

# Climate Change and Community Resilience

**Alan K. Betts**  
**Atmospheric Research**  
Pittsford, VT  
<http://alanbetts.com>

*UVM class*  
*“Smart Resilient Communities”*

*January 30, 2018*



# Strategies for Resilience

- Understand technical/ecological issues
  - Don't build bridges with alternative facts
- Engineer for efficiency and resilience
  - Not “cost effective for today's bottom line”
- Spend \$1 trillion on climate resilience
  - saves \$60 trillion later this century
- If we ignore climate change
  - costs to human civilization and Earth's ecosystem catastrophic
- Community resilience!



# Fundamentals

- ***Burning fossil fuels: transforming climate***
  - *Many water cycle amplifying feedbacks*
  - *Heading for high CO<sub>2</sub> “Carboniferous era climate”*
  - *Climate extremes increasing.*
  - *Severe weather costs: \$300B in US this year*
  - *Decadal to centennial - long timescales*
- **Avoidance of responsibility for decades**
  - Politicians, professionals, public
  - Climate change: Incompatible with business-as-usual
- **Linked to unmanaged technology**
  - Soluble by changing system guidelines
  - Create efficient society, based on renewable energy
- **Choices are value based**
  - Beyond science and economics
  - Community based

# 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, energy, human health, ecology?
- What strategies and mindset are needed to mitigate, adapt and build resilience in Vermont, US and the world?
  - 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; how can ecosystems adapt?

# Strategies and Mindsets

- **Technology will save us**
  - No need to change our behavior
  - Economics based on individual consumerism produces wealth
  - Future costs can be discounted
- **Climate, life & humanity interwoven**
  - Environmental intelligence crucial
  - Community resilience and values essential
  - Intergenerational time-frame

# Aside: Economic ‘Doctrines’

- “Free market” promotes material growth
- “Regulation” interferes with growth, & the exploitation of Earth’s resources & the poor
- The assets and interests of the wealthy must be protected, since they fund politicians
- Choices must be “cost-effective” now: future costs can be discounted and paid for later
- *Climate change and current economics are incompatible since Earth does not discount the future - accumulates energy imbalance*
  - *Catastrophe ahead for our children and all life*

# Environmental Intelligence

- **“Blend of natural science, social science and indigenous knowledge that helps humans interact constructively and creatively with the living natural world”**
  - (Rather than exploiting the environment to support the profits of corporate donors)
  - (Dumping current and future costs on the poor, the indigenous, our children and all life)
- **Conscious challenge for this class**

# Community Resilience

- Shared local infrastructure, resources, knowledge and awareness
  - Designed to maximize efficiency and renewable energy use
  - Localized shared food supply
  - Shared efficient transport system
  - Support ecosystems long-term
  - *Contrast to 'happy isolated individuals addicted to consumerism, escapism and the media'*  
(Joanna Macy)
  - *Cannot make the shift without community*



# Local Food

- Rapid growth in local food
  - Year-round market in Rutland
  - Farm to plate; to schools/institutions
- Local community and state support of shift to (organic) local food supply
  - *Diversification of crops and growers*
- Technology shift
  - *Unheated high tunnels and row covers*
- Favorable climate shift: 1 climate zone

# Gardening in Vermont for 40 years

- How long was growing season in 1970s?
  - About 125 days: now 155 days
- How long was the ground frozen?
  - About 155 days: now 125 days +-
    - No longer hard freeze in November
- Winter climate zones in 1970's were?
  - Zones 4-5: now zones 5-6 (10F warmer)
- BUT variability increasing

