Evaluation of WindBorne data and problems with two radiosonde types

GRUAN ICM-16, Tenerife (BI remote), 25 November 2025

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ECMWF

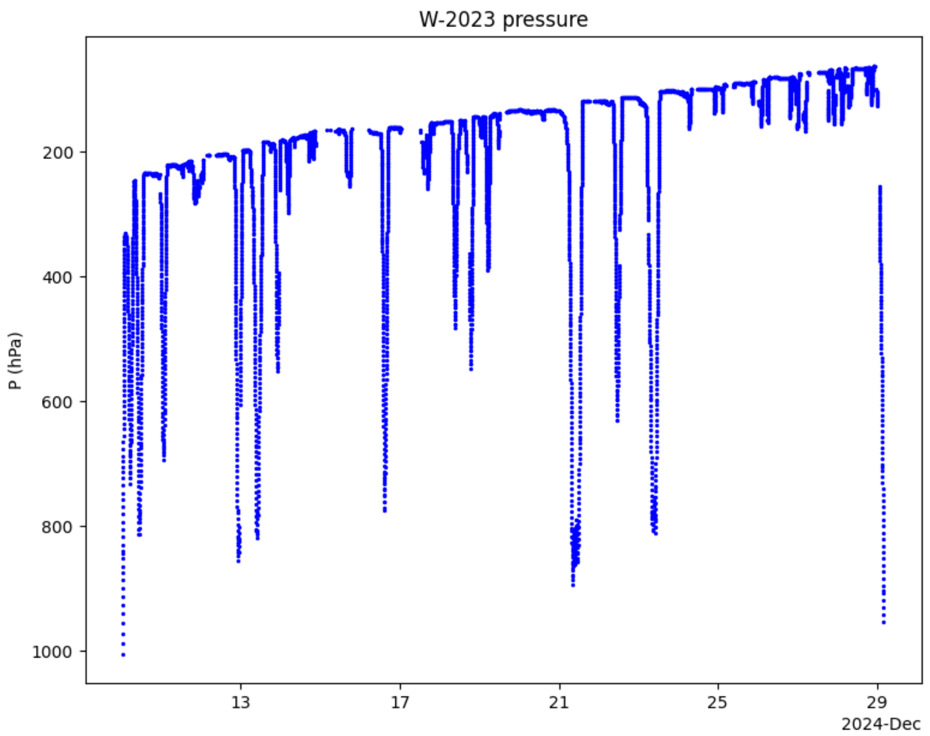
Overview

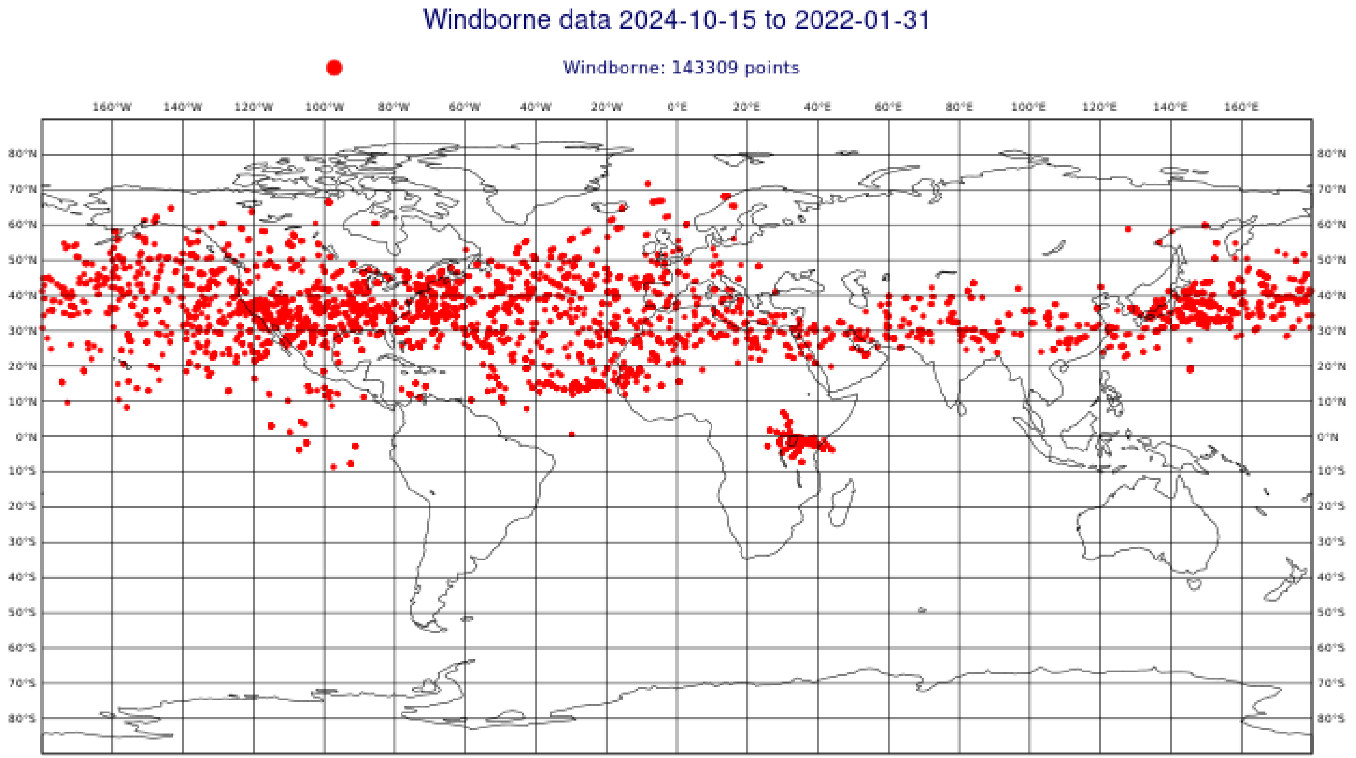
- Evaluation of WindBorne data and use of GNSS altitude as coordinate (4 slides)
- Problems with Weathex and Meteosis radiosonde data (8 slides)
- Summary

