



Climate Change – a global and local perspective

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Climate Change

- **One of the great challenges for 21st C**
- **We are already decades late in taking action**
 - *Sawyer (1972): Man-made CO₂ 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*
- **Perspective of Earth system scientist**
 - *Technical solutions: managing Earth system*
 - *Choices, challenges and self-deception*

My background:

Peterhouse Cambridge

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



My background:

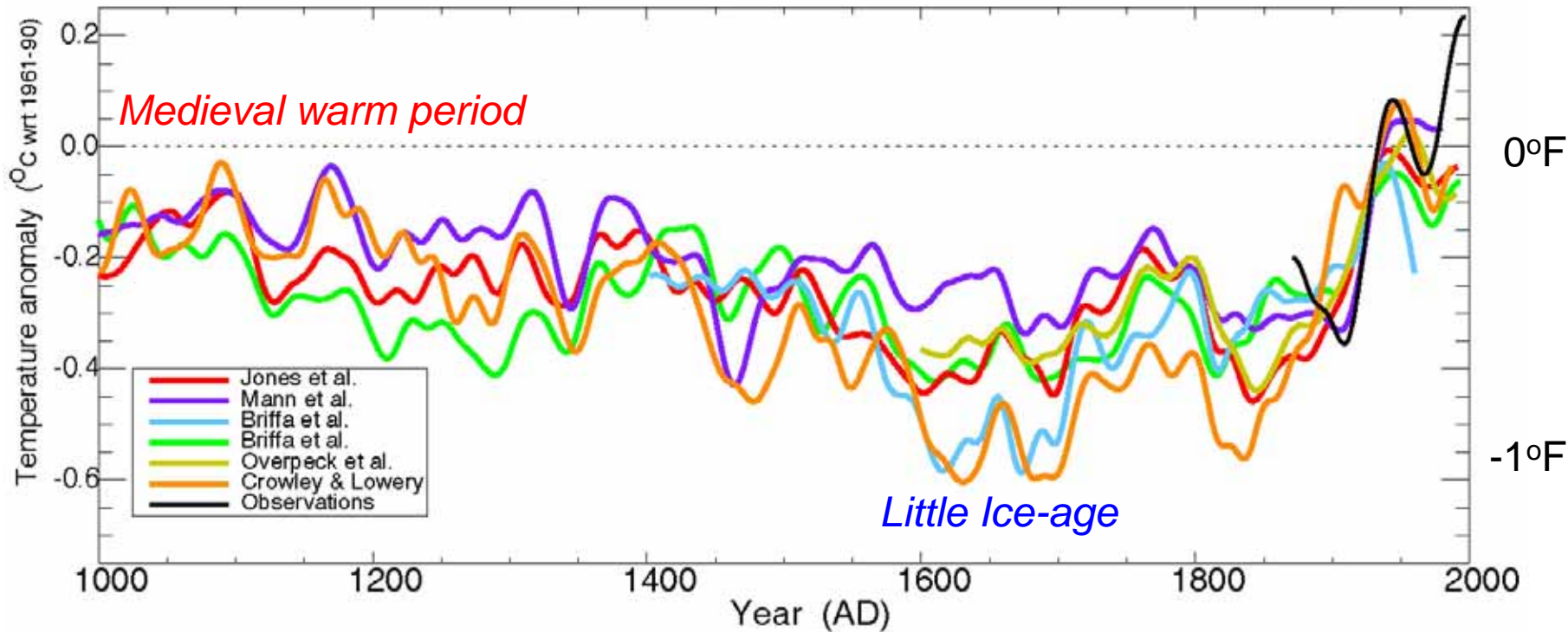
