Greatness from small beginnings

Impact of oceanic mesoscale on weather extremes and large-scale atmospheric circulation in midlatitudes

Joakim Kjellsson, GEOMAR/CAU
Eric Maisonnave, CERFACS
Wonsun Park, GEOMAR
Torge Martin, GEOMAR
Mojib Latif, GEOMAR

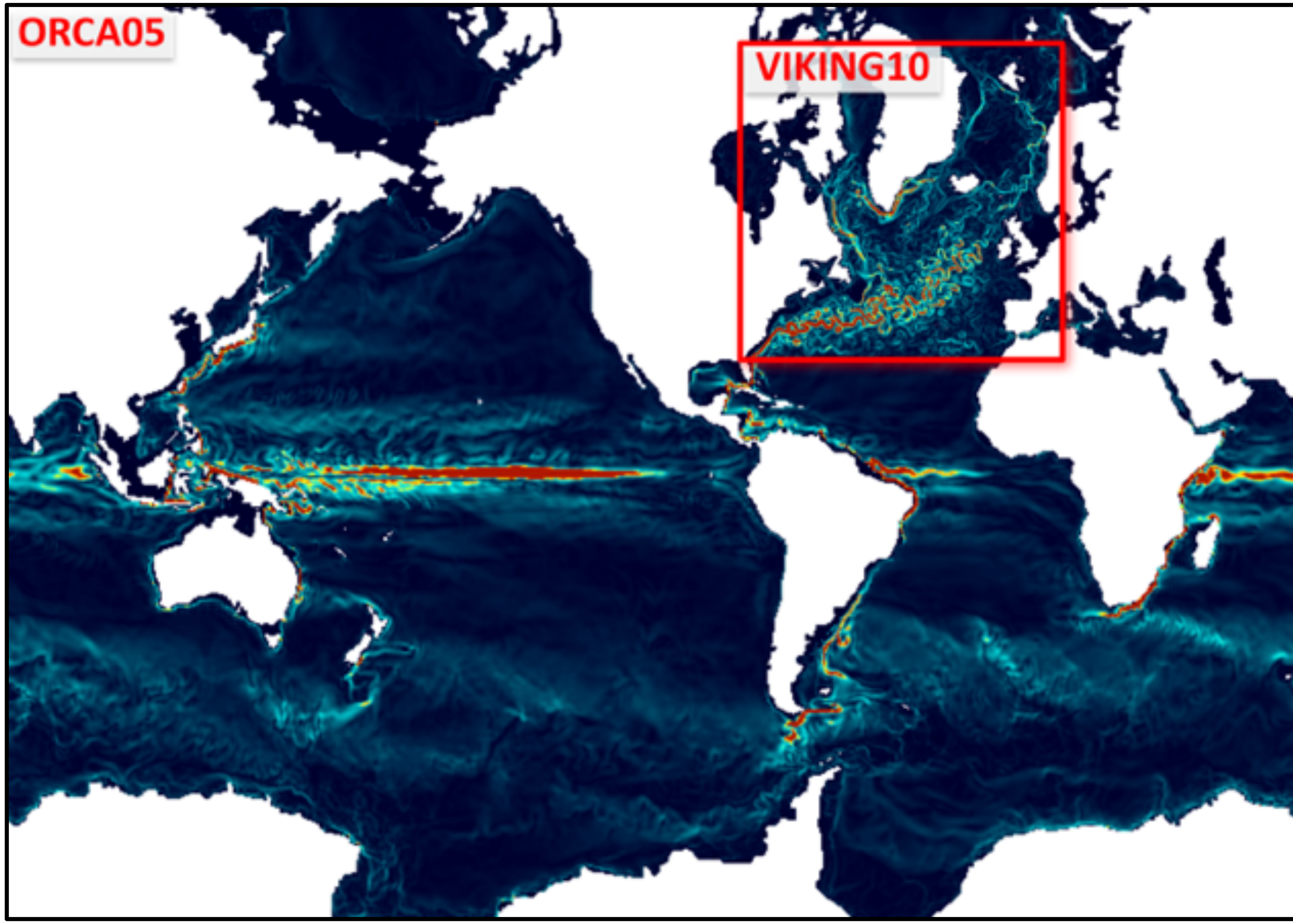
GEOMAR Helmholtz Centre for Ocean Research Kiel

CAU Christian-Albrechts-Universität zu Kiel

Background

- ROADMAP (JPI Oceans) project to investigate role of ocean on atmospheric circulation and extremes.
- What is the specific role of the oceanic mesoscale? Requires mesoscale-resolving models!
- Global models with dx ~ 10 km insanely expensive. Unstructured/nested grids a way forward.
- But fluxes are calculated on atmosphere grid => loss of detail in coupling with low-res atmosphere.

