9B.6

REAL-TIME AND RECENT HISTORICAL WEATHER DATA IN GOOGLE EARTH

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1. Introduction

Scientists at the University of Oklahoma and the National Severe Storms Laboratory have used Google Earth as an important scientific visualization tool for experimental real-time severe weather analysis products since mid-2005. Initially, we intended to simply share experimental multi-radar, multi-sensor data fields with a wide cross-section of potential users (such as National Weather Service forecasters) to gain feedback on the utility of this information. However, once implemented, the combination of high-resolution severe weather analysis fields along with high-resolution geographic information proved to be a powerful combination that may lead to more temporally and spatially accurate warnings for severe weather hazards.

We began experimenting with Google Earth as a display system for experimental severe weather products in July 2005, when the documentation for the Keyhole Markup Language (KML) specification was released to the public. KML is an Extensible Markup Language (XML) dialect that describes data so that it may be interpreted and plotted in Google Earth (Google 2008). It provides a mechanism to easily import and display image overlays, point data, and polygon data (Smith and Lakshmanan 2006). This manuscript

Product	Update Rate (min)	Resolution (km)
Composite Reflectivity	5	1
Low-altitude Reflectivity	5	1
VIL*	5	1
MESH **	5	1
Hail Swath (30, 60, 120, 360 min)	5	1
Echo Top (18, 30, 50 dBZ)	5	1
Reflectivity on isotherms (0, -10, -20 C)	5	1

Product	Update Rate (min)	Resolution (km)
Low-altitude azimuthal shear	2	0.5
Low-altitude Rotation Tracks (30, 120 min)	2	0.5
SPC Storm Reports	1	-
Satellite: Visible	15	4
Satellite: Infrared and Water Vapor channels	15	4
NWS Warnings and Watches	1	-
Storm Classification	5	-

Table 1: Selected products from the wdssii.nssl.noaa.gov web site that are available for viewing in Google Earth and other KML-compatible displays. (* VIL = Vertically Integrated Liquid; ** MESH = Maximum Expected Size of Hail)

