Constant Level Balloon Data

Roy Jenne
1 Sep 2000

This collection of papers is about the world's constant level balloon data during 1970 through 1980. These balloons were not allowed to overfly the land masses of the Northern Hemisphere so they had to remain in the Southern Hemisphere. The data include:

EOLE: Many balloons over the Southern Hemisphere Aug 1971 – Dec 1972. NCAR has the dataset of balloon locations.

TWERLE: Data on NCAR tape for 13 Jun 1975 to 09 Aug 1976. The Southern Hemisphere balloons floated near 150 mb. By 17 Aug 1975, there were 95 balloons up and working, and more later.

FGGE: Jan 1979 – on. About 10 balloons were operational by 8 Jan 1979 and a peak of about 80 operational by about 3 Feb 1979. Since there were no more launches, the active balloons decreased to about 18 by 5 Mar 1979. (This was for the Winter Monex period.) Maybe there were more launches for summer Monex?

Constant Level Balloon Data

Roy Jenne
5 Sep 2000

NCAR has been using most of the available constant level balloon data for reanalysis. However, when (and if) time becomes available for more work, a significant amount of additional wind data could be added. Table 1 shows the constant level balloon data at NCAR.

TABLE 1. CONSTANT LEVEL BALLOON DATA (STATUS SEP 2000)

Data	Dates	NCAR Dataset Number	Comment
EOLE	08/71 – 12/72	DS 800	No winds yet. They need to be calculated.
TWERLE	07/75 – 08/76	DS 615.0	There are not enough winds. Work should be done to add more.
FGGE	Mostly 1979	DS 800.1	We used this and it should include all Monex balloon data.
Monex	Mostly 1979	DS 800.2	Did not use this. The best version should be in the FGGE dataset (in 2nd version FGGE).

Notes:

a. We should have the EOLE balloon data for 21 Aug 1971 through 23 Dec 1972 (16 months). The coverage for the Southern Hemisphere was good. The tapes give time and location data. Winds are no longer available and need to be calculated.

b. Monex. At the time, we got the advice that it was best to use the Monex data from the FGGE dataset source. This sounded reasonable because the preparation of the data went through different paths. There is a little lack of proof; we never had time to check to be certain that the data are in the FGGE dataset.

c. This text is a collection of papers that give a lot of information about the constant level balloon data.

Constant Level Balloons for Southern Hemisphere
(We propose a new set of balloons)

It would help data coverage a lot if we had a set of 100 active balloons in the Southern Hemisphere, located near 150 mb. The French EOLE experiment gave us this coverage and TWERLE also gave it (along with an altimeter), but these experiments were soon gone.

When an observing platform can give valuable data for an isolated region, and do it at a very low cost then we need a more active discussion. In 1989 – 90, a company proposed a continuous set of 100 balloons near 150 mb, at a cost of $1.6m per year. This seems very attractive.

A list of some of the papers in this text:

1. Data for Constant Level Balloons (2 p) 21 Apr 1999 - Rev 11 Sep 2000
2. Try for More Observations for Southern Hemisphere (1 p) 1 Sep 2000
3. The TWERLE Experiment, *Bull. AMS*, Sep 1977
4. The TWERLE Balloon Dataset (Jenne, 5p) 8 Apr 1996
5. The EOLE Format-2 Tape (2 p), a letter in 1972
6. DS 800 EOLE Balloon Data (Jenne, 6p) 11 Apr 1973
7. TWERLE Data (Jenne, some notes, 2 p) 7 Jul 1995
8. TWERLE Balloon Data to Send NMC (Jenne, notes) 27 Feb 1996
9. EOLE Experiment, Early Results… (Morel, *Bull. AMS*) Apr 1973
10. EOLE, some letters and messages
11. GARP: FGGE, Winter Monex… (drifting balloons, 4p)
12. A Balloon System to Give Us Data (Jenne, information on proposal)

Data from Constant Level Balloons

Roy Jenne
21 Apr 1999
Rev 11 Sep 2000

We can use constant level drifting balloons for reanalysis. The three main periods are:

Experiment	Time	Comment
a. EOLE	Aug 71 – Dec 1972	100 balloons over Southern Hemisphere. Down to about 35 balloons in Jul 1972.
b. TWERLE	Jul 75 – Aug 1976	Many balloons
c. FGGE	Mostly 1979	Some data in FGGE dataset

1. Constant Level Balloon Data, Southern Hemisphere

   a. EOLE balloons (21 Aug 1971 – 23 Dec 1972). Near 150mb. An archive of balloon locations is available at NCAR (See *Bull. AMS* Apr 73). Does our archive stop in Jul 1972? Winds need to be calculated and there is no time.
   - New winds have not been calculated yet (valid Sep 2000).
   - The data can't be used for reanalysis as yet, because there are no winds (as of Apr 1999).

   b. TWERLE (Jul 1975 – Aug 1976) some later. Near 150mb. (See *Bull. AMS* Sep 1977)
   This is an important archive to include in reanalysis. TWERLE balloons had a good tiny altimeter that could measure the distance from balloon to the ocean. When used along with the pressure at balloon level, this gives us data like one mandatory level in a rawinsonde report.
   - They gave good data coverage for Southern Hemisphere, near 150mb.
   - Ready for reanalysis on 15 March 1996 (it was used for NCEP/NCAR reanalysis).
   - Some more work on the primary archive may allow us to extract more good data.

   c. The FGGE data for 1979 is being used for reanalysis. The FGGE data includes some constant level balloon data.

≻≻≻≻≻ More information about EOLE and TWERLE follows ≺≺≺≺≺

2. EOLE Balloon Experiment (over Southern Hemisphere), 1971, more information

Time: For 21 Aug 1971 – 23 Dec 1972. (*Note:* This dataset does end in Dec 1972, not July.)
The constant-level balloons drifted near 200mb.
Balloons: 50 were up in Sep 1971, 130 in early Oct, 280 in Nov 1971, about 40 balloons in July 1972. There were 155 days with more than 100 balloons aloft. The French made a motion picture of balloon tracks. It outlines the evolving big waves in the circulation pattern and is very interesting. See paper about EOLE by Morel and Bandeen, *Bull. AMS* Apr 1973.

- The archive of balloon location data is available from NCAR. In about 1997, NCAR gave a copy of the archive back to France.
  - Someone needs to calculate winds
  - These data have not been used for reanalysis

Note: I have seen literature that used winds from EOLE balloons. But it appears that the winds were not archived.

EOLE balloons

- Aug 1971 – Dec 1972
- No winds yet
- We need to calculate winds

3. TWERLE Balloon Data (Jul 1975 – Aug 1976). (See *Bull. AMS*, Sep 1977)

Constant level balloons near 150mb gave rather good data coverage of the Southern Hemisphere during this period. The TWERLE balloons had a tiny altimeter that gave the distance to the ocean (or land) with an accuracy of about 10 meters. The reports also give the pressure, and over water they can be used like one mandatory level (near 150mb) in a rawinsonde ascent.

- Ready for the NCEP/NCAR 50-year reanalysis on 15 March 1996 (it was used).
- It was provided to ECMWF on Jul 30, 1998.
- Some more work on the primary archive may allow us to extract <u>more good data</u>. So far, winds are not given for one general case where they could be calculated.
- History: The data were also used to give better information about the elevation of the Antarctic ice cap.

Note: I think that only the TWERLE wind data were used in reanalysis (not heights).

- It would be useful to see how well the reanalysis (near 150 mb) fits the pressure – height data from the TWERLE balloons.
- Not enough TWERLE winds are available. More should be derived.

Try for More Observations for Southern Hemisphere

(a proposal)

Roy Jenne
1 Sep 2000

There are very few *in situ* observations for the Southern Hemisphere in the west wind belt about 35 to 65 South Latitude. It would really help to have more observations there, such as a continuing set of 100 balloons near 150 mb, as for TWERLE.

In 1989 – 90, I tried to see if it might be possible to establish such a program. We even got a proposal to do it for $1.6m per year plus some donated help (like balloon launches). This is very, very cheap for what it would give to the world, yet we could not make it happen.

- Perhaps I could not free up enough time to really sell it in a more active way.
- There is a paper about this proposal in this set of papers.

Rory Jenne

Balloons over So. Hemisphere.

The TWERL Experiment

The TWERLE Team [1]

Sept 1977

This paper is dedicated to two men from the University of Wisconsin, Mr. Charles Blair and Mr. John Kruse, who helped to develop the balloon-borne scientific equipment used in the TWERL Experiment. These men lost their lives in an aircraft accident when returning from a systems test, five years before the full importance of their contributions was realized. We hope the results reported in this paper will serve in some small way to testify to their good work.

Abstract

One of the experiments aboard the Nimbus-6 satellite was a data collection and Doppler location system used in conjunction with a fleet of instrumented superpressure balloon platforms. The acronym TWERLE stands for Tropical Wind, Energy Conversion, and Reference Level Experiment, after its principal scientific objectives. A brief system description is given together with a discussion of the launch, in the tropics and Southern Hemisphere, of the 400 balloon platforms. The platforms were designed to float at a nominal pressure of 150 mb. A number of preliminary scientific results are discussed in different subject areas. The large, or hemispheric scale, dispersion of the platforms exhibited definite nonrandomness in that clustering in certain regions of the tropics occurred while other regions were avoided. Owing to the fact that the balloons drift with the wind on a surface of constant density, the basic data are quasi-Lagrangian in nature. Some interesting aspects of such data are discussed. Notable was the fact that ~25% of the balloons launched from Christchurch, New Zealand (44°S), at some time in their history entered the Northern Hemisphere. The TWERLE platforms carried sensors for measuring pressure, temperature, and altitude. Such sensor data permit investigations of various kinds of wave motion that influence the balloon platforms. Among those motions investigated and discussed are gravity waves, orographic lee waves, and forced wave flow over developing convective clouds. The subjects covered here are intended to demonstrate the extraordinary flexibility and utility of an instrumented superpressure balloon system using a satellite vehicle for data collection and for location determination.

1. Introduction

The Nimbus-6 spacecraft carries an experiment designed to locate and collect data from a large number of drifting platforms. In the case of the Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE), these platforms were instrumented balloon platforms designed to float on a constant density surface. The design, launching, and tracking of these balloon platforms represents the work of a large number of people, all of whom while essential to the success of TWERLE cannot be acknowledged individually here. TWERLE is a joint program of the NASA Goddard Space Flight Center, the University of Wisconsin, and NCAR.

The original scientific objectives of the experiment were:

1) to obtain an adequate density of wind and temperature measurements in the tropical upper troposphere with the purpose of studying the interactions of tropical circulation systems with those of middle latitudes;
2) to obtain data on the pressure gradients along balloon trajectories that can be related to the rate at which potential energy is converted to kinetic energy in the upper atmosphere;
3) to study the need for and the characteristics of an *in situ* measurement of pressure and temperature at a known geometric altitude (the principal use of reference information would be to provide a fiducial point for remote atmospheric temperature sounders such that sounder data can be more accurately assimilated by large global atmospheric circulation models).

The modification of eight of the TWERLE balloon platforms to allow recording of the sensor data for several hours each day permitted a global investigation of gravity and other wave activity at balloon altitude.

Thus another scientific objective was added:

4) to investigate various modes of gravity waves in the upper tropical troposphere and lower mid-latitude stratosphere.

