**Contrasting the performance of the High-Resolution Rapid Refresh (HRRR) model during severe weather events with fair weather days using observations from the US Climate Reference Network**

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ABSTRACT

(forthcoming)

SIGNIFICANCE STATEMENT

From < <https://www.ametsoc.org/index.cfm/ams/publications/author-information/significance-statements/>>: “Significance Statements are optional non-technically written explanations of why the research or development described in an AMS journal article is important. They should focus on why the work matters and provide additional context for why the work is relevant to science and society. They are written in such a way that educated laypersons can understand the subject without formal training in the atmospheric or related sciences. A significance statement is not a plain-language repeat of the abstract. Significance statements will be peer-reviewed and will appear after the abstract in the published paper. The statements must answer the following questions in 120 words or less, without jargon or technical wording”

1. Introduction

The High Resolution Rapid Refresh (HRRR) is a 3-km convection-allowing model that has been used to support operational weather forecasting in the US (Benjamin et al. 2016, Dowell et al. 2022, James et al. 2022). Since its inception in 2014, numerous studies have evaluated the performance of the HRRR to study its robustness and to motivate improvements to future versions of the model.

(Include some background on previous studies that have evaluated the model and what they have found; I have listed a few studies below that should be discussed, but there are certainly others out there that we will need to reference.)

Fovell, R. G., and A. Gallagher, 2020: Boundary layer and surface verification of the High-Resolution Rapid Refresh, version 3. Wea. Forecast., **35**, 2255-2278, <https://doi.org/10.1175/WAF-D-20-0101.1>.

Lee, T. R., M. Buban, D. D. Turner, T. P. Meyers, and C. B. Baker, 2019: Evaluation of the High-Resolution Rapid Refresh (HRRR) model using near-surface meteorological and flux observations from Northern Alabama. Wea. Forecast., **34**, 635-663, https://doi.org/10.1175/WAF-D-18-0184.1.

Min, L., D. R. Fitzjarrald, Y. Du, B. E. J. Rose, J. Hong, and Q. Min, 2021: Exploring sources of surface bias in HRRR using New York State Mesonet. J. Geophys. Res. Atmos., **126**, e2021JD034989, https://doi.org/10.1029/2021JD034989

Yue, H., and M. Gebremichael, 2020: Evaluation of high-resolution rapid refresh (HRRR) forecasts for extreme precipitation. Environ. Res. Commun., **2**, 065004, <https://doi.org/10.1088/2515-7620/ab9002>.

Fovell and Gallagher (2020) analyzed the HRRRv3 0000 and 1200 UTC runs to evaluate temperature and wind forecast accuracy in the planetary boundary layer (PBL). They determined that the 1200 UTC run started with a negative 2-m temperature bias before disappearing. Lee et al. (2019) used HRRRv2 to identify potential model biases with respect to near-surface flux processes. While near-surface temperature and dewpoint predictions were generally in agreement with observations, the HRRRv2 lacks the means to make surface exchange and atmospheric coupling effects accurate. Min et al. (2021) had a similar motivation but evaluated the HRRRv3 over different seasons. With respect to surface meteorology, they found a consistent warm and dry bias regardless of day or nighttime in the warm season, but no consistent bias in the cold season for the same parameters. Yue and Gebremichael (2020) used recent versions of the HRRR to analyze their performance during extreme precipitation events. They found the 1-hr lead time to be less accurate on average, with the additional lead times not varying much in accuracy with respect to each other.

However, no known studies have evaluated HRRR’s performance under contrasting meteorological conditions. Knowledge of the HRRR’s performance under e.g. synoptically quiescent fair weather days versus synoptically-disturbed days is essential to motivate improvements to the model’s replacement, i.e. the Rapid Refresh Forecast System (RRFS), which will replace the HRRR in 2024 (Dowell et al. 2022). Observations from the US Climate Reference Network (USCRN) are well-suited to achieve this goal. To this end, we used observations from the USCRN to evaluate the performance of the latest version of the HRRR (i.e., HRRR version 4).

2. Datasets

a. USCRN

The purpose of the USCRN is to study long-term trends in climate over the continental US using high-quality near- and sub-surface meteorological observations. At each USCRN station, temperature, humidity, precipitation, and wind speed are sampled 1.5 m above ground level (AGL), in addition to surface temperature and incoming shortwave radiation. The network has been fully operational over the continental US since 2008. The addition of soil moisture and temperature measurements across the network was completed in 2011. Soil moisture and temperature are sampled at depths of 5, 10, 20, 50, and 100 cm. We refer the reader to e.g. Bell et al. (2013), Diamond et al. (2013), and Lee et al. (2023) for more details about the USCRN and instruments used.

Figure 1: Map showing the stations used in your analyses.

b. HRRR

Details about the HRRR configuration and parameterizations used therein have been discussed extensively in previous studies (e.g., Benjamin et al. 2016, Dowell et al. 2022, Lee et al. 2023) and are briefly summarized here.

(I will provide some more discussion here.)

