errors of radiosonde and rocketsonde temperature sensors

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Abstract

A method is proposed where two thermistors of different emissivities are used on the radiosonde to compute the corrected air temperature. This method could be extended to rocketsonde temperature measurements by using two bead thermistors of different sizes to determine temperature errors and aerodynamic heating errors.

1. Introduction

For many years, rocketsondes and radiosondes have been used to measure atmospheric temperatures at various altitudes employing a single sensor. Because of the significance of the error introduced by radiation from the sensor itself, much theoretical computation has been made to calculate the magnitude of this error. However, this has been difficult because of the many unknown factors to be considered.

This paper describes the use of two sensors on a radiosonde whereby the actual magnitude of the error caused by sensor radiation can be measured.

2. Theory

Let us assume that at some point in the atmosphere at some instant, the temperature is T . A thermometer will measure some temperature T_r as follows:

$$T_r = T + \epsilon_r \Delta T,$$

where ϵ_r is the emissivity of the thermometer and ΔT is the error caused by the physical size, shape, and materials of the thermometer, if it is a black body. The value of ΔT will vary with conditions in the atmosphere, and the magnitude of ΔT is directly related to the resultant balance reached by the rate of heat transfer from the gas and its surroundings to the thermometer by radiation balanced against the rate of heat transfer from the sensor by radiation and convection-conduction to the gas and surroundings and by conduction from the sensor to its support. If all the surroundings were at the same temperature, then the thermometer would indicate the temperature T ; i.e., $T_r = T$ and $\Delta T = 0$. In this case, all thermometers, regardless of size or emissivity, would indicate the correct gas temperature.

If we had two thermometers *identical* in size, shape, materials, and emissivities exposed to identical condi-

tions (radiation, aspiration, air density, etc.), they would both have the same value of ΔT (and also $\epsilon_r \Delta T$). If one of these thermometers were exposed such that everything was the same except the air density was reduced, then the thermometer exposed to the lower density would have a larger value of ΔT since the convective-conduction heat transfer would be smaller.

Now, assume that at some place in the atmosphere at some instant of time, we have two thermometers simultaneously measuring the same temperature, then we can write two equations as follows (where subscripts 1 and 2 refer to the two thermometers):

$$T_{T_1} = T + \epsilon_{T_1} \Delta T_1 \quad (2.1)$$

$$T_{T_2} = T + \epsilon_{T_2} \Delta T_2 \quad (2.2)$$

or subtracting Eq. (2.2) from Eq. (2.1),

$$T_{T_1} - T_{T_2} = \epsilon_{T_1} \Delta T_1 - \epsilon_{T_2} \Delta T_2. \quad (3)$$

If both thermometers are the same identical size, shape, and material, but have different emissivities,

$$T_{T_1} - T_{T_2} = (\epsilon_{T_1} - \epsilon_{T_2}) \Delta T. \quad (4)$$

If ΔT can be determined by measurement at any instant desired, then T can be found, assuming we know ϵ_{T_1} and ϵ_{T_2} since T_{T_1} and T_{T_2} are always known as they are the temperature the thermometer indicates.

3. Tests

To verify the theory, a model 3002 light-weight transponder (developed for the Atmospheric Research Facility of MSFC) was modified by replacing the humidity element with an additional rod thermistor. One of the two thermistors was painted black, the other white (see Fig. 1). This unit provided data from each thermistor alternately every 5 seconds by a clock-driven commutator that was independent both of the rise rate of the balloon and of pressure changes.

For this test, five radiosondes with two sensors (thermistors) each were released at varying times of the day (all sensors were previously calibrated in the standard radiosonde calibration chamber). Before release of the radiosonde for the first test, data were recorded with both sensors exposed to the sun and then in the shade. There was a temperature difference between the two

FIG. 1

sensors ($T_{T_1} - T_{T_2}$) of 2.9C in the sun and 1.5C in the shade, based on the assumption that both read the same temperature in the calibrated chamber. The other radiosonde tests were made during cloudy weather or at night.

The data presented in Table 1 show, with increasing elevation, the temperature differences between the white and black thermistors were greater in the daytime, and were smaller and of opposite sign at night. The data also show that there were variations from day to day and between night and day. Examination of the data shows that the temperature differences increase as the radiosonde rises, as would be expected since the air density is decreasing. When the radiosonde is in the sun, the black

thermistor is at a higher temperature than the white thermistor.

4. Example of error computation

Assume the black thermistor has an emissivity of 0.95 based on available tables on flat black paint. Specifications for manufacture of the rod thermistor requires the emissivity to be no greater than 0.08 when exposed to a 300-watt clear Mazda lamp in a test chamber. When the rod thermistor is exposed in the daytime, the effective emissivity (solar + sky + Earth) will be higher because the emissivity of the rod thermistor is greater than 0.90 for long wave radiation (sky and Earth's surface). Based on tests made before the radiosonde was released, the effective emissivity of the white thermistor in the daytime was apparently greater than 0.30, but the lower value of 0.30 has been assumed to illustrate the method of computation for a daytime release. The effective emissivity should also vary some with altitude (increase), but was not considered in this preliminary computation. Using the data from the 20 July 1967 release, values of preliminary true-temperatures were computed and compared to the black and white thermistor temperatures. (See Fig. 2.) At night, the white thermistor has an emissivity of nearly 1.00 (black), and therefore current radiosonde temperatures measured at night probably have larger errors of opposite sign from those measured in the daytime.

