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

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

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 (eg. 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 - ºC so TEMP precision is 0.2 degrees.

- Temperature offsets – look at one decimal place (1DP) case first:

TEMP coding			TEMP decoding
+13.4°C	→	134	+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

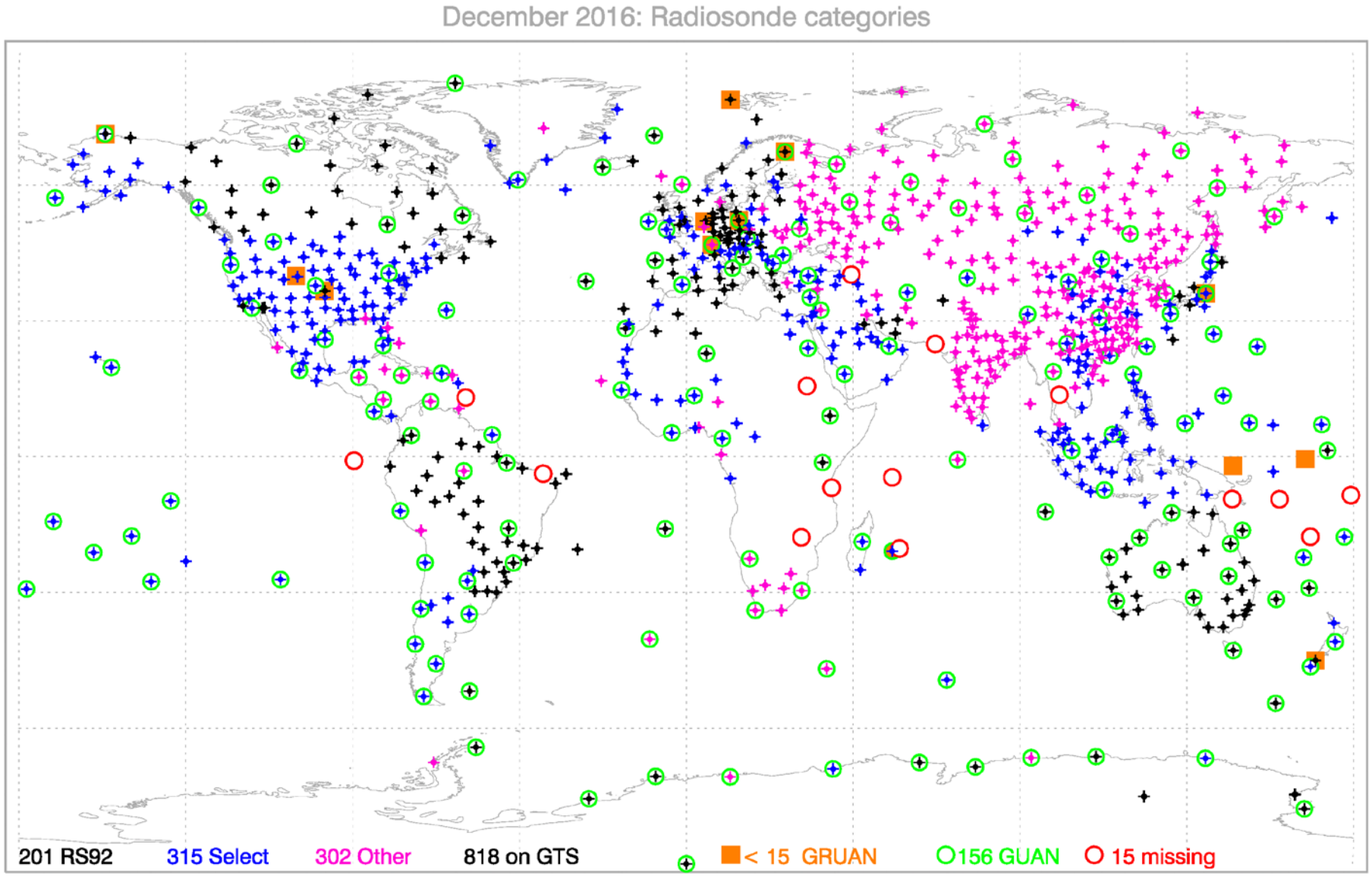
- Information on Vaisala processing from Matti Lehmuskero

