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A NOTE ON THE EFFECT OF REFLECTED SOLAR RADIATION ON AIRBORNE AND GROUND MEASUREMENTS IN THE THERMAL INFRARED

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
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Victor S. Whitehead
Manned Spacecraft Center
Houston, Texas

ABSTRACT

The magnitude of thermal solar radiation reflected from water surfaces is considered. It is shown both theoretically and by field observation that, for instruments with small fields of view, the reflected thermal solar radiation can contribute significantly to the measured energy. Comparison of thermal scanner data taken from aircraft at a 16° azimuth angle from the mirror point of the sun over the open ocean with data taken at a 164° azimuth angle from the mirror point of the sun at the same angle from nadir is indicative of a difference of 2.8° K in the equivalent black-body radiation temperature. Observations taken from a surface vessel into sunglint 80° from nadir are indicative of an equivalent black-body radiation temperature that is 34° K warmer than the temperature obtained at a similar nadir angle away from the sunglint.

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SUMMARY

Theoretically, reflected solar radiation from a plane water surface can contribute significantly to the energy measured by thermal sensors with small fields of view. In nature, a water surface is rarely plane; therefore, the reflected energy can be diffused considerably. Airborne measurements over open ocean, however, are indicative that the difference between the equivalent black-body radiation temperature on the sunlit side (azimuth angle departure from sunglint between 3° and 16°) and on the side away from the sun ranged from 1.2° to 3.2° K for a nadir angle from 22° to 30°. From a surface vessel, the equivalent black-body radiation temperature directly into sunglint at a nadir angle of 80° was 34° K warmer than that observed at the same nadir angle away from sunglint.

INTRODUCTION

A crossover point exists at a wavelength of approximately 0.0004 centimeter (4 microns) in curves that compare spectral flux originating in the sun and recorded from a distance of 1 astronomical unit, and that originating in the earth and measured from a short distance away from the earth. At wavelengths between 0.0008 and 0.0014 centimeter (8 and 14 microns) in the thermal window, 50 to 400 times as much upwelling flux from the earth as downward flux of solar origin passes through a unit area. This predominance of thermal flux originating in the earth and the earth atmosphere has misled some investigators into believing that radiation of solar origin in the 0.0008- to 0.0014-centimeter (8- to 14-micron) band can be safely ignored. However, the solar energy component is often present in measured signals to a significant degree and can exceed the component of thermal radiation of terrestrial origin in some cases. This effect is most serious in the instrument with high spatial resolution.

As an aid to the reader, where necessary, the original units of measure have been converted to equivalent values in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

SYMBOLS

A	total area of the field of view
A_s	area of field of view occupied by the sun
C_1	3.74×10^{-5} erg-cm^2-sec^{-1}
C_2	1.4385 cm-°K
E_m	measured energy
E_s	total energy emitted from the sun per unit time per centimeter wavelength
E_{sp}	energy originating in space (or atmosphere)
E_w	energy emitted from a water surface
$E_{\Delta\lambda}$	radiant energy contained in wavelength $\Delta\lambda$
E_λ	monochromatic radiant energy
I	intensity, energy$\left(\text{area}^{-1}\right)\left(\text{time}^{-1}\right)\left(\text{steradian}^{-1}\right)$
q	flux, energy$\left(\text{area}^{-1}\right)\left(\text{time}^{-1}\right)$
$q\downarrow$	monochromatic flux passing through a 1-cm^2 area normal to incident solar radiation vector at a distance of 1 AU
r_e	earth-sun distance, 1 AU, cm
r_s	solar radius, cm
T_a	temperature of air at measurement site, °K
T_{BB}	black-body radiation temperature, °K
T_e	earth temperature, °K
T_{EBB}	effective black-body radiation temperature, °K

T_g gray-body absolute temperature, °K

T_m measured temperature, °K

T_s black-body temperature of the sun in the thermal infrared region (5040° K)

T_{sp} assumed radiation temperature of space, °K

T_w water surface temperature, °K

ϵ emissivity

ϵ_θ emissivity at nadir angle θ

θ angle between the direction of the intensity vector and the normal to the plane (i.e., nadir angle, deg)

