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Description and evaluation of NorESM1-F: a fast version of the Norwegian Earth System Model (NorESM)

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1 Climate effects from changing the coupling frequency and component time steps

We performed a reference experiment to assess the effect of changing the coupling frequency, land and sea ice base time steps and sea ice sub-cycling. The experiment uses the NorESM1-M default settings with 120 cycles for the dynamic sub-cycling of sea ice, half-hourly exchange of information between atmosphere-sea ice and atmosphere-land matching half hour base time step of sea ice and land. Otherwise it is identical to the preindustrial spin-up experiment of NorESM1-F. We initialised the experiment from observational climatologies and ran it for 500 years. We then computed monthly climatologies over the 500-year period from this reference experiment and subtracted those from corresponding climatologies computed from the output of the pre-industrial spin-up experiment of NorESM1-F.

The aforementioned configuration changes have minor, though detectable impacts on the model climate. During boreal winter, Arctic sea ice extent (Fig. 1a) is slightly reduced except in the Greenland Sea where it is increased. In the Southern Hemisphere, the extent is slightly decreased in the Ross Sea and increased in the Weddell Sea. During boreal summer, slight reductions and no increases are simulated along the edge of the Arctic ice cap (Fig. 1e). In the Southern Hemisphere, the outer edge of the Weddell Sea shows a slight decrease whereas some increases are simulated closer to the continent.

The strongest surface temperature changes (up to 1 °C) are simulated (Fig. 1b,f) in regions with reductions in sea ice extent. Winter temperatures over the central Arctic are warmed by 0.2-0.4 °C, consistent with a slightly reduced sea ice thickness caused by the change in sub-cycling. The changed atmosphere-land coupling frequency and land time step cause a general warming over the continents (< 0.4 °C) except over parts of South America during boreal summer and southern China during boreal winter. Temperature changes over ice-free ocean regions are mostly small (< 0.1 °C), with notable exceptions being a slight warming over the subpolar North Atlantic and North Pacific - seemingly connected to the continental warming - and alternating patches of warming and cooling over the Southern Ocean.

Precipitation changes (Fig. 1c,g) are generally small and most pronounced in the tropical regions, with slight increases north of the Equator mirrored by slight decreases south of the Equator as well as over the South Pacific Convergence Zone. The latter is suggestive for a slightly reduced double ITCZ. In the Pacific sector, these precipitation changes represent a slight northward shift of the tropical rain belt that is consistent with the predominant warming over the Northern Hemispheric continents.

Sea level pressure changes (Fig. 1d,h) are most apparent over the Southern Ocean but generally small, indicating only minor adjustments of the large-scale atmospheric circulation.

