Vermont Climate Literacy

- what do we all need to know?

Dr. Alan K. Betts

Vermont Academy of Science and Engineering (VASE)

Atmospheric Research, Pittsford, VT 05763

akbetts@aol.com
http://alanbetts.com

DKG, Rutland

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NASA/JPL

Climate Change

- **One of the many great challenges for the 21st 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

- **Clash of Earth science with social values**

Outline

- **Science of climate change**
  - **Global and local scale**
  - **What is happening to Vermont**

- **The transition we face**
  - **Managing the earth system**
  - **Why is it difficult?**

Discussion

How can we explain climate to students? & ourselves!

Blend big picture issues and local issues

Explain concepts pictorially, using seasonal climate

- **What is seasonal climate?**

- **Seasonal transitions**
- ***Spring, Summer, Autumn and Winter***
- ***Familiar but poorly understood***

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***

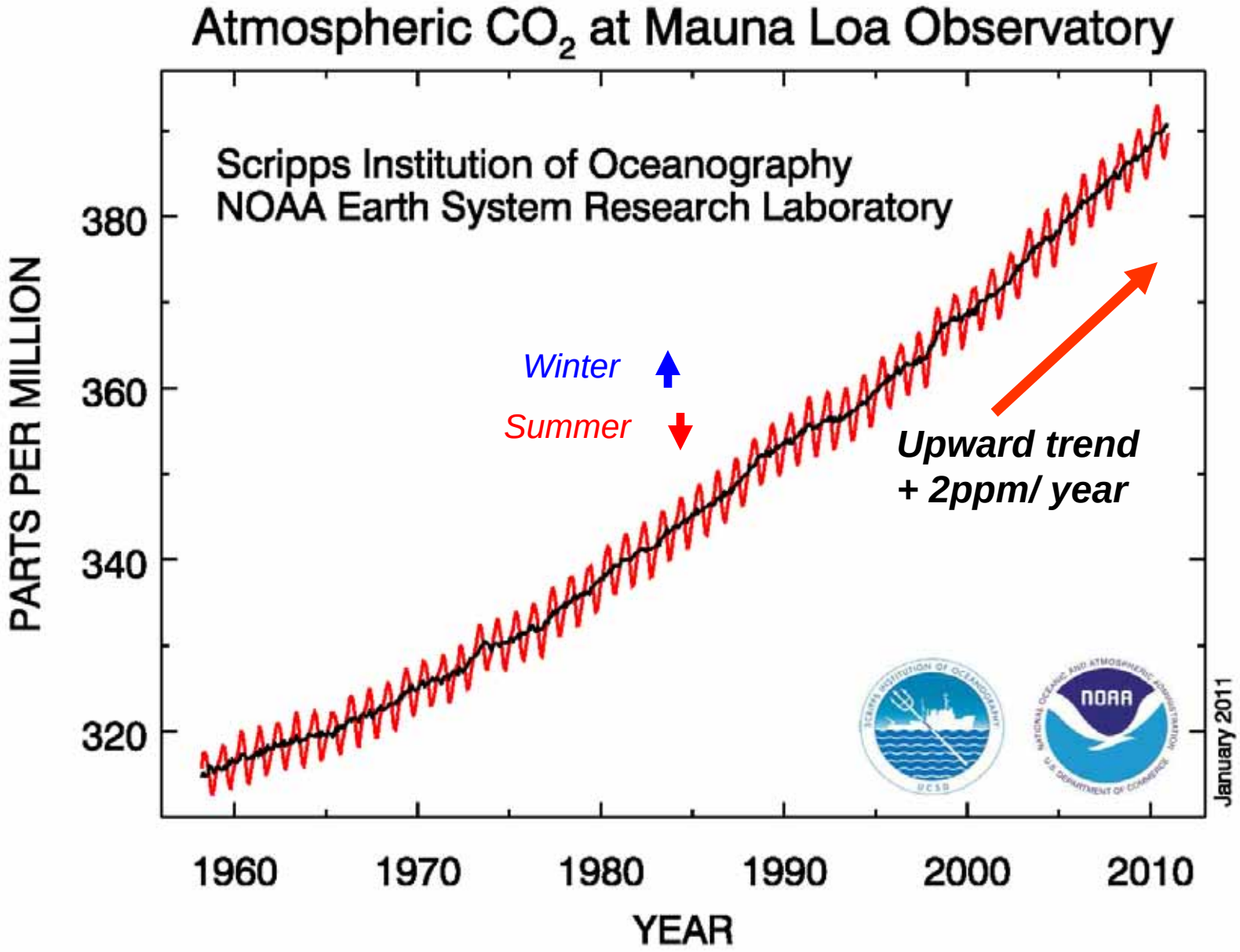
Spring transition

- **Warm dry week to ten days in Spring, after snowmelt, past equinox**
- **Followed by drop of temperature of ≈3C/5F with leaf-out –wave up the eastern seaboard**
- **Many key climate processes:**
- **Seasonal lags-melt of frozen soils**
- **Vegetation-evaporation coupling**
- **Latent heat of evaporation reduces temp.**
- **Evaporation-RH-cloud-WV greenhouse**
- **Clear-sky- large temperature range-frost**

Spring green-photosynthesis

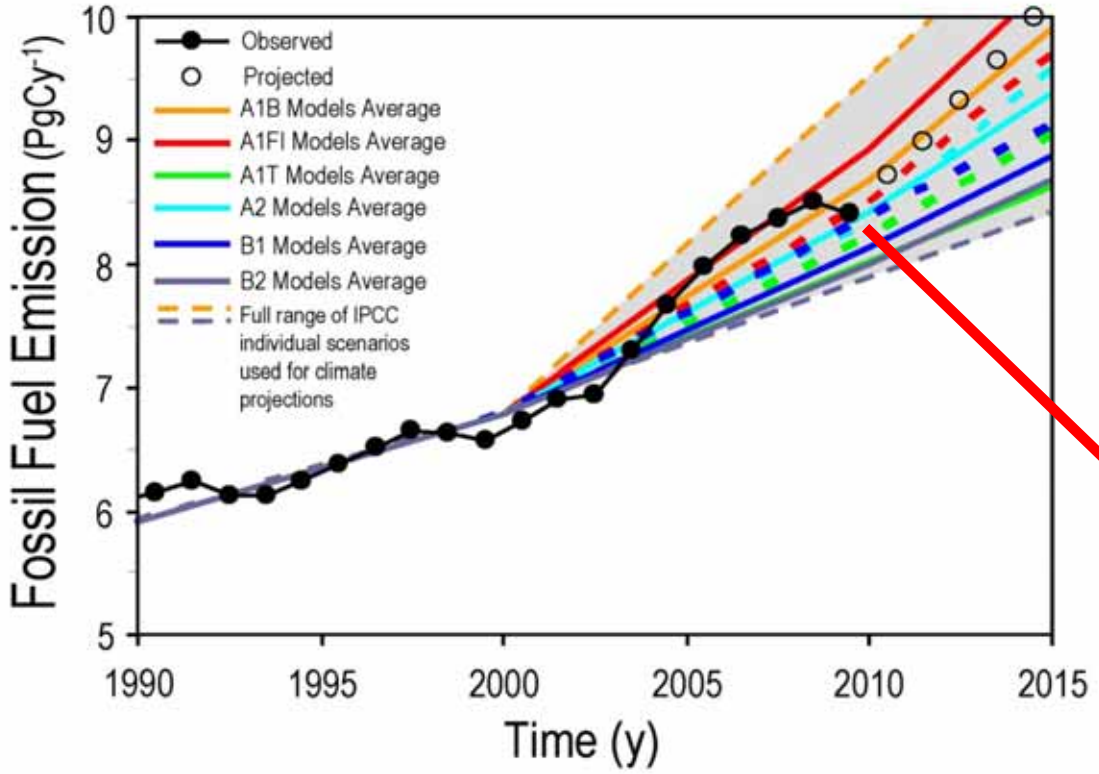
- **Leaves use red light to soak up carbon dioxide and grow. They give off oxygen.**

