Climate Catastrophe Ahead

Can we still stop it?

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Bennington College

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BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Outline

- Science of climate change
  - Global and local
  - What is happening to Vermont?
- The catastrophe we face
  - How can we stabilize the climate?
  - What are our responsibilities?
    - To our children
    - To the Earth
  - Will we sacrifice them to preserve "Business as Usual"

Strategies for Resilience

- **Understand technical/ecological issues**
  - **And place great value on the future**
- **Engineer for efficiency and resilience**
  - **Ask: Is this cost effective for our children?**
- **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 & resistance!**

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***
  - ***Long memory: decades to centuries***
- **Avoidance of responsibility for decades**
  - **Politicians, professionals, public**
  - **Climate change is Incompatible with business-as-usual**
- **Linked to unmanaged technology/economics**
  - **Soluble by changing system guidelines**
  - **Create efficient society, based on renewable energy**
- **Choices are value based: moral issue**
  - **Beyond science and economics**
  - **Must value the future of life on Earth**

Earth's climate sustains life

- Greenhouse gases keep Earth warm
  - Increase of CO_2 warms further
  - Evaporation of more water vapor triples warming
- Ice & snow melt; less reflection of sun
  - Arctic warms
  - Winters warm
- Oceans store heat & get warmer
- *Extreme weather is increasing as Arctic warms; westerlies slow down*

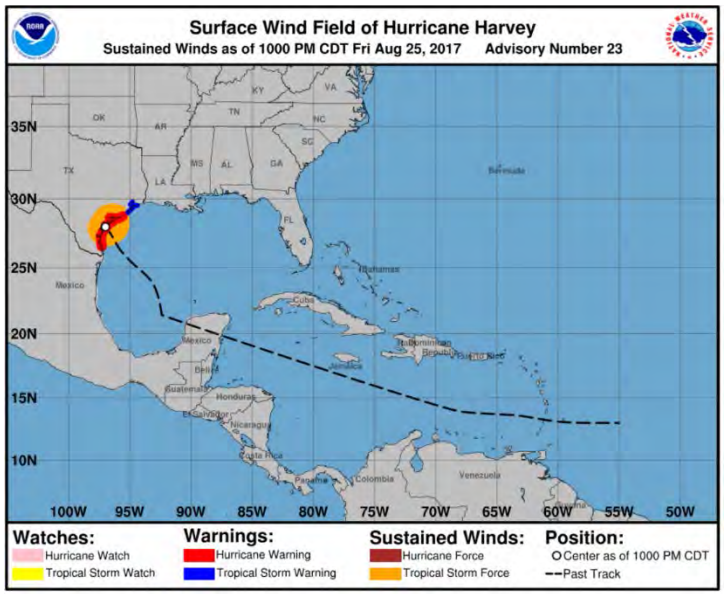
Hurricane season: 2017

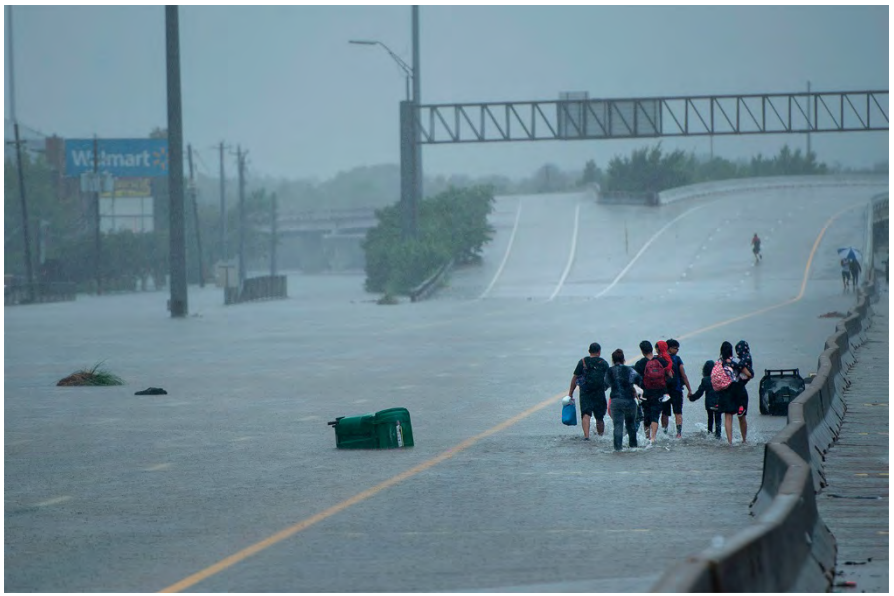
- **Earth is warming as greenhouse gases increase and reflective ice cover falls**
- **Oceans are storing 93% of heat**
  - **Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes; when vertical shear is low**

- ***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**



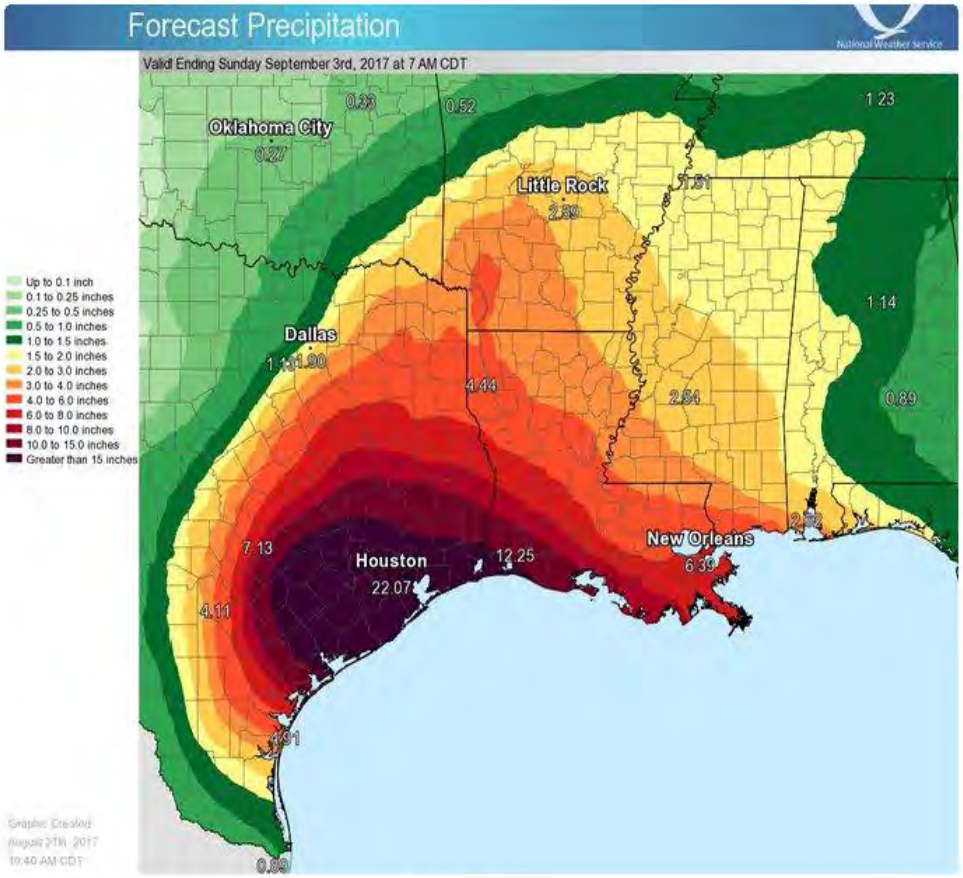


Challenged Forecast & Emergency Services

8/27/17: 36 hrs after landfall
Forecast >15 ins more

National Weather Service
@NWS

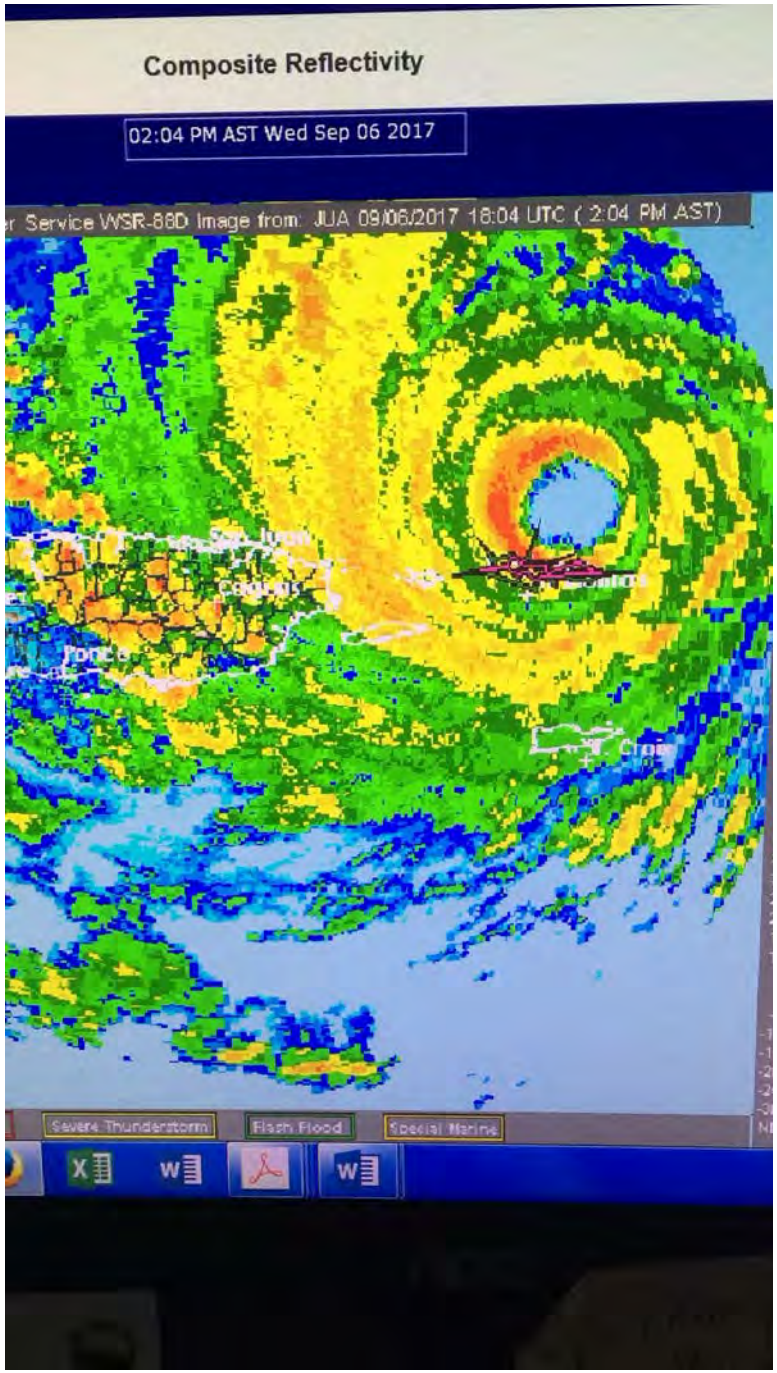
This event is unprecedented & all impacts are unknown & beyond anything experienced. Follow orders from officials to ensure safety. #Harvey



