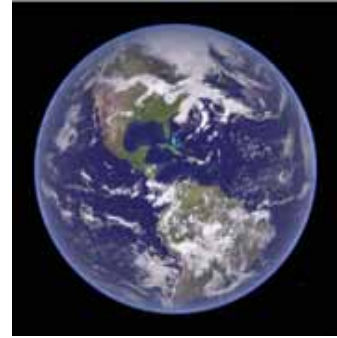




# Climate Change and Vermont



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**Dr. Alan K. Betts**

**Vermont Academy of Science and Engineering  
(VASE)**

**Atmospheric Research, Pittsford, VT 05763**

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

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***CCV, Winooski, Vermont***

**July 28, 2011**



# Climate Change

- One of the many great challenges for the 21<sup>st</sup> century
- We are already decades late in taking action

*J. S. Sawyer (1972): Man-made CO<sub>2</sub> 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 scale: actual and future**
  - **What is happening to Vermont**
- **The transition we face**
  - **Managing the earth system**
  - **Why is it difficult?**

**Discussion**

# My Background: Peterhouse, Cambridge - UK

- **Founded 1284**
- **Medieval warm period;  
Vinland colony  
flourishes**



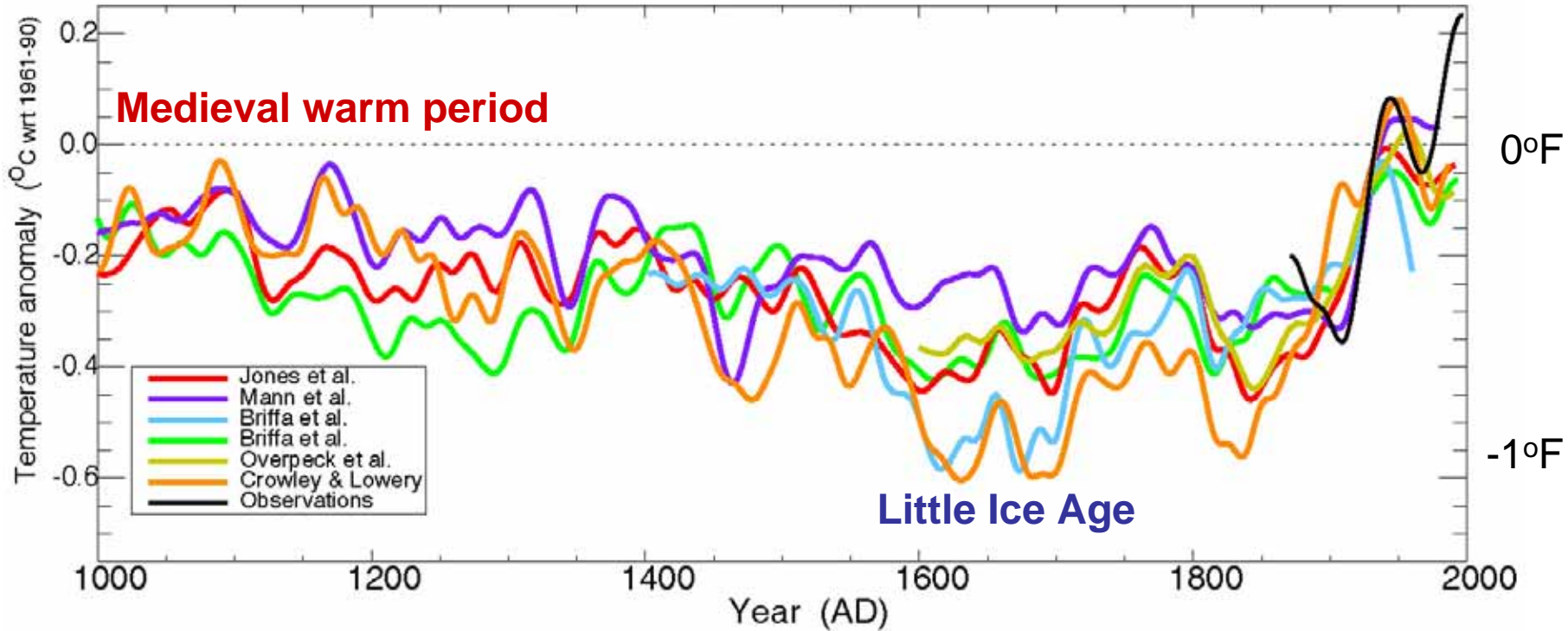
# My Background: Nottingham High School

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



# Millennial Temperature Record

2100: +5°F



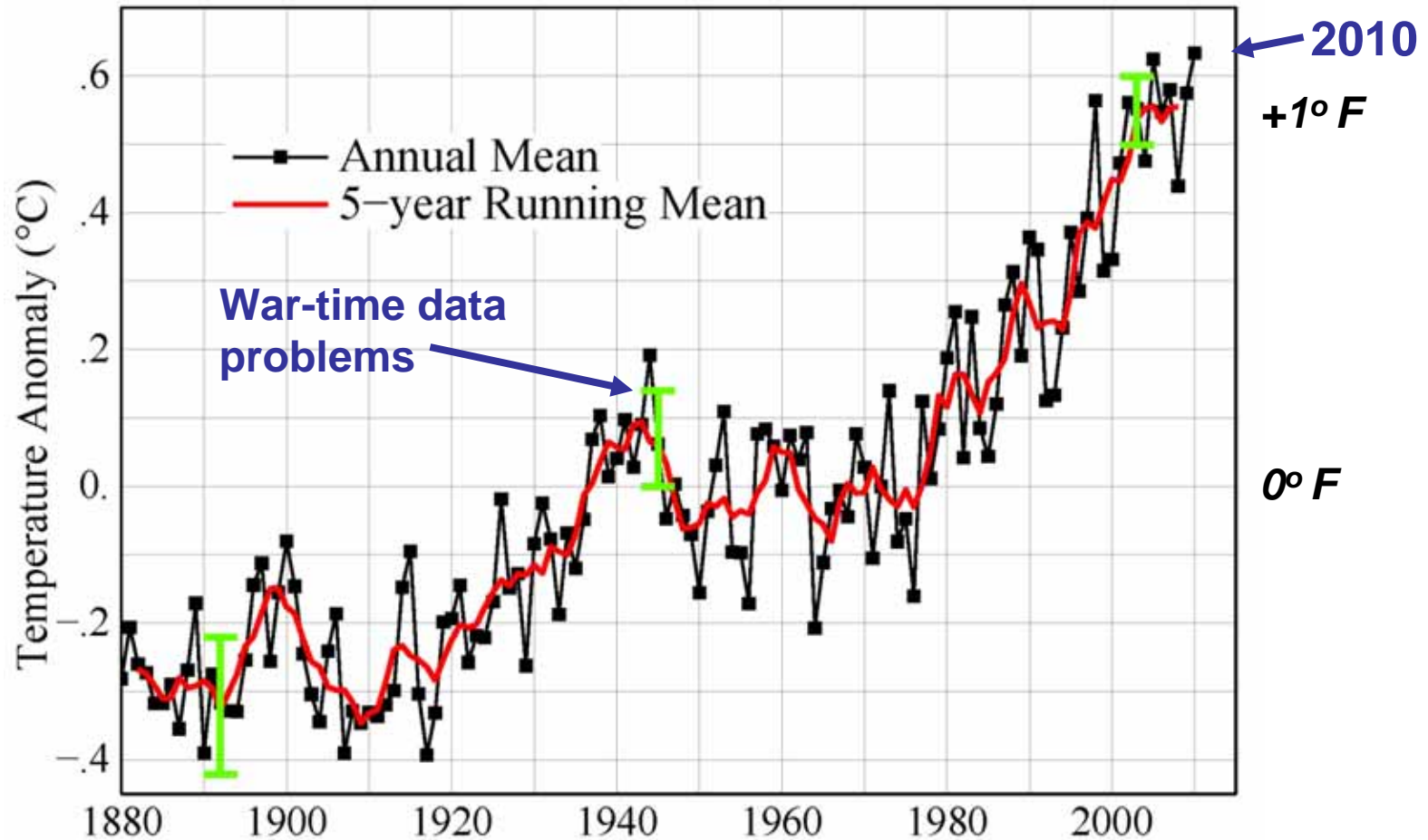
- “Proxy” records from before the time of thermometers provide uncertain data, but they’re all we have

