EVE: the science case.

Tim Palmer
Department of Physics

Oxford Physics

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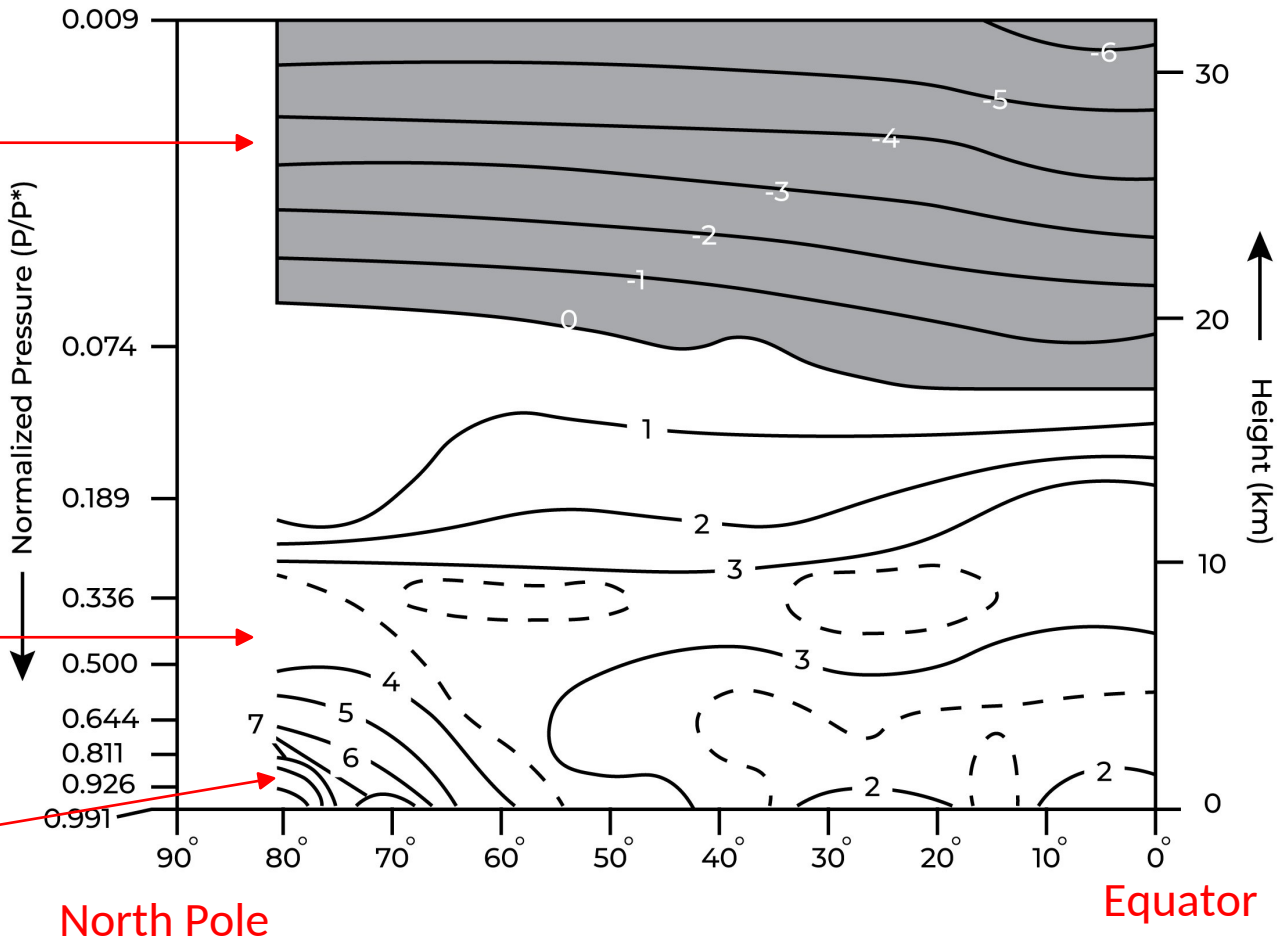
Suki Manabe: 2021 Nobel Prize for Physics

Upper atmosphere cools.

Lower atmosphere warms.

Polar hot spot



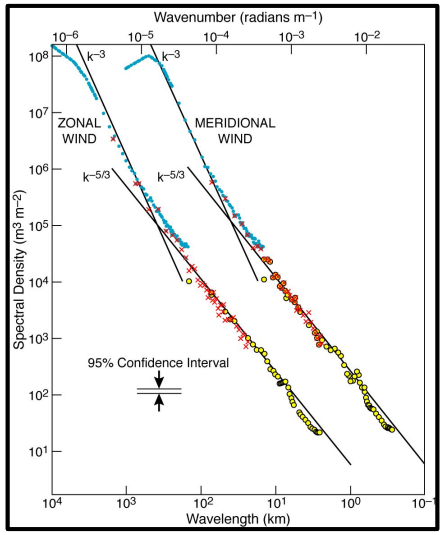
A climate model response to a doubling of CO_2.

