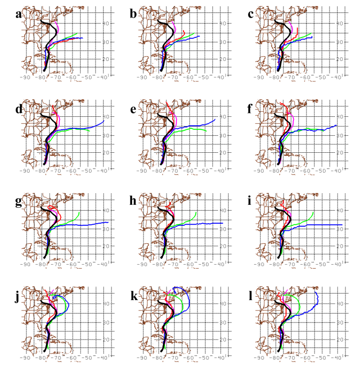
Accuracy of GFS and ECMWF Hurricane Sandy Track Forecasts Dependent on Cumulus Parameterization

Research Highlight

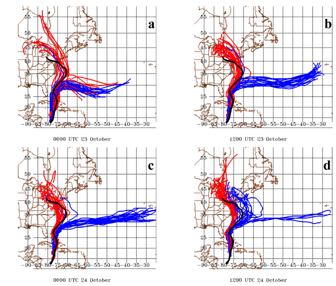
Hurricane Sandy (2012) was an extremely damaging late-season storm that significantly impacted much of the northeastern United States. Aside from the damage to life and property, Hurricane Sandy was also noteworthy for its large forecast track differences very early in its life cycle. Roughly one week before landfall, the European Center for Medium-range Weather Forecasting (ECMWF) model routinely forecasted a very accurate track while the Global Forecast System (GFS) model consistently forecasted a track that did not make landfall on the United States. These differences were also broadly true of their respective global ensembles at the time. In the aftermath of Hurricane Sandy, many ascribed the superior forecasts made by the ECMWF (and its ensemble) to either an improved data assimilation scheme compared to the GFS, or greater resolution compared with the GFS (or a combination of both). In this case, model physics differences were rarely suggested as a cause of the forecast track divergence. Using a Weather Research and Forecasting Model (WRF) framework, this research demonstrates that differences in the two models' cumulus parameterization were the primary drivers of forecast track differences, rather than differences in either model resolution or data assimilation.

The relative importance of cumulus parameterization (compared with resolution or initial conditions) for accurate long-term Sandy forecasts is examined using WRF-ARW version 3.3.1. Specifically, a series of 180-hour simulations are created across a number of different initialization times wherein the only difference is choice of cumulus parameterization. One is the Simplified Arakawa Schubert (SWRF), which is the WRF implementation of the actual GFS cumulus parameterization. The second is the Tiedtke (TWRF), which is a WRF approximation of the ECMWF cumulus parameterization (it should be noted this is not identical to that used in the current operational ECMWF model). These simulations were referred to as SWRF and TWRF, respectively. All other model parameterizations and parameters were kept constant, and all were initialized at 0000 and 1200 UTC on 23 and 24 October 2012. Additionally, these simulations were created for horizontal grid spacings of 30, 60, and 90 kilometers. Figure 1 shows the operational ECMWF (pink) and GFS (green) forecast tracks as well as the TWRF (red) and SWRF (blue) forecasts along with Hurricane Sandy's best track. Each panel represents a unique combination of grid-spacing and initialization time. Quite plainly, the SWRF accurately reproduces the operational GFS forecast track whereas the TWRF generally reproduces the operational ECMWF (the exception being the simulation initialized at 0000 UTC 23 October using 30-kilometer grid-spacing). For any case, the track error associated with the TWRF is smaller than that of the SWRF after 0600 UTC 28 October (not shown, refer to linked paper). This accurately reproduces the superior track forecasts of the operational ECMWF compared with the GFS at these times.

A separate set of WRF simulations was created for these four initialization times using WRF's global capability. For these, the 21 GFS ensemble members (20 perturbations + 1 control) were used to initialize 42 WRF simulations (21 each using the Simplified Arakawa Schubert (SWRFENS) and the Tiedtke (TWRFENS)). All simulations used a grid-spacing equivalent to 88.9 kilometers at the equator. Figure 2 shows the subsequent forecasts of the SWRFENS (blue), TWRFENS (red), and Hurricane Sandy best track. A clear bimodality of forecast tracks can be seen, with the SWRFENS generally tracking towards the central Atlantic Ocean while the TWRFENS almost exclusively makes landfall along the northeastern United States. These forecast tracks generally reproduce the observed forecast spread of the operational ensembles for these times. Similarly, the track error characteristics of these forecasts closely follow the track error characteristics of the operational ensembles (not shown, refer to linked paper). This research demonstrates that choice of cumulus parameterization was significantly more important than choice of initial conditions or resolution for accurate long-term Hurricane Sandy track forecasts.



Panels (a,b,c), (d,e,f), (g,h,i), and (j,k,l) represent initialization times of 0000 UTC 23 October, 1200 UTC 23 October, 0000 UTC 24 October, and 1200 UTC 24 October, respectively. ECMWF (pink), GFS (green), TWRF (red), and SWRF (blue) tracks are shown in addition to Hurricane Sandy's best track (black). Panels (a,d,g,j), (b,e,h,k), and (c,f,i,l) represent 30-km, 60-km, and 90-km simulations, respectively, for the TWRF and SWRF.



This figure shows 180-hour forecast tracks for the TWRFENS (red) and SWRFENS (blue), along with the Hurricane Sandy best-track (black) for simulations initialized at (a) 0000 UTC 23 October, (b) 1200 UTC 23 October, (c) 0000 UTC 24 October, and (d) 1200 UTC 24 October.

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Although it was suspected that the poor GFS forecasts were a result of inadequate initial conditions, this was demonstrated to be incorrect. Specifically, when these initial conditions were paired with a cumulus parameterization representative of that used in the ECMWF model, excellent forecasts were produced. Similarly, these forecasts were generally shown to be resolution independent (at the resolutions examined here). One major caveat is that these conclusions are reached using the WRF model (rather than the actual GFS or ECMWF model). Another caveat is that only a single case was examined, so it is quite possible that for other events, choice of cumulus parameterization would be of secondary importance to choice of initial conditions or grid-spacing. Regardless, this result highlights the importance of model physics development, testing, and improvement as an essential tool towards improving forecasts.

Reference(s)

Bassill NP. 2014. "Accuracy of early GFS and ECMWF Sandy (2012) track forecasts: Evidence for a dependence on cumulus parameterization." Geophysical Research Letters, , doi:10.1002/2014GL059839. ONLINE.

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