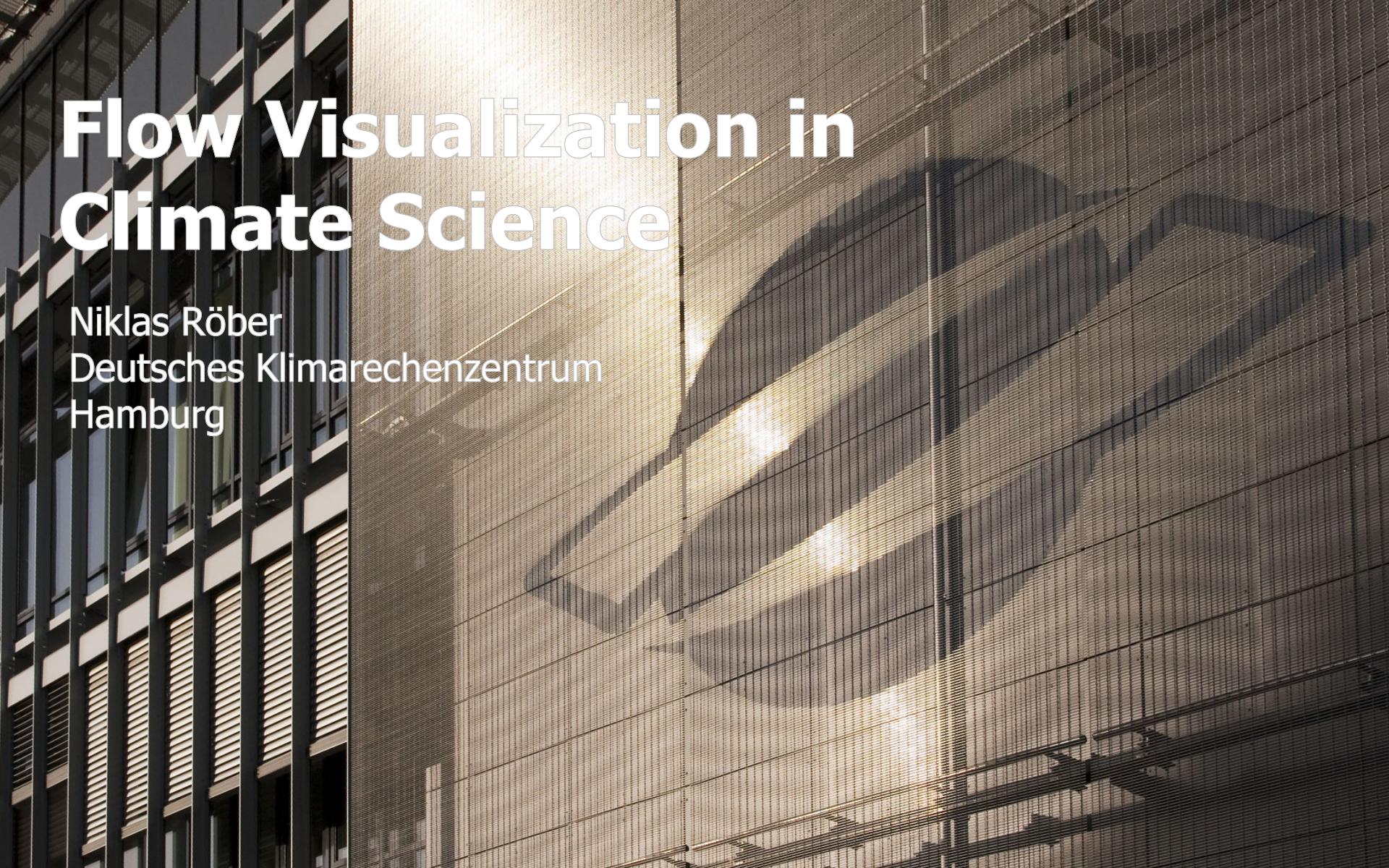
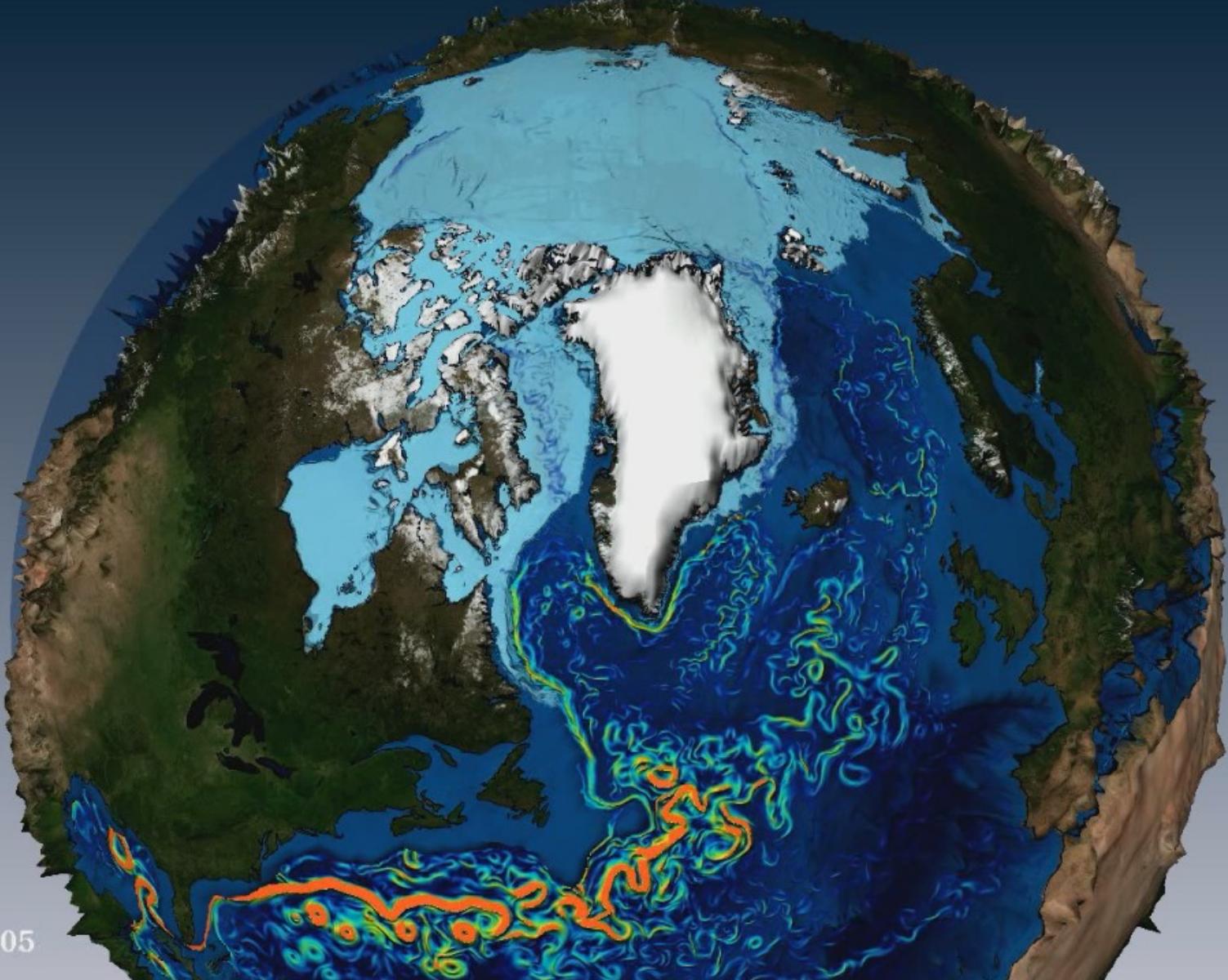


Flow Visualization in Climate Science

Niklas Röber
Deutsches Klimarechenzentrum
Hamburg





2002-06-05

DKRZ

(German Climate Computing Center)



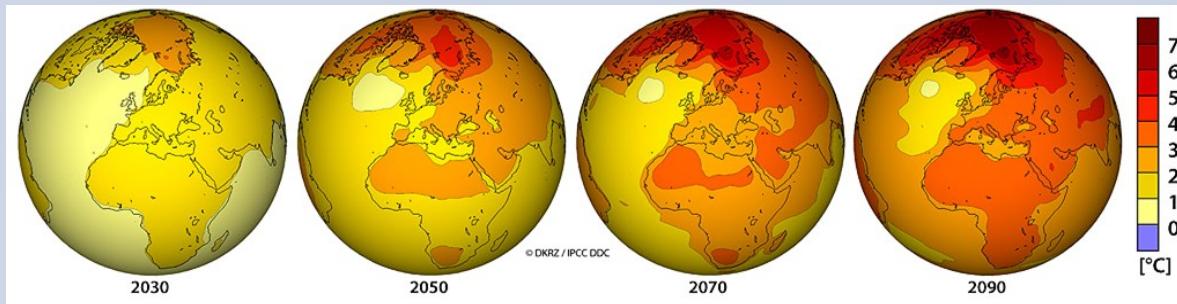
```
ENDDO
!$OMP END DO
!$OMP DO
  DO i3 = 1, snsP
    it = ssps-1+i3
    DO i2 = 1, 2
      DO i1 = 1, SIZE(ls2,1)
        ls_sp(k)%send_buffer(i1
          ENDDO
        ENDDO
      ENDDO
    !$OMP END DO
    !$OMP DO
      DO i3 = 1, snsP
        it = ssps-1+i3
        DO i2 = 1, 2
          DO i1 = 1, SIZE(ls3,1)
            ls_sp(k)%send_buffer(i1
              ENDDO
            ENDDO
          ENDDO
        !$OMP END DO
        IF (lm0s(k)) THEN
        !$OMP DO
          DO i2 = 1, nsnn0
            it = snn0+i2
            DO i1 = 1, SIZE(ls0,1)
              ls_sp(k)%send_buffer0
            ENDDO
          ENDDO
        !$OMP END DO
        ENDDIF
      !$OMP END PARALLEL
    #else
    !$OMP PARALLEL
    !$OMP WORKSHARE
      ls_sp(k)%send_buffer (:SIZE(
      ls_sp(k)%send_buffer (:SIZE(
      ls_sp(k)%send_buffer (:SIZE(
    !$OMP END WORKSHARE
```





IPCC AR5

- Modeling of different CO₂ scenarios
- 3D coupled systems (ocean, atmosphere)
- Full carbon cycle with biosphere & oceanbiogeochemistry
- Simulated time: 10.000 years
- Horizontal resolution: 50 – 100 km
- Multiple ensembles, result data: approx. 3 PB

