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IMPLEMENTATION AND USE OF A GLOBAL NONHYDROSTATIC MODEL FOR EXTENDED-RANGE WEATHER PREDICTION DURING THE RELAMPAGO FIELD CAMPAIGN

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EXECUTIVE SUMMARY

The Model for Prediction Across Scales (MPAS) was implemented and then executed on Blue Waters during the RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations) field campaign in 2018. MPAS is a new, nonhydrostatic weather and climate model that allows for local grid refinement. Because MPAS is also a global model, it is well suited for extended-range predictions, as was demonstrated by the four-day predictions made daily during the campaign. A configuration detail of particular relevance was the specification of 3-km gridpoint spacing over the entirety of South America, with 15-km gridpoint spacing elsewhere around the globe. The 3-km spacing is considered to be "convection permitting," thus allowing for the explicit representation of thunderstorms over large domains.

Two other models were also employed for separate projects: the Weather Research and Forecasting (WRF) model, for studies of hail and tropical cyclones using a pseudo-global warming approach, and the Cloud Model 1 (CM1), for high-resolution idealized simulations of individual thunderstorms.

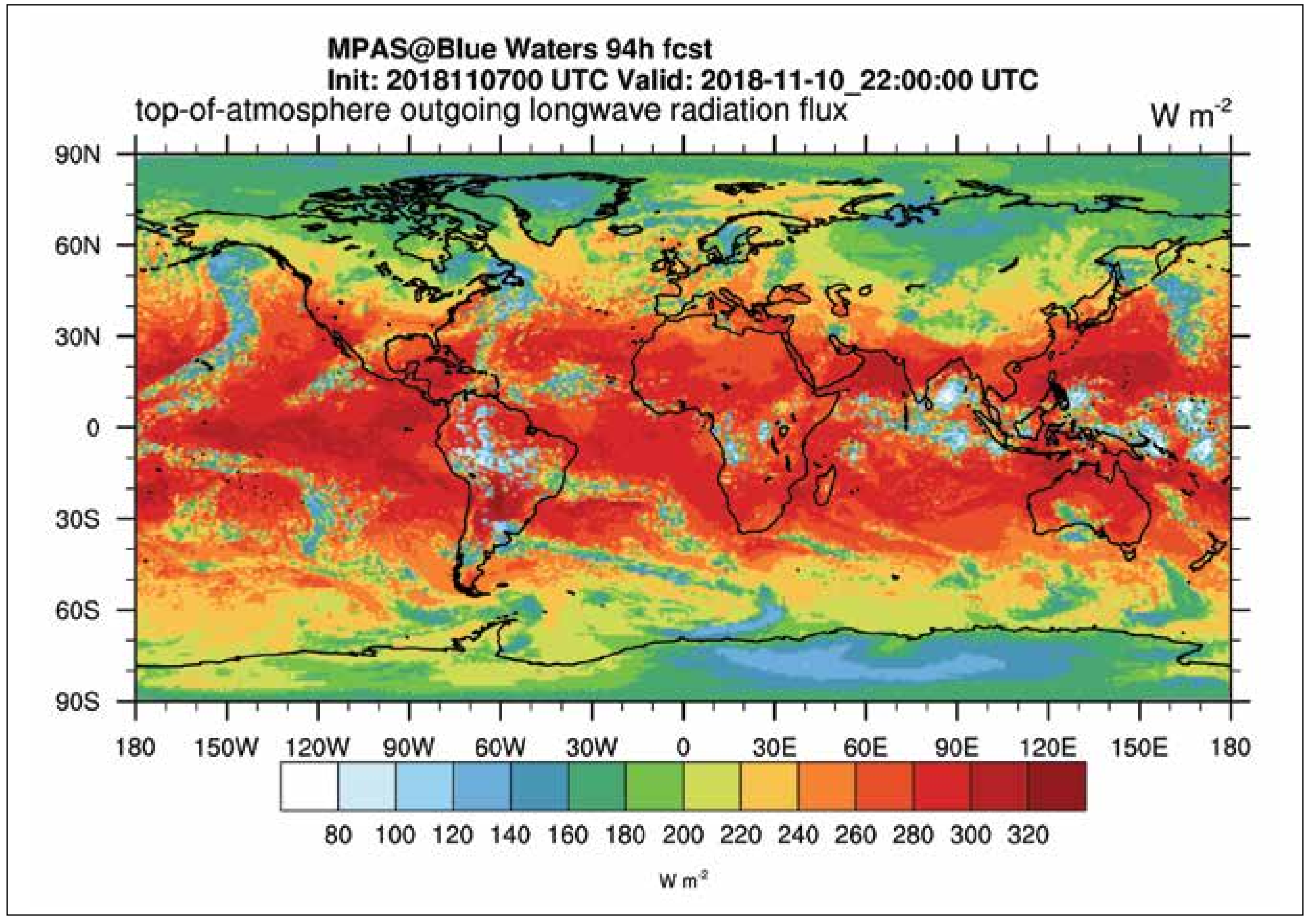

Figure 1: MPAS-simulated outgoing longwave radiation flux (W/m^2) at the "top-of-atmosphere," for a four-day prediction of severe thunderstorm activity over the Córdoba region of Argentina.

RESEARCH CHALLENGE

Thunderstorms and attendant phenomena such as hail, tornadoes, and extreme rainfall have high socioeconomic impact worldwide, thus motivating research to improve not only their predictions but also the understanding of their basic processes. One challenge is that their spatial and temporal scales are small relative to the scales of their meteorological forcing. To accurately predict and represent these storms and phenomena, an approach that can account for temporal scales ranging from days to seconds and spatial scales of thousands of kilometers to hundreds of meters is needed. In other words, very large geospatial domains that have fine gridpoint spacings and long time integrations with high rates of model output are required. The Blue Waters allocation is providing the research team with the resources needed to achieve this level of simulation.

METHODS & CODES

