The human influence on Hurricane Florence

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For Hurricane Florence, we present the first advance forecasted attribution statements about the human influence on a tropical cyclone. We find that rainfall will be significantly increased by over 50% in the heaviest precipitating parts of the storm. This increase is substantially larger than expected from thermodynamic considerations alone. We further find that the storm will remain at a high category on the Saffir-Simpson scale for a longer duration and that the storm is approximately 80 km in diameter larger at landfall because of the human interference in the climate system.

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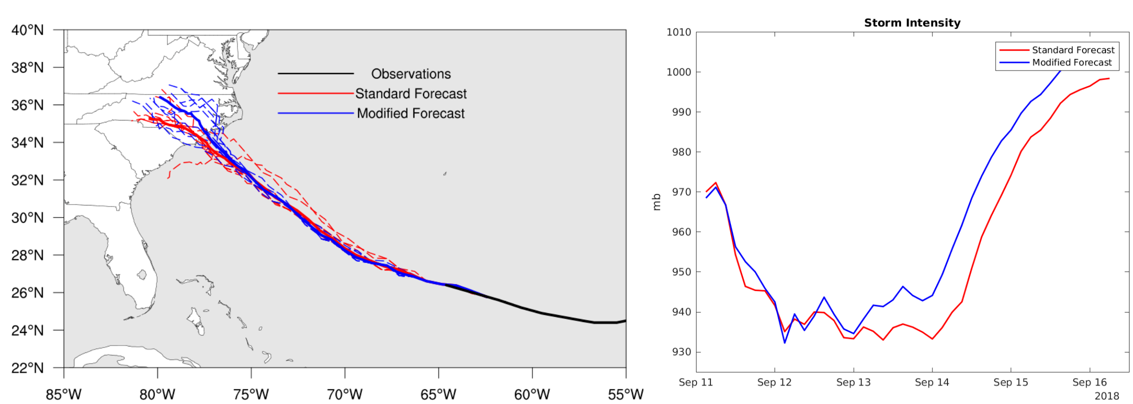
These attribution statements are enabled by real-time ensemble forecasts of Hurricane Florence performed using the Community Atmosphere Model (CAM) version 5. Two sets of ensembles forecasts were completed (***Initialized Sept 11, 2018 at 00Z***):

Standard Forecast: With observed initial atmospheric conditions and sea surface temperatures (SST) adapted from NOAA's operational Global Forecast System model. This is the forecast of the actual Hurricane Florence.

Modified Forecast: With observed initial conditions modified to remove the estimated climate change signal from the temperature, moisture, and SST fields to represent a world without climate change. This is a counterfactual forecast of Hurricane Florence if it were to occur in a world without human induced global warming.

Through comparison of the standard and modified ensemble forecasts for Hurricane Florence, we quantify the impact of climate change on the storm's size, rainfall, and intensity.

Intensity: *Hurricane Florence is slightly more intense for a longer portion of the forecast period due to climate change according to the forecasted minimum surface pressure.*



Left: Individual ensemble forecasts (dashed) and ensemble mean (solid) of Hurricane Florence.
Right: Time evolution of the ensemble average central minimum surface pressure.
Red: Florence in the world that is. ***Blue:*** Florence in the world that might have been without climate change.

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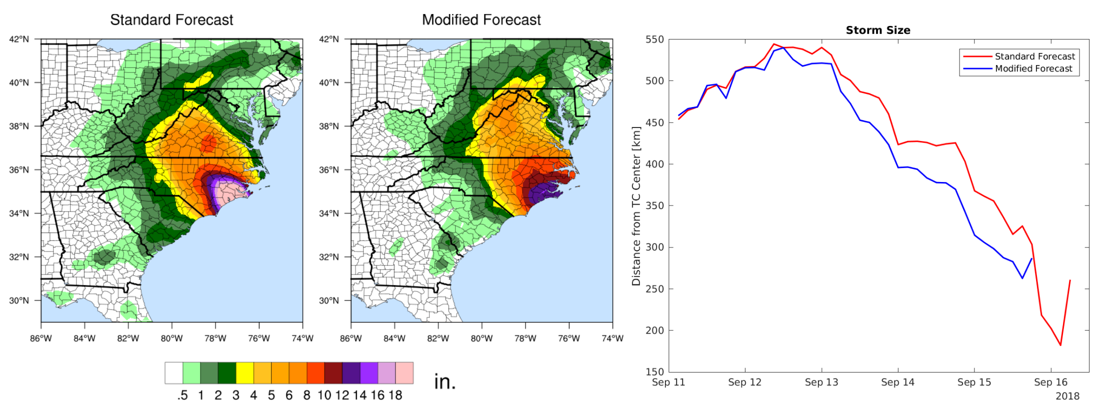
Rainfall: *The forecasted Hurricane Florence rainfall amounts over the Carolinas are increased by over 50% due to climate change and are linked to warmer sea surface temperatures and available moisture in the atmosphere.*

Storm Size: *The forecasted size of Hurricane Florence is about 80 km larger due the effect of climate change on the large-scale environment around the storm.*



Left: Ensemble average accumulated rainfall Hurricane Florence forecasts.
Right: Evolution of the ensemble average outer storm size (radius at peak wind speed of approximately 18 mph).
Red: Florence in the world that is. ***Blue:*** Florence in the world that might have been without climate change.

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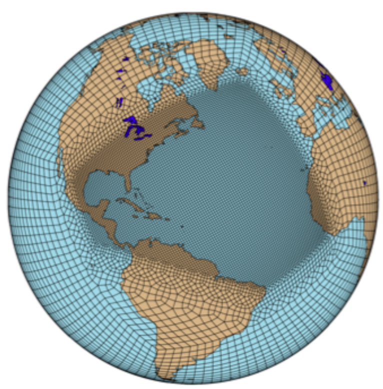
Methodology. The global atmospheric model CAM5 is set up in a variable-resolution configuration with a base grid spacing of ~100 km, similar to conventional atmospheric general circulation models, and a refined region over the North Atlantic basin with a grid spacing of ~28 km. The model is initialized with atmospheric analyses from NOAA's Global Forecast System (GFS) following the technique outlined in Zarzycki and Jablonowski (2015) and run for 7 days and the first 5 days are analyzed. For Hurricane Florence, the model is initialized on 9/11 at 00z. To account for model uncertainty in storm characteristics, a 10-member ensemble is created by randomly varying three parameters (c0_ocn, tau, and dmpdz) in the deep convective parameterization (Zhang and McFarlane 1995). TC tracks from the forecast runs are generated using the TempestExtremes algorithm (Ullrich and Zarzycki 2017). For modified forecasts with the climate change signal removed, the methodology follows the the framework of Wehner et al. (2018). In particular, the air temperature, specific humidity, and sea surface temperature from the observed initial conditions are modified to remove climate change effect. Data from the C20C Detection and Attribution project (portal.nersc.gov/c20c) define the initial conditions for the counterfactual "storm that might have been". Differences between global simulations driven by observed boundary conditions and simulations driven by conditions with the human induced climate change removed are calculated for September over the 1996-2016 period and approximate the change in the large scale environment attributable to climate change. Additionally, the greenhouse gas concentrations, solar radiation conditions, ozone concentration, and aerosol concentrations are all set to pre-industrial levels for the modified forecasts.



Depiction of the CAM5 variable-resolution computational grid.

References.

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