

The Climate Change Challenge

Alan K. Betts
Atmospheric Research

Pittsford, VT

<http://alanbetts.com>

***Vermont Tech.
Randolph Center***

April 13, 2018



Outline of this talk

- **What is happening to**
 - Global climate
 - Climate of Vermont
- **Broader issues**
 - System issues
 - Strategies, Responsibilities
 - Social issues (far beyond science)
- *Research on “winter”*



Fundamentals

- ***Burning fossil fuels: transforming climate***
 - *Many water cycle amplifying feedbacks*
 - *Heading for high CO₂ “Carboniferous era climate”*
 - *Climate extremes increasing*
 - *Decadal to centennial - long timescale challenge*
- **Avoidance of responsibility for decades**
 - Politicians, professionals, public
 - Climate change: Incompatible with business-as-usual
- **Linked to unmanaged technology: global impact**
 - Soluble by changing system guidelines
 - Create efficient society, based on renewable energy
- **Choices are value-based**
 - Science, technology and economics need guidance

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 and ecosystem health**
 - **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 better?**
 - **Can we better manage our relation to the Earth?**

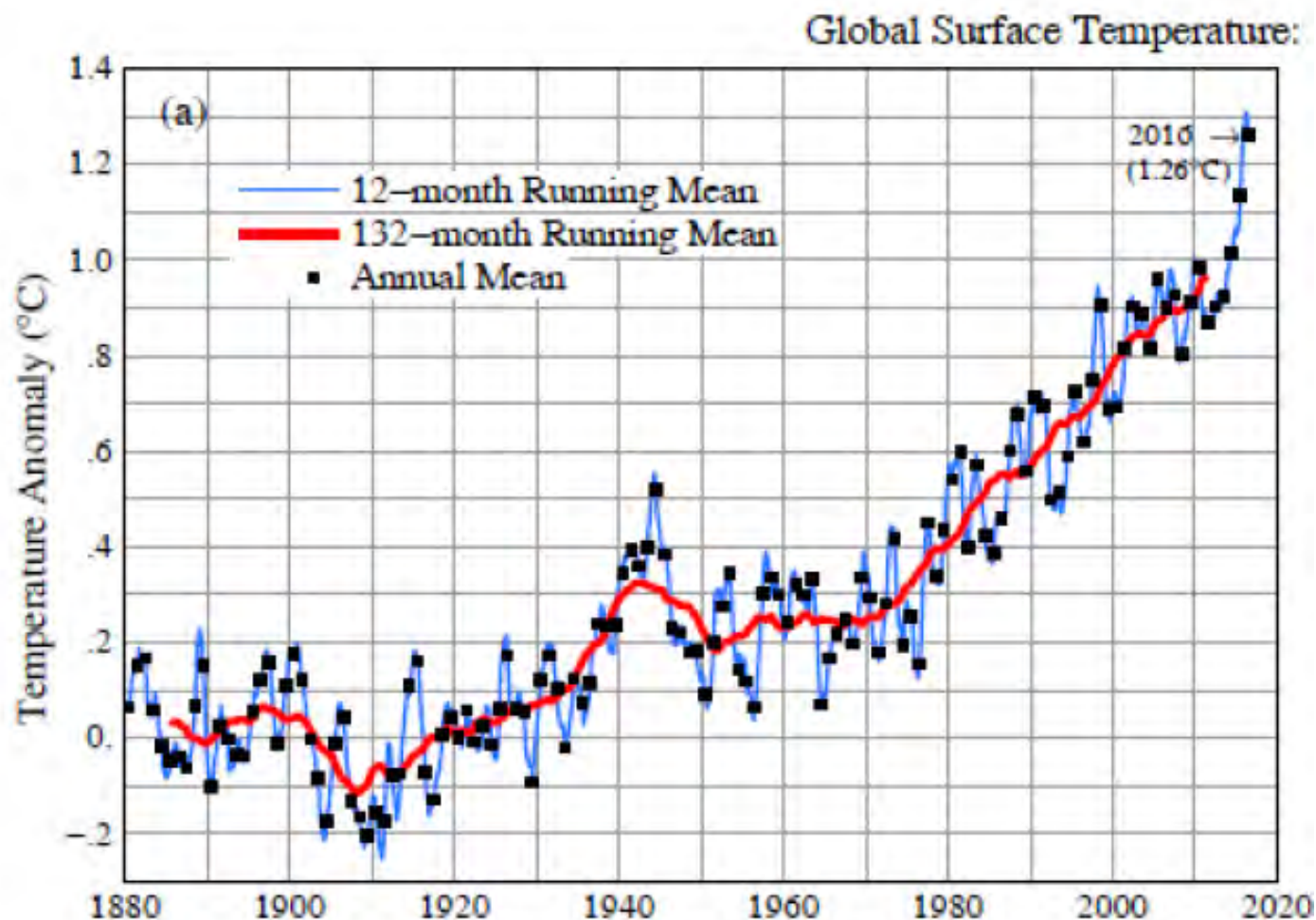
January 2, 2012: NASA

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



Long-term Global Mean Trend 1880-2016



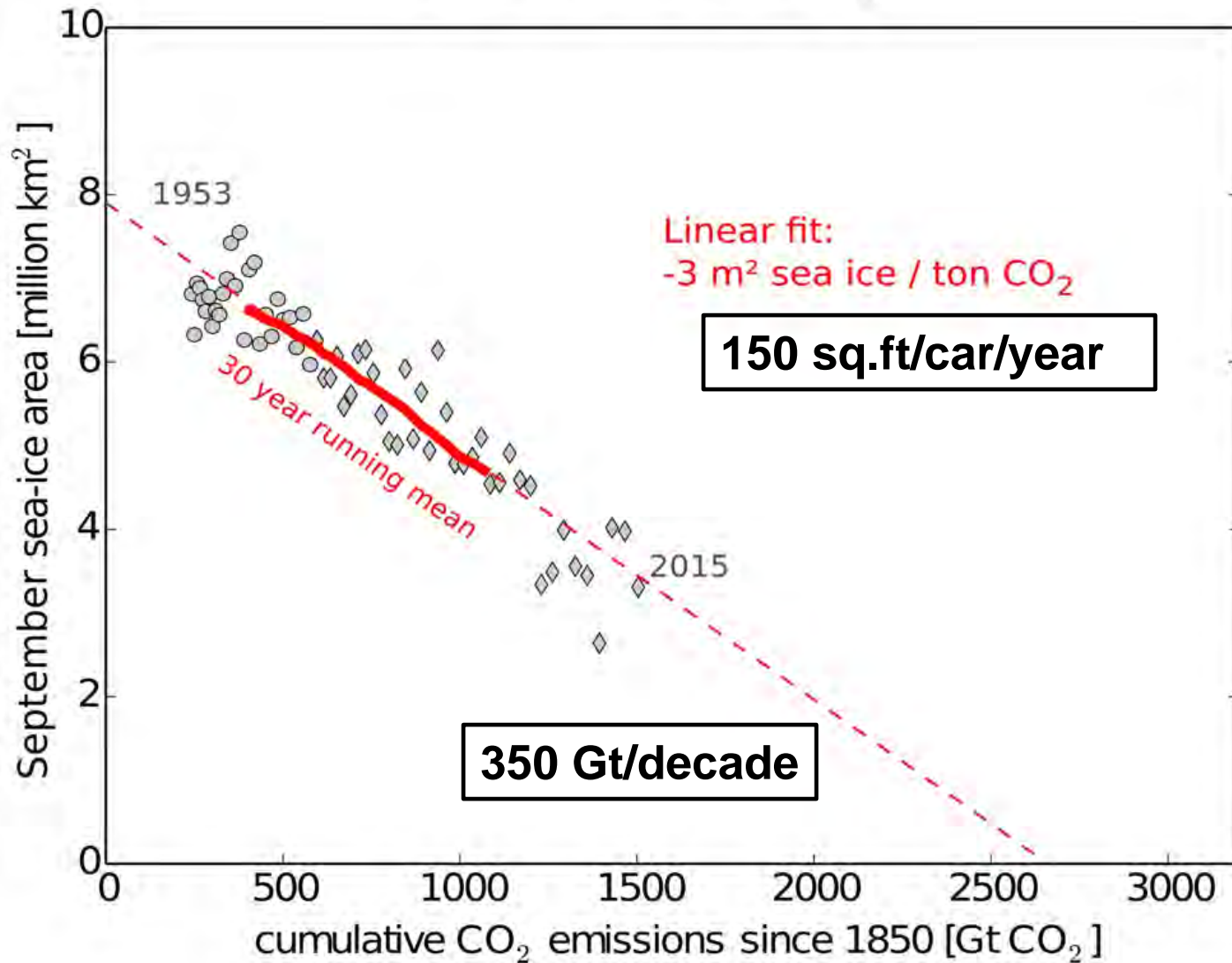
- Arctic warming twice as fast as globe
- Half the Arctic Sea Ice Melted in 2012
- Open water gives warmer Fall in Northeast

- Feedbacks amplify:
- *Less ice, less reflection of sunlight*
- *More evaporation, larger vapor greenhouse effect*
- *Our winters have same feedbacks*

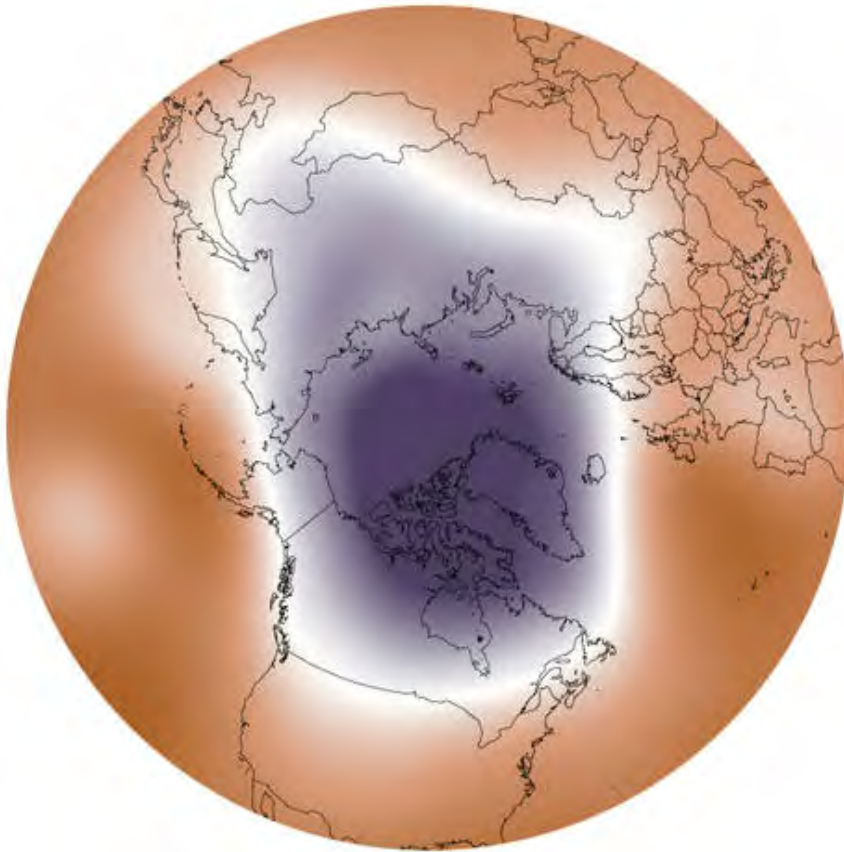
(This past winter, Arctic sea-ice reached new record lows)



