

The Climate Challenge Deepens

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Sept. 19, 2017



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 timescales
- **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*
 - *Resilience incompatible with exploitative model*

Background/my role as Scientist

- **Educated in UK (Univ. of Cambridge, London)**
- **Weather experiment in Venezuela, 1969.**
- **Post-doc. Colorado State, 1970; faculty, 1971-79**
- **1974, Convection Scientist for GATE (GARP Atlantic Tropical Experiment)**
- **1978: Built VT house, passive solar, solar electricity**
- **1979 – present. ‘Independent scientist’, funded by NSF, NASA: working on field projects and global forecast models**
- **2007: President of Vermont Academy of Science and Engineering – I realized I should accept responsibility for Vermont and climate change.**

(alanbetts.com)

What is our role?

- Honesty, accuracy, clarity, and depth
 - We should consciously accept responsibility for the Earth's future
 - *As the political and economic system will not*
 - Speak clearly to society: creative, hopeful frame in language that sidesteps ideology
 - *Realize that Earth system limits will need adaptive global governance and some systems engineering*
 - *May mean a paradigm shift in science & society*

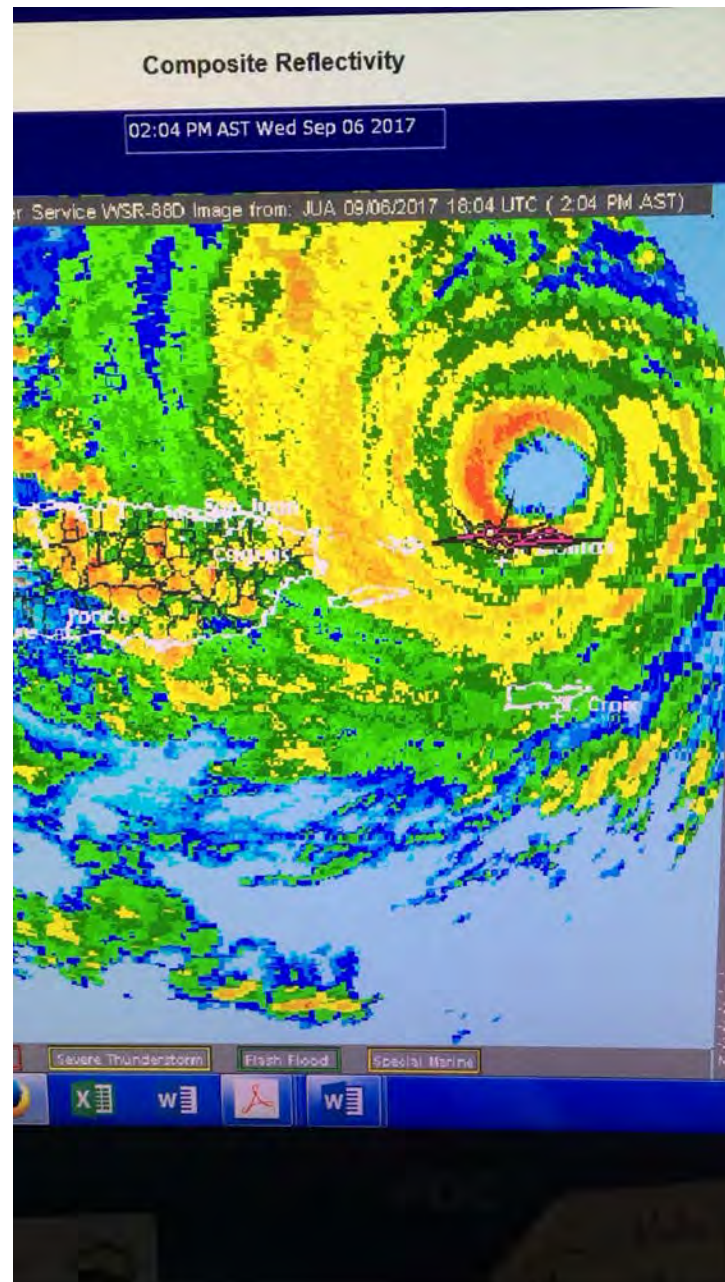
(alanbetts.com)

Our Present Challenge

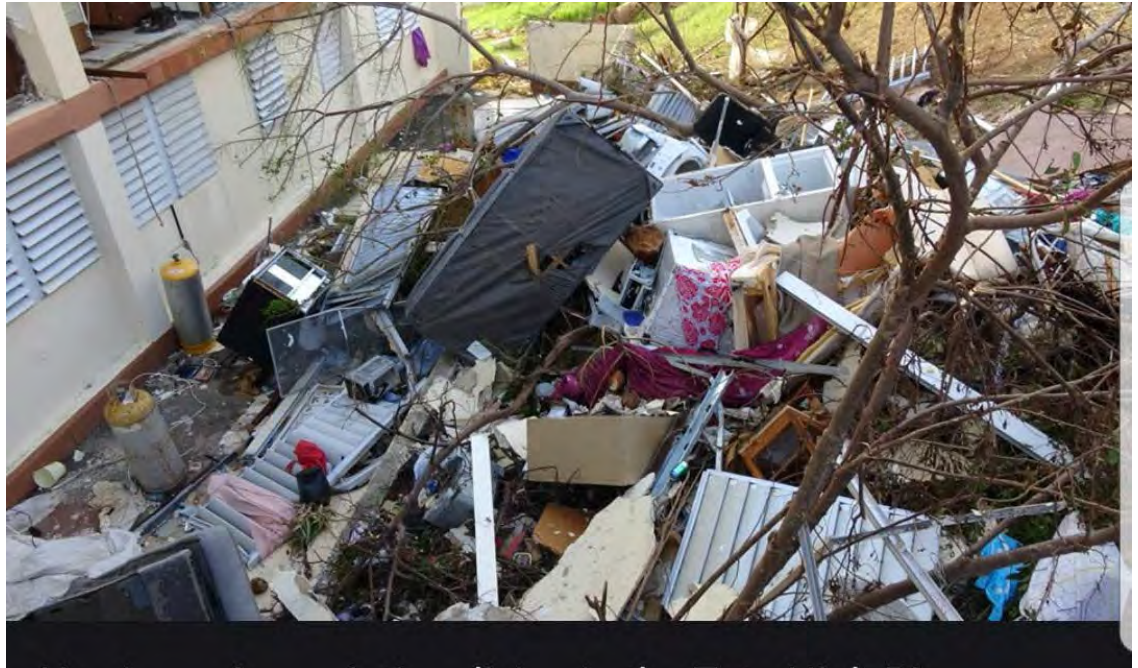
- How to reintegrate all that we know, understand and value
 - *given the deep interconnectedness of life & climate on Earth*
 - *given immense opposition to change (and fear of change)*

