Climate change: From basic nonlinear physics to policy-relevant science.

Tim Palmer
Department of Physics
University of Oxford

Oxford Physics

THE ROYAL SOCIETY

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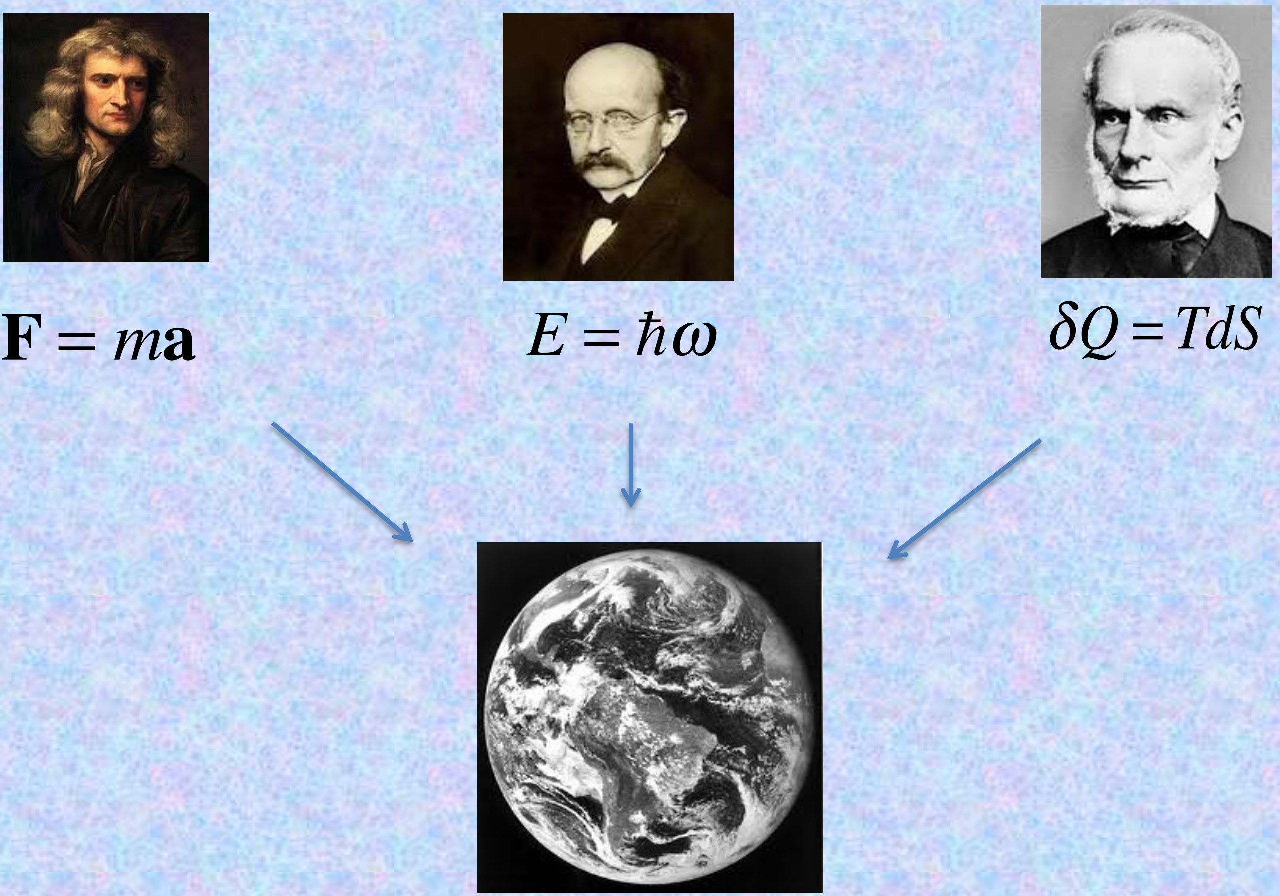
Suki Manabe: 2021 Nobel Prize for Physics

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



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

$E = \hbar\omega$

$\delta Q = TdS$

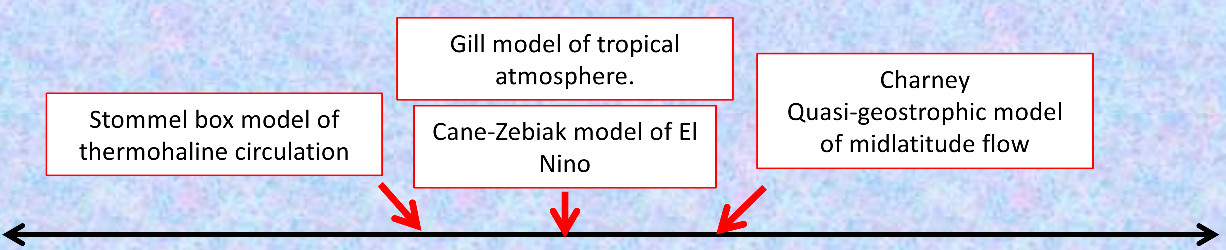
We need climate models for:

- **Understanding** (Of course!)
- **Mitigation** (How to transition to a decarbonised society.)
- **Adaptation** (How to make society more resilient to changing extremes of weather?)
- **Attribution** (Were observed weather events caused by climate change?)
- **Geoengineering** (Is there a Plan B?)

But is it all just

computing?

Model Hierarchy



Gill model of tropical atmosphere.

Stommel box model of thermohaline circulation

Cane-Zebiak model of El Nino

Charney Quasi-geostrophic model of midlatitude flow

Intermediate complexity

Simple

Complex

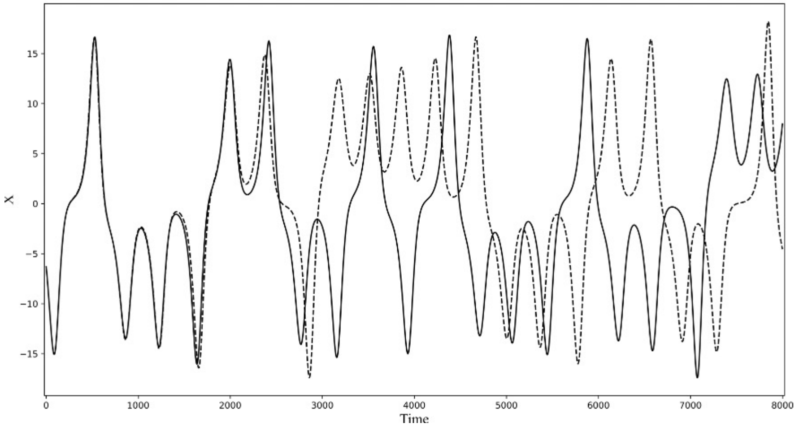
$$\frac{dX}{dt} = -10X + 10Y$$
$$\frac{dY}{dt} = -XZ + 28X - Y$$
$$\frac{dZ}{dt} = XY - \frac{8}{3}Z$$

3-dimensional
state space

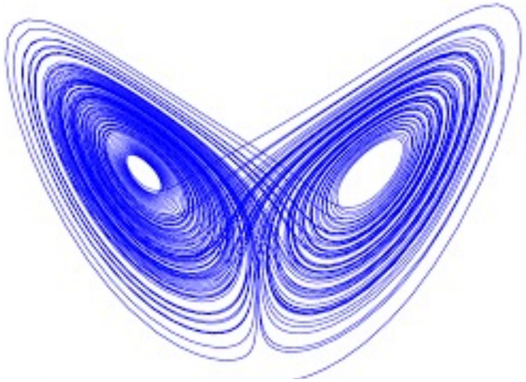
$$\rho\left(\frac{\partial}{\partial t} + \mathbf{u}.\nabla\right)\mathbf{u} = \rho\mathbf{g} - \nabla p + \mu\ \nabla^2\mathbf{u}$$

Infinite-dimensional state space.