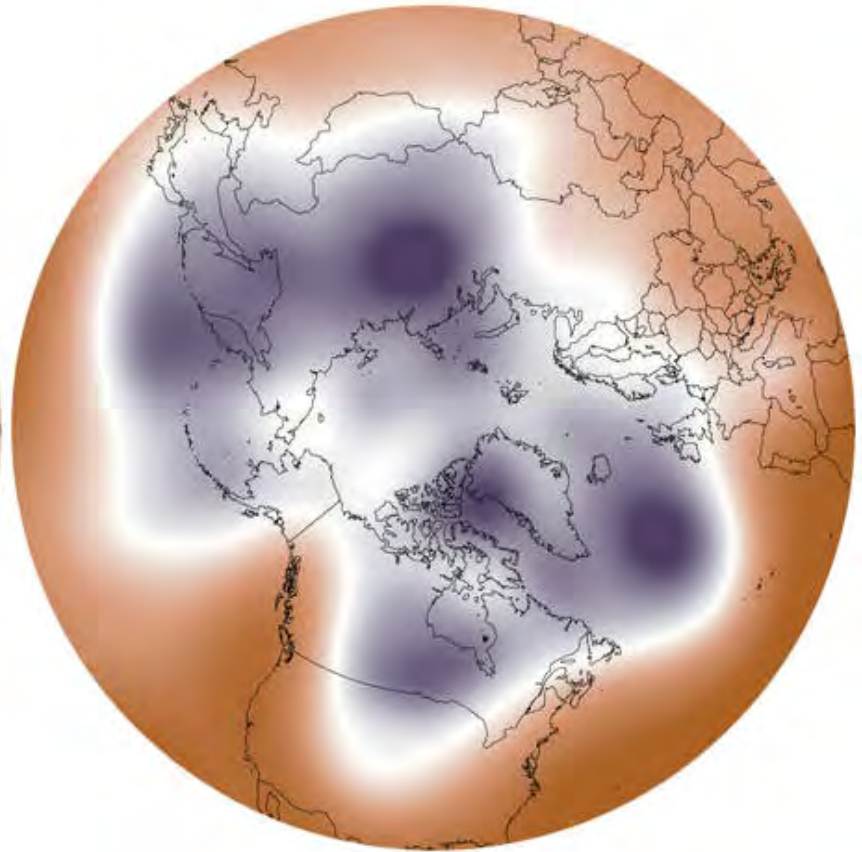
September Arctic Sea Ice Loss



As Arctic warms; Polar vortex weakens



December 2013: tight polar vortex



**January 2014: Vortex breaks up
- Same in 2018**

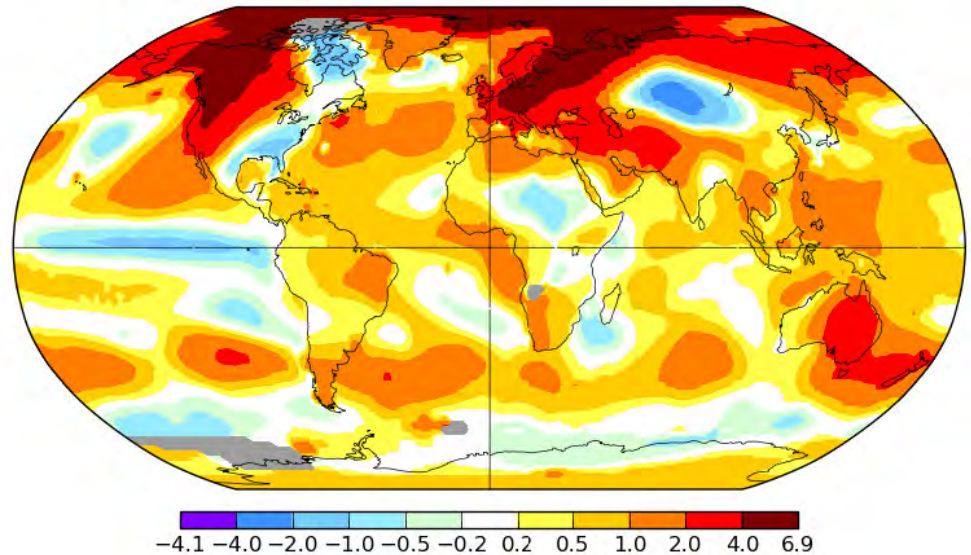
Jan-2018

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

January 2018

L-OTI(°C) Anomaly vs 1951-1980

0.79



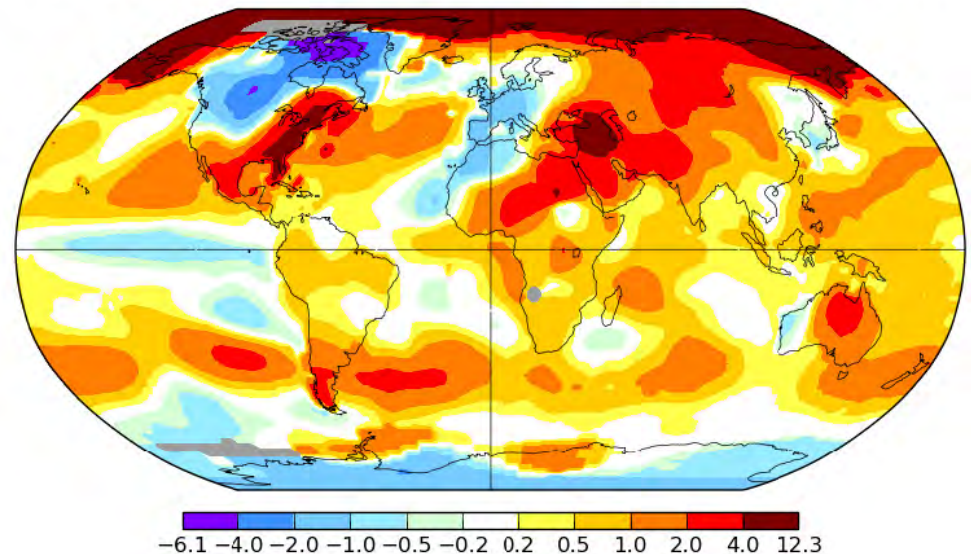
Feb-2018

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

February 2018

L-OTI(°C) Anomaly vs 1951-1980

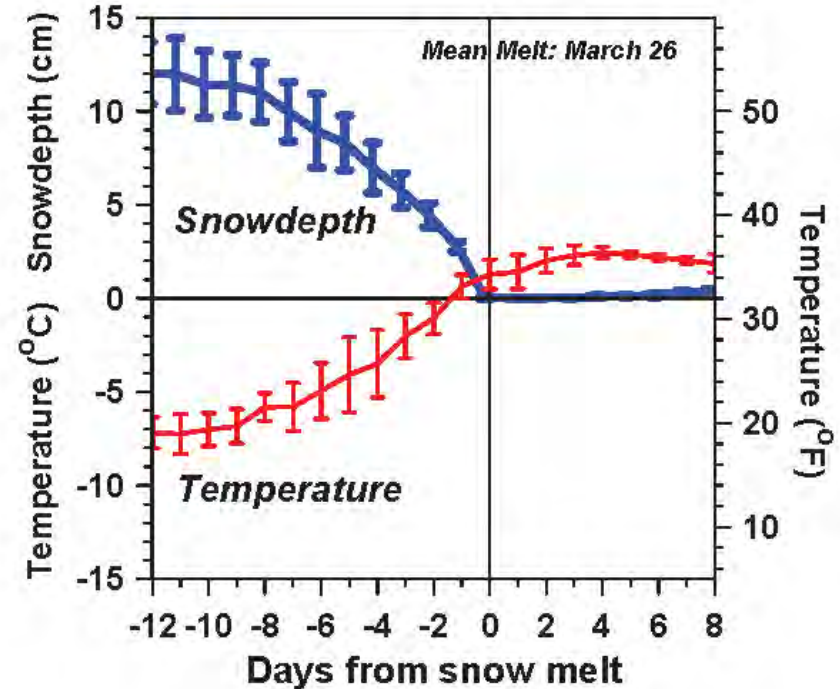
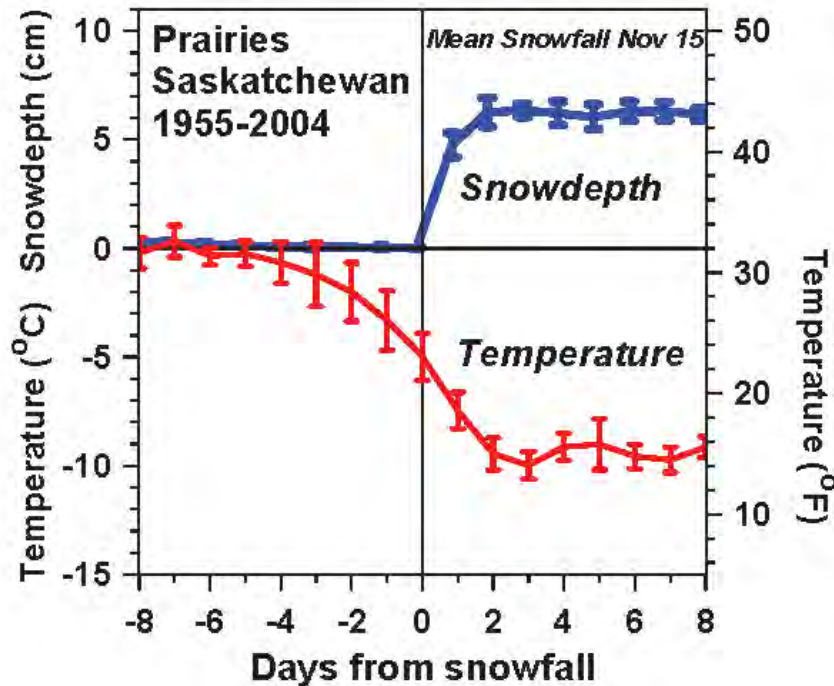
0.79