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



System Issues

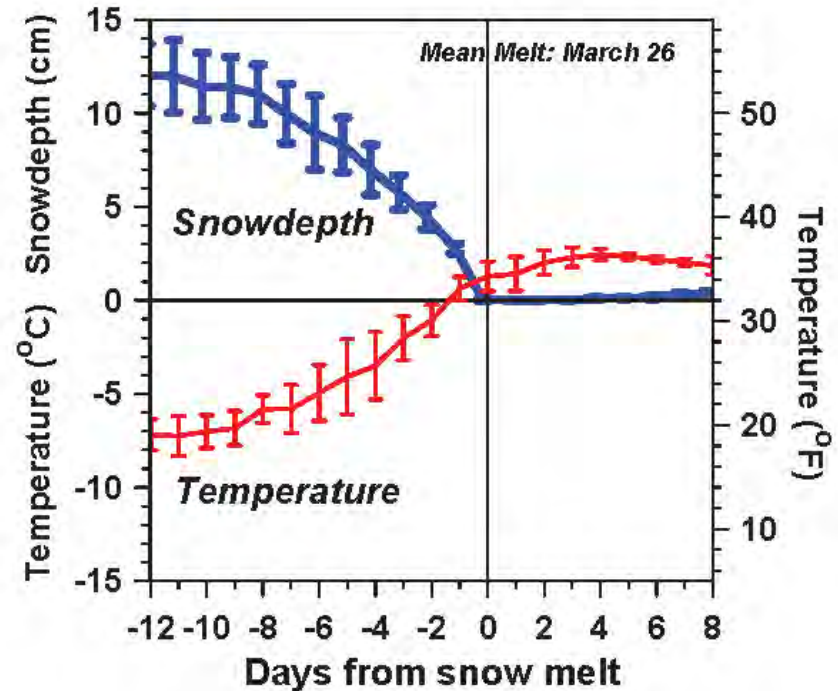
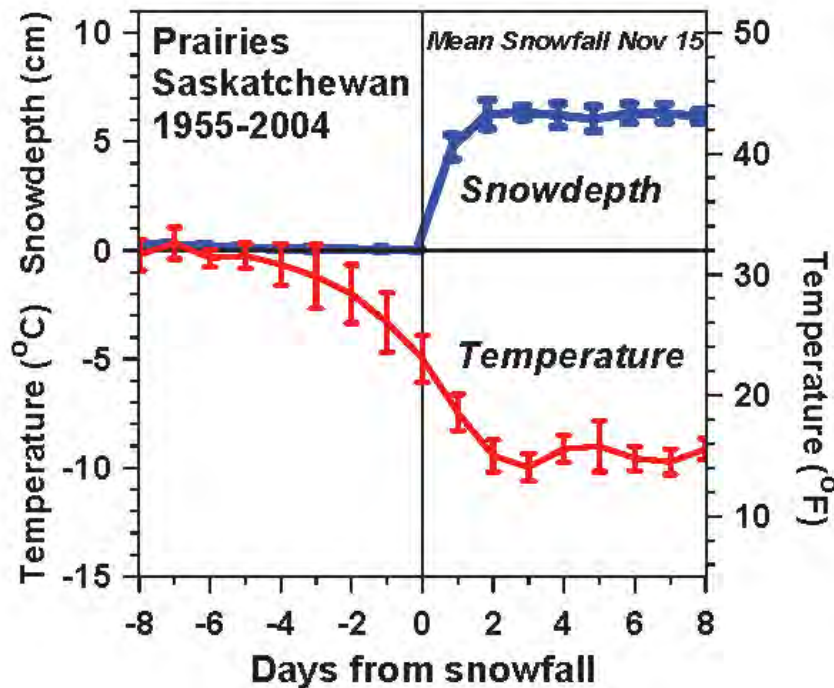
- **Human waste streams are transforming the Earth's climate, and human and natural ecosystems**
 - **That will affect landscape, water supplies, food system, human health – and natural world**
- **New strategies and mindset needed**
 - **Can we better manage our relation to the Earth?**
 - **Is this an efficient way of doing this?**
 - **Can we manage our waste streams better?**
 - **Can we replace profit as the primary guide?**

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 the oceans
- *In our disconnected human world, these are harder for us to deal with*

Snowfall and Snowmelt

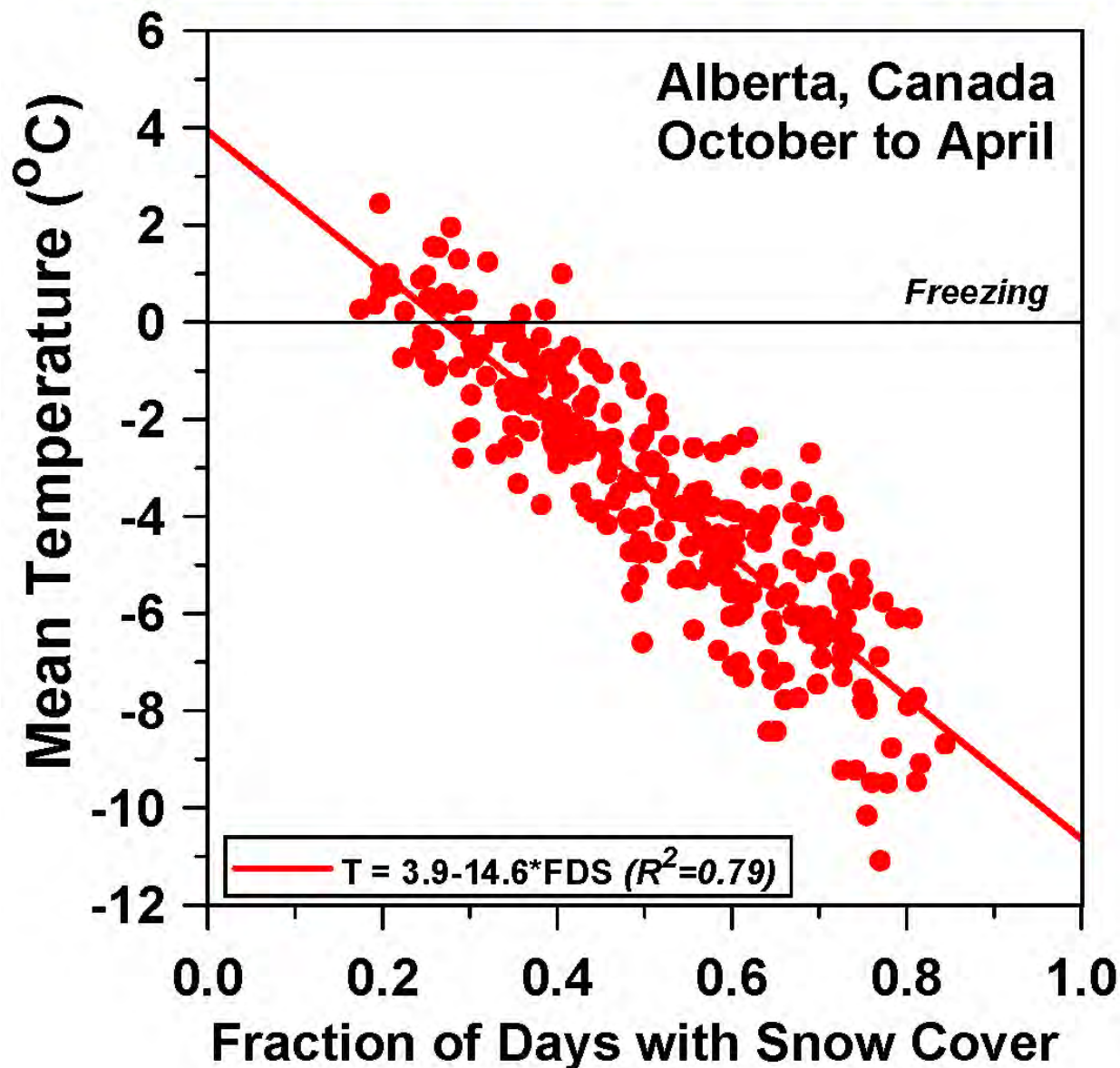
Winter and Spring transitions



- Temperature falls/rises about 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 “climate switch”**

