Climate Change: Is the Science Done and Dusted?

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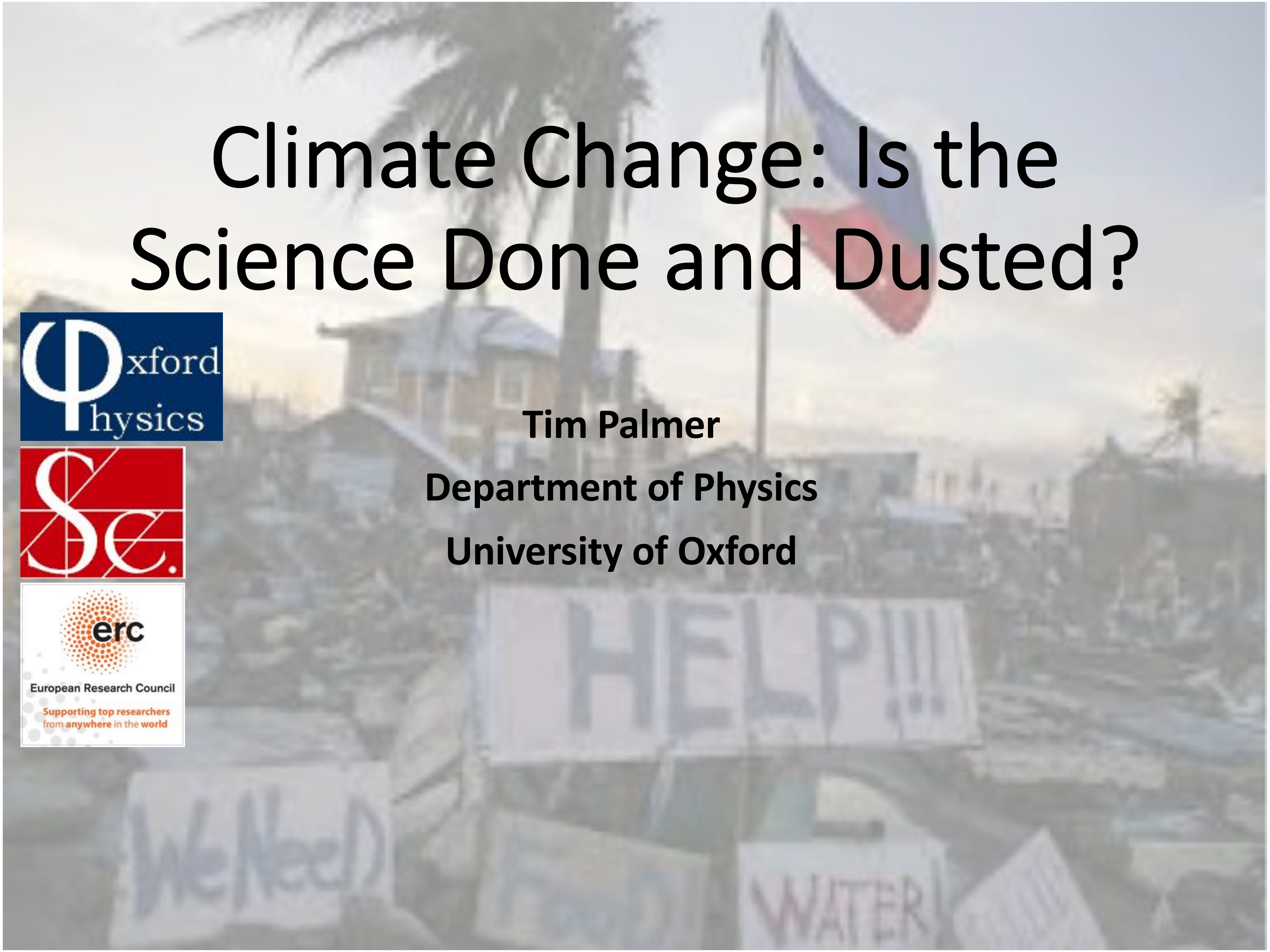

The Telegraph

The game is up for climate change believers

Charles Moore reviews The Age of Global Warming by Rupert Darwall (Quartet)

Power station emitting steam and smoke Photo: Reuters

By Charles Moore
9:42PM BST 06 Apr 2014

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Most of us pay some attention to the weather forecast. If it says it will rain in your area tomorrow, it probably will. But if it says the same for a month, let alone a year, later, it is much less likely to be right. There are too many imponderables.