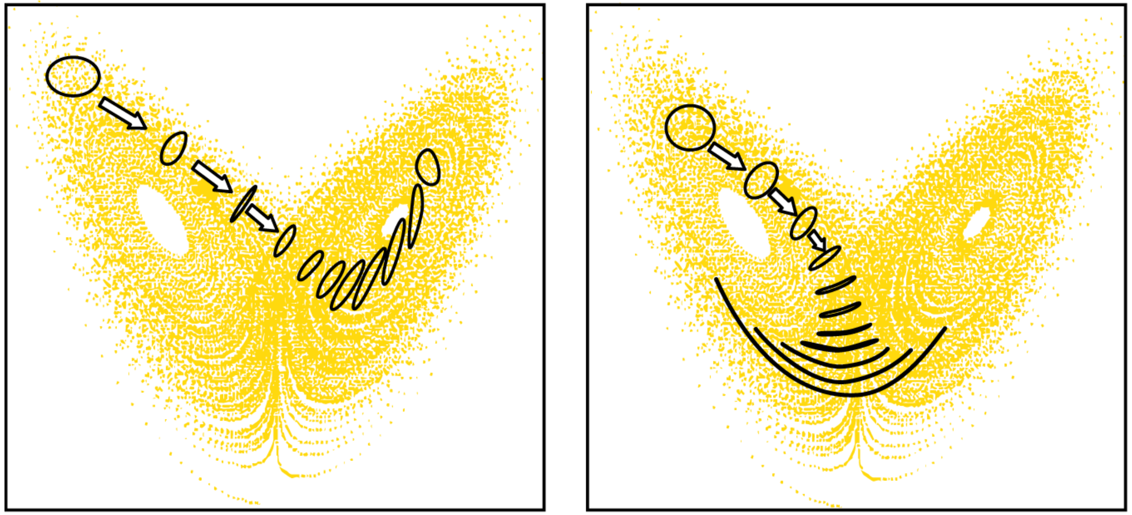
$$\frac{dX}{dt} = -10X + 10Y$$
$$\frac{dY}{dt} = -XZ + 28X - Y$$
$$\frac{dZ}{dt} = XY - \frac{8}{3}Z$$

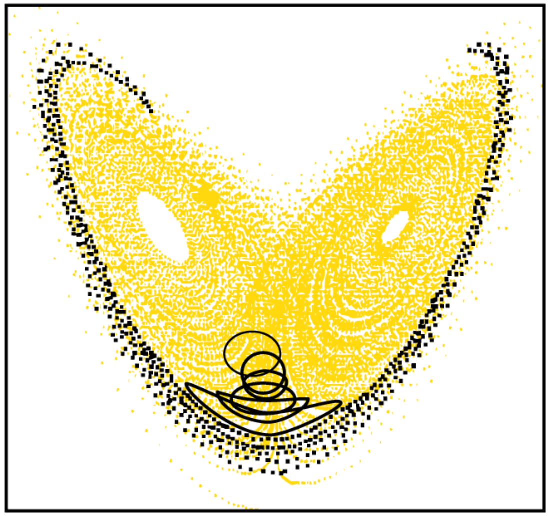


Sensitivity of Lorenz 1963 to initial conditions



The fractal Lorenz attractor





$$\frac{dX}{dt} = F[X]$$

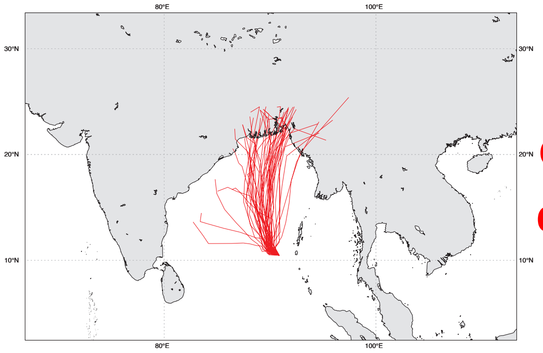
$\Rightarrow$

$$\frac{d\delta X}{dt} = \frac{dF}{dX}\delta X$$

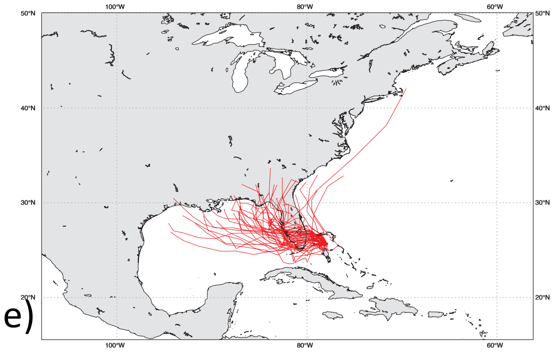
$\Rightarrow$ the growth of small perurbations depends on X

Week-long ensemble tropical cyclone/hurricane tracks.

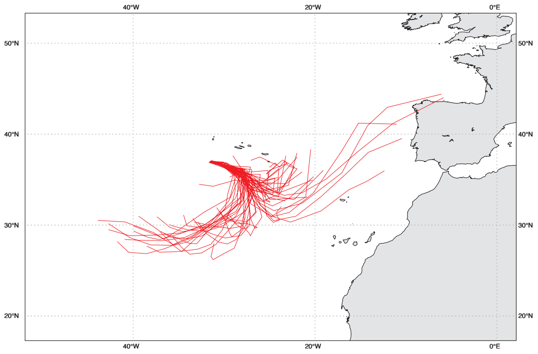
Sidr
(predictable)



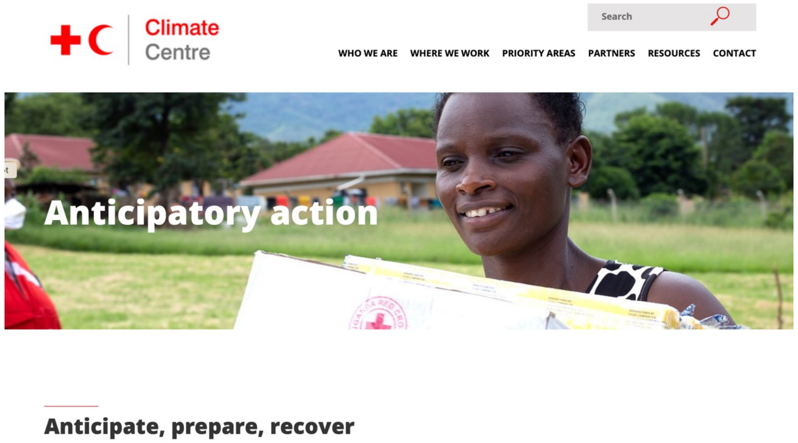
Katrina
(semi-predictable)



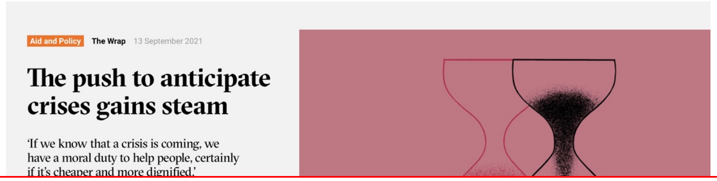
Nadine
(unpredictable)



Take anticipatory action when probabilities of extreme weather exceed a predetermined threshold.

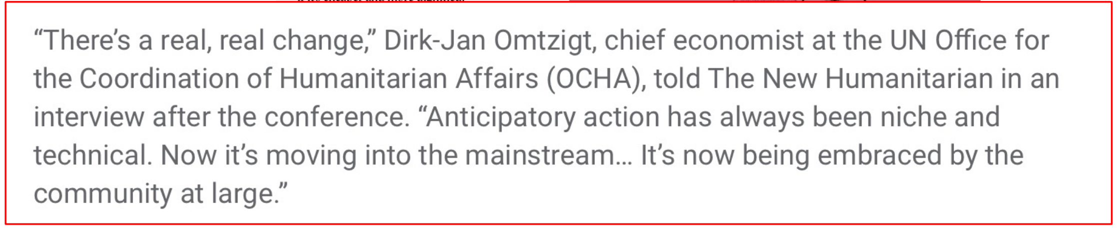


Anticipate, prepare, recover

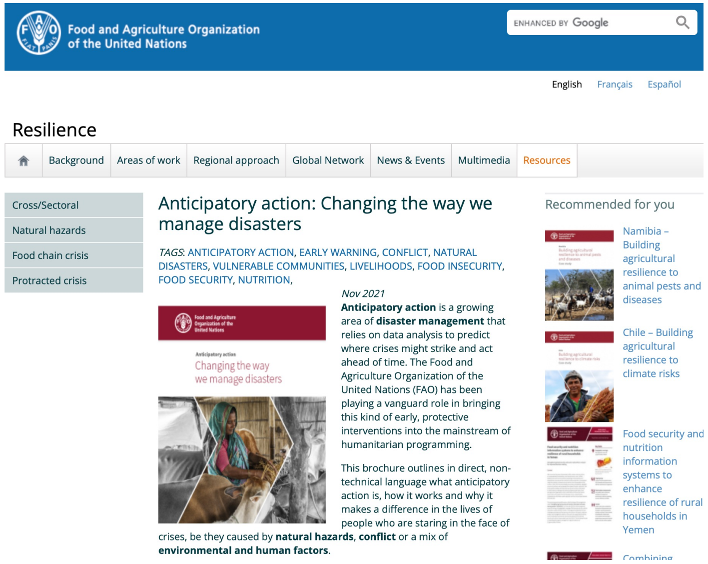


The push to anticipate crises gains steam

'If we know that a crisis is coming, we have a moral duty to help people, certainly if it's cheaper and more dignified.'



