Danish National Research Foundation

CENTRE FOR ICE AND CLIMATE

Computational Challenges for Climate Modelling

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with

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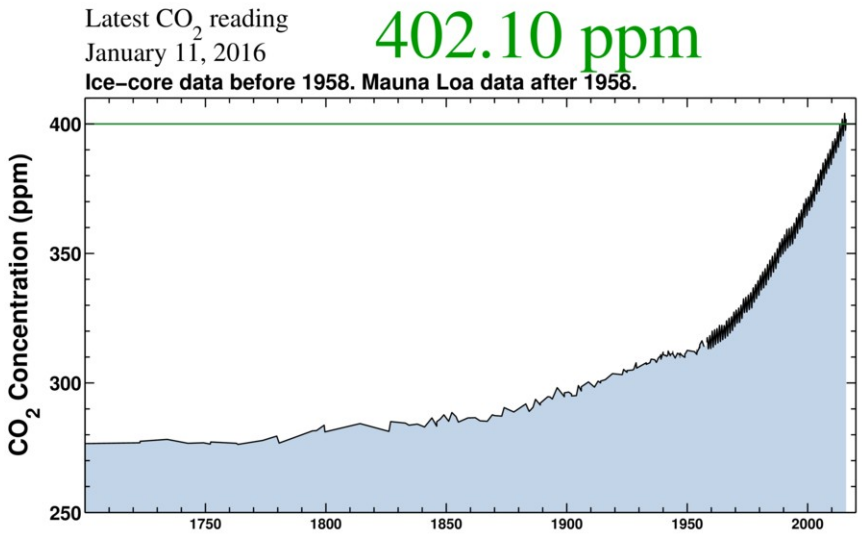
TeamOcean
NBI

Outline



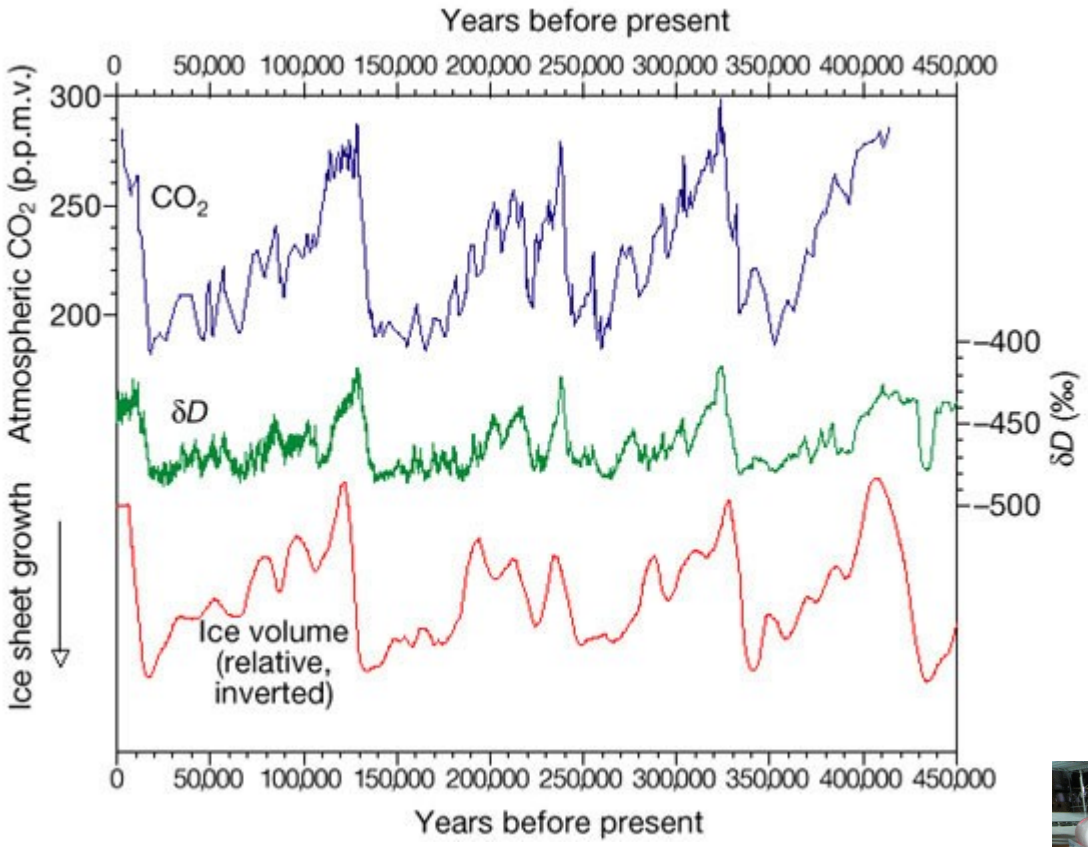
300 years of atmospheric CO2 concentration

NCAR supercomputing, 2012:
Yellowstone, IBM iDataPlex
72,000 cores, 145 TB memory
Computing: 5 MW
Cooling: 3 MW

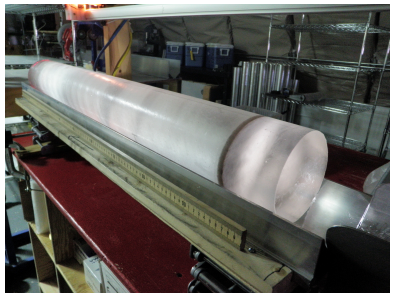
- the climate challenge
- ocean turbulence
- long time scales
- how can you help?

