Climate and Sea Level Change: Are UN Trouble?

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Brown University, DEEPS
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United Nations
Intergovernmental Panel on
Climate Change Coordinating
Lead Author

Boulder School for Condensed
Matter and Materials Physics
July 18, 2022

UK Natural History Museum Wildlife Photograph of the Year, 2015, by Don Gutoski.

SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

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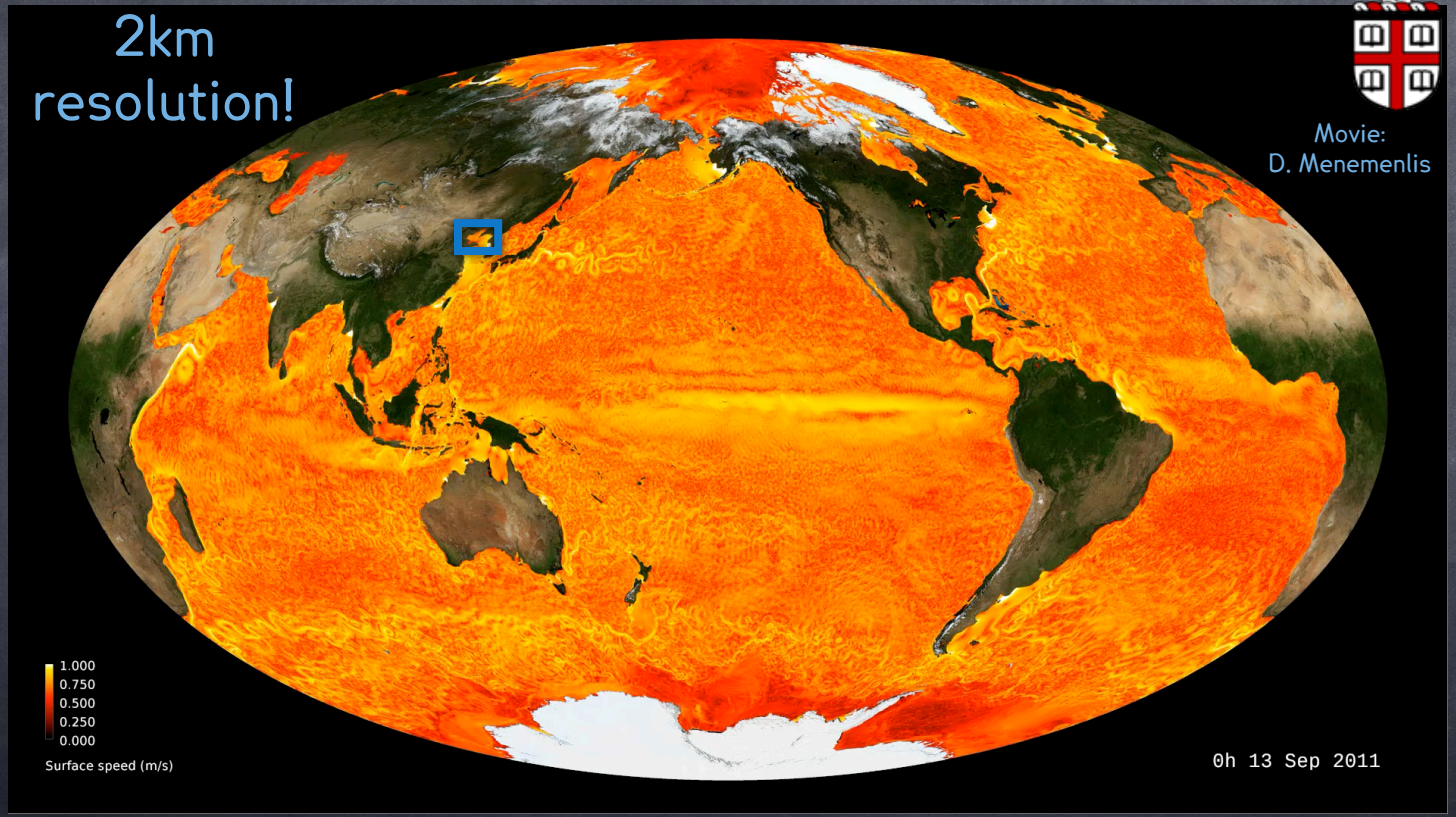
Estimating the Circulation & Climate of the Ocean LLC4320 Model



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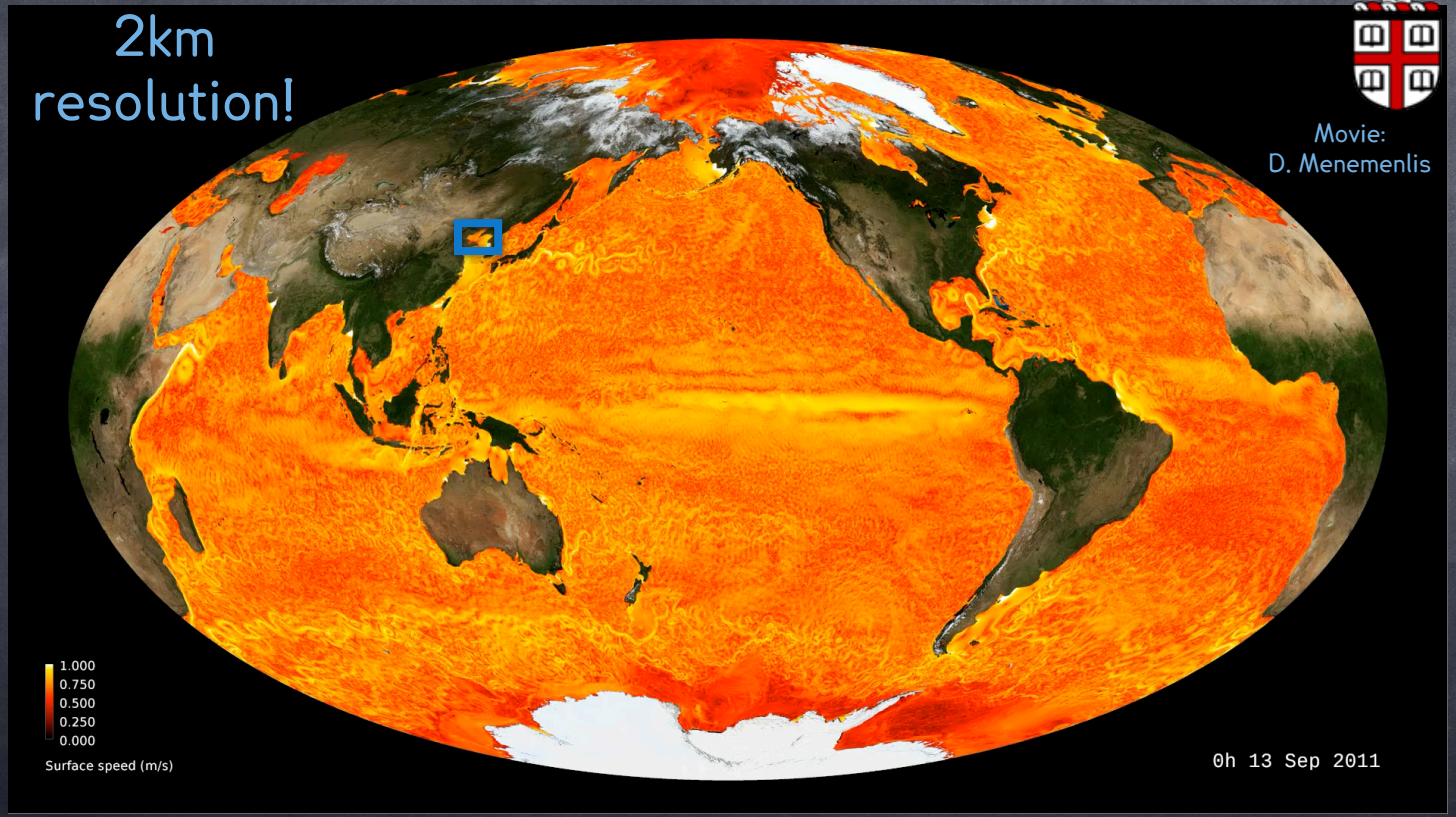

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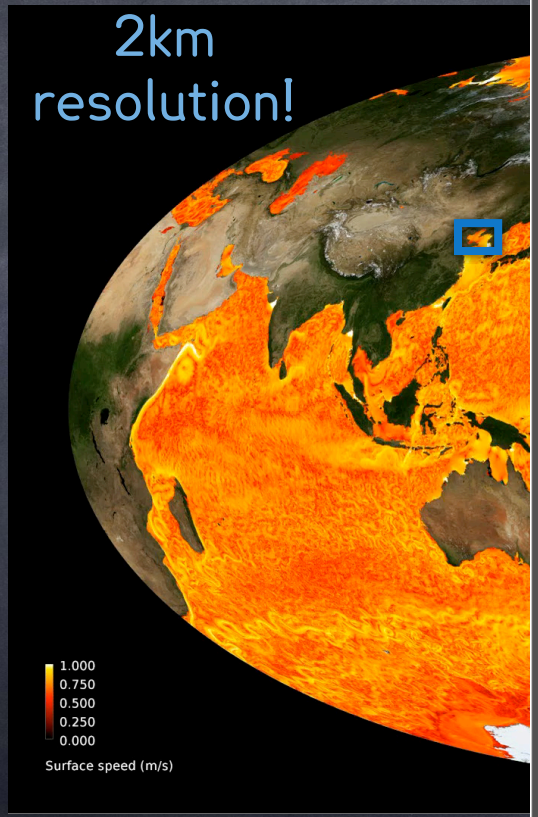

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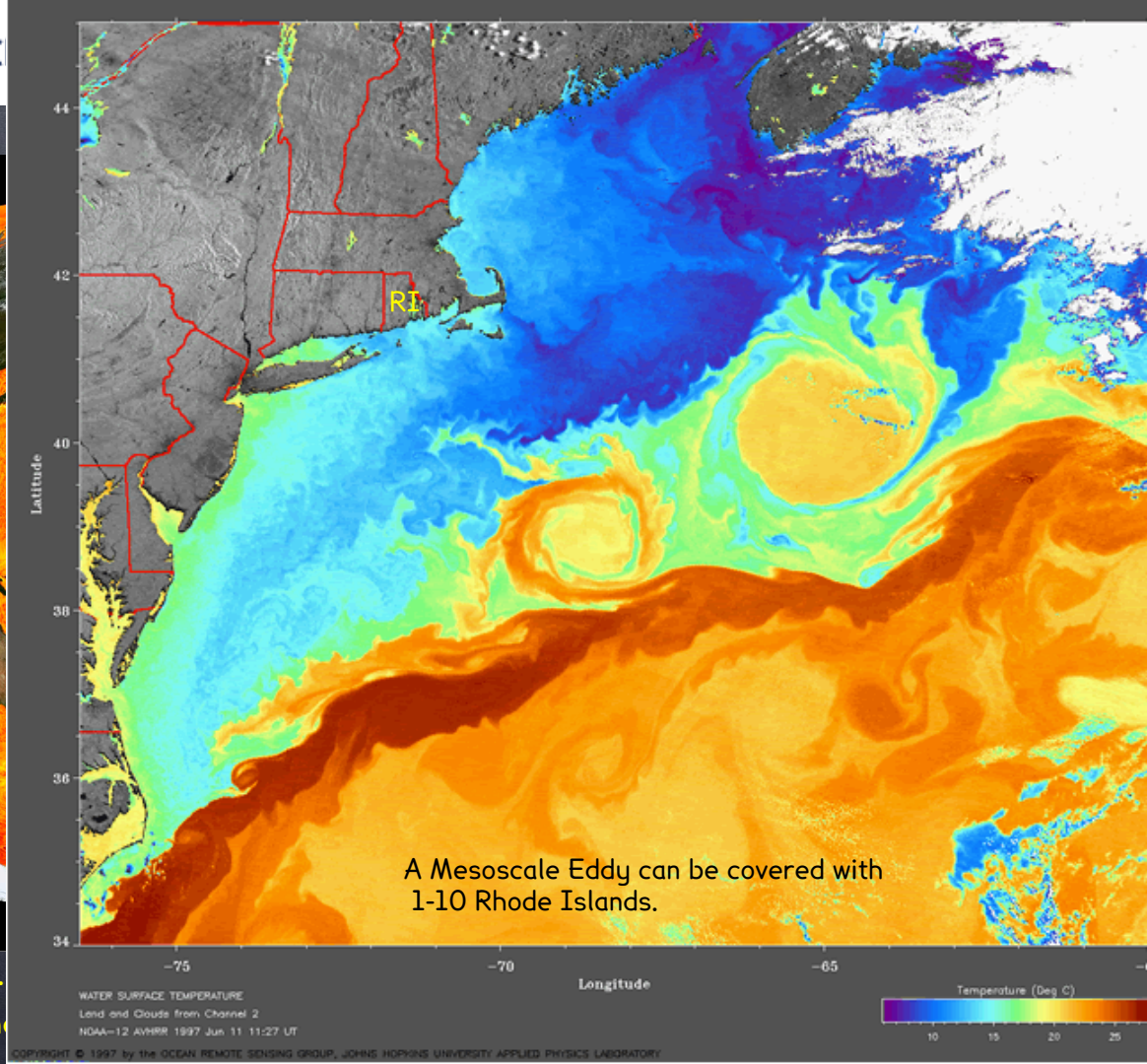
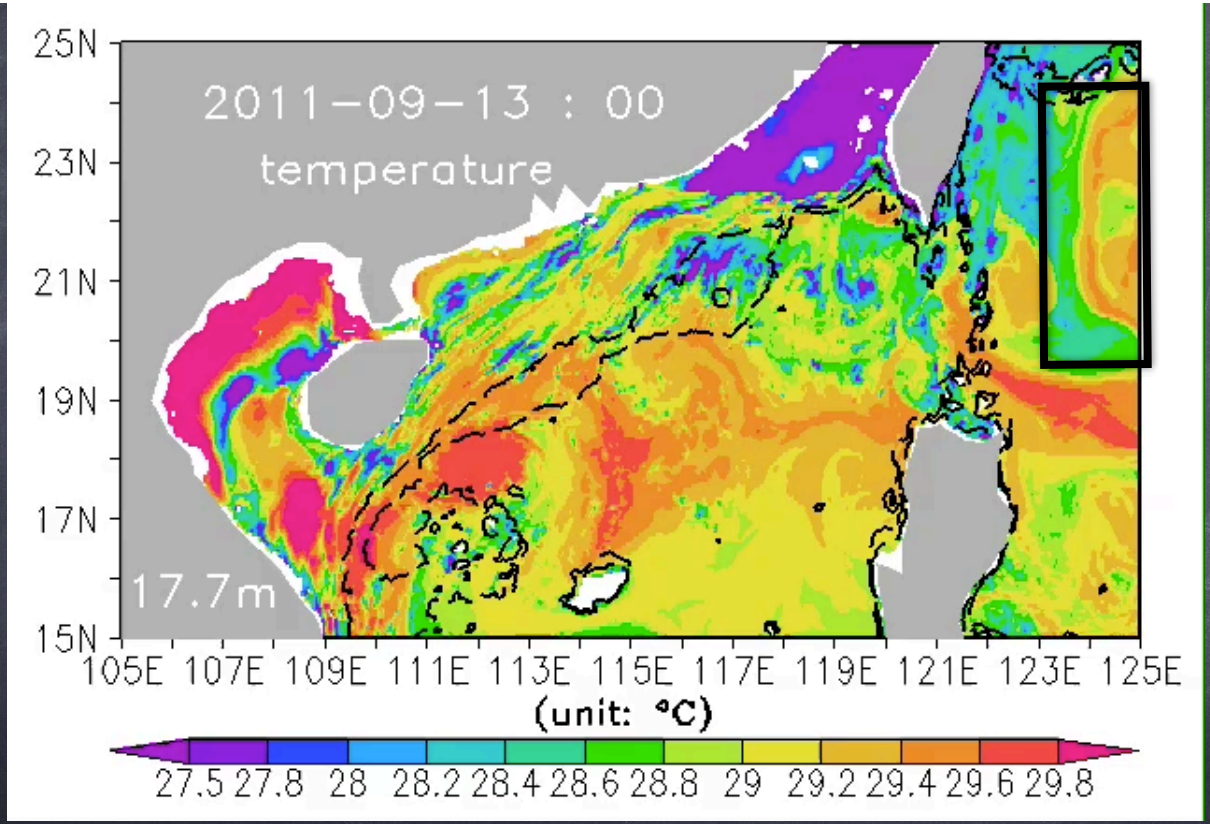


A Mesoscale Eddy can be covered with 1-10 Rhode Islands.



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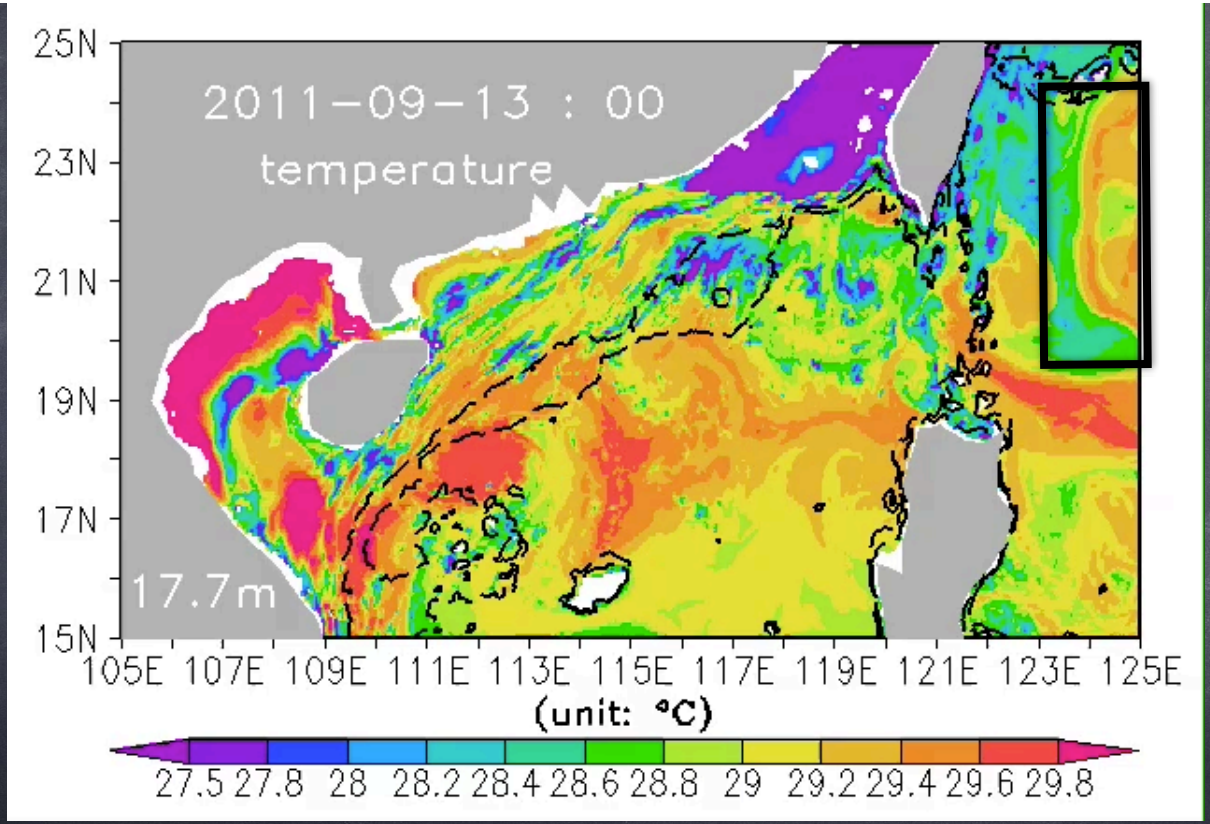

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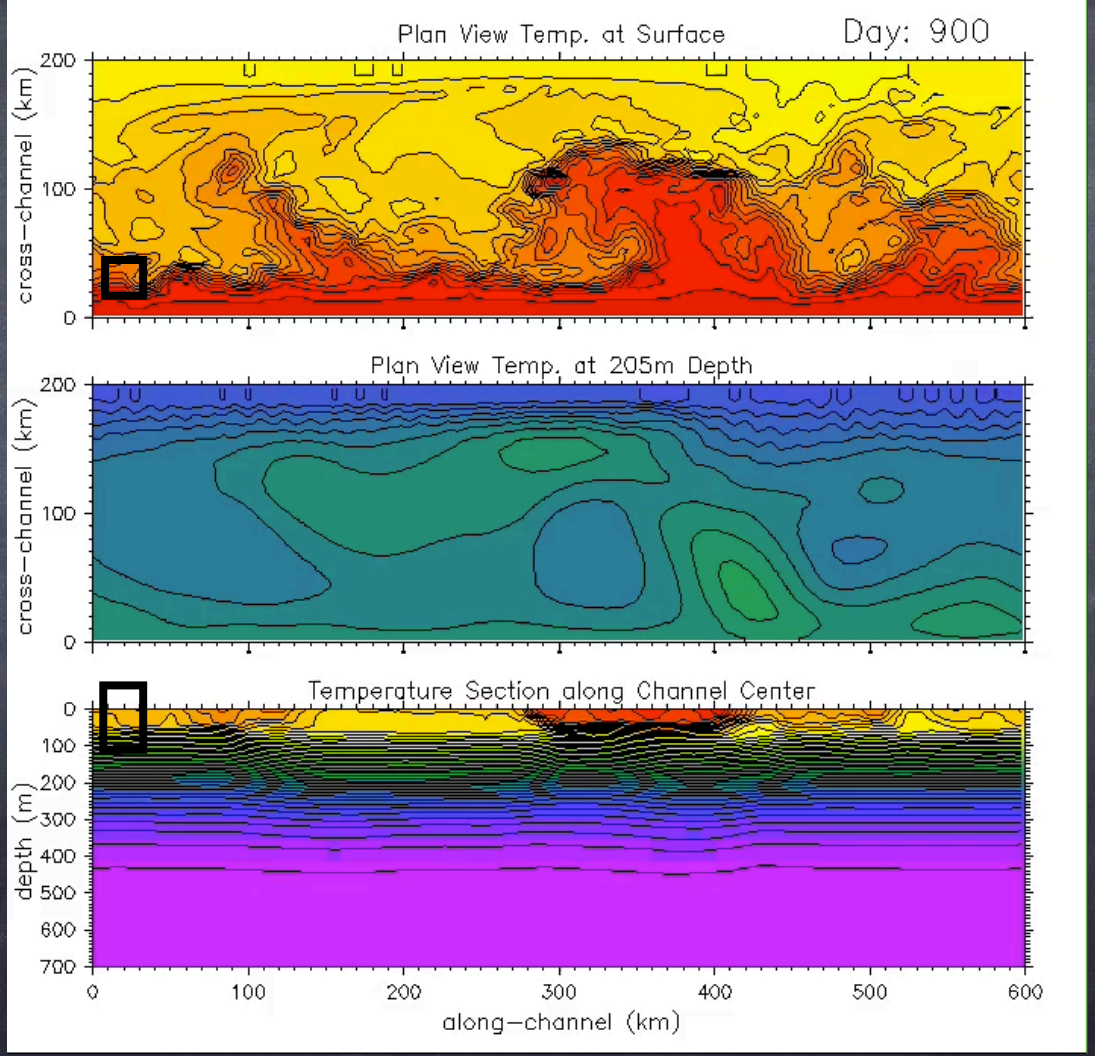
200km x 600km x 700m domain

1000 Day Simulation



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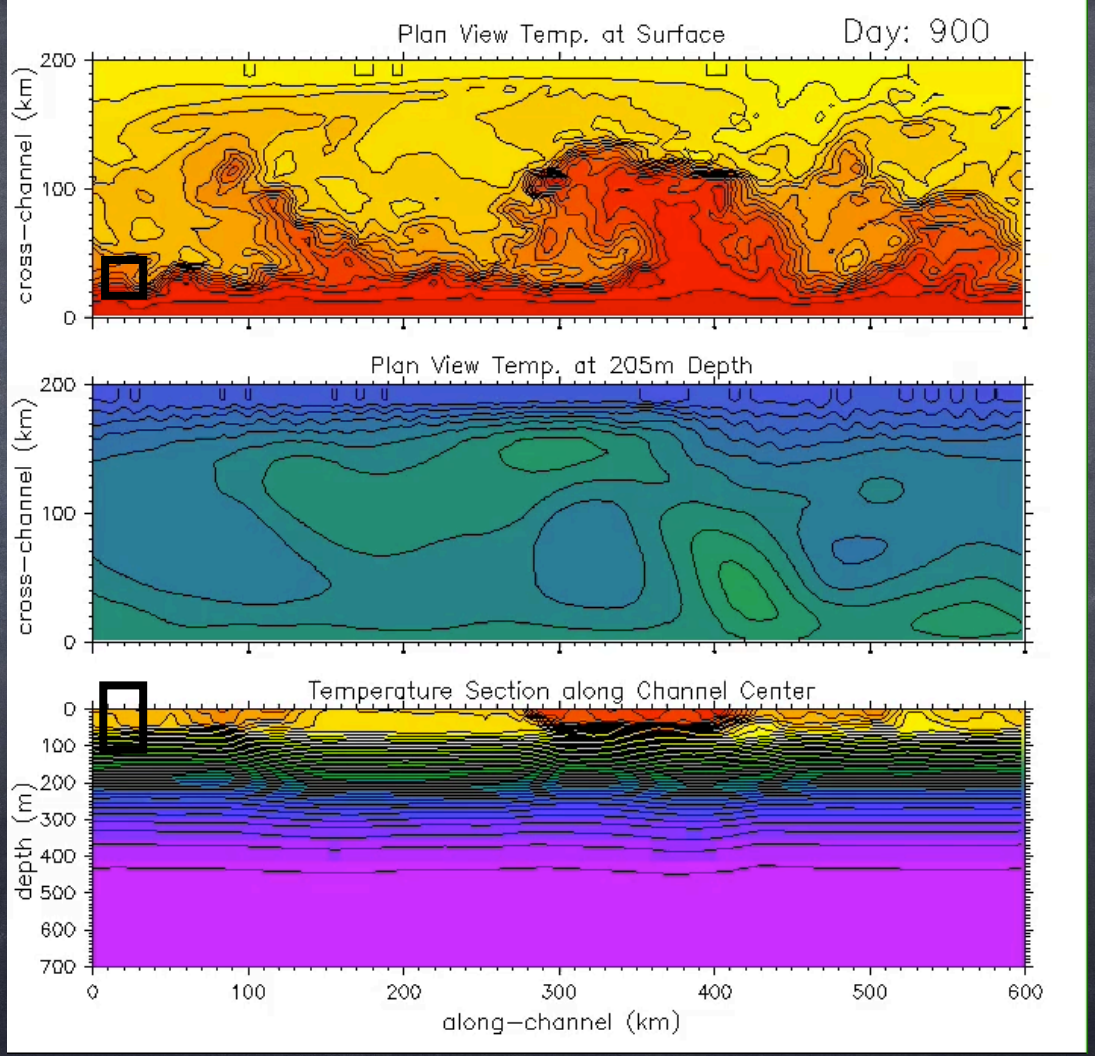

