Greenhouse Gases, and Related Measurement Techniques: GGMT-2011

Comprehensive observations are more important than hypothesis testing

25 October 2011

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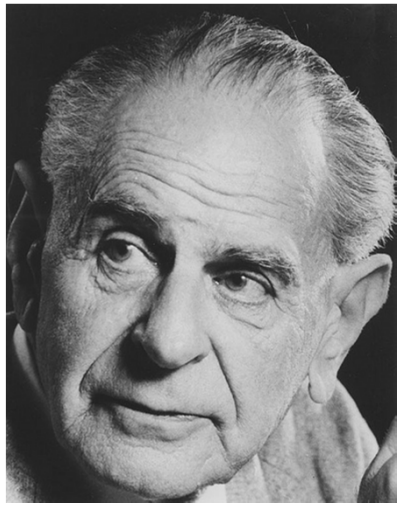
Outline

As our planet changes at a faster rate, the philosophy that lies behind science seems increasingly irrelevant

Should we be testing hypotheses – or avoiding surprises?

Better observations are becoming more essential – and there are becoming more and more questions

Philosophy of science



Karl Popper

(the most cited philosopher for science)

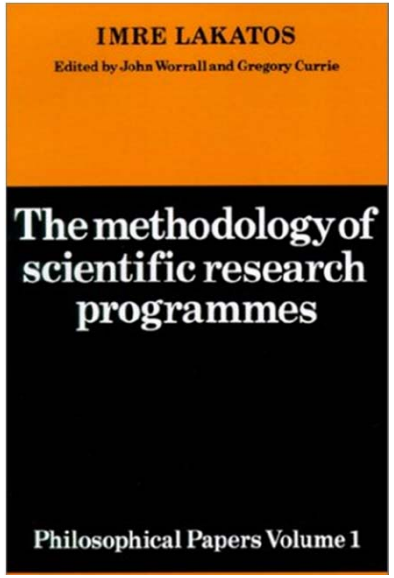
“Knowledge is an adventure of ideas.”

Science is not a quest for certain knowledge, but an evolutionary process in which hypotheses or conjectures are imaginatively proposed and tested, in order to explain facts or to solve problems.

Theories have to be constantly challenged and observational statements are theory-laden, hence fallible.

… e.g: *Conjectures and Refutations: The Growth of Scientific Knowledge*. 1963

Philosophy of science … is evolving



Imre Lakatos

Extended Popper's approach so as to cover steady evolutions of understanding …

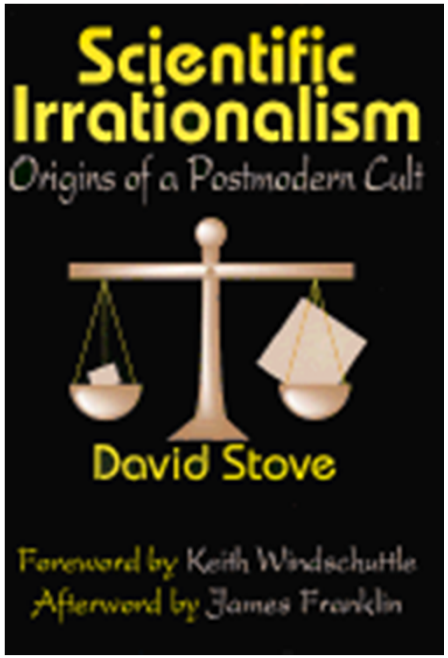
that are based on the continuing development of checks for consistency …

across groups of auxiliary hypotheses.

So there has been growing recognition of interdependence between different aspects of scientific understanding.

Philosophy … has become another debate

Thomas Kuhn's "The Structure of Scientific Revolutions"
– disagreed with Popper and led to a focus on identifying "paradigm shifts" in thinking.



David Stove … on Popper, Lakatos, Kuhn and Feyerabend.

"These authors' philosophy of science is in substance irrationalist. They doubt, or deny outright, that there can be any reason to believe any scientific theory; and *a fortiori* they doubt or deny, for example, that there has been any accumulation of knowledge in recent centuries."

"Scientific Irrationalism: Origins of a Postmodern Cult" 2000.
see: http://en.wikipedia.org/wiki/Popper_and_After

Lawyers have some different views

A 1993 US Supreme Court decision on dealing with uncertainties in science, set a demarcation of **science** from **pseudoscience** as being based on …

1. *The theoretical underpinnings of the methods must yield testable predictions by means of which the theory could be falsified.*
2. *The methods should preferably be published in a peer-reviewed journal.*
3. *There should be a known rate of error that can be used in evaluating the results.*
4. *The methods should be generally accepted within the relevant scientific community.*

"*Reference manual on scientific evidence*", Federal Judicial Center, USA, 2000

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3. *There should be … can be used …*

Some details of climate science are "testable" by monitoring changes and understanding cycles.

But many major aspects of global climate change may only occur once – and so the predictions are testable only after the impacts have occurred

"*Reference manual on …*

Hypothesis testing?

The UC Santa Barbara advice on NSF research proposals starts with …
"What is the main research problem? What hypothesis will you test?"

http://www.research.ucsb.edu/toolbox/

"A research hypothesis is the statement created by researchers when they speculate upon the outcome of a research or experiment."

http://www.experiment-resources.com/research-hypothesis.html

Another view …
"The reason students have problems understanding hypothesis tests is that they may be trying to think."

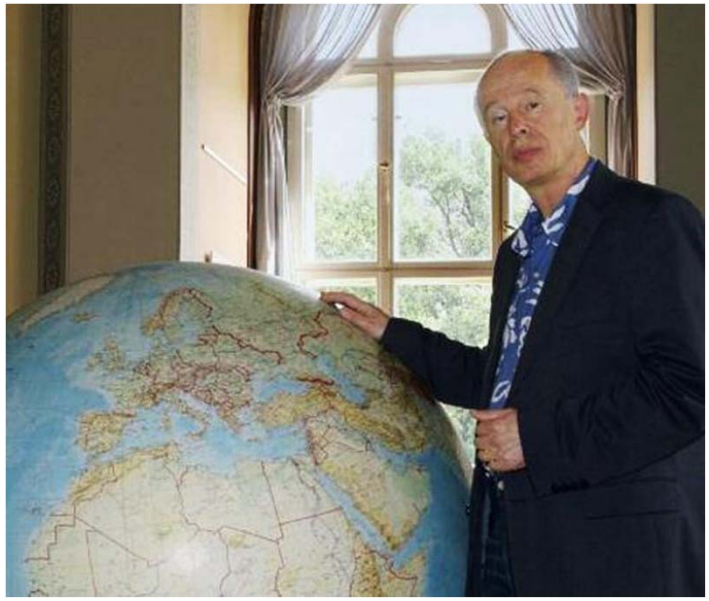
Edwards Deming (1975)

