Climate Challenges Facing Vermont

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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

- **Earth science clashes with social values**

Outline

- **Science of climate change**
  - **Global scale: actual and future**
  - **Locally: with Vermont as example**
  - **Seasons**

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

Discussion

My Background: Peterhouse, Cambridge - UK

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

My Background: Nottingham High School

- **Founded 1513**
- **1550:**

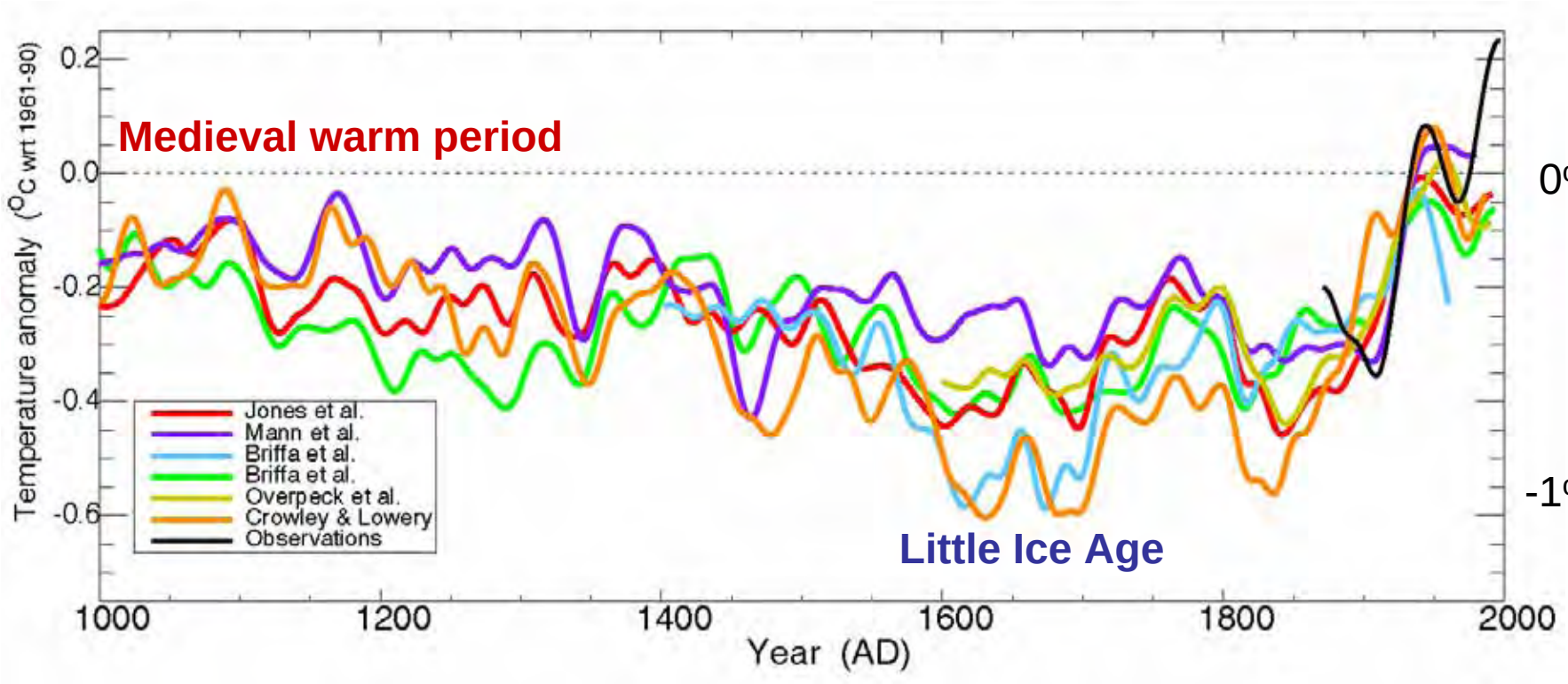
Heading into “Little Ice Age”