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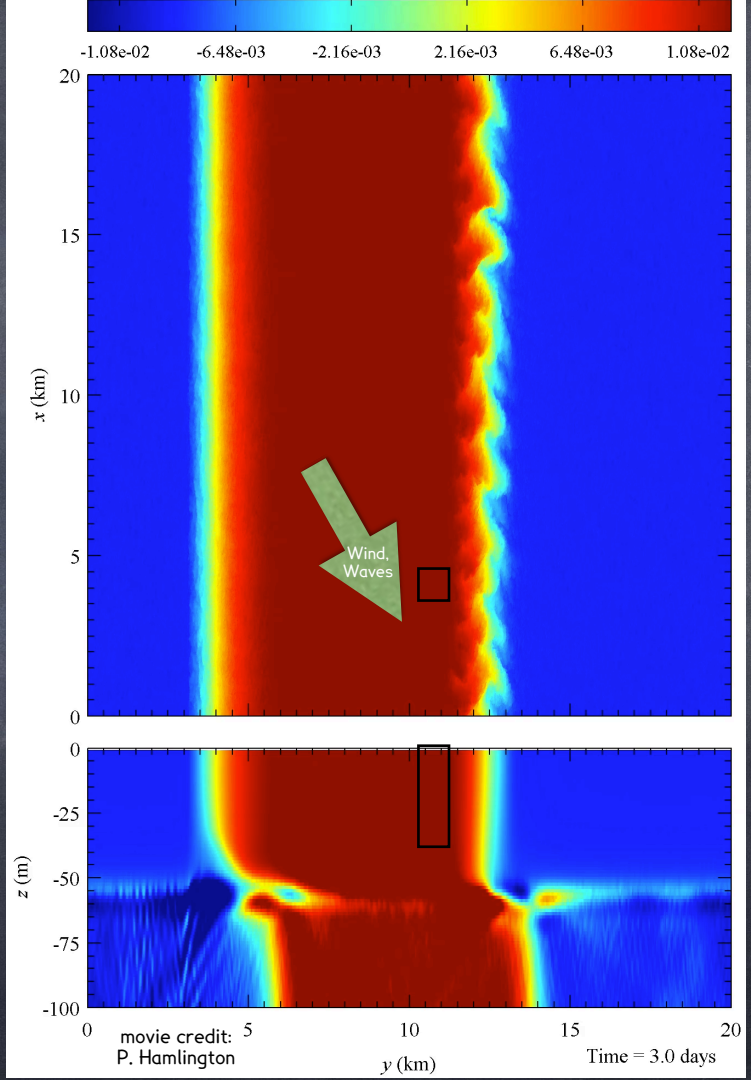
15 Day Simulation



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Colorado
University of Colorado at Boulder

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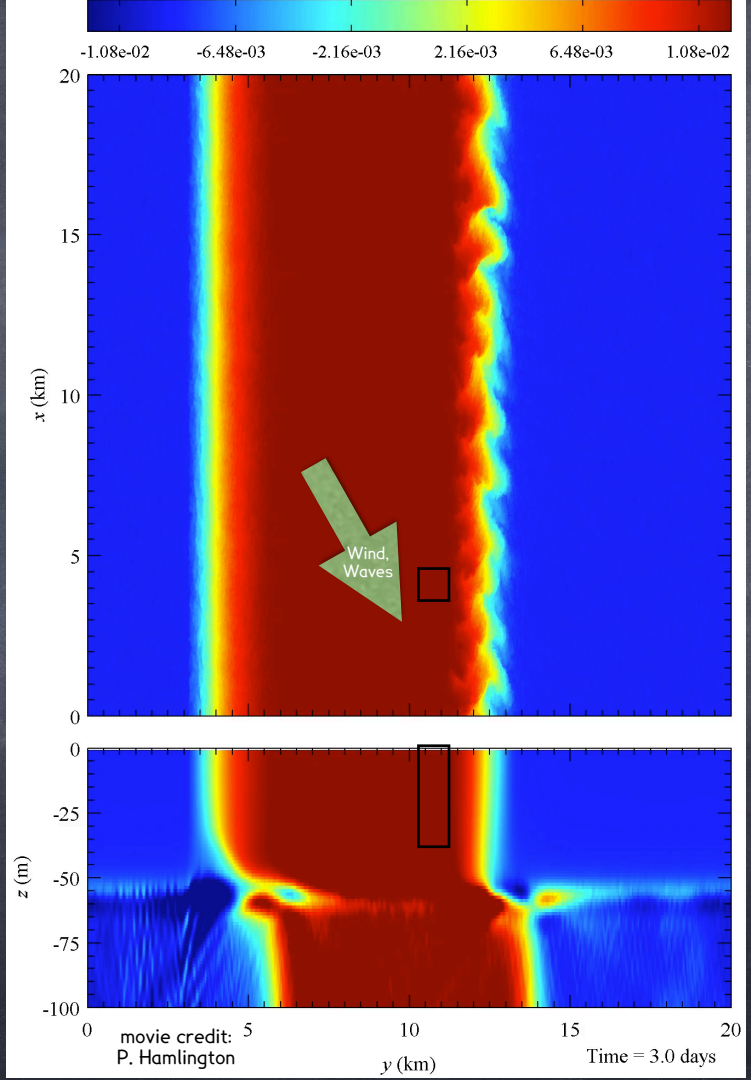

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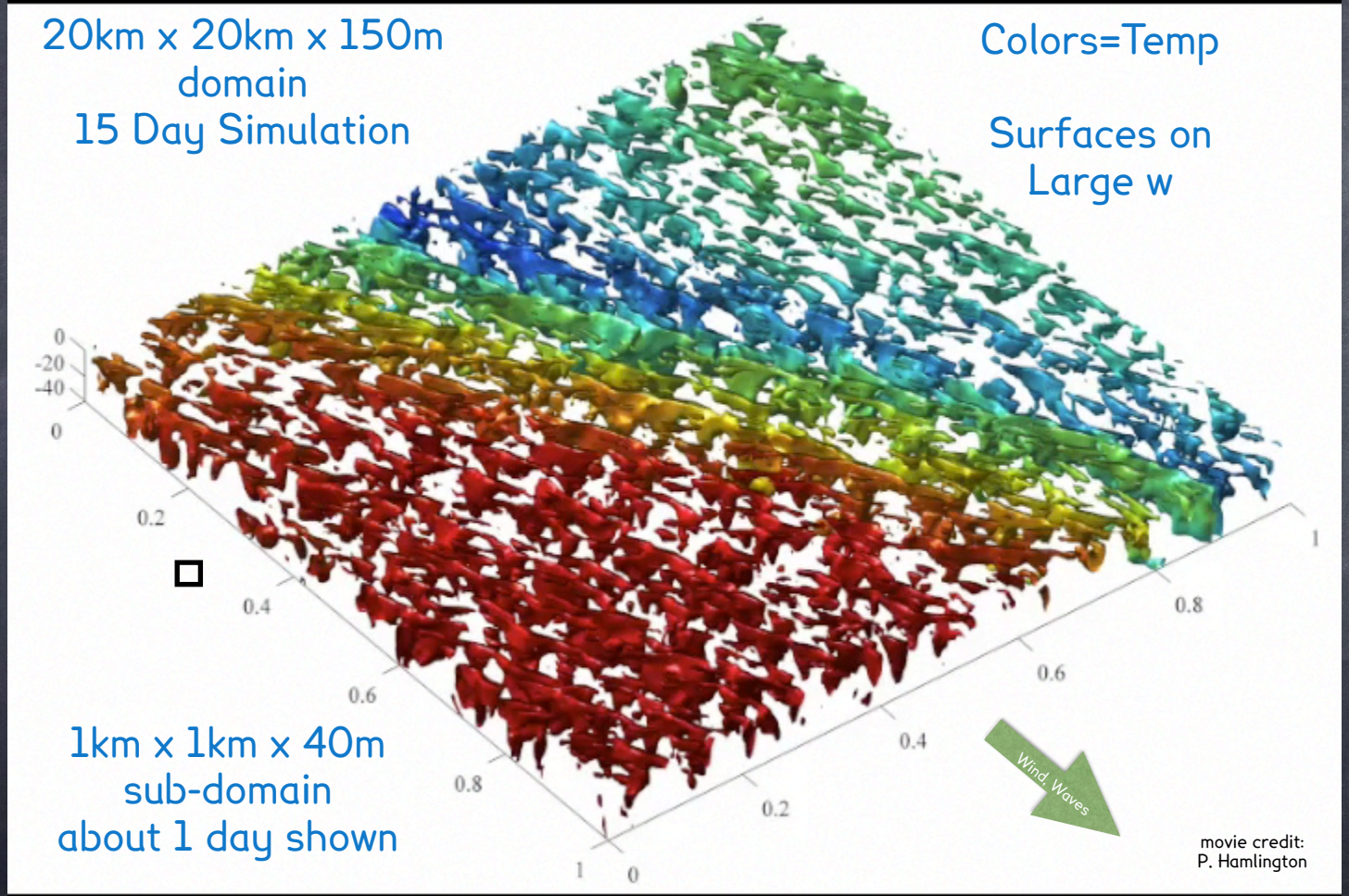

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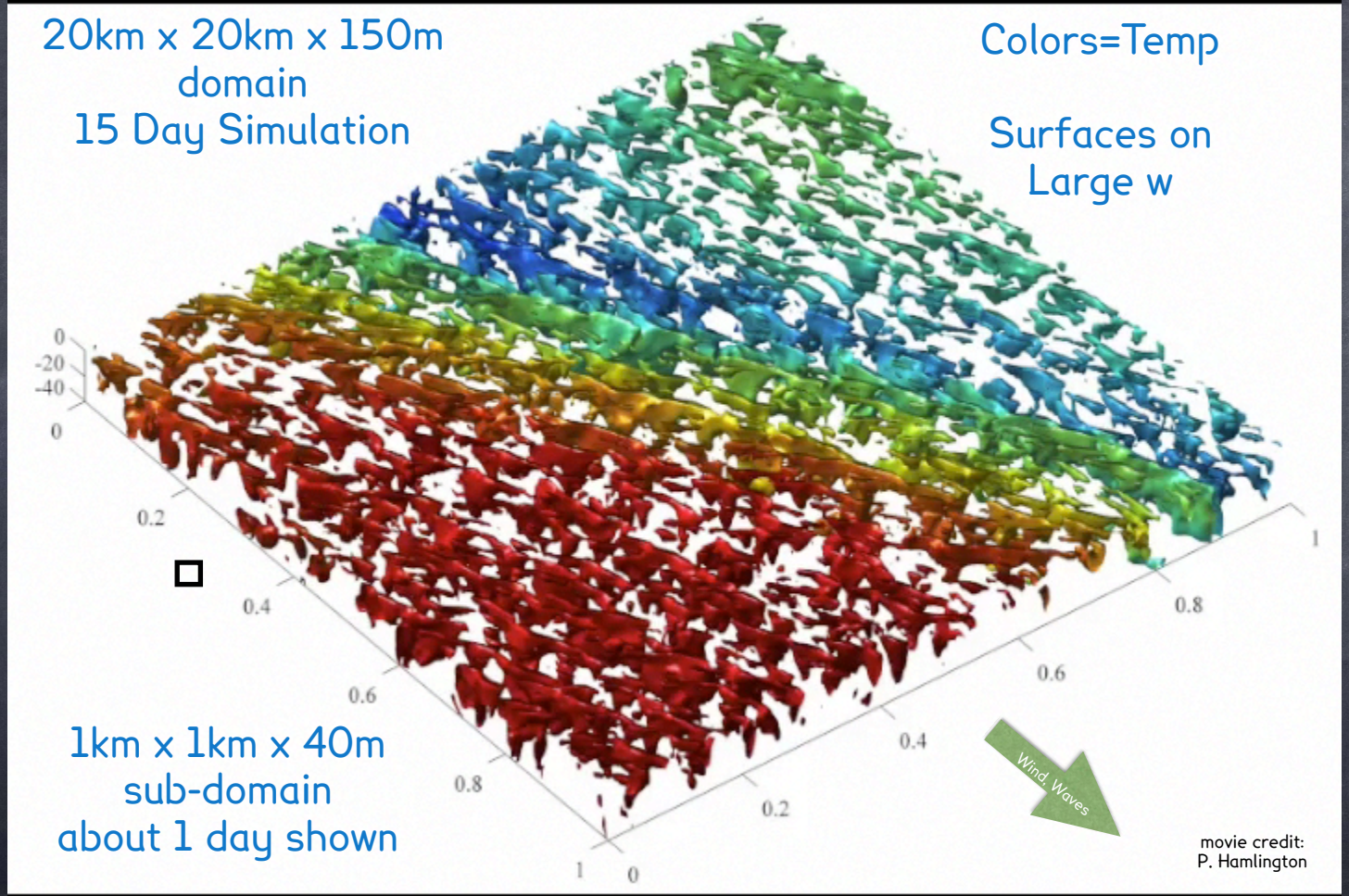

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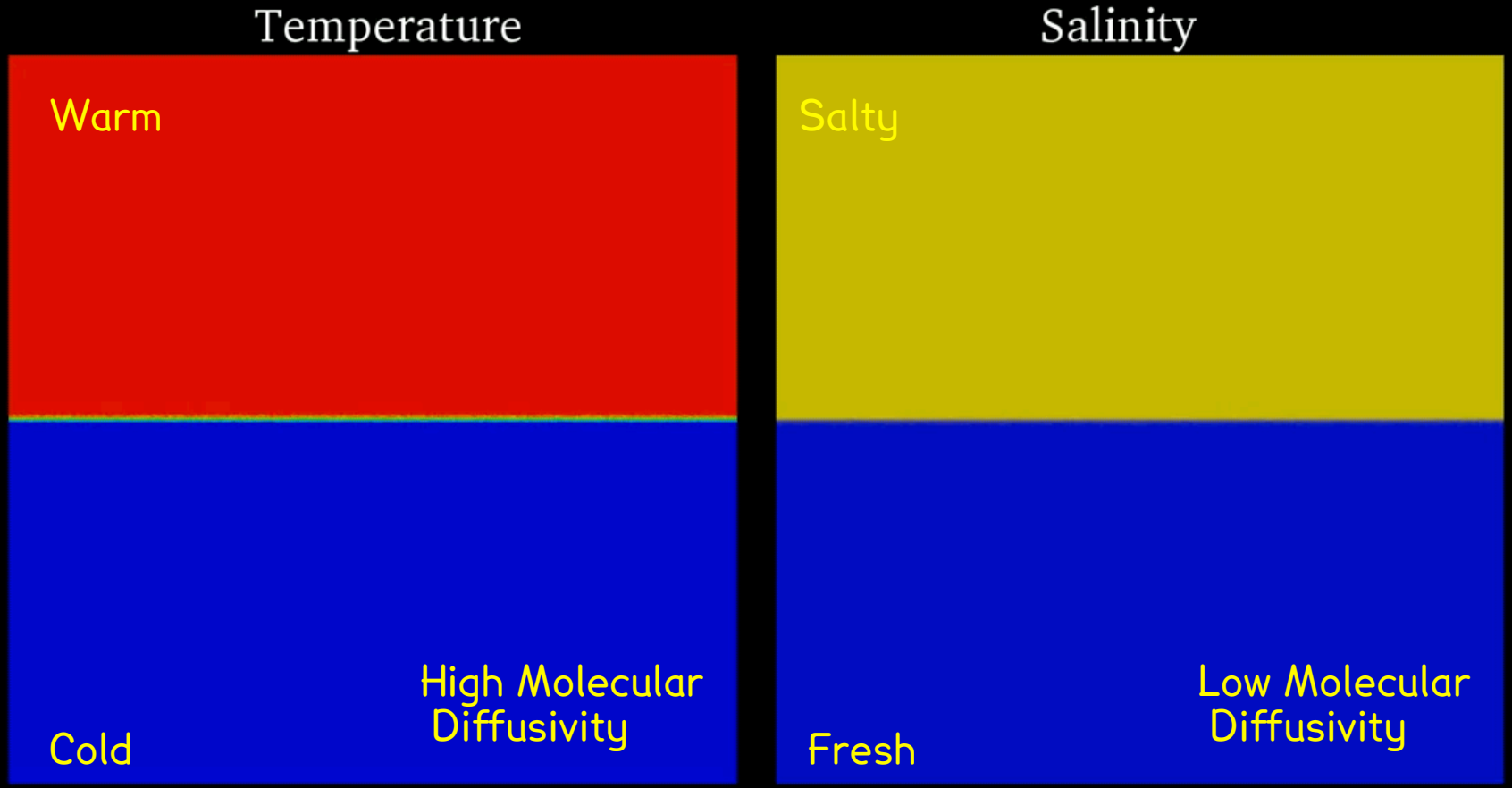
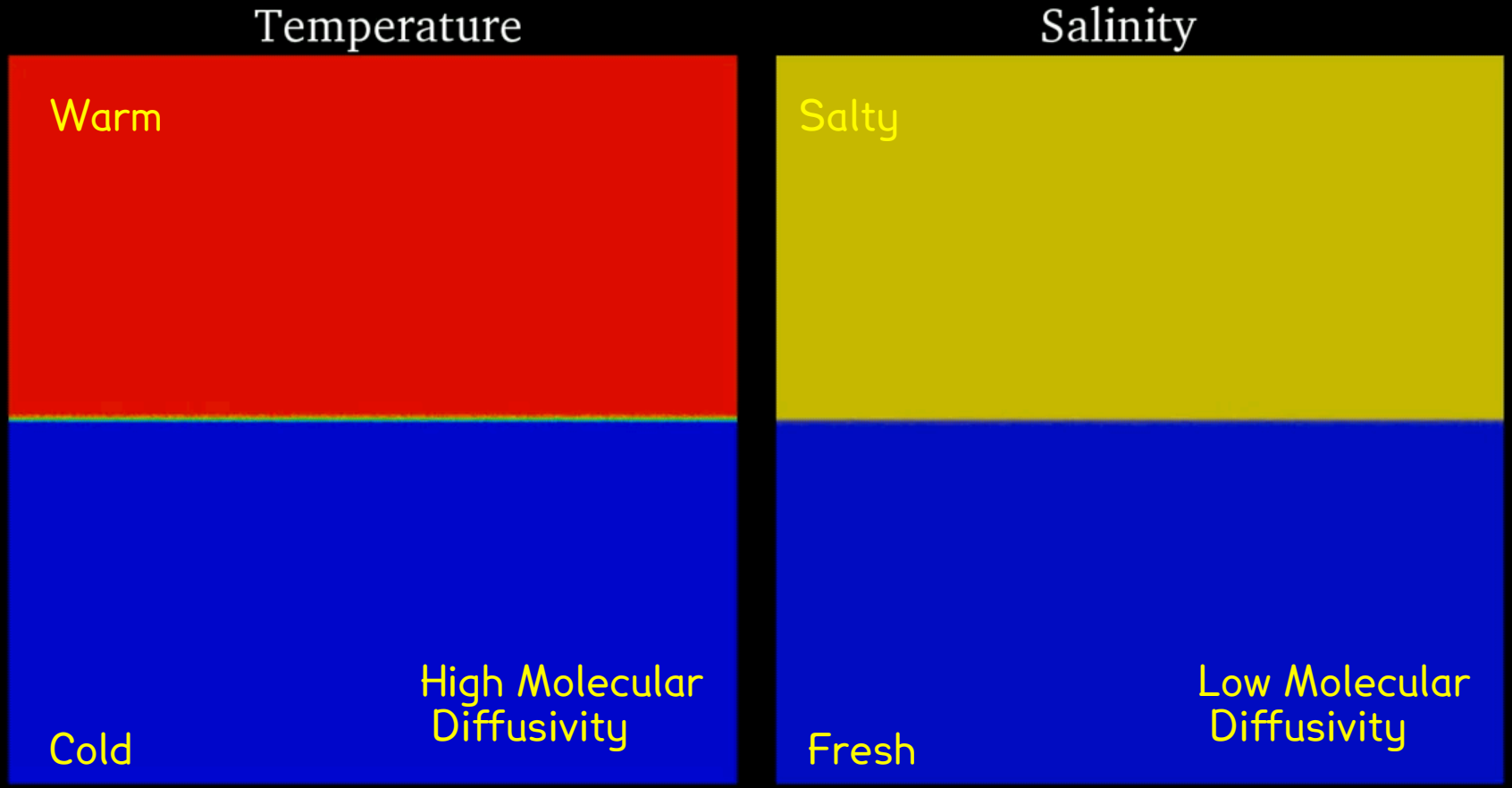


Top: Warm, salt water
Bottom: Cold, fresh water

Movie Credit: mmnasr on YouTube.



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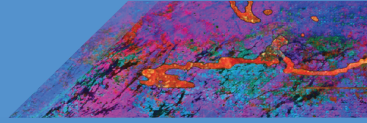

THE UN IPCC WGI AR6, Physical Sciences Basis: BY THE NUMBERS

Author Team

234 authors from **65** countries

28% women, **72%** men

30% new to the **IPCC**

Movie

Review Process

14,000 scientific publications assessed

78,000+ review comments

46 countries commented on Final Government Distribution

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CHAPTER 9:
OCEAN, CRYOSPHERE & SEA LEVEL CHANGE


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(CLA)


Helene HEWITT
UK
Met Office Hadley Centre
(CLA)


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Beijing Normal University
(CLA)


Unnikrishnan ALAKKAT
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CHAPTER 9
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Guðfinna
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Tamsin EDWARDS
UK
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Sophie NOWICKI
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Indonesian Institute of Sciences


Lucas RUIZ
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France
CNRS/Sorbonne Université


Aimée SLANGEN
Netherlands
NIOZ Royal Netherlands Institute for Sea Research

Plus 5 Chapter Scientists, Plus 73 Contributing Authors

97 Total Scientists in Chapter 9

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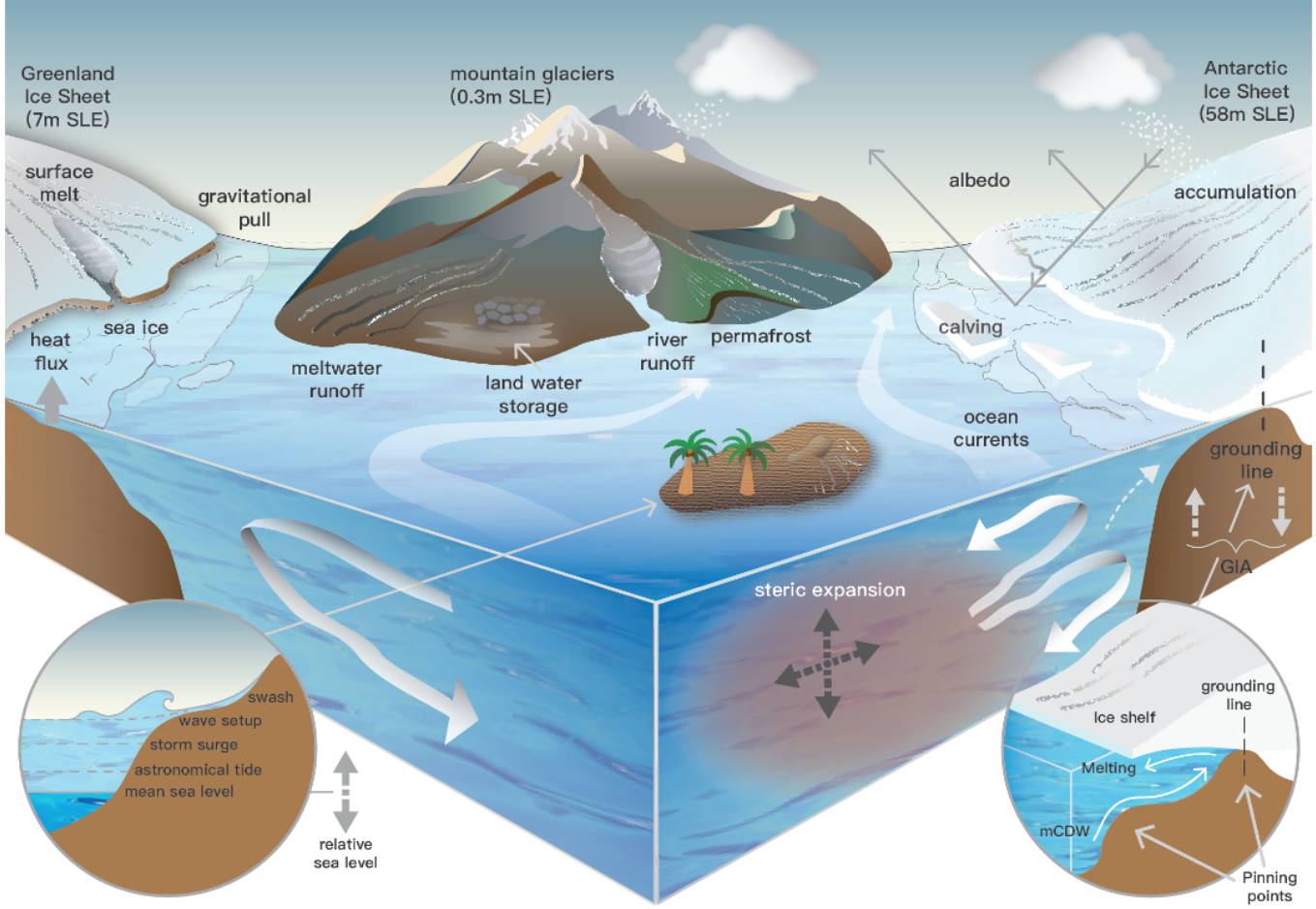


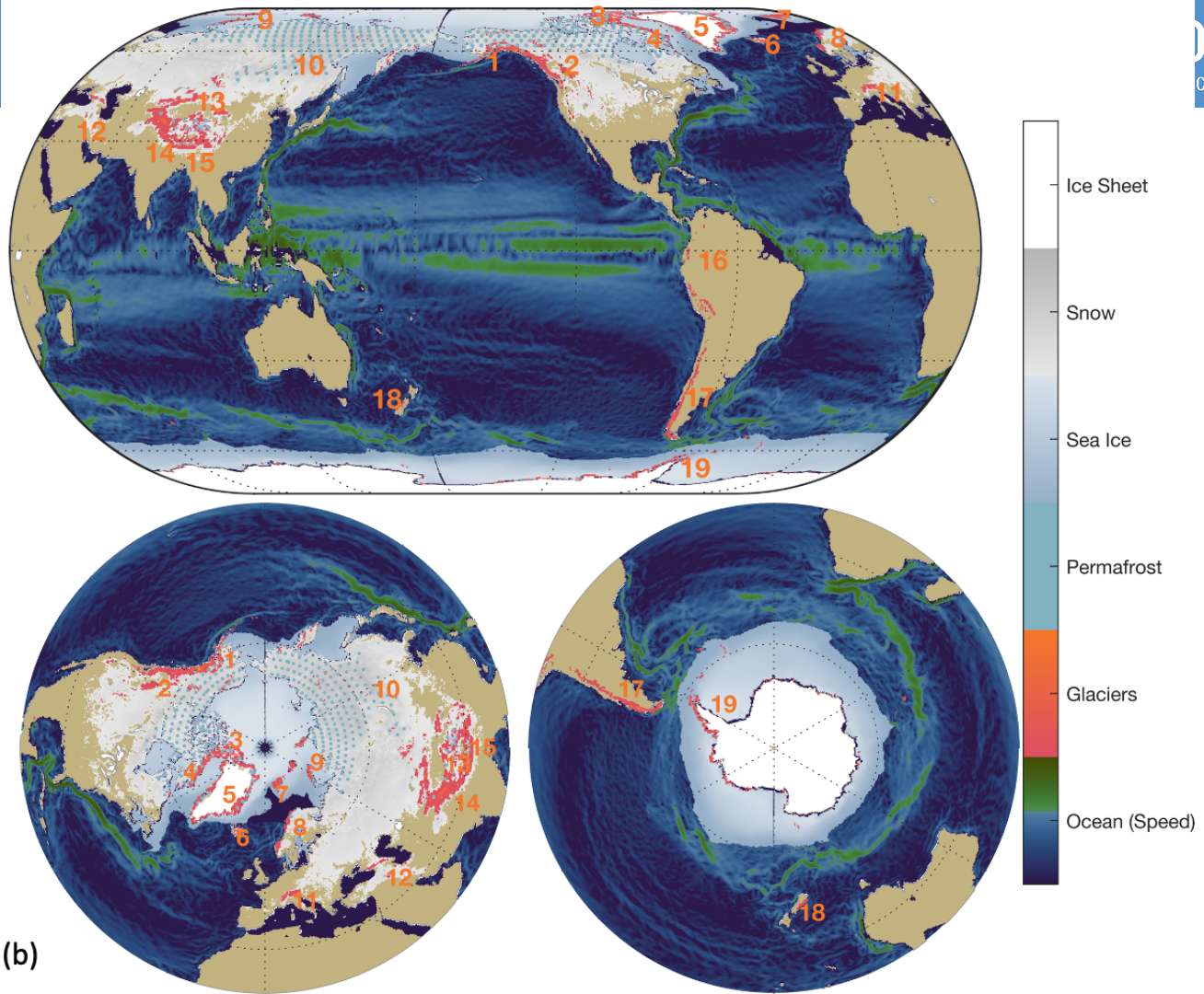
(a)

Components of ocean, cryosphere and sea level assessed in this chapter. (a) Schematic of processes (mCDW=modified Circumpolar Deep Water, GIA=Glacial Isostatic Adjustment). White arrows indicate ocean circulation. Pinning points indicate where the grounding line is most stable and ice sheet retreat will slow.