# My Wake-up Call: Gardening in January, Pittsford, VT



**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)





# January 10 and 12, 2018



**January 10, 2018**

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

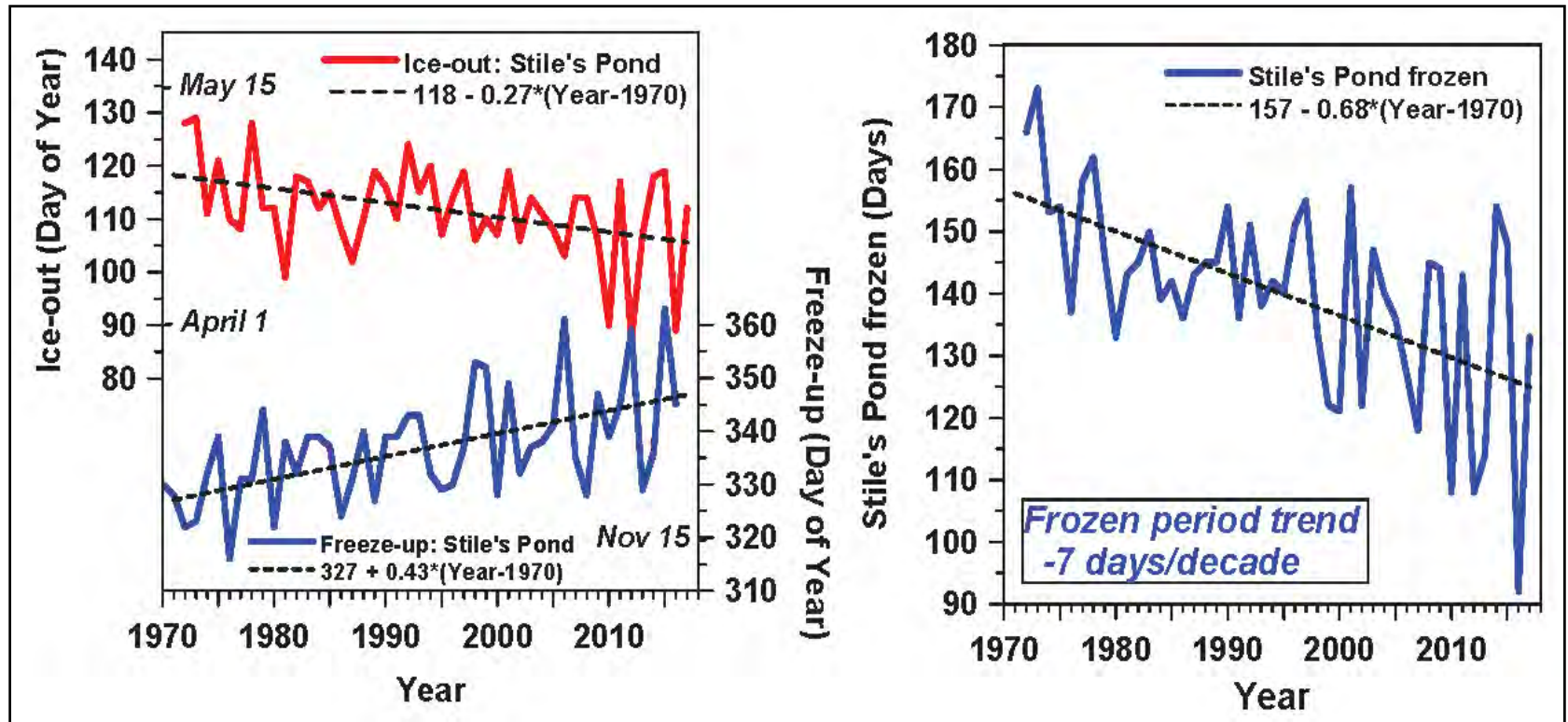


**January 12, 2018**

**After  $T_{\max}$  up to 50F**

# 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"*



# Stationary modes

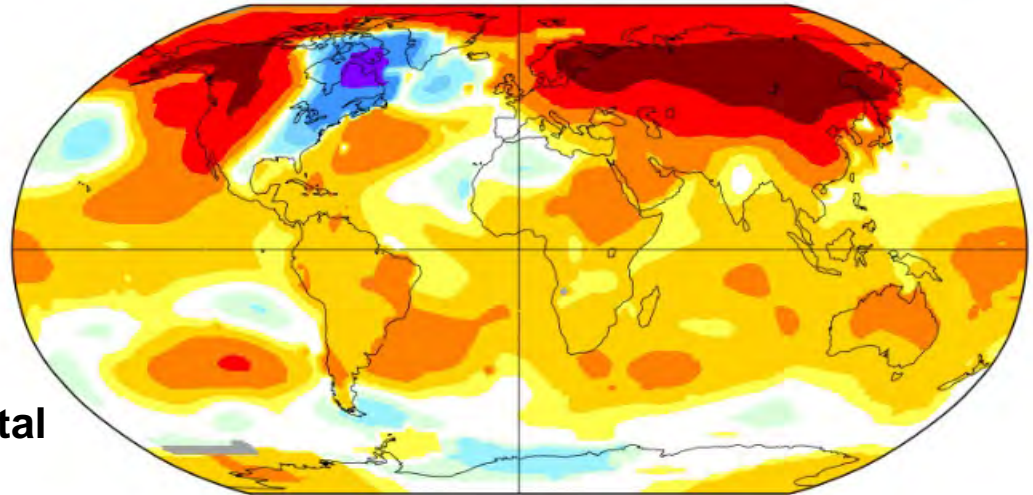
## *Jan-Feb-Mar 2015*

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

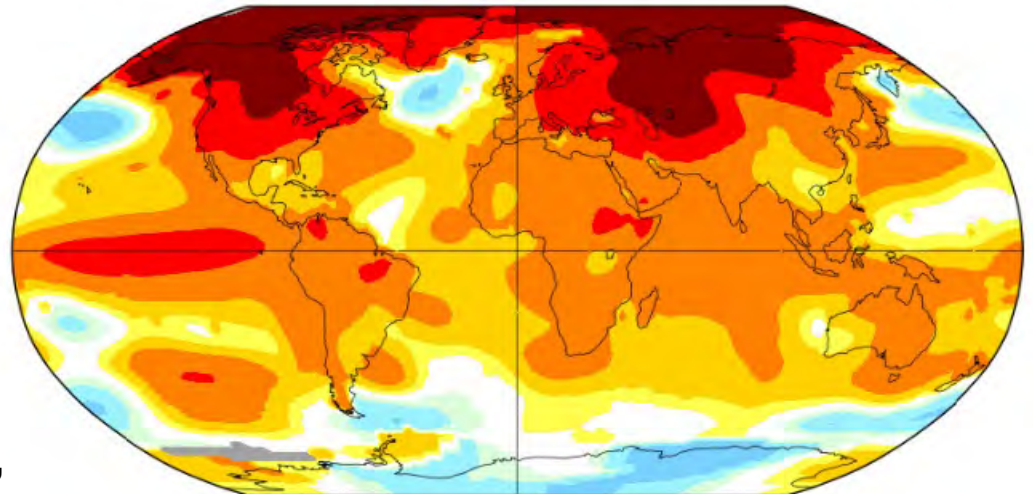
## *Jan-Feb-Mar 2016*

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



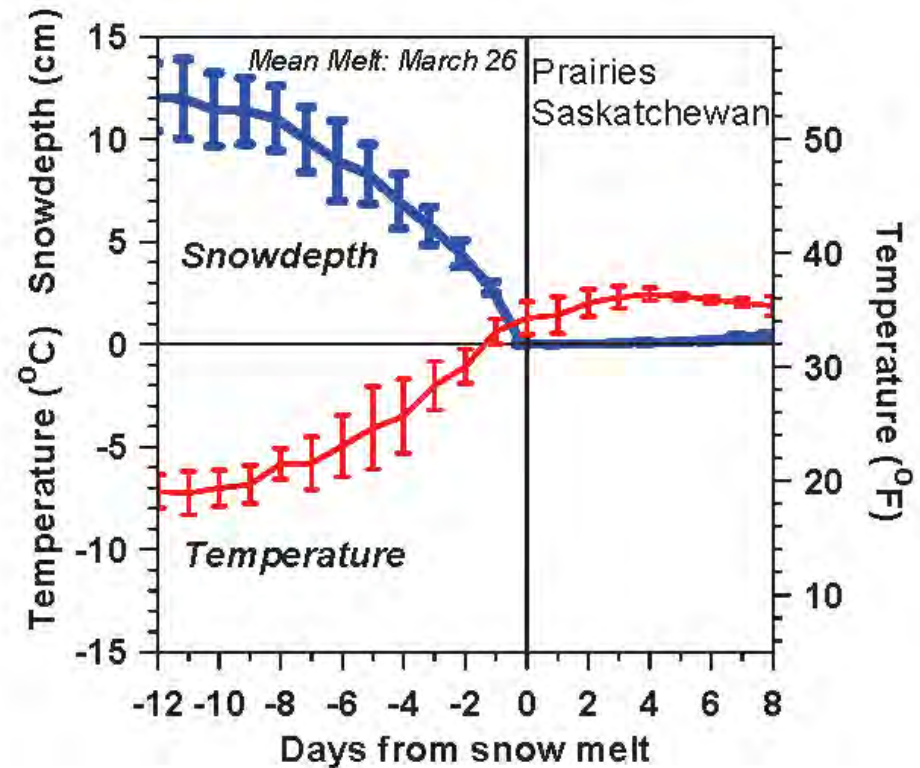
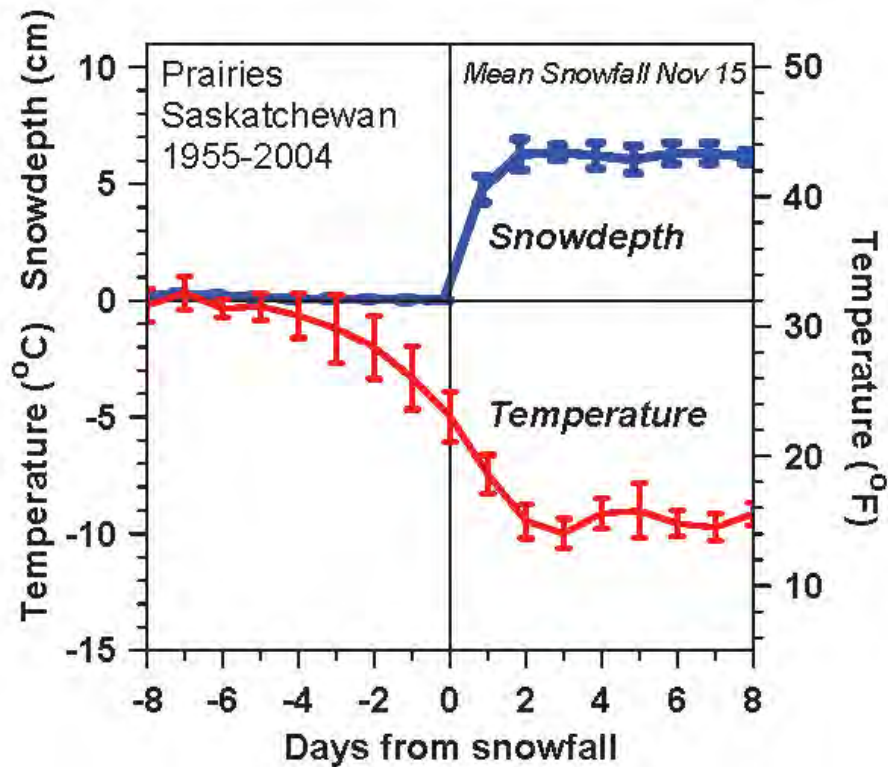
# Seasonal Climate