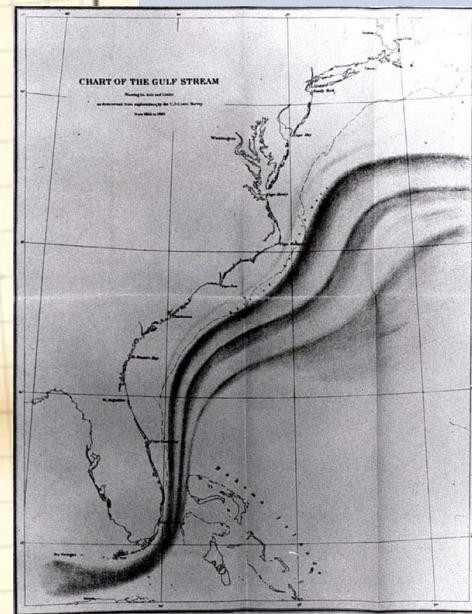
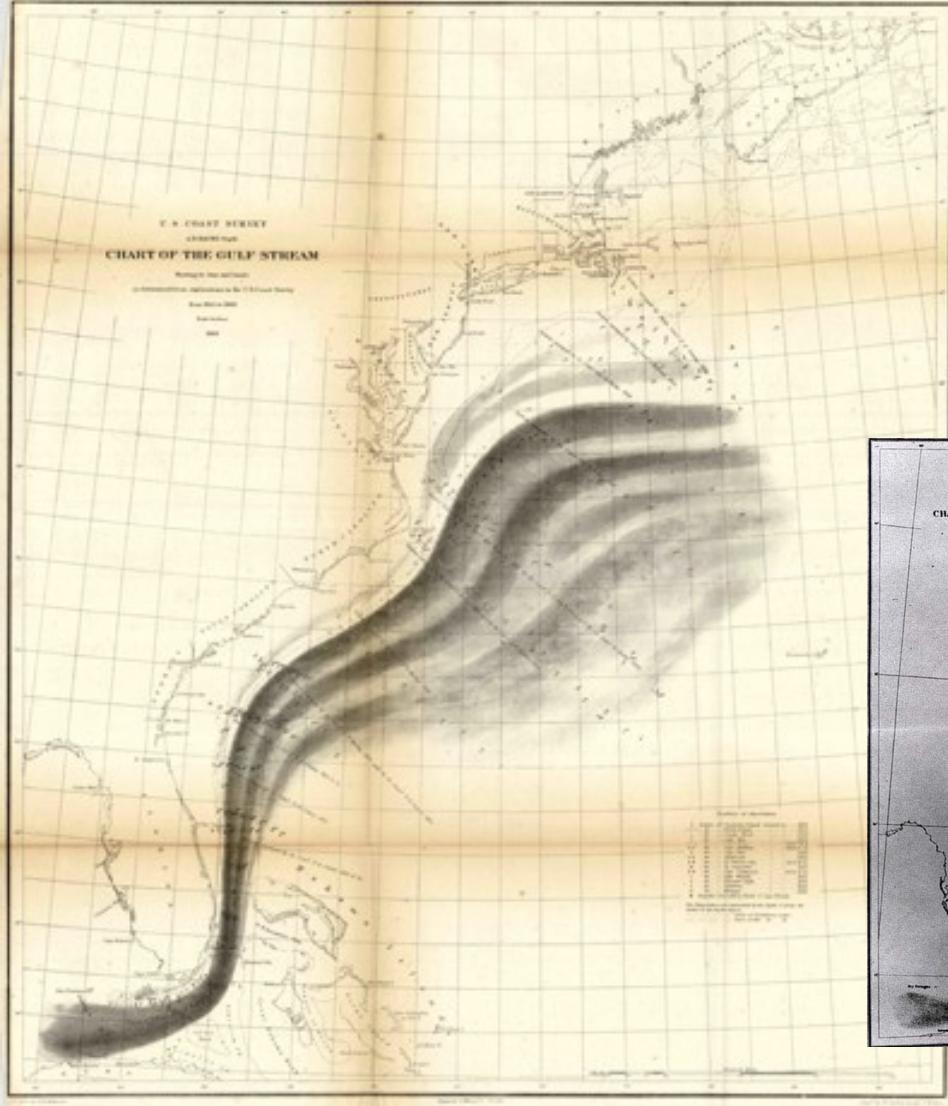


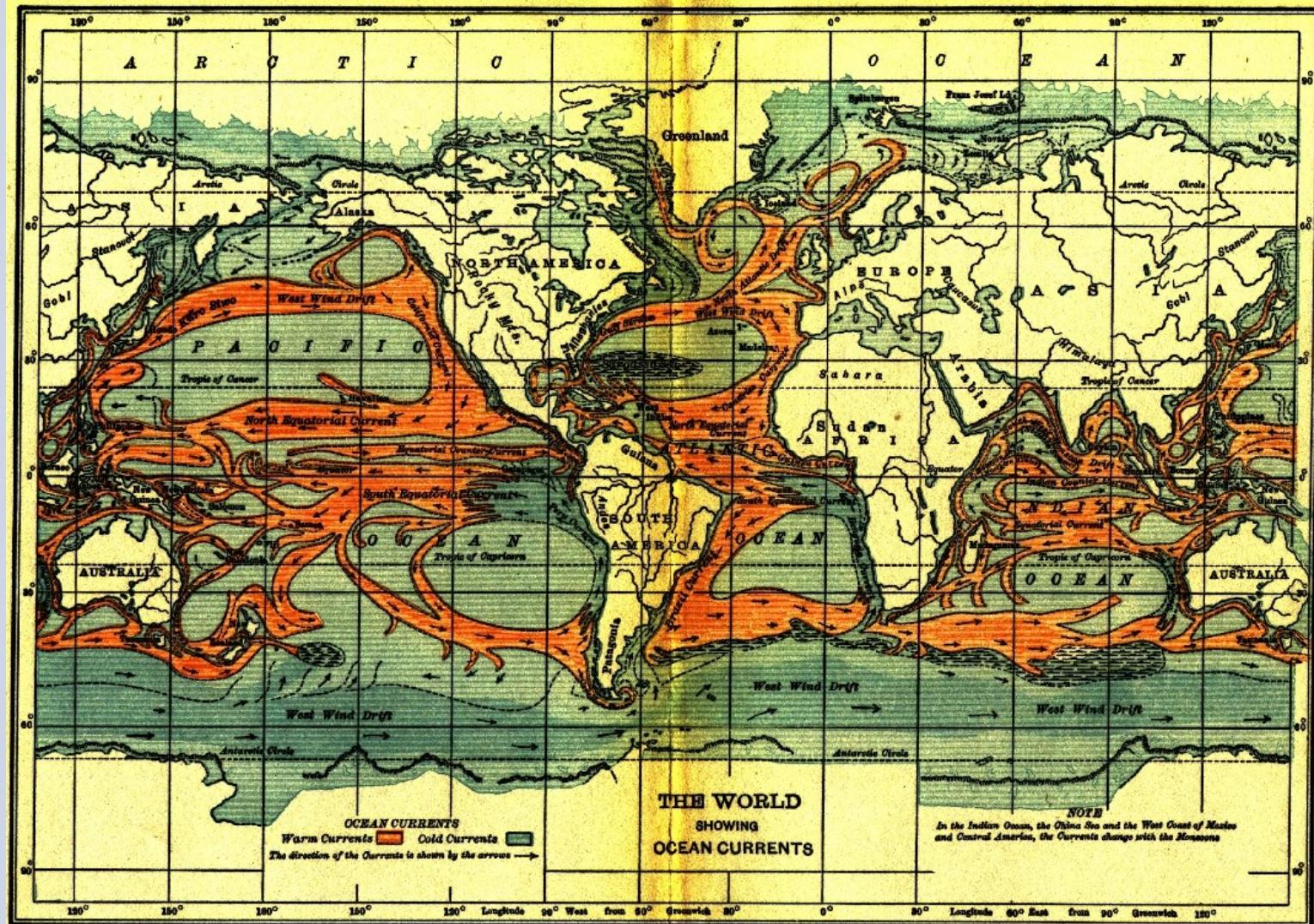
Understanding Ocean Currents



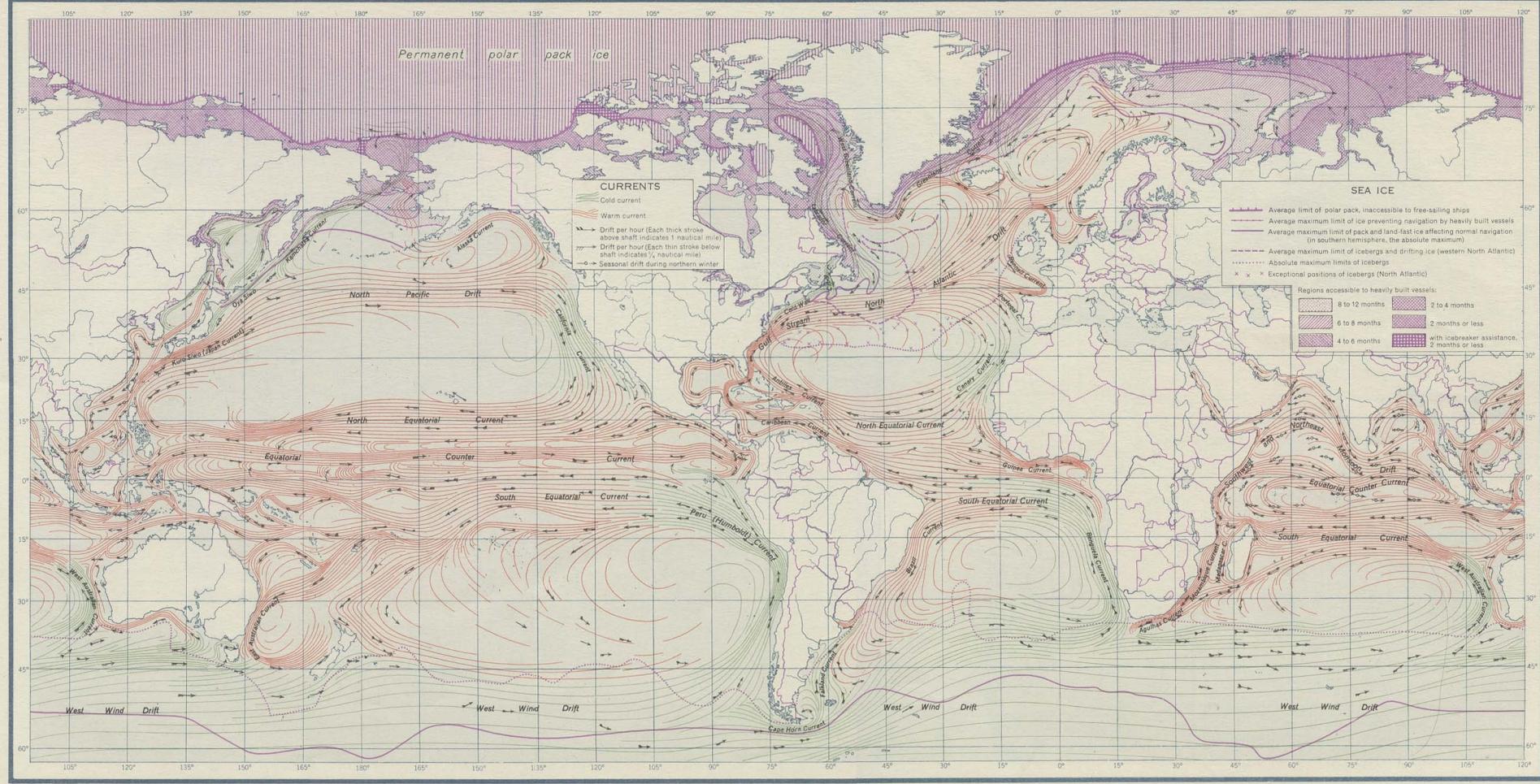
Benjamin Franklin
(1770)

US Coast Survey
(1860)