λ wavelength, cm

ρ reflectivity

ρ_θ reflectivity at nadir angle θ

Φ azimuth angle, deg

FLUX AND INTENSITY

The solar component of thermal radiation is often neglected as a result of the erroneous use of the terms flux and intensity interchangeably. Flux (irradiance) is the radiant energy leaving or approaching a differential element of area, or an imaginary plane, per unit time in all directions in the hemispheric solid angle bounded by the imaginary plane (ref. 1). Thus, flux q is the total rate of radiant energy flow and has the dimensions

$$q \equiv \text{energy}\left(\text{area}^{-1}\right)\left(\text{time}^{-1}\right) \tag{1}$$

Intensity (radiance) is the radiant energy that is leaving or approaching a differential area of an imaginary plane per unit time and that has a direction of propagation contained in a differential solid angle with a direction normal to the imaginary plane. Dimensions of intensity are

$$I \equiv \text{energy}\left(\text{area}^{-1}\right)\left(\text{time}^{-1}\right)\left(\text{steradian}^{-1}\right) \tag{2}$$

Intensity is a vector that will vary as the direction of the plane as the imaginary plane is rotated in space. Note that intensity is invariant along its propagation path in free space.

The relationship between intensity and flux is expressed by

$$q = \int_0^{2\pi} \int_0^{\pi/2} I \cos \theta \sin \theta \, d\theta \, d\Phi \qquad (3)$$

where θ = angle between the direction of the intensity vector and the normal to the plane

Φ = azimuth angle

Consider now how these two definitions apply to the sensors that are used commonly in remote thermal sensing. If a requirement exists to measure the upward flux (terrestrial plus atmospheric) and the downward flux (solar plus atmospheric), a pair of flat-plate radiometers can be installed. The upward-looking sensor would view space (and atmosphere) and the sun (32' of arc diameter). Any radiating body visible in the upward-looking hemispheric field of view would contribute to the measured radiative flux. The downward-looking sensor would view only earth, except at angles near 90°, when the sky would be visible. In measurement such as this, the upwelling radiation between 0.0008 and 0.0014 centimeter (8 and 14 microns) greatly exceeds the downwelling radiation of solar origin.

As the field of view of the two detectors is decreased, the zenith sun fills a greater fraction of the upward-looking field of view and the energy falling upon the detector changes very little. The downward-looking detector, however, views less earth as the field of view is restricted, and the energy falling upon the detector is decreased accordingly. When the field of view of the detectors decreases to 32' of arc, so that the sun just fills the field of view of the upward-looking detector, the detector is measuring the intensity of solar radiation (as modified by the atmosphere). Except for the effects of the atmosphere, this measurement would be the same as a measurement obtained if the sensor were viewing the sun from the solar surface. The equivalent black-body radiation temperature of the sun in the 0.0008- to 0.0014-centimeter (8- to 14-micron) band would be approximately 5040° K, compared to the equivalent black-body radiation temperature of approximately 300° K measured by the downward-looking sensor. The important point is that the detectors (except for hemispheric detectors) measure intensity, not flux; and when the field of view of the detector becomes small enough, the solar component of thermal radiation, direct and reflected, becomes more important.

COMPARISON OF FLUX OF SOLAR AND TERRESTRIAL ORIGIN

The total energy emitted from the sun per unit time per centimeter wavelength, as a function of wavelength, can be expressed as Planck's equation for flux times the surface area of the sun.

$$E_s = \frac{C_1 \lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T_s}\right) - 1} 4\pi r_s^2 \tag{4}$$

where $C_1 = 3.74 \times 10^{-5}$ erg-cm^2-sec^{-1}

$C_2 = 1.4385$ cm-°K

λ = wavelength, cm

T_s = black-body temperature of the sun in the thermal infrared region (5040° K)

r_s = solar radius (0.6957×10^{11} cm) (ref. 2)

The monochromatic flux that is passing through a 1-square-centimeter area normal to the incident solar radiation vector at 1 astronomical unit is

$$q\downarrow = \frac{C_1 \lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T_s}\right) - 1} \frac{r_s^2}{r_e^2} \tag{5a}$$

where r_e = 1 astronomical unit = 149.6×10^{11} cm

The monochromatic flux upward through a 1-square-centimeter area at the ground (assuming a black-body surface) is given by

$$q\uparrow = \frac{C_1 \lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T_e}\right) - 1} \tag{5b}$$

where T_e = earth temperature in degrees Kelvin

Computed values of the solar monochromatic flux at 1 astronomical unit and for a 300° K black-body earth are compared in table I, which shows the ratio of upwelling flux from the earth surface (assumed black body at 300° K) to the downward flux from the sun (neglecting the atmosphere) received by the earth surface as a function of wavelength. The values of this ratio are indicative that flux of terrestrial origin can be ignored safely in the visible and near-infrared regions, while at a 0.0015-centimeter wavelength, the flux of terrestrial origin is more than 400 times that of solar origin at the earth surface.