Nottingham High School

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



Millennial Temperature Record

2100: +5°F
↑

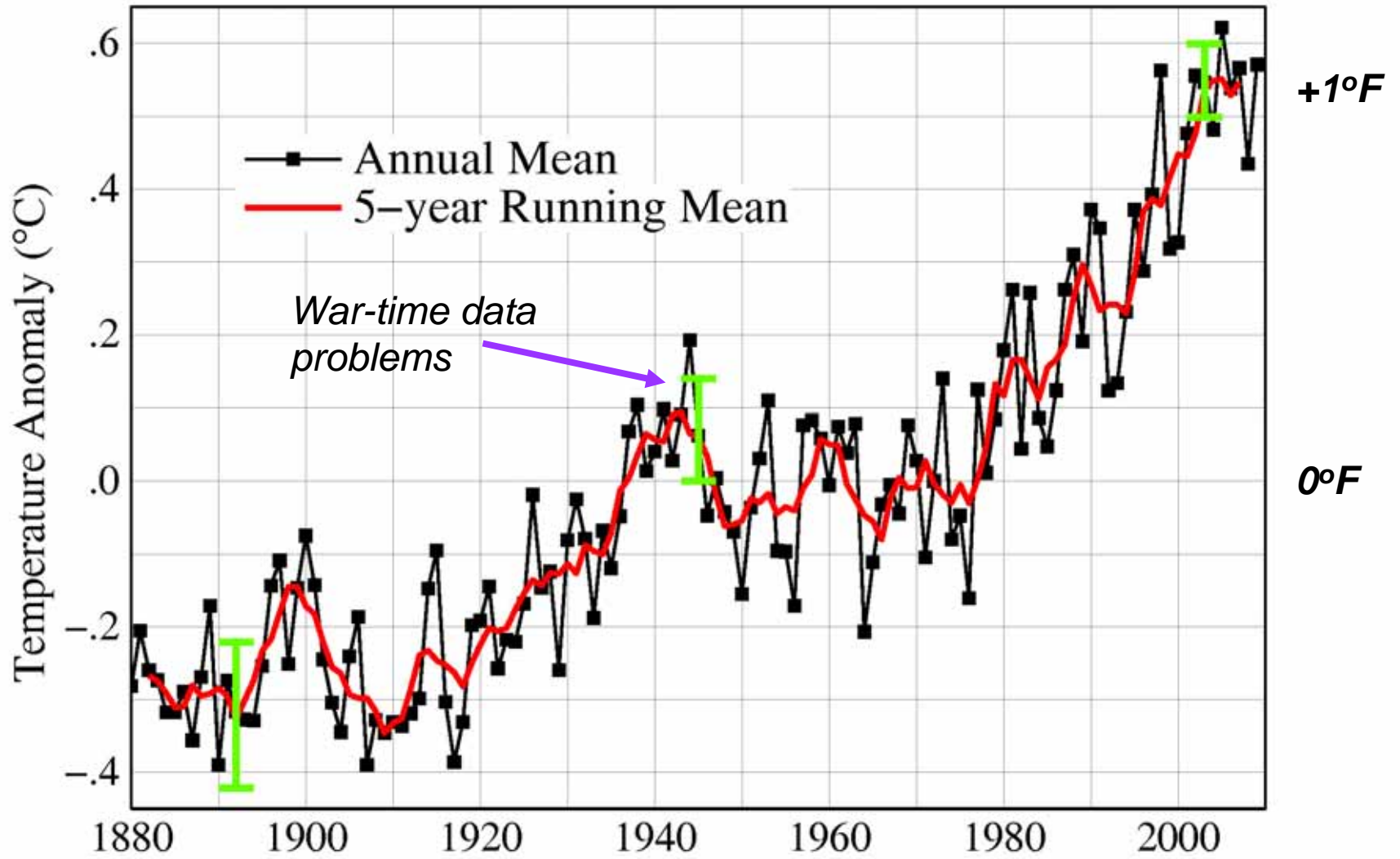


- Before thermometers
‘proxy’ records have large uncertainty

Global temperature rise 1880-present

2100: +5°F
↑

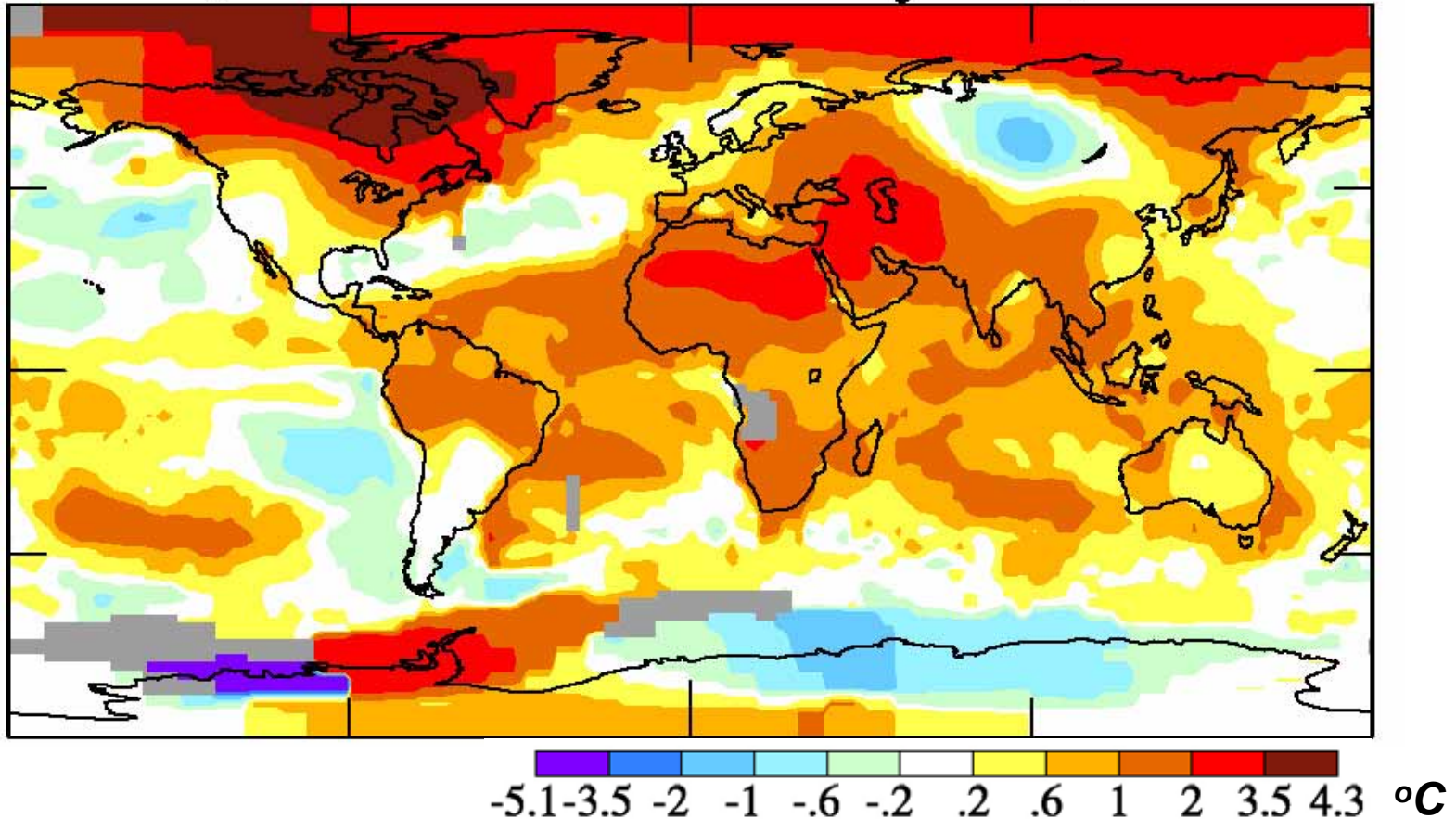
Global Land–Ocean Temperature Index



NASA-GISS, 2010

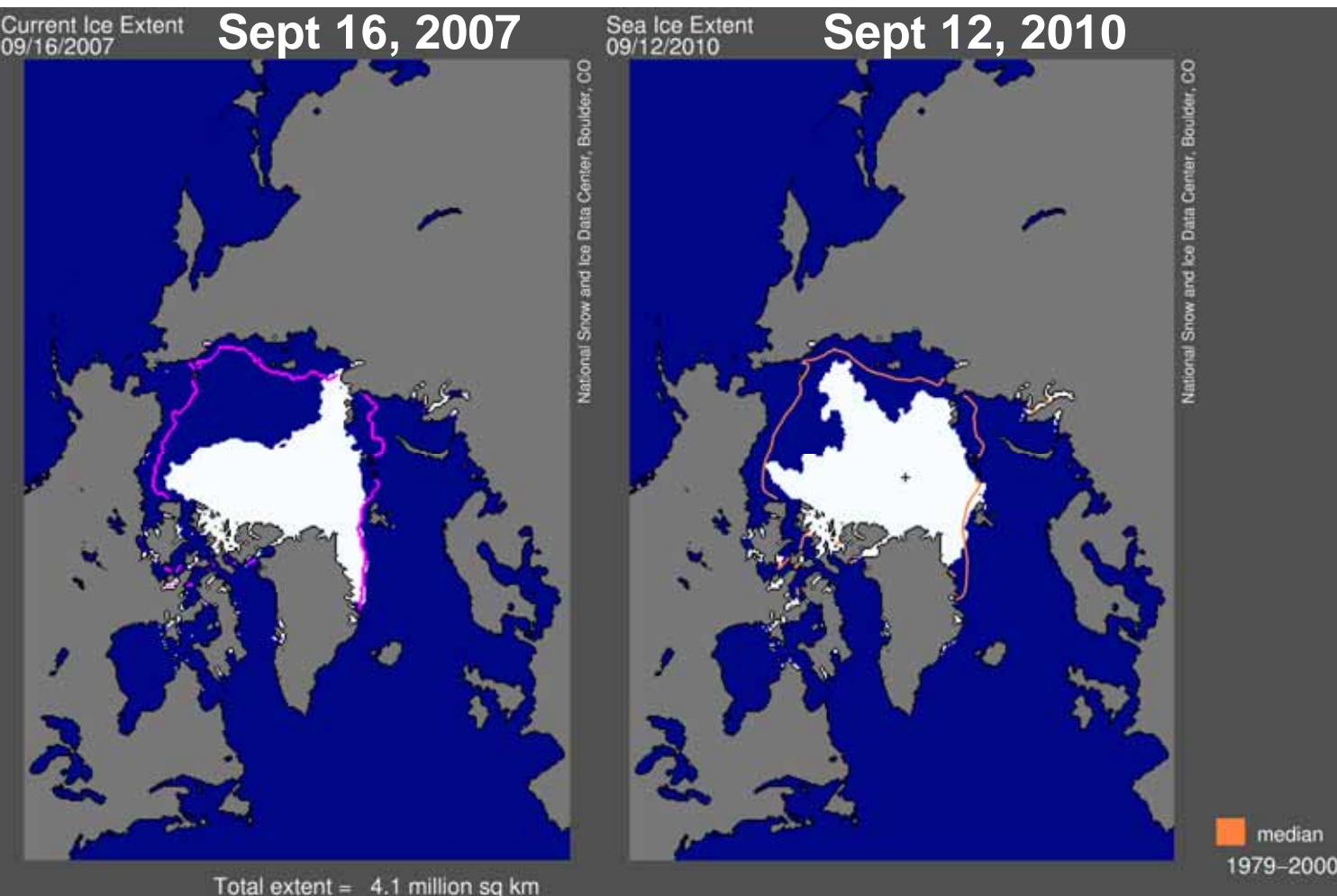
Global picture Jan-Aug 2010

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



- *Record summer temps in Russia (Moscow fires) and Pakistan (extreme monsoon floods)*