Carbon Dioxide Is Increasing



2009 Was “Good” for the Earth

Fossil Fuel Emissions: Actual vs. IPCC Scenarios

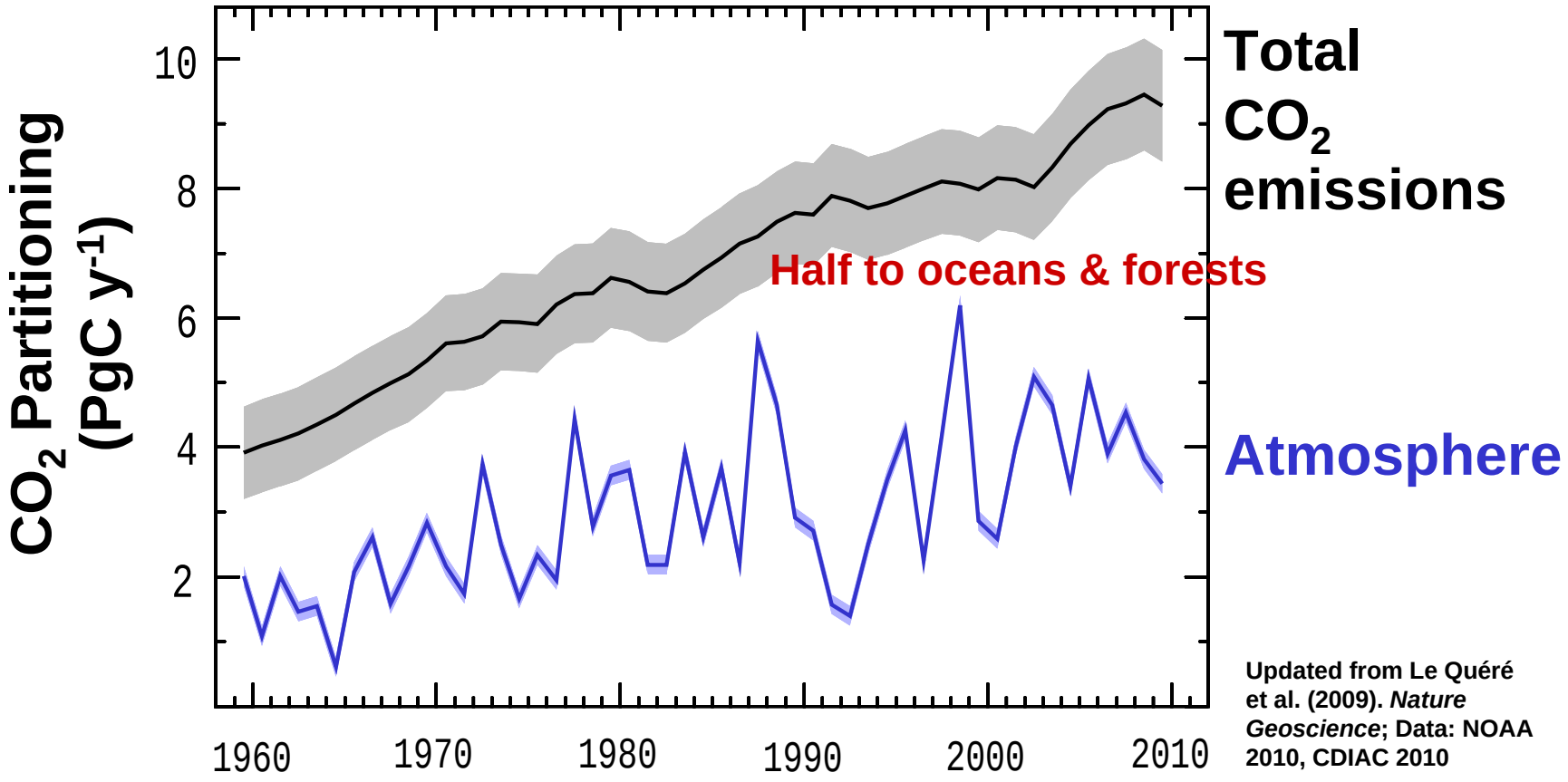


- 4%/year

Updated from Raupach et al. 2007, PNAS; Data: Gregg Marland, Thomas Boden-CDIAC 2010; International Monetary Fund 2010

Key Diagnostic of the Carbon Cycle

Evolution of the fraction of total emissions that remain in the atmosphere



It takes at least a century to remove CO_2 from the atmosphere, and many centuries to remove it from oceans

Why Is the Rise of Atmospheric CO_2 a Problem?

- **The atmosphere is transparent to light from the sun, but not to infrared radiation from the earth**
- **Greenhouse gases: H_2O, CO_2, CH_4**
  - **trap the earth's heat, giving pleasant climate**
- **CO_2 rise alone has a small effect, BUT…**

Why Is the Rise of Atmospheric CO_2 a Problem?

