Greatness from small beginnings
Impact of oceanic mesoscale on weather extremes and large-scale atmospheric circulation in midlatitudes

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- 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 $dx \sim 10$ 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.
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.

Figure 21: Mean SSH variance (1998-2007) in cm (contour lines indicate 25, 50, 100 and 500 cm levels) for the reference simulation of each model configuration in comparison to observations (AVISO). The SSH variance is used to illustrate the flow path of the NAC and its associated variability. ORCA05 and ORCA025 show distinct deficits in the NAC compared to the observations. The red box in the VIKING20 highlights the high resolution domain.

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

Spin-up phase

- T159 + ORCA05, piControl
  - 45 min/SY
  - 580 core-h/SY

- T159 + ORCA05 + AGRIF, piControl
  - 2 hr/SY
  - 1850 core-h/SY

piControl

- T159 + ORCA05, piControl
  - 9 hr/SY, 13 500 core-h/SY

- T159 + ORCA05 + AGRIF, piControl
  - 9 hr/SY, 14 000 core-h/SY

- T799 + ORCA05 + AGRIF, piControl

World Ocean Atlas + ERA-Interim

Year 0 (WOA)

Year 40

Start high-res atm.

Time

Year ~80

Today

~0.09 M core-h

~1.3 M core-h
Surface KE (FOCI = OpenIFS TL799 + ORCA05/VIKING10)

1/10° resolution. Eddy-rich

1/2° resolution. No eddies
Precip (FOCI = OpenIFS TL799 + ORCA05/VIKING10)

Rain band over Gulf Stream
Indicates mesoscale air-sea interactions (Minobe et al. 2008)
- 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?
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.
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?
- 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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### Bonus slide 1: The “zoo” of climate models with ECMWF IFS

<table>
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<tr>
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<th>ECMWF-IFS</th>
<th>EC-Earth3</th>
<th>CNRM-ESM2</th>
<th>FOCI2 (OpenIFS)</th>
<th>AWI-CM3.1</th>
<th>EC-Earth4</th>
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<td>Unstr. grid</td>
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<td>$T_{CO}^{199}/ORCA1$ / $T_{CO}^{399}/ORCA025$</td>
<td>$T_{L}^{255}/ORCA1$ / $T_{L}^{511}/ORCA025$</td>
<td>$T_{L}^{127}$ / ORCA1</td>
<td>$T_{L}^{159L91}/ORCA05$ / $T_{L}^{799L91}/ORCA05$ + VIKING10</td>
<td>$T_{CO}^{159}/CORE2$ / $T_{CO}^{319}/BOLD$</td>
<td>$T_{CO}^{159}/ORCA1$ / $T_{CO}^{319}/ORCA025$</td>
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<td>CMIP7</td>
</tr>
</tbody>
</table>

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- 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.
Bonus slide 3: Blending NEMO and AGRIF fields in OpenIFS

- All coupling fields from AGRIF are multiplied by sponge in OpenIFS. Interpolated by OASIS.
- A long (~1500 yr) spin-up is needed 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.