It is possible that in the near future you might be able to take wind measurements during a hot-air balloon (HAB) flight, combine them with location data from an ordinary Global Navigation Satellite System (GNSS), and transfer the information directly from your smartphone to a meteorological center. Subsequently, the data would be ingested in a data assimilation module of a numerical weather prediction (NWP) model, and the updated forecast with a balloon trajectory would be disseminated via a dedicated app or the normal communication channels to you as the front-end user, possibly improving the weather forecast and therefore the safety of your HAB excursion.

Adapted from “Opportunistic Sensing with Recreational Hot-Air Balloon Flights,” by Evert I. F. de Bruijn (KNMI), Fred C. Bosveld, Siebren de Haan, and Albert A.M. Holtslag. Published online in BAMS, February 2021. For the full, citable article, see DOI:10.1175/BAMS-D-19-0285.1.
this merely pie-in-the-sky conjecture, or could third-party data from a HAB actually improve NWP forecasts?

NWP models with a horizontal resolution of 2 km or finer need detailed information for estimating the initial state of the atmosphere. Ground-based remote-sensing instruments like sodars, Doppler lidars, and radar wind profilers already provide meteorological information about the atmospheric boundary layer (ABL). The observational network has been extended over the years, but there are still gaps, and it is not cost-efficient to extend the network infinitely.

Therefore, we have commenced research to investigate supplemental data from third parties, focusing on wind information about the ABL from recreational HAB flights primarily in the Netherlands, where HAB flights abound (at any given time there may be 30 HABs airborne, typically during the transition period when the atmosphere becomes stable), and in Austria. As with routinely launched weather balloons, the Global Navigation Satellite System (GNSS) data from consecutive positions of the HAB and the elapsed time are the basis of the calculation of the horizontal wind vector. The HAB responds to changing wind with a response length of approximately 100 m.

Data can be collected from the archived offline navigational data of a HAB flight. A real-time application, however, might involve smartphones. This method would rely on the collaboration of balloonists and passengers carrying smartphones and using a dedicated app in flight. Alternatively, the collection of data could be organized via air traffic control (ATC) using a transponder, but this is not a practical solution.

While HAB wind data have limited availability, HAB flights can give complementary and detailed wind information about the ABL. Of course, the HAB winds are only present in a small time slot, but if they are applied in a more flexible 4DVAR data assimilation module, the added value can be incorporated.
Data assimilation feasibility study

We assimilated HAB data from a flight from De Bilt (during 1602–1703 UTC 15 September 2012) into the HIRLAM model and conducted a data assimilation feasibility study. The flight ended in Amersfoort, covering a distance of 19.5 km.

The assimilation window ended at 1630 UTC, at which point the HAB reached the flight ceiling at 1,428 m and dramatically changed direction after apparently entering a layer with a different wind regime. We calculated a trajectory based on hindcasted NWP wind fields. The output field frequency was 15 min. For a fair comparison, the vertical displacement was completely prescribed by the HAB. We found that the NWP trajectory had a position error at the endpoint of 8.8 km. An updated run, which included assimilated HAB wind data (rejecting HAB data just after takeoff, because of restricted movement at that stage) during 28 min of the flight interpolated to the analysis time at 1600 UTC, generated a trajectory error at the endpoint of only 2.9 km. Outside the assimilation time window, the improvement was still present, which is also encouraging.

While acknowledging this positive result, the predictive value in this experiment was rather short, and the model improvement was very local. Ideally, the validation should be performed over a larger area with independent observations.
more effectively in an NWP model via a simple, straightforward measurement technique.

This is in contrast to obtaining data from gliders and sailplanes, which is more complicated because they also require the measurement of the relative airspeed. Wind turbines deliver wind data continuously at one location at a fixed height and may become another suitable future alternative, as their number is growing rapidly.

We started the investigation by comparing HAB wind data from a flight on 18 June 2013 at 1823 UTC with data from an instrumental tow and radio acoustic sounding system (RASS) wind profiler at the observatory in Cabauw, a village in the Dutch province of Utrecht. The site is in a flat rural area with scattered villages.

Touchdown of the HAB was 1.25 h after launch, 4.8 km from the observatory; data were gathered during the descent as the HAB approached from the north. The HAB wind observations are based on 30-s averages; all site data are available as 30-m averages. At lower levels, the HAB data are affected by local conditions, which adversely impact the match with the ground-based observations. However, at higher levels, where the wind is less disturbed and is representative of a larger footprint, the match improved markedly for wind direction and to a lesser extent for wind speed.

We launched a HAB flight in a mountainous region in Austria to determine whether this method would also work in more complex terrain, and used data from an automated weather station (AWS) 10 km south-southwest of the eventual landing point, in Hahnenkamm, as a basis for comparison. The takeoff was at 1018 UTC 16 January 2005 from Sankt Johann (Tyrol), and the flight lasted 96 min.

During the time of this flight, high pressure was centered over eastern Europe with a secondary center over northern Italy. The synoptic influence on the region was sufficiently weak to allow local wind effects to dominate. The surface was covered with snow, preventing development of thermals, and an inversion was in place in the valley. Nearer the ground, the HAB path was toward the north, but above the inversion it entered a different wind regime and began drifting to the south under the influence of a ridge set up by the synoptic pressure distribution. Descending after 1 h, southerly winds prevailed and the HAB passed through a layer with considerable wind shear. Close to the surface the HAB was again advected northward. The collected balloon data were in some agreement with the local AWS in this case.

We then compared HAB winds with analyses of an experimental version of the High-Resolution Limited Area Model (HIRLAM) during 2011–13. The data collected are from 71 flights from Dutch balloonists who shared their
flight tracks with the Royal Netherlands Meteorological Institute (KNMI), as well as a smaller number of flights from Belgium, France, and Austria. The majority of flights were during summer, with a small number during winter in snow conditions. Most of the flights were scheduled at dawn or 2 to 3 hours before sunset to take advantage of light winds and less turbulence.

The total vertical averaged values for bias and standard deviation were 0.4 and 2.3 m s⁻¹, respectively; both are acceptable values. Large biases were attributed to extreme cases, as in the presence of thermal updrafts, which were not captured by HIRLAM.

In summary, observations from HAB flights are in general agreement with other upper-air observations. Comparison with HIRLAM reveals that the error characteristics are acceptable. HAB-derived wind can be applied in data assimilation and have a positive impact on the forecast. However, the NWP model should be implemented in a rapid-update cycling method, and the timely availability of HAB observations is crucial for a successful application. Given the current state of the technique, it is a challenge to meet these requirements. Nonetheless, these third-party observations are a welcome supplement to the existing observation network and can be used for process studies, model validation, and forecasting through data assimilation. Moreover, mountain flights could provide data from local decoupled flows embedded in a larger-scale circulation, especially when such phenomena are not captured by an NWP model or by the regular observational network.

Finally, returning to the question posed at the beginning of this article, the answer is that yes, armed only with your smartphone, it is a realistic possibility that in the future you could enjoy a HAB flight while at the same time improving your weather forecast.