Global Climate Change

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"Global Warming below the Equator"
UNICAMP

November 12, 2008

Climate Change

- **One of the great challenges for this century**
- **What is happening?**
- **What are our choices?**

- **We are already decades late in taking action**

  - *Sawyer, Nature, 1972, Man-made CO_2 and the "greenhouse" effect*

  - *UN Framework Convention on Climate Change, 1992*

- ***Global issue: global agreements difficult!***

My background:

Nottingham High School

- Founded 1513

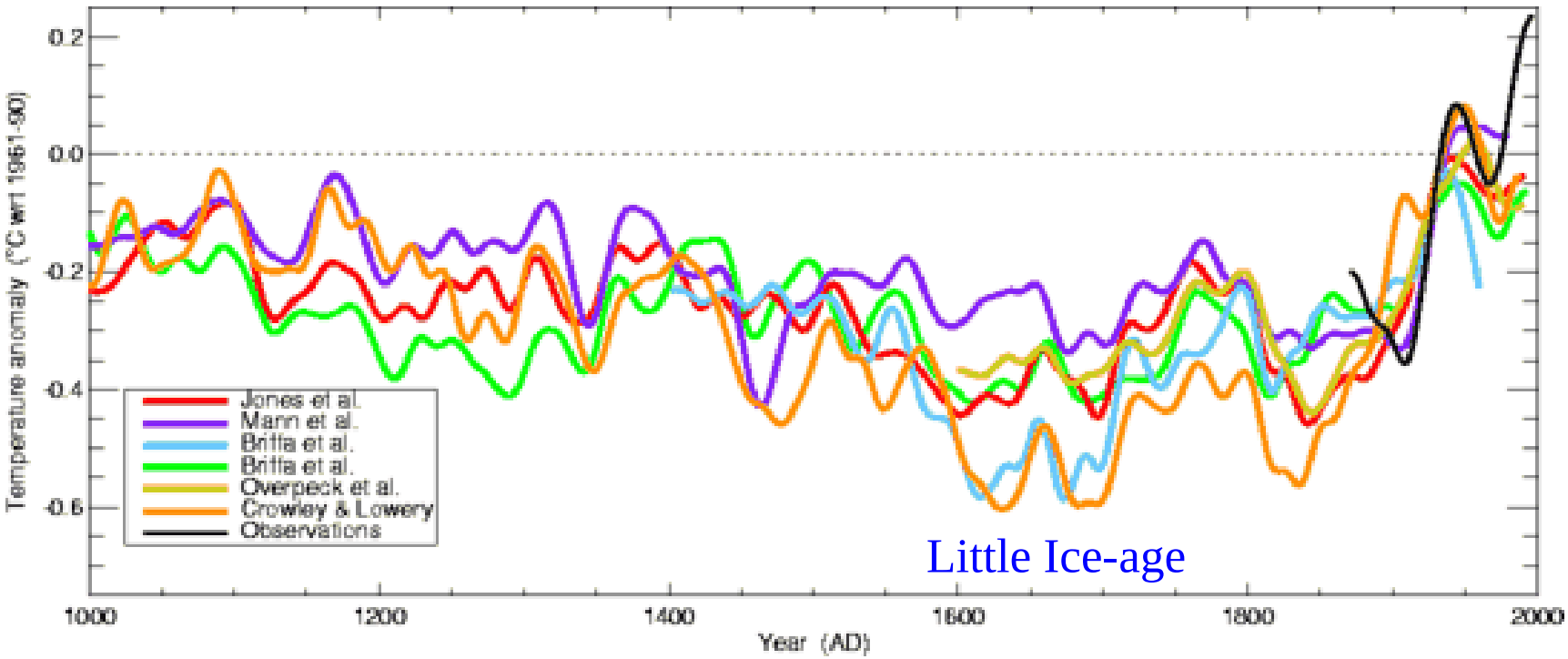
- *1550 heading into ‘little ice-age’*
- *1620 Pilgrim fathers face bitter winters*

Peterhouse, Cambridge

- Peterhouse, Cambridge: founded 1284

- *Medieval warm period; Vinland colony flourishes*

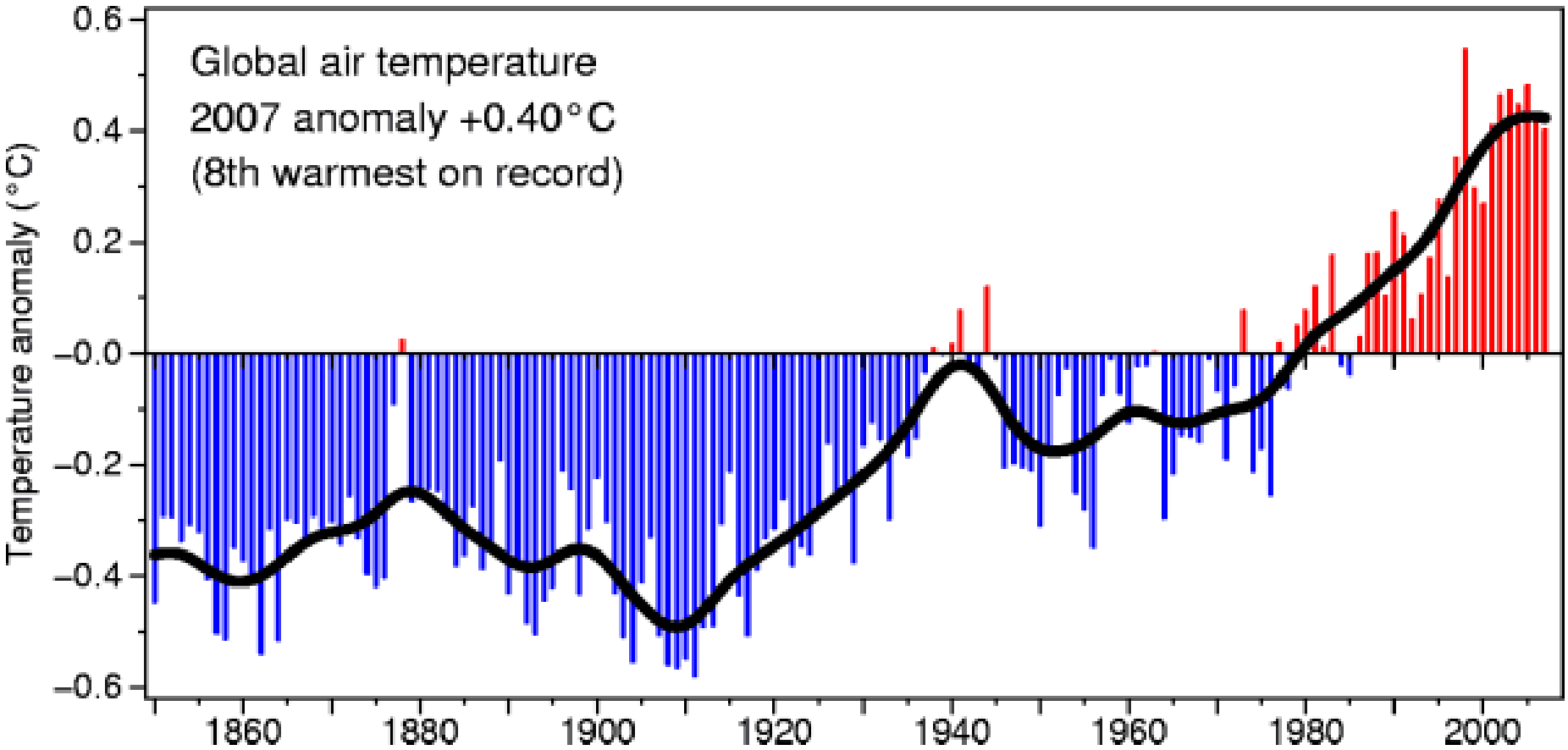
The Millennial Temperature Record



- 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'**

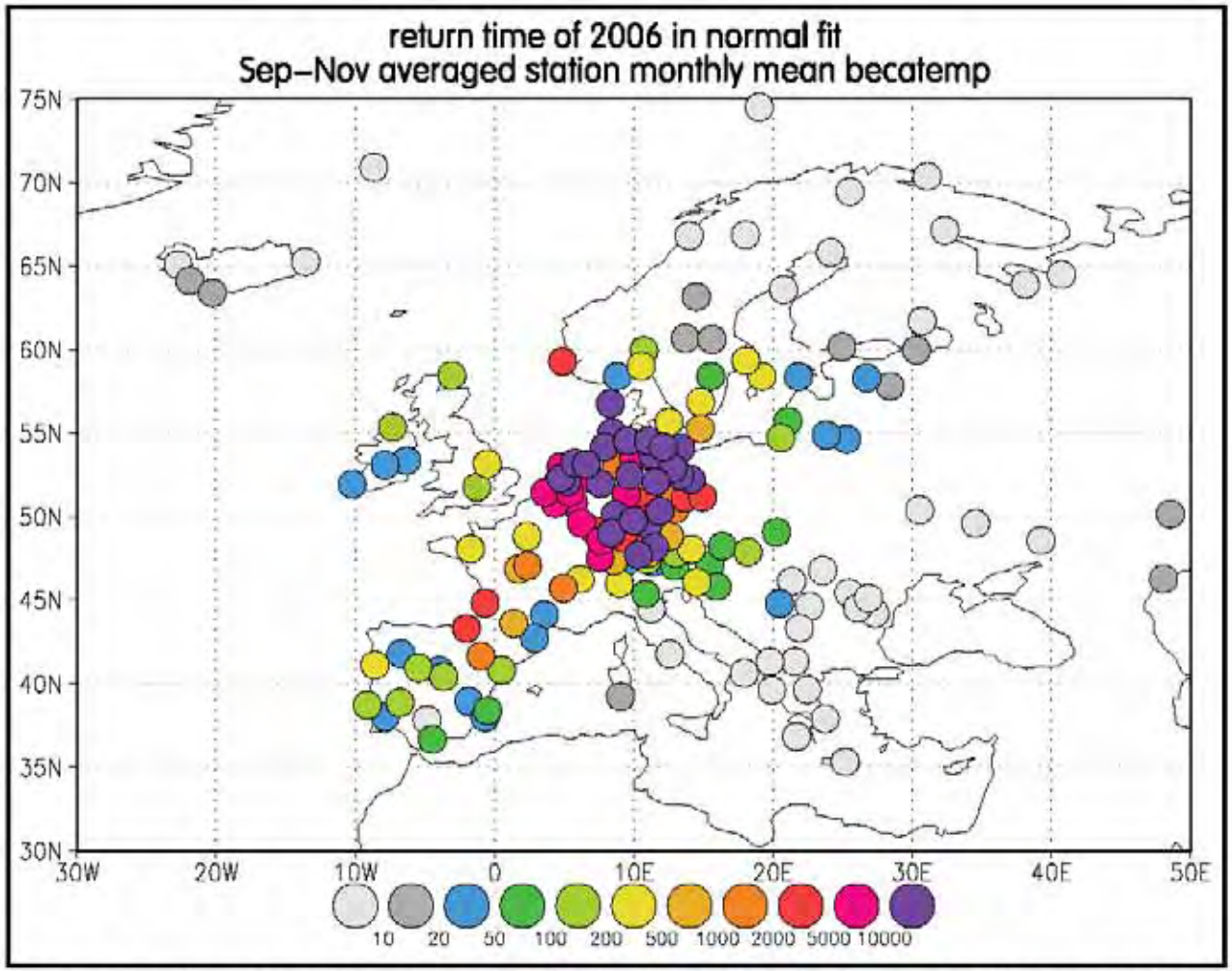
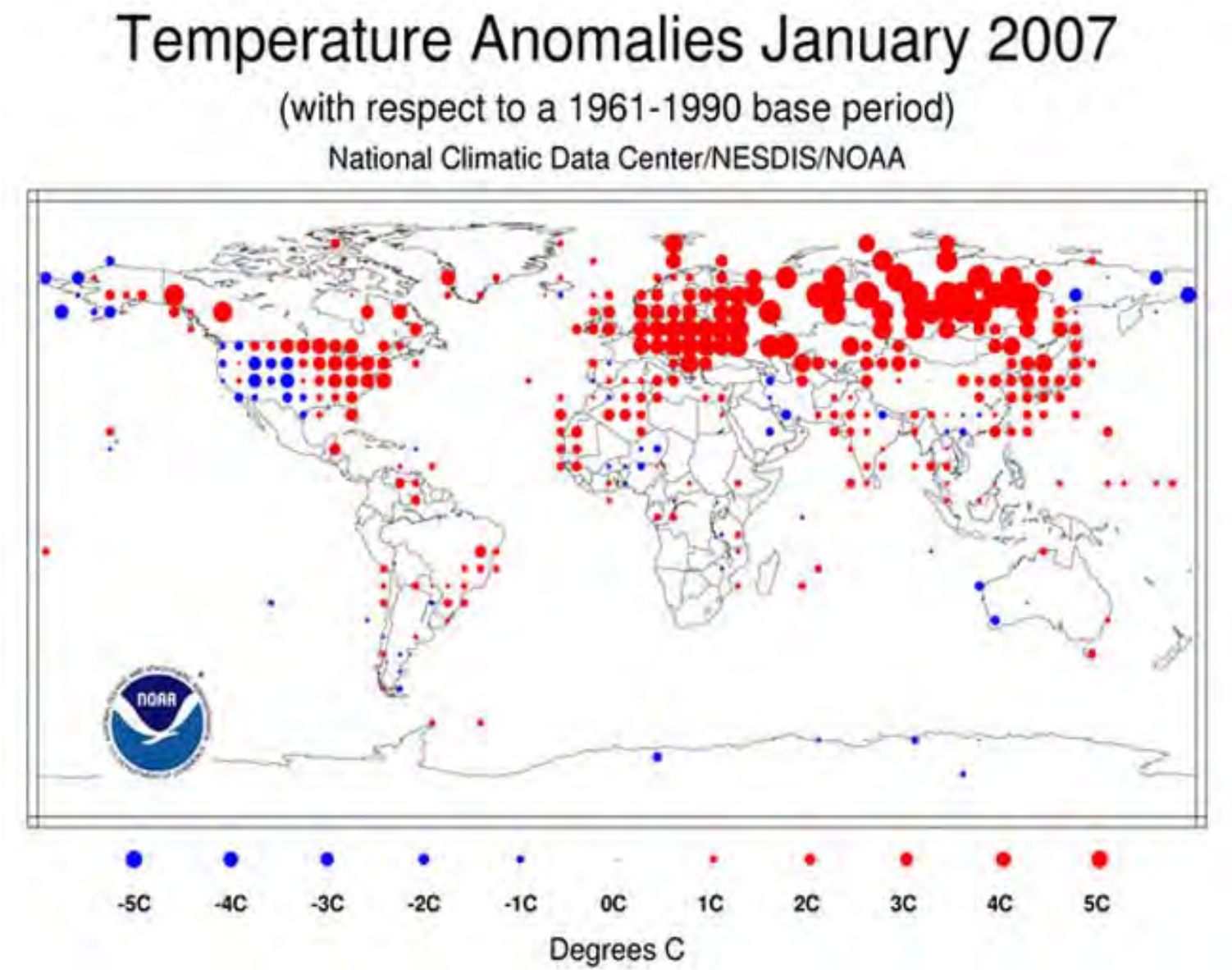


