

Climate Resilience and Sustainable Agriculture

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Strategies for Resilience

- **Grasp technical/ecological/economics**
 - **Alternative facts lead to collapse**
- **Plan for efficiency and resilience**
 - **Reject “cost effective for today’s bottom line”**
- **\$1 trillion spent 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 CO₂ “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 solutions 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, ecology, energy, human health,?
- 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 agriculture and ecosystems adapt?

Different 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’

- **Freedom to exploit Earth’s resources & poor**
- **“Free market” promotes material growth**
- **“Regulation” interferes with growth**
- **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***

Understand the Power of Oil

- US companies had global control of Oil
 - 1900 till 1973
 - Started with Standard Oil (JD Rockefeller)
 - Key to wars and who won them
 - To post-WWII growth of consumer society
 - The triumph of the automobile and suburbia
- Oil barons directed government policy for a century, and they still do
 - So world has not addressed *climate change*
 - Incompatible with business as usual for big oil

Oil, Power and War

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
 - Localized shared food supply
 - Support ecosystems long-term
 - Maximize efficiency & renewable energy
 - Shared efficient transport system
 - *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 winter 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**

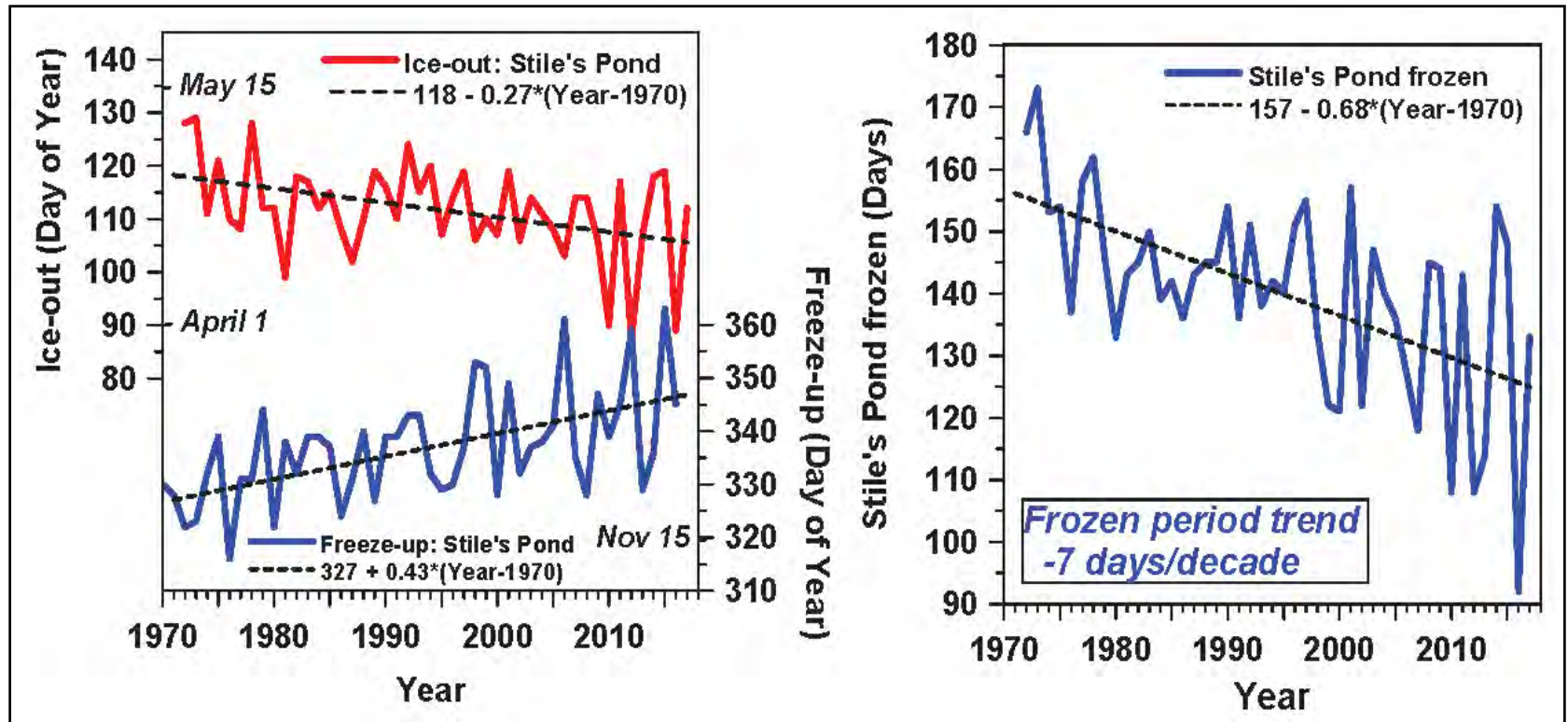


January 12, 2018

After T_{\max} up to 50F

Marker: Lake Freeze-up & Ice-out

Frozen Period Shrinking: variability huge



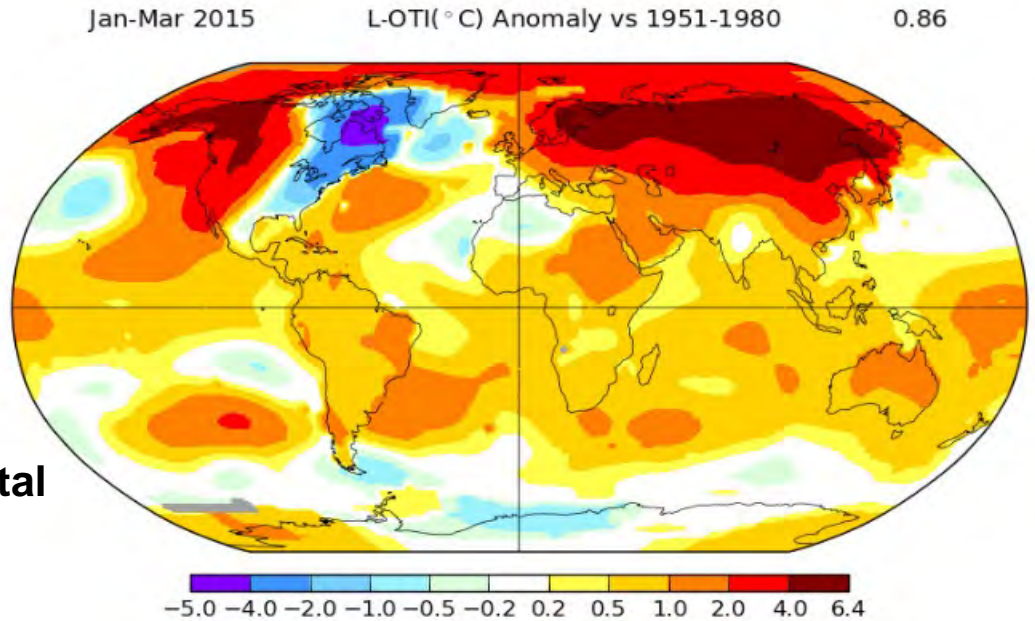
- Freeze-up later by **+4 days / decade**
- Ice-out earlier by **-3 days / decade**
- Lake frozen period trend **-7 days/decade**
- *Interannual variability \approx 50 yr trend*

