



Climate Change: ***How is it affecting us?*** ***What can we do about it?***



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Outline

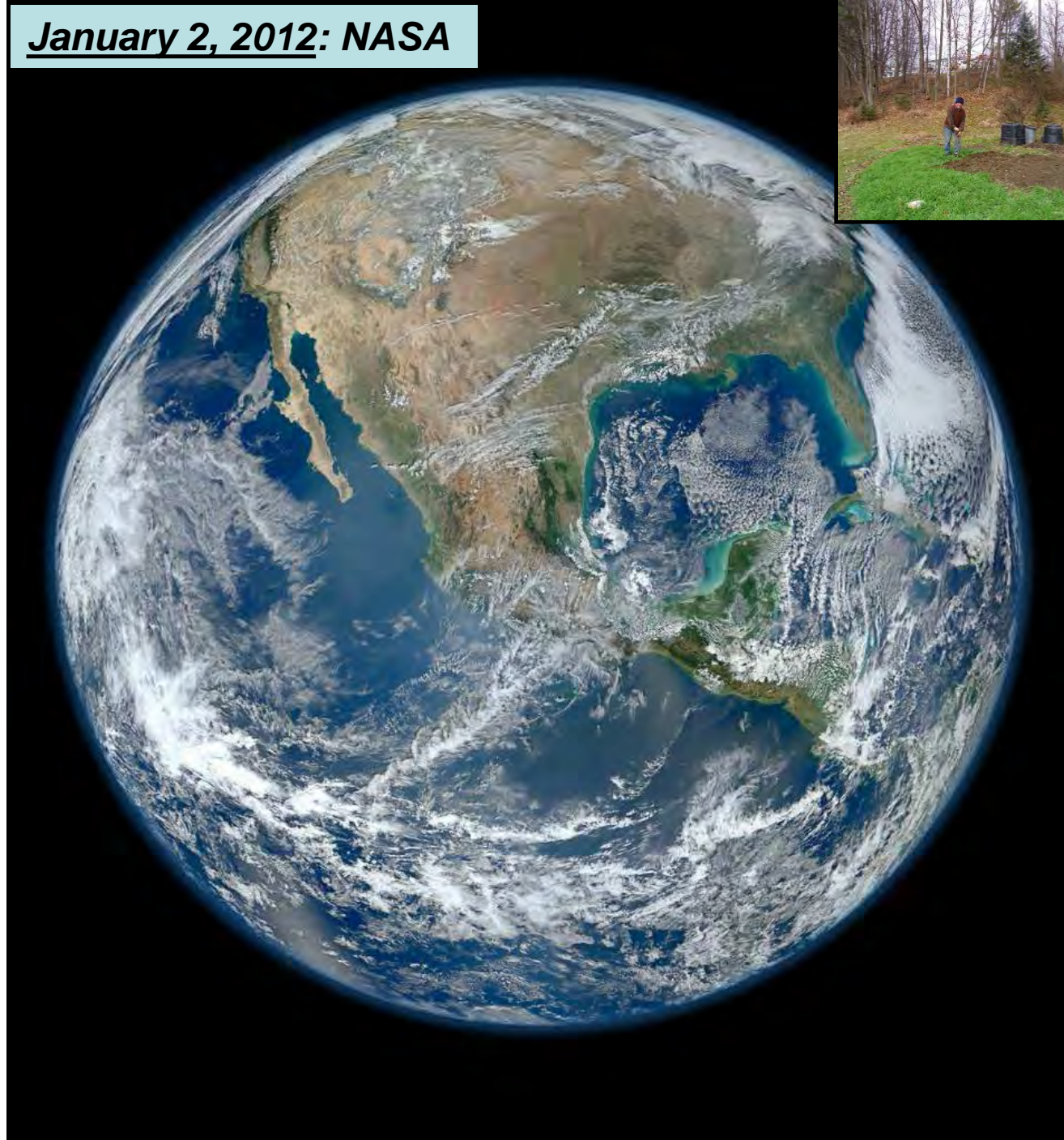
- **As climate changes**
 - What is happening to Vermont?
 - What is happening to the Earth?
 - **Discussion**
- **Can we slow down changes?**
 - How can we stabilize the climate?
 - Why is it difficult?
 - How do we deal with it?