- **As Earth warms, evaporation and water vapor increase and this amplifies warming a lot (3x)**
- **As Earth warms, snow and ice decrease and this amplifies warming in winter and northern latitudes, because less sunlight is reflected**

- **Doubling CO_2 will warm Earth about 5°F (3°C)**
  - **much more in the North and over land**

Summer transition

- **Summer dry-down; soil moisture falls, evaporation falls, BL drier, no precipitation**
- **Can lock into a dry spell, a ‘drought’ till upset by strong weather system**
- **But it can go either way…**
- **2008, 2009, 2011, we had wet Vermont summers with positive evaporation-precipitation feedback**

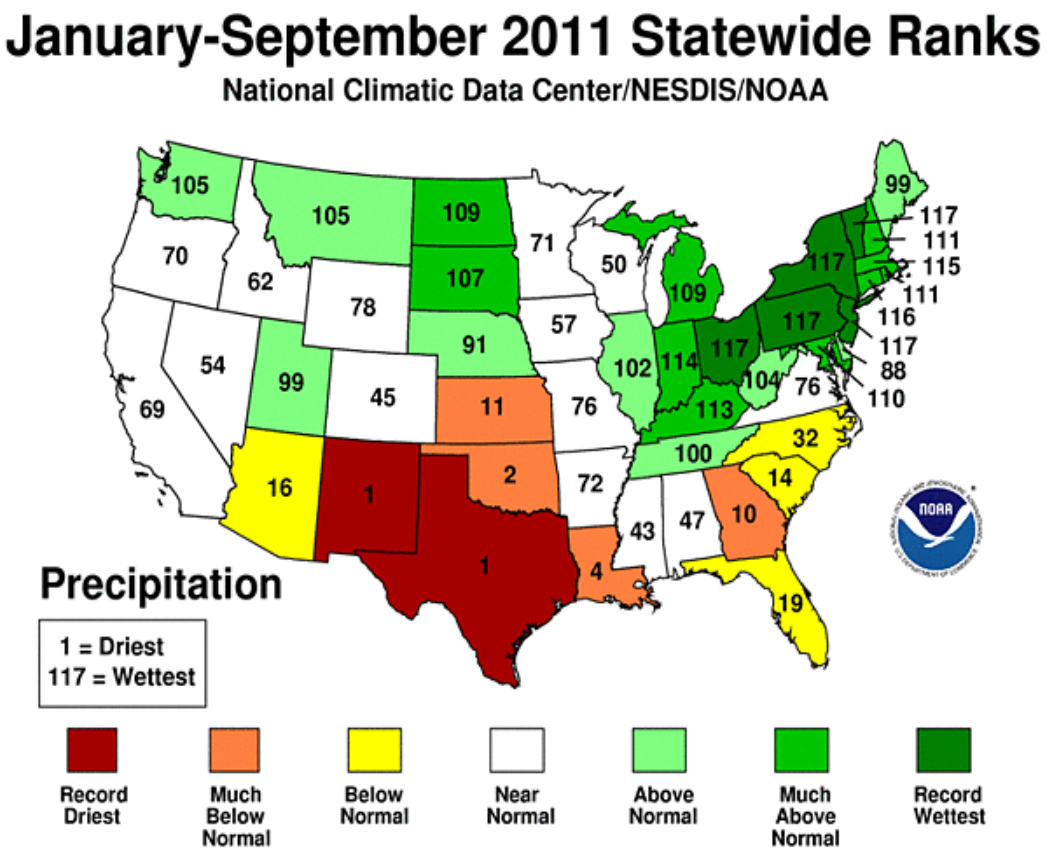
Wet summer – Dry summer

- *feedback can go either way*

- **Direct fast evaporation off wet canopies & more rain**
- **Dry-down of soil and less evaporation & less rain**
- **Depends on weather systems**

Year of Irene

- OH-VT wettest
- NM & TX driest
- ‘Fixed’ pattern all year
- Irene dumped 6+ inches of rain on saturated ground giving extreme flooding



Fall Climate Transition

- **Vegetation postpones first killing frost**
- **Deciduous trees still evaporating: moist air with clouds**
- **Water vapor & cloud greenhouse reduces cooling at night and prevents frost**
- **Till one night, dry air advection from north gives first hard frost.**
- **Vegetation shuts down, leaves turn, skies become clearer and frosts become frequent**
- ***The opposite of what happens in Spring with leaf-out!***

Clear dry blue sky after frost. Forest evaporation has ended; water vapor greenhouse is reduced, so Earth cools fast to space at night

Later frost: Growing season getting longer. In 2011, my first frost Oct.28th with snowfall.

Winter transition

- **First heavy snow brings plunge of Temp. because reflection of sunlight drops net radiation below zero**
- **Related to snow/ice-albedo feedback in climate system (Arctic Melting)**
- **Coupled to water vapor greenhouse feedback: evaporation falls with frozen temperatures & cloud decreases. With clear sky Earth cools to space and locks in colder temperatures**

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**

Gardening in Pittsford, Vermont in January

January 7, 2007

December 2006:

- **Warmest on record**

January 10, 2008

Warm Fall:

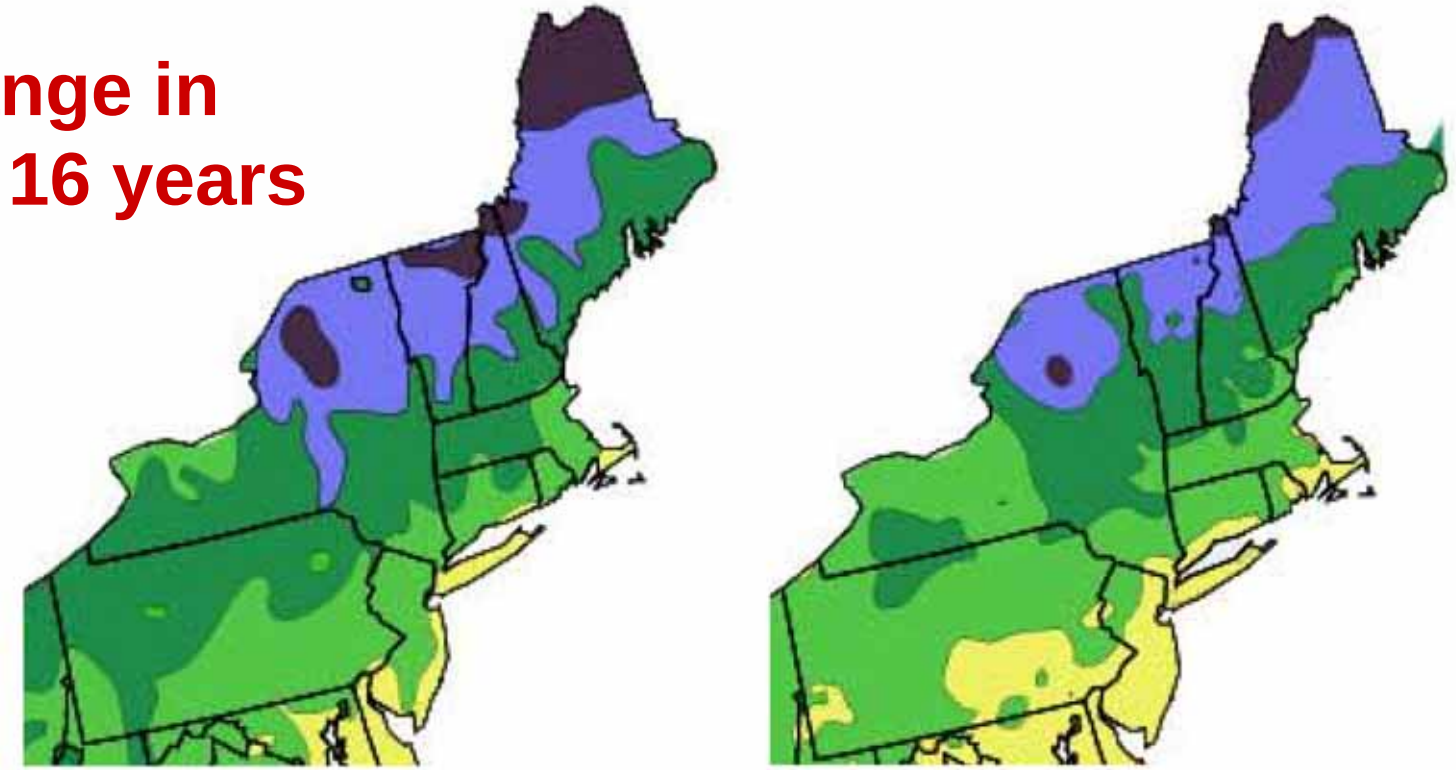
- **Record Arctic sea-ice melt**
- **Snow cover in December, ground unfrozen**