Atmospheric and climate science has to be different

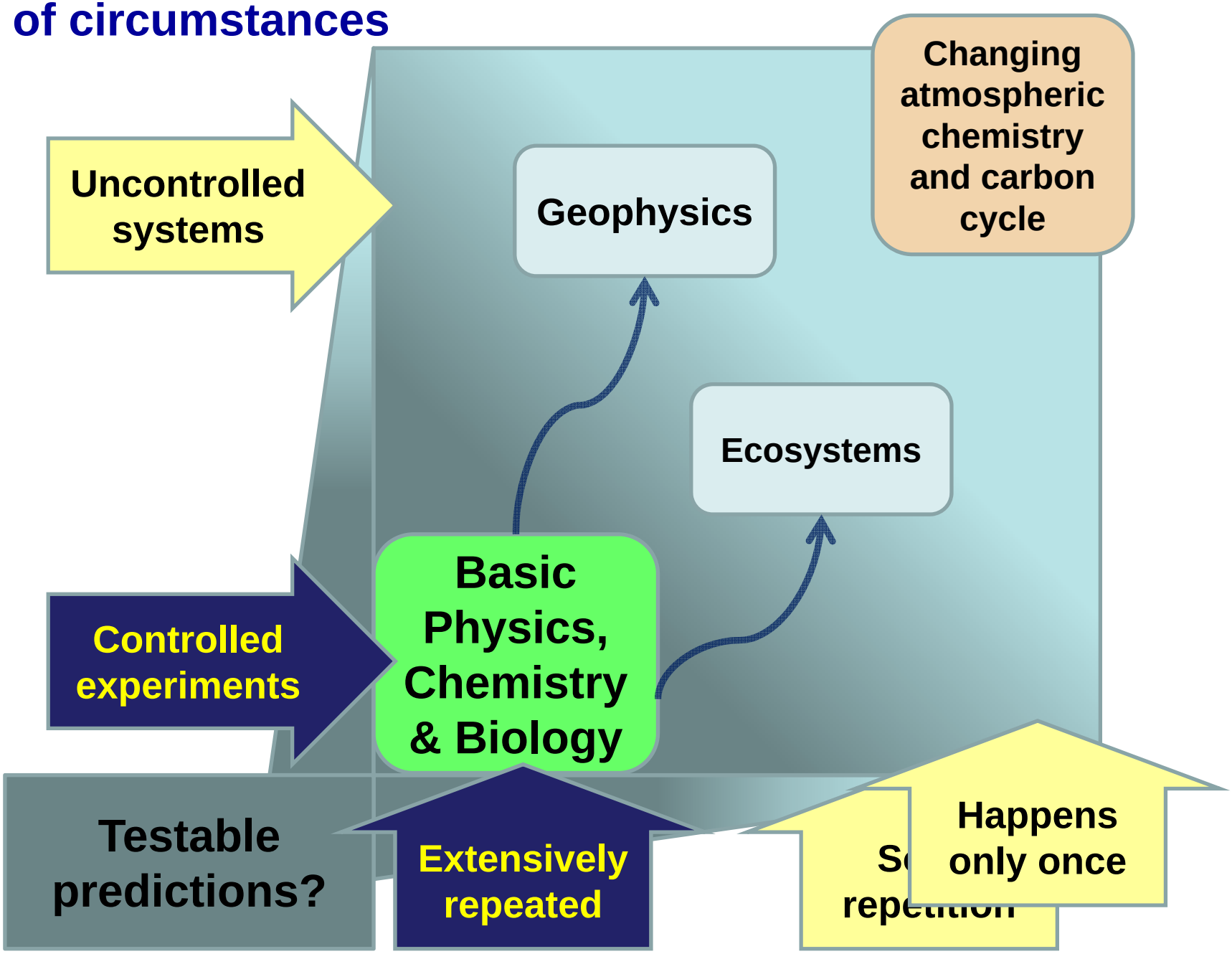
Hans-Joachim Schellnhuber:

“Hypotheses about global change are the less falsifiable the more they are relevant to humanity”

In: “*Earth System Analysis”. Springer-Verlag; 1998.*



Science has to cover a wide range of circumstances



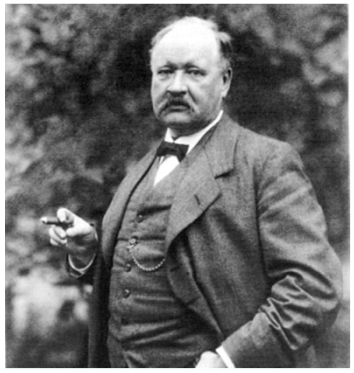
Science finds surprises

“Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve "surprises". In particular, these arise from the nonlinear nature of the climate system. When rapidly forced, nonlinear systems are especially subject to unexpected behaviour.

The Summary for Policymakers in the IPCC Second Assessment Report, 1995.

And these words were put together by Steve Schneider with some help from Martin Manning.

The first surprise



Svante Arrhenius won his Nobel prize in chemistry for a new understanding of how things dissolve. So expected most of the CO_2 produced by burning fossil fuels would be dissolved into the ocean and it would take 3,000 years to double CO_2 in the atmosphere.

Athol Rafter in DSIR, NZ, finds that carbon in the atmosphere was now getting much “older”.

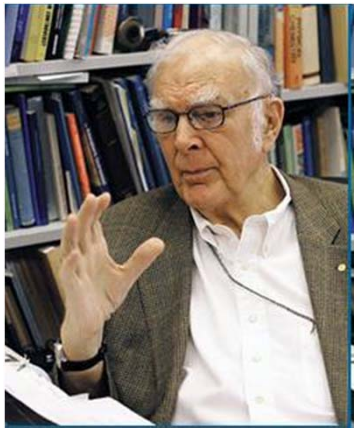
Rafter, T. A. New Zealand Journal of Science and Technology 37, 20-38 (1955)

Revelle & Suess explain why much of the CO_2 will not be dissolved into the oceans, except over thousands of years. …

“Thus human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future.”

Revelle, R. & Suess, H. E. *Tellus* **9**, 18-27 (1957)

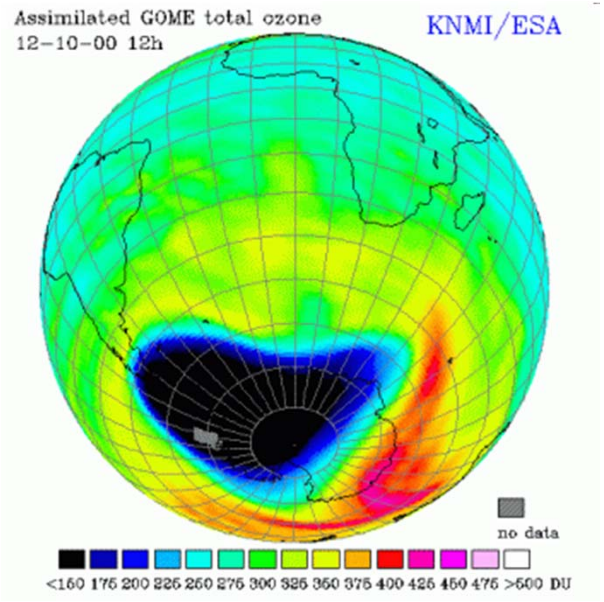
More surprises in the ozone layer



In the 1920s, Thomas Midgely invents CFCs for refrigeration and shows these are perfectly safe if you accidentally breathed them into your lungs.