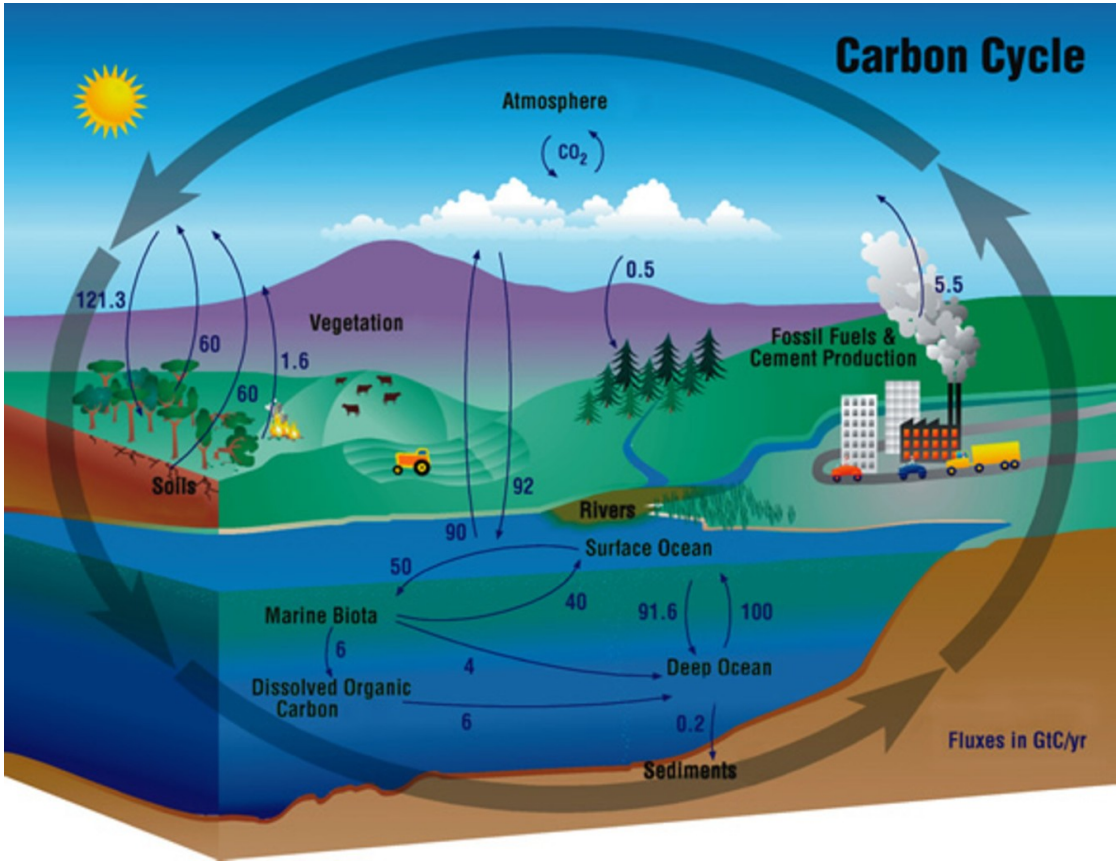
Climate's History

time



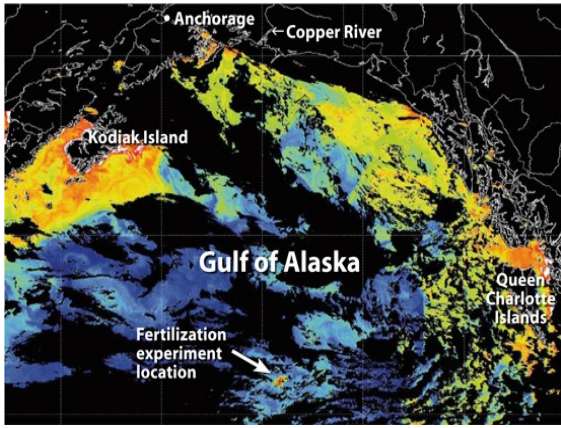
Carbon dioxide, and deuterium/hydrogen ratio from the Vostok Ice core; and global ice volume from sediment cores (inverted). (Sigman & Boyle, 2000)





The Global Carbon Cycle

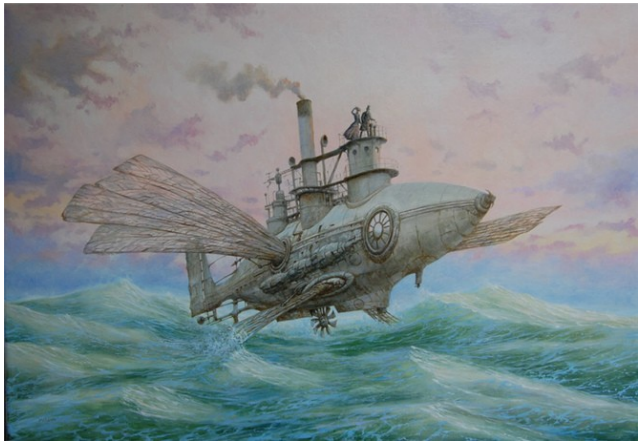
Leading Hypotheses to explain the observed variations in Atmospheric carbon dioxide:

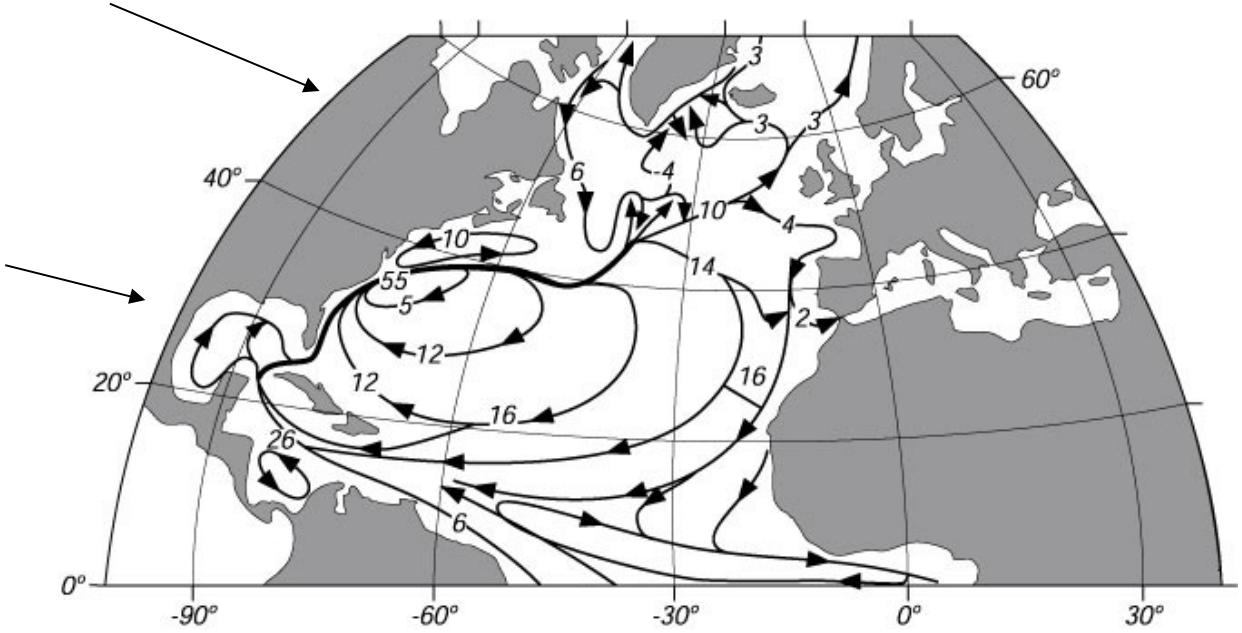


SeaWifS satellite

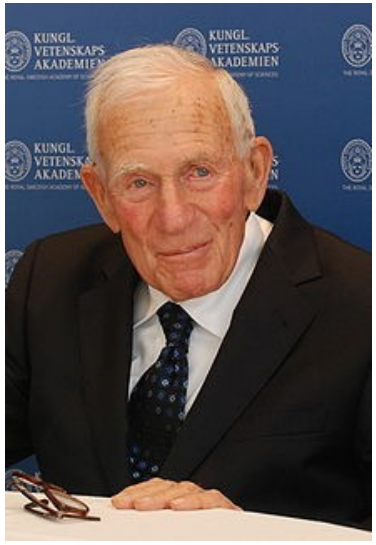
- temperature dependent solubility
- changes in Southern Ocean winds
- dust driven iron fertilization of phytoplankton
- change of biologically productive shelf area
- coral reef driven change of calcium-carbonate concentration
- change in ocean stratification
- interaction between icesheets and volcanism

