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MLS OBSERVATIONS OF LOWER STRATOSPHERIC ClO AND O_3 IN THE 1992 SOUTHERN HEMISPHERE WINTER

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Abstract. UARS MLS measurements of ClO in the 1992 southern hemisphere winter are described. Lower stratospheric ClO abundances greater than 1 ppbv were observed in the vortex beginning 1 June. The enhanced ClO reached largest areal extent in mid-August, then retreated poleward. ClO abundances at 22 hPa decreased in early September while those at 46 hPa remained high. O_3 decrease within the vortex was observed by mid-August, and was coincident with the enhanced ClO.

Introduction

Springtime loss of Antarctic O_3 [Farman et al., 1985] is due to enhanced chlorine chemistry triggered by processes on polar stratospheric clouds (PSCs) which form in the cold winter vortex [e.g., Solomon, 1990]. ClO, the dominant form of reactive chlorine that destroys O_3, has been observed in Antarctic regions in late winter and early spring at the approximate abundances to explain the O_3 loss [e.g., Anderson et al., 1989]. This letter presents lower stratospheric ClO and O_3 measurements made in the 1992 southern winter by the Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite (UARS). Waters [1993] describes the measurement technique.

Observations

MLS observed the 1992 southern winter between 1 June and 14 July, and between 14 August and 20 September. Maps were produced and analyzed for each day's data, except for 2–14 June when a UARS technical problem prevented observations. Figure 1 shows maps from selected days of ClO and O_3 retrieved on 22 and 46 hPa pressure surfaces, as well as the vertical columns represented by retrieval coefficients (see Waters et al., [1993]) for pressures of 46 hPa and less (corresponding to columns above ~70 hPa). Each map is made from measurements covering a 24-hour period on the 'day' side of the orbit. MLS data validation to date indicates individual measurement accuracies of ~0.4 ppbv for ClO, and ~0.3 ppmv for O_3, at these pressure surfaces.

Figure 2 shows the ClO and O_3 interpolated to 465 K potential temperature (θ), and related quantities. Temperatures in Figure 2 are from NMC, and the Rossby-Ertel potential vorticity (PV) was derived from NMC data [Manney and Zurek, 1993]. A 'liberal' boundary of the polar vortex, indicated by $PV = -2.5\times10^{-5}\,K\,m^2\,kg^{-1}\,s^{-1}$ [Manney et al., 1993], is the outer edge of red in PV maps.

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Time-series of ClO, O_3, and related quantities for the August and September measurements are shown in Figure 3. The ClO and O_3 values were obtained by integrating daily measurements throughout the vortex over $450K \leq \theta \leq 480K$ in the vertical [Manney et al., 1993].

Discussion

The 1992 southern lower stratosphere first cooled below 195 K around 10 May [Manney and Zurek, 1993], when PSCs could form and lead to conversion of HCl and $ClONO_2$ to Cl_2 [e.g., Solomon, 1990]. ClO enhanced to >1 ppbv was seen by MLS at the start of south-looking observations on 1 June (Figures 1 and 2). The enhanced ClO is consistent with PSC-processed air being in sunlight, which converts Cl_2 to ClO, and maintains high ClO and related O_3-destruction cycles. Enhanced ClO occurs within the polar vortex (small isolated patches outside are under investigation, and instrument noise could produce occasional spurious values of their magnitude). Less ClO is seen where the measurement solar zenith angle is greater than ~90°, as expected since there is less (or no) photolysis of the ClOOCl formed from ClO recombination, and temperatures are too low for significant ClOOCl thermal decomposition (see discussion in Waters et al. [1993]).

