

The Climate Change Challenge

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Killington Rotary
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Outline of this talk

- **What is happening to**
 - Global climate
 - Climate of Vermont
- **Broader issues**
 - System issues
 - Social issues (far beyond science)



Fundamentals

- ***Burning fossil fuels: transforming climate***
 - *Many water cycle amplifying feedbacks*
 - *Heading for high CO₂ “Carboniferous era climate”*
 - *Oceans warming; Climate extremes increasing*
 - *Decadal to centennial - long timescales*
- **Avoidance of responsibility for decades**
 - Climate change: Incompatible with business-as-usual
 - Soluble: if create efficient society, based on renewable energy
- **Choices are value-based**
 - Science and economics need guidance
 - Market economy simply maximizes current profit

Climate Drivers

- Burning fossil fuels increases CO₂ and CH₄
- Amplified 3 times by water vapor increase, also strong greenhouse gas
 - Reduce cooling to space, while solar heating increases as snow and ice decrease
- *93% of Earth's warming is stored in oceans, giving stronger storms*
- Warming doubled in Arctic and winter by shrinking ice and snow
 - Changing mid-latitude weather; more stationary

Florence: N. Carolina Coast

Friday, 9/14/18
12:35pm EDT

Warm ocean
Rain >24in
Major flooding



New Bern: Saturday, 9/15



System Problem

- Human waste streams are transforming the Earth's climate, and human and natural ecosystems
 - This affecting climate, weather, water supplies, food system and human health
 - *Current financial interests vs Earth's future*
- New strategies and mindset needed to mitigate, adapt and build resilience
 - Is this an efficient way of doing this?
 - Can we manage our waste streams better?
 - Can we better manage our relation to the Earth?

