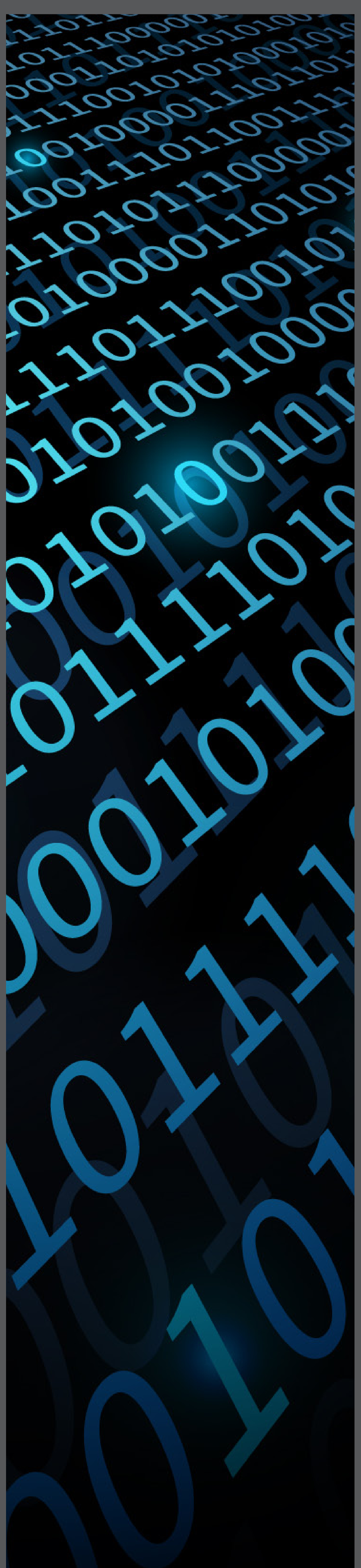

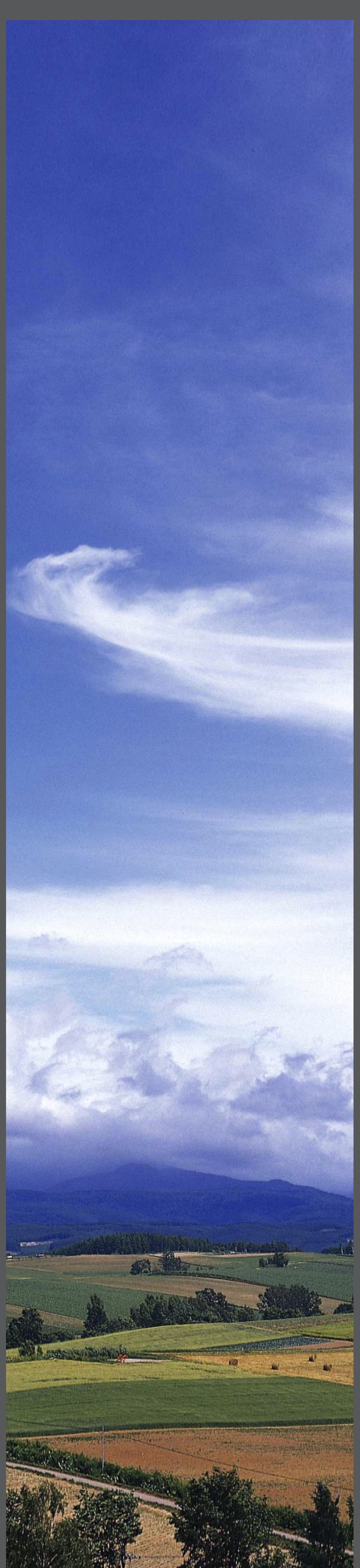

Use of BUFR radiosonde and surface observations at ECMWF

Bruce Ingleby, Enrico Fucile, Drasko Vasiljevic, Tomas Kral, Lars Isaksen
ECMWF, Shinfield Park, Reading, UK

