Climate Change and Resilience

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UVM class

"Resilient communities: designing at the nexus of food, energy and water systems"

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Strategies for Resilience

- Understand the technical issues
  - Don't build bridges with alternative facts
- Engineer for efficiency and resilience
  - Not just to maximize profit
- Spending $1 trillion now on climate
  - saves $60 trillion later this century
- Ignore or deny climate change
  - costs to human civilization and Earth's ecosystem catastrophic

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Fundamentals

- ***Burning fossil fuels: transforming climate***
  - ***Many water cycle amplifying feedbacks***
  - ***Heading for high CO_2 "Carboniferous era climate"***
  - ***Climate extremes increasing.***
  - ***Severe weather costs: $53B in US last 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**

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?**
- **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?**

Our Deepest Challenge

- **How to reintegrate**
  all that we know and understand
  - **given the deep interconnectedness of humanity, climate & life on Earth**
  - **systems engineering is one strategy**
  - ***in the face of immense opposition***

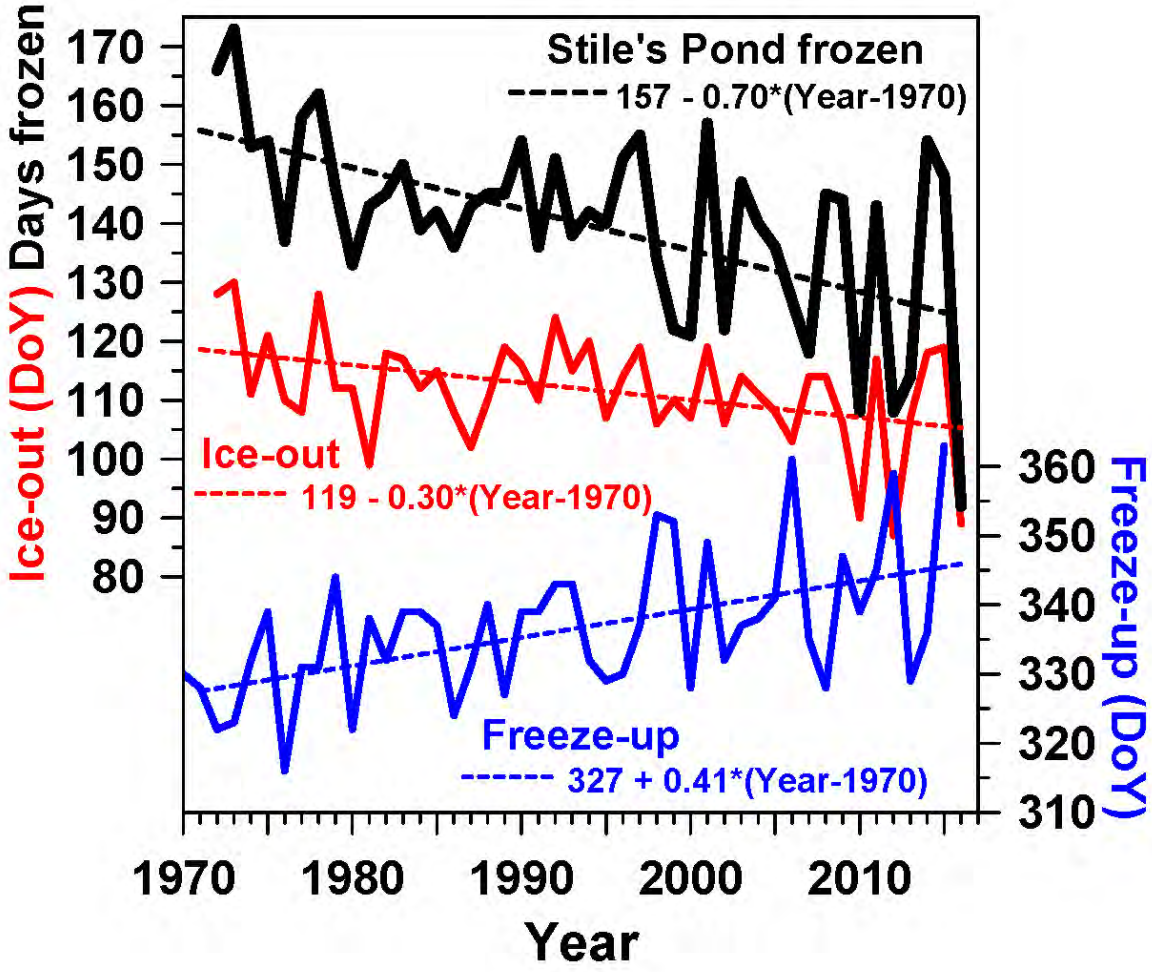
Gardening in Vermont for 40 years

- How long was growing season in 1970s?
- How long was the ground frozen?
- Winter climate zones in 1970's were?
- How much have these changed?

Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking: variability huge

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



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 or less
  - No longer hard freeze in November
- Winter climate zones in 1970's were?
  - Zones 4-5: now zones 5-6 (10F warmer)

Bennington & Brattleboro are becoming zone 6 *(T_{min} > -10F)*

- **Hardy peaches**
- **More pests survive winter**

- **What is this?**
  - **Oct 1, 2012**

Bennington & Brattleboro are becoming zone 6

- Hardy peaches: 2012
- More pests survive winter

- What is this?
  - Oct 1 2012

- **Avocado**
  - Didn't survive frost
  - 2100 survive in CT
  - Our forests?

My Wake-up call: Gardening in January, Pittsford, VT

January 7, 2007

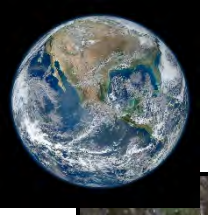
December 2006:

- **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)

Lake Freeze-up & Ice-out Changing

Frozen Period Shrinking: variability huge

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  - by -3 days / decade
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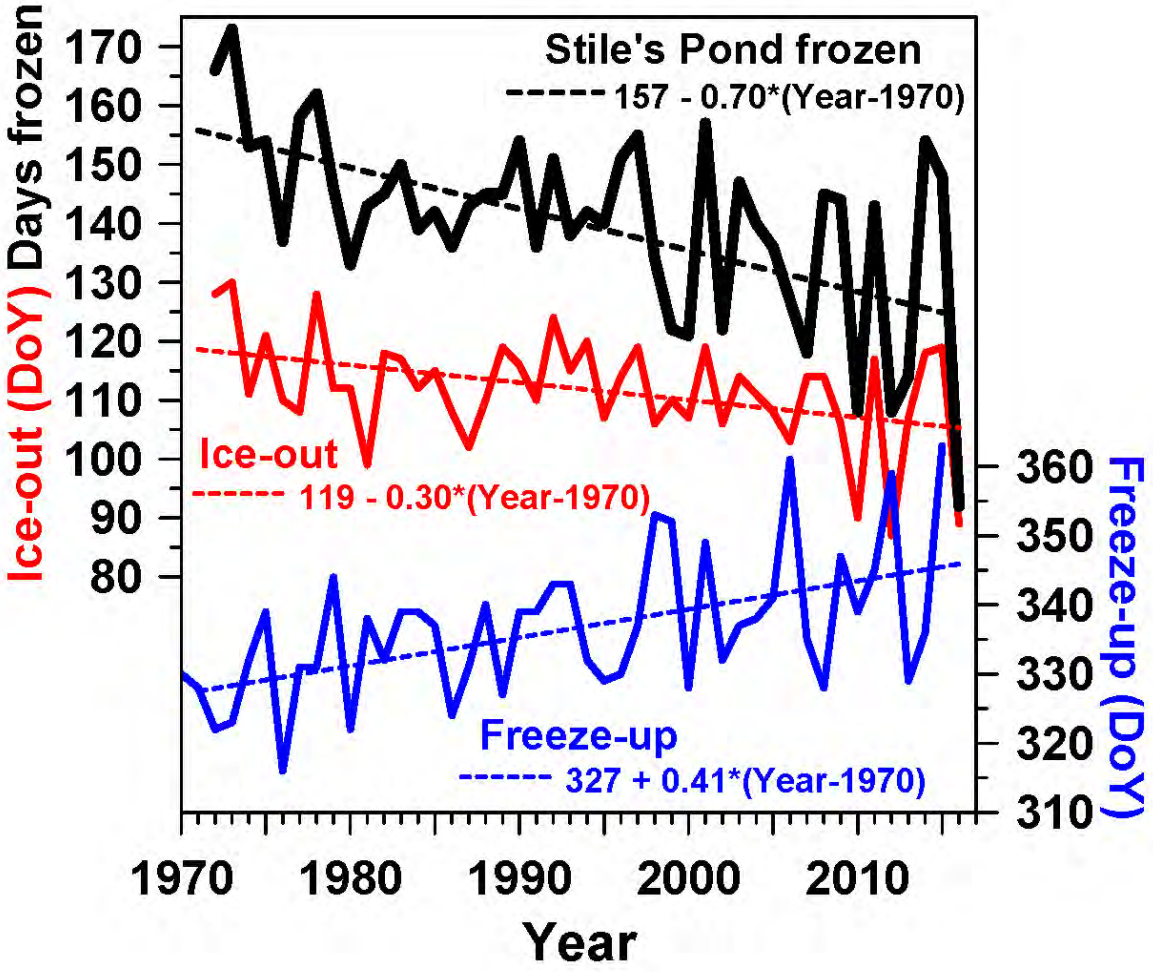
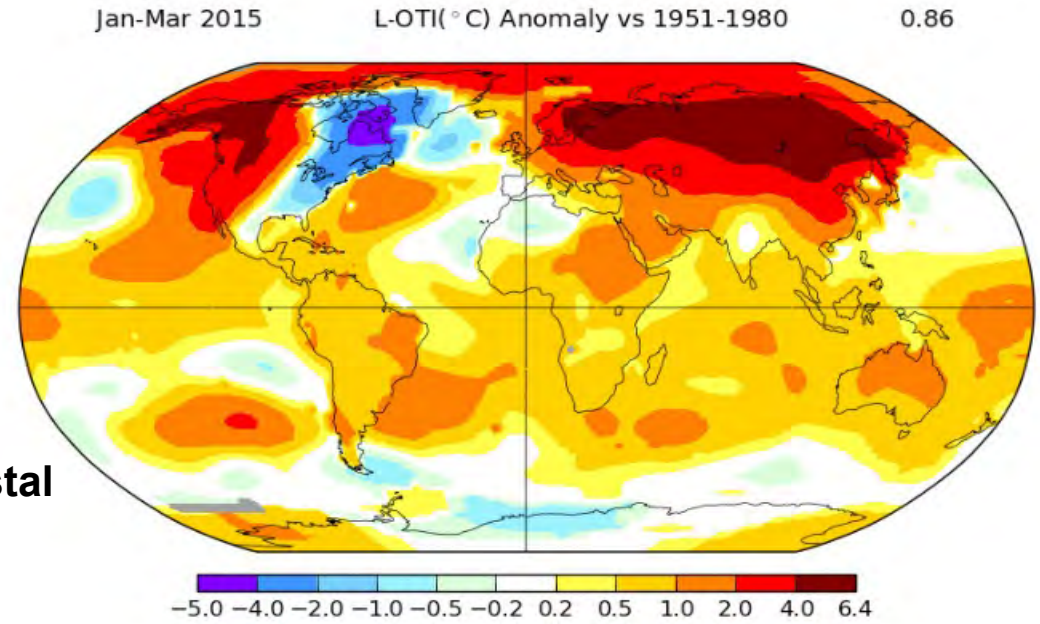