JPI OCEANS

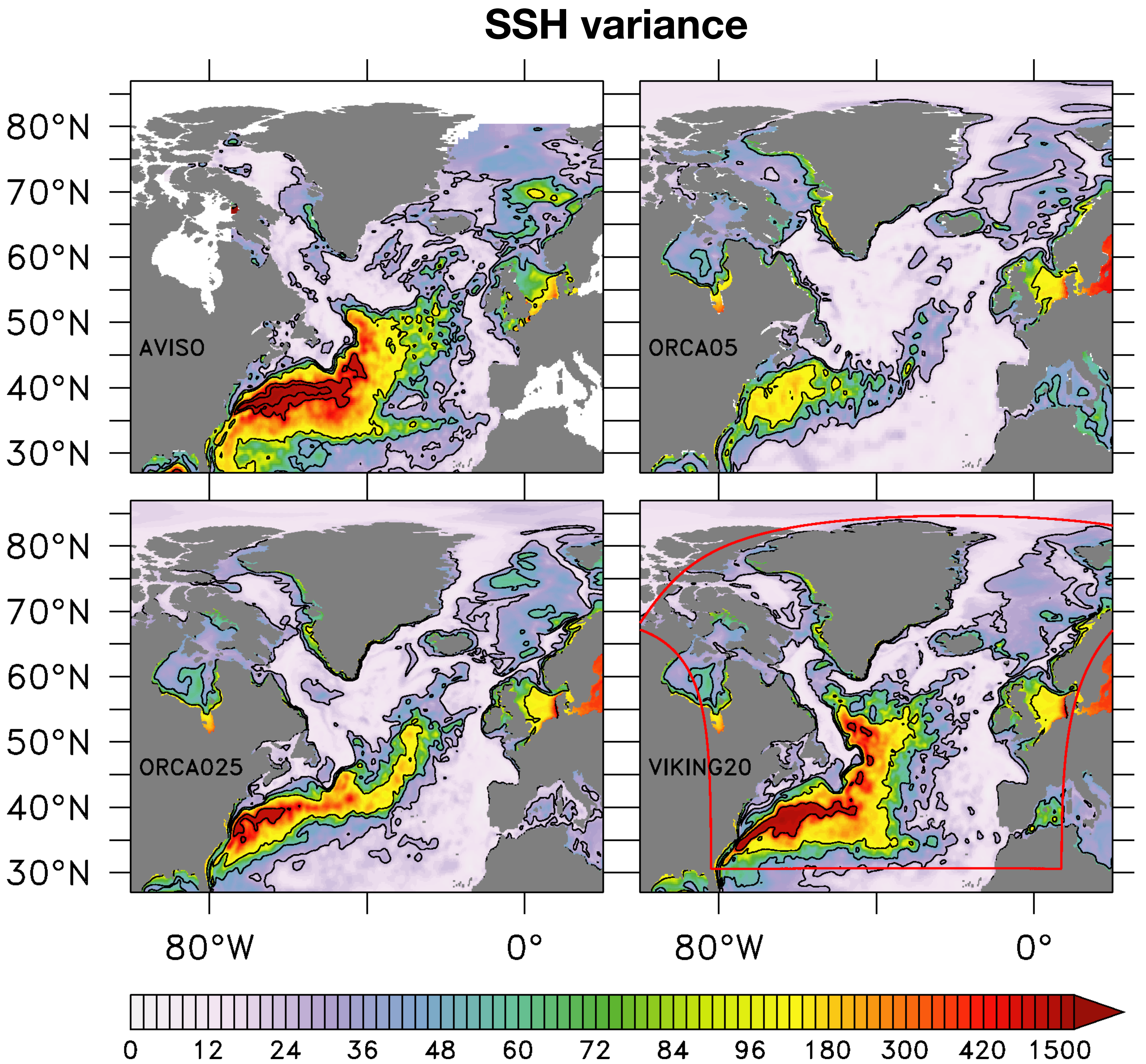


SSH variance in global 1/2° ocean model with 1/10° grid-refinement over North Atlantic

Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

Grid-refinement technique

- AGRIF = Adaptive Grid Refinement In Fortran (Debreu et al. 2008)
- Auto-generates code for a sub-model which communicates with the base model on the lateral boundaries.
- Refine grid by 4-5 times in AGRIF.
  Global 1/2° + N.Atl 1/10° or
  Global 1/4° + N.Atl 1/20°
  Reduce time step, mom. viscosity, tracer diffusion.
- Use cases in NEMO and ROMS
- Nest within nest possible, but not multiple nests in different regions.
  Only horizontal grid refinement. Vertical refinement in development.



Erik Behrens PhD thesis (2013)

The FOCI2 climate model

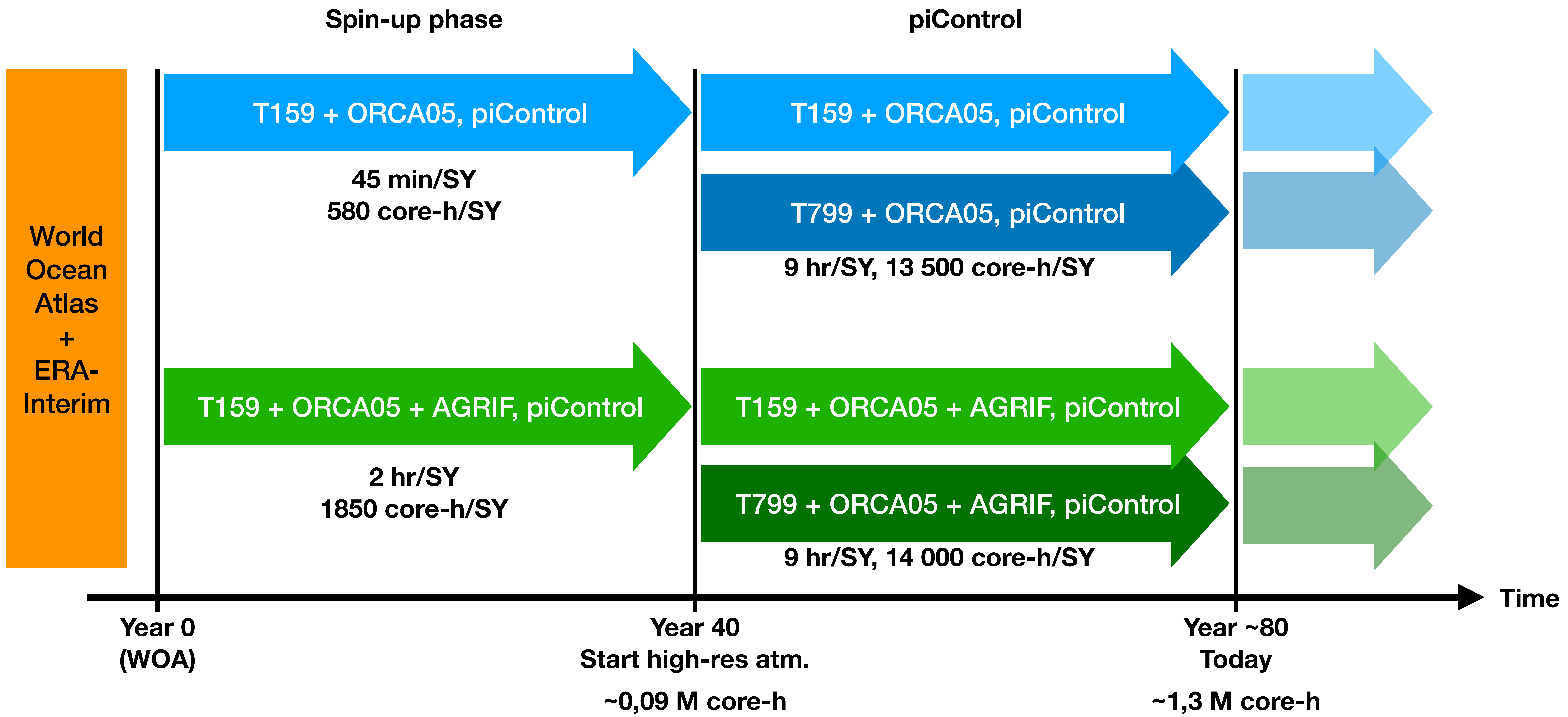
- OpenIFS 40r1. Either 125 km or 25 km horizontal resolution. Both 91 levels.
  Not feasible to run ECHAM6 at these resolutions…

