The Tiros II Radiation Experiment

By R. A. HANEL and W. G. STROUD, Goddard Space Flight Center, NASA, Washington, D.C.

(Manuscript received July 3, 1961)

Abstract

The TIROS II meteorological satellite, containing two television cameras and a family of electro-magnetic radiation experiments, was placed into orbit on November 23, 1960. The medium resolution radiometer is a cluster of five sensors, their optical axes inclined at 45° to the spin axis of the satellite. The spin of TIROS provides the scanning motion. Channels are sensitive to the following spectral bands: (1) 6 to 6.5, (2) 8 to 12, (3) 0.2 to 6, (4) 8 to 30, and 0.55 to 0.75 microns.

Introduction

TIROS II, the meteorological satellite launched last year on November 23 (1960), carried two television cameras and various detectors to sense infrared emission and reflected solar radiation from our planet. The systems aspect of the radiation experiments, the design of the radiometers, and the physical significance of the measurements have been discussed previously (HANEL and STROUD, 1960; BANDEEN ET AL, 1961., ASTHEIMER, DE WAARD and JACKSON, 1961; HANEL and WARK, 1961). The quoted publications also contain results in form of analog presentations of individual scan lines, of sample data points which show the apparent blackbody temperatures of certain geographical locations, and of maps where radiation emerging from the 8 to 12 micron atmospheric window has been plotted. Most of these data have been reduced by analog techniques. The main bulk of the information which is contained in more than 600 reels of magnetic tape, each 5,000 feet long, has to be processed by computers. Hand analyses of samples must precede automatic data reduction mainly to judge the validity of the experiment and to confirm proper functioning of the instruments. We are now at the point where we have gained confidence in the measurements, and where the computer programs are working. The five radiation maps shown in this paper are pilot runs of the automatic data reduction system.

The Five Channel Radiation Experiment

To give a better understanding of the meaning of the maps presented, the instruments which collected the information shall be discussed briefly. The medium resolution radiometer scans earth and outer space as TIROS spins about its axis. Each detector measures the radiation flux within its five degree instantaneous field of view and within the spectral range determined by filters and other optical elements. The nominal bandwidths of the five channels are:

1) 6 to 6.5 microns, water vapor absorption
2) 8 to 12 microns, atmospheric window
3) 0.2 to 6 microns, reflected solar radiation
4) 8 to 30 microns, terrestrial radiation
5) 0.55 to 0.75 microns, response of TV system

The optical axis of the instrument is inclined at 45° to the spin axis of TIROS. The radiometer responds to the intensity difference between two diametrically opposite directions. This configuration gives maximum coverage of the earth from a spin stabilized satellite and uses

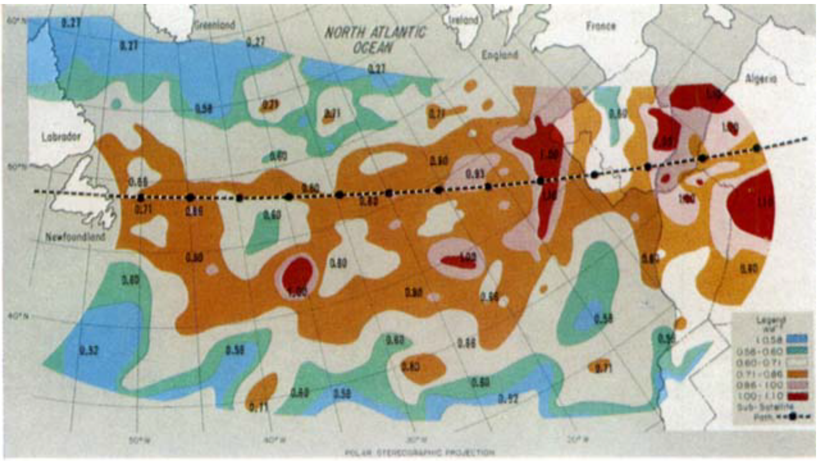

Fig. 1. Radiation map from Tiros II scanning radiometer: Channel 1 (6.0—6.5 μ) Orbit 30, Nov. 25, 1960, 1238 GMT to 1250 GMT.