TWERLE is a GARP-related experiment. The location and data collection system on Nimbus-6 resulted in a successful effort to fly a simple, reliable system that uses low-cost platform expendables. The concept of a random Doppler system allows simplicity and low cost with no sacrifice in position accuracy. The concept of an instrumented balloon platform not only allows the determination of Reference (Level) Information for a global-observing system but has also proven that probing of various kinds of wave activity at balloon altitude is possible.

The TWERL Experiment drew upon the expertise and technology of a number of previous experiments using the combination of GHOST-type balloons (Lally *et al.*, 1966) and orbiting satellites. These tracking and data collection experiments were summarized by Master-

[1] P. Julian, V. Lally, and W. Kellogg of NCAR; V. Suomi, University of Wisconsin; and C. Cote, NASA Goddard Space Flight Center.

Principal architects of this article are: P. Julian, NCAR, Boulder, Colo. 80307; W. Massman, University of Wisconsin, Madison, Wis. 53706; and N. Levanon, Tel Aviv University, Tel Aviv, Israel.

NCAR is sponsored by the National Science Foundation.

R. Jenne

TABLE 1. Statistics of TWERLE platform lifetimes as of 9 August 1976.

Launch Site	No. Launched	No. Flying	Average Life, days	Longest Life, days	Northern Hemisphere Cutdown, %	Southern Hemisphere Cutdown, %	Electronic Failure, %	Natural Weather Death, %
Ascension	109	0	50	264	42	14	6	38
Samoa	102	0	71	265	30	12	8	50
Ghana	47	0	23	185	66	6	11	17
Christchurch	135	29	>113	>364	7	0	14	79
	393				29	8	8	47

wand extending ∽1 m horizontally from the train and nearly at the train's end. The design accuracy of the thermistor as employed is 0.5°C and the resolution is ∽0.2°C. The pressure sensor is a specially designed aneroid system. The aneroid capsules are maintained in a chamber equipped with a relief value that opens just prior to arrival at float altitude. The purpose of this arrangement is to reduce the effect of hysteresis in the capsules. The design goal was 0.5 mb accuracy and a sensitivity of 0.25 mb.

The altimeter is a lightweight, low-power, radio altimeter operating in the 400 MHz range. The instrument is basically a pulse radar measuring the delay time between the transmission of a pulse downward and the detection of the return signal reflected from the ocean surface. The instrument has been described in full by Levanon *et al.* (1974b). The design accuracy of this instrument is, in principle, limited by the knowledge of the velocity of light, the delay times in the electronics, and the consistency in locking on the reflected wave form. The telemetry resolution was 3 m. Empirical tests of the accuracy and precision of the sensors are given in the following section.

3. System evaluation

The design parameters for the random Doppler system on Nimbus-6 were 5 km location and 1.5 m/s velocity accuracy (both vector rms). The accuracy realized by the system has been found (not unexpectedly) to be a function of platform-satellite relative geometry and the actual trajectory of the platform over the 2 h interval involved in contact with the satellite. Ground truth in the form of a dozen FPS-16 radar tracks of TWERLE platforms at Ascension Island during the 2 h interval in which the satellite was determining position and velocity indicates that the 1.5 m/s vector rms accuracy is met when optimum geometry and well-behaved platform motion exists. Moreover, the software algorithm used to solve the Doppler equations is capable of giving quantitative information on the nature of the solution so that vector errors >0.5 m/s may be anticipated. Position accuracy is, for stationary platforms with accurate satellite ephemeris, better than 3 km (rms).

Evaluation of the pressure, altitude, and temperature sensors has been completed. Experience gained by simultaneous FPS-16 radar altitude determination indicates 15 min average radio altitude to an accuracy of a few meters with system precision of ∽10 m (rms). Temperature accuracy is difficult to determine, but comparisons with radiosonde measurements indicate TWERLE temperatures average ∽1°C lower. The pressure accuracy is also difficult to state because of lack of independent measurements at altitude and the detection in at least a portion of the sensors of a creep or drift over time. In general, the design accuracy of 0.5 mb was not achieved, and we have undertaken an extensive program of adjusting each pressure sensor to a common datum depending upon conventional radiosonde data and climatological data derived from observations from all TWERLE platforms. The sensitivity of the pressure sensor, however, did prove to be good—on the order of 0.25 mb.

The launch strategy planned for TWERLE was based upon anticipated southward drift of the platforms, from the tropics where most of them were launched, into southern mid-latitudes. This behavior was observed and introduces a complication in interpreting the statistics of mean platform lifetimes, since the vicissitudes of flying in the upper tropical troposphere are much greater than in the lower stratosphere of mid- and polar latitudes. Table 1 provides a summary by launch site of the disposition and mean lifetimes of the TWERLE platforms. In constructing this table, some unresolvable causes of failure (electronic, balloon envelope, and weather-induced failure) are lumped into the "natural" category. In summary, TWERLE achieved a level of 95 platforms up and working on 17 August 1975, and the number remained above that level, but did not exceed 125, until mid-February. As of 1 December 1976, 16 platforms were still flying.

During the course of the experiment, in July 1975, it was noted that an unexpectedly large number of platforms were last heard from and presumably down over the higher latitudes of the southern Indian Ocean. Hurried analysis resulted in the detection of a problem in the magnetic cutdown device; the high magnetic field intensities of that region were causing the device to activate in spite of the design criteria to activate at much smaller intensities of opposite sign (i.e., Northern Hemisphere). This problem was quickly solved and modifica-

Roy Jenne
23 Feb 1996
Rev 08 Apr1996

The TWERLE Balloon Dataset

Data from TWERLE balloons (near 150 mb) over the S. Hemisphere are available in NCAR archives for 13 Jun 1975 to 09 Aug 1976.

Winds, temperatures, pressures, and altitudes were measured by the TWERLE super pressure balloons that flew over the southern hemisphere during 1975-76. A total of 393 TWERLE balloons were successfully launched from four sites in the S. Hemisphere during the second half of 1975 (The TWERLE Team, 1975). The span of data on tape is 13 Jun 1975 to 09 Aug 1976. The balloons floated near 150 mb. By 17 Aug 1975, 95 balloons were up and working. The number did not exceed 125 until mid Feb 1996. On 9 Aug 1976, 29 balloons were still flying (and this is the date when our tape archives stop). A total of 88,512 data reports are available for the 395 days of data on the tape (average of 224 per day).

During the period 15 Nov 1975 to 31 Jan 1976, the TWERLE data (and rawinsonde reports) were used to objectively prepare daily 150 mb height grids for about 45°S - 90°S (Levanon, et al., 1979).

1. The calculation of winds in TWERLE

As the constant pressure balloons drifted around the Southern Hemisphere, a satellite periodically went over the balloon. At that time, the satellite read data from all of the balloons within view and it determined the position of the balloon at the same time. In many cases, the satellite would also obtain data from the same balloon on the next orbit, about 105 minutes later. From the two balloon positions, the wind speed could be calculated and assigned to the mid point location. Most of the balloons were at heights where the pressure was between 120 and 175 mb. This keeps them high enough that they could have a long lifetime; the clouds and ice in the lower atmosphere cause short lifetimes.

Data reports that have winds based on two successive satellite passes are called 2-pass cases. More winds could be calculated from the 1-pass case, but that was not done when the dataset was created and we do not have time to do it now.

In Table 1 we see that there are a total of 88,512 data reports in the TWERLE dataset and 43% of these have winds.

Table 1. Data reports in the TWERLE dataset

Cases	Total Reports	Reports with Winds
1-pass	49,438	569
2-pass	39,074	37,257
Total reports	88,512	37,826

2. **What height to use for a wind report**

To use a wind, we need to know either the pressure at the level of the balloon or the balloon height above sea level (or both). In most cases there is a pressure or a height, and with good quality flags; but in some cases these values are missing or the quality flag says "not good." In our first runs at NCAR we were excluding 5139 reports with winds because the flags were poor on both the heights and the pressure. However, we think they were very fussy when they set the flags. To use a wind for an analysis, the height does not have to be known within one or two millibars. Therefore, in these cases, if the pressure is within the expected range of 120 to 175 mb, we advise NCEP to use the wind and NCAR will set a flag to say "use the wind at the reported pressure." Please note that the height comes from the altimeter, and for our purposes the height data will not be useful when the balloon is over land (we need height above sea level).

3. **Data like one level in a rawinsonde report**

The height data for a raob pressure level (such as a height at 150 mb) is very important for an analysis, because it helps the assimilation to produce correct pressure patterns (or correct heights on constant pressure levels). Many TWERLE balloon reports are over the ocean, and have good heights and pressure data. (There are 47,763 reports with good height and pressure, and most of these are over water.) These reports should be used in the same way that one mandatory level in a raob is used.

4. **Reports with temperature data**

There are a total of 88,512 TWERLE reports and 78,358 of these have a temperature with a "good" flag.

5. **TWERLE data; some differences from the expected**

When the satellite goes overhead, it reads out several transmissions from the balloon. These could be used together to control errors in the transmission. This should have led to at least one combined transmission during the overpass. The location should have been established to within about 2 km (as I recall), but still some ambiguity about which side of the satellite it was on. When the so-called 2-pass winds were calculated, they were based on the balloon locations on successive orbits. To calculate these winds, one must be satisfied that the balloon location of each orbit was correct. I think that the winds in the archive were no doubt calculated correctly, but I am very surprised that a number of the associated locations are flagged bad, and we found that some of them are grossly bad. We also found that in some cases, three locations in a row are flagged as bad because the middle one is bad. (Mar 96)

What shall we do now? Given more time, we probably could recover most of the data. The time is not available now, so NCEP should only use the data that is known to be good. The following table shows the portion of the reports and variables that we will lose because of the potential errors in the location of the data:

	TOTAL REPORTS	REPORTS LOST	PERCENT LOST
Number of whole reports	88166	23866	27.1
Wind variable	37713	4590	12.2
Temperature variable	78123	21020	26.9
Data like a raob level	40805	9608	23.5

6. **Archives that should be available:** ---- but they do not exist

Another archive we should have; there should be an archive of the best data read out on every satellite overpass, along with the two possible locations and an indication of which one was later found to be correct. This archive apparently does not exist. When data were combined to prepare the 2-pass wind cases, then it appears that they combined data from each end point used for the wind calculation, and did not separately save them. It would be best to have all the data at each end, and a wind assigned to the center location.

In summary, the archives that should exist are:

1. An archive of one good report for each overpass (not available)

2. An archive based on (1) but with the best estimate of balloon location, and an indication of sensor quality for different variables (not available).

3. An archive like the one we have. At least, this archive exists and it has a lot of what is needed.

7. **A Few Reports were Dropped**

Table 1 has a count of all the TWERLE reports. A few of these are not on the tape for reanalysis. We dropped reports North of 35° N (deleted 281 reports) and we dropped 65 reports because they were outside of pressure limits that we set.

Reference

The TWERLE Team; 1977. "The TWERLE Experiment," *Bul AMS*, Vol. 59, No. 9, pp. 936-948.

