Climate Change & Society

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BREE High School Teams

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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 our social challenges?**

Discussion

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 in 2017***
  - ***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: loss of reflective ice; more water vapor

Build Resilience

- **Understand technical/ecological issues**
  - **Can'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!**

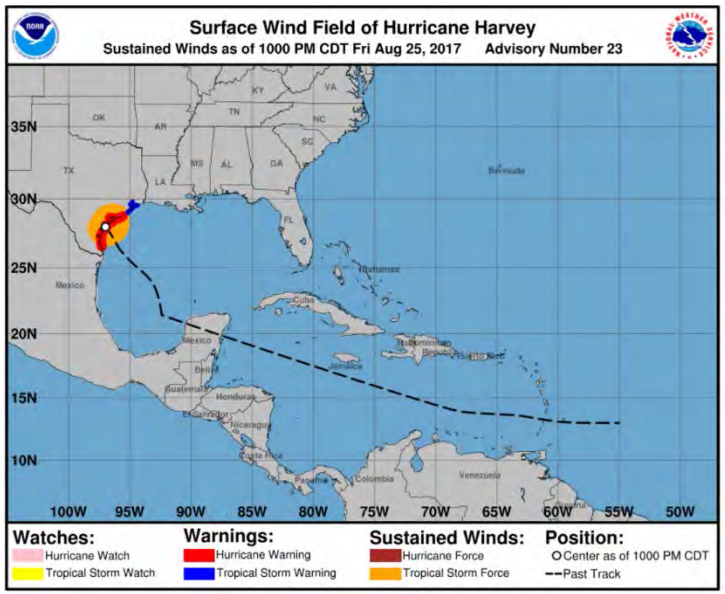
BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

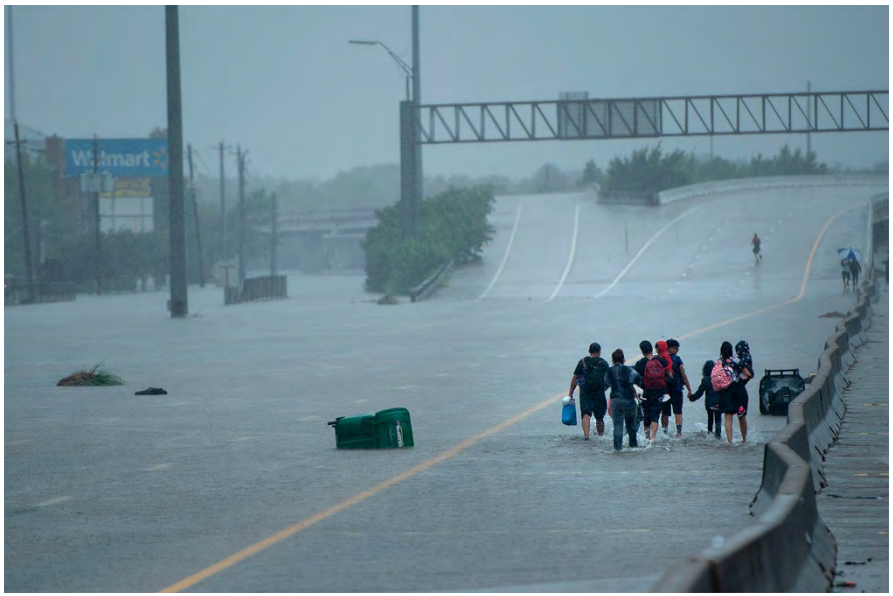
Hurricane season: 2017

- **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 landfall: Aug 25, 2017**
- **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**

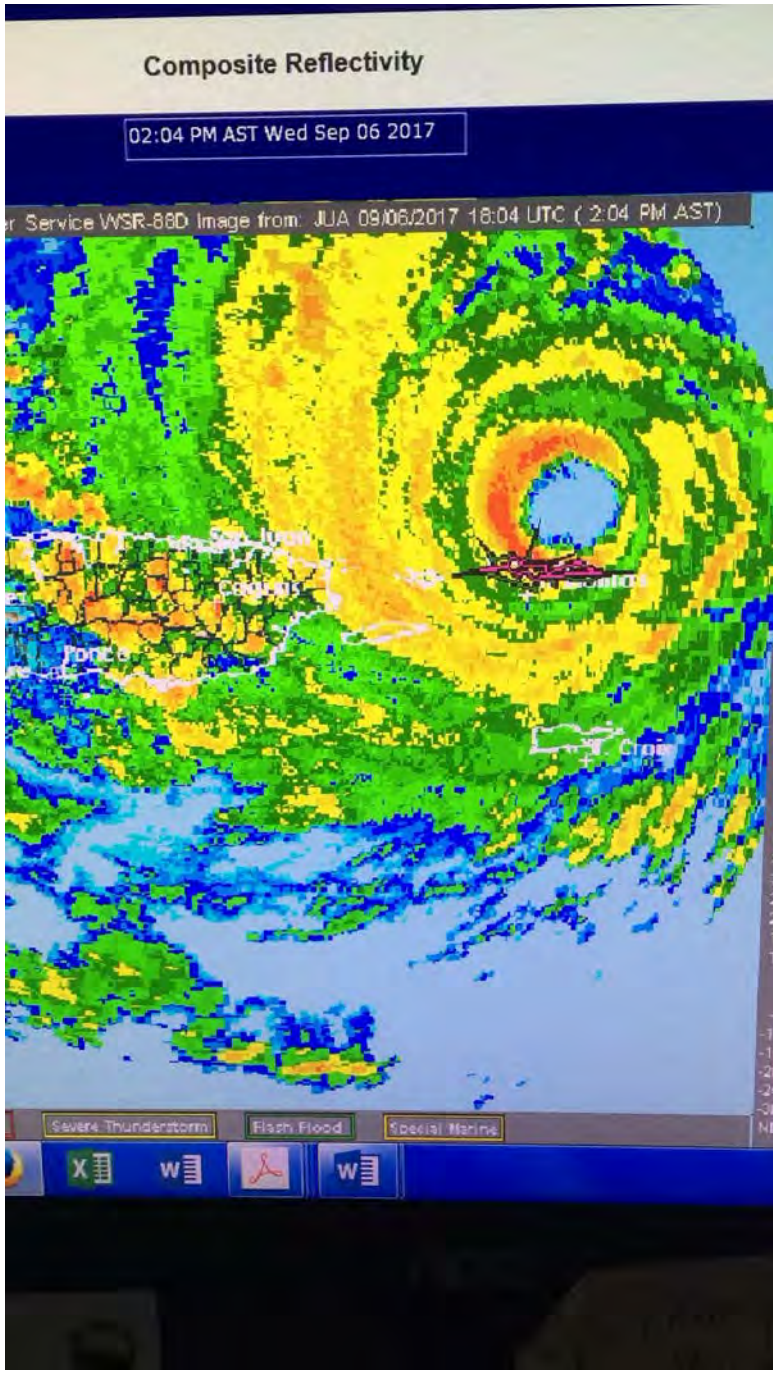
IRMA

grazing

St Thomas

Cat 5 >155mph

IRMA >180mph



Irma(Cat.5)
Sept. 6
St Thomas

Irma and Jose: Sept 7

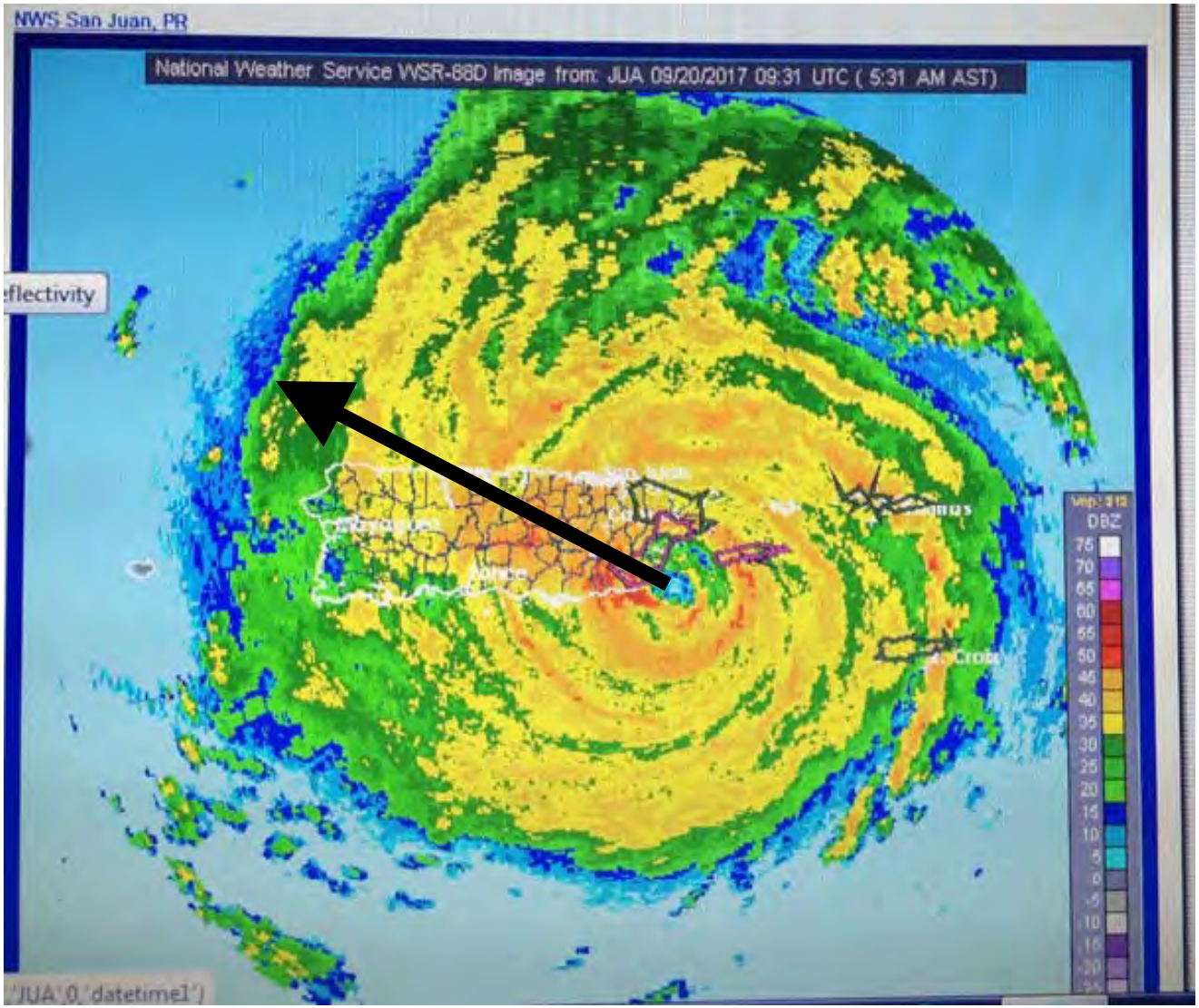
After Jose passed; East Wind Catamaran to Puerto Rico on Sept 11

