Evaluation of an ERTS-1 Data Collection Platform Installed in the Alpine Tundra, Colorado

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ABSTRACT

An ERTS-1 Data Collection Platform instrumented with meteorological sensors has been operated for more than a year at 3536 m in the Front Range, Colorado.

The interface system and sensor performance are shown to operate well although the message interval is suitable only for certain types of parameter with the present interface system.

1. Introduction

A major objective of recent space technology has been the communication of data in real-time to users from ground stations in remote areas. The Earth Resources Technology Satellite (ERTS)-1 included such a Data Collection System (DCS) with data telemetry from small battery-operated ground-based transmitters called Data Collection Platforms (DCP) to NASA communication stations at Goddard, Maryland, and Goldstone, California. From these stations, the information is relayed by landline links or provided within a few days by mailing of punched card or magnetic tape records. The system and various uses of it are described in Cooper and Ryan (1975).

The DCP accepts analog or digital data from up to eight sensors in the form of a 0 to +5 V signal. The data are transmitted approximately every 180 s, but they are only received and relayed to the NASA ground stations when the ERTS is within radio range and radio view of both the DCP and NASA station. The feasibility of collecting environmental data in extreme cold and windy environments using the ERTS DCP, has been investigated at an alpine site in the Front Range, Colorado. The DCP was installed on a broad topographic saddle on Niwot Ridge (40°03′23″N, 105°35′06″W) at 3536 m adjacent to alpine study plots of the U. S. Tundra Biome, International Biological Program (Fig. 1). This note summarizes the results of an evaluation of the system during 1973–74 by comparing the DCP records with those from conventional climatological measuring systems at a remote field site. Practical aspects of the use of such a DCS are also discussed.

2. Instrumentation

An eight-channel signal-conditioning system was developed in the University of Colorado, Physics Electronics Shop to interface meteorological sensors to the DCP (Clark and Wells, 1973). The interface was designed for moderately low power consumption and to provide for testing the interface performance and the DCP function. All circuits are mounted on cards so that any channel can be repaired or modified without curtailing the continuous operation of the other channels. Provision has been made to drive analog recorders from the interface outputs so that they can be utilized after ERTS becomes inactive. The normal power consumption is approximately 30 mA continuously from each of two 12 V automobile lead-acid storage batteries of 60–70 A h capacity. The design provides for possible additional circuits to regulate power and to switch off the interface system in order to conserve power when the DCP is not transmitting to ERTS.

An output circuit has been designed to allow switch selection of the output of 0 to +5 V or a recorder drive of either 0 to 1 mA or 0 to 5 mA. Continuous analog records provide supplemental data from four of the sensors. Strip-chart recorders are connected to the net radiation, wind speed, precipitation, and 2 m air temperature channels.

The sensors in use on Niwot Ridge (see Table 1) are as follows:

Channels 1 to 4. Thermistors for air and ground temperature over a −46 to +30°C range.

Channel 5. Funk-type net radiometer (for radiation between approximately 0.3 and 60 μm) in the range −1 to +2 cal $\mathrm{cm^{-2}\ min^{-1}}$.

Channel 6. U. S. Weather Bureau type F420C three-cup dc generating anemometer for measuring wind speeds up to 100 mph (45 $\mathrm{m\ s^{-1}}$) or 200 mph (90 $\mathrm{m\ s^{-1}}$) switch selected ranges.

FIG. 1. Data collection platform on Niwot Ridge, Colorado, 3536 m.

Channel 7. U. S. Weather Bureau weighing precipitation gauge. This channel is provided with a tare adjustment potentiometer so that the collection bucket and antifreeze charge weight can be eliminated from the transmitted signal.

Channel 8. Monteith-type pyranometer for global solar radiation measurements (between approximately 0.3 and 3.0 μm) in the range 0 to +2 cal $\mathrm{cm^{-2}\ min^{-1}}$.

3. Data output and evaluation

"Operational" data have been obtained on eight channels from 14 February 1973 (Julian Day 45/73) up to the time of writing. Data are received on four to five orbits per day with one to five messages per pass at approximately 180 s intervals. An analysis of message frequency during operational periods in 1973 shows a daily average of 14.4 messages received between 0800–1200 and 1830–2230 (all times MST).

A specimen printout of daily data prepared by a data processing program, from the punch-cards mailed out by NASA, is shown in Table 1. Data are often received simultaneously by Goddard and Goldstone due to the geographic location of Niwot Ridge. The program prints duplicate cards when they are present and gives the ID code for the ground station.

Slight irregularities may occur between consecutive messages due to the ± bit resolution of the DCP. This amounts to approximately the following units

TABLE 1. Specimen tabulation of daily transmissions of DCP data.

