The Climate Challenge Deepens

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Science Colloquium

Castleton University, VT

Sept. 15, 2017

Fundamentals

- **Burning fossil fuels: transforming climate**
  - **Many water cycle amplifying feedbacks**
  - **Heading for high CO_2 "Carboniferous era climate"**
  - **Climate extremes increasing**
  - **Decadal to centennial - long timescales**
- **Linked to unmanaged technology/waste streams**
  - **Soluble by changing system guidelines**
  - **Create efficient society, based on renewable energy**
- ***Avoidance of responsibility for decades***
  - ***Politicians, professionals, public***
  - ***Climate change: Incompatible with business-as-usual***
- ***Choices based on moral values essential***
  - ***Science and economics need guiding***
  - ***Resilience incompatible with exploitative model***

Background/my role as Scientist

- **Educated in UK (Univ. of Cambridge, London)**
- **Weather experiment in Venezuela, 1969.**
- **Post-doc. Colorado State, 1970; faculty, 1971-79**
- **1974, Convection Scientist for GATE (GARP Atlantic Tropical Experiment)**
- **1978: Built VT house, passive solar, solar electricity**
- **1979 – present. 'Independent scientist', funded by NSF, NASA: working on field projects and global forecast models**
- **2007: President of Vermont Academy of Science and Engineering – I realized I should accept responsibility for Vermont and climate change.**

(alanbetts.com)

What is our role as Scientists?

- **Honesty, accuracy, clarity, *and depth***
  - **Earth scientists should consciously accept responsibility for the Earth's future**
    - ***As the political and economic system will not***
  - **Speak clearly to society: creative, hopeful frame in language that sidesteps ideology**
  - ***Realize that Earth system limits will need adaptive global governance and some systems engineering***
  - ***May mean a paradigm shift in science***

(alanbetts.com)

Our Present Challenge

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

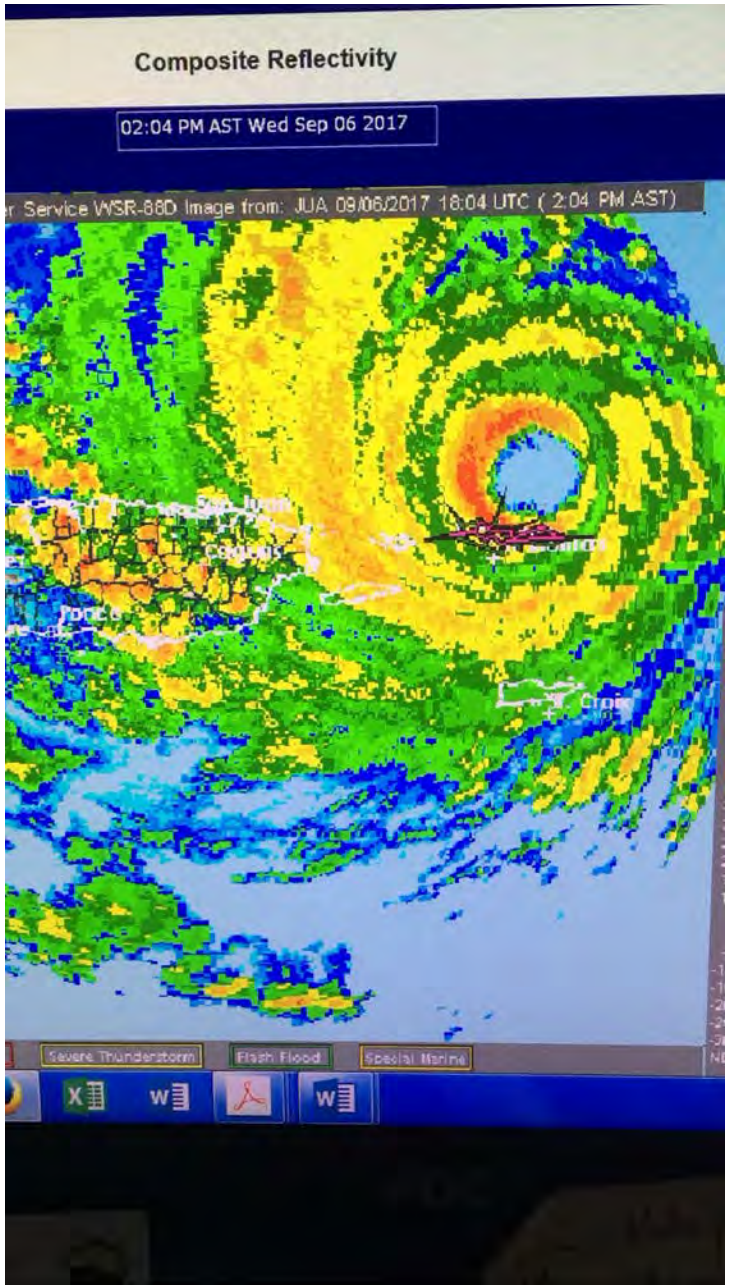
  – ***given the deep interconnectedness of life & climate on Earth***

  – ***given immense opposition to change (and fear of change)***

2pm Sept. 6
*Category 5**
IRMA
grazing
St Thomas

Cat 5 >155mph

IRMA >180mph



Sept. 6
Irma
(cat.5)
St Thomas

Irma and Jose: Sept 7

System Issues

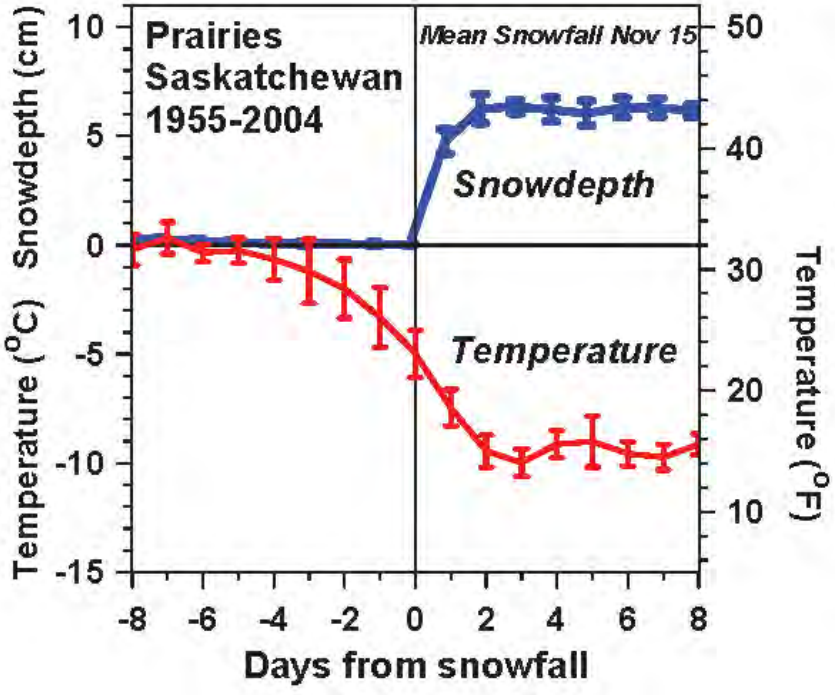
- **Human waste streams are transforming the Earth's climate, and human and natural ecosystems**
  - **That will affect landscape, water supplies, food system, human health – and natural world**
- **New strategies and mindset needed**
  - **Can we better manage our relation to the Earth?**
  - **Is this an efficient way of doing this?**
  - **Can we manage our waste streams better?**
  - **Can we replace profit as the primary guide?**

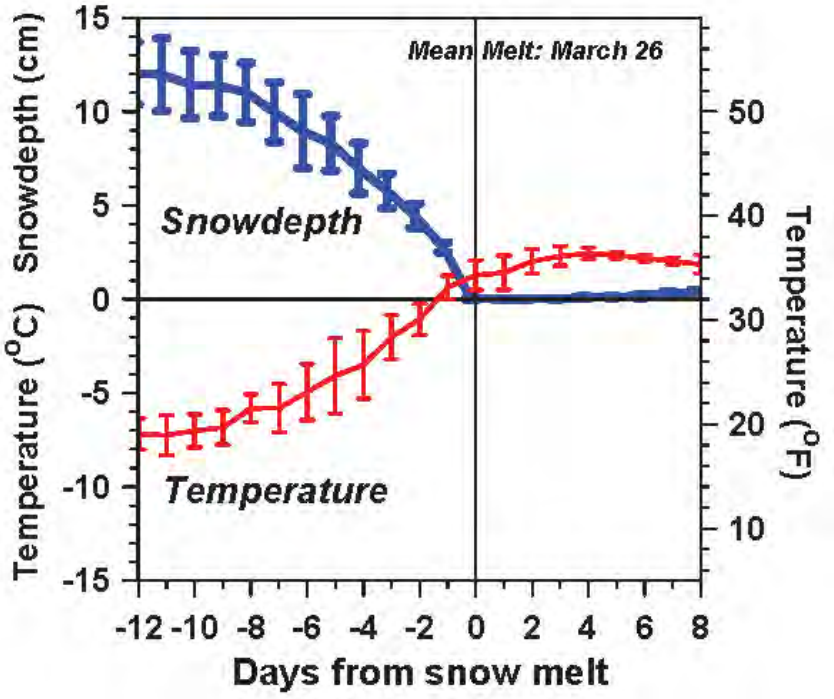
What is a pollutant?

- **First it was the obvious hazards to health**
  - **Smoke/smog from burning coal and exhausts**
  - **Toxic contaminants dumped in drinking water**
  - **These were regulated by the Clean Air and Clean Water legislation in 1980's & 1990's**
- **But many of our waste products that look harmless to humans are hazards to life on Earth!**
  - **CFCs that destroy the ozone layer that protects life**
  - **CO_2 from burning fossil fuels, driving climate change**
  - **Plastics dumped into the oceans**
- ***In our disconnected human world, these are harder for us to deal with***

Snowfall and Snowmelt

Winter and Spring transitions

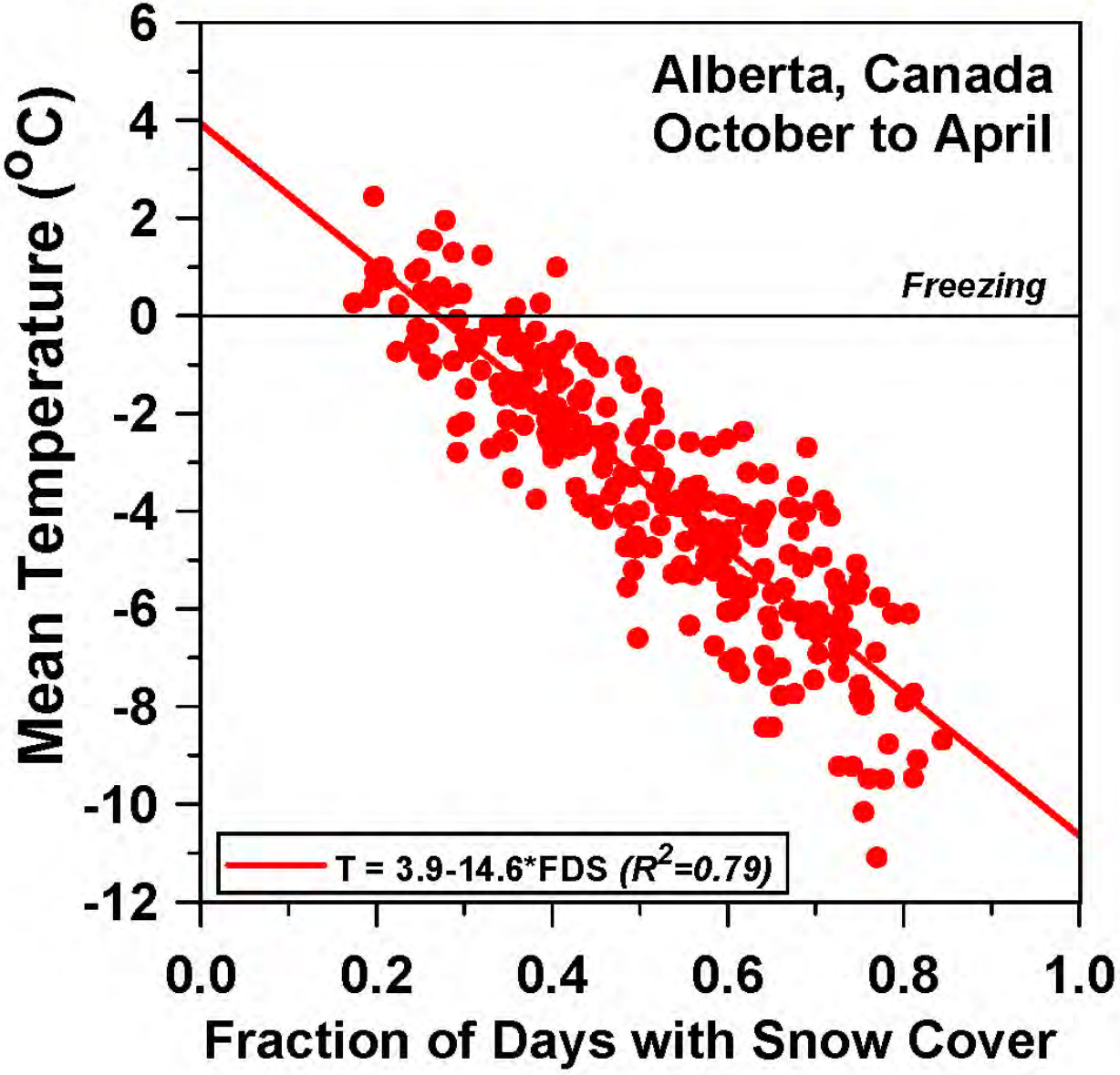




- **Temperature falls/rises about 18F with first snowfall/snowmelt**
- ***Snow reflects sunlight; shift to cold stable BL***
  - ***Local climate switch between warm and cold seasons***
  - ***Winter comes fast with snow***