The TWERL Experiment

Bulletin AMS
Sep 1977

Balloons Over Southern Hemisphere

1. Data on tape
   13 Jul 75 - 09 Aug 76

2. Launches
   393 successful launches

3. Main instruments
   * Pressure
   * Temperature
   * Altimeter

4. History

History	Balloons Working
17 Aug 75:	95
Feb 76:	125
9 Aug 76:	16
1 Dec 76:	16

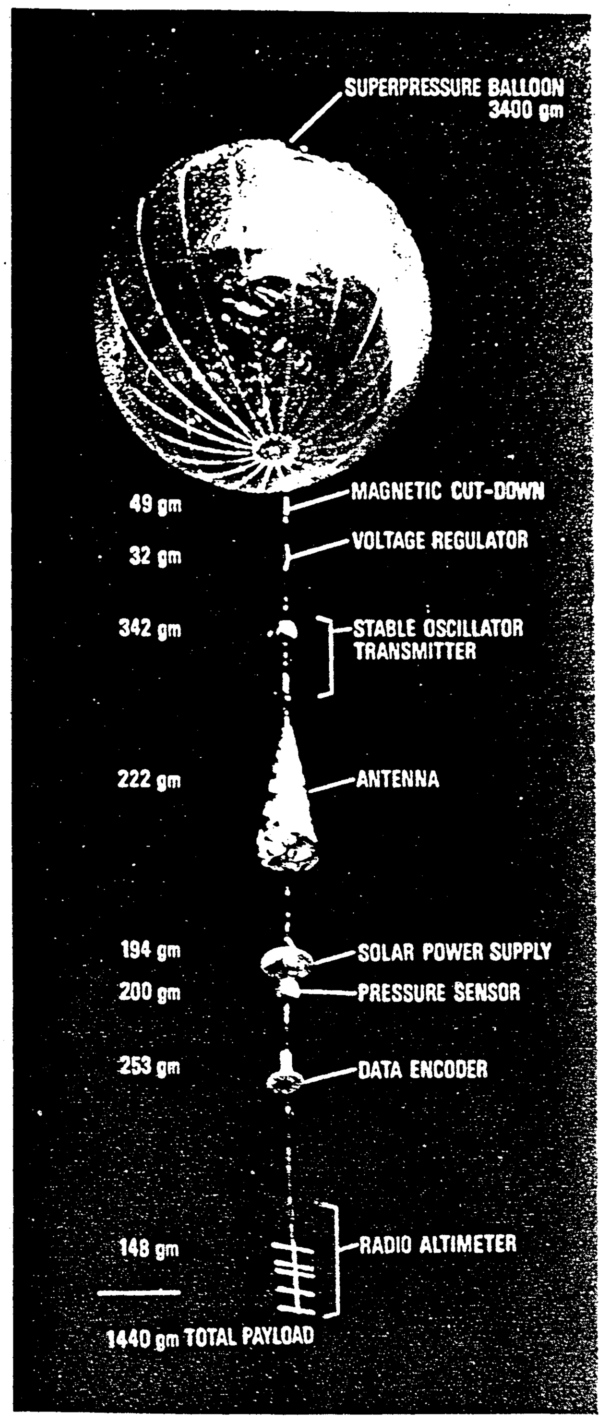

FIG. 1. Schematic photograph of TWERLE platform at

Roy Jenne
Apr 1996

NCAR/TN-141+STR
NCAR TECHNICAL NOTE

July 1979

Daily High-Latitude 150 mb Pressure Maps from TWERLE and Rawinsondes Part I: 16 November 1975 - 31 January 1976

Nadav Levanon
Yona Eyal
Tel-Aviv University

Paul R. Julian
Dennis Shea
NCAR

Verner E. Suomi
William Massman
University of Wisconsin

ATMOSPHERIC ANALYSIS AND PREDICTION DIVISION

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
BOULDER, COLORADO

A sample of stations had data for the following years: 1956-60, 1957-61, 1954-62, 1954-60, etc.

Bob will next convert the data and run it through the hydrostatic check.

3. **China raobs (1954-62)**

   Bob has an inventory of China raobs, but it isn't converted yet. These raobs are for early years.

4. **MIT raobs (1958-63)**

   The MIT 00Z raobs are on two tapes and the 12Z raobs are on other tapes. The earlier MIT data had data each 50 mb. This has only the 850, 700, etc., levels. Station pressure might always be a calculated SLP (check this). A calculated 1000 mb level is there.

5. **TWERLE balloon data (about 1976)**

   There are about 50,000 1-pass cases; only about 570 of these cases have winds. This would give few winds in the Tropics.

6. **Aircraft data from New Zealand**

   There are aircraft data mostly for 1979-88 from New Zealand, and some data for 1978. We compared the data with NCEP and threw out the exact duplicates. NCEP should have used all of this data for reanalysis.

7. **Data for GATE, summer 1974**

   The GATE experiment was in the tropical Atlantic, west of Dakar, Africa. The data are nearly ready for:

   - Raobs from ship, land, aircraft drops
   - Satellite soundings (what is this?)
   - Winds aloft (wind by pressure and wind by height)
   - Sampled winds from research aircraft
   - Aircraft winds from commercial aircraft recorders

   Notes: (1) NCEP doesn't have GATE data yet.
   (2) There is also a special collection of surface synop data for GATE. It has ship and land data for the GATE region. In the interest of time, we are not planning to send it to NCEP.

TWERLE
March 1996

```
mssin msread status =  0 on file /DATTORE/twerle to fort.11
  msread successful
```

— input records

flag bad

7

SUMMARY:

INPUT REPORTS READ:	88166									
INPUT PRECS READ:	712									
INPUT SIZE (bytes):	5654016									
POSITION QUAL (0:9):	34	11979	5059	1480	943	3209	1162	982	28887	34431
NUMBER OF WINDS:	37713									
WINDS BY POS QUAL:	0	67	4523	0	0	0	0	0	0	33123
NUMBER OF TEMPS:	78123									
TEMPS BY POS QUAL:	27	10464	4395	1313	899	2904	1018	889	26561	29653
NUMBER OF RAOB LEVS:	40805									
RAOBS BY POS QUAL:	10	5319	1773	519	362	1168	457	453	15294	15450

Using 7 as cut-off
lose 23866 reports (27%)
lose 4590 winds (12%)
lose 21020 temps (27%)
lose 9608 raob levels (24%)

Bob Dattore prepared these lists
— Roy Jenne

Twerle data / Feb 1996

```
SUMMARY of dataset Y25967:
   NUMBER of files        :          386
   TOTAL NUMBER OF RECORDS:         5782
   TOTAL NUMBER OF REPORTS:        88512  <- total reports
   DATASET SIZE (bytes):        21430936
   ************************************
   BAD ALTITUDE QUALS FOUND:       44463
   BAD TEMPERATURE QUALS FOUND:    10052
   BAD PRESSURE QUALS FOUND:       14443
   ************************************
   MISSING ALTITUDES FOUND:        32305
   MISSING PRESSURES FOUND:         2882
   MISSING TEMPERATURES FOUND:      3055
   MISSING WINDS FOUND:            43396
   ************************************
   REPORTS SKIPPED - NO DATA:        759
   REPORTS SKIPPED - NO HEIGHT:    11480
     TOTAL REPORTS W/WIND:          5139  - there should be more than this
     RPTS NORTH OF 35 S W/WIND:     1122
     RPTS SOUTH OF 35 S W/WIND:     4017
   REPORTS SKIPPED - BAD POSN:       281
   REPORTS SKIPPED - BOTH HEIGHT
     AND PRES SET TO MISSING:      11480
       REPORTS OVER WATER:          8019
       REPORTS OVER LAND:           3461
   ************************************
   OUTPUT REPORTS WRITTEN:         75992
   OUTPUT PHYS RECS WRITTEN:         613
   OUTPUT FILE SIZE (bytes):     4873296
```

SUMMARY TABLE for TWERLE FILE Y25967

LAT BELT	TOTAL POINTS	1-PASS CASES	2-PASS CASES	1-PASS WITH WIND	1-PASS WITHOUT WIND	2-PASS WITH WIND	2-PASS WITHOUT WIND	POINTS OVER WATER	POINTS OVER LAND	PTS NORTH OF 35N	NO POSN
N. HEM	4704	2954	1750	81	2873	1632	118	3100	1323	281	0
0 - 10S	5058	3042	2016	67	2975	1901	115	3937	1121	0	0
10 - 20S	6957	4210	2747	74	4136	2647	100	5535	1422	0	0
20 - 30S	9015	5648	3367	53	5595	3307	60	6869	2146	0	0
30 - 40S	11595	7487	4108	52	7435	4051	57	10359	1236	0	0
40 - 50S	14903	9713	5190	43	9670	5018	172	14334	569	0	0
50 - 60S	14439	7082	7357	67	7015	7003	354	14215	224	0	0
60 - 70S	10119	4920	5199	52	4868	4873	326	9136	983	0	0
70 - 80S	8618	3612	5006	56	3556	4631	375	2375	6243	0	0
80 - 90S	3104	770	2334	24	746	2194	140	0	3104	0	0
TOTALS	88512	49438	39074	569	48869	37257	1817	69860	18371	281	0

```
REPORTS W/ PRES < 120 MB:                      52
REPORTS W/ PRES >= 120 MB AND < 130 MB:        34
REPORTS W/ PRES >= 130 MB AND < 140 MB:       540
REPORTS W/ PRES >= 140 MB AND < 150 MB:     22318
REPORTS W/ PRES >= 150 MB AND < 160 MB:     31503
REPORTS W/ PRES >= 160 MB AND < 170 MB:     31105
REPORTS W/ PRES >= 170 MB:                   2960

REPORTS W/ BOTH HEIGHT AND PRES GOOD:       47763

REPORTS W/ GOOD TEMPERATURES:               78358
REPORTS W/ BAD TEMPERATURES:                10154

I/O SUMMARY:
   TOTAL FILES READ:          386
   TOTAL RECORDS READ:       5782
   TOTAL REPORTS READ:      88512
   FILE SIZE (bytes):    21430936
```



```
mssin msread status =  0 on file /DATTORE/twerle to fort.11
  msread successful

SUMMARY:
   INPUT REPORTS READ:       88166
   INPUT PRECS READ:           712
   INPUT SIZE (bytes):     5654016
   POSITION QUAL (0:9):         34   11979    5059    1480     943    3209    1162     982   28887   34431
   NUMBER OF WINDS:          37713
   WINDS BY POS QUAL:            0      67    4523       0       0       0       0       0       0   33123
   NUMBER OF TEMPS:          78123
   TEMPS BY POS QUAL:           27   10464    4395    1313     899    2904    1018     889   26561   29653
   NUMBER OF RAOB LEVS:      40805
   RAOBS BY POS QUAL:           10    5319    1773     519     362    1168     457     453   15294   15450
```

EOLE: Good Balloon Coverage, Southern Hemisphere

- Data for 21 Aug 1971 – 23 Dec 1972
- The active balloons

Date	Active Balloons
Sep 1971	50
Early Oct 1971	130
Nov 1971	280
July 1972	40

- 155 days with more than 100 balloons
- Paper about EOLE: In *Bull. AMS*, Apr 1973
- NCAR has archive of balloon locations
- But no winds yet; the data could not be used for reanalysis
- The French made a motion picture of the drifting balloons. Very interesting.

