Automated Aircraft Observations: Their importance to Future Aviation Transportation Operations

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Every aspect of aviation operations, from arrival of passengers at the airport, to flight planning and crew scheduling, to deicing decisions, to turbulence/icing avoidance and improving fuel use, to aircraft arrival and passenger departures, can be severely affected by weather, both locally and globally. Numerical Weather Prediction (NWP) models will continue to play increasing roles in improving international, national and local aviation weather forecasts, as well as future air traffic management and overall aviation operations. Observation of many kinds, include those made automatically from commercial aircraft, can play key roles in improving the consistency and accuracy of these products. This paper reviews the impact of past and future observations from the WMO Aircraft Meteorological DAta Relay (AMDAR) program on operational NWP forecasts at both regional and global scales. Examples of the use of the aircraft observation in improving local aviation forecasts will also be included in the full presentation.

Tests conducted by numerous NWP centers for over 25 years have demonstrated that high-quality and high-frequency AMDAR temperature and wind observations increase the skill of forecasts at both regional and global scales and for both short- and medium-range forecasts (Fig. 1).
the US NWS Global Forecast System (GFS) and the UK Met Office (UKMET) global forecast model. Separate plots shown for wind speeds greater than 80 knots.

Results show that aircraft data taken at cruise levels and during ascent/descent provide important information for improving forecasts, both in terms of long-term average performance and for individual events. Improvements in 3-48 hours forecast range occur in forecast parameters that are most important to aviation (Fig.2). Additionally, they have been largest in regions where the automated reports 1) are most numerous, 2) cover a broad area, and 3) are available at multiple levels, e.g., made during aircraft ascent and descent.

Figure 2: Impact of AMDAR Wind (top) and Temperature (bottom) observations on 12, 24 36 and 48 hour forecasts at 100, 200, 300, 500 hPa and for 100-500 hPa layer average over Northern Hemisphere (left) and North America (right).

Improvements in weather forecasts due to these data have already had major impacts on a variety of aspects of airline operations, ranging from fuel savings from improved wind/temperature forecasts used in flight planning to passenger comfort and safety due to better awareness of en-route and near-terminal weather hazards.

In areas with denser data coverage aloft and abundant ascent/descent reports (Fig. 3), they have become the single most important data set for use in shorter-range, regional NWP applications. These automated aircraft observations also provide a low-cost alternative for obtaining tropospheric profiles both in areas of diminishing conventional observation and as a supplement to existing data sets, both in time and space.
A unique feature of AMDAR reports is that they provide both temperature and wind data at the same locations and in profiles made during ascent/descent throughout the day, thereby furnishing explicit 4-dimensional information needed for future NWP analysis systems, including information about gradients of wind and temperature near high-energy jet stream regions. Most importantly, these in-situ reports can be incorporated in the analysis systems with minimal effort, unlike many remotely sensed observations. Tests of their impacts in other parts of the globe and as potential alternatives for “off-time” raobs will also be discussed.

Although global, ‘all-weather’ satellite microwave observations have the largest average influence on medium-range global forecasting system (especially currently in the Southern Hemisphere), AMDAR observations have become recognized as a critical component of these systems around the world (Fig.4). Aircraft observations rank 3rd in importance globally (especially in the NH) and contribute between 10-15% to 24-h forecast skill improvement, with impacts extending to 48 hours and beyond. AMDAR data are also the most cost effective, with benefit to cost ratios that are approximately 5 times better than any other observing system. For reference, automated aircraft observations have an annual cost globally on the order of $6-8M (about 1/400th of the annual cost of the total Global Observing System (GOS)).
Wind and temperature data, however, are not sufficient alone, since they don’t directly improve our understanding of how smaller-scale humidity variations can affects forecasts of humidity, clouds, precipitation and related phenomena that impact aviation. High resolution moisture observations are now available from over 130 aircraft (primarily in the US) using a new laser-based, Water Vapor Sensing System (WVSS) moisture observing systems being deployed as part of the global AMDAR enhancement effort.

Evaluations of these new moisture-observing systems against operational rawinsondes reports in the US show that WVSS observations both provide excellent quality horizontally and vertically, even across sharp inversions (a critical factor in forecasting the development of hazardous convection). Specific Humidity (SH) observations agree with co-located RAOBs to within <1.0 g/kg and with minimal biases (approximately 0.15 g/kg – Fig. 5a). In addition, the observations display remarkable consistency between different aircraft (co-located SH RMS of <0.2 g/kg), indicating that WVSS observations perform as well as, or better than, high-quality RAOBs (Fig. 5b).
Figure 5: A – Comparison of WVSS observations to collocated US rawinsonde observations from 2015. Vertical coordinate is scaled from earth’s surface to 200 hPa for all reports. B - Variability (RMS, Solid) amongst pairs of nearby WVSS observations sorted by separation distance (red) and time difference (blue) intervals from the surface to 5km from 3 seasons of 2009-2010. Vertical axis shows RMS differences in g/kg and horizontal axis shows 15-km distance and 15-minute time co-location bins. Thin lines indicate linear fits to observed differences, including projections to fits for perfect co-locations. Dashed green line shows similar differences between WVSS and RAOB SH observations as a function of time differences.

Forecasters have been able to readily incorporate WVSS reports (along with AMDAR temperature and wind profiles) into their forecasting process. The value of these observations in improving local aviation forecasts throughout the day will be shown for a variety of short-range forecasts of a number of high-impact weather phenomena, ranging from forecasts of fog and ceiling height to determining precipitation type and improving severe weather outlooks.

The volume of WVSS data available over the CONUS has recently grown to a level that can support data impact tests in NWP models. Results (Fig. 6) have shown short-range forecast impacts larger than from any other moisture observations, including twice-daily RAOBs. Humidity forecast improvements like these are essential to enhance prediction of both the timing and location of precipitation events, especially heavy precipitation events that can affect airport operations. Other tests show that the impact of WVSS reports over the US is statistically significant out to 66-hour forecasts.
Although the improvements attributable to WVSS observations have been concentrated in areas of highest data availability, similar advancements are expected in other areas as the spatial and temporal coverage of the reports increases globally. This will be particularly important both in areas where the continuation of upper-air observing programs are under budgetary threat and in forecast situations where additional observations are needed to fill the time and space gaps between once- or twice-daily RAOB launches.

Existing AMDAR observations are extremely cost effective, currently contributing only about 0.25% of the expense of the global observing system (Eyre and Reid 2014), with temperature/moisture/wind profiles typically costing less than 5% of a full RAOB launch. Although these data do not meet all balloon-borne observing requirements (in particular, data in and above the stratosphere are needed for both weather and climate purposes), the availability of high-quality tropospheric profiles over land at space and time resolutions not affordable using conventional observing systems offers a unique opportunity for improving weather forecasts across the globe, including terminal and weather hazard forecasts benefiting airlines. In order to assure continued improvement in global and local NWP products essential for the full air transportsations system in future decades, programs should be supported which both increase the number of aircraft providing humidity information and expand the AMDAR observing network into areas not currently covered adequately.

References:


