The Climate Change Challenge

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Rutland High School
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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)**

VERMONT EPSCoR

BREE Basin Resilience to Extreme Events in the Lake Champlain Basin

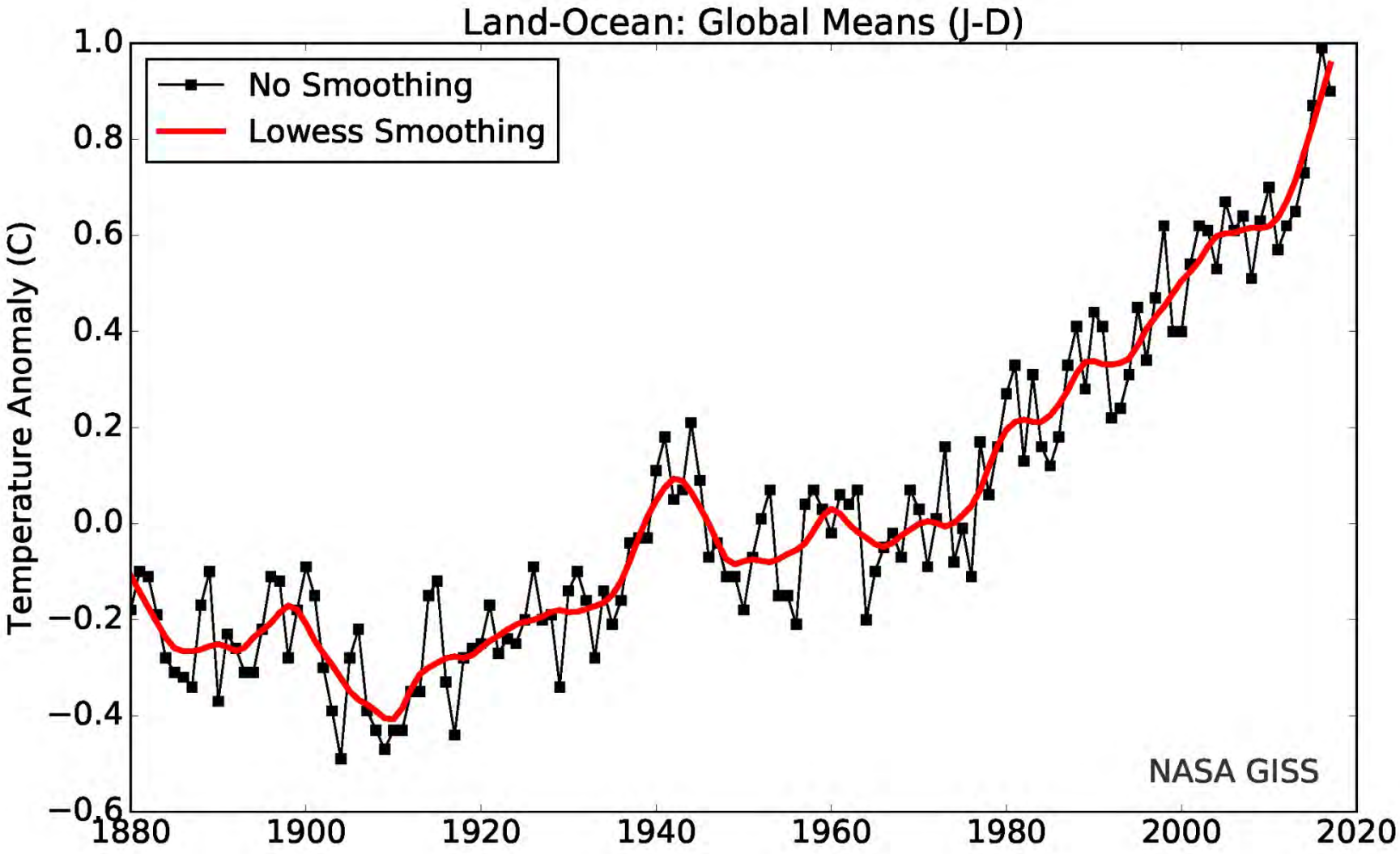
Fundamentals

- ***Burning fossil fuels: transforming climate***
  - ***Many water cycle amplifying feedbacks***
  - ***Heading for high CO_2 "Carboniferous era climate"***
  - ***Oceans warming; Climate extremes increasing***
  - ***Decadal to centennial - long timescales***
- **Avoidance of responsibility for decades**
  - **Climate change*: Incompatible with business-as-usual***
  - **Global ecology threatened by present path**
  - **Soluble: 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 CO_2**
- **Amplified 3 times by water vapor increase, also strong greenhouse gas**
  - ***Reduces cooling to space, and 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; larger amplitude jet stream waves, moving more slowly**

