

# Climate Change in Vermont



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**Dr. Alan K. Betts**

**Pittsford, VT 05763**

**[akbetts@aol.com](mailto:akbetts@aol.com)**  
**<http://alanbetts.com>**

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***Waitsfield, Vermont***

**Friday, March 23, 2012**

- Earth is beautiful
- Weather changes fast
- Climate changes slowly
- Burning fossil fuels – coal, oil and gas - is having a big effect on climate



*January 2, 2012: NASA*

# Climate Change

- **Big challenge for our lifetime**
- **Climate is being affected by global energy use**
- **What is happening to Vermont as climate changes?**
- **What is happening to the Earth?**
- **What can we do about it**

# In England, I went to a college called Peterhouse, Cambridge

- **Founded 1284**
- **Medieval warm period;**  
**Vinland colony**  
**flourishes on Greenland**
- **Ships crossed Atlantic**  
**to America**





# My High School was Nottingham High School

- **Founded 1513**
- **1550:**  
Heading into “Little Ice Age”
- **1620:**  
Pilgrim fathers face bitter winters



# What Is Happening to Vermont?

- **Climate of Vermont is changing**
- **Warming in winter twice as fast as in summer**
- **Lakes frozen less by 7 days each decade**
- **Spring coming earlier by 3 days each decade**

**January 2, 2012**



**March 11, 2012**



**Freeze-up was January 3**

**Unfrozen by March 10**

**Short Winter 2011-12**

*(Ground frozen for 67 days - used to be  
120-150 days)*

- **2<sup>nd</sup> warmest winter on record**
- **No permanent snow cover  
west of Green Mountains**

# Why is it warm when there is no snow?

- **When snow falls, it reflects sunlight, so it doesn't get warm in the daytime and the temperature still drops at night**
- **When there is no snow, sunlight heats the ground and it doesn't get so cold**



# Vermont Winter 2006



- Snow reflects sunlight, so it stays cold
- No snow – usually warmer

# January 7, 2007



- **Grass still green, and no snow**
- **Sunlight heats ground and it stays warmer**