Arctic sea-ice loss has accelerated



*Feedbacks -
speed melting*

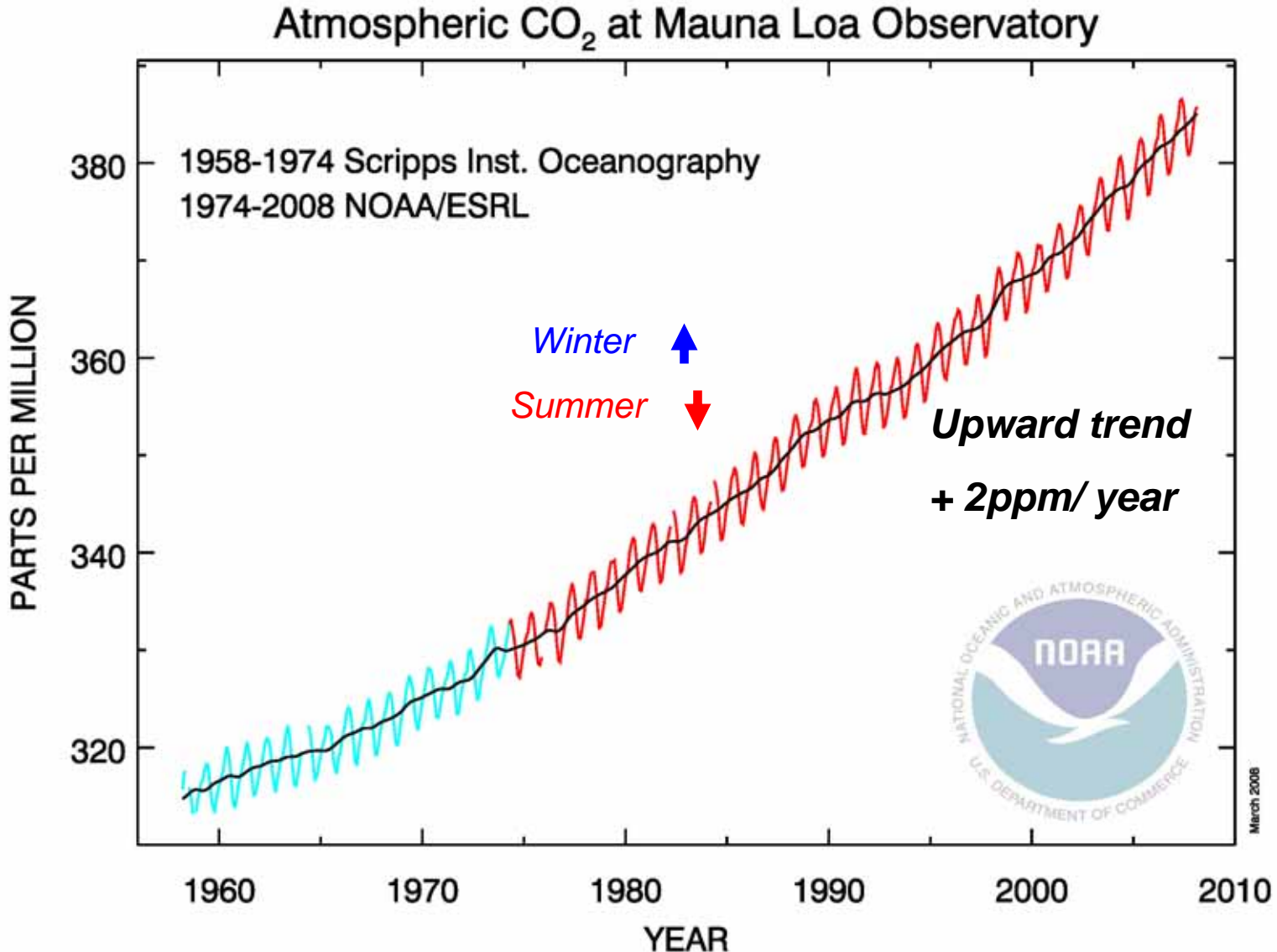
*-less ice, less
sunlight reflected*

*-more evaporation,
larger water vapor
greenhouse*

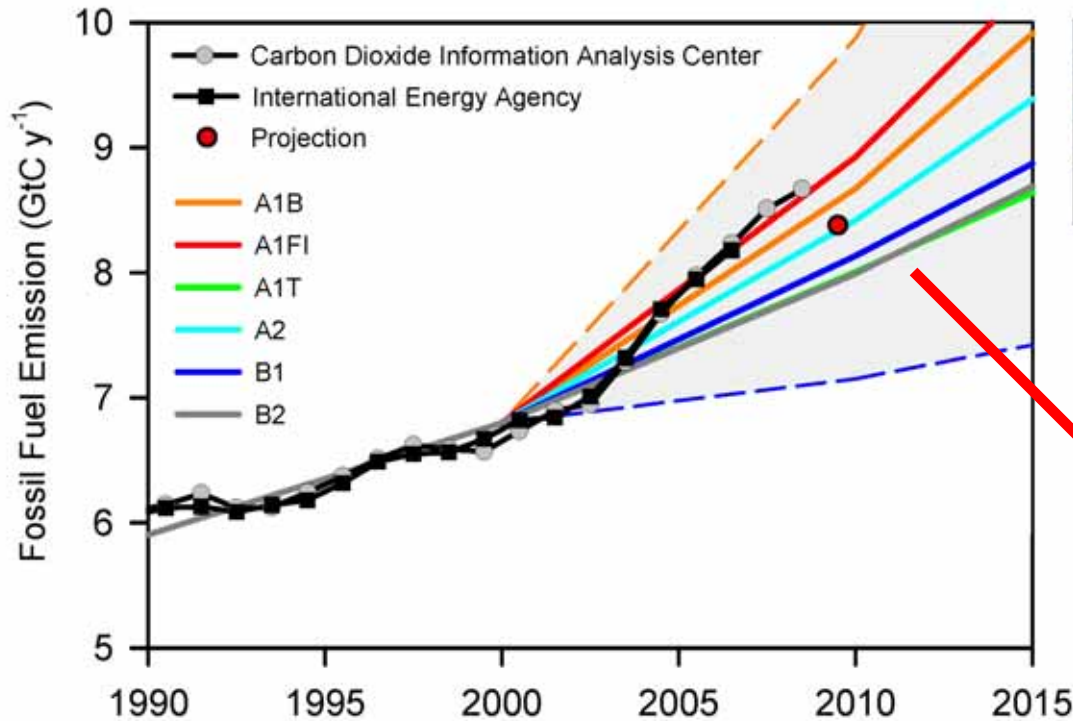
(www.nsidc.org)

- 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



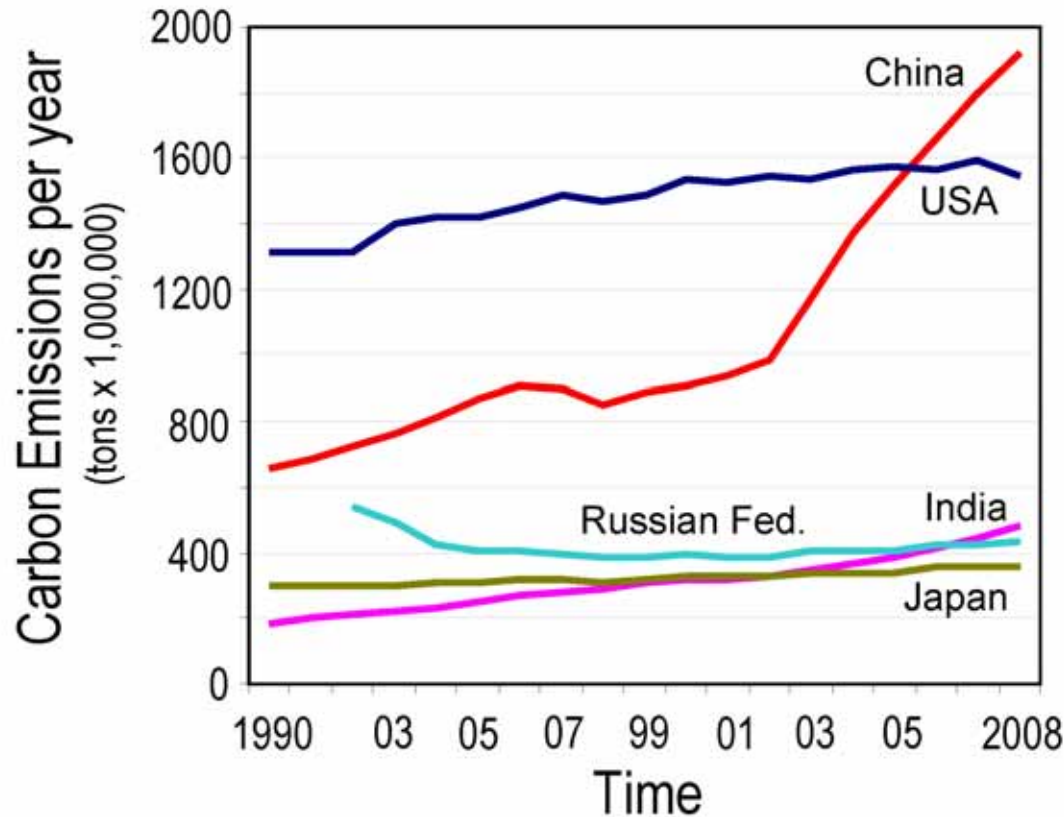
Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature Geoscience; International Monetary Fund 2009



- 2009 was 'good' for the Earth

Need 80% drop by 2050

Fossil Fuel Emissions: Top Emitters (>4% of Total)