Physical Oceanography

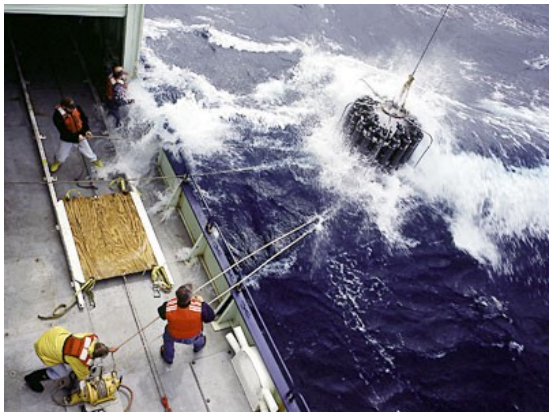




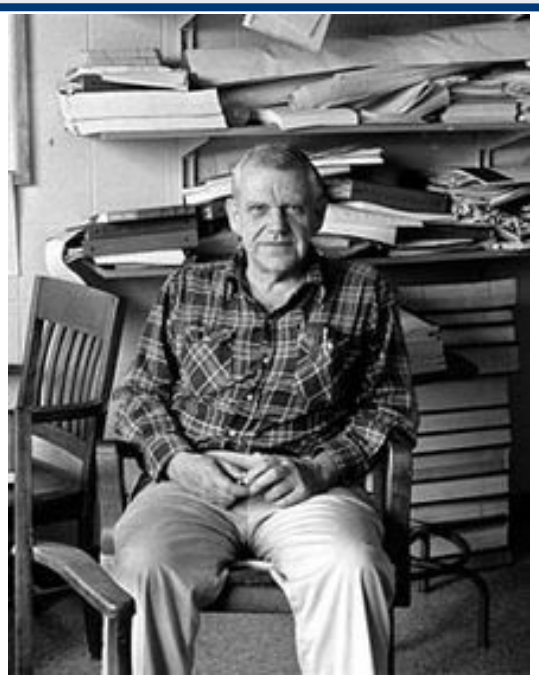
Probing the Unknown



Walter Munk, 1917-

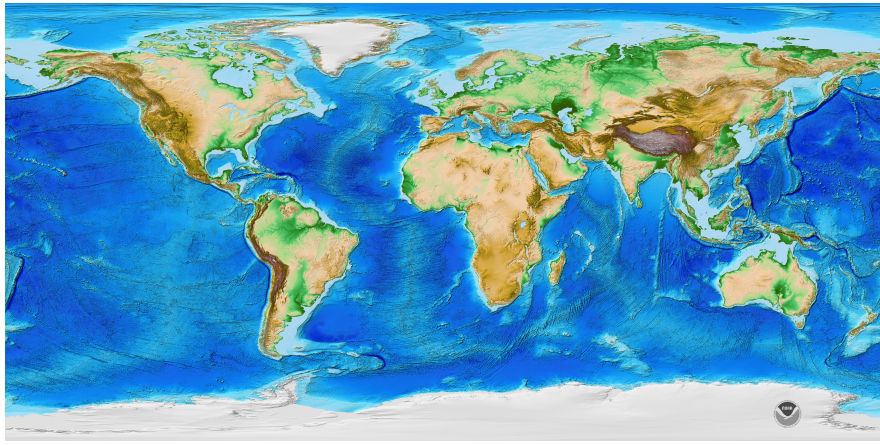


100 yrs of water catching

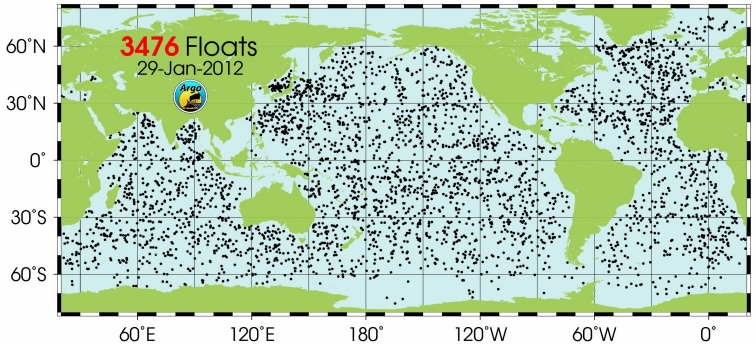


Henry Stommel, 1920-1992

USS San Francisco after crushing into seamount



Real Ocean, Real Men



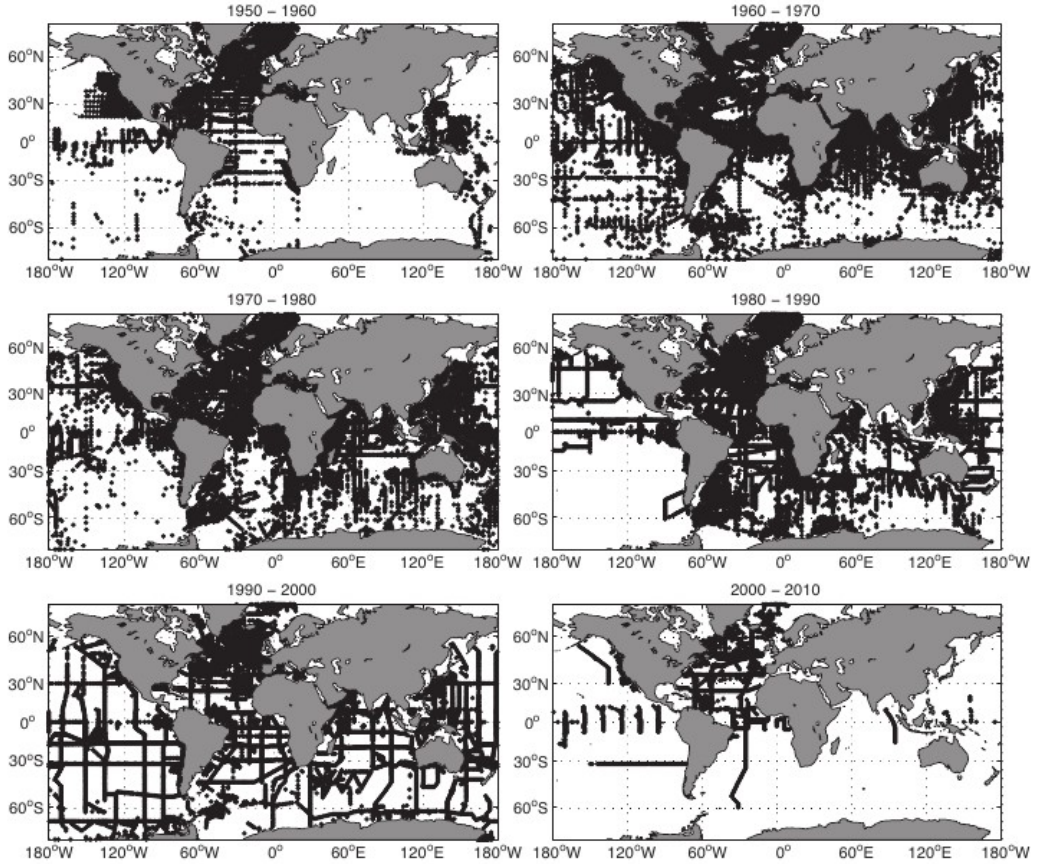
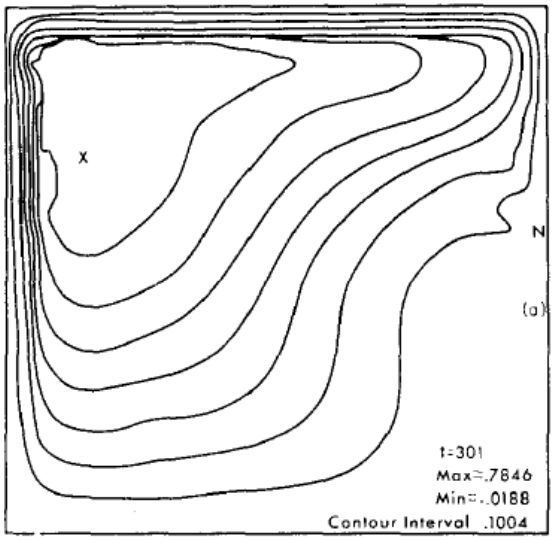
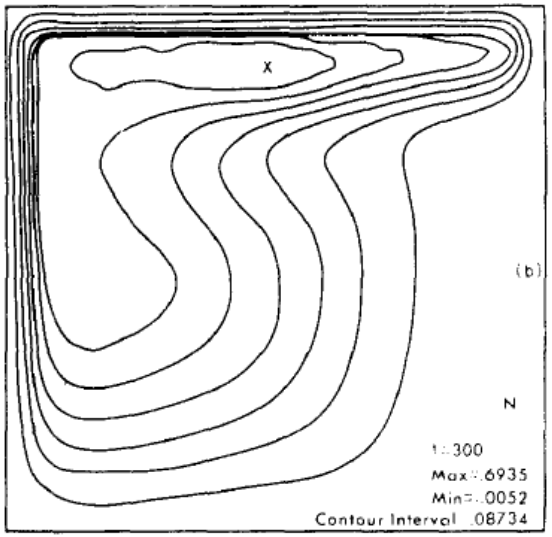
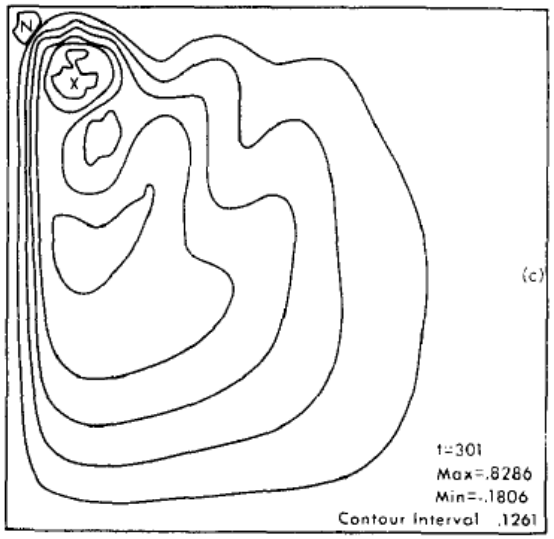