Roy Jenne
Sept 2000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

REPLY TO ATTN OF: 120

The EOLE Format 2 tape

FILE 8323

DEC 13 1972

Dr. Paul Julian
National Center for Atmospheric Research
Boulder, Colorado 80301

Dear Paul:

On December 4, 1972, Professor Pierre Morel hand-carried to me a copy of LMD (Laboratoire de Meteorologie Dynamique) Format 2 Eole Tape, containing balloon, time, location, and ambient temperature and pressure data from orbit 151 (August 27, 1971) to orbit 4622 (July 4, 1972). The LMD Format 2 tape was produced by Pierre Morel and his staff at LMD by applying additional filtering to the CNES Reduced Data Tapes (the GSFC Reduced Data Tapes containing 31-Element Data Groups, which have previously been sent to you, are essentially copies of the CNES Reduced Tapes). Because of the extensive additional filtering invoked at LMD, Pierre Morel has high confidence that most of the (relatively few) location errors that remained on the CNES tapes have been eliminated. Consequently, the LMD Format 2 tape lists only the single high-confidence location of each balloon. Each Record consists of one 3-Element Header Group followed by 25 or fewer 7-Element Data Groups intended solely for scientific analysis (all position ambiguities, engineering quantities, and differential correction matrices having been eliminated—the single balloon locations on the LMD Format 2 tape have already been differentially-corrected for balloon motion).

I am forwarding to you under separate cover a copy of the LMD Format 2 tape for your retention and use as you may see fit. The format specification for this tape is enclosed with this letter.

In summary, you already have received on the GSFC RDT's all of the Eole data contained on the one LMD Format 2 tape; however, the differential correction matrix has already been applied in the LMD tape, only the single high-confidence primary location has been retained, and the data have been made more compact by retaining only information required for scientific data analysis. Finally, Pierre Morel told me that even though he has high confidence in the LMD Format 2 tape, on rare occasions a false location may still have slipped through the filtering.

Sincerely,

Bill

William R. Bandeen, Chief
Meteorology Program Office

Enclosure

R Jenne
11 apr 73

DS 800 Eole balloon data

We just got the last Eole tape. These show locations of French drifting balloons mostly in the southern hemisphere for (dates) the period 21 Aug 71 thru 23 Dec 72. Positions by satellite fixes. Some locations are questionable and are flagged in the format.

Paul Julian says some of the locations flagged with a 1 still look bad and should really be called # 2 flag.

Paul wants us to save tapes:

NCAR 03, 4, 5, 6, 7, 8, 10

and NCAR 09 which has most of the data in condensed form.

See folder D-44 for more info on these data.

Note: The Rptout tapes have the orig 252 characters in each log rec put into words 2-27 of a rec in display code.

Program 549 puts the data onto tape in Rptout form
Program 555 reads the EOLE data from Rptout.

R. Jenne
27 Apr 73

	Assigned Our tape #	Rptout Copy	Log rec	Out Phys Rec
NCAR 03	C3519	18 Sep 72 C3316	36696	2823
04	C3520	18 Sep 72 3317	40333	3103
05	C3521	15 Sep 72 3351		
06	C3522	18 Sep 72 3471	32490	2500
07	R ~~C3523~~	19 Sep 72 (27 Apr 73 C3765) R ~~3472~~ R	28137	2165
08	R ~~C3524~~	19 Sep 72 ~~3509~~ R	7692	592
10	R ~~C3999~~	27 apr 73 ~~3878~~ R	12845	989

(07, 08, 10: 3746 phys rec)

		Copy — not rptout	
NCAR 09	C3701	C3663	6518 records 6 to 126 words, BCD even parity

27 apr 73 C3875 Copy merge of NCAR 7, 8, 10 C3472, C3509, C3878

27 apr 73 C3438 Copy of C3875 (3746 rec)

Note: in this project, NASA sent us 12 tapes which we are considering to now be our property. (after rel below)

Summary: Above, we are saving 6 tapes with all of the data plus ~~9~~ 6 backup tapes

// Trouble reading 3472 for the merge so rebuilt it onto 3765 for the merge copy

01 May 73 Release C3472, C3765, C3509, C3878 Cards out

#

Eole Data Interpretation Group (EDIG) Distribution Log

"GSFC REDUCED DATA TAPES"

This now replaced

Dr. Akira Kasahara
c/o Dr. Paul Julian
Laboratory of Atmospheric Science
National Center for Atmospheric Research
Boulder, Colorado 80302

RPTOUT copy	# in our library (red labeled)	Item	Tape No.	Orbits (incl.)	Dates (incl.)	Date Mailed	Remarks
~~2958~~ R	~~C3525~~ R	1	NCAR01	2408-2584	Feb.1-13,1972	March 28,1972	
released		2	NCAR02	2672-3334	Feb.19-Apr.5 '72	May 22,1972	
released		3	NCAR02B	2672-3334	Feb.19-Apr.5 '72	May 26,1972	replaces NCAR02
~~2922~~ R ✓	~~C3518~~ R	4	NCAR02C	2672-3334	Feb.19-Apr.5 '72	June 16,1972	replaces NCAR02 &NCAR02B
3316 ✓	C3519 ✓	5	NCAR03	0065-1044	Aug.21-Oct.28'71	June 29,1972	
3317 ✓	C3520 ✓	6	NCAR04	1048-1599	Oct.29-Dec.6'71	June 29,1972	
3351 ✓	C3521 ✓	7	NCAR05	1601-2134	Dec.6'71-Jan.12'72	June29,1972	
3471 ✓	C3522 ✓	8	NCAR06	2135-2835	Jan.12-Mar.1'72	June29,1972	
3472 ✓	C3523 ✓	9	NCAR07	2836-4127	Mar.1-May31 '72	July 11,1972	replaces tape NCAR02C which overlapped with NCAR06 ;adds additional new Data.
3509 ✓	C3524 ✓	10	NCAR08	4128-4755	May 31-July 14, 72	Sept 7, 72	
(copies of RPTOUT) 3663	C3701	11	NCAR09	151-4622	Aug 27, 1971 – July 5, 1972	Dec 11, 1972	LMD tape #2 (not CNES)
			→ 6518 records	6 to 126 words	– BCD even parity		
	C3999	12	NCAR10				

NASA TT F-10,297

EOLE

NASA TT F-10,297

Roy Jenne

SCIENTIFIC DEFINITION OF THE SATELLITE FR-2 PROJECT (PROJECT EOLE)

Plans
Sep 1966

Pierre Morel

NCAR Data Support has this text with about 45 pages

Translation of "Définition scientifique du projet de Satellite FR-2 (Projet Eole)".
Centre National de la Recherche Scientifique.
Service d'Aéronomie, No.101, May 1966.

NOTICE

Up in ~ 1969

Plus a few from our own satellite in 1969 also.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON SEPTEMBER 1966

Hope by Sep 67 many more [illegible]

TABLE OF CONTENTS

Page

TWERLE data

Roy Jenne
7 Jul 95

Note that word length is 60 bits

1) First record for each balloon is 510 words long
- ID
- launch day
- last day heard

WD10 – please print the non blank part of this so we can scan the messages

2) The data records (in records 510 wds (60 bit) long)

wd 1
- ID – get
- launch site, change to a 3 bit number
- launch ~~#~~
- launch day
- Launch time
- memory — skip this one

word 2

3) Last days for data
Need to print out these for a few 100 records.

4) wd 3 Type balloon death, pressure corr.

5) word 4
note: During a pass the satellite may ~~see~~ hear the balloon for about 10 minutes. During this time similar data may be received several times.
We want the __first__ contact and the __last__ one.
Create a real year 1976
- mo
- day
- whole hour 0–23
- and keep the seconds.

• for first and last contact

WD6 - satt loc. Keep for us, NMC doesnt need this

WD7 - keep these numbers

WD8 - preferred balloon location
get this
get definition of longitude

WD9 - alternate balloon location
get this

Create a ~~two~~ bit number
1: this was a one pass case
2: this was a 2 pass case

WD10 only save the quality # for this subset
5 bits - 0 to 9 scale (poor to excellent)

WD11 Save all 4 wind numbers. NMC will get dir & speed
• say wind speed is zero for 1 pass case.
Please create a table as follows

Lat belt	total data points	# with winds	# not with wind
N Hem			
0 - 10 S			
10 - 20 S			
etc			

WD12-17 save numbers - ~~winds~~ altitude
WD 16 is what we will give NMC

WD18-20 temp

WD 21-23 pressure

WD 24-27 ignore these - not for NMC

Roy Jenne
18 Dec 1995
& 27 Feb 96

TWERLE balloon data to send NMC

Take the data from the original records where the word length is 60 bits.

1. First record for each balloon - dont need this
2. word 1
   - ID - get ID of balloon
   - Launch site: change it to a 3-bit number
   - Launch day - get this
   - Skip the rest
3. word 2 Dont need
4. word 3 Only get the pressure correction. This is for info only. We Don't really need this because the correction has been applied. NMC does not need this

(Comments on how to process the Twerle data
— Roy Jenne)

Twerle 615.0

EOLE 800

FGGE 800.1

Monex 800.2

5. Date and time of the balloon data

We need the date/time of the observation:

- real year, eg 1976
- month
- day
- synop hour (do we need this?)
- whole hour (0-23)
- and keep seconds

At first I thought that word 4 and word 5 were the first ever and last ever dates for the balloon. But there is no other date/time for the observation.

So WD 4 & 5 must be date/time for this obs. I suppose that 1st contact and last, are for pass 1 (this means that the time difference should be 10 or 15 minutes, and not 2 hours (for a 2-pass case). True?

6. Word 6 Satellite location. Ignore this for NMC

7. Word 7 About contacts and passes. Don't send total passes to NMC. Keep the other 3 numbers.

- NMC only needs to input the number of passes.

Note: During a pass of the satellite overhead, the satellite may hear the balloon for about 10 minutes. During this time, similar data may be received several times. The repeat transmissions ~~are~~ have been used to eliminate errors in the data as received. (in early processing years ago)

8. Location of balloon (Words 8–10)

a. Get the preferred Lat and preferred Lon.
   - also keep flag for land-sea index
   ~~* Keep reports if index = 0 or 1~~
   ~~* Toss whole report if not both~~

b. Keep quality flag 0 to 9 assigned by NCAR (Word 10)

c. Alternate Lat/Lon. Dont give this to NMC

Note: I think that this is probably the location of pass one, but in a two pass case it might be an average. I wish they had separately saved the time and location for pass one and pass two.

9. balloon wind

WD 11 Give NMC the wind direction and total speed (Or missing codes

(See item 20)

10. Is there data like a good raob level?

With a normal Airep we do not have both altitude and pressure with enough accuracy and precision to use the data like one mandatory level in a raob. For TWERLE balloons we have such accuracy for cases over the ocean.

NCAR will set a flag to say whether the data can be used like a raob level

Flag = 0, it can be used like raob (balloon pressure and altitude both are in data file for NMC). This also means the quality of each was very high.

Flag = 1, cant be used like raob.

11. Altitude of balloon (words 12-17)
    a. Use altitude from combined passes if available (wd 23)
    b. Or use altitude from pass one (WD 12)
    c. Only give an alt if quality code = 0.
    d. Otherwise give missing code.
    e. Ignore the alternate altitudes

(think)

12. Air temperature (word 18-20)
    Give to NMC
    a) WD 20 Use combined pass temp if it is avail
    b) WD 18 or Pass one temp
    c) Only give a temp if quality code = 0 (good)
    d) Otherwise give missing code

13. balloon pressure (word 21-23)

a. Use pressure from combined passes if available (wd 23)

b. Or use pressure from pass one (wd 21)

c. Only give a pressure if quality code = 0 (good) — think this chg

d. Otherwise give missing code

14. Other info, density etc (Words 24-30)

Not needed for NMC

Feb-1996 (R Jenne)

37.6
3.2
.9
41.7

(19) When to toss a TWERLE report

If there is a bad pressure and a bad height and no wind, and no temperature, then toss the report.

