

Climate Change

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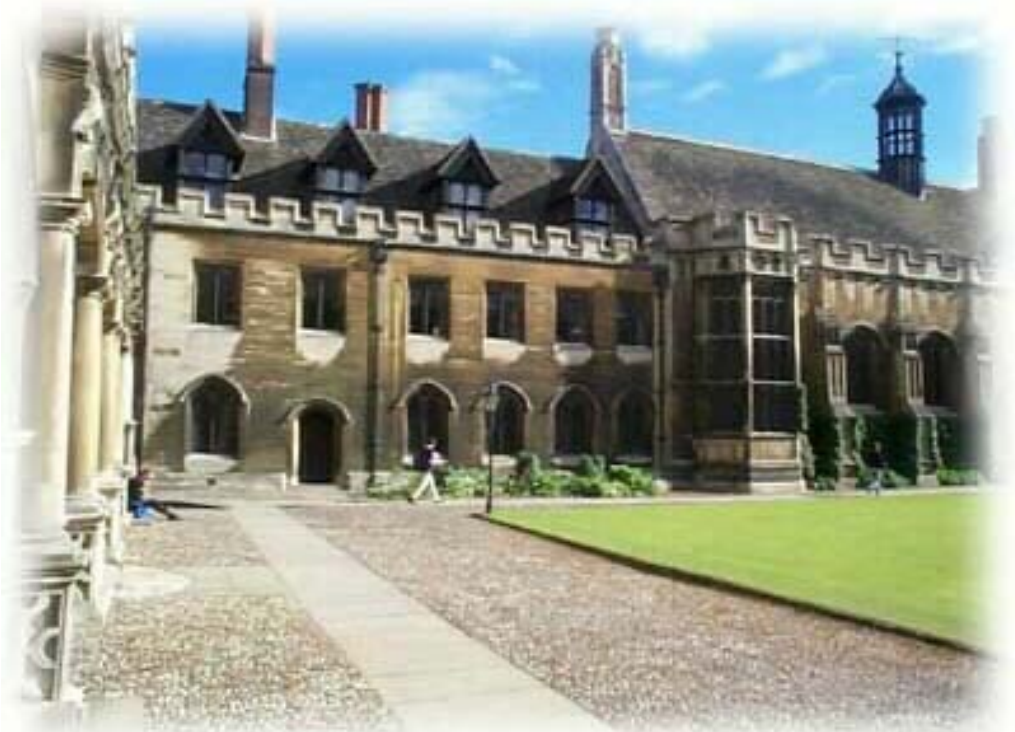
Climate Research:

a scientist's view of the past 30 years

- Alan K. Betts
- Born 9/10/1945, Southend-on-Sea, England
- Nottingham High School [grades 5-13]
- Peterhouse, Cambridge [Lord Kelvin scholar;
Natural Science Tripos, Theoretical Physics]
- Imperial College, London [PhD, Meteorology,
1970, “Cumulus Convection”]
- Colorado State Univ. [1970-78]
- Atmospheric Research [1978-present, Vermont]

Peterhouse, Cambridge

- Peterhouse is the oldest college in Cambridge: it was founded in 1284 by Hugo de Balsham, Bishop of Ely.
- Peterhouse has approximately 250 undergraduates, 90 graduate students, and 45 fellows.
- My advisors were Drs. Kendrew (myoglobin); Klug (viruses); Scheuer (astro-physics)



