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USING GOES TOTAL COLUMN OZONE TO DIAGNOSE STRATOSPHERIC INTRUSIONS AND NOWCAST NON-CONVECTIVE CYCLONE WINDSTORMS: METHODOLOGY AND INITIAL RESULTS

John A. Knox *
University of Georgia, Athens, Georgia

Christopher C. Schmidt
CIMSS/University of Wisconsin, Madison, Wisconsin

1. INTRODUCTION

Mesoscale features in the upper troposphere referred to as “stratospheric intrusions” or “tropopause folds” have long been identified in meteorological observations (Shapiro and Keyser 1990; Browning 1997). As the first name implies, these features contain signals of air of stratospheric origin—such as low relative humidities, high ozone values, and/or high stability and potential vorticity—but are located within the altitude and pressure regions normally associated with the troposphere.

Despite decades of observation, the connections between these mesoscale tropopause features and near-surface conditions are yet to be fully understood. For example, some stratospheric intrusions are able to convey ozone and strikingly low relative humidities all the way to the surface in the absence of intense near-surface dynamical features (Lamb 1977; see also http://cimss.ssec.wisc.edu/goes/misc/990329.html). Other episodes are associated with some, but not all, intense cyclones. Comparatively little research appears to have been devoted to relating the mesoscale folds/intrusions to vertical motion fields.

The relationship between downward vertical motion and these folds/intrusions appears to be of critical importance in understanding non-convective cyclone-generated windstorms. One such event occurred across the upper Midwest on 10 November 1998 (Iacopelli and Knox 2001). Ten deaths, 34 injuries and at least $40 million in damage occurred in connection with winds in a record-setting mid-latitude cyclone, with the most intense winds (60-81 kts) developing behind the center of the low along a path from La Crosse to Wausau, WI. These winds were associated with a significant tropopause fold whose prominent ozone signature was captured by the then-new GOES Sounder Ozone imagery (Li et al. 2001; see Figure 1).

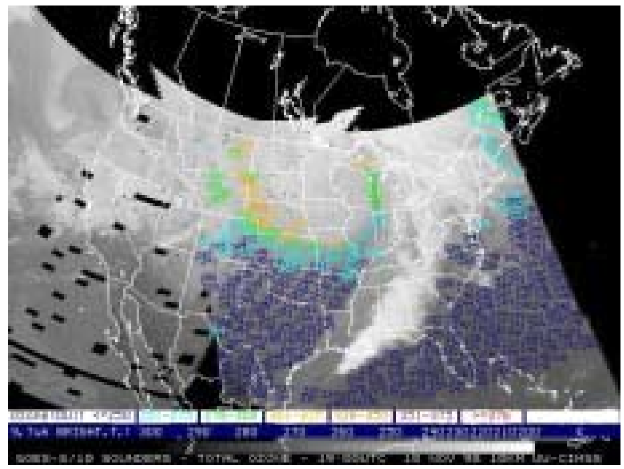
Figure 1. GOES total column ozone product at 1900 UTC on 10 November 1998. Ozone values are plotted numerically and are also color-coded (green and yellow indicate highest values). The tongue of high ozone values across Lake Michigan was coincident with a “dry slot” associated with a record-breaking cyclone and damaging surface wind gusts over the upper Midwest.

Close inspection of GOES water vapor images from that storm revealed a mesoscale “hook” of dry air, a lobe of the intrusion, that was dynamically wrapped around the cyclone's mid- to upper-tropospheric circulation. This hook was closely correlated in both space and time with surface “storm reports” from the National Weather Service (Iacopelli and Knox 2001), suggesting that in at least some cases this feature could be used for pinpoint nowcasting purposes.

The close relationship between features in GOES imagery and the surface wind events in the 10 November 1998 cyclone has led to the current investigation. Below, we discuss the development and current status of the GOES total ozone derived product. We also show initial results of the application of this project to the problem of forecasting non-convective windstorms associated with intense mid-latitude cyclones.

* *Corresponding author address:* John A. Knox, Univ. of Georgia, Faculty of Engineering, Driftmier Engineering Center, Athens, GA 30602; e-mail: jknox@engr.uga.edu

2. METHODOLOGY

Since 1998, data from the GOES Sounder has been employed to estimate total column ozone. These estimates are made using linear regression against cloud-free and partly cloudy brightness temperatures from the GOES Sounder, latitude, month, and surface pressure. The regression coefficients are derived from the NOAA88b atmospheric temperature, moisture, and ozone profile set provided by the National Oceanic and Atmospheric Administration (Schmidt et al. 2001). The relatively small size of the NOAA88b profile introduces biases into the estimates. However, Li et al. (2001) demonstrated that regression is preferred to physical retrievals, because the latter fail to improve the accuracy and in fact perform worse than the regression-based estimates in many cases.