NIWOT RIDGE SADDLE DCP DATA LAT. 40 DEG. 3 MIN. 33 SEC. LONG. 105 DEG. 35 MIN. 00 SEC. 3536 M. ELEVATION

CALENDAR DATE (LOCAL)	TIME MST	JULIAN DAY (GMT)	TIME GMT	1 TEMP (C) AIR 100 CM MAST	2 TEMP (C) AIR 150 CM SCREEN	3 TEMP (C) GND 15 CM	4 TEMP (C) INTFC INTERNAL	5 NET RAD LY/MIN	6 WIND SPEED M/S	7 PRECIP ACCUM CM	8 GLOBAL RAD LY/MIN
74/ 1/14	9 10 36	14	16 10 36	-7.59	-8.35	-7.08	-9.33	-.05	15.70	12.85	.21
74/ 1/14	9 14 10	14	16 14 10	-5.29	-6.33	-7.08	-9.08	-.05	14.02	12.85	.23
74/ 1/14	10 50 8	14	17 50 8	-7.59	-8.11	-7.08	-7.59	-.06	12.27	12.95	.23
74/ 1/14	10 53 40	14	17 53 40	-8.35	-8.35	-7.08	-7.59	-.06	10.52	12.95	.23
74/ 1/14	10 57 13	14	17 57 13	-6.83	-7.59	-7.08	-7.59	-.06	16.13	12.95	.27
74/ 1/14	11 0 45	14	18 0 45	-7.08	-7.59	-7.08	-7.59	.02	16.83	12.95	.76
74/ 1/14	19 9 23	15	2 9 23	-6.58	-7.34	-7.08	-6.33	-.09	25.95	14.94	.03
74/ 1/14	20 44 32	15	3 44 32	-6.33	-6.58	-7.08	-7.08	-.09	25.24	15.24	.04
74/ 1/14	20 48 4	15	3 48 4	-6.58	-7.08	-7.59	-6.83	-.12	23.49	15.24	.04
74/ 1/14	20 51 36	15	3 51 36	-7.59	-7.08	-7.08	-7.08	-.11	27.70	15.34	.03
74/ 1/14	22 27 2	15	5 27 2	-7.59	-6.58	-7.08	-7.34	-.08	24.19	15.44	.04
74/ 1/14	22 30 34	15	5 30 34	-5.29	-6.58	-7.08	-7.34	-.08	30.15	15.44	.03
74/ 1/14	22 34 6	15	5 34 6	-8.59	-6.58	-6.33	-7.34	-.09	24.89	15.44	.03
			MIN	-8.59	-8.35	-7.59	-9.33		10.52		
			MAX	-5.29	-6.33	-6.33	-6.33		30.15		
			MEAN	-7.02	-7.24	-7.06	-7.55		20.55		

13 TRANSMISSIONS

1.0 LANGLEY(LY)/MIN = 1.0 GM.CAL/SQ.CM/MIN = 69.7 MW/MIN

per bit:

Temperature	0.297°C, wide range 0.098°C, narrow range (operated Julian day 44 to 191, 1973)
Solar radiation	0.0132 ly
Net radiation	0.0117 ly
Wind speed	0.176 m s^{-1} at 45 m s^{-1} 0.352 m s^{-1} at 90 m s^{-1}
Precipitation	0.099 cm

Evaluation of product errors that we attribute to the DCS has been performed as follows. DCP input can be tested on any or all channels by supplying a constant 4.000 V signal, switch selected on the analog signal output circuit card. This should initiate DCS output on the user card of 4.000 V on all channels. Cards we received when tests were conducted indicated an output of 4.06 V on all channels. Field tests verified the interface output to the DCP analog inputs of 4.00 V, and it was concluded that final data from the DCS are two bits high on all channels.

This analysis demonstrates the necessity of designing a test capability into the sensor interface in order to verify data accuracy from the sensor input, through signal conditioning, A/D conversion, coding, transmission, to final product. Modification of the interface is possible so that this test is performed automatically after a selectable number of transmissions, utilizing the DCP "Datagate Pulse" feature.

During periods of constant temperature (e.g., in the soil at 15 cm) we have noticed ±1 to 2 bit changes which could be attributed to circuit instabilities or sensor and cable connections. This is apparent on all channels. For example, the accumulated precipitation increased by 0.10 cm between 0914 and 1050 on 14 January 1974 (Table 1) as a result of this factor. Comparing thermistors for air temperature (Channels 1 and 2) with standard thermometers in a thermometer shelter, confirms interface output agreement within 1.0°C. Interface circuit component failures occurred twice and emphasized the necessity for following careful grounding practice with all sensor and cable installations. The plus and minus 12 V battery power supply is connected to ground via the common conductor. The DCP has operated without failure during the entire project.