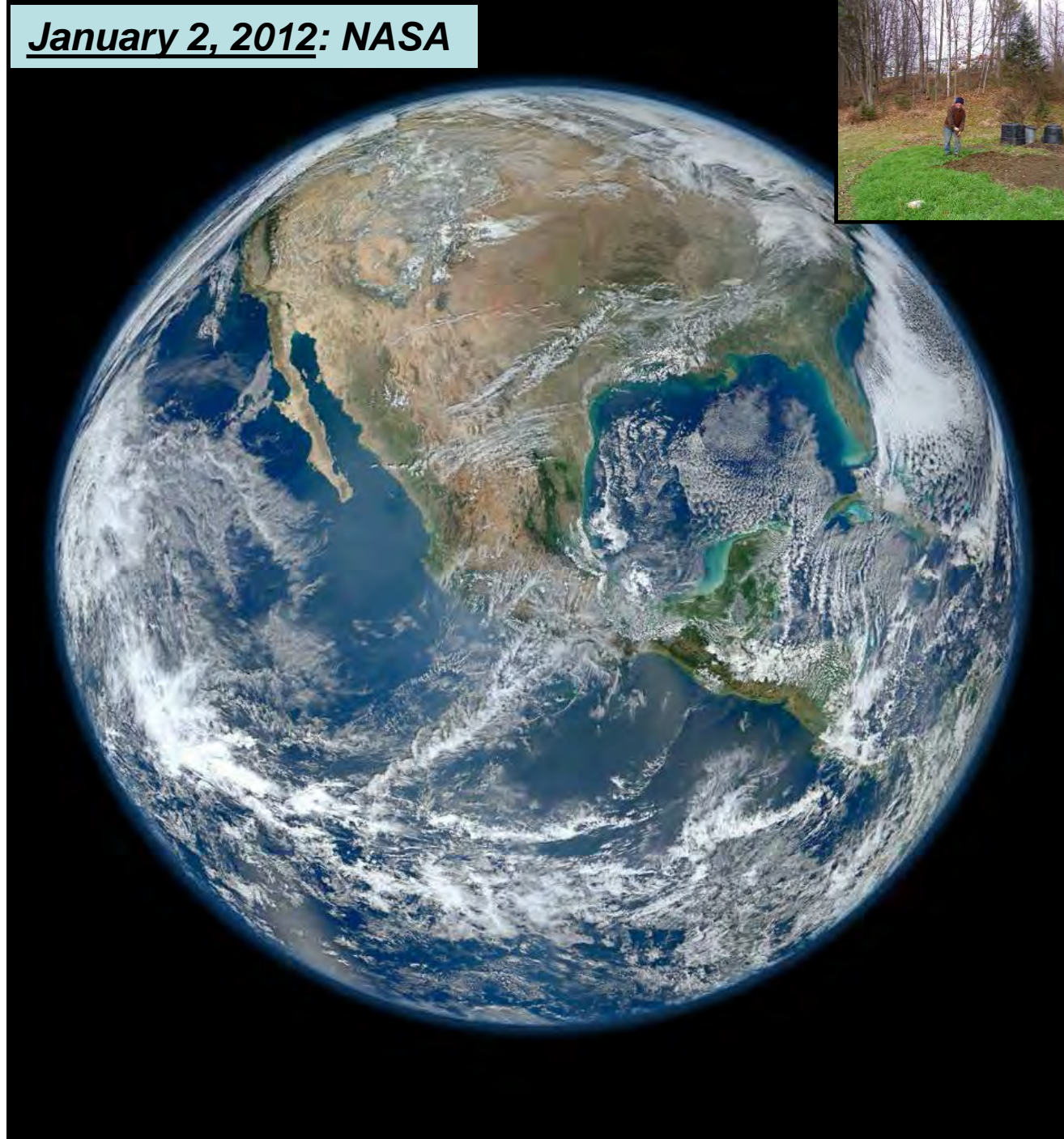
With snow

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

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
- Global patterns changing

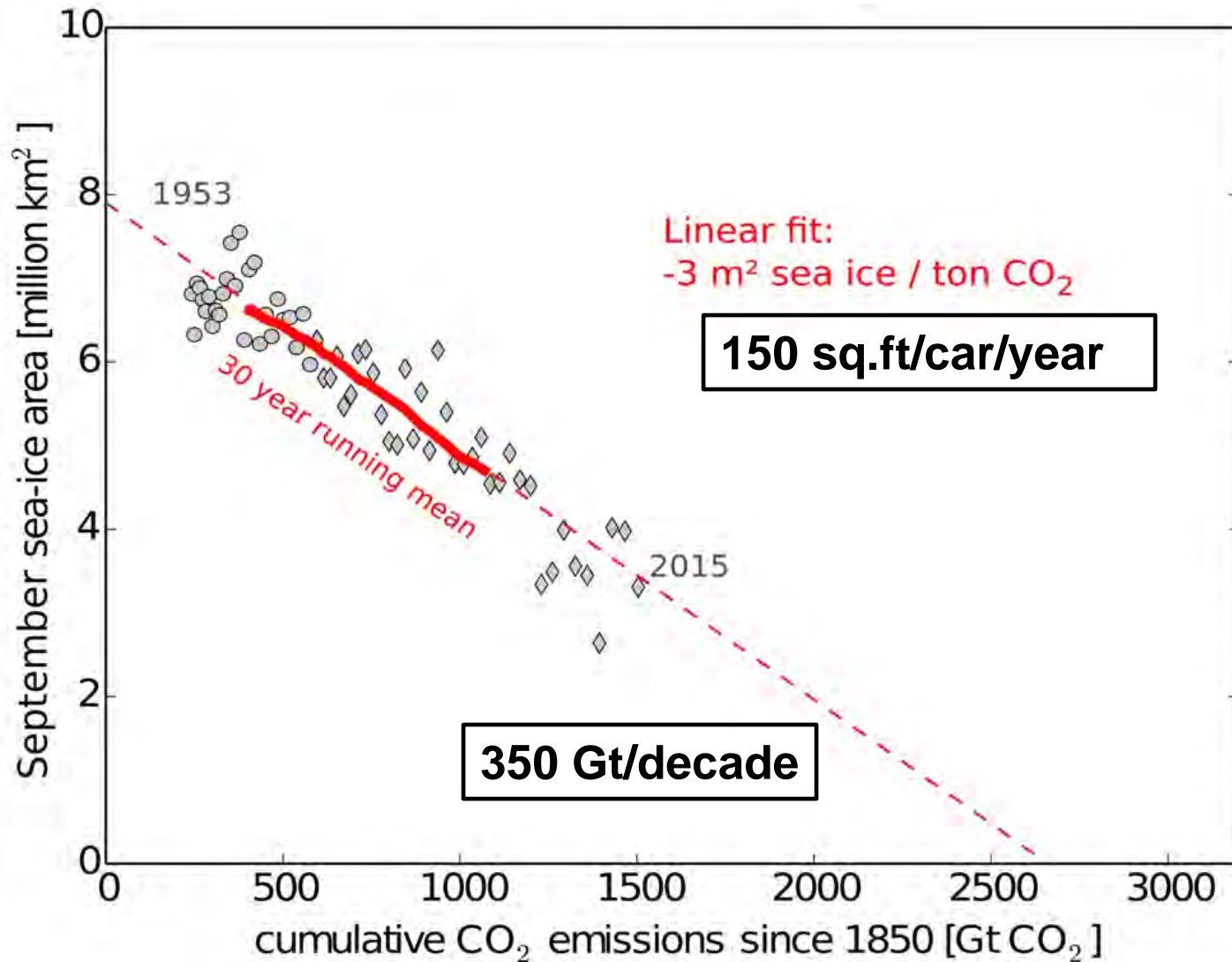


- Half the Arctic Sea Ice Melted in 2012
- Open water in Oct. Nov. gives warmer Fall in Northeast