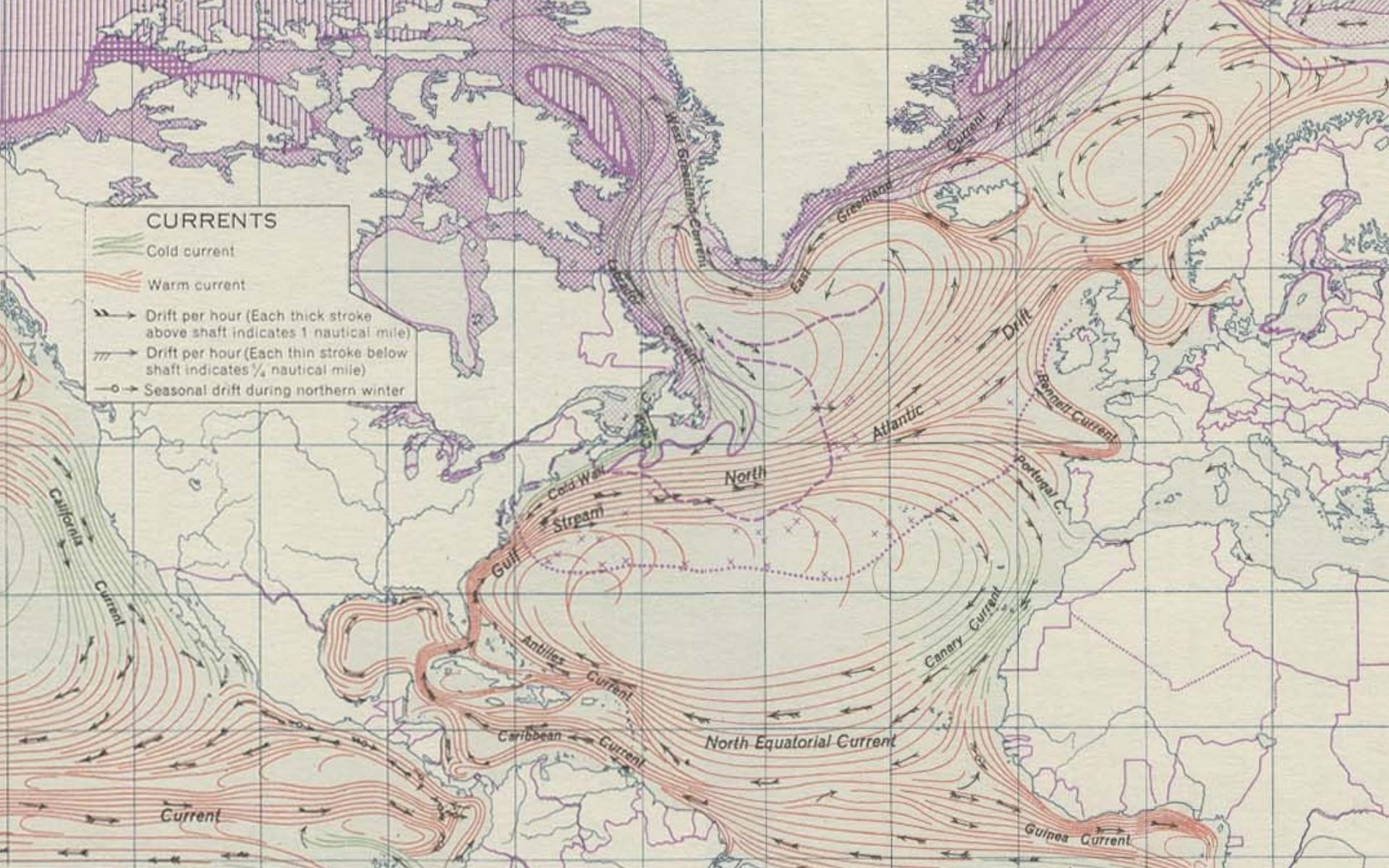




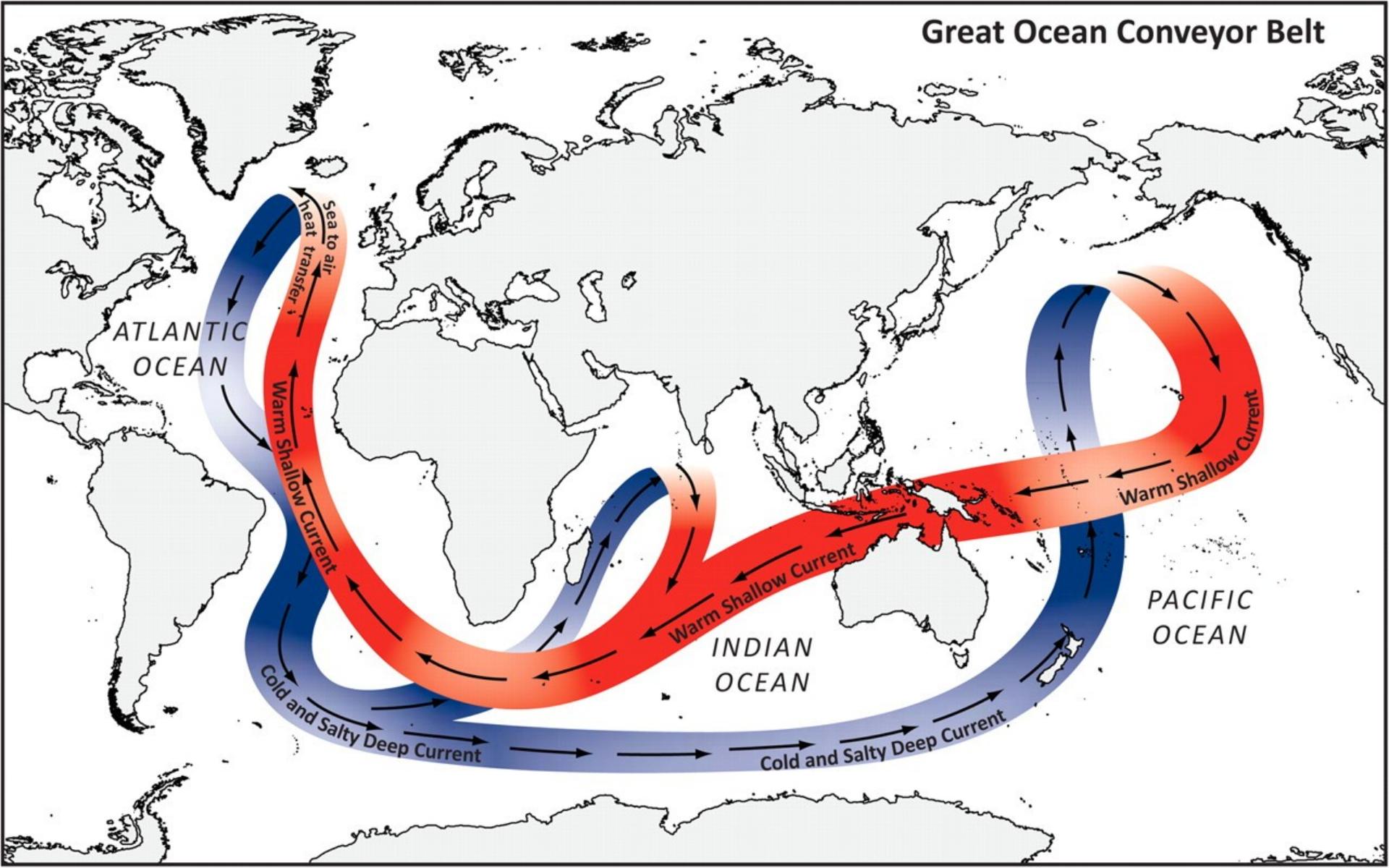
Ocean Currents (1911)



Ocean Currents (1943)