Cumulus Convection

Physics of shallow cumulus

Cloud water, no rain

Condensation, upward
transport, evaporation

Reflect/absorb sunlight,
‘black’ to LW radiation

Huge climate impact

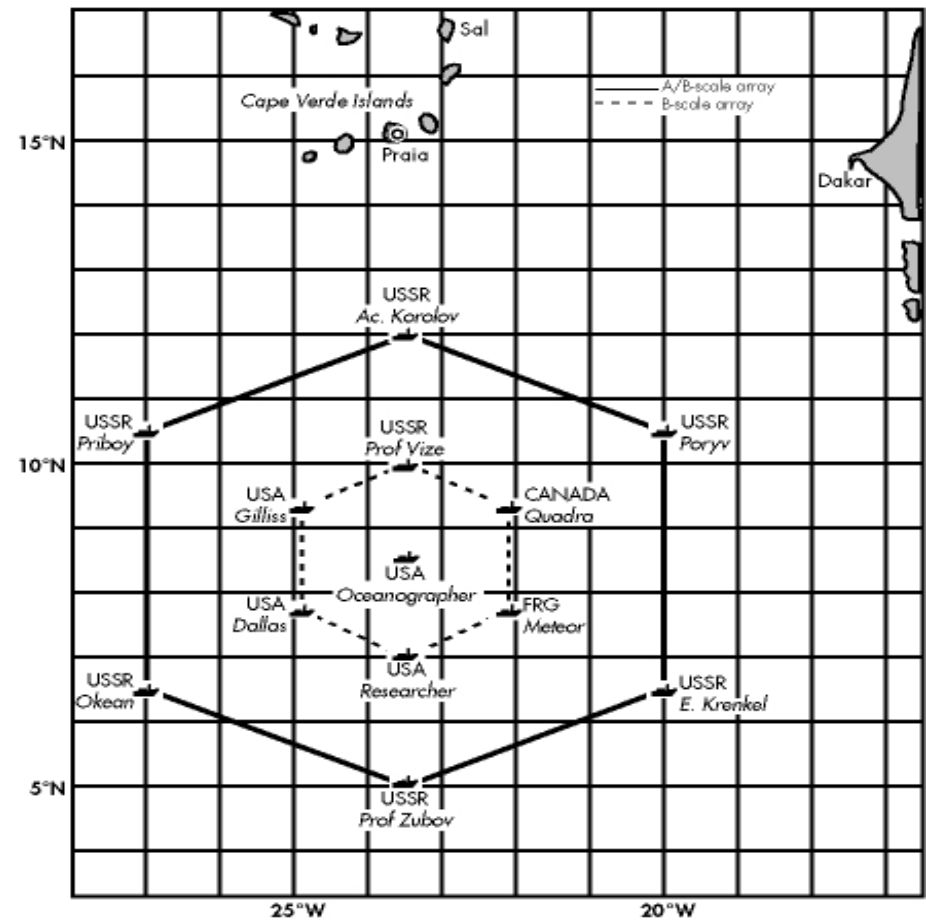
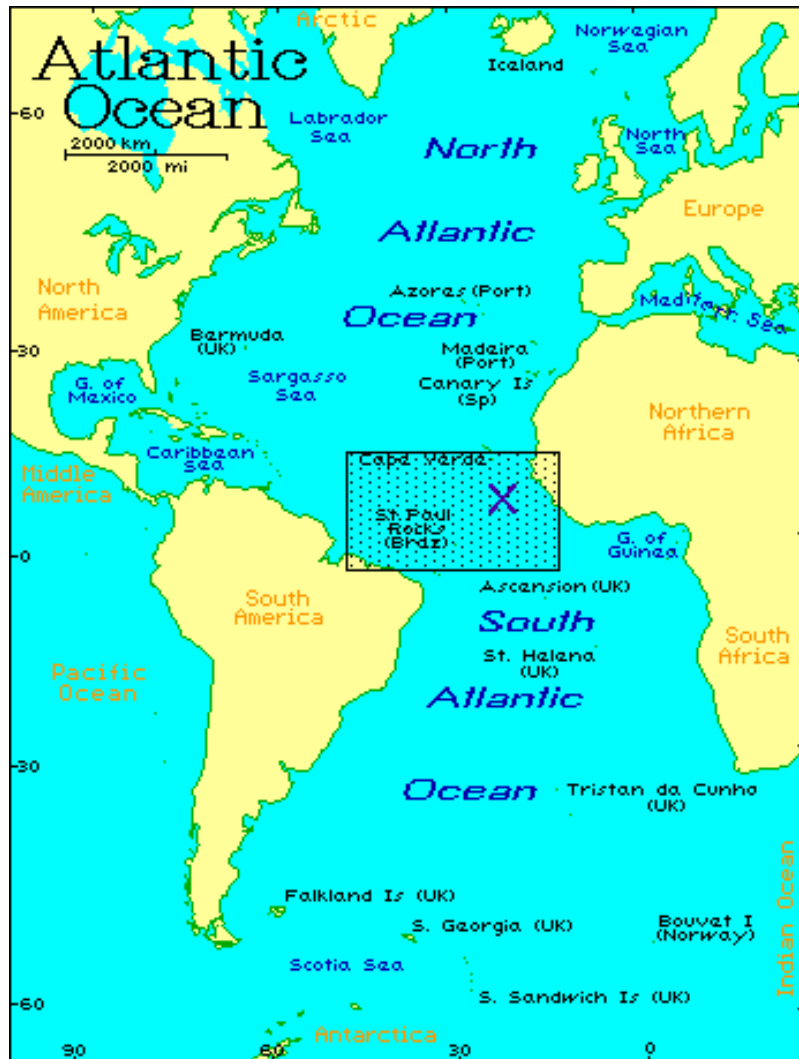


Anaco, Venezuela, 1969

Field Experiments

- Anaco, Venezuela [VIMHEX-1969]
- Carrizal, Venezuela [VIMHEX-1972]
[Organized by Prof. Riehl of CSU]
- GATE 1974 [Convection Subprogram Scientist]
Many nations, ships, aircraft

