



# Global Warming and New England

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*ILEAD course: Facing Global Warming*  
***October 20, 2010***

# Climate Change

- **One of the great challenges for 21<sup>st</sup> C**
- **We are already decades late in taking action**
  - *Sawyer (1972): Man-made CO<sub>2</sub> and the “greenhouse” effect*
- ***Global issue & local issue;  
societal & personal issue***
- **Clash of Earth science & social values**

# Outline

- **Science of climate change**
  - *Global scale: actual and future*
  - *Local scale: Vermont*
- **Perspective of Earth system scientist**
  - *Managing Earth system: technical solutions*
  - *Choices, challenges and self-deception*

# My background:

## Peterhouse Cambridge

- Peterhouse, Cambridge: founded 1284
- *Medieval warm period; Vinland colony flourishes*



# My background:

## Nottingham High School

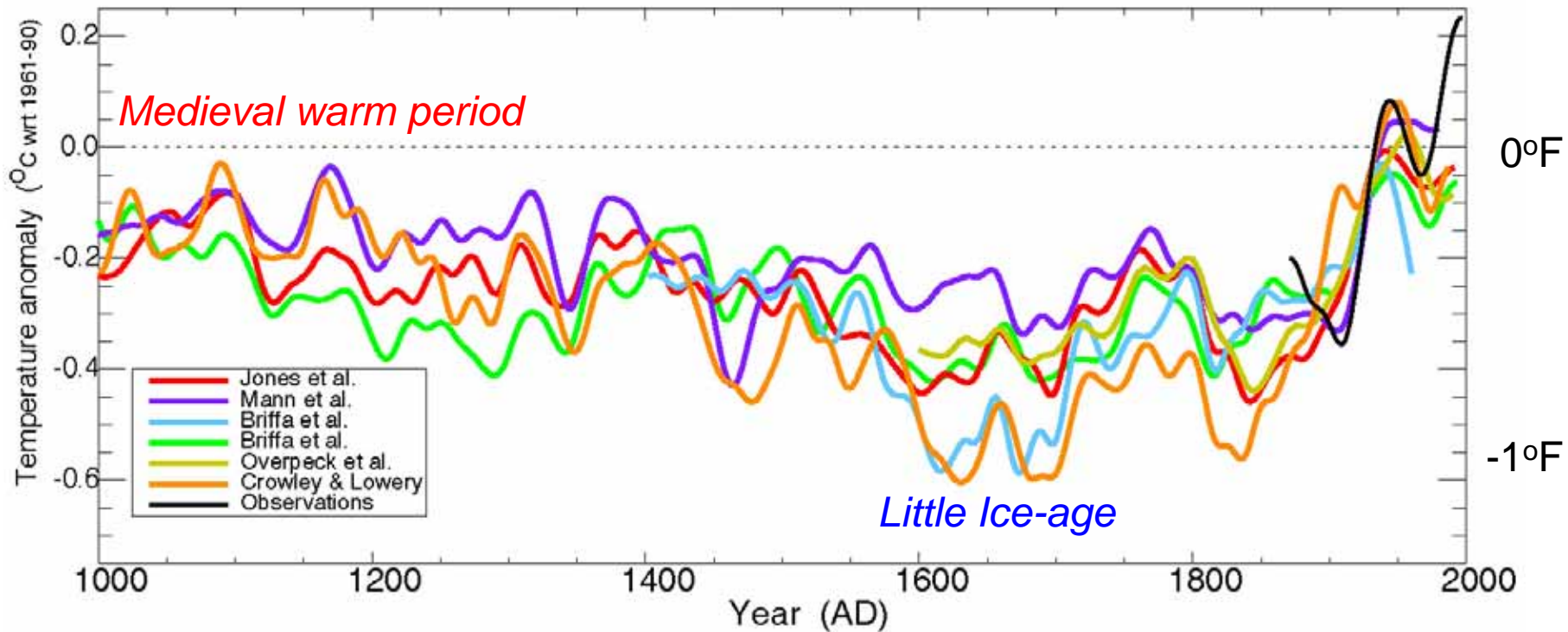
- Founded 1513
- *1550 heading into 'little ice-age'*
- *1620 Pilgrim fathers face bitter winters*