*Stiles Pond:
"Eye on the Sky"*

Stationary modes

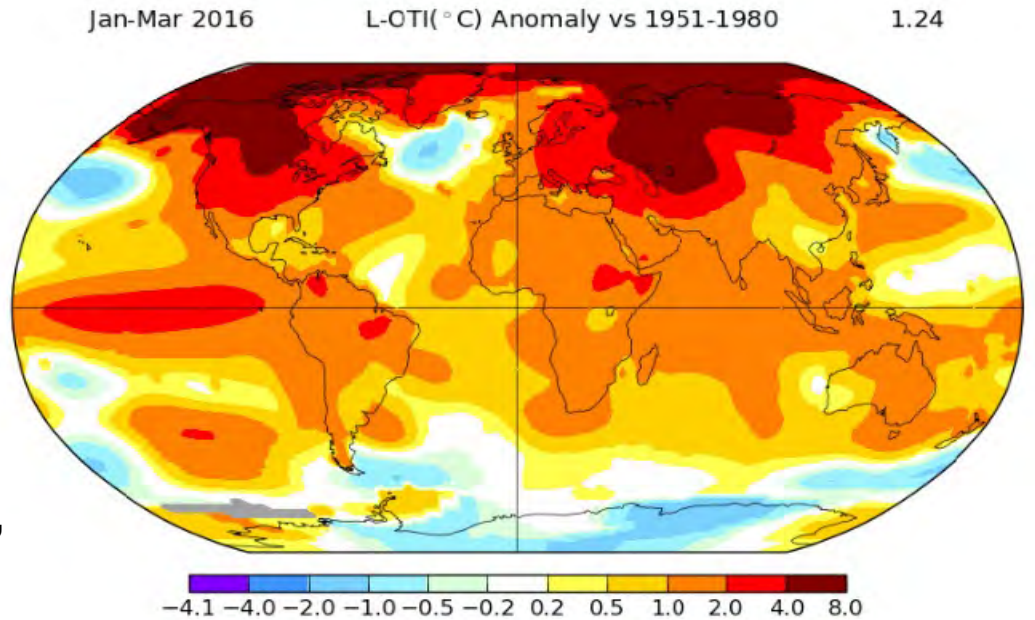
Jan-Feb-Mar 2015

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



Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



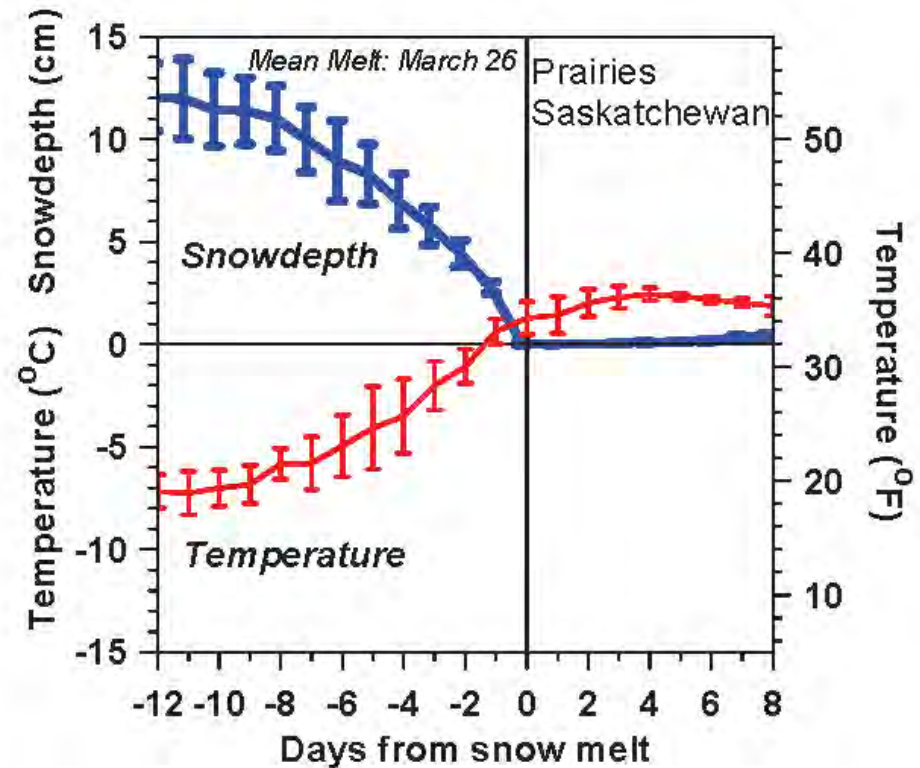
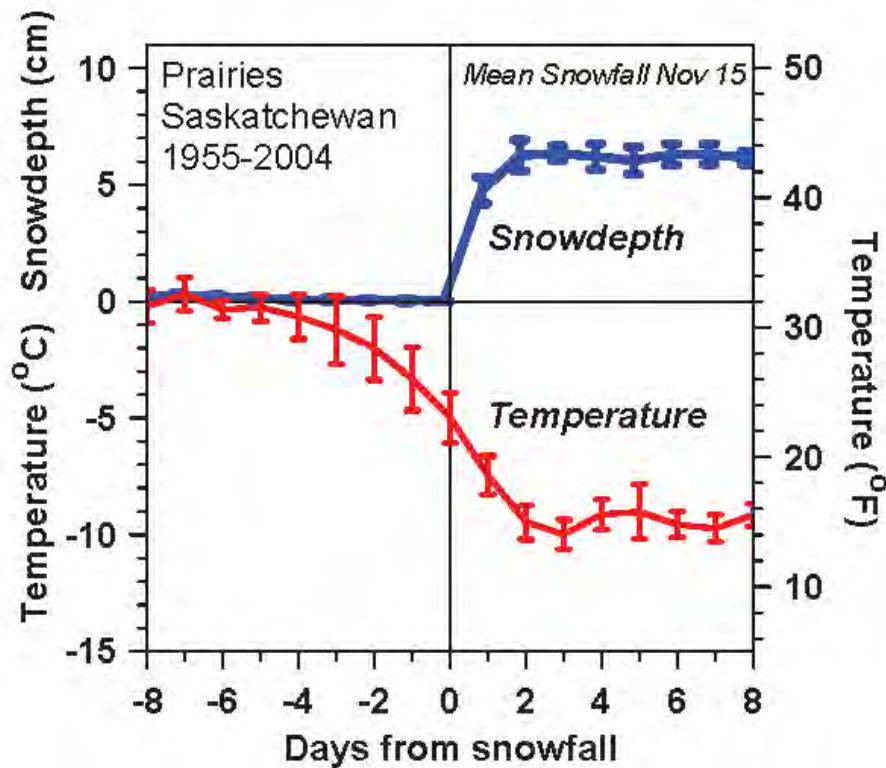
Seasonal Climate