"There's a real, real change," Dirk-Jan Omtzigt, chief economist at the UN Office for the Coordination of Humanitarian Affairs (OCHA), told The New Humanitarian in an interview after the conference. "Anticipatory action has always been niche and technical. Now it's moving into the mainstream… It's now being embraced by the community at large."



Resilience

Anticipatory action: Changing the way we manage disasters

TAGS: ANTICIPATORY ACTION, EARLY WARNING, CONFLICT, NATURAL DISASTERS, VULNERABLE COMMUNITIES, LIVELIHOODS, FOOD INSECURITY, FOOD SECURITY, NUTRITION,

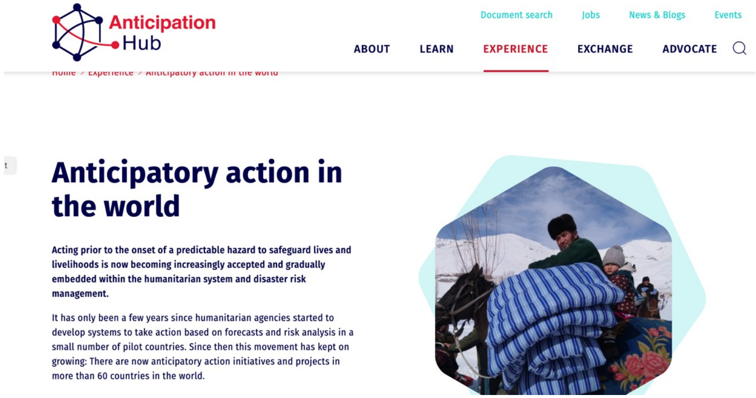
Nov 2021

Anticipatory action is a growing area of **disaster management** that relies on data analysis to predict where crises might strike and act ahead of time. The Food and Agriculture Organization of the United Nations (FAO) has been playing a vanguard role in bringing this kind of early, protective interventions into the mainstream of humanitarian programming.

This brochure outlines in direct, non-technical language what anticipatory action is, how it works and why it makes a difference in the lives of people who are staring in the face of crises, be they caused by **natural hazards**, **conflict** or a mix of **environmental and human factors**.

Recommended for you

- Namibia – Building agricultural resilience to animal pests and diseases
- Chile – Building agricultural resilience to climate risks
- Food security and nutrition information systems to enhance resilience of rural households in Yemen
- Combining



Anticipatory action in the world

Acting prior to the onset of a predictable hazard to safeguard lives and livelihoods is now becoming increasingly accepted and gradually embedded within the humanitarian system and disaster risk management.

It has only been a few years since humanitarian agencies started to develop systems to take action based on forecasts and risk analysis in a small number of pilot countries. Since then this movement has kept on growing: There are now anticipatory action initiatives and projects in more than 60 countries in the world.

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

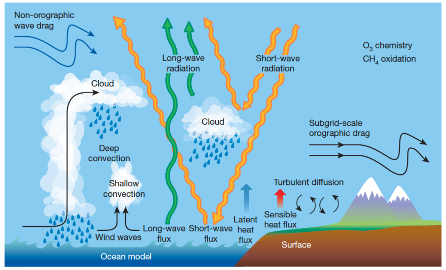
Resolved scales

Unresolved scales

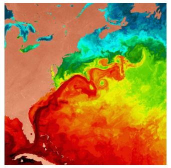
Dynamical Core

Parametrisations

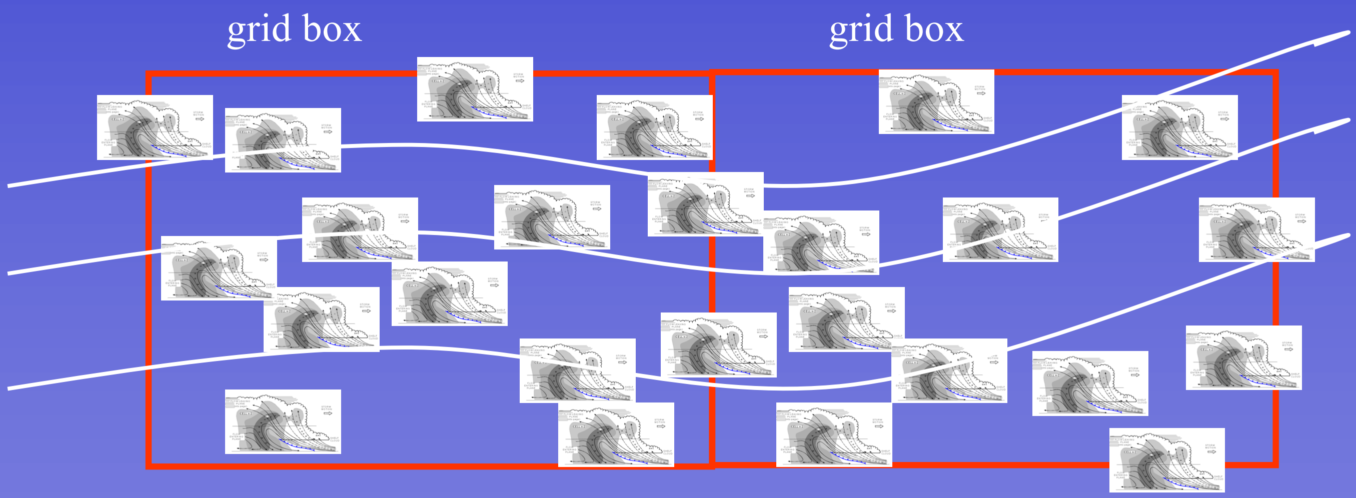
$$P\left(X_{\mathrm{Tr}};\alpha\right)$$



$$D=P$$



Parametrisation based on the assumption that the world looks like this…



C.f. Statistical Mechanics

Navier Stokes

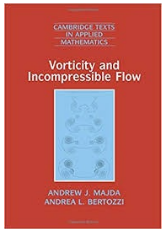
$$\rho\left(\frac{\partial}{\partial t}+\mathbf{u}.\nabla\right)\mathbf{u}=\rho\mathbf{g}-\nabla p+\mu\ \nabla^2\mathbf{u}$$

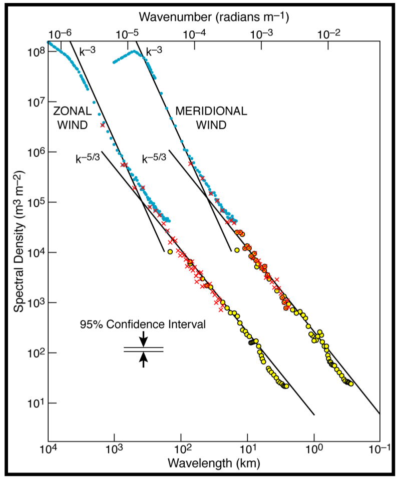
If $u(x,t)$ is the velocity field and $p(x,t)$ is the pressure field associated with a solution to the Navier-Stokes equations, then so is

$$u_\tau(x,t)=\tau^{-1/2}u\left(\frac{x}{\tau^{1/2}},\frac{t}{\tau}\right),$$

$$p_\tau(x,t)=\tau^{-1}p\left(\frac{x}{\tau^{1/2}},\frac{t}{\tau}\right)$$

where $\tau>0$ is a dimensionless scaling parameter.

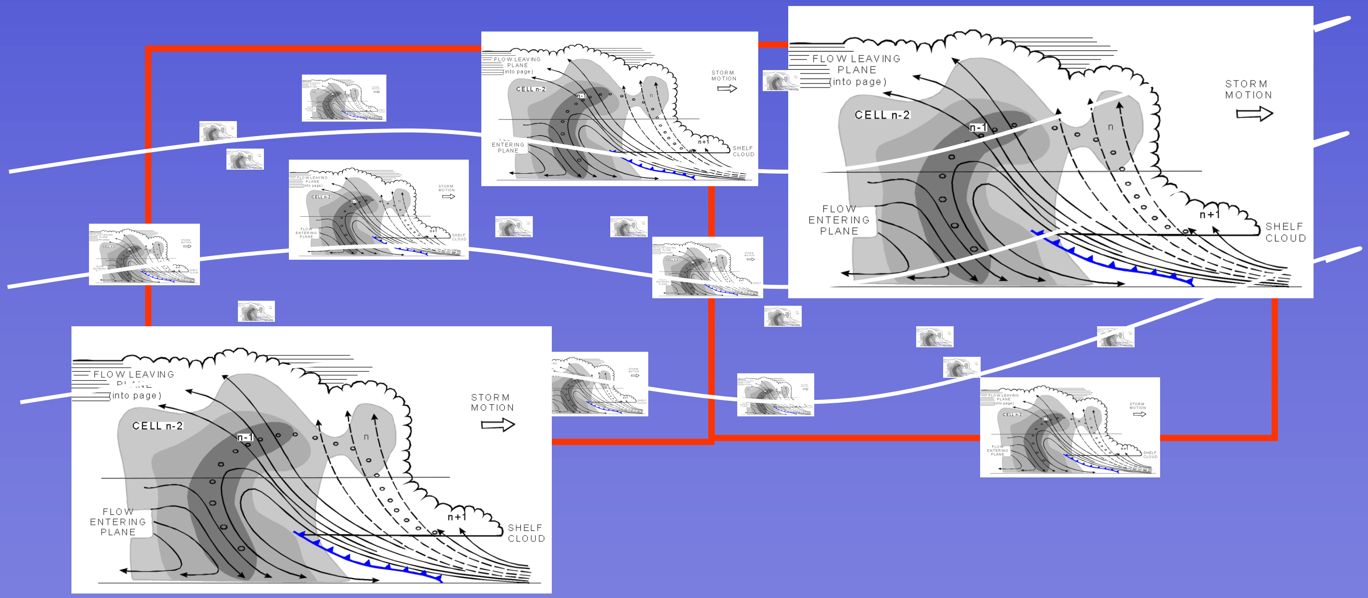




The reality of the situation
(consistent with power-law structures)