# Global Temperature Rise 1880 – Present

2100: +5°F



Global Land–Ocean Temperature Index

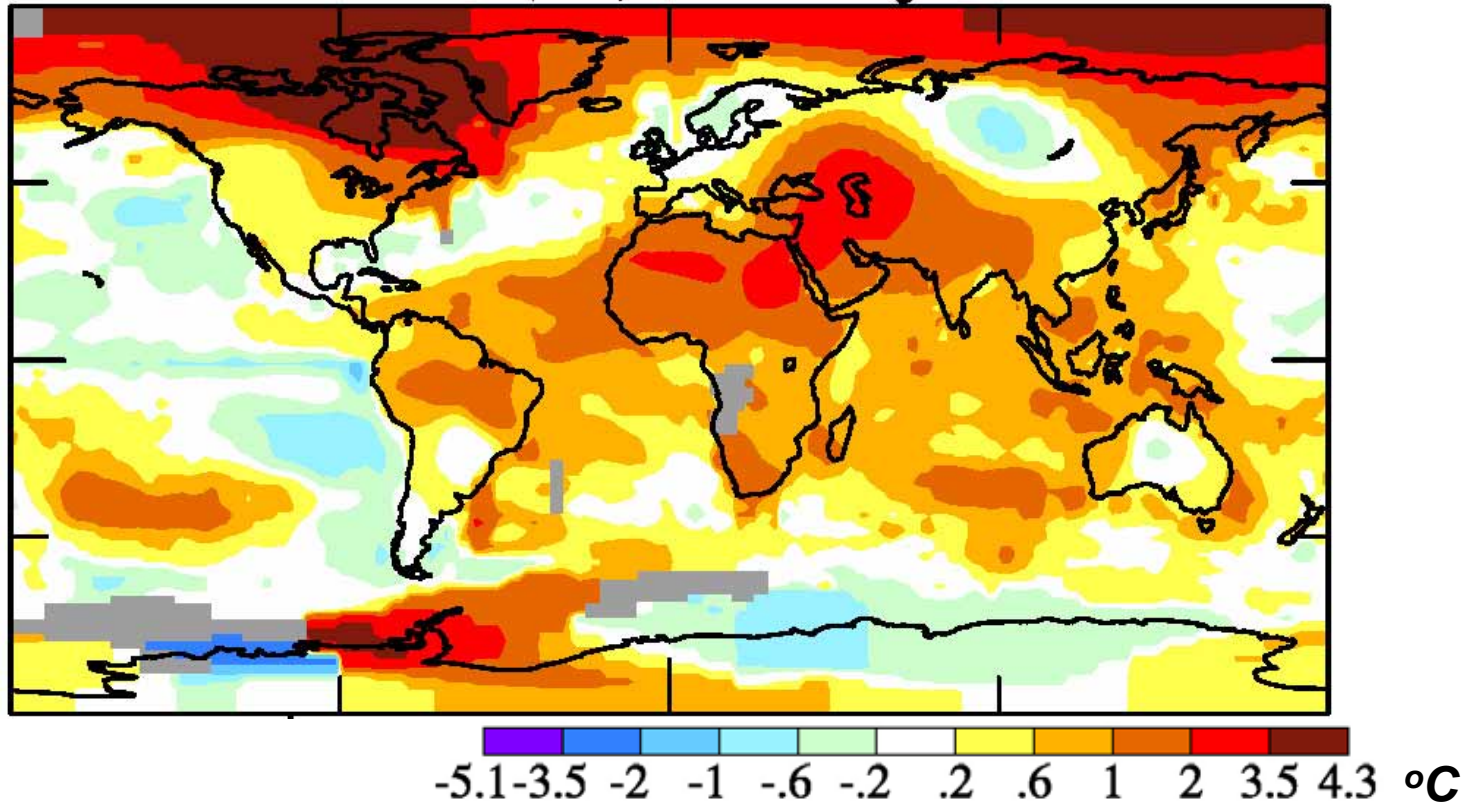


NASA-GISS, 2011



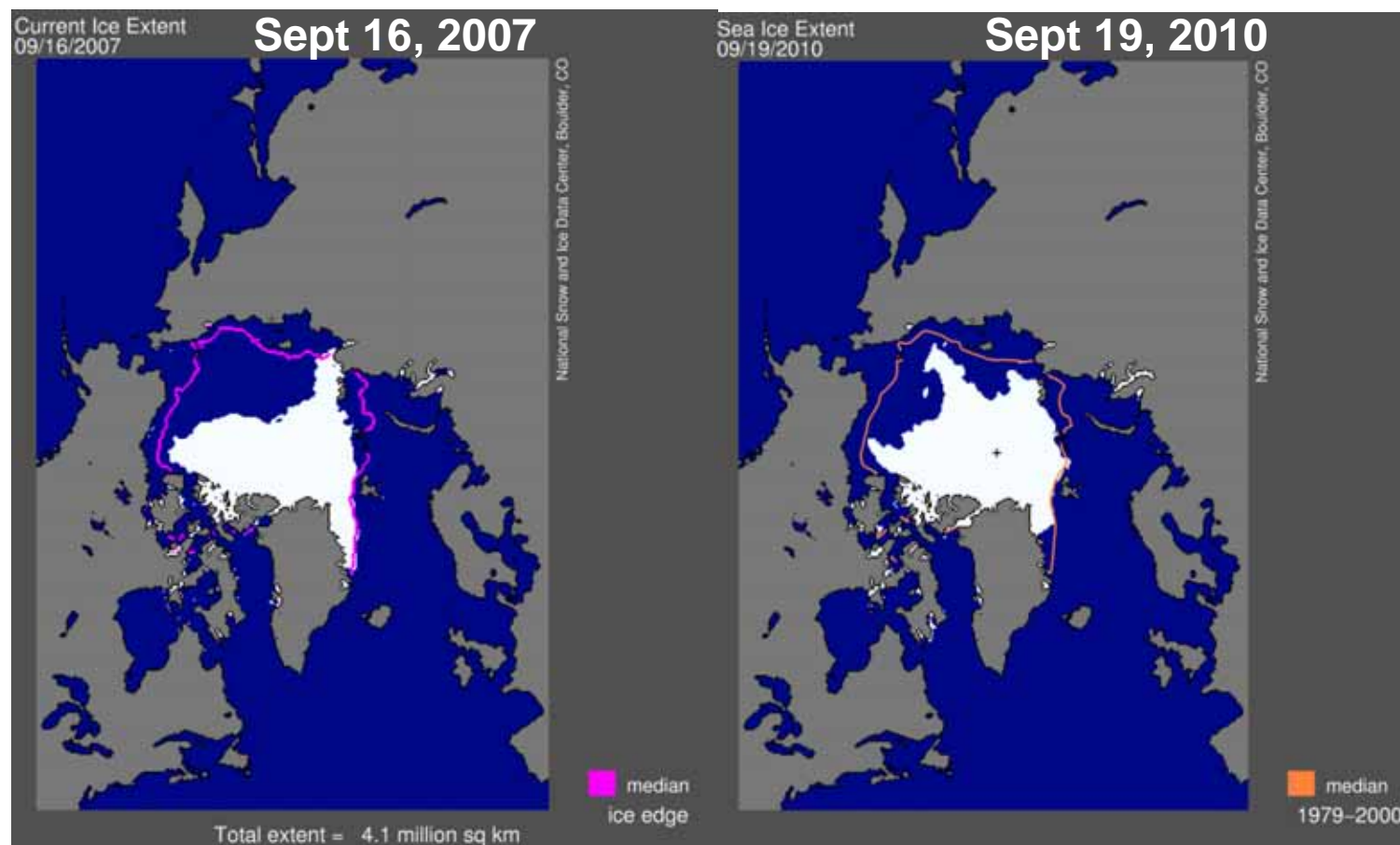
# Global Picture 2010

2010, warmest (tie) of 131 years  $0.63^{\circ}\text{C}$  ( $1.2^{\circ}\text{F}$ )



- **Record summer temps**
  - **Russia** ( $100^{\circ}\text{F}$ ) Moscow fires
  - **Pakistan** ( $128^{\circ}\text{F}$ ) Extreme monsoon floods