Figure 3.A.6 | Distribution of oxygen measurements at 300 dbar for the decades 1950 to 1960 (upper left) to 2000 to 2010 (lower right frame). (From Stramma et al., 2012.) [Note that additional oxygen data have become available for the 2000–2010 period since that study was completed.]

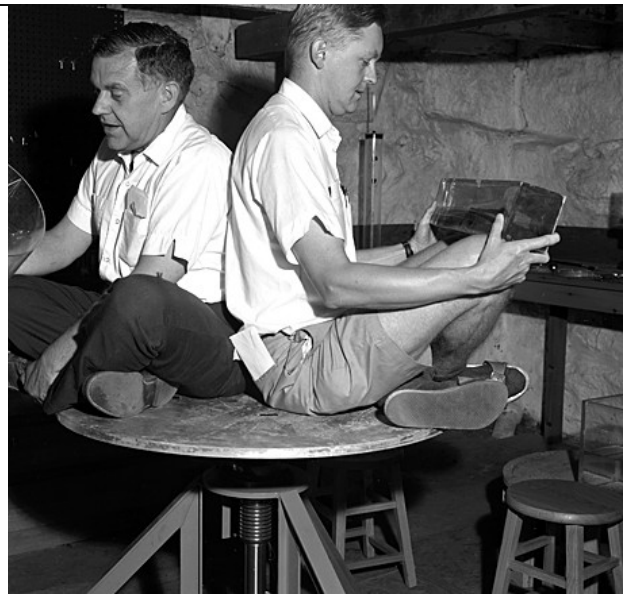
A Mathematician's Ocean



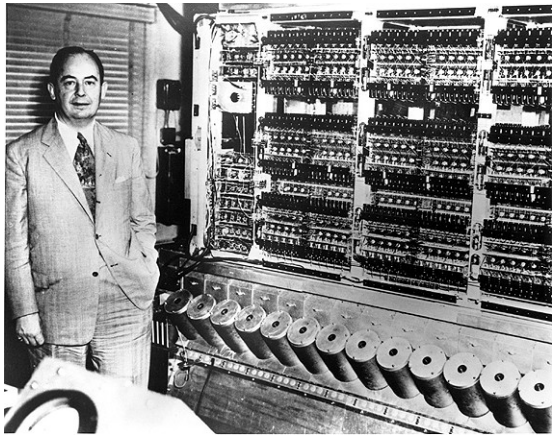




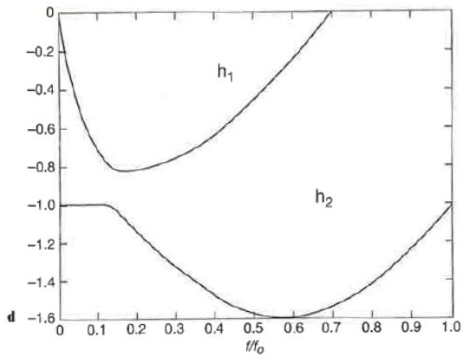
Blandford '71

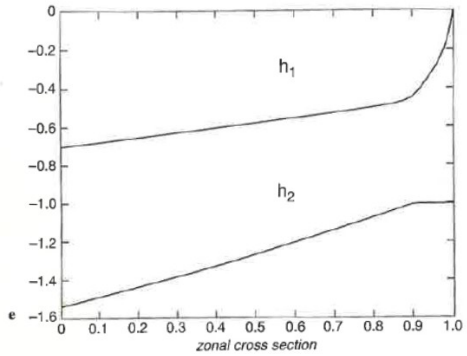


Stommel & Howards



The Golden Age – one big happy family





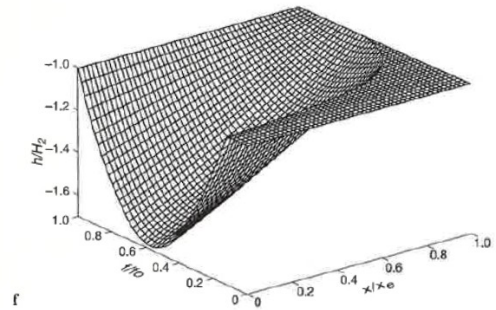
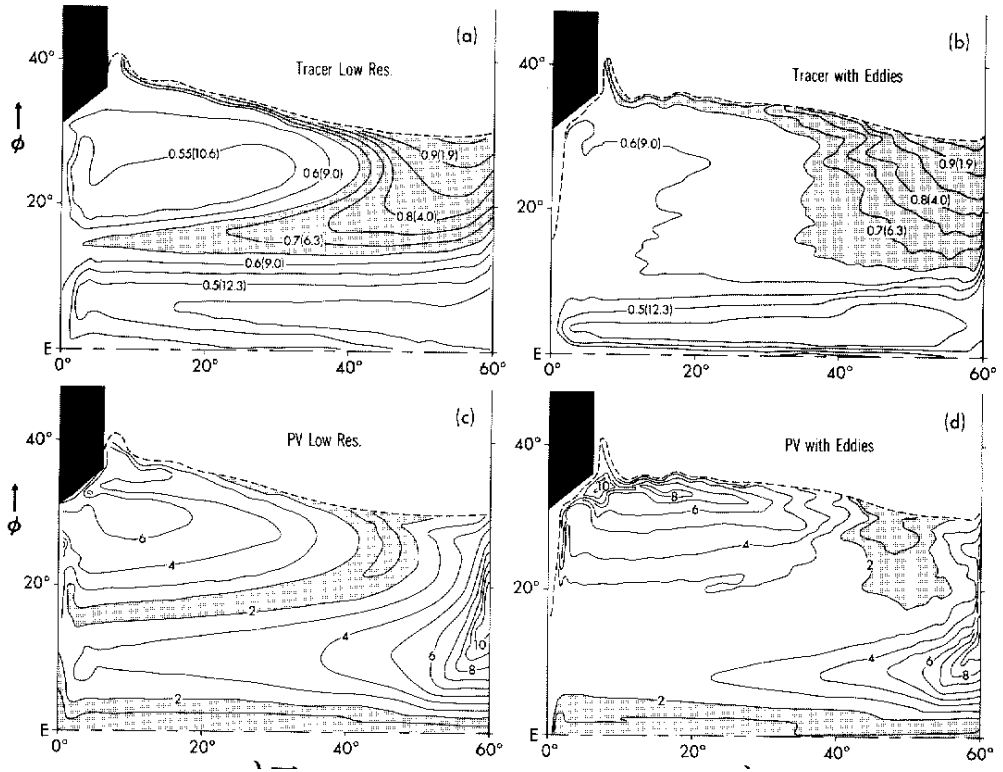
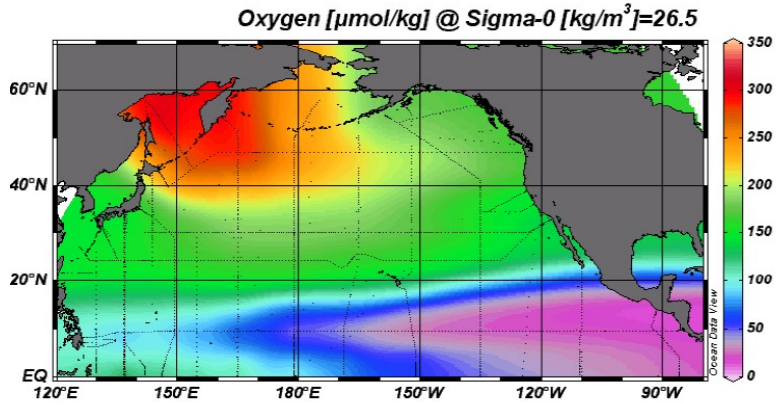


