## Reply

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Two points are made by Capt. Kern in his comment on our paper (Nordberg *et al.*, 1962). One, that our statement that the temperature measured by the satellite over the African Desert region "is probably very close to the surface temperature," is incorrect and two, that the measurements presented by us do not reflect very low water vapor content over the African Desert. We believe that Kern is correct in pointing out that actual ground temperatures of the African desert should be higher than the effective blackbody radiative tem-

peratures measured in the "window" channel and given in our paper. We still believe, however, that the TIROS Data as well as applicable radiosonde soundings indicate that the total water vapor content in the atmosphere over the African desert in this case is very probably lower than over all other regions quoted in our paper.

An inference of the water vapor content at higher altitudes over the African desert should be made from the 6.3-micron channel data rather than from the window channel data. The 6.3-micron channel, which is most sensitive to moisture in the atmosphere, indicated an equivalent blackbody temperature of 260K over the desert, which is about 13 deg higher than the temperature in the same channel over the tropical ocean. Over Africa, the temperature in this channel decreases rapidly and considerably as we progress toward the Libyan Uplands and Northwestern Sudan where the photographs still indicate clear skies. Since we may assume that the temperature profile in the stratosphere and upper troposphere is similar in all these regions, we conclude that a difference in the water vapor content is primarily responsible for this large temperature difference. Furthermore, balloon soundings made at approximately the time of TIROS III passage and in the general vicinity of the areas under consideration indicate that the water vapor over the tropical Atlantic Ocean varies from a mixing ratio of 19.0 g $kg^{-1}$ near the surface to 1.0 g $kg^{-1}$ at 400 mb. Over the African Desert radiosonde data corresponding to the time of satellite passage were not available, but a sounding taken over Aoulef, Algeria, at 1200 GMT on 25 August 1960 was taken as typical of the summer African Desert near noon and used in several subsequent calculations. In this sounding, the water vapor mixing ratio varied from 4.1 g $kg^{-1}$ at the surface to 0.24 g $kg^{-1}$ at 400 mb (considerably lower than over the Atlantic Ocean).

Regarding the difference between the measured equivalent blackbody temperature and true surface temperature, one must consider that a portion of this difference is excessive and cannot be accounted for. This fact was tacitly implied in our paper but not spelled out.

One of us (W. R. Bandeen) has calculated the energies which should be transmitted to the satellite, using the water vapor and temperature profiles over the respective areas from these soundings, and the absorption coefficients and methods given by Wark *et al.* (1962). Over the tropical Atlantic Ocean an equivalent blackbody temperature of 287K should have been obtained for a measured ocean temperature of 301K. The satellite gave an average temperature of 276K in the window channel, which is approximately 11 deg below the calculated value. Whether this deficiency is due to our insufficient knowledge of absorption by water vapor in this spectral region or due to additional absorbing agents in the atmosphere, is not known at this time. In the case of the African desert, Bandeen's calculations show that a surface temperature of 320K was necessary to account for the equivalent blackbody temperature of 309K measured by the satellite. This again was obtained by using the radiosonde water vapor and temperature profiles.

Unfortunately, no measurement exists of the true surface temperature over the desert at the time of satellite passage. At the time of writing our paper we believed a true sand temperature of about 320K to be reasonable. This had led us to the conclusions of no *unaccountable* energy deficiency over the low water vapor desert region while over the Atlantic Ocean, as Bandeen's calculations show, an energy of about 8 watts $m^{-2}$ (11K) is unaccounted for. (See Table 1). This is about 35 per cent of the energy difference in the "window" channel between the radiant emittance from the surface and the emittance observed at the satellite.

We are now inclined to believe that the upper limit of the temperature range quoted by Kern (60C = 333K) is a better estimate of the surface temperature. From Table 1, it may be seen that Bandeen in this case computed a temperature of 318K to be measured by the satellite. Thus, we now conclude that even over the desert, still with a very low water vapor content, an unaccounted energy deficiency of 10 watts $m^{-2}$ exists (Table 1). This is again about 35 per cent of the total energy difference in this channel. This *unaccountable* energy deficiency is approximately the same as that over the Atlantic Ocean. However, since we still think the water vapor contents over the two areas were quite different, it is not necessarily true that this deficiency is largely due to water vapor. Messrs. Suomi, Moeller and Fritz, among others, have suggested to the writers that dust layers in the upper troposphere, aerosols, or thin cirrus clouds (not susceptible to observation by the TIROS photographs) may contribute to the atmospheric absorption and re-emission, but are not contained in the calculations.

TABLE 1. Radiant emittance in "window channel" of TIROS III (watts per square meter).

| | From surface | Seen by satellite (computed) | Seen by satellite (measured) |
|---|---|---|---|
| Desert (Case I) | 89 (320K) | 76 (309K) | 76 (309K) |
| Desert (Case II) | 104 (330K) | 86 (318K) | 76 (309K) |
| Atlantic Ocean | 66 (301K) | 51 (287K) | 43 (276K) |

We must emphasize that the TIROS radiometer does not have an onboard calibration, and hence, our remarks above assume that no changes occurred in the instrumental response within the first nine days after launch. Statistical investigations employing large quantities of data and using the earth itself for a check-of-calibration are now under way, looking for possible instrumental

changes which might be reflected in our results. As of this writing, there is some evidence that part, but not all, of the "unaccountable" energy deficiencies may be instrumental in nature. These investigations are progressing, and we plan to report on them in the near future.

REFERENCES

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