The receipt of messages primarily at morning and evening hours and the 1½ h "spread" of the message time over a 9–10 day cycle, presents major problems of data analysis for meteorological purposes. For example, the diurnal course of temperature or solar radiation makes averaging of instantaneous data from 4–5 message periods inadequate to represent mean daily values.

Analysis of wind speed data (m s^{-1}) at 8 m above ground from the DCP and estimates from a corresponding analog record over the 24 h period gives the comparison shown in Table 2. The analysis indicates that useful monthly mean wind speeds can be obtained with the present message interval with approximately 15 transmissions per day concentrated in the morning and evening hours. However, the DCP data cannot be used to estimate individual daily means unless the interface system incorporates an accumulating run-of-wind counter.

Comparison of soil temperatures at 15 cm measured by thermistors linked to the DCP and at 10 cm by thermistors linked to a Rustrak analog recorder system

TABLE 2. DCP and analog records of wind speed.

Month	Number of days	DCP Mean	DCP Standard deviation	Analog record Mean	Analog record Standard deviation	Correlation coefficient
March	14	6.5	3.8	6.9	3.9	+0.88
April	27	6.7	4.5	8.3	4.3	+0.83
May	30	7.2	4.2	8.4	4.2	+0.88
December	24	11.8	3.5	11.4	3.0	+0.87

for the period 12–31 May 1973 gave mean values of −0.5°C for the former and −2.3°C for the latter at both 1030 and 2030 (approximate time). The systematically higher reading of the DCP thermistor (at a greater depth) than the Rustrak thermistor probably reflects a difference between the sites of the installations, some 50 m apart, as well as the slight bias of 0.2°C due to the DCS product error. The time trends are in parallel during the period of comparison so that the DCP records appear to provide a good representation of this slowly-changing parameter.

Fig. 2 shows a tracing of the precipitation record for 6–7 January 1974 with the DCS values converted to match the chart scale units. The DCP data show an increment of 2.07 inches from 0825 on 6 January to 0833 on 7 January while the recorder measured 2.08 inches in close agreement. Such comparisons of transmitted and analog data require good time synchronization in most instances and are not possible, for example, if the chart drives have lost speed due to low temperatures.

4. System evaluation

The DCP performed excellently in alpine conditions. Environmental extremes during the period of operation were as follows:

Minimum air temperature	−25.5°C (31 December 1973)
Electronic interface internal temperature at circuit cards	−18.6°C
Maximum wind speed	40.9 m s^{-1} (12 December 1973)

Data quality was consistently maintained. However, the present message interval (with a concentration of passes in the morning and evening) is unsatisfactory for many meteorological/climatological applications unless more sophisticated and costly interface units, incorporating data storage capabilities, are developed. The present message frequency is usable only for parameters which change very slowly during 24 h, such as ground temperatures, or which can be incremented between successive readings, such as accumulated precipitation.

Meteorological data from remote mountain locations are rare and many stations are sited for convenience in accessible valleys. For example, the climatological station at 3750 m on Niwot Ridge, which has been serviced at weekly intervals (weather and manpower permitting) by INSTAAR personnel since 1952, represents the longest such data series at this elevation in western North America. There are few weather stations at or above 3500 m. Data from mountain stations are of importance as current weather reports to foresters, highway maintenance staff, tourists, and pilots of light aircraft, or to provide a basis for short-term forecasts. Precipitation data are especially valuable from remote mountain areas because of their usefulness in runoff and watershed yield forecasting and the weighing storage gauge is ideally suited to applications such as the ERTS DCS.

Given either an alternative mode of data collection and transmission, such as that provided by the NOAA GOES data collection system, or improved interface systems incorporating accumulating registers and storage of maximum and minimum values, such as that proposed by the U. S. Geological Survey (Preble, 1975), the DCP has the potential for making a valuable contribution to meteorological data acquisition in remote areas. A particular application of current interest would be the installation of platforms

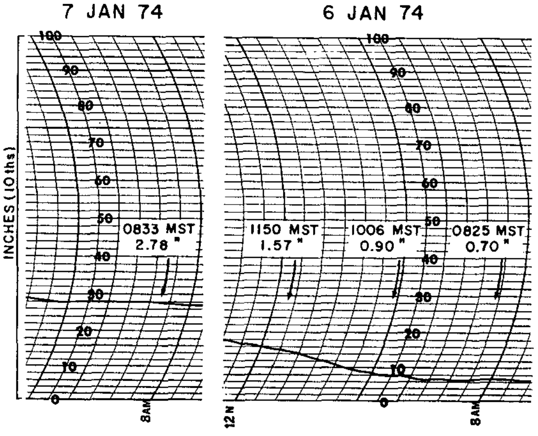

FIG. 2. Record of precipitation accumulation for 6–7 January, 1974: inserted values were received from DCS.

to monitor the wind power potential in mountain locations.

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