Comparing Simulated, Synthetic Tropical Cyclones in Unstructured Climate Models Downscaled from 25 to 3 Kilometer Grid Spacing

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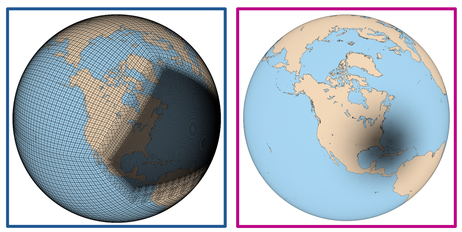
Motivation

Tropical cyclones (TCs) can be devastating and costly events and the aftermath of exceptionally destructive storms in recent years has prompted stakeholder demand for output from high-resolution models. Particularly, there is a growing desire to understand the perils associated with historically unrealized – but climatologically plausible – hazards, which are critical for catastrophe risk planning and mitigation. While advances in computing capacity foster TC-permitting climate simulations with grid spacings of ~25 km, these cyclones remain under-resolved, demonstrating that finer grid spacing is required to permit more realistic storm structure akin to that observed in nature.

Methodology



- The **Community Atmosphere Model v5 (CAM5-SE)** is the atmospheric component of the Community Earth System Model with a spectral element, hydrostatic dynamical core and an unstructured, quasi-uniform, quadrilateral ("cubed-sphere") mesh.
- Likewise, the atmospheric component of the **Model for Prediction Across Scales (CAM5-MPAS)** deploys a non-hydrostatic dynamical core, and a dual icosahedral-triangular, variable-resolution unstructured mesh.
- Both models use **CAM5** physics.
- Originally, nine unique **CAM5-SE** model outputs contained ~300 years of potential TCs identified by **TempestExtremes**, a Lagrangian tracking software.
- Of these potential TCs, eight tracks were identified as suitable **"parent"** simulations (informed by stakeholders active in the field) and were used as initial conditions within **CAM5-MPAS** to re-initialize eight unique **"child"** simulations.
- Only one pair of these **parent**/**child** simulations is shown here.
- Prioritization was given to working with unstructured, "native" data rather than interpolated, "regridded" data.

