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WRF Simulations of the 2009 Southeastern United States Convective Season Onset in a Future Climate Scenario

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Abstract

This work uses the Weather Research and Forecasting model to project how precipitation patterns may change under a warmer climate in the Southeast United States (SE US). Two simulations are performed using boundary conditions from the 6-hourly 0.5 degree Global Forecasting System (GFS) reanalysis data and daily 0.5 degree Real-Time Global Sea Surface Temperature High Resolution data. The first simulation, used as a control in this experiment, models weather in the SE US from March – June in 2009, and is used to represent the seasonal current climate in the region. The second simulation is performed using a pseudo-global warming method assuming an RCP8.5 future climate scenario, using Coupled Model Intercomparison Project Phase 5 multi-model mean temperature anomalies to adjust GFS reanalysis temperature variable values, to model a warmer climate estimated as the 2090 – 2100 decade. Changes in precipitation organization in the warmer climate will be analyzed within a framework which separates precipitation features into two classifications, isolated and mesoscale, depending on whether the precipitation feature is greater or less than 100 km in contiguous horizontal length. This analysis will identify if there are changes in the convective season onset date, and/or in precipitation patterns according to precipitation classification, as well as identify mechanisms that influence precipitation pattern changes in the SE US.

Project Goals

- Analyze WRF simulation output to determine projected changes in:
  - o Isolated precipitation features
  - o Mesoscale precipitation features
- Seasonal onset timing in precipitation features
- Determine potential mechanisms causing precipitation feature changes

Background

- Interested in the Southeast United States (SE US) as shown in Figure 1
- SE US seasonal climate consists of distinct regimes of extratropical cyclone activity and isolated convection (Rickenbach et al. 2015; Figure 2 and 3)
- Precipitation can be categorized as mesoscale precipitation features (MPF) and isolated precipitation features (IPF; Houze 2004, Rickenbach 2015)
  - o MPF and IPF are defined by their feature lengths:
    - ▪ MPF ≥ 100 km; Figure 2
    - ▪ IPF < 100 km; Figure 3

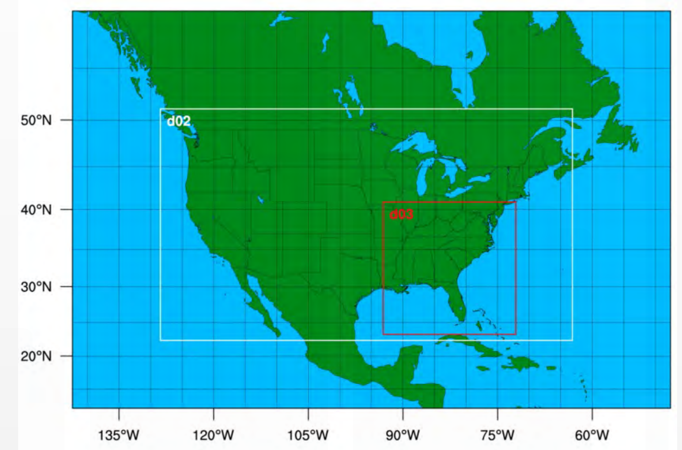

Figure 1: Region of interest, SE US (red box)

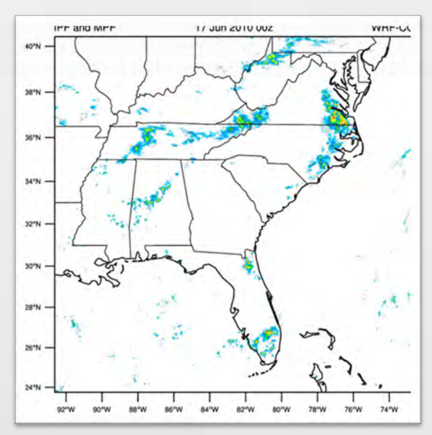

Figure 2: Map showing precipitation features

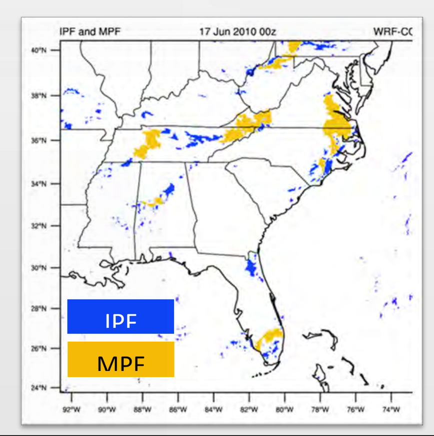

Figure 3: Features categorized by size classifications (IPF and MPF)

Figures courtesy of Mark Nissenbaum, Florida State University

- Under the RCP8.5 climate change scenario:
  - o Global temperatures rise ~ 3.7°C (Table 1)
  - o SE US temperatures rise ~ 3°C and 5°C (Figure 4, top right; IPCC AR5 WGII 2014)
  - o There is agreement that SE US annual precipitation totals increase (Figure 4, bottom right); not clear what changes will occur in precipitation features

