



Climate Catastrophe Ahead

How do we deal with it?



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Outline

- **Science of climate change**
 - **Global and local**
 - **What is happening in the Northeast?**
- **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 “Business as Usual”?*
 - *Or will we creatively transform society?*

Strategies for Resilience

- Understand technical/ecological issues
 - And place great value on future
- Engineer for efficiency and resilience
 - Reject: “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 & resistance!
 - Needs imagination and creativity - which inspire!

Different Mindsets

- ***Technology will save us***
 - *No need to change our behavior*
 - *Economics based on individual consumerism produces 'wealth'*
 - *Oil has made us rich*
 - *Inventions will power the future*
- **Climate, life & humanity interwoven**
 - Environmental intelligence crucial
 - Community imagination & creativity essential
 - Intergenerational time-frame

Aside: Economic ‘Doctrines’

- “Free market” promotes material growth
 - Freedom to exploit Earth’s resources & poor
 - “Regulation” interferes with growth/profits
 - The assets and interests of the wealthy must be protected, since they fund politicians
 - Choices must be “cost-effective” now: future costs can be discounted or paid for later
- Climate change and current economics are incompatible
 - *since Earth does not discount the future - accumulates energy imbalance in oceans*
 - *Catastrophe ahead for our children and all life*

Fundamentals

- ***Burning fossil fuels: transforming climate***
 - *Many water cycle amplifying feedbacks*
 - *Heading for high CO₂ “Hot-house 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 CO₂ 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***

January 4, 2012: NASA



Hurricane seasons

- 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, Maria*
- *2018: Florence, Michael*
- *2019: Barry, Dorian*



Major Hurricane Harvey - August 25-29, 2017

Weather.gov > Corpus Christi, TX > Major Hurricane Harvey - August 25-29, 2017

Corpus Christi, TX
Weather Forecast Office

[Current Hazards](#) [Current Conditions](#) [Radar](#) [Forecasts](#) [Rivers and Lakes](#) [Climate and Past Weather](#) [Local Programs](#)

Category 4 Hurricane Harvey: South Texas Landfall & Impacts from August 25th to 29th, 2017

[Overview](#) [Stats](#) [Radar](#) [Satellite](#) [Winds](#) [Storm Surge](#) [Rainfall](#) [Rivers](#) [Seadrift](#) [Tornado](#) [Storm Reports](#) [Photos](#) [One Year Later](#)

[Hurricane Harvey Summary PDF](#)

...Hurricane Harvey is the first major hurricane to make landfall along the Middle TX Coast since Celia in 1970...

...Hurricane Harvey is the first Category 4 hurricane to make landfall along the TX Coast since Carla in 1961...



ESRI, HERE, GARMIN | EARTHSTAR GEOGRAPHICS

NHC Final Best Track of Harvey (Click points above to view additional information.)

Why was Harvey so Damaging?

- **Huge evaporation off warm ocean**
- **Category 4 hurricane** developed fast
- **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

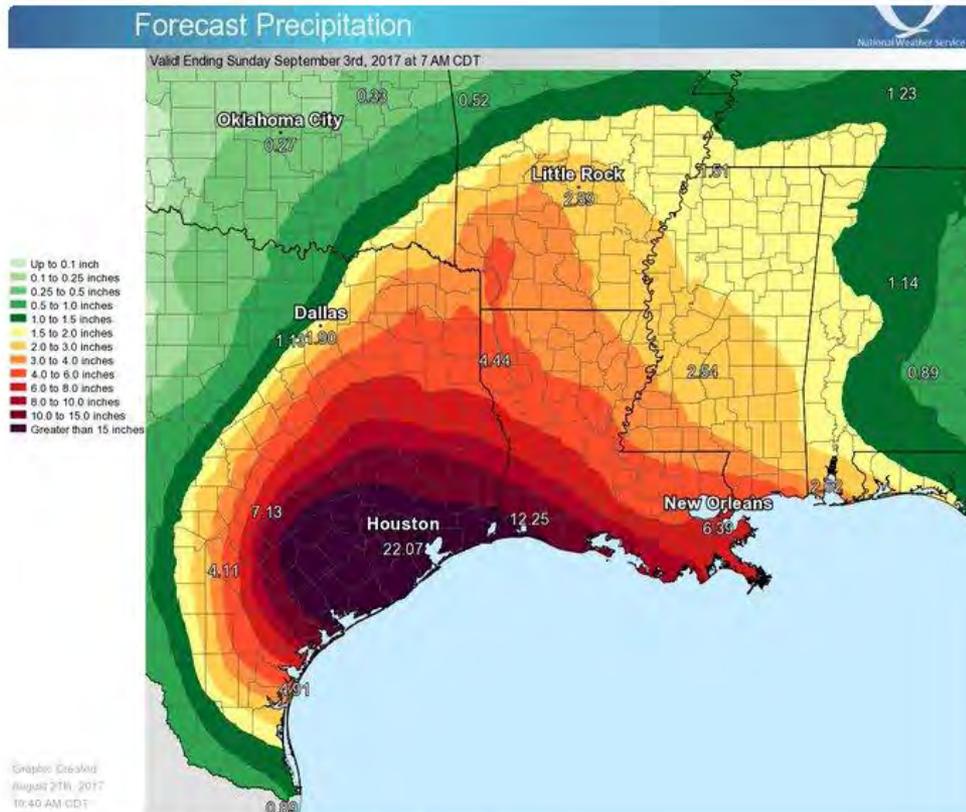


Challenge to Forecast & Emergency Services



National Weather Service
@NWS

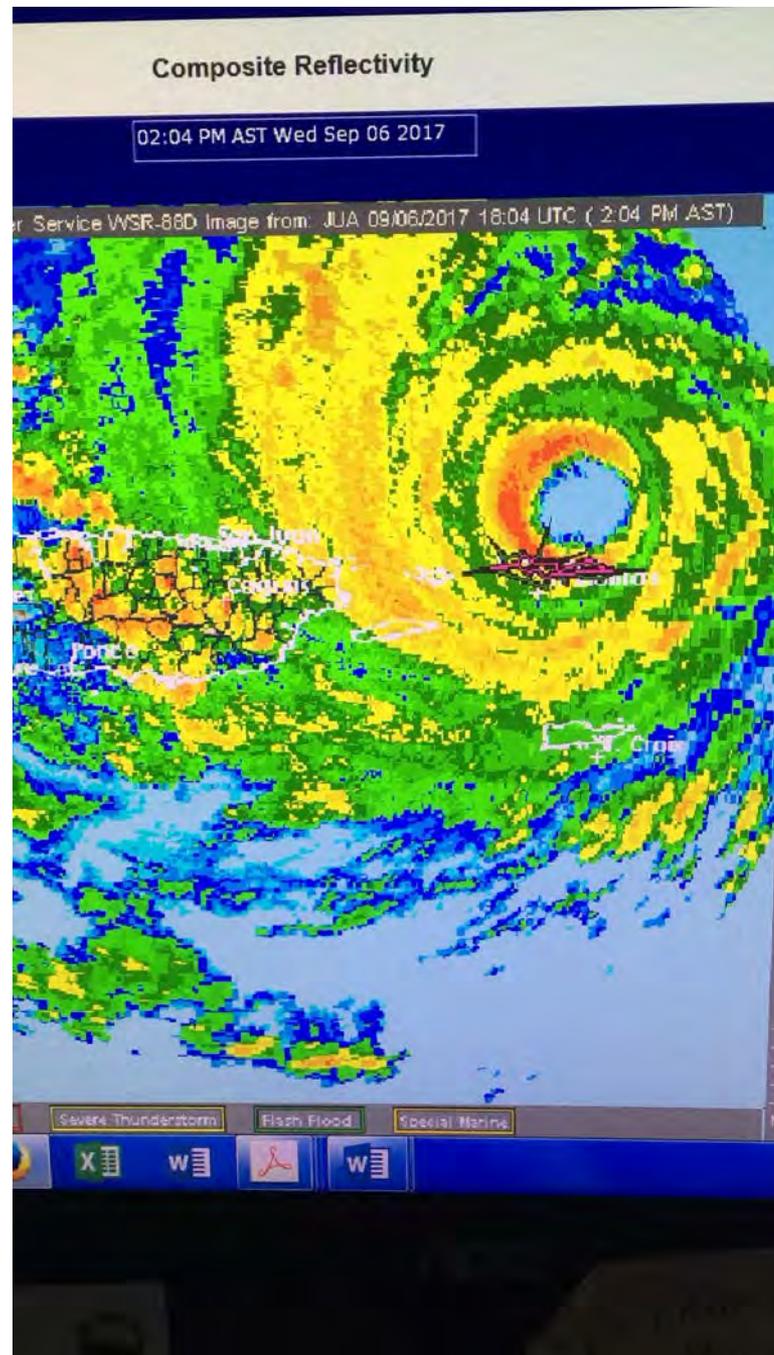
This event is unprecedented & all impacts are unknown & beyond anything experienced. Follow orders from officials to ensure safety. #Harvey



