

Climate Change and the Future

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Mountain School, Vershire

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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**
- **2010: alanbetts.com**

Fundamentals

- **Burning fossil fuels: transforming climate**
 - Water cycle accelerates changes
 - Heading for high CO₂ “Carboniferous era climate”
 - Earth warming: 90% of heat stored in oceans
 - Climate extremes increasing
- **Linked to unmanaged technology/waste streams**
 - Soluble by changing system guidelines
 - Create efficient society, based on renewable energy
- ***Avoidance of responsibility for decades***
 - *Politicians, professionals, public*
 - *Climate change: Incompatible with business-as-usual*
- ***Choices based on moral values essential***
 - *Science and economics need guiding*
 - *[Guidance is now based on profit and exploitation]*

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?**

(alanbetts.com)

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 to change (and fear of change)*

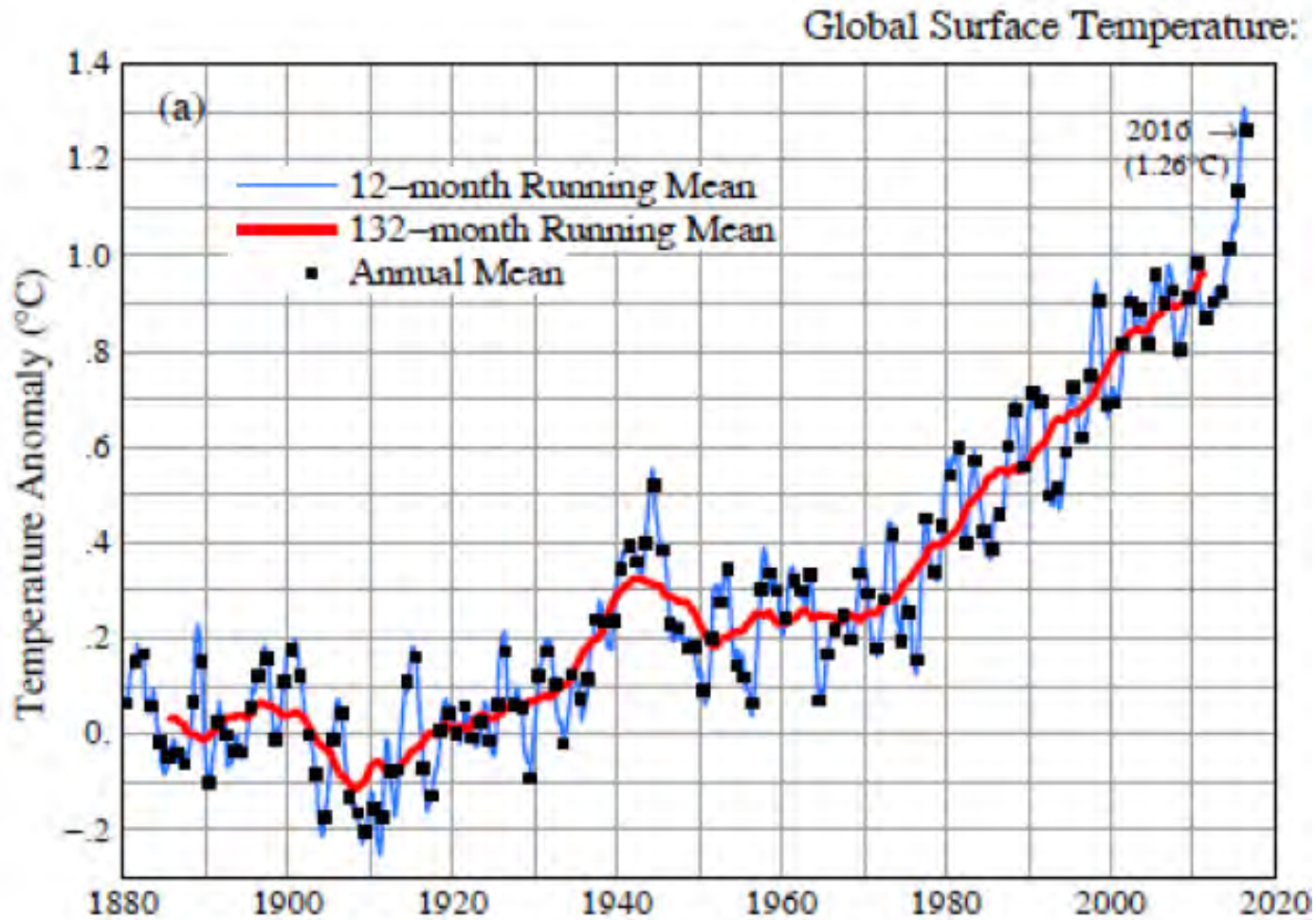
January 2, 2012: NASA

Earth's climate sustains life

- Burning fossil fuels increases greenhouse gases
- LW cooling to space reduced
- **Climate warms**
 - Oceans warm
 - Evaporation up
 - Water vapor up
 - Ice is melting
 - Extreme weather is increasing
- Weather patterns changing/slowing