- Other radiosonde news from ECMWF:
- Aug 2024 use of all RS41 descent wind profiles (TECO-2024 poster)
- May 2025: ECMWF Tech memo 926 issued “Diagnostics of radiosonde uncertainties” (work produced for GAIA-CLIM in 2018)
- QJRMS (under review) paper on stratospheric seasonality and its implications for radiosonde requirements
- 2026 ECMWF will switch on humidity assimilation in the lower stratosphere (Noureddine Semane), including use of RS41 humidities up to 60 hPa

WindBorne data

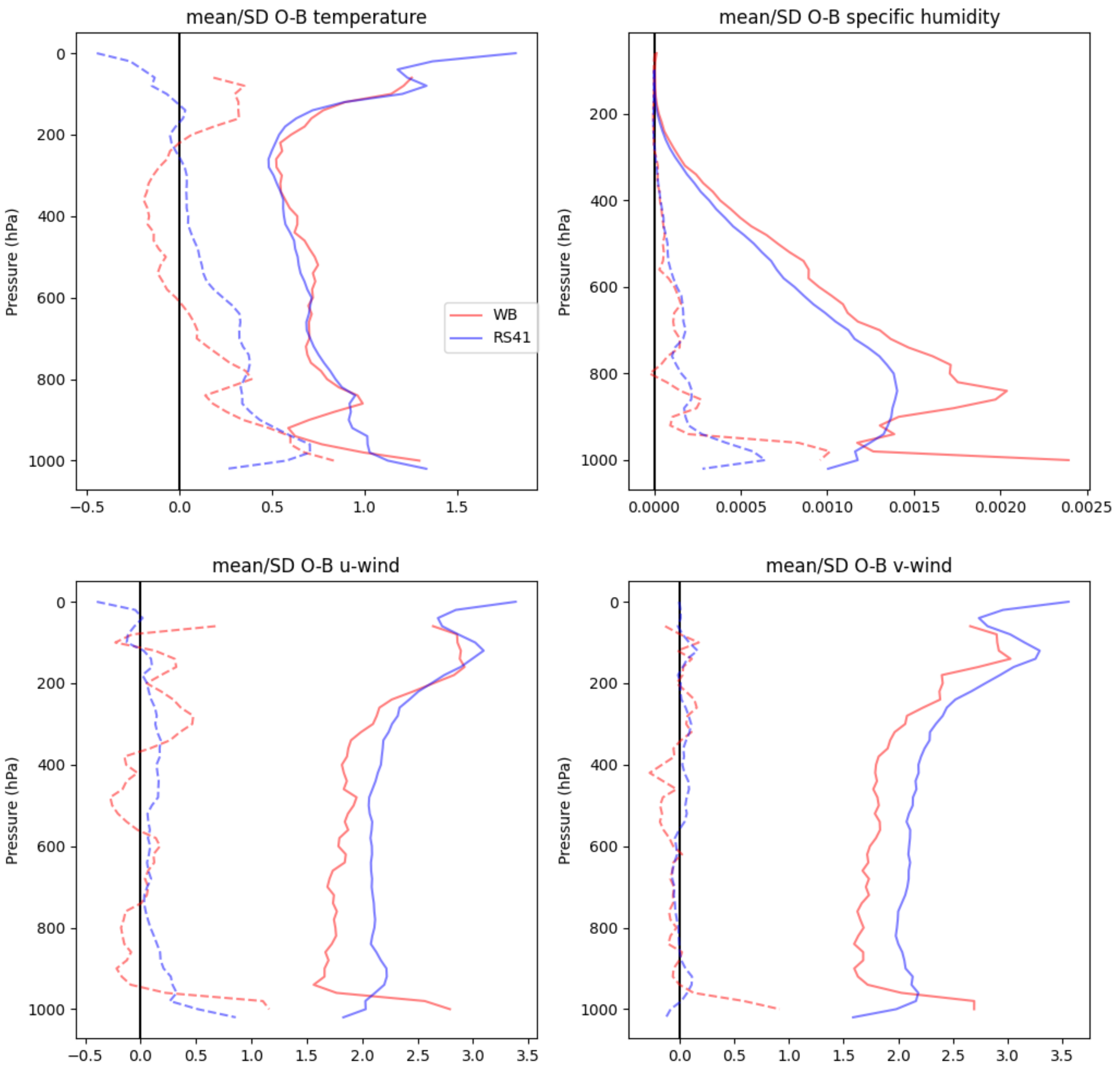
- WindBorne (GTS from June 2024), numbers smallish but some oceanic coverage
- Balloon but can make multiple ascents and descent and last up to ~20 days
- Treated as honorary aircraft; so far impact small and mixed