- What determines seasonal climate?
  - Sun heats the earth
  - Clear sky: shortwave mostly transmitted
  - Reflected by clouds and snow
  - Sun elevation is low in winter
  - Earth cools to space in longwave/infrared
  - Trapped by atmosphere and clouds
  - Reradiated down to surface
  - (Increasing GHGs reduce cooling)

# Winter Ice and Snow



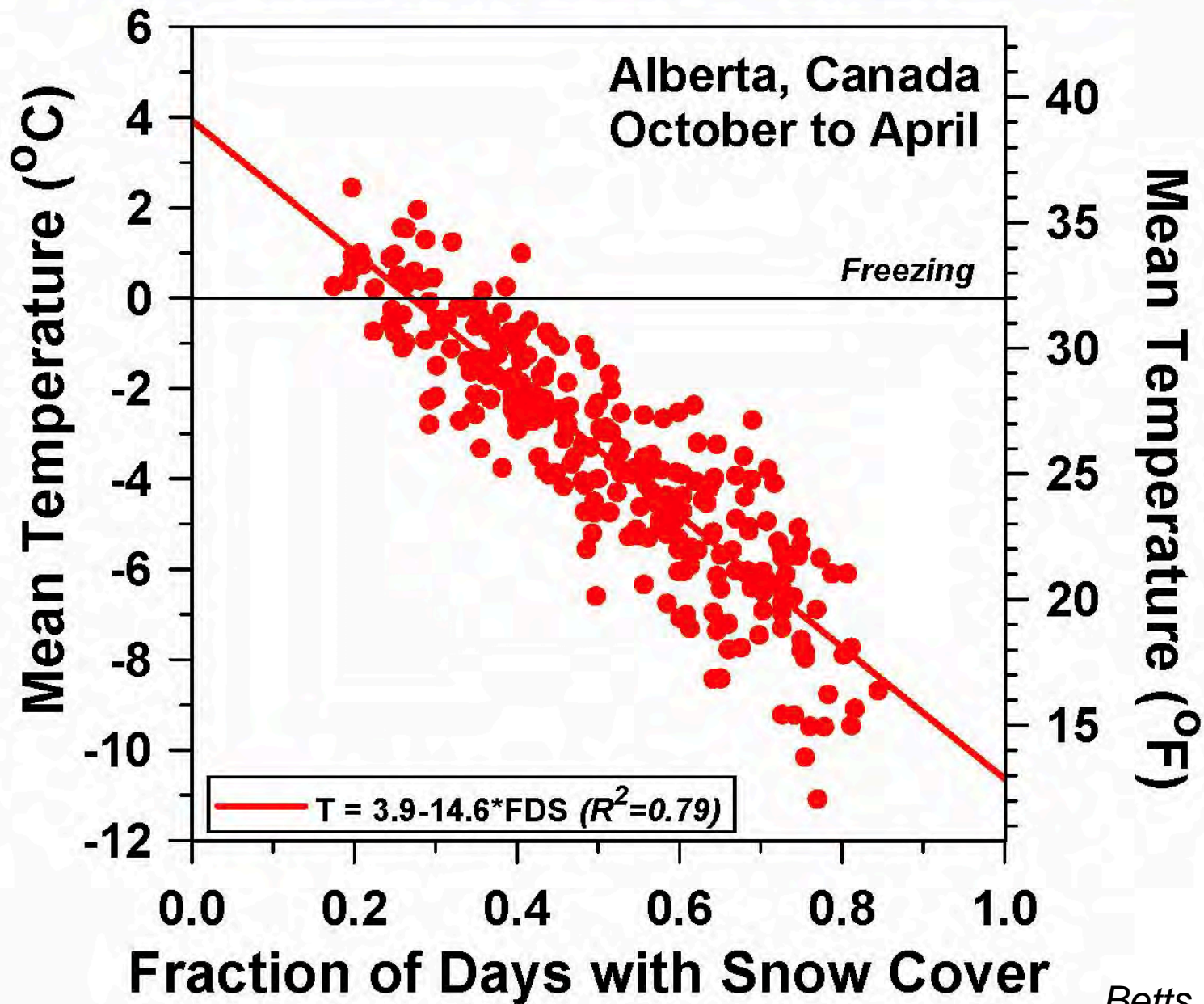
# Snowfall and Snowmelt



- Temperature falls 10C (18F) with first snowfall
- And rises again with snowmelt
- *Fast transitions in 'local climate'*
  - *Snow reflects sunlight: Climate Switch*
  - *Reduces evaporation and water vapor greenhouse*

