Two assimilation/observation problems found via diagnostic maps

Bruce Ingleby. *bruce.ingleby@ecmwf.int*
Research Department, ECMWF, Reading, United Kingdom

ECMWF

Workshop on Diagnostics for Global NWP

Overview

ECMWF uses many different types of satellite and *in situ* observations and has an extensive monitoring system to check the performance. Many maps and timeseries are openly available, see Dahoui and Sihan, 2024. Sometimes a subset of observations 'disappears', in simple cases an email to the right person reinstates the data.

For checking observation quality observation minus background (O-B) statistics are routinely used. **Observation minus analysis (O-A) statistics are used rather less but have the useful feature that maps of the standard deviation are less noisy than SD(O-B) maps so that anomalies stand out more.** This poster shows two recent examples where SD(O-A) maps led to the discovery of assimilation or observation problems.

High-resolution aircraft data: Mode-S

Mode-S data is used by air traffic control systems, but they are also processed into meteorological reports by EMADDC (KNMI), de Haan, 2011. The Mode-S aircraft winds over Europe were introduced at ECMWF in August 2020. This was earlier than planned because of the Covid pandemic (Ingleby et al, 2021). Their use was switched off in November 2022, because we found that locally the data were too dense for our system making the forecasts worse. The problem was first noted via large O-A statistics over central Europe (Figure 3).

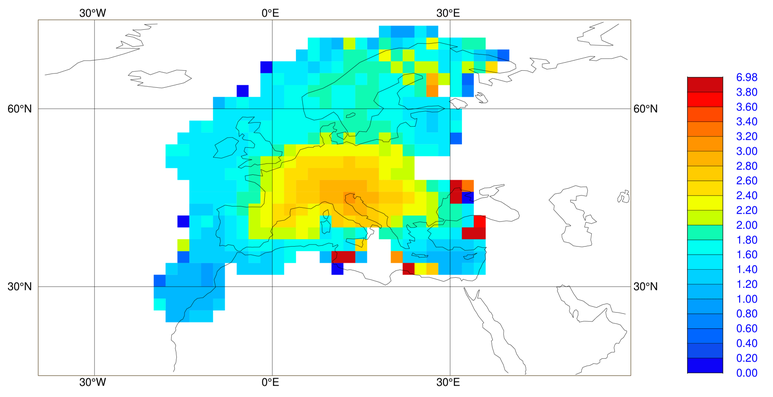

Figure 3. The standard deviation of windspeed analysis departure (O-A) for Mode-S at ~200 hPa, August 2022.

The 'track thinning' used was not sufficient with the many 100s of flights over Europe. Improved thinning was developed, tested and introduced operationally in November 2023. The short-range benefits of using Mode-S winds over Europe are again clear especially for upper tropospheric wind (Figure 4). The improvements from use of Mode-S over Europe are stronger and longer lasting than seen in previous LAM studies (eg Li, 2021) due to the much wider coverage now. Figure 5 shows the numbers of aircraft reports assimilated from January 2020 onwards. Numbers dropped by about 75% in March/April 2020 (Ingleby et al, 2021) and have largely recovered since, although this hides regional variations. In 2020 ECMWF was using about 5% of the Mode-S reports, now it is about 1.25%. By Summer 2022 a huge number of Mode-S reports were being used over Europe, causing ill-conditioning in the ECMWF 4D-Var analysis.

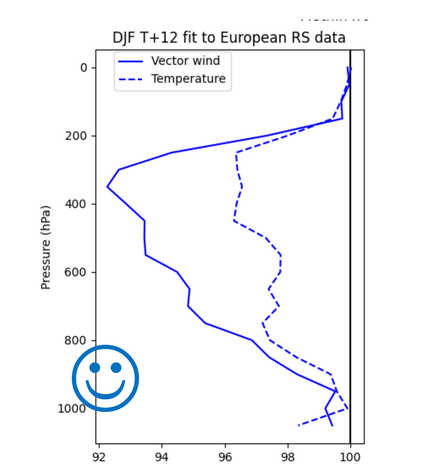

Figure 4. Change in RMS T+12 fit to radiosonde data relative to noMode-S: over Europe for three winter months (summer results, not shown, are similar).

