

# Global Warming

Wendell Wiggins  
Spring/Summer, 2010

# Global Warming

## Jargon

- Weather - the state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc
- Climate - the composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years
- IPCC - Intergovernmental Panel on Climate Change, organized by the UN
- CRU – the Climate Research Unit of the University of East Anglia (UEA)

# Global Warming

## Jargon and Misc. Facts

- FAR – First Annual Report of the IPCC
- SAR – Second annual Report of the IPCC
- TAR – Third Annual Report of the IPCC
- AR4 – Fourth Annual Report of the IPCC
- GHG – greenhouse gas
- Anthropogenic - generated by human activity
- CO<sub>2</sub> – carbon dioxide
- CH<sub>4</sub> – methane; natural gas
- Absolute zero temperature - -273° C or -459° F
- At room temperature, a 5° C change can increase the evaporation of water by 37%

# Global Warming

## Evidence of warming

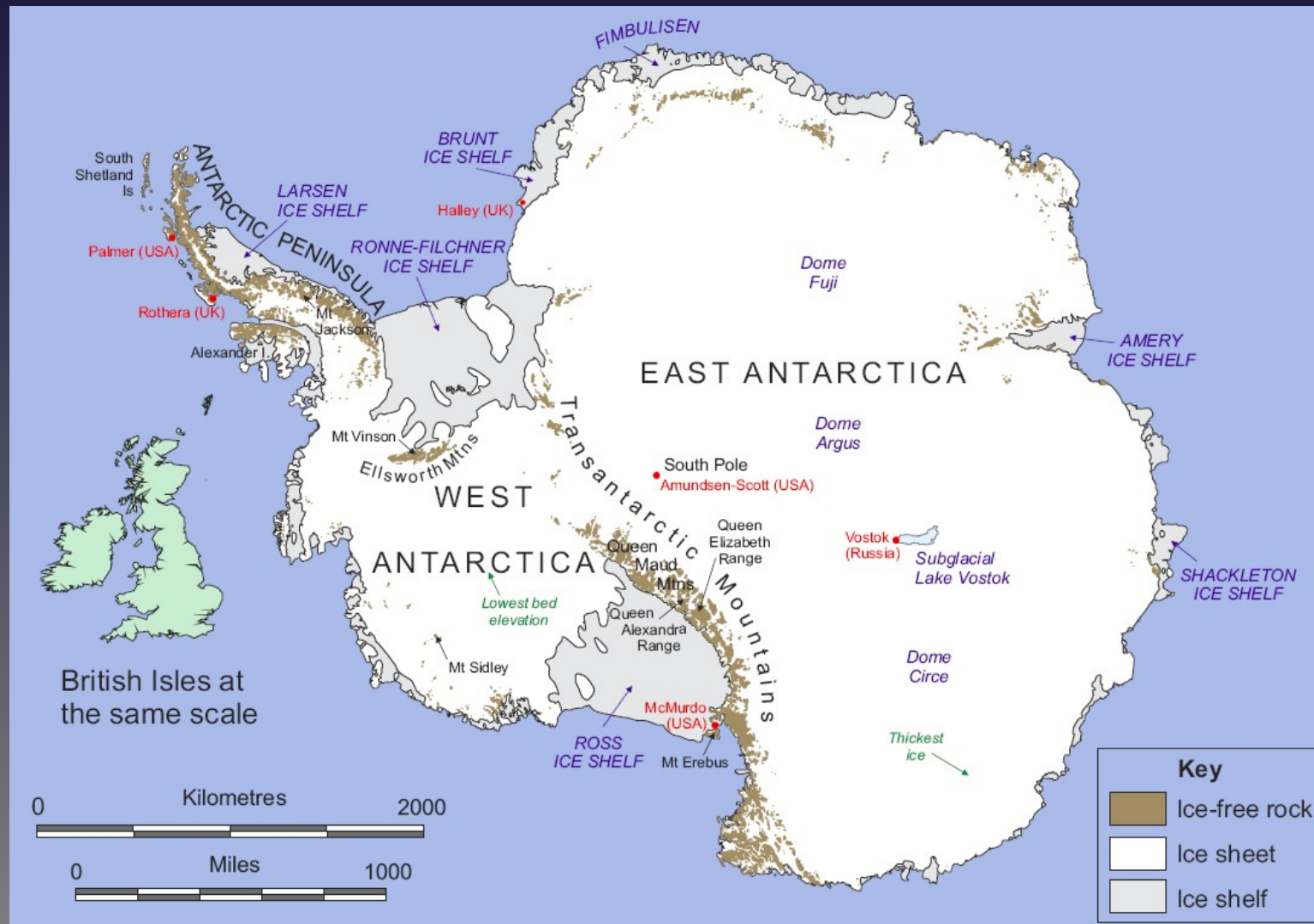
Items of evidence taken from a column by Colin Summerhayes, a Professor at Cambridge University and Director of the Scientific Committee on Antarctic Research. Professor Summerhayes is a well-known “moderate in the climate debate.”

<http://timesonline.typepad.com/science/2010/02/if-global-warming-is-real-then-why-is-it-cold.html>

# Global Warming

## Evidence of warming

“We can see the West Antarctic glaciers are shrinking at a rate fast enough to contribute to a sea level rise of 1.4 m by 2100”



# Global Warming

## Evidence of warming

“Ocean temperatures are increasing and ocean heat content has increased considerably over the upper 700 metres since 1965, as shown by a wide variety of ocean thermometers including those from the Argo float programme.

“As a result of that warming, the ocean has expanded, and sea-level has risen, as shown by tide gauge data on the one hand and satellite altimeters on the other hand.”

Expansion coeff. of water = 0.069 parts per thousand/°C

# Global Warming

## Evidence of warming

“The warmer ocean waters are penetrating beneath the outlet glaciers in Greenland and in the Amundsen Sea Embayment of West Antarctica, where they are contributing to the melting and thinning of those glaciers, which, as a consequence have speeded up and are now discharging significantly more ice from the land into the sea, thus adding to the rate at which sea level is rising.”

# Global Warming

## Evidence of warming

“Warm air is contributing to the melting of Arctic sea ice and the latest records show that this downward trend continued through 2009 and into 2010. We do not see this around Antarctica, where the sea ice is growing in area by 1% per year, but we now know that this is because of the shielding effect on the continent and its surrounding surface waters by a vortex of circumpolar winds, which have been strengthened by 15% since the mid 1970s because of the effects of the ozone hole. The effect of the ozone hole on the winds is protecting Antarctica from global warming. The wall of winds keeps warm air out, except locally, over the Antarctic peninsula.”



# Global Warming

## Evidence of warming

“Glaciers are in retreat in most mountain areas, including Patagonia and the Antarctic Peninsula. The rate at which these glaciers are retreating has increased significantly since about 1970.”

# Global Warming

## Evidence of warming

“Plants, animals, birds, and insects, especially in north temperate regions, are advancing their ranges northwards at significant rates, and seasonal migrations are starting earlier, in response to warming.”

# Global Warming

## Evidence of warming

“UEA data aside, there are other records of air temperature from around the world that confirm that the air temperatures on balance are warming. All of these analyses attempt to remove from the data set measuring sites that are suspect in some way. Not surprisingly this means that to some extent they will be using the same data sets. But some, like the NASA GISS set cover additional areas (the Arctic) to that covered by the UEA set.”

# Global Warming

## Evidence of warming

“The sun's energy has not increased significantly since around 1970, during which time global temperatures in both atmosphere and ocean have continued to increase.

# Global Warming

## Evidence of warming

“Permafrost is melting in many parts of the Arctic, causing damage to housing and infrastructure.”

