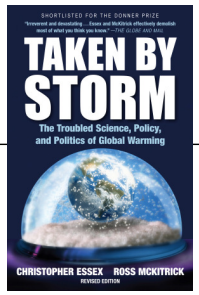
Some complicating factors in understanding climate change and making policy plans

Ross McKitrick
Dept of Economics
University of Guelph
February 2008

About me



- Associate professor of economics, specializing in environmental economics
- Coauthor, *Taken By Storm*
- Published in economics journals, as well as *Climate Research, Geophysical Research Letters, Journal of Non-Equilibrium Thermodynamics, Journal of Geophysical Research*
- Participant in 2006 US National Academy of Science Review of Paleoclimatology methods

Outline

- What do we mean by "global warming"
- How do measurements compare to predictions?
- Why isn't it a simple issue?
  - Underlying theory
  - Measurement problems
- What should we do about it?

What do we mean by "global warming"?

- "Since the late 1960s, much of the North Atlantic Ocean has become less salty, in part due to increases in fresh water runoff induced by global warming, scientists say."

  -Michael Schirber, LiveScience
  June 29, 2005

- "The surface waters of the North Atlantic are getting saltier, suggests a new study of records spanning over 50 years. They found that during this time, the layer of water that makes up the top 400 metres has gradually become saltier. The seawater is probably becoming saltier due to global warming, Boyer says."

  -Catherine Brahic, New Scientist
  August 23, 2007

What do we mean by "global warming"?

- 2 recent reports help clarify:
  - Intergovernmental Panel on Climate Change 2007
  - US Climate Change Science Program 2006
- Both identify the key regions for observing GHG-induced warming:

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Sources

IPCC Working Group I 4th Assessment Report (AR4)

http://www.ipcc.ch/ipccreports/ar4-wg1.htm

CCSP Report

http://www.climatescience.gov/Library/sap/sap1-1/finalreport/default.htm

What do we mean by "global warming"?

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  The Arctic and the Tropical Troposphere

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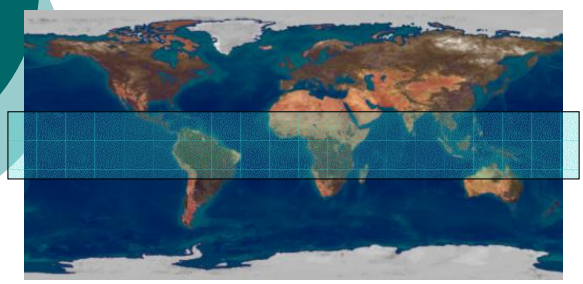
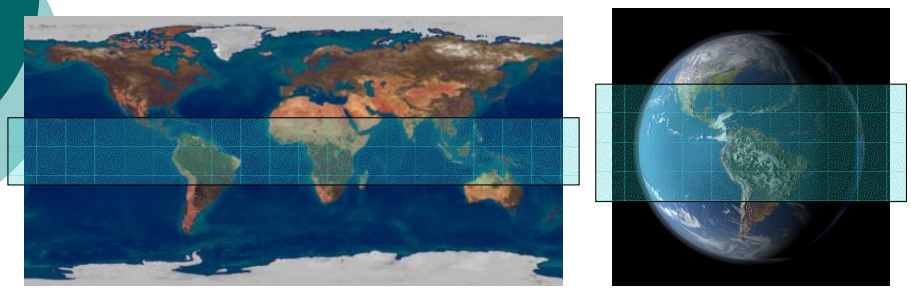
Tropical troposphere



- 1-16 km above the surface
- 30N to 30S
- Half the atmosphere

Tropical troposphere



- 8-16 km above the surface
- 30N to 30S
- Half the atmosphere

Predicted warming centers

- Tropical troposphere
- Arctic surface layer
- (Antarctica)

- Questions
  - Is the response to GHG's rapid?
  - Is the pattern unique to GHG's?

Predicted warming centers

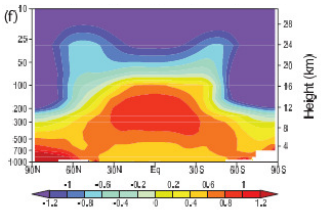
- Tropical troposphere
  - Yes- rapid adjustment
  - Yes- unique
- Arctic
  - Unclear- model-dependent
  - No- not unique

IPCC
Hindcast

1890-
1999

AR4

Fig9.1



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Each graph panel shows:

-latitude on horizintal axis (N to S = left to right),

-altitude on vertical axis.

Thus equator is on horizontal axis in centre, north pole at surface is in bottom left, etc.

IPCC Hindcast

1890-1999

AR4

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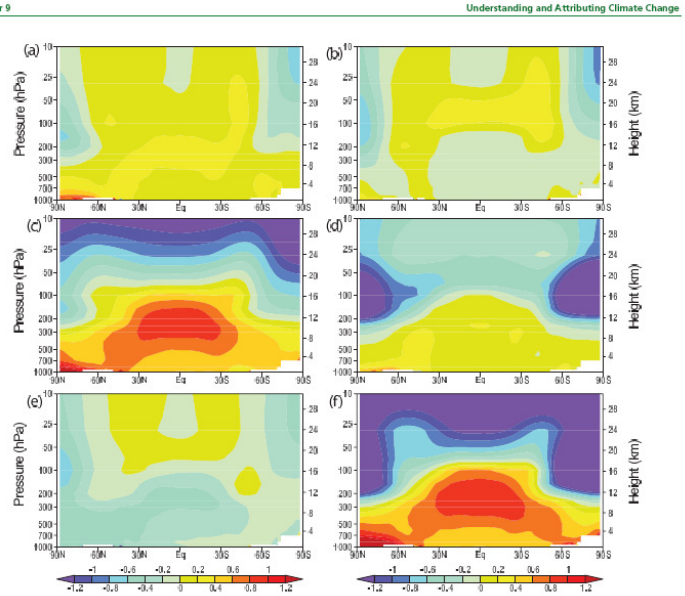

Figure 9.1. *Zonal mean atmospheric temperature change from 1890 to 1999 (°C per century) as simulated by the PCM model from (a) solar forcing, (b) volcanoes, (c) well-mixed greenhouse gases, (d) tropospheric and stratospheric ozone changes, (e) direct sulphate aerosol forcing and (f) the sum of all forcings. Plot is from 1,000 hPa to 10 hPa (shown on left scale) and from 0 km to 30 km (shown on right). See Appendix 9.C for additional information. Based on Santer et al. (2003a).*

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IPCC Hindcast

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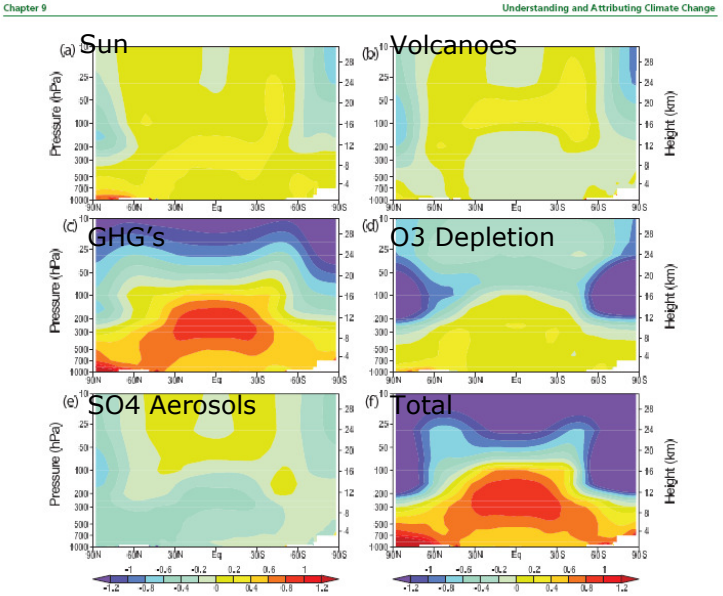