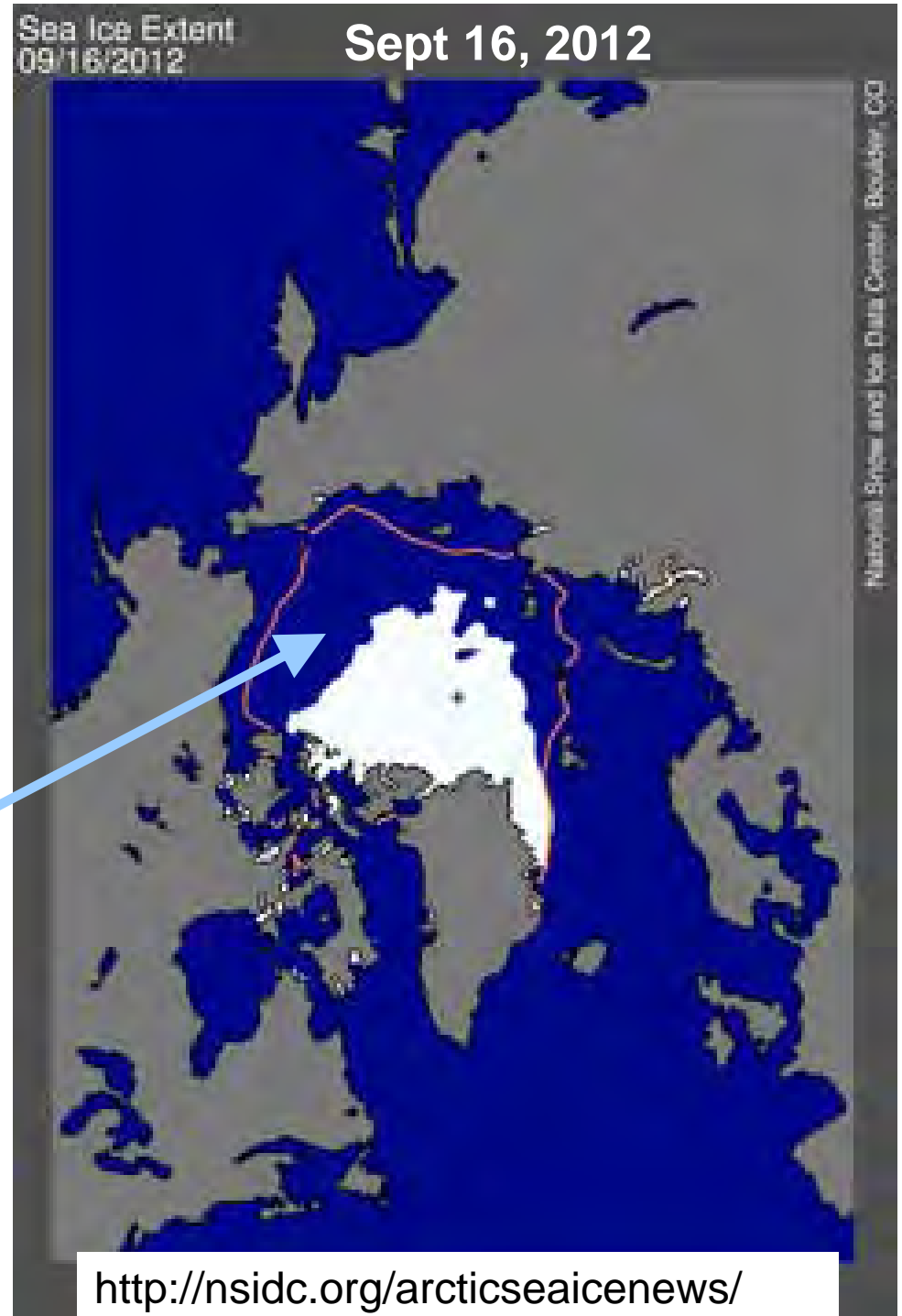


Long-term Global Mean Trend 1880-2016

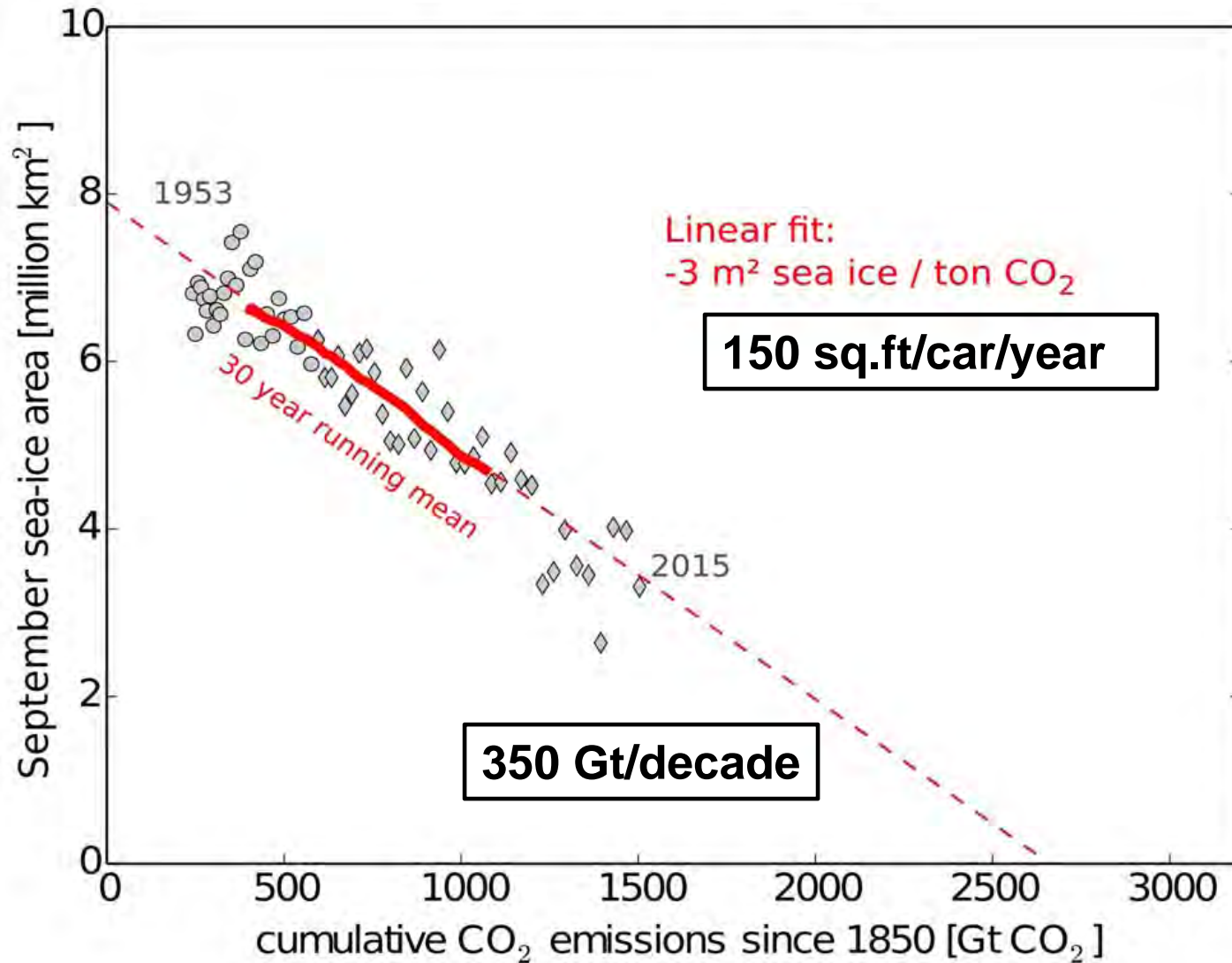


- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

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

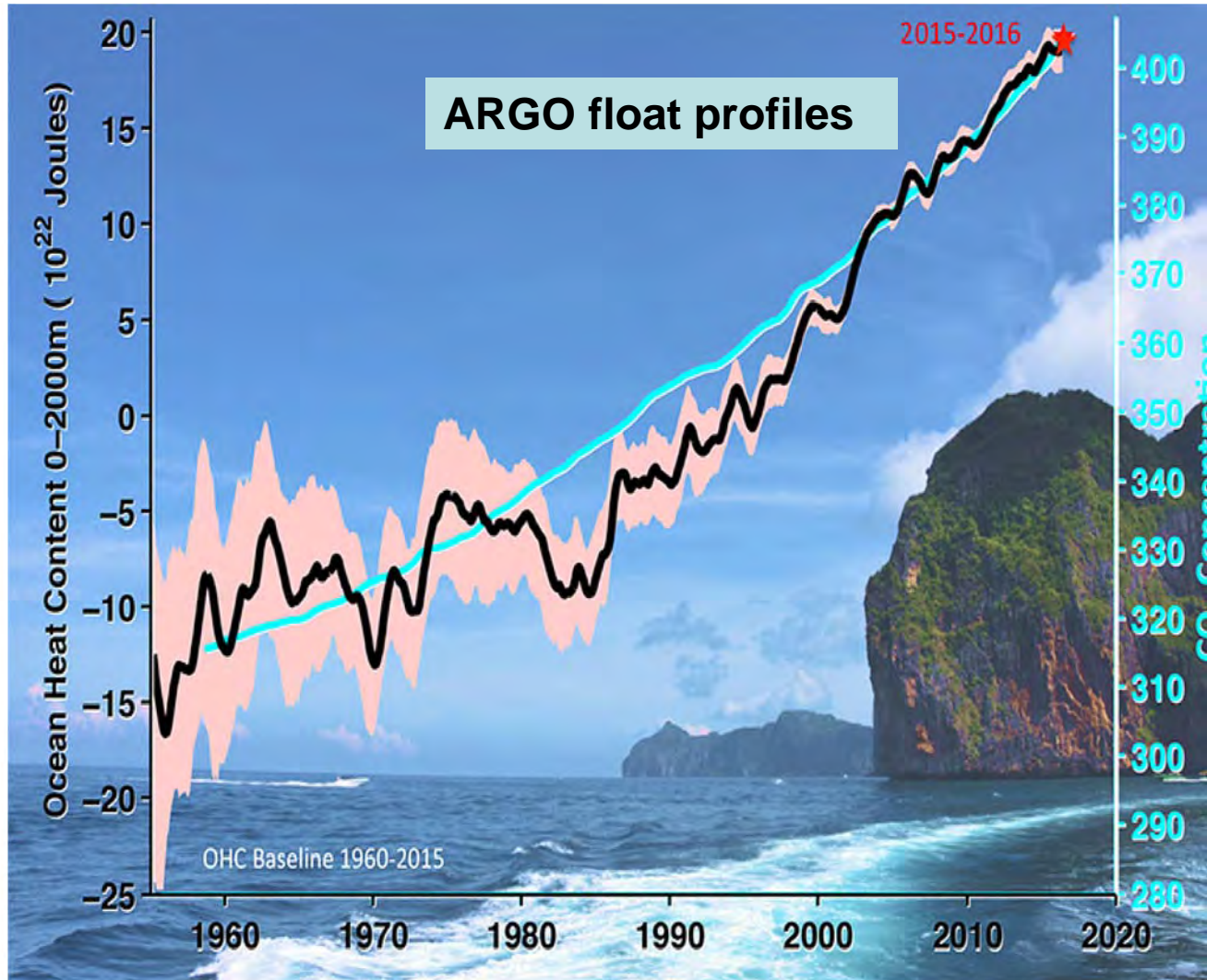


September Arctic Sea Ice Loss



J. Stroeve/National Snow and Ice Data Center

Ocean Heat Storage – CO₂

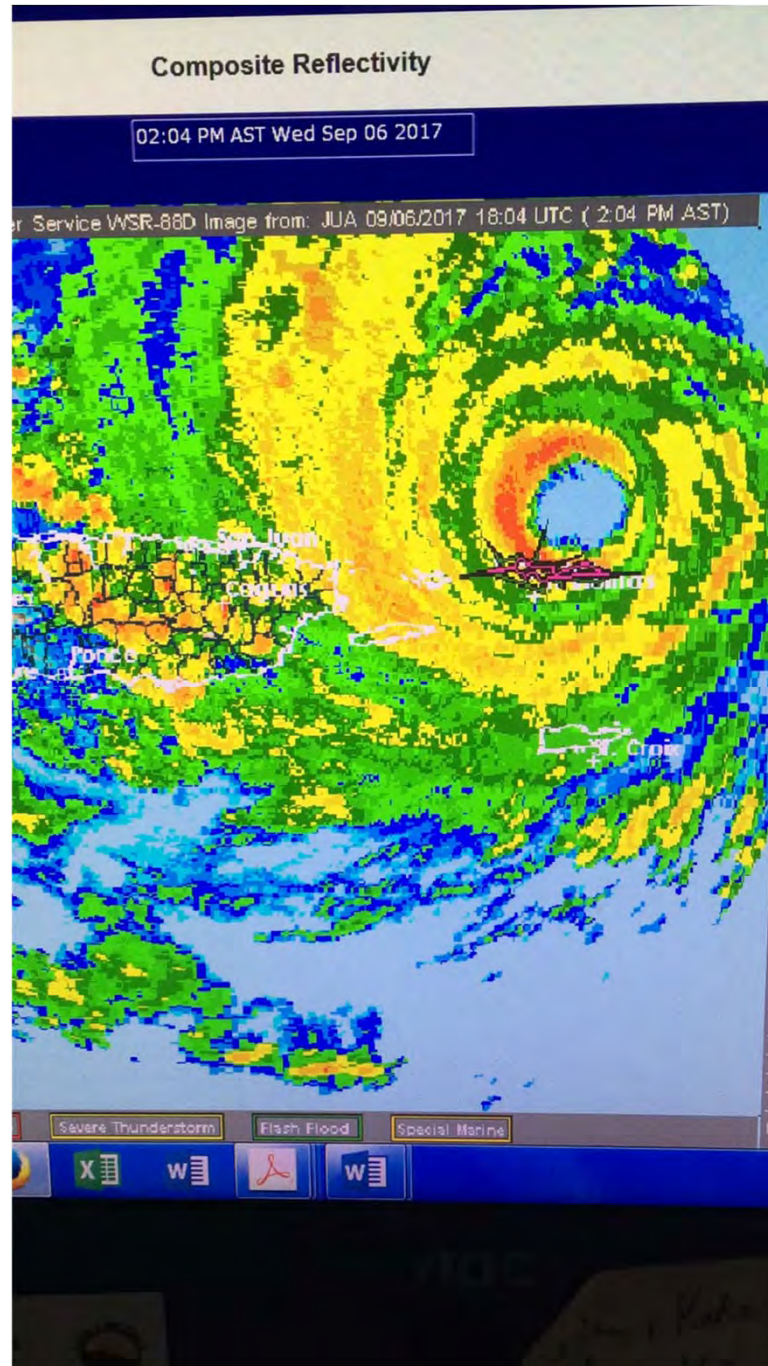


Hurricane season: 2017

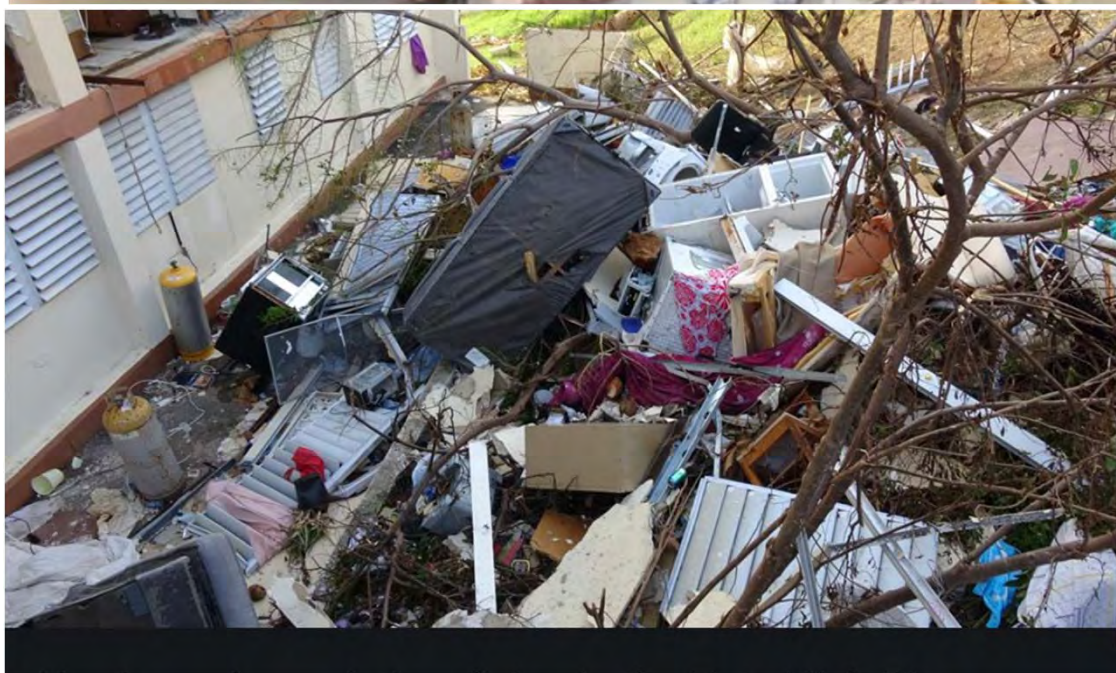