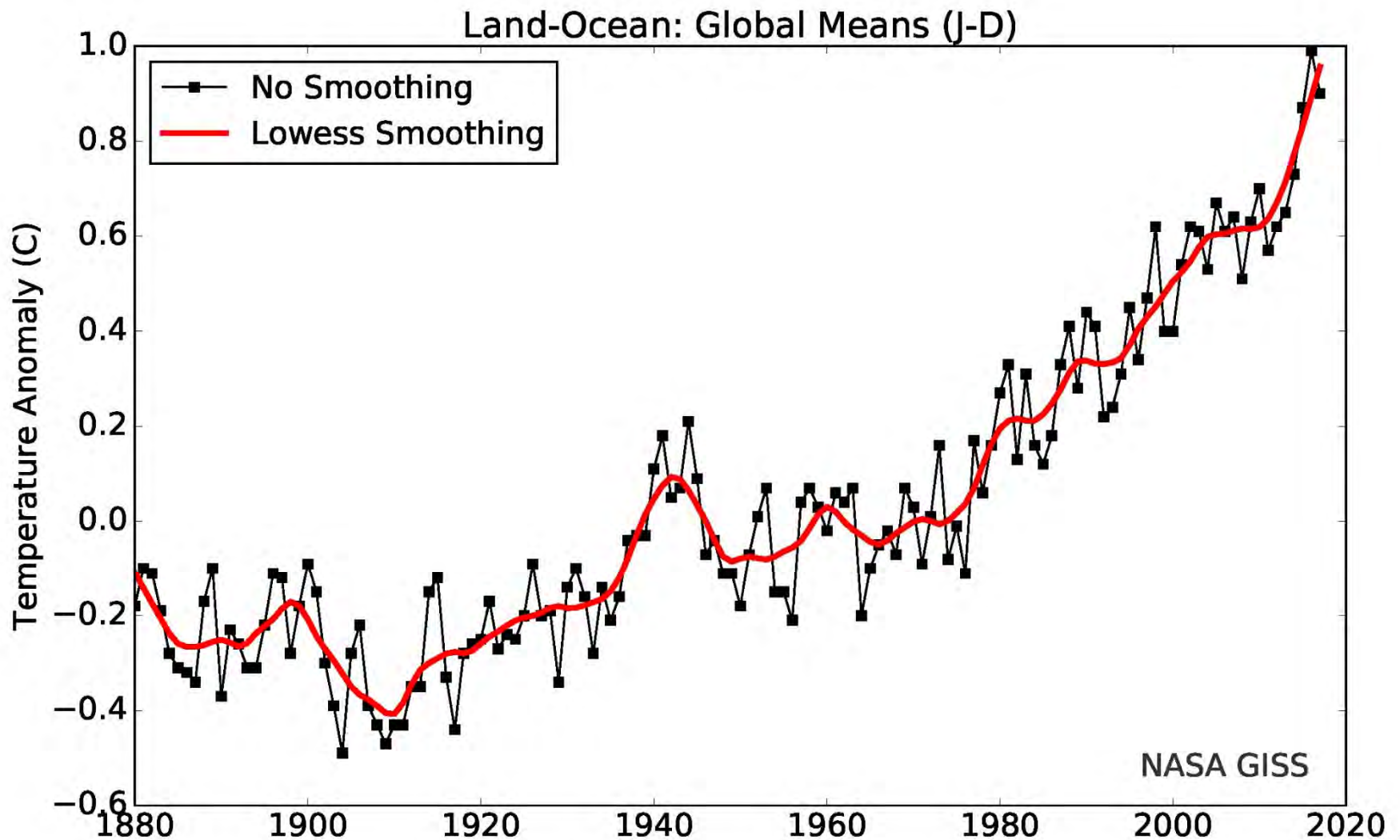
January 2, 2012: NASA

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: jet-streams changing



Global Trend: 1880-2017



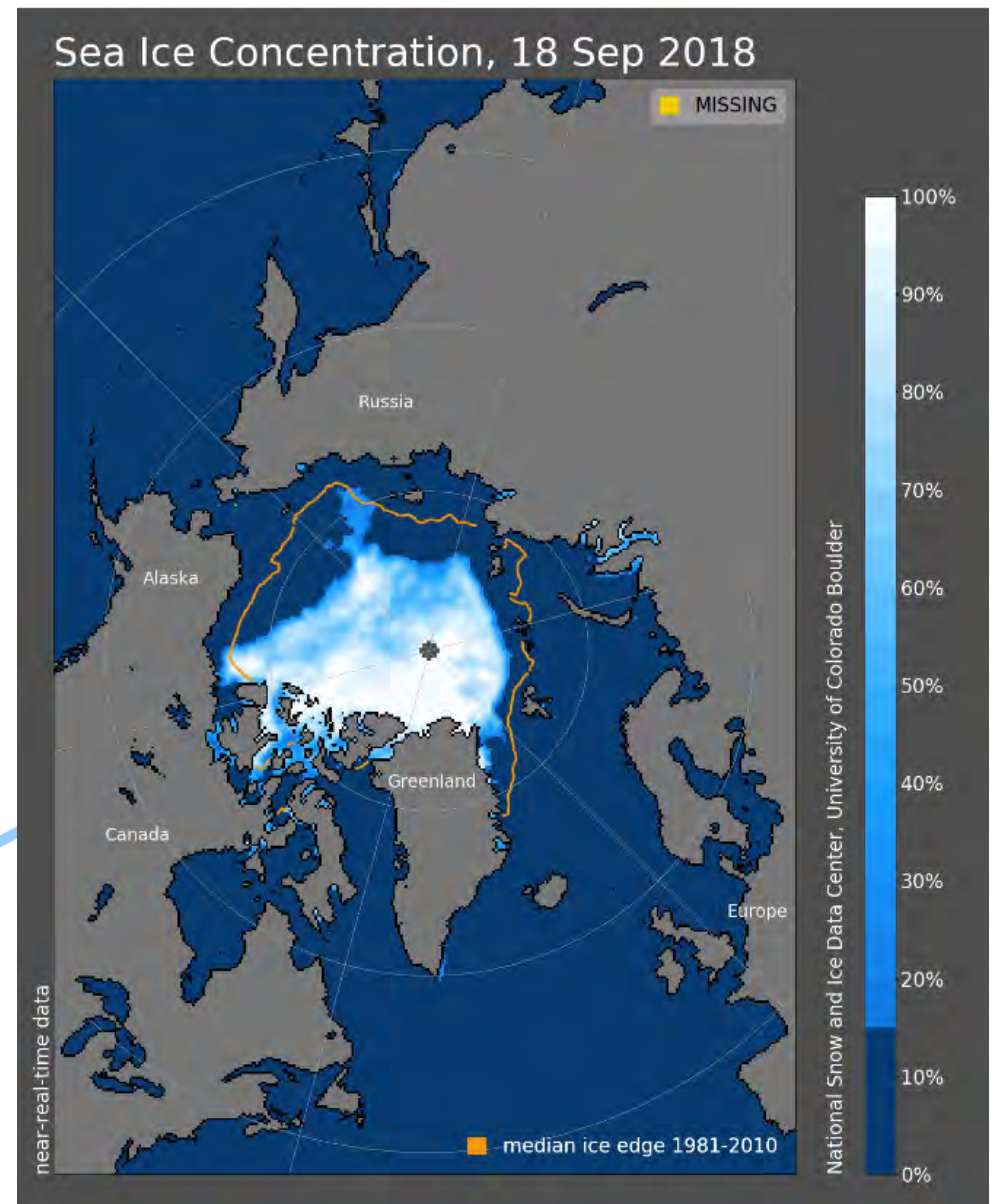
- Arctic warming twice as fast as globe
- Half the Arctic Sea Ice Melted in 2012
- Open water gives warmer Fall in Northeast

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



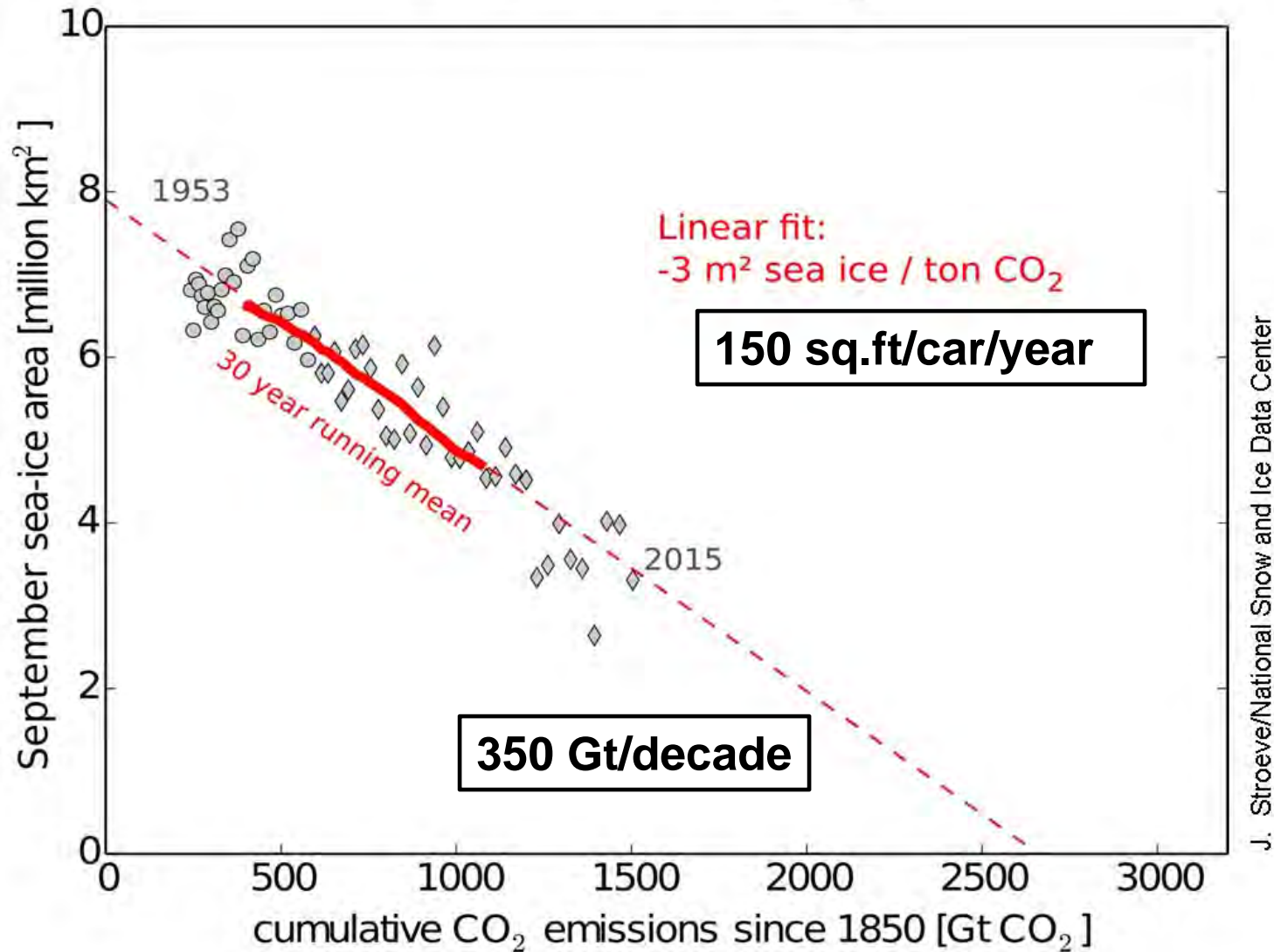
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<http://nsidc.org/arcticseaicenews/>

September Arctic Sea Ice Loss



Transport: big CO₂ source

- High tech solution: convert all to electric cars
 - Means large investment in new infrastructure: good for economy!
- *Cheap solution: plug-in hybrids, which reduce fossil fuels use by 80% with no compromises*
- Annual auto fuel efficiency in Vermont: 25mpg
- *Plug-in hybrid: 135 mpg: fixes problem, saves \$*



2017 Prius Prime

**Cost \$30000, less \$4500
tax credit**

**All-electric range: 28
miles**

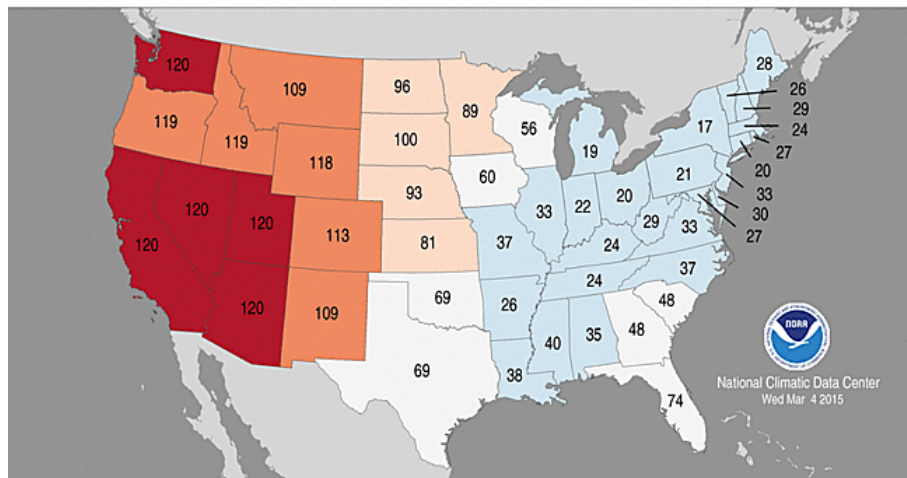
Hybrid range: 600+ miles

(I am not a salesman!)

