



# Global and Local Climate and our Future



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***BREE Intern Orientation***  
***June 1, 2017***



# 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 scientists' responsibilities?

## Discussion

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 crucial



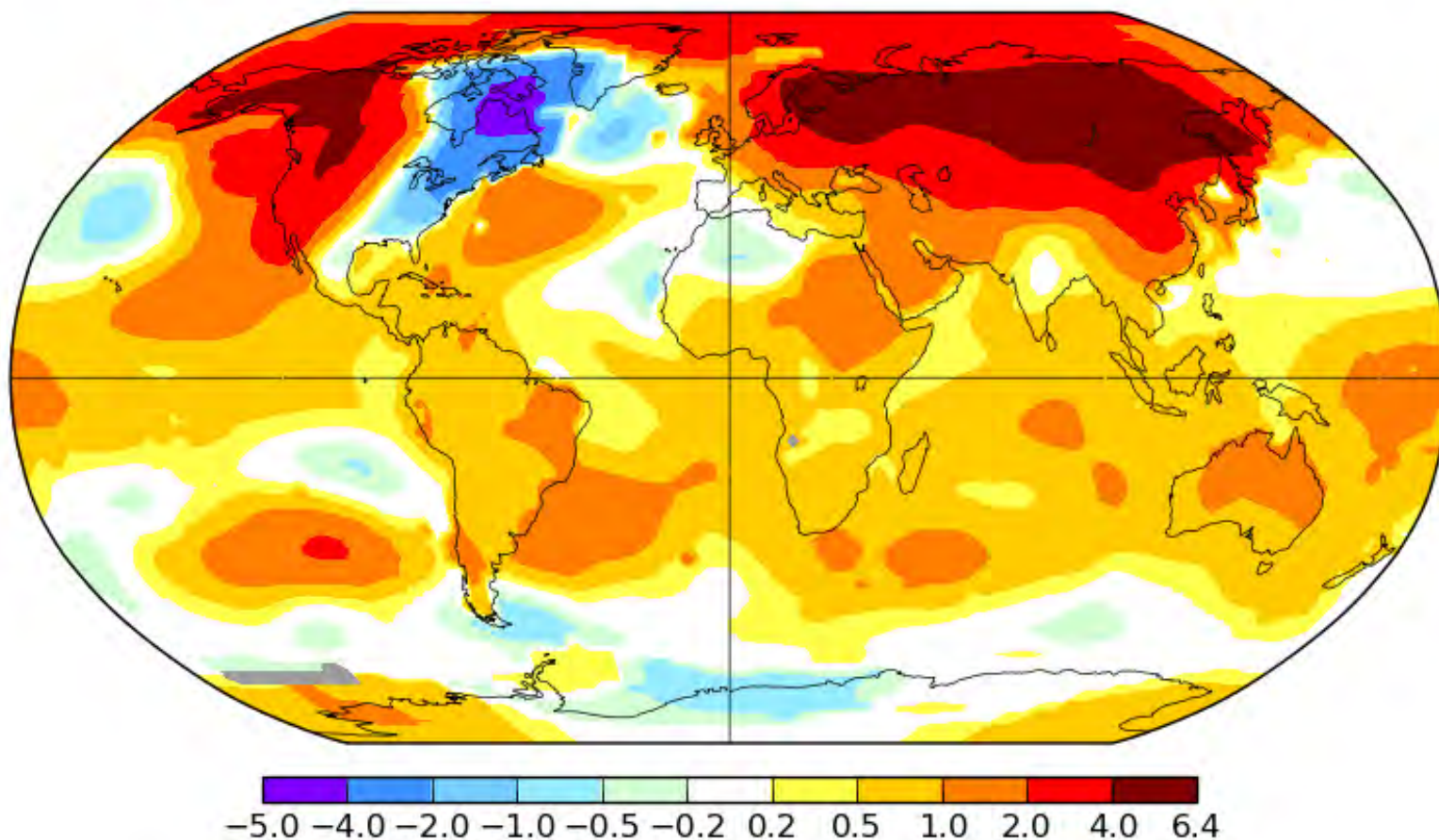


# Jan-Feb-Mar 2015

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86

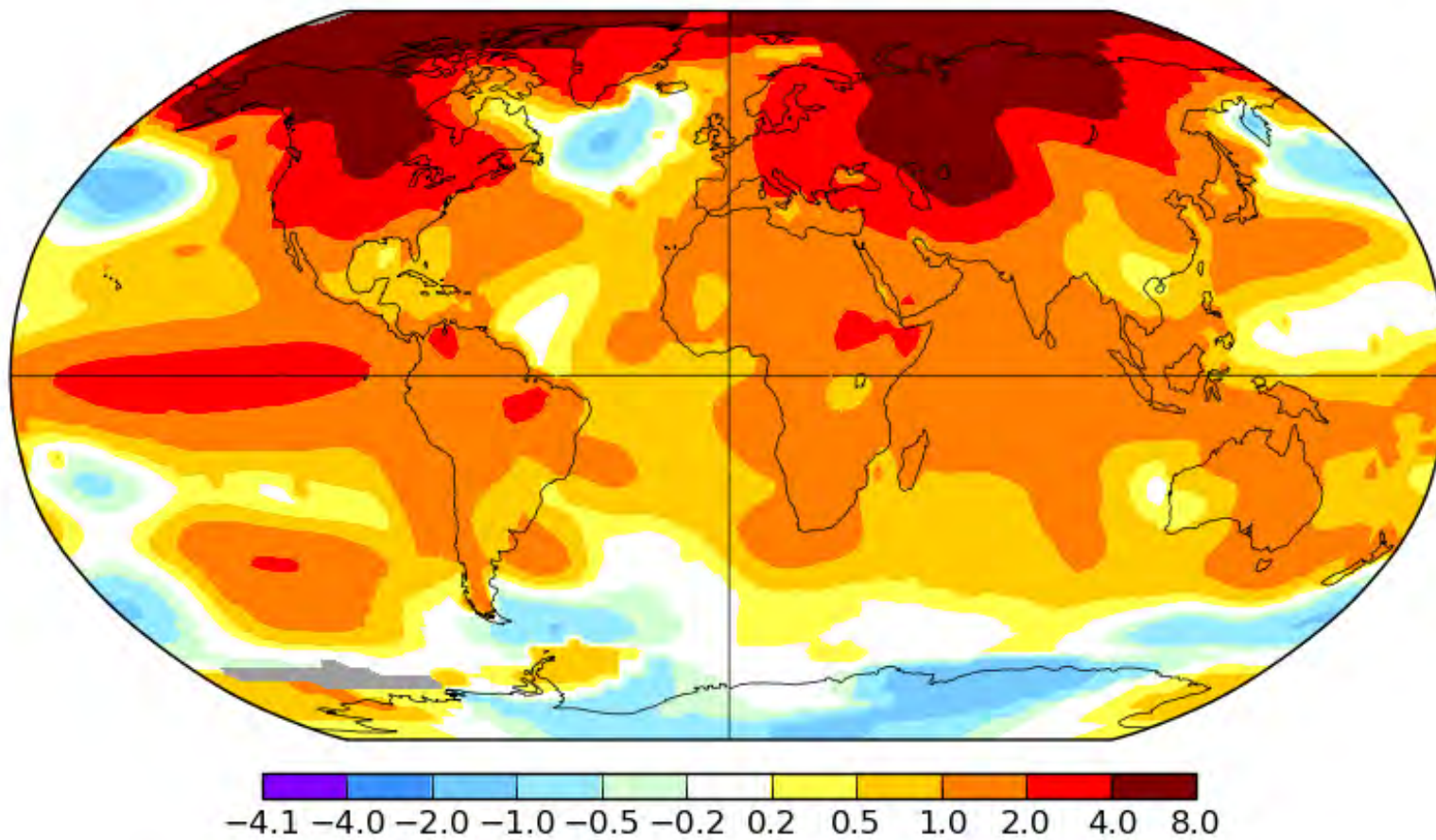


# Jan-Feb-Mar 2016

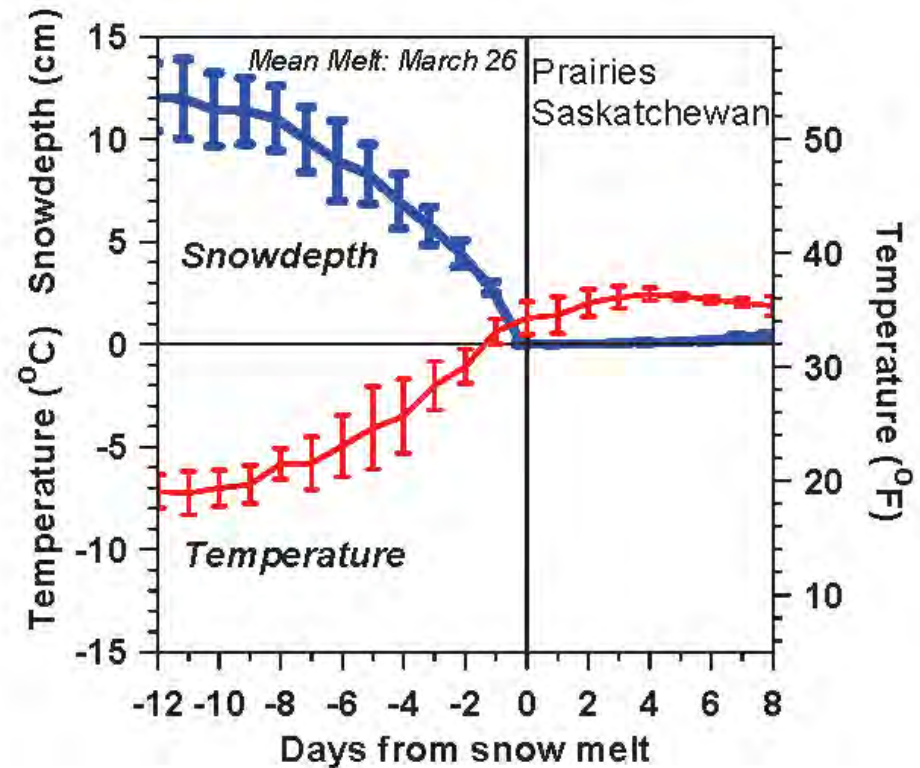
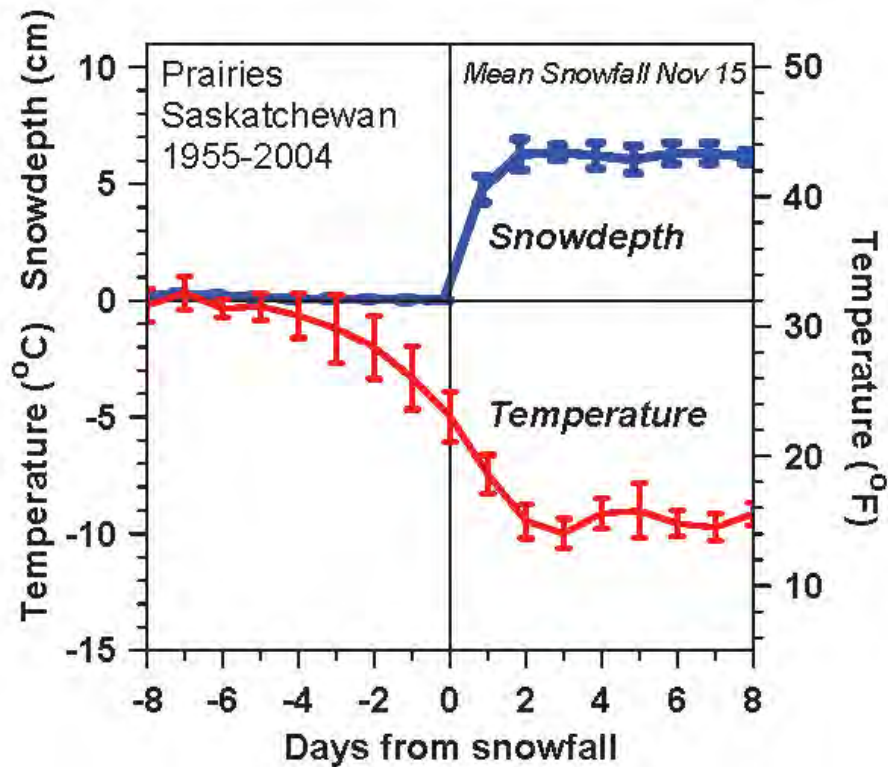
Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24