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



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**



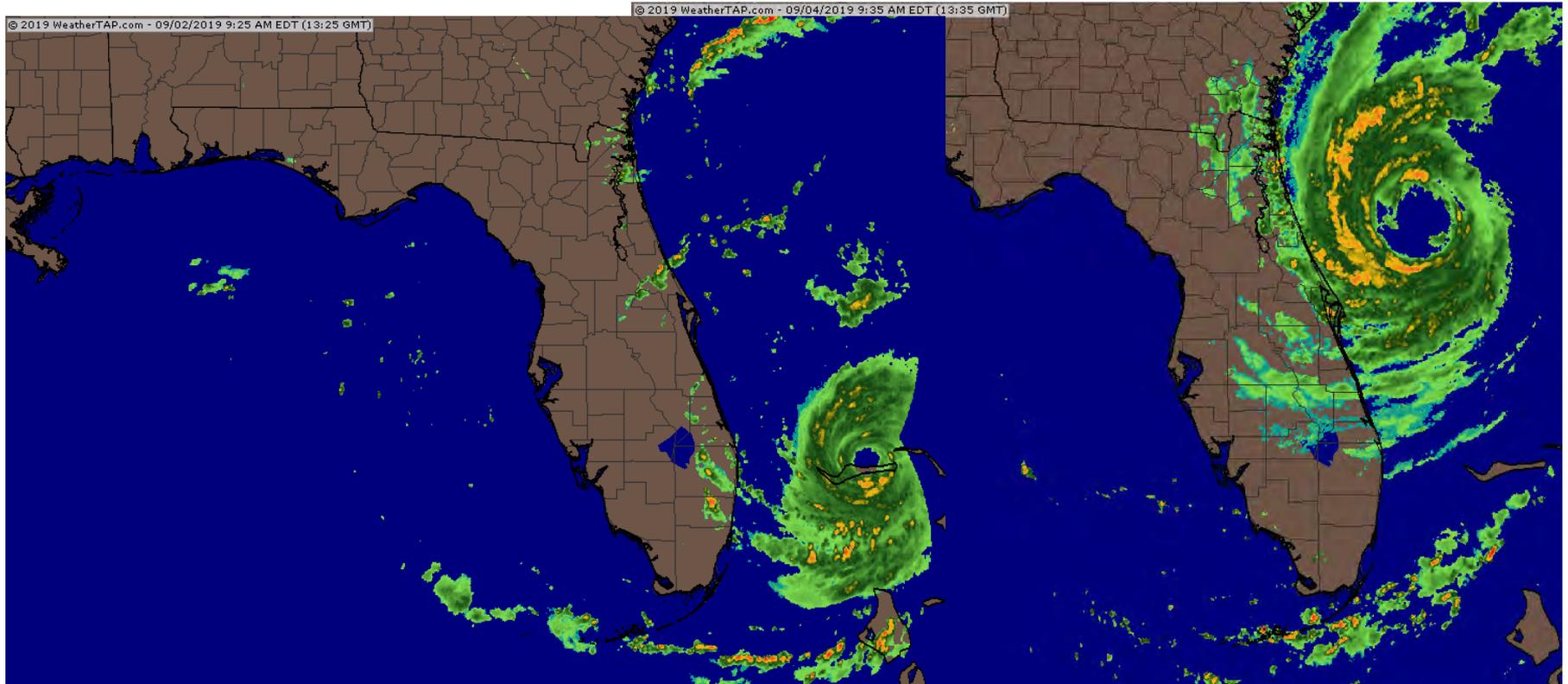
July 2019: track of Barry



Started as band of thunderstorms in Kansas, traveled in slow circle, intensified over warm water of Gulf to weak hurricane, rained on wet Louisiana [Cost: \$1 billion]

Dorian: Cat 5

Cat 2/3



**Sept 2, 2019
Stationary over
Grand Bahama**

**Sept 4, 2019
Off Florida
Coast**

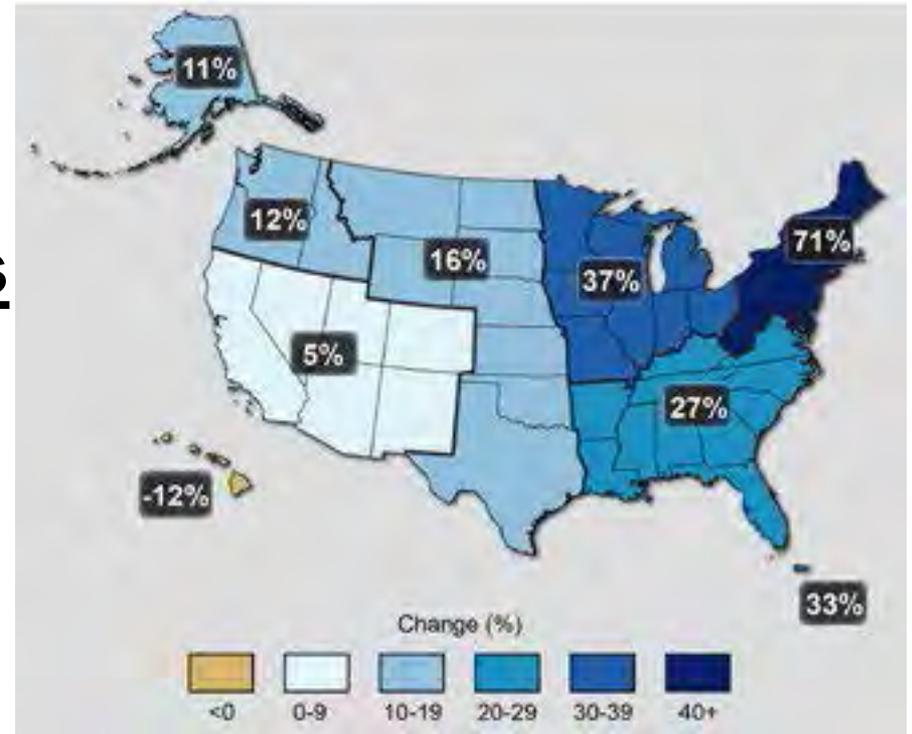
Two Severe Tropical Cyclones hit Mozambique: 2019

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



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





**Mouth of Connecticut River from Irene
2011**



Lake Champlain, Spring 2011, Courtesy LCBP

2011 Classic Flood Situations

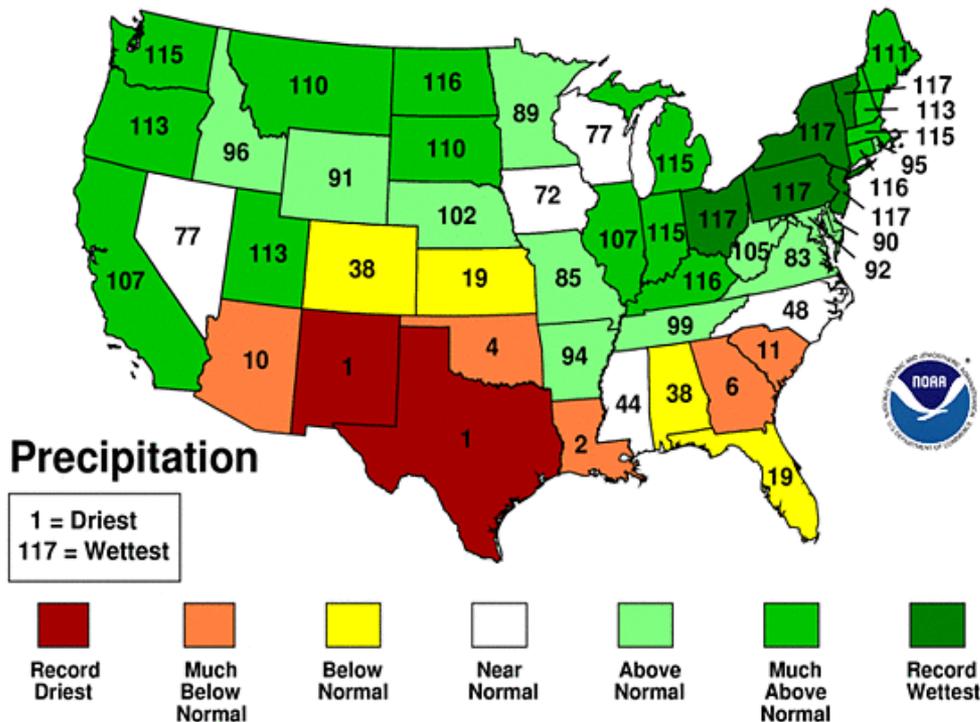
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010-11 winter
 - 70F (April 11) and 80F(May 27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical 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 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