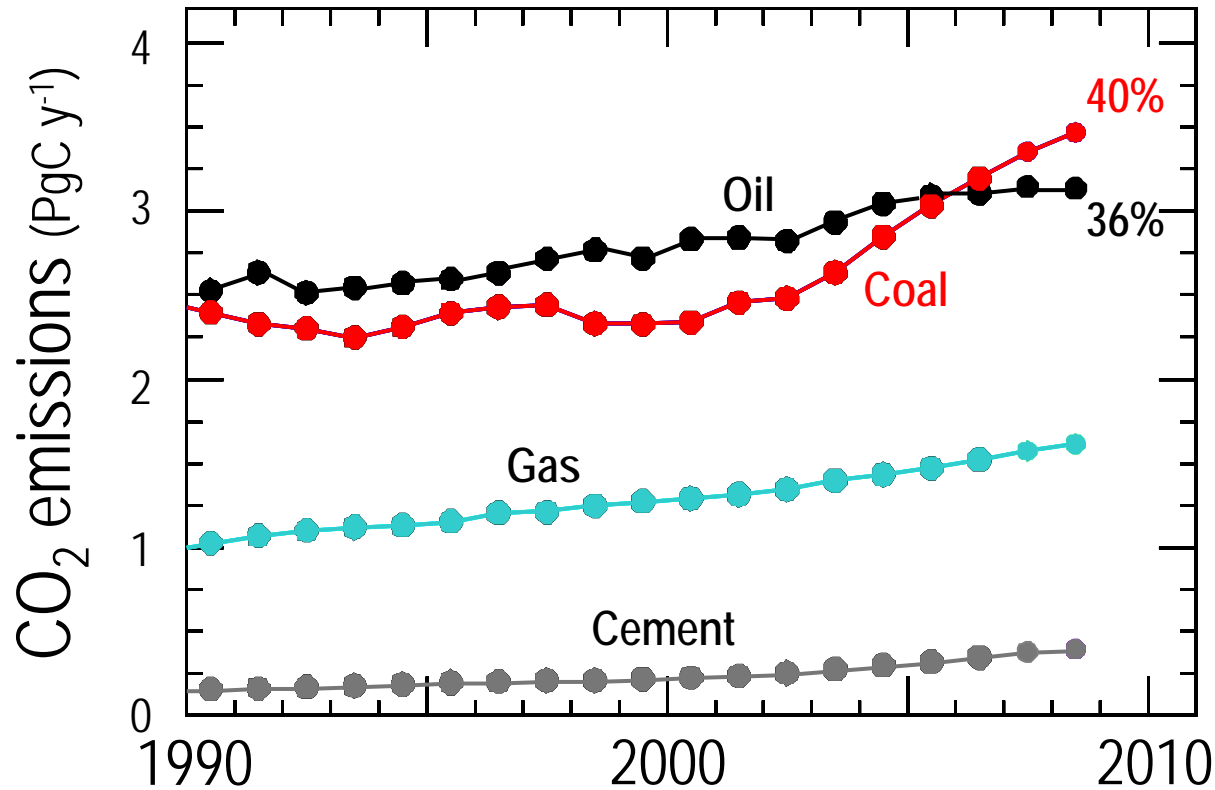


Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009



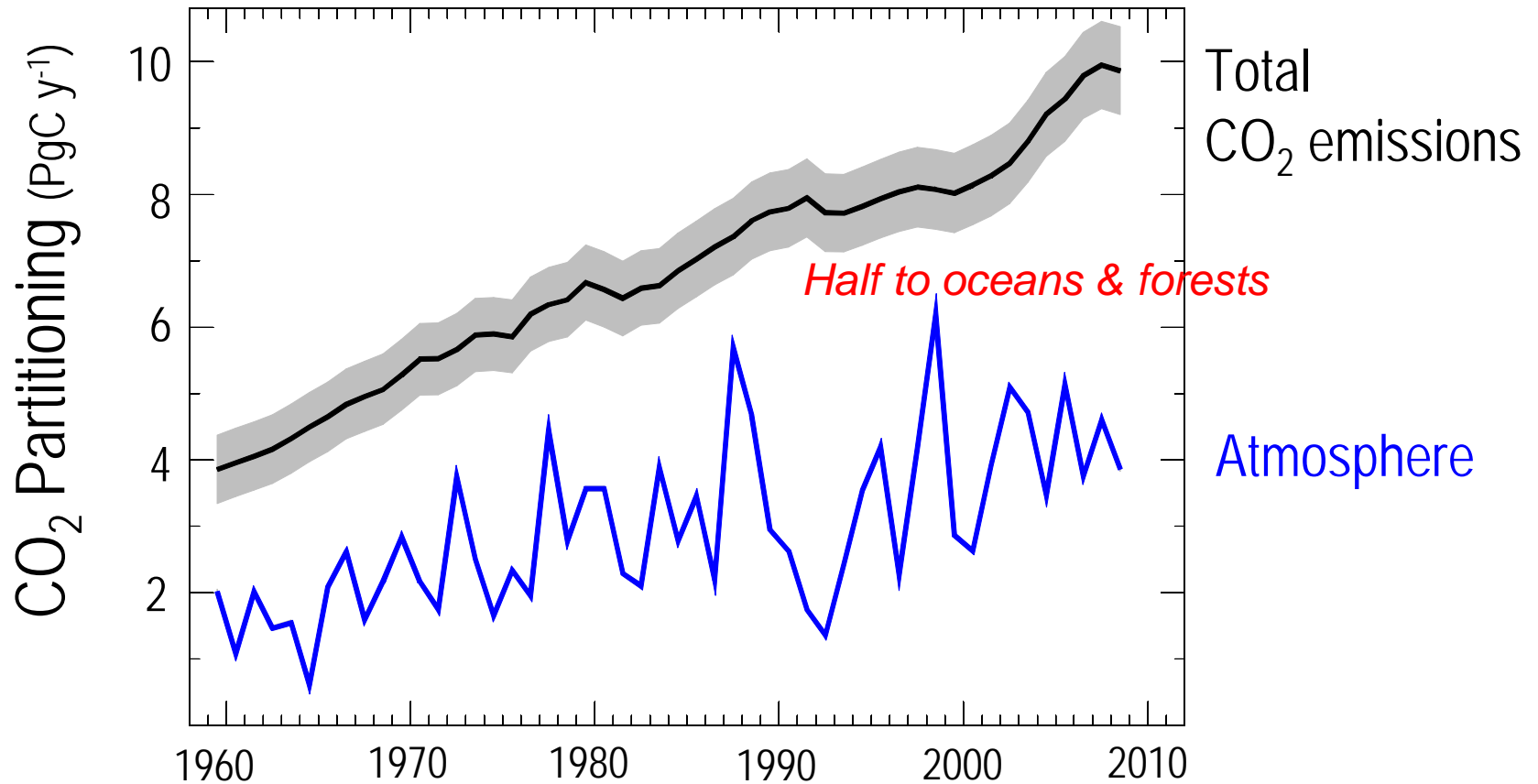
- China has overtaken the US [4 X population]

Components of FF Emissions



Key Diagnostic of the Carbon Cycle

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



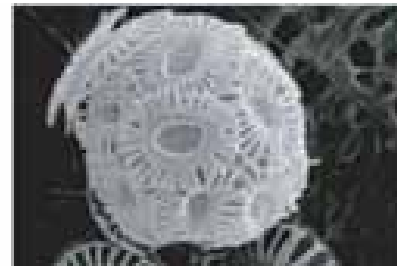
*It takes a century or more to remove CO₂ from
atmos., and many centuries from the oceans*

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 CO₂ a problem?

- Atmosphere is transparent to 'light' from sun but not to 'infrared' radiation from earth
- Greenhouse gases: H₂O, CO₂, CH₄, HCFCs...
- trap the earth's heat
- CO₂ 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 CO₂ will warm Earth about 3C (5F)

IPCC, Feb 2, 2007

Global Warming is *unequivocal*

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:

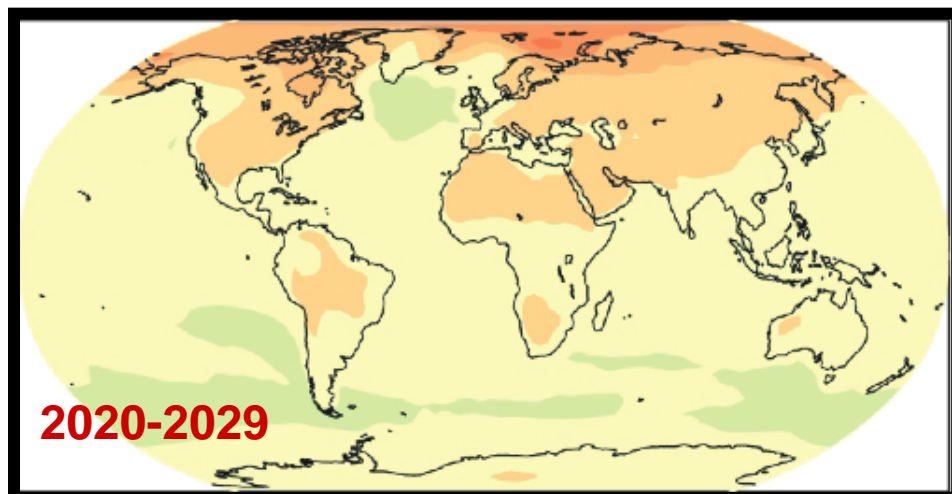
- NH Snow extent
- Arctic sea ice
- Glaciers
- Ocean pH [increasing acidity]

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



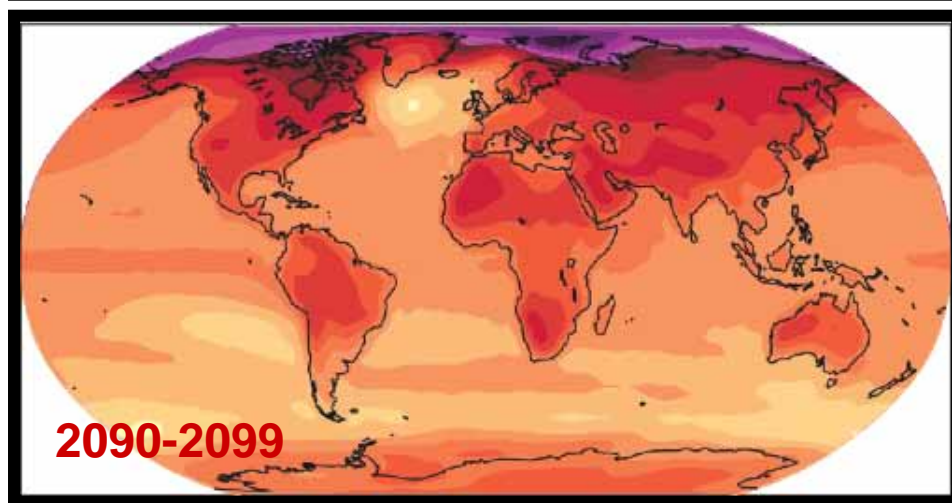
Multi-model Predicted Percent Change in Temperature (2020-2029 and 2090-2090 relative to 1980-1999) [$^{\circ}\text{C}$]

'Committed'

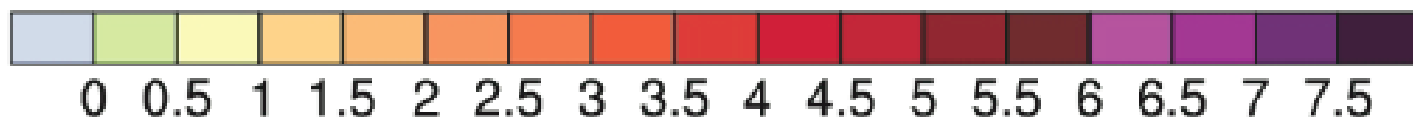


(We did nothing for the last 20 years)

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..

