Historical Arctic Rawinsonde Archive (HARA) Radiosonde Systems

The information in this document has been taken from the following sources:

Elliott, W. P., and D. J. Gaffen. 1991. On the utility of radiosonde humidity archives for climate studies. *Bulletin American Meteorological Society* 72(10): 1507-1520.

Garand, L., C. Grassotti, J. Halle, and G. L. Klein. 1992. On differences in radiosonde humidity - reporting practices and their implications for numerical weather prediction and remote sensing.*Bulletin American Meteorological Society* 73(9):1417-1423.

Lally, V. E. 1985. Upper Air in situ Observing Systems. *Handbook of Applied Meteorology.* David D. Houghton, editor. John Wiley & Sons, Inc. 352 -360.

Vaisala Inc. 1989. RS 80 Radiosondes. Upper-Air Systems product information. Reference No. R0422-2. Vaisala Inc., 100 Commerce Way, Woburn, MA 01801.

Summary

The term "rawinsonde" is often used to describe radiosonde systems that measure winds, along with pressure, temperature and humidity; "rawinsonde" will be used interchangeably with "radiosonde" in the following paragraphs.

Radiosondes carry temperature, pressure and relative humidity sensors and report up to six variables: pressure, geopotential height, temperature, dewpoint depression, wind direction and wind speed. While there are many effective instrument designs in use, in the United States, a typical radiosonde configuration consists of a baroswitch that implements a temperature-compensated aneroid capsule to move a lever arm across a commutator plate, a lead-carbonate coated rod thermistor about 0.7 mm in diameter and 1-2 cm long, and a carbon humidity element that swells with a rise in humidity, made of a glass or plastic substrate thinly coated with a fibrous material. A radio transmitter and ground-based radar, navigation aid, or other tracking system complete the rawinsonde instrumentation.

Measurements are used in weather forecasting, and are of increasing interest to those studying climate change; however, the variety of instruments in use (consider manufacturing differences and those that occur over time, with improvements in technologies), coupled with divergent reporting and calibration practices have the potential to threaten the integrity of the data archive; researchers should take care that computations based on data reflect actual climate changes, not changes in practice and equipment. Because of this concern, the World Meteorological Organization (WMO) conducts periodic comparisons of radiosonde systems.

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1. Document Information

Document Type: Instrument Document
Revision Date: December 1995

2. Instrument Information

Instrument Introduction

Upper air measurements began with temperature soundings made in Glasgow, 1749, using a thermometer attached to a kite. Subsequent efforts in the 18th and 19th centuries progressed through the use of box kites, manned balloons, and free balloons and expanded to include measurements of temperature, pressure, electrical field and humidity. Early devices were replaced by aircraft carrying first, meteorographs, and then radiosondes. Today, rawinsondes are flown on balloons made of natural or synthetic rubber, which, expanding as they ascend, will eventually burst. Some balloon designs are vented, such that the balloon descends and can be recovered, others are tethered, and other, super-pressure balloons are designed to fly anywhere from three days to several months.

Given the limitations of the platform, rawinsondes must be expendable and factor in their design considerations the possibility of being struck by jet aircraft (Lally 1985).

Radiosonde systems comprise pressure, temperature and humidity sensors, complemented by transmitting electronics. Winds are calculated based on ascent velocity and air density. As concerns upper air practice, the World Meteorological Organization sets accuracy requirements and performance limits for instruments used to derive these parameters. Pressure must be measured to an accuracy of +/- 1 mb (1 mb = 1 hPa), temperature to an accuracy of +/-. 5 degrees Celsius, and relative humidity to an accuracy of +/- 5 percent. 1989 tests of several models of radiosondes used in the United States in the 1980's showed pressure measured to an accuracy of about +/- 2 mb, temperature measured to an accuracy of +/-0.3 degrees Celsius, and relative humidity to an accuracy of +/- 2 percent.(Elliott and Gaffen 1991).

