# Incorporating TOMS Ozone Data into the Prediction of a Winter Snowstorm

Kun-Il Jang*, X. Zou, Q. Zhao
*Department of Meteorology, The Florida State University, Tallahassee, Florida*

A. Kruger
*JCEST, The University of Maryland Baltimore County, Baltimore, MD 21250*

M. A. Shapiro
*NOAA/ETL, Boulder, Colorado*

## 1 Introduction

A satellite carrying the NASA Total Ozone Mapping Spectrometer (TOMS) has provided quantitative measurements of vertically integrated column ozone concentration. Meteorologists have noted that ozone distributions near the tropopause contain significant information about dynamical characteristics of synoptic-scale and mesoscale flow regimes and associated weathers. Ozone concentrations in the vicinity of the tropopause could be viewed as a surrogate for stratospheric potential vorticity (PV). A strong correlation between vertically integrated ozone and upper-level troughs and ridges was observed (Danielsen, 1968).

Investigations of the correlation between ozone and vertically integrated potential vorticity (IPV) have focused primarily on total ozone at large-scales (Allaart *et al.*, 1993). The objective of this paper is to examine the ozone-IPV relationship at mesoscales and carry out a four-dimensional variational assimilation (4D-Var) of TOMS ozone to access the impact of TOMS data upon a winter snowstorm prediction.

## 2 Synoptic Overviews

The case chosen for this study is the snowstorm of 24-25 January 2000. During January 2000, temperatures across the U. S. were initially mild. But, a significant storm system affected the eastern seaboard beginning 22 January 2000. Soon, a severe ice storm hit northern Georgia and portions of northwest South Carolina on 22-23 January 2000. Then, a rapidly deepening low pressure developed along the same frontal boundary. The storm moved northward along the coast. It dumped heavy snow from the Carolinas into New England. In fact, Raleigh-Durham, N.C., reported a total snowfall total of 20.3 inches from Monday evening (the 24th) to 3 p.m. on the 25th, breaking the historical record for a single storm event. Up to 17 inches of snow fell in parts of Virginia during this snowstorm.

### 2.1 Experimental design

The MM5 4D-Var system (Zou et al. 1997;1998) is used for the numerical experiments. The large domain (Domain 1) covers the North America and the small domain (Domain 2) is located in the southeast regions of America (Fig. 1). The model grid-spacing for both domains is 30 km. The total grid points for domains 1 and 2 are 109X225X27 and 60X80X27, respectively. Domain 1 is used for control forecasts and domain 2 for 4D-Var experiments.

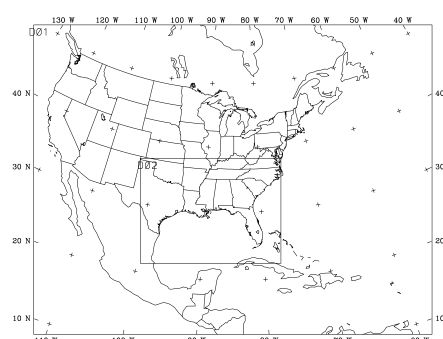


Figure 1: Domain configuration for the experiment.

Twenty control forecasts using the Penn State/NCAR mesoscale model version 5 (MM5) are made to calculate the hourly IPV, which are used to define the

*Corresponding author address: Mr. K. Jang, Department of Meteorology, The Florida State University, Tallahassee, FL 32306-4520. Email: kijang@met.fsu.edu

correlation relationship with TOMS ozone observations during 15-25 January 2000.

Starting from 12 UTC 24 January 2000, a 7-h assimilation window is used for the MM5 4D-Var system to incorporate the TOMS ozone. In this 7-h window (from 12 UTC to 19 UTC 24 January 2000), TOMS ozone data covered most areas of Domain 2 (Fig. 2).

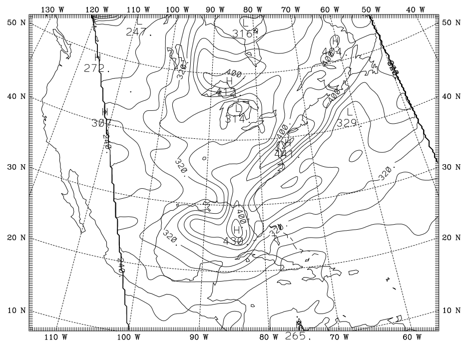

Figure 2: TOMS ozone observations from 12 to 19 UTC 24 January 2000 (unit: Dobson). The contour interval is 20 Dobsons.

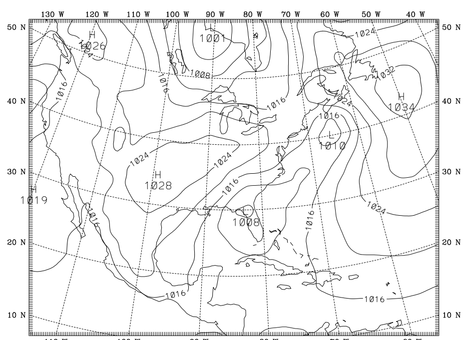

Figure 3: The analysis of sea level pressure for 12 UTC 24 January 2000 (unit: mb). The contour interval is 4 mb.