3. Methods

a. Identification of PERiLS cases

We used observations from the USCRN to evaluate the performance of the HRRR during the Propagation, Evolution, and Rotation in Linear Storms (PERiLS) field campaign. PERiLS is an ongoing field study in the Southeast US that builds upon previous studies in the region, i.e. the Verification of the Origins of Rotation in Tornadoes Experiment-Southeast (VORTEX-SE), that have focused on understanding the physical processes that are most important to severe weather genesis and tornadogenesis in this region of the US (e.g., Lee et al. 2019a,b, Wagner et al. 2019). During the spring 2022 PERiLS campaign, there were four intensive observation periods (IOPs).

(More details here about the different IOPs.)

Table 1: Dates, duration, and any other pertinent information about the spring 2022 PERiLS IOPs.

|  |  |  |  |
| --- | --- | --- | --- |
| **Observational Period** | **Start Date and Time (UTC)** | **End Date and Time (UTC)** | **Duration** |
| **IOP 1** | 22 March 2022 1200 UTC | 23 March 2022 0400 UTC |  |
| **IOP 2** | 30 March 2022 1200 UTC | 31 March 2022 0400 UTC |  |
| **IOP 3** | 05 April 2022 0600 UTC | 05 April 2022 2100 UTC |  |
| **IOP 4** | 13 April 2022 1200 UTC | 13 April 2022 2300 UTC |  |

b. Identification of fair weather days

We identified fair weather days at the USCRN stations of interest between 1 January 2022 and 30 April 2022 using observations of incoming shortwave radiation from the USCRN stations to compute a clearness index, . As noted in e.g. Lee et al. (2023), the represents the ratio of the total incoming shortwave radiation measured at a site and summed for a given day to the total theoretical maximum amount of incoming solar radiation that could be received on that day at that particular location. The theoretical maximum amount of incoming solar radiation is calculated using the algorithm described by Whiteman and Allwine (1986).

4. Results

This section will discuss the HRRR performance with respect to different forecast periods (01-, 03-,06-, 12-, and 18-hr) relative to surrounding stations during an event passage within each IOP. Stations are detailed in Table TBD.

1. HRRR performance during PERiLS IOPs

We will need to think about how best to present your results in this section. For each IOP and for each variable for say, the 01-hour forecast, maybe show a plot of the model – observation at each station and then overlay the mean difference across all stations for that IOP. We will also want to discuss (but maybe not show) the HRRR performance for the other forecast periods (03-, 06-, 12-, and 18- hour forecasts). A table of the MBE and RMSEs will probably be sufficient here, but we will need to see what the results look like first.

IOP 1:

Air Temperature:

The HRRR 1-hr lead time did not have a significant air temperature bias as the MBE for majority of these stations remain within a -2 ℃ and +2 ℃ difference (slide 41). These stations are in the most agreement in the 8 hours after the event passage relative to each station between +4 hr. and +12 hr. Generally, as lead time increases, the HRRR forecast accuracy decreases for all stations (slide 45).

Cumulative Precipitation:

The range of MBE differences were generally large for all forecast hours, with differences ranging between +20 mm to -60 mm for the 1-hr lead time, with Newton, MS, Gainesville, AL, and Selma, AL being outliers (slide 80). These differences are most notable during the early hours relative to the event passage, between -12 hr. and -4 hr. A similar trend to the 1-hr HRRR output is present for later lead times, however these trends are amplified as forecast hour increases. The range of differences increases to +30 mm and -60 mm at 18-hr (slide 84).

Surface Temperature:

Similar to air temperature, MBE increases as a function of forecast hour, however, the increase is not as significant as ???. For the 1-hr forecast hour, surface temperature differences ranged between -5 ℃ and +5 ℃ (slide 121). By the 18-hr lead time, this range has only increase by +1 ℃ or -1℃. The large spike in the USCRN data at +6 hr. for Selma, AL is invalid data that can be disregarded.

Incoming Radiation:

MBE for both 1-hr and 18-hr lead times was significant with the average difference between HRRR and USCRN being roughly 400 across all stations (slide 162 and 166). The notable outlier at 18-hr was Selma, AL and there were no outliers at the 1-hr forecast hour.

Soil Temperature:

Soil temperature follows a similar trend to air temperature where HRRR forecast accuracy decreases as lead time increases (slide 204). The differences shift from positive values in the early hours (-12 hr. to -4 hr.) to negative values later on in the observational period (-3 hr. to 12 hr.). This is prevalent for both the 1-hr and 18-hr lead times.

Soil Moisture:

MBE for soil moisture was not significant across all stations for all lead times (slide 245 and 249). The average range of differences was between -0.3 and +0.2 .

b. HRRR performance on fair weather days

Once you have completed analyses of the PERiLS IOPs, we can determine the HRRR’s biases for the same stations you identified but for clear, fair weather days (e.g. days with ).

5. Discussion

Here we will want to discuss the salient differences that we find between the performance of the HRRR during the PERiLS IOPs versus fair weather days and place these differences in context to what previous researchers have reported.

6. Summary and conclusions

In the present study, we used surface observations from the US Climate Reference Network to evaluate the performance of the HRRR model under two contrasting meteorological regimes in spring 2022. We found …

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Data Availability Statement.

The USCRN datasets used in this study are available from <https://www.ncei.noaa.gov/access/crn/qcdatasets.html>, and the HRRR forecasts can be accessed through the Amazon Web Services HRRR archive at <https://registry.opendata.aws/noaa-hrrr-pds/>.

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