Global Atmospheric Research Program Atlantic Tropical Experiment



GATE , 1974

Global Atmospheric Research Program Atlantic Tropical Experiment



15 + research ships

Vanguard [NASA], Quadra [Canada],
Dallas [US Coastguard]

7 research aircraft

NCAR Electra

Vermont : 1978-present

- 1978 Built solar home in W. Pawlet with photovoltaic electricity, passive solar heating and wood-stove
- Now ‘Atmospheric Research’ in Pittsford, VT
- Funded by National Science Foundation, NASA [and NOAA]: on 3-5 year grants
- Plan and analyze field programs and improve models at European Weather Centre, NASA and NOAA

Field Experiments-2

- Kansas grassland prairie: 1987-89: FIFE
- Boreal forest, Canada, 1994-96: BOREAS
- Amazonia, 1999- : LBA
- Land-surface-atmosphere studies over different ecosystems
- Represent processes in global models

Research Interests

- 1970's Moist thermodynamics; shallow Cu
Tropical convection over land /ocean
- 1980's Moist thermodynamics: “Saturation level”
Cumulus parameterization
Climate equilibrium in tropics
- 1990's Global model diagnostics/field data
Land-surface processes: grassland/forests
Soil water-evaporation-precipitation
River basin budgets

Moist Thermodynamics

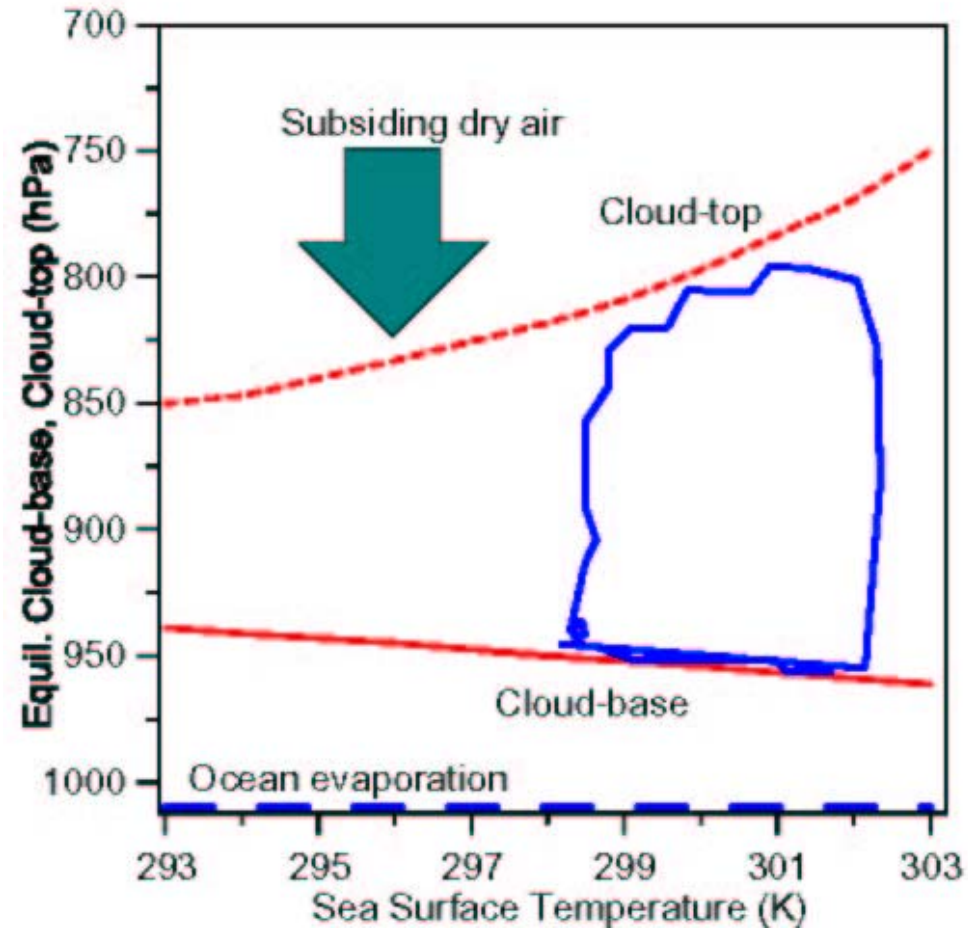
- Enthalpy and total water conserved
- Phase change gives downward energy transport ['refrigerator']
- Saturation level and relative humidity
- From leaf resistance to free atmosphere