Results

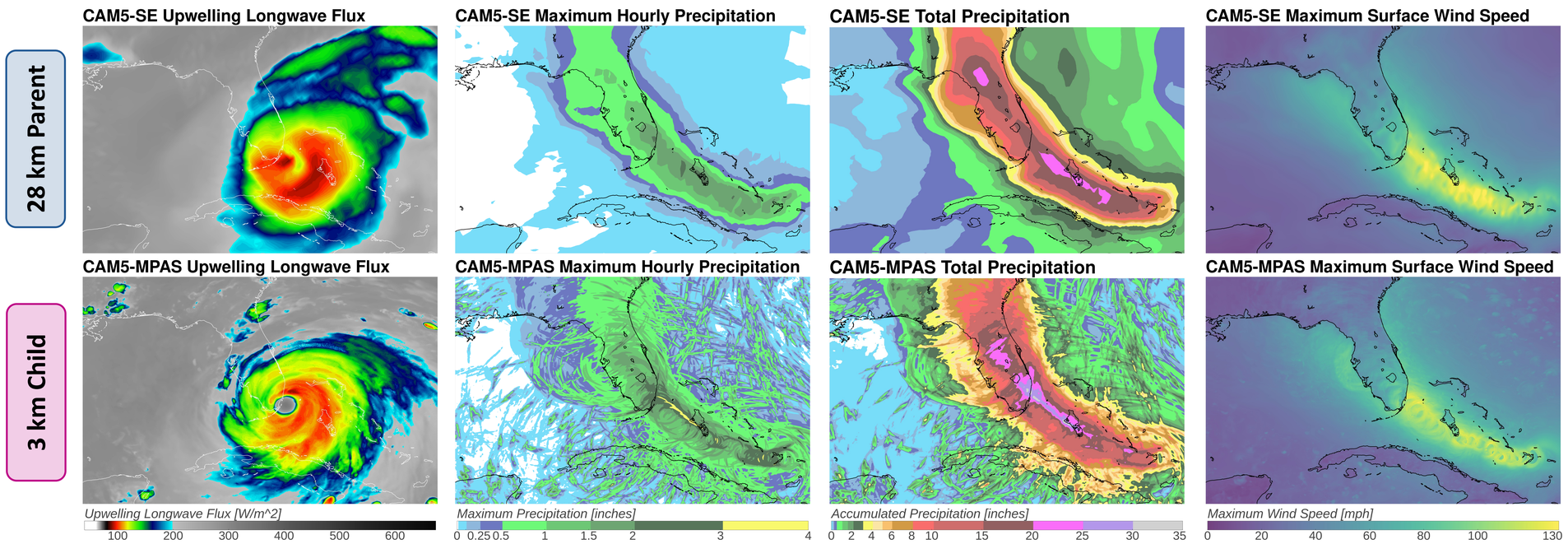


Fig. 1. Storm structure for CAM5-SE (top) and CAM5-MPAS (bottom) using upwelling longwave flux.

Fig. 3. Spatial distribution maps of the storm maximum hourly precipitation rate for CAM5-SE (top) and CAM5-MPAS (bottom).

Fig. 5. Spatial distribution maps of the storm total accumulated precipitation for CAM5-SE (top) and CAM5-MPAS (bottom).

Fig. 7. Spatial distribution maps of the storm maximum surface wind speed for CAM5-SE (top) and CAM5-MPAS (bottom).

Fig. 2. Time series of minimum sea level pressure for both simulations.

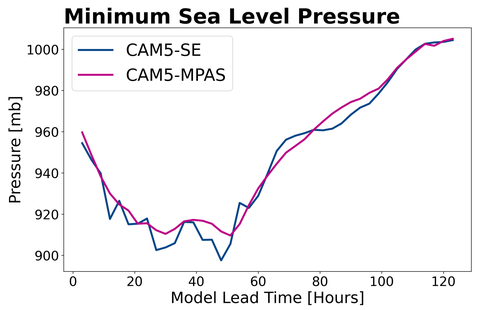


Fig. 4. Histogram of a subset of Fig. 3 centered over southern Florida for both simulations.

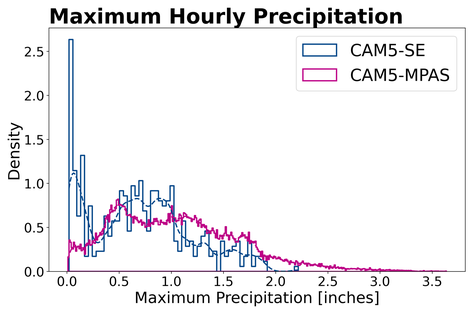


Fig. 6. Histogram of a subset of Fig. 5 centered over southern Florida for both simulations.

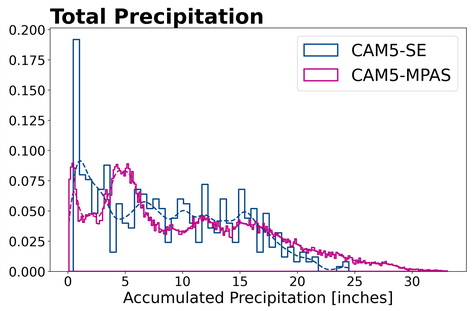
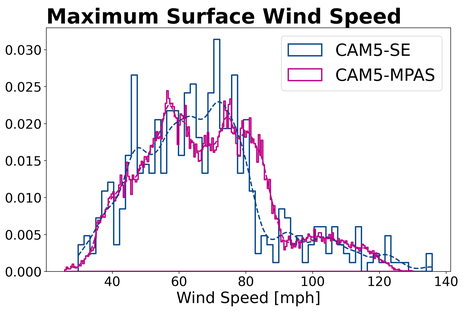


Fig. 8. Histogram of a subset of Fig. 7 centered over southern Florida for both simulations.



Discussion

- Storm structure and discrete, localized precipitation totals are better resolved within the 3 km **child** simulation over the 28 km **parent** simulation, demonstrating the potential benefits for risk management planning and climate hazard projection.
- An eyewall replacement cycle is apparent in the **child** simulation, whereas the **parent** simulation struggles to resolve this feature.
- The **child** simulation achieves more extreme precipitation rates and totals, which is also shown by the longer distribution tails in the corresponding histograms.
- The **child** simulation does not quite reach the same minimum sea level pressure and maximum surface wind speed extrema forecasted by the **parent** simulation.
- Current tools for visualizing unstructured weather and climate data remain sparse and those that do exist tend to rely on methods such as triangulation that do not necessarily faithfully represent underlying grid structures. More effort is needed to develop such tools for the atmospheric science community.

References, Acknowledgements, and uviz GitHub repo