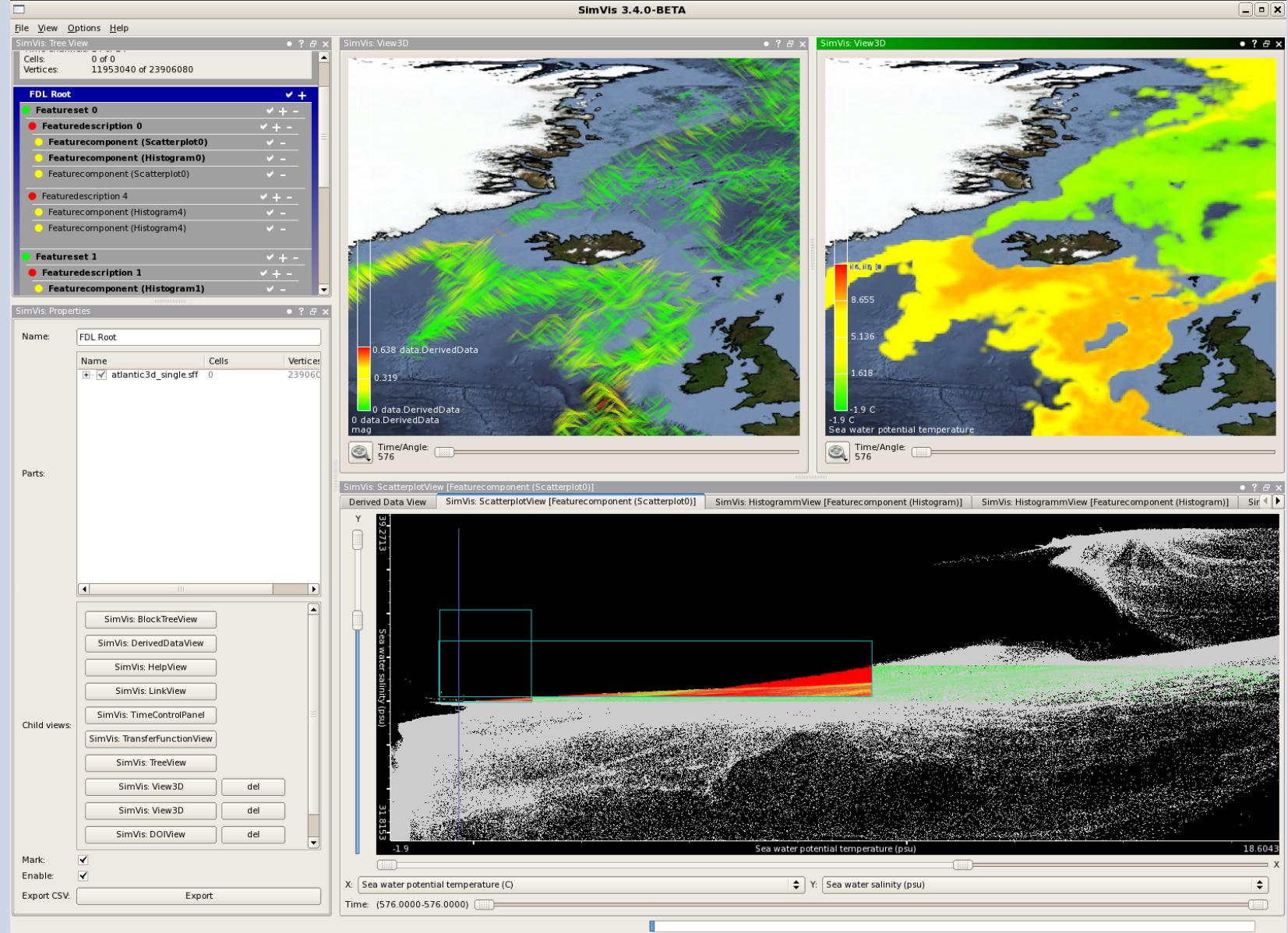
Great Ocean Conveyor Belt

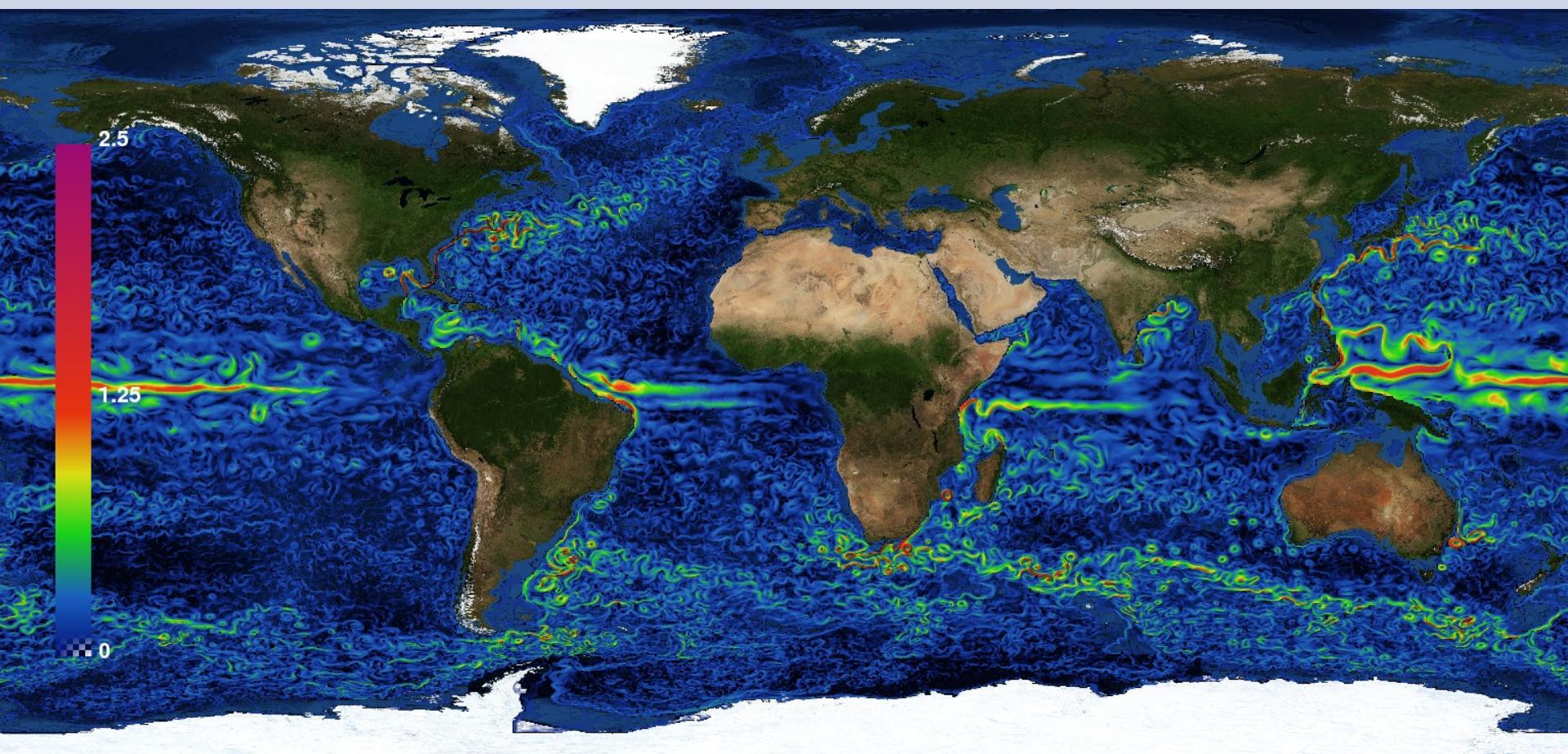


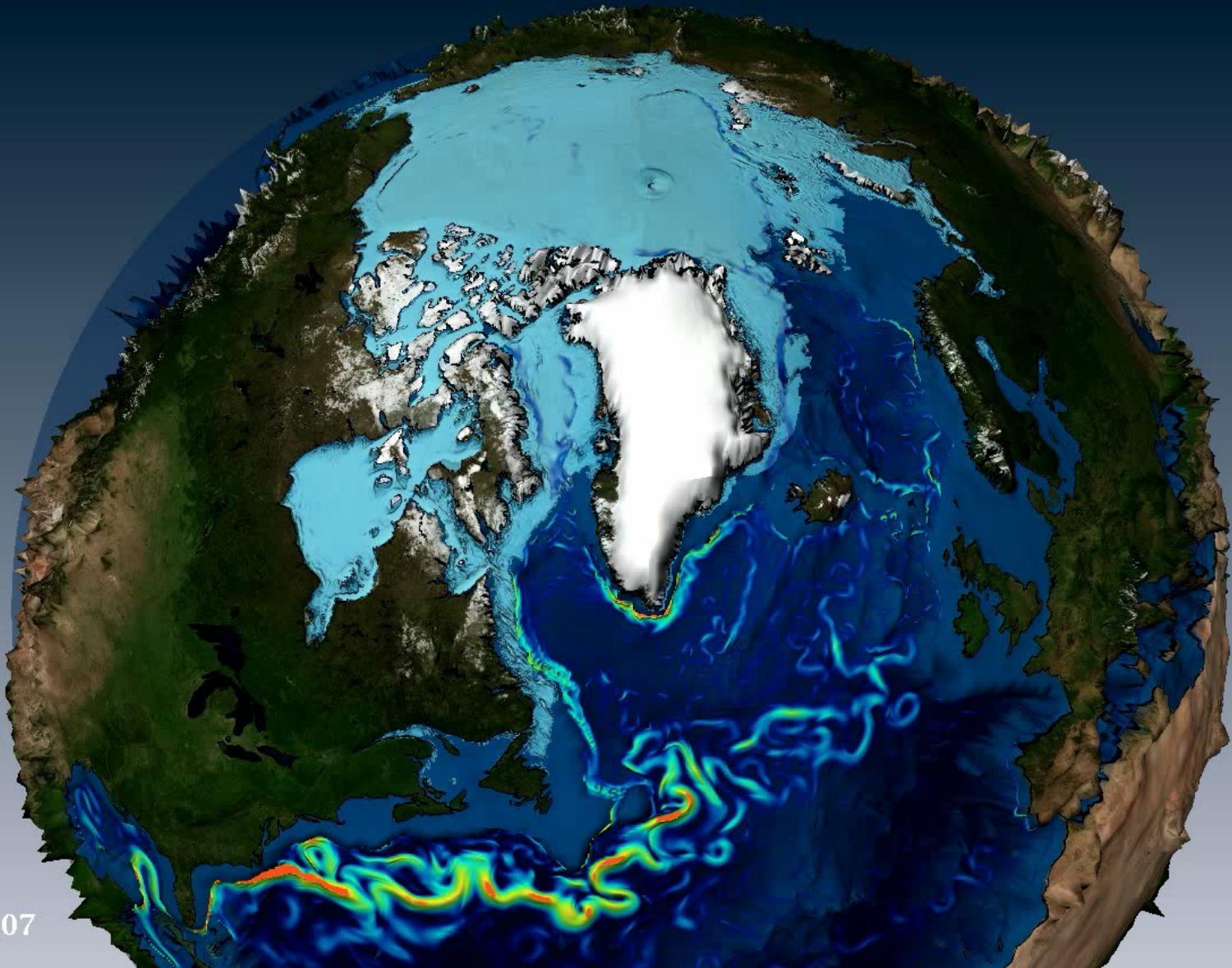
Thermohaline Circulation

- Temperature and salinity differences
- Mass (water, minerals, gases) and energy (heat) transport
- Transit time around 1600 years









2002-01-07

[m/s]

