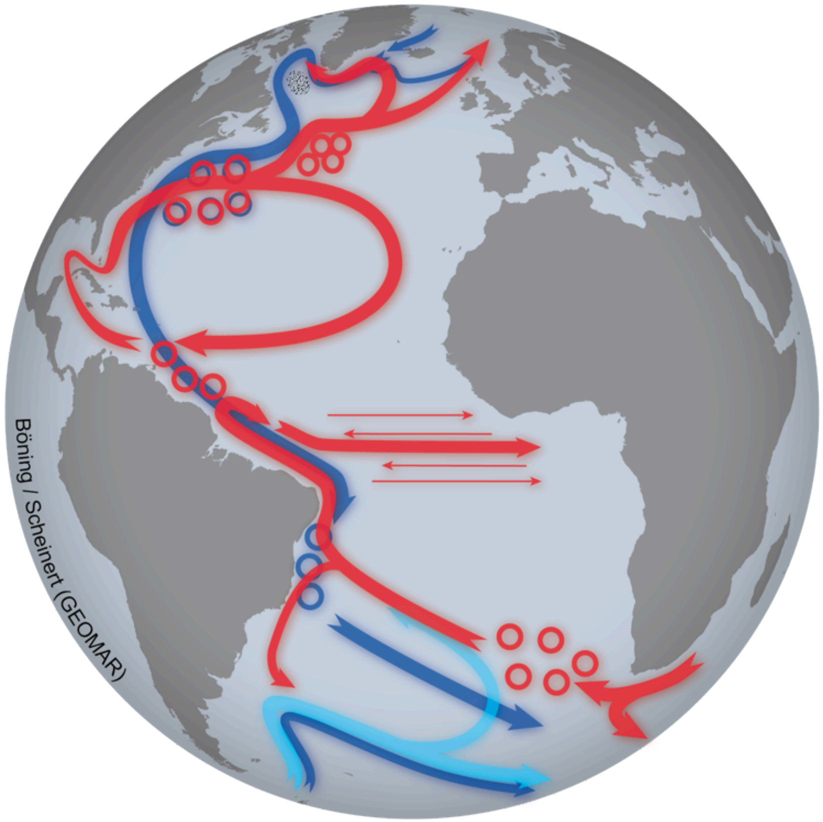
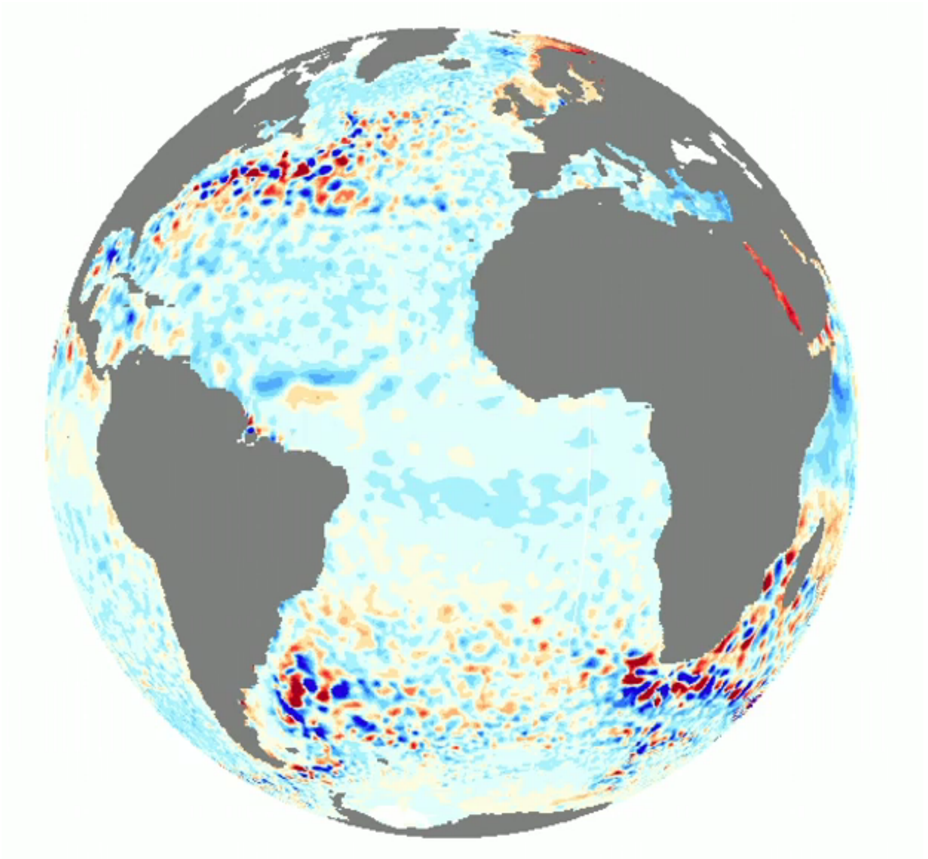
Arne Biastoch
GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

The Potential of Nested Ocean Modelling

Why Nested Ocean Modelling?

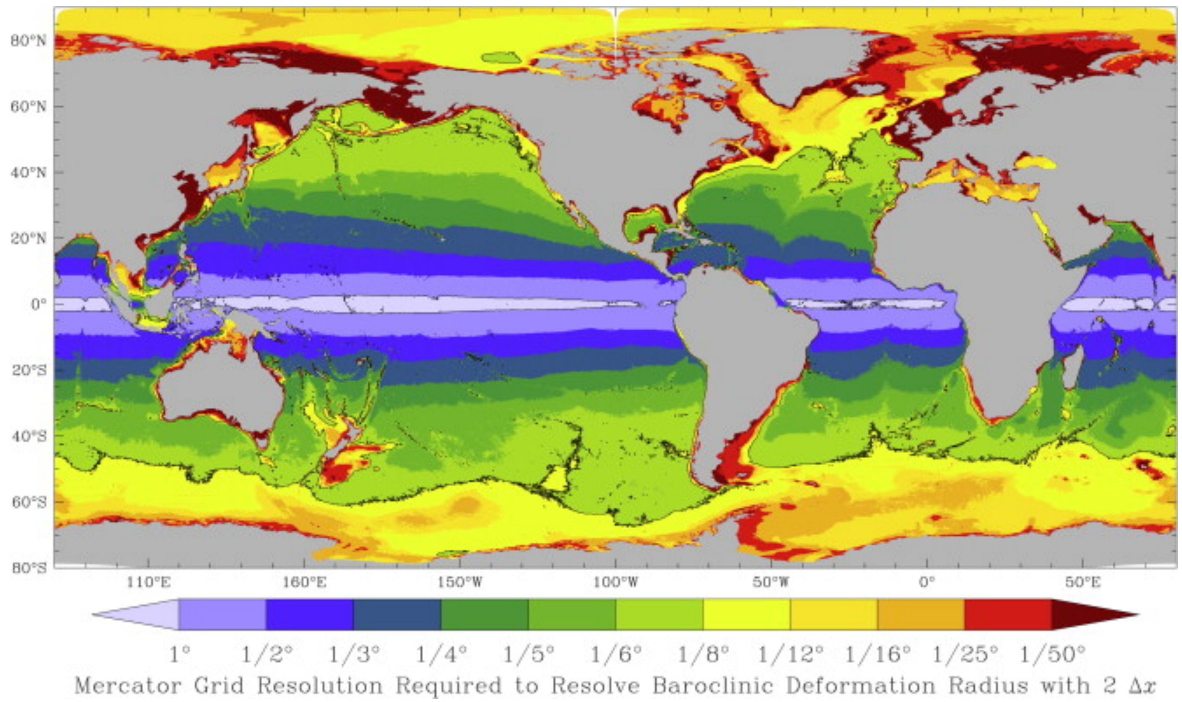


Large-scale circulation in the Atlantic
(cold and warm flows)



Mesoscale variability in the Atlantic
(from satellite altimetry)

Why Nested Ocean Modelling?



Required horizontal resolution to simulate the mesoscale

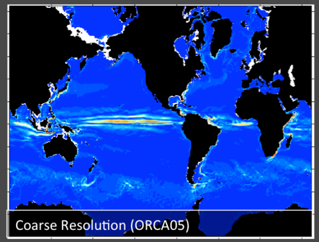
Hallberg (*Ocean Modell.*, 2013)

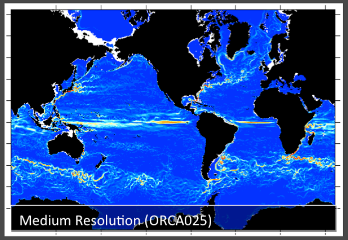
Why Nested Ocean Modelling?

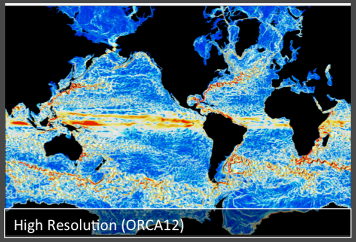
GEOMAR

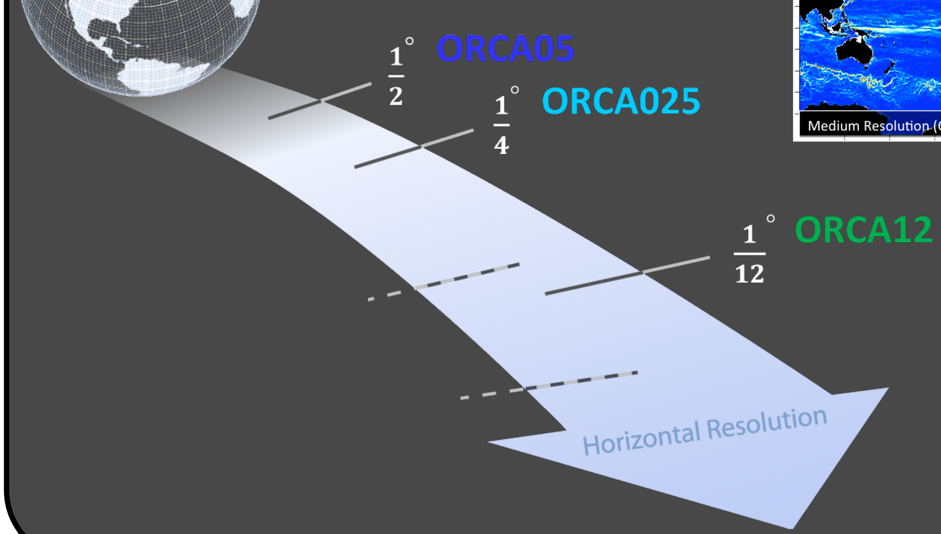
Ocean Modeling at GEOMAR

	Grid size	Nº grid points	Time-step	Usage
ORCA05	1/2°	17 x 10^6	36 min	Several 100y-experiments
ORCA025	1/4°	68 x 10^6	24 min	
ORCA12	1/12°	608 x 10^6	6 min	Very few decades