(Betts et al. 2014a)

More snow cover - Colder temperatures



Winter is colder if more snow cover

Impact of Snow

- **Distinct warm and cold season states**
- **Snow cover is the "climate switch"**

With snow

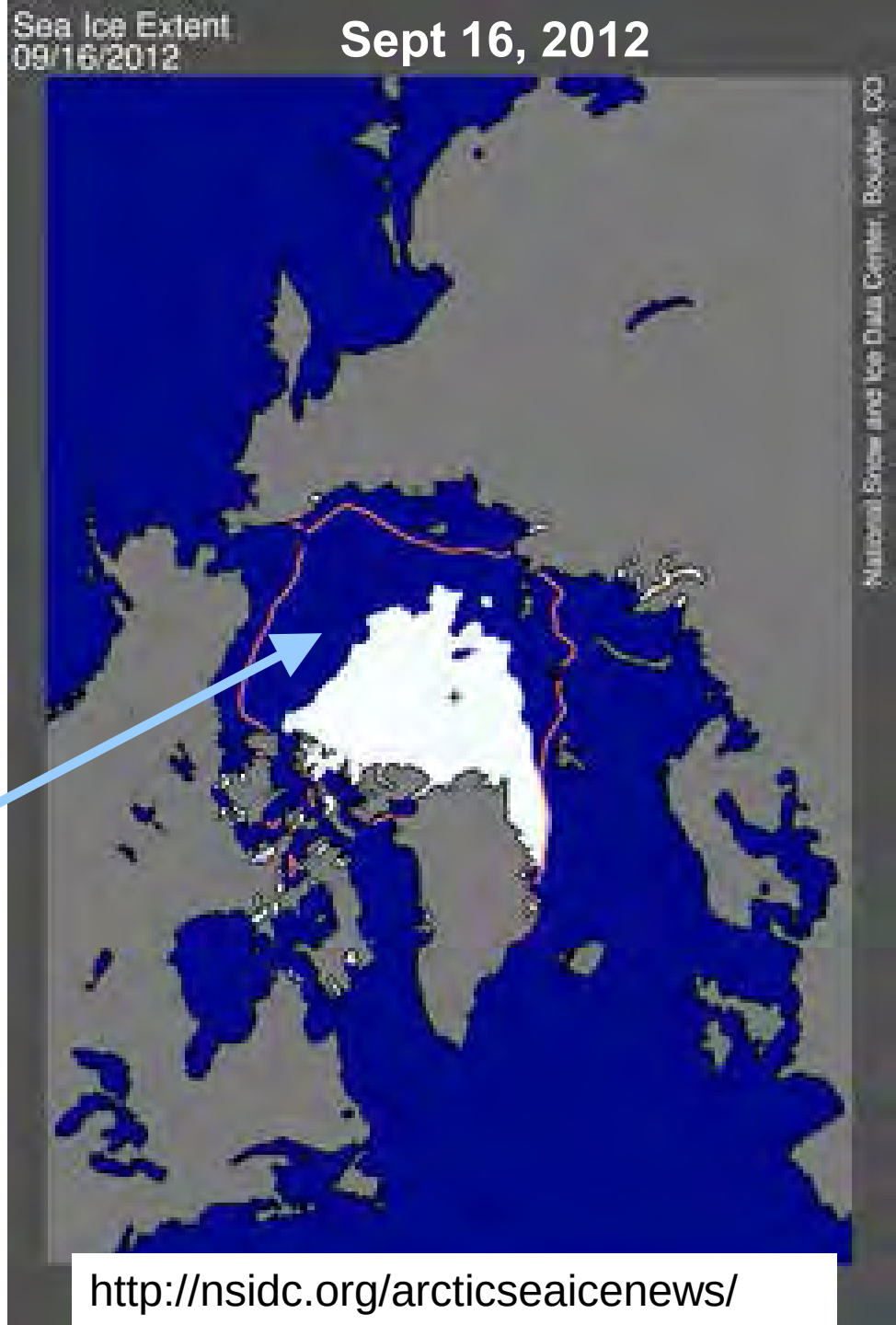
- **Prairies: Temperature falls 18°F**
  - **snow reflects 70%**
- **Vermont: Temperature falls 10°F**
  - **snow reflects 35% (because more forest)**

Earth's climate sustains life

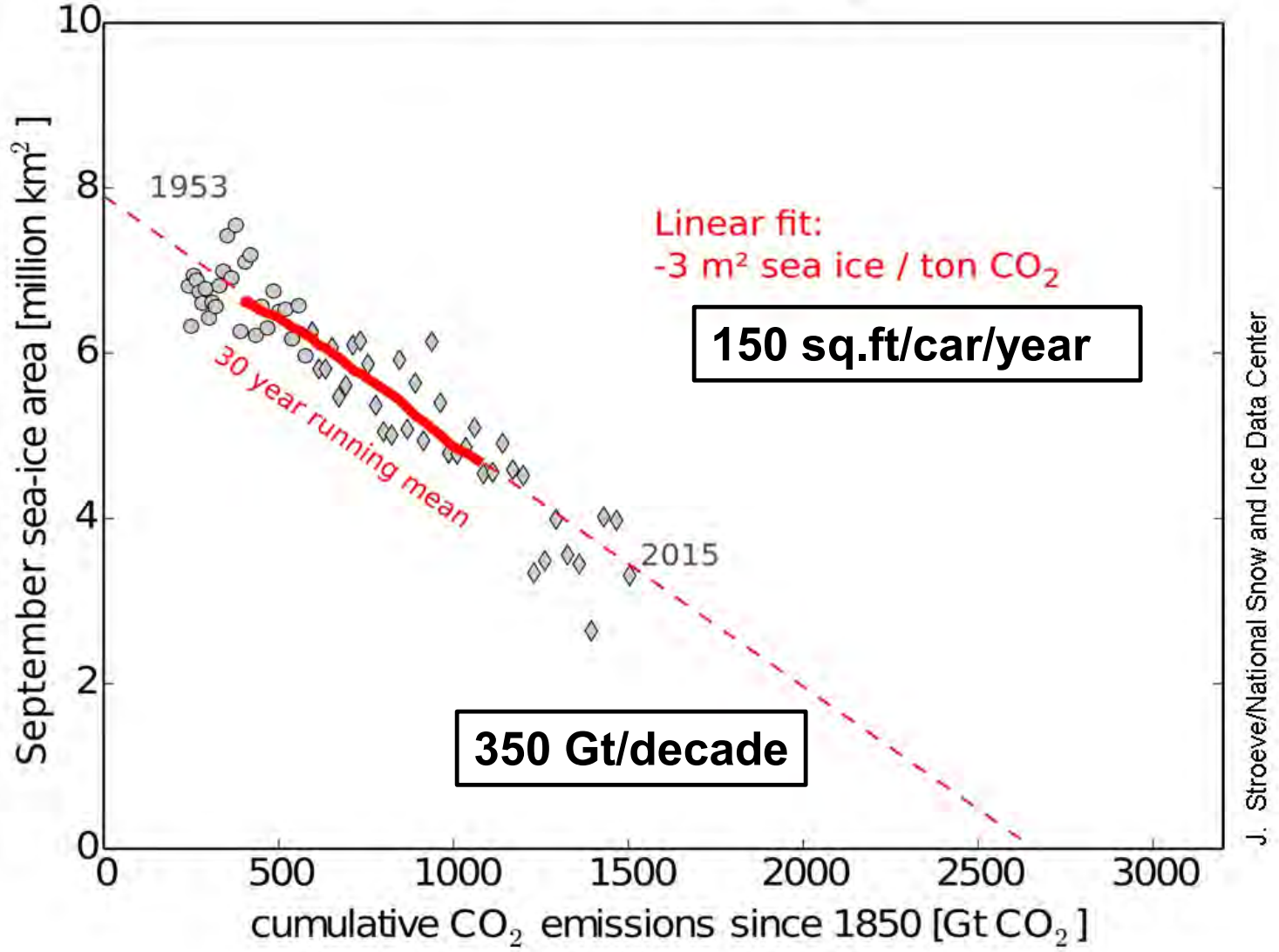
- Burning fossil fuels is increasing greenhouse gases
- Climate is warming: ice is melting, extreme weather is increasing
- Water plays crucial amplifying role
- Global patterns changing

