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NASA

PROGRESS REPORT

METEOROLOGICAL DATA PROCESSING

NASA CONTRACT NASw-65

1 July 1961 to 31 March 1962

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University of Wisconsin

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PROGRESS REPORT - CONTRACT NASw-65

TECHNICAL REPORT

I. Status of Explorer VII and TIROS Data Processing

(a) Explorer VII Data Processing

Explorer VII data processing consists of three phases. First, the extraction of the subcarrier signals from the telemetry tapes and their conversion into a special digital computer tape which is used as an input to an IBM 704, secondly, data tapes and printouts of the bolometer and auxillary data including incorporation of calibration curves, and thirdly, the "marrying" of this information with the world map data tape to give a final tape and printout of reduced bolometer data, and orbit position. The first stage of data analysis is complete for the first year's data and essentially complete for those portions of the second year's data where operation of the payload was satisfactory. The final step in data processing is complete for data through May, 1960. This marks the beginning of the time when Explorer VII operated only during the sunlit portions of the orbit, with no operation - not even the carrier available during the dark period of the orbit. Portions of the data for this period will be machine processed only for special cases. Much of the data is too noisy to warrant processing all tapes.

(b) TIROS Data

About 10 orbits of TIROS III data and 5 orbits of TIROS IV data have been evaluated by hand. We now know enough to say that TIROS IV data is much better than TIROS III data for two reasons. First, the data on the sunlit portion of the earth is not continuous on TIROS III because of false triggering of the electronic commutator from the sun pulses. About 1/3 of the data is lost. Sometimes the loss is greater than 1/3, sometimes less, because the sun pulses tend to synchronize with the commutator. Second, the sensitivity of the "white" sensor is low, especially at high temperatures. The temperature range was set wide to be sure the subcarrier signals stayed within the band limits. The quality of the nighttime signals is very good. There is no loss of synchronism and the sensors are in a sensitive portion of the range. The quality of the signals from TIROS IV is excellent both day and night. Moreover, the sensor ranges just fill the subcarrier band to give maximum sensitivity. We expect to get high quality albedo measurements from TIROS IV as well as the usual long wave radiation measurements. There is considerably less wow and flutter in the signals from TIROS IV too. The many "meteorological" things we can do with this data must await the automatic data processing system.

does this refer to Suomi's bolometer only?

(c) TIROS Data Processing System

Technical details of the data processing system to be used for recovery of the omnidirectional bolometer data are being assembled into a technical report by Professor Parent. In brief the system consists of two distinct sections:

1. Equipment which converts the channel 6 subcarrier signals from TIROS series satellites into a new digital magnetic tape compatible with our CDC 1604 computer.

2. Computer programs for the 1604 which separate the different sensor signals, apply the appropriate calibration conversions, and "marry" this information to the orbit positions so that radiation as a function of position on the earth can be computed.

The hardware for section one makes use of the fact that the data (the subcarrier) is really already digitalized, and therefore amenable to high accuracy recovery. The period ratio between the subcarrier containing the data, (450 CPS $\pm$ 5%) and the subcarrier containing the reference 550 CPS is established once and for all the instant it is recorded on the satellite tape recorder. Playback later at a different speed or with wow and flutter superimposed does not change the ratio. To be useful it is necessary to measure the ratio with high resolution. This cannot be done directly in this case because the ratio of the reference frequency to the data frequency is not far from unity. It is possible to raise the reference frequency by frequency multiplication (in this case by a factor of 64 by doubling it six times successively). The reference frequency is now high enough so that the ratio can be established to a resolution of 1 part in 6400 if we use 100 periods of the signal data. In principal it should be possible to measure the ratio to 1 part in 6400 in the absence of noise. This has been established experimentally.

A real time system using the above outlined principles was constructed from equipment available in the laboratory. It showed that the basic system was sound although non-uniform time delays in the filter elements reduced the resolution to about 5 parts in 7500. Tests showed that the loss in resolution was due to the subcarrier filters and not the basic system. These tests were made using TIROS III and TIROS IV data. It should be mentioned that the low speed system was tested "portal to portal", that is from TIROS tape through the system and into the CDC 1604 computer with completely satisfactory results.

