Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

Wind measurements from hot-air balloon flights

Cisco de Bruijn*, Siebren de Haan*, Fred C. Bosveld*, Albert A.M. Holtslag**

Trajectories from commercial hot-air balloon flights can provide interesting wind information on the lower atmosphere. The displacement of a hot-air balloon is closely related to the wind speed and direction and thus a potential source for wind observations in the atmospheric boundary layer. This part of the atmosphere is not frequently sampled, apart from radiosonde launches and measurements taken at atmospheric remote sensing sites and airports.

1. Introduction

Hot-air balloons float in the air and travel with the wind. Global Navigation Satellite System (GNSS) navigation data acquired during the flight, provide a displacement during a time interval which is a measure of the airspeed. This wind information is obtained in the Atmospheric Boundary Layer (ABL) where in general few observations are present.

2. Response time

During the flight the balloon feels the drag as soon as the relative speed is not zero anymore, for instance when the balloon enters a layer with vertical wind shear. In

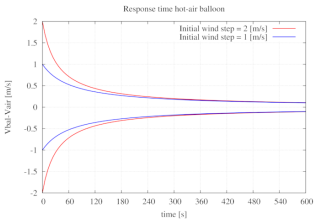


Figure 1: Response function, solution of $\frac{dv}{dt} = -\frac{c_d \rho \pi R^2}{2 m_b} v^2$

the beginning the response is fast and levels off as the speed difference becomes less. From the theory we know that the balloon reacts with a response length of $\frac{8}{3}\frac{R}{c_d}$ [1]. Due to the inertia of the hot-air balloon, its displacement does not capture the small scale variations in the wind pattern. The wind observations represent an average in space and time.

3. Thermal wind

In Figure 3 we compare the balloon wind data during the last 20 minutes of the flight of 18 June 2013 with NWP data and with the observations at Cabauw. The NWP data consist of the +01 and +02 forecasts starting from the analysis at 18:00 UTC. The wind-profiler is located at Cabauw and the

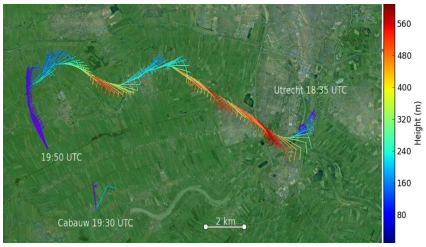


Figure 2: Sampling a baroclinic ABL in the surroundings of Cabauw during 18 June 2013

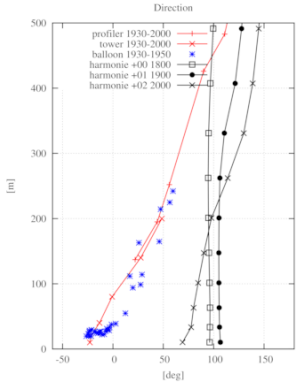


Figure 3: Validation of wind direction profiles at Cabauw during 18 June 2013

data is available as a 30 min average. The observations suggest a stronger baroclinicity than in the NWP model.

4. Low level jet

A jet is observed in the 28-Sep-2013 flight and is located in a small vertical zone not higher than 500 [m] (see Fig. 5). The sharp gradient in the wind speed is recognized in the model and in wind data from the hot-air balloon track. Note that the first 10 minutes are shown and the model and observations are in good accordance.

5. Conclusions and outlook

Hot-air balloon flights can provide useful wind information. The first validation results are encouraging. Using smart-phones, data

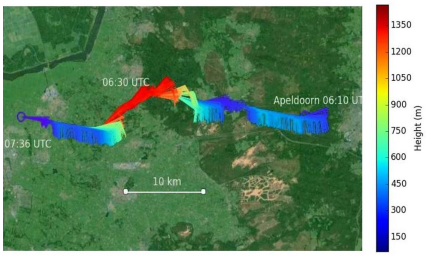


Figure 4: Sampling a stable ABL with a strong wind gradient near Apeldoorn during 28 September 2013

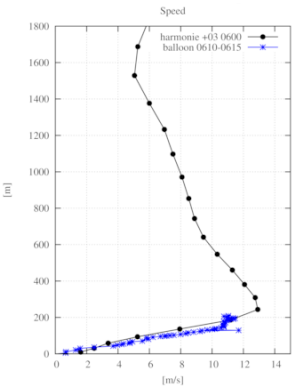


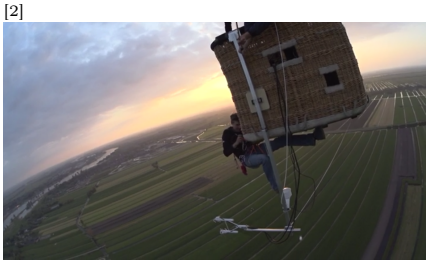
Figure 5: Validation of the speed profile using HARMONIE data during 28 September 2013

will be collected in a simple way. An experimental flight has recently been conducted with a SONIC anemometer attached to the gondola, to measure the relative wind speed around the balloon [2]. We will validate the response time function and improve the algorithm for the processing of the data.

6. References

[1] Evert I.F. de Bruijn, Siebren de Haan, Fred C. Bosveld, Ben Wichers Schreur, Albert A. M. Holtslag, 2016: Observing boundary layer winds from hot-air balloon flights, *Weather and Forecasting*, accepted for publication.

[2]



Recent balloon flight with a SONIC anemometer

* Royal Netherlands Meteorological Institute (KNMI), P.O. Box 201, 3730 AE De Bilt, The Netherlands.

** Wageningen University, The Netherlands.