Then in 1974 Sherry Rowland and Mario Molina discover CFCs are starting to destroy the ozone layer and so will increase skin cancers.

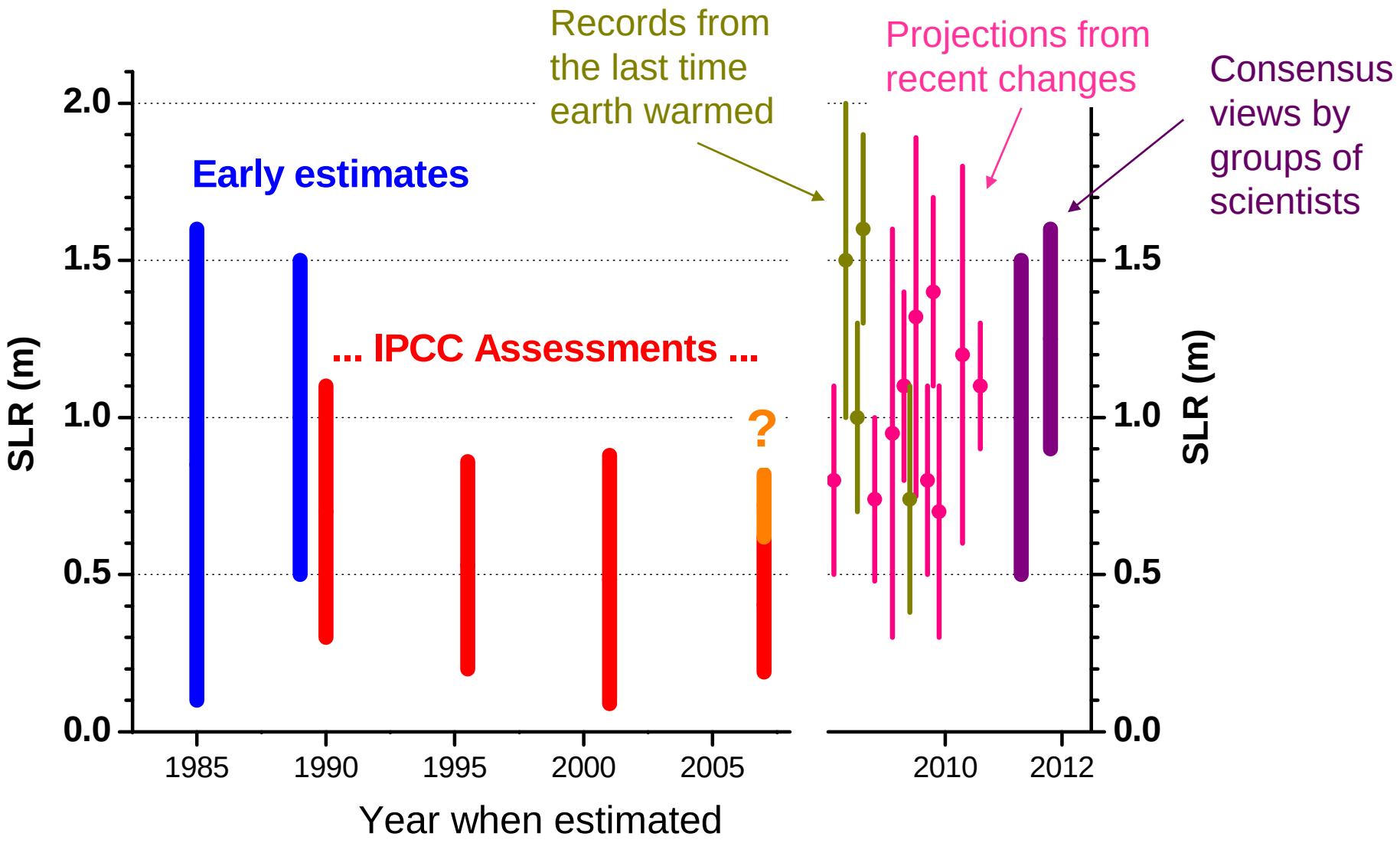
This deserves the Nobel prize in chemistry, but …

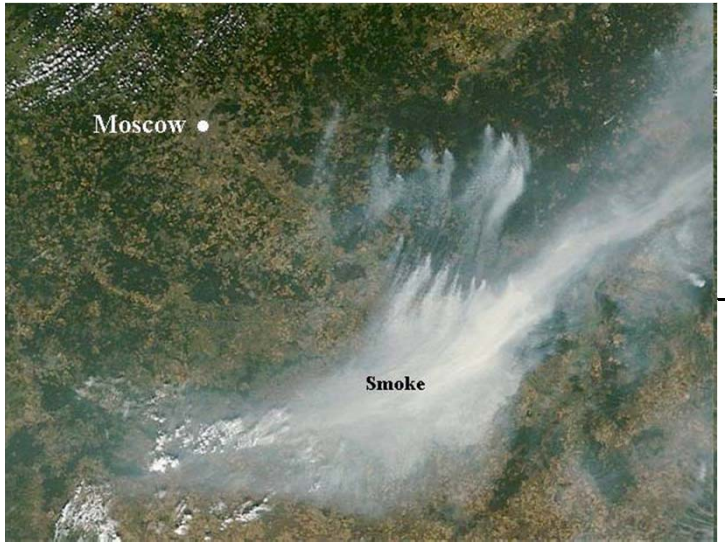


Then in 1985 comes the … **Bigger surprise** … over much of Antarctica most of the ozone layer is getting wiped out in spring time by CFCs.

So pollutants emitted in the Northern Hemisphere can have more impact on the other side of the world.

Sea level rise estimates have changed significantly in the last three years





Record drought and fires in Russia

August 2010

Record flooding of Indus Valley in Pakistan

Extreme events seem to be creating a challenge for climate science.

Kevin Trenberth, has an explanation for this due to links between Arctic ice sheet loss and the warming Indian Ocean leading to blocking weather patterns.