# Arctic Sea Ice Loss Has Accelerated



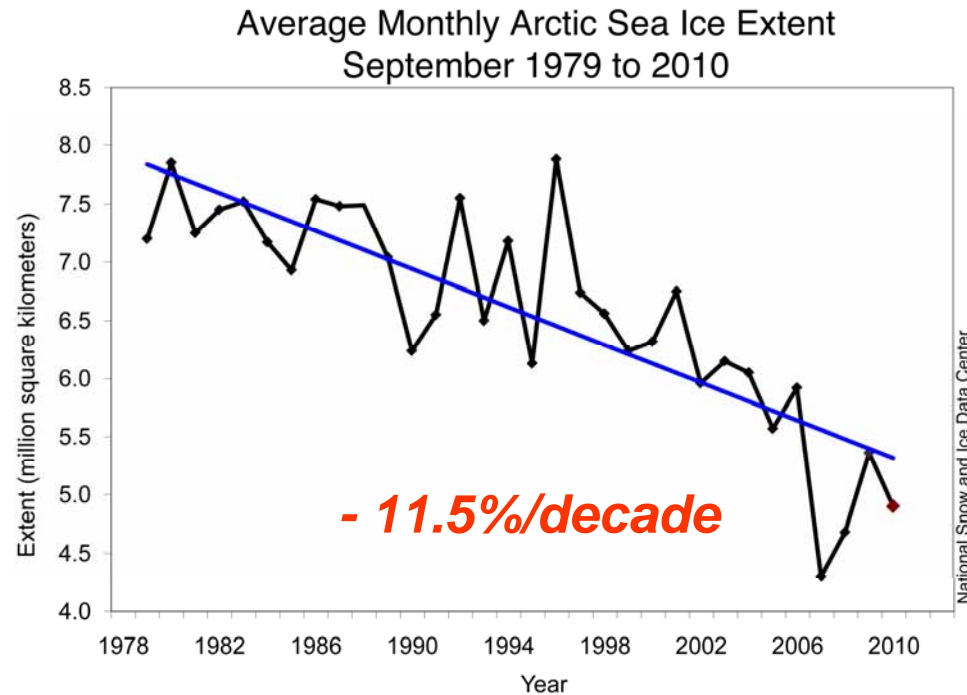
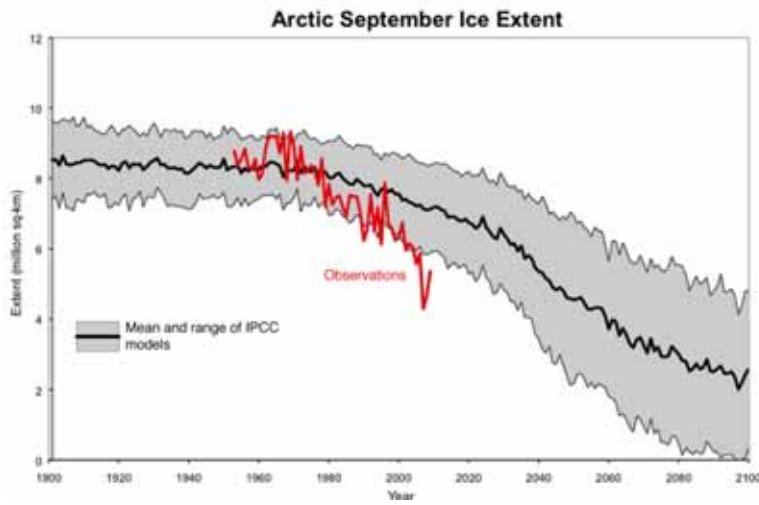
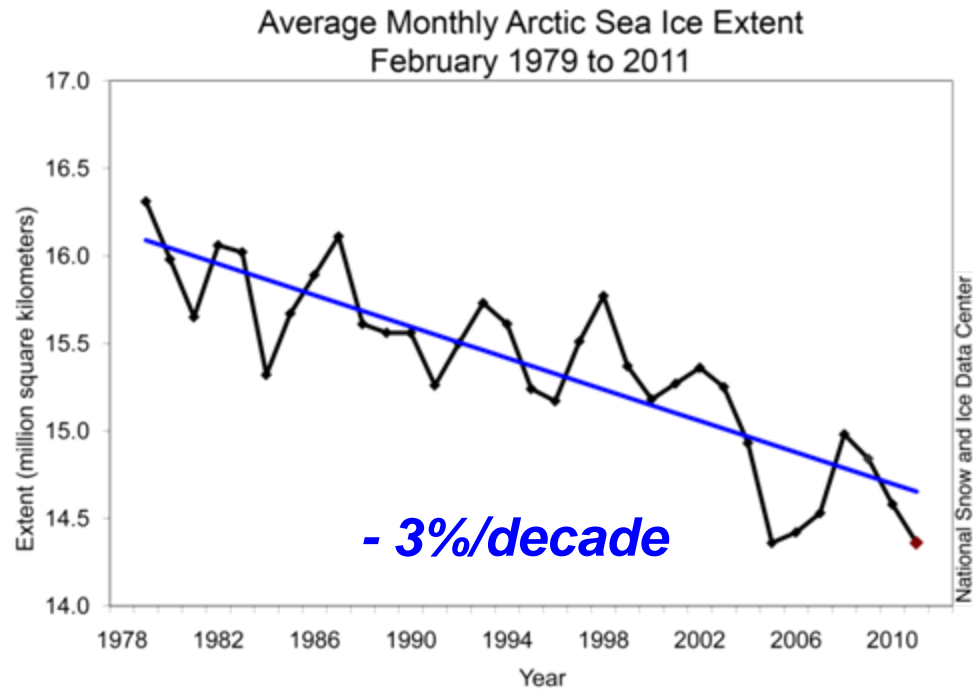
- **Feedbacks speed melting**
- **Less ice, less sunlight reflected**
- **More evaporation, larger water vapor greenhouse effect**

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

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

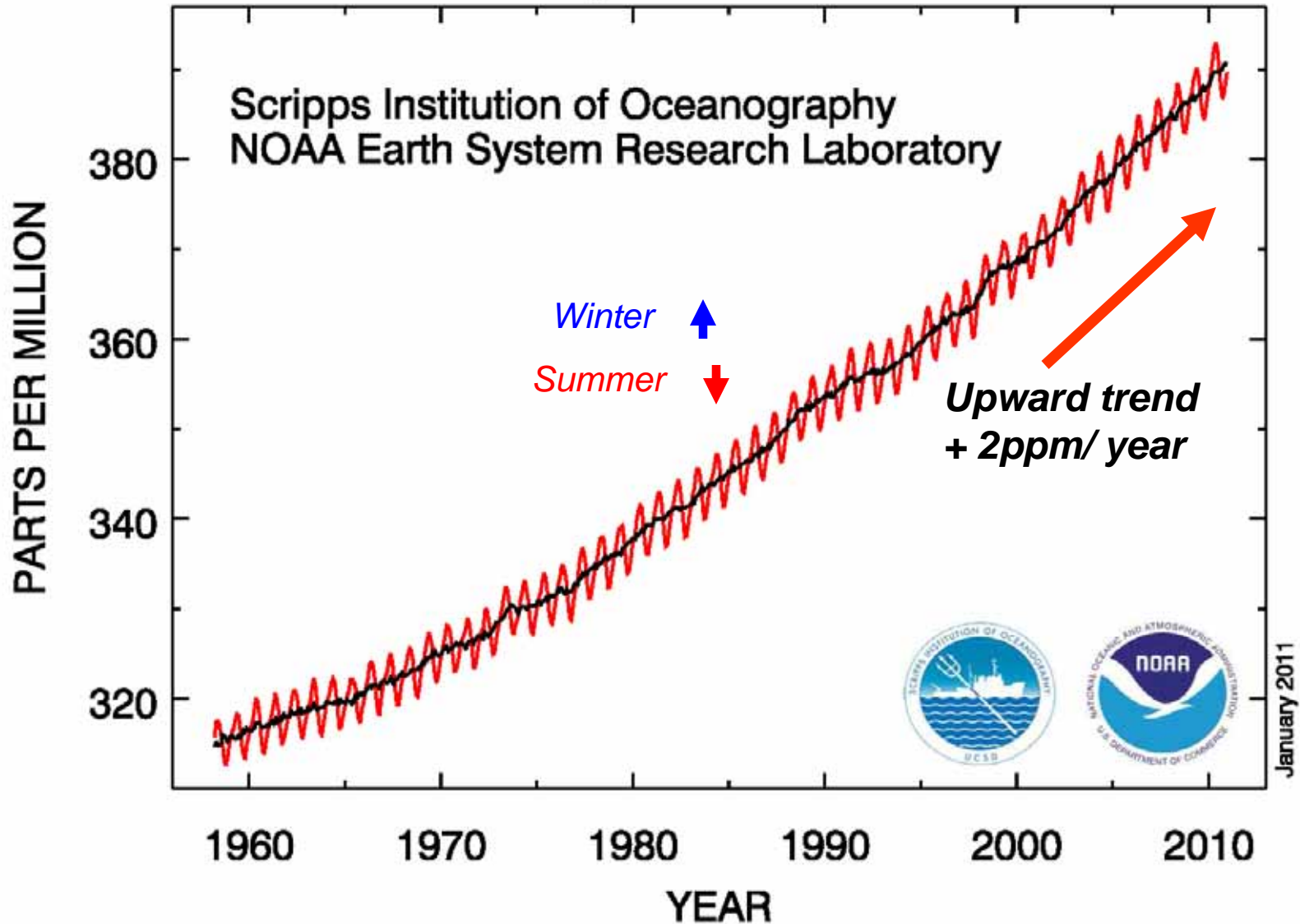
# Sea Ice Trends

- Sea ice is thinning rapidly
- Observed September decline appears to be faster than IPCC climate model projections



