# Operational HiRes radiosonde data: the good, the bad and the unknown

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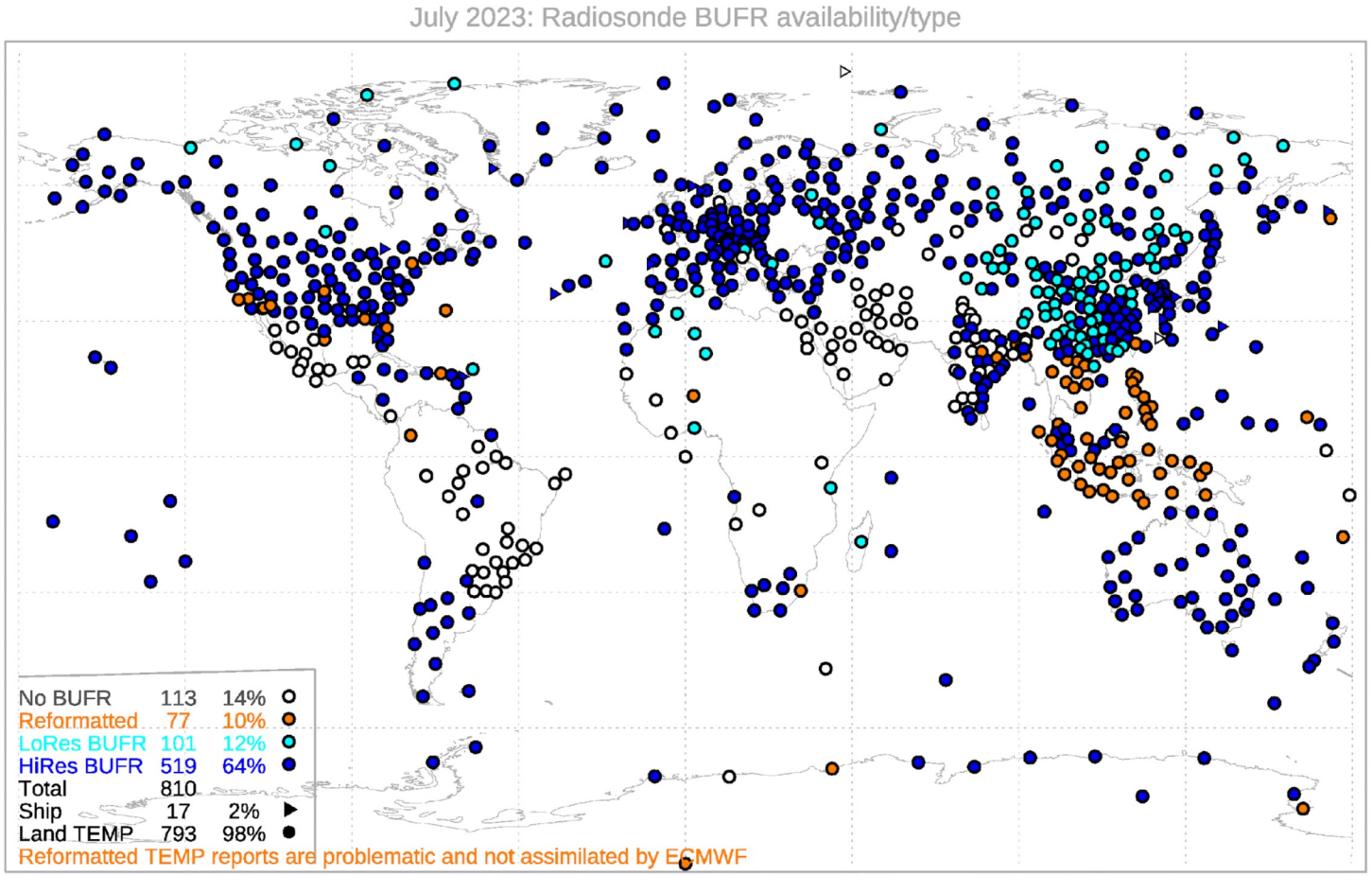
# Overview

- Data coverage and usage at ECMWF
  - Comparing with 12-hour forecasts (O-B)
- Examples of bad data (‘good/bad’ might depend on user)
- Wave examples
- Comparing RS41 ascent and descent profiles
- The archive and how to read BUFR
- Summary

- Ingleby, Pauley et al (BAMS, 2016): WMO mandated BUFR
- Many NMSs sent TEMP reformatted to BUFR at the time ☹
- Most HiRes on the GTS from Europe at that time

# Migration to BUFR and Hi(ish)Res, status July 2023

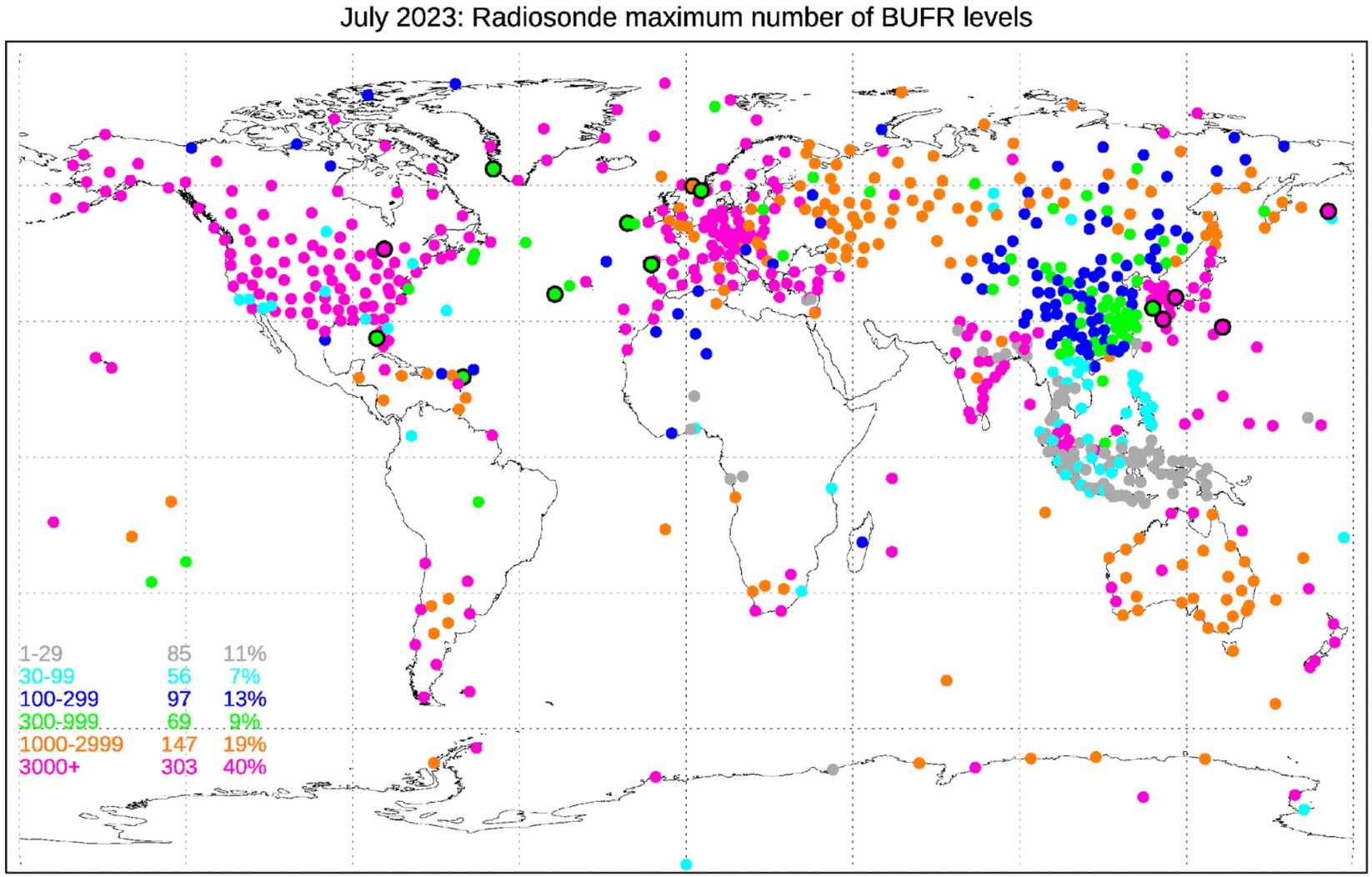
- 76% of stations sent valid BUFR data:
  64% Hi(ish)Res ☺ ☺
  12% LoRes ☺
- 10% Reformatted ☹
  14% No BUFR ☹
- 2022: some Indian stations started HiRes BUFR, but issues ☺/☹
- 2023: Canada, Caribbean ☺, Mexico hacked ☹
- Oct 2021 WMO agreed GBON plan – all HiRes by Jan 2023!
- Big gap in East Africa