- Earth cannot cool as fast to space because of increasing greenhouse gases
- Oceans are storing 90% of heat
 - Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes – *when windshear low*

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

***Cat 5 >155mph**
IRMA >180mph



Sept. 6
Irma
(cat.5)
St Thomas



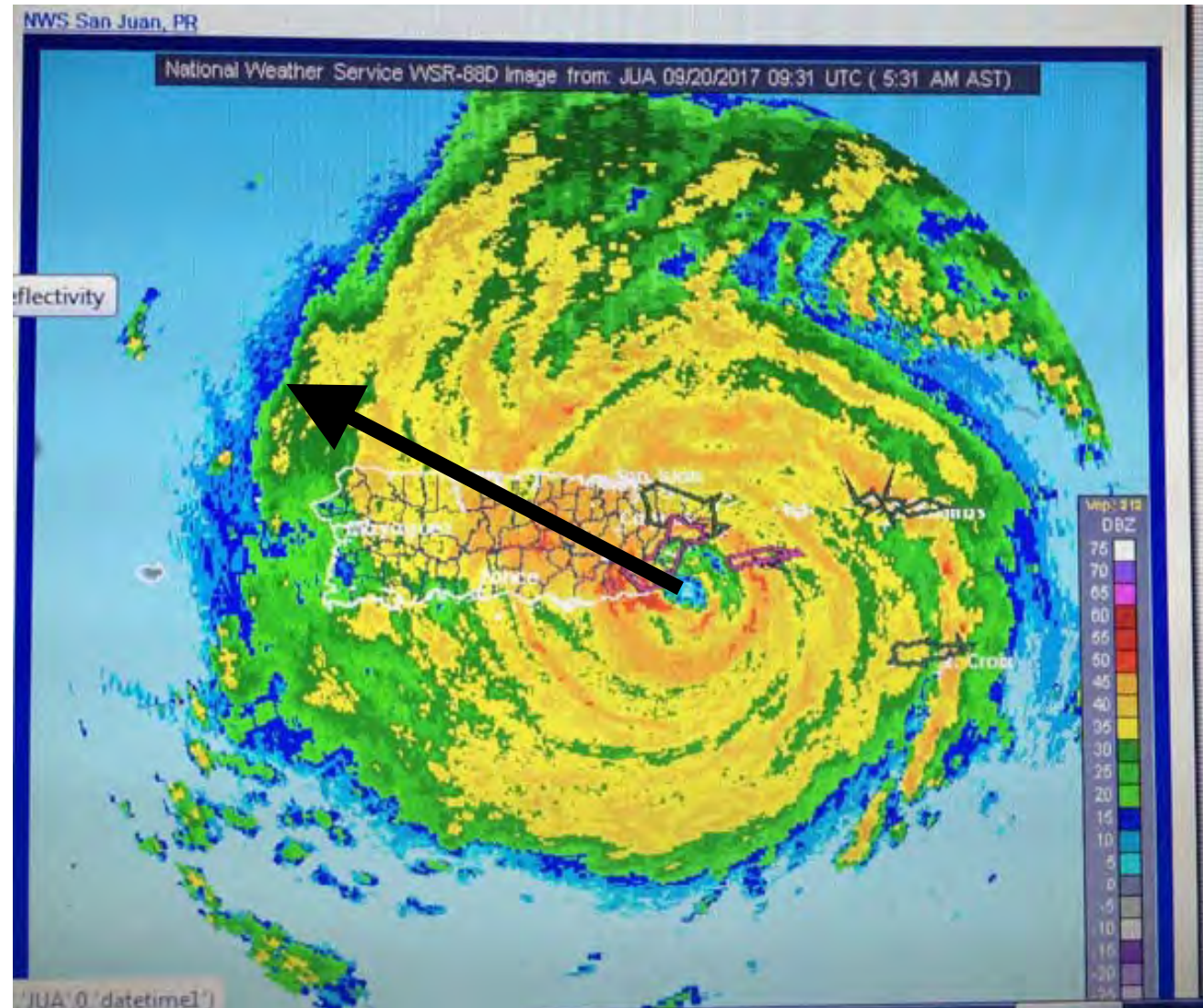
Irma and Jose: Sept 7



After Jose passed; Boat to Puerto Rico on Sept 11

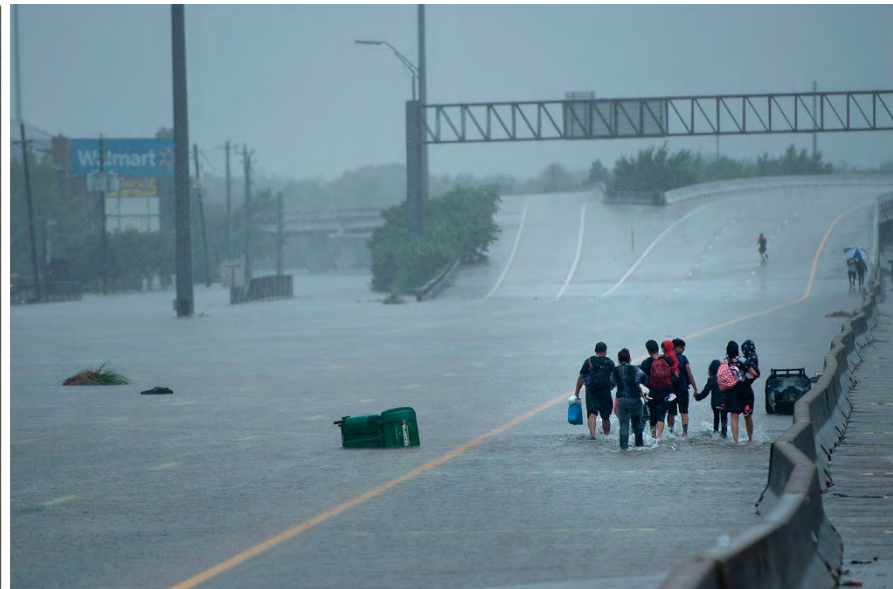
Maria: 5:30am Sept. 20 ***Category 4 hits Puerto Rico***