21.8K 11:44 AM - Aug 27, 2017

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

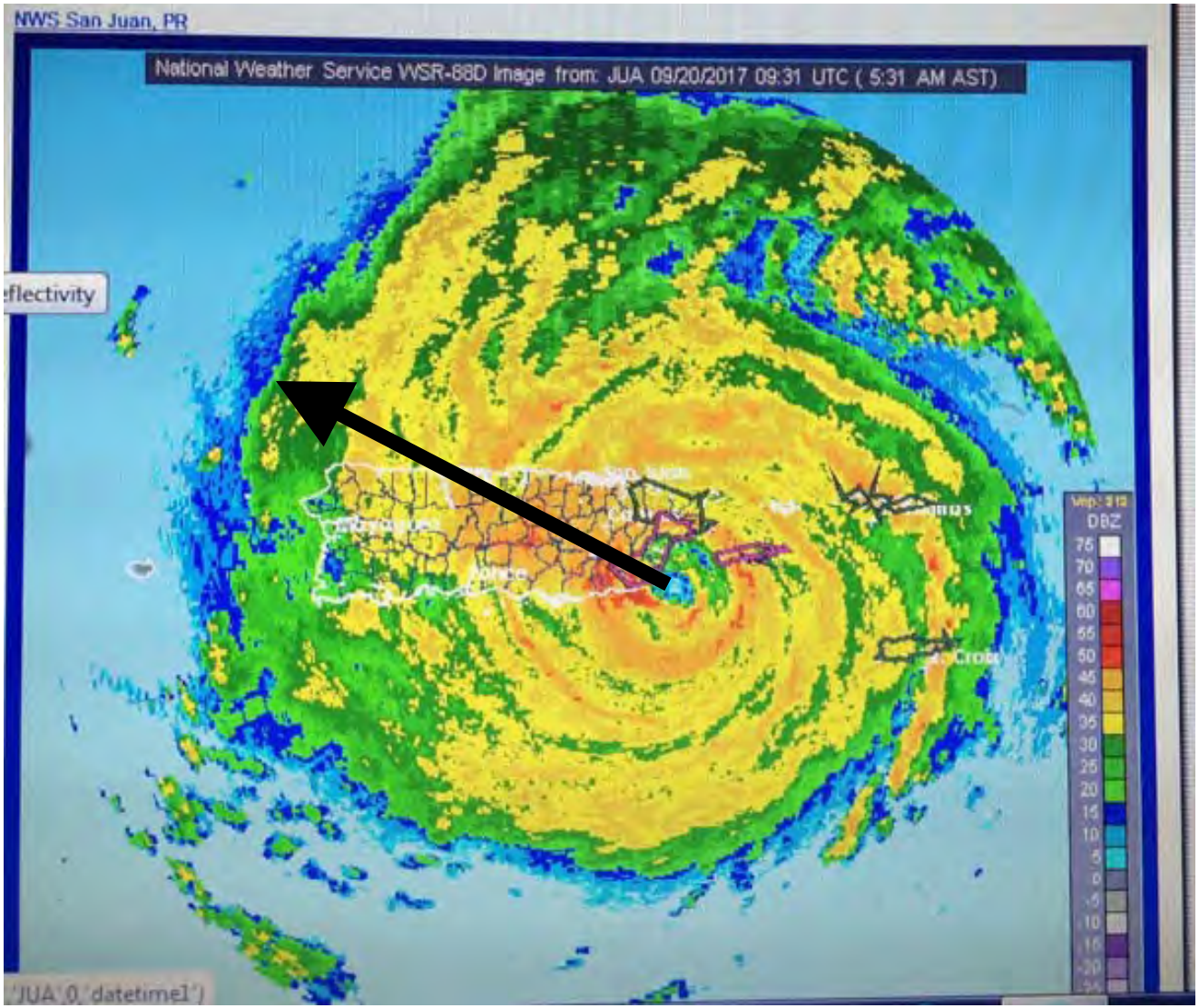
After Jose passed; Catamaran to Puerto Rico on Sept 11

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!)

Narratives: alanbetts.com



Two Severe Tropical Cyclones hit Mozambique: 2019

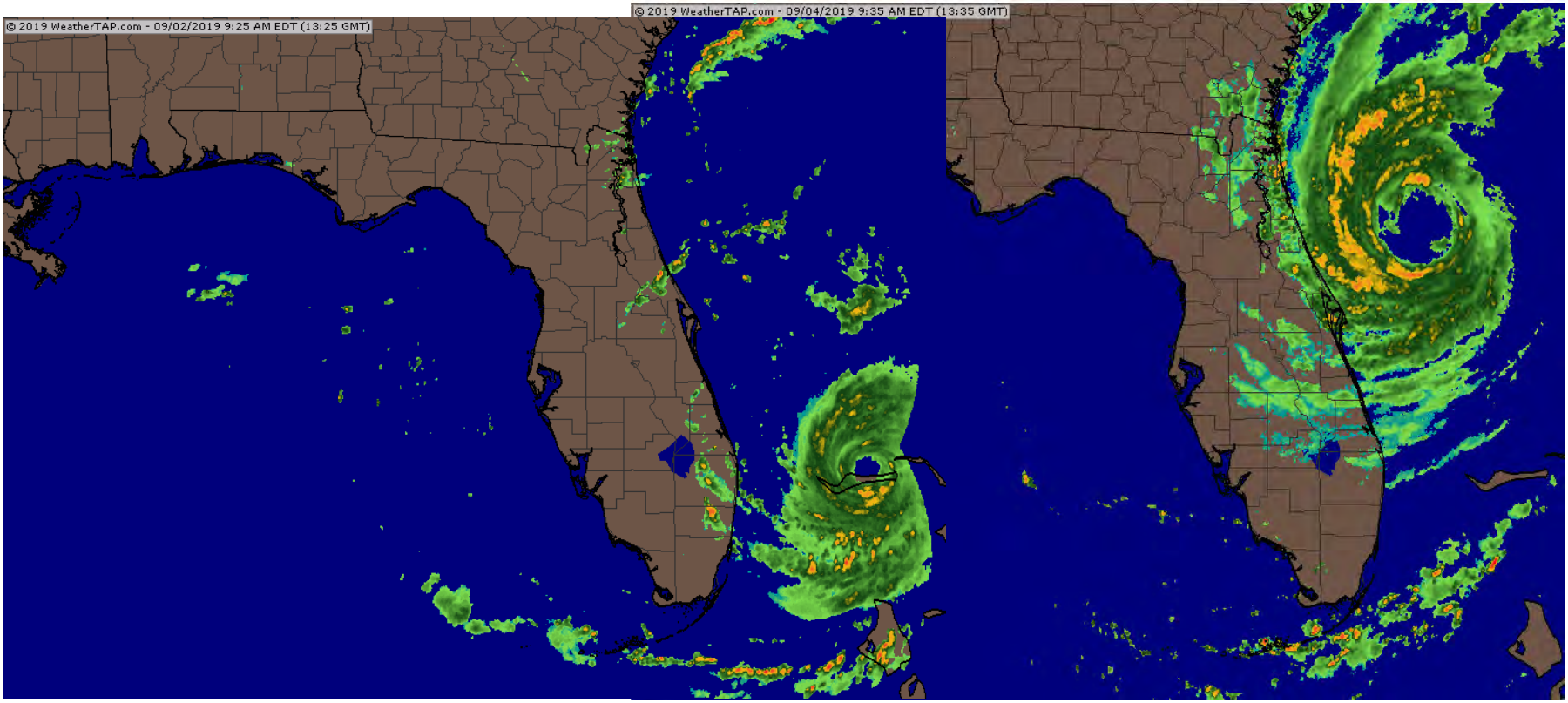
- **Southeast Africa cyclones were very rare**
- ***Idai* in March left 1000 dead from flooding**
- **Cat 4 *Kenneth* in April, 2019**
  - **60 in of rain**

July 2019: track of Barry

Started as band of thunderstorms in Kansas, traveled in slow circle, intensified over warm water of Gulf, rained on wet Louisiana

[Flooding cost $billions]

Dorian: Cat 5 Cat 2/3



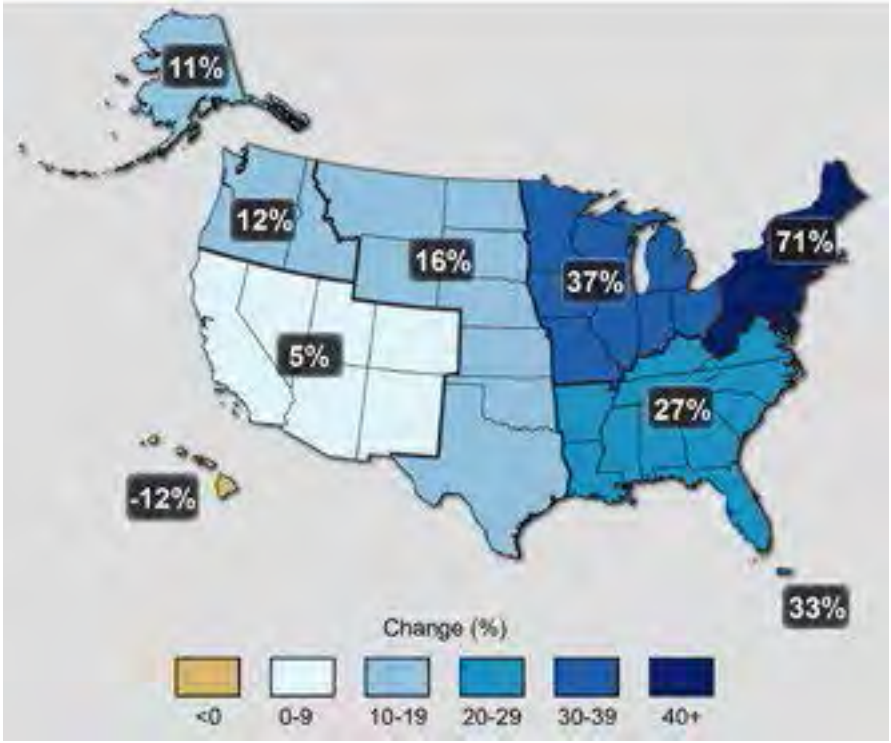
Sept 2, 2019
Stationary over
Grand Bahama