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 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]

Management of water

- **Engineering approach was to get it off the land into streams & rivers (“manage it”)**
 - **Now oversize all culverts/ bridges**
- **Poor policy as extremes of flood and drought increase**
 - **Need to store in ground for summer use**
- **Summer water extraction by roots from ground storage damps 60% of precipitation anomalies: maintains evaporation in dry years**

Environmental Intelligence

- **“Blend of natural science, social science and indigenous knowledge that helps humans interact constructively and creatively with the living natural world”**
 - (Contrast exploiting the environment to support the profits of corporate donors)
 - (Dumping current and future costs on the poor, the indigenous, our children and all life)
- **Huge conscious challenge for society**
 - **Key to community resilience**

Community Resilience

- **Shared local infrastructure, resources, knowledge and awareness**
 - Designed to maximize efficiency and renewable energy use
 - Localized shared food supply
 - Shared efficient transport system
 - Support ecosystems long-term
 - *Needs imaginative community*
 - ***Contrast to ‘happy isolated individuals addicted to consumerism, escapism and the media’***
(Joanna Macy)

Gardening in Vermont for 40 years

- How long was growing season in 1970s?
 - About 125 days: now 155 days
- How long was the ground frozen?
 - About 155 days: now 125 days +-
 - No longer hard freeze in November
- Winter climate zones in 1970's were?
 - Zones 4-5: now zones 5-6 (10F warmer)
- BUT winter variability increasing

My Wake-up Call: Gardening in January, Pittsford, VT



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)



March 3, 2017



January 10 and 12, 2018



January 10, 2018

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

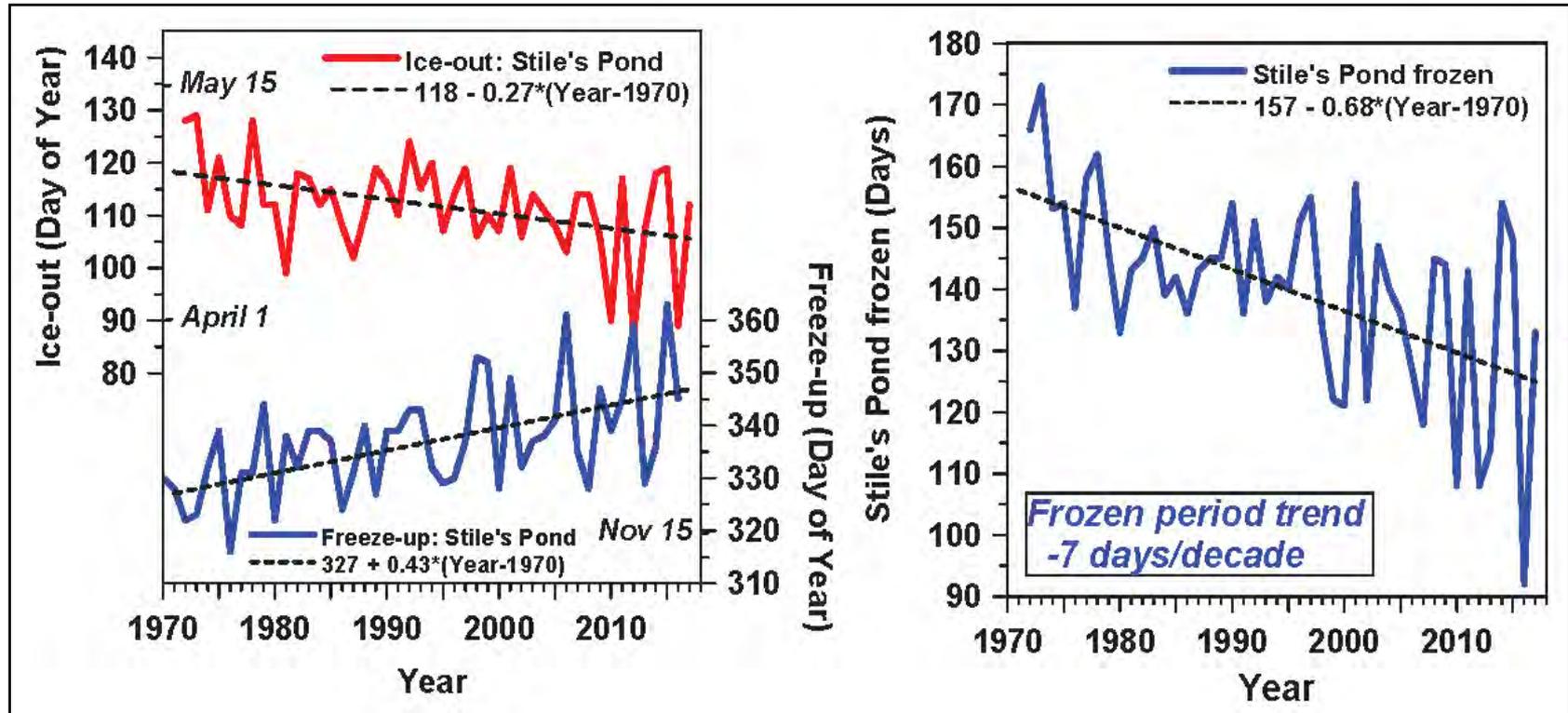


January 12, 2018

After T_{\max} up to 50F

Marker: Lake Freeze-up & Ice-out

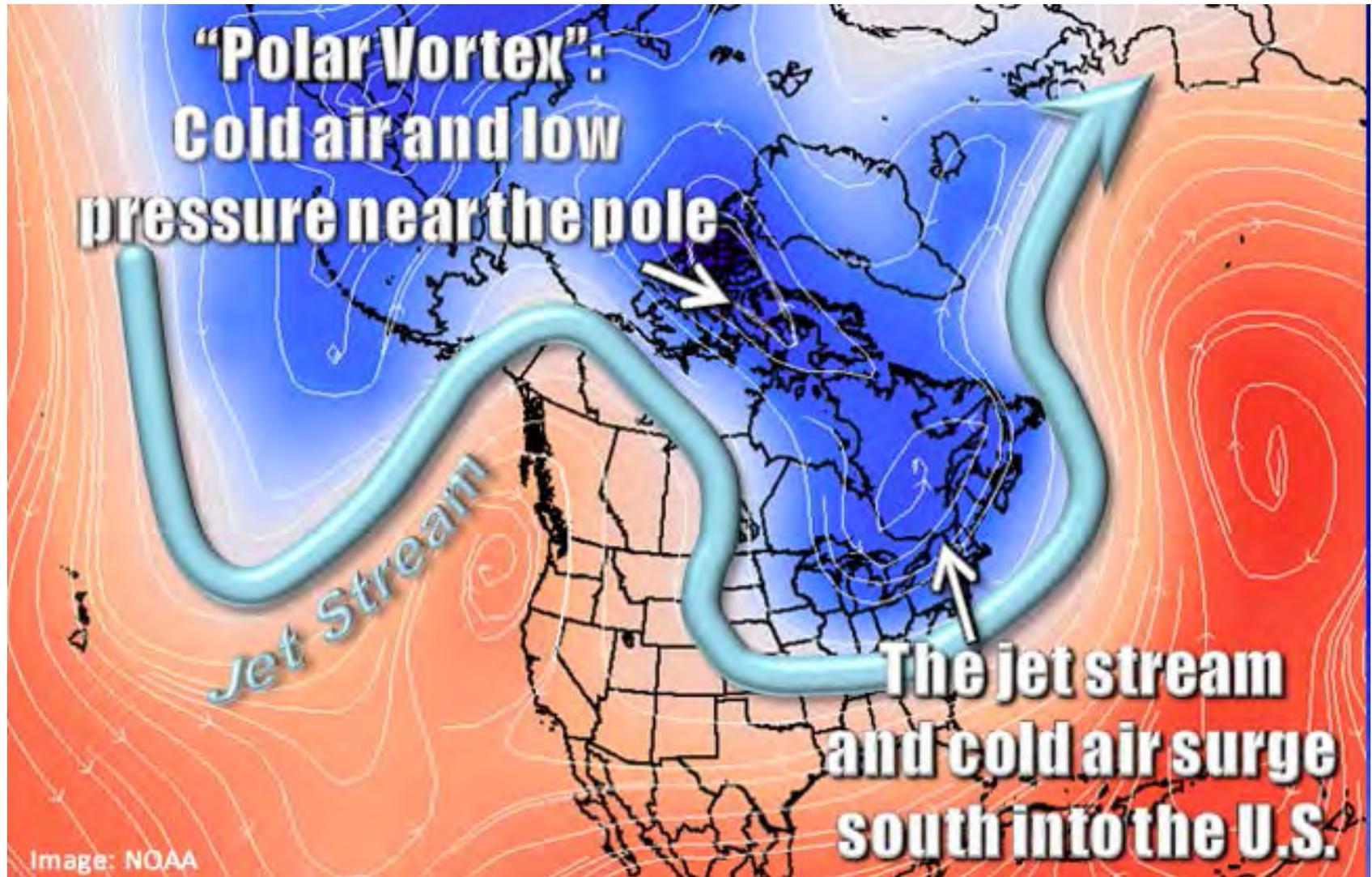
Frozen Period Shrinking: variability huge



