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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10. S. Twomey, *ibid.*, p. 363.
11. H. E. Fleming has been mainly responsible for the mathematical formulation, development of the inversion processes, and the evaluation of the SIRS data.
12. E. R. Westwater and O. N. Strand, *J. Atm. Sci.* **25**, 750 (1968).
13. W. L. Smith, ESSA Technical Report NESC 48 (1969), Clearinghouse for Federal Scientific and Technical Information.
14. We thank many people in the Environmental Science Services Administration, the National Aeronautics and Space Administration, universities, and private industry who have contributed to the success of this experiment.

19 May 1969; revised 14 July 1969

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 technique should be a comparison of the results from the new method with the results from well-established, older methods. Such a comparison of the IRIS-derived temperature, humidity, and ozone profiles with corresponding data from radiosondes and ground-based spectrometers is being carried out in four control areas.

One control area is over the central United States from the Canadian border to Texas. The second area is near the United States Trust Territories in the Pacific. The third and fourth areas, primarily devoted to research on ozone, are in Switzerland and western Texas. In the first two control areas, intensive radiosonde and ground-based meteorological observations are being carried out by the Environmental Science Services Administration (ESSA) simultaneously with satellite observations. Spectroscopic observations of the ozone bands at 9.6 μm are being made from the Jungfraujoch (H. J. Bolle, Munich) simultaneously with ozone sondes released nearby (H. U. Dütsch, Zürich; W. Attmanspacher, Hohenpeissenberg). Hanel has made similar measurements from the McDonald Observatory, using a ground-based interferometer and radiosonde support from a mobile balloon launch facility (ESSA support group, NASA, Wallops Island, Virginia).

One comparison profile is shown in Fig. 2 where atmospheric temperatures derived from IRIS are in good agreement with temperatures obtained from a nearby radiosonde. A similar example for water vapor is shown in Fig. 3, and an ozone profile derived from IRIS data is shown in Fig. 4. Unfortunately, IRIS data obtained simultaneously with ozone measurements *in situ* are not yet available.

The application of temperature, humidity, and ozone profiles derived from IRIS data to numerical models of the general circulation will be a major step toward the realization of a Global Atmospheric Research Program (GARP). In a meteorological sense, the atmosphere interacts at its upper boundary with the sun and outer space by the process of radiation and with the thermosphere by convection and conduction. The transfer of water, frictional effects, and heat exchange take place at the lower boundary of the atmosphere. Between these boundaries the atmosphere is governed by laws of hydrodynamics that were well known long before the turn of the century. Because of the highly nonlinear character of these differential equations, general solutions have not been found.

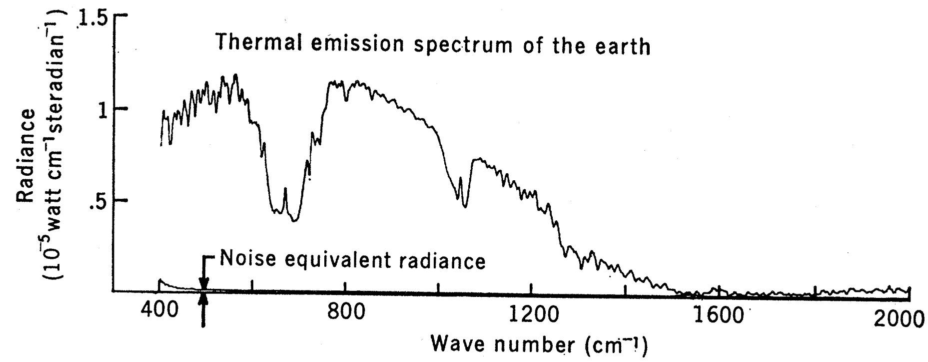

Fig. 1. Thermal emission spectrum of the earth obtained with the infrared interferometer spectrometer (IRIS) carried in the Nimbus 3 satellite. The spectrum was recorded over the equatorial Pacific Ocean on 15 April 1969.