TABLE I. - COMPARISON OF FLUX OF SOLAR AND TERRESTRIAL ORIGIN AT THE EARTH SURFACE

Wavelength, λ, cm	Flux from sun at 1 AU, erg $cm^{-2} sec^{-1} (cm^{-1})$	Flux from earth at 300° K, erg $cm^{-2} sec^{-1} (cm^{-1})$	Terrestrial to solar flux ratio
0.00005	8.6865×10^{9}	2.45×10^{-15}	2.82×10^{-25}
.0001	4.9388×10^{9}	5.8×10^{-6}	1.17×10^{-15}
.0002	7.9747×10^{8}	4.953×10^{3}	6.2×10^{-6}
.0003	2.0923×10^{8}	1.914×10^{6}	6.5×10^{-3}
.0004	7.5789×10^{7}	2.275×10^{7}	3.0×10^{-1}
.0005	3.3618×10^{7}	8.187×10^{7}	2.43
.0006	1.7061×10^{7}	1.628×10^{8}	9.54
.0007	9.556×10^{6}	2.362×10^{8}	24.7
.0008	5.760×10^{6}	2.867×10^{8}	49.7
.0009	3.667×10^{6}	3.089×10^{8}	84.2
.0010	2.448×10^{6}	3.134×10^{8}	128.0
.0011	1.694×10^{6}	3.036×10^{8}	179.2
.0012	1.211×10^{6}	2.833×10^{8}	233.9
.0013	8.86×10^{5}	2.609×10^{8}	294.4
.0014	6.65×10^{5}	2.351×10^{8}	353.5
.0015	5.09×10^{5}	2.115×10^{8}	415.5

COMPARISON OF SOLAR AND TERRESTRIAL RADIATION INTENSITY

Intensity of monochromatic radiation emitted by a black body is given by Planck's equation

$$I = \frac{C_1 \lambda^{-5}}{\pi\left[\exp\left(\frac{C_2}{\lambda T}\right) - 1\right]} \tag{6}$$

Intensity values as a function of wavelength for black bodies of 5040° K (brightness temperature of the sun at 0.0011 centimeter (11 microns) (ref. 2)) and 300° K are given in table II. Note that even at 0.0011 centimeter (11 microns) the solar intensity is approximately 260 times that of terrestrial origin, while the upwelling terrestrial flux is 179 times the downward flux of solar origin (table I).

TABLE II. - RADIATION INTENSITY FOR BLACK BODIES OF 5040° AND 300° K

Wavelength, λ, cm	Intensity, I, $erg\text{-}cm^{-2}\text{-}sec^{-1}\text{-}sr^{-1}(cm^{-1})$	
	Body at 5040° K	Body at 300° K
0.00005	1.280×10^{14}	7.802×10^{-16}
.0001	7.282×10^{13}	1.847×10^{-6}
.0002	1.175×10^{13}	1.577×10^{3}
.0003	3.084×10^{12}	6.084×10^{5}
.0004	1.117×10^{12}	7.244×10^{6}
.0005	4.956×10^{11}	2.606×10^{7}
.0006	2.314×10^{11}	5.186×10^{7}
.0007	1.408×10^{11}	7.522×10^{7}
.0008	8.488×10^{10}	9.130×10^{7}
.0009	5.406×10^{10}	9.836×10^{7}
.0010	3.608×10^{10}	9.980×10^{7}
.0011	2.480×10^{10}	9.668×10^{7}
.0012	1.785×10^{10}	9.022×10^{7}
.0013	1.306×10^{10}	8.308×10^{7}
.0014	9.802×10^{9}	7.486×10^{7}
.0015	7.502×10^{9}	6.734×10^{7}

The wavelength at which the flux of solar origin at 1 astronomical unit is equal to that emitted by a black-body earth is dependent on the temperature of the earth. By equating the fluxes

$$\frac{C_1\lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T_s}\right) - 1}\left(\frac{r_s}{r_e}\right)^2 = \frac{C_1\lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T_e}\right) - 1} \qquad (7)$$

it is possible to solve for T_e to obtain

$$T_e = \frac{C_2}{\lambda \ln\left\{\left[\exp\left(\frac{C_2}{\lambda T_s}\right) - 1\right]\left(\frac{r_s}{r_e}\right)^{-2} + 1\right\}} \qquad (8)$$

The wavelength of equal flux is given as a function of earth temperature in figure 1, which shows that as the terrestrial (black body) temperature varies from 330° to 250° K, the crossover point, neglecting the atmosphere, shifts from 0.0004 to 0.00055 centimeter.

