



Global and Local Climate and our Future



Dr. Alan K. Betts

Atmospheric Research, Pittsford, VT 05763

akbetts@aol.com
<http://alanbetts.com>

BREE High School Teams
June 20, 2018



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 responsibilities?**

Discussion

Fundamentals

- ***Burning fossil fuels: transforming climate***
 - *Many water cycle amplifying feedbacks*
 - *Heading for high CO₂ “Carboniferous era climate”*
 - *Climate extremes increasing.*
 - *Severe weather costs: \$300B in US last year*
 - *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

January 4, 2012: NASA

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



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*

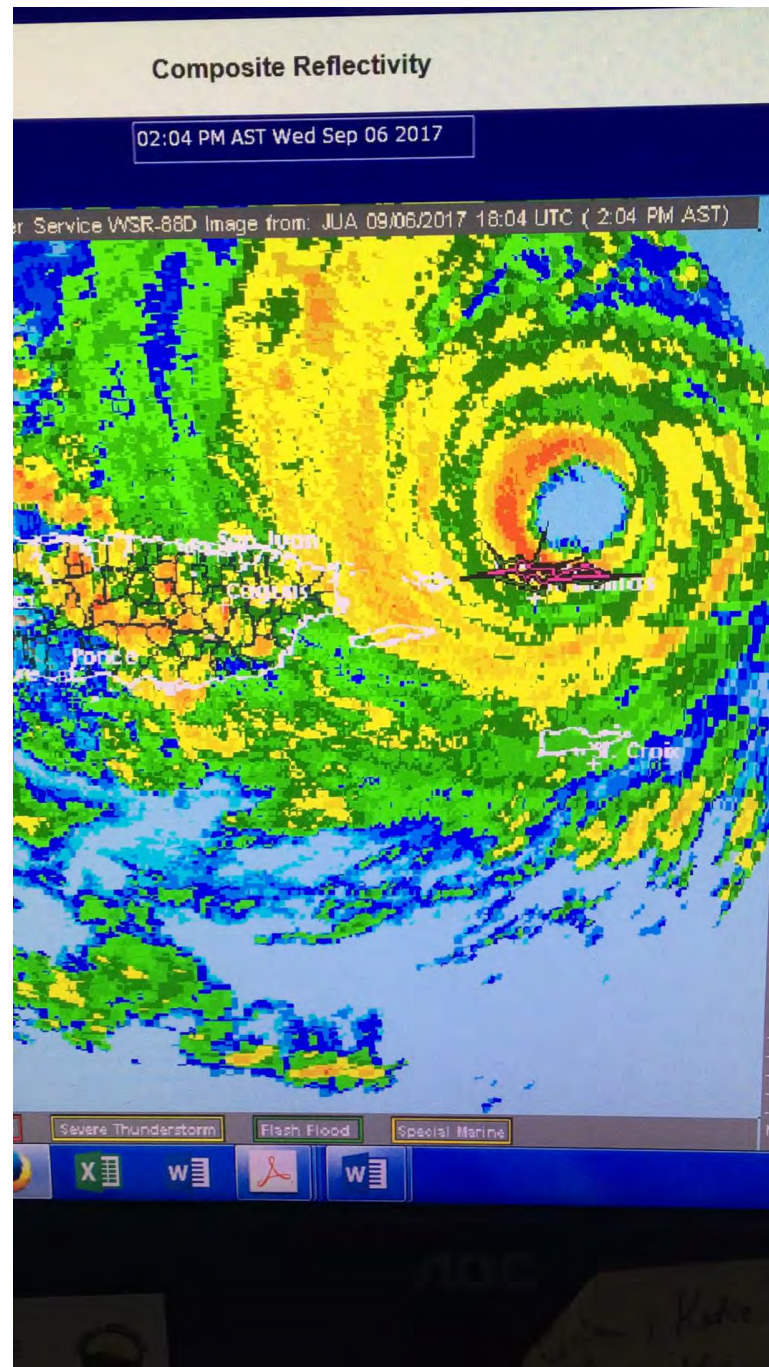
Why was Harvey so Damaging?

- 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



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



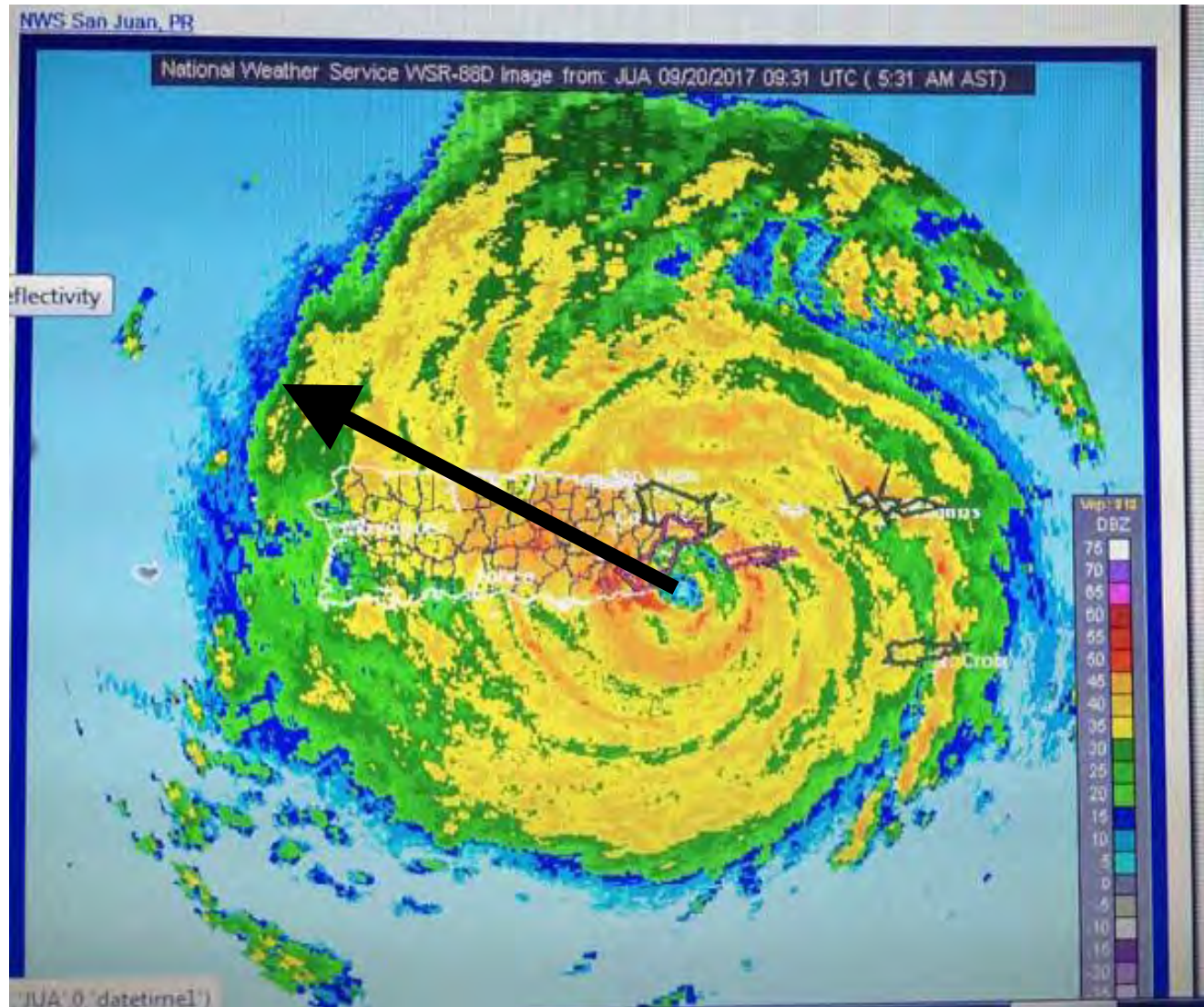
**After Jose passed; East Wind Catamaran to Puerto Rico
on Sept 11**