2 Other supplementary figures

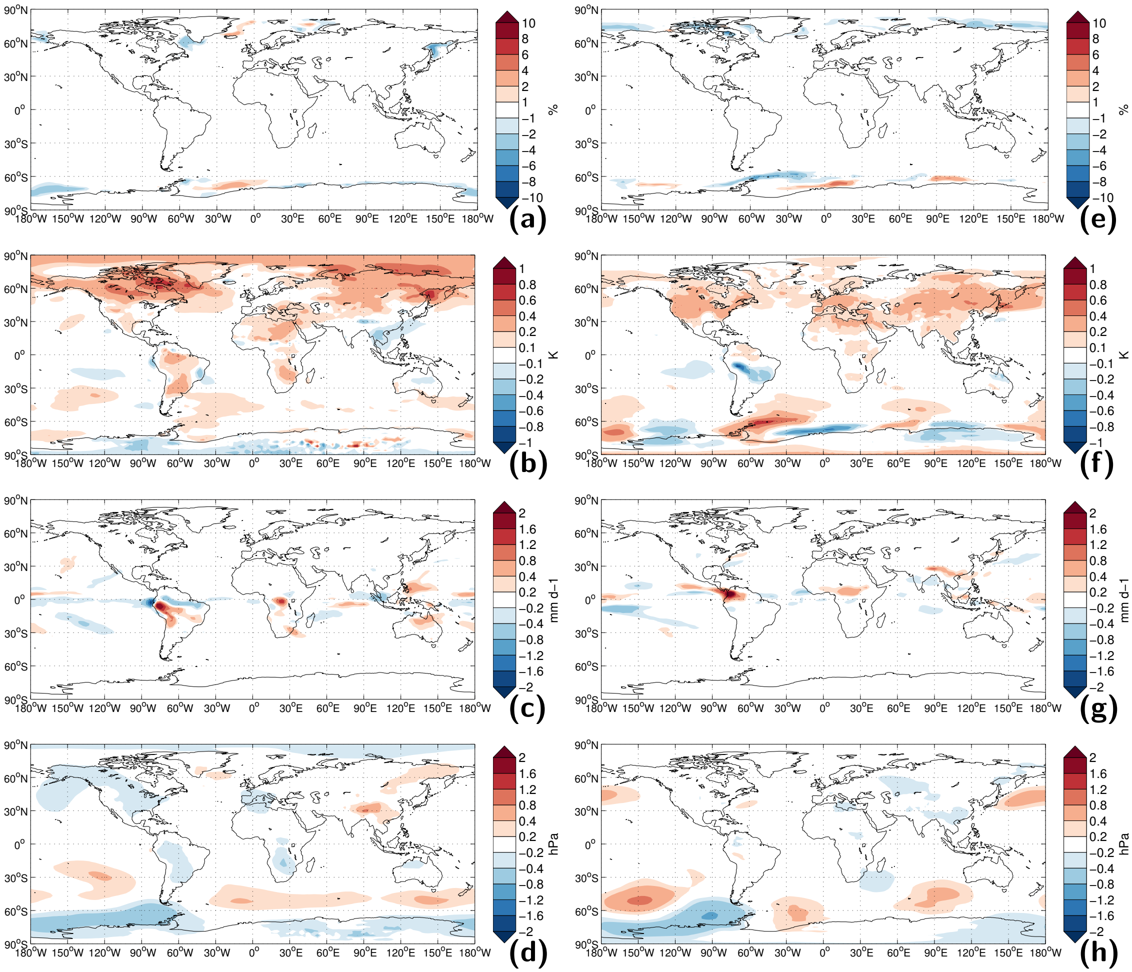

Figure 1. Effect of changing coupling frequency and component time steps. Boreal winter (DJF) response in a) sea ice concentration, b) 2m air temperature, c) total precipitation, and d) sea level pressure. Panels (e-h) show the same for boreal summer (JJA).

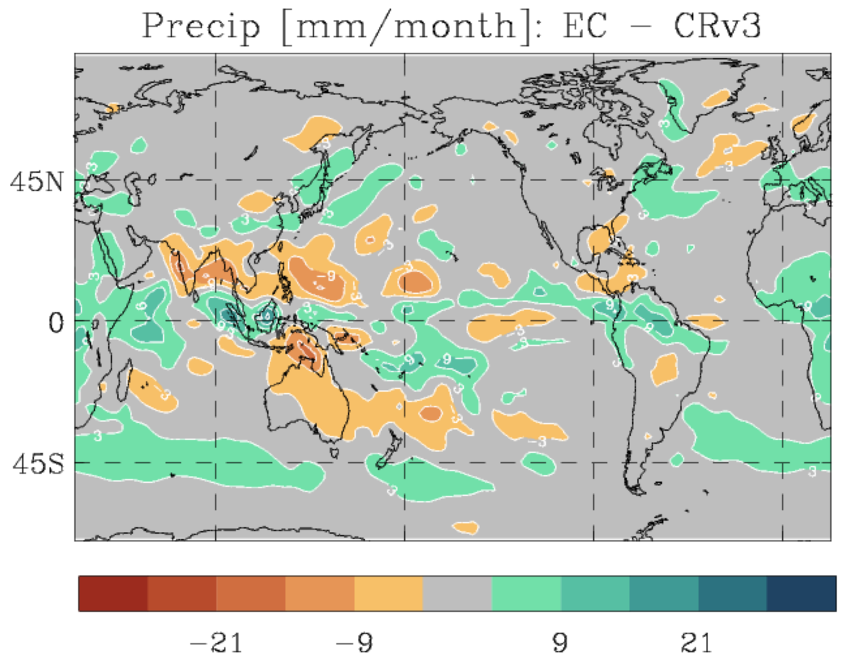

Figure 2. Effect of energy correction on annual-mean total precipitation rate in AMIP (1979-2005) simulations with CAM4. The increase over continental areas near the Equator stems from the rainy season, i.e. DJF, with a slight drying in the dry season (JJA).

