AN EVALUATION OF THE CLIMATE FORECAST SYSTEM VERSION 2 AS AN EXTENDED RANGE FORECASTING TOOL IN THE STORM PREDICTION CENTER

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ABSTRACT

As of today, extended range forecasts cannot be made on a consistent day to day basis. The ability of forecasters to predict severe weather beyond a three day lead time is limited. If it is made possible for forecasters to make reliable and consistent extended range forecasts, then the safety of the public will be enhanced by severe weather warnings several days in advance.

In order to potentially give forecasters a new tool in assisting with extended range forecasting of severe weather, the Climate Forecast System Version 2 (CFSv2) and its forecasts are being examined and compared with the Storm Prediction Center (SPC) Day 4–8 forecasts and also compared with actual reported events.

Granted that there are days without severe weather, few of SPC Day 4–8 Severe Weather Outlooks have actual forecasts. The CFSv2 has shown an ability to reliably forecast severe (or lack of severe) weather with a day four lead time and moderate reliability at day five. Although the CFSv2's capability to forecast reliably beyond day five is, to some degree, limited, in this paper it is shown that the CFSv2 does have potential as an extended range forecasting tool.

1. INTRODUCTION

The Climate Forecast System Version 1 (CFSv1) is a fully coupled ocean-land-atmosphere prediction model that was used at the National Centers for Environmental Prediction (NCEP) beginning in August of 2004. It was the first quasi-global dynamical seasonal prediction system. It is made up of four independent systems: the R-2 NCEP/Department of Energy Global Reanalysis, the NCEP Global Ocean Data Assimilation System (GODAS), a lower

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resolution of the NCEP Global Forecast System (GFS), and the Geophysical Fluid Dynamics Lab (GFDL) Modular Ocean Model Version 3 (MOM3) (Saha et al. 2006).

The CFSv2 became operational and implemented in March of 2011. It had improvements to the four previous components as well as an upgraded four level soil model, an interactive three layer sea-ice model, and an inclusion of historically prescribed CO_2 concentrations. A key upgrade was the improved consistency between the model and initial states created by the data assimilation system. The CFSv2 has a 0.5 by 0.5 degree resolution (Saha et al. 2012).

The Supercell Composite Parameter (SCP) is a dimensionless quantity which gives a value of one or greater if the atmospheric conditions for a supercell to develop are sufficient (Thompson et al. 2002). The version of SCP that was used in this study is made up of three components the most unstable convective available potential energy (MUCAPE), the 0–3km storm relative helicity (SRH), and the 10m to 500mb bulk wind difference (BWD). When in the right combination, these ingredients can describe an environment favorable for supercell thunderstorms and severe weather.

The Storm Prediction Center (SPC) issues one Day 4–8 Severe Weather Outlook every day over the continental United States (CONUS). If severe weather is forecasted for an area, then there is a 30% or higher probability for severe weather within twenty-five miles of any point in that area. Note these forecasts are for individual days (4–8). There are two non-forecasting outlooks in which predictability is too low or potential is too low. “Predictability Too Low” indicates some models show severe weather, but there are some inconsistencies from run-to-run and between different models. “Potential Too Low” indicates that the occurrence of severe weather “appears highly unlikely” (less than 30% probability) across the CONUS during the entire forecasted period (SPC 2013).

2. METHODS

The datasets that were used for this study were the forty-five day forecasts from the CFSv2. Every day the model produces a forecast for every six hours out to forty-five days. The time period for this study was May 1st, 2013 through June 30th, 2013. This time period was selected because it gave a good forecast month for the SPC (May) and a bad forecasts month for the SPC (June) while being a small enough data set for the time limitations of the project. Although the CFSv2 is a global system, for this study a masked region of North America was used that only includes the CONUS, a region containing 845 grid points. Although the CFSv2 is a seasonal prediction model, its application to daily forecasting of severe weather beyond three days is examined.

2.1 *SCP*

From the CFSv2 forecasts, components of the SCP were gathered, calculated, and normalized. The SCP was calculated for all the grid points in the domain, and a 12 UTC to 12 UTC average value and maximum 6-hour forecast value of SCP were computed.