Maria: 5:30am Sept. 20

Category 4 hits Puerto Rico

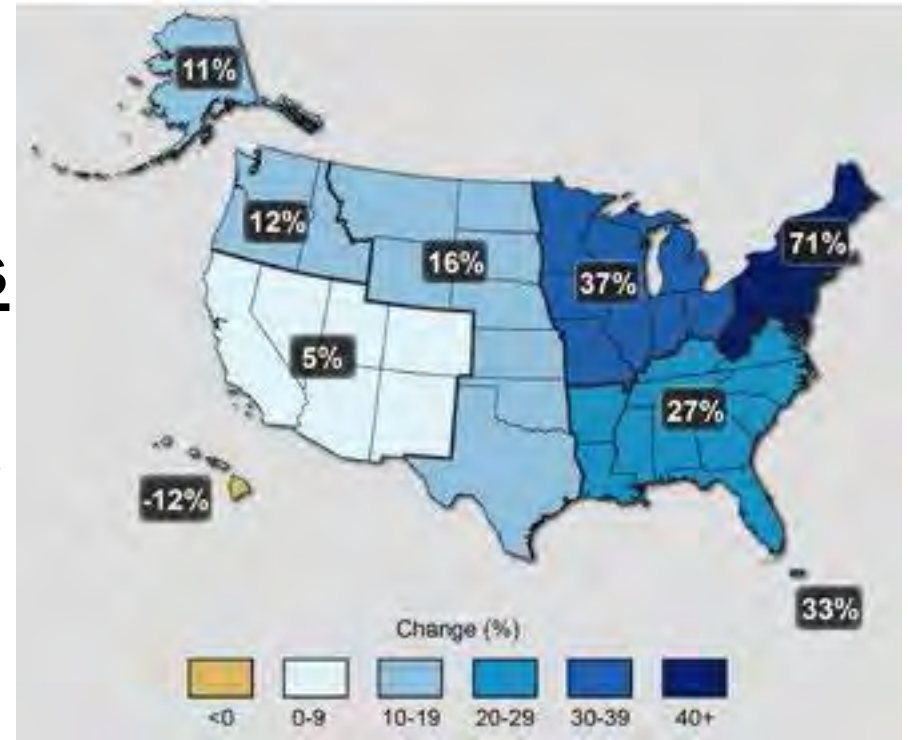
Cat 4
>130mph
Maria
>150mph

***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**

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



**Mouth of Connecticut River from Irene
2011**

Lake Champlain, Spring 2011, Courtesy LCBP

2011 Classic Flood Situations

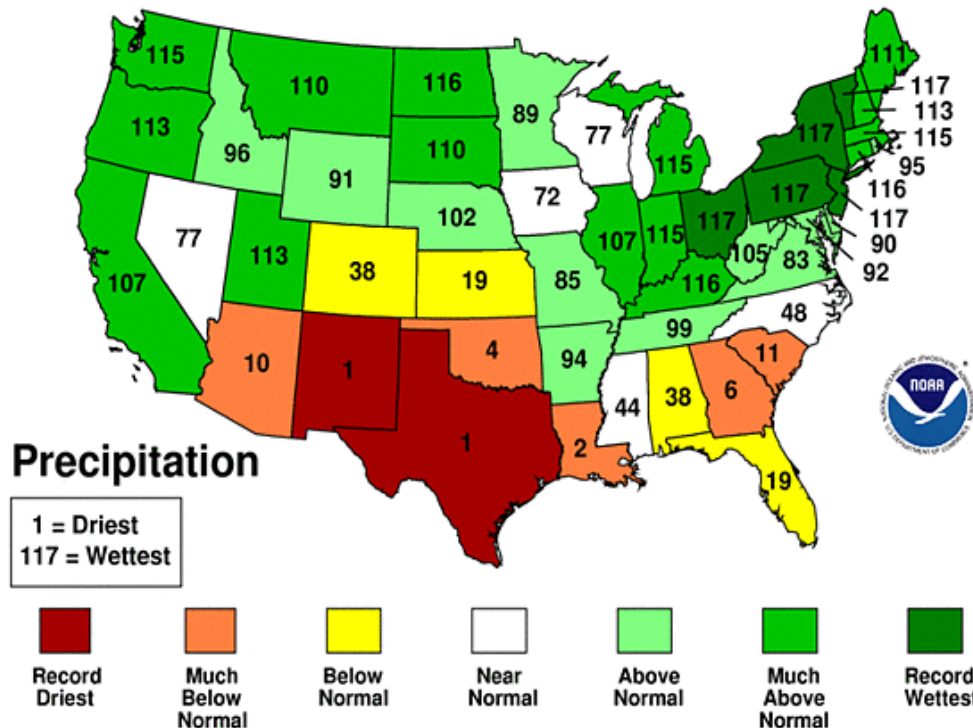
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010-11 winter
 - 70F (April 11) and 80F(May 27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical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

- 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.”*

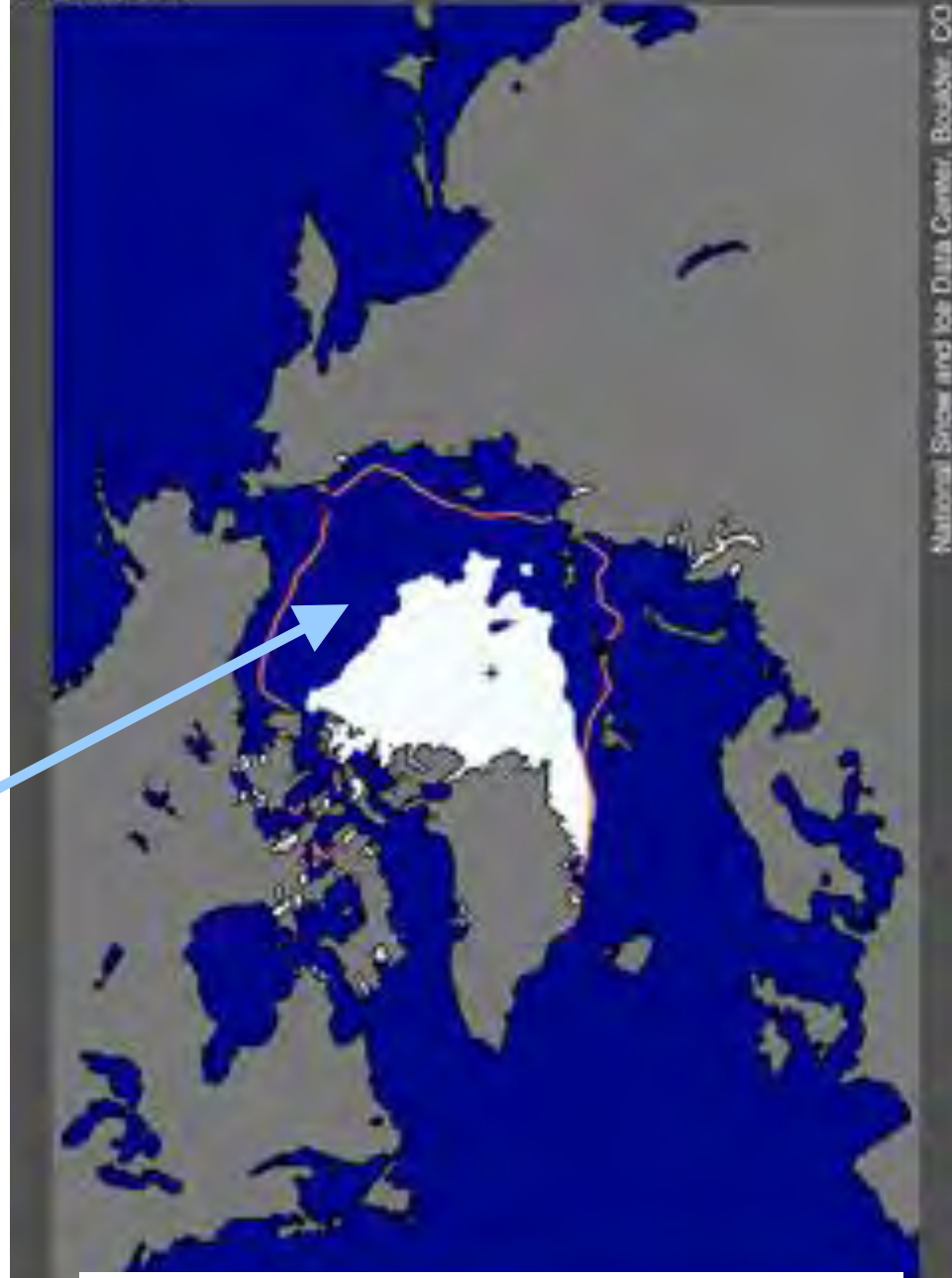
(Liberty Hill dairy farm, Rochester)