- Height precision better in BUFR than TEMP

GUAN and other radiosonde subsets

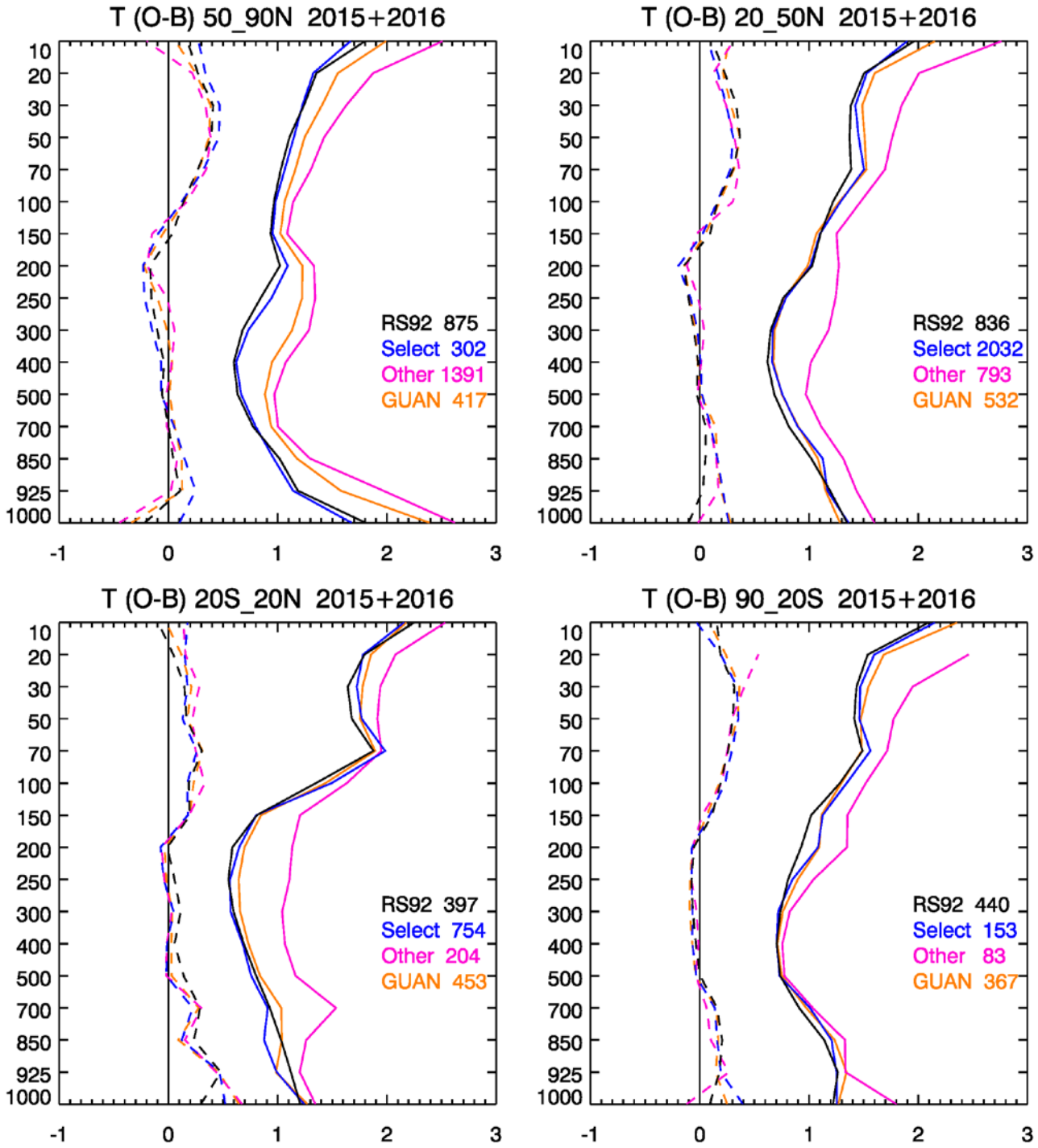
- 15 GUAN stations not reporting in December, esp island/African stns
- Some are temporary, but this is typical
- GUAN not distinguished in NWP

- GRUAN dominated by (now restricted to) northern extratropics – some Australian stns in the pipeline



