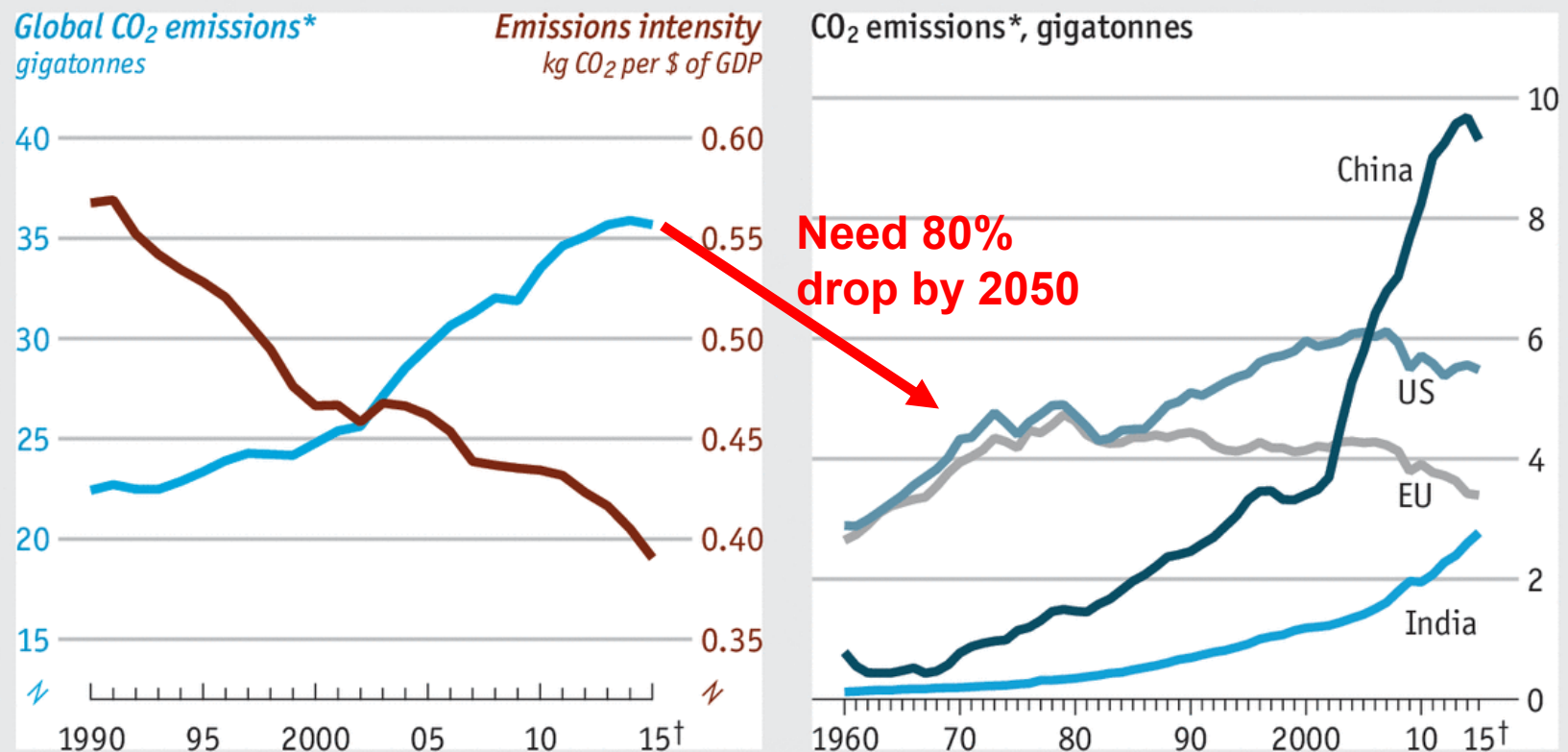


<http://nsidc.org/greenland-today/>

Daily Tracking, monthly summaries

Growth of CO₂ Emissions Slowing