It has only recently become possible to attack this problem by numerical integration with high-speed computers. In these numerical models, the atmosphere is divided into many volume elements, and each element is specified by its temperature, density, mass flow across its boundary, and composition. In specifying the composition, the atmospheric gases of interest are water vapor and ozone. The equations, sometimes in a simplified form, are then integrated numerically from a set of initial values that specify atmospheric conditions at a particular time for the whole globe. To verify the results of the integration, the predictions must be compared to atmospheric conditions at later times. The present radiosonde network adequately covers only a small fraction, perhaps 20 percent, of the earth. Therefore, the global character of satellite measurements is most important. The IRIS experiment now provides some of the required information such as temperatures, humidity, and ozone profiles for times near local noon and midnight. No infrared technique can directly yield information below the level of dense clouds. However, methods for the extrapolation of temperatures are being developed. Even though extrapolation of humidity is more difficult, the analysis of ozone is affected very little since the bulk of the ozone is above the cloud level. It is hoped that those doing research in general circulation will be able to make full use of the IRIS data to test and develop their models.

The above data may also be displayed on a global scale for conventional meteorological analysis. Even displays of limited spectral information will be useful. Such displays may include stratospheric temperatures (690 cm^{-1}), surface temperatures (900, 940, and 990 cm^{-1}), weak water vapor bands (780 to 1000 and 1100 to 1250 cm^{-1}), the ozone band (1010 to 1060 cm^{-1}), and the like. Two or more spectral intervals may be combined or the main emphasis may be on the horizontal gradients of the analyzed parameters. Differences in the radiance values may sometimes be the preferred display.

The spectra derived from IRIS may be used for specific research tasks in meteorology, radiative transfer, and oceanography. A few samples of such

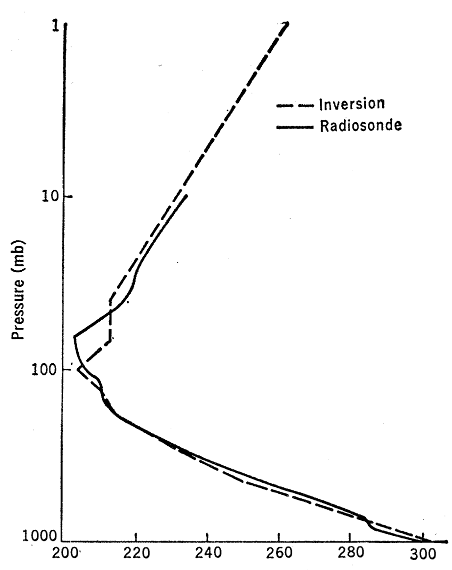

Fig. 2. Temperature profile derived from IRIS data by inversion of the radiative transfer equation; data were recorded near Brownsville, Texas, 22 April 1969 at 1737 G.M.T. Data from a radiosonde ascent at 1800 G.M.T. are shown for comparison.

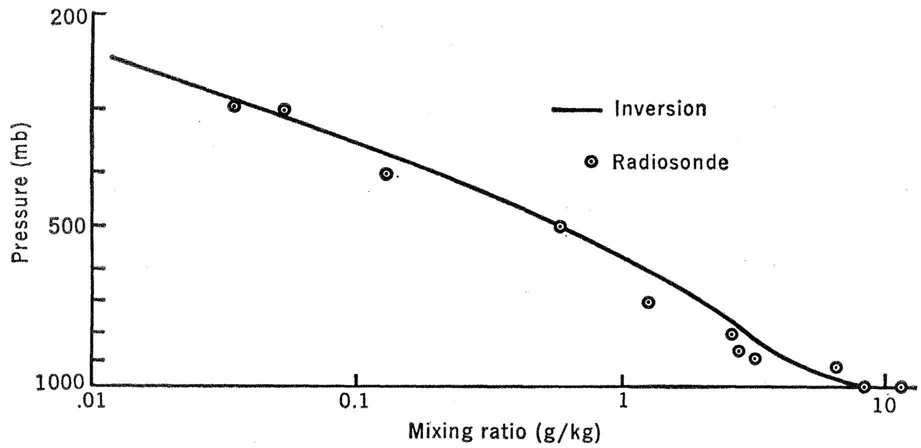

Fig. 3. Humidity profile derived from IRIS data near Brownsville, Texas, on 22 April 1969 at 1737 G.M.T. Humidity data from a radiosonde at 1800 G.M.T. are shown for comparison.

research tasks may be listed, but the list may easily be expanded.

How well can the humidity in the lowest atmospheric layers be determined in the tropics?

How well can tropospheric temperature inversions in the polar regions be recognized?

How well can one obtain the surface temperatures of the oceans from space?

Is it possible to see residual ray phenomena in desert areas where minerals are exposed? Can minerals be identified by this technique?

