Eastern Region Technical Attachment
No. 2006-01
July 2006

USING A MESOSCALE MODEL TO IDENTIFY CONVECTIVE INITIATION IN AN AIR ROUTE TRAFFIC CONTROL CENTER/CENTER WEATHER SERVICE UNIT (ARTCC/CWSU) ENVIRONMENT

Warren R. Snyder
NOAA/NWS Weather Forecast Office
Albany, New York

Mark R. McKinley
NOAA/NWS Center Weather Service Unit
Oberlin, Ohio

Allison R. Vegh
Department of Earth and Atmospheric Sciences
University at Brockport State University of New York
Brockport, New York

Abstract

Thunderstorms account for 24% of weather-related air traffic delays by significantly diminishing the National Airspace System's (NAS) capacity to route aircraft. The NAS is managed at Air Route Traffic Control Centers (ARTCC) by Federal Aviation Administration (FAA) personnel, who receive their weather forecasts and data from co-located Center Weather Service Units (CWSU), operated by the National Weather Service. This study provided real-time mesoscale model output from the Work Station Eta (WSEta) to one of these CWSUs located at Oberlin, Ohio. The model data was assessed to determine whether thunderstorm/convective initiation was forecastable from model fields. In addition anecdotal evidence was sought to determine the data's usefulness to the CWSU forecasters. This study, using a 29 case dataset from August 2004 to June 2005 over the Oberlin CWSU area of responsibility, identified three WSEta meteorological parameters that were credible predictors of thunderstorm initiation: hourly convective precipitation, 700 hPa omega, and 250 hPa divergence.

1. Introduction.

In the United States, 76% of air traffic delays involve weather (Cobb 2005). The leading contributor is thunderstorms and related phenomena 24% of the time, followed closely by low ceilings (17%), and visibilities and winds, each 14% of the time. Each airport has a maximum acceptance rate, which is the number of aircraft that can land per hour. The acceptance rate is set based on the airports construction, facilities, location, surrounding terrain, and other engineering factors under ideal weather conditions. Usually light winds, clear skies, and no obstructions to visibility or no ongoing construction projects are conditions when an airport can operate at its maximum acceptance rate. Once weather conditions (winds, ceilings, visibility) fall below established criteria, the acceptance rate of a specific airport is reduced, hence fewer aircraft per hour can land. This reduction is accomplished by one of two mechanisms available to the National Airspace System (NAS), the Ground Stop Program (GSP), and the Ground Delay Program (GDP).

The GSP prohibits flights destined to the affected airport by holding them at their departure point for the duration of the Ground Stop. It is implemented for events that are expected to keep conditions well below criteria for an extended amount of time. Snowstorms, high wind conditions, low ceilings, and widespread convective outbreaks are typical causes of GSPs. The GSP is also implemented when a rapid decrease in the number of aircraft destined for a particular airport is needed to bring the actual acceptance rate down to a much lower mandatory reduced acceptance rate.

The GDP reduces the number of aircraft entering the system destined for a particular airport by assigning the aircraft a controlled departure time, prior to which they can not take off. This reduces the numbers of aircraft arriving at the affected airport to a number in line with the reduced acceptance rate. Radiation fog, isolated convective cells, ceilings and visibility in specific ranges, airport snow removal operations, and transient meteorological phenomena are typical causes of GDPs.

Both of these approaches, while strongly emphasizing safety, are still very costly to the industry and disruptive to passengers. GSPs and GDPs, if not implemented in a timely fashion, incur costs to the aircraft operators. These costs range from a few thousand dollars for a small propeller driven aircraft, to in excess of $100,000 for a jumbo jet.

The project had two focuses. This paper focuses on comparing WSEta (Rozumalski 2000) model forecast parameters that might identify convective initiation to lightning data and other data sources indicative of thunderstorm occurrence. Convective initiation is the time and place of the initial convection, during a convective event.