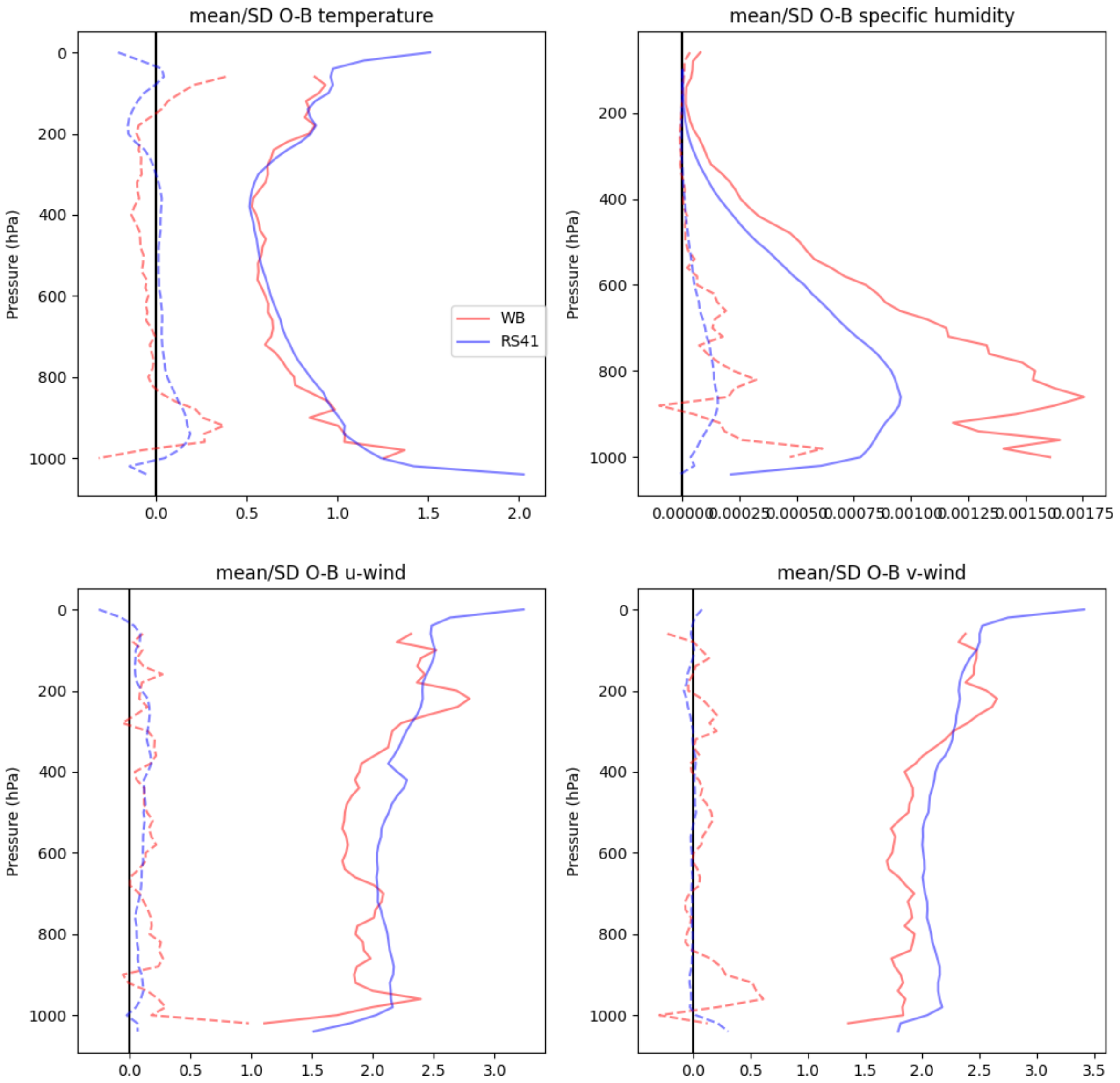


WindBorne O-B stats vs RS41 in two latitude bands

WindBorne, 30S - 30N, 6 Aug - 30 Nov 2024 (iiov)



WindBorne, 30N - 90N, 6 Aug - 30 Nov 2024 (iiov)