# Global Warming

## Evidence of warming

- What's going on?
- We need an explanation—a theory

# Global Warming

## Models and Theories

- Many theories require a model to connect the observations to the underlying explanation
- For example, suppose you get a statement from the bank and find that you have \$1 Million now. This is an observation
- But suppose you want to know how much you will have six months from now
- You need a model of how your balance changes with time
- The model will express the details of your theory of the balance

# Global Warming

## Models and Theories

- Simple model
  - $\text{Balance later} = \text{Balance today} * (1 + \text{Interest Rate} * \text{elapsed time}) =$
  - $\$1 \text{ Million} * (1 + 0.05 * \frac{1}{2} \text{ year}) = \$1,025,000$
- But suppose your ex is allowed to withdraw \$500/week. Then we need a more sophisticated model
  - $\text{Balance later} = \text{Balance today} * (1 + \text{Interest Rate} * \text{Elapsed time}) - \$500 * \text{number of weeks}$
  - $\$1 \text{ Million} * (1 + 0.05 * \frac{1}{2} \text{ year}) - \$500 * 26 \text{ weeks} = \$1,012,000$
- But you'll also withdraw some, so etc., etc.,....



# Global Warming

## Models and Theories

- As your model gets more complex, you get tired of figuring it by hand, so you decide to program it in a spreadsheet program
- You now have a *computerized model* of your balance

# Global Warming

## Climate Models

- Connecting observations to global warming
- Observations:
  - Temperature of atmosphere and oceans
  - Atmospheric gases
  - Volcanic activity
  - Sun brightness
  - Land use
  - Others

Climate Model  
Components

Climate Model  
Resolution

# Global Warming

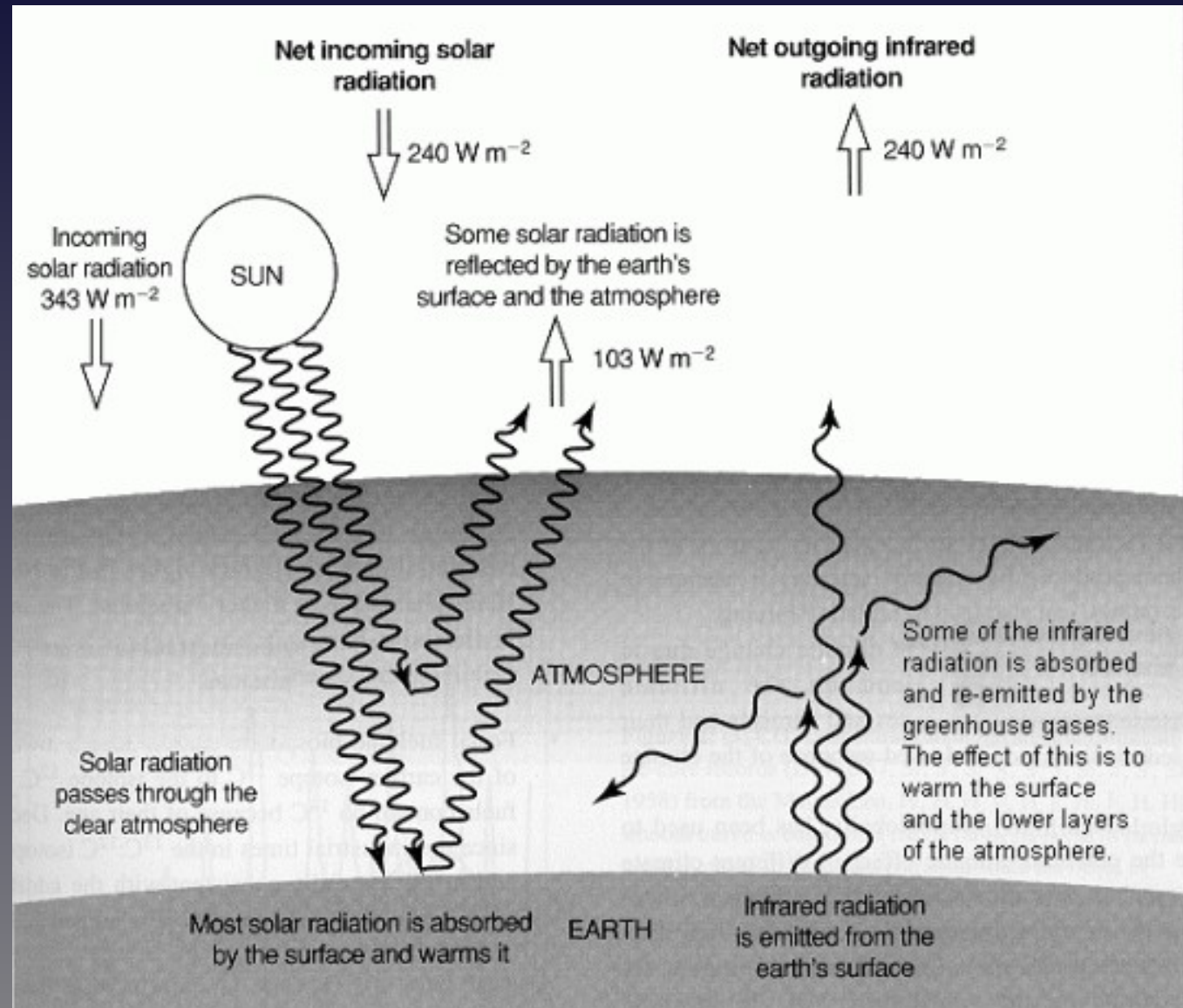
## Models and Theories

- Time is also divided into steps. 30 min is typical today
- The models are tested by starting in the past and seeing how well they “predict” the present
- Then the model is run to predict a future period using actual observations up to today
- Several independent research groups have their own models that differ in details
- The predictions of the several groups can be compared

# Global Warming

## The Greenhouse Effect

**Greenhouse gases are those in the atmosphere that absorb and radiate energy within the thermal infrared range**



# Global Warming

## Atmospheric Transmission

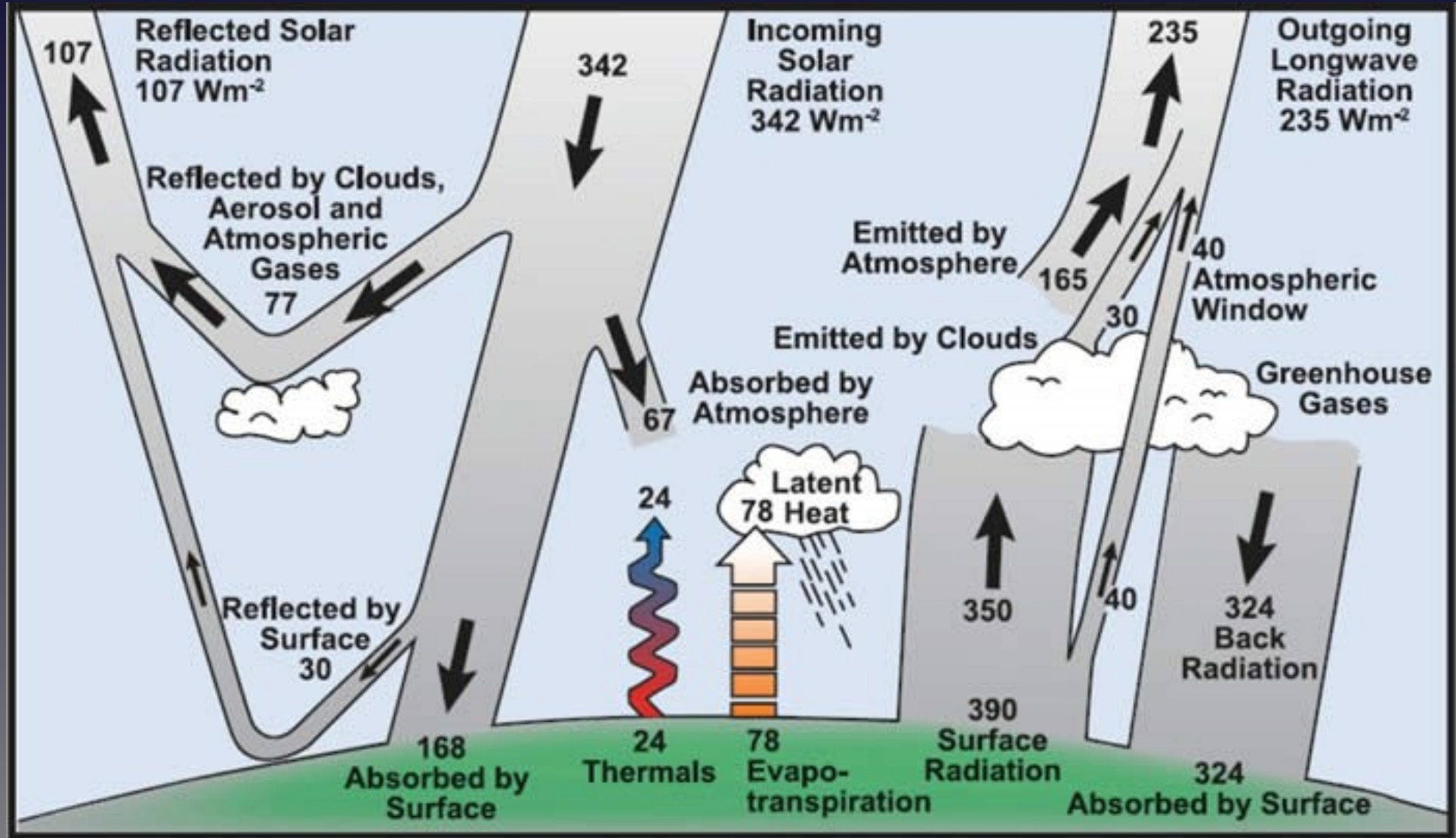
- Electromagnetic radiation is partially transmitted by the atmosphere
- Most fortunately, the atmosphere is relatively transparent in the visible and the infrared reradiation windows



