



Climate, Energy & Community

Dr. Alan K. Betts

Vermont Academy of Science and
Engineering (VASE)

Atmospheric Research, Pittsford, VT 05763

akbetts@aol.com

Osher, Rutland

March 27, 2009



Climate Change

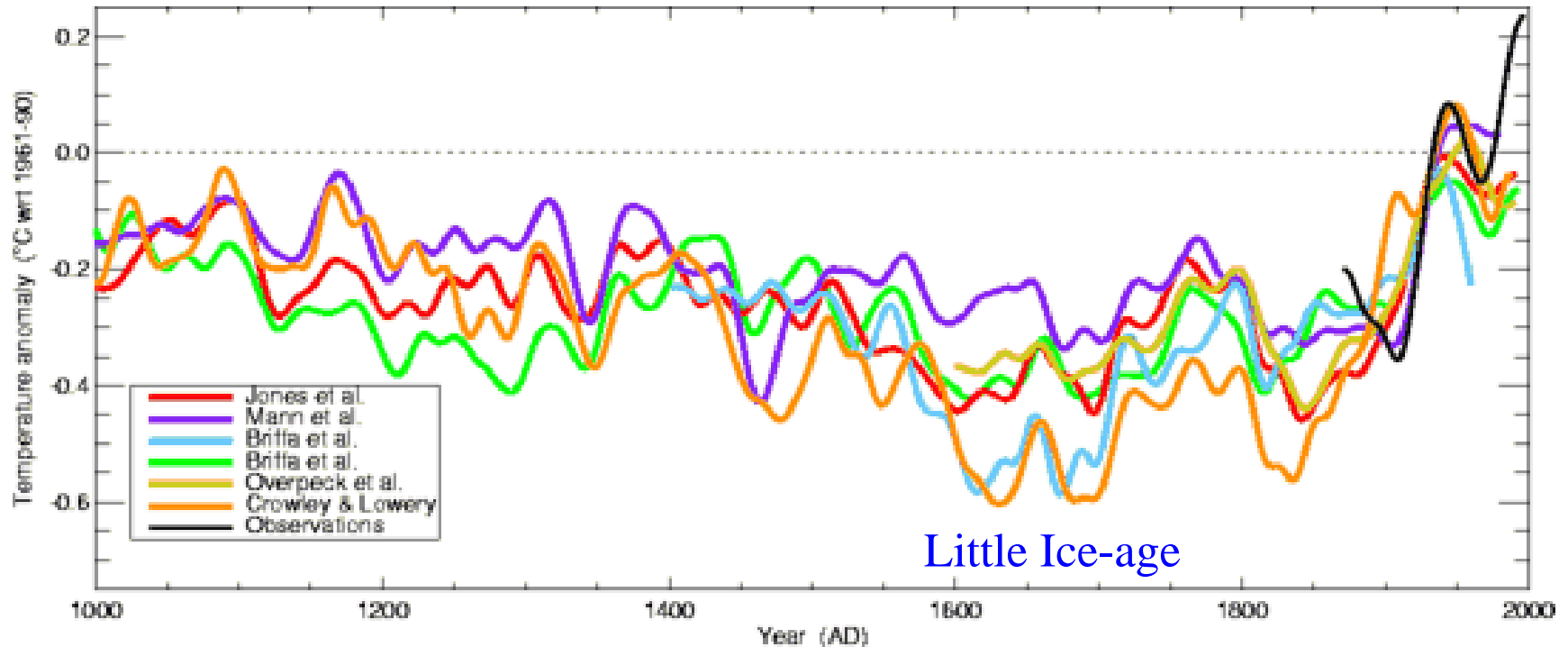
- **One of the great challenges for this century**
- **2009 is a critical year**
- **Dec 7-18, 2009: COP-15, Copenhagen**
 - *UN Framework Convention on Climate Change, 1992*
- **We are already decades late in taking action**
 - *Sawyer, Nature, 1972, Man-made CO₂ and the “greenhouse” effect*
- ***Global issue & local issue;
societal & personal issue!***

Peterhouse, Cambridge

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



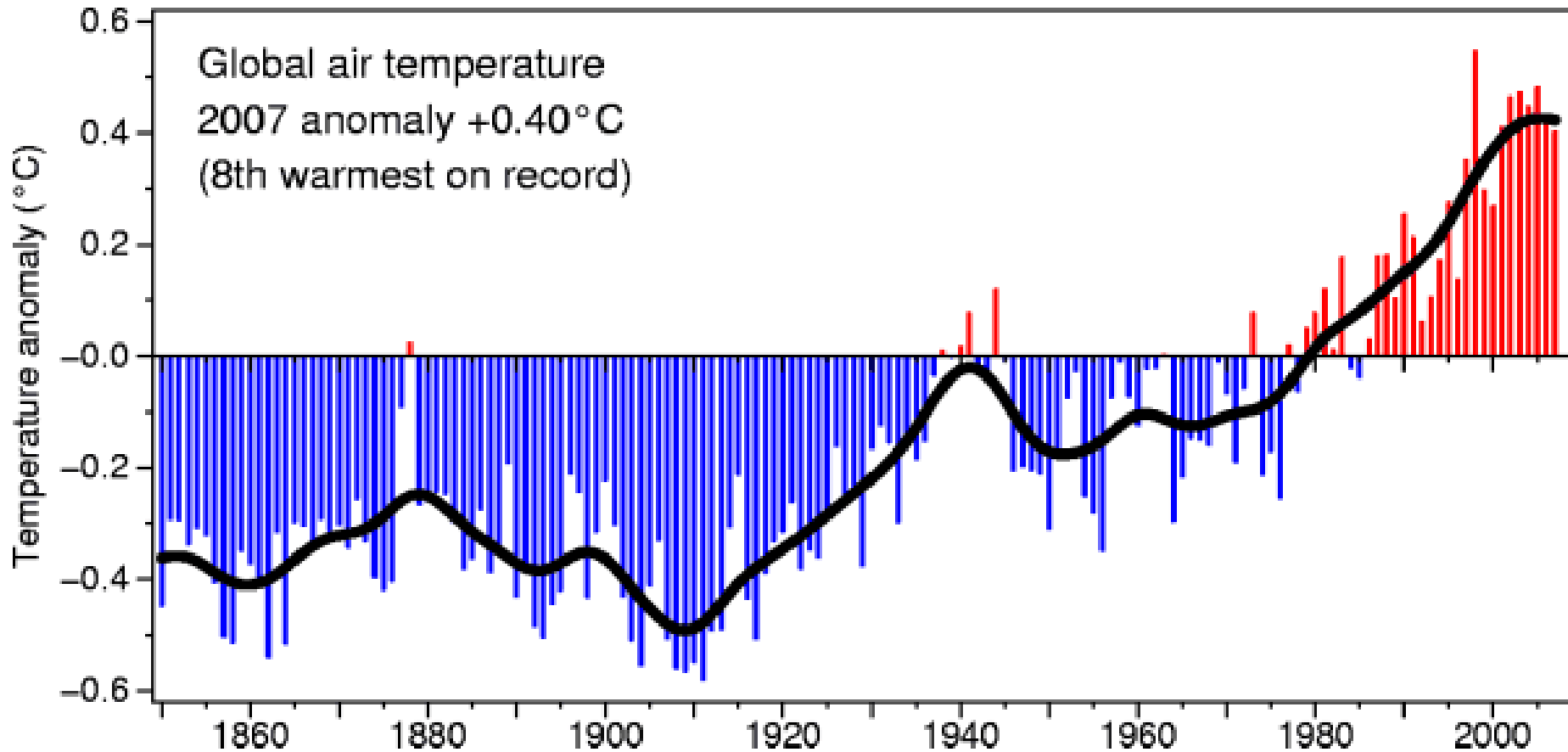
The Millennial Temperature Record



- Before thermometers
‘proxy’ records have large uncertainty
- Jones: <http://www.cru.uea.ac.uk/cru/info/milltemp/>

Last 150 years temperature record

• *Jones, 2008*



Warmest years: 1998 and 2001-2007

Sept-Nov. 2006 in N. Europe shattered all records

- Fall 2006 in Europe so warm that ‘return time’ **>10000 years**
- **Moving into a new ‘climate’**

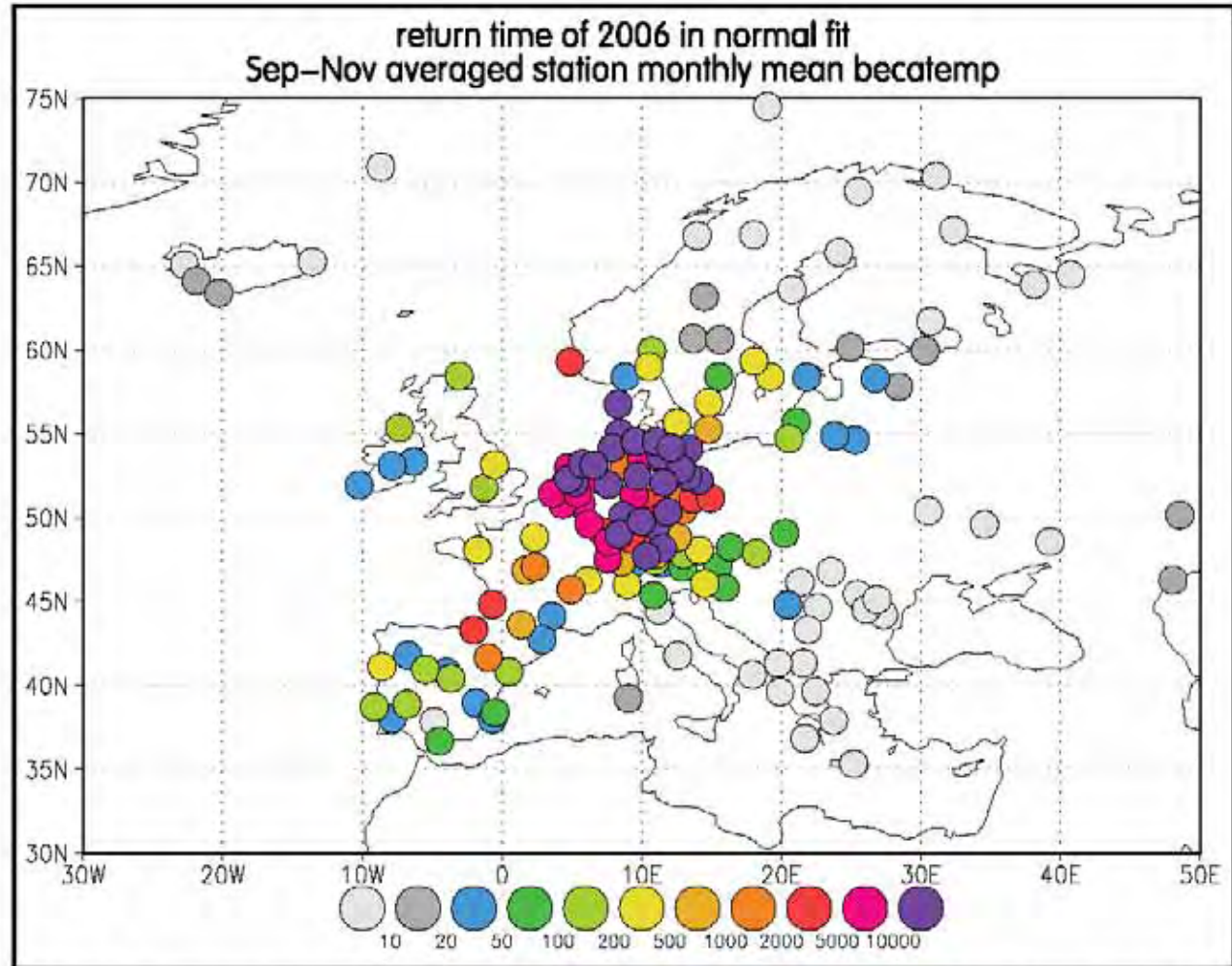


Figure 2. The return period of the autumn of 2006 at De Bilt, the Netherlands, computed from the distribution of the years 1901–2005 for all ECA&D stations with at least 40 years of data, using a Gaussian extrapolation (the GPD gives higher return periods).