(20) Instructions for using the balloon wind data

A flag is set to give info about using the wind.

0 – There is no wind

1 – The pressure is good. Use the wind at that pressure level.

3 – The pressure is flagged bad, but it is in the proper range (120 to 175 mb). Use the wind at the reported pressure

2 – The height has a good flag, and the balloon is over water, and the pressure has a bad flag. Use the wind at the reported height

~~Note: If~~

(21) Instructions for using the balloon temperatures

I do not have info (other than the flags) about how good the temperatures ~~are~~. If there is a temperature, and if it has a good flag then ~~the flags set for the winds could also be used for the temperature,~~ it could be used at the given pressure level, if it is between 120 and 175 mb.

the Eole experiment: early results and current objectives

Pierre Morel
Laboratoire de Météorologie Dynamique
Centre National de la Recherche Scientifique
Paris, France

and

William Bandeen
NASA Goddard Space Flight Center
Greenbelt, Md. 20771

Bulletin AMS April 1973

Abstract

The Eole Experiment with 480 constant level balloons released in the Southern Hemisphere is described. Each balloon, floating freely at approximately the 200-mb level, is a precise tracer of the horizontal motion of air masses, the accuracy of which is limited only by the laminated structure of the stratospheric flow, within an rms uncertainty of 1.5 m sec^{-1}. The balloons were found after 2 months to distribute at random over the whole hemisphere outside the tropics, irrespective of their original launching site. Early results of Eulerian and Lagrangian averages of the Eole wind data are given for describing the mean 200-mb zonal and meridional circulations. The effect of the small scale eddies of two-dimensional turbulence has been studied with respect to the relative eddy diffusion of pairs of balloons and the relative dispersion of triangular clusters. New estimates of the rms divergence of the 200-mb flow are given, together with their scale dependence which was found to be a logarithmic law.

Introduction

As a prelude to the most extensive constant level balloon experiment attempted so far, the Eole navigation and data collection satellite was launched by a Scout rocket from NASA's Wallops Island facility on 16 August 1971. The deployment of free floating constant volume balloons started shortly thereafter from three sites in the Republic of Argentina, and culminated in November 1971 with a maximum network of 280 balloons operating simultaneously. At that time, the 480-balloon supply allocated for the experiment was nearly exhausted and the population started to decrease as expected from estimates of the electronic package failure rate and balloon icing. As of this writing, 5 Eole balloons are still floating around the Southern Hemisphere and tracked by the satellite; all of these have exceeded a one-year operational life. But of course, the most significant information expected from the program has already been acquired, processed, and made available to the Laboratoire de Météorologie Dynamique (principal investigator) and several investigators in the United States in NASA, NOAA, Colorado State University, the National Center for Atmospheric Research, the University of California at Los Angeles, and the University of Wisconsin, constituting the Eole Data Interpretation Group.

In addition, the Eole navigation and data collection satellite offered the opportunity for a preliminary test of current measurements by means of automatic instrumented drifting buoys, a program which might eventually evolve into a kind of marine Eole experiment on an ocean-wide scale. With the cooperation of the Marine Sciences Directorate, Pacific Region, Environment Canada, 10 drifting buoys equipped with temperature sensors and a large sea-anchor or drogue, were built, launched in the northeastern Pacific and tracked by the satellite. This buoy experiment was only the first of a series of supplementary scientific and technical programs utilizing the extra-capacity of the Eole satellite, some of which are still in operation as of this writing (such as tracking ships, a variety of drifting buoys, and icebergs). So, even though the Eole satellite is still operating nominally at the present time and still in use for these supplementary experiments, the main experiment with constant level balloons is completed and it is appropriate to take stock of the scientific data and interpretation obtained so far.

The concept of horizontal sounding

The Eole program must be placed in perspective in a long series of ballooning experiments that began in the early fifties with the instrumented quasi-horizontal transosonde flights over the United States and later from Japan across the Pacific Ocean (Anderson and Mastenbrook, 1956; Mastenbrook, 1962). The idea of a world-wide horizontal sounding system based on over-pressurized constant level balloons and satellite communications for navigation and data relay was proposed by Lally (1959) and Giles and Angell (1963). This project was not in fact implemented in the United States beyond developing the experimental Interrogation Recording and Location System (IRLS) for the Nimbus 3 and 4 satellites (Cote, 1970) and tracking about thirty stratospheric balloons (Angell, 1972). The idea was taken up then by the French Centre National d'Etudes Spatiales (CNES) and implemented in cooperation with the United States (NASA). CNES developed and built the Eole satellite as well as 500 constant level balloons and their sensors and communication packages. NASA provided a Scout rocket for launching the Eole satellite into a quasi-circular orbit at a mean altitude of 800 km and an inclination angle of 50° to the equator. The Eole experiment is by no means the final word on this technique of data collection and tracking Lagrangian tracers; another large program of this nature, the Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE), is being prepared by a team of experimenters in the United States to fly on the Nimbus F satellite in 1974 (Masterson, 1970).

"Constant level" balloons are nothing but constant volume craft capable of floating stably at one nominal density level, corresponding in this case to the 200-mb pressure level of the standard atmosphere. It is not, of course, as easy to build a rigid "hull" for such a light craft as it is for a marine floater. The rigidity of constant volume is obtained by stressing an inextensible spherical polyethylene-terephthalate or Mylar[1] envelope with a moderate overpressure of the order of 10% of the outside atmospheric pressure. Even so, the stress on the envelope material is very large indeed because the balloon skin is very thin (50 μm); about 1/10 of the ultimate tensile strength of steel is reached in maximum stress areas. This explains why such a small overpressure (20 mb in our case) must be used, even though it does not give much reserve in the case of gas loss or accidental accretion of mass, e.g., accumulation of frost by sublimation in saturated air at night or deposition of ice particles in dense cirrus clouds. For this reason, about half the balloon failures observed eventually can be attributed to loss of pressurization in the moist tropical atmosphere, particularly in three active convective regions: the Amazon basin, Central Africa, and a zone in the Tropical Pacific Ocean, between 150° and 180° west longitude. This meteorological failure mode, together with electronic package failures, accounts for the observed decrease of the balloon population (Fig. 1). A very unfortunate event depicted in Fig. 1 was the accidental destruction of about 100 balloons on telecommand from the Eole satellite on 11 September 1971, due to an operator mistake in keying the spacecraft operational schedule for one orbit. One will observe that the total active balloon population rose eventually to 280 in November 1971 and remained larger than 200 during a 50-day period in the Southern Hemisphere Spring (155 days with a population of 100 balloons or more). The mean operational lifetime of the constant level balloon (excluding from the statistics the September catastrophe) was finally established at 103 days. Also,

- 35 balloons lasted less than 10 days
- 178 balloons lasted more than 3 months
- 66 balloons lasted more than 6 months
- 14 balloons lasted more than 1 year.

[1] Dupont trademark.

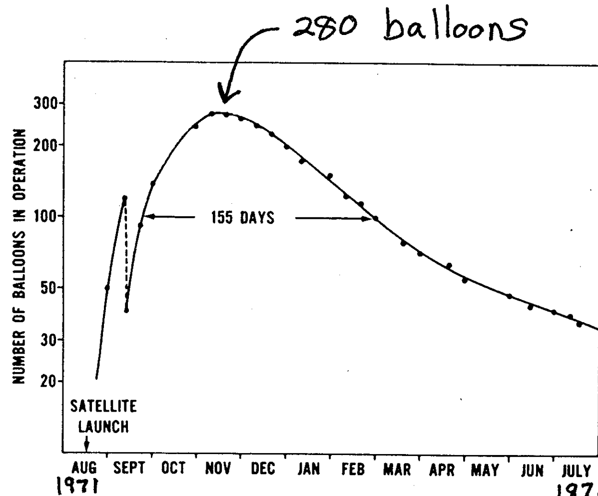

FIG. 1. Record of the number of balloons operating simultaneously during the Eole experiment (August 1971–July 1972).

The Eole data collection and tracking system

The Eole satellite system has been designed to communicate with and locate a maximum of 512 addressable platforms, i.e., establish a two-way radio link successively with each individual platform, acquire and store the satellite-to-platform range r and range-rate $\dot{r}$ information together with precise timing data, and acquire and store meteorological data measured *in situ* by instruments on the platform and telemetered on the platform-to-satellite return link.

The spaceborne data collection equipment consists of a 464/402 MHz UHF interrogation/reception package with a helical antenna permanently oriented toward the earth by passive gravity-gradient attitude stabilization. Upon successful interrogation of one platform, a two-way phase-coherent link is established between the platform transponder and the satellite, allowing a very precise measurement of the propagation delay (range r) and the Doppler shift (range rate $\dot{r}$). These measurements, together with accurate timing and excellent determination of the orbital parameters, provide simultaneously two geometrical loci of the platform position. Knowing in addition the altitude of the platform, one can then determine the geographical location of the platform with an accuracy of 1 to 2 km. The experience gained with the operation of the Eole system using fixed platforms or beacons has definitely proven that we reach here the ultimate accuracy allowed by usual orbit determination methods currently applied to scientific and meteorological satellites. Future systems will require instead the more accurate methods used for geodetic and navigation satellites, or alternatively, use a global array of fixed platforms to *update the satellite trajectory* on an orbit-to-orbit basis (Brachet, 1972).

The range and range-rate data processing was performed by the CNES Computing Center on a moder-

Subject:
Date: Tue, 18 Nov 1997 08:58:53 GMT
From: Vial <vial@lmdx06.polytechnique.fr>
To: jenne@ncar.ucar.edu

EOLE

(The EOLE Project)

Dear Dr. Jenne,

As you probably know, the french space agency (cnes) and nasa conducted a large balloon expriment in 1971-1972. Around 400 superpressure balloons were launched and drifted around 200 hPa in the Southern Hemisphere. The name of this experiment is EOLE.

I have a question and I am sure you are the right person to contact. Indeed I am wondering if, in the frame of the NCEP NCAR reanalysis project, these data were used...

Sincerely yours
Francois Vial

19 Nov 1997

Dear Dr Francois Vial

NCAR has a copy of the primary EOLE data (The positions and date/time, but not derived winds). I did a literature search and found that winds had once been calculated, but we did not find any archive. We did not have time to calculate winds ourselves, so EOLE winds were not used in the NCEP/NCAR project. Do you have an archive of derived winds for EOLE.

In Jan 1997, a place in France ordered the original archive of primary EOLE data. Perhaps we at NCAR had the world's only archive of the original EOLE data.

— Roy Jenne

Subject: Eole
Date: Fri, 21 Nov 1997 15:20:12 GMT
From: Vial <vial@lmdx06.polytechnique.fr>
To: joseph@ncar.ucar.edu
CC: basdevan@ella.ens.fr, claude.huc@cnes.fr, jenne@ncar.ucar.edu, vduval@ella.ens.fr, vial@lmdx04.polytechnique.fr

EOLE

Nov 1997

Dear Dennis Joseph,

Claude Huc sent me a copy of your mail about the Eole data. I am working at Laboratoire de Meteorologie Dynamique (LMD) and our laboratory was the French Scientific PI of the Eole experiment (at that time LMD director was Pierre Morel). We had a copy of this data but, at the end of the 70', the tapes were erased and the data destroyed. It is why I contacted Claude as CNES (the French Space Agency) was deeply involved in Eole. CNES managed balloons launches, worked on the Eole satellite and on the ground segment among other things.