The Supercell Composite Parameter is calculated from MUCAPE, (0–3 km) SRH, and (10m – 500mb) BWD (Carbin 2013a). These components are normalized to a supercell threshold provided from previous studies , and then multiplied together. If the resulting SCP value is greater than or equal to one, then the environment is favorable for supercells and possibly severe weather.

$$SCP = \frac{MUCAPE}{1000\left(\frac{J}{Kg}\right)} \cdot \frac{SRH}{50\left(\frac{m^2}{s^2}\right)} \cdot \frac{BWD}{20\left(\frac{m}{s}\right)}$$

The bulk wind difference term is further normalized as follows: if the BWD has a value less than 10(m/s) or greater than 20(m/s), then it is set to zero or one respectively (Thompson et al. 2004).

2.2 *SPC Storm Reports*

The SPC Storm Reports are a collection of reports from NWS Local Storm Reports. Reports of tornados, wind, high wind (≥ 65 kts), hail, and large hail (≥ 2” in diameter) across the CONUS are all recorded in the SPC Storm Reports (SPC 2013). The SPC Filtered Storm Reports were used for comparisons against actual events. These reports have a filtering process that removes duplicate reports with respect to time and place for tornados, wind, and hail separately (all high wind and large hail reports are kept). The reports are considered duplicates if the following are true:

1. The reports have the same regular expression of deaths/fatalities.
2. The reports' spatial/temporal differences are:
    a. Less than 5 miles and 5 minutes for tornados
    b. Less than 10 miles and 15 minutes for hail and wind reports.

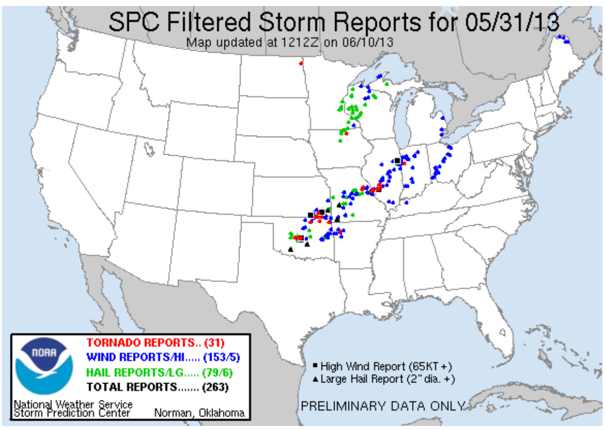

Figure 1 – Example of a SPC Filtered Storm Reports valid for May 31st, 2013 (SPC 2013).

2.3 *Significant Severe Weather Days*

Looking at the SPC Filtered Storm Reports, the Daily Severity Index (DSI) will be defined to be one-fifth of the sum of each reported categories divided by that month's daily average of the same category. Now, if the DSI is greater than or equal to two for a given day, then that day is considered to be a significant severe weather day. For example the monthly averages of tornado, wind, high wind, hail, and large hail reports for May were 7.97, 61.65, 1.55, 44.39, and 4.74 respectively, and the numbers of reports for May 28th were 29, 85, 2, 90, and 12 respectively (SPC 2013). Now, for May 28th the following calculation is made:

$$\frac{1}{5}\left(\frac{29}{7.97}+\frac{85}{61.65}+\frac{2}{1.55}+\frac{90}{44.39}+\frac{12}{4.74}\right)$$

$$=\frac{1}{5}(10.87)=2.17\geq 2.$$

Thus, May 28th is a significant severe weather day. Hence if the DSI is less than one, equal to one, or greater than one, then that day is a below average, average, or above average day for severe weather. Again however, if the DSI is greater than or equal to two then that day is considered a significant day for severe weather. This DSI threshold was chosen in a way to approximately identify each month's five most active days. Six days from May and five days from June exceed the DSI threshold. Table 1 shows the days during May and June that met this threshold and their number of reports. Note if a daily average is zero for a given month, then that entire term is set to one.