Coarse Resolution (ORCA05)


Medium Resolution (ORCA025)

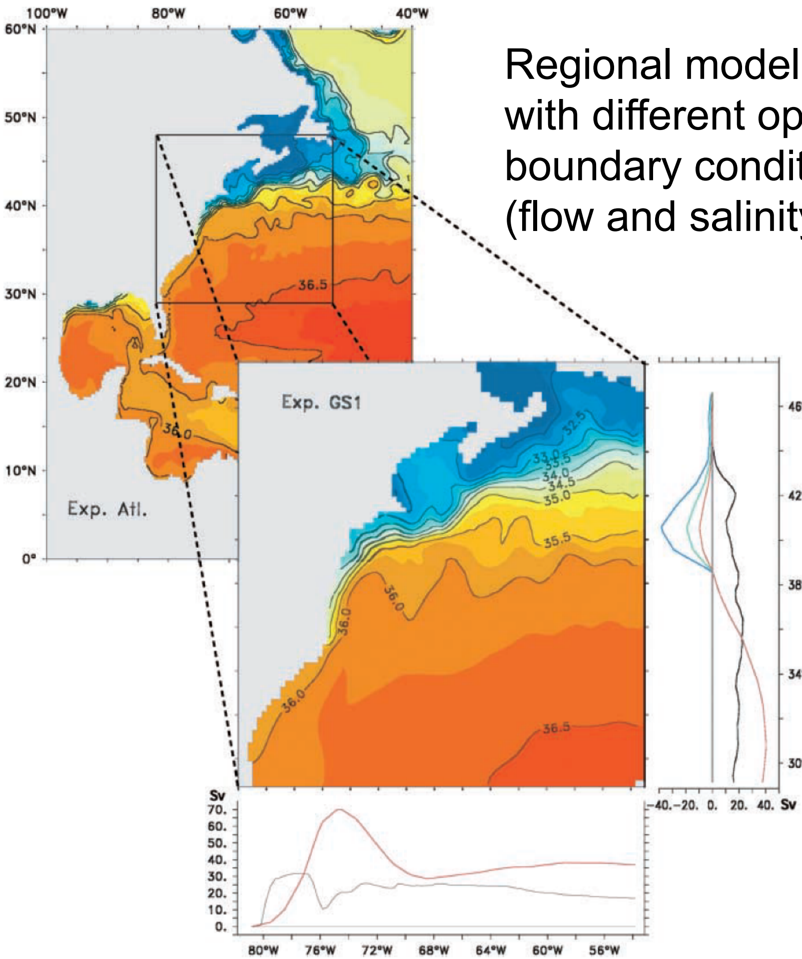

High Resolution (ORCA12)



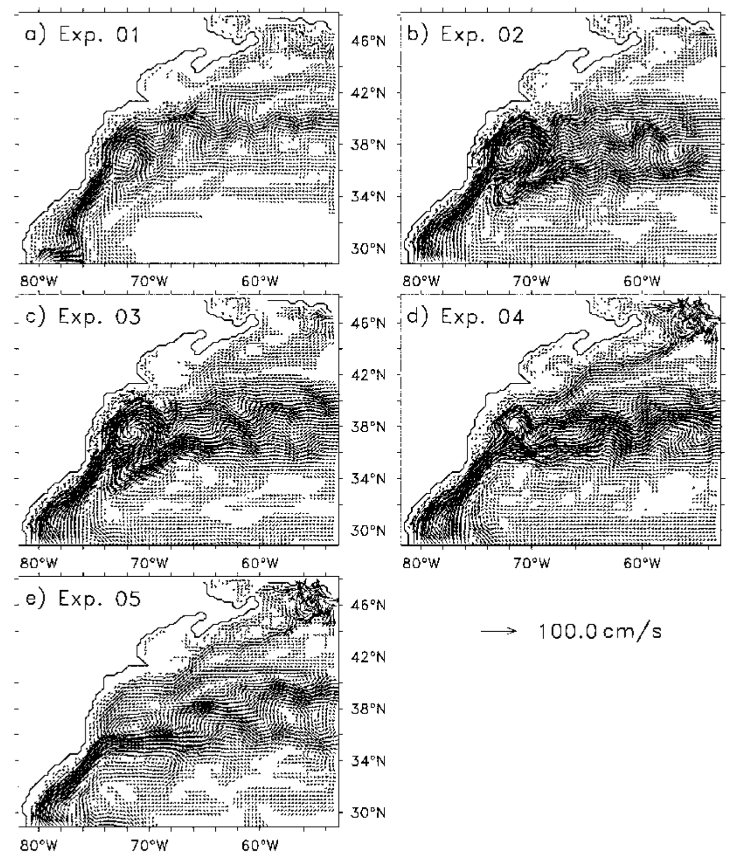
NEMO
DRAKKAR

Global models

Why Not Regional Ocean Modelling?



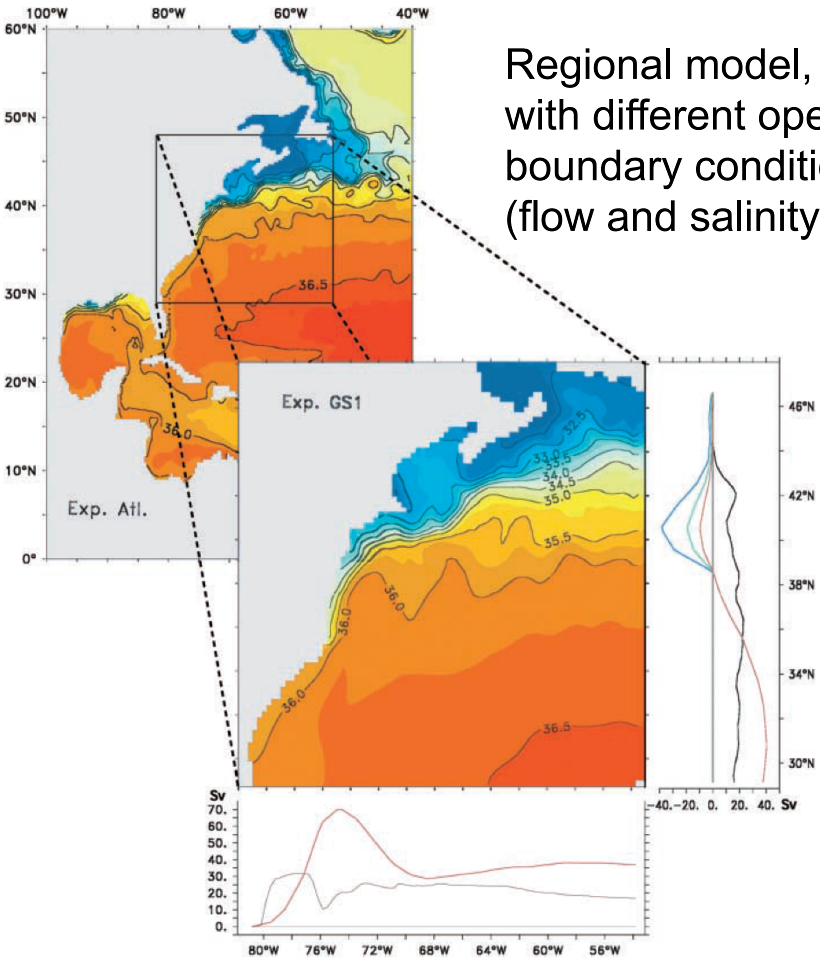
Regional model, exps. with different open boundary conditions (flow and salinity)



Upper-ocean velocities (10-50m)

Gerdes et al. (*Clim. Dyn.* 2001)

Why Not Regional Ocean Modelling?



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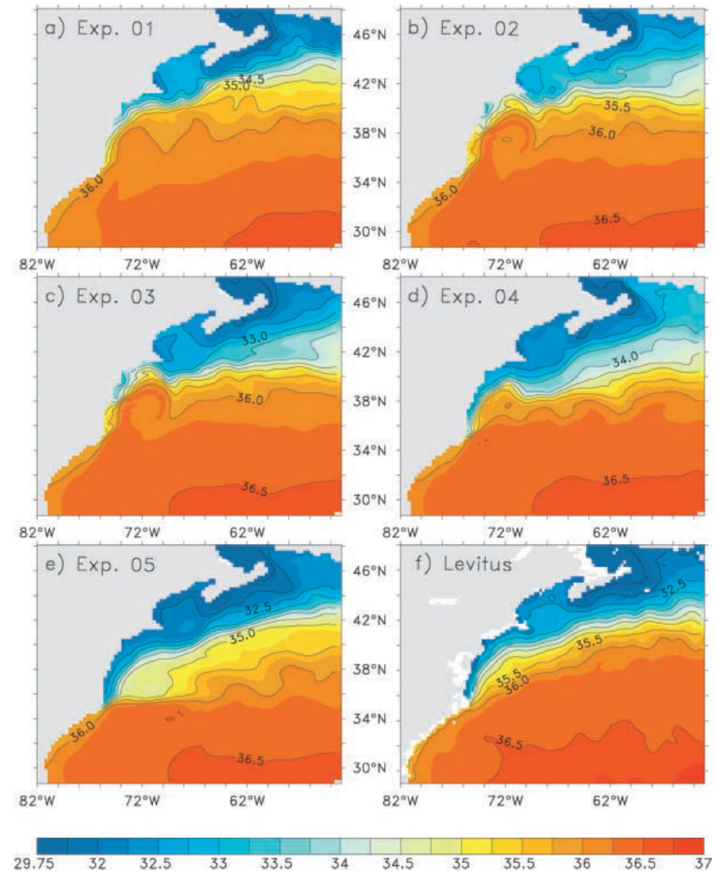
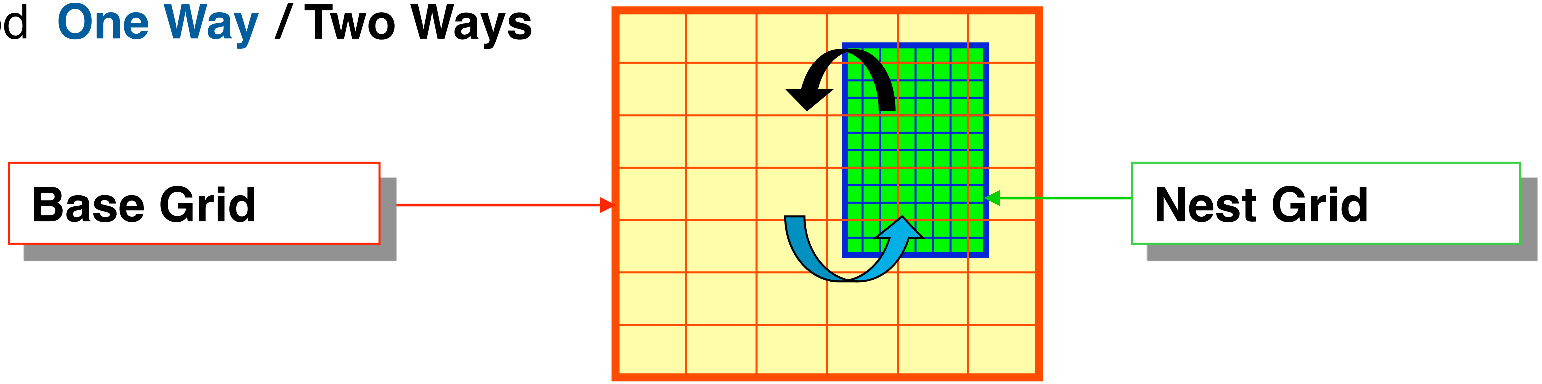