The team used MPAS with the aforementioned hybrid 3-km/15-km grid configuration and the convection-permitting suite of physics parameterizations. The model was integrated daily for four-day periods, using initial (and lower-boundary) conditions from the Global Forecast System model. This was done for the 45-day duration of the field campaign. The team also employed two other models for separate projects: the WRF model, under a pseudo-global warming approach, and the CM1 model, for high-resolution idealized simulations of individual thunderstorms.

RESULTS & IMPACT

The team concluded, based on the 45-day experiment, that MPAS offers some skill in extended-range, South American forecasts at convection-permitting scales. It would appear that the implied predictability is provided in part by the significant terrain-associated forcing, including that owing to the Andes Mountains and the Sierras de Córdoba Mountains. The researchers did notice, in some cases, that the predictability actually appeared to degrade rather than improve over shorter integration lengths. This could possibly be associated with model spinup; efforts to understand and quantify this are underway.

In the non-MPAS efforts, the team completed the simulation work on tropical cyclones and hailstorms (WRF, pseudo-global warming), and idealized thunderstorm simulations (CM1). The latter simulations were used to examine the strong connections, within storms, between the physical sizes of vertical drafts ("updrafts" and "downdrafts") and the depth of the pool of cool air generated through these drafts. These physical sizes have impacts on tornado intensity and, more generally, have implications on how convective storms are parameterized in coarse-resolution models.

WHY BLUE WATERS

The project staff provided tremendous assistance in helping to install the model and associated software on Blue Waters. The staff also set up a daily reservation for the model runs. Compared to other high-end high-performance computing resources, Blue Waters is incredibly stable and reliable, which ensured timely delivery of the daily forecasts.

PUBLICATIONS & DATA SETS

G. R. Marion and R. J. Trapp, "The dynamical coupling of convective updrafts, downdrafts, and cold pools in simulated supercell thunderstorms," *J. Geophys. Res.-Atmos.*, vol. 124, 2019, doi: 10.1029/2018JD029055.

D. Carroll–Smith, L. C. Dawson, and R. J. Trapp, "High resolution real-data WRF modeling and verification of tropical cyclone tornadoes associated with Hurricane Ivan 2004," *EJSSN*, vol. 14, no. 2, pp. 1–36. 2019.

R. J. Trapp, G. R. Marion, and S. W. Nesbitt, "Reply to 'Comments on the regulation of tornado intensity by updraft width,'" *J. Atmos. Sci.*, vol. 75, pp. 4057–4061, 2018, doi: 10.1175/JAS-D-18-0276.1.

R. J. Trapp, K. A. Hoogewind, and S. Lasher–Trapp, "Future changes in hail occurrence in the United States determined through convection-permitting dynamical downscaling," *J. Clim.*, 2019, doi: 10.1175/JCLI-D-18-0740.1.