underground explosions trigger earthquakes up to about 32 hours afterward. The data available to us show that in the 32-hour interval after the explosions there were 228 earthquakes, or an increase of about 62 percent over the expected number of 141.

By dividing the area under consideration into several annuli and by comparing, within each annulus, observed versus expected number of earthquakes, we have verified that the seismic effect of the explosions extends to the 860-km limit of our search. It may still be noticeable at greater distances.

While it is clear from the available evidence that man can affect earthquake activity, Carter (*5*) reports on conflicting views and feelings among scientists, engineers, and politicians regarding the proposed underground nuclear test at Amchitka Island, Alaska. There is some concern that this test may trigger an earthquake as disastrous as that of 1964 and some propose to limit underground nuclear tests to low-yield systems or to ban them altogether.

It would seem to us that properly spaced and properly timed deep underground nuclear tests could be used, possibly together with previous fluid injection in appropriate quantities, to release stresses in the lithosphere and therefore limit the severity of earthquakes. Stress in the lithosphere is built up by convection in the upper mantle, energized mainly by radioactive decay. It is to be expected that the longer the stress builds up, the more severe will be the earthquake activity releasing it. If so, it might be convenient to place a number of high-yield (1 to 10 megaton) nuclear devices in deep (3000 to 5000 m) wells appropriately spaced (20 to 50 km) along an active fault zone and release the accumulated stress by activating the devices. This procedure could then be repeated at appropriate time intervals (10 to 25 years), thus preventing large stress accumulation and disastrous earthquakes.

The proposed Amchitka test provides an excellent opportunity to evaluate our suggestion, if the nuclear device will be placed at sufficient depth and if the test were to be followed a few months later by a second identical test at the same location and depth. If nuclear devices have indeed a potential for earthquake activity control, the second test should trigger much less activity than the first one.

While the western end of the Aleutian Island Arc appears to be an excellent laboratory to test the feasibility of using nuclear devices for earthquake control, actual application should exclude all inhabited seismic areas which have been free of major earthquakes for 25 years or more and should be initiated in areas recently (less than 10 years) affected by major seismic activity. It should then be continued at appropriate time intervals (10 to 25 years).

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Atmospheric Temperature: Successful Test of Remote Probing

Abstract. *The Nimbus III satellite carries the satellite infrared spectrometer (SIRS). It measures the radiance of the earth and the atmosphere in seven narrow spectral intervals in the 15-micrometer carbon dioxide band and in one interval of minimum absorption at 11.1 micrometers. Seven simultaneous equations are solved to obtain the vertical temperature profile; the eighth measurement is used to determine the boundary condition (cloud or surface temperature). Results agree with those obtained from conventional radiosondes.*

The launch of the Nimbus III satellite 14 April 1969 has introduced a new era in the application of satellites to meteorological observations. The satellite infrared spectrometer (SIRS) has measured infrared spectral radiances from which temperature profiles have been retrieved.

The proposals of King (*1*) and Kaplan (*2*) pointed out that one might infer the temperature structure of the atmosphere from measurements of the earth's radiance in the absorption band of carbon dioxide centered at 15 μm (*3*). The SIRS was designed to measure simultaneously the radiances in the vertical direction from seven narrow intervals in the carbon dioxide band and in one interval in the 11.1-μm window (Table 1). The field of view is approximately a 200-km square and the radiances are sampled every 8 seconds.

The device is a conventional diffraction-grating spectrometer with special detectors (*4*) and electronics (*5*) for each channel (*6*). Included in the design is a means of checking the instrument's calibration in orbit. A zero-signal measurement, an internal blackbody radiance measurement, and a wavelength test are provided in sequence. Satisfactory calibration was accomplished each 32 minutes during the first week in orbit, and thereafter each 256 minutes.

The response calibrations before flight were standardized against the Canadian National Research Council low temperature blackbody (*7*). The absolute accuracy of the earth radiance measurements is believed to be ± 2 erg $sec^{-1}cm^{-2}sr^{-1}cm$. The measurements compare within about 1 erg $sec^{-1}cm^{-2}sr^{-1}cm$ with those made by the Nimbus III infrared interferometer spectrometer (IRIS) (*8*). The relative accuracy between simultaneous measurements in the various spectral channels appears to be better than 0.5 erg $sec^{-1}cm^{-2}sr^{-1}cm$. Standard deviations of the zero and the internal blackbody radiance measurements were less than [illegible] erg $sec^{-1}cm^{-2}sr^{-1}cm$ after the launch.