# Number of levels reported

- 2-second data ~3000 levels; ~10 m
- 1-second data ~6000 levels: ~5 m

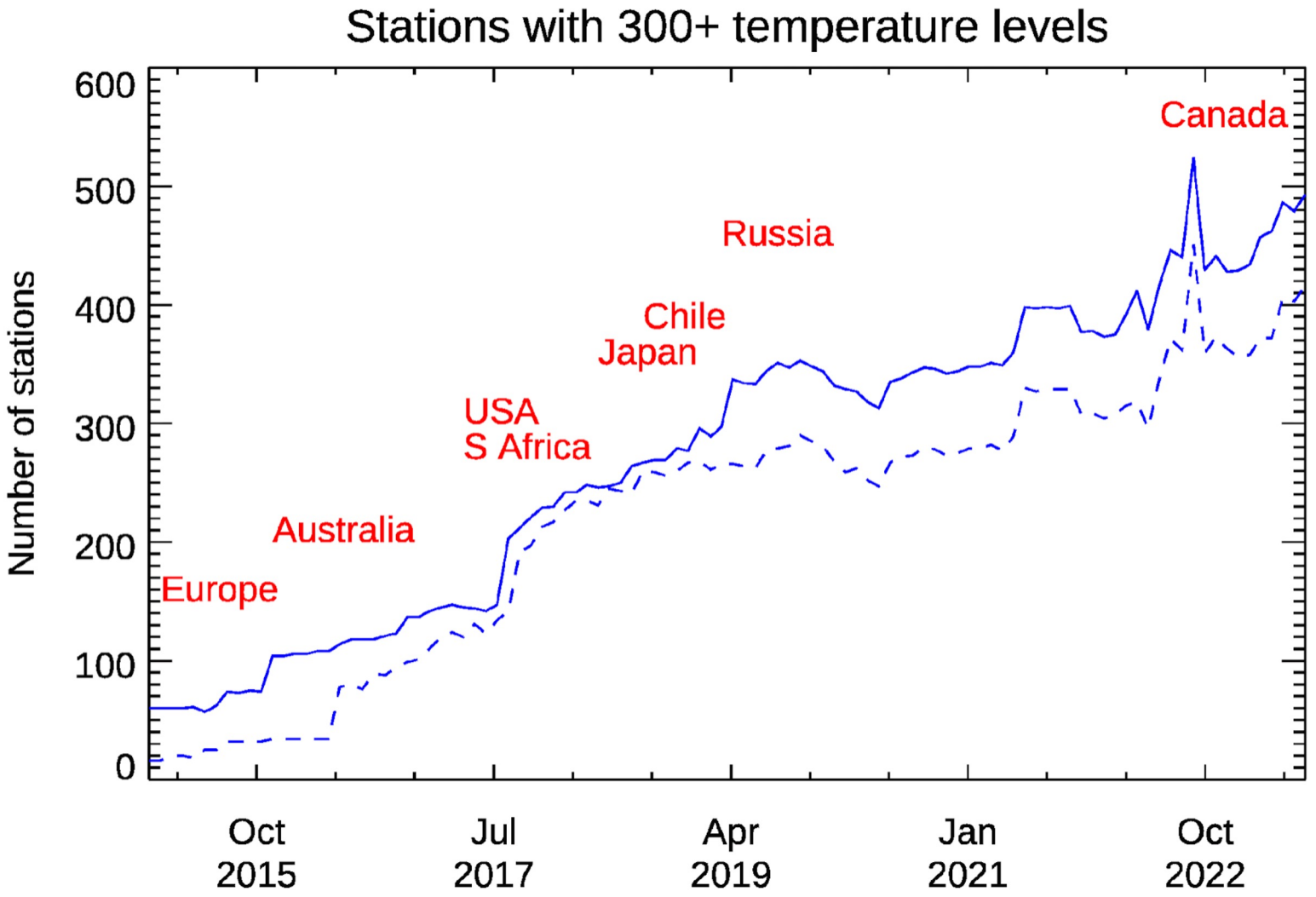
- BUFR = Binary Universal Form for Representation of Meteorological Data (WMO Format)
- WMO GBON requirement is for 100 m resolution



# More HiRes data over time (Dec 2014 to July 2023)

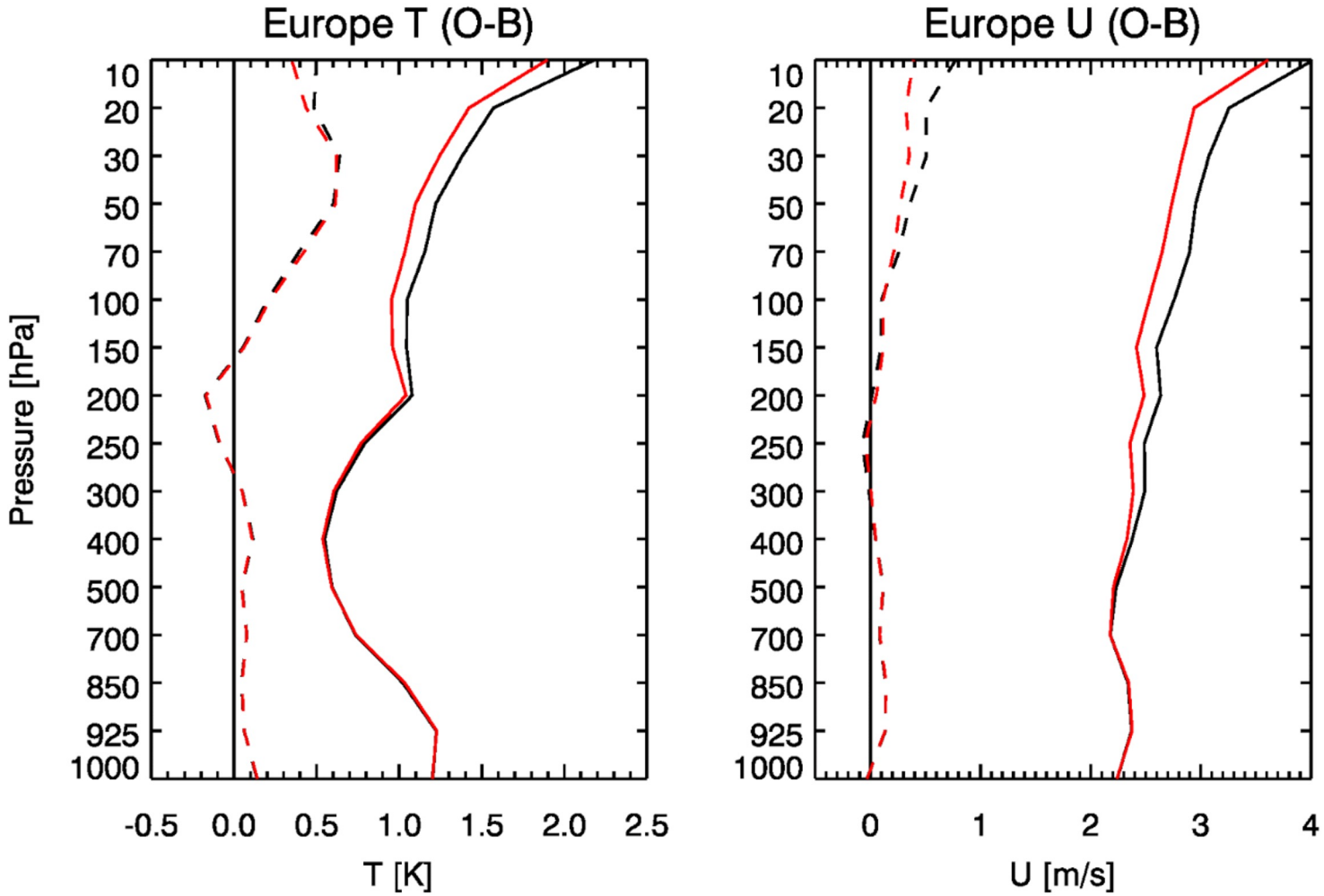
- Solid – stations reporting
- Dashed – BUFR used at EC

- Main events marked
- Europe/USA “fill in” later
  - Mainly 2 second data
- Russia (radar) winds lower resolution than temperatures
- China: medium-res 2021
- Brazil/Mexico start-stop
- India – messy (see later)



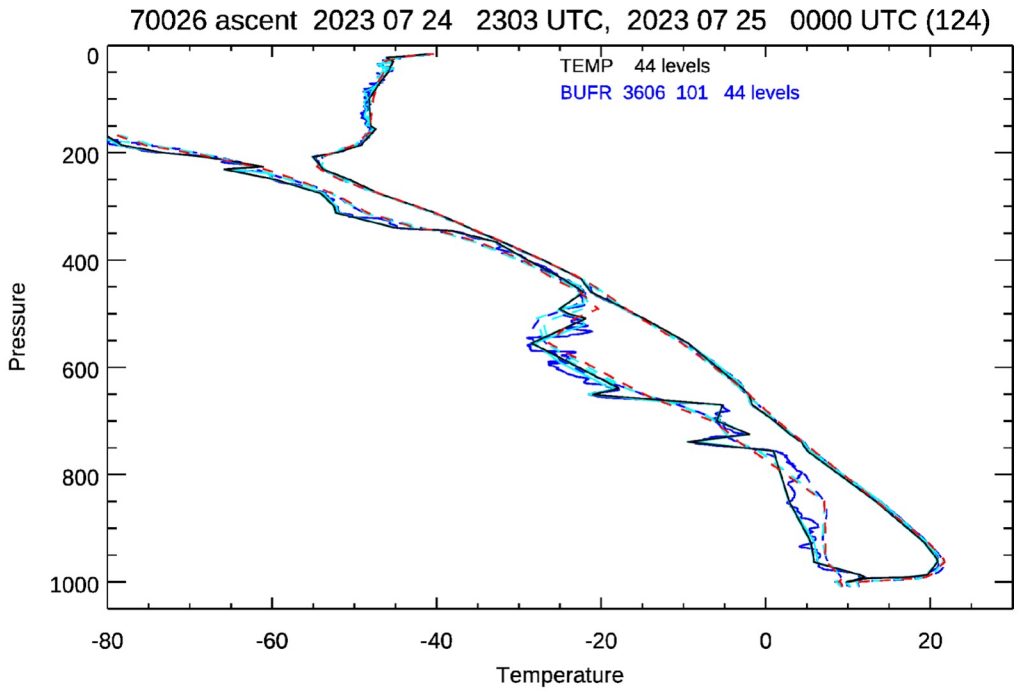
# ECMWF use of BUFR radiosonde data

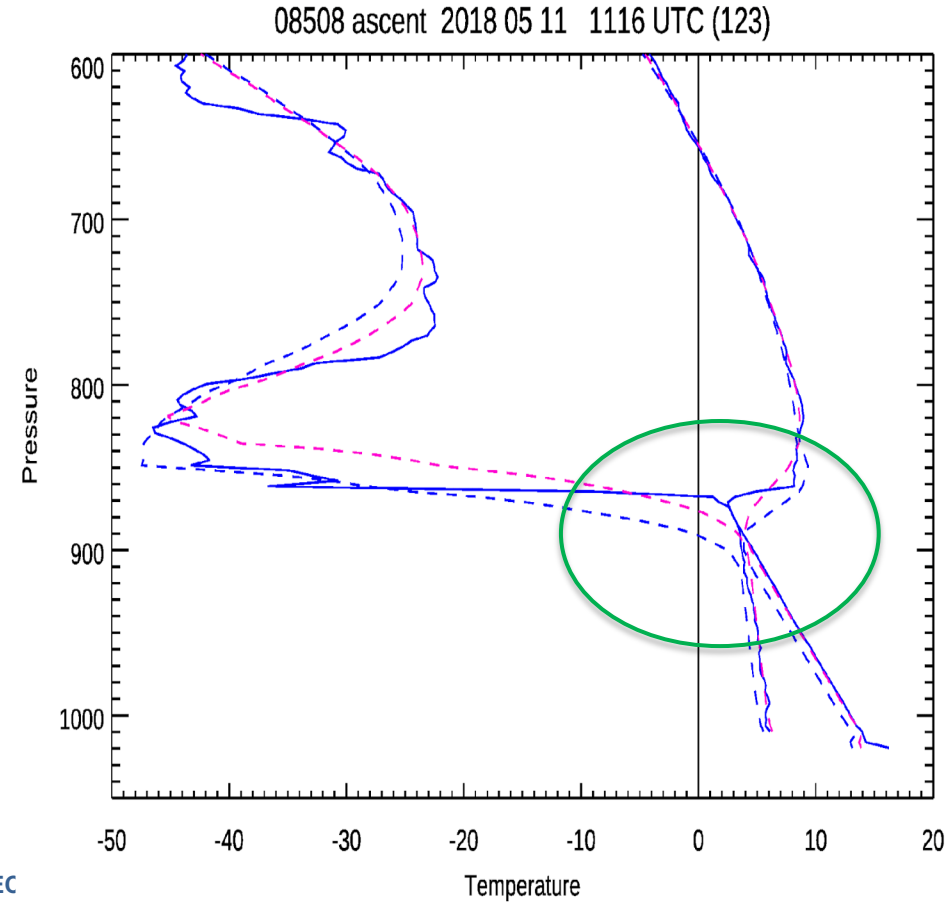
- ECMWF model has 137 levels
- Reports are thinned to ~3 points per model level (max ~350)
- Split into 15-minute sub-profiles to account for radiosonde drift
- Sub-profile has fixed lat/lon/time
- Drift processing gives 5-10% improvement in upper-level fit
- O-B = Observation – Background (B = 12-hour ECMWF forecast)
- Red with, black without drift processing (mean and SD)
- Ingleby et al (2018, EC newsletter)