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

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

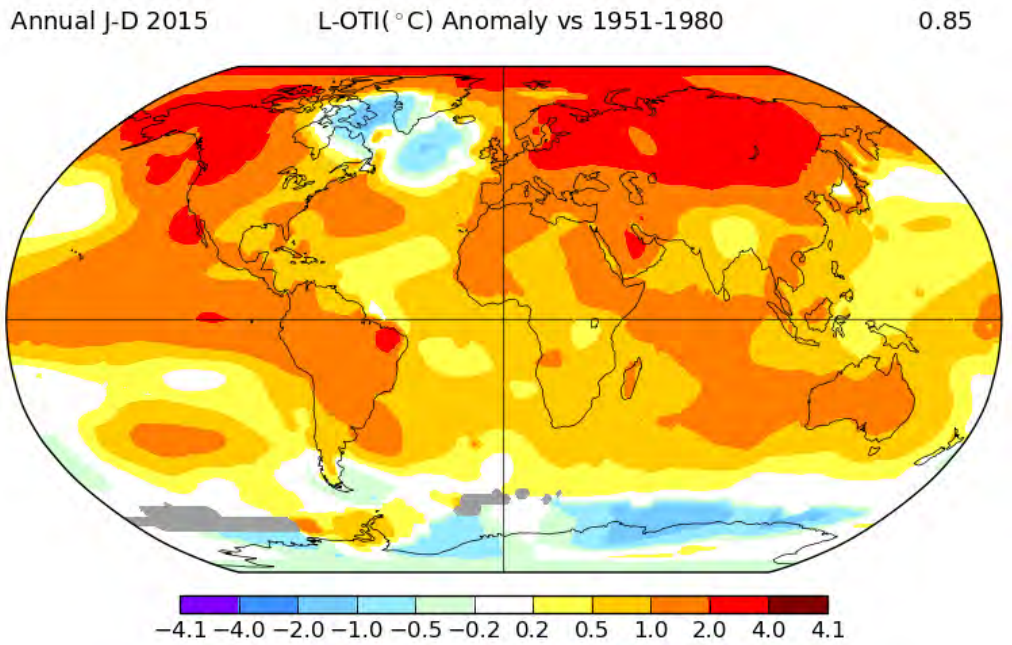


September Arctic Sea Ice Loss



2015

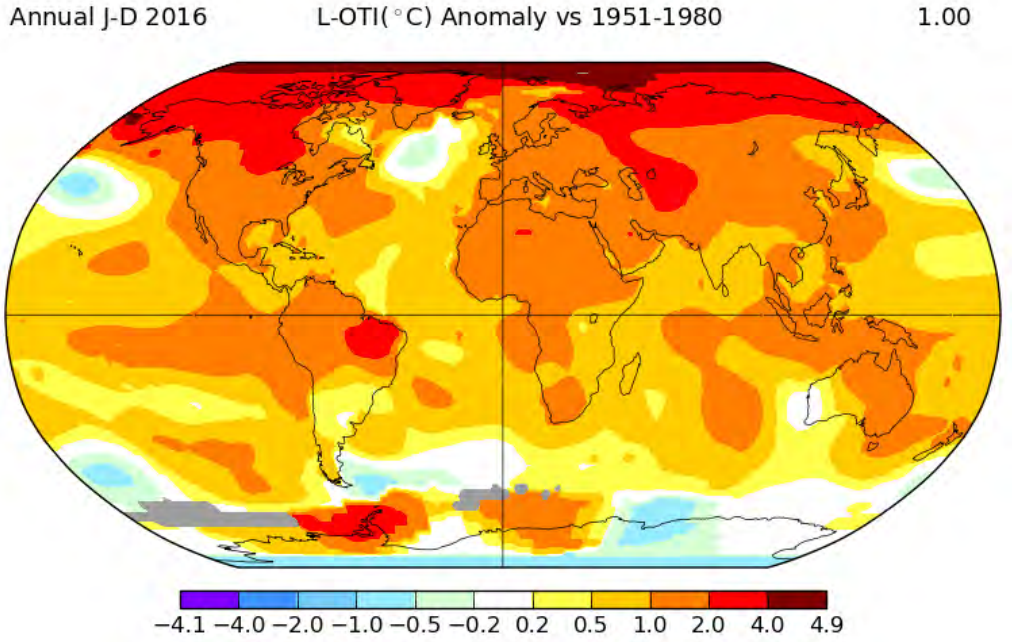
1.5F warmer



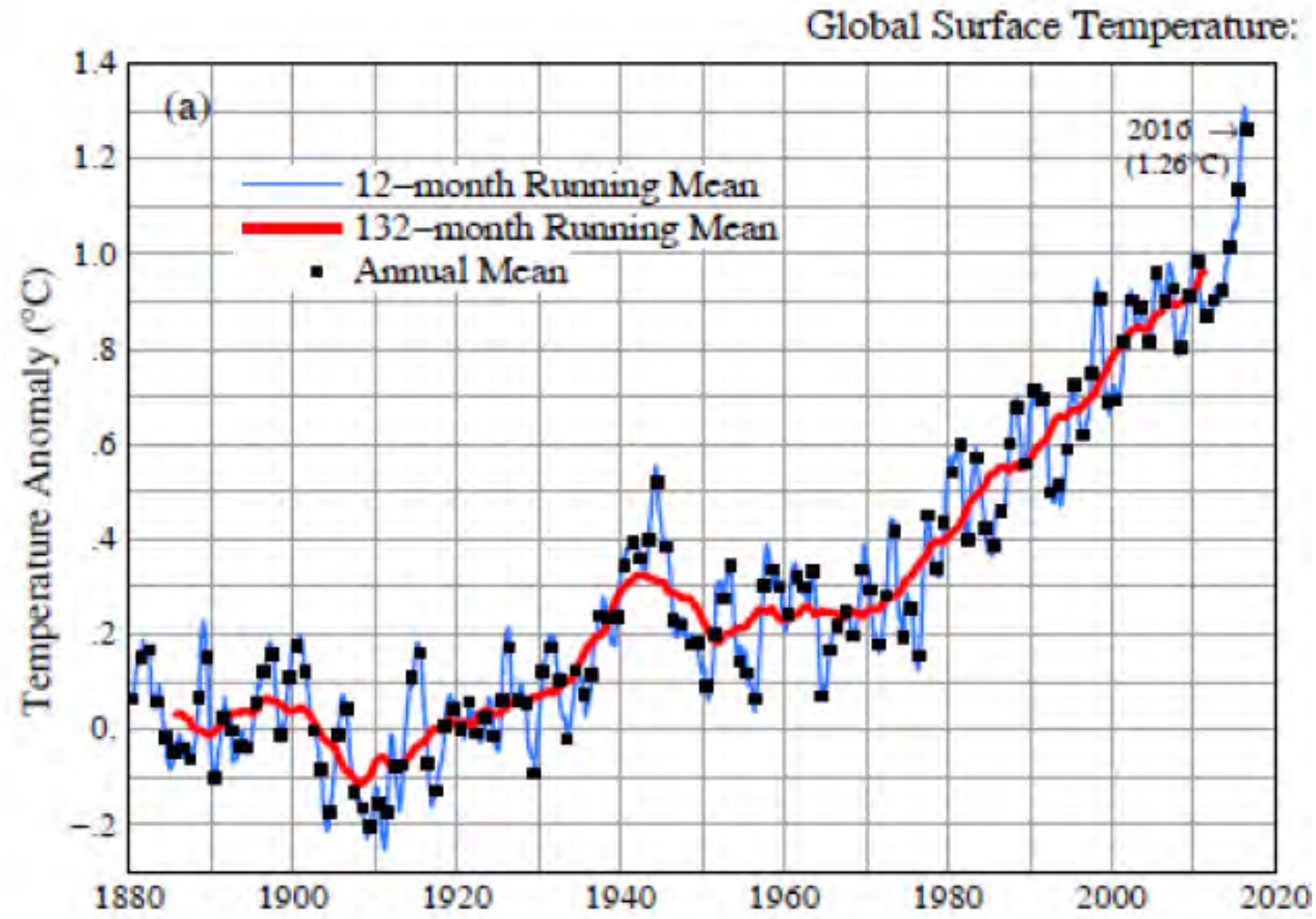
2016

1.8F warmer

(Arctic ice lowest ever in winter)



Long-term Global Mean Trend 1880-2016



Gardening in Pittsford, Vermont in January

January 7, 2007

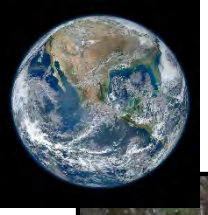
December 2006:

- **Warmest on record**

January 10, 2008

Warm Fall:

- **Record Arctic sea-ice melt**
- **Snow cover in December, ground unfrozen**



January 2, 2012

March 11, 2012

October 2011– March 2012

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

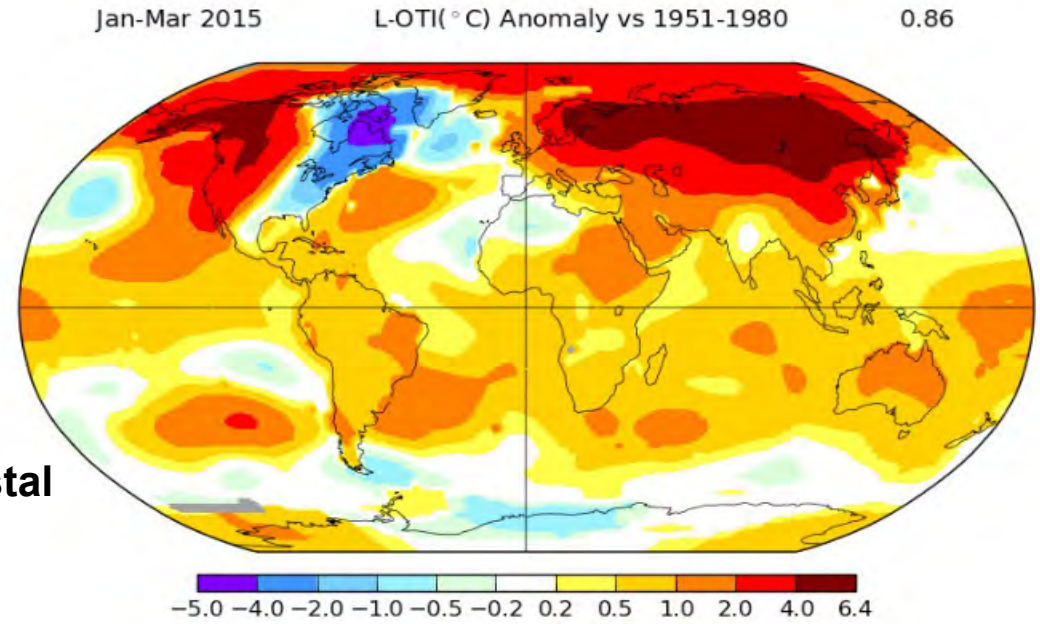
•January 15, 2013

February 5, 2016
(Digging in Feb. first time ever)

March 3, 2017

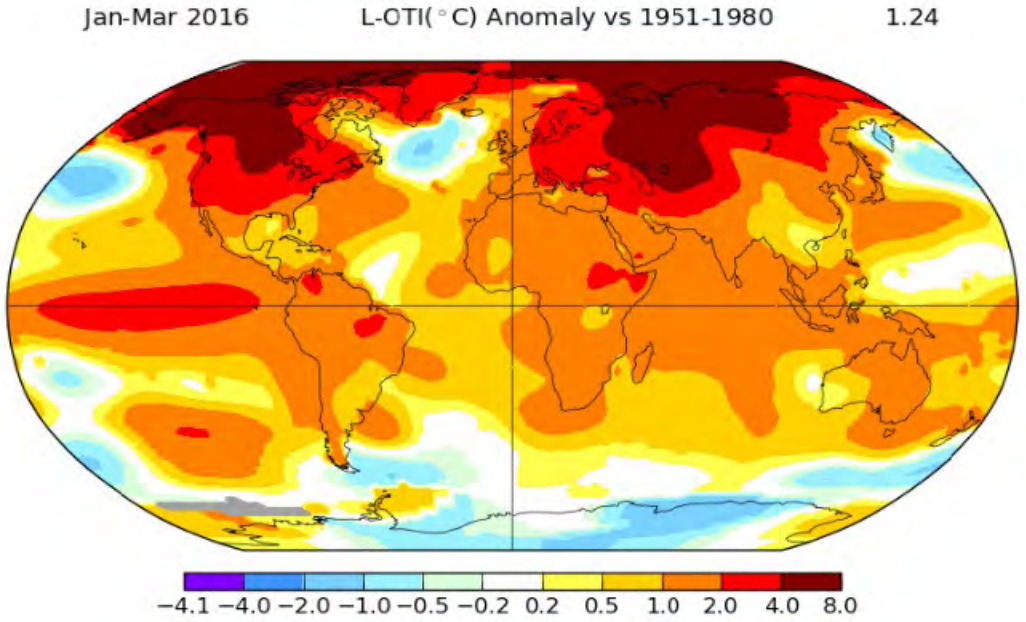
Jan-Feb-Mar 2015

Warm Atlantic, cold NE, strong coastal storms - Boston record snow



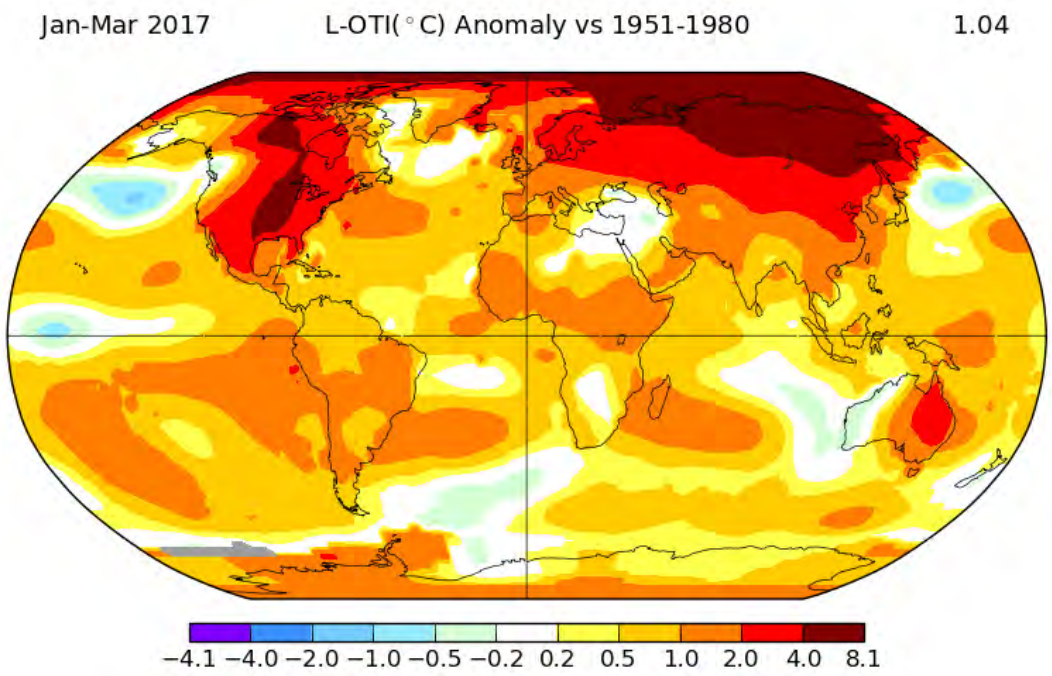
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



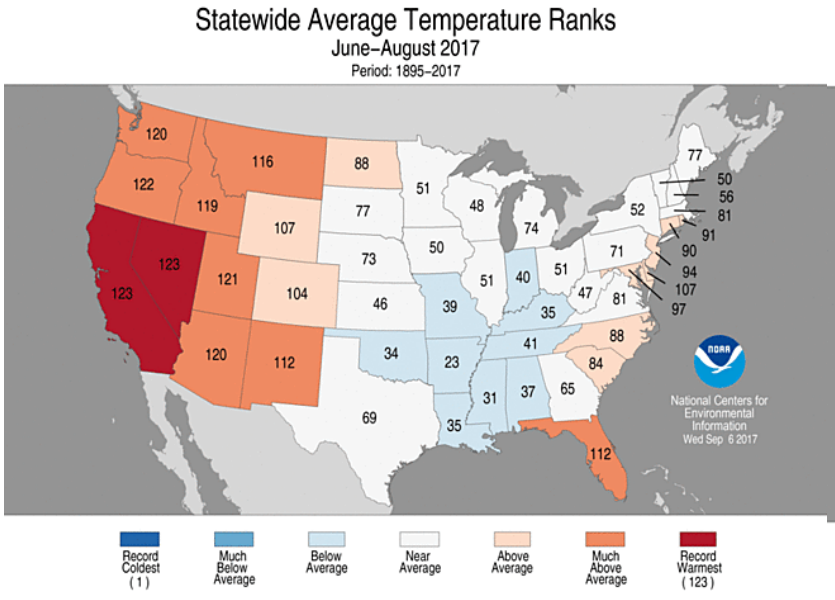
Jan-Feb-Mar 2017

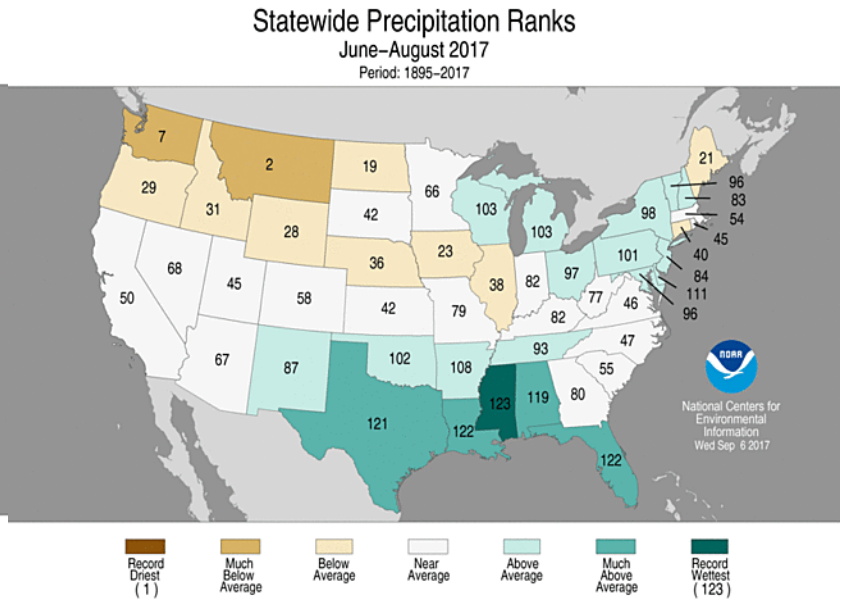
(In between 2015, 2016)