Figure 2. The return period of the autumn of 2006 at De Bilt, the Netherlands, computed from the distribution of the years 1901–2005 for all ECA&D stations with at least 40 years of data, using a Gaussian extrapolation (the GPD gives higher return periods).

January 2007 warmest on record

[Exceeded 2002 record over land by 0.8°F]



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 (CO_2) 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 CO_2

Earth system- critical issues

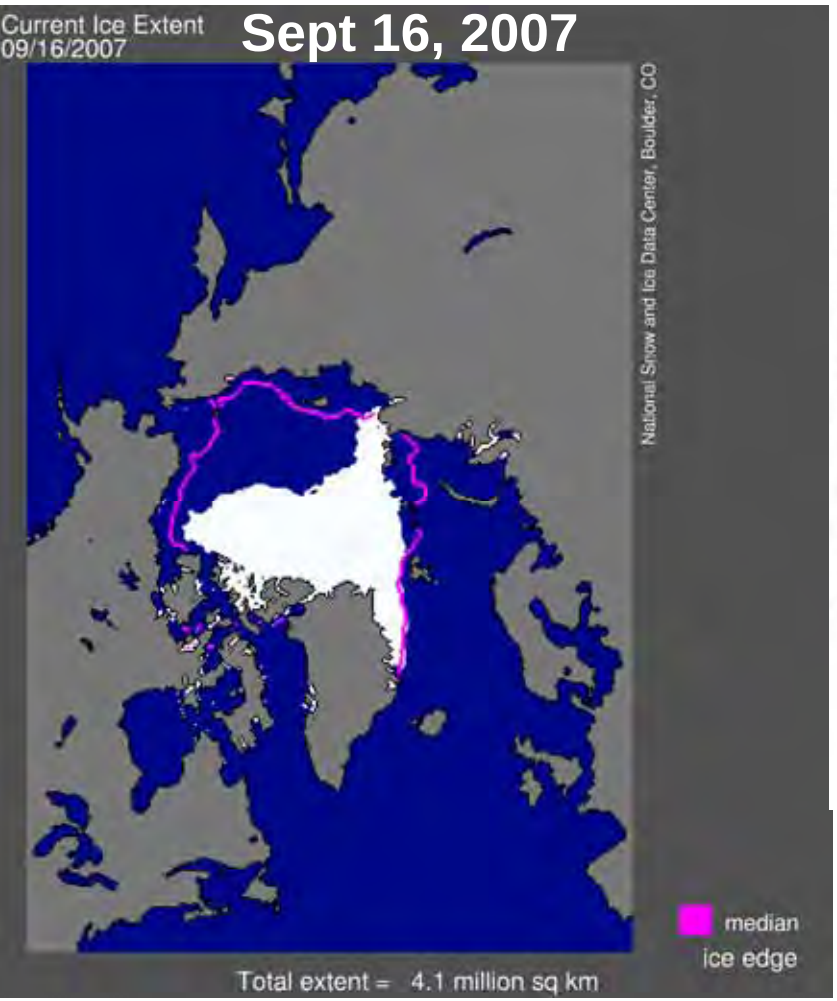
- **CO_2, H_2O, clouds & Greenhouse effect**
- **Ice-albedo feedback**
- **Ice-melt and sea-level**
- **Ocean acidification**
- Melting permafrost; tundra regrowth, CH_4
- Unstable feedbacks

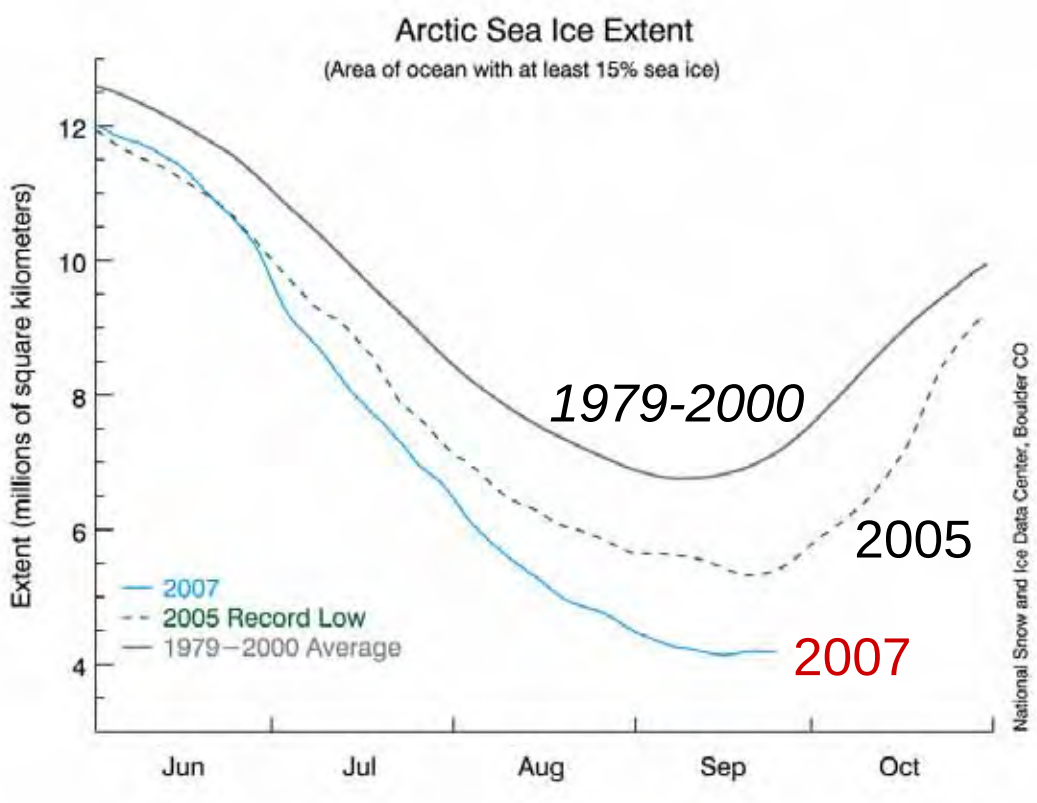
Atmosphere is transparent to ‘light’ but not to ‘infrared’ radiation

- **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 32^{o}C warmer - so oceans don’t freeze
- Increasing greenhouse gases are warming earth further: ≈ 3^{o}C 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)

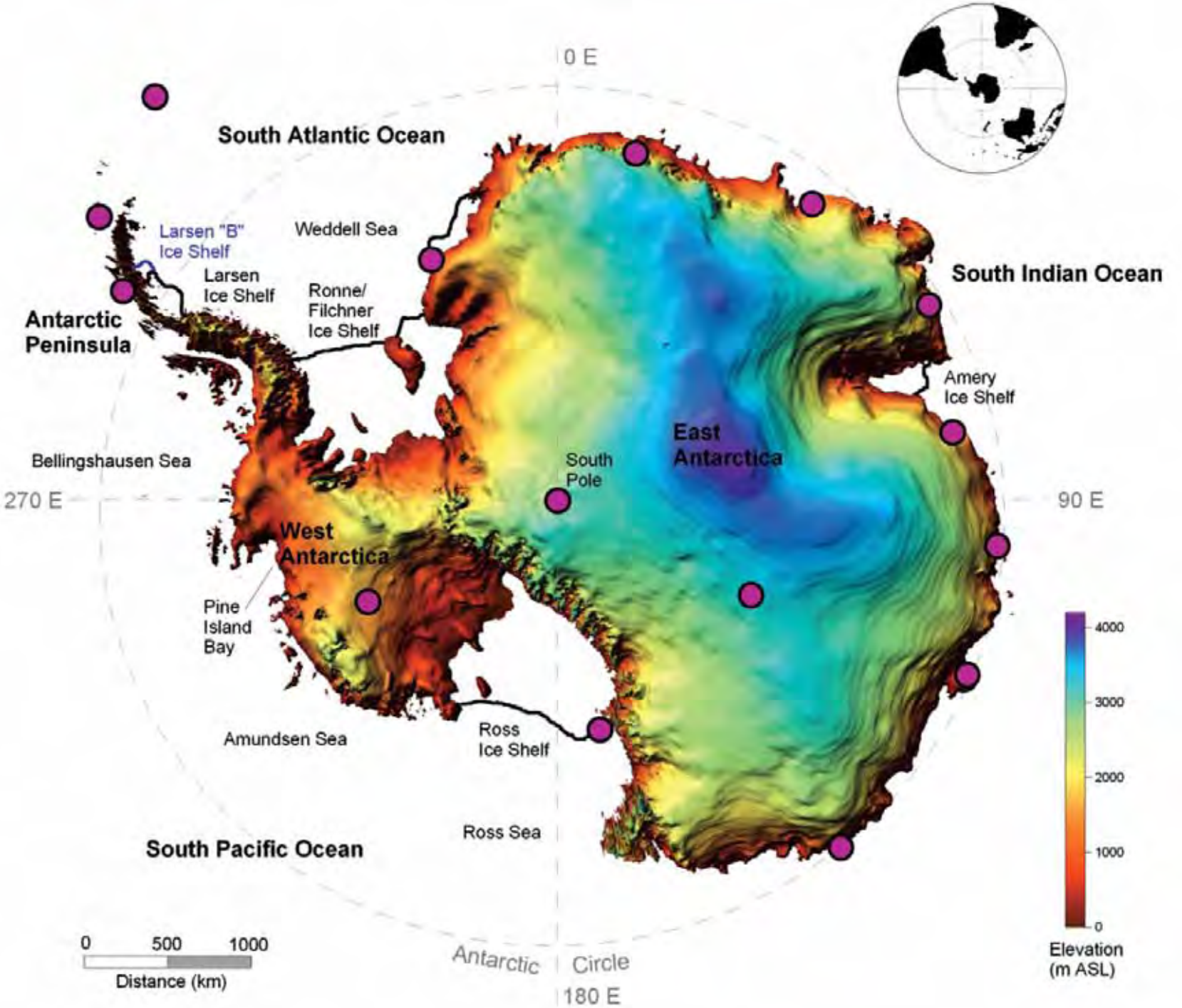
- 2007 saw new record ice-loss by huge margin
- 40% melted by September → warm Fall