Date	Tor.	Wind	Hi. W.	Hail	Lg. H.	DSI
5/19	29	255	4	142	12	3.22
5/20	32	219	5	105	8	2.97
5/28	29	85	2	90	12	2.17
5/29	30	166	4	105	11	2.75
5/30	21	206	3	64	6	2.12
5/31	31	153	5	79	6	2.53
6/12	23	249	4	86	5	2.48
6/13	14	462	3	62	3	2.15
6/21	13	148	6	110	17	2.98
6/24	10	267	12	66	4	2.40
6/27	2	233	14	56	7	2.31

Table 1 – Number of reports and DSI values for significant severe weather days in May and June of 2013 (SPC 2013).

2.4 *CFSv2 Severe (SCP) Forecasts Chiclet Chart*

The CFSv2 Severe (SCP) Forecasts Chiclet Chart is a visual representation of the number of CFSv2 grid points across the CONUS with a daily average SCP value equal to or above one. The chart has the current day's 45-day forecast and each previous 45-day forecast back 45 days. The chart also produces a verification map for every day that the grid count is 50 or above, or the maximum SCP value is 5 or above (Carbin 2013a). These are the maps that are used to compare the CFSv2 to the SPC forecasts, and to identify forecast valid dates with run-to-run

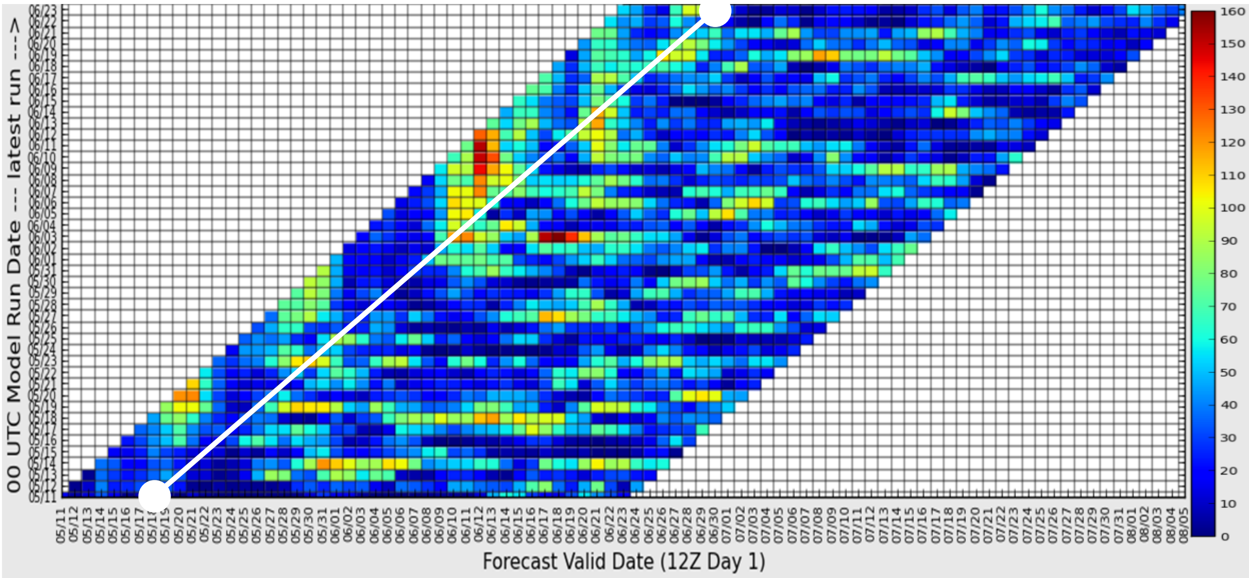

Figure 2 – Example of a CFSv2 Severe (SCP) Forecasts Chiclet Chart from June 23rd, 2013 (Carbin 2013a).