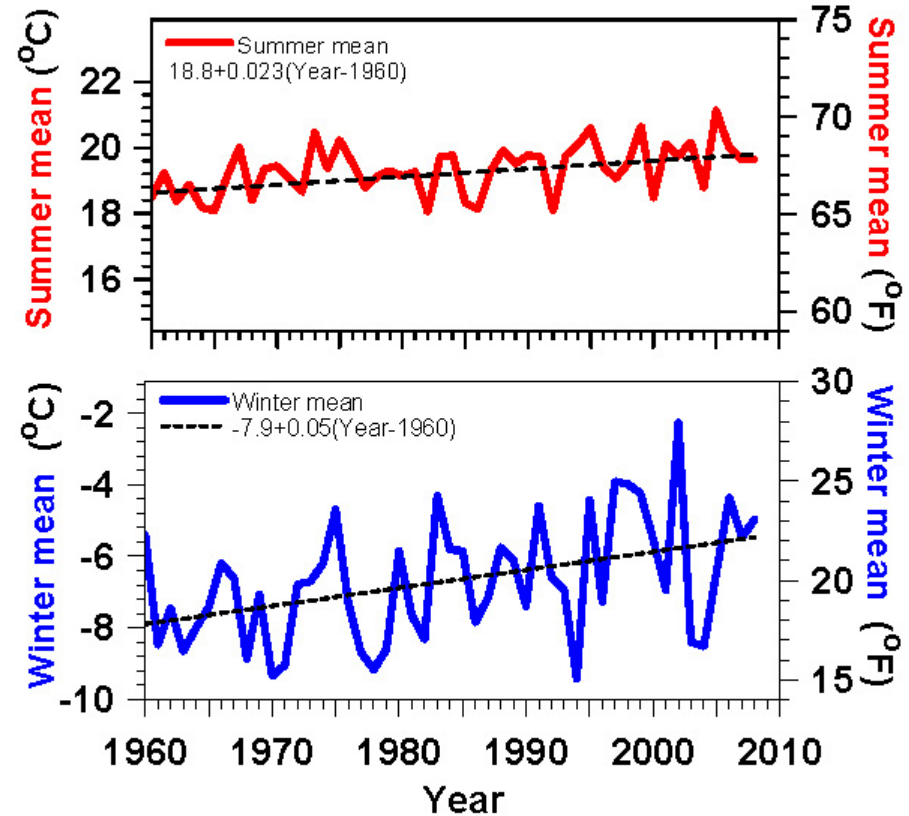
- Melting Arctic and permafrost – methane release?
- Extreme weather: floods, fires & drought
- Collapse of many ecosystems, including perhaps forest and ocean ecosystems
- Collapse of unsustainable human population

What is happening to Vermont?

- Local climate change indicators
- Easier for citizens 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*

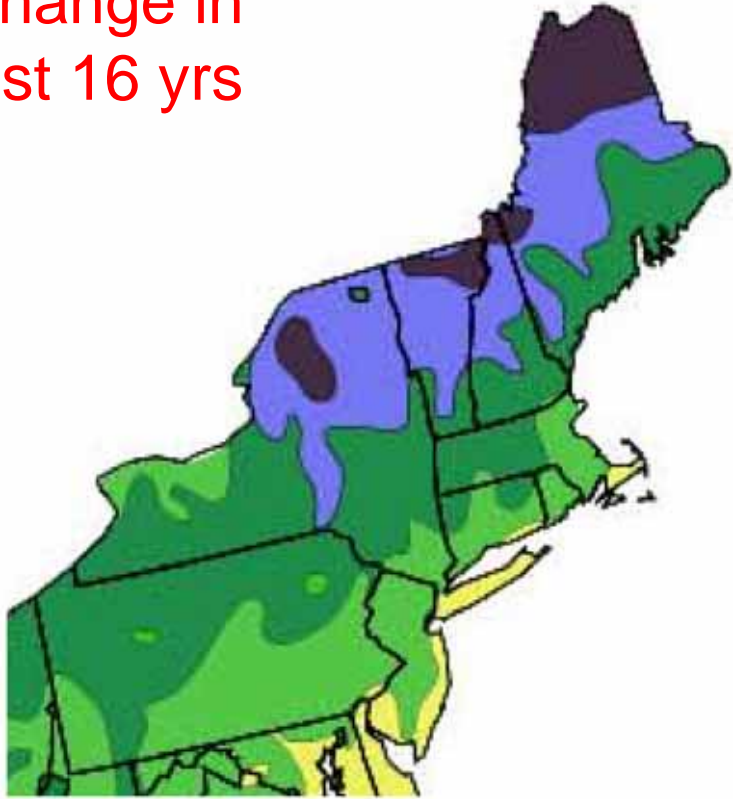
Vermont temperature trends

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

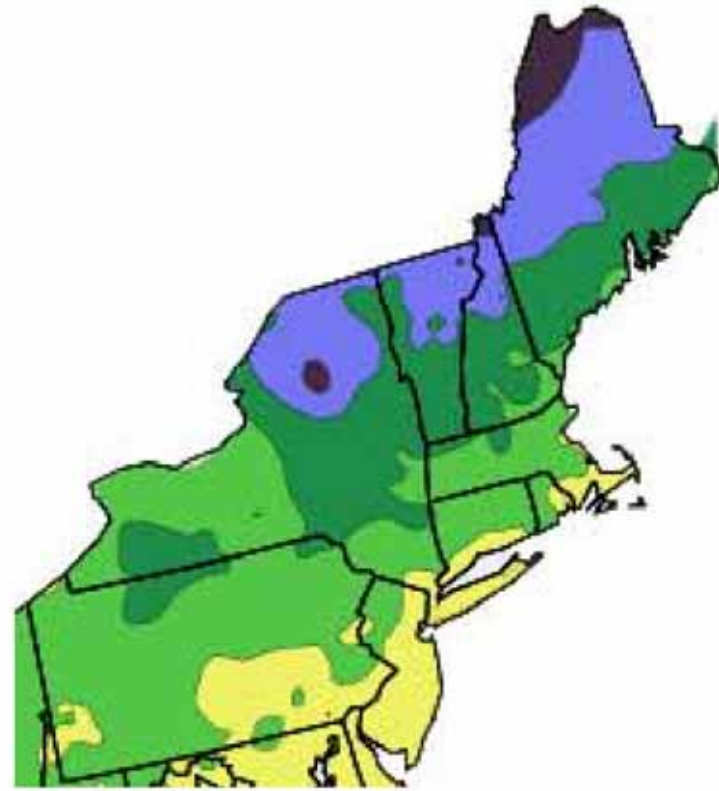


USDA Hardiness Zones - Northeast

Change in
last 16 yrs

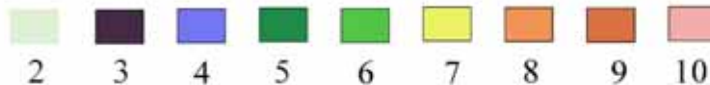


1990



2006

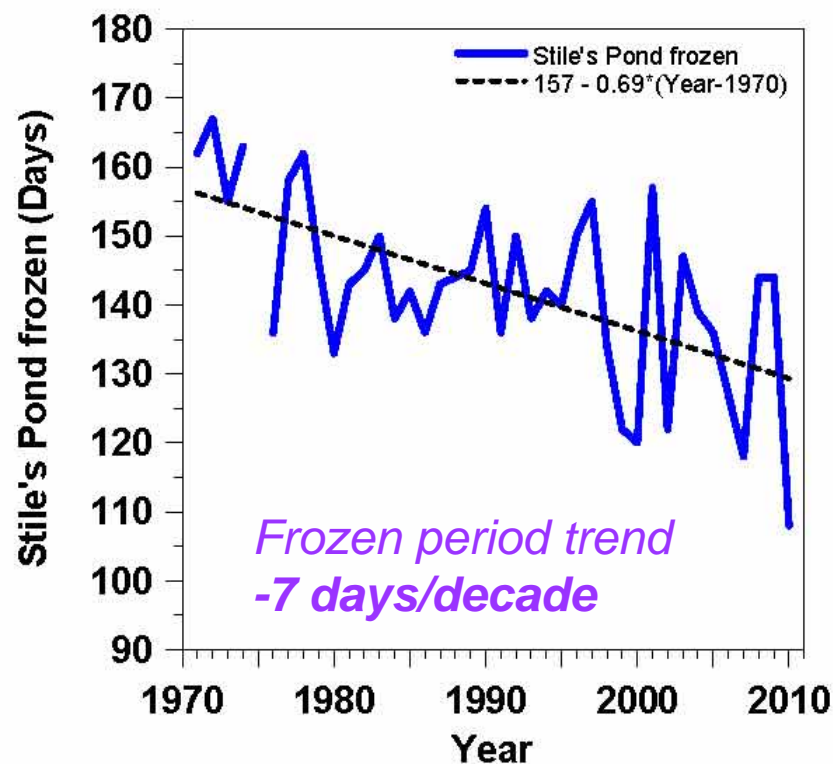
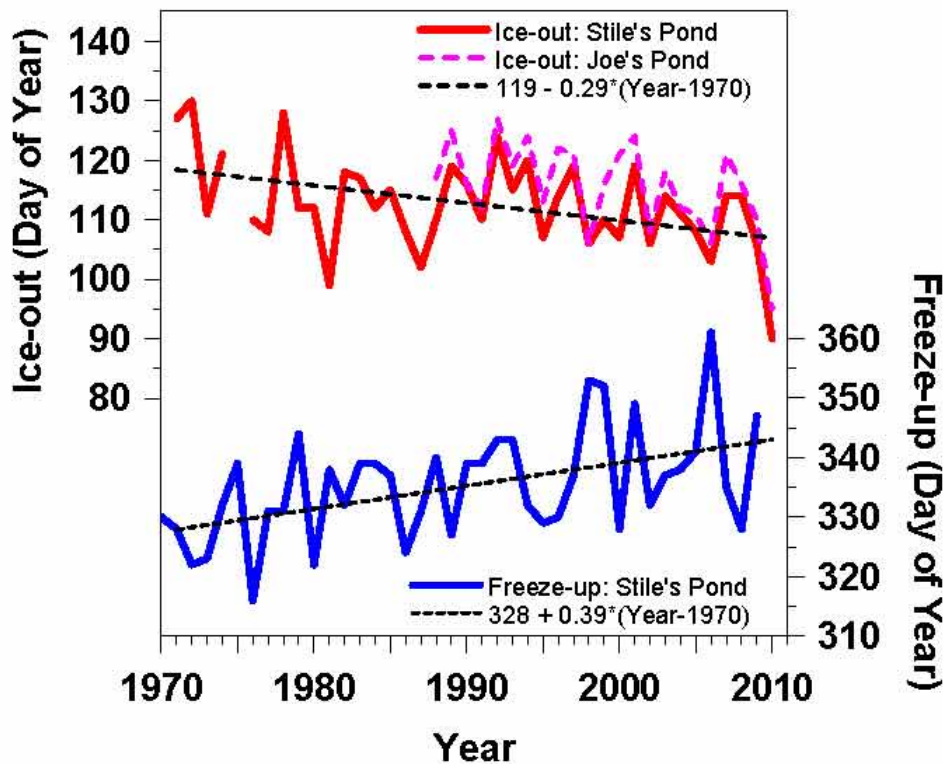
Zone