# 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**

# Mild winter: crops survived

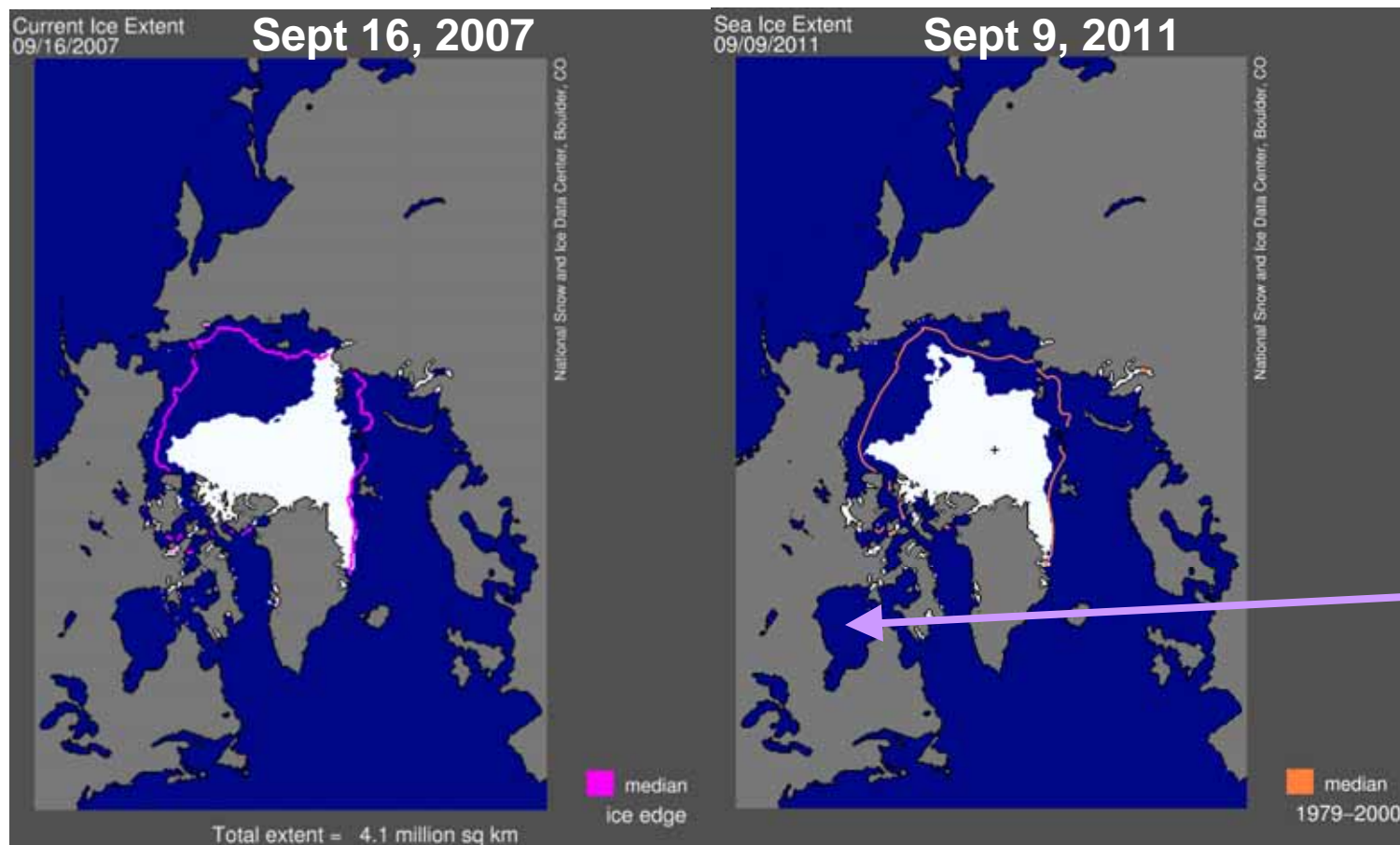
*Pittsford: March 22, 2012*



- **Kale survived, covered with glass in January and February – tastes good!**



# Arctic Sea Ice Melting



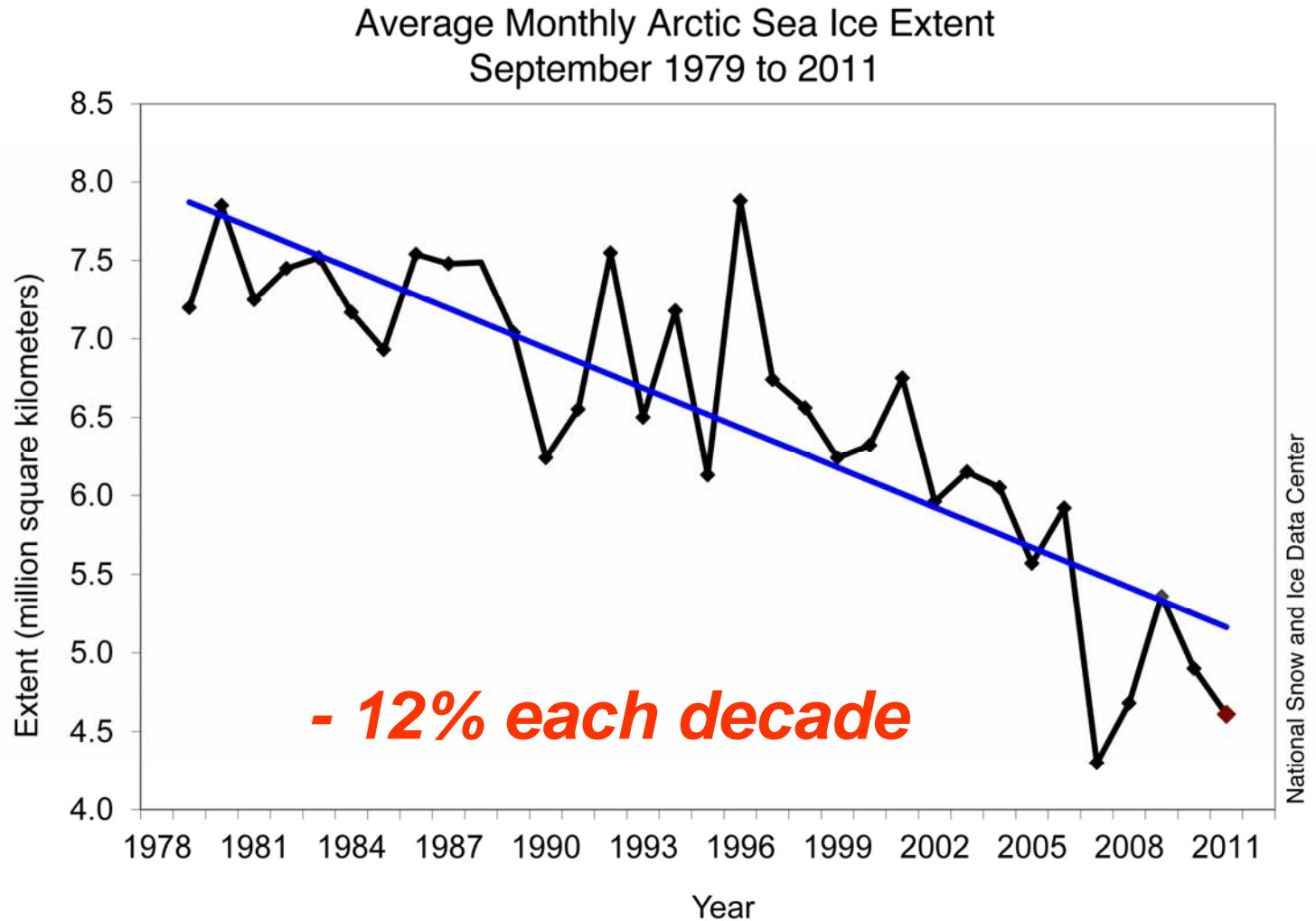
- **Less ice, less sunlight reflected, so gets warmer**

Hudson's Bay is freezing much later, and melting much sooner

([www.nsidc.org](http://www.nsidc.org))

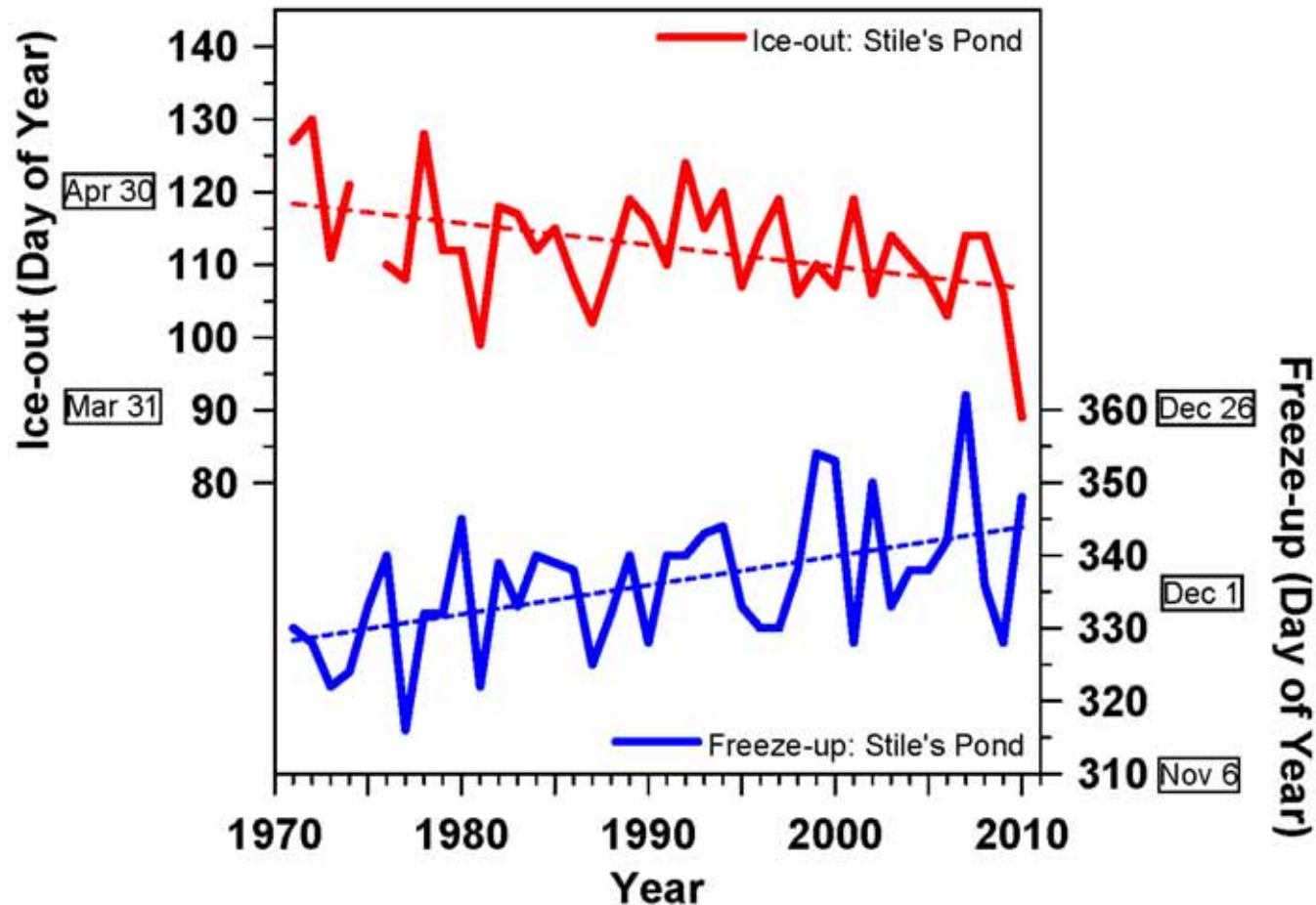
- **Record ice melt in 2007**
  - most ice now thin and only 1-2 years old
- **Open ocean in October gives warmer Fall**