2.5

2.0

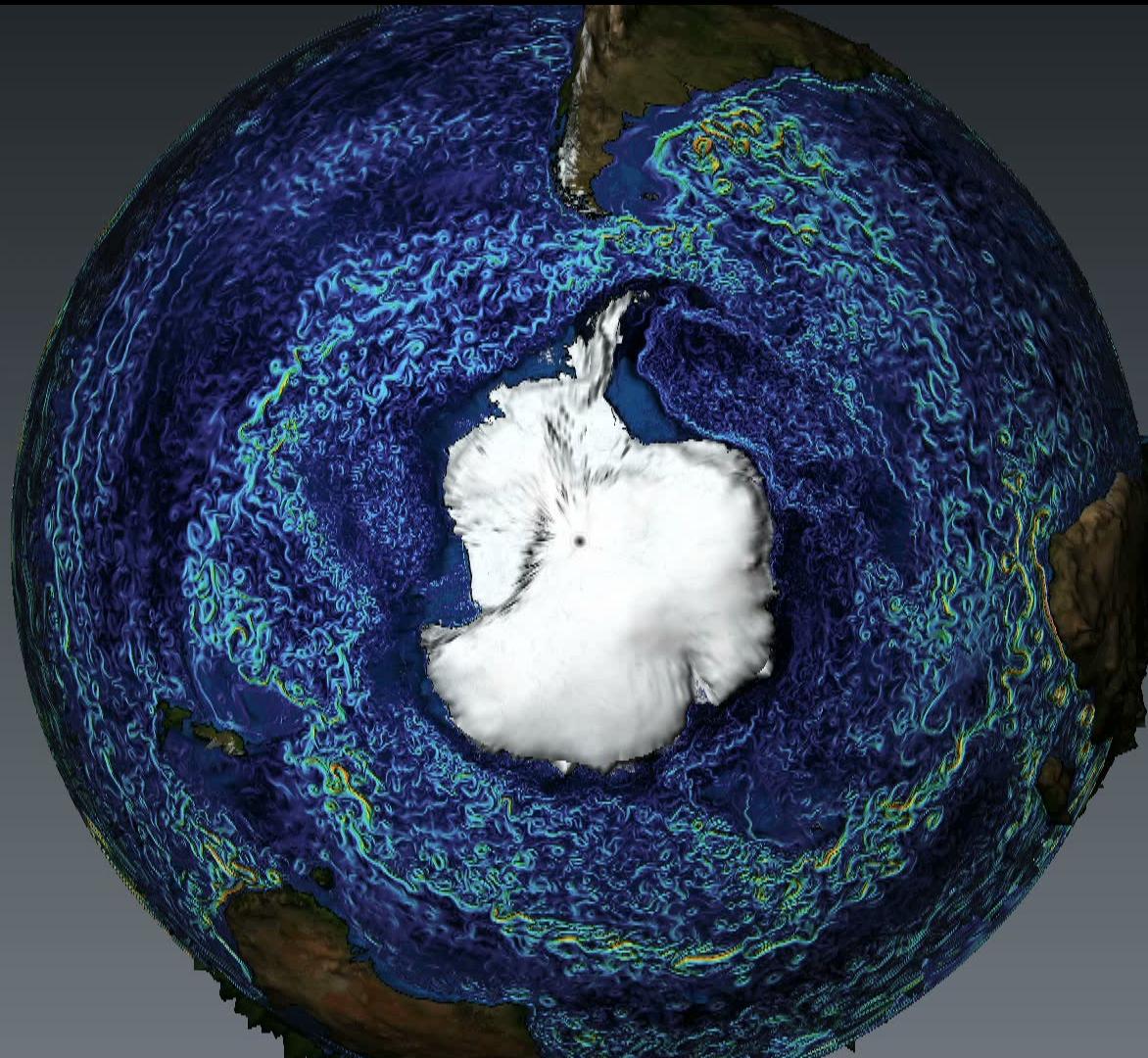
1.5

1.0

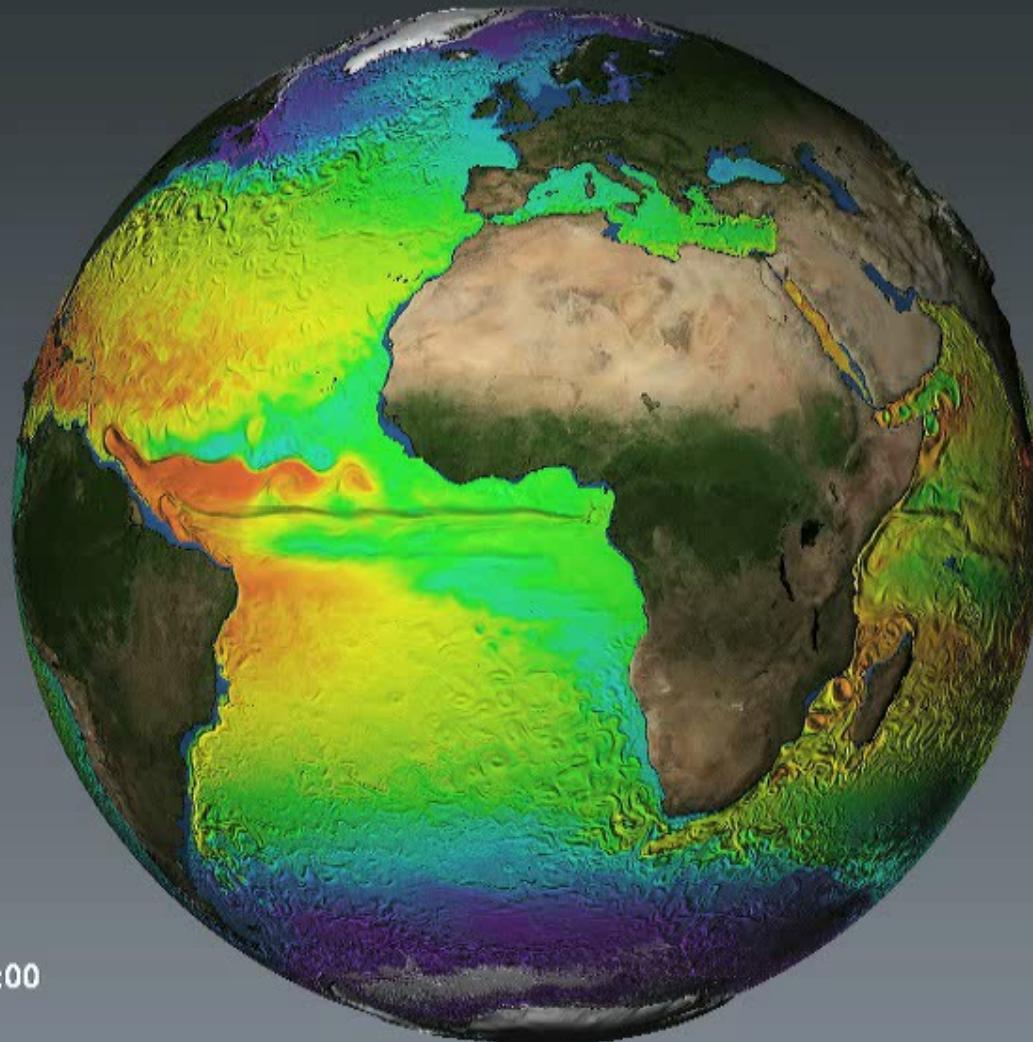
0.5

0.0

01/01/09



MPI-OM (0.1°)
(C) DKRZ / MPI-M



Temperature and Velocity
at 75m depth

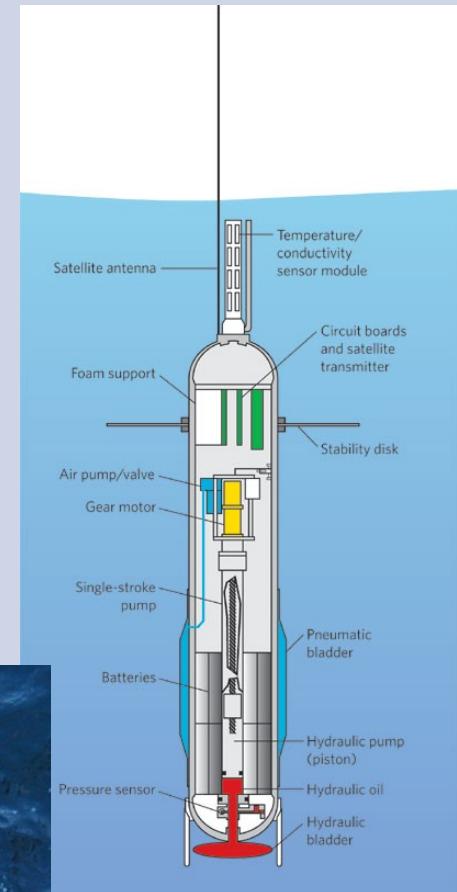
MPI-OM TP6M

01/01/0030 02:00

(C) DKRZ / MPI-M / KlimaCampus

Measurement of Ocean Currents

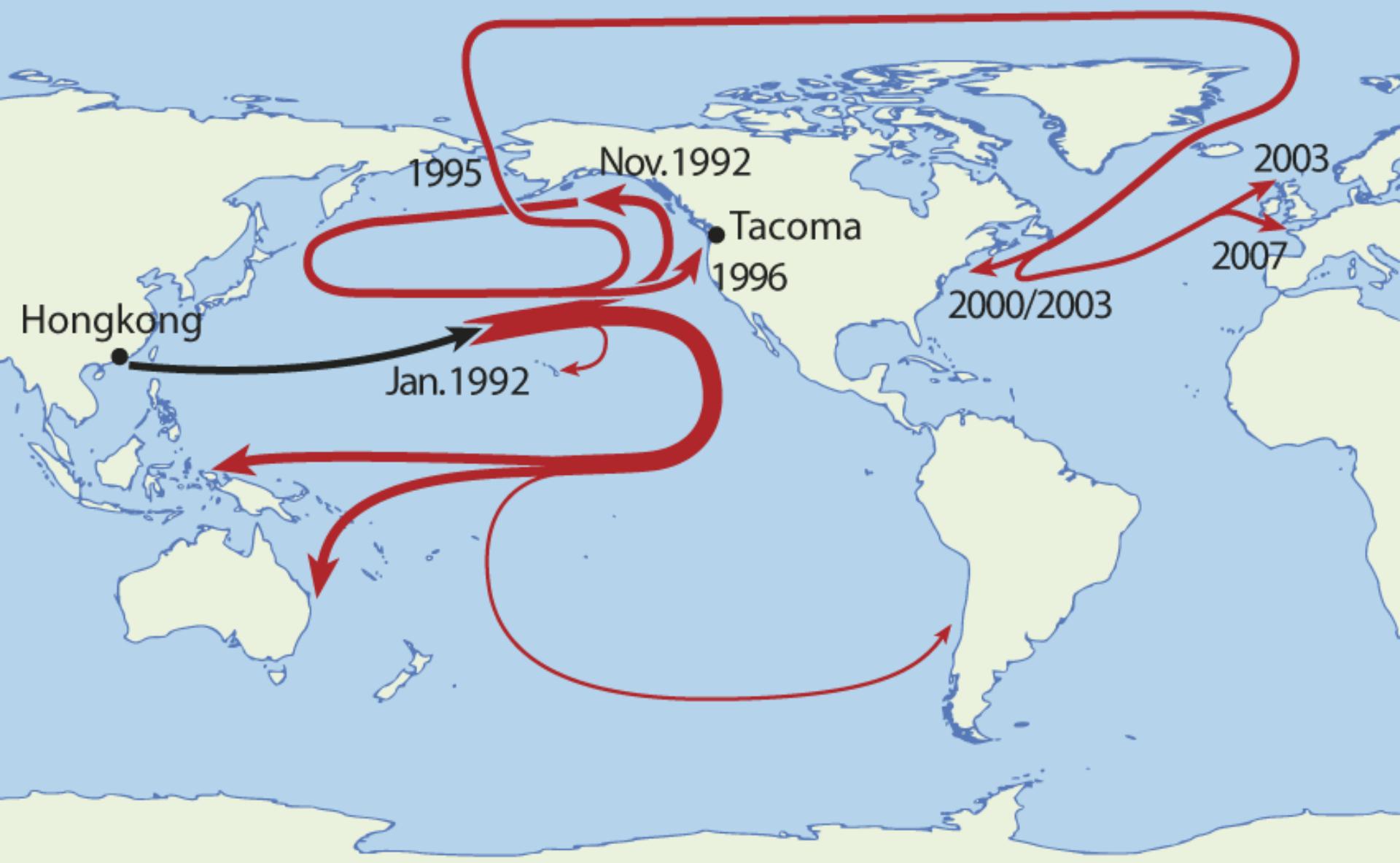
Ocean Buoys



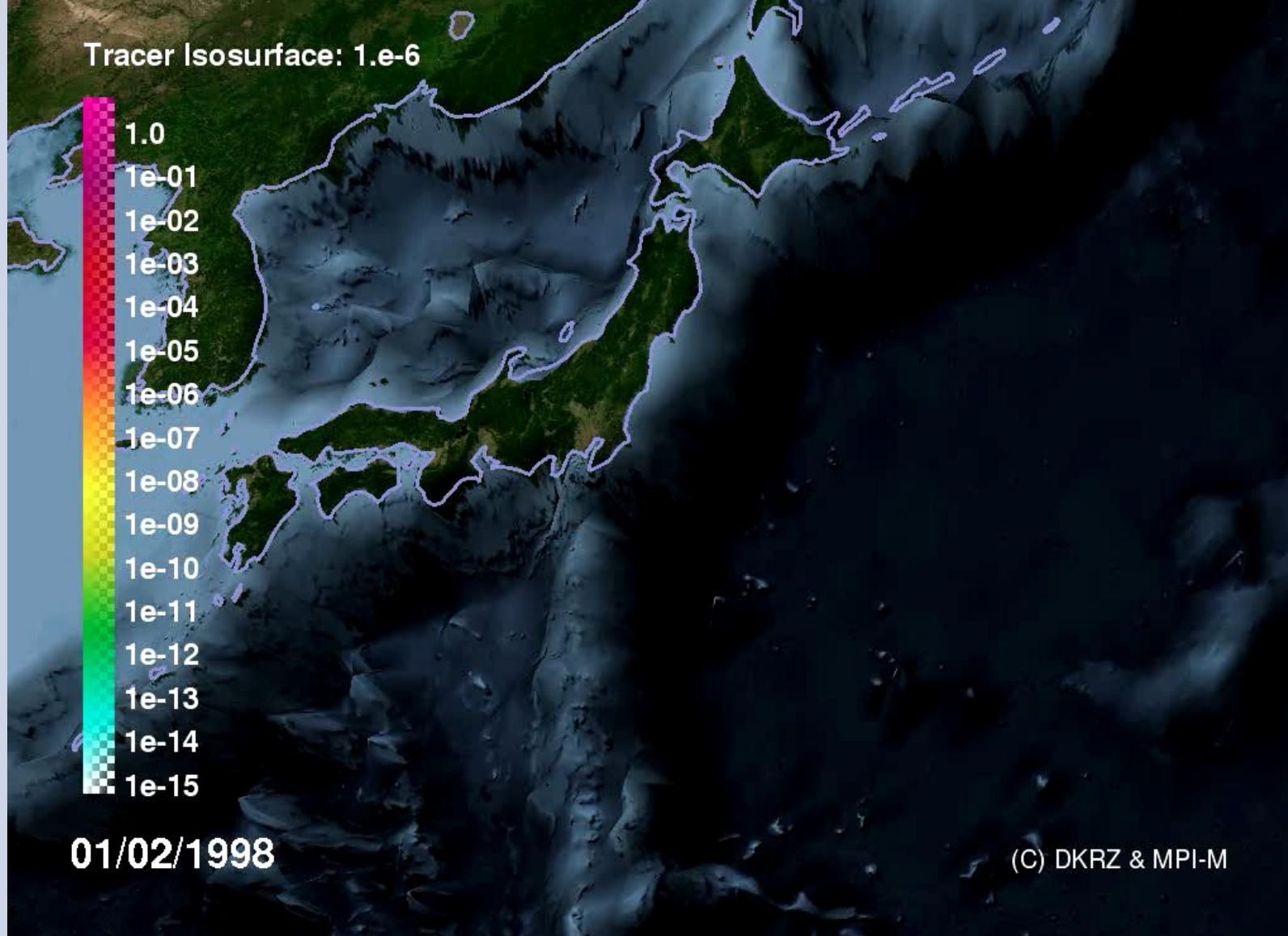
Friendly Floatees

- Accident in the Pacific in 1992
- Around 29.000 plastic toys went over board
- Washed up on shore around the world





Tracer Isosurface: 1.e-6



MIT General Circulation Model
(8 Km Resolution)

