**Summary of benefits of using BUFR (Binary Universal Form for the Representation of meteorological data) in preference to TAC (Traditional Alphanumeric Codes) from the perspective of NWP centres – for the example of radiosonde data**

* **Higher precision of observations**

With BUFR encoding radiosonde temperatures can now be reported with a precision of at least 0.1 K. This was different for temperatures in TEMP messages, where the precision was 0.2 K because of restrictions in telecommunication speed and costs at the time when TEMP was introduced. Furthermore, this rounding can introduce a small bias during encoding/decoding (see Ingleby and Edwards 2015). In TEMP code wind direction was stored to a precision of just 5° and dew point depressions larger than 5 K were stored to a precision of 1 K (see Ingleby et al. 2016). In BUFR wind direction can be made available with a precision of up to 1°, wind speed with a precision of 0.1ms-1, and dewpoint temperature with a precision of 0.1K (if RH is reported, its precision can be up to 0.1%). Geopotential height is another important measurement for which precision is improved in BUFR reports. In TEMP messages the height was coded to nearest decametre (10m) above 500hPa, with BUFR the precision is 1m throughout the whole profile.

* **More data because of more levels**

Typically radiosondes provide measurement data in intervals of 1 or 2 seconds to their ground stations. For a two hour ascent this provides up to 3600 or 7200 levels. As long as the TAC code TEMP was used, only a very limited number of about 50-100 levels was exchanged internationally. The availability of more levels is beneficial for NWP models, even those having comparatively few vertical levels, as the improved representation of structures within a profile allow for more accurate vertical averaging. Other users of radiosonde data (e.g. climatologists, forecasters) will also benefit from high-resolution data, now and even more in the long run when NMHS start exchanging and archiving such high-resolution data.

* **Better usage of data because of accurate time and position information for all levels**

Radiosonde balloons can drift 200 km or more when winds are strong. The TAC codes used for radiosonde data (TEMP and PILOT) make no allowance for reporting drift times or locations; drift in this context can only be estimated from the low-resolution wind data and an assumed ascent rate for the balloon. On the other hand, BUFR accommodates observations of time and position at each level, which are more accurate than drift estimates based on low-resolution TAC winds. Using radiosonde drift in NWP has shown promising results (Laroche and Sarrazin, 2013; Ingleby and Edwards, 2015; Choi et al, 2015). Knowing the precise time and location of observations is essential for the accurate numerical predication of mesoscale weather systems or mesoscale features embedded within larger-scale systems.

* **More sophisticated quality control and bias corrections possible**

With BUFR encoding it is now possible to not only send the observational data but also relevant metadata. And, this can be more than just station identifier, location and observation time. For example, the radiosonde type, serial number, and software version number used for a particular sounding can be reported with the BUFR message, and therefore NWP centres can now make more reliable automated decisions on a case-by-case basis about usage of data of a particular variable in a certain height range. For example, NWP centres do not use radiosonde humidity measurements from all radiosonde types in the upper troposphere. Furthermore, this information can also provide information about any radiation correction that was applied prior to transmission of the data. If corrections haven’t been applied by the data providers then NWP centres have to do it before actual usage of the measurements. It is important to avoid that either no correction is applied at all or that a correction is applied twice. With BUFR the opportunity exists to report much more up-to-date metadata than can be provided via the historically maintained separate metadata files, such as the WMO Pub9 VolA flatfiles.

* **All data in one report makes usage simpler**

Before actual assimilation of radiosonde data, they have to undergo some preparatory treatment, e.g. vertical consistency checks and quality control. For that purpose NWP centres usually merge the different TEMP parts. In BUFR format radiosonde data shall be sent when 100 hPa have been reached and all data shall be sent again, when the sounding has reached the burst height. Ingleby et al. 2016 state that having all the data in a single BUFR report is a significant advantage. To achieve most benefits especially for km-scale models having shorter cut-off times than global models, BUFR reports up to 100 hPa ideally should be created and transmitted with same high-resolution as the BUFR reports of the entire sounding.

**Final remark:
With a simple conversion of TEMP reports to BUFR, yielding reformatted TEMP reports, NONE of the aforementioned benefits can be achieved.**

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