Climate equilibrium in the Tropics-1

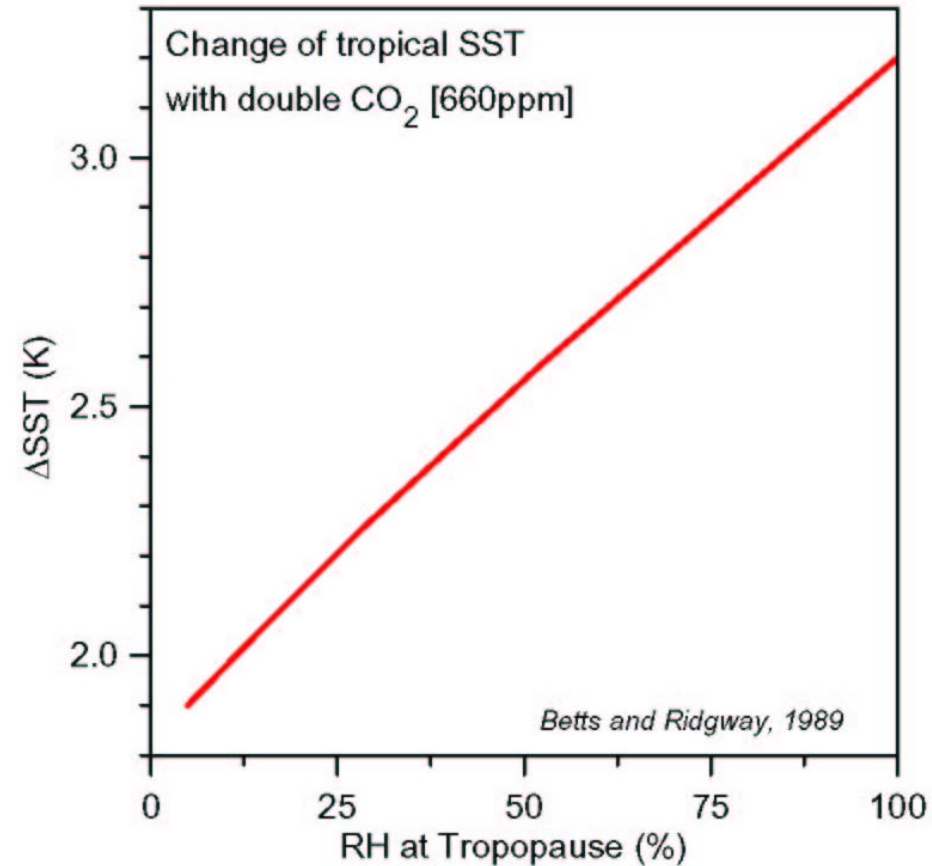
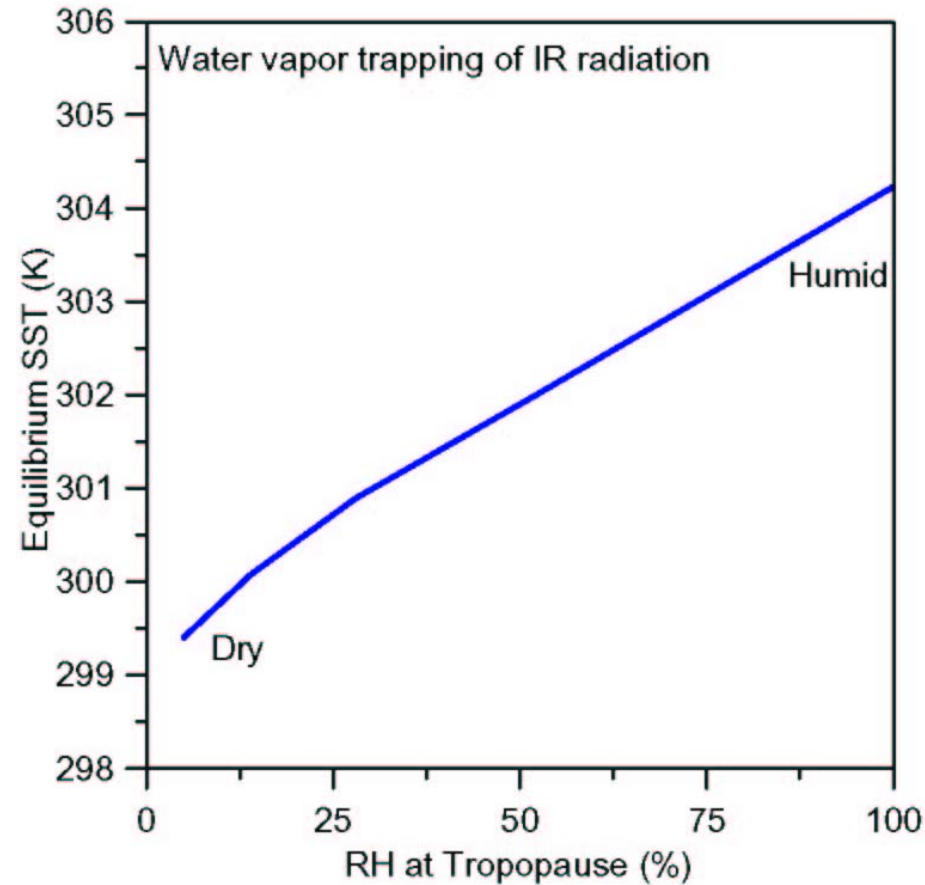