Brussel sprouts can now survive VT winter [protected by leaves & snow]

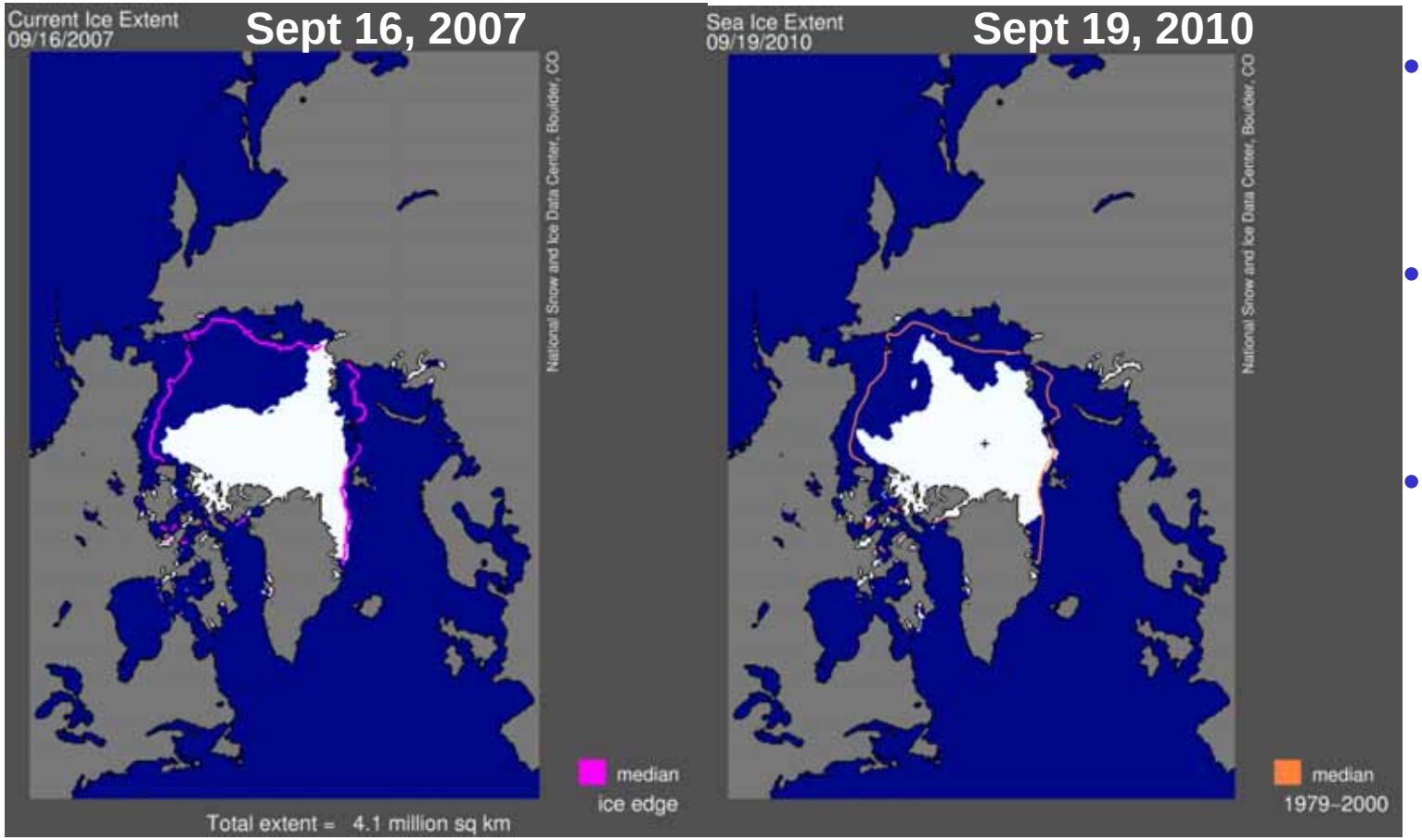
Picked February 10, 2008, Pittsford, VT

USDA Hardiness Zones - Northeast

Change in last 16 years



Arctic Sea Ice Loss Has Accelerated



- **Feedbacks speed melting**
- **Less ice, less sunlight reflected**
- **More evaporation, larger water vapor greenhouse effect**

(www.nsidc.org)

- **Record ice loss in 2007**
  - **most ice now only 1-2 years old**
- **Open water in October contributes to warmer Fall**

What Is Happening to Vermont?

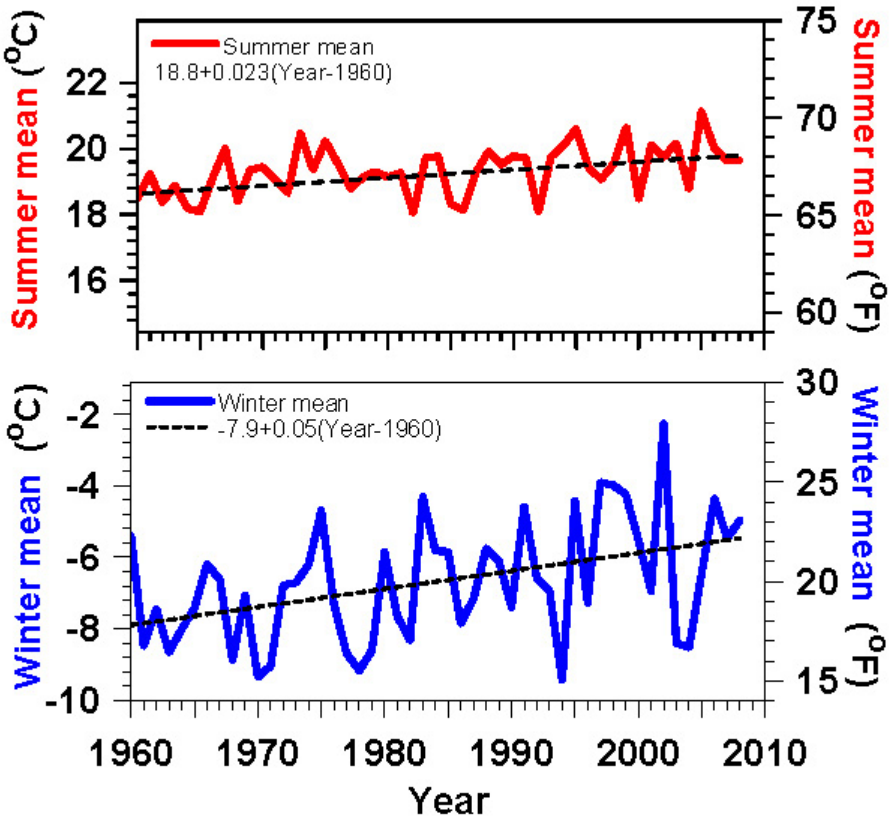
- **Local climate change indicators**
- **Easier to grasp than global view**