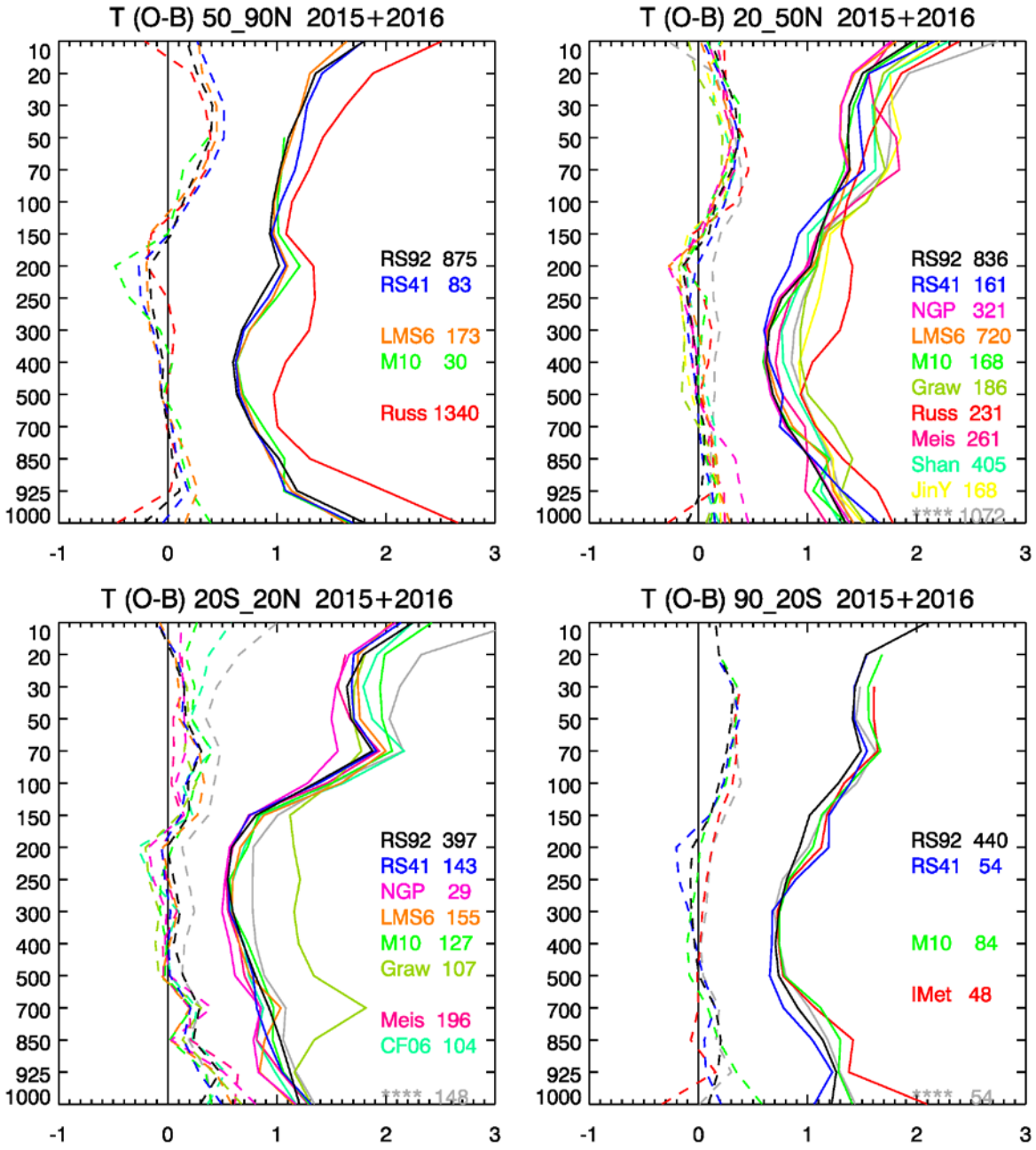
GUAN 2

- 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



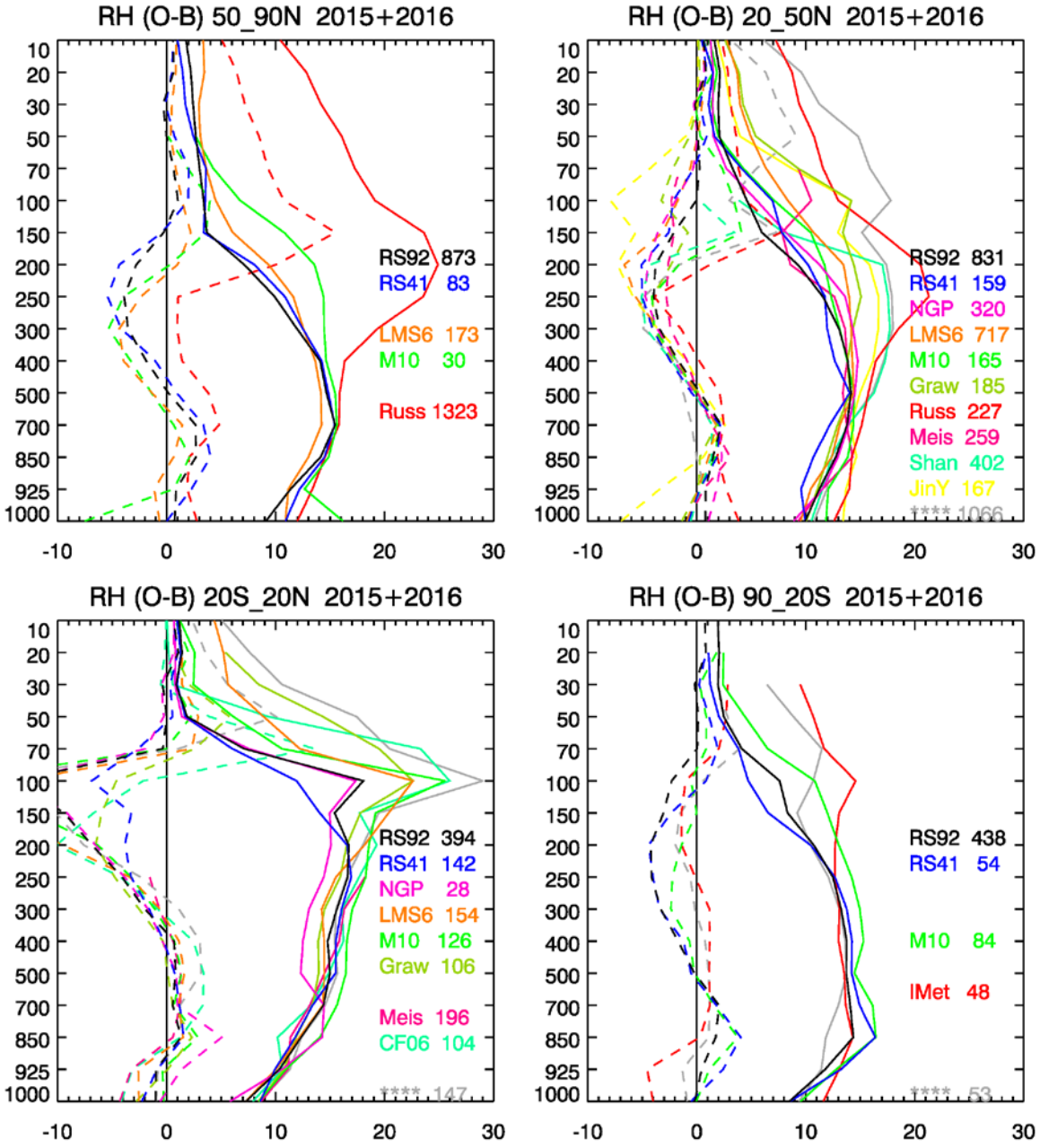
2015-2016 temperature O-B

- 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)



