Understanding Climate Change: Policy and Practical Implications

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Vermont Interfaith Power & Light
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Manchester, VT

My Background as a scientist

- Educated in UK (Univ. of Cambridge, London)
- Weather experiment in Venezuela, 1969.
- Colorado State faculty, 1971-79
- 1970's Worked on tropical field experiments
- 1978: Built VT house, passive solar, solar electricity
- 1979 to present. Independent scientist, funded by NSF, NASA: working on field projects and global forecast models
- 2005: President of Vermont Academy of Science and Engineering – I realized I should help Vermont deal with climate change.

(alanbetts.com)

Fundamentals of Climate Change

- **Burning fossil fuels: increases CO_2, greenhouse gas**
  - **More evaporation increases water vapor, greenhouse gas**
  - **Heading for high CO_2 "Carboniferous era climate"**
  - **Earth warming: <u>90% of heat stored in oceans</u>**
  - **Climate extremes increasing**
  - **Decadal to centennial - long timescales**
- **Linked to unmanaged technology/waste streams**
  - **Soluble by changing <u>system guidelines</u>**
  - **Create efficient society, based on renewable energy**
  - **Technology and economics need moral guidance**
- ***Vermont's climate is changing***
  - ***Less severe winters (but extremes increasing)***

This Talk

- Our challenges; our responsibilities
- Hurricanes Irma and Maria in the Caribbean
- The climate of winter
- Global and local climate change
- Flooding issues
- Can we stop “dangerous climate change”?
- Mitigation and adaptation?
- What are some practical steps?

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Our Present Challenge

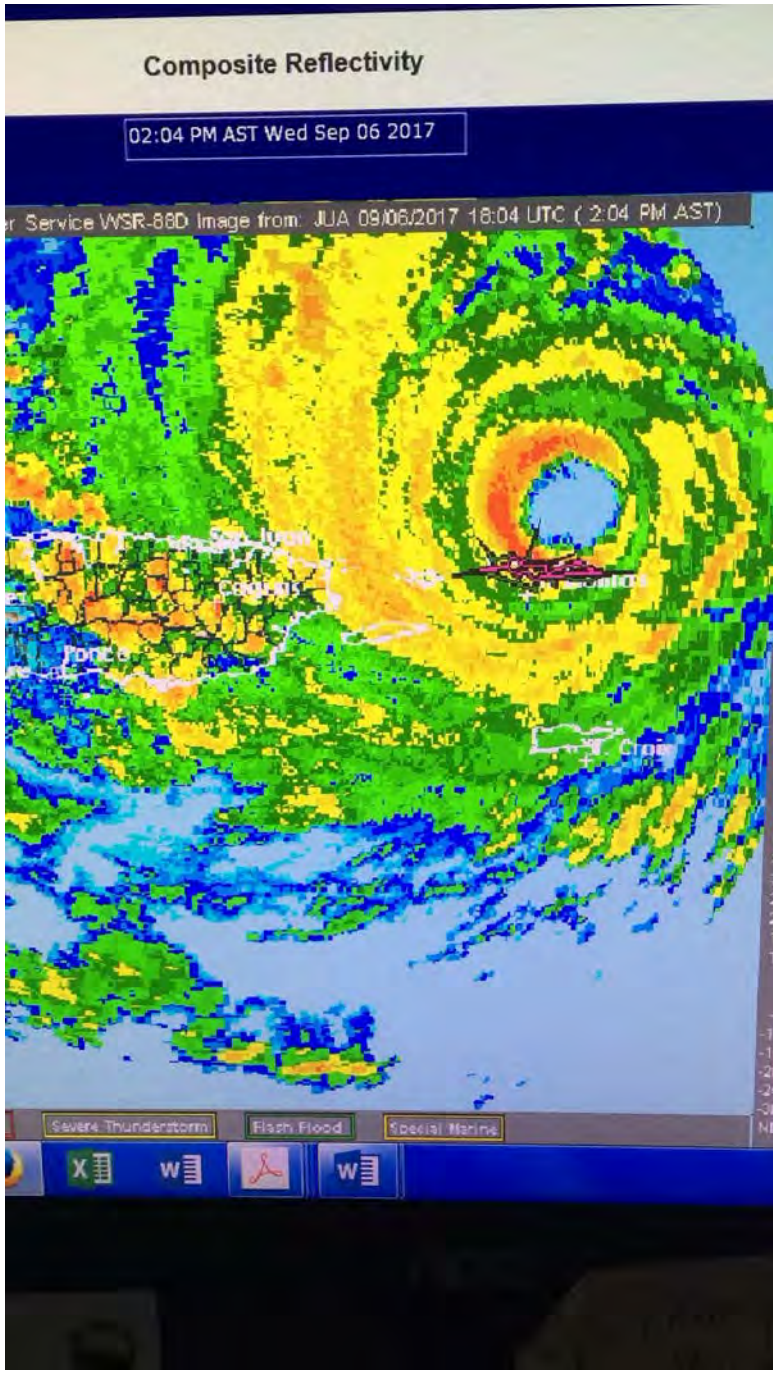
- **How to integrate all that we know, understand and value**
  - ***given the deep interconnectedness of life & climate on Earth***
  - ***given immense opposition and fear of change***

Hurricane season: 2017

- **Earth cannot cool as fast to space because of increasing greenhouse gases**
- **Oceans are storing 90% of heat**
  - **Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means <u>stronger hurricanes</u>**