# The (super)power of comparing with B

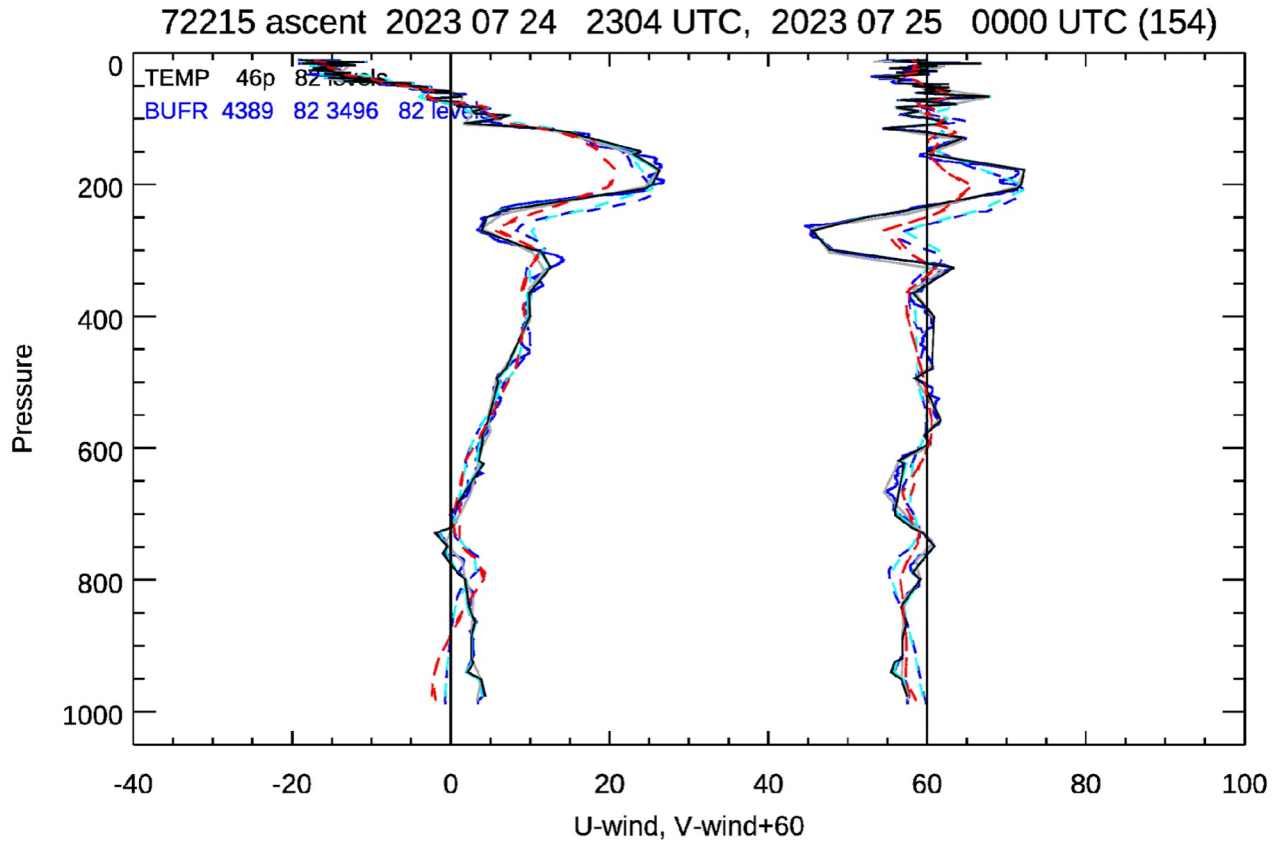
- Black: T and TD alphanumeric report
- Blue: T and TD BUFR reports
- Dashed lines: ECMWF background – usually very good
  - Not perfect, tends to smooth inversions
  - Purple dashed (right) – ECMWF analysis



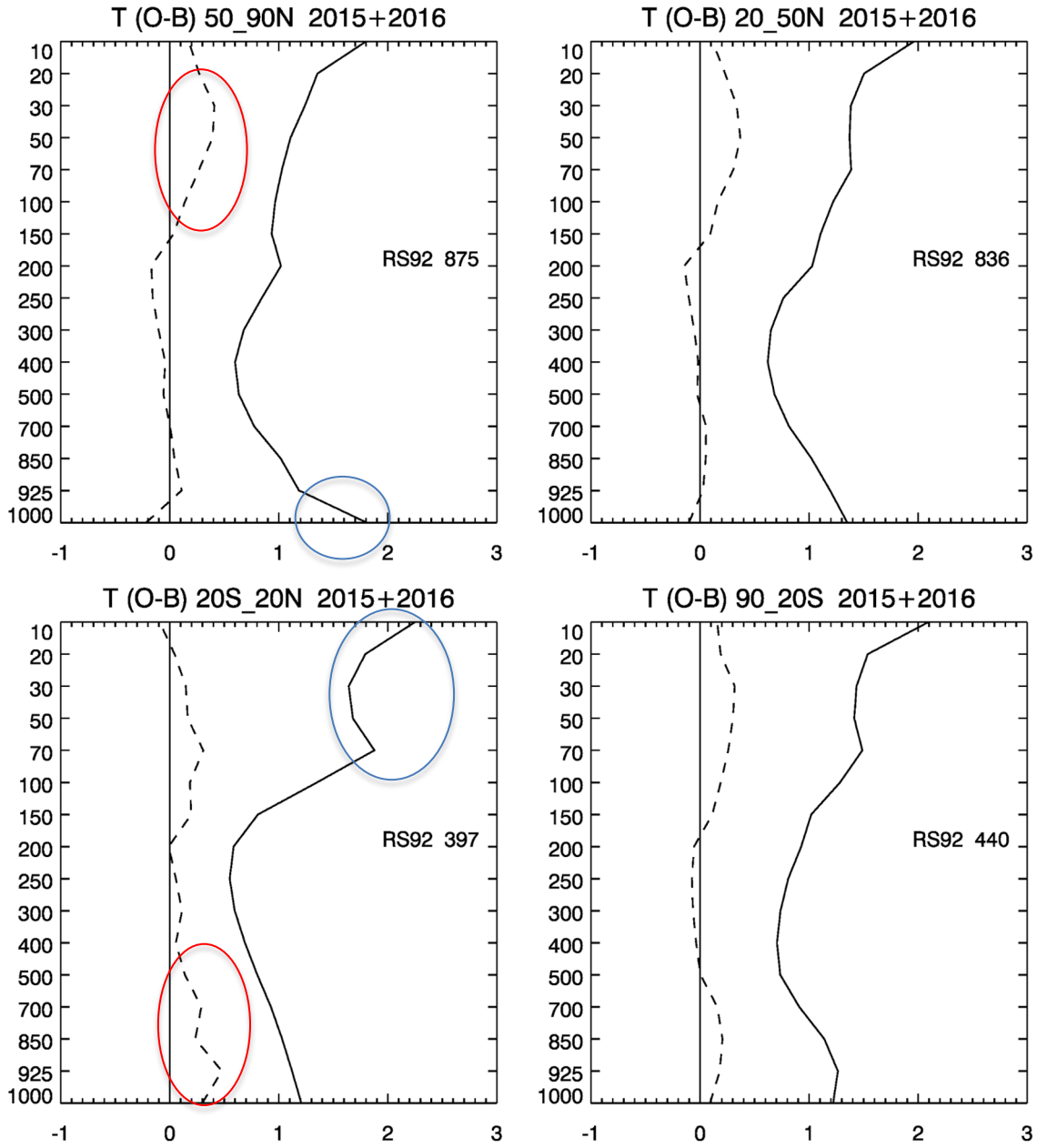
# Wind: a wave example

- U and V components plotted separately (60 m/s added to V)
- Wave partially represented by the model
- Drift processing (blue dashed) better than not (red dashed)