Carbon crunching



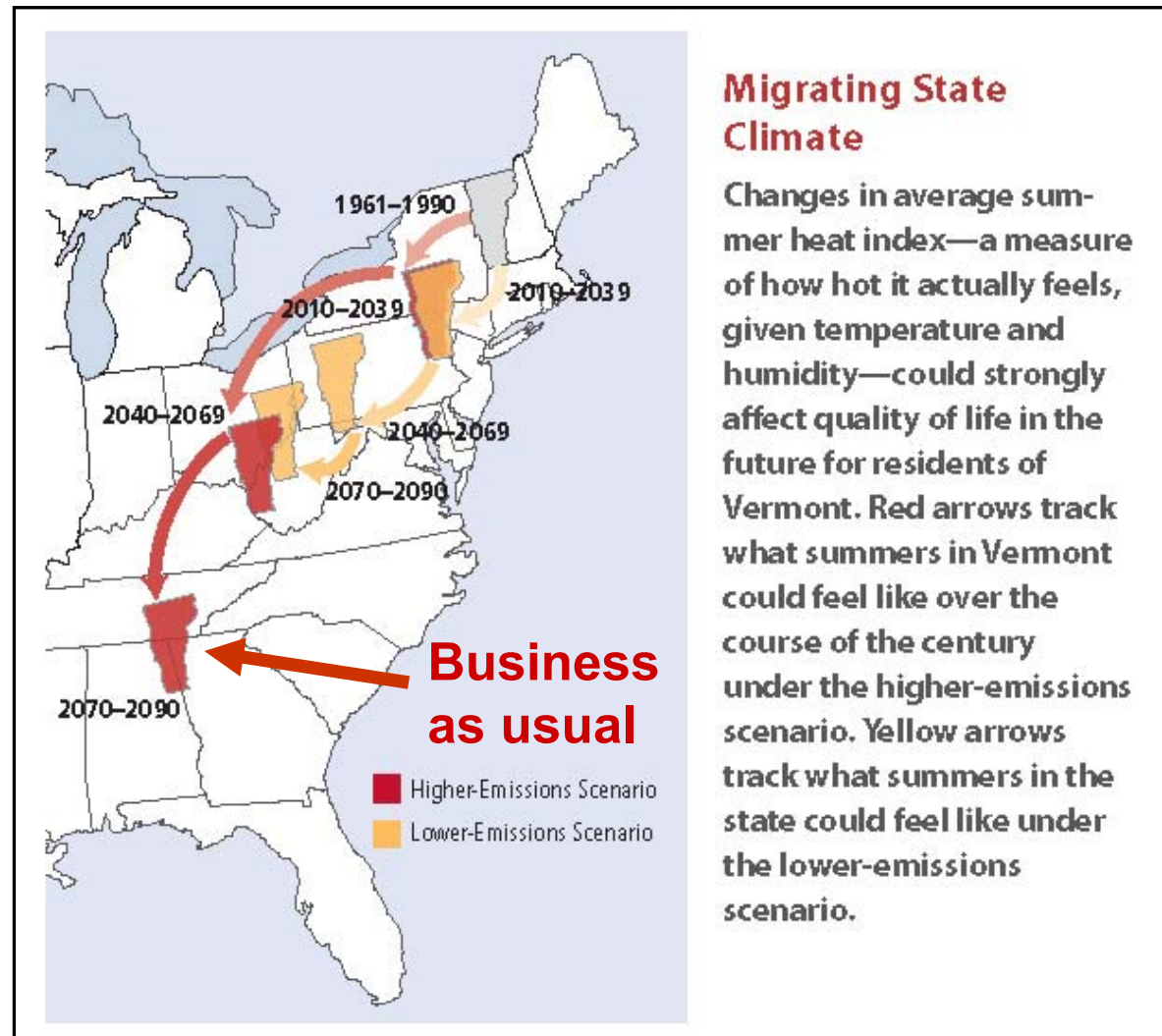
Source: "Reaching peak emissions", by R. Jackson et al. *Nature Climate Change*. 2015