The theory of global warming is a gigantic weather forecast for a century or more. However interesting the scientific inquiries involved, therefore, it can have almost no value as a prediction. Yet it is as a prediction that

"The theory of global warming is a gigantic weather forecast for a century or more…therefore it can have almost no value as a prediction. "

The Guardian

Search · UK edition

The real reason some scientists downplay the risks of climate change

Climate deniers often accuse scientists of exaggerating the threats associated with the climate crisis, but if anything they're often too conservative

▲ Sea ice on the ocean surrounding Antarctica. Photograph: Ted Scambos/AP

Although the results of climate research have been consistent for decades, climate scientists have struggled to convey the gravity of the situation to laypeople outside their field. If anything, the wider public only recently seems to have awakened to the threat of the climate crisis. Why?

SUNDAY REVIEW · The New York Times · PLAY THE CROSSWORD · Account

How Scientists Got Climate Change So Wrong

Few thought it would arrive so quickly. Now we're facing consequences once viewed as fringe scenarios.

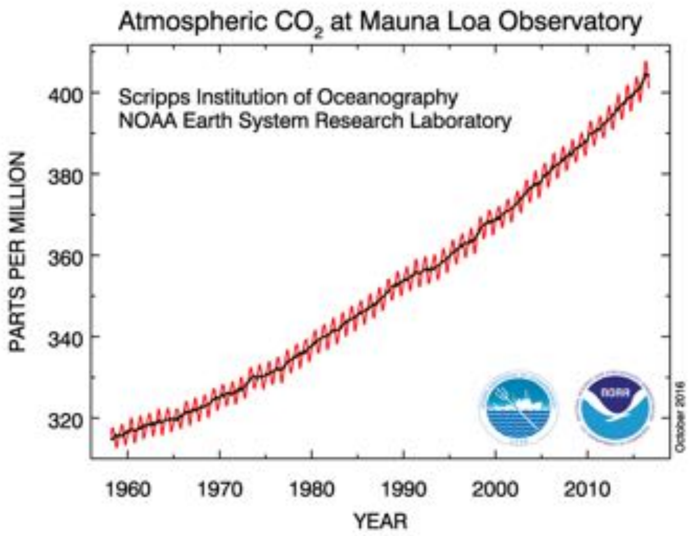
By Eugene Linden

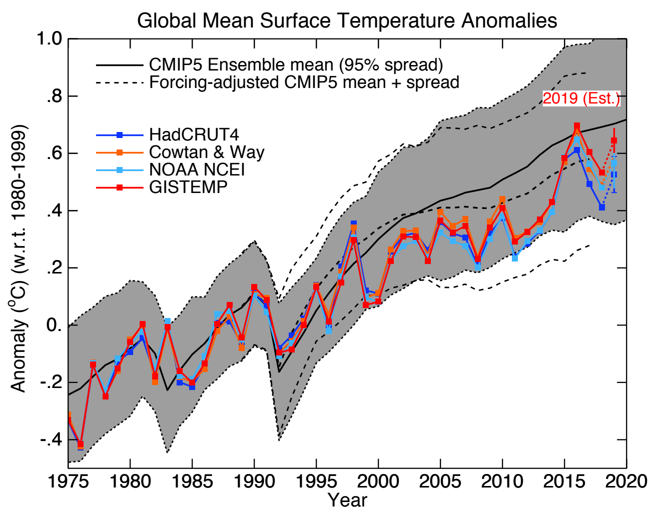
Mr. Linden has written widely about climate change.

Nov. 8, 2019

For decades, most scientists saw climate change as a distant prospect. We now know that thinking was wrong. This summer, for instance, a heat wave in Europe penetrated the Arctic, pushing temperatures into the 80s across much of the Far North and, according to the Belgian climate scientist Xavier Fettweis, melting some 40 billion tons of Greenland's ice sheet.

"… for ordinary citizens, it is important to recognize that scientists have done their job."





To determine whether carbon emissions are unequivocally changing climate, look to a climatic variable which maximises "signal to noise": global mean temperature.

The "signal": the forcing of the climate system associated with anthropogenic emissions of greenhouse gases.

The "noise": the chaotic internal variability of the climate system.

Public Health England

Global hazards weekly bulletin

Which of these has been made more likely by climate change to significant extent?

Requires models to simulate such extreme events.