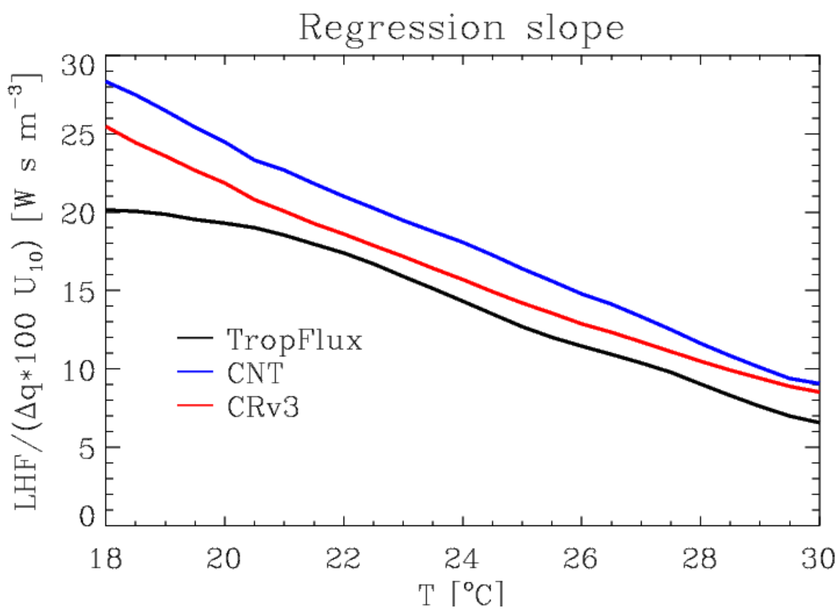

Figure 3. Regression slope by SST class (in one-degree bins) between latent heat flux from the ocean to the atmosphere and surface air temperature subsaturation and wind-speed in AMIP simulations with CAM4. Standard CAM4 is indicated by the blue line, and CAM4 with the COARE-3 surface-layer parameterisation (Fairall et al., 2003) by the red line. The observational product for comparison is TropFlux (Praveen Kumar et al., 2012).