Pressure and GNSS altitude uncertainties

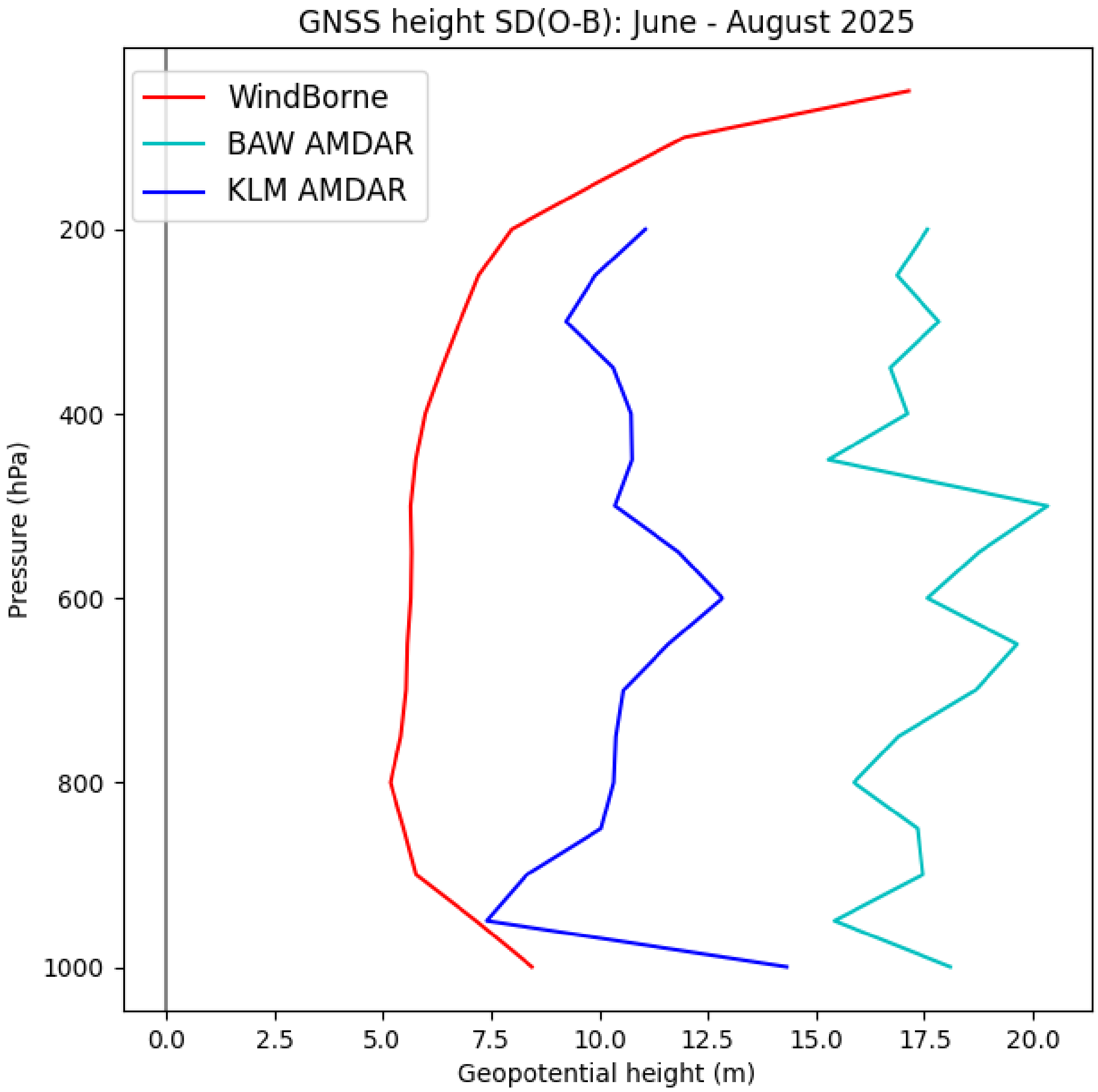
- RS41-SGP pressure error ~ 0.2 hPa (Sommer et al, 2023, GRUAN)
- WindBorne pressure error ~ 0.2 hPa (Jake Spisak, pers. comm.)
- Aircraft pressure error ~ 1 hPa at best (WMO No 8)
  - Aircraft disturbs the air pressure nearby
  - Measures both dynamic and static pressure
  - Errors larger in static pressure ☹, Gratton, 2018
  - Constraint is the use of flight levels with 1000 ft spacing (RVSM)
    - Static pressure from 2 or 3 different ports should agree within 200 ft (Aviation News) ☹
  - Also issues from rounding in older AMDAR software (next slide)

- In 2023 my guestimate of GNSS altitude error was 10 m
- With WindBorne O-B stats my estimate is now ~5 m
  - Similar for WindBorne and aircraft and ~independent of height (up to 40+ km)

Height O-B statistics – Std Dev

- Exclude points with |O-B| > 70 m
- Best stats are for WindBorne
- SD(O-B) ~6m, 950-300 hPa
- Bias small (not shown)
- Next best KLM SD ~11m
- Then BAW SD ~18m, large bias
  - Larger SD due to flight level rounding ☹

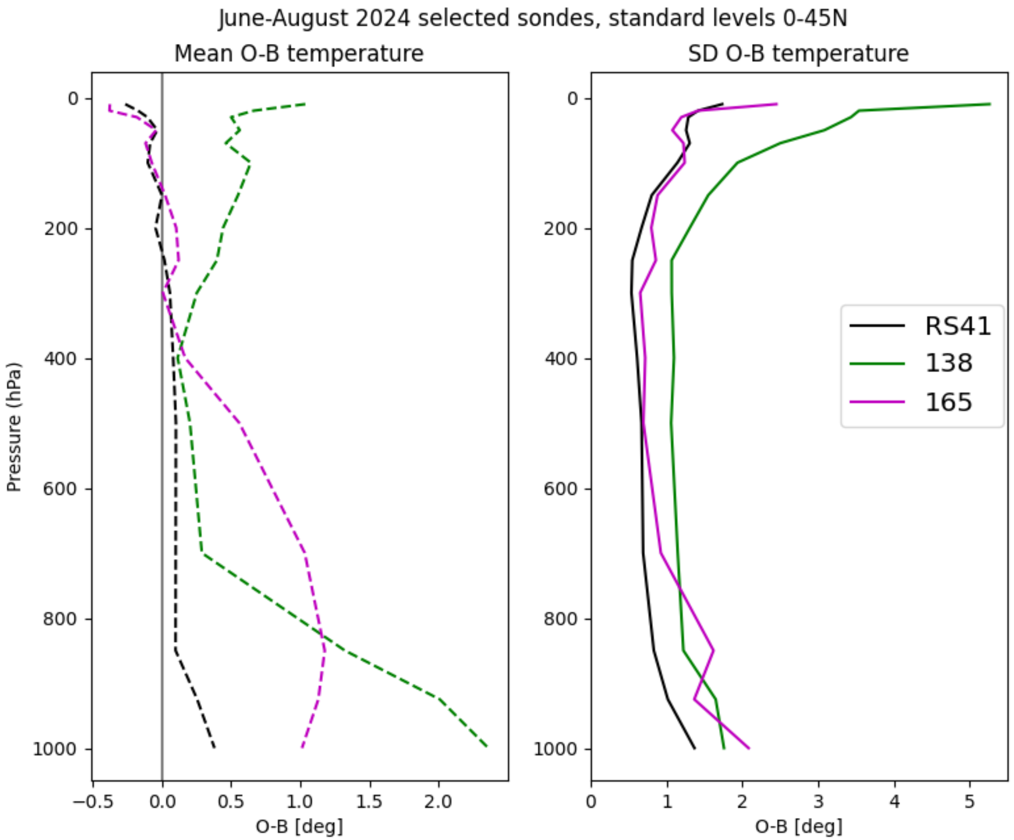
- GNSS height errors should be similar (approx. 5m?)
- Main differences come from pressure errors (more difficult at 250 m/s) …