- NEMO v3.6 + LIM2. 1/2° + 1/10° North Atlantic grid. 46 levels.

- 3-hourly coupling (ongoing work to compare 1hr vs 3hr coupling).

- ESM-Tools as runtime environment to modify namelist files, link input files, post process output, etc.
  OpenIFS, ECHAM, ICON, FESOM2, NEMO, MPIOM standalone + any combination as a coupled model via OASIS.
  See display by Dirk Barbi et al. (ESSI 2.11, Thu 16:15-18:00, D802)

Simulations



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Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

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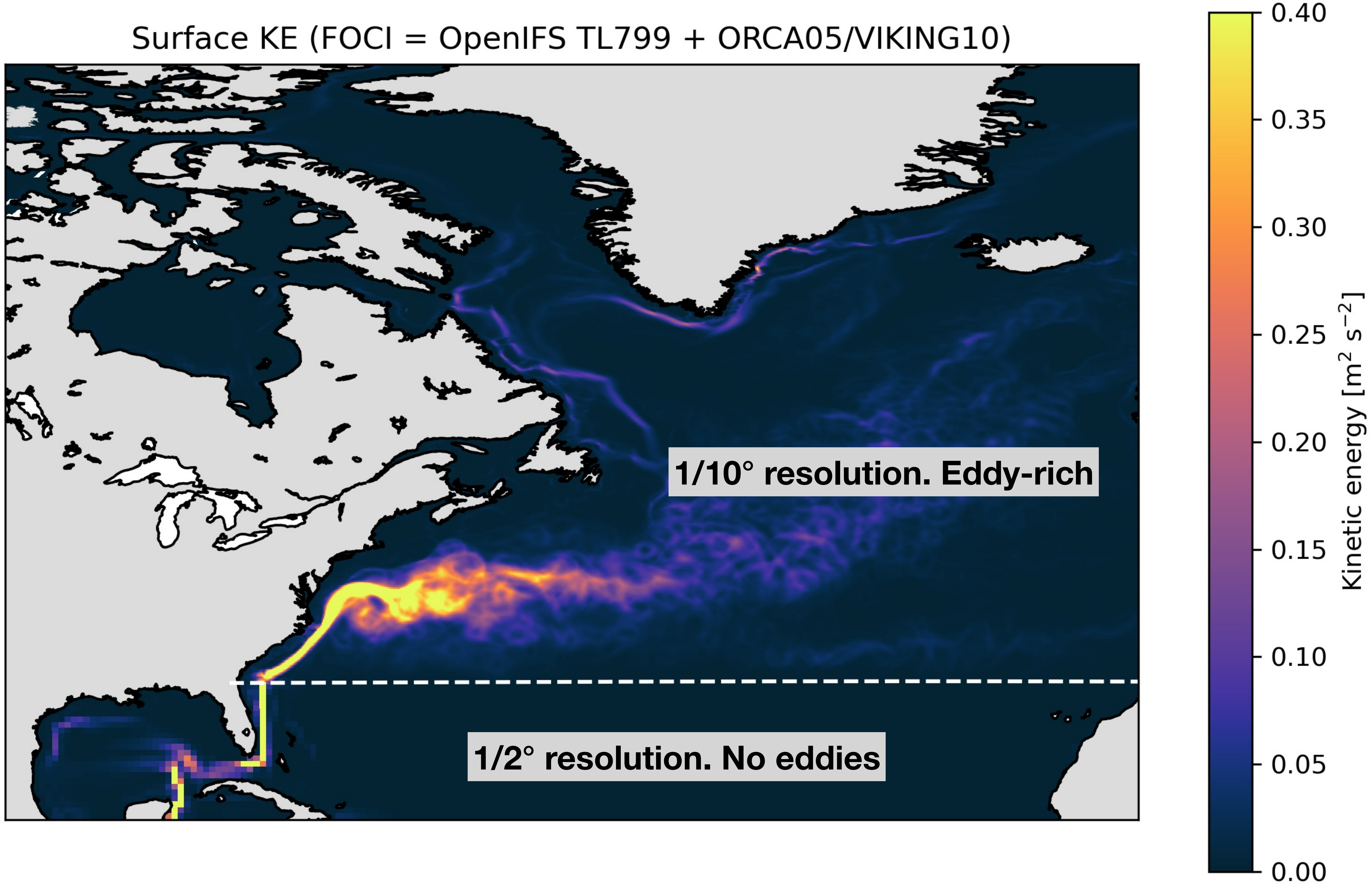
MKE in FOCI



