Links between GRUAN and the global radiosonde network

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Overview

• Introduction
• Move to BUFR and HiRes, rounding in old format
• GRUAN, GUAN and global network
• 2015-2016 O-B statistics
  • RS92 statistics for all German stations
  • Global variation by radiosonde type
• Summary
Introduction

• My background is at the Met Office and (from 2013) ECMWF – mainly Numerical Weather Prediction (NWP) but also some climate work

• Theme: How can GRUAN and related initiatives improve the global radiosonde network and help its users?

• Work supported by EU H2020 GAIA-CLIM project (and separate project for Vaisala)
  • Information from various people – notably Sasha Kats
Most of the GRUAN stations report on the GTS

- List compiled with help from Jordis Tradowski
- Real-time GTS reports use Vaisala/other processing

<table>
<thead>
<tr>
<th>Station</th>
<th>WMO id</th>
<th>Freq</th>
<th>Country</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAR</td>
<td>Barrow</td>
<td>70027</td>
<td>USA, AK</td>
<td>(70026, NWS, adjacent)</td>
</tr>
<tr>
<td>CAB</td>
<td>Cabauw</td>
<td>06260</td>
<td>NL</td>
<td>Aka De Bilt</td>
</tr>
<tr>
<td>LAU</td>
<td>Lauder</td>
<td>93817</td>
<td>NZ</td>
<td>Not in GRUAN v2</td>
</tr>
<tr>
<td>LIN</td>
<td>Lindenberg</td>
<td>10393</td>
<td>4/day</td>
<td>DE Lead centre</td>
</tr>
<tr>
<td>NYA</td>
<td>NyAlesund</td>
<td>01004</td>
<td>1/day</td>
<td>NO</td>
</tr>
<tr>
<td>PAY</td>
<td>Payerne</td>
<td>06610</td>
<td>CH</td>
<td>Mainly Meteolabor</td>
</tr>
<tr>
<td>SGP</td>
<td>Southern Great Plains</td>
<td>74646</td>
<td>4/day</td>
<td>USA Aka Lamont. No WMO position metadata for years</td>
</tr>
<tr>
<td>SOD</td>
<td>Sodankyla</td>
<td>02836</td>
<td>2/day</td>
<td>FIN</td>
</tr>
<tr>
<td>TAT</td>
<td>Tateno</td>
<td>47646</td>
<td>JAP</td>
<td>Mainly Meisei</td>
</tr>
</tbody>
</table>
WMO migration to BUFR data (and high resolution)

- Migration from alphanumeric to binary codes promoted by WMO
- Radiosonde more complicated than surface data: change structure (no parts A/B/C/D); allow high resolution reporting plus time/lat/lon at each level; allow extra metadata (e.g. software version, radiosonde serial number).
- Currently 20% of radiosonde stations send high resolution BUFR 😊😊, 8% send low resolution native BUFR 😊, 44% send reformatted TEMP 😊, 28% don’t send BUFR 😞
- ECMWF set up https://software.ecmwf.int/wiki/display/TCBUF/ to help
- Paper Progress towards high-resolution, real-time radiosonde reports, Ingleby et al (2016, BAMS)
- BUFR data not currently in an open archive 😞: discussions with NCEI regarding addition to IGRA
Rounding in TEMP code – climate issue?

• Comparison between TEMP and BUFR (Ingleby and Edwards, 2015, ASL) showed up some issues with TEMP coding/decoding, last bit used to indicate + or - °C so TEMP precision is 0.2 degrees.

• Temperature offsets – look at one decimal place (1DP) case first:
  TEMP coding   TEMP decoding
  +13.4°C        +13.4°C (+273.1) MO 😞
  +13.5°C        +13.45°C (+273.15) EC 😊

  RS92 with DigiCORA III: the values as decoded by ECMWF are 0.05° low

  MW41 (some RS92, ~all RS41): values in °C are truncated to 1DP (towards 0) before TEMP coding: positive/negative values are 0.05° low/high!

  Modem M10 TEMP reports seem OK, Graw DFM-09 0.05° high comparing TEMP & BUFR at ECMWF

• Information on Vaisala processing from Matti Lehmuskero

• Height precision better in BUFR than TEMP

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
GUAN and other radiosonde subsets

- 15 GUAN stations not reporting in December, esp island/African stns
- Some are temporary, but this is typical
- GUAN not distinguished in NWP
- GRUAN dominated by (now restricted to) northern extratropics – some Australian stns in the pipeline
GUAN 2

- Mean and rms O-B for two years by latitude band
- GUAN is not homogenous in quality: Russian radiosondes worse.
- ‘Select’ group RS41, LMS6, M10, Meisei, Shanghai similar T stats to RS92 (some worse for UT humidity)
- Mean O-B very similar except at top and bottom
- ECMWF B too cold between 100 and 20 hPa
2015-2016 temperature O-B

- Statistics on standard levels, split by radiosonde type (colours) and latitude band (plots). Bias – dashed, rms – solid.