- 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

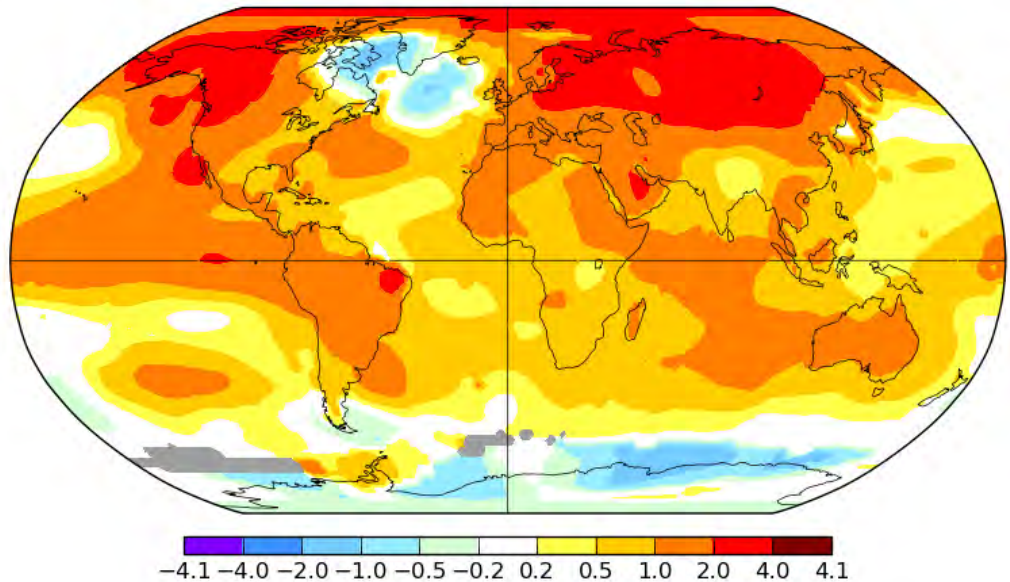


Annual J-D 2015

L-OTI(°C) Anomaly vs 1951-1980

0.85

2015
1.5F warmer

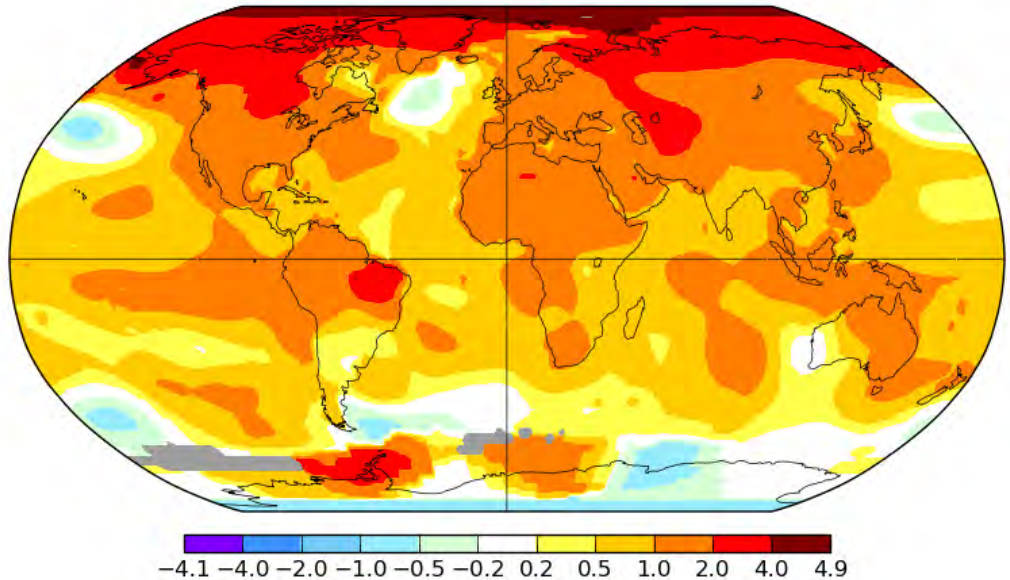


Annual J-D 2016

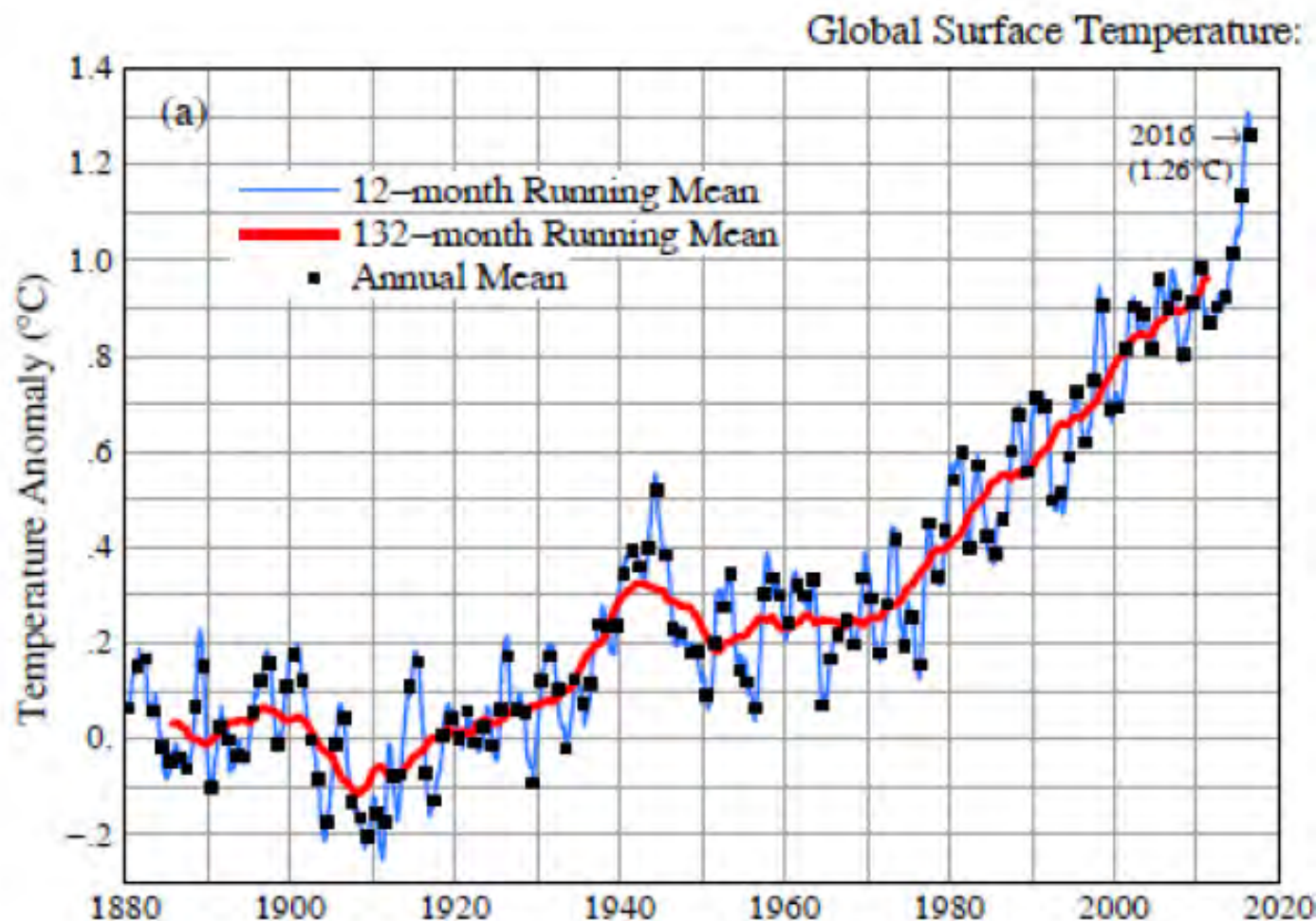
L-OTI(°C) Anomaly vs 1951-1980

1.00

2016
1.8F warmer
*(Arctic ice lowest
ever in winter)*



Long-term Global Mean Trend 1880-2016



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)