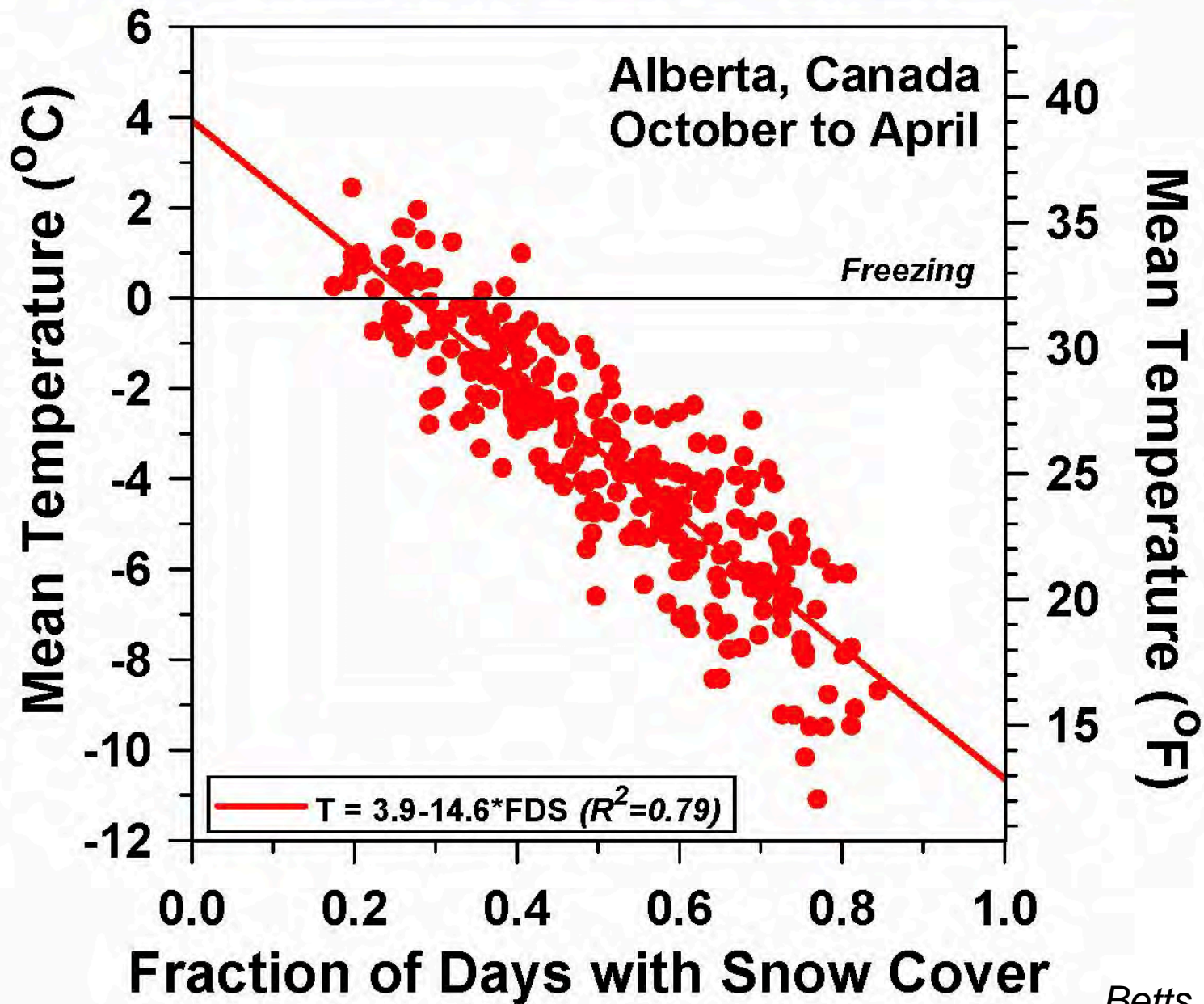
# Snowfall and Snowmelt



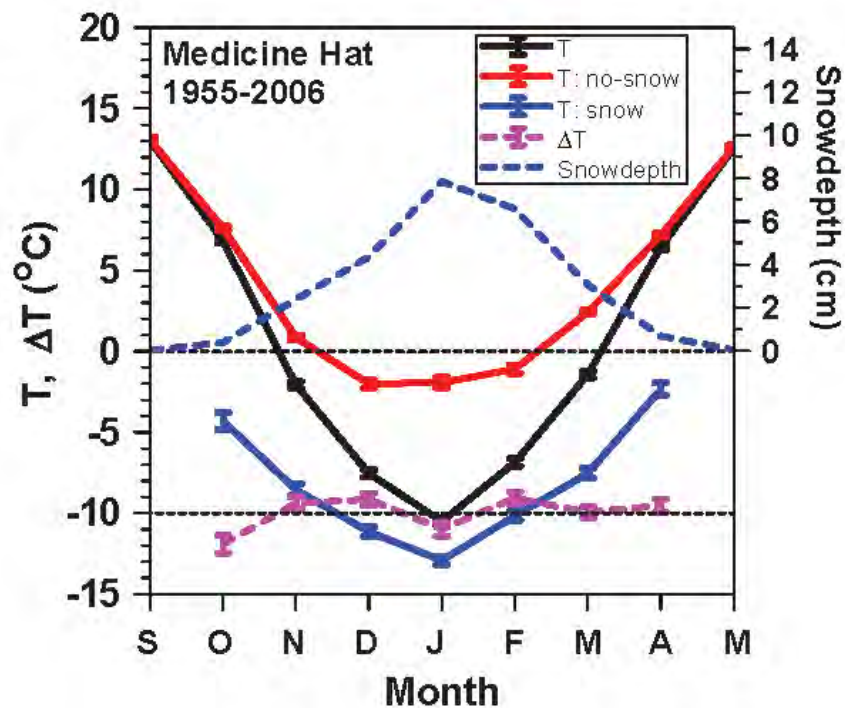
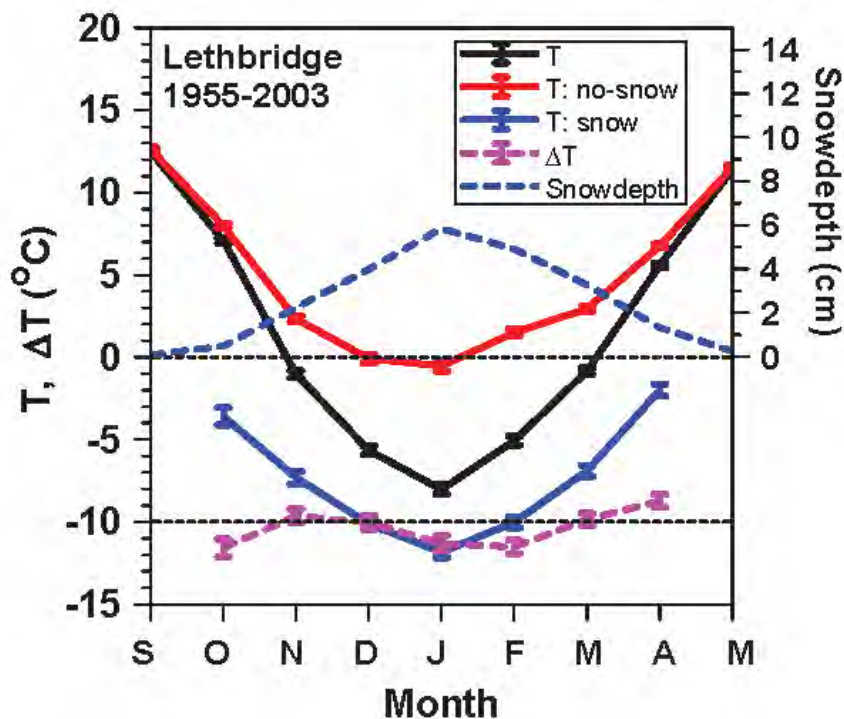
- Temperature changes 10°C with snow cover
- Snow cover is a 'climate switch'
- *Fast transitions in 'local climate'*
  - *Snow reflects sunlight*
  - *Reduces evaporation and water vapor greenhouse*



## More snow cover - Colder temperatures



# Impact of Snow on Climate

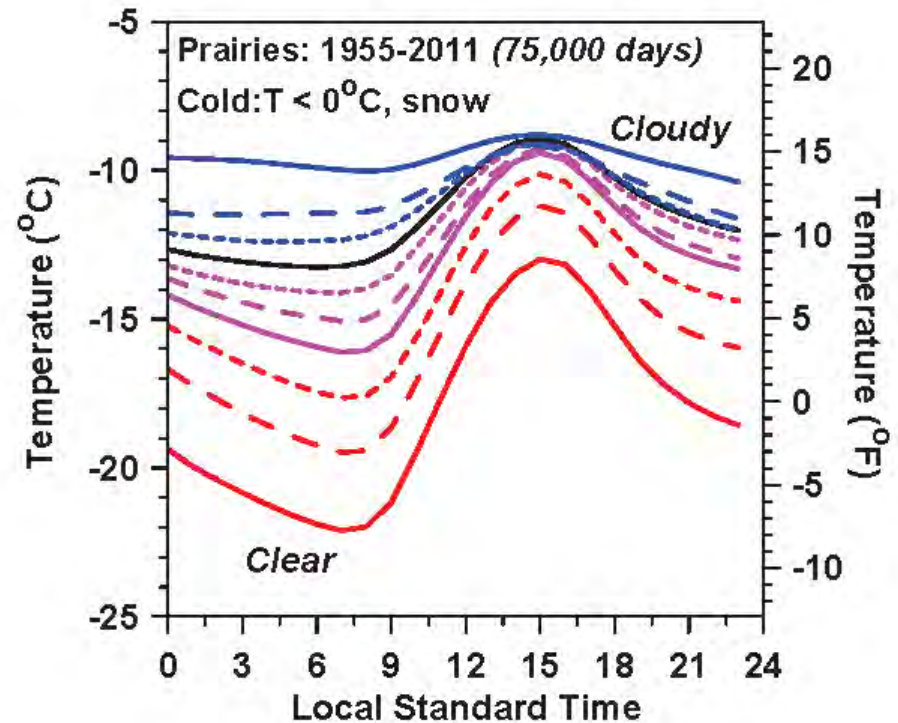
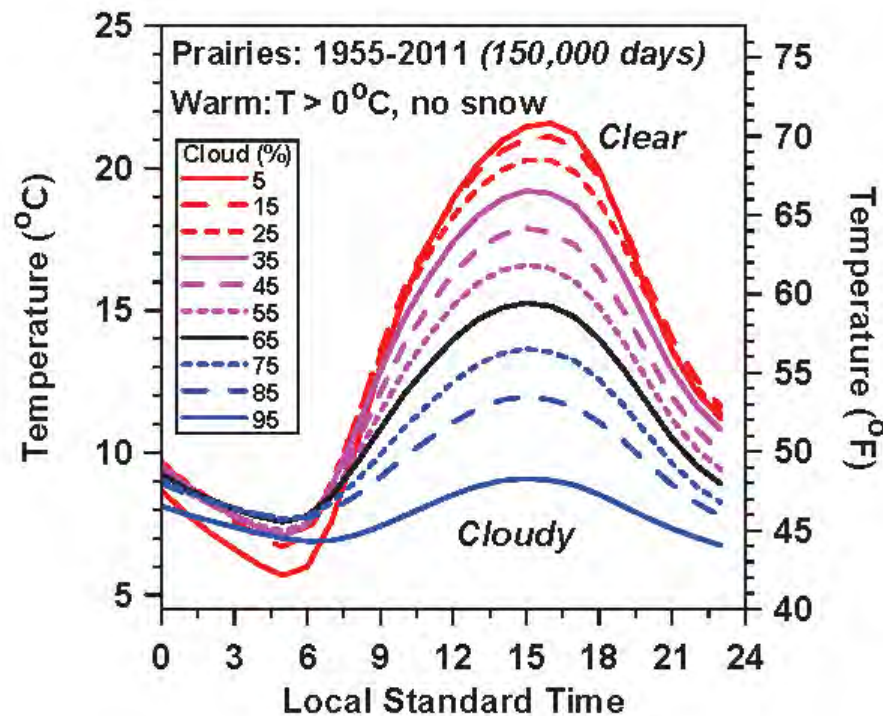