Global Trend: 1880-2017



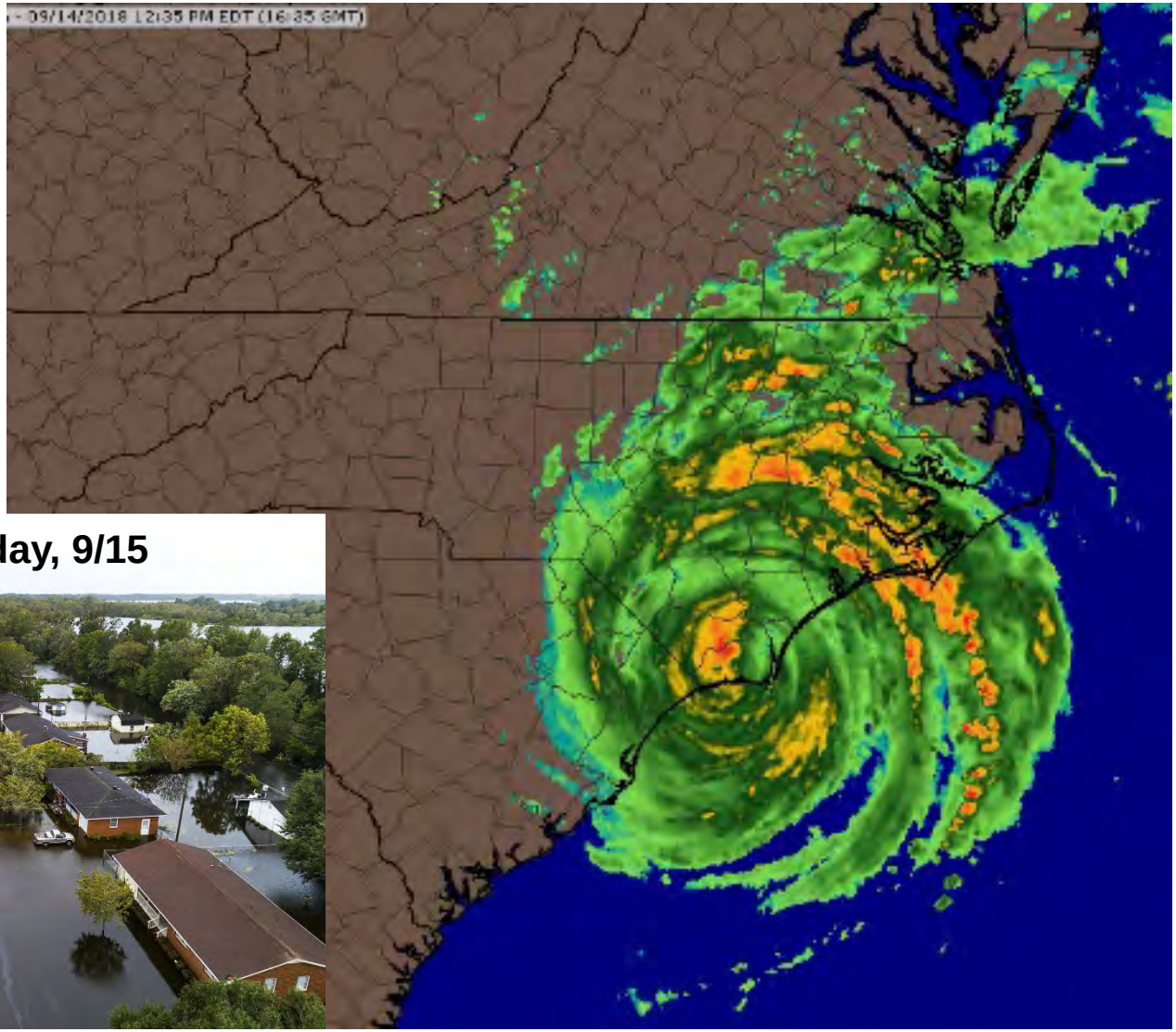
Earth's climate sustains life

- 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

Florence: N. Carolina Coast

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

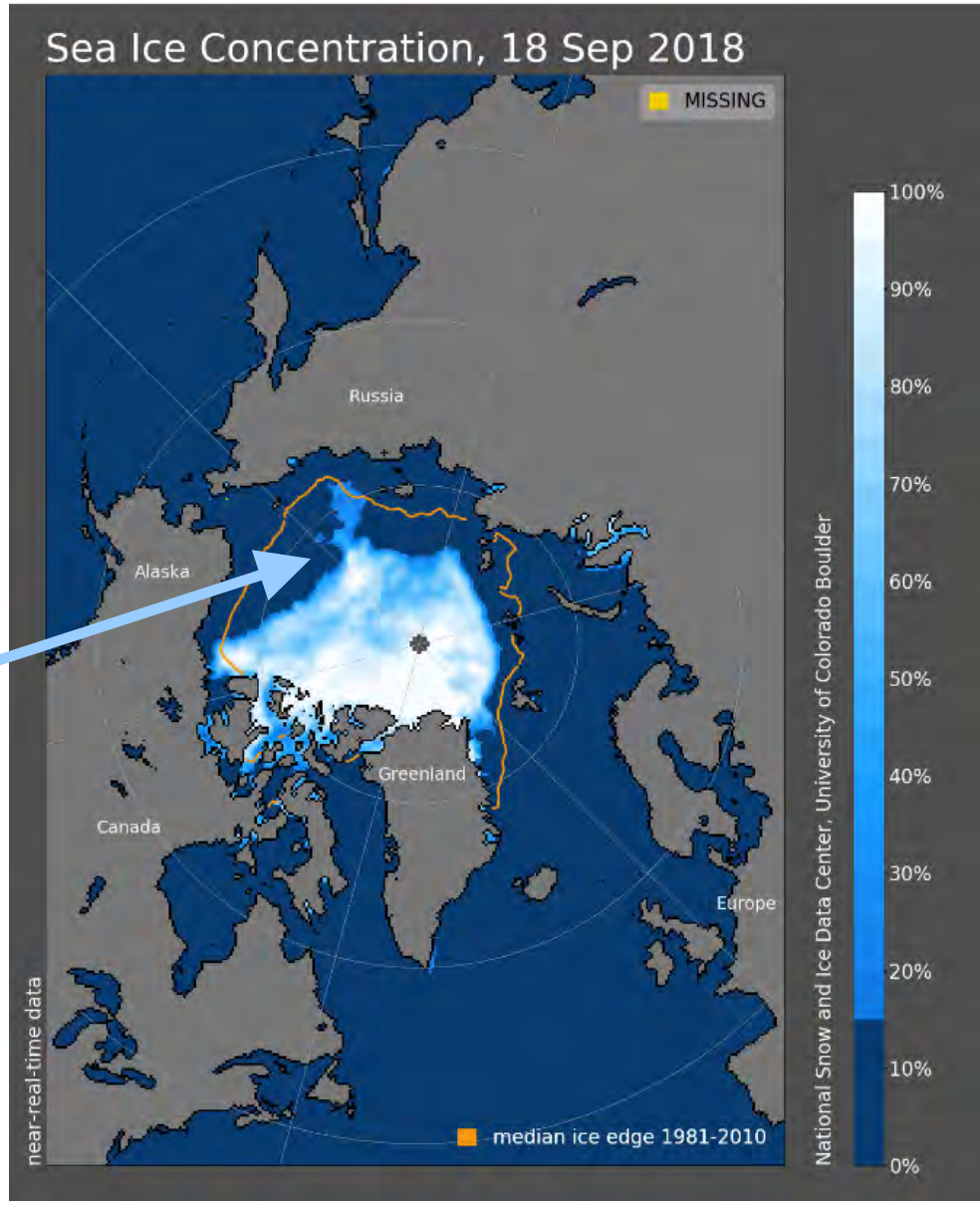
Warm ocean
Rain >24in
Major flooding



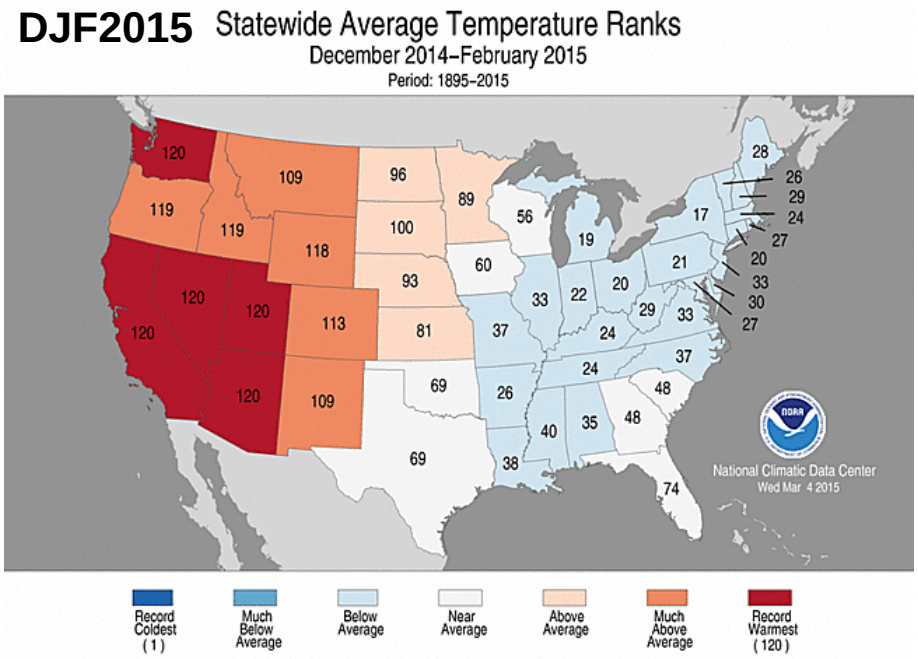
New Bern: Saturday, 9/15

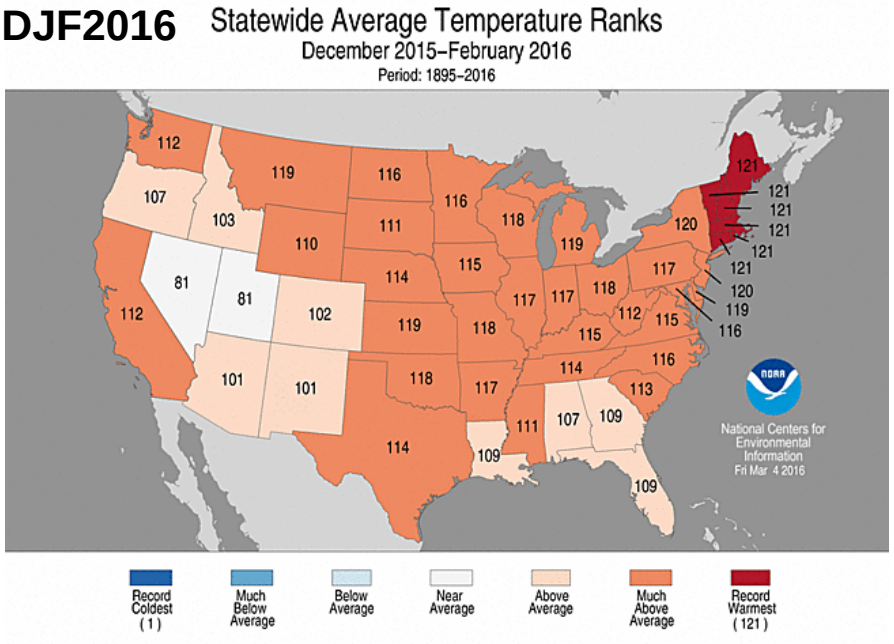
- **Arctic warming twice as fast as globe**
- **Losing Arctic Sea Ice**