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

Stiles Pond:
"Eye on the Sky"

Arctic Warming: Polar Vortex Unstable



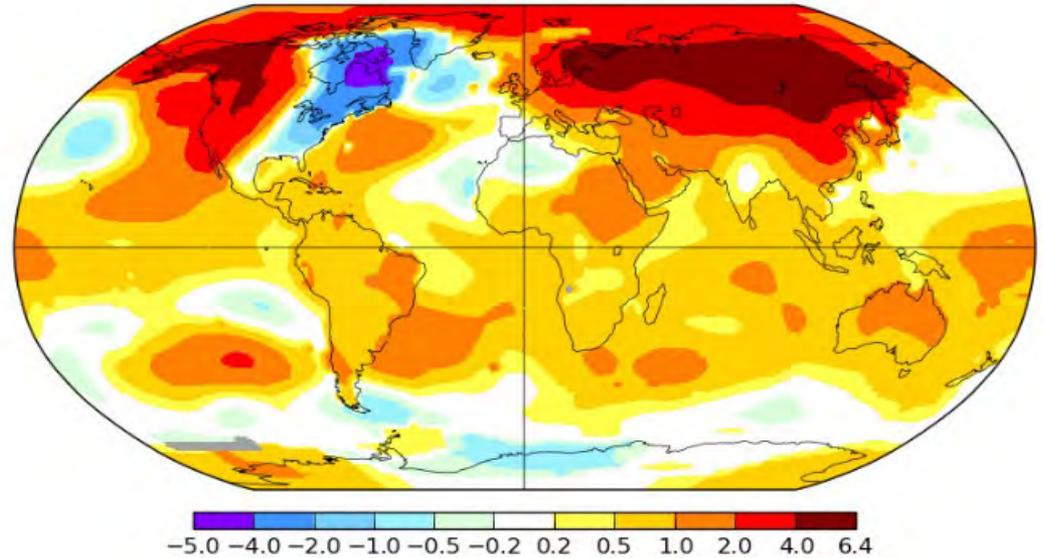
Jan-Feb-Mar 2015

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

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



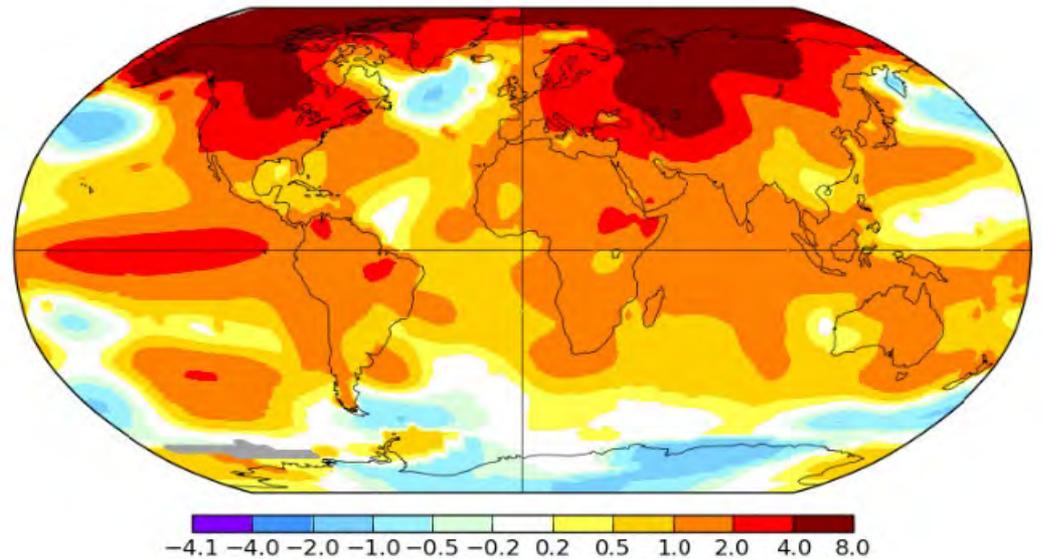
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little
snow, warm Arctic

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24



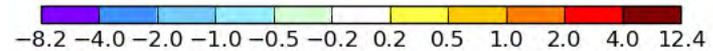
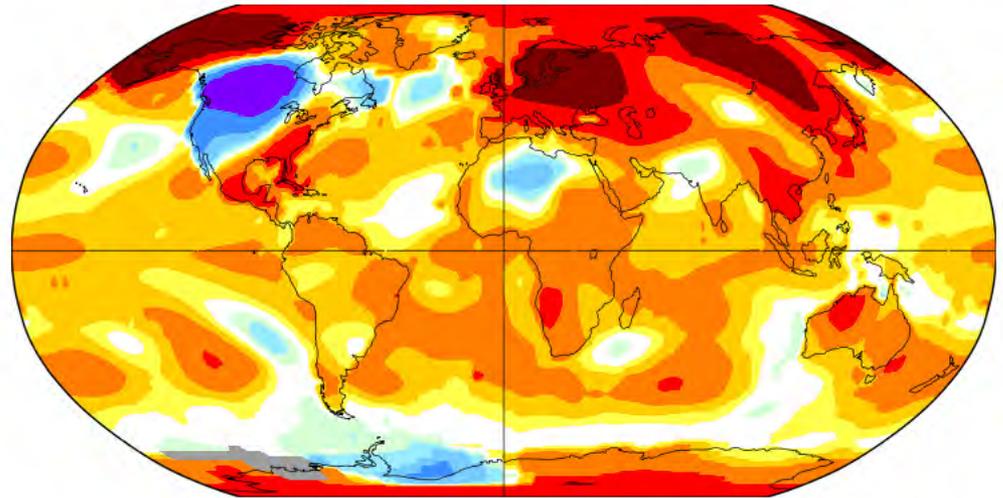
Feb-2019

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

February 2019

L-OTI(°C) Anomaly vs 1951-1980

0.94



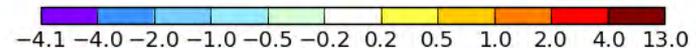
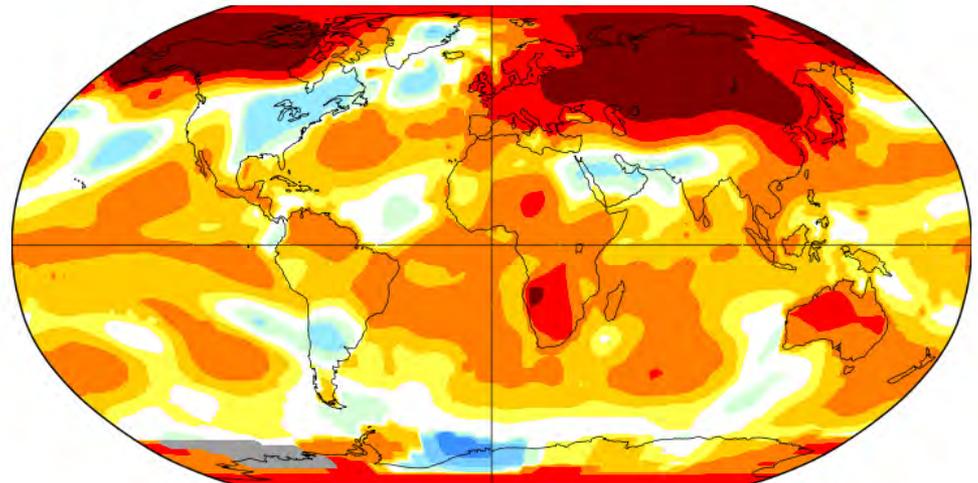
March-2019