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Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de
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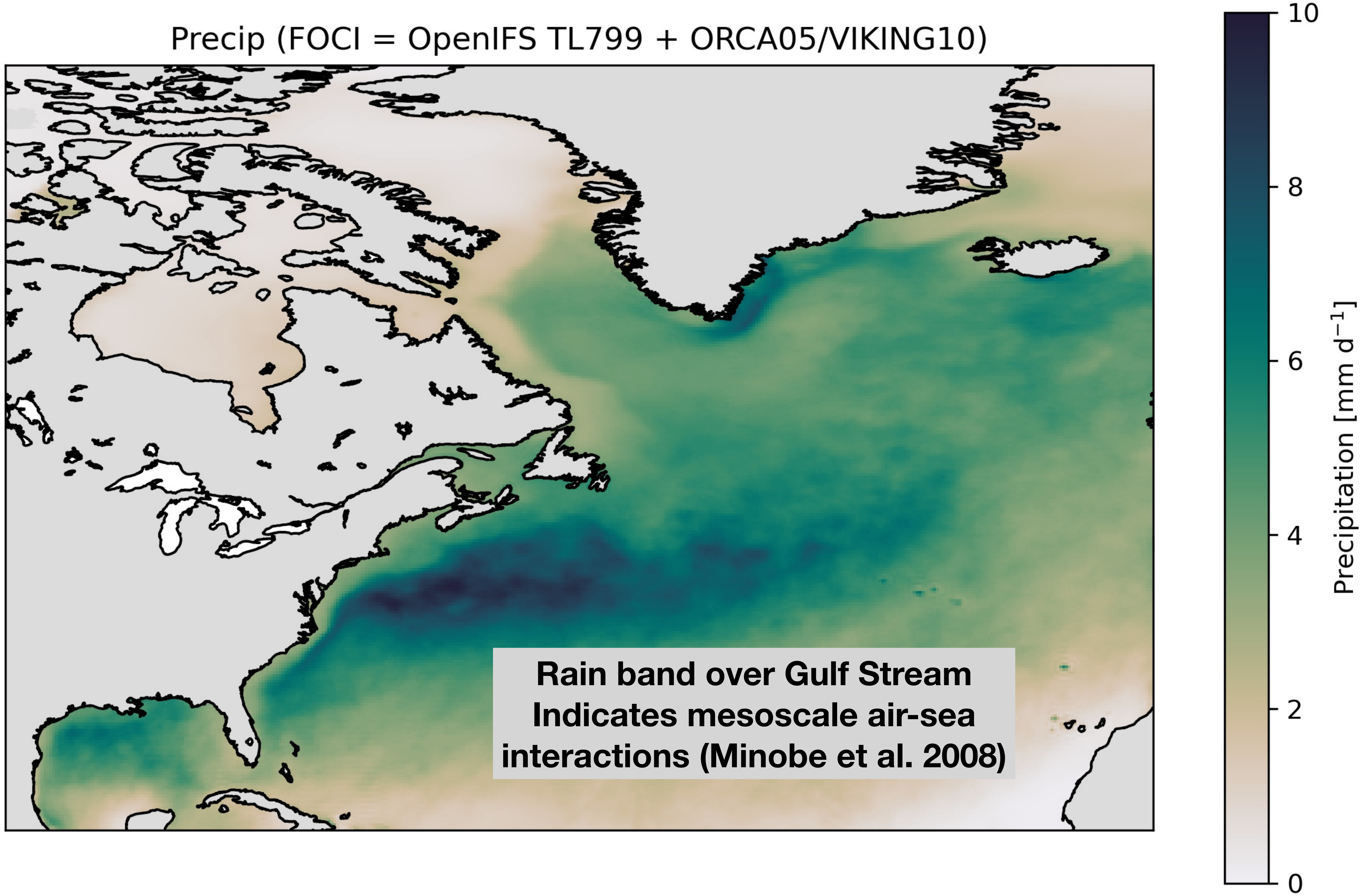
Precip in FOCI



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Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

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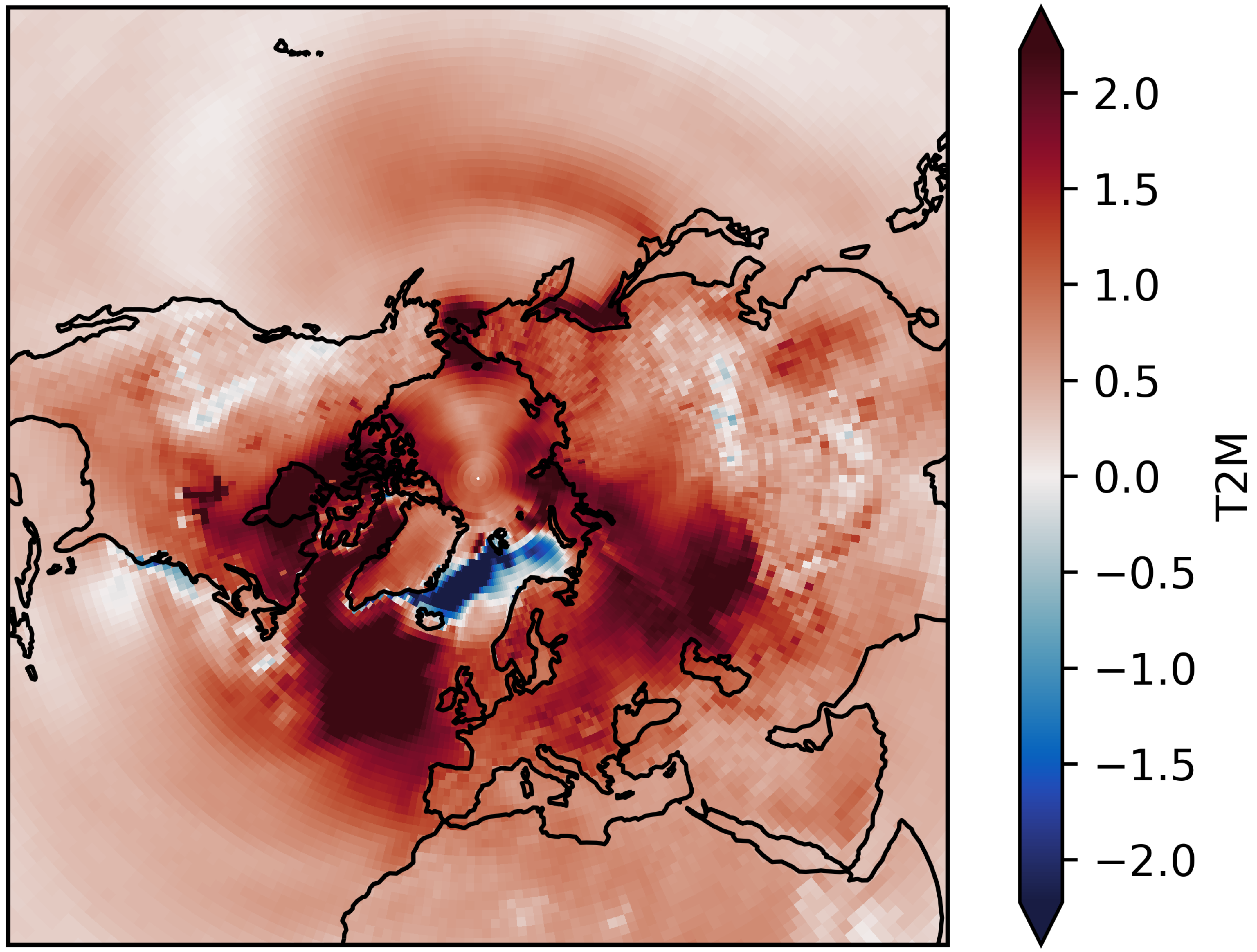
Impact of high ocean resolution on atmosphere