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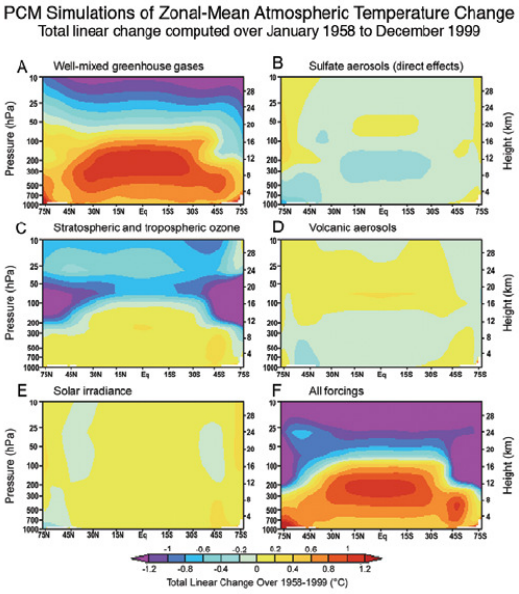
US Climate Change Science Program Report (2006) Page 25

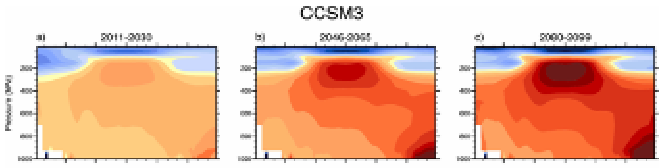
1958-1999 Hindcast

Same outcome

TT Trend should be underway



Future projections in IPCC AR4 (Figure 10.7)



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This and next 11 all taken from IPCC Supplementary info web site
http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/Ch10_indiv-maps.html

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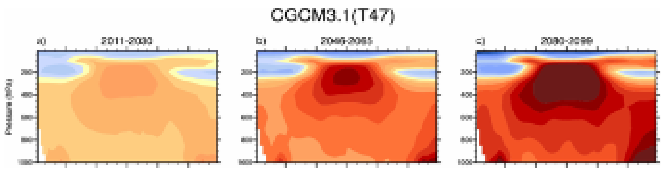

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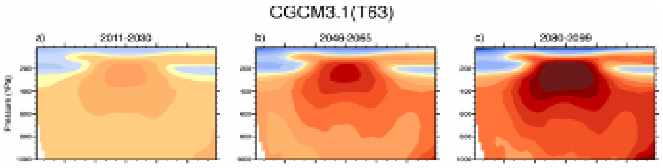

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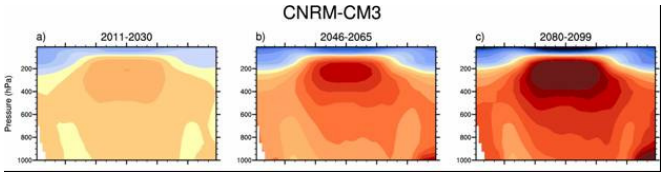

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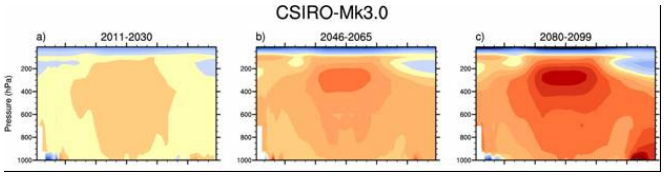

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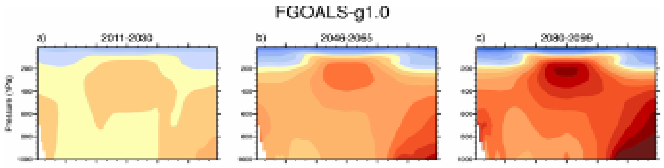

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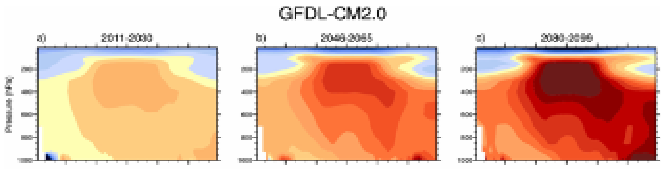

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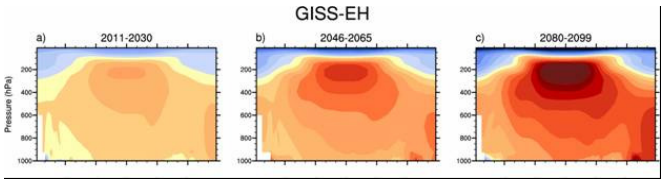

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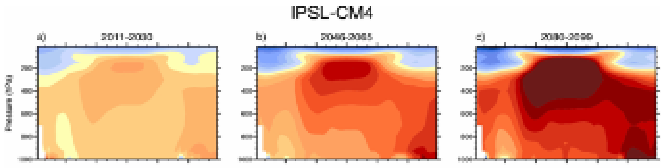

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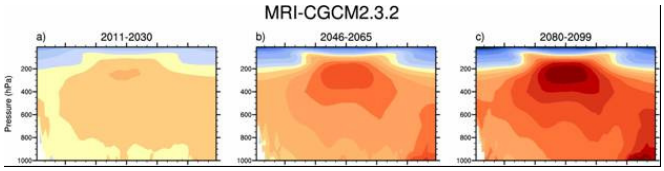

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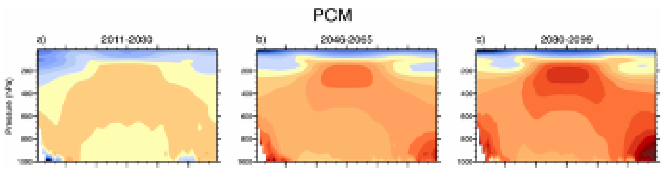

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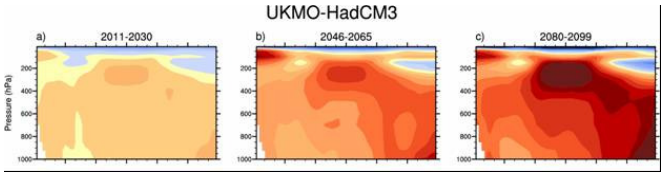

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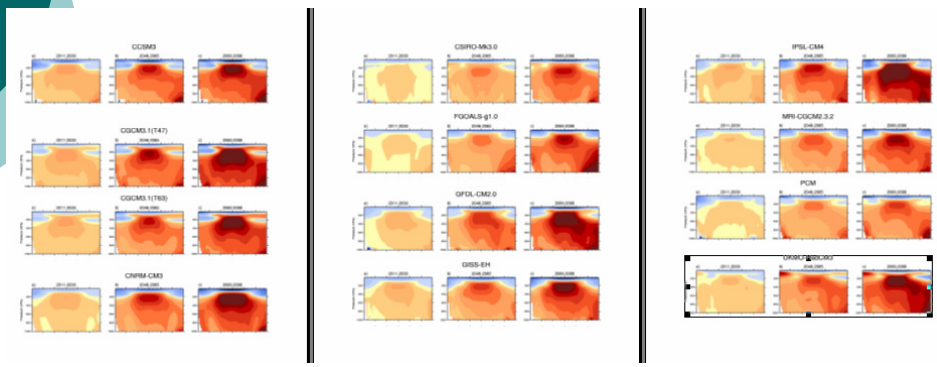


Concentrated, rapid warming expected in tropical troposphere

- IPCC Report pp 763-764:

Upper-tropospheric warming reaches a maximum in the tropics and is seen even in the early-century time period. The pattern is very similar over the three periods, consistent with the rapid adjustment of the atmosphere to the forcing. These changes are simulated with good consistency among the models.