Jun-Jul-Aug, 2017

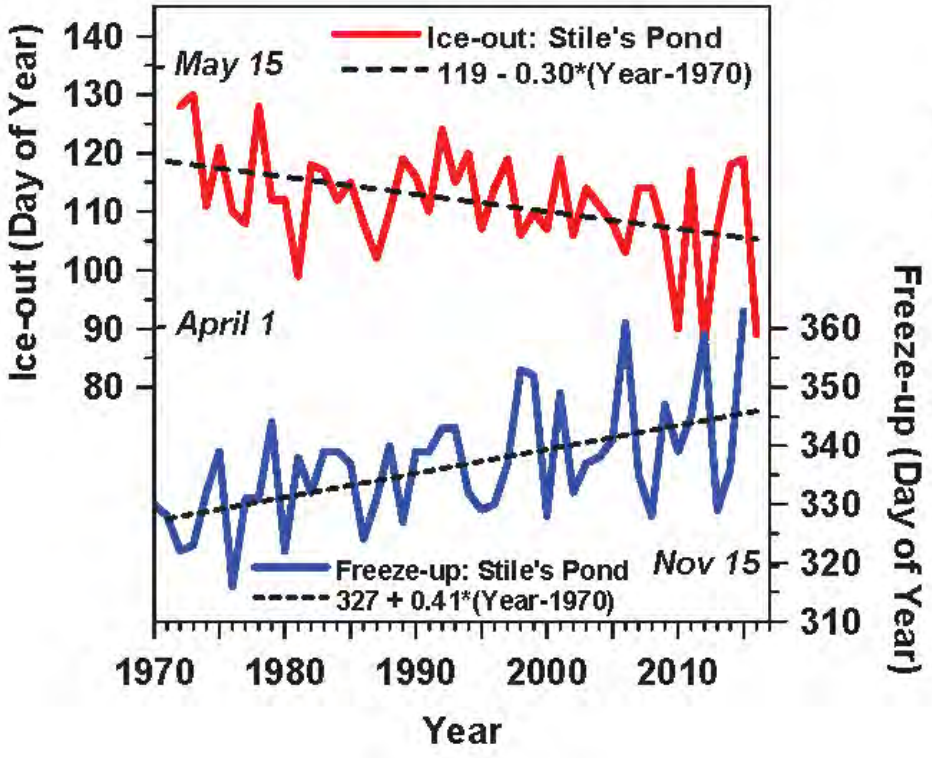
(West: hot and dry;
South/East: cool and wet)

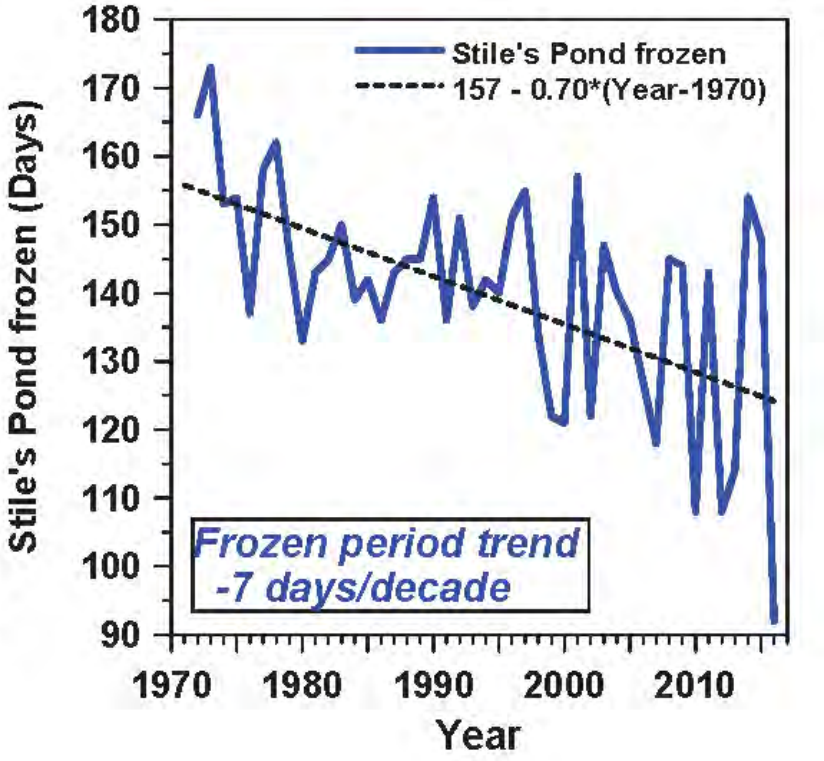




Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking: variability huge





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

Stiles Pond: Steve Maleski: "Eye on the Sky"

Warm winter with little snow
Early Spring: *79ºF on March 22, 2012*

Pittsford Vermont

3/22/12

Pittsford Vermont

3/24/12

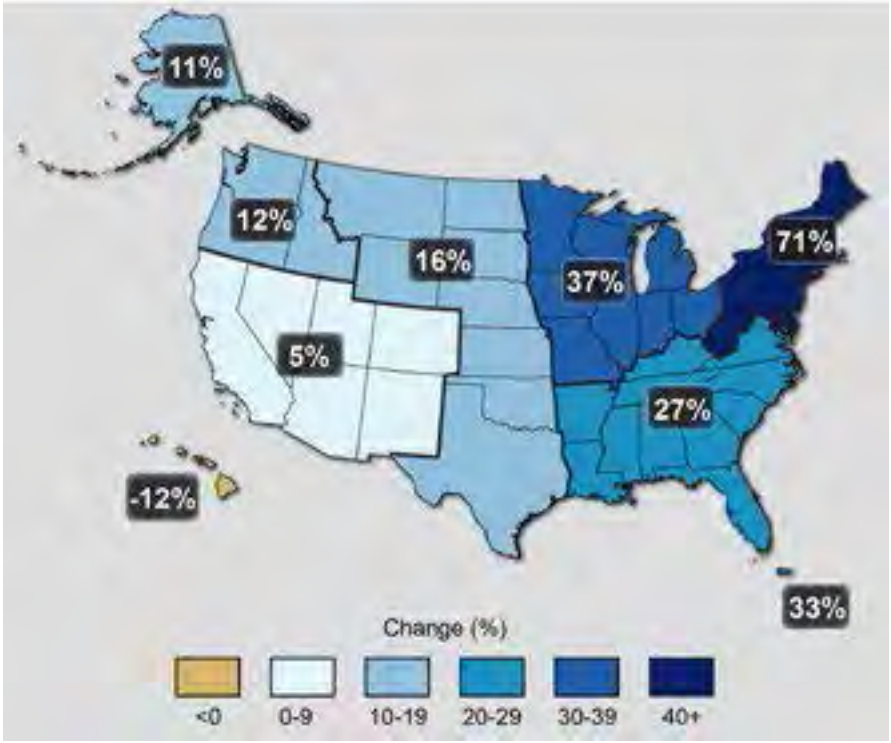
2012: Daffodils, forsythia bloomed 3/23/2012

2017: Daffodils and forsythia bloomed 4/17/2017

Very Heavy Precipitation Is Increasing

- **Precipitation Extremes**

- **Most of the observed precipitation increase during the last 50 years has come from the increasing frequency & intensity of heavy downpours.**



(Walsh et al., 2014)

- **71% increase in Northeast**

Brattleboro, VT, Courtesy of Caleb Clark, CNN

Brattleboro, M. Reston

Wilmington, J. Cantore

TS Irene

Roads in valleys

Massive damage

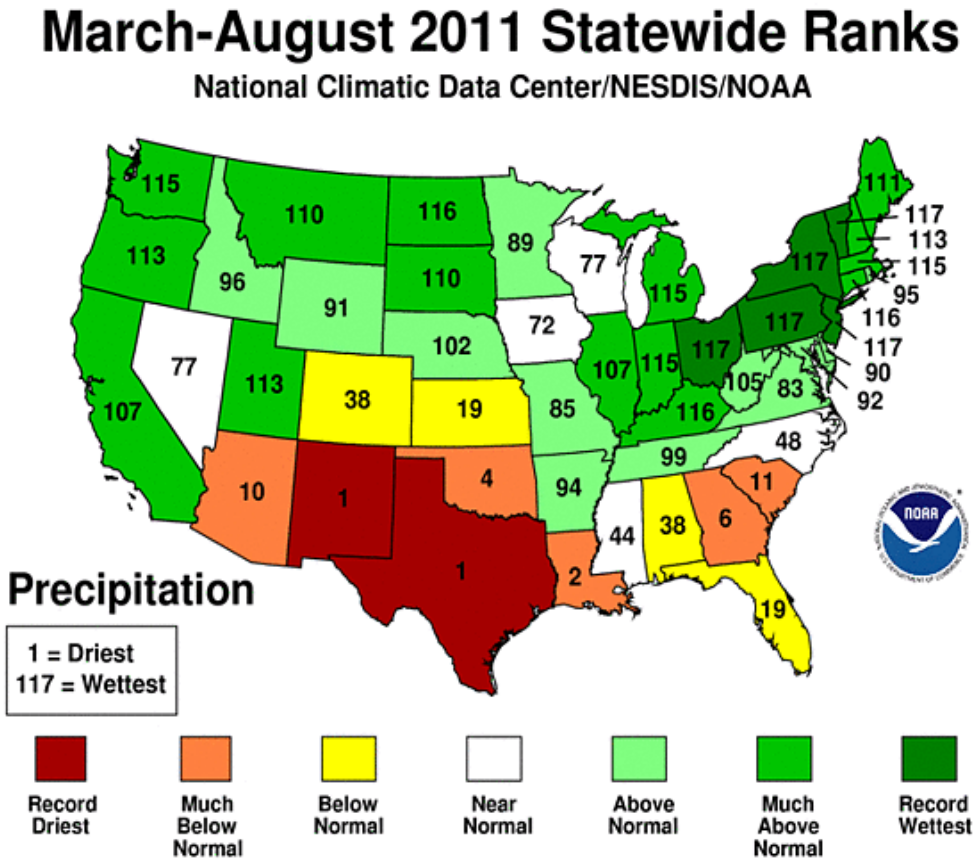
Some roads took months to repair

Rte 131, Cavendish

Sept, 2011

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**

- ***Pattern nearly stationary***

Value of Flood Plains

- **Otter Creek after Irene on August 30, 2011**
  - **River rose ten feet: flood plain saved Middlebury**