Flooding Issues

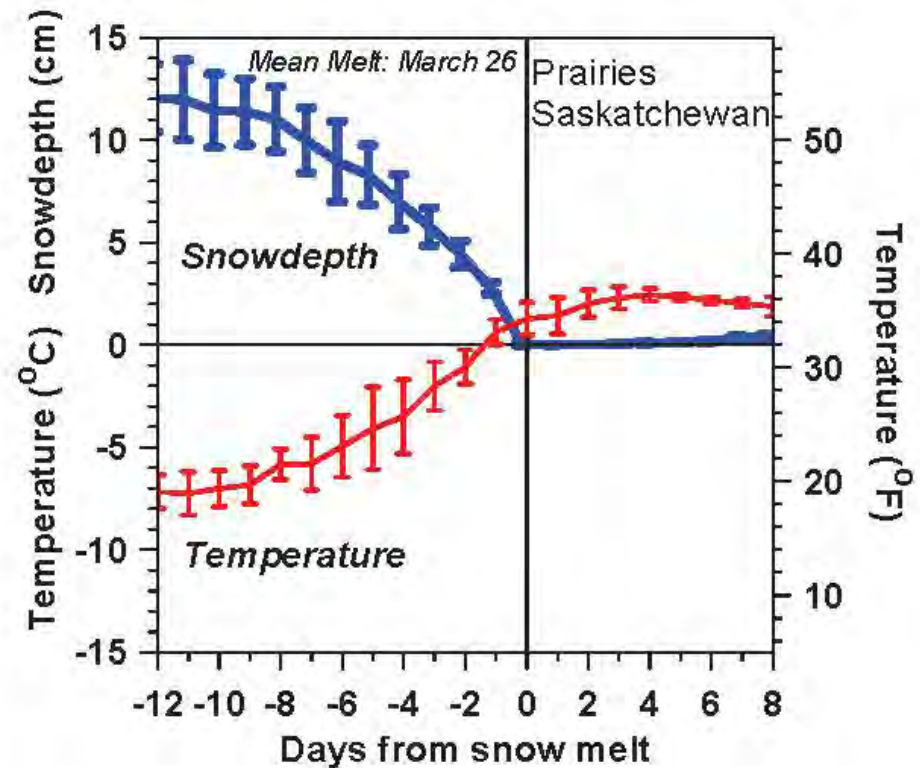
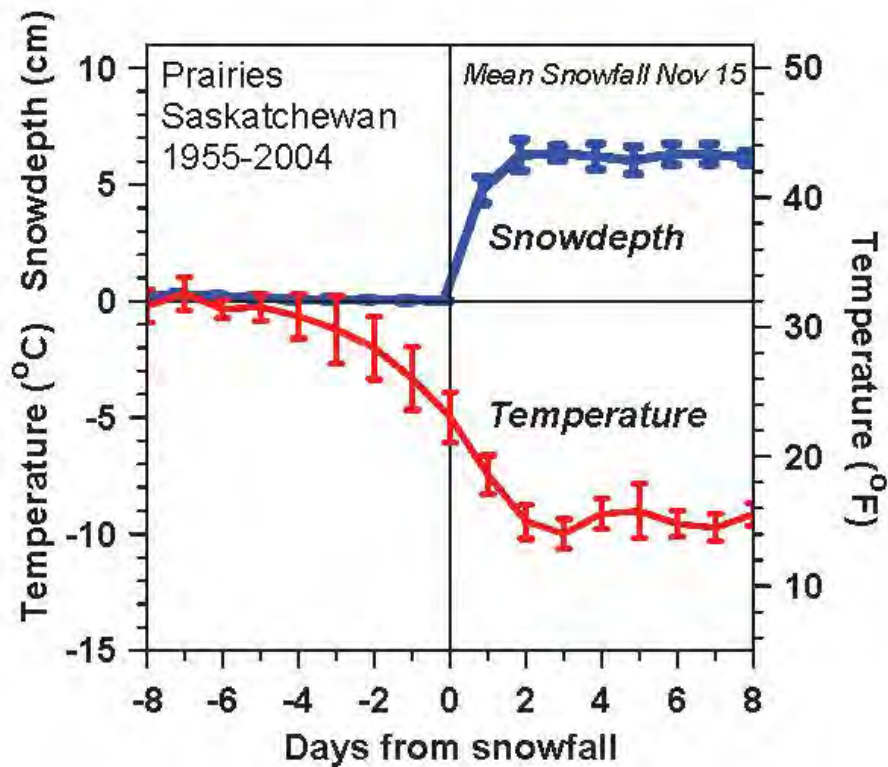
- **Maintain mountain forest cover**
 - Devastating floods in 1920's, 30's with reduced forest cover
- **Manage water/pollutants on landscape**
 - Maximize infiltration: urban and on farms
 - Don't wall-in rivers
- **Preserve flood plains**
 - Saves downstream towns (Middlebury)
 - Stop building houses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

