

# Multi-resolution simulations with the AWI Climate Model (AWI-CM)

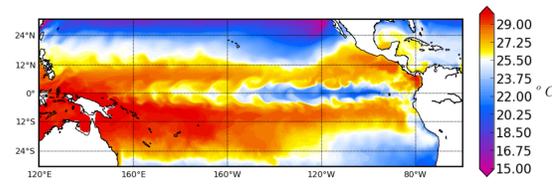
## Abstract

- Our novel approach to gain higher resolution in oceanic key regions is to use a dynamical core (FESOM, the Finite Element Sea ice Ocean Model developed at Alfred Wegener Institute) supporting unstructured meshes
- FESOM is available in a coupled configuration with ECHAM6 (Max Planck Institute for Meteorology): the AWI Climate Model (AWI-CM)
- Several 100yr pre-industrial climate simulations are performed with a hierarchy of ocean model grids

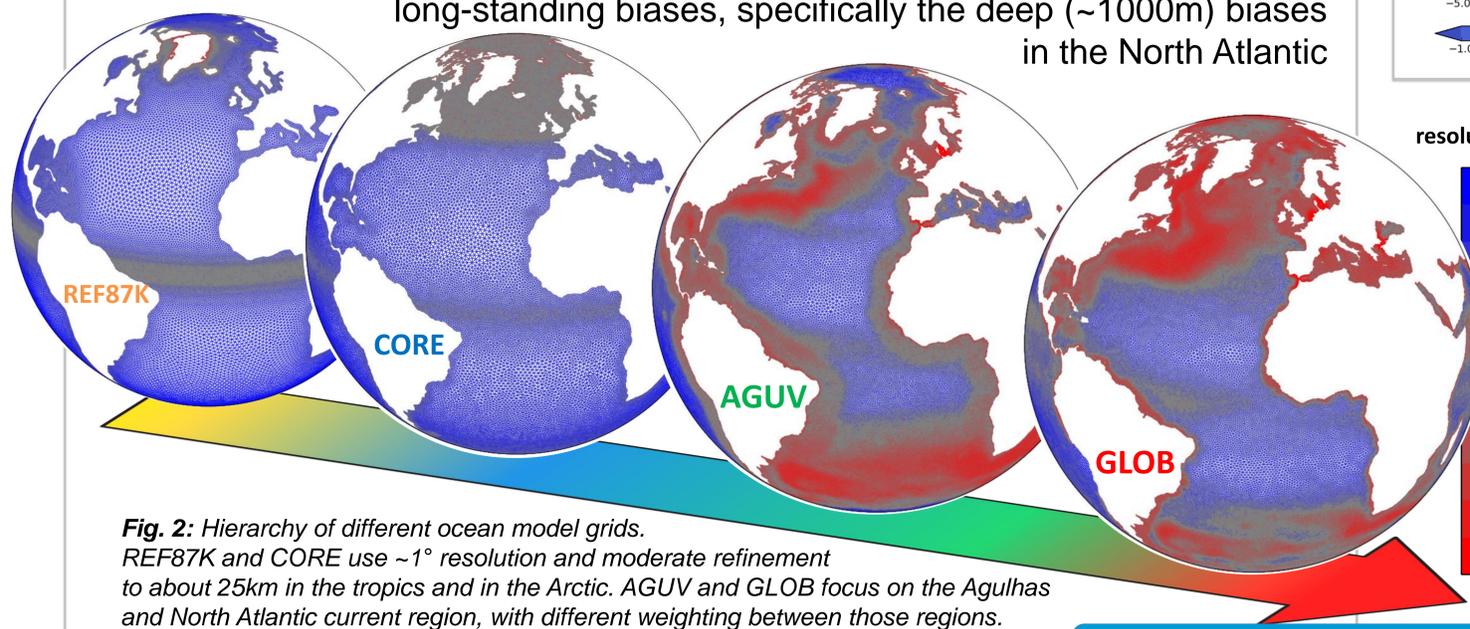
## Hierarchy of model grids

- A benchmark set-up of AWI-CM with the REF87K grid (Fig.2) achieved a similar simulation realism regarding basic atmospheric and oceanic quantities when compared to CMIP5 models, as shown by *Sidorenko et al. (2015)* and *Rackow et al. (2016)*