(alanbetts.com/writings)

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)



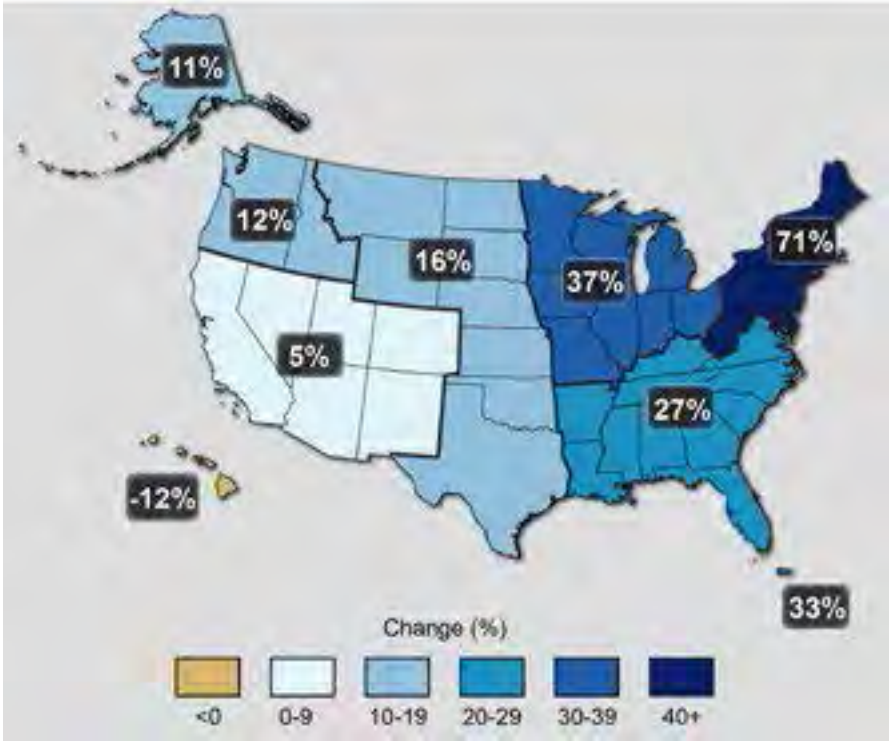
Two Severe Tropical Cyclones hit Mozambique

- ***Southeast Africa cyclones were very rare***
- ***Idai* in March left 1000 dead from flooding**
- **Cat 4 *Kenneth* in April**
  - **60 in of rain**

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

Aug 29, 2011

Roads in valleys

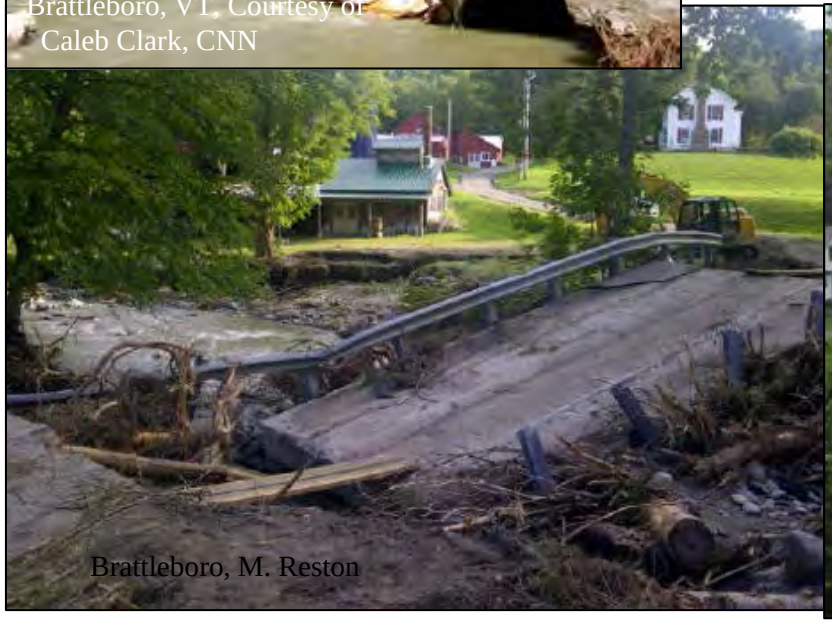
Massive damage

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 Sept 2011

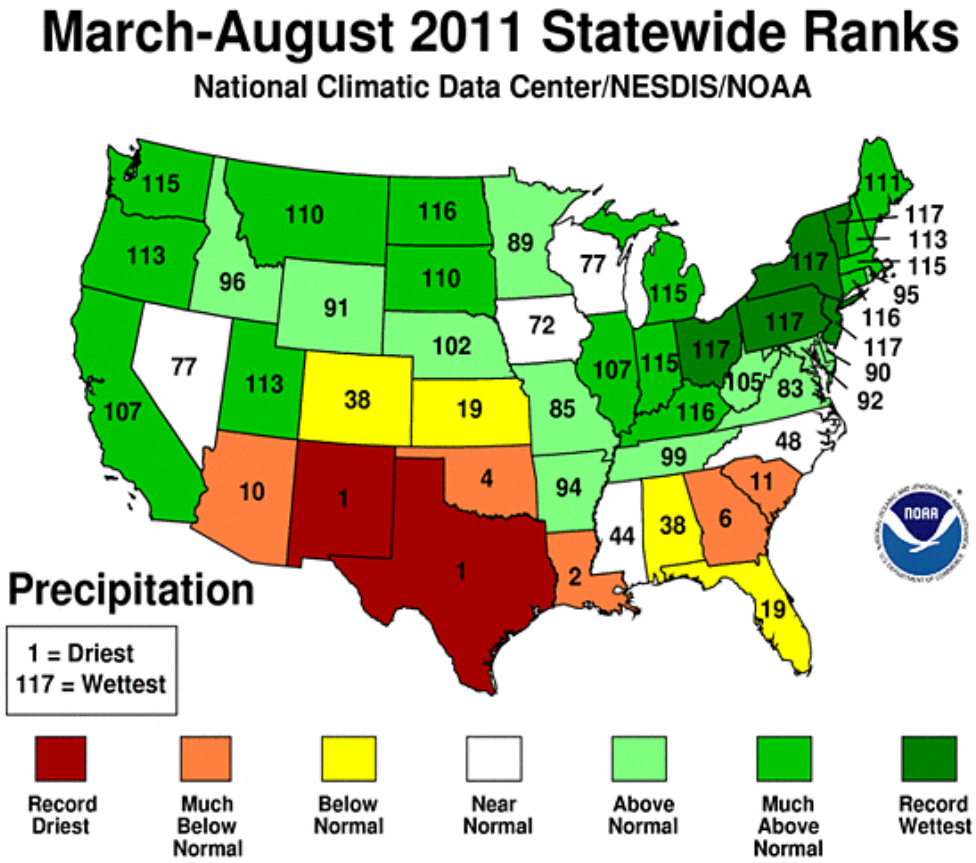
2011 Classic Flood Situations

- **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**

Historic floods: Otter Creek

1927

1811
2011
Irene

1938

1913

Ask around in your towns: Are there other markers for past floods?

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."***

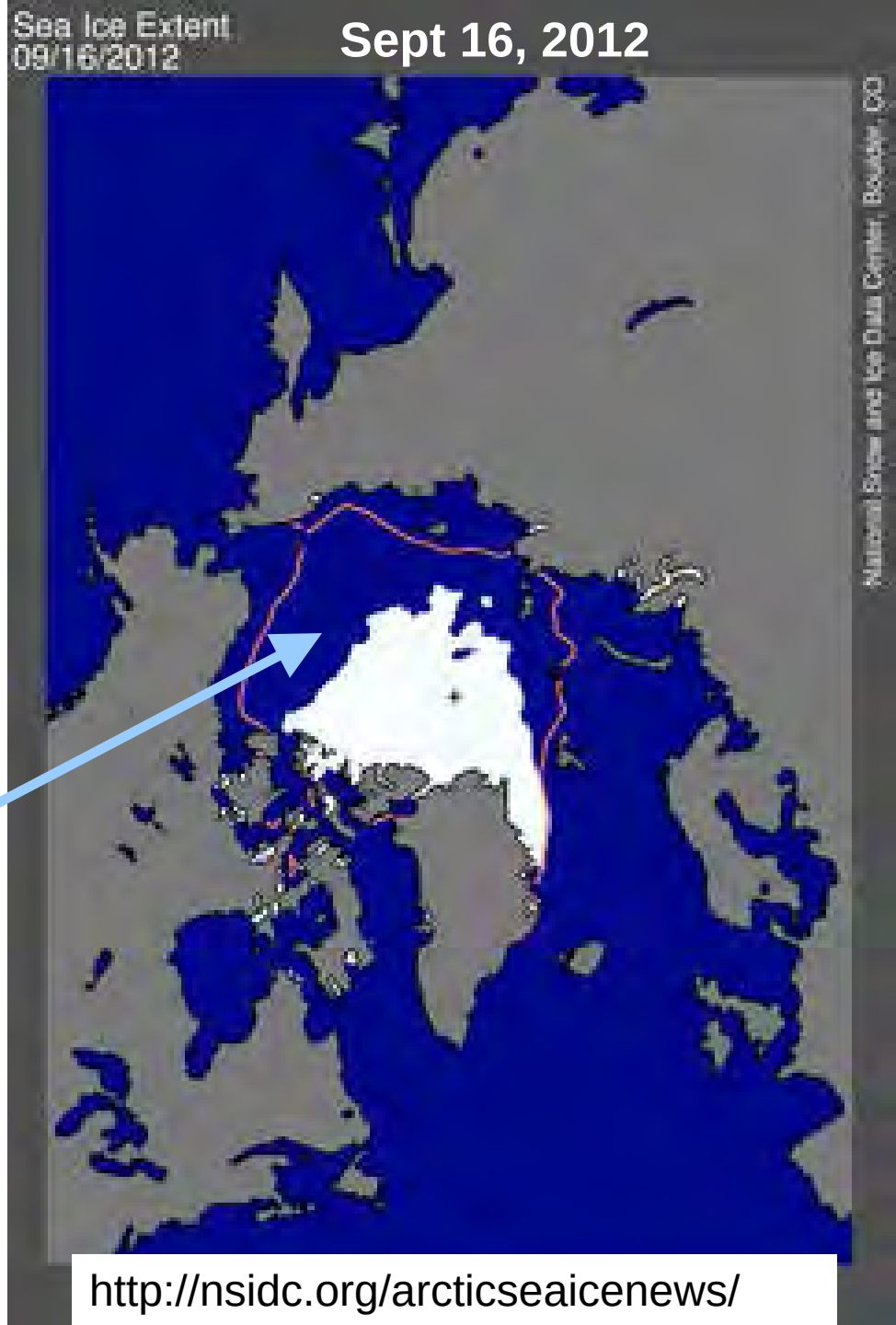
(Liberty Hill dairy farm, Rochester)