The method of reducing the data was discussed by Wark and Fleming (*9*) and by Twomey (*10*). Subsequent efforts have substantially improved the interpretive schemes.

In brief outline, the derivation of a vertical temperature profile for cloudless areas involves the solution of the integral form of the radiative transfer equation,

$$I(\nu_i) = B[\nu_i,\ T(p_s)]\ \tau(\nu_i,\ p_s) - \int_1^{\tau(\nu_i,\ p_s)} B[\nu_i,\ T(p)]\ d\tau(\nu_i,\ p), \quad (1)$$
$$i = 1, \cdots, 7$$

where I is the measured radiance at frequency ν_i; B is the Planck radiance at ν_i, pressure p, and temperature T; τ is the fractional transmittance from p to the top of the atmosphere, and the subscript s refers to the surface boundary. The radiance in the window, channel 1, is used to evaluate the boundary term for the other channels. A solution of the set of Eq. 1 takes the discrete form (*11*)

$$B[\nu_r, T(p_j)] = \overline{B}[\nu_r, T(p_j)] + \Sigma C_{ij}\Delta I(\nu_i) \quad (2)$$

where ν_r is a reference frequency intermediate in the spectral range, $\overline{B}$ is the mean Planck radiance of a statistical sample of temperature soundings which are used as a basis of solution, ΔI is the difference in radiance between the observed value and the value which the mean of the ensemble of sample soundings would have, and j is an index of pressure. The coefficients, C_{ij}, are identical with the matrix $S_f A^T H^{-1}$ of Westwater and Strand (*12*). It is now simple to transform the left-hand side of Eq. 2 to $T(p_j)$.

Equation 2 contains all the elements of Eq. 1. Implicit are the transmittances, the statistical variances and covariances of measured temperature profiles obtained from balloons and rockets, the variances and covariances of the errors in the radiance measurements taken from the calibrations, the linearization to the reference frequency, and the absorption by water vapor as derived from a simple regression. In practice, C_{ij} is weakly dependent upon the solution, so that Eq. 2 must be iterated once or twice from an initial guess. Clouds introduce a modification of this solution which is not discussed here.

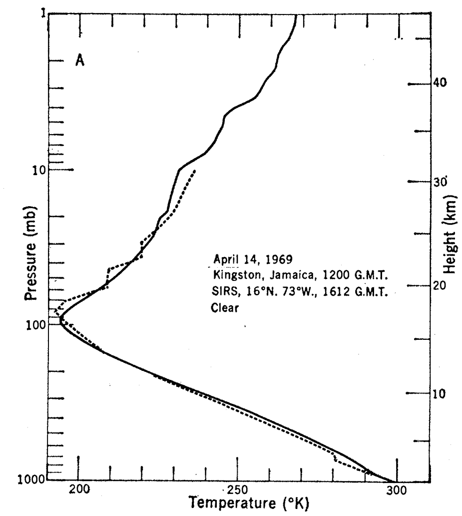
The quality of the SIRS data is attributed to design features of the instrument and to the very stable environment provided by the Nimbus spacecraft. Thorough testing of the Nimbus spacecraft before flight resulted in complete compatibility of the instrument with all other experiments and systems.