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

March 2019

L-OTI(°C) Anomaly vs 1951-1980

1.18



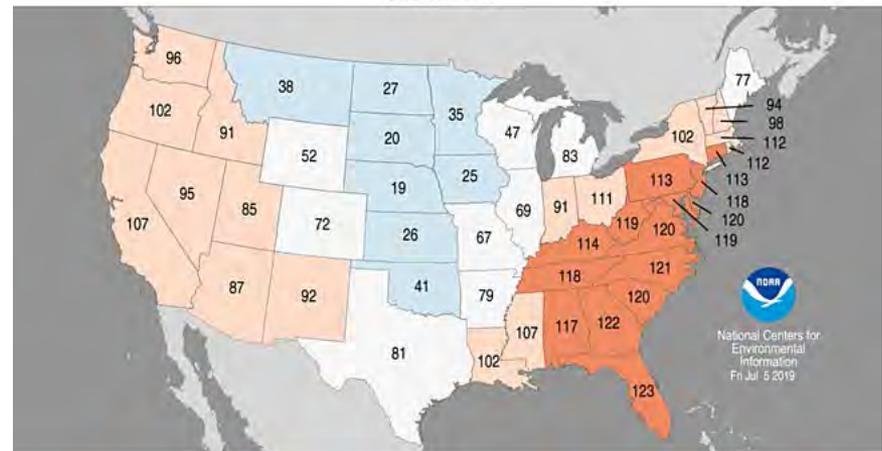
Jul-2018 to Jun-2019

*Warm in South-east
Cold in north-central*

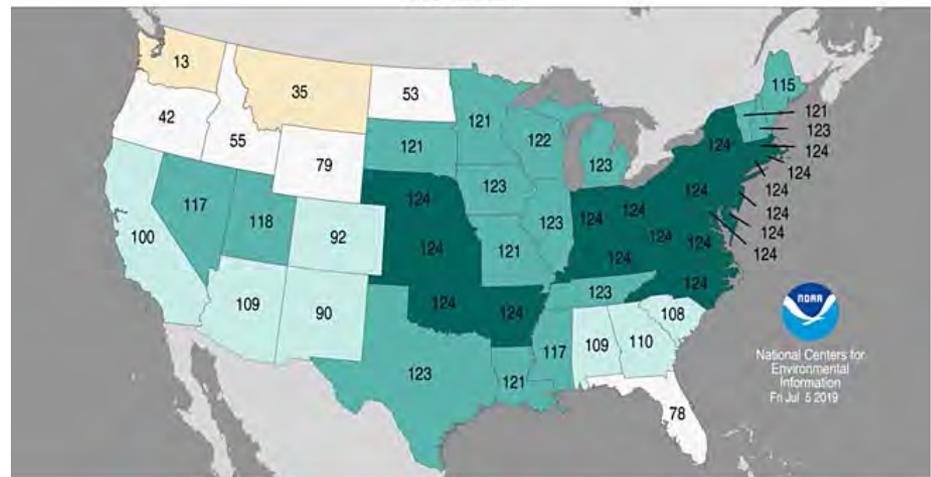
*Very wet across eastern
& central US*

*2019 Mississippi flooding
longest on record*

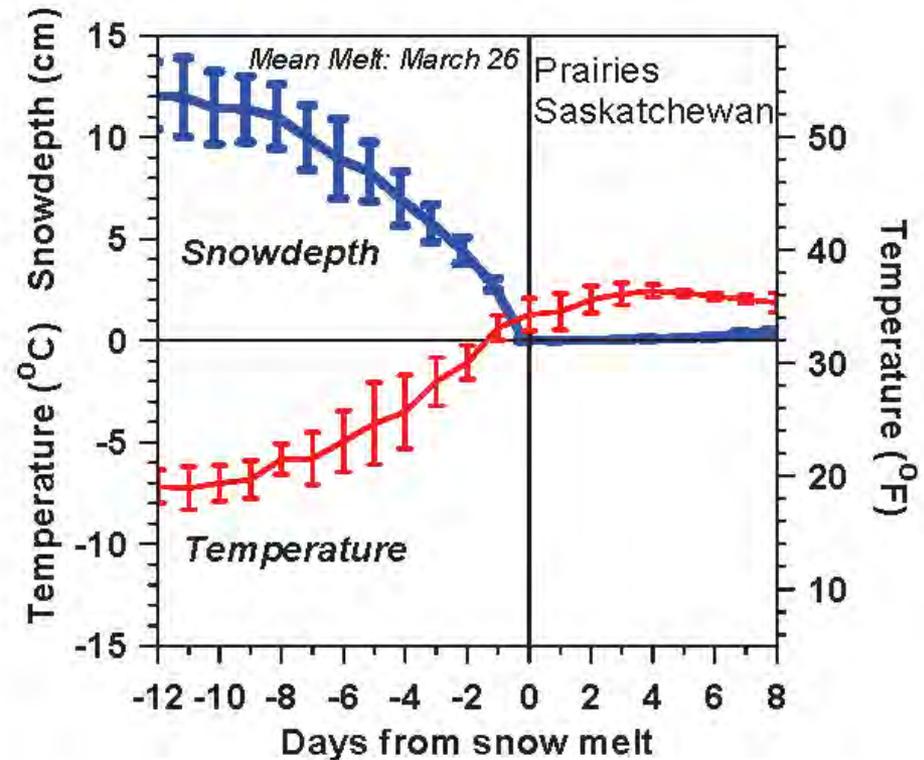
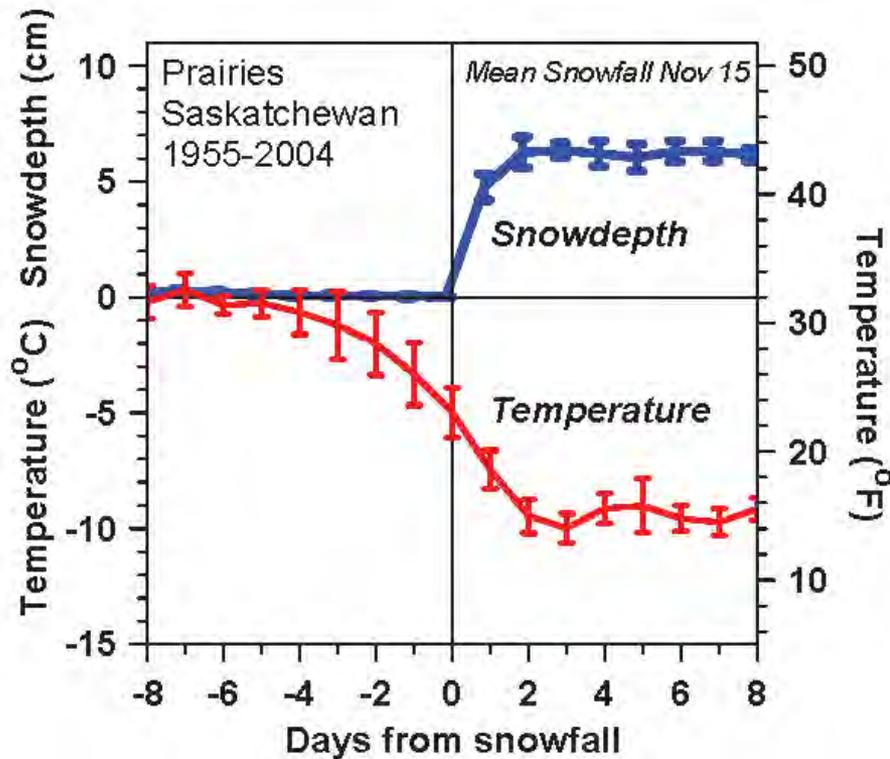
Statewide Average Temperature Ranks
July 2018–June 2019
Period: 1895–2019