grid box

grid box



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

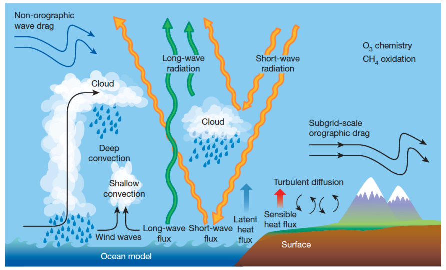
Resolved scales ←

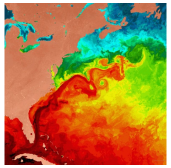
Unresolved scales →

Dynamical Core

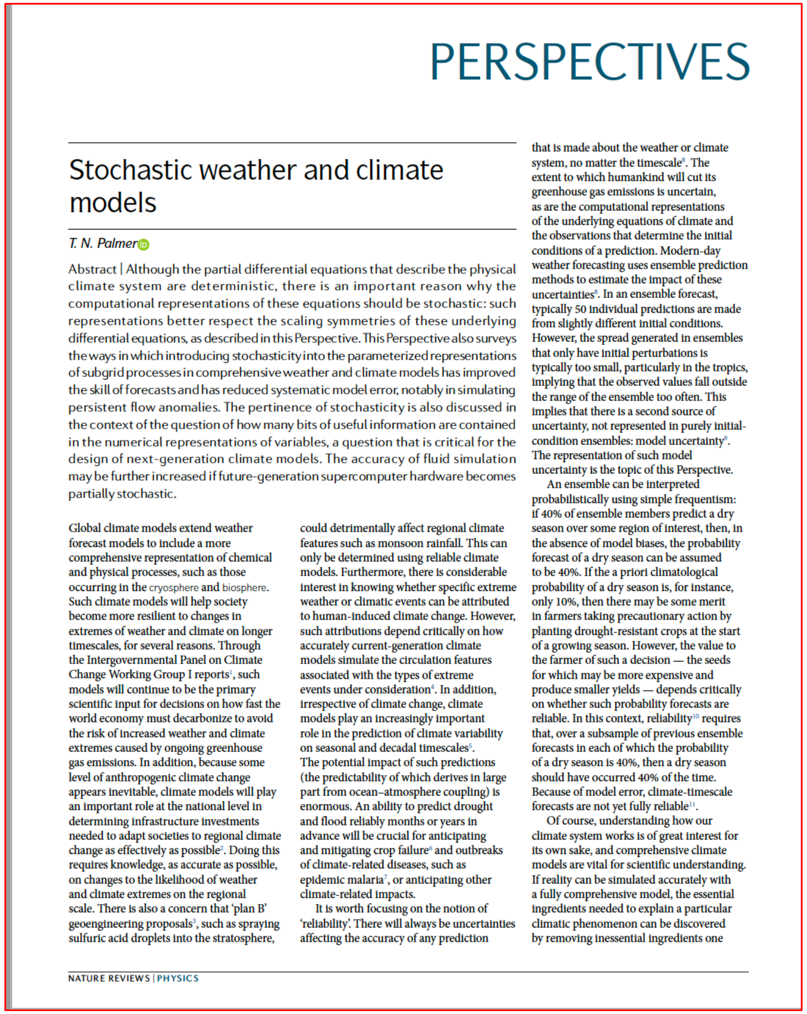
Stochastic Parametrisations

$$(1+r)P(X_{tr};\alpha)$$





$$D=P$$



Stochastic weather and climate models

T. N. Palmer

Abstract | Although the partial differential equations that describe the physical climate system are deterministic, there is an important reason why the computational representations of these equations should be stochastic: such representations better respect the scaling symmetries of these underlying differential equations, as described in this Perspective. This Perspective also surveys the ways in which introducing stochasticity into the parameterized representations of subgrid processes in comprehensive weather and climate models has improved the skill of forecasts and has reduced systematic model error, notably in simulating persistent flow anomalies. The pertinence of stochasticity is also discussed in the context of the question of how many bits of useful information are contained in the numerical representations of variables, a question that is critical for the design of next-generation climate models. The accuracy of fluid simulation may be further increased if future-generation supercomputer hardware becomes partially stochastic.

Global climate models extend weather forecast models to include a more comprehensive representation of chemical and physical processes, such as those occurring in the cryosphere and biosphere. Such climate models will help society become more resilient to changes in extremes of weather and climate on longer timescales, for several reasons. Through the Intergovernmental Panel on Climate Change Working Group I reports[1], such models will continue to be the primary scientific input for decisions on how fast the world economy must decarbonize to avoid the risk of increased weather and climate extremes caused by ongoing greenhouse gas emissions. In addition, because some level of anthropogenic climate change appears inevitable, climate models will play an important role at the national level in determining infrastructure investments needed to adapt societies to regional climate change as effectively as possible[2]. Doing this requires knowledge, as accurate as possible, on changes to the likelihood of weather and climate extremes on the regional scale. There is also a concern that 'plan B' geoengineering proposals[3], such as spraying sulfuric acid droplets into the stratosphere, could detrimentally affect regional climate features such as monsoon rainfall. This can only be determined using reliable climate models. Furthermore, there is considerable interest in knowing whether specific extreme weather or climatic events can be attributed to human-induced climate change. However, such attributions depend critically on how accurately current-generation climate models simulate the circulation features associated with the types of extreme events under consideration[4]. In addition, irrespective of climate change, climate models play an increasingly important role in the prediction of climate variability on seasonal and decadal timescales[5]. The potential impact of such predictions (the predictability of which derives in large part from ocean–atmosphere coupling) is enormous. An ability to predict drought and flood reliably months or years in advance will be crucial for anticipating and mitigating crop failure[6] and outbreaks of climate-related diseases, such as epidemic malaria[7], or anticipating other climate-related impacts.

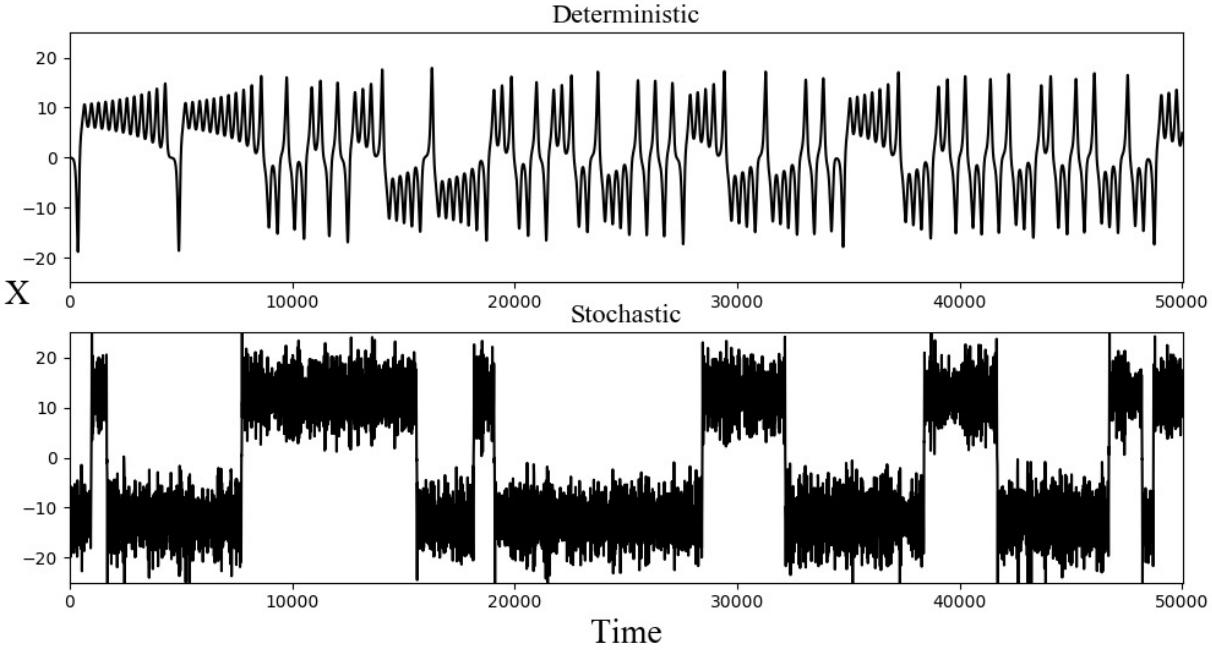
It is worth focusing on the notion of 'reliability'. There will always be uncertainties affecting the accuracy of any prediction that is made about the weather or climate system, no matter the timescale[8]. The extent to which humankind will cut its greenhouse gas emissions is uncertain, as are the computational representations of the underlying equations of climate and the observations that determine the initial conditions of a prediction. Modern-day weather forecasting uses ensemble prediction methods to estimate the impact of these uncertainties[8]. In an ensemble forecast, typically 50 individual predictions are made from slightly different initial conditions. However, the spread generated in ensembles that only have initial perturbations is typically too small, particularly in the tropics, implying that the observed values fall outside the range of the ensemble too often. This implies that there is a second source of uncertainty, not represented in purely initial-condition ensembles: model uncertainty[9]. The representation of such model uncertainty is the topic of this Perspective.