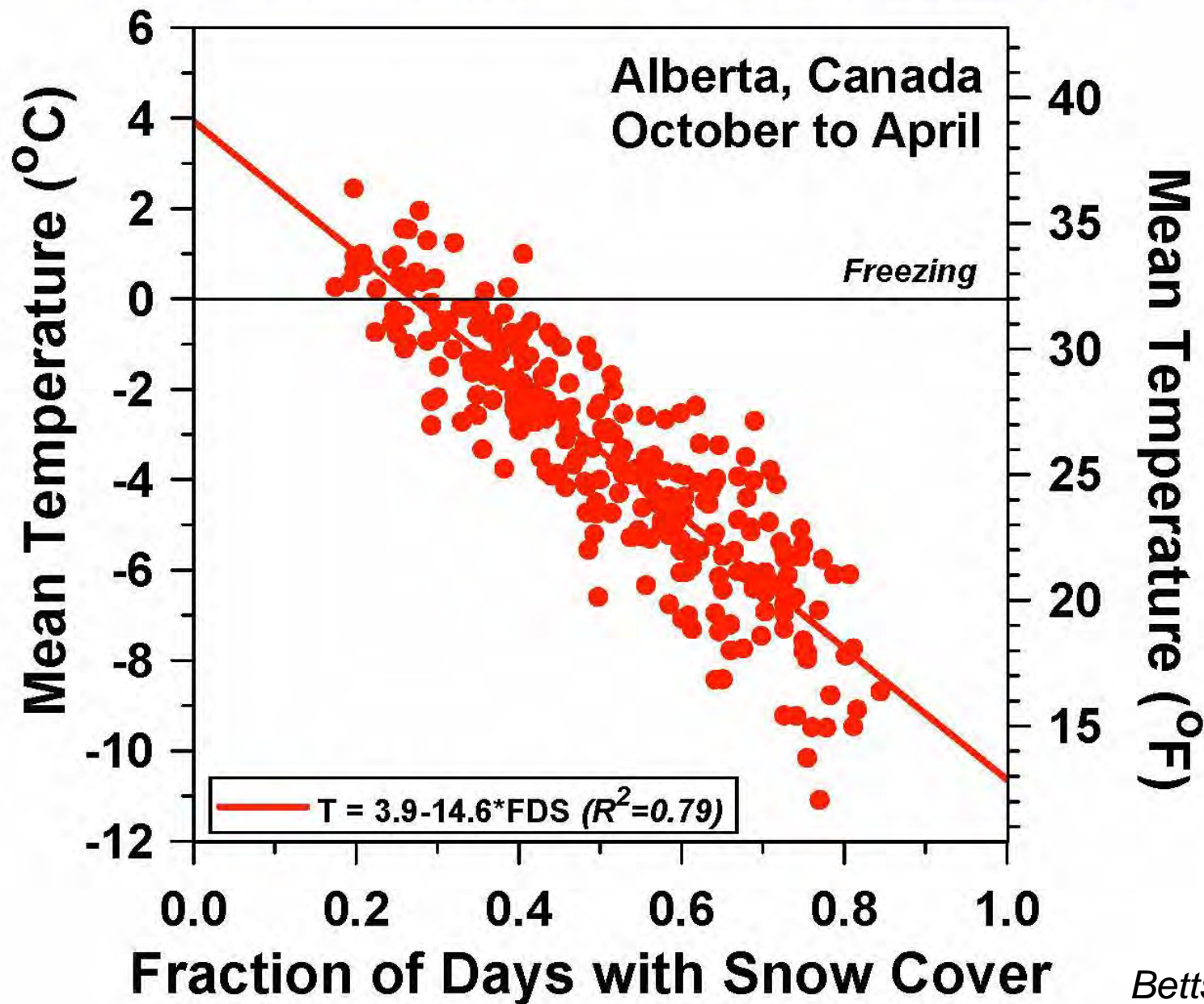


Snowfall and Snowmelt



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

More snow cover - Colder temperatures



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**

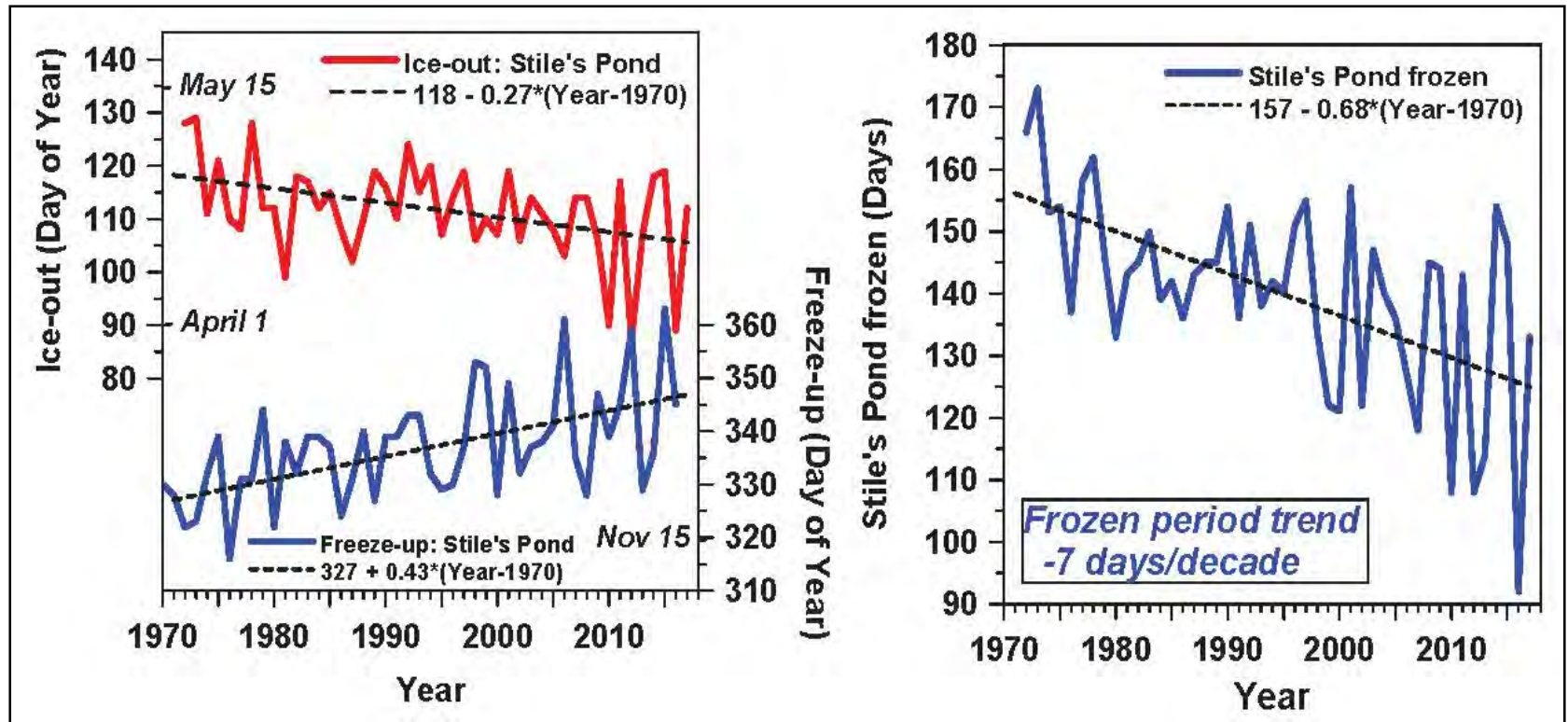


January 12, 2018

After T_{\max} up to 50F

Marker: Lake Freeze-up & Ice-out

Frozen Period Shrinking: variability huge



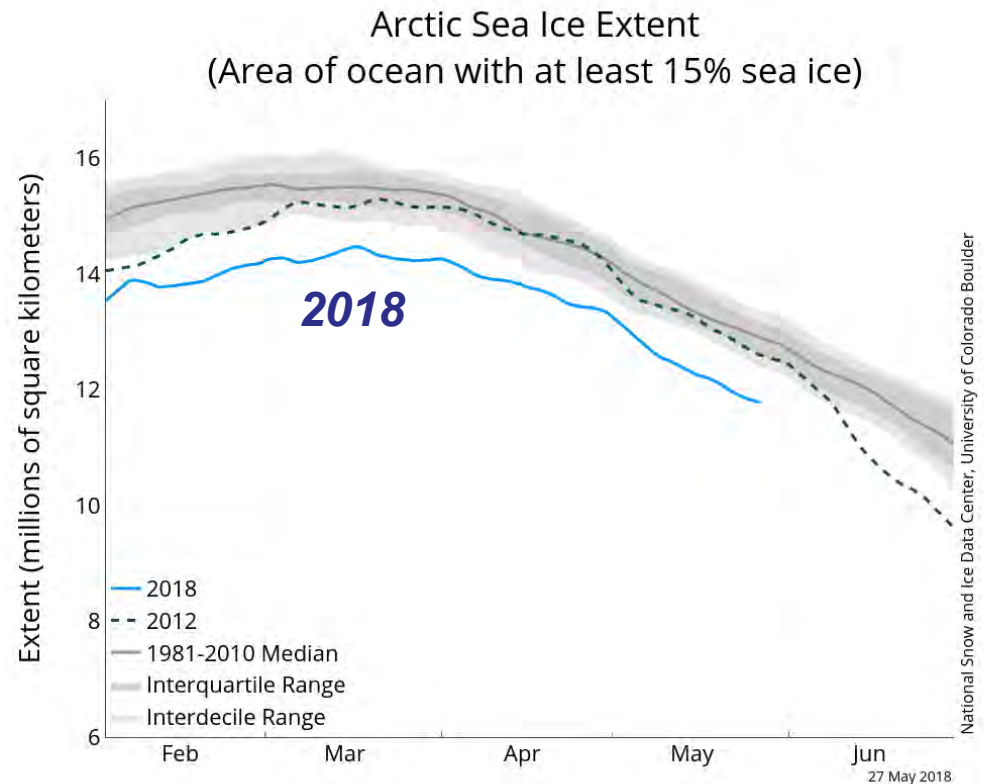
- Freeze-up later by **+4 days / decade**
- Ice-out earlier by **-3 days / decade**
- Lake frozen period trend **-7 days/decade**
- *Interannual variability \approx 40 yr trend*