Cat 4
>130mph
Maria
>150mph



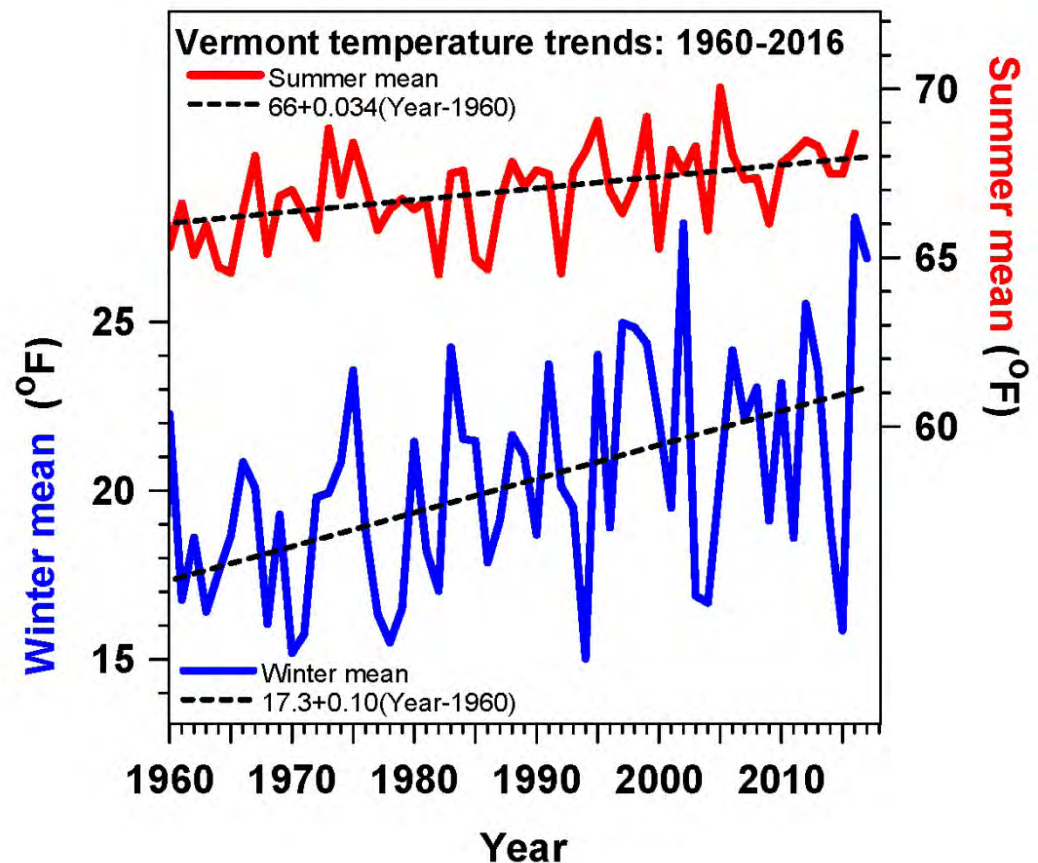
Why was Harvey so Devastating?

- Huge evaporation off warm ocean
- Category 4 hurricane developed
- Very heavy rain-rate: 12 inches per day
- Two stationary high pressure systems to north **trapped** Harvey for 4 days over Houston
- Result **48 inches** of rain and massive flooding!



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)

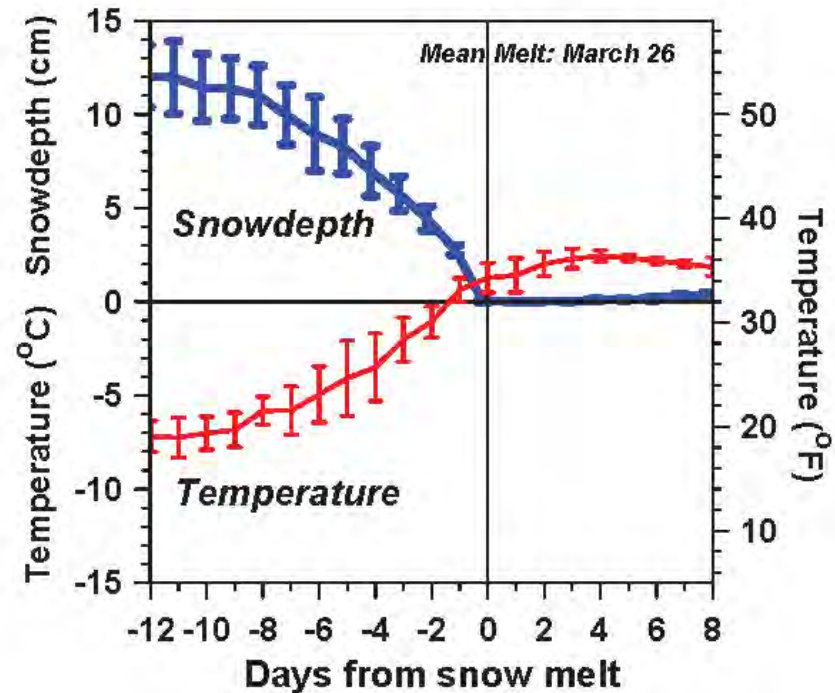
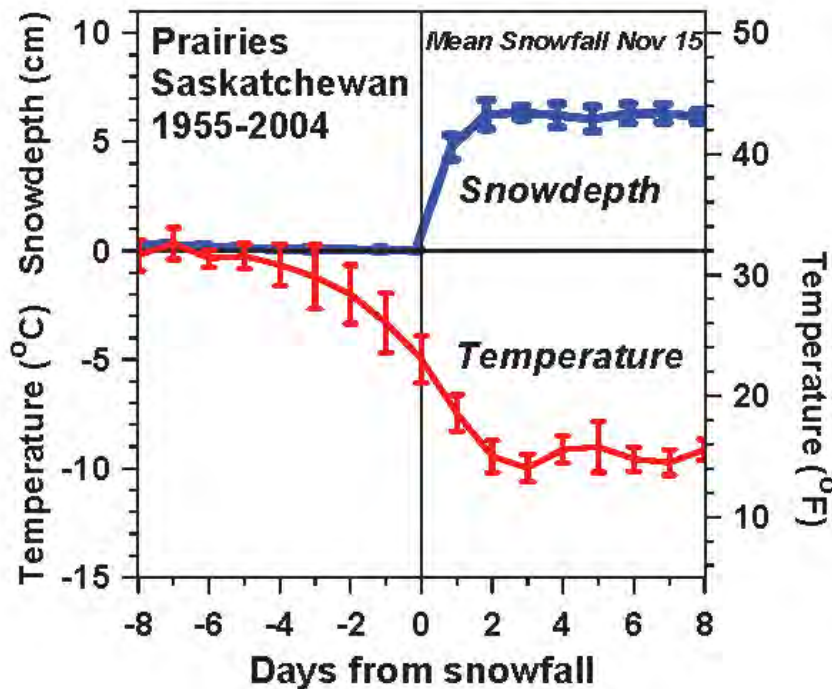


March 3, 2017



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)