USDA Hardiness Zones

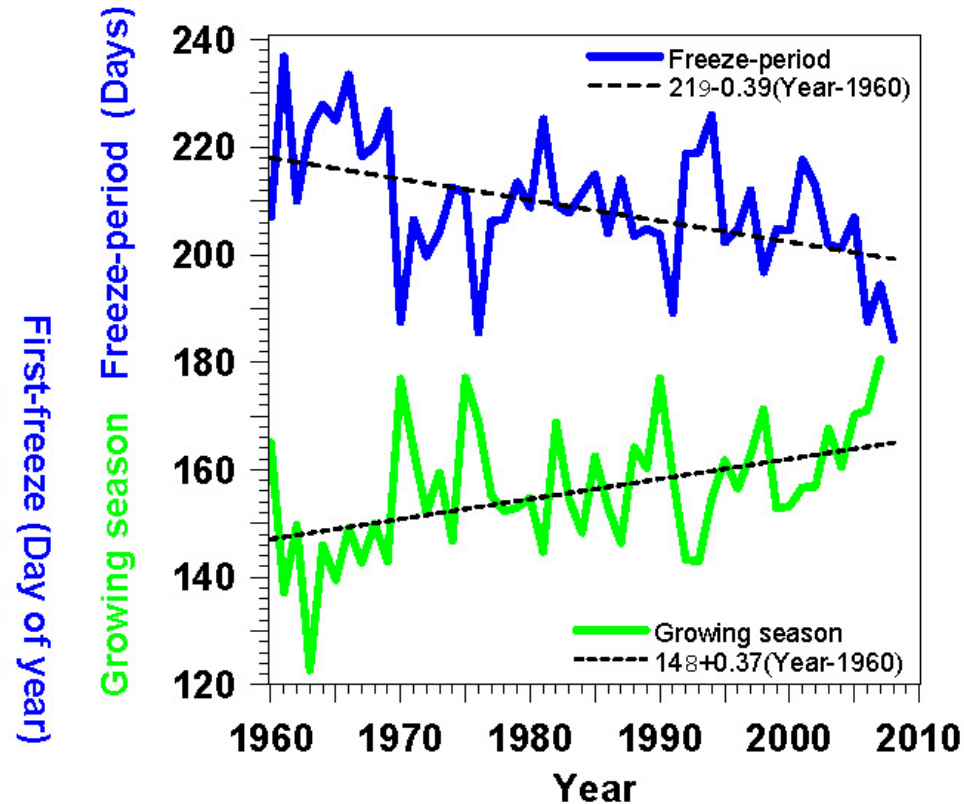
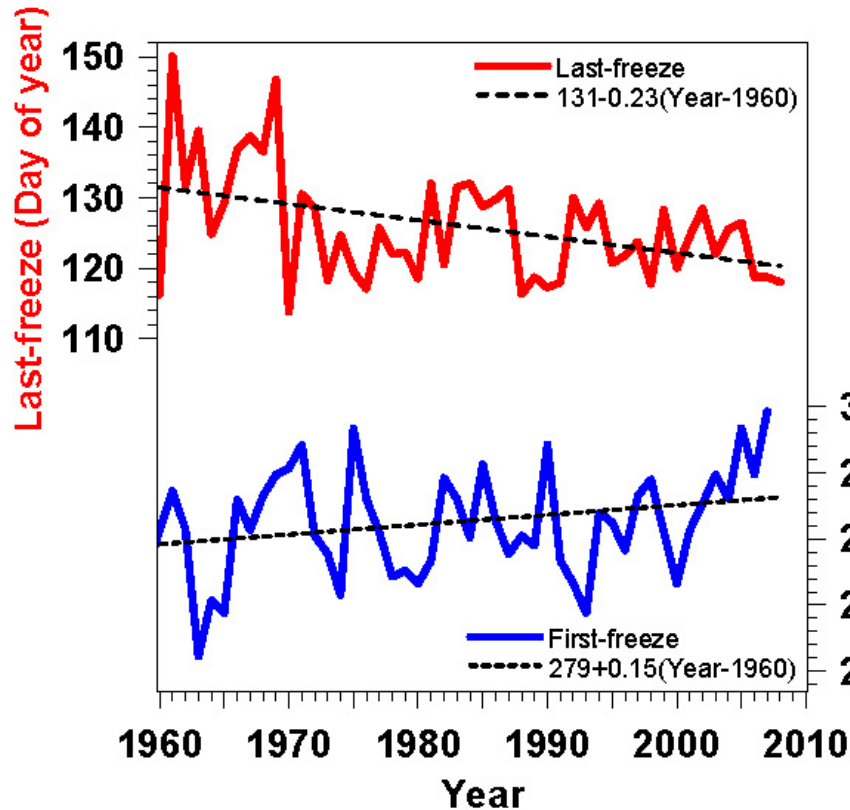
Lake freeze-up & Ice-out changing

– *frozen period shrinking fast*



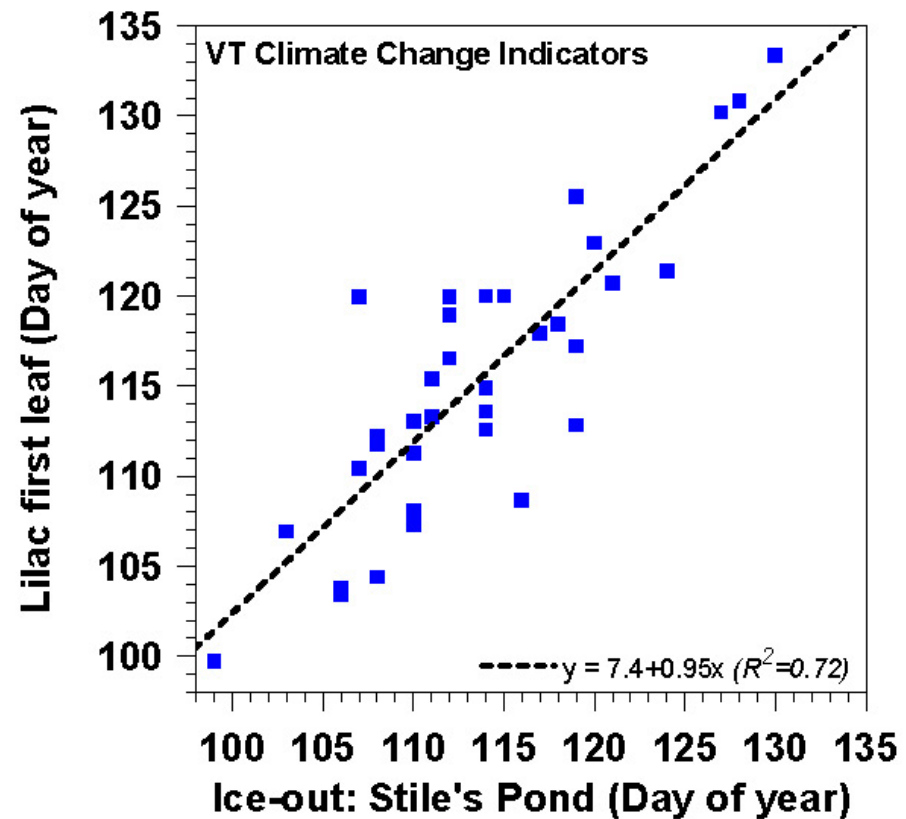
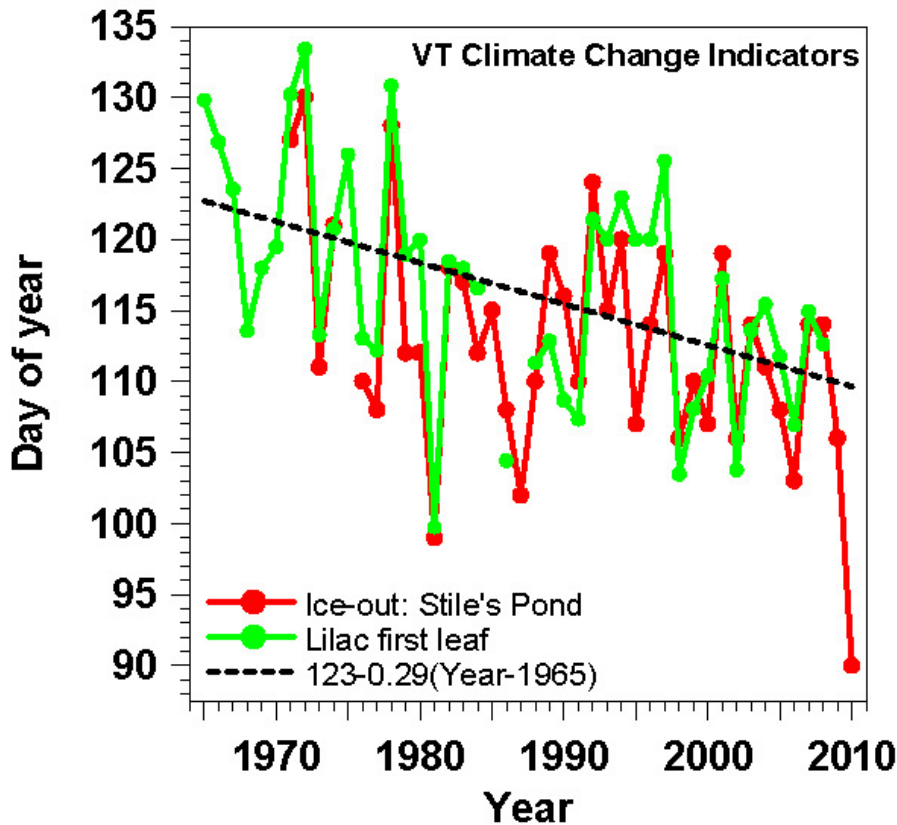
- *Ice-out earlier 3 days/decade*
- *Freeze-up later 4 days/decade*