Shallow Trade-wind cumulus
flowing into deep precipitating
tropical convergence zone



Trade cumulus balance
between ocean evaporation
and sinking of dry air

Climate equilibrium in the Tropics-2



Water vapor in upper atmosphere traps infrared and warms ocean equilibrium

Double CO₂ warms ocean by 2 to 3K in tropics [more at poles]

Climate Change

- One of the great challenges for this century
- Very broad; very complex: biosphere
- What is known? What might we face?
- What does the public know?
- [Actions: Mitigation vs. adaptation]

Scientific issues

- social and political conflicts

- Where does the science stand?
- Can science gives us answers?
- Do we need more science to act?
- What are the political pressures acting in the US and around the world?
- How do these impact on atmospheric science and on us as scientists.
- What are our responsibilities to the science, to society and to the earth?

Primary driver of climate change

- Greenhouse gases from fossil fuel burning and other industrial sources
- ‘blanket earth’ by trapping of infrared radiation; driving up equilibrium temperature
- Water vapor and snow/ice amplify effects
- Clouds add complex ‘fast’ feedbacks:
oceans react more slowly
- Biosphere controls our long-term fate

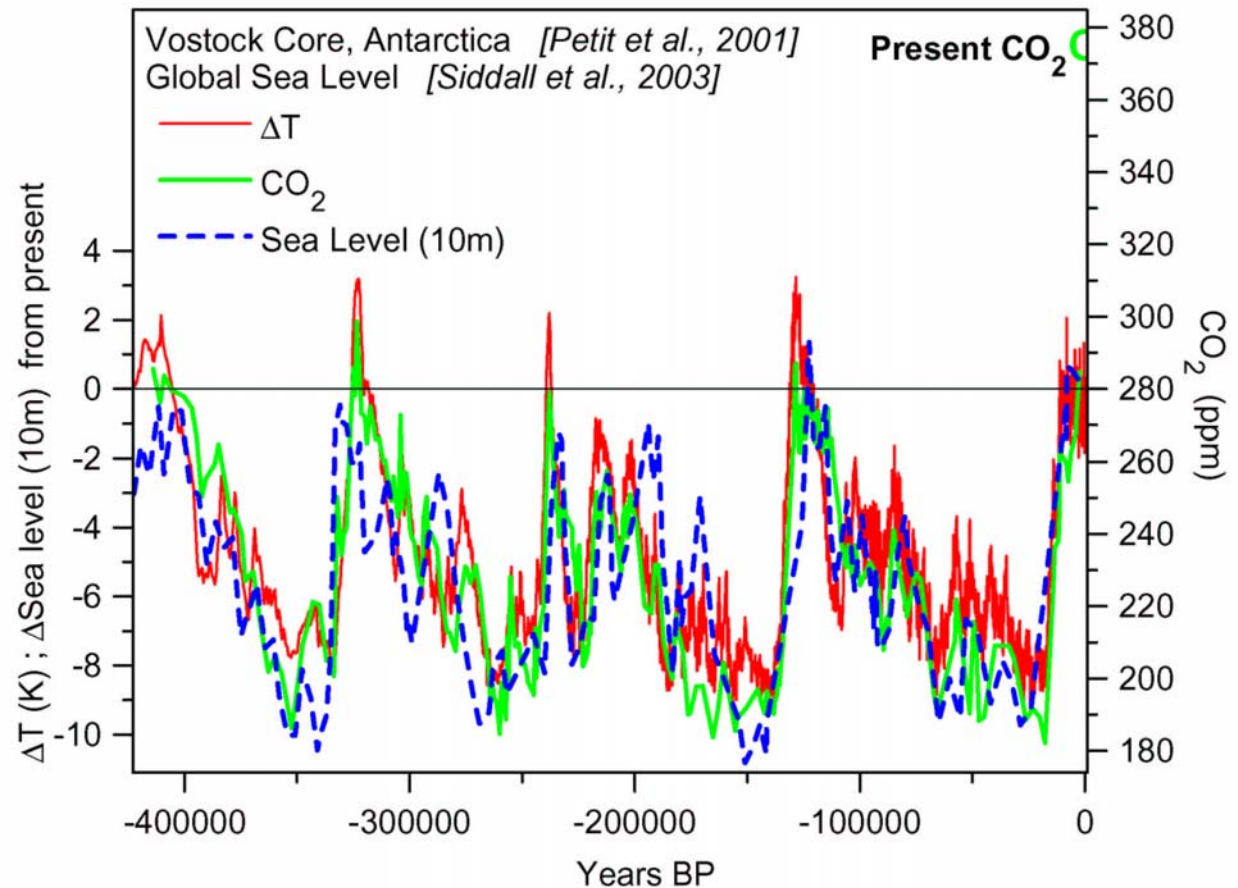
Slow warming or ‘surprises’