# Millennial Temperature Record

2100: +5°F  
↑

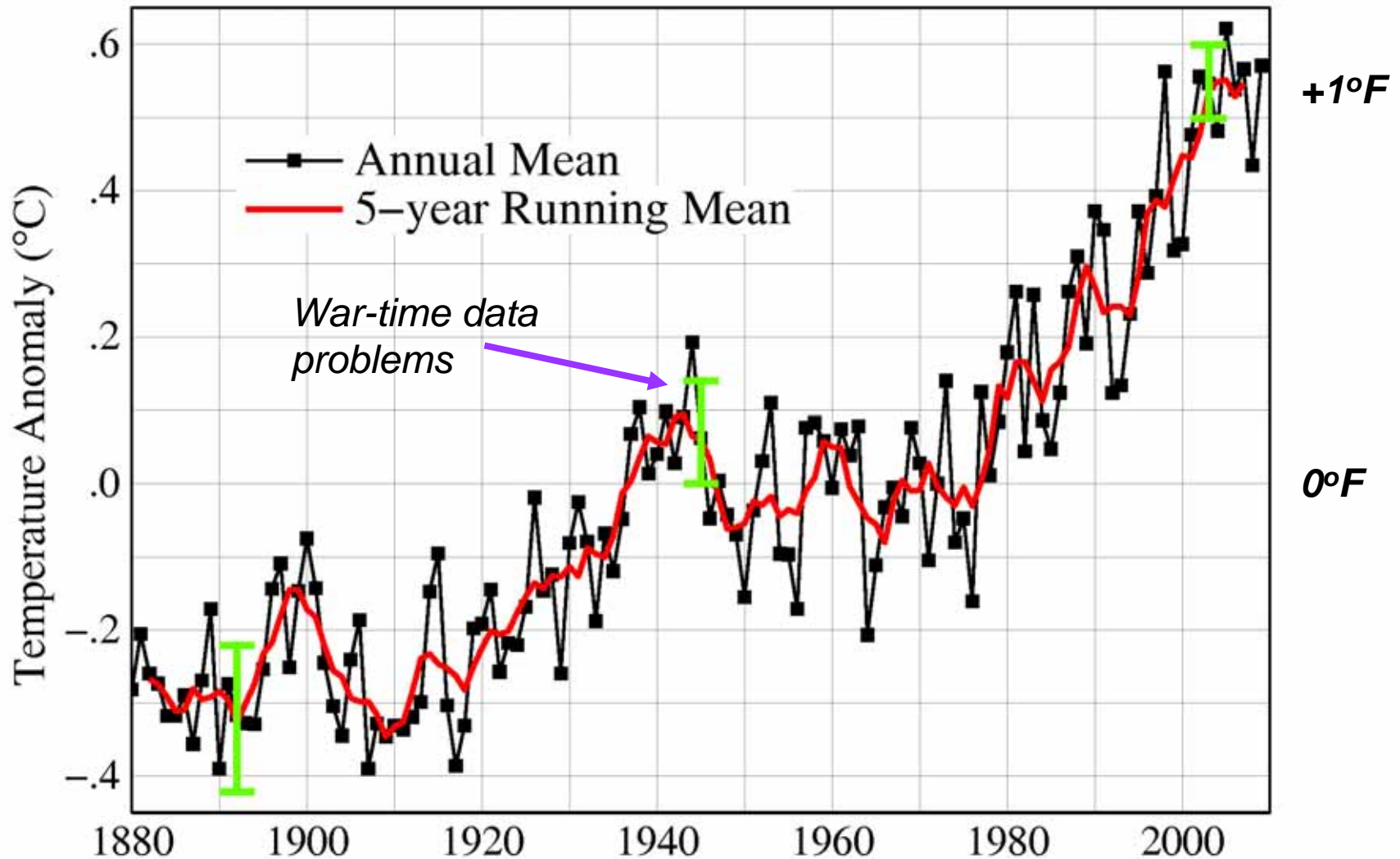


- Before thermometers  
‘proxy’ records have large uncertainty

# Global temperature rise 1880-present

2100: +5°F  
↑

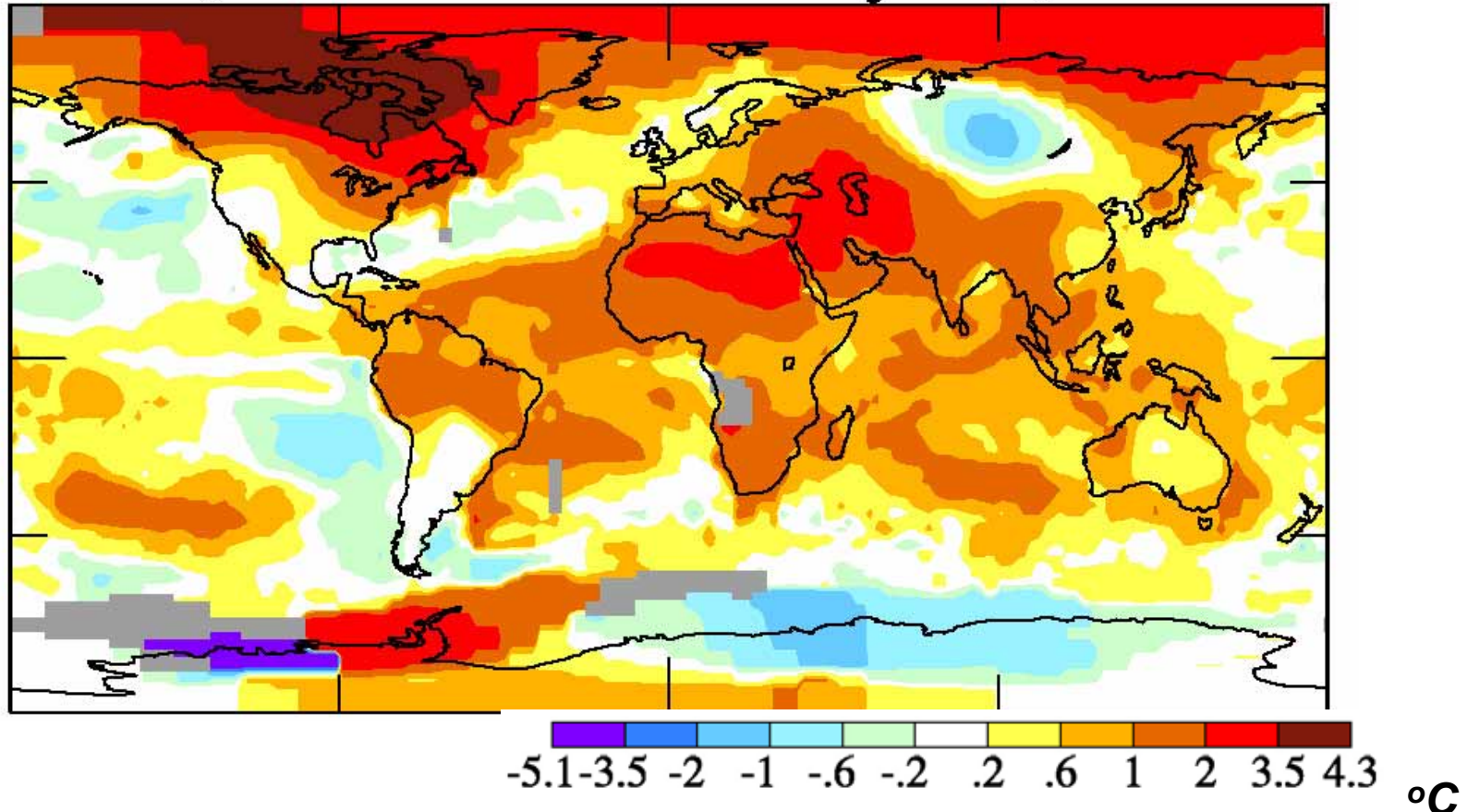
## Global Land–Ocean Temperature Index



**NASA-GISS, 2010**

# Global picture Jan-Aug 2010

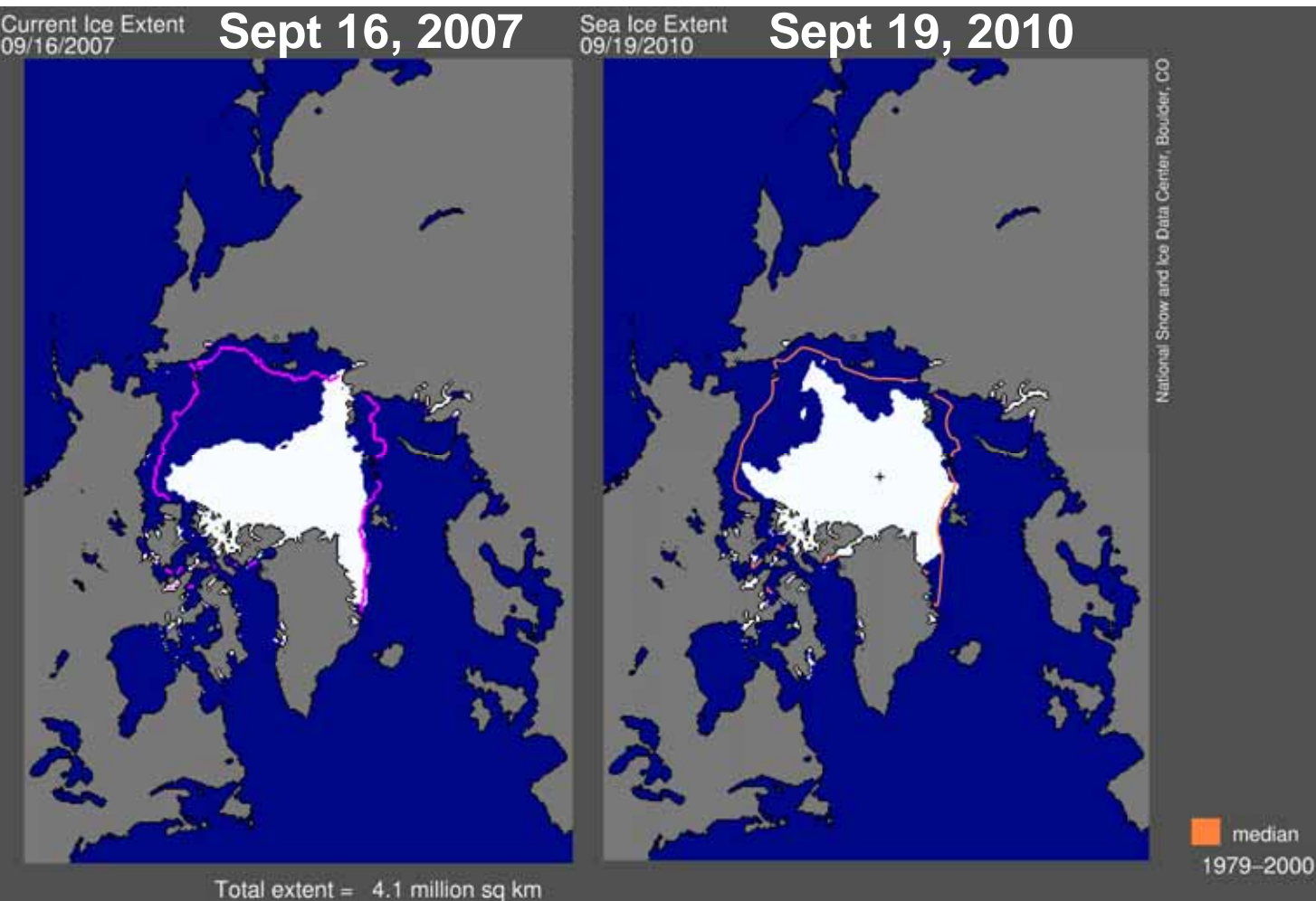
2010 (the warmest of 131 years)      0.67 °C(1.2F)



- *Record summer temps in Russia (99F) (Moscow fires) and Pakistan (128F) (extreme monsoon floods)*
- *April rain in Ellef Ringnes Islands, Nunavet, at 78°N*