## 3 Statistical Relationship

We compared TOMS ozone with IPV calculated from three different model fields: the 90-km MM5 analysis (case 1), the 30-km MM5 analysis (case 2), and a total of 20 one-day forecasts at 30-km resolution (case 3). the wind and temperature analyses or forecasts are used to calculate IPV values, which are used to define a linear regression model:

$$O_3 = \alpha * (IPV) + \beta \qquad (3.1)$$

where IPV is calculated at an hourly interval after 6 h into the prediction, and $O_3$ represents the level-2 TOMS ozone data (McPeters et al. 1998).

The linear relationship between IPV and ozone in three cases is found to depend on the latitude, with the strongest linear correlation in middle latitudes and a weaker linear correlation in the tropics and high latitudes (Figure 4). The values of the coefficients $\alpha$ and $\beta$ in equation (3.1) are shown in Tables 1 and 2, respectively. Differences of the values of $\alpha$ at different resolutions are smaller than differences between latitudes. The values of $\alpha$ is largest at mid-latitude, and smallest at the equator. On the contrary, the values of $\beta$ is largest in the tropic and smallest at high latitudes.

Figure 5 shows a scatterplot of the TOMS ozone as a function of IPV. The solid line shows the linear regression model between TOMS ozone and IPV in mid-latitude bands of case 3. TOMS ozone and IPV values have a good linear relationship.

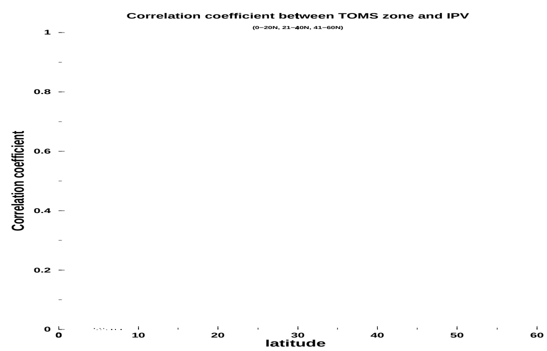

Table 2: $\beta$ of a linear regression model between TOMS ozone and IPV in three cases

| **Latitude bands** | 90 km analysis | 30 km analysis | 30 km 24-h fcst |
|---|---|---|---|
| $00-20N$ | 259.716 | 262.787 | 262.749 |
| $20-40N$ | 228.177 | 256.353 | 259.528 |
| $40-60N$ | 220.564 | 253.049 | 252.586 |

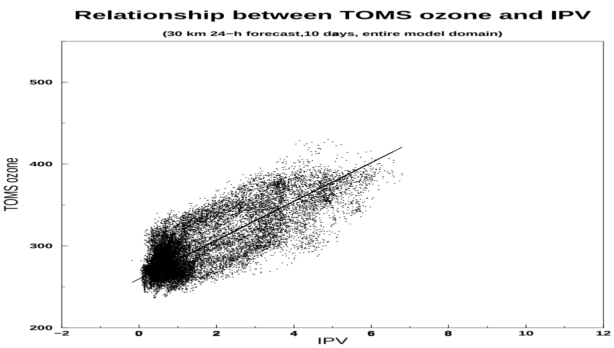


Figure 5: Scatterplot of TOMS Ozone vs. IPV in 20-40N (case 3). Solid line is the regression line obtained by a least-square fit procedure.

at high latitudes) and the drift after 1.5 years of operation is less than $\pm 0.6\%$ (McPeters et al. 1998). It is assumed that TOMS ozone data are not spatially correlated. Through this assumption, the observation error covariance matrix becomes diagonal. A constant value of 9 $\text{Dobson}^2$ is used for all the diagonal elements. The observation operator $H$ for TOMS ozone data assimilation calculates IPV and transforms it into the simulated ozone. The ozone data are assimilated at their exact time.

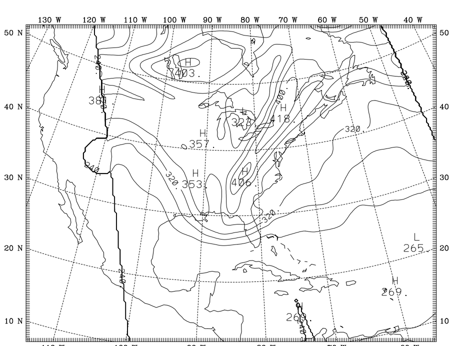


Figure 6: Simulated total ozone in case 3 from 12 to 19 UTC 24 January 2000 (unit: Dobson). The contour interval is 20 Dobsons.

Compared with the model simulated total ozone (Fig. 6), the observed TOMS ozone (Fig. 2) shows a much stronger ozone anomaly in the south coast of Alabama where the low-pressure system is located (Fig. 3). We would like to find out the impact of this new source of information on the prediction of the snowstorm.

# 4 Summary

The linear relationship between the TOMS ozone and IPV seems working at mesoscale in mid-latitudes. The linear regression model for these two quantities provides a direct method to incorporate the TOMS ozone observations into mesoscale data assimilation. The 7-h TOMS ozone data assimilation experiment, however, produced an excessive amount of computational noises near the model top. Reasons for the occurrence of these noises are being analyzed. Results will be presented at the conference.

# Acknowledgment

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