- **1620:**

Pilgrim fathers face bitter winters

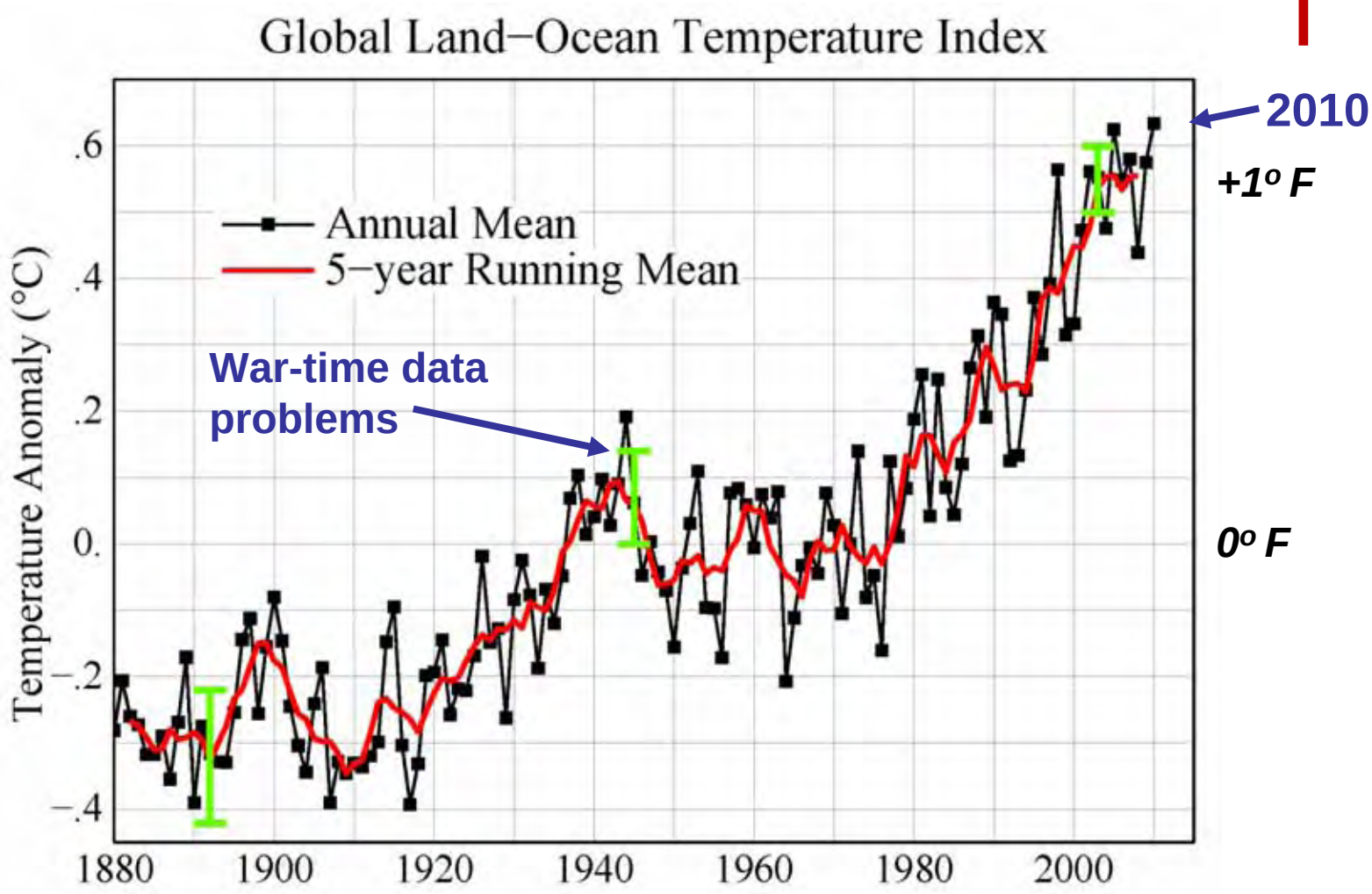
2100: +5°F

Millennial Temperature Record



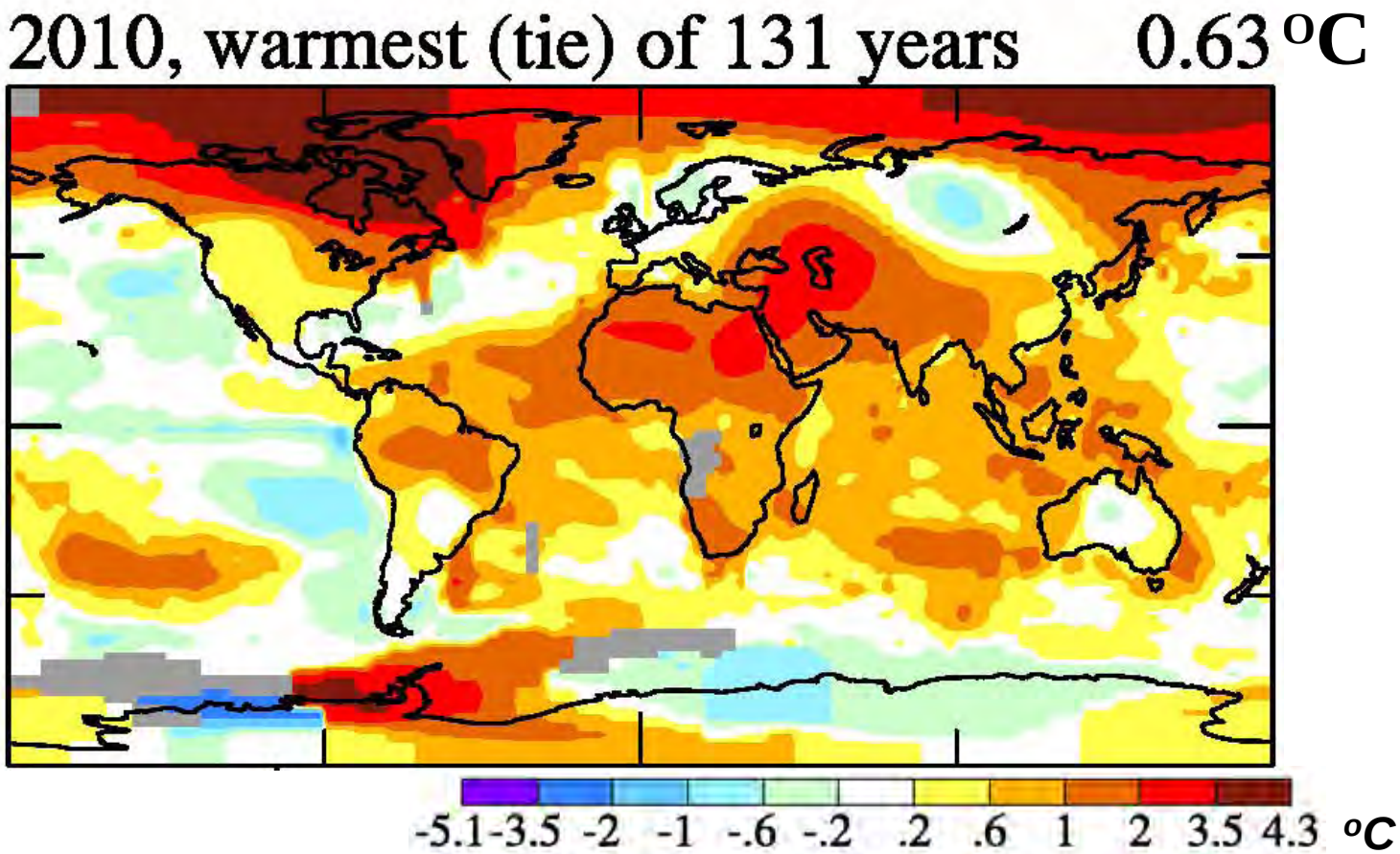
- **“Proxy” records from before the time of thermometers provide uncertain data, but they’re all we have**

Global Temperature Rise 1880 – Present



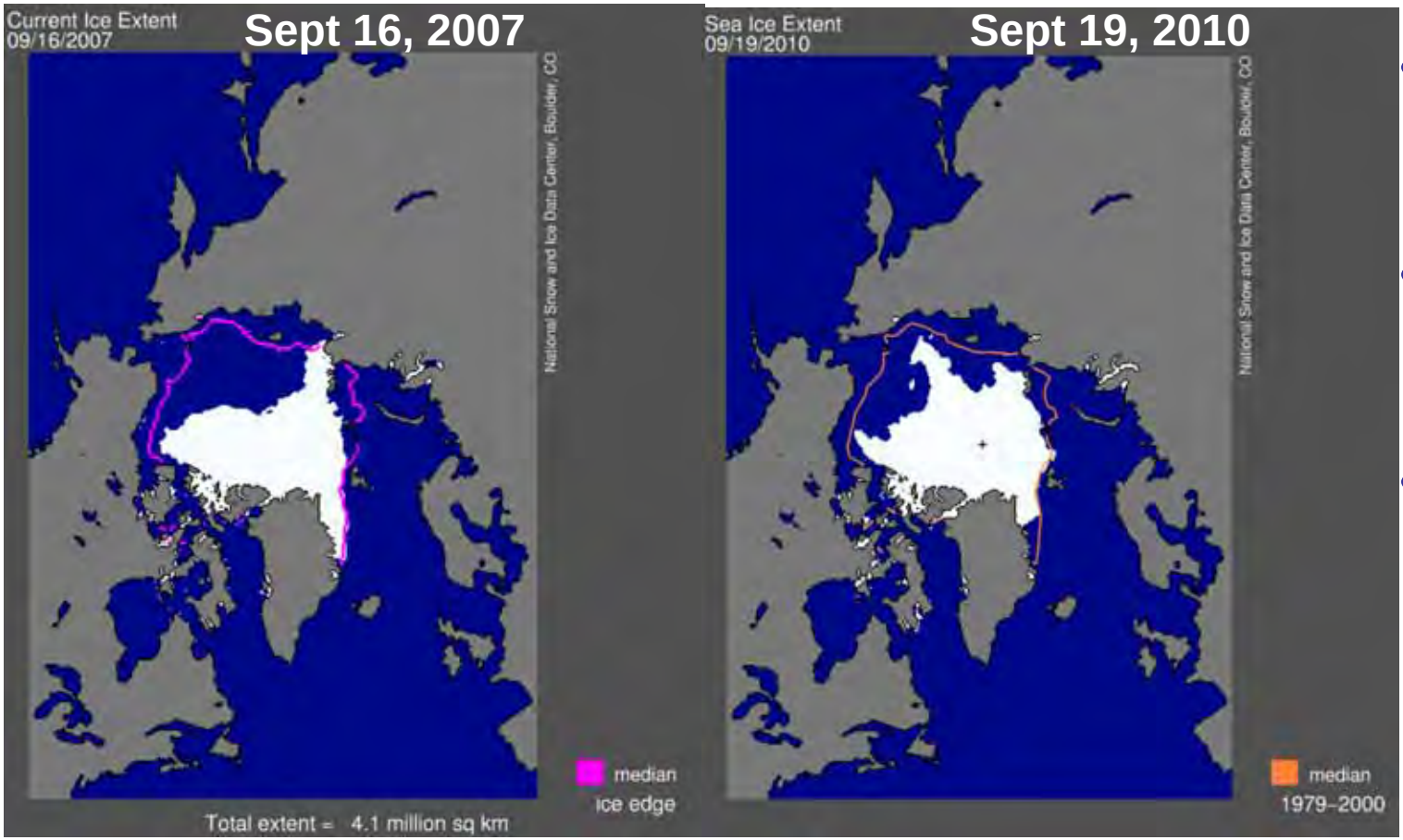
NASA-GISS, 2011

Global Picture 2010



- **Record summer temps**
  - **Russia (100°F) Moscow fires**
  - **Pakistan (128°F) Extreme monsoon floods**

Arctic Sea Ice Loss Has Accelerated



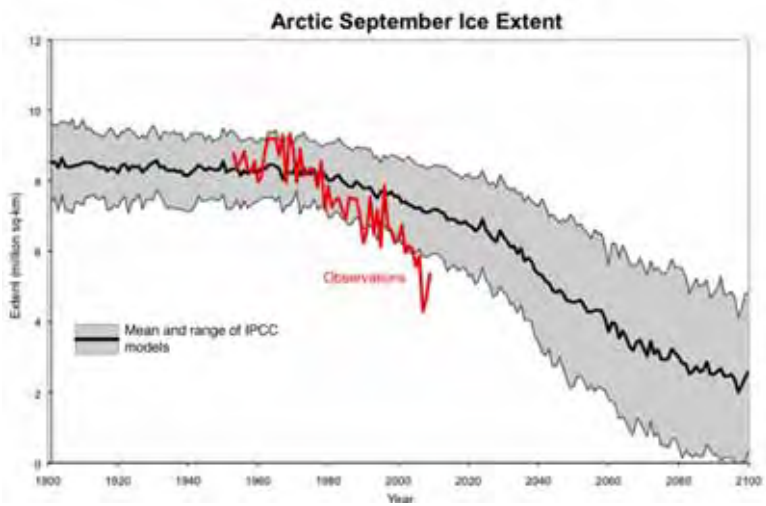
- **Feedbacks speed melting**
- **Less ice, less sunlight reflected**
- **More evaporation, larger water vapor greenhouse effect**

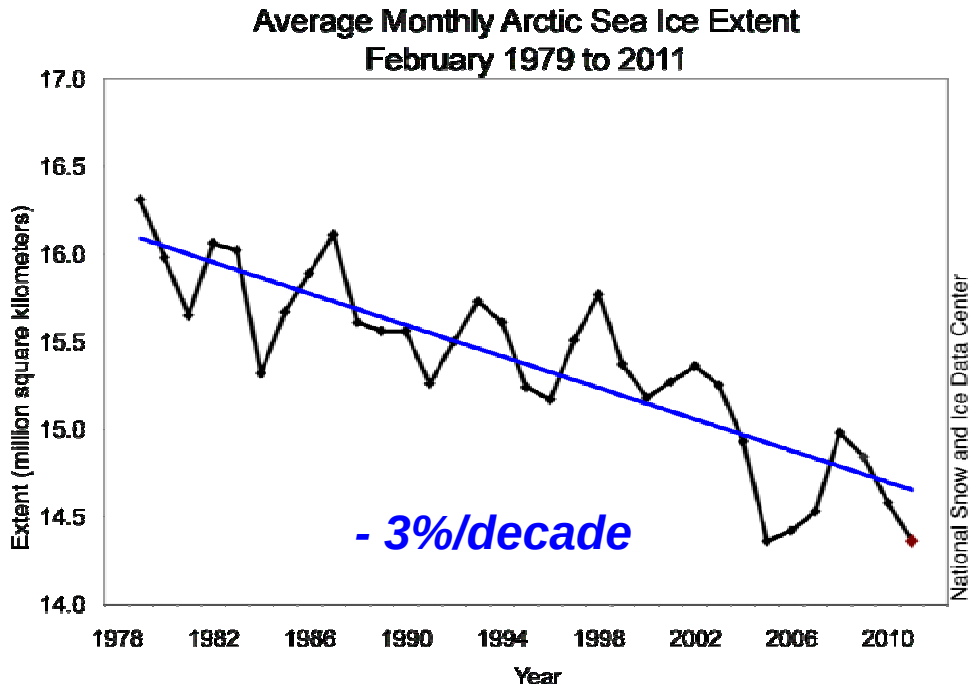
(www.nsidc.org)