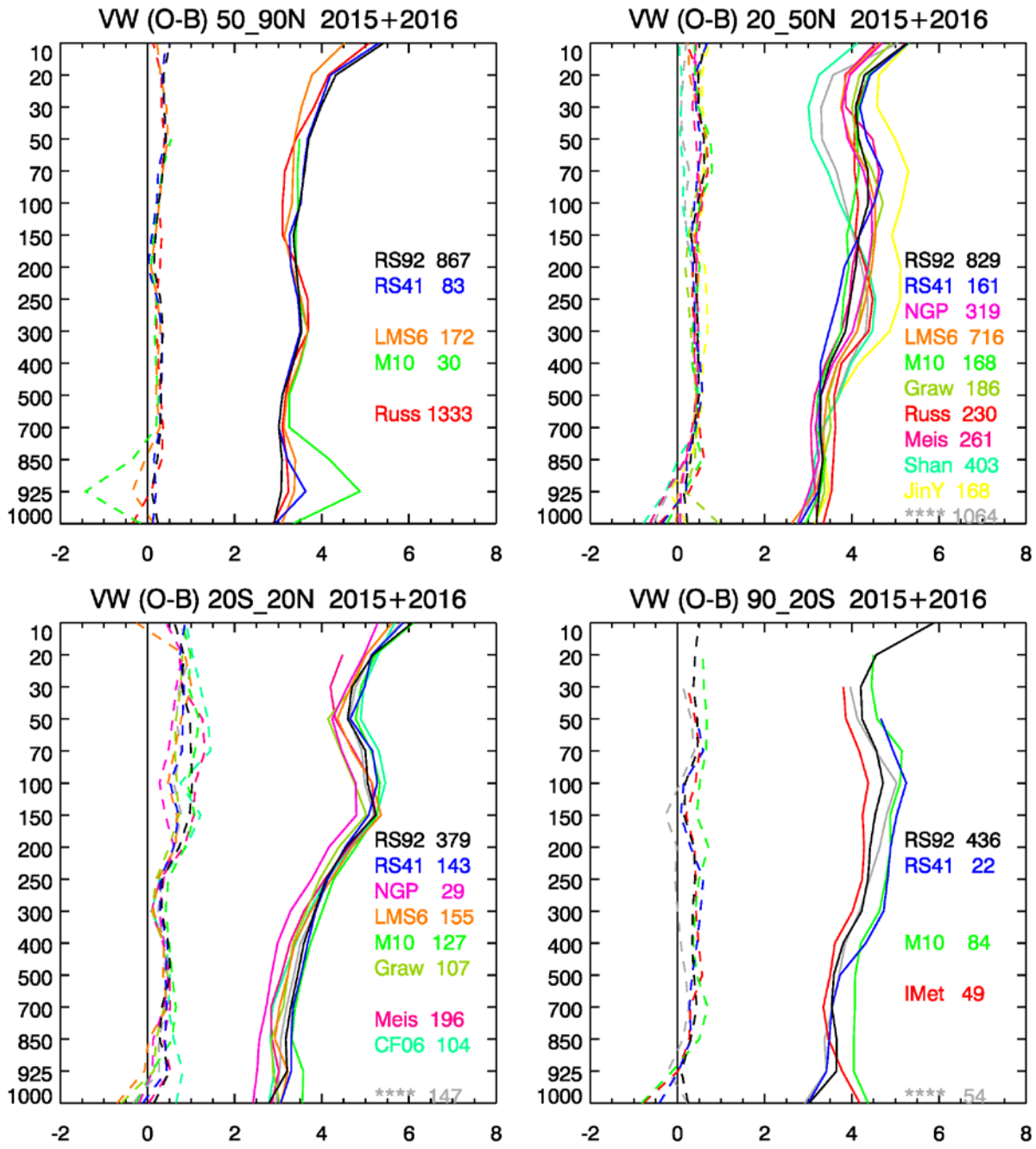
2015-2016 RH O-B

- 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

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

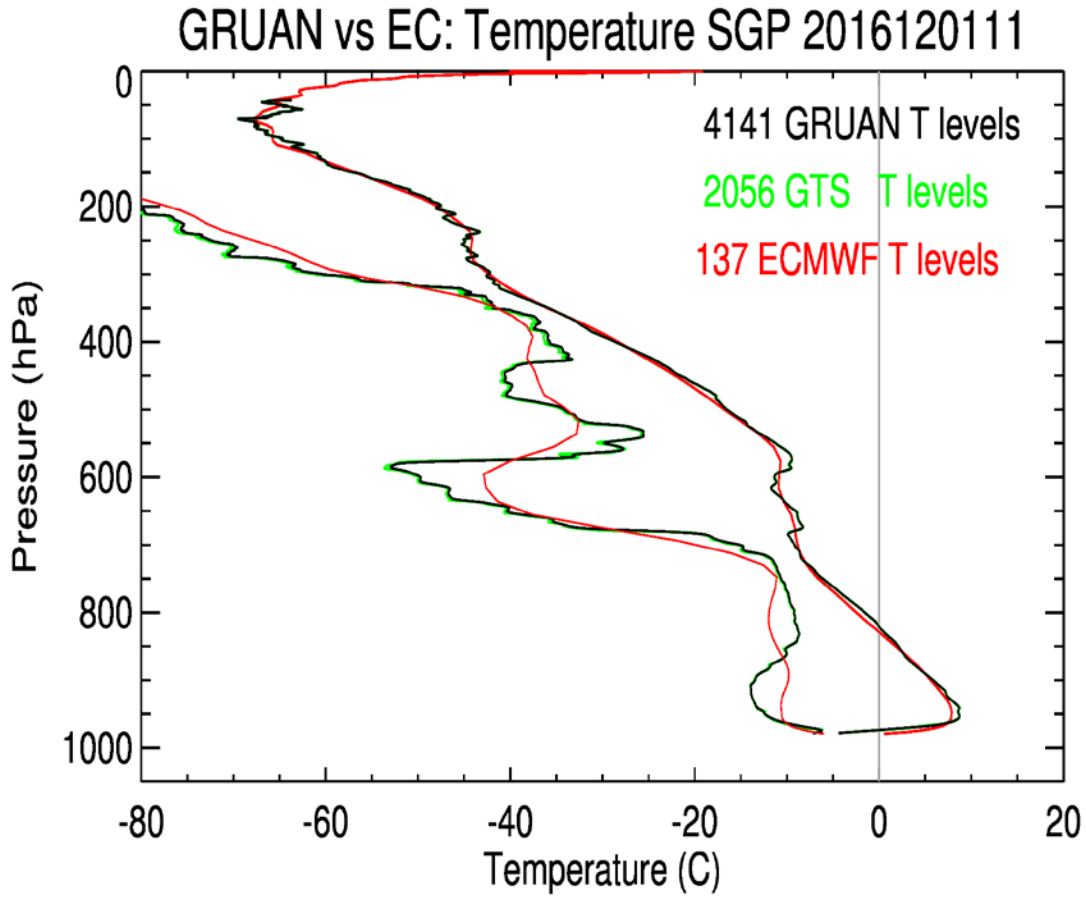
US NWS implemented its Radiosonde Replacement System from 2005-13. various conference abstracts/presentations about ‘data continuity study’ by R Brown et al, but no report.

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?