2pm Sept. 6
*Category 5**
IRMA
grazing
St Thomas

Cat 5 >155mph
IRMA >180mph



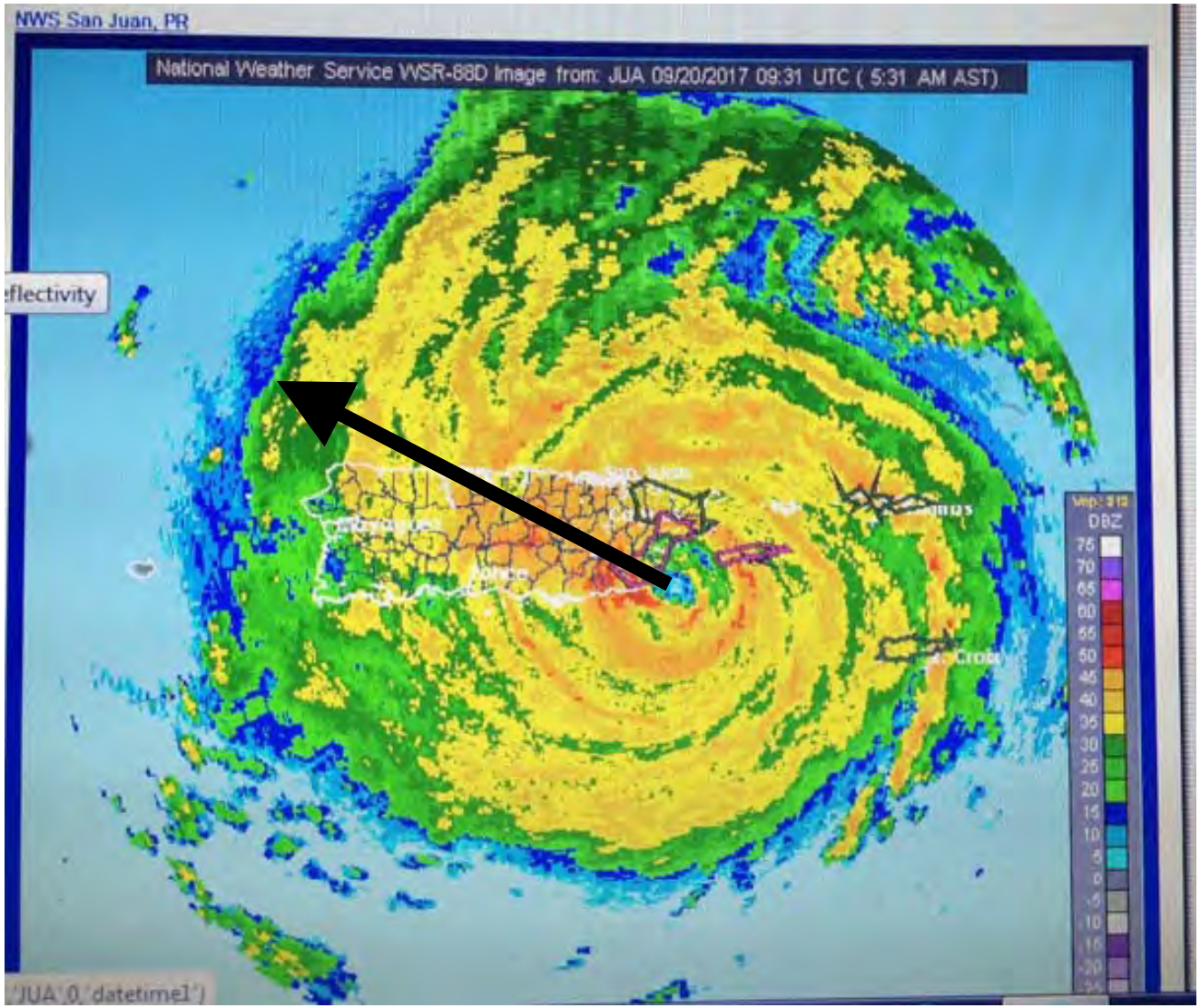
Sept. 6
Irma
(cat.5)
St Thomas

Irma and Jose: Sept 7

After Jose passed; Boat to Puerto Rico on Sept 11

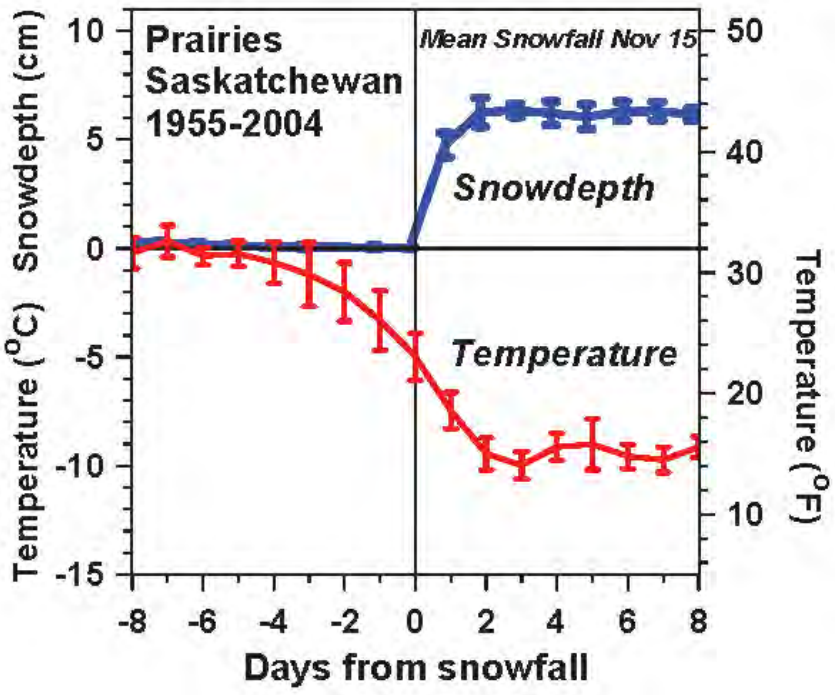
Maria: 5:30am Sept. 20
Category 4 hits Puerto Rico

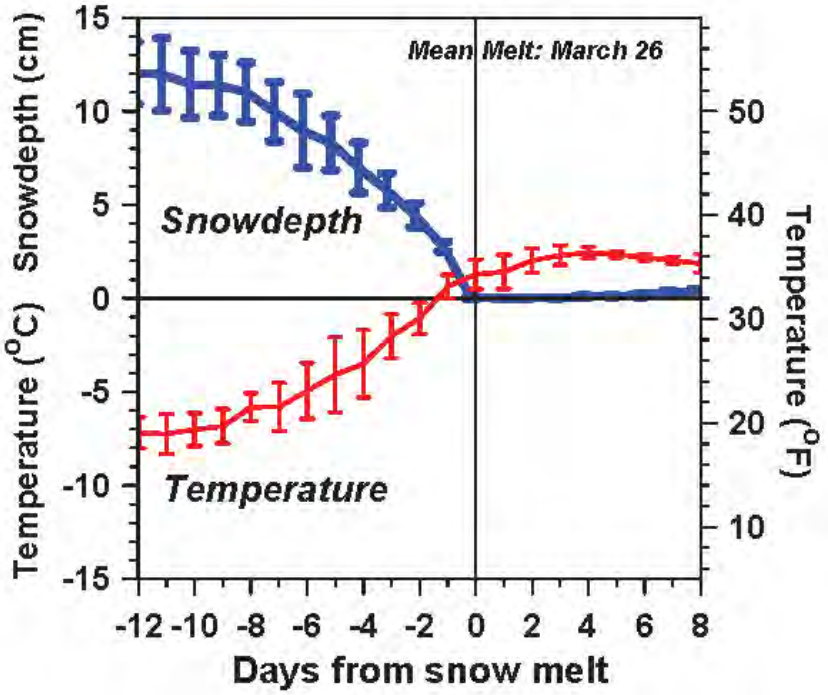
Cat 4
>130mph
Maria
>150mph



Winter

Snowfall and Snowmelt

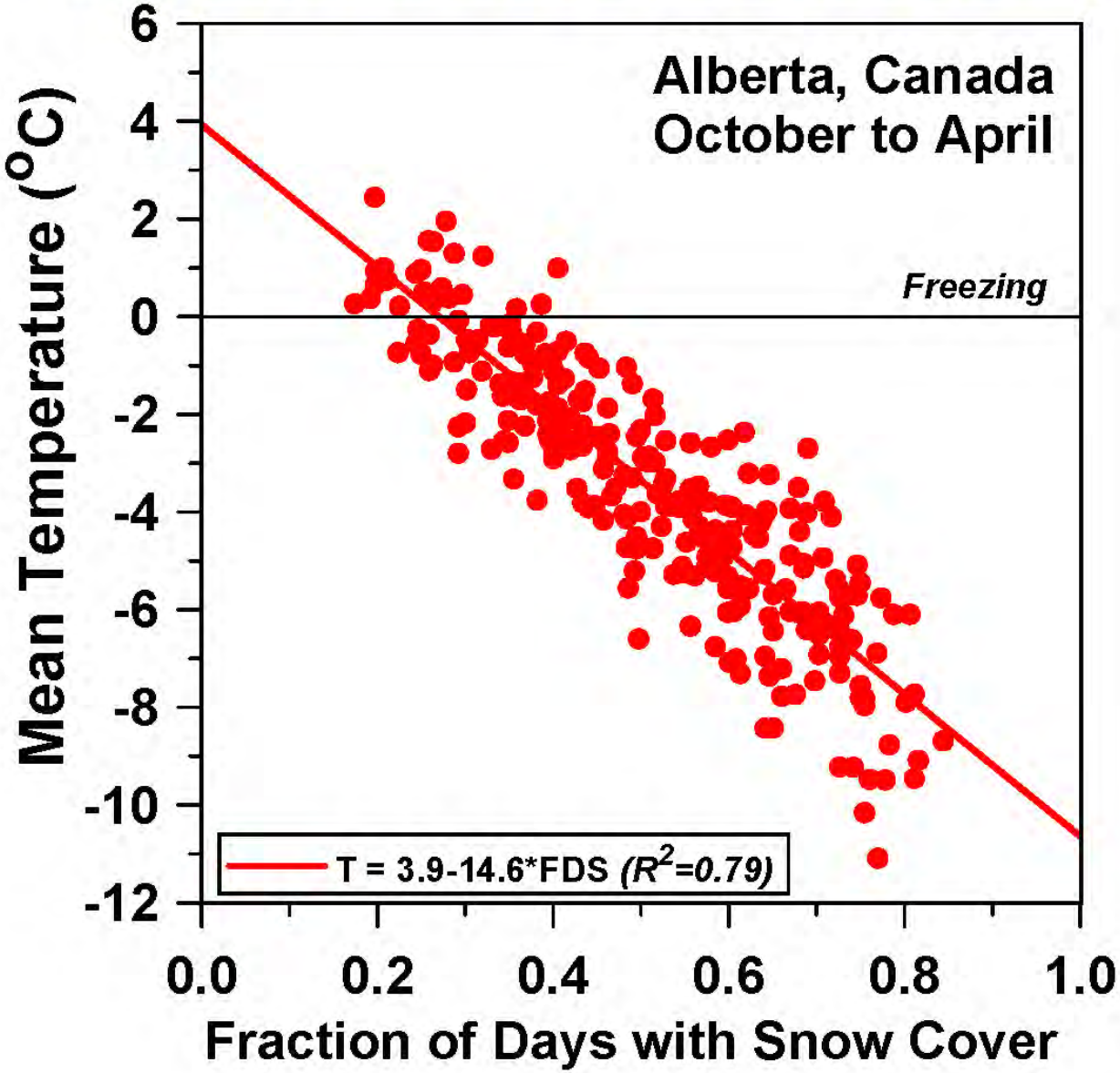




- **Temperature falls/rises about 10C/18F with first snowfall/snowmelt**
- ***Snow reflects sunlight; shift to cold stable BL***
  - ***Local climate switch between warm and cold seasons***
  - ***Winter comes fast with snow***