- Climate system not very stable
- Last 420K years, Milankovic cycles

CO₂ Oscillation:
280 and 180 ppm:
biosphere coupled

Slow temperature fall,
fast rise: 10°C at pole

Slow ice growth; rapid
collapse:
Sea level rise: 110m



Ice-age dynamics

Earth's orbit changes high latitude insolation by $\sim 50\text{W/m}^2$

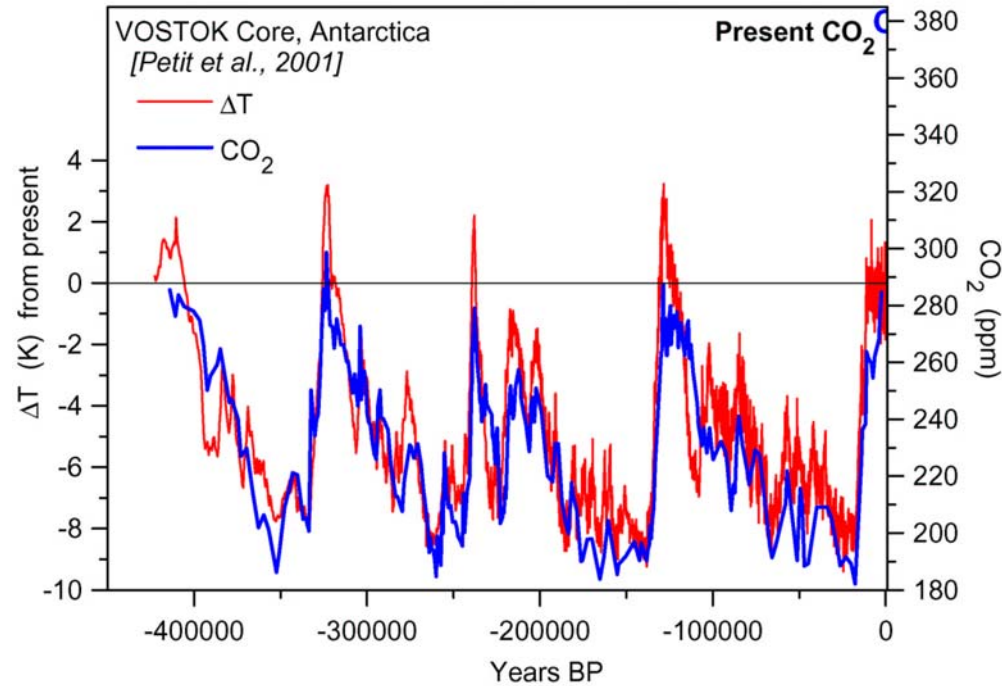
Icesheet grows: positive feedback

Slow ice growth: rapid collapse

[Sea level rise +120m]

Temperature changes amplified at poles

CO_2 [and CH_4] rise with T
[CO_2 released from tropical oceans]



Onset of glaciation on earth

- 34 million years ago, CO₂ fell below 1000ppm and first Antarctic ice sheet formed
- Unchecked we will be back to 1000ppm in 100years [ice melt takes millenia]