# Sea Ice Trend in September



- Sea ice is shrinking and thinning rapidly

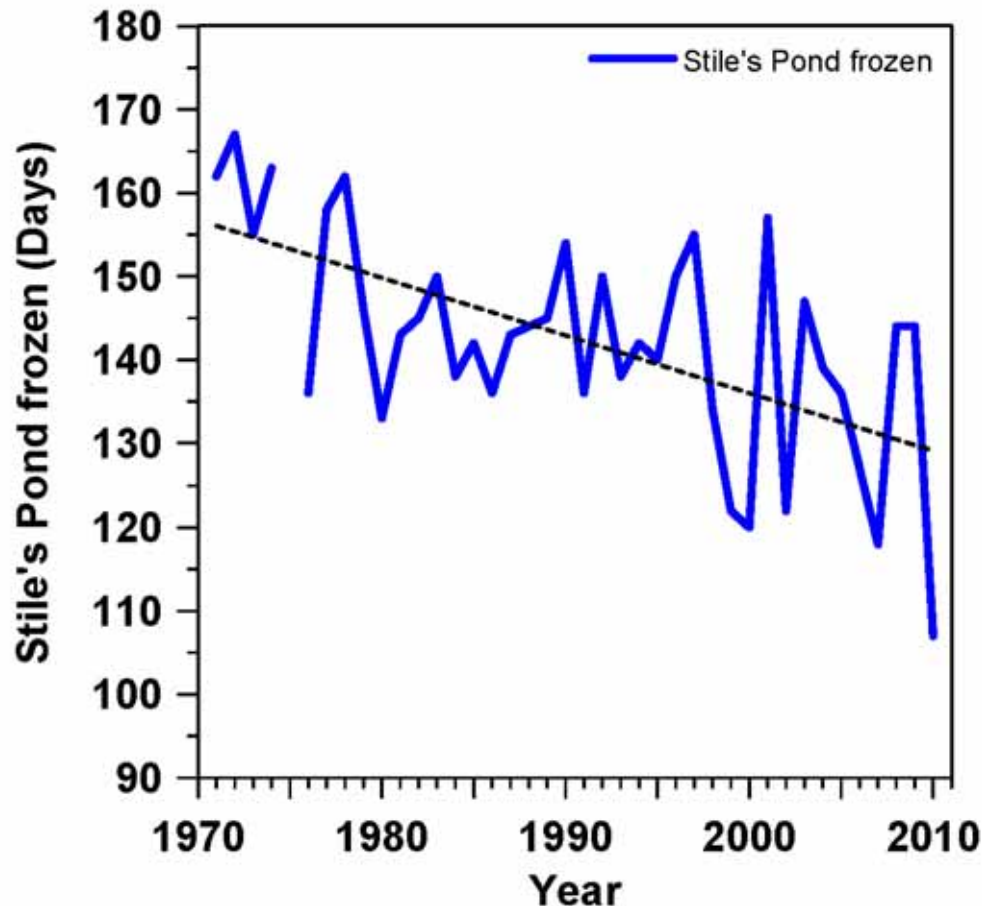
# Stiles Pond: near St. Johnsbury: 1970-2010



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

# Lake Frozen Period Shrinking

*Stiles Pond: east of St. Johnsbury: 1970-2010*



- Frozen period is decreasing by 7 days each decade***



# Very Early Spring This Year

*Pittsford: March 22, 2012*



- **Daffodils up**

**Forsythia blooming**

- **Does this usually happen in March?**
- **Spring is coming earlier by 3 days each decade**

# Spring Climate Transitions



- **After snow and ground melt**
- **Before forest leaf-out**
  - Little evaporation** → Dry atmosphere, clear sky
  - Warm days, cool nights and frost
- **After forest leaf-out**
  - Large evaporation** → Wet atmosphere, low cloudbase
  - Cooler days for a while
  - But warmer nights and no frost
- ***Spring is coming earlier***
- ***Last spring frost coming earlier***

**Why is the climate getting warmer and ice melting?**

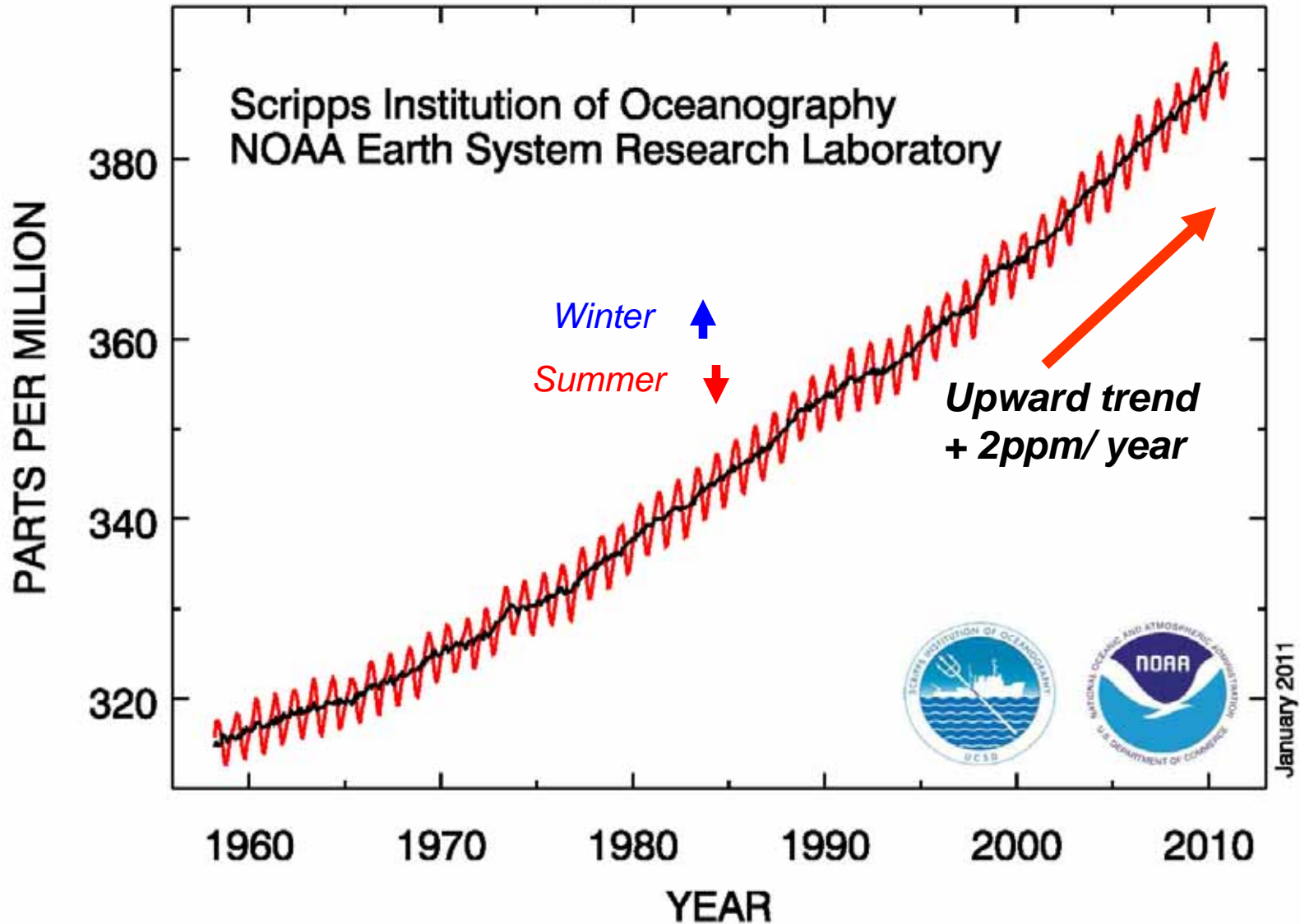
# Why is the climate getting warmer and ice melting?