*Fossil-fuel use and industry †Forecast

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US

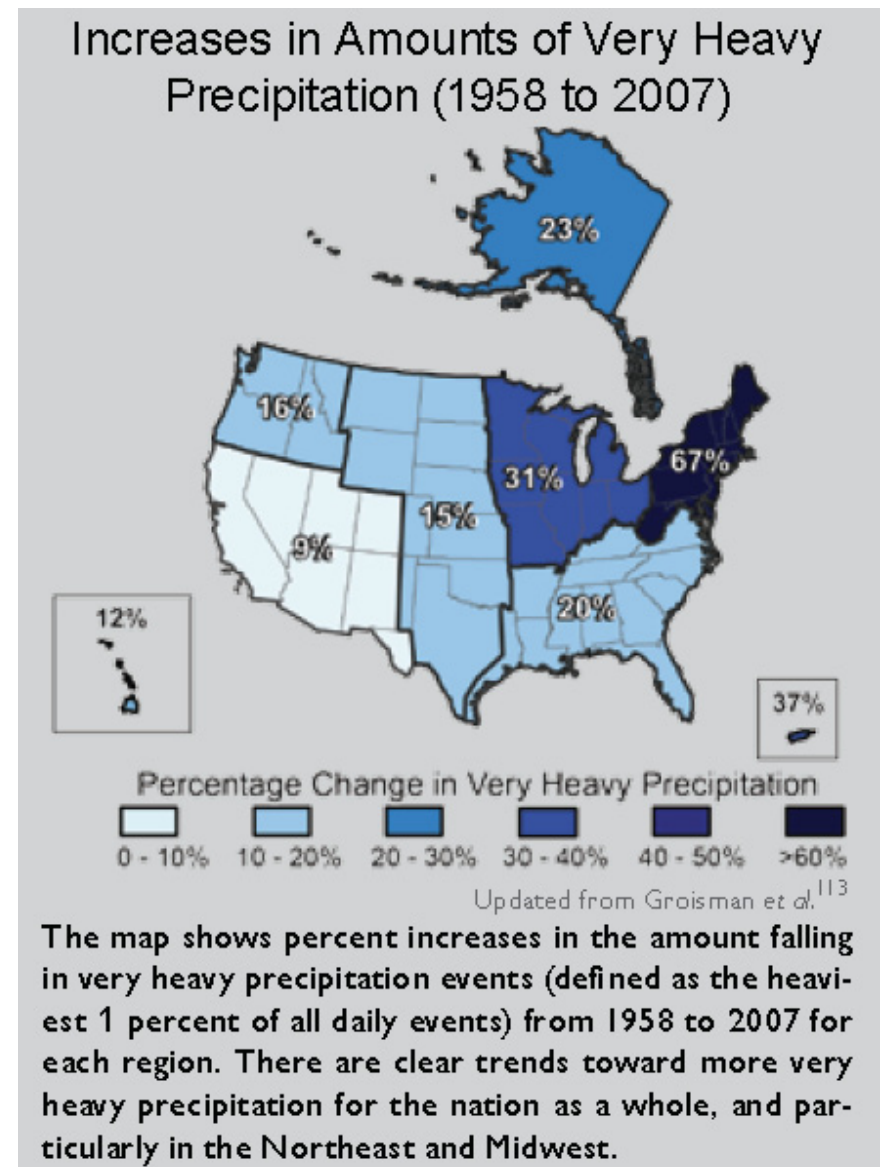


**NECIA,
2007**

Very Heavy Precipitation Is Increasing

(USGCRP, 2009)

- **Precipitation Extremes**
- Most of the observed precipitation increase during the last 50 years has come from the increasing frequency and intensity of heavy downpours.
- **67% increase in Northeast**