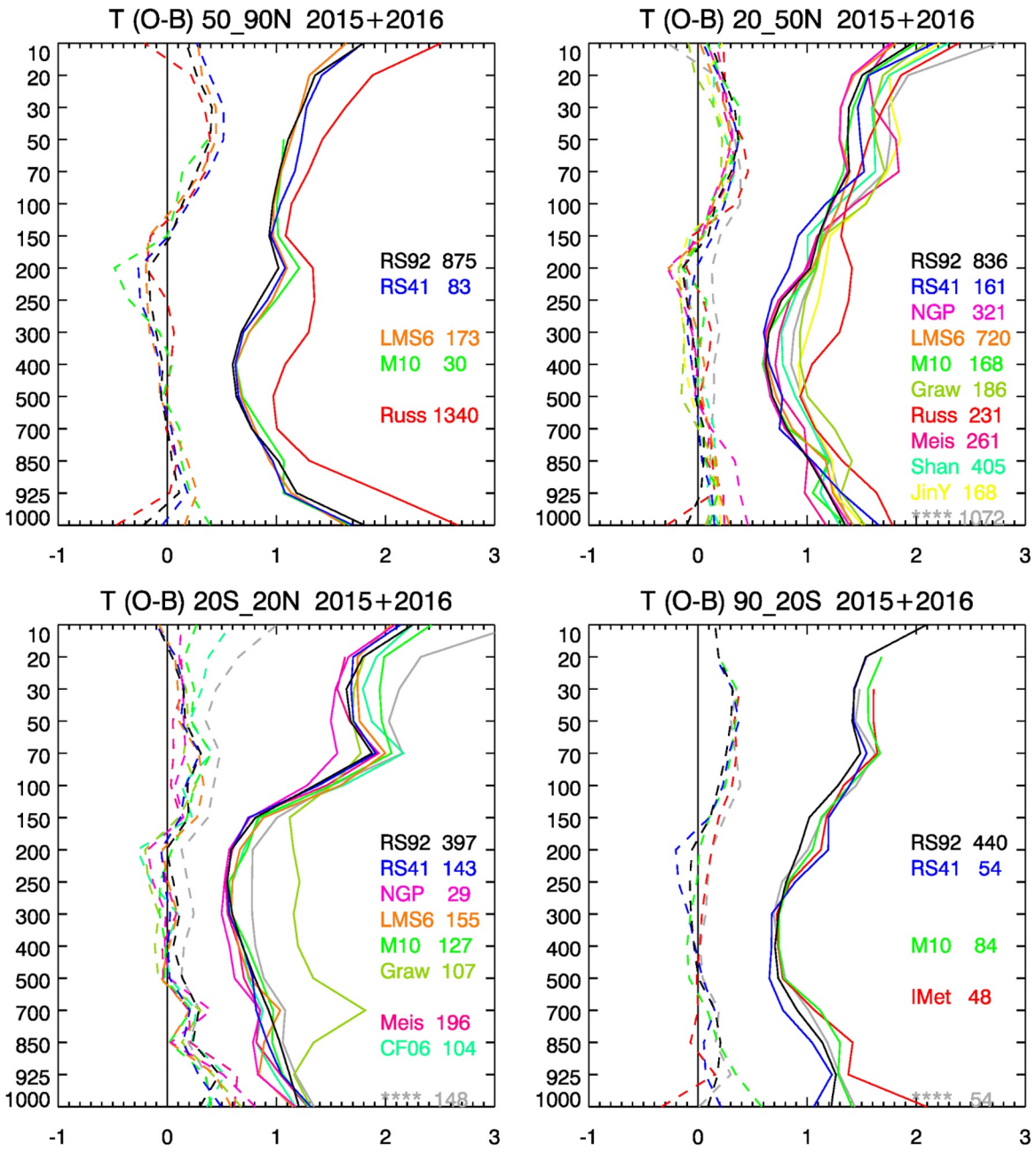
# 2015-2016 temperature results (Vaisala RS92)

- Statistics on standard levels, split by latitude band.
- Bias – dashed, rms – solid.
- Biases:
- Lower stratospheric (100-20 hPa) cold bias in B, largest N of 50°N, smaller in tropics.
- Tropical cold bias in B at low levels (1000-700 hPa)
- Rms differences:
- Large low level rms in NH Winter, model smooths inversions
- Stratospheric rms larger in tropics, more gravity waves there



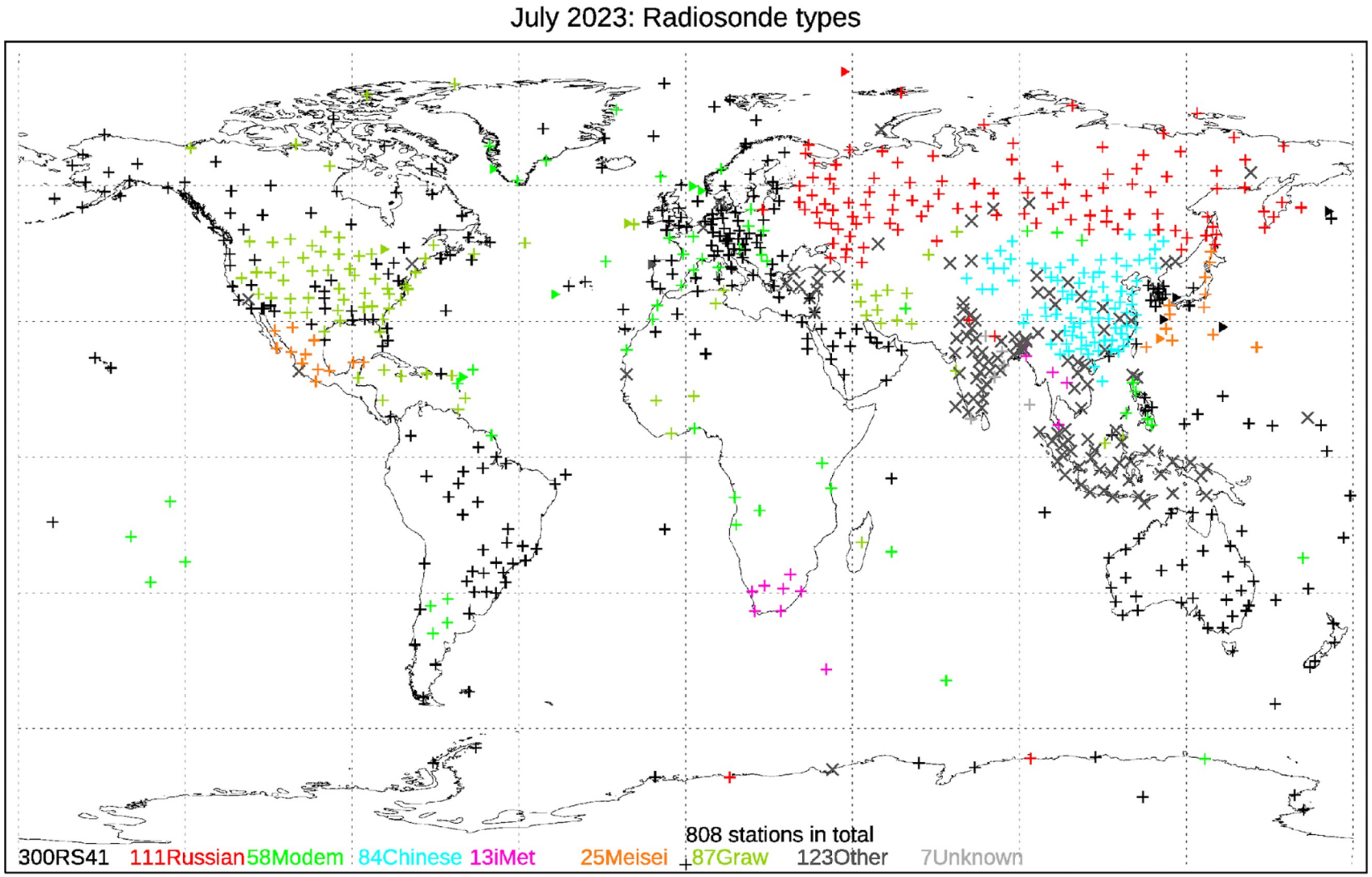
# 2015-2016 temperature O-B

- As before but showing different radiosonde types by colour.
- Russian types (N of 50°N) have worse rms
- So does Graw in Tropics (mainly Indian stations, handling issue?)
- Various other types have similar rms to Vaisala RS92
- See Ingleby 2017 (EC TM 807) for many more results



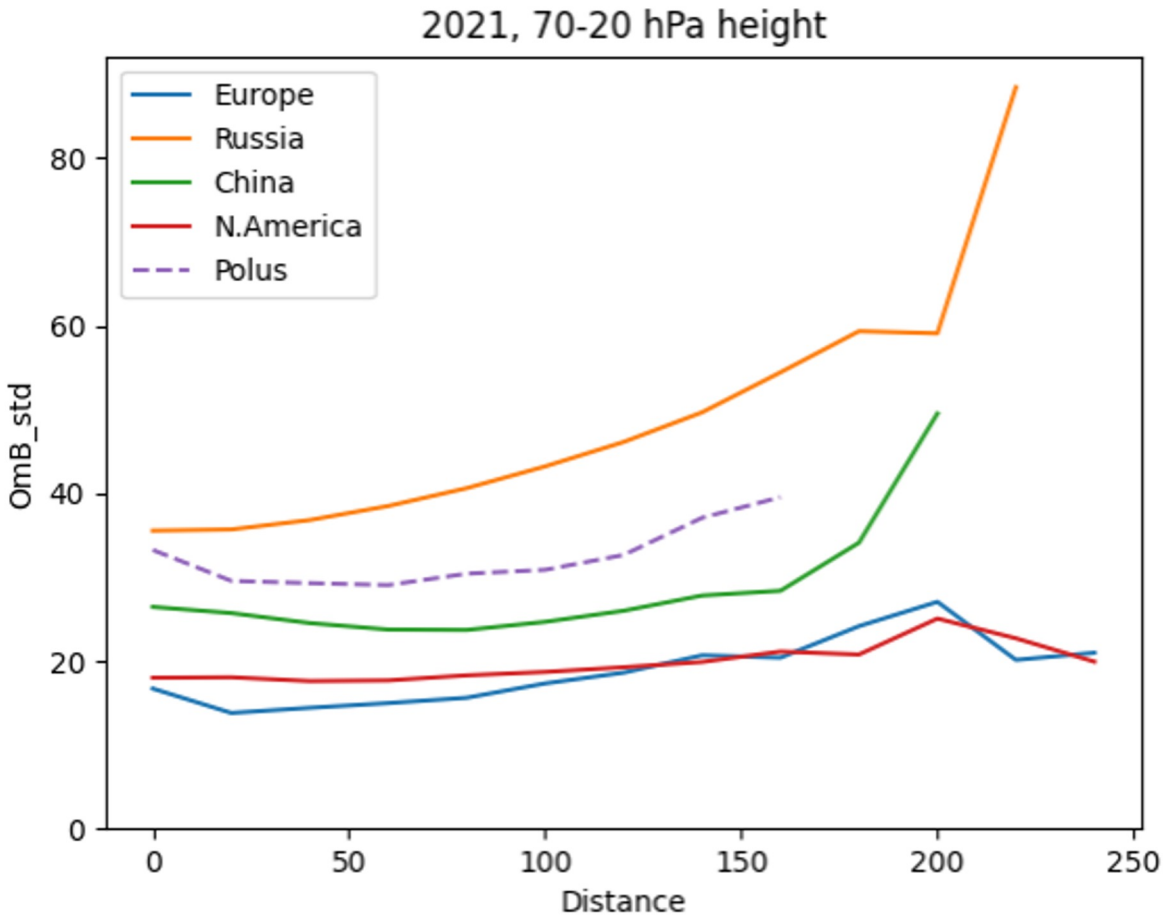
# July 2023 radiosonde types

- Vaisala RS41 used at 300 stations (out of ~800)
- Many US stations changed from LMS6 to Graw DFM-17 in 2022
- Should have results of 2022 RS intercomparison soon