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

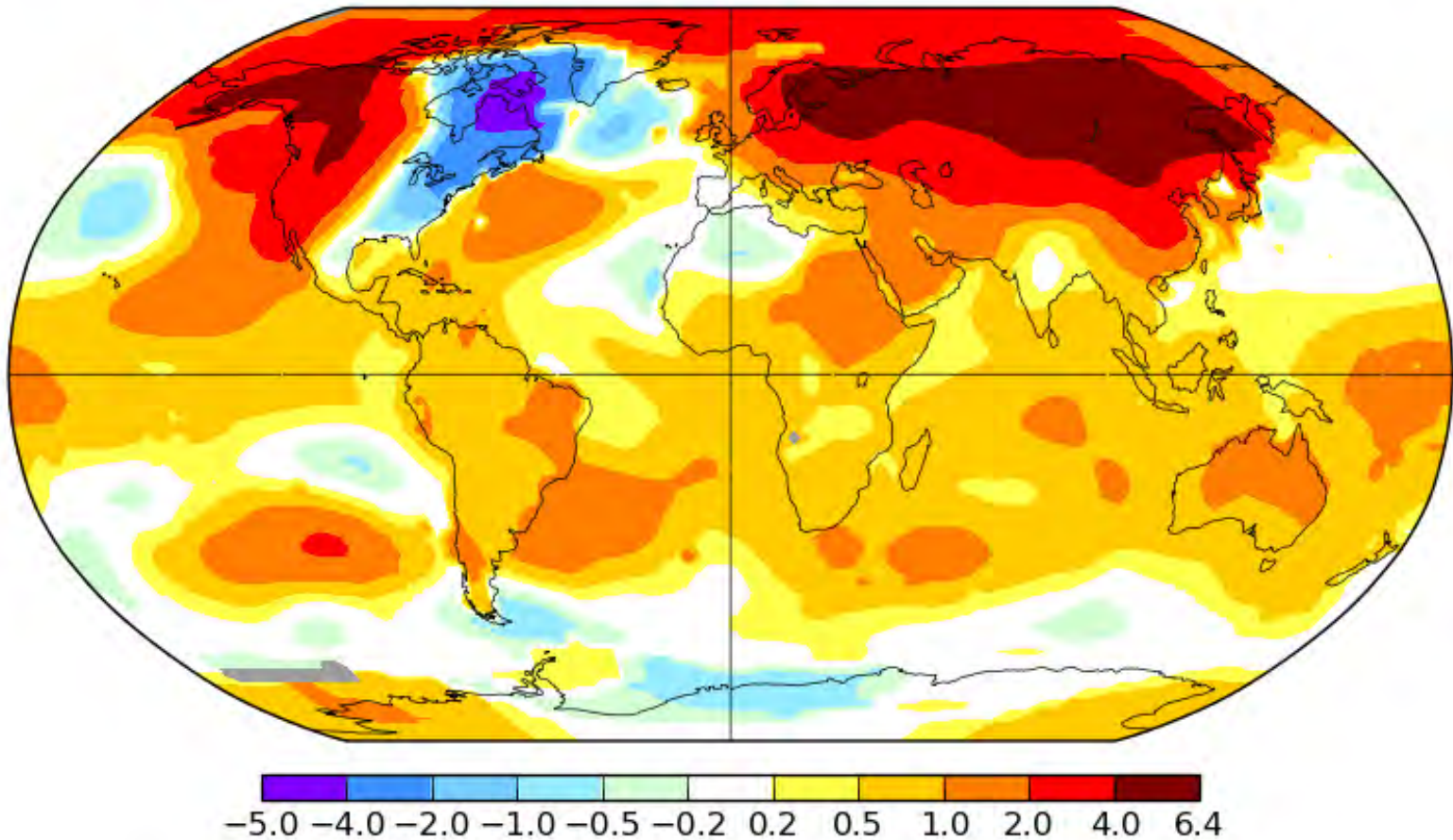


Jan-Feb-Mar 2015

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



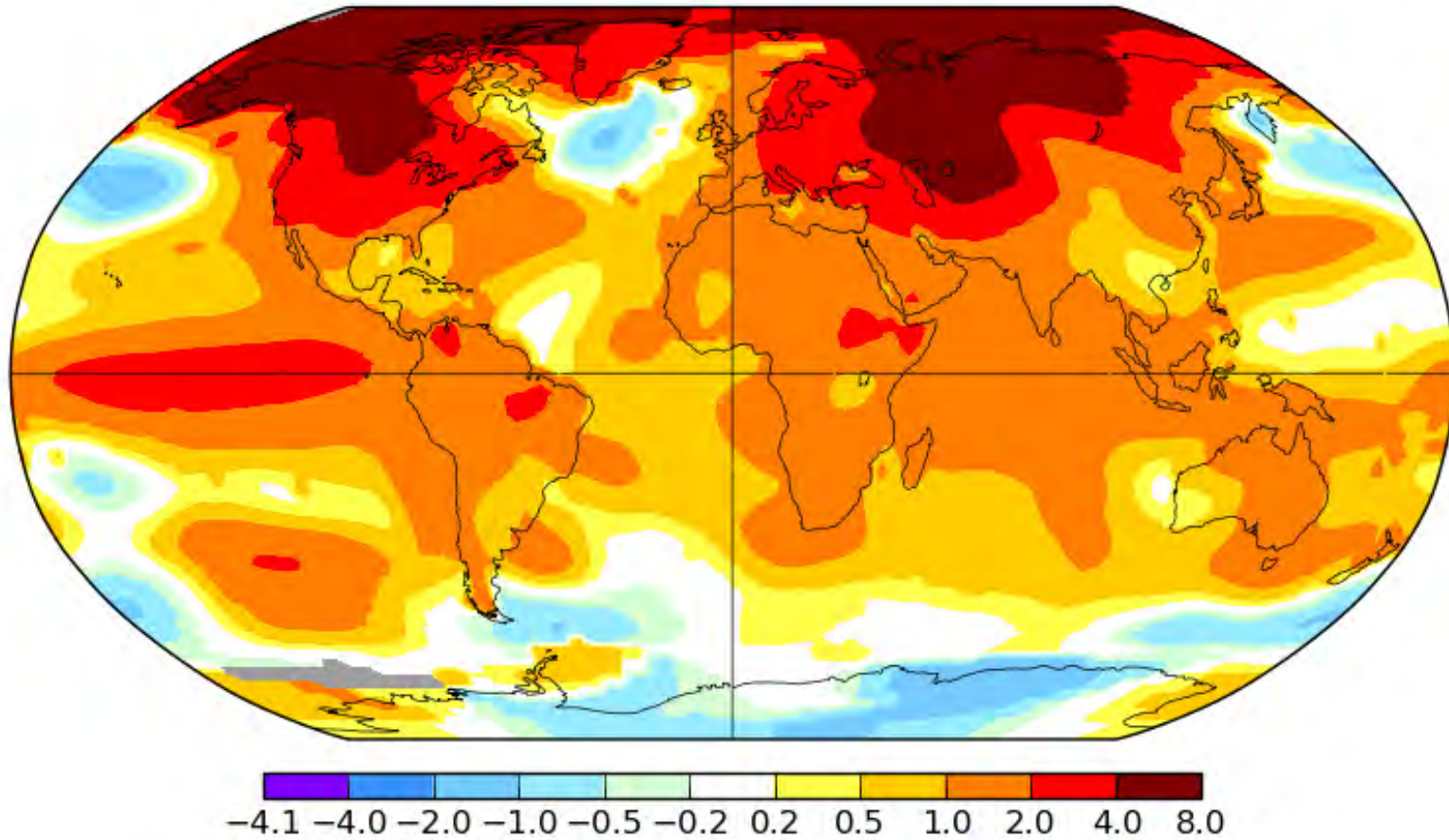
Vermont was cold – with a lot of snow cover

Jan-Feb-Mar 2016

Jan-Mar 2016

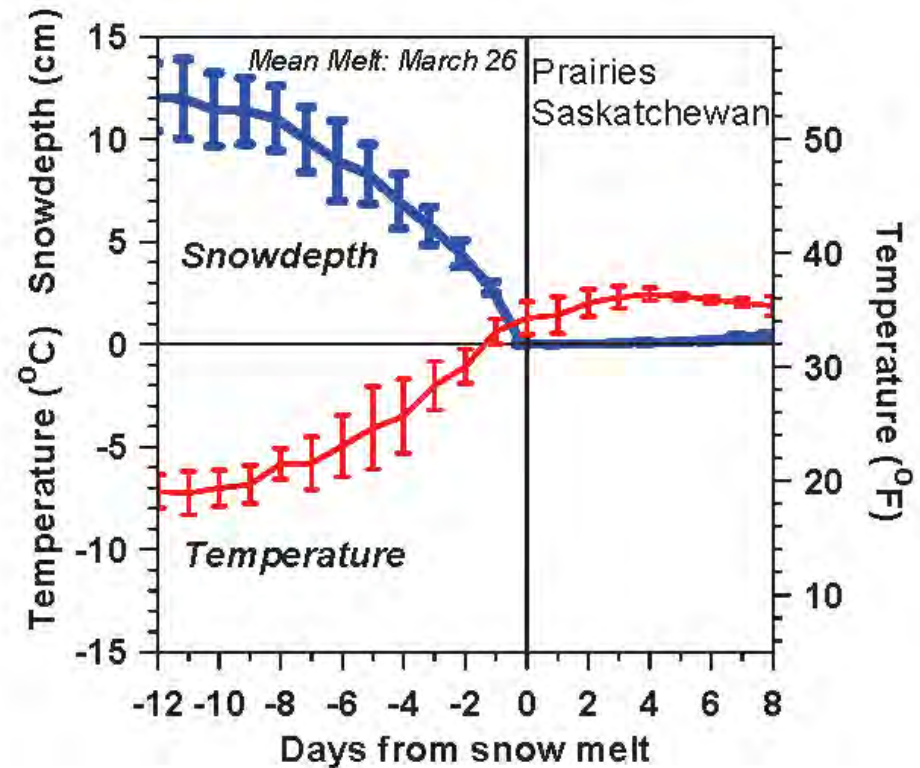
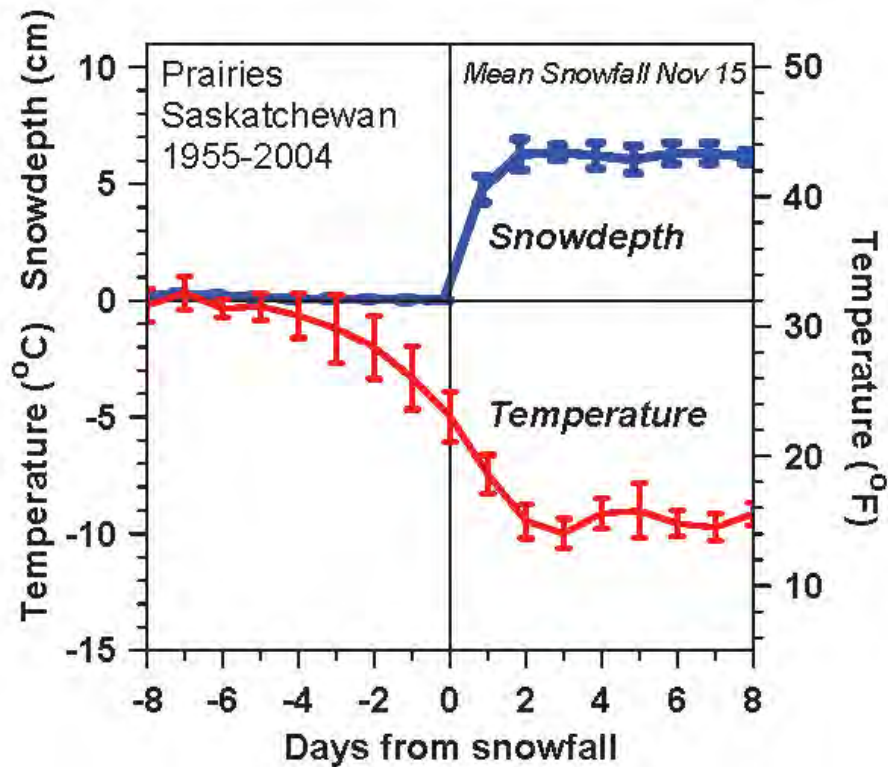
L-OTI(°C) Anomaly vs 1951-1980

1.24



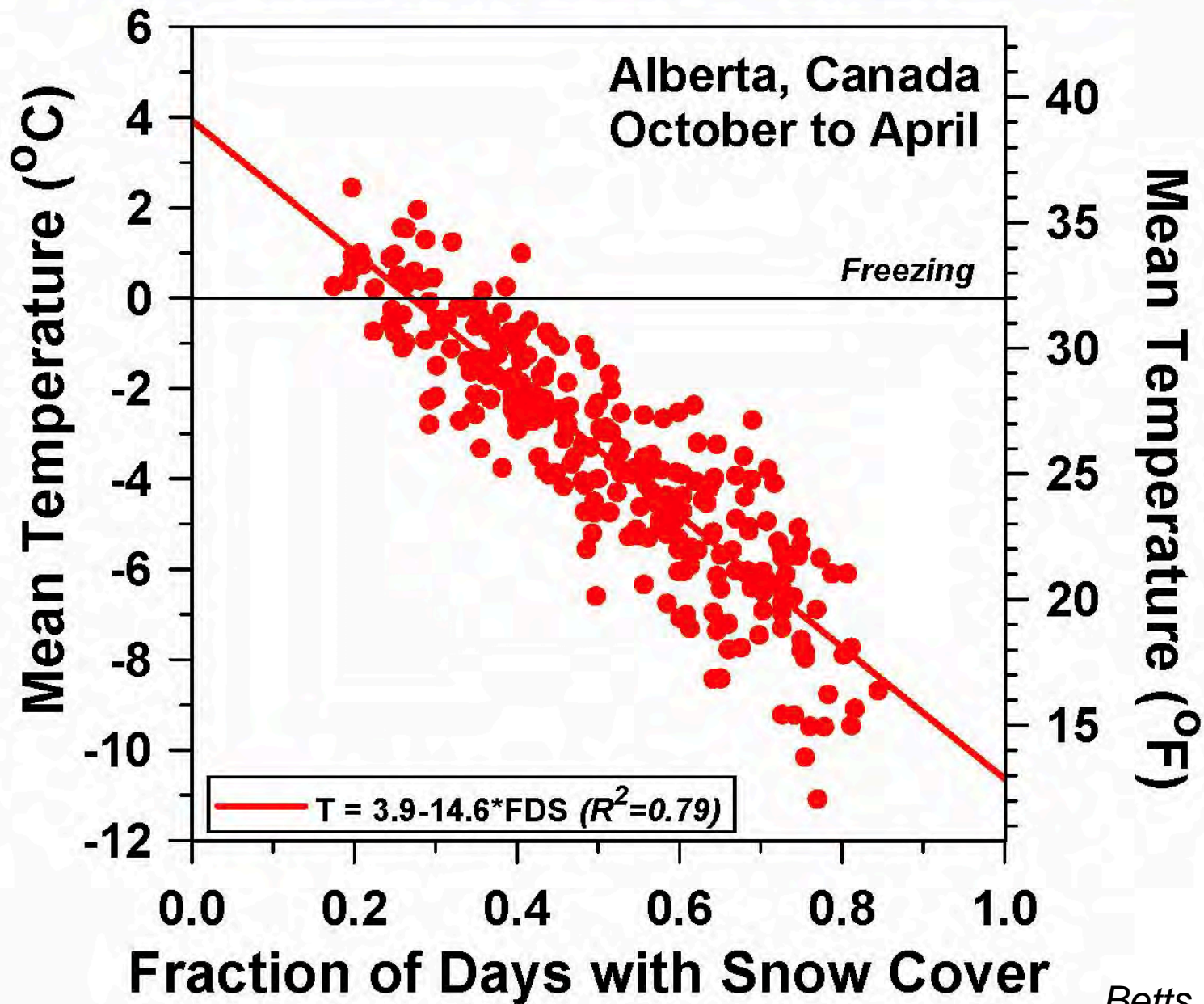
Vermont was warm – with little snow cover