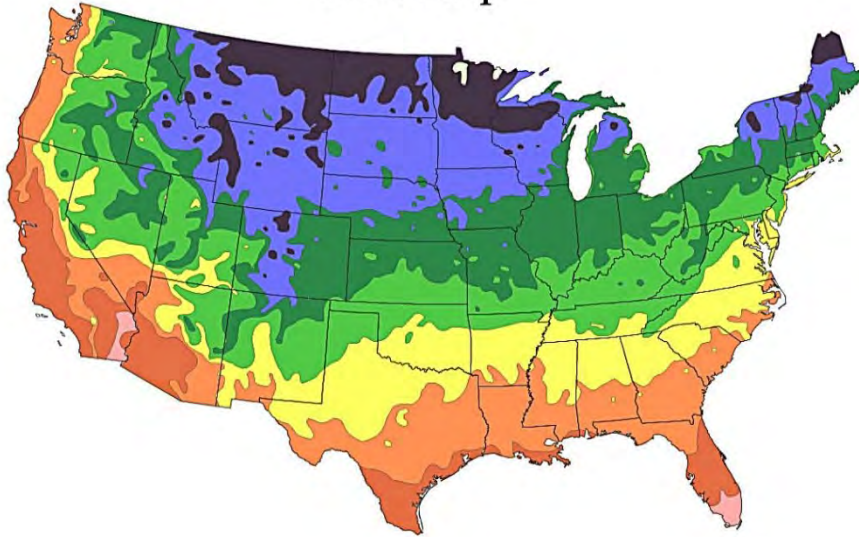


March 3, 2017



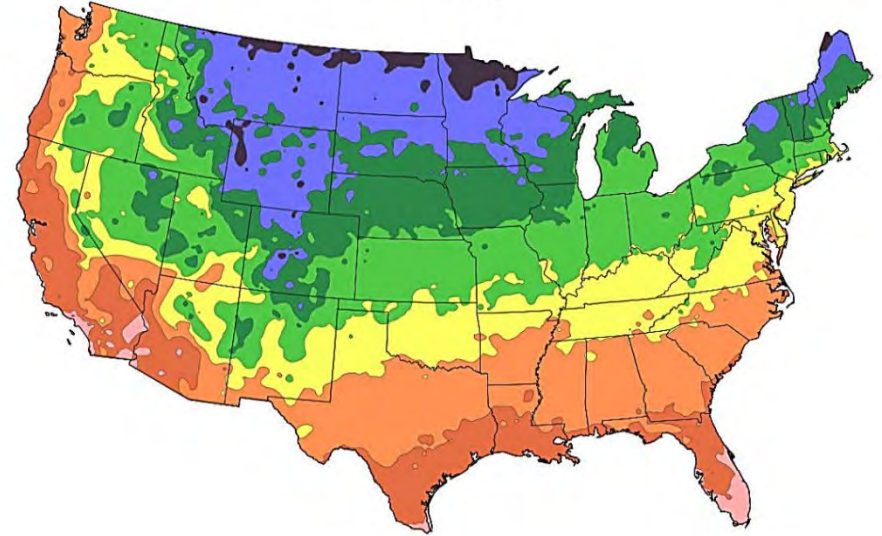
Plant Hardiness Zones

1990 Map



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

2015 Map



Arbor Day Foundation Plant Hardiness Zone
Map published in 2015.

Zone



© 2015 Arbor Day Foundation®

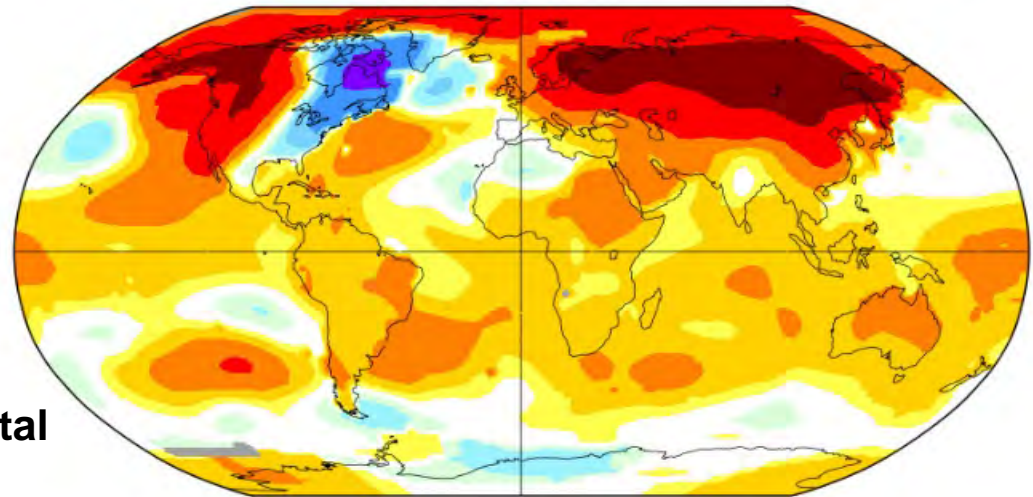
Jan-Feb-Mar 2015

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

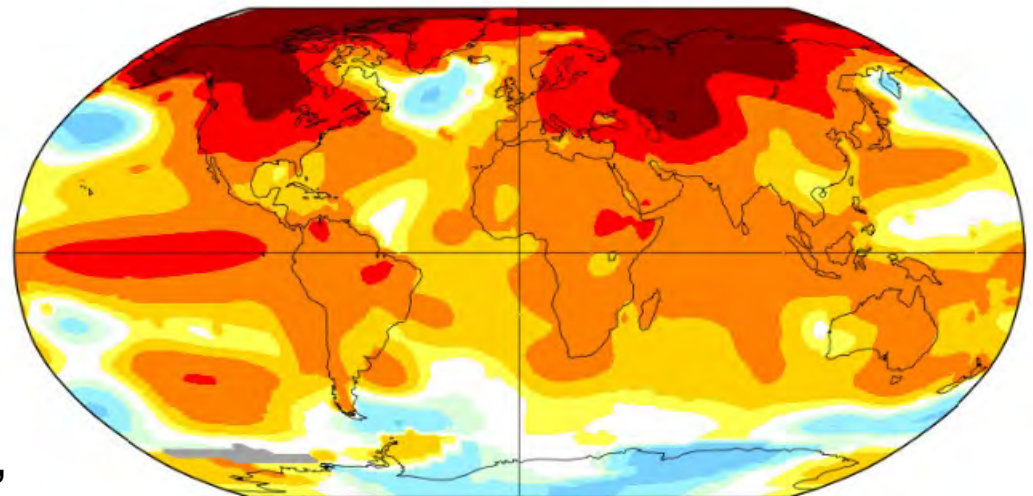
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow,
warm Arctic