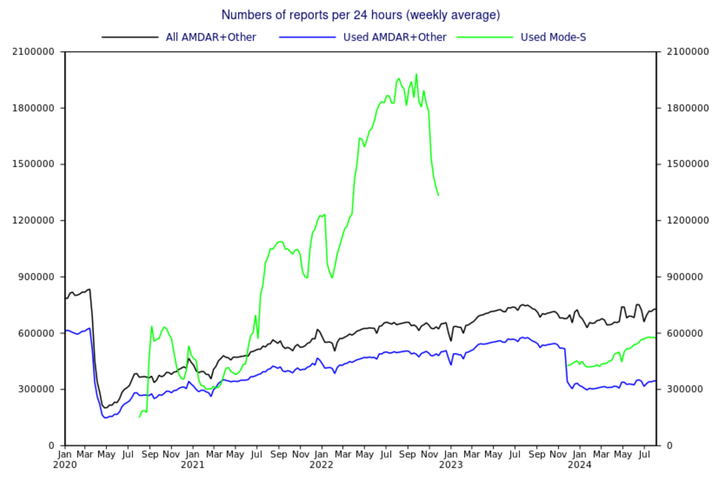

Figure 5. Global aircraft numbers reported (black) and used (blue), excluding Mode-S. Used Mode-S numbers in green.

Note

Over the next few years European AMDAR coverage will be reduced where there is good Mode-S coverage. Other NWP centres should consider using Mode-S data from https://emaddc.com if they aren't already planning to do so.

A data problem in the West Pacific

In late 2023 a problem was suspected in the tropical west Pacific from looking at a map of O-A statistics Figure 1 (bottom); the corresponding O-B statistics (top) also show large deviations in that area but there are several other areas with comparable O-B magnitudes. The problem was soon identified as coming from Chinese AMDAR reports, Figure 2, some B787 flights between China and Australia were reporting the wrong sign of latitude when south of the equator. CMA was notified via WMO and the affected data were removed from distribution.

