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# No. 94 SOLAR COMPARISON SPECTRA, 1.0–2.5μ, FROM ALTITUDES 1.5–12.5 km

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ABSTRACT

Infrared spectra of planets and stars taken from aircraft require solar calibrations showing the telluric spectrum in its dependence on the altitude of observation. In addition, since numerous solar lines are present as well, the blending of these with the telluric spectrum must be known in the analysis of the planetary spectra. The latter contain the same blends, in turn superposed on the absorption spectrum of the planetary atmosphere. This paper reproduces the solar spectra obtained on June 23, 1967, with the NASA 990 Jet and the Block interferometer, the same equipment used in the observation of Venus and Mars. The records were made from various altitudes; the increment is 5000 ft (1.5 km) up to 35,000 ft, with 1000 ft (0.3 km) increments near the ceiling altitude of 41,000 ft (12.5 km). Attention is called to the remarkable internal agreement of the records testifying to the excellent performance of the Block interferometer.

While the normal procedure of observing planetary spectra from the NASA CV 990 Jet has been to include lunar calibration spectra with the planetary spectral runs, it was, nevertheless, felt that direct solar observations from different altitudes would prove indispensable. The sunlight was observed through the borosilicate crown window, 12 × 14 in. in size, moved from its normal position in the 65° window port, to one of the ceiling ports of the aircraft. The sunlight fell on a screen freshly coated with magnesium oxide, and the interferometer was pointed directly at the MgO screen without intervening telescope. Because of the gradually decreasing reflectivity of MgO beyond 2.0 μ and because of the absence of the four reflecting surfaces used in the planetary observations (heliostat, two aluminized telescope mirrors and a 90° mirror near the focus), the distribution of the continuum in the solar spectra is not strictly comparable with that of the planetary and lunar observations published elsewhere in this series. The differences will not be large, however, and of no consequence for the purposes of this study, which is to provide high precision records of the solar and telluric absorption features with the precise resolution used in the planetary spectra. The times of observation are found in Table 1 together with the geographic longitude and latitude of the aircraft, the hour angle of the sun and its altitude above the horizon, the zenith distance, the air mass, and the outside temperature. The observations were conducted by Mr. Steinmetz alone; the analysis of the spectra shown in the figures was made by Dr. Kuiper. The records were made on magnetic tape, as usual; the interferograms were co-added by Mr. I. Coleman at Block Associates who also performed the computation of the spectra and the machine plotting of the results. We are deeply indebted to Mr. Coleman for his interest and competent handling of this phase of the operations.

The figures herewith reproduced show, without any retouching whatever, the original spectral traces. We have added single dashes denoting solar line

TABLE 1

NASA CV 990 SOLAR FLIGHT, JUNE 23, 1967

| ALT (1000 FT) | UT | LONG. | LAT | $H_\odot$ | ALT.$_\odot$ | $Z_\odot$ | SEC $Z_\odot$ | OUTSIDE TEMP C | CABIN ALT (1000 FT) | FIG. NO. |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | $18^h42^m$ | 121.40 | 37.70 | $1^h26^m$ | 66°44′ | 23°16′ | 1.089 | — | — | 1 |
| 10 | 18 51 | 120.65 | 38.00 | 1 14 | 68 49 | 21 11 | 1.072 | +11 | — | 1 |
| 15 | 19 00 | 119.55 | 38.45 | 1 00 | 70 17 | 19 43 | 1.062 | +03 | — | — |
| 25 | 19 09 | 118.30 | 38.90 | 0 46 | 71 31 | 18 29 | 1.054 | −22 | — | — |
| 30 | 19 19 | 116.90 | 39.40 | 0 31 | 72 43 | 17 17 | 1.047 | −32 | 5 | 3 |
| 35 | 19 35 | 116.45 | 40.05 | — | 73 10 | 16 50 | 1.045 | −48 | 8 | 3 |
| 38 | 19 44 | 117.95 | 40.00 | — | 73 16 | 16 44 | 1.044 | −54 | 8 | 3 |
| 39 | 19 50 | 118.80 | 40.00 | — | 73 22 | 16 38 | 1.044 | −54 | 8 | 4 |
| 40 | 19 58 | 119.90 | 39.99 | — | 73 29 | 16 31 | 1.043 | −54 | 9 | 4 |
| 41 | 20 04 | 120.75 | 39.85 | — | 73 34 | 16 26 | 1.043 | −54 | 9 | 4 |
| 25 | 20 26 | 123.55 | 39.15 | 0 10 | 74 02 | 15 58 | 1.040 | −25 | 6.8 | 2 |
| 20 | 20 35 | 122.95 | 38.25 | 0 21 | 75 00 | 15 00 | 1.035 | −02 | — | 2 |
| 15 | 20 44 | 122.50 | 37.50 | 0 32 | 74 22 | 15 38 | 1.038 | +01 | 1 | 2 |

absorptions, with the members of the Paschen and Bracket series identified. Nearly all of the remaining identifications may be taken from "An Atlas of the Infrared Solar Spectrum from 1 to 6.5 $\mu$ Observed from a High-Altitude Aircraft," by J. T. Houghton, N. D. P. Hughes T. S. Moss, and J. S. Seeley, 1961 (*Phil. Trans. Roy. Soc. London*, **254**, 47–123).

The series of solar spectra demonstrates very graphically the tremendous importance of spectral observation in the infrared from altitudes above 40,000 ft (12 km). The spectra taken at 5000 and 10,000 ft (1.5 and 3.0 km) may be regarded as typical for what can be done from a mountain observatory under average and excellent conditions, respectively. The spectrum taken at 15,000 ft represents what has been achieved at the mountain observatories in the southwestern United States during the coldest parts of winter, after an invasion of an Arctic air mass. Even this condition is very far from achieving the almost complete absence of water-vapor absorptions around 40,000 ft (12 km). At the same time, of course, the $CO_2$ absorptions are greatly reduced. The spectra also demonstrate, as had been anticipated from the moisture profile in the atmosphere discussed elsewhere in this series, that no appreciable further gains can be expected by going still higher. This conclusion is not expected to hold for the heaviest absorptions of water vapor at still longer wavelengths nor for the strongest absorptions of $CO_2$, $CH_4$, and $N_2O$ at longer wavelengths. This may be seen from the atlas by Houghton, *et al.* referred to above.

A quantitative review of the telluric $H_2O$ absorptions shown by the records will be published elsewhere.

*Acknowledgments.* The work here reported was made possible by the facilities of the NASA CV 990 Jet and its expert staff. The spectral observations themselves were made with the Block interferometer graciously made available by its owner, Mr. Lawrence Mertz. As mentioned in the text, the reductions were carried out with the facilities at Block Associates by Mr. Isaiah Coleman, to whom we are deeply indebted. The high-altitude program was supported by a grant by the Space Sciences Committee of the University of Arizona.