Upper-ocean salinities (10-50m)

Gerdes et al. (*Clim. Dyn.* 2001)

Nesting

Method **One Way** / **Two Ways**



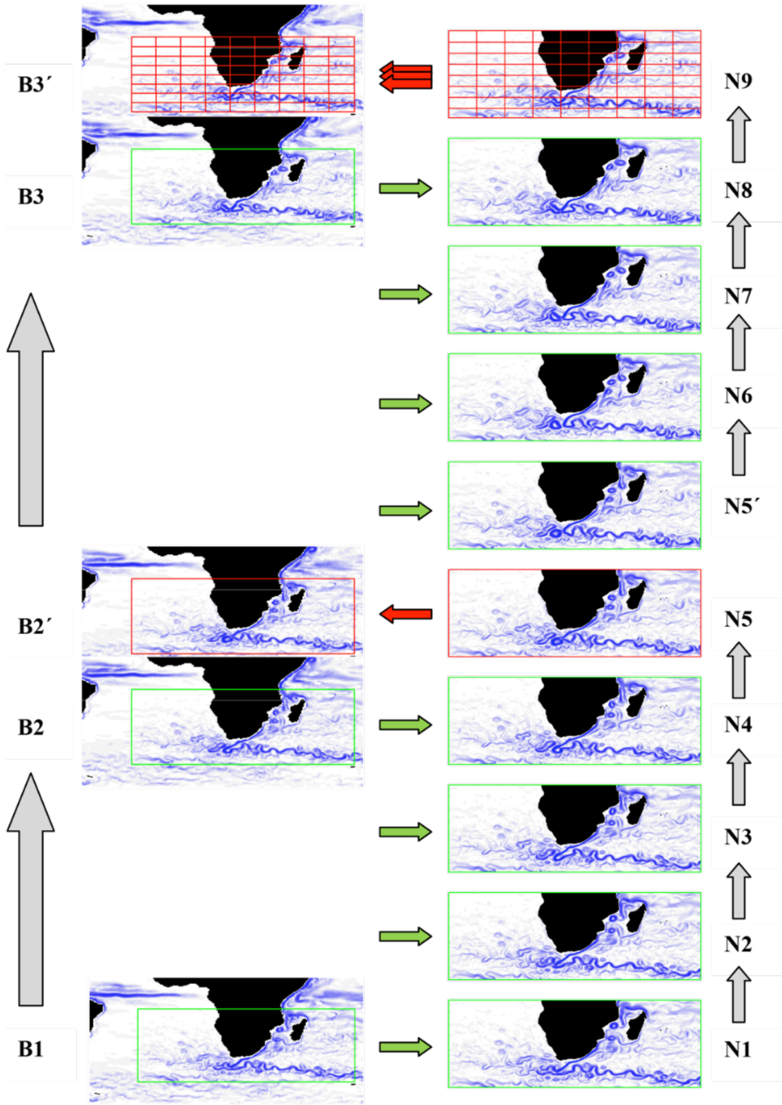
AGRIF (Adapted Grid Refinement in FORTRAN)

- Both models are integrated simultaneously:
    - The nest grid gets information from the base grid at the boundary
    - The nest grid updates the base grid
- Available in NEMO and ROMS
- Individual parameters/parameterizations for base and nest
- Online interpolation of forcing fields

Debreu et al. (Comp. Geosci., 2008)

Nesting

Global Base Model



Nested Model

Ocean Modeling at GEOMAR

	Grid size	Nº grid points	Time-step	Usage
ORCA05	1/2°	17×10^6	36 min	Several 60y-hindcasts
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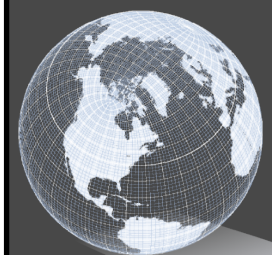
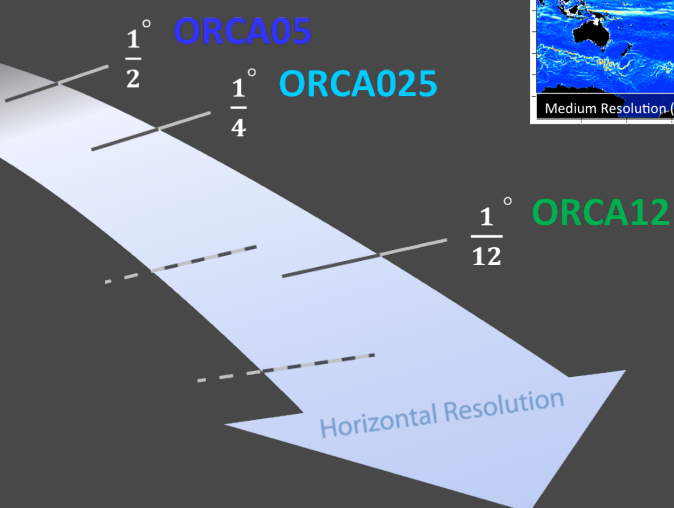
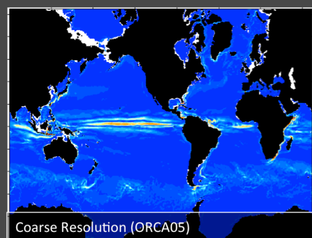
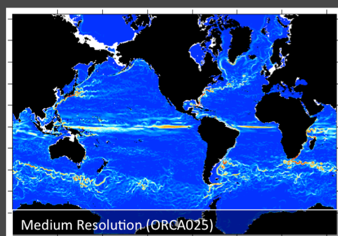
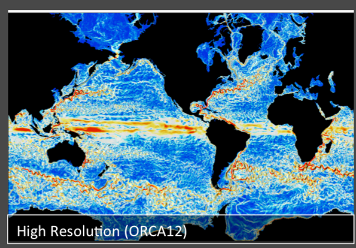




Coarse Resolution (ORCA05)


Medium Resolution (ORCA025)


High Resolution (ORCA12)

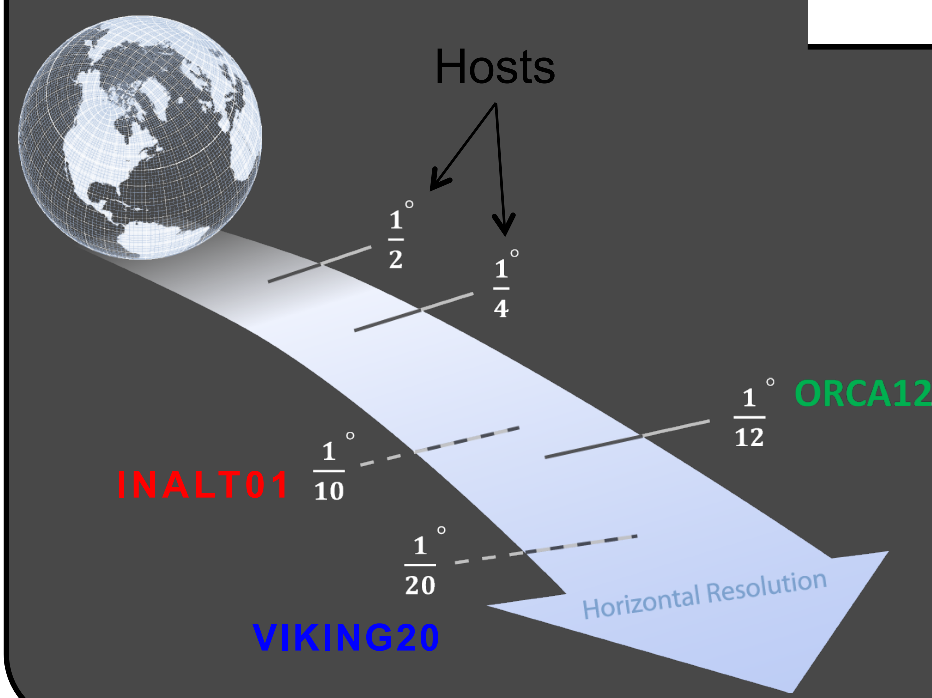
Global models

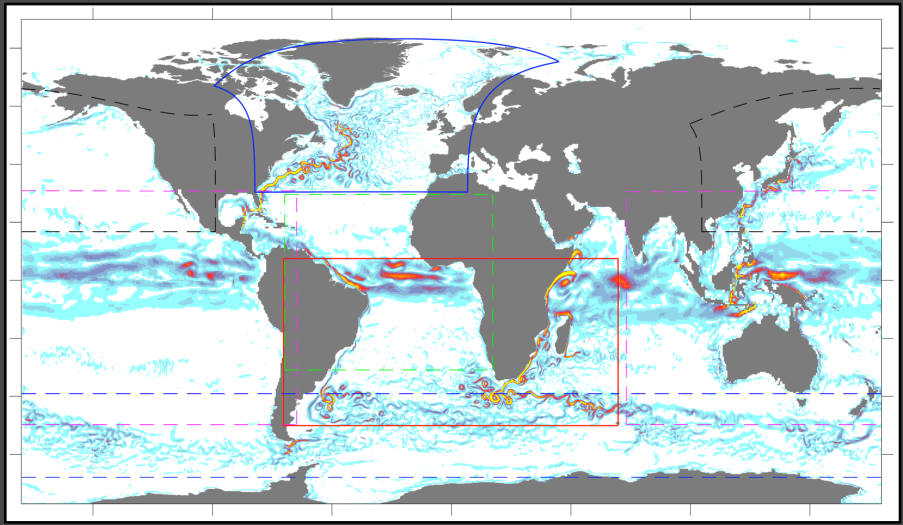
Why Nested Ocean Modelling?

