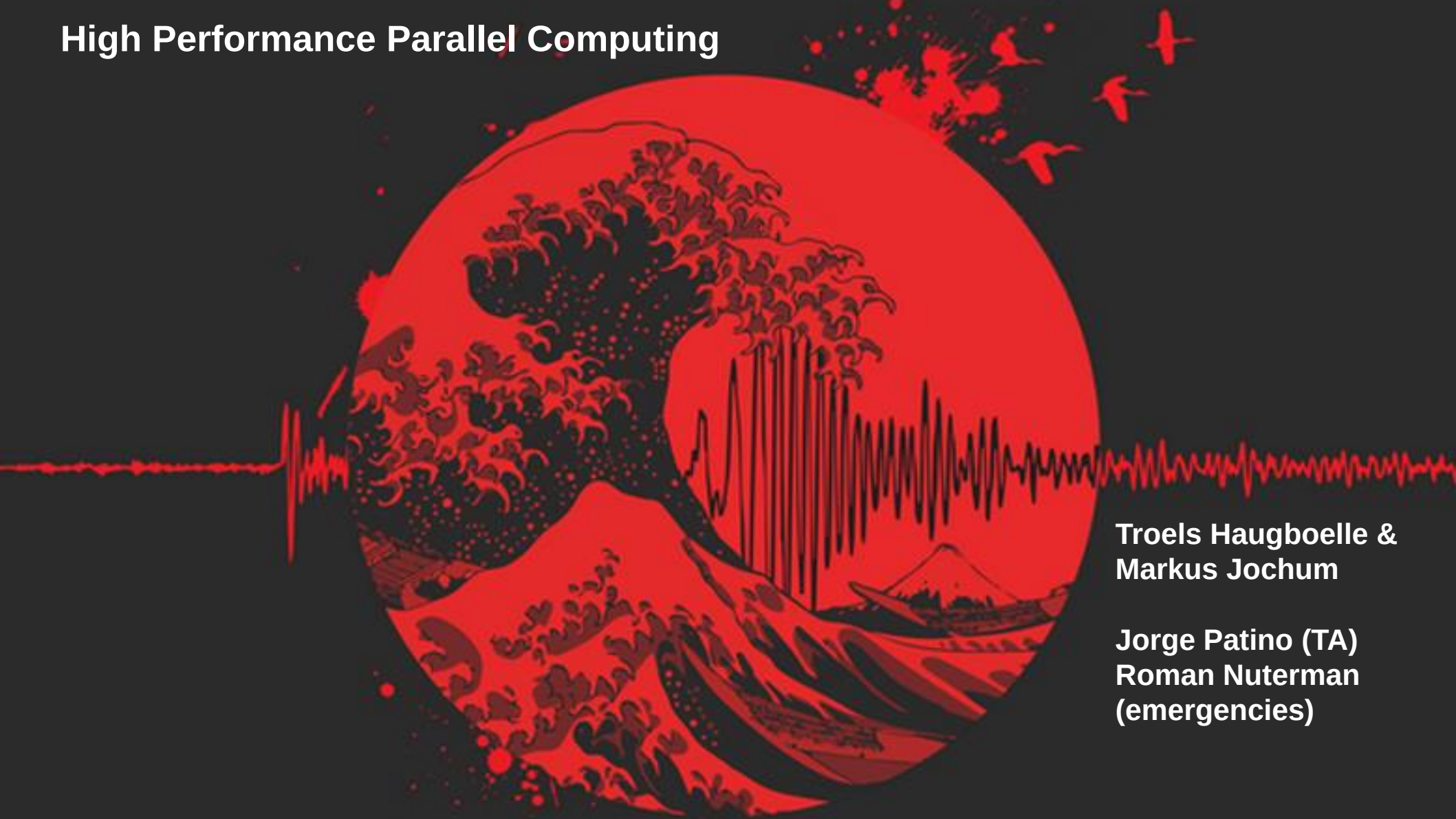
High Performance Parallel Computing

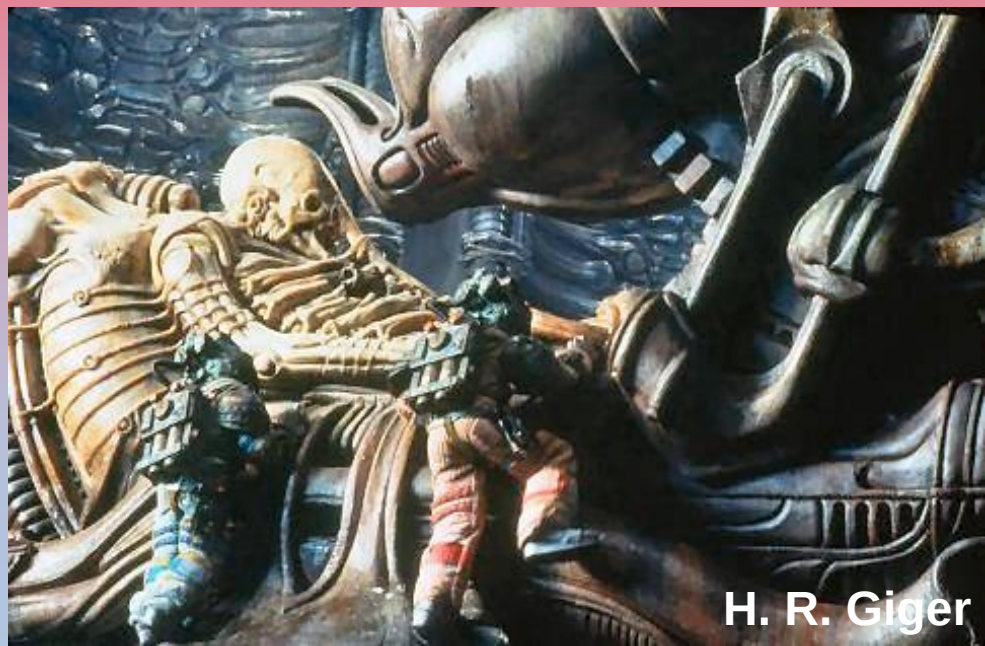


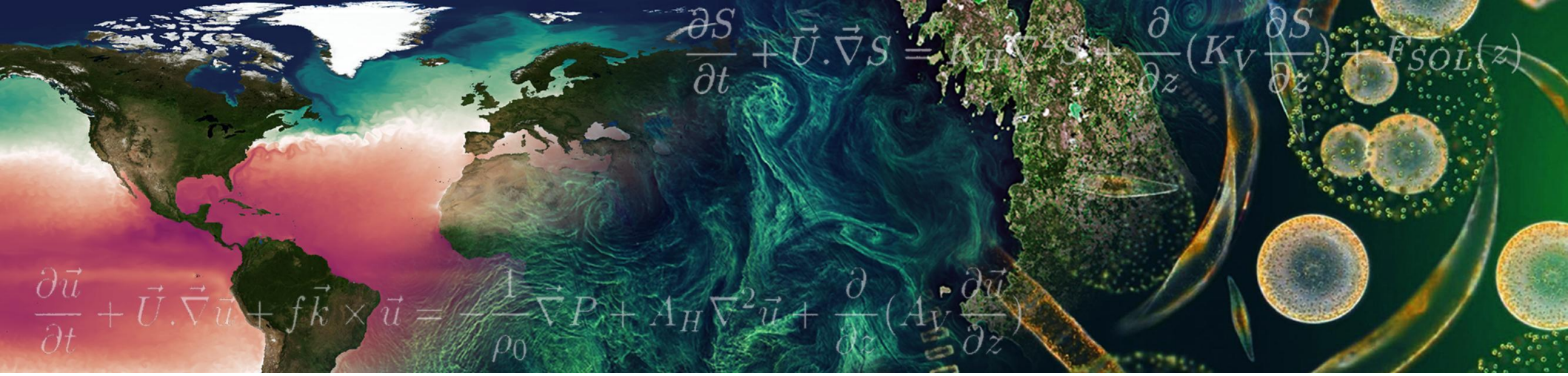
Troels Haugboelle &
Markus Jochum

Jorge Patino (TA)
Roman Nuterman
(emergencies)

Why do physicists need HPPC?

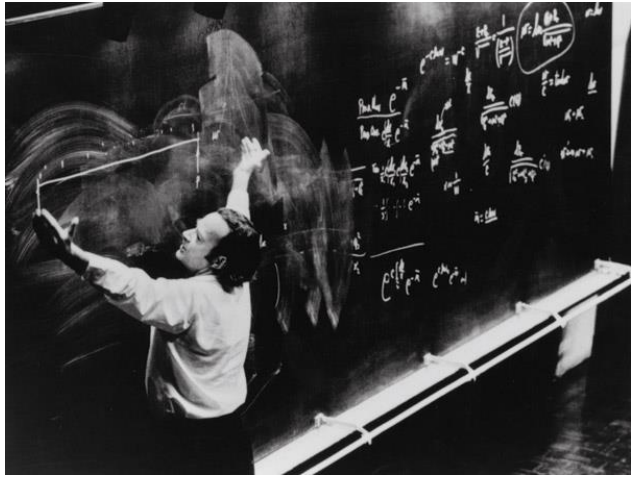
- data analysis and visualization
- pattern recognition or machine learning
- ***in silico* experiments or digital twins**