Atmospheric  
Transmission

# Global Warming

## The Greenhouse Effect





# Global Warming

## Warming and CO<sub>2</sub>

### Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica

J. R. Petit\*, J. Jouzel†, D. Raynaud\*, N. I. Barkov‡, J.-M. Barnola\*, I. Basile\*, M. Bender§, J. Chappellaz\*, M. Davis, G. Delaygue†, M. Delmotte\*, V. M. Kotlyakov¶, M. Legrand\*, V. Y. Lipenkov‡, C. Lorius\*, L. Pe´pin\*, C. Ritz\*, E. Saltzman & M. Stievenard†

\* *Laboratoire de Glaciologie et Ge´ophysique de l’Environnement, CNRS, BP96, 38402, Saint Martin d’He`res Cedex, France*

† *Laboratoire des Sciences du Climat et de l’Environnement (UMR CEA/CNRS 1572), L’Orme des Merisiers, Baˆt. 709, CEA Saclay, 91191 Gif-sur-Yvette Cedex, France*

‡ *Arctic and Antarctic Research Institute, Beringa Street 38, 199397, St Petersburg, Russia*

§ *Department of Geosciences, Princeton University, Princeton, New Jersey 08544-1003, USA*

k *Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149, USA*

¶ *Institute of Geography, Staromonetny, per 29, 109017, Moscow, Russia*

***“Atmospheric concentrations of carbon dioxide and methane correlate well with Antarctic air-temperature throughout the record. Present-day atmospheric burdens of these two important greenhouse gases seem to have been unprecedented during the past 420,000 years.”***

# Global Warming

## Evidence of warming

**Analyze ice cores to find conditions over a long time period**

**The temperature when the snow froze is determined from measuring the concentration of deuterium (heavy hydrogen) and  $^{18}\text{O}$  (heavy oxygen) in the ice**

**The concentrations of  $\text{CO}_2$ ,  $\text{CH}_4$ , and  $\text{O}_2$  are also measured**

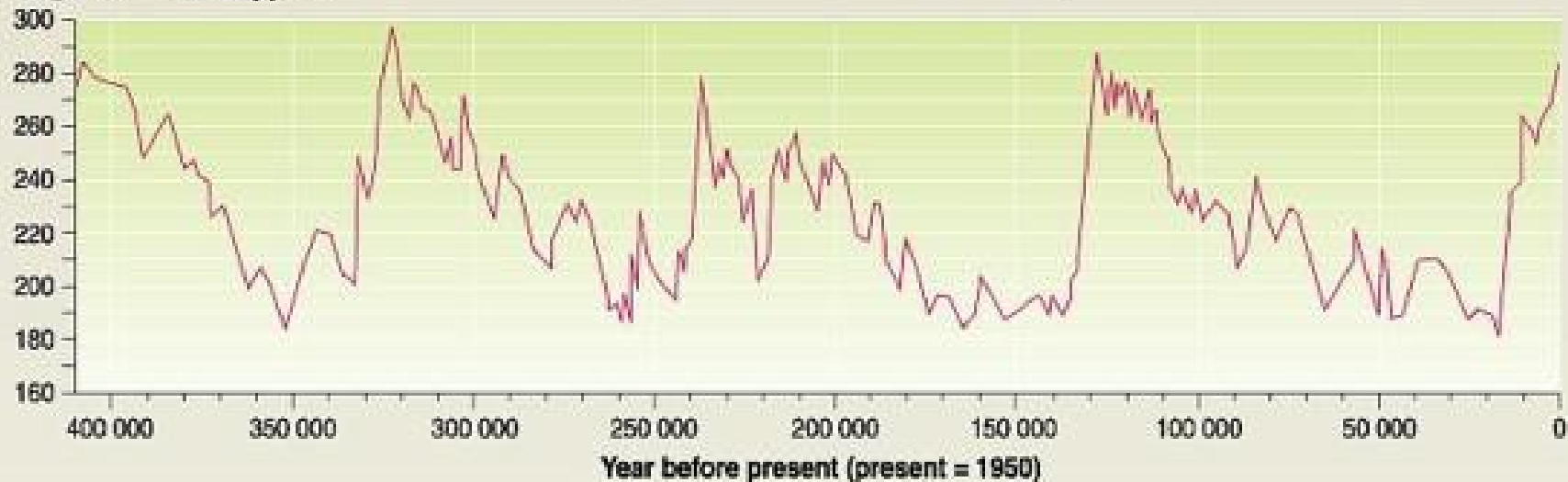


# Global Warming

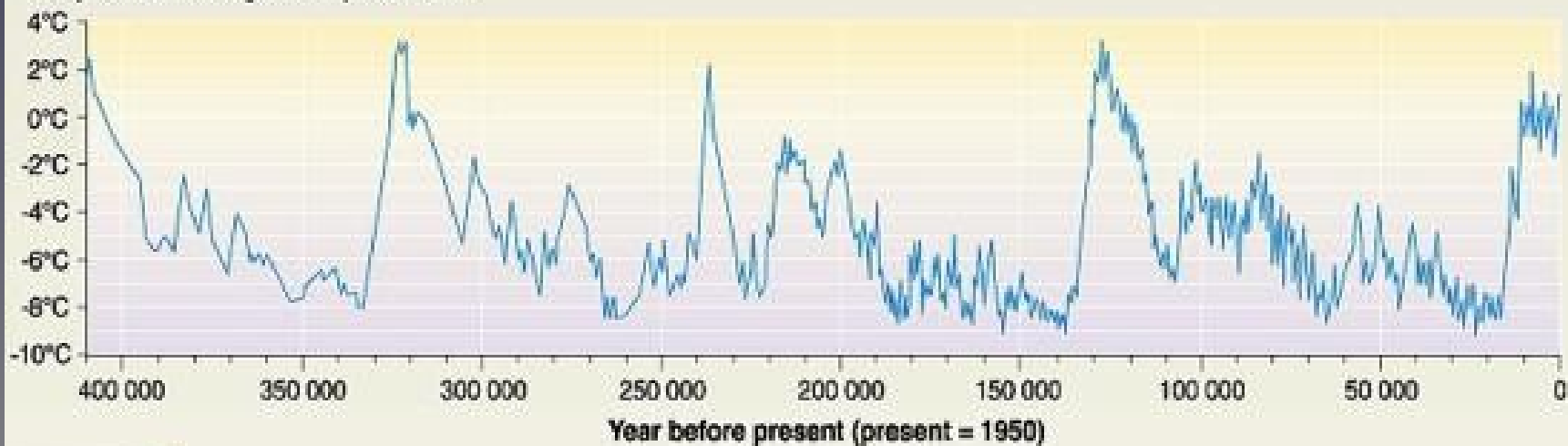
More

Temperature and CO<sub>2</sub> concentration in the atmosphere over the past 400 000 years  
(from the Vostok ice core)