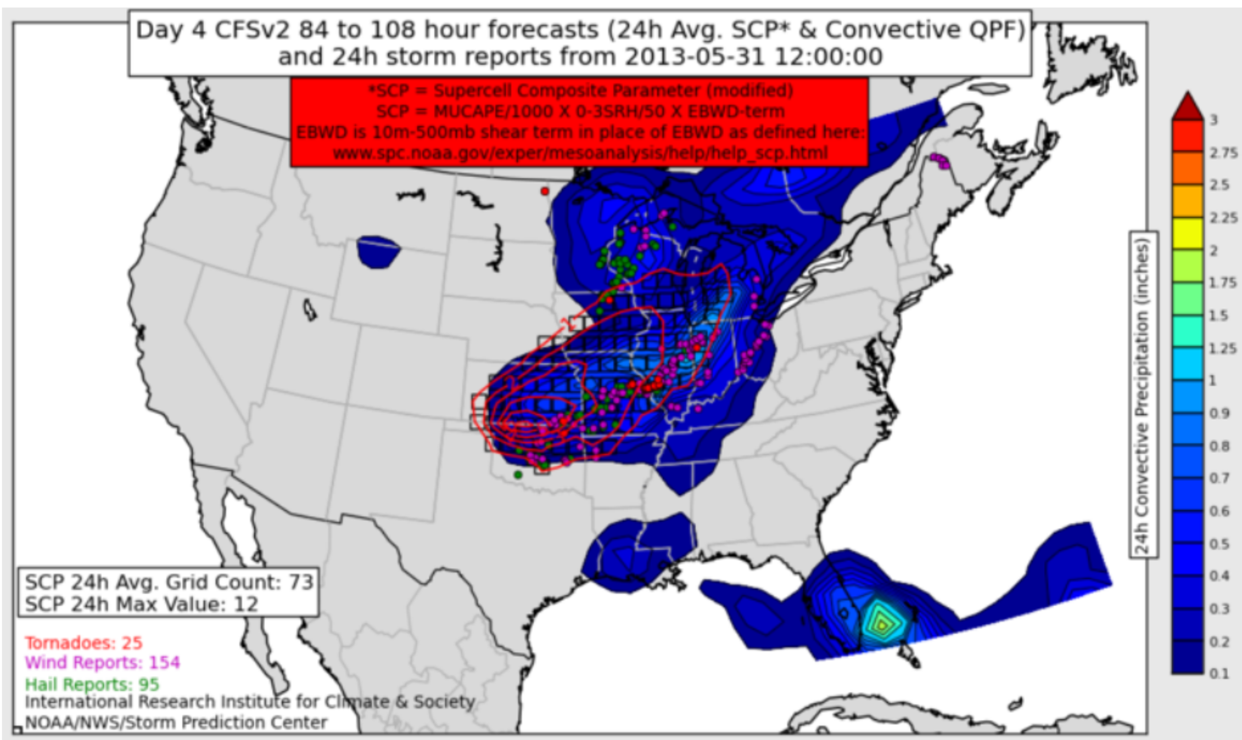

Figure 3 – Example of a CFSv2 verification map produced May 27th, 2013 (Carbin 2013b).

consistencies of high or low grid point counts with respect to the SCP threshold.

From Figure 2, which is a chiclet chart that has valid forecasts from May 11th through August 5th, 2013, vertical columns of the "chiclets" can be seen with similar colors or grid point counts. These columns represent consistent severe weather or lack of severe weather forecasts between runs. Also note in Figure 2, that beyond about eight days (the white line) the chart becomes "noisy" or inconsistent. This seems to show that the CFSv2's forecast reliability drops off considerably after eight days.

2.5 *CFSv2 Verification Maps*

A CFSv2 verification map is produced if the number of grid points with SCP ≥ 1 exceeds or is equal to 50, or the maximum SCP value at any forecast hour in the 12 UTC to 12 UTC time frame is greater than or equal to five (Carbin 2013a). The SPC day 4-8 outlook will be compared to these verification maps visually. The verification maps display the grid points with an SCP ≥ 1, with contour lines showing areas of similar SCP values, and the maps also show areas of convective precipitation. In addition, reports of severe weather are indicated by colored dots on the map, but for this study only the reports found in the SPC Filtered Storm Reports will be taken into account.

2.6 *CFSv2 Forecast Validation*

In order for a forecast from the CFSv2 to be considered valid, it must cover the majority of areas with reported severe weather and especially those areas with tornados, high winds, and large hail, with a minimal false alarm area. Furthermore, a CFSv2 forecast beyond day four is only considered valid if it and all subsequent forecasts up to and including day four are valid. For example, the day six forecast can only be considered valid if the day six, five, and four forecasts are all valid. Figure 3 is an example of a valid forecast because it covers the majority of the reported severe weather. Figure 6 is an example of a non-valid forecast.