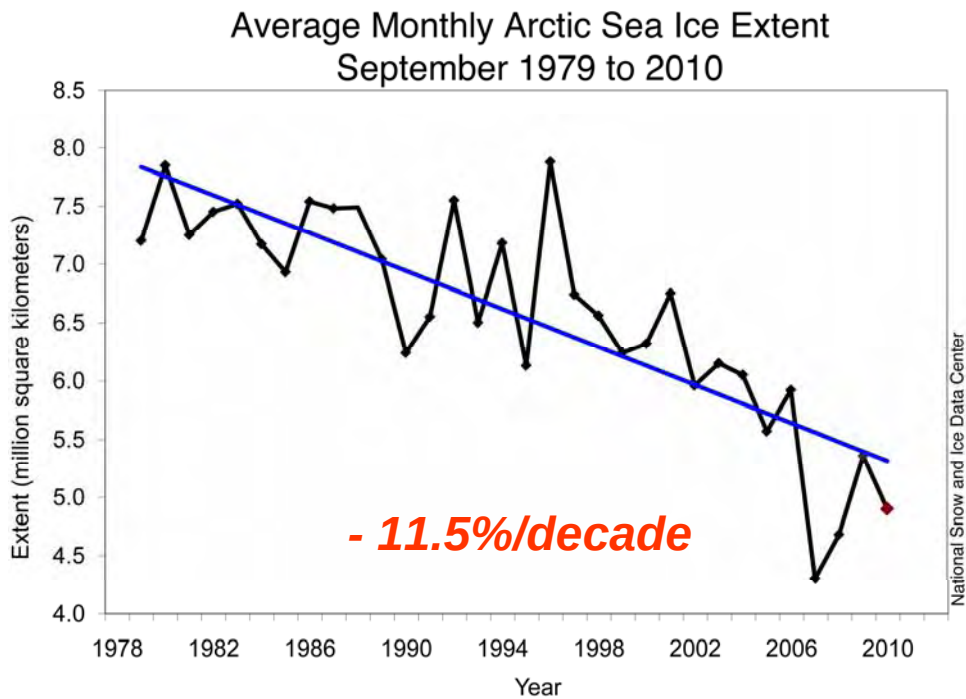
- **Record ice loss in 2007**
  - **most ice now only 1-2 years old**
- **Open water in October contributes to warmer Fall**

Sea Ice Trends

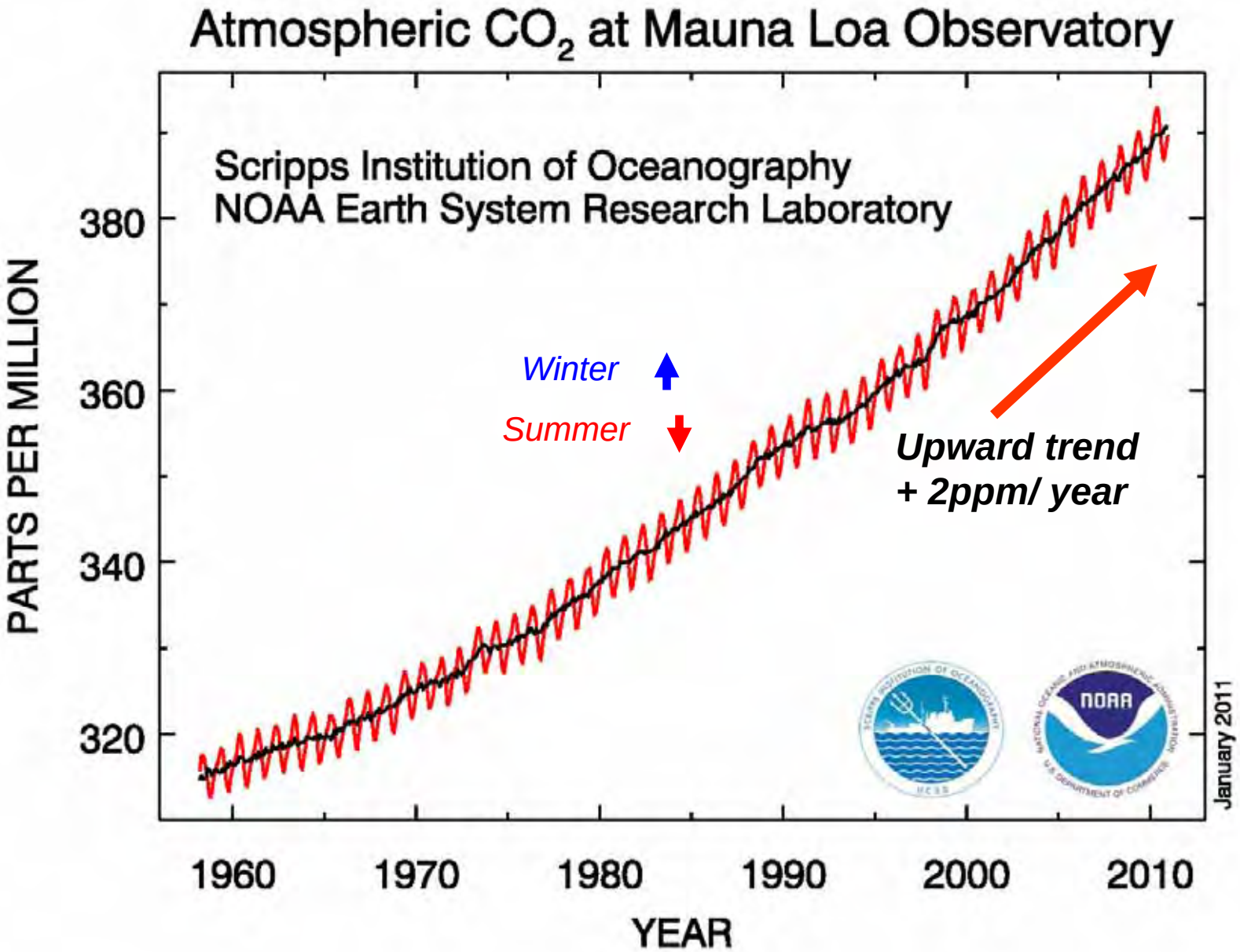
- Sea ice is thinning rapidly
- Observed September decline appears to be faster than IPCC climate model projections