ClO increased during the early winter and by mid-August ~2 ppbv ClO is seen at 22 and 46 hPa in most of the region poleward of 60° S. The outer boundary of enhanced ClO at θ=465 K generally follows PV contours; the inner boundary is near the edge of daylight, consistent with expected chemistry. The 'gap' in the ClO distribution near 180° longitude on 17 August occurs where PV contours indicate air with enhanced ClO moves nearer darkness where decreased photolysis of ClOOCl causes less ClO. The ClO 'notch' east of the Antarctic peninsula on 1 September, however, is not believed due to ClOOCl as the more poleward measurements on that day occur later in the morning at higher sun (see 'lst' and 'sza' maps in Figure 2) where more, not less, ClO would be expected from the photochemistry. The 'notch' is apparently due to dynamics of the enhanced ClO outer boundary (PV contours show meridional deflections in its general vicinity), and its evolution can be followed in maps over a few days (not shown). Ricaud et al. (to be submitted to GRL, 1993) discuss ice clouds in western Antarctica during this time period, and their potential effect on ClO.

The enhanced ClO outer boundary retreated poleward in late winter (Figures 1 and 2), and the ClO abundance at 22 hPa decreased greatly during 1–17 September. Vortex-integrated ClO at 465 K decreased between 25 August and 20 September, at the same time that the area in the vortex with temperatures above the PSC thresholds was increasing (Figure 3). The decrease in total ClO during this period suggests that, overall, it was affected more by increasing photolysis of HNO_3 (releasing NO_2 which quenches