Separate mean climatology into days  
with no-snow and snowdepth >0

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



# Clouds, Snow and Climate



- **Above freezing:** Opaque clouds reflect sunlight
  - Less cloud, much warmer in afternoon
- **Below freezing:** Clouds are greenhouse
  - Snow reflects sun
  - Less cloud, temperatures fall at night, very cold at sunrise

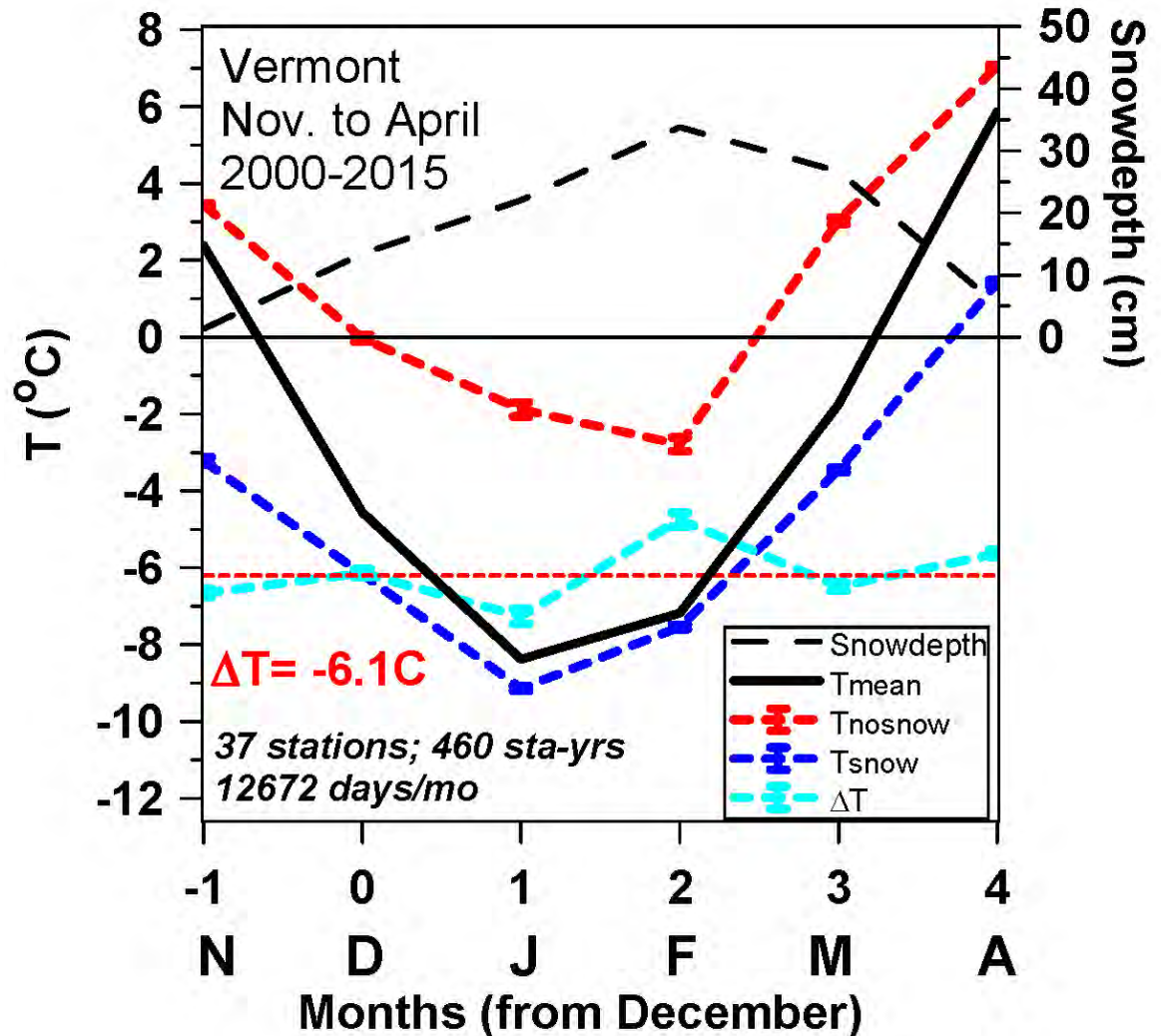
# Climatological Impact of Snow: Vermont