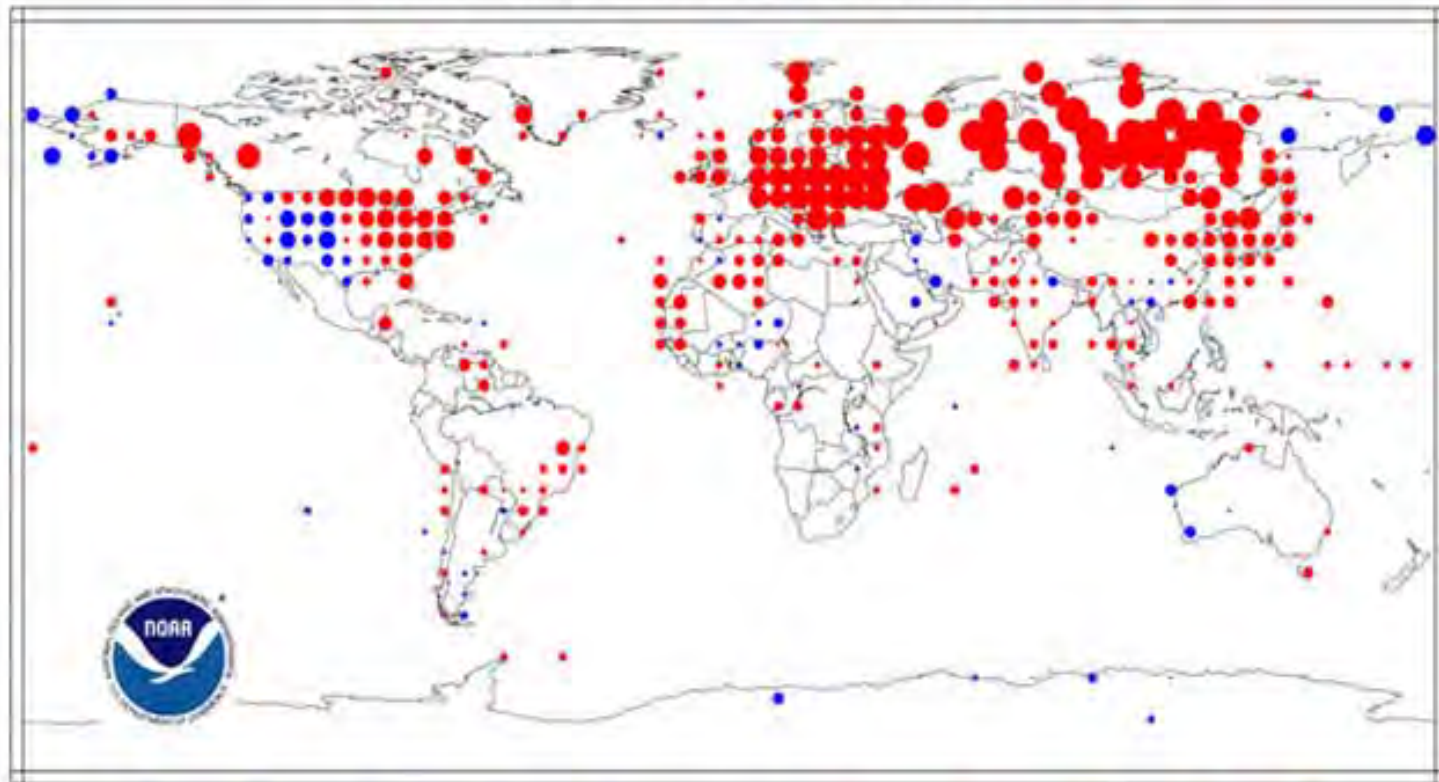
January 2007 warmest on record

[Exceeded 2002 record over land by 0.8°F]

Temperature Anomalies January 2007

(with respect to a 1961-1990 base period)

National Climatic Data Center/NESDIS/NOAA



● -5C ● -4C ● -3C ● -2C ● -1C 0C ● 1C ● 2C ● 3C ● 4C ● 5C

Degrees C

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

Earth system - climate change

- Earth's orbit around sun; small solar fluctuations
- Volcanic eruptions: stratospheric aerosol
- **Greenhouse gases from fossil fuel burning (CO₂) and other industrial sources trap more infrared radiation**
- Water vapor and snow/ice amplify effects
- Instabilities of atmosphere, oceans and ice
- Oceans and ice-sheets - slower response
- Biosphere and the oceans control long-term fate, because they use and remove CO₂

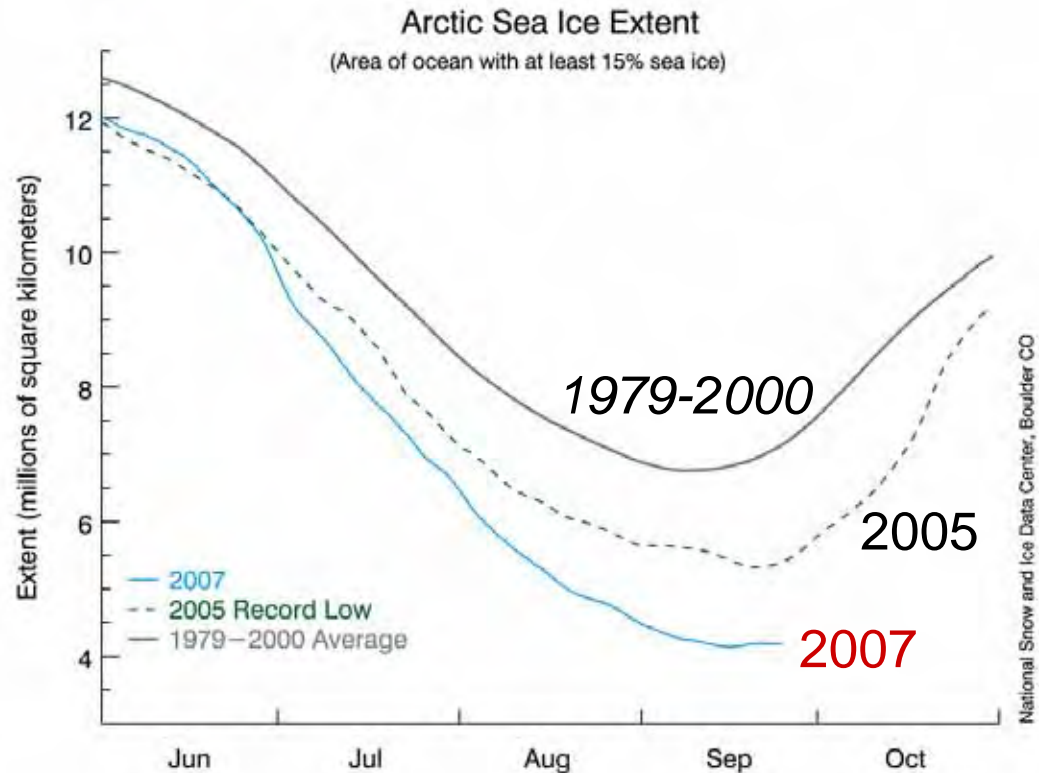
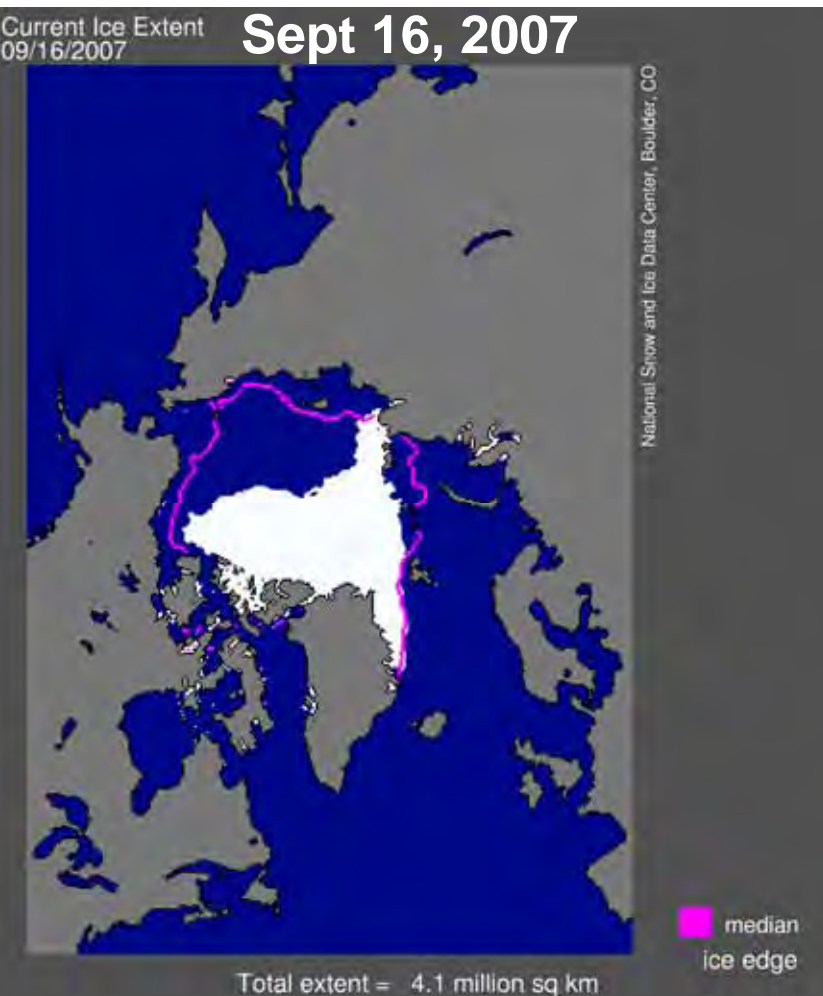
Earth system- critical issues