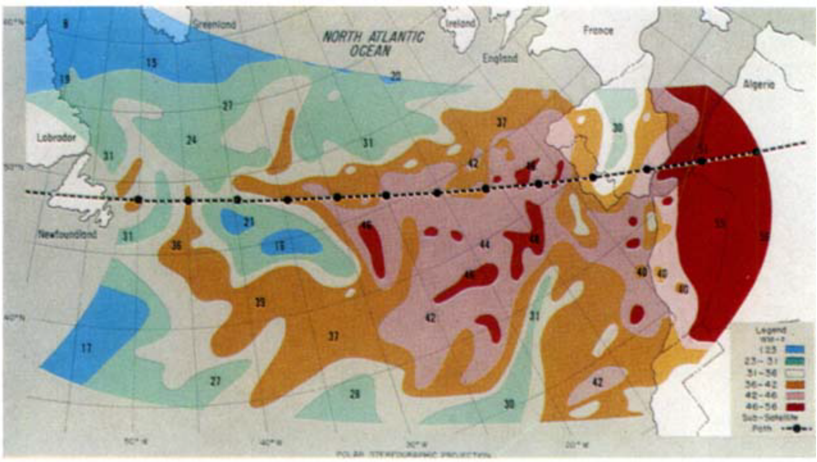

Fig. 2. Radiation map from Tiros II scanning radiometer: Channel 2 (8—12 μ) Orbit 30, Nov. 25, 1960, 1238 GMT to 1250 GMT.

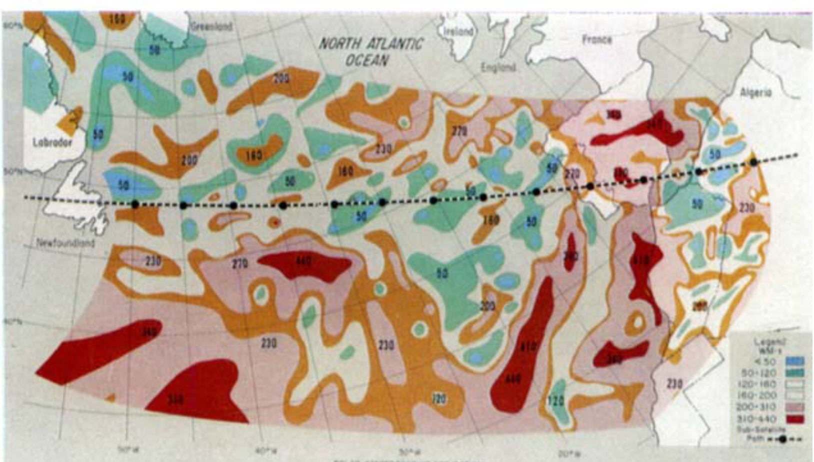

Fig. 3. Radiation map from Tiros II scanning radiometer: Channel 3 (0.2—6.0 μ) Orbit 30, Nov. 25, 1960, 1238 GMT to 1250 GMT.

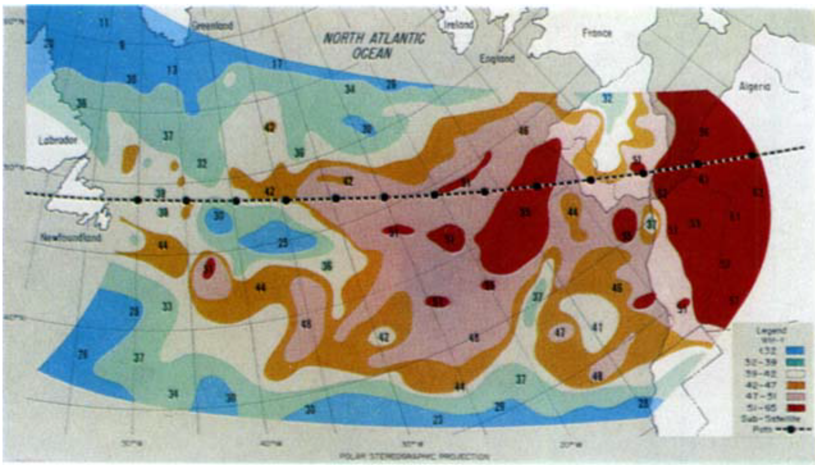

Fig. 4. Radiation map from Tiros II scanning radiometer: Channel 4 (7.8—30 μ) Orbit 30, Nov. 25, 1960, 1238 GMT to 1250 GMT.

