GEOPHYSICAL RESEARCH LETTERS, VOL. 28, NO. 10, PAGES 1999-2000, MAY 15, 2001

Reply to Comment on: "New method for inferring total ozone and aerosol optical thickness from multispectral extinction measurements using eigenvalue analysis by G. Taha and G.P. Box" by Xia Xiangao and Wang Mingxing

G. P. Box and G. Taha[1]

School of Physics, University of New South Wales, Sydney, Australia.

Xia and Wang point out that, for the eigenvector analysis method, the error in the ozone optical thickness will be directly correlated with aerosol optical thickness at that wavelength, thus the presence of measurement errors can lead to instability in the ozone retrieval. The nature of the error propagation means that the instability may increase as the number of wavelengths used for making predictions increases. Stability analyses they undertook using both the eigenvector method and that of King and Byrne (1976), led them to conclude that the King and Byrne method is more stable, especially when the number of wavelengths is large, although both methods yield the same average value for the ozone column.

When using another larger wavelength set which had several close pairs of wavelengths, we noted large errors in the predictions. In that case the presence of the pairs was the main problem because they tended to cancel one another, hence our recommendation that in such situations only one of the pair be used. (Similar effects were reported by Livingston and Russell (1989).) This is in line with Twomey's (1977) suggestion that for predicting one kernel as a linear combination of the others, the kernels should be well spaced. In cases where there is a large number of wavelengths, a simple way of determining whether or not the eigenvector method gives stable retrievals is to also apply the method to one or more subsets of these wavelengths.

All methods for retrieving ozone from a set of radiometer measurements have their advantages and disadvantages, which are partly related to the assumptions made by the method. The relative merits of the King and Byrne method and the second derivative method are discussed by Flittner et al. (1993). Our purpose was to develop a simple, easily applied method, which makes maximum use of the information contained in the measurements. The advantage of the eigenvector method is that it relies on the dependence of the Mie kernels rather than an assumed functional relationship between optical thickness and wavelength, and it can be used when only a small number of wavelengths is available. In a paper we were not aware of at the time of writing, Steele and Turco (1997) use an eigenvector method to extract ozone from SAGE II measurements. They found that, although there is more noise in ozone retrievals due to propagation of errors, there was no bias in the aerosol extinction or ozone values so that when averaged temporally or spatially, the propagated errors tend to cancel out.

Xia and Wang recommend an alternative set of wavelengths which they show to be more stable than the MFRSR set. While this is undoubtedly the case, our work was based on an existing, widely used instrument (Augustine et al., 2000) and thus we could not choose the wavelengths. Instrument wavelengths are chosen for a variety of reasons which include species to be measured and cost. The suggested wavelengths satisfy the need for a well-spaced set of kernels and to minimize contamination from NO_2, however the 0.34 μm channel has other problems. This wavelength is close to the detection limits of the filters thus the signal to noise ratio is low, and also the Rayleigh contribution to optical thickness is large. This channel will also be contaminated by ozone, a problem which is easily handled by the eigenvector method (but not the King and Byrne method).

On the question of NO_2 absorption in the 0.414 μm channel of the MFRSR, the effect is likely to be small, and will affect all retrieval methods. In principle, the eigenvector method could also be used to extract the NO_2 contribution to this channel, however the signal to noise ratio is probably unfavourable. Other users of this instrument appear not to correct for NO_2, although corrections are made for ozone, for example Michalsky et al., (1995).

In conclusion, we acknowledge that error propagation can lead to instability in ozone retrievals, and that these effects become larger as the number of wavelengths increases. However, we would like to point out that when we applied this method to almost 170 days data, the difference between the weekly average ozone column obtained using our method, and the satellite TOMS measurements was of the order of 2%, compared to 10% for the King and Byrne method. It should be pointed out here that the eigenvector method has potential for inter-comparison of instruments with different wavelength sets.

[1]Now at University of Arizona and Radiation and Aerosols Branch, NASA Langley Research Center, Hampton, Virginia.

Paper number 2001GL013210
0094-8276/01/2001GL013210$05.00

References

Augustine, J. A., J. J. DeLuisi and C. N. Long, SURFRAD-A National Surface Radiation Budget Network for Atmospheric Research, *Bull. Amer. Meteor. Soc.*, 81, 2341-2357, 2000.

Flittner, D. E., B. M. Herman, K. J. Thome and J. M. Simpson, Total ozone and optical depth inferred from radiometric measurements in the Chappuis absorption band, *J. Atmos. Sci.*, 50, 1113-1121, 1993.

King, M. D. and D. M. Byrne, A method for inferring total ozone content from the spectral variation of optical depth obtained with a solar radiometer, *J. Atmos. Sci.*, 33, 2242-2251, 1976.

Livingston, J. M. and P. B. Russell, Retrieval of aerosol size distribution moments from multiwavelength particulate extinction measurements, *J. Geophys. Res.*, 94, 8425-8433, 1989.

Michalsky, J.J., J. C. Liljegren and L. C. Harrison, A comparison of Sun-photometer derivations of total column water vapor and ozone to standard measures of the same at the Southern Great Plains Atmospheric Radiation Measurement site, *J. Geophys. Res.*, 100, 25,995-26,003, 1995.

Steele, H.M. and R. P. Turco, Separation of aerosol and gas components in the Halogen Occultation Experiment and the Stratospheric Aerosol and Gas Experiment (SAGE II) extinction measurements: Implications for SageII ozone concentrations and trends, *J. Geophys. Res.*, 102, 19,665-19,681, 1997.

Twomey, S., *Introduction to the mathematics of inversion in remote sensing and indirect measurements*, 243pp., Elsevier, New York, 1977

G. P. Box and G. Taha, School of Physics, University of New South Wales, UNSW SYDNEY 2052 Australia.
(email: gpb@newt.phys.unsw.edu.au, g.taha@larc.nasa.gov)

(Received: December 1, 2000
Accepted: December 18, 2000)