- **CO₂, H₂O, clouds & Greenhouse effect**
- **Ice-albedo feedback [sea-ice melt]**
- **Ice-melt and sea-level [rising faster]**
- **Ocean acidification [impacts severe]**
- **Melting permafrost; CH₄, tundra regrowth**
- **Unstable feedbacks**
- **Many unknowns**

Atmosphere is transparent to 'light' but not to 'infrared' radiation

- The earth cools by emitting infrared or heat radiation, but molecules H_2O , CO_2 , CH_4 and O_3 vibrate and absorb it: 'Greenhouse gases'
- Atmosphere blankets the earth and keeps it about 59°F warmer - so oceans don't freeze
- Increasing greenhouse gases are warming earth further: $\approx 5^\circ\text{F}$ this century, unless emissions reduced

Arctic sea-ice loss is accelerating



Double feedback: loss of reflective ice and increased water vapor greenhouse from more evaporation

(www.nsidc.org)

- 2007 saw new record ice-loss by huge margin
- 40% melted by September → warm Fall

Vermont winter, 2006

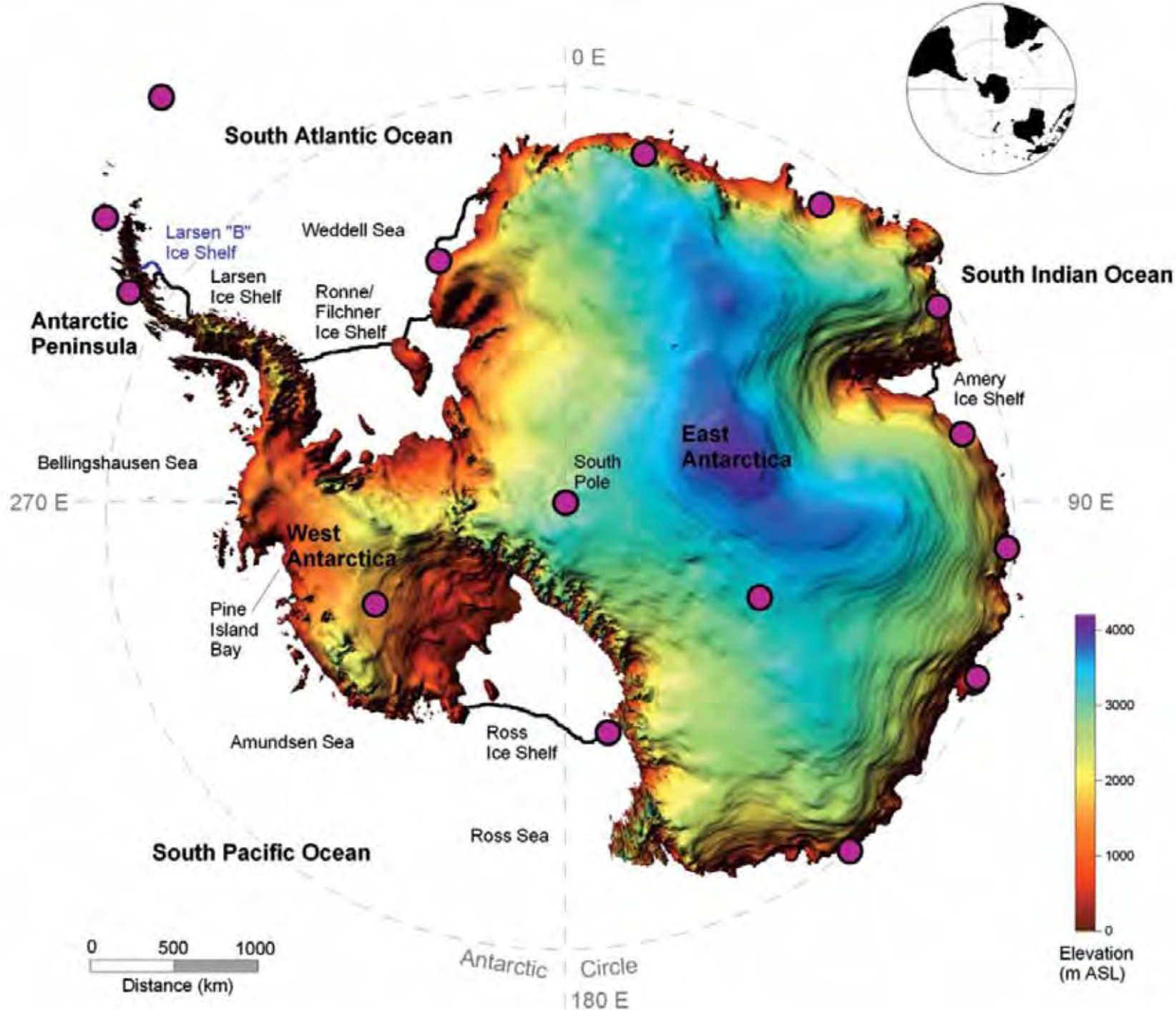


- Sun is low; and snow reflects sunlight, except where trees!
- Sunlight reflected, stays colder; little evaporation, clear sky

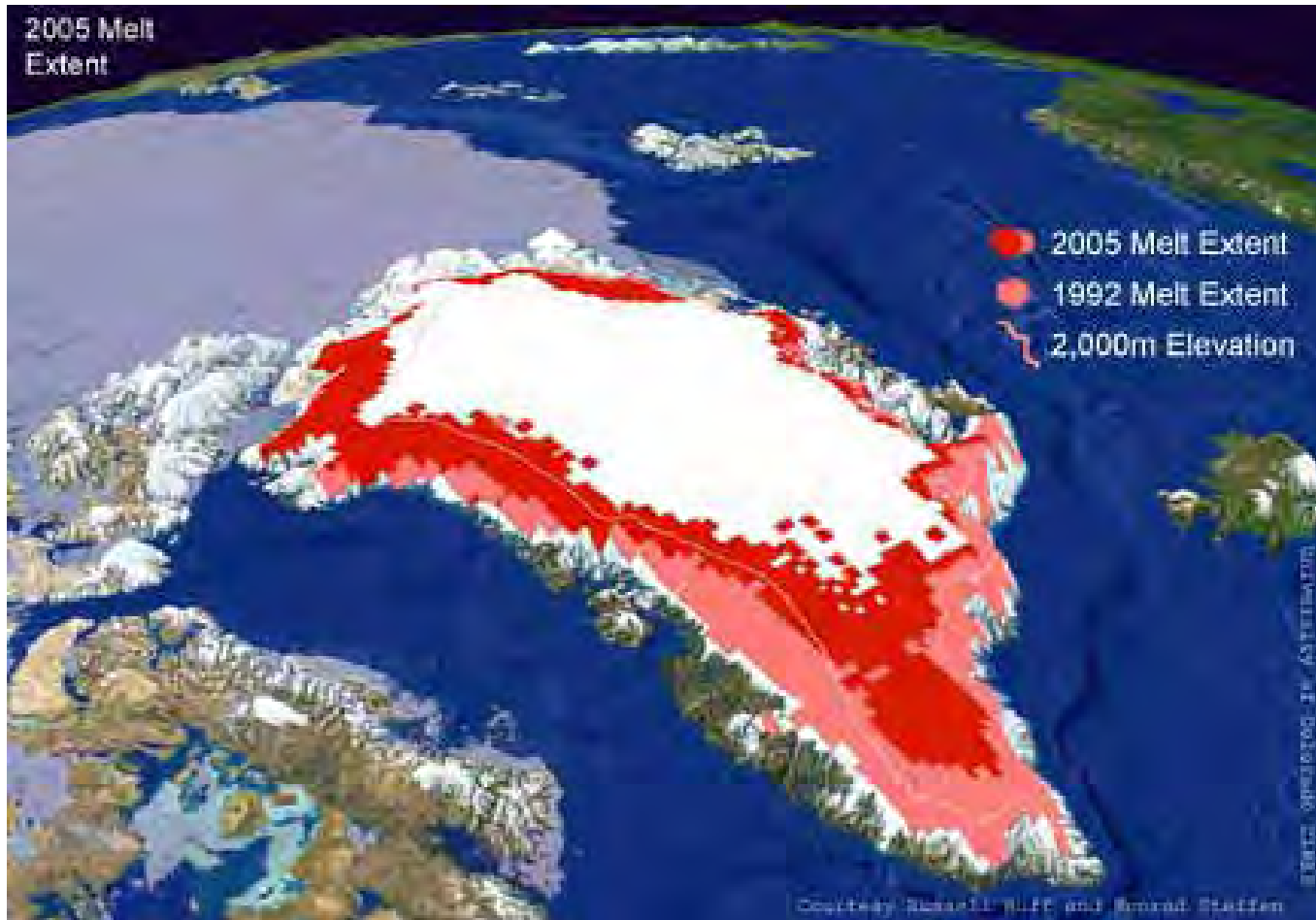
January 7, 2007



- **Rain, not snow; grass still green, evaporation continues**
- **Sunlight absorbed, not reflected; stays warmer, sky cloudy**



Greenland ice-cap melt rapidly increasing



*(Sea-level rise
of 20 ft if ice-
cap melts)*

- Summer melt area increase from 1992 to 2005
- Ice loss doubled 1996 to 2005; ***2007 larger still***

Melting water
cascades down a
crevasse to the
base of the
Greenland ice
sheet in summer

Glaciers speeding up:
when will the
ice-sheet become
unstable?

*Source: Roger Braithwaite,
University of Manchester (UK)*



Icesheet break-up?