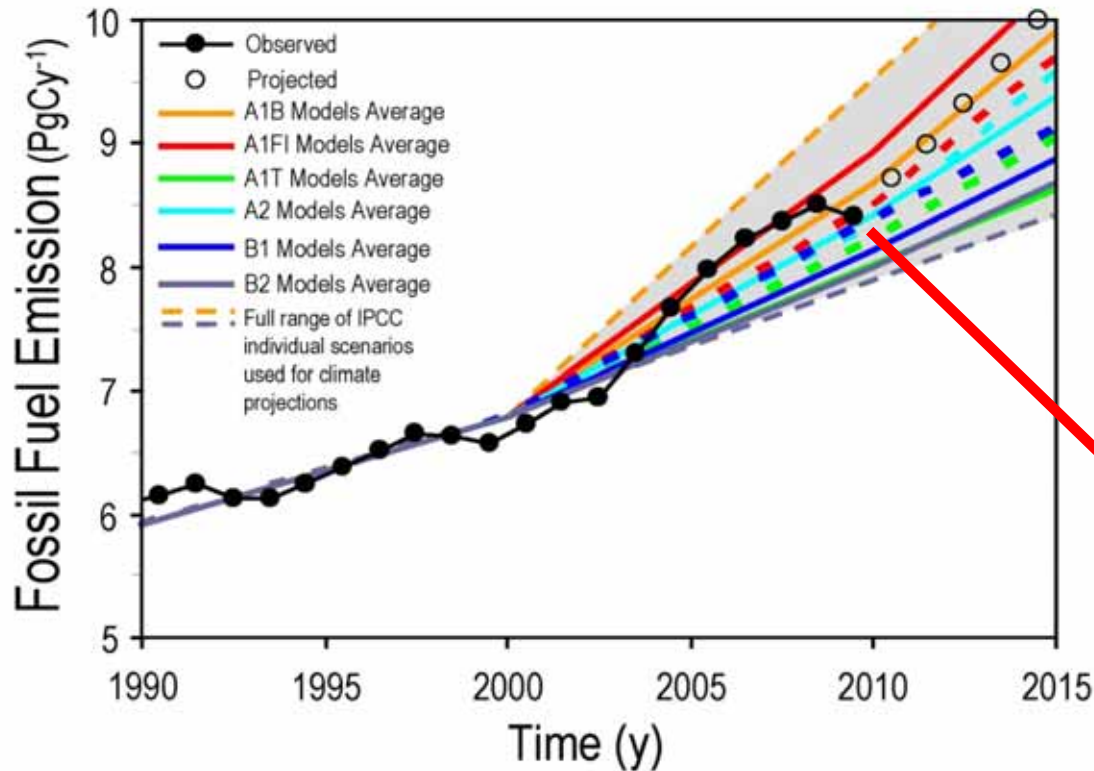
# Carbon Dioxide Is Increasing

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



# 2009 Was “Good” for the Earth

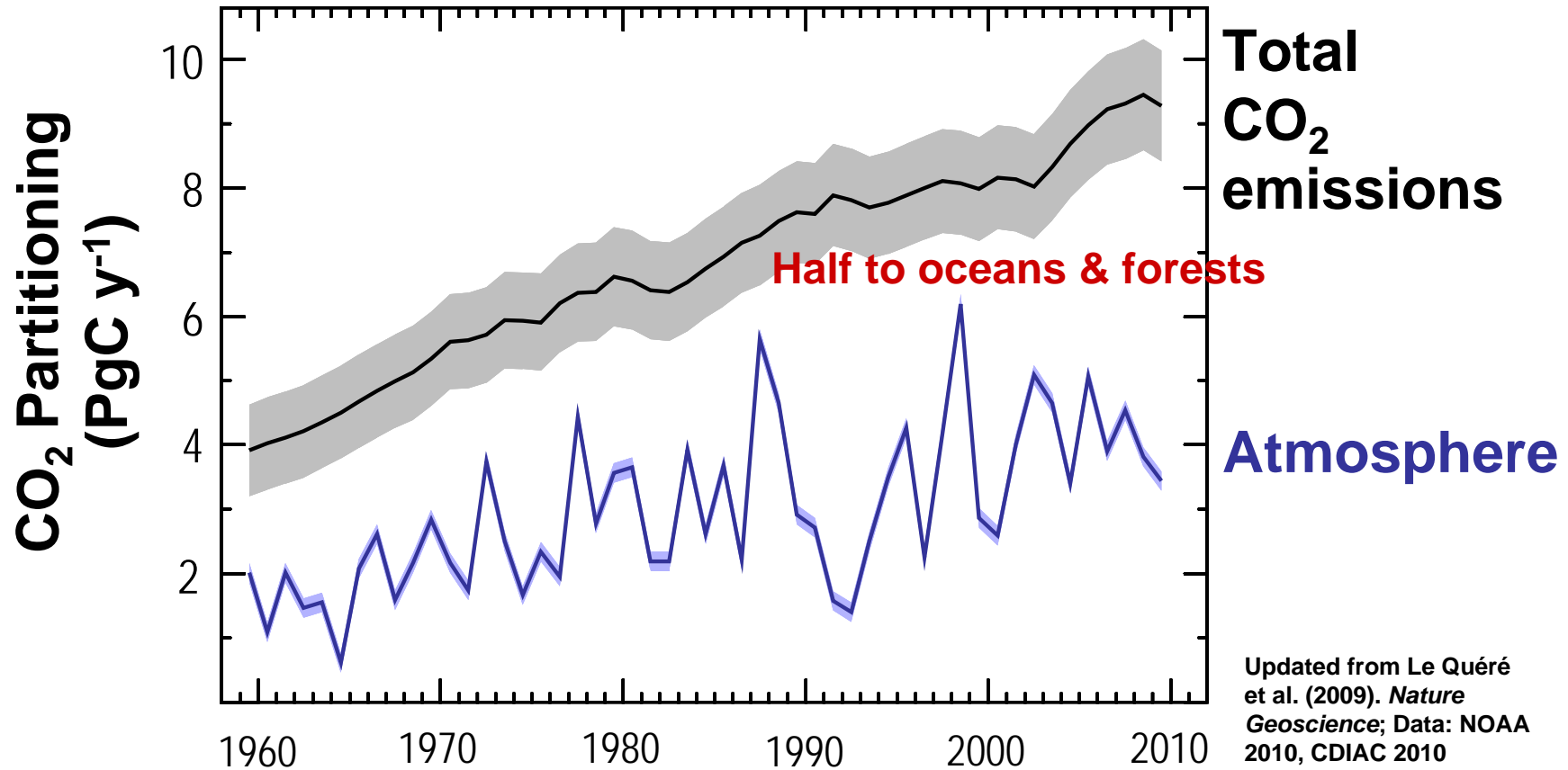
## Fossil Fuel Emissions: Actual vs. IPCC Scenarios



- 4%/year

# 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<sub>2</sub> from the atmosphere, and many centuries to remove it from oceans

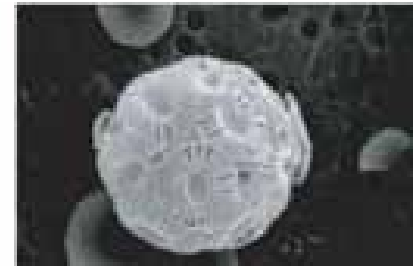
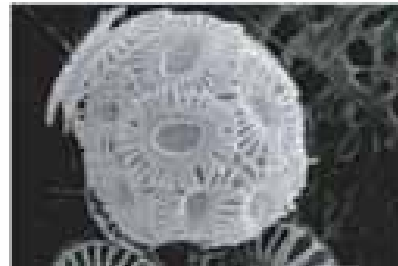
# Rising Ocean Acidity Threatens Organisms



- From the Tropics to the Arctic, the seas are sucking up emissions of  $\text{CO}_2$  — from burned fossil fuels
- When  $\text{CO}_2$  dissolves in water, carbonic acid is produced; the oceans are becoming more acidic



(Ruttiman, *Nature*, 31 Aug. 2006)



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

- The atmosphere is transparent to light from the sun, but not to infrared radiation from the earth
- Greenhouse gases: H<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub>
  - trap the earth's heat, giving pleasant climate
- CO<sub>2</sub> rise alone has a small effect, BUT...



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

- As Earth warms, **evaporation and water vapor increase** and **this amplifies warming** a lot
- As Earth warms, **snow and ice decrease** and **this amplifies warming** in winter and northern latitudes, because less sunlight is reflected
- **Doubling CO<sub>2</sub> will warm Earth about 5°F (3°C)**
  - much more in the North and over land

# Global Warming Is Unequivocal

## IPCC: February 2, 2007

### Since 1970, a rise in:

- Global surface temperature
- Lower atmosphere temperatures
- Global sea-surface temperatures
- Global sea level
- Ocean heat content
- Water vapor
- Rainfall intensity
- Extratropical precipitation
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves

### Decrease in:

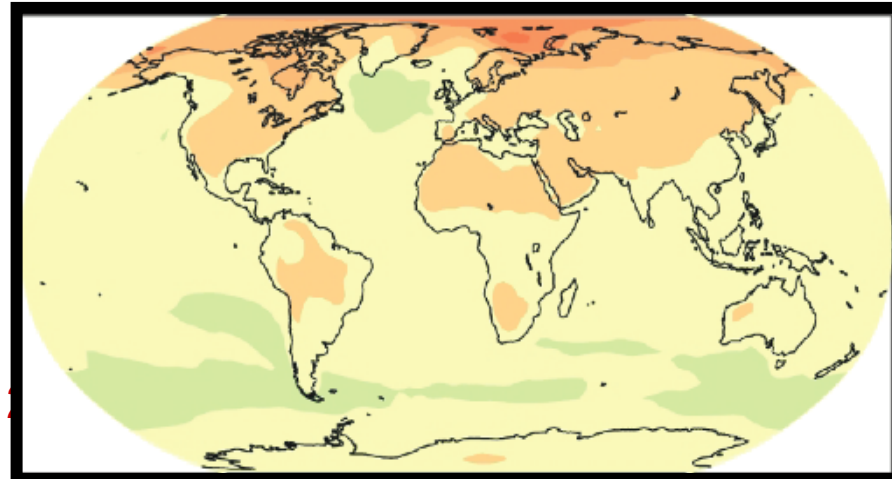
- NH snow extent
- Arctic sea ice
- Glaciers
- Ocean pH (increasing acidity)



# Predicted Change in Temperature

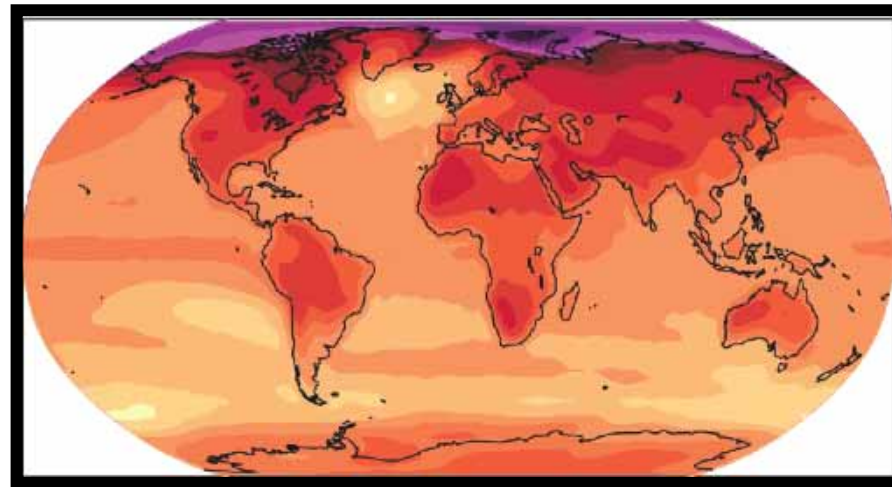
2020-2029 and 2090-2099, relative to 1980-1999 (°C)