The second focus placed the WSEta model data in the hands of CWSU forecasters in real time, to incorporate this information into the forecast process in their preparation of Meteorological Impact Statements (MIS) and Center Weather Advisories (CWA), or briefings to Air Route Traffic Control Center (ARTCC) staff. They continue to have the data available to them as of this writing. The results from this part were only anecdotal in terms how the CWSU forecasters used the data, and their opinions of the data.

The main objective of this project was to assess the WSEta's ability to forecast convective initiation. Six WSEta model output parameters were selected for study based on ease of use, availability and operational experience. These parameters were: 850 hPa theta-e ridge axis, hourly convective precipitation, 700 hPa Omega, 850 hPa jet axis, 250 hPa divergence and boundary layer (BL) convergence. These were compared to various indicators of thunderstorm occurrence. This study evaluated the hypothesis that if a mesoscale model could produce a better forecast of location and time of convective initiation, the impact of Ground Stops and Ground Delays could be mitigated by using that forecast to better anticipate the triggering events of GSP or GDPs. With this knowledge, re-routings prior to the aircraft being airborne and other air traffic management tools could be implemented less disruptively.

2. Methodology

The WSEta was chosen as the mesoscale model, due to its ready availability in the National Weather Service Forecast environment, its ease of configuration, and national support. Beginning in July 2004, Weather Forecast Office (WFO) Albany, NY, began running the WSEta for the Oberlin CWSU area of responsibility (Fig. 1).

Fig 1. Oberlin ARTCC (CWSU) area of responsibility. (Image courtesy of ARTCC Oberlin, Ohio, webpage)

This area is the second most heavily traveled airspace in North America (FAA Administrator's Fact Book, 2006). WSEta forecasts were prepared for 24 hours, at hourly intervals. The WSEta was run twice per day at 0600 UTC and 1800 UTC. This provided a current forecast to CWSU meteorologists at the beginning of the workday, in the late afternoon, and for use in the overnight briefing. The data was made available to the CWSU via a special web page on the Collaborative Science Technology and Applied Research (CSTAR) website at WFO Albany. Full WSEta model datasets were archived for future study. In the spring of 2005, a Linux based computer with GEMPAK Analysis and Rendering Program (GARP) (Cowie 1997) software for the display of the full model set of data was provided to CWSU Oberlin. During the late spring and summer of 2005 archived WSEta model output for six parameters were compared with a variety of observational data to ascertain the performance of the model in forecasting convective initiation. Convective initiation is the time and place of the initial convection, during a convective event.

Thunderstorm occurrence and event selection were determined from the following: CWSU log sheets, CWAs, MISs, the Forecast Systems Laboratory (FSL) Real Time Verification System (RTVS) website data, http://www-ad.fsl.noaa.gov/fvb/rtvs/index.html and the Collaborative Convective Forecast Product (CCFP) verification, http://aviationweather.gov/products/ccfp/. Twenty nine events from 4 August 2004 through 9 June 2005 over the Oberlin, Ohio airspace were identified for this study. The following WSEta fields for each hour were compared to the data from the convective events: 850 hPa theta-e ridge axis, hourly convective precipitation, 700 hPa Omega, 850 hPa jet axis, 250 hPa divergence and boundary layer (BL) convergence.

The WSEta performance in determining convective initiation was assessed using a three-level classification system: good, acceptable, or poor defined in Table 1. Data were examined for each forecast hour separately, and segregated based on whether a small (less than 25%), medium (25% to 75%) or large (greater than 75%) percentage of a CCFP verification overlapped the area of the model forecast convection. For each data field on each event the full data set is shown (Table 2).

Potential issues in using the CCFP Verification, the CWA, and the MIS for thunderstorm determination are they are derived using 1-hour aggregates of lightning activity form the National Lighting Detection Network (NLDN; NLDN 2005) data. This was problematic when determining the exact time a thunderstorm either entered or formed over the study airspace, because data was only available on the hour. This was not a problem when the convection was associated with synoptic features such as fronts or boundaries, or for storms that persisted over an hour. It may have missed events where convection formed and dissipated between hourly charts. Hence, the model may have actually performed better.