March 2018: 4 Nor'Easter snowstorms

Snowfall and Snowmelt

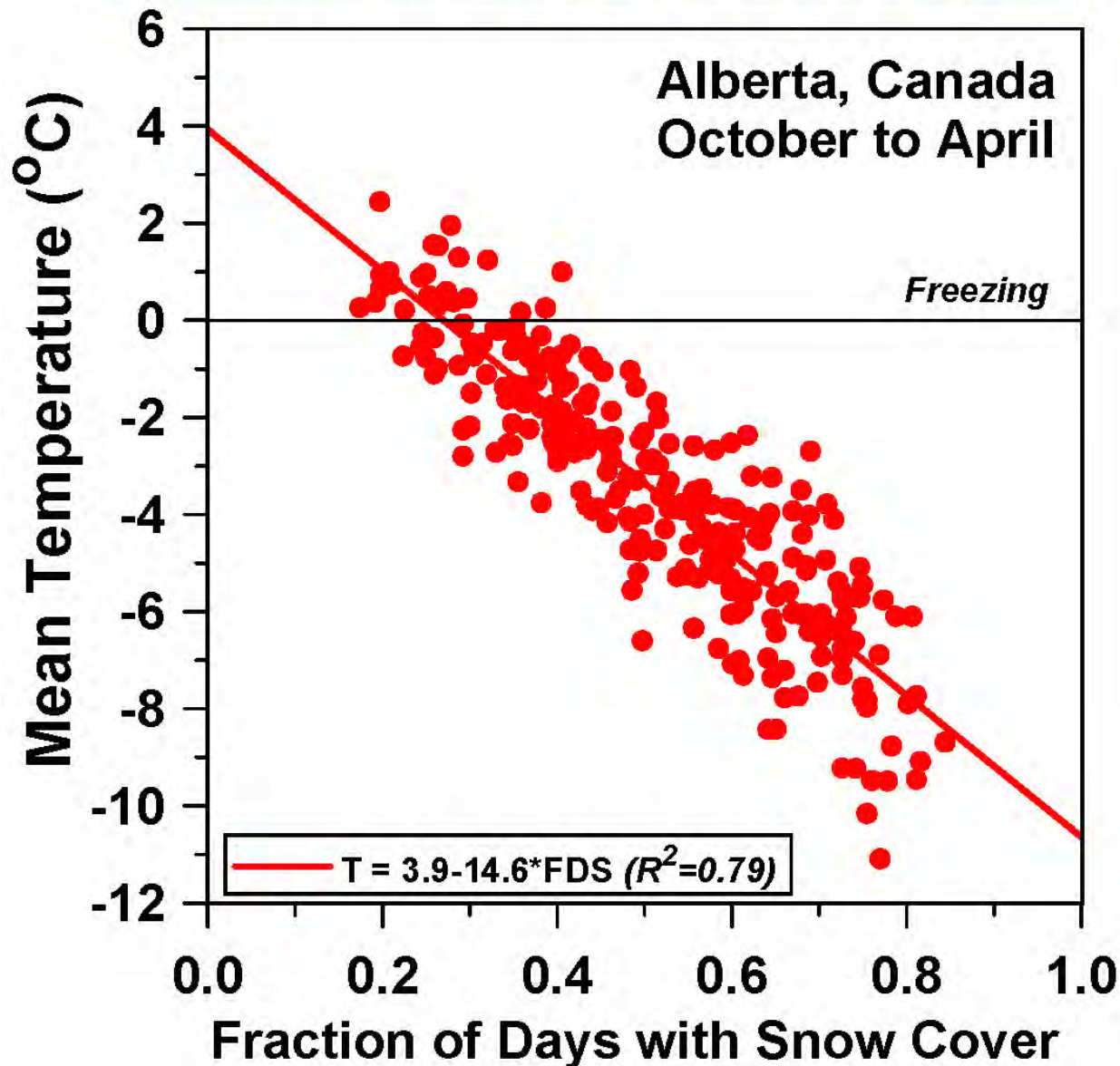
Winter and Spring transitions



- 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)

More snow cover - Colder temperatures



Winter is
colder if
more snow
cover

Impact of Snow

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

With snow

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

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)



