Initial Verification of a Probabilistic Gridded Model for Forecasting of Lightning Strokes over Alaska using Independent Data from 2022

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RMRS/CSU, Fort Collins CO
July, 2023

Introduction

The Rocky Mountain Center for Fire-Weather Intelligence (RMC) developed a statistical logistic model predicting the probability of cloud-to-ground lightning strokes over Alaska that is driven by weather forecast fields from the NCEI Global Forecast System (GFS) updated twice per day. The derivation of the model equations utilized 2 databases: (*a*) the North America Regional Reanalysis (NARR) providing 3-D meteorological fields of 3-hour temporal resolution; and (*b*) the Alaska Lightning Detection Network (ALDN) owned and maintained by the Alaska Fire Service (AFS) providing geo-referenced, lightning stroke data. The training data sets covered the period from 2012 through 2021.

We built weather and lighting climatologies beginning in 2012, because during the summer of that year, ALDN switched from using VISALA's *Impact* sensors (detecting lighting flashes) to *Time-Of-Arrival* (TOA) sensors (recording lightning strokes). Comparison studies conducted by AFS indicated that the new TOA ALDN reports 2.25 times the lightning recorded by the older VISALA sensors. About 60% of that increase can be attributed to a difference in reporting strokes vs. flashes with the remaining 40% increase resulting from improved detection efficiency, expanded spatial sensor coverage and a longer detection range.

Since the TOA sensors will continue to be used in the future, we decided not to utilize lightning-flash data collected by VISALA *Impact* sensors prior to 2012. The methods used to create the necessary climatologies from raw data and perform statistical analysis were similar to those employed in the development of probabilistic equations for predicting lightning flashes over ConUS described in a 2019 RMC Report. Each month of the active fire season (spanning the period from May through September) was represented by an average diurnal cycle of 3-hour resolution containing 8 temporal bins. Logistic probability equations were derived for *each* temporal bin of *every* fire-season month. This yielded 5 x 8 = 40 total predictive equations for Alaska.

This document presents initial quantitative verification of the AK lightning-stroke probability model using *independent* lightning strike data from June, July and August of 2022.

Statistical Measures of Model Performance

Two primary statistical metrics were employed: (*a*) Reliability Diagram (RD) comparing model-forecast probabilities to observed relative frequencies of lighting strokes over Alaska; and (*b*) Receiver Operating Characteristic (ROC) curves quantifying the relationship between *False Positive Rates* (on the X axis) and *True Positive Rates* (on the Y axis) at different classification thresholds. A key feature of ROC is the Area Under the Curve (AUC), which provides an aggregate measure of performance across all possible classification thresholds. The closer the AUC is to 1.0, the more accurate the spatial forecast of the model. RDs and ROC curves were calculated for model predictions driven by observed weather fields from NARR, GFS re-analyses, and 3- hourly weather parameters forecast by GFS.

As a qualitative assessment, we generated forecast maps of modeled probabilities of lightning-strikes overlaid with the observed number of lighting strokes in each 20-km grid cell. Such maps were produced for all 3-hour time periods of June, July and August 2022. In addition, for the most prominent lightning events during the summer of 2022, we produced maps of maximum 24-h lightning-forecast probabilities overlaid with the observed number of lightning strokes over the same time period.

Results

Figure 1 depicts an average Reliability Diagram for all 3-hour periods during the May – August fire season of 2022. Predicted (modeled) probabilities of 1 or more lightning strikes are calculated from observed weather fields provided by NARR. If lighting forecasts were perfect, then the red curve would exactly overlap the diagonal black line. The closer the red curve is to the black line, the better the model's ability to predict the chance of lightning strikes over the Alaskan domain. The portion of the red curve above the central black line indicates probabilities that are *underpredicted* by the model. Alternatively, the model *overpredicts* probabilities when the red curve is below the black line. The small bar-chart insert in the lower right corner of RD shows the spatial distribution of lightning frequencies. Note that only a very small portion of the Alaskan territory experiences lightning-stroke probabilities greater than 0.3 (30%).

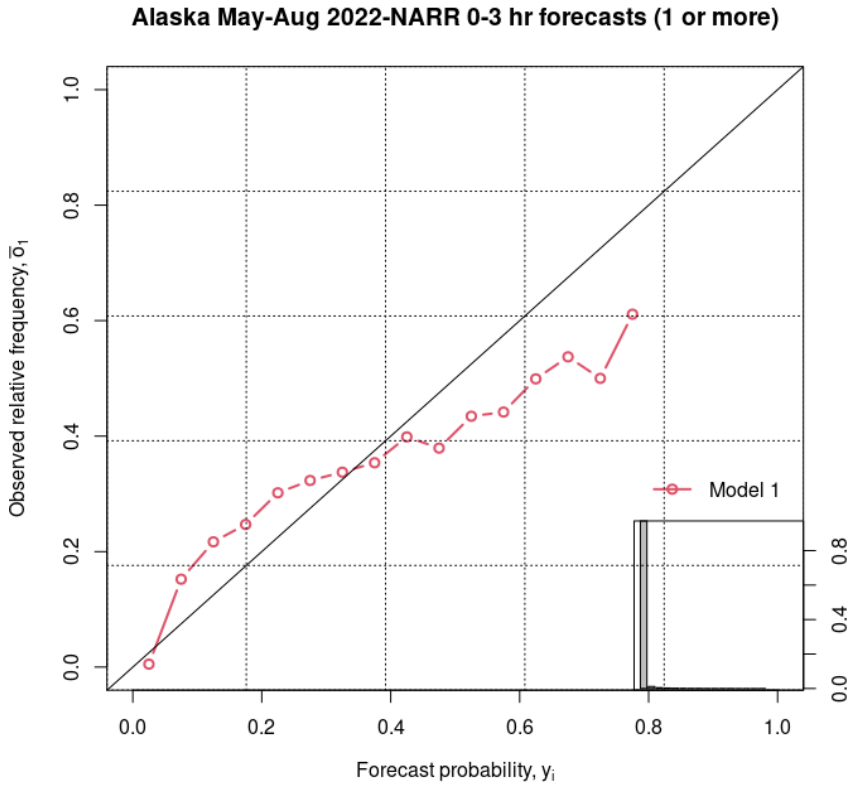

Figure 1. Reliability Diagram of modeled probabilities of 1 or more lightning strokes over AK for all 3-hour periods from May 01 through Aug 31, 2022. The lightning model was driven by NARR weather fields.

Figure 2 compares average model Reliability Diagrams based on weather data from NARR (to left) and GFS initializations (to the right) for the period June – August, 2022. Figure 3 displays Reliability Diagrams and ROC curves of modeled lighting strikes over AK driven by GFS forecast fields for all 3-h periods of June – July, 2022. The ROC AUC shows high values (> 0.92) up to forecast hour 75, i.e. for the first 3.12 days of the forecast.