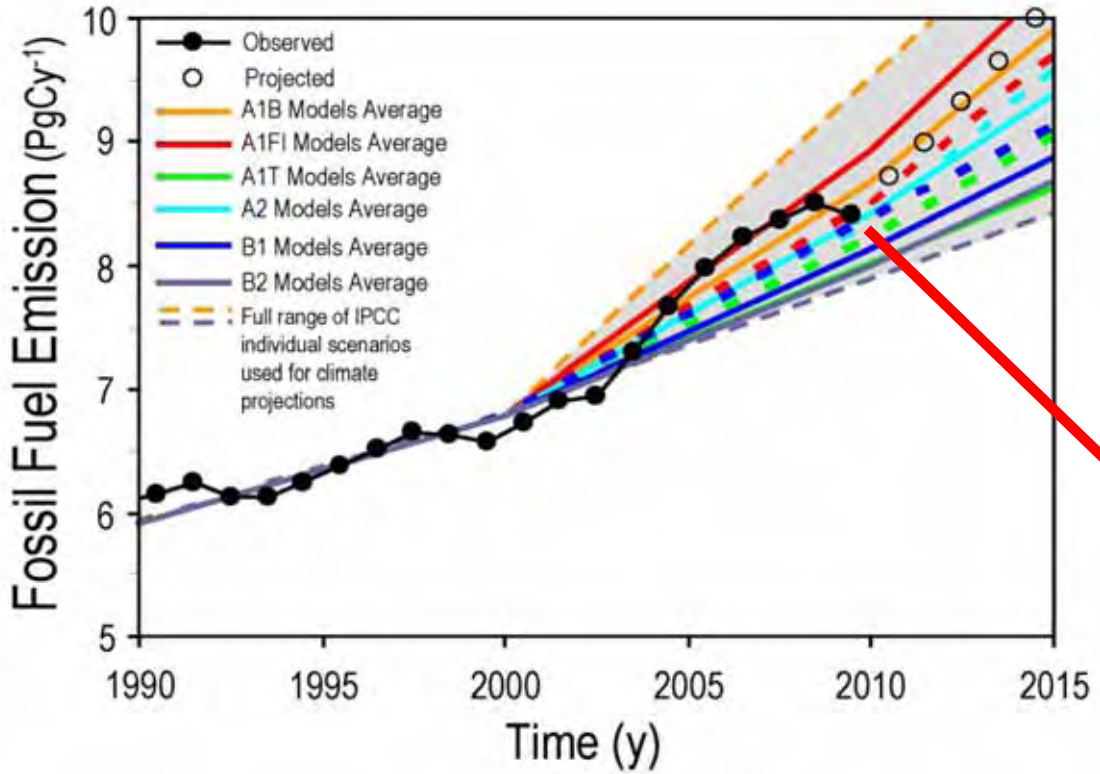


Carbon Dioxide Is Increasing



2009 Was "Good" for the Earth

Fossil Fuel Emissions: Actual vs. IPCC Scenarios

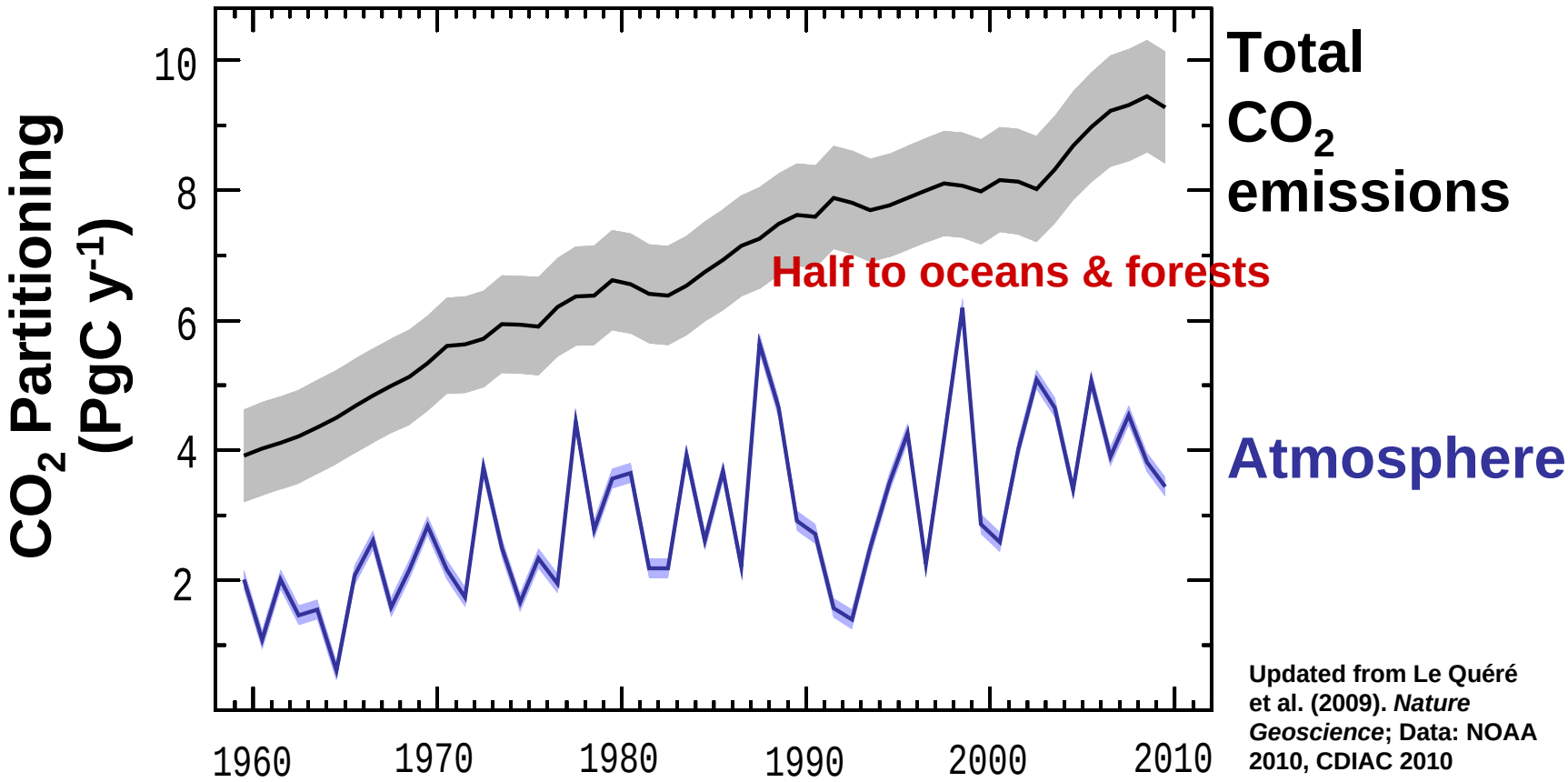


- 4%/year

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

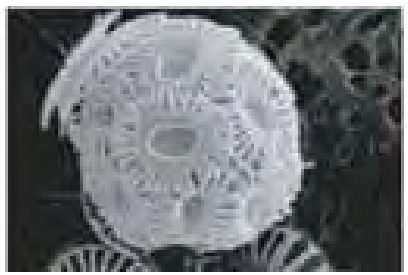


It takes at least a century to remove CO_2 from the atmosphere, and many centuries to remove it from oceans

Rising Ocean Acidity Threatens Organisms

- **From the Tropics to the Arctic, the seas are sucking up emissions of CO_2 — from burned fossil fuels**
- **When 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_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**
- **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**

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

(www.ipcc.ch)

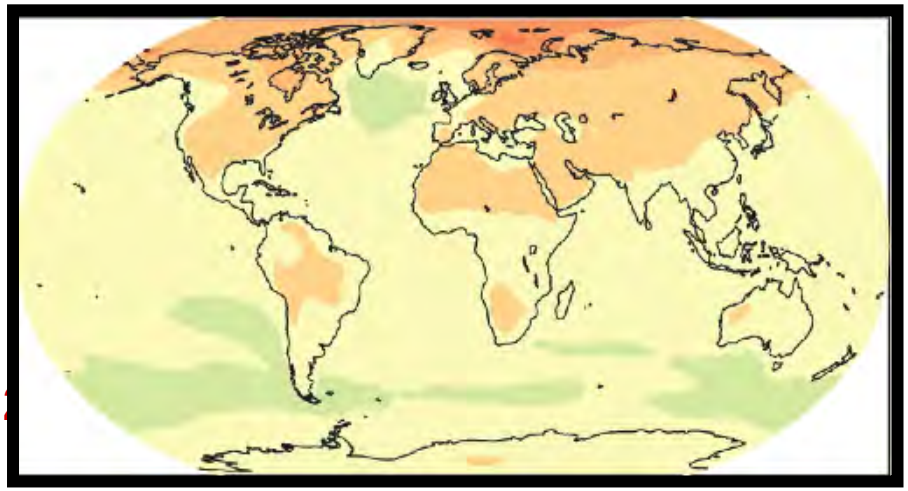
Decrease in:

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

Predicted Change in Temperature

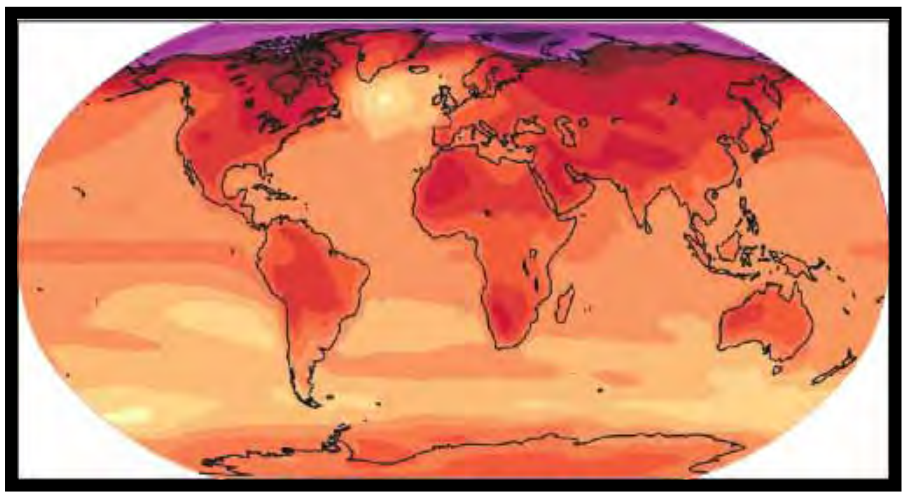
2020-2029 and 2090-2099, relative to 1980-1999 (°C)

“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 20th-century sea-level rise: 1 foot / century**
- **21st 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?

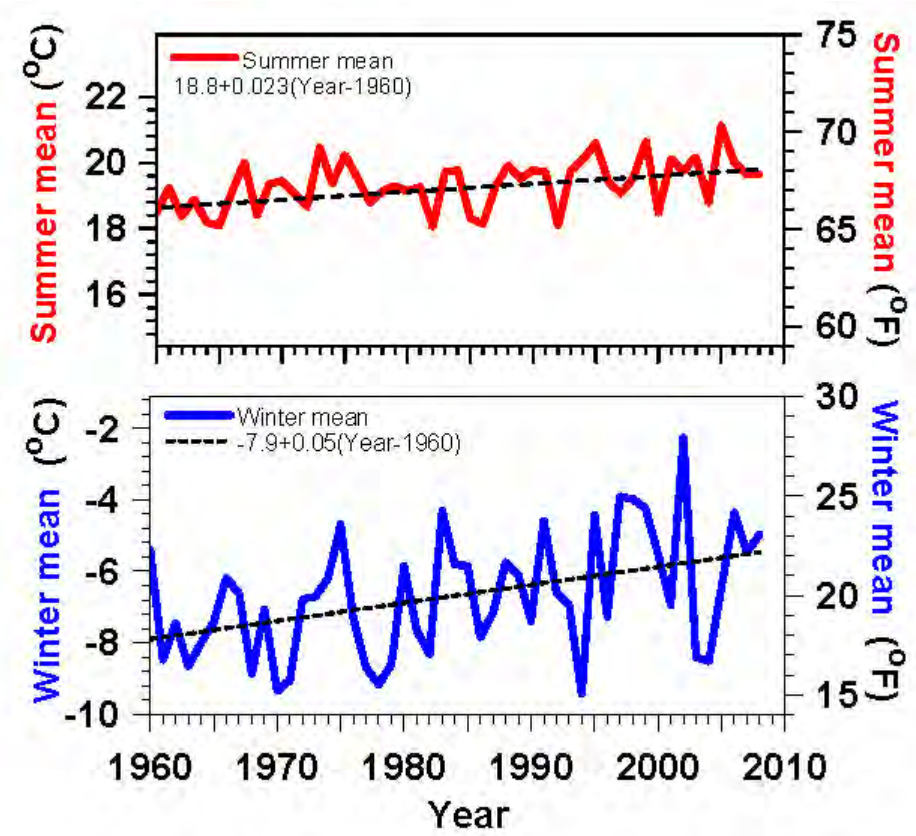
- **Local climate change indicators**
- **Easier to grasp than global view**