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

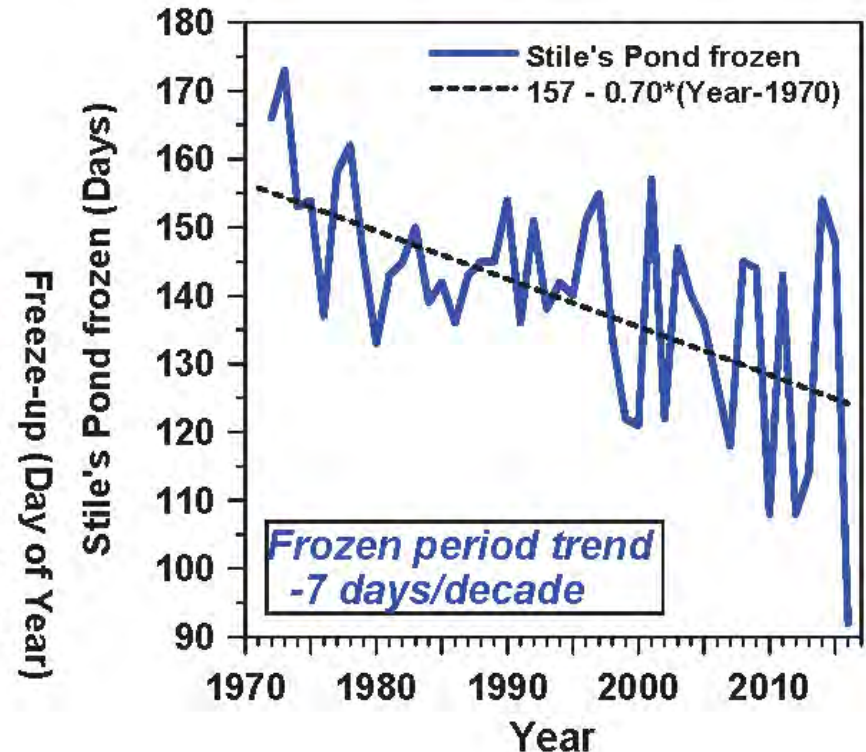
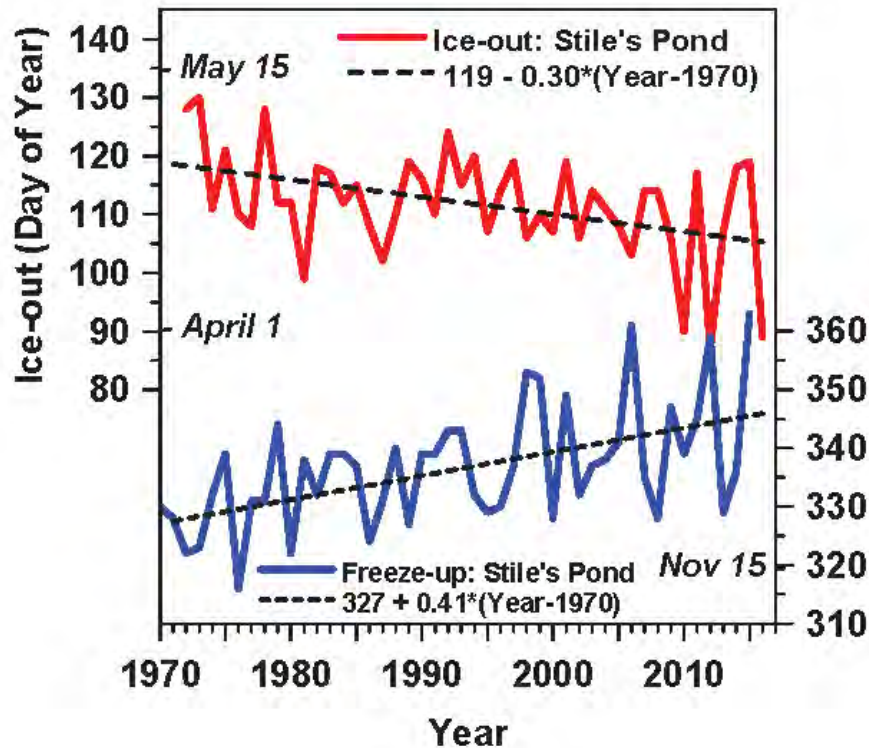
1.24



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

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"

Warm winter with little snow

Early Spring: *79°F on March 22, 2012*



Pittsford Vermont

3/22/12



Pittsford Vermont

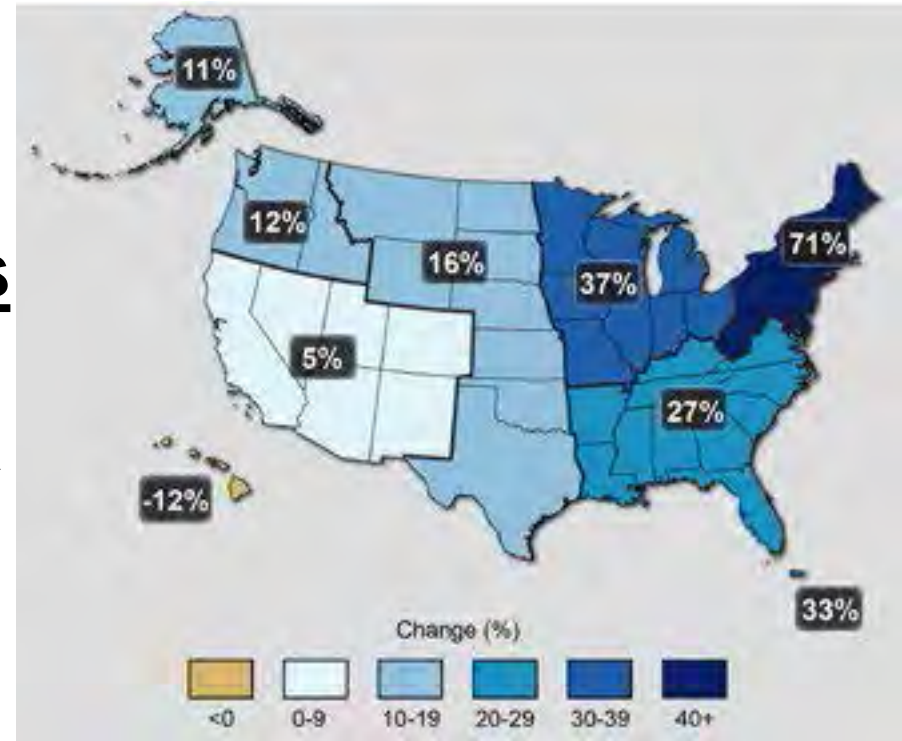
3/24/12

2012: Daffodils, forsythia bloomed 3/23/2012

2017: Daffodils and forsythia bloomed 4/17/2017

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**



(Walsh et al., 2014)