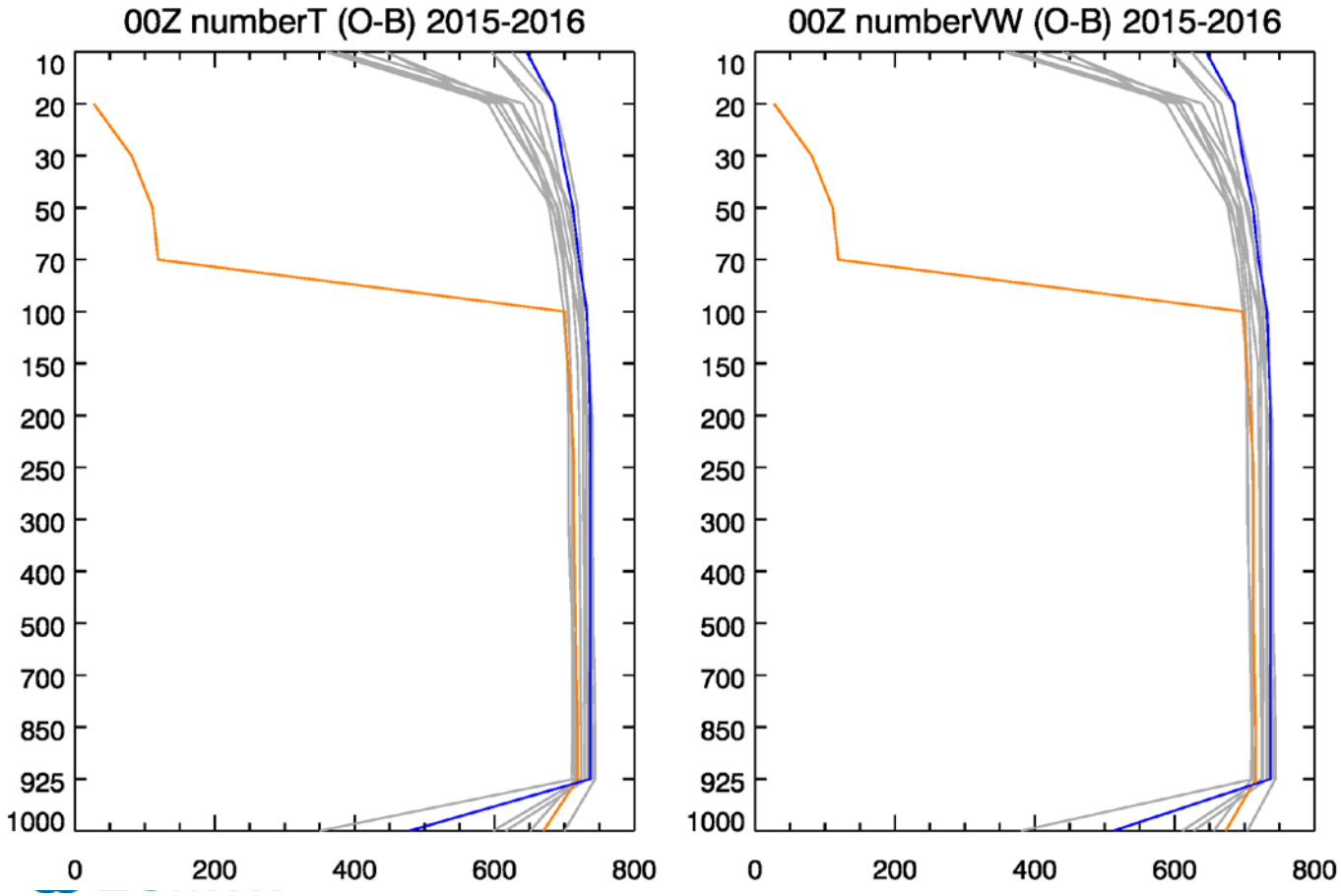
GRUAN vs operational (HiRes) data

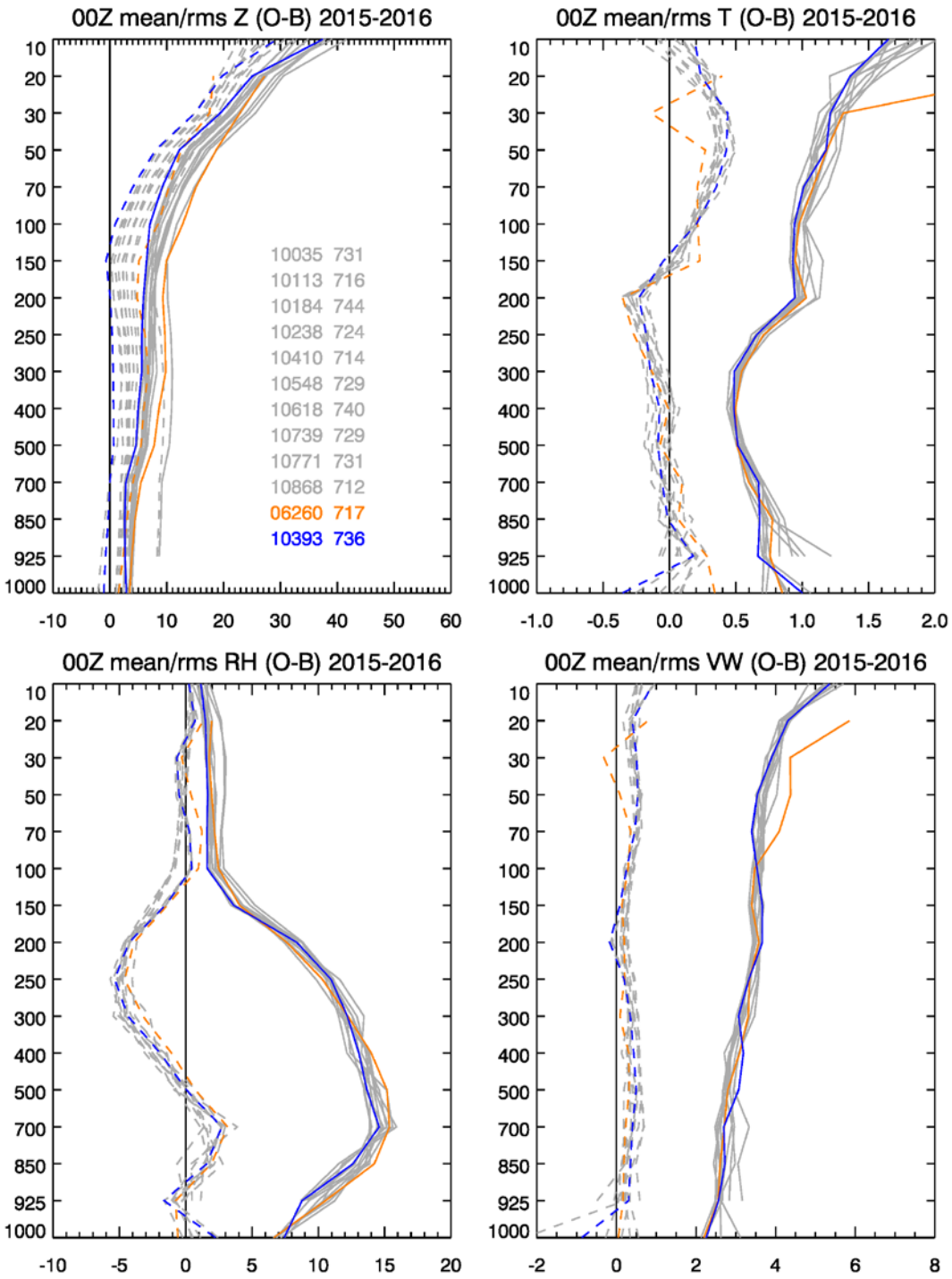
- Some stations now report HiRes BUFR (often 2 second data) in real time (Ingleby et al, 2016, BAMS)
- For RS92 temperature this is almost identical to GRUAN profile
- There are slight differences for humidity (Td shown)
- ECMWF profile is smoother
- The BUFR includes position of each level and extra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