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

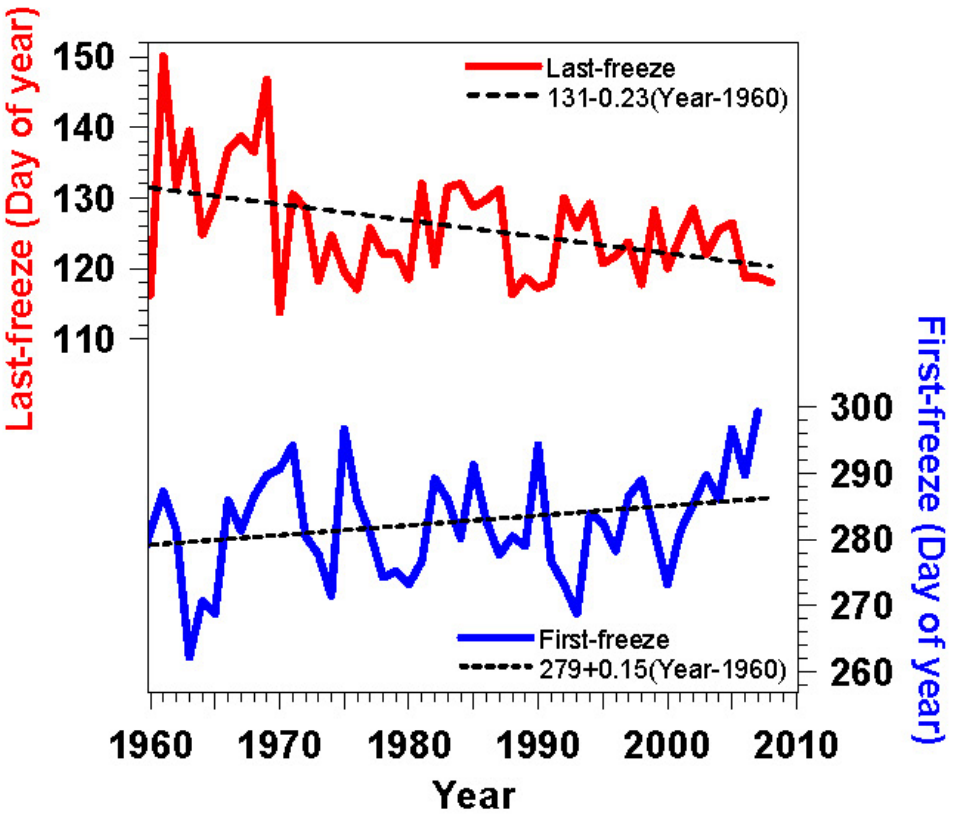
- **Growing season longer by 3.7 days / decade**
- **Spring coming earlier by 2-3 days / decade**

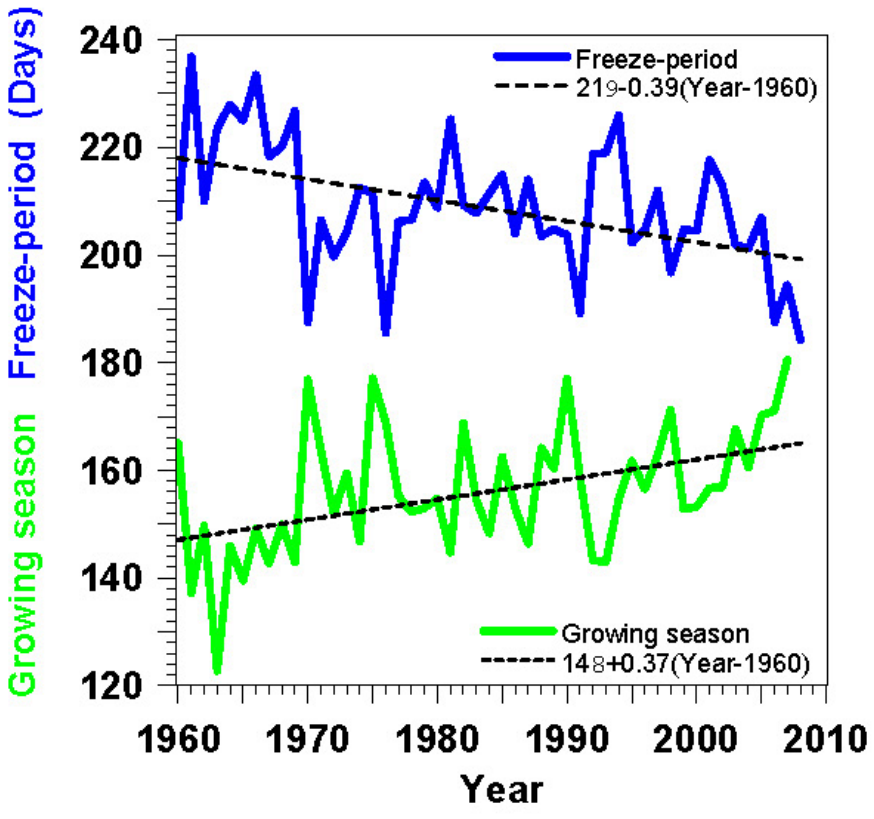
Vermont Temperature Trends

- **Summer +0.4°F / decade**
- **Winter +0.9°F / decade**
- **Less snow drives larger winter warming (last winter, snowy and cold)**



