Global and Local Climate and our Future

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BREE Intern Orientation

May 30, 2018

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Vermont EPSCoR
CWDD
Center for Workforce Development & Diversity

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

Strategies for Resilience

- Understand technical/ecological issues
  - Don't build bridges with alternative facts
- Engineer for efficiency and resilience
  - Not "cost effective for today's bottom line"
- Spend $1 trillion on climate resilience
  - saves $60 trillion later this century
- If we ignore climate change
  - costs to human civilization and Earth's ecosystem catastrophic
- Community resilience!

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Fundamentals

- ***Burning fossil fuels: transforming climate***
  - ***Many water cycle amplifying feedbacks***
  - ***Heading for high CO_2 "Carboniferous era climate"***
  - ***Climate extremes increasing.***
  - ***Severe weather costs: $300B in US last year***
  - ***Decadal to centennial - long timescales***
- **Avoidance of responsibility for decades**
  - **Politicians, professionals, public**
  - **Climate change: Incompatible with business-as-usual**
- **Linked to unmanaged technology**
  - **Soluble by changing system guidelines**
  - **Create efficient society, based on renewable energy**
- **Choices are value based**
  - **Beyond science and economics**
  - **Community based**

Earth's climate sustains life

- Increasing greenhouse gases reduces cooling to space
- Climate is warming: ice is melting, extreme weather is increasing
- Water plays crucial amplifying role

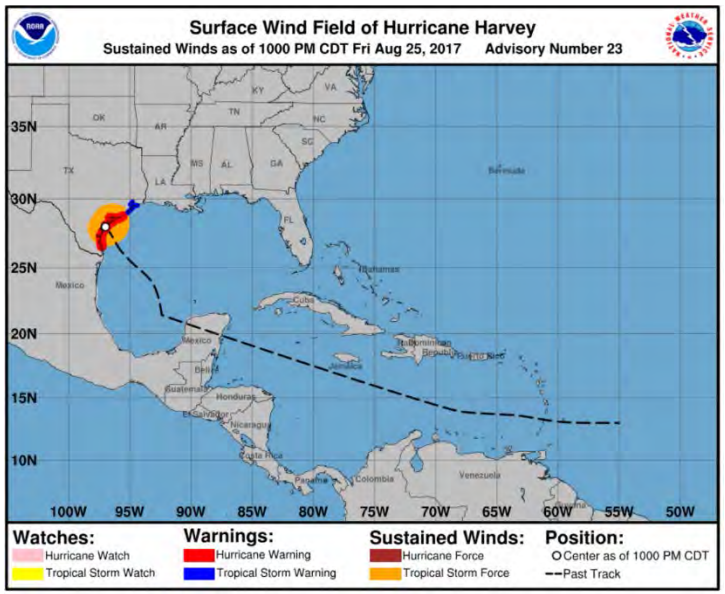
Hurricane season: 2017

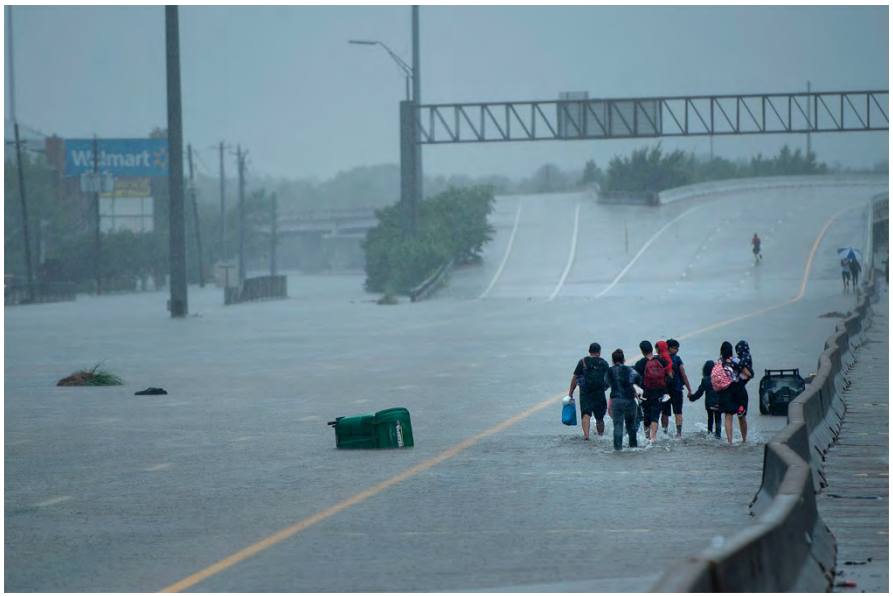
- **Earth is warming as greenhouse gases increase and reflective ice cover falls**
- **Oceans are storing 93% of heat**
  - **Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes; when vertical shear is low**

- ***2017: Harvey, Irma, (Jose), Maria***

Why was Harvey so Damaging?

- **Huge evaporation off warm ocean**
- **Category 4 hurricane developed**
- **Very heavy rain-rate: 10-12 inches per day**
- **Two stationary high pressure systems to the north trapped Harvey for 4 days over Houston**
- **Result 40+ inches of rain & massive flooding**





