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Reply [to "Comment on 'The space shuttle's impact on the stratosphere' by Michael J. Prather et al."◆]

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Reply

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Aftergood [this issue] argues that in addition to the global-scale long-term perturbations studied by *Prather et al.* [1990], there is at least some evidence that the exhaust of a solid rocket can cause immediate large reductions in ozone, resulting in the formation of a local hole in the ozone layer. If this proposed rapid loss mechanism is having an impact on ozone large enough to be of real concern in terms of enhanced ultraviolet sunlight at the ground, it should be visible in the ozone image data from the total ozone mapping spectrometer (TOMS) on Nimbus 7. We have examined the ozone data record for evidence of rapid local decreases in ozone following a shuttle launch.

Nimbus 7 is in a south-north polar orbit with TOMS scanning across the orbital track in 35 individual ozone measurements every 8 s to produce an almost complete map of ozone each day. Since TOMS has an approximately 40-km-square field of view (FOV), a plot of every individual measurement produces an ozone image as shown in Plate 1. (The outermost scan positions, those at large cross-track scan angles, are shown with small gaps in the ozone record.) On August 30, 1983, the shuttle was launched at 0632 UT. The TOMS overpass used to produce Plate 1 was 10 hours later, at 1635 UT. Shuttle-tracking data show that the shuttle trajectory was not quite vertically aligned, that when it passed through the ozone layer at 25 km it was 9.2 km north and 18.5 km east of the launch site. In 10 hours the shuttle exhaust should have had time to spread enough to be visible at the TOMS resolution, and stratospheric winds could have carried the exhaust plume no more than a few hundred kilometers. Careful inspection of Plate 1 shows no evidence of reduced ozone anywhere near the launch site. A fairly sensitive color scale has been used here: steps of 12.5 DU. If ozone were depleted by 40% over an area a quarter the size of the TOMS FOV (i.e., $20 \times 20 \text{ km}^2$), the 120-DU reduction would have been measured by TOMS as a 30-DU average change, a shift of about three color steps. No such reduction is visible in either Plate 1 or Plate 2, a map of the same area the following day, 34 hours after launch. After 34 hours the plume should certainly be sufficiently dispersed to fill a TOMS FOV.

Plate 3 is a similar image for October 3, 1985. In this case, launch was at 1515 UT, while the TOMS image was made at 1616, only 1 hour after launch. If no ozone decrease is seen in Plates 1 and 2 because the shuttle exhaust disperses more quickly than we might expect, the 1-hour image should show the decrease, yet no decrease is apparent. Finally, we examined the ozone field after a recent winter launch, on February 28, 1990 (Plate 4). Again, no decrease is visible in this image 8 hours after launch. We examined images for five other launches with uniformly negative results.

The data presented here do not support the existence of a measurable localized depletion of ozone following a shuttle launch. One can argue that the ozone decrease takes place over such a small area that TOMS is not capable of detecting it, but then the question is whether a decrease so localized can be considered significant. Further, given the slant path of the launch as noted above, column-averaged perturbations to ozone cannot be more than tens of kilometers squared. The global-scale long-term decreases predicted by *Prather et al.* are too small to be readily detected by the simple analysis presented here and, if they are as small as predicted, probably could not be detected in TOMS data at all.

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Plate 1. The column ozone distribution 10 hours after a shuttle launch on August 30, 1983. The white bands are gaps of no data at large TOMS scan angles.

Plate 2. The column ozone distribution 1 day after the same launch.

Plate 3. Column ozone 1 hour after a launch on October 3, 1985.

Plate 4. Column ozone 8 hours after a winter launch on February 28, 1990.