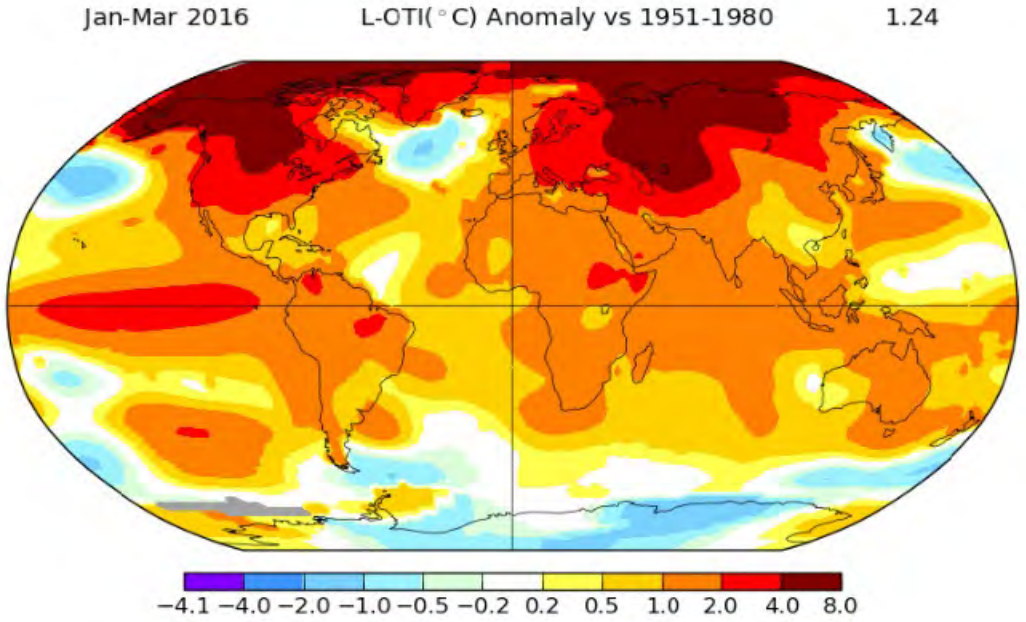
Jan-Feb-Mar 2015

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



Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic



Spring Climate Transition

- **Before leaf-out**

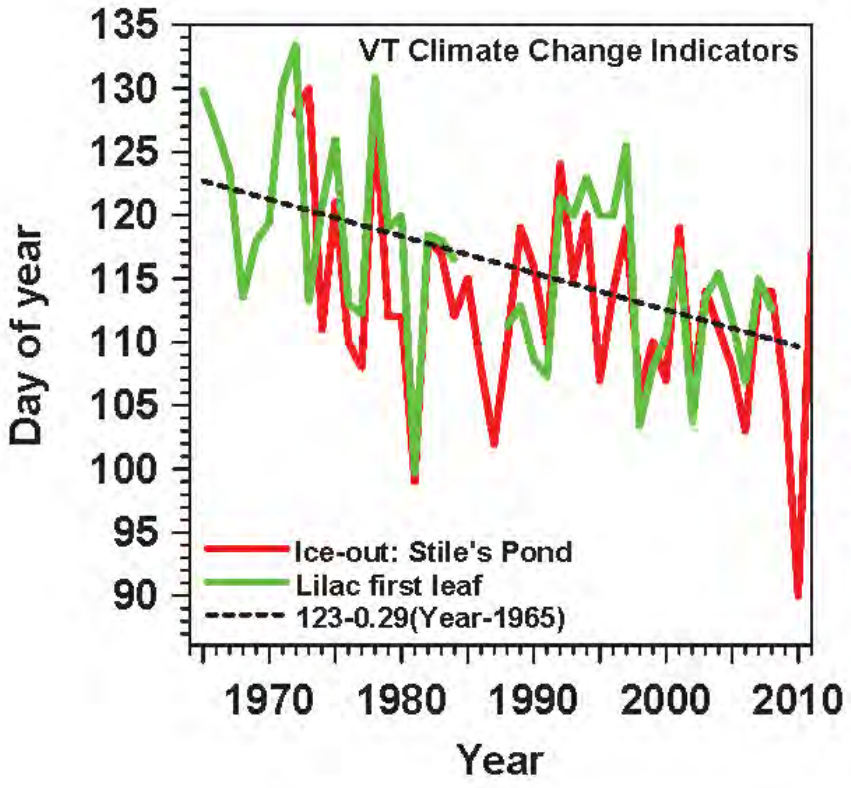
Little evaporation → **Dry atmosphere, low humidity**
→ **Low water vapor greenhouse**
→ **Large cooling at night**
→ **Large diurnal temp. range**
giving warm days, cool nights and frost

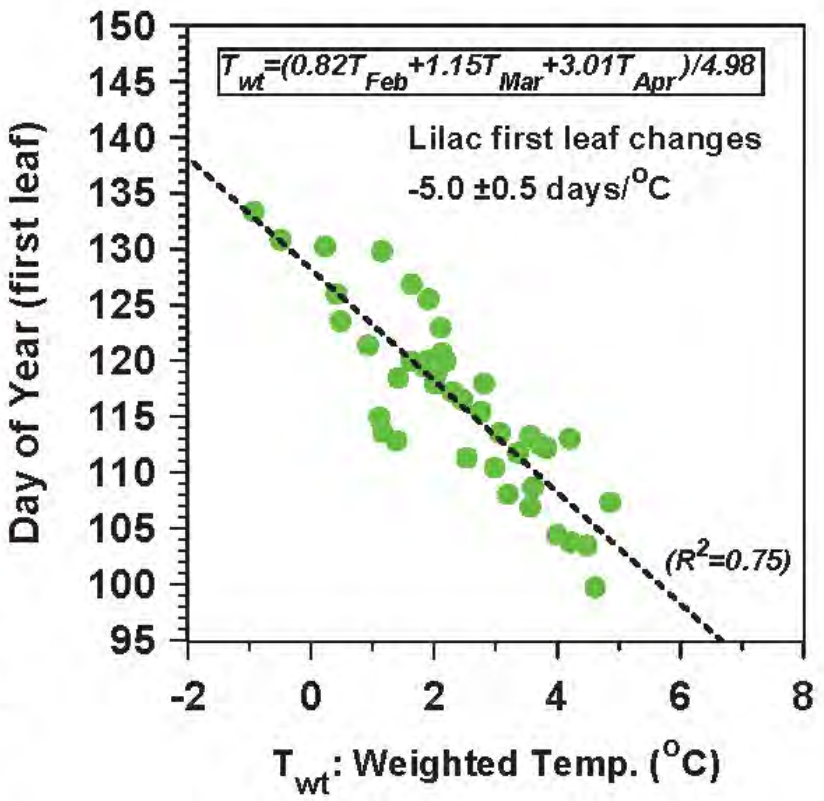
- **After leaf-out**

Large evaporation → **Wet atmosphere, low cloudbase**
→ **Small cooling at night**
→ **Reduced maximum temperature**
→ **Reduced chance of frost**