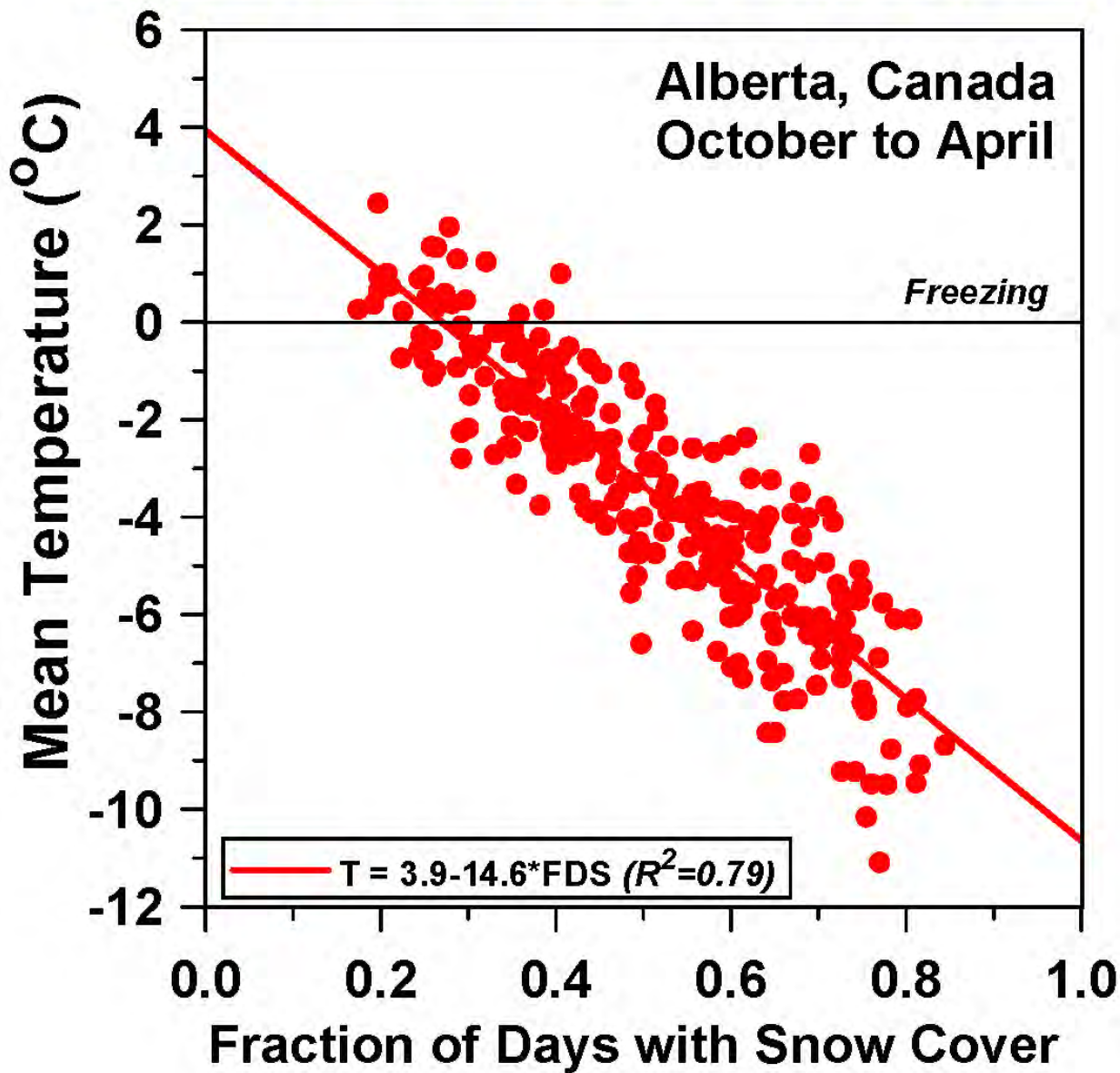
Impact of Snow

- **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)

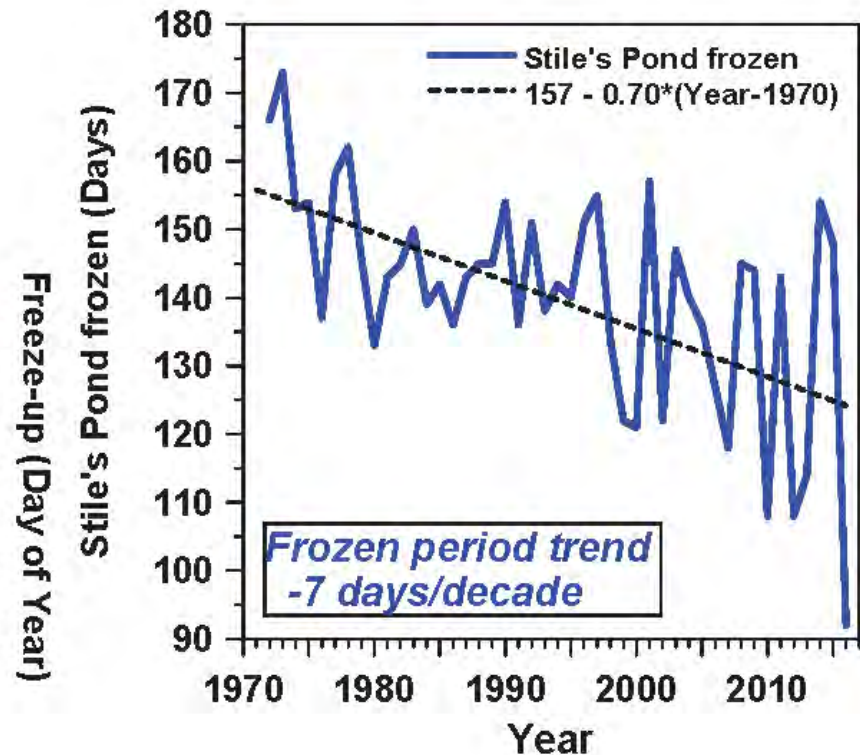
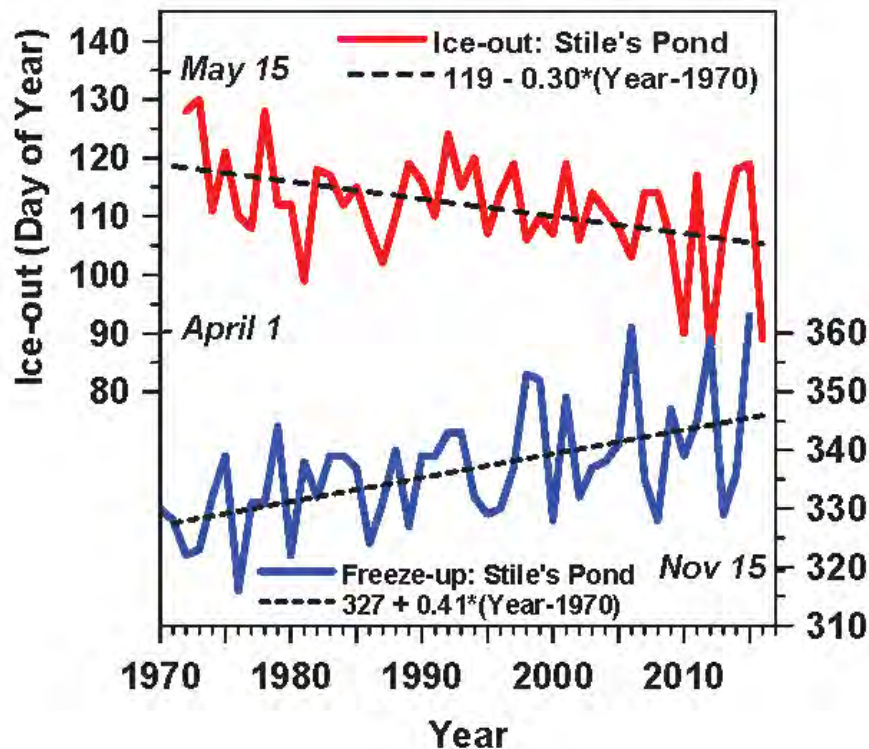
More snow cover - Colder temperatures



Winter is
colder if
more snow
cover

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**
- Lake frozen period trend **- 7 days/decade**

Stiles Pond: "Eye on the Sky"

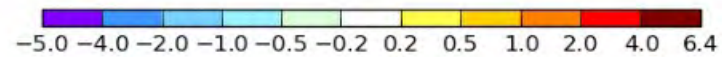
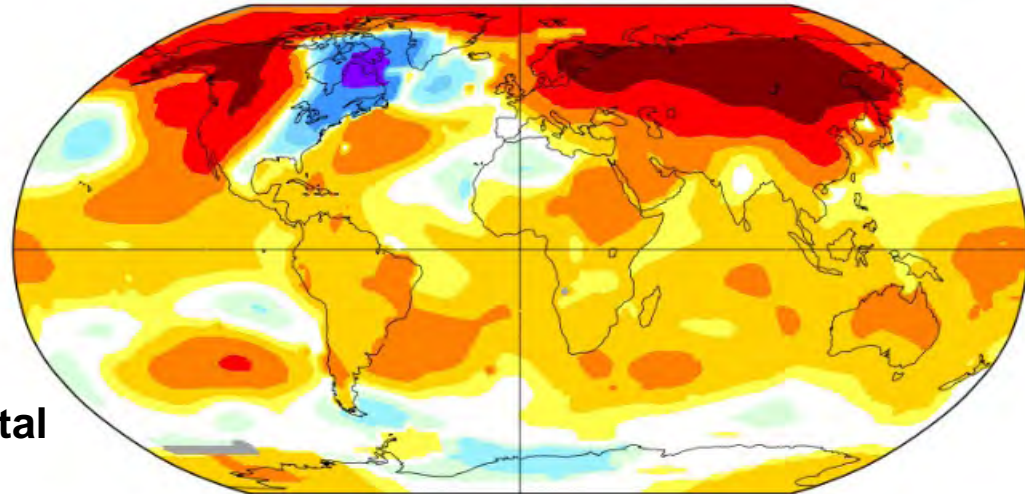
Jan-Feb-Mar 2015

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

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



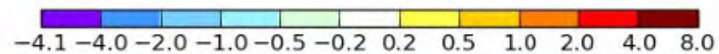
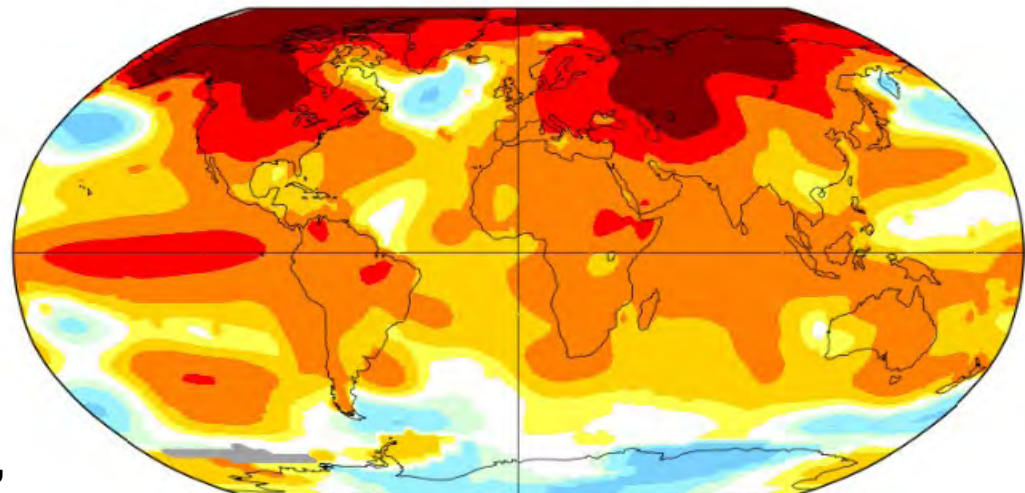
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic

Jan-Mar 2016

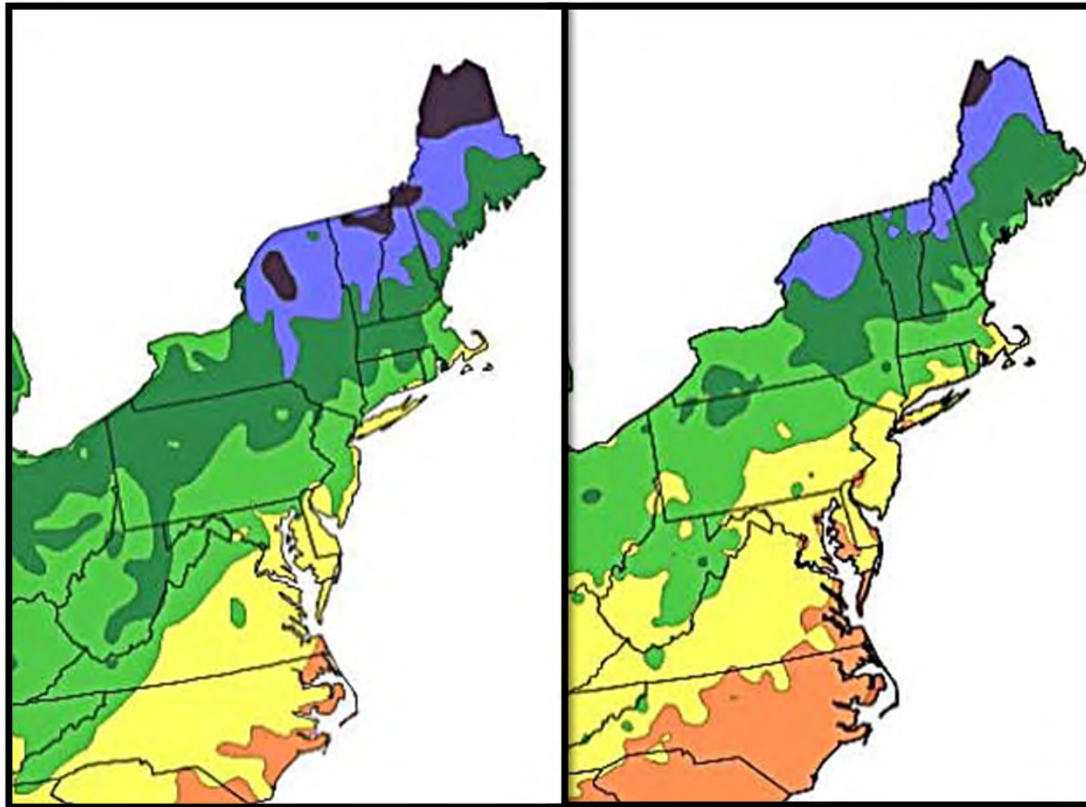
L-OTI(°C) Anomaly vs 1951-1980

1.24



Winter Hardiness Zones

– winter cold extremes



Minimum winter T

4: -30 to -20°F

5: -20 to -10°F

6: -10 to 0°F

**One Zone
in 25 years**

1990

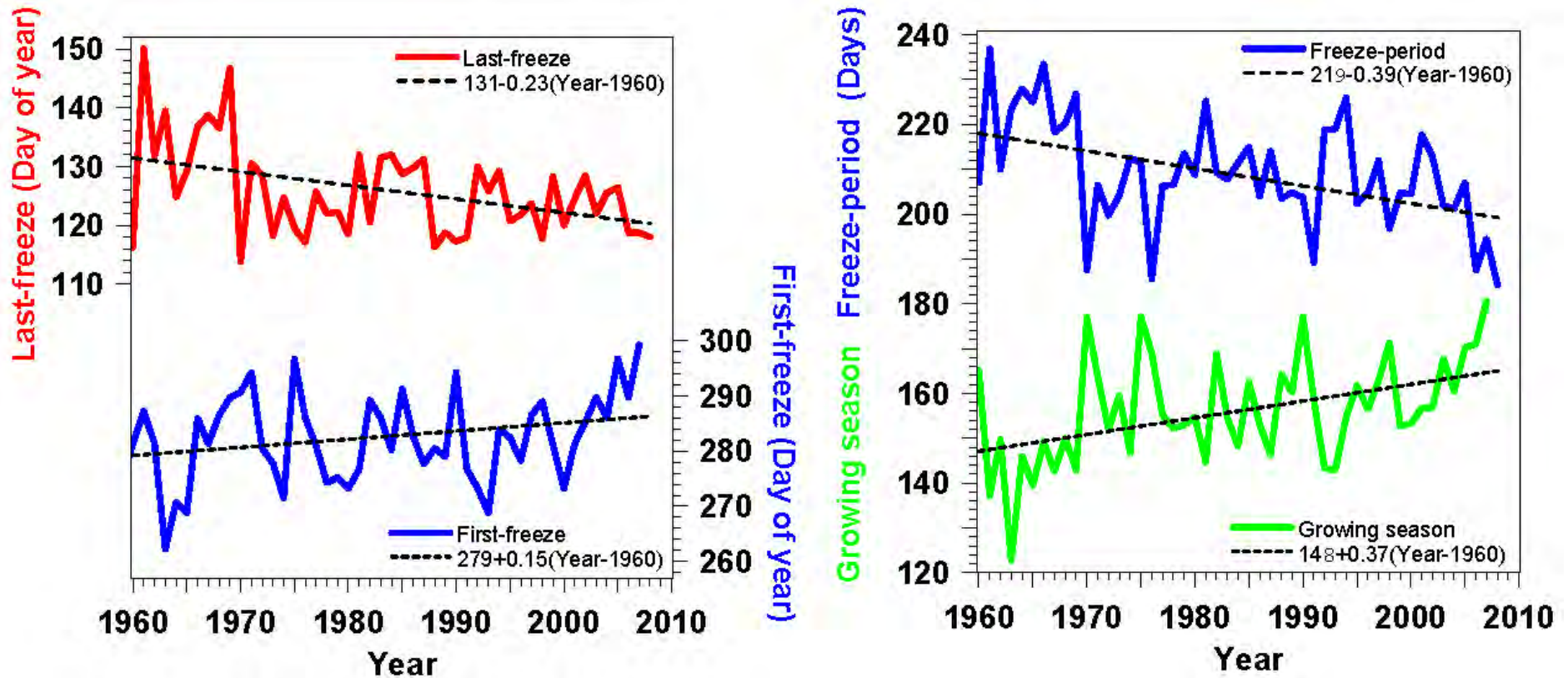
2015

Zone



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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

- **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!*

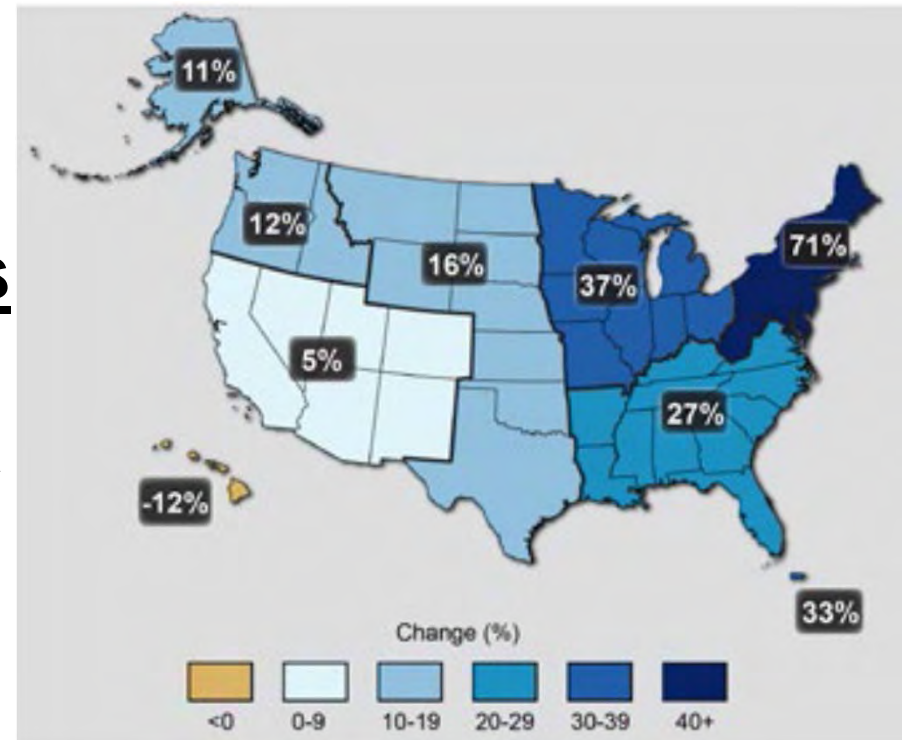


Clear dry blue sky after frost. Forest evaporation has ended; water vapor greenhouse is reduced, so Earth cools fast to space at night