Introduction

Traditional alphanumeric codes (TACs; including TEMP and SYNOP codes) have been used for more than 50 years and are restrictive in some respects. For about 15 years the World Meteorological Organisation (WMO) has been promoting and coordinating a transition to the binary BUFR format. BUFR surface reports contain extra metadata and facilitate higher frequency reporting but the basic content is much the same. BUFR radiosonde reports allow much higher vertical resolution (removing the need to select "significant" levels) and the reporting of time/position at each level. The transition process has been slow because in each country it involves experts in observations, codes, telecommunications, databases, and finally Numerical Weather Prediction (NWP). Currently approximately 50% of SYNOP and radiosonde observations are available on the GTS in BUFR. From Autumn 2014 circulation of some reports in alphanumeric format may cease.

ECMWF has been working on decoding and storing the BUFR observations and on their use in the NWP system. Validating the reports is important, various errors have been found and reported to the data producers (either directly or via EUCOS and WMO) and some of the errors have been resolved. We are in contact with other NWP centres to pool experience of using the data (see *https://software.ecmwf.int/wiki/display/TCBUF/TAC+To+BUFR+Migration*) and have discovered and requested BUFR bulletins that weren't reaching ECMWF.

Current BUFR coverage

Figures 1 and 2 show current global coverage for radiosonde and SYNOP reports, respectively. BUFR reports are available from about 45% of radiosonde stations worldwide and over 60% of SYNOP stations (although some of these stations have missing BUFR reports). The best coverage is over Europe. For land stations BUFR reports include position information. TAC reports rely on the separate provision of positions in WMO Publication 9, Volume A. *Ingleby* (2014) found that about 3% of SYNOP reports were unusable because the position information was not available. The change to BUFR should avoid that problem (although a few stations report missing or zero positions) but some positions in BUFR reports are erroneous (often due to wrong conversion from degrees/minutes to decimals). Some of the position errors have been corrected over the last year but some remain.

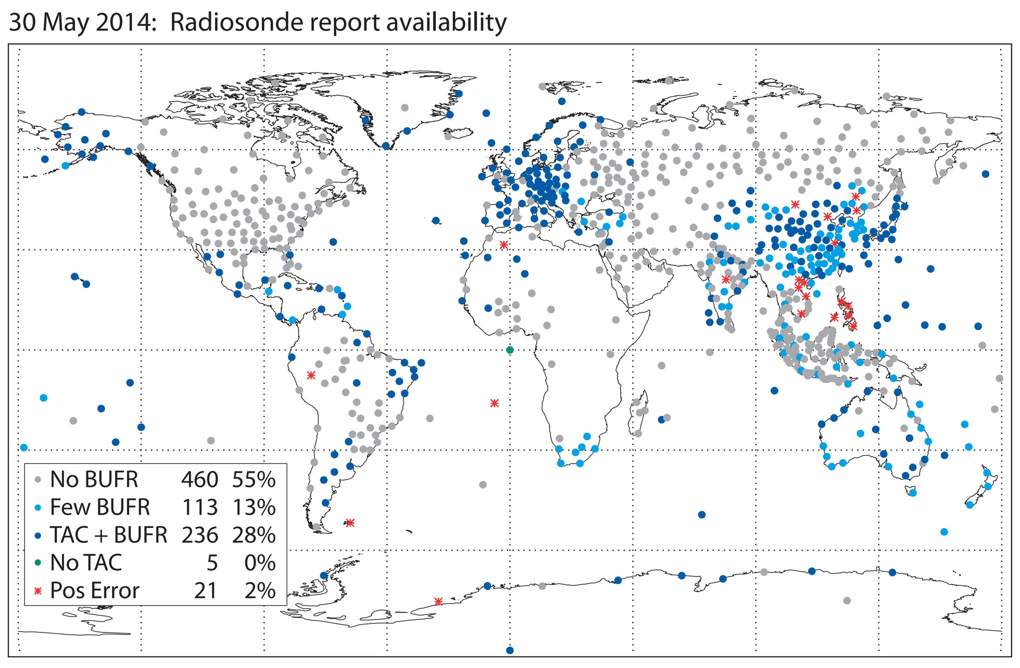

Figure 1 Land radiosonde reports. Grey: no BUFR reports; light/dark blue: less/more than 60% of reports available in BUFR; green no TAC reports; red: position difference between TAC and BUFR. Key gives number and percentage of stations in each category.