Sept 4, 2019
Off Florida
Coast

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

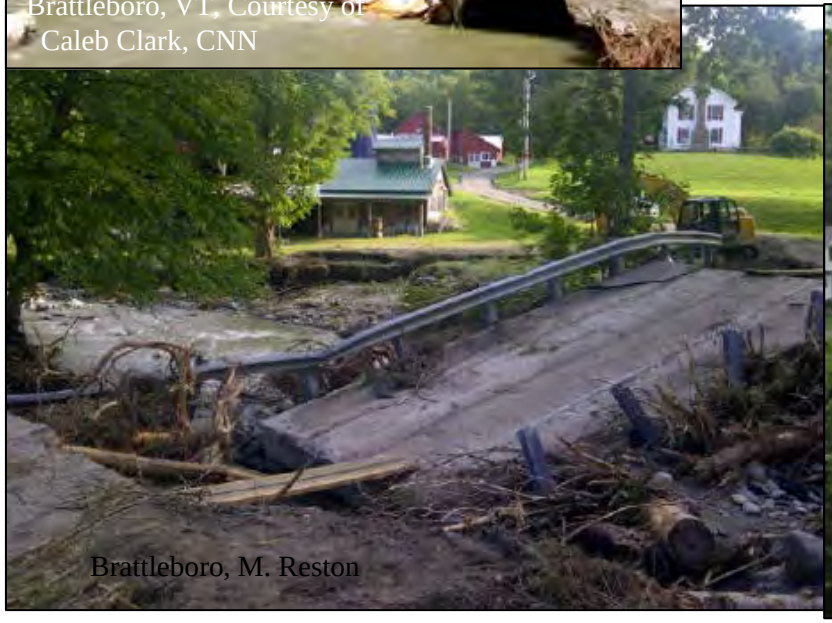
Massive damage

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

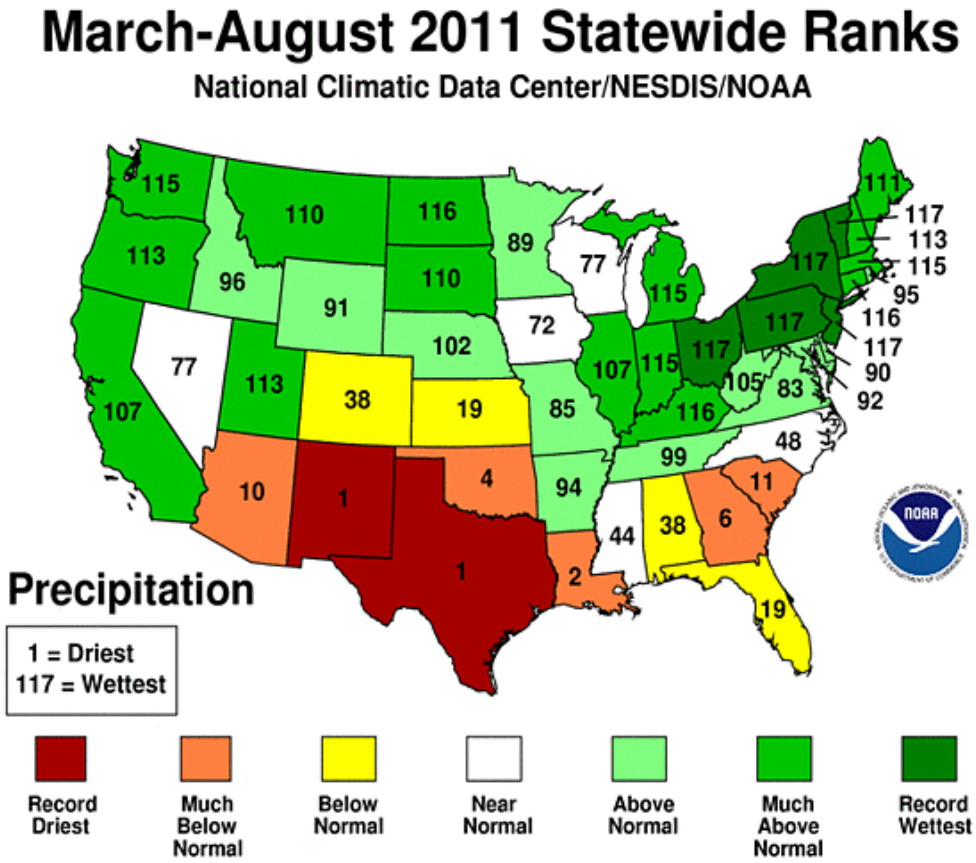
2011 Classic Flood Situations

- **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***

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**

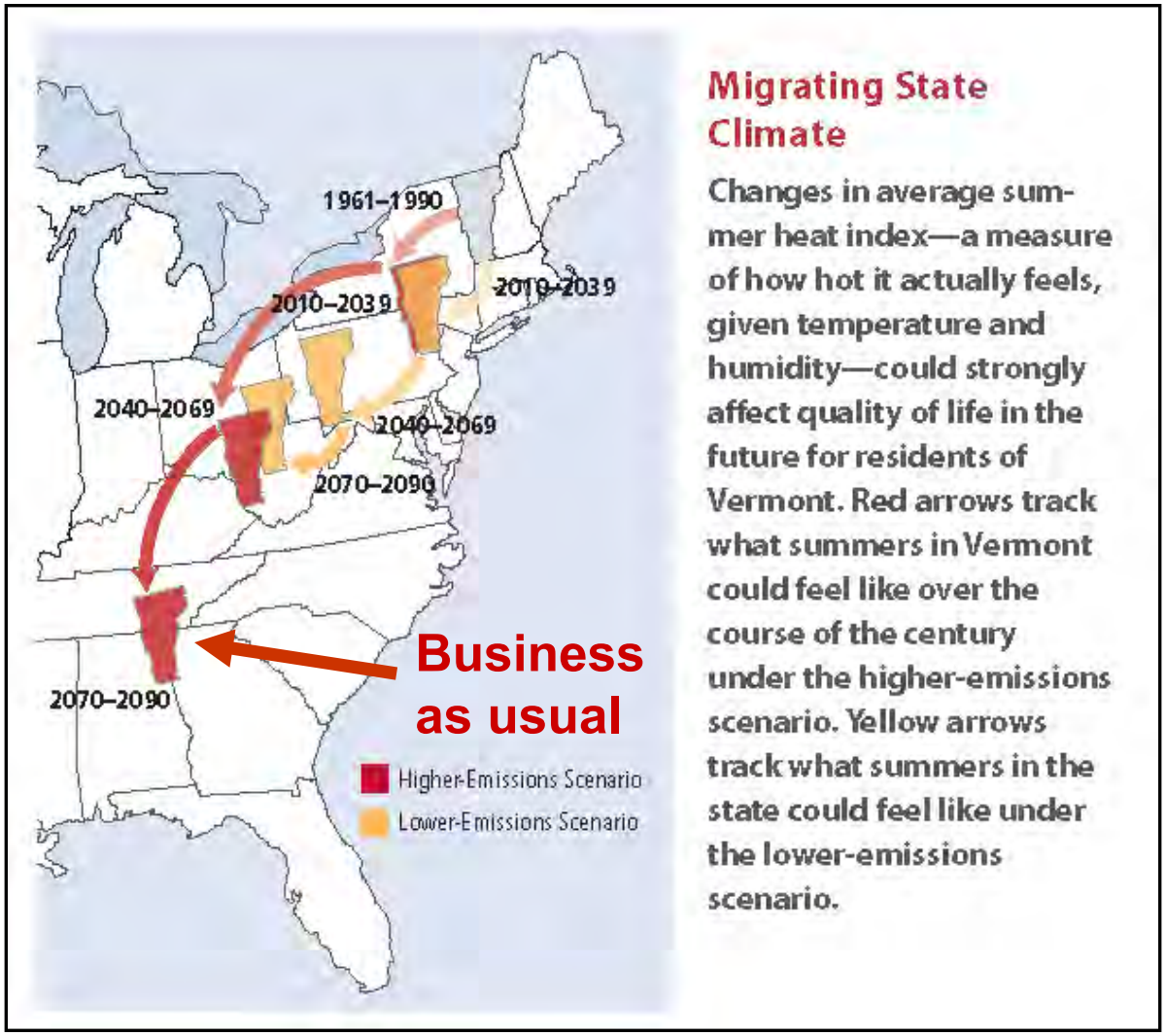
Flooding increasing

- **Warmer temps = higher rain-rate (4%/°F)**
- **As Arctic warms faster than equator**
  - **N-S temperature gradient decreasing**
  - **Westerly jet-stream slowing & meandering**
  - **Patterns stationary for longer**
- ***Slower moving storms mean more rain over one place - more flooding***
- **Harvey stayed 4 days over Houston, raining 10 in/day *[Florence 3 days; NC]***

Vermont's Future with High and Low GHG Emissions

What about VT forests?

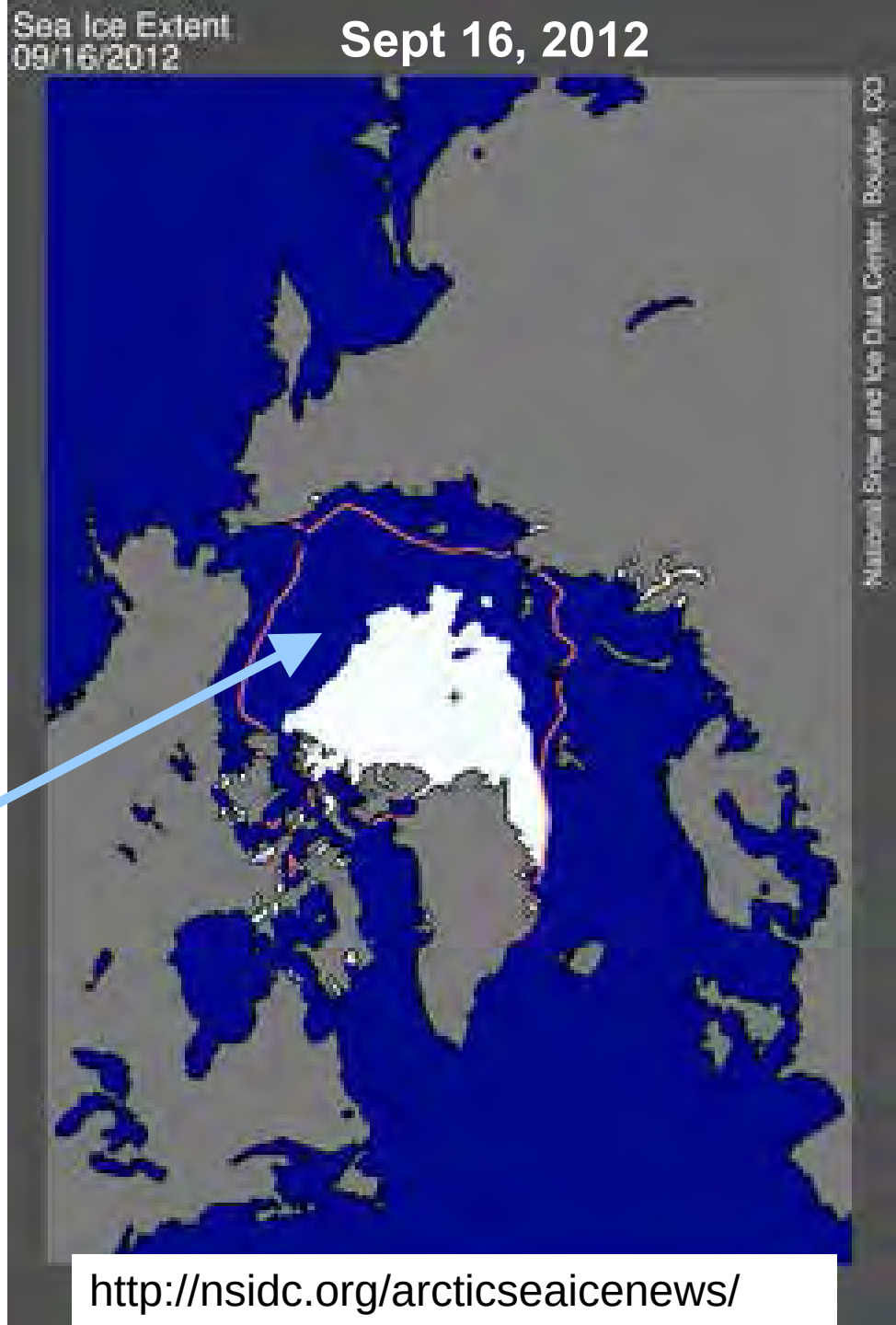
Sub-tropical drought areas moving into southern US