IPCC climate change

our chapter emphasizes

PROCESSES



Whose domains span the GLOBE

Components of ocean, cryosphere and sea level assessed in Chapter 9.

The former site of Okjökull, now known as simply Ok.

Rice University

A letter to the future

Ok is the first Icelandic glacier to lose its status as a glacier. In the next 200 years all our glaciers are expected to follow the same path. This monument is to acknowledge that we know what is happening and what needs to be done. Only you will know if we did it.

August 2019

415 ppm CO_2

-Andri Snær Magnason

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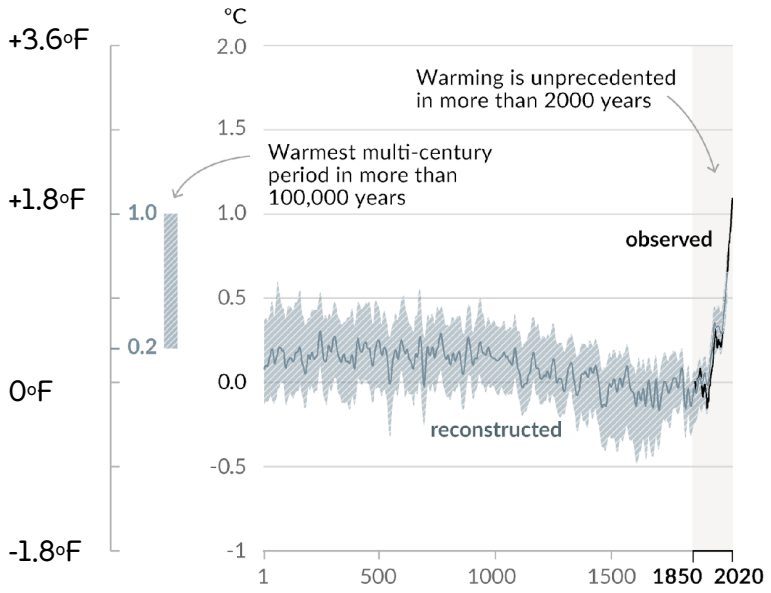
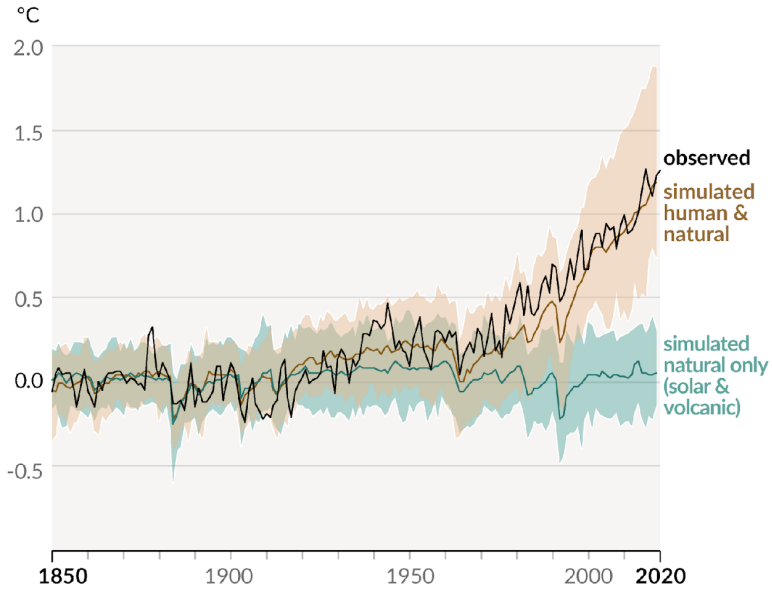
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850-1900

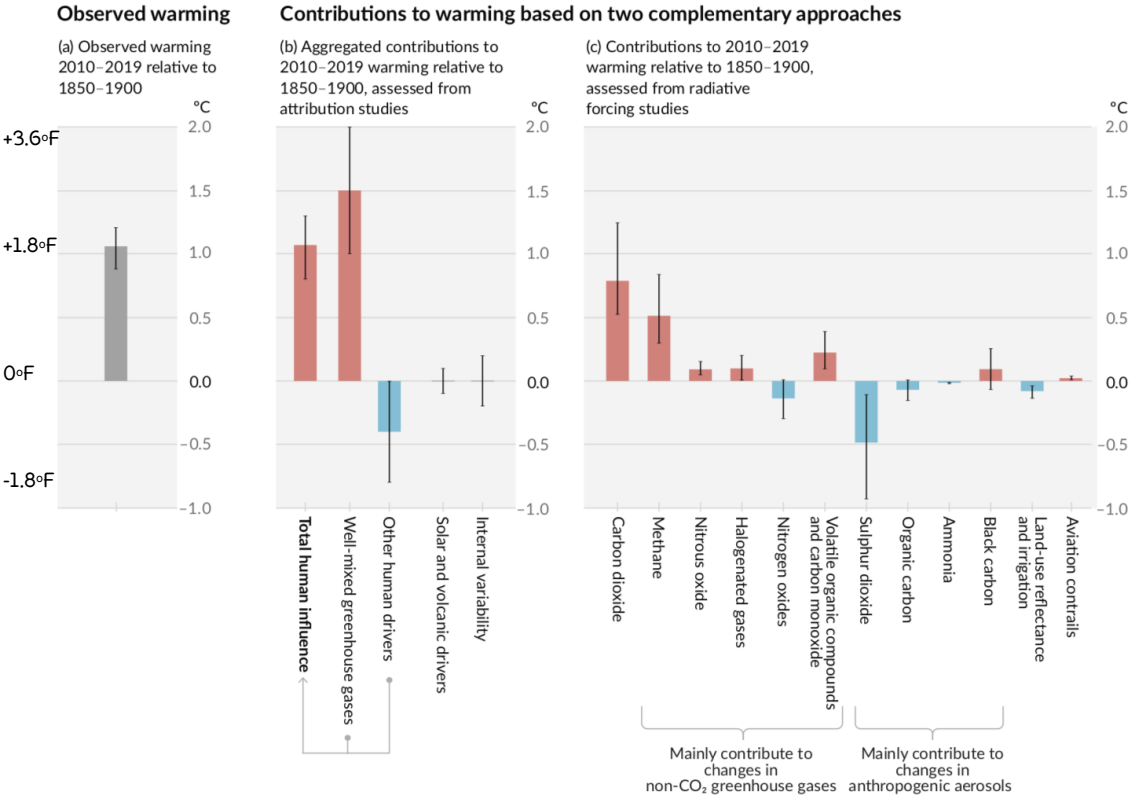
a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and **observed** (1850-2020)



b) Change in global surface temperature (annual average) as **observed** and simulated using human & natural and only natural factors (both 1850-2020)



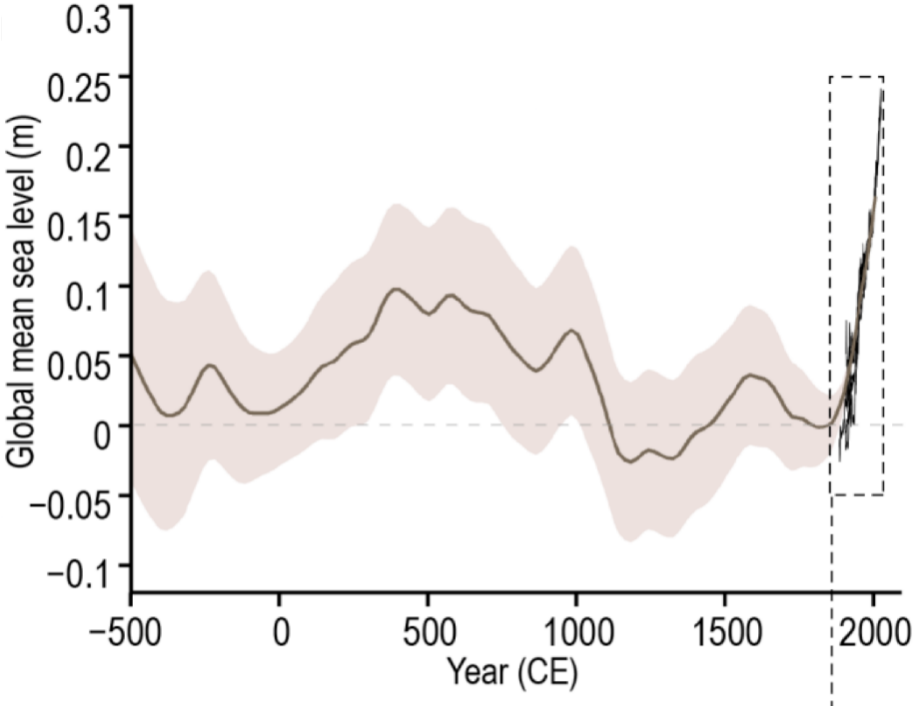
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling



Human influence is no longer assessed with a confidence level:

That means it is taken as a FACT according to IPCC procedure.

Global mean sea level rose faster since 1900 than over any prior century in at least the last 3000 years (high confidence)



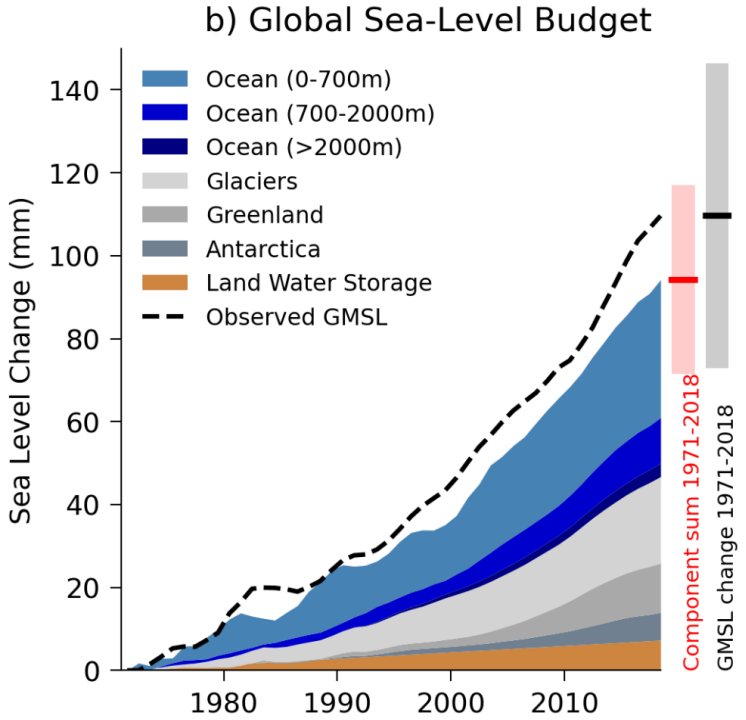
Global mean sea level increased by
20 [15 to 25] centimeters between 1901-2018, or
7.8 [5.9 to 9.8] inches between 1901-2018.

The rate of global mean sea level rise is increasing
The average rate of sea level rise was (high confidence):
1.3 [0.6 to 2.1] mm per year between 1901-1971
1.9 [0.8 to 2.9] mm per year between 1971-2006,
3.7 [3.2 to 4.2] mm per year between 2006-2018

Human influence was very likely the main driver of these increases since at least 1971.

High confidence = multiple measurements in agreement
Very likely > 90% chance of being true

Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming (high confidence)



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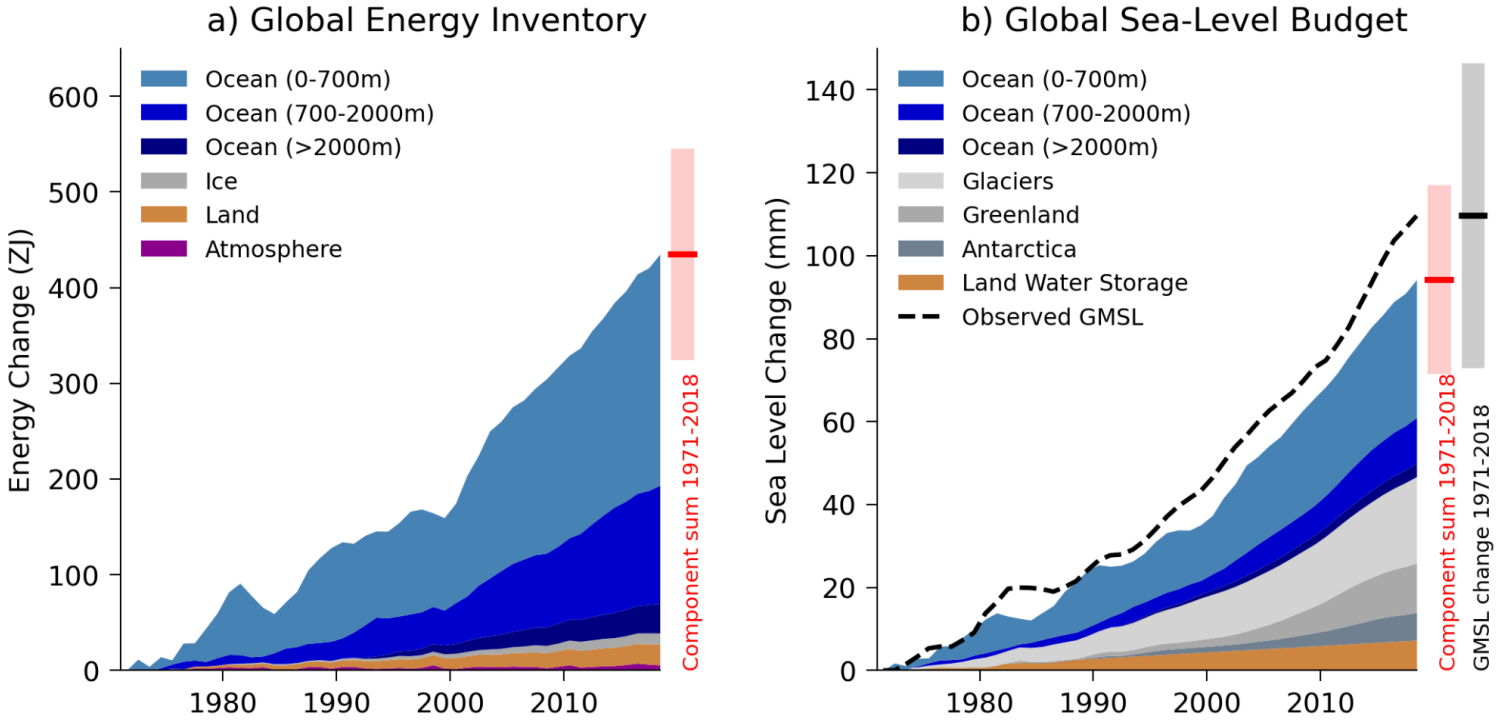

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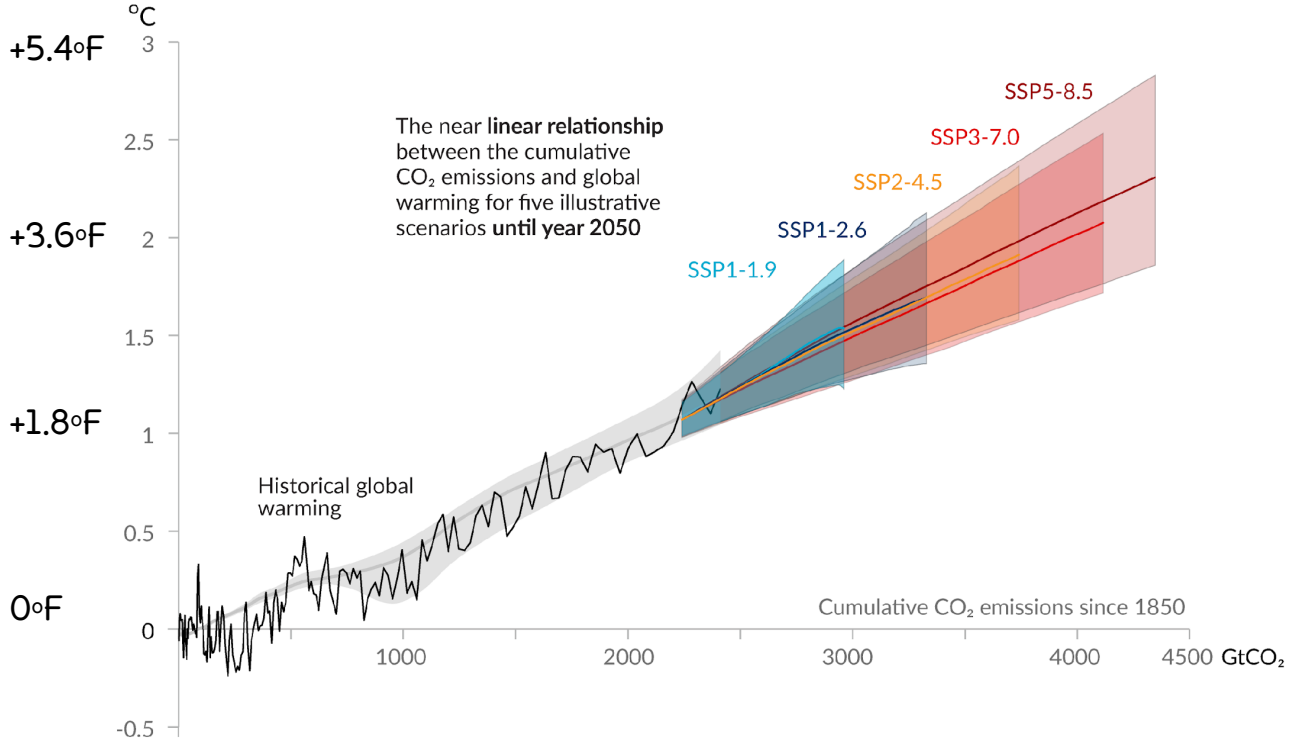
Every tonne of CO_2 emissions adds to global warming

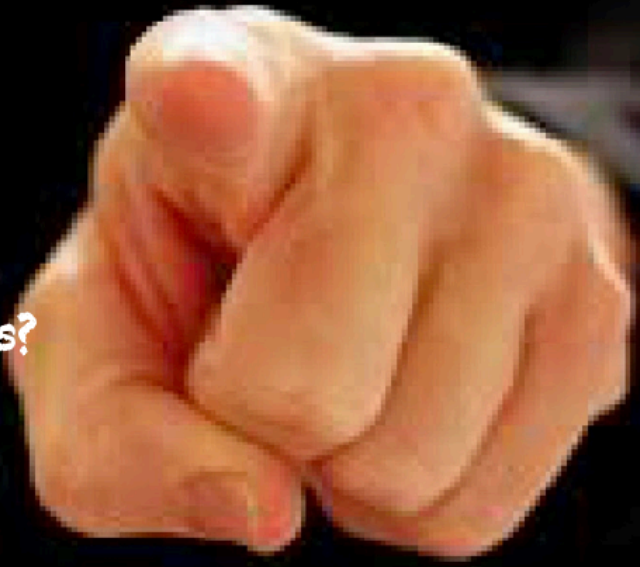
Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Shared Socioeconomic Pathways (SSPs) illustrate potential future emissions.

WHO IS...

- Individuals?
- Nations?
- Coal?
- Corporations?
- Me?
- You?



..TO BLAME ?