Flooding Issues

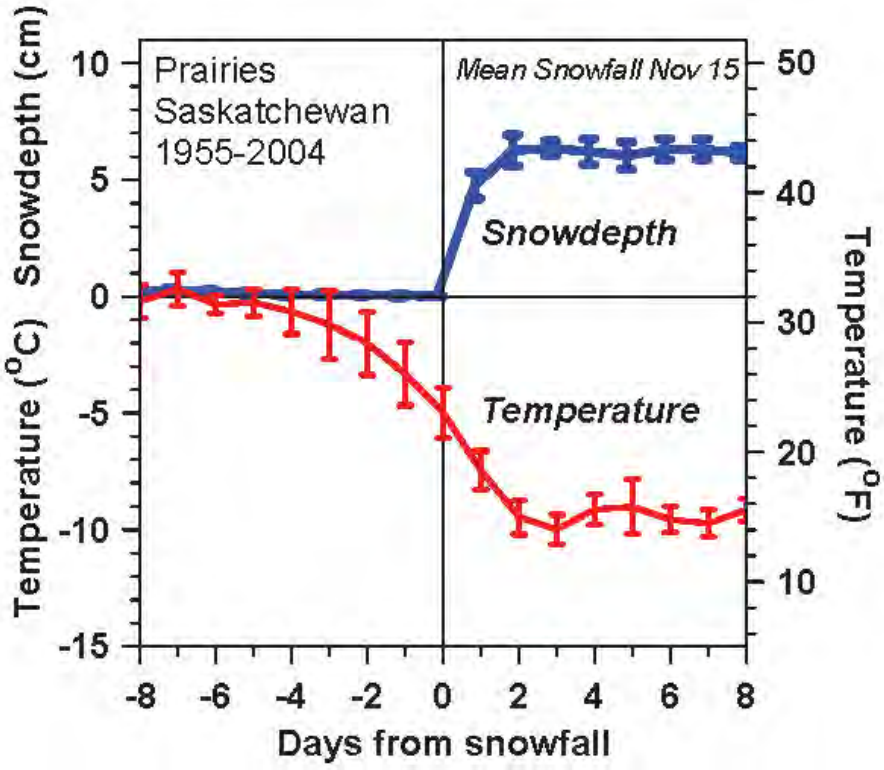
- **Maintain mountain forest cover**
  - **Devastating floods in 1920's, 30's with reduced forest cover**
- **Manage water/pollutants on landscape**
  - **Maximize infiltration: urban and on farms**
  - **Don't wall-in rivers**
- **Preserve flood plains**
  - **Saves downstream towns (Middlebury)**
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

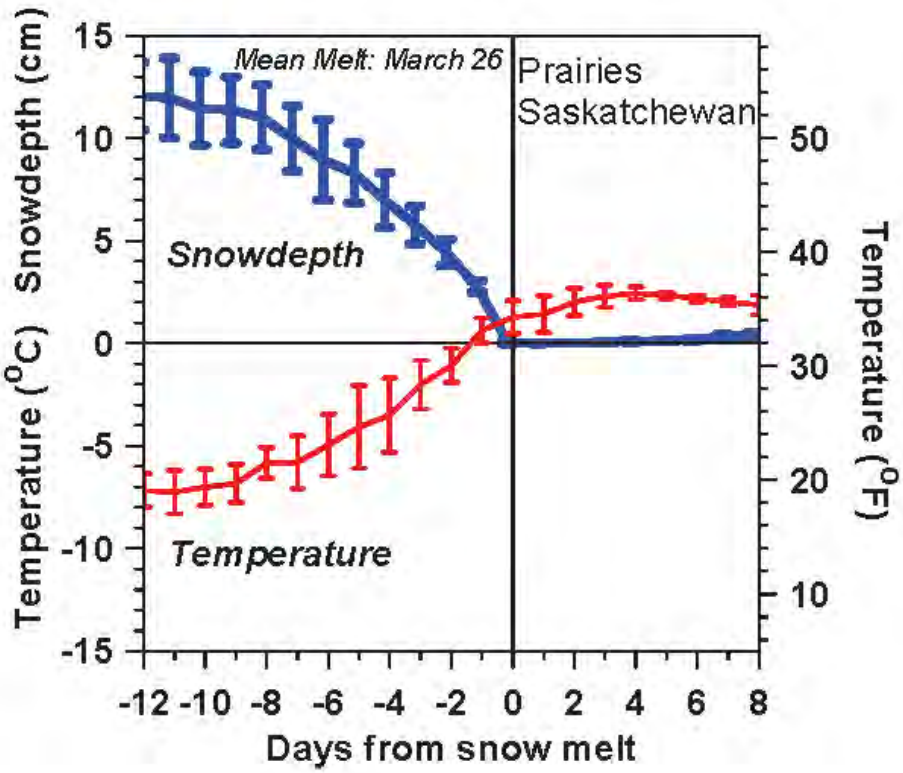
- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

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



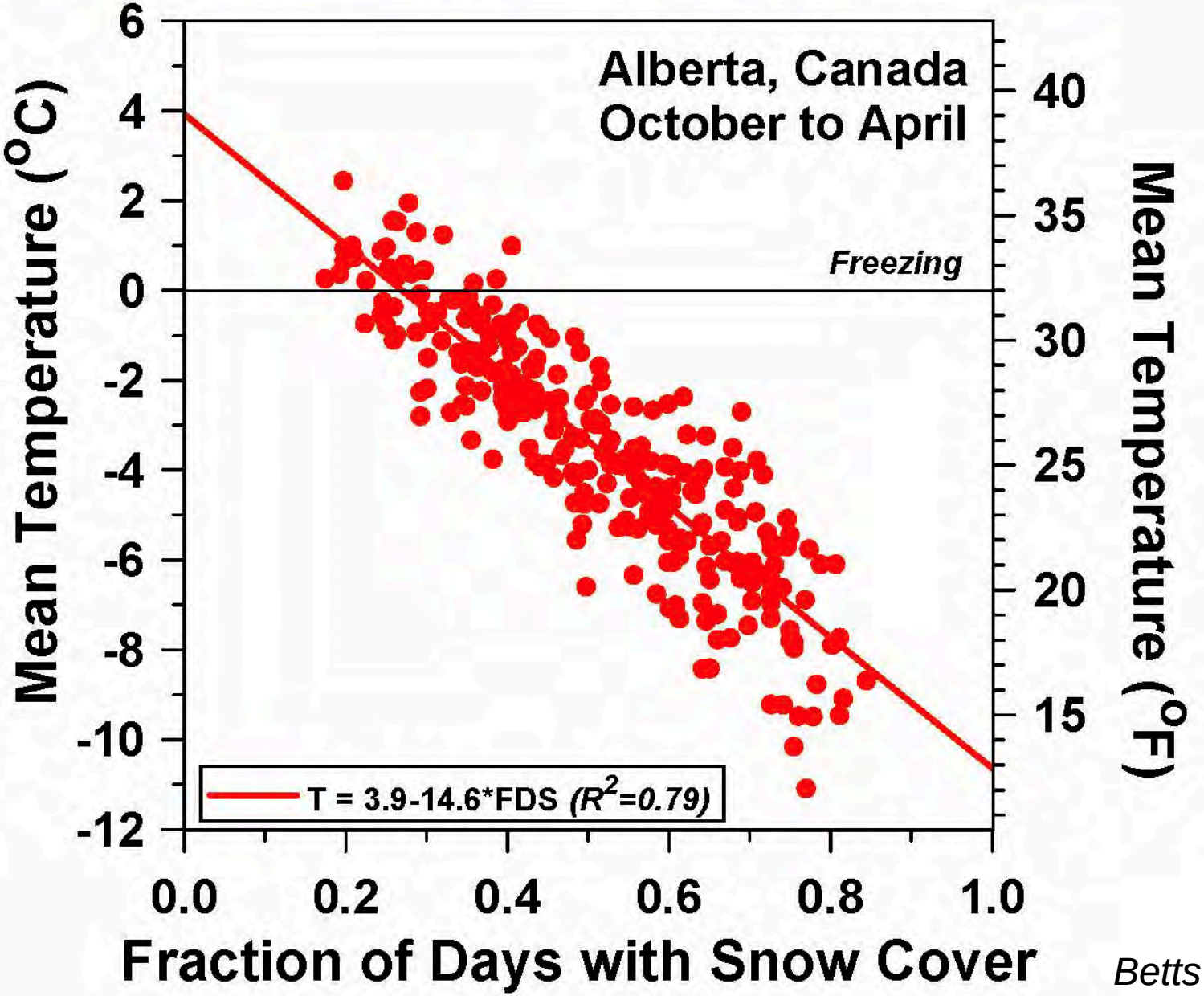
Snowfall and Snowmelt





- **Temperature changes 10°C (18°F) with snow cover**
- **Snow cover is a ‘climate switch’**
- ***Fast transitions in ‘local climate’***
  - ***Snow reflects sunlight; insulates ground***
  - ***Reduces evaporation and water vapor greenhouse***