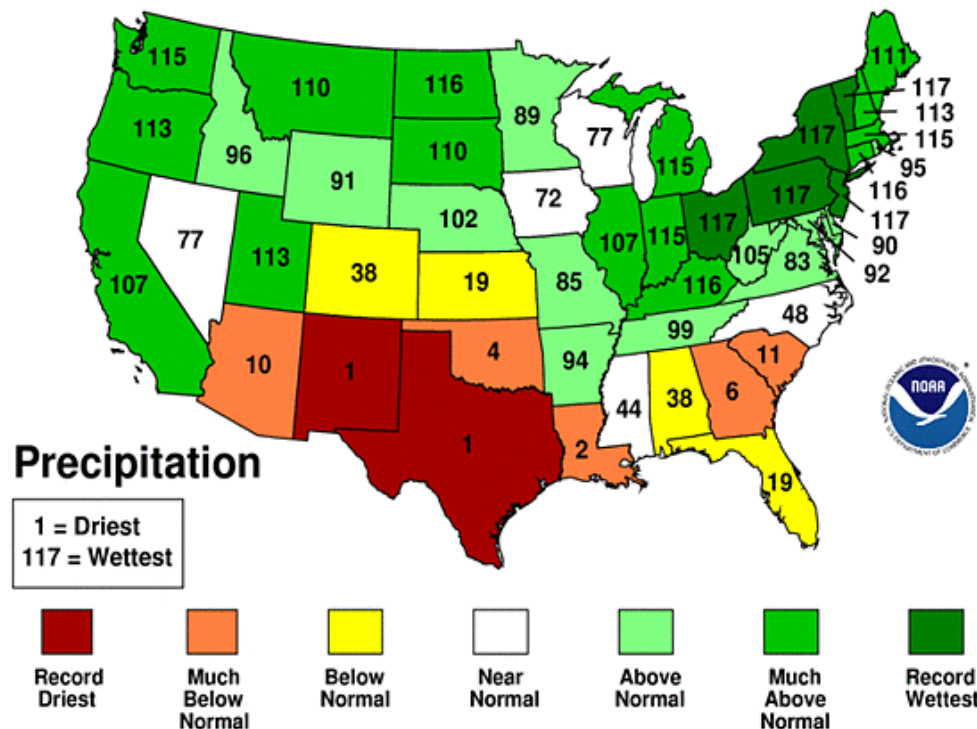


2011 Floods: VT and NY

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

March-August 2011 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



March-August, 2011

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



Preparing for the Storm; Reflections on Flooding, Community Resilience and the Important Role of Climate Science. *Secretary Deb Markowitz, Vermont Agency of Natural Resources*



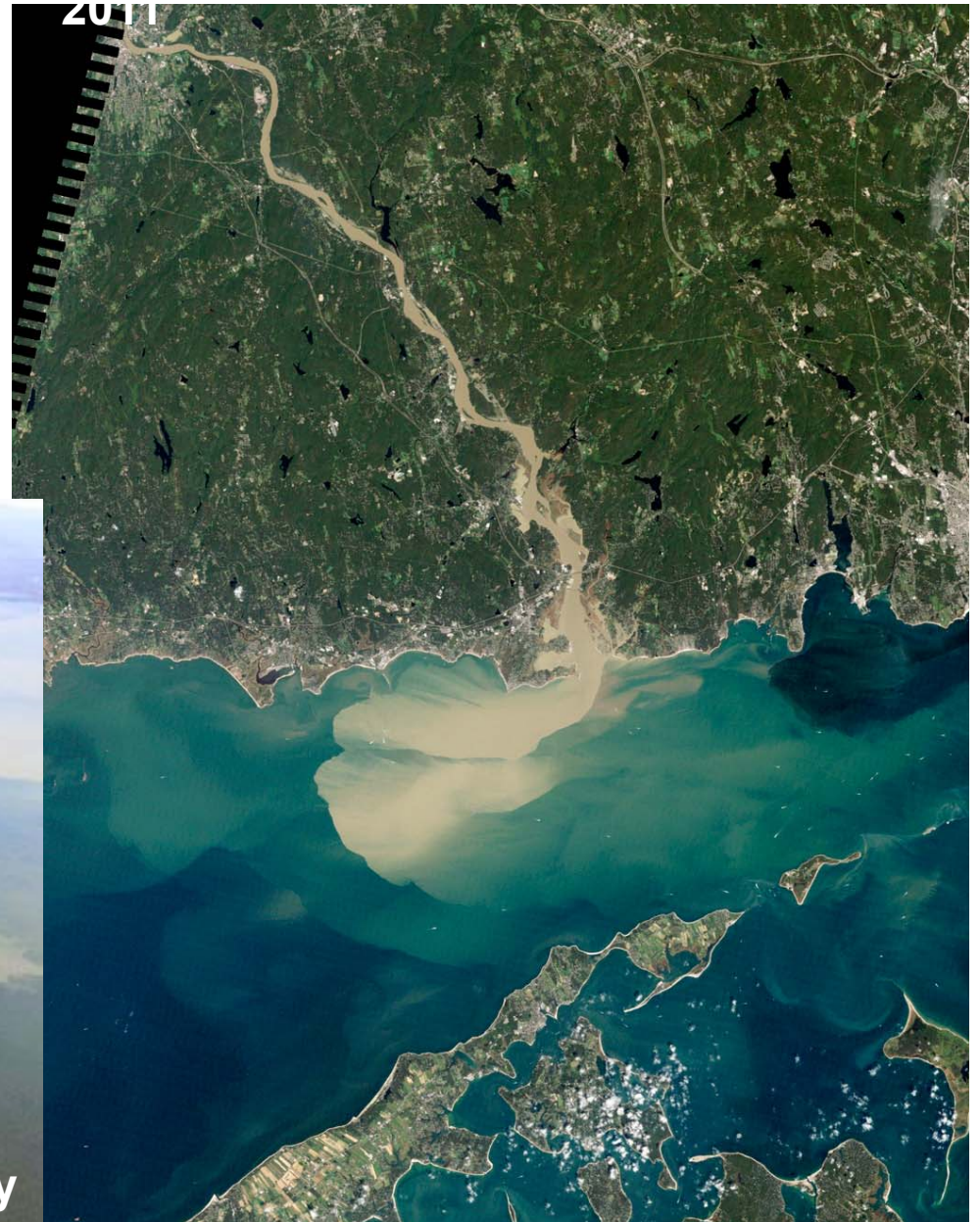
Brattleboro, VT, Courtesy of
Caleb Clark, CNN