*Stiles Pond:
"Eye on the Sky"*

Northern winters are changing

- as Arctic warms and melts
- the Arctic Vortex weakens

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

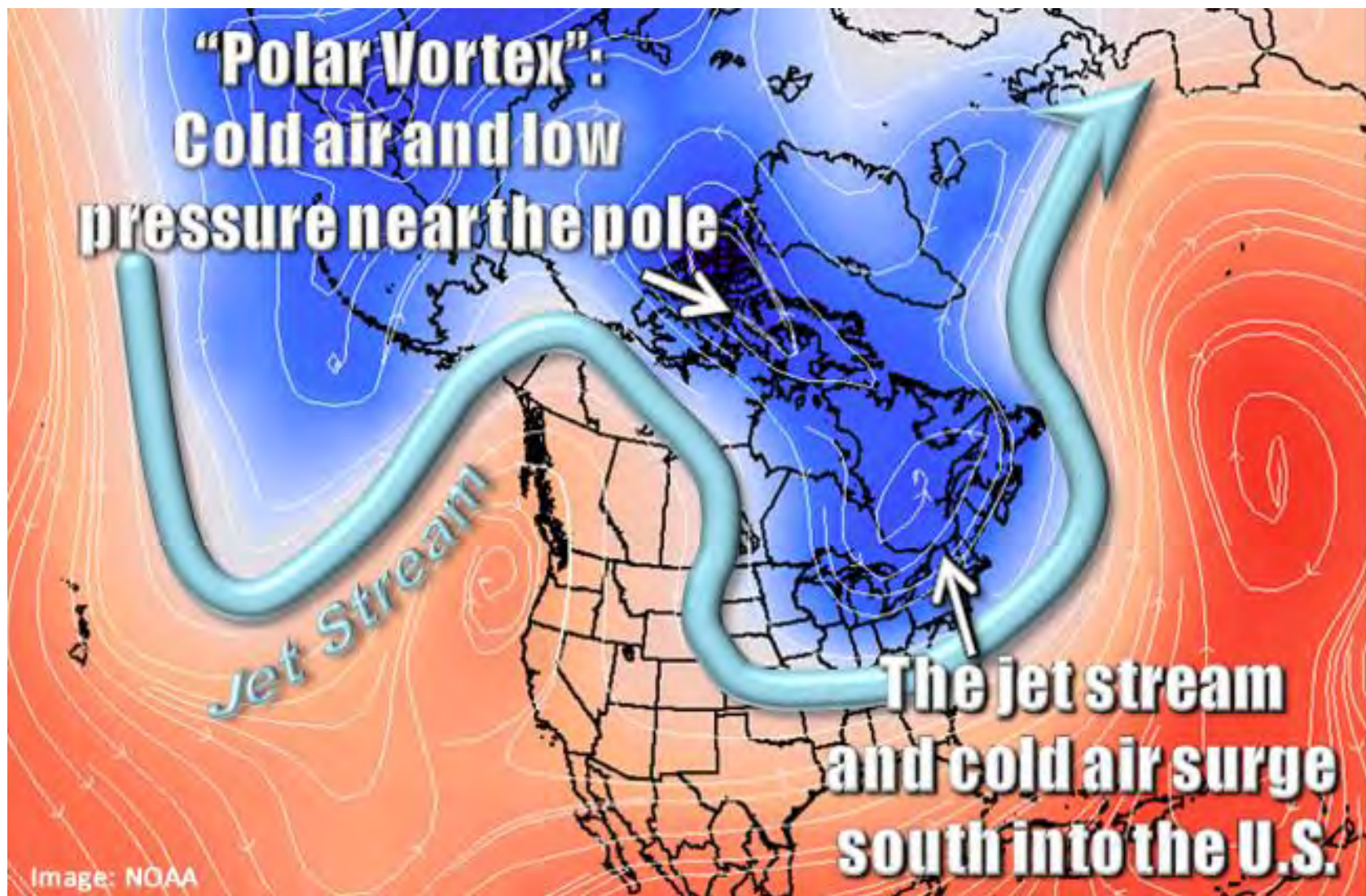


**"Polar Vortex":
Cold air and low
pressure near the pole**

Jet Stream

**The jet stream
and cold air surge
south into the U.S.**

Image: NOAA



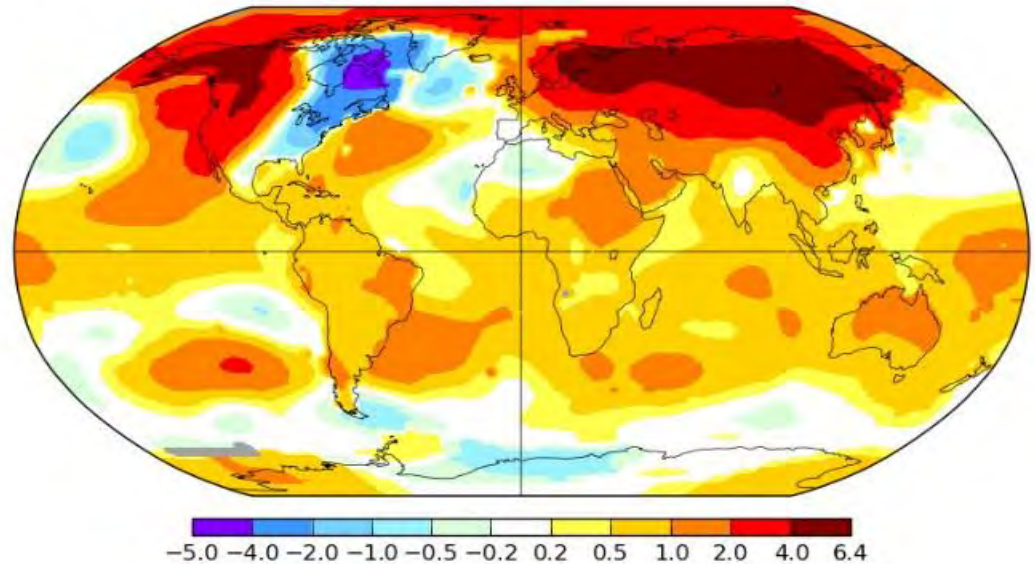
Jan-Feb-Mar 2015

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

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



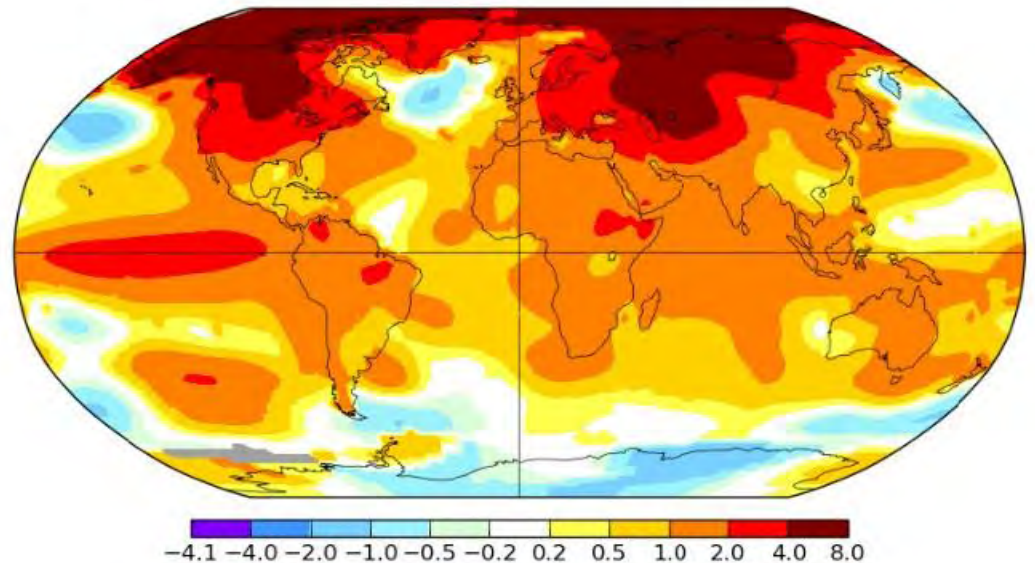
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little
snow, warm Arctic