CO<sub>2</sub> concentration, ppmv



Temperature change from present, °C



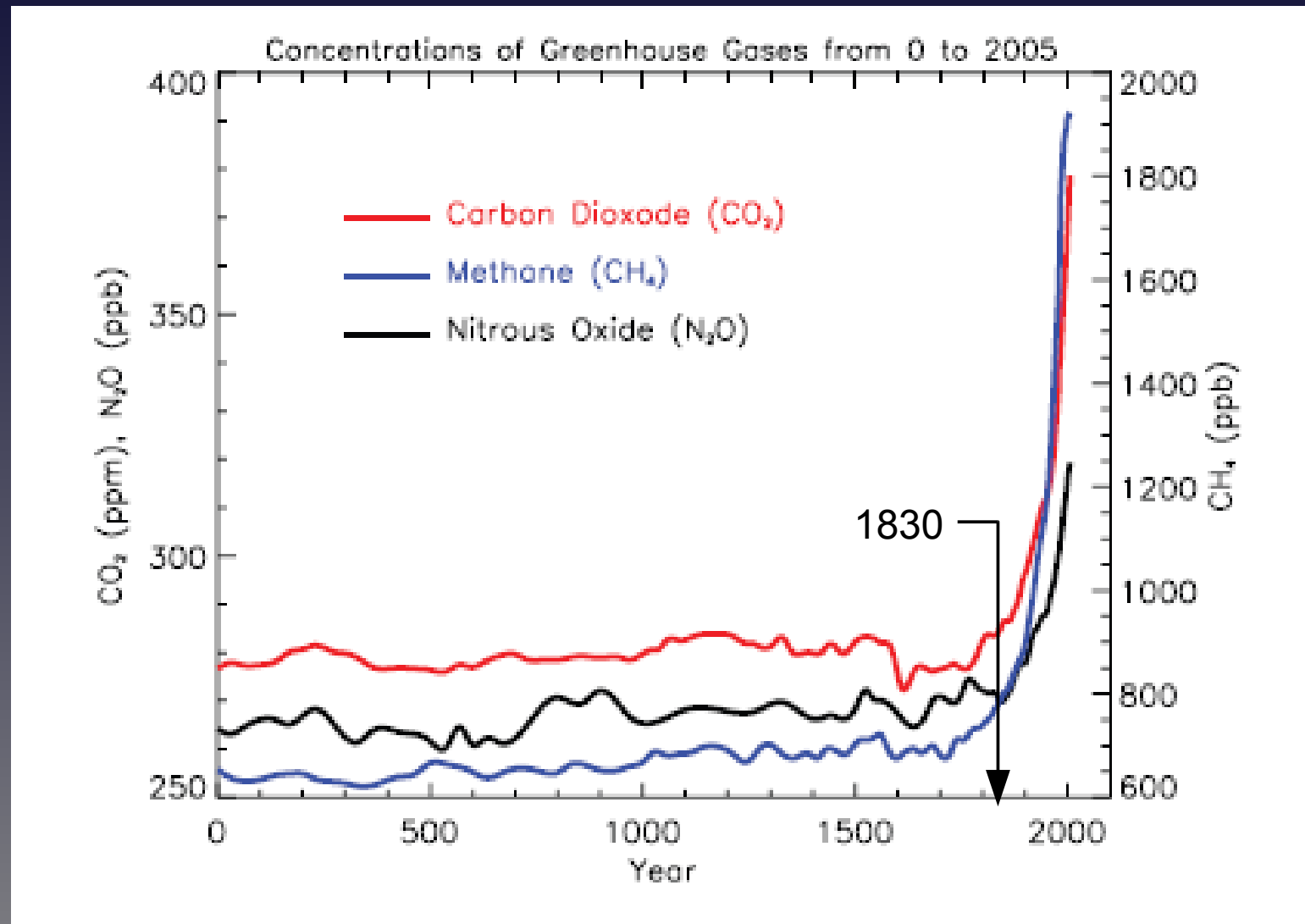
GRIP  
Arendal UNIP

GRAPHIC DESIGN: PHILIPPE FOUCAUD

Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3/June), pp 429-436, 1999.

# Global Warming

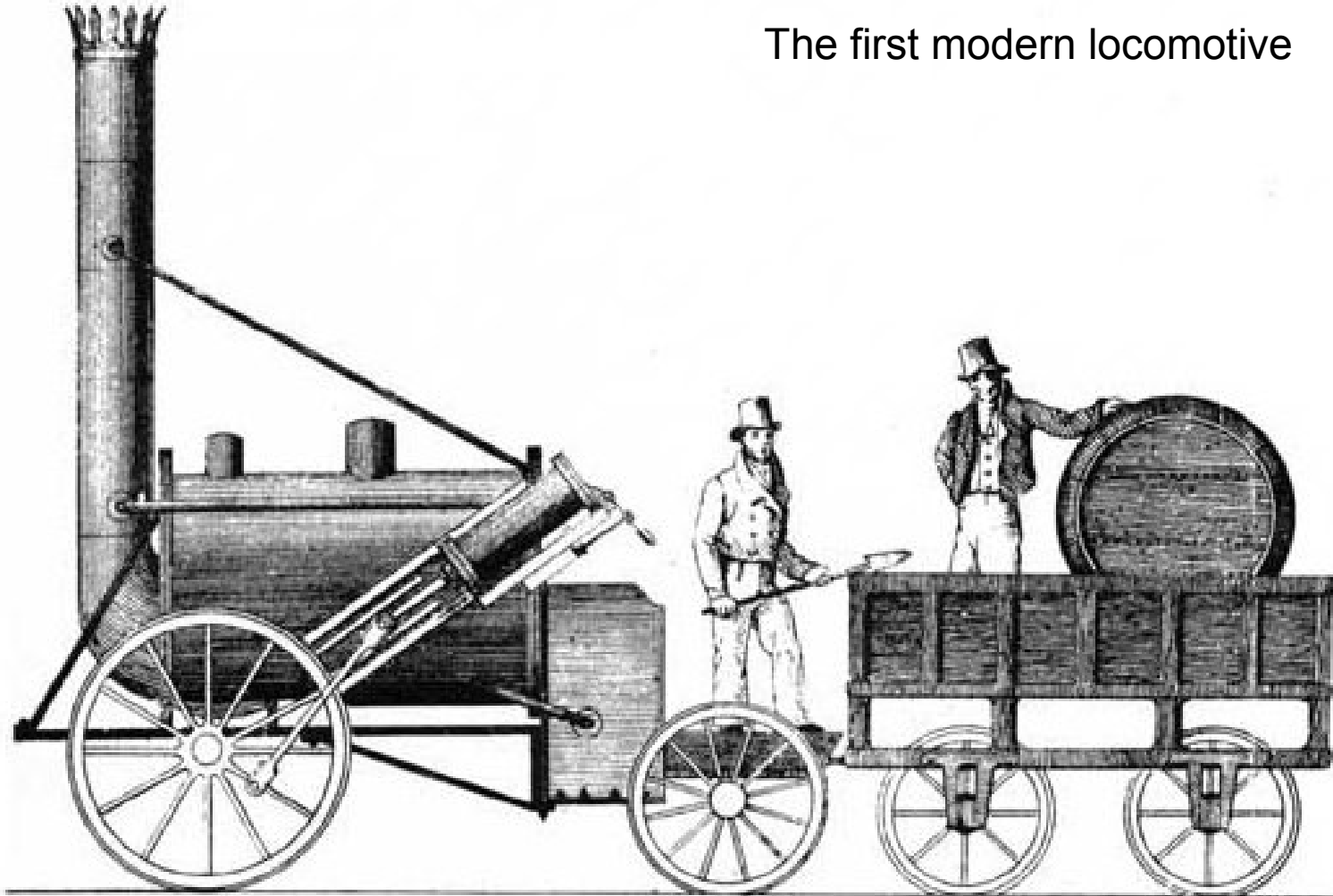
## Greenhouse gases



# Global Warming

## The Stephenson Rocket, 1829

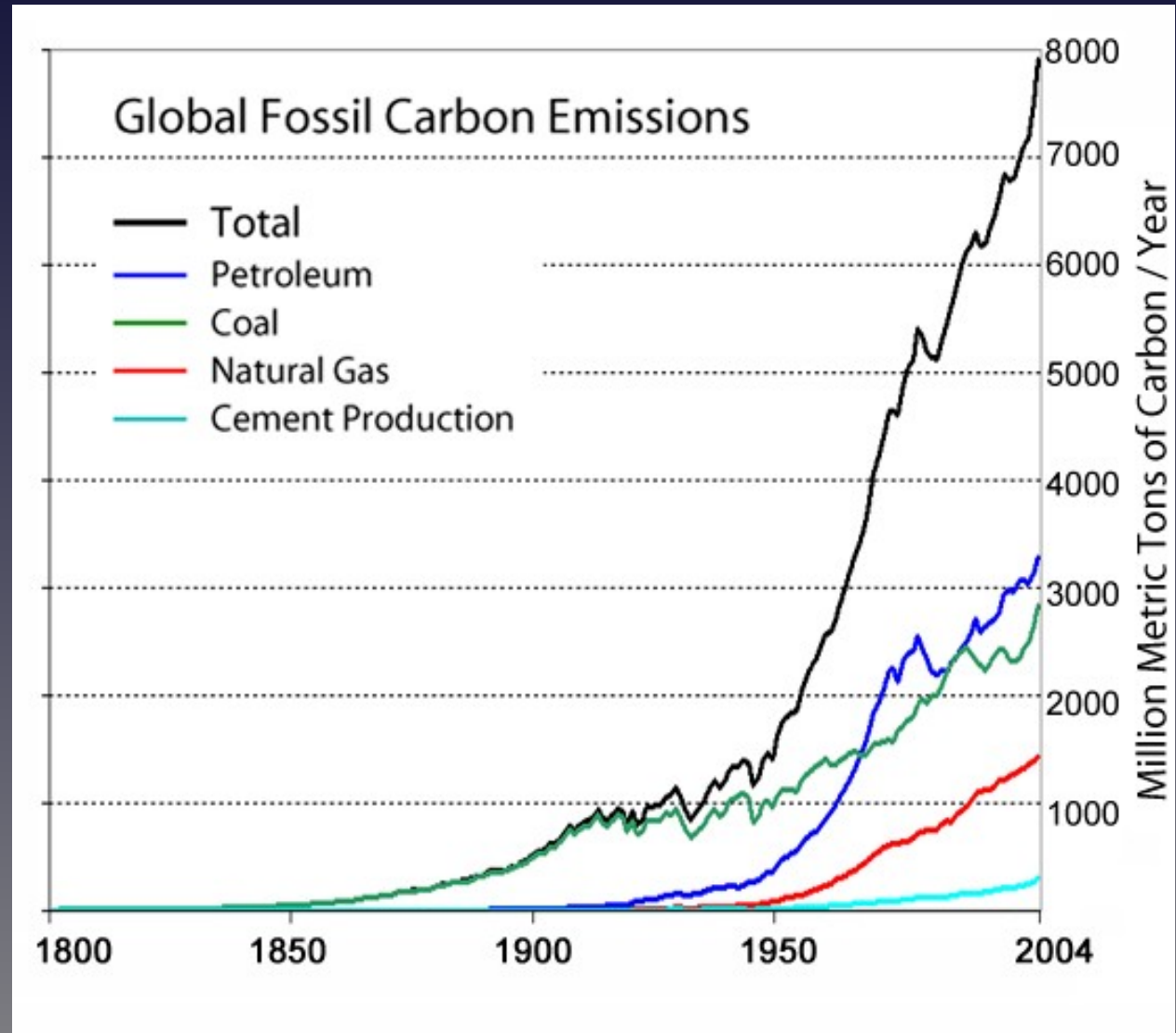
The first modern locomotive



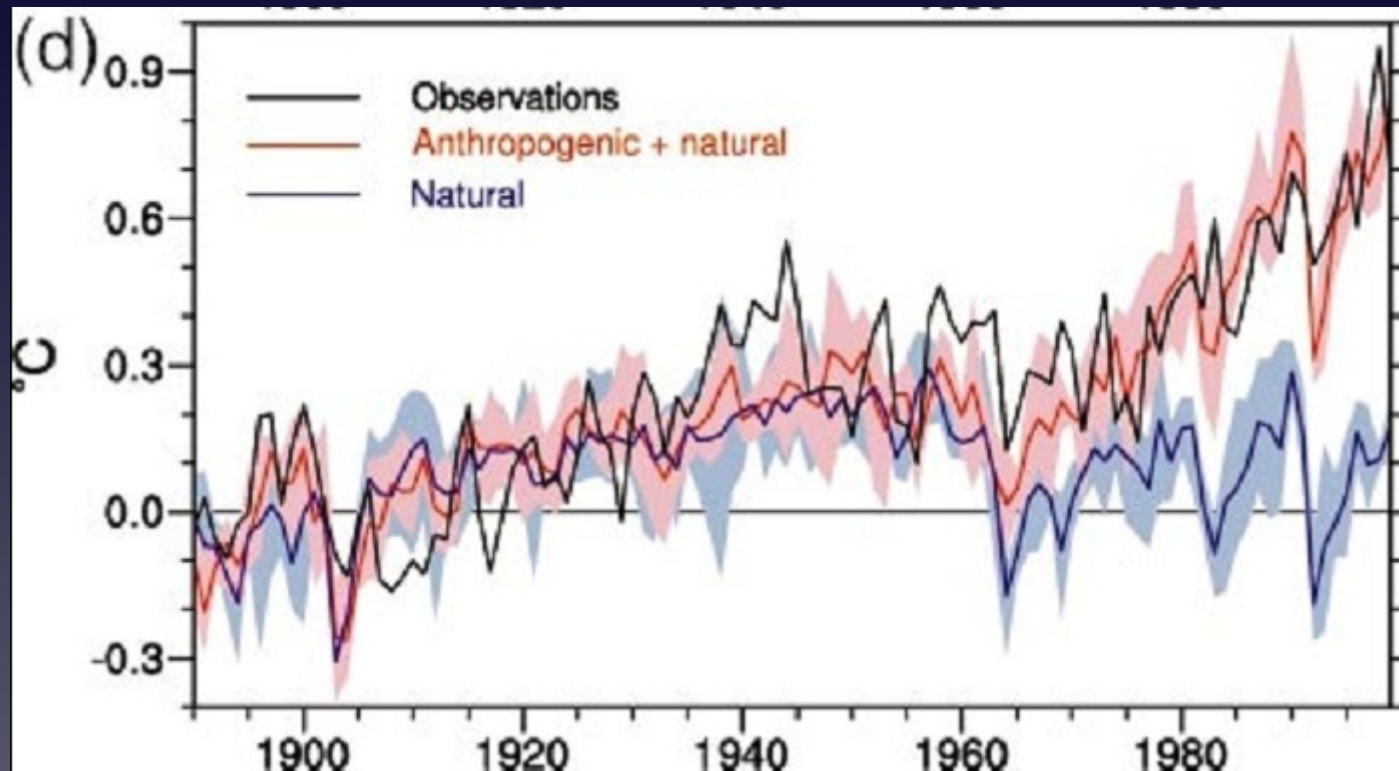
# Global Warming

## Warming and CO<sub>2</sub>

*Emissions of  
greenhouse gases  
over time*



# Global Warming



The blue curve accounts for volcanic eruptions, changes in the brightness of the Sun, and other natural variations

## **Combinations of Natural and Anthropogenic Forcings in Twentieth-Century Climate**

GERALD A. MEEHL, WARREN M. WASHINGTON, CASPAR M. AMMANN, JULIE M. ARBLASTER,  
T. M. L. WIGLEY, AND CLAUDIA TEBALDI

*National Center for Atmospheric Research,\* Boulder, Colorado*

# Global Warming

## The IPCC report

**The United Nations Intergovernmental Panel on Climate Change (IPCC) releases a report on climate change based on all the latest and best science**