3. Results

Refining a convective initiation forecast to a general geographical region on the order of 6000 sq km, or an hour or two of the event would result in less disruption to the NAS. This could be achieved with planned re-routings. It would also produce considerable fuel savings every day there are thunderstorms, not to mention many other applications the model could address including wind forecasts.

The performance of each WSEta's forecast parameter was ranked using the combined percentage of cases where the parameter performed acceptable and good (Table 3). They were ranked as follows: 700 hPa Omega 93%, Convective Precipitation 83%, 250 hPa Divergence 69%, Boundary Level Convergence 62%, the 850hPa theta-e ridge 49%, and the 850hPa jet axis 31%. The two best performing WSEta fields were 700 hPa upward omega and hourly convective precipitation, with 93% and 86% rating model performance as good or acceptable respectively.

When thunderstorms occur, a lifting mechanism, upward vertical motion, and moisture need to be present. Hence, upward directed 700 hPa omega, 250 hPa divergence, and convective precipitation are inferred to be more highly correlated with the occurrence of thunderstorms, and would be better indicators of convective initiation. The 850 hPa theta-e and jet axis, and boundary layer convergence had a lesser correlation with convective initiation. However this was probably due to their not being one of the basic requirements for thunderstorm formation. These parameters were more often indicative of an environment that will allow thunderstorms to become more severe. The various stratifications often resulted in small sample sizes. The relative performance of the sub groups of model forecast parameters was not substantially different from the overall performance of each parameter, so only the total dataset is presented here.

Overall, the two best model fields (700 hPa omega and hourly convective precipitation), did an acceptable job based on this limited dataset and methodology. These fields would be useful in improving a CWSU's ability to forecast convective initiation within one to two hours. Further study is planned with summer 2005 data using these WSEta fields and more exact individual stroke data with NLDN data from the University at Albany.

4. Conclusion

While anecdotal evidence, CWSU meteorologists found the real time WSEta model forecasts useful in preparation of MIS and CWA products, and for briefing FAA Air Traffic Controllers. According to the CWSU supervisor they liked and used the data for a variety of meteorological situations. The WSEta was consulted as part of their forecast process on most days. It was particularly useful to time fronts, lake breezes, wind shifts, and for convective forecasting. On those infrequent occasions when the model data was not available, forecasters at the CWSU took note and called the Albany office to restart the model. This was indicative of their use of the model and its importance in the forecast process. From the authors operational experience at WFO Albany it is clear that mesoscale model winds have been very effective in a wide range of applications in WFO forecasting, including aviation forecasts

From this study the WSETA has forecast skill in identifying convective initiation. Operational CWSU forecasters find the data very useful in a variety of meteorological environments. If this can be validated with further study, routine operational use of these forecasts would allow the CWSU staff to make more accurate thunderstorm forecasts, and the FAA staff they support to make more accurate GSP and GDP decisions. It is believed that putting a full set of mesoscale model forecasts in the hands of air traffic controllers via CWSU meteorologists, will have a significant impact on improving the performance of the NAS, and result in cost savings and a reduction in weather related delays to the airline industry.

Mesoscale forecasts from the Weather Research and Forecasting model will be available beginning later in 2006. This model offers more sophisticated initialization methods and more convective parameterization methods than the WSEta. It also offers explicit prediction of convection on time scales of minutes. Mesoscale model potential in the operational aviation forecasting arena is only just beginning to be realized.

5. References

Cobb, D. K., 2005: The Impact of Weather on Air Traffic Management. COMET MetEd [available online at http://meted.ucar.edu/nas/index.htm]

NLDN, 2005: NWS Contract # DG133W05CQ1012 between National Weather Service and Vaisala Group. [available from NWS Office of Operational Systems}

Rozumalski, R., 2000: **SOO/STRC** Workstation Eta User's Guide. National Weather Service Office of Climate, Water and Weather Services. [available online at http://strc.comet.ucar.edu/model/wseta_userguide.htm]

Cowie, J.,S. Drake, D. Himes, S. Jesuroga, 1997: Garp Users Guide. COMET [available online at http://weather.ou.edu/computing/gempak/garp/Title.html]

FAA, cited 2006: FAA Administrator’s Fact Book, August, 2005 [Available online at http://www.atctraining.faa.gov/factbooks/]

Table 1. Three-level classification system for WSEta performance in determining convective initiation.

