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Using Short-Term Forecasts of Total Lightning to Improve Numerical Weather Forecasts

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1. Introduction

The fatality rate due to cloud-to-ground (CG) lightning is the third highest among weather-related causes in the U.S. annually. A new dynamic approach to forecasting CG and IC lightning rates runs operationally (see www.lighting-forecast.com). Although, Weather It is, LTD uses high resolution RAP data to initialize their WRF forecasts, experiments were conducted to see if assimilating lightning at the start of forecasts could lead to further improvement in lightning forecasts in subsequent forecast periods. The forecasts presented assimilate lightning from the EarthNetworks total lightning network using an approach developed by Fierro et al. (2012).

2. Dynamic Lightning Method

The dynamic lightning forecast method is based on the production rate of potential electrical energy within convective and stratiform clouds. A lighting event occurs each time the electrical energy exceeds a threshold and it is then accumulated for each model time step. Dissipation of electrical charge due to turbulence and changes due to horizontal transport are also considered. For further details on the dynamic lightning prediction method, see Yair et al. (2010) and Lynn et al. (2012).

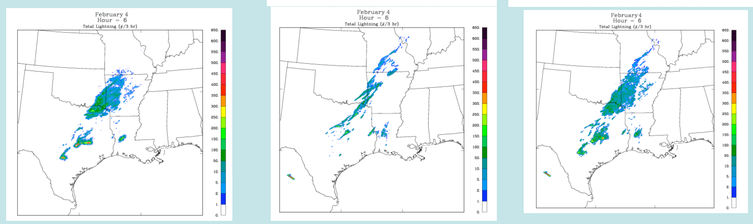
The assimilation of lightning into forecast models has been shown to improve the initial positioning and short-term development of convection (and distribution of radar echoes). Here, we assimilate lighting during a three hour period, and then evaluate forecasts in subsequent three-hour periods, up to 12 and (even) 15 hours out.

3. *February 4th, 2012* (Wintertime Storm)

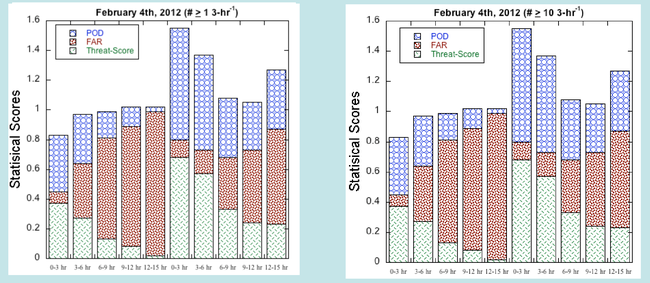
Obs. Total Lightning

Forecast Total Lightning No Assimilation

Forecast Total Lightning With Assimilation



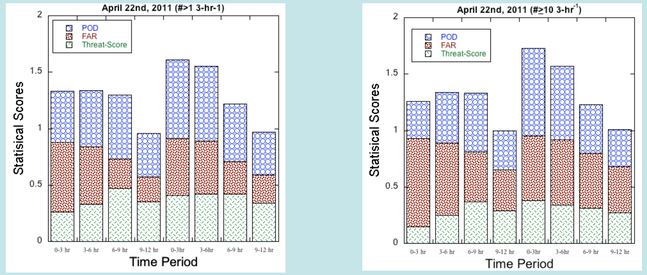
An example of the effect of assimilating lightning in a RAP-WRF weather forecast on forecast total lightning during the first 3 hour period of assimilation. The map on the left shows the observed lightning, the map in the middle shows the forecast without lightning assimilation, and the map on the right shows the forecast with assimilation.



Statistical Validation of lightning forecast threshold values during three hourly periods. The graphs show the Probability of Detection (POD), False Alarm Ratio (FAR), and Threat Score for forecasts without (left side of each graph) and with lightning assimilation (right side of each graph). The assimilation of lightning data improves the forecast quite dramatically.

4. April 22nd, 2011 (St. Louis Aiport Tornado Event)

Statistical Validation of lightning forecast threshold values during three hourly periods. The graphs show the Probability of Detection (POD), False Alarm Ratio (FAR), and Threat Score. The first three hours, during the period of data assimilation, stimulated small convective cells in their correct location (not shown). The convective storms associated with the tornadoes occurred during the second three hour period. The positive impact of the data assimlation "wore" off in the subsequent time periods.



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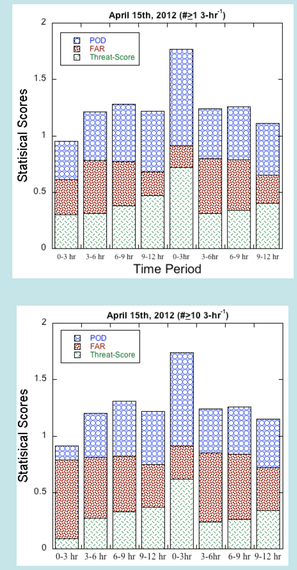
References

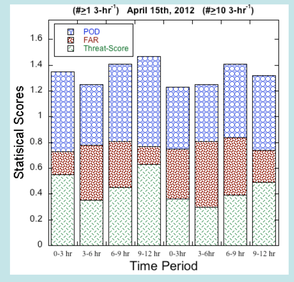
Lynn, B, Yair Y., Price C., Kelman, G., and Clark, A., 2012: Predicting Cloud-to-Ground and Intracloud Lightning in Weather Forecast Models. Wea. Forecasting, in Press.

Yair, Y., Lynn, B., Price, C., Kotroni, V., Lagouvardos, K., Morin, E., Mugnai, A., and Llasat, M. C., 2010: Predicting lightning density in Mediterranean storms based on the WRF model dynamic and microphysical fields. J. Geophys. Res.

Fierro, Alexandre O., Edward R. Mansell, Conrad L. Ziegler, Donald R. MacGorman, 2012: Application of a Lightning Data Assimilation Technique in the WRF-ARW Model at Cloud-Resolving Scales for the Tornado Outbreak of 24 May 2011. Mon. Wea. Rev., 140, 2609–2627.

5. April 15th, 2012 (Squall-Line)





Statistical scores for different lightning thresholds. Top figure: ≥1 lighting event without (left) and with (right) lightning assimilation. Middle figure: ≥10 lighting events without (left) and with (right) lightning assimilation. Bottom Figure left: ≥1 lighting event, right: ≥10 lighting events with assimilation, but with a different microphysical scheme that more realistically develops convection and simulates thermodynamic feedbacks after the initial three hour assimilation period.