First and Last Frosts Changing

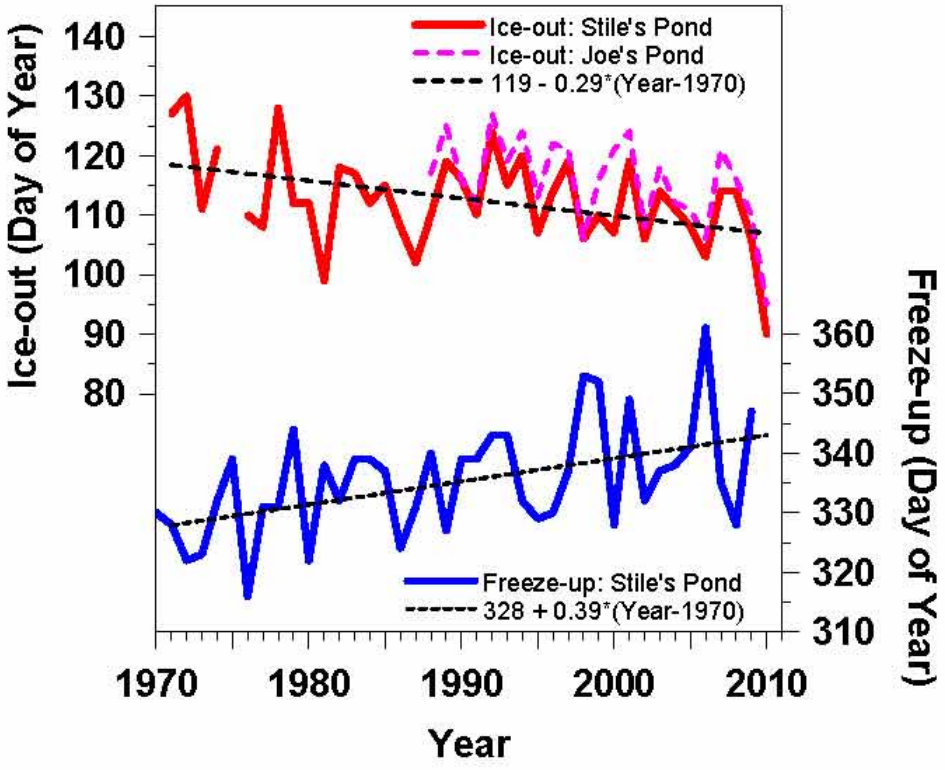


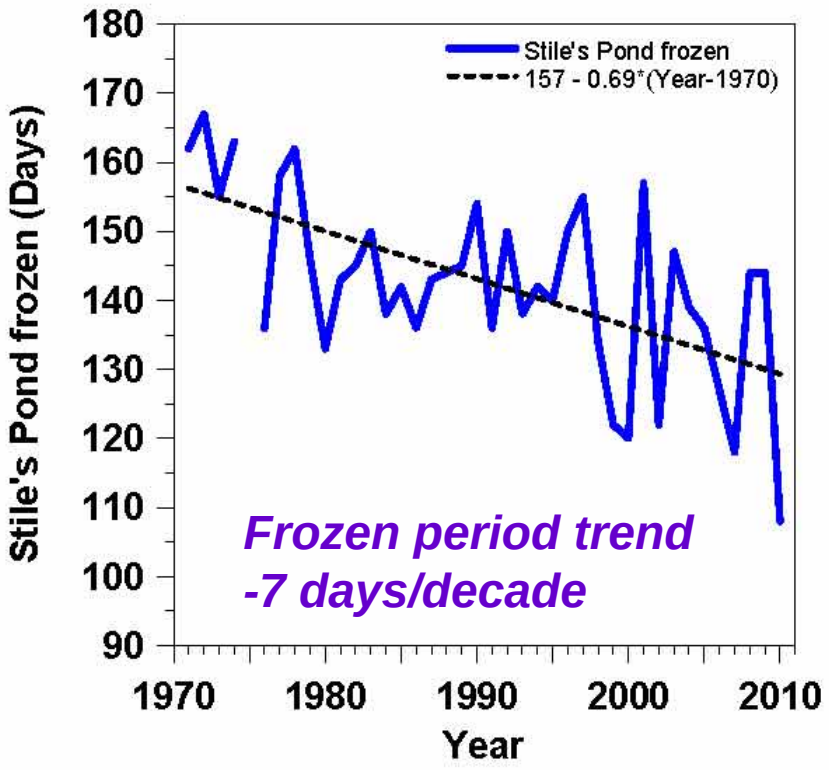


- **Growing season for frost-sensitive plants increasing 3.7 days / decade**
- **A help for growing “local food”**