# Arctic sea-ice loss has accelerated



*Feedbacks -  
speed melting*

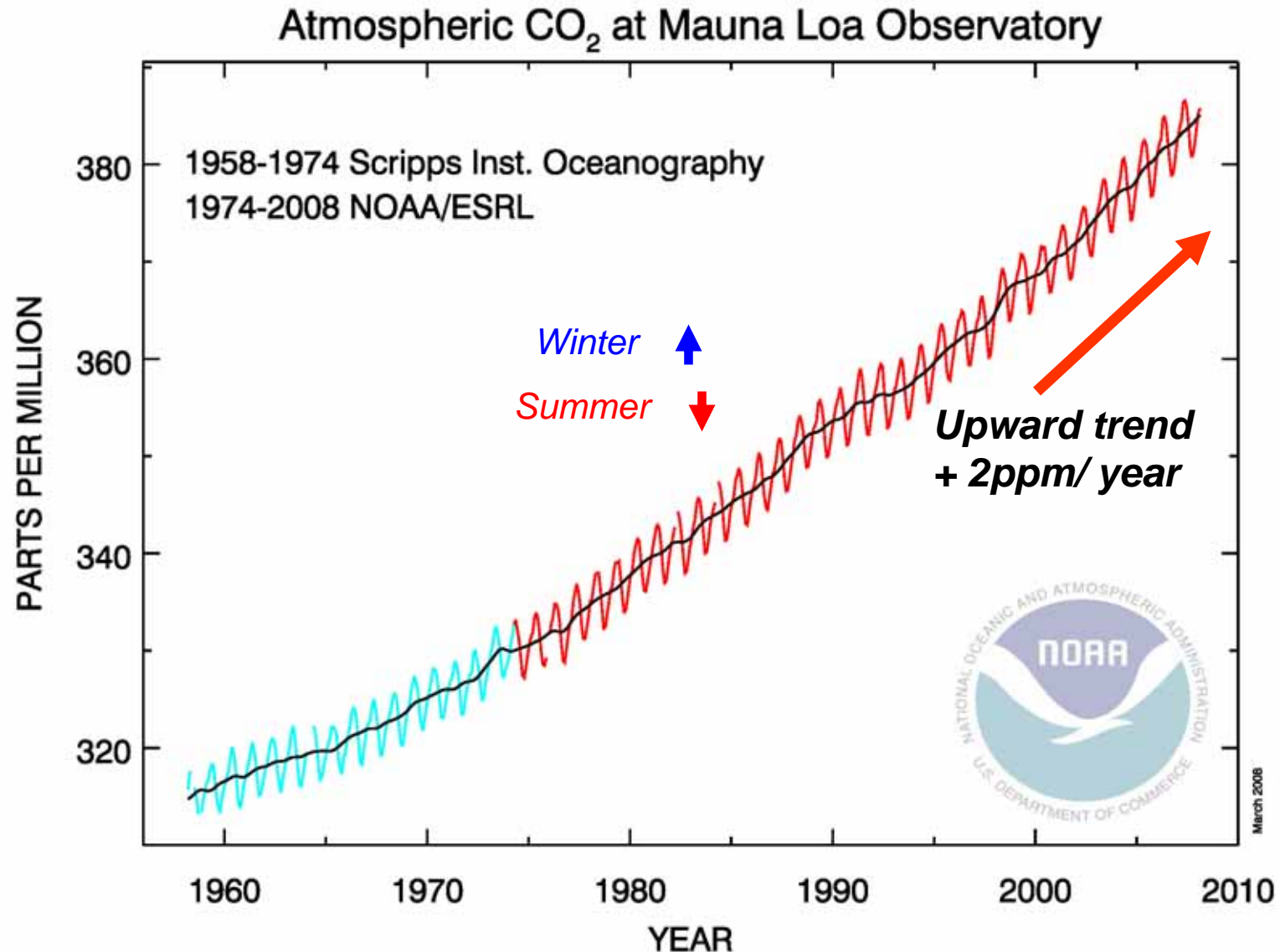
*-less ice, less  
sunlight reflected*

*-more evaporation,  
larger water vapor  
greenhouse*

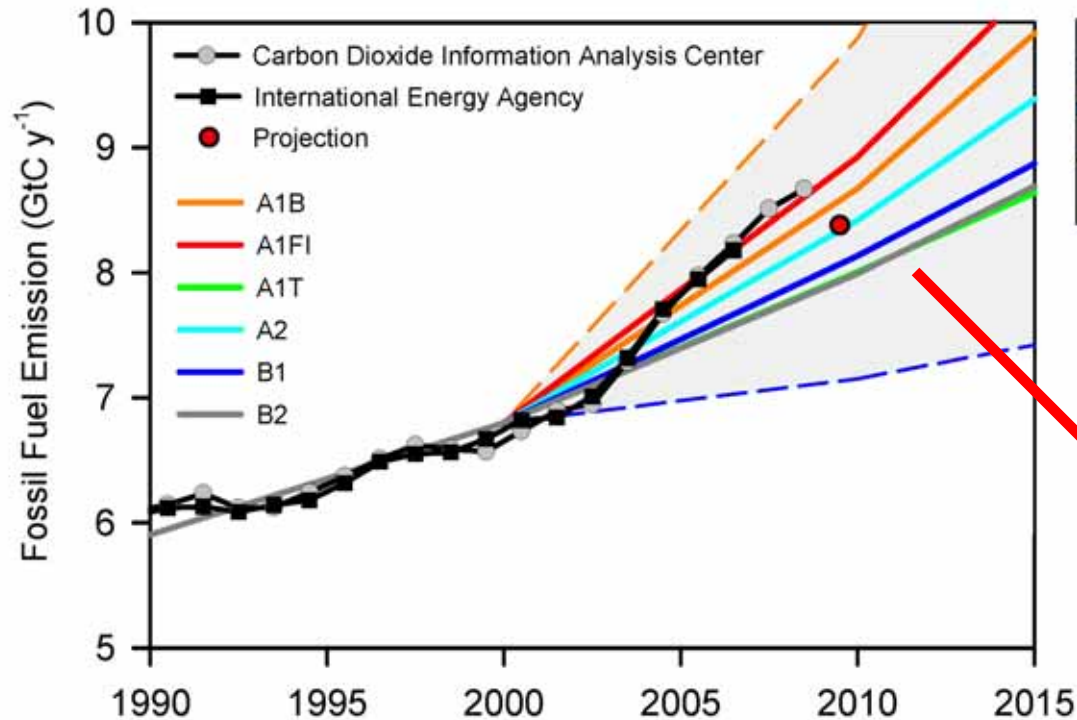
([www.nsidc.org](http://www.nsidc.org))

- 2007 saw record ice-loss: most ice now only 1-2yrs old
- Open water in October contributes to warmer Fall

# Carbon dioxide is increasing



# Fossil Fuel Emissions: Actual vs. IPCC Scenarios



Projection **2009**  
Emissions: -2.8%  
GDP: -1.1%  
C intensity: -1.7%

- 4%/year



Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature Geoscience; International Monetary Fund 2009