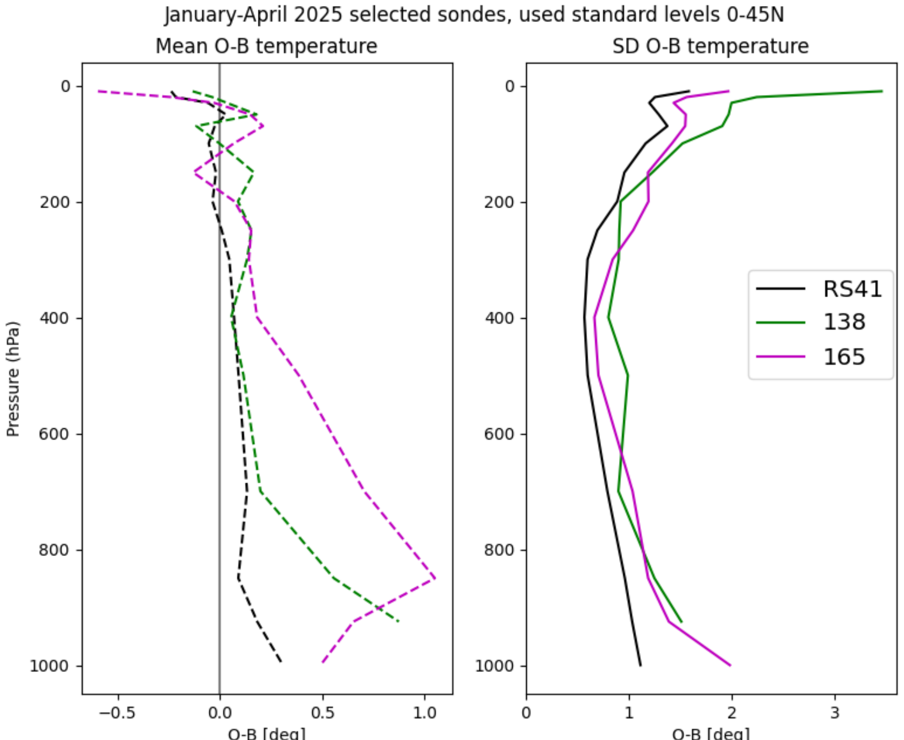


SONDE PROBLEMS ☹, T O-B stats

- JJA 2024 (right), presented at TECO 2024
- RS41, Weathex (138), Meteosis (165)

- Still problems after blocklisting the ‘worst’ subsets
- Jan-April 2025 (below)





