Vermont Climate Change Indicators

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Climate Change

- **One of many great challenges for this century**
- **We are already decades late in taking action**

  J. S. Sawyer (1972): Man-made CO_2 and the "greenhouse" effect

- **It is a global issue & a local issue;**
  a societal issue & a personal issue
- **Earth science clashes with social values**
- **What is our responsibility as scientists?**

Strategy

Issues for the public

- ***Global changes are beyond direct experience***
- ***Complex models for future - limited credibility***
- ***Scientific literature is unintelligible jargon***

Instead

- **Identify what is happening locally, to link collective experience of local communities with global picture**
- **Deepens community understanding and acceptance of the reality of climate change**
- **Provides conceptual basis for adaptation planning (along with model projections)**

Local Example: What Is Happening to Vermont?

- **Local climate change indicators**
- **Easier to grasp than global view**

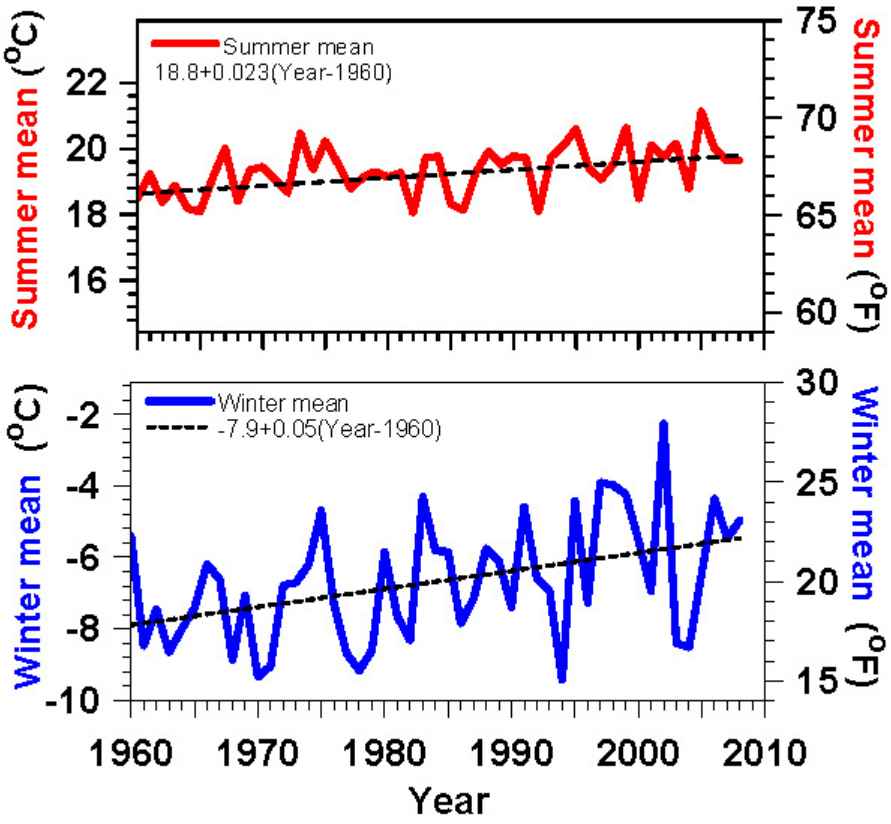
- **Warming twice as fast in winter than summer**
- **Winter severity decreasing**
- **Lakes frozen less by 7 days/decade**

- **Growing season longer by 3.7 days/decade**
- **Spring coming earlier by 2-3 days/decade**