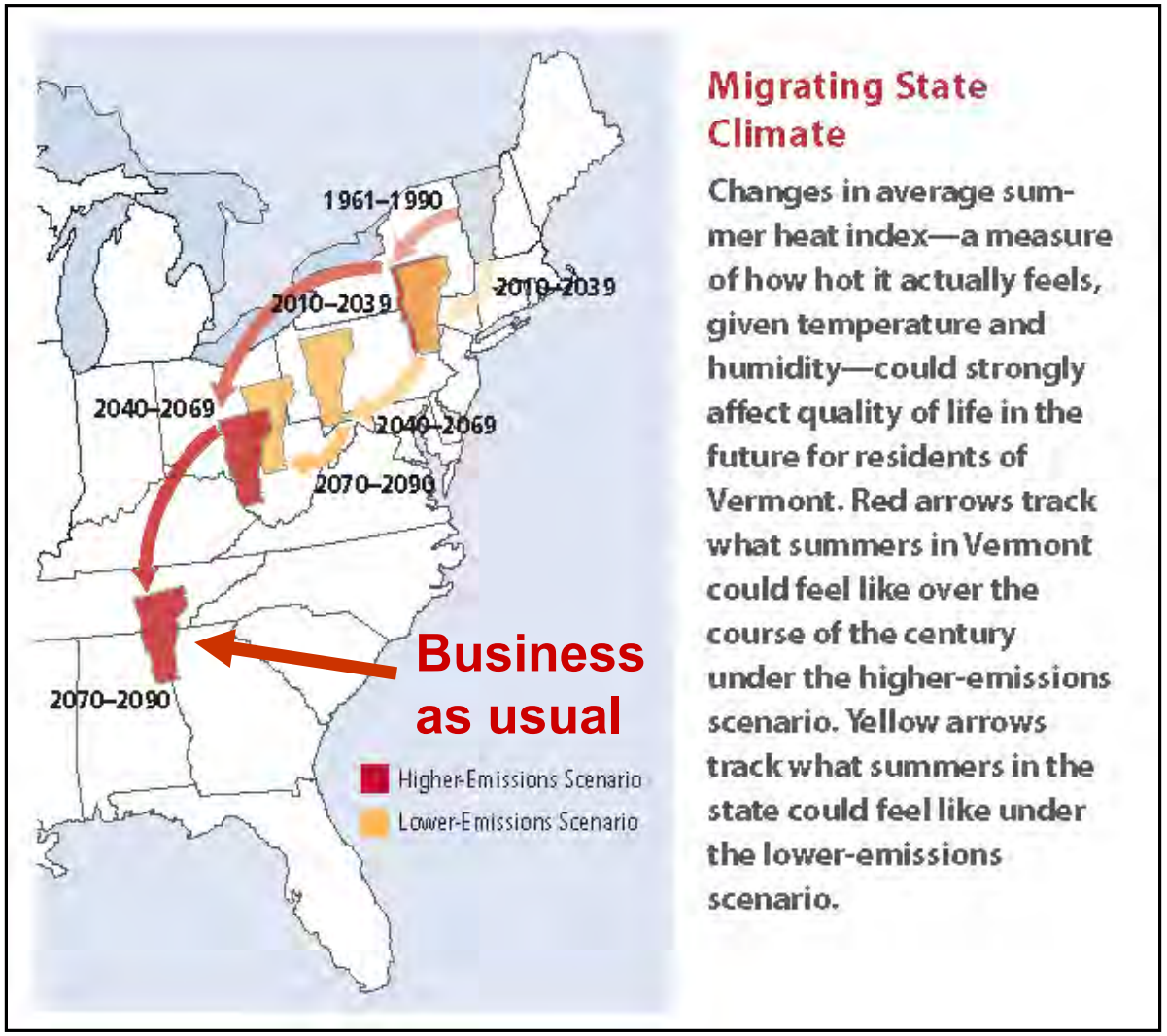
Flooding Issues

- **Maintain mountain forest cover**
  - **Devastating floods in 1920's, 30's with reduced forest cover**
- **Manage water on landscape**
  - **Maximize infiltration: urban and on farms**
  - **Don't wall-in rivers!**
- **Preserve flood plains**
  - **Saves downstream towns (Middlebury)**
  - **Stop building houses and trailer parks in flood plains**

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



NECIA, 2007

Can We Stop "Dangerous Climate Change"?

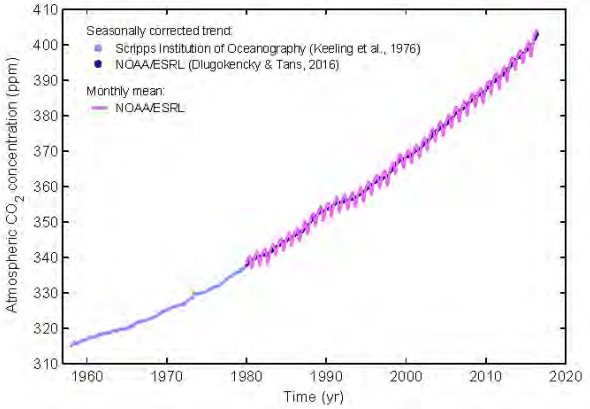
(UNFCCC 1992)

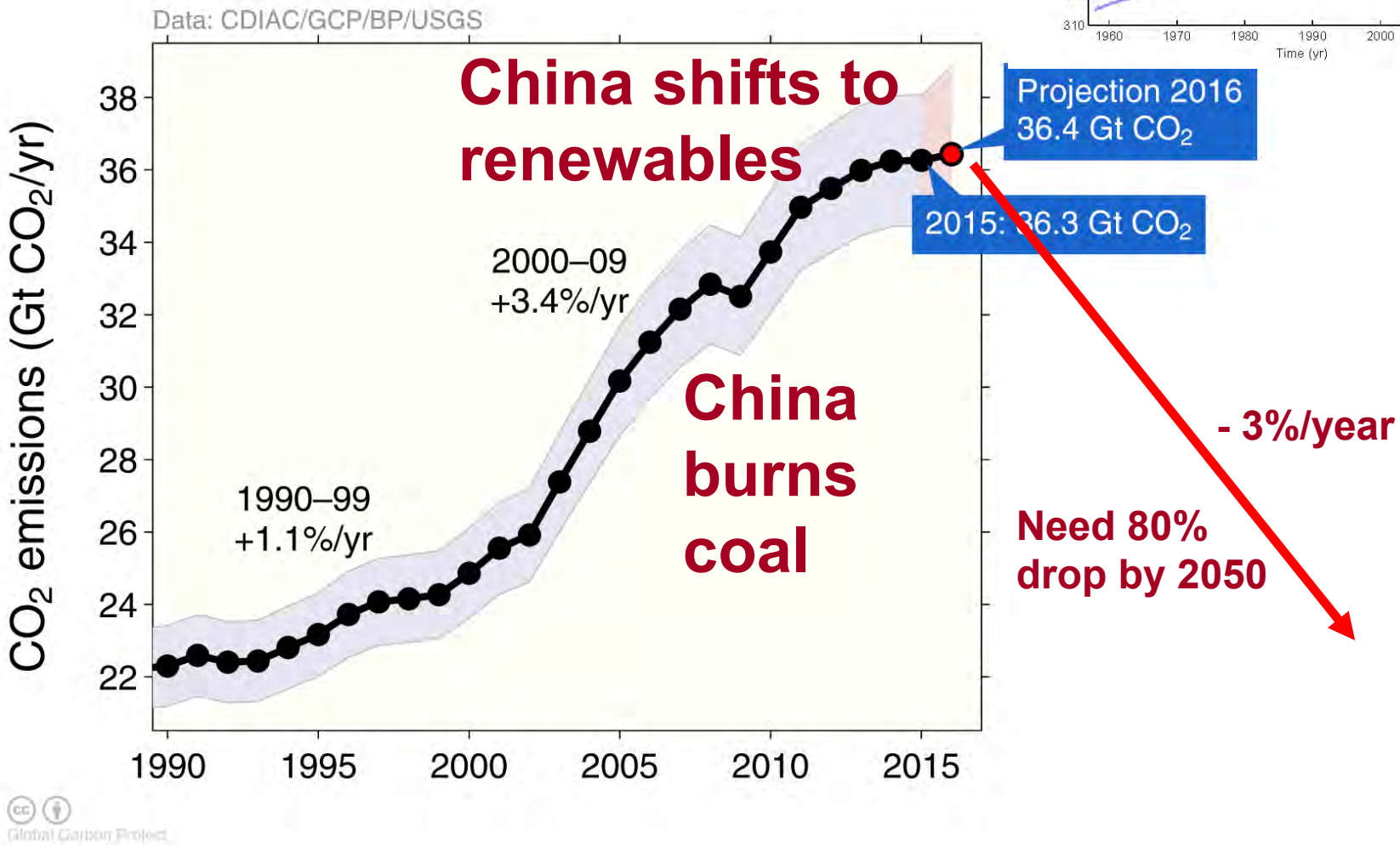
- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 emissions!**
- **This is possible but very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **"Lifestyle" has become dependent on fossil fuels**
  - **Powerful vested interests: $trillions at stake**

2015 was Transition Year

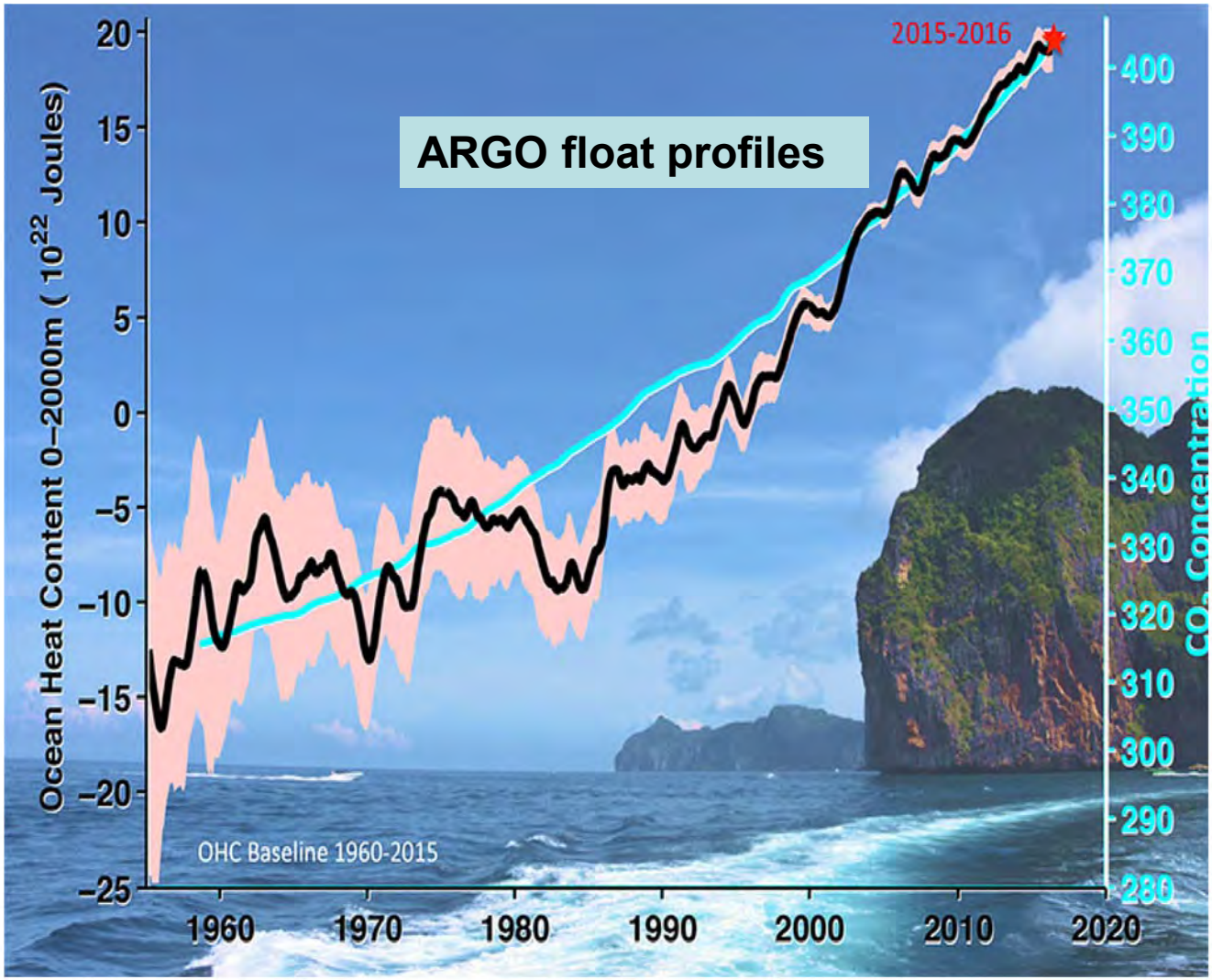
- **Climate meeting in Paris in December**
  - **188 Nations made 'national commitments'**
- **Pope Francis encyclical on the environment, climate change and our responsibilities to the Earth**
  - ***Exploitation of the Earth and the poor are inseparable***
  - ***Short-term profit as primary motive is immoral***
- ***2017: US wants to avoid the commitments it made; - China and Europe have to take lead***

Growth of CO_2 Emissions Flat for 3 years





Ocean Heat Storage – CO_2



What can we “safely” burn?