Statewide Precipitation Ranks
July 2018–June 2019
Period: 1895–2019

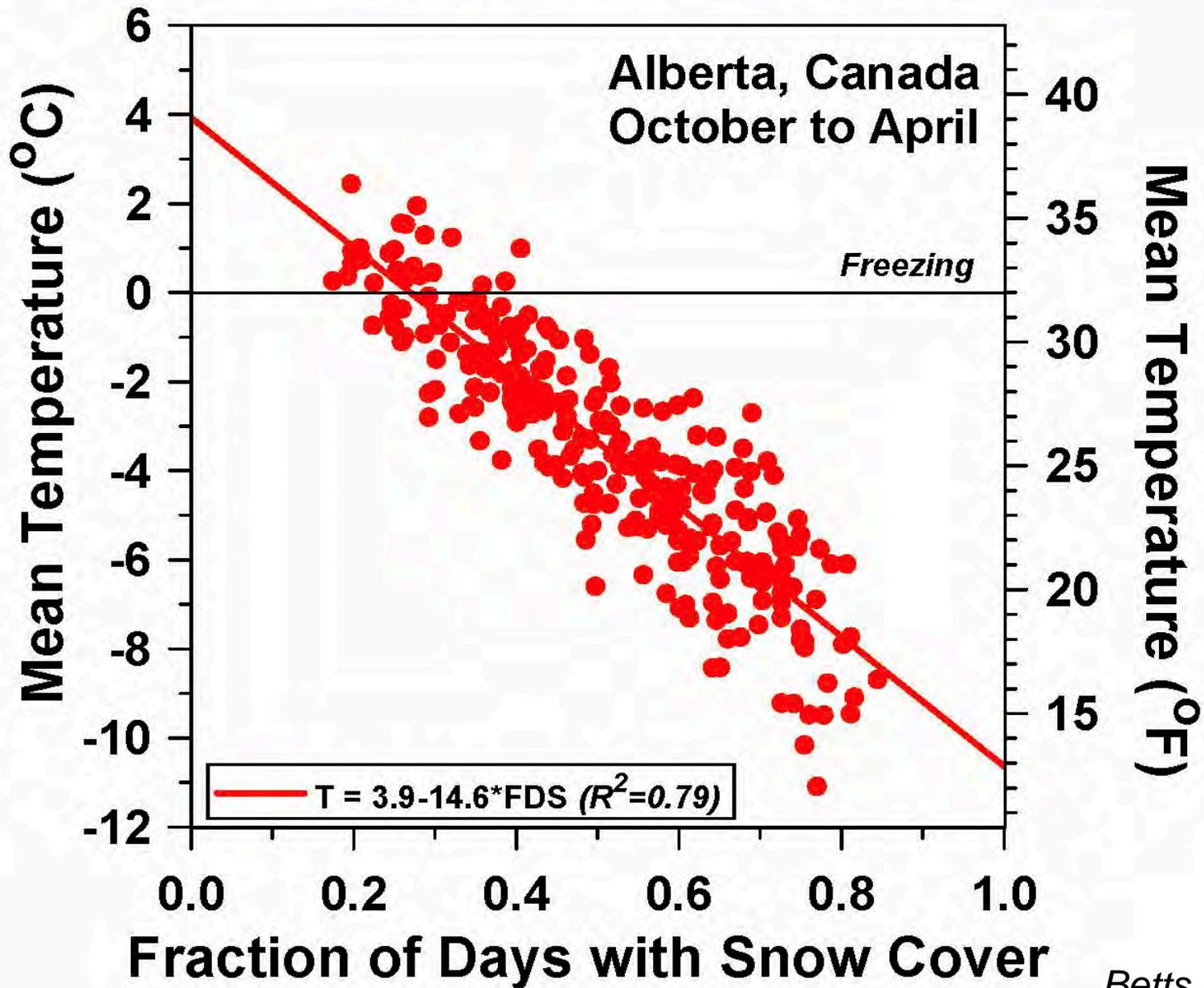


Snowfall and Snowmelt

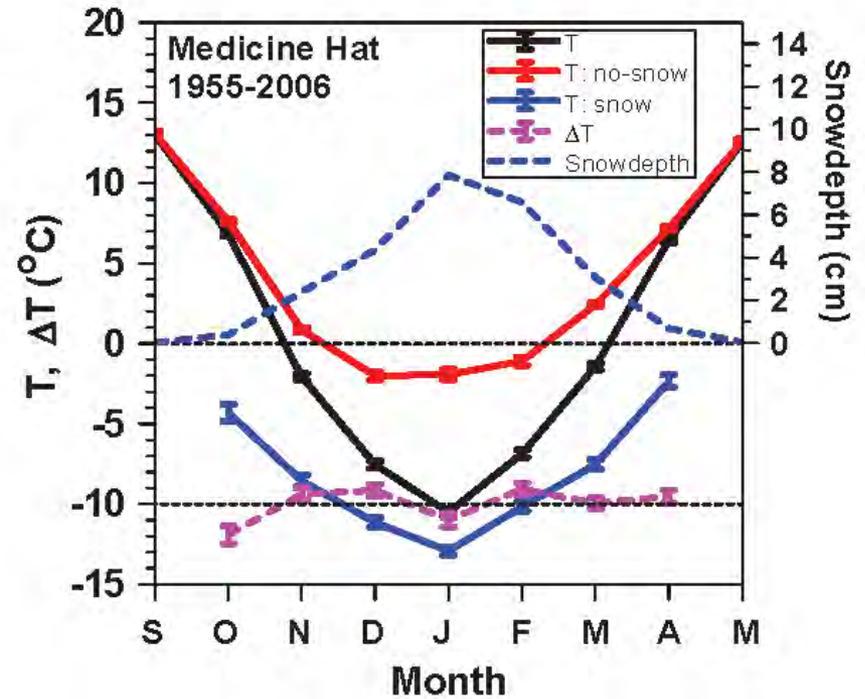
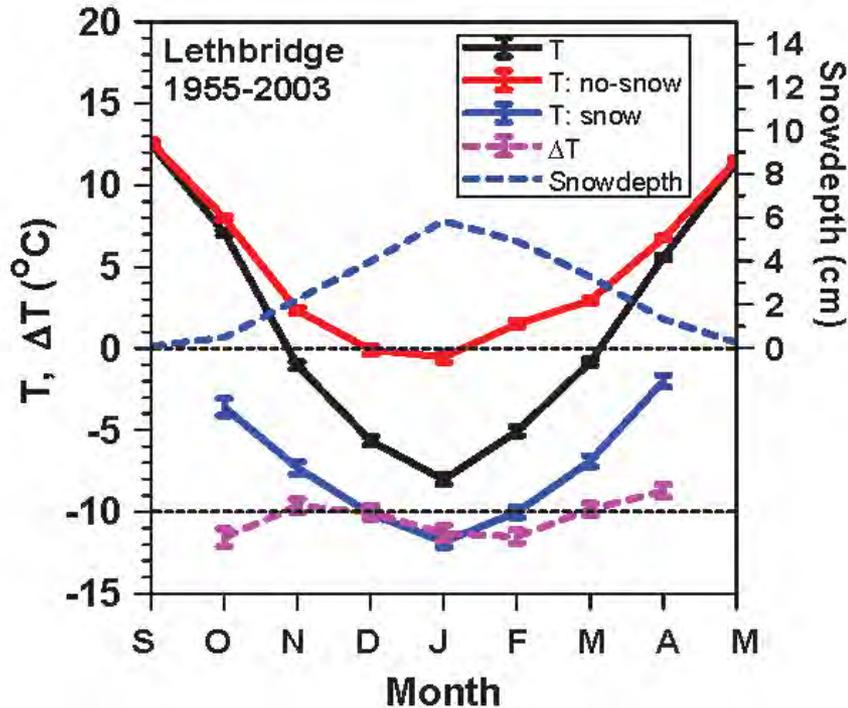


- Temperature changes 10°C with snow cover
- Snow cover is a 'climate switch'
- *Fast transitions in 'local climate'*
 - *Snow reflects sunlight*
 - *Reduces evaporation and water vapor greenhouse*