3. RESULTS

3.1 *SPC Day 4–8 Outlooks*

For the first six months of 2013, there were only 31 days with an actual forecast in the SPC Day 4-8 Severe Weather Outlook, which is only 17%. Note some of these days do have multiple day forecasts, so there is some overlap. Over half of the outlooks are "Predictability Too Low." The other roughly 33% are "Potential Too Low." Understanding that severe weather does not occur every day in the CONUS, these numbers have room for improvement.

During the month of May, there were 10 days with an SPC forecast, which is almost double the average for the first six months of 2013. So, during May the SPC's models were consistent, and the forecasters showed more confidence in them. Because of this, the SPC predicted five of the six significant severe weather days in May.

During June however, no SPC forecasts were made, and thus no significant severe weather days were predicted.

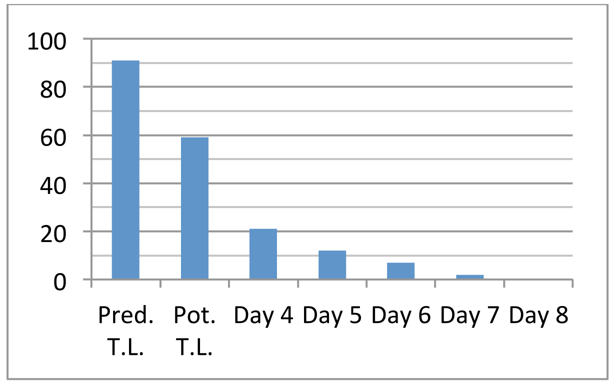

Figure 4 – Number of SPC Day 4–8 Outlooks in each category during January through June of 2013.

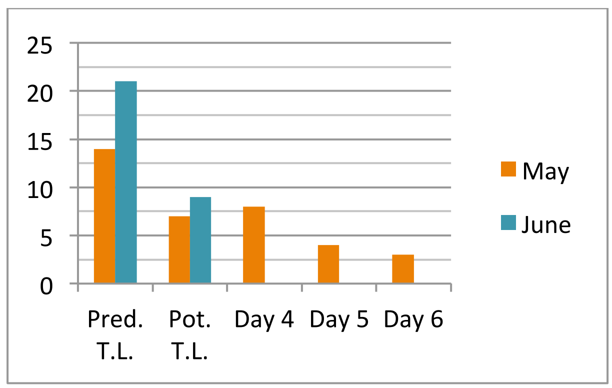

Figure 5 – Number of SPC Day4–8 Outlooks in each category during May and June of 2013. (There were no Day 7 or 8 outlooks for this period.)

During May, several SPC day 4-8 outlooks were confirmed by reports. However of the six significant severe weather days in May (based on DSI), only two were forecasted beyond four days, and one was not forecasted at all. The 19th and 20th had forecasts for days four, five, and six. The 29th, 30th, and 31st only had a day four forecast, and the 28th was not forecasted. The SPC also produced day four, five, and six forecasts valid for May 18th. This day was slightly below the DSI threshold, and the SPC forecasts covered the area of reported events well. In addition, the SPC forecasted severe weather for June 1st and 2nd, but these two days had minimal severe weather.