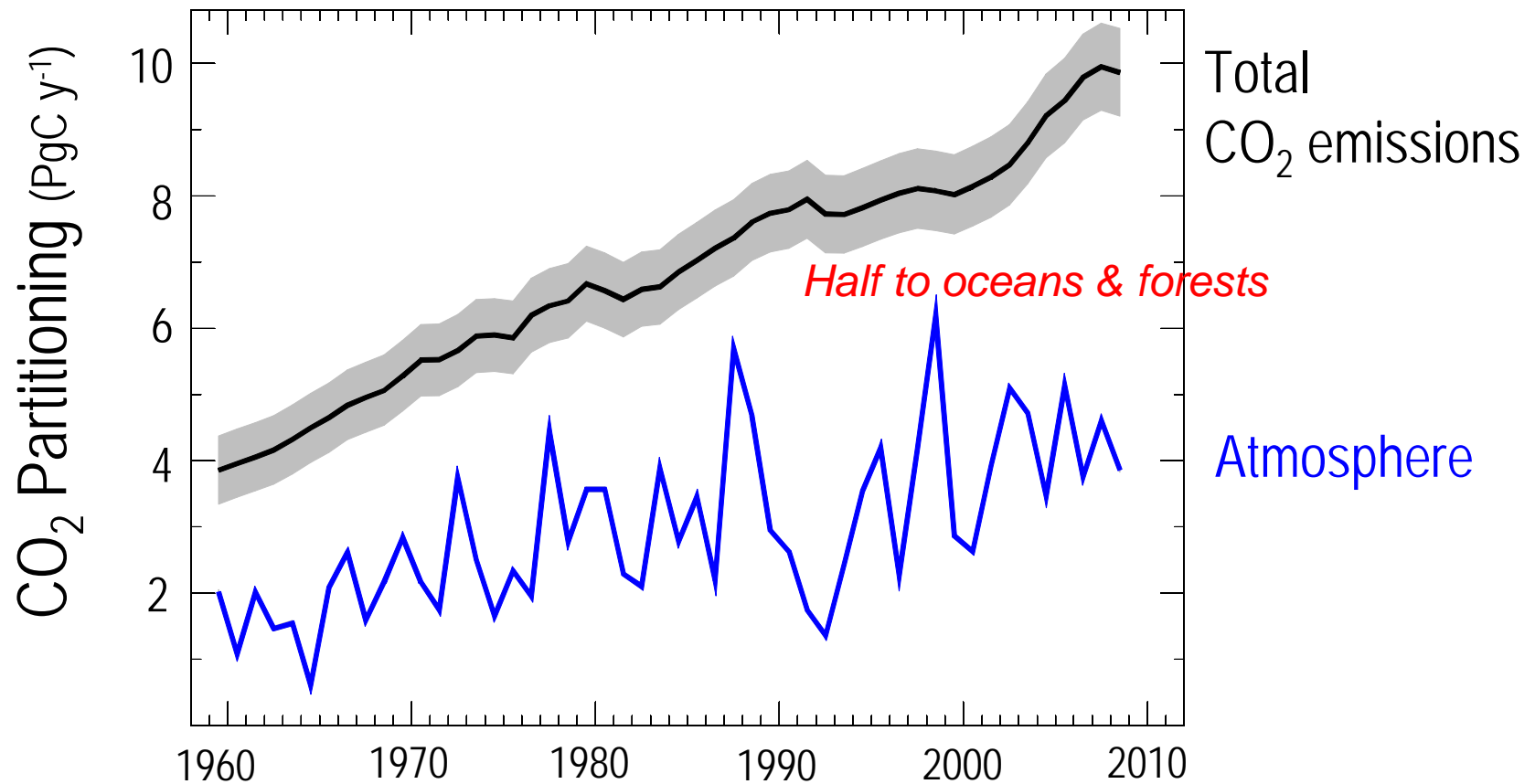


- 2009 was 'good' for the Earth

Need 80%  
drop by 2050

# Key Diagnostic of the Carbon Cycle

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



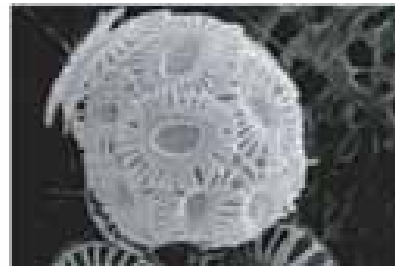
*It takes a century or more to remove CO<sub>2</sub> from atmos., and many centuries from the oceans*

# Rising ocean acidity threatens organisms

- From the tropics to the Arctic, the seas are sucking up emissions of carbon dioxide—from fossil-fuel burning.
- When carbon dioxide dissolves in water, carbonic acid is produced, so the oceans are becoming more acidic.



*[Ruttiman, Nature, 31 Aug., 2006]*





# ***Why is rise of atmospheric CO<sub>2</sub> a problem?***

- **Atmosphere is transparent to 'light' from sun but not to 'infrared' radiation from earth**
- **Greenhouse gases: H<sub>2</sub>O, CO<sub>2</sub>, CH<sub>4</sub>, HCFCs...**  
- trap the earth's heat
- **CO<sub>2</sub> alone has a small effect, BUT**
- 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 high lats, because less sunlight is reflected
- **Doubling CO<sub>2</sub> will warm Earth about 3C (5F)**

# ***IPCC, Feb 2, 2007***

## ***Global Warming is unequivocal***

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Since 1970, rise in:

- Global surface temperatures
- 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:

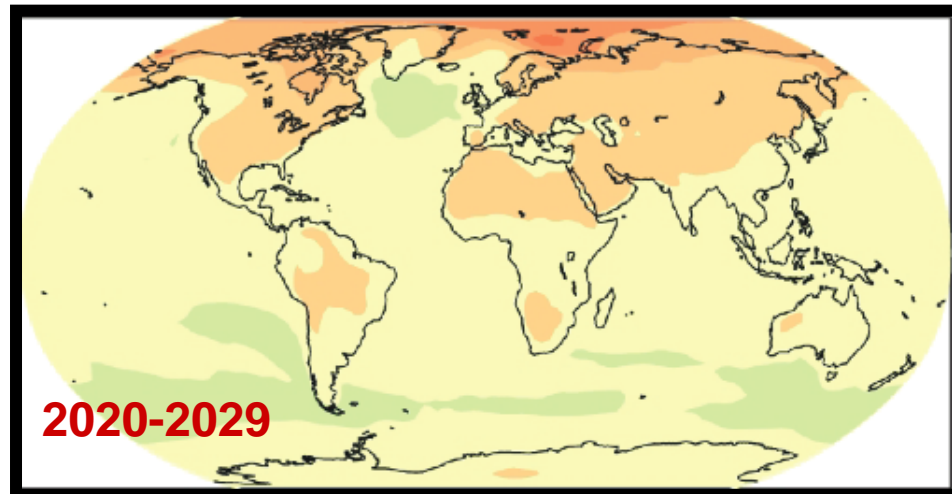
- NH Snow extent
- Arctic sea ice
- Glaciers
- Ocean pH [increasing acidity]

[\[www.ipcc.ch\]](http://www.ipcc.ch)



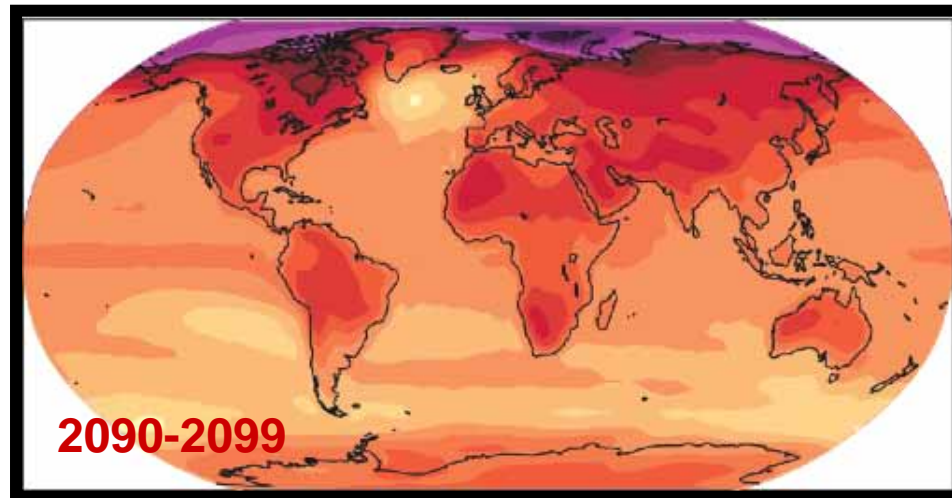
# Multi-model Predicted Percent Change in Temperature (2020-2029 and 2090-2090 relative to 1980-1999) [ $^{\circ}\text{C}$ ]

**‘Committed’**

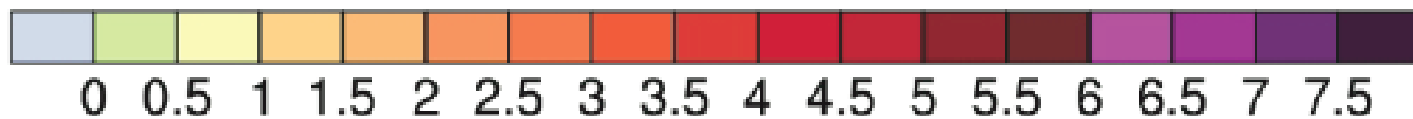


**(We did  
nothing for  
the last 20  
years)**

**Still up to us!**



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



# Sea-level rise will flood coastal cities

- Late 20thC sea-level rise 1ft/century
- 21stC -likely to triple to 3-4 ft/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 too late!*