John Shores

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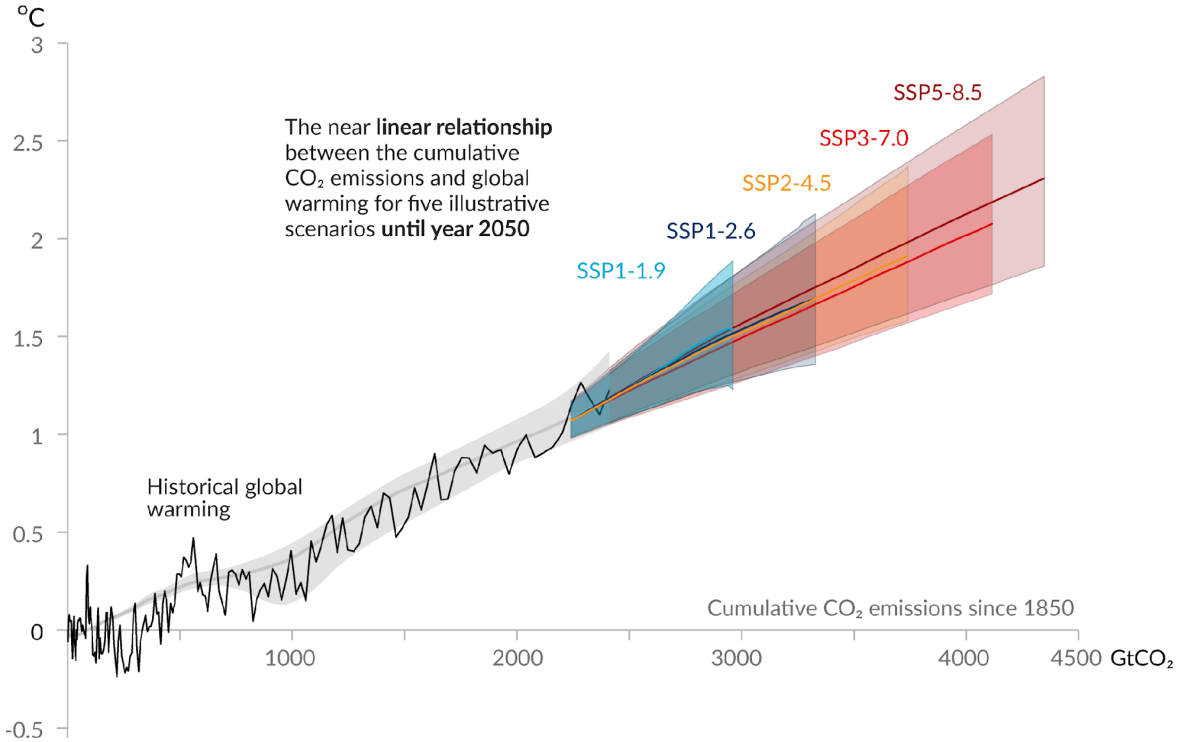

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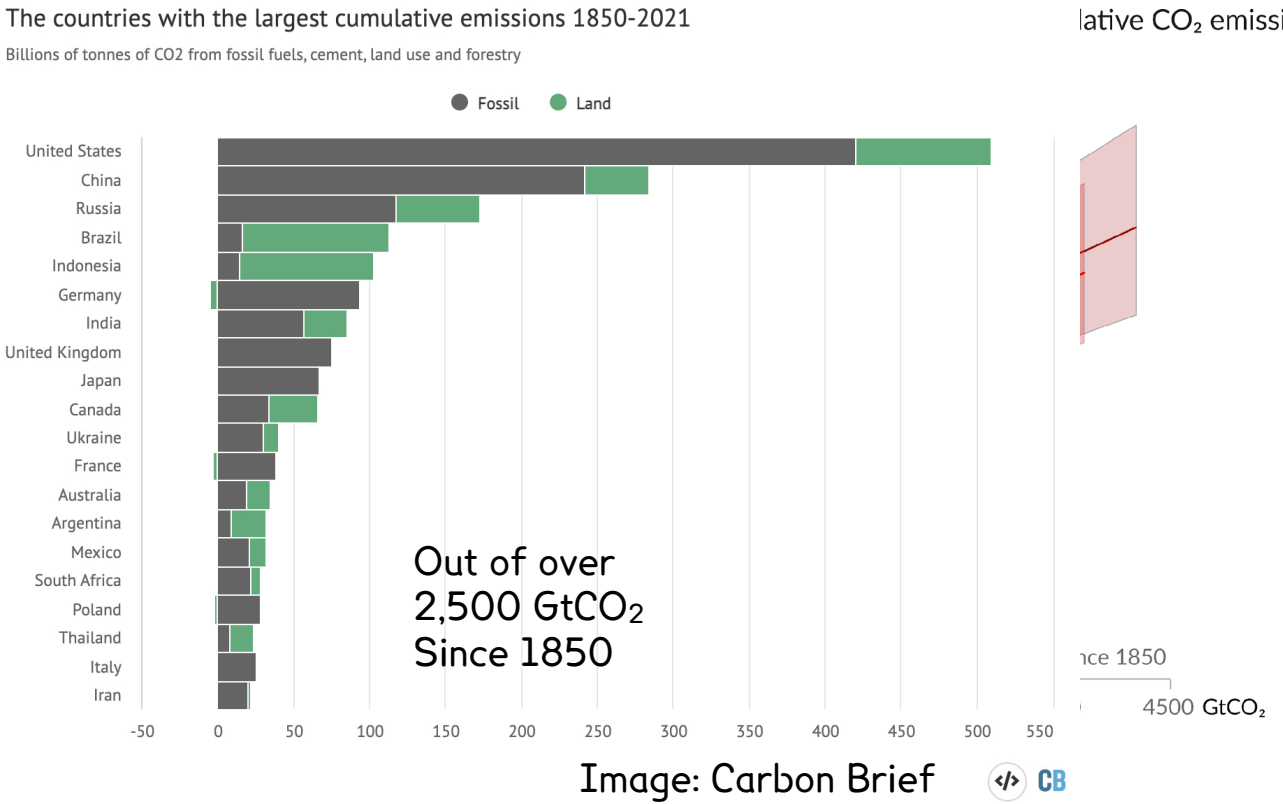

Image: Carbon Brief

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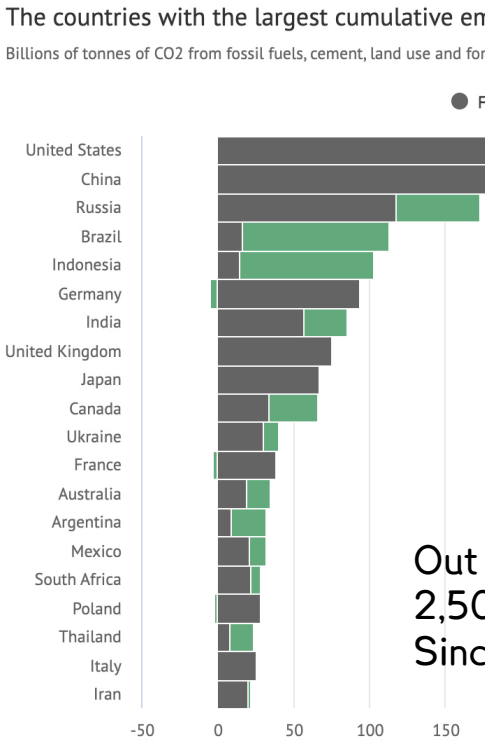

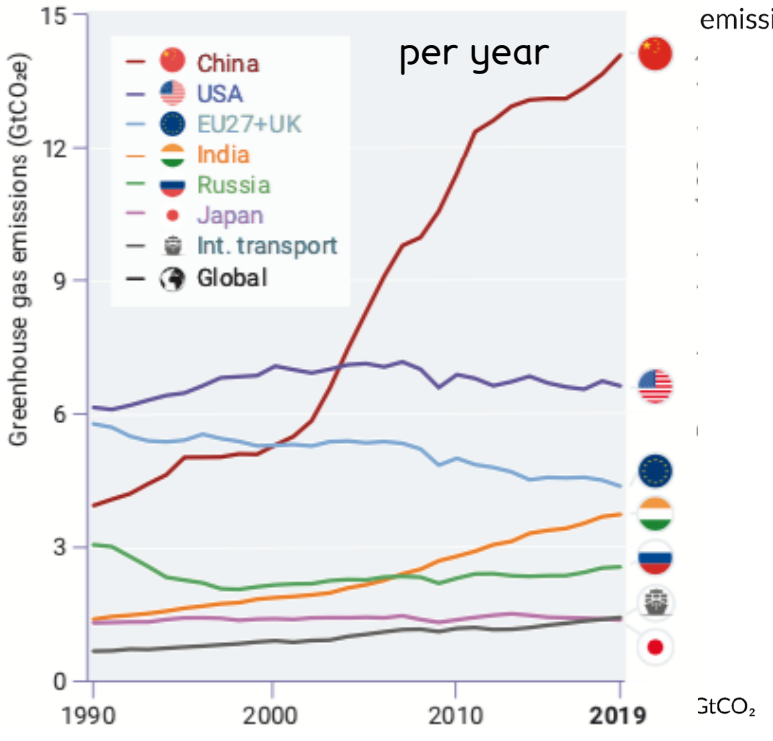

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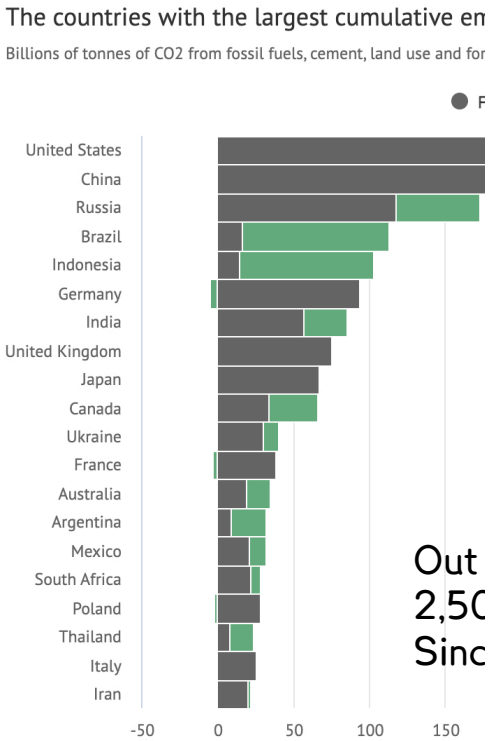


per year and per person

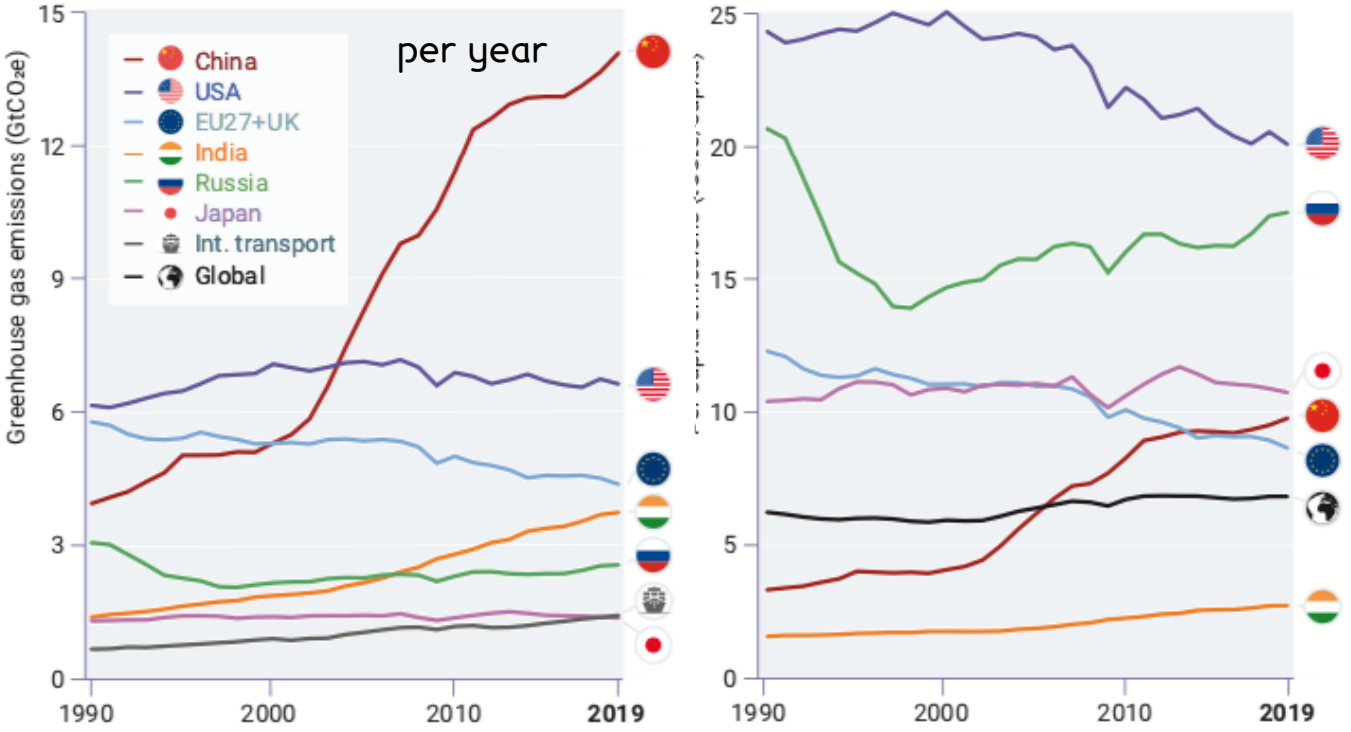
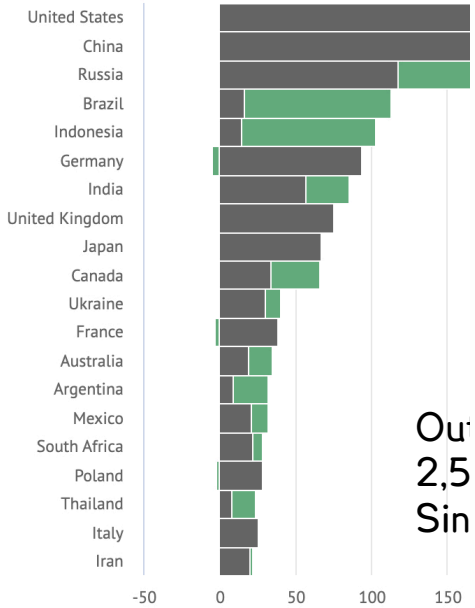


Image: Carbon Brief CB

Every tonne of CO

The countries with the largest cumulative e

Billions of tonnes of CO2 from fossil fuels, cement, land use and



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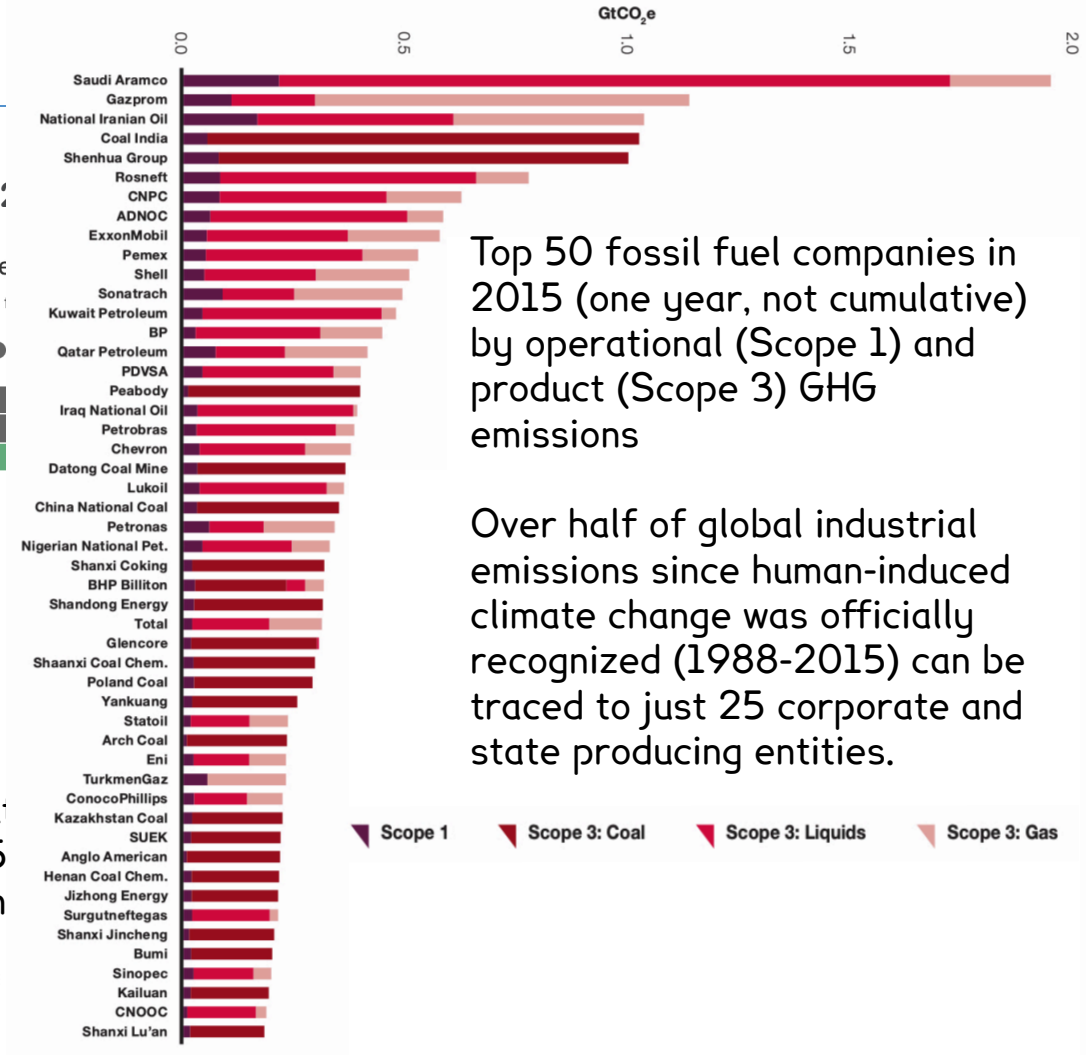
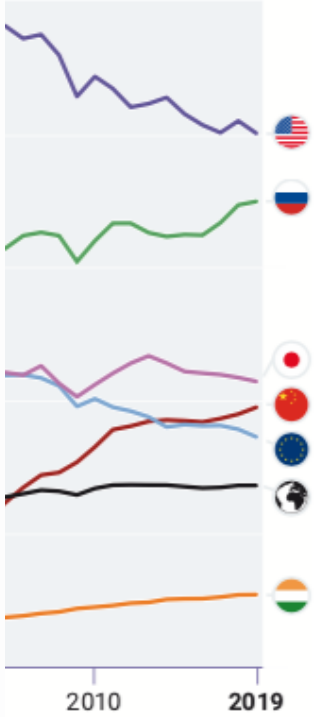


Top 50 fossil fuel companies in 2015 (one year, not cumulative) by operational (Scope 1) and product (Scope 3) GHG emissions

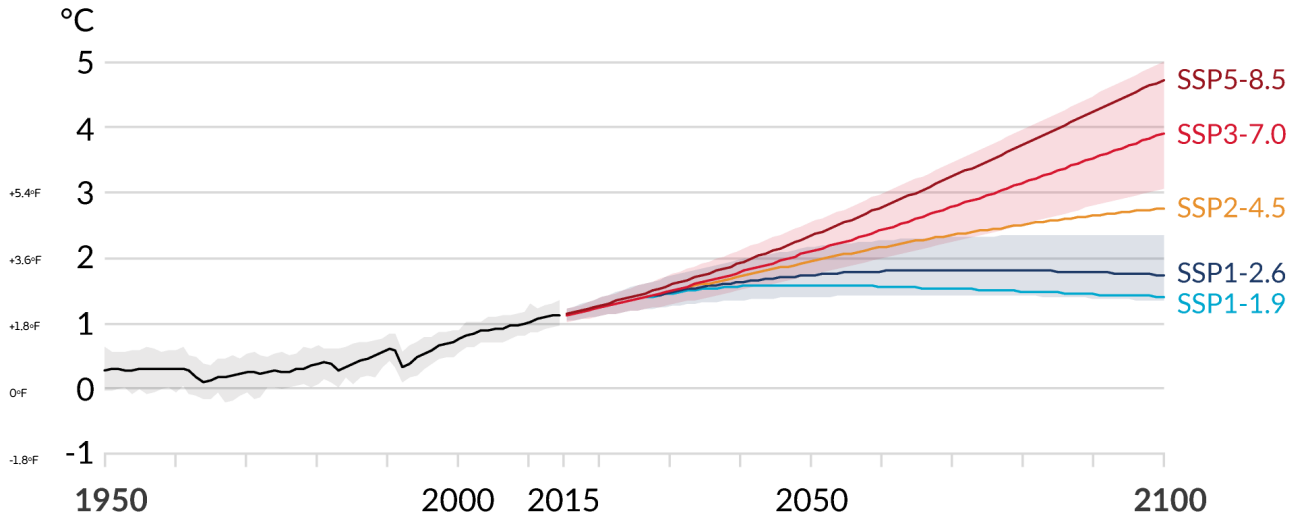
Over half of global industrial emissions since human-induced climate change was officially recognized (1988-2015) can be traced to just 25 corporate and state producing entities.

and per person



Human activities affect all the major climate system components, with some responding over decades and others over centuries

a) Global surface temperature change relative to 1850-1900



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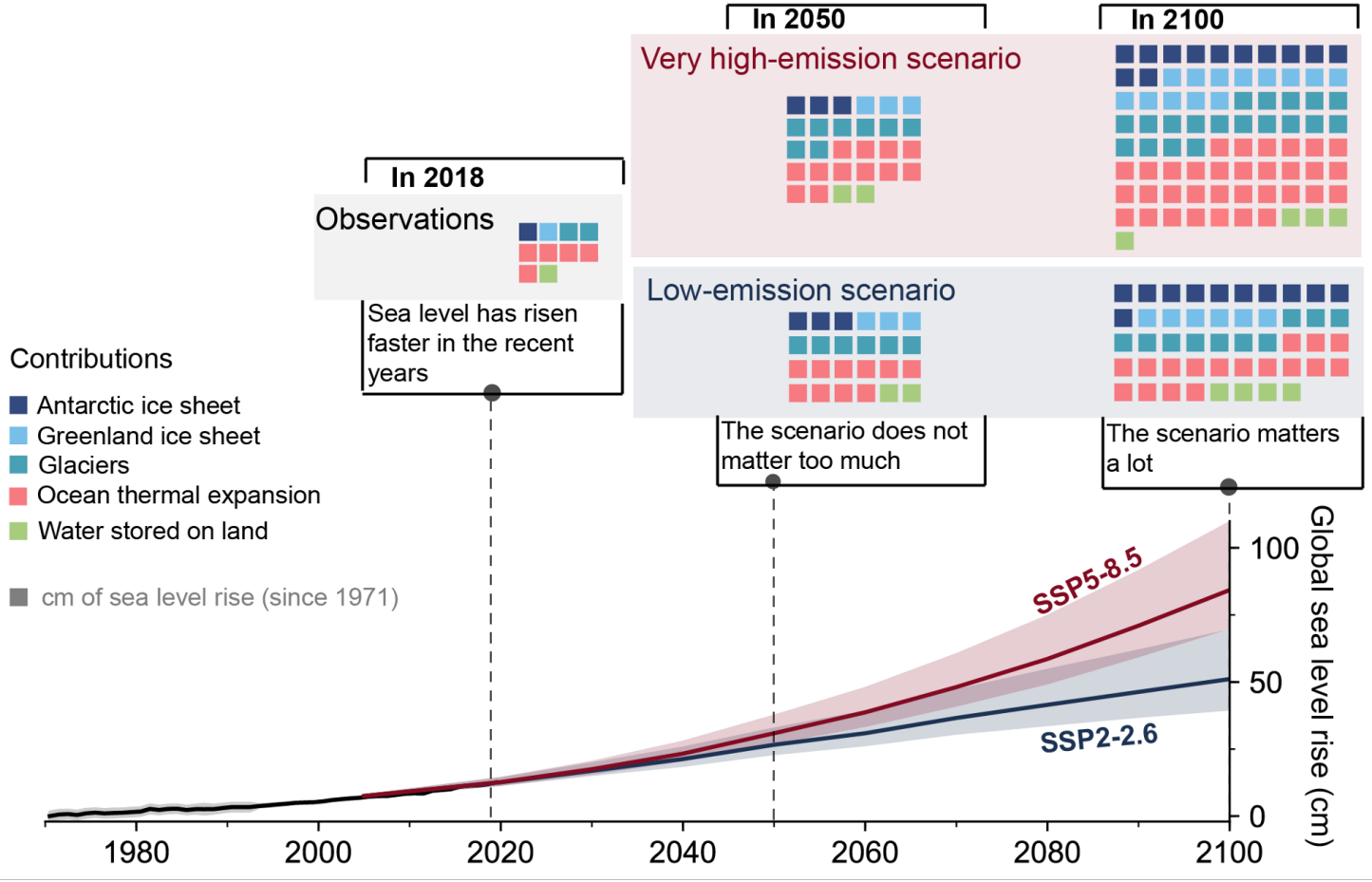
FAQ 9.2: **How much will sea level rise in the next few decades?**

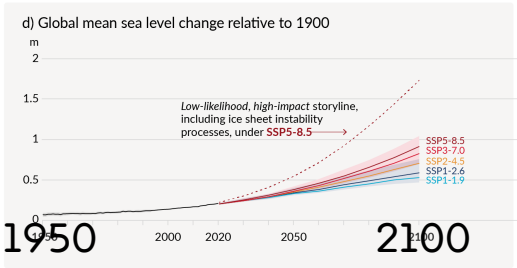
Emissions scenarios influence little sea level rise of the coming decades but has a huge effect on sea level at the end of the century.

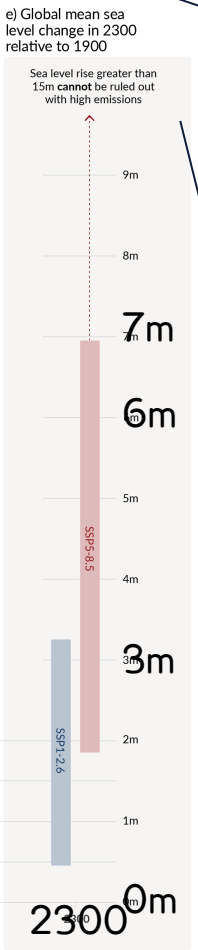


Observed and projected global mean sea level rise and the contributions from its major constituents.

Human activities affect all the major climate system components, with some responding over decades and others over centuries

Combining the slow responses of deep ocean warming, glacier loss, and ice sheet loss, far future sea level rise will greatly exceed the rise to be seen this century.