- Ice-age termination
- Sea level has risen as fast as 3ft every 20 years for centuries with break-up of large ice-sheets

J. Hansen, Scientific American, March, 2004

[3+ft this century]



Current sea level rise only 2.8mm/yr [0.28m/100 years]

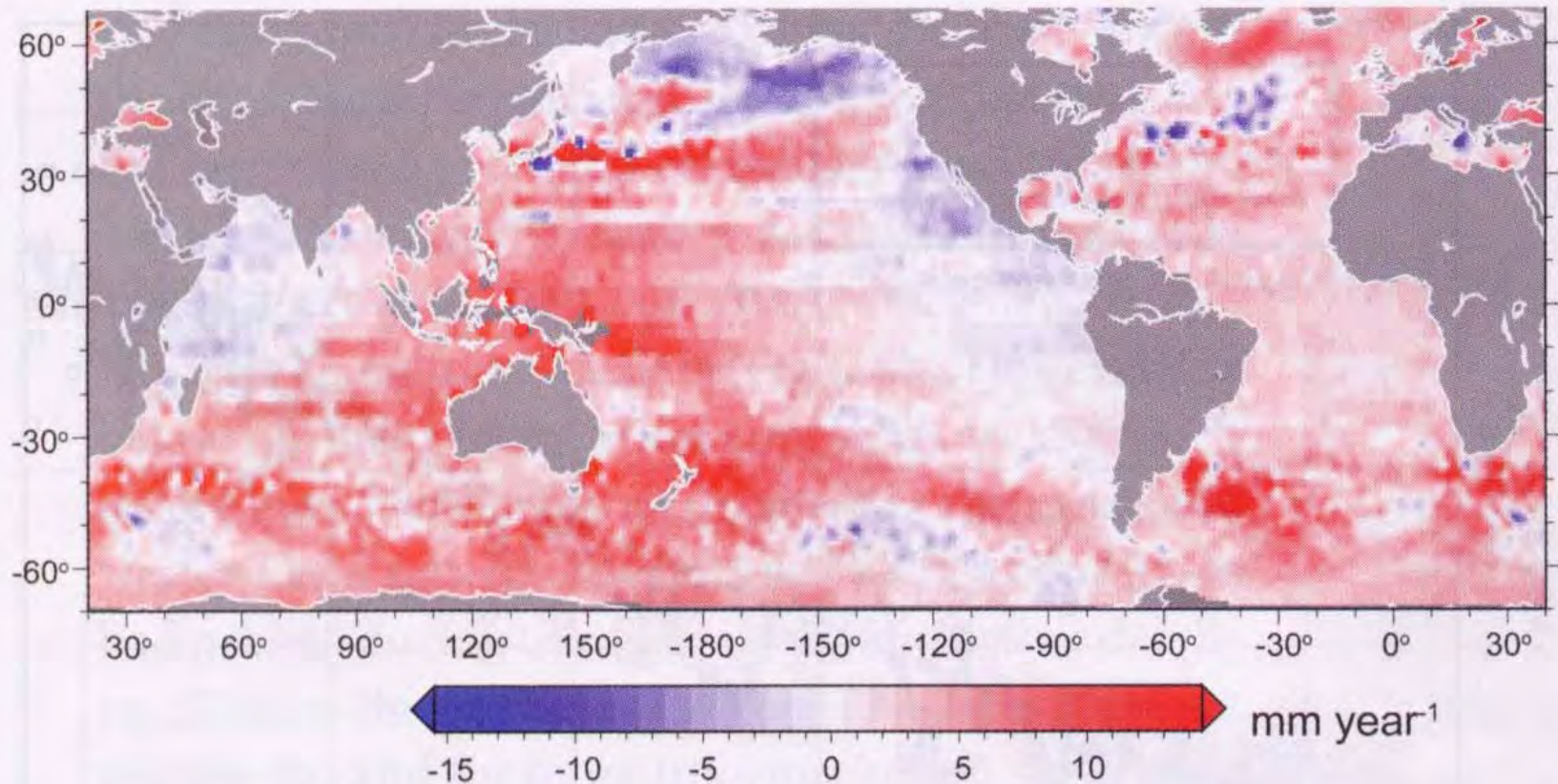


FIG. 2.11. Sea level trends over the period 1993–2004 determined from TOPEX and Jason-1 satellite altimeter observations. The global mean of this map gives the 2.8 mm yr⁻¹ value shown in Fig. 2.10.

Sea-level rise will flood coastal cities

- Current sea-level rise 1ft/century
- Expected 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

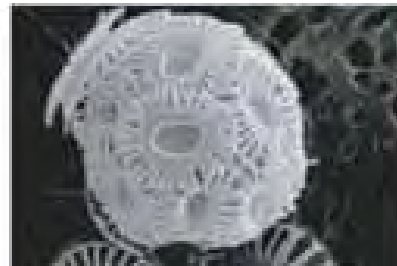
Rising ocean acidity threatens organisms



- 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]



Climate, energy, water and carbon dioxide linked

- CO₂ is low in atmosphere because of *Photosynthesis by plants***
- CO₂ + H₂O + sunlight (1%) → Carbohydrates + O₂
- *Respiration/metabolism*
- Carbohydrates + O₂ → CO₂ + H₂O + energy
- almost in balance – over millions of years, small conversion to fossil fuels: *Coal, oil, gas:*
- *Stored sunlight, concentrated energy*

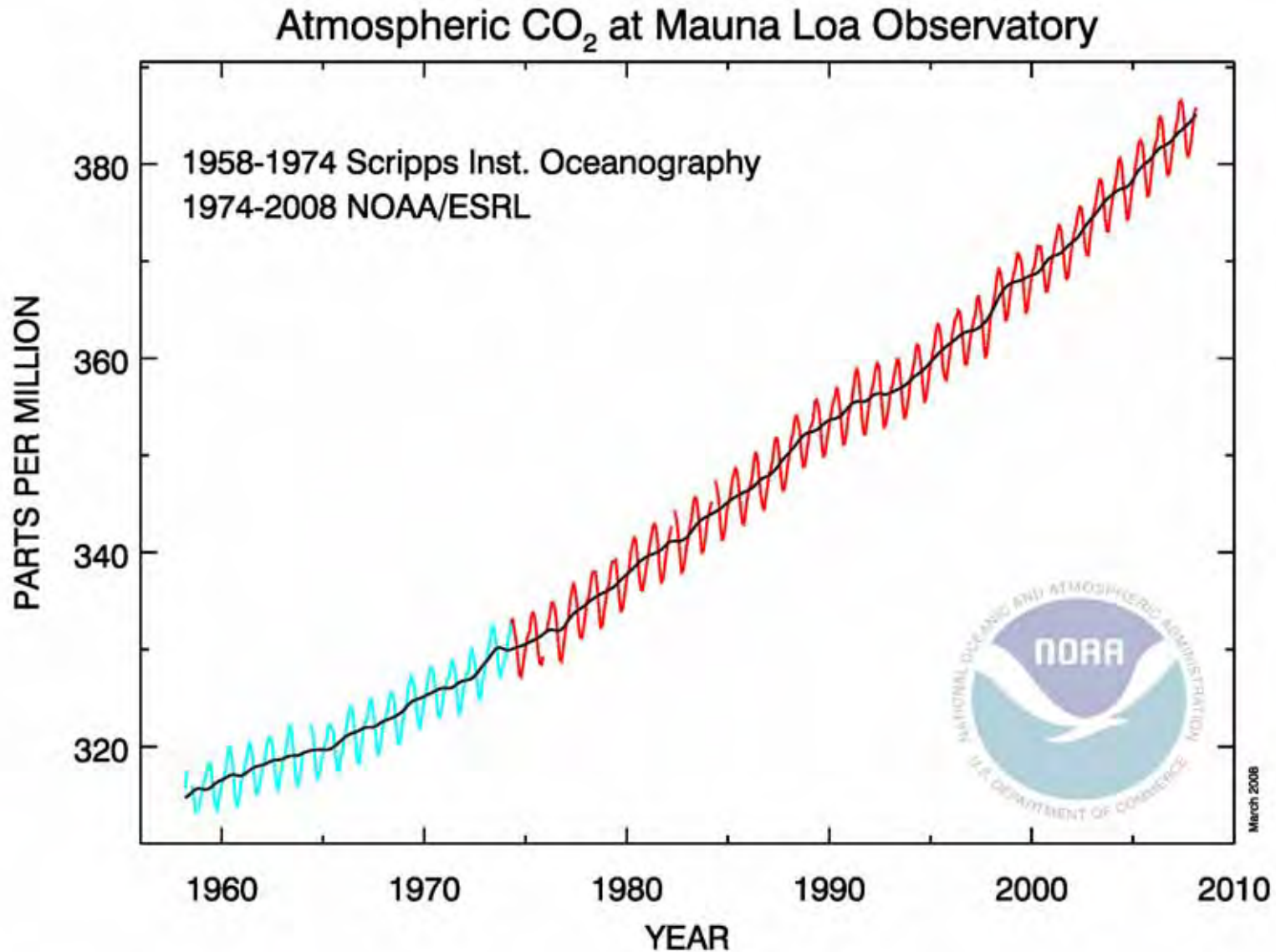
** *and carbon sequestration in the oceans*

Photosynthesis: northern summer



- Leaves use **red light** to soak up carbon dioxide and grow. They give off oxygen.

Carbon dioxide is increasing



Burning fossil fuels upsets the balance



- **Half this ‘fossil’ carbon dioxide stays in the atmosphere for centuries**
- **This has upset the energy balance of the earth, increasing the ‘*greenhouse blanket*’**
- **So earth will get warmer, *as long as we burn fossil fuels [coal, oil and gas] at present rate***

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:

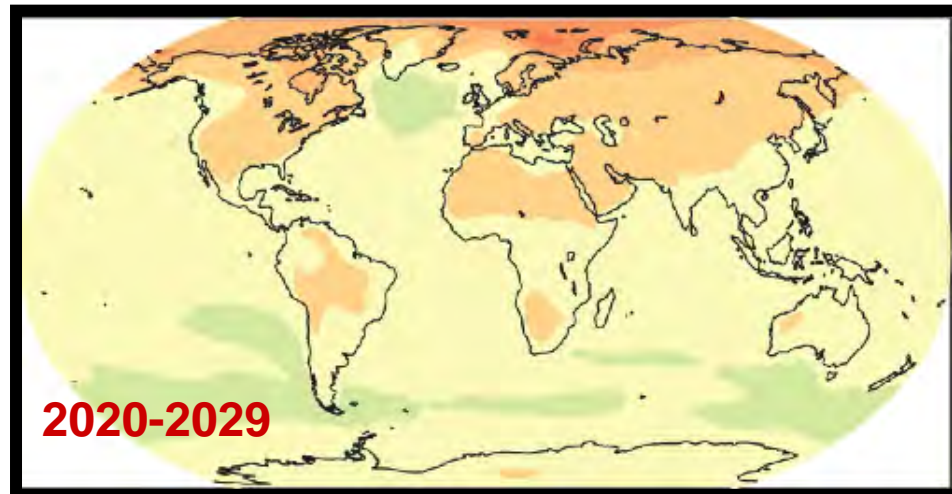
- NH Snow extent
- Arctic sea ice
- Glaciers
- Ocean pH [increasing acidity]