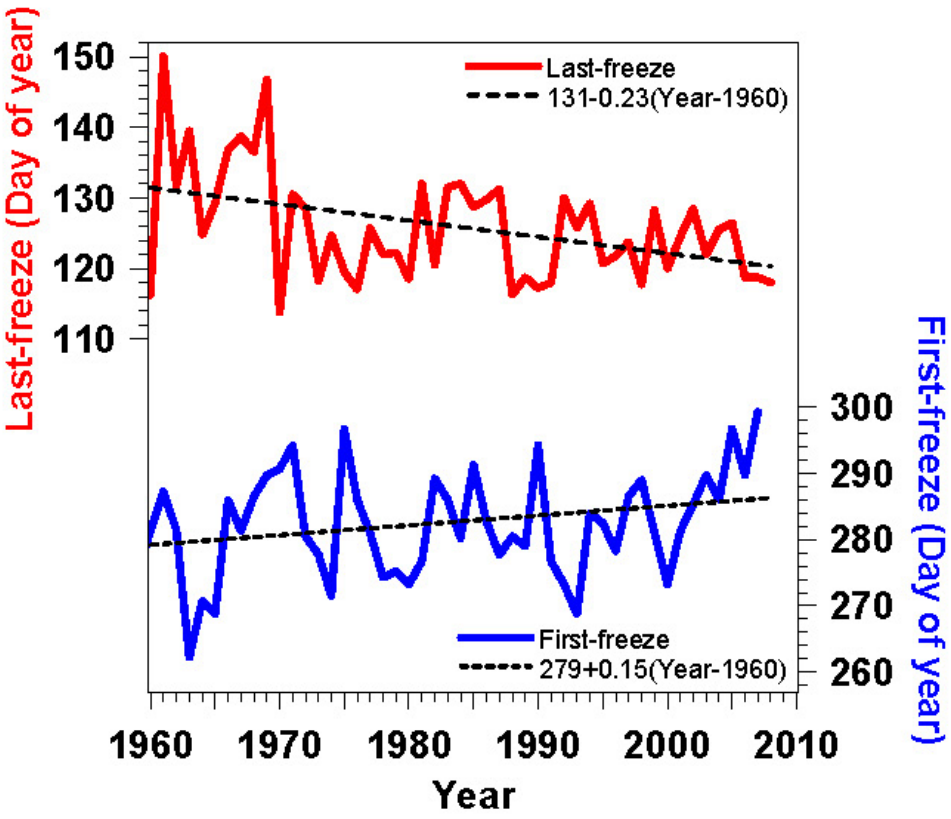
- ***Betts, A. K. (2011), Vermont Climate Change Indicators. Weather, Climate and Society, 3, doi: 10.1175/2011WCAS1096.1. (in press).***
  http://alanbetts.com/research