- ***Spring is coming earlier***

Lilac First Leaf Earlier





- **First leaf and ice-out changing: -3 days/decade**
- **Large variability linked to temperature:**
- **-5 days/ °C or -3 days/ °F**
  - **(No-snow – Snow) winter = 6*5 ≈ -30 days earlier leaf-out**

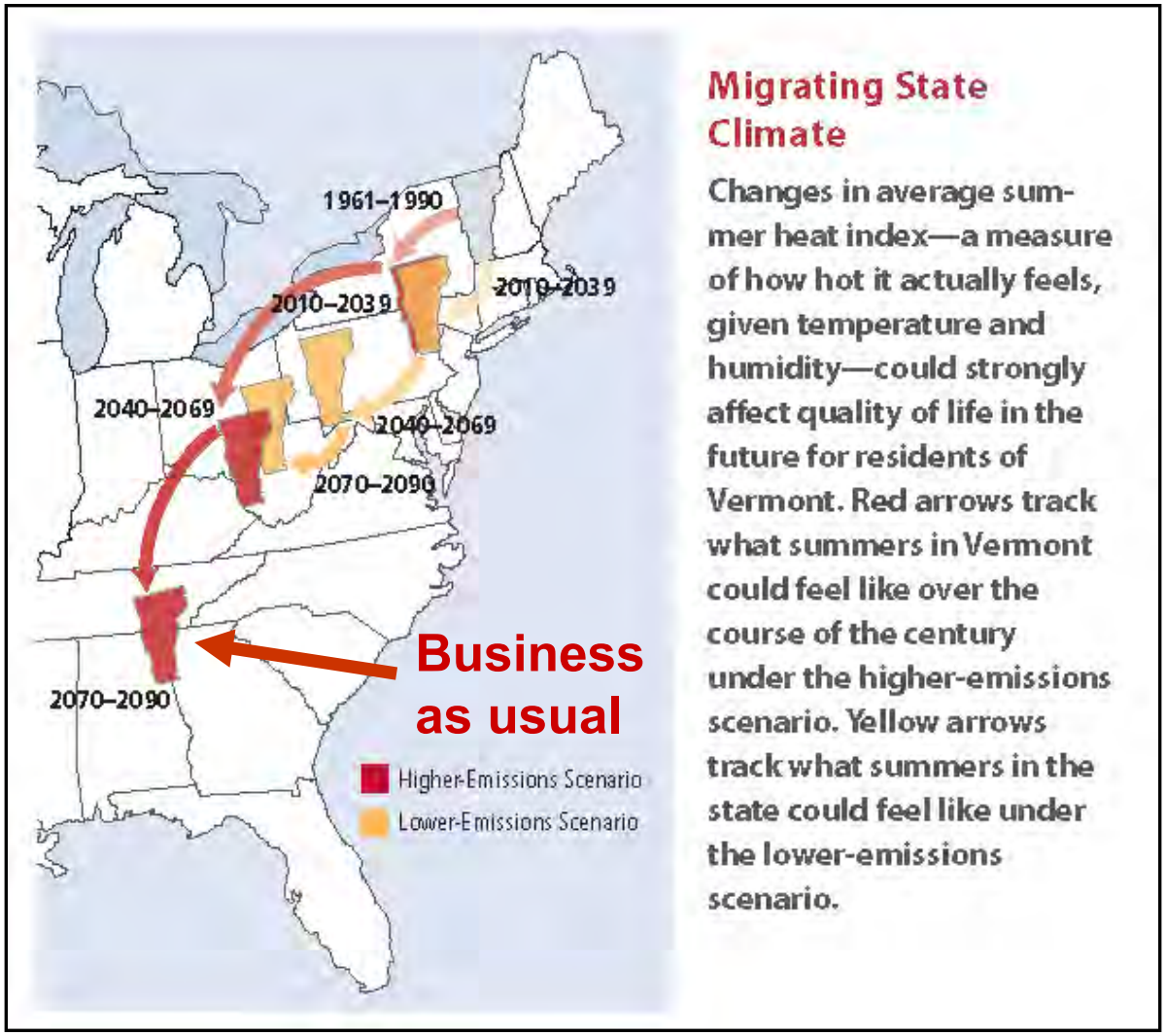
Climate Trends

- **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***

Vermont's Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US



NECIA, 2007

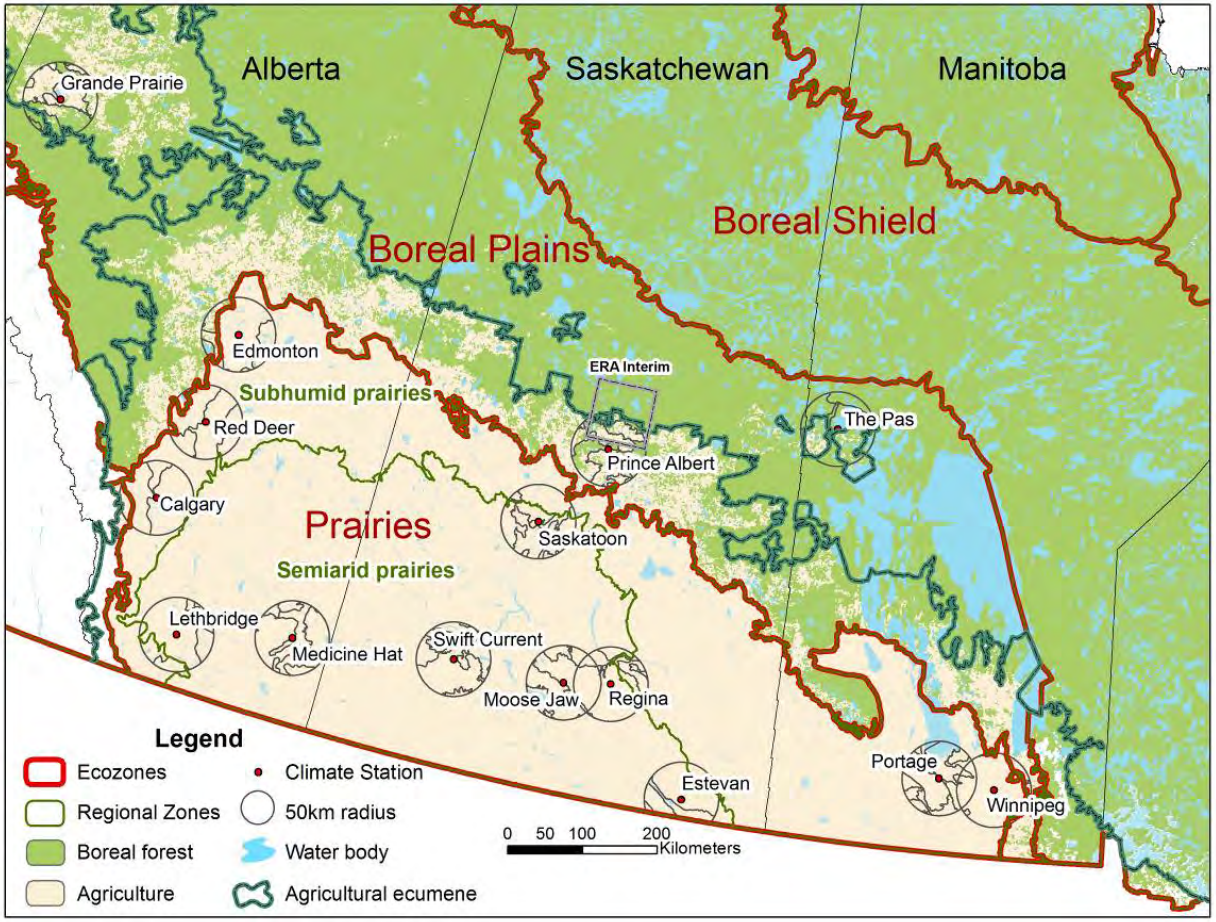
Understand winter climate!

- **Winters are changing *fast***
  - ***Winter variability large***
  - ***Variability of snow cover large***

- **January 2016, 2017 had no temperatures below 0°F**

- **What are the connections between climate & snow?**
- **How much does temperature fall with fresh snow?**

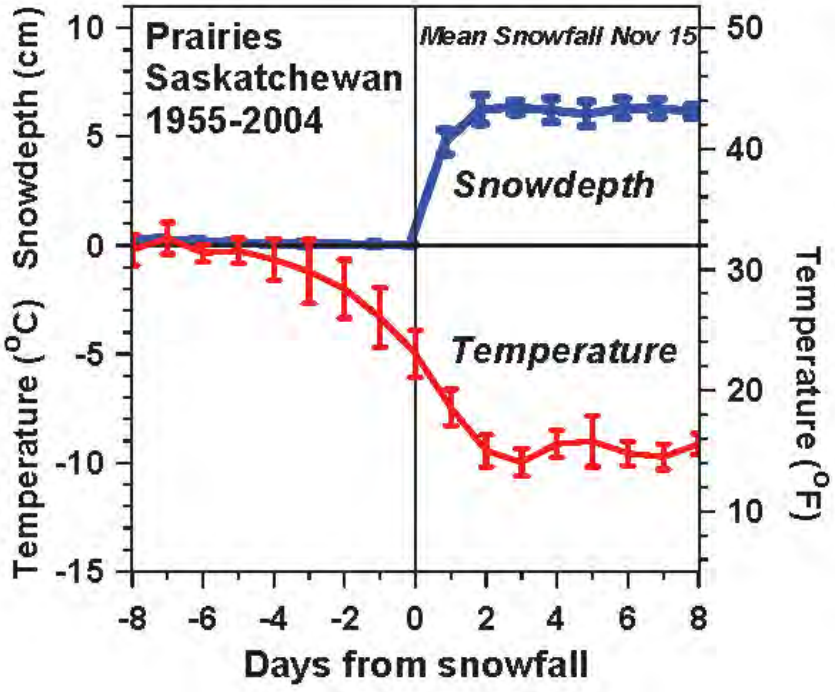
15 Prairie stations: 1953-2011

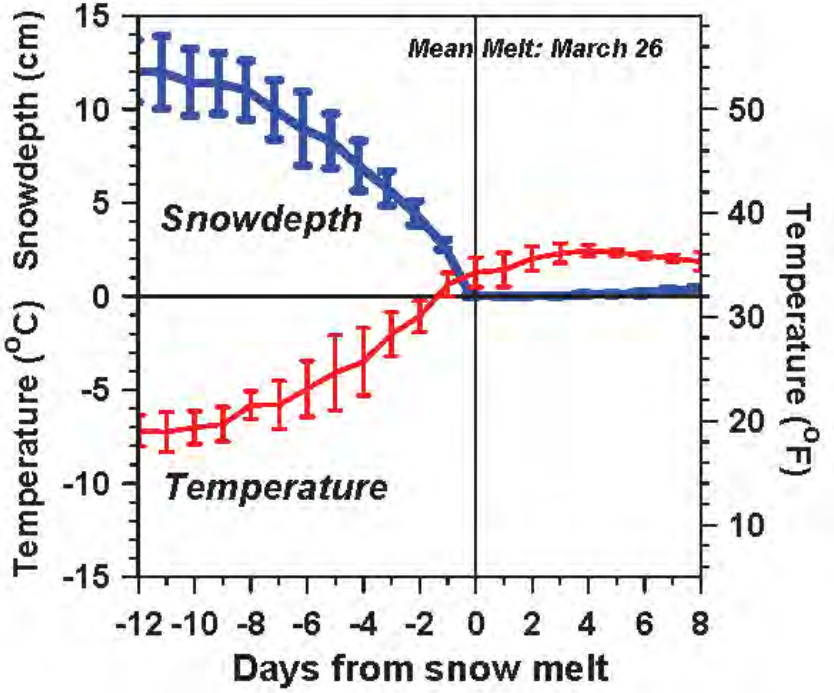


- ***Hourly*** **p, T, RH, WS, WD, Opaque Cloud (SW_{dn}, LW_{dn})**
- ***Daily*** **precipitation and snowdepth**
- **Ecodistrict crop data since 1955**
- **Albedo data since 2000**

Snowfall and Snowmelt

Winter and Spring transitions

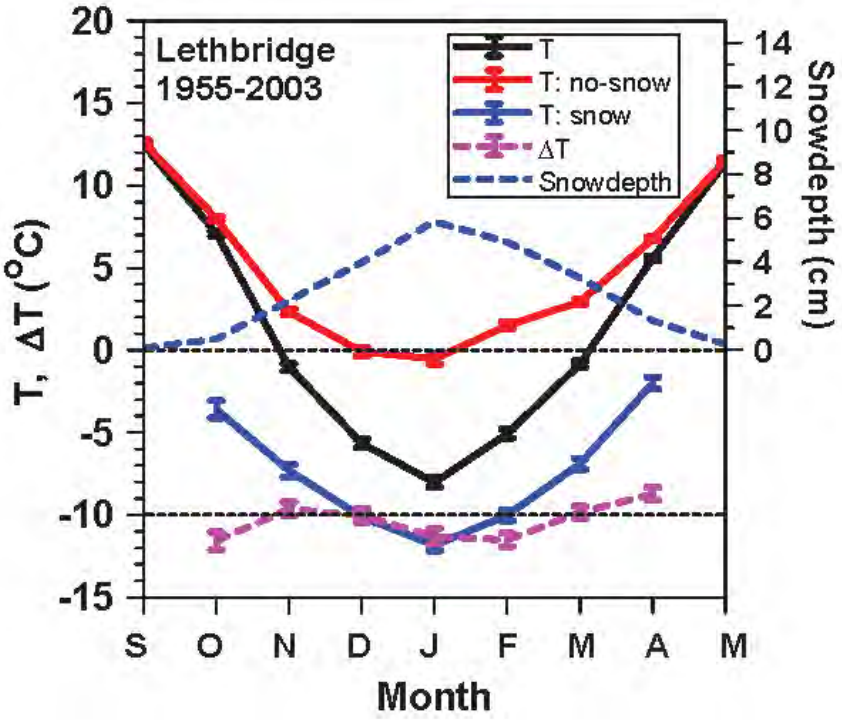


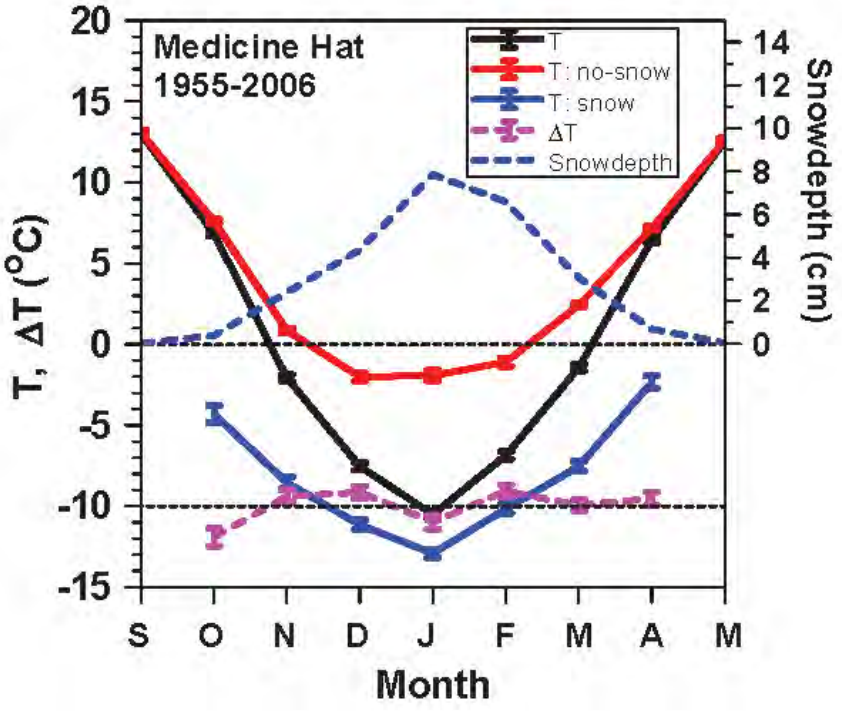


- **Temperature falls/rises about 10°C with first snowfall/snowmelt**
- ***Snow reflects sunlight; shift to cold stable BL***
  - ***Local climate switch between warm and cold seasons***

(Betts et al. 2014a)

Impact of Snow on Climate





Separate mean climatology into days with no-snow and Snowdepth >0

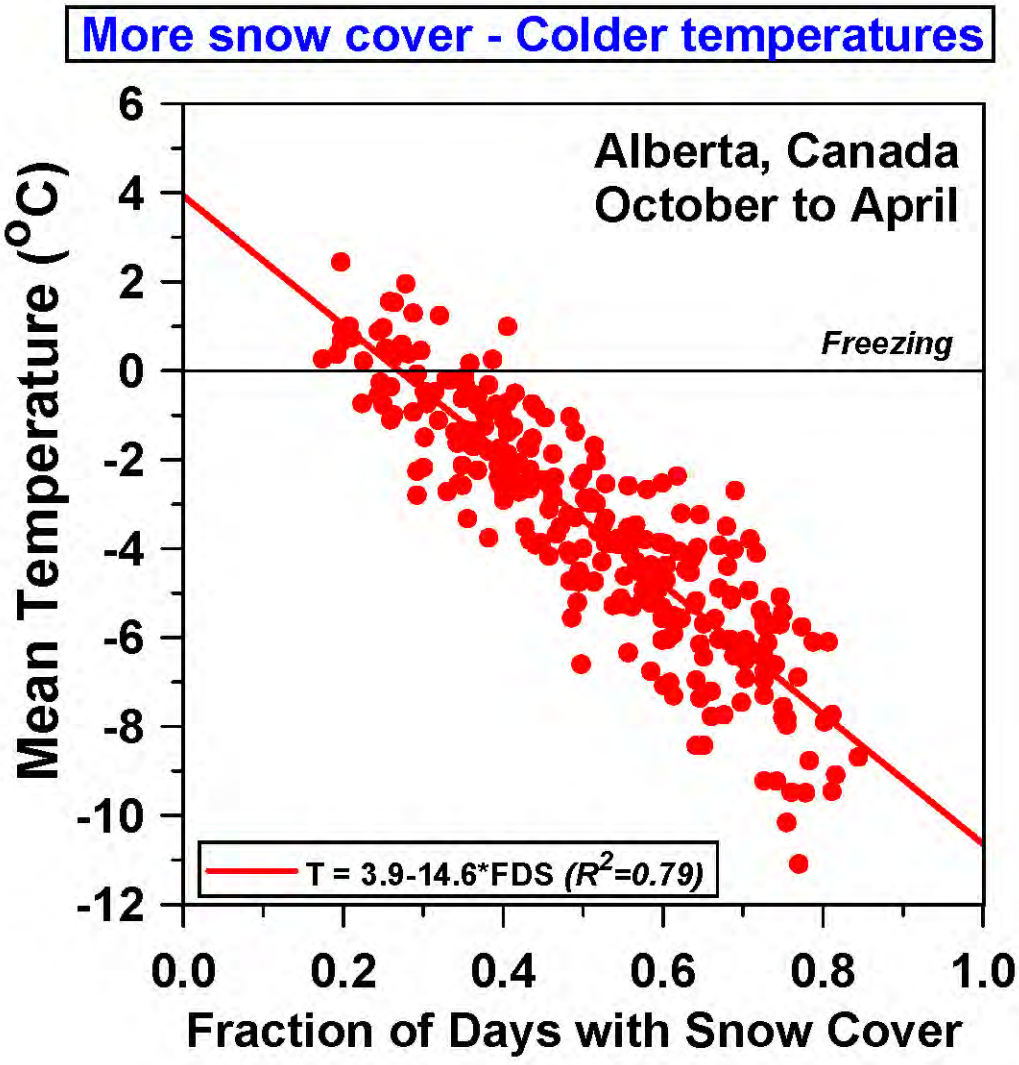
ΔT = T:no-snow –T:snow = -10.2(±1.1)°C

Betts et al. (2016)

Interannual variability of T coupled to Snow Cover

- Alberta: 79% of variance
- Slope T_m -14.7 (± 0.6) K

10% fewer days with snow cover = 1.5°C (2.6F) warmer on Prairies



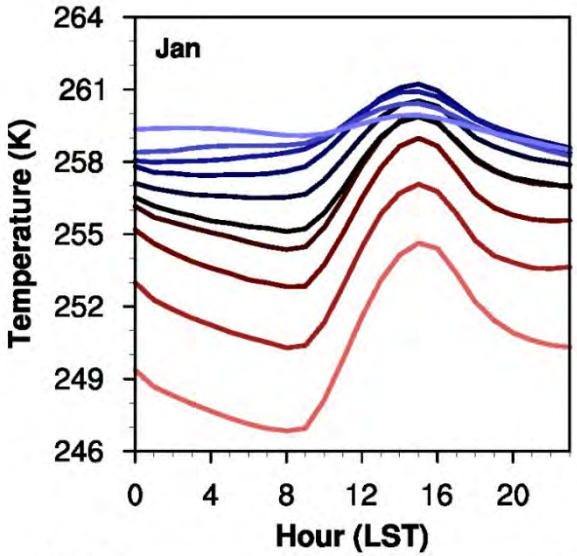
Diurnal cycle: Clouds & Snow

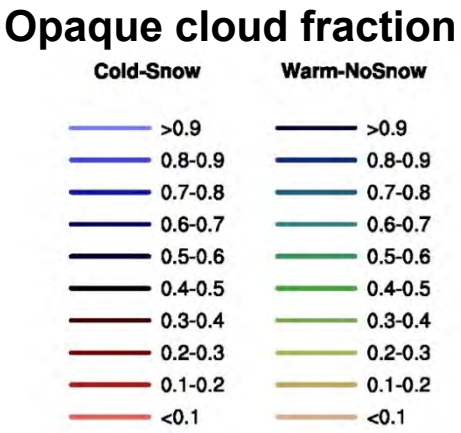
Canadian Prairies
660 station-years of data

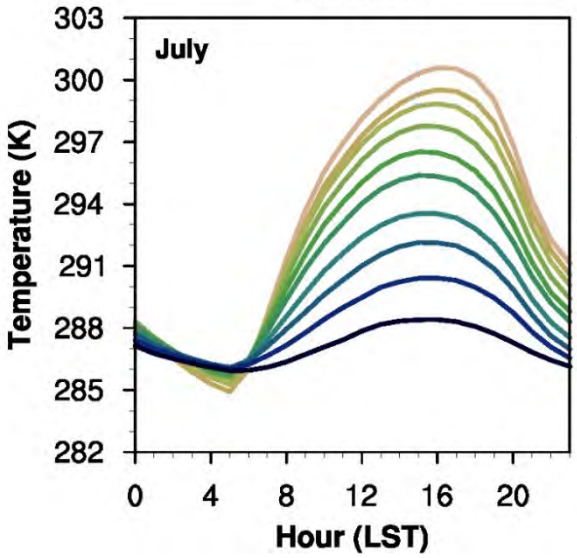
Winter climatology
- Snow reflects sunlight: cold
- Cools more when clear
- Warmest when cloudy

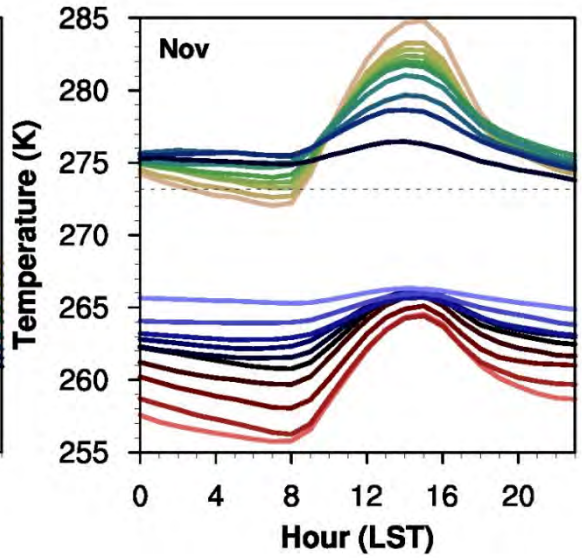
Summer climatology
- Clouds reflect sunlight
- Warmest when clear
- Coolest when cloudy

Transition months:
- Show both climatologies
- With 11K separation
- Fast transitions with snow
- Snow is “Climate switch”









Warm and Cold Seasons

- **Clouds - reflect sunlight**
- **Less cloud - Warm in afternoon**

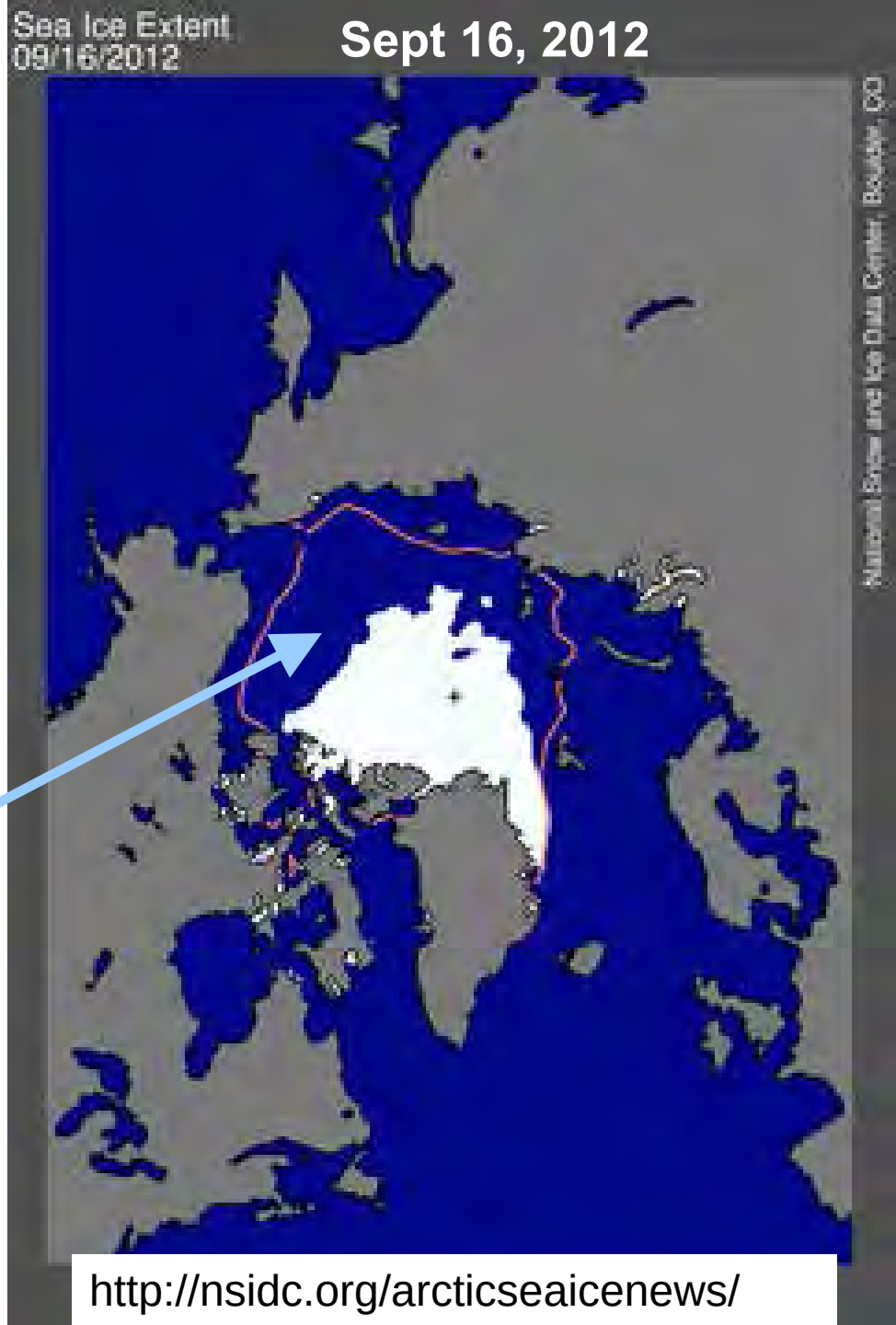
- **Snow - reflects sunlight**
- **Clouds: reduce cooling at night**
- **Less cloud: very cold at sunrise**

Earth's climate sustains life

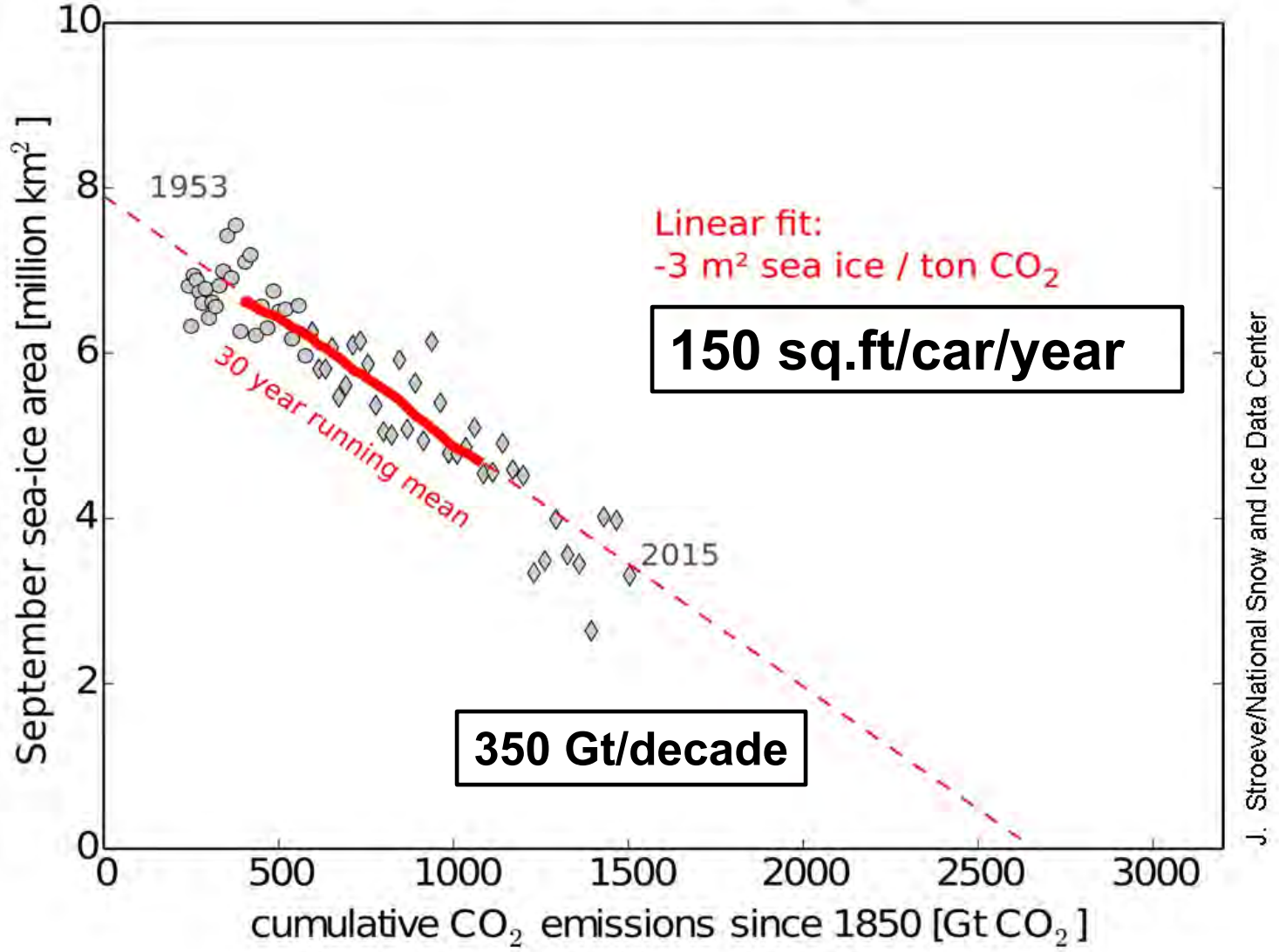
- Burning fossil fuels is increasing greenhouse gases
- Climate is warming: ice is melting, extreme weather is increasing
- Water plays crucial amplifying role
- Planetary modes crucial

- **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

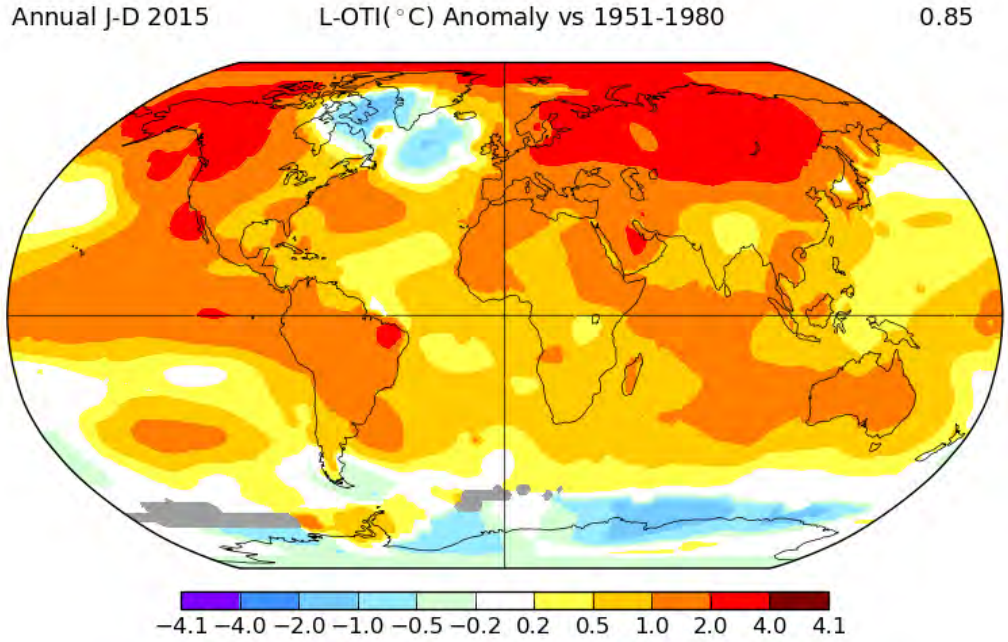


Trucks or lightweight Trikes!