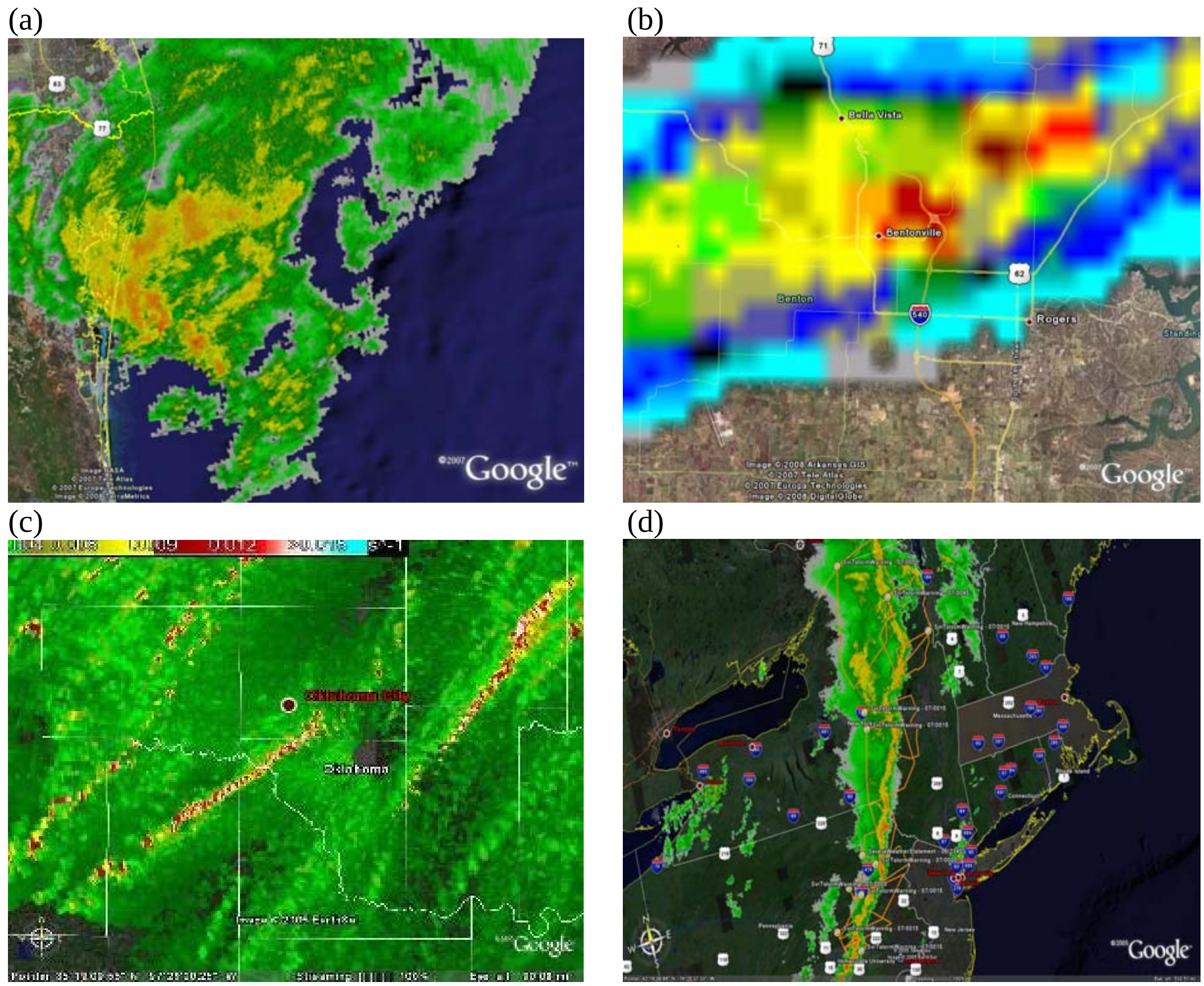

Figure 1: An example of the several severe weather analysis products displayed in Google Earth: (a) Reflectivity at Lowest Altitude, (b) Maximum Expected Size of Hail, (c) Rotation Tracks, (d) National Weather Service warnings and watches. For each product, the red colors usually indicate higher intensities of the data being sampled.

describes several severe weather analysis products that have been imported into Google Earth for use in real-time severe weather analysis, as well as for post-event verification and emergency response.

2. Severe Weather Products

The National Severe Storms Laboratory and the Storm Prediction Center cooperatively run an experimental Warning Decision Support System – Integrate Information (WDSS-II) system that generates high-resolution three-dimensional radar reflectivity data and other severe weather guidance products for the continental United States (Lakshmanan et al 2006). These data fields are updated in real-time every 1 to 15 minutes (Table 1), depending on the product, and are available online at http://wdssii.nssl.noaa.gov. Some of the more useful (and most-viewed) products during the first two years since going online include:

- *Reflectivity at Lowest Altitude*: a CONUS-scale representation of the reflectivity values nearest the surface, from any radar (Figure 1a). This is analogous to the "hybrid scan reflectivity" of the WSR-88D except that it is a multiple radar mosaic;
- *Maximum Expected Size of Hail (MESH) Swath for 30, 60, 120, and 360 minutes*: a spatial representation of the maximum radar-estimated hail size over the given time period (Figure 1b);
- *Rotation Tracks for 30 and 120 minutes*: a spatial representation of the maximum intensity of low-altitude circulations (e.g. mesocyclones) over the given time period (Figure 1c); and
- *National Weather Service Watches and Warnings* (Figure 1d).

Other heavily-used products, based on feedback from National Weather Service forecasters who have used the data, include the current (most recent, in a real-time sense) snapshot of the MESH fields as well as Reflectivity data plotted on various isothermal surfaces. A new Storm Classification algorithm (Guillot *et al*. 2008) was recently added to the suite of data available online as well.