Manabe and Wetherald, 1975

Navier Stokes Equations

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

Power Law

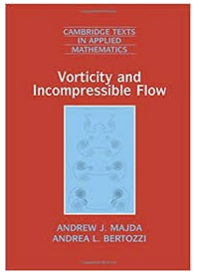


Scaling Symmetry

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

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

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



where $t > 0$ is a dimensionless scaling parameter.

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

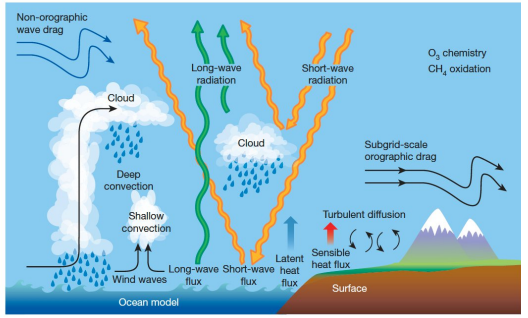
Large scales ⟵ Truncation Scale c. 100km ⟶ Small scales

Dynamical Core

Parametrisations

$$\boldsymbol{P}\left(\boldsymbol{X}_{\mathrm{Tr}};a\right)$$

Semi-empirical heuristic formulae



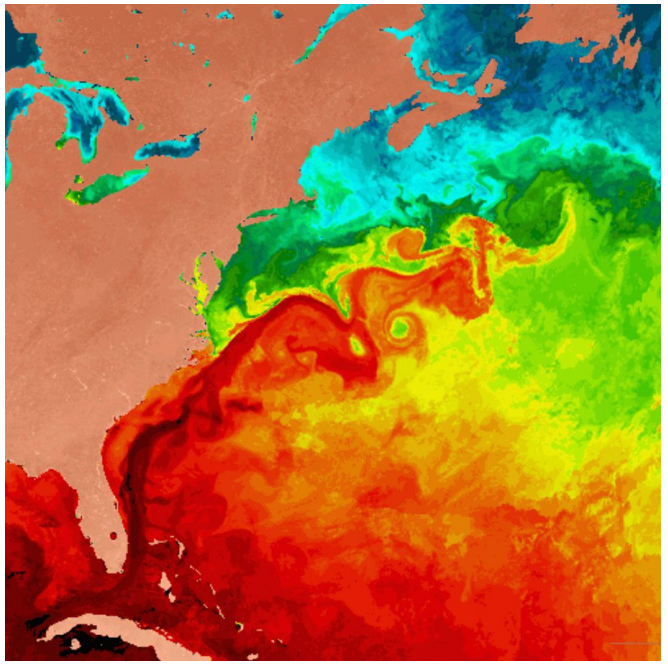
$$\boldsymbol{D}=\boldsymbol{P}$$

The larger the truncation scale, the more the Navier-Stokes scaling symmetry is violated and the more our simulations of climate degrade.

Deep convective clouds

Orographic drag

Ocean eddy mixing



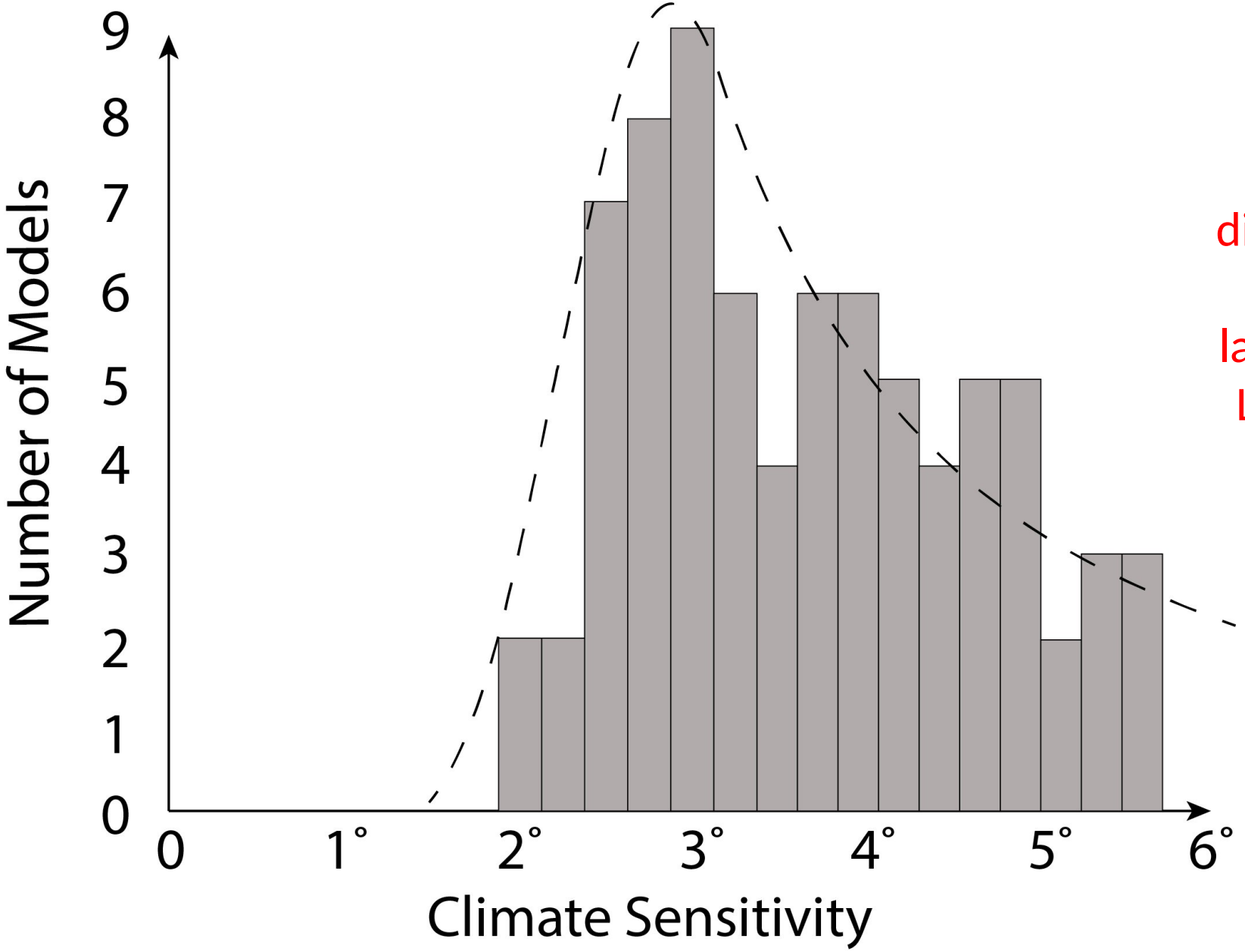
Currently, these processes are represented by inaccurate heuristic formulae in climate models.