(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 <u>"climate switch"</u>**

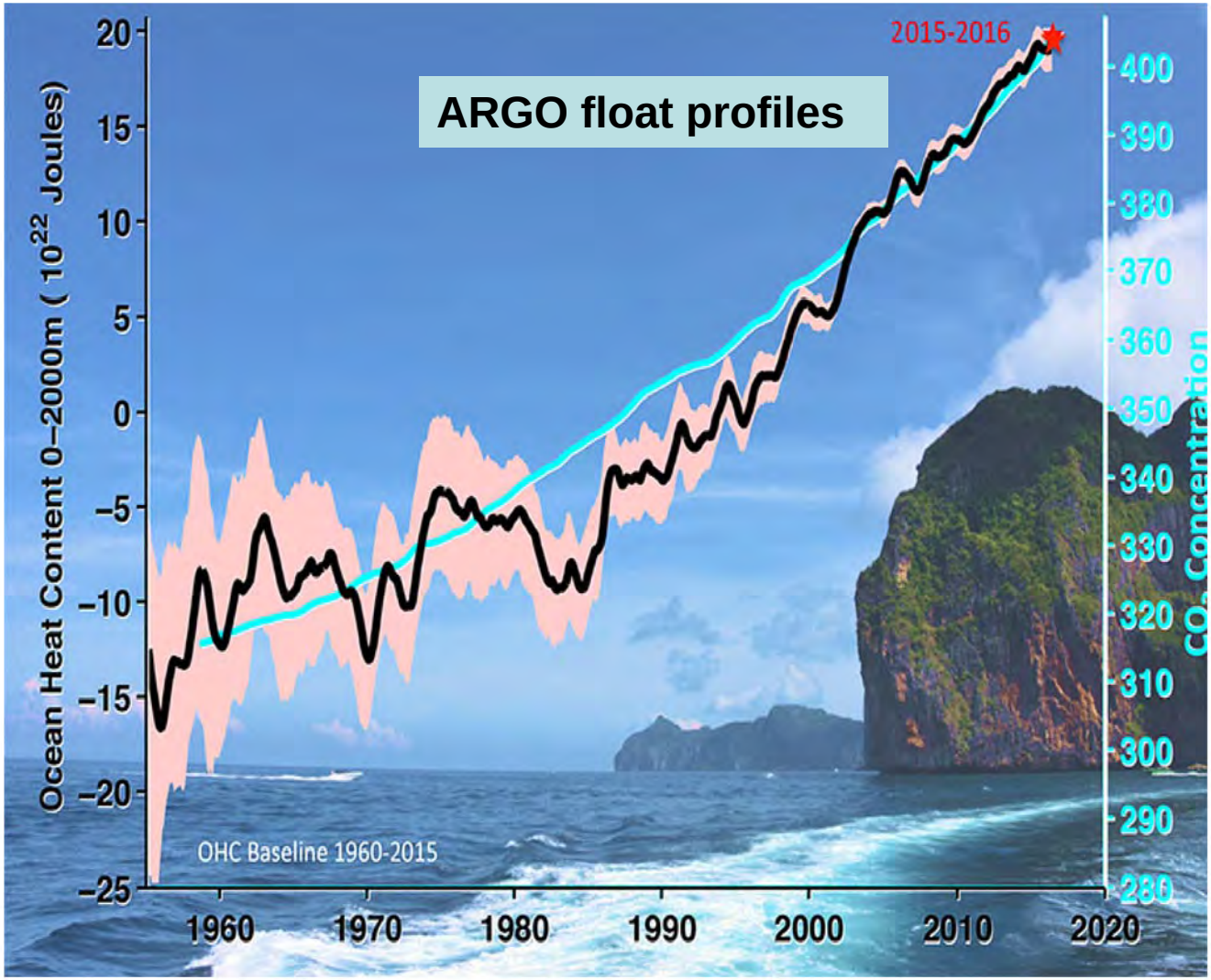
With snow

- **<u>Prairies:</u> Temperature falls 18ºF**
  - **snow reflects 70%**
- **<u>Vermont:</u> Temperature falls 10ºF**
  - **snow reflects 35% (because more forest)**

Earth's climate sustains life

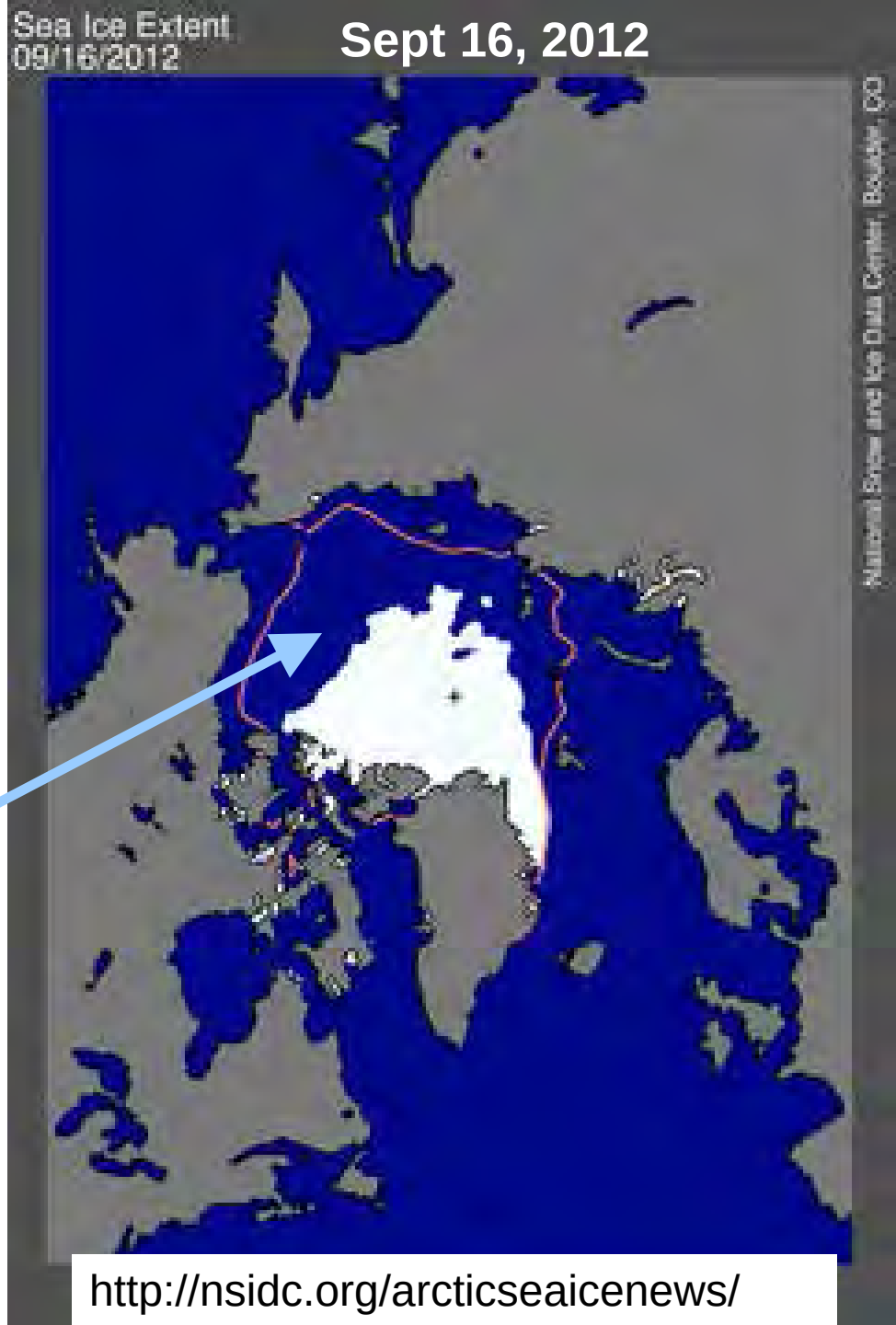
- Burning fossil fuels is increasing greenhouse gases
- LW cooling to space reduced
- Climate is warming: ice is melting, oceans warming, extreme weather is increasing
- Water plays crucial amplifying role
- Global patterns changing