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



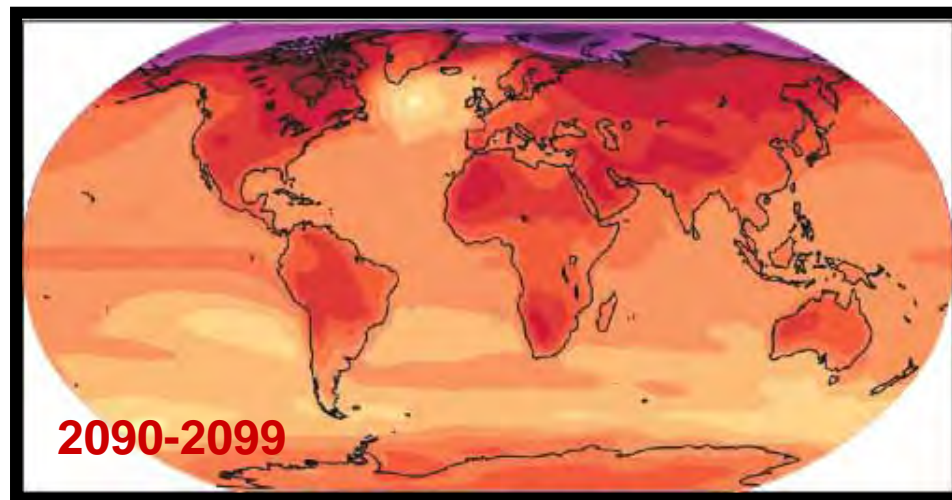
Multi-model Predicted Percent Change in Temperature (2020-2029 and 2090-2090 relative to 1980-1999) [°C]

'Committed'



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

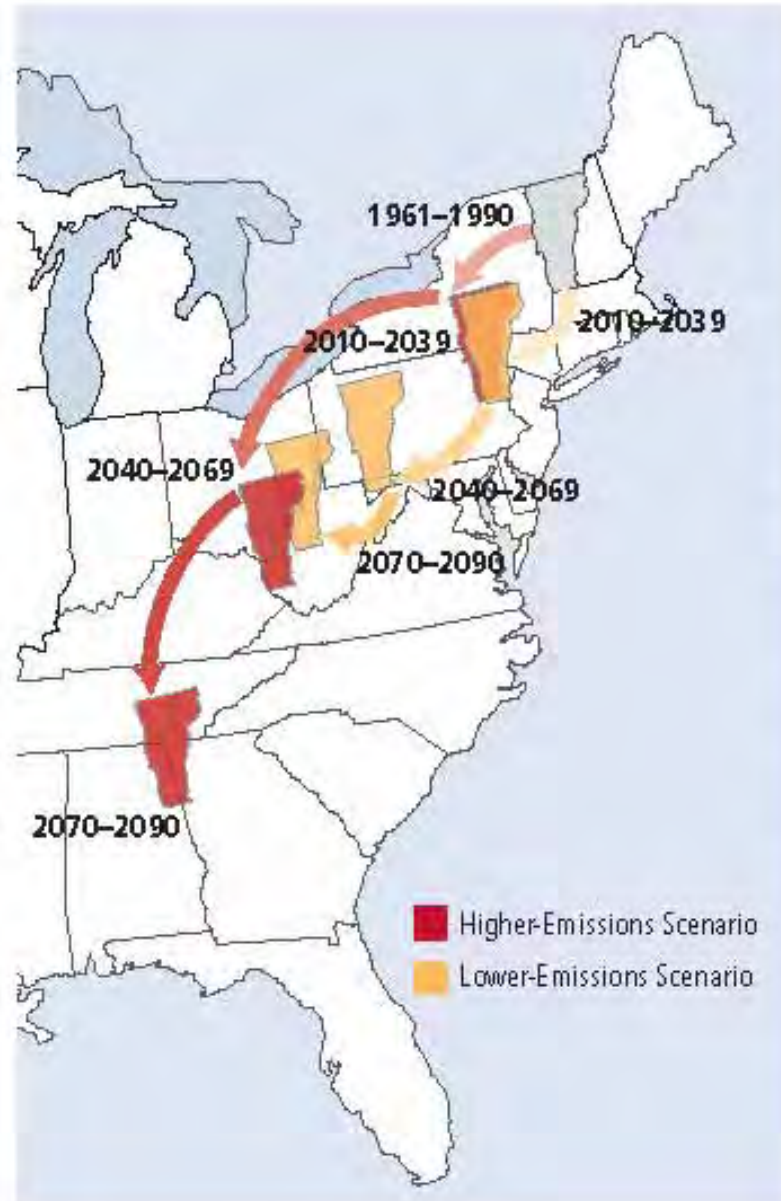
Still up to us!



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



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.

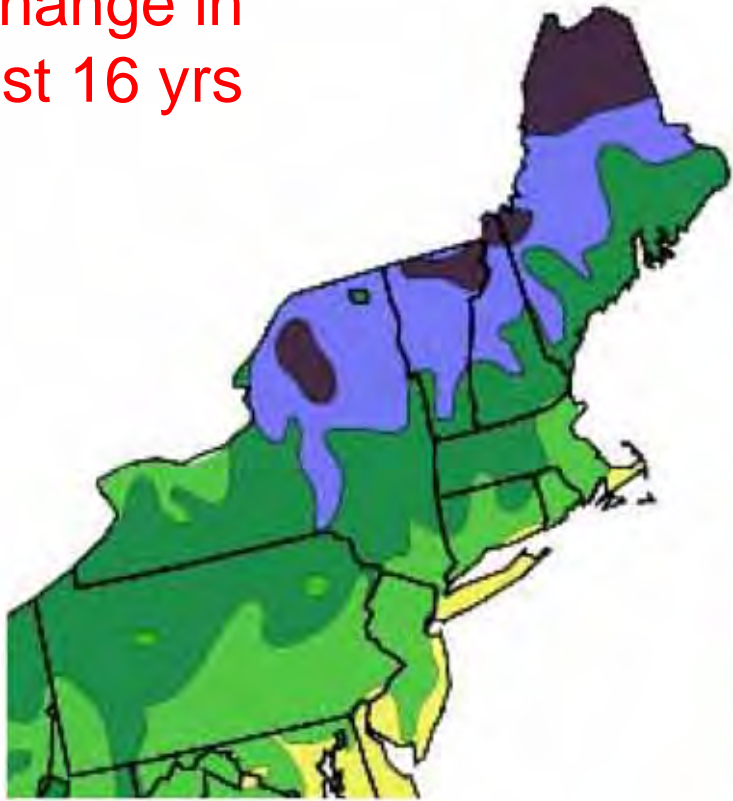
Red is high emissions

What about the tropics?

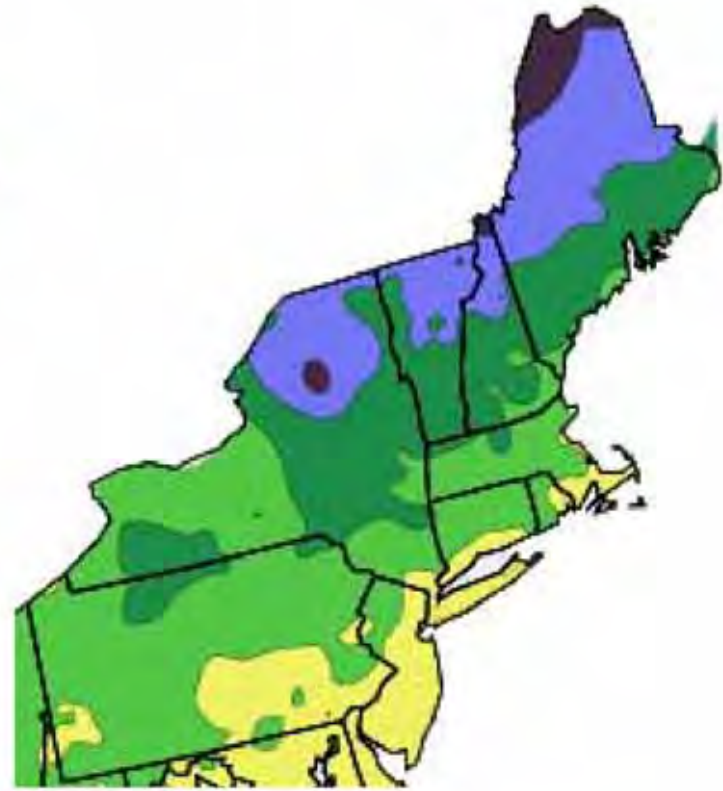
NECIA, 2007

USDA Hardiness Zones - Northeast

Change in
last 16 yrs



1990



2006

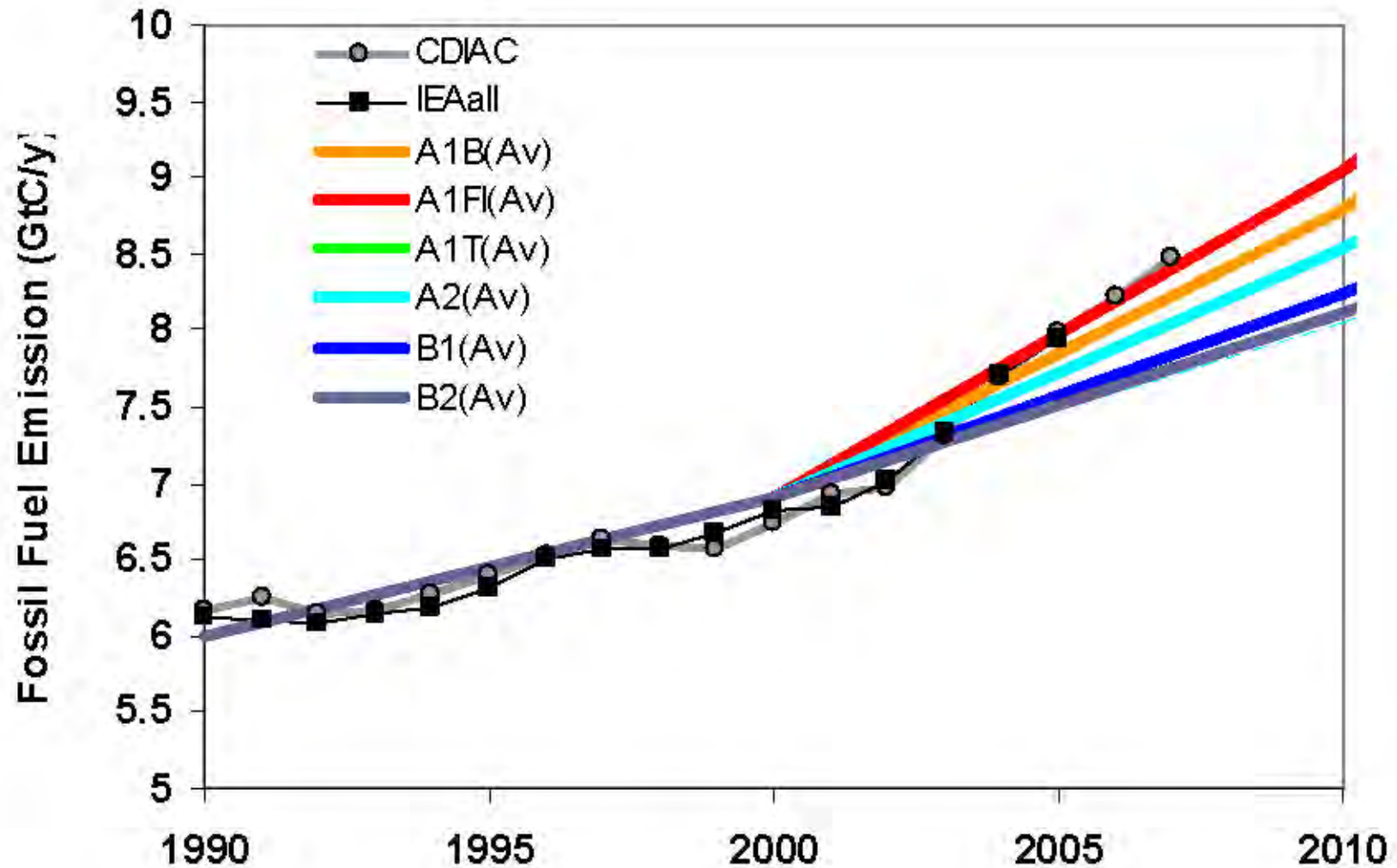
Zone



USDA Hardiness Zones

Trajectory of Global Fossil Fuel Emissions

(Raupach et al. 2007, Global Carbon Project 2008)