- **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**

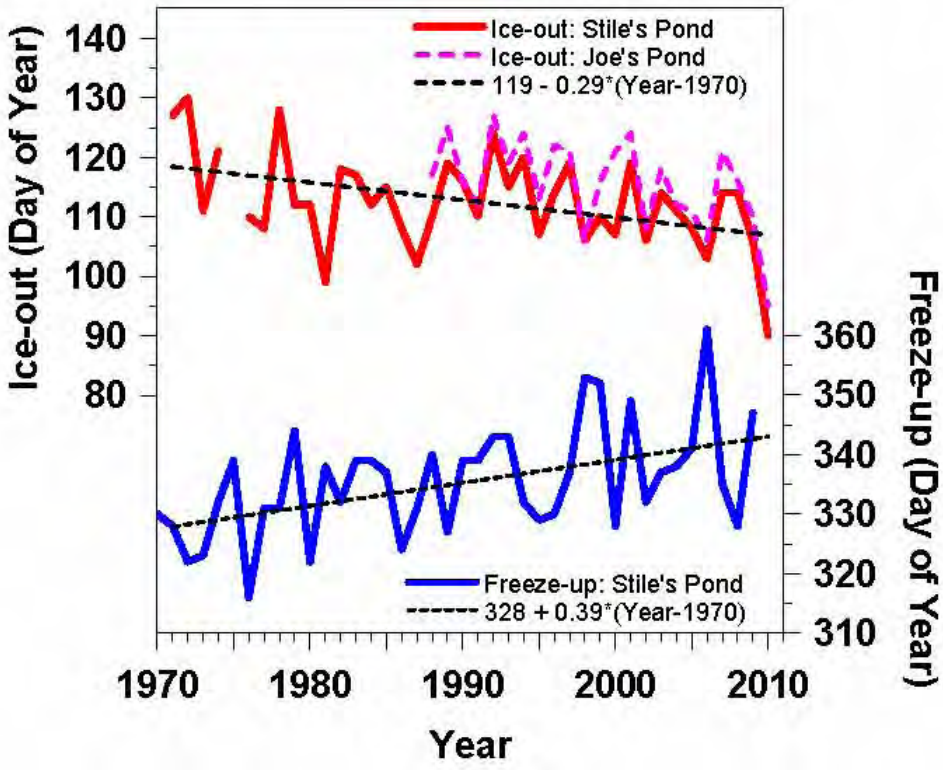
Vermont Temperature Trends

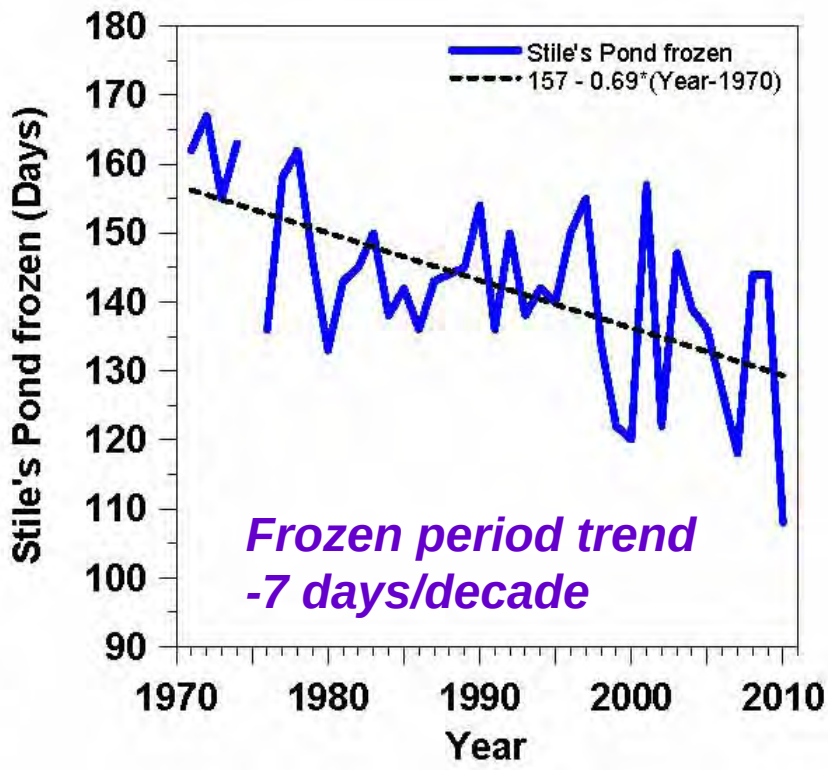
- **Summer +0.4°F / decade**
- **Winter +0.9°F / decade**
- **Less snow drives larger winter warming**



Lake Freeze-up & Ice-out Changing

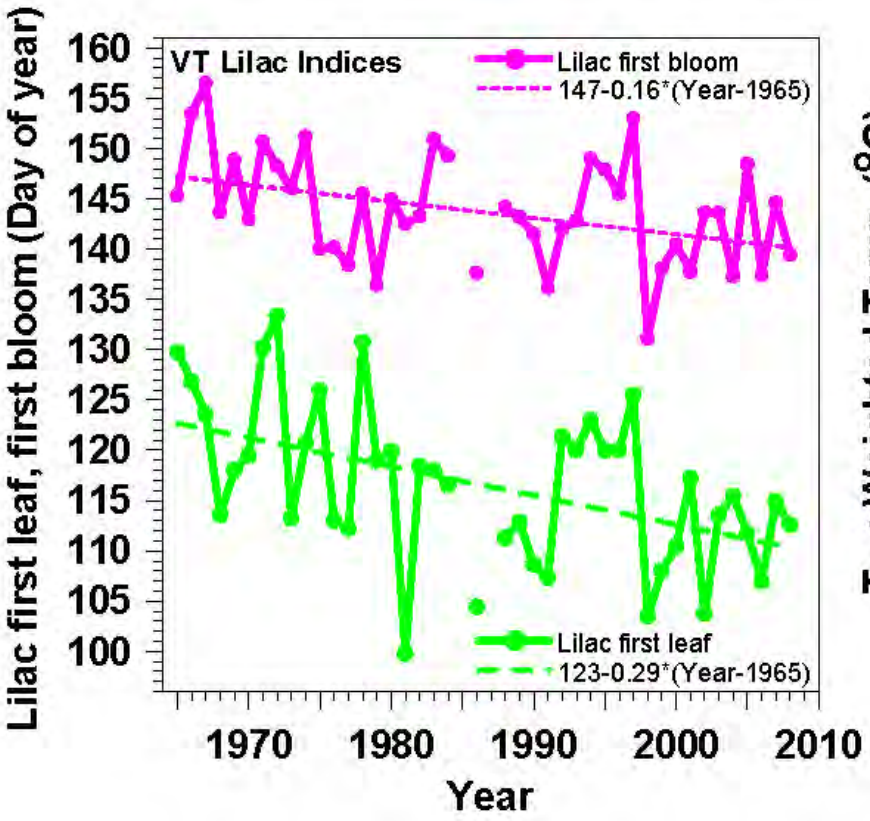
Frozen Period Shrinking Fast

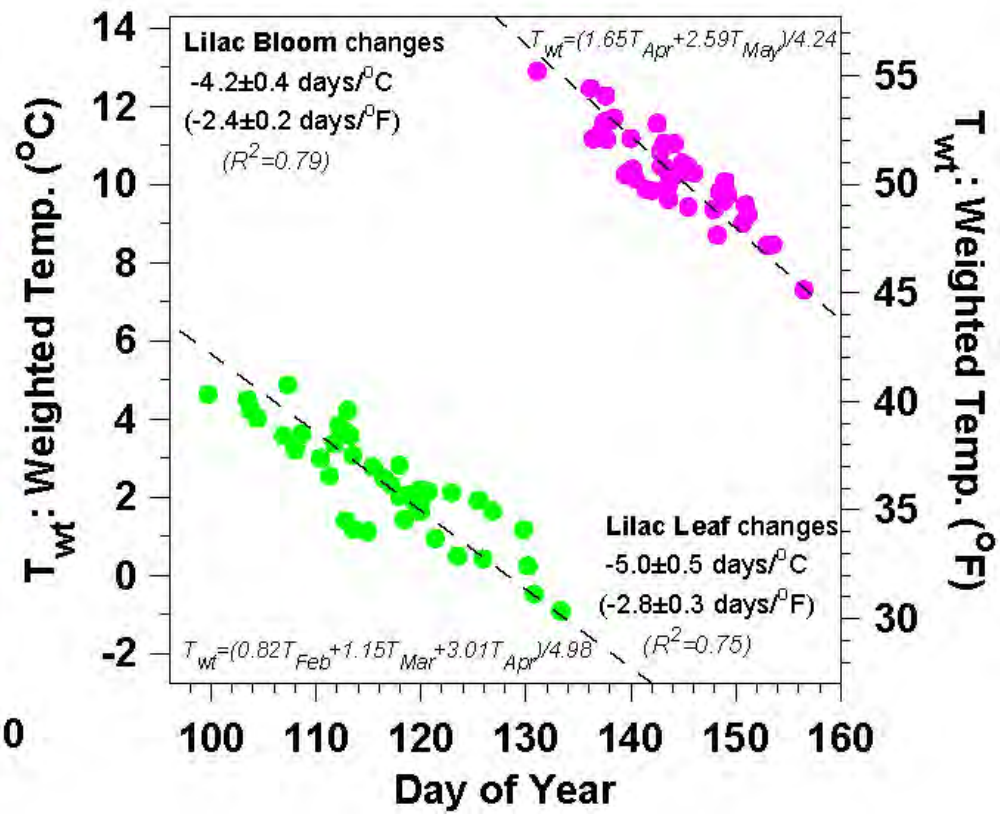




- Ice-out earlier **by 3 days / decade**
- Freeze-up later **by 4 days / decade**