Ocean Heat Storage – CO_2

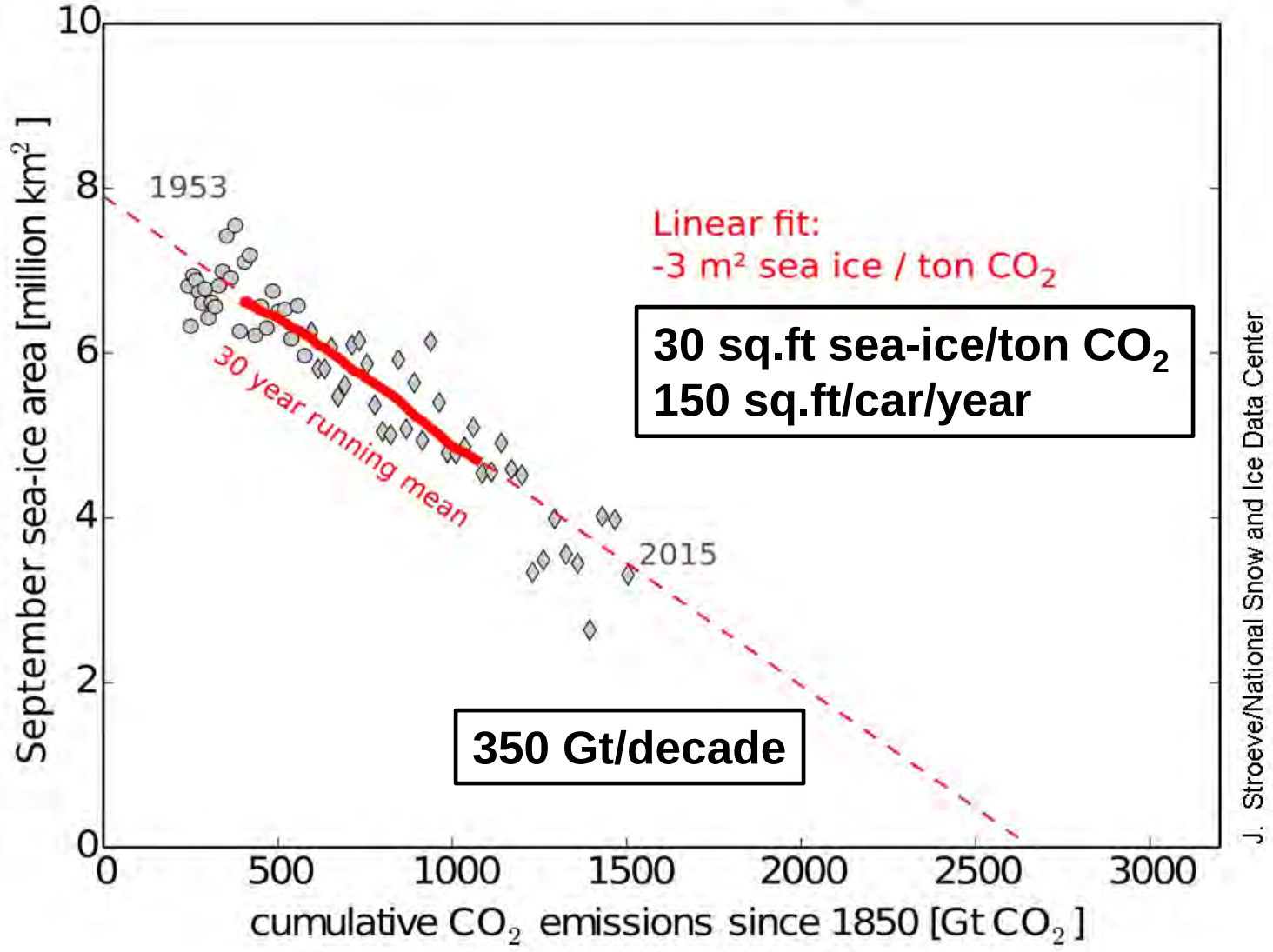


- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

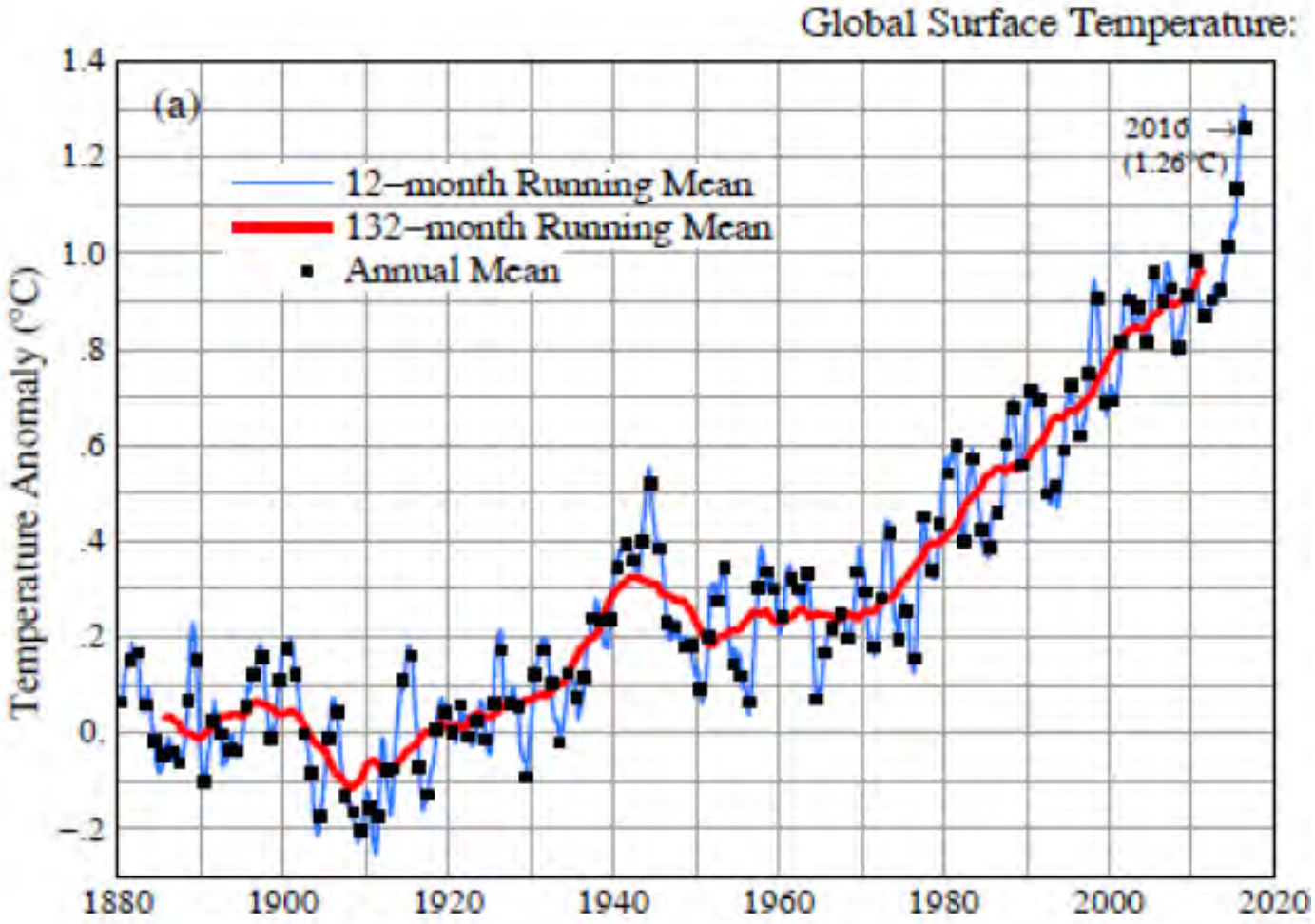
- ***Feedbacks amplify:***
- ***Less ice, less reflection of sunlight: warming***
- ***More evaporation, larger vapor greenhouse effect***
- ***More sunlight, reduced cooling: Earth warms***
- ***Same feedbacks as in our winters***



September Arctic Sea Ice Loss



Long-term Global Mean Trend 1880-2016

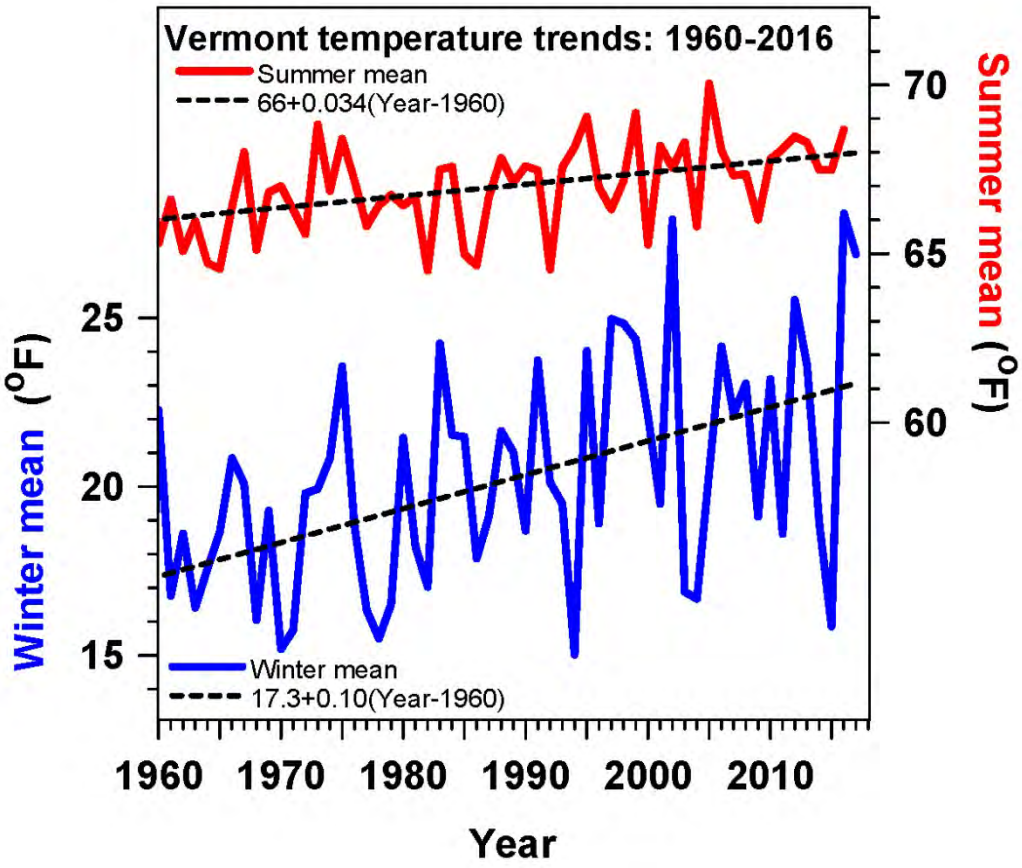


Vermont Temperature Trends 1961-2008

- **Summer +0.34°F/decade**

- **Winter +1.0°F/decade**
- **Larger variability, larger trend**

- ***Less snow (& more water vapor) drive larger winter warming***



Gardening in Pittsford, Vermont in January

January 7, 2007

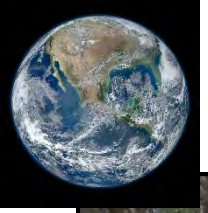
December 2006:

- **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**

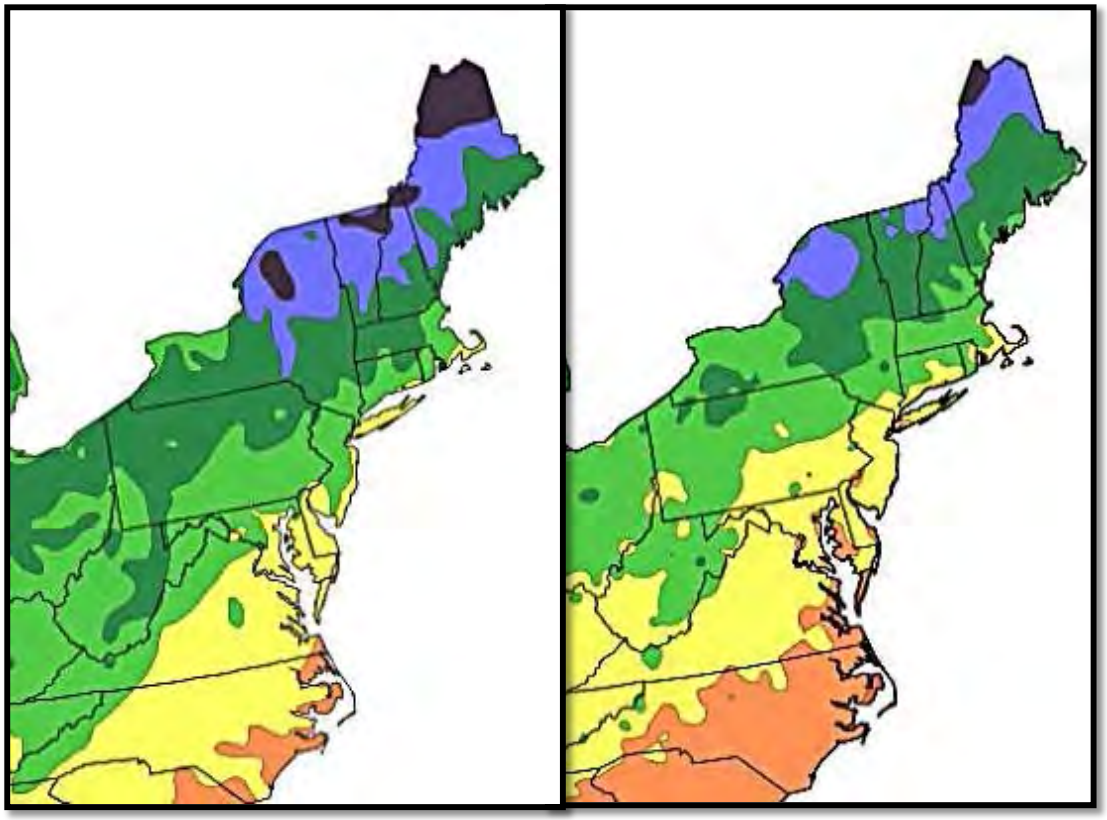
- **January 15, 2013**

February 5, 2016
(Digging in Feb. first time ever)