Global Hazards Weekly Bulletin: 2nd - 8th November 2019

Global Hazards Weekly Bulletin - 2nd - 8th November 2019

Australia

NSW and Queensland fires: emergency warnings for 17 fires in NSW

Properties lost as NSW fires continue to burn at emergency levels

Cameroon

At least 42 people killed in Cameroon landslide

Canada

Ferocious windstorm leaves over 900 000 without power in Quebec

Colombia

Colombia - Floods and Landslides Hit Tolima and Antioquia

France

Storm Amelie leaves thousands without electricity in France

Storm Amelie: 140,000 homes without power in France

Guatemala

Guatemala - 4 Dead, Hundreds Evacuated After Heavy Rain Triggers Landslides

Hundreds displaced as heavy rains trigger deadly floods and landslides

India

New Delhi: Health emergency as Indian capital shuts schools due to smog

Maharashtra: Post-monsoon rain damages crops on 136,000 hectares

Iran

At least five people confirmed dead as 5.9 magnitude earthquake hits north-western Iran

Japan

Ten killed as storms ravage eastern Japan

Pakistan

Schools forced to close as smog chokes Pakistan's second city

Philippines

Death toll in Philippine earthquakes climbs to 21

At least 17 dead in Cotabato earthquakes

Tonga

Volcanic eruption creates new island in Tongan archipelago

Uganda

Persistent heavy rains trigger floods and landslides in Uganda, at least 6 dead

Dozens killed in Uganda after landslides destroyed homes and buried animals

United Kingdom

England flooding: Homes evacuated as rain causes travel chaos

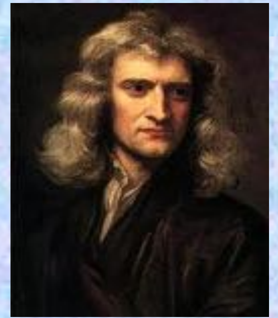
Vietnam

Typhoon Matmo injures 14, leaving 1 missing

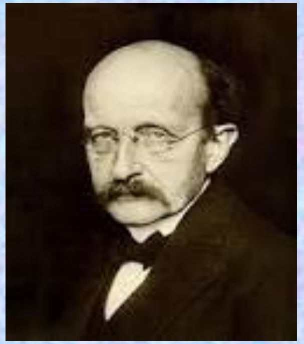
Zimbabwe

More than 100 elephants die amid severe drought in Zimbabwe

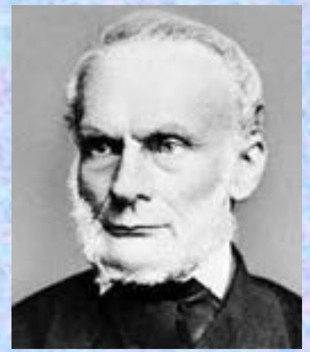
Comprehensive weather and climate models are based on the primitive laws of physics eg



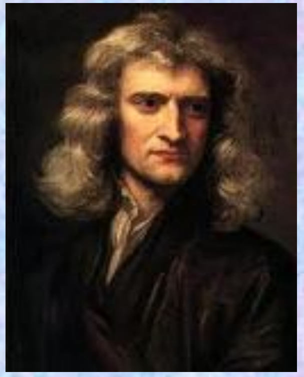
$$\mathbf{F} = m\mathbf{a}$$



$$E = \hbar\omega$$



$$\delta Q = TdS$$



$$\rho\left(\frac{\partial}{\partial t}+\mathbf{u}.\nabla\right)\mathbf{u}=\rho\mathbf{g}-\nabla p+\mu\ \nabla^2\mathbf{u}$$

Navier-Stokes Equations

$$\rho\left(\frac{\partial}{\partial t}+\mathbf{u}.\nabla\right)\mathbf{u}=\rho\mathbf{g}-\nabla p+\mu\ \nabla^2\mathbf{u}$$

Unpacks into many, many trillions of individual equations, describing scales of motion from planetary scales to microscopic scales.

Even the world's biggest computers aren't big enough to represent all scales of motion