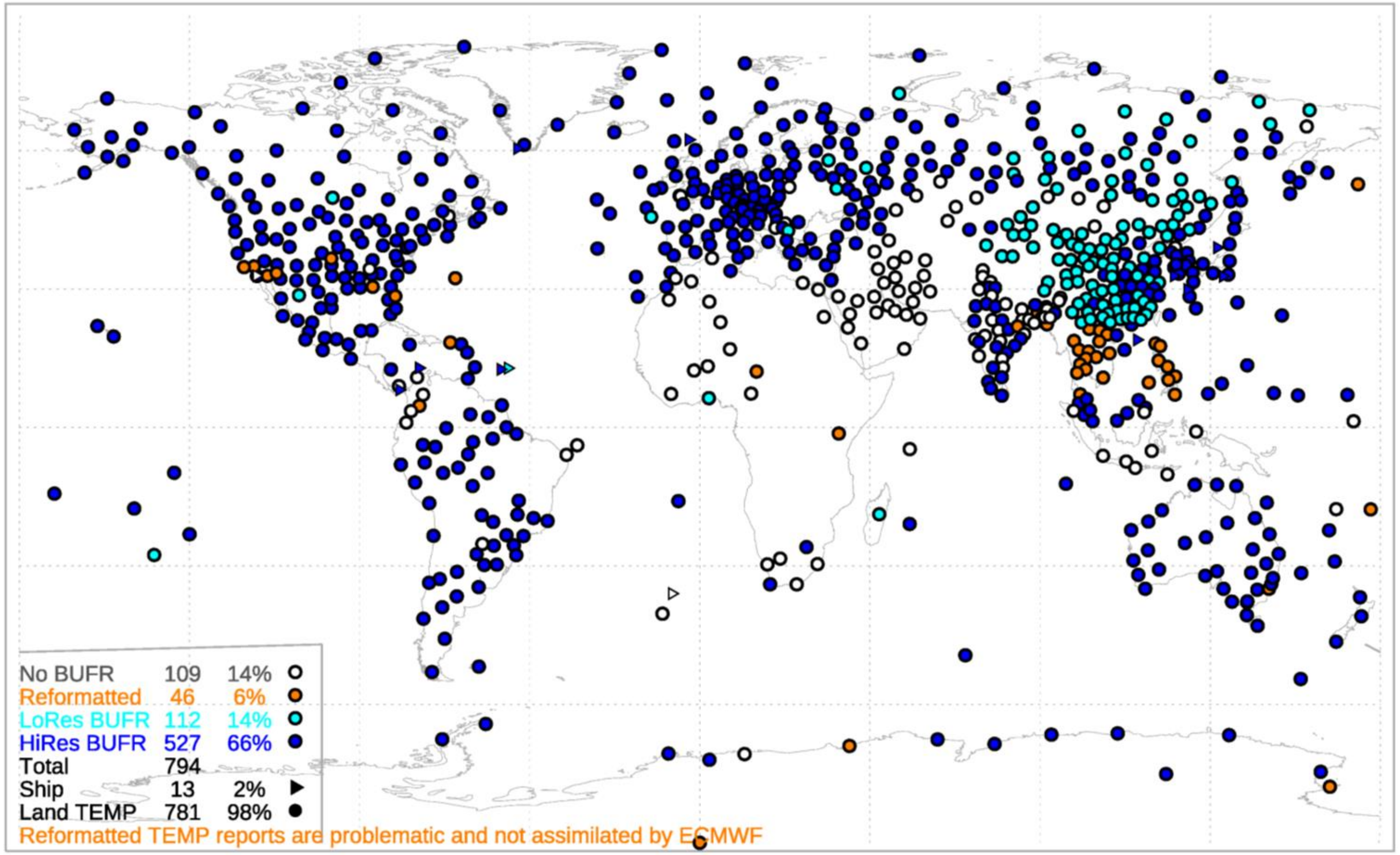
Weathex 138 (Korea) used in India and Malaysia
- Wrong wind units in BUFR (fixed)
- BL T biases and sometimes oscillations
- Some junk profiles, bad P => bad winds

Meteosis 165 (Turkiye)
- Low level T problems (GPS interference?)

Migration to BUFR is still incomplete ☹

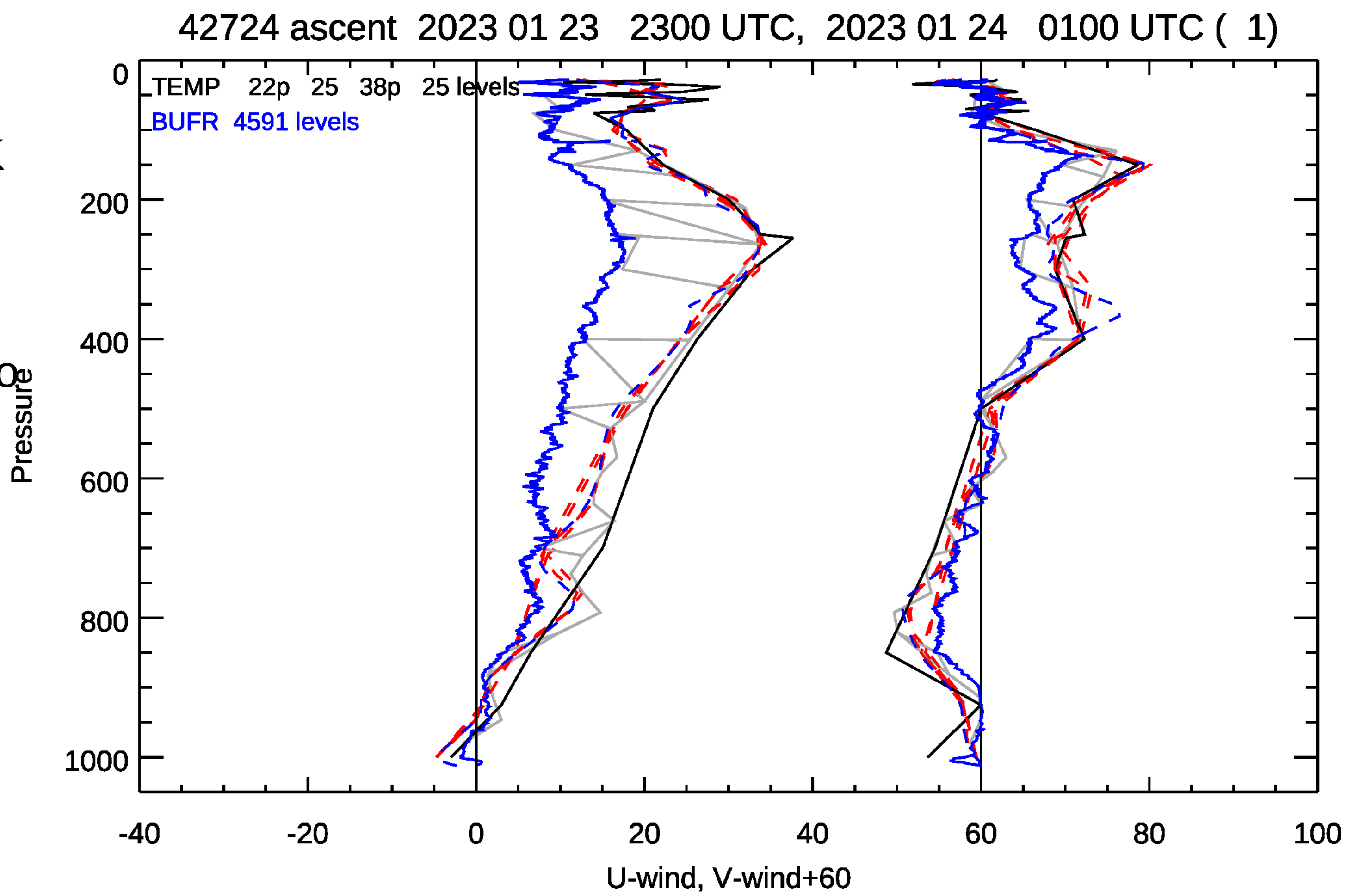
- 20% of stations are still not providing good BUFR (empty O – no BUFR 14%; orange O – TAC reformatted as BUFR)
- WMO plan – migration complete in 2014!
- LoRes BUFR (less than 300 levels, 14%)
- "HiRes" BUFR (more than 300 levels, 66%)
- In some cases (inc. India) the BUFR data is patchy – comms problems?
- Early 2023 I was looking at whether to 'switch on' use of BUFR data from Indian stations