**The latest report is the fourth, called AR4**

**AR4 is composed of four sections**

**The Physical Science Basis**

**Impacts, Adaptation and Vulnerability**

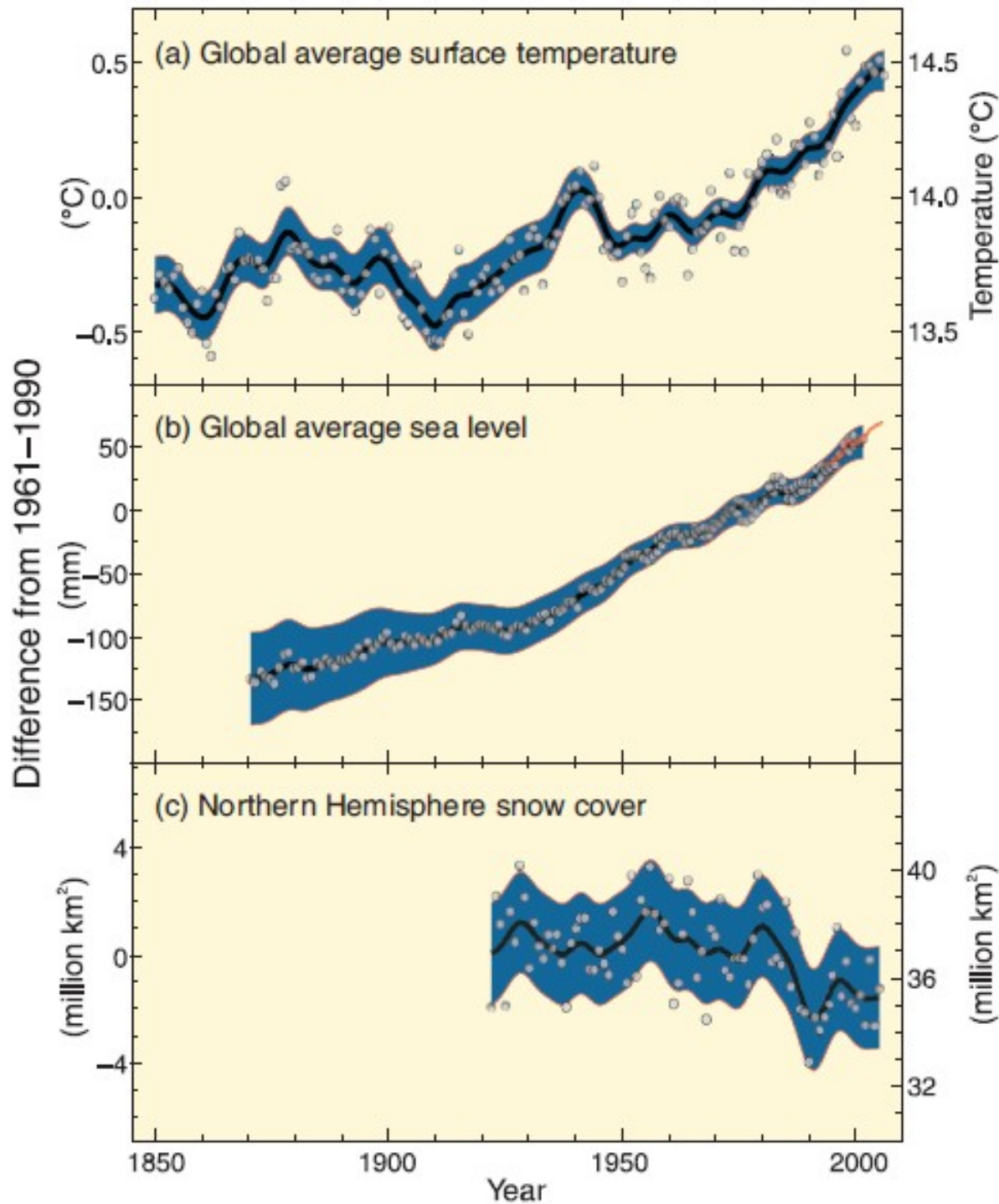
**Mitigation of Climate Change**

**Synthesis Report (summary)**

**The full report is nearly 3,000 pages**

**A single chapter of *The Physical Science Basis* covering some of the physical data is 235 pages with 16 pages of references**

## Changes in temperature, sea level and Northern Hemisphere snow cover



## Global Warming IPCC report conclusions

“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.”



# Global Warming

## IPCC report conclusions

“Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.”

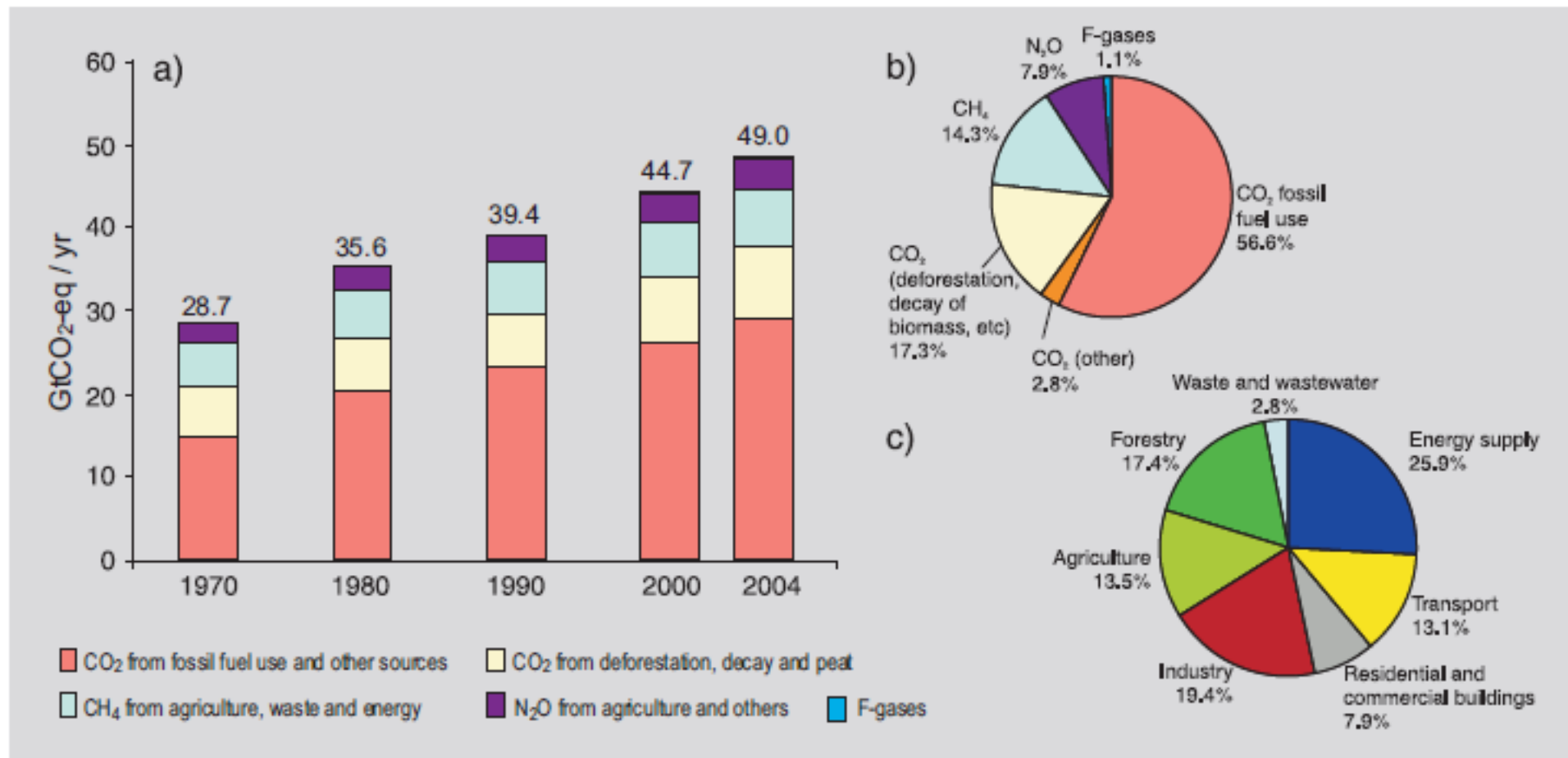


# Global Warming

## IPCC report conclusions

“Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.”