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*

When do we get the first frost?

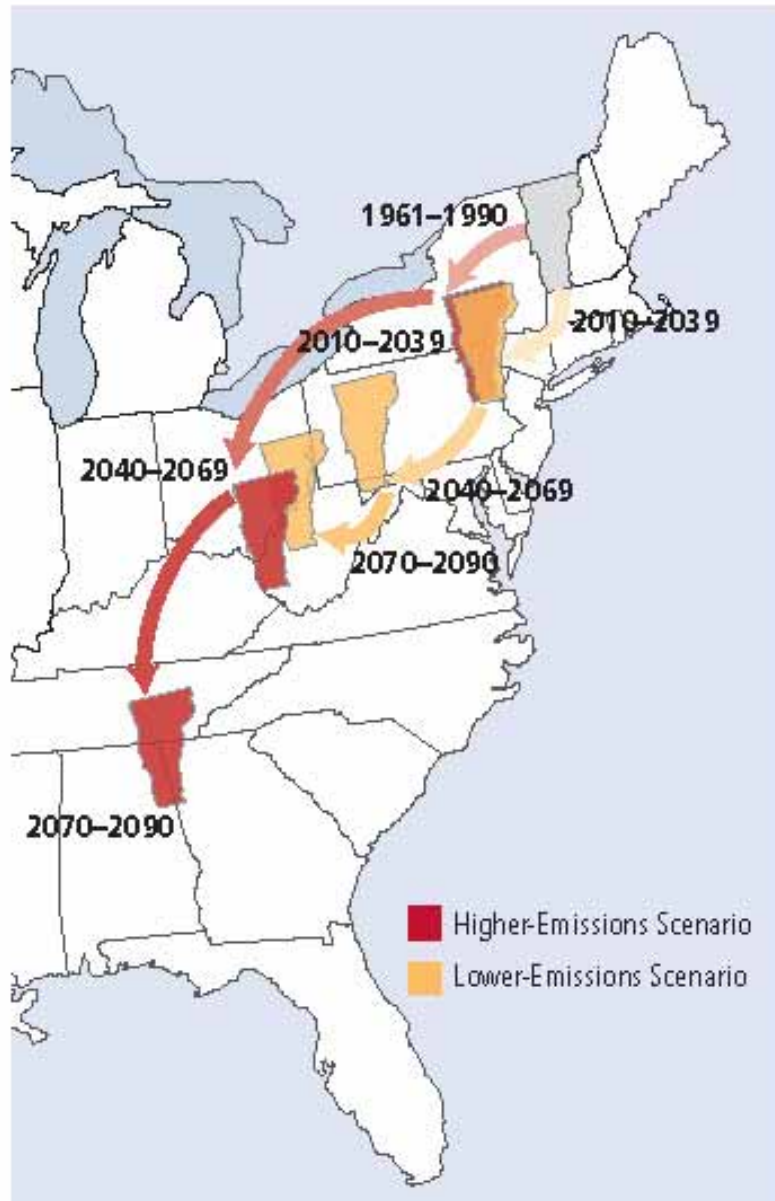
- **Vegetation tries to postpone first killing frost in fall**
- **Deciduous trees still evaporating: moist air with clouds**
- **Water vapor & cloud **greenhouse** reduces reduces cooling at night and prevents frost**
- **Till one night, dry air advection from north gives first hard frost.**
- **Vegetation shuts down, leaves turn, skies become clearer and frosts become frequent**



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

The opposite happens in Spring with leaf-out – think it through!

Vermont's future with high and low GHG emissions



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.

Red is high emissions

What about the tropics?

NECIA, 2007

Outline

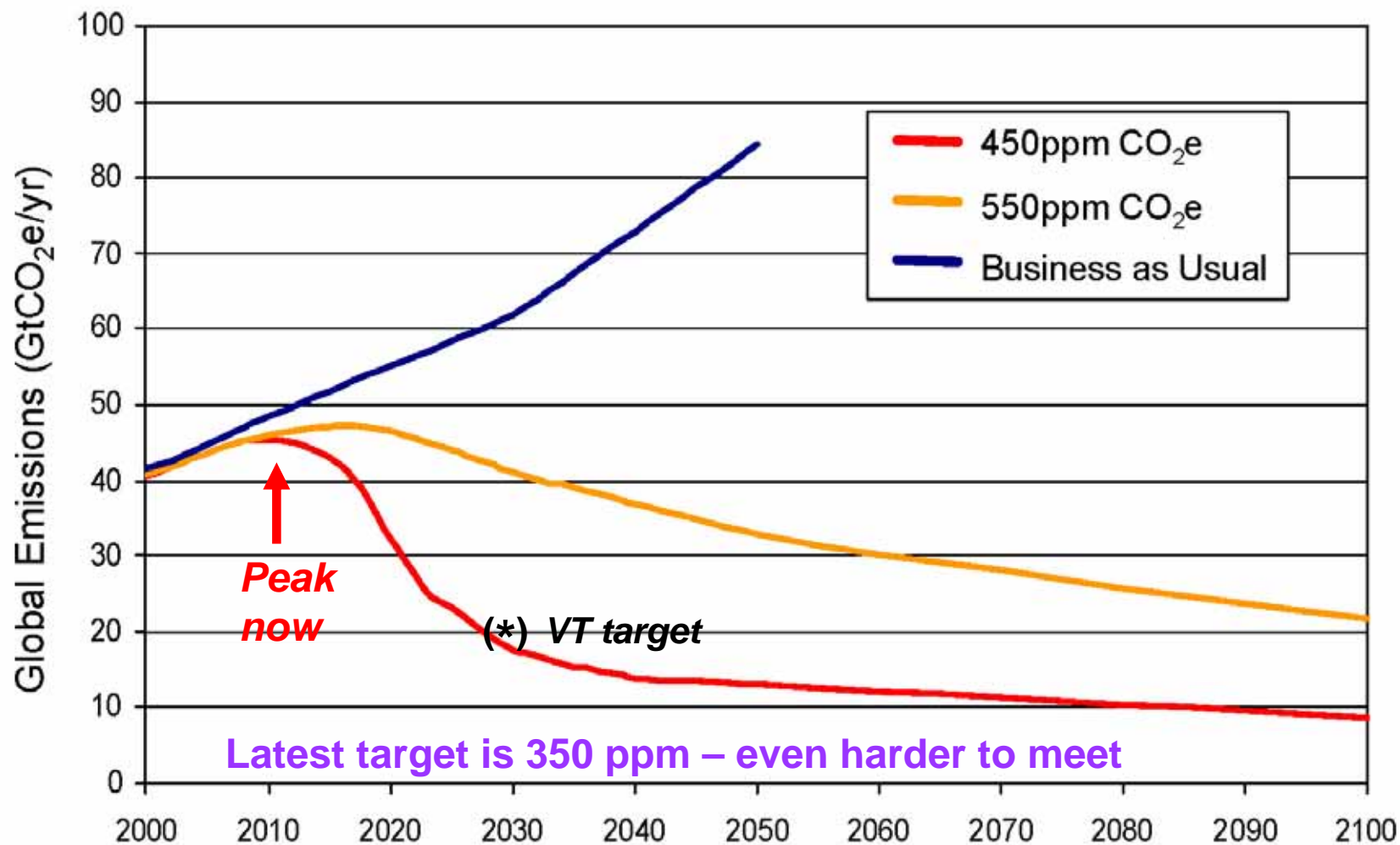
- **Science of climate change** **Questions?**
 - *Global scale: actual and future*
 - *Local scale*
- **Perspective of Earth system scientist**
 - *Technical solutions: managing Earth system*
 - *Choices, challenges and self-deception*

Can we stop dangerous climate change?