- **Only 750 Gt more for an *even chance* of keeping warming below 2°C [3.8°F]**
- ***Requires leaving 2/3 of remaining fossil fuels in ground***
- **At 36 Gt/year - only 21 years left**
- ***Rapid phase-down extends period***

‘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 and climate*

- **We need new ‘rules’ because**
  - ***Our numbers and industrial output are so large***
  - ***Maximizing consumption and profit have contributed to present predicament***

Efficiency Comes First

- **We need to double or triple our energy efficiency because…**
  - **We cannot replace current fossil fuel use with biofuels & renewable energy**
  - **Fossil fuel reserves are enough to push CO_2 to 1,000 ppm**
    - ***Radically change climate/wipe out many species***
    - ***In time melt icecaps, raise sea-level >100ft***

New Value-based Guidelines

- ***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?***
- **Develop renewable energy**
  - **Maximize energy efficiency: housing, transport, power**
  - **Add and monitor renewable power**
- **Examine all waste-streams**
  - **Aim to recycle/remanufacture everything**
  - **Fully cost all waste streams**
- **Relocalize food system**
  - **Compost all organic waste**
- **Understand water and the landscape**
  - **Limit phosphorus/nitrogen loads on streams/lakes**
- ***Reconnect with natural world***
  - ***Fundamental if we are to embrace transition***

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**

Powerful interests are threatened

- **Fossil fuels reserves are worth $20-30T**
  - **Big money: 'of course we will burn them'**
  - **Regulating or taxing emissions of CO_2 is an 'unfair cost to the free market'**
  - **Too bad if the Earth's ecosystems are destroyed: '*others/future*' can pay the price**
- ***Our politics are facing collapse:***

  fantasy disconnected from real world
  - ***We are deeply embedded in system!***

Step back from dark side

- **Cannot solve with mindset that created it**
  - ***Oppose new fossil fuel "solutions"***
  - ***Understand climate science: stand for the Earth***
- **Push practical solutions**
  - ***Efficiency and renewables***
  - ***And a fossil-carbon tax***
- ***Social and moral shift needed***
  - ***Identify your personal & community role***
  - ***Future needs creative approaches!***

Practical Local Solutions

- **Vermont is well on its way**
  - **Large solar development**
  - **Battery storage on its way**
    - **California installing 100MWh storage units**
  - **Energy efficiency for homes and businesses underway**
  - ***Need net-zero building codes***
  - ***Need transportation shift***
  - ***Need lifestyle awareness!***

Efficient transport

- **Gasoline to hybrid: 50% gain to 50mpg**
- **Hybrid to plug-in hybrid: now 140mpg**
- **Electricity from community solar array**

>3000lbs and 140 mpg
Payload: 750 lbs at 55 mph

180lbs gets “1800 mpg” or 100 mp(1000Cals)
Payload: 350lbs at 25mph

"Many things have to change course, but it is we human beings above all who need to change. We lack an awareness of our common origin, of our mutual belonging, and of a future to be shared with everyone."

Pope Francis, Encyclical 2015

"If something is worth doing, do it. If, in fact, you fail, there'll be no cause for regret. You can try again. To die without even having tried, will be to die disappointed. We all have opportunities to contribute making a better world; we must seize them with far-sighted vision"

Dalai Lama, 26 June 2017

Discussion

alanbetts.com

(articles and talks)

Paradigm shift for science?

- **Great value of science is its honesty, integrity and its cooperative global vision**
  - **It deals with the measurable world**
  - **It communicates openly**
  - **Priceless to a society lost in corruption & deceit**

- **Greatest challenge is that humanity is embedded in a deeply interconnected living Earth's system**
  - **That cannot be separated and objectified**
  - **In fact the separation of our social frames from the Earth's ecosystem is driving climate change**

Voice the Ethical Issues

- **Do we just exploit the Earth's 'wealth'**
  - **For greater 'economic growth'**
  - **For a wealthy few**
  - **What will be left for our children?**
  - **What about the Earth's ecosystems?**
- **Fundamental practical moral issue**
  - **Don't we need to co-operate with the Earth?**
  - ***Shift in understanding and mind-set needed***

The Cabal of Libertarian Billionaires

- **Aim: *purchase control of the Republican Party***
  - **US Congress ("Freedom Party"); many state legislatures**
- **Doctrine: *limited role for government***
  - **protect wealth, property and the rule of law**
- **Freedom to exploit the earth:**
  - **Shall not be limited by environmental regulation**
  - ***Doctrine in direct conflict with Earth's ecosystem***

(Dark Money, Jane Mayer, 2016)

- **Leading to**
  - ***Climate science is a (fictitious) conspiracy***

How do we plan/adapt?

- **Future needs creative approaches**
  - **Community support**
  - **Efficient society run on renewable energy**

- **We need to work with the Earth**
  - ***People reconnected to landscape***
  - **Manage water on landscape**
  - **Manage forest diversity for a warmer climate**
  - **Manage diversified year-round agriculture**
  - **Manage energy crops and solar farms**

Social, moral, spiritual shift

- ***The Future Is Not Our Past***
  - ***an economic, technological and financial system driven by short-term profit***
- ***Collectively, we create the future***
  - ***plan for a transition to a sustainable society***
  - ***Put community values and systems thinking above short-term profit***
- ***Creation will overwhelm human folly***
  - ***So accept (repent!) with joy***

As Climate Changes….

- *Everything is interconnected*

- **Human society and waste streams: people's choices and actions**
- **Precipitation, seasons, streams, and forests; habitat and wildlife**

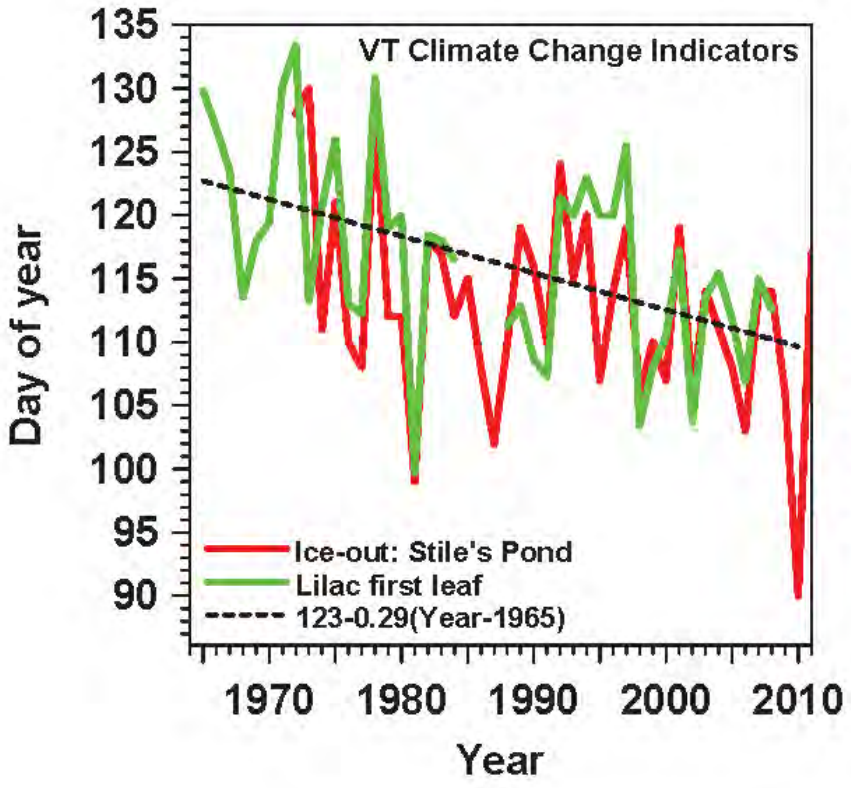
- **Keep your eyes open to the big picture and see connections**
- **Speak out: talk to your neighbors; ask what we can do**

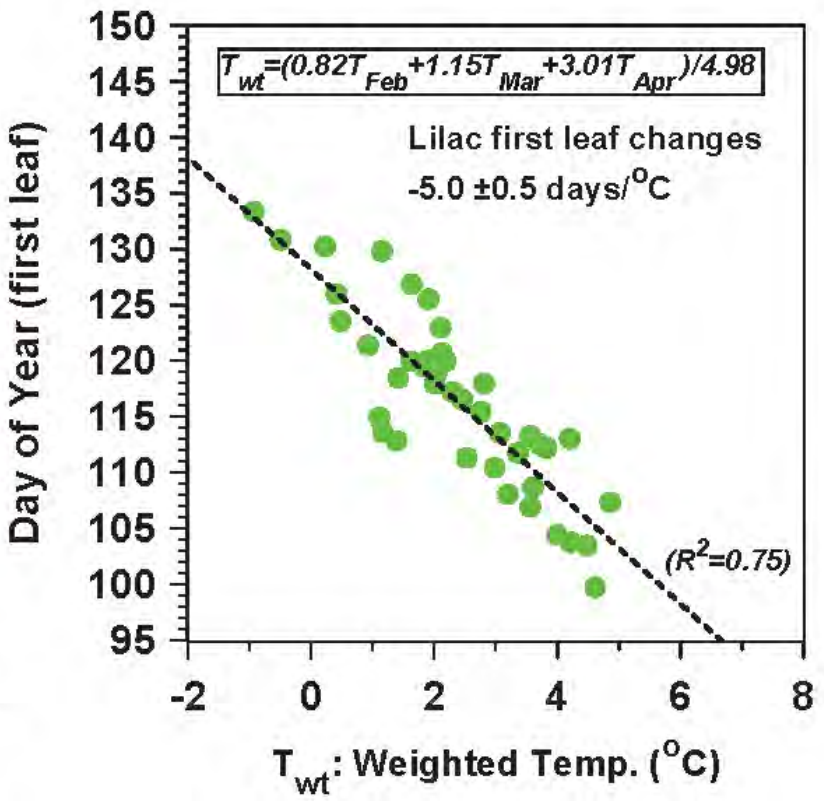
- **Stay connected to Vermont's natural environment**

"Systems Engineering" for a Sustainable Society

- **Minimize the lifetime of human waste products in the Earth system: remove dangerous wastes**
- **Maximize the efficiency with which our society uses energy and fresh water, and**
- **Maximize the use of renewable energy**
- **Minimize the use of non-renewable raw materials, and**
- **Maximize recycling and re-manufacturing**

Lilac First Leaf Earlier





- **First leaf and ice-out changing: -3 days/decade**
- **Large variability linked to temperature:**
- **-5 days/ °C or -3 days/ °F**
  - **(No-snow – Snow) winter = 6*5 ≈ -30 days earlier leaf-out**

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

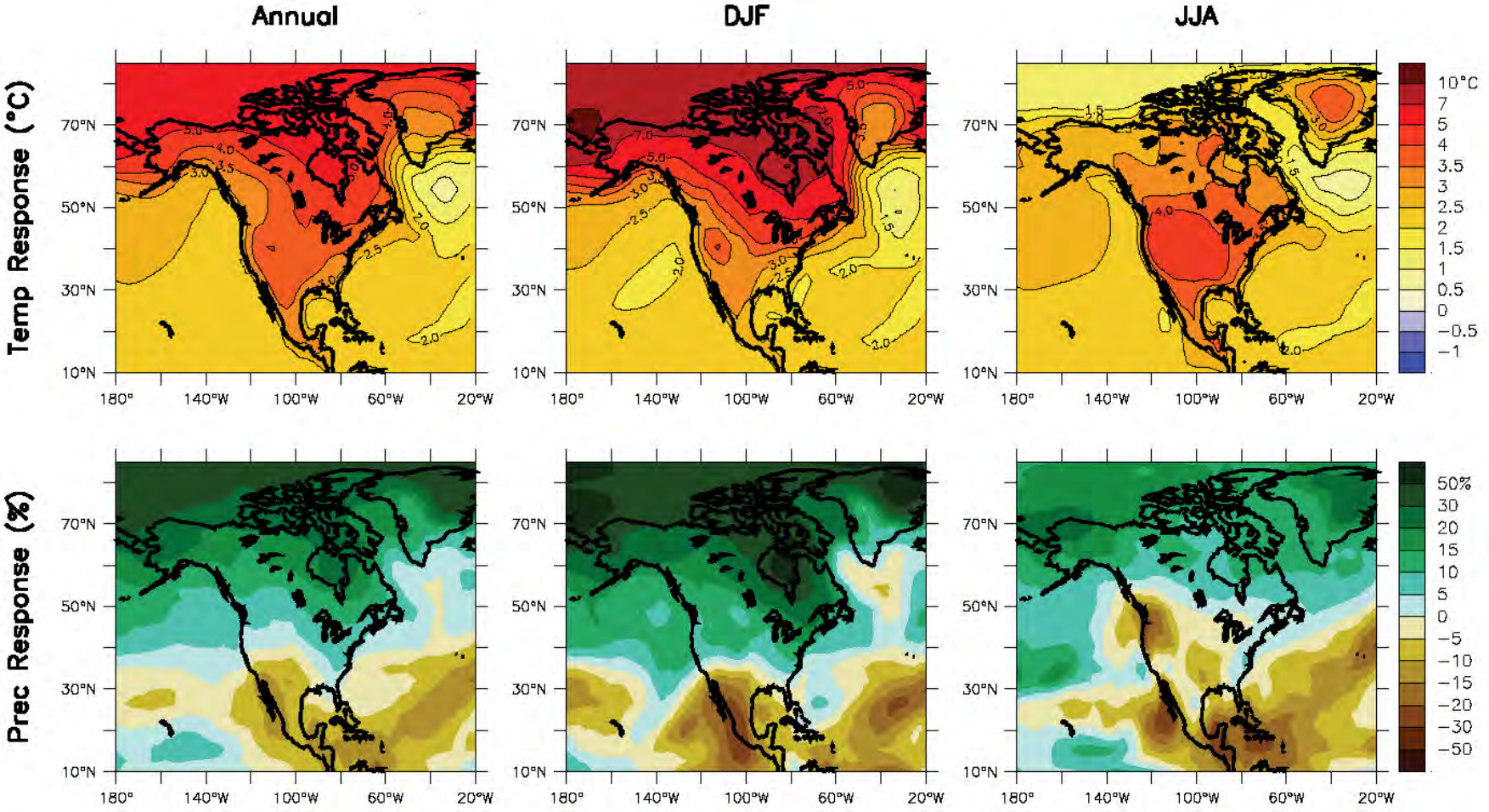
Will Attitudes Change?