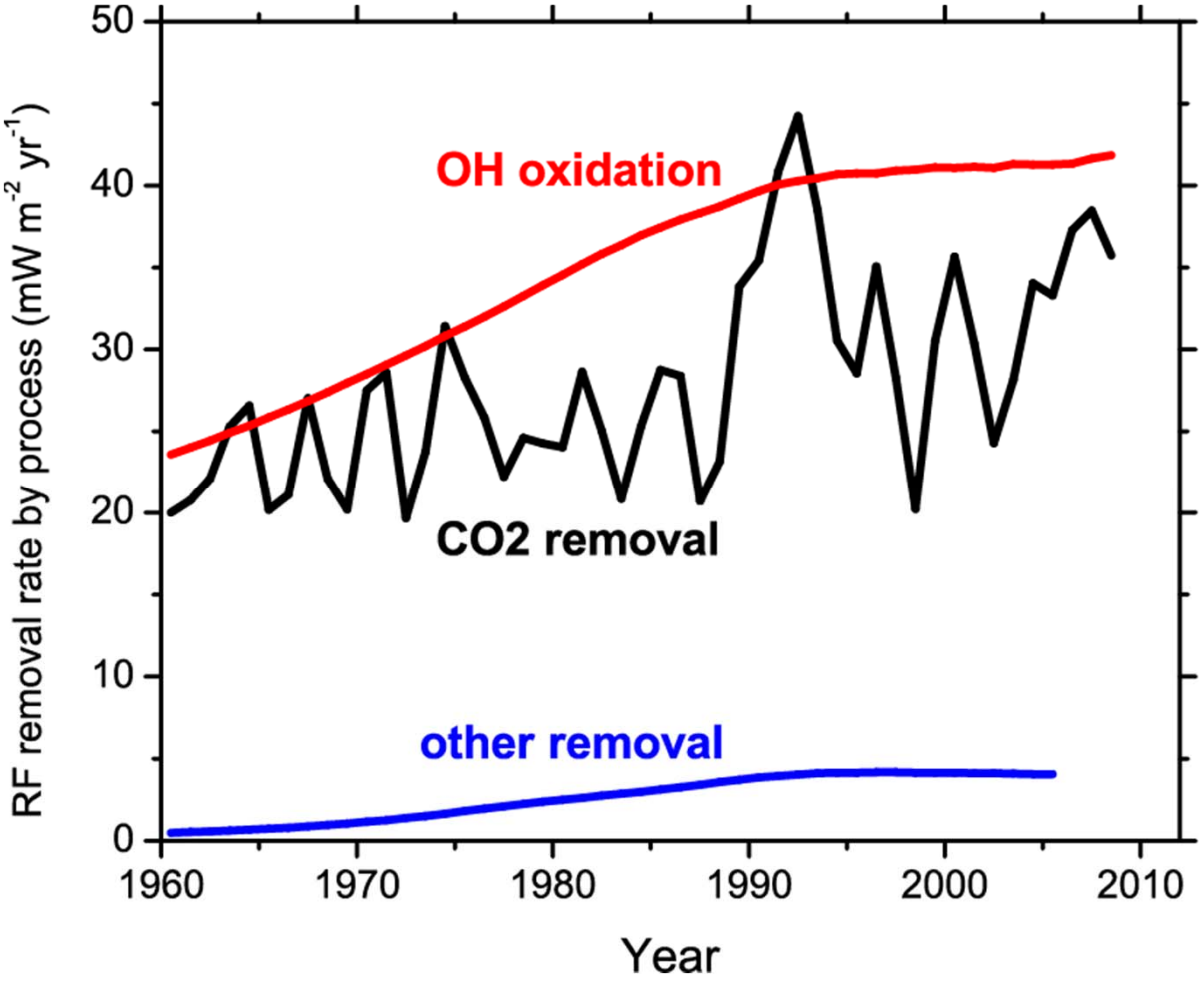
But some scientists have other types of explanation.

It has also been shown that the trend in extreme events over the last 50 years is more than twice that predicted by climate models (so far).

Min et al. Nature, 470:378-381, (2011)

We should expect surprises to increase
… so some sense of where to look
is becoming important

OH - vs - the carbon cycle



This compares the removal processes for the 9 most significant greenhouse gases in terms of the rate at which radiative forcing (RF) of the climate is being reduced.

OH oxidation covers CH_4 and three other greenhouse gases.

Manning and Reisinger (2011) Phil Trans Roy Soc, 369:1891-1905

CO_2 vs Methane: fighting for first place?

Atmospheric CO_2 concentrations are about 36% higher than the previous highest values in the last 800,000 years.

CO_2 is removed by a carbon cycle that now has changes in the carbon fluxes of about 3%.

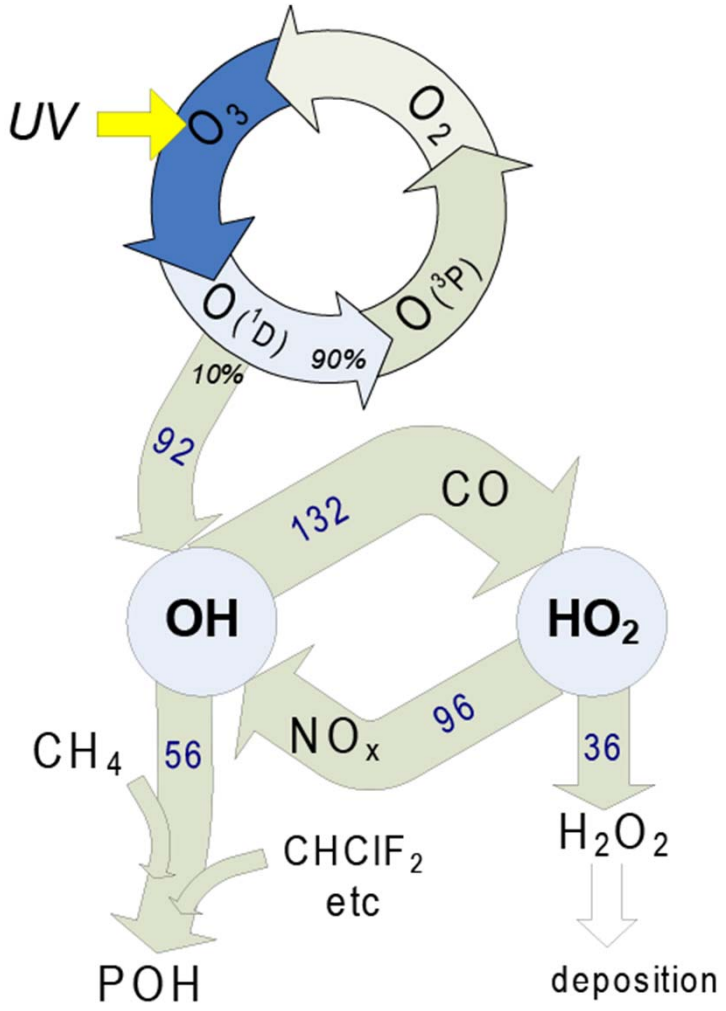
While some CO_2 is removed quickly, the rest goes slowly and 20% or more of it will stay in the atmosphere for over 10,000 years !

But atmospheric methane is more than 150% higher!

But methane is removed by atmospheric chemistry and the rates now have to be more than twice as large as they were !

Methane has a lifetime of only about 10 years in the atmosphere, but adding more methane can modify what is a highly non-linear system ?