Snowfall and Snowmelt

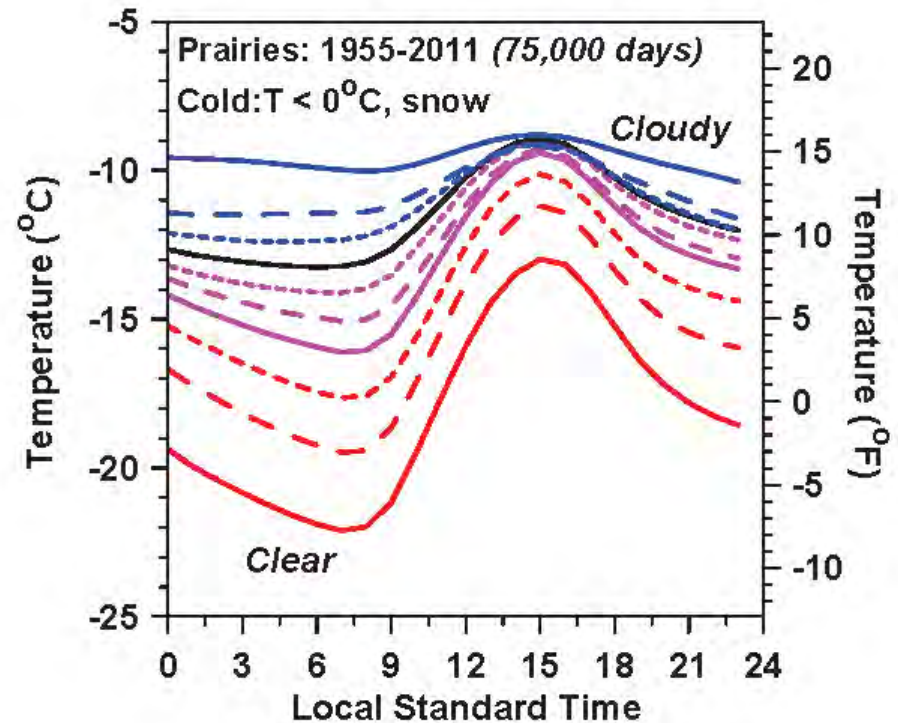
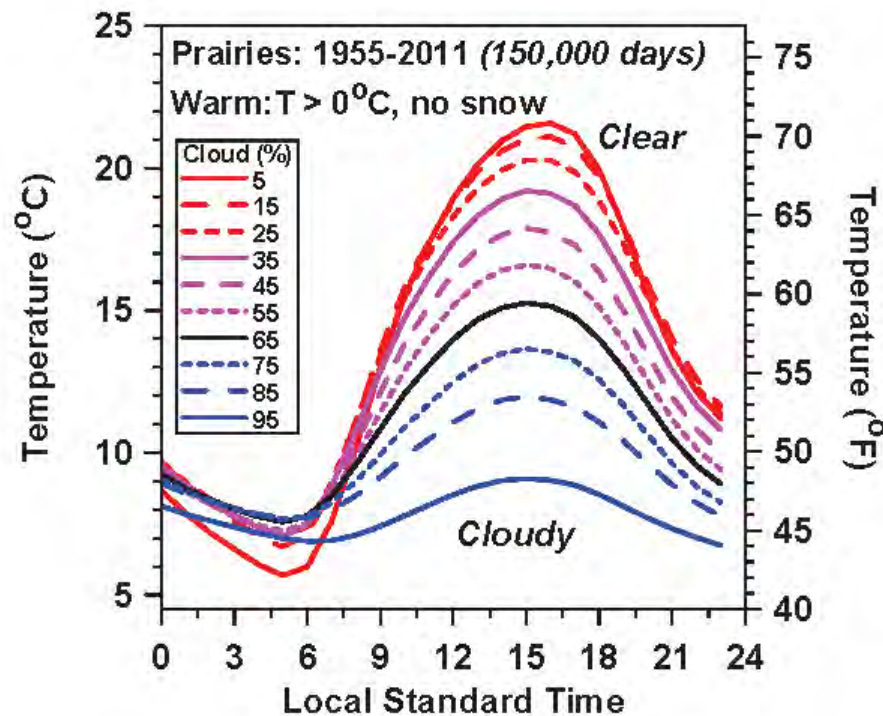


- Temperature falls 18F (10C) with first snowfall
- Reverse change with snowmelt
- *Fast transitions in 'local climate'*
 - *Snow reflects sunlight*
 - *Reduces evaporation and water vapor greenhouse*