GEOMAR

Ocean Modeling at GEOMAR

	Grid size	Nº grid points	Nest:Base	Usage
INALT01	1/10° nest + 1/2° base	43×10^6 $+17 \times 10^6$	10:1	Several hindcasts (past ~60 years)
VIKING20	1/20° nest + 1/4° base	141×10^6 $+ 68 \times 10^6$	10:1	





Global nested models

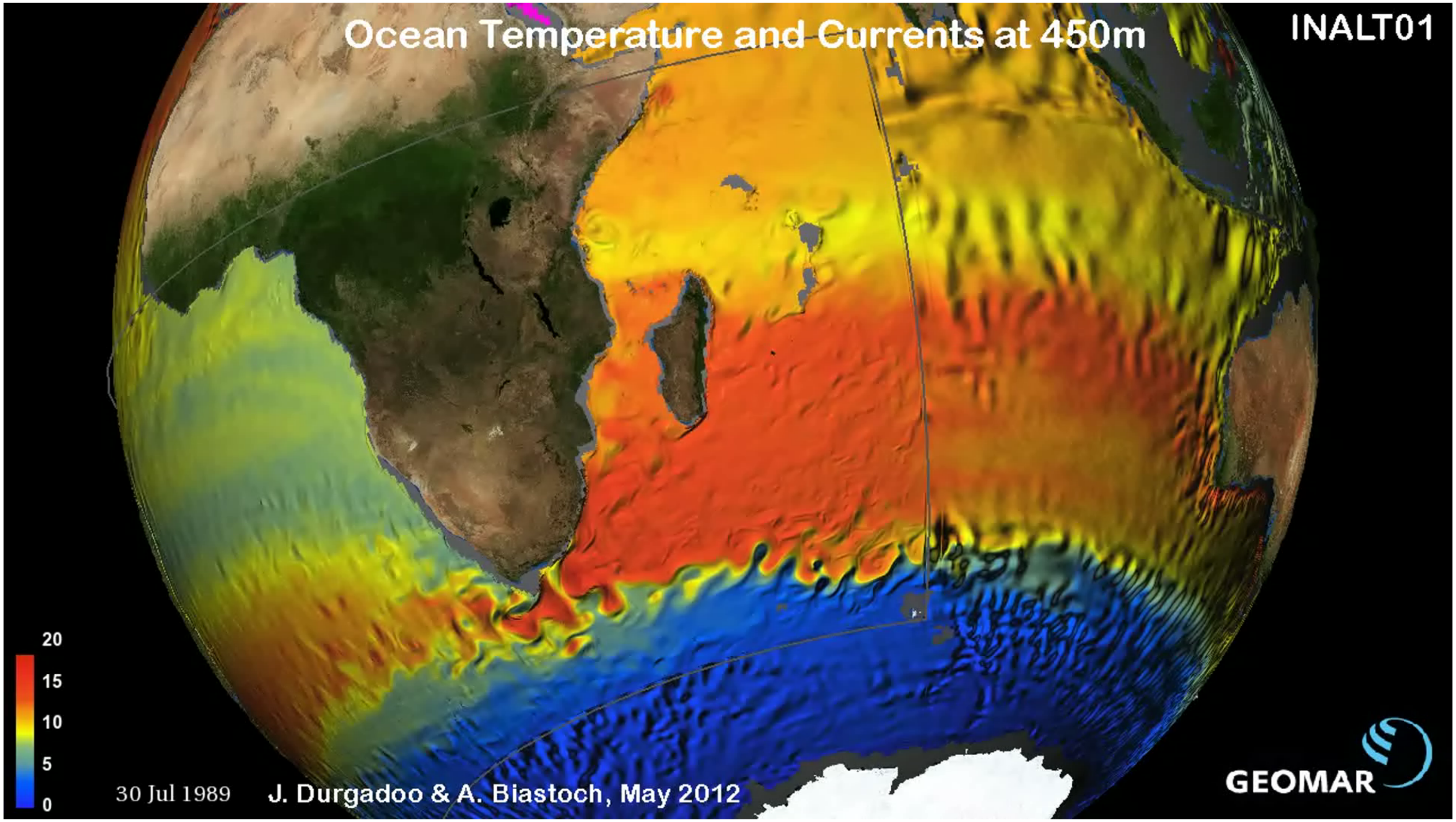
Biastoch et al. (*CLIVAR Exchanges,* 2014)

HELMHOLTZ ASSOCIATION

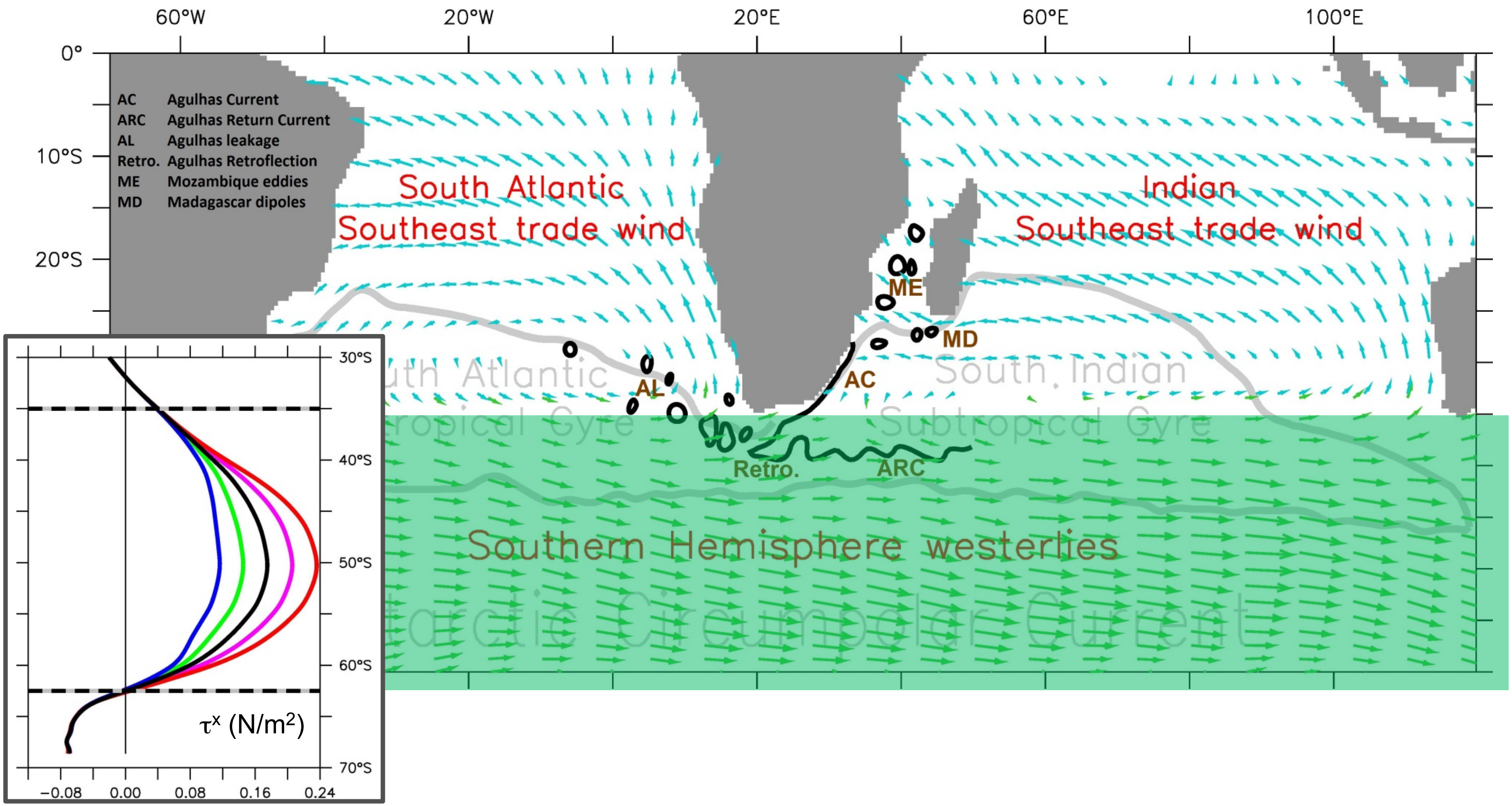
Online Simulation of Open Boundary Conditions