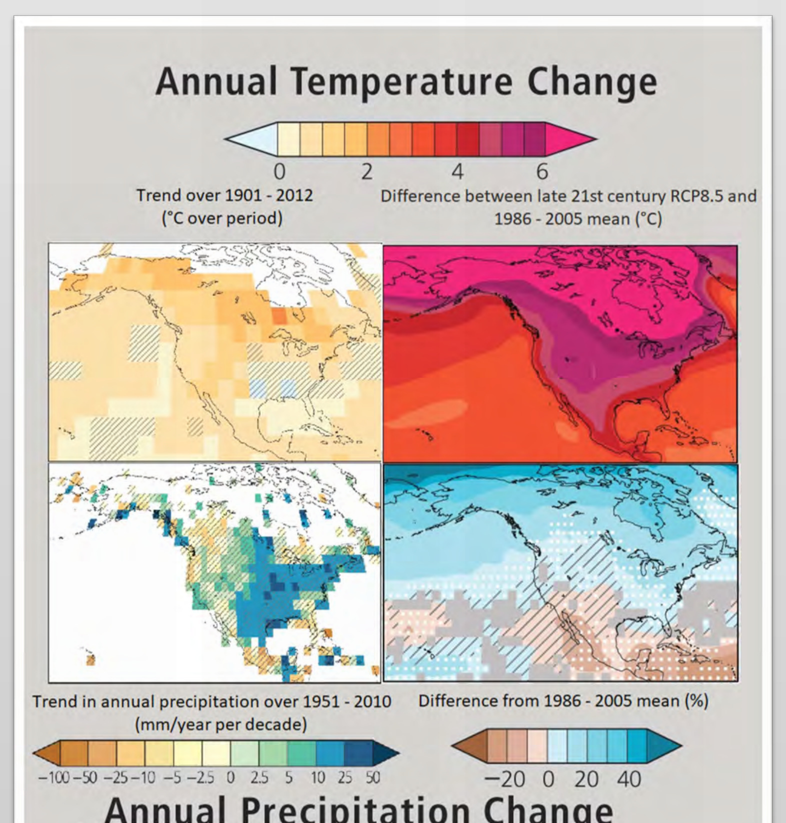

Figure 4: Projected Climate Change Scenario

TABLE				
[redacted]				
Scenario	*Radiative Forcing (Wm^{-2})*	*CO_2 by 2100*	*Global Mean Surface Temperature Change (°C)*	
			2046-2065	2081-2100
RCP2.6	2.6	100	1.0	1.0
RCP4.5	4.5	538	1.4	1.8
RCP6.0	6.0	670	1.3	2.2
RCP8.5	8.5	936	2.0	3.7

Table 1: Descriptions of RCP climate change projections

Methodology

- WRF Version 3.9 is run with 3 nested grids from 01 March 2009 – 30 June 2009 (Figure 1; Table 2) using real-time global sea surface temperature (RTG SST) and 6-hour Global Forecasting System (GFS) reanalysis data

	Domain 1	Domain 2	Domain 3
Resolution	300 x 200	619 x 349	598 x 598
Grid spacing	27 km	9 km	3 km
Microphysics	WRF Single Moment 3	WRF Single Moment 3	Thompson Graupel
Cumulus	Betts-Miller-Janjic	Betts-Miller-Janjic	none (explicit)
Surface physics	Noah	Noah	Noah
LW/SW Radiation	RRTMG	RRTMG	RRTMG
Boundary layer	Yonsei	Yonsei	Yonsei

Table 2: Parameterizations for simulations

- Two WRF simulations were run on NCAR's "Cheyenne" supercomputer, one simulating the current climate in 2009, the other simulating the future climate decade (2090 – 2100) under RCP8.5
  - o In the current climate simulation, GFS and RTG SST data were directly ingested into the WRF model from the WRF Preprocessing System (WPS)
  - o In the future climate simulation, Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model mean (MMM) variable anomalies are added to GFS and RTG SST data following the pseudo-global warming method (PGW; Lackmann 2013)