news and views

Nature, 1/16/2003

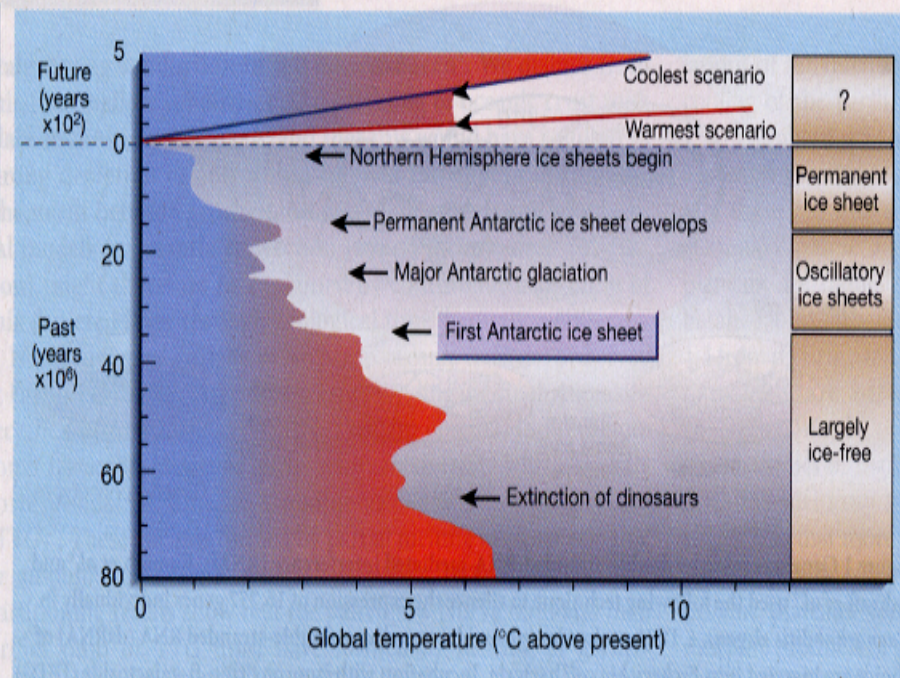


Figure 1 Decline in average global temperature over the past 80 million years of Earth's history. This global temperature curve is inferred from deep-sea isotope data¹, the zero point being today's temperature of 15 °C. Of the significant transitions in glacial history¹ shown, the sharp cooling associated with the formation of the first Antarctic ice sheet, 34 million years ago, is ascribed by DeConto and Pollard² to a decrease in the concentration of atmospheric CO₂. Global temperature projections for the future, produced by the Intergovernmental Panel on Climate Change (IPCC)³, are shown on a greatly expanded timescale. According to the warmest IPCC scenario, by the end

What are we now in 2003?

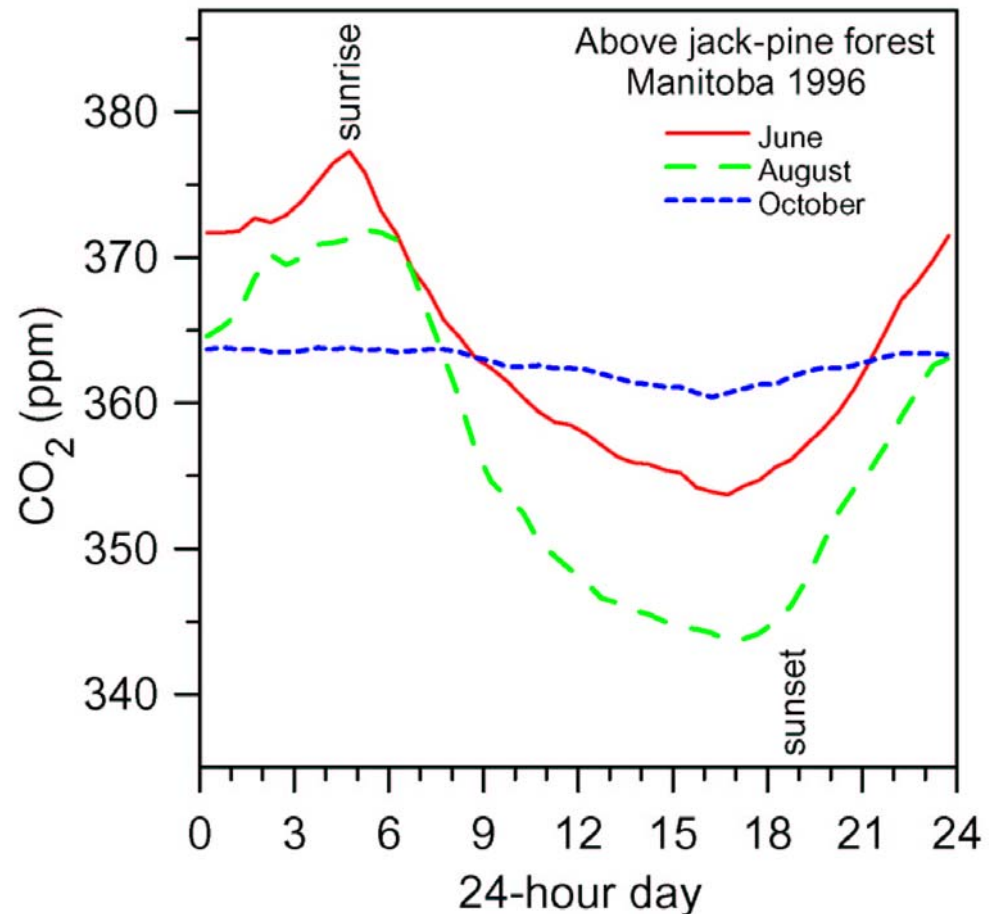
- CO₂ up from 280 to 375ppm; 600ppm 'inevitable' [given attitude of USA]
- Far beyond range of 'recent' climate record
- Mean temperature risen about 1°C; predicted rise 2-5°C this century
- Decade of 1990's warmest on record
- Permafrost melting; tundra greening; ice shelves melting; frost-free season longer

Climate, energy, water and carbon dioxide linked

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

Diurnal cycle of CO₂

- October flat: Northern hemisphere mean
- Daytime photosynthesis
- Night-time respiration
- Hemispheric drawdown in August



Humanity needed concentrated energy.