Example: Indian Ocean

Online Simulation of Open Boundary Conditions



Impact of SH Westerlies on Agulhas Current



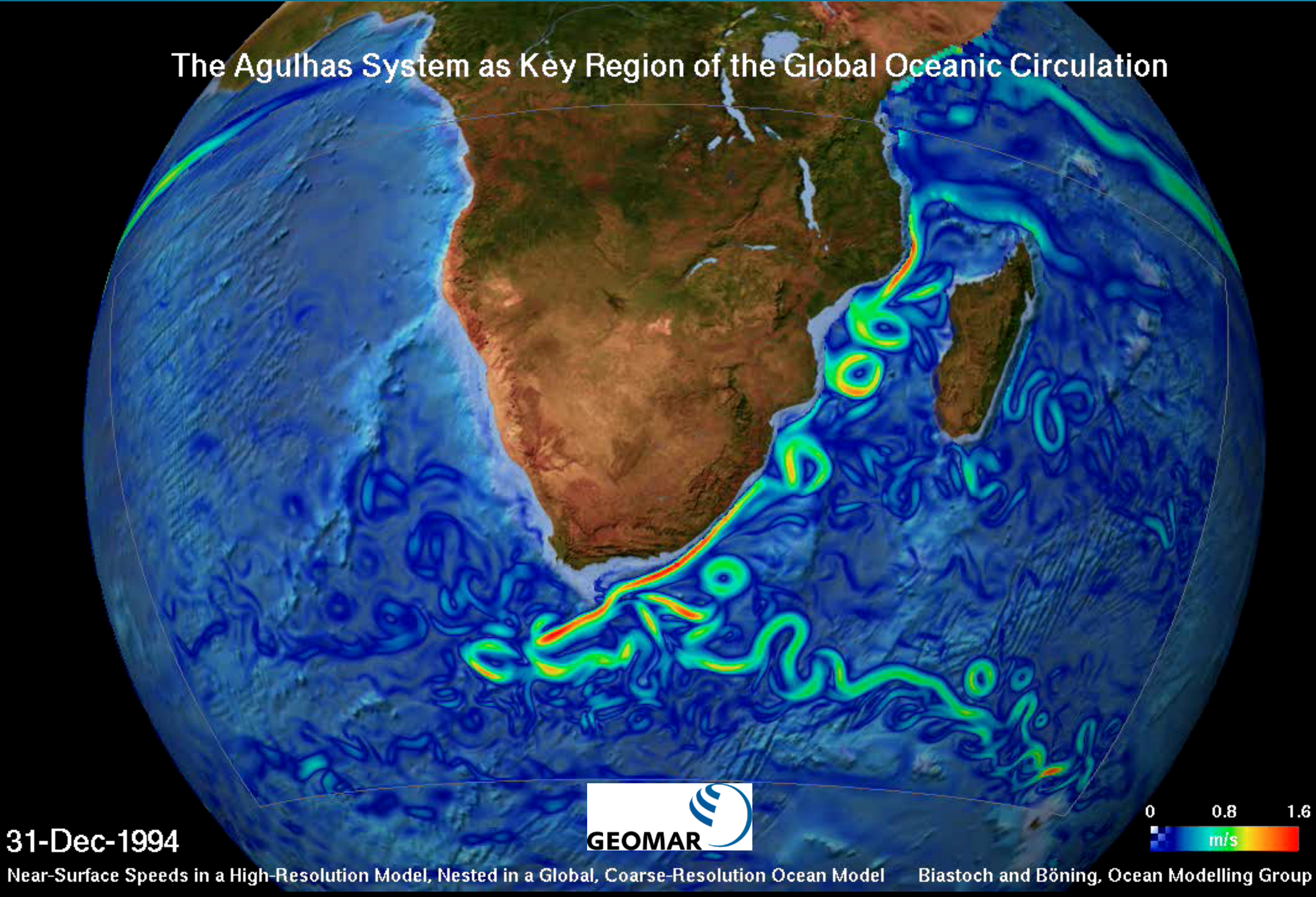
Durgadoo et al. (*J. Phys. Oceanogr.*, 2013)

Flexible Use of Nest Region

Example: Upstream Perturbations and Agulhas Leakage

Upstream Perturbations and Agulhas Leakage

GEOMAR

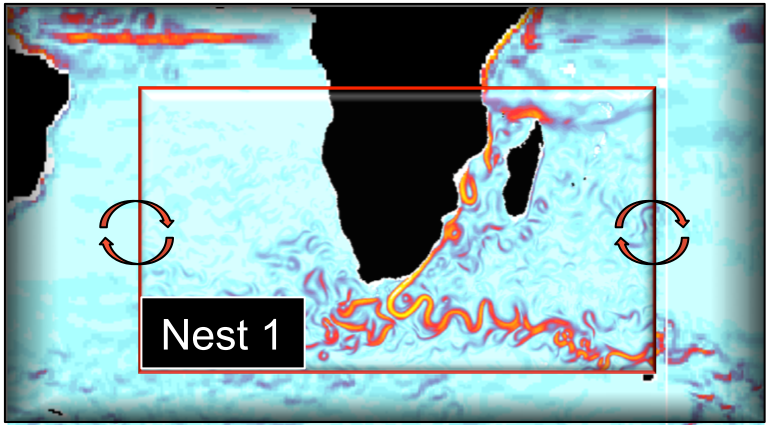


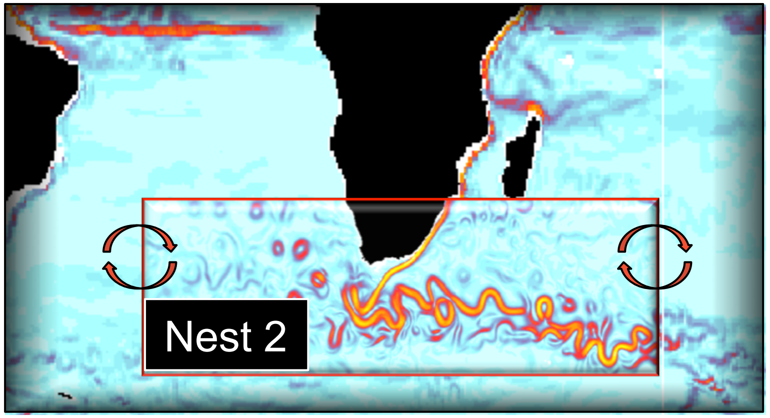
Upstream Perturbations and Agulhas Leakage

GEOMAR

<u>Question</u>: What regional physics controls the exchange between Indian and Atlantic?

→ need high-resolution





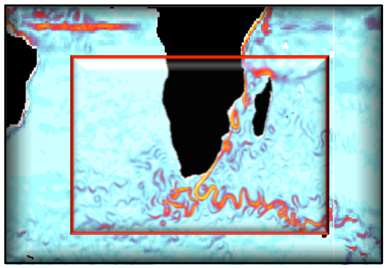
1/10° nests in 1/2° base model (ORCA05)

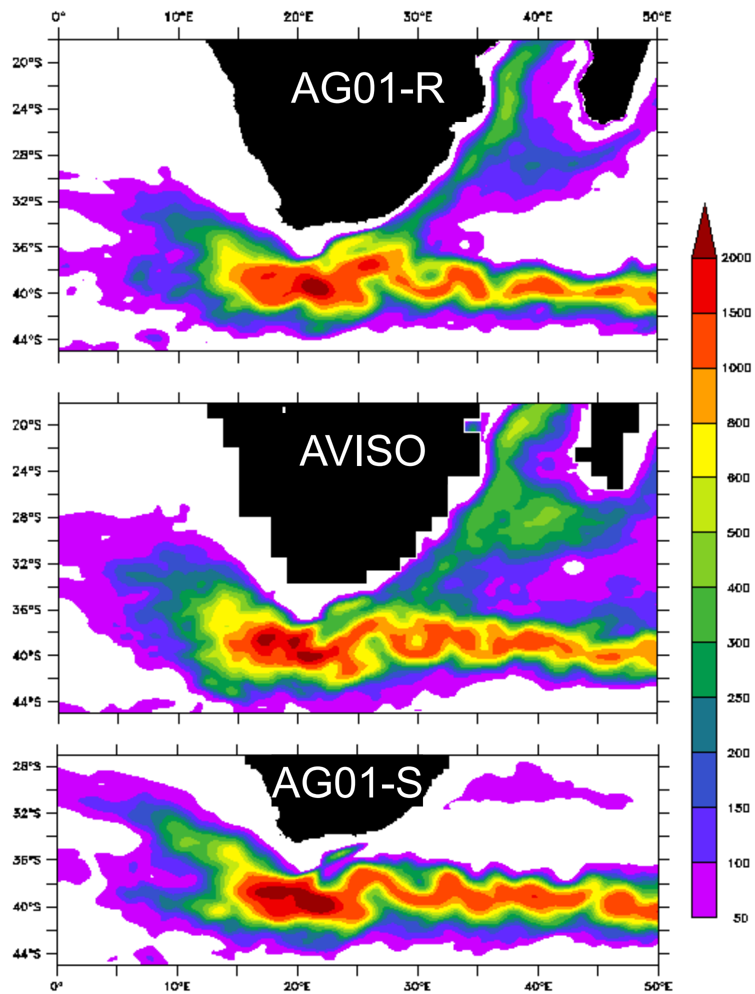
Biastoch et al. (*Geophys. Res. Lett.*, 2008)

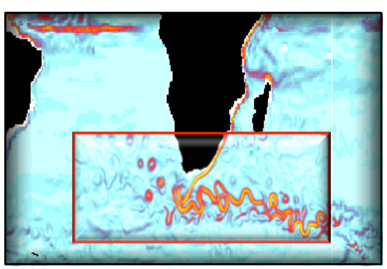
HELMHOLTZ ASSOCIATION

Upstream Perturbations and Agulhas Leakage

GEOMAR







Sea surface height variance from satellite altimetry and sensitivity experiments

Biastoch et al. (*Geophys. Res. Lett.*, 2008)

HELMHOLTZ ASSOCIATION

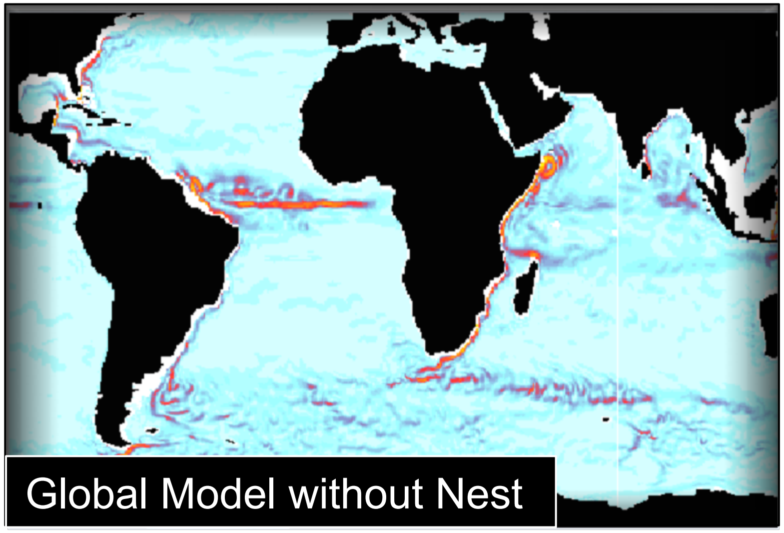
Identification of Key Processes

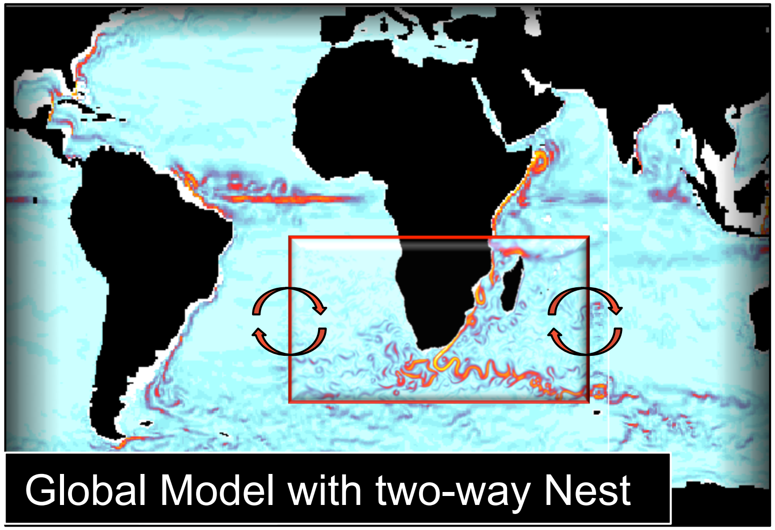
Example 1: Impact of Agulhas Mesoscale on the Large-scale Circulation