- Irene changed Vermont's attitude

- State moving in right direction
- Local community solutions essential

- Federal government now out-to-lunch

T, Precip. Changes (2090-1990)



- 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%]**

Fall Climate Transition

- **Vegetation delays first killing frost**
- **While deciduous trees still evaporating: moister air with clouds**
- **Water vapor & cloud greenhouse reduces cooling at night and prevents frost**
- **Till one night, dry air advection from north gives first hard frost.**
- **Vegetation dies, skies become clearer and frosts become frequent**
- ***The opposite of what happens in Spring with leaf-out!***

Clear dry blue sky after frost. Forest evaporation has ended; water vapor greenhouse is reduced, so Earth cools fast to space at night

Later frost: Growing season getting longer

Role as Writer

- I am a scientist, a writer & public speaker
  - I speak and write about what I know
  - Connect local issues to global issues
  - Science matters – *but issues far beyond 'science'*
  - Clash between Earth system reality and political and economic ideologies
  - *"Earth wins hands-down"*
  - Many difficult ethical and moral choices
- The transition we face is huge: *must be faced*
  - Can we stabilize the climate?
  - Can we build a sustainable future?
  - Why we need community

Vermont Newspaper Columns

Environmental journalism revisited (Betts and Gibson 2012)

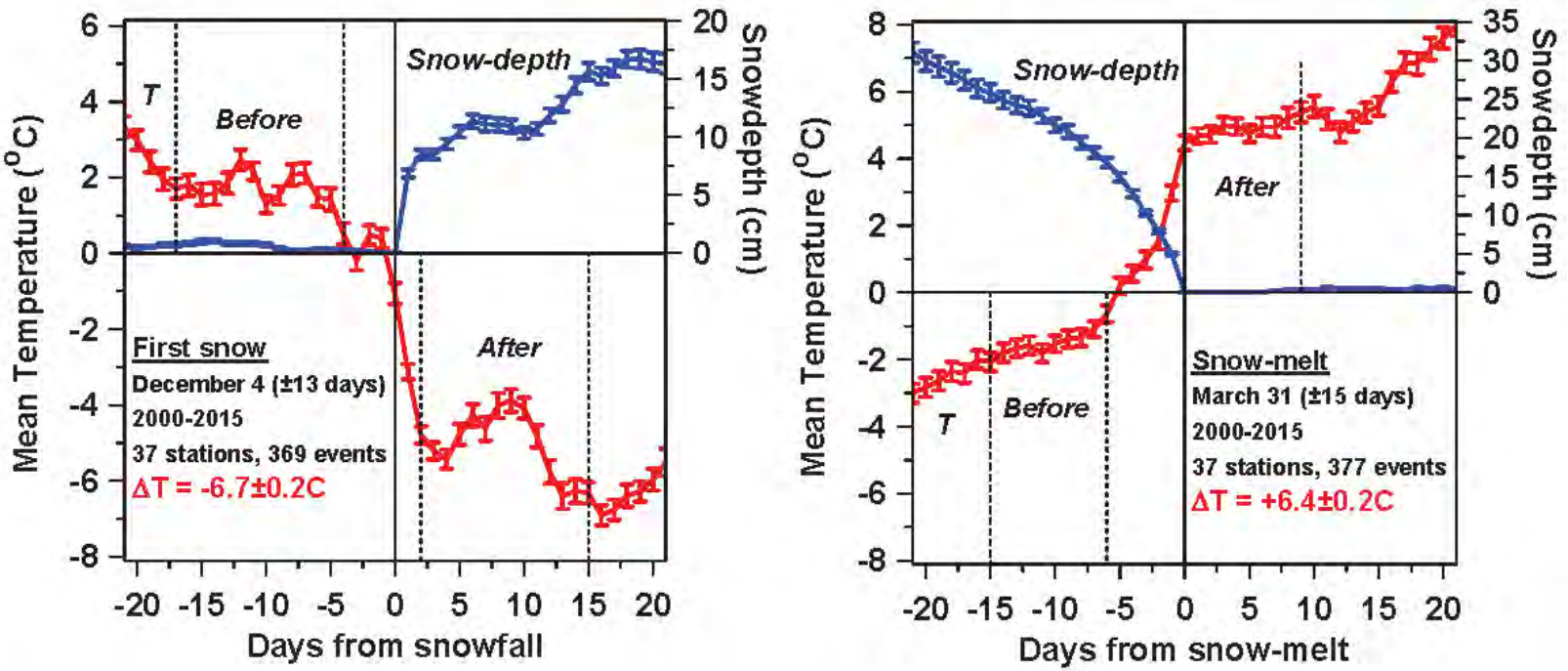
2008-2016: 90 articles: "They blend science with a systems perspective, and encourage the reader to explore alternative and hopeful paths for themselves, their families and society"

(Rutland Herald and the Barre-Montpelier Times Argus)

Today's communities must understand the connections between energy use, climate and food to make the transition to an efficient, resilient and sustainable society.

(alanbetts.com/writings)

Snowfall and Snowmelt
ΔT Vermont



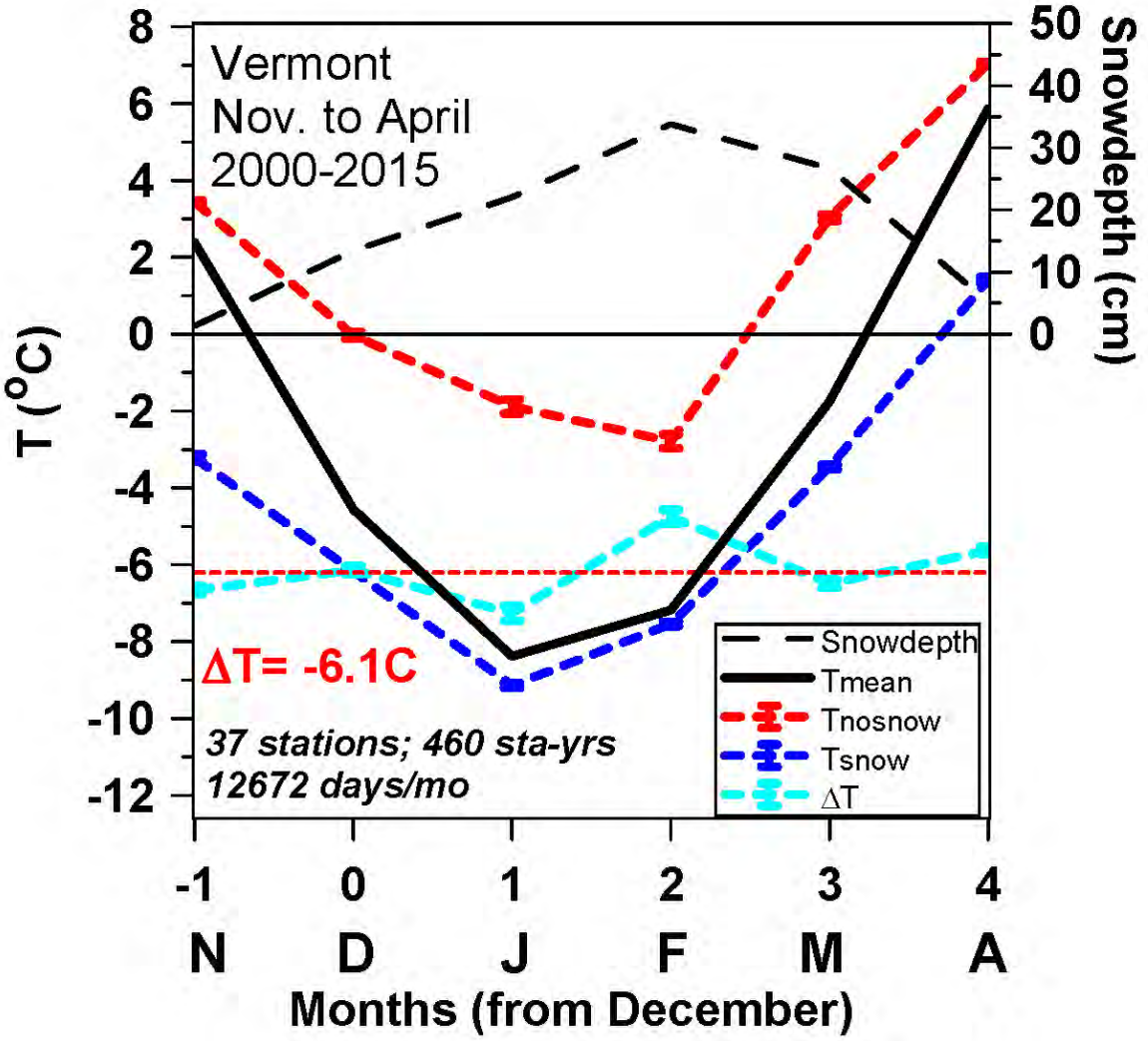
- **Temperature falls/rises 6.5 °C with first snowfall/snowmelt**
- **Albedo with snow less than Prairies**

Climatological Impact of Snow: Vermont

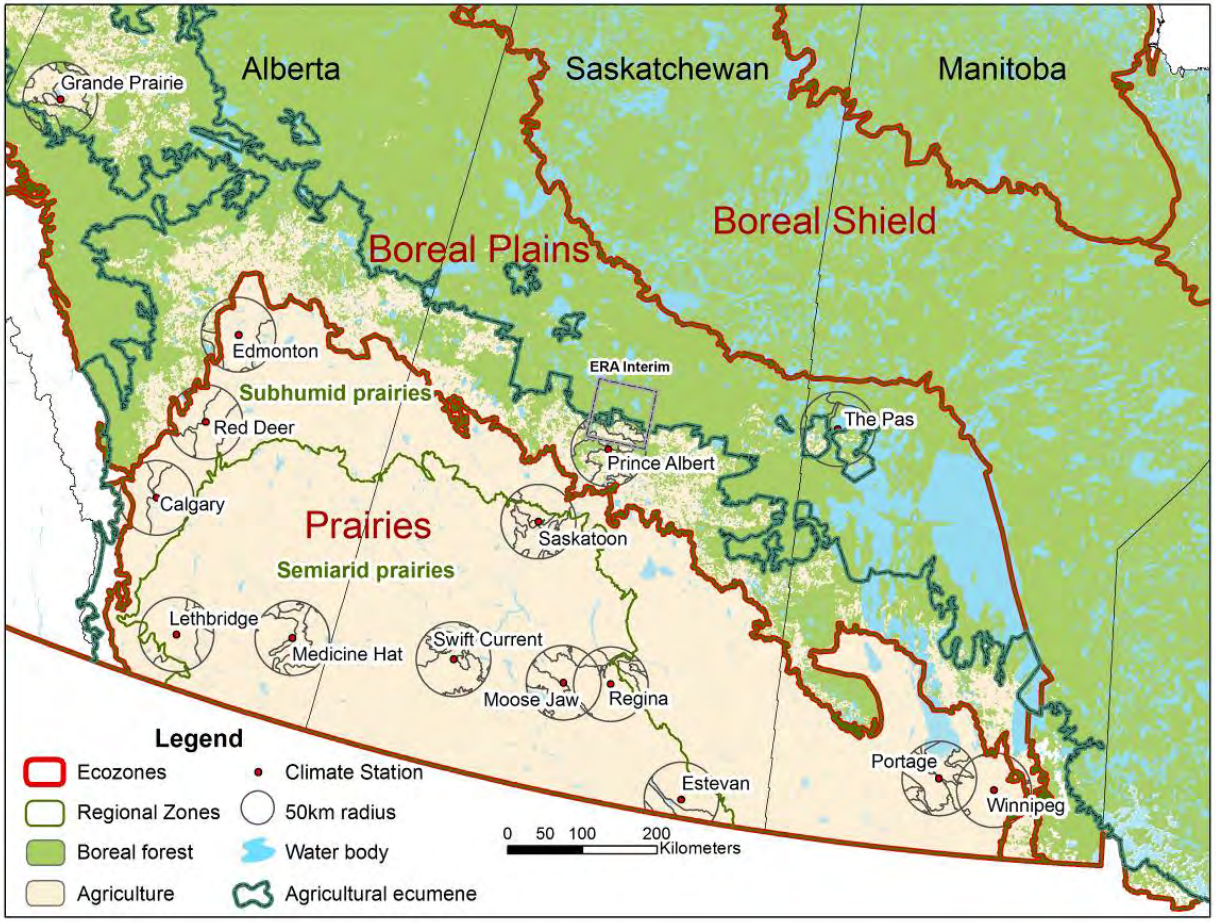
Separate mean climatology into days with no-snow and with snow