NECIA, 2007

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

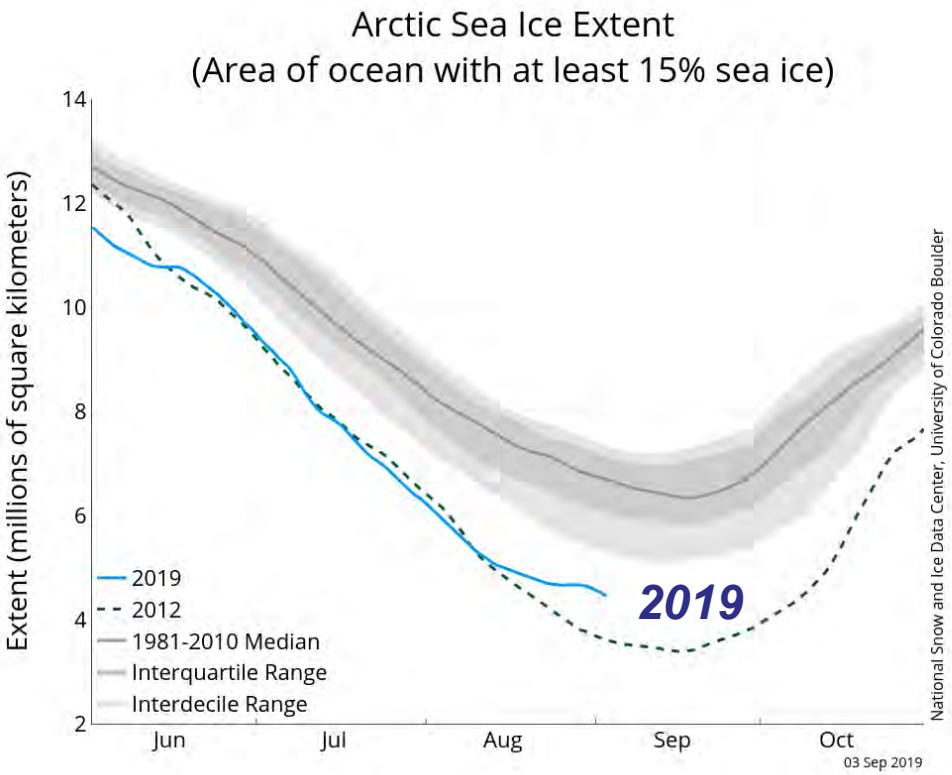
- ***Positive feedbacks:***
- ***Less ice, less reflection of sunlight***
- ***More evaporation, larger vapor greenhouse effect***
- ***Same feedbacks as in our winters***

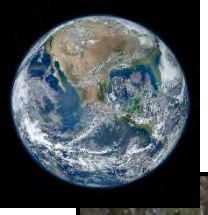


Winters are changing
- as Arctic warms and melts

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

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





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

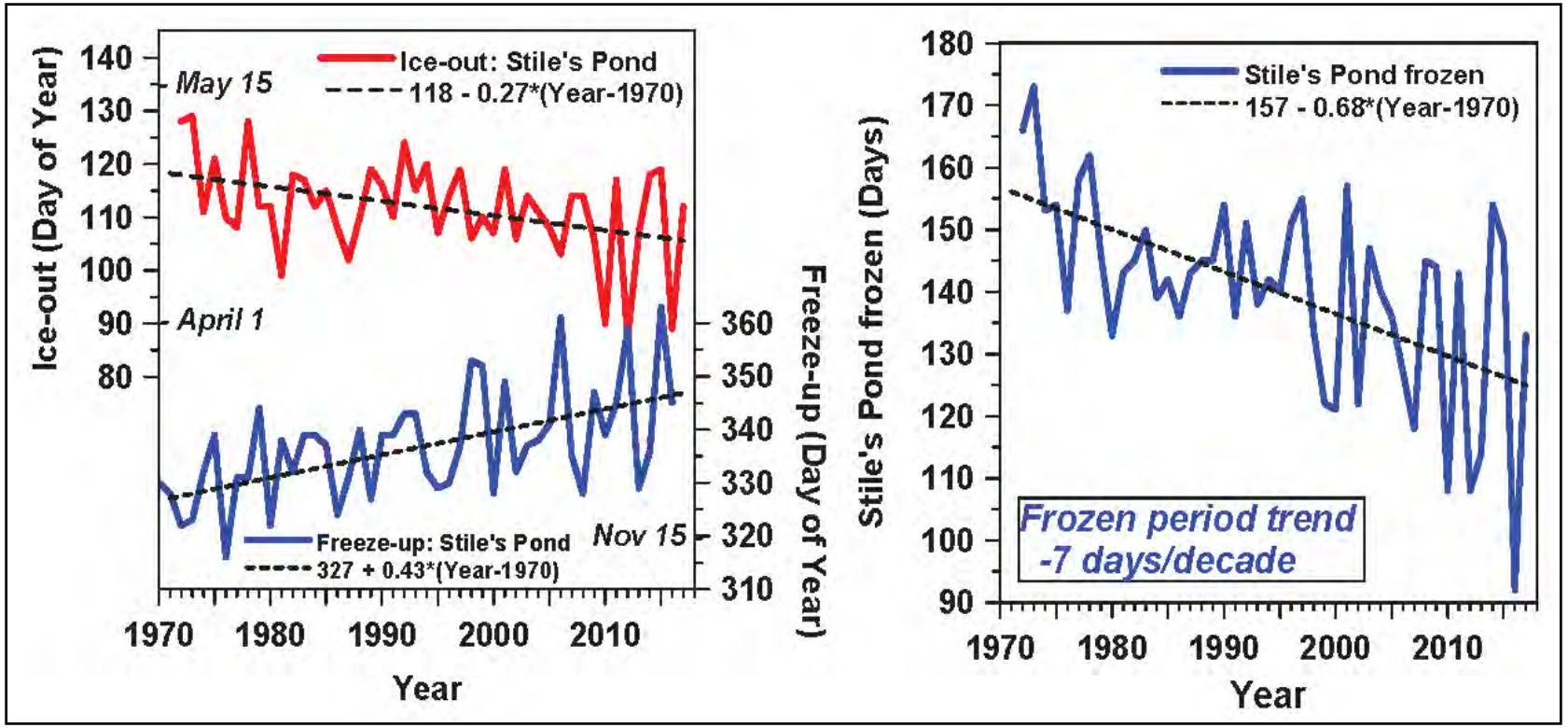
After cold snowy period
T_{min} down to -10 to -20F

January 12, 2018

After T_{max} up to 50F

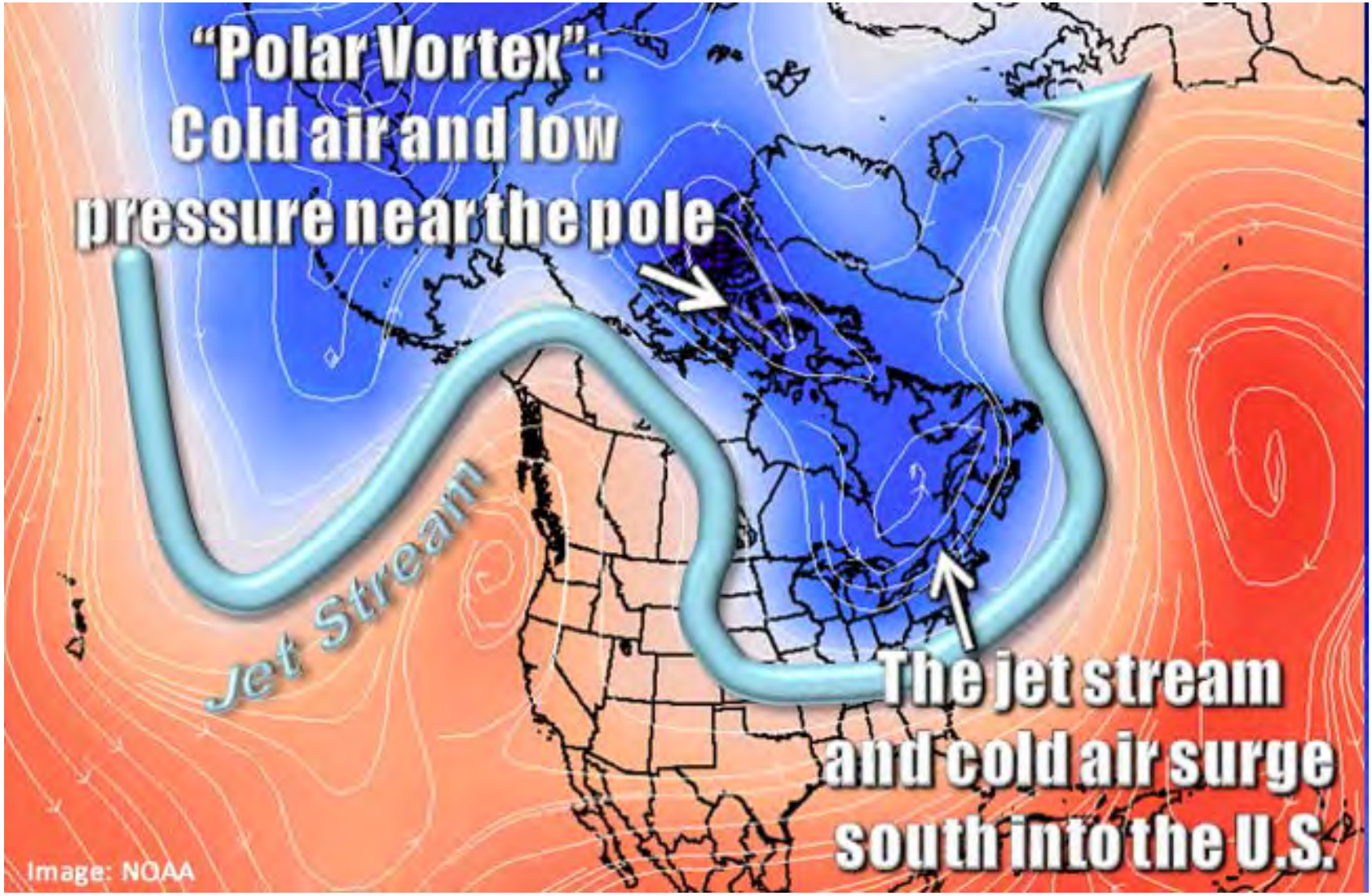
Marker: Lake Freeze-up & Ice-out

Frozen Period Shrinking: variability huge



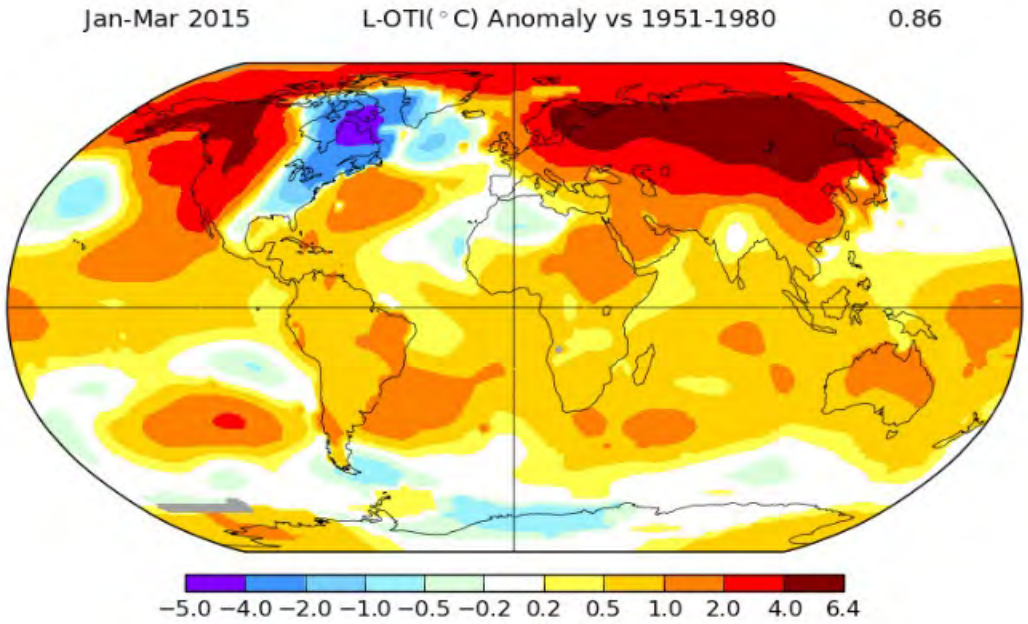
- **Freeze-up later by +4 days / decade**
- **Ice-out earlier by -3 days / decade**
- **Lake frozen period trend - 7 days/decade**
- ***Interannual variability ≈ 40 yr trend***