Brattleboro, M. Reston



Wilmington, J. Cantore



Lake Champlain, Spring 2011, Courtesy

Three Examples of Partnerships

Science to Action



- Supporting local decision making on floodplain management
- Supporting strategic climate-resilient conservation
- Developing tools for understanding floodplains

Water, Snow & Ice Give Positive Radiative Feedbacks

- As Earth warms, evaporation and water vapor increase and this is 3X amplifier on CO₂ rise
- As Earth warms, snow & ice decrease and reduced SW reflection amplifies warming in Arctic in summer and mid-latitudes in winter
- Doubling CO₂ will warm globe about 5°F (3°C)
 - Much more in the cold regions and over land, which responds faster than oceans
 - Change the global circulation

Global Climate Change

- One of the many great challenges for the 21st century - present path is unsustainable
- Known about it for 35 years:
 - *First National Academy of Science Report in 1979*
- Earth science conflicts with political values (and vested interests in fossil fuel economy)
- It is a global issue and local issue

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, shale-gas & shale-oil reserves are sufficient to push CO₂ to 1,000 ppm—and in time melt icecaps**
 - **Need to leave 1/3 oil; 1/2 gas; 4/5 coal in ground**

Why Is It Difficult for Us?

- **Fossil fuels reserves are worth \$20-30T**
 - Regulating emissions of CO₂ is an “unfair cost” to the “free market”
 - Carbon tax needed to change economics
- **Politics conflicts**
 - Prefer to ignore climate issues
 - Society ignores future costs
 - Manhattan within 1-ft of flooding with Irene
 - Did they put waterproof doors on tunnels?
 - NO! Sandy did \$5B of damage to subway system

Why Is It Difficult for Us?

- The “American dream” is crumbling
 - “Economic growth” based on **fossil fuels, debt, and consumerism is unsustainable**
 - Global market capitalism is 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

‘Engineering’ Rules to Minimize Impacts

- **Minimize the lifetime of human waste products** in the Earth system and eliminate waste with critical biosphere interactions
- **Minimize use of non-renewable raw materials**
- **Maximize recycling and re-manufacturing**
- **Maximize efficiency** of energy use and fresh water use
- **Maximize the use of renewable resources**
- *(These need priority over short-term profit)*

Change of Attitude Needed?

- **Do we just exploit the Earth's wealth**
 - For greater 'economic growth'
 - For a wealthy few
 - What is left for our children?
 - What happens to the ecosystems we depend on?
- **Moral Issue**
 - Don't we need to co-operate with the Earth?
 - Shift in understanding and mind-set needed

Discussion

Scientific Integrity

- **What are the challenges scientists face?**
 - Insufficient knowledge to give a balanced accurate assessment
 - Social resistance to change
 - Political hostility/attempts to silence scientists
 - Corruption in the system at many levels
- **Rapid change over your lifetime**
 - Climate refugees, internal and from overseas

What are the Responsibilities of Environmental Scientists?

- Just do research?
- Publish in the usual jargon in copyrighted journals not available to the public?
- Avoid public discussion and politics?
- Or accept that with understanding comes responsibility
 - To society
 - To the Earth
 - To the future

2015 was Transition Year

- **Climate meeting in Paris in December**
 - 196 nations made commitments to cut emissions
 - Need follow-through!
- **First Papal Encyclical on the environment, climate change, our responsibilities to the Earth**
 - Shifts the position of the churches
 - Shift from short-term profit as primary motive
- *New values that respect the Earth*

Technical solutions

- **Electrical power**
 - Renewable: solar, wind, hydro
 - Storage: lithium batteries down to \$150/kWh
 - Electric car industry will generate massive storage
- **New technologies: electricity to liquid fuels**
- **Net-zero housing**
- **Rethink transport**

Radically change 'transport'



From heavy SOVs to light vehicles with separate lanes/roads



Danish electric tricycle

The Future Is Not Our Past

- **Collectively, we create the future, so we need to plan for a transition to a sustainable society**
- **In the face of a powerful economic and financial system driven by short-term profit**
- **Needs deep community discussion**
 - *New values that respect the Earth*

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 limits**
 - **That accept our moral responsibilities**