Evidence of the Dependence of Reflected Solar Radiation on Viewing Geometry in a TIROS IV Radiation-Data Sample¹

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1. Introduction

Recent experimental data (*e.g.*, Kozlov and Fedorova, 1962) and theoretical data (*e.g.*, Deirmendjian, 1964) have emphasized the dependence of solar radiation scattered and reflected by cloud surfaces and atmospheric aerosols on the sun angle and the viewing angle. Evidence of the anisotropy of solar radiation reflected by the earth and its atmosphere has been found in the measurements from the solar reflectance channels of TIROS III by Larsen *et al.*, (1963) and by Viezee *et al.*, (1964), from analyses of data samples obtained when the earth-scanning pattern of the TIROS radiometer was an alternating open mode (during the alternating open mode, scan spots on the earth are

obtained alternately from views through the floor side and the wall side of the satellite). Both cases suggest that additional analyses of alternating open mode data may accumulate useful information on the directional dependence of reflected solar radiation and its effect on the interpretation of TIROS daytime measurements. This note presents the results from an analysis of alternating open mode data from TIROS IV.

2. Data analysis

The selected TIROS IV data from Channels 3 and 5 (reflected solar radiation in the intervals 0.2–6.0 microns and 0.55–0.75 micron, respectively) were obtained during Orbit 3, 8 February 1962, between 1750 and 1804 GMT. During this time period the earth-scanning pattern of the radiometer changed from a single open mode through the wall side of the satellite, to an alternating open mode, back to a single open mode

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FIG. 1. Isopleth analyses of alternating open mode data from Channel 3, TIROS IV, Orbit 3, 8 February 1962, 1757 GMT-1804 GMT. (a) Data from "floor" view. (b) Data from "wall" view.

through the floor side of the satellite (Staff Members, Goddard Space Flight Center, 1963). Because of the intermediate alternating directions of view, over certain regions the scanlines from the floor sensor overlapped those obtained previously through the wall sensor, with a time delay of 3 to 4 minutes. Since the solar zenith angle and the state of the atmosphere remain essentially unchanged during this short time period, differences between the overlapping Channel 3 and Channel 5 data may be thought of as due to differences between the "wall" and the "floor" directions of earth-viewing.

Fig. 1 displays analyses of the overlapping Channel 3 data. Isopleths were constructed after all scan-spot locations and corresponding values of effective radiant emittance (watts per square meter) were handplotted from the standard radiation-data listings. The data of Fig. 1a were obtained through the floor side with

FIG. 2. U. S. Weather Bureau analysis of surface fronts, sea-level isobars (mb) and precipitation patterns for 8 February 1962, 1800 GMT in area of radiation-data analysis.

earth-scanning directions generally toward the west. The patterns of Fig. 1b were analyzed from data obtained about 3 to 4 minutes earlier for the same area through the wall side, while earth-scanning in directions toward the east. The isopleths of local solar zenith angle, superposed on the analyses of Fig. 1, indicate the general direction of the sun.

A comparison between the two analyses shows distinctly the "brightening" that takes place in the southeastern part of the data-area, when the radiometer views the earth through the wall side in the general direction of the sun. Since the brightening is clearly evident in the large-scale patterns, it is unlikely that local differences in the backgrounds seen through the floor and wall sides are responsible. The spatial resolution of the radiometric view varies with the nadir angle of the radiometer. At each point in the area of "brightening," overlapping data from the floor and wall views were associated with nadir angles that differed by less than five degrees. The zero isopleth of radiometric-nadir angle difference is indicated by a heavy dashed line (lettered A through F) in Figs. 1a and 1b. Along this isopleth of mutual floor-wall background the "brightening" does not appear to be reduced. Continuity in rectification seems to be satisfactory judging from a comparison of patterns in the Pacific Ocean where distortion due to brightening is small.

The spatial variability of the amount and type of cloudiness in the area of the radiation-data analysis cannot be determined with certainty, since television cloud photographs cannot be obtained during alternating open mode. However, some information as to what the sensors are viewing can be inferred from the U. S. Weather Bureau analysis of Fig. 2, based on the

FIG. 3. Variation of the Channel 3 and Channel 5 "apparent planetary albedo" for "floor" and "wall" view along the zero isopleth of radiometric-nadir angle difference (α -radiometric-nadir angle; θ -solar zenith angle; ψ -scattering angle).

conventional network of hourly surface reports. The viewed background conditions vary from A through F. Frontal precipitation is analyzed between C and F. Around point B, a decrease in cloudiness can be inferred from the plotted ship reports of cloud cover that show 4/10 to 5/10 coverage of stratocumulus. Cloud cover increases again toward A, judging from the ship report of 10/10 stratocumulus just to the north. These inferred conditions are consistent with the relative changes in effective radiant emittance shown in the Channel 3 data analyses of Fig. 1: relatively low values are found around B, increasing toward the areas of analyzed precipitation.

Fig. 3 illustrates the variation of grid-averaged Channel 3 data from both the floor and wall sides along the zero isopleth of radiometric-nadir angle difference. Listings of effective radiant emittance have been converted to "apparent planetary albedo." Solid dots and open circles represent albedos that were obtained by

averaging data points within a 2-by-2-degree latitude grid centered at each of the indicated points, A through F. Points have been connected by straight lines for convenience of presentation. Results from a similar analysis of the Channel 5 data are shown also. The radiometric-nadir angles (α), the solar zenith angles (θ) and the scattering angles (ψ) are given at the bottom of the figure. At each lettered point the solar zenith angle and the radiometric-nadir angle are identical for both "wall" and "floor" views, but the scattering angles differ. For both Channels 3 and 5, lowest albedos are found at B, located in region of relative minimum cloudiness. Highest albedos occur in the area of frontal precipitation in the southwestern United States. The outstanding feature in the figure, is the large difference between "wall" and "floor" albedo in the area of the southwestern United States. For the points D, E, and F, the scattering angles that are associated with the "wall" direction of viewing are between 52° and 60°, while those associated with the "floor" direction of viewing are between 77° and 86°. It is noteworthy that for each of these three points, the larger "wall" albedo corresponds to the smaller scattering angle, which may indicate the effects of large forward scattering solar radiation by the viewed background (mostly clouds for this data sample).

3. Conclusions

The large increase in Channel 3 and Channel 5 albedo observed over the southwestern United States with a change from "floor" viewing to "wall" viewing suggests that a consideration of viewing geometry is an important factor in the interpretation of reflected solar radiation data from TIROS. The analysis suggests that the change in albedo is predominantly due to a change of earth-viewing directions with respect to the direction of solar illumination, although only limited information on the angular dependence of reflected solar radiation can be deduced from a single data-sample. Contributions to the apparent brightening from uncertainties in the scan-spot locations, irregularities in the illumination of the viewed background (especially for partial cloudiness), and residual uncertainty in the radiometric calibrations for both the wall and floor views, have not been entirely eliminated in the analysis, but are judged to be of secondary importance.

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