Earth’s Surface is Complex and Heterogeneous

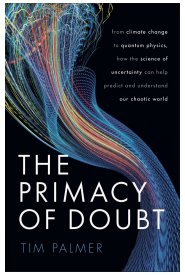
Unrealistic to expect that land-atmosphere interactions (of heat, moisture, momentum) can be modelled without significant bias when topography is averaged over hundreds of kilometres.

What, as a result, we don’t know

- How bad the warming will get (lukewarm, existential?)
- Will we shortly be passing a point of no return?
- What the regional impacts of climate change will be.



Amount of global warming for a doubling of carbon dioxide –from models contributing to the last two IPCC reports. Large uncertainties.



The biggest, most important, source of uncertainty: how clouds will respond to our CO_2 emissions.

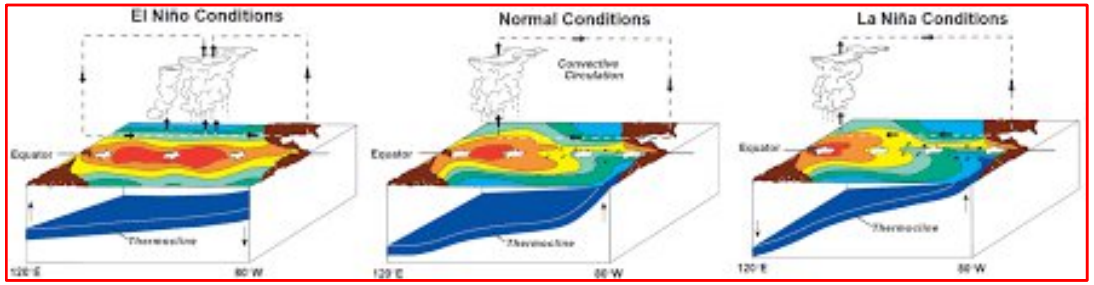
Cirrus Cloud

Warms the surface

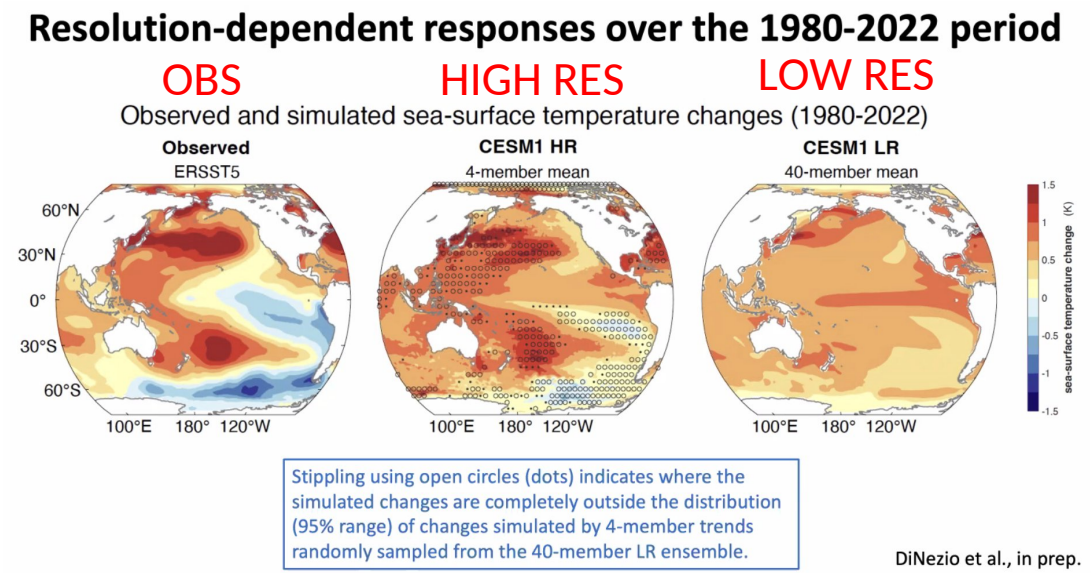
Stratus Cloud

Cools the surface

Global cloud cover depends e.g. on state of El Nino / Southern Oscillation



Will El Nino or La Nina become more likely under climate change? **We don't know.**