# And much more..

- Melting Arctic and permafrost – methane release?
- Extreme weather: floods, fires & drought
- Collapse of many ecosystems, including perhaps forest and ocean ecosystems
- Collapse of unsustainable human population

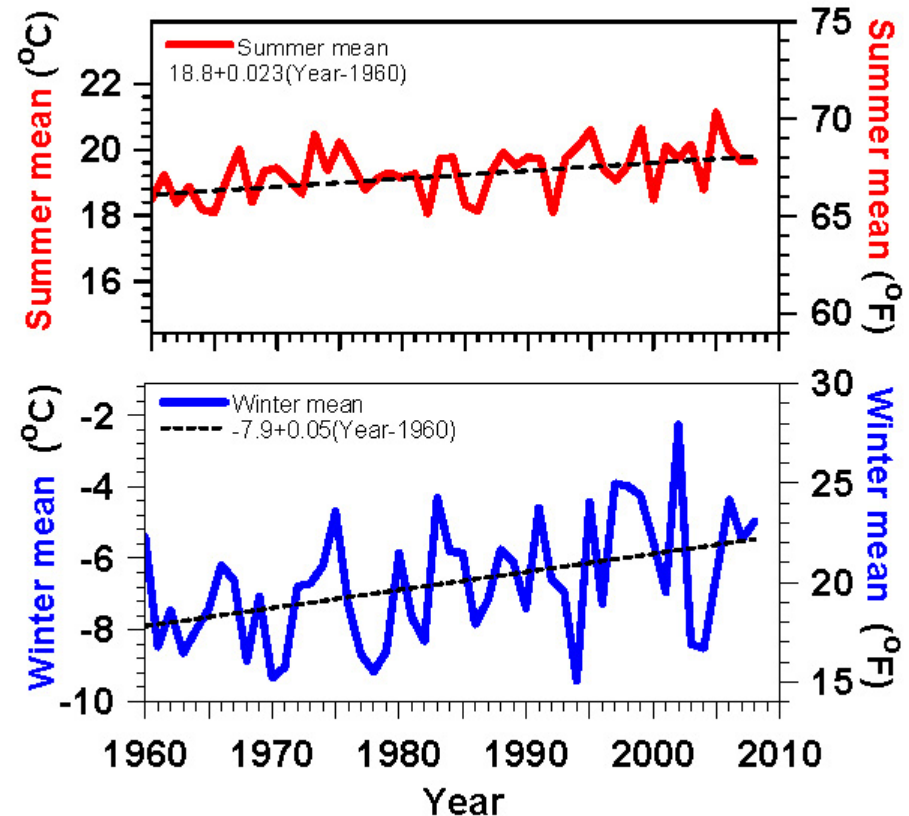


# What is happening to New England? – *Vermont!*

- 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 3.7 days/decade*
- *Spring earlier by 2-3 days per decade*

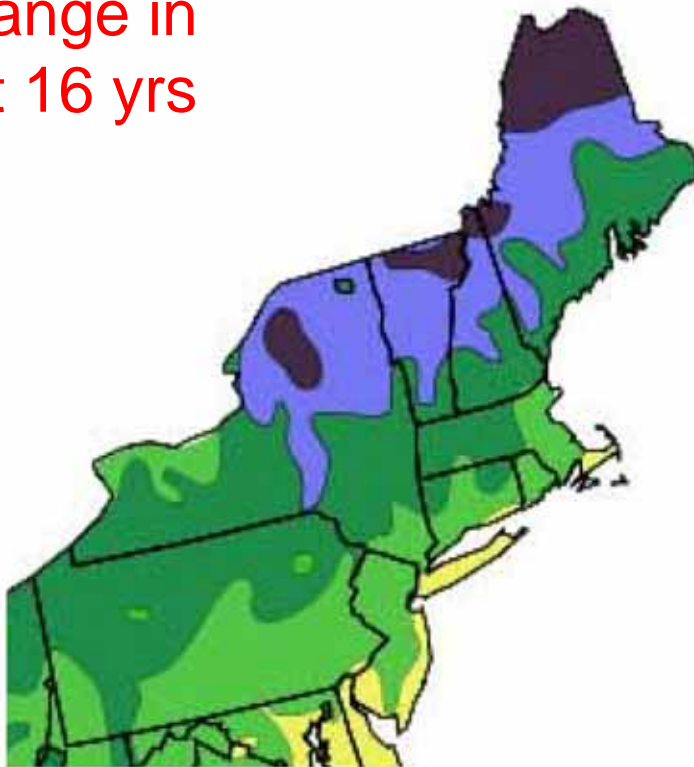
# Vermont temperature trends

- summer +0.4F/decade
- winter +0.9F/decade
- Less snow drives larger winter warming

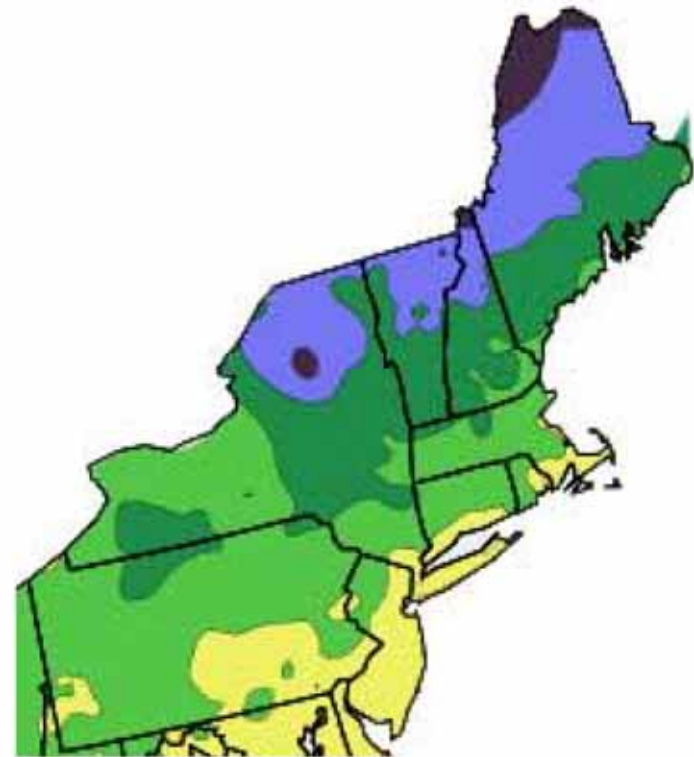


# USDA Hardiness Zones - Northeast

Change in  
last 16 yrs

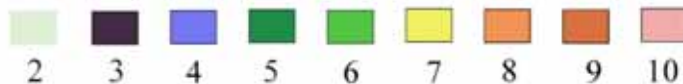


1990



2006

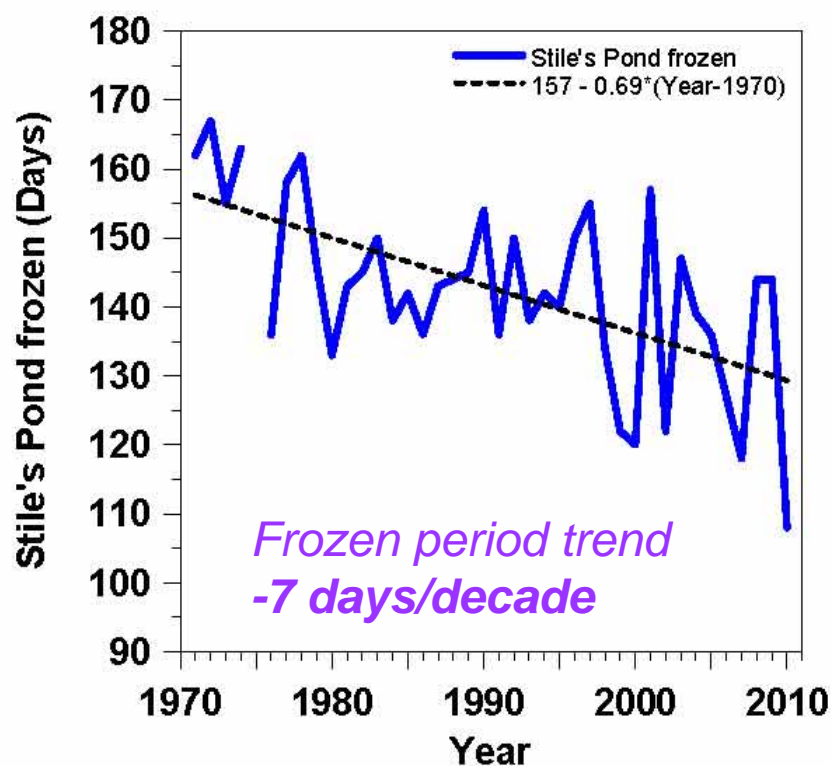
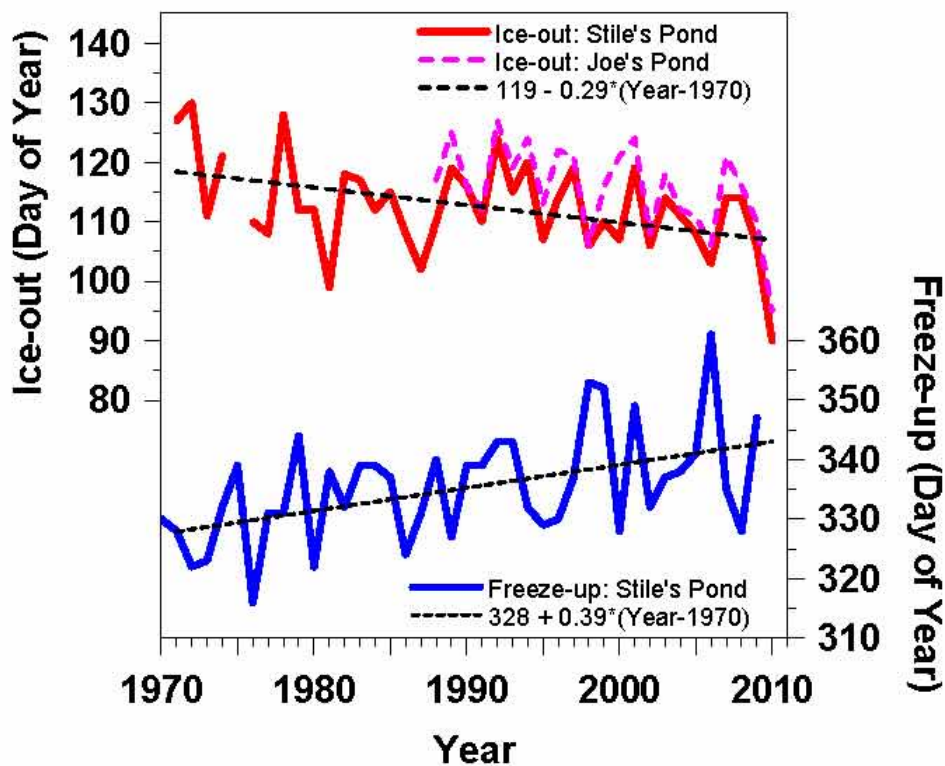
Zone



USDA Hardiness Zones

# Lake freeze-up & Ice-out changing

– *frozen period shrinking fast*



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



# Vermont winter, 2006



- Sun is low; and snow reflects sunlight, except where trees!
- Sunlight reflected, stays colder; little evaporation, clear sky



# Gardening in Pittsford, VT in January



Jan 7, 2007

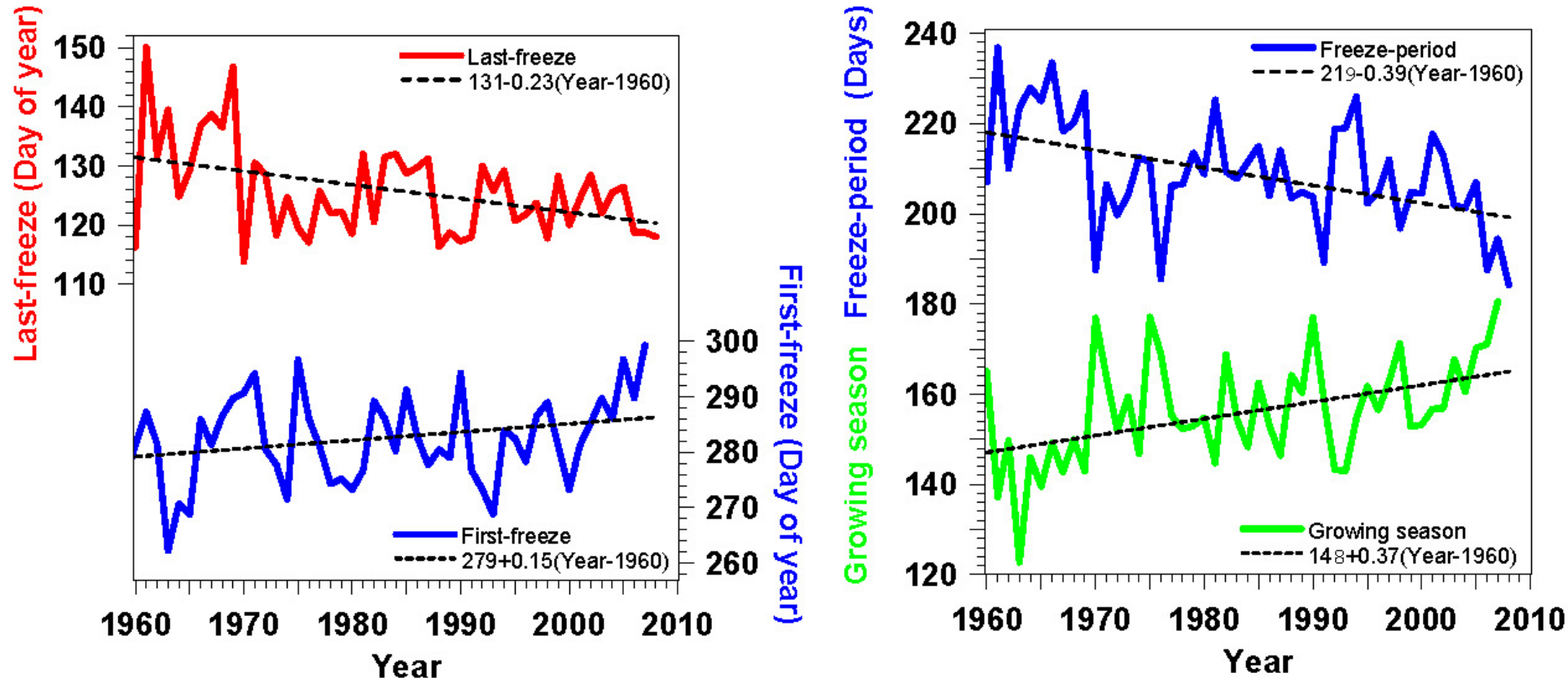
December, 2006, *warmest on record*  
[since 1894]