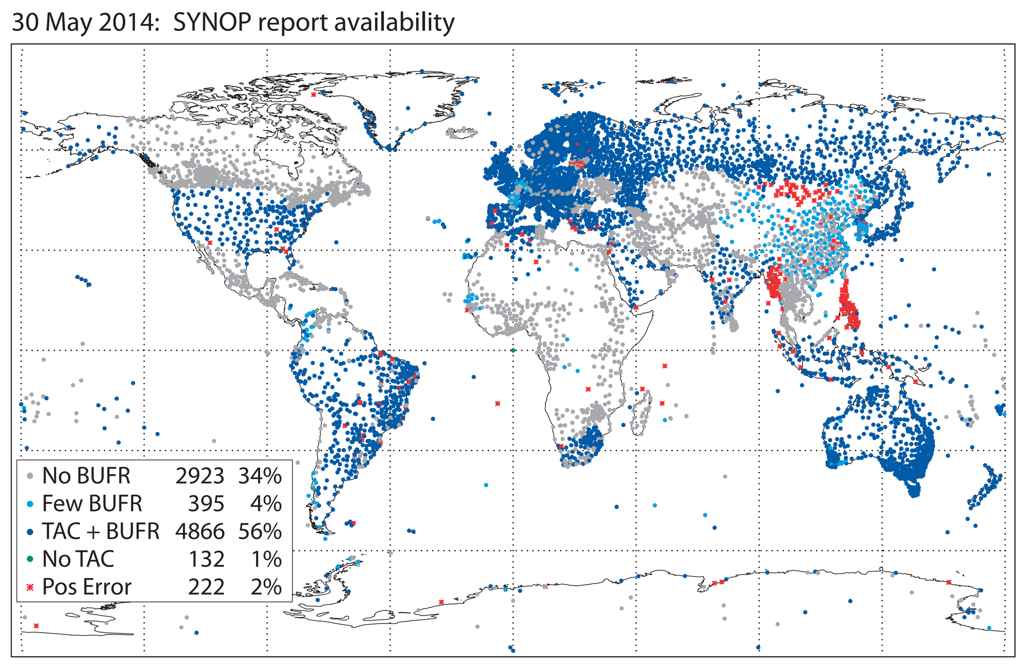

Figure 2 SYNOP report availability, as Figure 1 except for smaller symbols.

Changes to radiosonde reporting

For radiosondes there are major changes to report structure going from TAC to BUFR. For each radiosonde ascent there should be one BUFR report when the radiosonde reaches 100 hPa, and one report containing the whole ascent following balloon burst. For some stations there is also a move to reporting of high resolution data (e.g. every two seconds during the flight) which can result in 5000 or more levels compared to typically 100 for TEMP code (all parts combined), Figure 3 shows an example. For some stations the BUFR reports provide position/time information at each level which facilitates more accurate treatment of radiosonde drift. Figure 4, from *Ingleby and Edwards* (2014), shows that correct treatment of the balloon drift improves observation-minus-background (O-B) statistics at upper levels (there is also a small offset in the temperatures due to rounding in the TEMP report). *Laroche and Sarrazin* (2013) demonstrated that taking account of radiosonde drift (calculated from the winds and an assumed rate of ascent) gave a positive impact for global NWP. Treatment of radiosonde drift is planned for the ECMWF NWP system, but the immediate priority is making sure that we can correctly use the BUFR reports before they become the only source of radiosonde data.

Some of the BUFR reports are currently reformatted from TEMP code (still as separate parts A, B, C and D which complicates processing and breaches the BUFR coding rules). Figure 5 shows that many European stations report proper, high-resolution BUFR (the UK and France will do so very soon) whereas elsewhere the coverage is more patchy and many reports are of separate parts. In BUFR there is some extra metadata and an extended table for radiosonde type. There is a trend for GPS radiosondes not to include a pressure sensor, and one BUFR template includes height but not pressure.