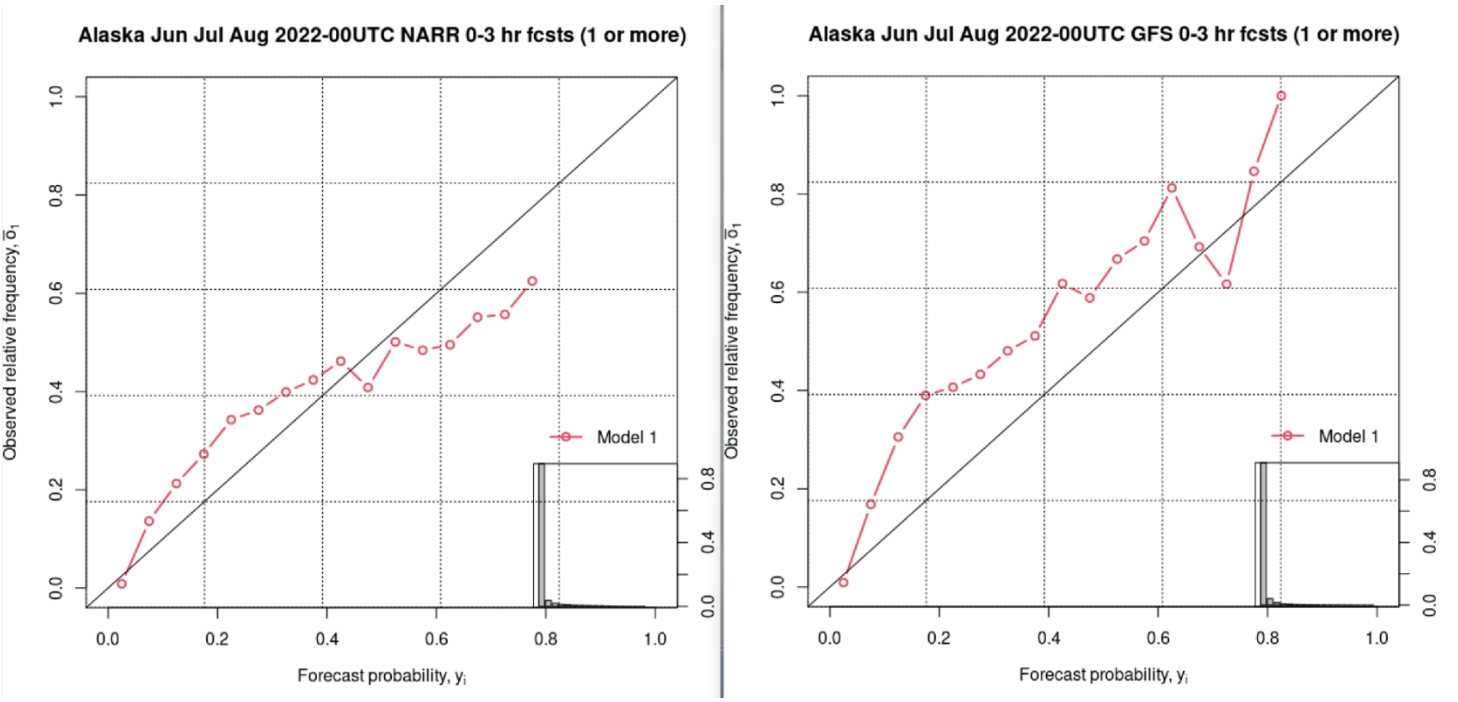

Figure 2. Reliability Diagram of modeled probabilities of 1 or more lightning strikes over AK for all 3-hour periods between June 01 and Aug 31, 2022. *Left panel*: model driven by NARR data (ROC AUC = 0.9398); *Right panel*: model driven by 0-3 h GFS initialization fields (ROC AUC = 0.9444).