Impact of Agulhas Mesoscale on the Large-scale Circulation

Goal: isolate the net effect of the mesoscale Agulhas variability on the large-scale circulation

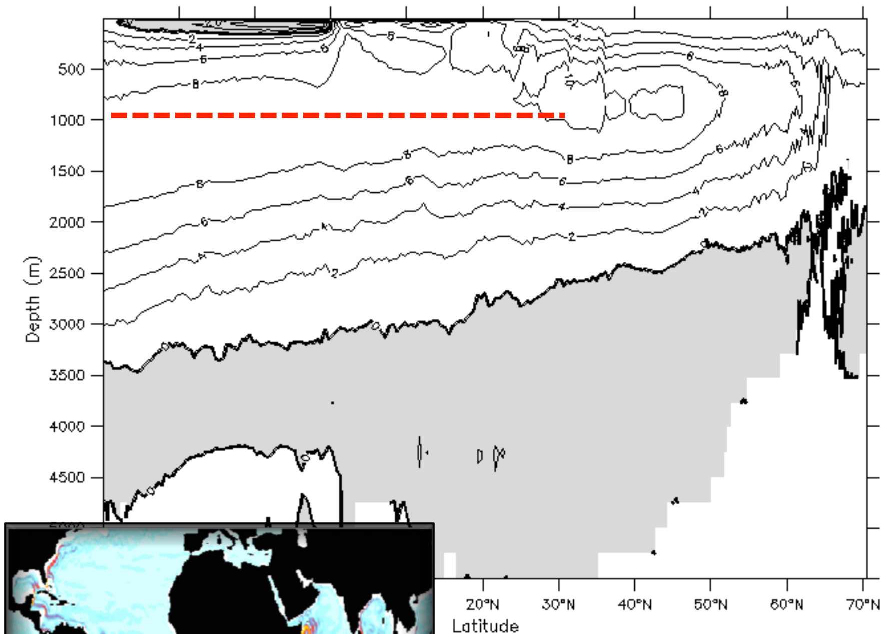
→ need two-way nesting

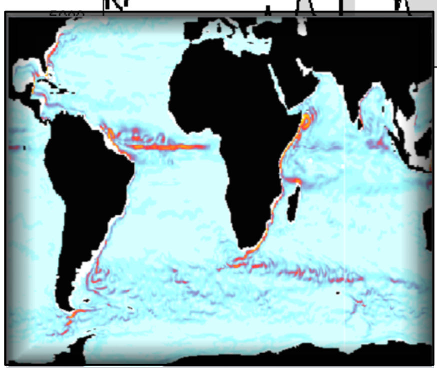




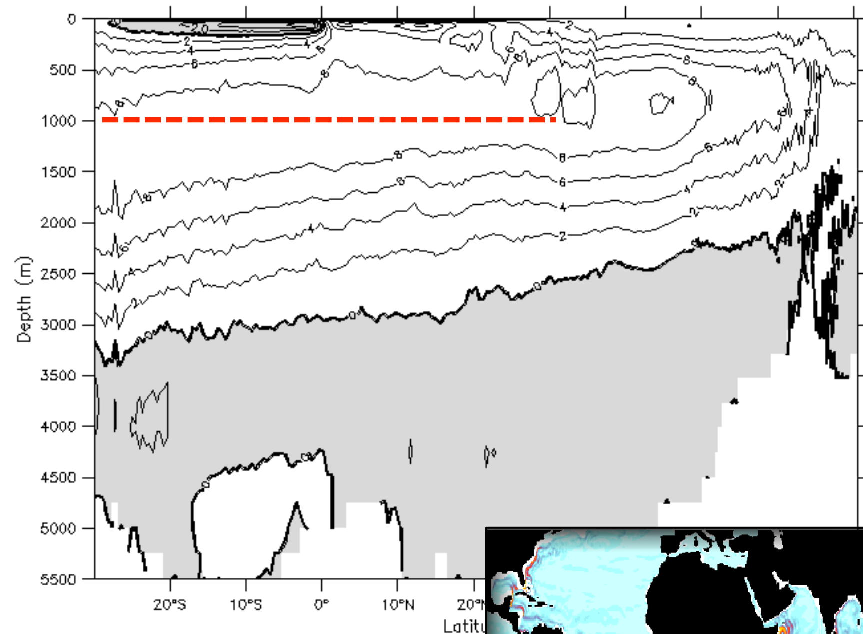
Biastoch et al. (*Nature*, 2008)

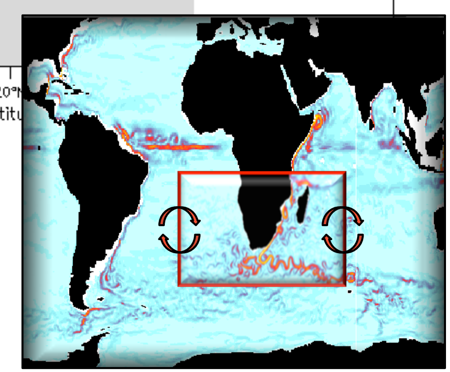
Impact of Agulhas Mesoscale on the Large-scale Circulation





Without Agulhas nest
(net Agulhas leakage:
~30 Sv)



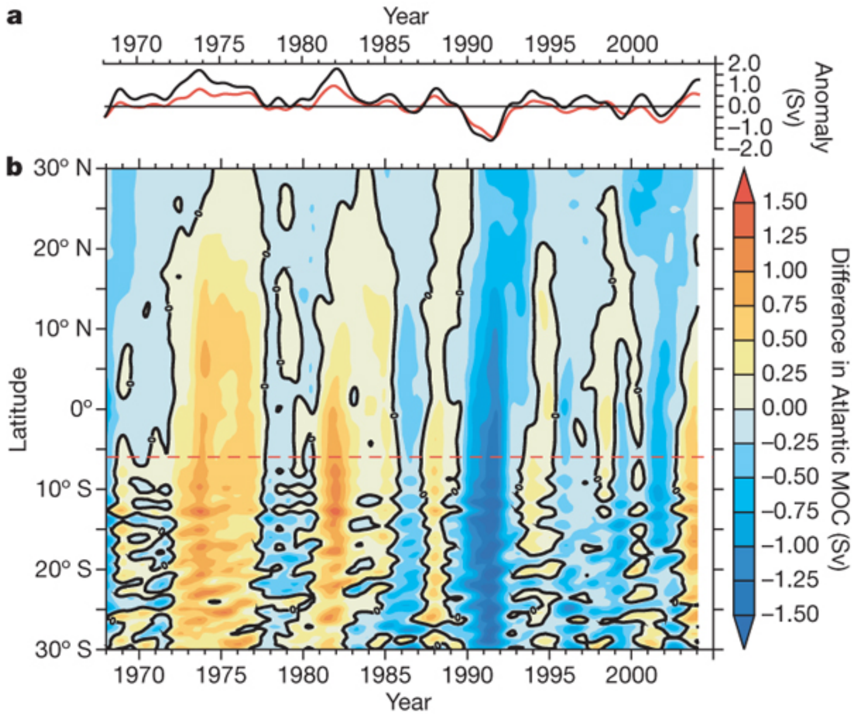


With Agulhas nest
(net Agulhas leakage:
~15 Sv)

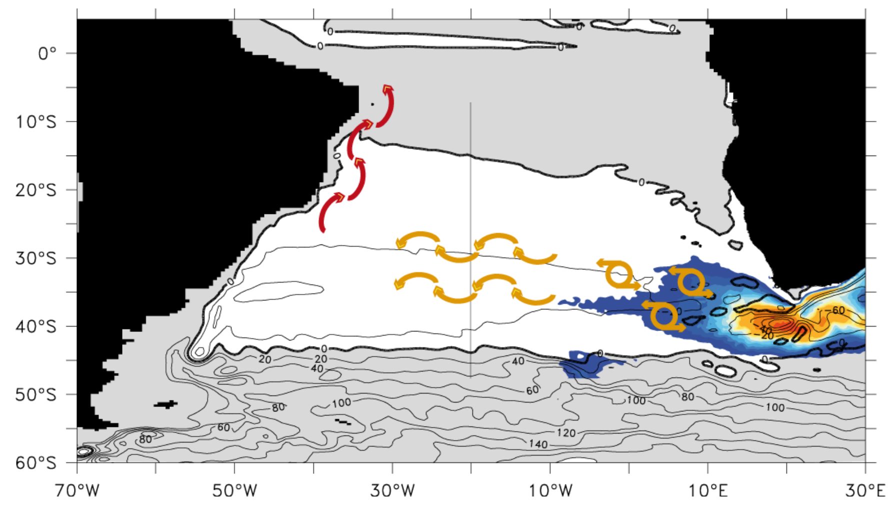
Biastoch et al. (*Nature*, 2008)

Impact of Agulhas Mesoscale on the Large-scale Circulation

GEOMAR



Interannually filtered AMOC-difference at 1000m:
Exp. with minus without Agulhas nest