- **We are burning so much fossil fuel for our energy**
- **Fossil fuel contains carbon from ancient shrubs and trees**
- **Burning coal, oil and gas converts carbon to carbon dioxide in the air**



# Carbon Dioxide Is Increasing

## Atmospheric CO<sub>2</sub> at Mauna Loa Observatory



# Why Is the Rise of Atmospheric CO<sub>2</sub> a Problem?

- The air is transparent to sunlight, which warms the Earth
- But some gases in the air trap the Earth's heat and keep the Earth warm
- These are “Greenhouse gases”- water vapor, carbon dioxide, ozone, methane  
(symbols are H<sub>2</sub>O, CO<sub>2</sub>, O<sub>3</sub>, CH<sub>4</sub>)
- CO<sub>2</sub> is rising fast: by itself only a small effect

# But as CO<sub>2</sub> increases...

- Earth warms, and evaporation and water vapor in the air increases and this triples the warming
- As Earth warms, snow and ice decrease, so less sunlight is reflected, so winters and the Arctic are warming faster
- Doubling CO<sub>2</sub> will warm Earth about 5°F
  - And much more in the North and over land
  - So the climate change we are seeing in Vermont will continue

# So what can we do?

- **Understand what is happening to climate where you live, so you can be prepared for changes to come**
- **Study how we use energy and how changes can reduce climate change in the future**



# Understand what is happening to climate where you live

- **How is the climate different today than 10, 20, 30 years ago? Find out by talking to local farmers, your parents and grandparents, others who have lived here for a long time**
- **Ask farmers about the seasons. Have they changed? When did they plant and harvest and what crops did they grow?**
- **When did lakes, rivers and the ground freeze – 30 years ago and in recent winters?**
- **How often could you skate on the ponds and rivers? And snowmobile through the woods. How long could you ice-fish in winter, and how thick was the ice?**
- **When were the last frosts in spring and the first frost in the Fall?**
- **When did maple sap flow? When did trees and shrubs leaf out in spring? When did the leaves turn in Fall?**
- **What were the summers like? Were they wet or dry?**

# What do we use energy for? Where does energy come from?

- We use energy for electricity, heating and transport
- Where does it come from?
- How much does your school use?
- How much do you use at home?
- How much does it cost?
- Can we reduce energy use by making things more efficient?

# **This is why we are seeing**

- **Houses are being insulated more with better windows**
- **Solar panels that generate electricity from sunlight**
- **Wind farms that make electricity from the wind**
- **More wood being burnt in homes, schools and power plants, because trees grow back and take CO<sub>2</sub> from the air**

# This is why

- We need more efficient cars that burn less gasoline
- Like hybrid cars that have gas and electric motors - and batteries that store energy when the car slows down



55 miles per gallon at 50 mph  
45 miles per gallon at 70 mph



# What Will This Mean For You?

- **Our fossil fuel energy use is changing the climate of the Earth and Vermont – we need to slow down the changes**
- **This is a challenge for society, because this is what we have used for 100 years**
- **So there is a lot to explore and find out about what is happening and what we can do about it**

# Discussion

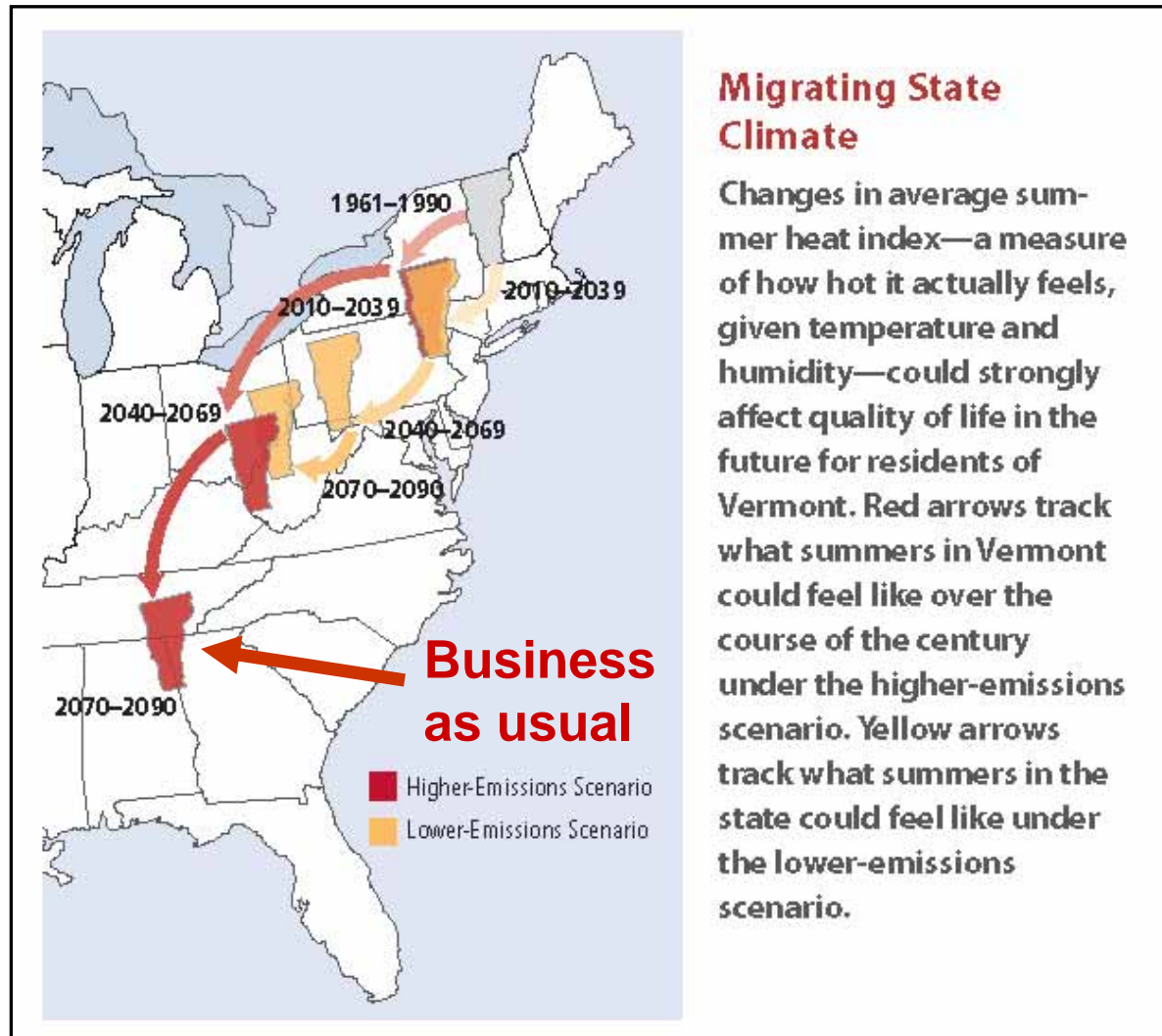
- <http://alanbetts.com>
  - this talk <http://alanbetts.com/talks>
  - newspaper articles at <http://alanbetts.com/writings>
- *Seasonal Climate Transitions in New England*



# Vermont's Future with High and Low GHG Emissions

What  
about  
skiing?