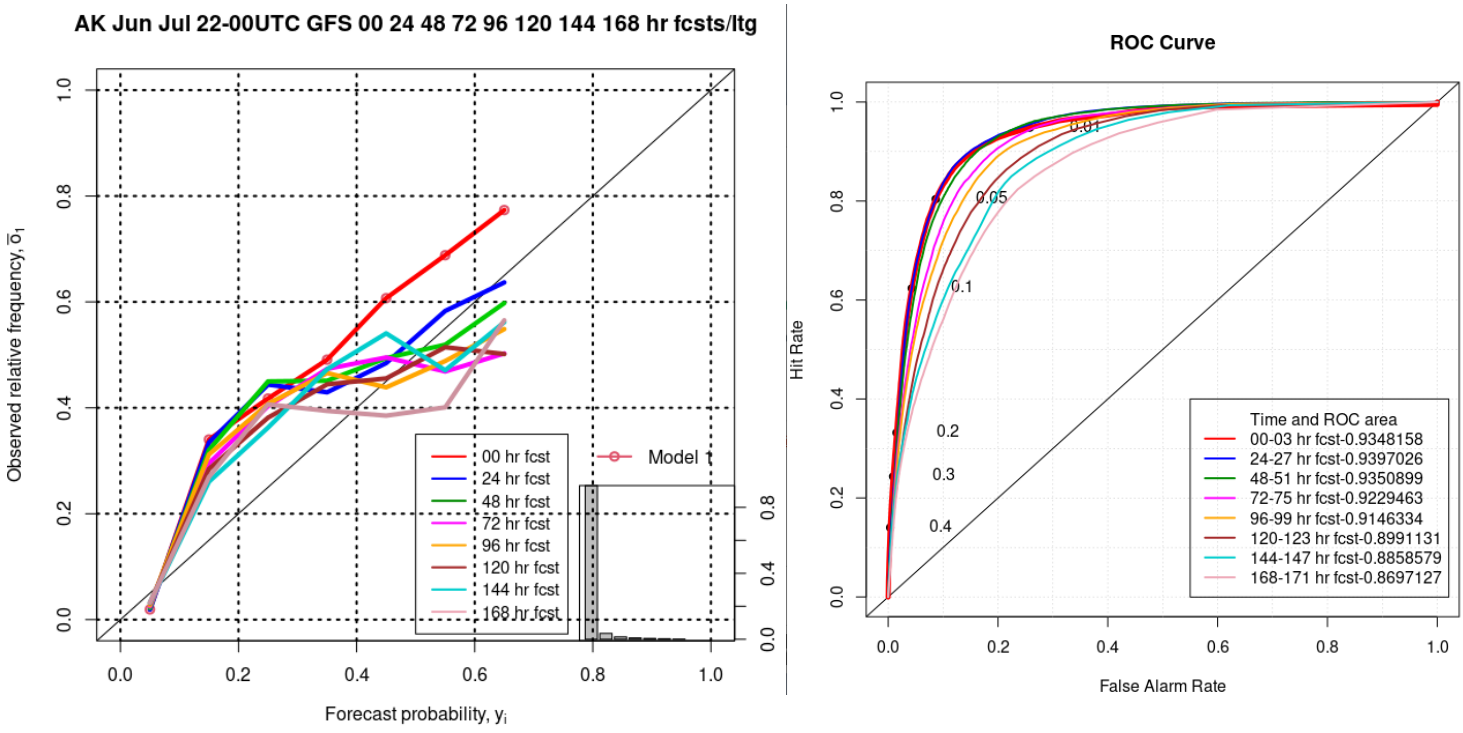

Figure 3. Reliability Diagrams (*left panel*) and ROC curves (*right panel*) of modeled probabilities of 1 or more lightning strikes over AK for all 3-hour periods between June 01 and July 31, 2022 based on forecast weather fields provided by GFS.

Figures 4 through 9 show the first-day maximum probability forecasts for 1 or more lighting strikes over Alaska overlaid with observed lightning strokes during the same 24-h period for major storms that occurred during the summer of 2022.

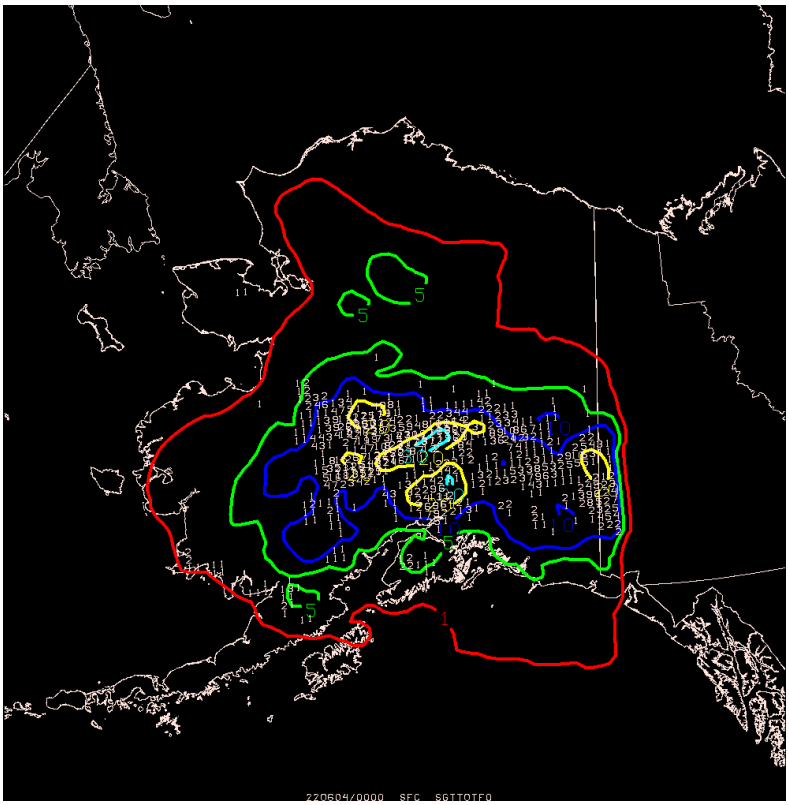

Figure 4. June 4, 2022: lightning observations (number of strikes per grid cell in white) overlaid on the first 24-hour maximum probability forecast displayed as color contours of strike probabilities: 1% (red); 5% (green); 10% (blue); 20% (yellow); 30% (cyan).