Current speed at 100 m depth
Simulated Oil Slick spreading

20 Apr 2010

1.5 m/s

1.0

0.5

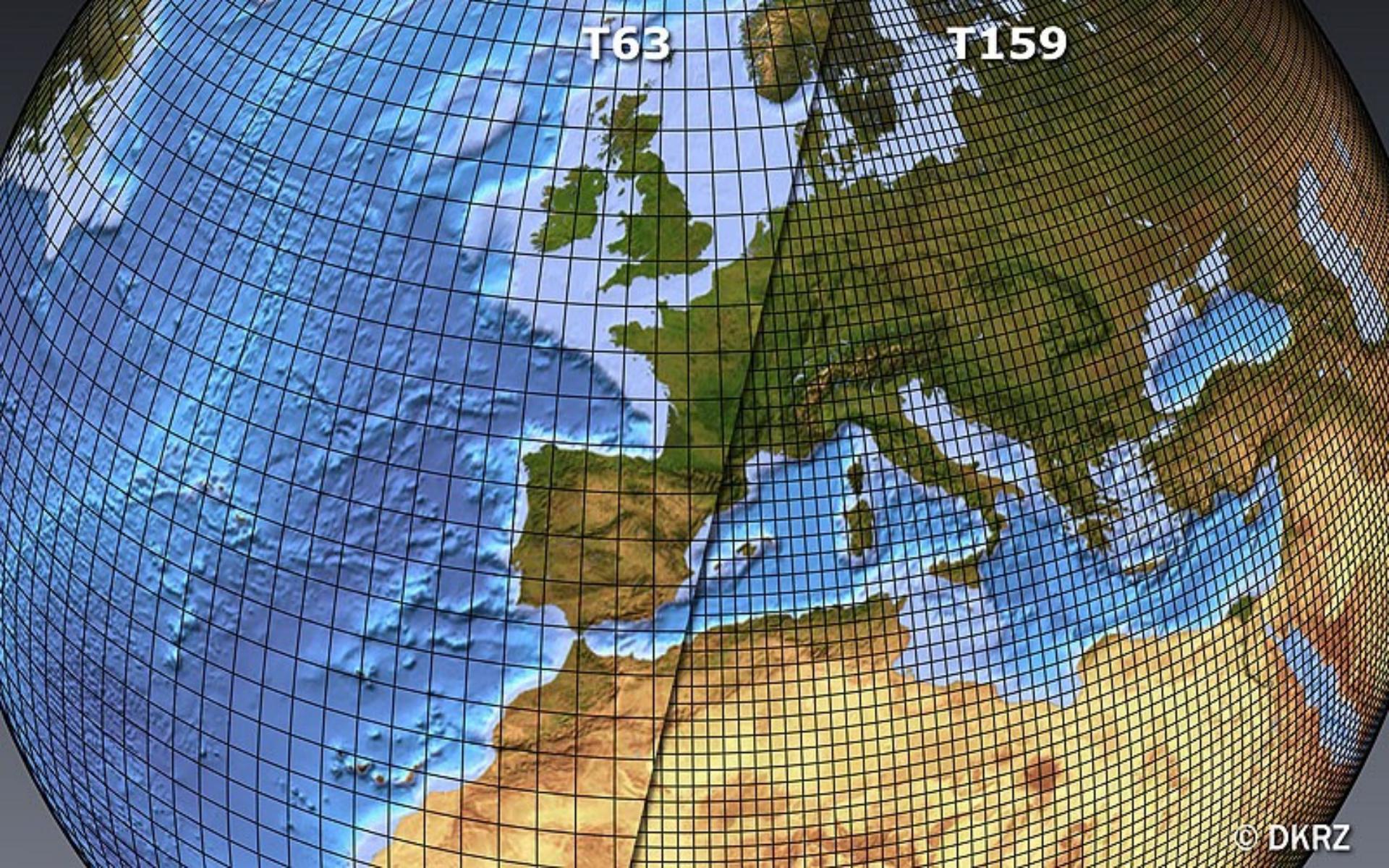
0



KlimaCampus

© KlimaCampus, DKRZ - Hamburg

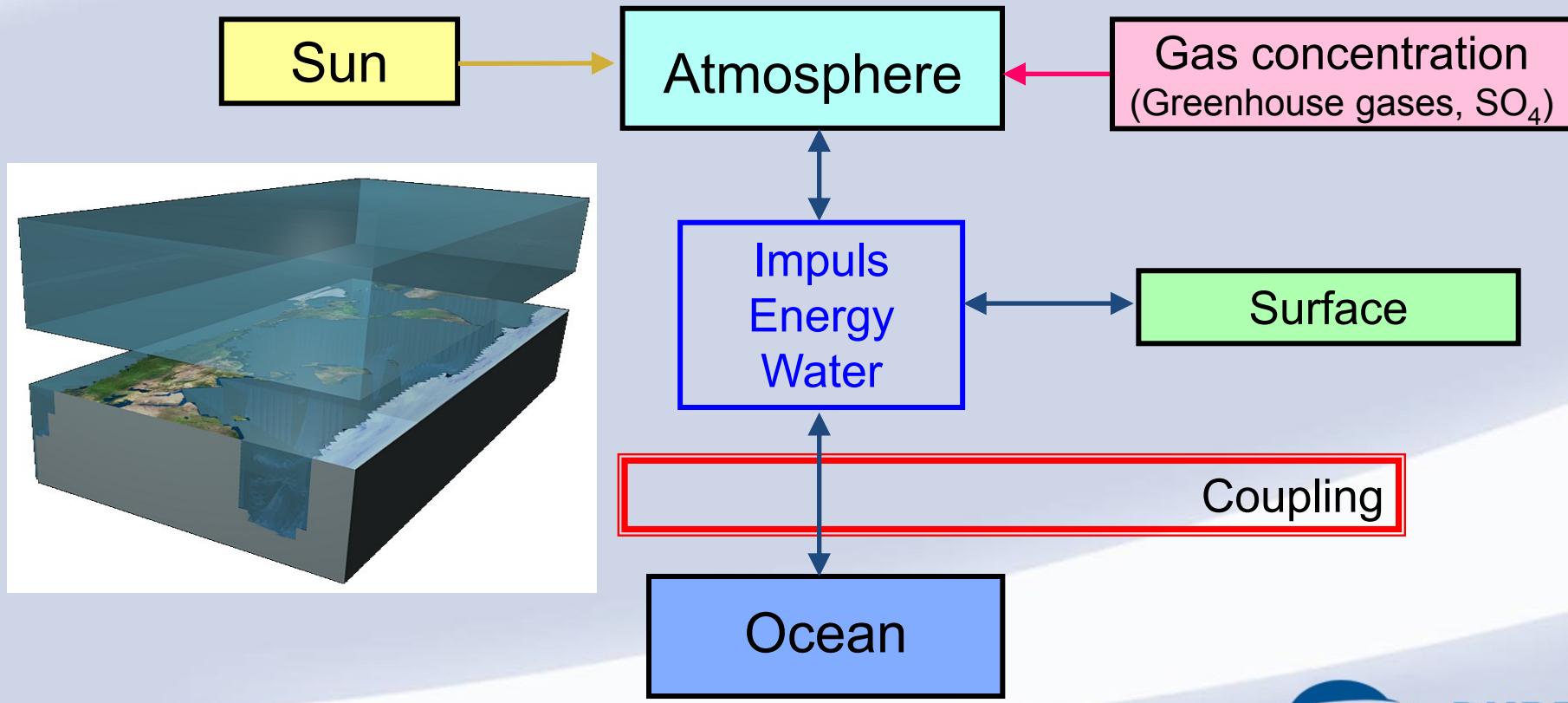
Climate Modeling



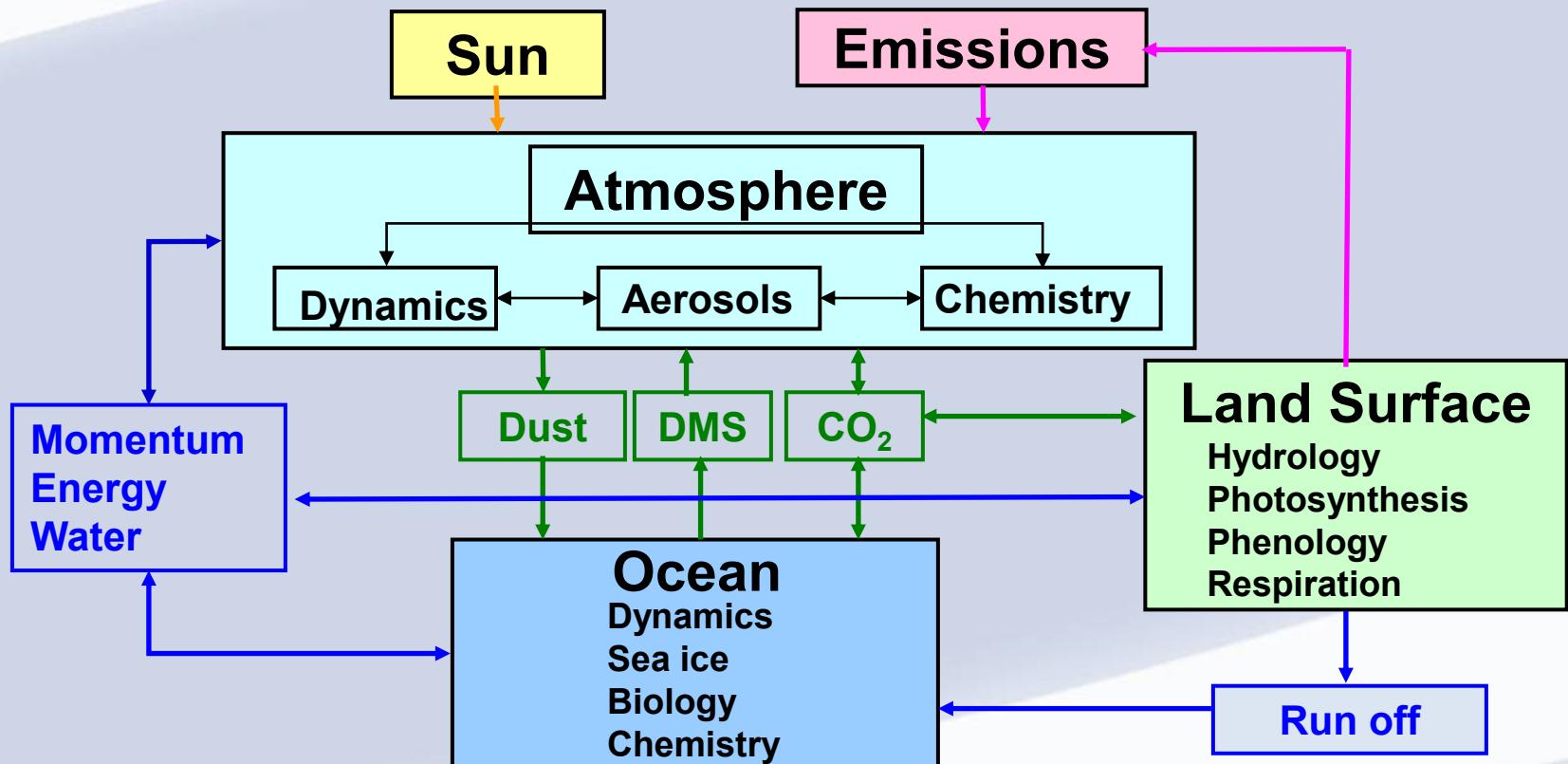
T63

T159

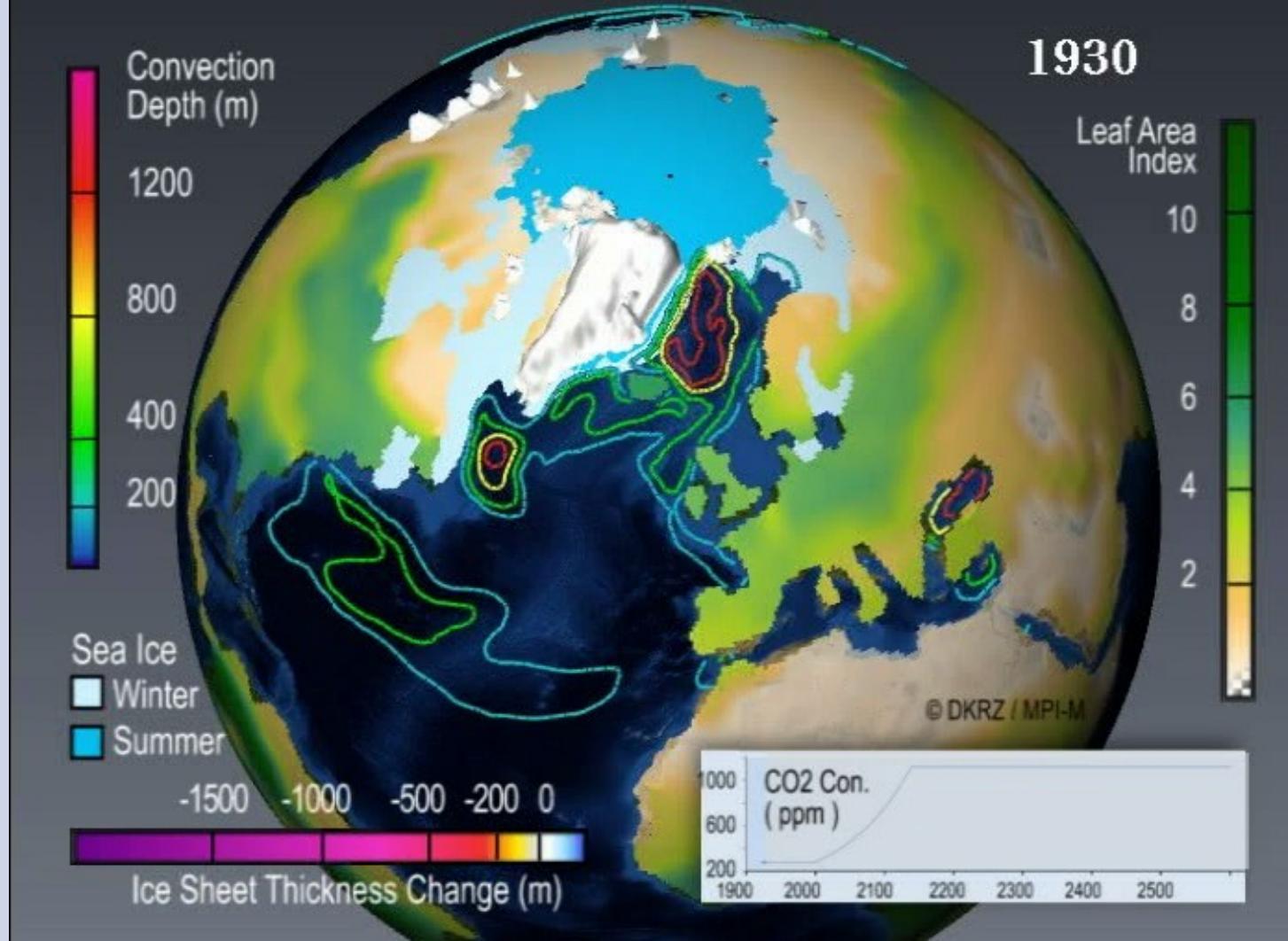
Physical climate model



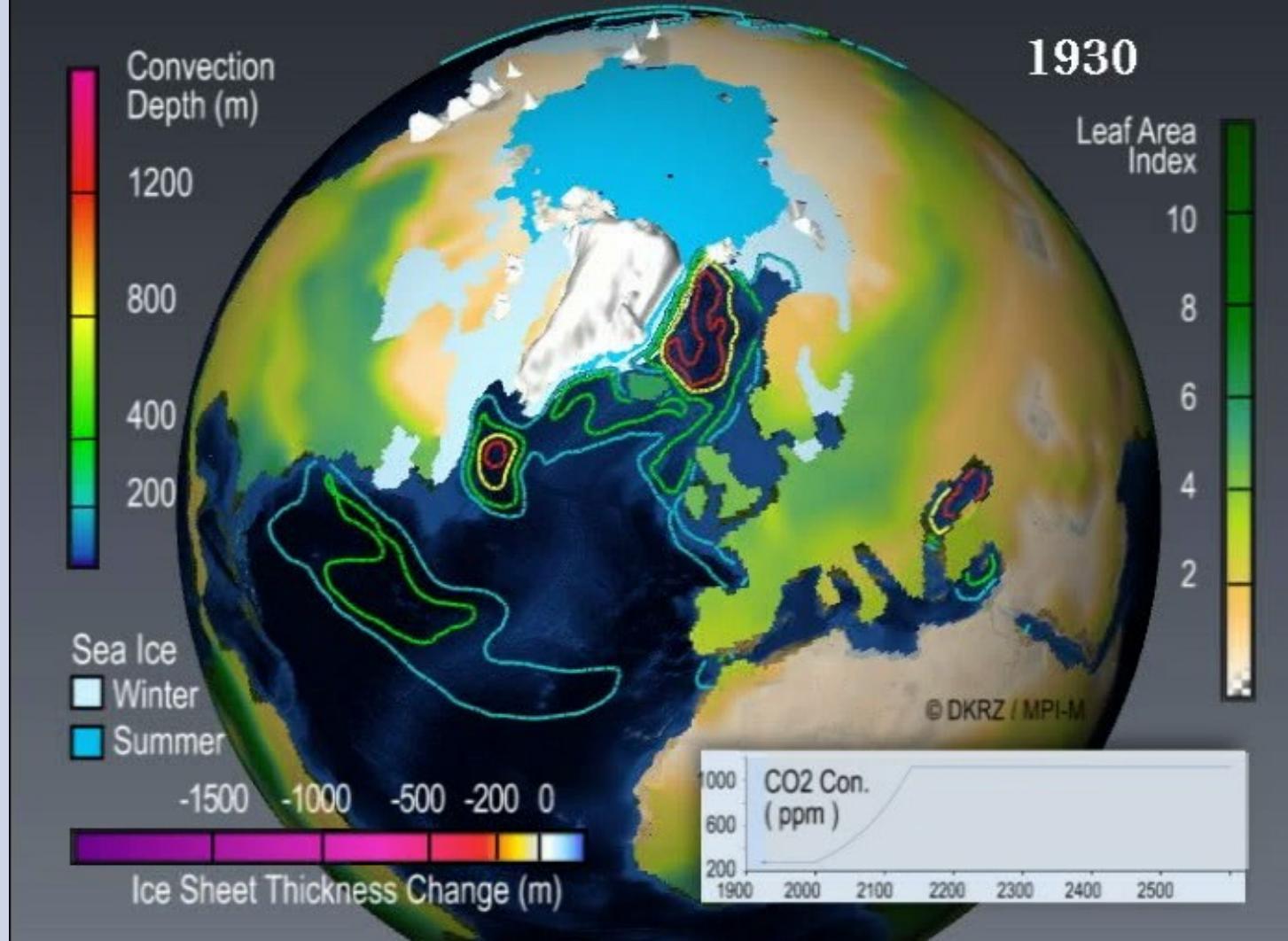
Earth system model



ECHAM / MPI-OM + LPJ + SICOPOLIS: 1% CO₂ Increase up to 4 x CO₂



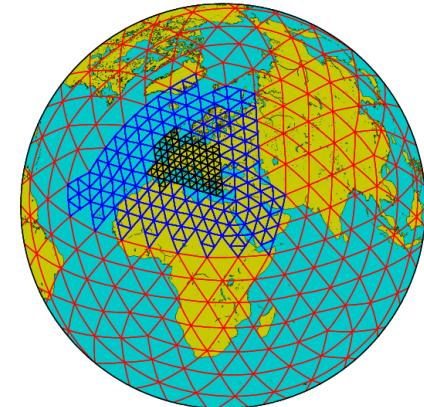
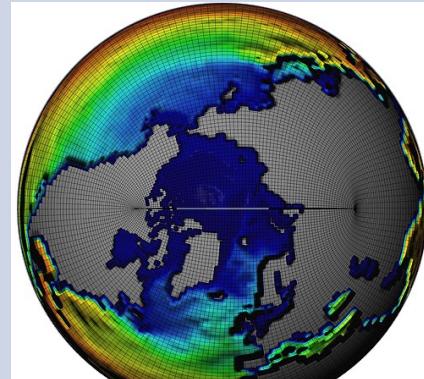
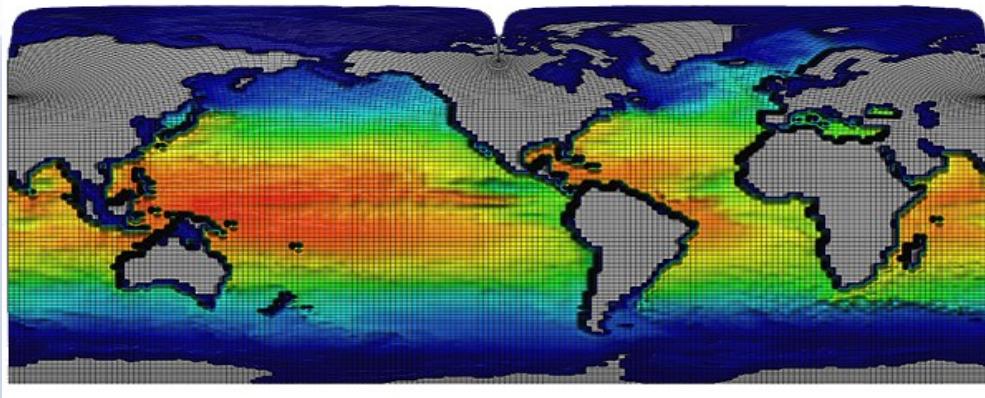
ECHAM / MPI-OM + LPJ + SICOPOLIS: 1% CO₂ Increase up to 4 x CO₂



Models

- MPI-OM (ocean)
 - HAMOCC (ocean carbon cycling)
- ECHAM (atmosphere)
 - JSBACH (biosphere)