2pm Sept. 6

*Category 5**

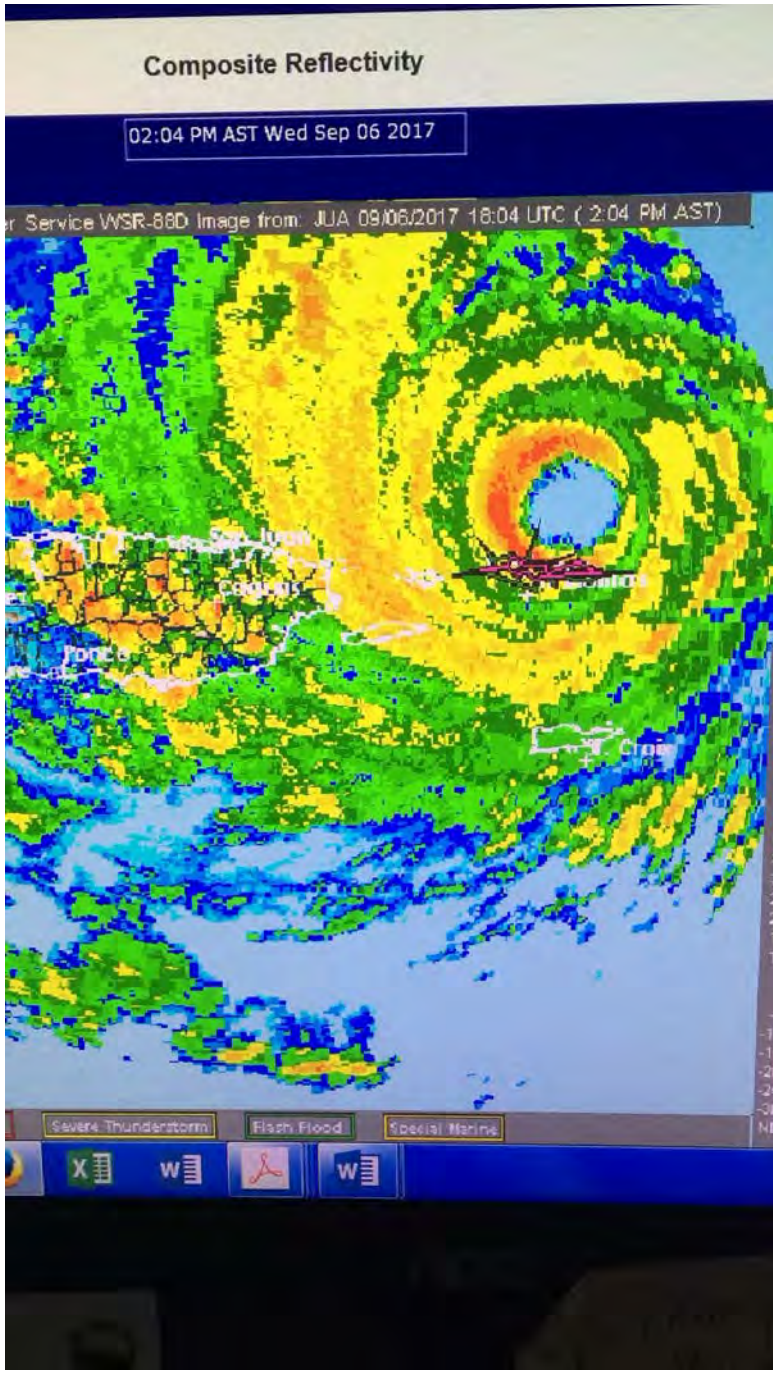
IRMA

grazing

St Thomas

Cat 5 >155mph

IRMA >180mph



Irma(Cat.5)
Sept. 6
St Thomas

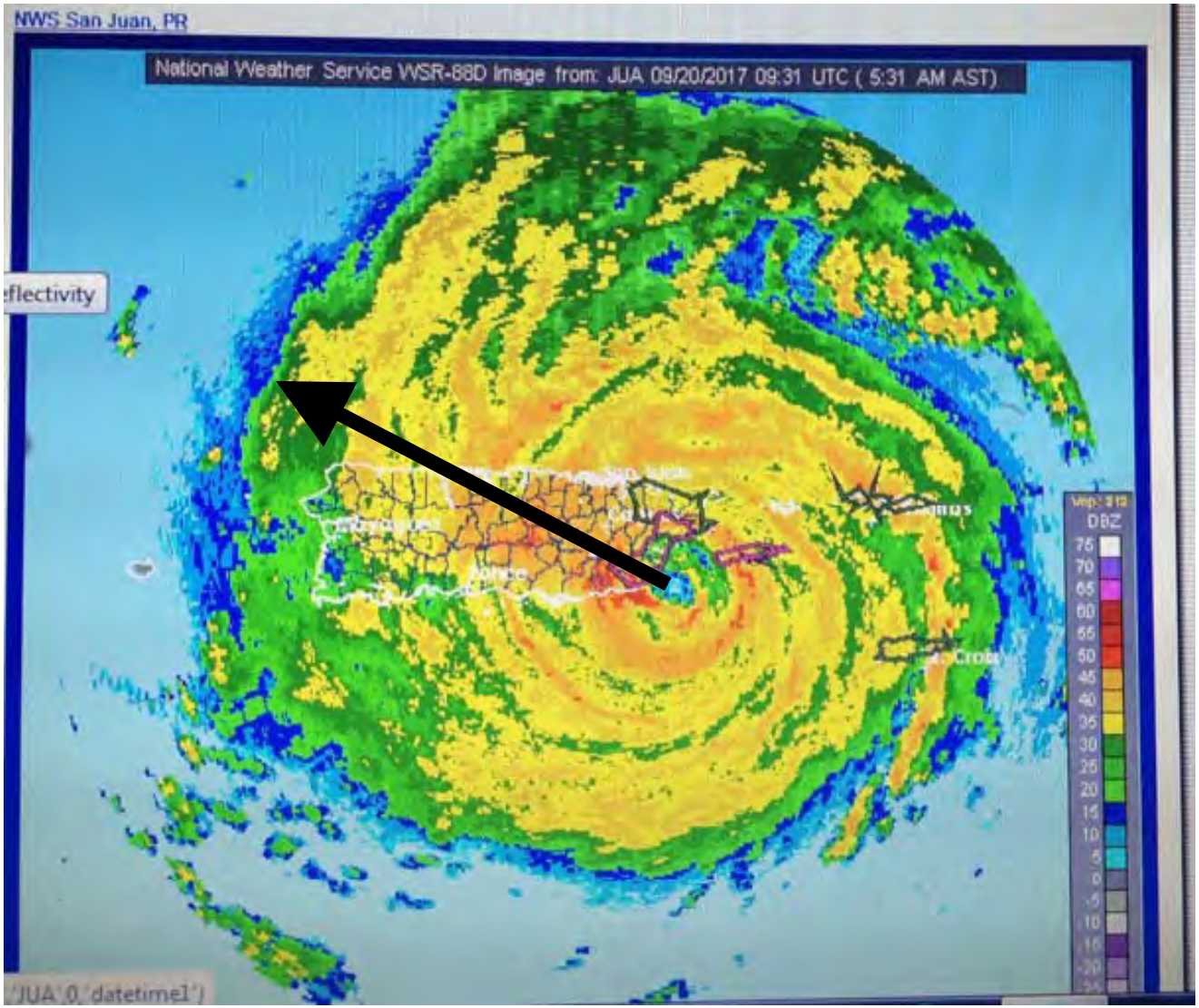
Irma and Jose: Sept 7

After Jose passed; Catamaran to Puerto Rico on Sept 11

Maria: 5:30am Sept. 20
Category 4 hits Puerto Rico

Cat 4
>130mph
Maria
>150mph

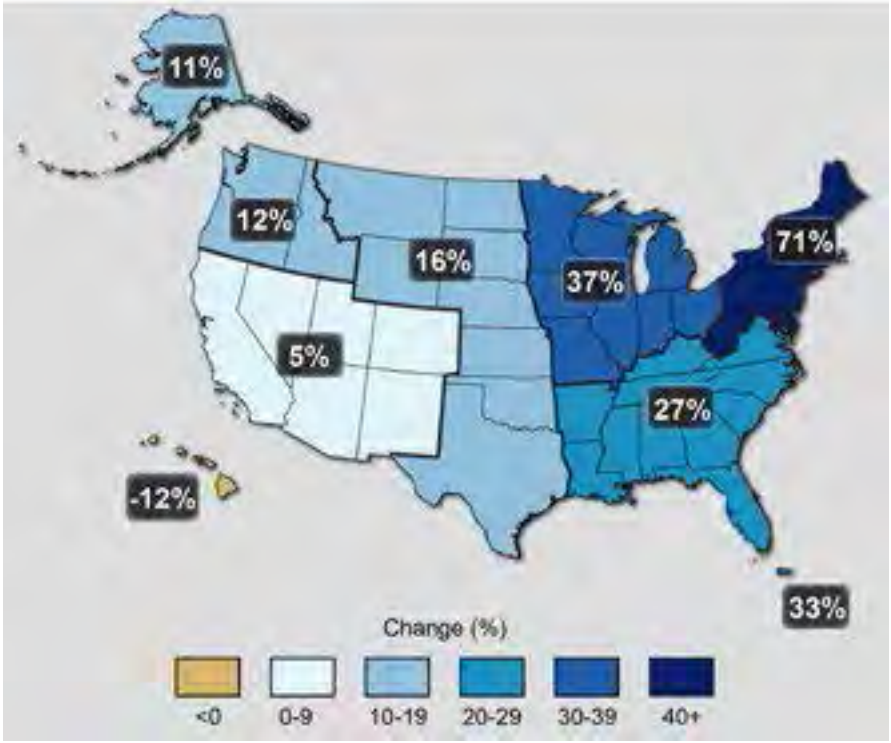
Wiped cell towers and power grid
(90% back after 6 mos!)



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**

TS Irene

Rte 131, Cavendish

Sept, 2011

Roads in valleys

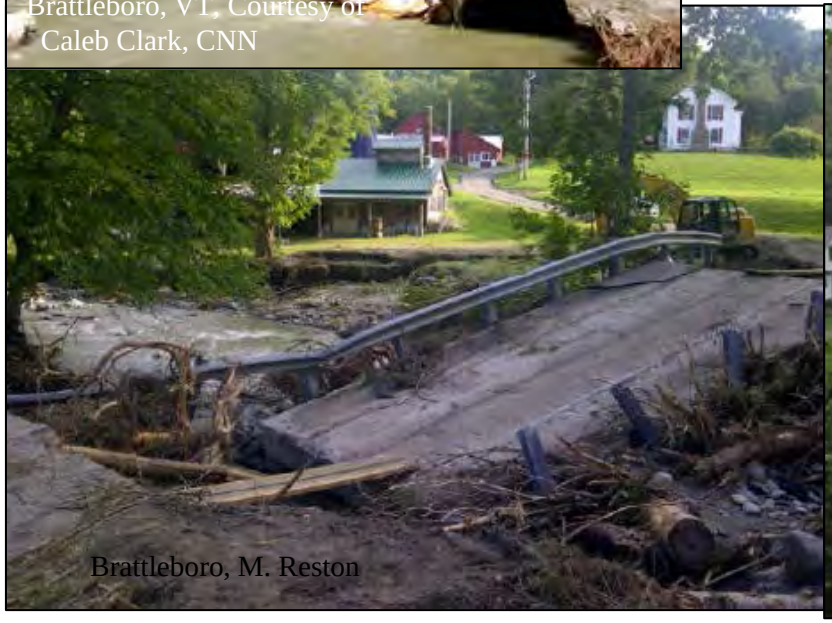
Massive damage

Some roads took months to repair

Wake-up call

TS Irene: 2011


Brattleboro, VT, Courtesy of Caleb Clark, CNN


Brattleboro, M. Reston


Wilmington, J. Cantore

Lake Champlain, Spring 2011, Courtesy LCBP

Mouth of Connecticut River from Irene 2011

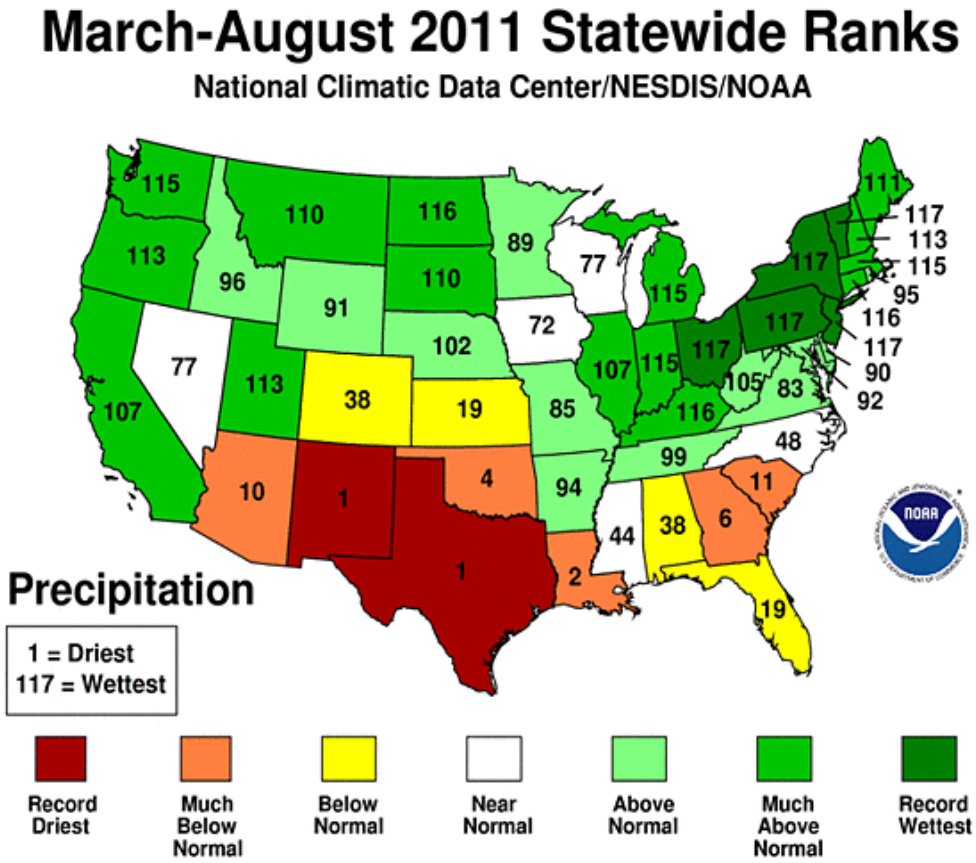
2011 Classic Flood Situations

- **Spring flood**: heavy rain and warm weather, melting large snowpack from 2010-11 winter
  - 70F (April 11) and 80F(May 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 6-10 ins rain
  - Extreme flooding

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**

Irene: Resilience

- 13 towns cut off overnight
- State emergency systems flooded
- FEMA: no road access
- Communities reorganized overnight
- Those with equipment stepped in
  - "Can fix this in 72 hrs": will need engineer to check bridge (Brandon)
  - "We worked 120hrs last week…" (Wardsboro)
  - Social networks collected supplies; and rescue services across mountains
  - ***Communication networks critical***

- **The Wardsboro excavator Harvey Plimpton spoke for Vermont's community spirit when he said: *"Nobody gave us permission. We just started because we knew what had to be done. We put in 120 hours last week. We worked until we couldn't work. We still have a long way to go."***

- ***When a stranded guest took Beth aside to ask what would happen when she ran out of food, she just looked at him, incredulous. "We're a farm," she said finally. "This is where food comes from."***

(Liberty Hill dairy farm, Rochester)