Fig. 4.4.4d–f

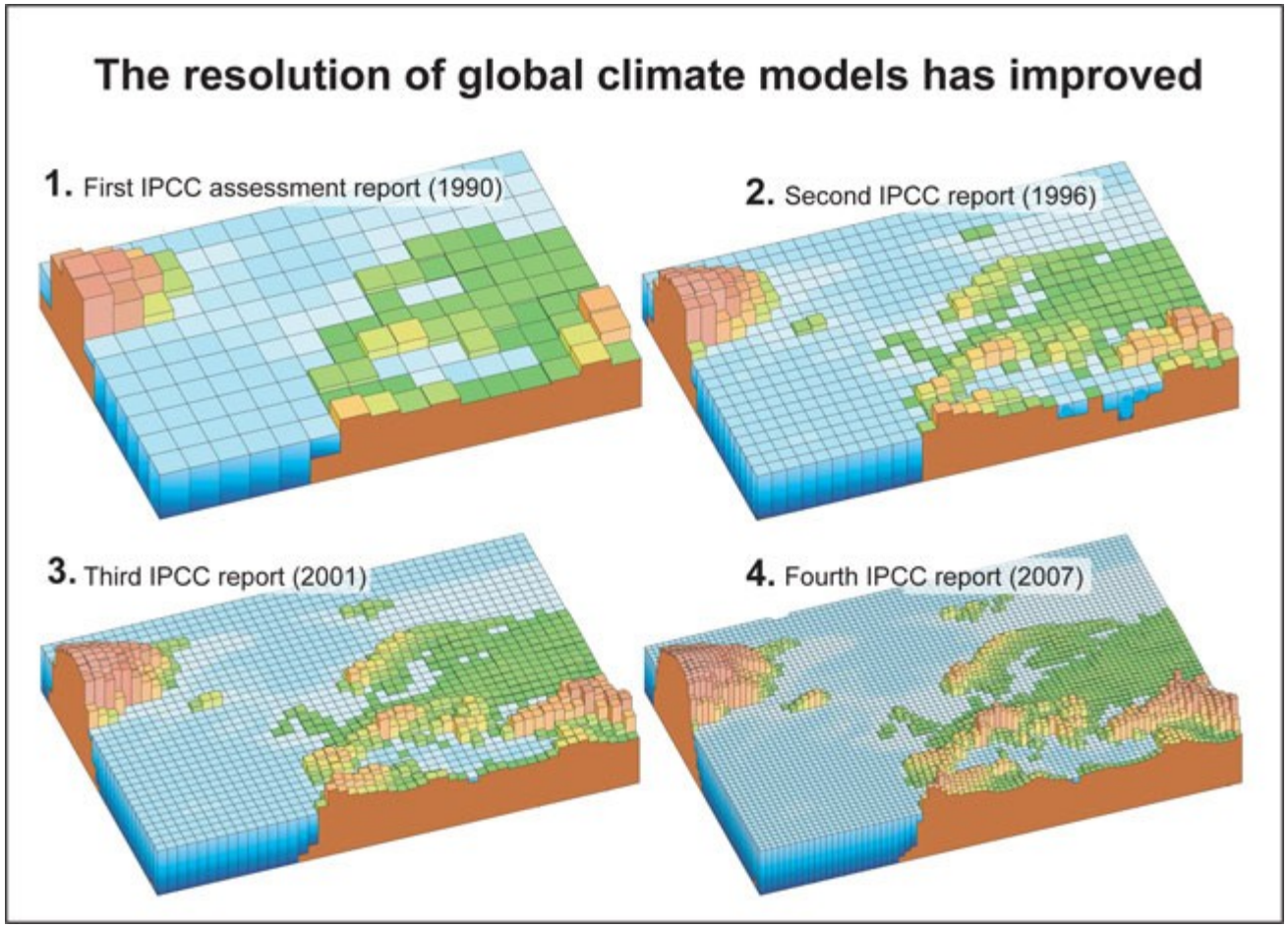
Luyten et al. '83



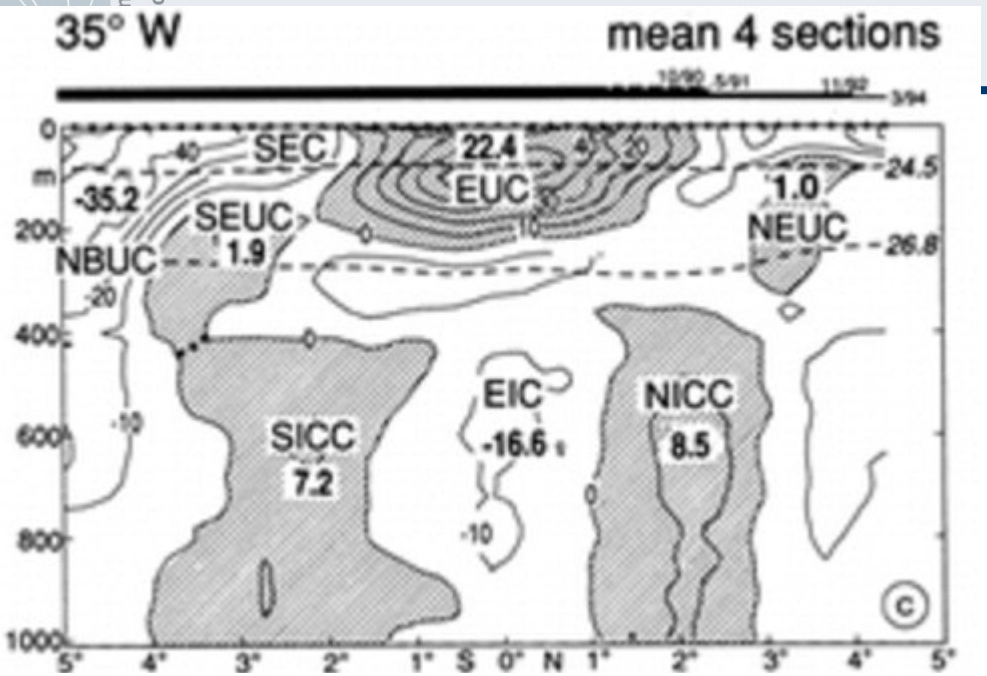
Cox '85



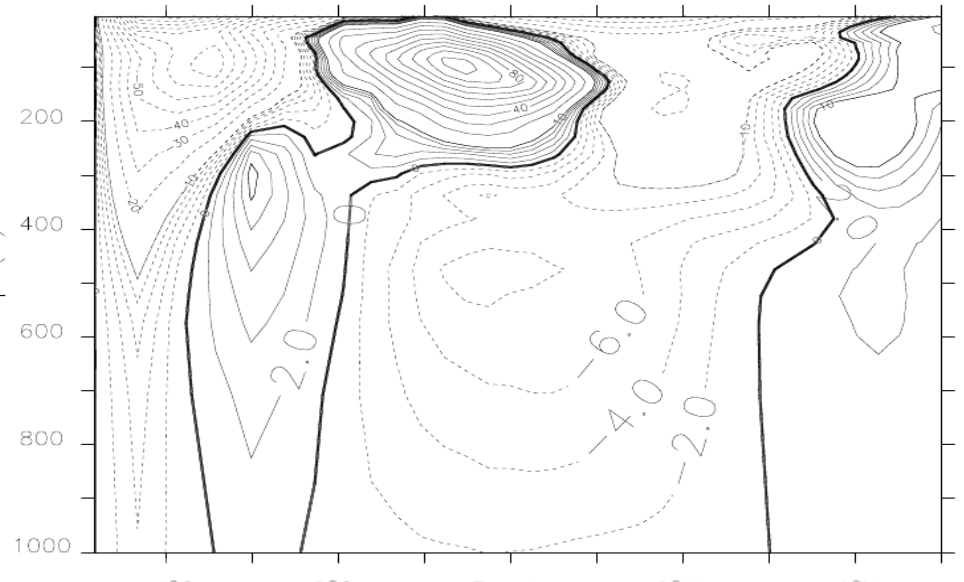
The Rise of the Machine ...



The Case Against Observations I



Observations, Schott et al. '98