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24



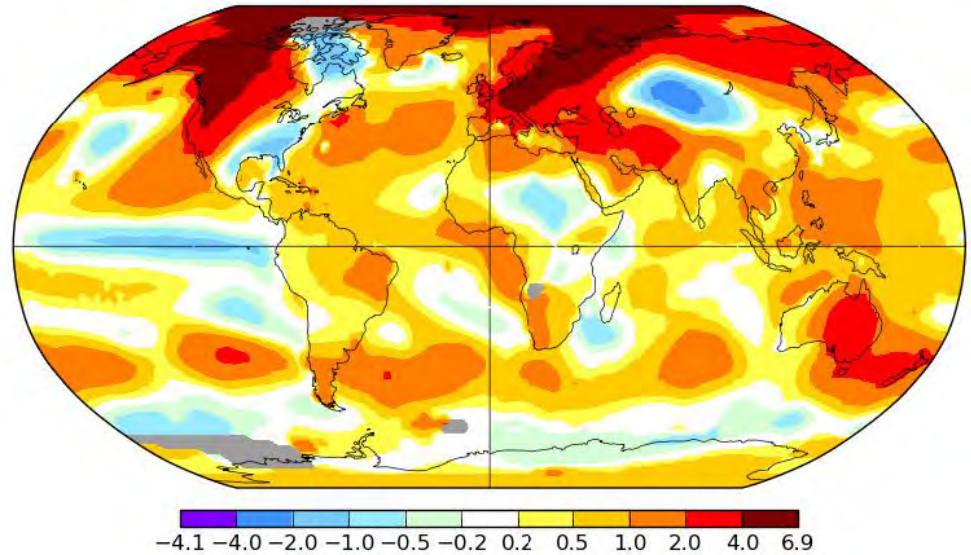
Jan-2018

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

January 2018

L-OTI(°C) Anomaly vs 1951-1980

0.79



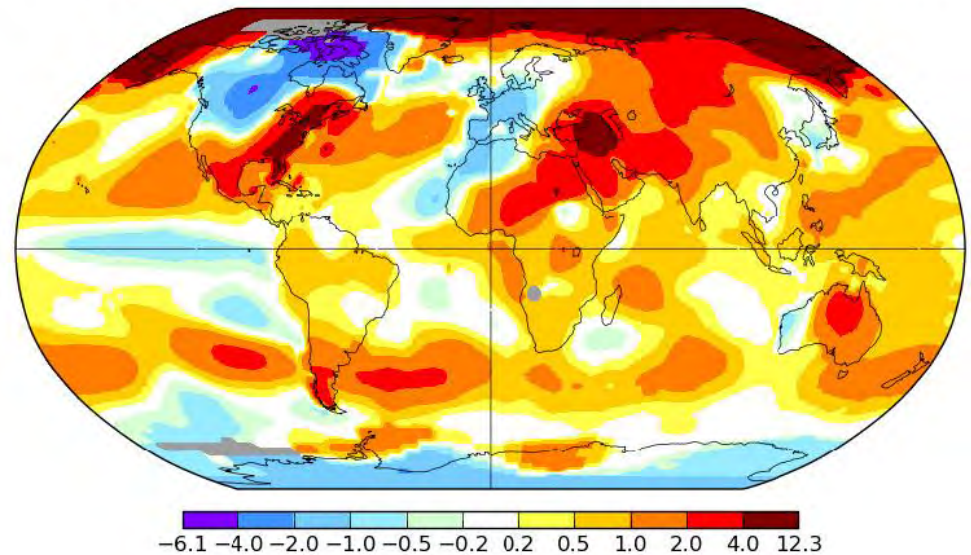
Feb-2018

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

February 2018

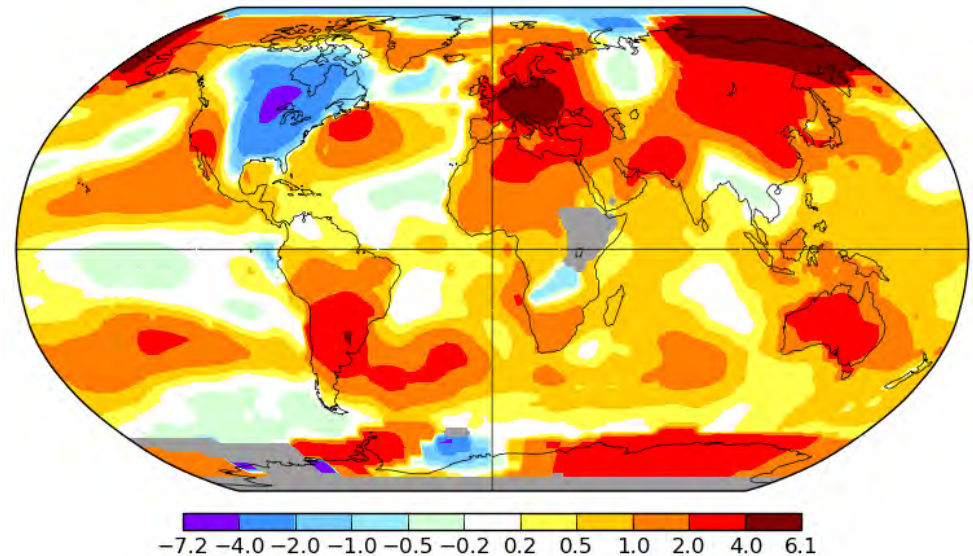
L-OTI(°C) Anomaly vs 1951-1980

0.79

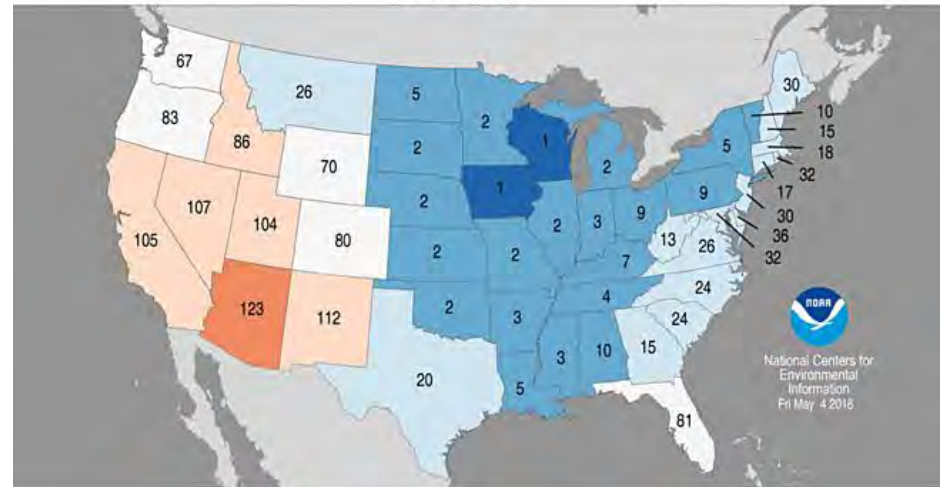


April-2018