**“Committed”**

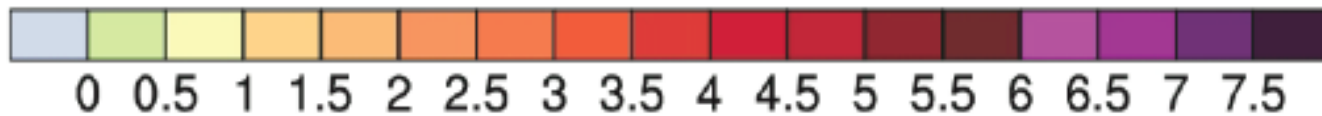


**(We did nothing for the last 20 years)**

**Still up to us!**



**(We could halve this if we act now)**



**[°C]**

# Sea-level Rise

## Will Eventually Flood Coastal Cities

- Late 20<sup>th</sup>-century sea-level rise: 1 foot / century
- 21<sup>st</sup> century: Likely to triple to 3 - 4 feet / century
  - And continue at this rate for centuries
- Unless we drastically reduce burning of fossil fuels by 80% by 2050
- Sea-level rise will get our attention
  - But it will be too late!

# Many Challenges Face Us

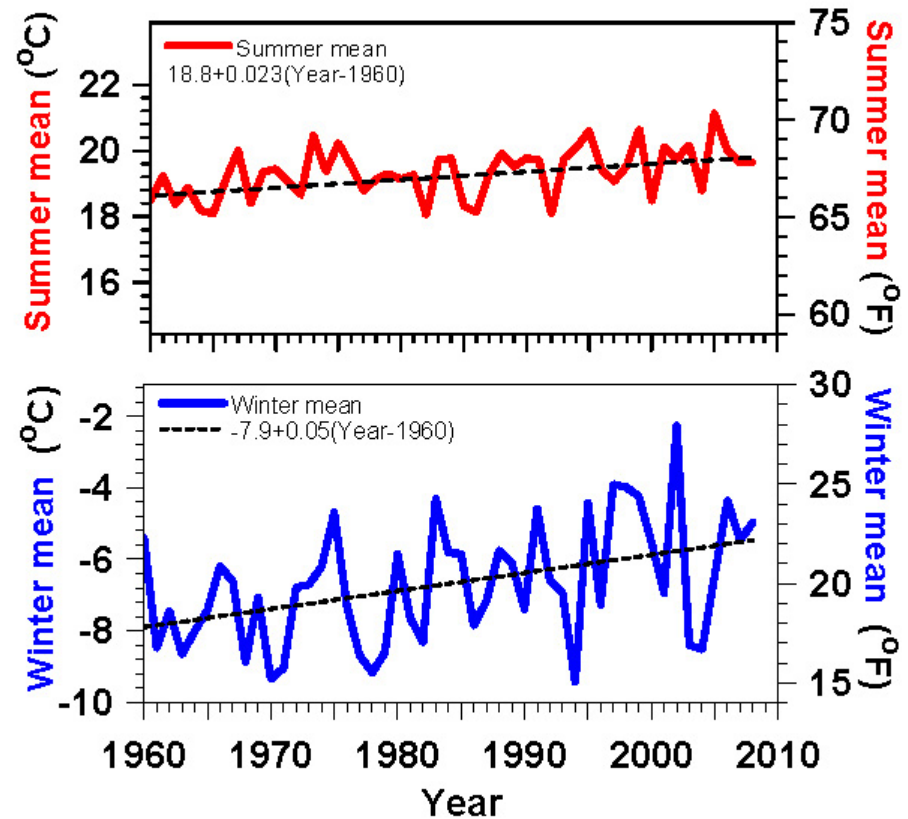
- **Extreme weather: Floods, fires, & drought**
- **Melting Arctic and permafrost—methane release?**
- **Ecosystem collapse, including perhaps forest and ocean ecosystems**
- **Collapse of unsustainable human population**

# 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**

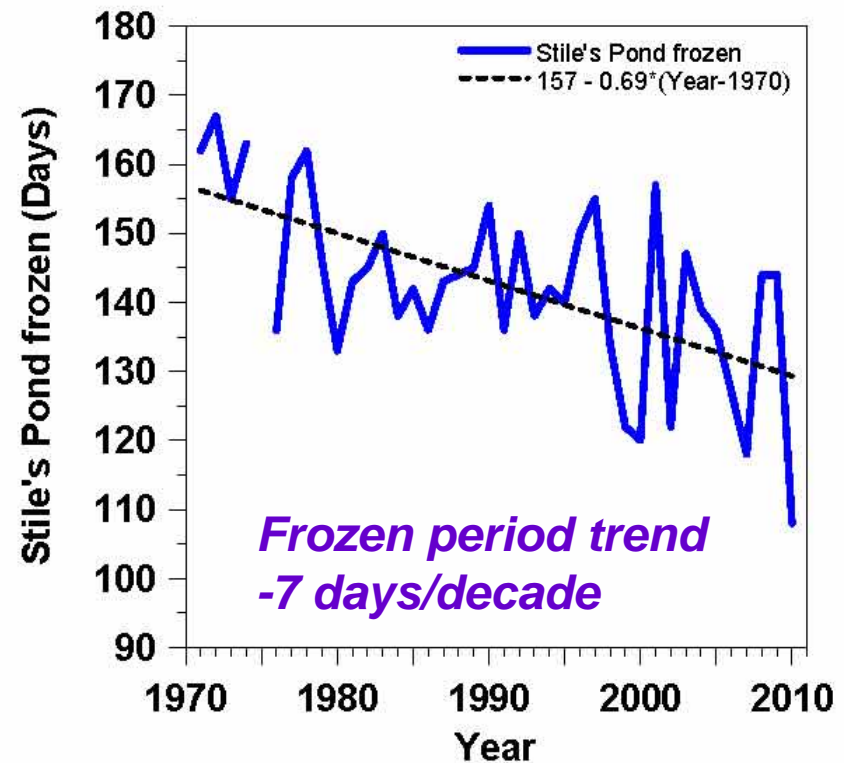
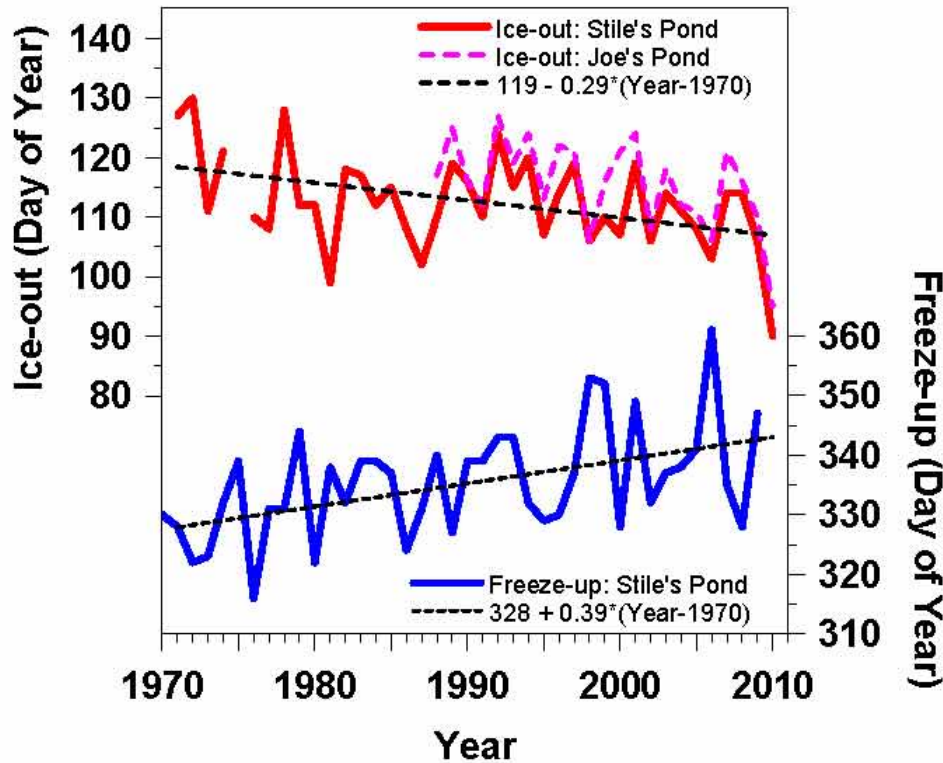
# Vermont Temperature Trends