March 3, 2017



January 10 and 12, 2018



January 10, 2018

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

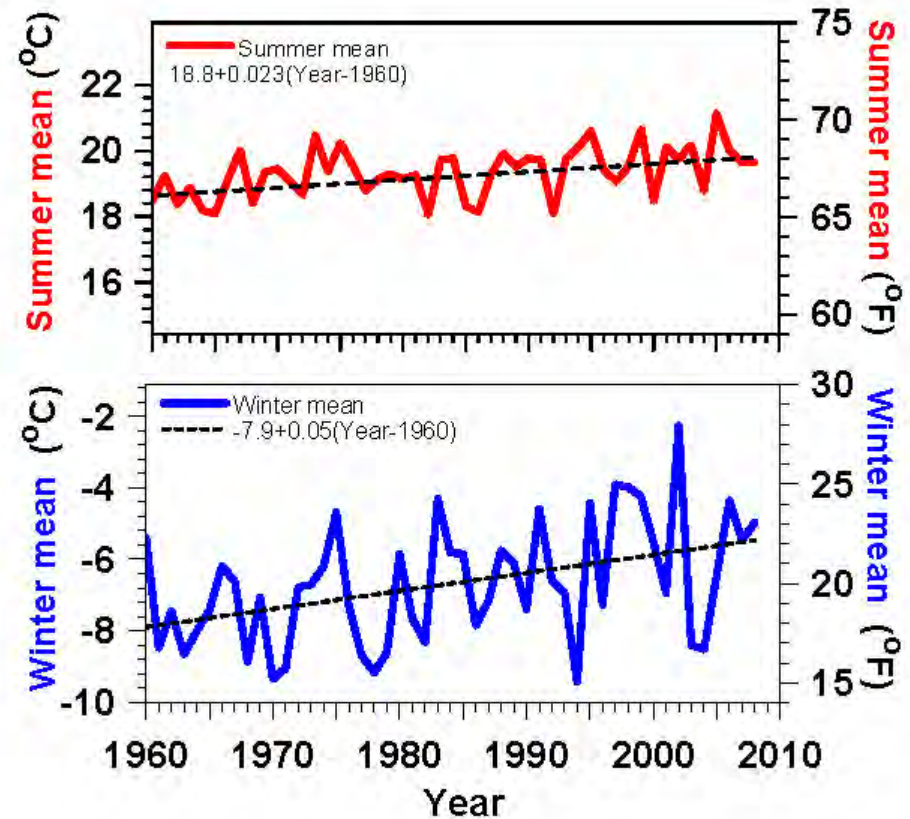


January 12, 2018

After T_{\max} up to 50F

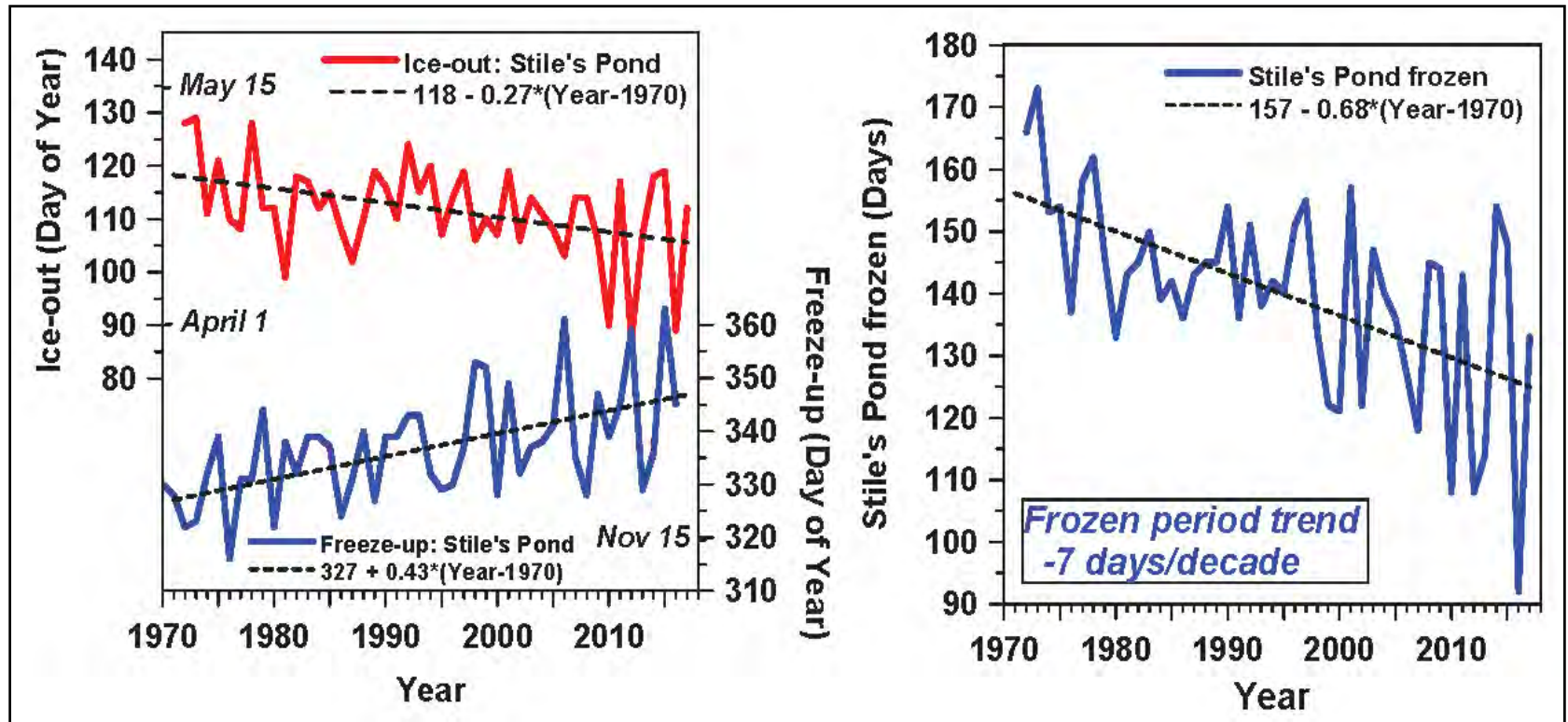
Vermont Temperature Trends 1961-2008

- **Summer $+0.4^{\circ}\text{F}$ / decade**
- **Winter $+0.9^{\circ}\text{F}$ / 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



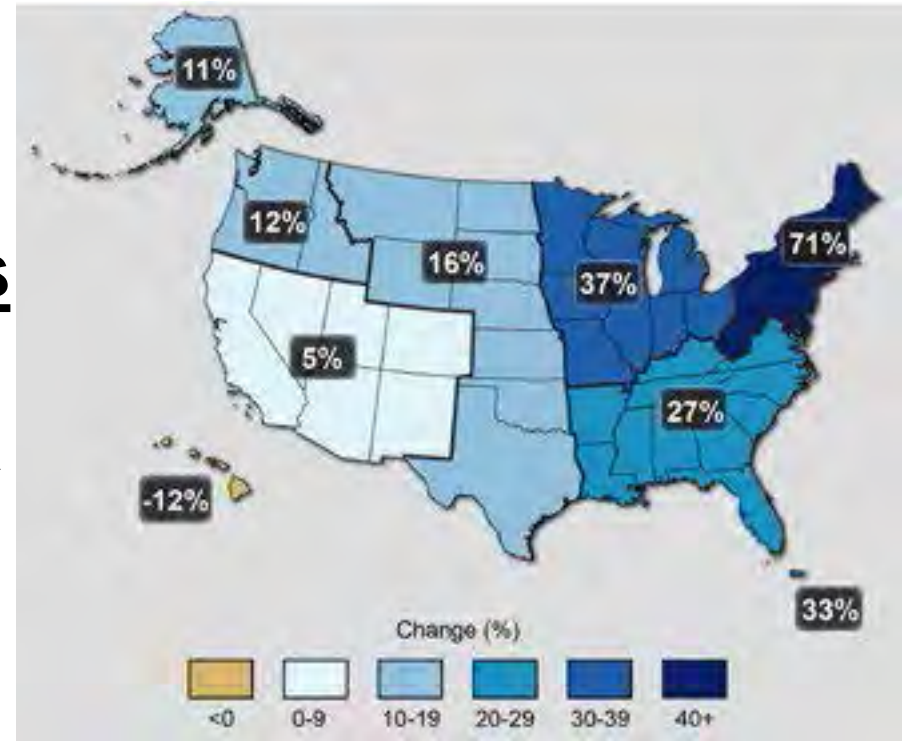
- Freeze-up later by +4 days / decade
- Ice-out earlier by -3 days / decade
- Lake frozen period trend - 7 days/decade
- *Interannual variability \approx 50 yr trend*

*Stiles Pond:
"Eye on the Sky"*

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

Roads in valleys

Massive damage

**Some roads took
months to repair**

***Rte 131,
Cavendish
Sept, 2011***





Brattleboro, VT, Courtesy of
Caleb Clark, CNN



Brattleboro, M. Reston



Wilmington, J. Cantore

Value of Flood Plains



- **Otter Creek after Irene on August 30, 2011**
 - **River rose ten feet: flood plain saved Middlebury**