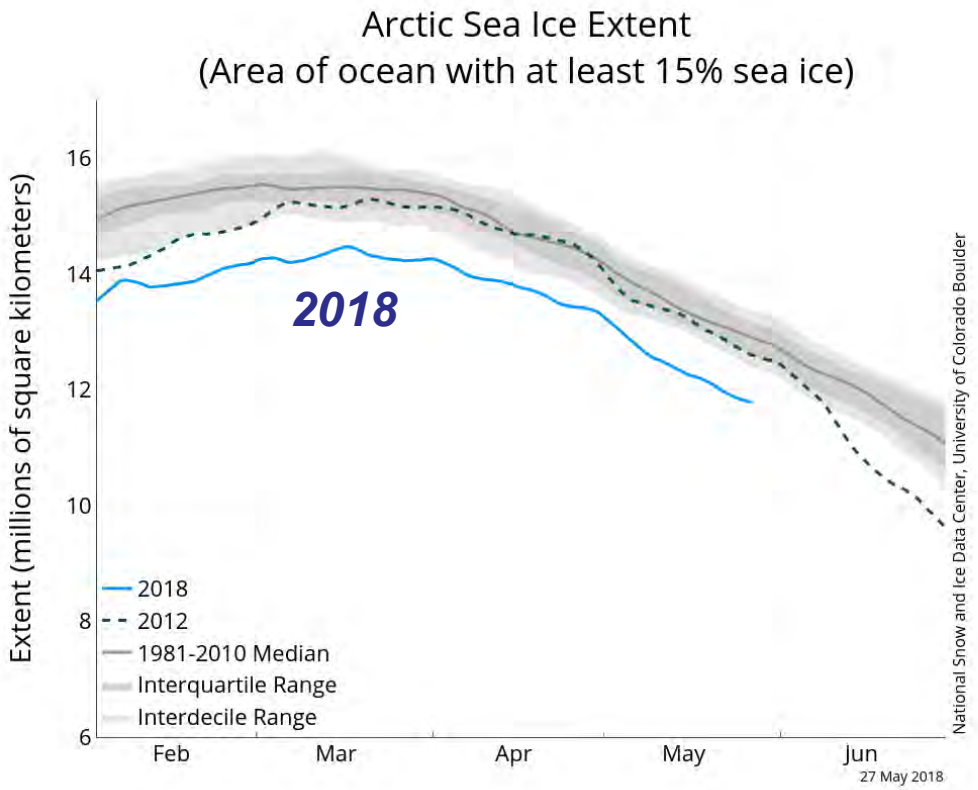
Flooding Issues

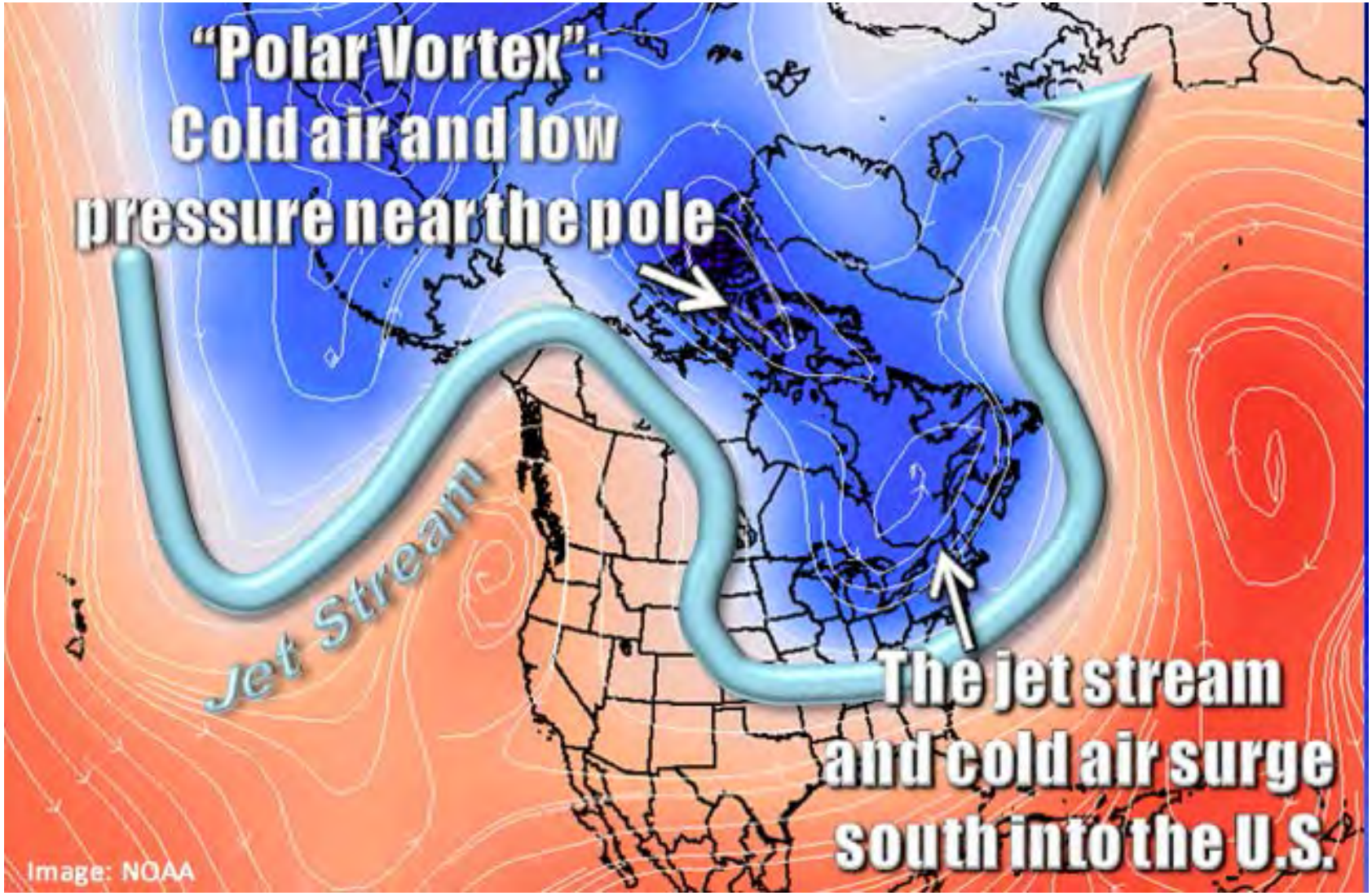
- **Maintain mountain forest cover**
  - **Devastating floods in 1920's, 30's with reduced forest cover**
- **Manage water/pollutants on landscape**
  - **Maximize infiltration: urban and on farms**
  - **Don't wall-in rivers**
- **Preserve flood plains**
  - **Saves downstream towns (Middlebury)**
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

Winters are changing
- as Arctic warms and melts

- **Sea-ice minimum mid-September**

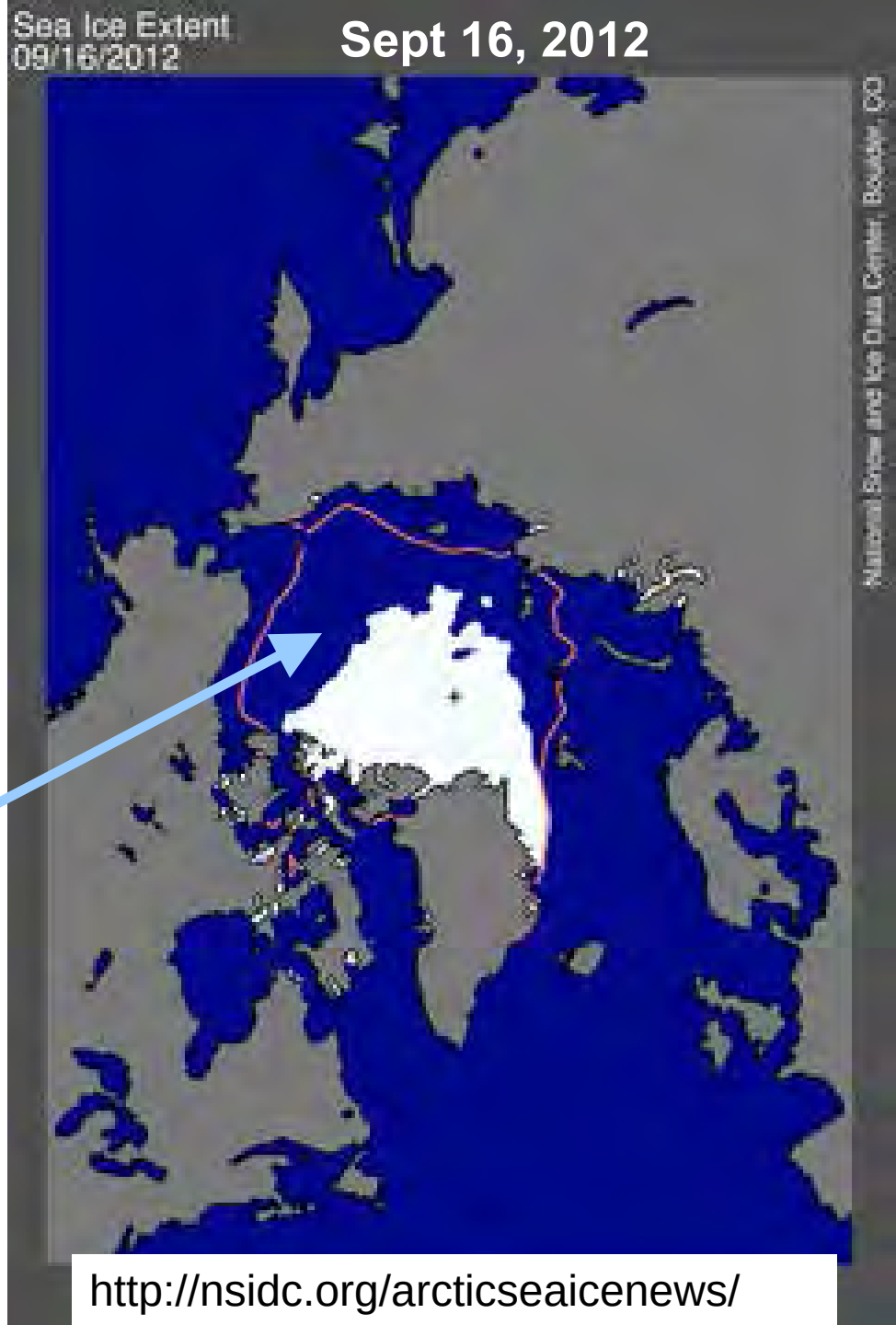
- **Winter sea-ice coverage falling**
- **Sea-ice thinning**
- **Polar vortex weakening**

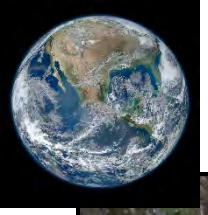



"Polar Vortex":
Cold air and low
pressure near the pole
Jet Stream
The jet stream
and cold air surge
south into the U.S.
Image: NOAA

- **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***





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

January 10 and 12, 2018

January 10, 2018

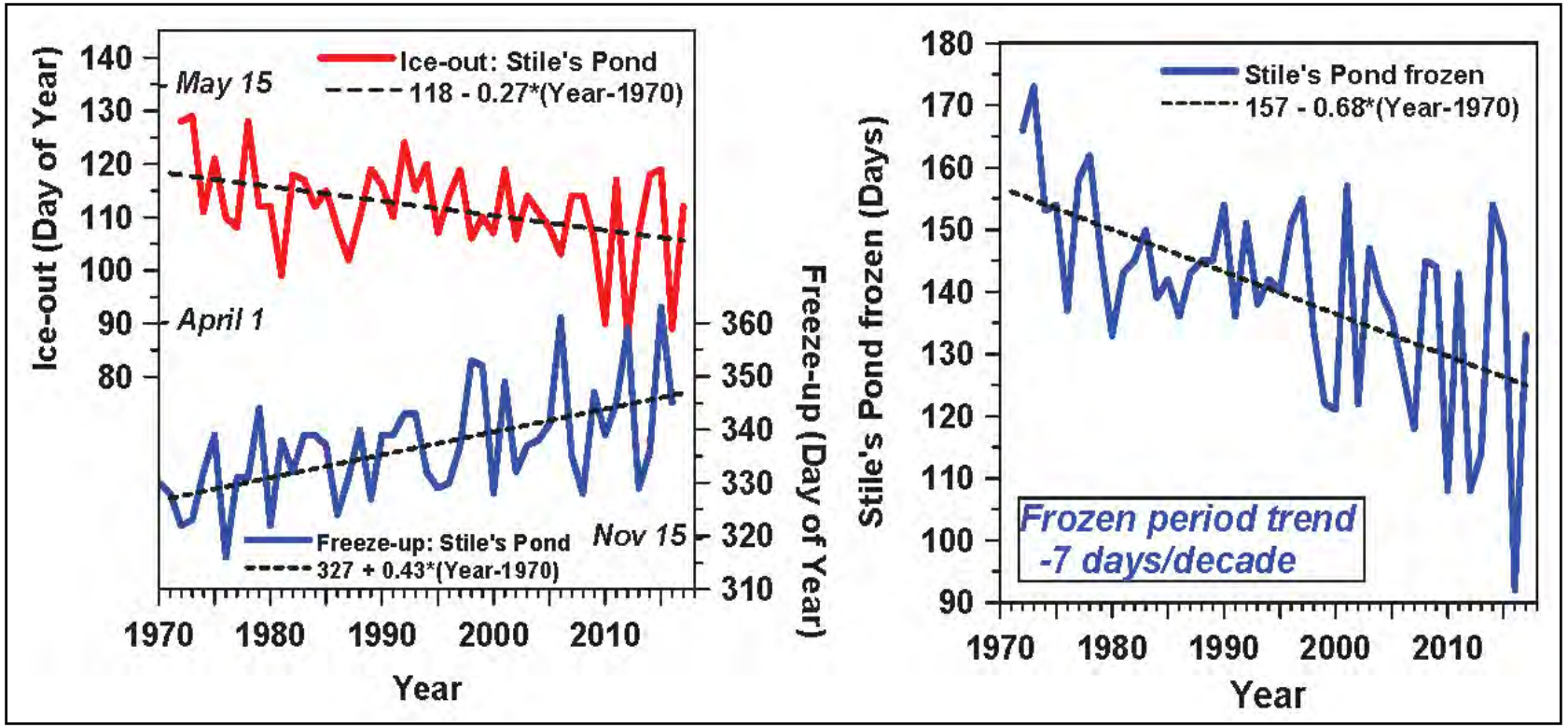
After cold snowy period
T_{min} down to -10 to -20F