More snow cover - Colder temperatures



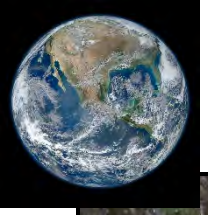
Betts et al. 2014

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)**



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

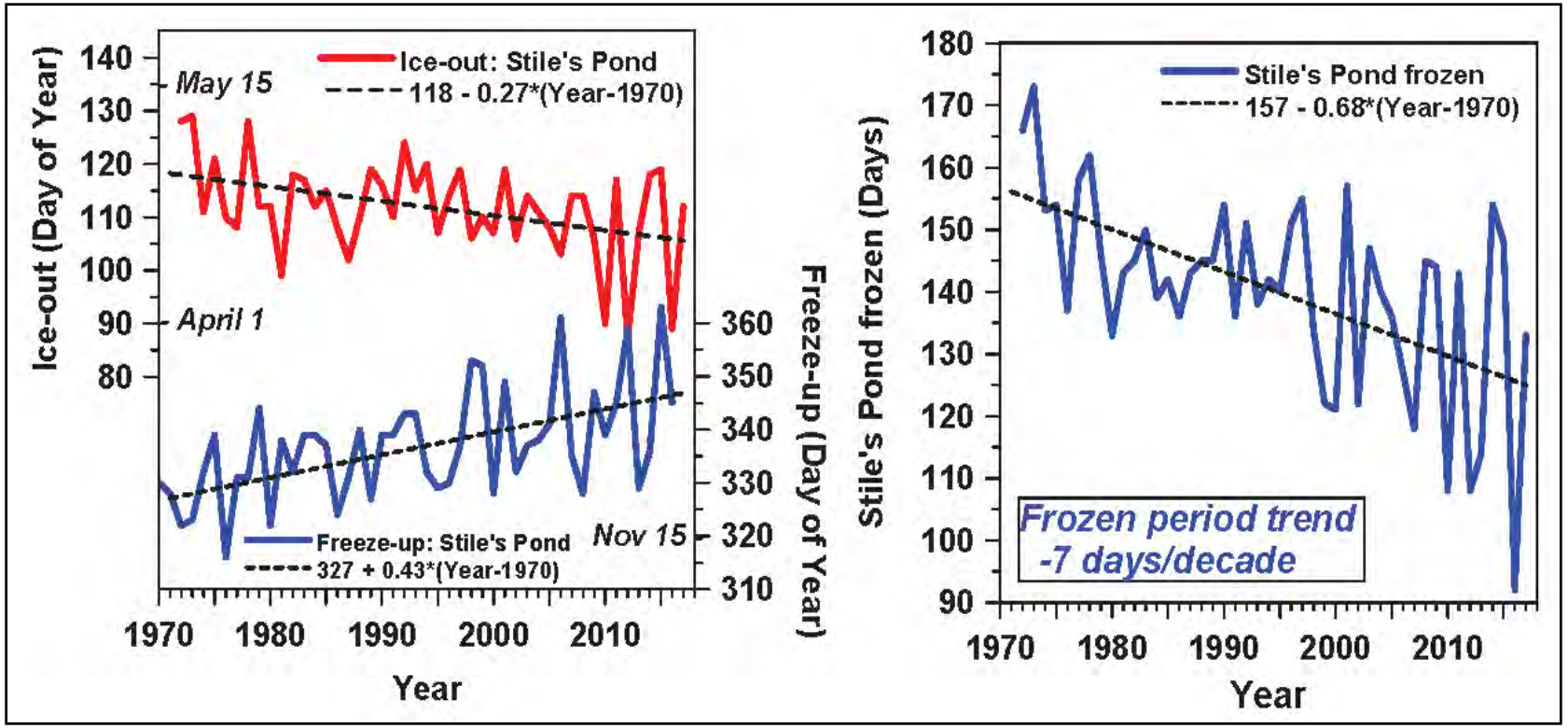
After cold snowy period
T_{min} down to -10 to -20F

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***

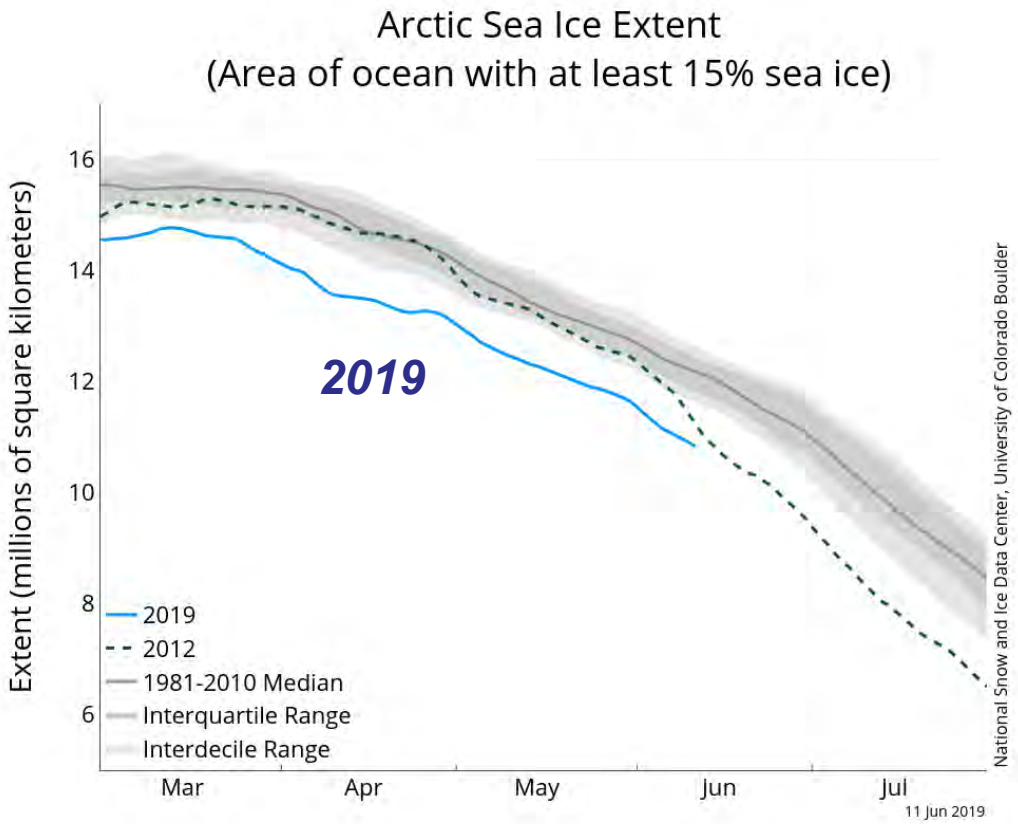
Stiles Pond:
"Eye on the Sky"