- **22000 miles; 50% electric, 50% hybrid: 136 mpg**
 - **12000 miles/year: 88 gallons/year; 1400 KWh/year**
 - **Compare 25 mpg car: 480 gals, cost \$1344**
 - **Saves: \$1344 – (246+252) = \$846 annual savings**
- **Most efficient car on market (*better than Tesla!*)**
 - **Running hybrid gets 68 mpg on VT roads at 50 mph**
 - **Long-trip: 2100 mile: avg 82 mpg (night plug-in)**
- ***So why doesn't Toyota advertise them?***

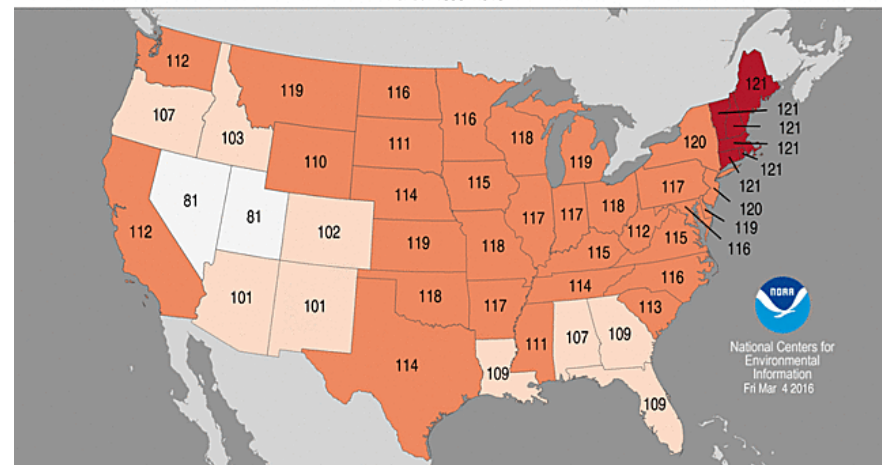
DJF2015 Statewide Average Temperature Ranks

December 2014–February 2015
Period: 1895–2015



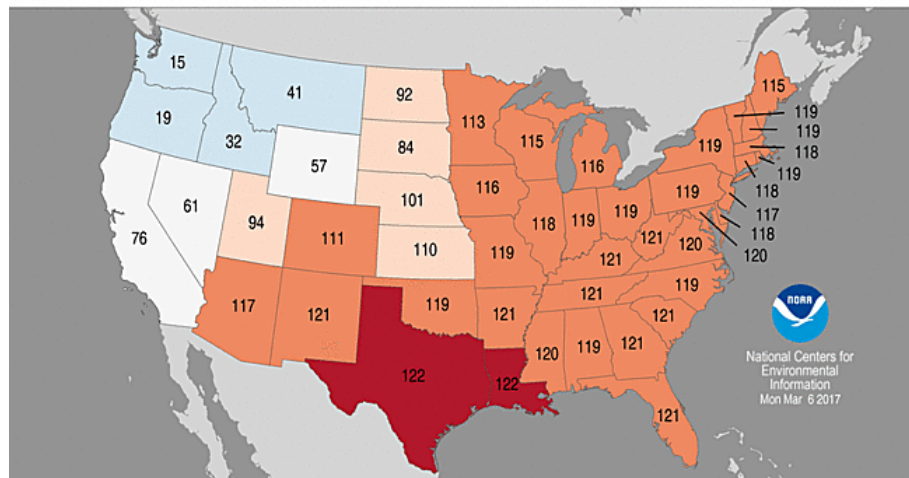
DJF2016 Statewide Average Temperature Ranks

December 2015–February 2016
Period: 1895–2016



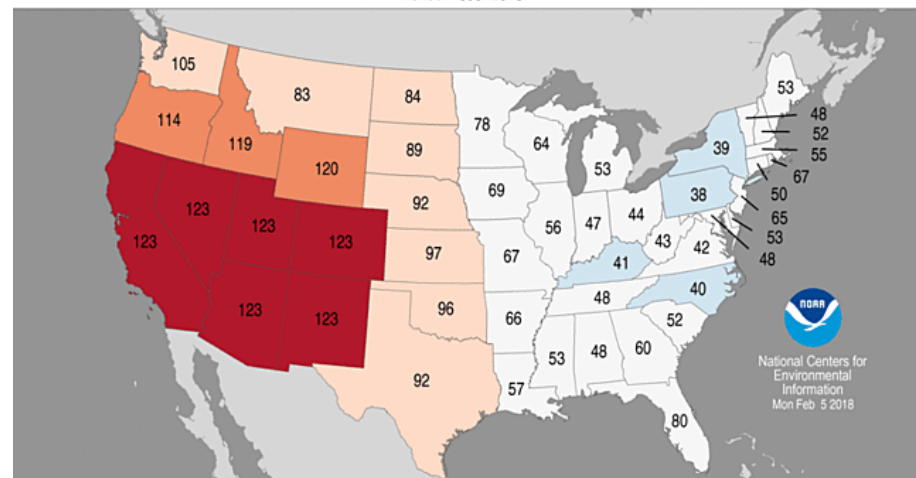
DJF2017 Statewide Average Temperature Ranks

December 2016–February 2017
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NDJ2018 Statewide Average Temperature Ranks