- Most climate models have a cold bias in North Atlantic due to poorly resolved North Atlantic Current.
- Using 1/10° nest in North Atlantic gives much better ocean dynamics and reduces cold bias.
  I.e. a local warming over North Atlantic is expected.
- Warming also propagates in over the Eurasian continent.
- Also strong warming of Labrador Sea and cooling of Nordic Seas.
  Changes in ocean circulation and/or sea-ice distribution?

DJF mean 2m temperature
Difference between run with ocean nest and without nest



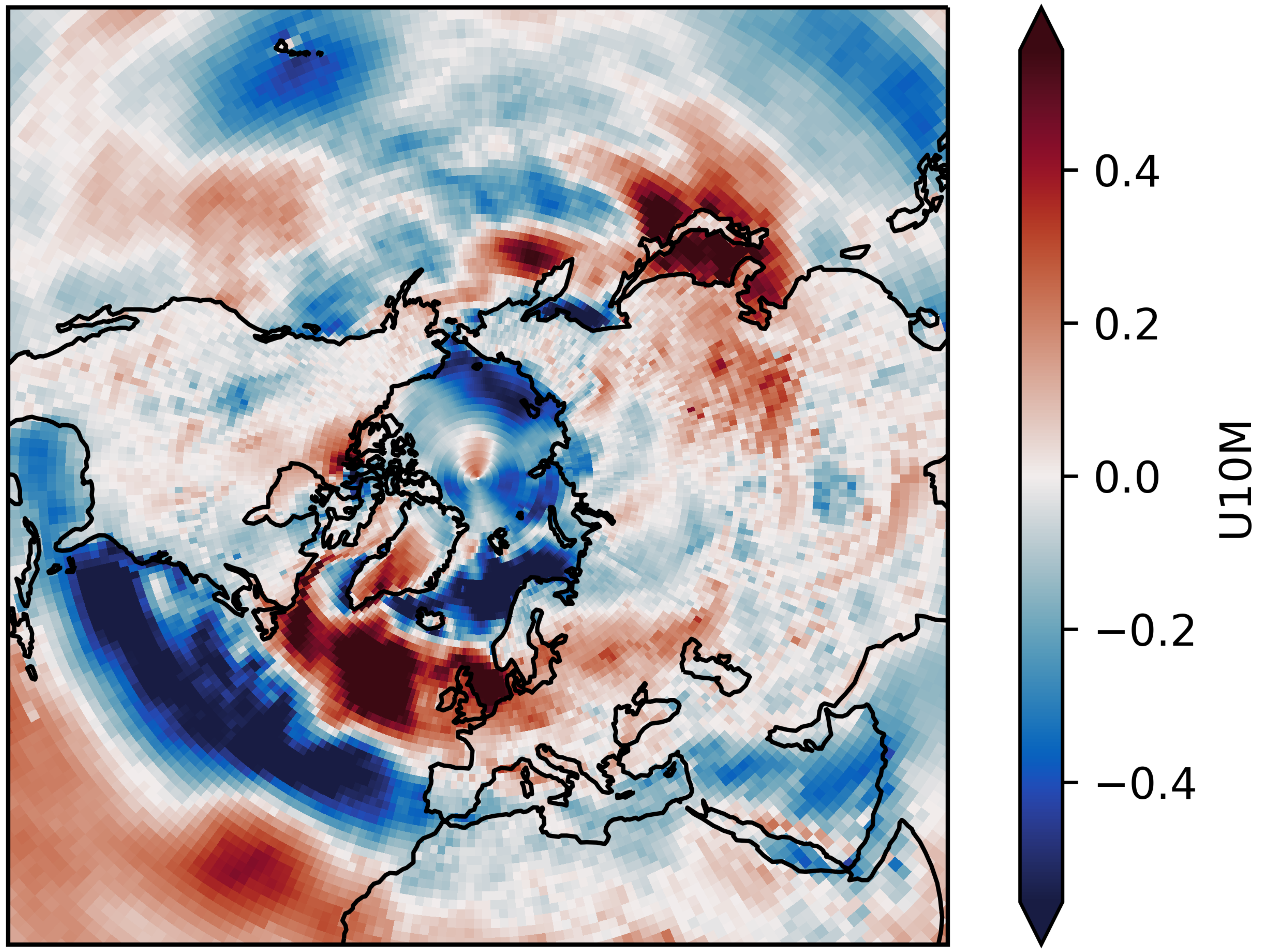
Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

Impact of high ocean resolution on atmosphere

- In the run with eddy-rich ocean nest the westerlies (here 10m zonal wind) shifts northward over the North Atlantic.

- Can explain how warming over North Atlantic spreads in over the continent due to simple advection.