- REMO (regional atmospheric model)
- MITRAS / METRAS (micro- and mesoscale atmospheric models)
- ICON (atmosphere, ocean)

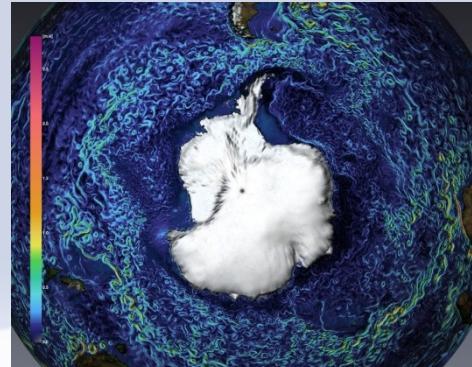
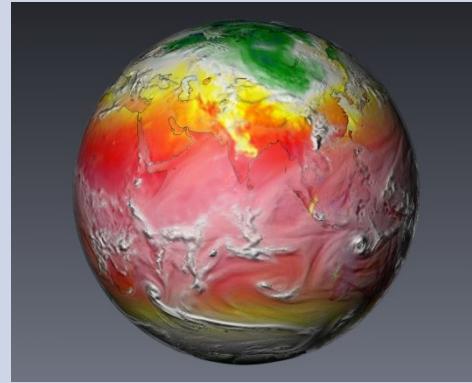
Grids



- Regular, rectilinear, rotated and curvilinear grids using NetCDF CF-1.0
- ICON (ICOsaHedral Non-hydrostatic)
no poles, nested grid

Data Sizes

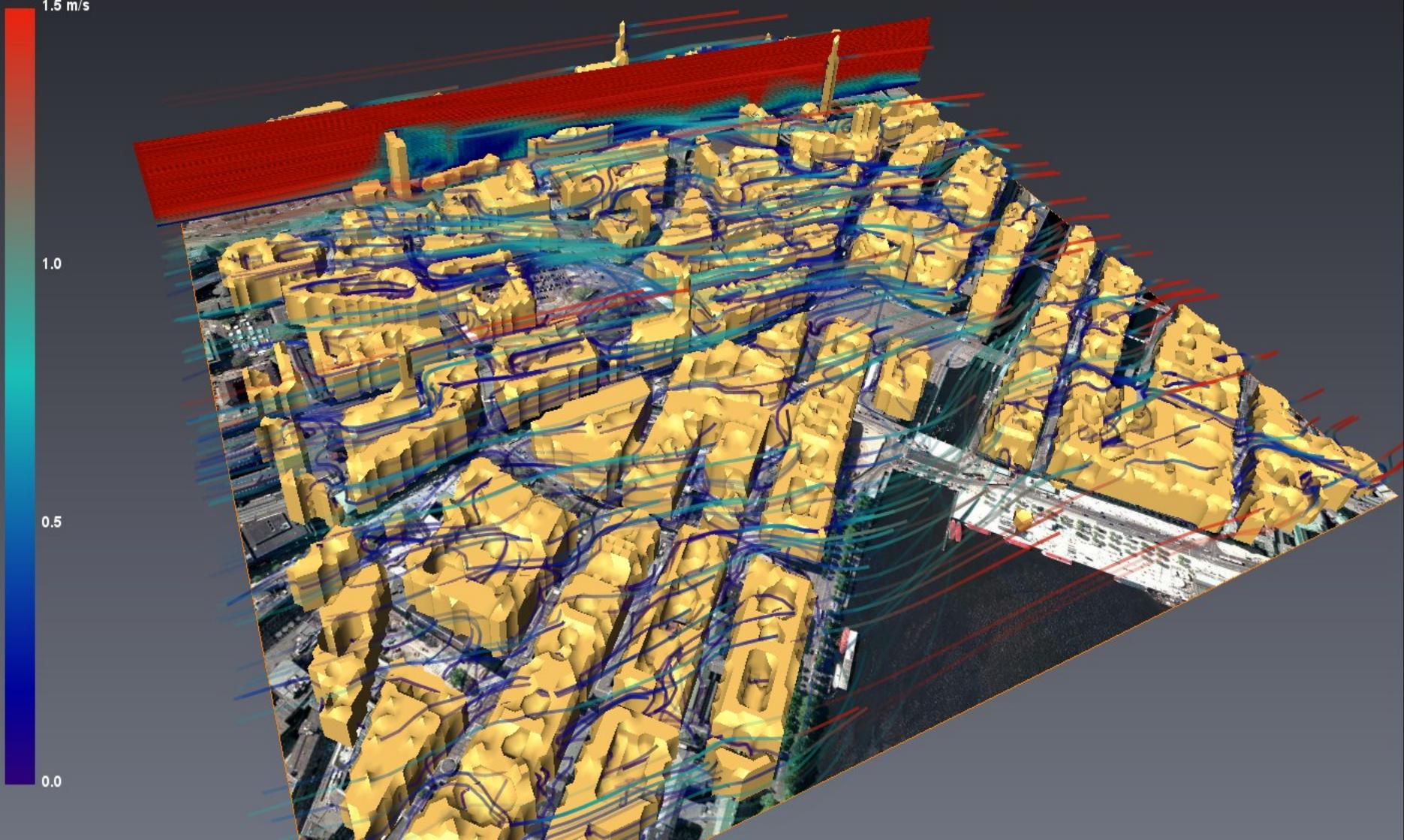
- Projekt STORM:
 - Atmosphere(768 x 394 x 199)
 $(u, v, w, t, p, q, ws, sn, \dots)$
 - Ocean (3002 x 2394 x 80)
 $(uko, vke, wo, tho, sao, \dots)$
 - Ocean now up to 1/20 degree resolution



Software & Techniques

- 2D: Grads, Ferret, NCL, IDL, Matlab, ncview
- 3D: AvizoGreen, SimVis, (Vapor, Paraview)
- Methods: Stream- and Pathlines, Embossed Slice, Arrows & Glyphs, LIC, Iso Surfaces