The Predictions

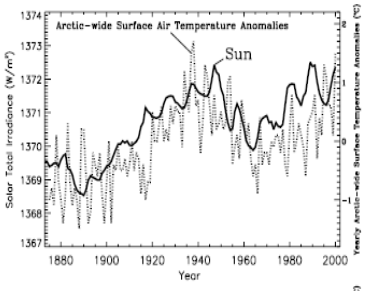
- Tropical region:
  - Troposphere should warm faster than the surface
  - Pattern should be already showing up
- Arctic region:
  - Surface should warm faster than troposphere
  - But pattern may not emerge until 2040's

Arctic region

- Sensitive to
  - Arctic Oscillation
  - Solar changes
  - Atmospheric circulation
  - Ocean currents
- These have a lot of explanatory power

Arctic region – Other influences

- The Sun



- Soon (GRL 2005 http.//www.agu.org/pubs/crossref/2005/2005GL023429.shtml)

Arctic region – Other influences

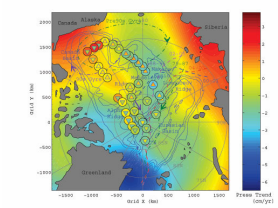
- The Ocean

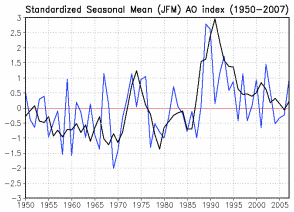
NASA Sees Arctic Ocean Circulation Do an About-Face
November 13, 2007
http://www.jpl.nasa.gov/news/news.cfm?release=2007-131

PASADENA, Calif. – A team of NASA and university scientists has detected an ongoing reversal in Arctic Ocean circulation triggered by atmospheric circulation changes that vary on decade-long time scales. **The results suggest not all the large changes seen in Arctic climate in recent years are a result of long-term trends associated with global warming**.

Morison et al. (GRL 2007):

- "Our study confirms many changes seen in upper Arctic Ocean circulation in the 1990s were mostly decadal in nature, rather than trends caused by global warming," said Morison.





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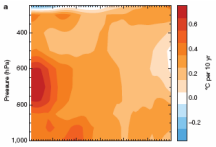
GRL = Geophysical Research Letters

Morison, J., J. Wahr, R. Kwok, and C. Peralta-Ferriz (2007), Recent trends in Arctic Ocean mass distribution revealed by GRACE, Geophys. Res. Lett., 34, L07602, doi:10.1029/2006GL029016

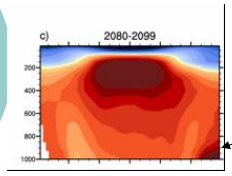
Arctic region – Other influences

- Large-scale circulation patterns



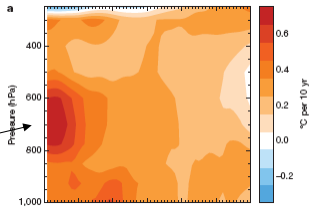
- "Our results do not imply that studies based on models forced by anticipated future CO2 levels are misleading when they point to the importance of the snow and ice feedbacks. It is likely that a further substantial reduction of the summer ice-cover would strengthen these feedbacks and they could become the dominant mechanism underlying a future Arctic temperature amplification. **Much of the present warming, however, appears to be linked to other processes, such as atmospheric energy transports**."

Arctic region – Other influences



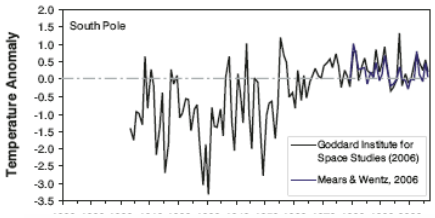
Models predict Arctic amplification near surface

But observations place it in troposphere

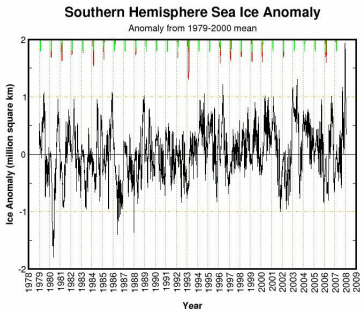


Antarctica

- No increase in mean temperature since 1960



- SH sea ice above 1979-2000 mean



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Data compiled for the ISPM Figure 8:

http://www.uoguelph.ca/~rmckitri/research/ispm.html

Sources:

Goddard Institute for Space Studies (2006). Annual mean Land-Ocean Temperature Index in 0.1C selected zonal means. Data available online at http://data.giss.nasa.gov/gistemp/tabledata/ZonAnn.Ts+dSST.txt.

Mears, C.A., and F.J. Wentz (2006). MSU Data, Remote Sensing Systems, Santa Rosa, California. Data available online at http://www.remss.com/data/msu/monthly_time_series/RSS_Monthly_MSU_AMSU_Channel_TLT_Anomalies_Land_and_Ocean_v03_0.txt.

Good data exist for troposphere

- Daily measurements by NOAA satellites, analysed by independent teams at RSS and UAH
- 2 weather balloon networks (RATPAC and HADAT2)

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RSS = Remote Sensing Systems

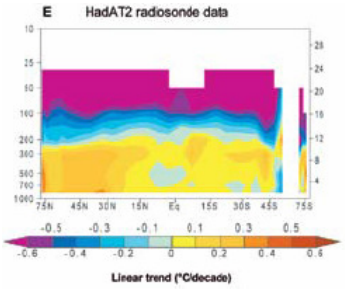
http://www.remss.com/msu/msu_data_description.html

UAH = University of Alabama-Huntsville

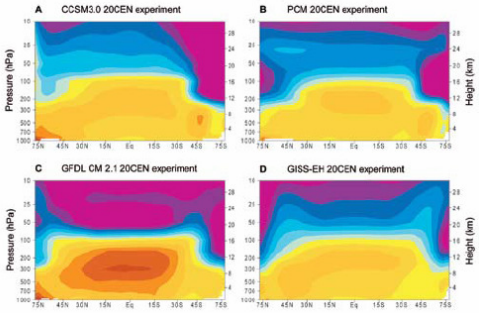
http://www.nsstc.uah.edu/data/msu/

Weather Balloons & Satellites 1979-1999 (CCSP p. 116)

- Balloon record



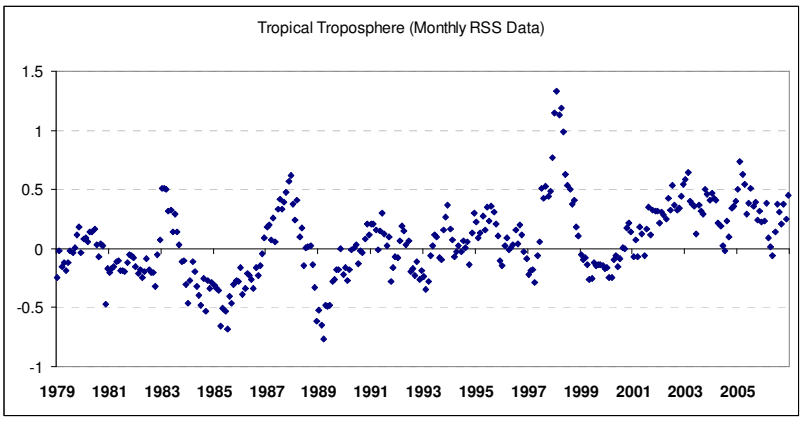
- Model hindcasts



"Another noticeable difference is that the HadAT2 data show a relative lack of warming in the tropical troposphere where all four models simulate maximum warming."