What  
about  
tropics?

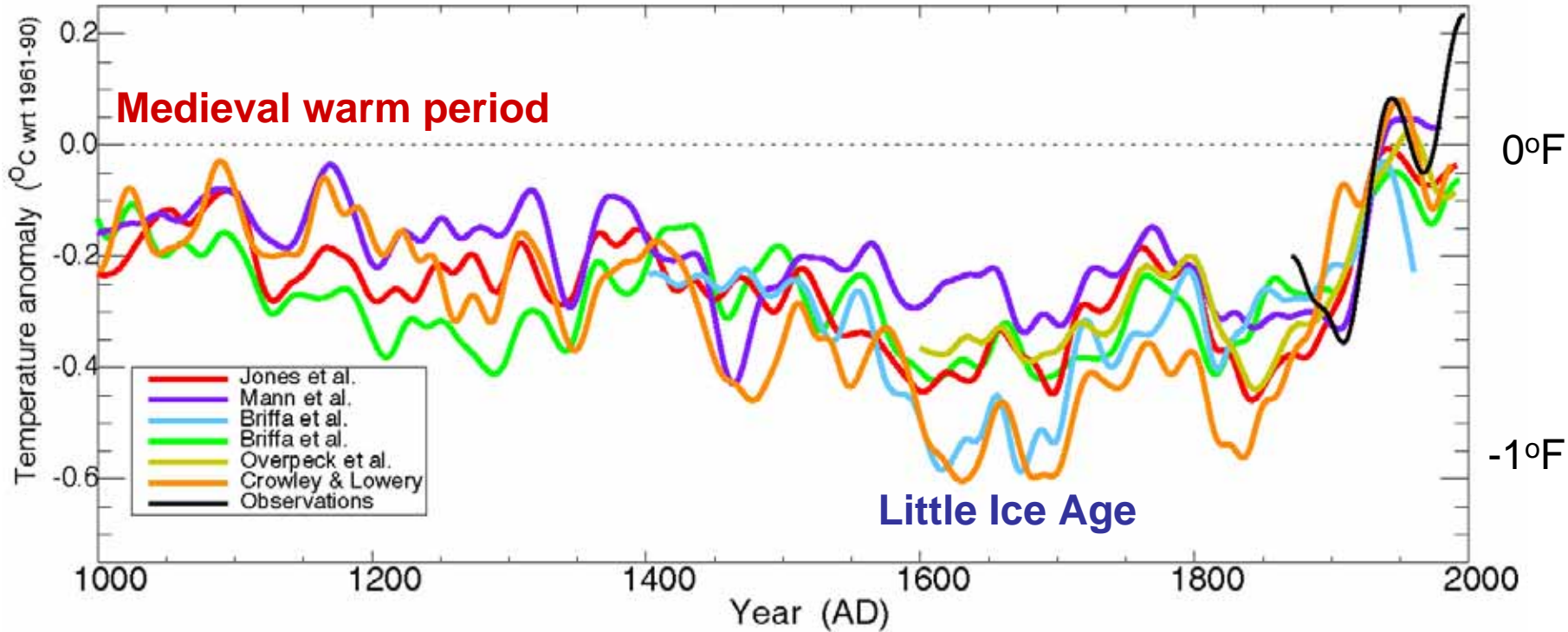


NECIA,  
2007



# 1000-year Temperature Record

2100: +5°F



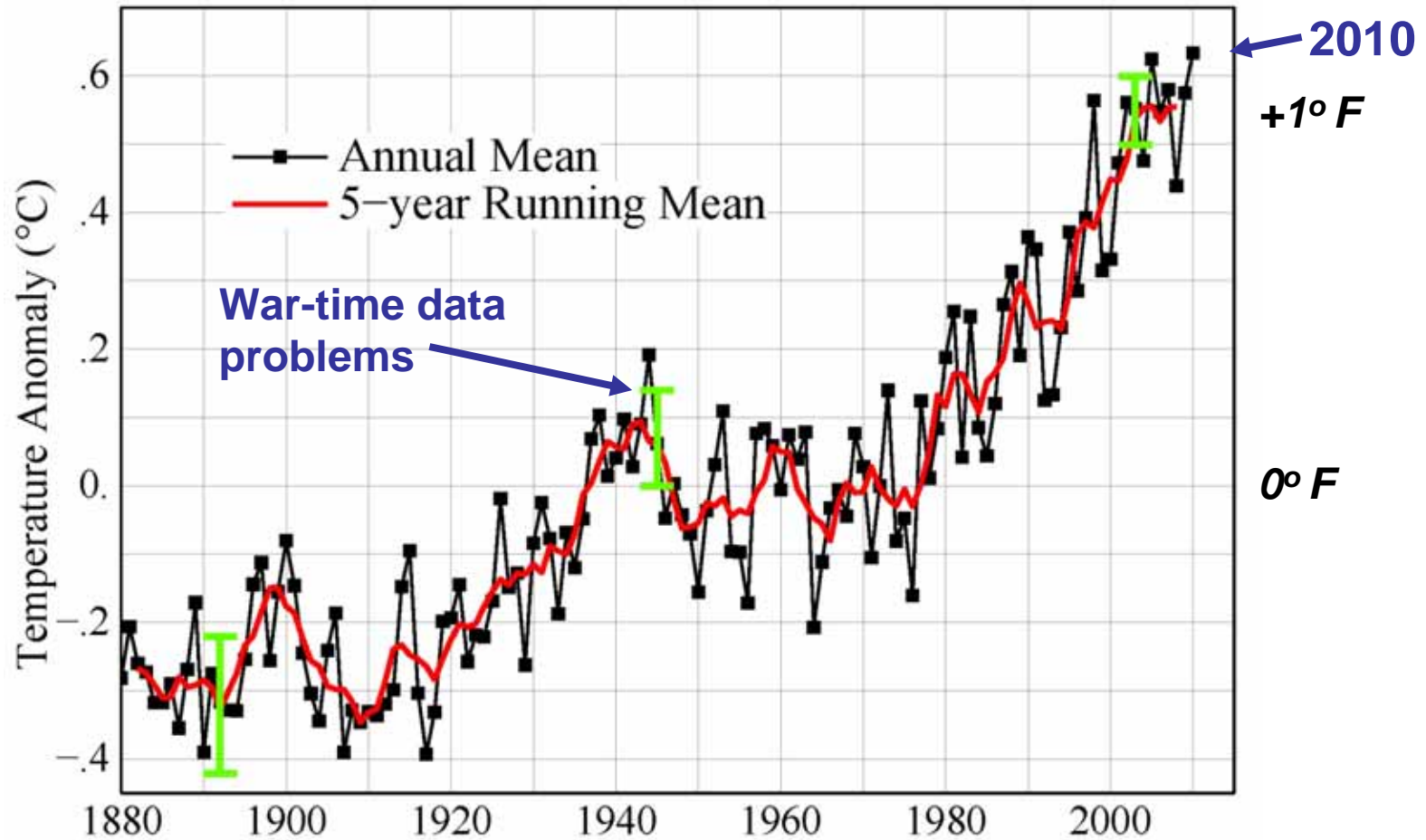
- **Black line is 150-yr thermometer record**
- **Before thermometers, we have only rough estimates from tree-rings, ice-cores, stalagmites...**