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


0 E
South Atlantic Ocean
Larsen "B"
Ice Shelf
Weddell Sea
Larsen
Ice Shelf
Ronne/
Filchner
Ice Shelf
South Indian Ocean
Antarctic
Peninsula
Amery
Ice Shelf
East
Antarctica
Bellingshausen Sea
South
Pole
270 E
90 E
West
Antarctica
Pine
Island
Bay
Amundsen Sea
Ross
Ice Shelf
Ross Sea
South Pacific Ocean
0
500
1000
Distance (km)
Antarctic Circle
180 E
4000
3000
2000
1000
0
Elevation
(m ASL)

Ocean interactions melting Greenland and West Antarctica ice-sheets

Stored water: sea-level rise

Large latent heat:
ice-heat exchange

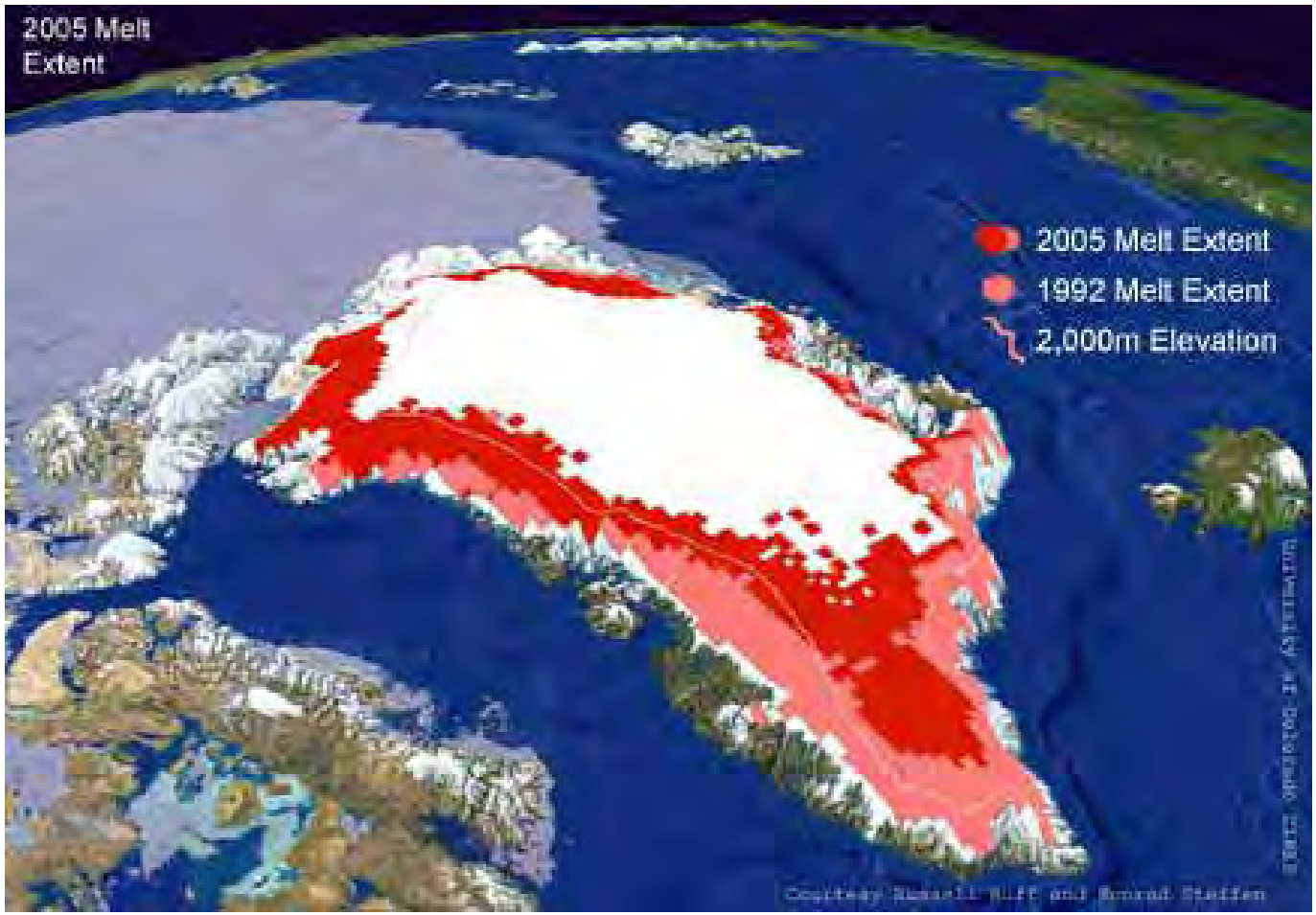
Melt mechanisms:

oceans, atmosphere

Ice coming off Jakobshavn Isbræ glacier surged after warm ocean water arrived.

- *DOI: 10.1126/science.322.5898.33*

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 1 m every 20 years for centuries with break-up of large ice-sheets

J. Hansen, Scientific American, March, 2004

[1+ m this century]

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

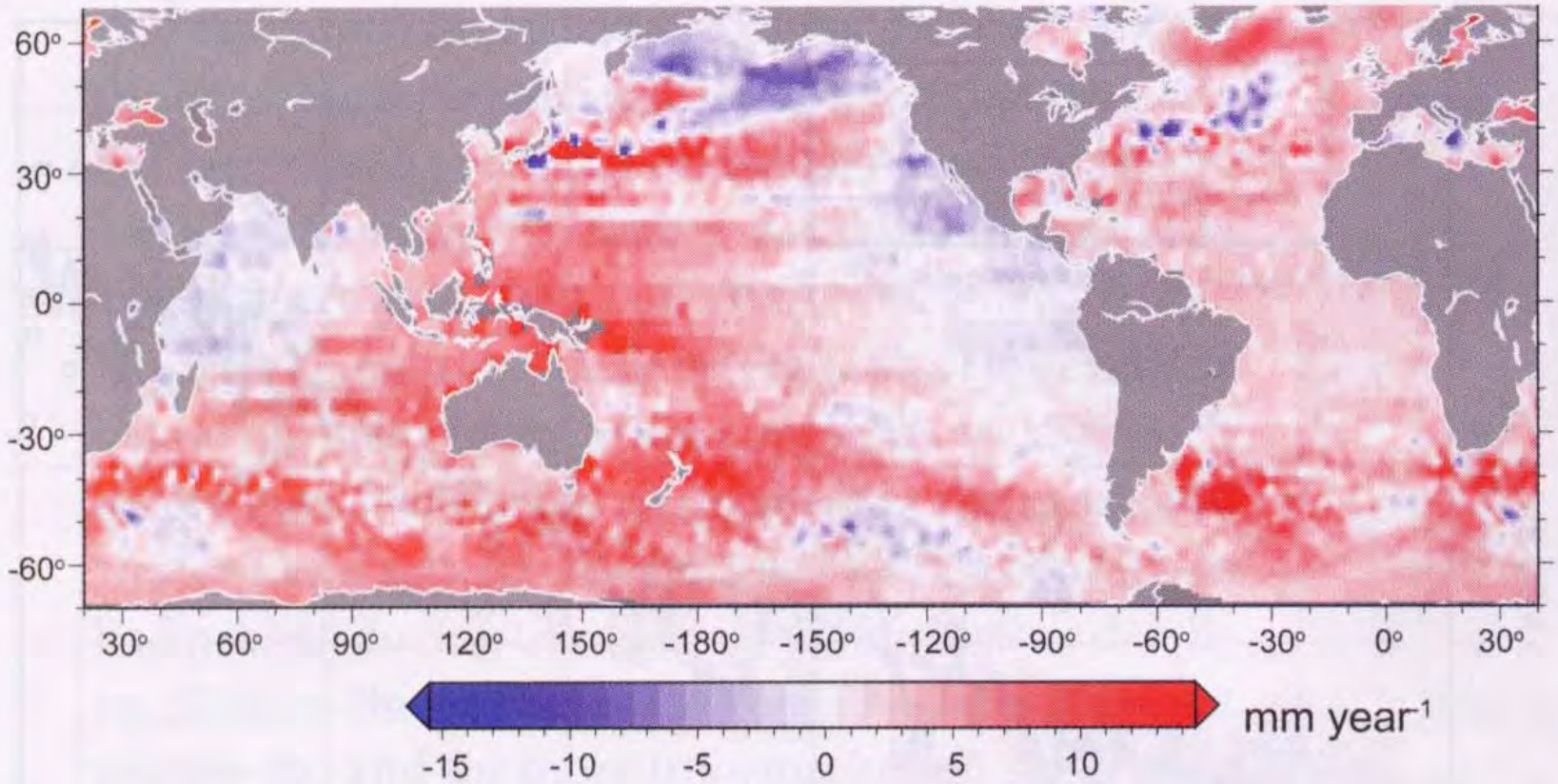


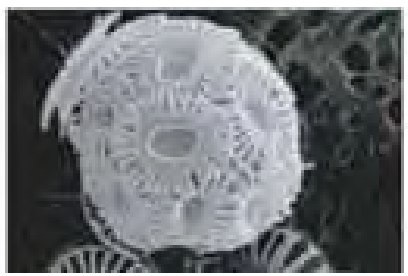
FIG. 2.11. Sea level trends over the period 1993–2004 determined from TOPEX and *Jason-1* satellite altimeter observations. The global mean of this map gives the 2.8 mm yr^{-1} value shown in Fig. 2.10.