- **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

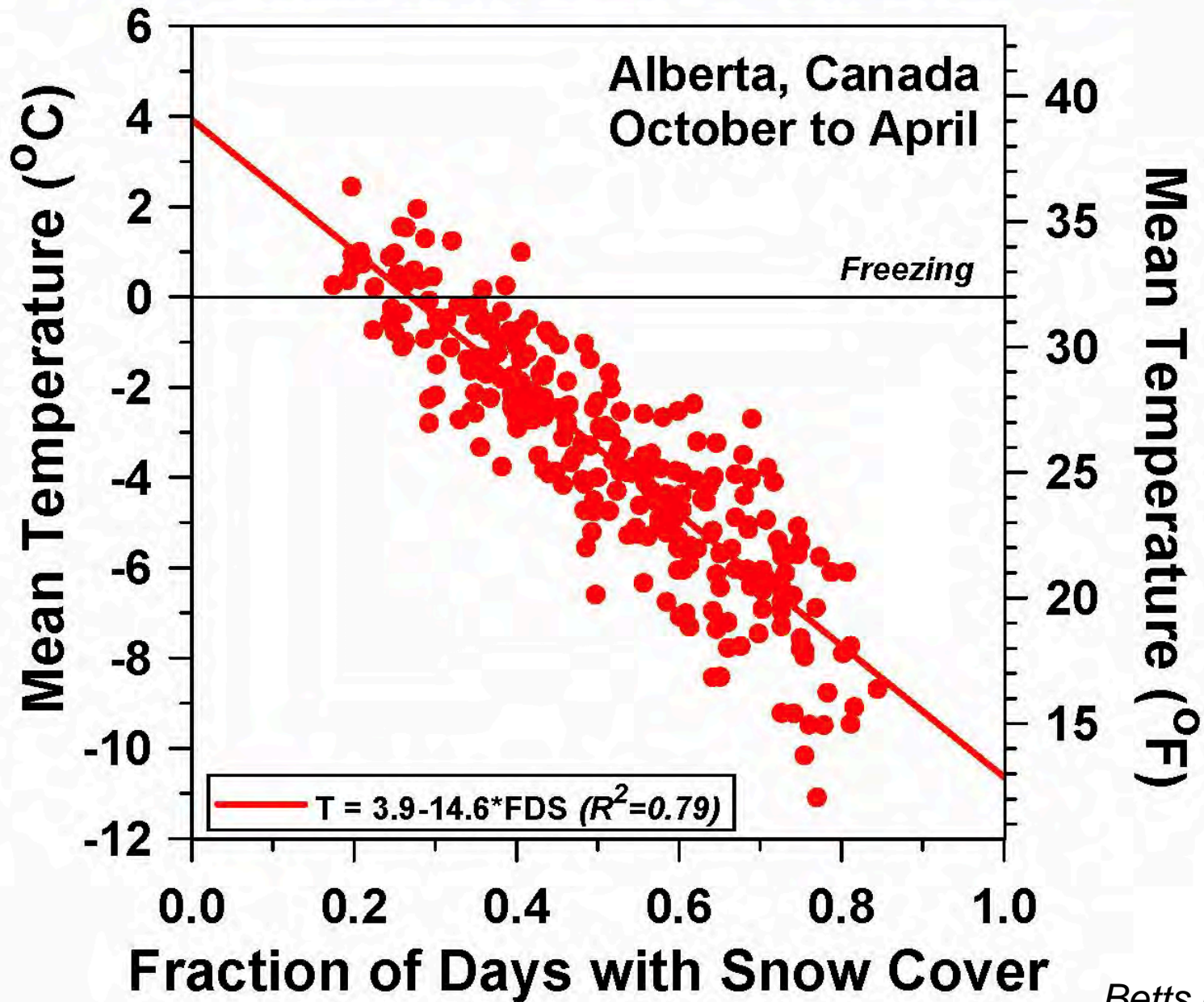


Snowfall and Snowmelt



- 