- Discovered coal, oil and gas Y industrial revolution
Burning fossil fuels is putting stored CO₂
back into atmosphere *in a hurry*
- Trees, plants and oceans are taking up about half,
but rest is accumulating, and CO₂ is rising
faster than biosphere can adapt
- Centuries to burn all stored carbon,
millenia for earth [oceans/ice] to equilibrate

Political response [in USA]

- Here is money to do more research to study climate change, improve climate prediction
- You scientists must reduce the ‘uncertainties’, so we ‘leaders’ can make a plan that is ‘economically viable’

Sounds reasonable but it isn't....

- Natural world is very complex and alive
we can't predict very well: many surprises
- Unlike the world of machines & computers,
which are man-made and predictable
- ***Current problem arises because our
technology is having a global impact on
the natural world***
- ***Climate change is not fully predictable***

Information and disinformation in [US] media

- You would think from the talk shows that climate change was in doubt
- Yes, it is complex; yes, ‘predictions’ are uncertain..
 [but the direction and its cause is clear]
- ‘Truth’ is elusive in the face of uncertainty and complexity
- **But honesty is not**

Is it a question of science?

- Our knowledge has expanded 10-fold in two decades, but uncertainty remains same
- Suppose we knew ‘global sensitivity’ of ΔT to doubling CO_2 ?
- Does our/your government listen to scientific advice? What does it hear?
- [In US: Academy reports and NOAA say: We need more research .. the ‘safe, self-serving’ and ‘true’ response]

What would be an alternative for government?

- Admit 'deep uncertainty'
- Admit fossil fuel society is responsible nonetheless
- Start nation and world on a new path
- [chorus: it might be bad for the economy; it might reduce growth by 0.x %]
- It would take courage in the face of vested interests and financial backers

Mitigation and adaptation

- We have the technology to stabilize CO₂ at 450-550ppm [no action - 1000ppm possible]
- Shift from C to H as energy source, H₂O has short atmospheric lifetime; unlike centuries for CO₂
- Reduce fossil fuel use; increase photovoltaics and wind, and biomass uses
- Prepare for added environmental stress from climate change [in addition to population growth]
- US can afford new technology; developing world cannot

So who speaks for the earth?

- Those ‘foolish environmentalists’ who want this great nation[USA] to ‘freeze in the dark’?
- We ‘objective scientists’, asking for more funds for research?

Bull. American Meteorol. Soc., 57, April 1976

To the Editor:

I was dismayed by the President's page in the November 1975 BULLETIN (56, 1152-1153) on the subject of a scientist's responsibility to society. **Though it is noble and well intended, it in no way faces the real responsibilities of scientists ... for the trends society has followed, and still continues to follow.** Instead, it pretends that their responsibilities lie only in the area of "presenting the facts" relevant to the questions posed by society, or more bluntly, in answering impartially the questions they are paid to answer.

I can appreciate the desire that scientists should not deliberately "distort the facts" as advocates of a particular cause, but to pretend that our knowledge even in physics, let alone in the environmental sphere, is simple fact ("objective statements") is pure wishful thinking.

The proposed creed is a twofold distortion. On the one hand, it implies that there are such things as factual answers. There may be, but they exist only if science is construed in the broadest possible sense to include our whole understanding of the natural world, including man. On the other hand, it suggests a physicist is accountable only within a very narrow field of knowledge. This is a doctrine of the compartmentalization of knowledge, comfortable perhaps for the scientist in his own little field but a disaster for the world because it leaves no one to take account of the broad human predicament.

The seriousness of the plight of science in the United States is also evident if we consider this possible hierarchy of allegiances of a researcher :

- 1) to the planet Earth;
- 2) to mankind;
- 3) to science;
- 4) to the United States;
- 5) to one's own science (e.g., atmospheric science);
- 6) to one's own specialization;
- 7) to a specific research contract.

Most research appears to owe allegiance to the lowest level, occasionally rising a few levels. This is a dismal prospect for this planet, for mankind, and of course for science itself.

ALAN K. BETTS Department of Atmospheric Science, Colorado State University, Ft. Collins, Colo. 80523 April, 1976

So who speaks for the earth?

- 27 years have passed since this youthful polemic, but it is still true that no-one will take responsibility ... even though
- It is quite clear that the fate of human civilization, and the 'natural world' on this planet are intertwined

There is a price to pay ...

- For human ignorance and arrogance
- Objective science will not save the earth: *it can only document the collapse*
- We as environmental scientists must honestly spell out some of the details
- And help the global society to search deeply for a path forward