January 12, 2018

After T_{max} up to 50F

Marker: Lake Freeze-up & Ice-out

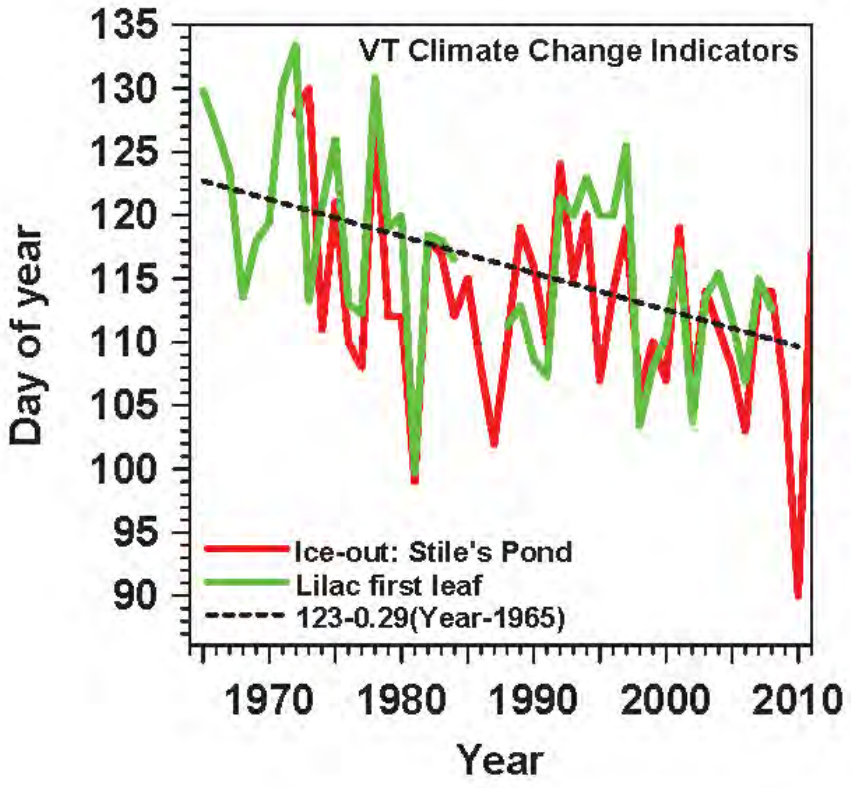
Frozen Period Shrinking: variability huge

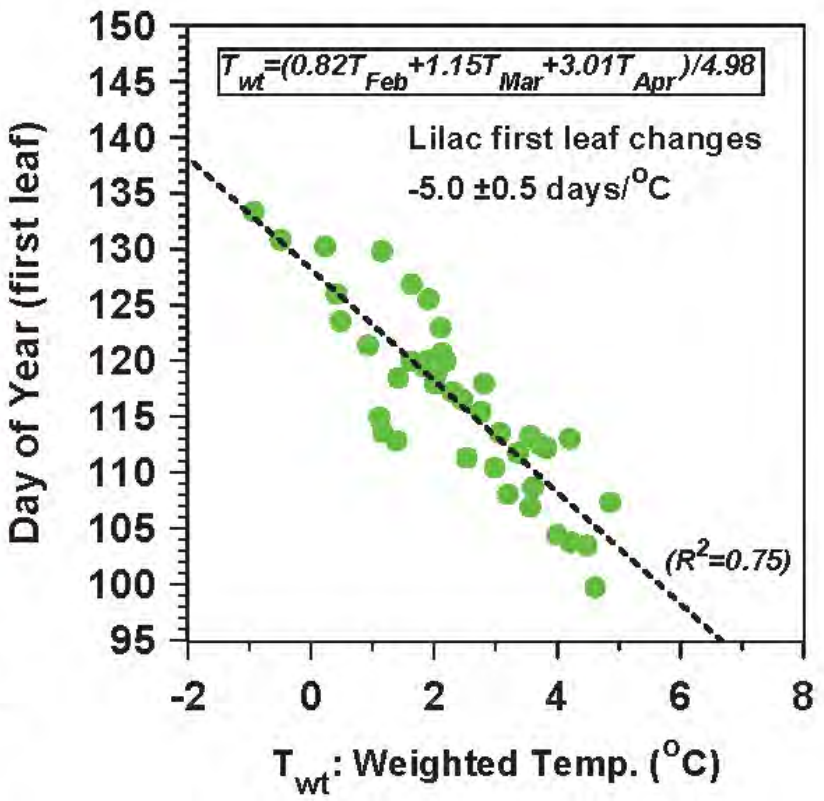


- **Freeze-up later by +4 days / decade**
- **Ice-out earlier by -3 days / decade**
- **Lake frozen period trend - 7 days/decade**
- ***Interannual variability ≈ 40 yr trend***

Stiles Pond: "Eye on the Sky"

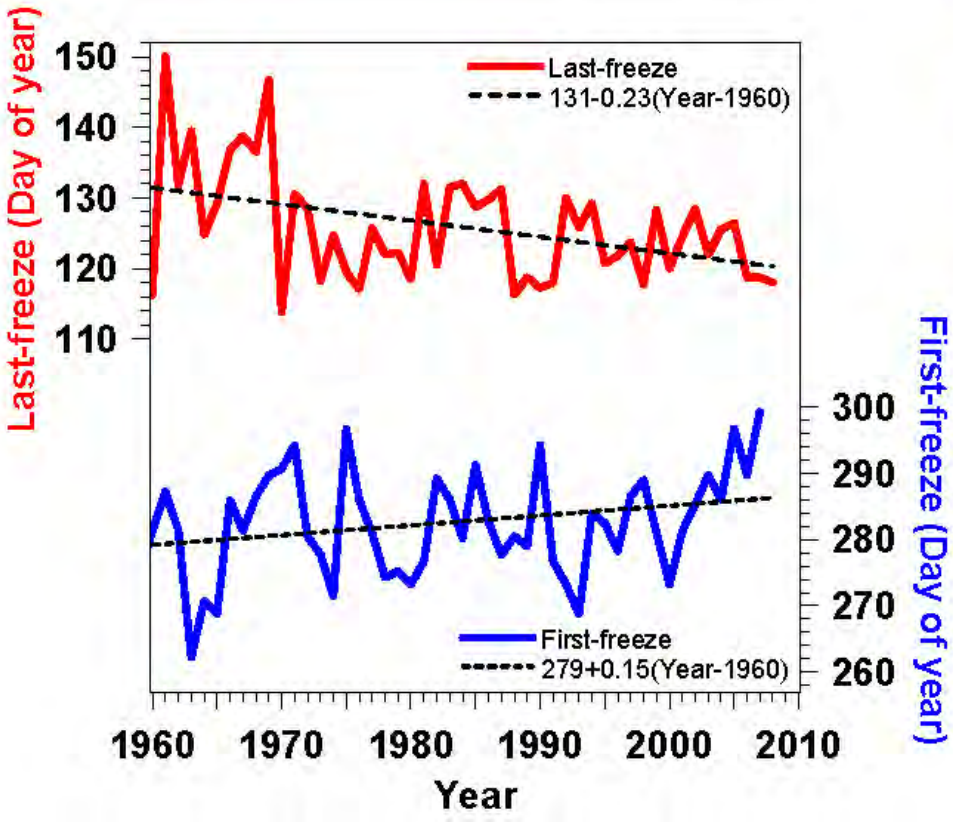
Lilac First Leaf Earlier

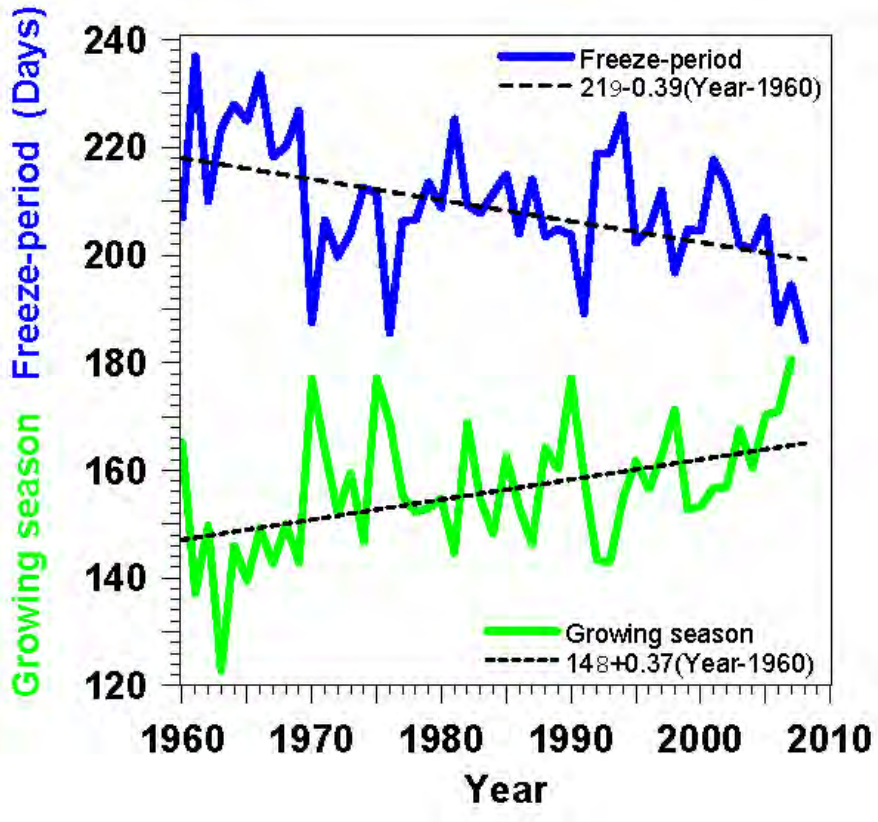




- **First leaf and ice-out changing: -3 days/decade**
- **Large variability linked to temperature: -5 days/ °C**
- **(No-snow – Snow) winter = 6*5 ≈ -30 days earlier leaf-out**

First and Last Frosts Changing



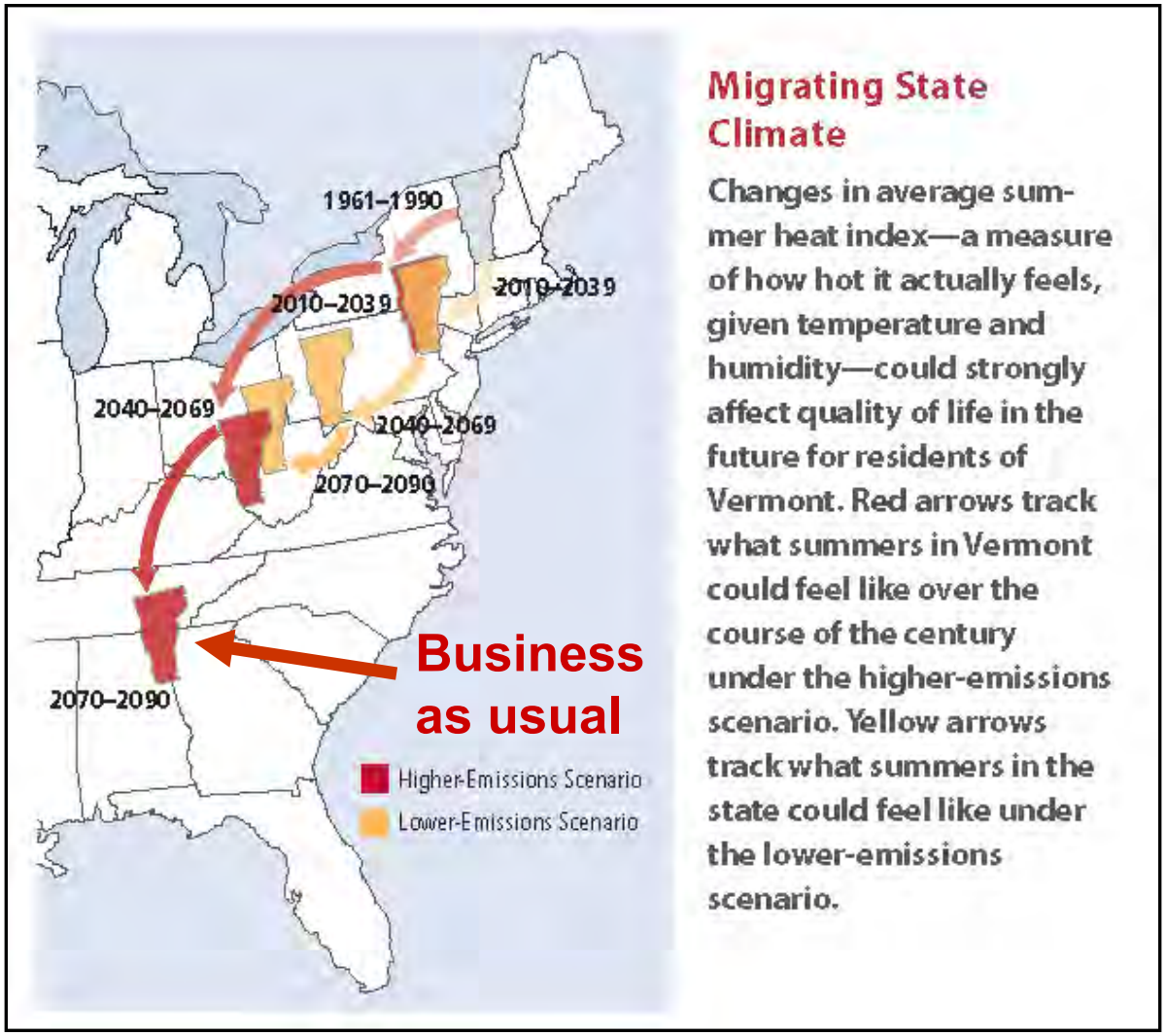


- **Growing season for frost-sensitive plants increasing 3.7 days / decade**
- **A help for growing "local food"**

Vermont's Future with High and Low GHG Emissions

What about VT forests?

