P2.4

VAISALA DROPSONDES: HISTORY, STATUS, AND APPLICATIONS

Ilkka Ikonen II[1], Nicholas W.S. Demetriades[2], and Ronald L. Holle[2]
Vaisala Inc.
[1]Helsinki, Finland
[2]Tucson, Arizona

1. INTRODUCTION

Vaisala has been the manufacturer of commercial dropsondes for many years, and was recently awarded a renewed five-year NOAA production contract for model RD94 dropsondes after an open bid process. In 1994, Vaisala joined the National Center for Atmospheric Research (NCAR) and German Aerospace Research Establishment (DLR) to develop a new dropsonde that was to use GPS for improved windfinding.

The first few NCAR-built sondes (model RD93) were received by NOAA in 1996, the same year that NCAR selected Vaisala to produce sondes for delivery. In 1998, subsequent open competition for dropsonde production was awarded in a five-year contract (Hock and Franklin 1999), followed in 2004 by another five-year production contract. In 2008, NCAR issued a design for the new dropsonde. In 2009, Vaisala acquired the license from NCAR to provide dropsondes to users outside the U.S. government, model RD94.

The experience in dropsondes has been built upon the design and manufacture of radiosondes since the beginning of Vaisala over 70 years ago. The now-global company Vaisala was established on the success in terms of quality and reliability of the first Vaisala radiosondes developed in the 1920s and 1930s by Professor Vilho Vaisala.

2. DROPSONDE RD94

The form factors of the current dropsonde RD94 is the same as for the RD93 shown in Figure 1. It sends temperature, humidity, pressure and wind speed and direction data to the aircraft every 0.5 seconds; it weighs 390 grams. A drop from 20,000 feet (6.1 km) takes seven minutes as it descends while stabilized by parachute, and 15 minutes from an altitude of 14 km. They can be operated up to an altitude of 24 km in both arctic and tropical environments.

Corresponding author address: Ronald L. Holle, Vaisala Inc., Tucson, AZ 85756; e-mail: ron.holle@vaisala.com.

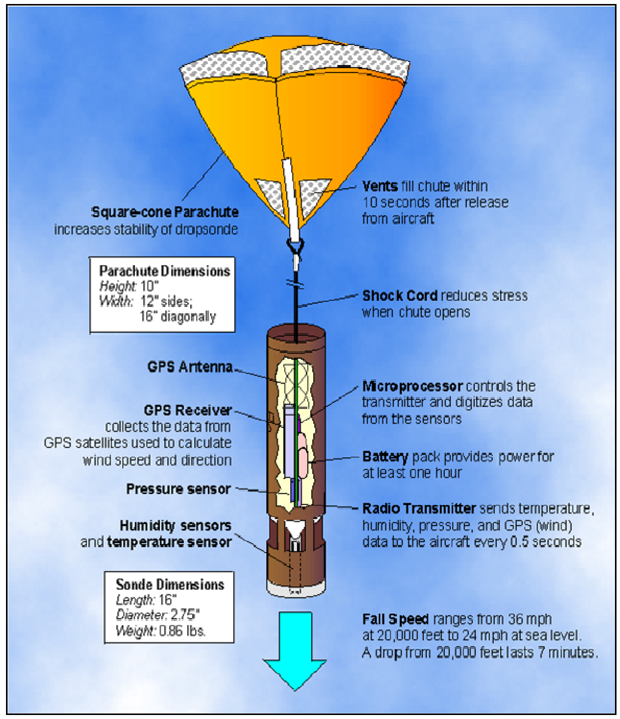

FIGURE 1. Overview of dropsonde RD93.

The exterior housing and interior electronics of the RD94 dropsonde are shown in Figure 2. A close-up view of the pressure, temperature, and humidity sensors is shown in Figure 3. The sensors are the same as those used in Vaisala radiosondes with the exception of a somewhat more rugged temperature sensor design for aircraft ejection.