October 2025: Radiosonde BUFR availability/type



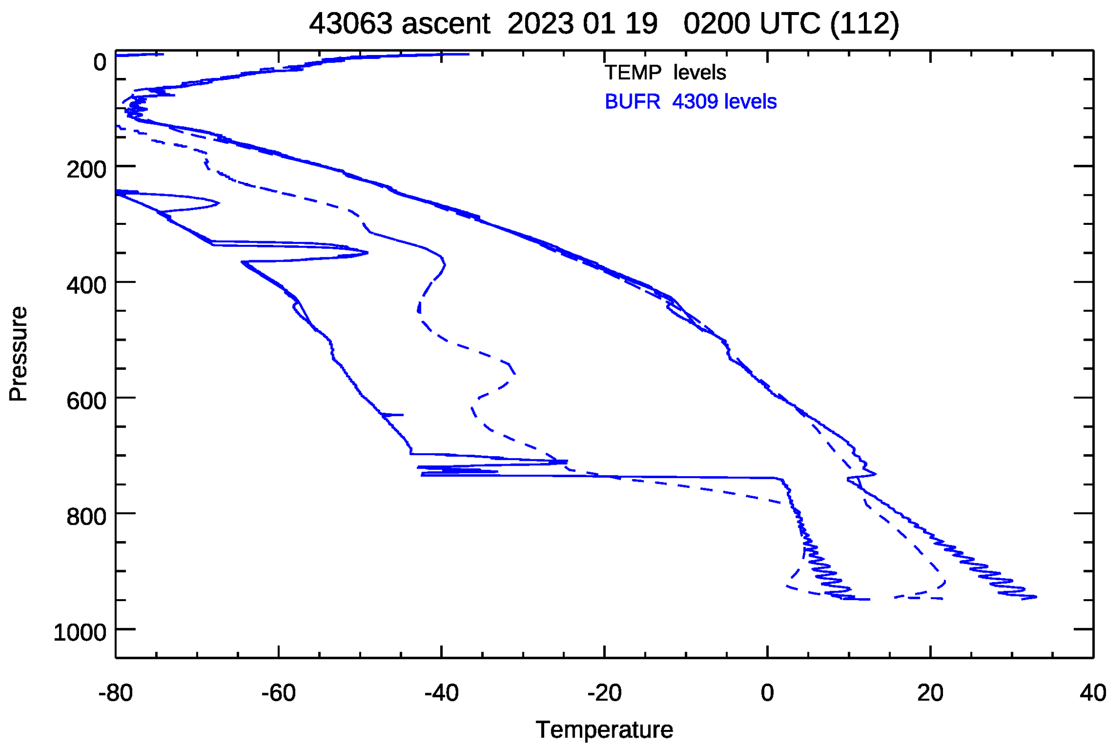
Wind problem in BUFR, case from Jan 2023 (India)

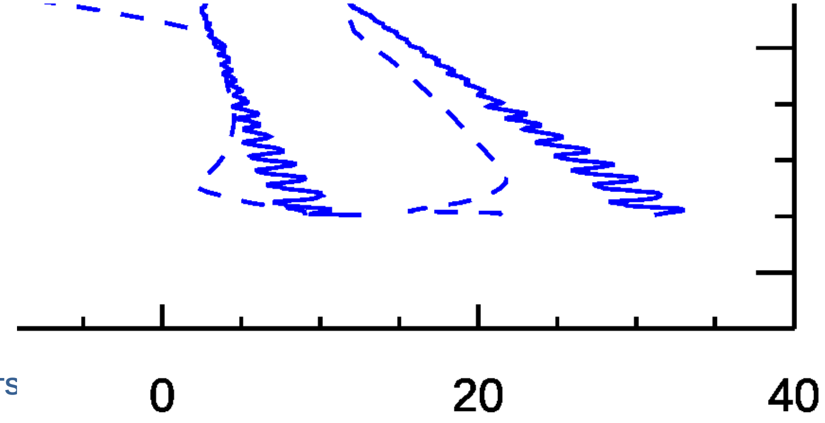
- Dashed lines (blue/red) ECMWF background (U&V)
- Solid black line – TAC TEMP report, OK
- Solid grey line – TAC PILOT report (sig. levels wrong)
- Solid blue line – BUFR TEMP report, too weak by factor of ~2 (units problem?)
- Problem reported to India Meteorology Department (IMD) early Feb 2023
- Weathex: “the winds are in knots”
- BI: “in BUFR the winds must be in m/s” (Nov 2023, problem solved soon after)
- Malaysia also using Weathex sondes, BUFR winds too strong: km/h), but mostly speeds are low – problem less clear cut