Over-winter: March 3, 2017

Winter Hardiness Zones

– *winter cold extremes*



1990 **2015**

Zone

2 3 4 5 6 7 8 9 10

Minimum winter T

4: -30 to -20ºF

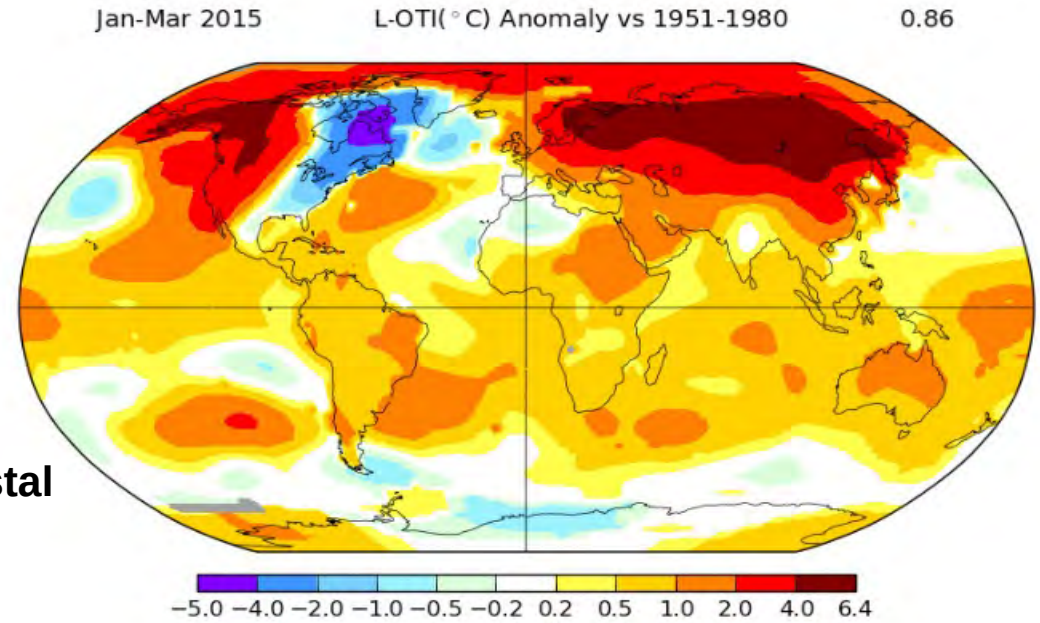
5: -20 to -10ºF

6: -10 to 0ºF

One Zone in 25 years

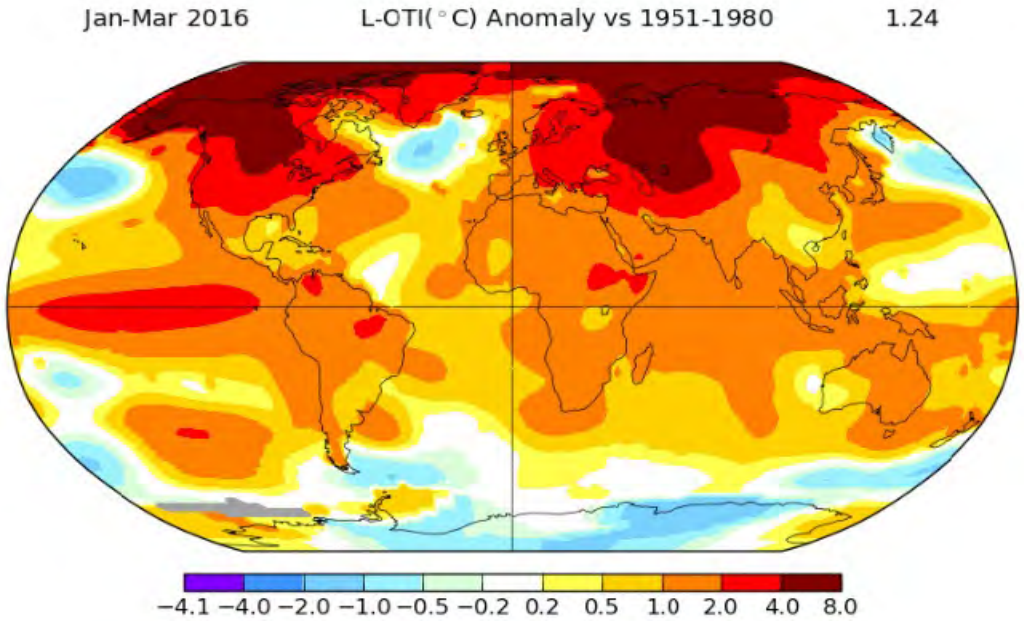
Jan-Feb-Mar 2015

Warm Atlantic, cold NE, strong coastal storms - <u>Boston record snow</u>



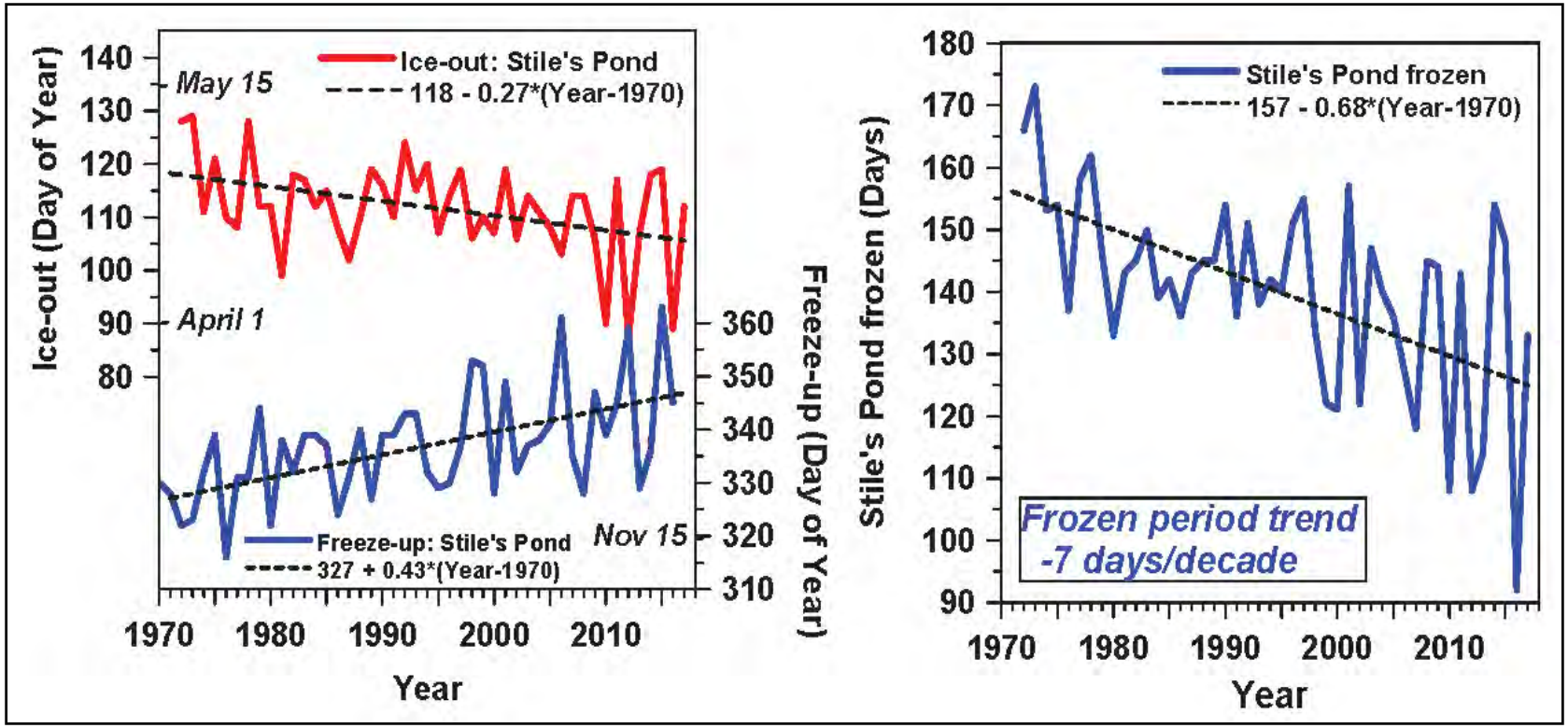
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking: variability huge