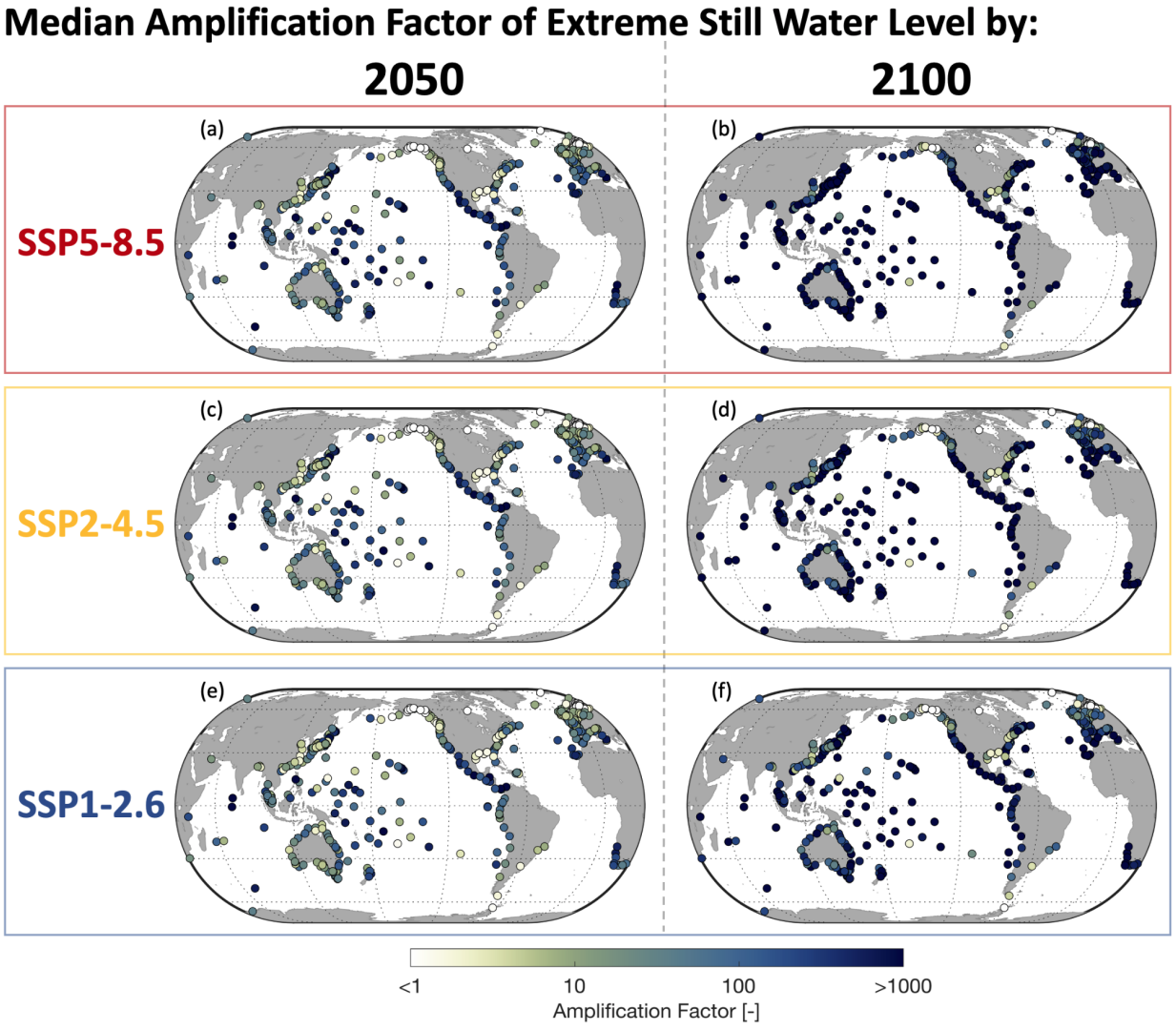
e) Global mean sea level change in 2300 relative to 1900

Sea level rise greater than 15m **cannot** be ruled out with high emissions

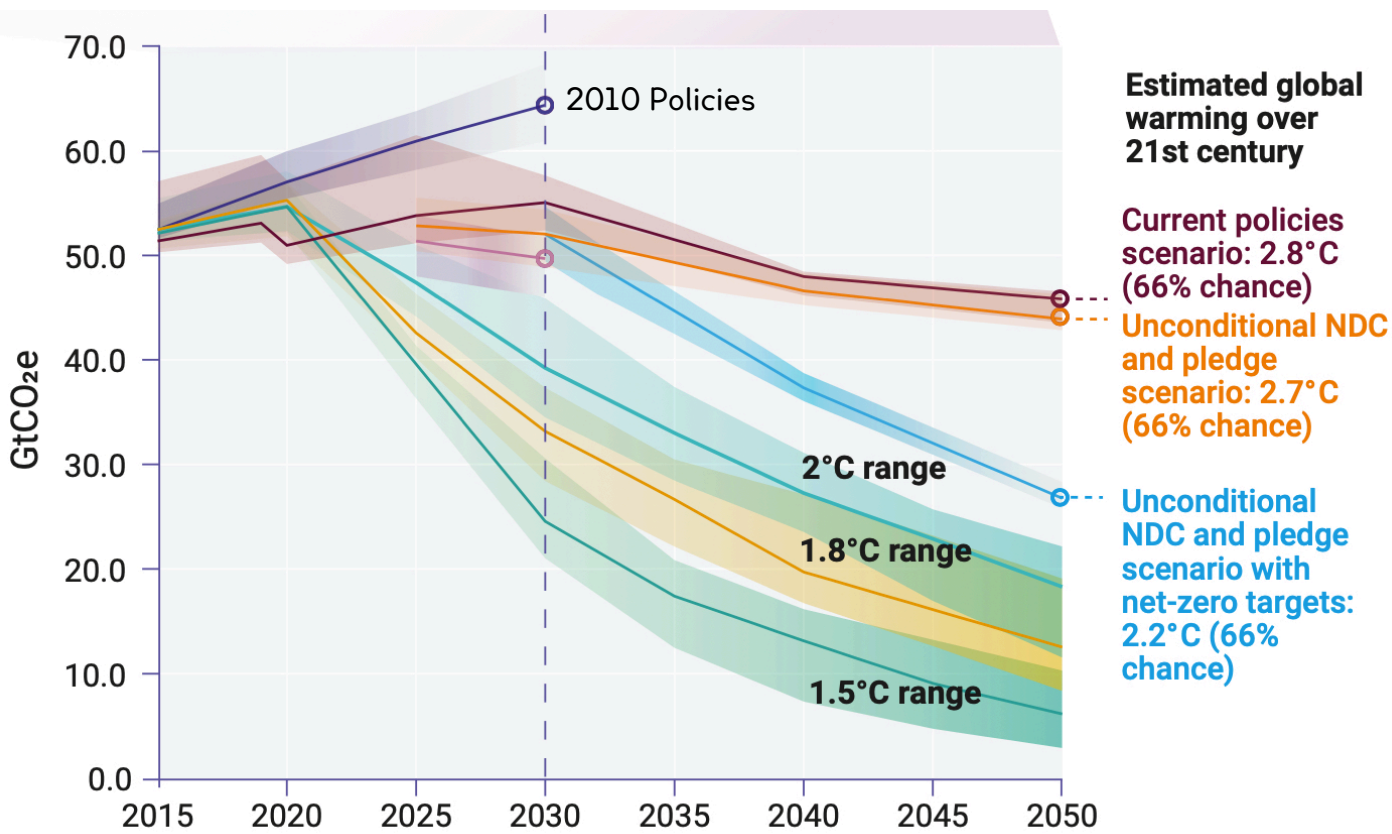
Providence, 1938

Providence, 1954

Images: Brown U. Joukowsky Institute



The way that **sea level rise will show itself** in coastal communities this century is **more frequent extreme events.**

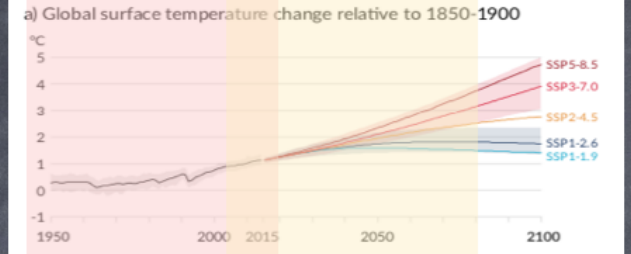


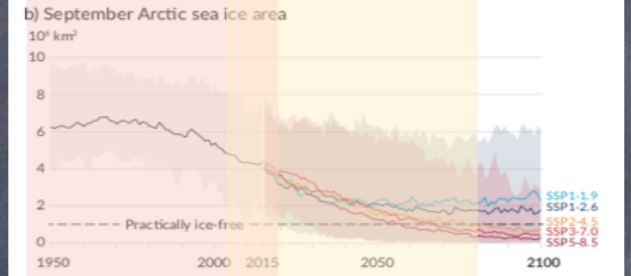
NDC=Nationally Determined Contribution

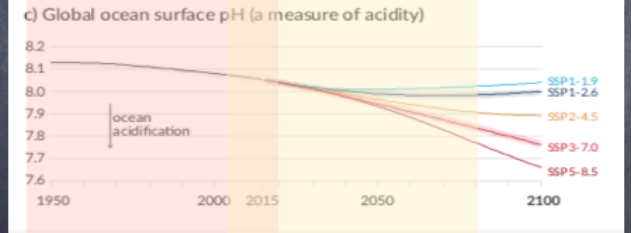
Future Projections

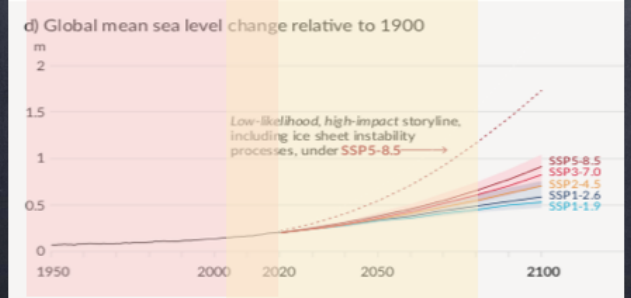
floridapolitics.com

vatican news









IPCC AR6 (2021)

A Message about Kids These Days...

See also:

https://doi.org/10.1126/science.abi7339

Intergenerational inequities in exposure to climate extremes

To Stay Below +2C

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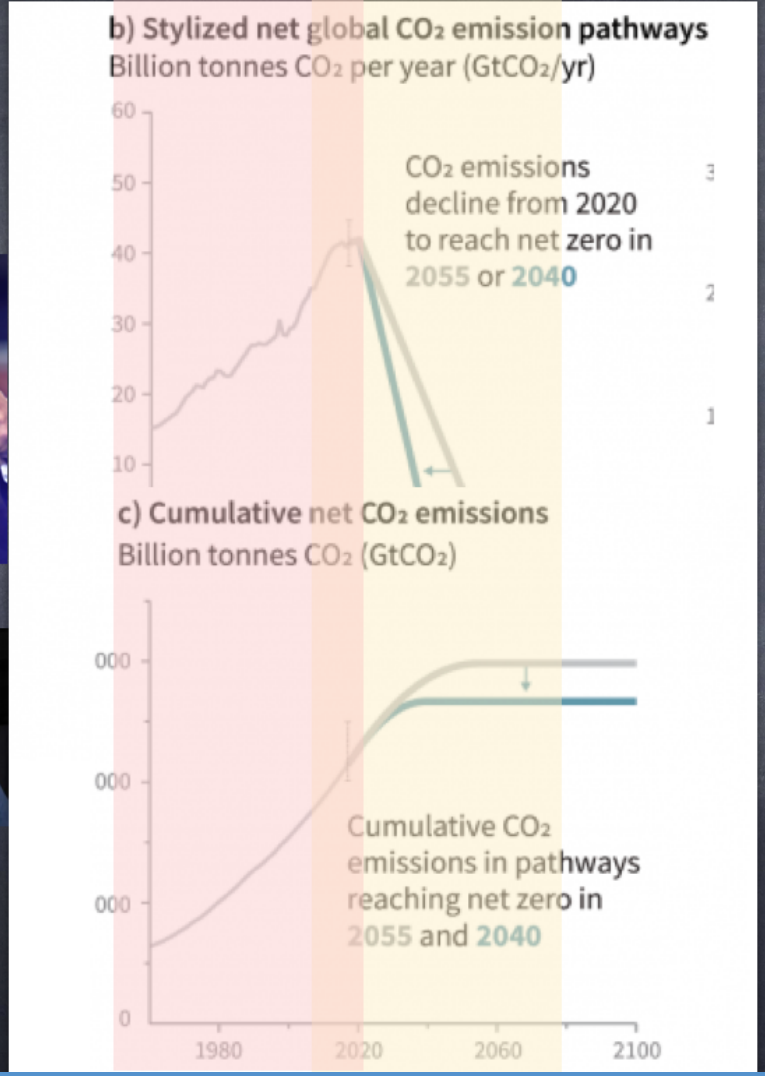

IPCC SR1.5 (2018)

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Intergenerational inequities in exposure to climate extremes

SIXTH ASSESSMENT REPORT
Working Group I – The Physical Science Basis

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Outline:

The Oceans are Vast & Diverse
What is the United Nations IPCC AR6?
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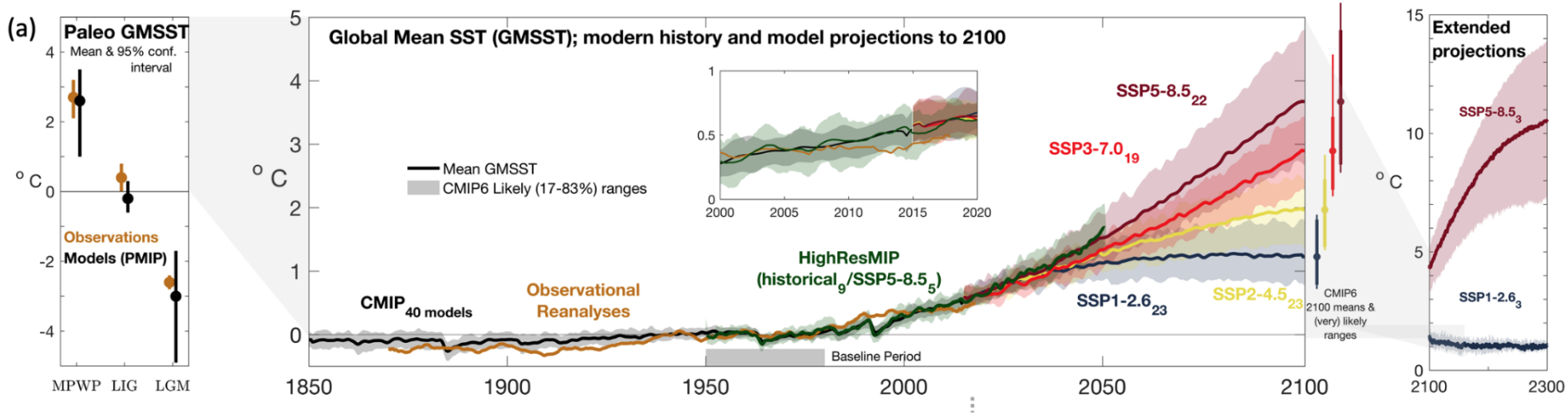
Projected Future Changes
Effects of Unresolved Scales—Ocean Physics Viewpoint
Online Repositories

Sea Surface Temperature (SST) and its changes with time.

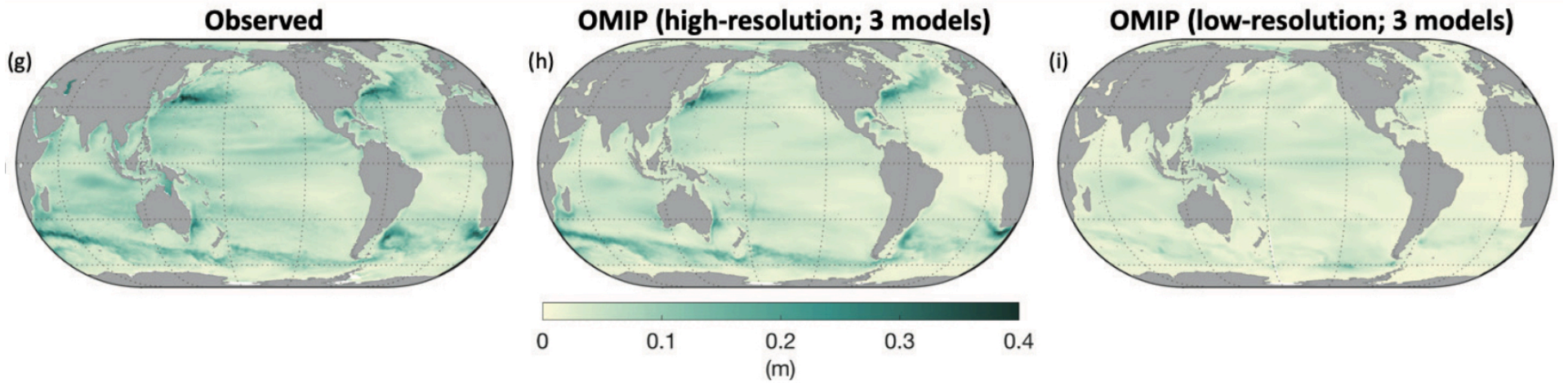
Sea Surface Temperature (SST) Anomalies and Maps

Observation-based estimates and CMIP6 multi-model means, biases and projected changes



In many ways, models resolving eddies behave like those "parameterizing" eddies.

Standard deviation of Sea Surface Height

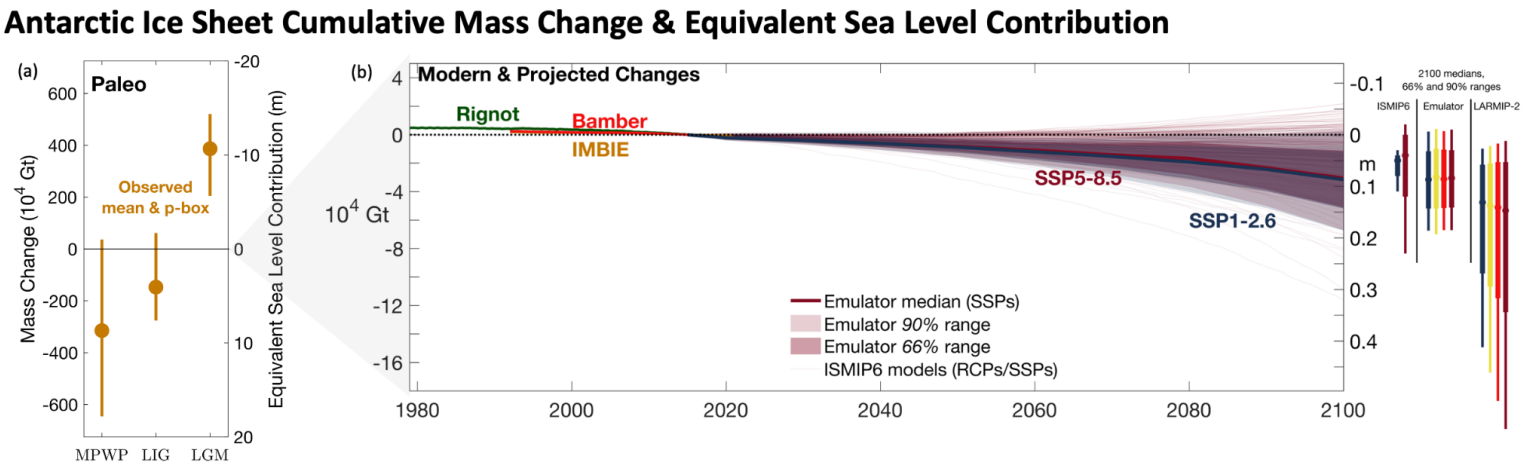


But, sometimes not! (Sea Surface Height variability)

The small scales of the ocean may hold the key to surprises

Sharp fronts and eddies that are ubiquitous in the world ocean, as well as features such as shelf seas and under-ice-shelf cavities, are not captured in climate projections. Such small-scale processes can play a key role in how the large-scale ocean and cryosphere evolve under climate change, posing a challenge to climate models.

Helene Hewitt, Baylor Fox-Kemper, Brodie Pearson, Malcolm Roberts and Daniel Klocke



Hewitt et al., *Nature Climate Change*, 2022

But, global models won't resolve these small processes for decades.

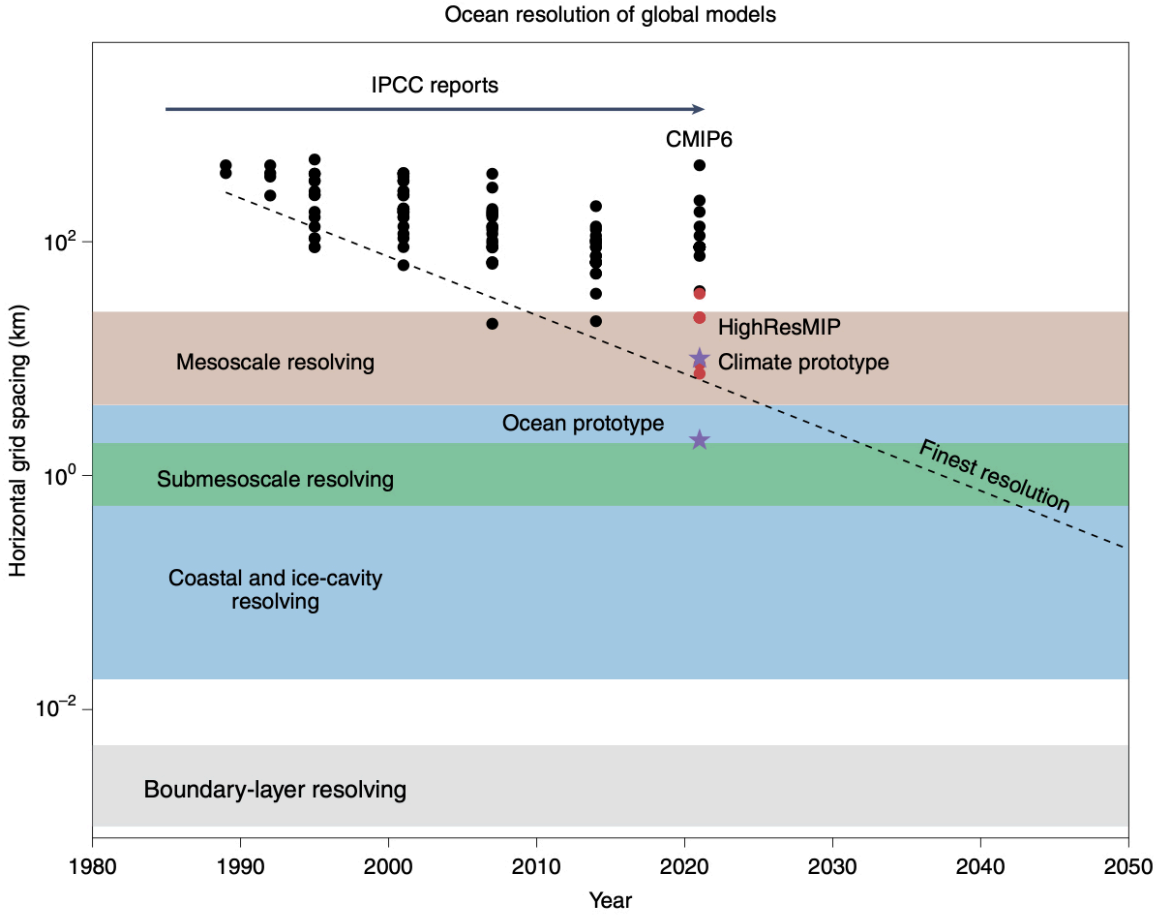


Fig. 2 | The evolution of global ocean model resolution by publication year. Shown are models from

Hewitt et al., *Nature Climate Change*, 2022

Modeling of variability

A stochastic, predictable persistence model:
Frankignoul & Hasselmann (77)

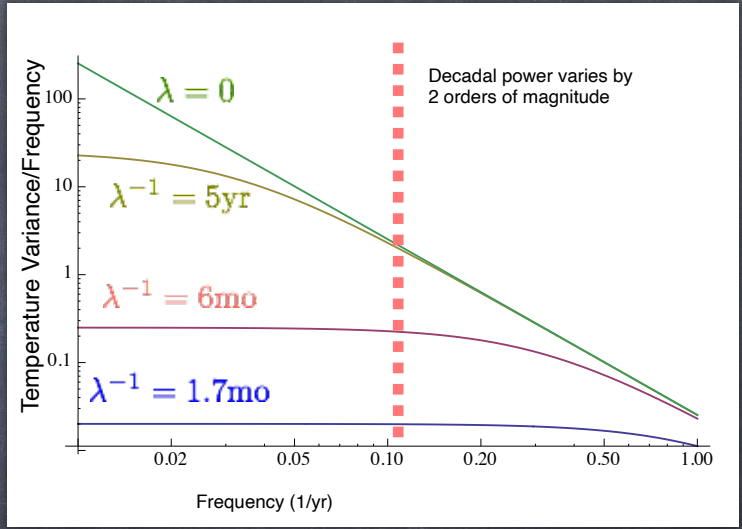
Temp Change

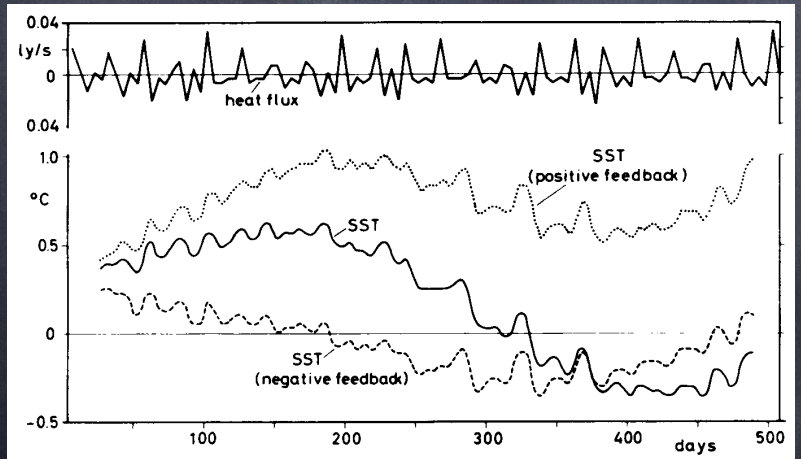
$$\frac{dT}{dt} = \frac{f_1'}{h} - \lambda T$$

Random Atmosphere

Restoring

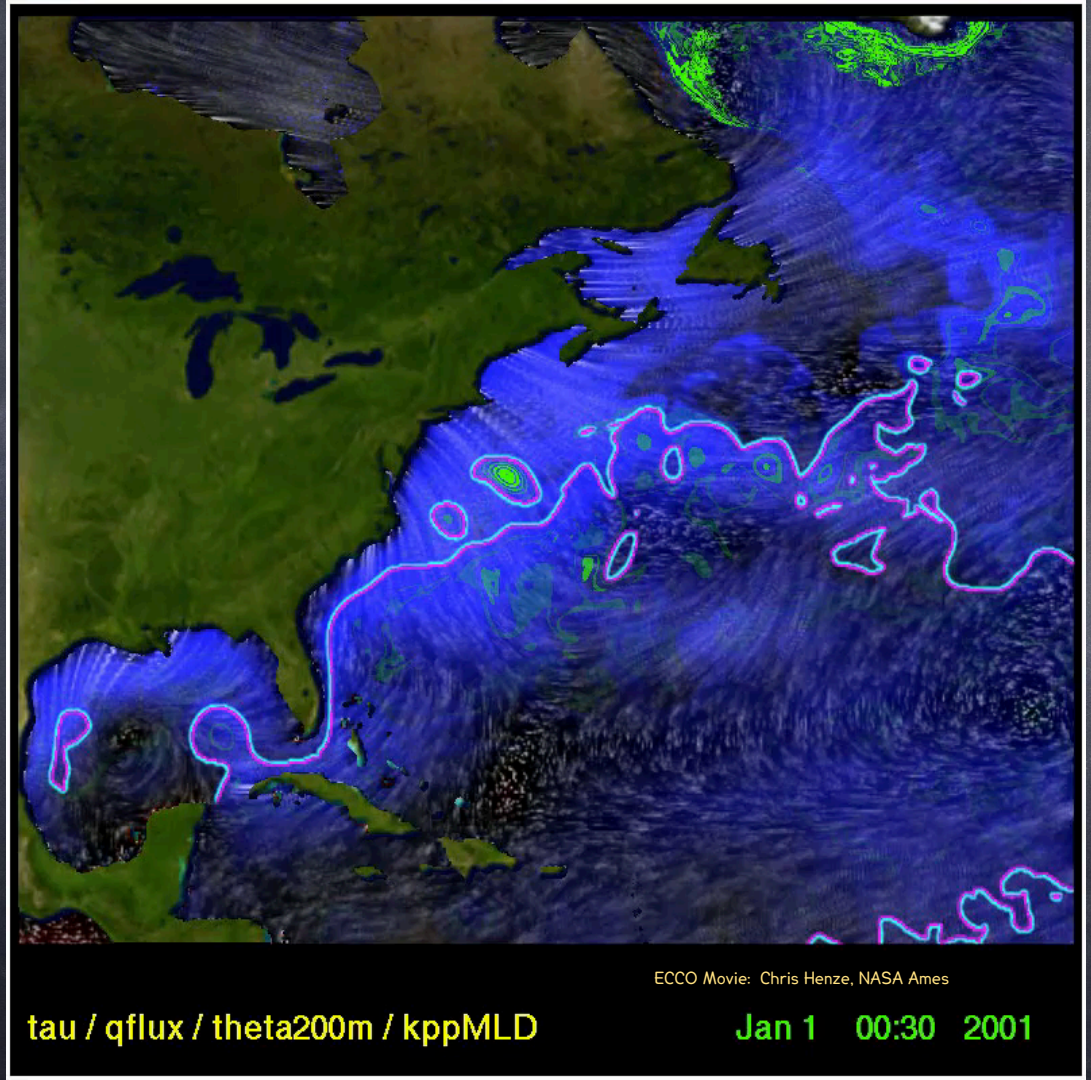
h Mixed Layer





$$\lambda = \rho^a C_p^a (\rho^w C_p^w)^{-1} C_H (1 + B) \langle |U| \rangle h^{-1}$$