Separate mean climatology into days with no-snow and with snow

Difference  $\Delta T = -6.1(\pm 0.7)^{\circ}\text{C}$

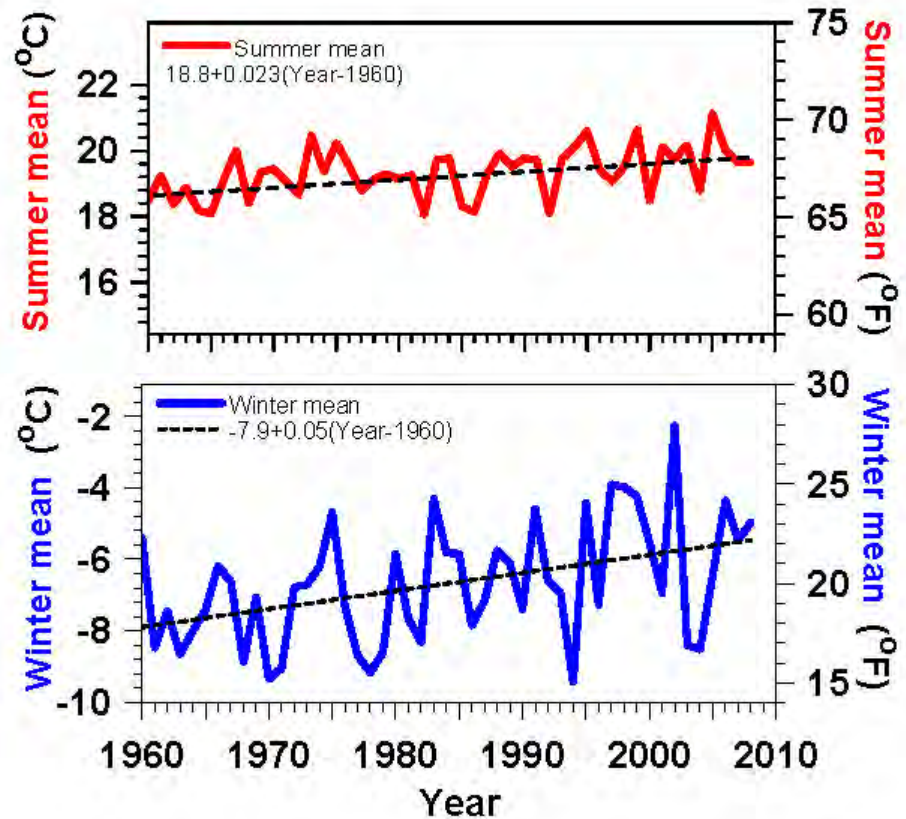
$= -11 (\pm 1.3)^{\circ}\text{F}$

*Less than Prairies:  
Vermont has more forest*



# 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***



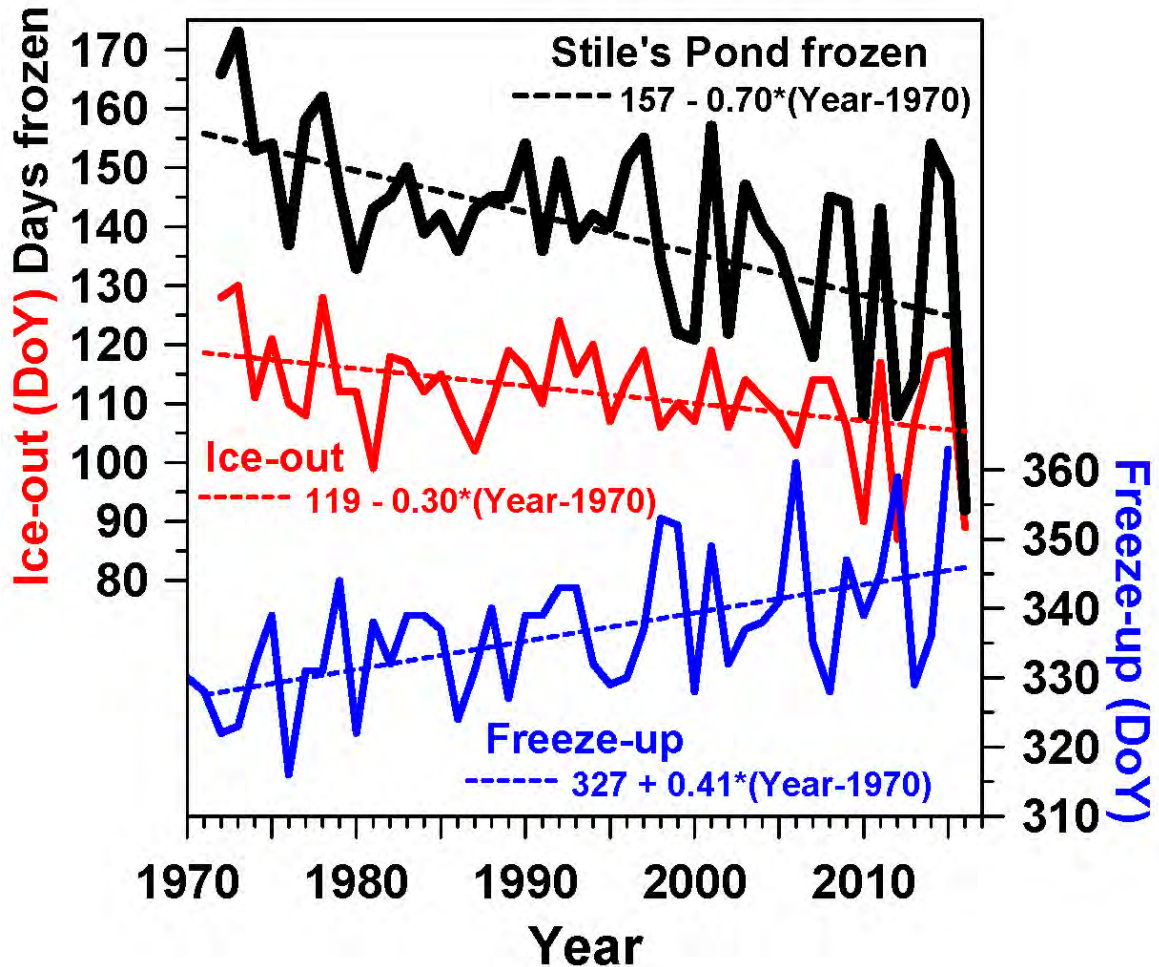


# Lake Freeze-up & Ice-out Changing

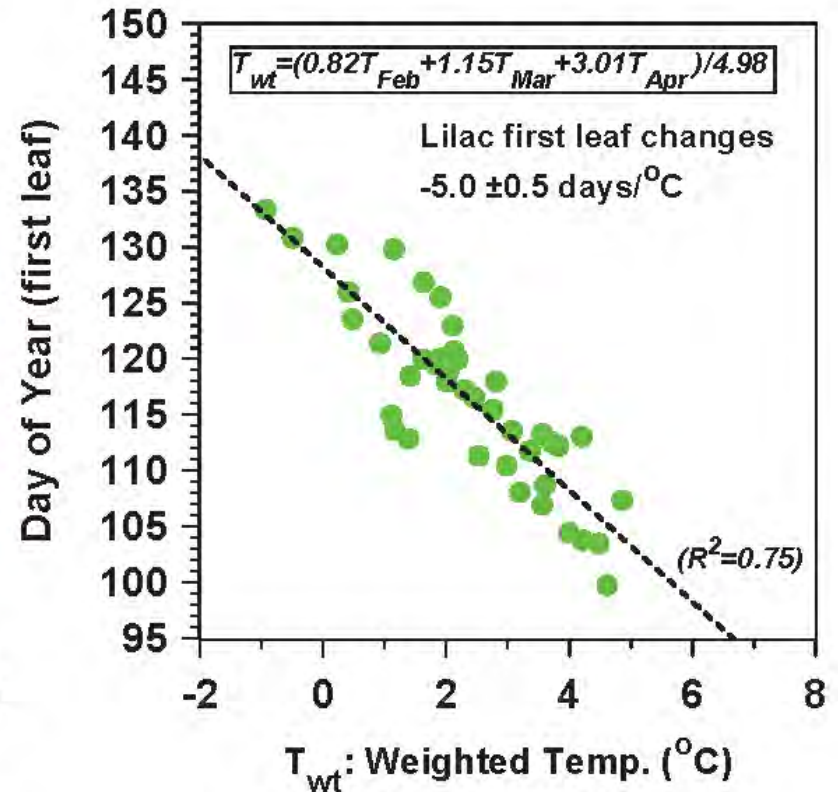
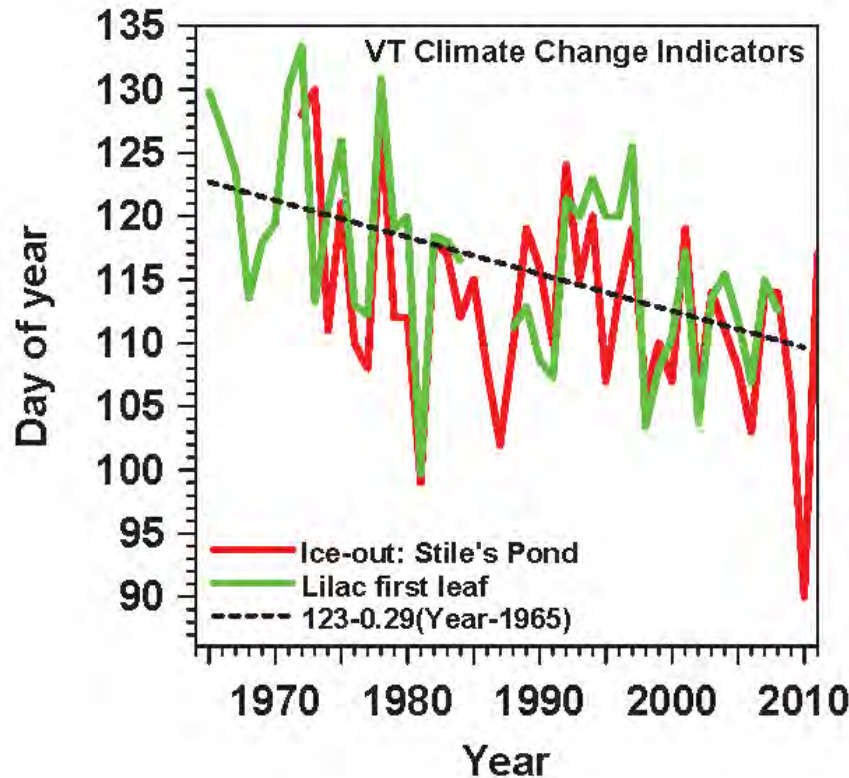
## Frozen Period Shrinking: variability huge

### STILES POND

- Ice-out earlier
  - by -3 days / decade
- Freeze-up later
  - by +4 days / decade
- Lake frozen trend
  - - 7 days/decade