November 2017–January 2018
Period: 1895–2018



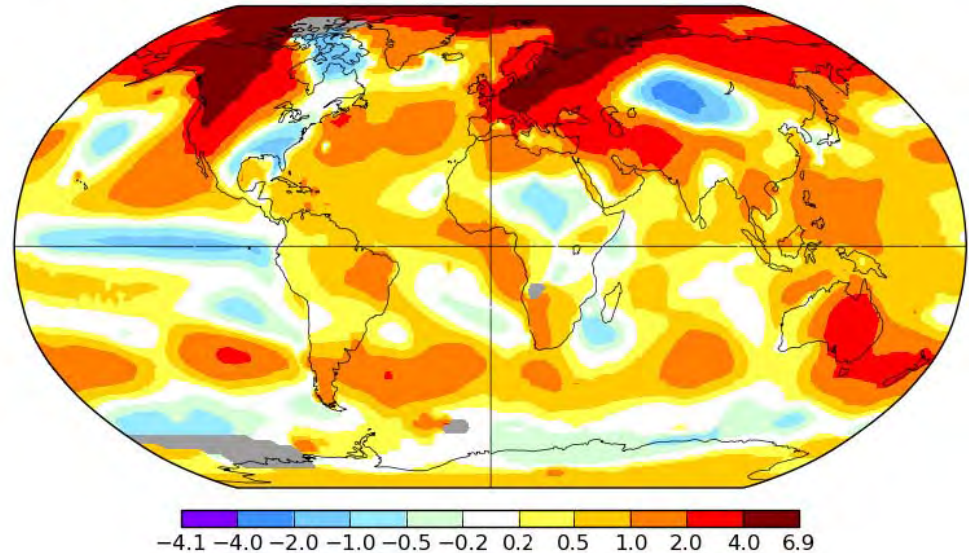
Jan-2018

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

January 2018

L-OTI(°C) Anomaly vs 1951-1980

0.79



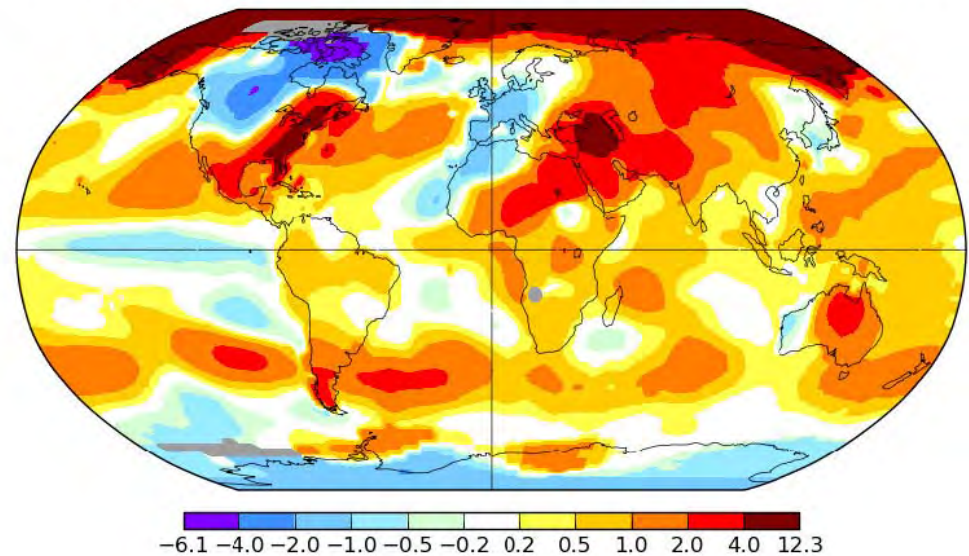
Feb-2018

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

February 2018

L-OTI(°C) Anomaly vs 1951-1980

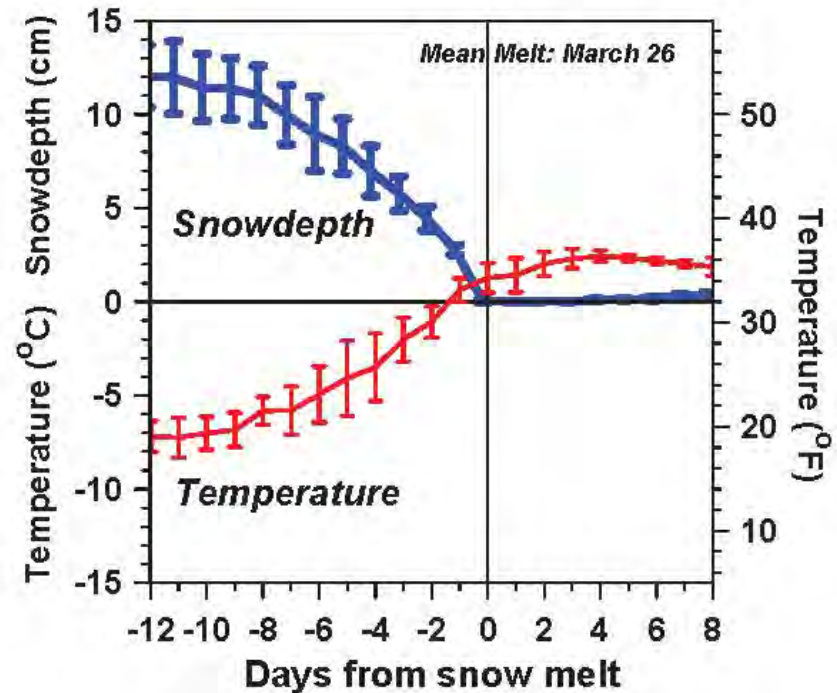
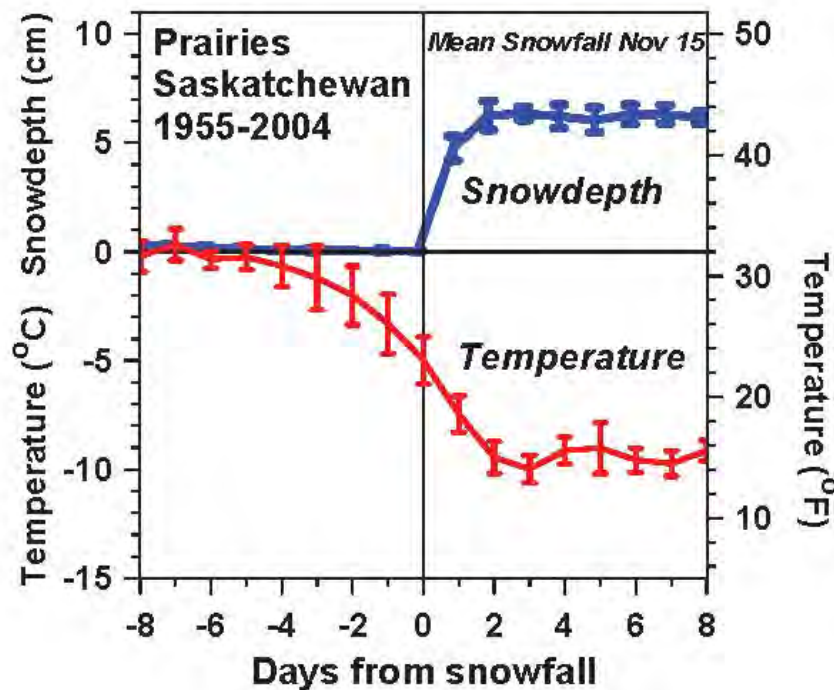
0.79