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*

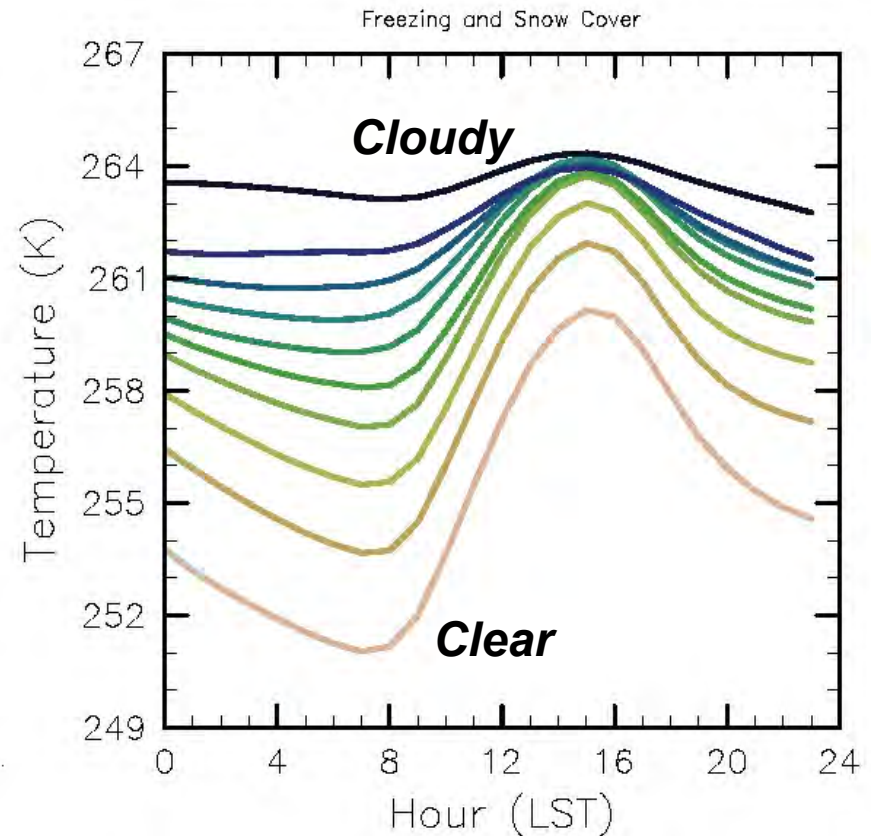
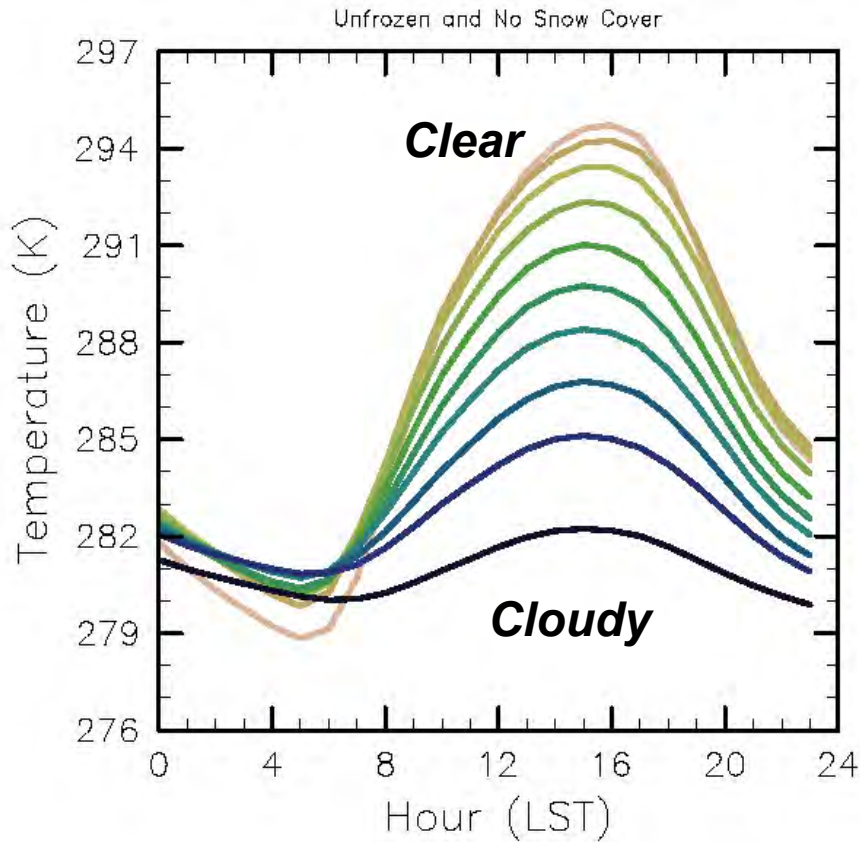
More snow cover - Colder temperatures