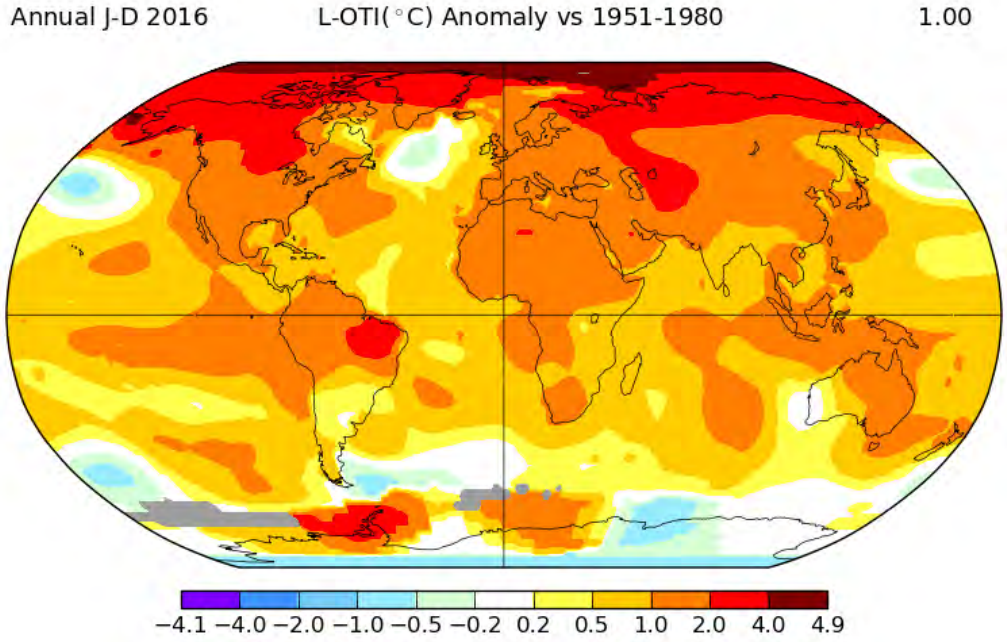
25 mph Danish electric tricycle: (not in production)

20 mph Organic Transit ELF: N. Carolina

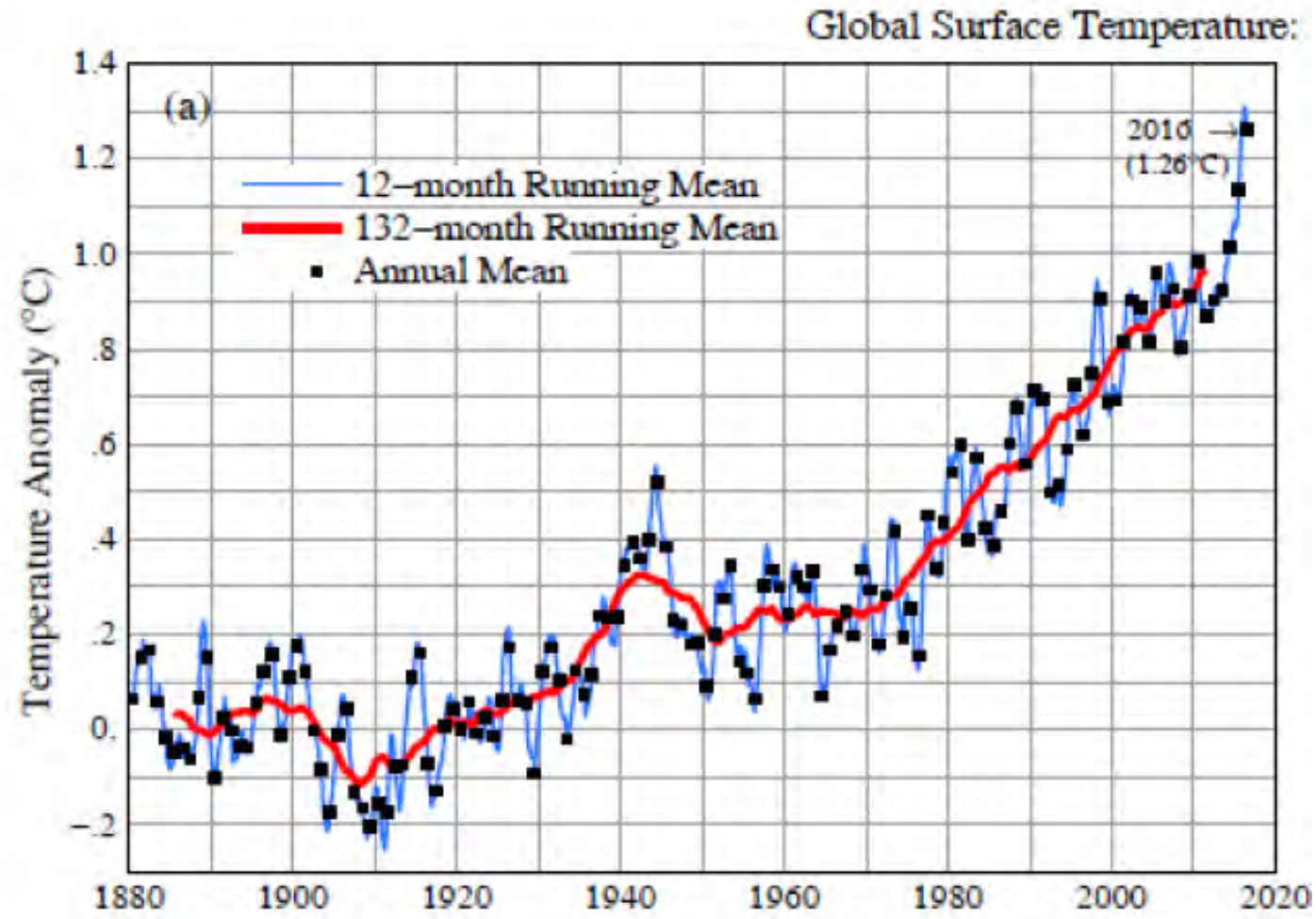
2015


Annual J-D 2015
L-OTI(°C) Anomaly vs 1951-1980
0.85
−4.1 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 4.1