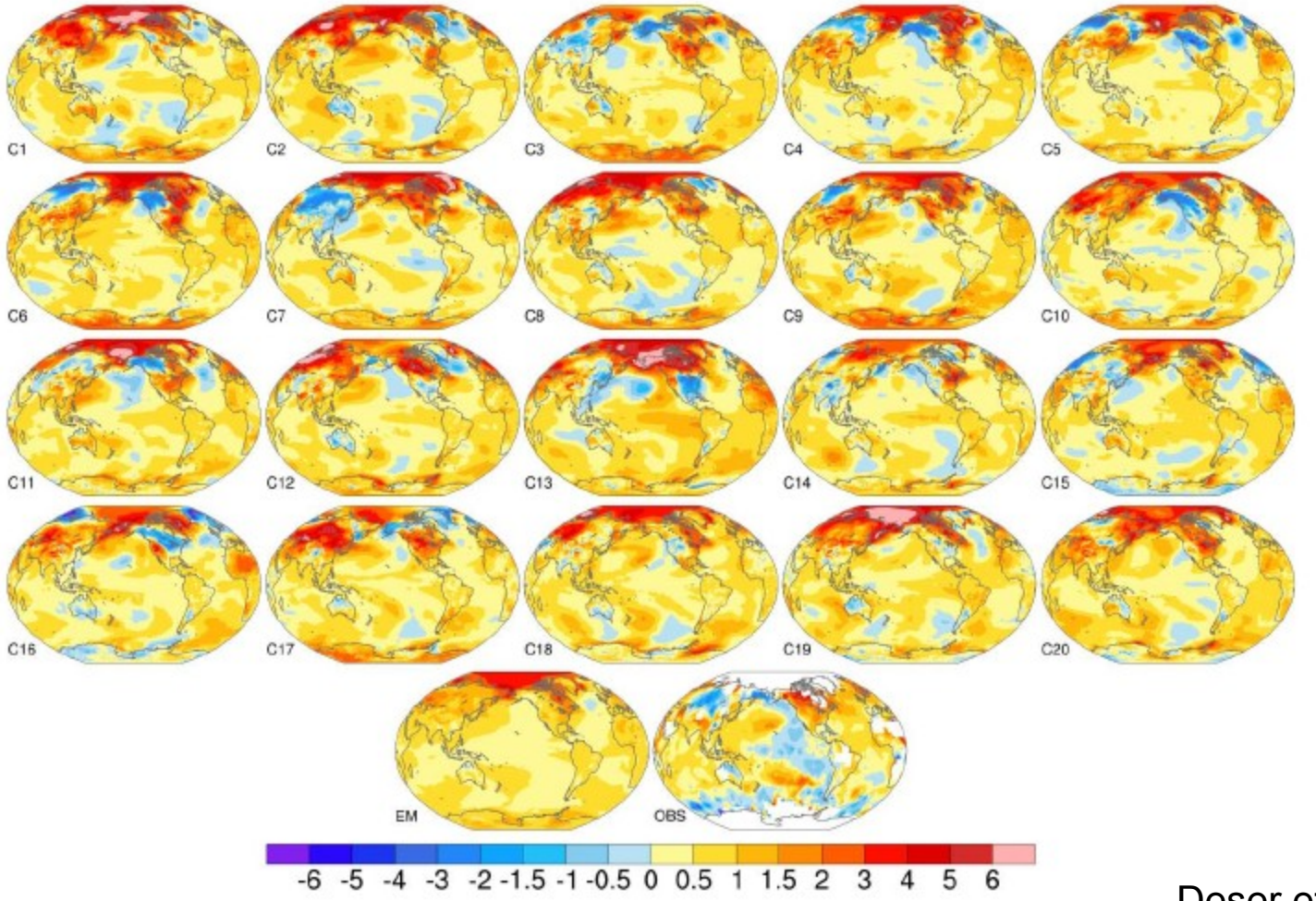


Model, Jochum & Malanotte Rizzoli '03

The Case against Observations II

The single realization problem

SAT Linear Trends DJF 1979-2012



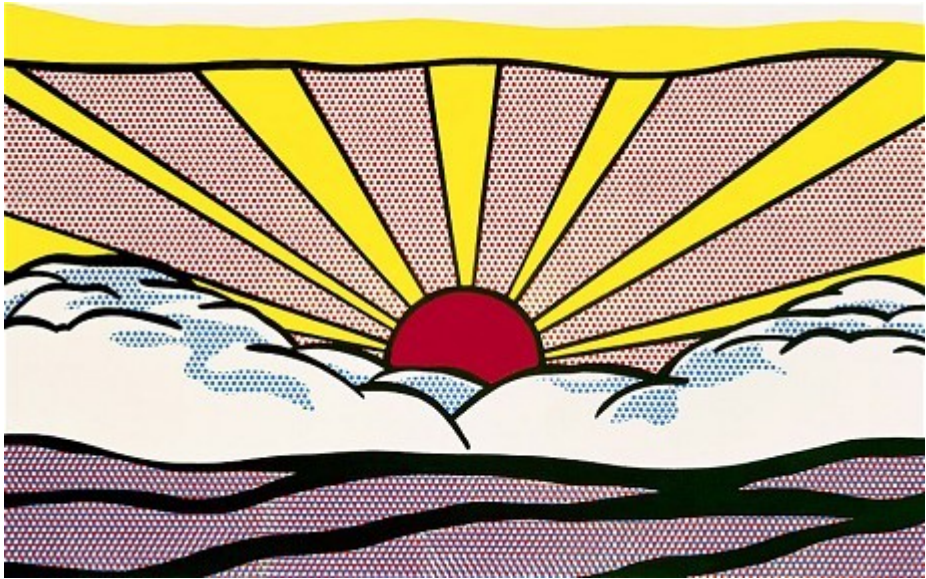
Deser et al.'14

How can you help?