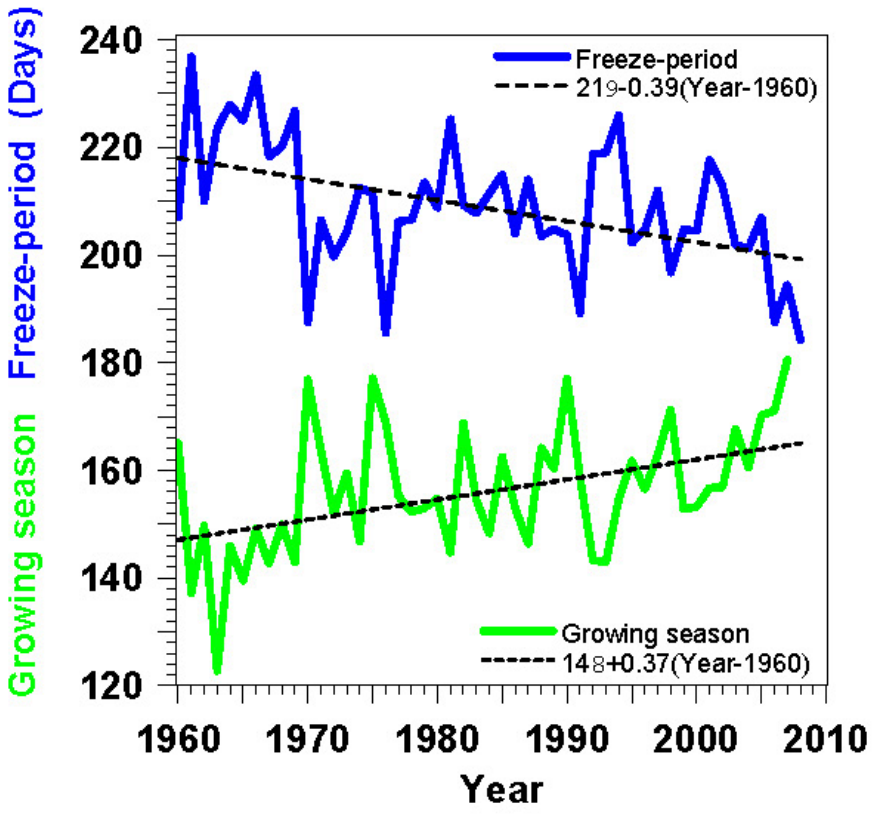
Vermont Temperature Trends

- **Summer +0.4°F/decade**
- **Winter +0.9°F/decade**
- **Less snow drives larger winter warming**