Tropical Troposphere

- 1979-2007



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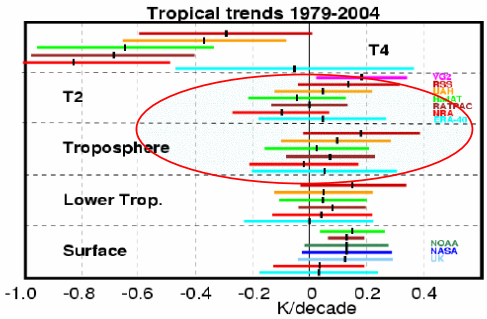
UAH tropical tropospheric data record

Compilation of current trends (IPCC AR4, Fig 3.4.3)

- At present: positive but insignificant trend in tropical troposphere



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This is from the Second Order Draft of the IPCC WG1 Assessment Report

8 data comparisons (CCSP)

- Surface (T_s); Troposphere (T_{2LT})
  - Models: $(T_s - T_{2LT}) < 0$: negative
  - Data: $(T_s - T_{2LT}) > 0$: positive

- US CCSP Report p. 111

8 data comparisons (CCSP)

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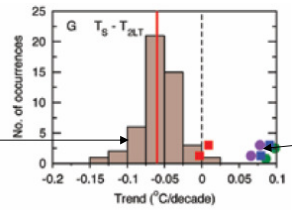
Models:

negative

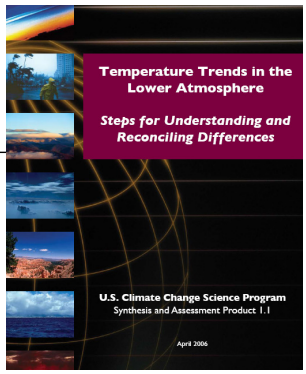


Data:

positive

- US CCSP Report p. 111

US CCSP page 11



- "A potentially serious inconsistency, however, has been identified in the tropics. Figure 4G shows that the lower troposphere warms more rapidly than the surface in almost all model simulations, while, in the majority of observed data sets, the surface has warmed more rapidly than the lower troposphere. In fact, the nature of this discrepancy is not fully captured in Fig. 4G as **the models that show best agreement with the observations are those that have the lowest (and probably unrealistic) amounts of warming."**

Preliminary conclusions

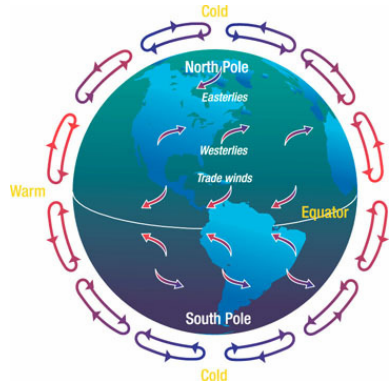
- IPCC & CCSP Reports identify 2 areas where we expect to see dominant GHG effects
  - Arctic and tropical troposphere
- Arctic
  - Multiple influences, unclear response timeline
    - Many competing explanations for late 20th century warming
    - warming is stronger aloft than at surface: not consistent with model projections
- Tropical troposphere
  - Consistent prediction across models of rapid response to GHG's
    - No observed warming pattern beyond natural variability
    - Warming weaker aloft than at surface: not consistent with model projections

Why is the issue complicated?

- Lack of underlying theory for fluid dynamics on climatic scales
- Natural variability hard to estimate
- Measurement problems at surface

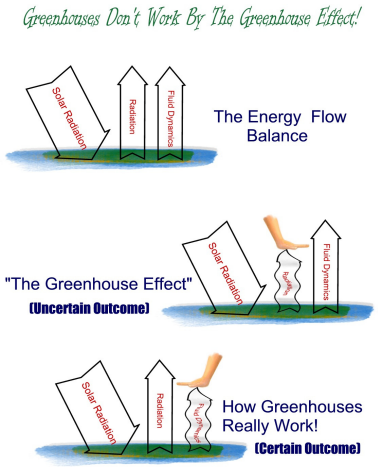
Fluid dynamics on climate scales

- Energy balance mechanisms at the surface:
  - *Fluid Dynamics*
  - *Radiation*



Fluid dynamics on climate scales

"The Greenhouse Effect"



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Fluid dynamics on climate scales

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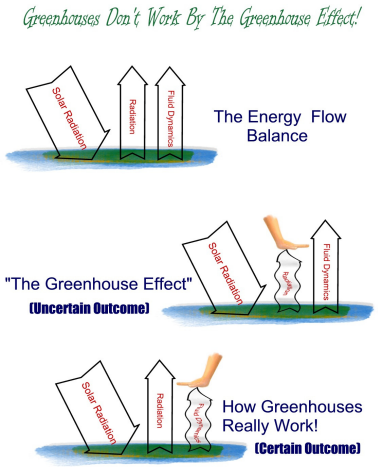

Radiative Transfer

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Fluid dynamics on climate scales

"The Greenhouse Effect"

Fluid Dynamics (Navier-Stokes)

Radiative Transfer

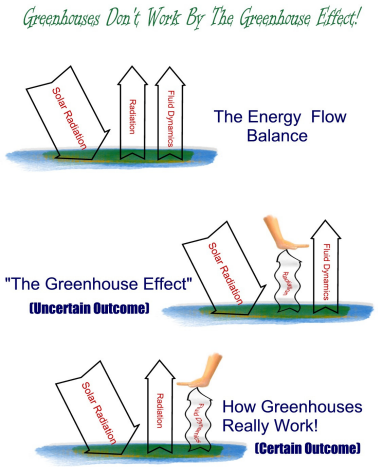

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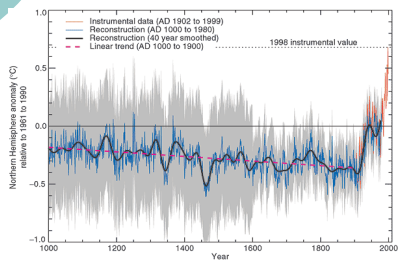
Diagram and discussion from Essex&McKitrick *Taken By Storm*

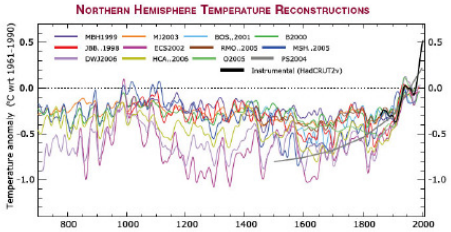
Natural variability: Paleoclimate context

- NAS panel, page 107 (referring to M&M criticisms)
  - …taken together, they are an important aspect of a more general finding of this committee, which is that uncertainties of the published reconstructions have been underestimated.
- Wegman Panel pp. 4-5
  - Overall, our committee believes that Mann's assessments that the decade of the 1990s was the hottest decade of the millennium and that 1998 was the hottest year of the millennium cannot be supported by his analysis.