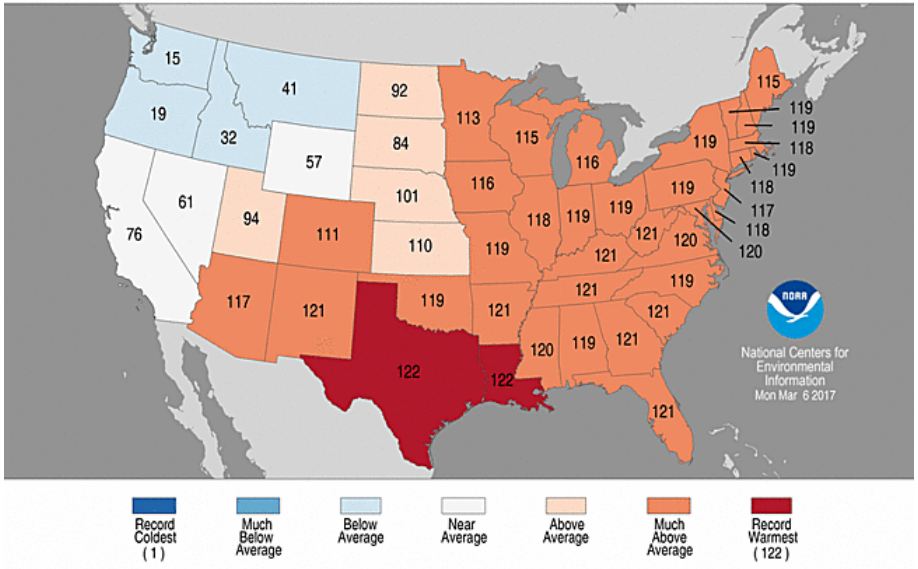
- ***Feedbacks amplify:***
- ***Less ice, less reflection of sunlight***
- ***More evaporation, larger vapor greenhouse effect***
- ***Same feedbacks as in our winters***

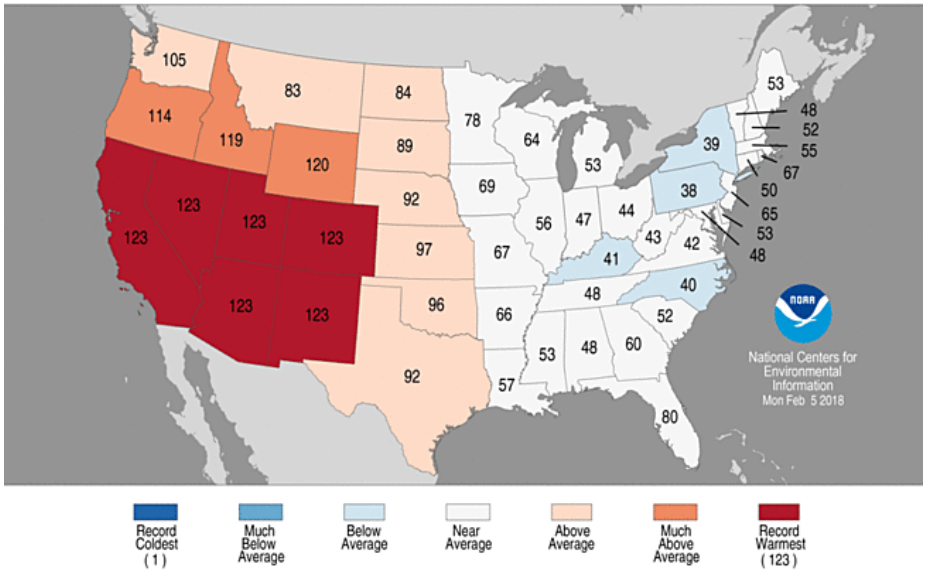


http://nsidc.org/arcticseaicenews/

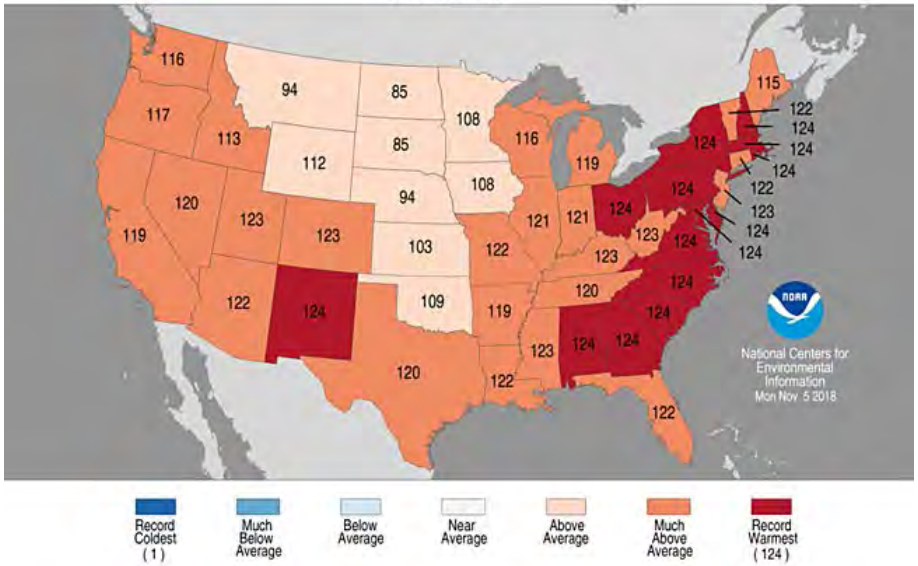

DJF2015
Statewide Average Temperature Ranks
December 2014–February 2015
Period: 1895–2015
National Climatic Data Center
Wed Mar 4 2015
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (120)


DJF2016
Statewide Average Temperature Ranks
December 2015–February 2016
Period: 1895–2016
National Centers for Environmental Information
Fri Mar 4 2016
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (121)