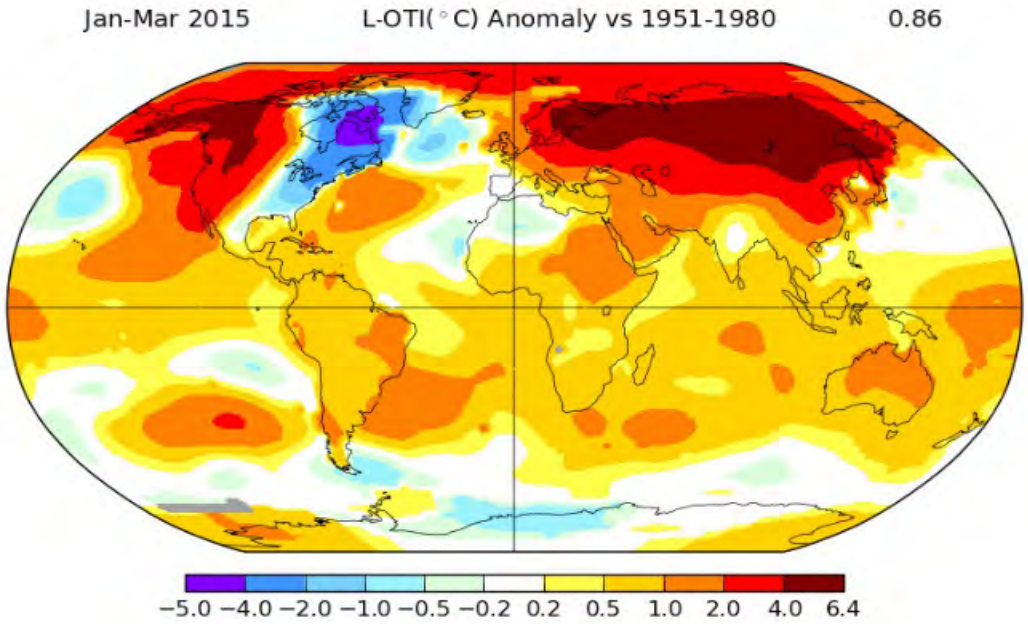
Sub-tropical drought areas moving into southern US



NECIA, 2007

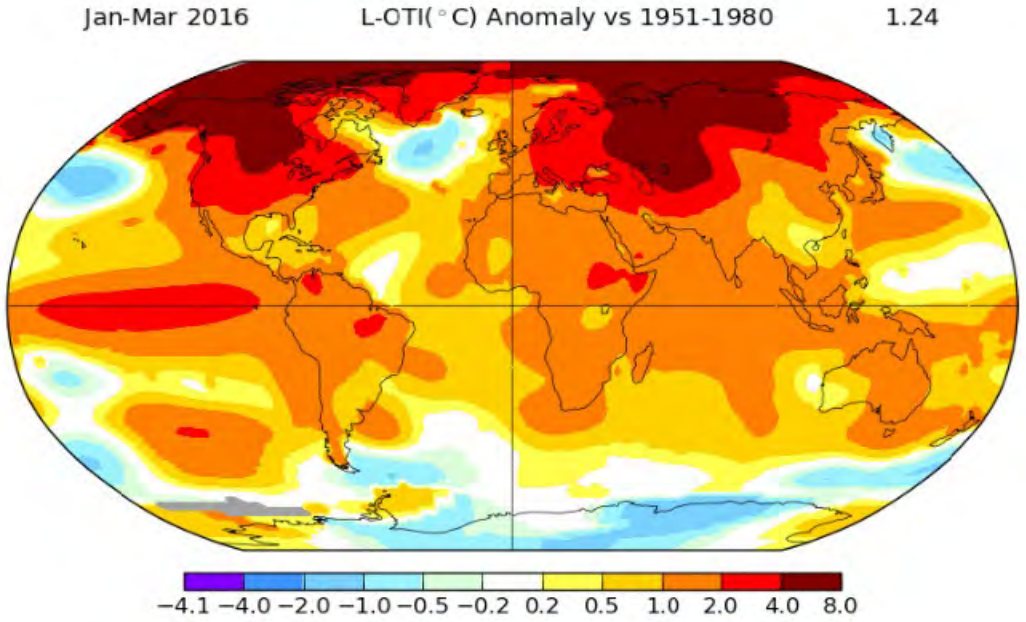
Jan-Feb-Mar 2015

Warm Atlantic, record temp in west; cold NE, strong coastal storms - Boston record snow



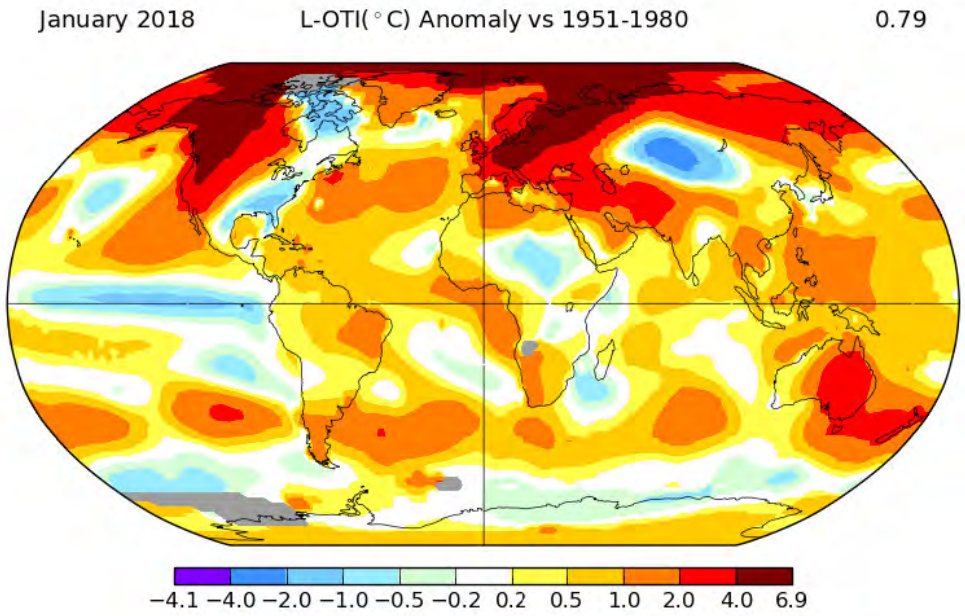
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



Jan-2018

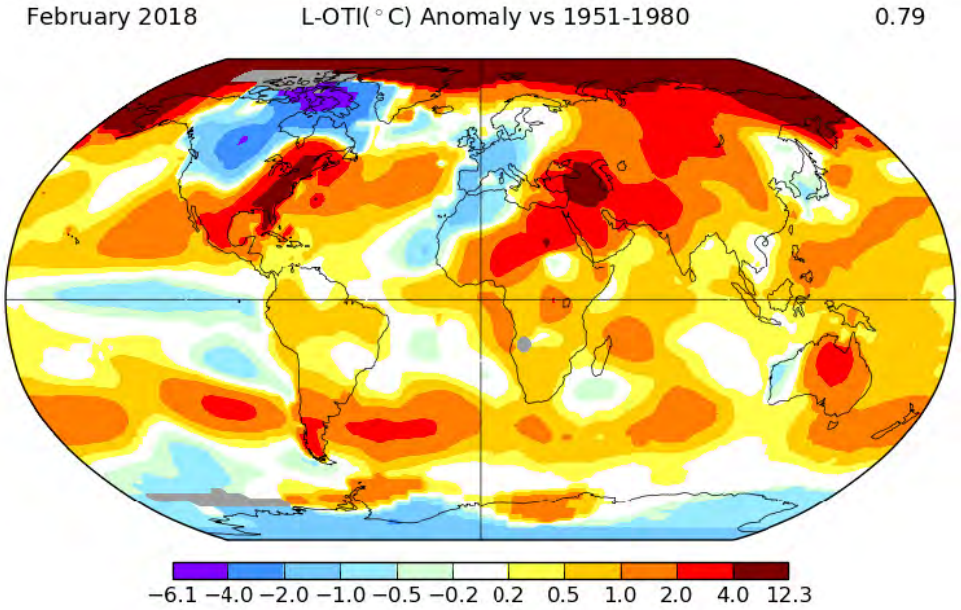
Warm Atlantic, Warm Arctic, west-NA; cold east-NA; warm Europe



Feb-2018

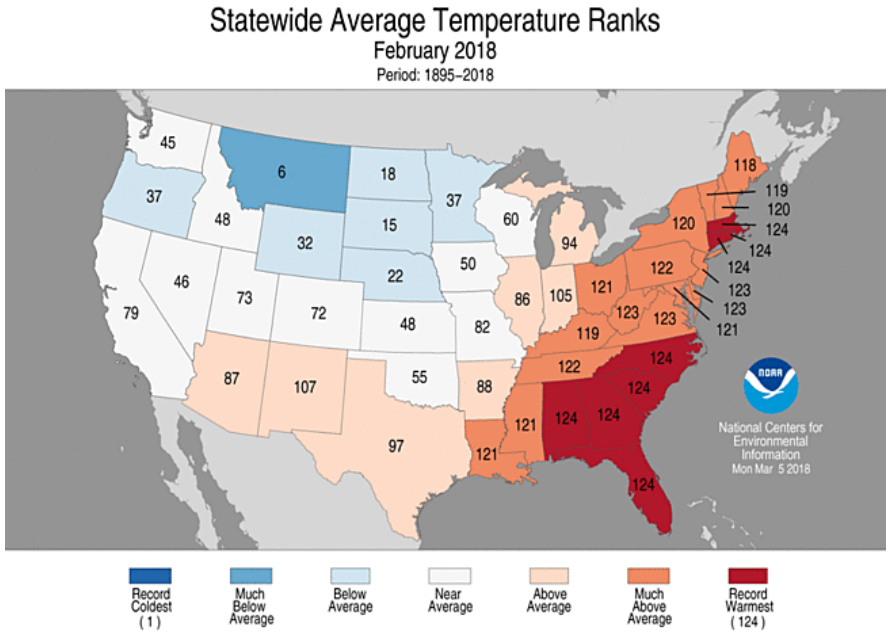
Warm Atlantic, Warm Arctic, east-NA; cold west-NA and Europe