DJF mean 10m zonal wind
Difference between run with ocean nest and without nest



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Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

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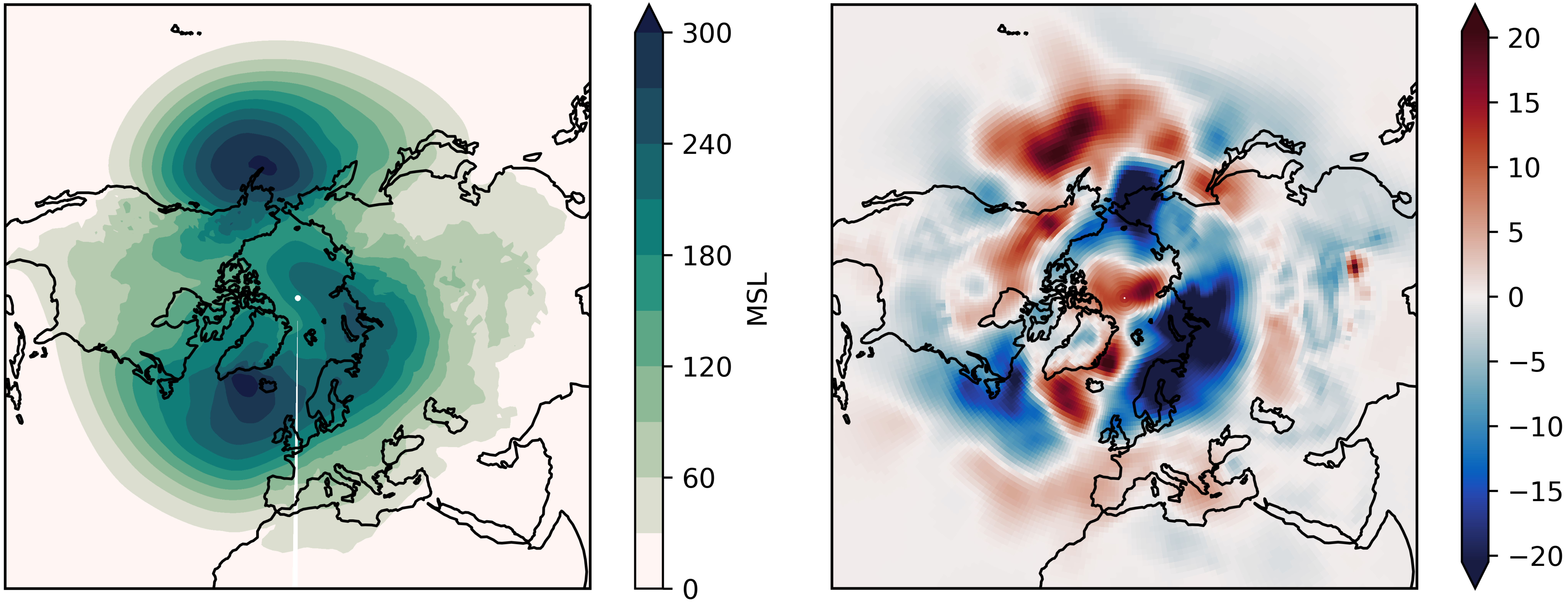
MSLP and storm tracks

Variance in daily MSLP (DJF) [hPa^2]

Difference in variance with and without nest



Increased variance near peak MSLP variance over N. Atlantic and N. Pacific.
Less variance over Northern Europe and Barents Sea.
Warming due to ocean nest weakening storms over Northern Europe?

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Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

CAU
Christian-Albrechts-Universität zu Kiel

Summary & Outlook

- Eddy-rich ocean nest (1/10°) gives better ocean dynamics than 1/2° ocean model.
  Reduces N. Atl. cold bias => warming of lower troposphere.

- Model with ocean nest shows warming over most of the midlatitudes.

- How does the ocean nest impact midlatitude cyclones?
  Weaker storms over Northern Europe? Use cyclone-tracking code?

- The simulations are part of a testing phase of coupled model with ocean nests.
  Multi-ensemble HighResMIP-like simulations planned for the coming years.
  More robust results with more data?

- Do you want to work on this?
  3-year postdoc position at GEOMAR available! Get in touch!

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INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

GEOMAR

Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

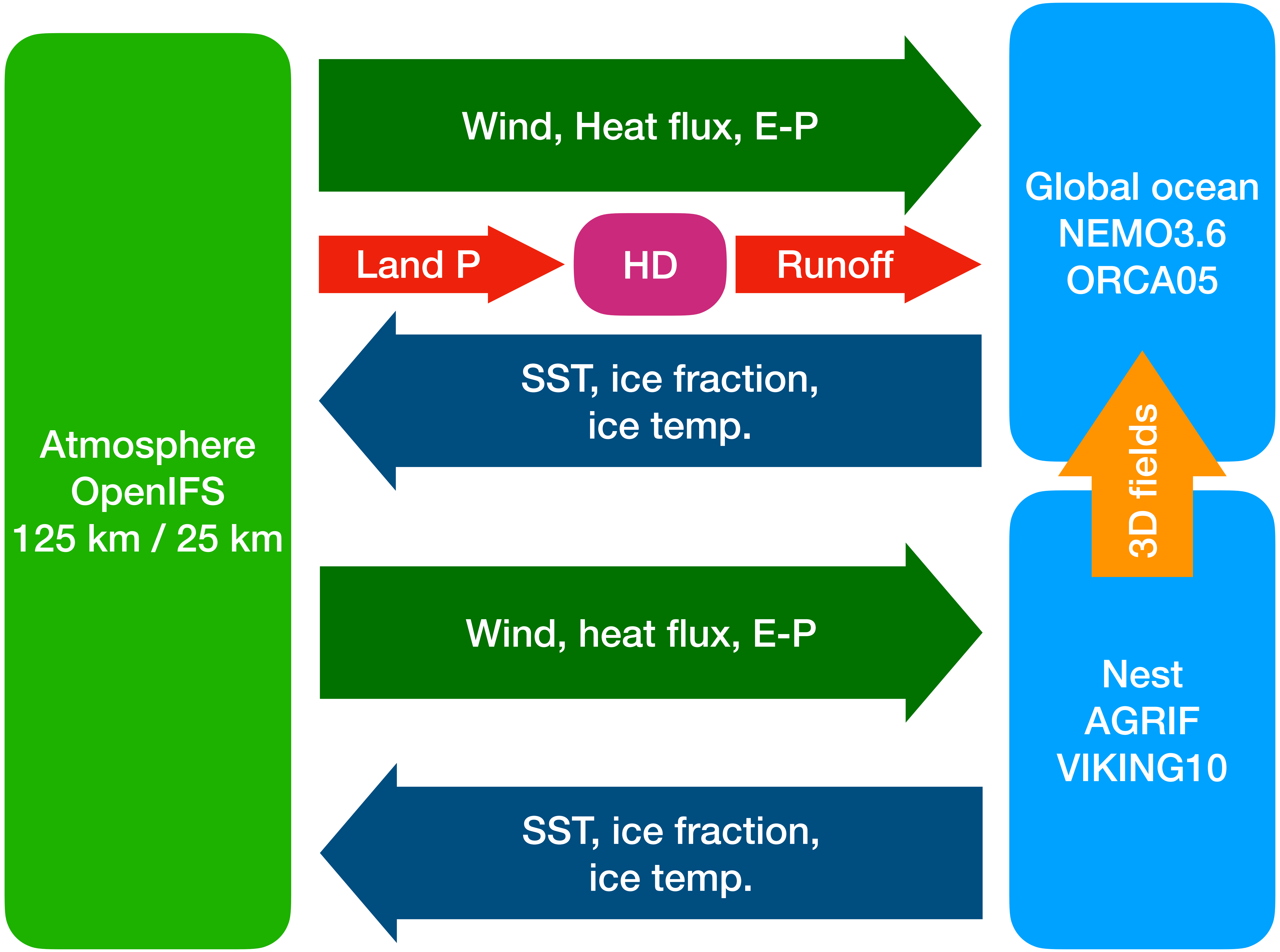
CAU
Christian-Albrechts-Universität zu Kiel