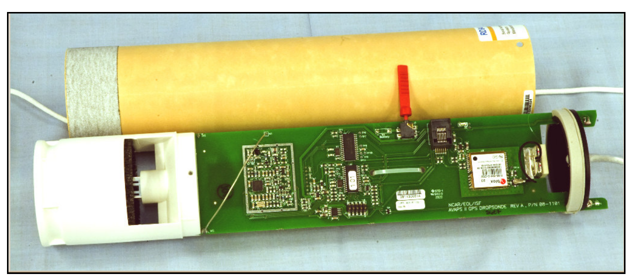

FIGURE 2. Exterior and interior views of RD94 dropsonde.

FIGURE 3. Close-up view of the pressure, temperature, and humidity sensors in the RD94 dropsonde.

One of the important features is the development of the square-cone parachute. It reduces the initial shock load, slows and stabilizes the dropsonde, and has a very small gliding factor (Figure 4). As a result, dropsondes can be deployed at indicated airspeeds up to 250 knots.

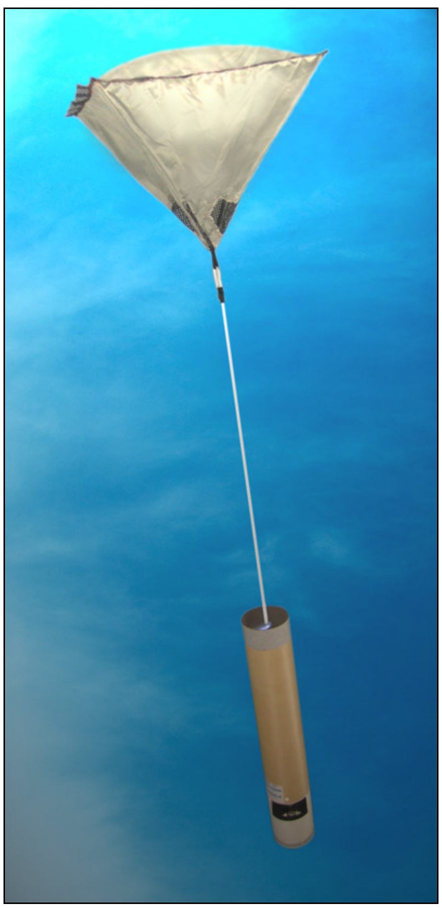

FIGURE 4. RD94 dropsonde with square-cone parachute.

3. AVAPS DATA ACQUISITION SYSTEM

The data acquisition system on the aircraft is AVAPS (Airborne Vertical Atmospheric Profiling System). It collects two independent PTU and four wind measurements per second and transmits the data in real time to users. AVAPS can handle up to four dropsondes descending simultaneously, and is operated by one person. The preparation time for each dropsonde is less than two minutes.

AVAPS measures the atmospheric profile of the ambient air as the dropsonde descends from the aircraft's flight level to the surface. Temperature, relative humidity, and wind are measured using the Vaisala RS904 sensor unit, and wind with the uBlox GPS receiver. This GPS receiver tracks the movement of the dropsonde to obtain wind speed and direction. Typical profiles of temperature and relative humidity are shown in Figure 5, and wind speed and direction in Figure 6.

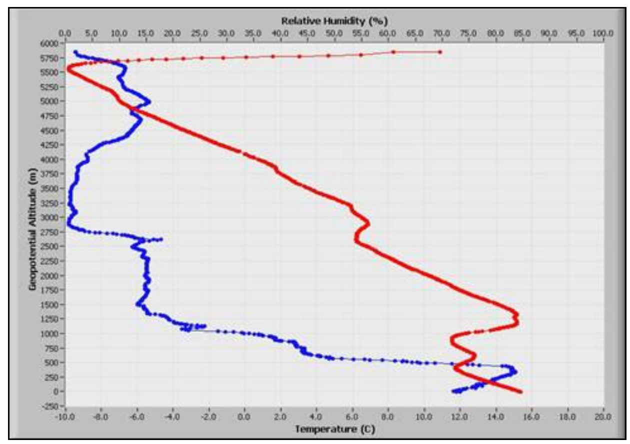

FIGURE 5. Vertical profiles of temperature and relative humidity from a dropsonde.