More snow cover - Colder temperatures



Impact of Snow on Climate



Separate mean climatology into days
with no-snow and snowdepth >0

$$\Delta T = T:\text{no-snow} - T:\text{snow} = -10.2(\pm 1.1)^{\circ}\text{C}$$

Impact of Snow

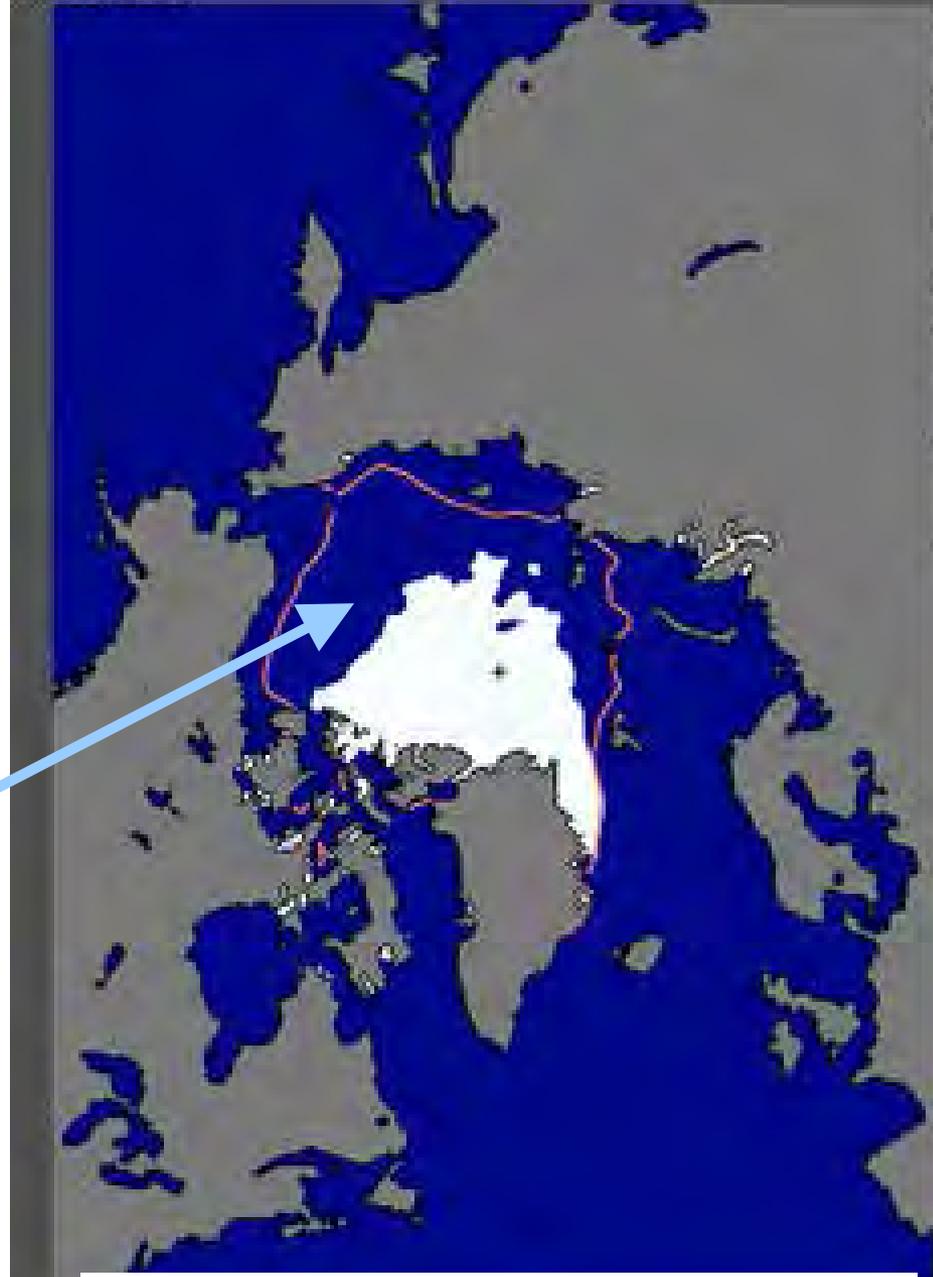
- **Distinct warm and cold season states**
- **Snow cover is the “climate switch”**

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)