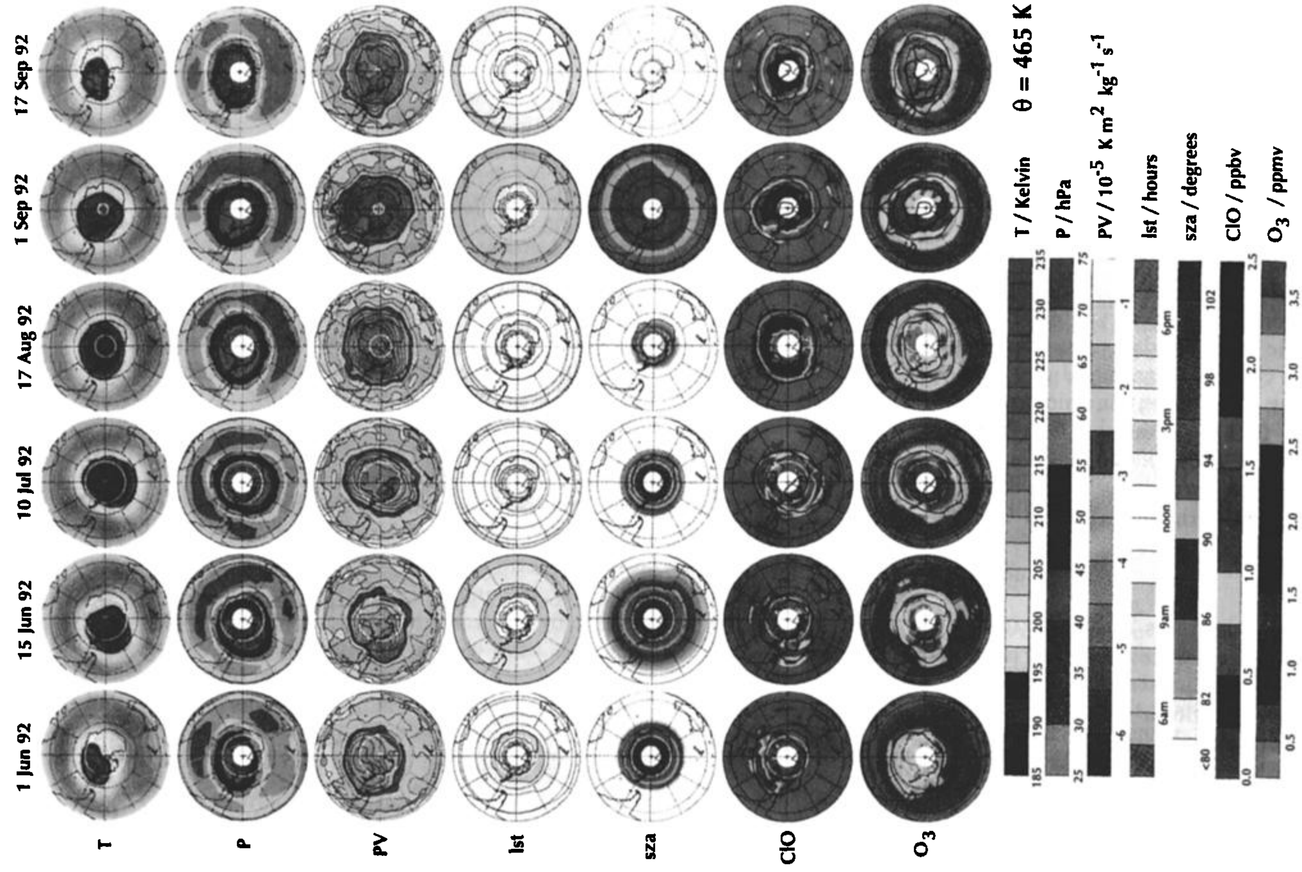

Fig. 2. (continued)

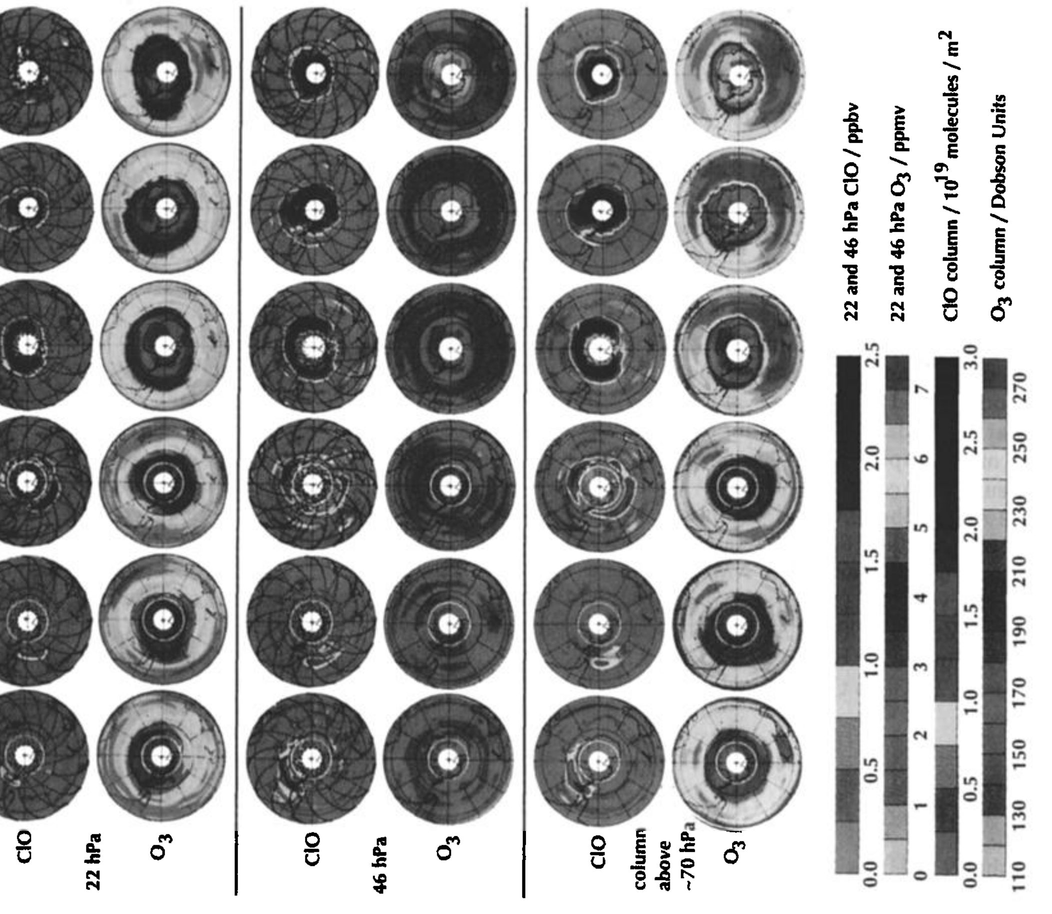

Fig. 1. (continued)