Stiles Pond: "Eye on the Sky"


"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

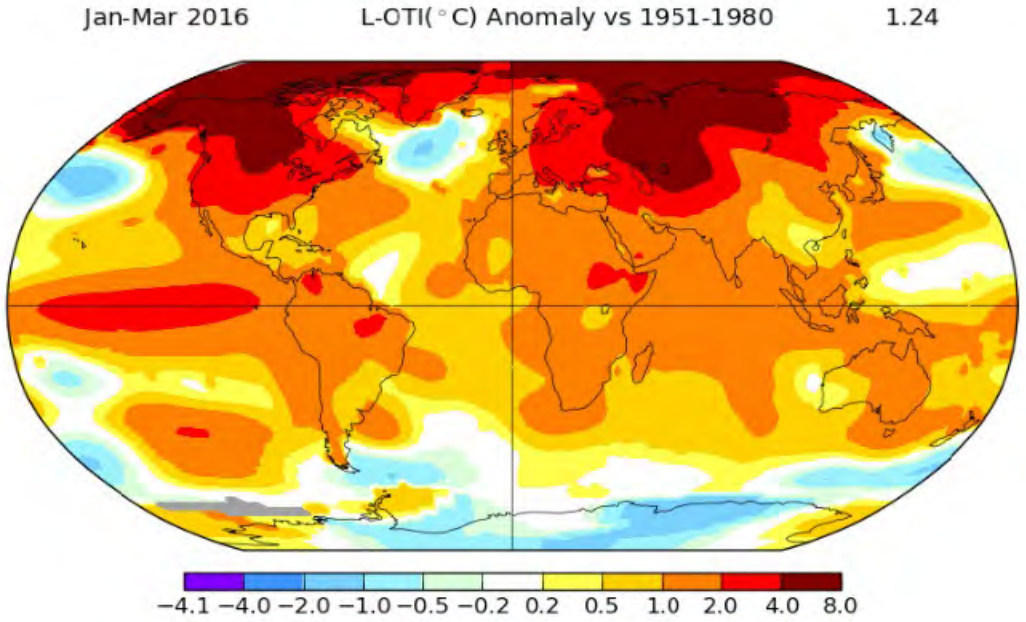
Jan-Feb-Mar 2015

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



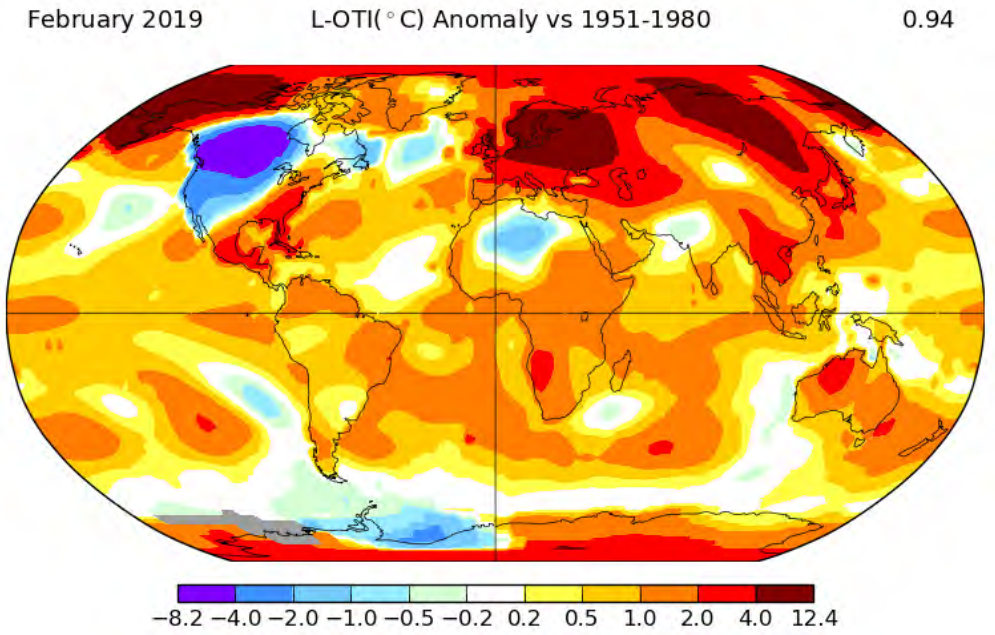
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