Brattleboro, VT, Courtesy of
Caleb Clark, CNN



Brattleboro, M. Reston



Wilmington, J. Cantore

TS Irene

Roads in valleys

Massive damage

**Some roads took
months to repair**

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

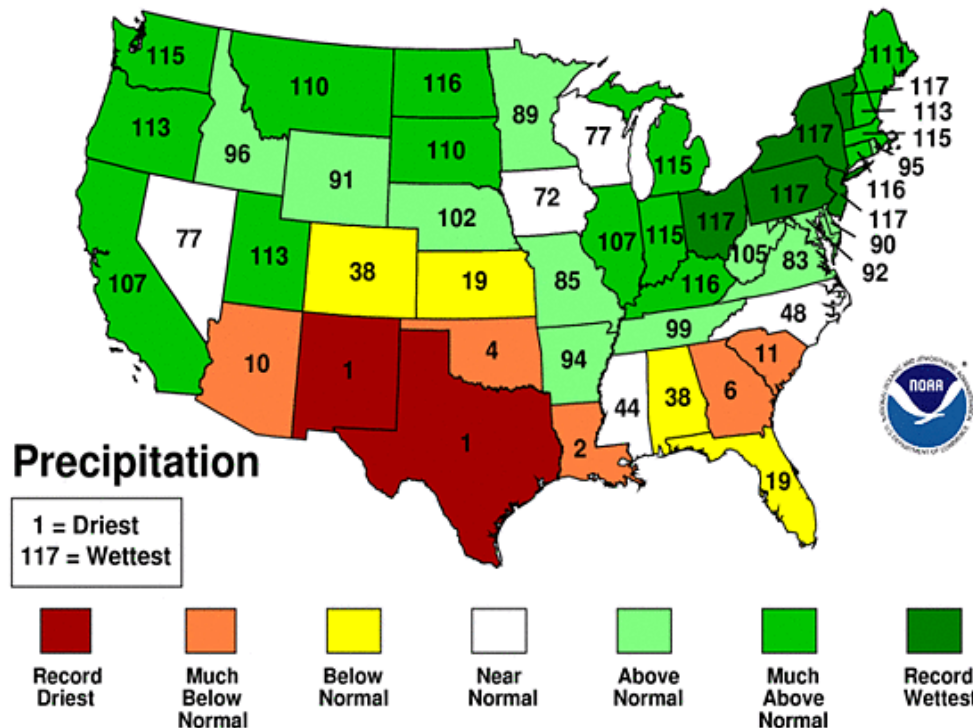


2011 Floods: VT and NY

- 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**

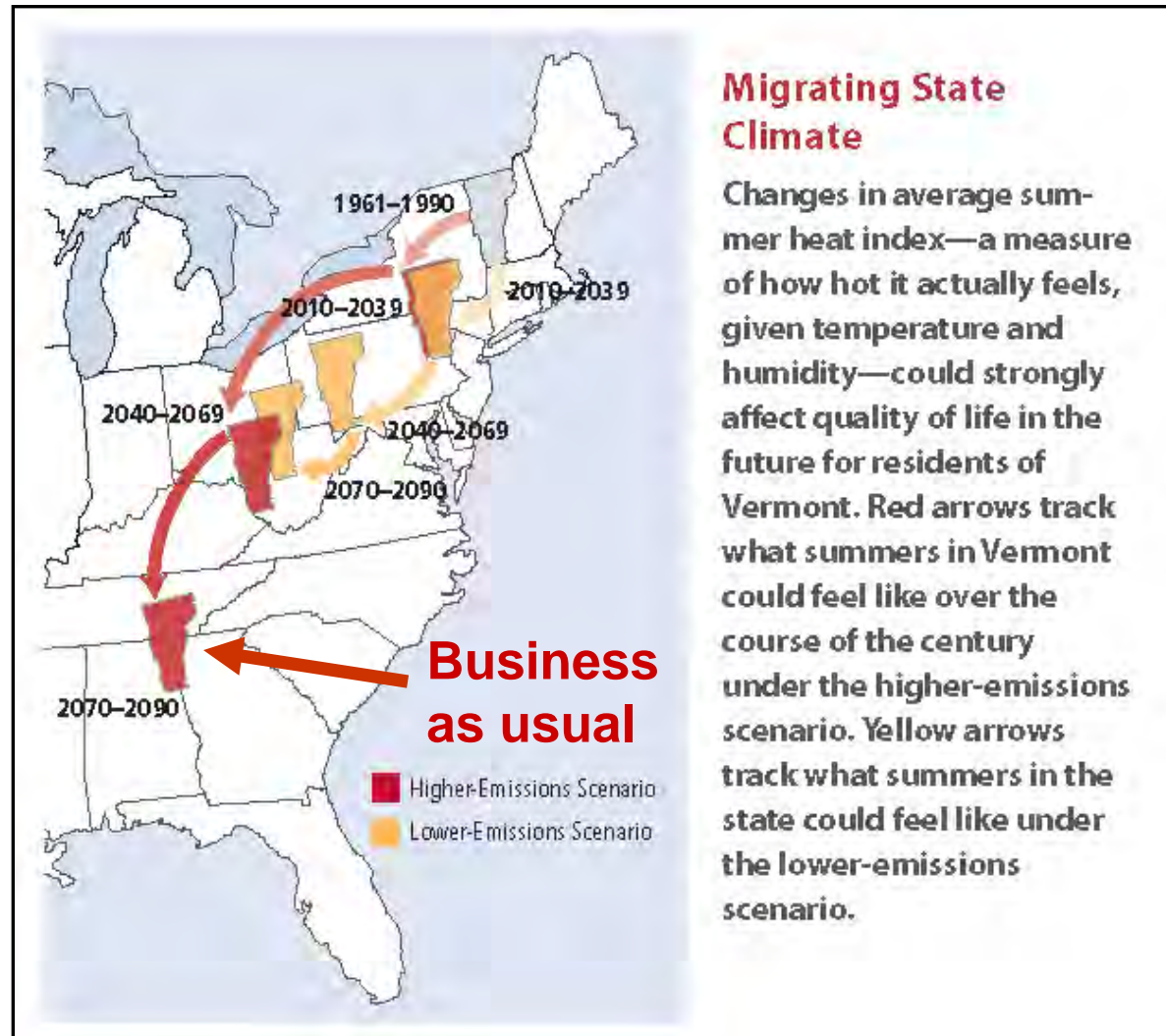
Flooding Issues

- **Maintain mountain forest cover**
 - Devastating floods in 1920's, 30's with reduced forest cover
- **Manage water 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

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



Can We Stop “Dangerous Climate Change”?