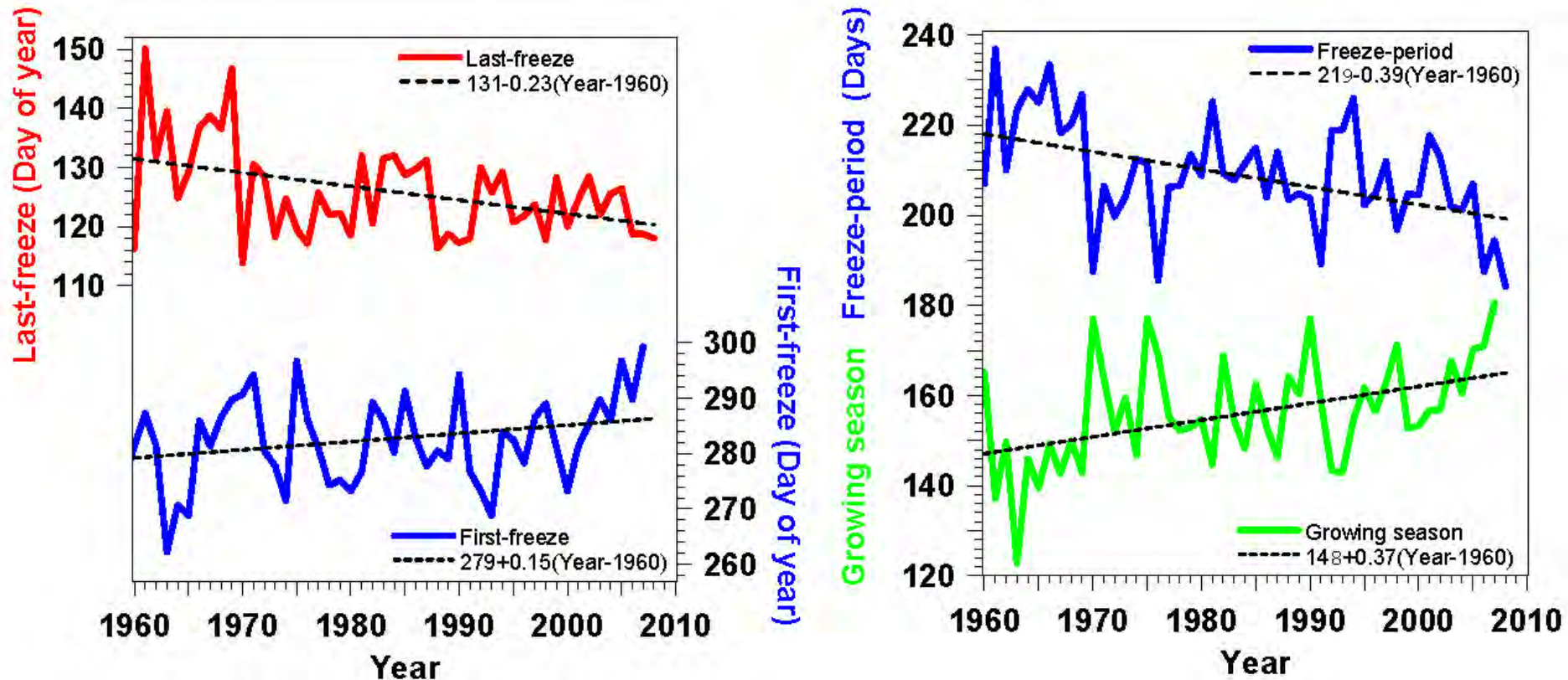


# Lilac First Leaf Earlier



- First leaf and ice-out changing: -3 days/decade
- Large variability linked to temperature: -5 days/  $^{\circ}\text{C}$
- (No-snow – Snow) winter =  $6 \times 5 \approx -30$  days earlier leaf-out

# First and Last Frosts Changing



- Growing season for frost-sensitive plants increasing **3.7 days / decade**
- A help for growing “local food”





**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**

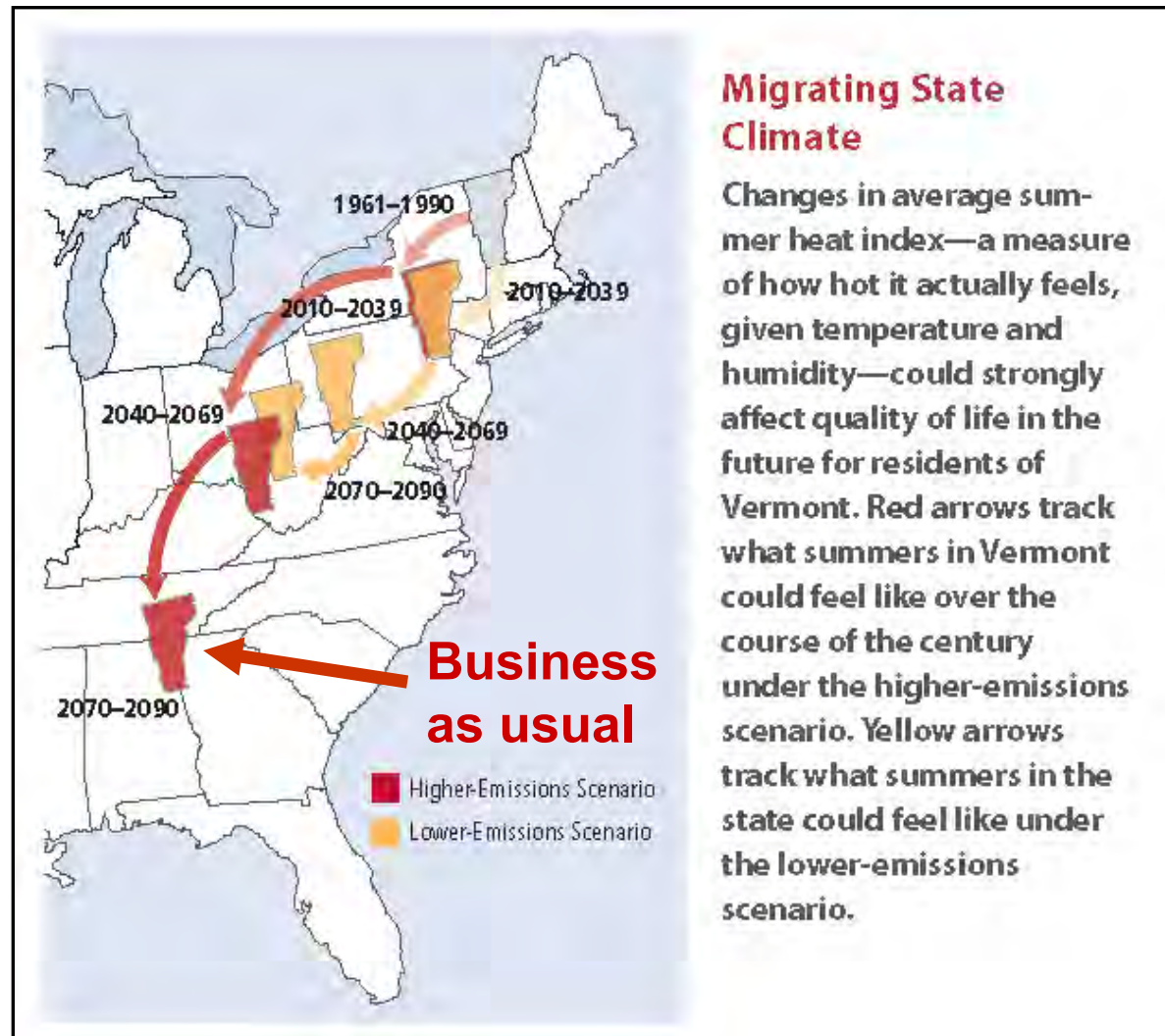




# Vermont's Future with High and Low GHG Emissions

What  
about VT  
forests?