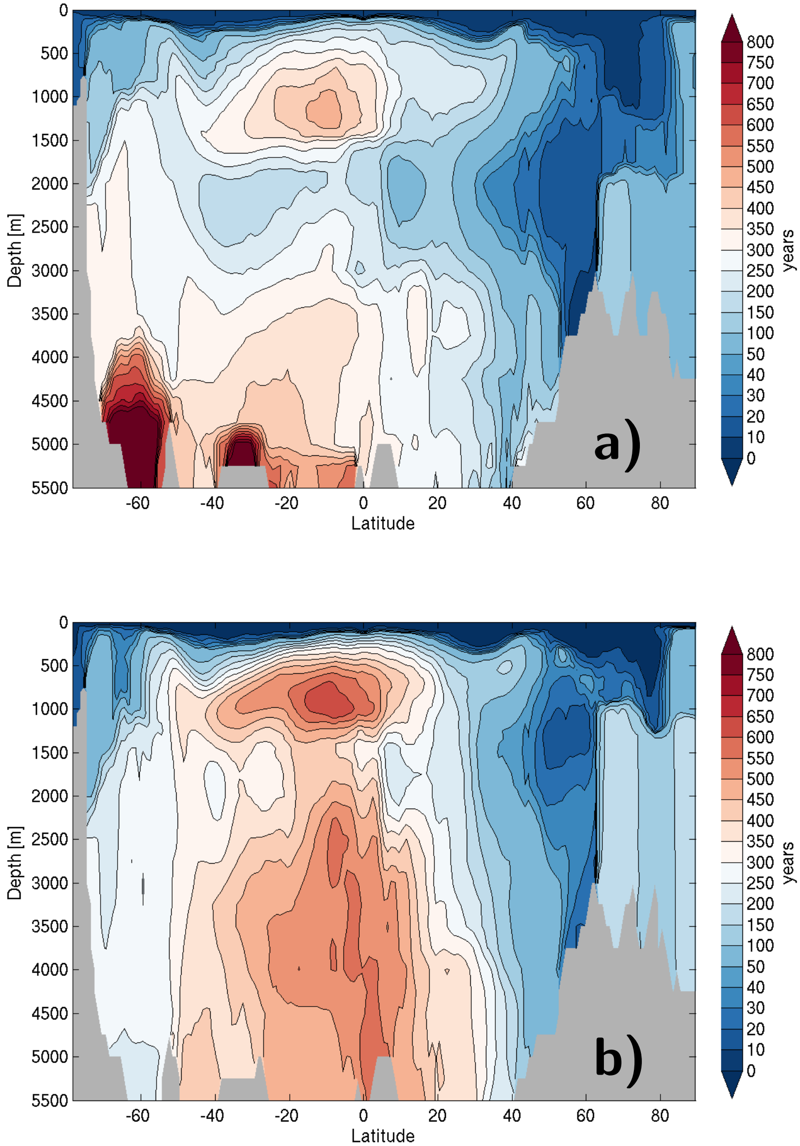

Figure 4. Atlantic zonal mean ideal age 1200 years after the model initialization for a) NorESM1-M, and b) NorESM1-F.

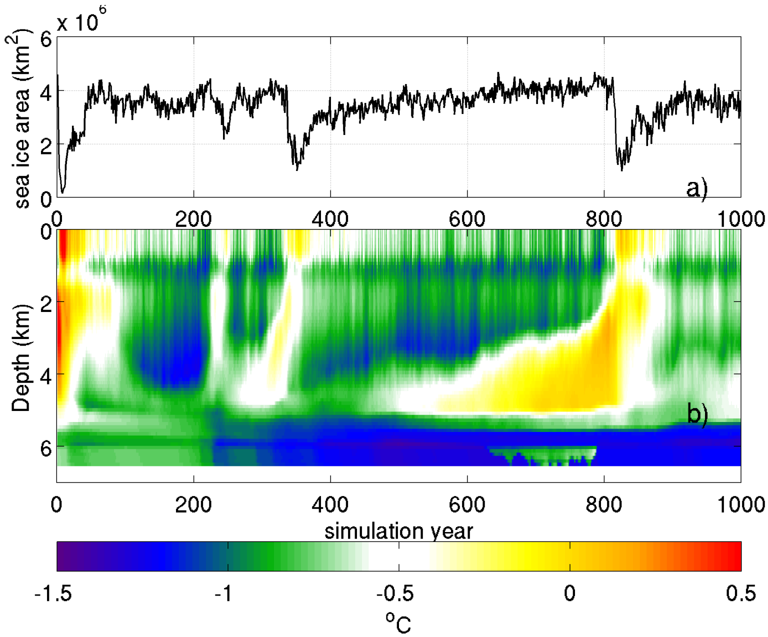

Figure 5. Simulated evolution of a) September sea ice area and b) vertical profiles of potential temperature around the Weddell Sea polynya region (30°W-30°E, 55°S-70°S). Two pronounced polynya events are captured in the first 1000 years of the PI spin-up experiment, with the first occurred in year 350 and the second in year 820.

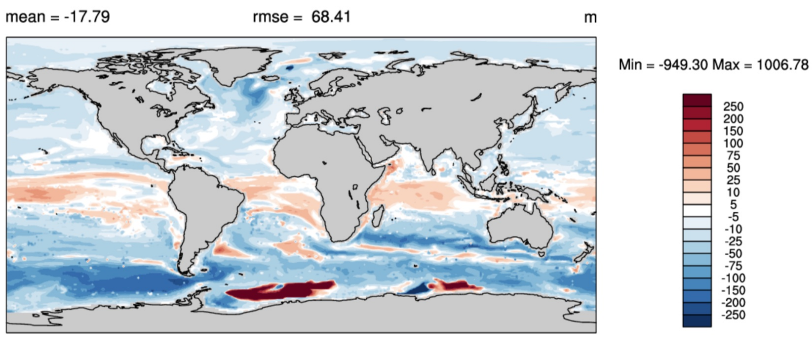

Figure 6. Global map of September mixed layer depth anomaly (NorESM1-F minus NorESM1-M). The mixed layer depth is defined as σ_0(z) - σ_0(10 m) = 0.03 kg m^{-3} according to de Boyer Montégut et al. (2004). The calculations are based on the mean of last 50 years PI control experiments for both model versions.