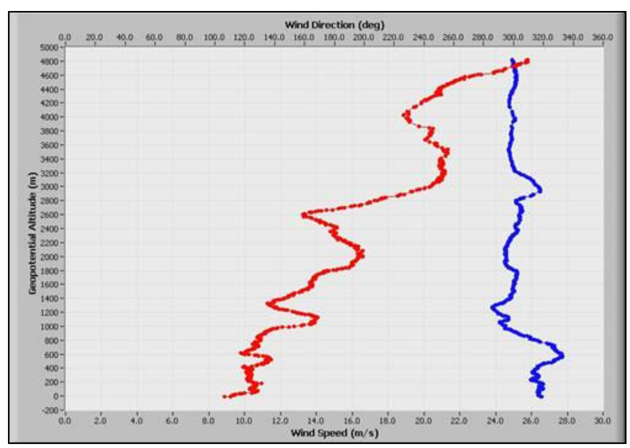

FIGURE 6. Vertical profiles of wind speed and direction from a dropsonde.

Sounding data from the AVAPS system are stored on a computer hard disk drive in simple space-separated ASCII format. The typical size is 1MB per sounding, and the real-time serial line output can be connected to other data systems. A data sample is shown in Figure 7.

Sounding Data Example

```
AVAPS-T02 STA 020615064 020417 010754.9
AVAPS-T02 COM                  GMT      GMT       Air    Air     Rel   Wind   Wind   Vert        GPS        GPS   Geopoten GPS  Sonde  Sonde GPS  Wind
AVAPS-T02 COM    Sonde        Date     Time     Press   Temp   Humid    Dir    Spd  Veloc  Longitude   Latitude   Altitude Wnd  RH #1  RH #2 Snd Error
AVAPS-T02 COM      ID       yymmdd hhmmss.s     (mb)  (degC)    (%)   (deg)  (m/s)  (m/s)      (deg)      (deg)        (m) Sat    (%)    (%) Sat (m/s)
AVAPS-T02 COM --------- ------ -------- ------- ------ ------ ------ ------ ------ ---------- ---------- -------- --- ------ ------ --- -----
AVAPS-D02 S00 020615064 020417 012106.2  874.96  17.22  44.94 130.60   7.28 -12.50  -87.86343   28.34475  1337.26   8  44.94  45.34   8  0.00
AVAPS-D02 S00 020615064 020417 012106.7  875.58  17.30  44.77 130.01   7.31 -12.53  -87.86346   28.34477  1331.16   8  44.77  45.17   8  0.00
AVAPS-D02 S00 020615064 020417 012107.2  876.15  17.33  44.60 129.76   7.27 -12.38  -87.86349   28.34479  1325.67   8  44.60  44.82   8  0.00
AVAPS-D02 S00 020615064 020417 012107.7  876.73  17.38  44.61 129.89   7.30 -12.49  -87.86353   28.34481  1319.93   8  44.61  44.83   8  0.00
```

FIGURE 7. Data file from a dropsonde descent.

4. INSTALLATION OF DROPSONDE SYSTEMS

AVAPS has been installed on a wide variety of aircraft, including the P-3 Orion, Gulfstream II and G-IV-SP, Lockheed Hercules C-130 and Electra, Convair 580, Falcon 20, Pilatus PC-6, Canberra, and DC-8.

Since the dropsonde system requires modifications to an existing aircraft, it is important to identify the issues involved in the installation.

Vaisala provides the following equipment to enable the dropsondes:

- AVAPS telemetry rack
- PC with AVAPS drop software
- (Optional) launcher, to release the dropsonde through the body of the aircraft
- Aircraft UHF and GPS antennas, antenna cables etc.
- Training.