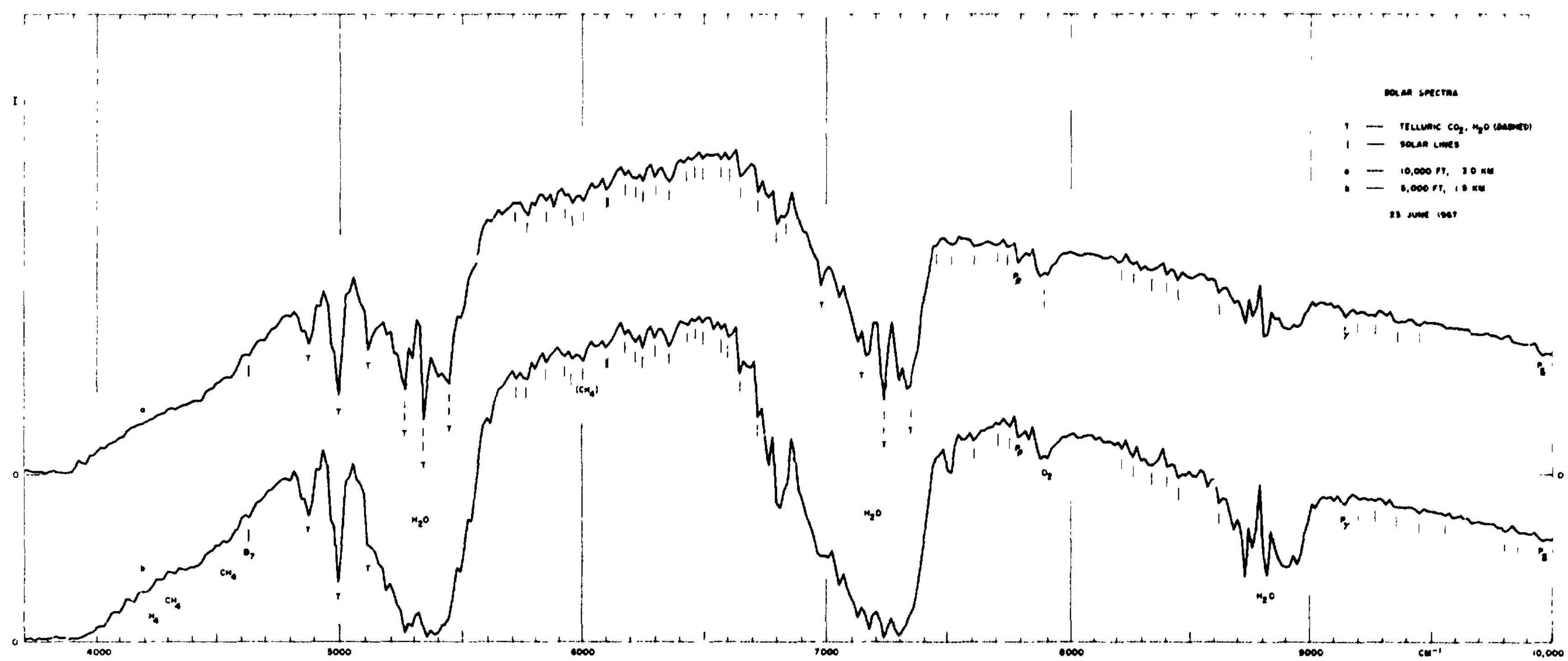


*Fig. 1* **Solar spectra observed from 1.5 and 3.0 km (5,000 and 10,000 ft).**

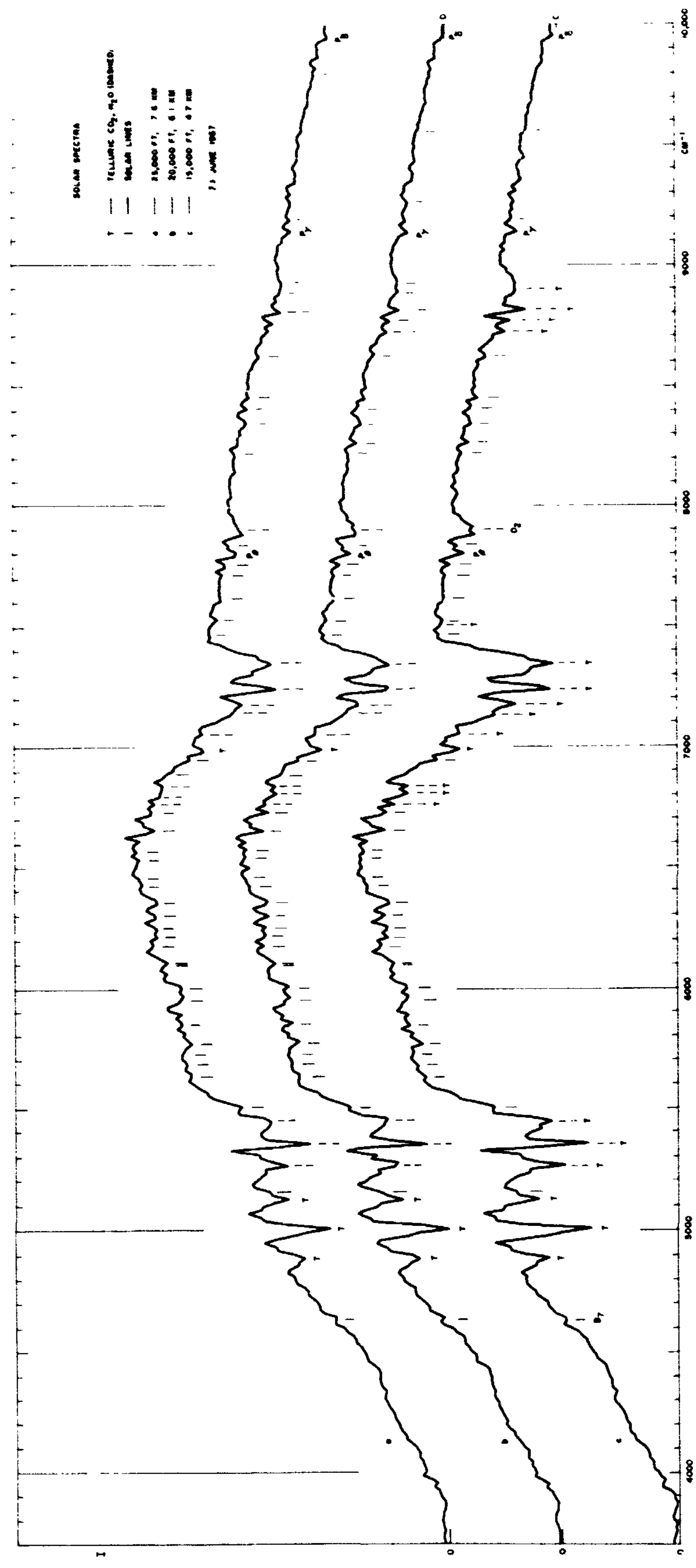

*Fig. 2* Solar spectra observed