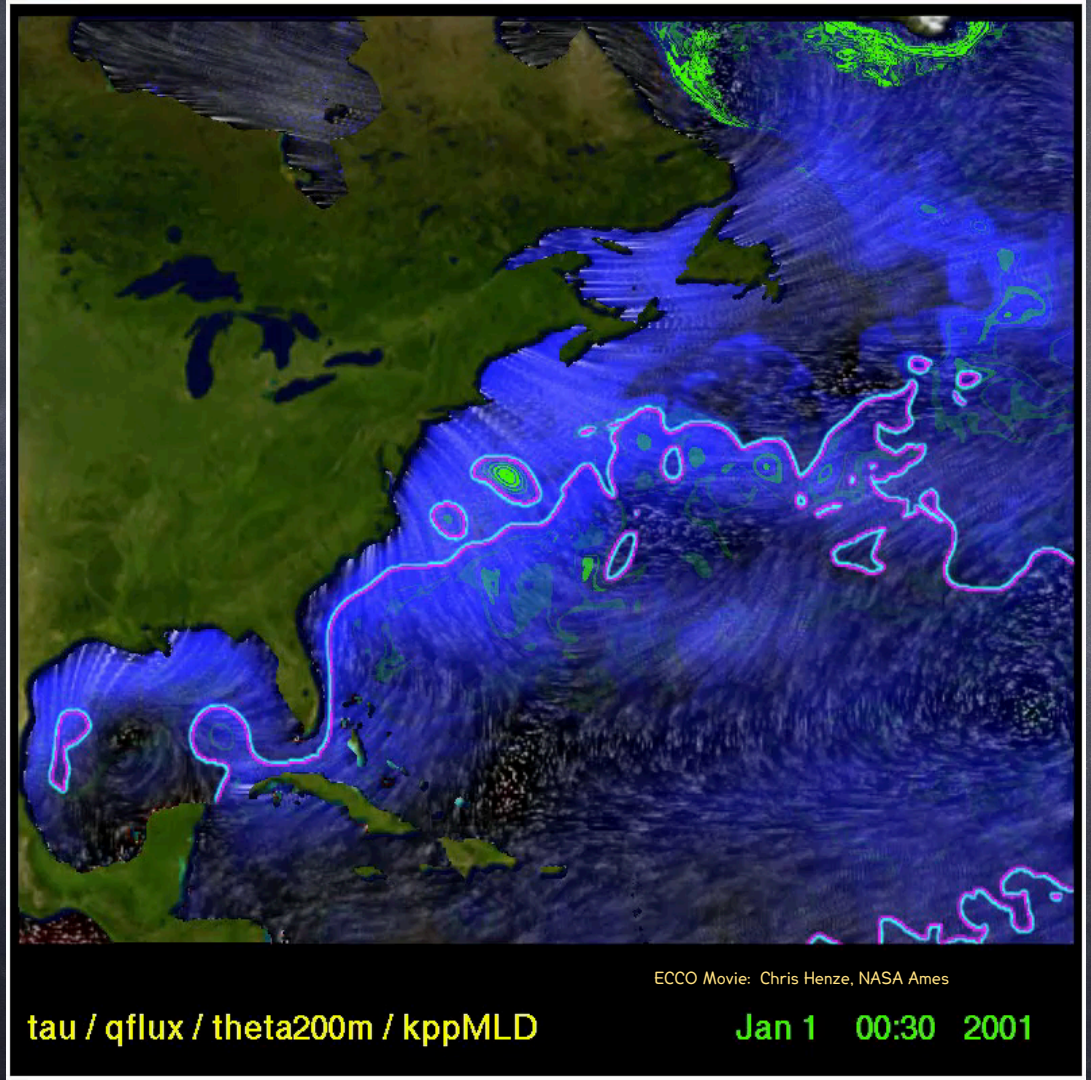
$$= (1.7 \text{ month})^{-1}$$



Weather, Atmosphere Fast

Ocean, Climate Slow

3.4m of ocean water has same heat capacity as the WHOLE atmosphere



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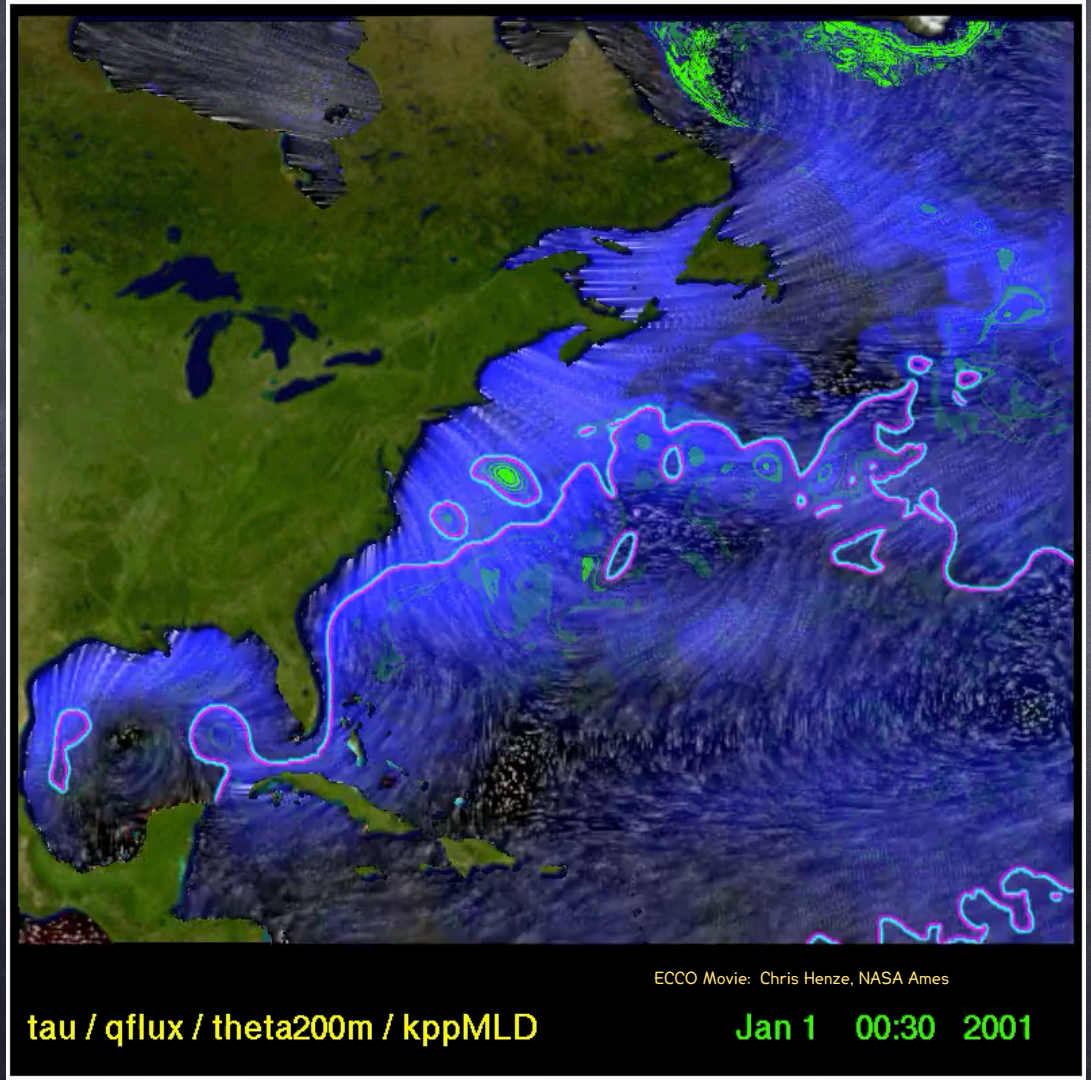

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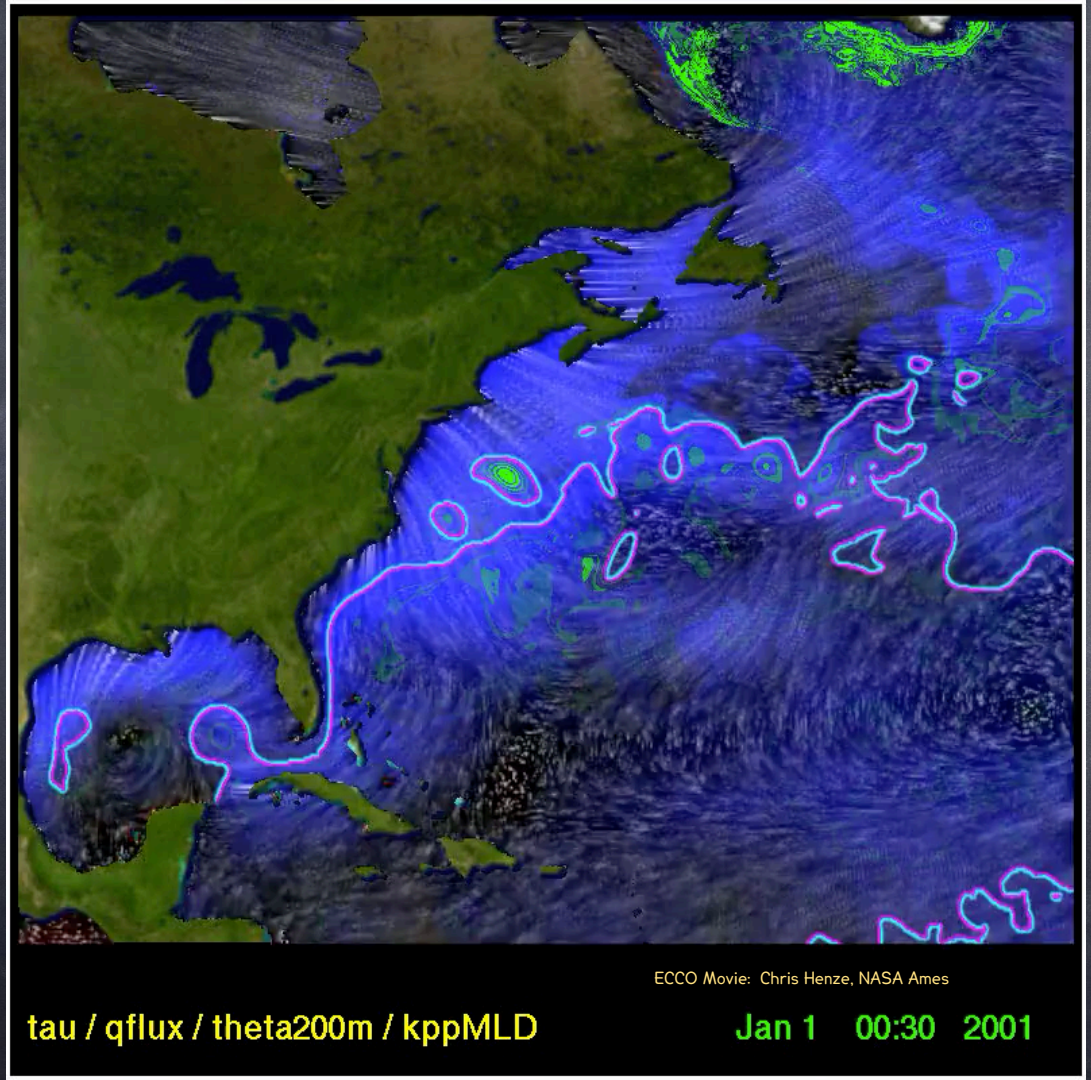
The essence of the Hasselmann 2021 Nobel in Physics!



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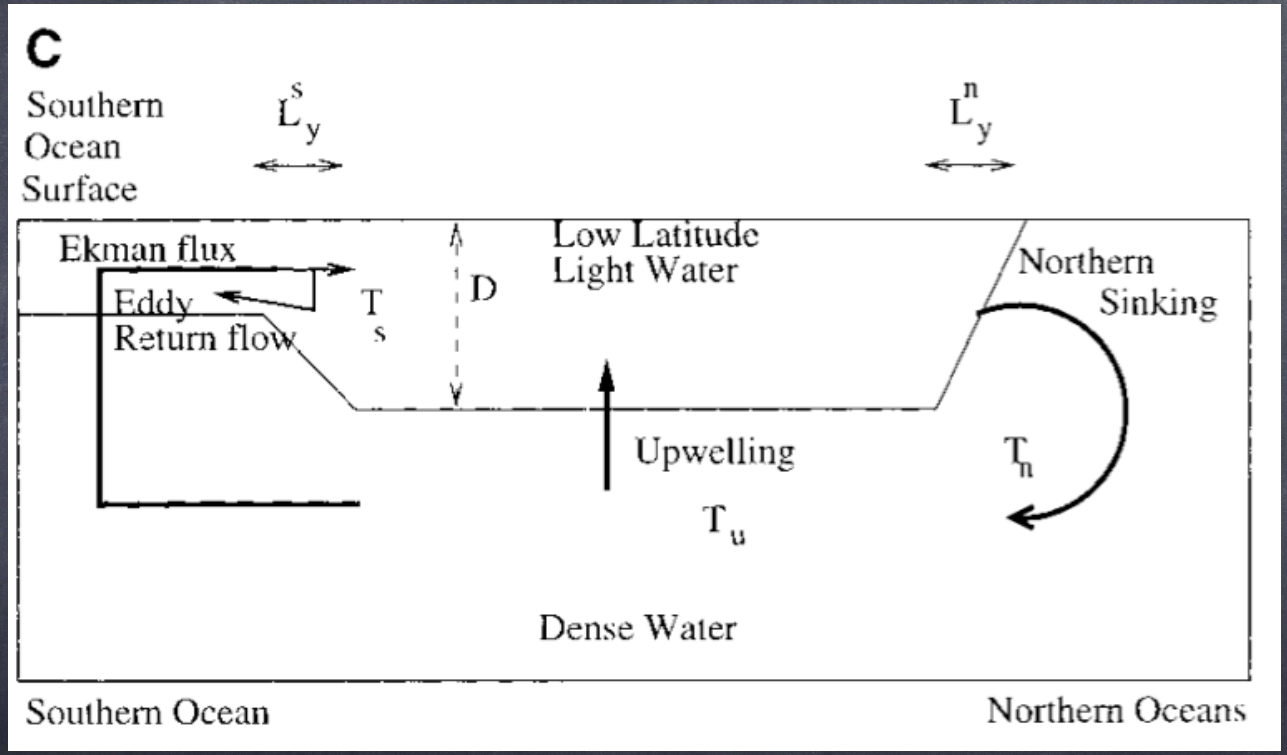
World Ocean



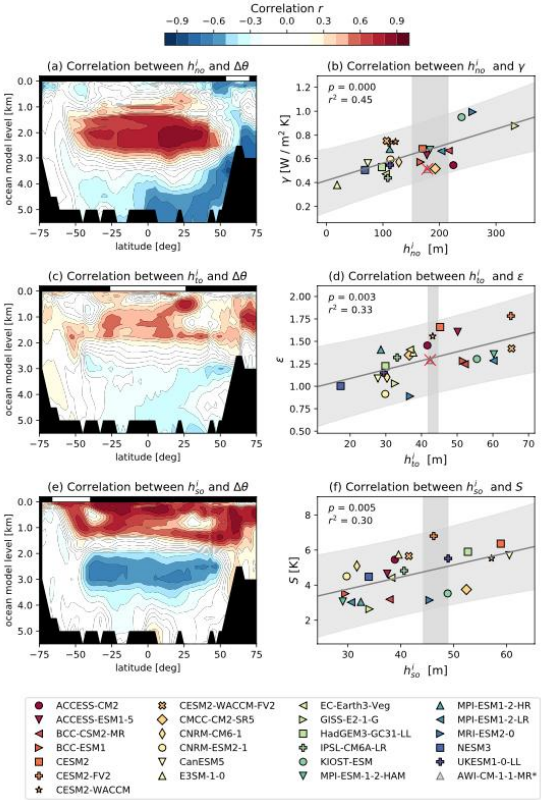
Gnanadesikan

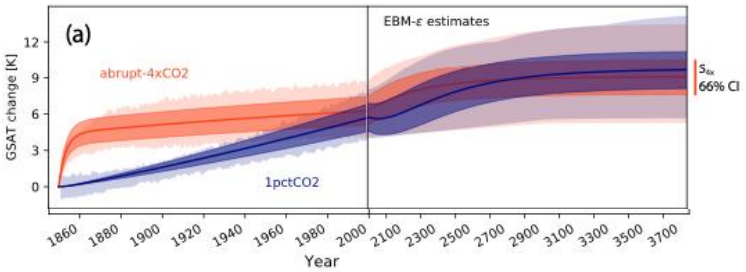
SCIENCE VOL 283 26 MARCH 1999

Even Simpler: 2-Layer Homogeneous Energy Balance Model (Gregory, 2000)

So, we study the consequences of different parameterizations on modeled climate change

Regional mixed layer depth as a climate diagnostic and emergent constraint





"Using these correlations and observations from the Argo float network, we revise the ensemble mean and narrow the 66% range of equilibrium climate sensitivity (ECS) for the particular CMIP6 model collection from 4.51 (3.13–5.71) °C, to 4.66 (3.88–5.43) °C, amounting to a 40% reduction in the span of the uncertainty range."

Emulate CMIP6 model oceans with 2-layer ocean emulator.
Shows climate sensitivity depends on mixed layer depth which depends on submesoscale and smaller turbulence

Hall & Fox-Kemper, Submitted to *GRL*, 2021

PANGEO
CMIP6 data via pangeo.io
Code at repository.library.brown.edu

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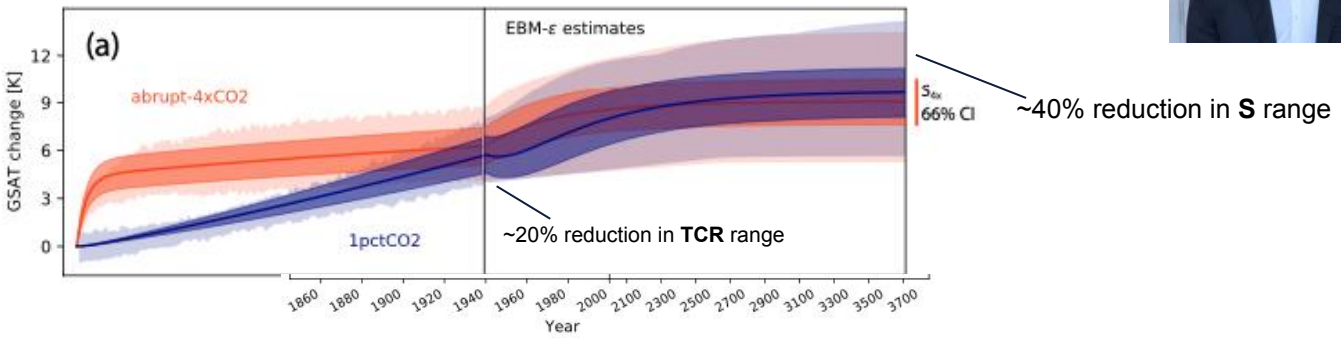

Approximately halving the uncertainty range for [transient climate response] has a net present value of about $10.3 trillion (year 2005 US$) if accomplished in time for emissions to be adjusted in 2020, falling to $9.7 trillion if accomplished by 2030.

-C. Hope, 2015, *Phil. Trans. A.*, https://doi.org/10.1098/rsta.2014.0429

Hall & Fox-Kemper, Submitted to *GRL*, 2021

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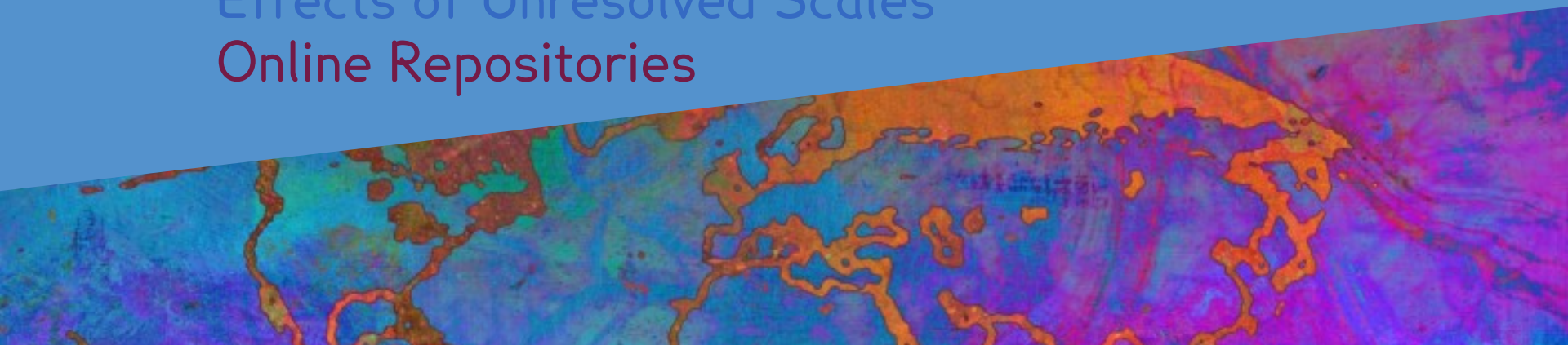
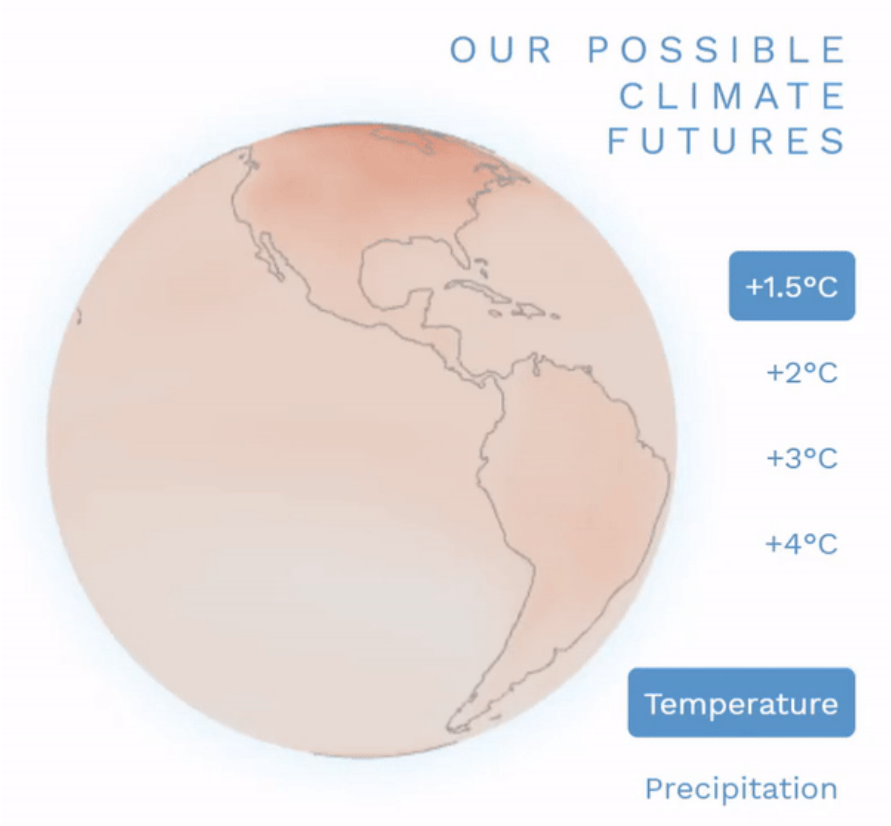


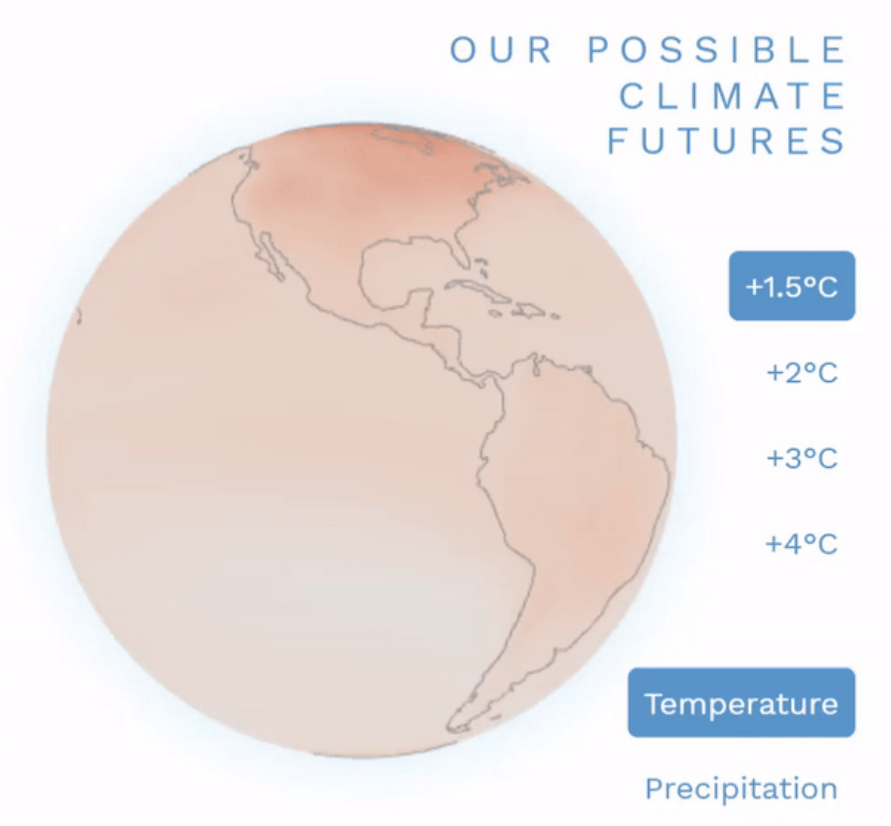
Interactive atlas



https://interactive-atlas.ipcc.ch/

#IPCCData

Interactive atlas



https://interactive-atlas.ipcc.ch/

#IPCCData

Interactive Atlas

interactive-

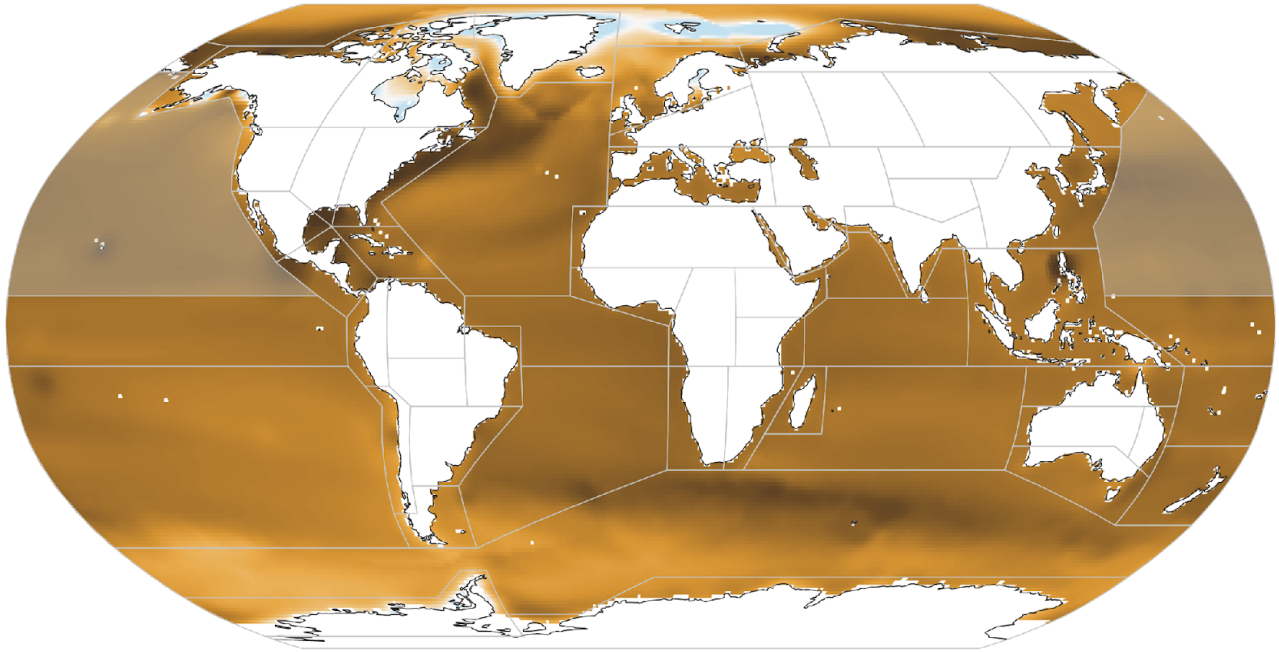
IPCC WGI Interactive Atlas: Regional information

Home About Guidance License

DATASET VARIABLE VALUE & PERIOD SEASON

Region Set:
WGI reference-re...