More snow cover - Colder temperatures



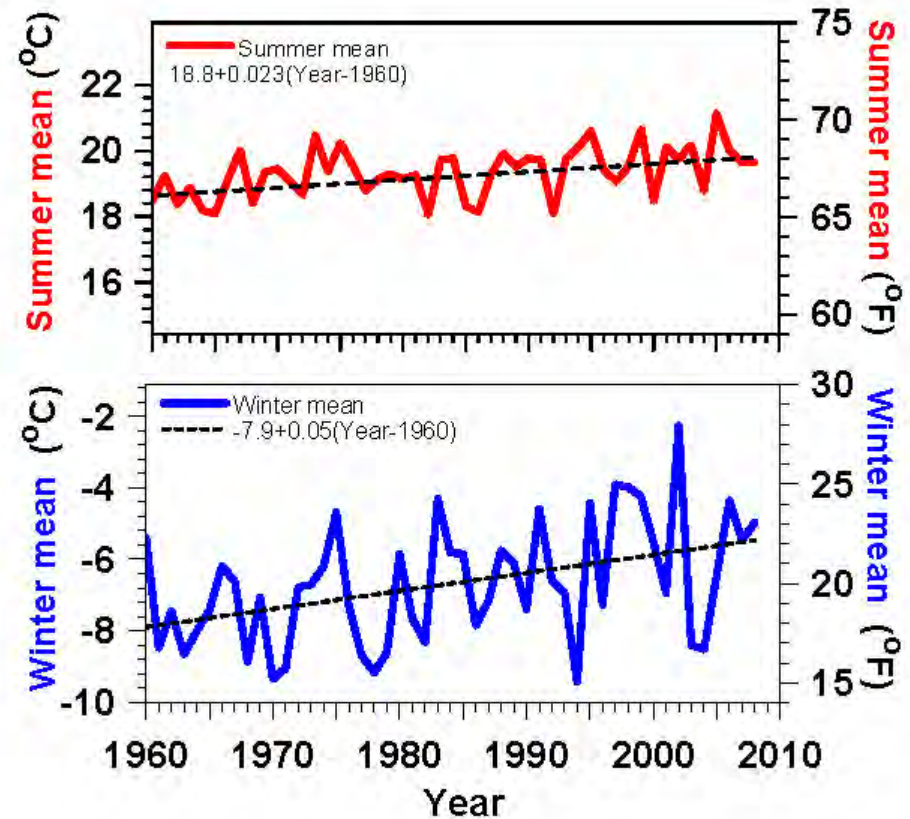
Clouds, Snow and Climate



- **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

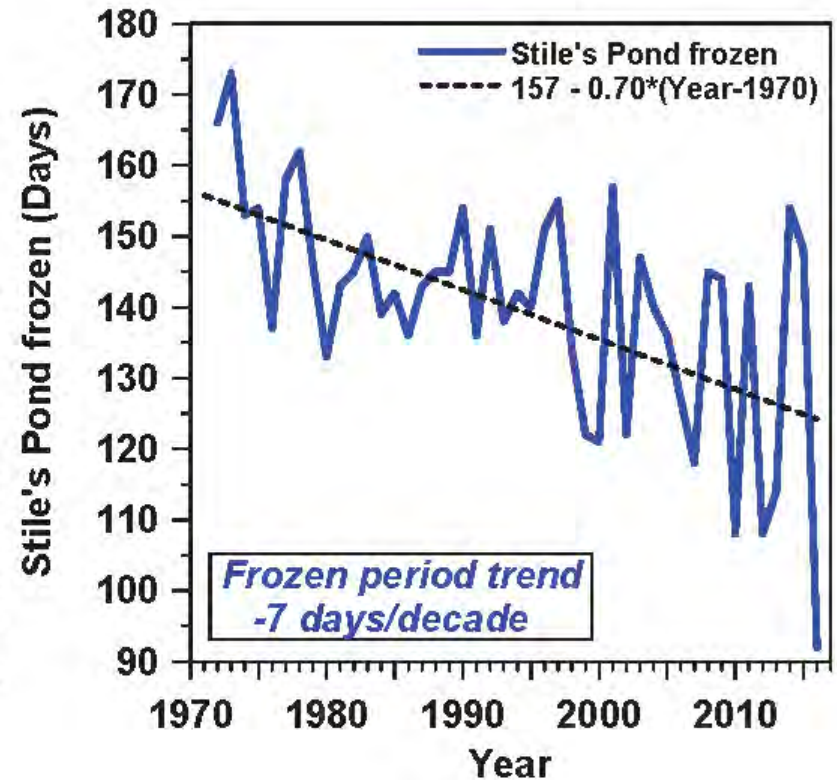
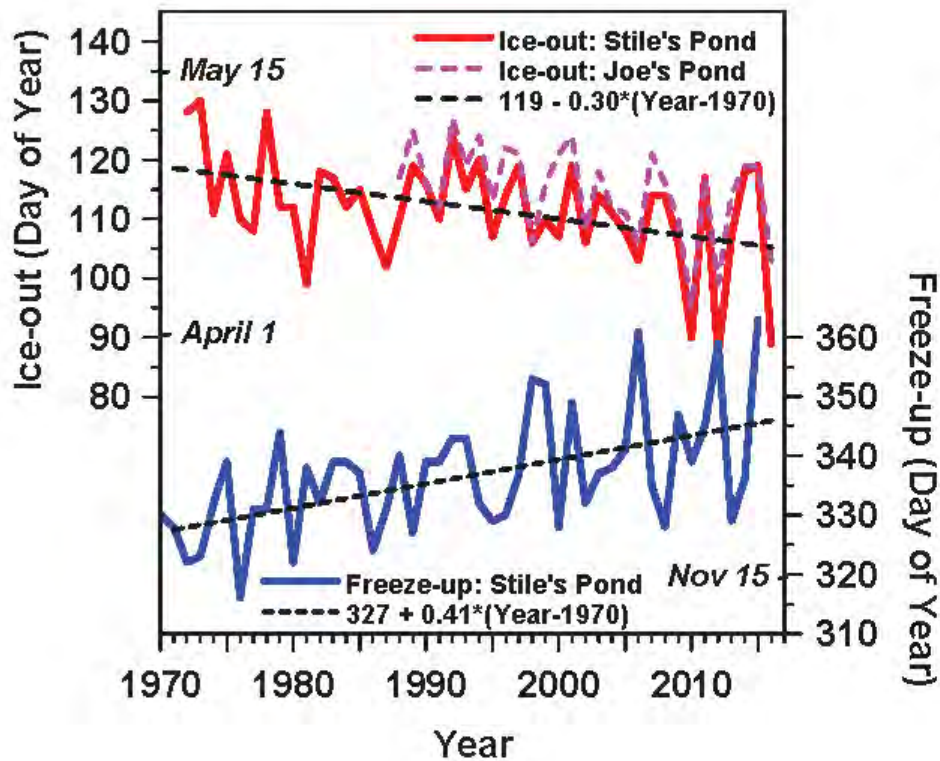
Vermont Temperature Trends 1961-2008

- **Summer $+0.4^{\circ}\text{F}$ / decade**
- **Winter $+0.9^{\circ}\text{F}$ / 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**



January 2, 2012



March 11, 2012



October 2011– March 2012

- **Warmest 6 months on record**
- **My garden frozen only 67 days**
- **January 15, 2013**
- **Jan 2014, 2015 frozen**



February 5, 2016

(Digging in Feb. first time ever)



Discussion

**What have you seen
in your lifetime?**

2011: IRENE woke up VT



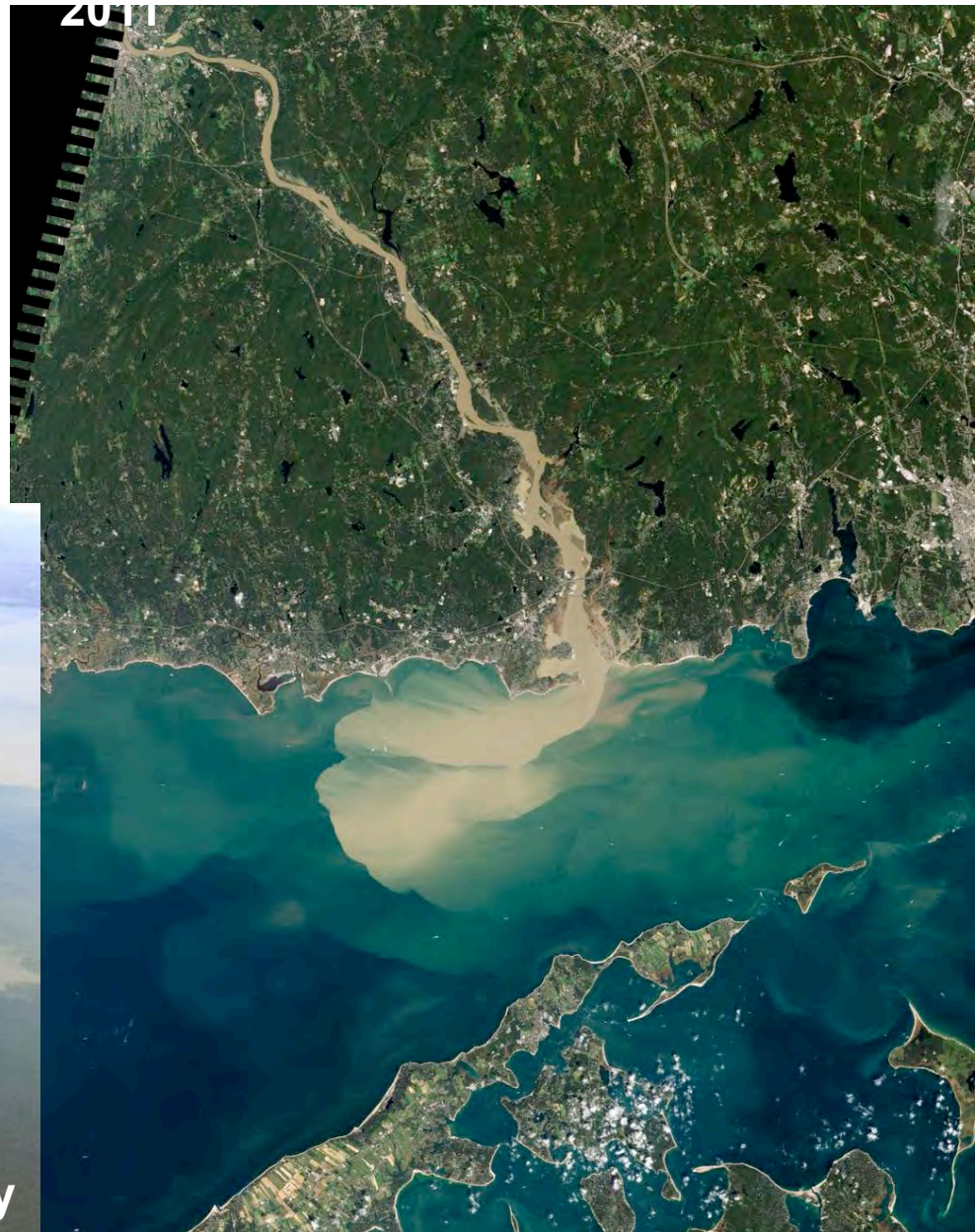
Brattleboro, VT, Courtesy of
Caleb Clark, CNN



Brattleboro, M. Reston



Wilmington, J. Cantore



Lake Champlain, Spring 2011, Courtesy

**What is happening
to the Earth?**

And why?

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

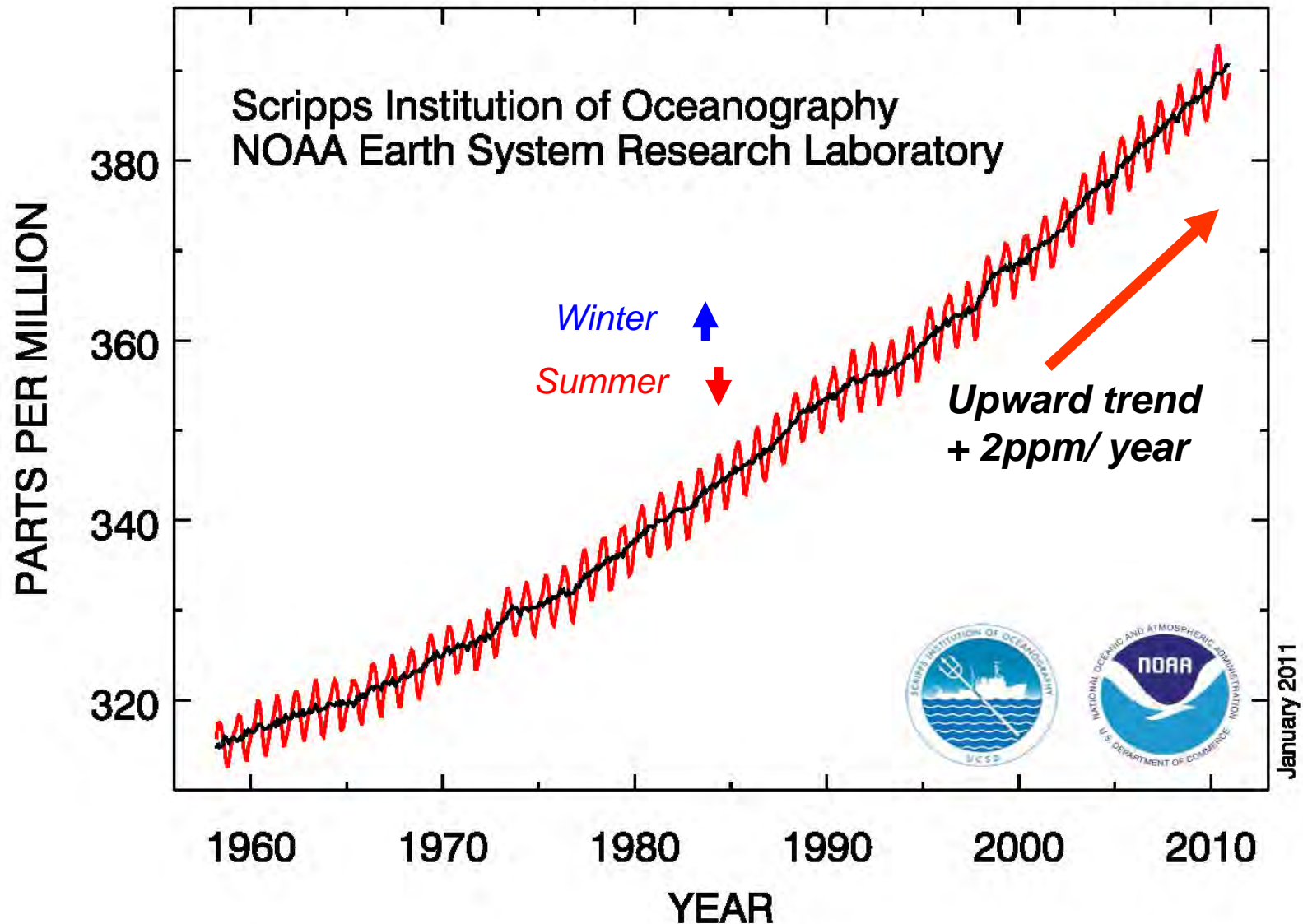
- Positive feedbacks:
- *Less ice, less reflection of sunlight*
- *More evaporation, larger vapor greenhouse effect*
- Same feedbacks as in our winters