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, longer NE growing season**
 - Over-winter more crops; start spring crops earlier under cover
 - But increasing variability of snow/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*
 - *Vulnerability increasing*

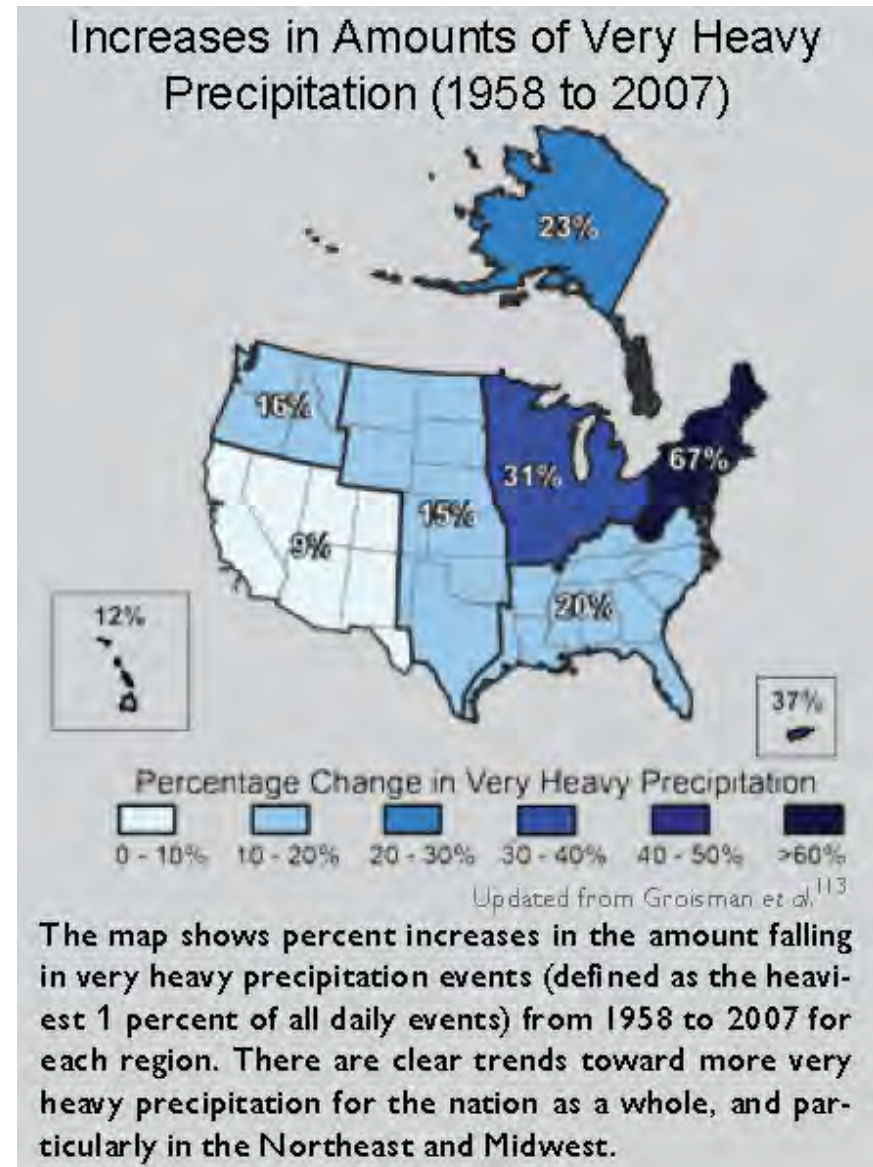
Extreme Precipitation Increasing

- **Rain rates** go up steeply with temperature, because vapor pressure does
- **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