Instrument Mission Objectives

Soundings are used in synoptic meteorology and climatology.

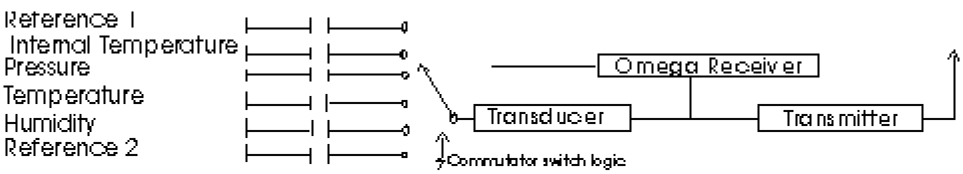
Key Variables

Instrument performance is sometimes seen to degrade in cold, dry regions, because the instrument responds to the number of water molecules present in the atmosphere.

Scanning or Data Collection Concept/Principles of Operation

The number and variety of instruments in use (see section 4) make it infeasible to describe the particulars of each; the following information, provided courtesy of Vaisala Inc., is representative and does not constitute a product endorsement by NSIDC. The following description is reprinted with permission. Please direct all questions to the manufacturer.

The PTU (pressure, temperature, humidity) measuring system of the Vaisala RS 80 radiosonde is based on a time multiplexing principle. Each of the capacitive sensors controls the frequency of the AF oscillator through an electronic commutator switch. The switch is formed by solid state logic gates. The oscillator frequency is fed through a modulator to the radio transmitter. A water-activated battery provides power for the radiosonde.



RS 80-15N radiosonde block diagram

The frequency generated by the transducer is the measure of the meteorological parameters. Relationship between the frequency and corresponding parameter value is established in the calibration process.

The set of solid state sensors consists of an aneroid capsule (BAROCAP) with capacitive transducers in the inside vacuum, a ceramic temperature sensor (THERMOCAP) and a thin film humidity sensor (HUMICAP) which is an improved version of the one produced earlier.

All the sensors are capacitive with compatible dynamic ranges which essentially simplifies the transducer electronics.

In the radiosonde only one reference capacitor is needed to eliminate the influence of drift of the transducer electronics. The basic capacitance of the transducer oscillator circuit is used as the second reference.

Other viewpoints when selecting the sensing principle were the existence of the capacitive humidity sensor, a simple stable and frictionless barometer construction and small risk of self-heating problems in temperature and humidity measurements.