An ensemble can be interpreted probabilistically using simple frequentism: if 40% of ensemble members predict a dry season over some region of interest, then, in the absence of model biases, the probability forecast of a dry season can be assumed to be 40%. If the a priori climatological probability of a dry season is, for instance, only 10%, then there may be some merit in farmers taking precautionary action by planting drought-resistant crops at the start of a growing season. However, the value to the farmer of such a decision — the seeds for which may be more expensive and produce smaller yields — depends critically on whether such probability forecasts are reliable. In this context, reliability[10] requires that, over a subsample of previous ensemble forecasts in each of which the probability of a dry season is 40%, then a dry season should have occurred 40% of the time. Because of model error, climate-timescale forecasts are not yet fully reliable[11].

Of course, understanding how our climate system works is of great interest for its own sake, and comprehensive climate models are vital for scientific understanding. If reality can be simulated accurately with a fully comprehensive model, the essential ingredients needed to explain a particular climatic phenomenon can be discovered by removing inessential ingredients one

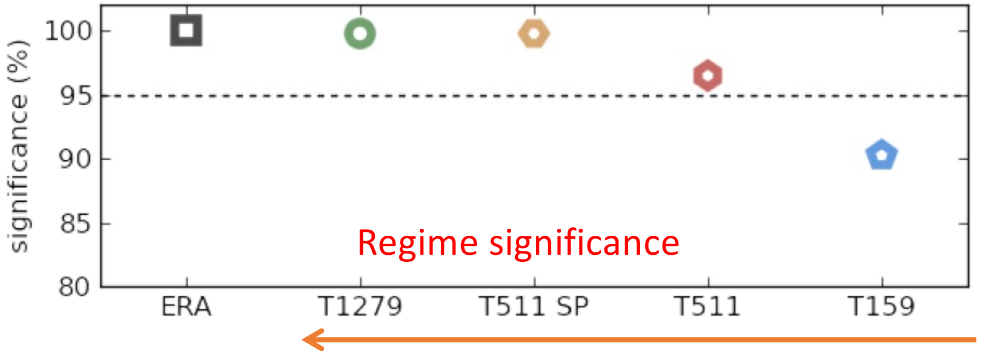
Nature Reviews Physics

$$\frac{dX}{dt} = -10X + 10Y + \eta_1$$
$$\frac{dY}{dt} = -XZ + 28X - Y + \eta_2$$
$$\frac{dZ}{dt} = XY - \frac{8}{3}Z + \eta_3$$



Adding noise to Lorenz 63 equations helps stabilize the regimes

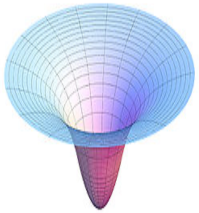
Simulating Regimes in Comprehensive Climate Models

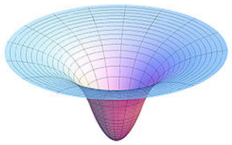


Regime significance

Model resolution

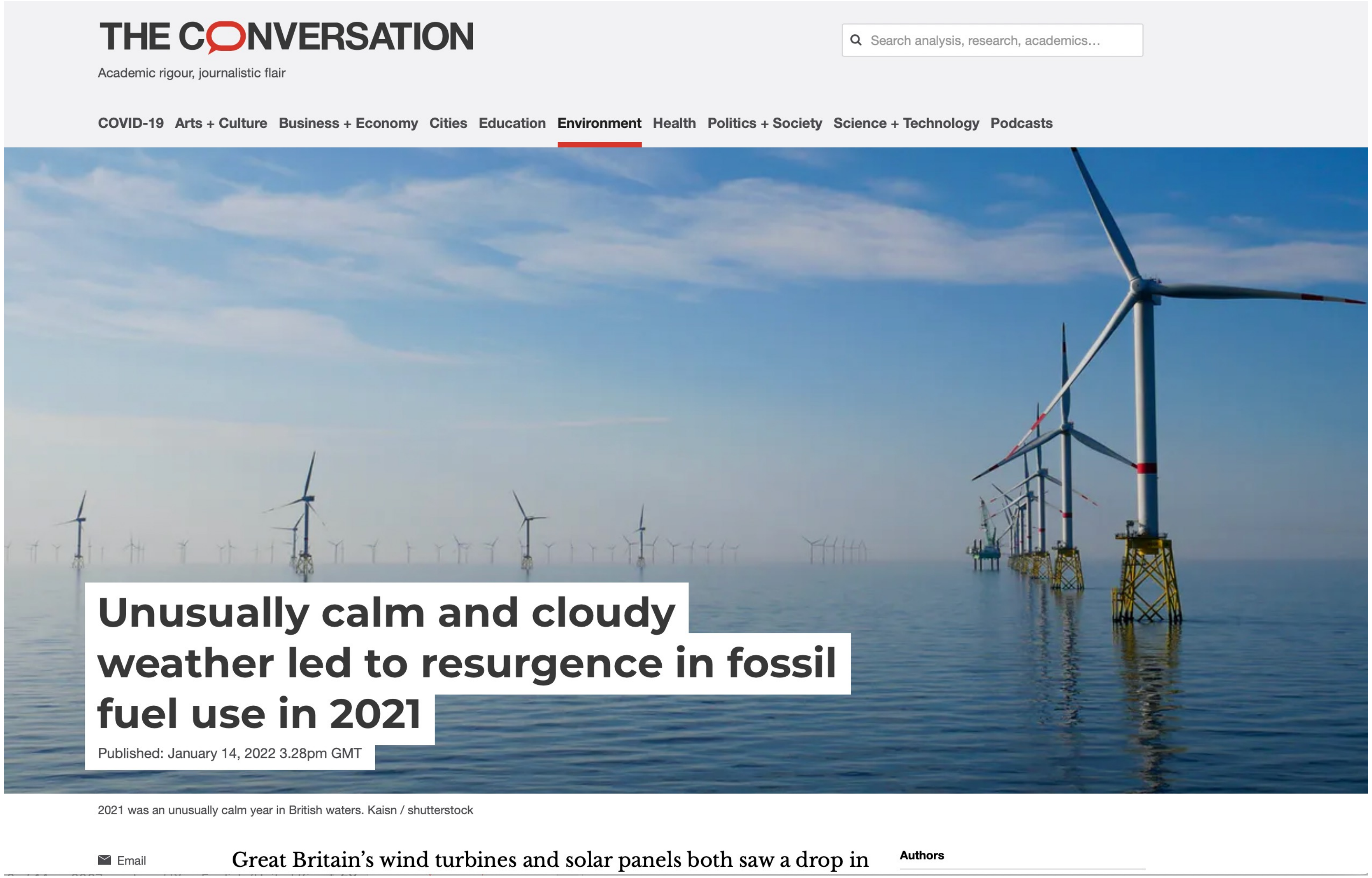
Dawson et al, 2012





As potential wells, the regimes in contemporary climate models are too shallow.

Both enhanced resolution topography and stochastic parametrisations help improve regime significance.