**Fig. 1:** Resolved Tropical Instability Wave (TIW) activity in the equatorial Pacific with the REF87K mesh improved the Pacific mean state and ENSO simulation (*Rackow et al., 2016*)



- The flexible layout of AWI-CM allows to use eddy-resolving resolutions in key ocean areas ( $1/12^\circ$  corresponding to 9-10km). The goal is to reduce long-standing biases, specifically the deep (~1000m) biases in the North Atlantic



**Fig. 2:** Hierarchy of different ocean model grids. REF87K and CORE use  $\sim 1^\circ$  resolution and moderate refinement to about 25km in the tropics and in the Arctic. AGUV and GLOB focus on the Agulhas and North Atlantic current region, with different weighting between those regions.

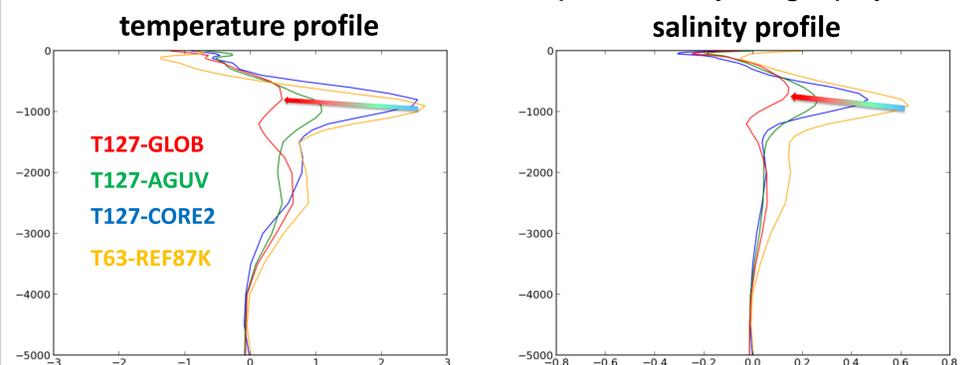
## Configuration & throughput

	grid points (2D)	#CPUs FESOM	#CPUs ECHAM	time step FESOM	time step ECHAM	coupling interval	throughput (sim. years per day)
T127-GLOB	830,000	1920	1152	10 min	3.3 min	1h	6.4 years/day
T127-AGUV	810,000	2304	1152	7.5 min	3.3 min	1h	6.2 years/day
T127-CORE2	127,000	192	576	15 min	3.3 min	1h	5.6 years/day
T63-REF87K	87,000	384	192	30 min	7.5 min	1h	21.8 years/day

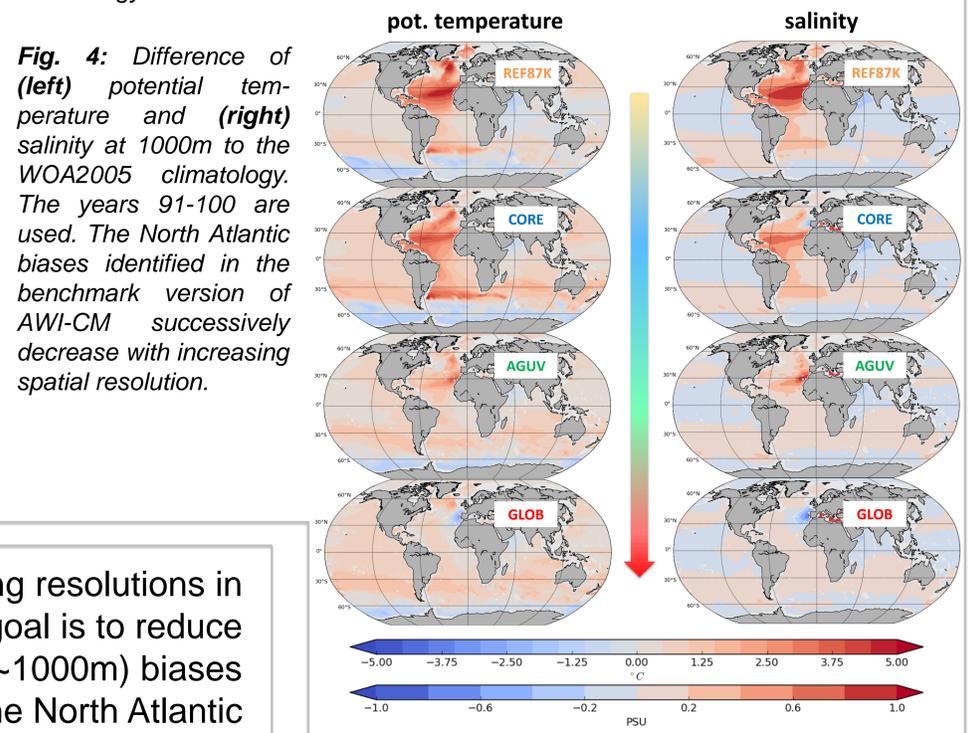
**Table 1:** Model settings and throughput for the four different AWI-CM configurations. The atmospheric resolution is T127 except for the coarsest setup with REF87K (T63).

