Bridging the Upper-Air Data Gap

WMO's Aircraft Observations for Enhanced Forecasting and Greener Aviation

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Since the late 1990s, the World Meteorological Organization (WMO) Aircraft-based Observations Programme (ABOP)[1] has concentrated on enhancing aircraft-based meteorological observations (ABO) to improve numerical weather prediction (NWP) and severe weather forecasting. There has been a particular emphasis on expanding coverage in data-sparse upper-air regions, such as Latin America, Africa and parts of Asia. By leveraging existing aircraft infrastructure, WMO's Aircraft Meteorological Data Relay (AMDAR)[2] observing system collects real-time in-situ data from commercial aircraft and relays to NWP centres, complementing existing radiosonde network. A key innovation involves retrofitting aircraft with high-accuracy water vapour sensors to fill critical data gaps, particularly in regions with limited observational capacity. Additionally, accurate water vapour monitoring at flight cruise levels is critical for ice-crystal icing, contrail avoidance studies and mitigation as well as climate science.

ABO contributions from national meteorological and hydrological services (Figure 1) worldwide for global NWP are instrumental in reducing the aviation sector's environmental impact. The optimisation of flight routes and fuel efficiency, enabled by the provision of more accurate weather forecasts for flight dispatch, can be facilitated by the enhancement of NWP products such as those within ICAO's world area forecast system (WAFS), and the delivery of essential products to end-users in the meteorological field. The enhancement of NWP capabilities enables airlines to minimise weather-related delays, reduce excess fuel consumption, and decrease CO_2 emissions, while also facilitating the implementation of contrail avoidance programmes. Consequently, these efforts are in alignment with global climate mitigation objectives.

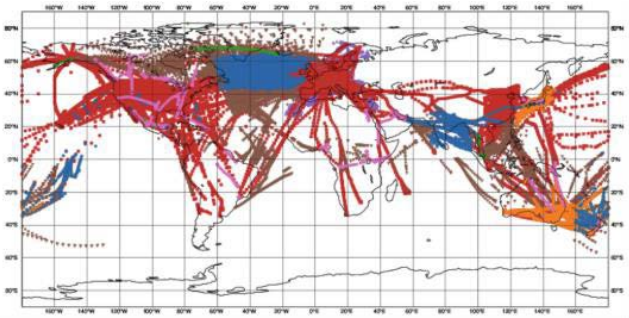

FIGURE 1: Coverage for all ABO-related sources - ingested by ECMWF Operational NWP between 03:00 and 06:00UTC - 09 January 2025. Each colour represents type of ABO -in-situ data: red and orange shows "AMDAR" coverage; brown for "Wx ADS-C"; blue for "AIREP"; pink for "AFIRS"; purple for "SSR Mode S"; and green for "FLYHT TAMDAR". Source: Data assimilation monitoring of ECMWF[3].

WMO ABOP delivers measurable benefits, including a projected 10-25% increase in weather prediction accuracy in data-sparse regions using data from targeted airlines. This can translate into millions of dollars in annual savings for the aviation industry through optimized operations and reduced carbon footprints, as well as lower fuel consumption in those regions. Qualitatively, it strengthens the social contribution of the aviation industry and enhances

1 https://community.wmo.int/en/activity-areas/aircraft-based-observations
2 https://community.wmo.int/en/activity-areas/aircraft-based-observations/amdar
3 https://www.ecmwf.int/

climate resilience through providing observations for early warning systems for extreme weather for civilian communities such as the United Nations Early Warnings for All (EW4All) Initiative[4] among others.

Despite these benefits, ABO programmes have been reduced in their contribution since the aviation industry was impacted by the consequences of the COVID-19 pandemic (Figure 2).

Over the next three years, WMO plans to expand AMDAR coverage by partnering with aviation stakeholders to recover the 2019 levels by 2027. Long-term goals include achieving a sustainable and resilient increase in global water vapour aircraft-based observations by 2030, fostering airline participation, green climate funds and regulation-related entities supporting the reduction of the sector's carbon footprint through precision meteorology for operations and improved support for future contrail avoidance systems. By bridging ABO data gaps with targeted airlines participation and through WMO and its Members supporting ICAO green aviation policies, this initiative positions itself as a catalyst for both aviation operational efficiency and environmental stewardship in the coming decade.

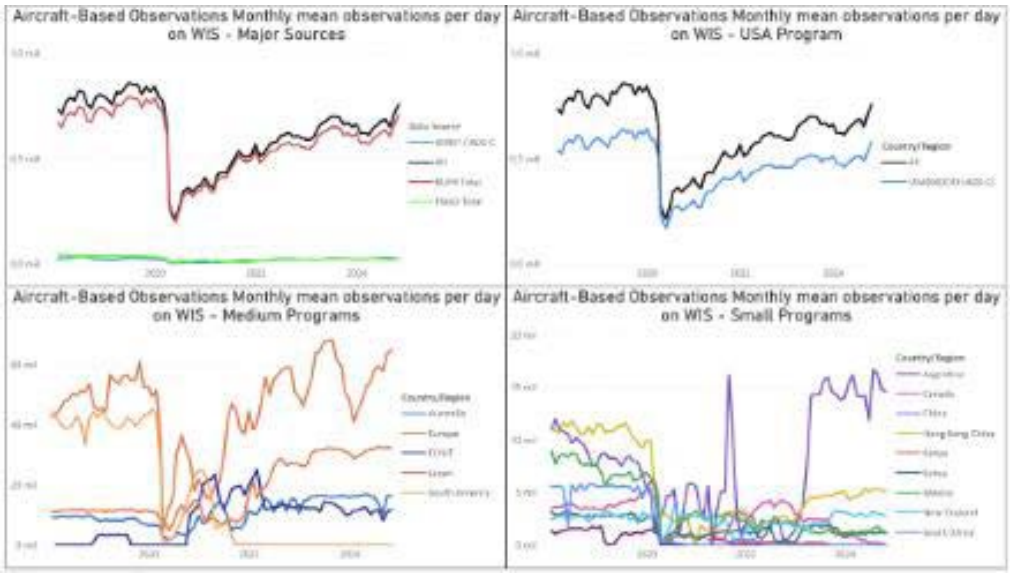

FIGURE 2: Evolution of daily Aircraft-based Observations data provided by national meteorological and hydrological services (NMHS) into the WMO Information Systems for the period January 2018 to October 2024. Source: WMO ABO Monitoring site[5] with data provided by Environment and Climate Change Canada[6].

4 https://earlywarningsforall.org/site/early-warnings-all
5 WMO ABO Monitoring site
6 https://www.canada.ca/en/environment-climate-change.html