Jan 10, 2008

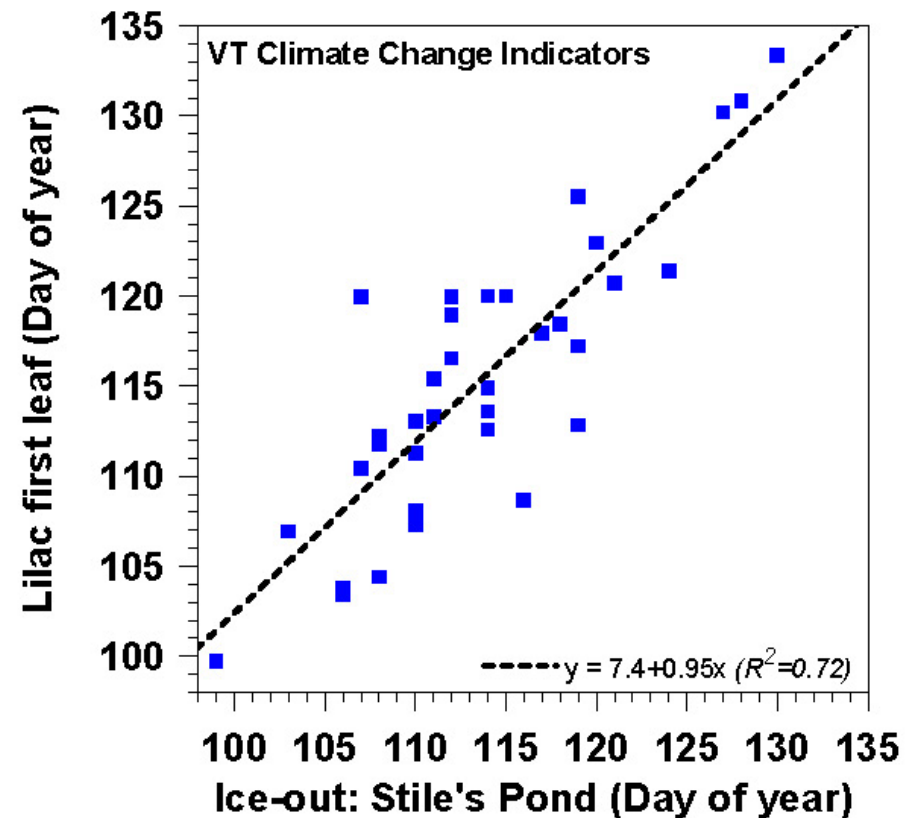
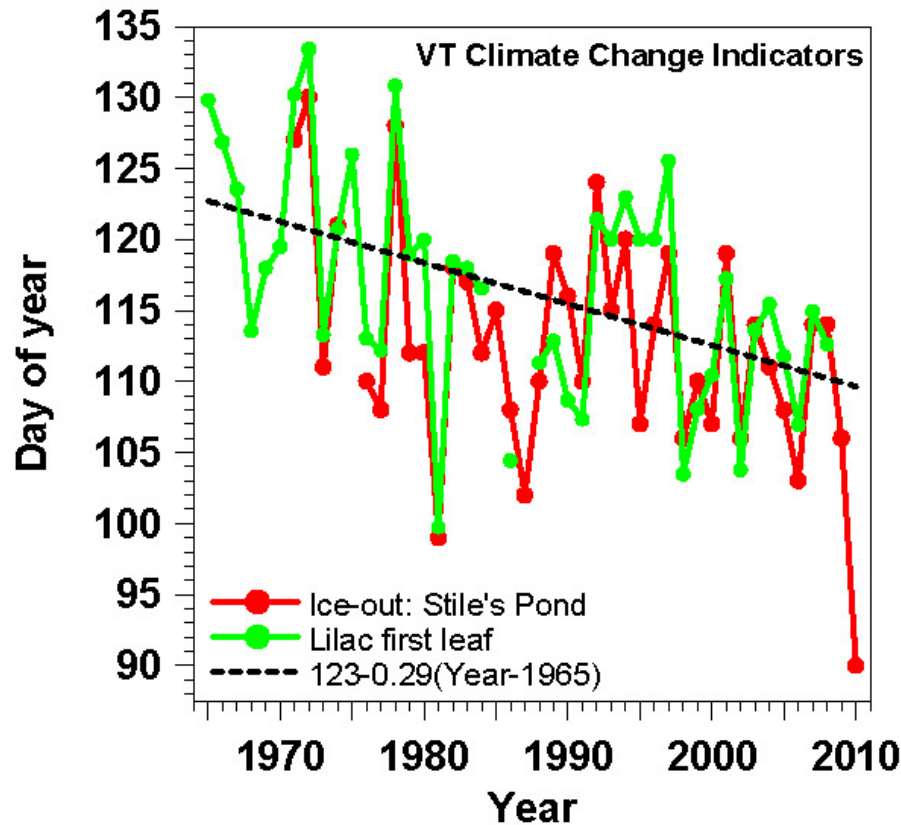
Warm Fall, *record Arctic sea-ice melt*  
Snow cover in December, ground unfrozen

# First & last frosts changing



- *Growing season for frost sensitive plants increasing 3.7 days/decade*

# Lilac leaf-out and Ice-out coupled



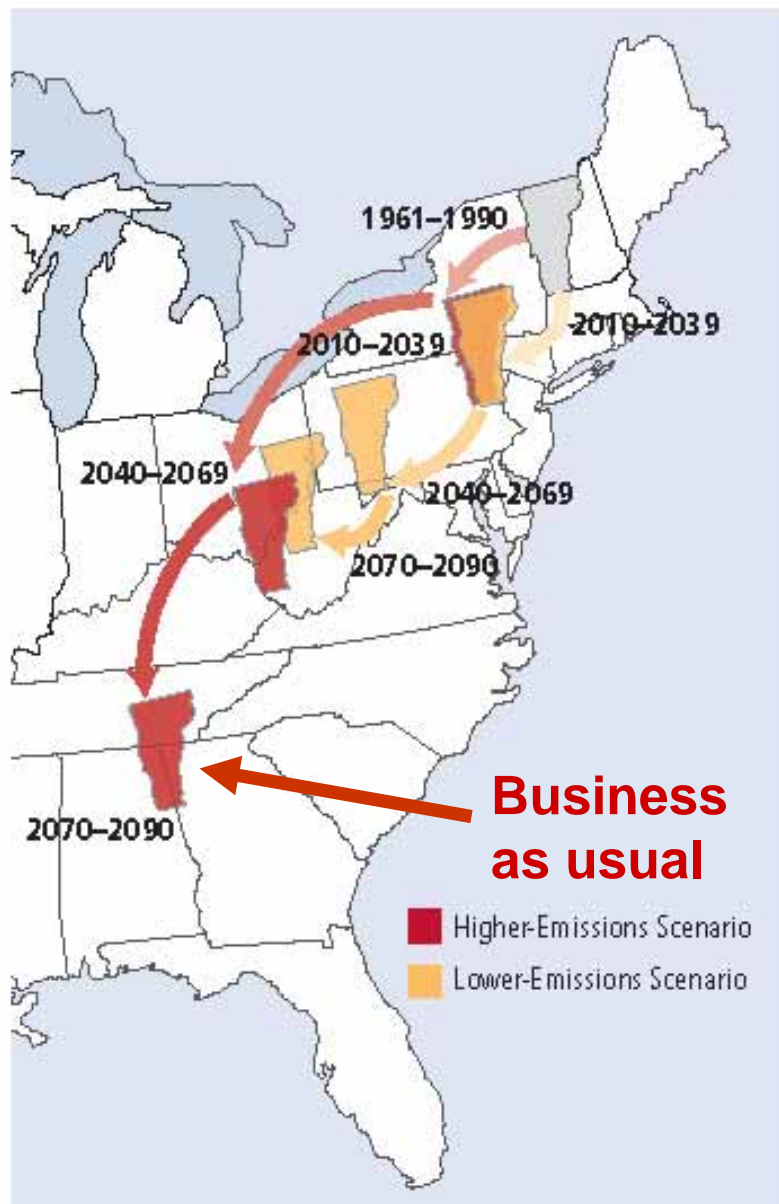
- Lilac leaf and lake ice-out depend on same Feb. Mar. and April temperatures*