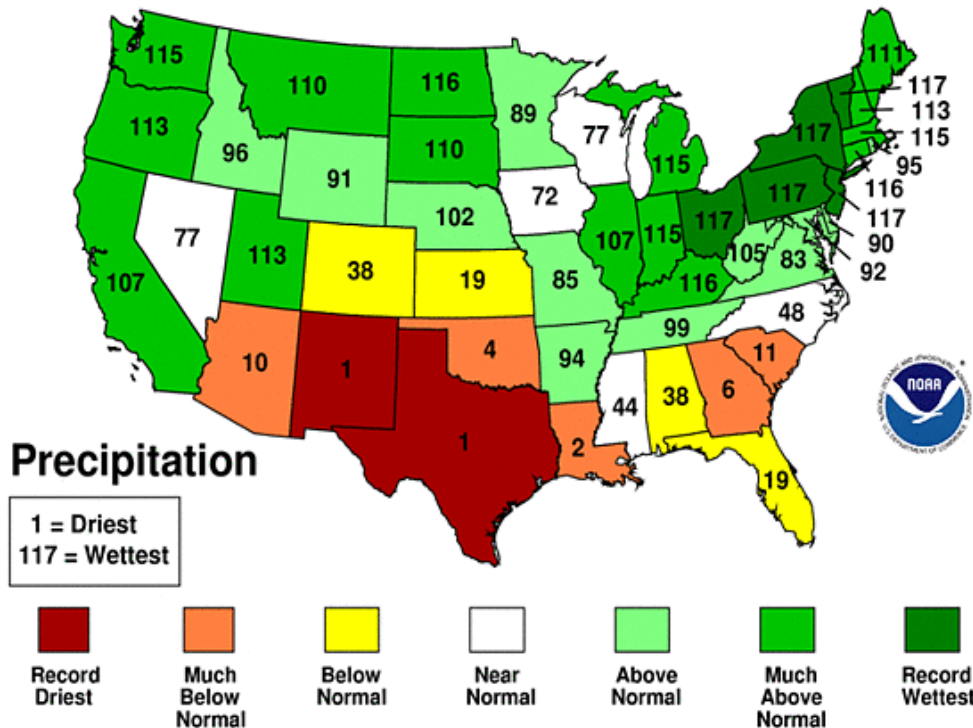
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010 winter
 - 70F (4/11) and 80F(5/27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical storm** 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!



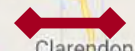
Pittsfield, Rochester isolated. Thursday, 9/1, CVPS restores power; Rutland bakery supplies 100 loaves