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



# Lake Freeze-up & Ice-out Changing

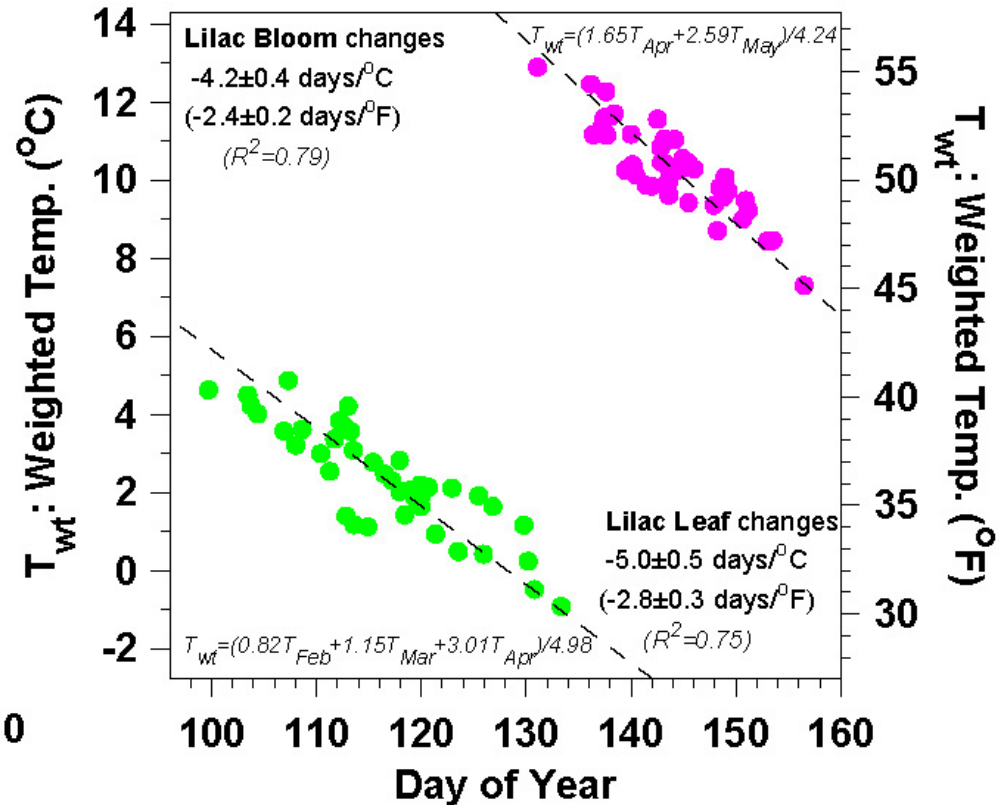
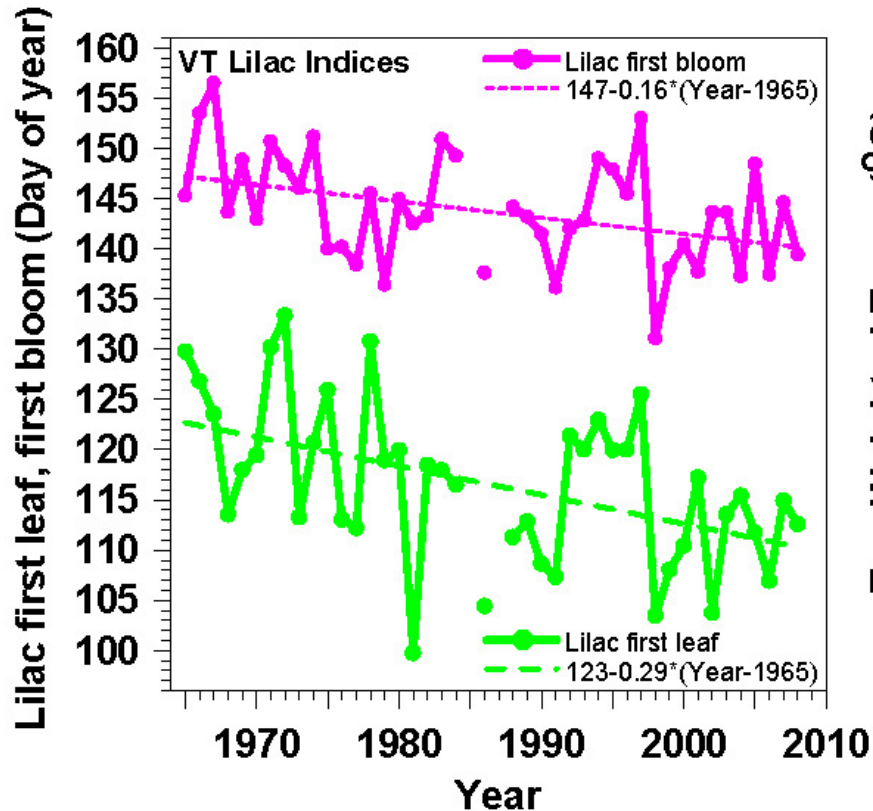
## Frozen Period Shrinking Fast



- 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**)

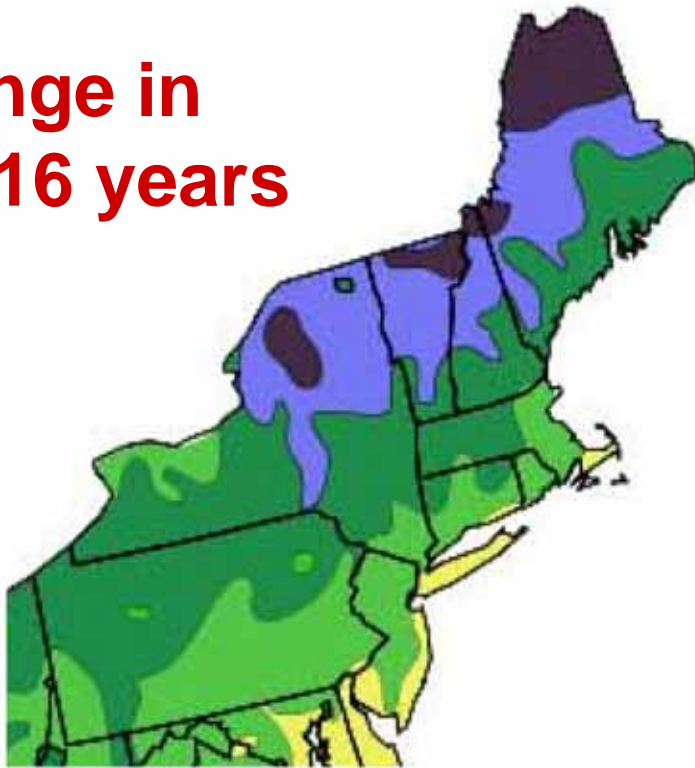
# Vermont Winter 2006



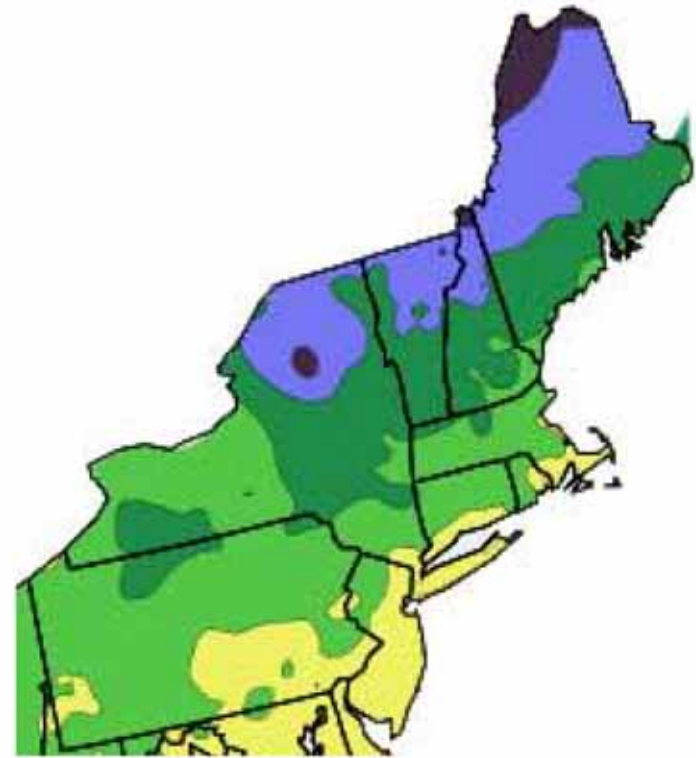
- **Sun is low; and snow reflects sunlight, except where there are trees!**
- **Sunlight reflected, stays cold; little evaporation, clear sky; earth cools to space**