March 2018: 4 Nor'Easter snowstorms

Snowfall and Snowmelt

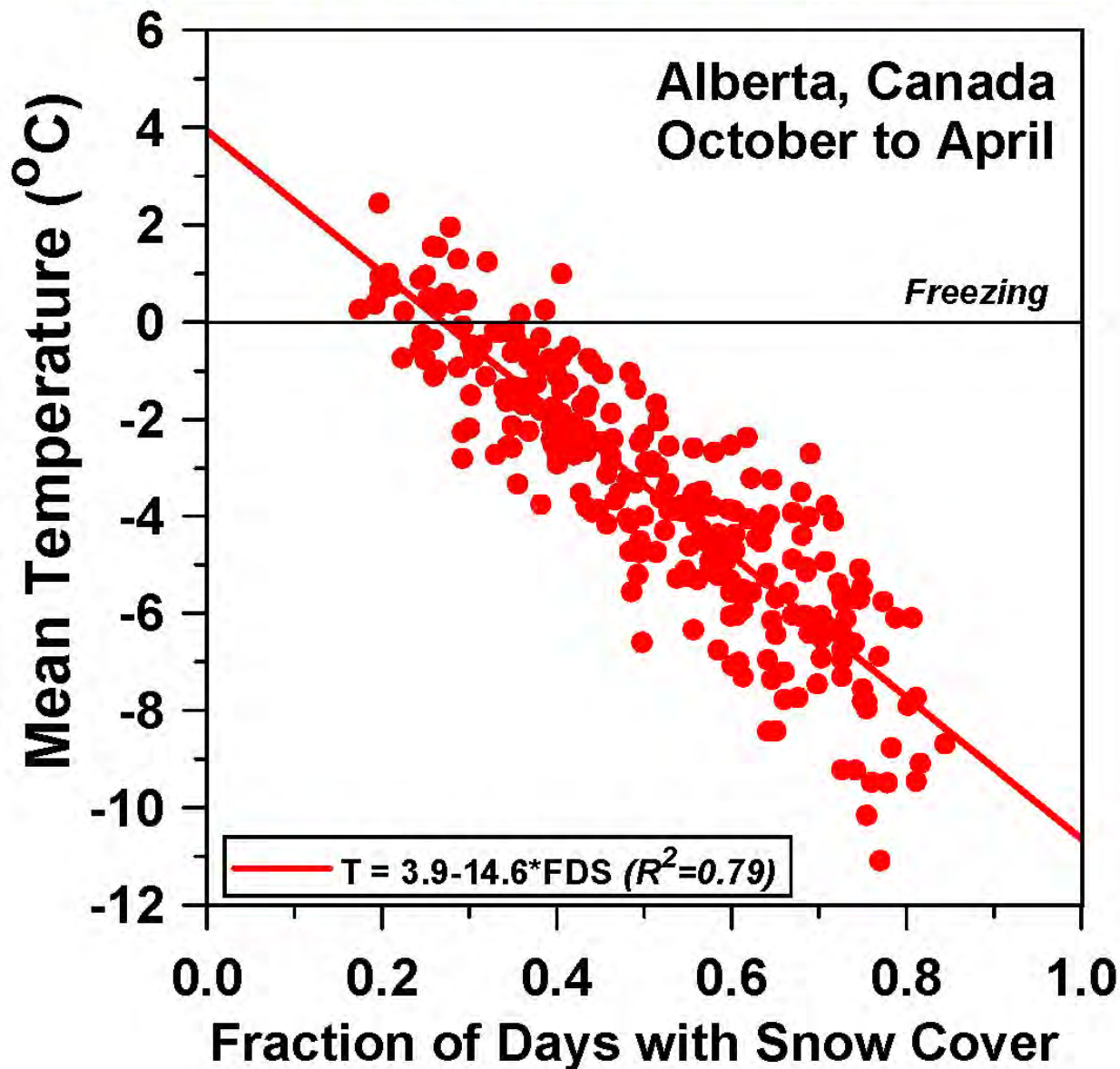
Winter and Spring transitions



- Temperature falls/rises about 18F with first snowfall/snowmelt
- *Snow reflects sunlight; shift to cold stable boundary layer*
 - 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

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)