Uncertainty:
Simple

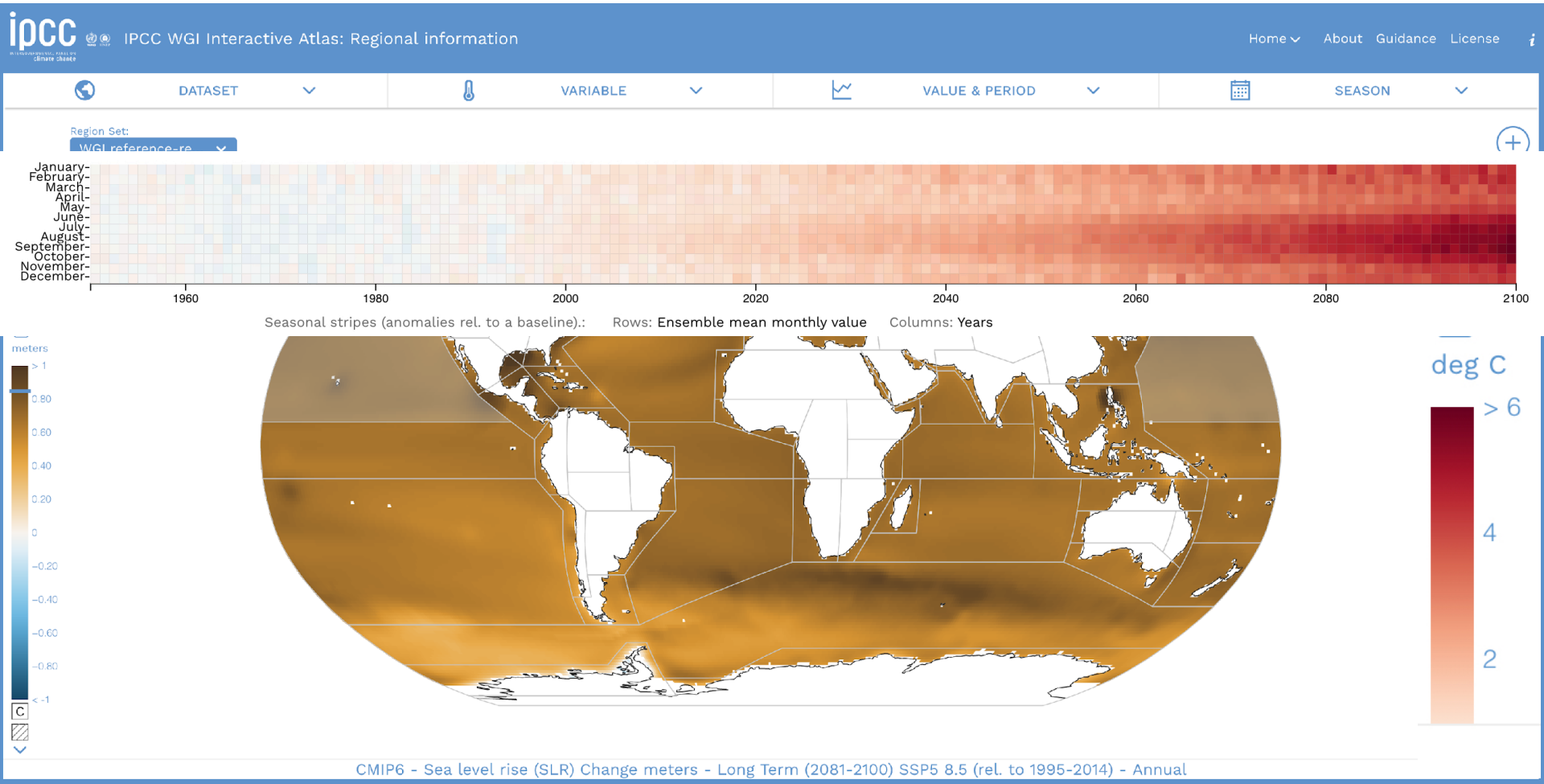


meters
> 1
0.80
0.60
0.40
0.20
0
−0.20
−0.40
−0.60
−0.80
< -1

CMIP6 - Sea level rise (SLR) Change meters - Long Term (2081-2100) SSP5 8.5 (rel. to 1995-2014) - Annual

Interactive Atlas

interactive-atlas.ipcc.ch



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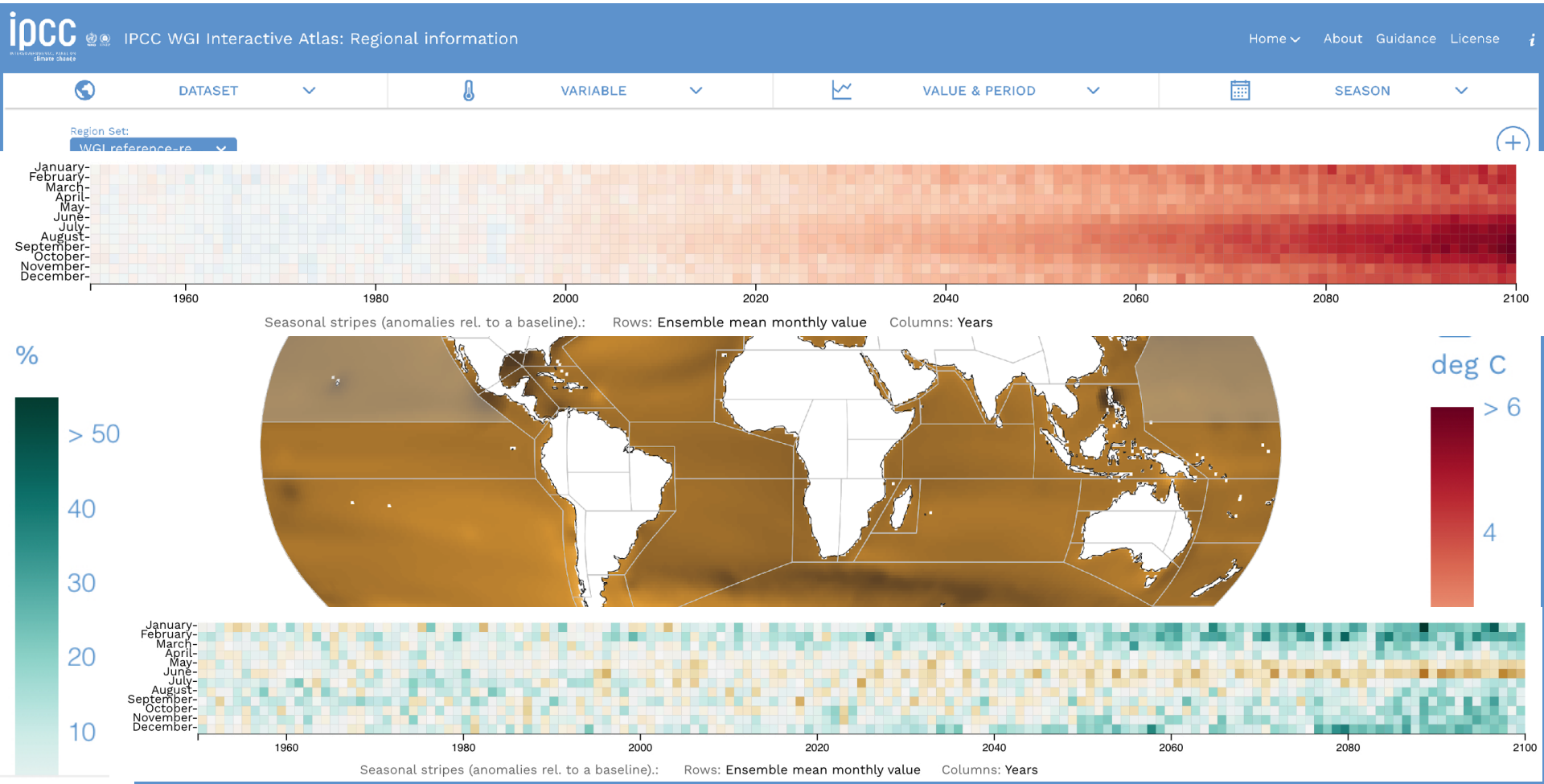
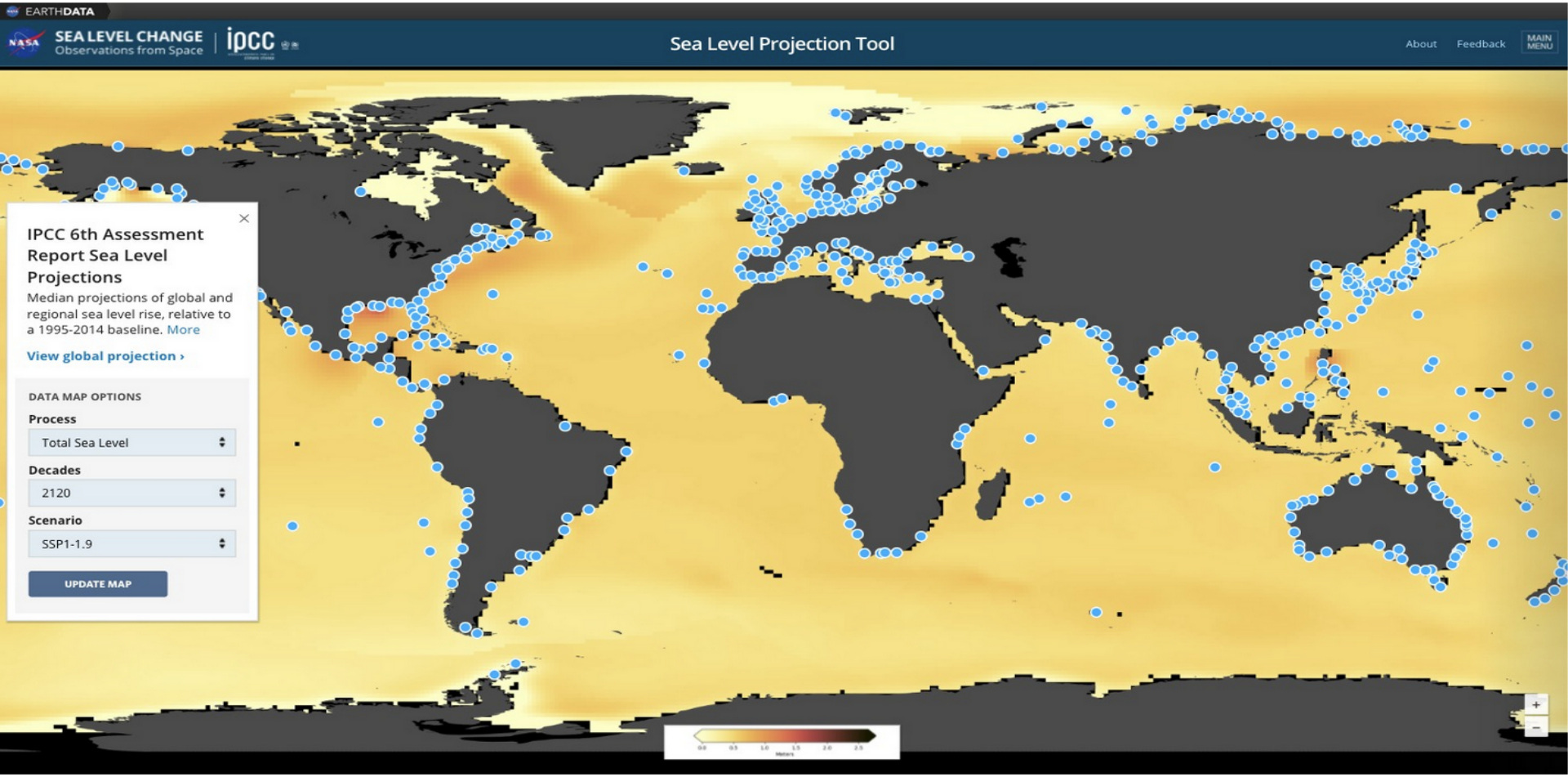
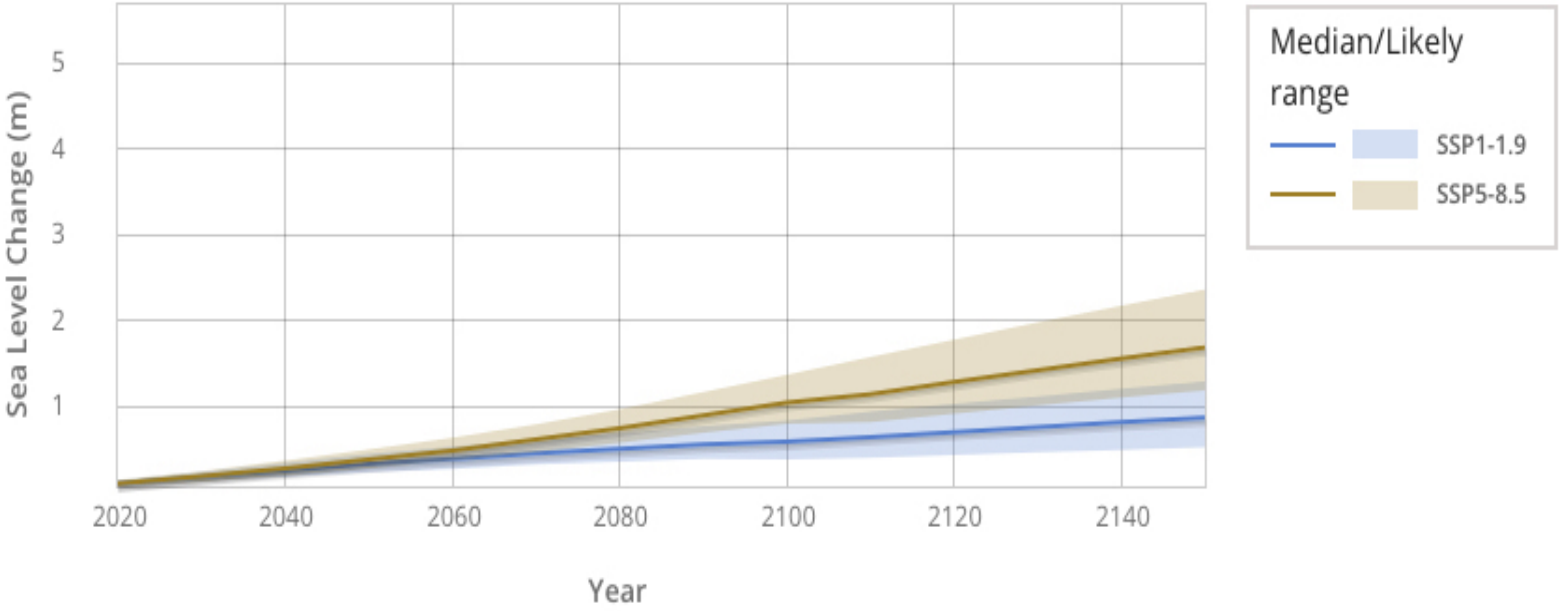


NASA sea level tool

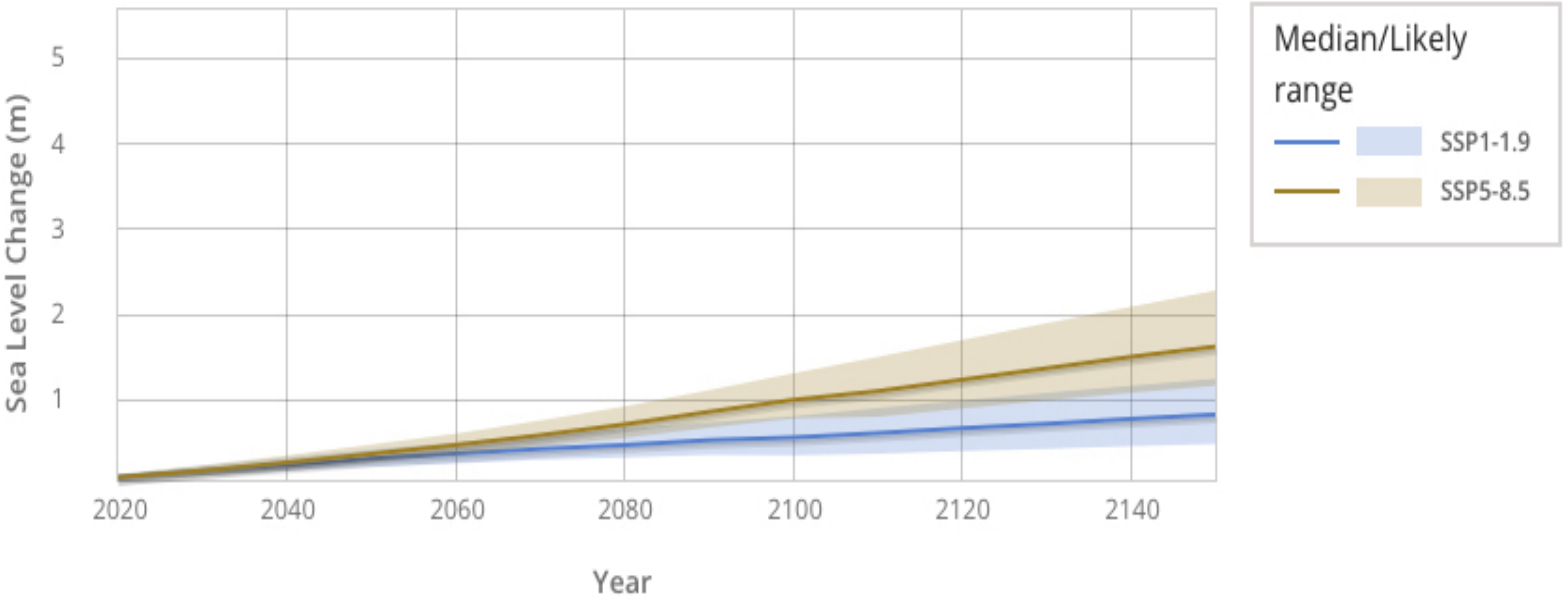
https://sealevel.nasa.gov

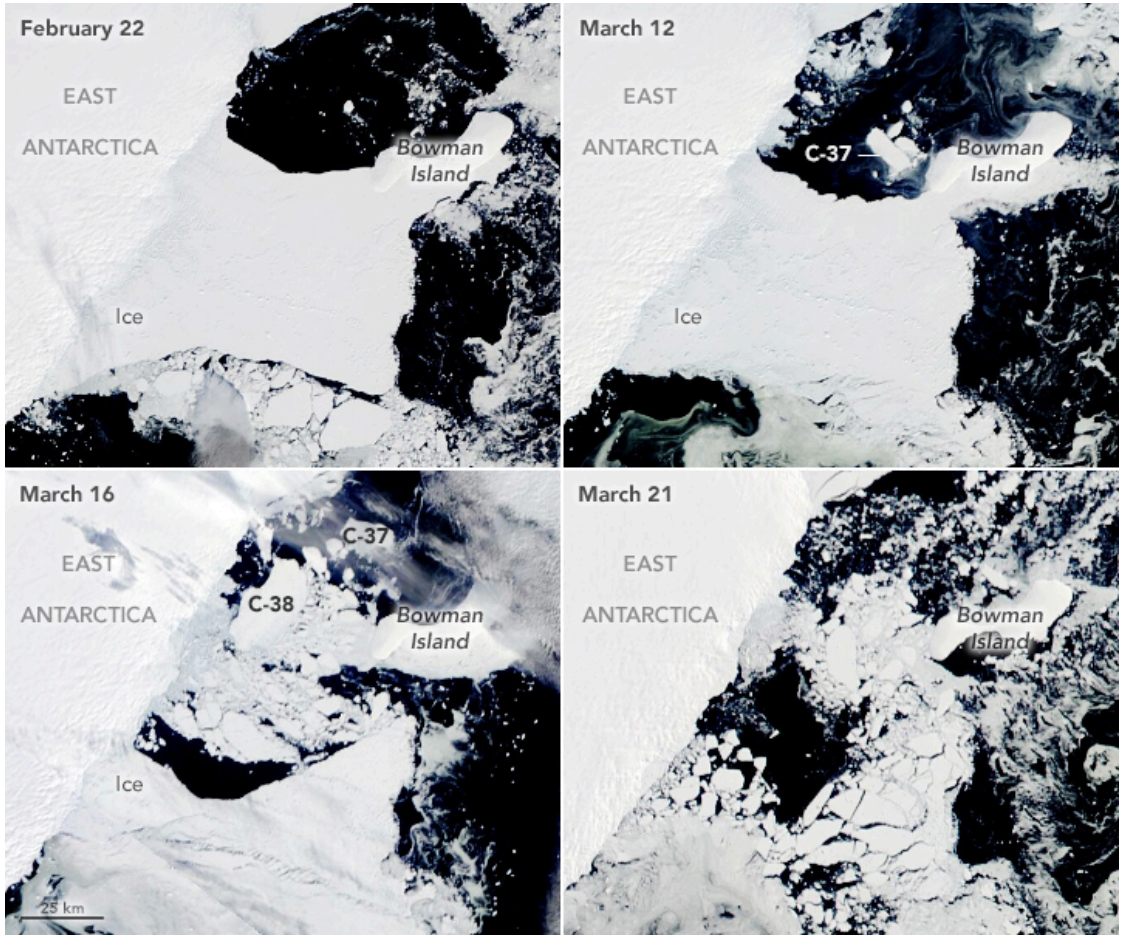


Sea Level Projection for Woods Hole, MA



Sea Level Projection for Bridgeport, CT



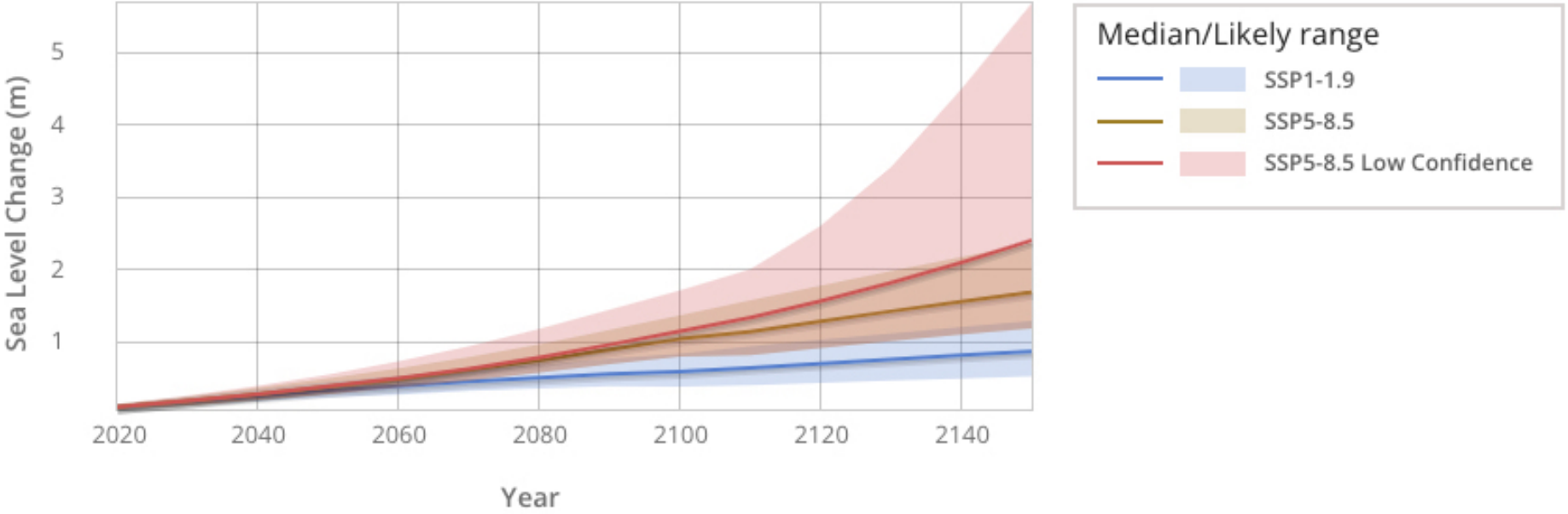


Climate change in remote places seems far away from Rhode Island, but…

Uncertainty about changes in Antarctica are is what makes sea level rise in Rhode Island uncertain…