Chittenden volunteer fire dept. 100 truckloads emergency supplies

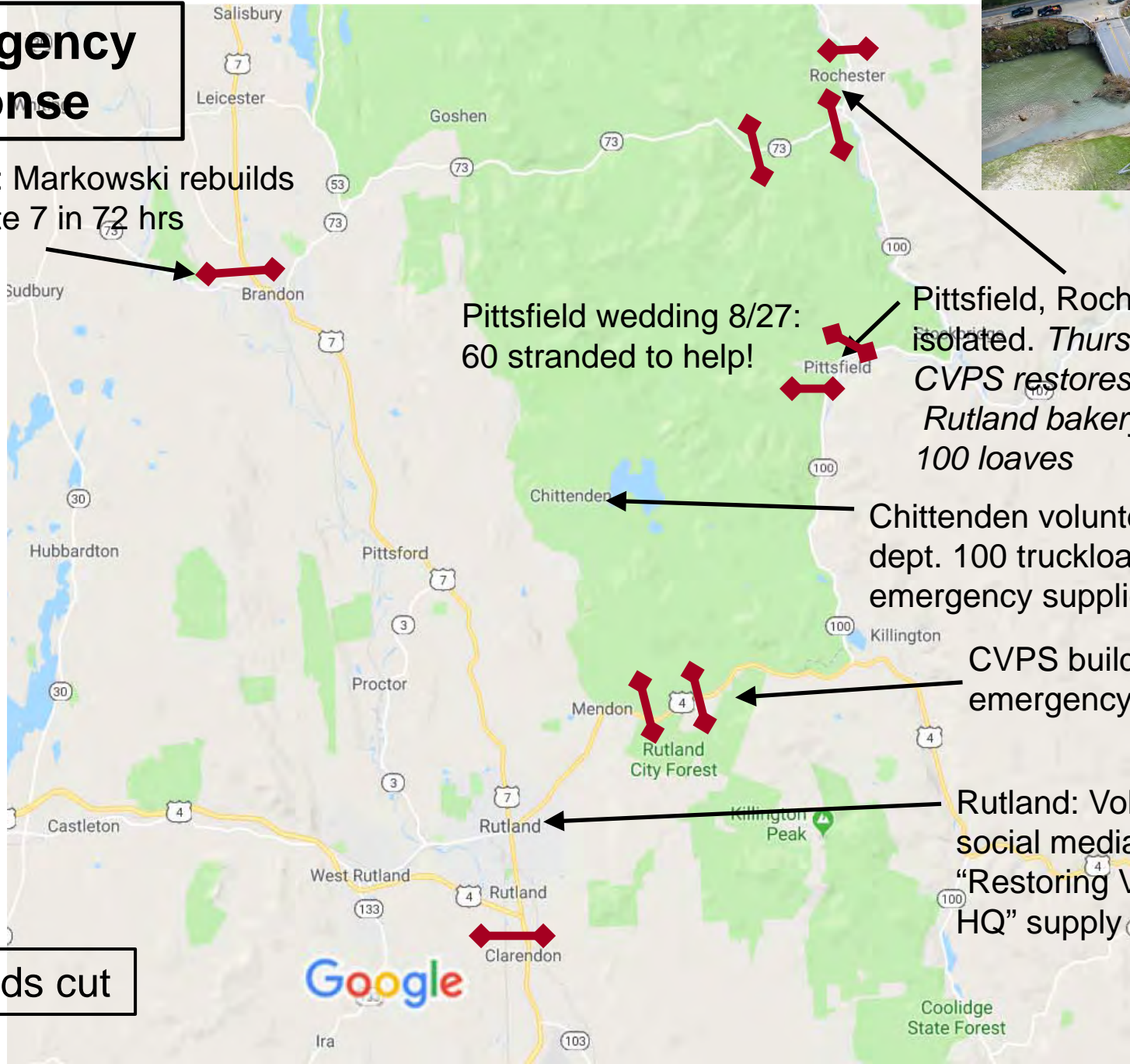


CVPS builds emergency route 4

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**

Agriculture Issues

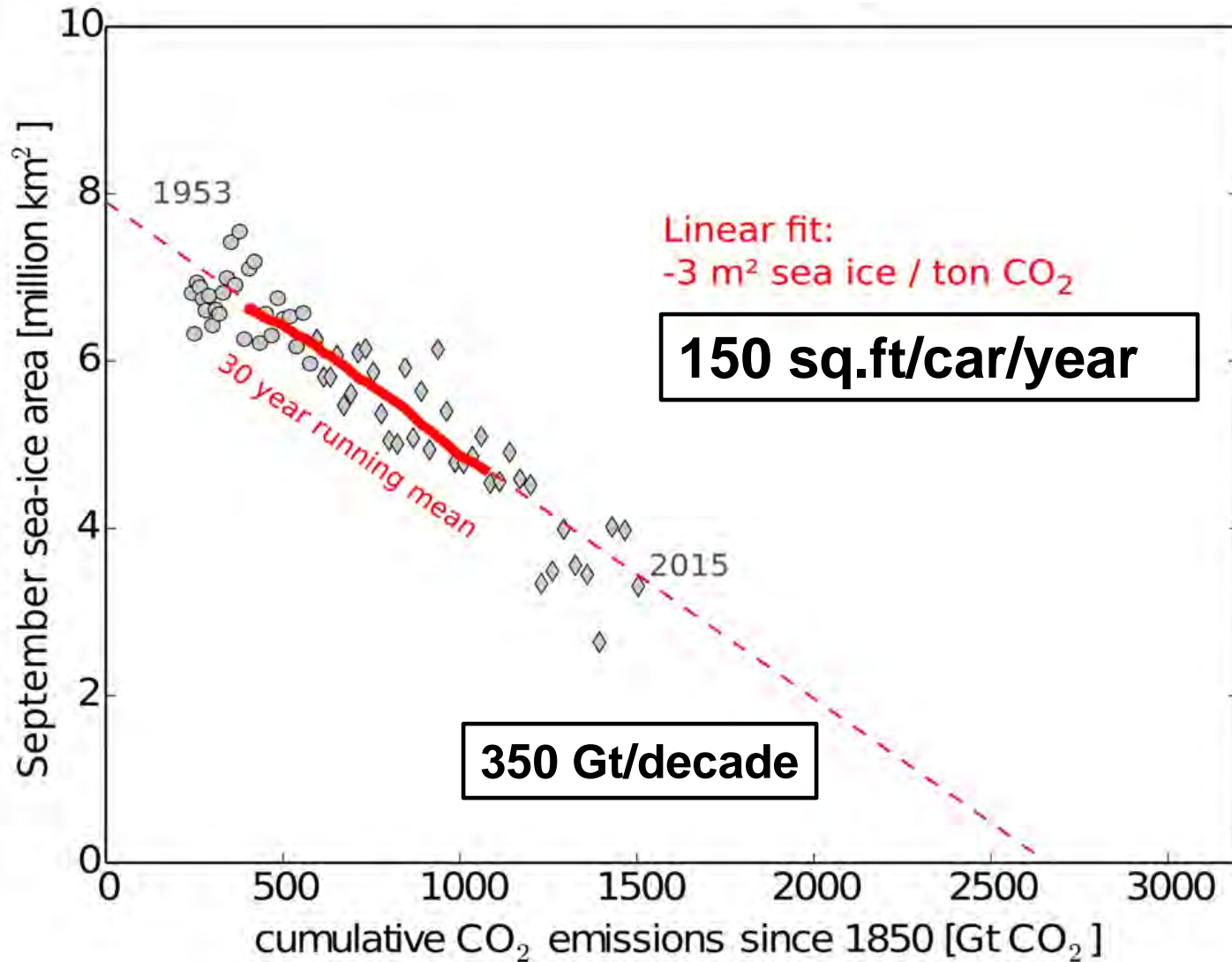
- *Crops need light, soil, nutrients, water*
- **Reduce soil loss: cover crops, no-till**
- **Minimize runoff of nutrients**
 - High carbon soils: “organic ag”
 - Deep-rooted buffer zones + trees
 - Preserve some forest cover
- **Manage water extremes on landscape**
 - Maximize ground storage by infiltration
 - Ponds for drought storage: drip irrigation

- **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



J. Stroeve/National Snow and Ice Data Center

Efficient transport

- **Gasoline to hybrid: 50% gain to 50mpg**
- **Hybrid to plug-in hybrid: up to 130mpg**
- **Electricity from community solar array**