March 2018: 4 Nor'Easter snowstorms

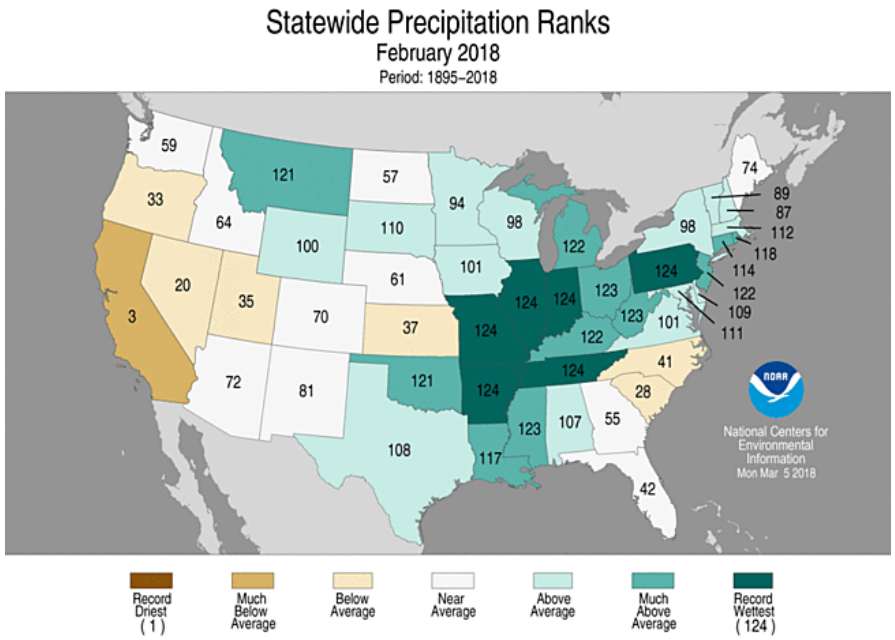


Feb-2018

Record warmest in South-east

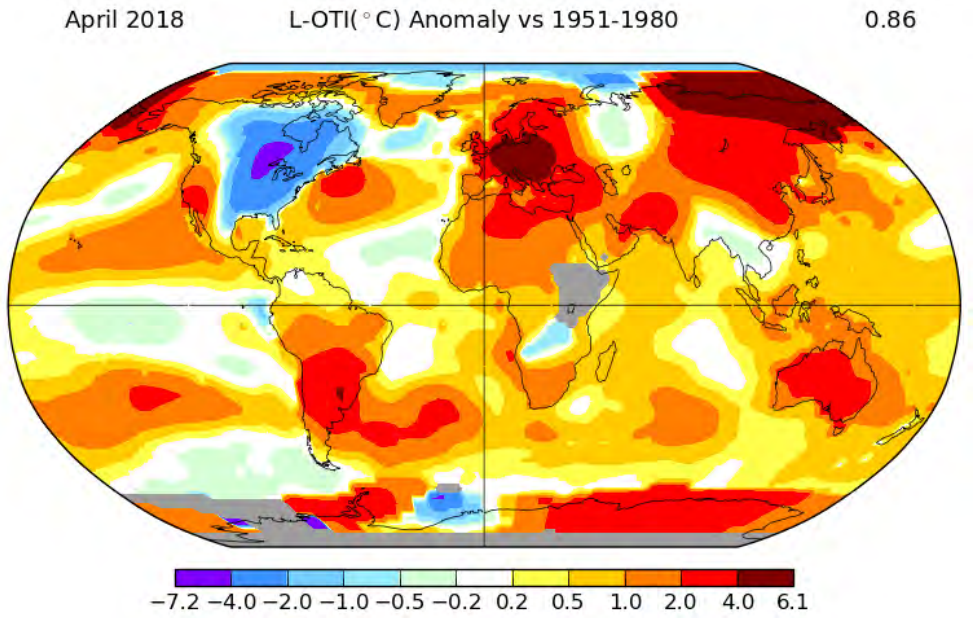


Record wettest in central US

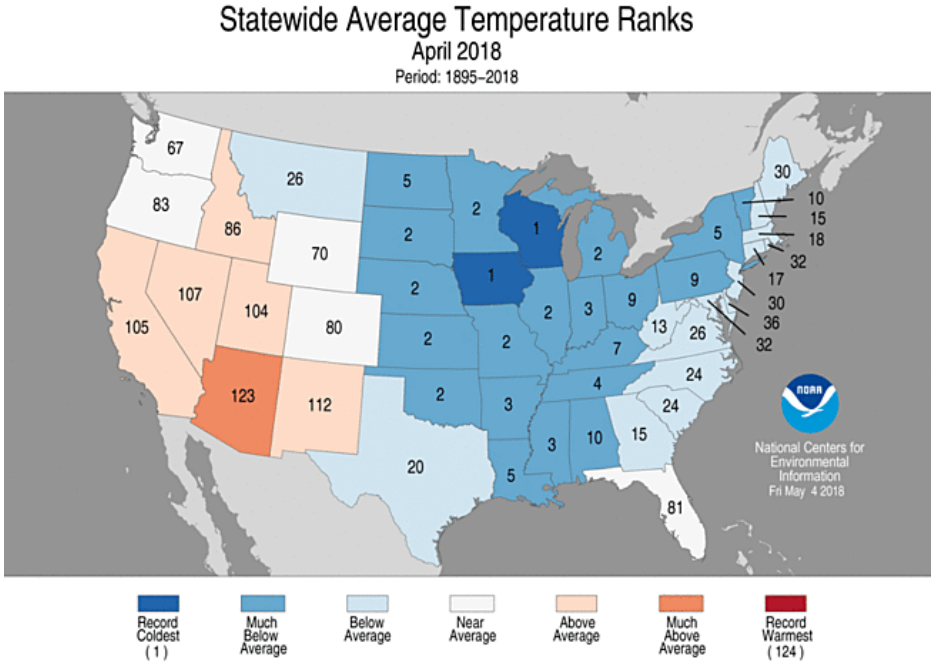


April-2018

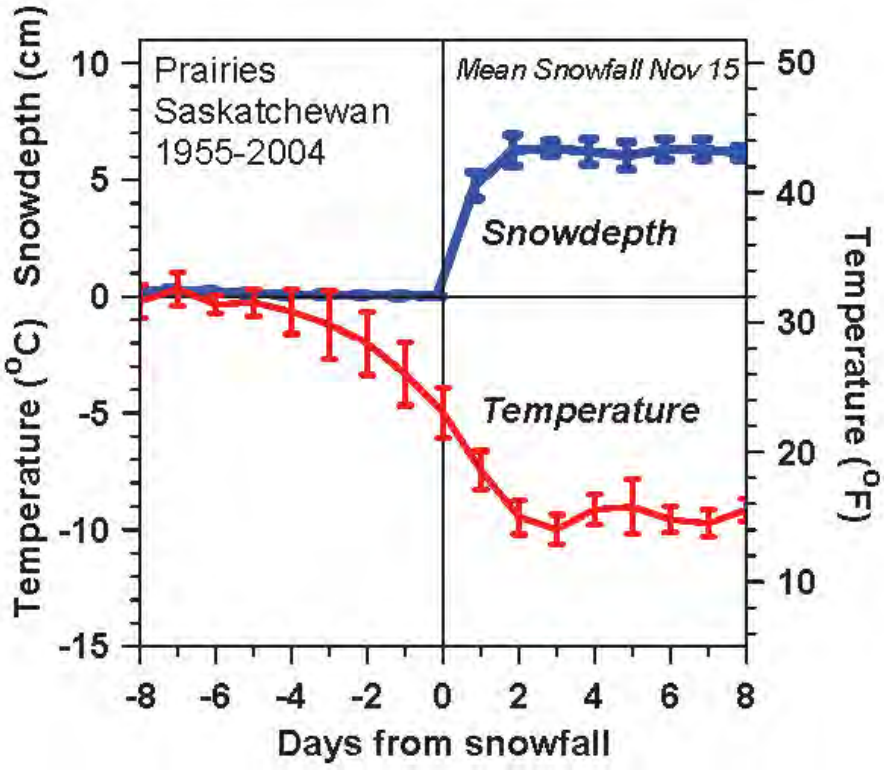
Warm Atlantic, (Record) cold NA; warm Europe

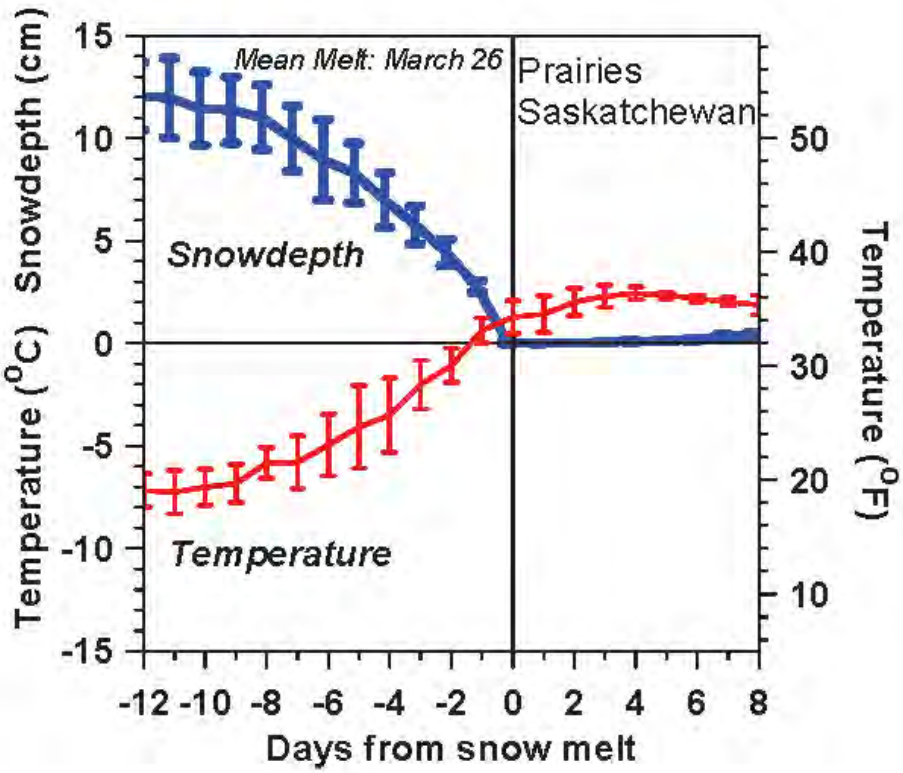


Record coldest: **Wisconsin, Iowa**
2nd coldest: **Minnesota, S.Dakota, Nebraska, Kansas, Oklahoma, Missouri, Michigan**