- **Freeze-up later by +4 days / decade**
- **Ice-out earlier by -3 days / decade**
- **<u>Lake frozen period trend</u> <u>- 7 days/decade</u>**

Stiles Pond: "Eye on the Sky"

Warm winter with little snow

Early Spring: *79ºF on March 22, 2012*

Pittsford Vermont

3/22/12

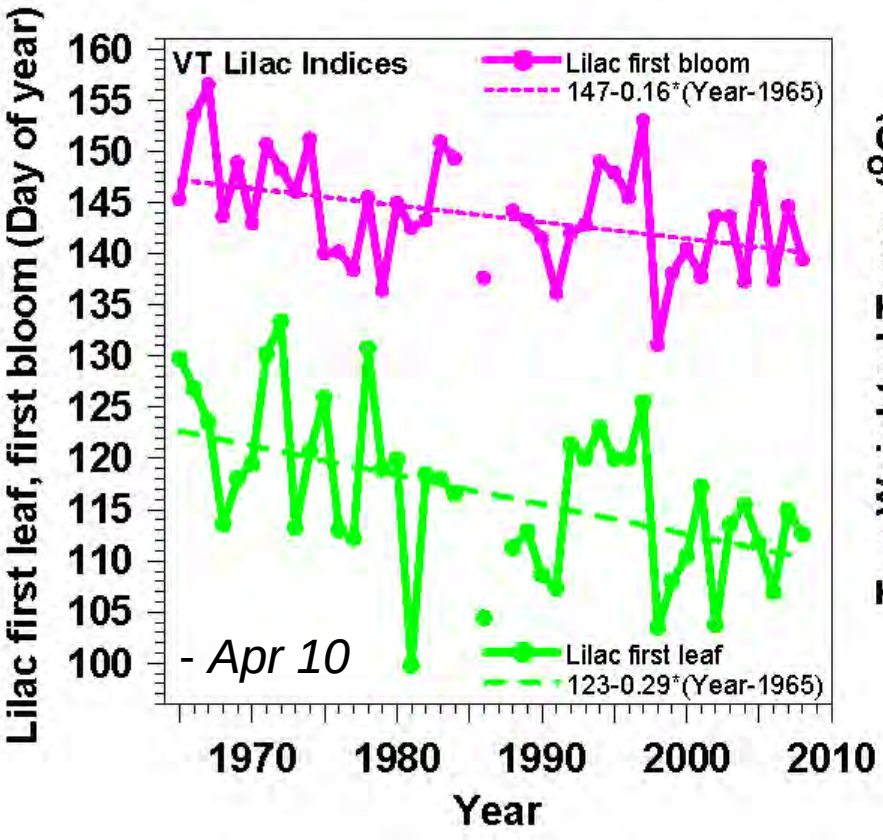
Pittsford Vermont

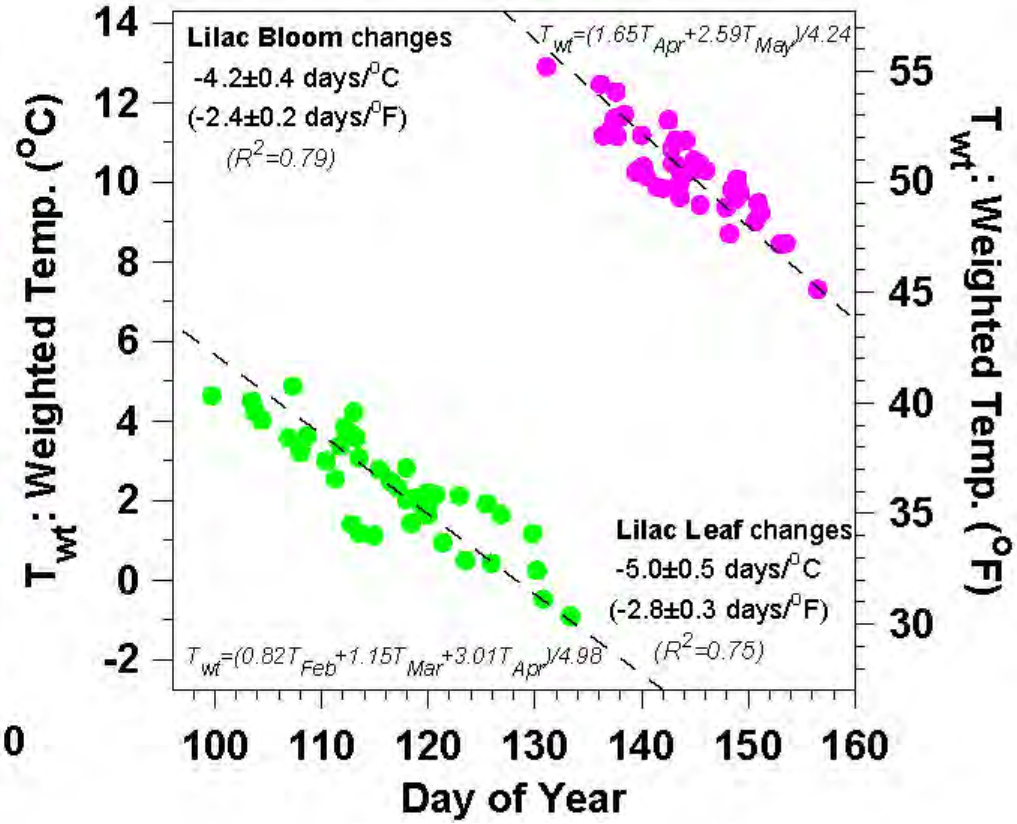
3/24/12

2012: Daffodils, forsythia bloomed 3/23/2012

2017: Daffodils and forsythia bloomed 4/17/2017

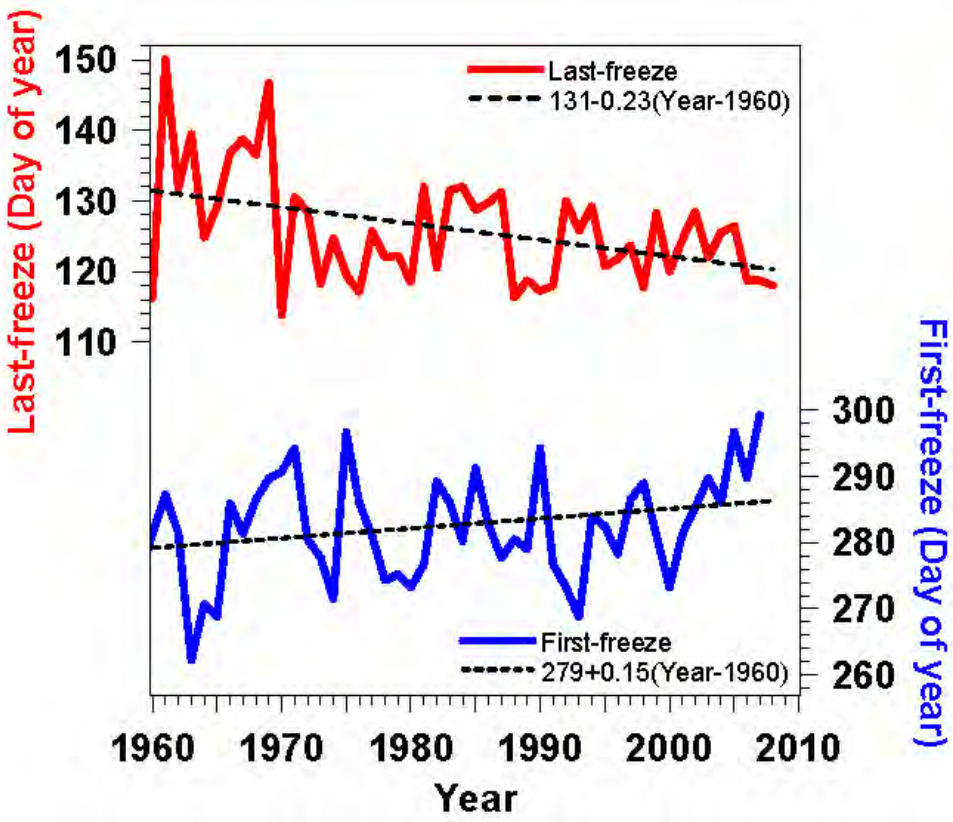
Lilac Leaf and Bloom

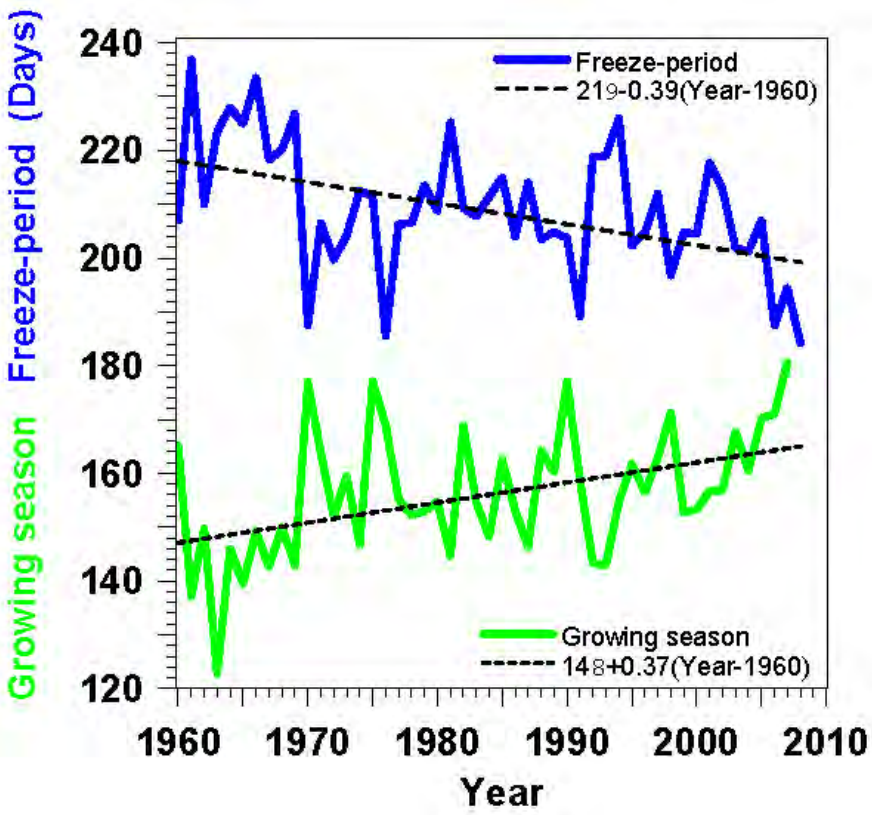




- **Leaf-out -2.9 days/decade; Bloom -1.6 days/decade**
- **Large year-to-year variation related to temperature: 2 to 3 days/ °F**