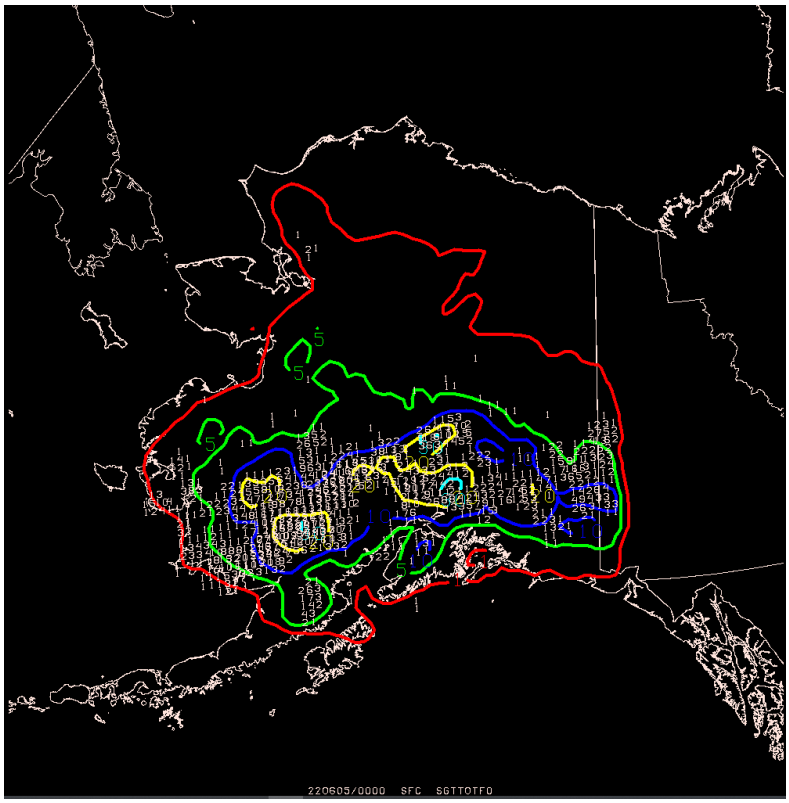

Figure 5. June 5, 2022: lightning observations overlaid on the first 24-hour maximum probability forecast.