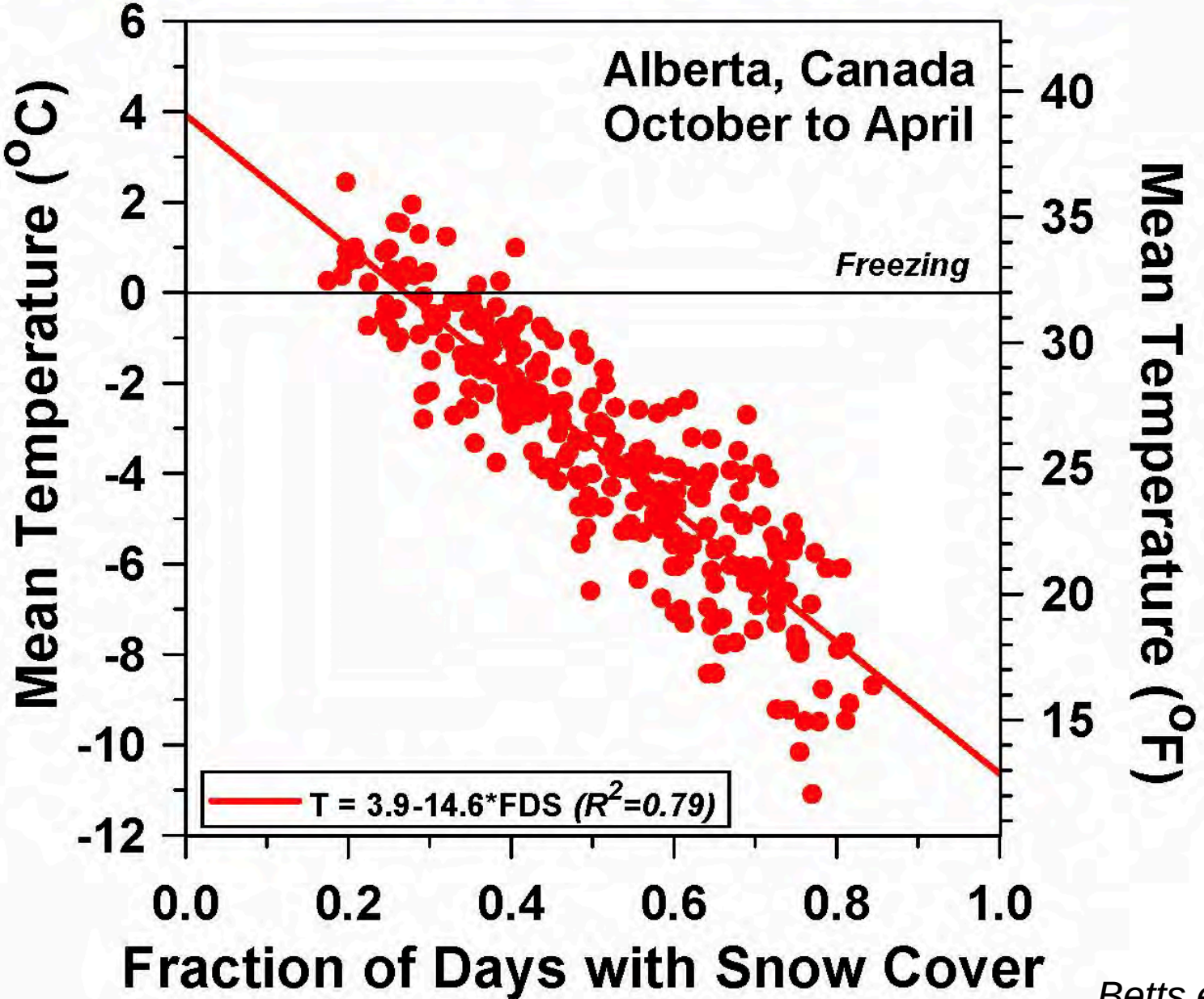
Snowfall and Snowmelt





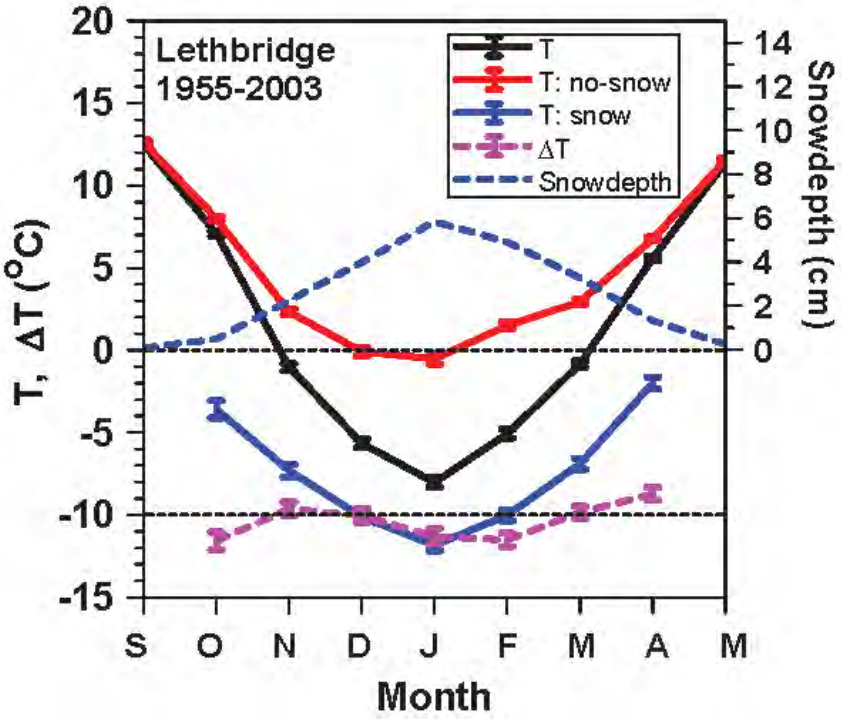
- **Temperature changes 10°C with snow cover**
- **Snow cover is a ‘climate switch’**
- ***Fast transitions in ‘local climate’***
  - ***Snow reflects sunlight***
  - ***Reduces evaporation and water vapor greenhouse***

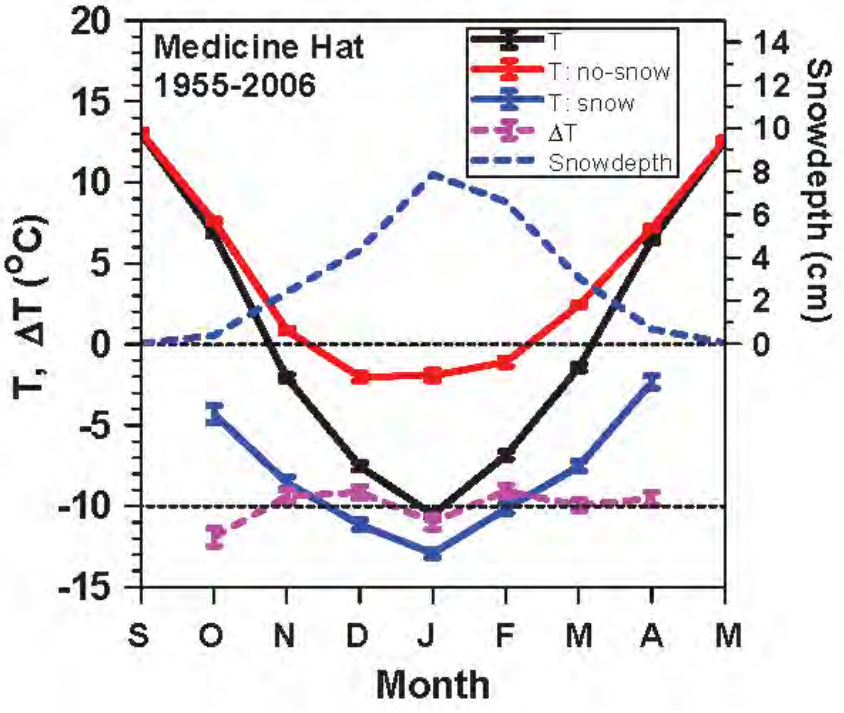
More snow cover - Colder temperatures



Betts et al. 2014

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)

Impact of Snow

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

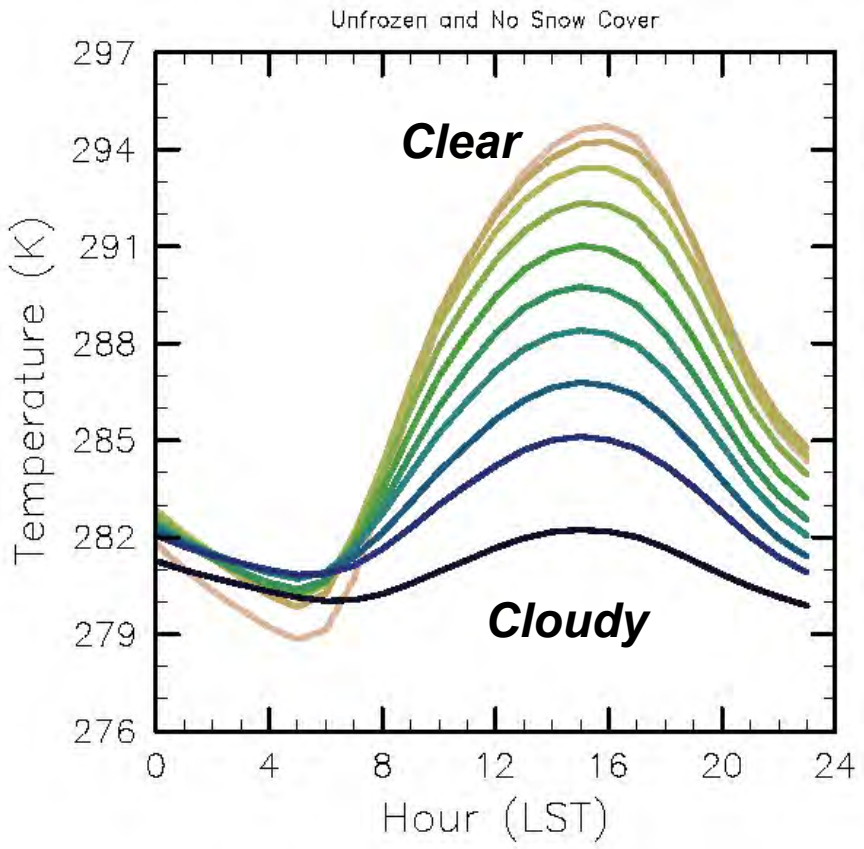
With snow

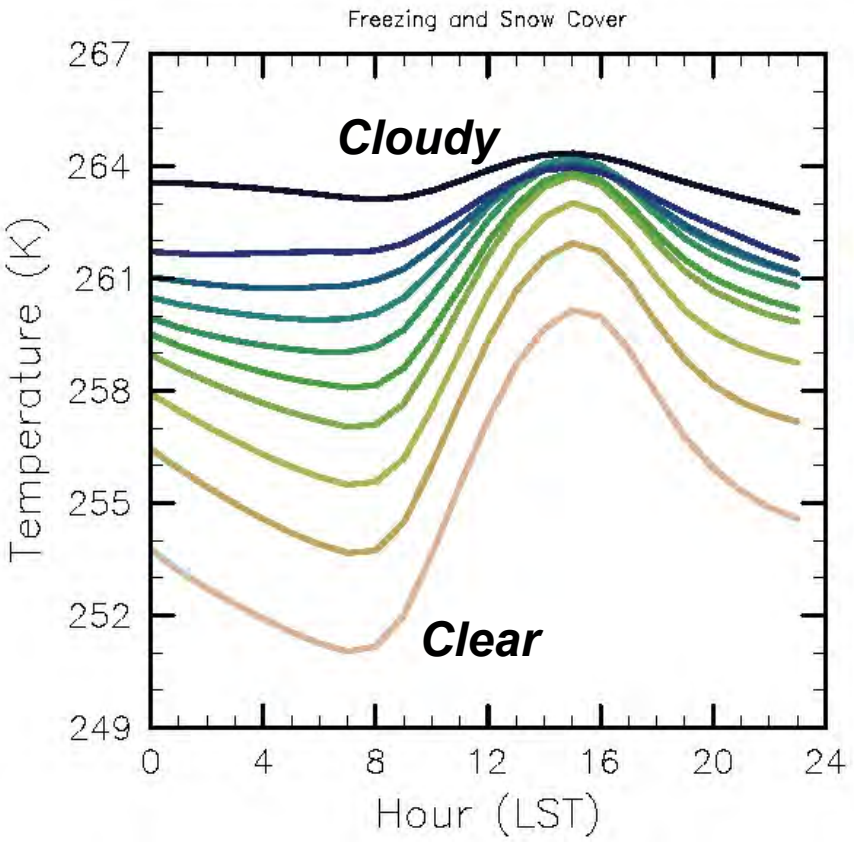
- **Prairies: Temperature falls 10°C (18°F)**
  - **snow reflects 70%**
- **Vermont: Temperature falls 6°C (10°F)**
  - **snow reflects 35% (because more forest)**