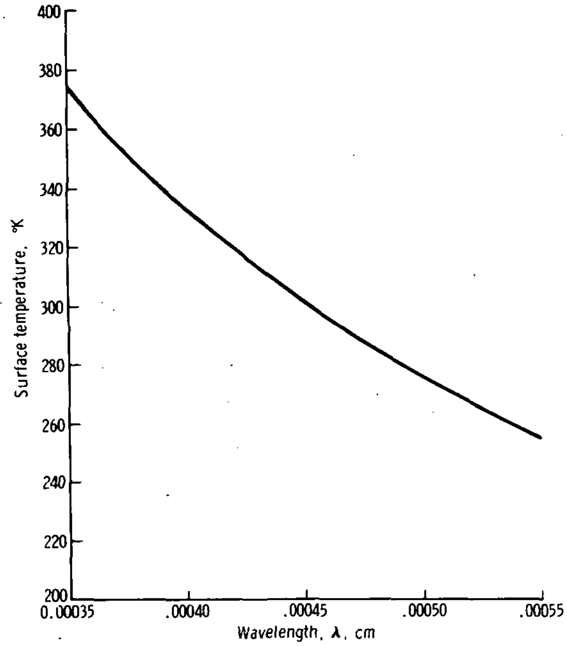

Figure 1.- Wavelength at which solar flux equals terrestrial flux at the earth surface.

OPERATIONAL IMPORTANCE OF REFLECTED SOLAR RADIATION

Assuming a 200° K space radiation temperature (originating primarily in the atmosphere) which fills the 2° field of view of the precision radiation thermometer (PRT-5), except for that portion filled by the sun (32' of arc diameter), the monochromatic equivalent black-body radiation temperature seen while looking at the sun (not recommended) would be

$$T_{BB} = \frac{C_2}{\lambda \ln\left[\frac{A}{\frac{A_s}{\exp\left(\frac{C_2}{\lambda T_s}\right) - 1} + \frac{A - A_s}{\exp\left(\frac{C_2}{\lambda T_a}\right) - 1}} + 1\right]} \qquad (9)$$

where A_s = area of field of view occupied by the sun

A = total area of the field of view

T_a = temperature of the air at the measurement site

Assuming further that 0.0011 centimeter (11 microns) is representative of the 0.0008- to 0.0014-centimeter (8- to 14-micron) band of instrument sensitivity, the equivalent black-body radiation temperature is computed to be 800° K.

If the instrument is directed to viewing a smooth water surface at a temperature T_w with a reflectivity of ρ, the expression for effective black-body radiation temperature becomes

$$T_{EBB} = \frac{\frac{C_2}{\lambda}}{\ln\left\{\frac{1}{\frac{\epsilon}{\exp\left(\frac{C_2}{\lambda T_w}\right) - 1} + \frac{\rho A_s}{A\left[\exp\left(\frac{C_2}{\lambda T_s}\right) - 1\right]} + \frac{\rho\left(A - A_s\right)}{A\left[\exp\left(\frac{C_2}{\lambda T_a}\right) - 1\right]}} + 1\right\}} \tag{10}$$

where ϵ = emissivity (function of nadir angle)

ρ = reflectivity (function of nadir angle)

Assuming a nadir view of a water surface at 300° K with a reflectivity of 0.02, the effective black-body radiation temperature is computed to be 321.8° K. If the smooth water is viewed at an angle 75° from nadir with the PRT-5 and the reflected solar image is contained in the field of view, assuming a reflectivity of 0.3 (fig. 2), the effective black-body radiation temperature is computed to be 505° K. This value compares to a value of 277° K when the sun is excluded (i.e., only space at 200° K is reflected from the surface viewed).