Lilac leaf and bloom in spring





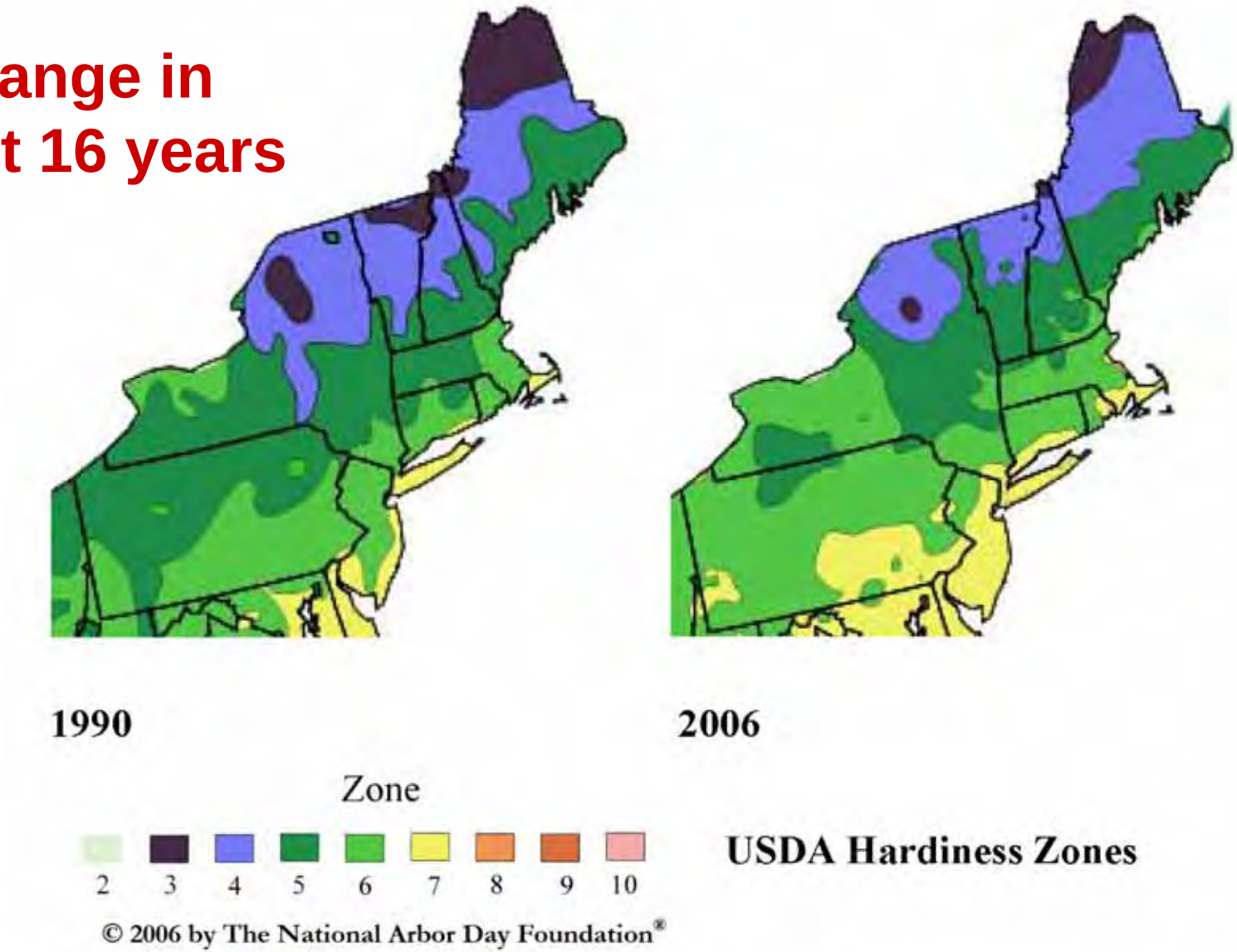
- **Leaf-out earlier by 3 days/decade (tracks ice-out)**
- **Bloom earlier by 1.5 days/decade**
- **Leaf & bloom change 2.5 days/°F (4.5 days/°C)**

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



Gardening in Pittsford, Vermont in January

January 7, 2007

December 2006:

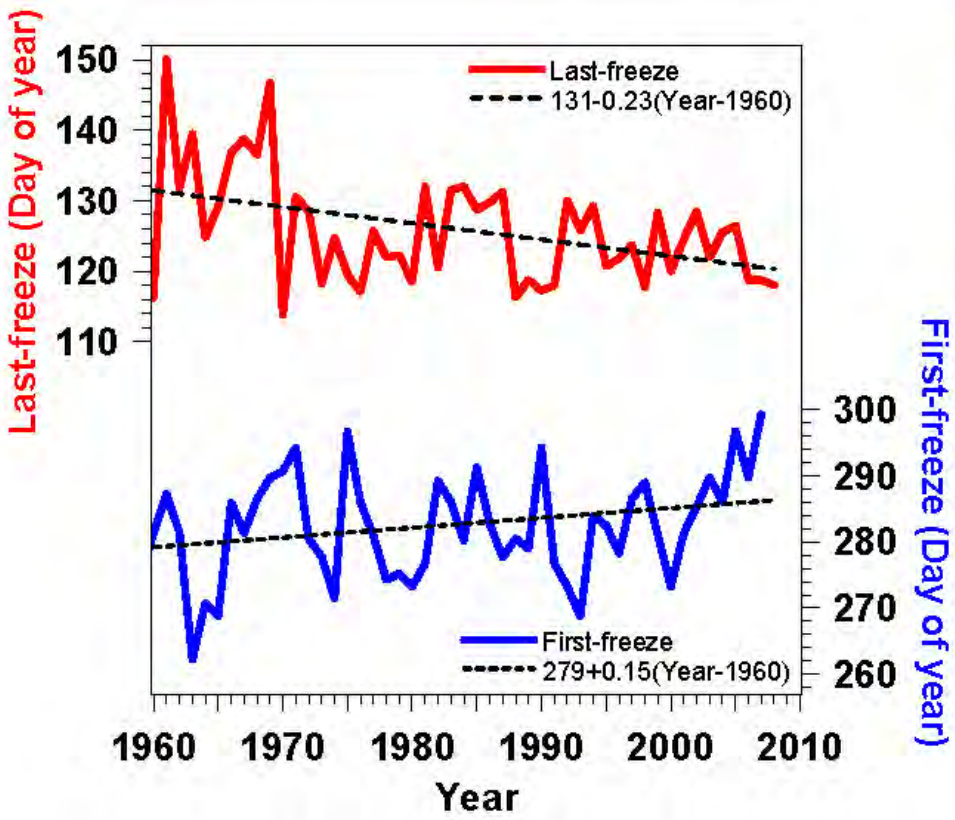
- **Warmest on record**

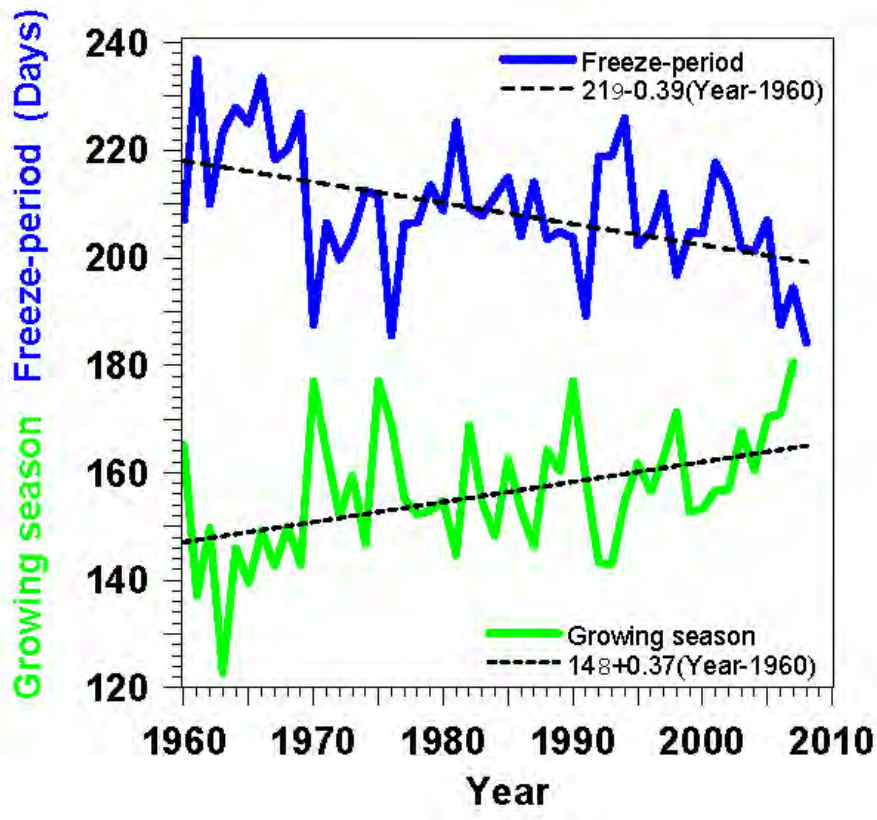
January 10, 2008

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 RH
→ Deep dry BL
→ Large outgoing LW_{net}
→ Large diurnal temp. range
giving warm days, cool nights and frost

Low water vapor greenhouse

- **After leaf-out**

Large evaporation → Wet atmosphere, low cloudbase
→ Small outgoing LW_{net}
→ Reduced T_{max}
→ Reduced chance of frost

- ***Spring is coming earlier***

Fall climate transition - *first frost*

- **Vegetation tries to postpone first killing frost in fall**
- **Deciduous trees still evaporating: moist air with clouds**
- **Water vapor & cloud greenhouse reduces 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!