Paleoclimate context

- Hockey stick versus spaghetti graph





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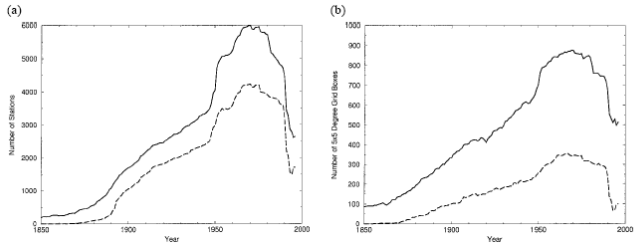
Left: IPCC 2001 Hockey stick graph (Mann, Bradley Hughes); Right: IPCC 2007 spaghetti graph

Measurement problems

- Sampling problems of surface temperature, especially after 1990



- Peterson&Vose, BAMS (1997) 2837-2849.

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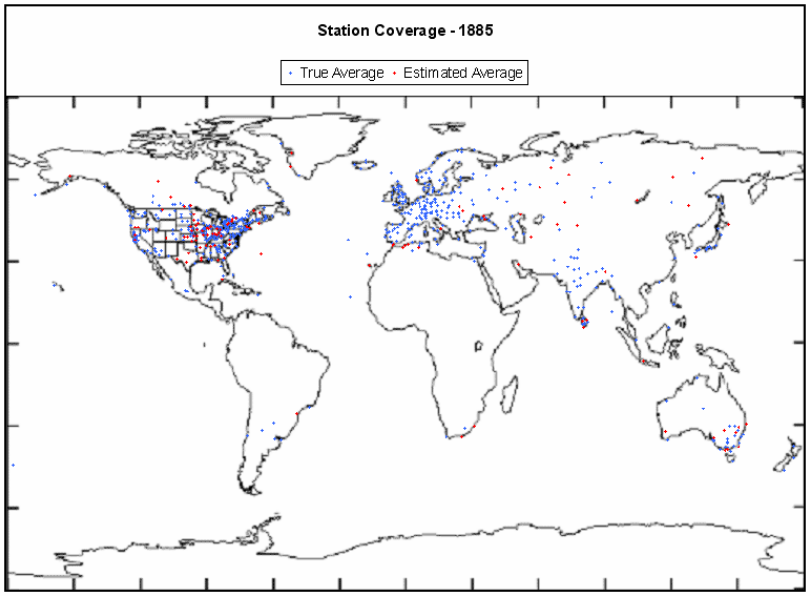
Diagrams show availability of weather monitoring stations over 20th century

Peterson T.C. and R.S. Vose (1997) "An Overview of the Global Historical Climatology Network Temperature Database." *Bulletin of the American Meteorological Society* 78:2837—2849.



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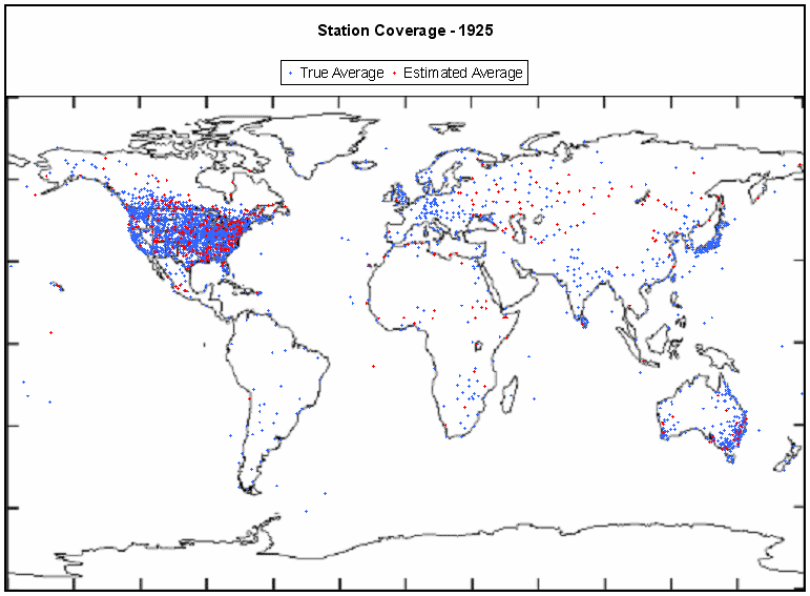
This map and the next 5 were compiled by John Goetz using the GHCN archive. See http://www.climateaudit.org/?p=2711. The same sequence was developed by the Center for Climatic Research at the University of Delaware, see http://climate.geog.udel.edu/~climate/index.shtml.



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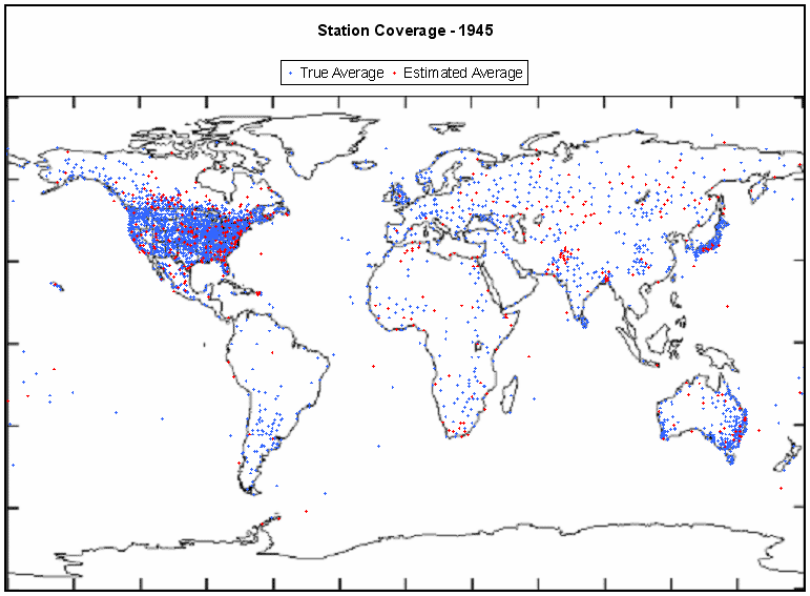