# Global Temperature Rise 1880 – Present

2100: +5°F



Global Land–Ocean Temperature Index

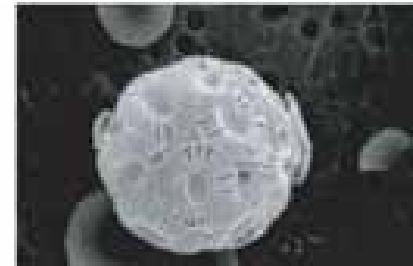
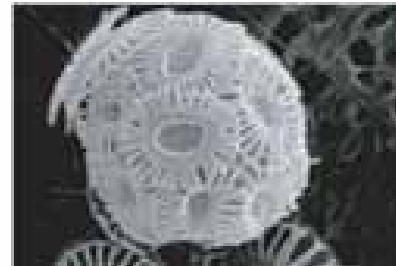


NASA-GISS, 2011

# Rising Ocean Acidity Threatens Organisms



- Oceans are sucking up  $\text{CO}_2$  — from burning fossil fuels
- When  $\text{CO}_2$  dissolves in water, carbonic acid is produced; the oceans are becoming more acidic
- Affects life in oceans



# 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/ 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**



# 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<sub>2</sub> to 1,000 ppm—and in time melt icecaps**
    - **Can we “sequester” CO<sub>2</sub> (put it back in the earth)?**

# Examples of Long-Lived 'Waste'

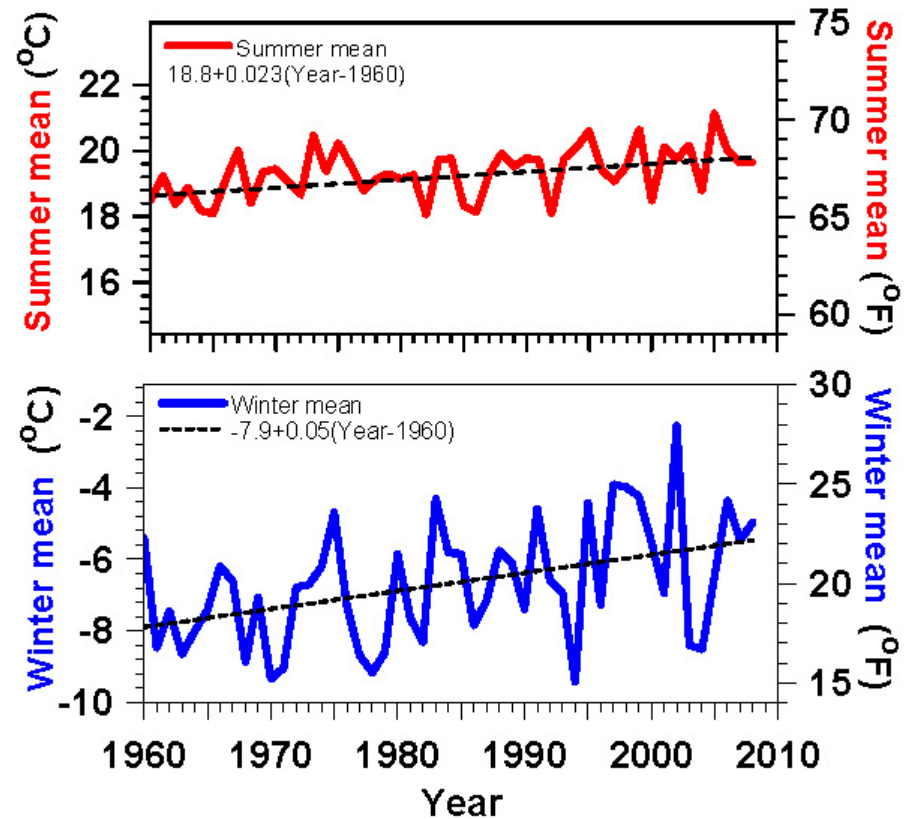
- **CFCs** – refrigerants – very stable – lifetime centuries - broken down by sunlight in stratosphere – catalyze ozone destruction, which protects earth from UV
- **CO<sub>2</sub> from fossil fuels** – lifetime centuries – a greenhouse gas that traps earth's heat radiation – pushing earth to warmer climate
- **Nuclear waste** – plutonium-239: half-life 24000 years – nuclear weapons