Lake Freeze-up & Ice-out Changing

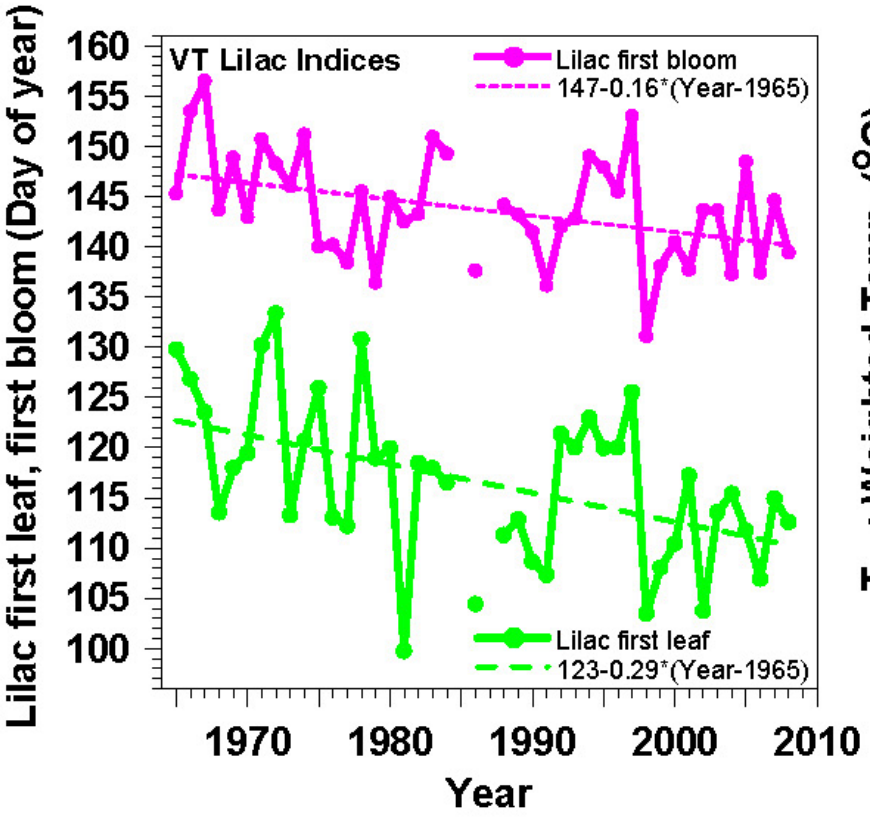
Frozen Period Shrinking Fast

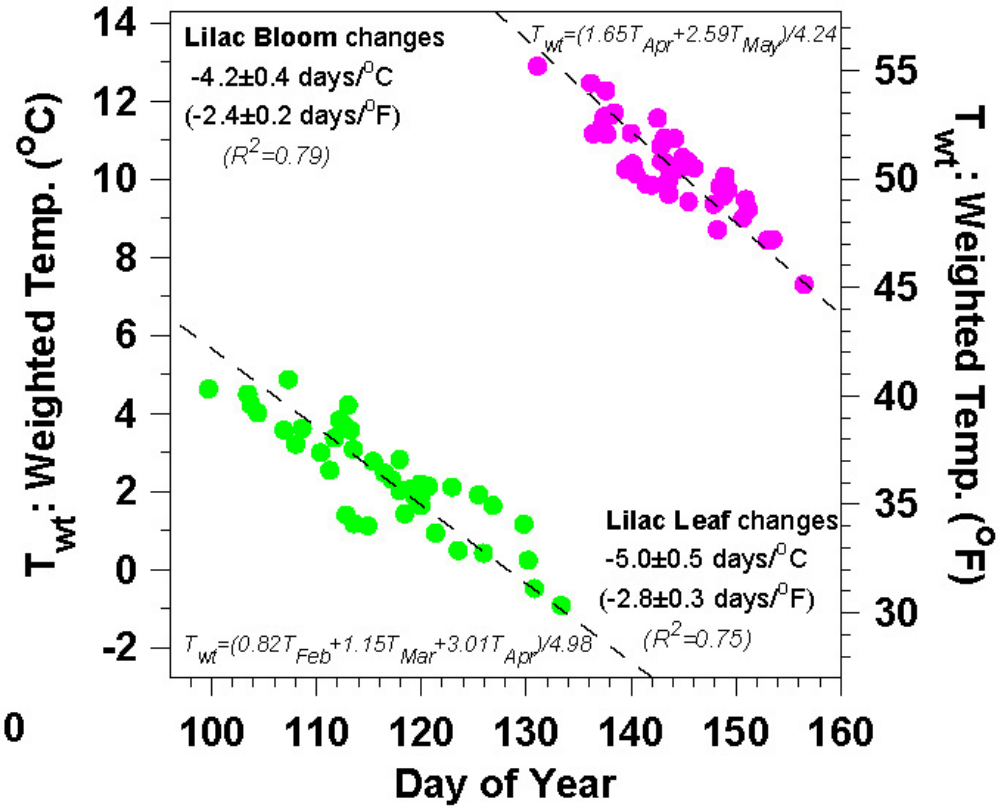




- Ice-out earlier **by 3 days / decade**
- Freeze-up later **by 4 days / decade**

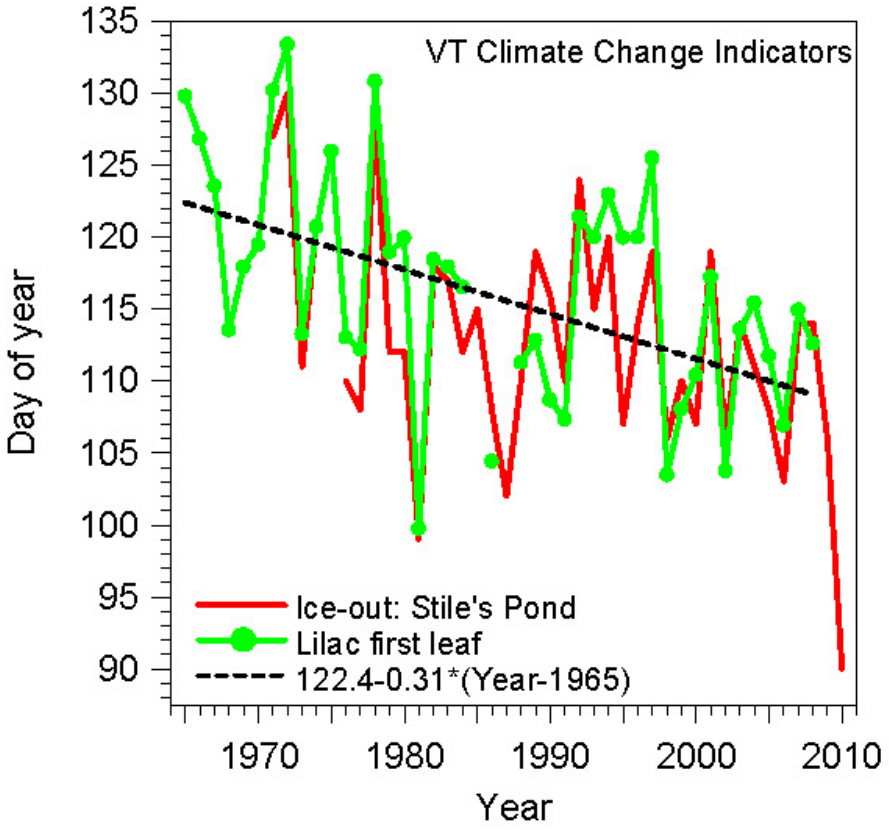
Lilac Leaf and Bloom in Spring

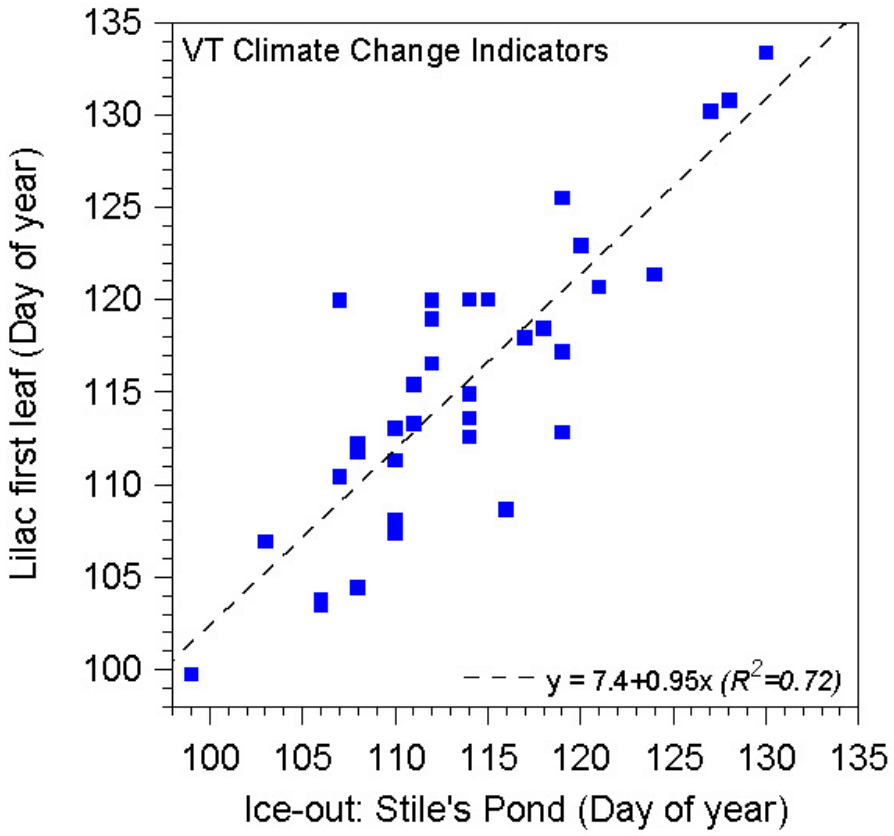




- **Leaf-out earlier by 3 days/decade (tracks ice-out)**
- **Bloom earlier by 1.5 days/decade**
- **Leaf & bloom change 2.5 days/°F (4.5 days/°C)**