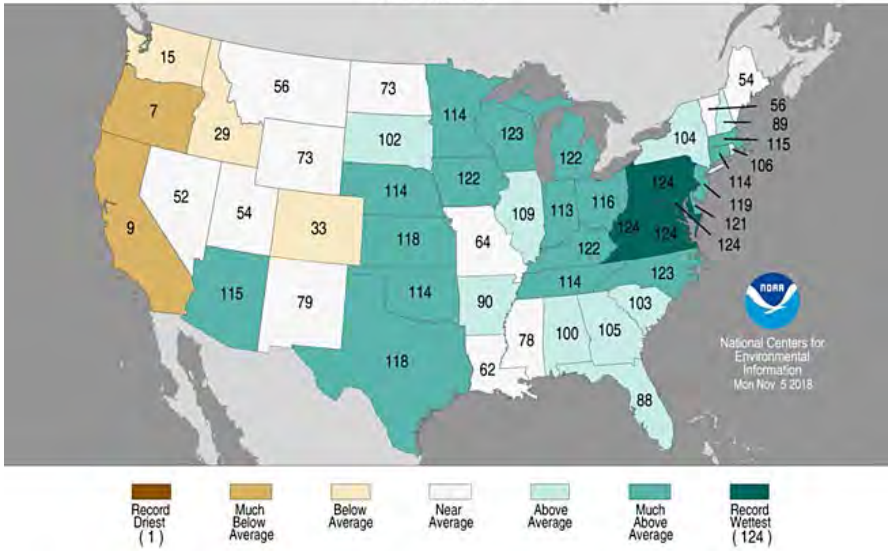

DJF2017
Statewide Average Temperature Ranks
December 2016–February 2017
Period: 1895–2017
National Centers for Environmental Information
Mon Mar 6 2017
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (122)


NDJ2018
Statewide Average Temperature Ranks
November 2017–January 2018
Period: 1895–2018
National Centers for Environmental Information
Mon Feb 5 2018
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (123)

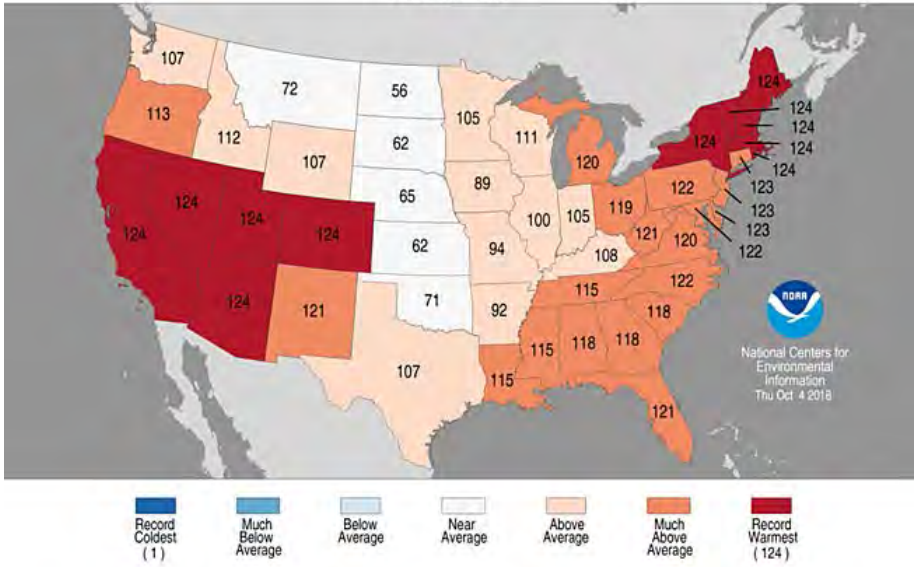
MJJASO 2018



MJJASO 2018



JAS 2018



The NOAA website you are trying to access is not available at this time due to a lapse in appropriation.

Gardening in Pittsford, Vermont in January

January 7, 2007

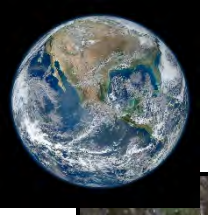
December 2006:

- **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

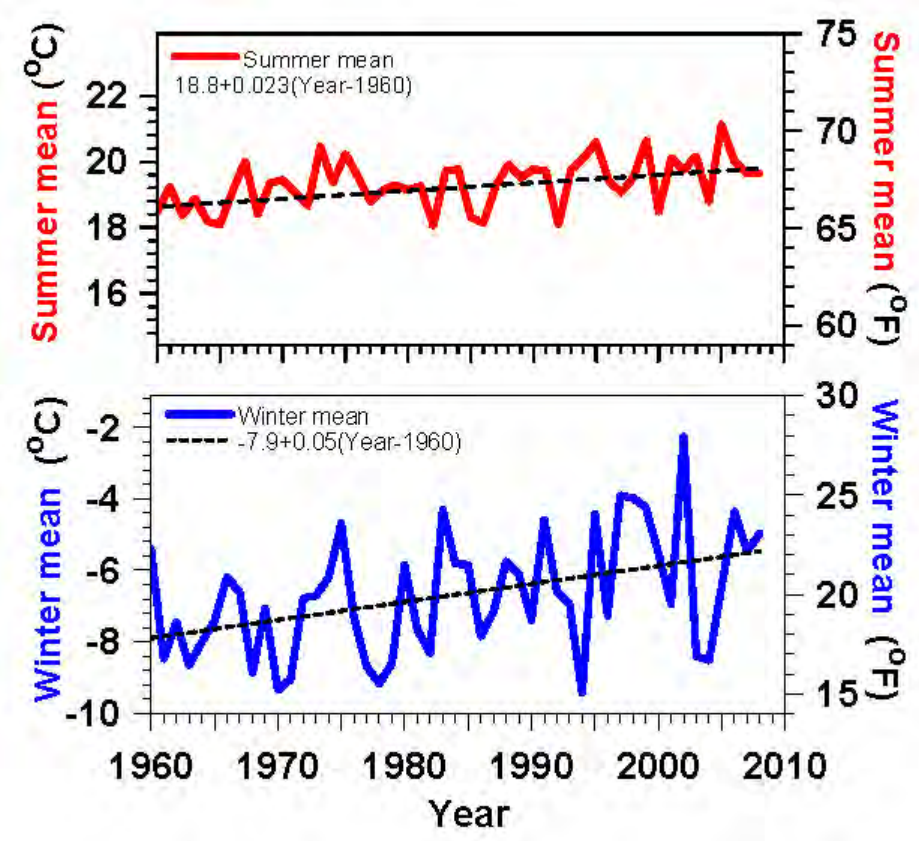
- **Warmest 6 months on record**
- **My garden frozen only 67 days**