THE CONVERSATION
Academic rigour, journalistic flair

Unusually calm and cloudy weather led to resurgence in fossil fuel use in 2021

Published: January 14, 2022 3.28pm GMT

2021 was an unusually calm year in British waters. Kaisn / shutterstock

Great Britain’s wind turbines and solar panels both saw a drop in

Policy-relevant climate modelling is computationally expensive

- High-resolution stochastic atmosphere-ocean dynamical cores
- Ensembles
- Representations of cryosphere, biosphere, chemical cycles

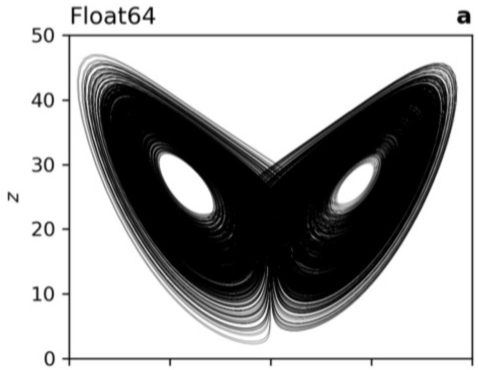
Currently available HPC constrains what is possible

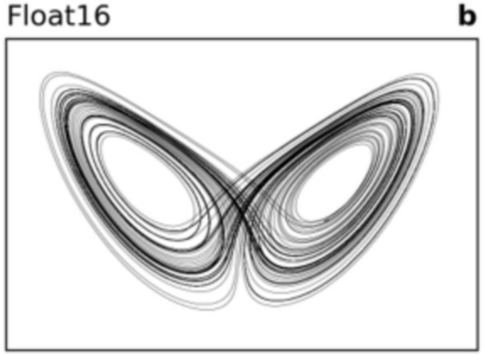
How can we make models cheaper?

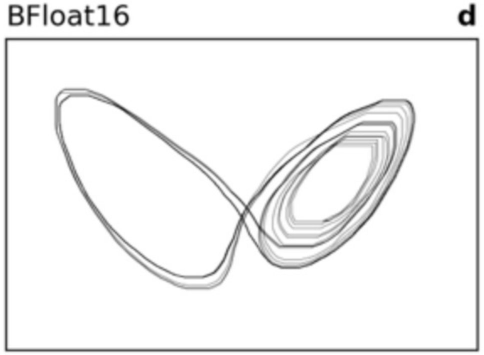
Do we need 64-bit precision (default for traditional scientific computation) if the computational equations are stochastic?

Explosion of AI has seen development of 16-bit chips

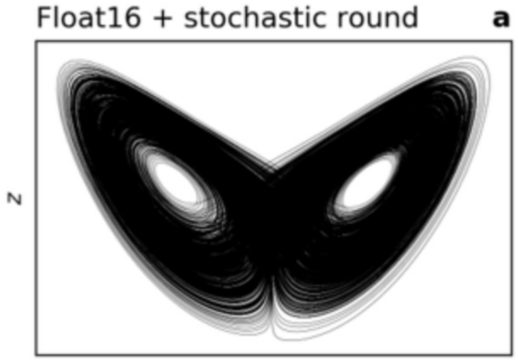
Can we run high resolution climate models with 16-bit floating-point numbers?
Potential for a substantial (32 times) speed up?



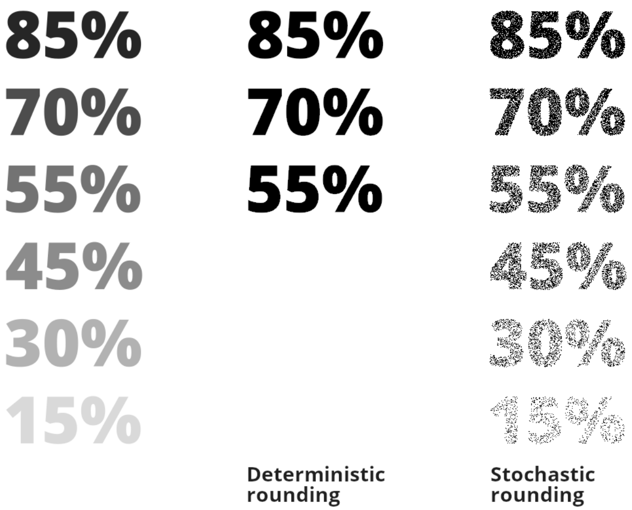




Too periodic!



3-bit deterministic | 1-bit deterministic | 1-bit stochastic

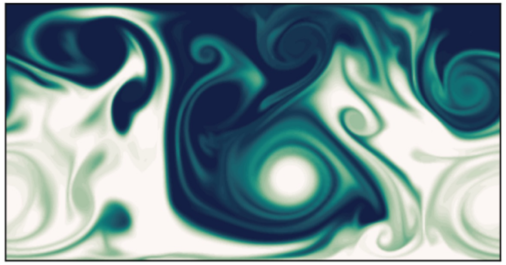


Noise can be a positive resource!

Integration of Shallow-Water Equations

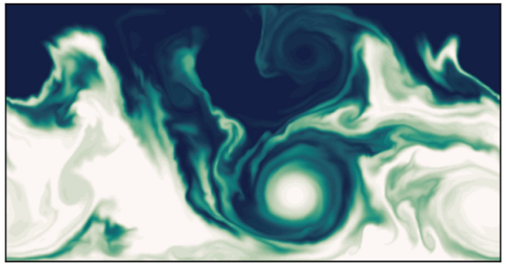
64 bit floats

Float64



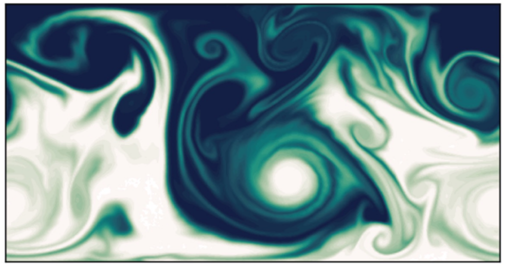
16 bit floats

Float16



16 bit floats with
stochastic rounding

Float16 + stochastic rounding



Milan Klouwer

COMMENT

A simulation of Earth's atmosphere generated by the Community Atmosphere Model.

LAWRENCE BERKELEY NATL LAB/DATA: MICHAEL WEHNER (LBNL)/VISUALIZATION: PRABHAT (LBNL)

Build imprecise supercomputers

Energy-optimized hybrid computers with a range of processor accuracies will advance modelling in fields from climate change to neuroscience, says **Tim Palmer**.

Today's supercomputers lack the power to model accurately many aspects of the real world, from the impact of cloud systems on Earth's climate to the processing ability of the human brain. Rather than wait decades for sufficiently powerful supercomputers — with their potentially unsustainable energy demands — it is time for researchers to reconsider the basic concept of the computer. We must move beyond the idea of a computer as a fast but otherwise traditional 'Turing machine', churning through calculations bit by bit in a sequential, precise and reproducible manner.

In particular, we should question whether input — and with the same high level of precision. I argue that for many applications they do not.

Energy-efficient hybrid supercomputers with a range of processor accuracies need to be developed. These would combine conventional energy-intensive processors with low-energy, non-deterministic processors, able to analyse data at variable levels of precision. The demand for such machines could be substantial, across diverse sectors of the scientific community.

MORE WITH LESS

Take climate change, for example. Estimates of Earth's future climate are based on solv- grid cells of 100 kilometres in width — can resolve the large, low-pressure weather systems typical of mid-latitudes, but not individual clouds. Yet modelling cloud systems accurately is crucial for reliable estimates of the impact of anthropogenic emissions on global temperature[1].

The resolution of this computational grid is determined by the available computing power. Current petaflop computers can perform up to 10^{15} additions or multiplications — floating-point operations — per second (flops). By the early 2020s, next-generation exaflop supercomputers, capable of 10^{18} operations per second, will be able to resolve the largest and most vig-

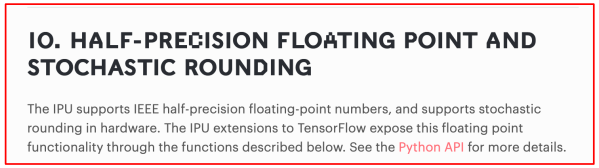
Nature 2015

GRAPHCORE

Designed for AI

INTELLIGENCE PROCESSING UNIT

The world's most complex processor, co-designed with Poplar software, so it's easy to deploy



10. HALF-PRECISION FLOATING POINT AND STOCHASTIC ROUNDING

The IPU supports IEEE half-precision floating-point numbers, and supports stochastic rounding in hardware. The IPU extensions to TensorFlow expose this floating point functionality through the functions described below. See the Python API for more details.