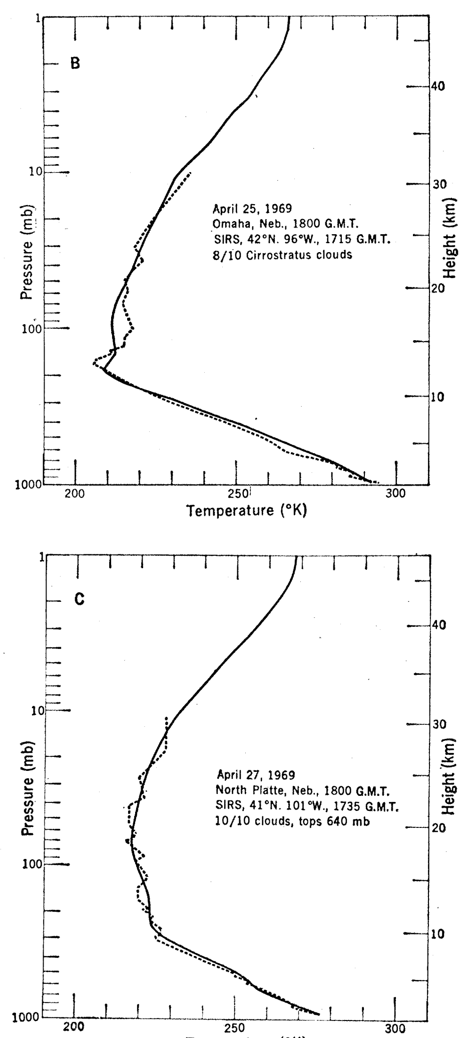
During the first 2 weeks of the Nimbus III flight, a verification and testing program was in force. Special radiosonde ascents were made by the Weather Bureau at selected stations in the United States and in the western Pacific, which were within the field-of-view of the SIRS instrument. Other areas were also examined for coincident observations. Five examples have been selected for presentation here (Table 1 and Fig. 1).

Figure 1A is the historical first sounding derived from satellite measurements. It shows the Kingston, Jamaica, sounding about 400 km to the northwest of the SIRS observation. The main difference between the two soundings lies in the middle troposphere, where the SIRS sounding is warmer. This should not be interpreted as a deficiency in the concentration of carbon dioxide. Instead, it indicates that the transmittances, which were calculated from theory and laboratory measurements, are slightly in error.

Figure 1B is especially significant because the sky was mainly covered by high clouds. Despite this, the solution indicated that thin, high clouds have little effect upon the radiances and upon the solutions. Figure 1C represents an undercast. North Platte reported an overcast sky with mixed rain and snow at the time of the radiosonde release. In this figure the sounding between 640 mb and the surface was interpolated between the satellite-derived temperature and the known surface temperature. Parts D and E of Fig. 1 represent mid- and high-latitude soundings, respectively, with clear skies.

From these examinations we con-





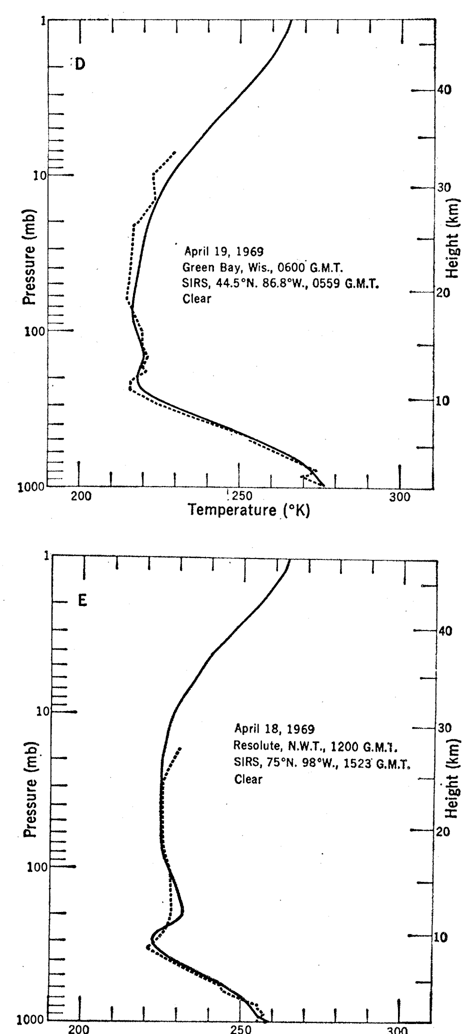


Fig. 1. Comparison of temperature profiles derived from SIRS data with radiosonde data. Solid curves, SIRS retrievals; dotted lines, radiosonde profiles. Dates, times, stations, geographical locations, and cloud conditions are shown in each set of profiles, A through E.

Table 1. The Nimbus III SIRS channels, central positions, and spectral bandwidths; the sample sets of measured radiances in c.g.s. units are used to construct the temperature profiles presented in Fig. 1.