from 4.7, 6.1, and 7.6 km (15,000, 20,000, and 25,000 ft).

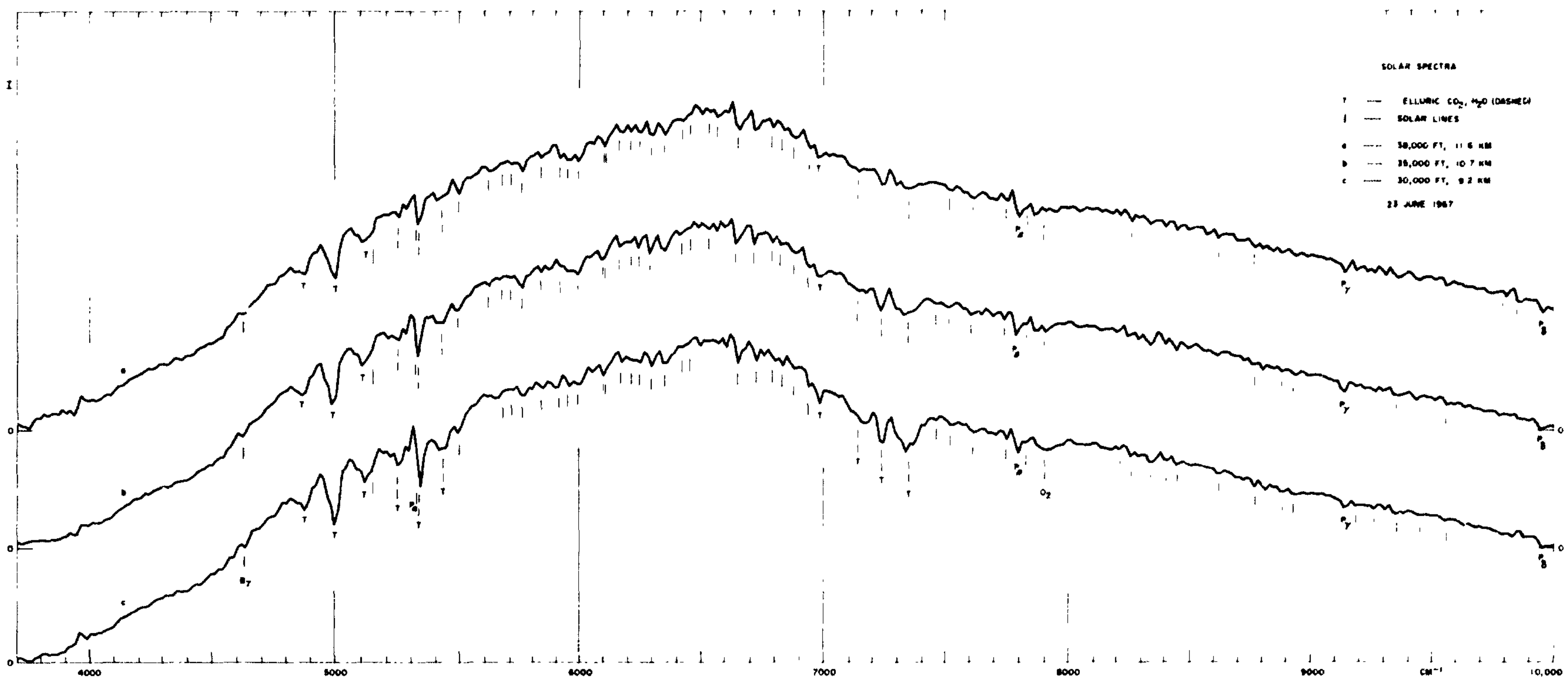


*Fig. 3* **Solar spectra observed from 9.2, 10.7, and 11.6 km (30,000, 35,000, and 38,000 ft).**