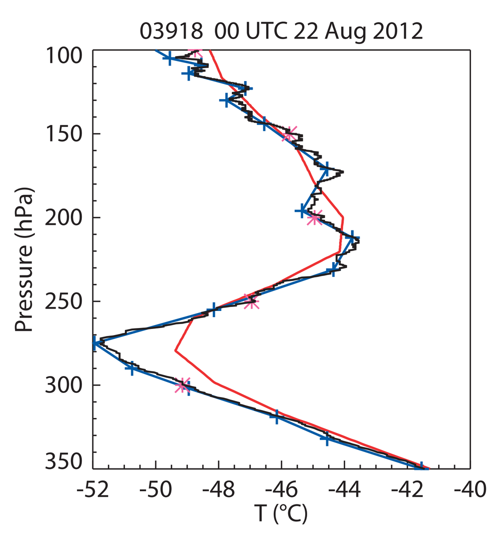

Figure 3 Part of a temperature profile from a radiosonde ascent. Black: high resolution, blue + joined by blue lines: significant levels, purple *: standard levels; red: interpolated background values

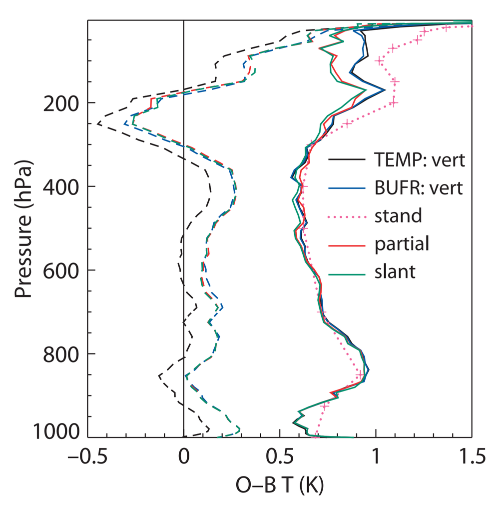

Figure 4 Mean (dashed) and standard deviation (solid) of temperature O-B for UK stations vs UKV model, Dec 2012 – Feb 2013. Except for standard levels (+ symbols) the observed values have been averaged over model layers. The lines are for vertical processing (TEMP black and BUFR blue); slant (green) processing of BUFR data. (Red uses the correct horizontal position but the time of launch.)