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]



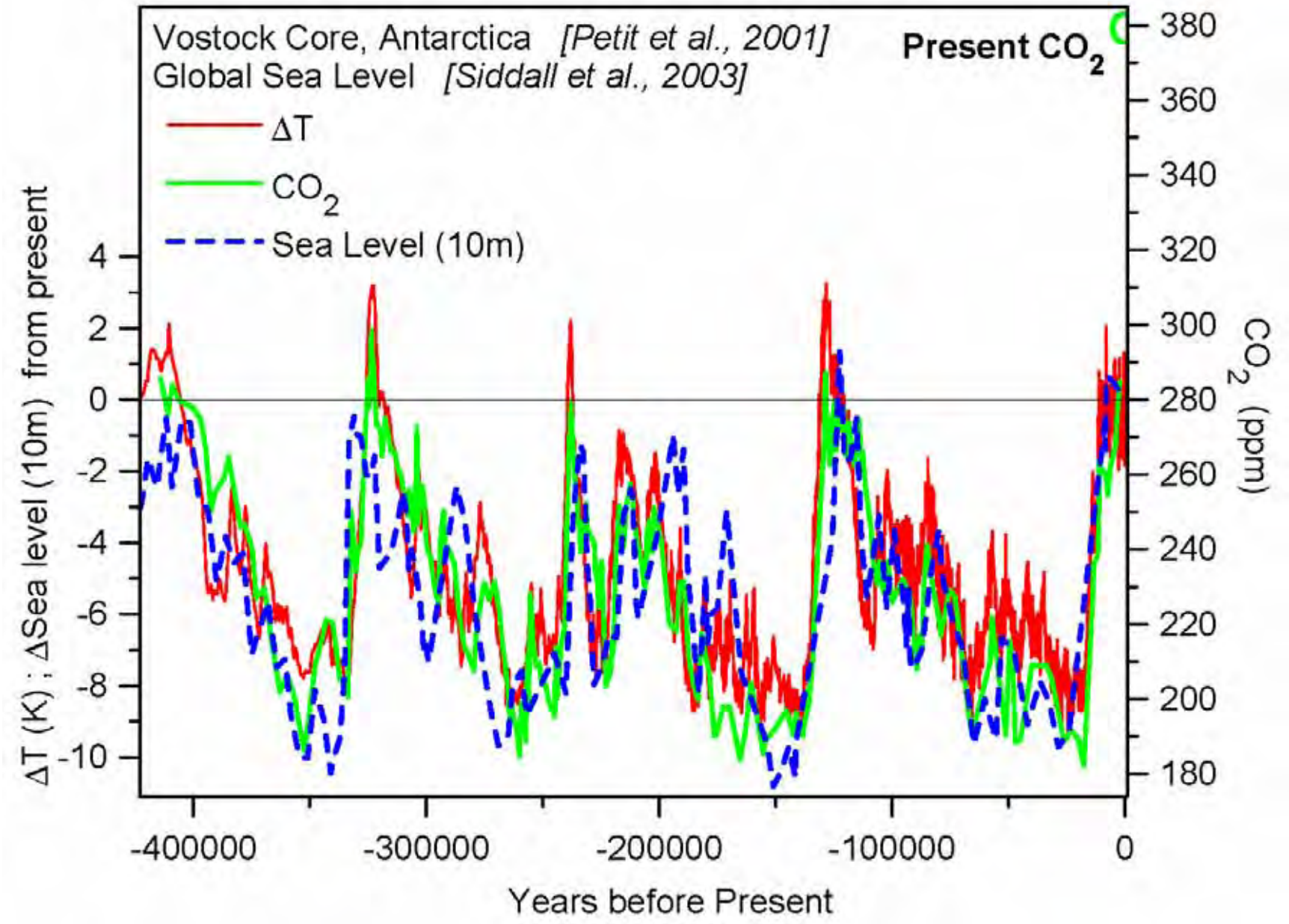
What do we know from past?

- **Reconstruct past climate**

- Ice core history: T, CO_2, CH_4 through many ice-ages - nearly a million years
- Ocean sediments
- Tree rings – a few thousand years

Ice-core history!

Last four ice-age cycles



Climate, energy, water and carbon dioxide linked

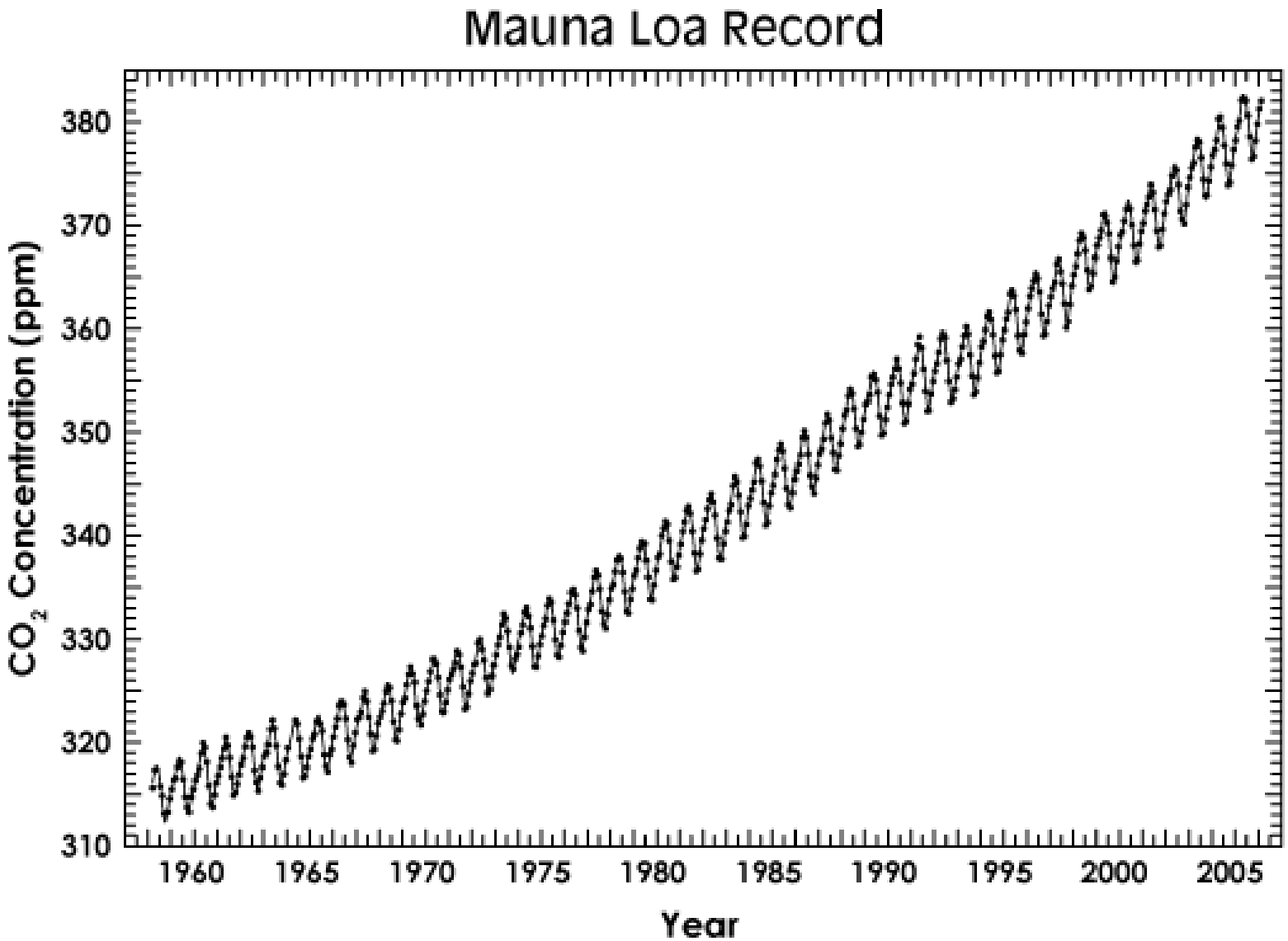
- CO_2 is low in atmosphere because of *Photosynthesis by plants***
- $CO_2 + H_2O +$ sunlight (1%) → Carbohydrates + O_2
- *Respiration/metabolism*
- Carbohydrates + O_2 → $CO_2 + H_2O +$ energy
- almost in balance – over millions of years, small conversion to fossil fuels: *Coal*, *oil*, *gas*:
- ***Stored 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

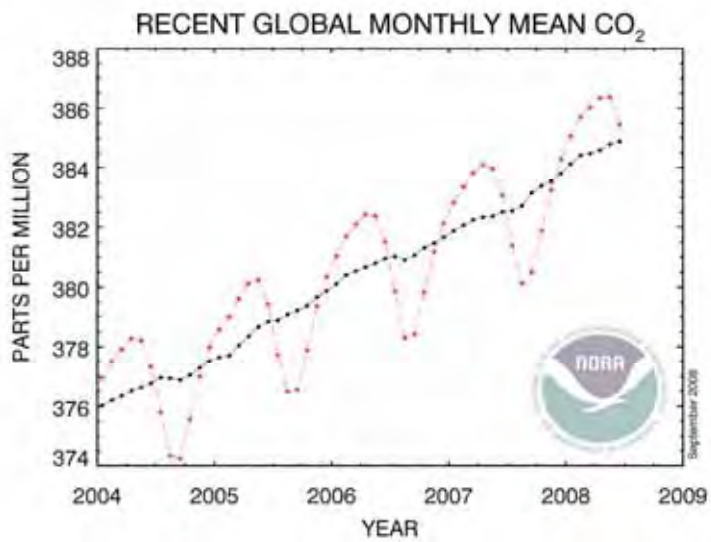


Atmospheric CO_2 Concentration

Year 2007
Atmospheric CO_2 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}

Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

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

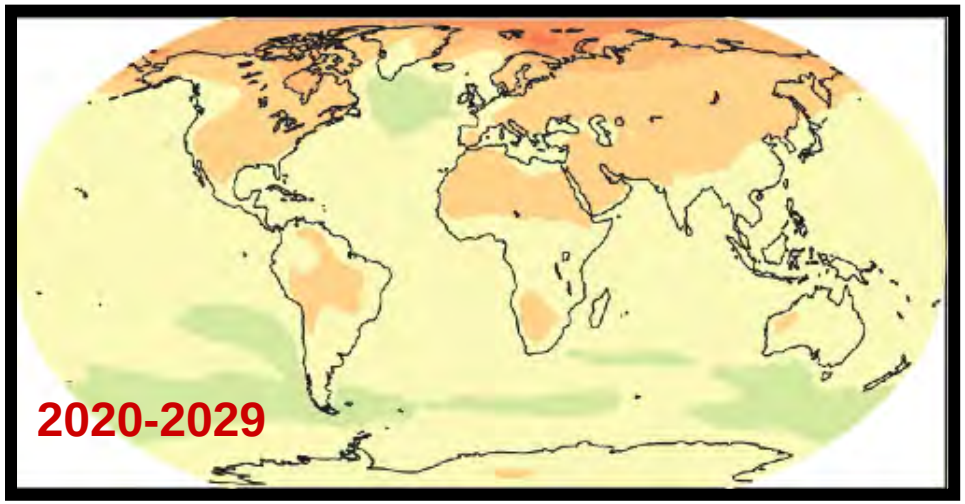
[www.ipcc.ch]

Decrease in:

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

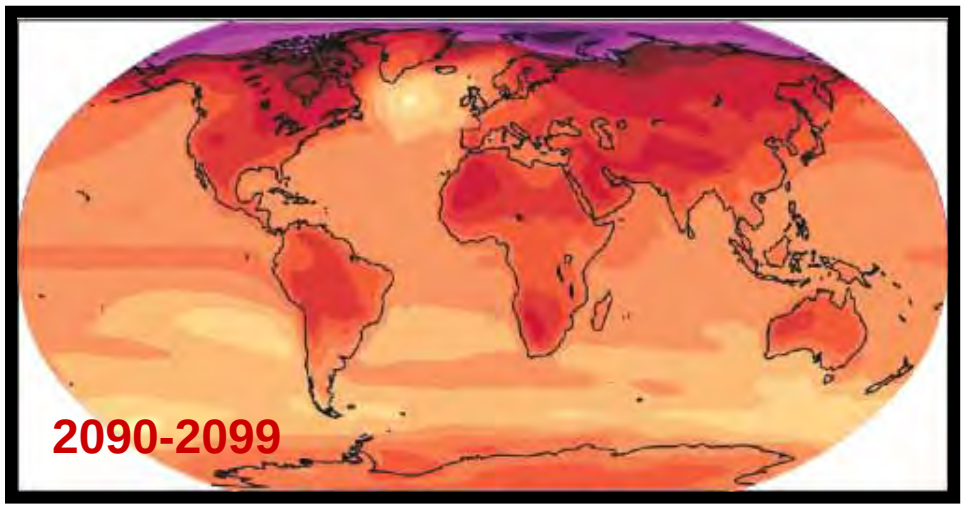
Multi-model Predicted Percent Change in Temperature (2020-2029 and 2090-2090 relative to 1980-1999) [^{o}C]

‘Committed’

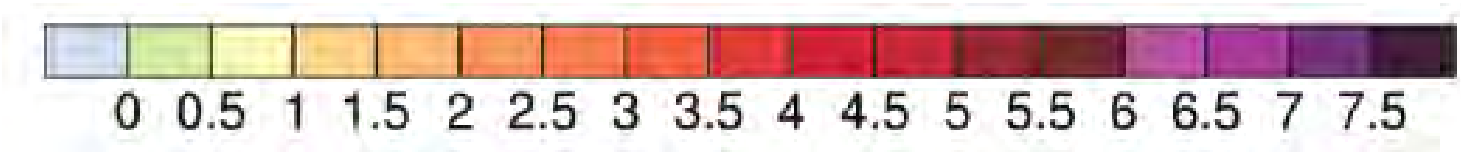


(We did nothing for the last 20 years)

Still up to us!