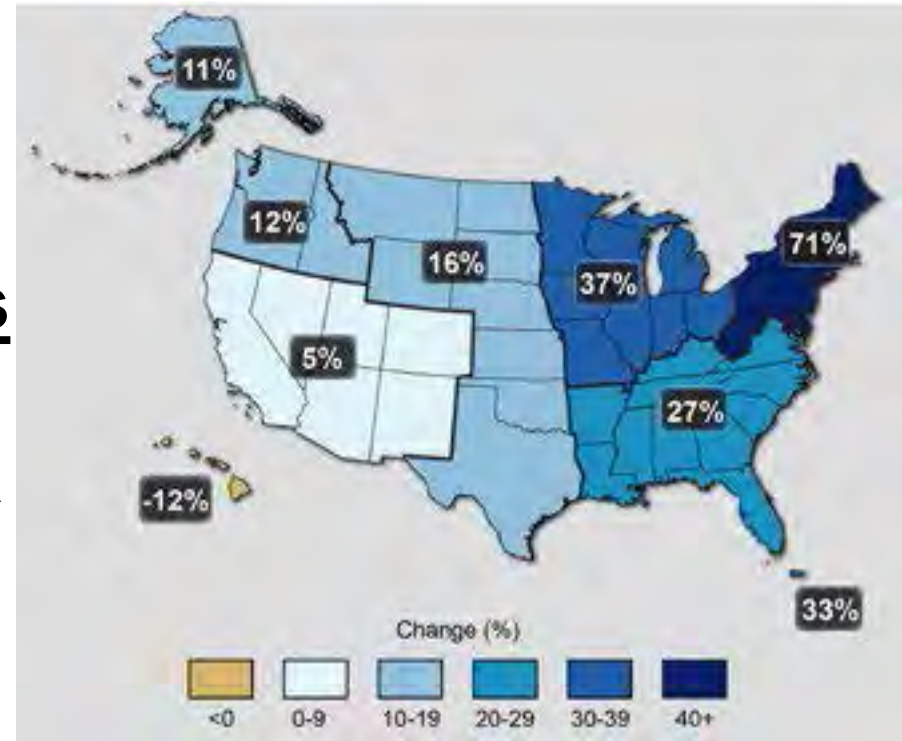
Sub-tropical  
drought areas  
moving into  
southern US



*NECIA,  
2007*

# 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.
- **71% increase in Northeast**
- *Recent study: abrupt shift in 1996*



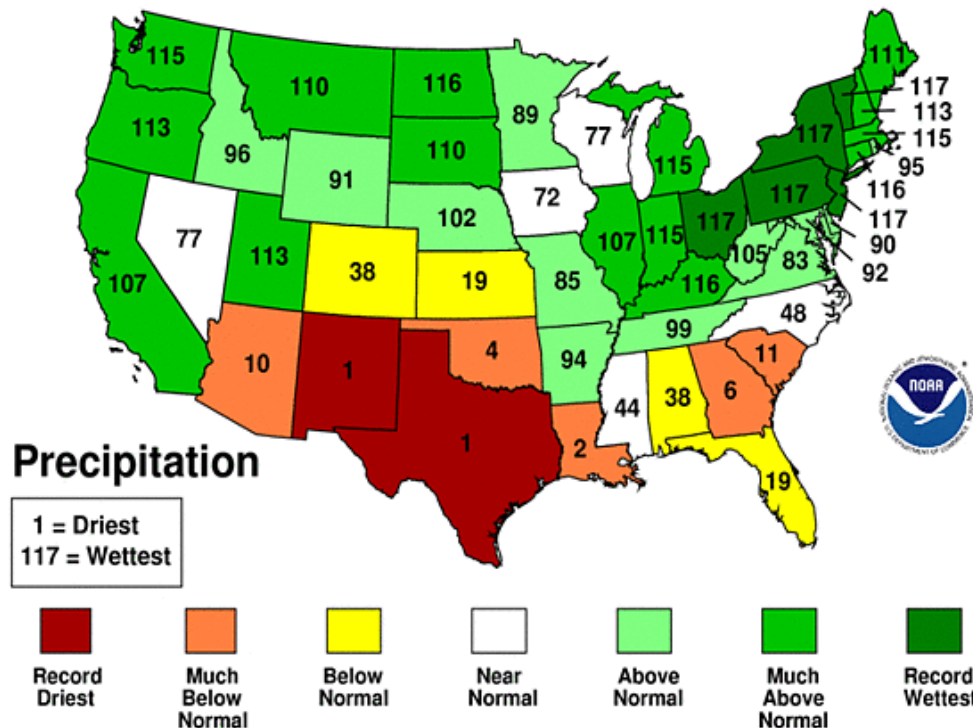
(Walsh et al., 2014)

# 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
- ‘Quasi-stationary’ pattern



# TS Irene

**Roads in valleys**

**Massive damage**

**Some roads took  
months to repair**

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







**Mouth of Connecticut River from Irene  
2011**

**Lake Champlain, Spring 2011, Courtesy LCBP**

# Value of Flood Plains



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



# **Flooding Issues**

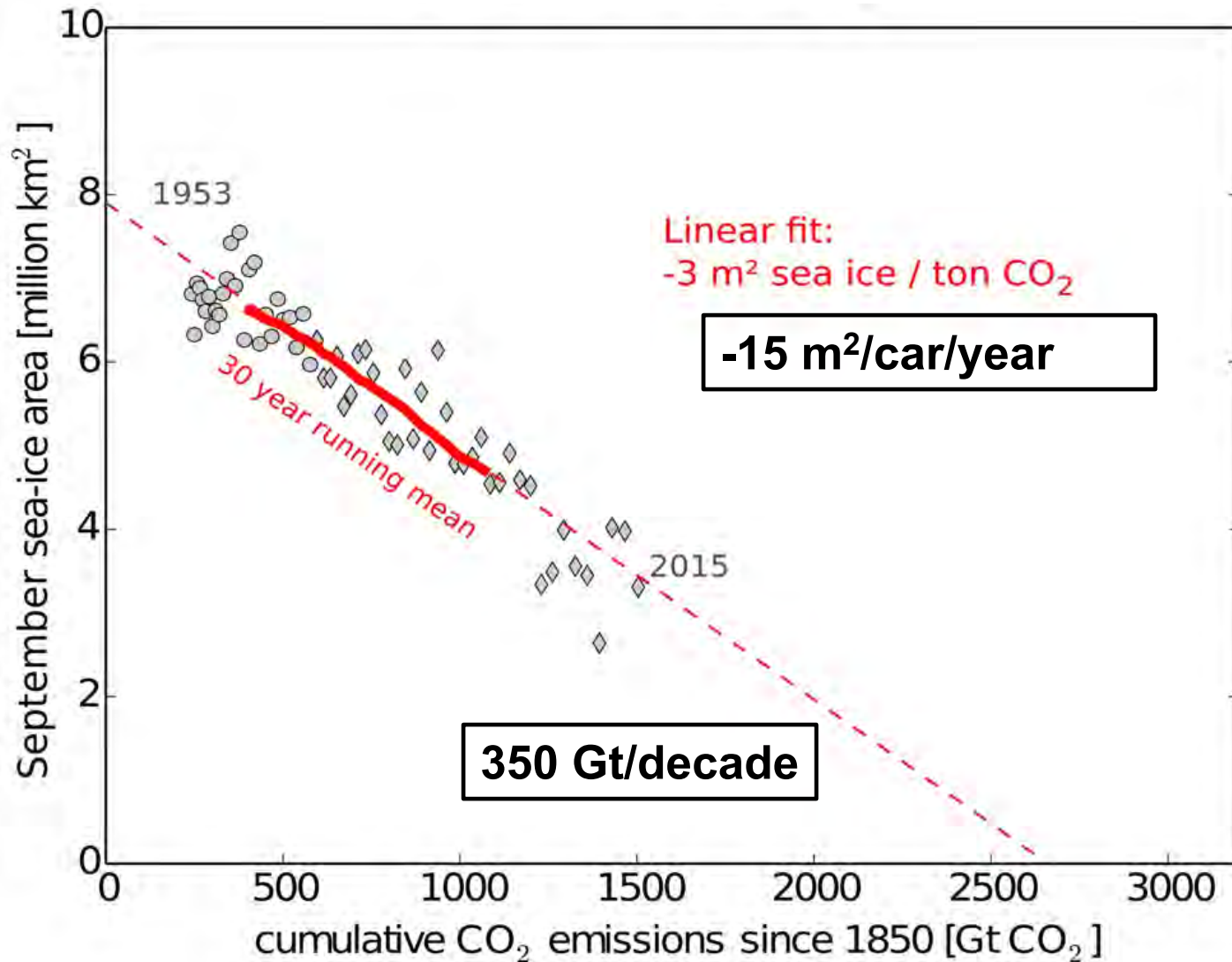
- **Maintain mountain forest cover**
  - Devastating floods in 1920's, 30's with reduced forest cover
- **Manage water/pollutants on landscape**
  - Maximize infiltration: urban and on farms
  - Don't wall-in rivers
- **Preserve flood plains**
  - Saves downstream towns (Middlebury)
  - Stop building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