Warm Atlantic, (Record) cold NA;
warm Europe



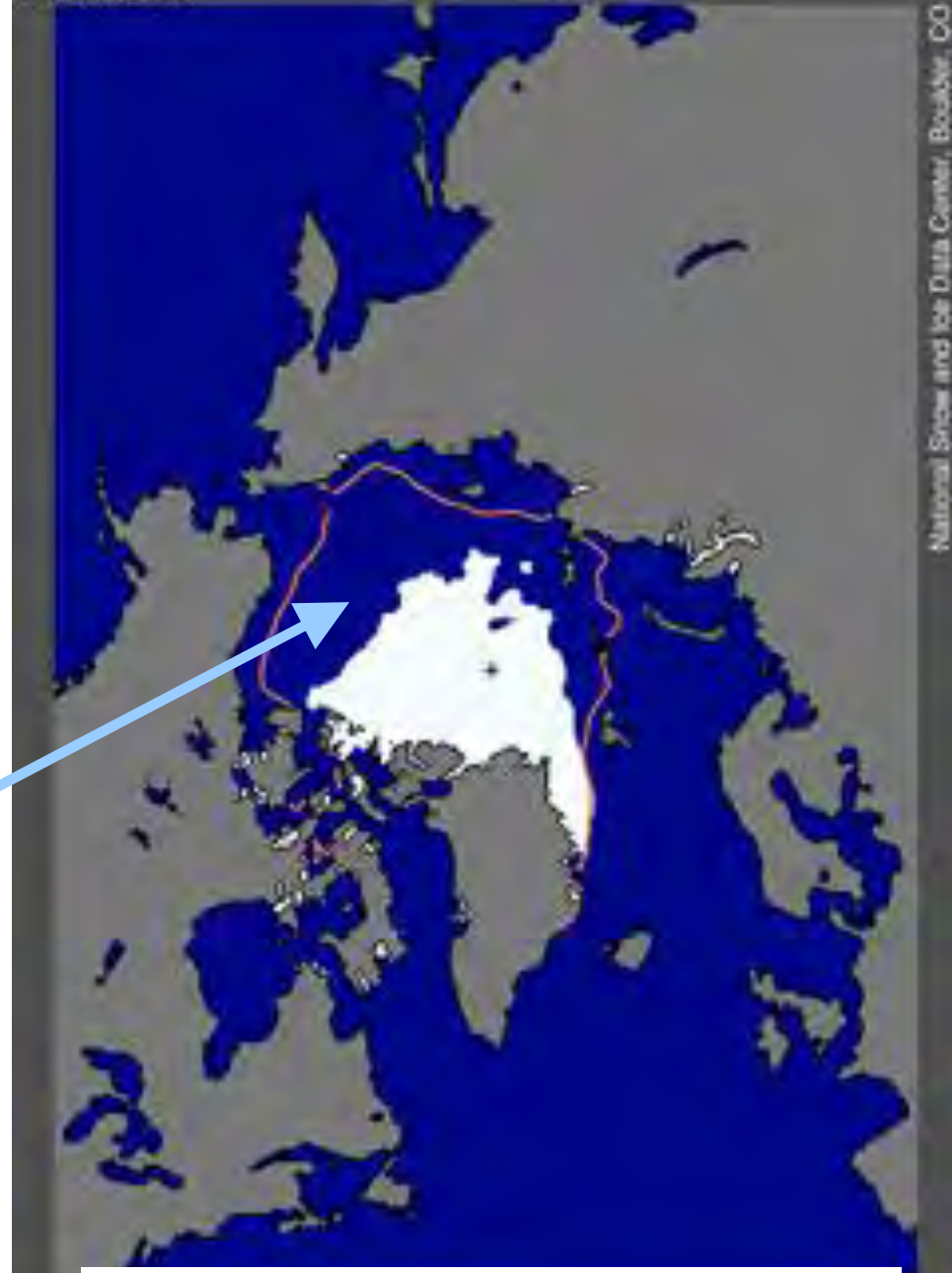
Statewide Average Temperature Ranks
April 2018
Period: 1895–2018



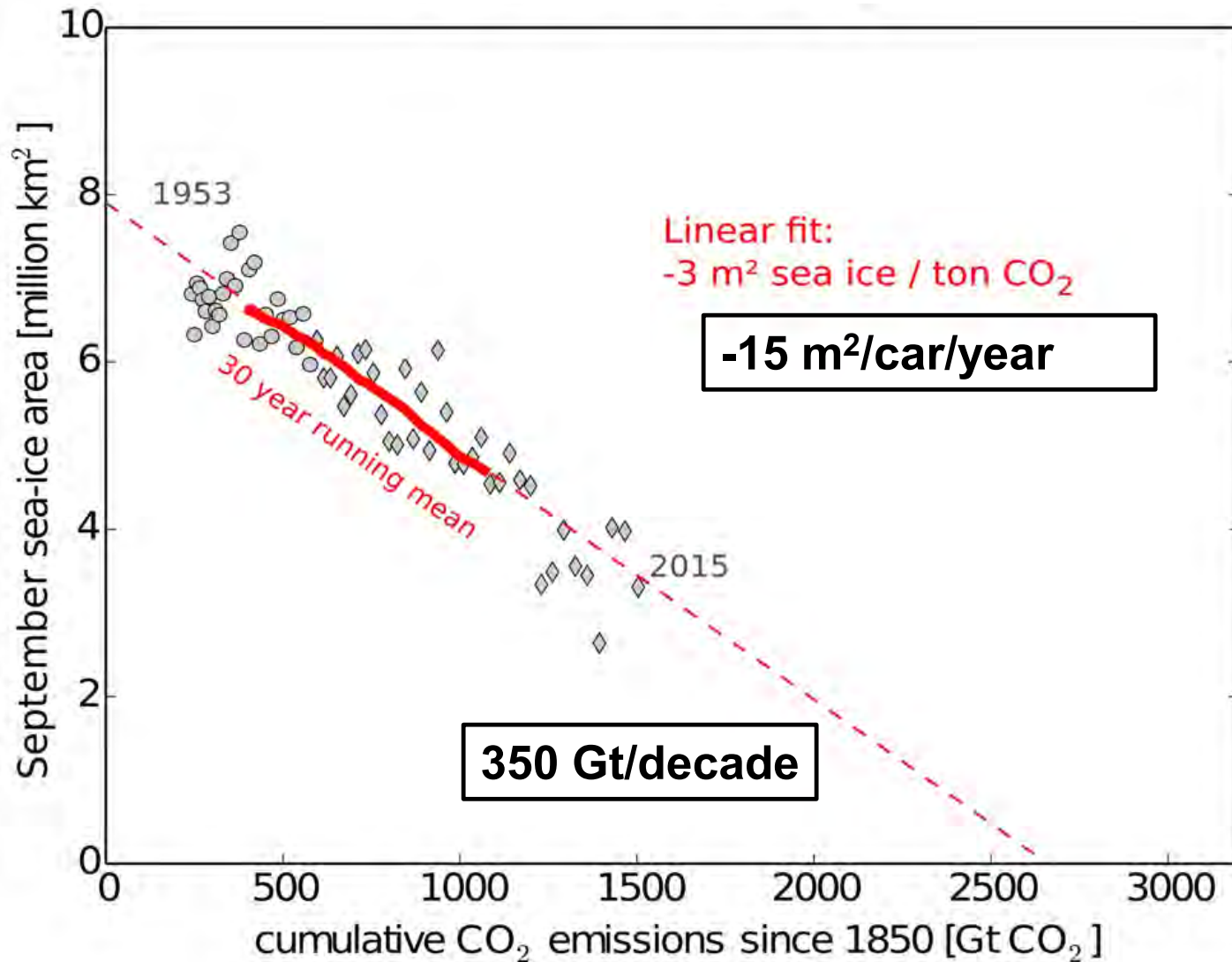
Record coldest: Wisconsin, Iowa
2nd coldest: Minnesota, S.Dakota,
Nebraska, Kansas, Oklahoma,
Missouri, Michigan

- **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 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”?

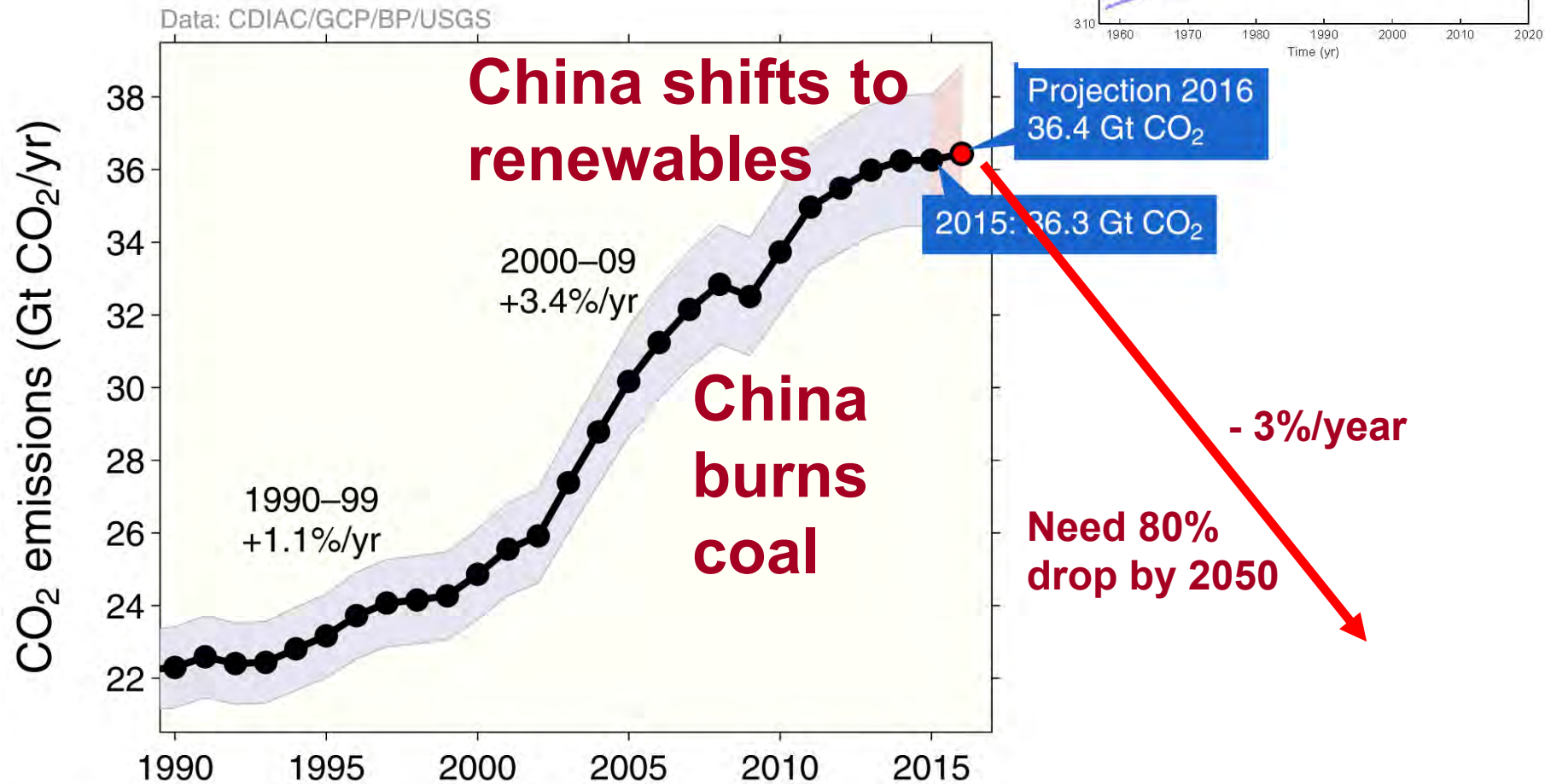
(UNFCCC 1992)