In practice, however, observers do not normally record such extremely high radiation temperatures when viewing sunglint, because a "smooth" water surface is almost nonexistent in a natural environment. Small gravity waves are almost always present; and, with only a light wind, capillary wave action is generated. These waves disperse the image of the sun so that

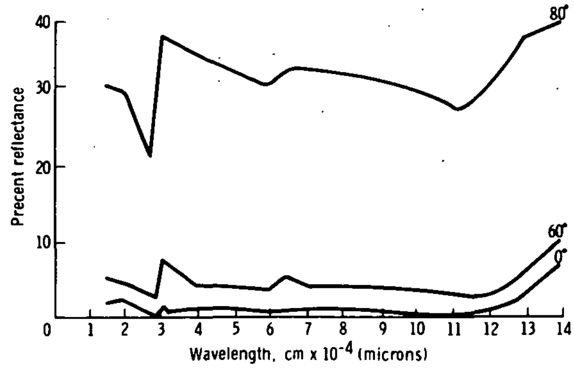

Figure 2. - Water reflectance at varying angles of incidence.

only a small fraction of solar image is viewed at any one pointing angle, even with the 2° field of view of the PRT-5.

Saunders (ref. 3) asserts that, because of this scattering action of the waves, a radiometer (field of view unspecified) directed nearly normal to the surface will not be affected by sun glitter at the 0.1° K level except in very calm seas; or if viewed obliquely, at the 1.0° K. His computed values appear much smaller than those observed values reported here, however.

OBSERVATION OF SUNGLINT FROM WATER SURFACES IN THE THERMAL INFRARED

The effect of reflected solar radiation on the signal that is received by sensors in the thermal infrared region was first noted in the data collected by the RS-14 scanner on Earth Resources Aircraft Program mission 130 in which the NASA NP3A aircraft flew lines at several altitudes and headings at three locations over water surfaces (two over the Gulf of Mexico and one over Galveston Bay) on two different days. In every case, if the sun was to the left of the aircraft track, the left side of the signal was greater; if the sun was to the right of the aircraft track, the right side of the signal was stronger. An example is shown in figure 3. On the five flight lines shown, the sun is to the right and slightly to the rear of the aircraft. The curves represent the difference between the signal received on the right side of the scanner and that at the same angle from nadir on the left side of the scanner in terms of computer bin number scale (left ordinate). On the right ordinate, approximate black-body radiative temperature differences are plotted. Arrows denote the computed angular departure of the mirror point of the sun from nadir. This angle, of course, varied as the afternoon progressed. The maximum temperature difference observed in this sample is 2.6° K (2.6° C) at an aircraft altitude of 609 meters (2000 feet). Note that in no case would the disk of the sun have been reflected into the field of view of the sensor from a smooth water surface because of azimuth angle of sun offset from the scan. The roughness of the water dispersed the image of the sun so much that the maximum difference was observed when the azimuth departure angle was 16° at a 609-meter (2000-foot) aircraft altitude rather than at the azimuth departure angle of 3° at the 1890-meter (6200-foot) aircraft altitude. The curves indicate a decrease in temperature differences near nadir. This is not to be interpreted as indicating that sunglint is not a factor at nadir; rather, it is characteristic of the type of display. The values plotted at 30° from nadir represent the output differences between the value 30° to right of nadir minus the value 30° to left (a difference of 60°), while the plot at nadir represents the difference between points separated by less than half a degree. All plots are indicative that a large portion of the field of scan is affected significantly by reflected thermal radiation of solar origin.

Another series of measurements was made November 24, 1970, from the deck of the Texas A. & M. University research vessel Excellence during a cruise along the Houston Ship Channel. The instrument used for this series of measurements was the PRT-5 with a 2° field of view. The detector was mounted on a tripod that was scaled to permit a crude determination of departure of viewing angle from nadir. Light surface winds coupled with contaminants in the water suppressed capillary wave action significantly. Small gravity waves were present at all times, however. The day was quite cool and dry, with 270.2° K (-3° C) minimum and 280.2° K (7° C) maximum temperature. The sky was cloud free except for a few thin cirrus visible during the late