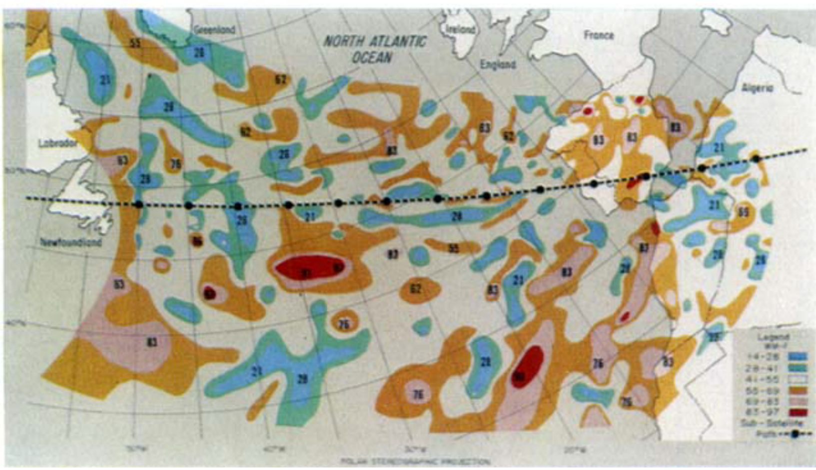

Fig. 5. Radiation map from Tiros II scanning radiometer: Channel 5 (0.55—0.75 μ) Orbit 30, Nov. 25, 1960, 1238 GMT to 1250 GMT.

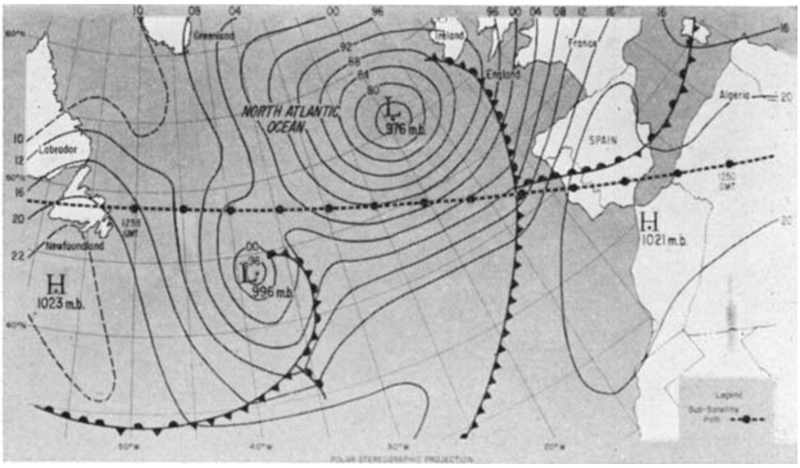

Fig. 6. Surface weather chart for 1200 GMT Nov. 25, 1960 showing Orbit 30 of Tiros II.

outer space as a radiation reference. The output of the detectors is stored on magnetic tape in the satellite and transmitted to earth once each orbit. The receiving stations at Pt. Mugu and Ft. Monmouth interrogated the TIROS II radiation experiment close to 2,000 times successfully.

Data Reduction

Each ground station sends the magnetic tape to the Aeronomy and Meteorology Division, Goddard Space Flight Center, in Greenbelt, Maryland. The analog information is then screened and translated into digital form suitable for the IBM 7090 computer of the Meteorological Satellite Laboratory, United States Weather Bureau. The computer output, also on magnetic tape and in digital form, gives radiant emittance in watts per square meter, position of the satellite, geographical location of the area observed, viewing angle, sun angle, and Greenwich mean time for all data points. The maps shown in this paper have been hand drawn from computer printouts. Eventually mapping will be done automatically by contour plotters.