•January 15, 2013

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

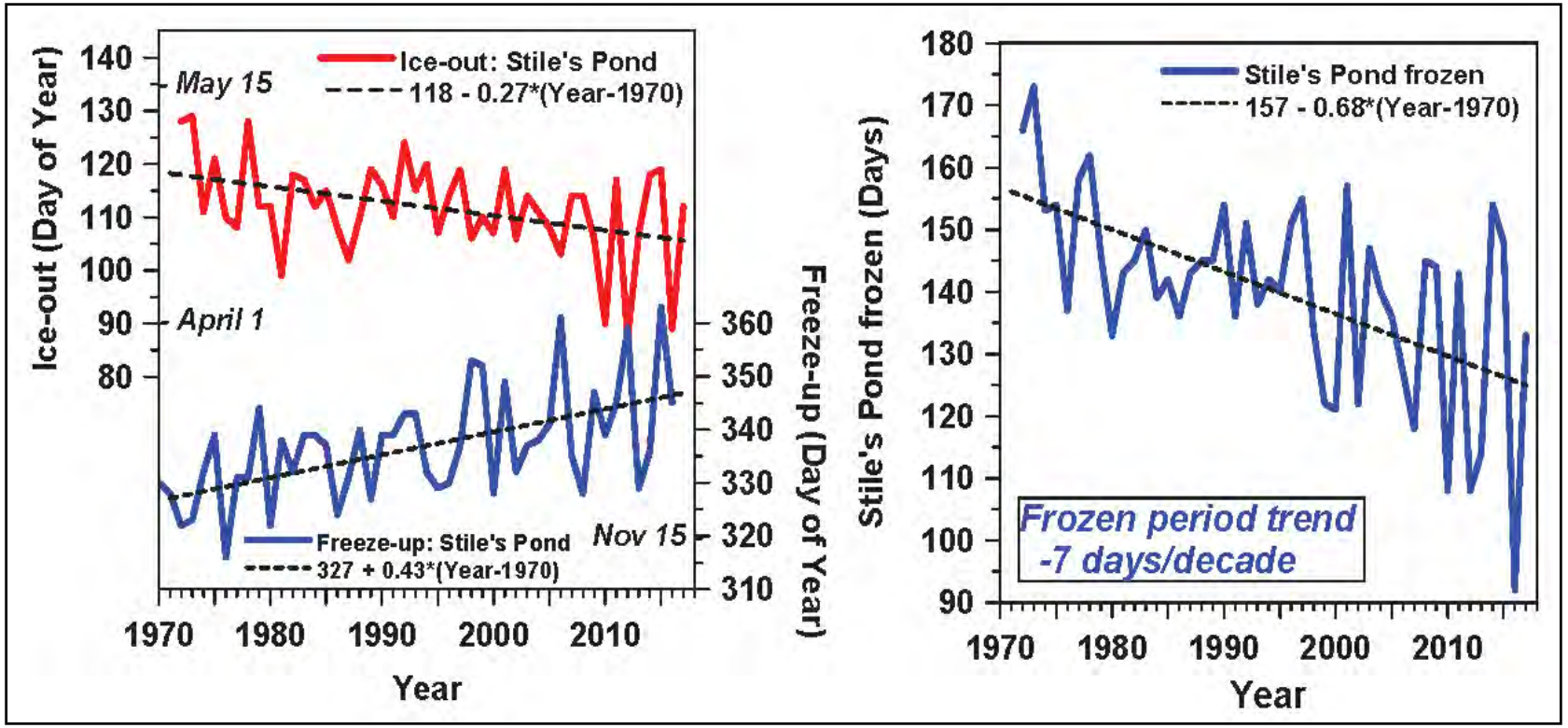
Vermont Temperature Trends 1961-2008

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



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 ≈ 50 yr trend***

Stiles Pond:
"Eye on the Sky"

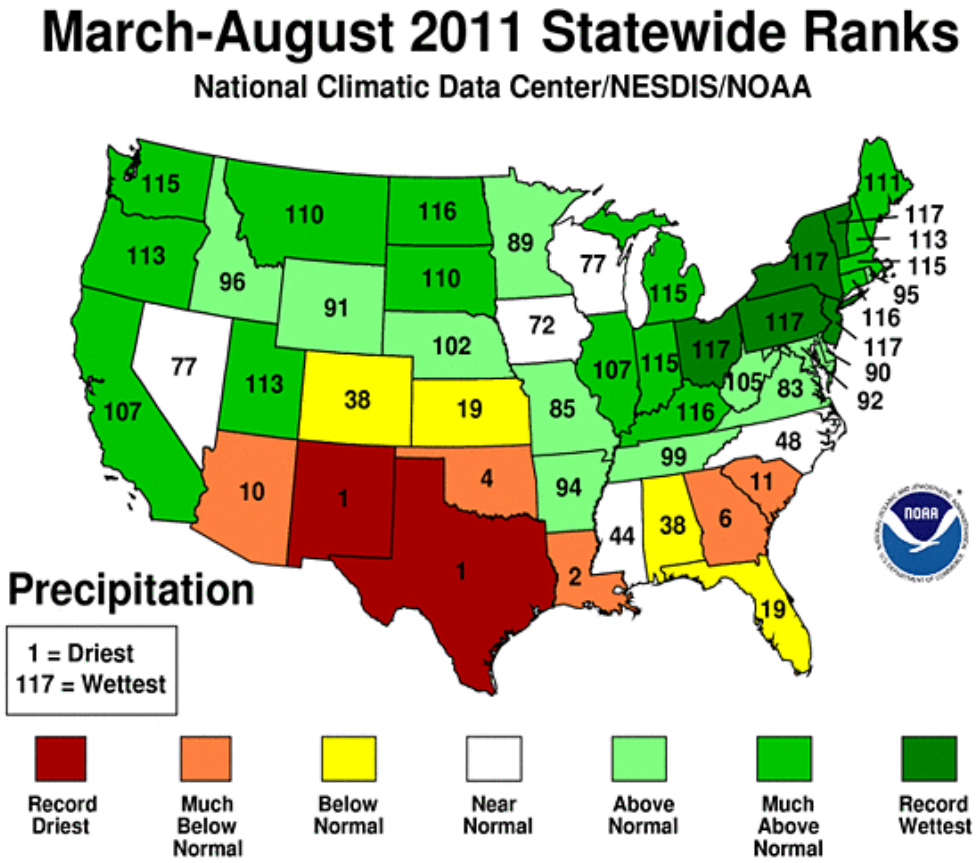
2011 Classic Flood Situations

- **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

- **Record wet : OH to VT**
- **Record drought: TX & NM**

- ***Pattern nearly stationary***

Can We Stop "Dangerous Climate Change"?

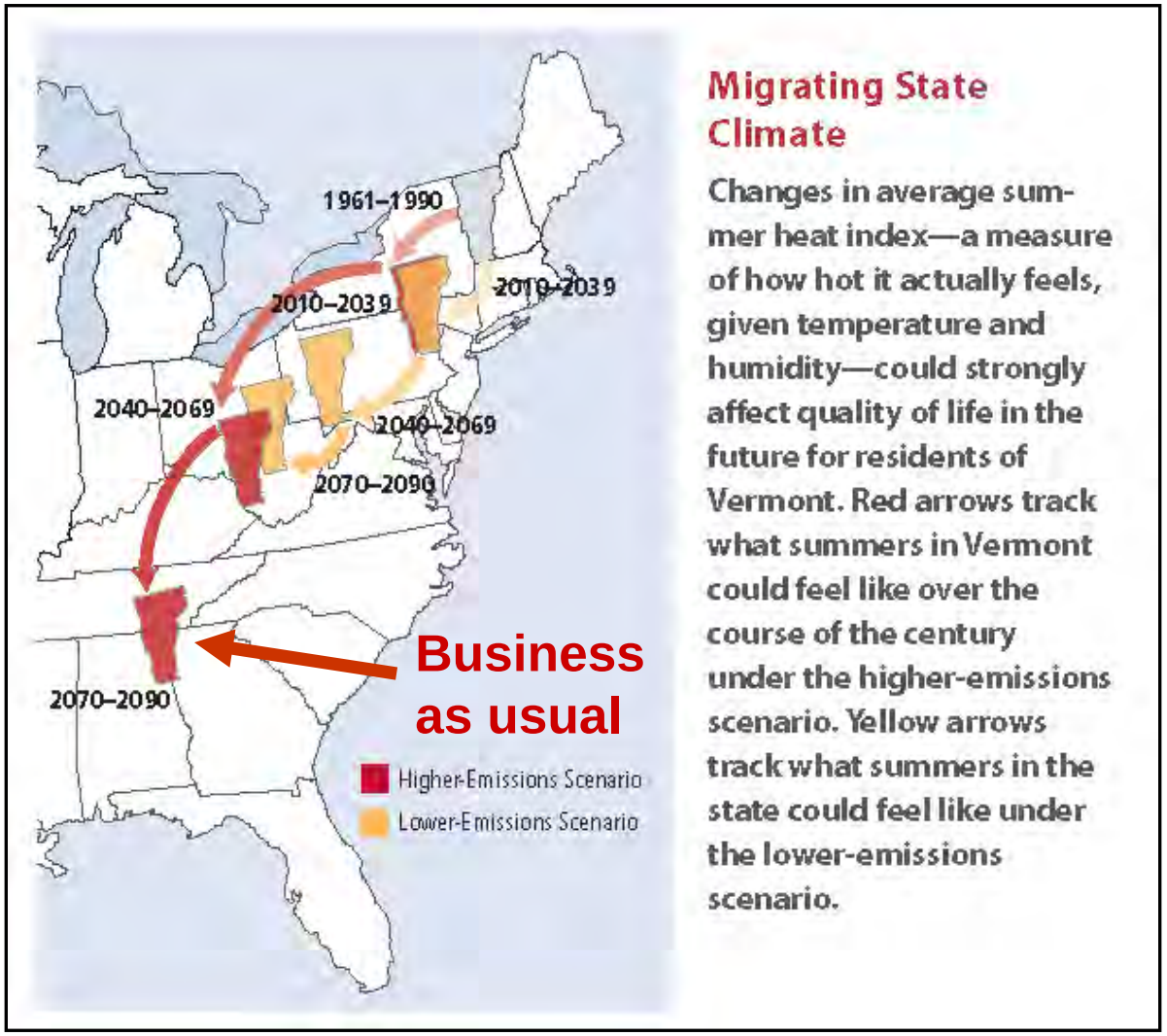
(UNFCCC 1992)