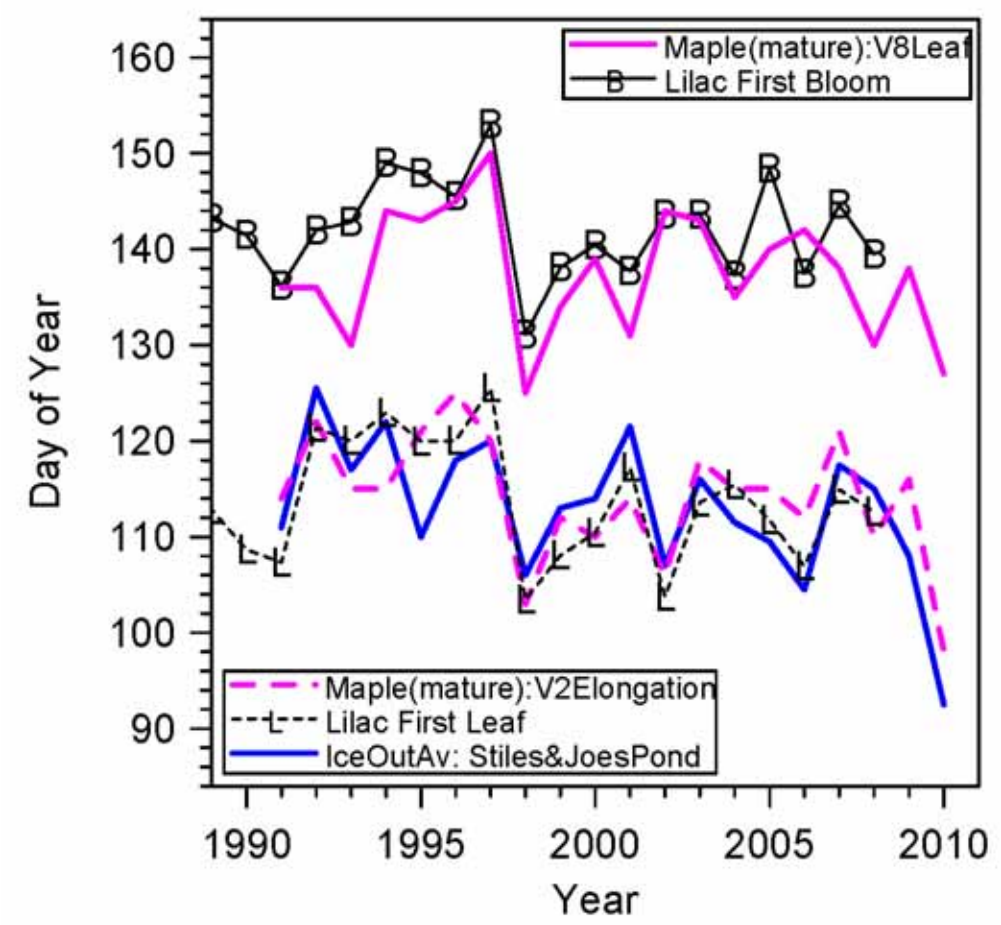
Lilac first leaf matches ice-out!





- **Lilac first leaf correlated with spring ice-out**
- **Trend for both is -3 days/decade**
- **Frost-hardy plants are following ice-out trend**

What about the sugar maples?



- **Ice-out, lilac leaf, maple bud elongation correlated**
- **Lilac bloom and maple leaf-out correlated**

Conclusions -1

- **Understanding seasonal climate transitions helps us understand key climate processes & grasp the local and global nature of what is happening to the Earth**
- **Local climate change indicators provide a clear framework for communities – for understanding, acceptance and adaptation planning**

What can students do?

- **Track seasonal changes locally**
  - **Ice-out and freeze-up**
  - **Leaf-out and flowering (www.usanpn.org/)**
  - **Bird migrations**
- **Snapshots of daily cloud cover**
  - **Record Max-Min temperatures, rainfall**
  - **Measure water vapor (IR thermometer)**
- **Collect past records from farmers, orchards and maple syrup makers**

Outline

- Science of climate change
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- The transition we face
  - Managing the earth system
  - Why is it difficult?

Discussion

Can We Stop "Dangerous Climate Change"?

- **Yes: Quickly stabilize atmospheric CO_2**
- **This means an 80% drop in CO_2 emissions!**
- **This is very difficult**
  - **Fossil fuels have driven our industrial growth and population growth for 200 years**
  - **Our "lifestyle" has become dependent on fossil fuel**

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

- **Need a long time horizon:**
  - **Generational to century *(Forest timescale)***
- **We need some new rules / 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 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 (success!)**
- **CO_2 from fossil fuels – lifetime centuries – a greenhouse gas that traps earth’s heat radiation – pushing earth to warmer climate**
- **Nuclear waste – plutonium-239: half-life 24000 years – nuclear weapons**

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 sufficient to push CO_2 to 1,000 ppm—and in time melt icecaps**
    - **Can we "sequester" CO_2 (put it back in the earth)?**

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**

Climate Neutrality?

- We know what we need
  - Energy-efficient society
  - Energy sources renewable: not fossil
  - Step-by-step transformation for decades

- What are the obstacles?
- Why are we taking such a huge risk for this planet?

What Do We Need?

- So we need honest, truthful, smart pathways forward
  - That will not frighten people into paralysis
  - That will spread hope, not anger or despair
  - That sidestep ideological barriers with new language
  - That develop adaptive governance
    - The US Constitution gives no rights to the Earth
  - That respect Earth system processes & limits

What Do We Need To Do?

- **The transition to a sustainable society will take decades and a community effort**

- **Food: local agriculture & gardens**
- **Energy: Double energy efficiency ….**
  - home heating – district heating + cogen
  - renewable electricity mix
  - efficient transportation system
  - careful forest management
- **Finance: relocalization in real world**

Conclusions -2

- ***We have the tools & knowledge***
  - but not yet the wisdom!
- **We need to look beyond our traditional silos and creatively accept our individual and collective responsibilities**
- **We create the future – it is not a given!**
  - **Is this an efficient and sustainable way of doing this?**
  - **Do I have a deep understanding and connection to Earth?**

So What Can We Do in our Lives and in Schools?

- **Start the transition: reducing energy use as continual transformation: electricity, heating, auto – choices every time we buy & use something (build-in efficiency)**
- **Healthy local food is also a path - support Farm-2-Plate movement in VT schools**
- **Reduce consumption, waste and debt – all linked to unsustainable future**
- **Cultivate Earth-system thinking & connections – we love what we understand**