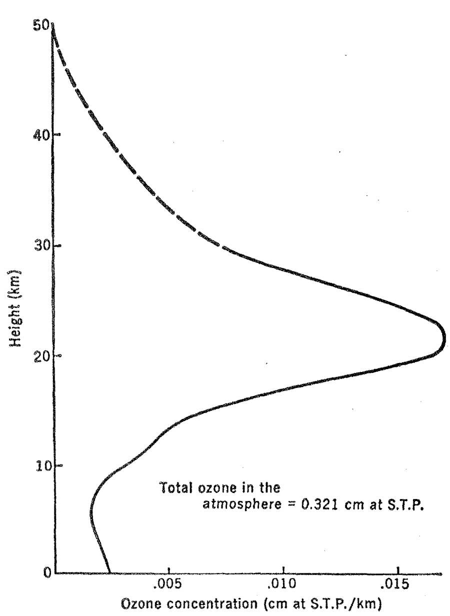

Fig. 4. Ozone profile [expressed in terms of centimeters at standard temperature and pressure (S.T.P.) per kilometer of altitude] derived from the same data as the temperature and humidity profiles (Figs. 2 and 3). The values above 30 km are extrapolated. The ozone profile was derived by C. Prabhakara.

Can air pollutants be detected?

These examples show the broad scope of scientific investigations made available by measurement of the thermal emission spectrum.

If present plans go well, calibrated spectra will be deposited in the National Space Science Data Center (*1*) in the near future. Details on the format of the magnetic tapes may be obtained from the Nimbus 3 User's Guide (*2*).

An improved IRIS experiment will be flown on the next Nimbus (D). The improvements include an extended spectral range toward longer wavelength, 200 to 1600 cm^{-1}, and a spectral resolution of 3 instead of 5 cm^{-1}. Increases in the signal-to-noise ratio and a decrease in the field of view to a cone of about 2.5° half angle will also be implemented.

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References and Notes

1. Interested researchers may obtain these data by writing to the National Space Science Data Center (Code 601), Goddard Space Flight Center, Greenbelt, Maryland 20771.
2. This guide was prepared as part of the Nimbus Project, R. R. Sabatini, editor.
3. Even though only a few people can be mentioned, many have contributed to the success of the experiment. L. Chaney (University of Michigan) helped in the early instrument development, which culminated in a 1966 balloon flight. B. Schlachman (Goddard Space Flight Center) and the group at Texas Instruments under J. Taylor and C. Prokesh contributed to the production of the flight instrument. C. Prabhakara, V. Kunde, M. Forman, A. Simmons, and G. Wolford helped in the analysis and data reduction. Credit goes to the Nimbus team for placing the instrument in a perfect orbit.

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Heterogeneity of Presumably Homogeneous Protein Preparations

Abstract. *Some highly purified glycolytic enzymes have been subjected to isoelectric focusing and found to contain a number of enzymatically active species. Crystalline aldolase A and glyceraldehyde-3-phosphate dehydrogenase from rabbit muscle were resolved into five components, crystalline aldolase from yeast was resolved into three components, pyruvate kinase from rabbit muscle yielded four components, and yeast enolase was resolved into two components. Rabbit muscle lactate dehydrogenase (M_4) gave one major peak of protein and enzymatic activity. The profiles of aldolase, glyceraldehyde-3-phosphate dehydrogenase, and yeast aldolases suggest random combinations of two closely related subunits into tetramers and dimers, respectively. The molecular heterogeneity of the other enzymes is not so easily related to subunit structure.*

Multiple forms of enzymes (isoenzymes) have been detected and isolated by a variety of procedures. Each isolated species may appear homogeneous by conventional criteria (sedimentation, electrophoretic, and immunological properties, as well as crystallizability); such behavior is compatible with, but does not prove, homogeneity. The degree of heterogeneity of an enzyme population is of considerable interest on chemical, physiological, and genetic grounds. For example, studies of the molecular and catalytic properties of enzymes as well as their regulatory characteristics usually require or assume a homogeneous population of molecules.

The technique of electrofocusing, which involves separation of proteins of differing isoelectric points by electrophoresis in a *p*H gradient, has extraordinary resolving capability (*1*). Using this technique, we showed that crystalline aldolase A (E.C. 4.1.2.7) from rabbit muscle, homogeneous by standard criteria, was composed of five catalytically active major components (*2*). This result suggested that the two subunits previously detected in this enzyme (*2, 3*) interacted randomly to form aldolase tetramers. This five-membered hybrid "subset" then seems analogous to the five-membered hybrid sets previously produced from binary combinations of aldolase A, B, and C subunits (*4*). This