- **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**

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



NECIA, 2007

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***
- ***2018: Progress slows:***
  - ***Reports get stark: ten years to drop emissions 40%***

System Problem

- **Human waste streams are transforming the Earth's climate, and human and natural ecosystems**
  - **This affecting climate, weather, water supplies, food system, human health and ecosystems**
  - ***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?**
  - **Will humanity better manage our relation**
    - **To the natural world, Earth's ecosystems?**

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***
    - ***Flood coastal cities as icecaps melt: and over centuries raise sea-level 50-100ft***

We have the technology!

- **Improve efficiency of buildings, cars and electricity use**
- **Install more solar, wind and hydro with battery storage.**
- ***Replace gasoline cars with plug-in hybrids and electric vehicles***

2017 Prius Prime

Cost $30000, less $4500 tax credit
All-electric range: 28 miles
Hybrid range: 600+ miles

(I am not a salesman!)

- **26000 miles; 50% electric, 50% hybrid: 135 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?***

Efficient transport

- **Gasoline to plug-in hybrid**
  - **80% gain to 135mpg**
  - **enough to solve climate problem <u>NOW</u>**
- **Electric trikes: almost no cost to run**

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

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

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: our kids can pay the price)***
- ***Our politics are facing collapse:***

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

Fourth National Climate Assessment (NCA-4)

- **Maps out adaptation costs, and strategies**
  - **300 scientists and 13 govt agencies**
  - **Released Nov 23, 2018**
  - **“What we can/must do in next few decades to limit climate change and save ecosystems”**
- **President refused to read it, saying: *“I am so smart that I don’t need scientists to tell me what is happening to the climate”***

Why is the transition so hard?

- **We have the technology**
- **The long-term costs are unpayable**
- **Your future is at stake!**

- ***"Business as Usual" and Climate Change are incompatible!***
- ***WHY?***

Answer lies in our Economic System

- **We base decisions on short-term profit**
- **We place little value on the future**
  - **Economic models discount the future**
  - **While Earth accumulates heat & extreme weather increases**
- **Solutions must be "cost-effective" for today's shareholders**
  - ***Not cost-effective for Earth's ecosystems nor for our children and grand-children***

- **We revere the “growth” economy**
- **We revere the global market**
- **We assume we have the right to exploit the Earth, its resources, and the poor**
- **Human population and exploitation has grown with no controls**
- ***We are approaching Earth system limits in many areas***
  - ***Climate, fresh water, resources***
  - ***Losing coral reefs, fish, forests, pollinators***
  - ***Earth’s limits win over our technology!***

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***

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)

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**

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**

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***

Impact of Snow

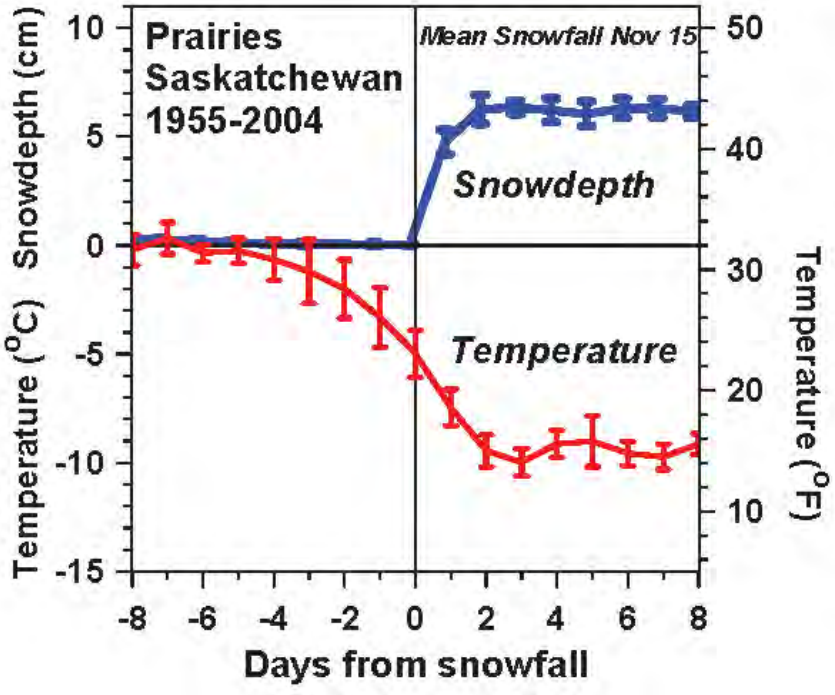
- **Distinct warm and cold season states**
- **Snow cover is the "climate switch"**