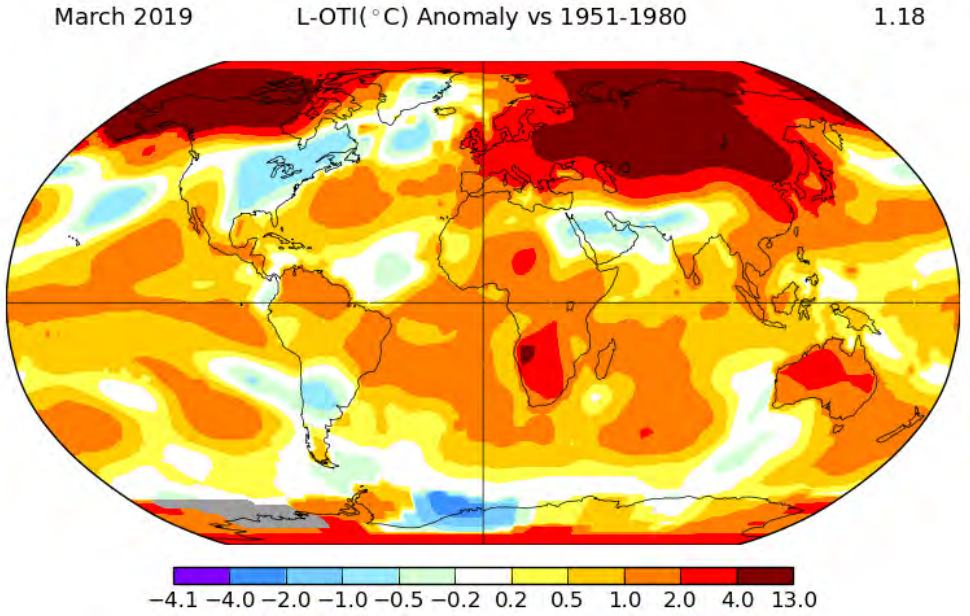
Feb-2019

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



March-2019

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



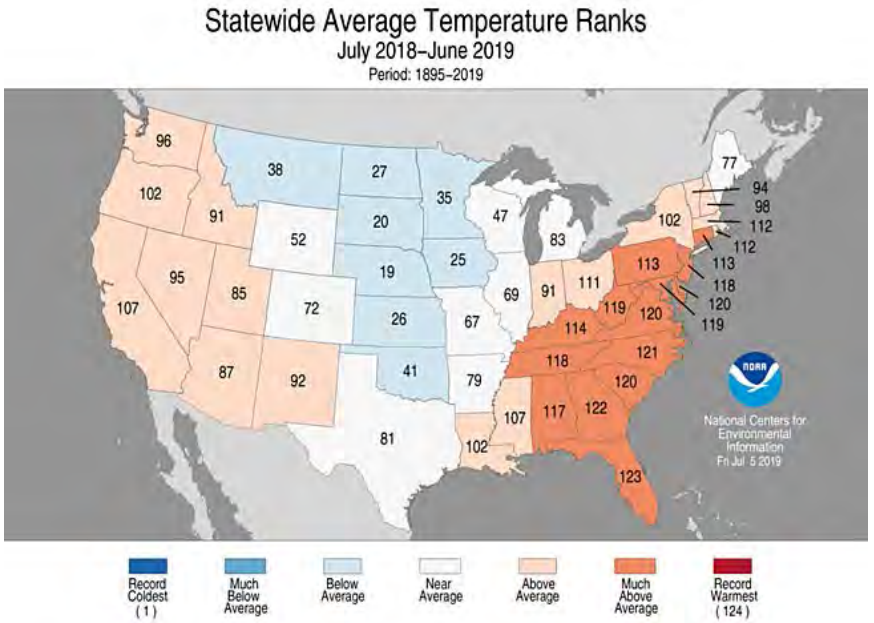
Jul-2018 to Jun-2019

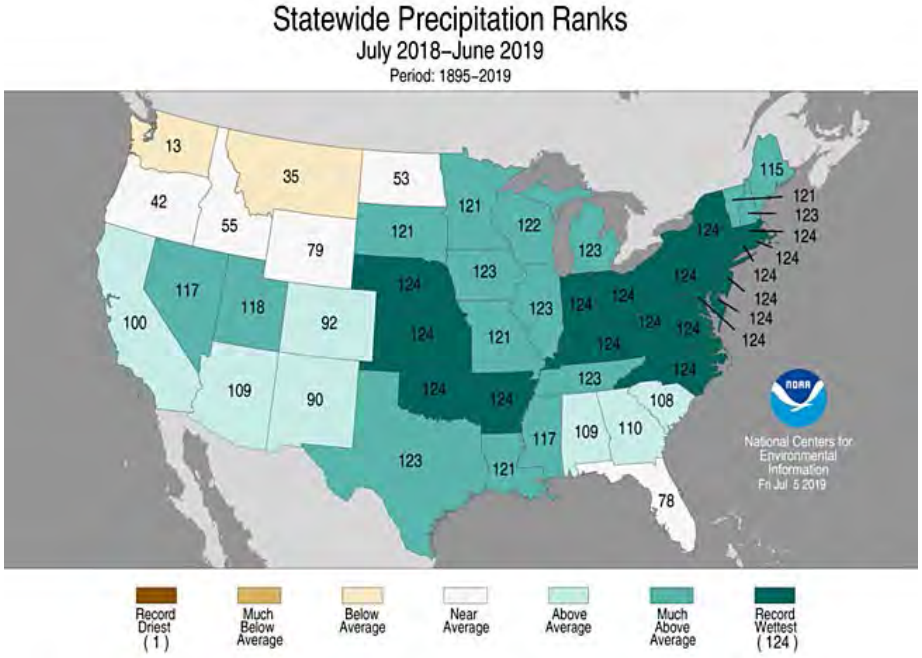
Warm in South-east

Cold in north-central

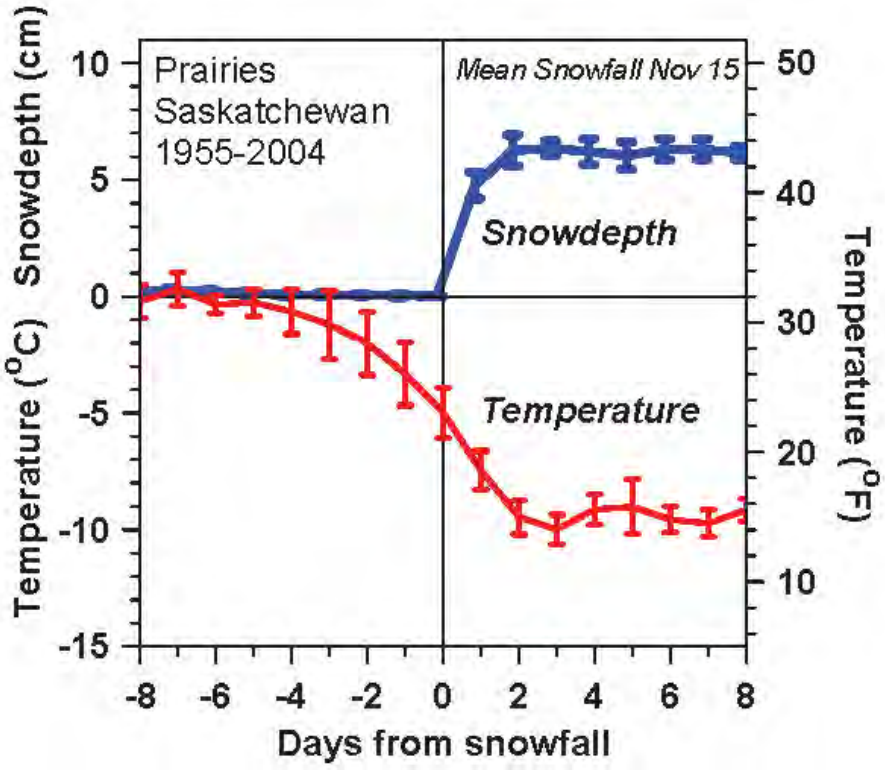
Very wet across eastern & central US

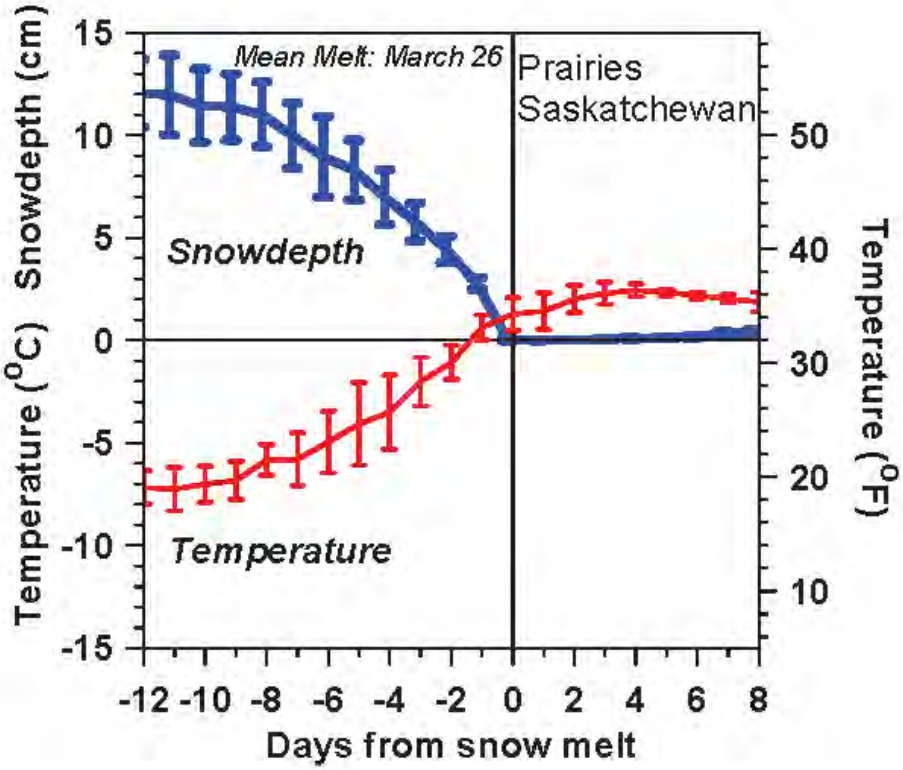
2019 Mississippi flooding longest on record





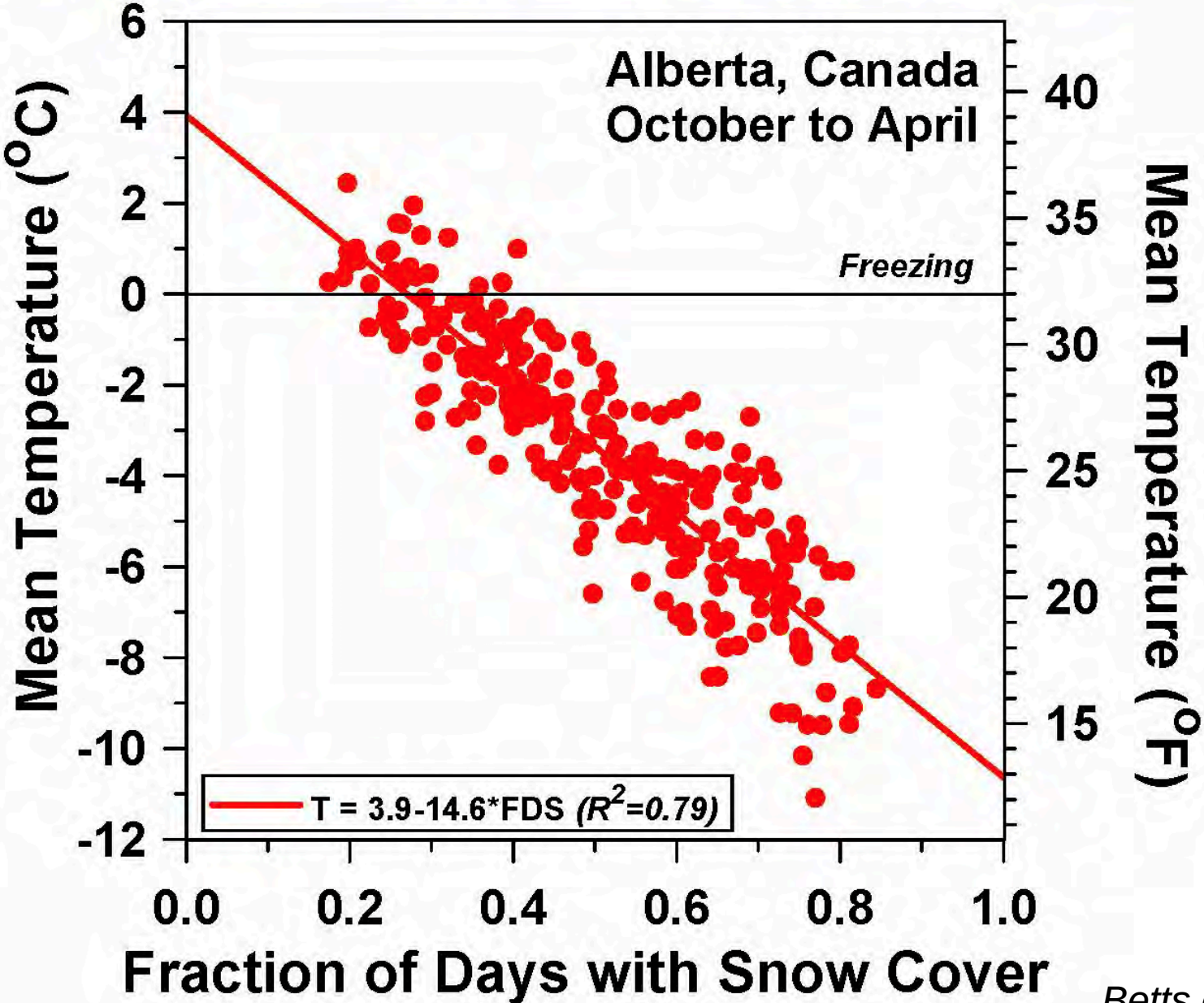
Snowfall and Snowmelt





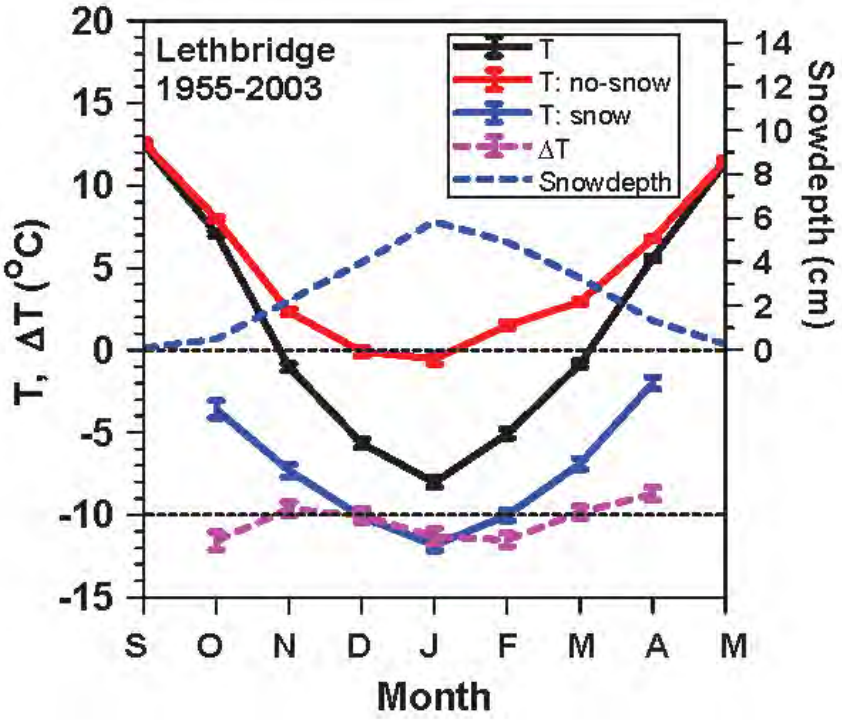
- **Temperature changes 10°C with snow cover**
- **Snow cover is a ‘climate switch’**
- ***Fast transitions in ‘local climate’***
  - ***Snow reflects sunlight***
  - ***Reduces evaporation and water vapor greenhouse***