**2000-2007 growth in C emissions was 3.3%
- above the highest fossil fuel intensive IPCC scenario)**

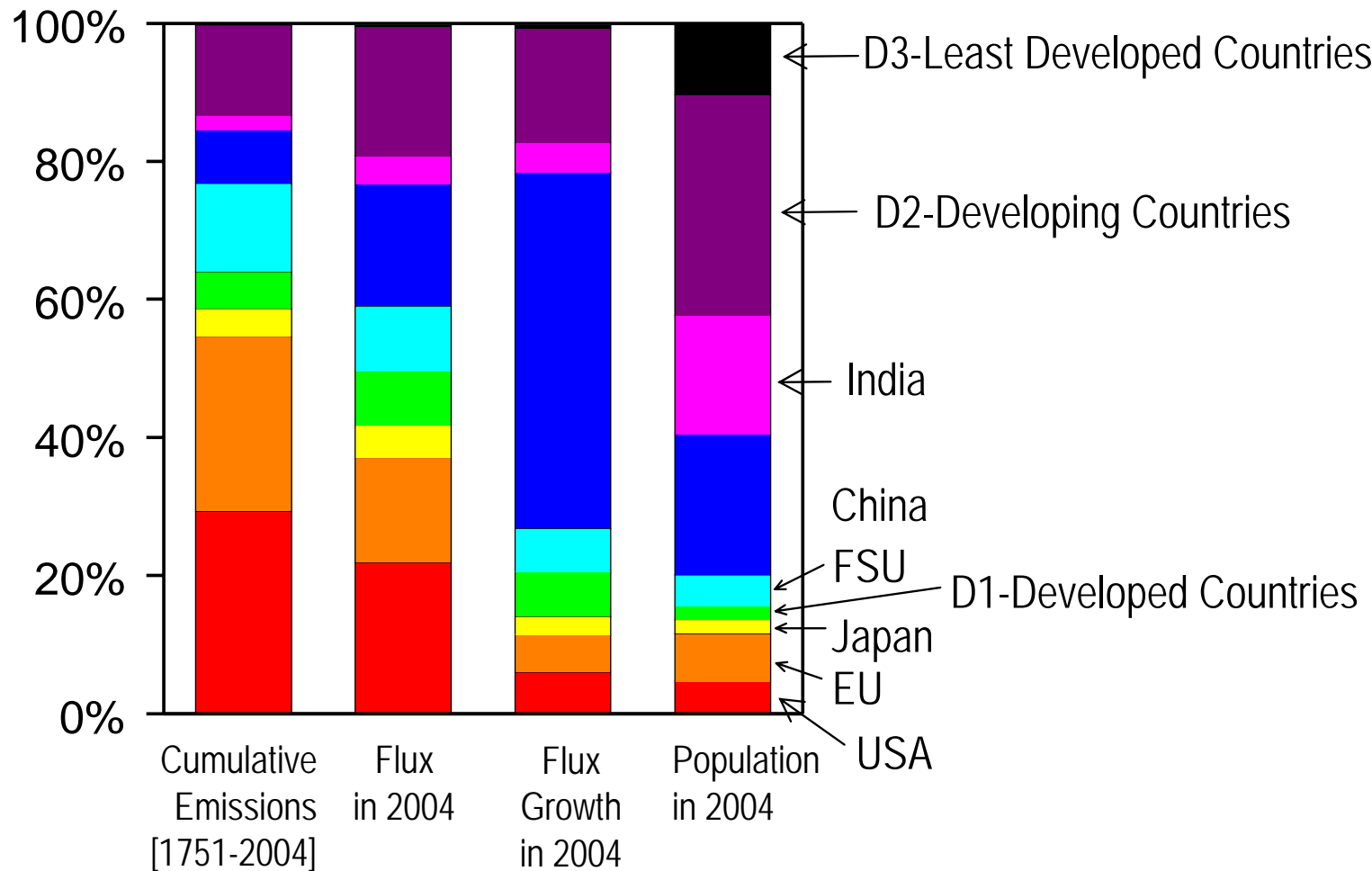
Our responsibility for future of the Earth



- **Discovery of fossil fuels drove the industrial revolution**
- **Current problem arises because our technology is having a global impact on the natural world**
- *As long as we burn fossil fuels [coal, oil and gas] at present rate, the earth will be driven 'rapidly' towards a warmer state*
 - *the climate system has many instabilities*
 - *ecosystems are vulnerable*



Regional Share of Fossil Fuel Emissions

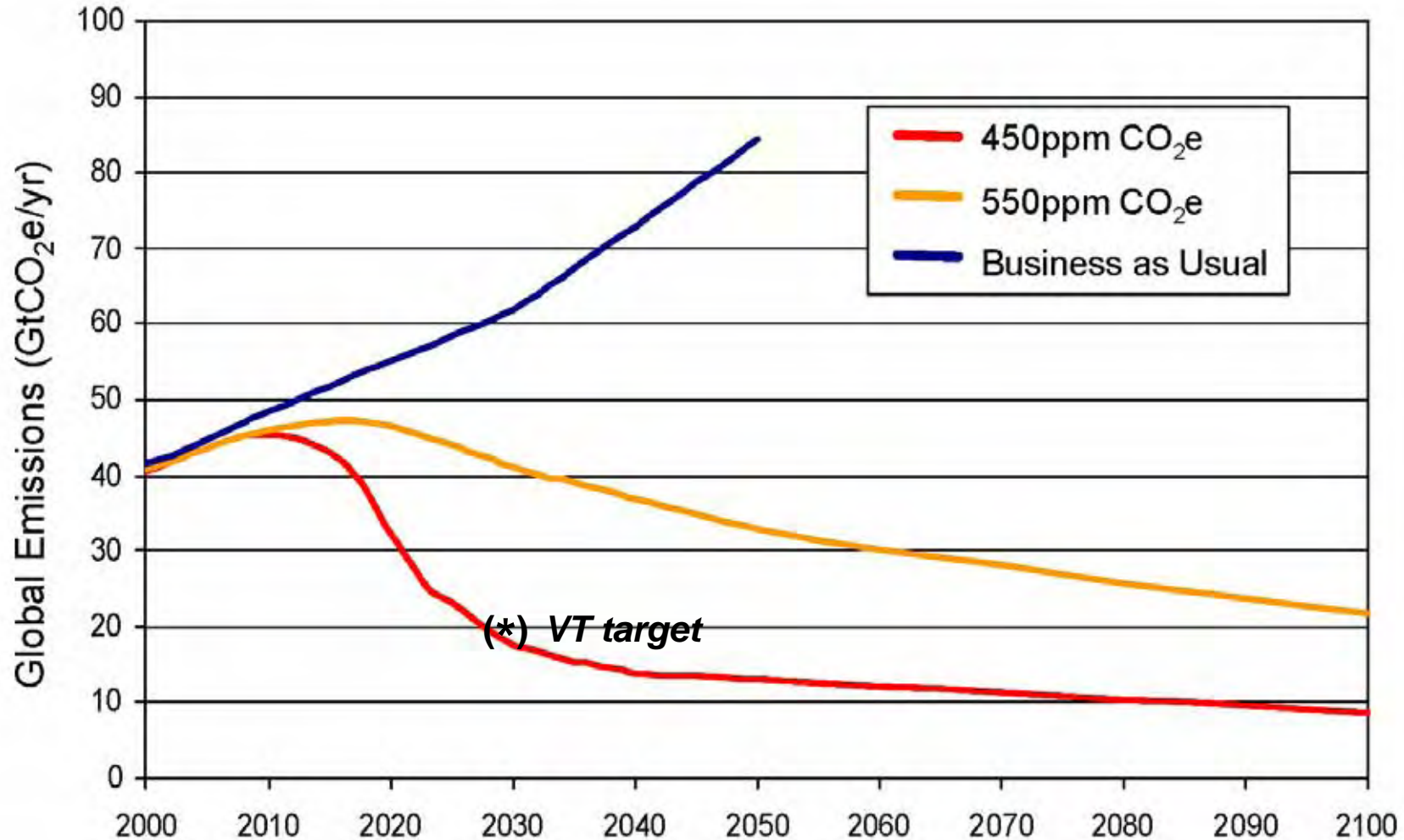


Developed countries produced 75% of cumulative emissions

- Others will suffer the most from climate change

How do we avoid 'Dangerous Climate Change'?

Emissions Paths to Stabilisation [Stern, 2006]



Climate Change is a huge challenge for humanity



- **Current problem arises because our technology is having a global impact on the natural world**
- **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*

Climate Neutrality?