We are now preparing a new experiment, named Strateole, during which around 200 superpressure balloons will be launched in the Southern Hemisphere lower stratosphere. The goal is to studythe dynamics of the polar vortex at the end of winter and spring. In order to prepare the experiment, we have developed, at LMD, a numerical simulation of superpressure balloon trajectories. It is clear that, at this stage, we are deeply interested in comparison of real and simulated trajectories. It is why the Eole data is of high interest for us. On the other hand, we also need to have winds as input for our trajectory model. We plan to use the NCEP/NCAR Reaaanalysis for that. The large amount of Eole data should allow us to get a statistically significant comparison between the two type of trajectories.

A new experiment in So. Hemis.

A second study we plan to do is to compare the NCEP/NCAR reanalysis with the stream function which was deduced in 1972 form the Eole data. Unfortunately, this stream function is a vailable only as daily map on paper sheet (no data on a magnetic support).

Clearly we would like to know if the Eole data were used in the Reanalysis to see to what extend our simulatioons fo trajectories is biased toward the Eole observations. I Contacted Roy Jenne on this matter few days ago.

I hope you get a better understanding of what we are doing with the Eole data you kindly sent to Claude. At the present time, our main task was to look at the data themselves in order to fully understand the meaning of each parameters in the files and to get a precise idea of balloon behaviors. We have now a clear picture of every thing, although there is some differencies in the balloon positions between the files y06060 to y06064 and the file y06065 we do not understand yet. Clearly there was some reproceessing on the original data which is unknown.

I saw also in your mail that your are looking some information about point K. I am noy sure but I think it was a boat in Atlantic. Nevertheless the best is probably to contact Meteo-France (the French Met. Office). I know a person there who is in charge of old archived data. Her e-mail address is: francoise.benichou@meteo.fr

She is probably able to give you an answer. If she does not reply (she is maybe away of her office for a while) please let me know. I will give you other contact point.

Your sincerely
Francois Vial

From Claude.Huc@cnes.fr Tue Nov 18 23:57:12 1997
Return-Path: <Claude.Huc@cnes.fr>
Received: from chappe by niwot.scd.ucar.EDU (NCAR 12/5/96/ NCAR Mail Server 04/10/90)
id XAA21943; Tue, 18 Nov 1997 23:57:11 -0700 (MST)
Received: from pasteur.cnes.fr (pasteur.cnes.fr [132.149.22.8]) by chappe (8.6.13/RH-1996
Received: from imhotep.cst.cnes.fr (unverified [132.149.9.45]) by pasteur.cnes.fr
(Integralis SMTPRS 2.04) with SMTP id <B0000531355@pasteur.cnes.fr>;
Wed, 19 Nov 1997 07:52:47 +0100
Received: from pc-huc.cst.cnes.fr (pc-huc.cst.cnes.fr [132.149.40.18]) by imhotep.cst.cne
Message-Id: <2.2.32.19971119070212.006be828@imhotep.cst.cnes.fr>
X-Sender: huc@imhotep.cst.cnes.fr
X-Mailer: Windows Eudora Pro Version 2.2 (32)
MIME-Version: 1.0
Content-Type: text/plain; charset="us-ascii"
Date: Wed, 19 Nov 1997 08:02:12 +0100
To: joseph@niwot.scd.ucar.edu (Dennis Joseph)
From: Claude Huc <Claude.Huc@cnes.fr>
Subject: Re: EOLE Data
Content-Length: 1148
Status: RO
X-Mozilla-Status: 0000

EOLE

Projects in France 1997

Dear Dennis

You will find my name and address in the signature of this message.

Sincerely
Claude

At 15:58 18/11/97 -0700, you wrote:
>Last January, I believe you obtained some of the French EOLE drifting
>balloon data from us. We have had someone else in France express interest
>in this data and I could not locate your name and address to pass on to
>them. I have only your email address. Thanks.
>
>Dennis
>
> Dennis Joseph email - joseph@ncar.ucar.edu
> Data Support Section voice - (303)-497-1216
> NCAR/SCD fax - (303)-497-1298
> PO Box 3000
> Boulder, CO 80307
>
> DSS anonymous ftp information area - ncardata.ucar.edu (128.117.108.16)
> WWW - http://www.scd.ucar.edu/dss
>
>

Claude HUC Tel: 33 (0) 5 61 27 44 21
CNES DGA/T/TI/PS/AP Bpi 1501 Fax: 33 (0) 5 61 27 30 84
18, Av. Edouard Belin Email : HUC@cst.cnes.fr
31401 Toulouse Cedex 4 France

From Claude.Huc@cnes.fr Fri Nov 21 03:24:00 1997
Return-Path: <Claude.Huc@cnes.fr>
Received: from chappe by niwot.scd.ucar.EDU (NCAR 12/5/96/ NCAR Mail Server 04/10/90)
id DAA13722; Fri, 21 Nov 1997 03:23:58 -0700 (MST)
Received: from pasteur.cnes.fr (pasteur.cnes.fr [132.149.22.8]) by chappe (8.6.13/RH-1996
Received: from imhotep.cst.cnes.fr (unverified [132.149.9.45]) by pasteur.cnes.fr
(Integralis SMTPRS 2.04) with SMTP id <B0000546791@pasteur.cnes.fr>;
Fri, 21 Nov 1997 11:18:39 +0100
Received: from pc-huc.cst.cnes.fr (pc-huc.cst.cnes.fr [132.149.40.18]) by imhotep.cst.cne
Message-Id: <2.2.32.19971121102902.006c86ac@imhotep.cst.cnes.fr>

X-Sender: huc@imhotep.cst.cnes.fr
X-Mailer: Windows Eudora Pro Version 2.2 (32)
MIME-Version: 1.0
Content-Type: text/plain; charset="us-ascii"
Date: Fri, 21 Nov 1997 11:29:02 +0100
To: joseph@niwot.scd.ucar.edu (Dennis Joseph)
From: Claude Huc <Claude.Huc@cnes.fr>
Subject: Re: EOLE Data
Content-Length: 1713
Status: RO
X-Mozilla-Status: 0000

Dennis

I am not directly concern by the EOLE data, i am in charge of various activity in the area of scientific data management and archiving. I received a request from people who were working about a new french balloon project : STRATEOLE.

I send them a copy of your message and asked them to reply to you message.

Sincerely
Claude

At 14:29 19/11/97 -0700, you wrote:
>Claude,
>
>Thanks for sending your address. Have you been working with
>the EOLE data? Have you done anything like attempt to compute
>winds from the data? We hope to eventually be able to use
>that data to get winds for input into Reanalysis projects.
>
>In connection with NCEP/NCAR Reanalysis, we have been working
>with some older French raobs. We have run into a station
>called "Point K" which covers 1949-1971, but we are unable to
>identify the station and get proper lat-lon and elevation.
>Does that name mean anything to you or do you know of someone
>we might ask about it.
>
>Thanks.
>
>Dennis
>
> Dennis Joseph   email - joseph@ncar.ucar.edu
> Data Support Section   voice - (303)-497-1216
> NCAR/SCD   fax   - (303)-497-1298
> PO Box 3000
> Boulder, CO 80307
>
> DSS anonymous ftp information area - ncardata.ucar.edu (128.117.108.16)
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>

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31401 Toulouse Cedex 4   France

Transport processes in the Atmosphere and the Oceans (TAO)

1996/97 TAO General Workshop

ABSTRACTS

1st Annual Workshop, Palma de Mallorca, 8-12 January 1997
Abstracts of Oral and Posters presentations - Wednesday 8
January 1997de Meteorologie Dynamique, Ecole Normale Superieure, Paris, France

BALLOON MEASUREMENTS AND THE STRATEOLE EXPERIMENT

Claude Basdevant
Laboratoire de Meteorologie Dynamique, Ecole Normale Superieure, Paris, France

The aim of the STRATEOLE experiment, planned by the French Space Agency (CNES), is to stu the dynamics of the southern polar vortex at the end of the austral winter and at the beg of spring when it dilutes. The experiment will consist in launching 200 isopycnal balloon hPa and 70 hPa levels in the stratosphere, near the vortex border. The balloons are desig survive as passive tracers for at least 3 months and will provide detailed information on trajectories as well as on physical and chemical parameters. Numerical simulations using analysis of the stratosphere have been conducted to study the behaviour of such balloons define the launching strategy. The proper behaviour of the polar vortex is related itself VP gradient and the stratospheric jet, the transport and mixing properties of the flow ar correlated to the vortex behaviour.

STRATEOLE: A project to study Antarctic polar vortex dynamics and its impact on ozone chemistry

F. Vial, A. Babiano, B. Brioit, C. Basdevant, B. Legras, R. Sadourny, H. Ovarlez, J. Ova H. Teitelbaum, D. Cariolle, F. Lefevre, P. Simon, F.P.J. Valero, C. Mechoso, J. Fararra Kelder, C. Camy-Peyret, T. Hart, and M.E. McIntyre

Phys. Chem. Earth, Vol. 20, No. 1, pp. 83-96, 1995

The STRATEOLE experiment is designed to study the wintertime Antarctic lower stratosphere polar vortex and its springtime breakdown. To this end, it is planned to fly a large numb (around 200) of long-lived (3 months), small isopycnic drifting balloons instrumented wit temperature and pressure sensors, GPS and transmitters. The main goal of STRATEOLE experiment is to provide an unprecedented documentation of the wind in the vicinity of th vortex edge in order to study vortex porosity and erosion, filimentation and mixing prope the air masses. In addition, by the use of other sensors on some gondola, like radiometer tuneable laser diodes, STRATEOLE will also provide in situ and/or column-integrated trace species measurements (like NO2, O3, CH4, H2O, aerosols...) and information on the radiati budget of the Antarctic lower stratosphere during this period. This will permit to obtain understanding of mechanisms responsible for ozone depletion occurring during the springti vortex dilution.

GLOBAL ATMOSPHERIC RESEARCH PROGRAMME (GARP)

FGGE — THE GLOBAL WEATHER EXPERIMENT

FIRST GARP GLOBAL EXPERIMENT OPERATIONS REPORT SERIES

VOLUME 7

WINTER MONEX FIELD PHASE REPORT

Drifting balloons

Prepared by

the International MONEX Management Centre (Winter)
Kuala Lumpur

April 1980

8.2 Tropical Constant Level Balloon System

Reference (3e) describes the operations plan for the FGGE Tropical Constant Level Balloon System. In summary, approximately 80 constant level balloons (CLB) were planned to be launched for the first SOP from each of the two launch sites, located at Canton Island in the Pacific (2.8°S, 171.5°W) and Ascension Island in the Atlantic (7.9° S, 14.4°W). They were designed to fly on a constant density surface of $0.225 kg/m^3$ (approximately 15 km or 140 mbar). A nominal 6-hour launch rate was planned to begin on 6 January 1979. A report on the operations during SOP-1 has been prepared by the US FGGE Project Office and the FGGE Operations Centre Geneva and can be found in reference (15). The following section summarizes some of the information relevant for Winter MONEX.