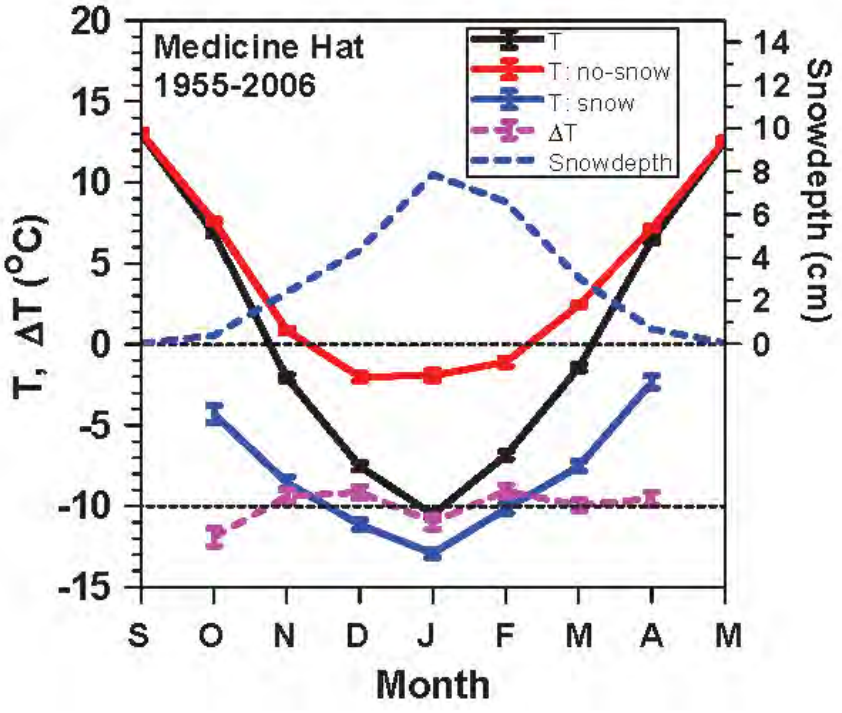
More snow cover - Colder temperatures



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"**

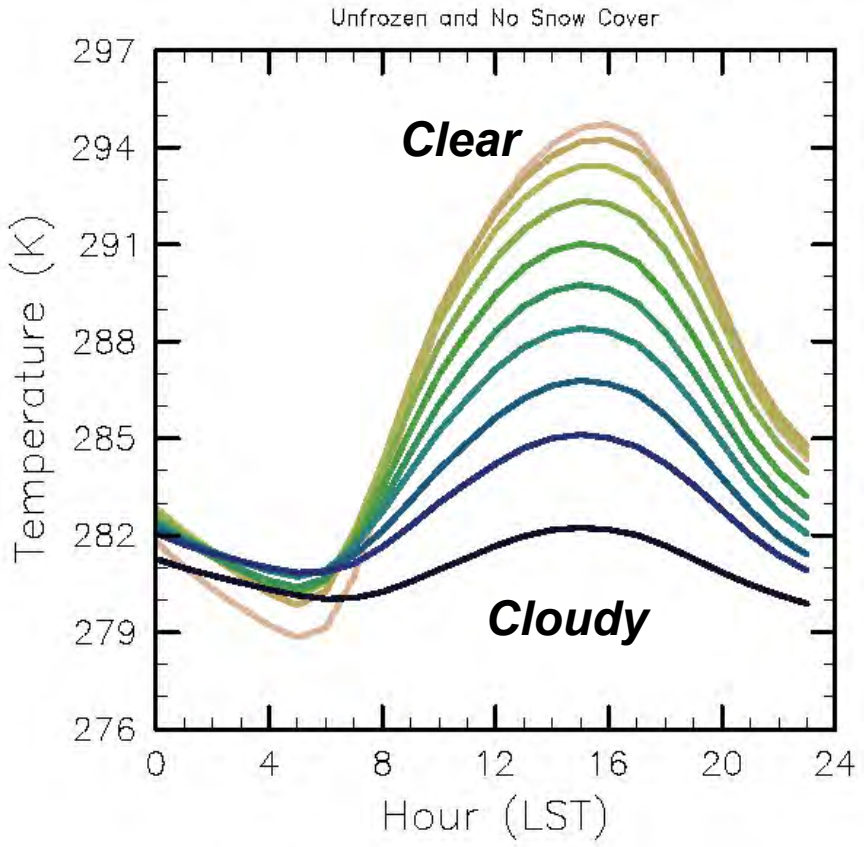
With snow

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

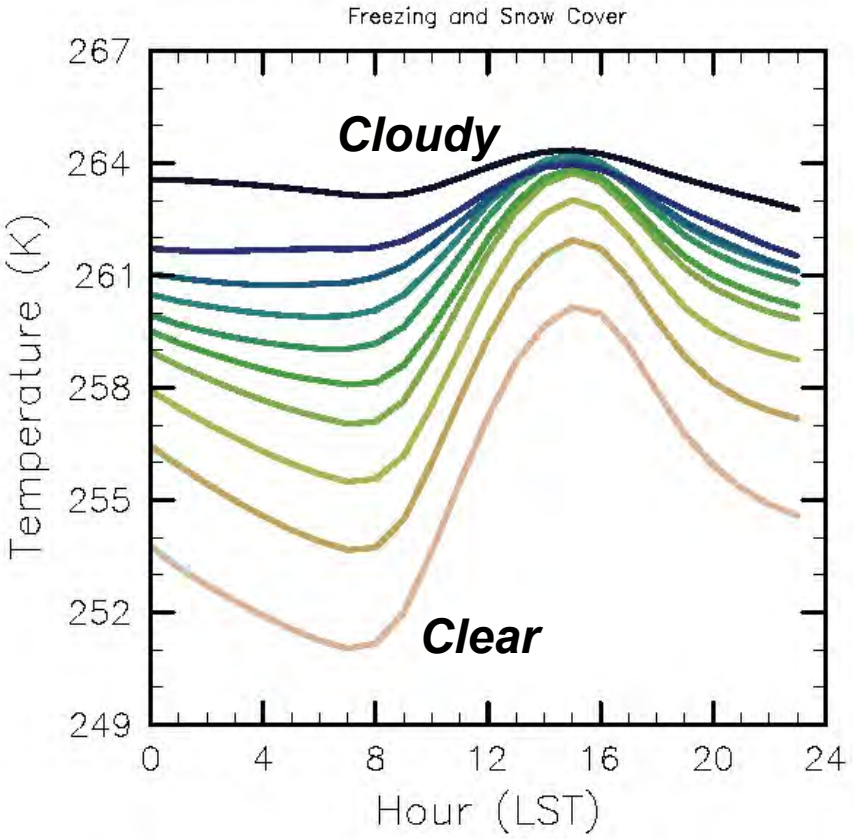
Warm & Cold Climates: T><0°C

Effect of Clouds 'Reversed'