Watch 2016 at
<http://nsidc.org/arcticseaicenews/>



Carbon Dioxide Is Increasing

Atmospheric CO₂ at Mauna Loa Observatory



Rise of Greenhouse Gases (GHG)

Shift Energy Balance of Planet

- The atmosphere is **transparent to light** from the sun, **but not to infrared radiation** from the earth
- **GHG:** H_2O , CO_2 , CH_4 , O_3 , CFCs trap the infrared from the surface, giving climate suitable for life by warming planet 60°F
- Rise of CO_2 alone has only a small warming effect

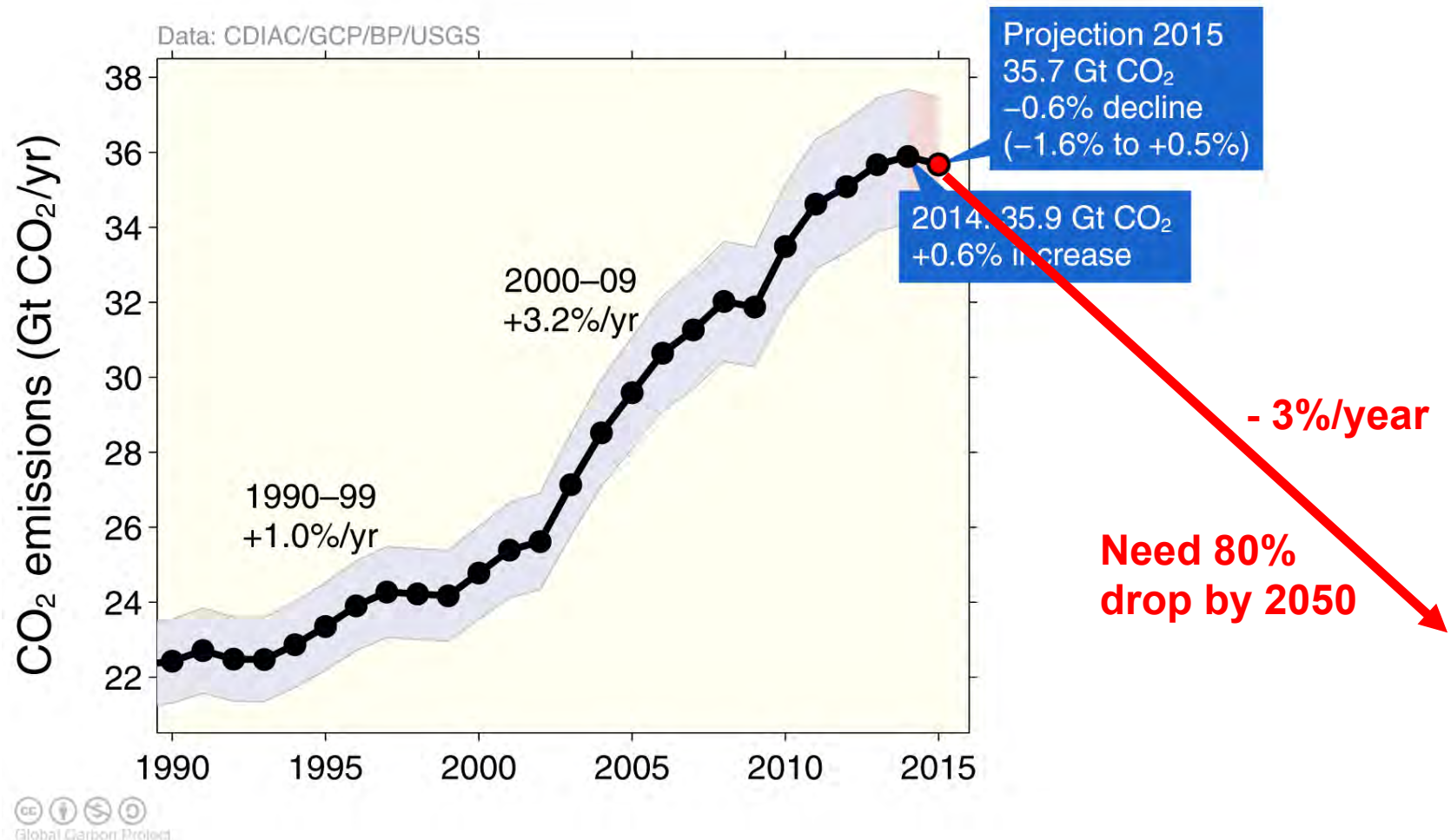
BUT...



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

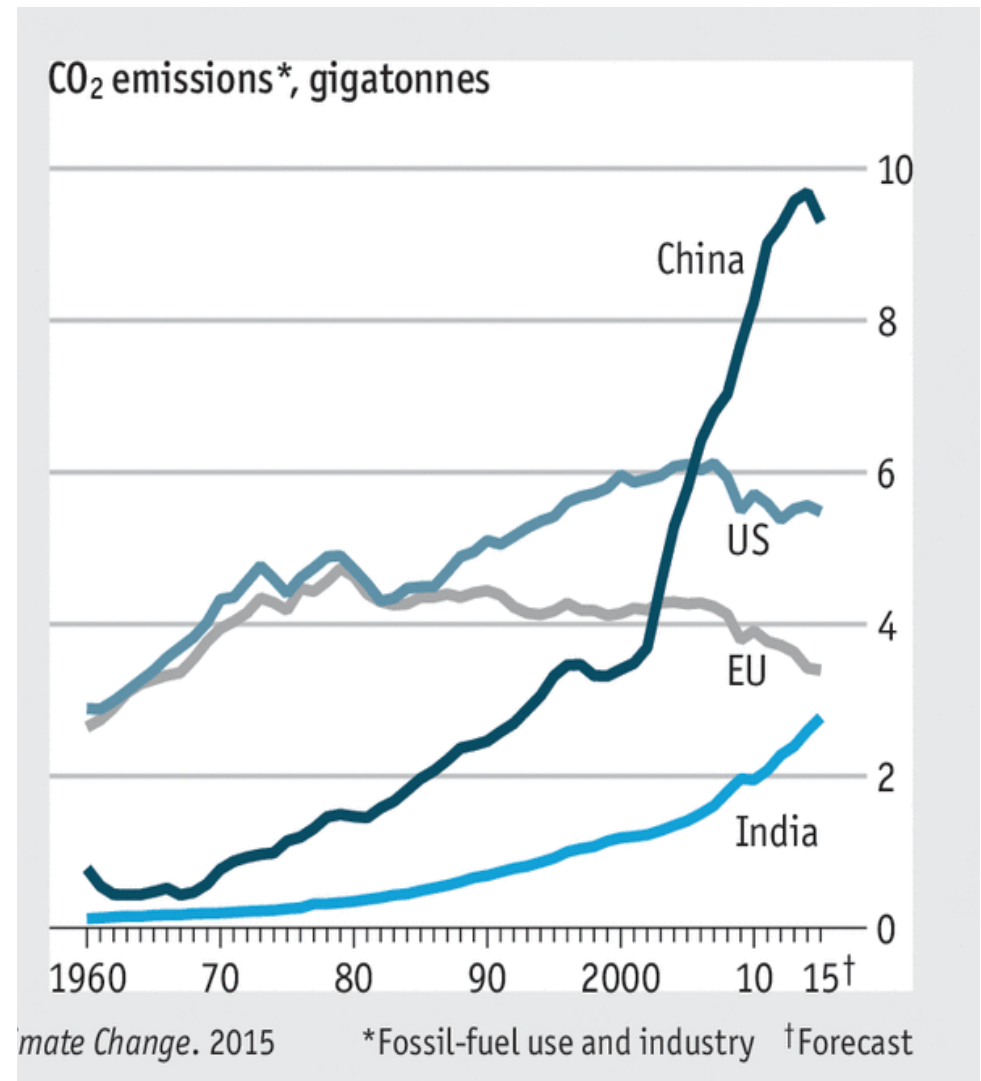
Growth of CO₂ is Driver: peaking?



Where is CO₂ increase coming from?