The photochemistry is complex



rates in blue are given in 10^{12} mol yr^{-1}

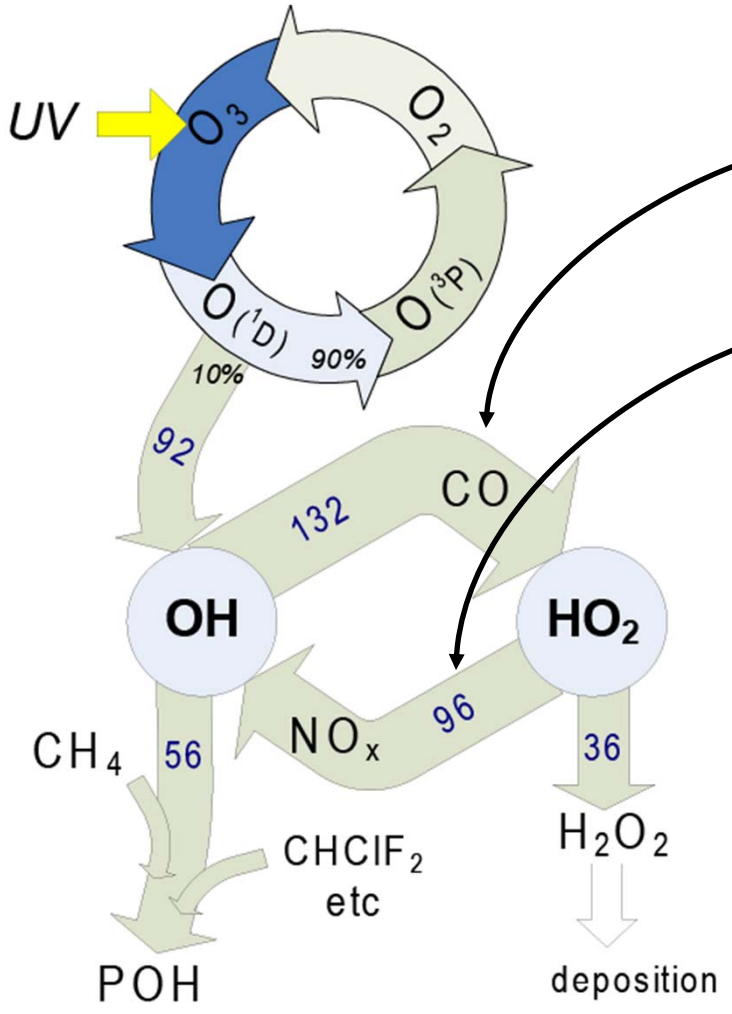
Absorption of UV by O_3 is the initial driver with about 10% of activated oxygen species becoming OH

OH and HO_2 control most of the removal of other species by atmospheric chemistry

An atmospheric chemistry model to cover this typically involves about 50 species with about 100 reactions and photolytic processes

Are the models right?

Push and pull on OH



rates in blue are given in 10^{12} mol yr^{-1}

The CO removing OH has a lifetime of ~ 80 days

Whereas NO_x restoring OH has a lifetime of ~1 day

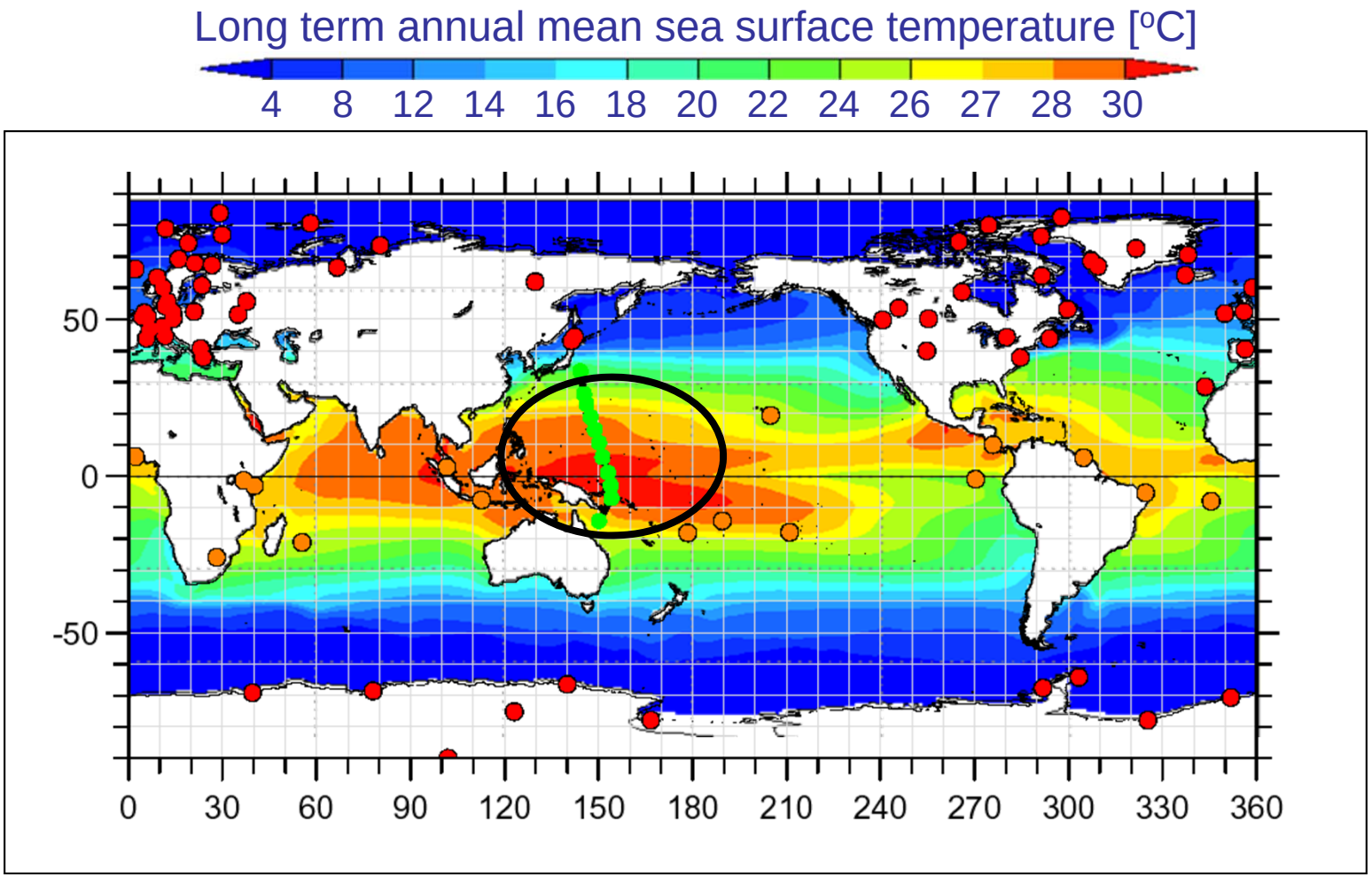
Much of the sources for CO and NO_x are over land

So we can expect different effects on OH over land and ocean

This can also mean structural differences between the Southern and Northern hemispheres