A high speed system which allows 1 orbit to be processed in 6 minutes is now nearing completion. The procurement of filters with constant time delay should allow almost ideal resolution and therefore very accurate data. It is expected that the whole high speed system will be operating in about a month from now.

The computer programs needed to process the TIROS data are virtually complete. These include:

1. LOID Locate and interpret data. The output is temperature of the various sensors.

2. Recopy of orbit tapes into CDC 1604 48 bit floating point words.

3. Marriage of the orbit and data tapes to give temperature and orbit position plus auxillary data.

4. Consideration is being given to the processing of NASA's cone radiometer data as well. These data will be collected and assembled as part of the data recovery system for the omni-directional bolometers anyway. At present they are discarded. The computer programs are virtually ready to go. Hardware completion is now a temporary bottleneck.

II. Data Analysis

Data analysis is concerned with extracting the meteorological content of the satellite data tapes which have been suitably edited and processed for input into the computer. This is the last step in the chain of handling the enormous volumes of data characteristic of the satellite program.

As mentioned in earlier reports, a major time consumer in data analysis for Explorer VII is the fitting together of the many pieces of telemetry along the orbit to make a continuous strip of data. The computer program to accomplish this automatically is extremely difficult and to date we have not been successful. Instead we have found it much more expedient (and less costly) to evaluate the earth's radiation for each pass on a small computer, the IBM 1620, which is available right in the analysis laboratory. With the input and output in card form it is easy to shuffle the cards into proper sequence, edit out noisy observations, and make corrections. The actual radiation computation is so simple that the small machine handles it easily. Further, the programs, written in Fortran, are completely compatible with the CDC 1604 if it is desirable to use that machine. To date the analysis objective has been to obtain good case studies of intense "classical" storms in areas where good weather map coverage also exists.

A program which presents radiation data from the omnidirectional sensors as a map similar to a weather map has been completed and is now in operational use. The input to the map program consists of orbit position information for the subsatellite point and sensor temperature. The radiation for the sub-satellite point is calculated as a first step. Then a weighting factor is applied to this observation as a function of distance from the subsatellite point to grid points on 5° latitude and longitude intersections. The total weighting function for each latitude and longitude square is calculated and finally the position of discrete radiation values is interpolated between squares and entered on a Mercator projection map. In addition the radiation data at uniform grid points instead of along the orbit path is available directly from the computer on a magnetic tape, punched cards or a printed map. Of course radiation along the orbit path is also available.

As a result of an analytical solution for the heat transfer of a semi-infinite body exposed only to radiation, given by H. H. Lettau of the Meteorology Department of the University of Wisconsin (See JGR Dec. 1961), it is possible to write a more exact expression for radiation detected by the bolometers on Explorer VII. The net result of this more exact expression is to increase the calculated range of variation of the earth's radiation, i.e., the high values are higher and the low values lower, but there has been no difference in the average values of outgoing radiation as obtained formerly by a simpler equation.

An advantage of the mapping system outlined above, over and beyond speed and labor savings, is the completely objective radiation data analysis. This analysis can be compared with actual weather maps in order to compute whether or not available eddy potential energy is being generated by differential cooling.

III. Results to Date

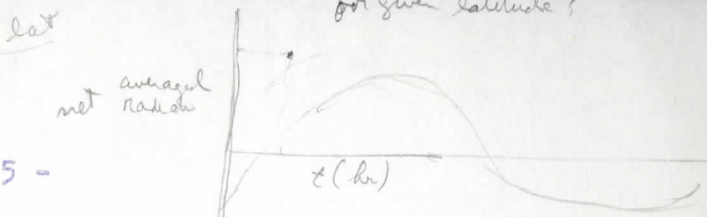
(a) A paper describing the general synoptic features of the outgoing radiation patterns as a function of weather systems has been published in the Monthly Weather Review, December, 1960. Other similar case studies for selected storms are in preparation.