First and Last Frosts Changing

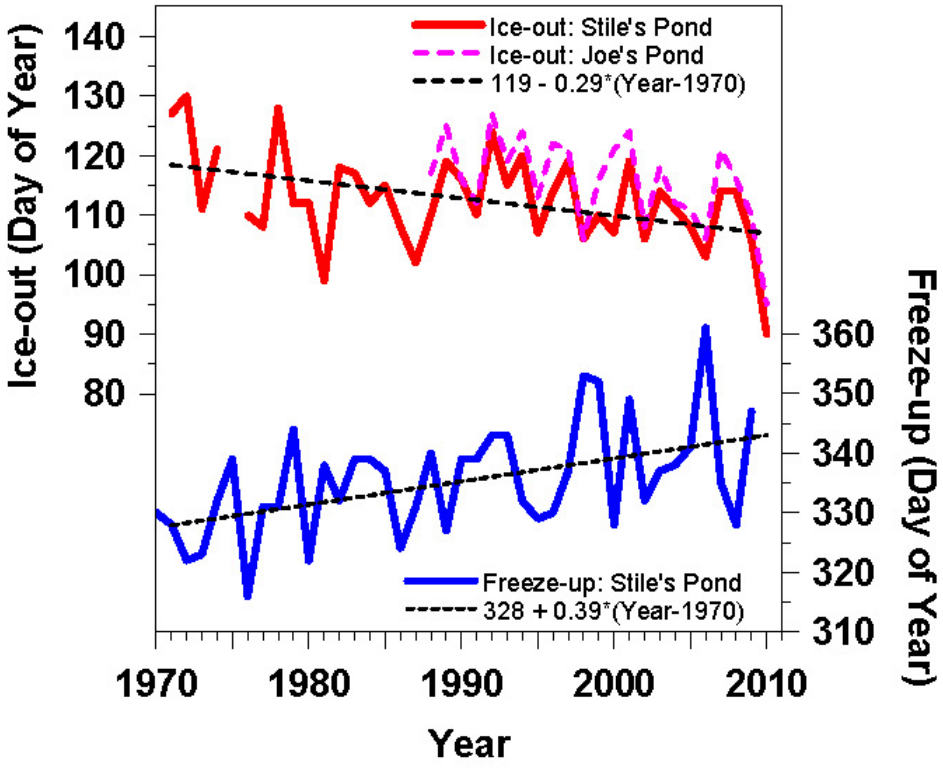


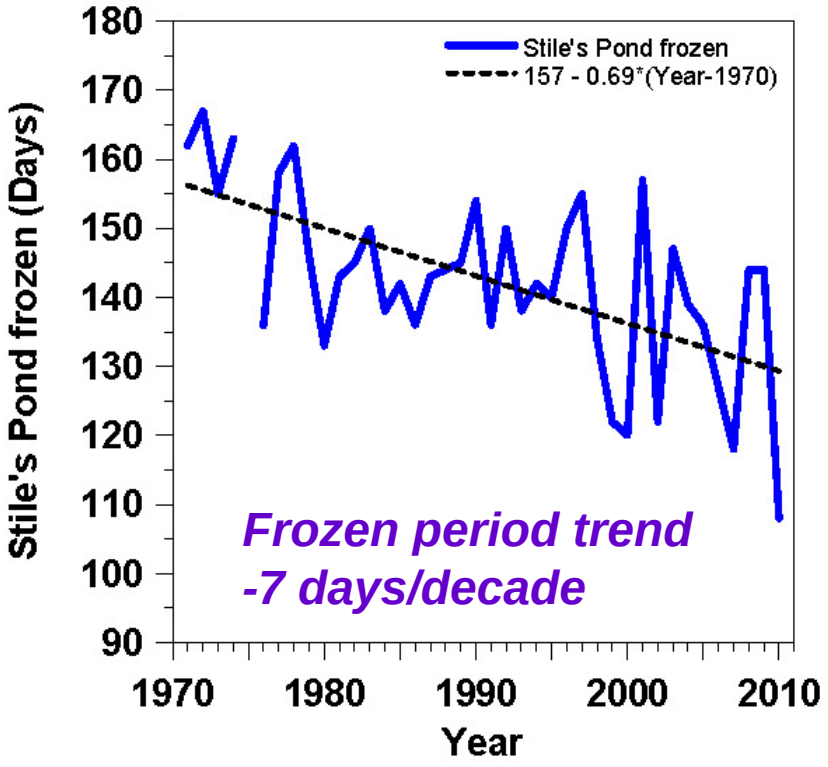


- **Growing season for frost-sensitive plants increasing 3.7 days/decade**
- **A help for growing “local food”**