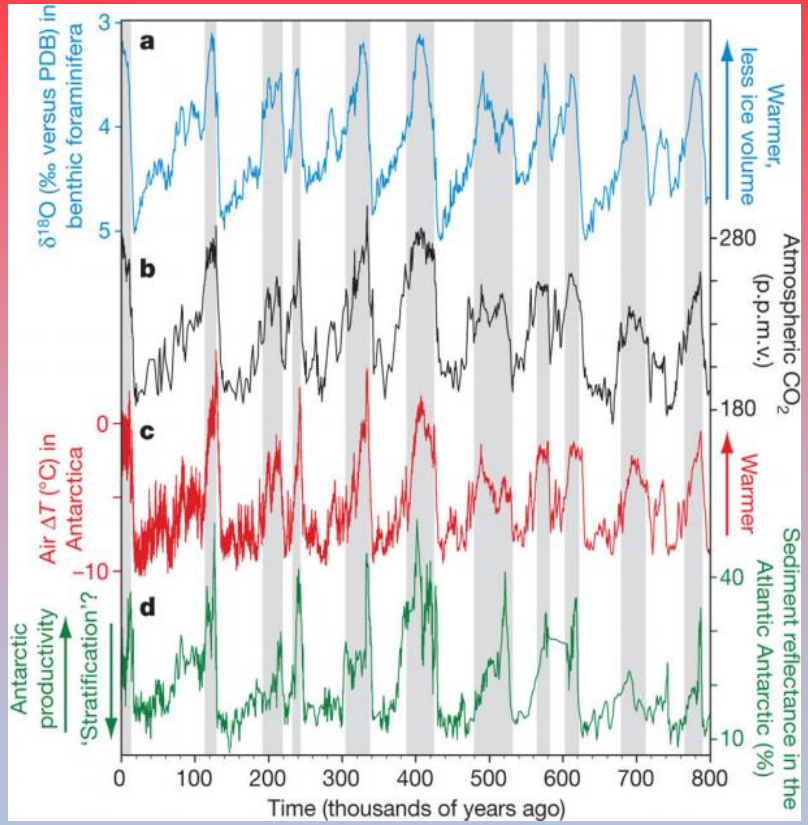
Earth as an example of a Silicon World

- we do not understand climate or CO2
- computer simulations of climate
- the turbulence closure problem
- Moore's Law and its discontents
- Solutions!

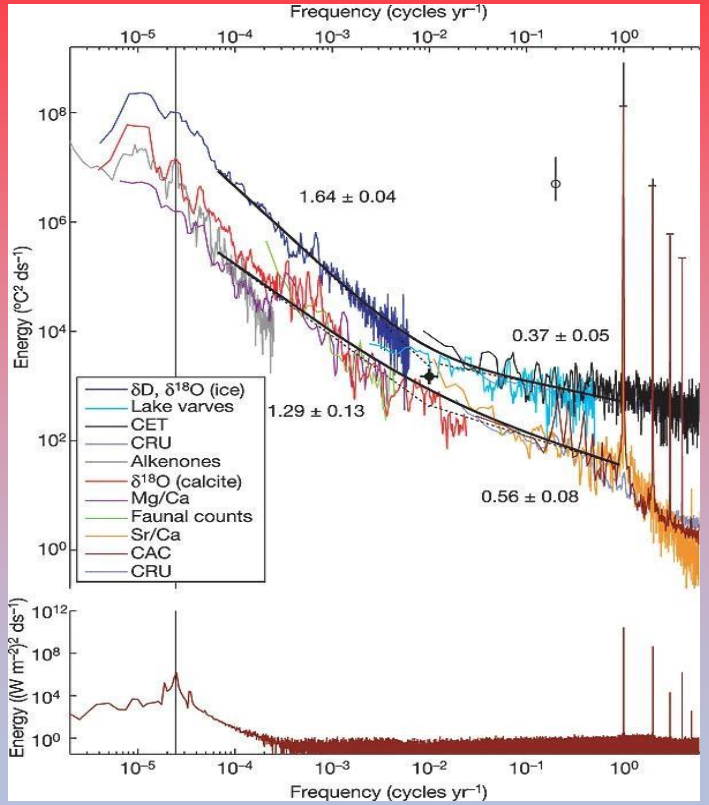


What I cannot build, I do not understand.
(Richard Feynman)

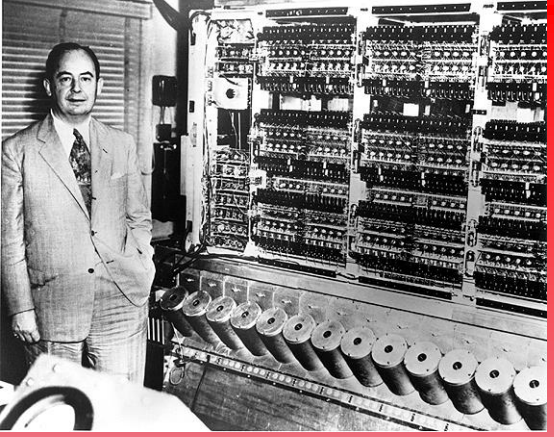
We do not understand the last million years of climate history.