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

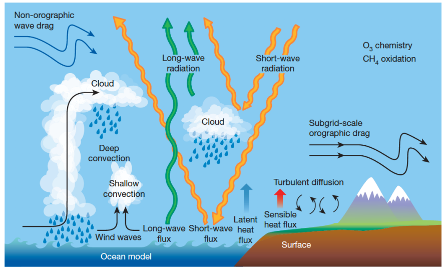
← Resolved scales

Unresolved scales →

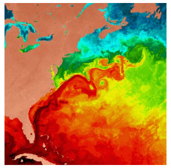
Dynamical Core

Stochastic Parametrisations

$$(1+r)P(X_{tr};\alpha)$$

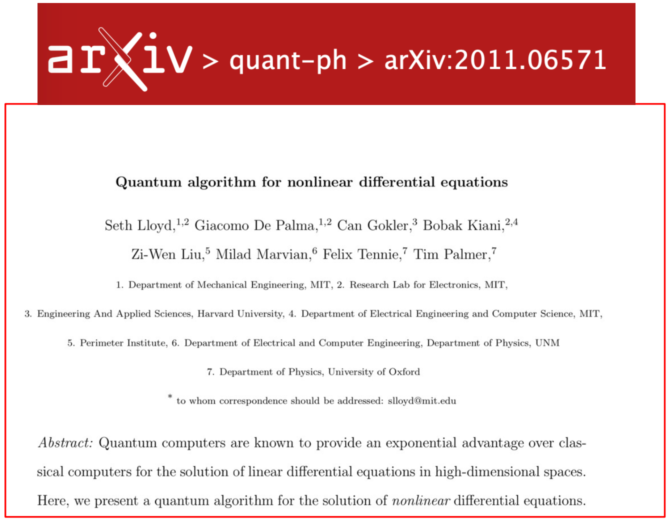


$$D=P$$



Replace RHS with 16-bit AI.

Could Quantum Computers Help? Maybe.



arXiv > quant-ph > arXiv:2011.06571

Quantum algorithm for nonlinear differential equations

Seth Lloyd,[1,2] Giacomo De Palma,[1,2] Can Gokler,[3] Bobak Kiani,[2,4]
Zi-Wen Liu,[5] Milad Marvian,[6] Felix Tennie,[7] Tim Palmer,[7]

1. Department of Mechanical Engineering, MIT, 2. Research Lab for Electronics, MIT,
3. Engineering And Applied Sciences, Harvard University, 4. Department of Electrical Engineering and Computer Science, MIT,
5. Perimeter Institute, 6. Department of Electrical and Computer Engineering, Department of Physics, UNM
7. Department of Physics, University of Oxford

[*] to whom correspondence should be addressed: slloyd@mit.edu

Abstract: Quantum computers are known to provide an exponential advantage over classical computers for the solution of linear differential equations in high-dimensional spaces. Here, we present a quantum algorithm for the solution of *nonlinear* differential equations.

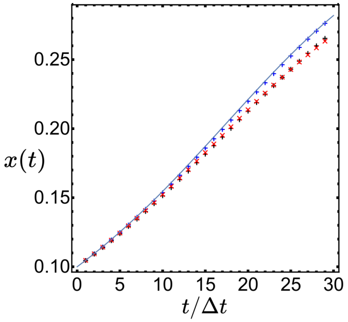
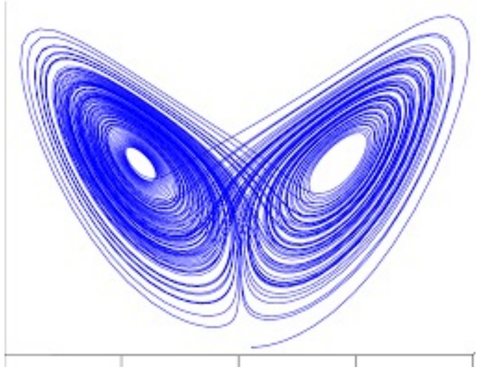
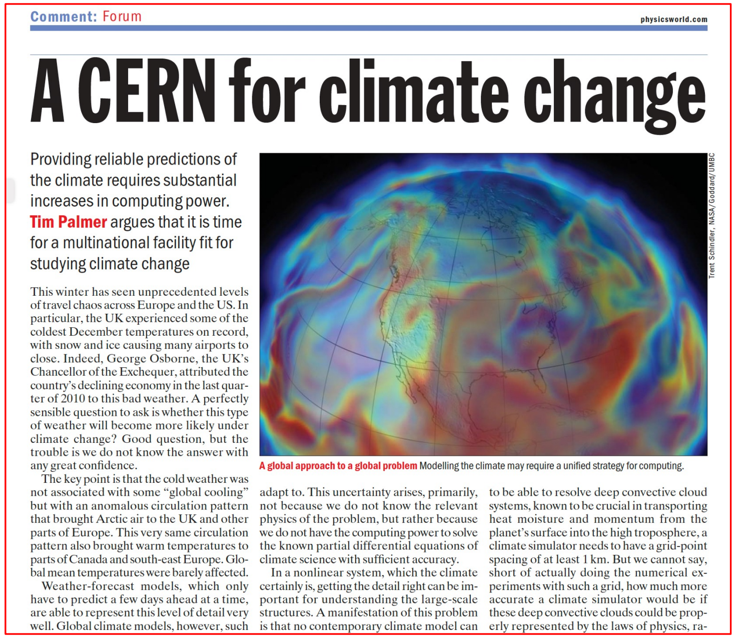


Fig. 3. Integration of $\dot{x} = x - 8x^3$. Comparison of a classical forward Euler solution (blue horizontal/vertical crosses) with an ensemble-averaged solution (black horizontal/vertical crosses) and the quantum solver output (red diagonal crosses). The solid blue line represents a Runga-Kutta method based solution. The step size was chosen as $\Delta t = 0.05$ and the quantum solver was initialised with $N = 10$ identical copies.

Work in progress:





Comment: Forum physicsworld.com

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

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

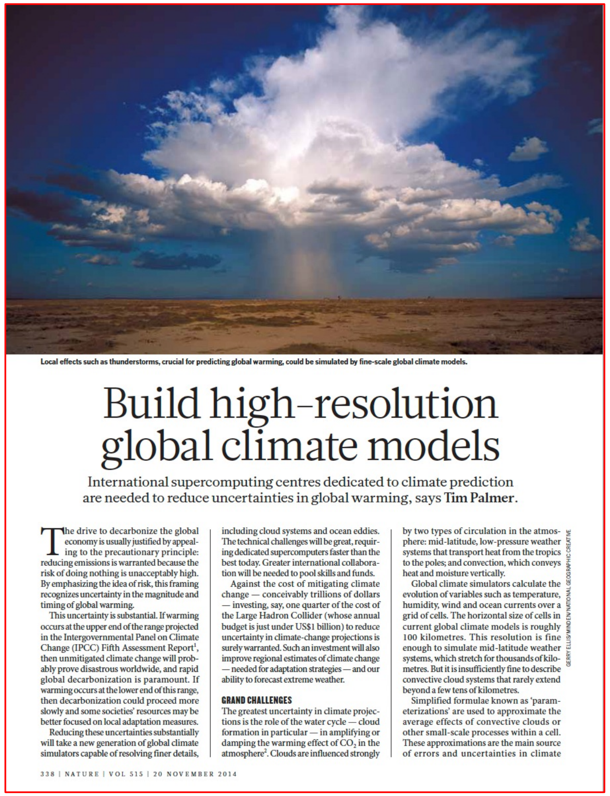
adapt to. This uncertainty arises, primarily, not because we do not know the relevant physics of the problem, but rather because we do not have the computing power to solve the known partial differential equations of climate science with sufficient accuracy.

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 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, ra-

Trent Schindler, NASA/Goddard/UMBC

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

Physics World



Local effects such as thunderstorms, crucial for predicting global warming, could be simulated by fine-scale global climate models.

GERRY ELLIS/MINDEN/NATIONAL GEOGRAPHIC CREATIVE

Build high-resolution global climate models

International supercomputing centres dedicated to climate prediction are needed to reduce uncertainties in global warming, says **Tim Palmer**.

The drive to decarbonize the global economy is usually justified by appealing to the precautionary principle: reducing emissions is warranted because the risk of doing nothing is unacceptably high. By emphasizing the idea of risk, this framing recognizes uncertainty in the magnitude and timing of global warming.

This uncertainty is substantial. If warming occurs at the upper end of the range projected in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report[1], then unmitigated climate change will probably prove disastrous worldwide, and rapid global decarbonization is paramount. If warming occurs at the lower end of this range, then decarbonization could proceed more slowly and some societies' resources may be better focused on local adaptation measures.

Reducing these uncertainties substantially will take a new generation of global climate simulators capable of resolving finer details, including cloud systems and ocean eddies. The technical challenges will be great, requiring dedicated supercomputers faster than the best today. Greater international collaboration will be needed to pool skills and funds.

Against the cost of mitigating climate change — conceivably trillions of dollars — investing, say, one quarter of the cost of the Large Hadron Collider (whose annual budget is just under US$1 billion) to reduce uncertainty in climate-change projections is surely warranted. Such an investment will also improve regional estimates of climate change — needed for adaptation strategies — and our ability to forecast extreme weather.