# Radiosondes: GNSS vs radar in the stratosphere

- Plot shows fit of stratospheric heights to model SD(O-B) vs the distance drifted (km)
- Many radiosondes now use GNSS for position+wind finding (OK with or without a pressure sensor) ☺ ☺
- China uses radar + P sensor – OK ☺
- Russia uses radar without P sensor – not good especially at large distance (low radar elevation angle) ☹
  - They are starting to deploy new Polus GNSS radiosondes – small sample so far
  - Problems clearest for height – used for verification but not assimilation

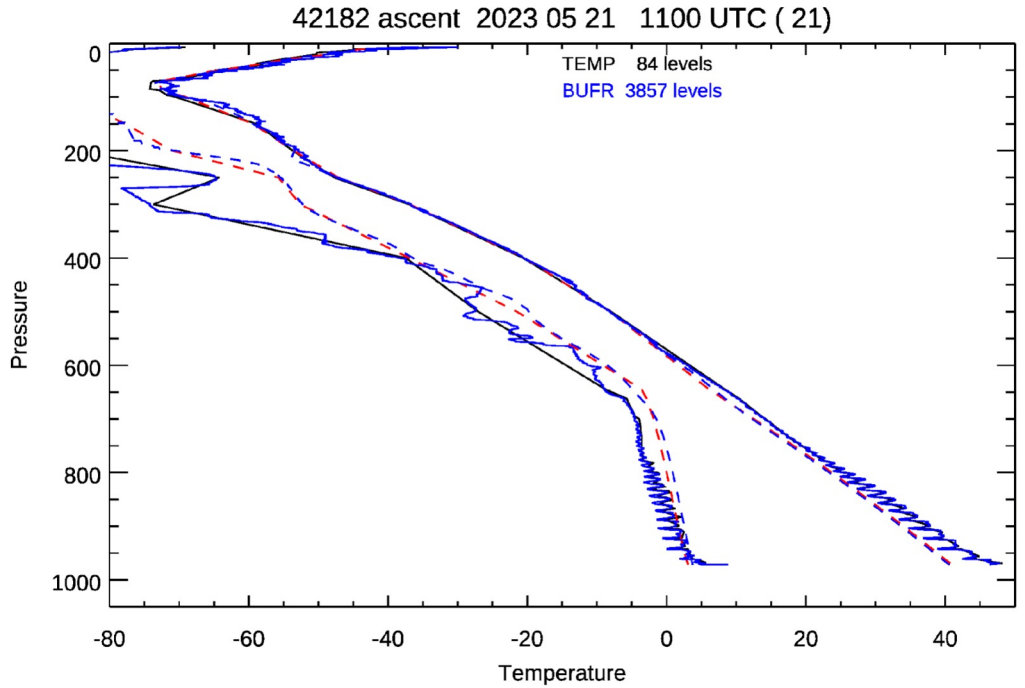


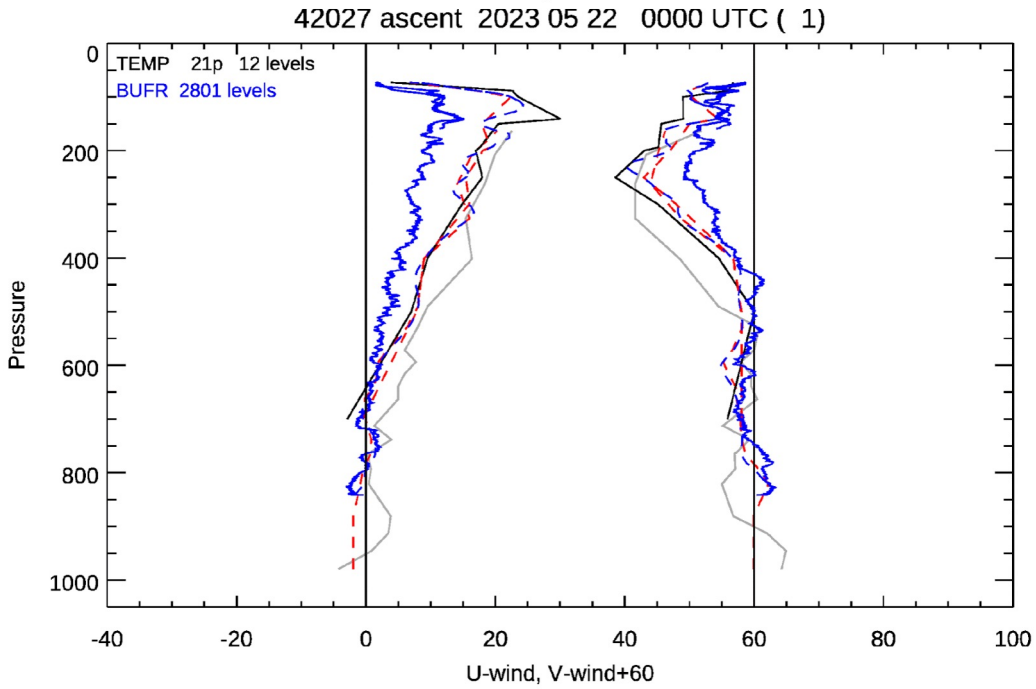

Distance drifted (km)

# Indian HiRes data ☹

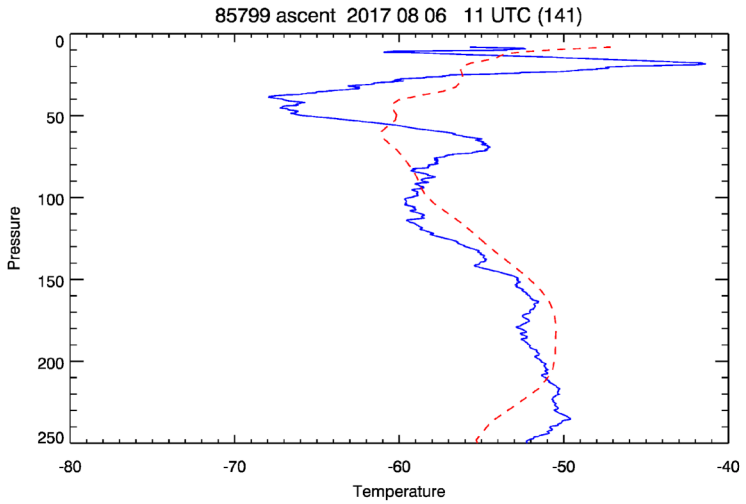
- Indian HiRes data has been start-stop
- Started again late 2022 using new Indian-made radiosondes
- Some of the profiles are OK, others have quality problems:
- Low level temperature oscillations/biases (top)
- Wind speeds ~half of what they should be (bottom)

- India Meteorological Department were informed January 2023 and reminded since
- “The concerned IMD team has been again requested to take necessary action to resolve the issue at the earliest.” June.