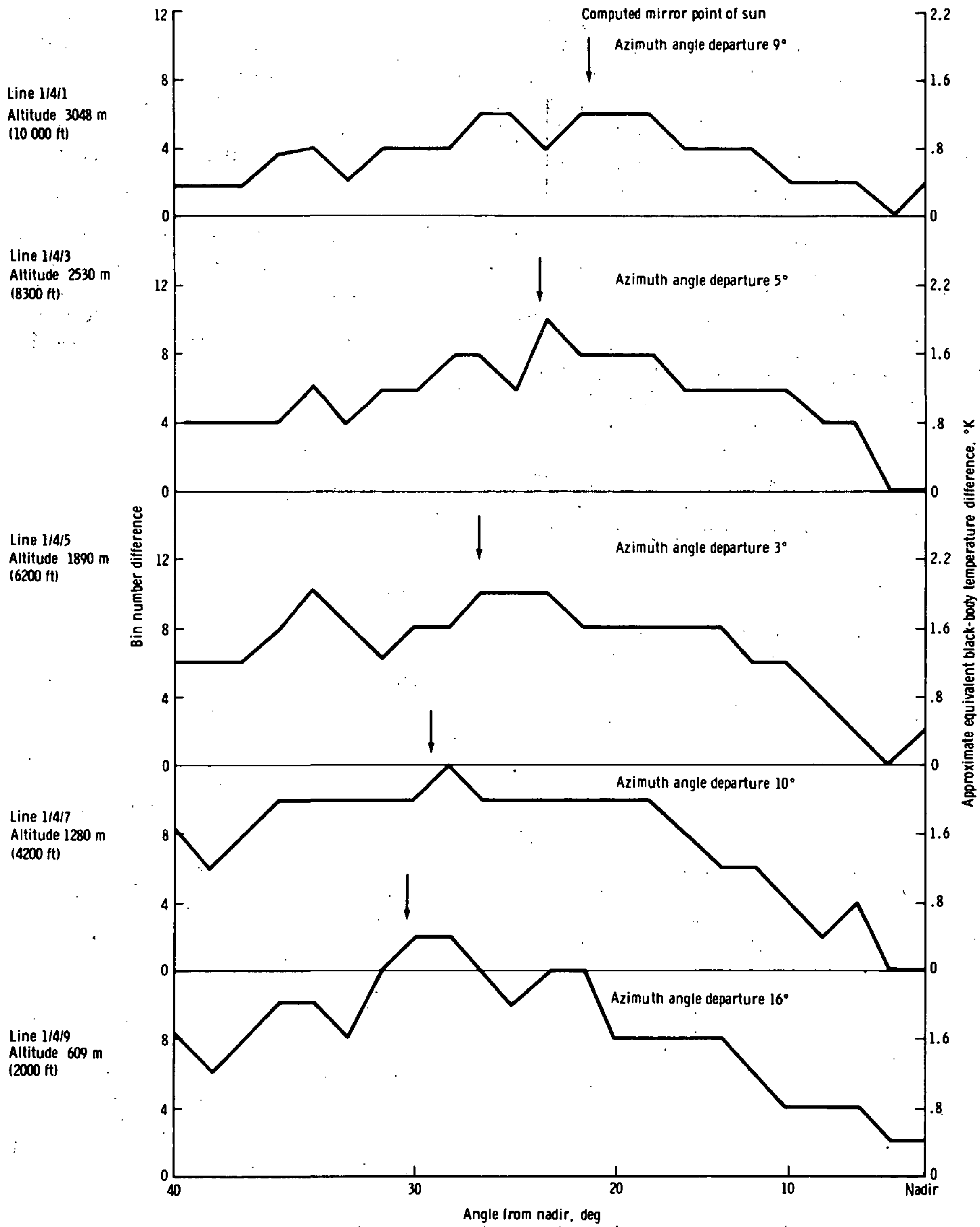

Figure 3. - RS-14 scanner output temperature difference (side towards sun minus side opposite sun).

afternoon. Because of the coldness of the air compared to the water (289.2° K (16° C)) and the dryness of the air, the water skin should have been cooler than the subsurface temperature. This difference was quite noticeable in the remote temperature measurements, as the wake radiation temperature was 1° to 3° K warmer than that of the undisturbed surface. Because of the coldness and dryness of the air and sky, radiation temperature was not measurable on the PRT-5, as the low end of the output scale cuts off at 253.2° K (-20° C).