January 10 and 12, 2018



January 10, 2018

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

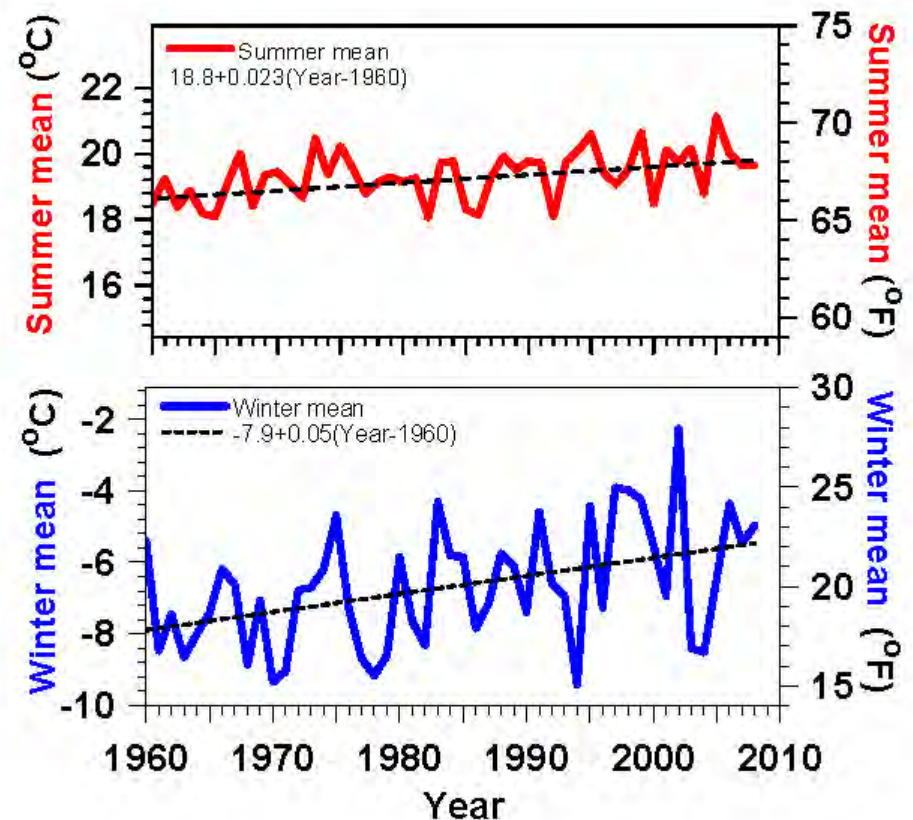


January 12, 2018

After T_{\max} up to 50F

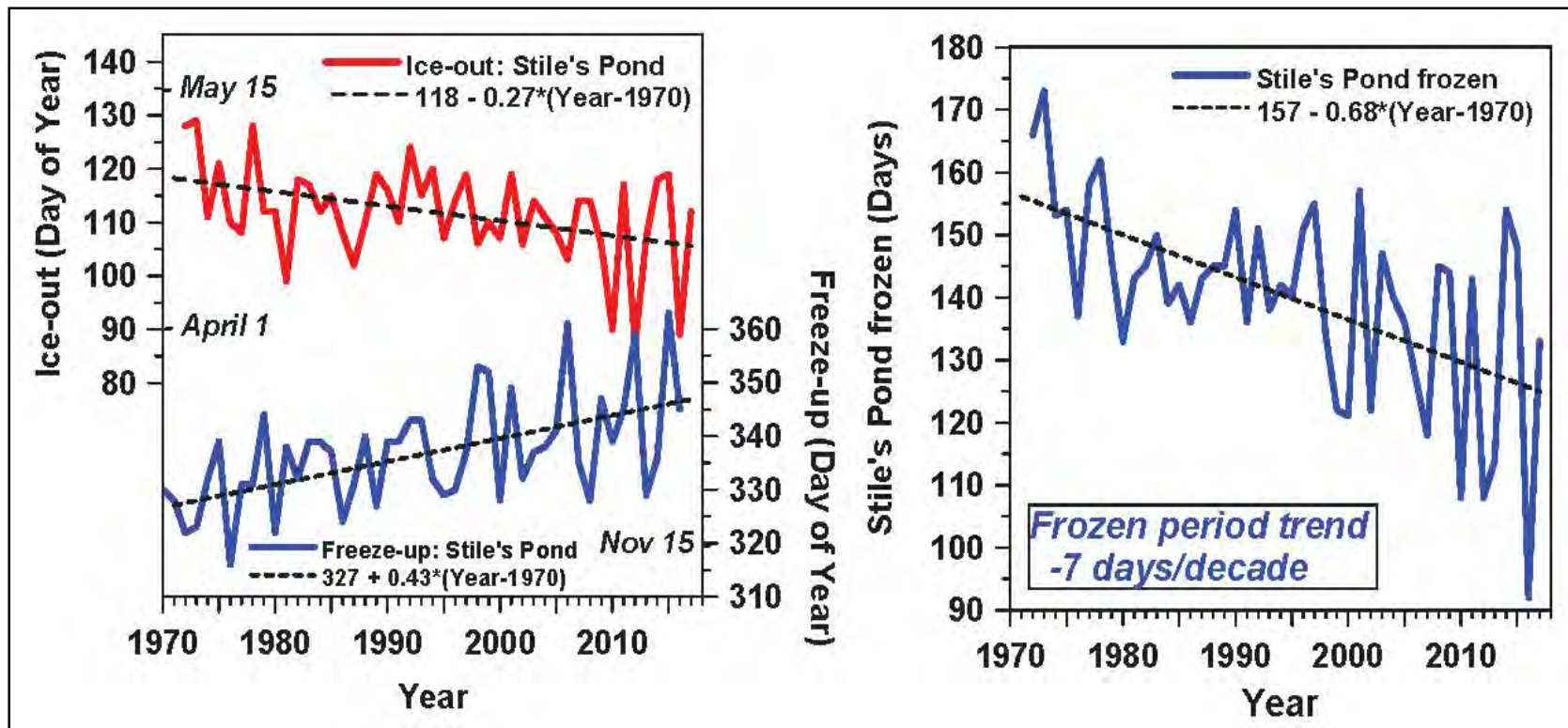
Vermont Temperature Trends 1961-2008

- **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***



Marker: Lake Freeze-up & Ice-out

Frozen Period Shrinking: variability huge

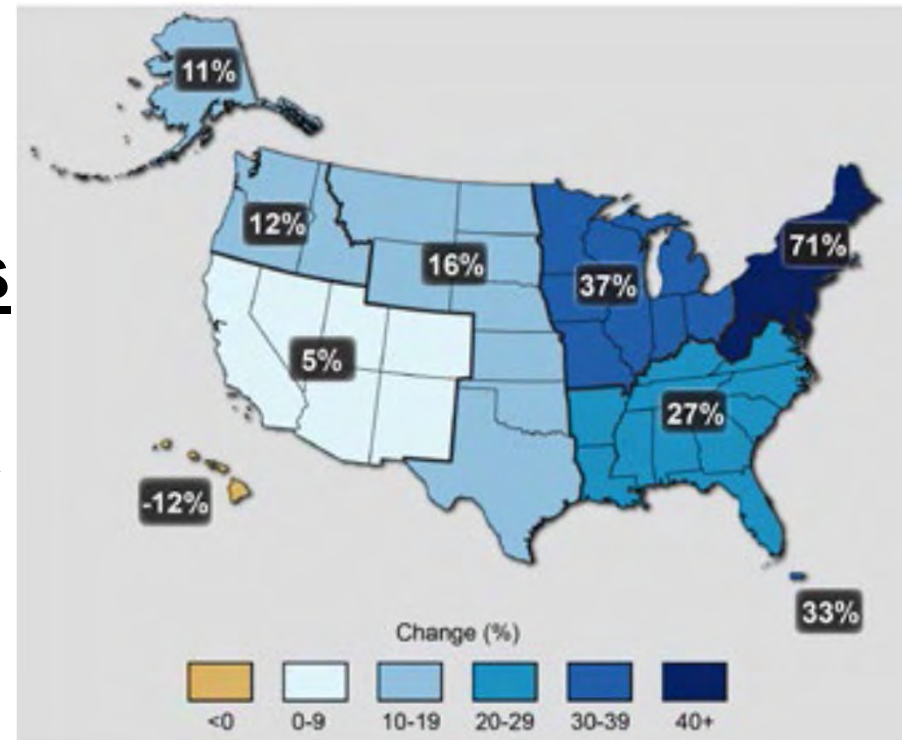


- Freeze-up later by **+4 days / decade**
- Ice-out earlier by **-3 days / decade**
- Lake frozen period trend **- 7 days/decade**
- *Interannual variability \approx 50 yr trend*

*Stiles Pond:
"Eye on the Sky"*

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***



Value of Flood Plains



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

2011 Classic Flood Situations

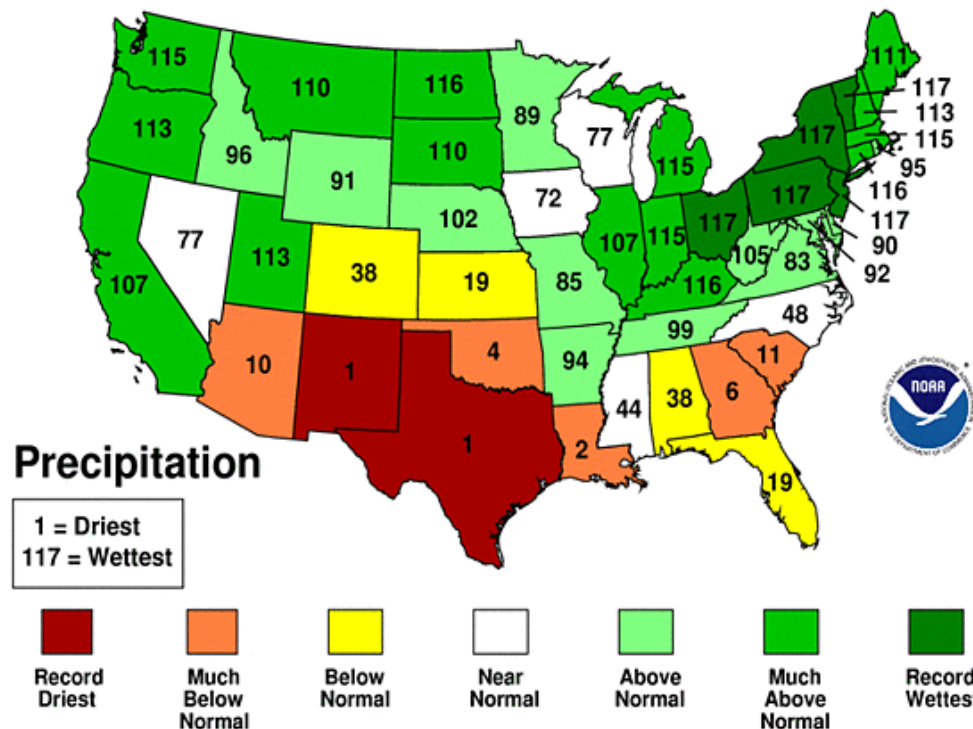
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010 winter
 - 70F (4/11) and 80F(5/27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical storm**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