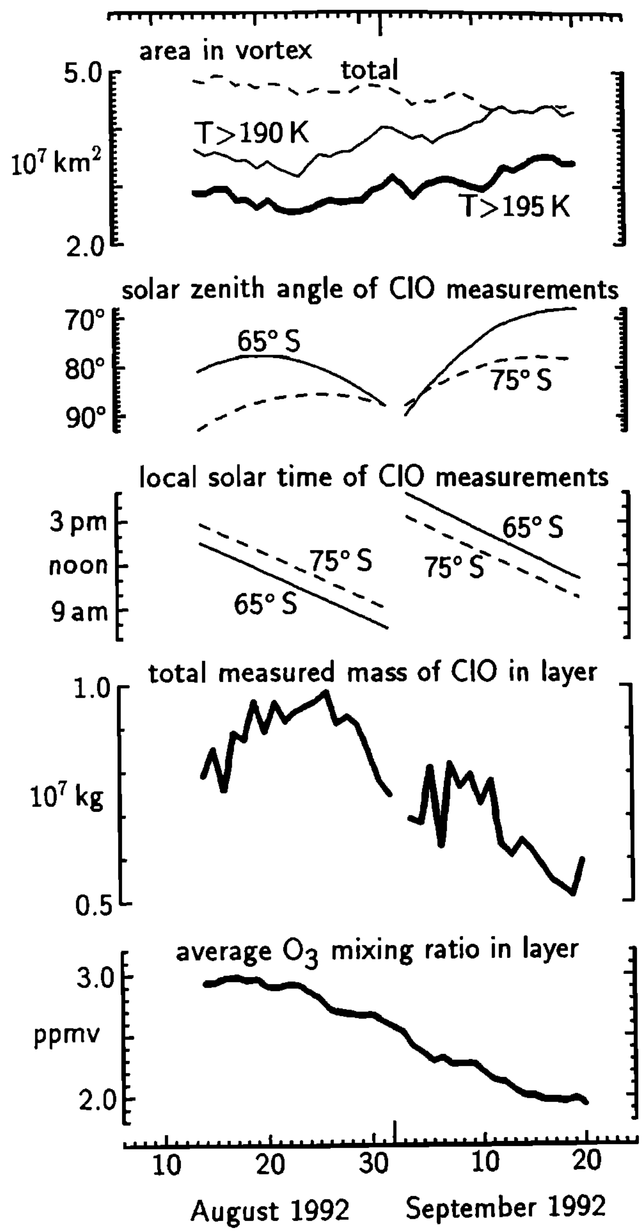

Fig. 3. Temporal variation of quantities in a layer at 465 K potential temperature within the south polar vortex during August and September 1992, where the vortex boundary is taken as the -2.5×10^{-5} K m^2 kg^{-1} s^{-1} potential vorticity contour. Breaks in the curves in the middle panels are where the 'day' side of the orbit for MLS measurements switched from south-going to north-going.

ClO) than by increasing photolysis of ClOOCl (which produces ClO). CLAES shows high 'collars' of $ClONO_2$ and HNO_3 outside the region of enhanced ClO, with HNO_3 decreasing and $ClONO_2$ increasing during this period [Roche et al., 1993] as expected for conversion of ClO to $ClONO_2$ by NO_2 released from HNO_3. The September decrease in 22 hPa ClO is being investigated: the ClO abundances decreased greatly at $\theta \sim 550$–650 K (not shown), but remained enhanced at ~465 K (Figure 2).