Results

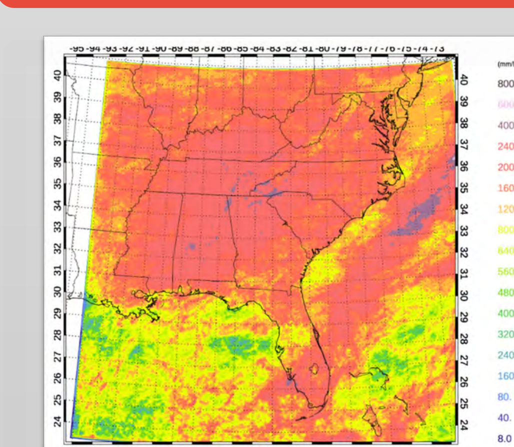

Figure 5: Simulated current climate total precipitation between March and June

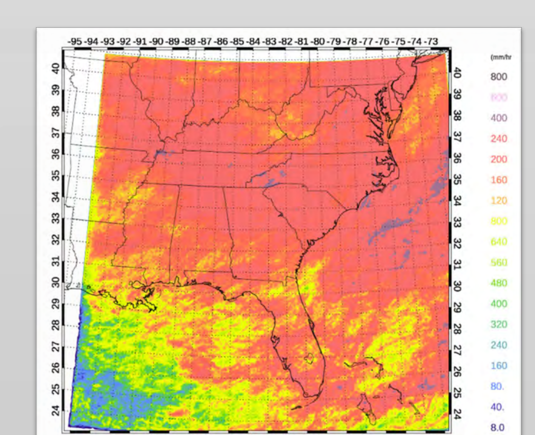

Figure 6: Simulated future climate total precipitation between March and June

- Figures 5 and 6 show combined IPF and MPF (all rainfall):
  - o Comparing future to current climate there is more precipitation over some areas, less in others; why?
  - o Minimum in precipitation in Central Gulf of Mexico in both figures
    - ▪ Minimum becomes stronger in future climate simulations
  - o Minimum in precipitation along US East Coast in both figures
    - ▪ Possibly due to change in sea/land breeze
    - ▪ More precipitation in future climate within minimum

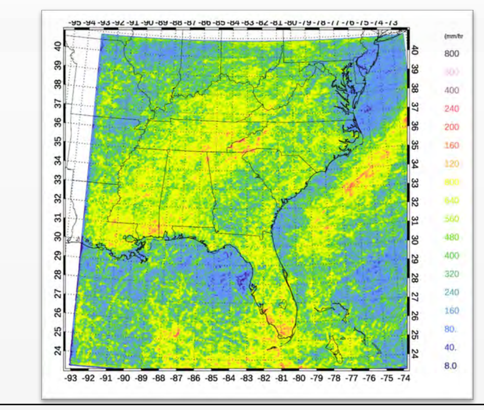

Figure 7: Simulated current climate IPF between March and June

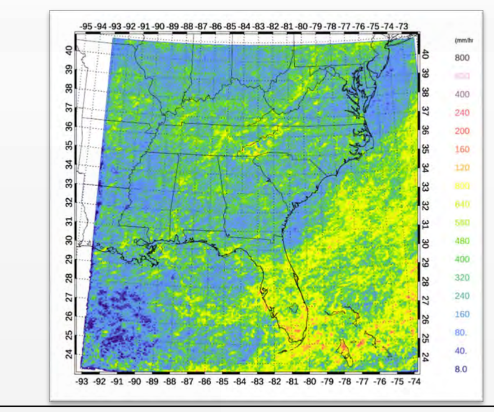

Figure 8: Simulated future climate IPF between March and June

- Figure 7 and 8 show only IPF component of total:
  - o IPF projected to generally weaken
  - o Weakens most over land
  - o Noticeable minimum in Central Gulf of Mexico develops

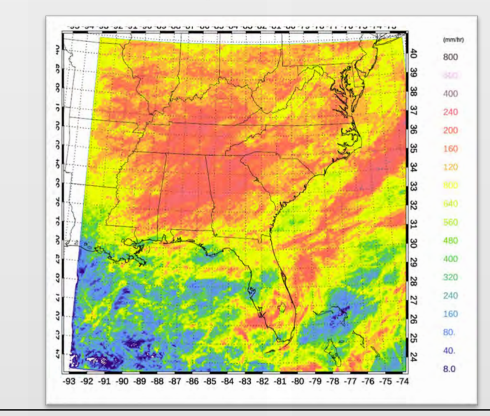

Figure 9: Simulated current climate MPF between March and June

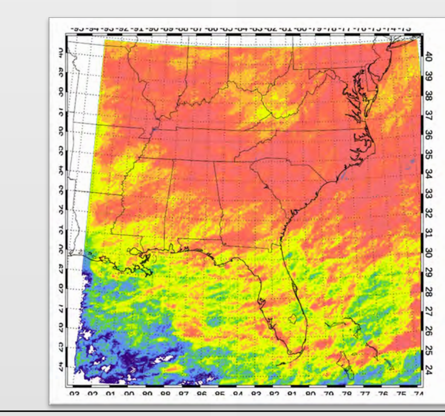

Figure 10: Simulated future climate MPF between March and June

- Figure 9 and 10 show MPF component of total:
  - o Precipitation generally increases over region, indicating more organized convection
  - o Strengthens along East Coast, potentially stronger sea breeze

Future Work

- Perform analysis to determine onset convective season dates in both current climate and future climate simulations (Rickenbach, Ferreira, and Wells 2019)
- Determine if the onset dates differ
- Correlate parameters such as CAPE and CIN to the convective season onset dates and perform statistical analysis
- Attempt to determine mechanisms for the convective season onset
- Determine how synoptic features external to the region, such as positioning of the North Atlantic Subtropical High, affect onset and features of the convective season (Ferreira and Rickenbach 2019)
- Fill in missing and corrupted model output (about 7% of time period)