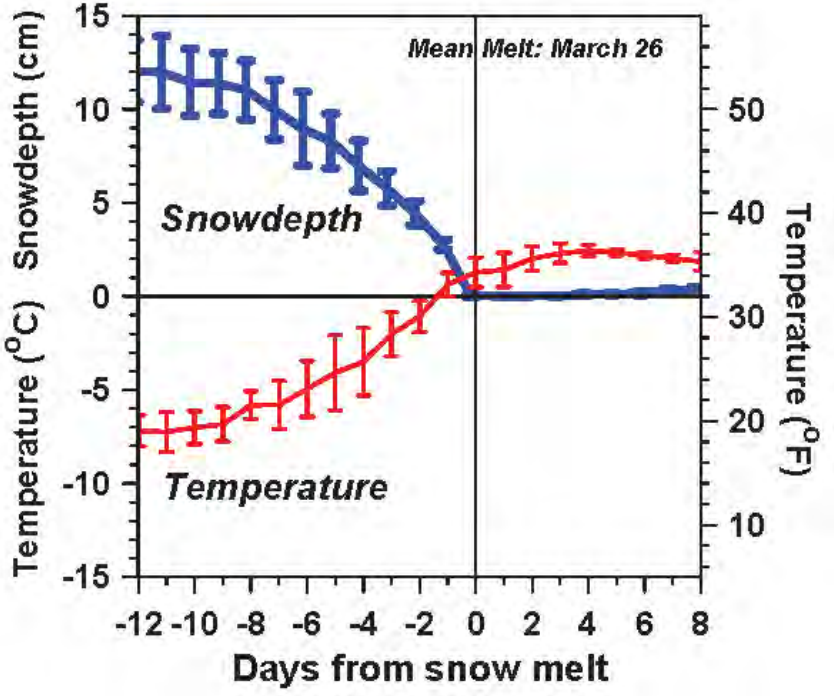
With snow

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

Snowfall and Snowmelt

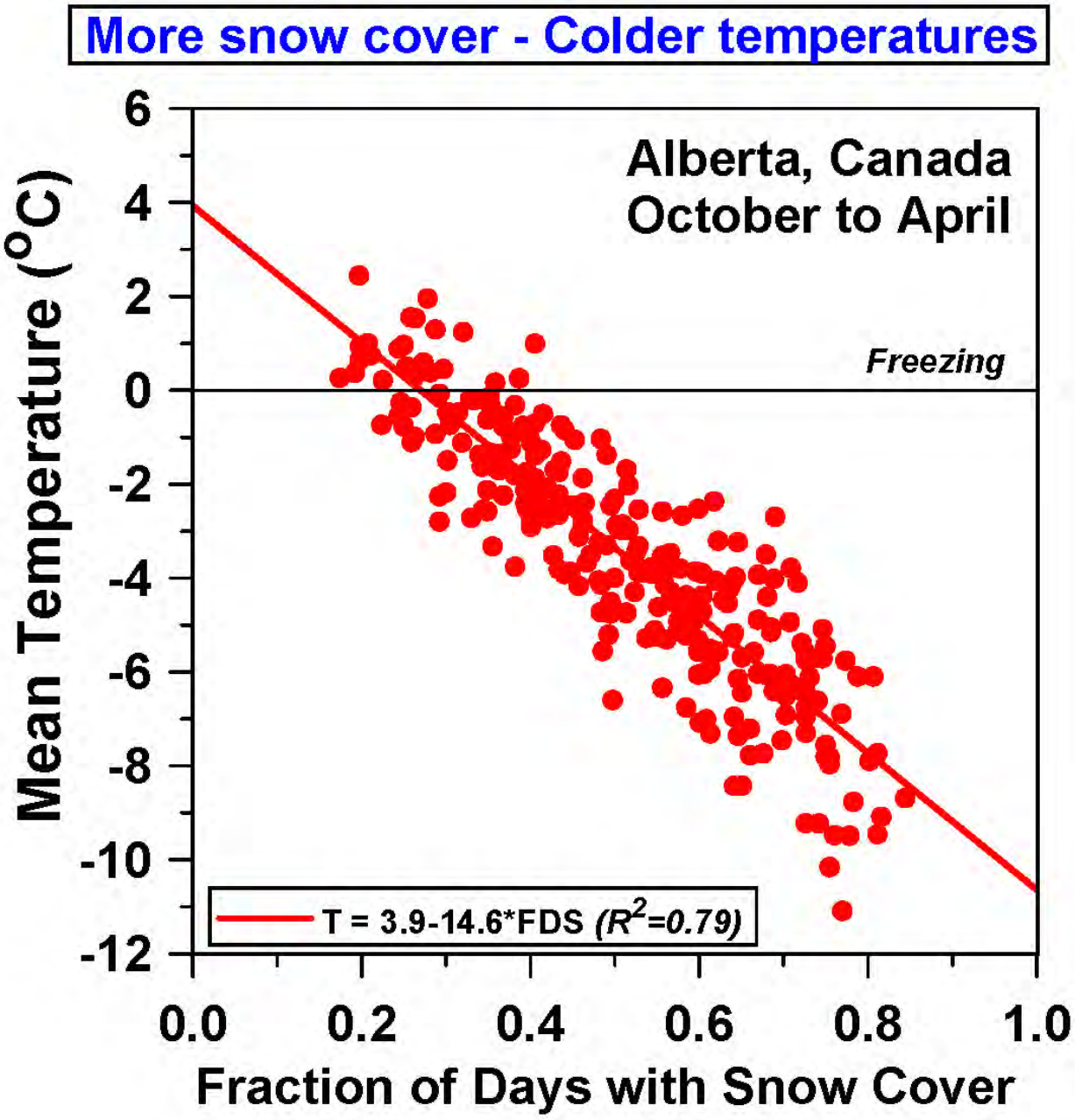
Winter and Spring transitions





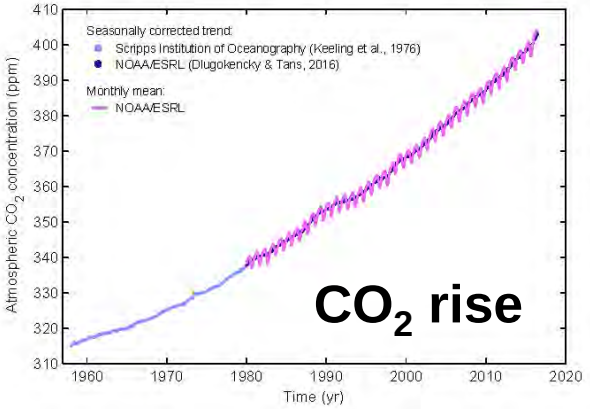
- **Temperature falls/rises about 18F with first snowfall/snowmelt**
- ***Snow reflects sunlight; shift to cold stable boundary layer***
  - ***Local climate switch between warm and cold seasons***
  - ***Winter comes fast with snow***

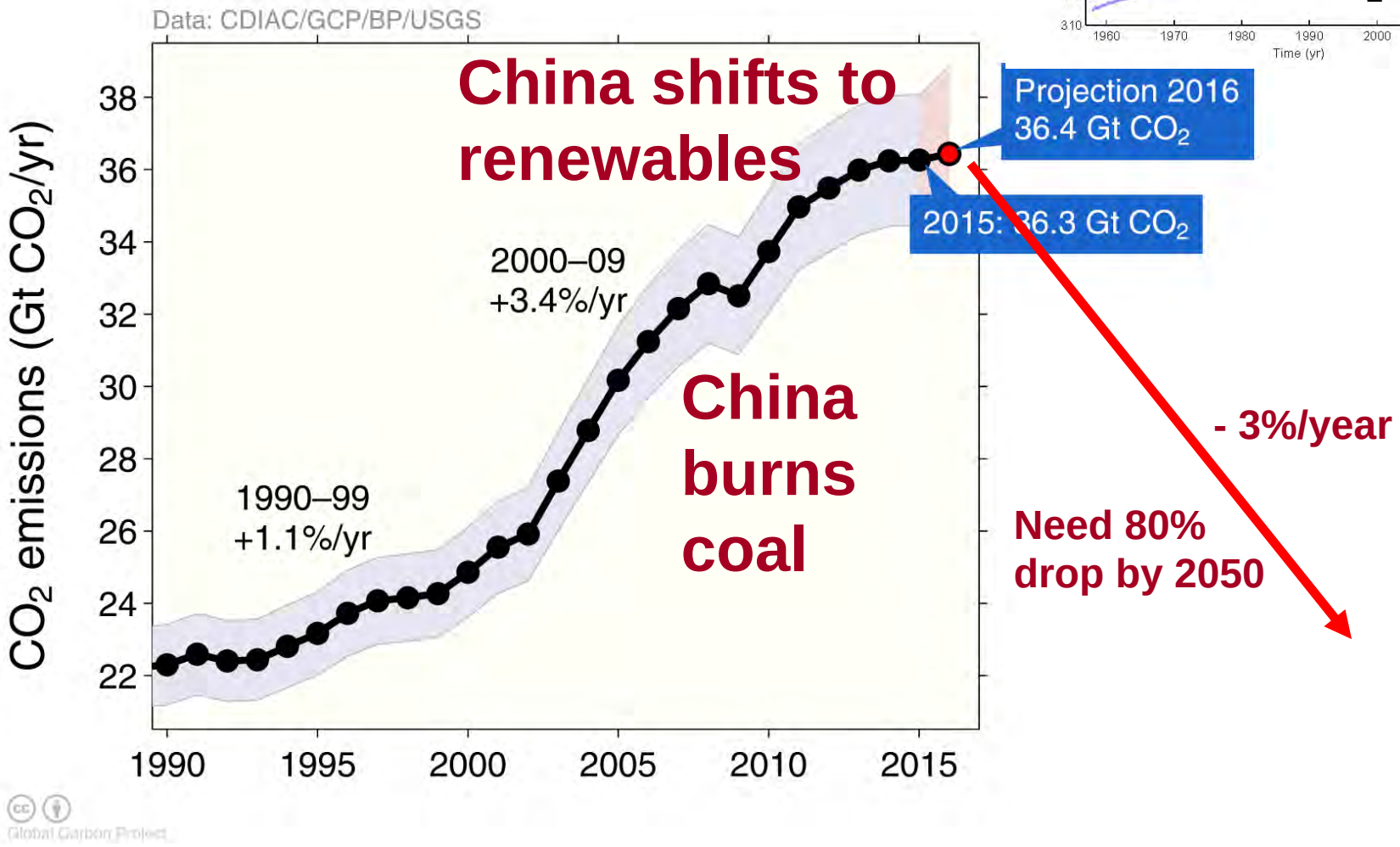
(Betts et al. 2014a)