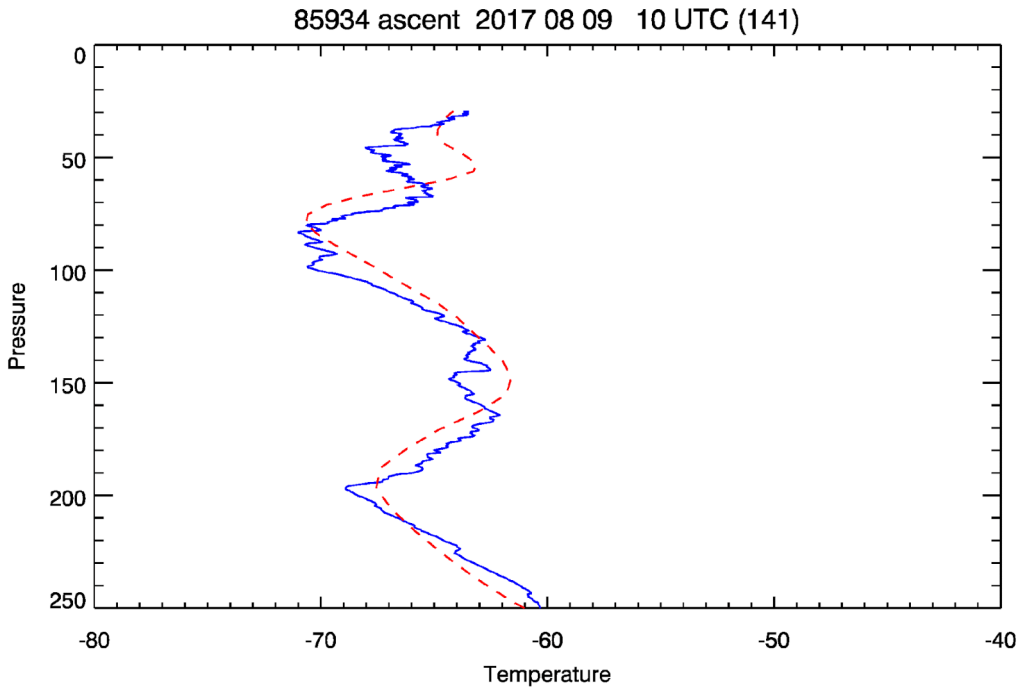
# Gravity wave T cases - Chile

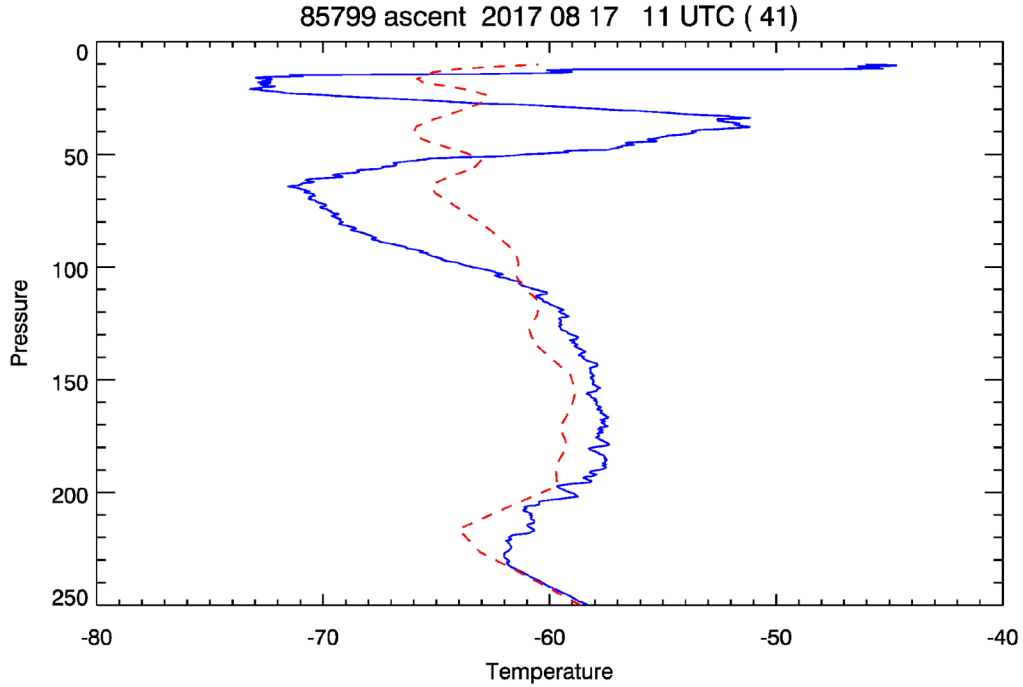


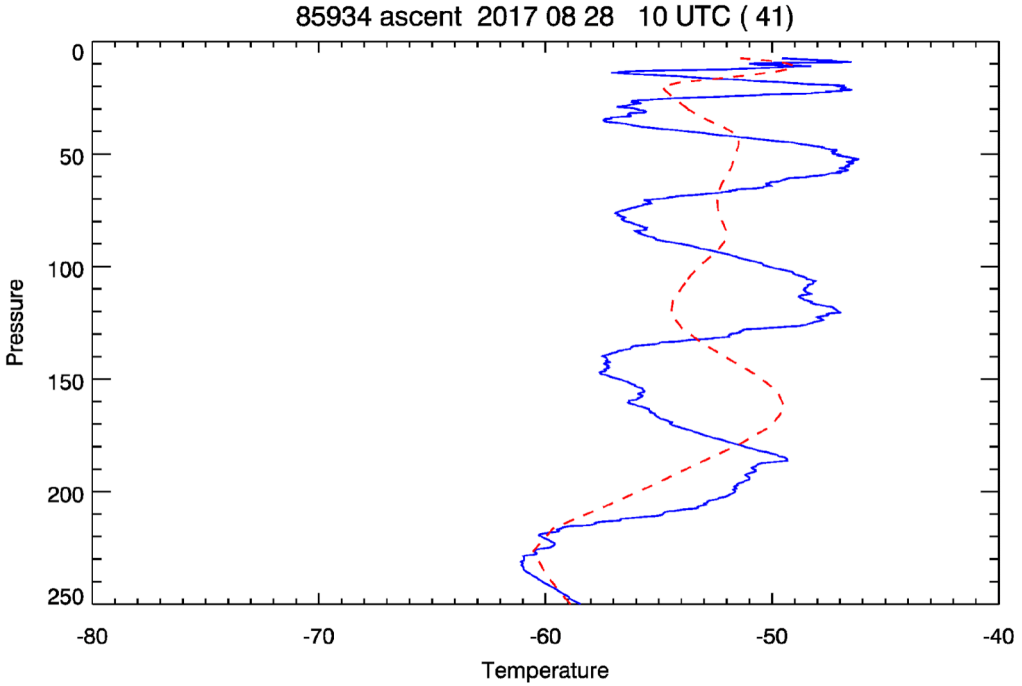

< 41°S

53°S >

HiRes sonde
Background

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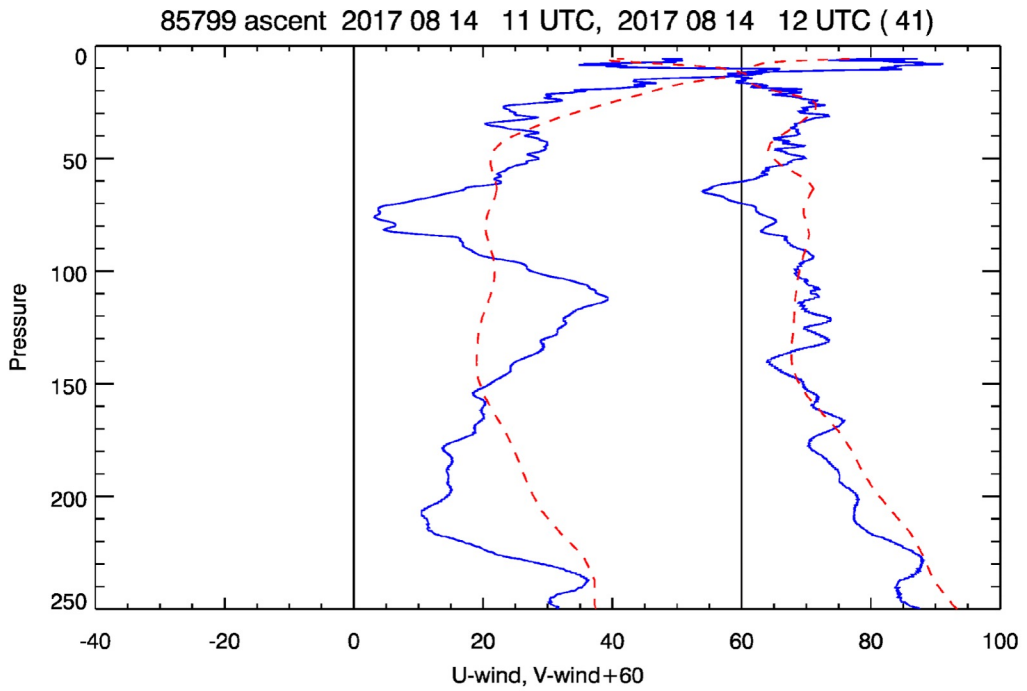
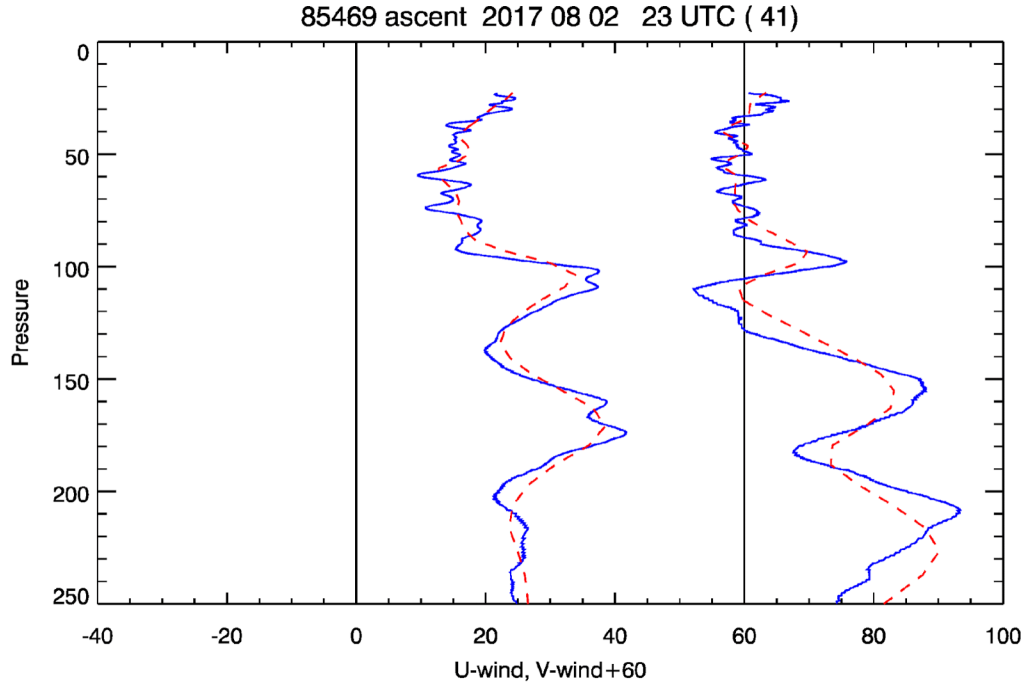
# Wind cases - Chile

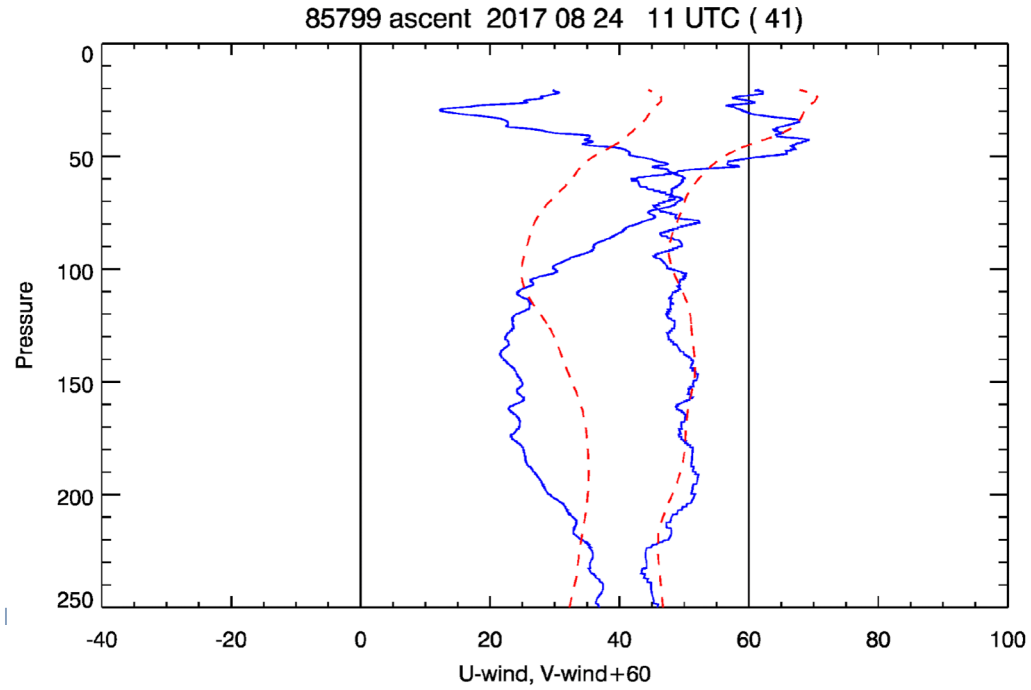
- Again background is OK in some cases but not others
- A challenge for data assimilation!

