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3.5 EVIDENCE OF CO_2-INDUCED PROGRESSIVE COOLING OF THE MIDDLE ATMOSPHERE DERIVED FROM RADIO OBSERVATIONS

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Reflection heights of low-frequency radio waves in midlatitude summer, which are closely associated with the neutral atmosphere isobaric level of 0.0052 hPa, exhibit a statistically significant downgoing trend from 1962 through 1987. This indicates a systematic decrease of air pressure at 80 km height by 10.3 ± 4.9% over this period, to be regarded as a sufficient evidence of a true signal of progressive cooling of the middle atmosphere, expected with the growing content of CO_2 and other "greenhouse" gases in the atmosphere. It is quantitatively consistent with a temperature decrease at the stratopause by about 4 K, as predicted by the recent model of interactive greenhouse and ozone processes of Brasseur and de Rudder [1987].

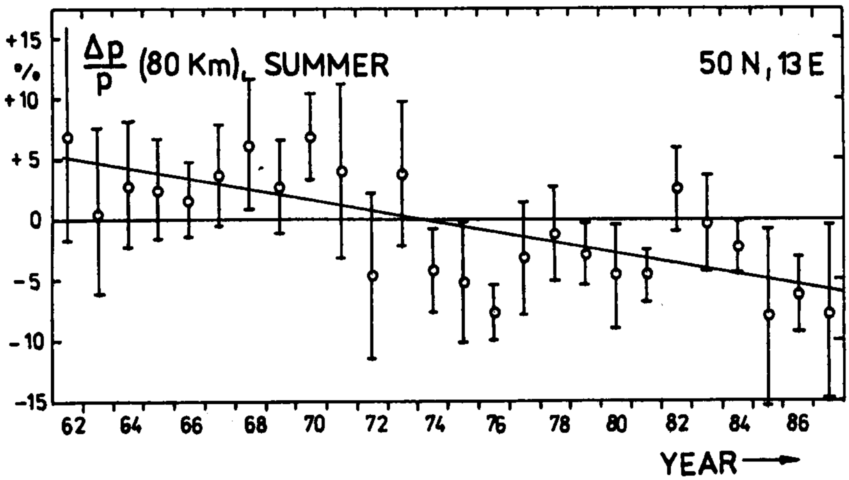

Figure 1. Mean values of air pressure at 80 km altitude in summer half-years (April-September) 1962 through 1987, determined from low-frequency radio wave reflection height measurements for the geographic location 51°N, 13°E, after eliminating the solar-cycle variation. Values are expressed as percentage deviations from the long-term average. Error bars indicate the 95% confidence limits. Analysis uses the straightforward connection of radio wave reflection heights with an isobaric surface, if nitric oxide content is sufficiently constant. Winter variability of NO near the mesopause is avoided by taking summer months only, a possible long-term NO trend causes only minor modification of the results.

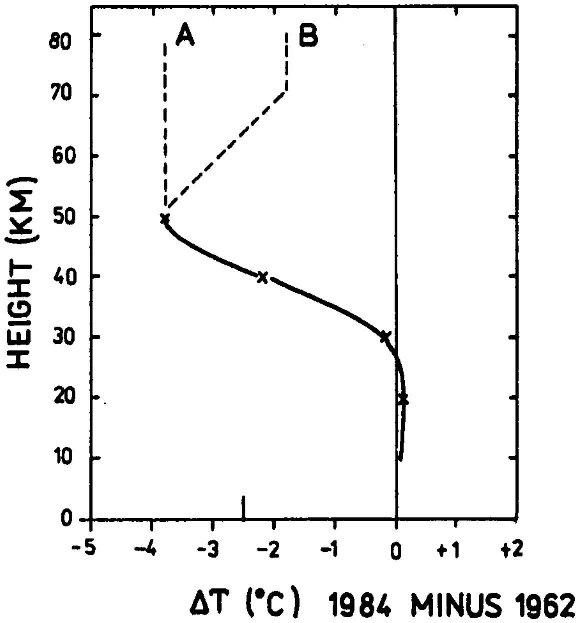

Figure 2. Temperature change in the middle atmosphere between 1962 and 1984 as predicted by the model of Brasseur and de Rudder (crosses), with two optional arbitrary extensions up to 80 km. The one-dimensional Brasseur-de Rudder model (its scenario No. 5c being adopted here) takes into account CO_2 greenhouse processes together with stratospheric ozone decrease. Using the barometric formula, options A and B produce pressure decrease at 80 km by 9.6 and 6.7%, respectively, in good agreement with the observations shown in Figure 1.