- **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*

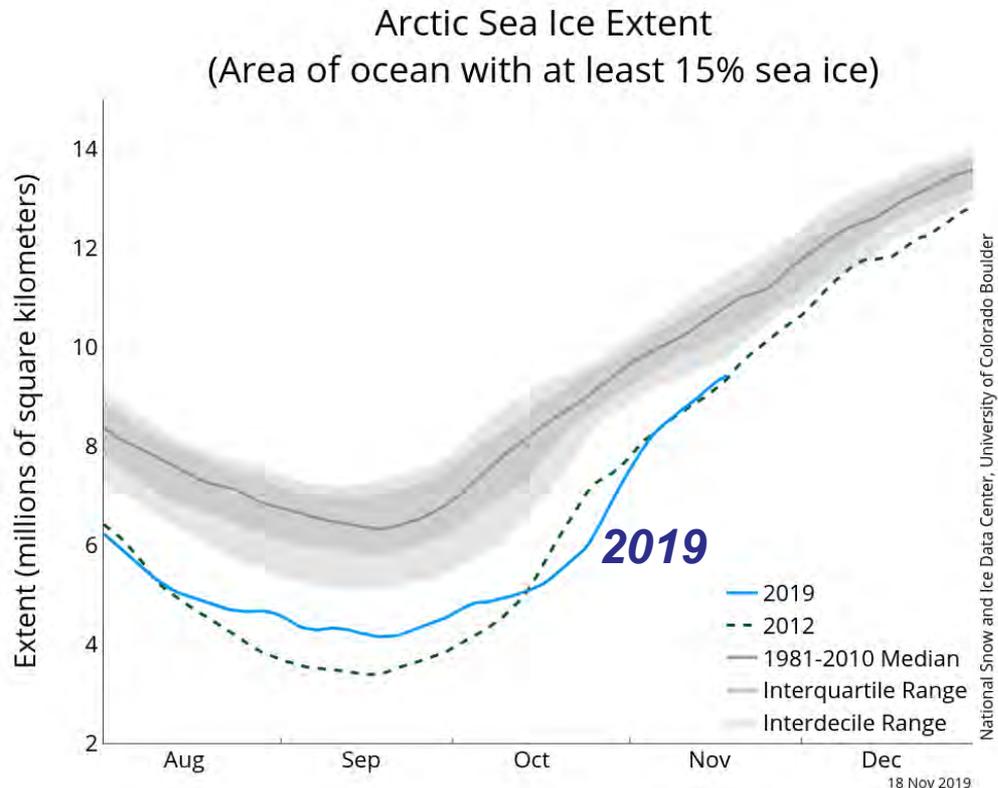


Winters are changing

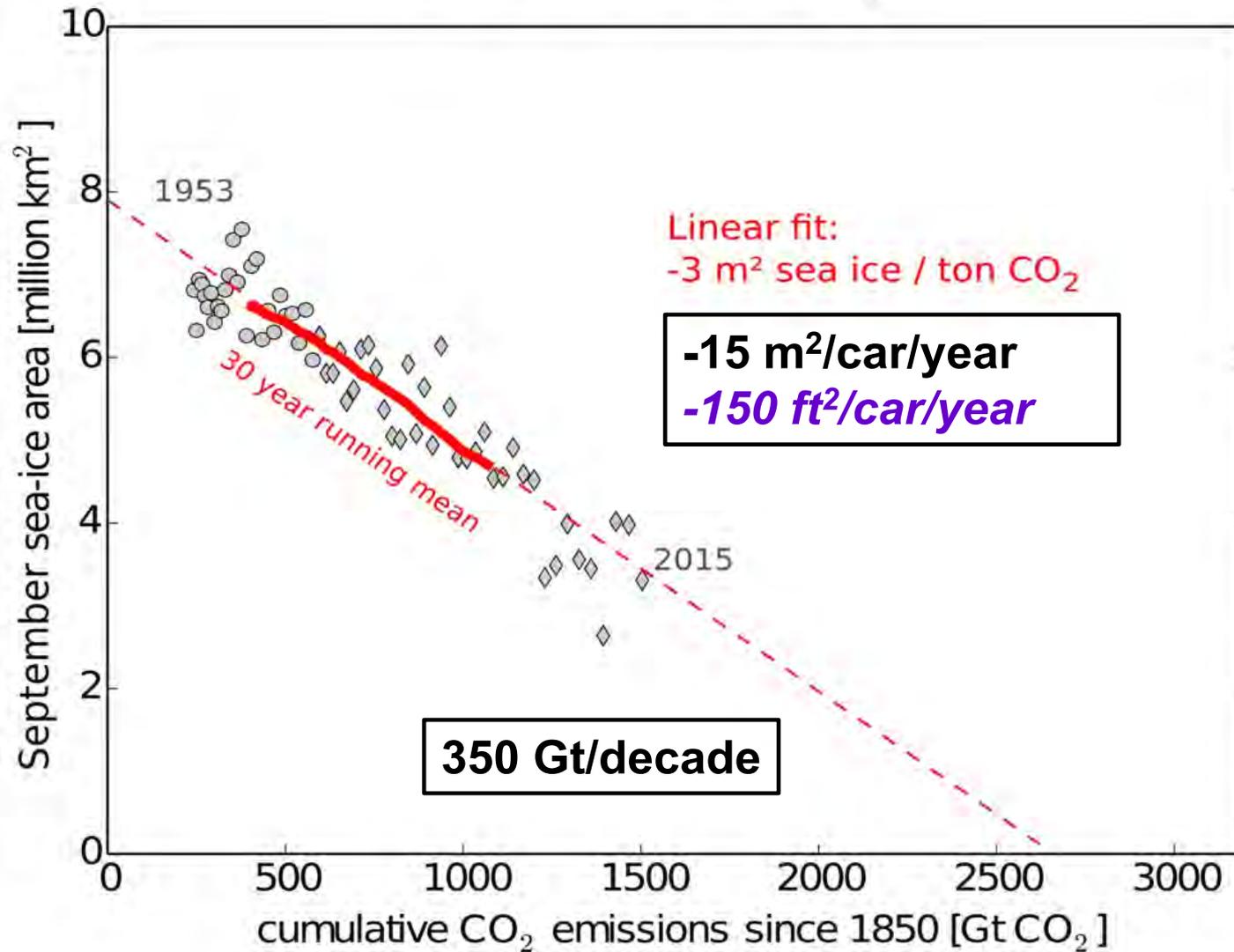
- as Arctic warms and melts

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

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



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



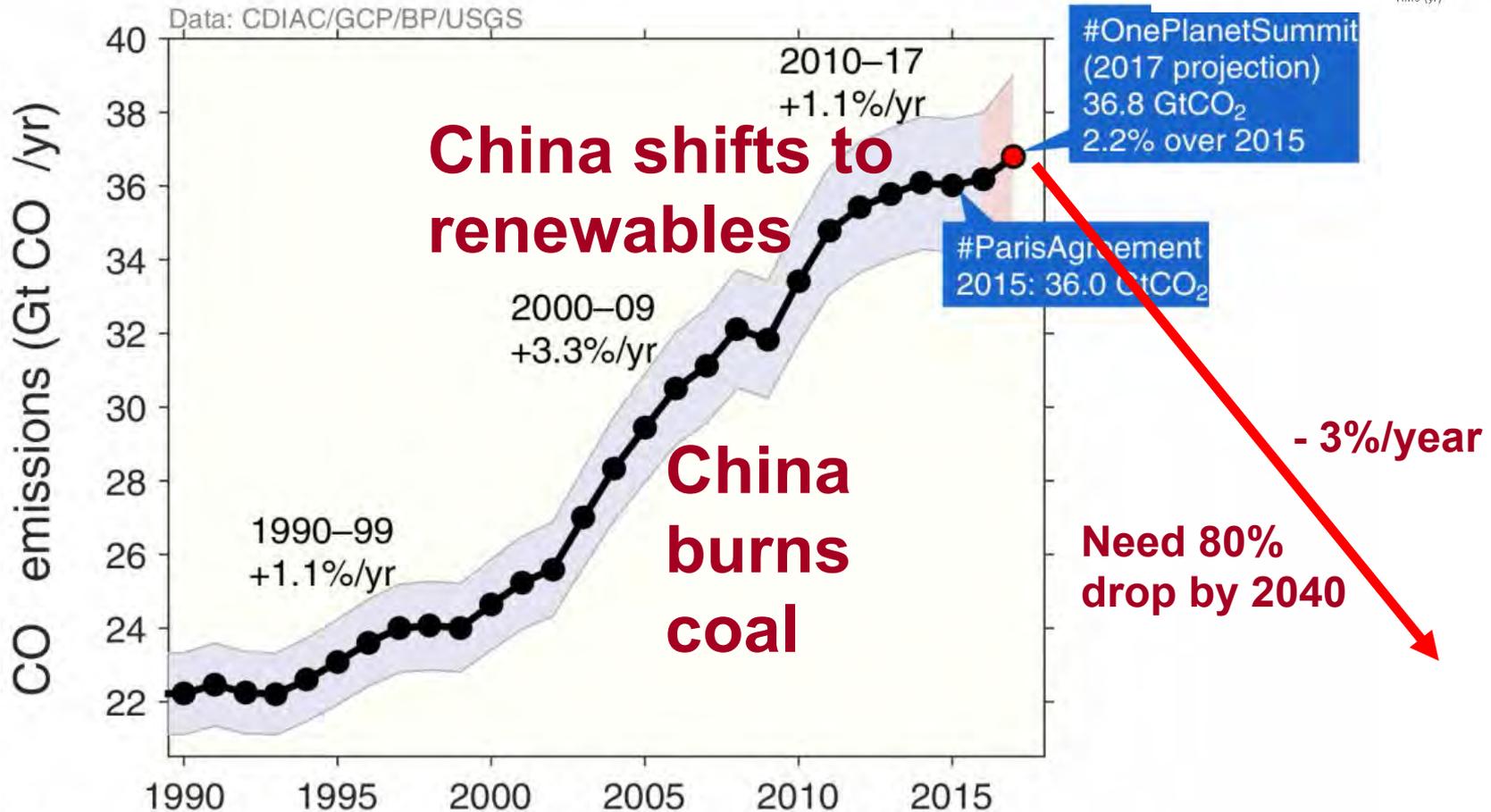
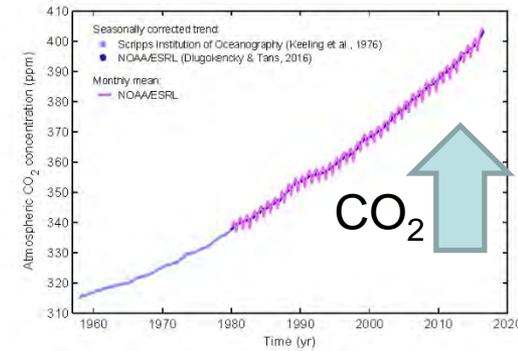
We promised to stop “Dangerous Climate Change”? *(UNFCCC 1992)*

- **How?** Quickly stabilize atmospheric 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

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*
- **2017/19: 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 CO₂ 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*
- *Needs systems engineering*

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*
 - *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 have failed to **guide and manage technology** — result is tremendous successes and catastrophic failures
- *Individual & corporate “rights” and the needs of humanity cannot be given priority over 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 CO₂ 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 80yrs***
 - Fueled ‘fossil’ capitalism and exploitation of the Earth and the poor
 - *Hidden by web of lies: now driving ‘ecocide’*

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***

Greta Thunberg (born Jan 2, 2003)

[Fridaysforfuture.org](https://fridaysforfuture.org)



Swedish parliament last year

Crossing Atlantic in August



September 20-27, 2019

- 7.6 million, 185 countries: School strikes demanding climate action (*Next: Nov 29*)



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 till UK and Scottish governments declared “Climate Emergency”
- October 7-14: actions in 60 cities around the world
 - *Motto: Compassion; awareness; courage*
 - *Visionary and creative* [**https://rebellion.earth**](https://rebellion.earth)
 - Force large reductions in C-emissions this decade

What are Your Responsibilities?

- **Just do what society expects?**
 - Be docile servants; leave policy to ‘others’
 - Avoid public engagement and politics?
- **Or recognize**
 - Understanding brings responsibility
 - Climate change is existential issue for humanity, the future of the Earth and its ecosystems
 - *Business as usual is driving disaster*
 - *Your skills essential to create livable future*

Discussion

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

Rebellion: 350.org, Fridaysforfuture.org,
Rebellion.earth

<https://alanbetts.com>