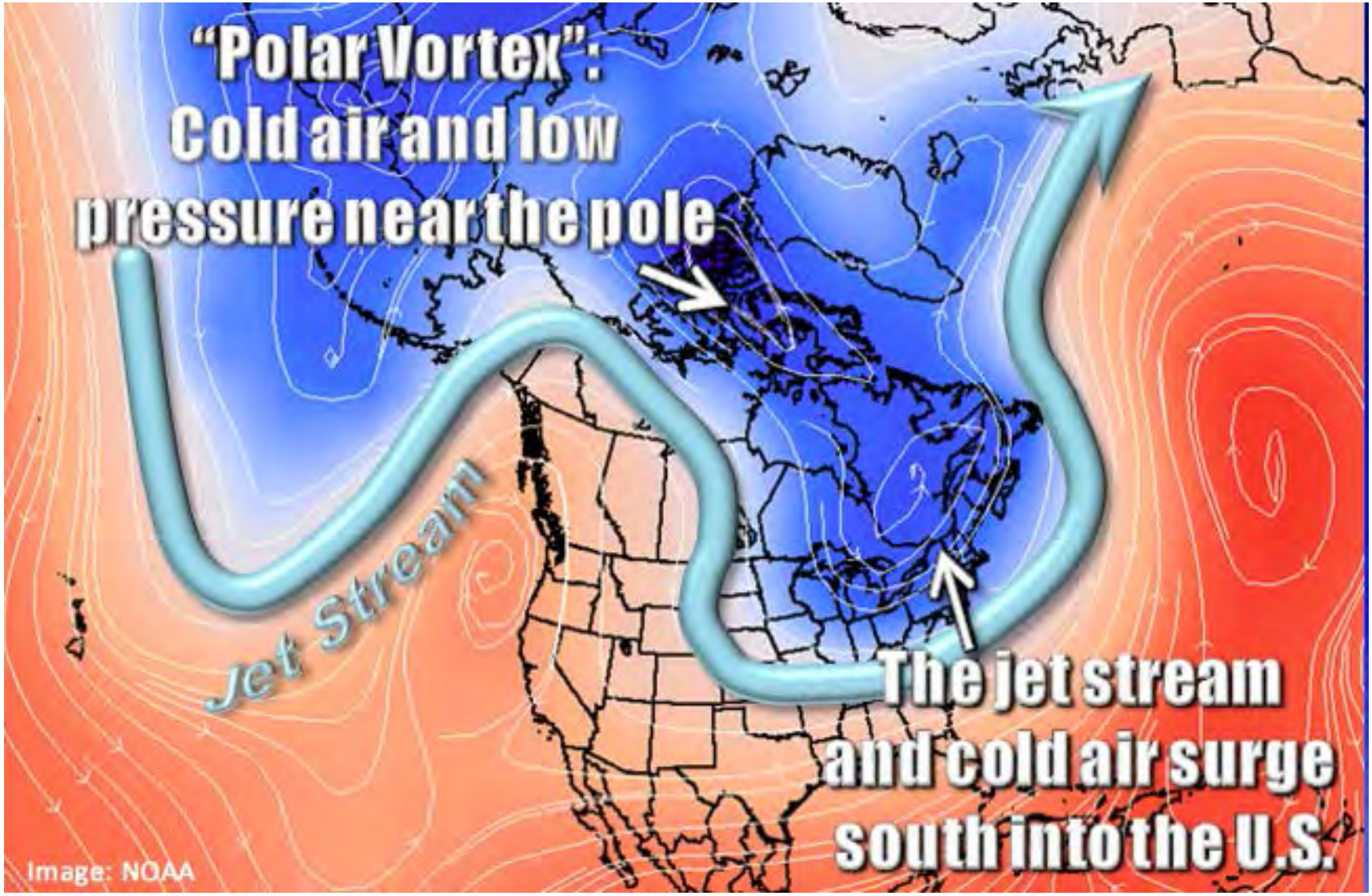
Winters are changing

- Arctic warming twice as fast as tropics so Arctic vortex weakening

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

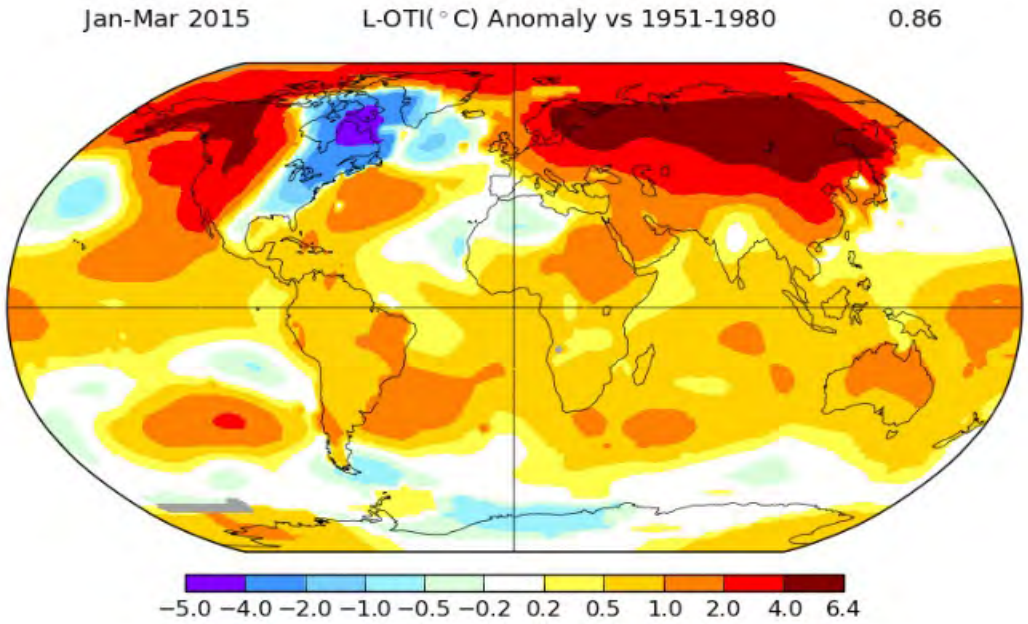
- **Winter sea-ice coverage falling**
- **Sea-ice thinning**
- **Polar vortex weakening**




"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

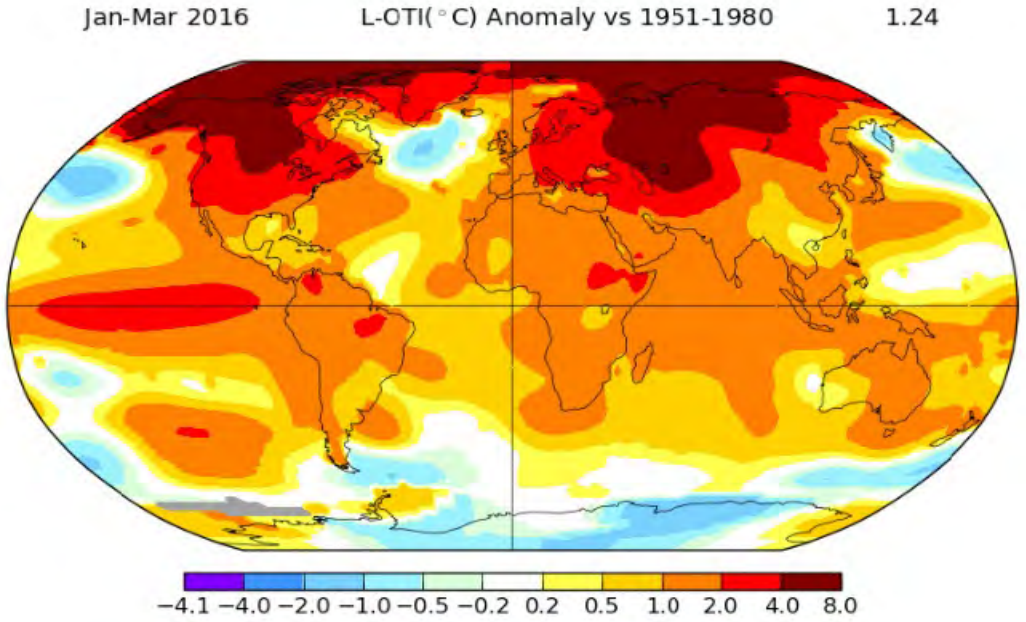
Jan-Feb-Mar 2015

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



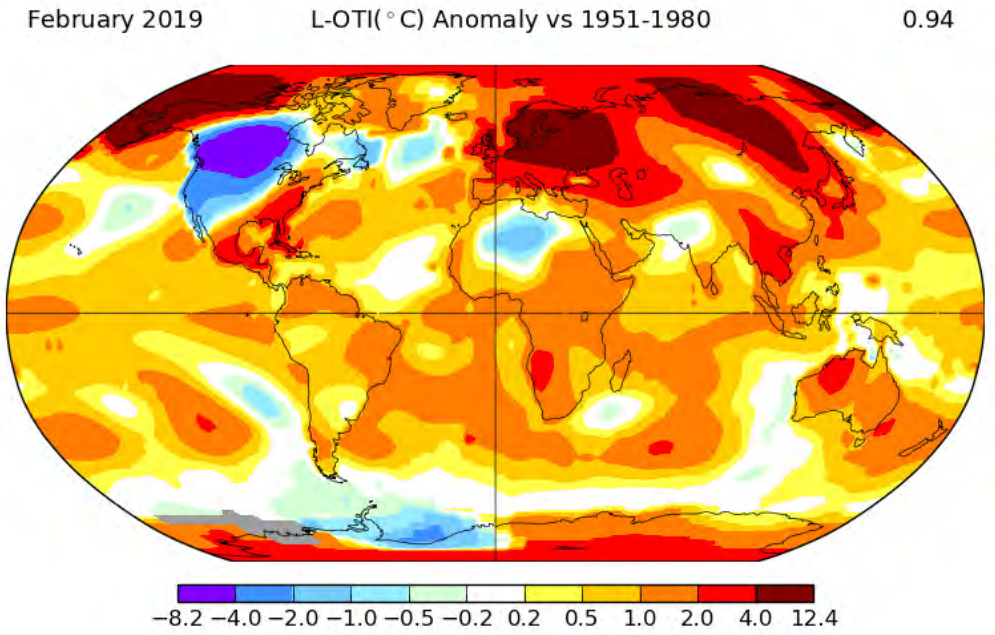
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