# 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

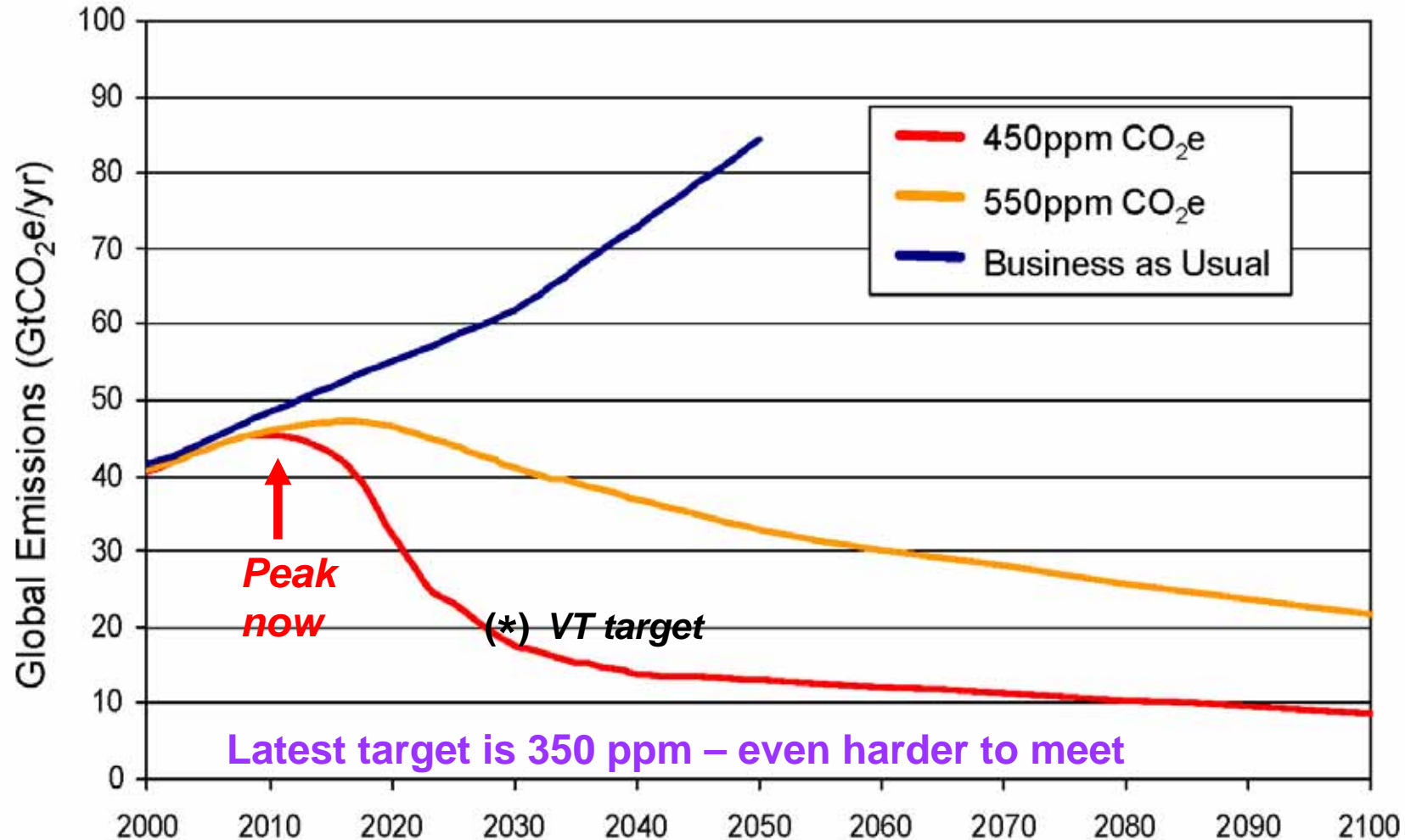
# Can we stop dangerous climate change?

- Yes – Quickly stabilize atmospheric CO<sub>2</sub>
- This means 80% drop in CO<sub>2</sub> emissions!



# *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*
- *Relocalize to regain control/responsibility and minimize transport*

# Three broad guide-lines or ‘rules’

## *Minimize impacts*

- **Minimize lifetime of human waste in the Earth system and eliminate waste with critical biosphere interactions**
- **Minimize the use of non-renewable raw materials; maximize recycling and remanufacturing**
- **Maximize the efficiency with which our society uses energy and water, and maximize the use of renewable resources.**

# Efficiency comes first

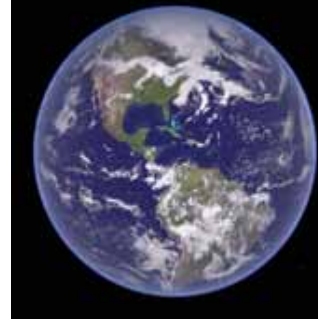
- Need to double or triple our energy efficiency because..
- Cannot replace current fossil fuel use with biofuels & renewable energy
- Oil and gas reserves are limited, but coal & oil-shale reserves are sufficient to push CO<sub>2</sub> to 1000ppm [*and in time melt ice-caps*]. Can we “sequester” CO<sub>2</sub> [put it back in the earth]?

# Why is it difficult for us?

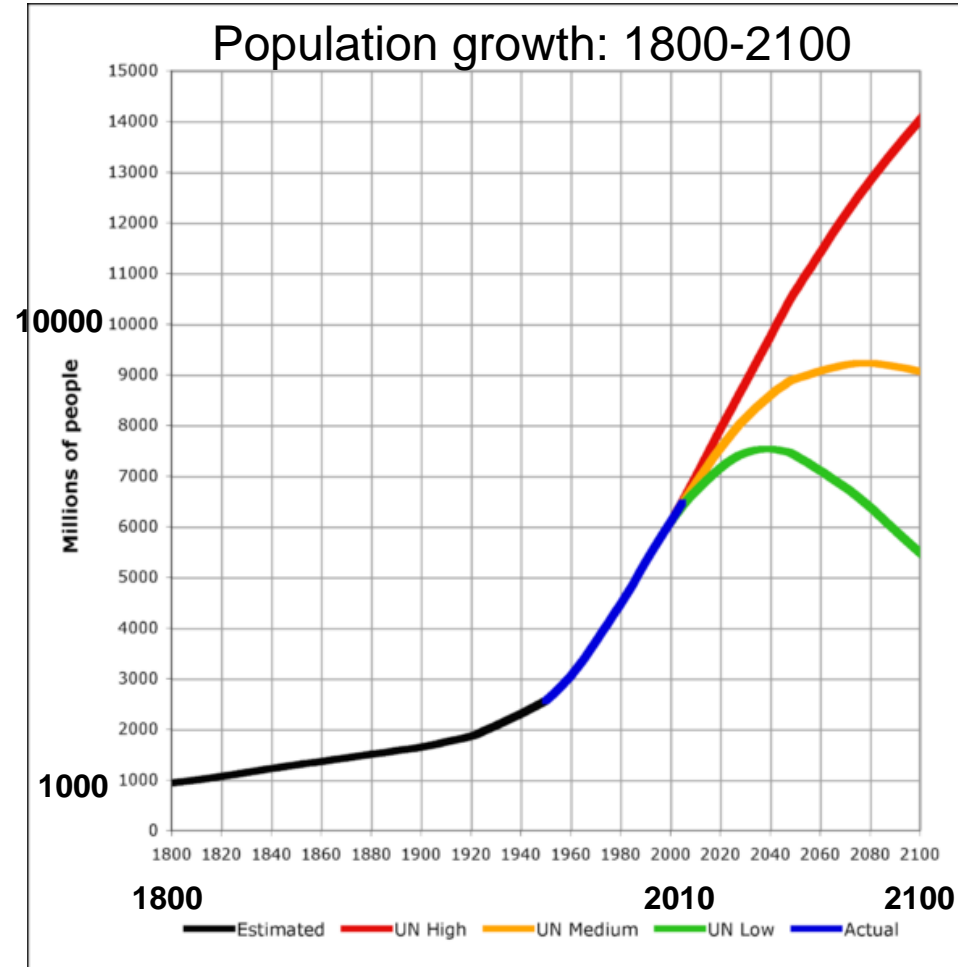
- *Three pillars of American dream are crumbling*
- “Economic growth” based on **fossil fuels, debt and consumerism** is **unsustainable**
  - and a disaster for the planet!
- **Individual “rights”** & needs of humanity must be balanced against the needs of the **earth’s ecosystem**
- **We have no workable paradigm to guide and manage technology** – so result is tremendous successes and catastrophic failures



# We passed the carrying capacity of the Earth in the 1980s



- **The problem with “Growth”**
- Population is still rising
- Consumption is still rising
- Fossil fuel use is still rising
- *We still ‘believe’ in Growth*
- *Global poverty & suffering are still 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, controllable, except when we are careless.*
- 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* [E. F. Schumacher, 1977]
- *Now our world of technology is having a global impact on the natural world and it must be heavily managed – but this is incompatible with our ideology.*

# 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
- That sidestep ideological barriers with new language
- That develop adaptive governance  
*[US constitution gives no rights to the Earth]*
- That respect Earth system processes & limits