

Idealized overshoot experiments simulated with NorESM2-LM - technical description

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We have run a set of seven idealized overshoot simulations with NorESM2-LM. This document provides a short description of these simulations and the output data archived at the NIRD Research Data Archive. “Overshoot” refers to a simulation that has *net negative emissions* (or carbon dioxide removal, CDR) for some period of time. All simulations are CO₂-emission driven, and CO₂ is the only variation in forcing that is applied. Land use and non-CO₂ forcings are kept constant at pre-industrial levels. We have run three ensemble members for most of the simulations as indicated in Tables 1 and 2.

The set of simulations comprises one reference simulation reaching approximately 1.7 degrees in the long term without overshoot and 6 overshoot simulations of different magnitude and duration. The reference simulation (referred to as B^{1500}) has 1500 Pg of cumulative carbon emissions during the first 100 years and zero emissions thereafter (Fig. 1a). Three simulations with the same emission profile but higher carbon emissions (B^{1750} , B^{2000} , and B^{2500} ; Table 1) serve as positive emission phases of the overshoot simulations, as described in more detail below. From these simulations we branch off negative emission phases of 250, 500, and 1000 Pg cumulative carbon removal, applied over a time span of 100 years. At the end of the negative emission phases all simulations have experienced the same amount of cumulative carbon emissions (1500 Pg C, Fig. 1c). To simulate overshoots of different duration, we vary the branch point in time such that there are either 0 or 100 years of zero emissions before CDR is applied. Thus, we get six different overshoots relative to the reference simulation, which we refer to as OS_0^{250} , OS_{100}^{250} , OS_0^{500} , OS_{100}^{500} , OS_0^{1000} , and OS_{100}^{1000} (Table 2). Here, the superscript refers to the cumulative amount of CDR applied, and the subscript refers to the length of the zero emission phase before the start of the simulated CDR.

Table 1: Overview of B -simulations with positive emissions during the first 100 years and 300 years of zero emissions thereafter.

Simulation short name	Cumulative emissions	Final SAT*	Ensemble members	Simulation name**
B^{1500}	1500 Pg C	1.70°C	3	esm-bell-1500PgC
B^{1750}	1750 Pg C	2.09°C	3	esm-bell-1750PgC
B^{2000}	2000 Pg C	2.36°C	1	esm-bell-1750PgC
B^{2500}	2500 Pg C	3.37°C	3	esm-bell-2500PgC

* ensemble mean where available

** this is the name used in directory- and filenames

Table 2: Simulation overview for the negative emission simulations

Simulation short name	Parent simulation (segment 1 of the overshoot)	Cumulative positive emissions	Cumulative CDR	Time between positive and negative emissions	Ensemble members	Simulation name
OS_{0}^{250}	B^{1750}	1750 Pg C	250 Pg C	0 years	3	esm-brch-bell-1750PgC-000y-cdr0250PgC
OS_{100}^{250}	B^{1750}	1750 Pg C	250 Pg C	100 years	3	esm-brch-bell-1750PgC-100y-cdr0250PgC
OS_{0}^{500}	B^{2000}	2000 Pg C	500 Pg C	0 years	1	esm-brch-bell-2000PgC-000y-cdr0500PgC
OS_{100}^{500}	B^{2000}	2000 Pg C	500 Pg C	100 years	1	esm-brch-bell-2000PgC-100y-cdr0500PgC
OS_{0}^{1000}	B^{2500}	2500 Pg C	1000 Pg C	0 years	3	esm-brch-bell-2500PgC-000y-cdr1000PgC
OS_{100}^{1000}	B^{2500}	2500 Pg C	1000 Pg C	100 years	3	esm-brch-bell-2500PgC-100y-cdr1000PgC

Technical details

The positive and negative emission phases of the overshoot simulations have technically been run as separate simulations, and therefore have a separate name and are stored in separate directories. To construct a specific overshoot (e.g., “high overshoot of short duration”, OS_{0}^{1000}) two simulations must be concatenated as described below (Table 3). The different simulations are visualized by different colors in Figure 1.

The reference simulation B^{1500} has positive emissions during the first 100 years, and zero emissions afterwards until year 400. The 6 overshoots simulations also cover a period of 400 years after the two 2 segments of these runs have been concatenated:

- a phase of positive emissions for 100 years (simulations B^{1750} , B^{2000} , and B^{2500} for the “low”, “medium”, and “high” overshoot cases, respectively), followed by 100 years of zero emissions for the “long” overshoots. This is the “parent simulation” or “segment 1” indicated in Tables 2 and 3
- a phase of negative emissions for 100 years (with 250, 500, or 1000 PgC removed) followed by zero emissions for 200 (“short”) or 100 years (“long overshoot”)

The B -simulations nominally start at year 1850, although this has no significance beyond the naming of output files (no time dependent forcing other than the idealized CO₂ emissions is applied). The emission curves follow the ZECMIP (Zero Emissions Commitment Model Intercomparison Project; Jones et al. 2019, <https://doi.org/10.5194/gmd-12-4375-2019>) protocol, i.e., the emission curves are bell shaped with 50 years of increasing emissions and 50 years of decreasing emissions (Fig. 2 of Jones et al. 2019). Negative emission curves are constructed in the same way, but with a negative sign.