- **We know what we need**
 - **Energy-efficient society**
 - **Energy sources renewable: not fossil**
- **What are the obstacles?**
- **Why are we taking such a huge risk for this planet?**

Efficiency comes first

- **Need to double or triple our energy efficiency**
- **Cannot replace current fossil fuel use with biofuels & renewable energy**
- **Oil and gas reserves are limited, but coal reserves are sufficient to push CO₂ well above 1000ppm [*and in time melt ice-caps*]. Can we sequester CO₂?**

Wind to electricity

- Oregon-Washington



Cattle graze among turbines at the 300 MW Stateline wind park on the Oregon/Washington state border

- Germany
- *We need 1 million 3MW wind turbines, replacing electricity from coal*
- *3000 GW*

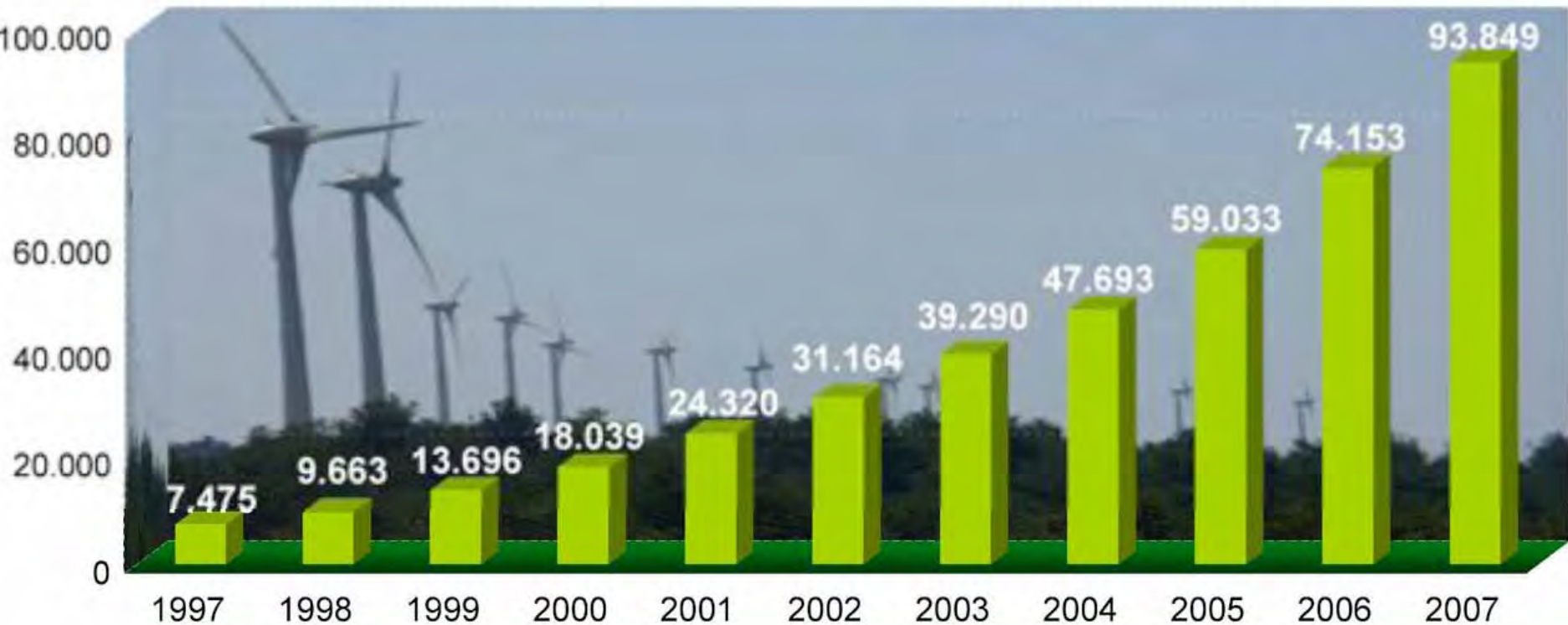


- 170GW by 2010

- 120GW end of 2008



World Wind Energy - Total Installed Capacity [MW] 1997-2007



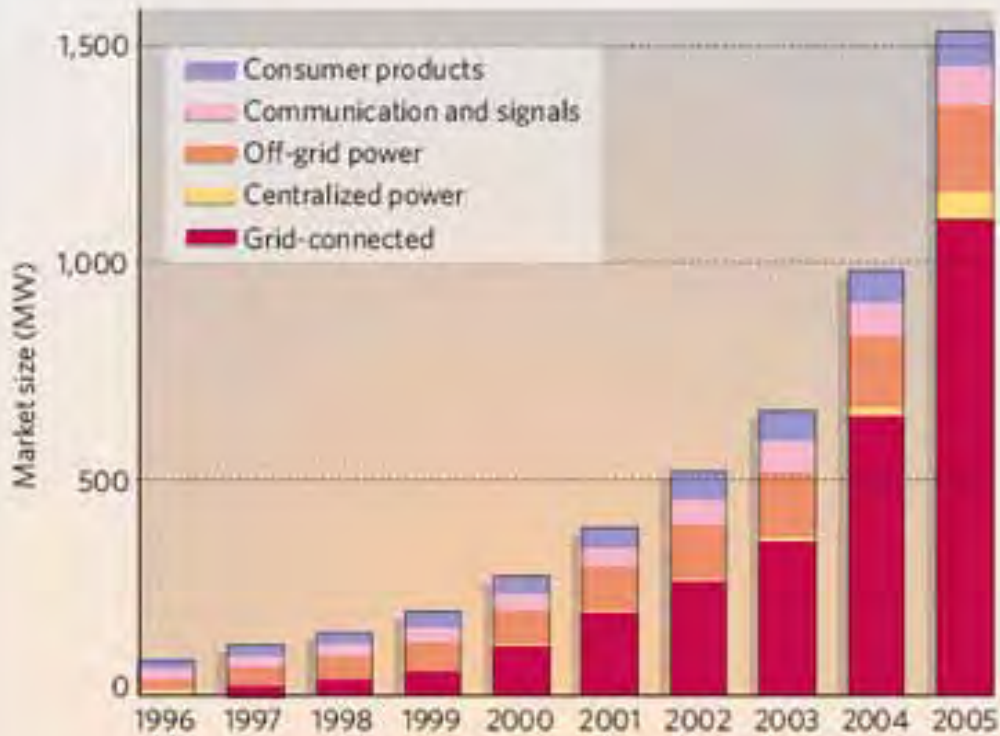
Wind: 30 percent/year growth rate over last ten years.

<http://www.earth-policy.org/Indicators/Wind/2006.htm>

Photovoltaic growth: > 30%/year

Daytime peak power

THE BOOM GOES ON



Right: **NRG Systems:** *Andy Schapiro,*

William Maclay Architects and Planners

NRG, Hinesburg

So what do we need?

- **Individual & societal understanding**
- **Local, State and Federal legislation to build an efficient society based on renewable energy**
- **Transforming infrastructure takes decades!**
- **Sustainable system** not “growth economy”
- *Yet despite the fiscal/economic crash; (almost) all want to return to “business as usual”!*
- *What would a sustainable society look like?*

Discussion of choices

- **What can society do?**
- **What can you and your families do?**
- they are all interconnected!
- *How do we make the transition?*

Vermont energy needs

Fuels for heating to replace oil/propane

- ***Much better building codes + housing retrofits***
- Wood/grass pellets for stoves, residential and commercial
- **District heating of towns with co-generation of electricity**

Liquid fuels for transportation

- ***More efficient autos and public/shared transportation***
- Biodiesel from algae/crops
- Ethanol from cellulose: perennial grasses, shrubs and wood

Renewable sources of electricity

- ***More efficient use of electricity: OFF unless needed!***
- Woodchips for power plants
- Wind-power and hydroelectric power
- Methane from manure and landfills

Lifelong Learning!

- “Knowledge”, values & assumptions are intertwined
- **You know what society used to believe!**
- **Study why it is not sustainable!**
- *How do we transition to a sustainable system?*
- *How do we sidestep entrenched beliefs?*

Honest information is essential

- Until recently US media pretended that climate change was still in doubt! For 10+ years, political and economic ideologies have trumped the science using deceptive propaganda.
- **Few have grasped how deep the issue really is and what it means for the global economy**

(Self)-deception is still an issue

- *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”** 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

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What is this?

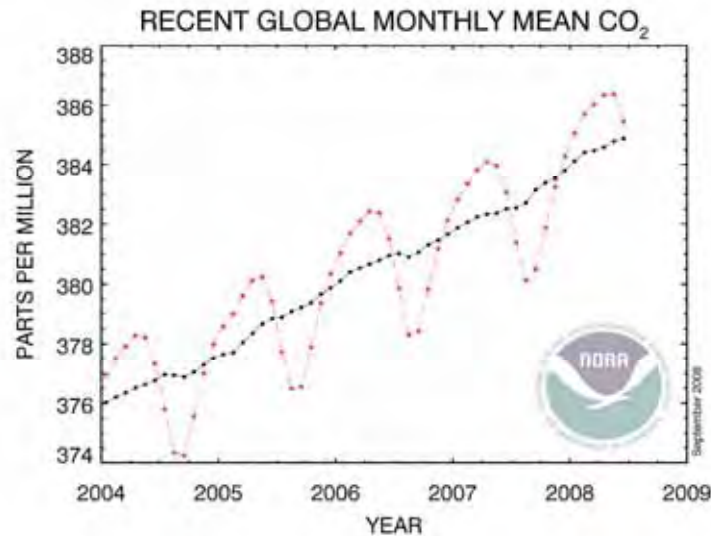


Where should Rutland go from here?

- **Discussion**
- **RRPC Energy Committee website**
<http://rrpcenergy.blogspot.com>.

Atmospheric CO₂ Concentration

Year 2007
Atmospheric CO₂
concentration:
383 ppm
37% above pre-industrial



1970 – 1979: 1.3 ppm y⁻¹

1980 – 1989: 1.6 ppm y⁻¹

1990 – 1999: 1.5 ppm y⁻¹

2000 - 2007: **2.0 ppm y⁻¹**

2007: **2.2 ppm y⁻¹**



- **Strengths of science:**

- integrity, honesty and communication
- *particularly valuable in a society lost in ignorance and deceit*

- **Limits of science:**

- tangible, measurable and communicable
- *hard to deal with the complexity and interconnectedness of the living natural world*

‘Anti-global warming’ tactics in US

[delay, confuse and deny]

- Fabricate ‘data’ or cherry-pick the science for unsolved issues and ignore the big picture. ‘This disproves global warming’ *or* ‘Science isn’t resolved; we need more science.’
- Models can’t predict the future with certainty, so the models are ‘unreliable’, ‘can’t be trusted’. Given this uncertainty, *we cannot be held responsible for the future.*
- If climate change were real, it would require collective government regulation of the ‘free market’, which we opposed; so *climate change must be a ‘hoax/conspiracy’*
- *It is too costly to make structural changes to our society, and it would affect profit margins.*
- [We will wait till China and India take action]
- [The poor in Africa need energy]