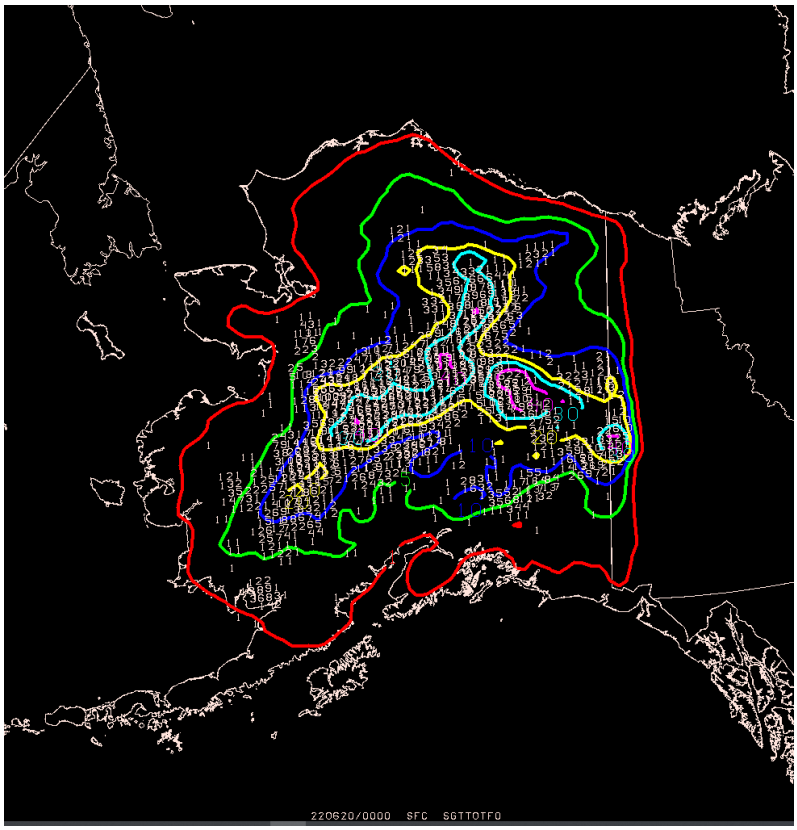

Figure 6. June 20, 2022: lightning observations overlaid on the first 24-hour maximum probability forecast.

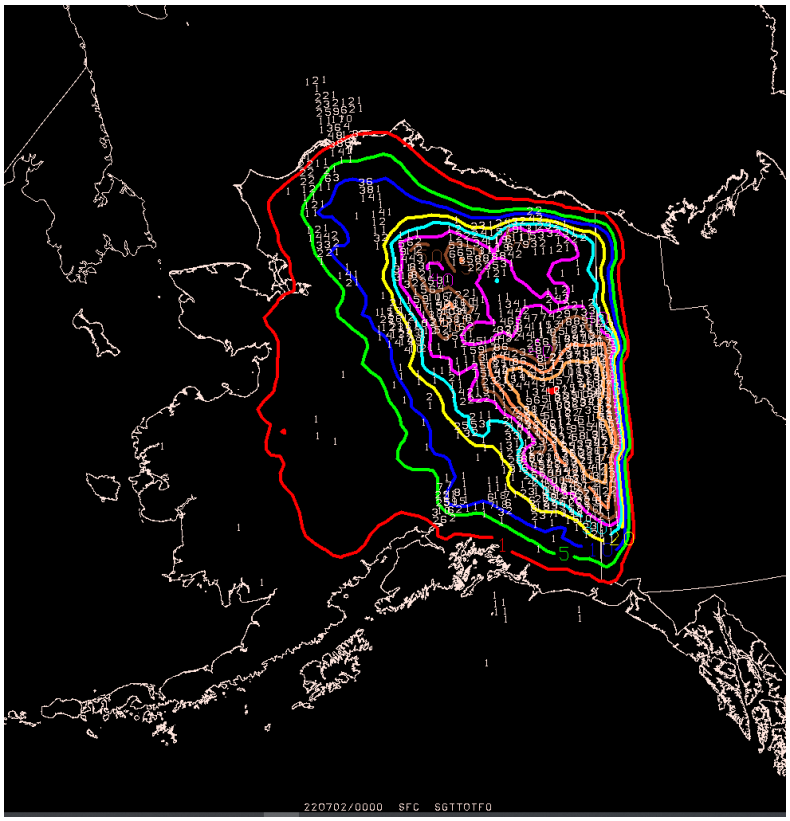

Figure 7. July 02, 2022: lightning observations overlaid on the first 24-hour maximum probability forecast.