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



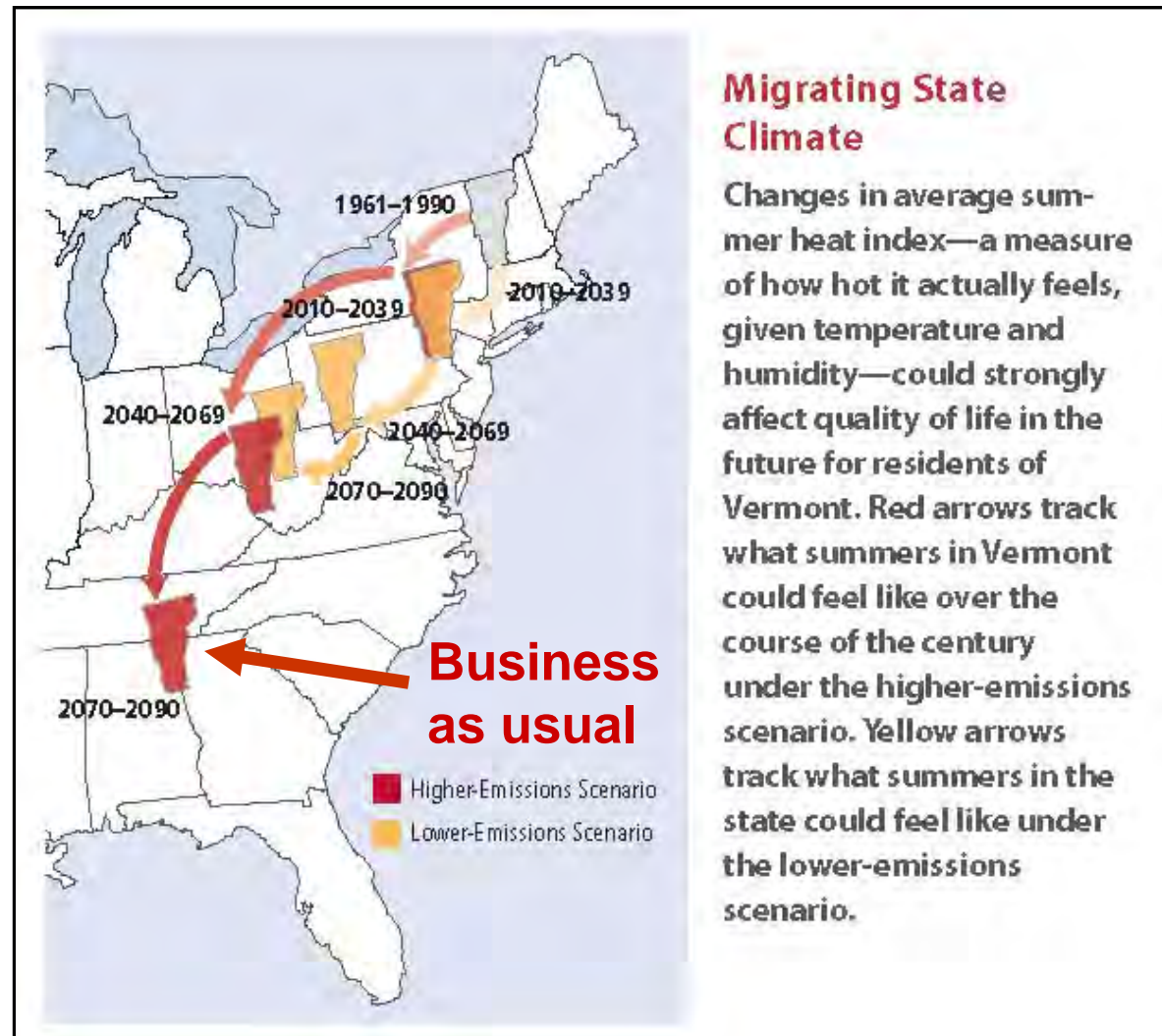
March-August, 2011

- Record wet : OH to VT
- Record drought: TX & NM
- Pattern nearly stationary

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



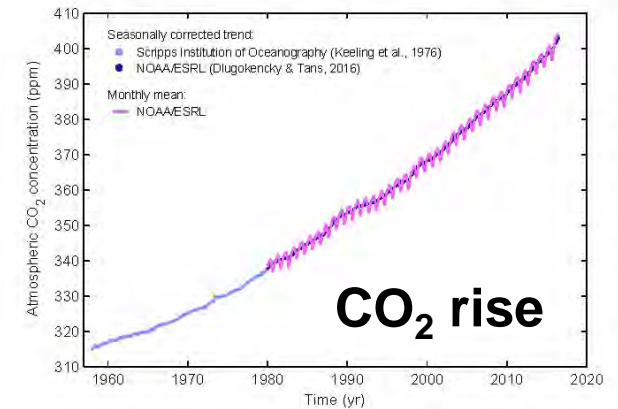
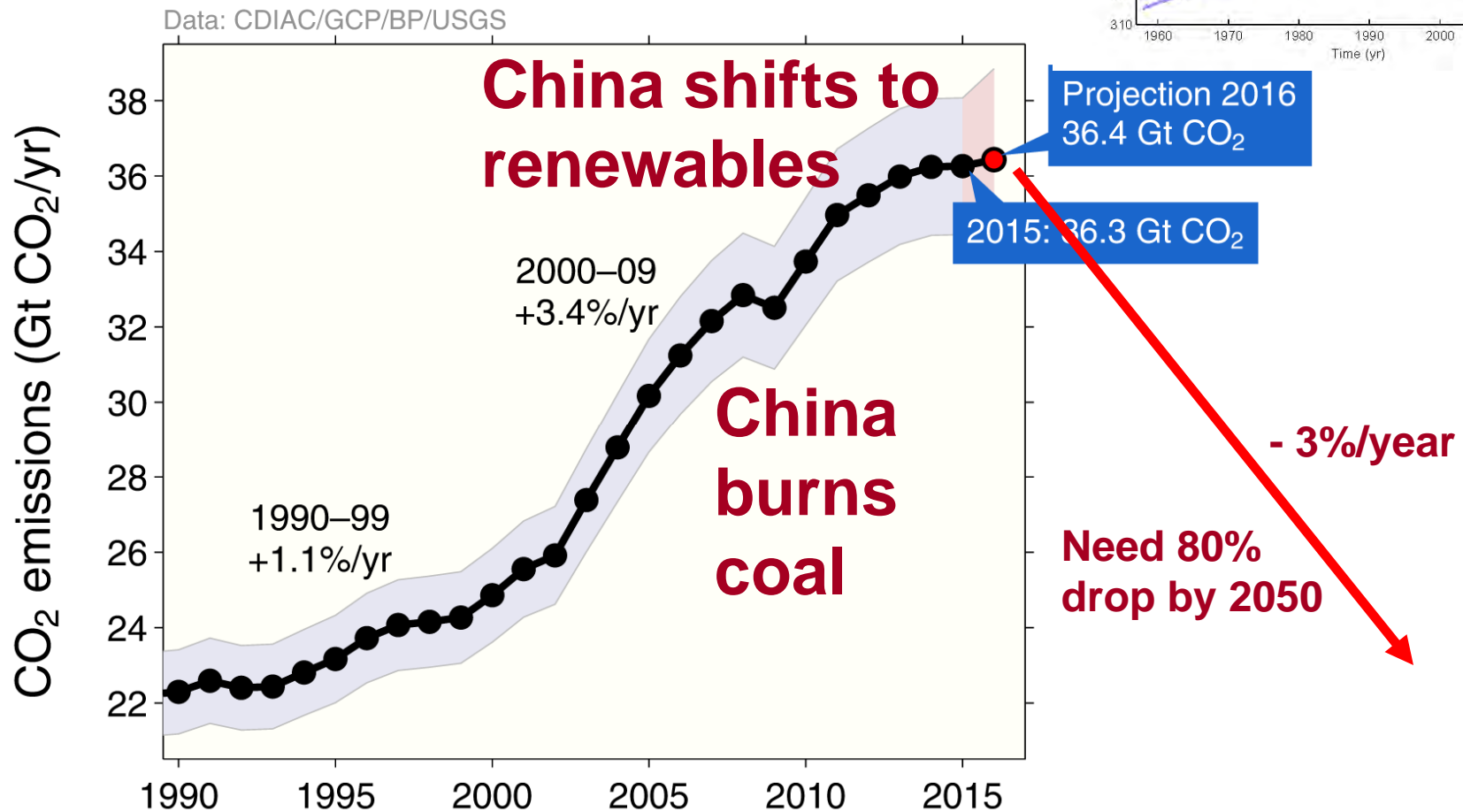
**NECIA,
2007**

Can We Stop “Dangerous Climate Change”?