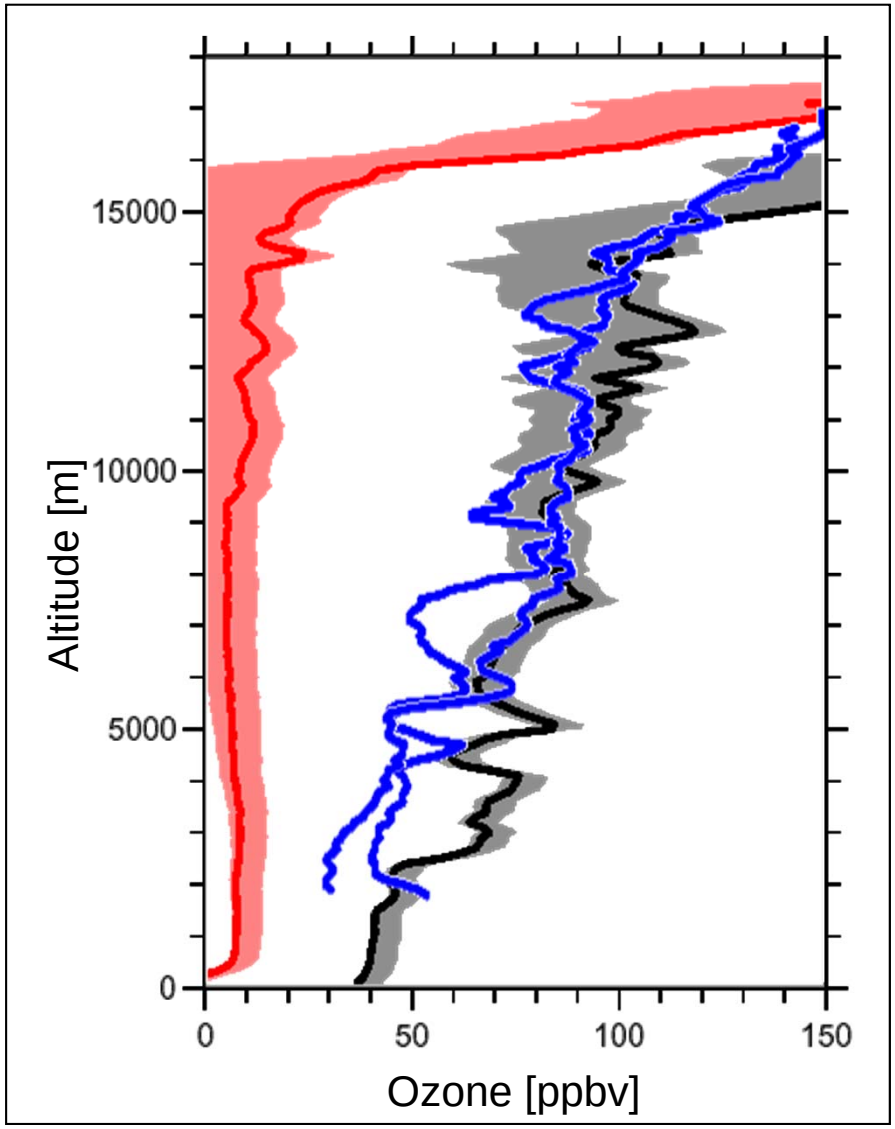
Global ozonesonde station network and SSTs

TransBrom cruise 2009



From Markus Rex et al, Alfred Wegner Inst, Potsdam:
"Is There a Hole in the Global OH Shield Over the Tropical Western Pacific Warm Pool?" IUGG, Melbourne, July 2011

Ozone profile measurements in the West Pacific



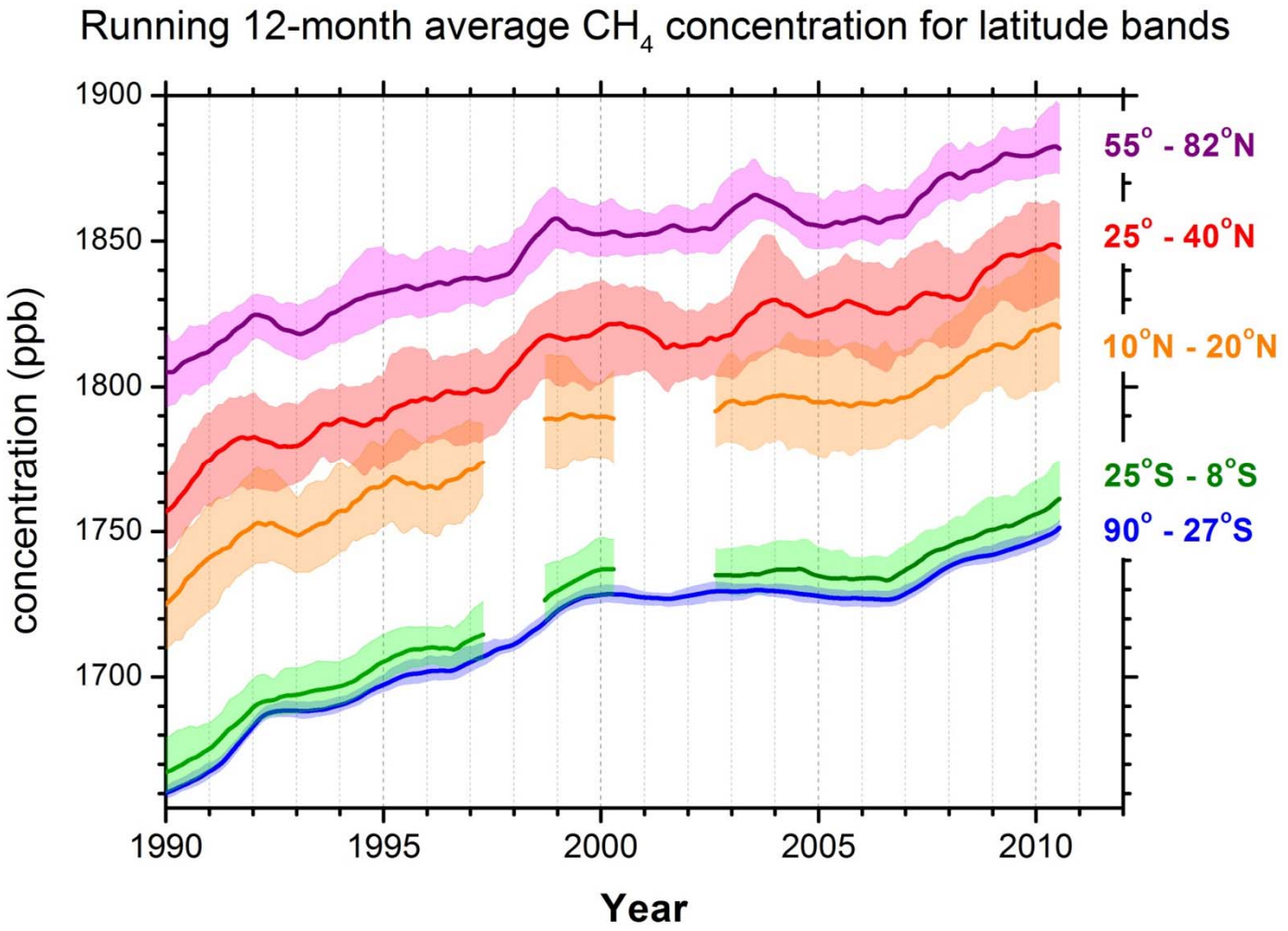
Extratropical West Pacific ~30°

Tropical Atlantic

Tropical West Pacific

From Markus Rex et al, “Is There a Hole in the Global OH Shield Over the Tropical Western Pacific Warm Pool?” IUGG, Melbourne, July 2011

Methane changes by latitude bands



ESRL methane data by Ed Dlugokencky et al, from cmdl.noaa.gov October 2011.