Lake Freeze-up & Ice-out Changing

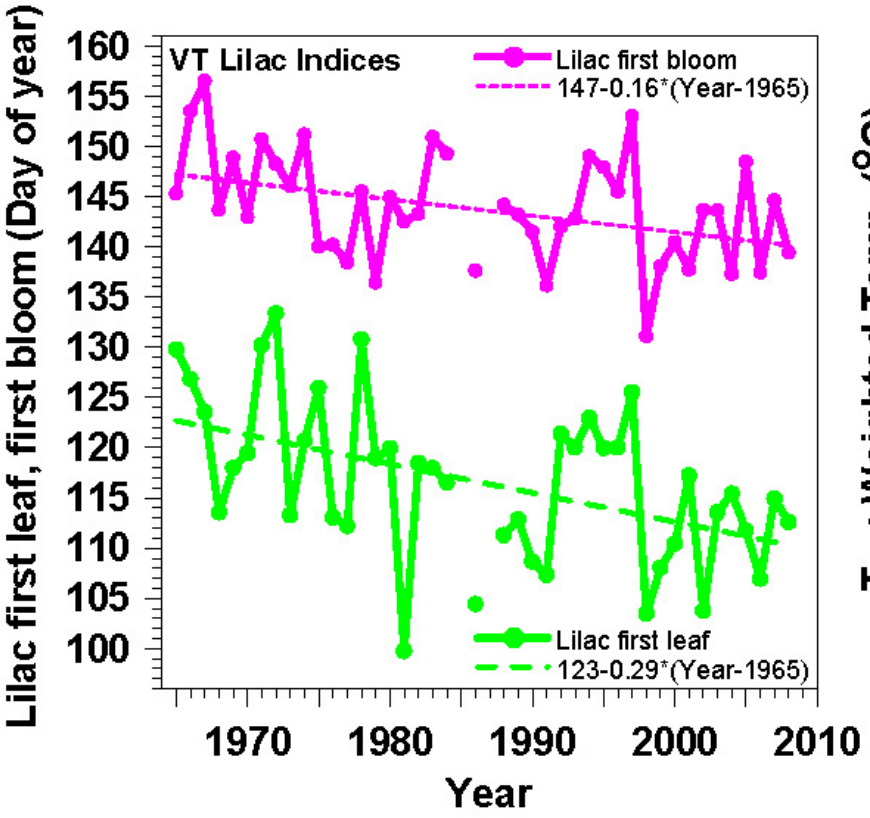
Frozen Period Shrinking Fast

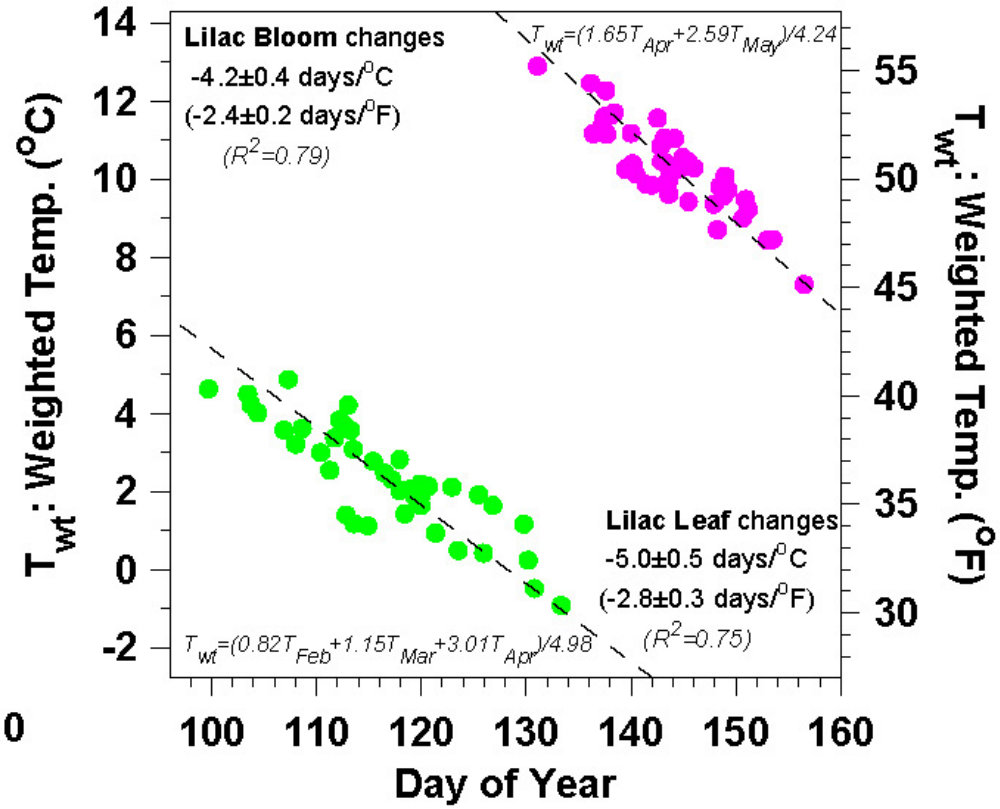




- **Ice-out earlier by 3 days/decade**
- **Freeze-up later by 4 days/decade**

Lilac Leaf and Bloom In Spring





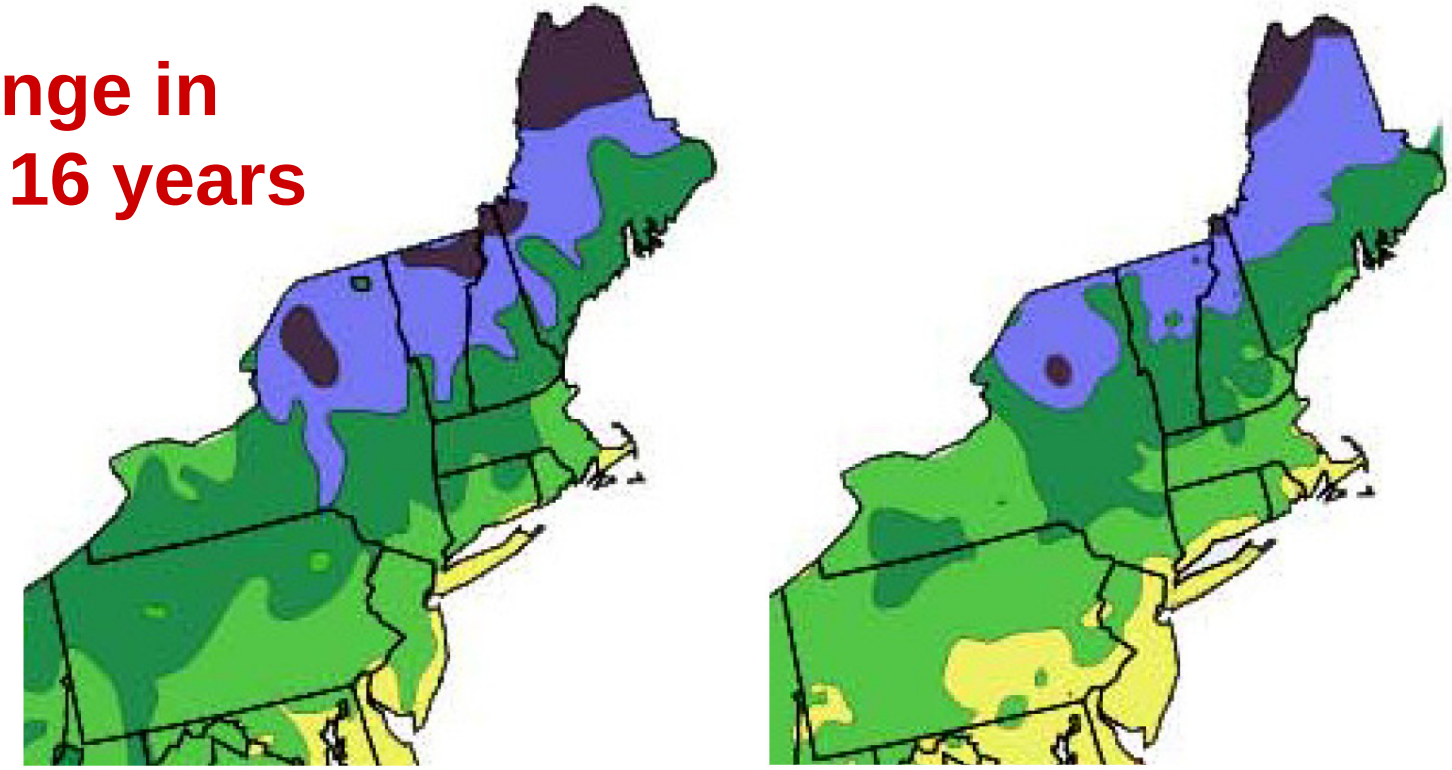
- **Leaf-out earlier by 3 days/decade (tracks ice-out)**
- **Bloom earlier by 1.5 days/decade**
- **Leaf & bloom change 2.5 days/°F (4.5 days/°C)**

Vermont Winter 2006

- **Sun is low; and snow reflects sunlight, except where there are trees**
- **Sunlight reflected, stays cold; little evaporation, clear sky; earth cools to space**

USDA Hardiness Zones - Northeast

Change in last 16 years



1990 2006

Zone

2 3 4 5 6 7 8 9 10

USDA Hardiness Zones

Gardening in Pittsford, Vermont in January

January 7, 2007

December 2006:

- **Warmest on record**

January 10, 2008

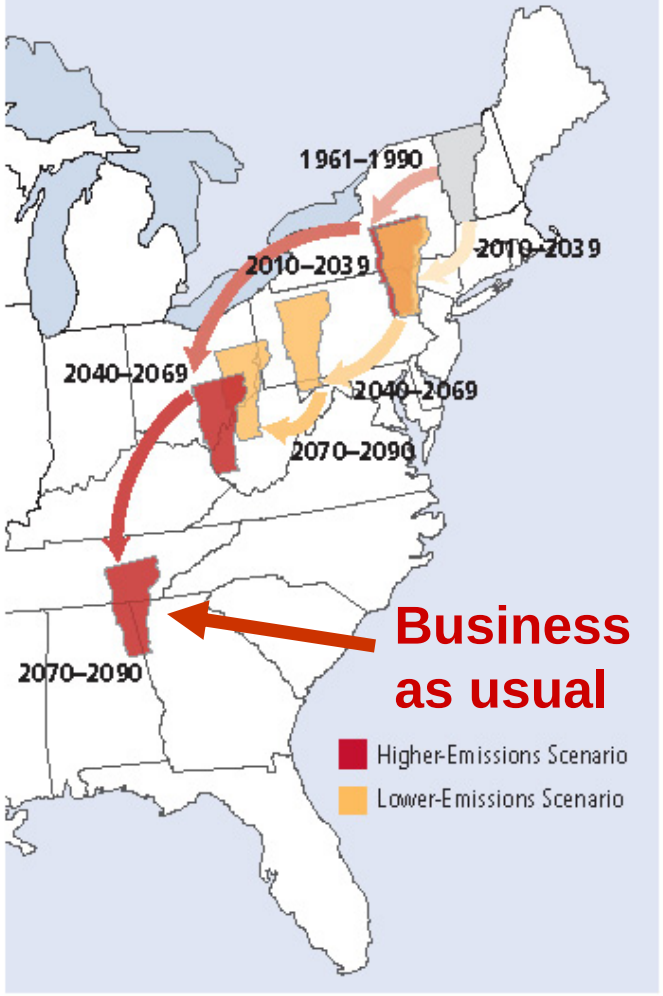
Warm Fall:

- **Record Arctic sea-ice melt**
- **Snow cover in December, ground unfrozen**

Vermont's Future with High and Low GHG Emissions

What about skiing?

What about tropics?



Migrating State Climate

Changes in average summer heat index—a measure of how hot it actually feels, given temperature and humidity—could strongly affect quality of life in the future for residents of Vermont. Red arrows track what summers in Vermont could feel like over the course of the century under the higher-emissions scenario. Yellow arrows track what summers in the state could feel like under the lower-emissions scenario.

NECIA, 2007

Conclusions

- **There are significant climate trends in New England in the past fifty years**
- **They are consistent with climate model projections for the next few decades**
- **Together these provide a basis for communities understanding climate change and making adaptation plans**

- **http://alanbetts.com/research**
- **http://www.anr.state.vt.us/anr/climatechange/Adaptation.html**

Additional Material

- Following slides

How Do We Manage the Earth?
(When there is so much we don't know)

- **Need a long time horizon:**
  - **Generational to century**
- **We need some new rules or guidelines!**
  - **Our numbers are so great**
  - **Our industrial impact is too large**
  - **Maximizing profit as a guiding rule has failed us**
- **Re-localize to regain control & responsibility and minimize transport**

Broad Guidelines or Rules to Minimize Impacts

- **Minimize the lifetime of human waste products in the Earth system and eliminate waste with critical 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**

Examples of Long-lived ‘Waste’

- **CFCs – refrigerants – very stable – lifetime centuries - broken down by sunlight in stratosphere – catalyze ozone destruction, which protects earth from UV**
- **CO_2 from fossil fuels – lifetime centuries – a greenhouse gas that traps earth’s heat radiation – pushing earth to warmer climate**
- **Nuclear waste – radioactive – plutonium-239 half-life, 24000 years – nuclear weapons**

What are Scientists' Responsibilities?

- **Climate science is under attack because it is politically and economically relevant**
- ***Traditionally scientists "stuck to science"***
- **How do we proactively defend the science and maintain trust and integrity of science?**
- **Needs deeper ethical/historical understanding**
- **Needs greater public engagement by scientists**
- ***Betts, A. K. (2011): Communicating Climate Science. EOS Transactions, 92, No. 24, 14 June 2011.***