Bonus slide 1: The "zoo" of climate models with ECMWF IFS

	ECMWF-IFS	EC-Earth3	CNRM-ESM2	FOCI2 (OpenIFS)	AWI-CM3.1	EC-Earth4
IFS	IFS cy43r3	IFS cy36r4 (atm. only)	ARPEGE-Climat v6	OpenIFS cy43r3	OpenIFS cy43r3	OpenIFS cy43r3
NEMO	NEMO v3.4	NEMO v3.6	NEMO v3.6	NEMO v3.6	FESOM2	NEMO v4
Coupler	Single-executable	OASIS3-MCT3	OASIS3-MCT3	OASIS3-MCT4	OASIS3-MCT4	OASIS3-MCT4
Grid refinement	No	No	No	AGRIF	Unstr. grid	No
Hor. res.	T_{CO}199/ORCA1 T_{CO}399/ORCA025	T_L255/ORCA1 T_L511/ORCA025	T_L127 / ORCA1	T_L159L91/ORCA05 T_L799L91/ORCA05 + VIKING10	T_{CO}159/CORE2 T_{CO}319/BOLD	T_{CO}159/ORCA1 T_{CO}319/ORCA025
ESM	No	ESM	ESM	AOGCM	AOGCM	ESM*
MIPs	HighResMIP	~all MIPs	~all MIPs	No MIPs	No MIPs	CMIP7

Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

Bonus slide 2: Coupling strategy OpenIFS+NEMO/AGRIF



- OpenIFS-AGRIF coupling via OASIS, i.e. MPI and not I/O.
- OpenIFS sees mesoscale eddies and fronts.
- OpenIFS sends one set of surface fluxes and OASIS duplicates.
- OpenIFS receives two sets of SST, sea-ice etc. and must blend the data.
- Developed by Eric Maisonnave supported by IS-ENES3.