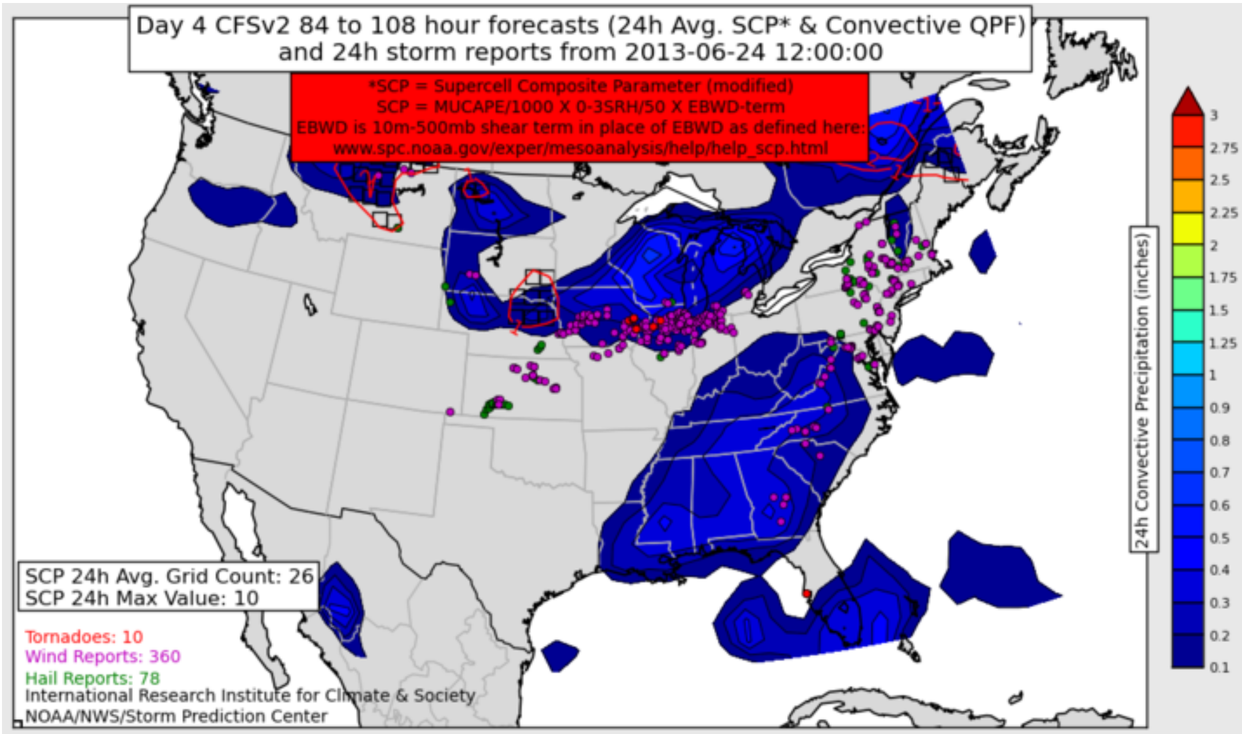

Figure 6 – Example of a non-valid forecasts from the CFSv2 produced June 21st, 2013 (Carbin 2013b).

3.2. *SPC/CFSv2 Forecast Evaluation*

Reliable forecasts from the CFSv2 decrease with lead time. For May and June of 2013, the CFSv2 had a good amount of valid day four forecasts for significant severe weather days. Whereas, it had a lower number of valid day five forecasts. Note the SPC only had only 5 day four and 2 day five forecasts for the 11 significant severe weather days during both months.

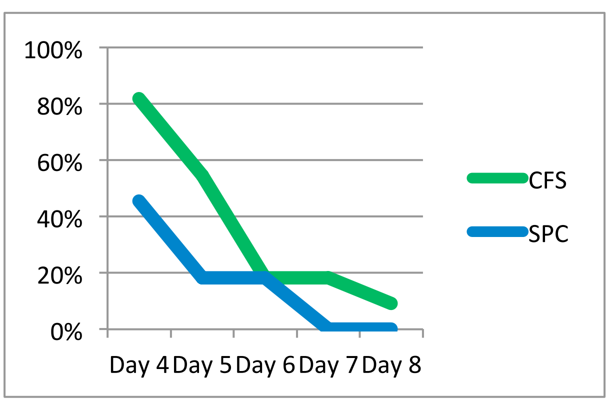

Figure 7 – Percentage of valid forecasts for significant severe weather days during May and June for the SPC and the CFS.

From Figure 7, the day four forecast success rate for the CFSv2, during days with a DSI above the stated threshold, is above 80%. The percentage of valid forecasts for day five is 55%. This shows an increase in valid day four and five forecasts versus the SPC outlooks.

Table 2 evaluates the quality of each forecast from the CFSv2 and the SPC outlooks. For the CFSv2, the table gives a value of 1 if the forecast covered the majority of the severe weather reports. Otherwise, a dash is given. If there is no forecast produced from the chiclet chart, then a value of 0 is given. For the SPC outlooks, the table gives a value of 1 for all for forecasts made and a value of 0 for "Potential Too Low." A dash is given for "Predictability Too Low."