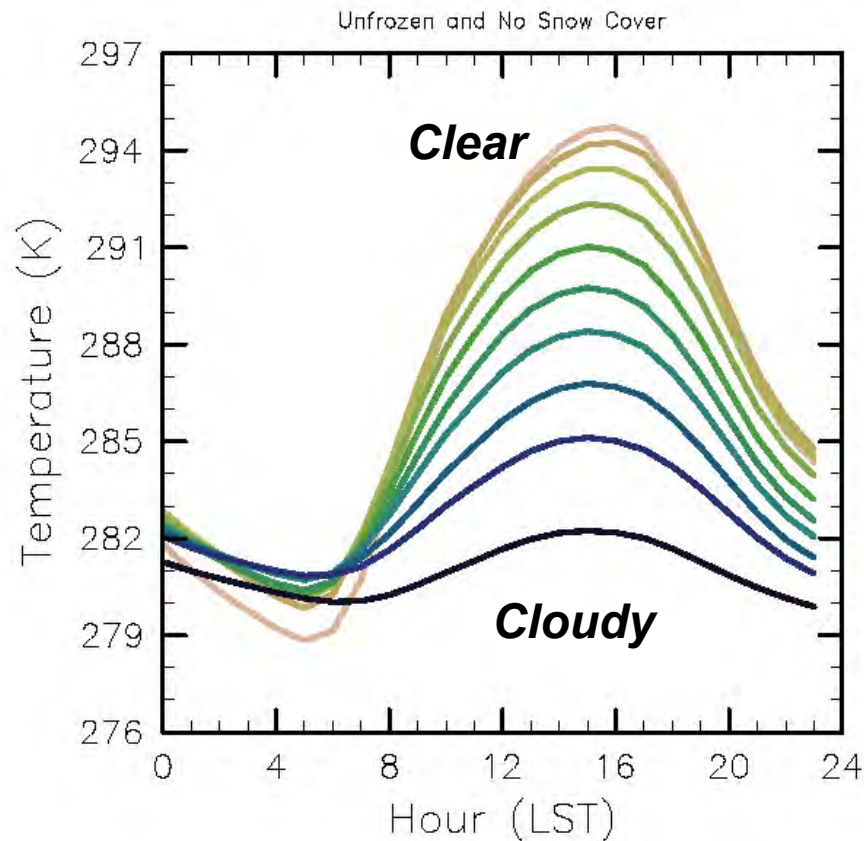


## More snow cover - Colder temperatures

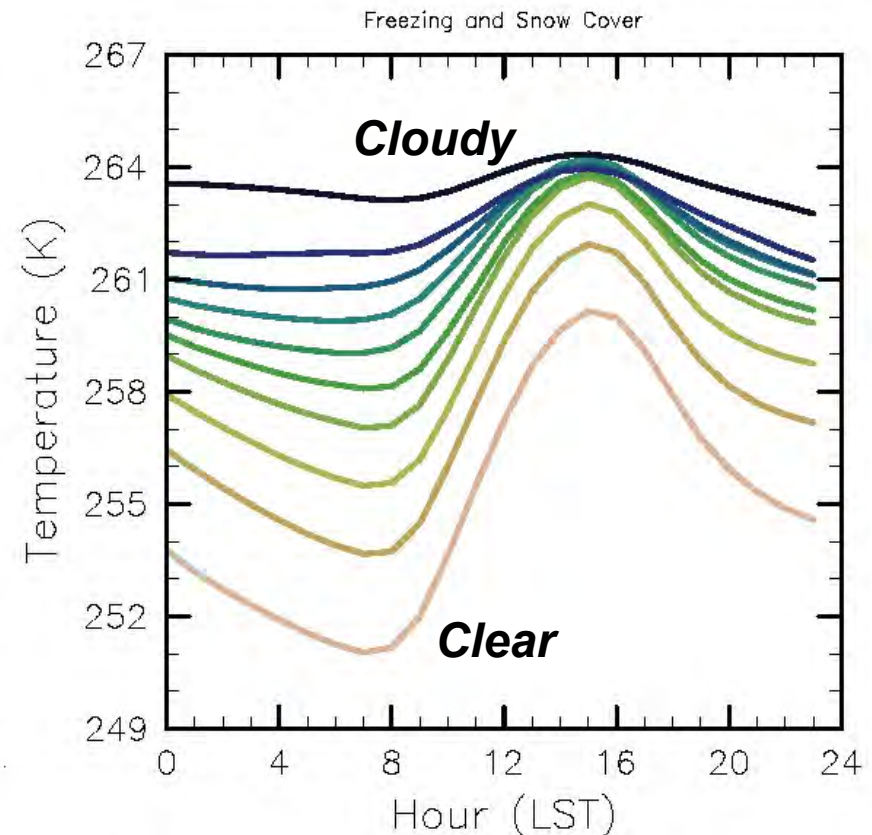


# Warm & Cold Climates: $T > < 0^{\circ}\text{C}$

$T_m > 0^{\circ}\text{C}$ : no snow: 150,000 days



$T_m < 0^{\circ}\text{C}$ : snow: 75,000 days



- **Warm  $> 0^{\circ}\text{C}$ : Clouds reflect sunlight**
- **Cold  $< 0^{\circ}\text{C}$ : Clouds are greenhouse & snow reflects sun**

# Food Issues

- **Milder winters and longer growing season in Northeast**
  - Over-winter more crops; start spring crops earlier under cover
  - But increasing variability of winter weather
- **Summer changing also**
  - Increasing precipitation extremes
  - Flood-plain and soil water management
- **Increasing drought in central and western US**
  - Fire threats rising
  - *Critical fresh water issues world-wide*
  - *Many pumped aquifers near exhausted*