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**

TS Irene: 2011

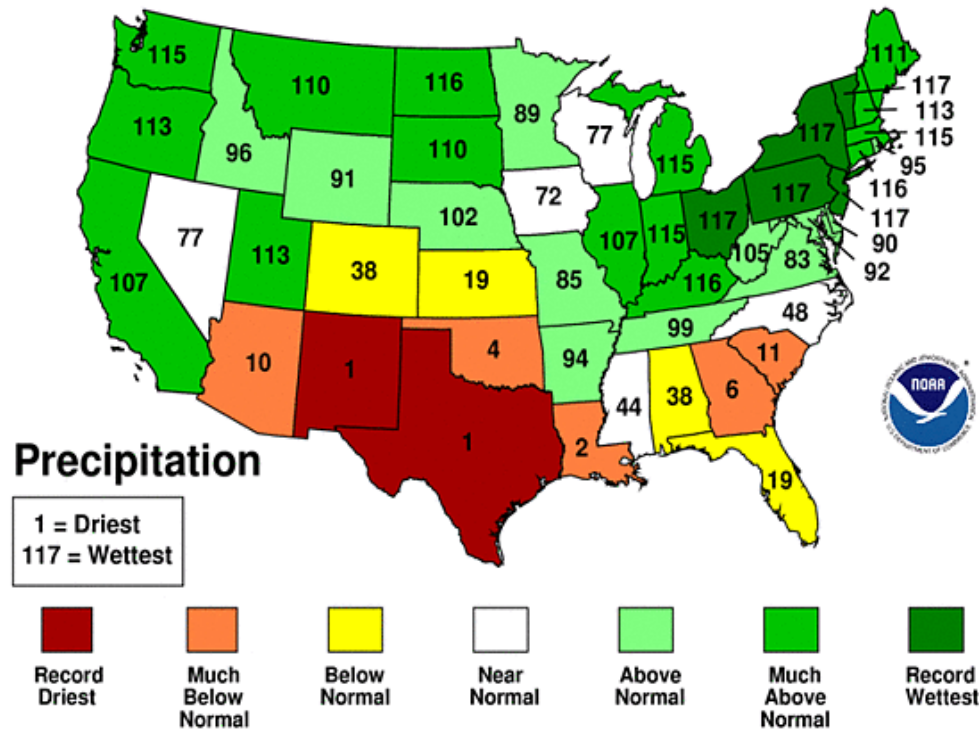


2011 Floods: VT and NY

- 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**

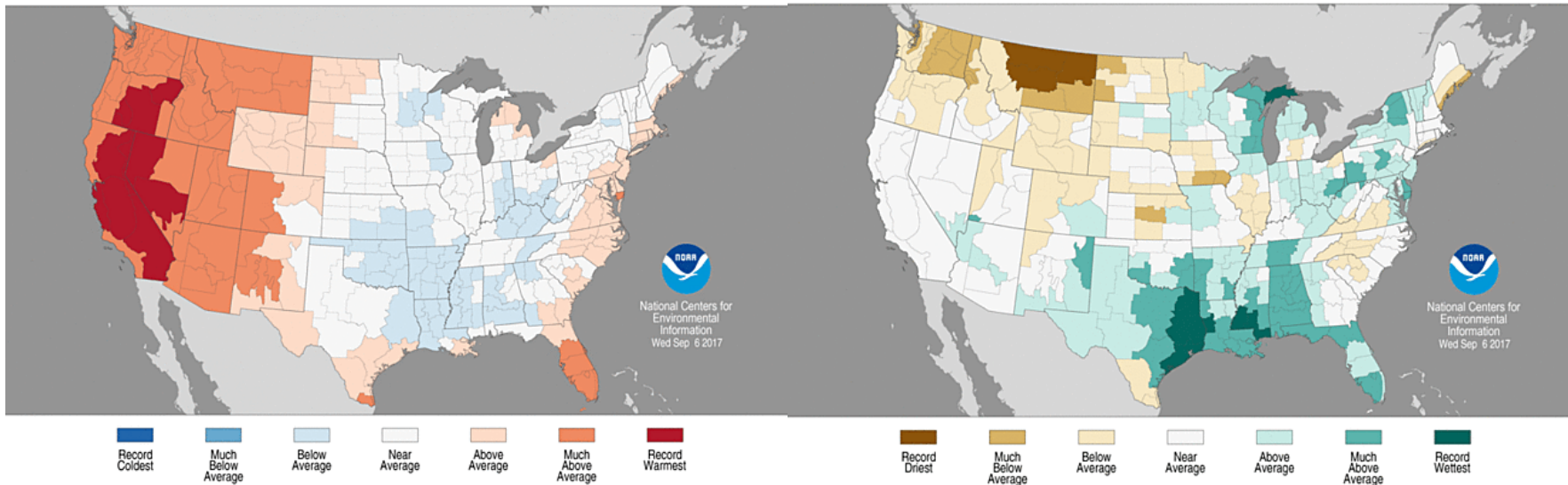
Warm Dry Climate Extremes Lead to Widespread Fires

