Cloud Discrimination in Probability Density Functions of Limb Scattered Sunlight Measurements

E. N. Normand, J. T. Wiensz, A. E. Bourassa, and D. A. Degenstein
Institute of Space and Atmospheric Studies, University of Saskatchewan, Canada

We thank both reviewers for helpful and encouraging comments. We have addressed these with a revision of the paper and our reply to these comments in given in the text below, with reviewer comments in bold. The most significant change that we have made is to add a new set of modelled results to Figure 2 that show the scattering residual expected at the threshold optical depth for subvisible cirrus clouds, which helps to clarify the expected behaviour for cloud versus aerosol scattering.

Response to comments by Referee 2:

- **How is the local tropopause height calculated? There is no explanation and reference in the paper.**

  The local tropopause height is defined by the cold point tropopause and is calculated from European Center for Medium-Range Weather Forecasts (ECMWF) reanalysis interpolated in time and space to the position of the OSIRIS measurement. This explanation was added in Section 3.1 where reference to the local tropopause is first introduced.

- **Fig.1b: Where is the cloud top in that example?**

  The exact cloud top position detected in this particular example is at 16 km altitude. This is determined by applying the technique and overlaying the cloud-free threshold line from the PDF over the residual profile and noting the highest occurrence that exceeds the threshold line.

  However, the point of Figure 1 is to show the radiance measurement is greatly enhanced when a cloud is measured. The figure illustrates that for an optically thin atmosphere the radiance measurements in the cloud-free condition closely follow the concentration of the particles, and where clouds occur the measured signal is greatly enhanced.

- **Chapter 4.3: PDFs are calculated on a monthly basis. Then why not showing an example in Fig.2? Also in Fig.3 4-month averages are shown.**

  Figures 2 and 3 have been substituted for equivalent monthly plots.

- **Fig. 5: Tropopause heights can be as low as 7 km in the polar regions, which is the lowermost tangent height of the instrument (as said in the paper). Does this affect the detection of polar clouds? Why altitudes below 7km are then plotted in figure 5b?**

  The lower range of tangent height altitudes for most scans is around 7 km, however OSIRIS occasionally nods far enough to acquire scans as low as 4 to 5 km tangent altitude.

- **Fig. 6: Why the occurrence frequency above about 17 km is not close to zero? Is that the influence of aerosols?**

  As shown in the zonal average in Fig. 5(b), in the tropics particularly, there is a non-zero detection frequency and this is reflected in the profiles in Fig. 6. The detection

frequency goes to zero within approximately 5-10% for altitudes above 20 km in the tropics and for altitudes above approximately 15 km at high latitudes. This small remaining value is an indication of the uncertainty in the technique, which is like partly due to aerosols and the choice of the position of the threshold line on the PDFs.

- **Fig. 7: The patterns in the tropical regions are similar from year to year. But in the extratropical regions (roughly $> \pm 40^{\circ}$), there is a year to year variance. Is this explainable or is the method not that reliable there? Over Greenland the cloud frequency drops from about 50% to 10% within 4 years.**

  The year-to-year variance in middle to high latitude regions can be explained: There is more variance in cloud occurrence at middle and high latitude compared to the common occurrences of clouds in the tropical belt, namely those highly convective regions over Indonesia and the western part of the Pacific Ocean, Central and South America, and western-central Africa (Wang et al., 1996; Dessler and Sherwood, 2004; Fu et al., 2007; Sassen et al., 2009). The variance of cloud occurrence is naturally greater at higher latitudes. However it is true that the uncertainty in the technique increases with increasing latitude. As latitude increases, the cloud-free and cloudy PDF distributions, as in Figure 2, tend to merge at the lower tangent altitudes, which at these latitudes is closer to the tropopause, and increases the uncertainty in the technique. This is now noted in the paper.

- **Fig 1 and 3: the lines are too thin.**

  The lines in the figures were made thicker.

- **Fig 1: Is this one measurement or an average May-August? May07-Aug07 is confusing as a title.**

  The figure shows particular scans that were measured anytime within the four-month term from May to August 2007. Specifically, they were measured sometime in May 2007. The time interval was removed from the title and the caption was adjusted to explain when the scans were measured.

- **Fig 2: The y-Axis title: is it the tangent altitude? I think it is something like TH-TP bins.**

  The vertical axis is the tangent altitude measured with respect to the local tropopause. Thus, the local tropopause is at zero. The y-axis label was changed to *Tangent Altitude wrt Local Tropopause (km)*.

- **Fig 3: What is ROI?**

  ROI means Region of Interest. This explanation was added in the text and in the figure caption.