# Extreme Precipitation Increasing

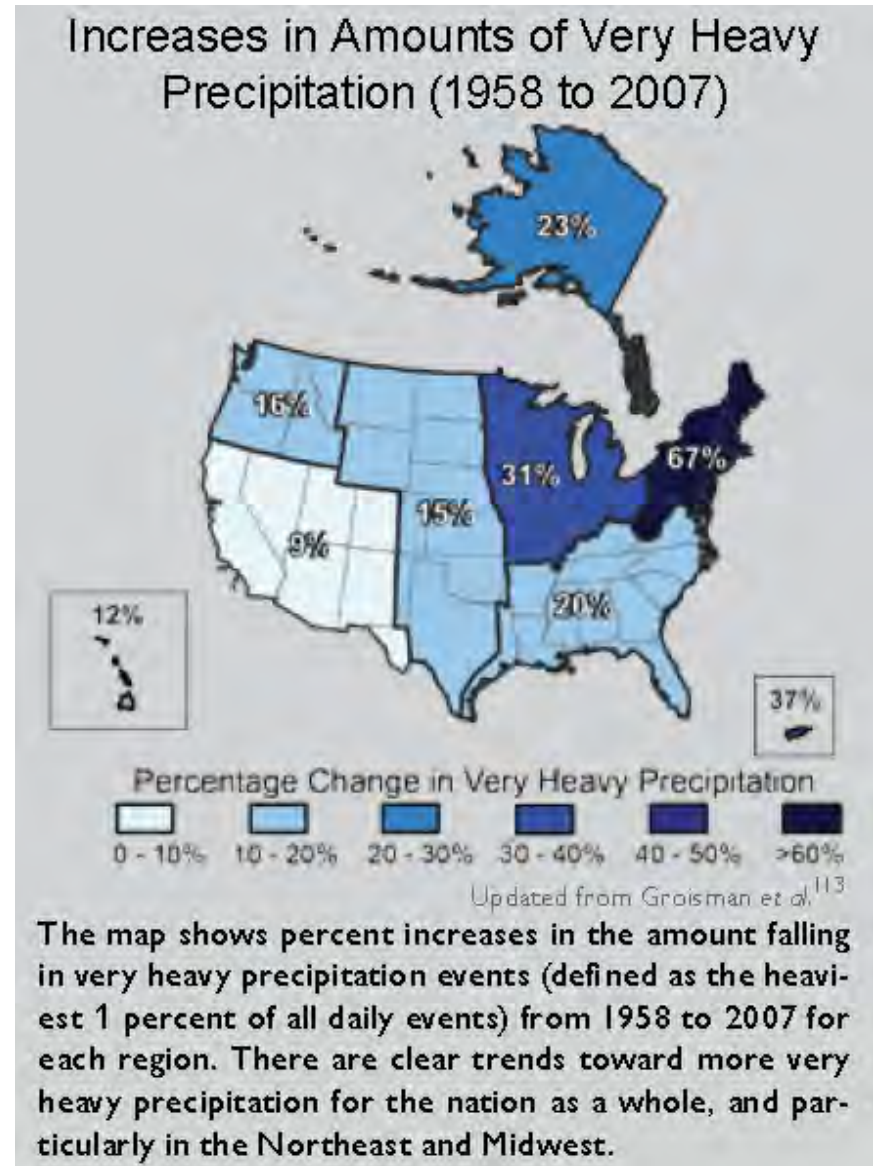
- Vapor pressure and rain rates go up steeply with temperature
- Background drivers
  - Lakes are warming as winter ice shrinks
  - Oceans are warming as GHGs reduce cooling of Earth to space: store 90% of energy imbalance
  - Evaporation goes up steeply as water warms
  - Coastal storms and hurricanes become stronger
  - *Hurricane Maria intensified from Cat 1 to 5 in 24h*
- More *quasi-stationary* weather patterns
  - So it rains for longer
  - *Hurricane Harvey sat over Houston for 4 days, raining 10 in/day*



# Very Heavy Precipitation Is Increasing

**(USGCRP, 2009)**

- **Precipitation Extremes**
- **Most of the observed precipitation increase during the last 50 years has come from the increasing frequency and intensity of heavy downpours.**
- **67% increase in Northeast**





# 2011 Classic Flood Situations

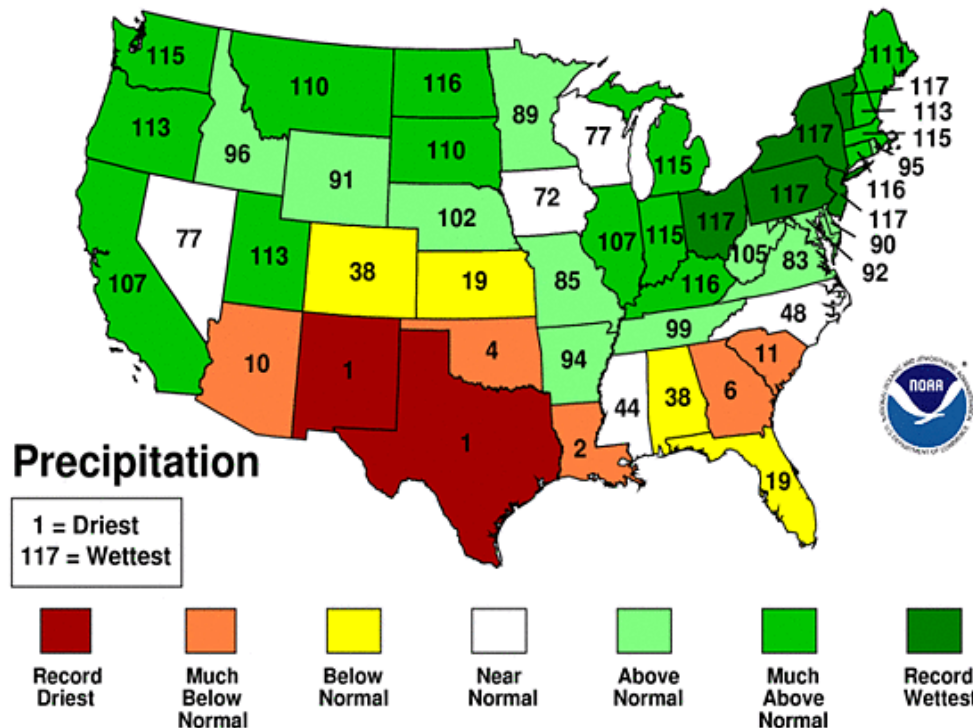
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010 winter
  - 70F (4/11) and 80F(5/27) + heavy rain
  - record April, May rainfall: 3X at BTV
  - Severe floods on Winooski and Adirondack rivers
  - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical storm** moved up east of Green Mountains and Catskills
  - dumped 6-8 ins rain on wet soils
  - *Extreme flooding*
  - (Floyd on 9/17/1999 had similar rain - but with dry soils there was less 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
- ‘Quasi-stationary’ pattern

# TS Irene

**Roads in valleys**

**Massive damage**

**Some roads took  
months to repair**

**“Resilient  
Communities”**

*Rte 131,  
Cavendish  
Sept, 2011*



# Irene: Resilience

- 13 towns cut off overnight
- State emergency systems flooded
- FEMA: no road access
- Communities reorganized overnight
- Those with equipment stepped in
  - “Can fix this in 72 hrs”: will need engineer to check bridge (Brandon)
  - “We worked 120hrs last week...” (Wardsboro)
  - Social networks collected supplies; and rescue services across mountains
  - Communication networks critical

- The Wardsboro excavator Harvey Plimpton spoke for Vermont's community spirit when he said: *"Nobody gave us permission. We just started because we knew what had to be done. We put in 120 hours last week. We worked until we couldn't work. We still have a long way to go."*
- ***When a stranded guest took Beth aside to ask what would happen when she ran out of food, she just looked at him, incredulous. "We're a farm," she said finally. "This is where food comes from."***

*(Liberty Hill dairy farm, Rochester)*



# Emergency response

Brandon: Markowski rebuilds gravel Rte 7 in 72 hrs

Pittsfield wedding 8/27:  
60 stranded to help!