Signal propagation through Rossby and topographic shelf waves

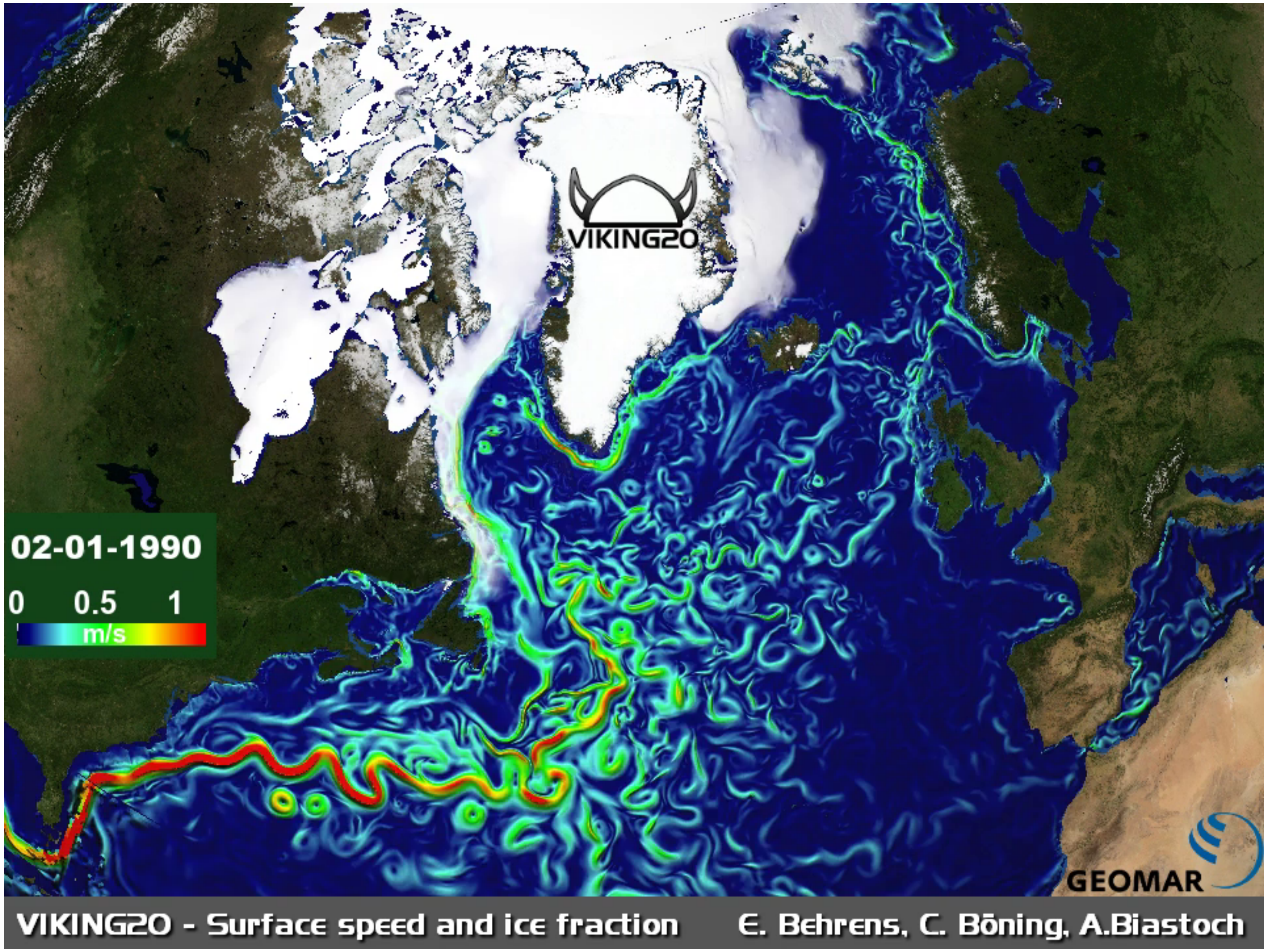
Biastoch et al. (*Nature*, 2008)

HELMHOLTZ ASSOCIATION

Identification of Key Processes

Example 2: Impact of European Nordic Sea Overflow on Deep Western Boundary Current

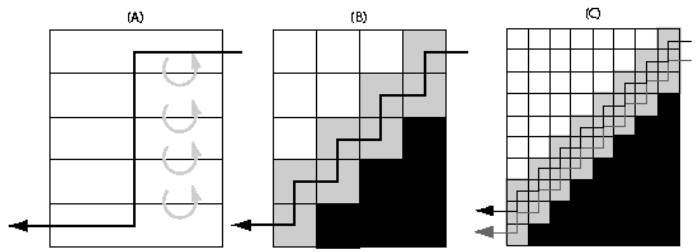
VIKING20

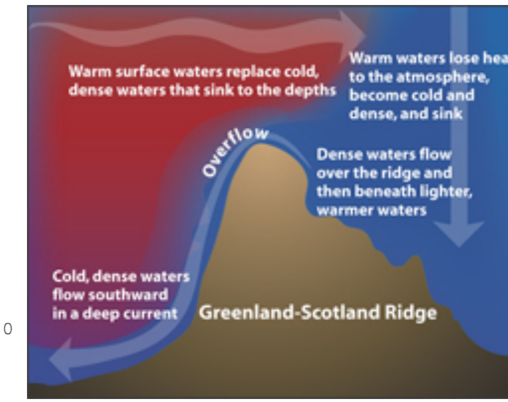


- 1/20° nest (30°-80°N)
  1/4° base (ORCA025)
- CORE-II (1948-2007) atmospheric forcing, interpolation on-the-fly
- Includes refinements of sea-ice and idealized tracers

Impact of European Nordic Sea Overflow on Deep Western Boundary Current

Spurious mixing in z-coordinate models

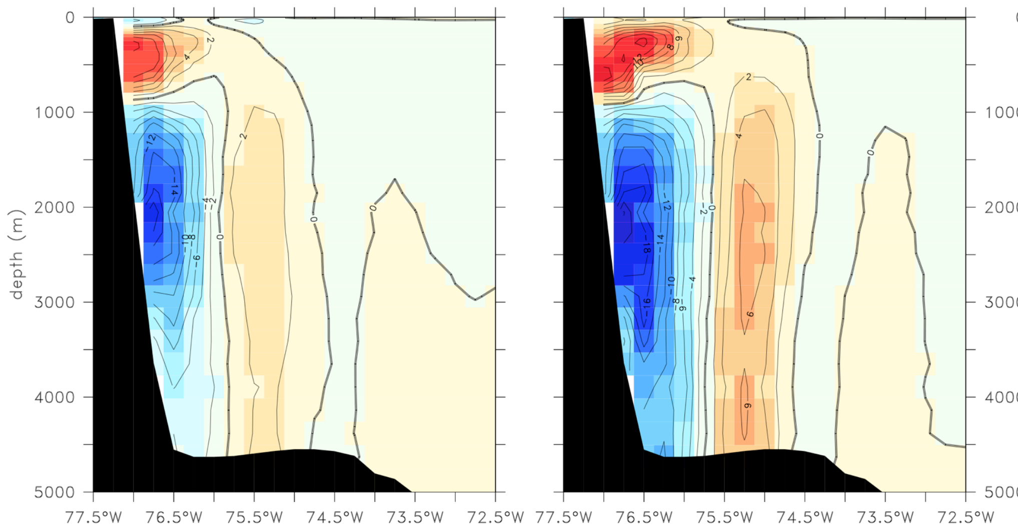




Overflow from the Nordic Seas into the North Atlantic

Antilles Current

Deep Western Boundary Current



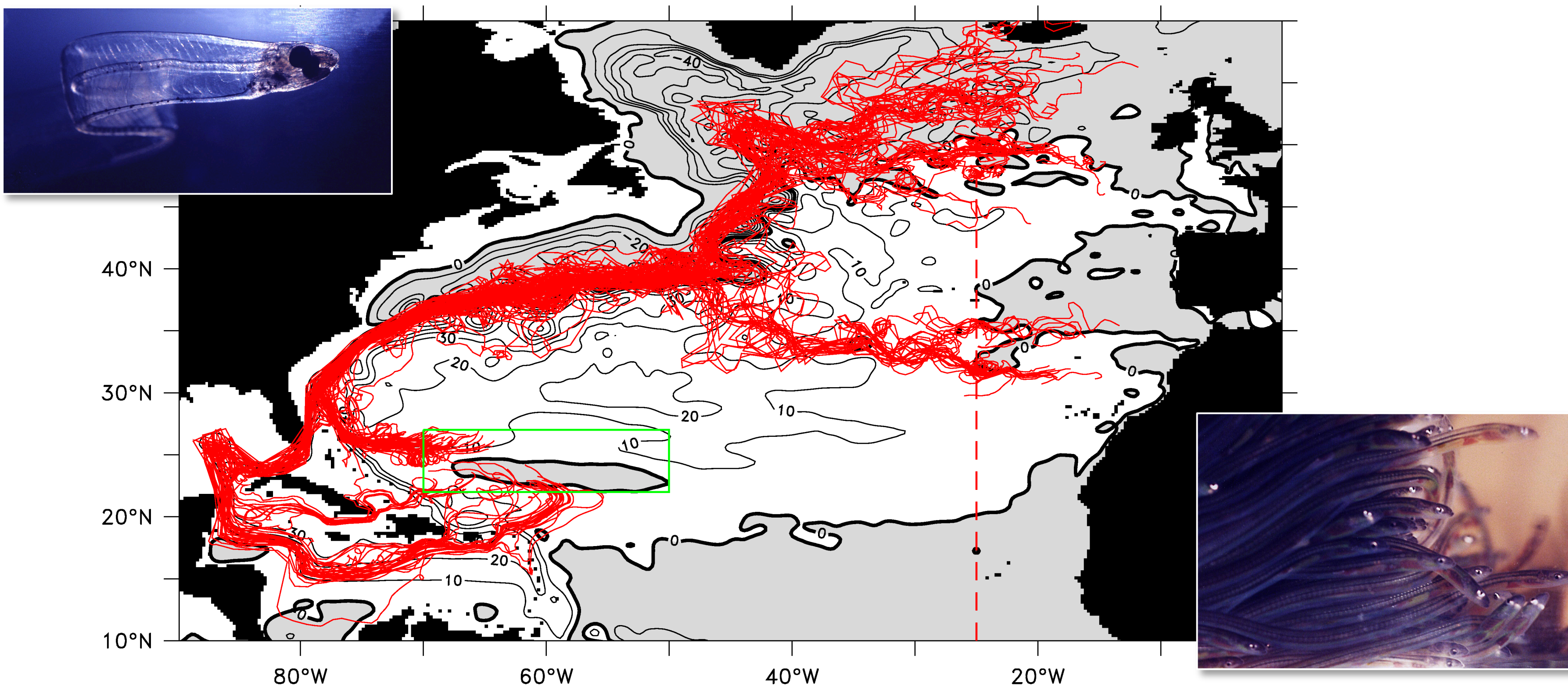
Section at 26°N in base model without… and with high-resolution nest