(We could halve this if we act now)

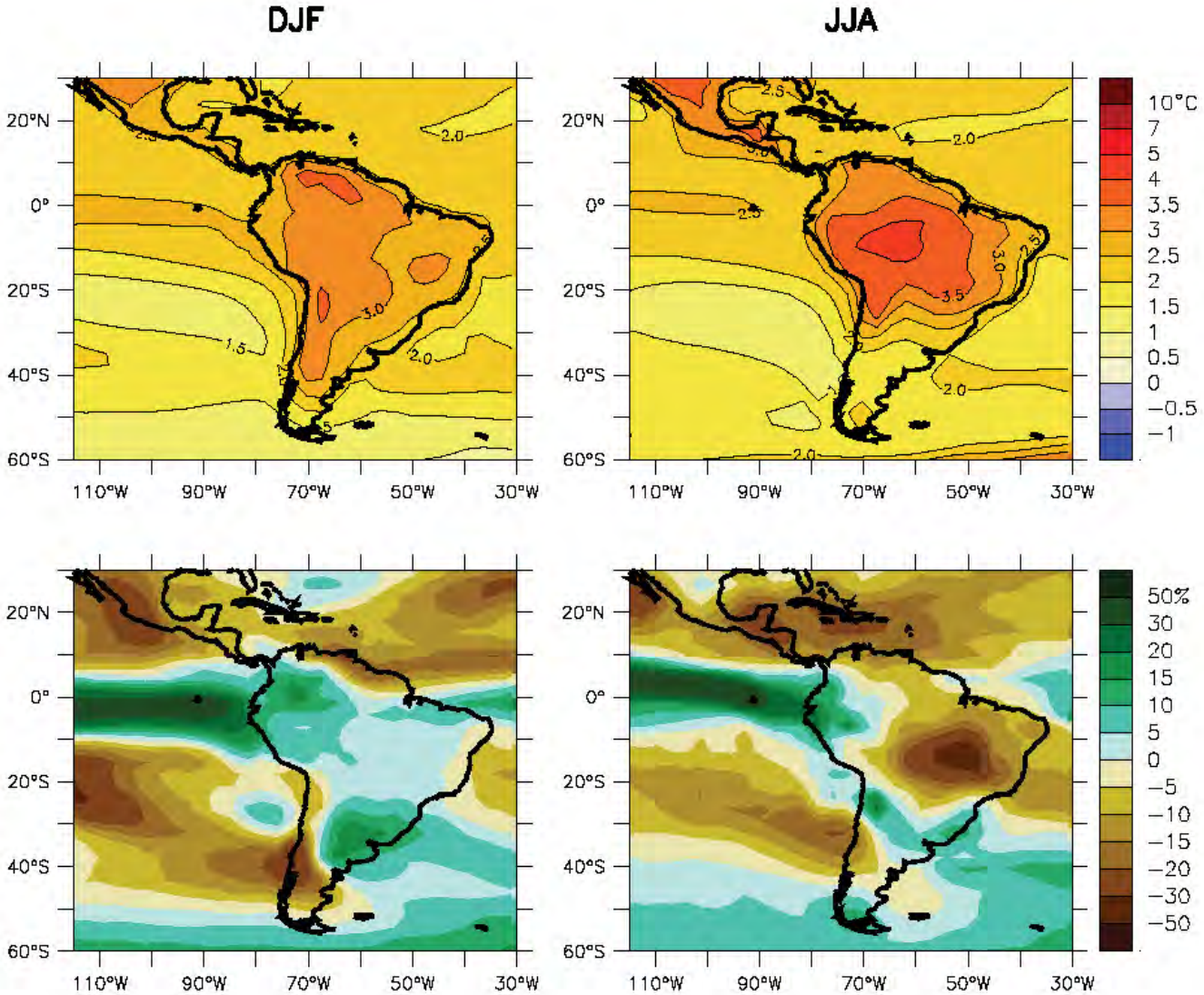


[^{o}C]

Change 1990-2090

Temperature

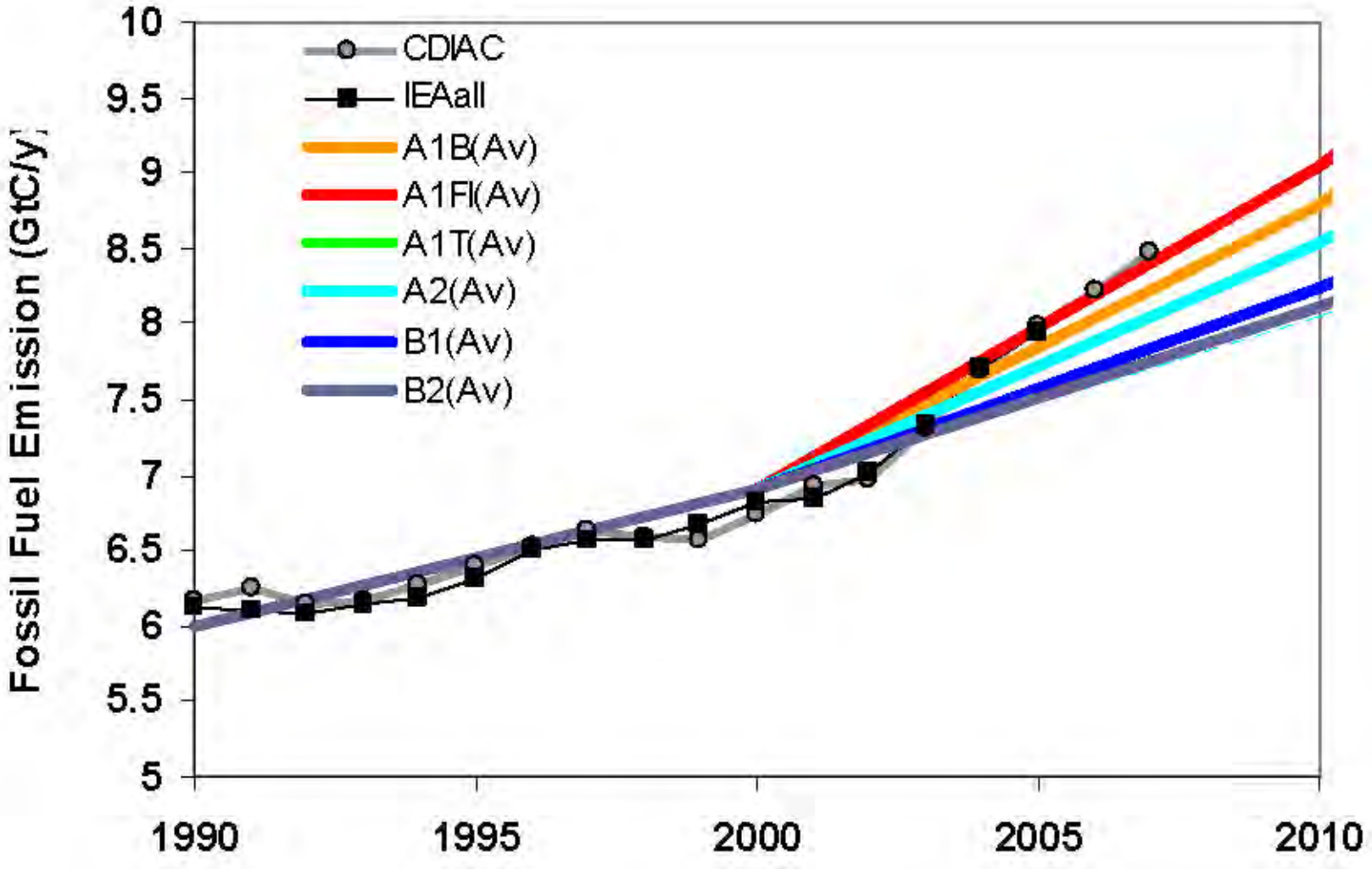
Precipitation



- **Temperature and precipitation changes over South America from an average of 21 AOGCM projections for A1B (high emission) scenarios.**

Trajectory of Global Fossil Fuel Emissions

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



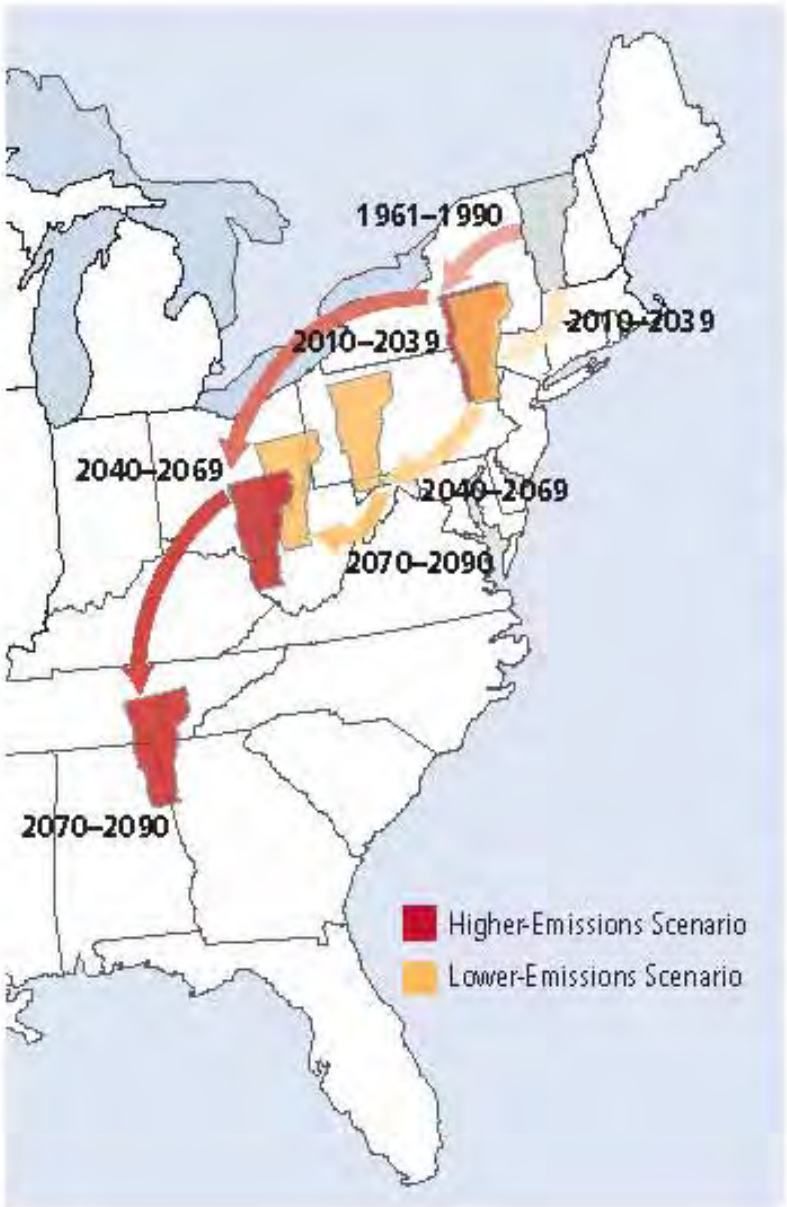
2000-2007 growth in C emissions was 3.3%

- above the highest fossil fuel intensive IPCC scenario)

Vermont's future with high and low GHG emissions

Red is high emissions

What about the tropics?