Sea Level Projection for Woods Hole, MA with Rapid Antarctic Ice Sheet Loss

(& other similar unresolved ice sheet issues per expert opinion)



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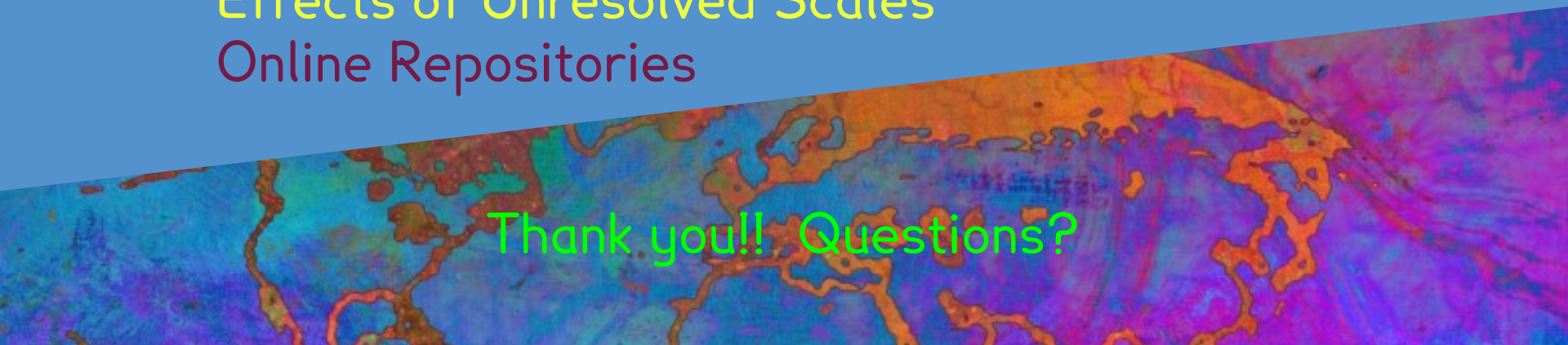
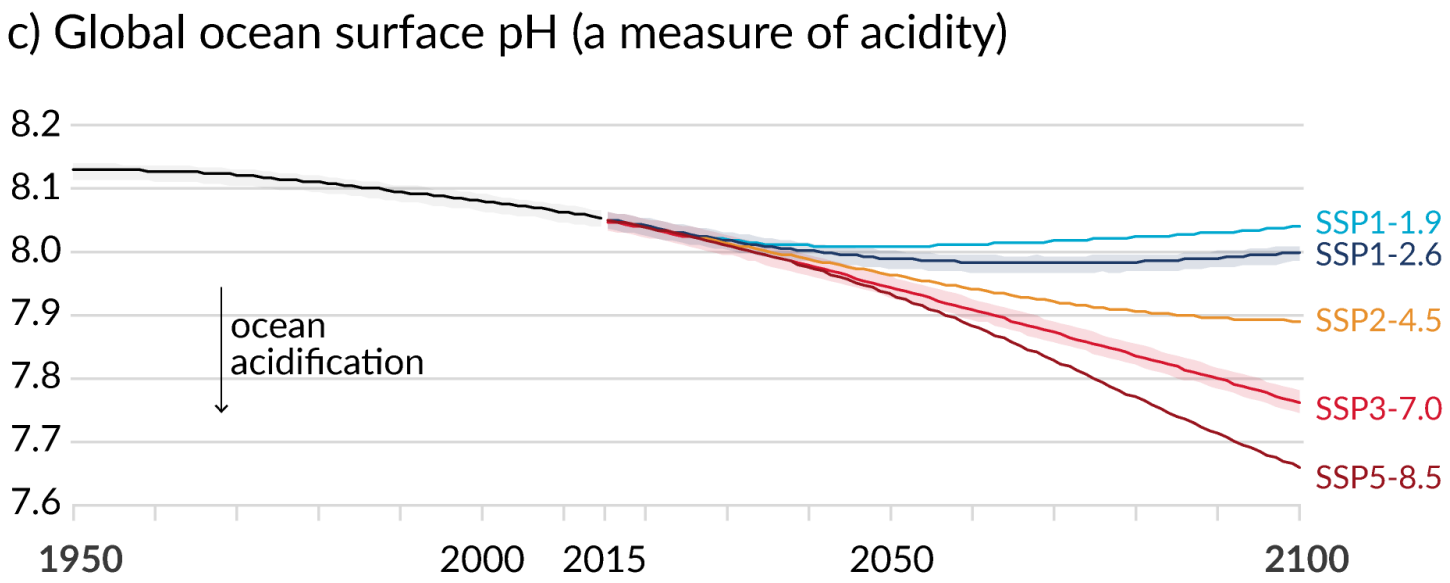


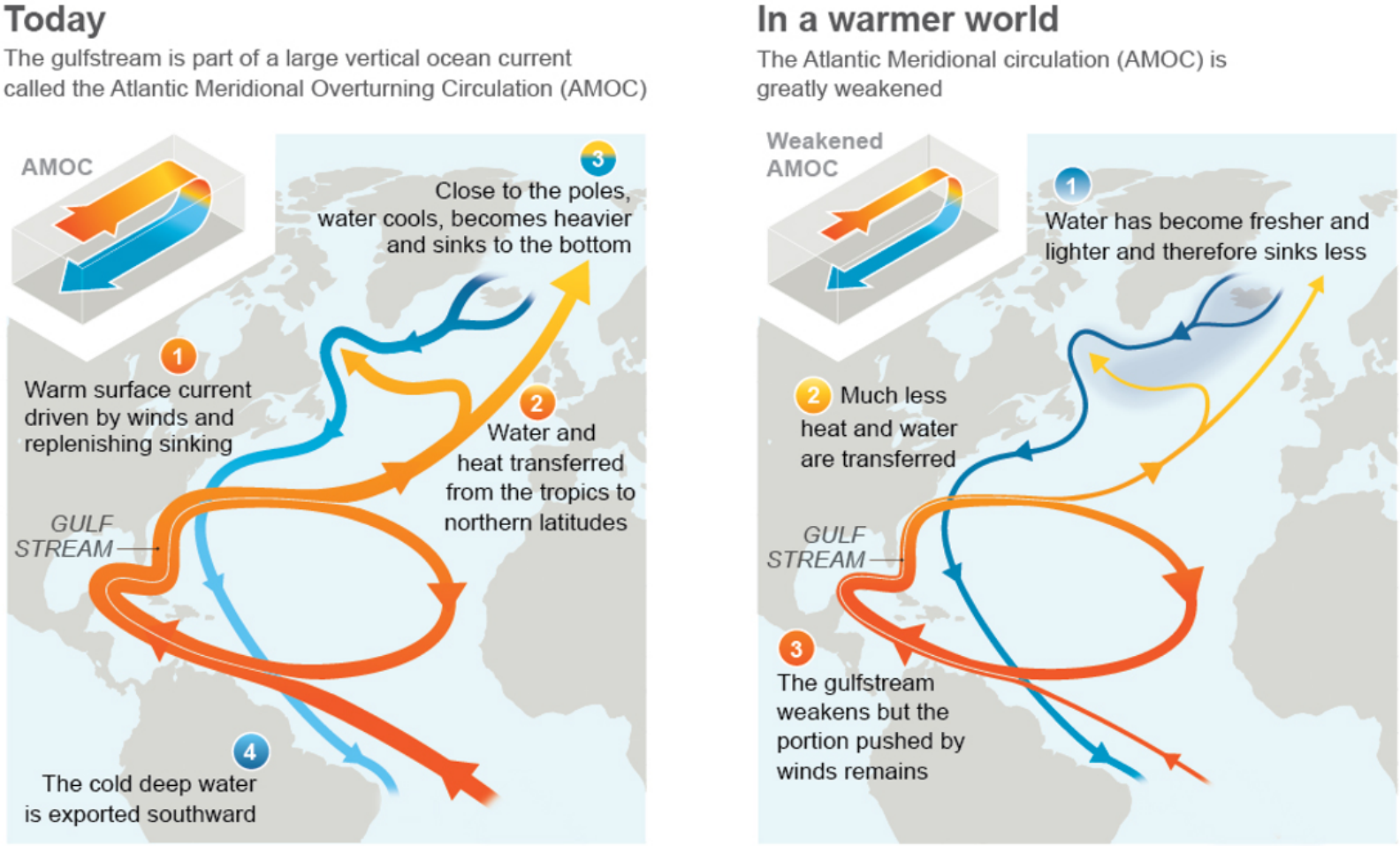
Thank you!! Questions?

Human activities affect all the major climate system components, with some responding over decades and others over centuries



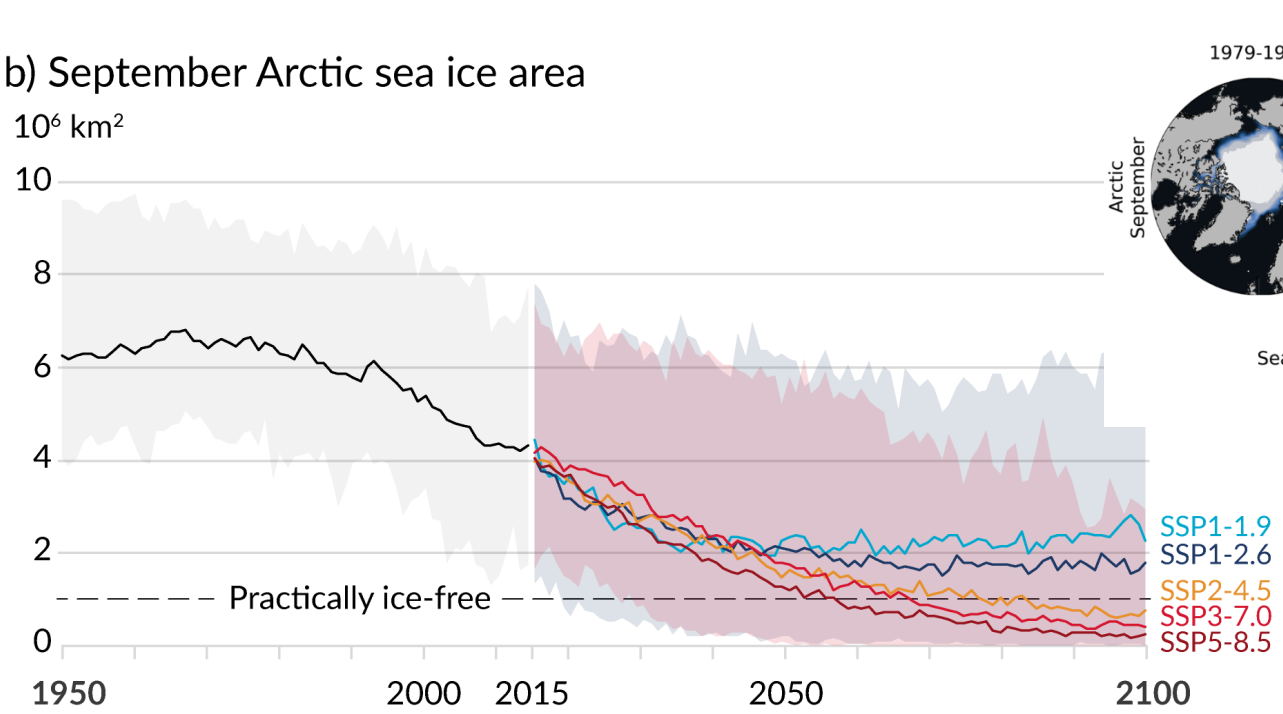
FAQ9.3: **Will the Gulfstream shutdown?**

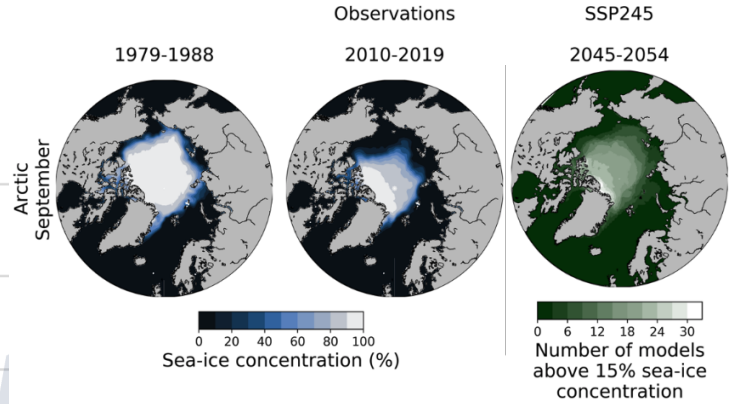
The warm current is expected to weaken but not cease, which will affect regional weather and sea level



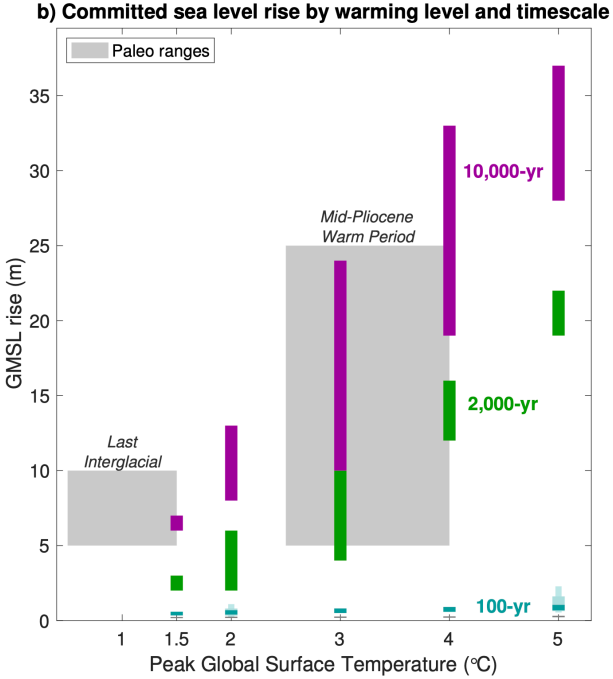
While the AMOC is expected to slow in a warming climate, the Gulf Stream will not change much and would not shut down totally, even if the AMOC did. **Most climate models project that the AMOC slows in the later 21st century under most emissions scenarios.** The Gulf Stream affects the weather and sea level, so if it slows, **North America will see higher sea levels** and Europe's weather and rate of relative warming will be affected.

Human activities affect all the major climate system components, with some responding over decades and others over centuries





In the longer term, sea level is committed to rise for centuries to millennia and will remain elevated for thousands of years.



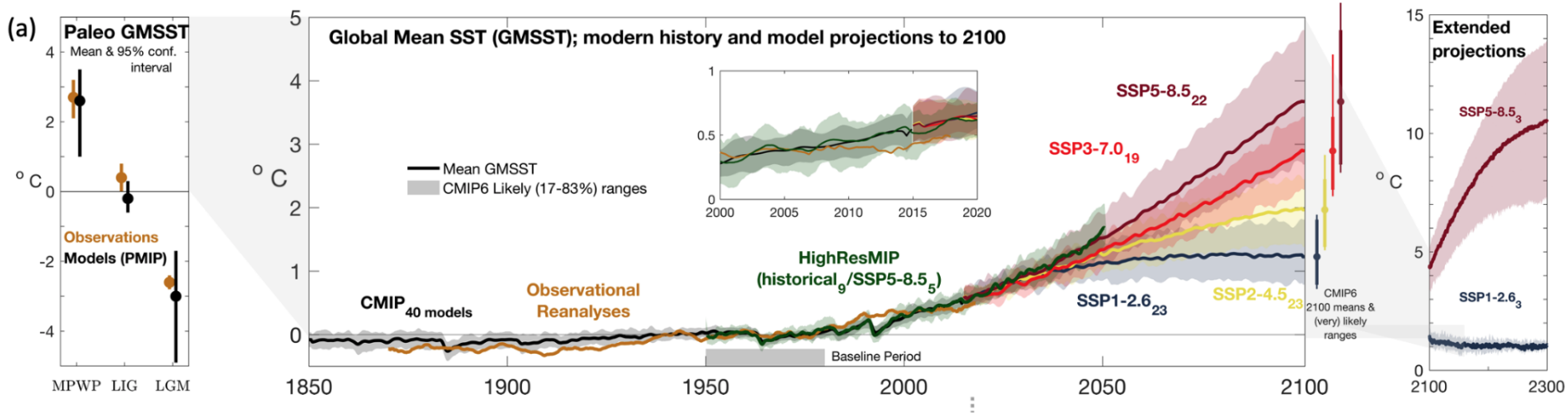
Over the next 2000 years, global mean sea level will rise by about
2 to 3 m if warming is limited to 1.5°C,
2 to 6 m if limited to 2°C and
19 to 22 m with 5°C of warming,
and it will continue to rise over subsequent millennia
(low confidence)

Projections of multi-millennial global mean sea level rise are consistent with reconstructed levels during past warm climate periods:
likely 5–10 m higher than today around 125,000 years ago, when global temperatures were very likely 0.5°C–1.5°C higher than 1850–1900;
and very likely 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher (medium confidence).

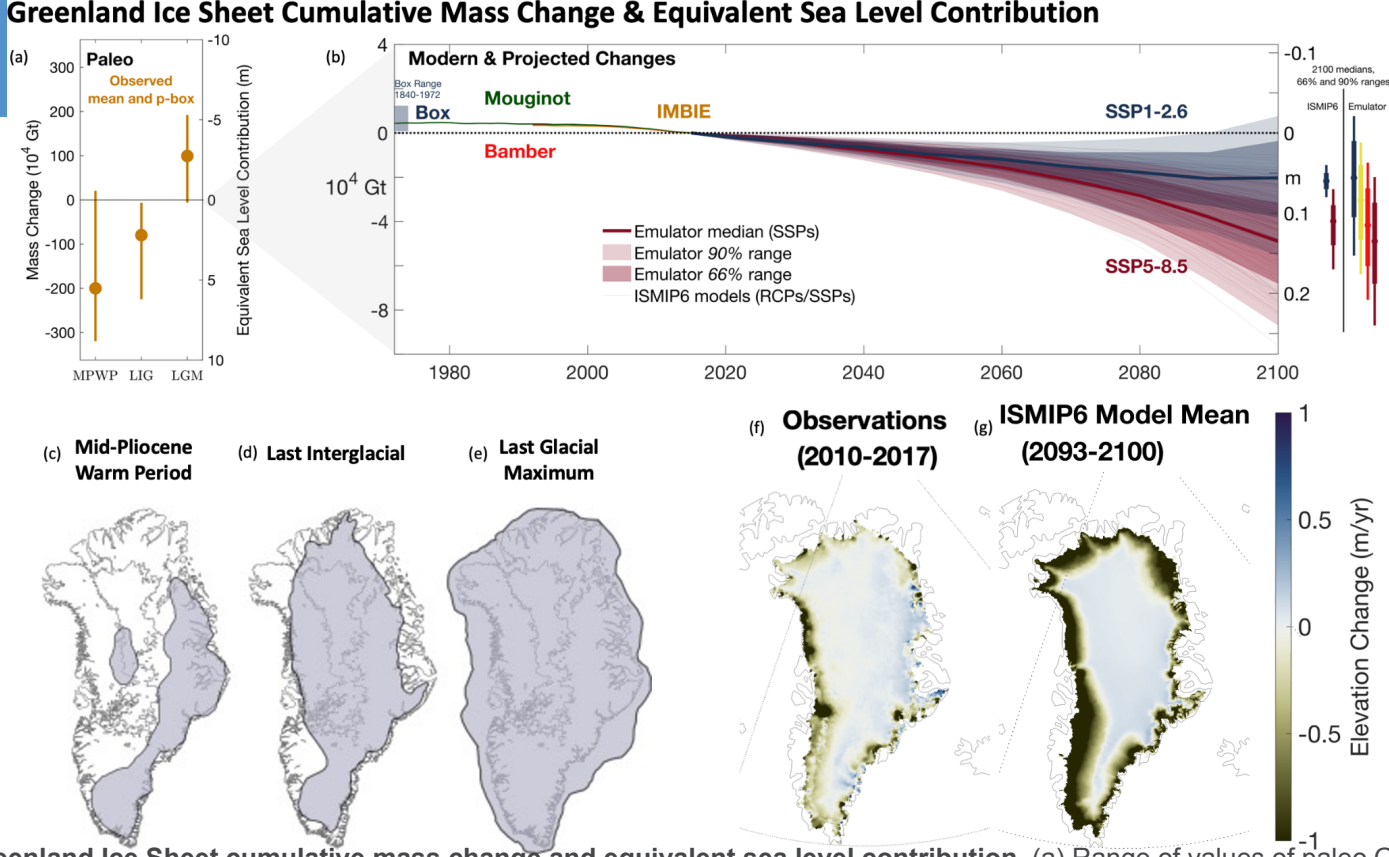
Sea Surface Temperature (SST) and its changes with time.

Sea Surface Temperature (SST) Anomalies and Maps

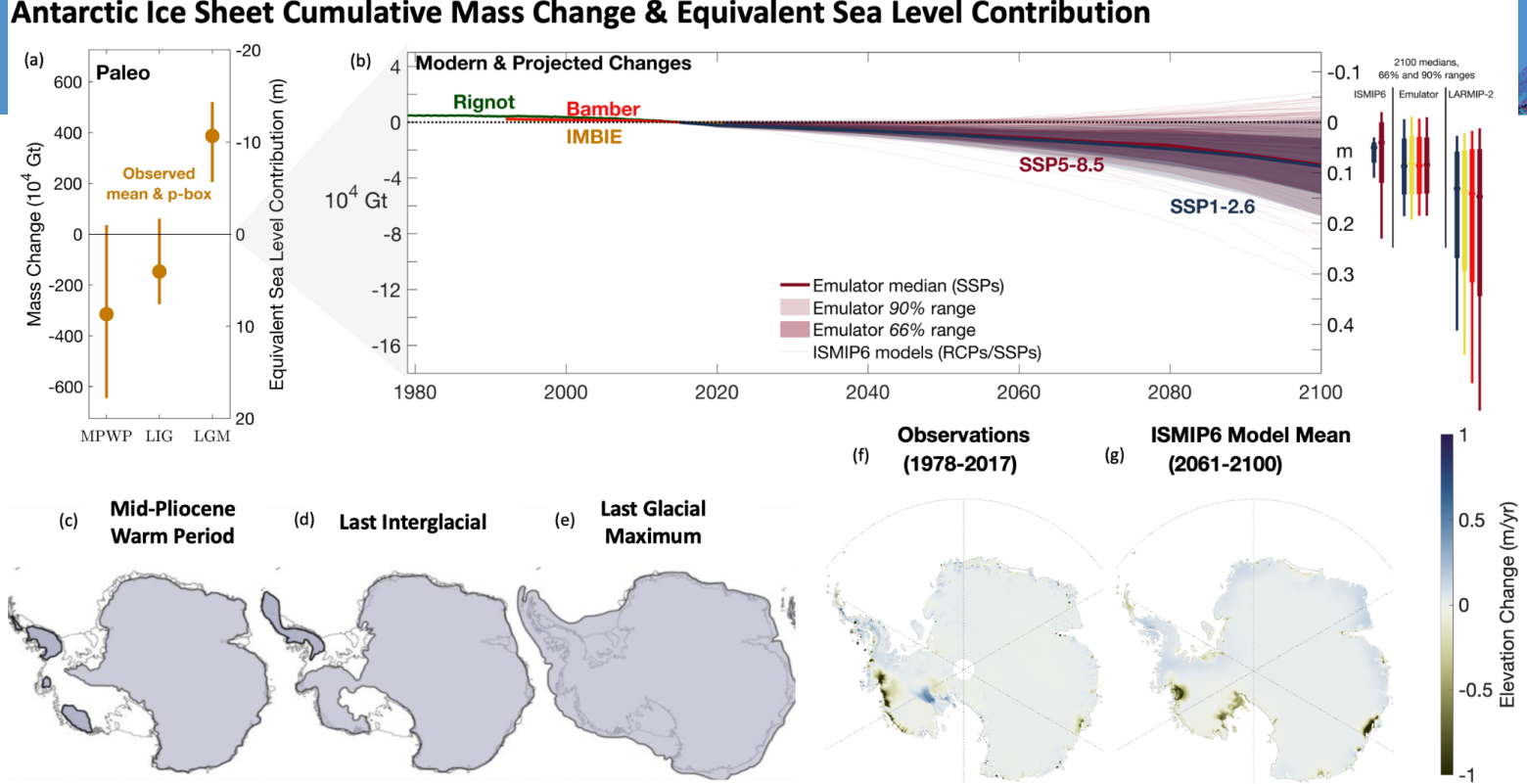
Observation-based estimates and CMIP6 multi-model means, biases and projected changes



Warming over oceans is slower than over land.



Greenland Ice Sheet cumulative mass change and equivalent sea level contribution. (a) Range of values of paleo Greenland ice sheet mass and sea level equivalents relative to present day and the median. (b) Cumulative mass loss (and sea level equivalent) from 1972 and 1992, the estimated mass loss from 1840 indicated with a shaded box and projections from ISMIP6 by 2100 under 2 scenarios and likely range of the ISMIP6 emulation are shown. (c-e) Schematic interpretations of individual reconstructions of the spatial extent of the Greenland ice sheet, grey shading shows extent of grounded ice. Maps of mean elevation changes (f) 2010-2017 derived from CryoSat 2 radar altimetry and (g) ISMIP6 model mean (2093-2100) projected changes for the MIROC5 climate model under the RCP8.5 scenario.



Antarctic Ice Sheet cumulative mass change and equivalent sea level contribution. (a) A p-box (Section 9.6.3.2) based estimate of the range of values of paleo Antarctic ice sheet mass and sea level equivalents relative to present day and the median over all central estimates. (b) Cumulative mass loss (and sea level equivalent) since 2015, with satellite observations shown from 1993 and observations from 1979, ISMIP6 projected changes by 2100 under scenarios and 17th to 83rd, 5th to 95th percentile ranges of the ISMIP6 emulation, with 17th to 83rd, 5th to 95th percentile ranges for ISMIP6, emulator, and LARMIP-2 including SMB at 2100. (c-e) Schematic interpretations of individual reconstructions of the spatial extent of the Antarctic ice sheet, grey shading shows extent of grounded ice. Maps of mean elevation changes (f) 1978-2017 derived from multi-mission satellite altimetry and (g) ISMIP6 (2061-2100) projected changes for an ensemble using the NorESM1-M climate model under the RCP8.5 scenario.