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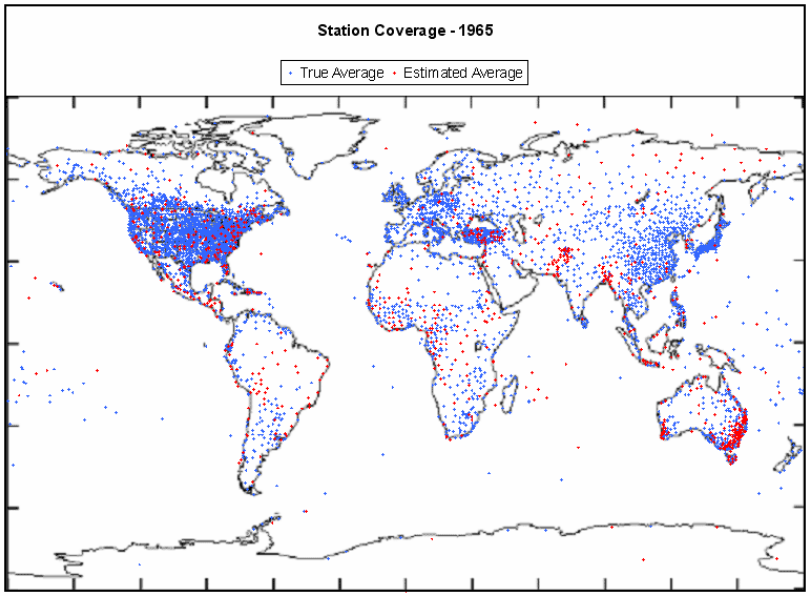

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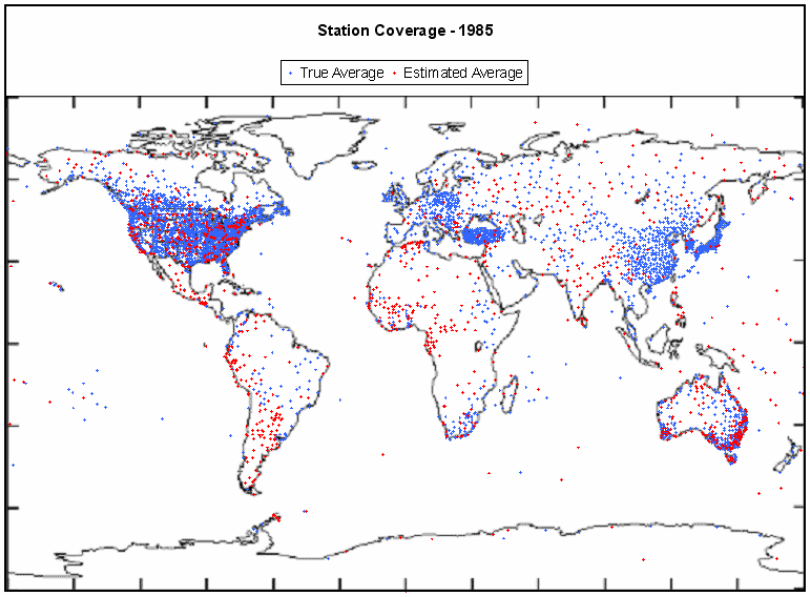

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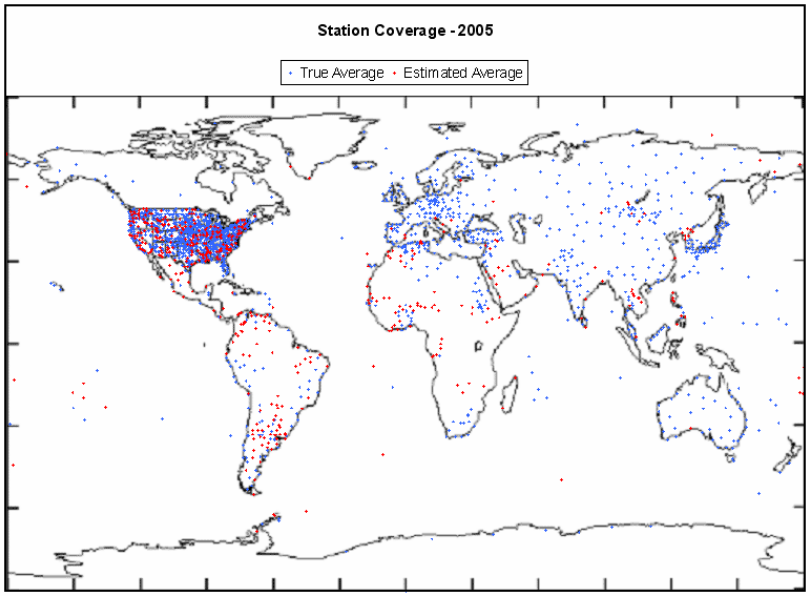

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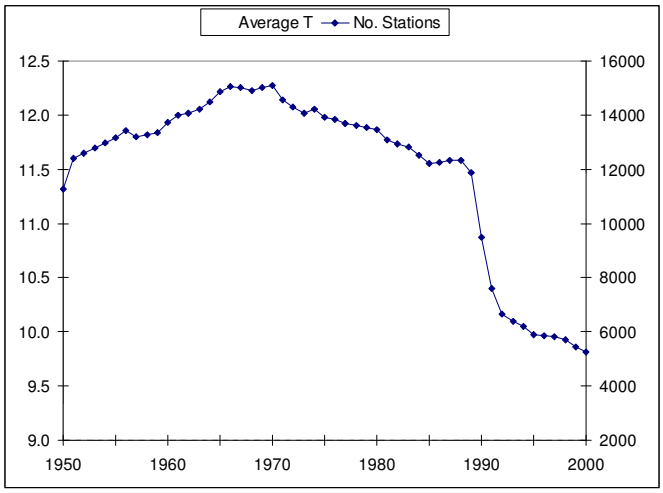
57

Number of weather records



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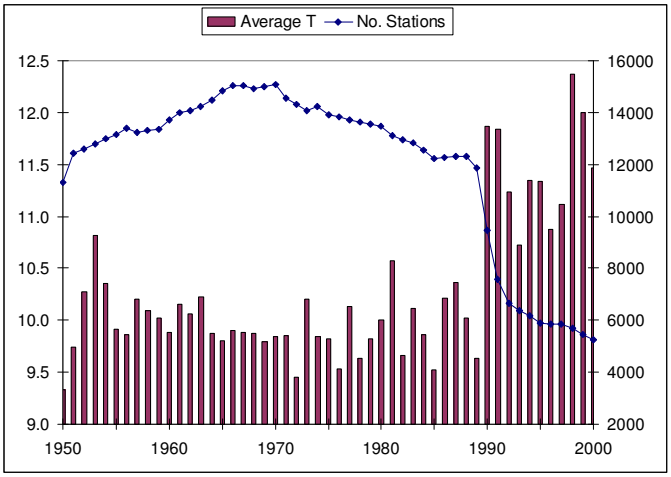
See http://www.uoguelph.ca/~rmckitri/research/nvst.html for sources

Number of weather records



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See http://www.uoguelph.ca/~rmckitri/research/nvst.html for sources

Problems of interpretation: Surfaces

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **26**: 897–913 (2006)
Published online 27 March 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1292

EVIDENCE FOR INFLUENCE OF ANTHROPOGENIC SURFACE PROCESSES ON LOWER TROPOSPHERIC AND SURFACE TEMPERATURE TRENDS

A. T. J. DE LAAT* and A. N. MAURELLIS
Netherlands Institute for Space Research (SRON), EOS, Utrecht, Netherlands

- Anthropogenic surface processes
  - Land-use changes, urbanization, data quality problems introduce false trends in data
  - Large literature shows these cause warming bias in meteorological data, e.g.

De Laat, A.T.J., and A.N. Maurellis (2006). “Evidence for Influence of Anthropogenic Surface Processes on Lower Tropospheric and Surface Temperature Trends.” International Journal of Climatology 26:897—913.