The results of the two periods of observations are presented here. At 16:40 G.m.t., three series of observations were made: (1) a series viewing away from the sun at nadir, at 45° from nadir, at 60° from nadir, and at 75° from nadir; (2) a similar series of measurements normal to the sun observer plane; and (3) a series into the sunglint. The resulting measured radiation temperatures are shown in figure 4. Note that the measurement taken into the sunglint may not represent the brightest point, because the peep sight on the PRT-5 is somewhat coarse. Figure 5 is a plot of measurement made somewhat later in the day. In these measurements, the area of apparent maximum sunglint was scanned,

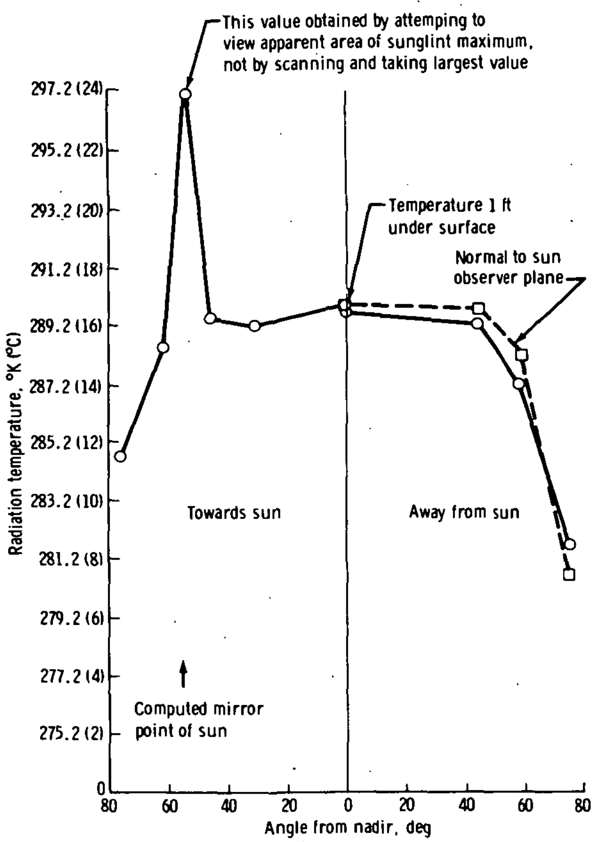

Figure 4. - Radiation temperature measurements made at mile 16 on the Houston Ship Channel at 16:41 G.m.t.

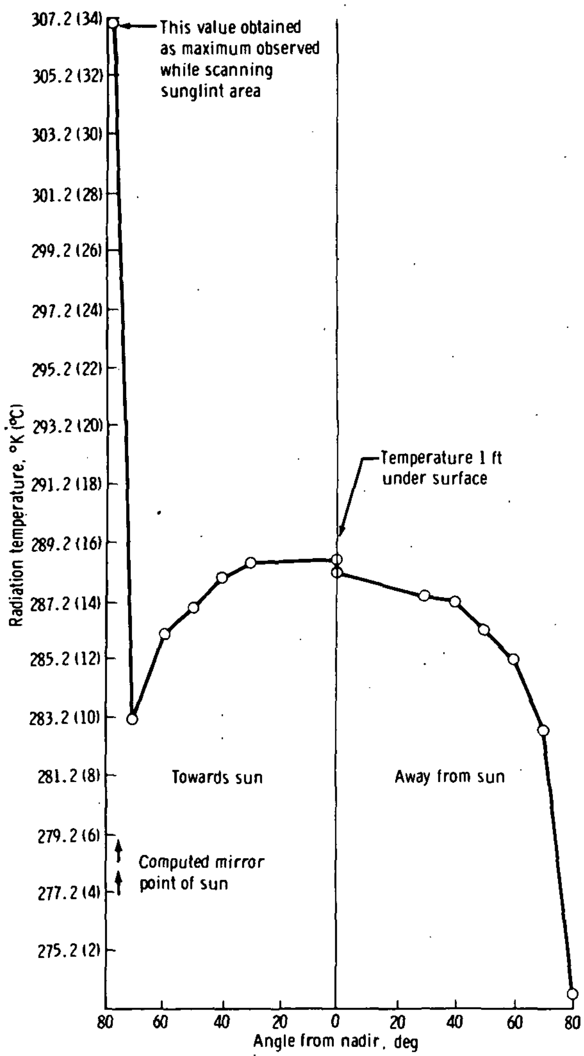

Figure 5. - Radiation temperature measurement made at the San Jacinto River at 22:20 G.m.t.

and the maximum reading obtained was considered the brightest point of sunglint. Both sets of observations show higher radiation temperatures at or very near the computed mirror point of the sun; both show a tendency to colder radiation temperatures at a large angle from nadir when the sensor was not directed towards the sun, indicating an increasing contribution by cold reflected sky radiation at these angles. The differences in measured radiation temperature values near nadir in figure 5 may be attributed to relatively unstirred water in the San Jacinto River Channel away from the sun and well-stirred water in the Houston Ship Channel towards the sun.