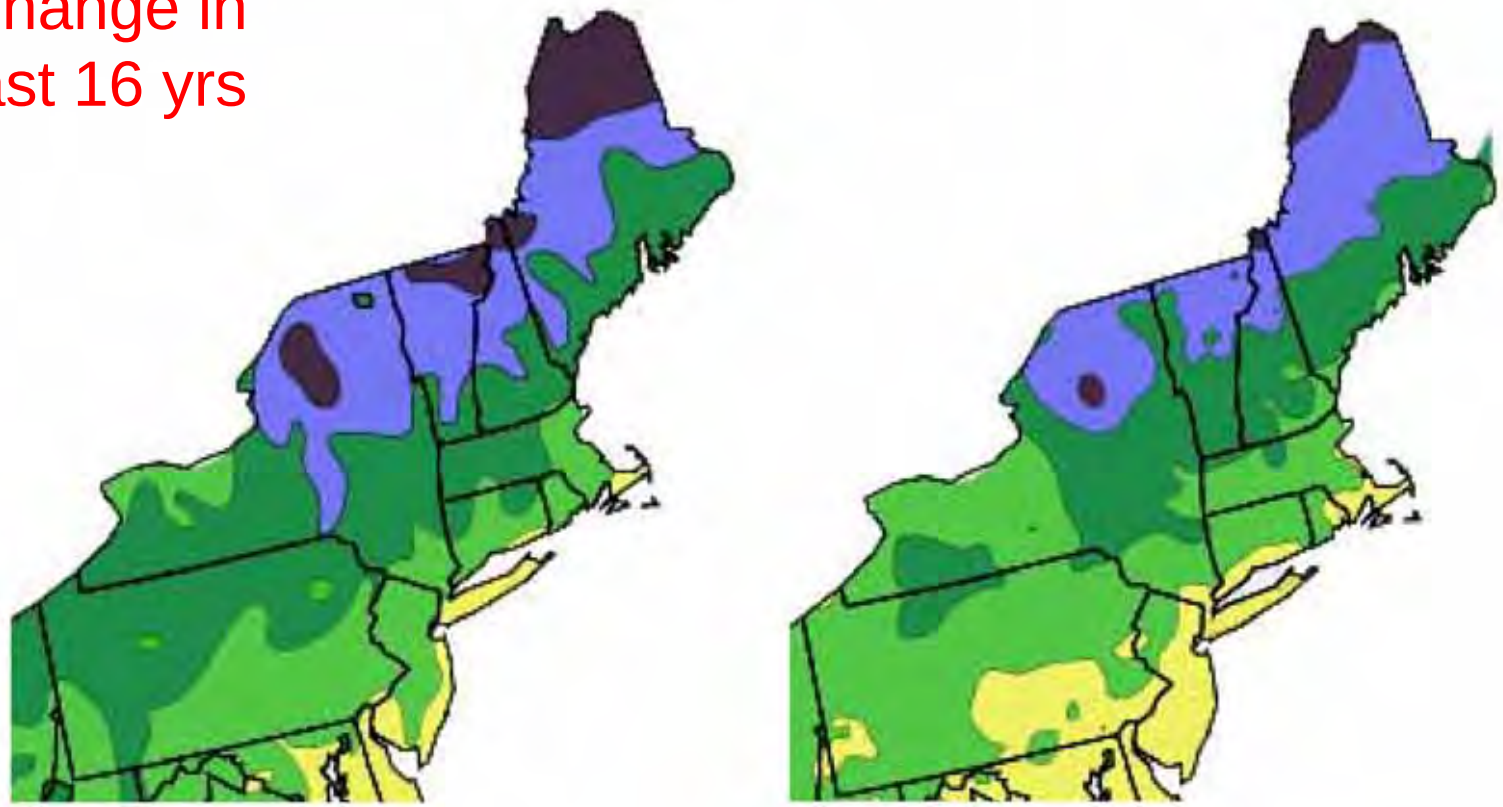
Migrating State Climate

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

USDA Hardiness Zones - Northeast

Change in
last 16 yrs



1990

2006

Zone

2 3 4 5 6 7 8 9 10

USDA Hardiness Zones

Human system issues

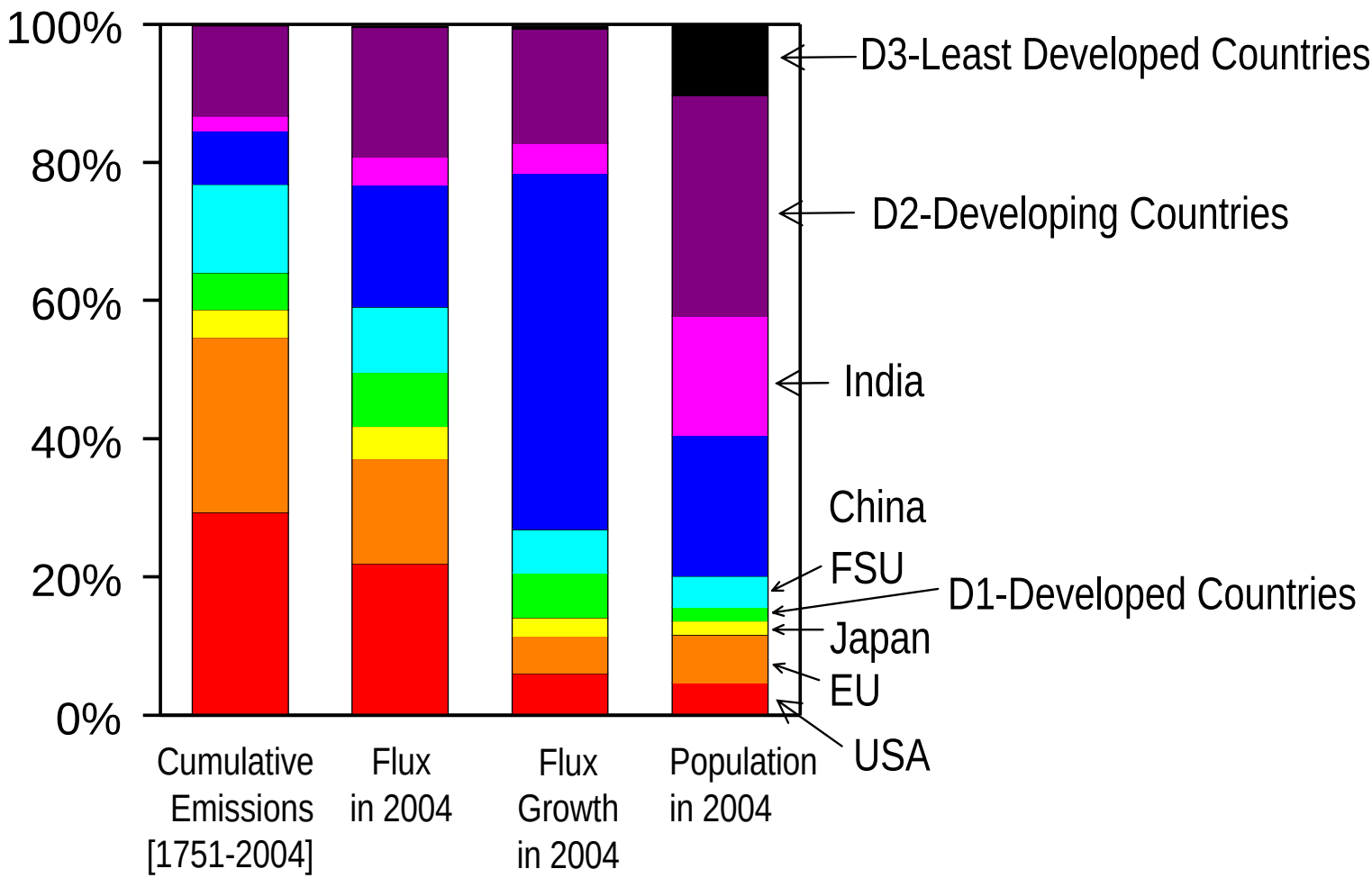
- **Human responsibility for planet's future**
- Fossil vs. renewable energy choices

- **Interdependence of energy, food and water**
- Relocalization vs. globalization
- Economic and financial system regulation
- Economic growth vs sustainability

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

Raupach et al. 2007, PNAS

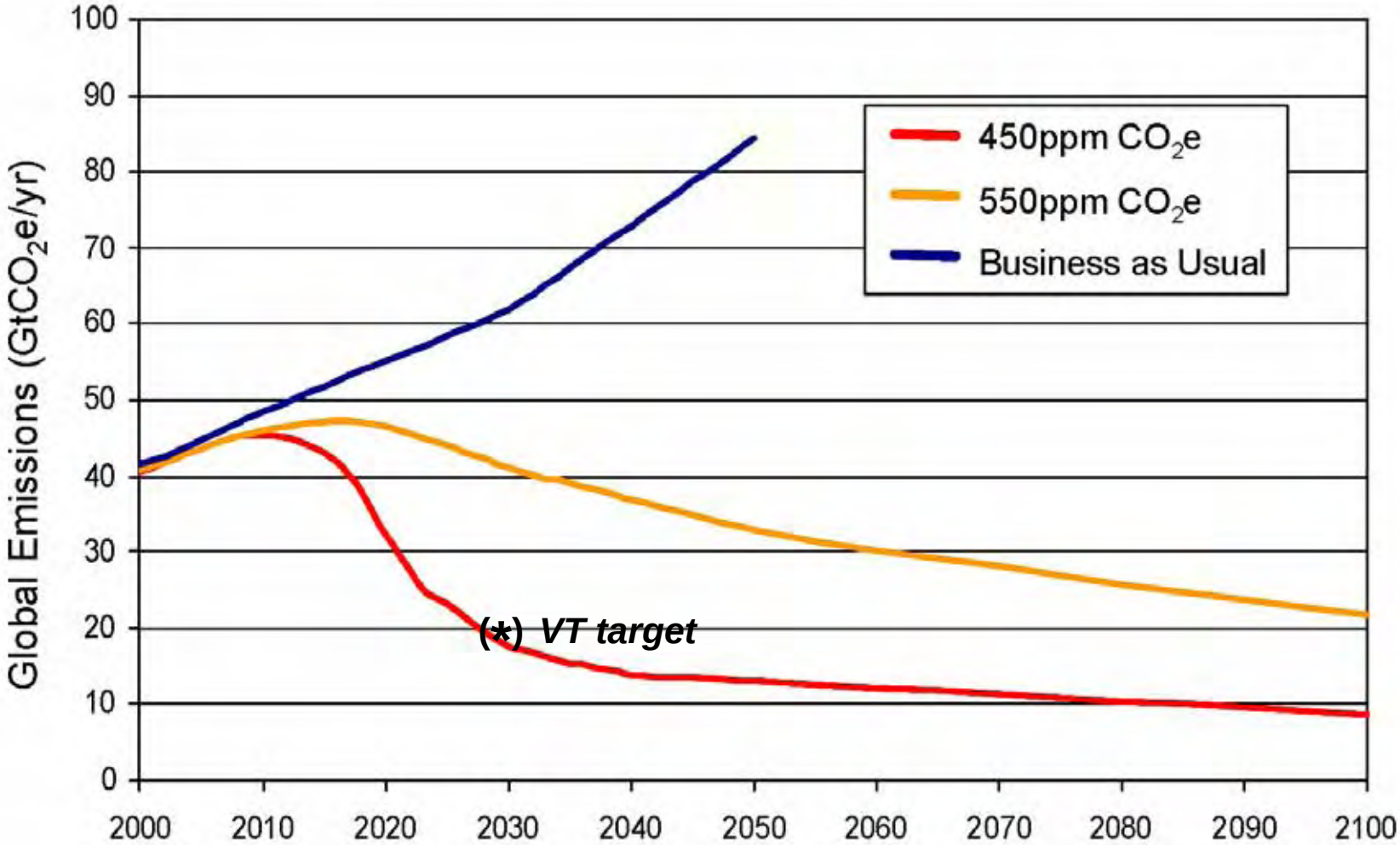
Climate Change is a huge challenge for humanity

- **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***

How do we avoid 'Dangerous Climate Change"?