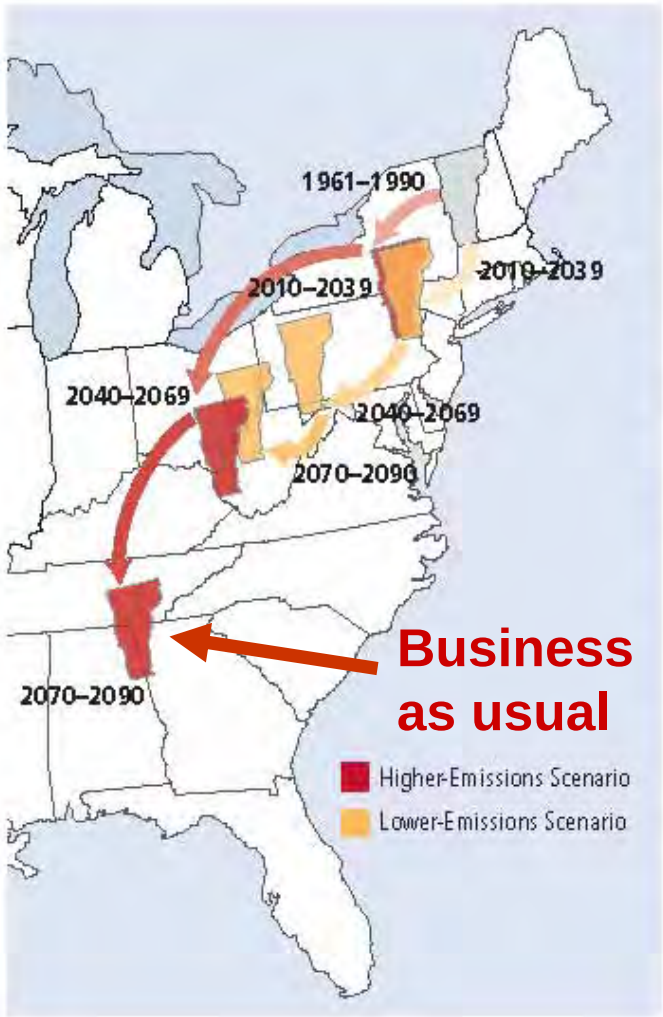
Clear dry blue sky after frost. Forest evaporation has ended and water vapor greenhouse is reduced so Earth cools fast to space at night

Later frost: Growing season getting longer

Vermont's Future with High and Low GHG Emissions

What about skiing?

What about tropics?



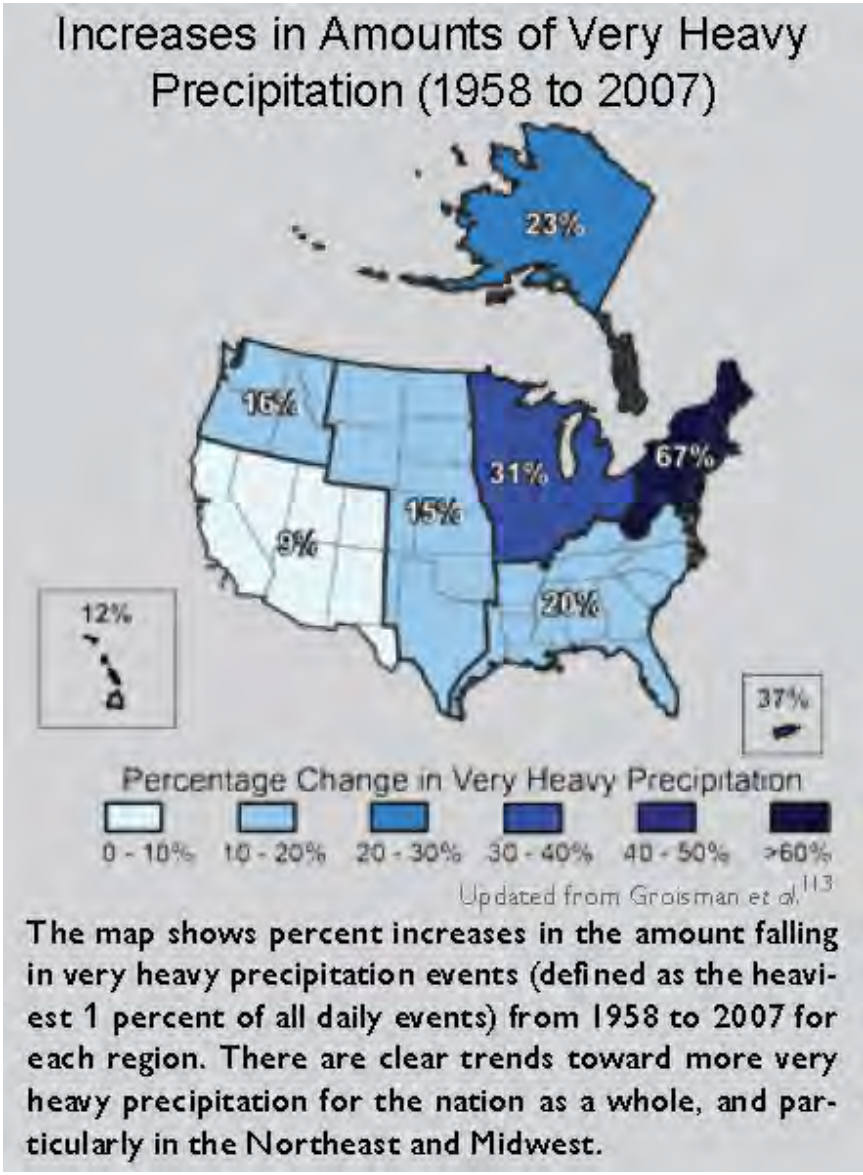
Migrating State Climate

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

Very Heavy Precipitation is Increasing

- **Most of the observed increase in precipitation during the last 50 years has come from the increasing frequency and intensity of heavy downpours.**
- **67% increase in Northeast**
- **Little change or a decrease in the frequency of light and moderate precipitation**
- **Vermont streamflow is increasing**