# September Arctic Sea Ice Loss





# Water, Snow & Ice Give Positive Radiative Feedbacks

- As Earth warms, evaporation and water vapor increase and this is 3X amplifier on CO<sub>2</sub> rise
- As Earth warms, snow & ice decrease and reduced SW reflection amplifies warming in Arctic in summer and mid-latitudes in winter
- Doubling CO<sub>2</sub> 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

# Can We Stop “Dangerous Climate Change”?

(UNFCCC 1992)

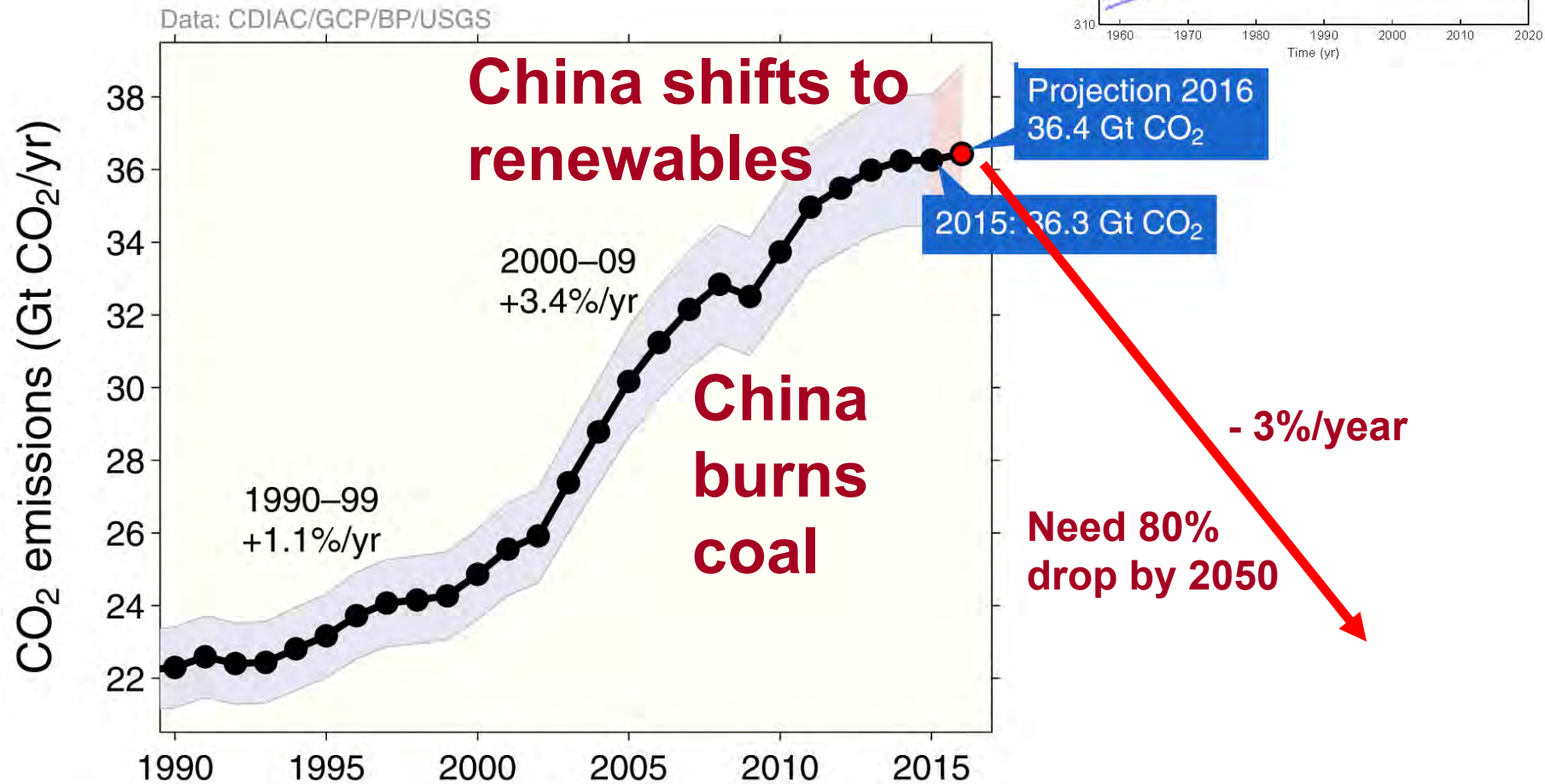
- **Yes:** Quickly stabilize atmospheric CO<sub>2</sub>
- This means an 80% drop in CO<sub>2</sub> emissions!
- **This is possible but very difficult**
  - Fossil fuels have driven our industrial growth and population growth for 200 years
  - “Lifestyle” has become dependent on fossil fuels
  - Powerful 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 CO<sub>2</sub> Emissions Flat for 3 years



# 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*

# System Issues

- Human waste streams are transforming the Earth's climate, and human and natural ecosystems
- How will this affect landscape, water supplies, food system and human health?
- What strategies and mindset are needed to mitigate, adapt and build resilience
  - Can we better manage our relation to the Earth?
  - Is this an efficient way of doing this?
  - Can we manage our waste streams better?
  - How can we adapt?



# **“Systems Engineering” for a Sustainable Society**

- **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**

# 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<sub>2</sub> 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<sub>2</sub> 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!*

# Step back from dark side

- **Cannot be solved with mindset that created it**
  - **Oppose new fossil fuel “solutions”**
  - ***But stand for the Earth and ‘reality’***
- **Push practical solutions**
  - **Efficiency and renewables**
  - **And a fossil-carbon tax**
- **Social, moral, spiritual shift needed**
  - **Your personal role**
  - **Role of community**

# How do we plan/adapt?

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



# Scientific Integrity

- **What are the challenges scientists face?**
  - **Insufficient knowledge to give a balanced accurate assessment**
  - **Social resistance to change**
  - **Political hostility/attempts to silence scientists**
  - **Corruption in the system at many levels**
- **Rapid change over your lifetime**
  - **Scientific, technical and social challenges**
  - **Climate refugees, internal and from overseas**

# What are the Responsibilities of Environmental Scientists?

- **Just do research?**
  - Publish in the usual jargon in copyrighted journals not available to the public?
  - Avoid public discussion and politics?
- **Or accept that with understanding comes responsibility**
  - To the future of society
  - To the Earth

# **Discussion**

**(<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<sub>2</sub> 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*

# ‘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*



# 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**

# Efficient transport

- Gasoline to hybrid: 50% gain to 50mpg
- Hybrid to plug-in hybrid: now 120mpg
- Electricity from community solar array



**>3000lbs and 120 mpg**  
**Payload: 750 lbs at 60 mph**



**180lbs gets “1800 mpg”**  
**Payload: 350lbs at 25mph**

# The Cabal of Libertarian Billionaires

- **Aim: *purchase control of the Republican Party***
  - US Congress (“Freedom Party”); many state legislatures
- **Doctrine: *limited role for government***
  - protect wealth, property and the rule of law
- **Freedom to exploit the earth:**
  - Shall not be limited by environmental regulation
  - *Doctrine in direct conflict with Earth’s ecosystem*
- **Leading to**
  - *Climate science is a (fictitious) conspiracy*

(*Dark Money*, Jane Mayer, 2016)