10,000km

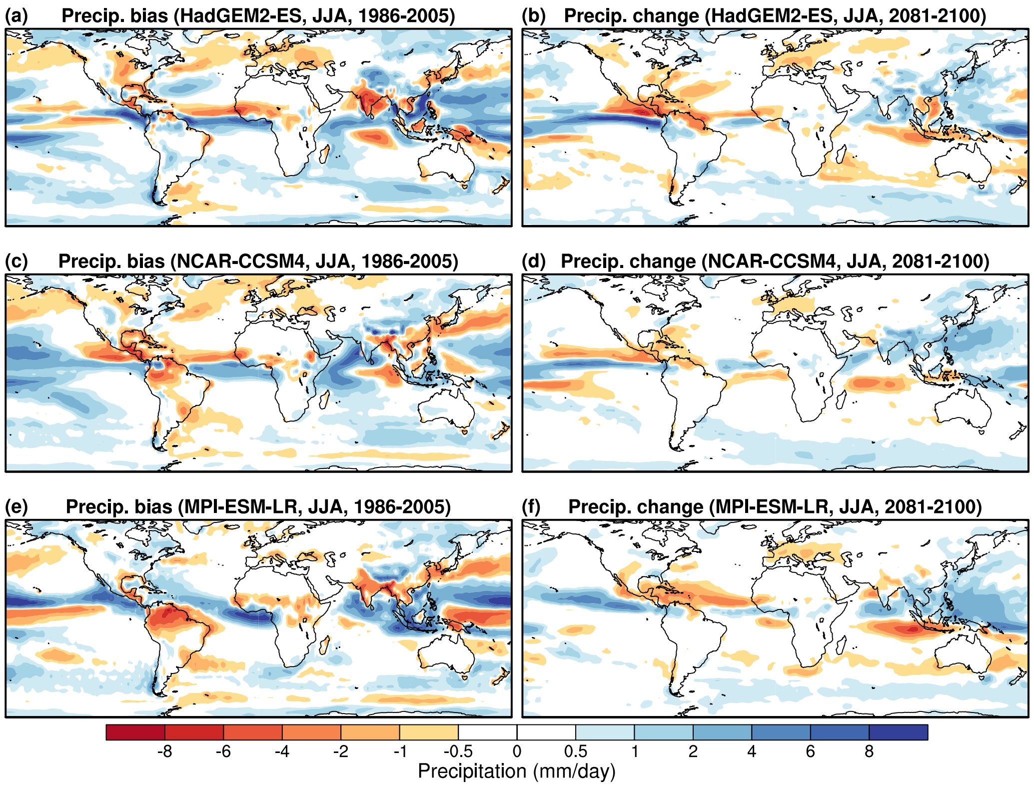
20km

billions of individual equations

Simplified approximate "sub-grid" formulae to describe the effect of atmospheric processes (eg clouds) that the model can't resolve.

Different models have different approximate sub-grid formulae

Because of their dependence on the sub-grid parametrisations, models are an imperfect simulators of climate on regional scales.



Palmer and Stevens, PNAS to appear

Model bias against observations

Model predictions

Alan Turing

Implications for Mitigation Policy

- Can we afford to be less aggressive with emissions cuts now, on the basis that by mid-late century we will have the technology to suck CO_2 out of the air?
- There is a risk that by mid-late century we will have reached "tipping points" which cannot be reversed by sucking CO_2 back out of the air.
- Understanding and predicting such tipping points requires much greater accuracy in simulating and predicting climate at the regional scale than we currently have.
- We currently cannot reliably predict the risk of reaching such tipping points in the coming 50 or so years.

Implications for Adaptation Policy

- Our historical and ongoing emissions will change climate over the coming century, regardless of emissions cuts.
- We have to make society more resilient to the changing intensity of weather/climate extremes.
- Nowhere is this more important than in the developing world.
- A modern-day Marshall Plan is needed to stem the migration crisis away from the tropics and towards the poles.
- However, for such a plan to be effective, we need a much sharper picture of how climate change will play out in the different regions of the developing world.
- This requires much greater precision in our ability to simulate and predict climate at the regional scale.

BOX ES.1

The Triple Dividend in Action

Avoided losses:

- Early warning systems save lives and assets worth at least ten times their cost. Just 24 hours warning of a coming storm or heat wave can cut the ensuing damage by 30 percent, and spending $800 million on such systems in developing countries would avoid losses of $3–16 billion per year.
- Making infrastructure more climate-resilient can add about 3 percent to the upfront costs but has benefit-cost ratios of about 4:1. With $60 trillion in projected infrastructure investments between 2020 and 2030, the potential benefits of early adaptation are enormous.

INVESTING IN ADAPTATION YIELDS

AVOIDED LOSSES

\+ ECONOMIC BENEFITS

\+ SOCIAL & ENVIRONMENTAL BENEFITS

= A TRIPLE DIVIDEND

Source: Adapted from ODI, GFDRR, and the World Bank.

Economic benefits:

- Reducing flood risks in urban areas lowers financial costs, increases security, and makes investments that would otherwise be too vulnerable to climate risks more viable. London's Canary Wharf and other developments in East London would have been impossible without flood protection from the Thames Barrier.
- Drip irrigation technologies, first developed to address severe water scarcity, are spreading because they lead to higher crop productivity than traditional irrigation systems.