## Deep ocean bias reduction

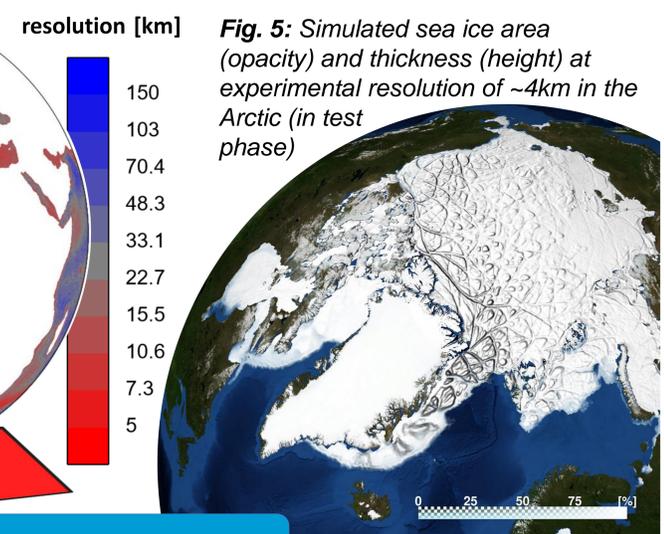
- 100-yr simulations show improvements with increasing resolution in North Atlantic deep-ocean hydrography:



**Fig. 3:** Global profiles of potential temperature and salinity for years 71–100 of the pre-industrial simulations. Shown is the difference to the WOA2005 climatology.



**Fig. 4:** Difference of (left) potential temperature and (right) salinity at 1000m to the WOA2005 climatology. The years 91-100 are used. The North Atlantic biases identified in the benchmark version of AWI-CM successively decrease with increasing spatial resolution.



**Fig. 5:** Simulated sea ice area (opacity) and thickness (height) at experimental resolution of  $\sim 4$ km in the Arctic (in test phase)

## Outlook

- FESOM2 (finite volume discretisation) is  $\sim 3$  times faster than FESOM 1.4. Planned to be ready for use in CMIP6.
- It is not straightforward *a priori* how to design unstructured meshes in an optimal way for CMIP-type simulations.
- At high resolution of  $\sim 4$ km (Fig. 5), linear kinematic features appear in the modeled sea ice cover. Leads are known to have a strong impact on heat fluxes and biology.

## References:

- *Sidorenko, D., Rackow, T. et al. (2015):* Towards multi-resolution global climate modeling with ECHAM6-FESOM. Part I: model formulation and mean climate. *Clim. Dyn. Vol. 44, Issue 3, pp 757–780, doi: 10.1007/s00382-014-2290-6*
- *Rackow, T. et al. (2016):* Towards multi-resolution global climate modeling with ECHAM6-FESOM. Part II: climate variability. *Clim. Dyn., doi: 10.1007/s00382-016-3192-6*