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A REGIME BASED CLIMATOLOGICAL ASSESSMENT OF WRF SIMULATED DEEP CONVECTION AND ASSOCIATED PRECIPITATION

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1. INTRODUCTION

To generate better model forecasts of severe convective storms, it is important to continually improve the models that are used to explicitly simulate these storms. Output from Convection Allowing Models (CAMs) such as from the Weather Research and Forecasting Model (WRF) has the potential to improve operational forecasts by providing greater detail and accuracy to operational forecasters (Kain et al. 2006). CAMs have a grid spacing of ≤ 4 km, as this is the coarsest spacing to sufficiently represent the evolution and structure of Mesoscale Convective Systems (MCS, Weisman et al. 1997).

Despite these advantages, the high resolution of CAMs can make it more difficult to evaluate the accuracy of the model's forecast. Using traditional forecast verification statistics that only match spatial placement of storms, a forecast model that generates a storm with fine-scale (more realistic) properties but slightly displaced in space in space may perform more poorly a coarse resolution forecast lacking small-scale features (Baldwin et al. 2001).

There are alternatives to traditional verification techniques which are useful in evaluating CAM performance. Goines and Kennedy (2017) utilized Hovmöller diagrams to investigate a multiple year database of convective allowing WRF simulations. While the models showed higher skill in predicting propagating precipitation, propagating streaks were too short in time. Physically, this suggested convection such as MCSs decayed too early. While this bias was present, it was unclear whether this changed based off of the forcing mechanism. A regime based analysis of model performance would help to identify specific synoptic patterns that models struggle with to a) potentially hint at ways to improve model performance, and b) better inform forecasters of model biases.

2. METHODOLOGY

This study evaluates deep convection and associated precipitation in a multi-year (2007-2014) database of WRF simulations over five regions of the United States (Northern Plains (NP), Southern Great Plains (SGP), Midwest (MW), Gulf Coast (GC), and Northeast (NE); Fig. 1). These WRF simulations were run daily in support of the NOAA Hazardous Weather Testbed (HWT) by the National Severe Storms Laboratory (NSSL) for operational forecasts.

To conduct this analysis, a competitive neural network known as the Self-Organizing Map (SOM, Kohonen et al. 1996) will be used. SOMs allow the user to represent atmospheric patterns in an array of nodes that represent a continuum of synoptic categorizations. North American Regional Reanalysis (NARR) data during the warm season (April-September) will be used to perform the synoptic typing over the study domains and precipitation data from NCEP Stage IV dataset will be used to evaluate model precipitation bias.

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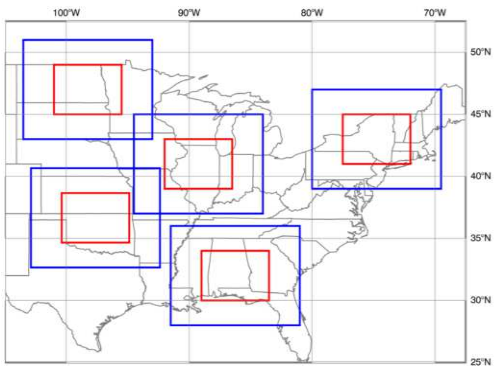

Figure 1. Five regions of interest in this study. The blue boxes represent the domain for the synoptic patterns and the smaller red boxes represent the area where precipitation data will be analyzed.

To mitigate issues with verification of marginal (low-impact) cases, Cumulative Distribution Functions (CDFs) of total daily precipitation (12-12 UTC) were calculated for the warm seasons (April- September) of 2007-2014. Cases were objectively selected based on position within the CDF to remove weaker cases that did not significantly impact the hydrological budget. In total, three sets of SOMs were produced for each region:

- Climatological: Produced from all available warm season days (precipitating and non-precipitating).
- CDF90: Produced from precipitation days within the upper 90% of the CDF
- CDF50: Produced from precipitation days within the upper 50% of the CDF

This paper will discuss all five regions, with a focus on results from the SGP region.

3. RESULTS

Prior to investigating the SOMs, biases were calculated for the three sets of cases, and these biases were calculated for the entire forecast period (12–12 UTC) along with individual 6-hr periods (Table 1).

Table 1. Average bias for climatological, cdf90, and cdf50 SOMs. Biases are provided in mm.

Region	SOM	Cases	Average Bias					Description
			Total	12z to 17z	18z to 23z	0z to 5z	6z to 11z	
SGP	climo	1366	0.24	0.13	0.23	0.13	-0.25	all days
	cdf90	387	-0.38	0.10	0.39	0.15	-1.02	at least 3mm of total precip
	cdf50	106	-2.90	-0.03	0.20	-0.39	-2.68	at least 12mm of total precip
NP	climo	1374	0.57	0.13	0.28	0.20	-0.02	all days
	cdf90	421	0.99	0.21	0.53	0.43	-0.19	at least 2mm of total precip
	cdf50	111	0.25	0.20	0.72	0.09	-0.76	at least 8mm of total precip
MW	climo	1367	0.46	0.02	0.39	0.15	-0.10	all days
	cdf90	516	0.49	-0.07	0.67	0.28	-0.39	at least 2 mm of total precip
	cdf50	216	-0.31	-0.15	0.88	-0.02	-1.03	at least 8 mm of total precip
GC	climo	1369	0.74	0.20	0.50	0.05	-0.01	all days
	cdf90	505	0.90	0.29	0.65	0.04	-0.08	at least 3 mm of total precip
	cdf50	156	-0.12	-0.18	0.41	-0.04	-0.30	at least 9 mm of total precip
NE	climo	1335	0.64	0.11	0.41	0.03	0.10	all days
	cdf90	436	0.93	0.09	0.70	-0.06	0.19	at least 3 mm of total precip
	cdf50	131	0.31	-0.19	0.46	-0.34	0.39	at least 10 mm of total precip

A few notable properties stand out and these are consistent with work from Goines and Kennedy (2017). First, NSSL WRF simulations generally over predict precipitation regardless of region. The lone exception is for the cdf50 set of cases for the MW, GC, and SGP regions. In the remaining regions, positive biases were lower than the more comprehensive lists of cases. This suggests that overall positive biases are the result of weaker precipitating cases.

