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Letters to the Editor

Robustness of Statistical Gossip and the Antarctic Ozone Hole

I do not remember where I heard the story for the first time, but it went something like this:

> NASA, the scientific organization with the biggest collection of atmospheric data, would have been first to discover the Antarctic ozone hole had they not used modern statistical methods. However, the computer code to analyze the data was based on robust statistical procedures which suppressed the unusual low ozone readings. When British and Japanese scientists published their findings on the existence of an ozone hole over the Antarctic, NASA went back to reexamine their data and found that they could have recognized the ozone hole much earlier than their competitors had they given proper attention to the unusually low ozone readings.

My inquiries about these stories, at Oberwolfach meetings and on other occasions, were met with either a curious or a malicious smile. Some colleagues had heard the story from other sources, but nobody was able to provide any facts. The story resurfaced when I was shown the following article featuring prominently on page 3 of the national German newspaper *Frankfurter Allgemeine Zeitung* of 14 November 1987.

In eisiger Dunkelheit bilden sich Wolken über der Antarktis:
Ozonloch als signal für Veränderung des Lebensbedingungen auf der Erde

In icy darkness clouds loom over the Antarctic:
The ozone hole signals changing conditions of life on earth

by Caroline Möhring

> FRANKFURT, 13. November. They would not trust their instruments. Such low readings contradicted all expectations. The British scientists from the Halley Bay station sceptically checked their instruments, repeated the measurements in the following year and checked their results in various ways: Finally, in 1985, J. C. Farman and collaborators went public with their finding that at the beginning of the Antarctic spring the ozone in the upper atmosphere over the South Pole dwindles away. The stratospheric ozone layer which, at an altitude of about 20 kilometres, saves the earth from harmful ultraviolet radiation, temporarily develops a hole, they reported.
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> Japanese scientists had made similar observations, but published their paper in 1984 in a little read journal. Only the NASA satellites which also monitor the atmospheric ozone content seem to have missed the hole. However, a revision of the data proved that the satellites had indeed reported decreasing ozone readings – while the computer code had deliberately cast out values that it deemed not possible as measurement errors. Reconsideration of the same data set showed: Since the end of the seventies the September ozone content over Antarctica clearly decreases – and this effect increases from year to year ...

When I approached Dr. Möhring in December 1989 for more details, it turned out that they had moved offices and on that occasion had thrown away material that they thought obsolete. However, she directed me to Professor Paul Crutzen from the *Abteilung Chemie der Atmosphäre* of the *Max-Planck-Institut für Chemie* in Mainz. Dr. Crutzen responded that he knew about the "story" without being able to provide further detail. He suggested that I inquire further with NASA.

In April 1990, I received the following letter from Dr. Richard McPeters, Head of the Ozone Processing Team, NASA (Goddard Space Flight Center, Code 616, Greenbelt, MD 20771, USA), providing an account of the story. The upshot is that the unusually low ozone readings had been

looked at separately—as they should have been—and had been doublechecked against measurements from another station—as they should have been. The data set from the second station was much more in line with the experience available at that time, and hence the unusually low readings seemed doubtful. Unfortunately, it was this second data set, used for double-checking, that was in error. Here is his account:

Dear Dr. Pukelsheim:

This is in reply to your letter asking about NASA's role in the discovery of the Antarctic ozone hole. Unfortunately, everyone "knows" that NASA did not discover the ozone hole because the low values were "thrown out" by the computer code. This myth was the result of a statement made by one of my colleagues in reply to a question during an interview on the science program NOVA in which he was asked why NASA did not discover the ozone hole first. He was not directly involved in ozone processing at that time and his answer was *not* correct.

NASA scientists were studying the unusual low ozone values in July of 1984, almost a year before the publication of the Farman paper. Our software is designed so that data are *never* just thrown out. Rather, questionable data are "flagged" as not being of best quality. TOMS makes 5×10^7 individual measurements of ozone each year, and of these measurements some small fraction will be bad because of encoding errors, transmission errors, or possibly instrument effects (the effect of random noise is greater at large solar zenith angles). Screens are put in the software to detect out-of-bounds conditions and flag them. One such screen was on ozone such that ozone amounts less than 180 DU were flagged as possibly being in error. This was a reasonable check since no reliable measurement of ozone this low had ever been reported before 1983.

In July 1984 we were processing the data from October 1983, the first year in which the ozone hole was sufficiently well developed to drop below our 180 DU threshold. This was noticed in our quality control screening as a sudden increase in flags for ozone too low. Since this could have been the result of an instrument problem, we compared our measurements with the only Dobson ground station data then available, that from the Amundsen-Scott station at the South Pole. (Data from the Halley Bay station are *not* sent to the Canadian AES for archival.) Unfortunately, because of an error, the South Pole Dobson station was reporting ozone values of 300 DU when our satellite instrument was reporting less than 180 DU. As noted in a paper by Komhyr *et al.* (1986), "data previously reported for October-December 1983 have been identified as erroneous and uncorrectable (observations were incorrectly made on A', C', and D' rather than on A, C, and D wavelengths)."

Because of this error, we were necessarily very cautious in accepting our own data as valid. But after careful evaluation we could find no problems with the data and decided to report them. In late 1984 (months before the publication of the Farman *et al.* paper in the May 1985 issue of *Nature*) we submitted an abstract for the IAGA/IAMAP meeting in Prague, Czechoslovakia, August 1985, reporting these low ozone observations.

In conclusion, our failure to be first to report the Antarctic Ozone hole was largely the result of an unfortunate coincidence of erroneous Dobson values reported at the South Pole. (And note that Dr. Farman was likewise very cautious in checking his data before publication.) The myth that our computer code "threw out the data" is unfortunately very hard to correct without appearing defensive.

(signed) Dr. Richard McPeters

Abbreviations

NOVA	Name of a general science program on public television in the United States.
TOMS	Total Ozone Mapping Spectrometer: An instrument on the Nimbus-7 spacecraft that has been mapping ozone since October 1978.
DU	Dobson Unit: Equal to one milli-atm-cm of ozone.
AES	Canadian Atmospheric Environment Service: The organization that maintains the archive of world Dobson measurements.
IAGA	International Association of Geomagnetism and Aeronomy.
IAMAP	International Association of Meteorology and Atmospheric Physics.

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Binomial and Poisson Medians

Concerning the Letter to the Editor by X. He, published in the latest issue of *The IMS Bulletin* [Vol.19, No.3, May/June 1990, page 482], the results mentioned about binomial and Poisson medians are included in the paper entitled "Monotone convergence of binomial probabilities and a generalization of Ramanujan's equation" by Kumar Jogdeo and S. M. Samuels [*Ann. Math. Statist.* 39(1968):1191–1195]. Werner Uhlmann also obtained these results (independently of Jogdeo and Samuels) in the paper entitled "Vergleich der hypergeometrischen mit der Binomial-Verteilung" [*Metrika* 10(1966):145–158].

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