41°S >

Easter Island
27°S below



# Radiosonde descent data

- Vaisala ascents continue to provide very good quality data
- ECMWF assimilating RS41 descent data from German and ASAP stations (P>150)
- Expect to add more stations once there are ‘fall-rate’ corrections for T (and P) in Vaisala processing

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## On the quality of RS41 radiosonde descent data

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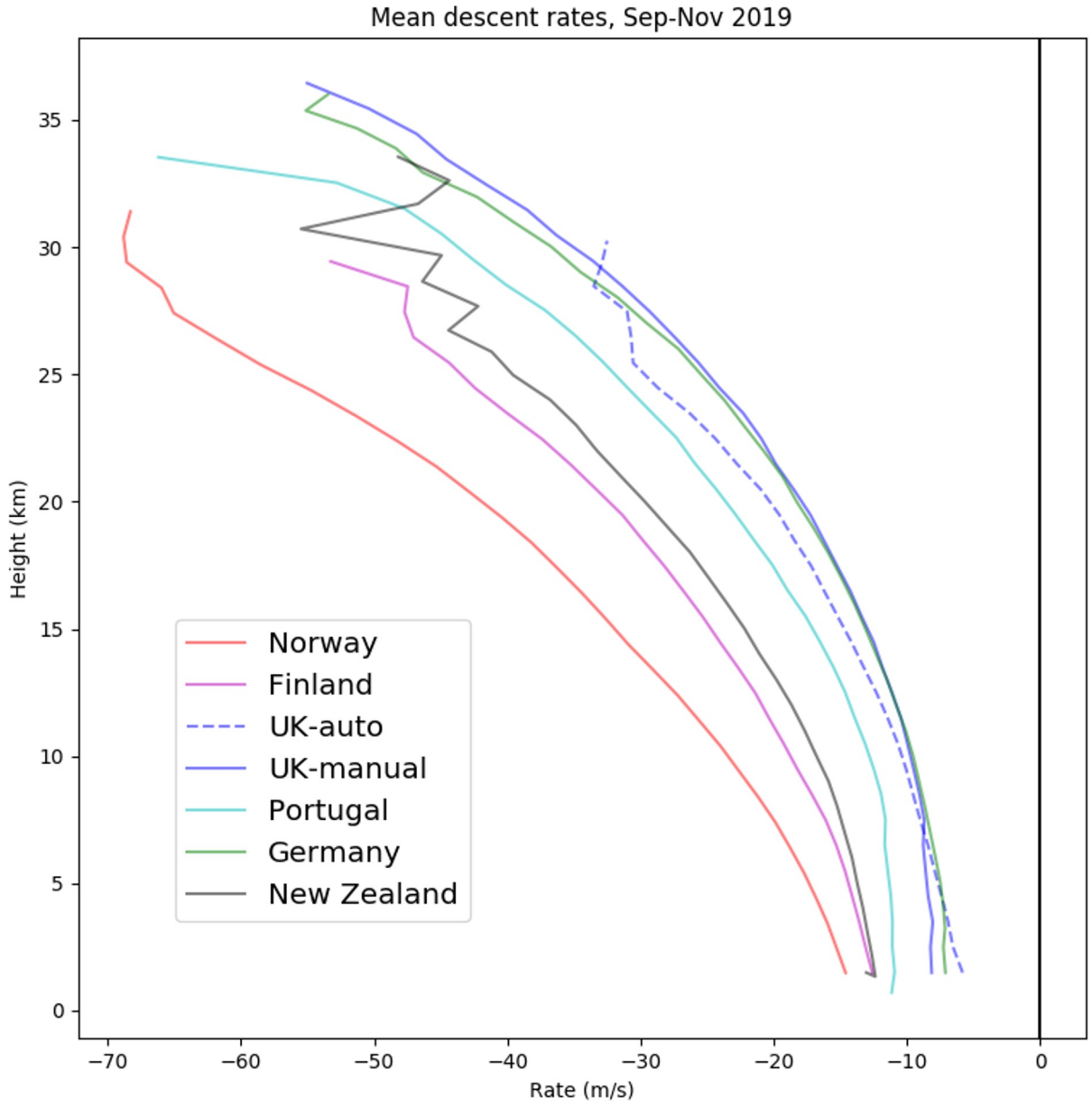
## Mean descent rates

Germany and UK use parachutes => slower fall rates, others don't.

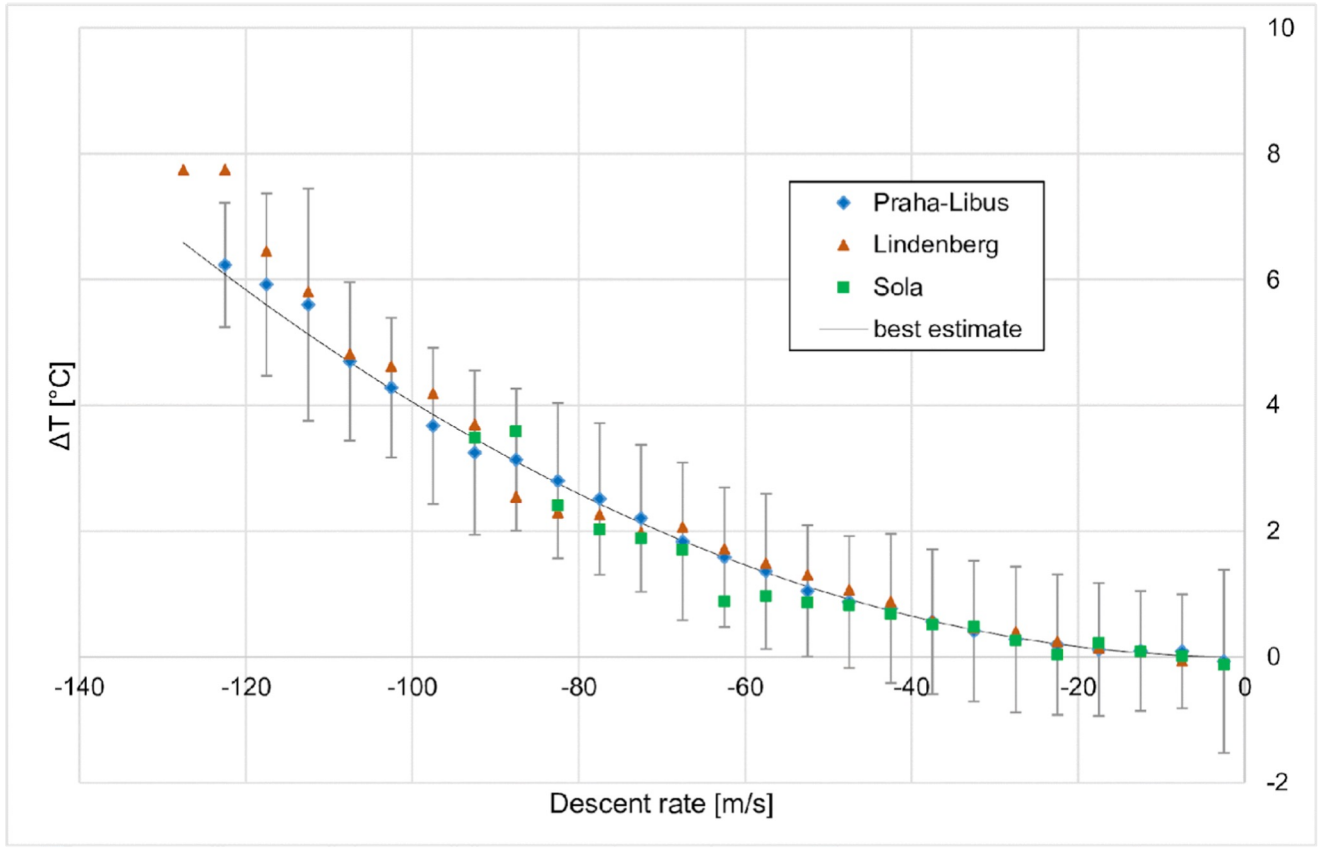
In some cases bigger balloons => faster fall rates (still remnants attached) but there are poorly understood aspects (eg intermediate rates for Portuguese)

Given large samples the mean profile looks smooth but this hides a lot of variability – not shown.



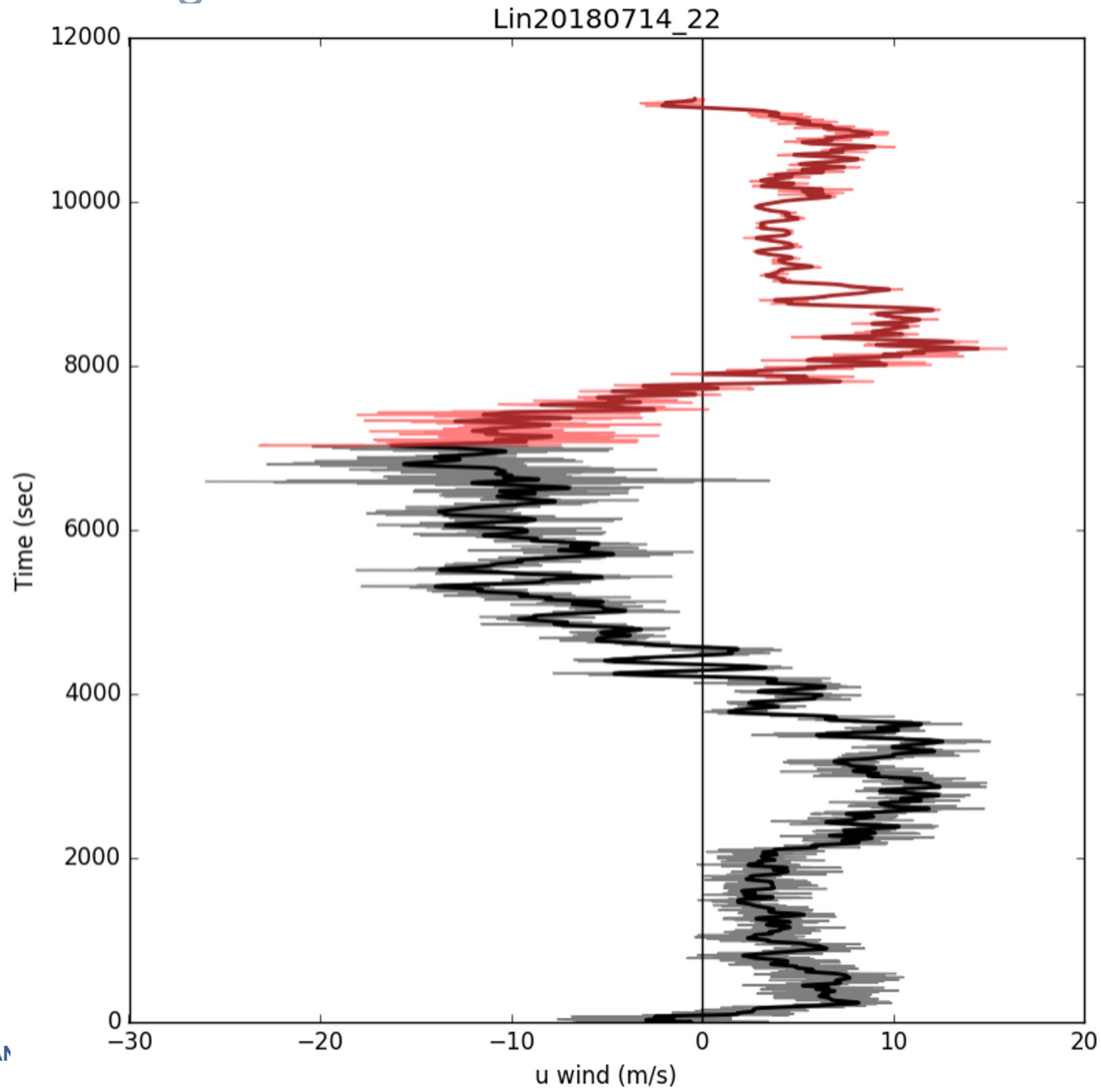
# Direct effect of fall rate on temperature