Winter is colder if more snow cover

Growth of CO_2 Emissions Flat for 3 years





March 3, 2017

January 10 and 12, 2018

January 10, 2018

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

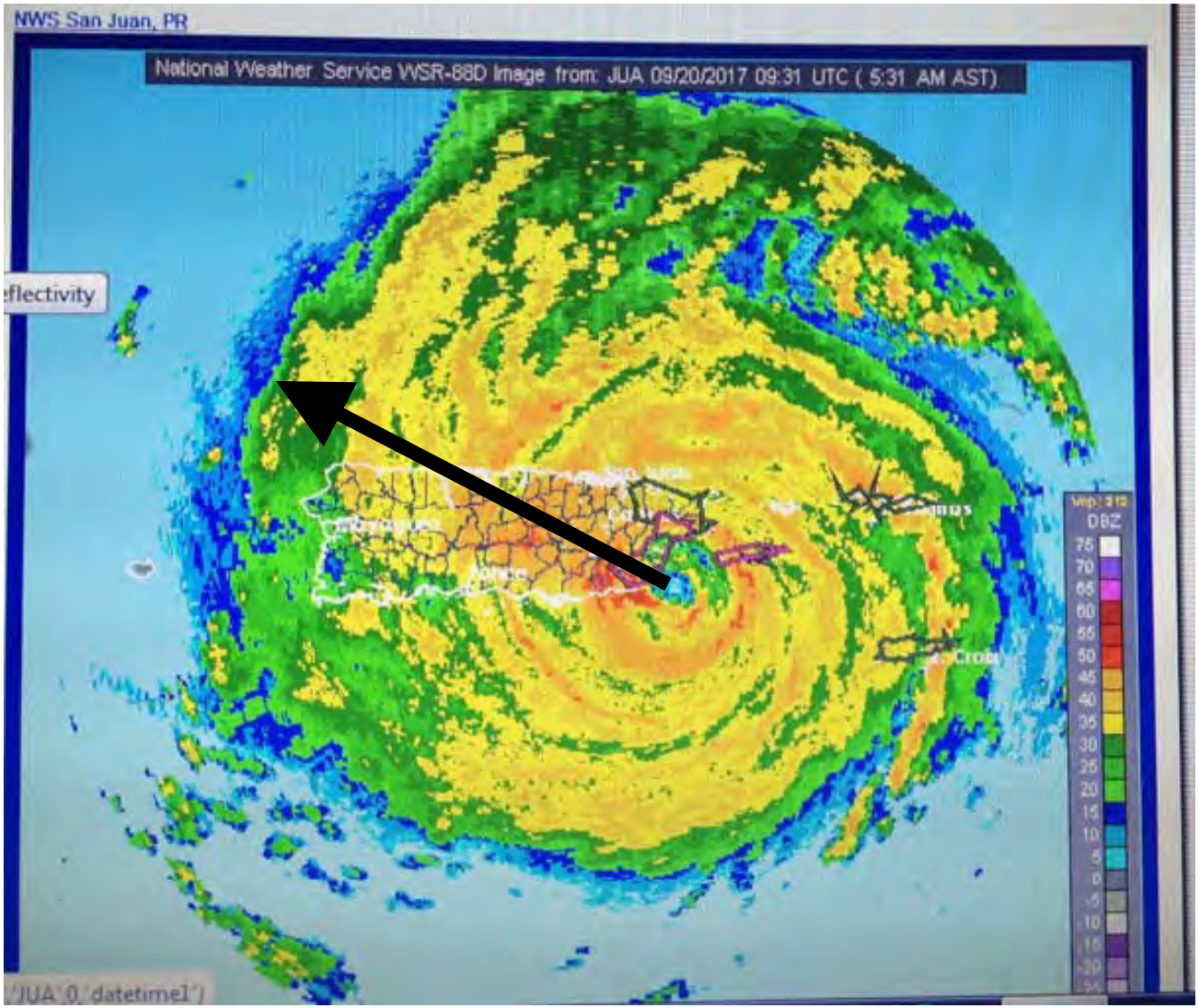
January 12, 2018

After T_{max} up to 50F

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

Cat 4
>130mph
Maria
>150mph

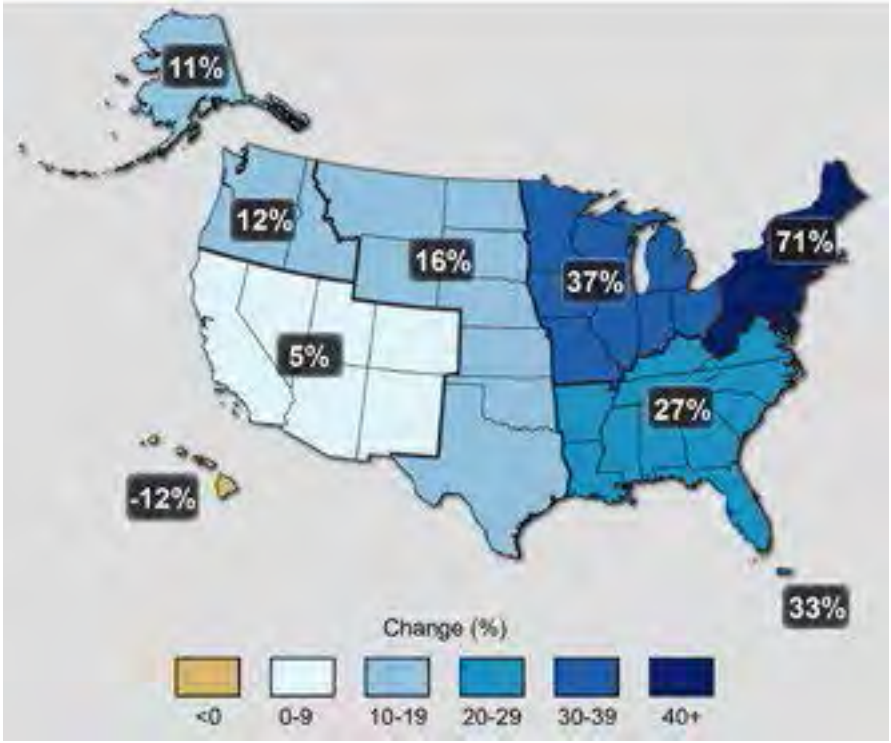
Wiped cell towers and power grid
(90% back after 6 mos!)



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**

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**

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 oceans, killing marine life**
- ***In our disconnected human world, these are harder for us to deal with***

System 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 loads on streams/lakes**
  - **Growth of algae in lakes, big issue in VT (and elsewhere)**
- ***Reconnect with natural world***
  - ***Fundamental if we are to accept transition***