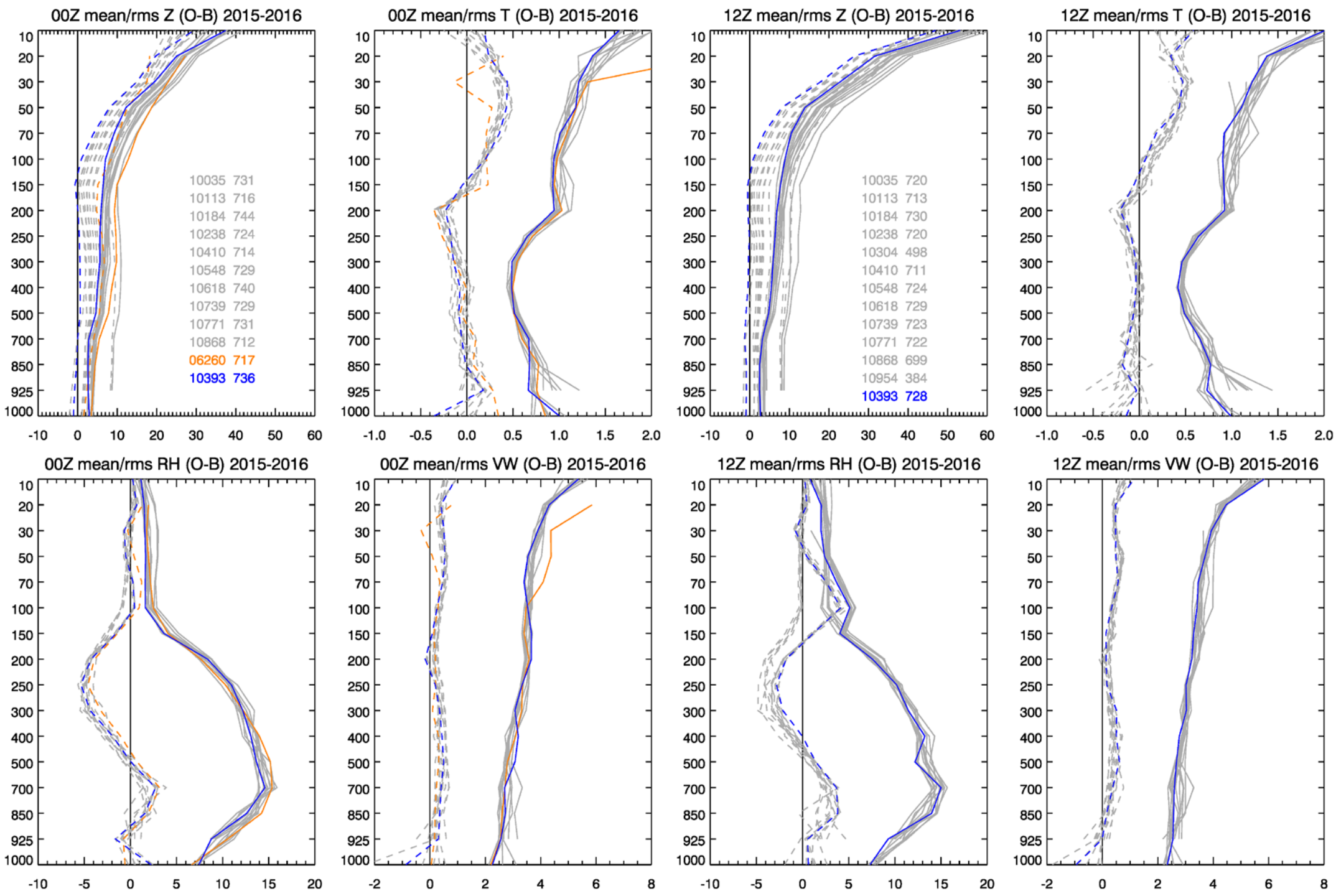
Comparison of Lindenberg with other German stations