2011 Classic Flood Situations

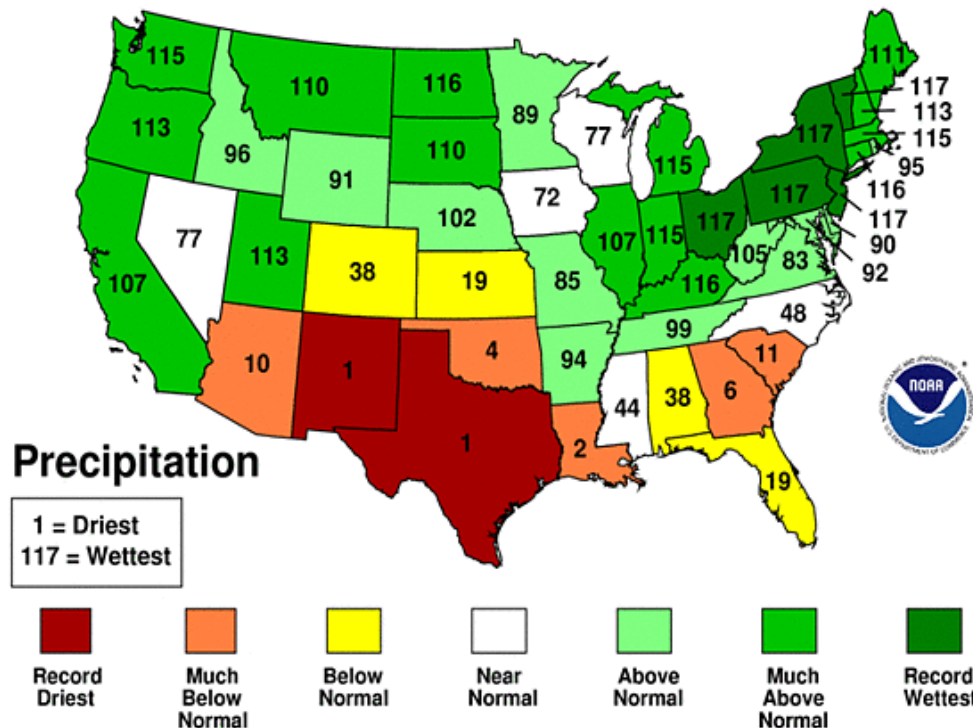
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010 winter
 - 70F (4/11) and 80F(5/27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical storm** moved up east of Green Mountains and Catskills
 - dumped 6-10 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



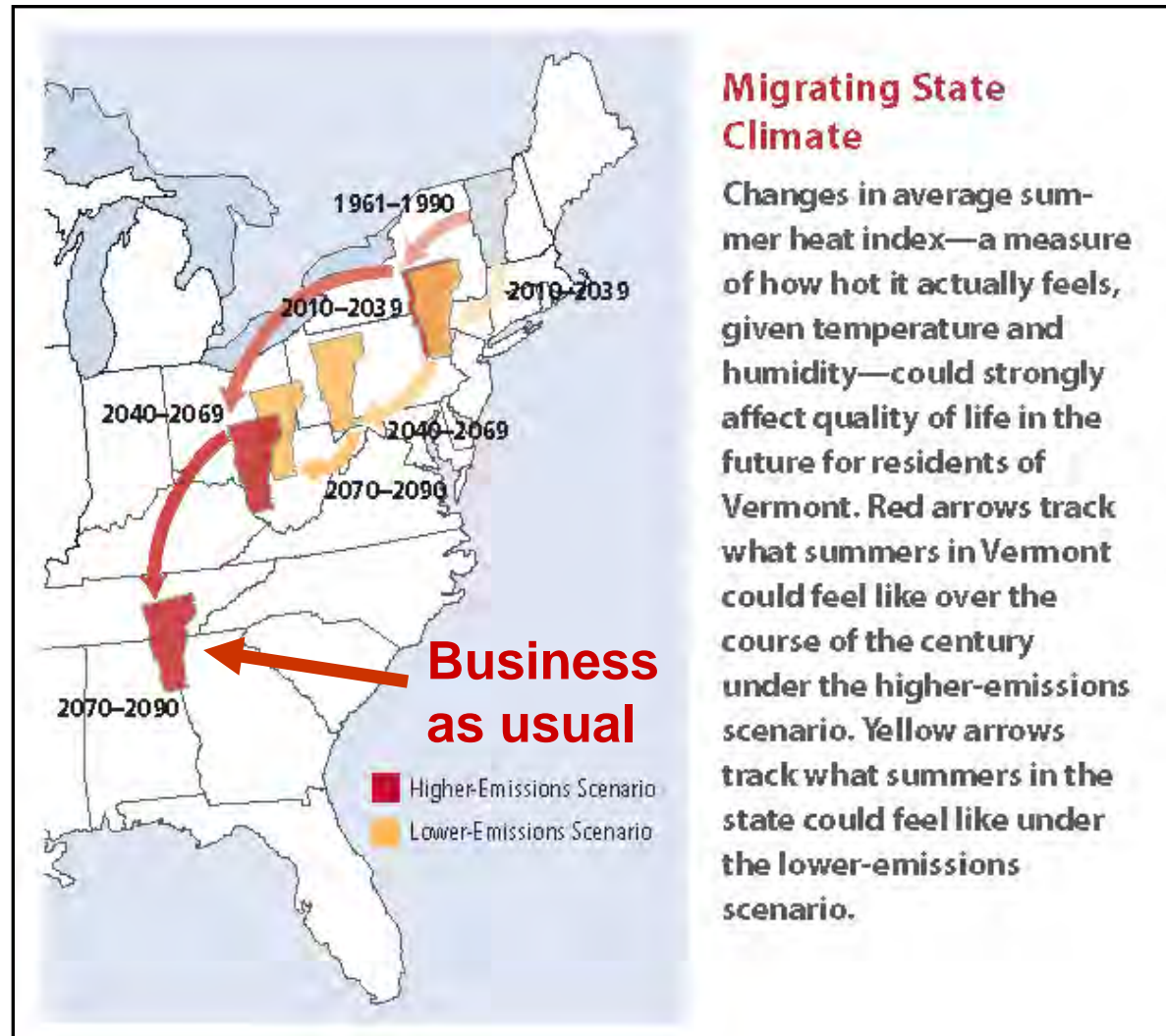
March-August, 2011

- Record wet : OH to VT
- Record drought: TX & NM
- Pattern nearly stationary

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



**NECIA,
2007**

Can We Stop “Dangerous Climate Change”?