Emissivity of the water was determined from data shown on the right side of figure 5 as described subsequently. Given

$$\rho(\lambda, \theta) + \epsilon(\lambda, \theta) = 1 \tag{11}$$

where ρ = reflectivity

ϵ = emissivity

λ = wavelength

θ = nadir angle

and

$$E_{\Delta\lambda} = \epsilon \int_{\lambda_1}^{\lambda_2} E_\lambda \, d\lambda = \epsilon \int_{\lambda_1}^{\lambda_2} \frac{C_1 \, d\lambda}{\lambda^5 \left[\exp\left(\frac{C_2}{\lambda T_g}\right) - 1\right]} \tag{12}$$

where C_1, C_2 = constants

λ_1, λ_2 = boundaries of the wavelength band of interest

T_g = absolute temperature of the gray body

$E_{\Delta\lambda}$ = total flux of emission of the gray body over the wavelength band λ_1 to λ_2

E_λ = monochromatic flux of emission

Computation of the emissivity of a water surface as a function of the viewing angle can be made by measuring the apparent radiation temperature of the surface.

$$E_{\Delta\lambda, m} = \epsilon_\theta E_{\Delta\lambda, w} + \rho_\theta E_{\Delta\lambda, sp} \tag{13}$$

or

$$\epsilon_\theta = \frac{E_{\Delta\lambda, m} - E_{\Delta\lambda, sp}}{E_{\Delta\lambda, w} - E_{\Delta\lambda, sp}} \tag{14}$$

where subscripts w and sp refer to water and space, respectively, and θ the nadir angle for which ϵ and ρ are to be determined. Assuming (1) that ϵ_λ and ρ_λ are represented by $\epsilon_{\bar{\lambda}}$ and $\rho_{\bar{\lambda}}$ (i.e., they are unchanged over the 0.0008- to 0.0014-centimeter (8- to 14-micron) band), (2) that space radiation temperature is 200° K (off scale on the PRT-5), (3) that water temperature measured remotely normal to surface is the true temperature, and (4) that no horizontal gradients occur in water temperature. Then

$$\epsilon_{\theta, 8\text{-}14\mu} = \frac{\left[\exp\left(\frac{C_2}{\lambda T_m}\right) - 1\right]^{-1} - \left[\exp\left(\frac{C_2}{\lambda T_{sp}}\right) - 1\right]^{-1}}{\left[\exp\left(\frac{C_2}{\lambda T_w}\right) - 1\right]^{-1} - \left[\exp\left(\frac{C_2}{\lambda T_{sp}}\right) - 1\right]^{-1}} \tag{15}$$

where $C_2 = 1.4385$ cm-°K

$\lambda = 0.0011$ cm

$T_w = 15°\ C + 273.2°\ C = 288.2°\ K$

$T_{sp} = 200°\ K$

T_m is given in figure 5 (right side)

The values for $\epsilon_{\theta, 8\text{-}14\mu}$ have been computed and are given in table III. (See ref. 4.)

If the possible sources of error in the measurement, such as uncertainty of attitude of the vessel deck, possible horizontal water temperature gradients, and assumed sky temperature are considered, the computed values are in very good agreement with Fresnel theory. The equivalent black-body radiation temperature that is measured while observing sunglint was much less than the computed value for a smooth reflecting surface. Computations could be performed to determine a roughness factor for the water surface observed.

TABLE III. - COMPUTED WATER SURFACE EMISSIVITY $\epsilon_{\theta,8-14\mu}$

Nadir angle, θ, deg	T_m, °K	Computed ϵ_θ	Theoretical ϵ_θ (a)
80	273.8	0.75	0.65
70	282.7	.89	.87
60	285.2	.94	.94
50	286.2	.96	.97
40	287.2	.97	.97
30	287.5	.98	.98
0	288.2	1.00	--

[a]Assume n = 1.333 (ref. 4).

CONCLUDING REMARKS

Both theory and observation are indicative that sunglint and reflected sky radiation in the thermal infrared should be considered in any quantitative application of data from both scanner and nonimaging systems. While this procedure complicates interpretation of infrared observations, this phenomenon may have useful applications. An example of the usefulness could be in the study of high-oblique observations of sunglint as a function of wavelength to determine if characteristic signatures can be obtained. An early study (using a multispectral scanner) to measure reflective properties of surfaces in and out of sunglint is recommended.

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National Aeronautics and Space Administration
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