Difference ΔT= -6.1(±0.7)°C

= -11 (±1.3)°F

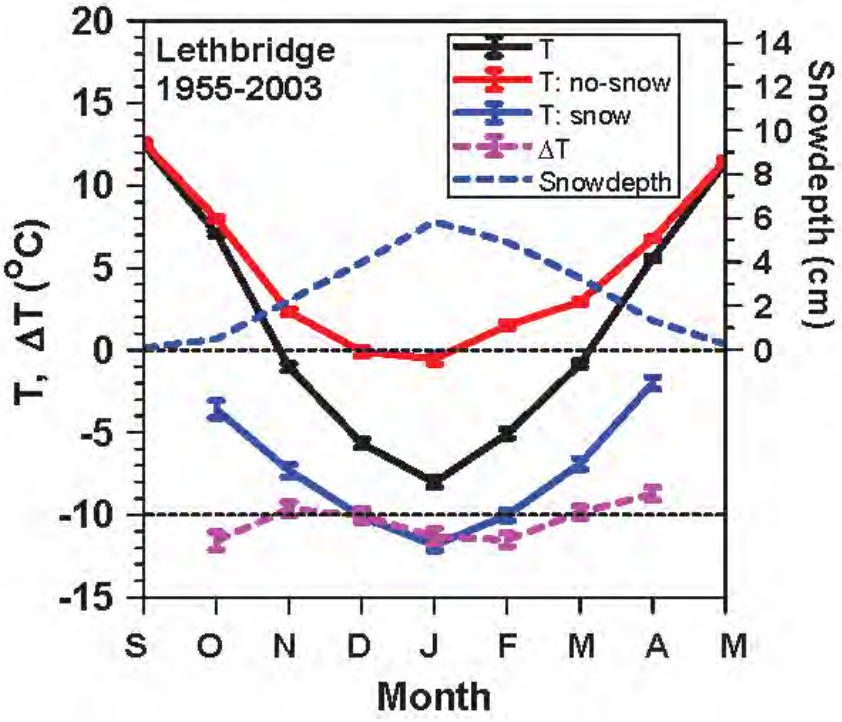


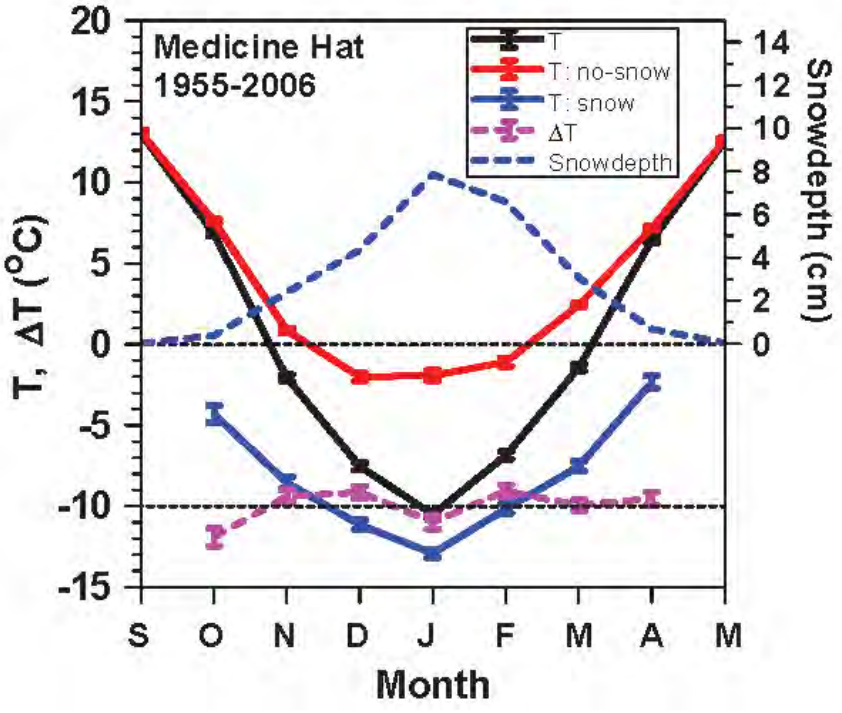
15 Prairie stations: 1953-2011



- ***Hourly*** **p, T, RH, WS, WD, Opaque Cloud (SW_{dn}, LW_{dn})**
- ***Daily*** **precipitation and snowdepth**
- **Ecodistrict crop data since 1955**
- **Albedo data since 2000**

Impact of Snow on Climate





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

ΔT = T:no-snow –T:snow = -10.2(±1.1)°C

Betts et al. (2016)

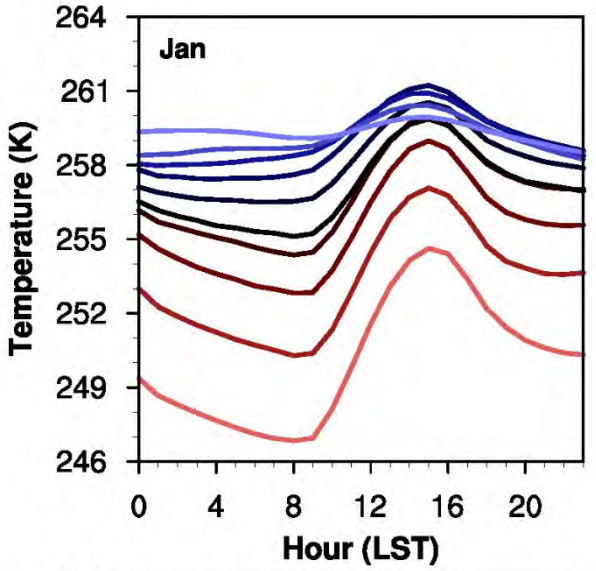
Diurnal cycle: Clouds & Snow

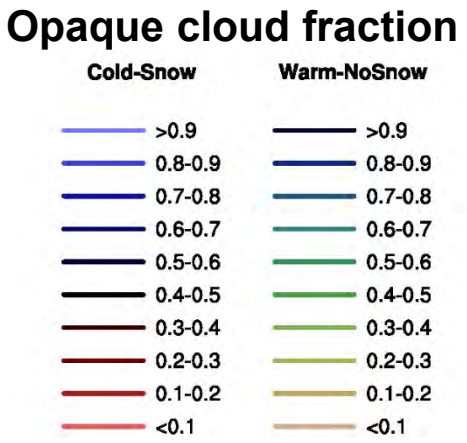
Canadian Prairies
660 station-years of data

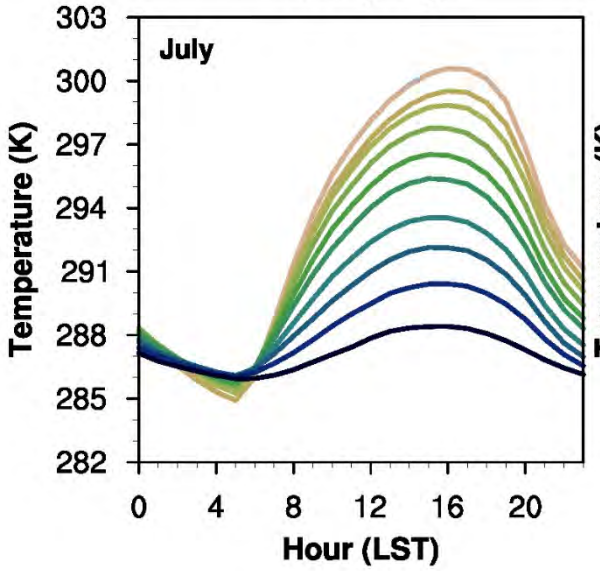
Winter climatology
- Colder when clear
- LWCF dominant with snow
- Stable BL

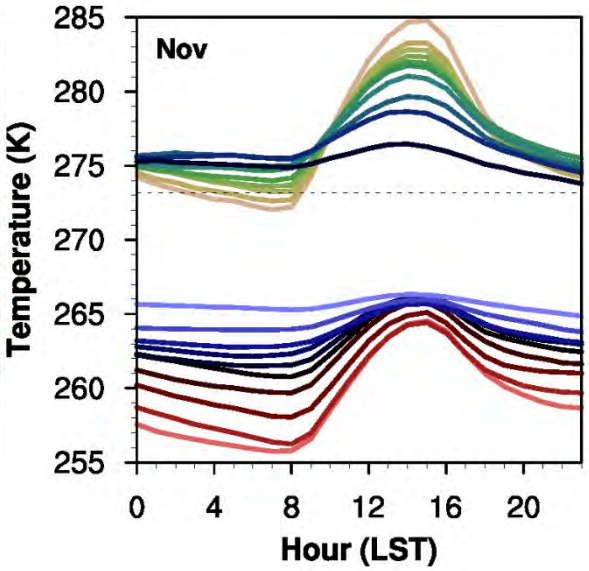
Summer climatology
- Warmer when clear
- SWCF dominant: no snow
- Unstable daytime BL

Transition months:
- Show both climatologies
- With 11K separation
- Fast transitions with snow
- Snow is “Climate switch”









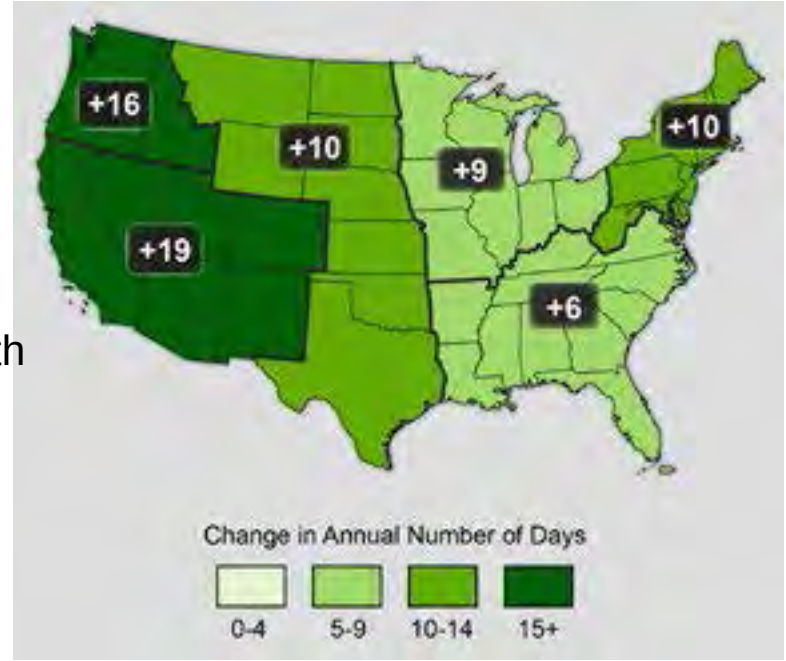
Warm and Cold Seasons

- **Clouds - reflect sunlight**
- **Less cloud - Warm in afternoon**

- **Snow - reflects sunlight**
- **Clouds: reduce cooling at night**
- **Less cloud: very cold at sunrise**

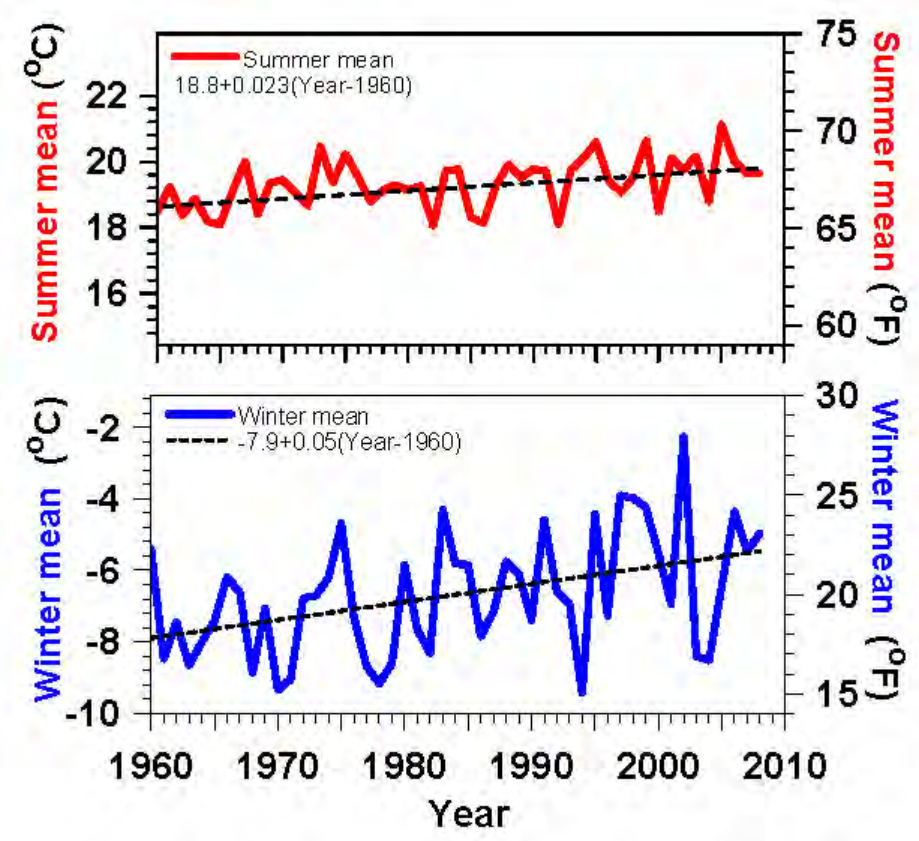
Frost-free days increasing

Figure 2.10. The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC / CICS-NC).



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***



What is our role as Scientists?

- **Honesty, accuracy, clarity, *and depth***
  - **"Bold humility"** ***(Francis Moore Lappé)***
  - **Earth scientists should consciously accept responsibility for the Earth**
    - ***As the political and economic system will not***
  - **Speak clearly to society: creative hope not despair**
  - **Search for language that sidesteps ideology**
  - ***Realize that Earth system limits will need adaptive global governance***
  - ***and a paradigm shift in science***

(alanbetts.com)