Social and environmental benefits:

- Mangrove forests provide more than $80 billion per year in avoided losses from coastal flooding—and protect 18 million people. They also contribute almost as much ($40–50 billion per year) in non market benefits associated with fisheries, forestry, and recreation. Combined, the benefits from mangrove preservation and restoration are up to 10 times the costs.

Implications for Geoengineering Policy

- “Plan B” if mitigation proves impossible to implement
- E.g. spray sulphuric acid in the stratosphere, creating sulphate aerosols to reflect sunlight back to space.
- What impacts might this have regionally, e.g. on monsoons, or moisture supply to tropical rainforests?
- We would never implement such a scheme without reliable knowledge of regional impacts
- Requires more accurate models than we have now.

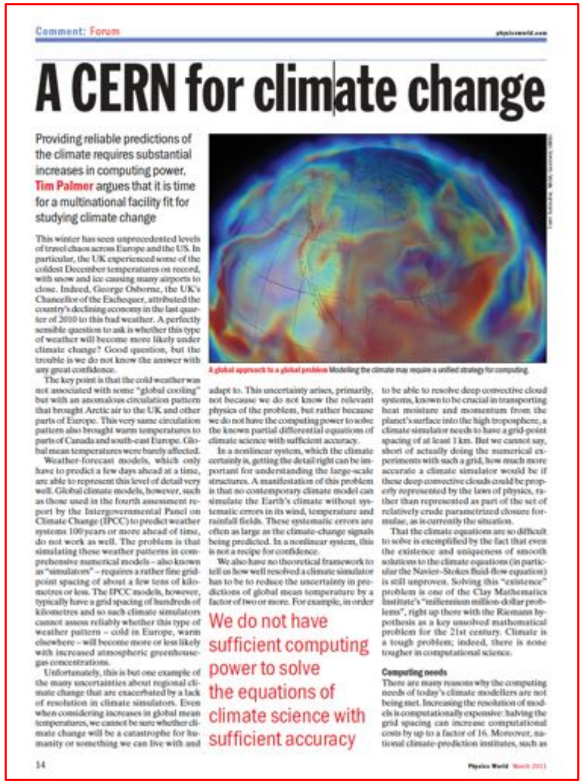
What to do?

10,000km

1km

If we could get our global grid spacing to c. 1km, could start to simulate important climatic features much more accurately and would not have to rely so extensively on approximate sub-grid formulae.

However, this will require dedicated exascale computing capability. Beyond the budgets of individual climate institutes.



Comment: Forum

A CERN for climate change

Providing reliable predictions of the climate requires substantial increases in computing power. Tim Palmer argues that it is time for a multinational facility fit for studying climate change

A global approach to a global problem Modelling the climate may require a unified strategy for computing.

This winter has seen unprecedented levels of travel chaos across Europe and the US. In particular, the UK experienced some of the coldest December temperatures on record, with snow and ice causing many airports to close. Indeed, George Osborne, the UK's Chancellor of the Exchequer, attributed the country's declining economy in the last quarter of 2010 to this bad weather. A perfectly sensible question to ask is whether this type of weather will become more likely under climate change? Good question, but the trouble is we do not know the answer with any great confidence.

The key point is that the cold weather was not associated with some "global cooling" but with an anomalous circulation pattern that brought Arctic air to the UK and other parts of Europe. This very same circulation pattern also brought warm temperatures to parts of Canada and south-east Europe. Global mean temperatures were barely affected.

Weather-forecast models, which only have to predict a few days ahead at a time, are able to represent this level of detail very well. Global climate models, however, such as those used in the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC) to predict weather systems 100 years or more ahead of time, do not work as well. The problem is that simulating these weather patterns in comprehensive numerical models – also known as "simulators" – requires a rather fine grid-point spacing of about a few tens of kilometres or less. The IPCC models, however, typically have a grid spacing of hundreds of kilometres and so such climate simulators cannot assess reliably whether this type of weather pattern – cold in Europe, warm elsewhere – will become more or less likely with increased atmospheric greenhouse-gas concentrations.

Unfortunately, this is but one example of the many uncertainties about regional climate change that are exacerbated by a lack of resolution in climate simulators. Even when considering increases in global mean temperatures, we cannot be sure whether climate change will be a catastrophe for humanity or something we can live with and adapt to. This uncertainty arises, primarily, not because we do not know the relevant physics of the problem, but rather because we do not have the computing power to solve the known partial differential equations of climate science with sufficient accuracy.