Now, if we consider a dash to be "Predictability Too Low" for the CFSv2, and a value of 0 to be "Potential Too Low," then we can compare the day four through eight forecasts from the CFSv2 and the SPC directly. This is graphically represented in Figure 8.

	CFSv2 Forecast Quality						SPC Forecast Quality				
Date	D4	D5	D6	D7	D8		D4	D5	D6	D7	D8
5/19	1	-	-	-	1		1	1	1	-	-
5/20	1	1	-	0	-		1	1	1	-	-
5/28	-	-	1	-	0		-	-	0	0	0
5/29	1	0	1	1	-		1	-	-	0	0
5/30	1	-	-	0	1		1	-	-	-	0
5/31	1	1	-	-	-		1	-	-	-	-
6/12	1	1	-	-	-		-	-	-	-	-
6/13	1	1	-	1	0		-	-	-	-	-
6/21	1	1	1	1	1		-	-	-	-	-
6/24	-	-	-	-	-		-	-	-	-	-
6/27	1	1	1	1	-		-	-	-	-	-

Table 2 – Evaluation of day four (D4) through day eight (D8) forecasts.

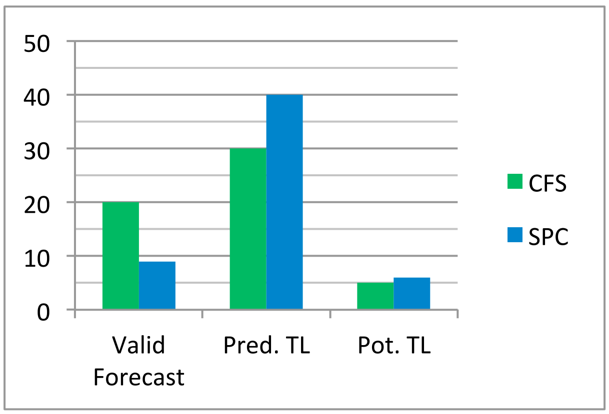

Figure 8 – Graphical representation of Table 2 (Recall definition of valid forecast for CFSv2).

3.3 *Run-to-Run Consistnecy on Non-Significant Days*

Previously the focus was on significant severe weather days as defined above, but the CFSv2 has shown the ability to consistently forecast days of severe weather that are below the DSI threshold. Looking at May 18th and June 14th, 15th, and 22nd these were days in which the average number of tornado reports was 5.4 and the average total number of reports was 159.4. During these five days the CFSv2 showed good consistency and coverage of the reported events of severe weather.

3.4 *Forecasting a Lack of Severe Weather*

As well as forecast severe weather, the CFSv2 can also forecast a lack of severe weather. For example, from June 1st through the 8th was a rather quiet phase of weather across the CONUS. This can be verified by looking at the SPC Filtered Storm Reports. The average number of severe weather reports for the first eight days of June is roughly half the average for the entire month. During that time frame, the CFSv2 was quiet as well. Examining the chiclet chart in Figure 2, the low number of grid counts that are above the SCP threshold can be seen clearly. Although the CFSv2 does produce some forecasts of severe weather during this time, the areas are small, and there are inconsistencies between runs.

4. CONCLUSION

The CFSv2 has shown applicability to the SPC Day 4–8 Severe Weather Outlooks. Although the sample size of May and June of 2013 is rather small, the day four and five CFSv2 forecasts have shown to be quite reliable with 82% and 55% success rates for significant severe weather days. It has even revealed an ability to forecast a lack of severe weather or days with few severe weather reports.

During May and June of 2013, the CFSv2 has shown a run-to-run consistency only when an event follows. Similar consecutive forecasts have reliably led to an event in the forecasted areas, but based on this study, using the CFSv2 alone to produce extended range forecasts of severe weather would not be entirely dependable due to its percentage of non-valid forecasts. Figure 8 shows that the CFSv2 is not flawless, but is an improvement upon the SPC outlooks for May and June.

The CFSv2's ability to forecast beyond day five during May and June 2013 was unsatisfactory, but its reliability at day four and five has shown that the CFSv2 can be used to increase the amount of SPC Day 4–8 Severe Weather Outlooks with actual forecasts, decrease the number of "Predictability Too Low" outlooks, and increase the time available to prepare for severe weather events.

5. ACKNOWLEDGMENTS

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