(b) A source of available potential energy

Two similar papers on differential radiational cooling as a new source of available eddy potential energy have been read at the International Satellite Conference held at NASA in November and at the New York meetings of the American Meteorological Society. Both papers have been completed for publication. Stated briefly, differential cooling of atmospheric columns on a scale comparable to that of weather systems can generate or remove the available eddy potential energy which drives individual weather systems. Clearly, this important finding must be verified by additional studies. This is being provided in two ways: additional case studies similar to those already presented using Explorer VII, TIROS III and TIROS IV data and with spectral studies. The latter is a statistical method where the size scale of the available potential energy is compared to the scale of the conversion into kinetic energy. It is similar to that done by Lorentz, Saltzman and Fleischer at MIT. What they have shown is that the scale size of the eddy available potential energy is mainly situated in low values of wave number (around the earth) whereas the conversion takes place at significantly higher wave numbers. In fact, they point out this inconsistancy. There is the possibility that differential long wave radiation cooling is the mode for energy transfer. We have already established that in certain cases the magnitude of the energy is more than sufficient. Most of our effort in the near future will be directed toward verifying this hypothesis.

(c) Albedo Studies

It is easy to obtain the albedo of clouds or various other surfaces and these have been reported in the literature. It is quite another thing to obtain the planetary albedo. The problem is mainly one of sampling. The albedo of a particular orbit or day is not too meaningful because it is highly dependent on the particular cloud distribution during that pass on that day. One could, of course, obtain the monthly or seasonal albedos by integrating each orbit's albedo to determine the monthly or seasonal mean. This is not easy to do because along a given orbit there is a rapid change in local time and hence in the amount of reflected radiation. There is an easier way to obtain the long time albedo. The orbit of Explorer VII and TIROS Series satellites precesses to the west an amount which has the effect of making each pass at a given latitude occur about 22 minutes earlier each day. Thus, in a time period of several weeks, samples will have been obtained at all hours of local time. The black bolometer yields the net radiation



loss from the earth including both long and short wave radiation. If net radiation averaged along a latitude circle is plotted against local time of satellite passage at that latitude, a curve is obtained which shows the diurnal variation of net radiation averaged for the several week period. The area under the "sinusoidal" part of the curve is the average reflected radiation. This is compared to the incoming solar radiation at the top of the atmosphere for that season and that latitude to obtain the albedo. The analysis has been completed and will be presented as a master's degree thesis by Mr. Takasugi.

do we have a copy?

(d) Climatological Studies

Summaries of radiation flux leaving the earth as a function of latitude and longitude for December, January, February 1960 have been completed. These data show a surprising amount of heat loss in the Caribbean area. The heat loss for this tropical region is equal to and sometimes greater than the total incoming solar energy. The warm water temperatures and dry air from the U. S. continent are responsible. An excess of loss over input for northern latitudes is usual but a loss balancing, or greater than, the input for tropical regions was not expected.

→ why is it so warm the water currents?

Calculations readily show this for clear skies.

A summer time summary is now being prepared for comparison.

IV. Related Studies

A considerable effort on balloon radiometry is under way. This effort is partly sponsored by NASA funds and partly by the U. S. Weather Bureau. These measurements form an important part of items already mentioned and are a back-up to the Weather Bureau's theoretical work on TIROS infra red data. It is mentioned here for information only as technical aspects have been reported in the literature. The most recent contribution resulting from balloon radiometry is a table of water vapor emmisivity obtained as partial fulfillment of a Ph.D. degree by P. M. Kuhn - Department of Meteorology, University of Wisconsin.

Two summaries of some 178 balloon radiometersonde flights have been prepared. The first shows that the net radiation divergence can be estimated to good accuracy from the outgoing radiation. The correlation coefficient between outgoing radiation and cooling of the atmosphere is almost .90. This finding is highly useful since it implies that estimates of atmospheric cooling rates can be made from satellite radiation measurements. A paper summarizing these results for different cloud distributions has been accepted for publication in an early issue of the Journal of Atmospheric Sciences.