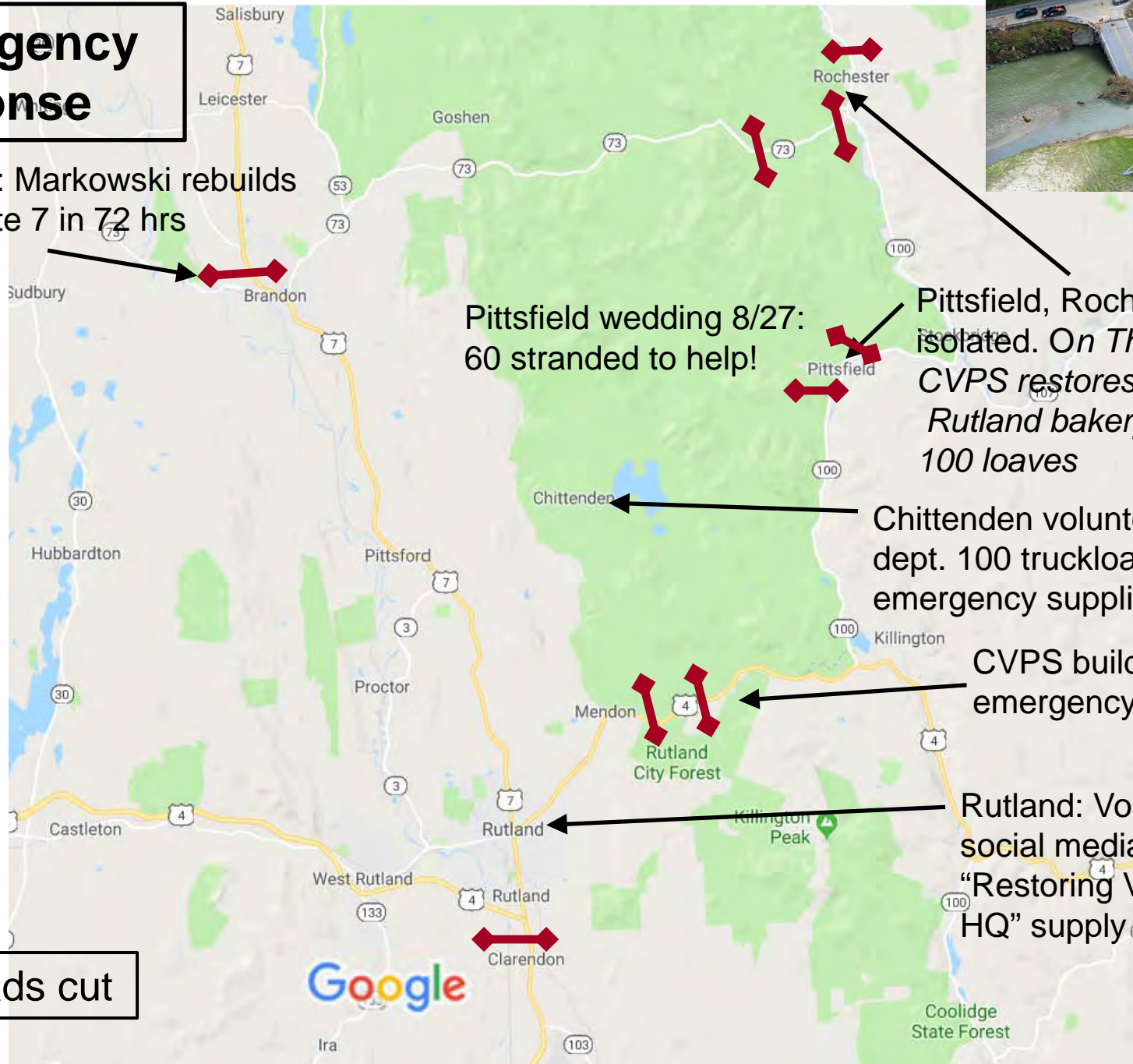
Pittsfield, Rochester isolated. On Thursday CVPS restores power; Rutland bakery supplies 100 loaves