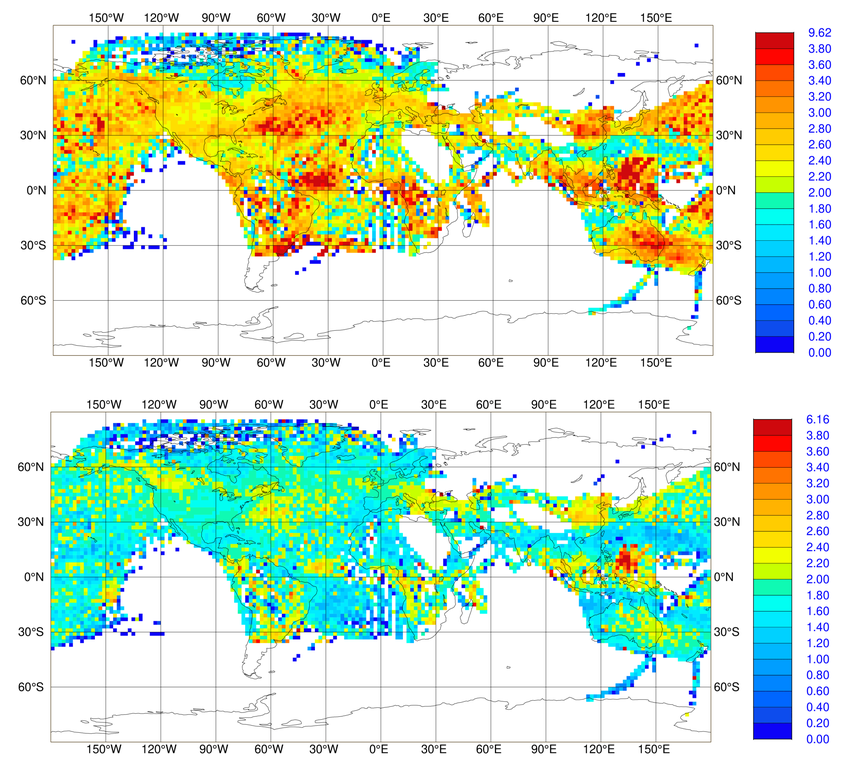

Figure 1. O-B (top) and O-A (bottom) maps of used AMDAR wind speed for pressure<400 hPa 6 Nov to 7 Dec 2023.

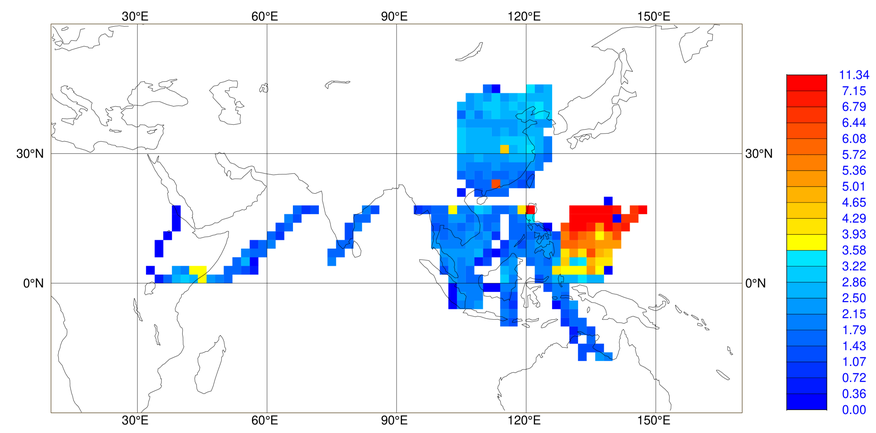

Figure 2. O-A maps of Chinese AMDAR wind speed (all data) for pressure<400 hPa 1-8 Dec 2023. The worst of the data points were not assimilated. (Figures 1, 2 and 3 are courtesy of M. Dahoui.)

Summary

The West Pacific case shows a relatively simple example of a fault in the observation data. The European case is more subtle: the observations are good quality but were being used inappropriately – at too high a density. Extensive work was required to develop and test improved aircraft thinning (Ingleby, 2024). In November 2023 ECMWF started assimilating Mode-S winds again and they give improved short-range forecasts over Europe.

Another useful diagnostic is Forecast Sensitivity to Observation Impact (FSOI), an estimate of the forecast benefit from each observation. One practical issue is the sheer number of diagnostic plots available - some automated anomaly detection is performed, and this may need to be extended. Even with automated warnings someone needs to look at the results and decide what action to take, if any.
In some cases better metadata are needed: aircraft type is only known for about half of AMDAR aircraft.

References

Dahoui, M, and Sahin, C. 2024: On-demand web plotting of observation monitoring statistics. ECMWF Newsletter No. 178, pp. 35-39. https://www.ecmwf.int/en/publications
See https://www.ecmwf.int/en/forecasts/quality-our-forecasts/monitoring-observing-system
de Haan, S. (2011), High-resolution wind and temperature observations from aircraft tracked by Mode-S air traffic control radar, J. Geophys. Res., 116, D10111, doi:10.1029/2010JD015264
Ingleby, B., et al, 2021: The impact of COVID-19 on weather forecasts: a balanced view. *Geophys. Res. Let.*, https://doi.org/10.1029/2020GL090699.
Ingleby, B. 2024: The benefits and challenges of using high resolution Mode-S aircraft winds at ECMWF (in preparation)
Li, Z. Impact of assimilating Mode-S EHS winds in the Met Office's high-resolution NWP model. Meteorol Appl. 2021; 28:e1989. https://doi.org/10.1002/met.1989