Although the results of the tests being reported in this paper are preliminary, it is believed that the results are significant and should be disseminated at the earliest possible time. These tests should be extended to higher altitudes using rocketsondes instead of the radiosonde because of the greater temperature errors

TABLE 1. Summary of radiosonde test data.

Test no.....		1 (afternoon)	2 (afternoon)	3 (morning)	4 (night, after sunset)	5 (night, before sunrise)
Date and time of test.....		July 17, 1967 21:47Z (16:47 CDT)	July 18, 1967 21:32Z (16:32 CDT)	July 20, 1967 14:42Z (9:42 CDT)	July 21, 1967 02:55Z (21:55 CDT)	July 24, 1967 08:54Z (3:54 CDT)
Surface temperature and weather.....		27C few small scattered cumulus	28C 2/10 cumulus	23.3C 10/10 altostratus	21.9C 1/10 altostratus	20.9C 9/10 stratocumulus
$(T_{T_1} - T_{T_2})$ values		(Temperature differences—black thermistor minus white thermistor)				
	Elapsed time from release (min)					
At surface in shade	-5	1.5C				
At surface in Sun	-4	2.9C				
At release	0	1.5C	0.8C	1.8C	0.4C	0.1C
At 20,000 ft	20	3.7C	1.9C	3.1C	0.2C	0.1C
At 50,000 ft	50	4.7C	2.7C	5.3C	0.5C	0.4C
At 75,000 ft	75	6.7C	5.1C	9.0C	0.2C	-0.1C
At 100,000 ft	100	10.3C	7.4C	11.1C	-0.1C	+0.6C**
Max. height of run		104,000 ft	102,000 ft	102,000 ft	120,000 ft	122,000 ft
Value of max. height of run		8.8C	9.1C	11.4C	-0.7C	+7.6C***

** 16 minutes before sunrise.

*** After sunrise.

† Elevations on this release are approximate because of apparent slow leak in the balloon.

FIG. 2. Comparison of temperatures measured with black and white thermistors and the computed true temperature.

in rocketsonde data. If the small bead thermistors are used, it would be more feasible to use two beads of different sizes (say a 5 mil and 15 mil) with the same

emissivity. Uncoated (black) beads would probably provide more uniformity in the emissivities, and Eq (4) would then become

$$T_{T_1} - T_{T_2} = \epsilon(\Delta T_1 - \Delta T_2),$$

where ϵ now is the emissivity of either bead and the ratio of ΔT_1 to ΔT_2 would depend on the ratio of the sizes and can be theoretically determined. By using beads of different sizes, the aerodynamic heating can also be evaluated.

5. Conclusions

If two thermistors of the same size and shape, but with different emissivities, are used on a radiosonde to measure atmospheric temperatures, the radiation error can be computed and correct temperature data obtained, providing the emissivities of the thermistors are known. The results of preliminary tests verify the feasibility of modifying radiosondes for better temperature measurements.

Acknowledgments. I wish to express appreciation to the personnel of the Atmospheric Research Facility at Marshall Space Flight Center for modifying the radiosondes and launching them both during daytime and at night to provide these data on short notice.

announcements

Two international symposia scheduled

IAMAP radiation symposium

An international symposium jointly sponsored by the World Meteorological Organization and the IUGG's International Association of Meteorology and Atmospheric Physics on *Radiation Including Satellite Techniques* will be held in Bergen, Norway, on 21-28 August 1968. Short (15 min) contributions on any of the following topics will be welcomed:

1) Satellite instrumentation; 2) satellite observations and results; 3) spectroscopy, theoretical and experimental; 4) radiation climatology; 5) surface and airborne instruments; 6) radiative transfer in aerosols and clouds; 7) radiation and atmospheric dynamics; 8) radiative transfer and planetary atmospheres.

All titles and abstracts of contributed papers together with an indication of the topic under which the paper is submitted should be forwarded to: Prof. J. London, Secretary, Radiation Commission (IAMAP), Department of Astro-Geophysics, University of Colorado, Boulder, Colo. 80302, USA. The deadline for titles and abstracts is 15 June 1968.

It is planned that all scientific sessions as well as residence for most of the delegates (and families) will be at the Hatleberg Congress Center in Bergen. All inquiries about local arrangements, housing, etc., should be sent to: Prof. H. Schieldrup-Paulsen, Geophysical Institute, University of Bergen, Bergen, Norway.

WMO climatology conference

The World Meteorological Organization will hold a Symposium on Urban Climates and Applied Climatology in Brussels, Belgium, on 16-25 October 1968.

Those who wish to attend should notify the Director, Environmental Data Service, ESSA, Gramax Bldg., Silver Spring, Maryland 20910, prior to 31 March 1968. Since the WMO funds for this symposium are limited, it will be necessary for participants to make their own arrangements for meeting the cost of attendance.

Participants wishing to present papers are requested to forward two copies of an abstract (not more than 200 words) together with time and projection requirements to the chairman of the symposium planning committee, Dr. T. J. Chandler, Department of Geography, University College London, Gower St., London, W.C. 1, U. K., before 1 May 1968. It is hoped that the proceedings will later be published, so speakers are requested to deliver the full manuscripts of their papers to Dr. Chandler at or before the time of the symposium.

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