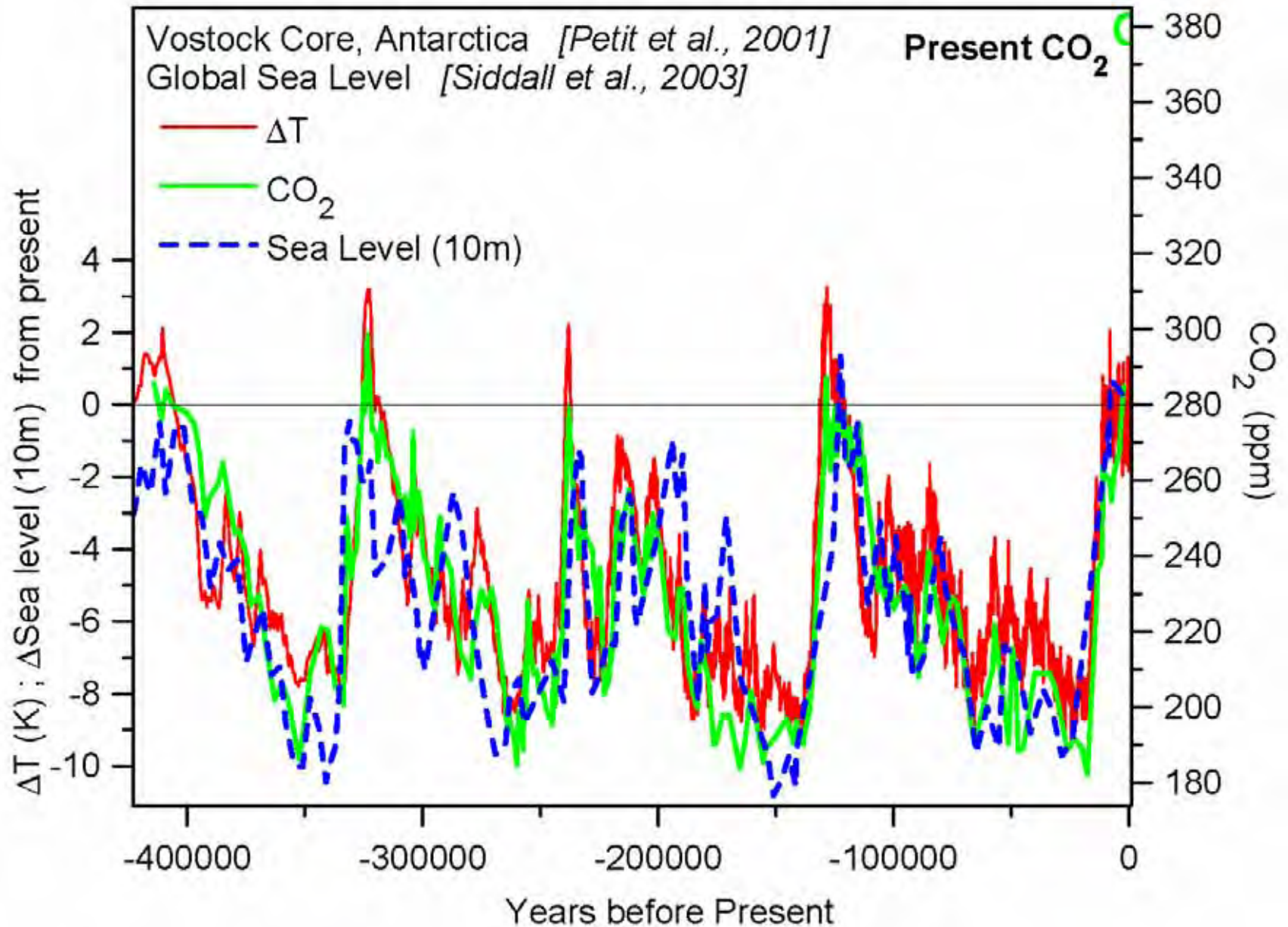
What do we know from past?

- **Reconstruct past climate**
- Ice core history: T, CO₂, CH₄ through many ice-ages - nearly a million years
- Ocean sediments
- Tree rings – a few thousand years

Ice-core history!



Last four ice-age cycles



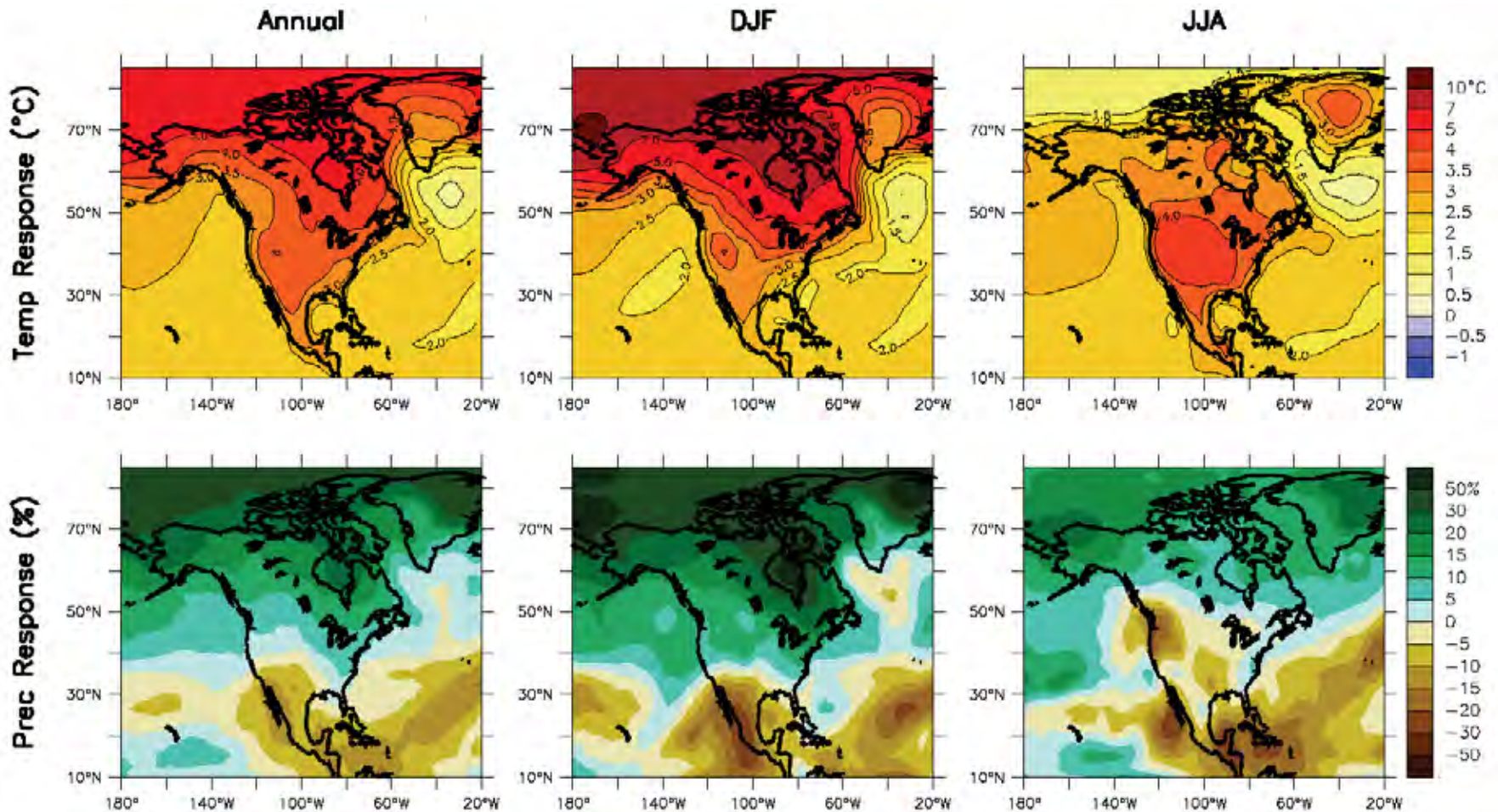
My background:

Nottingham High School

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



North American Changes: T, Precip.



- Temperature and precipitation changes over North America from an average of 21 AOGCM projections for A1B (high emission) scenarios.
- Top row: Annual mean, winter (DJF) and summer (JJA) temperature change between 1980 to 1999 and 2080 to 2099. [VT winter: 4.5C, 8F]
- Bottom row: same as top, but for fractional change in precipitation. [VT winter: 25%]

What will this mean for society?

- *Traumatic change for industrial societies:*
 - *the end of cheap fossil fuel and its waste*
 - *the end of the throw-away 'growth' economy*
- Need to transform infrastructure in 1-2 decades
- **To an efficient one** *[more efficient cars & industry, efficient use of electricity, better insulated buildings]*
- **Development of renewable energy economy**
[Wood/cellulose/sugar to fuels; algae to biodiesel; wind; solar; hydro; management of forests and land]
- **Costs will be significant** *but far less than the cost of doing nothing, and far less than the military/oil option, and less than the many stimulus packages!*

What will this mean for us?

- *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
- **Societal changes are needed** at all levels: from individuals to towns to global
- *[Unregulated globalization is unstable
- some relocalization of food; power; finance desirable]*
- **Ask: Is this an efficient and sustainable way of doing this?**

Honest information is essential

- Until recently US media pretended that climate change was still in doubt! For 10+ years, political and economic ideologies have trumped the science using deceptive propaganda.

[Nobel prize to the IPCC & Al Gore made a difference]

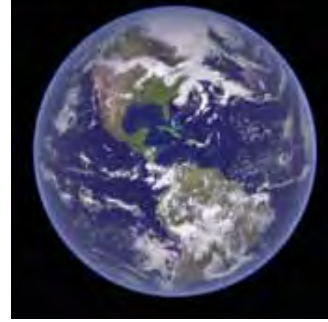
- Yes, it is complex. There are uncertainties as to exactly what will happen and when

[since the earth system and human behavior are complex]

but the direction, likely magnitude and cause of 'global warming' is clear

- Few have grasped how deep the issue really is and what it means for the global economy

The reality we face



- Competition for resources: water, food & energy.
- Fossil energy is transforming the earth and stressing its ecosystems: current path means loss of 30% of species and 100 millions of environmental refugees
- **Efficient society, based on renewable energy is the only solution: huge transformation; but technically possible at reasonable cost**
- **It will take honesty, courage, compassion and decades of sustained effort, starting now**

Human system issues

- **Human responsibility for planet's future**
- Fossil vs. renewable energy choices
- **Interdependence of energy, food and water**
- Relocalization vs. globalization
- Economic and financial system regulation
- Economic growth vs sustainability



Resources [Alan Betts' talk]

For science:

- www.realclimate.org for discussion/debate by scientists
- <http://www.climatewatch.org/> tracks govt. honesty
- *Jim Hansen's papers: archive at*
- <http://www.columbia.edu/~jeh1/>
- http://www.columbia.edu/~jeh1/case_for_vermont.pdf

Vermont Climate Change Commission :

- <http://www.vtclimatechange.us/>

Vermont Climate Action Network, VECAN

<http://www.vnrc.org/article/view/9452/1/625>

Vermont Earth Institute [<http://www.vtearthinstitute.org/>]