The Mean State of the Climate System Depends on a Small Number of Small-scale Extreme Weather Events

CLIMATE MEASUREMENT

Tropical cyclones may influence global climate, finds Scripps study

By DAN SYMONDS — June 22, 2023 2 Mins Read

Credit: Pixabay

Research from scientists at UC San Diego's Scripps Institution of Oceanography has found that tropical cyclones cause ocean turbulence that extends deeper than previously thought, causing mixing that transfers heat from the surface to waters nearly 300m (1,000ft) down.

The researchers suggest that the ocean warming caused by tropical cyclones goes deep enough to persist for months or years and travels far from its point of origin, potentially altering the broader patterns of ocean circulation that partly regulate Earth's climate.

LATEST NEWS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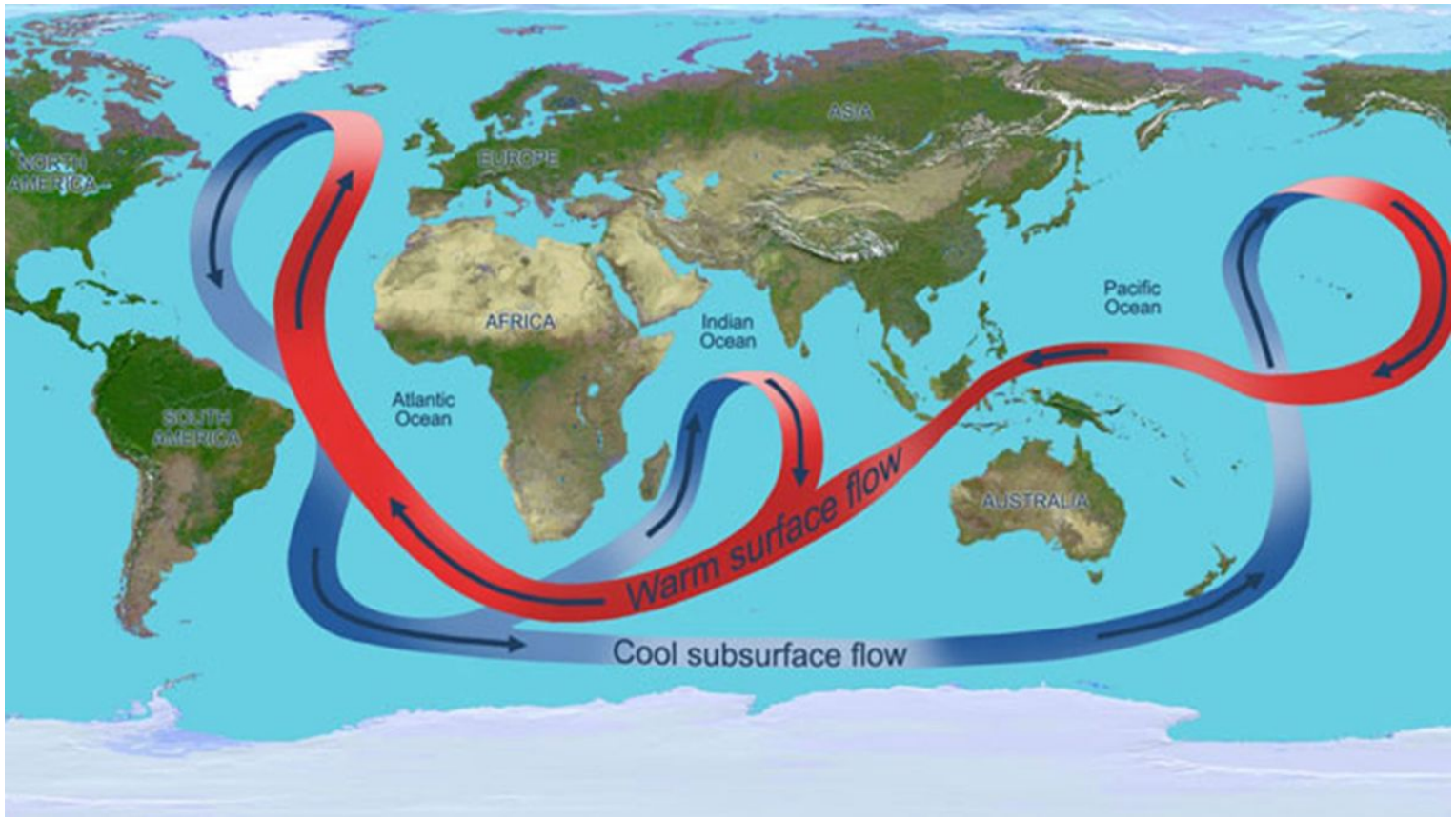
Tropical cyclones may influence global climate, finds Scripps study
June 23, 2023

What, as a result, we don’t know

- How bad the warming will get (lukewarm, existential?)
- Will we shortly be passing a point of no return?
- What the regional impacts of climate change will be.