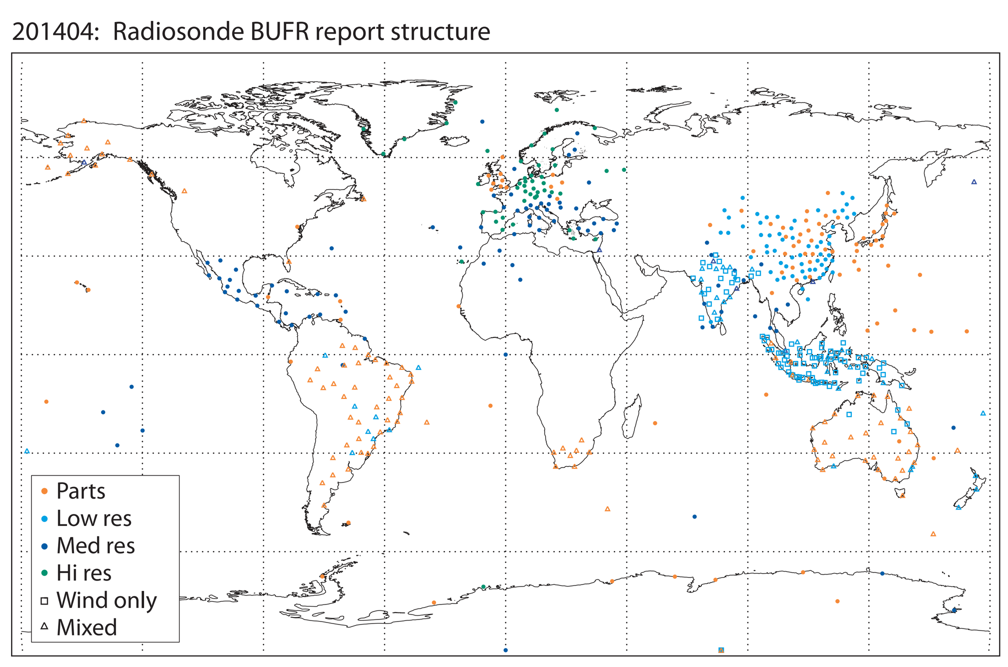

Figure 5 Orange shows reports that are received as separate Parts A/B/C/D (not 'proper' BUFR data). Green shows stations reporting over 400 levels; stations with fewer levels are shown in blue (light blue for less than 15 levels per report on average).

Other work on observation processing

SAPP (Scalable Acquisition and Pre-Processing system for observations) is about to take over the supply of observations to the NWP system. It is more efficient than the previous system, especially for very high volume satellite data. SAPP acquires ~300 million observations in various formats from more than 200 data sources, decodes the messages, performs some quality control and delivers observations in BUFR format. (NB For years ECMWF has used BUFR format internally even for observations arriving in alphanumeric formats; in general there are differences in BUFR template from the new data streams – and the arriving BUFR SYNOP data uses four different templates.)

SAPP passes the data to COPE (Continuous Observation Processing Environment), another new component system. COPE will run quasi-continuously, transforming variables as required and performing as much data selection and checking as possible before the start of each assimilation cycle.

As well as the new radiosonde and surface BUFR data streams, processing of extra aircraft data has been built into these new systems. Currently much of the extra aircraft data is over North America comprising a) AMDAR humidities from the WVSS-II sensor (*Vance et al*, 2014) and b) TAMDAR data (including humidity from capacitative sensors, *Gao et al*, 2012). The TAMDAR data (mainly from short-haul aircraft, using regional airports and making more ascents/descents than long-haul aircraft) is available for evaluation and research experimentation, agreement with the data provider would be needed before operational use. We also intend to make more use of temperature, humidity and wind reports from surface stations based on work done at the Met Office (*Ingleby*, 2014).

Near future use of BUFR at ECMWF

- Process TAC (TEMP/SYNOP) and BUFR data in parallel
- Start assimilating subsets of BUFR data (in place of TAC data) when the quality and reliability are acceptable
- Continue monitoring BUFR data and feedback any problems to data producers
- Share information with other NWP centres, directly and via https://software.ecmwf.int/wiki/display/TCBUF/TAC+To+BUFR+Migration
- Improve radiosonde processing (treatment of balloon drift, and possibly vertical averaging)
- Work on surface marine BUFR data

References

Gao F, **Zhang X**, **Jacobs NA**, **Huang X-Y**, **Zhang X**, **Childs PP**. 2012: Estimation of TAMDAR Observational Error and Assimilation Experiments. *Wea. Forecasting*, **27**, 856–877.

Ingleby B. 2014. Global assimilation of air temperature, humidity, wind and pressure from surface stations. *Q. J. R. Meteorol. Soc.*, accepted

Ingleby B, **Edwards D**. 2014. Changes to radiosonde reports and their processing for numerical weather prediction. Submitted to *Atmos. Sci. Lett.*

Laroche S, **Sarrazin R**. 2013. Impact of Radiosonde Balloon Drift on Numerical Weather Prediction and Verification. *Weather and Forecasting*, **28**: 772-782

Vance AK, **Abel SJ**, **Cotton RJ**, **Woolley AM**. 2014. Performance of WVSS-II hygrometers on the FAAM Research Aircraft. Submitted to *Atmos. Meas. Tech.*

WMO codes page. *http://www.wmo.int/pages/prog/www/WMOCodes.html*

bruce.ingleby@ecmwf.int