**Global anthropogenic GHG emissions**



# Global Warming

## IPCC report conclusions

**“Global atmospheric concentrations of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years”**

**“The atmospheric concentrations of CO<sub>2</sub> and CH<sub>4</sub> in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO<sub>2</sub> concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH<sub>4</sub> concentration is predominantly due to agriculture and fossil fuel use. The increase in N<sub>2</sub>O concentration is primarily due to agriculture.”**

# Global Warming

## IPCC report conclusions

**“There is very high confidence that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W/m<sup>2</sup>”**

**“Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations. This is an advance since the Third Assessment Report’s (TAR) conclusion that “most of the observed warming over the last 50 years is *likely* to have been due to the increase in GHG concentrations”**

# Global Warming

## IPCC report conclusions

**“Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate, including temperature extremes and wind patterns.”**

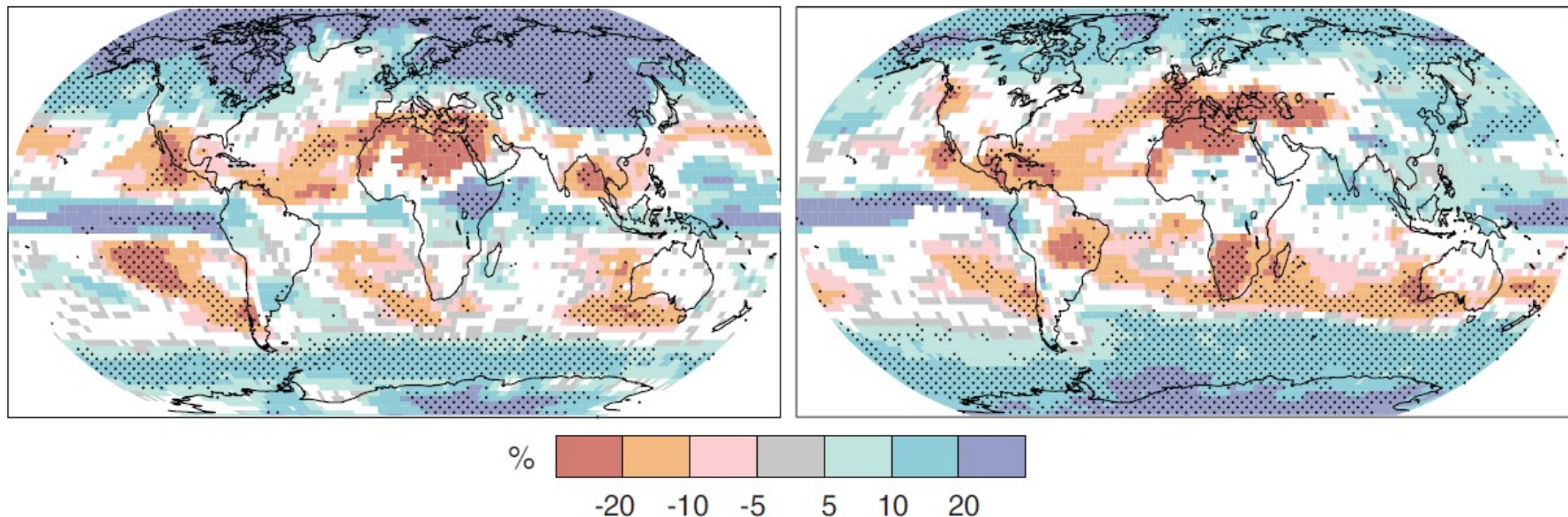
**“Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century.”**

# Global Warming

## IPCC report conclusions

**“There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and sea ice.”**

**Multi-model projected patterns of precipitation changes**



**Figure 3.3.** Relative changes in precipitation (in percent) for the period 2090-2099, relative to 1980-1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {WGI Figure 10.9, SPM}

# Global Warming

## IPCC report conclusions

**“Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilised.”**

# Global Warming

## IPCC report conclusions

**“Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.”**





# Global Warming

## IPCC report conclusions

**“Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change.”**

### **Example:**

**Permanently frozen arctic soil (permafrost) contains large amounts of CH<sub>4</sub>. When it is melted, the CH<sub>4</sub> is released. The newly released CH<sub>4</sub> increases the greenhouse effect, warming the arctic more, and releasing more CH<sub>4</sub>.**



# Global Warming

## Criticism of the IPCC report

**The report says that almost all the Himalayan glaciers will melt by 2035**

**This estimate was based only on an interview with Fred Pearce that appeared in New Scientist magazine on June 5, 1999**

**It is a correct report of Pearce's opinion, but it is based on limited evidence from one glacier and does not appear to be representative of all the Himalayan glaciers**

**The statement was not used in the Summary Report that makes recommendations**

**It should **not** have been included in the report unless more corroborating evidence was available**

# Global Warming

## Criticism of the IPCC report

**Better estimates of the Himalayan glacier melting are:**

**30% by 2030**

**40% by 2050**

**70% by 2100**

# Global Warming

## Criticism of the IPCC report

**The report says that 55% of the Netherlands is below current sea level**

**It should have said that 55% of the Netherlands is at risk of flooding; 26 per cent of the country is below sea level, and 29 per cent is susceptible to river flooding**

**The level of risk is not much modified by the mistake**

**Global warming is expected to increase rainfall and higher sea levels will also slow river drainage**

**It an unfortunate misstatement**

# Global Warming

## Criticism of the IPCC report

**Some data used in the IPCC AR4 was collected and tabulated by the Climate Research Unit (CRU) of The University of East Anglia (UEA), UK**

**Some of the researchers at UEA/CRU have come under criticism for the content of e-mails, thus casting a shadow on the IPCC report**

# Global Warming

## CRU scandal

**A researcher at CRU wrote a colleague that he was “using a trick” to “hide the decline” in some temperature data**

**The issue being discussed was that around 1960, data from tree rings began to misrepresent annual temperatures**

**No one understands why this unreliability of tree-ring data began, but given that we now have thermometers, most researchers just stopped using it**

**Several other indirect measures of annual temperature continue to agree with thermometers**

**The “trick” referred to is using actual thermometer data instead of tree-ring data after 1960**

**The tree-ring data is still used for long-ago years in which no thermometer data is available**

# Global Warming

## CRU tricks

“Quadratic equations are harder to solve than linear equations, because once you have them in standard form it is hard to simplify them any further, and in this form there are still two occurrences of the variable, so it's hard to see what we can do to get the variable alone.

So we have to find some clever **tricks** to get around this problem.

### Solving by Factoring

One **trick** is to solve the equation by factoring. This **trick** works because of the principle of zero products.”

<http://www.helpalgebra.com/>

# Global Warming

## CRU scandal

**Some of the researchers who accept the reality of global warming referred to skeptical scientists as “idiots”**

**They revealed that they felt under siege.**

**They revealed that they worried that any stray comment, small clerical error, or data glitch could be turned against them by the skeptics**

**They failed to fully respond to Freedom of Information requests and pondered erasing some of their e-mails**

**This behavior is understandable, but still seriously wrong for scientists holding influential positions**

# Global Warming

## CRU scandal

**No evidence has suggested that the data produced by the CRU is wrong**

**Data from completely independent groups show substantially the same global temperature history**

**The acts of the CRU researchers do not change the reliability of data in the IPCC report nor do they change any of the conclusions and recommendations**

**Other than claim that the e-mails are evidence of a conspiracy, the skeptics do not specify why the scandal undermines the evidence and prognosis of global warming**