Initially, these estimates were calculated on an hourly basis with 30 km by 30 km resolution (3 by 3 field of views, or FOVs). Comparisons with instantaneous, collocated ozone estimates from the Total Ozone Mapping Spectrometer (TOMS) were found to be within 4-7%, and within 21 Dobson units compared to three ground-based observation sites (Li et al. 2001).

The initial total column ozone estimates provided sufficient resolution in time, but not in space, to resolve the dynamics associated with stratospheric intrusions. Therefore, a 1 by 1 (single) FOV (SFOV) version of the algorithm is under development which will provide hourly total column ozone values with 10 km by 10 km resolution. The SFOV ozone estimation algorithm utilizes noise-filtered Sounder data as well as new regression coefficients that include the emissivity of the surface to further improve that data and reduce biases.

3. INITIAL RESULTS

We have examined the GOES SFOV total ozone product for one notable cyclone-related windstorm over the upper Midwest on 12-13 November 2003 (Figure 2).

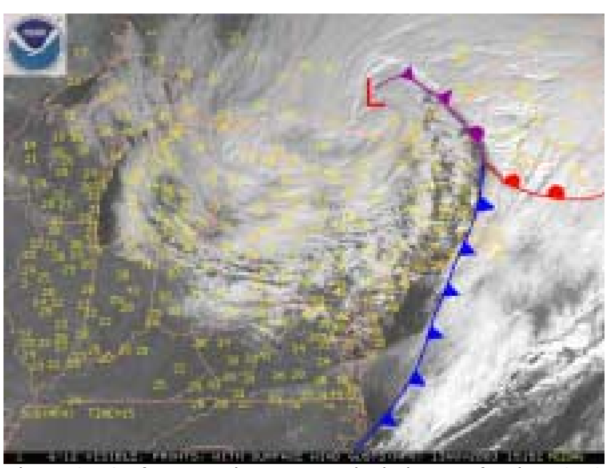

Figure 2. Surface weather map and wind gusts for the 12-13 November 2003 cyclone at 1515 UTC on 13 November 2003.

This cyclone caused $26.5 million in damage and winds up to 76 kt as it traversed the upper Midwest from Minnesota to Michigan (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms). Figure 3 illustrates the distribution of high winds across the southern Wisconsin (http://www.crh.noaa.gov/mkx/document/wind/wind_11-12-03.htm). As noted in Storm Data and National Weather Service writeups following the event, these winds occurred *after* the passage of the cold front and were not related to thunderstorm activity. The coincidence of a strong cyclone, damaging winds, and the lack of thunderstorm activity during the time of the winds all suggested the possibility of a stratospheric intrusion-related event. To investigate this possibility, we have examined this cyclone using the GOES SFOV total ozone product and GOES water vapor imagery.

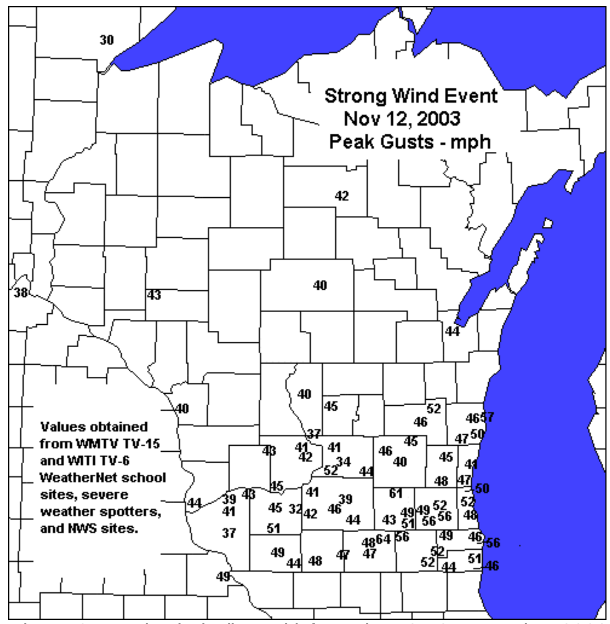

Figure 3. Peak winds (in mph) from the 12-13 November 2003 high wind event across the state of Wisconsin, from http://www.crh.noaa.gov/mkx/document/wind/images/wind_11-12-03.gif