Tipping Points



Will the thermohaline circulation switch off (“tipping point”) or just slow down?

We don’t know. Different models give different answers.

What, as a result, we don’t know

- How bad the warming will get (lukewarm, existential?)
- Will we shortly be passing a point of no return?
- What the regional impacts of climate change will be.

What will it be like where I live?

or

IPCC AR6

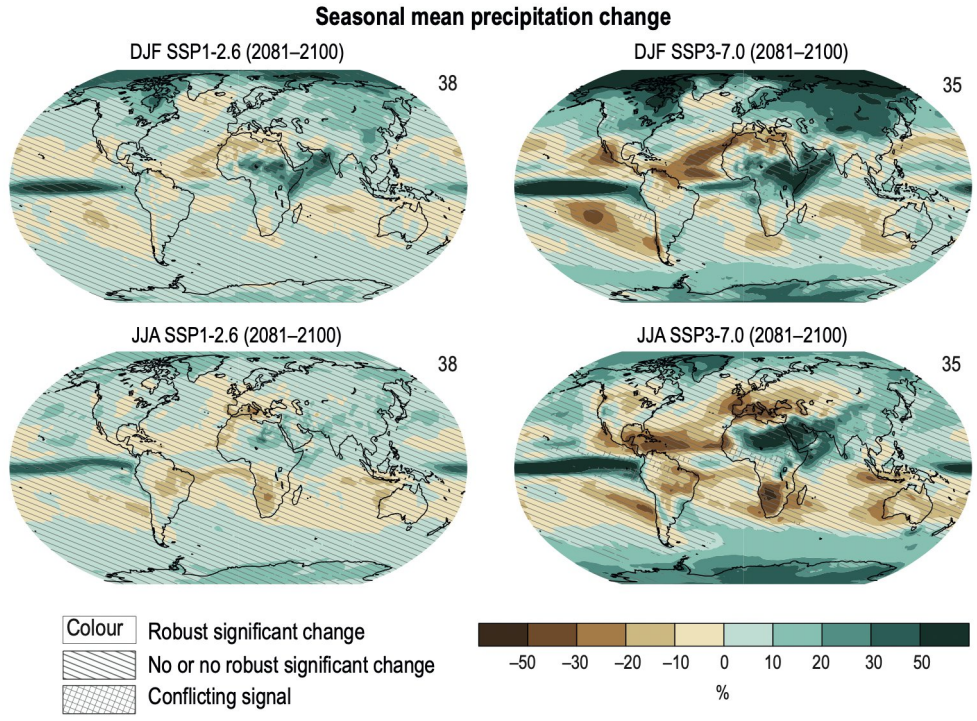


Figure 4.24 | Long-term change of seasonal mean precipitation. Displayed are projected spatial patterns of multi-model mean change (%) in **(top)** December–January–February (DJF) and **(bottom)** June–July–August (JJA) mean precipitation in 2081–2100 relative to 1995–2014, for (left) SSP1-2.6 and (right) SSP3-7.0. The number of models used is indicated in the top right of the maps. No map overlay indicates regions where the change is robust and *likely* emerges from internal variability, that is, where at least 66% of the models show a change greater than the internal-variability threshold (Section 4.2.6) and at least 80% of the models agree on the sign of change. Diagonal lines indicate regions with no change or no robust significant change, where fewer than 66% of the models show change greater than the internal-variability threshold. Crossed lines indicate areas of conflicting signals where at least 66% of the models show change greater than the internal-variability threshold but fewer than 80% of all models agree on the sign of change. Further details on data sources and processing are available in the chapter data table (Table 4.SM.1).

