Errors in the simulation of storms characteristics, and their tracks, in weather and climate global models

P.L. Vidale[1], M. Roberts[2], K. Hodges[1], R. Schiemann[1], M.-E. Demory[1], M. Mizielinski[2]
NCAS-Climate, University of Reading (1) and Met Office Hadley Centre (2)

Atmospheric storms are active agents of global transport and pose substantial risk to human activities, e.g. in the form of storm surge, extreme winds and precipitation. A number of routine and observational campaigns in the tropics focus on cataloguing storms according to intensity, track and landfall characteristics, so as to enable the computation of risk. No equivalently comprehensive resource exists for the extra-tropics: numerical models (e.g. used in re-analyses) are complementary to observations in this remit, but suffer from systematic errors in the simulation of storms; these errors interact, including with the large scale circulation, and substantially limit overall model predictive skill.

We have developed and analysed a hierarchy of global climate model simulations, in ensemble mode, producing a storm data set that comprises both tropical and extra-tropical cyclones. The models in our analyses use two distinct dynamical cores and span a broad range of resolutions, from over 100km to 10km. The quality of the simulation in terms of storm frequency, intensity, track density (genesis, lysis) in a number of domains (basins) worldwide has been assessed and also compared to other GCMs (e.g. within the CLIVAR Hurricane Working Group).

Results indicate that, for both tropical and extra-tropical cyclones, the choice of a more advanced dynamical core impacts the simulation of cyclone intensity, as well as the realism of the entire energy cascade. The impact of resolution is also robustly demonstrated: with each step of the resolution refinement, the error in the distribution of cyclone intensities, which are too weak at low resolution (both tropical and extra-tropical), is systematically mitigated; this is also revealed, in the case of Tropical Cyclones (TCs), by an improved wind/pressure relationship. Part of the improvement with resolution originates in the ability to exploit the high-resolution SST gradients in the OSTIA SST product used in our models.

The mid-latitude storm track itself, which is typically too zonal at the lowest resolution, is also improved, suggesting a potential role for scale interactions. A detailed investigation of the mechanisms behind the improvement in storm track has revealed, for the North Atlantic, the importance of the meridional eddy heat transport on the SW side of the basin, which is strongest at high resolution (particularly so in MAM and SON), leading to improved tilting and spatial extension of the storm track at its exit point, near Europe.

The forthcoming CMIP6 HighResMIP experiment, a deliverable of the EU-Horizon 2020 PRIMAVERA project, will produce a multi-model, multi-resolution ensemble of both atmosphere-only and coupled simulations. Detailed process-based analyses in PRIMAVERA and joint CLIVAR projects will allow us to assess the robustness of these findings, and implications for projections of future storm risks.

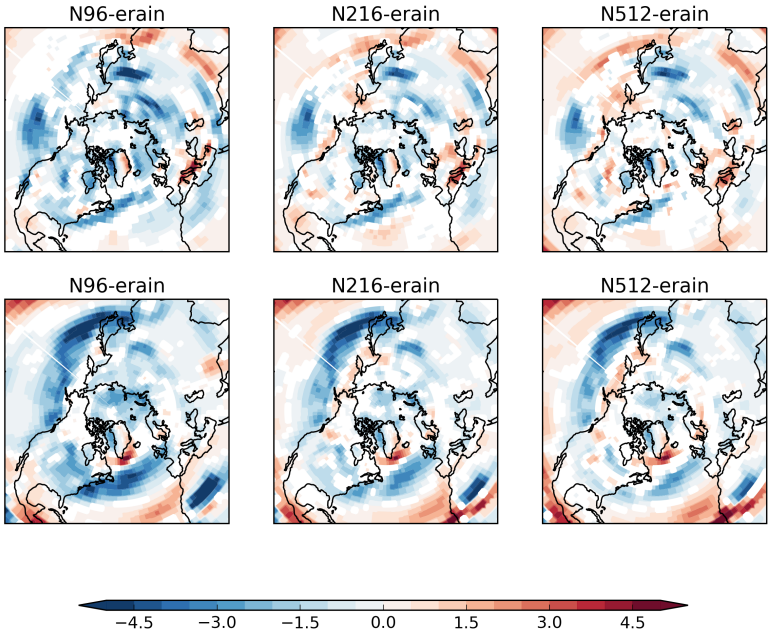

Fig 1: bias in the NH storm track density at low (N96), mid (N216) and high (N512) resolution for an ensemble of HadGEM3-GA3 global climate simulations: DJF (top) and JJA (bottom). Units: number density per 5° spherical cap / month