Class	Description
Good	Most or all of the observed convection was in the area forecasted by the model field of interest (75% or more)
Acceptable	Part of the observed convection was in the area forecasted by the model field of interest. Usually 25% to 75%
Poor	Less than 25%, but in most cases none of the observed convection matched the area forecasted by the model.

Table 2. Performance of each WSEta model parameter in forecasting convective initiation by event, using the three tier study classification system. Null means parameter not present.

Thunderstorm days	Time UTC	850 hPa Theta-E	Convective Precipitation	700 hPa Omega	850 hPa Jet	250 hPa Divergence	BL Convergence
8/14/04	1500	Poor	Accept	Accept	Poor	Accept	Good
8/18/04	2100	Good	Accept	Accept	Accept	Poor	Accept
8/20/04	1900	Accept	Accept	Accept	Accept	Accept	Accept
8/23/04	2100	Accept	Accept	Accept	Accept	Accept	Good
8/25/04	2100	Accept	Poor	Accept	Poor	Poor	Poor
8/27/04	2100	Poor	Poor	Accept	Accept	Poor	Good
8/28/04	1900	Accept	Accept	Accept	Null	Accept	Accept
8/29/04	2100	Accept	Accept	Accept	Poor	Accept	Accept
9/4/04	1900	Poor	Accept	Accept	Null	Poor	Accept
9/7/04	2100	Good	Good	Good	Good	Poor	Good
9/8/04	1500	Poor	Poor	Poor	Poor	Poor	Accept
9/16/04	2100	Good	Good	Good	Good	Good	Good
9/17/04	1500	Good	Accept	Accept	Good	Accept	Poor
10/13/04	1900	Poor	Good	Good	Poor	Good	Accept
4/19/05	1900	Good	Accept	Accept	Poor	Good	Good
4/20/05	1900	Good	Good	Accept	Poor	Accept	Accept
4/22/05	1500	Poor	Poor	Poor	Poor	Poor	Accept
4/23/05	1900	Poor	Good	Accept	Poor	Good	Poor
5/7/05	2100	Poor	Accept	Good	Poor	Poor	Poor
5/10/05	1900	Poor	Accept	Good	Poor	Accept	Poor
5/11/05	1500	Poor	Accept	Good	Poor	Accept	Accept
5/13/05	1500	Poor	Accept	Accept	Good	Accept	Poor
5/14/05	1900	Accept	Accept	Accept	Accept	Accept	Accept
5/19/05	1700	Accept	Accept	Accept	Poor	Accept	Accept
5/22/05	1700	Poor	Poor	Good	Poor	Accept	Poor
5/23/05	1500	Poor	Accept	Good	Poor	Poor	Poor
6/6/05	1500	Poor	Accept	Good	Poor	Good	Poor
6/8/05	1900	Accept	Accept	Accept	Poor	Good	Poor
6/9/05	1700	Poor	Accept	Accept	Null	Accept	Poor

Table 3. Summary performance of each WSEta parameter, first by number of events, then by percentage. 850 hPa Jet totals that do not add to 100% or 29 are the result of null cases. No jet was identified and no thunderstorms occurred. 850 hPa Theta-E total 101% due to rounding up.

Performance	**850 hPa Theta-E**	**Convective Precipitation**	**700 hPa Omega**	**850 hPa Jet**	**250 hPa Divergence**	**BL Convergence**
Good	6	5	9	4	6	6
Acceptable	8	19	18	5	14	12
Poor	15	5	2	17	9	11
Good	21%	17%	31%	14%	21%	21%
Acceptable	28%	66%	62%	17%	48%	41%
Poor	52%	17%	7%	59%	31%	38%