Jun-Jul-Aug, 2017

*(West: hot and dry after wet winter
South: cool and wet with Harvey)*

Divisional Average Temperature Ranks
June–August 2017
Period: 1895–2017

Divisional Precipitation Ranks
June–August 2017
Period: 1895–2017

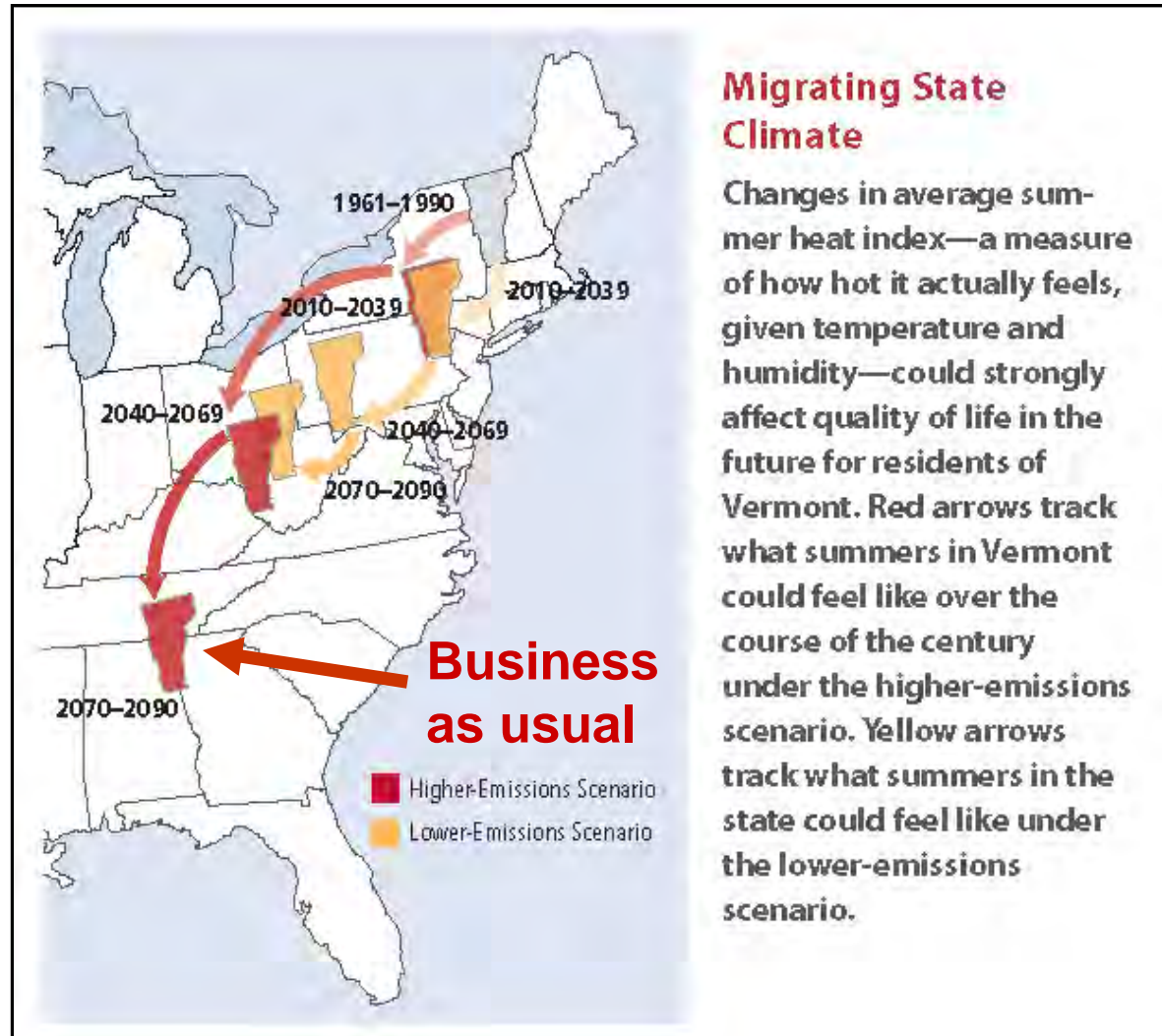


Caused severe fires in western US and Canada

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



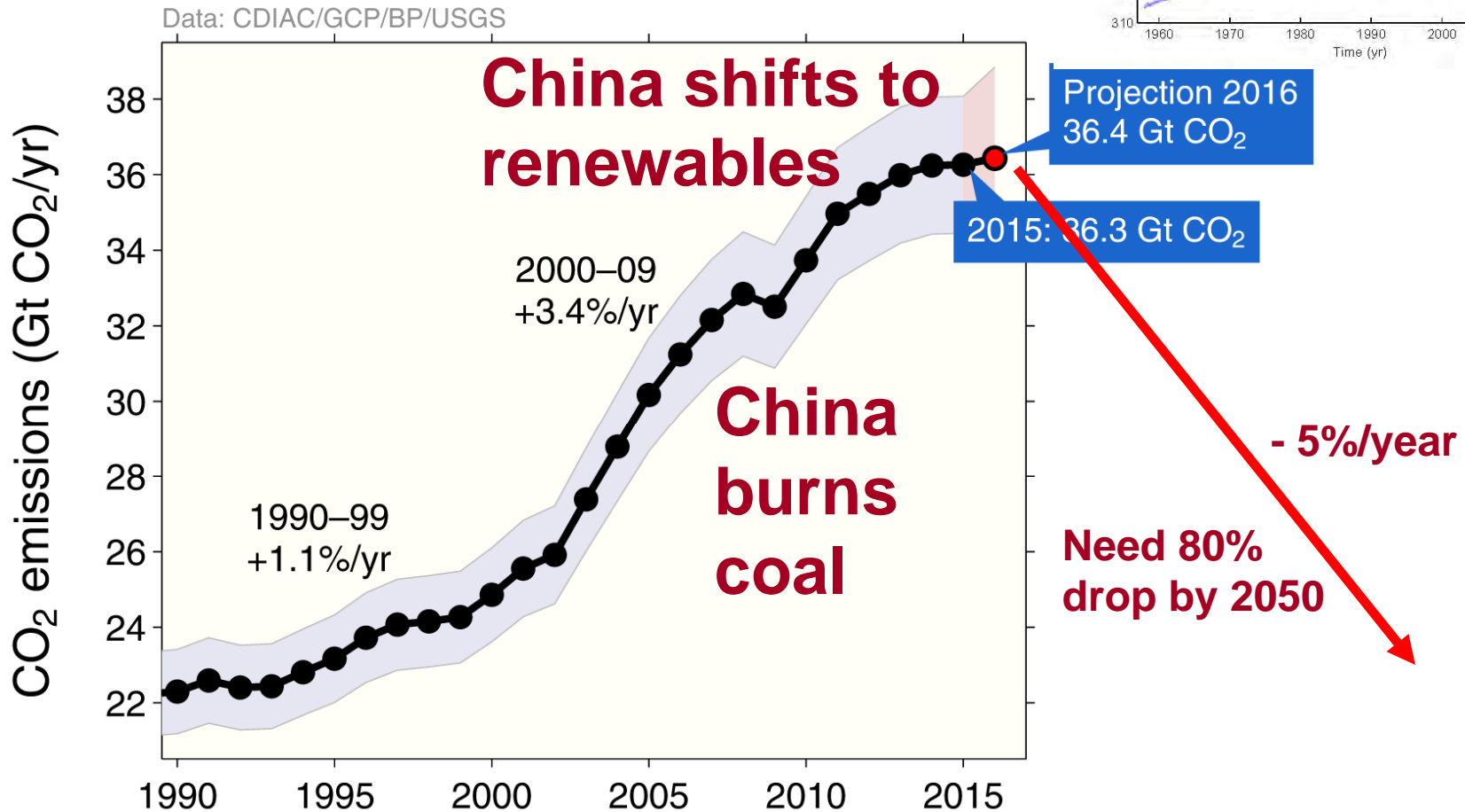
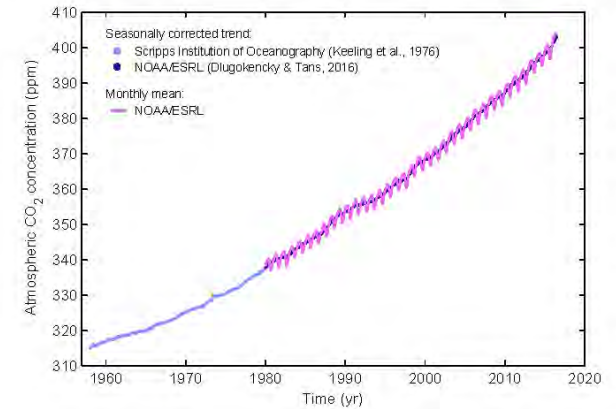
**NECIA,
2007**

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**

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
- At 36 Gt/year - only 21 years left
- *Rapid fossil-fuel phase-down extends period*

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*

New Guidelines Needed

- ***Re-education of society***
 - *The transition we face is huge*
 - *What will raise awareness: change paradigm?*
- **Develop renewable energy**
 - Maximize energy efficiency: housing, transport, power
- **Examine all waste-streams**
 - Aim to recycle/remanufacture everything
 - Fully cost all waste streams, including CO₂
- **Relocalize food system**
 - Compost all organic waste
- ***Reconnect with natural world***
 - *Fundamental if we are to embrace transition*
 - *Ask for spiritual guidance*

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 faith values above short-term profit*
- ***Earth will overwhelm human folly***
 - *So accept change with joy*

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*

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 145mpg
- Electricity from community solar array



>3000lbs and 145 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**
- ***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**

“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

alanbetts.com

(articles and talks)

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: ‘*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

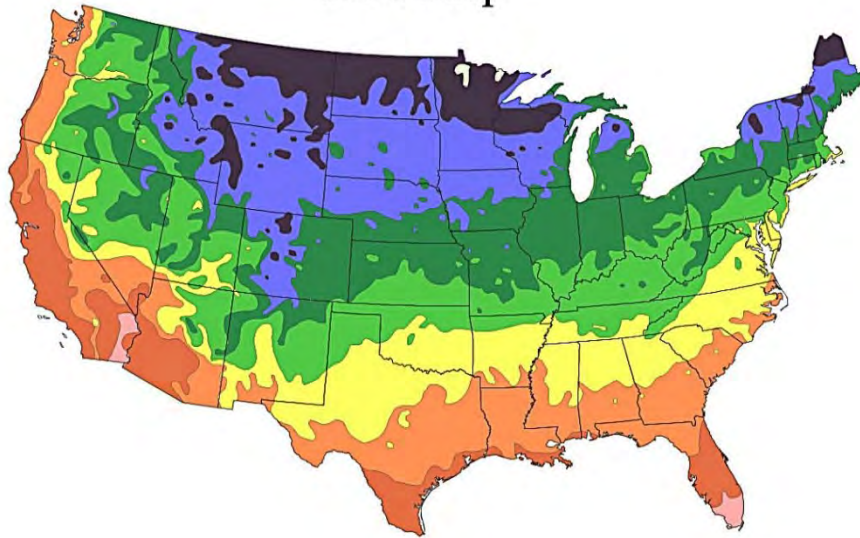
- **Aim: *purchase control of the Republican Party***
 - US Congress (“Freedom Party”); many state legislatures
 - **Doctrine: *limited role for government***
 - protect wealth, property and the rule of law
 - **Freedom to exploit the earth:**
 - Shall not be limited by environmental regulation
 - *Doctrine in direct conflict with Earth’s ecosystem*
 - **Leading to**
 - *Climate science is a (fictitious) conspiracy*
- (Dark Money, Jane Mayer, 2016)*

Voice the Ethical Issues

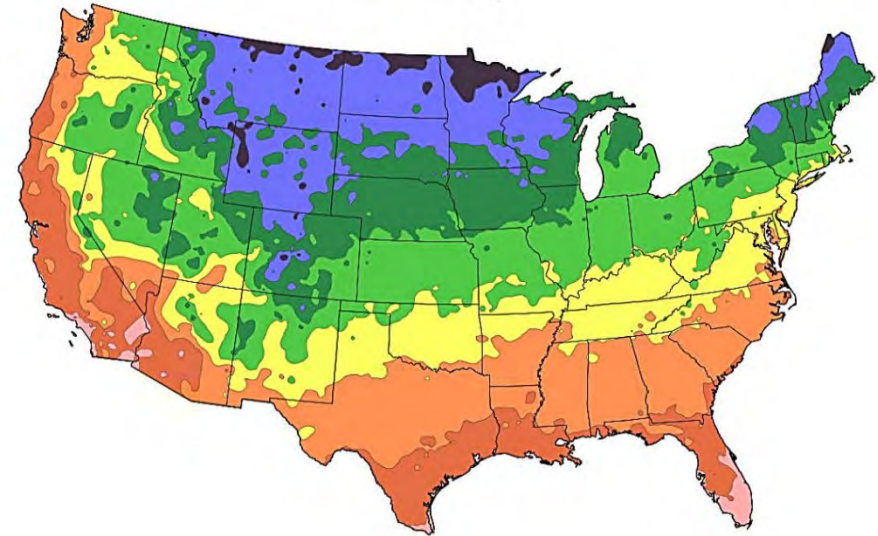
- **Do we just exploit the Earth's 'wealth'**
 - For greater 'economic growth'
 - For a wealthy few
 - What will be left for our children?
 - What about the Earth's ecosystems?
- **Fundamental practical moral issue**
 - Don't we need to co-operate with the Creation?
 - *Shift in understanding and mind-set needed*

Plant Hardiness Zones

1990 Map



2015 Map



After USDA Plant Hardiness Zone Map, USDA
Miscellaneous Publication No. 1475, Issued
January 1990.

Arbor Day Foundation Plant Hardiness Zone
Map published in 2015.

Zone



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