Warm & Cold Climates: T><0°C

T_m >0°C: no snow: 150,000 days

T_m <0°C: snow: 75,000 days

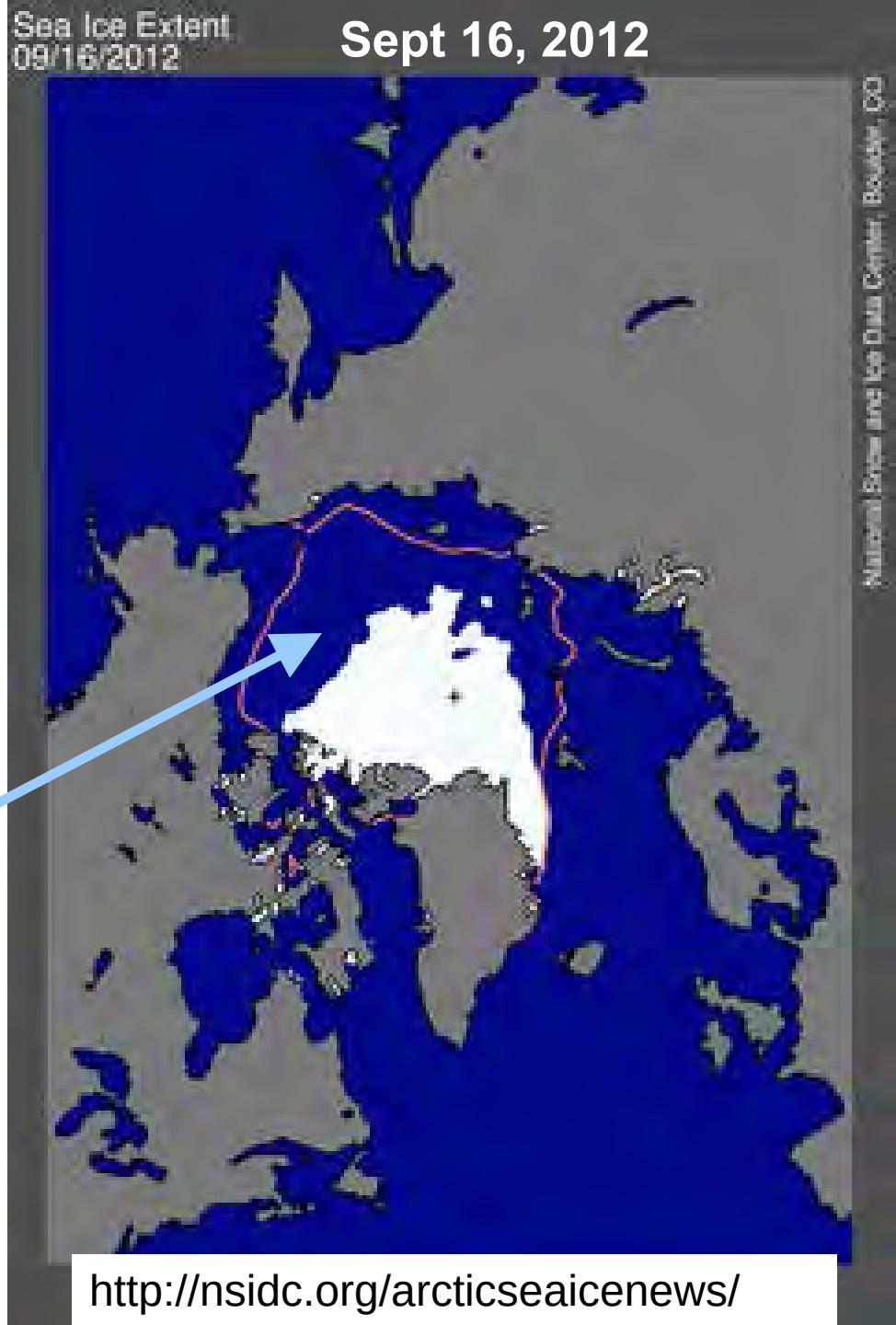




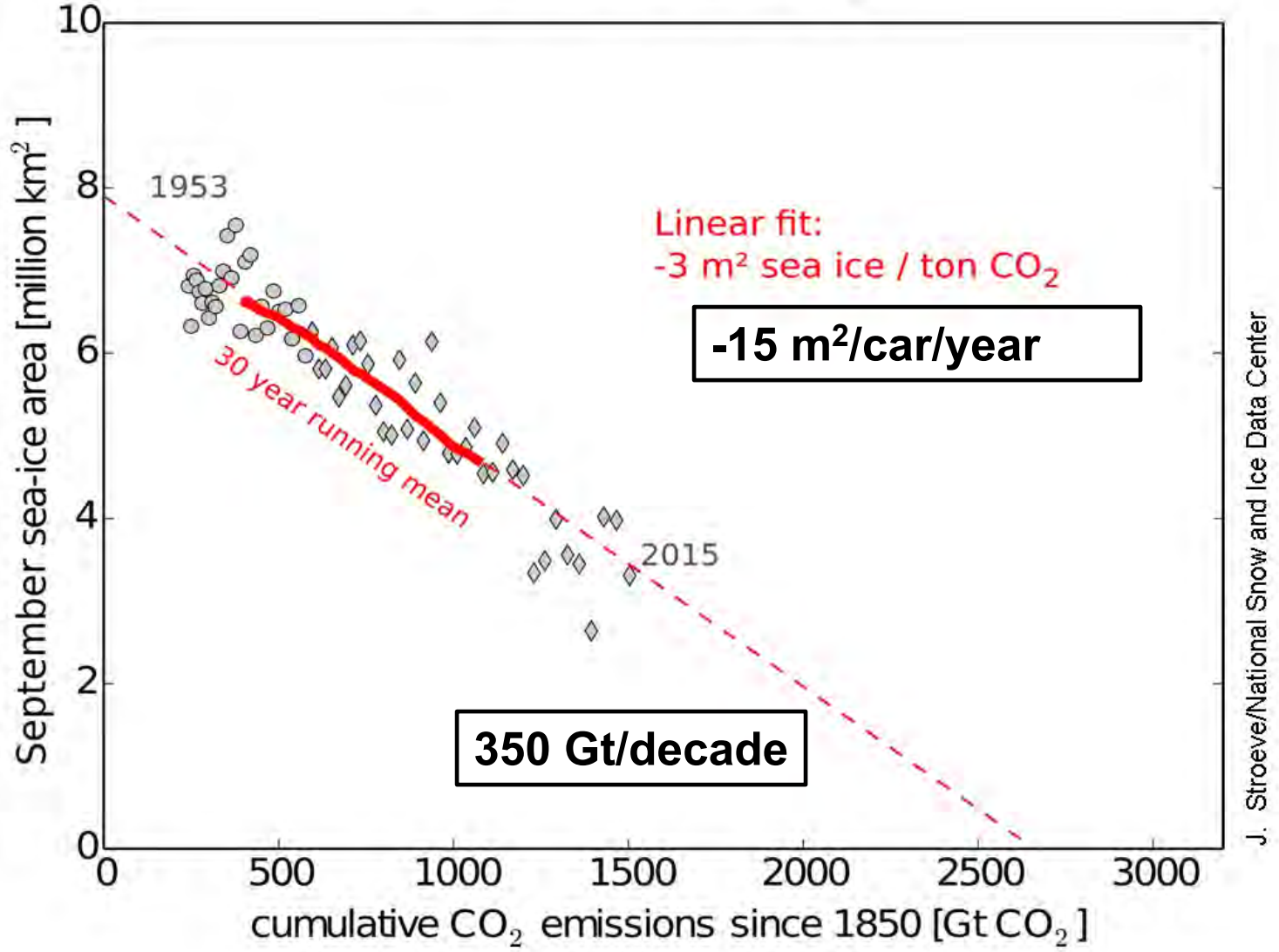
- **Warm >0°C:** Clouds reflect sunlight
- **Cold <0°C:** Clouds are greenhouse & snow reflects sun

- **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***



September Arctic Sea Ice Loss



Efficient transport

- **Gasoline to hybrid: 50% gain to 50mpg**
- **Hybrid to plug-in hybrid: now 130mpg**
- **Electricity from community solar array**

>3000lbs and 130 mpg
Payload: 750 lbs at 60 mph

180lbs gets “1800 mpg”
Payload: 350lbs at 25mph

Can We Stop "Dangerous Climate Change"?

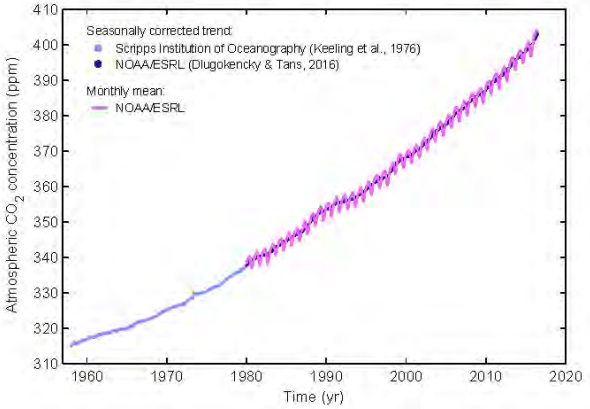
(UNFCCC 1992)

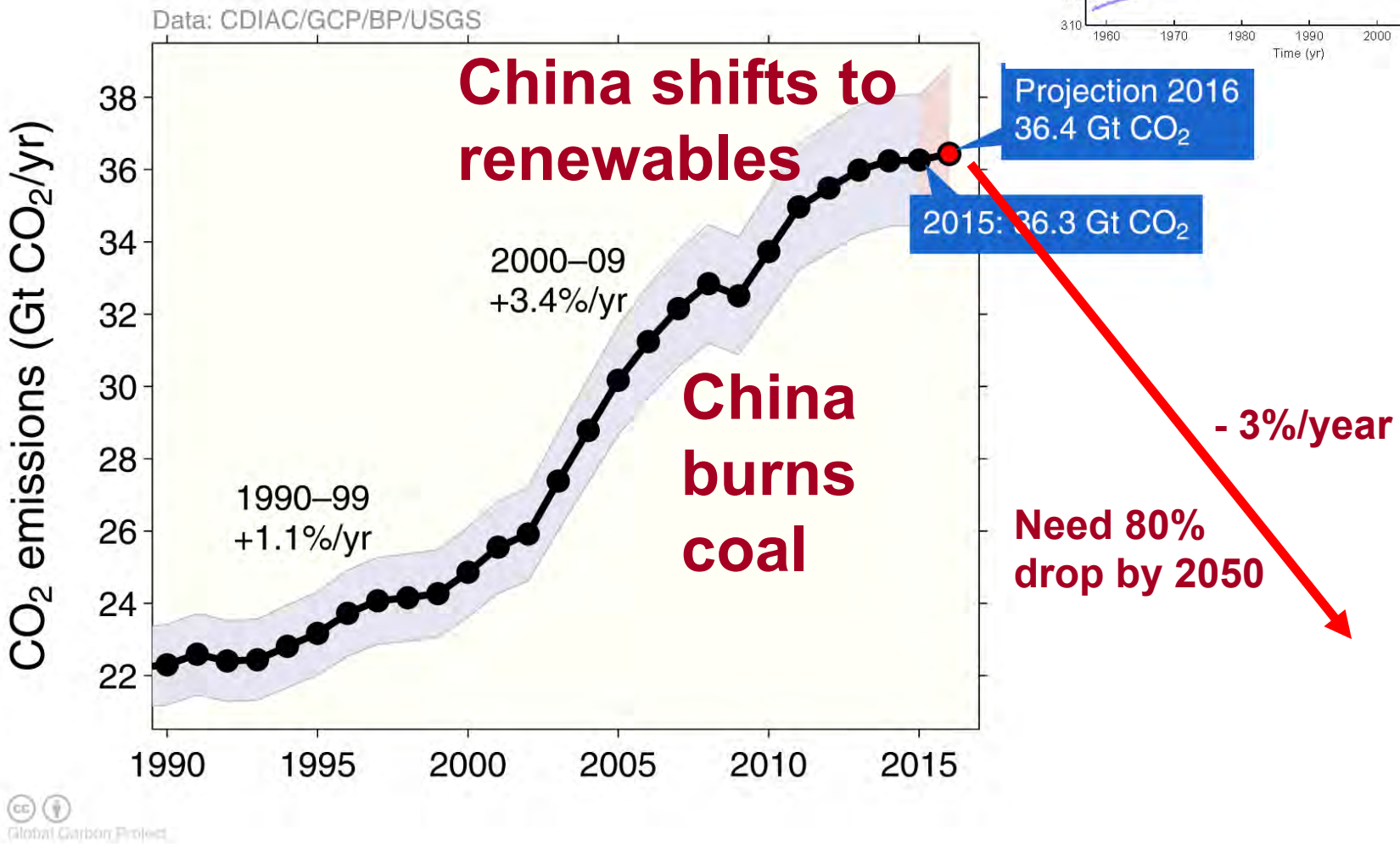
- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 emissions!**
- **This is possible but very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **"Lifestyle" has become dependent on fossil fuels**
  - **Powerful vested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

Growth of CO_2 Emissions has slowed





What can we “safely” burn?

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

How do we do it?
Systems Engineering

- ***Change the rule-book from Maximizing Profit***
- **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**

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***

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: '<u>others</u>' can pay the price**
- ***Our politics are facing collapse:***

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

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**

Scientific Integrity

- **What are the challenges scientists face?**
  - **Complex living systems: balanced, accurate assessment is always challenging**
  - **Social resistance to change**
  - **Political hostility/attempts to silence scientists**
  - **Corruption in the system at many levels**
- **Rapid change over your lifetime**
  - **Scientific, technical and social challenges**
  - **Climate refugees, internal and from overseas**

What are the Responsibilities of Environmental Scientists?

- **Just do research**
  - **The research funded by society**
  - **Leave policy to 'others'**
  - **Avoid public discussion, education and politics?**

- **Or accept that understanding brings responsibility**
  - **For the future of society**
  - **For the future of the Earth and its ecosystems**

Discussion

(http://alanbetts.com)

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***

‘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***