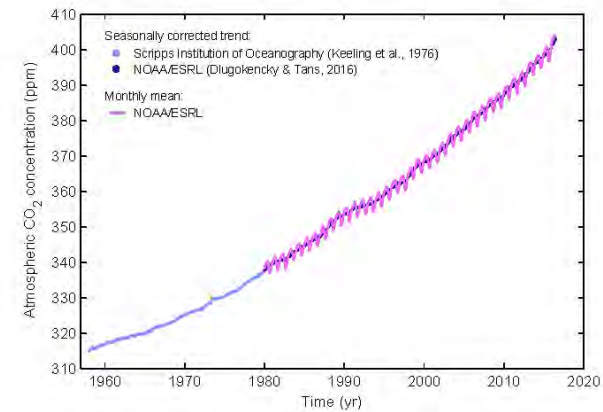
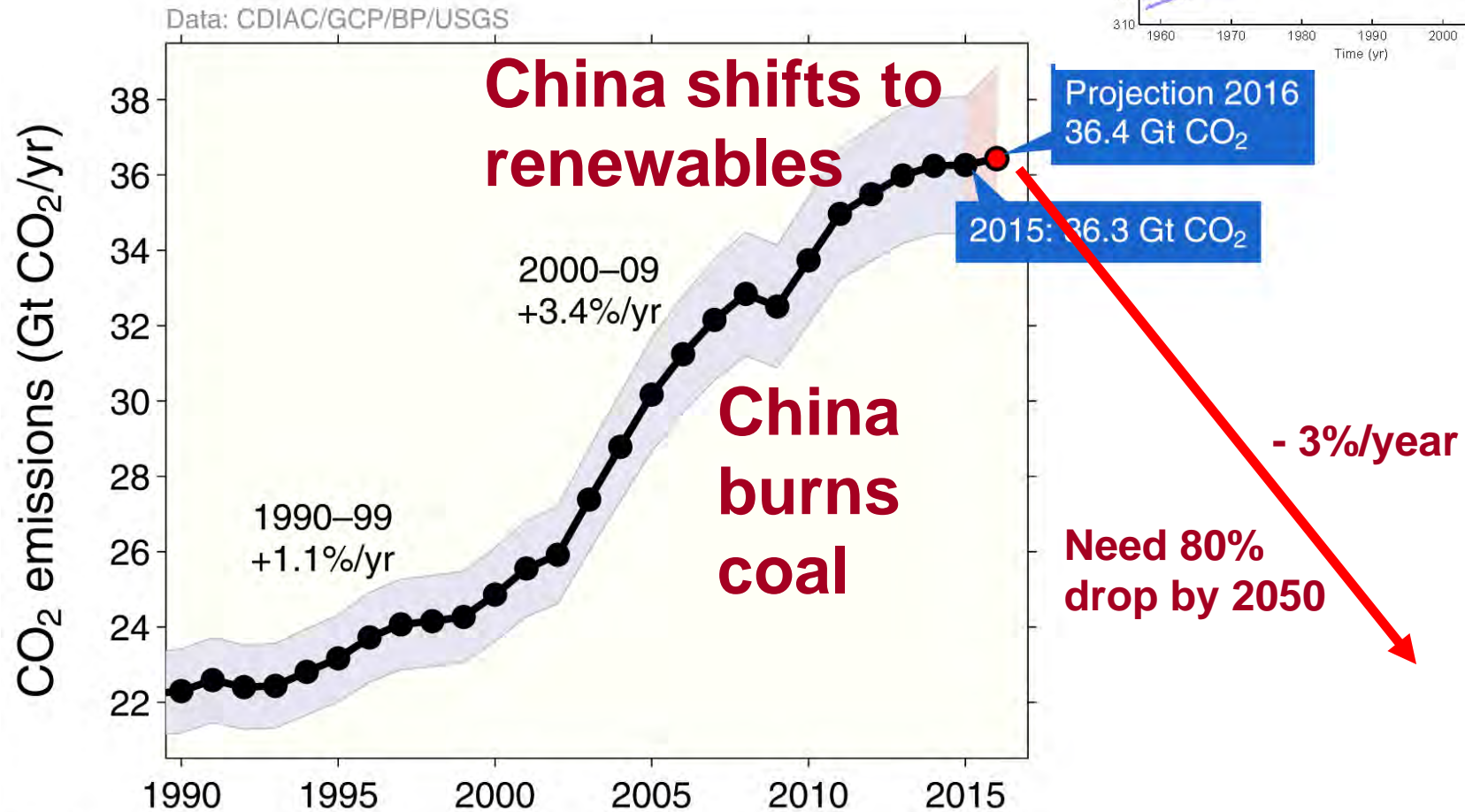
(UNFCCC 1992)

- **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

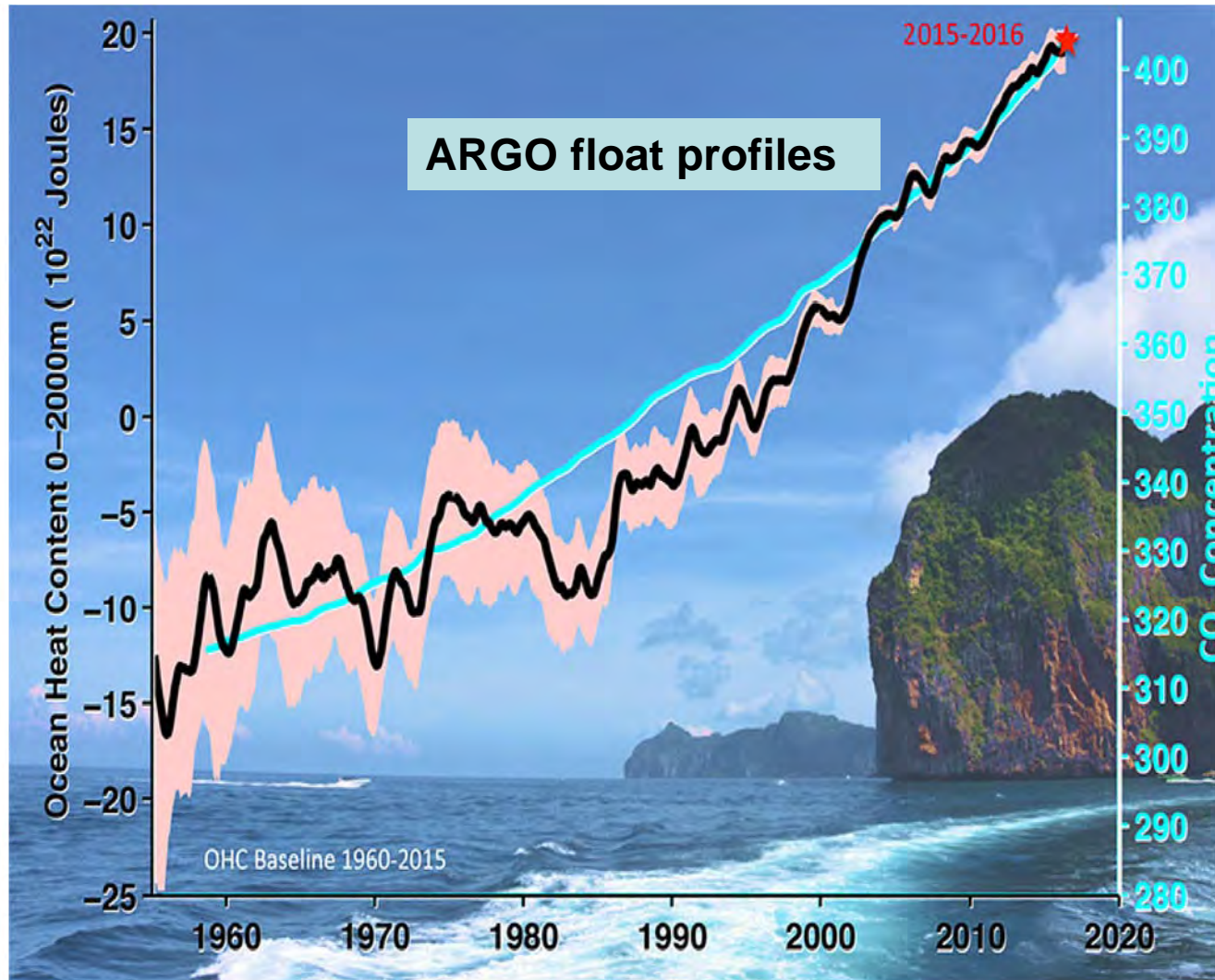
2015 was Transition Year

- **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



Ocean Heat Storage – CO₂



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 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*

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*

New Value-based 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/nitrogen loads on streams/lakes
- ***Reconnect with natural world***
 - *Fundamental if we are to embrace transition*

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
- ***Our politics are facing collapse:
fantasy disconnected from real world***
 - *We are deeply embedded in system!*

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!*

Practical Local Solutions

- **Where I live (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*
 - *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

“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)

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

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 Earth?
 - *Shift in understanding and mind-set needed*