- Computed from descent-ascent pairs (by Martin Motl)
- Fairly consistent with/without parachute
- Analagous to kinetic heating of aircraft sensors (details vary)



# 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) – thin line raw data, **bold curves show filtered u wind** (data from Lindenberg)
- The noise varies …
- How much is signal?
- Some operational radiosondes seem to over-smooth.
- Less noise in troposphere for descents? Fits with w results.
- G Marlton: parachute descents



## Wind results

Mean (dashed) and SD O-B stats: std levels
Black: ascent, Red: descent

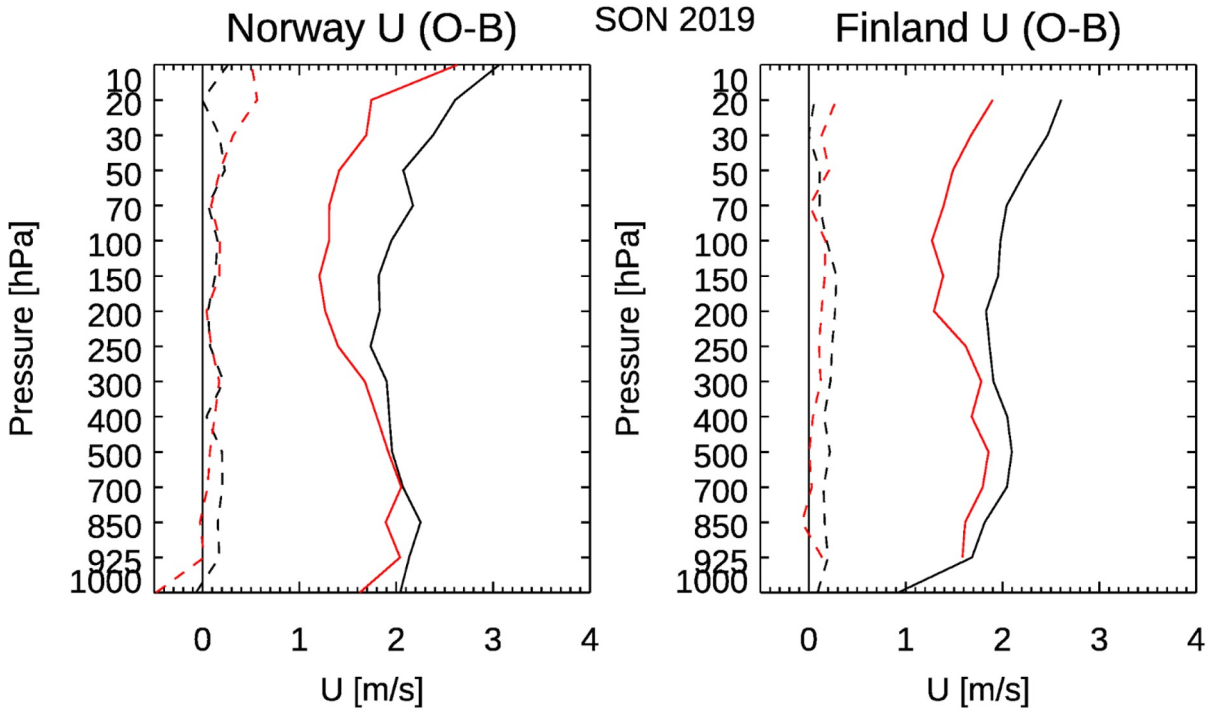
U shown (V similar, not shown)

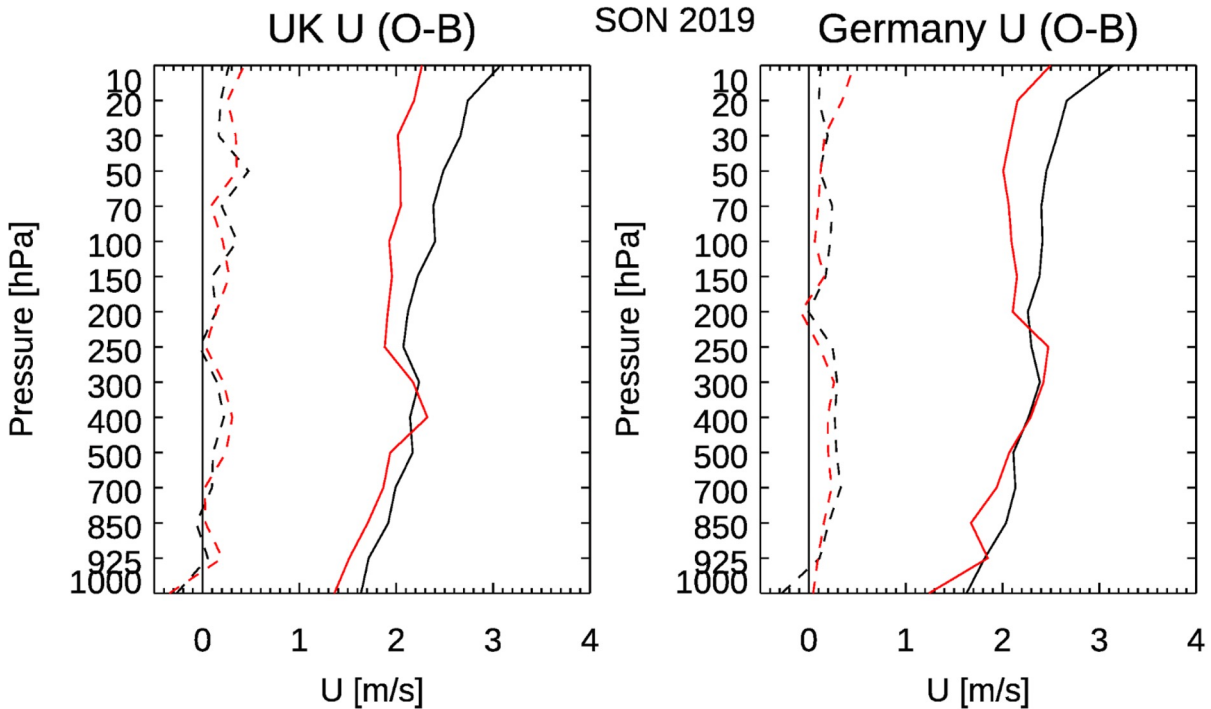
Descent winds are generally closer to the background than the ascent winds – especially at upper levels!

It seems that the descent winds are generally good quality and less susceptible to pendulum motion than ascent winds. ☺

Vaisala software applies smoothing (fn(time)) in the same way as for ascent – oversmooths? the profile, especially in stratosphere.

We don't have other observed wind profiles to compare with ☹ (radar wind profilers too coarse)



# The archive at NCEI

- https://www.ncei.noaa.gov/data/ecmwf-global-upper-air-bufr/ (separate NCEP link)
- Starts late 2014, one file per month (sent in my spare time!)
- Data in BUFR (WMO binary code), more-or-less as received over the GTS
  - Appended metadata from Aug 2019, PILOT & TEMP SHIP added again Jan 2020
- Decoder: https://github.com/ecmwf/eccodes (bufr_read_tempf example: F90 & py)
- Can have multiple reports from the same ascent
  - A) BUFR up to 100 hPa, B) full BUFR ascent ☺, C) TAC converted to BUFR ☹
- No quality control: eg occasional errors in launch position ☹
  - ECMWF appends positions from OSCAR/Surface https://oscar.wmo.int/surface/#/
- Descriptors (see https://confluence.ecmwf.int/display/TCBUF/Radiosonde+BUFR+templates )
  - 309050/051 PILOT, 309052/057 Ascent: 057 more metadata, more precision for T, Z
  - NB 309053 Dropsonde and 309056 Descent not in ECMWF NCEI archive (any call for them?)

# 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

# Short-term data rescue?

- Sometimes reports miss the GTS due to communication problems:
- 2016 Oden (ship): 120 radiosonde ascents in Arctic
- 2016 DACCIWA some routine+extra soundings in West Africa
  - Now in https://www.ncei.noaa.gov/data/ecmwf-global-upper-air-bufr/
- Late 2021 outage from Philippines after TC Rai
- Late 2021 ~2 weeks data from Mexico missing (IP problem)
- 13 April – 31 May data from Mexico missing (Cyber attack) HiRes not back ☹
- Other gaps.  TAC receipt better than BUFR from some NMSs

- There is no WMO or GCOS process to capture 'late' data – set one up?
- Would benefit climate users, reanalysis etc
- Historical data rescue well established (eg. ACRE)

# Summary

- HiRes data on the GTS has increased since late 2014
- Currently ~60% of stations send HiRes data
- WMO GBON requirement (100 m) will help
- Some subsets have variable quality ☹. Would log help?
- NWP background very useful for comparison ☺
  - Mixed performance on wave cases
- Descent winds smoother than ascent winds – which is better??
  - More research on radiosonde T and humidity than winds
- Notes on archive at NCEI and BUFR decoding tools
- Archive does not include dropsonde and descent data – any demand?
- NB. Data assimilation is my day job, the archive is a sideline

# Main references


•Dirksen et al, 2014: GRUAN data processing for the Vaisala RS92 radiosonde. *Atmos. Meas. Tech., 7, 4463-4490*

•Ingleby et al, 2016: Progress towards high-resolution, real-time radiosonde reports. *Bull. Amer. Meteor. Soc., 97, 2149–2161*

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