# USDA Hardiness Zones - Northeast

Change in  
last 16 years

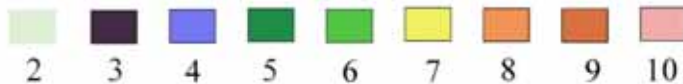


1990



2006

Zone



USDA Hardiness Zones

# Gardening in Pittsford, Vermont in January



**January 7, 2007**

**December 2006:**

- **Warmest on record**

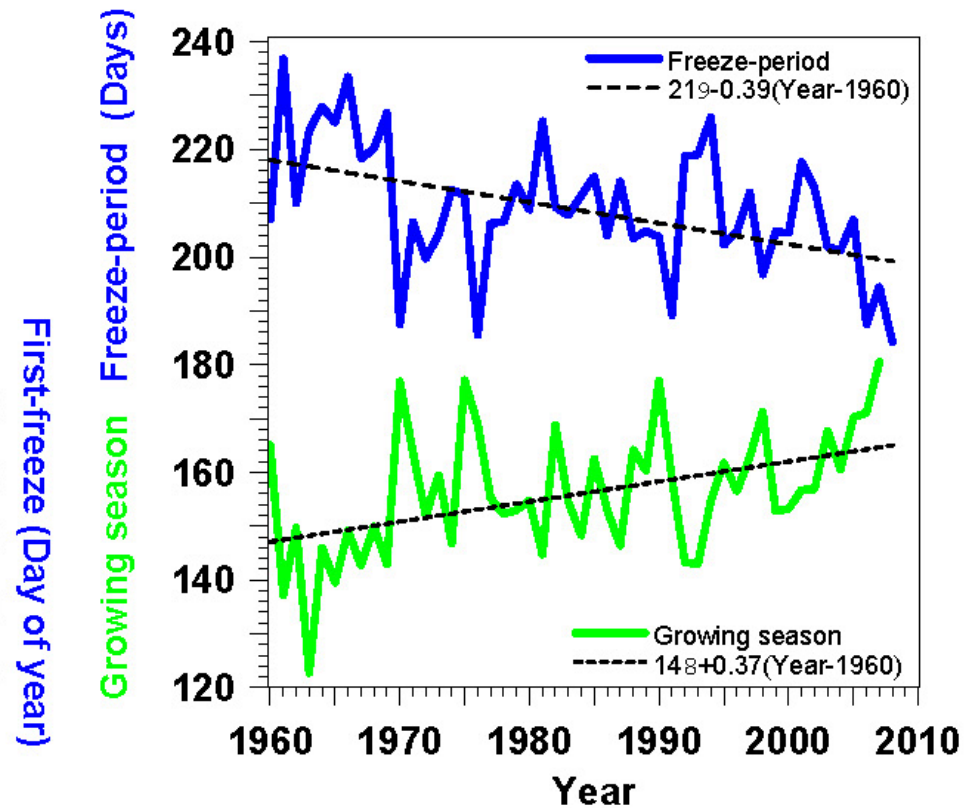
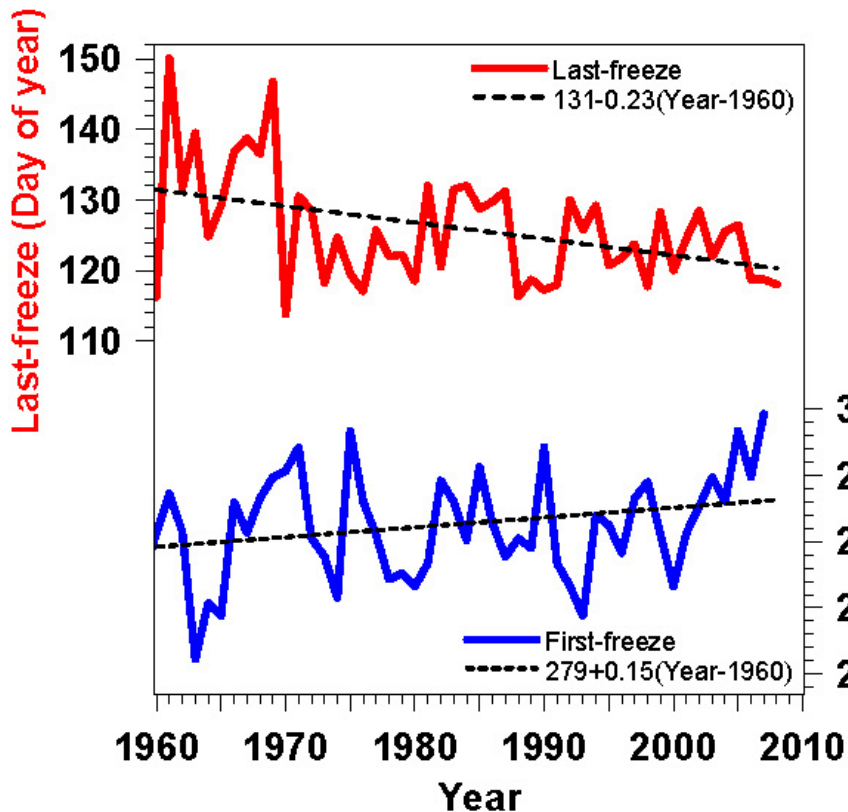


**January 10, 2008**

**Warm Fall:**

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

# First and Last Frosts Changing



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

# 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***

# 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!*



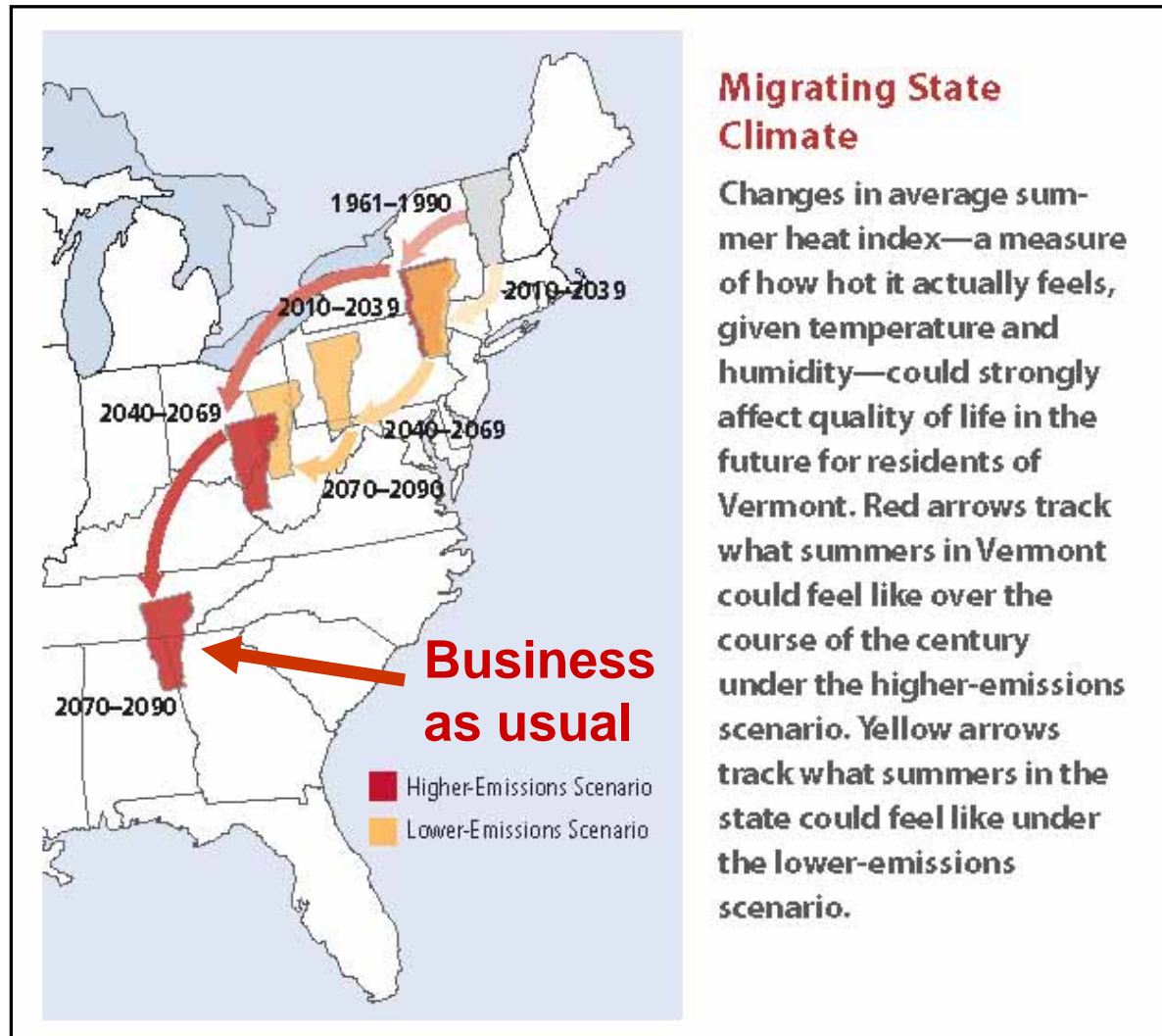
*Clear dry blue sky after frost. Forest evaporation has ended; water vapor greenhouse is reduced, so Earth cools fast to space at night*

***Later frost: Growing season getting longer***

# Vermont's Future with High and Low GHG Emissions

What  
about  
skiing?

What  
about  
tropics?