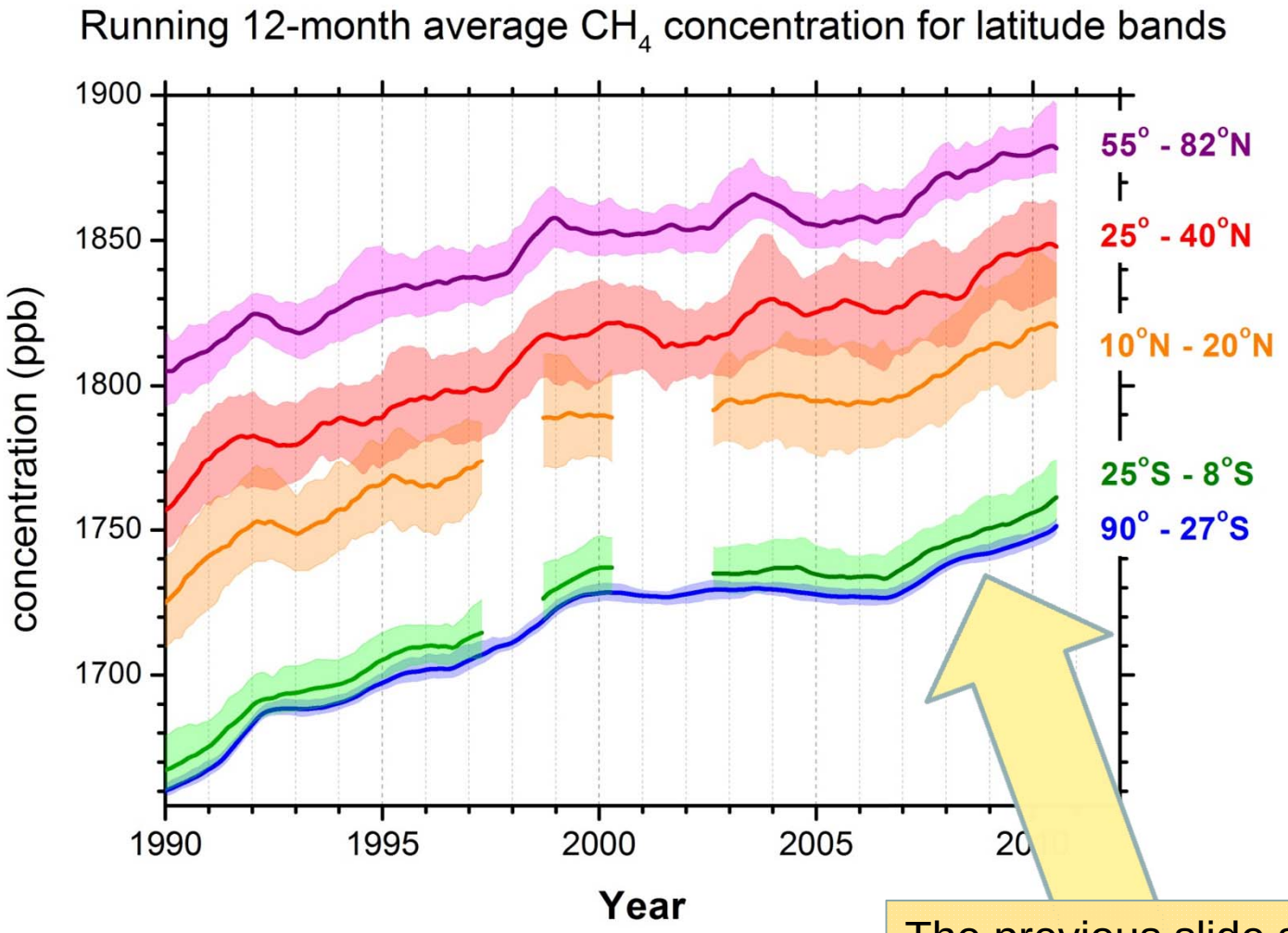
This shows average and range for data from 4 – 9 clean air stations for each latitude band.

The seasonal cycles were removed first by using running 12 month averages.

Some changes in methane appear correlated, but with time lags, between different latitudes that can indicate the cause.

The most recent increase seems to have started in the Southern Hemisphere.

Methane changes by latitude bands



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The previous slide showed reasons for now expecting low methane removal rates in parts of the Western Pacific.
Is that linked to this?

More questions about methane

Recent decreases in fossil-fuel emissions of ethane and methane derived from firn air

Murat Aydin[1], Kristal R. Verhulst[1], Eric S. Saltzman[1], Mark O. Battle[2], Stephen A. Montzka[3], Donald R. Blake[1], Qi Tang[1] & Michael J. Prather[1]

Reduced methane growth rate explained by decreased Northern Hemisphere microbial sources

Fuu Ming Kai[1]†, Stanley C. Tyler[1]†, James T. Randerson[1] & Donald R. Blake[2]

These two recent papers in Nature came up with quite different explanations for the changes in methane concentration over the last twenty years.

There are also significant differences between published methane source budgets, as well as limited recognition of there being at least four different removal processes.

Will data with more detailed spatial coverage lead to better analyses – or is this a problem with the models?

Keeping global warming to 2ºC depends on a lot of things – including the carbon cycle

The current round of climate model runs is based on Representative Concentration Pathways (RCPs). Preliminary results show a wide range of results even for the lowest RCP.

Meinshausen et al used the MAGICC model for a range of model parameters to suggests that for RCP3 global warming stays below 2ºC and comes down to ~1.5ºC by 2100.

But a more detailed model used by Arora et al says that warming is unlikely to stay below 2ºC.