Chittenden volunteer fire dept. 100 truckloads emergency supplies

CVPS builds emergency route 4

Rutland: Volunteers+ social media create: "Restoring Vermont HQ" supply facility

 Roads cut





# Morning After Irene

## 8/29/2011



**Streambank collapse brought  
down trees and powerlines**



# Value of Flood Plains



**Otter Creek: Aug 30, 2011 after Irene  
– rose 10 feet: floodplain saved Middlebury**

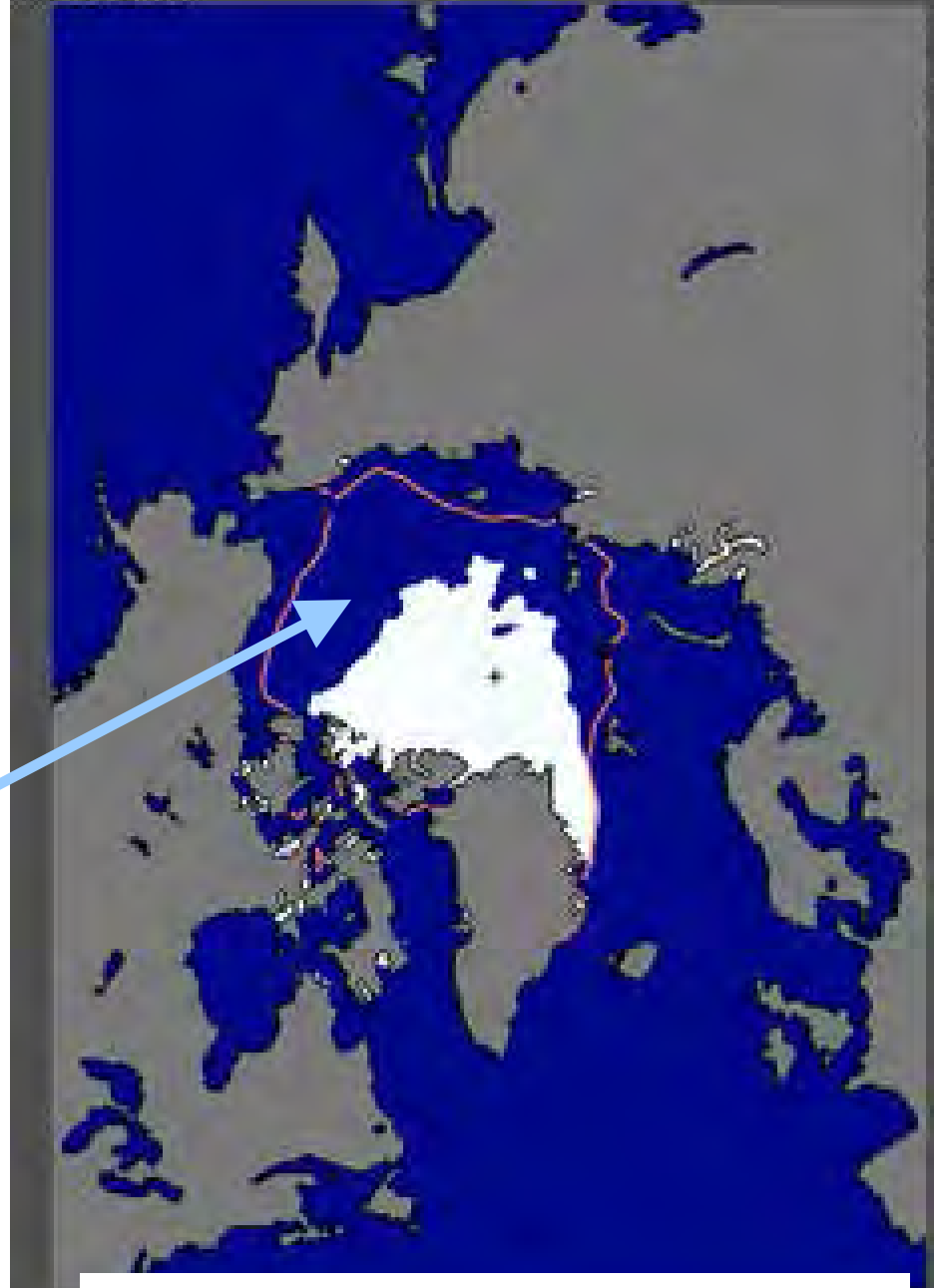


# **Flooding Resilience**

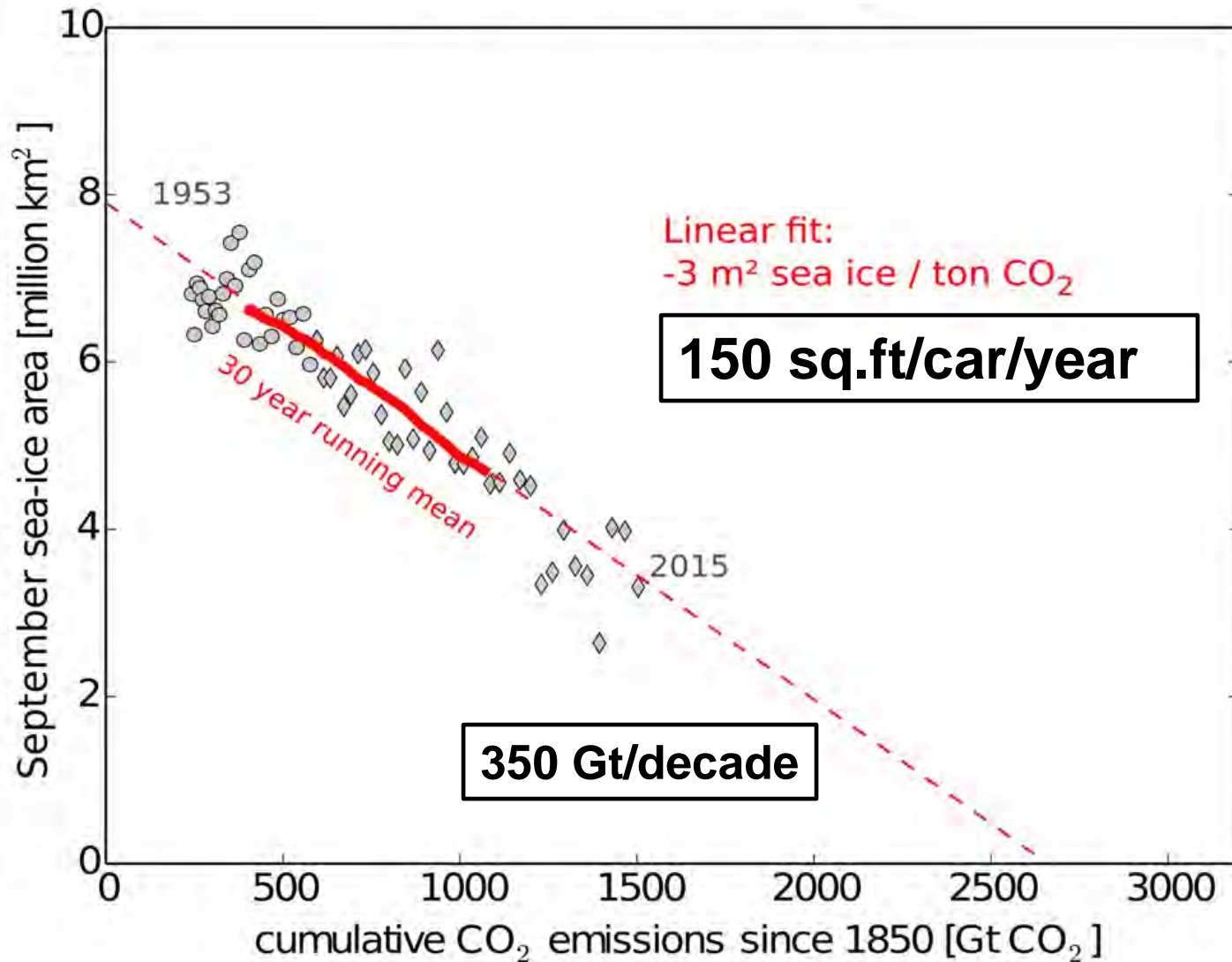
- **Preserve flood plains**
  - **Saves downstream towns (Middlebury)**
  - **Stop building houses and trailer parks in flood plains**
- **Manage water on landscape**
  - **Maximize infiltration: urban and on farms**
  - **Don't wall-in rivers!**
- **Maintain mountain forest cover**
  - **Devastating floods in 20's, 30's with reduced forest cover**

- 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



# Efficient transport

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



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

# ***Lightweight: half the speed and payload; electric***



**20+ mph US Radwagon  
72 lb cargo bike**



**20+ mph Organic Transit ELF:  
180lb – carries kids**

***Need bike paths to separate from trucks***

***Change of mindset: improves health and resilience***

# **Big Picture Issues**



# Systems Engineering Guidelines for a Sustainable Society

- **Minimize the lifetime of human waste products** in the Earth system and eliminate waste with critical climate/biosphere interactions
- Minimize the use of non-renewable raw materials, and
- Maximize recycling and re-manufacturing
- **Maximize the efficiency** with which our society uses energy and fresh water, and
- Maximize the use of renewable resources

# Efficiency Comes First

- **We need to double or triple our energy efficiency because...**
  - **We cannot replace current fossil fuel use with biofuels & renewable energy**
  - **Oil and gas reserves are limited, but coal & oil shale reserves are enough to push CO<sub>2</sub> to 1,000 ppm**
    - **in time melt icecaps, raise sea-level 150ft**



# The Future Is Not Our Past

- *Collectively, we create the future, so we need to plan for a transition to a sustainable society*
- In the face of a economic, technological and financial system driven by short-term profit
  - *Put systems-thinking above profit!*
- Needs deep community discussion
  - *New values that respect the Earth*

# Ethical issues must be faced

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

# 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, energy, human health, ecology?
- What strategies and mindset are needed to mitigate, adapt and build resilience in Vermont, US and the world?
  - 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; how can ecosystems adapt?