Biastoch et al. (*CLIVAR Exchanges*, 2014)

Interdisciplinary Applications

Example: Spreading of Glass Eels from the Sargasso Sea

Spreading of Glass Eeels

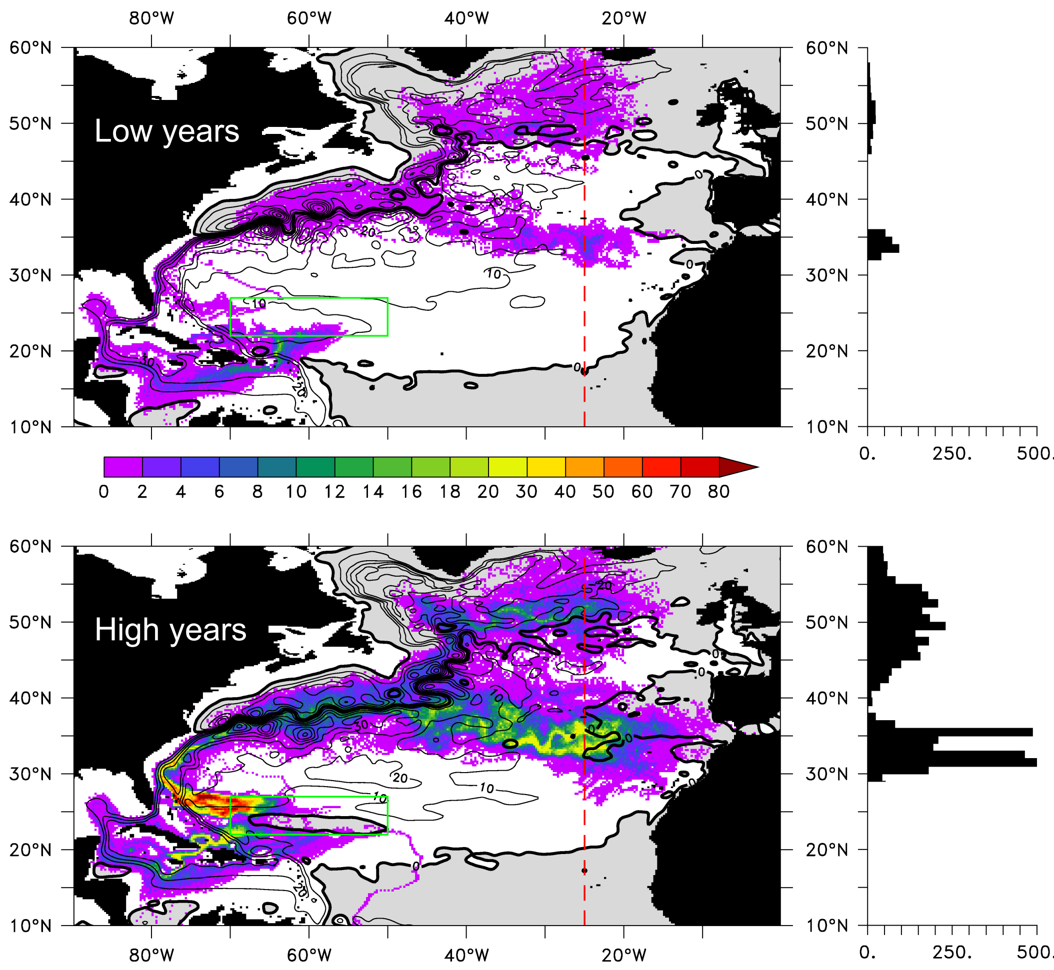


Example pathways of “virtual” glass eels, released in the Sargasso See and advected to 25°W within 2 years in a 1/20° nested model (30°-80°N)

Soares, Biastoch et al. (*Current Biology,* 2013)

Spreading of Glass Eeels

Probability map of v-eels

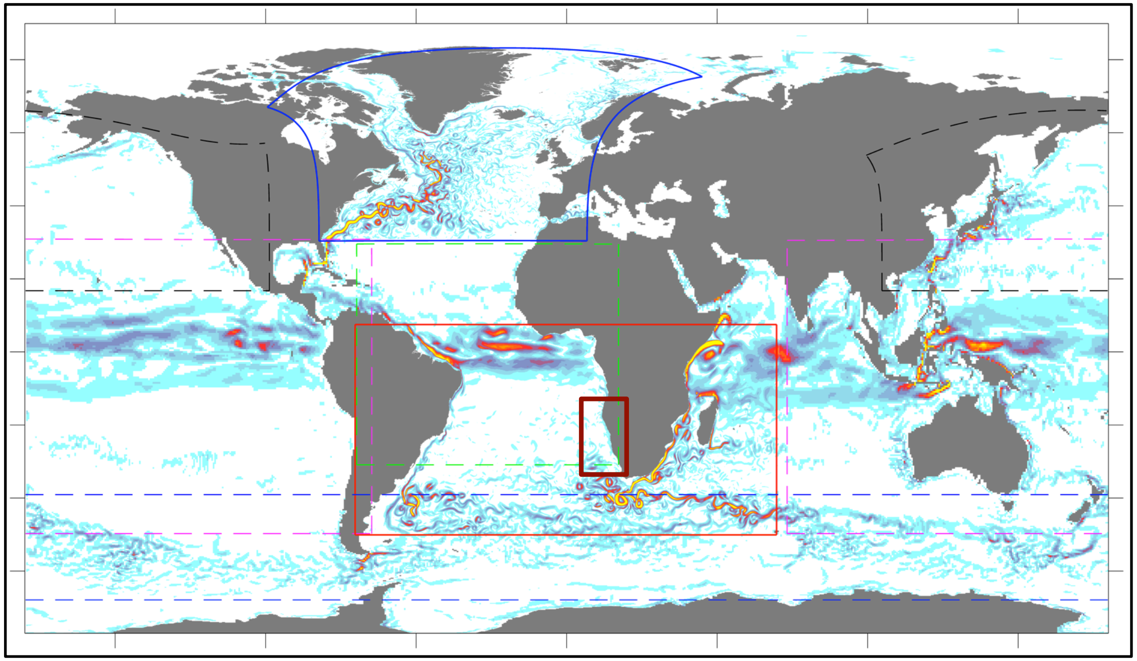


Number of v-eels arriving at 25°W

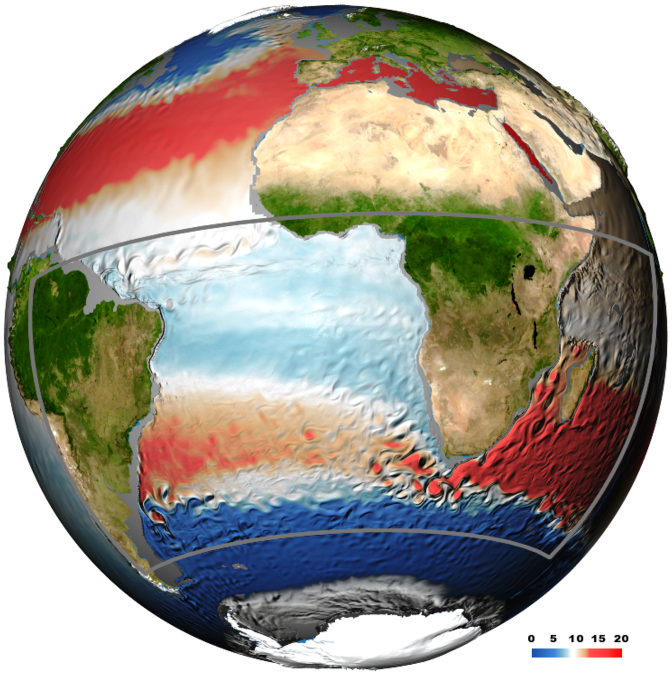
Soares, Biastoch et al. (*Current Biology,* 2013)

Summary

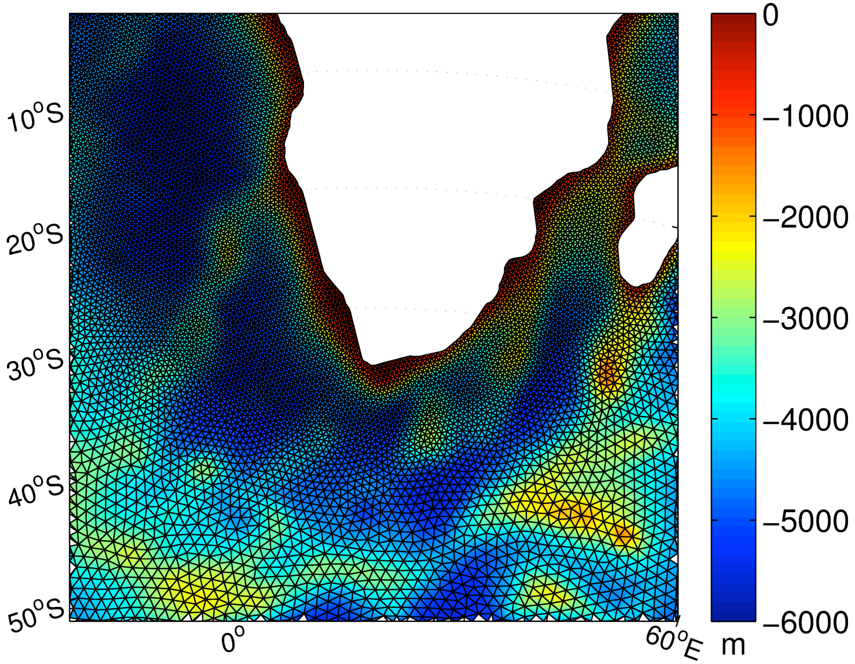
- Nesting is an online simulation of open boundary conditions <u>at all timescales</u>
- Flexible use (e.g., by varying nested domain)
- Allows to study impact of individual processes and regions (two-way nesting)
- Allows to introduce
  secondary nests



The Future?



INALT01
(1/10° nest in ORCA05, based on NEMO/AGRIF)



FESOM
(with regional focus on Agulhas dynamics)