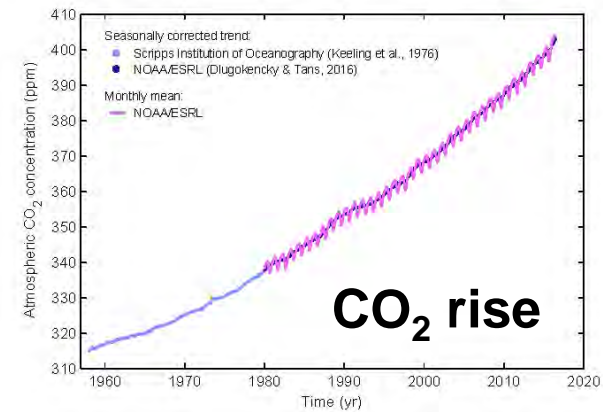
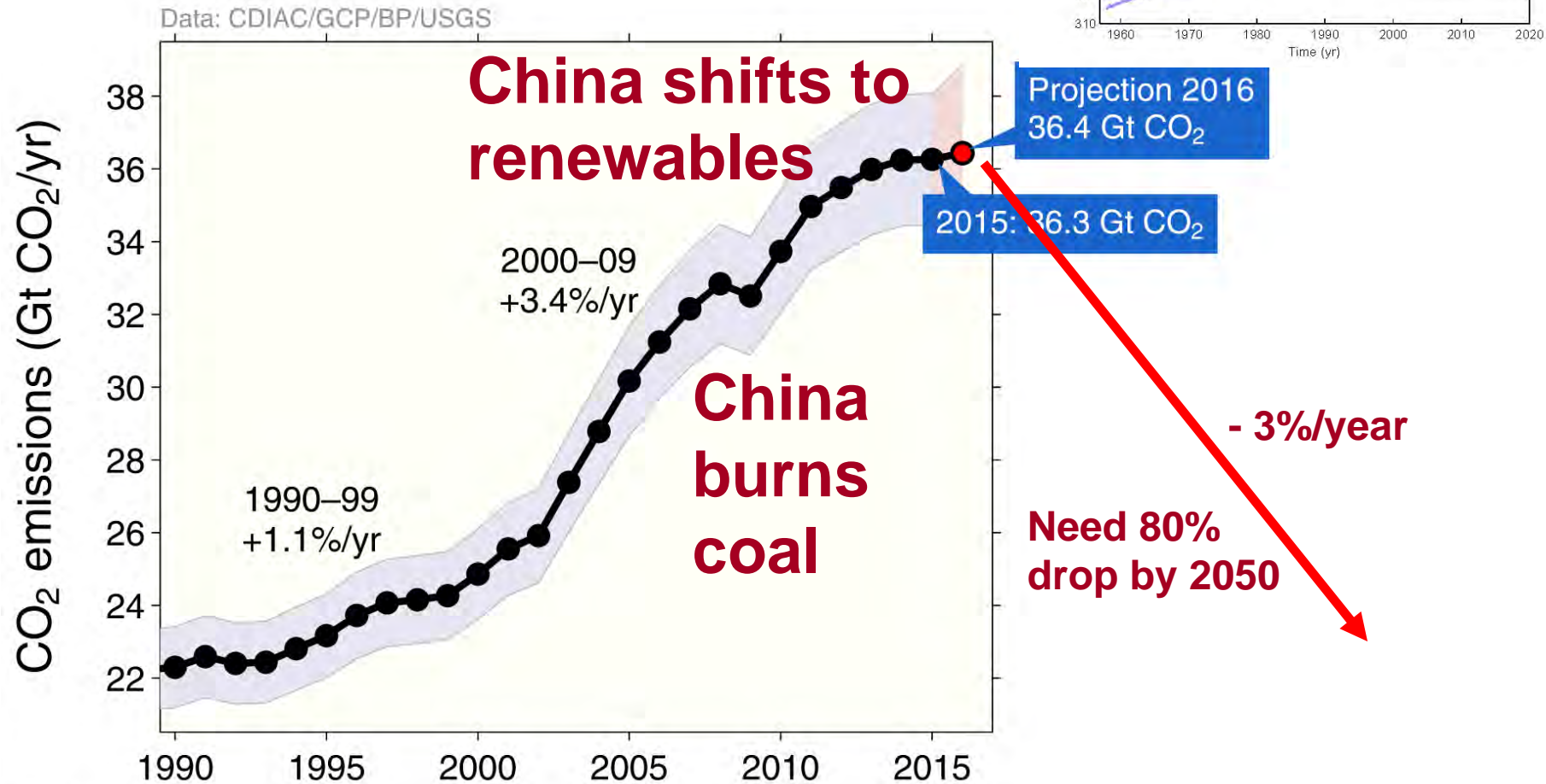
(UNFCCC 1992)

- **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 have to take lead*

Growth of CO₂ Emissions Flat for 3 years



What can we “safely” burn?

- Only 750 Gt more for an even chance of keeping warming below 2°C [3.8°F]
- *Requires leaving 2/3 of remaining fossil fuels in ground*
- Only 21 years left at 36 Gt/year
- *Rapid phase-down extends period*

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
 - CO₂ 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*

‘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*

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*

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*
 - *Flood coastal cities as icecaps melt: and over centuries 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 CO₂ is an ‘unfair cost to the free market’
 - (Too bad if the Earth’s ecosystems are destroyed: future can pay the price)
- ***Our politics are facing collapse:
fantasy disconnected from real world***
 - *We are all deeply embedded in system*

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*

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 65 mph



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

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*
- *How do we turn the ship around?!*

Discussion

alanbetts.com

(articles and talks)

“Disagreement in Science”