T_m >0°C: no snow: 150,000 days



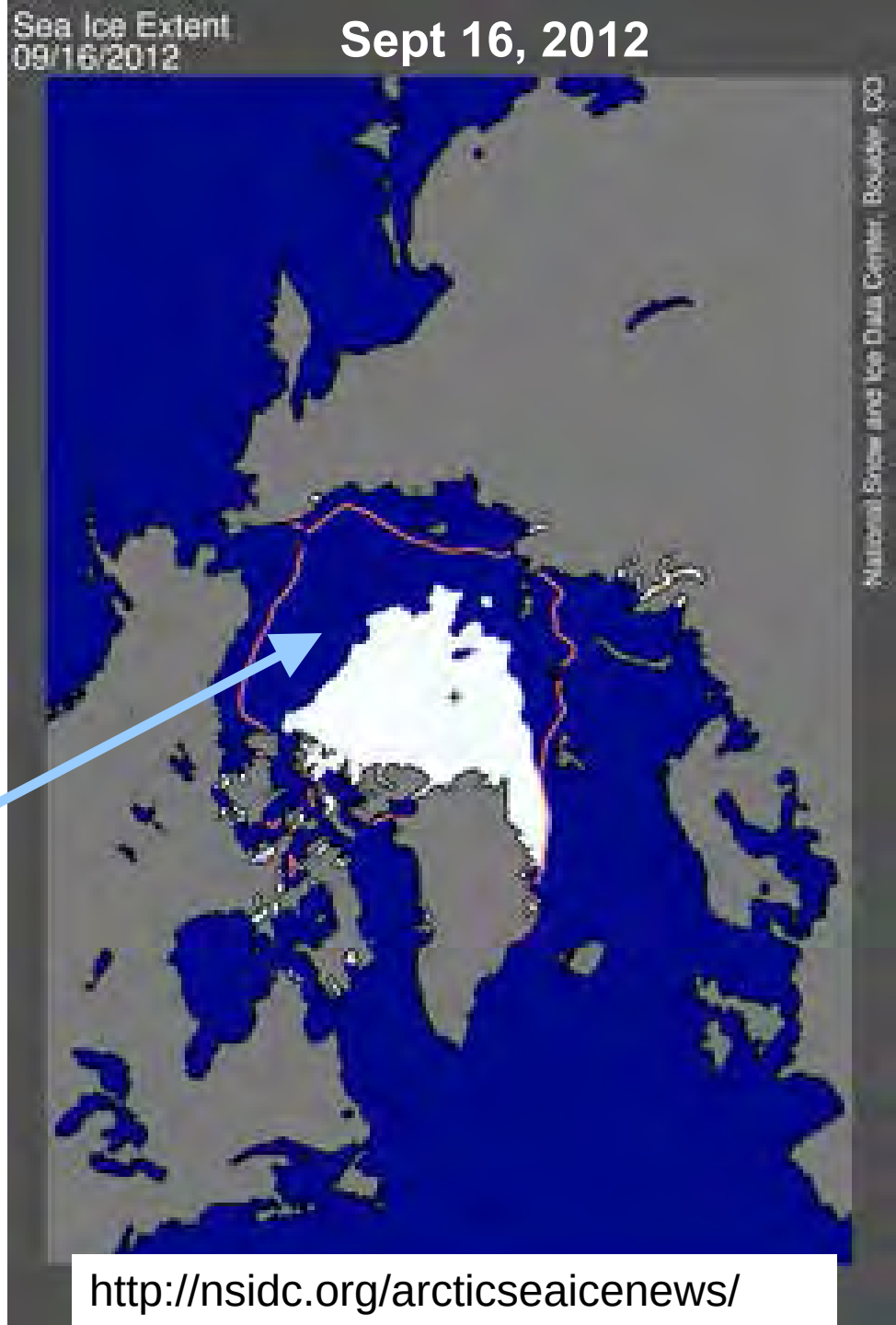
T_m <0°C: snow: 75,000 days



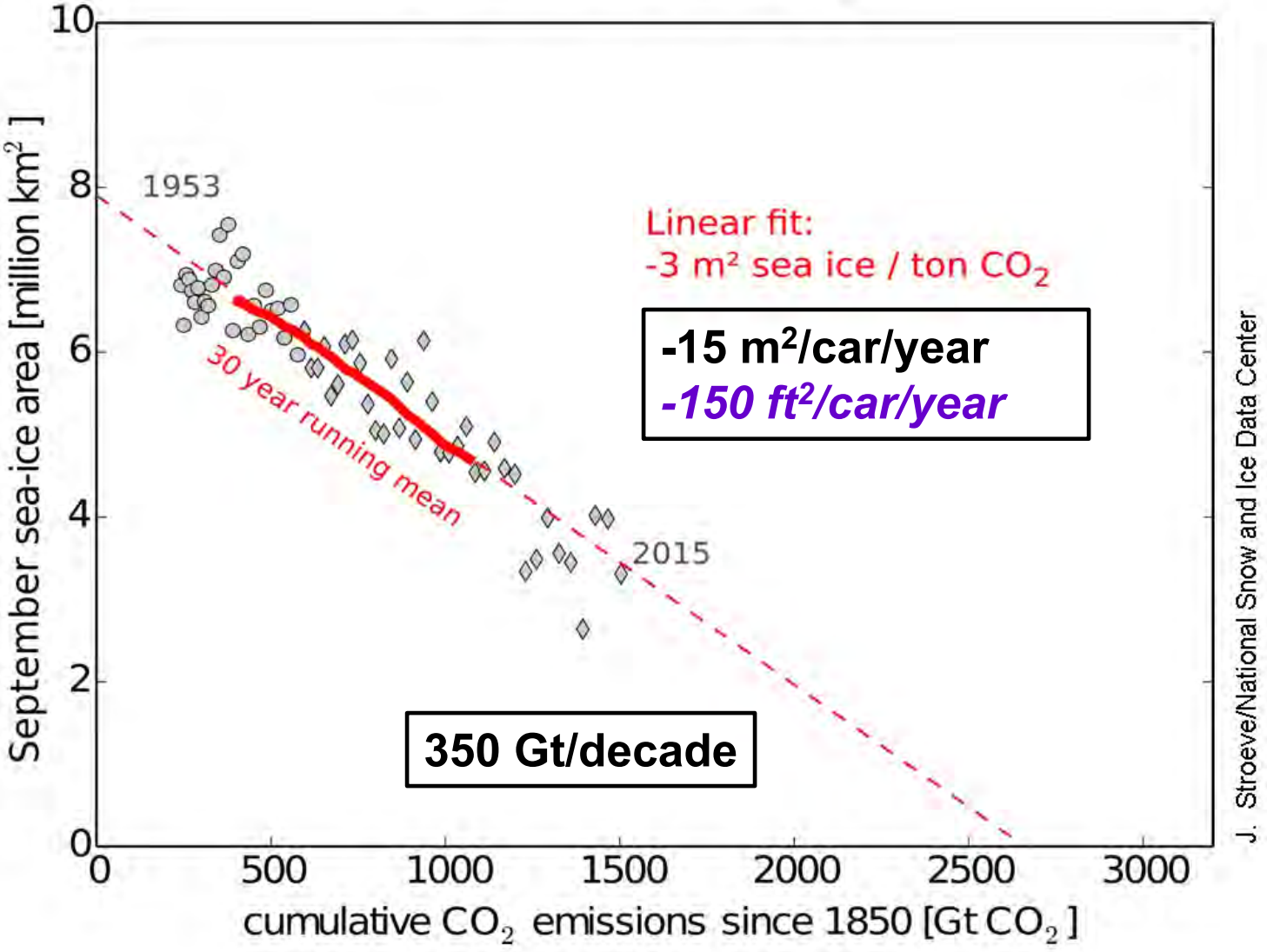
- **Warm >0°C:** Clouds reflect sunlight
- **Cold <0°C:** Clouds are greenhouse & snow reflects sun

- **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 135mpg
- Electricity from community solar array

>3000lbs and 135 mpg
Payload: 750 lbs at 60 mph

180lbs: solar panel on roof
Payload: 350lbs at 20 mph

73lb Cargo bike;
300 lbs at 20 mph

We promised to stop "Dangerous Climate Change"?

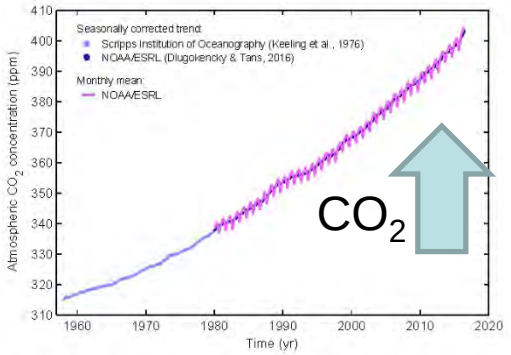
(UNFCCC 1992)

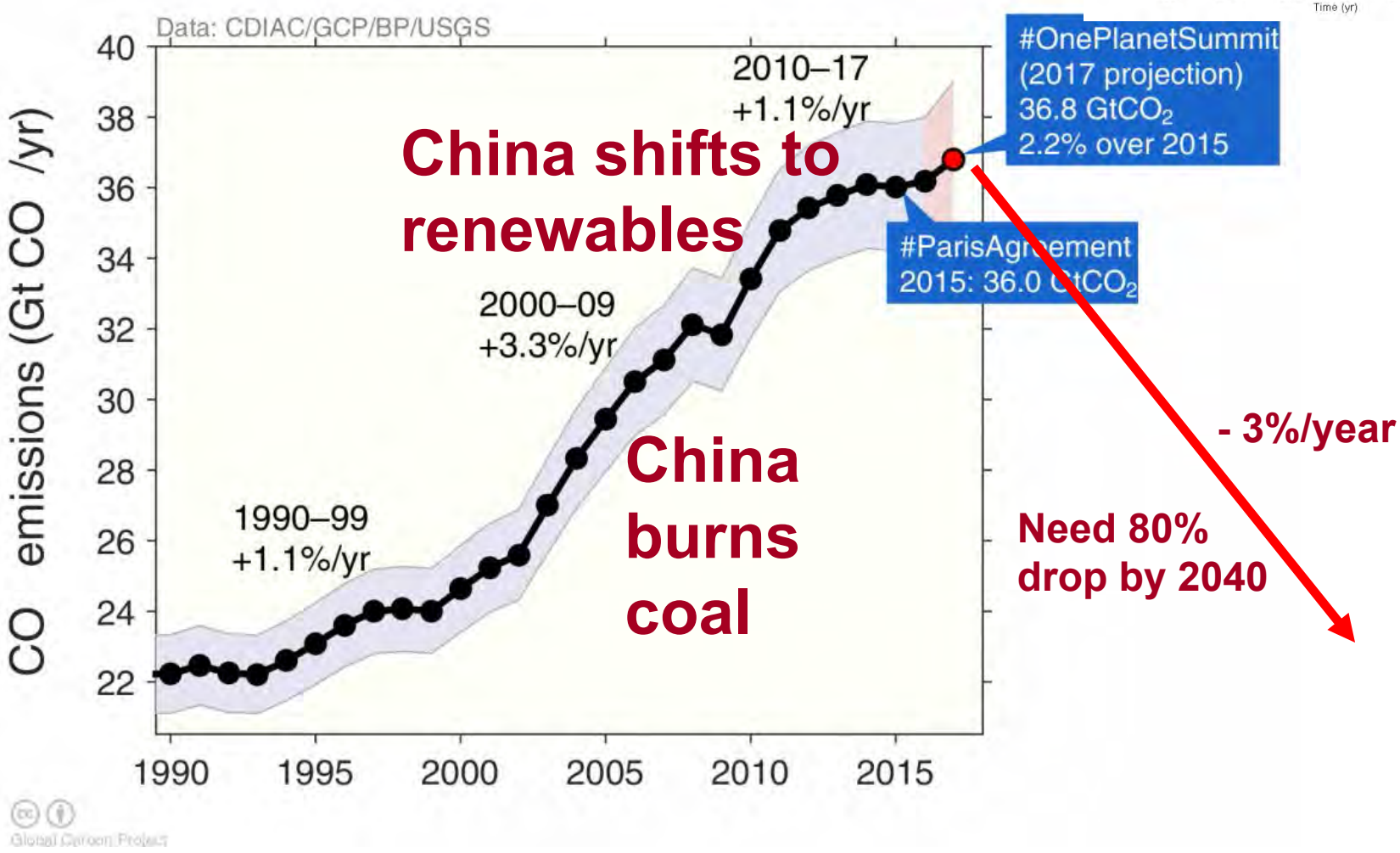
- **How? Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 emissions!**
- **This is possible but very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **"Lifestyle" has become dependent on fossil fuels**
  - **Powerful vested 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**
  - **Told Catholic Church to act: *institutional resistance***
- ***2017: US cancels 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***

How do we do it?
Systems Engineering

- ***Change the rule-book from maximizing profit***
  - ***Ask: Is this cost-effective for our children?***
- **Minimize human waste products dumped into the Earth's atmosphere and ocean**
  - ***Shift from fossil fuel ASAP***
- **Maximize the efficiency with which our society uses energy and fresh water**
- **Maximize the use of renewable energy**

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***

How do we plan/adapt?

- **Future needs creative approaches**
  - **Efficient society run on renewable energy…**
  - ***But it needs vision and deep change***
- **We need to work with the Earth's biosphere**
  - ***People reconnected to landscape; to Earth***
  - **Manage water on landscape**
  - **Manage forest diversity for a warmer climate**
  - **Manage diversified year-round agriculture**
  - **Manage energy crops and solar farms**

Why Is It Difficult for Us?

- **The "American dream" is crumbling**
  - **"Economic growth" based on fossil fuels, debt, consumerism and dumping waste streams is unsustainable — and a disaster for the planet**
- **We don't know how to guide and manage technology — so the result is tremendous successes and catastrophic failures**
- ***Individual & corporate "rights" and the needs of humanity must be balanced against the needs of the Earth's ecosystem***

Powerful interests 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**
- ***US controlled global oil supply/price for century***
  - ***Fueled 'fossil' capitalism and exploitation of the Earth and the poor***
  - ***Hidden by web of lies: now driving 'ecocide'***

Oil, Power and War: Matthieu Auzanneau

The Coming Catastrophe

- **What are the challenges ahead?**
  - **Complex living systems: nearing collapse**
  - **‘Fossil’ capitalism incompatible with livable Earth**
  - **Social and political resistance to change**
  - **Corruption in the system at many levels**
- **Moral issues surfacing at last**
  - **Sacrificing our Children**
  - **Extinction of species & stable biosphere**
- ***Global Rebellion has started***

March 15, 2019

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

Next is Sept. 20-27, 2019

Capetown

Greta Thunberg (born Jan 2, 2003)

Swedish parliament last year

Crossing Atlantic last week

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. She sat outside the Swedish parliament every day during school hours with the sign *Skolstrejk för klimatet* (*school strike for the climate*), demanding that the Swedish government follow its Paris agreement commitment to reduce carbon emissions.

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>

Fridaysforfuture.org

Global Strike: Sept. 20-27

"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
- Shut down London 4/15 to 4/17 until UK and Scottish governments declared "Climate Emergency"
- Other countries following

https://rebellion.earth

  - Large reductions this decade
  - By 2050, illegal to burn fossil carbon
  - "Carbon abolition" movement

Vermont Groups planning actions: October 2019

Discussion

Real info: climatecentral.org, cleanet.org
www.realclimate.org, vecan.net
skepticalscience.com

Rebellion: vermontclimatestrike.org
350Vermont.org, CastletonIndivisible.org
Rights and Democracy: RadVT.org
SunriseMovement.org
Fridaysforfuture.org, Rebellion.earth

(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***

Can Science & Policy be kept separate?

- ***Separation was the traditional frame***
  - **How scientists are trained**
  - **It protects the integrity of science**
  - **Invaluable for global cooperation**
  - **Frame of international projects**
- ***But can we solve global challenges with this mindset?***
  - ***Given the attacks on science by corrupt politicians?***

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**
  - **Climate change is existential issue for humanity**
  - **For the future of the Earth and its ecosystems**
  - **We need your skills to navigate the future**