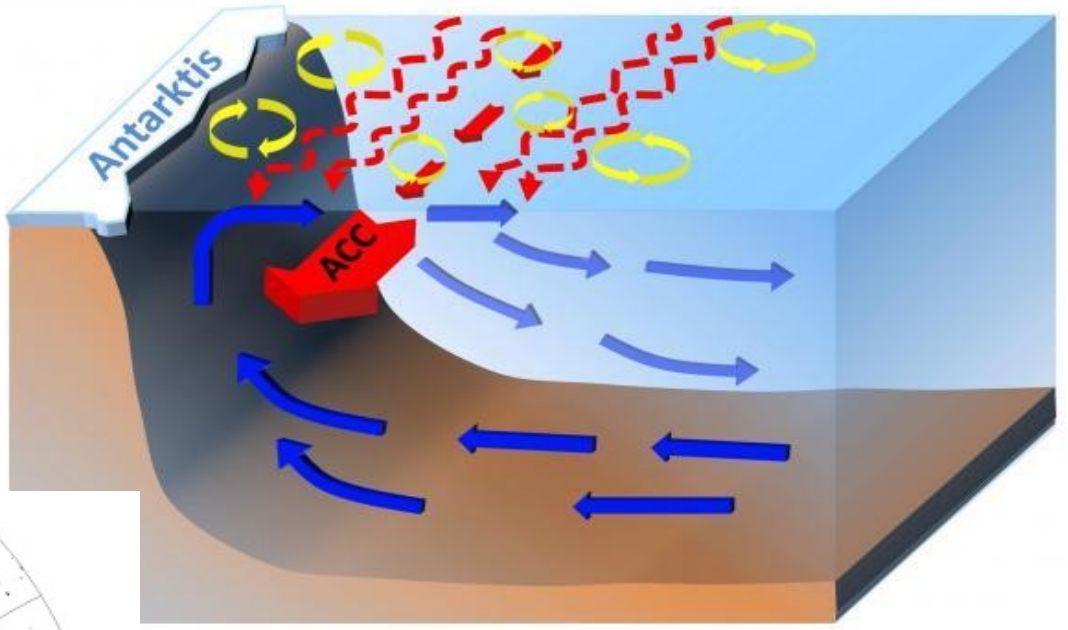
- order of magnitude faster and energy efficient chips

- more intuitive software, plug & publish

- better data managment

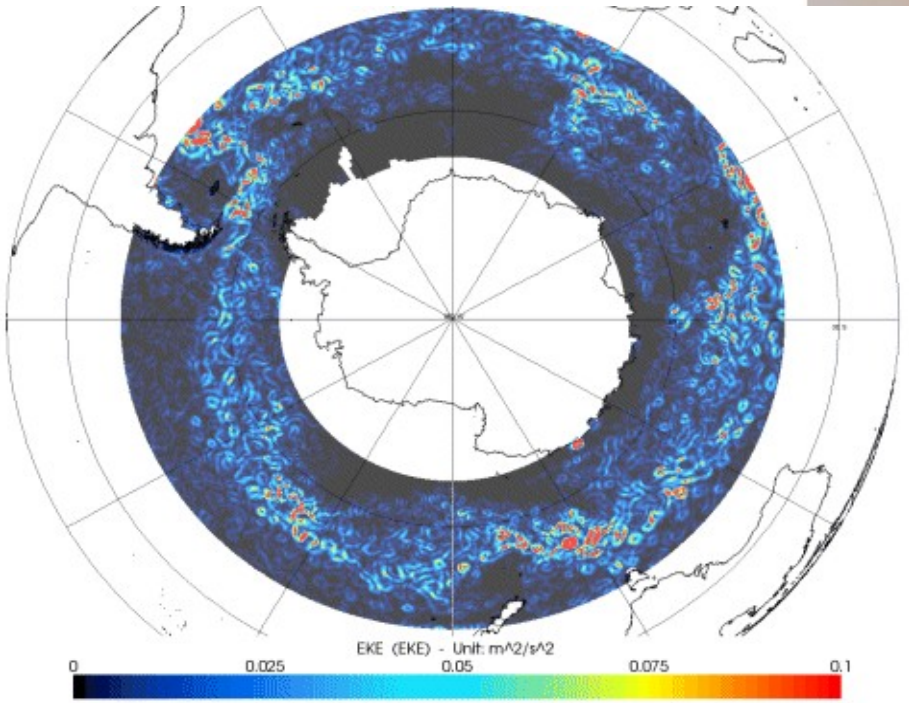


Example: The Southern Ocean Hypothesis



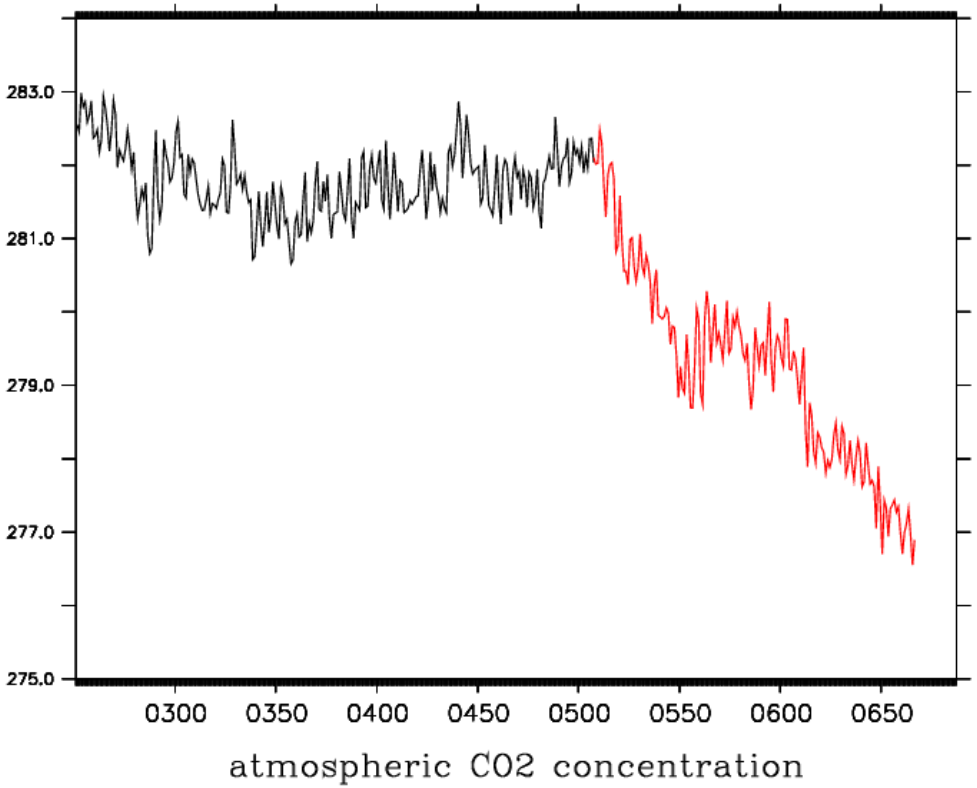
Circulation in the Southern Ocean

Observed Eddy Kinetic Energy



One integration ...

4 million grid points, 1000 years with 1 hour time steps



2011-12: spinup
'12: experiment
'14: funding
'15: found student
'16: implentation

-18 months … faster (x10) chips … less energy
- reproducible = no OS or compiler changes
- several months coding and testing

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… to accept the things one cannot change.