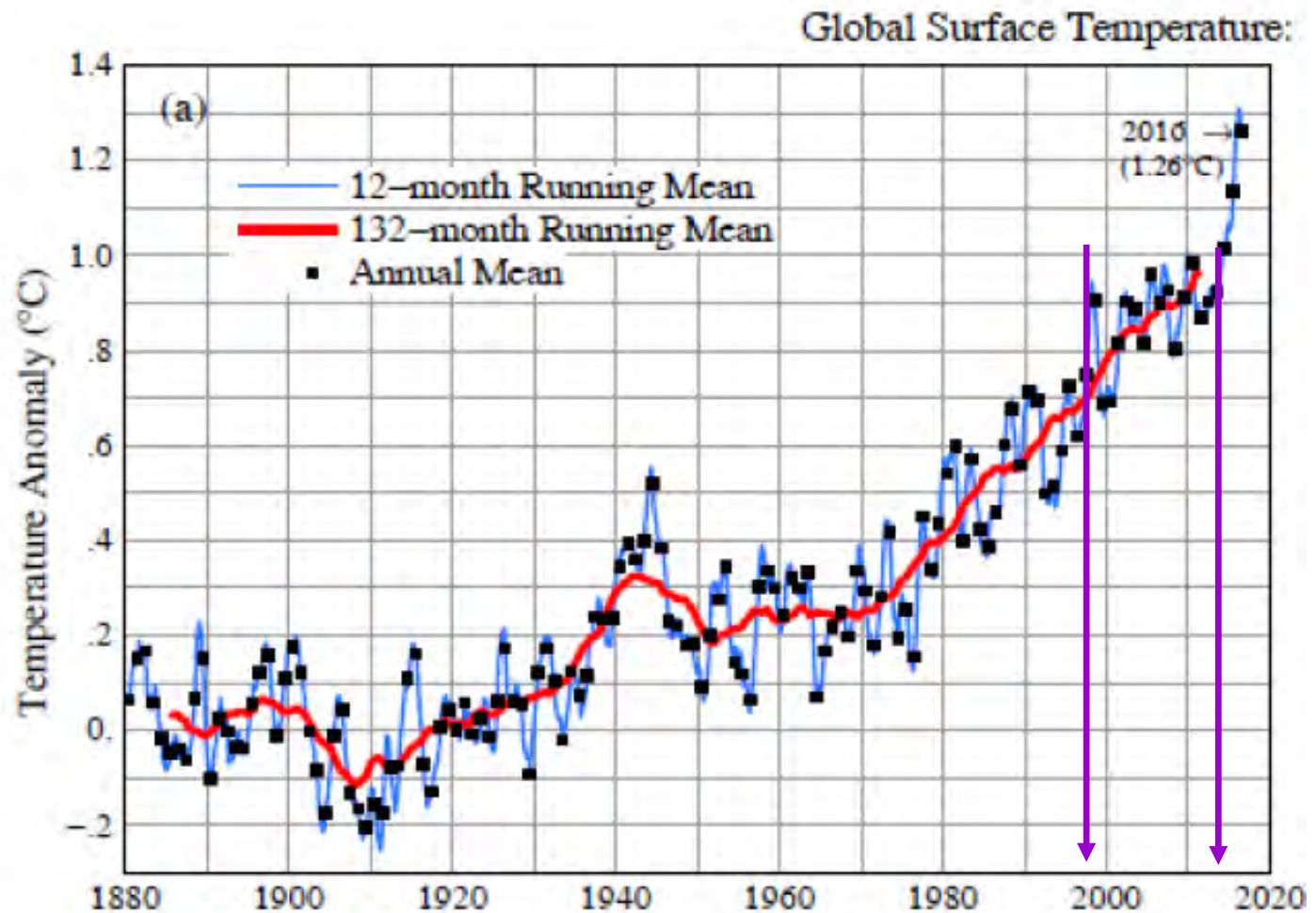
- **Climate science is very complex**
 - Basic greenhouse gas issue simple
 - But every month we discover new facets
- **Complexity means hard to understand who is telling the whole truth**
 - Oversimplifications common
 - Deliberate deception common
 - Check credentials and funding!
- **Check: <https://skepticalscience.com/>**

What is our role as Scientists?

- **Honesty, accuracy, clarity, and depth**
 - “**Bold humility**” *(Francis Moore Lappé)*
 - **Scientists & engineers should consciously accept responsibility for the Earth**
 - *As the political and economic system will not*
 - **Speak clearly to society: creative hope not despair**
 - **Search for language that sidesteps ideology**
 - *Realize that Earth system limits will need adaptive global governance*
 - *and a paradigm shift in science*

(alanbetts.com)

Take one decade and argue: 'Global warming has stopped'



Small change: 1998-2003

Paradigm shift for science?

- **Great value of science is its honesty, integrity and its cooperative global vision**
 - It deals with the measurable world
 - It communicates openly
 - Priceless to a society lost in corruption & deceit
- **Greatest challenge is that humanity is embedded in a deeply interconnected living Earth's system**
 - That cannot be separated and objectified
 - In fact the separation of our social frames from the Earth's ecosystem is driving climate change

- *“Many things have to change course, but it is we human beings above all who need to change. We lack an awareness of our common origin, of our mutual belonging, and of a future to be shared with everyone.”*

Pope Francis, Encyclical 2015

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**

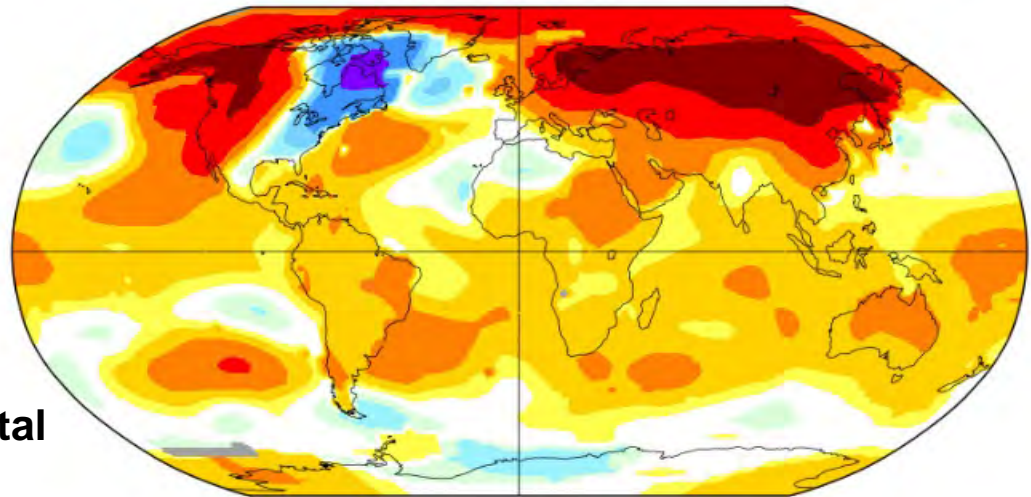
Jan-Feb-Mar 2015

Warm Atlantic, cold NE, strong coastal
storms - Boston record snow

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



-5.0 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 6.4

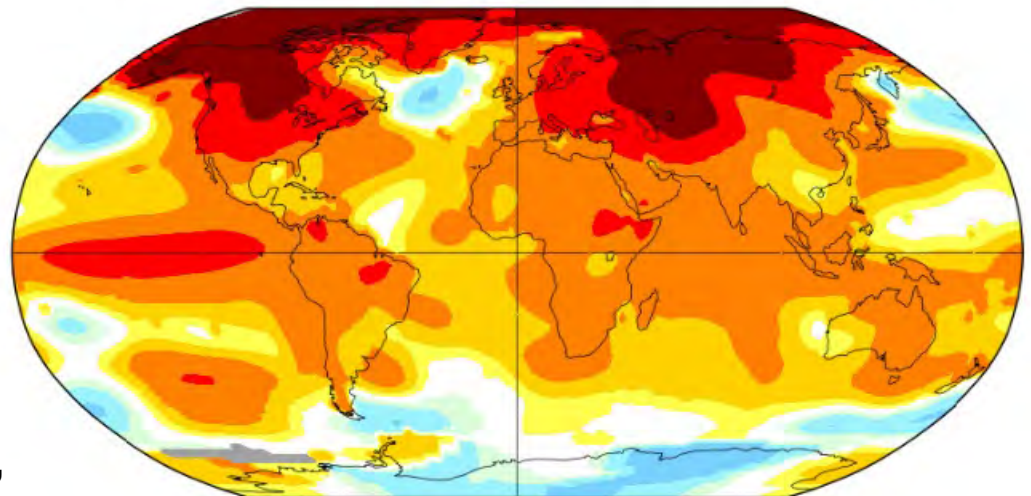
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow,
warm Arctic

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24



-4.1 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 8.0