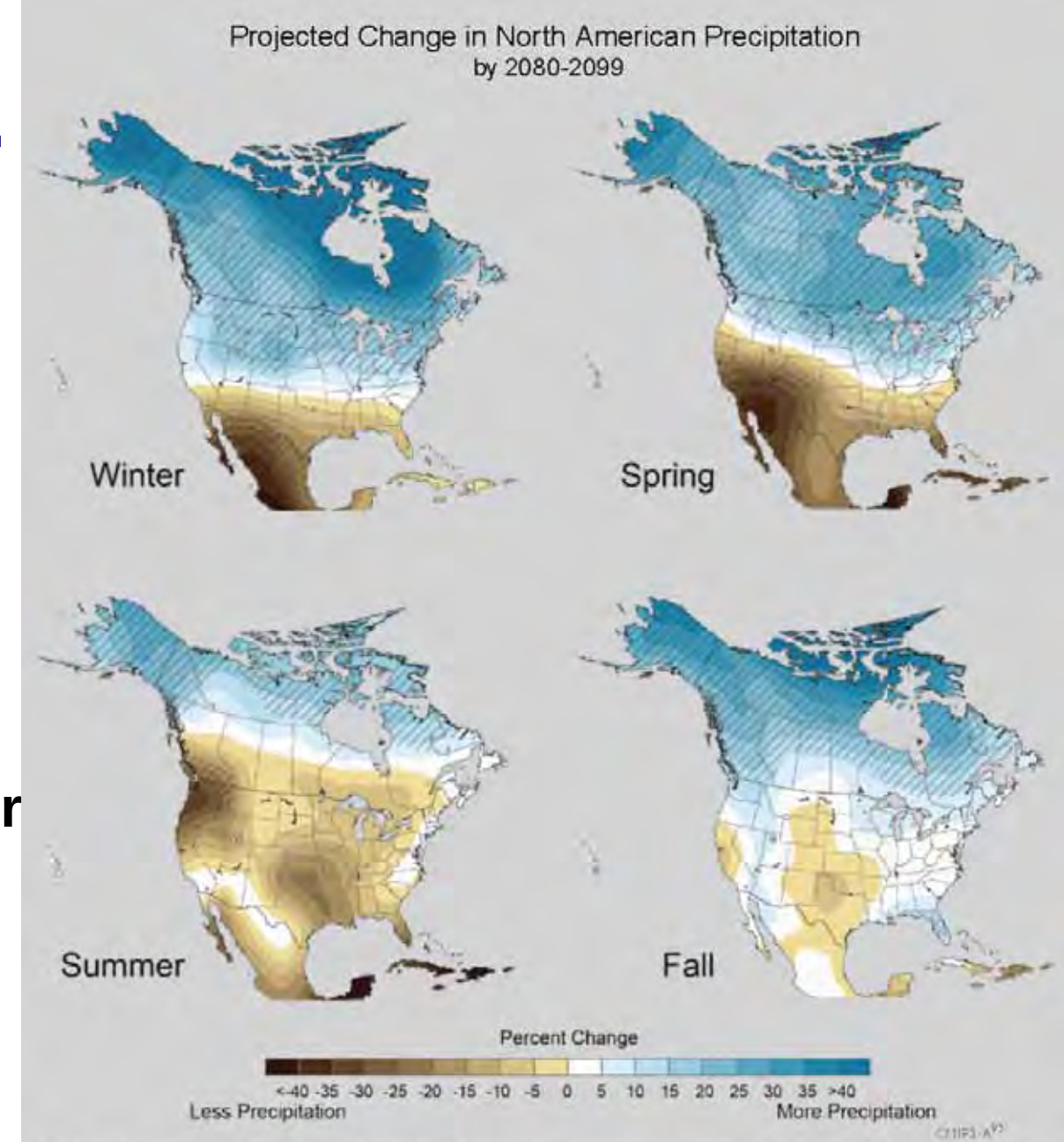


The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

Projected Precip. increase by 2090

- *For Vermont*
- **15% in winter,**
- **10% in spring**
- **5% in fall**

- **No change, summer**
- **Heavier rain and more drought**

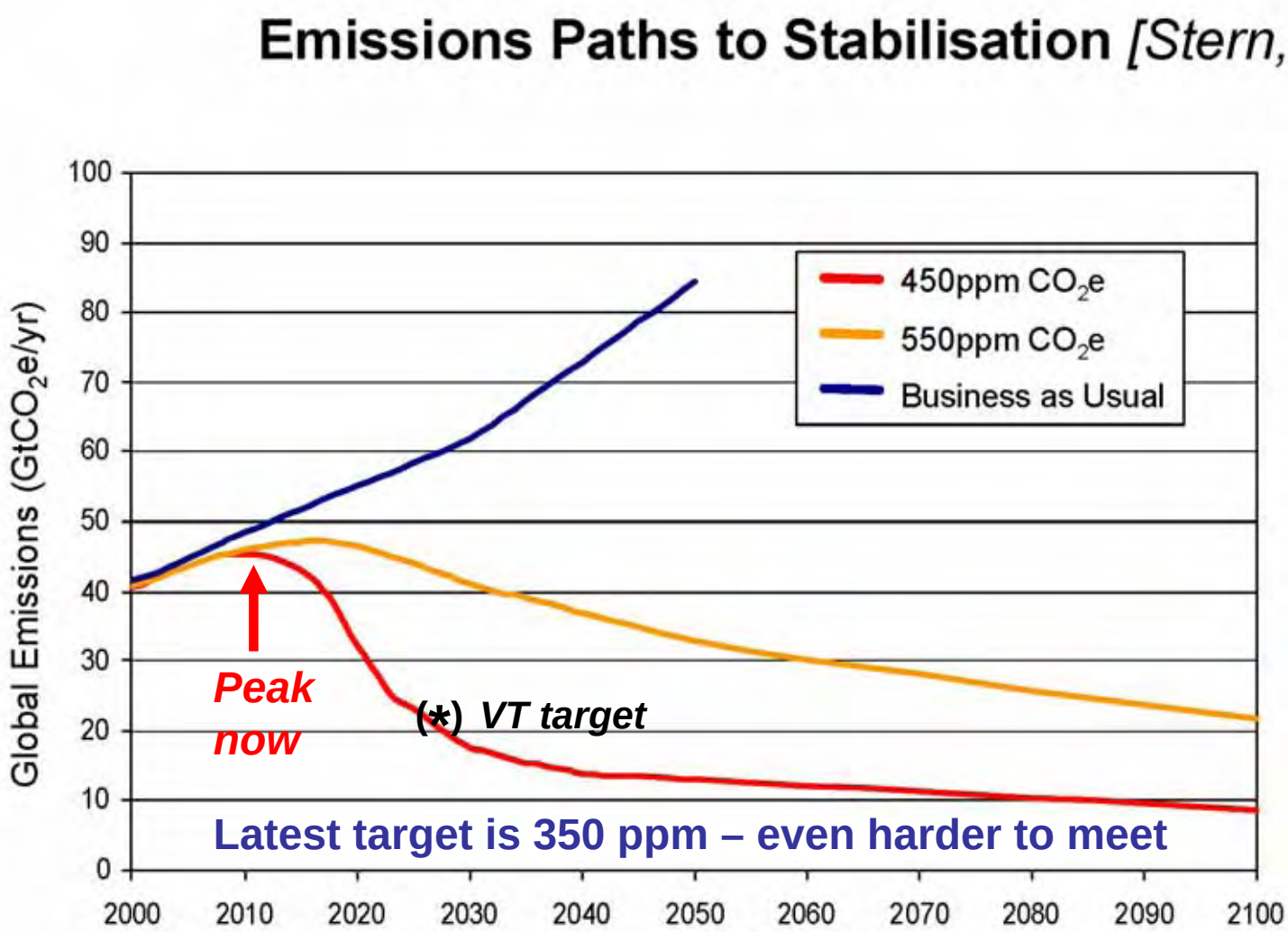


The maps show projected future changes in precipitation relative to the recent past as simulated by 15 climate models. The simulations are for late this century, under a higher emissions scenario.[1] For example, in the spring, climate models agree that northern areas are likely to get wetter, and southern areas drier. There is less confidence in exactly where the transition between wetter and drier areas will occur. Confidence in the projected changes is highest in the hatched areas.

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 Avoid "Dangerous Climate Change"?



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 / 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_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**

Efficiency Comes First

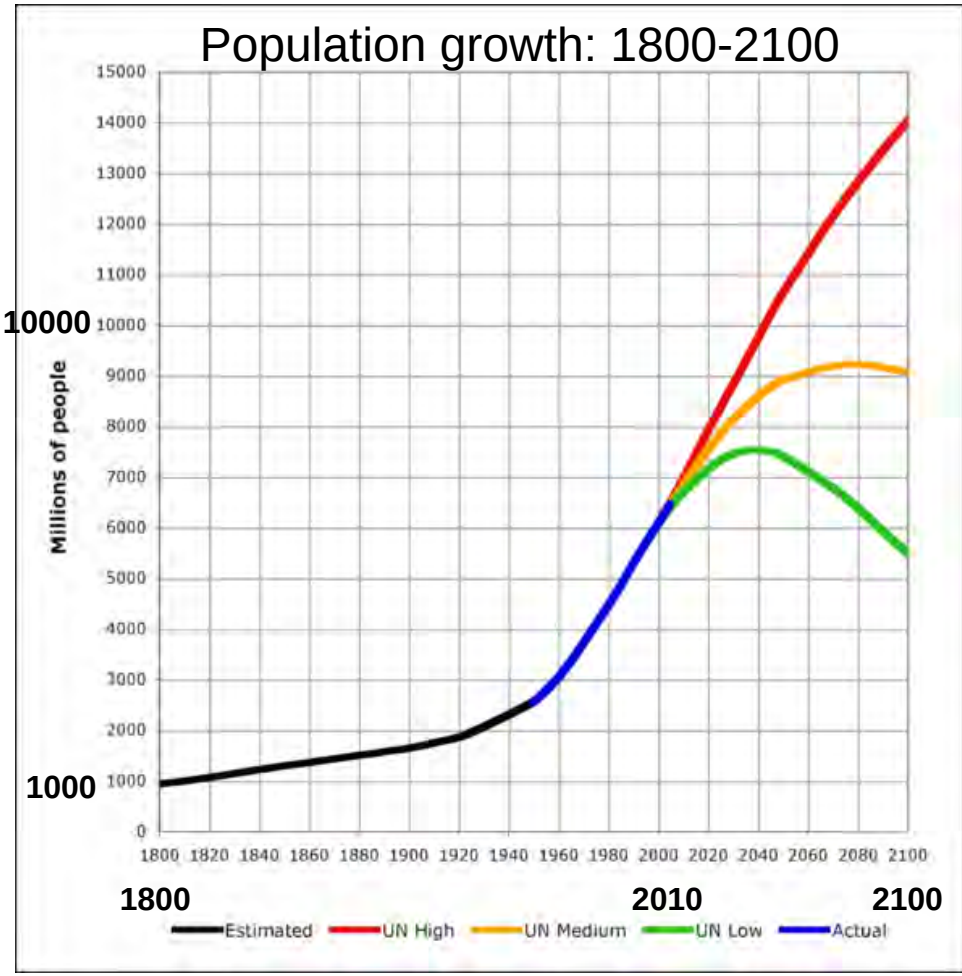
- **We need to double or triple our energy efficiency because…**
  - **We cannot replace current fossil fuel use with biofuels & renewable energy**
  - **Oil and gas reserves are limited, but coal & oil shale reserves are sufficient to push CO_2 to 1,000 ppm—and in time melt icecaps**
    - **Can we "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 have no workable paradigm 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
  - 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 plan for a transition to a sustainable society**

- **Communities are one key:**
  - **www.transitiontowns.org**

What do we need to do?

- **Plan for transition to a sustainable society**
- ***Recognize this will take decades and that it needs a community effort***

- **Food: local agriculture & gardens**
- **Energy: Double energy efficiency ….**
  - home heating – district heating + cogen
  - renewable electricity mix
  - efficient transportation system
- **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**
- **Local food; local power; community solutions**
- **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

Resilience for Farmers

- Trend to milder winters; longer growing season; earlier spring – variability large
- Trend to more precipitation in cool season; more wet snow and mixed in winter
- Warmer summers; heavier rain in summer; periods of drought – increase infiltration and water storage
- Build soil carbon and organic matter for water storage and fertility
- Recycle nutrients and phosphorus