(UNFCCC 1992)

- **Yes:** Quickly stabilize atmospheric CO₂
- This means an 80% drop in CO₂ 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

Growth of CO₂ Emissions Flat for 3 years



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*

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*
- Only 21 years left at 36 Gt/year
- *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 led 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 CO₂ to 1,000 ppm**
 - *Radically change climate/wipe out many species*
 - *Flood coastal cities as icecaps melt: and over centuries raise sea-level >100ft*

Powerful interests are threatened

- **Fossil fuels reserves are worth \$20-30T**
 - Big money: ‘of course we will burn them’
 - Regulating or taxing emissions of CO₂ is an ‘unfair cost to the free market’
 - *(Too bad if the Earth’s ecosystems are destroyed: **our kids can pay the price**)*
- ***Our politics are facing collapse:
fantasy disconnected from real world***
 - *We are all deeply embedded in system*

Step back from dark side

- **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*

Efficient transport

- Gasoline to hybrid: 50% gain to 50mpg
- Hybrid to plug-in hybrid: now 135mpg
- Electricity from community solar array



>3000lbs and 135 mpg
Payload: 750 lbs at 65 mph



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

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*
 - *Reconnect with the natural world*
- *Will we turn the ship around?!*

Discussion

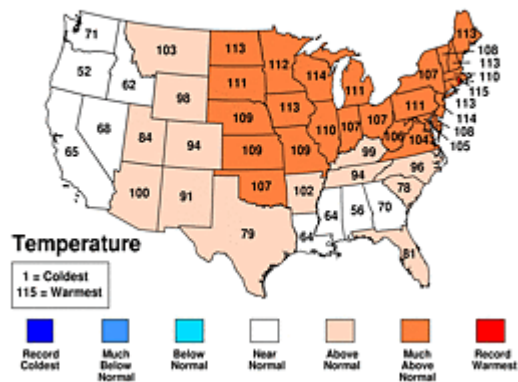
alanbetts.com

*(this talk and
many articles)*

November: 2009-2017: 5 'cool': 4 'warm'

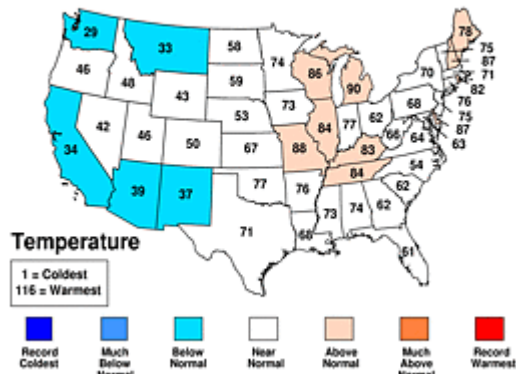
November 2009 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



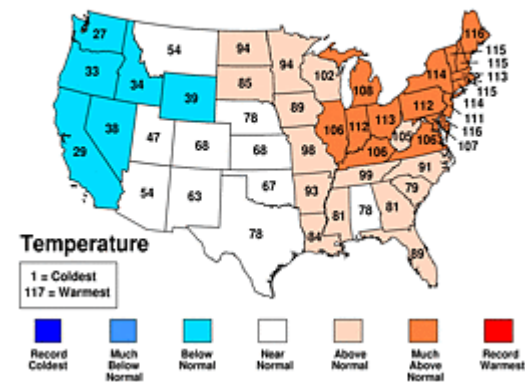
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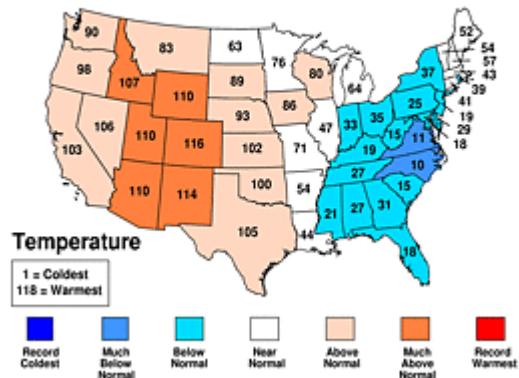
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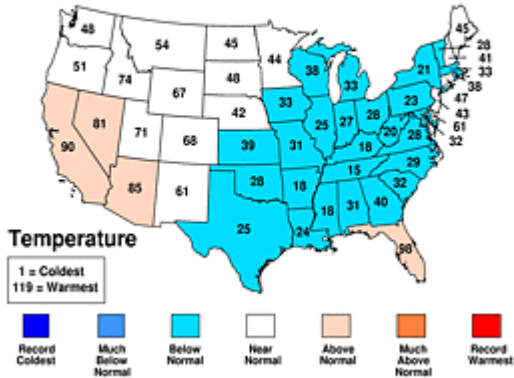
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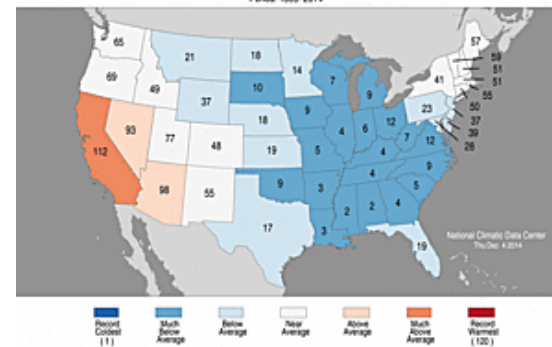
November 2013 Statewide Ranks

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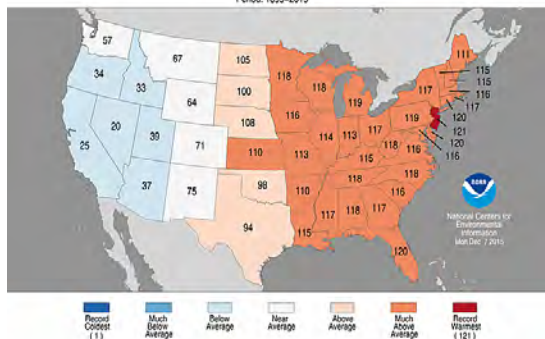
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November 2014
Period: 1895-2014



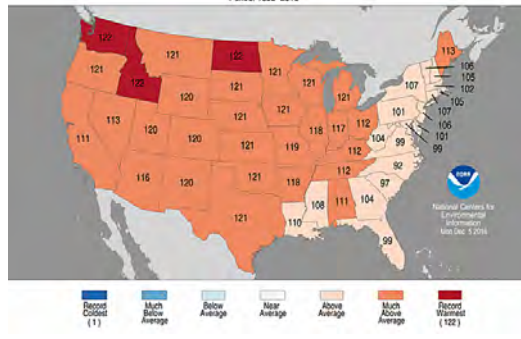
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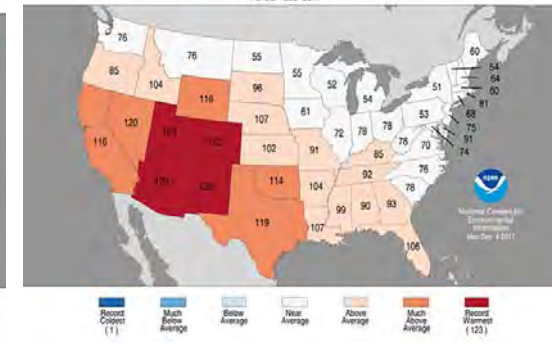
Statewide Average Temperature Ranks

November 2016
Period: 1895-2016



Statewide Average Temperature Ranks

November 2017
Period: 1895-2017



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)

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!)***