# Sustainability Issues for Vermont

- **Reeducation of society and its 'systems'**
  - What will raise awareness/change paradigm?
  - How can we better manage our relation to Earth?
- **Understand water and landscape**
  - Limit phosphorus loads on streams/lakes
  - Fresh water supply not critical in VT, but is elsewhere
- **Examine all waste-streams**
  - Aim to recycle/remanufacture & fully cost wastestreams
- **Default energy use should be 'OFF'**
  - Maximize energy efficiency: housing, transport, power
  - Add renewable power and microgrids; backup networks
- **Relocalize food system**
  - Compost all organic waste
- **Manage forests for changing climate**
- *Reconnect with natural world*
  - *Fundamental if we are to accept transition*

# Community is Central

- You can't deal with environmental issues alone
  - They were created by the community over time
  - You need a community to weigh the evidence, search for creative solutions, and tell the truth
  - For moral support: *to face resistance or opposition with hope (not fear or despair)*
- *You need grounding in yourself & as a group*
- *You need Earth system support*



- *“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***

# Discussion

**alanbetts.com**

**Betts, A.K. (2017):** Climate Change in Vermont. Vermont Climate Change Report for the Governor's Vermont Climate Action Commission.  
DOI:10.13140/RG.2.2.30544.81920



# Climate Trends

- Trend to **milder winters**; earlier spring
  - *longer growing season*
  - *grow winter greens in high tunnels*
- Trend to **more precipitation in cool season**; more wet snow and mixed in winter
  - Winter variability large: *snow/no-snow*
- **Warmer summers; heavier rain** in summer; periods of drought
  - increase infiltration and water storage
  - build soil carbon and organic matter for water storage and fertility
  - *forests stabilize climate and reduce runoff*

# Health Issues

- **Higher temperature extremes**
  - Offset by wet summers in Northeast
- **Winter survival of pests**
  - **Blacklegged Tick (Deer Tick):** A warming climate, combined with the spread of the invasive shrub Barberry, has allowed this pest to expand its range to the entirety of Vermont. This invasive is responsible for the spread of Lyme disease throughout New England.
- **Mosquito-borne diseases – EEE/West Nile**
  - Increased summer breeding: *nine out of ten recent summers have had well-above 'average' rainfall*



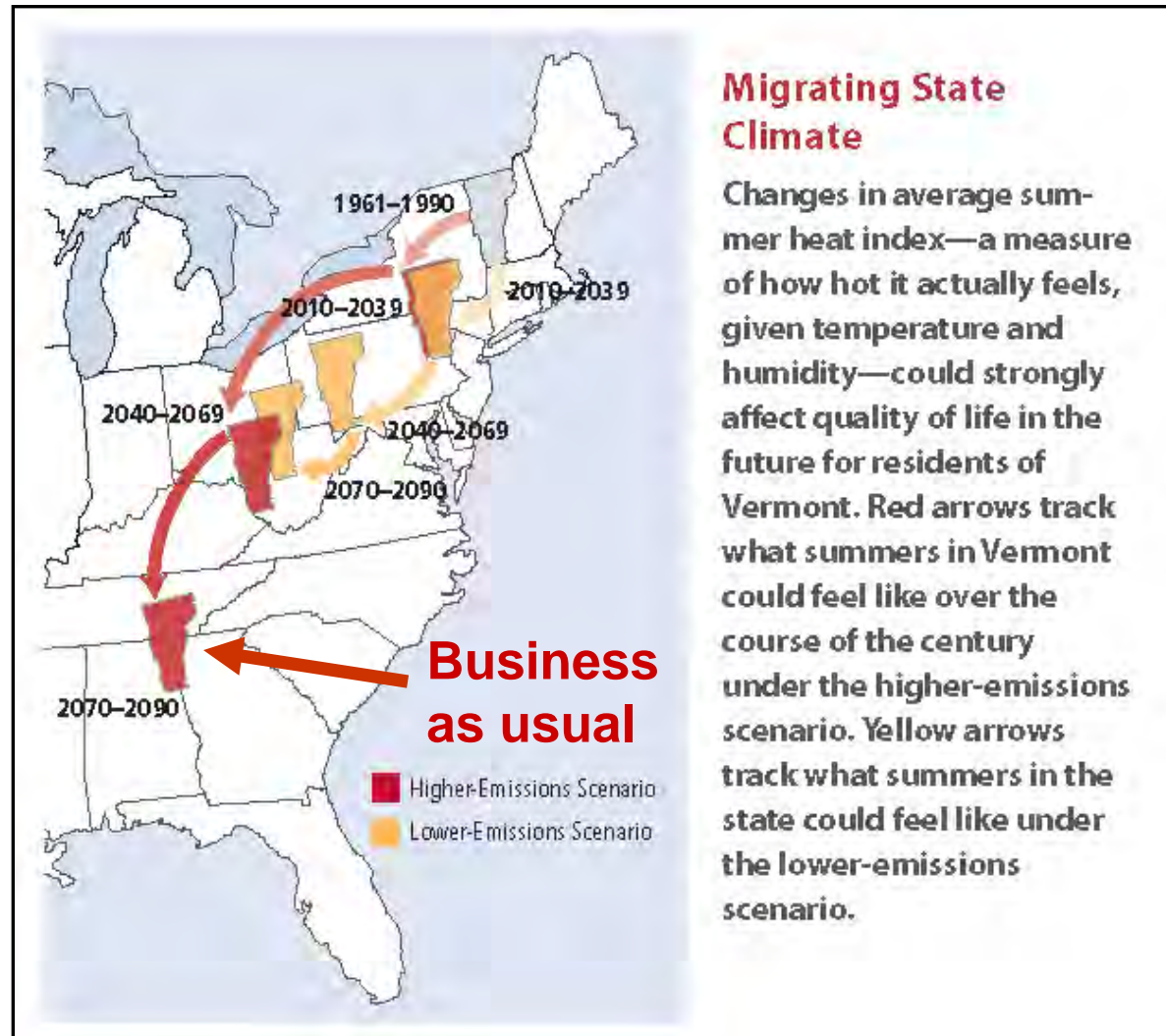
# Sustainability Issues for Vermont

- **Energy efficient society**
  - Passive solar homes, net-zero, geothermal
  - End-to-end recycling/remanufacturing
  - Efficient transport
  - Renewable energy microgrids
- **Landscape management of water and pollutants**
  - Flood/drought extremes, runoff
  - Manage forests for changing climate
- **Local food and composting**
- ***Dependent on community choices/decisions***

# Vermont's Future with High and Low GHG Emissions

What  
about VT  
forests?

Sub-tropical  
drought areas  
moving into  
southern US



**NECIA,  
2007**

# How do we plan/adapt?

- **Future needs creative approaches**
  - **Efficient society: renewable power**
  - **Efficient transport: networked? Electric?**
  - **People reconnected to landscape**
- **We need to work with the Earth**
  - **Manage water on landscape**
  - **Manage forest diversity for a warmer climate**
  - **Manage diversified year-round agriculture**
  - **Manage energy crops and solar farms**