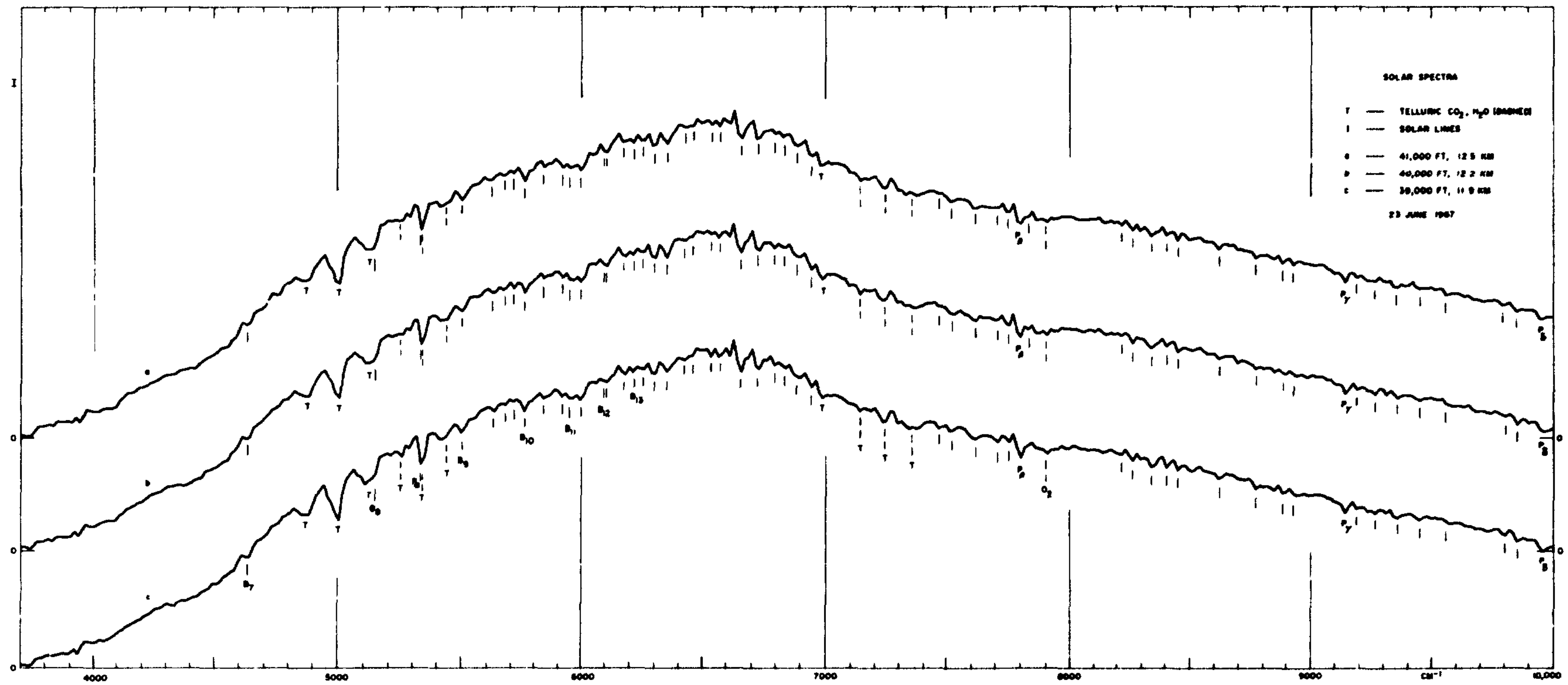


*Fig. 4* **Solar spectra observed from 11.9, 12.2, and 12.5 km (39,000, 40,000, and 41,000 ft).**