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Demonstrating the potential of km-scale multi-annual coupled global simulations in nextGEMS: a (urban) surface perspective

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The nextGEMS project is dedicated to develop global coupled earth-system models for multidecadal climate projections at a kilometre-scale resolution. By harnessing the strengths of high spatial resolution, the project seeks to improve the representation of physical processes and provide climate information at spatial scales that align with real-world measurements. Preparing for 30-year production runs, nextGEMS has achieved significant milestones, including the successful completion of five-year global coupled runs with a 5 km spatial resolution by two different Earth-System models: ICON, and ECMWF's Integrated Forecasting System (IFS) coupled to the sea ice-ocean model FESOM. In this work we focus on the km-scale IFS-FESOM configuration, along with a comparable set of coarser IFS simulations coupled to either FESOM or NEMO ocean models.

We first provide a brief overview of the most relevant scientific modifications on IFS and FESOM through the development cycles needed to perform multi-annual simulations: a reduction of the global water and energy imbalance by orders of magnitude, as well as the modification in cloud physics parameters to provide a stable climate, improved coupling of ocean surface currents and fluxes, and the addition of improved high-resolution land use and land cover maps.

We further investigate the impact that the new refined surface maps have on the representation of climate at the surface and near-surface. We first explore the spatio-temporal surface-atmosphere coupling in these km-scale simulations. We then focus on more local phenomena: In particular, we pioneer the study of urban climate via coupled global multiannual simulations and explore surface-atmosphere interactions over urbanized areas, by combining refined land use/land cover maps with the active urban scheme in IFS. We find a more realistic spatial distribution of surface temperature in both urban and rural areas, especially noticeable at spatial resolutions of 9km and finer. By showing that the diurnal cycle of urban heat island intensity exhibits improved accuracy in numerous large European urban areas, our global simulations can provide local granularity at the scale of individual cities The enhancements in representing urban climate features are quantified through reduced bias, root-mean square error, and increased correlation with successively increasing model resolution.