If needed, the customer also needs to make an installation rack (optionally from Vaisala). In addition, the customer installs the following in the aircraft:

- Launcher
- Antennas
- Installation rack
- Electric supply

Note that the customer needs to obtain a certificate for the aircraft modifications according to the national aviation rules that are in effect for such an installation.

5. APPLICATIONS OF DROPSONDES

Several thousand Vaisala dropsondes are launched annually from eight countries in meteorological research and operational hurricane reconnaissance; about 50,000 have been used since 1996. The first successful field project using dropsondes was their use in the 1974 GATE field program in West Africa and adjacent Atlantic Ocean examining the sources of the development of tropical cyclones (Simpson et al. 1975). Subsequently, the RD93 dropsonde and current RD94 model have been part of a variety of tropical and non-tropical meteorological research field projects such as FASTEX, CAMEX, NORPEX, SCATCAT, MAP, Lake-ICE, INDOEX, and Snowband. Ms. Kate Young of the Earth Observing Laboratory in the National Center for Atmospheric Research supplied the table of that group's dropsonde usage in field programs since 1990 that is shown in Figure 8.

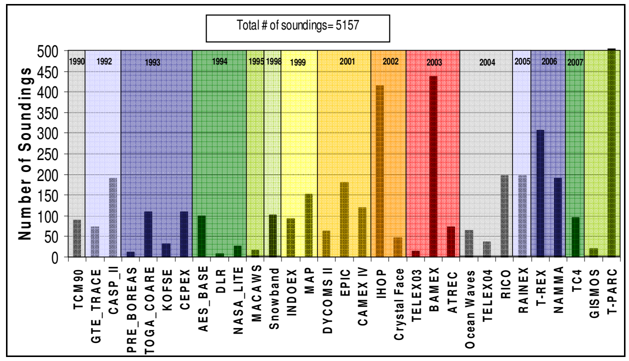

FIGURE 8. Dropsonde projects of the Earth Observing Laboratory of NCAR in field programs since 1990 (courtesy of Kate Young of NCAR/EOL).

The dropsonde has become an integral part of the reconnaissance of tropical storms and hurricanes in the Atlantic-Gulf-Caribbean basin. Beginning in 1982, dropsondes were deployed by NOAA aircraft. Burpee et al. (1984, 1996), Franklin and DeMaria (1992) and many others have documented the value of the data being assimilated into numerical weather prediction models to provide significant reductions in the position and intensity errors in model forecasts. For example, the addition of dropsondes provided a 16%-30% improvement for forecasts of 12-60 hours to the operational numerical model forecasts (Burpee et al. 1996). NOAA Gulfstream G-IV aircraft surveillance in 1997 revealed that GPS dropsonde observations improved the Geophysical Fluid Dynamics Laboratory (GDFL) track and intensity forecasts by as much as 32% and 20%, respectively, in the period within 48 hours of projected landfall (Aberson and Franklin 1999). Many other related and subsequent studies of specific storms and numerical models confirm the value of dropsondes in tropical cyclone monitoring leading to improved forecasting.

Continuing research into the underlying interactions of tropical cyclone motion and intensity with the surrounding flow has used dropsonde data, such as Franklin et al. (1996). Torn and Hakim (2009) showed that dropsondes provide larger improvements in ensemble position and intensity forecasts when deployed within the tropical cyclone.

As a result of these successes, the Dropwindsonde Observation for Typhoon Surveillance near the Taiwan Region (DOTSAR) program deployed Vaisala dropsondes for the purpose of assessing their value in improving forecasts of tropical cyclones affecting Taiwan (Wu et al. 2005; Chou et al. 2006). Analyses using and denying DOTSTAR dropsonde data show their value in forecasting tropical cyclones in the Taiwan region (Yamaguchi et al. 2009).