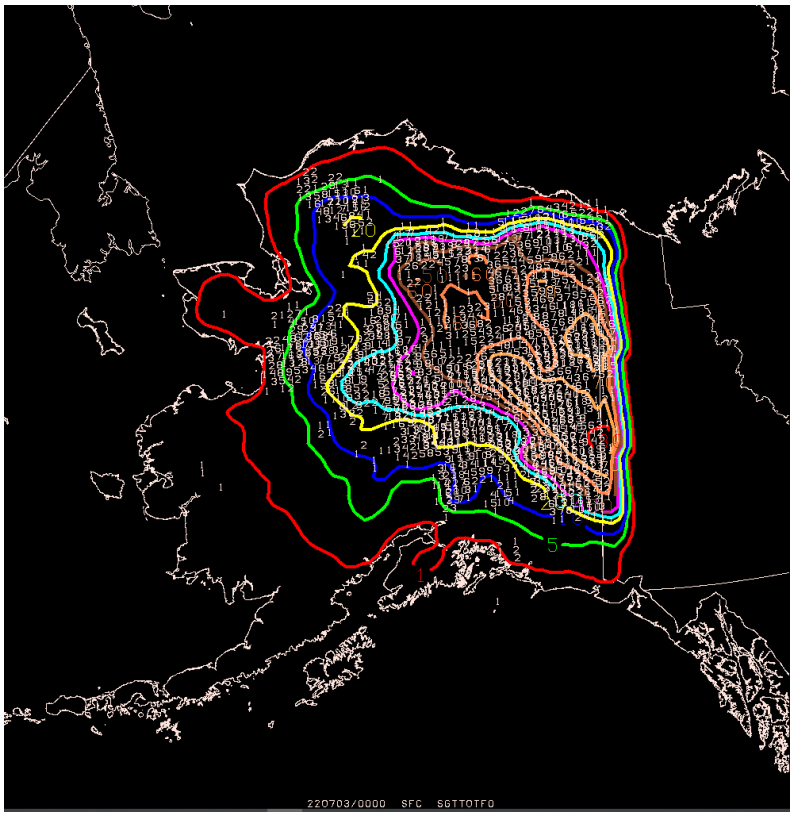

Figure 8. July 03, 2022: lightning observations overlaid on the first 24-hour maximum probability forecast.

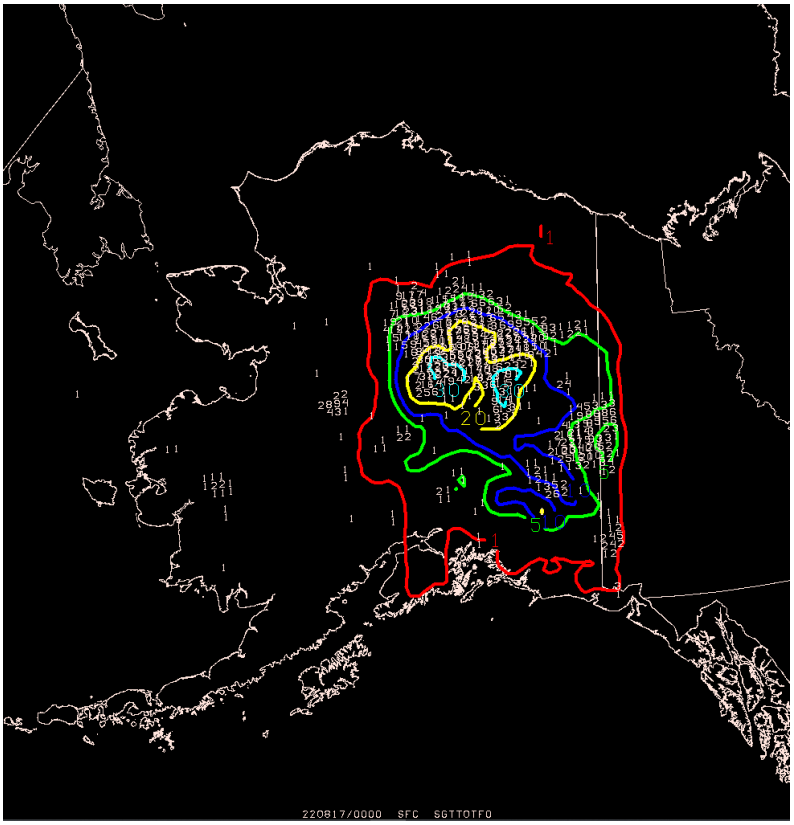

Figure 9. August 17, 2022: lightning observations overlaid on the first 24-hour maximum probability forecast.

Map loops of individual 3-h lightning-probability forecasts driven by NARR data overlaid with observed 3-hour lightning strikes for the period May 01 - Aug. 31, 2022 are available at this URL:

https://fireweather.cira.colostate.edu/forecast/narr_looper.php

The results from this initial statistical comparison between modeled probabilities of 1 or more lightning strikes and independently observed lighting strokes suggests that the new model has a significant skill in forecasting the spatial distribution and chance of occurrence of lighting phenomena over Alaska especially when the driving weather fields are close to reality. Hence, this lighting prediction model is suitable for inclusion as a component into a wildfire-ignition forecast model for Alaska currently under development at RMC.