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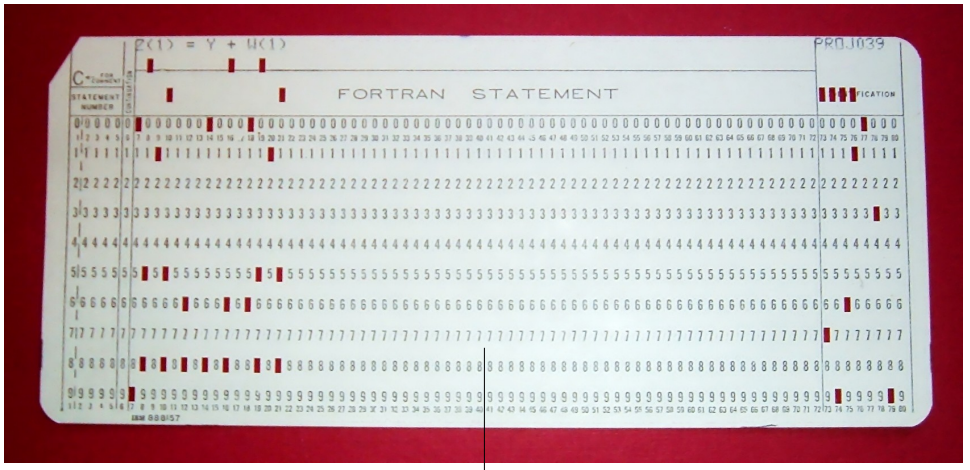
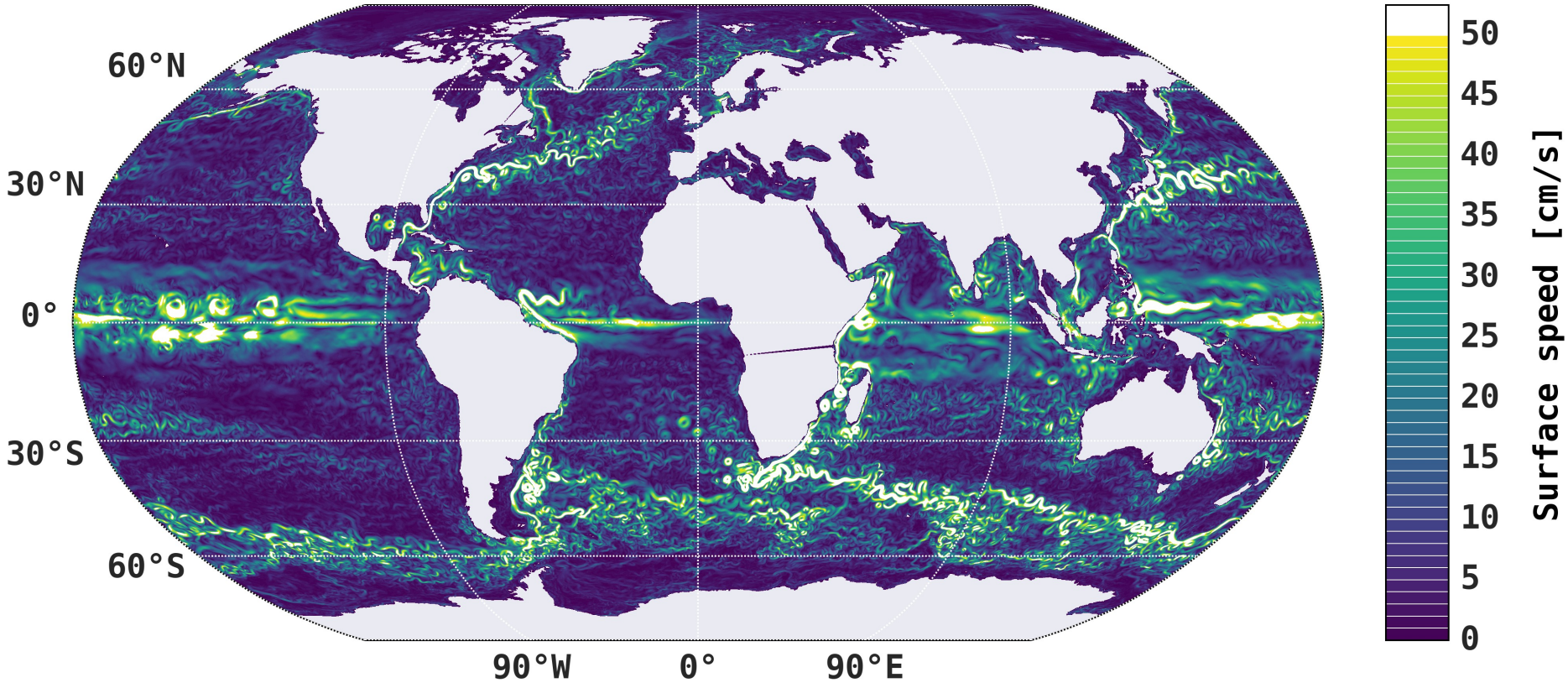


Bohrium
110101

The Eddy-Resolving Model

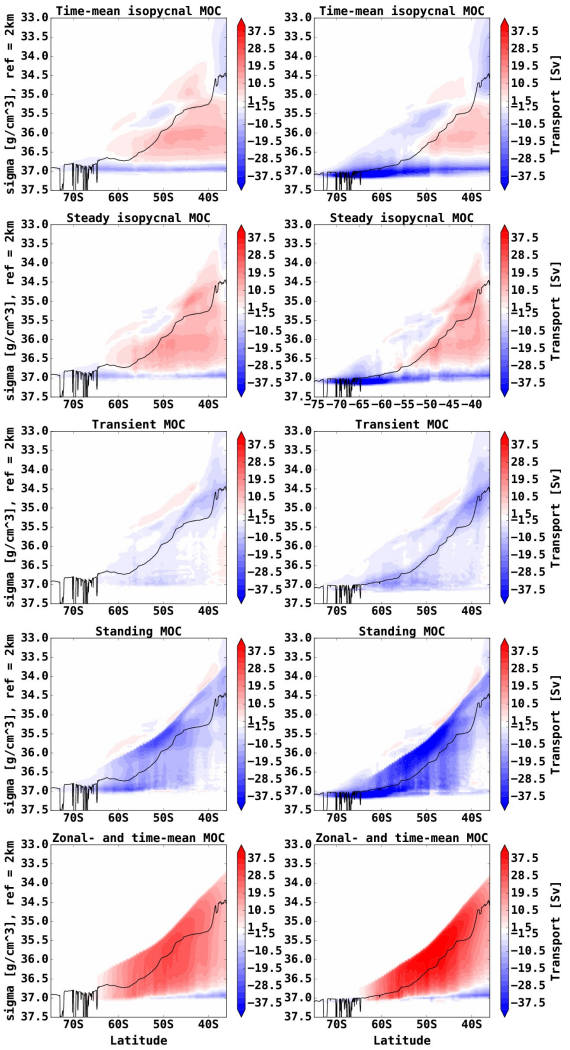


Ocean-Ice configuration of CESM (Small et al. 2014):
1/10 degree, 62 vertical layers, CORE forcing.

3-day means, 1 Tb/day, 0.1 yrs/day on 4096 cores at FSZ Juelich

A month per picture!

Control x 1.5



Residual Overturning

Steady

Transient

Standing

Eulerian

Time Slabs to Time Series

A B C D E F T5
A B C D E F T4
A B C D E F T3
A B C D E F T2
A B C D E F T1

→

A1 A2 A3 A4 A5 ...
B1 B2 B3 B4 B5 …
.
.
.

120 x 10 x 100 GB → 50 x 2TB

- better storage strategies
- parallel post-processing and visualization software

Conclusions

To address the climate challenge, we do not need bigger computers, but we do need:

- a science/ python/ fortran interface

- faster chips

- better data management