Why develop a new TOMS algorithm?

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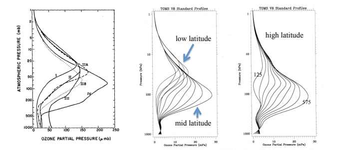
1. Introduction

The main criticism of the present TOMS algorithm is that we do not provide error bars. In Version 9 of the TOMS algorithm our approach is to simplify the algorithm so we can better estimate errors when they are spatially and temporally correlated.

2. TOMS Algorithm has Sound Foundation

- **Total O_3 dependent *a priori* profiles have been key – they capture a large degree of profile variance.**



Original profiles [*Dave and Mateer,* 1967] Currently Used in TOMS V8.5

Method works extremely well for retrieving total O_3 from variety of algorithms

Lambert-Equivalent Reflectivity (LER)

Assume the atmosphere is bounded by an opaque Lambertian surface at pressure P

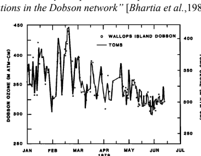
- Key Assumption: R does not vary with
- R can be derived from a non-O_3-absorbing and used at O_3-sensitive
- Get O_3 errors if absorbing aerosols are present
- Corrections for aerosol absorption are used.

$$I = I_0 + \frac{RT}{(1 - RS_b)}$$

$$R = \frac{I - I_0}{T + (I - I_0) S_b}$$

TOMS data have been high quality for decades

"We note that the TOMS instrument is producing daily global ozone maps with between 50 and 150 km resolution; each measurement on this map has accuracy and precision comparable to the best run stations in the Dobson network" [*Bhartia et al.*,1984]



1979 data at Wallops Island (37.8 N, 75.5 W) from *Bhartia et al.*, 1984.
TOMS ozone shifted @6% relative to Dobson to remove overall bias.

3. Activities Since 1984

- Instrument characterization – "soft calibration"
- Cloud correction for Rayleigh/cloud interaction & penetration inside clouds
- Volcanic effects - SO_2 and ash
- Aerosol correction for elevated dust & smoke layers
- Profile shape correction using 313 nm radiance residuals

Except calibration, these corrections affect less than 20% of all data

4. So Why Develop A New Version?

- Provide Error Bars
- Provide info to estimate systematic errors
- Extend Retrieval to 88° SZA
- Simplify Algorithm

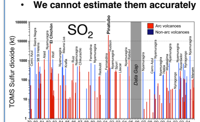
Improving data quality is not the primary objective.

5. Key Features of TOMS V9 algorithm

- Based on Rodgers' optimal estimation (OE) technique
  - *a priori* covariance matrix from MLS/sondes
  - Uses 3 O_3 sensitive wavelengths (313, 318, 331 nm)
  - Retrieved O_3 profiles are integrated to get column
  - Error bars/kernels provided by optimal estimation
- Simpler aerosol correction
  - based on method proposed by Dave in 1977
- Trap rather than correct unusual "Black Swan" events
  - deep convective clouds (DCC), thick aerosol plumes, volcanic plumes etc.

Trapping "Black Swan" events

- **They cause errors that are not Gaussian distributed**
- **We cannot estimate them accurately**



TOMS estimates of SO_2 injected into the atmosphere are the only data of their kind, and they demonstrate how "Black Swan"-type retrieval interferences can bring opportunities for new science.

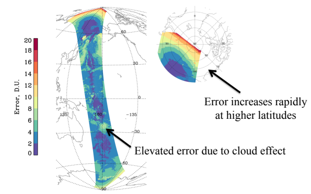
Ziemke et al. estimate very low ozone mixing ratios inside deep convective clouds in the Pacific region while near South America and Africa convection entrains elevated boundary layer O_3 into these clouds. Variability of O_3 sources and deep convection makes constructing an accurate tropospheric O_3 climatology difficult for DCC and prevents the reliable estimation of total O_3 errors.

Photo from STS-43 of stratospheric aerosol layers at ~20-25 km on Aug. 8, 1991, less than two months after the eruption of Mt. Pinatubo.

Error Considerations

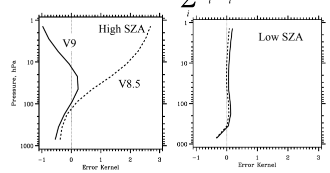
- To properly describe errors in the TOMS data we must provide two types of error bars:
  1. Error bars for a single measurement.
  2. Error bars for an ensemble mean of measurements, e.g. monthly means
- For nadir viewing sensors such as TOMS, error bars are difficult to provide because clouds and aerosols affect radiance measurements in complex ways.

1σ Error bars for total O_3 retrievals



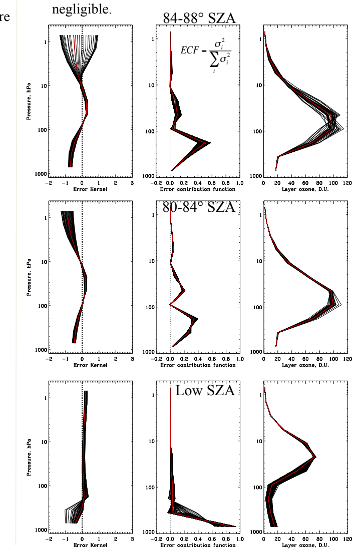
O_3 Profile Error Kernels (W)

$$\Delta\Omega = \sum_i w_i \Delta x_i$$



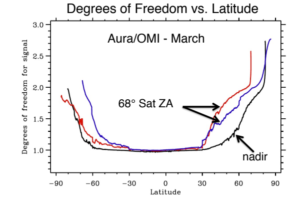
Error Contribution Functions

- Error contribution functions (ECF) indicate pressure levels where the error in the column originates.
- Most error contributes from the troposphere. At high SZA, errors contribute from the lower stratosphere as well. The error contribution from above 10 hPa is negligible.

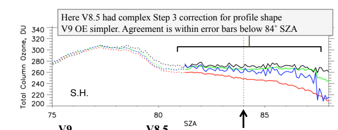


OE shows higher information content at large SZA

Degrees of Freedom vs. Latitude



V9 total O_3 vs. V8.5 at high SZA



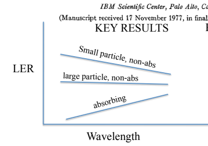
Aerosol Correction – Back to the Future

Effect of Aerosols on the Estimation of Total Ozone in an Atmospheric Column from the Measurements of Its Ultraviolet Radiance[1]

J. V. Dave

IBM Scientific Center, Palo Alto, Calif. 94304

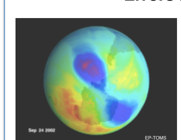
(Manuscript received 17 November 1977, in final form 17 January 1977)



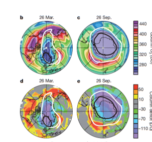
RECOMMENDATION

R could be measured at 340 and 380 nm and linearly extrapolated to O_3 wavelengths

Errors in context



An accurate *a priori* climatology is difficult to construct for every case. This rare pattern in for the Antarctic ozone hole highlights the issue. Errors for such cases are difficult to characterize.



[*Manney et al.*, 2011]

Interpretation of measurements showing Arctic ozone loss benefits from greater understanding of retrieval errors and how they aggregate in ensemble means typically studied, such as used in *Manney et al.*, 2011.

6. References

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7. Acknowledgements

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