# What Do We Need To Do?

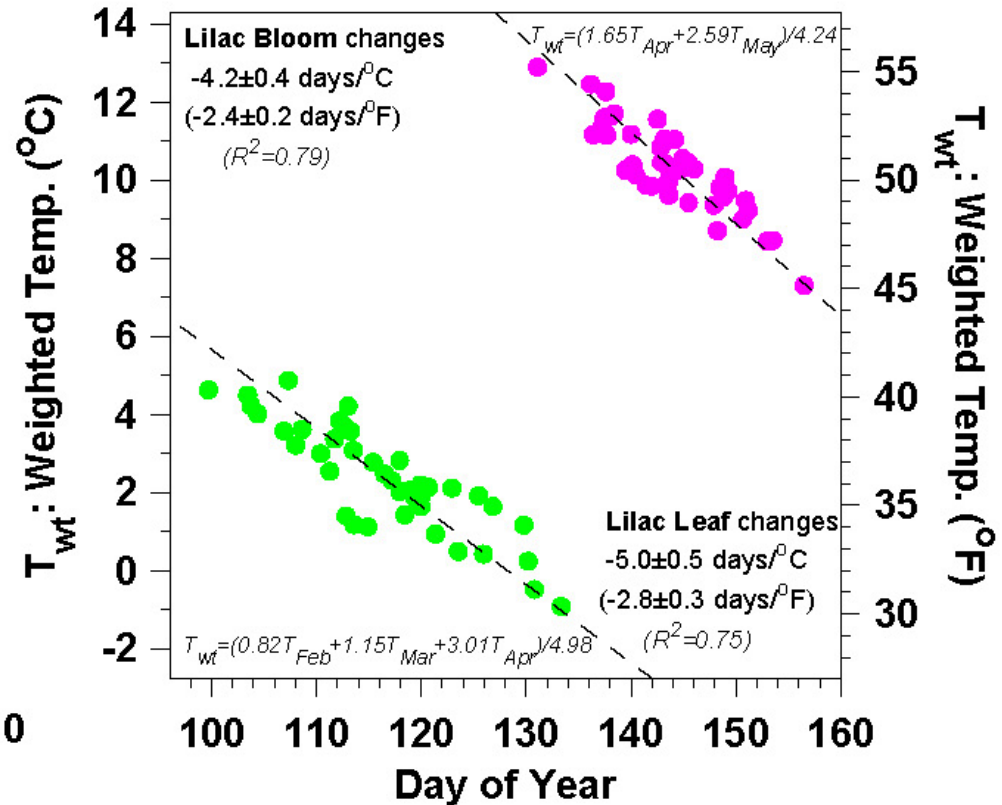
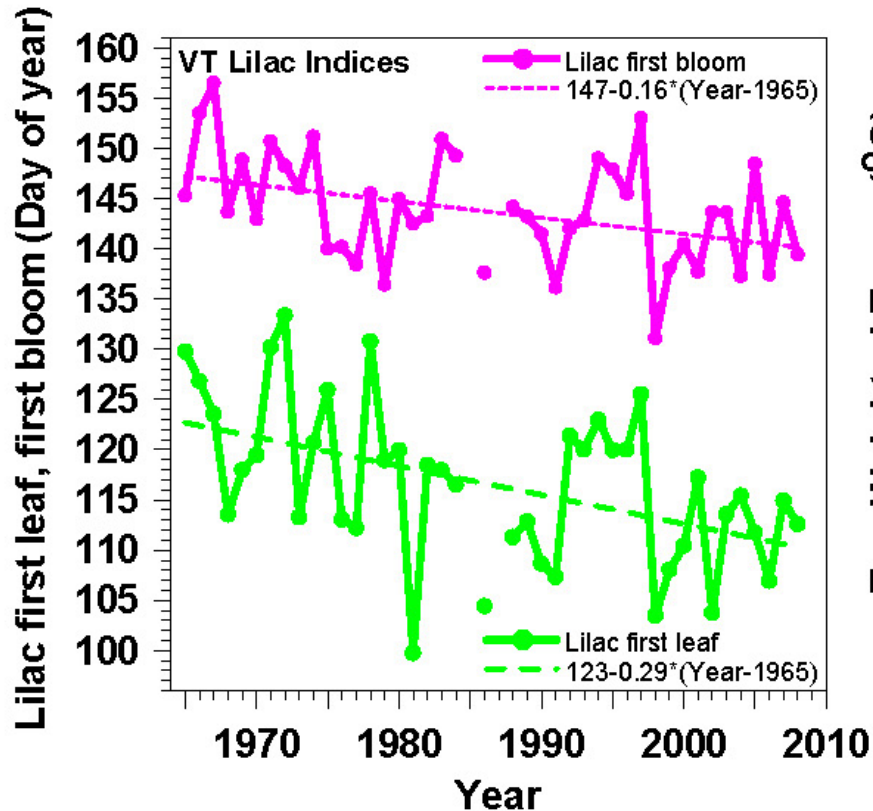
- **The transition to a sustainable society will take decades and a community effort**
- **Food:** local agriculture & gardens
- **Energy:** Double energy efficiency ....
  - home heating – district heating + cogen
  - renewable electricity mix
  - efficient transportation system
  - **careful forest management**
- **Finance:** relocalization in real world

# Vermont Temperature Trends

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



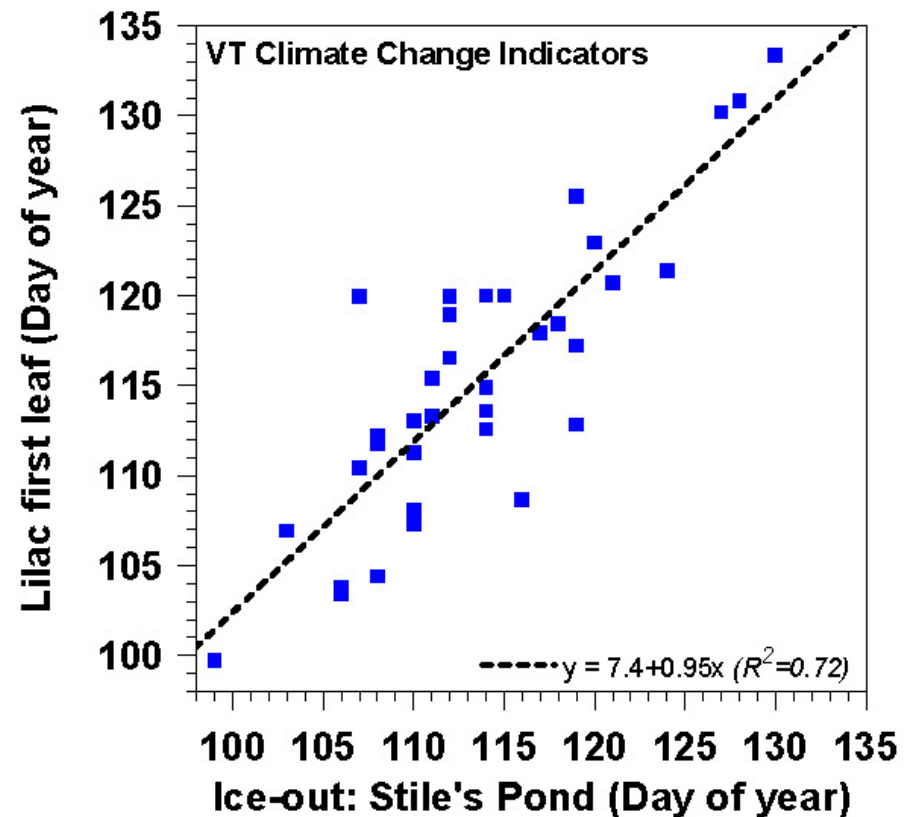
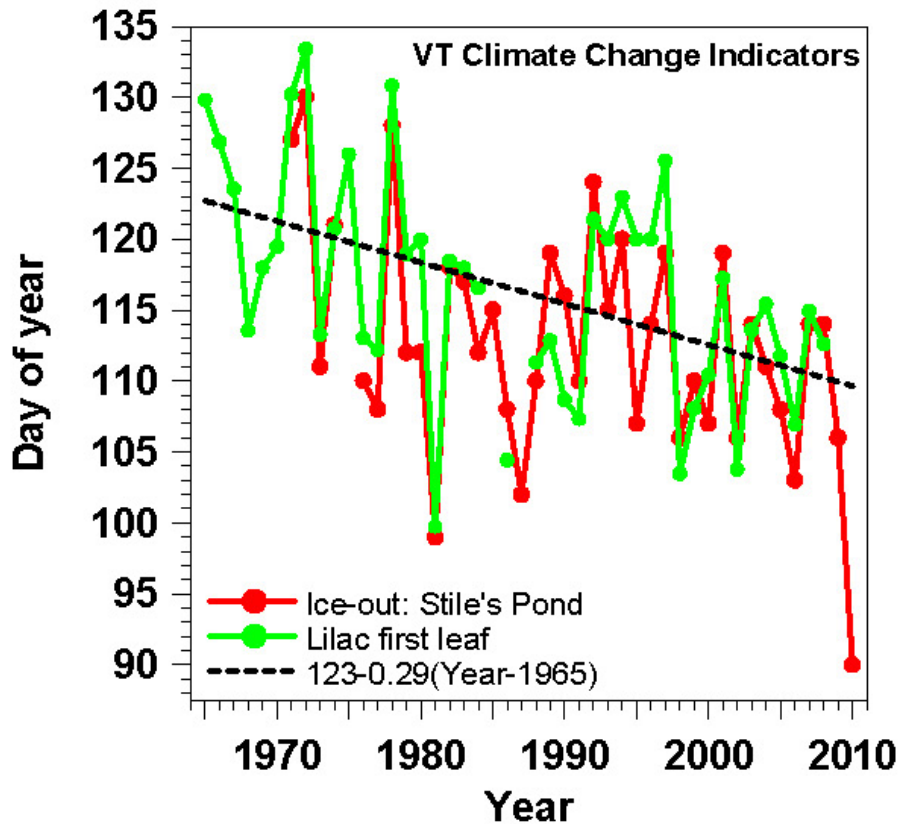
# Lilac Leaf and Bloom in Spring