Growth of CO₂ Emissions Slowing

- CO₂ emissions way too high but
- Declining in US and EU
- Reached peak in China
- *Why did China grow so fast in 2000's?*
- *Why has China peaked?*



Discussion

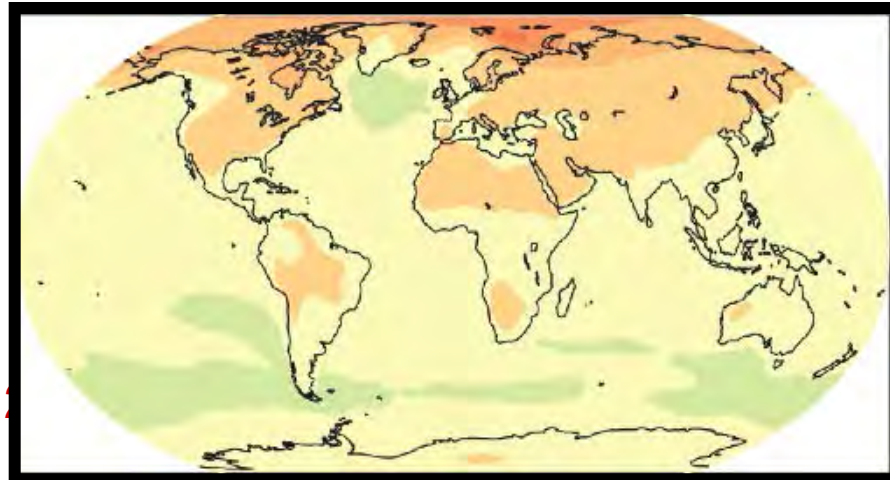
What is happening and why?

How fast can we cut burning of fossil fuels?

Predicted Change in Temperature

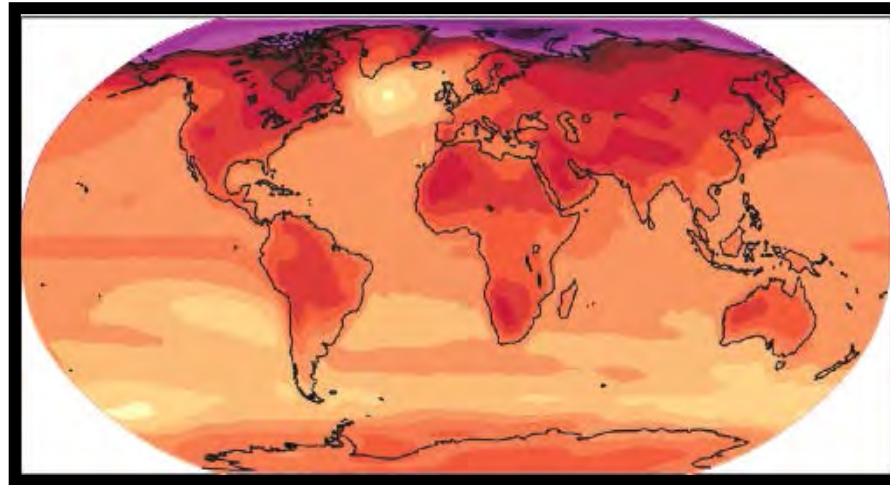
2020-2029 and 2090-2099, relative to 1980-1999 (°C)

“Committed”



**(We did
nothing for
the last 20
years)**

Still up to us!



**(We could
halve this if
we act now)**

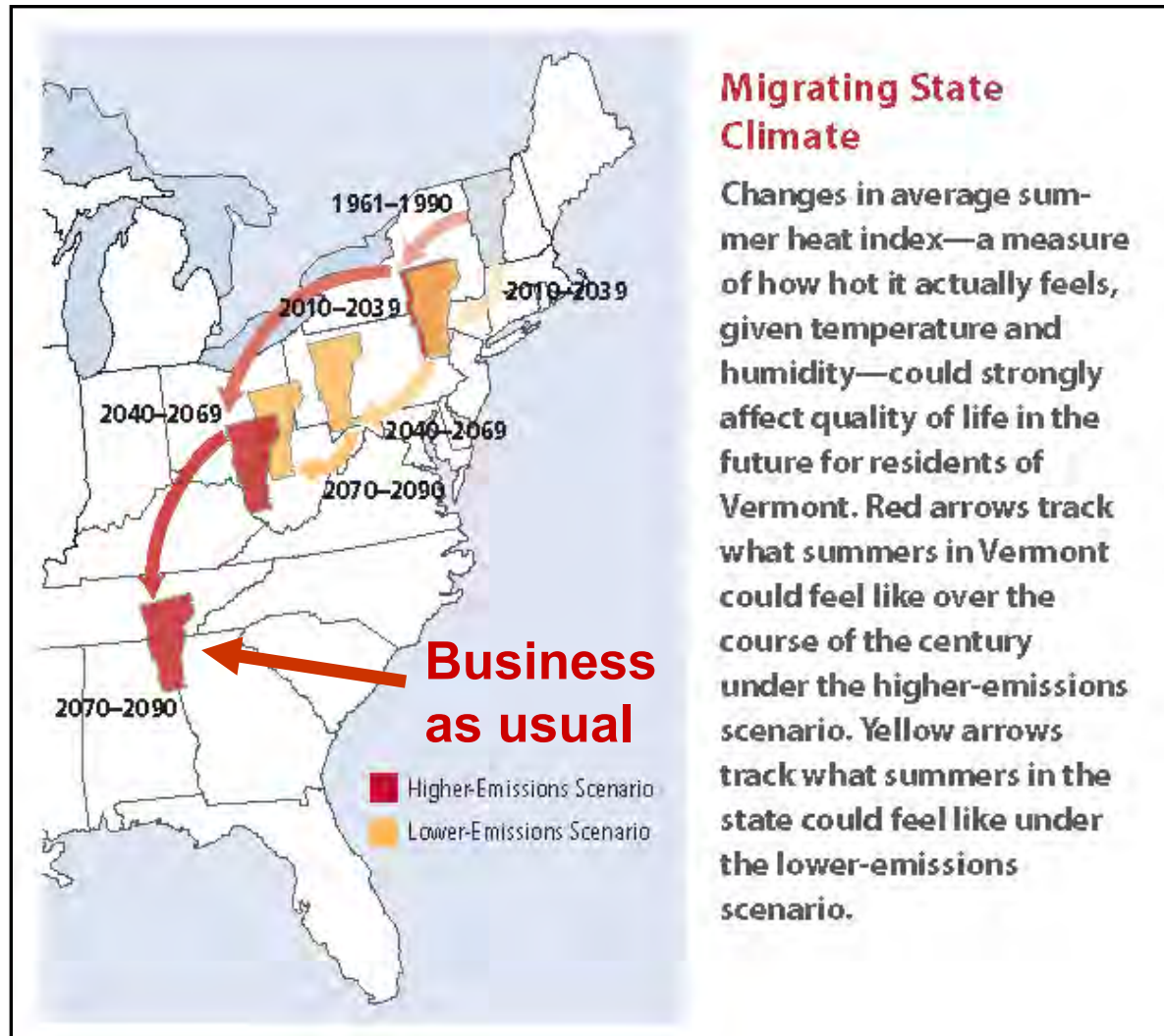


[°C]

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



**NECIA,
2007**

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)

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 — back to hothouse climate that will 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
- **Political 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

Technology can 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
- *(Earth needs 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

2015 was Transition Year

- **Climate meeting in Paris in December**
 - 196 nations made commitments to cut emissions
 - Now 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*

What do you agree with?

Disagree with?

What matters to you?

What do we need?

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: need standards**
- **Rethink transport: hard for us!**
 - Shipping all over the world? Or local suppliers?

Radically change 'transport'



From heavy SOVs to light vehicles with separate lanes/roads



Danish electric tricycle

Other paths for transport?

- **Smart phone/GPS ride sharing on Vermont roads.**
 - We have the App (Uber): China is trying!
- **Electric cars**
 - Continue with old – just a bit lighter!
 - Chevy Bolt: 200 mile range for \$30K this fall (?)



What about the rest of the world?

- Solar power for light, cell phones and internet and critical refrigeration (clinics)

Self.org

Columbian Kogi and Arhuaco tribes have come to believe that solar power complements their spiritual connection with nature and need to protect it.



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*

**So let us dream
And act!**

(<http://alanbetts.com>)

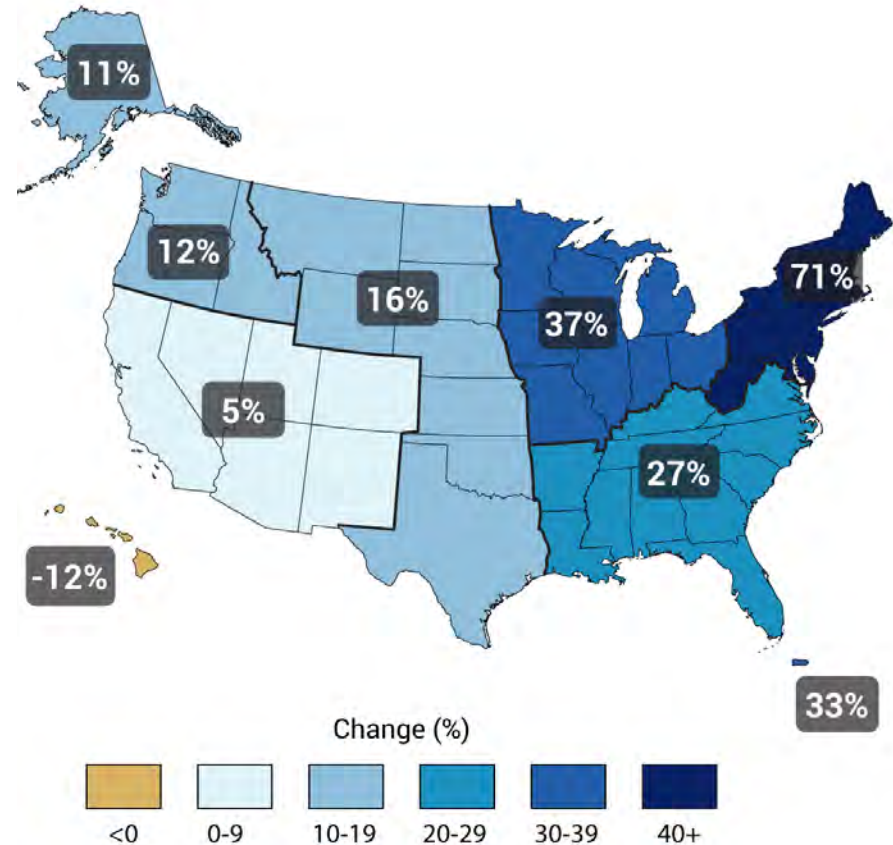
What Do We Need?