Most recently, the NOAA Gulfstream G-IV aircraft has used Vaisala dropsondes in a winter storm reconnaissance program from January through March 2010 in the North Pacific. These missions are in response to earlier winter storm flights that resulted in significant positive impact to global numerical weather prediction models.

6. CONCLUSIONS

The dropsonde has become a critical observation during the reconnaissance of tropical storms and hurricanes, as well as extratropical storms over oceans. In response to these operational requirements, Vaisala has developed a lean production line from the manufacturing to the final testing of the dropsondes, not forgetting the important task of materials management, and total quality assurance during the whole production process. These are based on the long experience as the world's leading radiosonde manufacturer.

Acknowledgments

The authors thank Matt Schneider and Dean Helgason of Vaisala in Tucson for their assistance in photographing the components of the dropsonde for this paper. The valuable contribution of the dropsonde usage table by Kate Young of the Earth Observing Laboratory in the National Center for Atmospheric Research is greatly appreciated.

REFERENCES

Aberson, S.D., and J.L. Franklin, 1999: Impact on hurricane track and intensity forecasts of GPS dropwindsonde observations from the first-season flights of the NOAA Gulfstream-IV jet aircraft. *Bull. Amer. Meteor. Soc.*, **80**, 421–427.

Burpee, R. W., D.G Marks, and R.T. Merrill, 1984: An assessment of Omega dropwindsonde data in track forecasts of Hurricane Debby (1982). *Bull. Amer. Meteor. Soc.*, **65**, 1050–1058.

—, S.D. Aberson, J.L. Franklin, S.J. Lord, and R.E. Tuleya, 1996: The impact of Omega dropwindsondes on operational hurricane track forecast models. *Bull. Amer. Meteor. Soc.*, **77**, 925–933.

Chou, K.-H., C.-C. Wu, P.-H. Lin, S. Aberson, M. Peng, and T. Nakazawa, 2006: The impact of dropsonde data from DOTSTAR on tropical cyclone track forecasting. Preprints, *27th Conf. on Hurricanes and Tropical Meteorology*, Monterey, CA, Amer. Meteor. Soc., XXBX. [Available online at http://ams.confex.com/ams/27Hurricanes/techprogram/paper_XXXXXX.htm.]

Franklin, J.L., and M. DeMaria, 1982: The impact of Omega dropwindsonde observations on barotropic hurricane track forecasts. *Mon. Wea. Rev.,* **120**, 381-391.

—, S.E. Feuer, J. Kaplan, and S.D. Aberson, 1996: Tropical cyclone motion and surrounding flow relationships: Searching for beta gyres in Omega dropwindsonde datasets. *Mon. Wea. Rev.*, **124**, 64–84.

Hock, T.F., and J.L. Franklin, 1999: The NCAR GPS Dropwindsonde. *Bull. Amer. Meteor. Soc.*, **80**, 407–420.

Simpson, R.H., P.K. Govind, and R. Holle, 1975: GARP Topics, Number 40: The GATE dropwindsonde program. *Bull. Amer. Meteor. Soc.*, **56**, 984-987.

Torn, R.D., and G.J. Hakim, 2009: Ensemble data assimilation applied to RAINEX observations of Hurricane Katrina (2005). *Mon. Wea. Rev.*, **137**, 2817–2829.

Wu, C.-C., P.-H. Lin, S. Aberson, T.-C. Yeh, W.-P. Huang, K.-H. Chou, J.-S. Hong, G.-C. Lu, C.-T. Fong, K.-C. Hsu, I-I Lin, P.-L. Lin, and C.-H. Liu, 2005: Dropwindsonde observations for Typhoon surveillance near the Taiwan region (DOTSTAR). *Bull. Amer. Meteor. Soc.*, **56**, 787-790.

Yamaguchi, M, T. Iriguchi, T. Nakazawa, and C.-C. Wu, 2009: An observing system experiment for typhoon Conson (2004) using a singular vector method and DOTSTAR data. *Bull. Amer. Meteor. Soc.*, **137**, 2801-2816.