Sigman et al. 2010

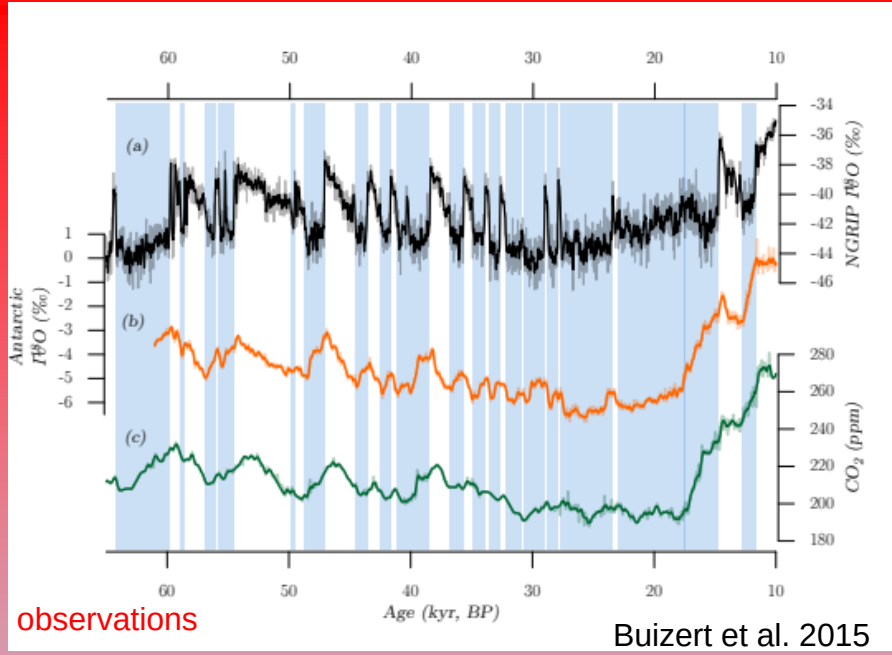


Huybers and Curry 2006



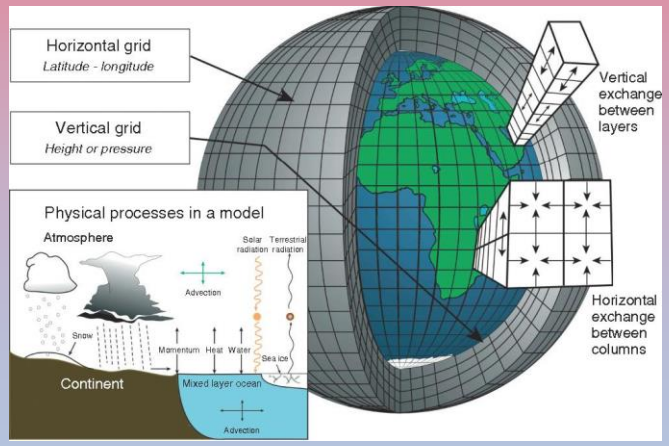
Von Neumann, 1945

From controlling the weather to understanding climate



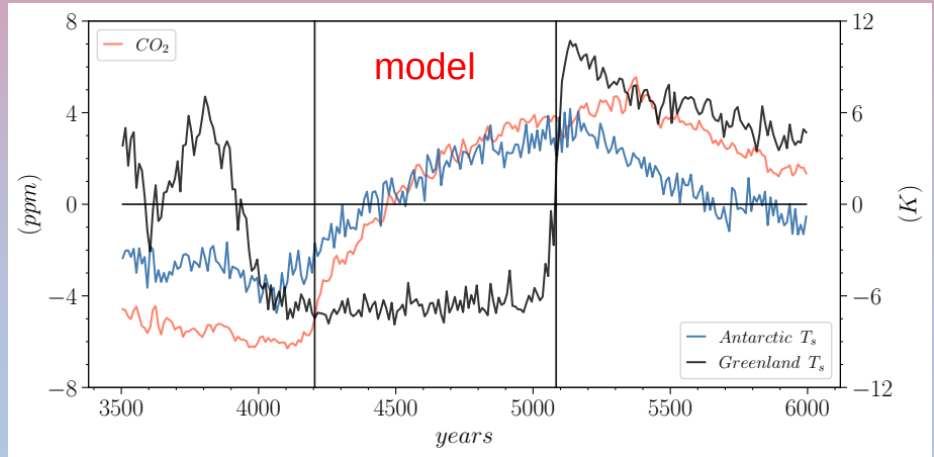
observations