In Figures 4 and 5, the GOES SFOV total column ozone product is juxtaposed with nearly contemporaneous AWIPS water vapor imagery. The bright yellow region in the AWIPS image in Figure 4 is indicative of low-relative humidity air, presumably of stratospheric origin. At 2245 UTC on 12 November 2003, this "dry slot" extends across southeastern Iowa and all of northern Illinois into Indiana and southwest Michigan, with the northernmost fringe along the Wisconsin-Illinois border. In addition, a regional minimum of below-freezing surface dew points are also found along this dry slot region in Iowa, suggesting that air from the dry slot may be reaching the surface. In general, the highest wind gusts in Illinois, Indiana and southwest lower Michigan are collocated with this region of driest relative humidities aloft.

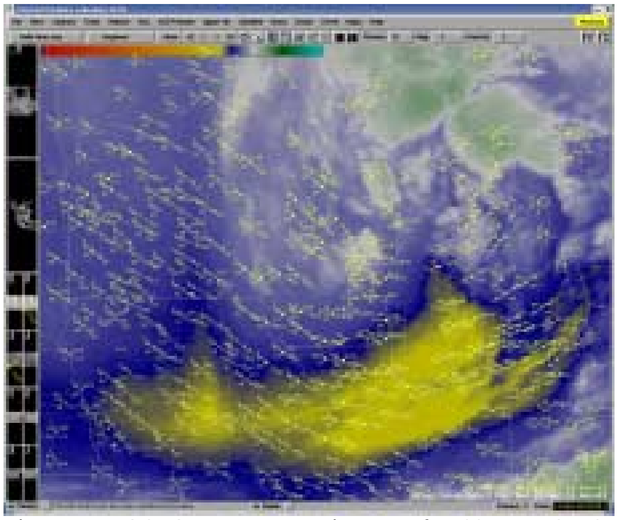

Figure 4. GOES water vapor imagery for 2245 UTC 12 November 2003. Hourly METAR observations are overlaid in this AWIPS screen capture. Image courtesy Scott Bachmeier, CIMSS.

Figure 5 depicts the GOES SFOV total column ozone product at 2246 UTC on 12 November 2003, one minute after the water vapor image in Figure 4. Highest values of ozone are in green and red. Note that the total column ozone product indicates high values along the Minnesota-Iowa border and along the Illinois-Wisconsin border. This region is north of the area of driest air in Figure 4.

However, by visual inspection it appears that the region of highest ozone in Figure 5 corresponds to the region of highest spatial *gradients* of water vapor in Figure 4. This observation is similar to that of Wimmers and Moody (2004), who found a quantitative relationship between tropopause folds and spatial gradients in an altered GOES water vapor product and in TOMS total ozone. This initial result suggests that the GOES SFOV total column ozone product is providing reliable information regarding the mesoscale dynamics of near-tropopause features in cyclones. At the conference, additional images and animations of GOES total column ozone will be presented.

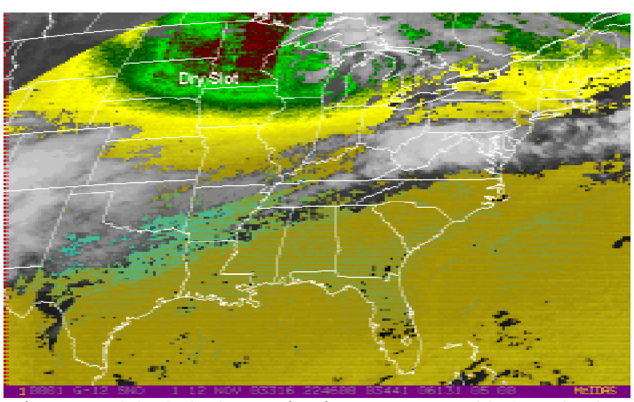

Figure 5. GOES SFOV total column ozone at 2246 UTC 12 November 2003.

4. SUMMARY AND DISCUSSION

An improved version of GOES total column ozone product is being employed to examine cyclone-related windstorms, for the purpose of identifying mesoscale tropopause features that may be related to these windstorms. In turn, better observations of these features may permit forecasters to anticipate and forecast these windstorms so that losses can be mitigated.

5. ACKNOWLEDGMENTS

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