- 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)

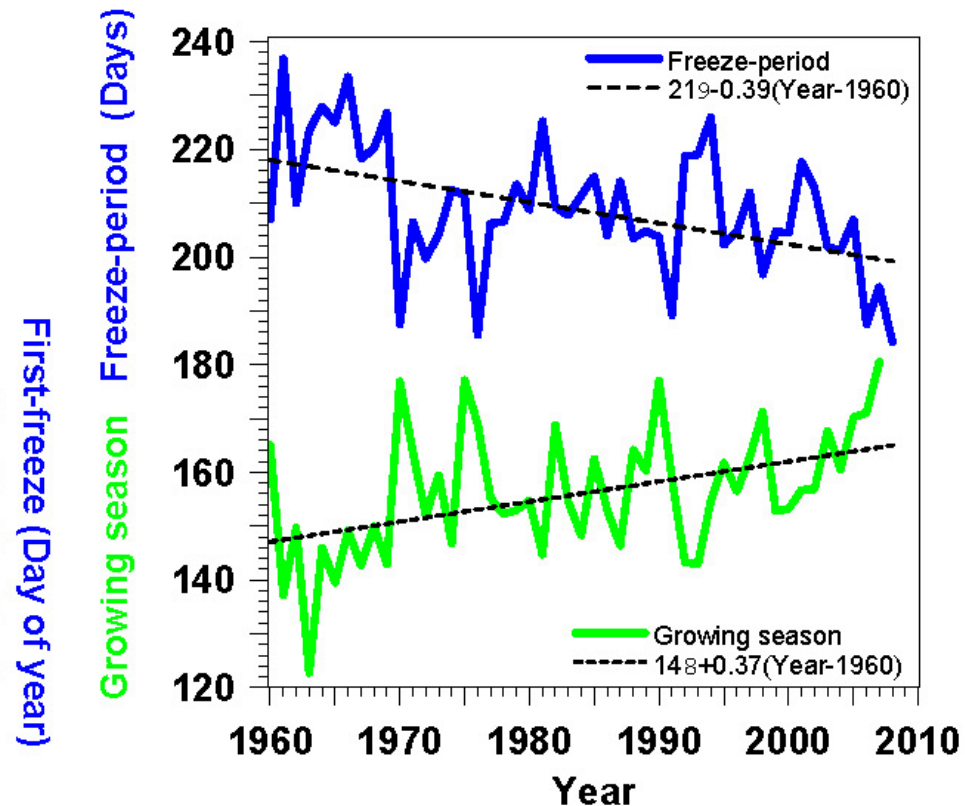
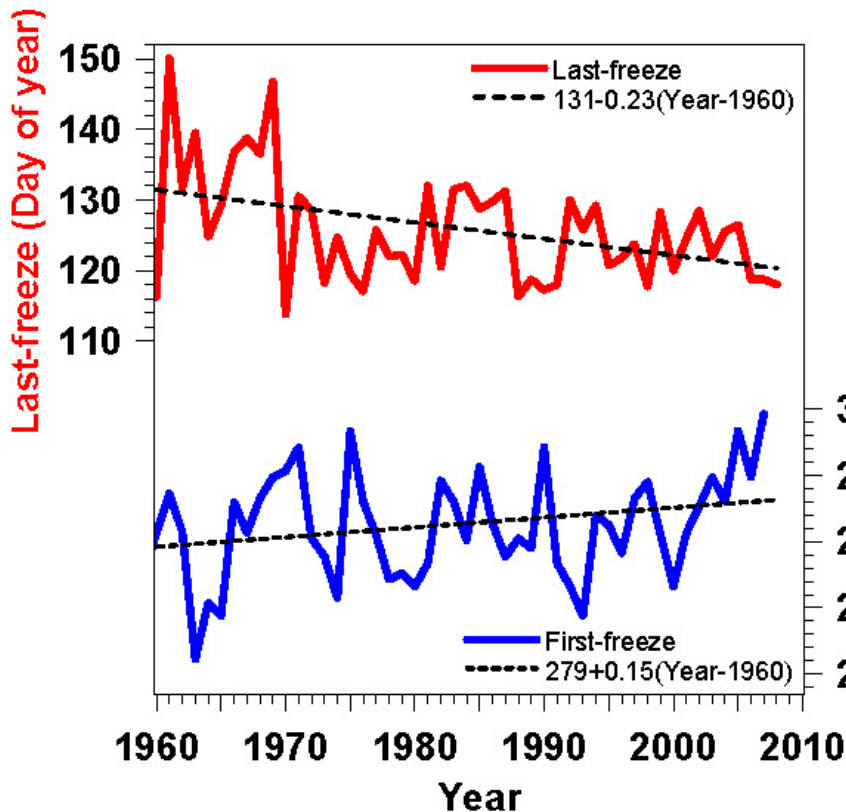


# Lilac Leaf-out and Ice-out Coupled



- Lilac leaf and lake ice-out both depend on Feb. Mar. and April temperatures
- Trends indicate earlier spring

# First and Last Frosts Changing



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

# What do we know from past?

- **Reconstruct past climate**
- Ice core history: T, CO<sub>2</sub>, CH<sub>4</sub> through many ice-ages - nearly a million years
- Ocean sediments
- Tree rings – a few thousand years

# Ice-core history!





# Last four ice-age cycles