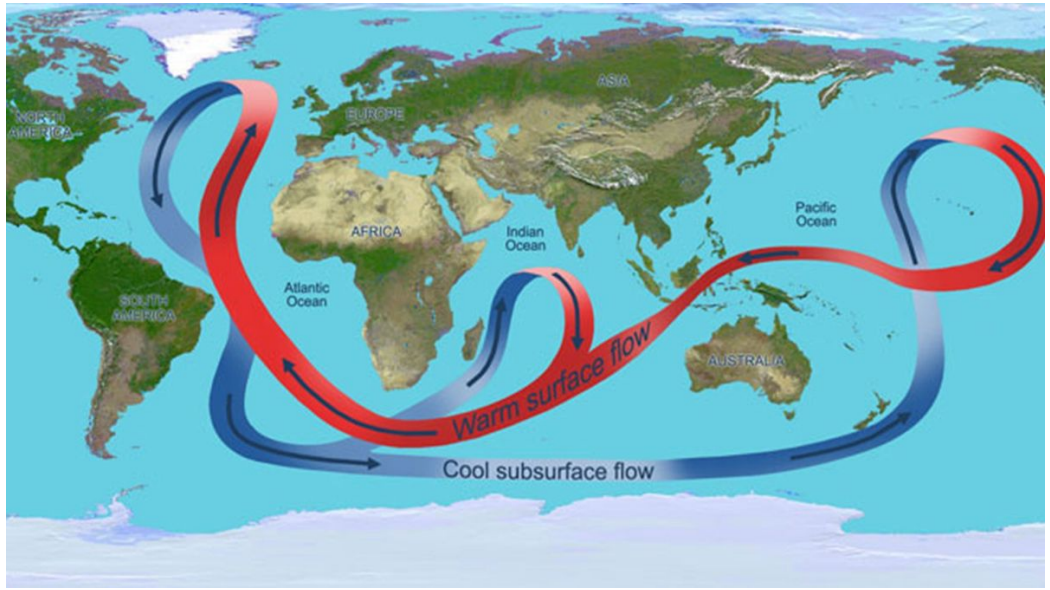
For most regions, **we don't know.**

How can we know if we don't know predict the ENSO trend with any confidence?

Our current inability to know these things has practical implications

4 reason why EVE is critical for society, going forward

1. EVE for Mitigation



What Europe's exceptionally low winds mean for the future energy grid

Published: October 21, 2021 4.17pm BST

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Through summer and early autumn 2021, Europe experienced a long period of dry conditions and low wind speeds. The beautifully bright and still weather may have been a welcome reason to hold off reaching for our winter coats, but the lack of

Author

Hannah Bloomfield
Postdoctoral Researcher in Climate Risk Analytics, University of Bristol

Reducing/cutting emissions will be ineffective after we have passed tipping points. Are these tipping points imminent?
Are we about to pass a point of climate no return?

Climate change may lead to weaker winds / more cloudy conditions in places we are building wind turbines/ solar farms? Stranded assets?

2. EVE for Adaptation

But what is a particular country adapting to?

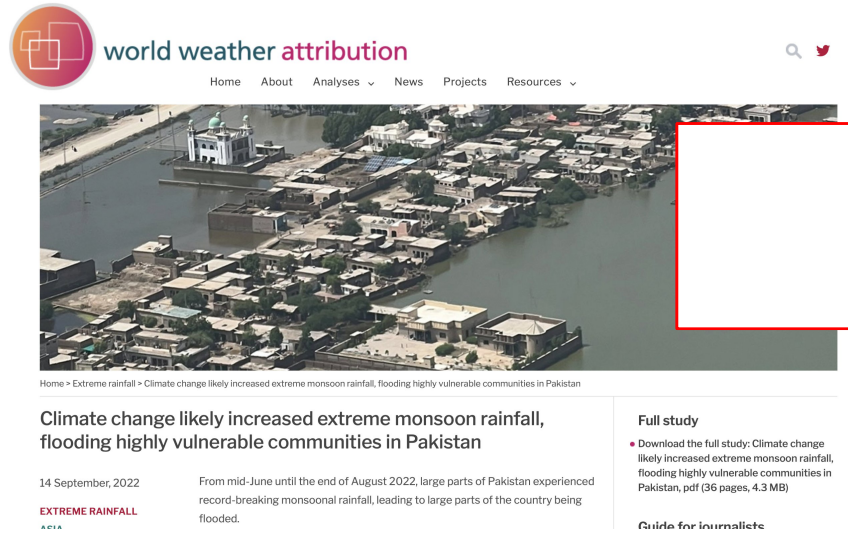
or

Can’t invest in infrastructure for adaptation unless we can answer this basic question!

3. EVE for Loss and damage

But how much of an extreme weather event was caused by our carbon emissions? We don't know.

From the WWA report


world weather attribution

Home About Analyses News Projects Resources

Home > Extreme rainfall > Climate change likely increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan

Climate change likely increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan

14 September, 2022

EXTREME RAINFALL

From mid-June until the end of August 2022, large parts of Pakistan experienced record-breaking monsoonal rainfall, leading to large parts of the country being flooded.