Aside from the originally intended audience (professional forecasters), making these products available for viewing in Google Earth has spurred interaction with several other types of potential end-users, including weather hobbyists, media outlets, and emergency management officials responsible for overseeing disaster response in various city and county jurisdictions.

3. Data collection for severe storm verification

The combination of high-resolution radar data, high-resolution geographic data, improved knowledge and modeling of storm structure and evolution, and technological improvements to warning dissemination methods will provide a mechanism by which warnings for severe weather hazards that are much more specific in space and time than issued at present. These very specific warnings, however, require that high-resolution validation data be collected for a wide variety of severe storm events in order to develop effective guidance tools. At present, warning validation data are collected by the same team of forecasters who issue the warnings either during or soon after warning operations. The validation data they collect is usually on the same temporal and spatial scale as the warnings they issue – roughly hourly and one county (very roughly 1000 km^2 to 3000 km^2). Because of the current mechanism in the way the verification data are collected, many temporal and spatial errors appear in the resulting publication, *Storm Data*, the official record of severe weather events for the United States (Trapp et. al 2006; Witt et. al 1998).

However, the Severe Hail Verification Experiment (SHAVE), conducted during the Spring/Summer of 2006 and 2007 (Smith et. al 2006; Ortega et. al 2006) showed that it is possible to collect very high-resolution validation data with a time and space scale on the order of 1-5 minutes and 10 km^2 by combining geographic information from Google Earth with real-