- 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



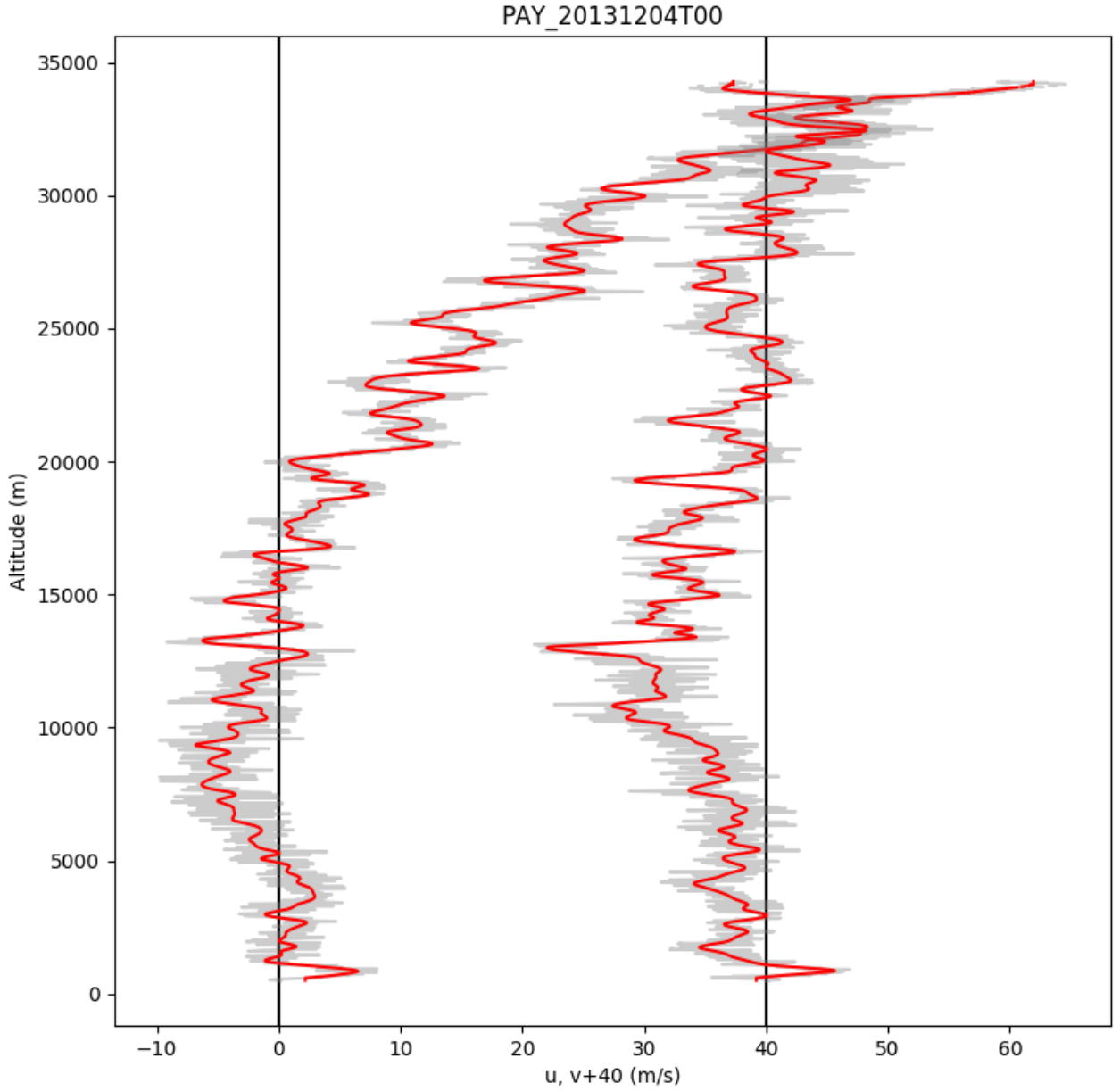


- 00 UTC O-B results
- Generally tight cluster of results, Lindenberg slightly closer to B for heights (extra near-surface scatter for T and wind)
- Cabauw similar – slightly worse fit for height and RH (B could be worse closer to Atlantic)
- One station appears to have height bias (from station height 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


00Z mean/rms Z (O-B) 2015-2016
10035 731
10113 716
10184 744
10238 724
10410 714
10548 729
10618 740
10739 729
10771 731
10868 712
06260 717
10393 736
00Z mean/rms T (O-B) 2015-2016
12Z mean/rms Z (O-B) 2015-2016
10035 720
10113 713
10184 730
10238 720
10304 498
10410 711
10548 724
10618 729
10739 723
10771 722
10868 699
10954 384
10393 728
12Z mean/rms T (O-B) 2015-2016
00Z mean/rms RH (O-B) 2015-2016
00Z mean/rms VW (O-B) 2015-2016
12Z mean/rms RH (O-B) 2015-2016
12Z mean/rms VW (O-B) 2015-2016

Pendulum motion and wind filtering

- Radiosonde swings under the balloon
- This adds high frequency noise to the GPS-derived winds – removed by filtering (eg 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