First and Last Frosts Changing





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

Fall Climate Transition

Clear dry blue sky after frost. Forest evaporation has ended; water vapor greenhouse is reduced, so Earth cools fast to space at night

- **Vegetation delays first killing frost**
- **While deciduous trees still evaporating: moister air with clouds**
- **Water vapor & cloud greenhouse reduces cooling at night and prevents frost**
- **Till one night, dry air advection from north gives first hard frost.**
- **Vegetation dies, skies become clearer and frosts become frequent**

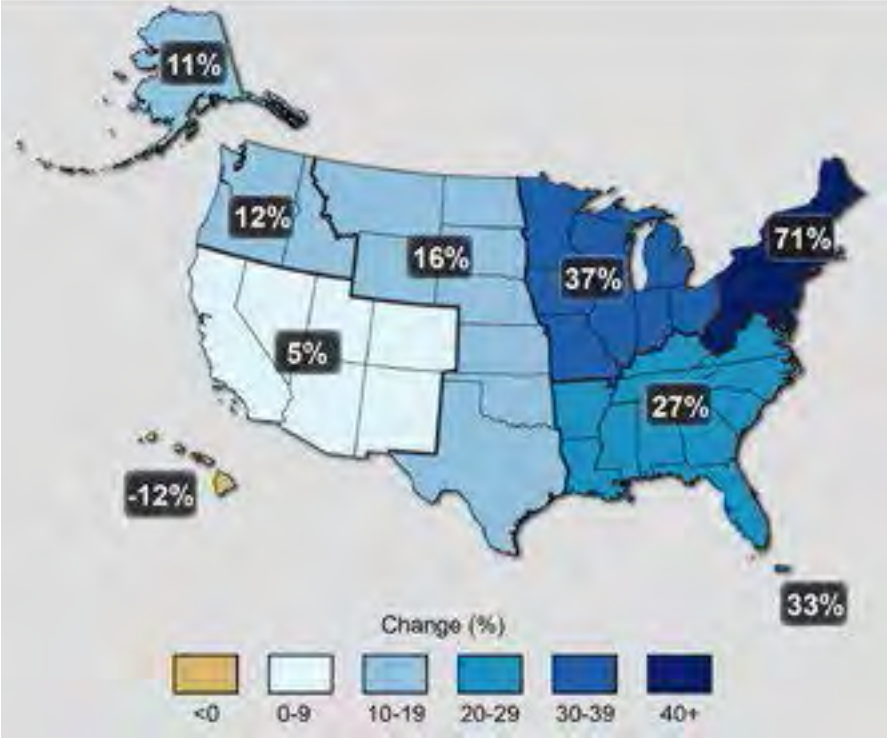
- ***The opposite of what happens in Spring with leaf-out!***

Later frost: Growing season getting longer

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**

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 6-8 ins rain <u>on wet soils</u>**
  - **<u>Extreme flooding</u>**

TS Irene: 2011

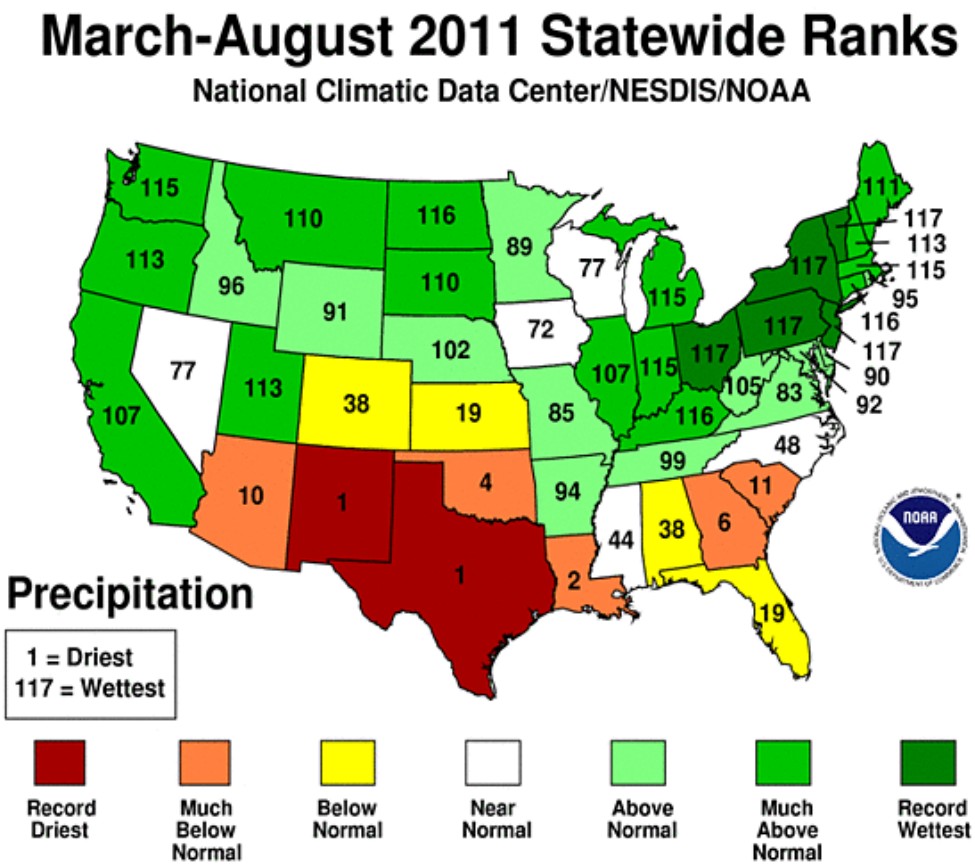
Brattleboro, VT. Courtesy of Caleb Clark, CNN

Brattleboro, M. Reston

Wilmington, J. Cantore

2011 Floods: VT and NY

- **Record spring flood: Lake Champlain**
- **Record flood with tropical storm Irene**



<u>March-August, 2011</u>

- **Record wet : OH to VT**
- **Record drought: TX & NM**
- ***<u>Pattern nearly stationary</u>***

Value of Flood Plains

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

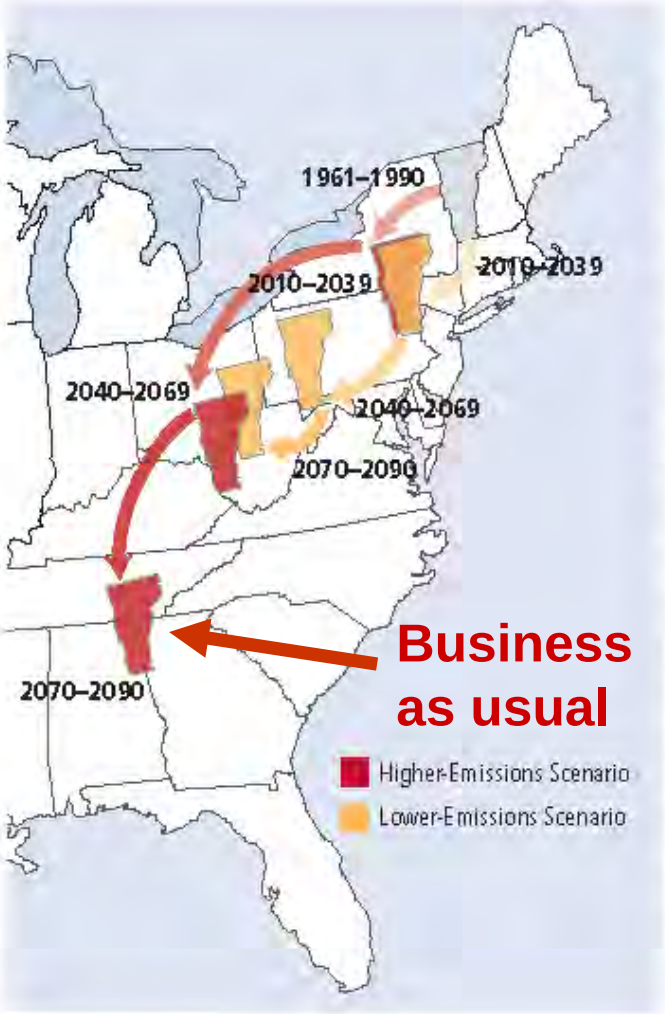
Flooding Issues

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

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



Migrating State Climate

Changes in average summer heat index—a measure of how hot it actually feels, given temperature and humidity—could strongly affect quality of life in the future for residents of Vermont. Red arrows track what summers in Vermont could feel like over the course of the century under the higher-emissions scenario. Yellow arrows track what summers in the state could feel like under the lower-emissions scenario.