- 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**

Very Heavy Precipitation Is Increasing

(USGCRP, 2014)

- **Precipitation Extremes**
- Most of the observed precipitation increase over the last 50 years comes from increasing frequency and intensity of heavy downpours.
- **71% increase in Northeast**

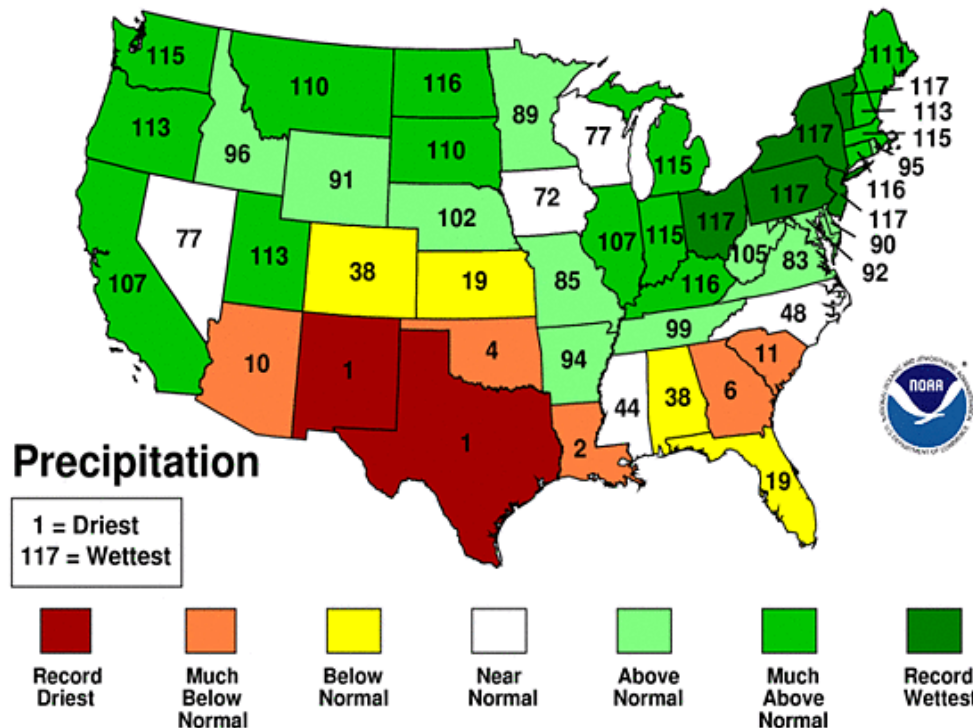


2011 Floods: VT and NY

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

March-August 2011 Statewide Ranks

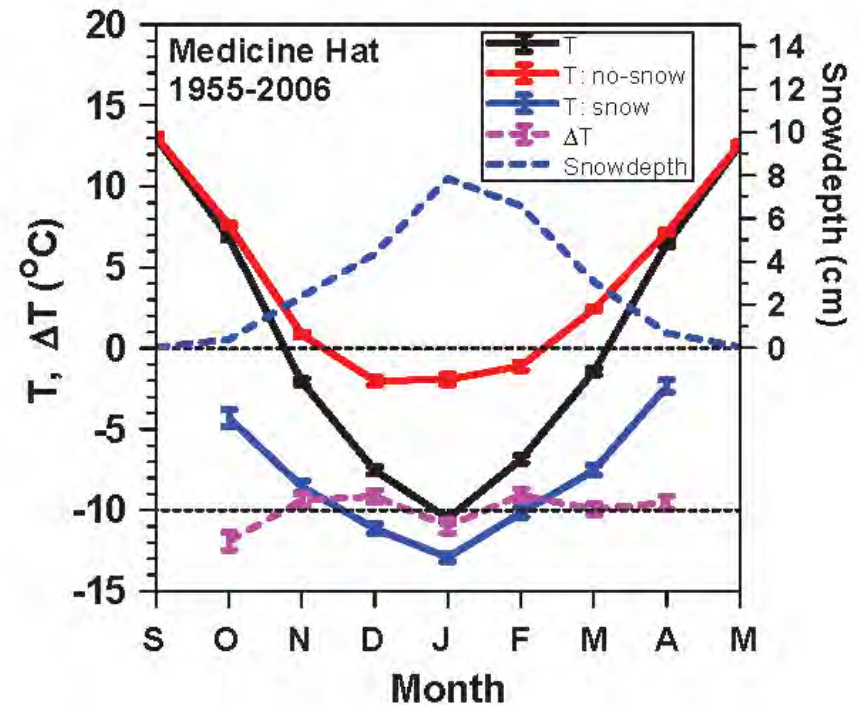
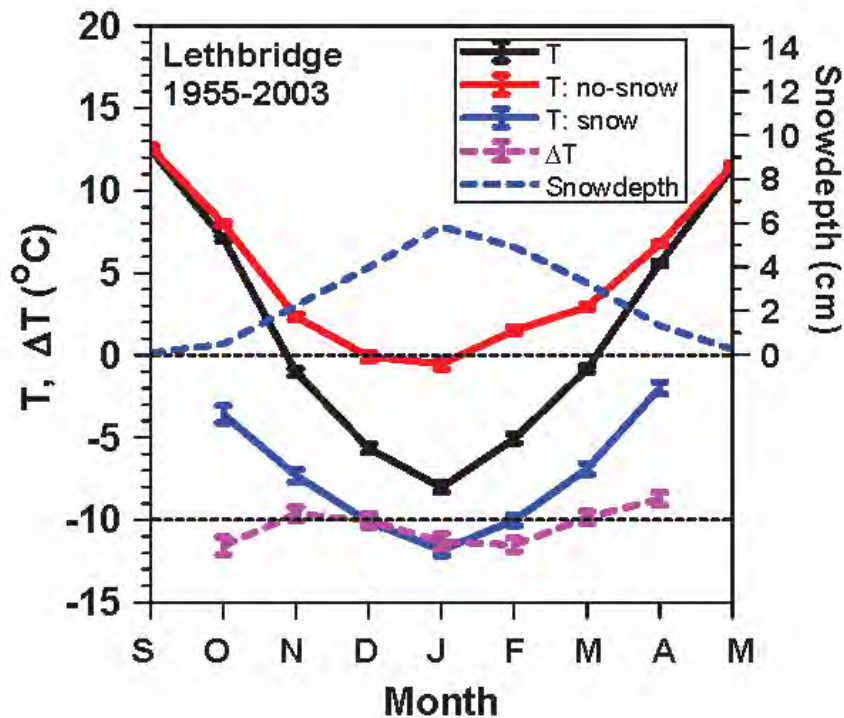
National Climatic Data Center/NESDIS/NOAA