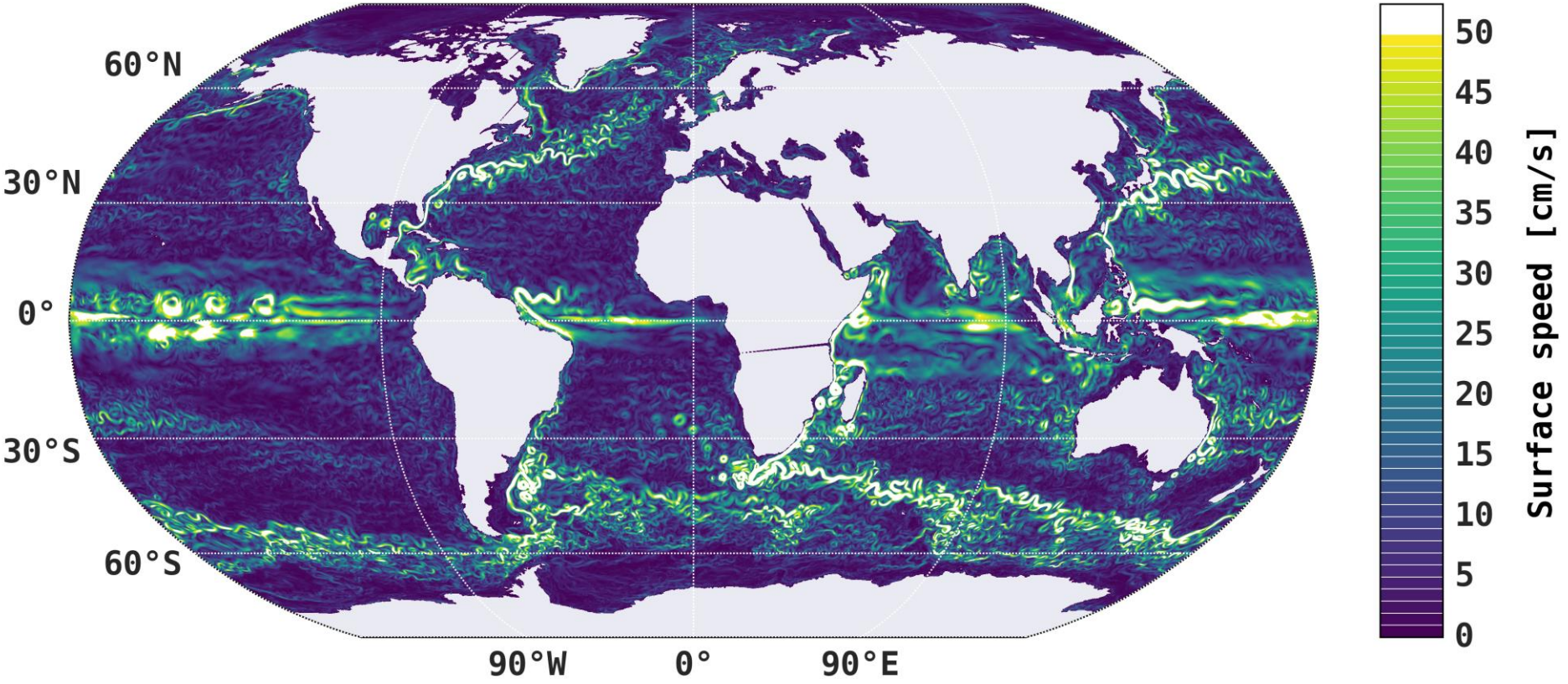
Buizert et al. 2015



Edwards, 2011

Anomalies in CO2 and Greenland and Antarctic temperature

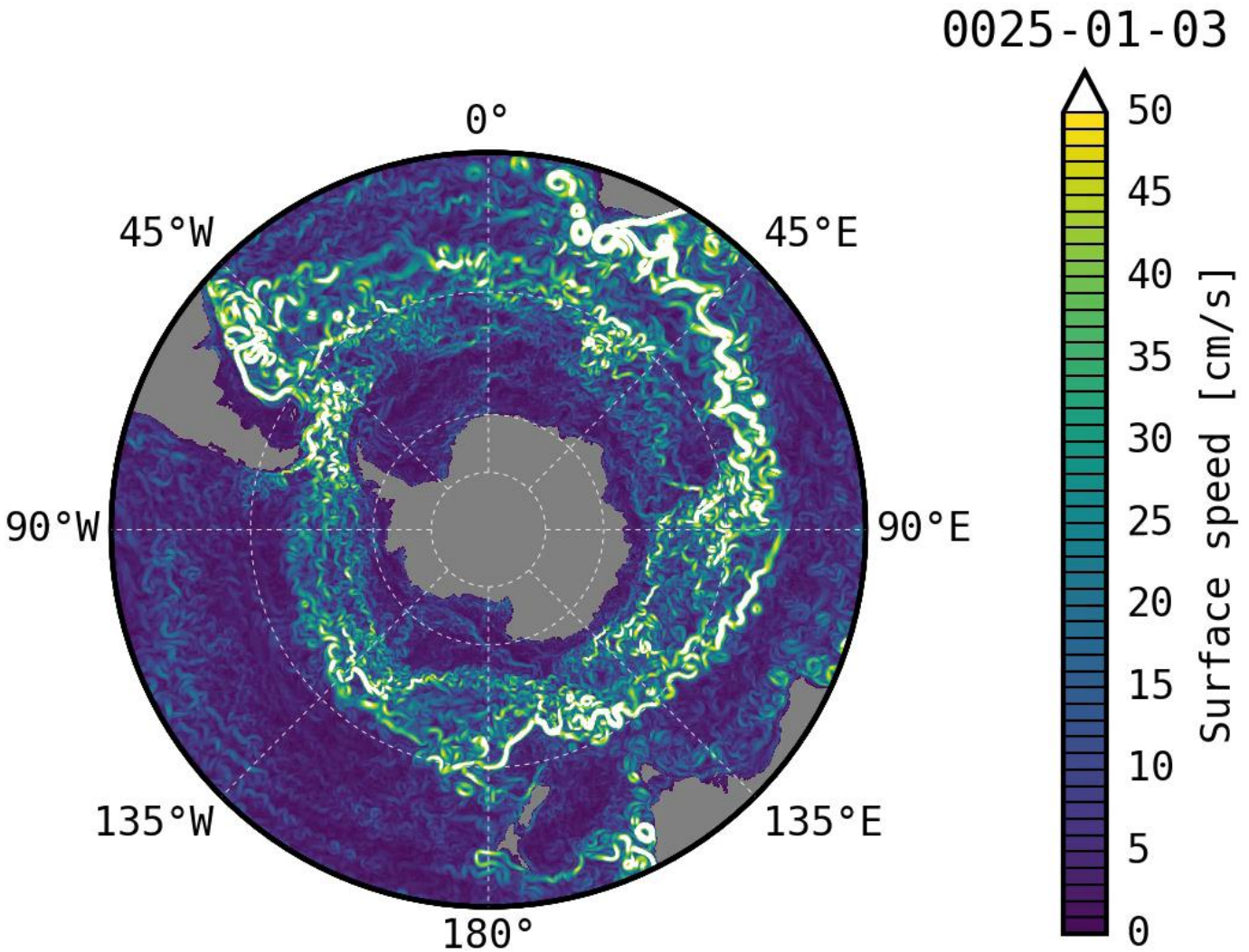




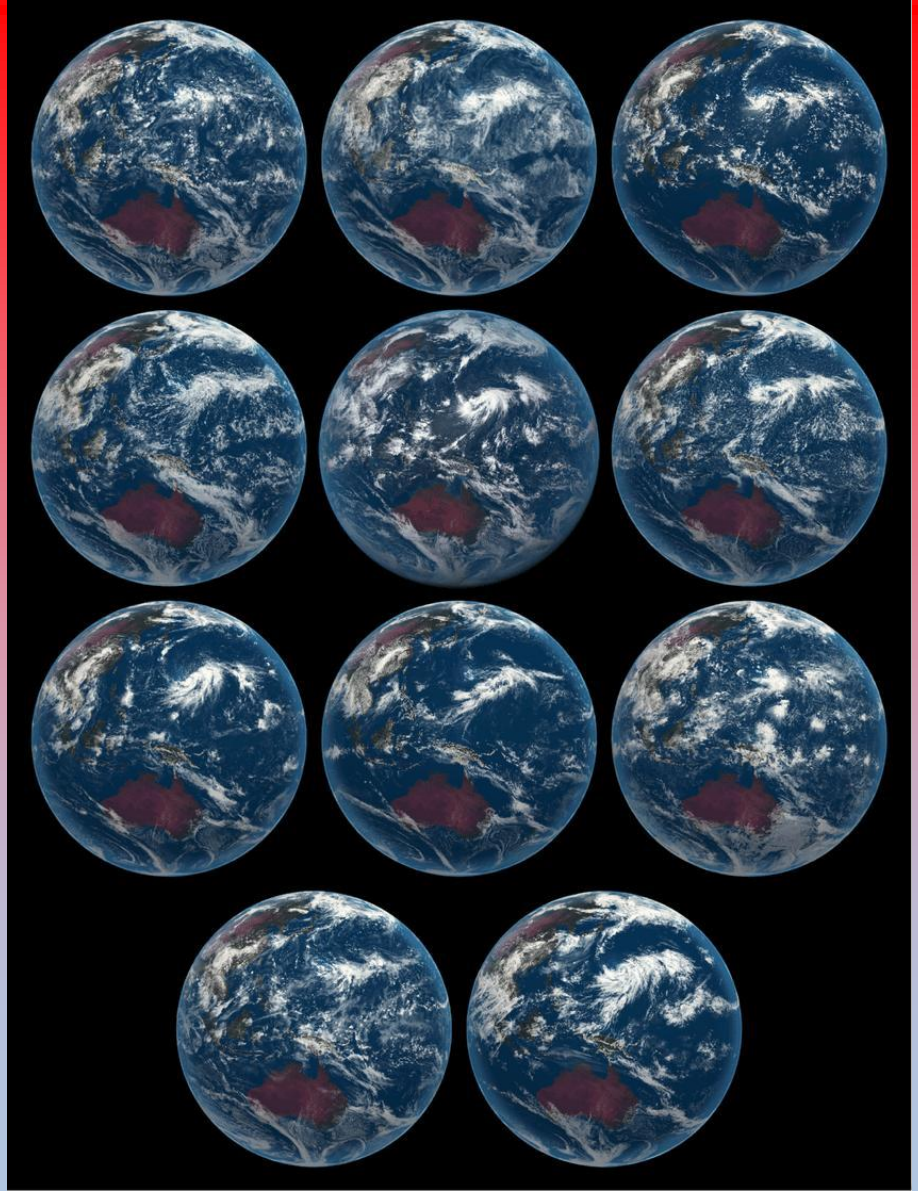
Ocean-Ice configuration of CESM (Poulsen et al. 2018):
1/10 degree, 62 vertical layers, CORE forcing. 3-day means,
1 Tb/day, 0.1 yrs/day on 4096 cores on Juqueen at FZ Juelich

Movie Time!

one of ~1 billion giant squids



A Turing Law for climate models!



Similar work is being done in biology, chemistry, geophysics and astrophysics:

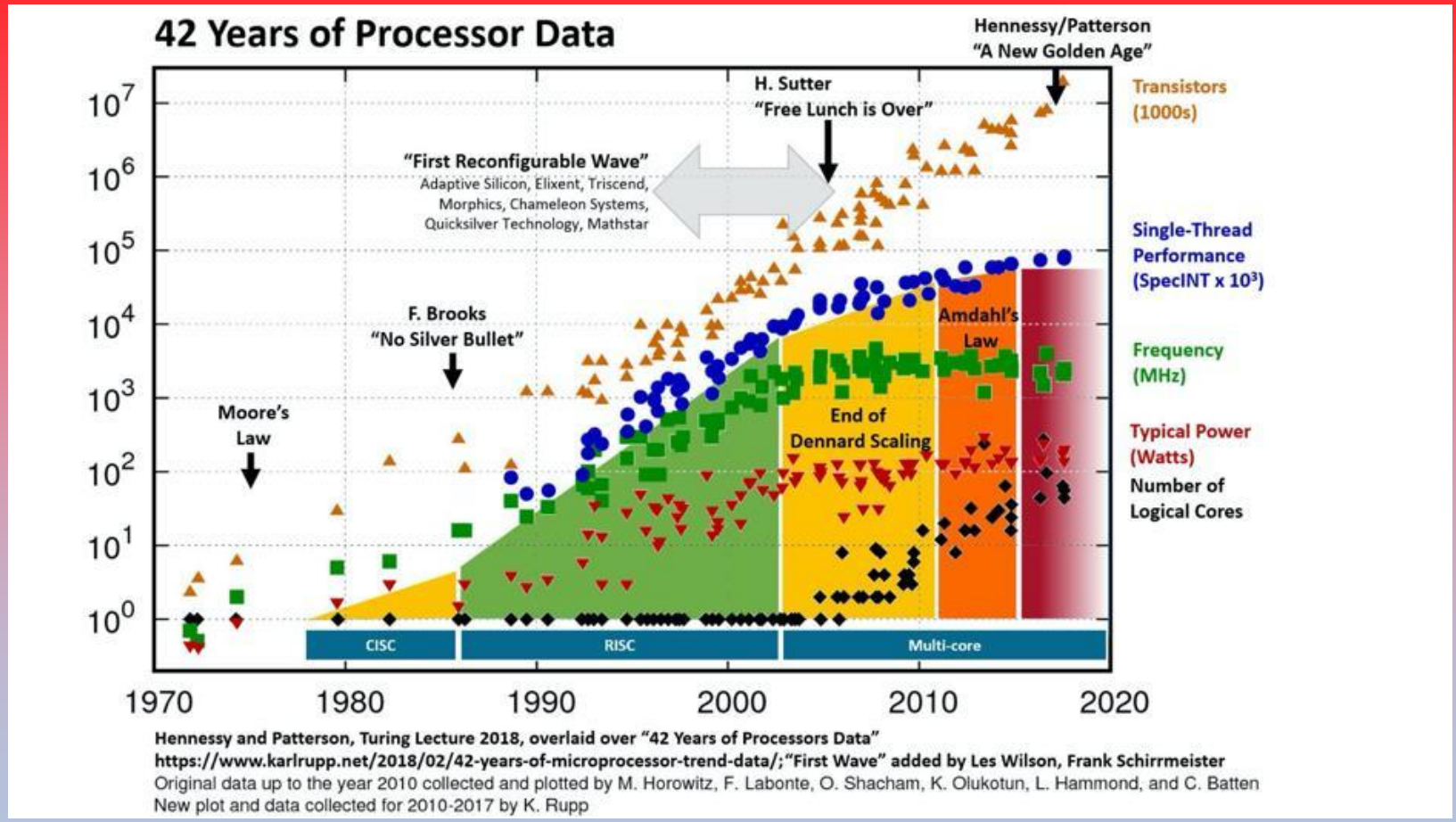
digitalworlds.lundgrafik.dk

100,000 cores, 2 days/ model-week for a coupled model

Stevens et al 2019

The HPC facility of the National Center of Atmospheric Research

150,000 Intel Xeon cores, 320 TB;
Power consumption 8 MW (from coal),
3 of which are for cooling.



Moore's Law and its Discontents

Problems beyond Dennard Scaling

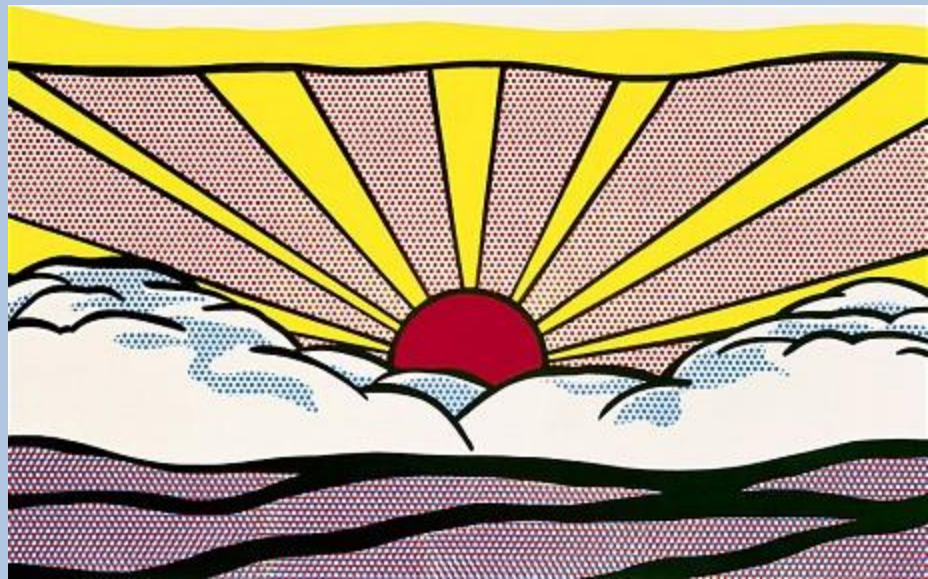
So, what can be done?