Emissions Paths to Stabilisation *[Stern, 2006]*



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*

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 CO_2 well above 1000ppm *[and in time melt ice-caps]*. Can we sequester CO_2?**

Wind to electricity

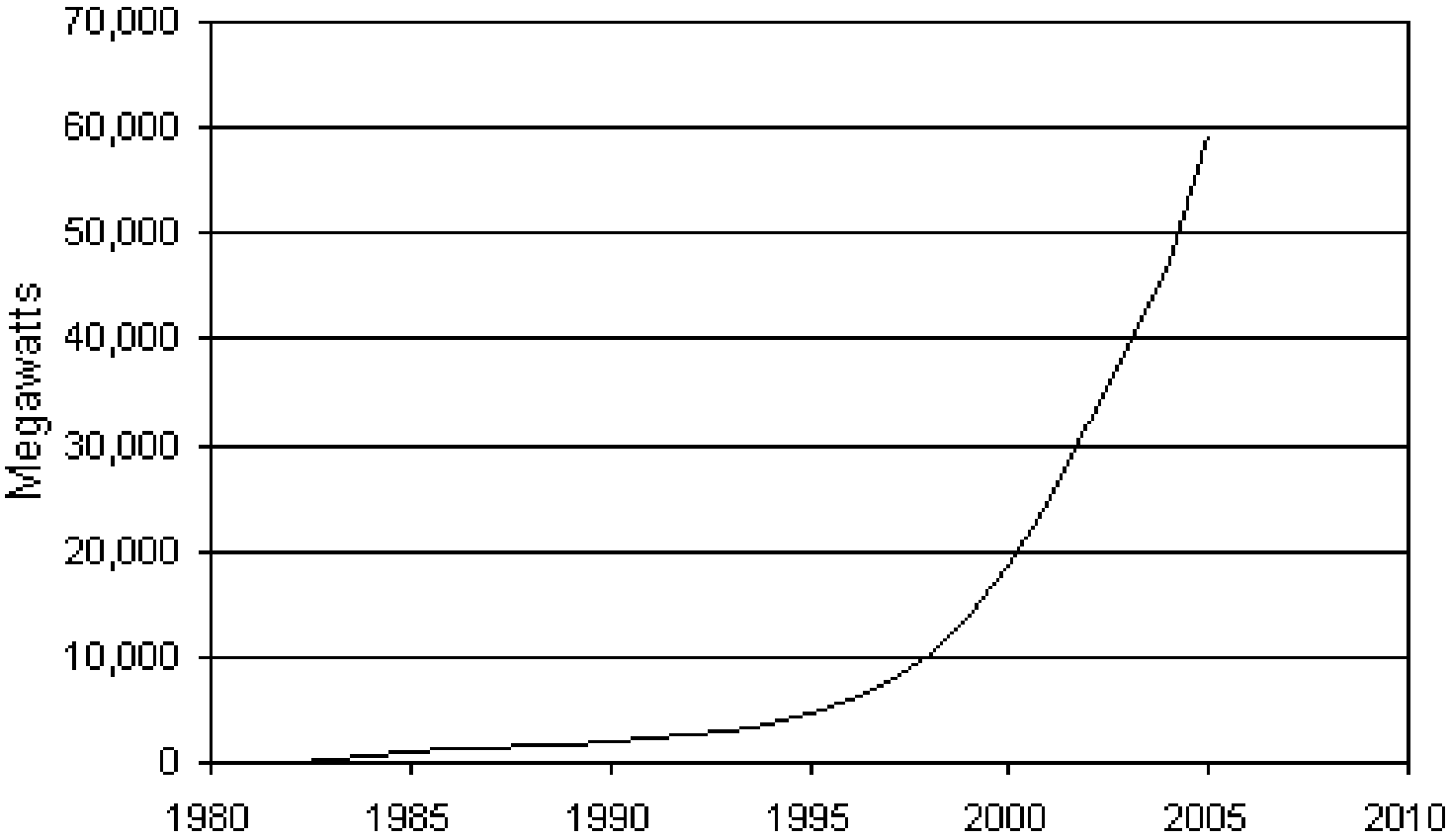
Cattle graze among turbines at the 300 MW Stateline wind park on the Oregon/Washington state border

- Oregon-Washington

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

- 94GW: 2007

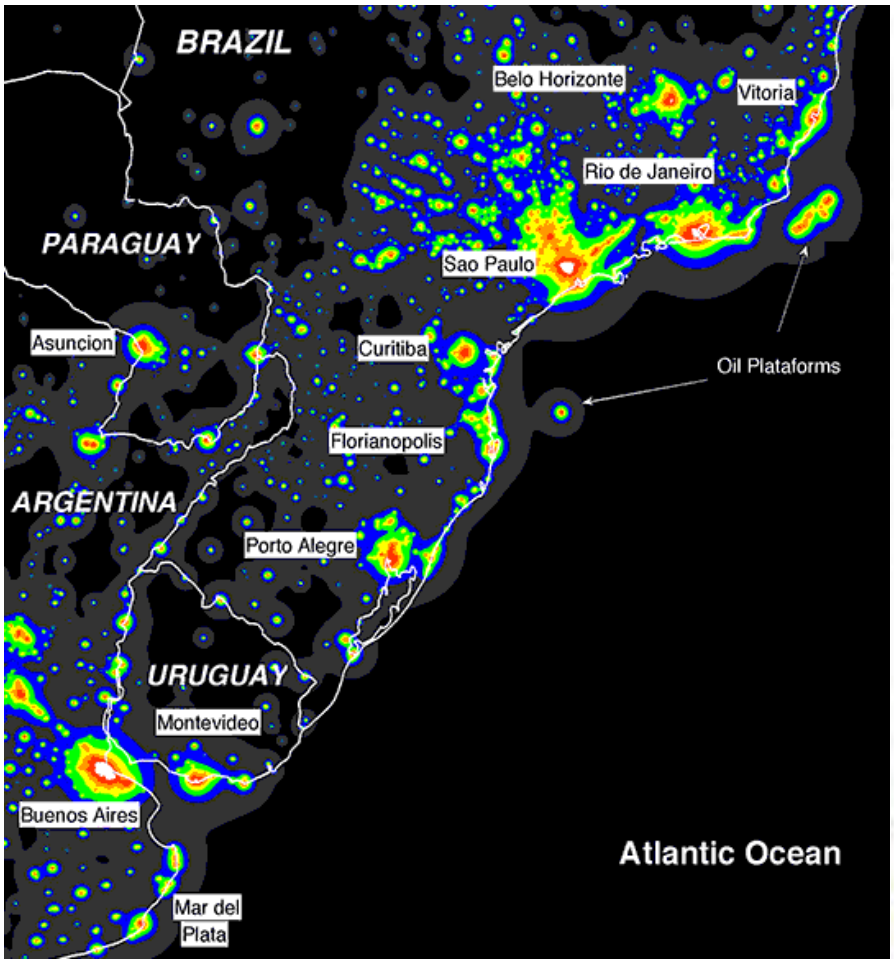
(280 GW by 2012)

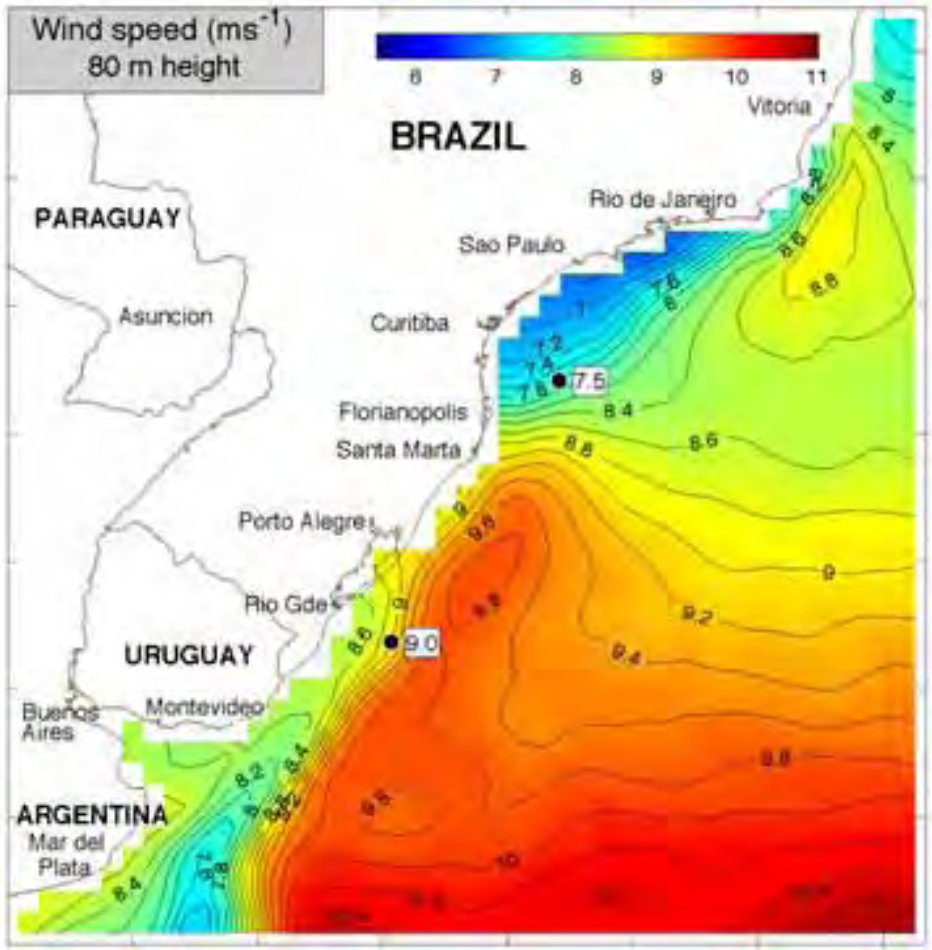


Wind: 30 percent/year growth rate over last ten years.

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

Wind resource offshore



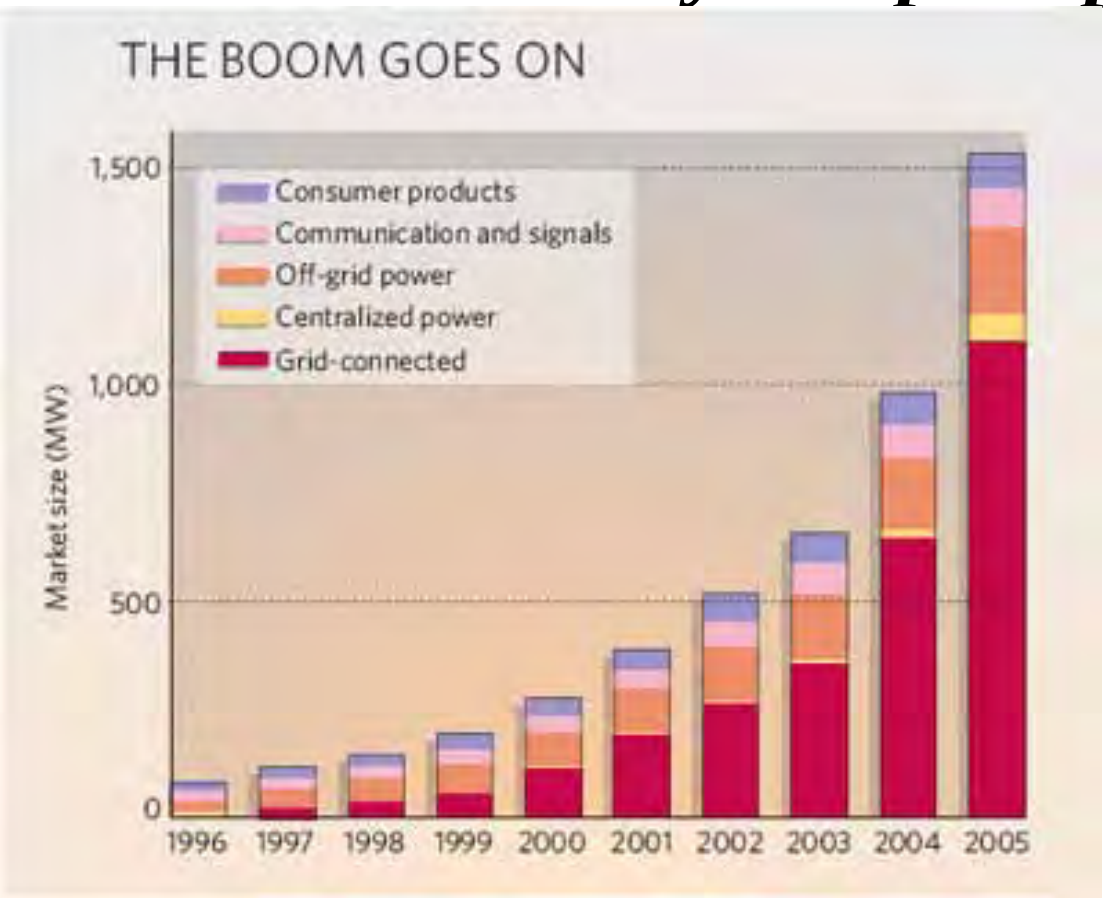


- Population density 80m wind-speed (QuikSCAT)
- Resource of order 100 GW in < 50 m water depth