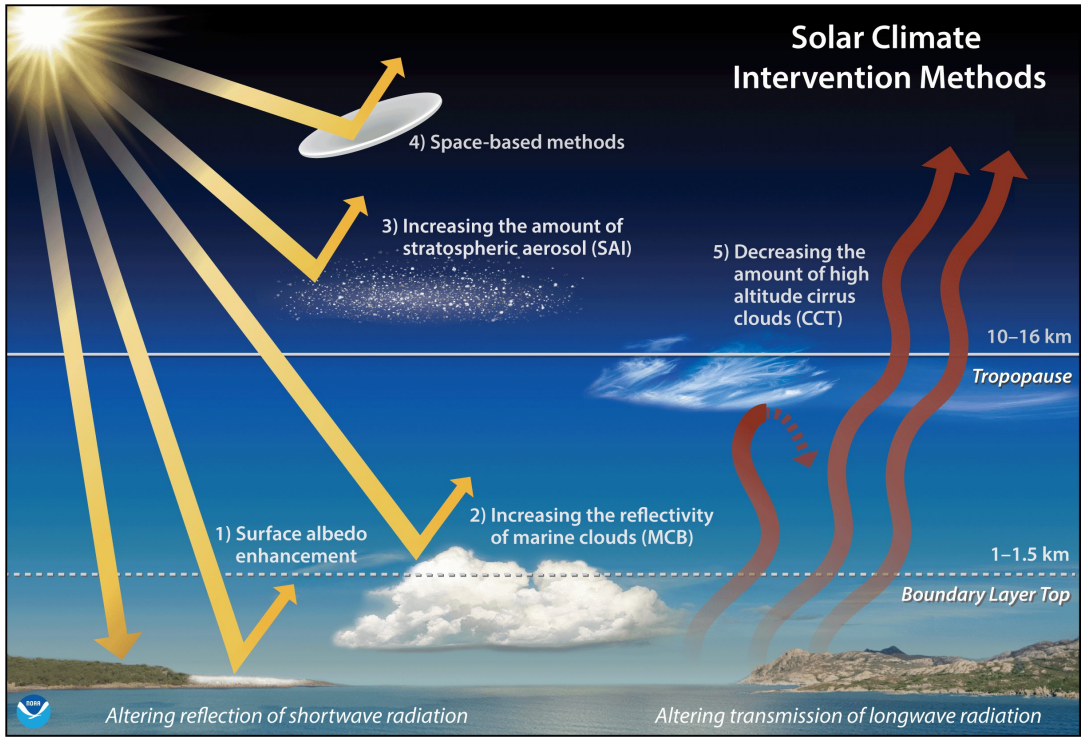
Full study

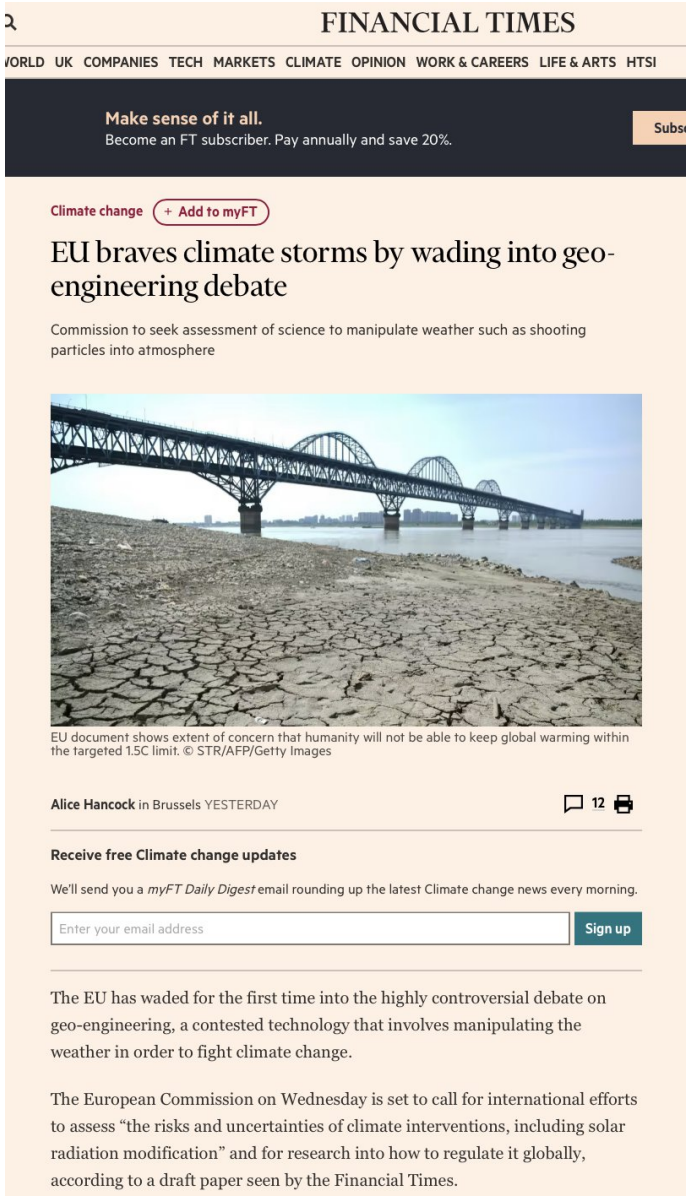
- Download the full study: Climate change likely increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan, pdf (36 pages, 4.3 MB)

Guide for journalists

As a conclusion, models are unable to provide a basis to confidently quantify the change in the monsoon season rainfall intensity with climate change up to now. Qualitative statements are however possible.

4. EVE for Geoengineering ("Plan B")





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EU braves climate storms by wading into geo-engineering debate

Commission to seek assessment of science to manipulate weather such as shooting particles into atmosphere

EU document shows extent of concern that humanity will not be able to keep global warming within the targeted 1.5C limit. © STR/AFP/Getty Images

Alice Hancock in Brussels YESTERDAY 12

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The EU has waded for the first time into the highly controversial debate on geo-engineering, a contested technology that involves manipulating the weather in order to fight climate change.