NECIA,  
2007



# Outline

- Science of climate change
  - Global scale: actual and future
  - What is happening to Vermont
- **The transition we face**
  - **Managing the earth system**
  - **Why is it difficult?**

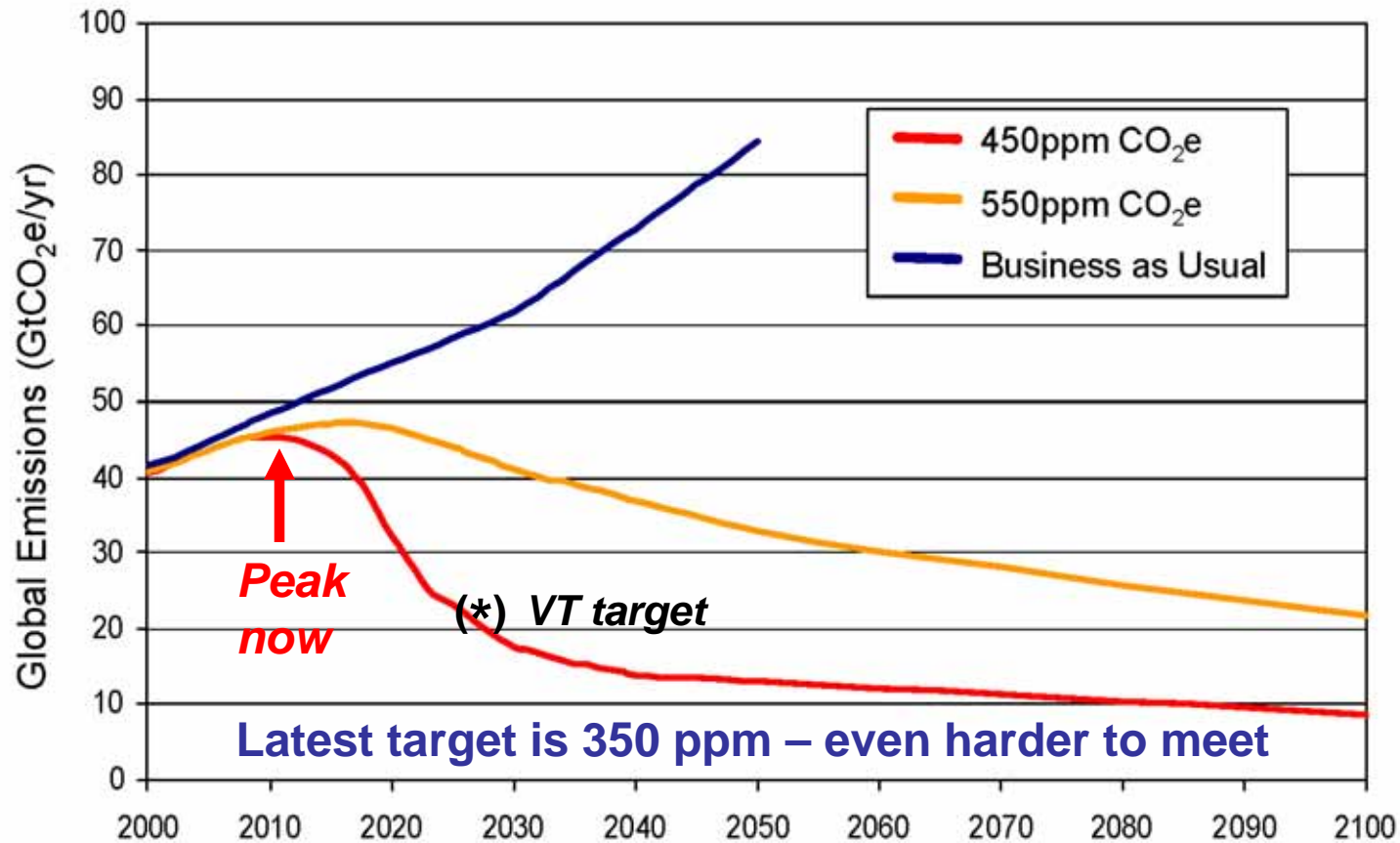
**Discussion**

# Can We Stop “Dangerous Climate Change”?

- **Yes: Quickly stabilize atmospheric CO<sub>2</sub>**
- **This means an 80% drop in CO<sub>2</sub> 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 Avoid “Dangerous Climate Change”?

Emissions Paths to Stabilisation [Stern, 2006]



# 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
- **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

# 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)?**

# Why Is It Difficult for Us?

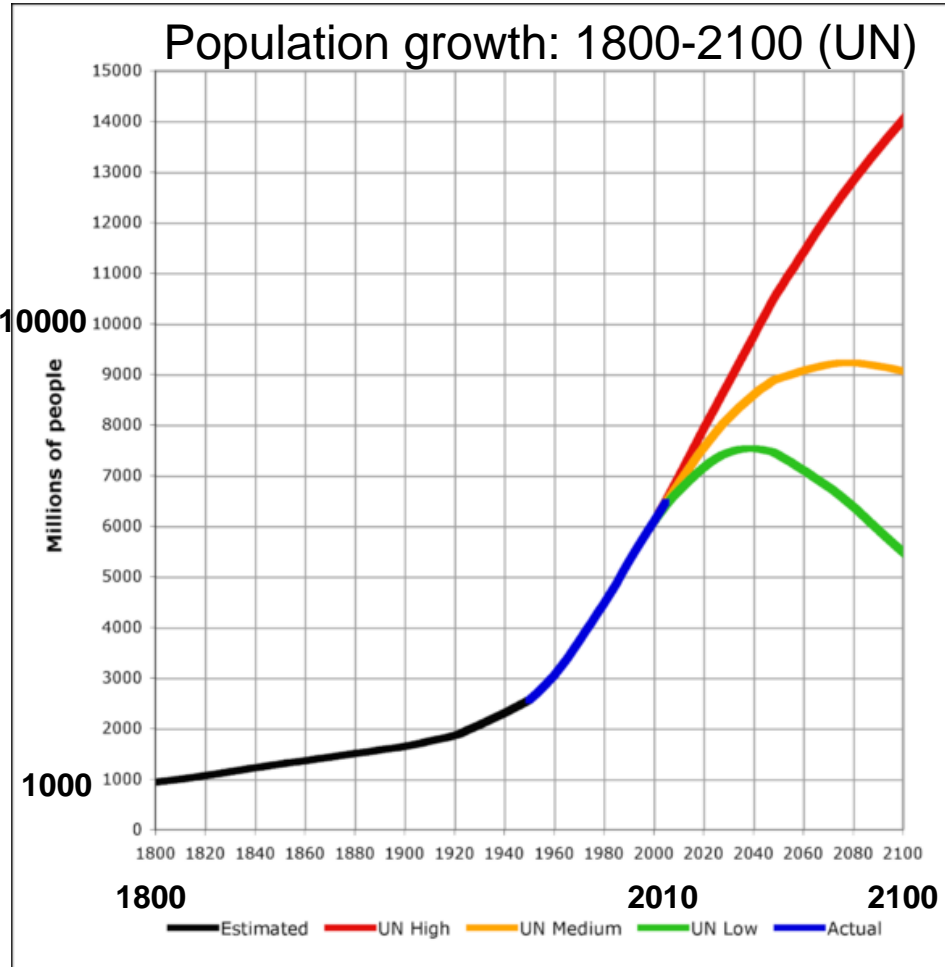
- The “American dream” is crumbling
  - “Economic growth” based on **fossil fuels, debt, and consumerism is unsustainable** — and a disaster for the planet!
- Individual “rights” and the needs of humanity must be **balanced** against the needs of the earth’s ecosystem
- We don’t know how to **guide and manage technology** —so the result is tremendous successes and catastrophic failures



# We Passed the Carrying Capacity of the Earth in the 1980s (?)



- Population is still rising
- Consumption still rising
- Fossil fuel use still rising
- *We still 'believe' in Growth*
- *Global poverty & suffering are growing: the future looks bleak for billions*
- *In a finite world, growth leads to overshoot & collapse*



# But If Growth Can't Save Us, Surely Technology Can?

- We have lost sight of the **critical distinction** between the human-made world and the natural world
- **We understand the human-made world, the world of computers & technology—because we made it—it is predictable and controllable, except when we are careless (& earthquakes)**  
[E. F. Schumacher (1977). *A Guide for the Perplexed*]
- **The same is not true of the natural world – which is far more complex and alive. Our understanding is limited; prediction & control are not possible**

# But If Growth Can't Save Us, Surely Technology Can?

- Now our world of technology is having a global impact on the natural world and it must be carefully managed
  - **But this is incompatible with our ideology**

# Some Technology Is Useful



**30 mph Danish electric tricycle:  
with 150 mile range**

# Our Choices Are Bounded



- *Whether we use technical, social or religious language*
- **Humanity is an integral part of the earth system and dependent on its stability**
- **We do not have the freedom to do what we wish, whatever our economic or theological doctrine**
- **The response of the Earth system to our human-centered arrogance will be sufficiently large this century that we will rethink our doctrine**
- **We would be wise to rethink sooner rather than later**

# 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**

# The Future Is Not Our Past

- **Collectively, we create the future, so we need to plan for a transition to a sustainable society**
- **Efficient society**
- **Renewable technologies to replace fossil fuels**

# 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



# What Will This Mean For You?

- **Society needs to rethink its relationship to the natural environment and its ecosystems in less than one generation**
- **Our 'lifestyle' is disconnected from what the earth can sustain and the large inertia of the earth system is masking the extent of the crisis we face**
- **Individual can rethink priorities but societal changes are needed: from towns to global**
- **Ask**
  - **Is this an efficient and sustainable way of doing this?**
  - **Do I have a deep understanding and connection to Earth?**

# Discussion

- <http://alanbetts.com>
  - this talk <http://alanbetts.com/talks>
  - articles at <http://alanbetts.com/writings>
  - papers at <http://alanbetts.com/research>
- *Vermont Climate Change Indicators*
- *Seasonal Climate Transitions in New England*

# Media Resources

- **Sunday Environment page in Rutland Herald/Montpelier Times Argus:  
*2008-2011 – see handout: 34 articles*  
<http://alanbetts.com/writings>**
- **VPR Commentaries: vpr.net or  
<http://alanbetts.com/talks>**