The primary cause of positive bias is due to diurnal convection, as seen by larger positive biases between 18-23 UTC. This positive bias is offset by negative biases during the overnight hours (6-11 UTC), and this signal is consistent at every location except for the NE. This result is consistent with Goines and Kennedy (2017) that found propagating streaks within precipitation hovmöller plots were too short (in time).

SGP is characterized by a variety of patterns responsible for precipitation events. Figs. 2 and 3 depict meteorological properties of a 28 class SOM for the cdf90 cases. In lee of the Rocky Mountains, the majority of cases have a dryline in the west. Stronger forced events are found on the right hand side (RHS) of the SOM, as evident by the strong surface lows (Fig. 2) and upper level troughing with tightly packed height anomalies (Fig. 3). Additional patterns of note include warm fronts under shortwave troughs (upper left) and relatively weak surface forcing underneath northwesterly flow (bottom center).

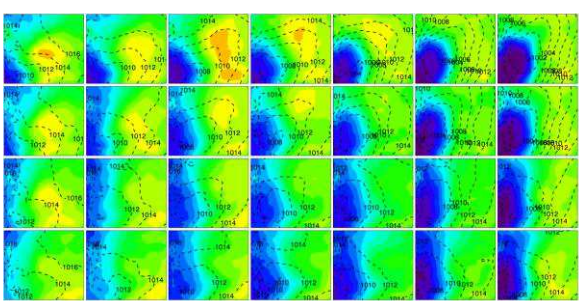

Figure 2. 7x4 (28-class) SOM for the SGP domain. MSLP is contoured with dashed lines while 900 hPa is filled (warmer colors = more humid).

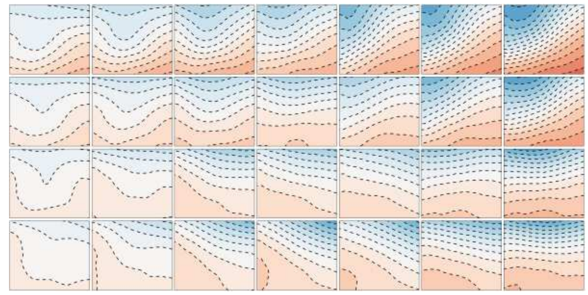

Figure 3. 7x4 (28-class) SOM for the SGP domain. 500hPa height anomalies are contoured (warm colors = positive anomalies).

Precipitation biases for the SGP SOM are provided in Fig. 4. Despite class-to-class variability, patterns of distinct biases are present across the SOM. In particular, the largest positive biases are found in the upper-left, associated with high RH and surface warm fronts. The strongest negative biases are found in the upper-right with the mid-latitude cyclones. Finally, an area of additional negative biases is found for the weakly forced events under northwest flow in the bottom-center of the SOM.

In the latter case, these biases appear to be responsible for the significant negative bias found for SGP during the overnight hours (6-11 UTC, Table 1). Meteorologically, these are believed to be Mesoscale Convective Systems (MCSs) that originated well away from the domain, then propagated over the region during these late hours. Figure 5 shows that many of the cases for those patterns experience the most 6 hour rainfall totals during the 6-11 UTC time period, indicating that the precipitation for the patterns is likely in the form of an MCS.

The classes with negative bias in the upper-right corner of the SOM also have several cases with maximum precipitation occurring in the 6-11 UTC time period (Fig. 5). Because the synoptic patterns indicate that these are drylines likely producing isolated convection, these could be cases where convection grows upscale into an MCS overnight.

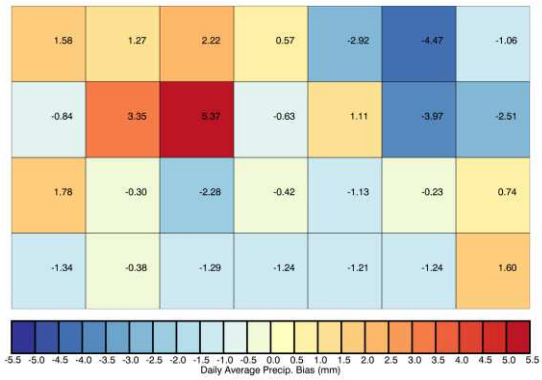

Figure 4. Daily average precipitation bias for the SGP SOM.

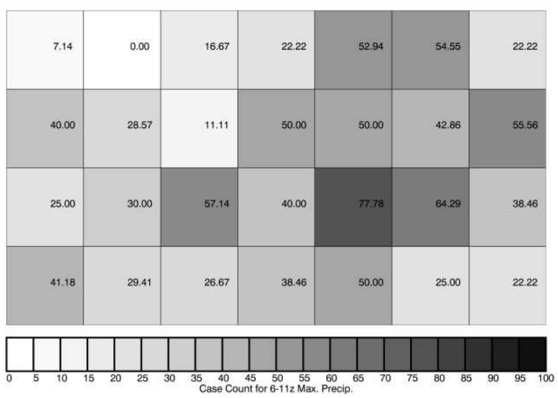

Figure 5. Percent of cases in each class that produced maximum 6 hour precipitation totals from 6-11 UTC.

4. REFERENCES

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