# Global Warming

## Other criticism of global warming evidence

**It is claimed that global warming stopped a decade ago**



# Global Warming

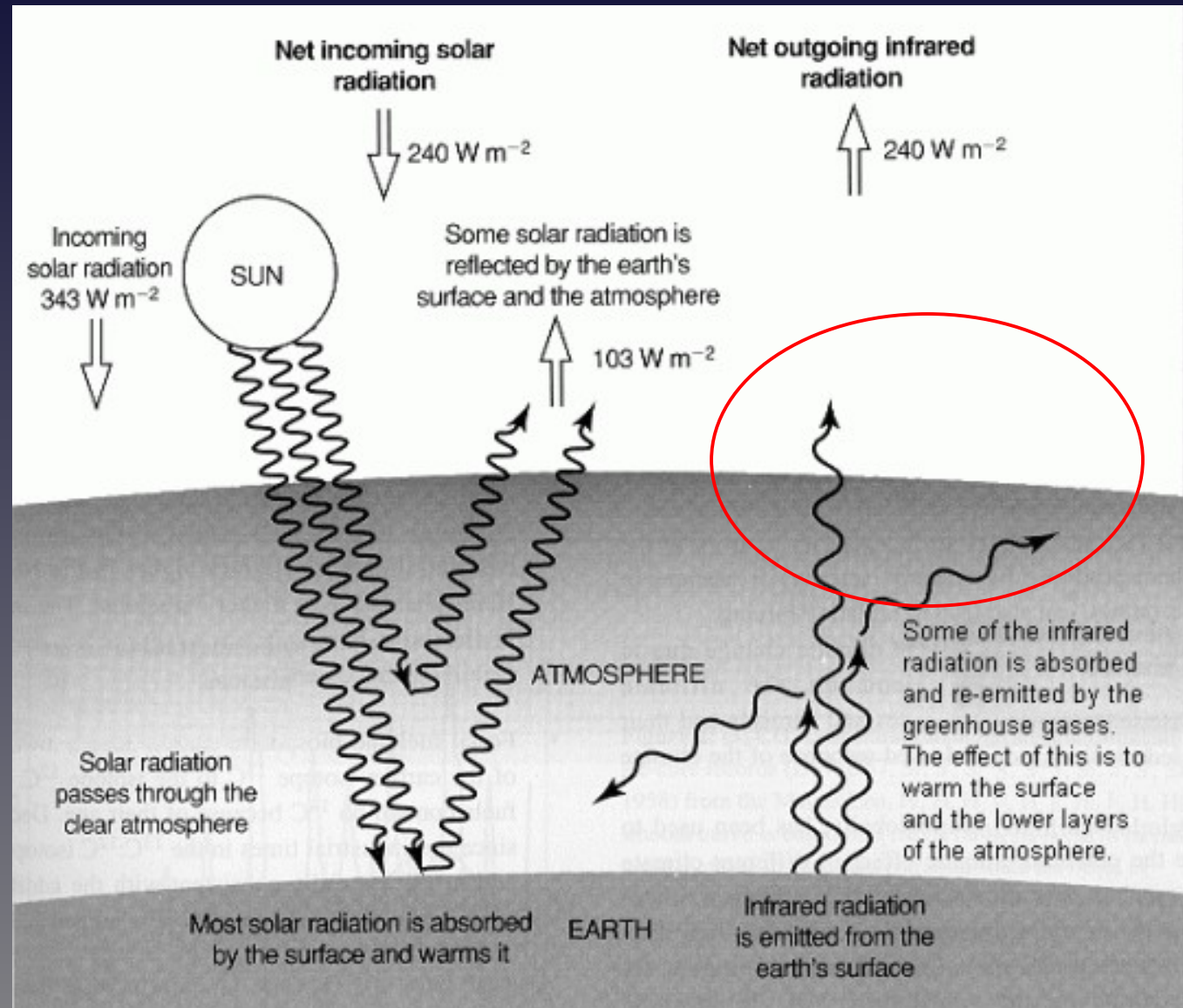
## Satellite measurements

**What if we could directly measure the earth's radiation back to space over time?**

**More greenhouse gases will partially block it**

**A hotter earth will radiate more**

**The measured radiation should tell us whether global warming is proceeding as expected**



# Global Warming

## Satellite measurements

**NASA Nimbus 4 satellite**

**Carried the Infrared Radiation  
Interferometer Spectrometer  
(IRIS)**

**Launched April 1970**

**Another satellite with a similar  
instrument was launched in  
1996**



# Global Warming

## Satellite measurements

In 1970, IRIS measured the brightness of the earth at the range of wavelengths where the earth radiates its thermal energy back to space

The similar satellite measured the thermal radiation in 1997

How had it changed?

Figures from the  
Harries paper



# Global Warming

## Other criticism of global warming evidence

- In an article in *American Thinker* magazine, Gary Thompson claims to have discovered a flaw in the data and interpretation from the work we just discussed

[http://www.americanthinker.com/2010/02/the\\_agw\\_smoking\\_gun.html](http://www.americanthinker.com/2010/02/the_agw_smoking_gun.html)

### Quotes from Thompson's article:

- “The 1997 OLR (outgoing long wavelength radiation) associated with CO<sub>2</sub> is identical to that in 1970.”
- “The authors perform this trick (there is that word again...) based on the climate models and not through actual measurements, and surprise, surprise -- these simulated results show a reduction in OLR emission with wavelengths that are absorbed by CO<sub>2</sub>.”
- “A key component of the scientific argument for anthropogenic global warming (AGW) has been disproven. The results are hiding in plain sight in peer-reviewed journals.”

# Global Warming

## Other criticism of global warming evidence

- **Thompson asserts a completely incorrect conclusion based on a completely incorrect observation about the data in the original paper**
- **Thompson refuses to accept any calculated results**
- **Thompson's conclusions are exactly opposite the conclusions of the original paper's authors**



# Global Warming

## Other criticism of global warming evidence

**Nevertheless, the readers of Thompson's article believe he has shown the scientists to be stupid, dishonest scam artists**

**“Now, when do we start and hold these people accountable for fraud and conspiracy to commit fraud on the federal government (a felony I beleive).”**

**“Global warming is the perfect scammers agenda science.”**

**“Why would liberals ever let the facts get in the way of their hoax?”**

**“This entire AGW hysteria has been one big scam from the start.”**

**“Excellent analysis that should add one more nail to the coffin of AGW.”**

# Global Warming Criticism

**The critics exaggerate problems with the global warming data and/or explanations without offering any alternate data or explanation**

**In the cases where alternate interpretation of the temperature data is offered, it is usually transparently wrong**

**Honest, capable scientists differ in their analyses of global warming. Most of the disagreement is about the magnitude of warming, the future predictions, and what we should do about it.**



# Global Warming

Science fact or fiction?

**Global Warming is an observational fact supported by many independent observations**

**The increase of atmospheric greenhouse gases since 1830 is an observational fact supported by several independent observations**

**The Greenhouse Effect theory explains Global Warming within the uncertainties of current data**

**Other theories for small Global Warming/Cooling effects exist (sun activity, volcanoes, etc) and others may be discovered**

**The magnitude and timing of global warming is explained only by anthropogenic greenhouse gas emissions**

# Global Warming

Science fact or fiction?

**Future theories of Global Warming are very unlikely to be significantly different than the current one**

**Predictions made from the theory will get better as more historical data is gathered, details of the Greenhouse Effect are understood and predictive methods are refined**

**The methods to understand and predict Global Warming are imperfect**

**The people who investigate and explain Global Warming are imperfect**

**BUT,**

**There is no factual basis on which to doubt the overall correctness of the current explanation of Global Warming**

# Global Warming

Science fact or fiction?

**We have only about forty years of historical data on which to base predictions of future Global Warming**

**Consequences are as likely to be more severe than the projections as they are to be less severe**

**The consequences of continued greenhouse gas emissions at current levels are likely to produce severe economic losses and human suffering**

**If global warming produces self-amplifying effects such as CH<sub>4</sub> release from the permafrost, the global impact may be uncontrollable and catastrophic**

# Global Warming

Science fact or fiction?

**Large reduction of greenhouse gas emissions as a top national priority can avoid the most serious consequences while generating huge benefits in economic security and job generation**

# Global Warming

## Warming and CO<sub>2</sub>

*The strongest correlate of opinion on climate change is partisan affiliation. Two-thirds of Republicans (67%) say either that the Earth is getting warmer mostly because of natural changes in the atmosphere (43%) or that there is no solid evidence the Earth is getting warmer (24%). By contrast, most Democrats (64%) say the Earth is getting warmer mostly because of human activity. ... The divide is even larger when party and ideology are both taken into consideration. Just 21% of conservative Republicans say the Earth is warming due to human activity, compared with nearly three-quarters (74%) of liberal Democrats. — Pew Research Center*

# Global Warming

## Warming and CO<sub>2</sub>

**Why do you think that the reality of Anthropogenic Global Warming is so controversial?**