NECIA, 2007

Can We Stop "Dangerous Climate Change"?

(UNFCCC 1992)

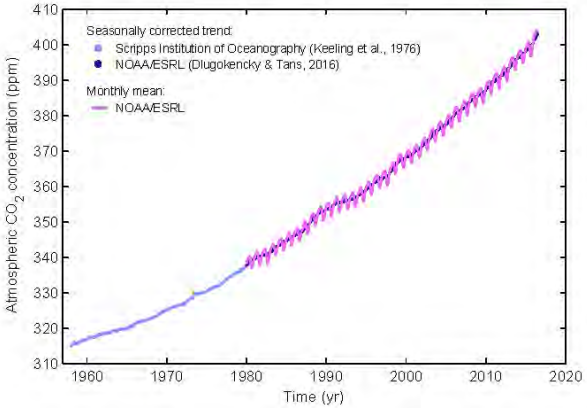
- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an <u>80% drop</u> in CO_2 emissions!**
- **This is <u>possible but very difficult</u>**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **"Lifestyle" has become dependent on fossil fuels**
  - **Powerful vested interests: $Trillions at stake**

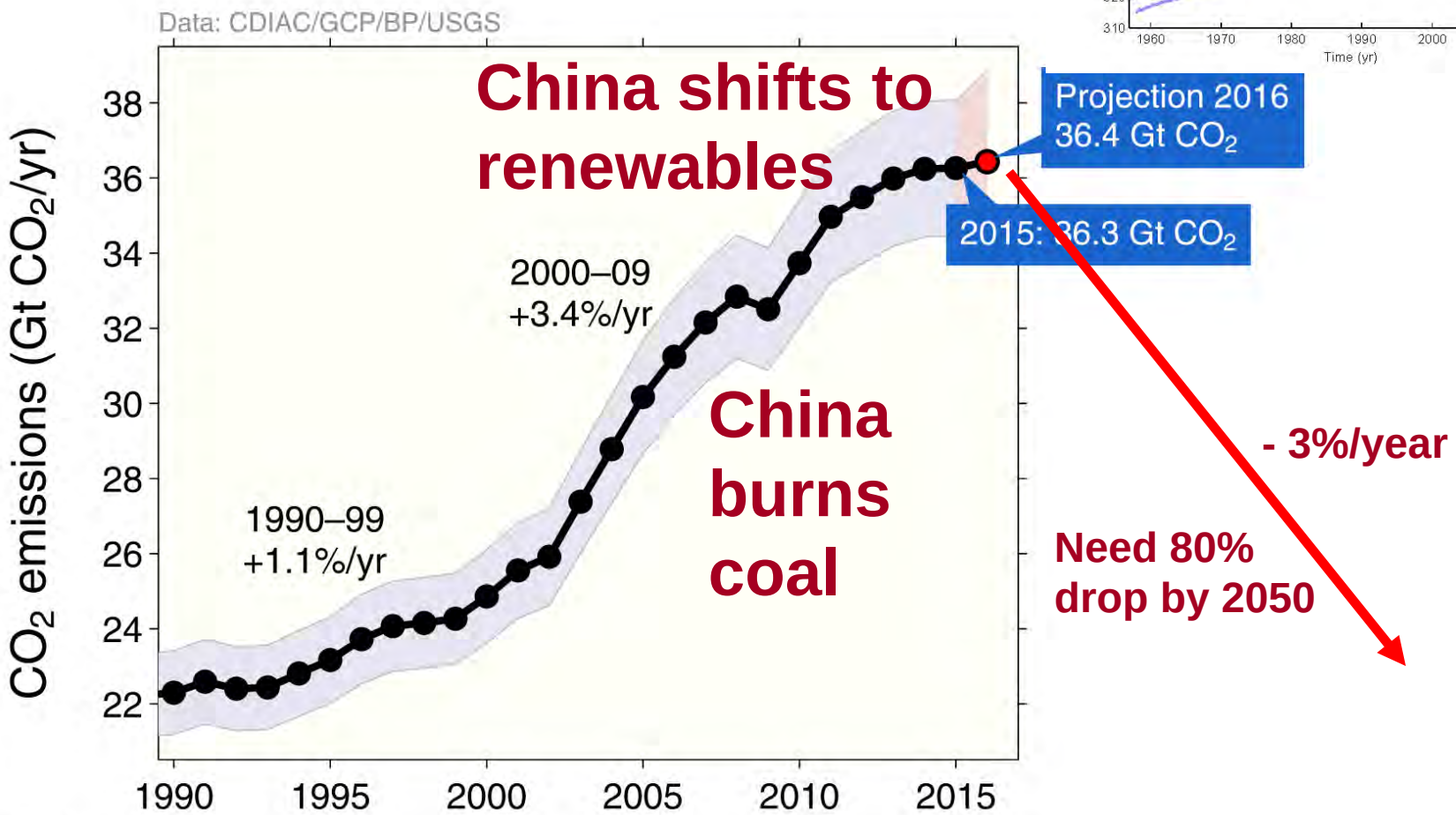
2015 was Transition Year

- **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 CO_2 Emissions Flat for 3 years





What can we “safely” burn?

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

‘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 and climate***

- **We need new ‘rules’ because**
  - ***Our numbers and industrial output are so large***
  - ***Maximizing consumption and profit have contributed to present predicament***

New Guidelines Needed

- ***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/nitrogen loads on streams/lakes**
- ***Reconnect with natural world***
  - ***Fundamental if we are to embrace 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 CO_2 to 1,000 ppm**
    - ***Radically change climate/wipe out many species***
    - ***In time melt icecaps, raise sea-level >100ft***

Practical Local Solutions

- **Vermont is well on its way**
  - **Large solar development**
  - **Battery storage coming**
    - **California installing 100MWh storage units**
  - **Energy efficiency for homes and businesses underway**
  - ***Need net-zero building codes***
  - ***Need transportation shift***
  - ***Need lifestyle awareness!***

Efficient transport

- **Gasoline to hybrid: 50% gain to 50mpg**
- **Hybrid to plug-in hybrid: now 140mpg**
- **Electricity from community solar array**

>3000lbs and 140 mpg
Payload: 750 lbs at 55 mph

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

How do we plan/adapt?

- **Future needs creative approaches**
  - **Community support**
  - **Efficient society run on renewable energy**
- **We need to work with the Earth, the Creation**
  - ***People reconnected to landscape***
  - **Manage water on landscape**
  - **Manage gardens, 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, 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_2 is an 'unfair cost to the free market'**
  - **Too bad if the Earth's ecosystems are destroyed: '*others/future*' can pay the price**
  - **"Freedom to exploit" trumps everything!**
- ***Our politics are facing collapse:***

fantasy disconnected from real world

  - ***We are deeply embedded in system!***

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***

(Dark Money, Jane Mayer, 2016)

- **Leading to**
  - ***Climate science is a (fictitious) conspiracy***

Step back from dark side

- **Cannot solve with mindset that created it**
  - ***Oppose new fossil fuel "solutions"***
  - ***Understand climate science: stand for the Earth***
- **Push practical solutions**
  - ***Efficiency and renewables***
  - ***And a fossil-carbon tax***
- ***Social and moral shift needed***
  - ***Identify your personal & community role***
  - ***Future needs creative approaches!***

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***
- ***Creation will overwhelm human folly***
  - ***So accept (repent!) with joy***

Voice the Ethical Issues

- **Do we just exploit the Earth's 'wealth'**
  - **For greater 'economic growth'**
  - **For a wealthy few**
  - **What will be left for our children, and the Earth's ecosystems?**
- **Confront the "economic immorality"**
  - ***Economics discounts the future and our children's lives; meanwhile oceans accumulate energy, and storms amplify***
  - ***"Cost effective" for present bottom line is <u>not</u> cost effective for the future, it is a <u>catastrophe</u>***

“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

“If something is worth doing, do it. If, in fact, you fail, there’ll be no cause for regret. You can try again. To die without even having tried, will be to die disappointed. We all have opportunities to contribute making a better world; we must seize them with far-sighted vision”

Dalai Lama, 26 June 2017

Discussion

alanbetts.com

(articles and talks)

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***

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**

Over-winter: March 3, 2017

What does it mean for Vermont?

- One climate zone warmer
  - Winter minimums up 10F: City zone 5/6
  - Add one climate zone every 20 years
  - What new species could be planted? Need to experiment, some will survive
  - Extremes a challenge: winter & storms
- More flash flooding
  - Boost organic matter in soil
  - Manage drainage

Winter

- Later arrival of ‘winter’ and snow
- Warmer winters: continuing upward shift of USDA climate zones
- More overwintering of pests
- Increased winter precipitation
- More wet snow and freezing rain
- More melt events in winter, possible flooding
- Shortened ski, snowmobile, ice-fishing seasons
- Increased variability between winters, linked to fraction of days with snow cover

Spring

- Sugaring season shifts earlier and ends earlier; possibly reduced productivity
- Earlier ice-out of lakes and ponds
- Earlier spring melt; larger stream flows and possible flooding if large snowpack
- Earlier arrival of spring for daffodils and forsythia;
- Earlier bloom dates for many plant species; but more ‘false springs’, when early bloom damaged by late frosts
- Earlier last spring frost (on average)

Summer

- Longer growing season
- Hotter summers, unless rainfall is above average
- More heavy rain events
- More frequent floods and flood damage
- Greater frequency of 1-2 month droughts
- Increased warm-weather pest species, such as mosquitoes, ticks, and algae in lakes
- Reduced productivity of cool-weather crops

Autumn

- **Warmer fall temperatures**
- **Later first fall frost**
- **Later fall color: possibly reduced fall color**
- **Possibly increased fall precipitation and stream flow**