In a nonlinear system, which the climate certainly is, getting the detail right can be important for understanding the large-scale structures. A manifestation of this problem is that no contemporary climate model can simulate the Earth's climate without systematic errors in its wind, temperature and rainfall fields. These systematic errors are often as large as the climate-change signals being predicted. In a nonlinear system, this is not a recipe for confidence.

We also have no theoretical framework to tell us how well resolved a climate simulator has to be to reduce the uncertainty in predictions of global mean temperature by a factor of two or more. For example, in order to be able to resolve deep convective cloud systems, known to be crucial in transporting heat moisture and momentum from the planet's surface into the high troposphere, a climate simulator needs to have a grid-point spacing of at least 1 km. But we cannot say, short of actually doing the numerical experiments with such a grid, how much more accurate a climate simulator would be if these deep convective clouds could be properly represented by the laws of physics, rather than represented as part of the set of relatively crude parametrized closure formulae, as is currently the situation.

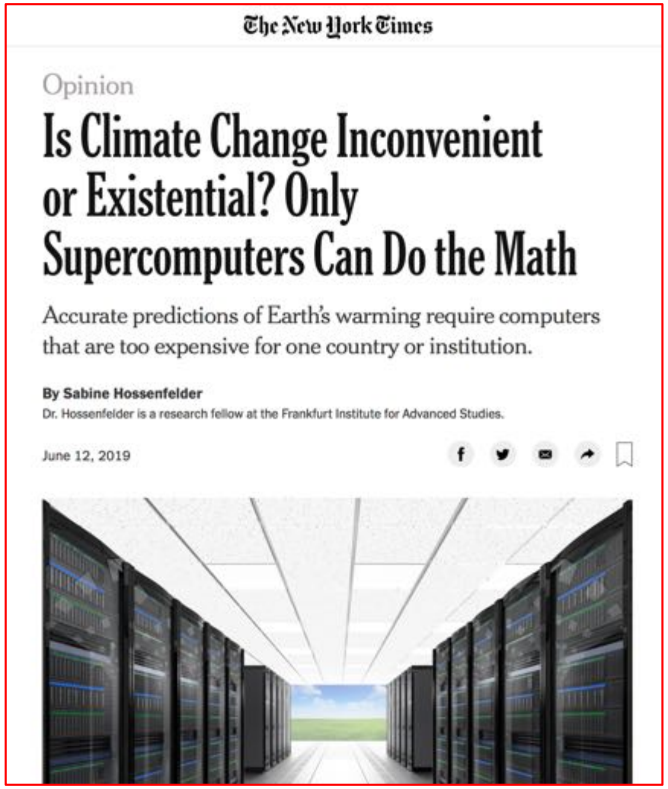
We do not have sufficient computing power to solve the equations of climate science with sufficient accuracy

That the climate equations are so difficult to solve is exemplified by the fact that even the existence and uniqueness of smooth solutions to the climate equations (in particular the Navier–Stokes fluid-flow equation) is still unproven. Solving this "existence" problem is one of the Clay Mathematics Institute's "millennium million-dollar problems", right up there with the Riemann hypothesis as a key unsolved mathematical problem for the 21st century. Climate is a tough problem; indeed, there is none tougher in computational science.

Computing needs

There are many reasons why the computing needs of today's climate modellers are not being met. Increasing the resolution of models is computationally expensive: halving the grid spacing can increase computational costs by up to a factor of 16. Moreover, national climate-prediction institutes, such as

14 Physics World March 2011



The New York Times

Opinion

Is Climate Change Inconvenient or Existential? Only Supercomputers Can Do the Math

Accurate predictions of Earth's warming require computers that are too expensive for one country or institution.

By Sabine Hossenfelder

Dr. Hossenfelder is a research fellow at the Frankfurt Institute for Advanced Studies.

June 12, 2019

Required budget. c. $100million per year

Extreme Earth (http://www.extremeearth.eu)

Conclusions

- Climate science is far from done and dusted. Instead, it needs to be ramped up several notches if we are to have a clearer picture at the regional scale of the effects of climate change – vital for informing policy on mitigation, adaptation and geoengineering.
- Climate is too complex and important a system to be modelled simply using resources at the institutional or even national level.
- The emergence of climate as the biggest threat facing society demands a more internationally coordinated effort – a CERN for Climate Change.