- order of magnitude faster and energy efficient chips 

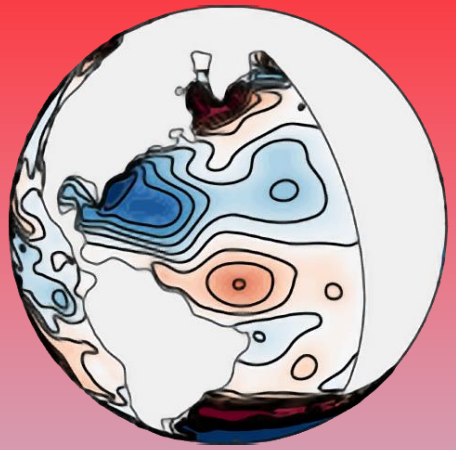
- more intuitive software, plug & publish 

- better data management

- new ideas



The Solution I

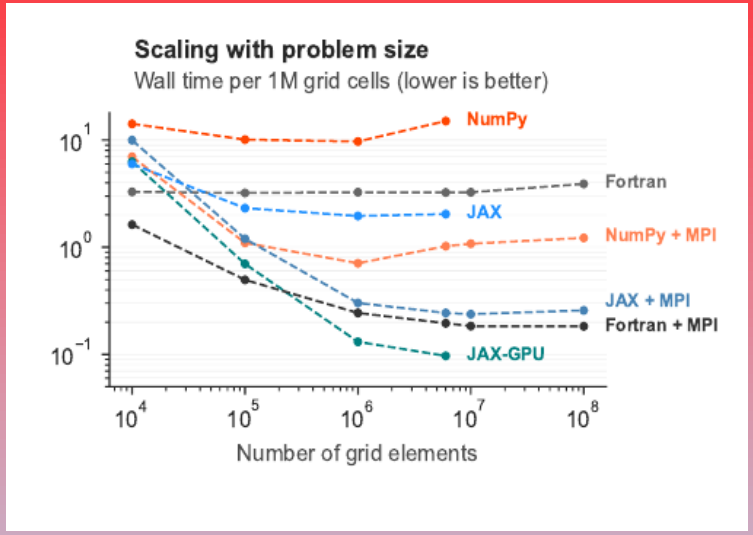
Ver  s

... because the Baroque is over.

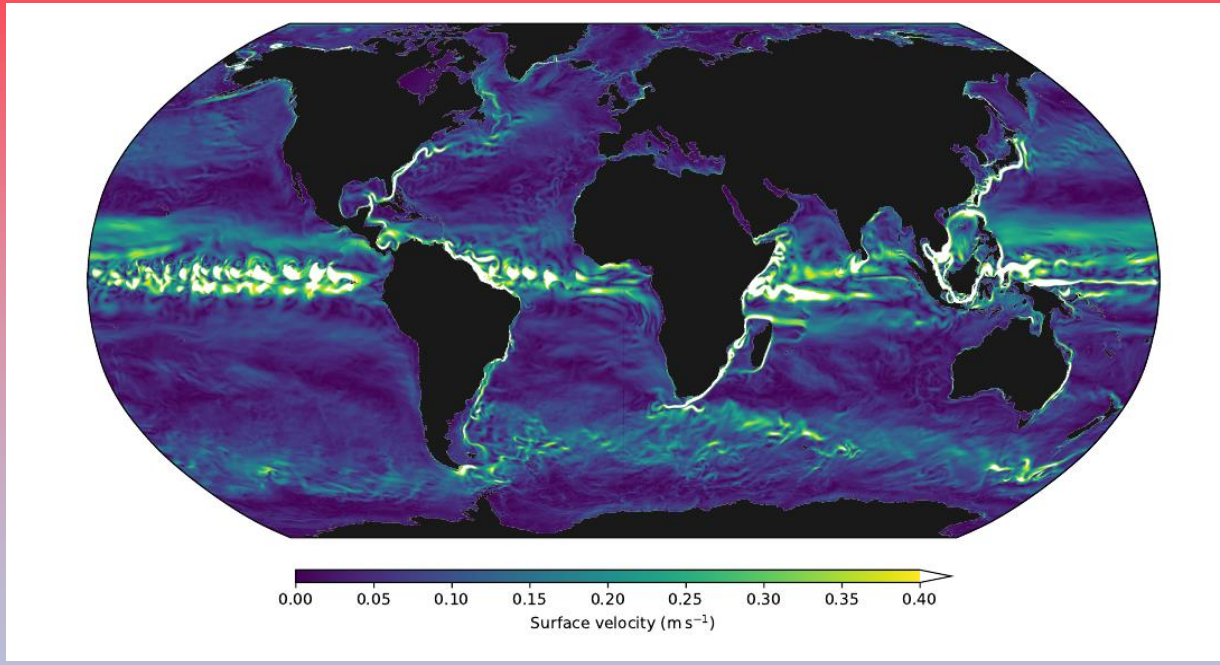
https://veros.readthedocs.io

Versatile Ocean Simulator (VEROS)

...the CRISPR of climate science!



Veros inception, 2016



Fortran on 2000 CPUs or Python/JAX on 16 A100 GPUS
.... at a third of the energy!!!

Haefner et al. 2022

Conclusion: the rate of progress in climate research is determined by the skill with which we can integrate biochemistry, physics & e-science

Worldbuilding at NBI:

Solid Earth:
Klaus Mosegaard

Cells: Weria Peseshkian

Life: Kim Sneppen

Suns & Galaxies: Troels Haugboelle

Oceans: Markus Jochum

The Solution II