- Lower stratospheric (100-20 hPa) cold bias in B, largest N of 50°N, smaller in tropics.

- Large near surface differences N of 50°N (esp in Winter), B not good at inversions; inversions too cold in Russian radiosonde data?

- Stratospheric rms larger in tropics than in extratropics – probably due to more gravity waves in tropics (Alexander et al, 2002)
2015-2016 RH O-B

- Lower troposphere statistics comparable, but big diffs in UT (ECMWF only uses RS92/41 in UT)

- Huge UT biases in Russian data – reduced by EC bias correction (would like to switch off EC biascorr for RH)

- Other sondes also suffer from cloud contamination to a lesser extent

- RS41 and RS92 best (esp in tropics)

- Tropical UT statistics improved by change to use Sonntag SVP eqn in late 2016 (not shown)
2015-2016 wind O-B

- Similar statistics for wind: bias of wind speed (dashed), vector wind rms (solid)
- B wind speeds slightly low (0.2 m/s) in general, but larger bias (~ 0.8 m/s vs RS92) in tropical UTLS
- Some Meisei iMS-100 winds over-smoothed?
- Less difference between radiosonde types for wind than for other variables
### Documentation of different radiosondes

<table>
<thead>
<tr>
<th>Type</th>
<th>Papers</th>
<th>GRUAN product?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaisala RS92</td>
<td>Many</td>
<td>Yes</td>
</tr>
<tr>
<td>Vaisala RS41</td>
<td>2</td>
<td>In progress</td>
</tr>
<tr>
<td>Meisei</td>
<td>2</td>
<td>Close for RS-11G</td>
</tr>
<tr>
<td>Modem M10</td>
<td>-</td>
<td>In progress</td>
</tr>
<tr>
<td>Lockheed LMS6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>- (in Chinese?)</td>
<td></td>
</tr>
<tr>
<td>Graw DFM-09</td>
<td>-</td>
<td>In progress</td>
</tr>
<tr>
<td>Intermet</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Meteolabor SRS-C34</td>
<td>1</td>
<td>Close</td>
</tr>
<tr>
<td>Russian</td>
<td>- (1 preprint)</td>
<td></td>
</tr>
</tbody>
</table>

Measurement uncertainty

• Most manufacturers provide uncertainty estimates
  • Not necessarily taken at face value
  • NWP convolves with representativeness uncertainty

• No uncertainty information in real-time GTS reports

• GRUAN RS92 temperatures very similar to Vaisala RS92 temperatures (Dirksen et al, 2014)
  • Can average GRUAN uncertainties be used for real-time RS92 reports, a) for GRUAN stations, b) for other stations using RS92?
  • Can they help with uncertainty estimates for other radiosonde types?
GRUAN vs operational (HiRes) data

- Some stations now report HiRes BUFR (often 2 second data) in real time (Ingleby et al, 2016, BAMS)
- For RS92 temperature this is almost identical to GRUAN profile
- There are slight differences for humidity (Td shown)
- ECMWF profile is smoother
- The BUFR includes position of each level and extra metadata, but not uncertainty estimates
Comparison of Lindenberg with other German stations

- Numbers of standard level reports for 2015+2016 for Lindenberg, other German stations and Cabauw (problem above 100 hPa)
- This plot for 00 UTC, 12 UTC similar but no Cabauw
• 00 UTC O-B results

- Generally tight cluster of results, Lindenberg slightly closer to B for heights (extra near-surface scatter for T and wind)

- Cabauw similar – slightly worse fit for height and RH (B could be worse closer to Atlantic)

- One station appears to have height bias (from station height error?) of about 8 m.

- At 12 UTC (next slide) the height and temperature fits are somewhat worse (expected)

- At 12 UTC the UTLS RH bias falls into two clusters – probably due to the processing version
Pendulum motion and wind filtering

- Radiosonde swings under the balloon
- This adds high frequency noise to the GPS-derived winds – removed by filtering (e.g., Dirksen et al., 2014) – red curve shows filtered wind
- The noise varies within ascent and from day to day
- How much is noise and how much is signal?
- Some operational radiosondes seem to over-smooth
- Can GRUAN provide advice?
Summary

• Most GRUAN stations report in real-time on the GTS – same raw data but different processing

• Insufficient GRUAN stations for comprehensive climate monitoring or validation/calibration of satellite data

• Operational RS92 similar quality to GRUAN (less so for RH) – could use GRUAN uncertainties? - Much better coverage ~300 stations
  • More variation of uncertainty from one GRUAN station to another than expected

• Documentation of operational radiosondes is patchy

• Sometimes coding problems or rounding – should WMO radiosonde intercomparison look at this as well as raw data?

• More guidance on vertical smoothing of wind data?

• NWP fields (not perfect!) are useful for comparing radiosonde quality

• GRUAN is helping to improve operational quality in some cases but more interaction would be useful