- **Yes:** Quickly stabilize atmospheric CO₂
- This means an 80% drop in CO₂ emissions!
- **This is possible but very difficult**
 - Fossil fuels have driven our industrial growth and population growth for 200 years
 - “Lifestyle” has become dependent on fossil fuels
 - Powerful vested interests: trillions \$ at stake

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 are taking lead*

Growth of CO₂ Emissions has slowed



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 CO₂ 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!
 - We demand: ***“Cost effective for today’s bottom line”***
- *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 CO₂ 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**

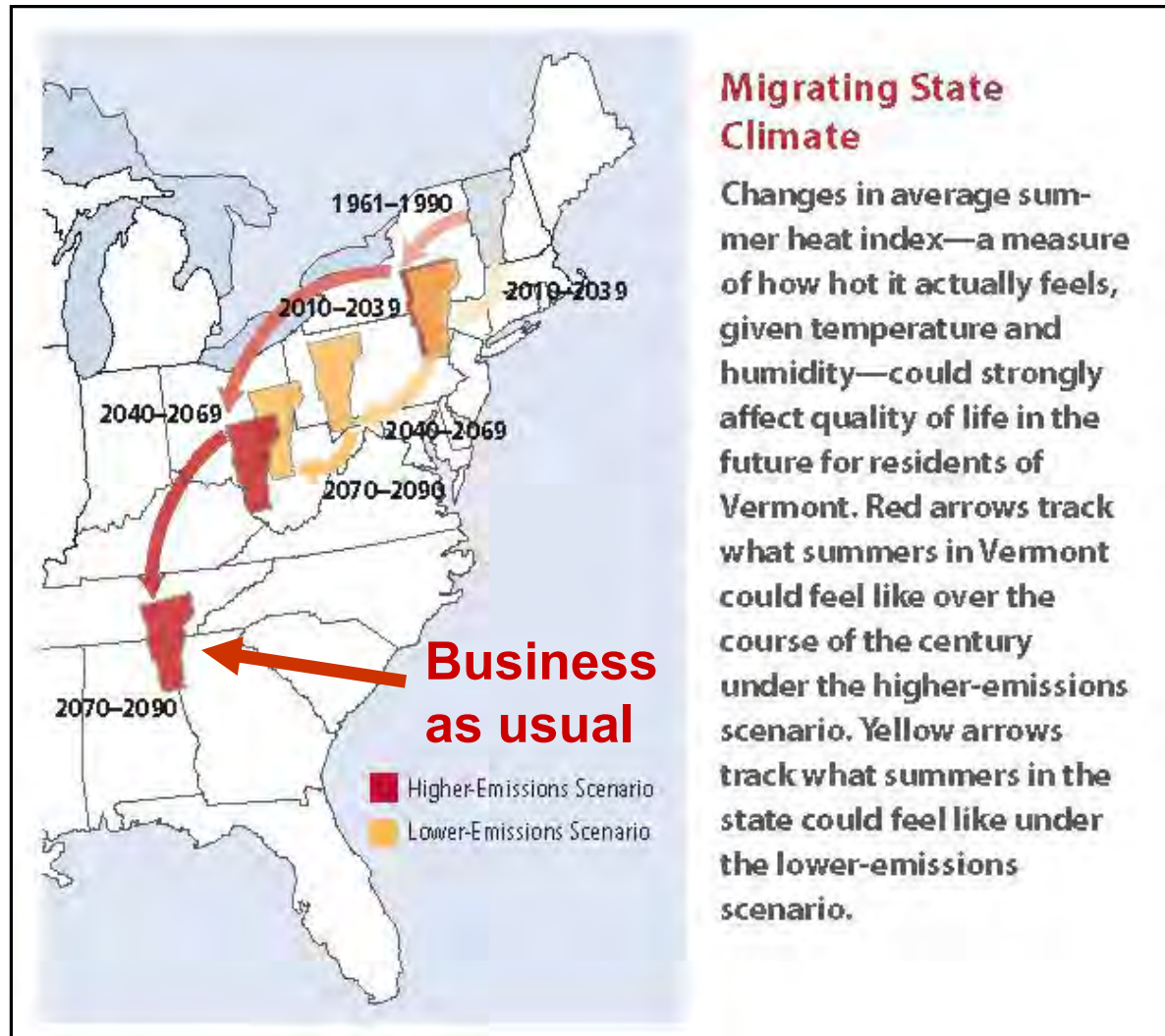
Discussion

(<http://alanbetts.com>)

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



**NECIA,
2007**

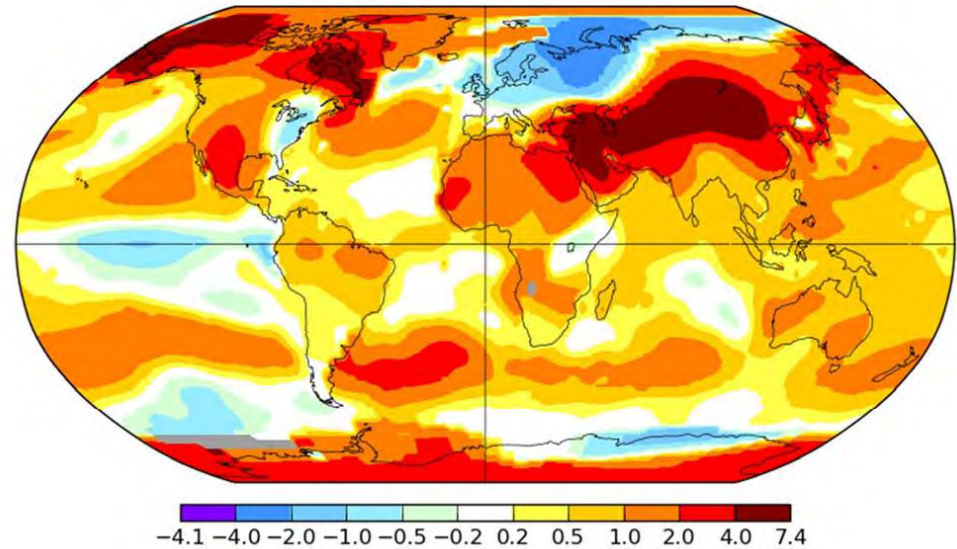
March 2018

L-OTI(°C) Anomaly vs 1951-1980

0.89

March-2018

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



April 2018

L-OTI(°C) Anomaly vs 1951-1980

0.86

April-2018

Warm Atlantic, (Record) cold NA;
warm Europe