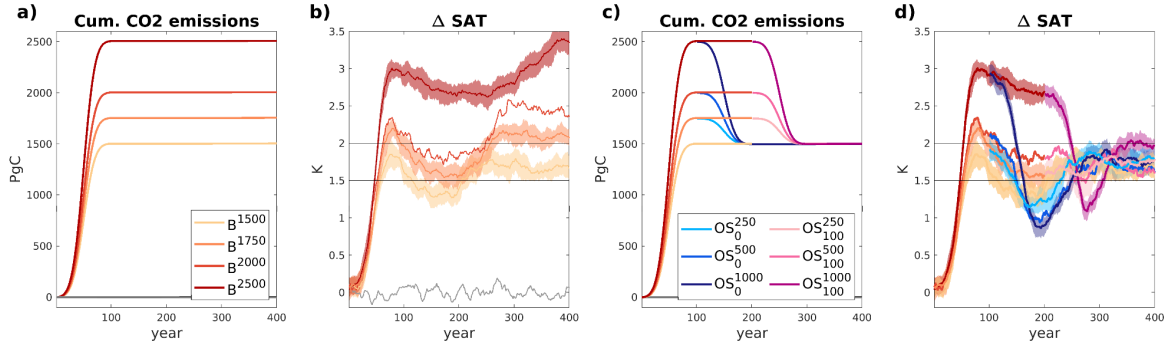


Figure 1: Cumulative carbon emissions and global average surface temperature change (ΔSAT) for the *B*-simulations with positive and zero emissions (a,b) and for the overshoot simulations (c,d). For temperature the ensemble mean (solid lines) and range (shading) is shown.

Data location and organization

NorESM2-LM output has been converted to comply with CMIP6 standards (“cmorized”). Each simulation has its own data directory as described in table 3 (directory name = simulation name). Ensemble members are identified by the standard CMIP6 convention (i.e the variant label r2i1p1f1 in a file name indicates output from the 2nd ensemble member), and all ensemble members of a given simulation are stored in the same directory.

Branch times

The first ensemble member of all *B*-simulations has been branched from the emission driven pre-industrial control simulation at 1851-01-01, the second ensemble member at 1861-01-01, and the third member at 1901-01-01. The negative emission segments of the overshoot simulations have always been branched from the corresponding ensemble member of the *B*-simulations. For example, the 2nd ensemble member of the negative emission phase of the OS_{0}^{250} simulation has been branched from the 2nd ensemble member of the B^{1750} simulation at the year indicated in table 3. Note that the branch time information in the metadata of the netCDF files is unfortunately erroneous.

Table 3: Details for the segments of overshoot simulations, baseline simulation and control simulation.

Description	Simulation name	Start/end year
Baseline, 1.7 degree without overshoot	esm-bell-1500PgC	1850-2249
OS_{0}^{250} (low-short)		
Segment 1	esm-bell-1750PgC	1850-1949
Segment 2	esm-brch-bell-1750PgC-000y-cdr0250PgC	1950-2249
OS_{100}^{250} (low-long)		
Segment 1	esm-bell-1750PgC	1850-2049
Segment 2	esm-brch-bell-1750PgC-100y-cdr0250PgC	2050-2249
OS_{0}^{500} (medium-short)		
Segment 1	esm-bell-2000PgC	1850-1949
Segment 2	esm-brch-bell-2000PgC-000y-cdr0500PgC	1950-2249
OS_{100}^{500} (medium-long)		
Segment 1	esm-bell-2000PgC	1850-2049
Segment 2	esm-brch-bell-2000PgC-100y-cdr0500PgC	2050-2249
OS_{0}^{1000} (high-short)		
Segment 1	esm-bell-2500PgC	1850-1949
Segment 2	esm-brch-bell-2500PgC-000y-cdr1000PgC	1950-2249
OS_{100}^{1000} (high-long)		
Segment 1	esm-bell-2500PgC	1850-2049
Segment 2	esm-brch-bell-2500PgC-100y-cdr1000PgC	2050-2249
PI-control simulation	esm-piControl	1850-2310

Contact

If you have any questions regarding this data set, please contact Jörg Schwinger (jorg.schwinger@norceresearch.no)