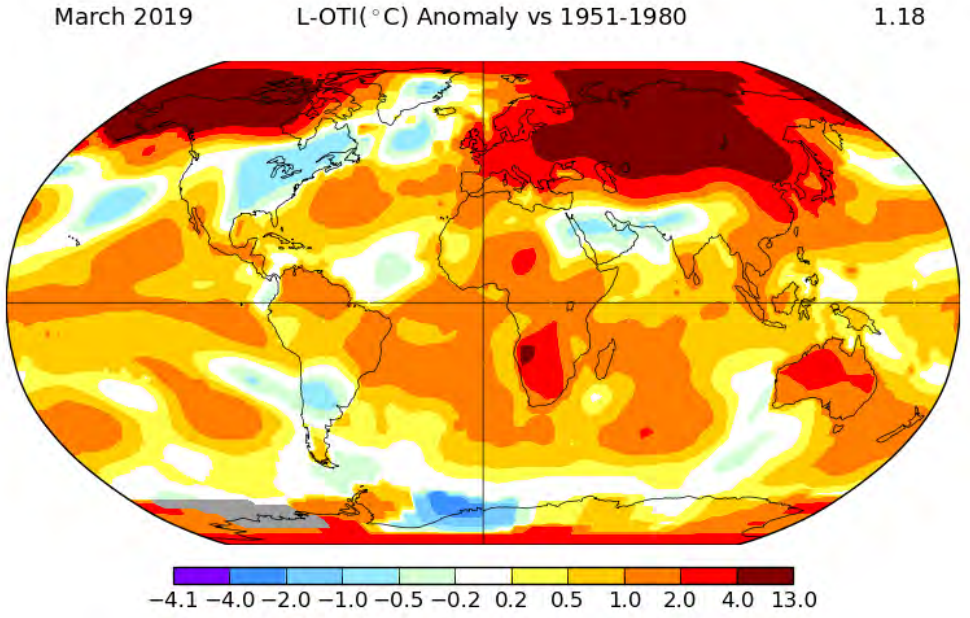
Feb-2019

Extreme cold, central US, Canada
Extreme warmth UK, Europe, Asia,
NW Alaska



March-2019

Cold eastern US, Canada
Extreme warmth UK, Europe, Asia
Alaska

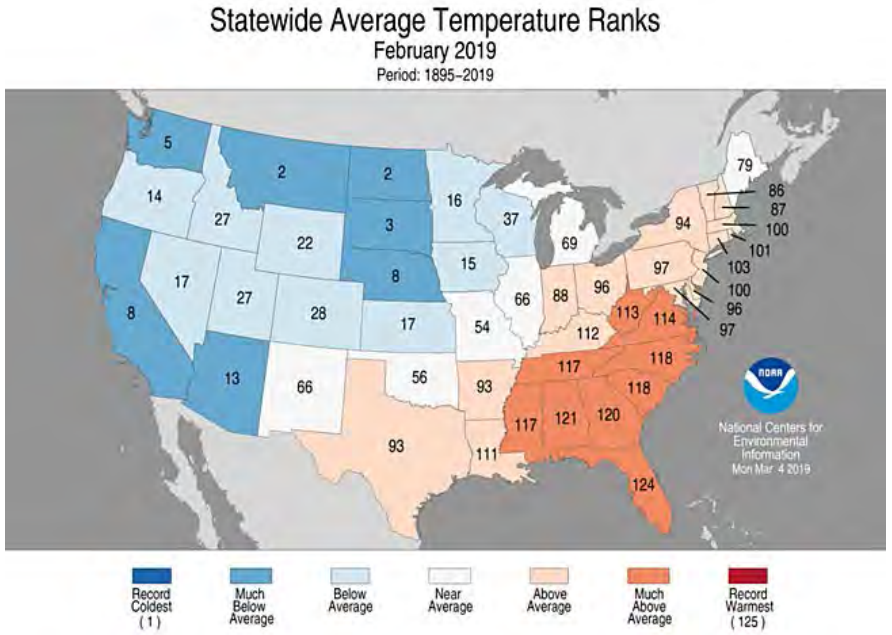


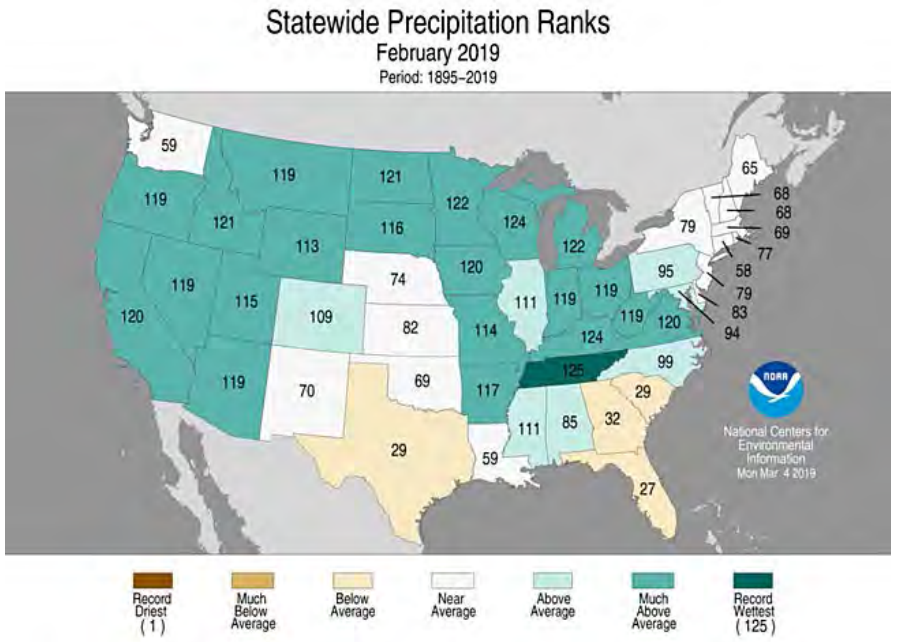
Feb-2019

Second warmest in South-east

Second coldest in north-central

Very wet across much of US



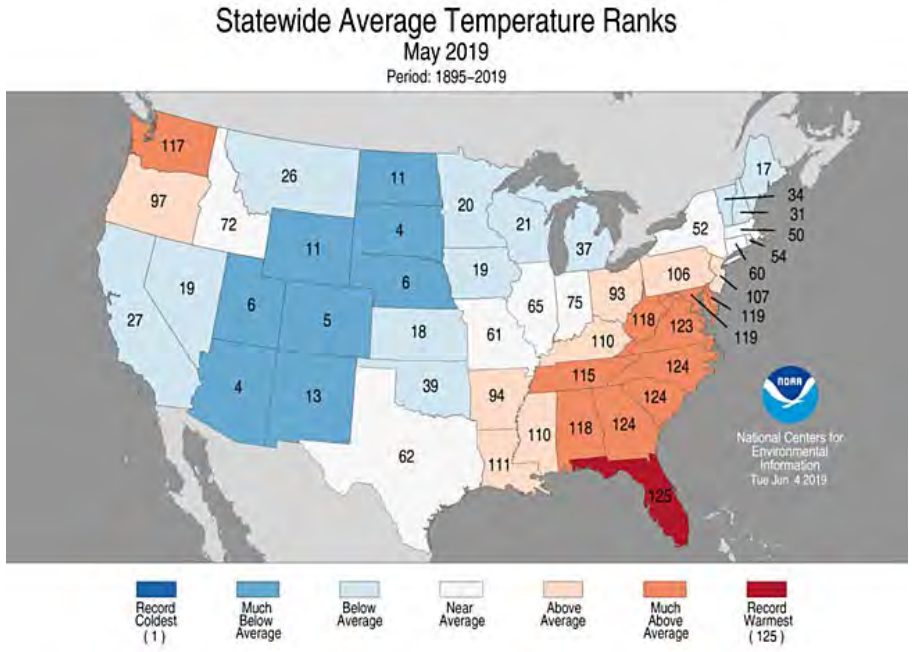


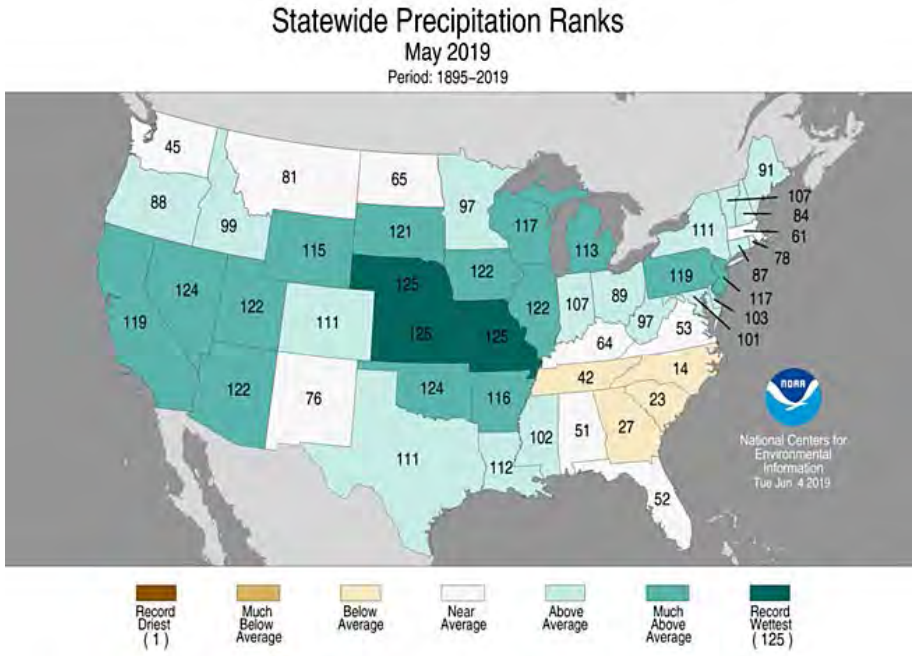
May-2019

Record temps in Florida & South-east

Still cold in north-central

Record wet across Central US





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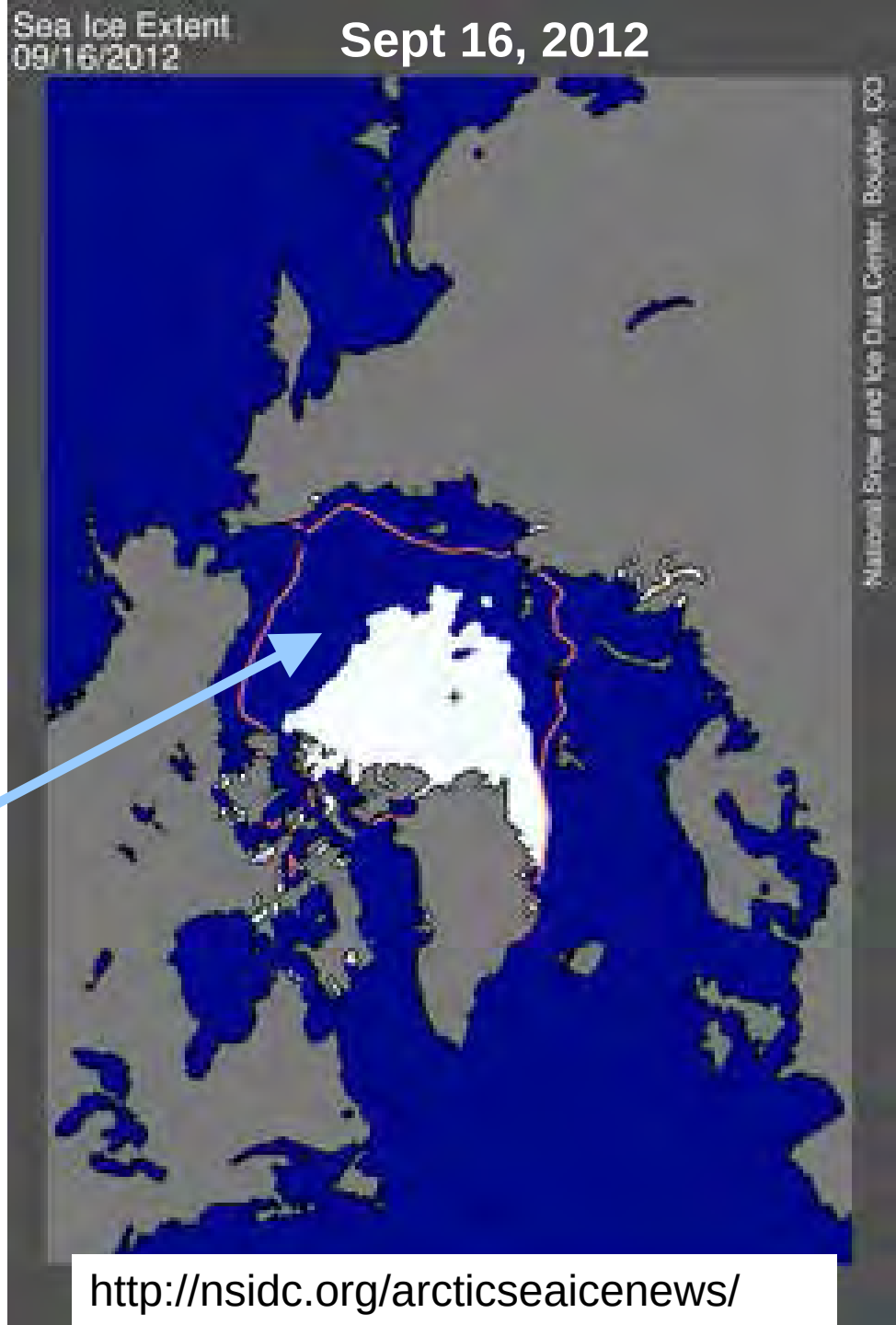
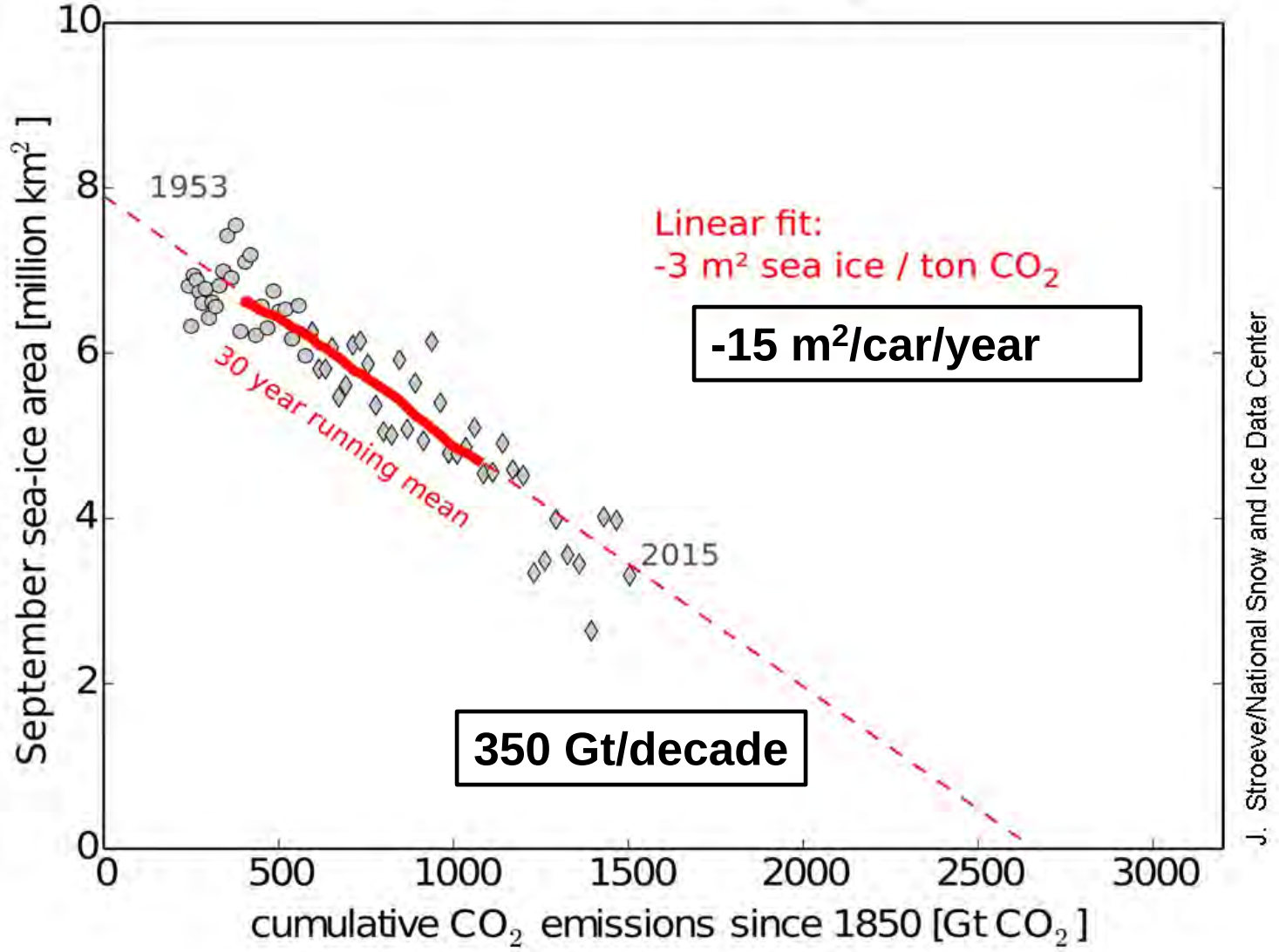


September Arctic Sea Ice Loss



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"?

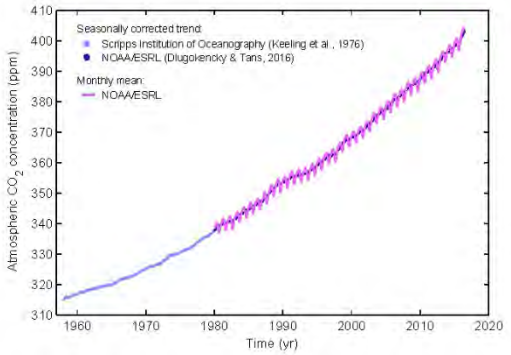
- signed by 197 countries *(UNFCCC 1992)*

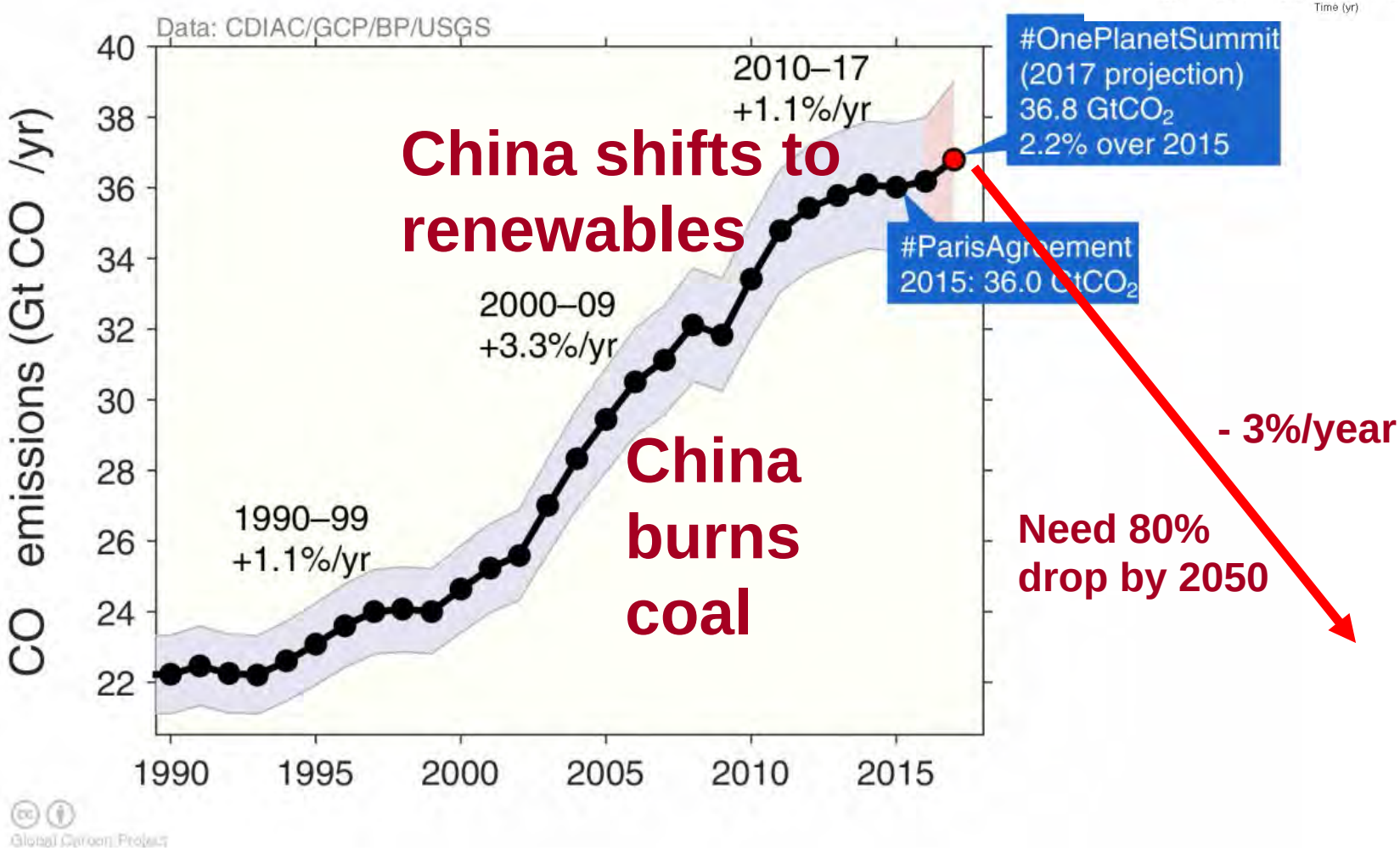
- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 emissions!**
- **This is possible but very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **"Lifestyle" has become dependent on fossil fuels**
  - **Powerful vested 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 plans to avoid the commitments it made***
  - ***2019 UN report says one million species will be gone in the next decade or two from habitat loss and climate change***

Growth of CO_2 Emissions slowed – now increasing





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***

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: *'others'* can pay the price**
- ***Our politics are facing collapse:***

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

We have technical solutions

- **Electrical power**
  - **Renewable: solar, wind, hydro**
  - **Storage: lithium batteries down to $150/kWh**
  - **Electric car industry generating massive storage**
- **New technologies: electricity to liquid fuels**
- **Net-zero housing**
- **Rethink transport**
- ***Needs change in attitude!***

So how do we deal with this?