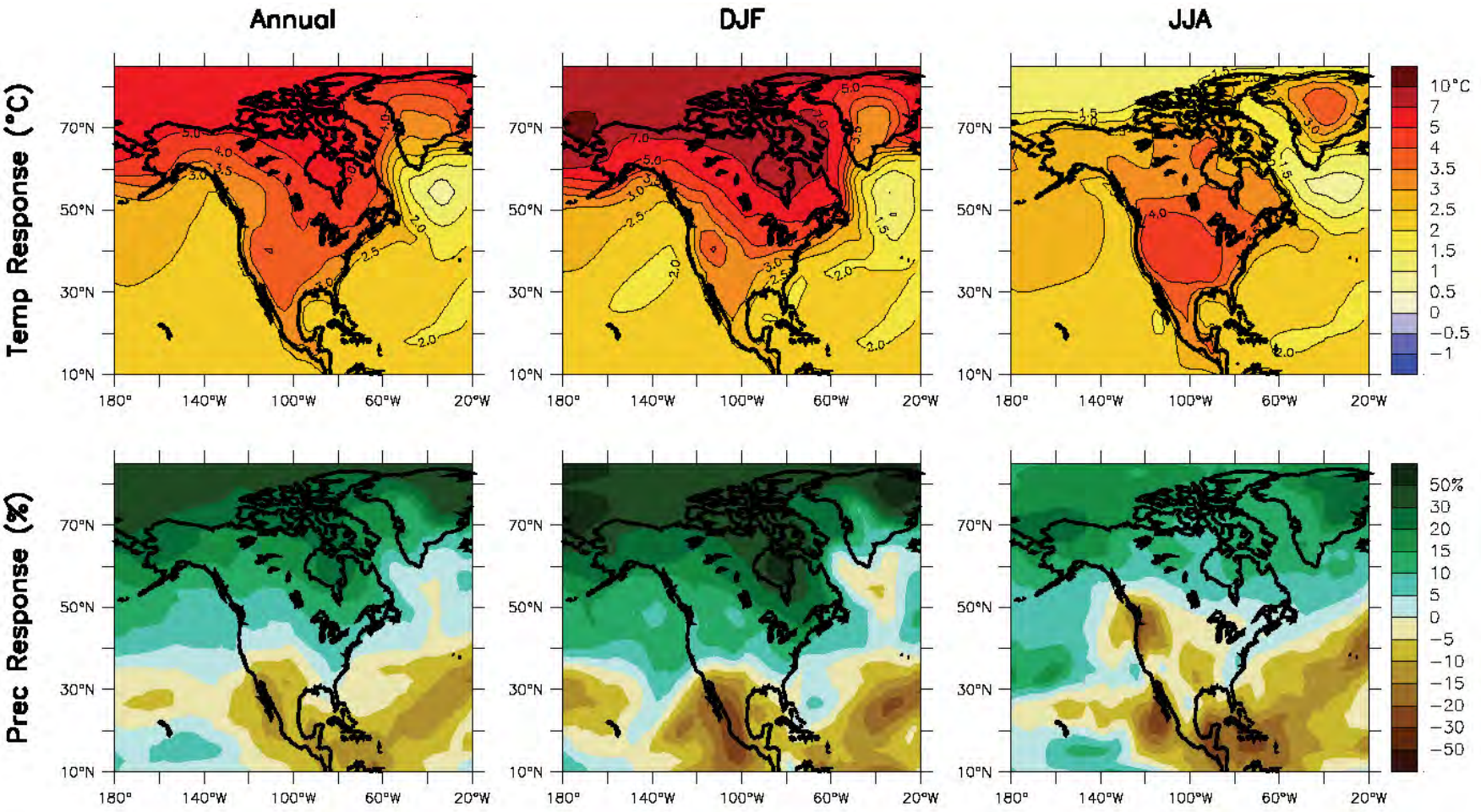
2016


Annual J-D 2016
L-OTI(°C) Anomaly vs 1951-1980
1.00
−4.1 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 4.9

Long-term Global Mean Trend 1880-2016



T, Precip. Changes (2090-1990)



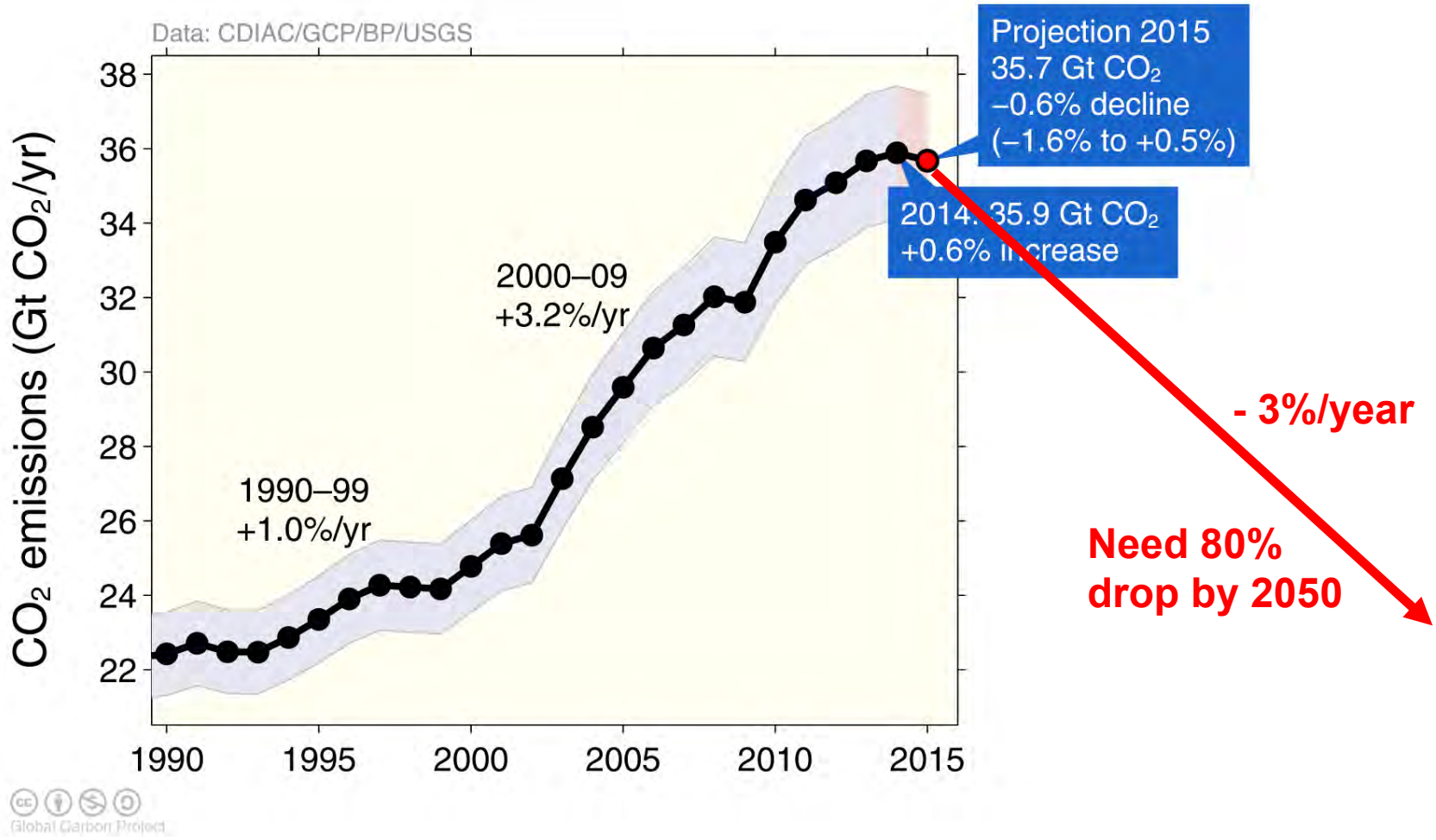
- Temperature and precipitation changes over North America from an average of 21 AOGCM projections for A1B **high emission scenarios**.
- Top row: Annual mean, winter (DJF) and summer (JJA) temperature change between 1980 to 1999 and 2080 to 2099. **[NE winter: +4.5C, +8F]**
- Bottom row: for fractional change in precipitation. **[NE winter: +25%]**

Can We Stop "Dangerous Climate Change"?

(UNFCCC 1992)

- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 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**

Growth of CO_2 Emissions Slowing?



If we go on ignoring issues?

- **Accelerating change, increasing extremes**
- **Increasing adaptation and rebuilding costs**
- **Environmental damage that will transform or destroy ecosystems- locally and globally**
- **Freely dumping waste streams from society into atmosphere, streams, lakes and oceans is unsustainable – long-term costs now exceed $1000 trillion – 'bankrupt US'**
- ***Will need fossil carbon tax (a "waste" tax) to incentivize mitigation and pay for the long-term costs***

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

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_2 to 1,000 ppm**
    - **in time melt icecaps, raise sea-level 150ft**
    - **Can we "sequester" CO_2 (put it back in the earth)?**

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 and human health?**
- **What strategies and mindset are needed to mitigate, adapt and build resilience in Vermont?**
  - **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?**

Food Issues

- **Milder winters and longer growing season in Northeast**
  - **Over-winter more crops; winters variable**
  - **Increasing variability of weather**
  - **Increasing precipitation extremes**
  - **Flood-plain and soil water management**
  - **Possible increase in summer pests**
- **Increasing drought in southern, central and western US**
  - **Critical fresh water issues world-wide**
  - **Many pumped aquifers near exhausted**

Sustainability Issues for Vermont

- **Energy efficient housing**
  - **Passive solar, net-zero, (geothermal)**
  - **Efficient lights, appliances**
  - **End-to-end recycling/remanufacturing**
- **Landscape management of water and waste-streams**
  - **Flood/drought extremes, runoff**
- **Community gardens and composting**
  - **Local food and waste management**
- **Renewable energy system/microgrids**
- **Efficient transportation/transit**

Simple Suggestions

- **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?
- **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 everything
  - Fully cost all waste streams
- **Relocalize food system**
  - Compost all organic waste
- **Default energy use should be 'OFF'**
  - Maximize energy efficiency: housing, transport, power
  - Add and monitor renewable power
- **Reconnect with natural world**
  - Fundamental if we are to accept transition

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

- **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***

- *“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

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

Discussion

alanbetts.com

(articles and talks)