Problems of interpretation: Surfaces

In this paper, we verify the robustness of the unsmoothing technique and confirm our earlier conclusions on the data of an extended analysis and two additional data sets. We confirm the presence of a temperature change–industrialization correlation by analyzing the data with an additional statistical method and further confirm the absence of the above correlation in climate model simulations of enhanced GHG warming. Our findings thus provide an important test of climate model performance on regional scales.

- Climate model predictions:
  - regional temperature trends under GHG warming do not correlate with surface pattern of industrialization
- Climate data:
  - observed regional temperature trends strongly correlate with surface pattern of industrialization

Biases in surface record

McKitrick & Michaels, *J. Geophys. Res.-Atmos* (2007)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, D24S09, doi:10.1029/2007JD008465, 2007

Click Here for Full Article

Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data

Ross R. McKitrick[1] and Patrick J. Michaels[2]

Received 26 January 2007; revised 3 May 2007; accepted 8 November 2007; published 14 December 2007.

- Correlation between spatial warming pattern at surface, and indicators of industrial development significant at p=1.7E-14.
- Explains about half of post-1980 surface warming over land

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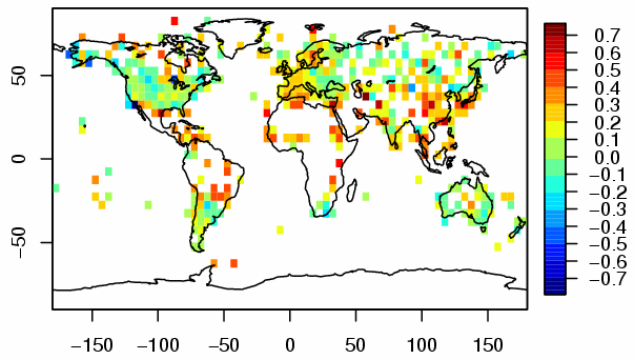
See http://www.uoguelph.ca/~rmckitri/research/jgr07/jgr07.html for paper and sources

Biases in surface record

McKitrick & Michaels, *J. Geophys. Res.-Atmos* (2007)



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Summary

- Temperature data collected at Earth's surface
  - Sparse
  - Contaminated by effects due to land surface
- Better option: use satellite data

Making Policy Plans

- Proposal: Put a tax on CO2 emissions tied to actual warming in the tropical troposphere
- Suppose we take the mean of the UAH & RSS measures of the mean tropical tropospheric temperature (T3)
- Calibrate these to a number (~ 5)
- Make this the tax per tonne on carbon emissions

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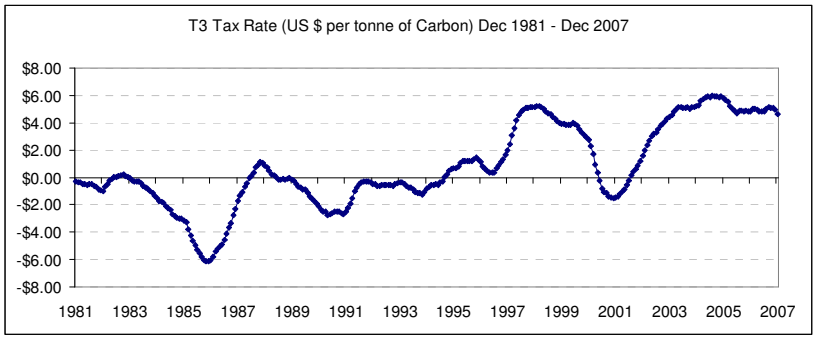
See http://ross.mckitrick.googlepages.com/#t3tax for discussion and details

T3 Formula

- 3-year moving average x 20

$$T3 = 20 \times \tfrac{1}{36} \sum_{i=0}^{35} \tfrac{1}{2} \left(SC(t-i) + RSS(t-i) \right)$$

T3 Rate since 1981



- Current value = $4.66

IPCC Projections

- 0.2 – 1.2 C/decade warming in Tropical Troposphere
- Implies $4 - $24 rise in T3 tax per decade
- Actual rate depends on actual warming

The T3 Tax

- If the mean tropical tropospheric temperature goes up, so does the tax
- If not, the tax does not go up
- It might even go down.

- Whatever happens, it is (approximately) the right outcome.
- We don't have to know in advance who's right.
- Everyone expects to get their preferred outcome.

Everyone expects to get their preferred outcome

- Skeptics expect the tax to stay flat or fall
- Believers expect the tax to soar
- Policymakers don't have to guess who's right, they get the right outcome either way
- But investors have to figure out who's more credible

But it kicks in too late! The warming will already have happened when the price changes

- No, for 2 reasons
  - The tropical troposphere is the atmosphere's "leading indicator"—warming there leads surface effects
  - Investors are forward-looking
    - Today's decisions are based on forecast of tax rates 5-10 years from now
    - Under this mechanism, investors incorporate projections of future warming into today's decisions

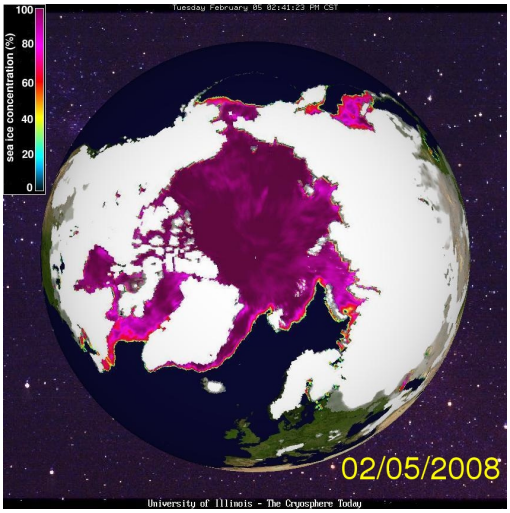
Added benefit:
market for ACCURATE climate forecasts

- Investors will need accurate forecasts of tropical troposphere climate
- If current GCM's are systematically wrong, the market will look elsewhere
- Market for accuracy may lead to new techniques in climate forecasting

Summary

- What do we mean by "global warming"?
  - *Watch for trend in tropical troposphere*
- How do measurements compare to predictions?
  - *The discrepancies are non-trivial*
- Why isn't it a simple issue?
  - *Underlying theory does not exist*
  - *Natural variability hard to estimate*
  - *Measurement problems contaminate basic surface data*
- What should we do about it?
  - *Enact a policy with a close feedback between the observed outcome and the stringency of the measure*

The End



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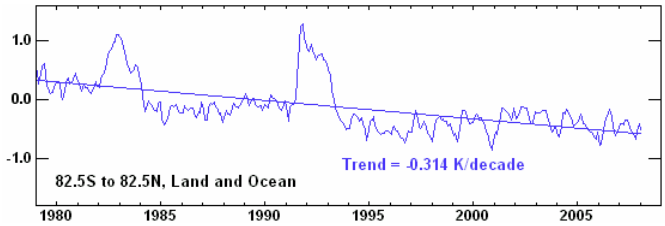
Stratospheric Cooling

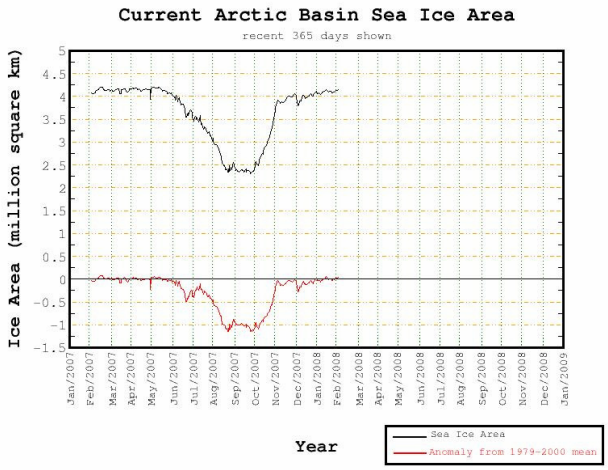
- RSS Data 1979-Jan 2007



- http://www.remss.com/msu/msu_data_description.html#figures

Arctic region – Ice variability

- Univ Illinois Polar Research Group http://arctic.atmos.uiuc.edu/cryosphere/

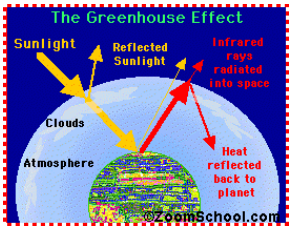


Why isn't it a simple issue?