>3000lbs and 130 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

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*

Efficiency Comes First

- **We need to double or triple our energy efficiency because...**
 - **We cannot replace current fossil fuel use with biofuels & renewable energy**
 - **Reserves of coal, oil & gas are enough to push CO₂ to 1,000 ppm**
 - **Industry determined to burn them**
 - **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*

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 waste-streams
- **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

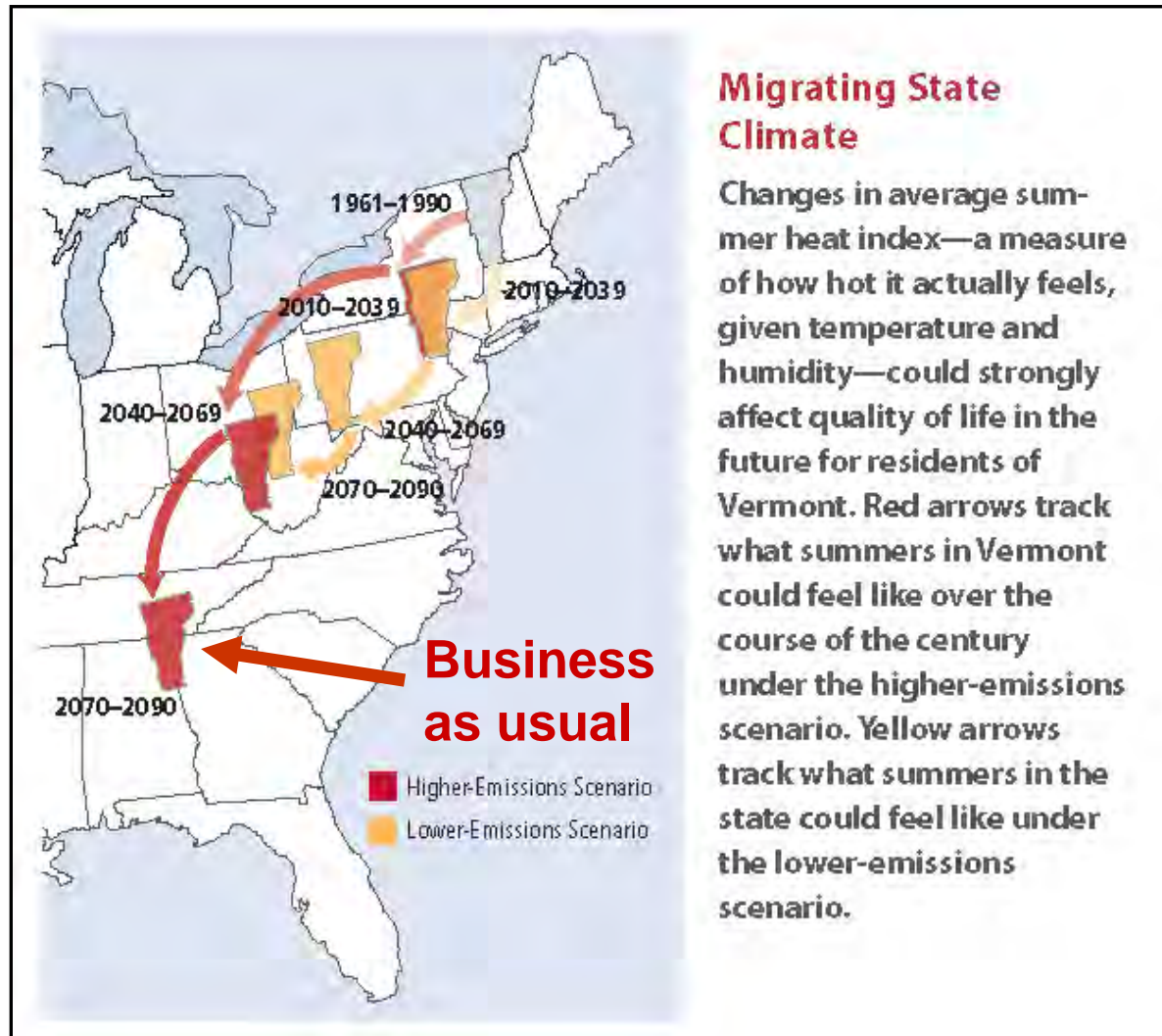
alanbetts.com

writings, talks and research

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



**NECIA,
2007**

System Issues

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- 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 agriculture and ecosystems adapt?

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

Role as Writer

- I am a scientist, a writer & public speaker
 - I speak and write about what I know
 - Connect local issues to global issues
 - Science matters – *but issues far beyond 'science'*
 - Clash between **Earth system reality** and political and economic ideologies
 - *“Earth wins hands-down”*
 - Many difficult ethical and moral choices
- The transition we face is huge: *must be faced*
 - Can we stabilize the climate?
 - Can we build a sustainable future?
 - Why we need community

Vermont Newspaper Columns

Environmental journalism revisited (Betts and Gibson 2012)

2008-2016: 90 articles: “They blend science with a systems perspective, and encourage the reader to explore alternative and hopeful paths for themselves, their families and society”

(Rutland Herald and the Barre-Montpelier Times Argus)

Today’s communities must understand the connections between energy use, climate and food to make the transition to an efficient, resilient and sustainable society.

(alanbetts.com/writings)

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



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*