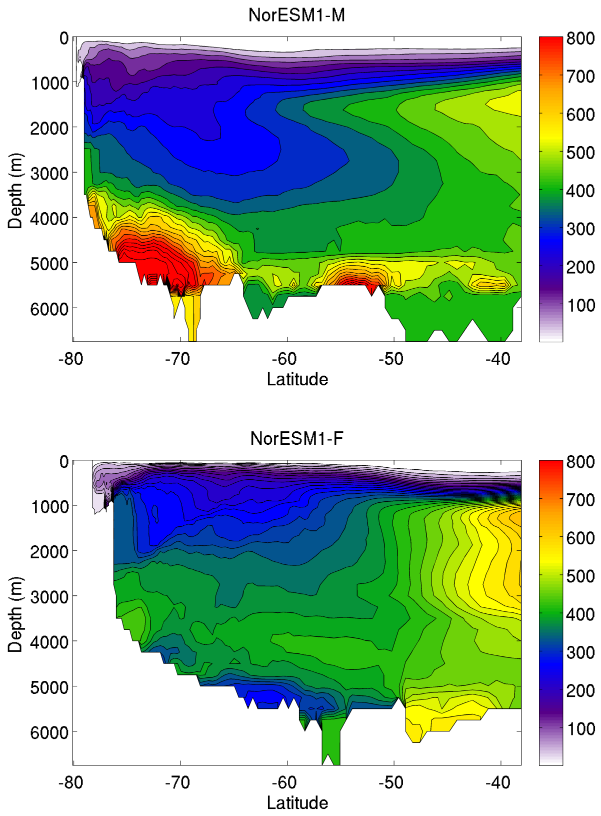

Figure 7. Southern Ocean zonal mean ideal age for NorESM1-M (upper panel) and NorESM1-F (lower panel).

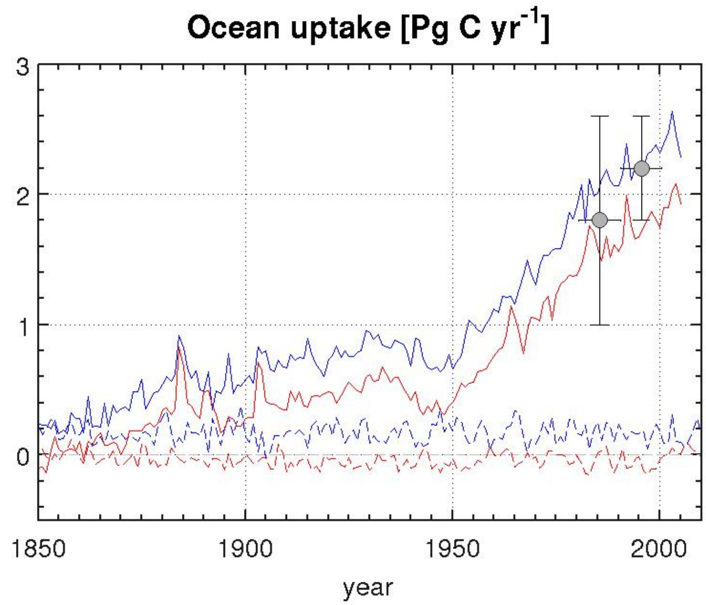

Figure 8. Time-series of annual oceanic carbon uptake over the historical period as simulated by NorESM1-ME (blue) and NorESM1-F (red). Shown are values from PI control (dashed-lines) and historical (solid-lines) simulations. Grey markers are observational-based estimates from Denman et al. (2007).

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