- Experts sometimes refer to "simple physics"
- But the physics of aggregate climatic behaviour is not simple

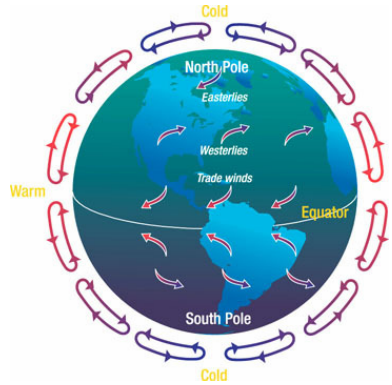
Argument from simple physics

- More carbon dioxide in the air = more heat trapped in the atmosphere



Energy is not just temperature

- Energy balance mechanisms at the surface:
  - *Fluid Dynamics*
  - *Radiation*



Background: CO_2 and Climate

"The Greenhouse Effect"

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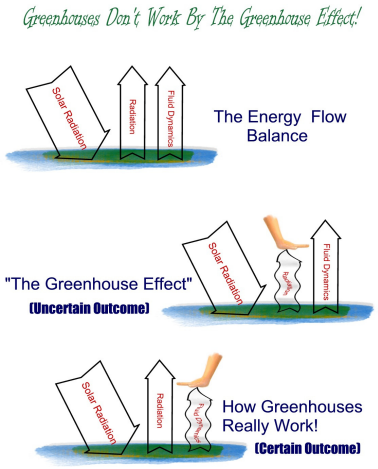
Diagram and discussion from Essex&McKitrick *Taken By Storm*

Background: CO_2 and Climate

"The Greenhouse Effect"



Background: CO_2 and Climate

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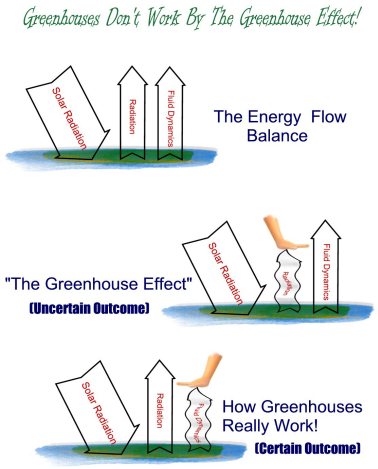

Radiative Transfer

Background: CO_2 and Climate

"The Greenhouse Effect"

Fluid Dynamics (Navier-Stokes)

Radiative Transfer

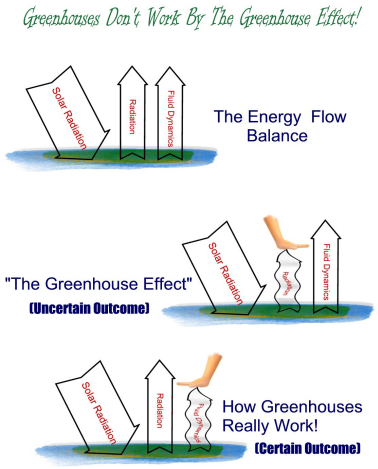

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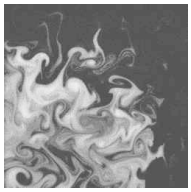
Diagram and discussion from Essex&McKitrick *Taken By Storm*

Navier-Stokes: the unsolved problem

- This is the equation which governs the flow of fluids such as water and air. However, there is no proof for the most basic questions one can ask: do solutions exist, and are they unique? Why ask for a proof? Because a proof gives not only certitude, but also understanding.



- Clay Institute Millennium Prize: $1million

Clay Institute

http://www.claymath.org/millennium/Navier-Stokes_Equations/

Climate Forecasting

- In climate research and modelling, we should recognise that we are dealing with a coupled non-linear chaotic system, and therefore that the long-term prediction of future climate states is not possible. The most we can expect to achieve is the prediction of the probability distribution of the system's future possible states by the generation of ensembles of model solutions.

- IPCC Third Assessment Report, Chapter 14.2.2.2

But what about the cartoon Greenhouse Effect?

- "If not for the greenhouse effect the planet would be 30 ^{o}C colder at the surface."

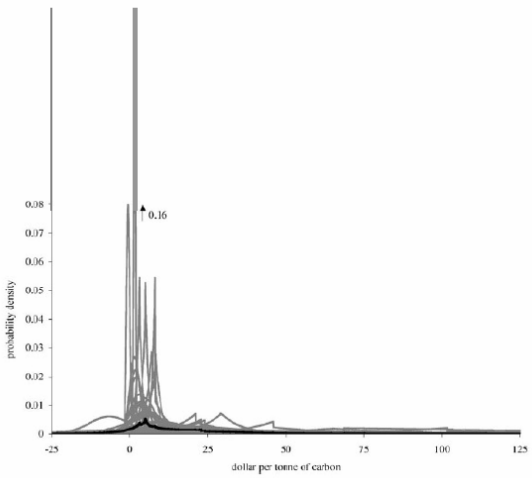
- Yes, but:
  - If not for convection, the planet would be 30 ^{o}C hotter at the surface.
  - The Moon's surface goes >100 ^{o}C during the day
  - We live in a greenhouse that has giant air conditioners running

It is complicated because

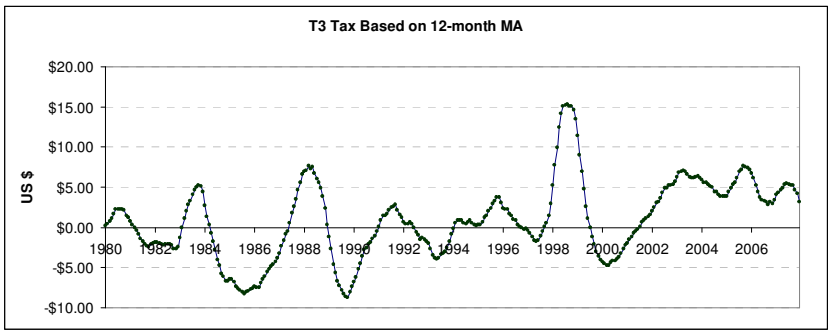
- Energy and temperature are not equivalent
- Climate change is a problem in fluid dynamics
- No known theoretical solution exists
- No computational solution exists

Marginal Damages

- Tol (2005)



T3 Rate since 1981 – 12 MA



- Current value = $3.20