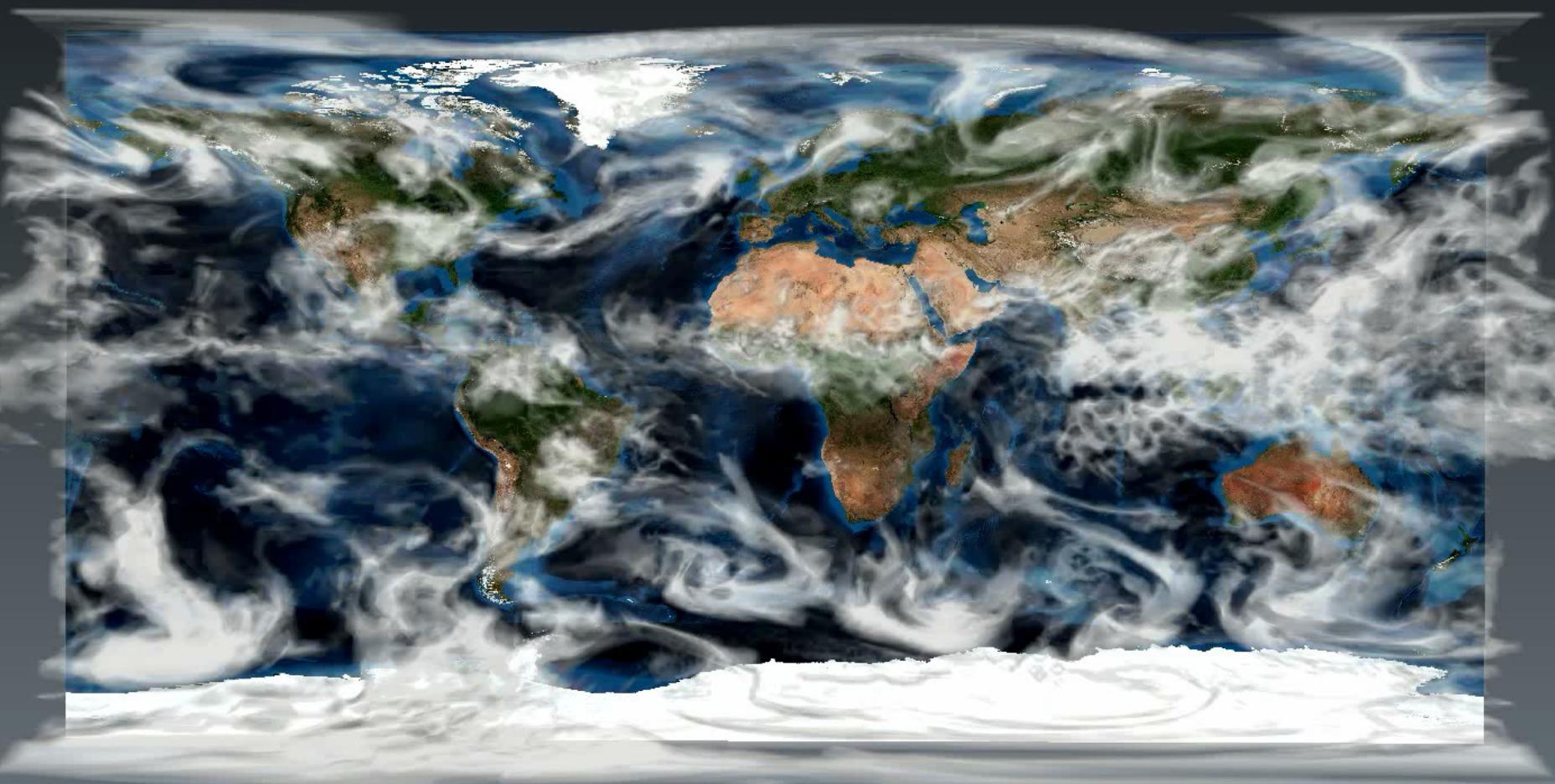
MITRAS - Wind Velocity in Hamburg encoded using Color (m/s)



Atmosphere

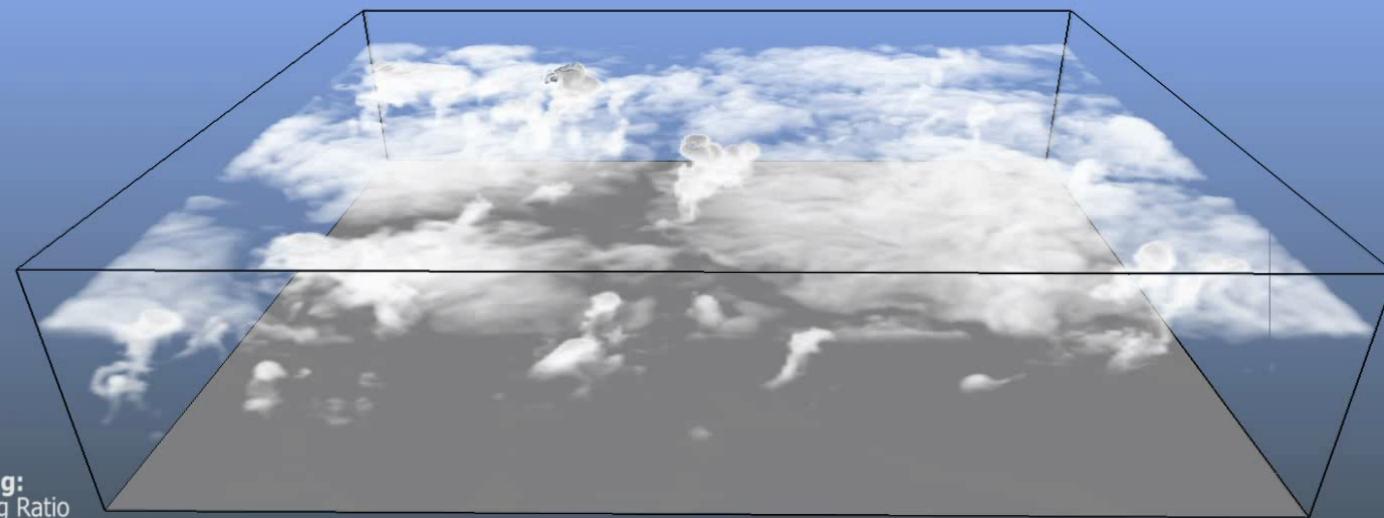
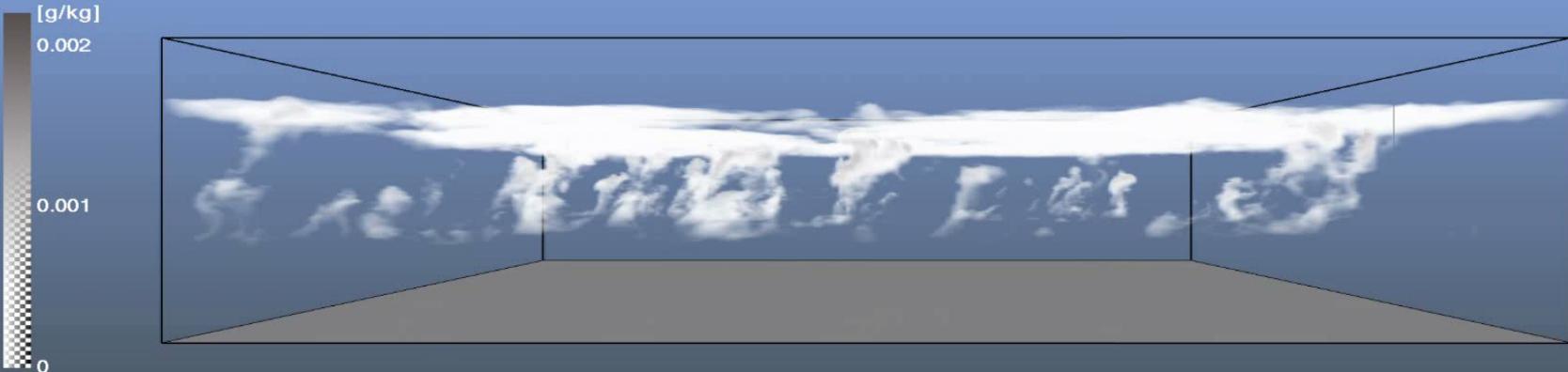
ECHAM6 T255

Relative Humidity



01/08/1985 00:02

(C) DKRZ / MPI-M



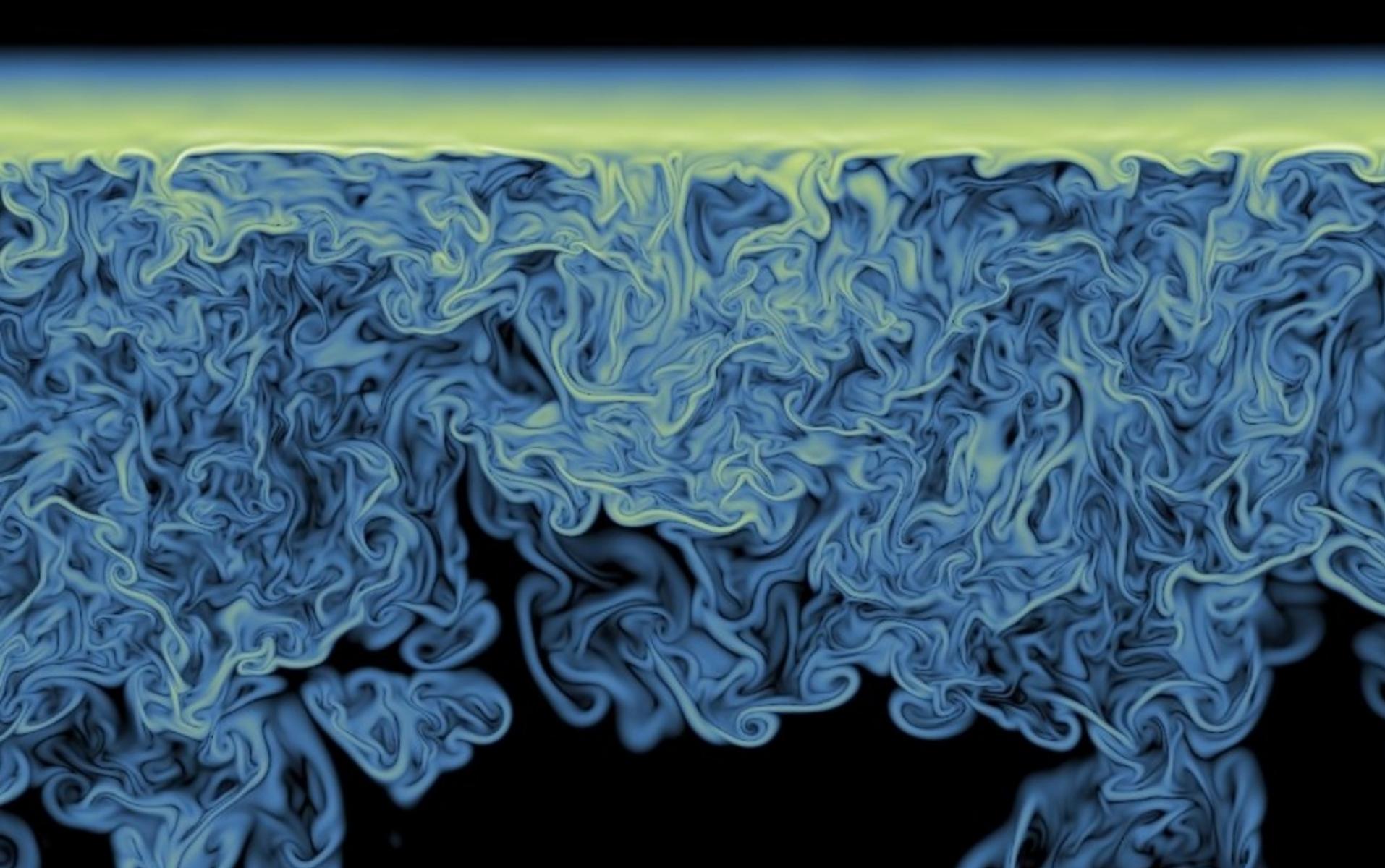
Volume rendering:
Liquid Water Mixing Ratio

Isosurface:

Rainwater Mixing Ratio 5×10^{-6} kg/kg

0 60 120 [min]

© DKRZ / MPI-M



Closing Thoughts

Challenges

- Ocean models now eddy resolving – lots to find and learn
- Topology can be of assistant. Can it?
- Still many regular visualization problems need to be solved
 - Zonal jets
 - Complete conveyor belt

General Issues

- I/O problems (data sizes are getting bigger and bigger)
 - Distributed and/or in-situ visualization?
 - Interactivity?
- Uncertainty visualization (through ensembles)
- (Multivariate data sets)
- New computing architectures (heterogeneous systems for simulation **AND** visualization)

Hamburg?

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