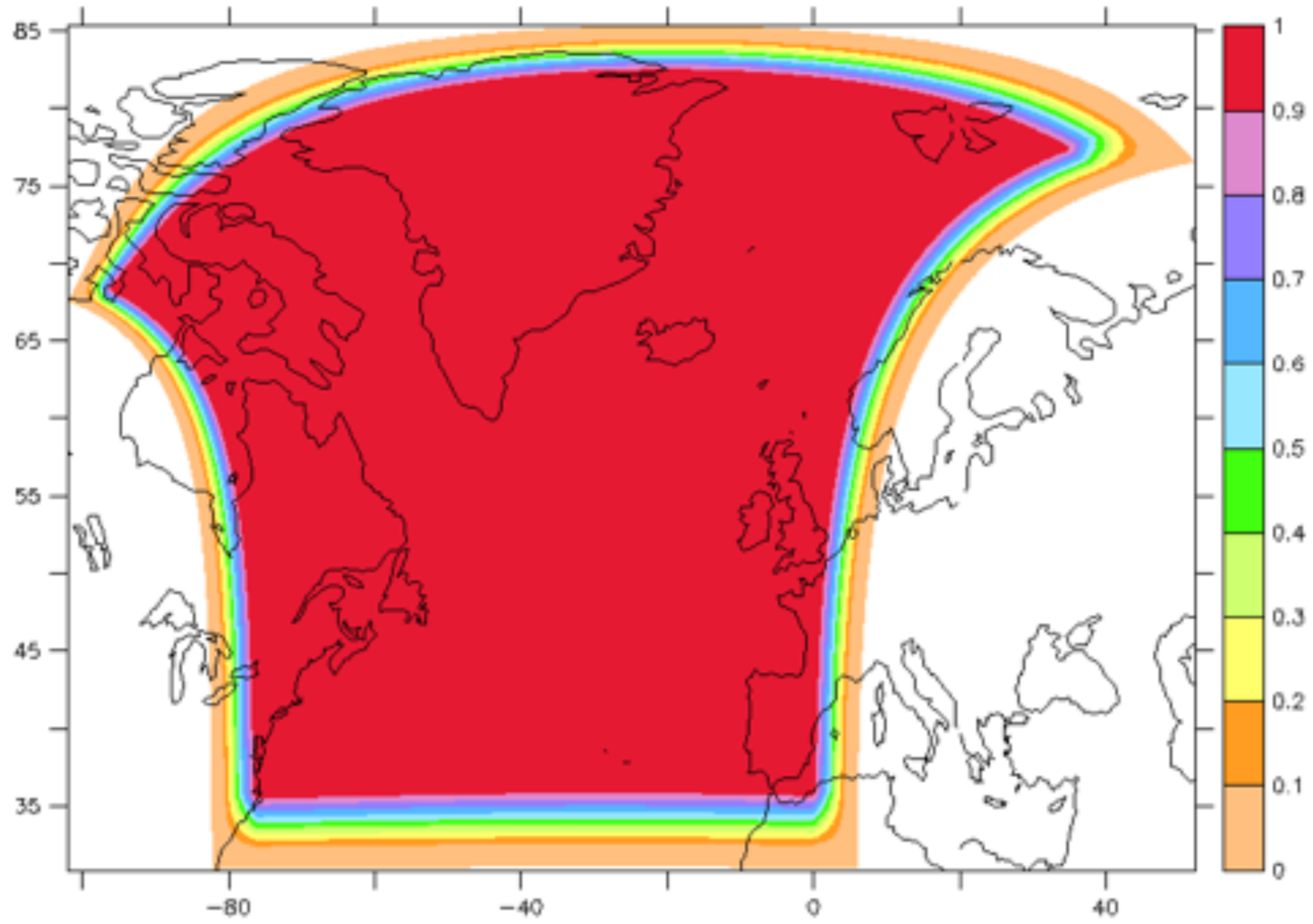
GEOMAR

Joakim Kjellsson
@joakimkjellsson / jkjellsson@geomar.de

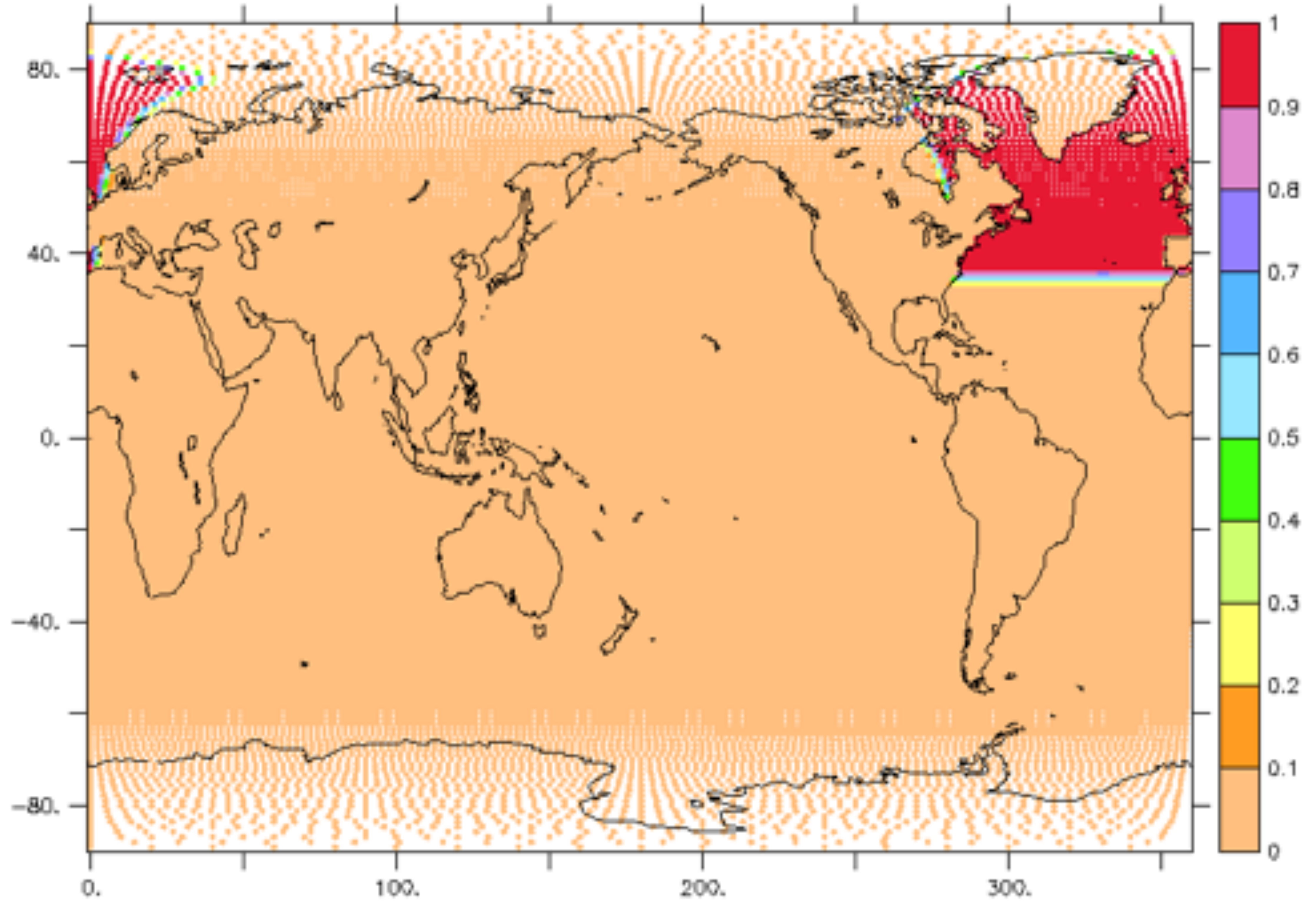
CAU
Christian-Albrechts-Universität zu Kiel

Bonus slide 3: Blending NEMO and AGRIF fields in OpenIFS

Local AGRIF sponge on NEMO global grid



Local AGRIF sponge on OpenIFS global grid



- All coupling fields from AGRIF are multiplied by sponge in OpenIFS. Interpolated by OASIS.

Bonus slide 4: Animation of spinning up ocean eddies

- A long (~1500 yr) spin-up is neede
  to study the full coupled system.
- But I'm inpatient, so I only do 40-year spin-up and only focus on upper ocean and atmosphere.