http://nasadaacs.eos.nasa.gov/articles/2008/2008_wind.html

Photovoltaic growth: > 30%/year

Daytime peak power



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

William Maclay Architects and Planners

Vermont, USA

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**

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?**

The reality we face

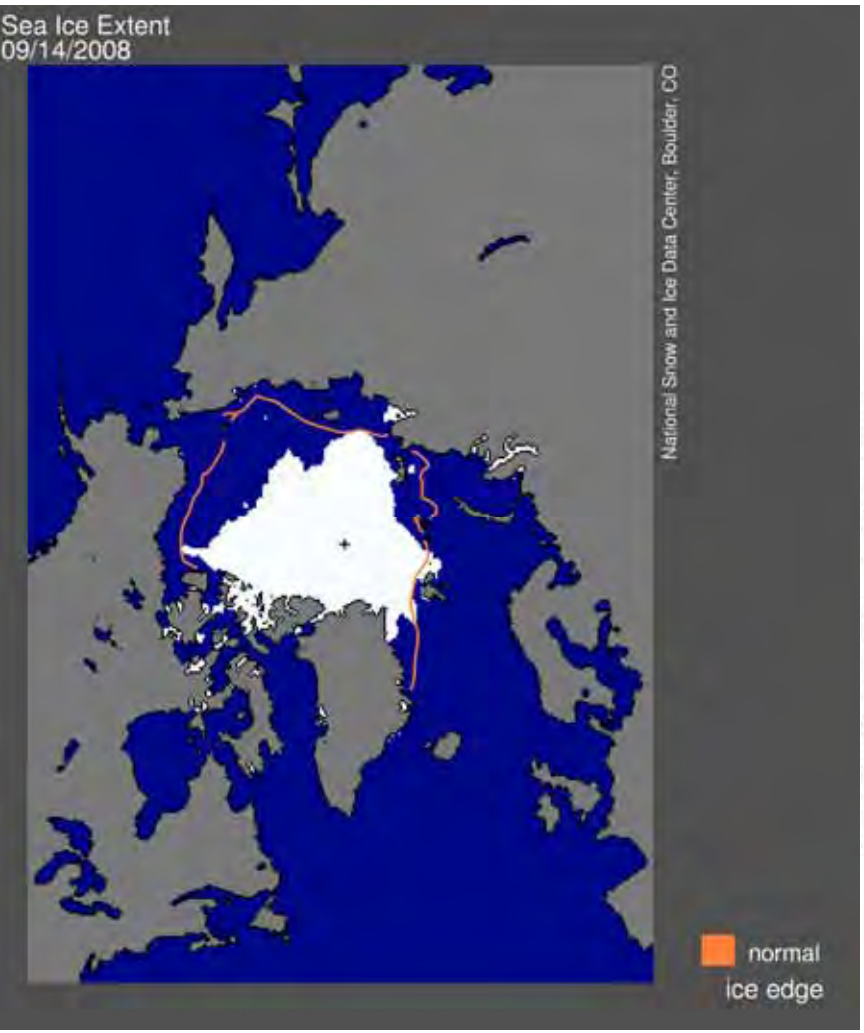
- Competition for resources: water, food & energy.
- Fossil energy is transforming the earth and stressing its ecosystems: current path means loss of 30% of species and 100 millions of environmental refugees
- **Efficient society, based on renewable energy is the only solution: huge transformation; but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

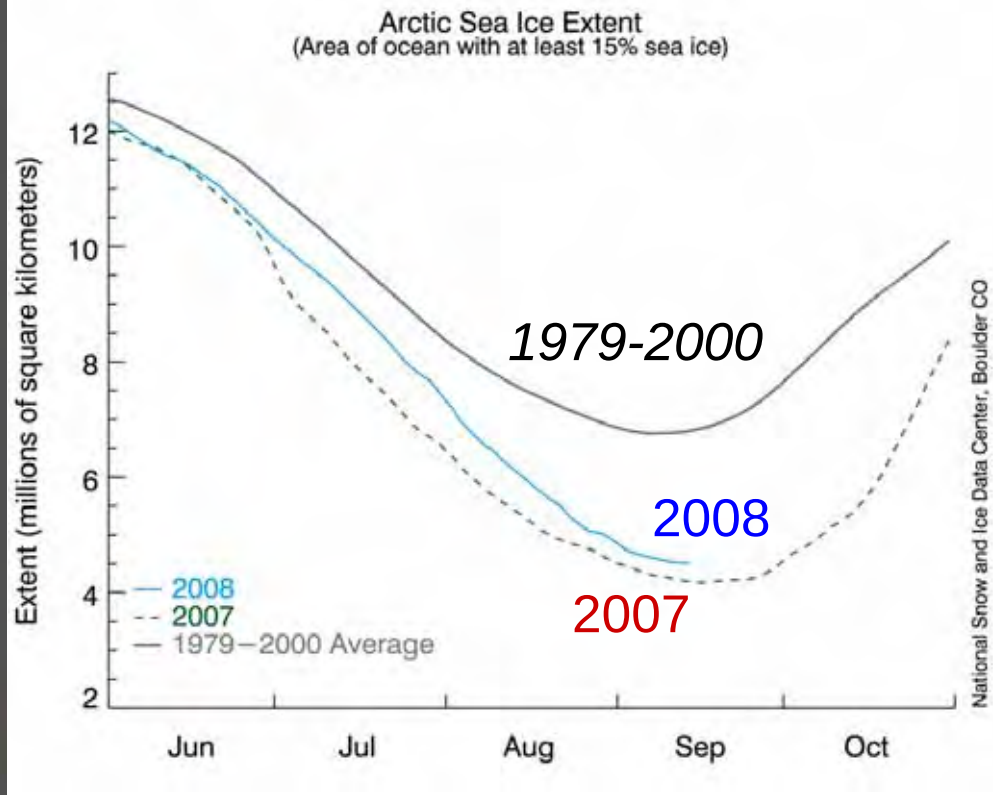
- **It will take honesty, courage, compassion and decades of sustained effort, starting now**

‘Anti-global warming’ tactics in US [*delay, confuse and deny*]

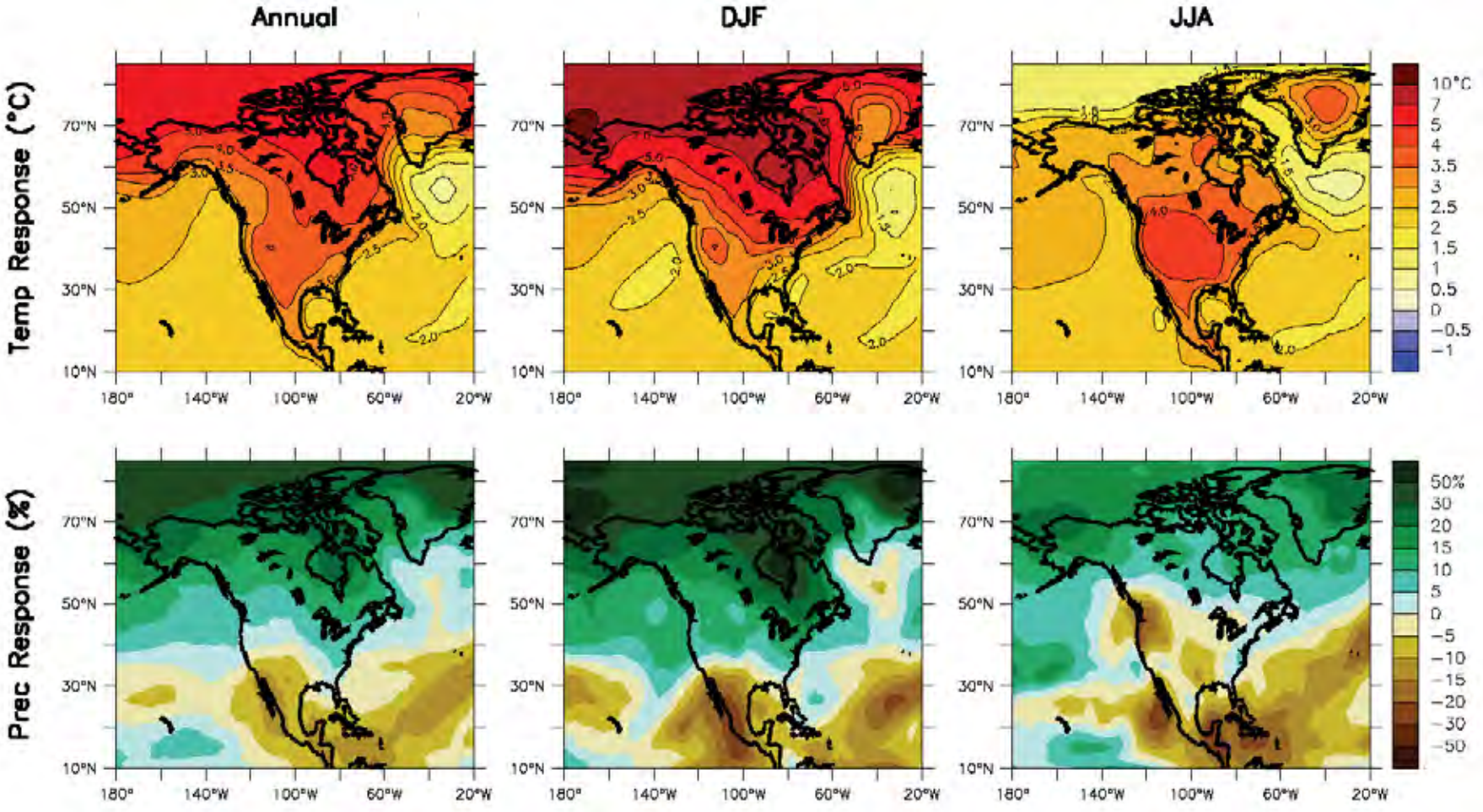
- Fabricate ‘data’ or cherry-pick the science for unsolved issues and ignore the big picture. ‘This disproves global warming’ *or* ‘Science isn’t resolved; we need more science.’
- Models can’t predict the future with certainty, so the models are ‘unreliable’, ‘can’t be trusted’. Given this uncertainty, *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]

2008 almost the same loss of ice





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 are we now in 2008?

- **CO_2 up from 280 to 382ppm; 560ppm 'inevitable'**
- **Far beyond range of 'recent' climate record**
- >34MY ago at 1000 ± 500ppm, no Antarctic ice-sheet!
- Mean temperature risen about 1°F:

  predicted rise 3-8°F this century
- Intense hurricanes are increasing
- Sea-ice, ice shelves and permafrost melting; tundra greening: *2005: Arctic 5°F warmer than 50 yr mean*
- Frost-free season longer; Fall colors later
- Birds, butterflies, insects moving [towards poles]

- **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*

Resources [Alan Betts' talk]

For science:

- www.realclimate.org for discussion/debate by scientists
- http://www.climatesciencewatch.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

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