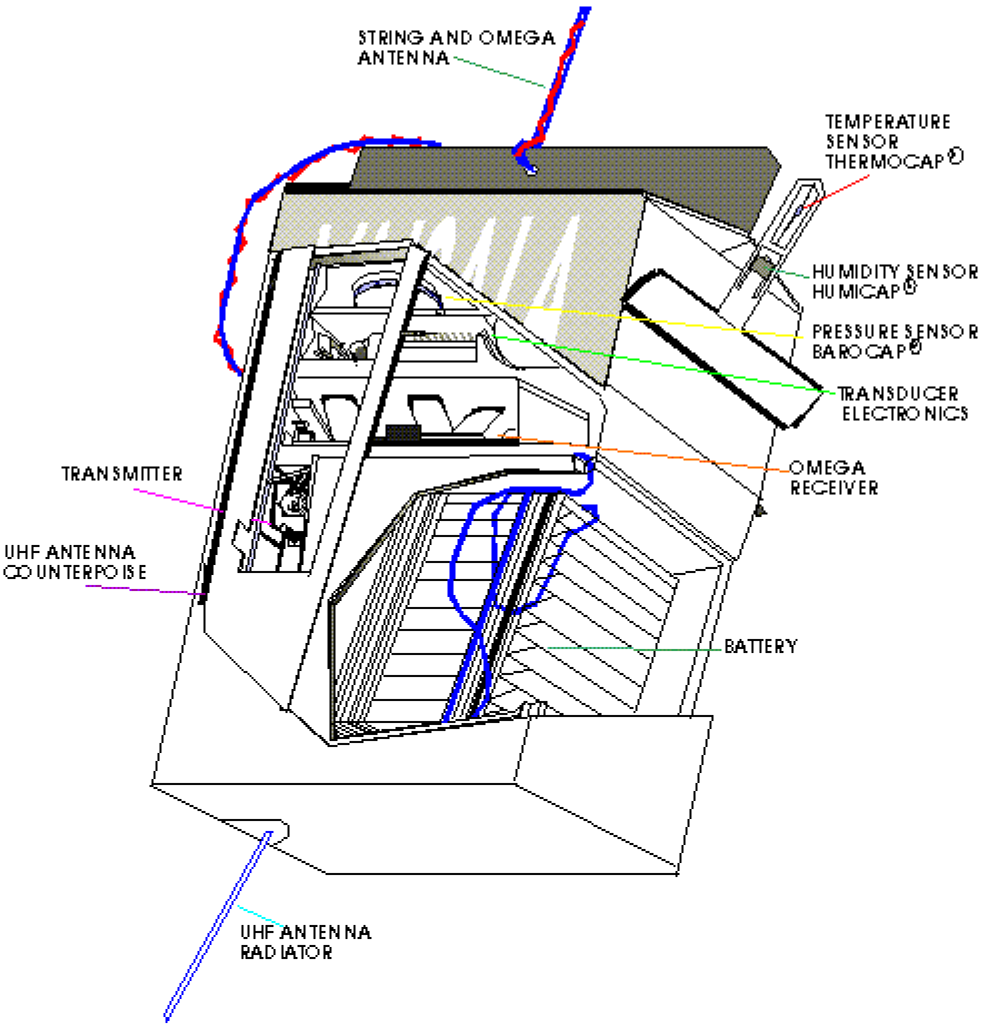
The transducer circuit developed for the RS 80 radiosondes is capable of measuring with a resolution of 1 fF. The electronic circuit is insensitive to changes of stray capacities between sensor terminals and electrical ground. This is of basic importance for the feasibility of the sensor design.

There is an additional temperature sensor to measure the temperature of the pressure sensor for elimination of its temperature dependence.

from: RS 80 Radiosondes, Vaisala Inc. Upper Air Systems product information, reference no. R0422-2, 26 May 1989.

Data collected in the Historic Arctic Rawinsonde Archive consists of land-based soundings taken one to four times per day for all available Arctic stations poleward of 65 degrees North. Most stations are located between 65 and 78 degrees north. Long term (30) year records are available for about 50 stations, most begin in 1958 and extend through 1987. Additional soundings obtained from the National Center for Atmospheric Research extend the data base through 1991. Soundings typically extend to at least 300 mb and contain a mixture of reports at mandatory (that is, surface, 1000 mb, 850 mb, 700 mb, 500 mb, 400 mb, 300 mb) and significant levels. Six variables, pressure, geopotential height, temperature, dewpoint depression, wind direction and wind speed are reported with associated quality codes at the 20 to 40 levels usually available per sounding.

3. Instrument Layout, Design, and Measurement Geometry



This view is a cutaway of a VAISALA RS 80. The radiosonde's dimensions are 55 X 147 X 90 mm, and it weighs less than 200 g.

List of Sensors

Radiosondes carry pressure, temperature and humidity sensors.

Sensor Descriptions

The number and variety of instruments in use (see section 4) make it infeasible to describe the particulars of each; the following information, provided courtesy of Vaisala Inc., is representative and does not constitute a product endorsement by NSIDC.