Launches commenced at both sites on 6 January as scheduled. The launch rate was adjusted at times according to the weather situation, but a total of 78 platforms were launched from Ascension and 75 platforms from Canton Island. Positions of the platforms from which the wind vector is computed were determined by means of the ARGOS system flown on TIROS-N. Temperature and pressure information were also provided. Lifetime of the balloons was shorter than expected. By the end of SOP-1, 19 per cent of the balloons were lost due to the magnetic cutdown in the northern hemisphere, and 8 per cent were cut down in the southern hemisphere because the constant density level on which the balloon flies intersected the cut-down pressure altitude (14.0 km). 73 per cent of the balloons were lost due to some other, mostly unknown, reasons. A summary of the operations during SOP-1 is presented in Figure 8.1. No exact breakdown is available as to the particular number of balloons over the Winter MONEX area although Table 8.6 gives some indication of the number over the area 10°S to 10°N, 90°E to 180 for SOP-1.

The data processing is proceeding according to schedule, and all CLB data of SOP-1 are available at the Level II-b Space-based and Special Observing System Data Centre (Sweden). According to reports from this Centre, quality checks for a test period in January 1979 show that the CLB data are in very good agreement with other wind data.

Launch sites

Ascension Isl - 78 launches

Canton Isl - 57 launches

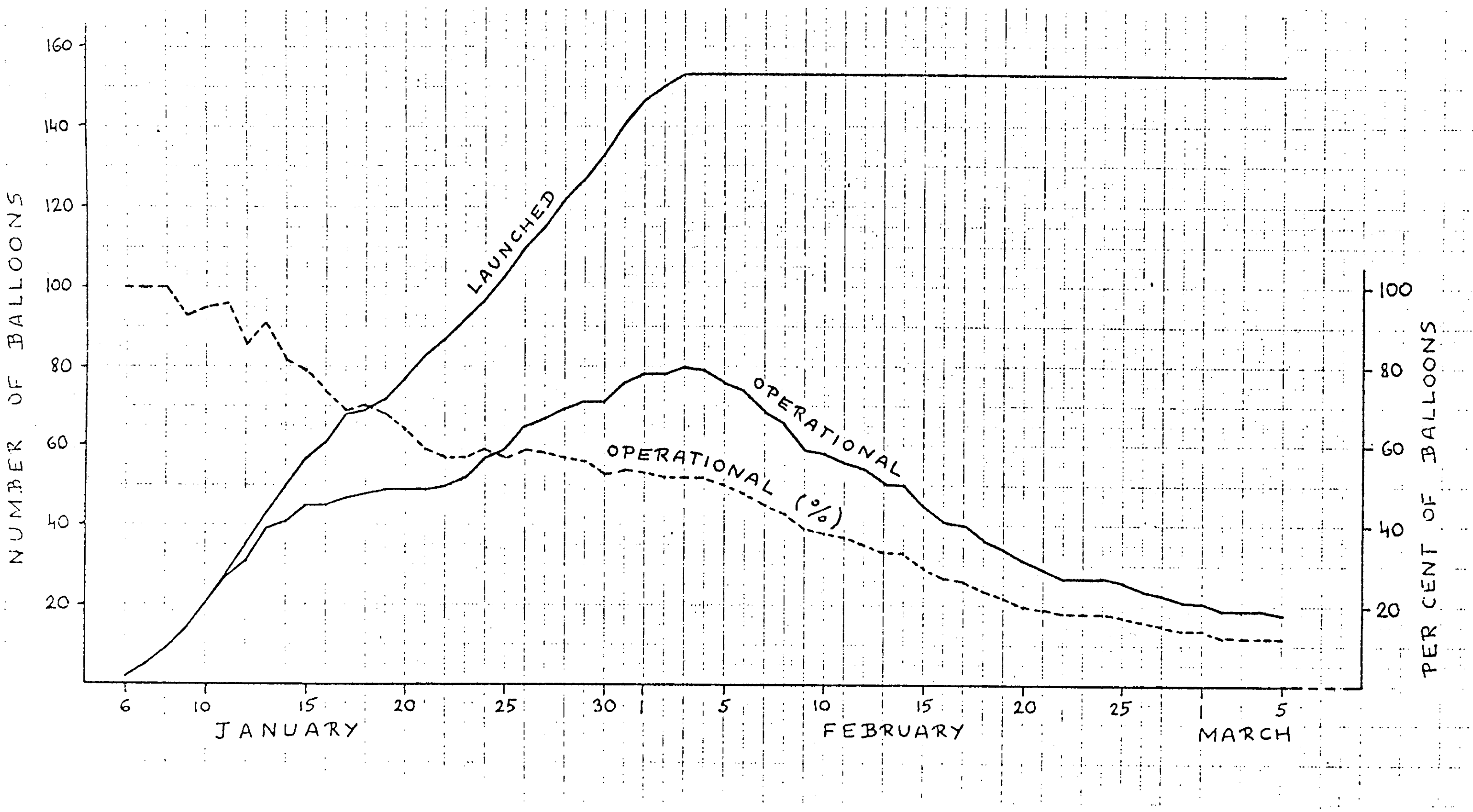


Figure 8.1 - Summary of the Tropical Constant Level Balloon operations during SOP-I. The line labelled "launched" includes the accumulated number of balloons launched as a function of time. The solid line labelled "operational" indicates the number of operational balloons each day. The dashed line indicates the percentage each day of the accunulated number of balloons launched to date which were operational on that date.

8.3 Tropical Wind Observing Ships

40 ships in SOP-1

A network of Tropical Wind Observing Ships (TWOS) was established during SOP-1 (5 January to 5 March 1979) in tropical oceans mainly between 10^{o} N and 10^{o}S. The purpose of the network was to supplement the basic observing system by regular upper air soundings, surface meteorological observations and observations for the FGGE oceanographic programme. Altogether 40 ships from 16 countries participated in SOP 1, with maximum coverage being achieved during the Intensive Observing Period. The fleet included research vessels, hydrographic and navy vessels of a variety of types and sizes. Detailed information on the nominal position, the scientific equipment and the observing programme and procedures of participating vessels can be found in reference (3c).

A special upper-air wind-finding system using the worldwide Omega navigational aid for balloon positioning had been developed for the purpose of FGGE and was deployed onboard the majority of the ships. Other ships used radar wind finding equipment. All soundings were supplemented by pressure, temperature and humidity information collected in the usual manner. A description of the Navaid system can be found in reference (3c) which includes a study of the accuracy of Omega-derived winds.

In the Winter MONEX sector, i.e. between 40^{o}E and 180^{o}E, a total of 16 TWOS were operating during SOP-1. (This number includes the five USSR vessels in the WMONEX area which played a dual role as MONEX research vessels and TWOS; see SECTION 4). Table 8.7 gives the day-by-day positions of the ships and the number of soundings per day. As a rule two soundings were launched per day, whereas the five USSR MONEX ships and the French vessel CORIOLIS performed an enhanced programme of four soundings per day. SPRIGHTLY (Australia) and WILKES (USA) experienced malfunctioning of the Navaid system.

In summary, the performance of the TWOS programme can be called successful. The data quality, as judged from a first quality check performed by the Swedish Level II-b Data Centre appears to be satisfactory. It is stated that "the reported winds fit very well with e.g. satellite wind reports, and the temperature profiles are consistent with closely situated radiosonde measurements".

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Scientific Computing Division •Data Support Section
P.O. Box 3000 • Boulder, Colorado 80307
Telephone: (303) 497-1215 • Telex: 989764
• *FAX (303) 497-1137* • *OMNET r.jenne*

February 28, 1990

MEMO TO: Those Needing Measurements from Balloon Platforms

FROM: Roy L. Jenne/NCAR Roy Jenne

SUBJECT: A Balloon System to Give Us Data

Two short documents are attached:

- Stratospheric Drifting Balloons. This gives information about the use of drifting balloons as a measurement platform.
- A proposal for a balloon system.

REQUEST:

In the research community, if we want some of the measurements that drifting balloons could provide, we will have to help articulate the need and define the measurements needed. It would be very difficult for an instruments group to accomplish this without interactions. I think that to develop support to launch a series of balloons, the research community and/or operational centers would have to define purposes (and goals) and build such plans into the budget process.

Could you take a look at this proposal and let me know if it is of interest for your area of science. At what altitudes would you want measurements, if you need other measurements than listed here? Are there cheap, lightweight sensors to measure what you need?

Larry Epply has given permission to pass this proposal on to other scientists who may be interested.

- End -

Roy Jenne
Feb 1990

Stratospheric Drifting Balloons

Drifting balloons offer a good platform to obtain valuable, low-cost observations that can serve a variety of purposes. They can help provide correlative data to use along with other stratospheric measurements. They provide wind measurements which are badly needed. They can measure pressure and altitude. Other lightweight sensors can be carried. The cost is attractive —to achieve about 100 operational balloons, at any one time, the cost would be about $1.6M per year, plus some donated help.

HISTORY:

- The French conducted the EOLE balloon experiment (S. hemisphere). Data for August 1971 to December 1972 are at NCAR. NCAR has a copy of a nice movie of the drifting balloons that France prepared from the data.
- TWERLE balloons (S. hemisphere). These balloons had a good altimeter, accurate to within about 20 m. It was a very nice experiment. The data for June 1975 to August 1976 are at NCAR.
- Balloons (closer to the equator) were also flown in 1978 - 79.

Note: I think that Cadet in France has aspirations to fly some new balloons. (He called me about a year ago.)

PRESENT PROPOSAL:

About a year ago, Larry Epply (expert on constant-level balloons) called me to see if our research community might have applications for balloon systems that he could develop (He has developed some systems under an ARPA grant). I have given him some encouragement to work up a proposal for an observing system. I noted what balloon choices and measurements were needed in the proposal. He just (January 31) gave me a proposal. The GPS positioning system (involves 17 satellites) would be used to locate the balloons within about 25 meters, in both vertical and horizontal dimensions. The output data would be wind, temperature, elevation, pressure. The cost for 100 operational balloons (working at any one time) would be about $1.6 M per year. The data would:

- Permit a much more accurate analysis of S. Hemisphere winds, heights and temperature for the 150-100 mb region (if a number of balloons are launched at these levels).
- Help the tropospheric analyses. Together with ocean buoys, the data would give a mean temperature between the surface and 150 mb.
- Provide a base-level to use for stratospheric analyses. Thus, LIMS thickness data would be "stacked" on this base level. The measurements would also provide in-situ data to compare with LIMS satellite sounder data.
- Help with the assessment of climate changes in the stratosphere.

#

January 1990

GLOBAL STRATOSPHERIC SURVEY PROGRAM

An Unsolicited Proposal

Presented to:
Mr. Roy Jenne
National Center for Atmospheric Research
Boulder, Colorado

From a talk with
Larry Epply on 29 Sep 1989
-Roy Jenne

By:
CIRRUS Aerospace Corporation
(703) 764-3123

January 31, 1990

GLOBAL STRATOSPHERIC SURVEY PROGRAM

An Unsolicited Proposal

INTRODUCTION: In-situ stratospheric measurements are needed to supplement satellite data and improve computer modeling. Stratospheric data is also important for studying global warming and ozone depletion. The purpose of this paper is to present an outline of the Global Stratospheric Survey concept. The concept is based on the use of a new generation of superpressure balloon and the Global Position System (GPS) for precise, three dimensional navigation[1]. CIRRUS is developing superpressure platform (SPP) technology for the Defense Department under a DARPA contract. The object of this work is to develop a reliable long endurance superpressure balloon. We believe that the availability of a low cost GPS combined with the development of a new generation of SPP and emerging research needs make the Global Stratospheric Survey program a very exciting opportunity.