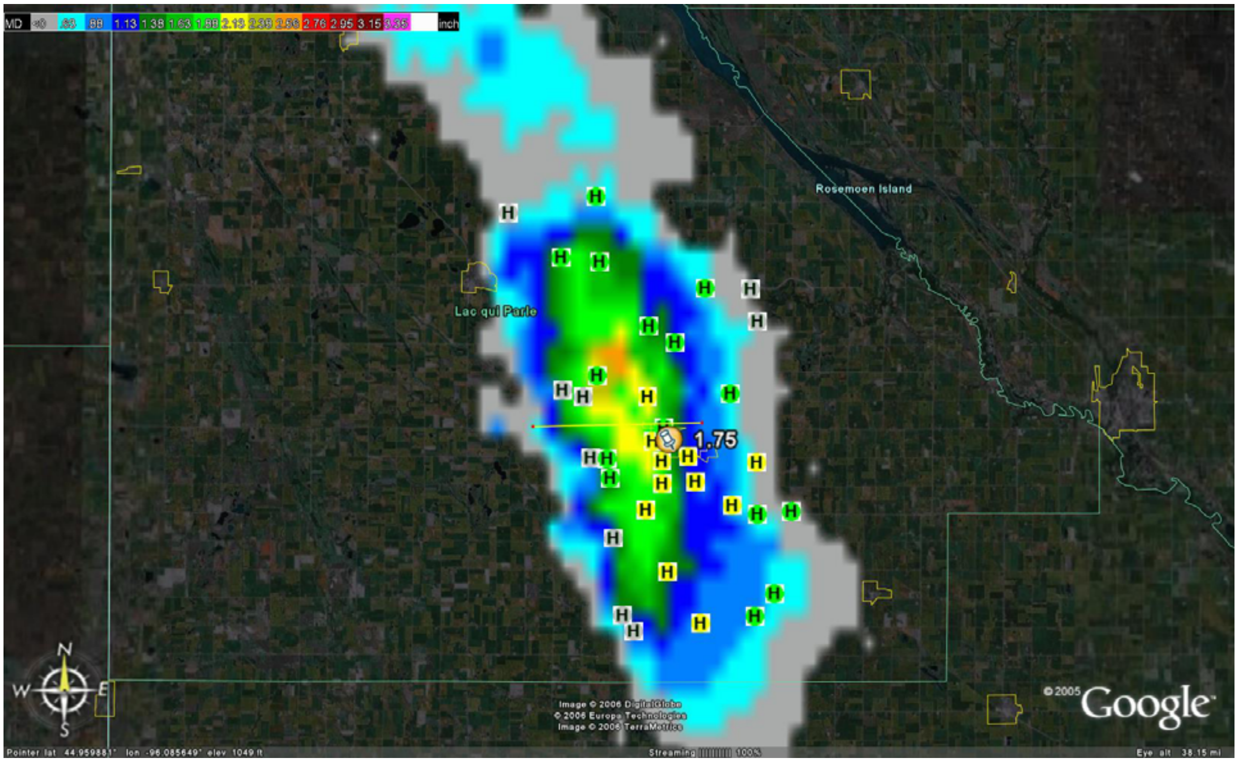

Figure 2: The NSSL Hail Swath algorithm showing radar-estimated maximum hail size during a 180 minute period for a storm that occurred in Lac qui Parie County, MN on July 27, 2006. The grey icons (no hail), green icons (hail up to 1" – 2.54 cm) and yellow icons (hail >1" to 2" – 2.54 cm to 5.08 cm) represent data points collected during the Severe Hail Verification Experiment. The single "push pin" icon represents two collocated data points collected in the county by the National Weather Service as part of warning verifications efforts and published on the Storm Prediction Center web site at http://www.spc.noaa.gov/climo. The yellow line is 10 km long in the scale of the map.

time high-resolution radar data over the CONUS (Figure 2) using unbiased resources that that are external to those entities actually issuing the warnings.

Additional information about the intensity and spatial extent of severe weather events may also be gathered by collecting media reports and mapping the reports in Google Earth. For example, a newspaper's website may have multiple photographs of tornado or wind damage with very specific descriptions of where the damage occurred. This information is extremely useful for determining specifics about the behavior of a storm.

Geospatial information describing the intensity of storms has been used to effectively guide post-event damage survey teams in several cases since these products were made available online. Manross et al (2008) describe a post-event analysis system that may be used to request radar-derived Hail Swath and Rotation Track products for this purpose. An example of a damage assessment conducted in this manner is shown in Figure 3. The survey team, in this case, carried a GPS logger and a digital camera that were time-synchronized. They used the Rotation Tracks product generated by WDSSII to circumnavigate the area of potential data to locate the path of the tornado damage. Following the survey, the GPS

Figure 3: The GPS log of the path taken by a survey crew assessing damage in El Reno, OK is shown in red on the overview map (upper left). A close-up view of some of the individual buildings (prior to the tornado) is shown in the upper right (some of these have been annotated as being damaged.) Geo-referenced photographs of the damage are plotted as icons in Google Earth and may be used to estimate the intensity and extent of the tornado damage (inset in upper right).

log was used to geo-reference the photographs so that they could be viewed in Google Earth in the proper location. By partially automating the process and adding geospatial information to the photographs, a more complete representation of the event is gained over the pencil-and-paper damage surveys that have been used in the past. Archiving these details in a digital format in a central location will preserve the integrity of the information for the long term (Scharfenberg et al. 2008).

4. Discussion

Severe weather events widely vary in spatial extent, intensity, and duration. New technology such as virtual globes, improved, targeted communications devices such as cell phones, and improved understanding of the onset and evolution of severe storms will make warnings for severe weather hazards more skillful and specific in time and space. Virtual globes and other geographic information systems enable geospatial and weather information to be organized such that the data are easily interpreted by a wide cross-section of end users.

We have found Google Earth to be a useful platform for sharing experimental severe weather guidance products with forecasters. It has also been helpful for data collection activities involving the verification of the extent and intensity of storm damage. Adding new weather products is a straightforward process – it is simple to import data into Google Earth using KML. One limitation of using Google Earth as a scientific application, however, is that it does not provide a mechanism by which to interrogate the specific values of data points, but instead relies on visual imagery alone to convey information. If one wants to examine the contents of individual data points, then another application is needed. It is our intention to continue to provide the output from new experimental severe weather applications as KML/KMZ files for evaluation and collaboration with a variety of users.

5. Acknowledgements

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