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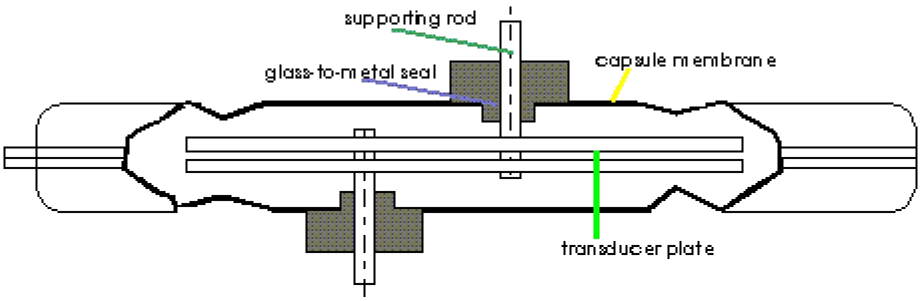
Pressure Sensor (BAROCAP)
(incorporated in the Vaisala RS 80 Radiosondes)
Type: Capacitive Aneroid
Measuring Range: 1060 hPa (mb) to 3 hPa (mb)
Resolution: 0.1 hPa
Accuracy*: 0.5 hPa
* repeated calibration method, standard deviation of differences

The pressure sensor is a small aneroid capsule with capacitive transducer plates inside. The external diameter of the capsule is 35.5 mm and the weight of the complete assembly only 5 g.



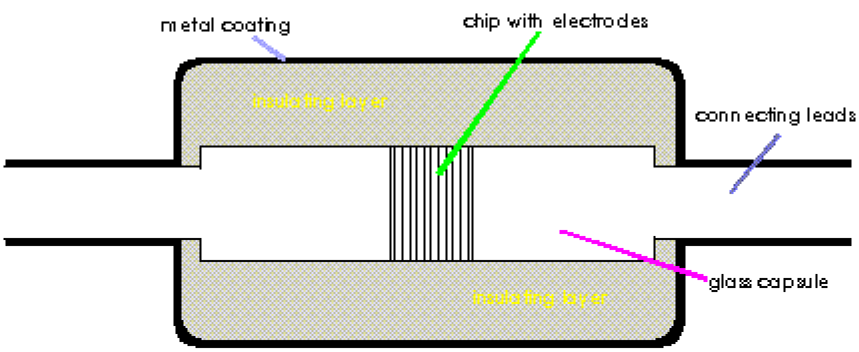
Pressure sensor (BAROCAP)

Transducer plates are supported by membranes made of special steel alloy. The supporting rods of the plates are fixed to the membranes with hermetic glass-to-metal seals. The inverted construction is used to obtain maximum sensitivity at low pressure....The transducer electronics senses the capacitance between the plates only, with no influence of stray capacitances between the transducer plates and the membranes, which are grounded.

Temperature Sensor (THERMOCAP)
Sensor type: Capacitive bead
Measuring range: +60 degrees C to -90 degrees C
Resolution: 0.1 degree C
Accuracy*: +/- 0.2 degrees C
Lag: less than 2.5 s (6m/s flow at 1000 hPa)

The temperature sensor is based on dielectric ceramic materials, the temperature dependence of which can be accurately controlled with selection of materials and processing parameters.

Metal electrodes are formed on both sides of a tiny ceramic chip (0.5 X 0.5 mm, thickness 0.2 mm). The capacitance between the electrodes is a function of temperature. To ensure complete moisture protection the sensor is hermetically sealed in a small glass capsule (2.5 X diameter 1.5 mm) with two connecting leads (diameter 0.4 mm). To avoid uncontrolled stray capacitances which could be caused, for instance, by water droplets on the glass capsule, an electrically grounded thin film aluminum coating is deposited on the sensor capsule and leads. This coating also has excellent radiation properties for minimizing the radiation error (max 2 degrees C at 10 mb and 45 degrees solar elevation) of the observation. An insulation layer on the leads prevents short circuits.