- Probably - Stabilize atmospheric CO₂
- This means 80% drop in CO₂ emissions

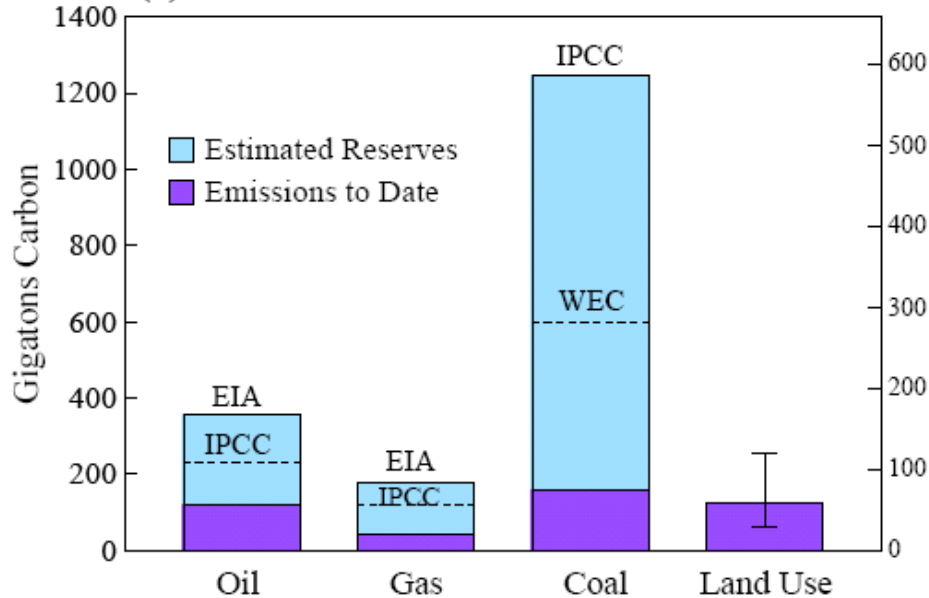
How do we avoid 'Dangerous Climate Change'?

Emissions Paths to Stabilisation [Stern, 2006]

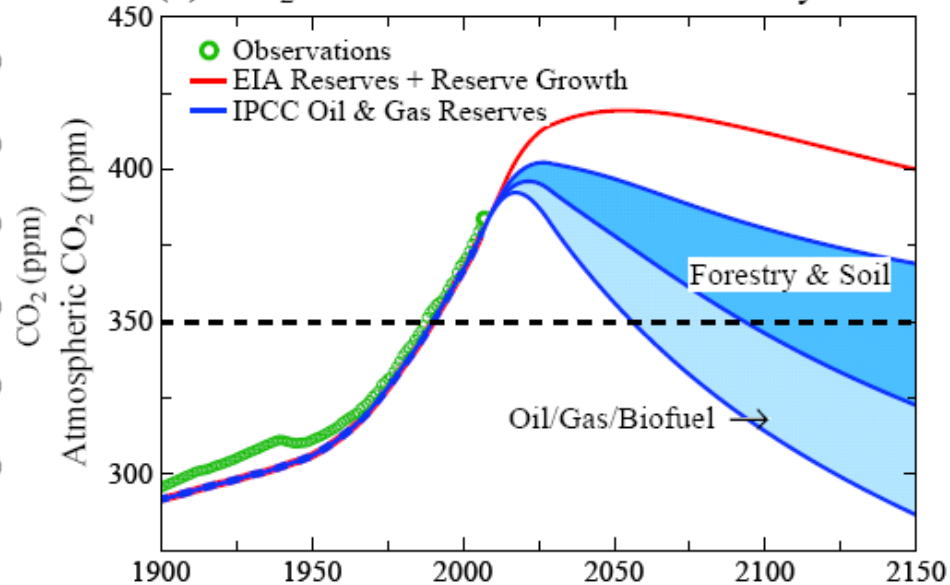


Coal reserves are the big problem

(a) Fossil Fuel and Net Land Use Emissions



(b) CO₂ Amount with Coal Phaseout by 2030



- Coal stores of 1000 Gt = 600ppm CO₂ of which 45% [or more] stays in atmosphere
- Suggested global total limit of 270 Gt fossil C means burning **no more coal**

Hansen et al. (OASJ 2008)

How do we manage the Earth?

(When there is so much we don't know)

- ***Long time horizon: generational to century***
- *All waste products must have short lifetime in biosphere [think CFCs, CO₂, Pu-239]*
- *Minimize use of raw materials by remanufacturing*
- *Maximize efficiency of use of energy and water*
- *Relocalize to regain control/responsibility and minimize transport*

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
- CO₂ 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**

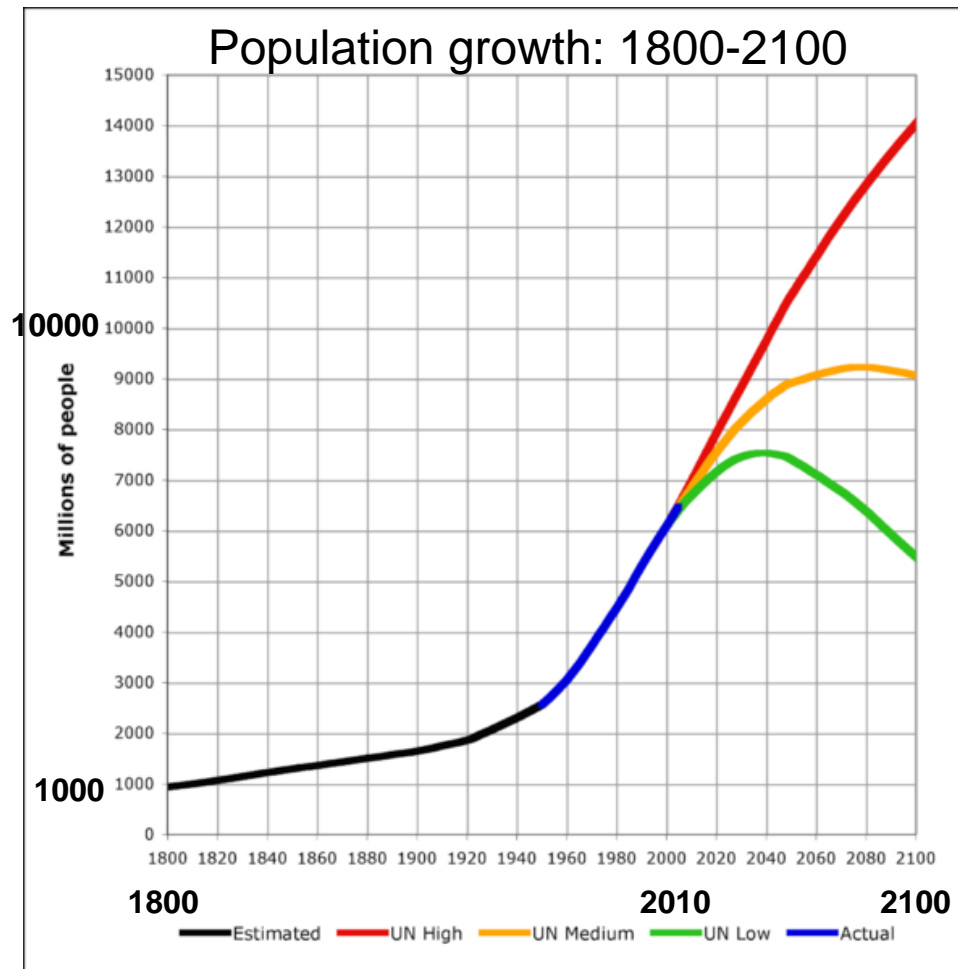
We live in a dream world, but..

- *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.*

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.**

Climate Change is a huge challenge for humanity



- **We haven't integrated our science/technology and our moral responsibility for the earth**
- **We have a large investment in a fossil fuel infrastructure, that must be replaced**
- **We have major political problems finding consensus**
- *We are already decades late in taking action and the lags in the earth system are long*

So what do we do?

What are scientists' responsibilities?

- Climate science is under attack because it is politically and economically relevant
- *Traditionally scientists “stuck to science”*
- How do we proactively defend the science and maintain trust and integrity of science?
- Needs deeper ethical/historical understanding

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

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 CO₂ to 1000ppm [*and in time melt ice-caps*]. Can we “sequester” CO₂ [put it back in the earth]?**

The future is not our past

- Faced with
 - climate change & limited oil
 - global population growth & ‘consumer growth’
 - past the carrying capacity of the Earth in 1980s
- What government can do is limited: too paralyzed by ideology/doctrine, bureaucracy & self-interest
- Communities are one key [transitiontowns.org]
- **We create the future**

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*
- **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** at all levels: 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?**

Conclusions



- **The issues humanity faces are deep**
- **We are all part of the problem/solution**
- *We have the tools & knowledge
- but not 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!**