Channel	Position		Bandwidth		Radiances from Fig. 1 (erg sec^{-1} cm^{-2} sr^{-1} cm)				
	(cm^{-1})	(μm)	(cm^{-1})	(μm)	A	B	C	D	E
1	899.3	11.12	5.353	0.0662	111.26	107.90	58.20	74.92	48.58
2	750.0	13.33	5.988	.1065	105.60	99.69	69.31	83.66	62.56
3	714.3	14.00	5.357	.1050	74.40	68.25	59.26	63.30	55.44
4	706.3	14.16	5.221	.1047	58.94	53.91	52.23	52.79	51.29
5	699.3	14.30	5.102	.1043	46.33	45.09	47.01	45.73	50.00
6	692.3	14.44	4.986	.1040	40.96	42.73	46.78	44.85	50.83
7	677.8	14.75	4.748	.1033	53.16	46.64	48.94	47.10	52.17
8	669.3	14.94	4.604	.1028	55.34	57.50	58.97	56.02	58.34

clude that (i) cirrus clouds are not the serious deterrent to temperature retrieval that had been feared by some people. Only when the thin cirrus is overcast is a significant effect noted in the temperature retrieval; under these circumstances, the detection and evaluation of the optical thickness is amenable to solution. (ii) The most serious impediment to the solution of Eq. 1 is the boundary term. Day and night heating and cooling of the surface causes enormous differences between the ground and air temperatures which make it often impossible to solve the equation when clouds are present. This can be circumvented by the simultaneous use of high-resolution measurements of the surface temperature in optical windows. The problem is almost nonexistent over water areas where the surface temperature is stable. (iii) The use of a single instrument to obtain all soundings has the advantage of eliminating biases arising from instruments of varying reliability and differences in design, calibrations, and manufacture. Further, the solar and thermal radiation effects, to which radiosondes are subject, have been eliminated. This is particularly striking in the stratosphere. (iv) The success of this experiment is dependent upon the high quality of the instrument. There must be no relaxation of effort to improve the standards of calibration and to minimize random errors in future instruments designed for similar purposes.

The figures show only the ability of measurements to reproduce single temperature profiles. The purpose of this experiment, however, is an attempt to reproduce fields, particularly over oceans, where data are sparse. W. L. Smith and H. M. Woolf have produced isobaric contour charts (*13*) from the SIRS data which indicate that the results from this experiment may be used to improve significantly the analyses in regions largely devoid of radiosonde observations.

Because the first SIRS points only in the vertical, many data are obtained along the line beneath the spacecraft, and between orbits (about 3000 km at the equator) there are no data. Future instruments will view to the side as well as straight down, to yield a more uniform grid of data.

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Interferometer Experiment on Nimbus 3: Preliminary Results

Abstract. *A Michelson interferometer spectrometer carried aboard the Nimbus 3 satellite, launched 14 April 1969, measured the spectrum between 400 and 2000 wave numbers with a resolution of 5 wave numbers. High-quality spectra have been obtained on a global scale, and preliminary results indicate that the absorption bands of carbon dioxide, water vapor, and ozone can be used to obtain vertical distributions of temperature, water vapor, and ozone.*

Among the instruments carried by the Nimbus 3 satellite, launched 14 April 1969, was a Michelson infrared interferometer spectrometer (IRIS). This instrument measures the thermal emission spectrum of the earth between approximately 400 and 2000 cm^{-1} (5 to 25 μm) with a spectral resolution of 5 cm^{-1}. Spectra of good quality have been obtained.

A sample spectrum calculated from a single interferogram taken over the Pacific Ocean is shown in Fig. 1. Comparison with two known calibration sources establishes the absolute intensity scale; the interstellar background serves as one source and an on-board warm blackbody provides the second calibration source. Random errors in the spectra, as estimated from the repeatability of calibration spectra, are about 5 to 10×10^{-8} watt cm^{-1}. The instrument's field of view is a cone of 4° half angle which corresponds to an area on the surface of the earth approximately 150 km in diameter.

In the spectral range investigated, the band of CO_2, at 667 cm^{-1}, that of O_3 at 1042 cm^{-1}, and numerous features of H_2O are available for analysis. Semitransparent regions between absorption lines make possible surface observations in areas free of clouds.

The scientific objectives of this experiment may be grouped into four categories: (i) a demonstration of the feasibility of measuring atmospheric profiles of temperature, humidity, and ozone; (ii) a study of the usefulness of the profiles for numerical modeling of the general atmospheric circulation; (iii) a display of certain parameters on a global scale for meteorological research; and (iv) investigations in meteorology, geophysics, and radiative transfer on regional scales.

The first step in applying a new tech-