The June and July maps in Figure 2 show increasing O_3 in the early winter vortex at 465 K, when enhanced ClO is seen in the sunlit regions. Our data appear consistent with diabatic descent of O_3-rich air from above, and O_3 influx into the region in early winter apparently masks chemical loss expected from the enhanced ClO seen during that time. The O_3 mixing ratio at 465 K within the vortex decreased between mid-July and mid-August (Figure 2). A 'ring' of low O_3 generally coincident with highest ClO is seen in the 17 August map. Vortex-integrated O_3 at 465 K dropped steadily from mid-August through late September (Figure 3), and large loss of O_3 coincident with enhanced ClO is evident in the 1 and 17 September maps (Figure 2). The three-dimensional evolution of southern hemisphere O_3 during August–September 1992 is discussed further by Manney et al. [1993] and Fishbein et al. [1993].

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References

Anderson, J. G., W. H. Brune, and M. H. Proffitt, Ozone destruction by chlorine radicals within the Antarctic vortex: the spatial and temporal evolution of ClO–O_3 anticorrelation based on in situ ER-2 data, *J. Geophys. Res.*, 94, 11,465–11,479, 1989.

Farman, J. C., B. G. Gardiner, and J. D. Shanklin, Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction, *Nature*, 315, 207–210, 1985.

Fishbein, E. F., L. S. Elson, L. Froidevaux, G. L. Manney, W. G. Read, J. W. Waters, and R. W. Zurek, MLS observations of stratospheric waves in temperature and O_3 during the 1992 southern winter, *Geophys. Res. Lett.*, this issue, 1993.

Manney, G. L. and R. W. Zurek, Interhemispheric comparison of the development of the stratospheric polar vortex during fall: a 3-dimensional perspective for 1991–92, *Geophys. Res. Lett.*, this issue, 1993.

Fig. 1. ClO and O_3 from MLS on selected days during the 1992 southern winter for retrieval coefficients at 22 and 46 hPa, and the column (above ~70 hPa) represented by the retrieval coefficients at 46 hPa and lower pressures. The map projection is orthographic with Greenwich meridian at the top. Latitude circles are drawn at 30° and 60° S; the thin white circle locates the polar night edge. Symbols in the 22 and 46 hPa ClO maps show MLS measurement locations.

Fig. 2. Various quantities on the 465 K potential temperature surface for selected days during the 1992 southern winter: temperature (T), pressure (P), potential vorticity (PV), local solar time (lst) and solar zenith angle (sza) of MLS measurements, ClO and O_3. PV contours of -3×10^{-5} K m^2 kg^{-1} s^{-1} and -5×10^{-5} K m^2 kg^{-1} s^{-1} are superimposed on the ClO and O_3 maps.

Manney, G. L., L. Froidevaux, J. W. Waters, L. S. Elson, E. F. Fishbein, R. W. Zurek, R. S. Harwood, and W. A. Lahoz, The evolution of ozone observed by UARS MLS in the 1992 late winter southern polar vortex, *Geophys. Res. Lett.*, this issue, 1993.

Roche, A. E., J. B. Kumer, and J. L. Mergenthaler, CLAES observations of $ClONO_2$ and HNO_3 in the Antarctic stratosphere between June 15 and September 17, 1992, *Geophys. Res. Lett.*, this issue, 1993.

Solomon, S., Progress towards a quantitative understanding of Antarctic ozone depletion, *Nature*, 347, 347–354, 1990.

Waters, J. W., Microwave Limb Sounding, chapter 8 in *Atmospheric Remote Sensing by Microwave Radiometry*, edited by M. A. Janssen, John Wiley & Sons, New York, 1993.

Waters, J. W., L. Froidevaux, W. G. Read, G. L. Manney, L. S. Elson, D. A. Flower, R. F. Jarnot, and R. S. Harwood, Stratospheric ClO and ozone from the Microwave Limb Sounder on the Upper Atmosphere Research Satellite, *Nature*, 362, 597–602, 1993.

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