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

- **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**

March 15, 2019

- **School strikes, 123 countries, 1.6 million students, demanding climate action**

Capetown

Greta Thunberg (born Jan 2, 2003)

On 20 August 2018, Greta Thunberg decided to not attend school until the 2018 Sweden general election on 9 September, after heat waves and wildfires in Sweden. Her demands were that the Swedish government reduce carbon emissions in accordance with the Paris agreement. She protested by sitting outside the Swedish parliament every day during school hours with the sign *Skolstrejk för klimatet* (*school strike for the climate*).

After the general elections, she continued to strike only on Fridays, gaining worldwide attention – <u>prompting global 'Friday' protests by students who realized they and their children were to be sacrificed</u>

"we can't change the world by playing by the rules, because the rules have to be changed."

Extinction Rebellion

- **Destruction of Earth now a Civil Rights issue**
  - **Can only be checked by civil disobedience**
  - **To defend the rights of our children**
  - **To defend the rights of the Earth's biosphere**
- **Shut down London (4/16) till UK and Scottish governments declared "Climate Emergency"**
  - **Government must act now to halt biodiversity loss and reduce greenhouse gas emissions to net zero by 2025**
  - **Government must create and be led by the decisions of a Citizens' Assembly on climate and ecological justice.**

https://rebellion.earth

Work on your high school science projects

Study the issues ahead

Discussion

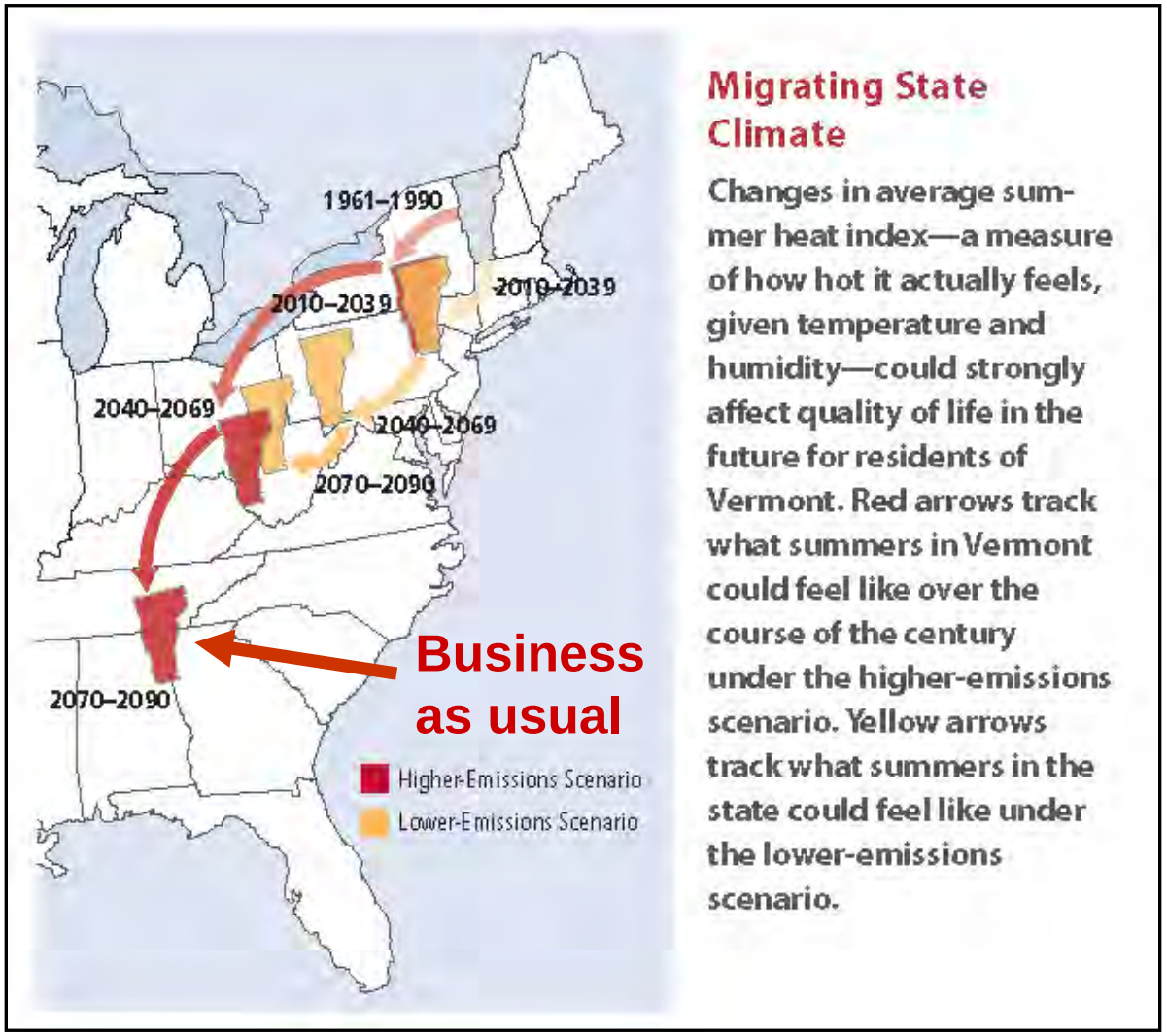
(http://alanbetts.com)

Tornadic Ca storm, 2” hail: 24 May 2019

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



NECIA, 2007

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**

‘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***

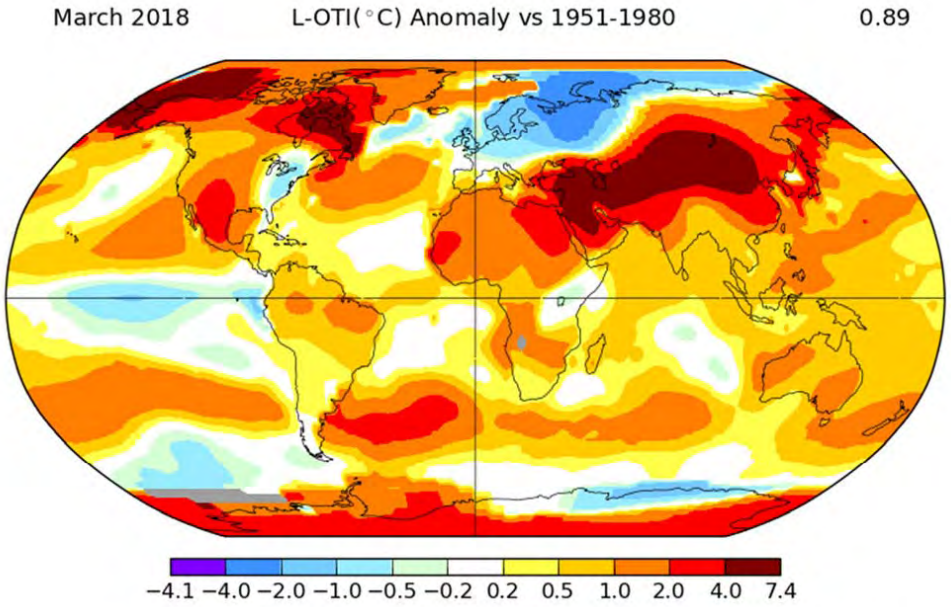
- **We need new ‘rules’ because**
  - ***Our numbers and industrial output are so large***
  - ***Maximizing consumption and profit have led to present predicament***

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***

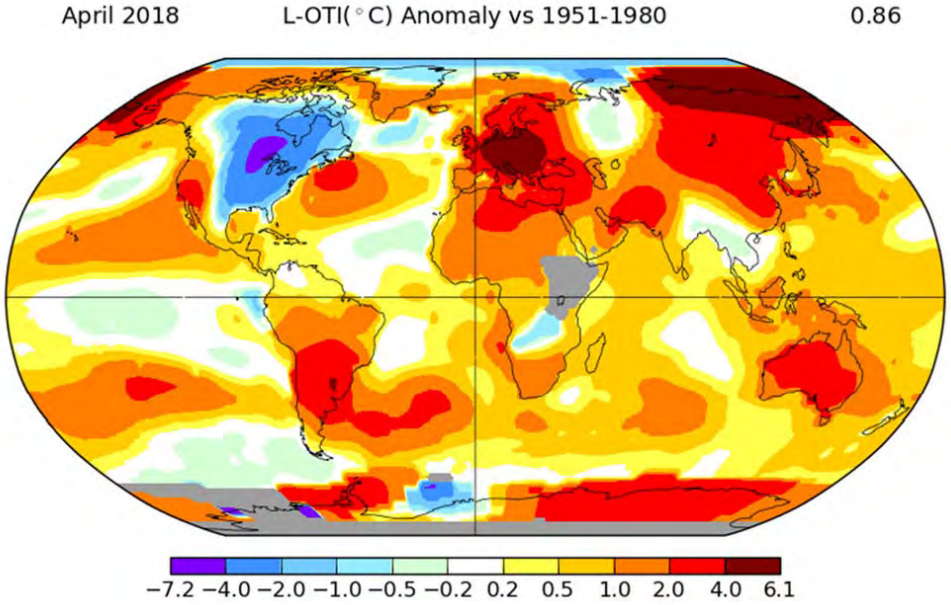
March-2018

Warm Atlantic, *4 Nor'Easter snowstorms;* Warm E. Canada; cold Europe



April-2018

Warm Atlantic, (Record) cold NA; warm Europe



Water, Snow & Ice Give Positive Radiative Feedbacks

- **As Earth warms, evaporation and water vapor increase and this is 3X amplifier on CO_2 rise**
- **As Earth warms, snow & ice decrease and reduced SW reflection amplifies warming in Arctic in summer and mid-latitudes in winter**
- **Doubling CO_2 will warm globe about 5°F (3°C)**
  - **Much more in the cold regions and over land, which responds faster than oceans**
  - **Change the global circulation**