A second summary which shows the distribution of cooling rates as a function of altitude has been prepared as a Master's thesis by Mr. R. Sabatini. He shows that there is good agreement between theory and observations in the lower troposphere but considerable disagreement at higher levels. The atmospheric radiation models used to calculate the radiative flux from the earth using TIROS scanning radiometer radiance measurements are very likely

subject to error. Suitable corrections can be made using the radiometer data for empirical corrections or for tests of new mathematical models which give better agreement with observations.

Some of these new models have been calculated by Mr. Kuhn on the basis of his work described above. One now gets the distinct impression that there are many "meteorological" things that one can do with evaluated radiation data. We now have reached the situation we have been waiting for.

V. Determination of Vertical Distribution of Atmospheric Temperature from a Satellite

Kaplan and others have suggested a means for obtaining the vertical temperature distribution in the stratosphere and upper troposphere using pressure broadening of the carbon dioxide band at 14.7 microns. While the theory for doing this is reasonably straight forward it is difficult to do in practice because the available energy is low and the resolution required is high. It is far more satisfactory to compare the line wings rather than the band wings because the theory for lines is well understood. However, it is technically extremely difficult in a satellite payload to obtain the necessary resolution using conventional spectrometer techniques. Brewer has suggested using interferometer spectrometry because the line spacing in the CO_2 band is rather uniform and this technique allows much more energy to enter the instrument. Data processing, however, requires power spectral analysis.

There is a possibility that gas analyzer techniques using CO_2 as the detector may work in this application. A study of this possibility is now under way. If successful, it would enormously simplify the required satellite instrumentation. Some preliminary tests of a gas flow pneumatic detector for the gas analyzer shows promise.

Instrumentation

Instrumentation for the University of Wisconsin Radiation Balance Experiment on the TIROS series of satellites has progressed on schedule and has performed very well.

To date instrumentation has been constructed, tested and flown on TIROS III and IV. The equipment for TIROS E is installed and that for TIROS F is ready.

As indicated elsewhere in this report some difficulty was experienced due to interference from sun pulses in TIROS III. This has been corrected in TIROS IV and following units.

A special report including a complete description of the instrumentation system is in preparation and should be available soon.

FINANCIAL REPORT

The financial status of the contract is tabulated in Table I. The figures contained were tabulated from records kept by the Departments of Meteorology and Electrical Engineering, and are not official figures from the Accounting Department of the University of Wisconsin. As a result some of the figures may not be precise but reflect current status better than the Accounting Department's figures because of time lag in posting, residuals in open orders for supplies, services and computing services.

Requests for extension of the contract under Amendment No. 3 from 31 August 1961 to 31 October 1961 and later from 31 October 1961 to 20 November 1961 without increase in funds were made and granted.

A proposal for extension of the contract was submitted 20 September 1961. Amendment No. 5 to the contract covering this proposal was issued 20 February 1962. Amendment No. 5 extends the contract to 31 August 1962.

A request for a time extension of the present contract without increase in funds will be prepared and submitted shortly.

TABLE I

SUMMARY OF FINANCIAL STATUS

TOTAL FUNDS ALLOTTED - Contract and Amendments 1, 2, 3, 4 and 5 $459,050.00

EXPENDITURES		Actual 27 May 1959 through 30 June 1961 (Revised)		Actual 1 July 1961 through 31 March 1962		Total 28 May 1959 through 31 March 1962
Salaries						
Academic	$46,290		$34,675		$80,965	
Student	11,190	$57,480	5,810	40,485	17,000	$97,965
Overhead and other indirect costs		21,410		15,025		36,435
Expendable Supplies and Services		24,430		10,690		35,120
Major Equipment		34,955		24,090		59,045
Travel, Communication, Express, etc.		15,750		5,900		21,650
Computer Rental		35,805		23,115		58,920
Space Rental		1,350		------		1,350
	Total	$191,180		$119,305		$310,485
					Balance 31 March 1962	$148,565

TABLE II

CHRONOLOGICAL SUMMARY

July 13, 1961	TIROS III launched.
November 9, 1961	TIROS IV instrumentation delivered.
January 31, 1962	TIROS V instrumentation delivered.
February 8, 1962	TIROS IV launched.
March 18, 1962	First routine low speed digital data reduction for TIROS.