March-August, 2011

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

Impact of Snow on Climate



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

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

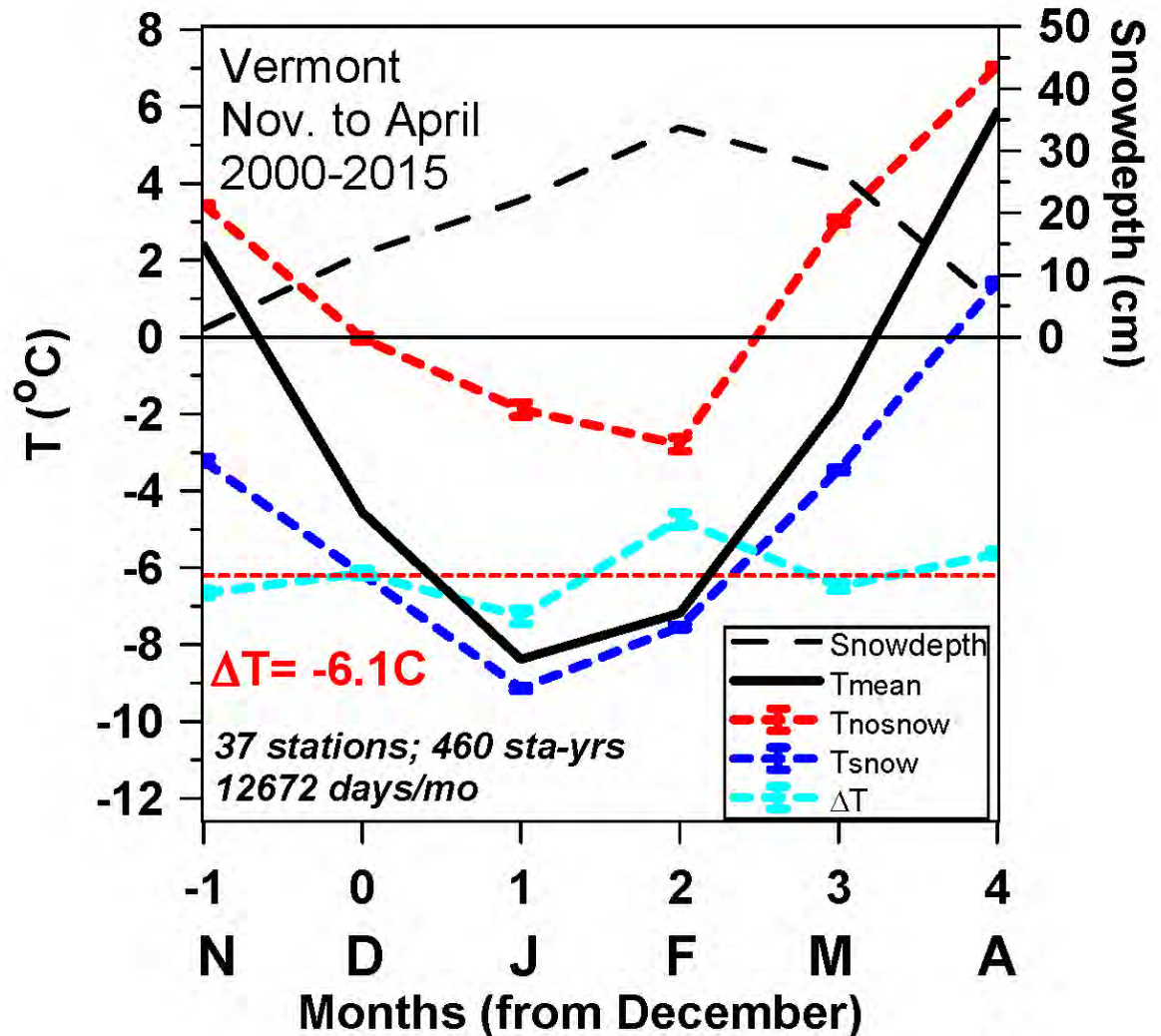
Climatological Impact of Snow: Vermont

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

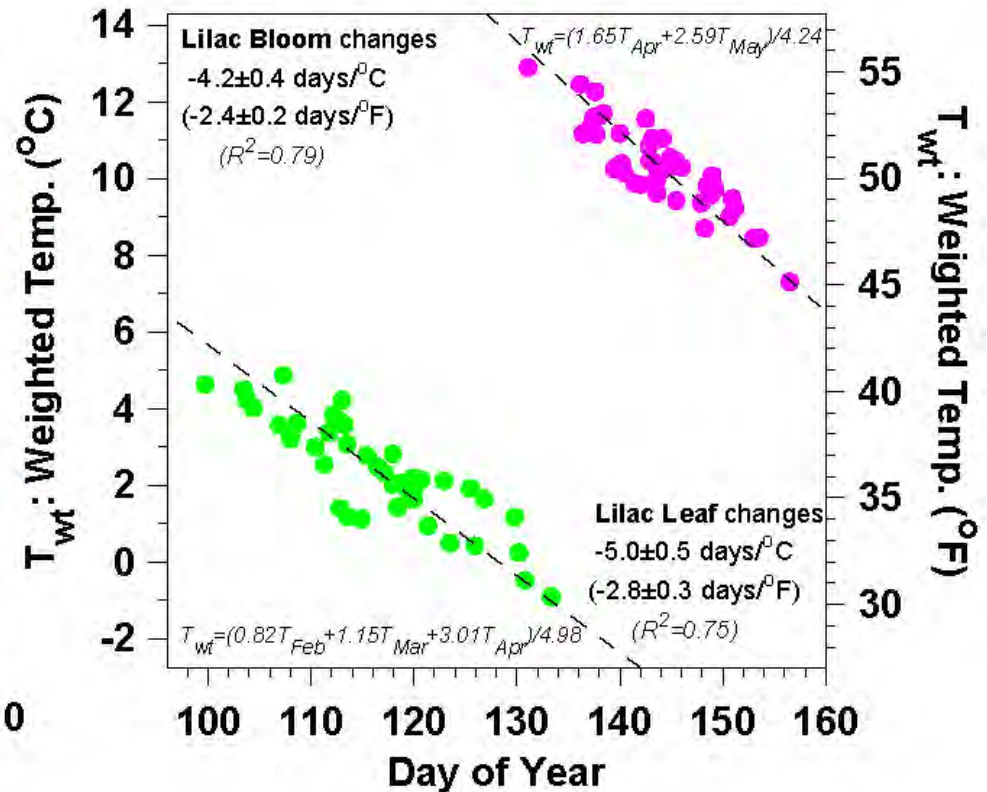
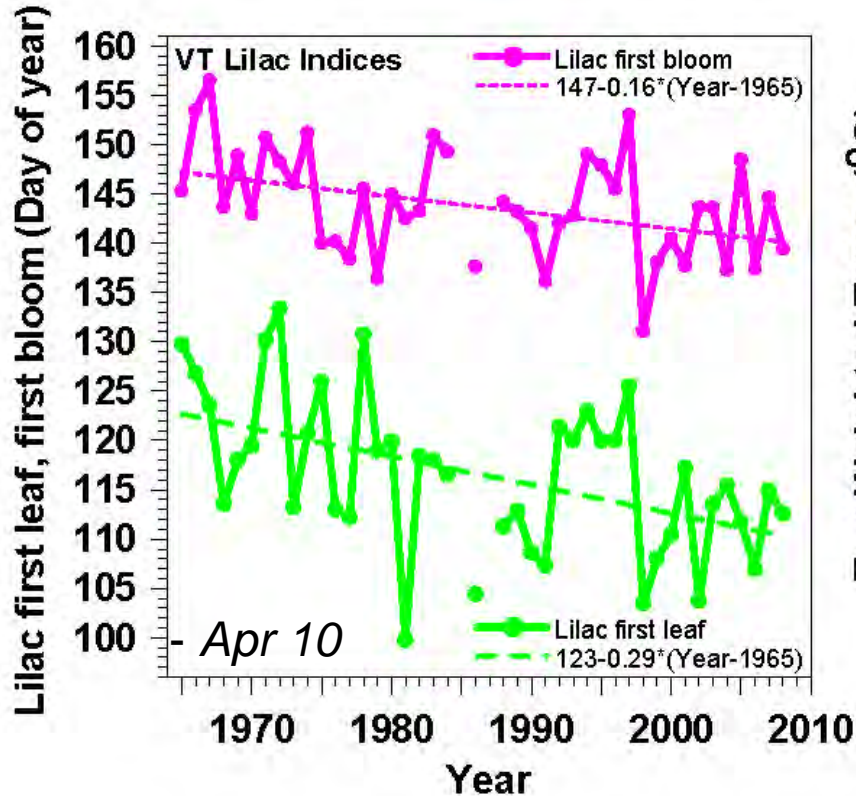
Difference $\Delta T = -6.1(\pm 0.7)^{\circ}\text{C}$

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

*Less than Prairies:
Vermont has more forest*

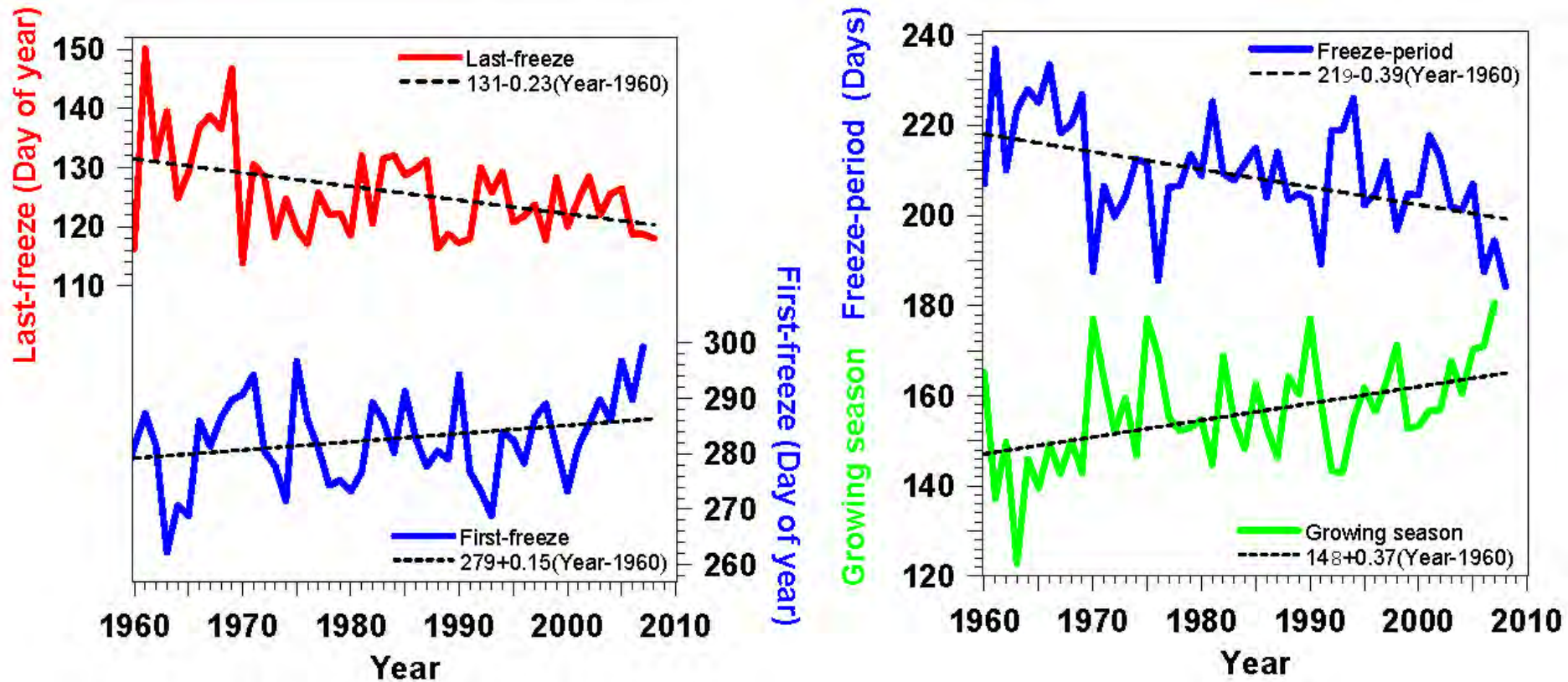


Lilac Leaf and Bloom



- Leaf-out -2.9 days/decade; Bloom -1.6 days/decade
- Year-to-year variation coupled to temperature
 - 4 to 5 days/ $^{\circ}\text{C}$: (No-snow – Snow) winter = $6 * 5 \approx 30$ days!

First and Last Frosts Changing



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