SYSTEM CONFIGURATION: The major elements of the Global Stratospheric Survey system is the superpressure platform (SPP), the GPS receiver/computer, the sensors, the telemetry link, and the data formatting and distribution system. The SPP subsystem is being developed for the Department of Defense for potential military uses. This project will provide a technology base for increased SPP reliability and lower cost. Several new materials are being tested and we expect significant cost reductions. The goal is to develop a one year SPP endurance capability.

Off-the-shelf GPS systems provide a navigation capability not previously available. Several companies are developing extremely low cost and light weight receivers that are ideally suited for balloon borne navigation. Typical systems are capable of better than 25 meter resolution[2]. The small acceleration of a balloon in float and nearly level altitude

---

[1] The system determines a three dimensional position in space and determines the GPS system time in nano-seconds. The simultaneous solution of all four states is a necessary bi-product of GPS.

[2] The accuracy of the navigation fix depends on the receiver sophistication, the vehicle dynamics and the basic accuracy of the satellite data. The military JCS have the capability to introduce inaccuracies into the system timing for military security reasons. There is a possibility that the military will not allow better than a 100 Meter accuracy to

provide an opportunity for improving on this performance even more. The GPS satellite constellation is expected to be fully deployed by 1992 but is usable today with occasional "coverage dropouts" which can last for several hours. Position is updated every second and horizontal velocity can be determined very precisely. Using GPS small scale velocity and gravity waves effects can be resolved.

Sensors will be chosen based on the specific needs of the users but navigation resolution must be consistent with sensor resolution. For example, the GPS height resolution, better that 25 meters, implies that the pressure can be resolved to 0.04 millibars. The standard pressure sensors will resolve about 0.5 millibars. A better sensor might be found or a pressure-rate sensor might be combined with the absolute pressure. It also may be possible to "calibrate" the balloon with temperature and stress measurements so that it will float at a precisely known constant pressure level. Temperature measurement is not expected to present any unusual problems. Vertical wind velocity is not observable as a function of platform movement. We feel that a simple device to measure it would be a valuable addition to the payload. Ozone measurements over an extended period of time may require a heavy and expensive sensor. We believe that a balloon based system for measuring temperature, and pressure alone will be a valuable in-situ supplement to satellite observations.

We feel that the best telemetry mechanism is Service Argos, the data service of the Tiros satellite. The government rate is $120 per month per balloon[3]. Each data point sent from the platform will consist of 256 bits. The data field contains position, time, pressure, wind (u,v), temperature, vertical wind speed (w) and an optional ozone measurement. CIRRUS could receive, reduce, format and distribute the data at two hour intervals. Alternately, the data can be compiled for a 24 hour period and distributed later. Delayed distribution would be less expensive for several reasons. A monitoring facility would be established to receive raw data, reformat it and transmit it to the users at a proscribed interval. The data could be transmitted to the users at six hour intervals for about the same cost as daily transmissions. Maintenance of the network and balloon replacement will be done as needed. We expect to use existing balloon launch sites. The balloons will be small at sea level pressure and launch should be easily accomplished by the same people who launch normal radiosondes. CIRRUS will provide complete systems and train

---

non-military users of the system. If resolution of more than 100 meters is absolutely necessary, this potential degradation must be considered.

[3] Commercial rate is $10/day for data only and $30/day for data and localization.

launch crews at remote sites so that the cost of specialized crews and facilities can be avoided.

RADIO ALTIMETER OPTION: As an alternative, a global survey system can be developed using a low cost radio altimeter and the localization feature of the Service Argos system. TYROS has the capability to resolve position to within one half kilometer[4]. A radio altimeter has been designed and used by NCAR in past programs. At this time we have been unable to locate a manufacturer currently building the altimeter but technical literature describing the design has been located and we can make the device for a reasonable price. Over water these altimeters could provide height resolution to as good as 25 meters. Over land the performance will depend on the topography. Our first approximation of the cost is that it would require $20,000 of non-recurring engineering and cost about $200 per unit. To simplify the cost comparison we have chosen to use a flat price of $300 per unit. The cost of Service Argos tipples to about $360 per month per balloon for the added localization feature. The total costs must be determined and weighed against the mission requirements in order to choose the most effective system but it seems that the GPS approach would be more cost-effective and provide greater flexibility.

PROPOSED PROGRAM: CIRRUS proposes a five year program. We would like to provide the full range of service from fabrication and test of the flight systems to receipt and distribution of the data. The first year will be the concept development, demonstration and evaluation. The second year would be limited operations with prototype hardware and balloons. The third through fifth years would be full operations in the Southern Hemisphere.

The first year development phase would consist of specific payload designs and test flights using a zero pressure balloon. We would work with users to determine distribution formats and frequency. During the second year prototype payloads would be evaluated in limited operations. Long duration superpressure balloons will be used to gather the first global data. The system architecture would be refined to meet specific users needs and lower cost subsystems would be evaluated. The system will be

---

[4] The accuracy depends on the balloon borne equipment and the satellite's relative flight geometry to the balloon. A good balloon transmitter should have a CEP (65%) of 150 meters. (95% of about 500 meters). A less expensive balloon transmitter will have a CEP of 500 meters and (95% case of 1300 meters).

maintained and operated by CIRRUS during the remaining three years. Our contract will be evaluated for renewal at the end of the fifth year. NCAR could, at their option, provide satellite relay, data reduction or data distribution without CIRRUS's involvement.

PRICE: The price depends strongly on the details of the system design and the life of the balloons. The results of the DOD program will important for validating our assumptions about the new balloons. Higher altitudes require larger, more expensive balloons. Special sensors such as ozone sensors may be developed for some balloons. High resolution navigation may not be required on all systems. The first year studies and user dialogue will establish specific cost-benefit relationship for special payloads. Our preliminary estimate of the first year cost is $150,000. The second year limited operations will cost about $1,000,000. The operational years could be priced on a per-unit basis to allow the users to configure the network as needed. We have evaluated the cost of several candidate global systems. For simplicity we have chosen a system of one hundred balloon "Nodes" as a basis of comparison. Specific system details must be worked out with individual users.

APPROXIMATE SYSTEM COSTS

The costs shown below are *very preliminary* and quite conservative. We believe that actual system costs will be significantly less than those shown below. Detailed pricing will be developed if a formal proposal is requested. The numbers are 1989 dollars.

STANDARD PAYLOAD:

GPS	$2000
SENSORS	200
TELEMETRY & FLIGHT COMPUTER	600
PRIME SYSTEM POWER	700
TOTAL	**$3500/unit**

RADIO ALTIMETER:

ALTIMETER	$ 300
SENSORS	200
TELEMETRY & FLIGHT COMPUTER	600
PRIME POWER	700
TOTAL	**$1800/unit**

Both payloads weigh less than six pounds, have a one year life at 5mb and are aircraft frangible.

BALLOONS vs ALTITUDE:

150mb	$6000
100mb	7000
50mb	8000
20mb	10000
10mb	12000
5mb	16000
2mb	20000

TELEMETRY[5]: $1440/Year/Balloon for data only.
$4320/Year/Balloon for data and localization.

DISTRIBUTION FACILITY WITH STAFF: $250,000 First Year; $200,000 for subsequent years.

MAINTENANCE[6]: $50,000/Year for training, travel and support.

ESTIMATED OPERATIONAL COSTS
100 BALLOON NETWORK

Three representative networks with GPS and Radio Altimeter were priced to provide an estimate of the total cost of the system. Each network is 100 balloons. A low medium and high altitude mix was arbitrarily chosen. The total is in millions of 1990 dollars and represents a full turn-key network cost, including data distribution.

ALTITUDE (Millibars)	NUMBER OF BALLOONS Low	Medium	High Altitude mix.
150	50	20	10
100	15	20	10
50	15	20	10
20	10	20	20
10	5	10	25
5	5	5	25
TOTAL COST (In Millions per year) GPS System	$1.51	1.56	1.84
Radio Altimeter system	$1.63	1.68	1.96

5 Includes an estimate for a small amount of handling by Service Argos for extra localizations.

6 Assumes the availability of facilities and crews at remote weather collection sites.

NASA looks to extended balloon flights

[WASHINGTON] The US National Aeronautics and Space Agency (NASA) hopes within the next few years to begin scientific balloon flights of up to 100 days duration as a way of conducting near-space research at a fraction of current launch costs.

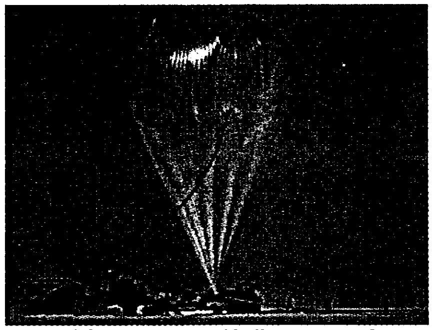
The so-called Ultra-Long Duration Balloons would carry payloads of 2,000 kg or more, including about a tonne of scientific instruments. They would typically circle the globe at altitudes of 40 km, high enough for astronomical observations as well as studies of the stratosphere.

NASA already launches 20 to 30 scientific balloons each year, including a few long-duration flights. But balloons can at present stay aloft for only a couple of weeks.

The new, much larger 'superpressure' balloons would be made of advanced plastics such as Mylar or polyethylene, with a lightweight lamination to add strength. The lamination techniques were pioneered in sails for racing yachts.

Several tests of the superpressure balloons are scheduled in the next two years, and NASA plans a demonstration flight, with a scientific payload, in the year 2000. Six candidate experiments were selected last April, one of which will be chosen this winter for the flight. If the demonstration is successful, regular 100-day flights could begin in 2001.

Such flights would be "almost like a satellite" for some kinds of research, says Jack Tueller, balloon-project scientist at NASA's Goddard Space Flight Center in Maryland. High-altitude balloons are ideal platforms for infrared and γ-ray astronomy, and for studies of the cosmic microwave background.



Longer life? Conventional balloons can only stay up for a couple of weeks before losing pressure.

M. COMBERIATE/NASA GSFC

And balloon experimenters usually get their scientific payload back, says Tueller. Their instruments can also have a wider variety of shapes and sizes, as they do not have to fit within the launch shroud of a rocket. Launch costs are another advantage of scientific balloons. A typical mission can launch for under $1 million, says Tueller, compared with up to $18 million using a Pegasus rocket.

NASA is working on designs for a 'ballooncraft' with standardized subsystems to provide power, communications and other essentials to scientific instruments on 100-day flights, which would further reduce development costs.

The technical obstacles facing superpressure balloons are thought to be fairly straightforward, but the programme still faces political barriers. Tueller says the 100-day flights would probably launch from the Southern Hemisphere at first, largely for political reasons.

Circumnavigating the globe in mid-northern latitudes would require overflight permission from many countries, including Libya and Iraq. Missions flying at higher northern latitudes would pass over Russia, which has not yet agreed to allow such flights.

Safety issues will also have to be resolved before the balloon programme gets under way. Balloon payloads have been known to fall to the ground, and Tueller concedes that scientists would face a greater risk of losing their instruments during a 100-day flight than on shorter missions.

NASA intends to begin almost immediately to take advantage of this cheap way of reaching the edge of space. The agency will soon be looking for low-cost space missions for its University Explorer programme, and will for the first time include the option of flying instruments on long-duration (10-20-day) balloon flights as well as on satellites or the space shuttle.

Tony Reichhardt

Nature 4 Dec 1997 Page 431

These are the big balloons, not like the smaller constant level balloons.