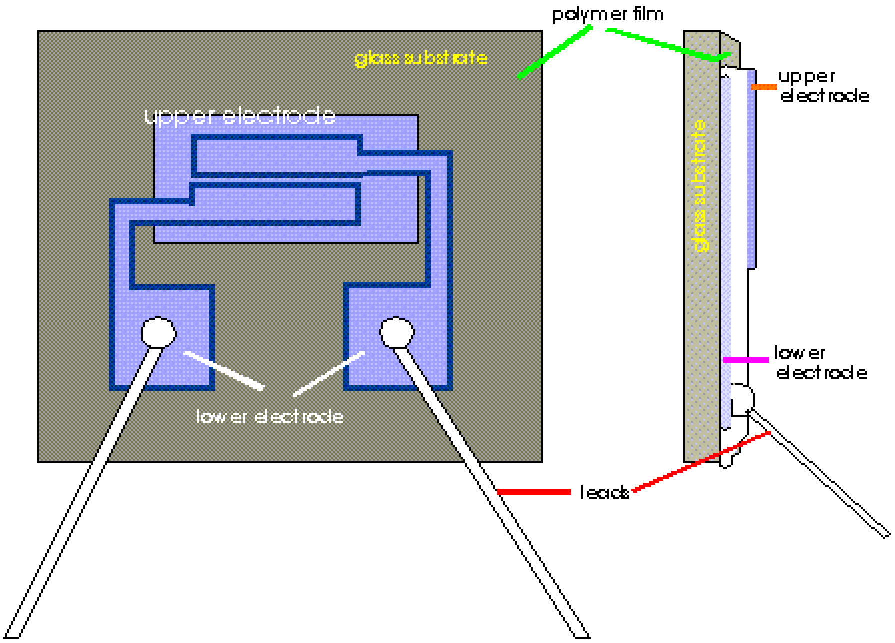
Temperature sensor (THERMOCAP)

Humidity Sensor (HUMICAP)
Sensor type: Thin film capacitor
Measuring range: 0 % RH to 100 % RH
Resolution: 1% RH
Lag: 1 s (6m/s flow at 1000 hPa, + 20 degrees C)
Accuracy*: +/- 2 % RH
* repeated calibration method, standard deviation of differences

The humidity sensor is a thin film capacitor with a polymer dielectric. The polymer is about 1 micron thick. The sensor capacitance is dependent on the water absorption in the sensor's dielectrical material.

The sensor is fabricated using thin film technology similar to that generally used in microelectronics. The sensor is small (4 X 4 X 0.2 mm), hence its thermal mass is also small and the sensor very closely and quickly follows the ambient air temperature. This is obviously necessary for obtaining true relative humidity values in the atmosphere.

Other attractive features of the sensor are fast response, good linearity, low hysteresis and small temperature coefficient. The sensor operates reliably in low temperatures to at least the -60 degree C level.



Humidity sensor (HUMICAP)

from: RS 80 Radiosondes, Vaisala Inc. Upper Air Systems product information. reference no. R0422-2, 25 May 1989.

4. Manufacturer of Instrument

The following list represents some of the instruments currently in use, their makers or the countries in which they are employed:

U.S. - ESSA External thermistor
U.S. - An/AMT-4 Military external thermistor
U.S. - ESSA 403 MHz duct-type
Finland - Vaisala Oy
France - Metox
Portugal - Canada Model IV
W. Germany - Graw H.50
Japan - Code sending
E. Germany - Freiberg
Britain - Kaw Mark IIB
the former USSR - A-22-III (IV)
NOAA-II (SIRS-B) Instrument 1
NOAA-II (SIRS-B) Instrument 2

5. Calibration

Frequency of Calibration

For the Vaisala Inc. RS 80 Radiosondes described in this document, calibration data is obtained separately for every radiosonde and delivered in the form of an eight-channel paper tape as well as a printout table. Fourth degree equation coefficients for each sensor with check sum for entry verification are provided.

Contact instrument manufacturers for further calibration specifics.