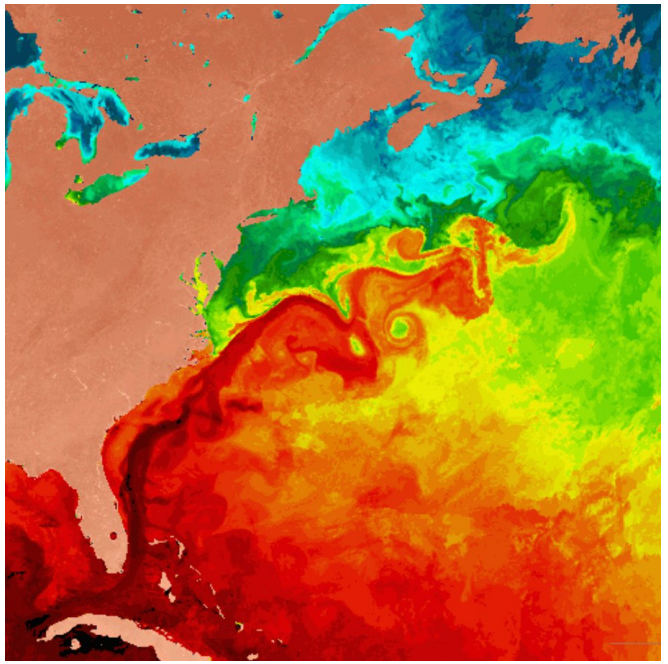
The European Commission on Wednesday is set to call for international efforts to assess "the risks and uncertainties of climate interventions, including solar radiation modification" and for research into how to regulate it globally, according to a draft paper seen by the Financial Times.

Do we really want to take the chance if we don't know whether we'll be shutting down the monsoons or reducing moisture supply to rainforests?

Deep convective clouds

Orographic drag

Ocean eddy mixing



What is needed to represent these processes using the laws of physics?

Increase model resolution (decrease gridbox sizes) to c. 1km

What's needed to increase resolution to c. 1km

- Dedicated exascale computing;
- ML to speed up earth-system modules, downscale to postcode scale, add synthetic ensemble members to EVE's k-scale skeleton ensemble, couple to impact models;
- Advanced numerical research to make computations as efficient as possible (e.g. stochastic rounding on mixed precision arithmetic);
- Above all, a focussed approach pooling international effort from scientists across the world.

What’s the natural prediction/projection timescale for EVE

- c. 30-50 years;
- complementing, not replacing CMIP.

TOWARD A NEW GENERATION OF WORLD CLIMATE RESEARCH AND COMPUTING FACILITIES

BY J. SHUKLA, T. N. PALMER, R. HAGEDORN, B. HOSKINS, J. KINTER, J. MAROTZKE, M. MILLER, AND J. SLINGO

To accelerate progress in understanding and predicting regional climate change, national climate research facilities must be enhanced and dedicated multi-national facilities should be established.

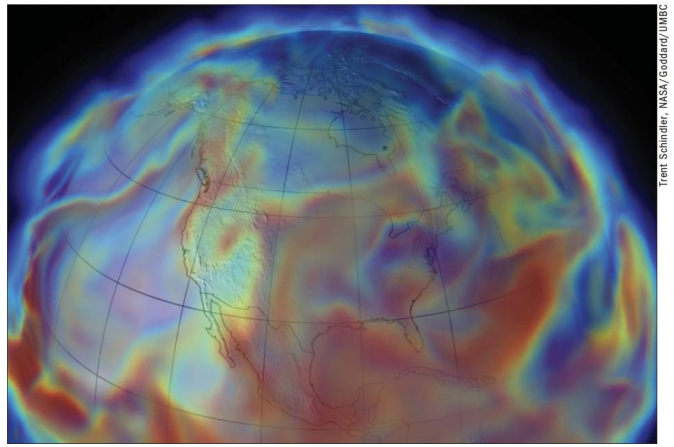
Weather and climate are undisputedly major factors for the well-being and development of society, impacting all scales from individual lives to global economies (Sachs 2008). Societies have flourished by adapting to and taking advantage of current climate conditions. However, this relationship between climate and society is fragile and volatile: during the past 25 years, weather-related disasters have caused more than 600,000 fatalities and $1.3 trillion (U.S. dollars) of economic losses. This paper is part of an ensemble of papers proposing an international multidisciplinary prediction initiative (Shapiro et. al. 2010).

Considering the increasing frequency of extreme weather and climate events (Alley et al. 2007) together with our enhanced vulnerability (WMO 2006) to weather and climate hazards caused by rapid economic and population growth, mortality and economic

Bulletin American Met Soc 2011

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



Trent Schindler, NASA/Goddard/UMBC

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

adapt to. This uncertainty arises, primarily, not because we do not know the relevant physics of the problem, but rather because to be able to resolve deep convective cloud systems, known to be crucial in transporting heat, moisture and momentum from the

Physics World 2011

Paul Nurse at al (2023):

"There are research areas of global strategic importance where new multinationally funded institutes or international research infrastructures could be contemplated, an obvious example being an institute of climate change built on the EMBL model. Such institutes are powerful tools for multinational collaboration and bring great benefit not only internationally but also for the host nation. "

EVE

Not incremental science but – in partnership with existing climate institutes around the world - *utterly transformational science!*