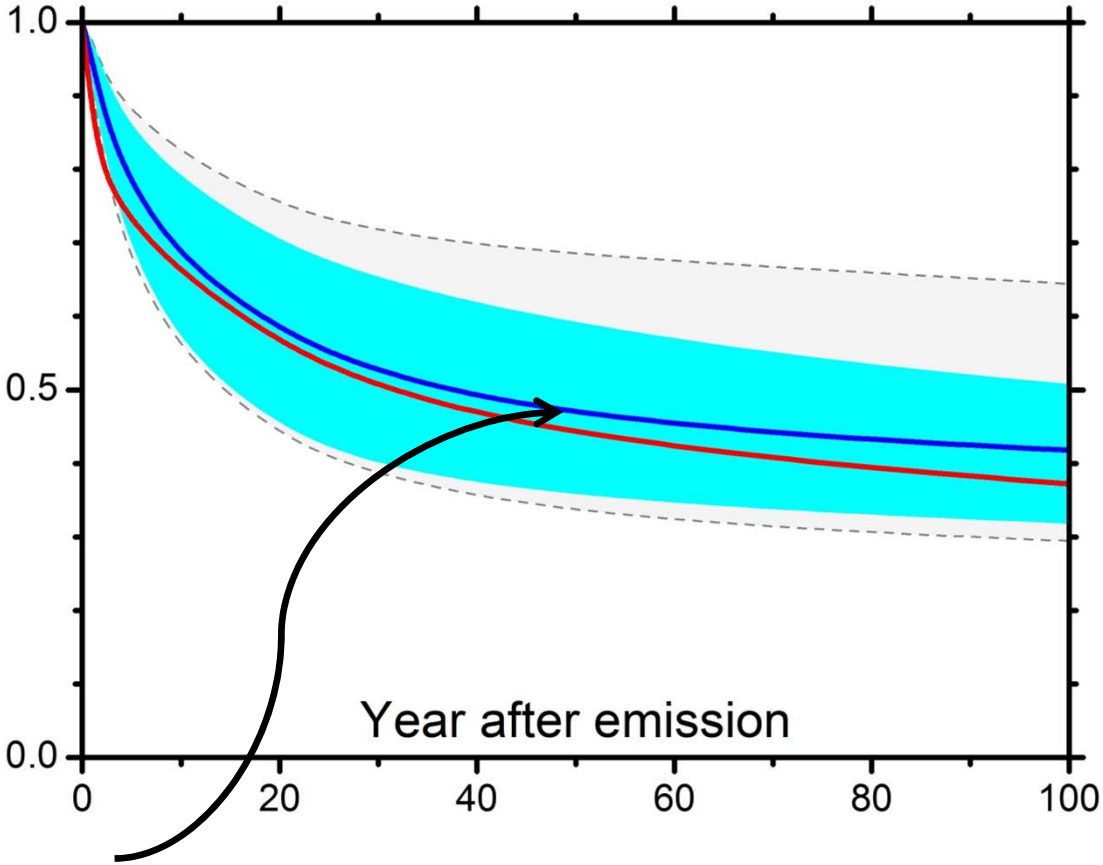
Both of these still leave out uncertainty in the carbon cycle that links future emission pathways to the RCP3 concentrations.

Has change in the carbon cycle been put in the “too hard” basket?

Meinshausen, M., et al., 2011: The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change,* Online 9 August 2011**.**

Arora, V.K., et al., 2011: Carbon emission limits required to satisfy future representative concentration pathways of greenhouse gases. GRL 38, L05805

Wide range of estimates for CO_2 removal



The dark blue line is the median for 170 model runs, the blue band is the 10% to 90% range and the dotted lines are the minimum and maximum.

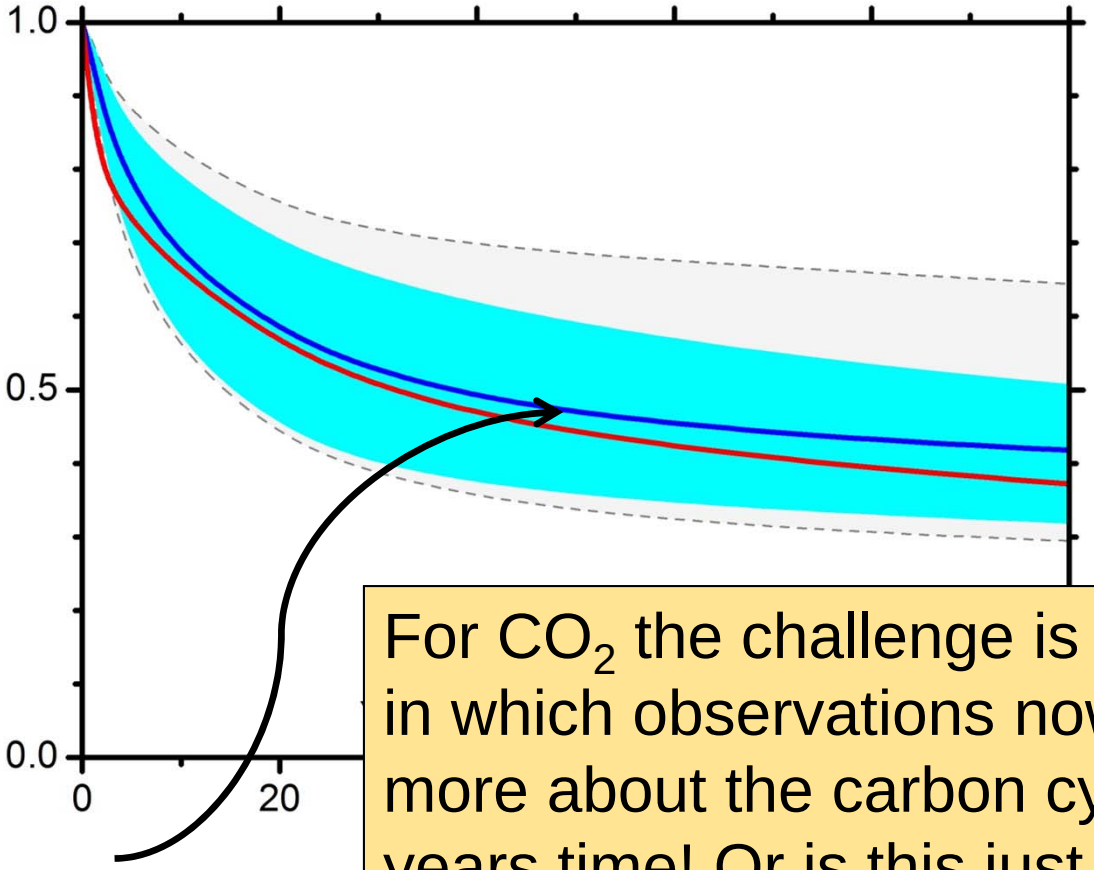
These are MAGICC simple climate model runs tuned to reproduce the range of models used in the IPCC Fourth Assessment Report.

Carbon cycle and climate models have to be closely coupled for projections of future climate change.

This shows the range of estimates for removal of 1 tonne of CO2 in models used for the last IPCC assessment report.

Policy is based on Global Warming Potentials that use the **red line** derived from the Bern Carbon Cycle model.

Wide range of estimates for CO_2 removal



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For CO_2 the challenge is to find ways in which observations now will tell us more about the carbon cycle in 100 years time! Or is this just another problem with the models?

Summary

In science, observations are the basis for all research – and this becomes much more important as rates of change increase.

The challenge now is to avoid more surprises in atmospheric chemistry, and

Improve our capacity to predict future CO_2 for a range of emission scenarios

A copy of these slides is available on request to:
martin.manning@vuw.ac.nz