GRAND CHALLENGES

The greatest uncertainty in climate projections is the role of the water cycle — cloud formation in particular — in amplifying or damping the warming effect of CO_2 in the atmosphere[2]. Clouds are influenced strongly by two types of circulation in the atmosphere: mid-latitude, low-pressure weather systems that transport heat from the tropics to the poles; and convection, which conveys heat and moisture vertically.

Global climate simulators calculate the evolution of variables such as temperature, humidity, wind and ocean currents over a grid of cells. The horizontal size of cells in current global climate models is roughly 100 kilometres. This resolution is fine enough to simulate mid-latitude weather systems, which stretch for thousands of kilometres. But it is insufficiently fine to describe convective cloud systems that rarely extend beyond a few tens of kilometres.

Simplified formulae known as 'parameterizations' are used to approximate the average effects of convective clouds or other small-scale processes within a cell. These approximations are the main source of errors and uncertainties in climate

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Frontiere

TELESCOPIO A BORDO DELLA MONGOLFIERA
Viaggerà a bordo di una mongolfiera stratosferica, grande come un campo da calcio, il telescopio Asthros che monito-

Emergenza siccità. Il fenomeno del riscaldamento globale è destinato a peggiorare nei prossimi anni: andranno prese misure drastiche, ai decisori servono previsioni precise (nella foto il Po a Ficarolo, in Veneto)

«*Il* mondo ha bisogno di un Cern sul clima per affinare le previsioni»

Tim Palmer. Il fisico dell'università di Oxford lancia un appello per creare un istituto in cui concentrare *risorse e conoscenze:* «Solo aumentando la potenza di calcolo, la modellistica potrà produrre previsioni per prendere le decisioni giuste nei territori»

Elena Comelli

La tragedia della Marmolada, il Po in secca, ma anche le inondazioni in Bangladesh che hanno distrutto 4mila villaggi il mese scorso, dipendono dalla crisi del clima dovuta alle attività umane e alle relative emissioni di gas a effetto serra. «Quello che sta succedendo in questo periodo è perfettamente coerente con le previsioni dei modelli climatici che abbiamo a disposizione e la situazione è destinata a peggiorare nei prossimi anni, se non si prenderanno drastici provvedimenti per fermare le emissioni», spiega Tim Palmer, fisico dell'università di Oxford, che sarà domani in Italia per intervenire al simposio di Trieste per il centenario dell'Unione Internazionale di Fisica Pura ed Applicata.

Palmer è un pioniere della modellistica climatica: è stato fra i primi a sviluppare la previsione probabilistica d'insieme e ha contribuito a lanciare la scienza del clima nella sua nuova era, che fa ampio uso di supercalcolatori. Ma non è soddisfatto dei livelli di accuratezza raggiunti finora.

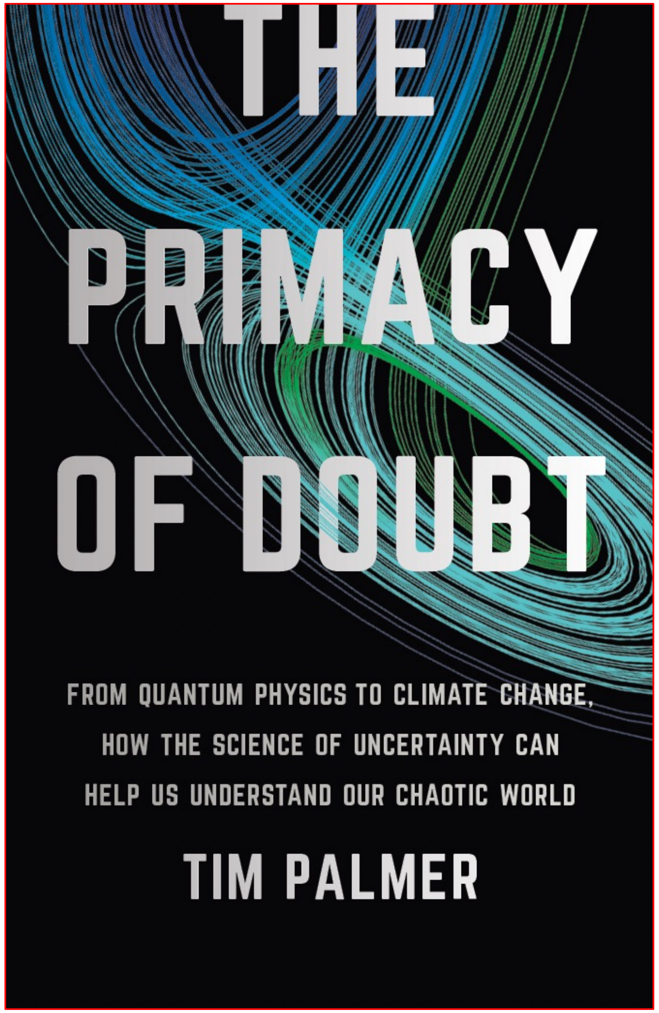
«A questo punto il mondo ha bisogno di un Cern per il clima», è l'appello di Palmer. «Se non vogliamo arrivare impreparati agli eventi sempre più catastrofici che dovremo affrontare, serve un salto di qualità negli investimenti di tutti i governi, per affrontare il problema centrale della nostra epoca con delle previsioni il più dettagliate possibile», spiega. Solo aumentando la potenza di calcolo dei suoi supercomputer la modellistica climatica potrà produrre previsioni abbastanza accurate da mettere a disposizione degli Stati, per prendere le decisioni giuste nella gestione del territorio davanti a questa crisi epocale.

«Per fare un esempio pratico, tutti i modelli concordano sul futuro del clima in Italia. Sappiamo che nei prossimi anni il clima del Sud Europa e in particolare quello italiano è destinato a diventare sempre più caldo e secco, con le conseguenze di cui vediamo i primi sintomi già oggi. Di conseguenza, il governo italiano sa quali misure andrebbero prese per affrontare la crisi, dal risparmio idrico alle nuove colture. Ma su molte altre parti del mondo, ad esempio per l'Africa, i modelli non concordano: non è chiaro se l'effetto serra si manifesterà con un clima sempre più caldo e secco oppure più tempestoso e umido», ragiona Palmer. Tutte e due le possibilità, per quanto ne sappiamo oggi, sono coerenti con la crisi del clima. «Questo diventa un problema per le misure di adattamento, perché i governi non capiranno quali infrastrutture costruire, non sapendo se si devono difendere dalla siccità o dalle inondazioni», fa notare Palmer.

Questo problema non interessa solo l'Africa, ma molte aree del mondo, che saranno anche le più colpite dalla crisi. «Nelle zone temperate le conseguenze dell'effetto serra saranno gravi, ma non così devastanti da impedire alla gente di continuare a viverci. Nelle zone tropicali e subtropicali, comprese alcune zone del Medio Oriente, le ondate di caldo invece porteranno a un esodo di massa probabilmente già a metà di questo secolo. Solo preparandoci a questi eventi con modelli accurati abbiamo una possibilità di evitare il fenomeno di massa dei rifugiati climatici», sottolinea Palmer. La crisi climatica innesca dinamiche molto complesse, che spesso si autoalimentano: il rallentamento della corrente del Golfo, la savanizzazione dell'Amazzonia, lo scioglimento del permafrost, sono tutti processi molto importanti, su cui non sappiamo ancora abbastanza. «I modelli climatici attuali non hanno un livello sufficiente di sofisticazione per poter fornire informazioni abbastanza dettagliate. Per questo abbiamo bisogno di un istituto centrale, in cui i governi del mondo possano concentrare al massimo le risorse, sia umane che materiali, con l'obiettivo di aumentare le conoscenze sulla crisi del clima», ribadisce Palmer, che lancerà questo messaggio domani da Trieste. Un primo passo avanti sarebbe avere a disposizione un computer a esascala, di cui esiste solo un esemplare negli Stati Uniti, il Frontier dell'Oak Ridge National Laboratory. «Sono macchine che di solito servono l'industria bellica», commenta tristemente Palmer. Ma il clima è più importante della guerra.

TIM PALMER
Fisico dell'Università di Oxford, tra i primi a sviluppare la previsione probabilistica d'insieme

Il Sole 24


THE PRIMACY OF DOUBT

FROM QUANTUM PHYSICS TO CLIMATE CHANGE, HOW THE SCIENCE OF UNCERTAINTY CAN HELP US UNDERSTAND OUR CHAOTIC WORLD

TIM PALMER

The science of uncertainty + ensemble prediction applied to:

- Weather and climate
- Economics
- COVID prediction
- Conflict prediction
- Quantum physics
- Human creativity
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