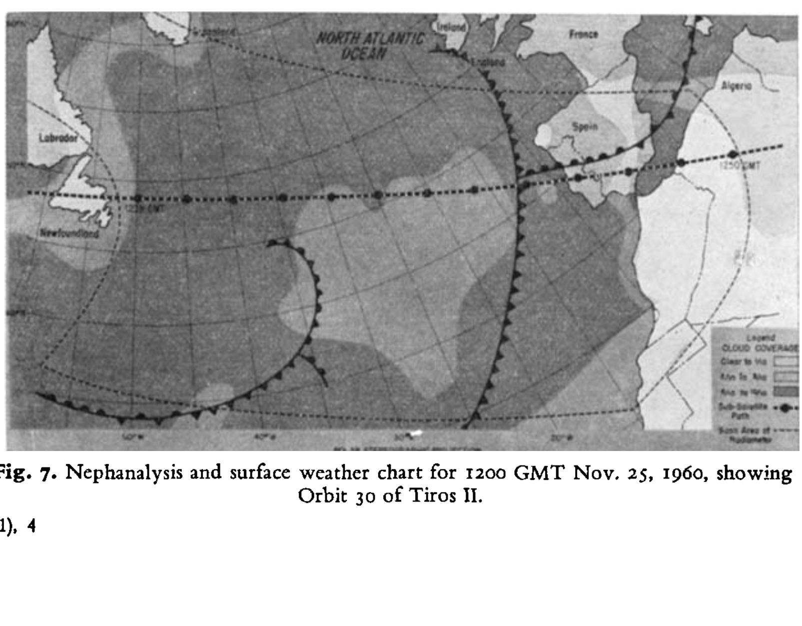

Fig. 7. Nephanalysis and surface weather chart for 1200 GMT Nov. 25, 1960, showing Orbit 30 of Tiros II.

Calibration

The maps show radiant emittance $\overline{W}$ in watts per square meter as seen through the instrument's filter.

$$\overline{W} = \int_0^\infty W_\lambda \phi_\lambda d\lambda$$

The spectral sensitivity of a channel is called ϕ_λ and W_λ is the spectral radiant emittance of the area within the field of view. Ideally ϕ_λ should be constant within the band specified and zero at all other wavelengths. Actual filters used approach this condition. Spectral sensitivities have been discussed in detail previously (BANDEEN ET AL., 1961; HANEL and WARK, 1961). During calibration channels 1, 2 and 4 were exposed to a blackbody of known emittance $W_\lambda(T)$. Relations between $\overline{W}$ and the blackbody temperatures are shown in Table 1.

Table 1.

Blackbody Temperature in deg. K	$\overline{W}$ Watts per square meter for channel		
	1	2	4
180	0.028	3.1	9.5
200	0.10	6.5	15
220	0.28	12	23
240	0.67	20	35
260	1.4	32	49
280	2.6	47	67
300	4.5	66	89

The interpretation of the results of channels 3 and 5 has to take spectral sensitivities into account also. A perfectly diffuse surface irradiated by one solar constant illuminates the detectors of channels 3 and 5 with 1,070 and 250 watts per square meter respectively. All scales show higher accuracy at higher radiation levels. Channels 2 and 4 exhibit a better signal to noise ratio then channel 1, and channel 3 data are superior to data from channel 5.

The radiation maps shown cover the Atlantic Ocean from Newfoundland to the Iberian Peninsula and North Africa. A surface pressure map and a cloud cover analysis based mainly on ship reports are shown in the same scale on Figs. 6 and 7.

The three thermal channels, Figs. 1, 2 and 4, show a general temperature gradient from left to right which is caused by latitudinal and diurnal effects. The local time over Labrador is 9 A. M. and over France about 1 P. M. Superimposed over this gradient are synoptic phenomena. The relatively clear area west of Spain can be identified as a warm area on channel 2 and 4. In contrast to this, dense clouds associated with frontal system (e.g., 35° W 45° N) appear cold in thermal channels 1, 2 and 4 and bright in channels 3 and 5.

As expected, bright areas in channels 3 and 5 which indicate solid overcast are very well correlated to low temperatures in channel 2 which measures radiation from the atmospheric window. This correlation will be used to extend cloud analysis to the nighttime side of the Earth, unobserved by channels 3, 5 and television.

All maps shown display data uncorrected for viewing angle and solar zenith angle. Low temperatures at the southern and northern boundary of the scan area in channels 1 and 4 are caused by limb darkening.

Calculations of the outgoing radiation based on temperature and humidity profiles obtained from balloon soundings and measurements using a TIROS radiometer on a balloon will provide additional information on the accuracy of the scales obtained in preflight calibrations.

Acknowledgement

The authors would like to thank Mr. L. J. Allison, Goddard Space Flight Center, and Mr. S. D. Soules, U. S. Weather Bureau, for preparing the maps.

REFERENCES

ASTHEIMER, R. W., DE WAARD, R. and JACKSON, E. A., 1961: Presented at the OSA meeting, Pittsburgh, March 3, 1961, published in the J. of O.S.A., Dec. 1961.

BANDEEN, W. R., HANEL, R. A., LICHT, J., STAMPFL, R. A. and STROUD, W. G., 1961: Presented at the AMS meeting, Jan. 1961, New York, published in the J. G. R., Oct. 1961.

HANEL, R. A. and STROUD, W. G., 1960: *Journal of the SMPTE*, **69**., Jan. 1960.

HANEL, R. A. and WARK, D. Q., 1961: Presented at the OSA meeting Pittsburgh, March 3, 1961, to be published in the J. of O.S.A., Dec. 1961.