Boundary layer oscillations in temperature (India)

- BUFR only example: T and Td plotted
- Intermittent problem, cases from Jan 2023 reported to IMD early February
- IMD/Weathex reported it as ‘fixed’ a few months later – frequency reduced but cases were still seen
- As with low-level biases (next slide) Weathex suggest that the problem is worse at temperatures over 20 or 25C – but no real explanation



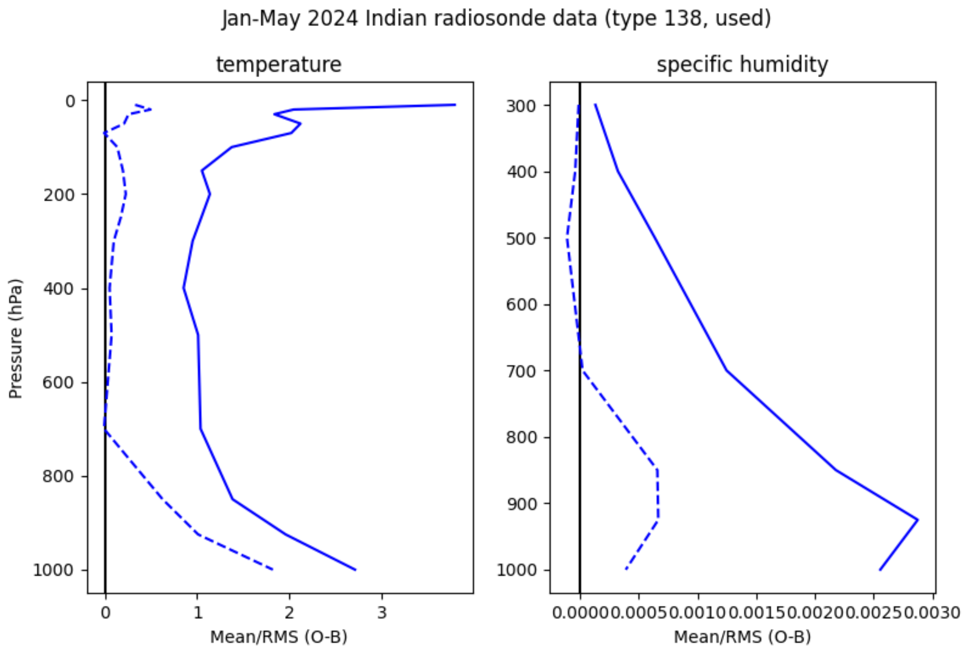


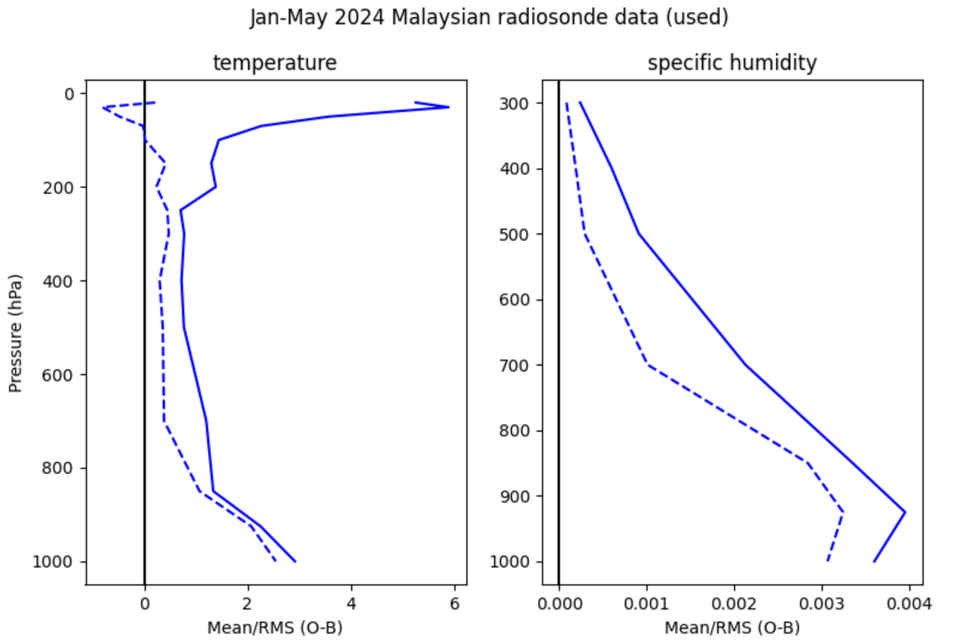
Low level temperature biases (1-2 degrees)

May 2024 Günther Zängl (DWD) got in touch with ECMWF asking about biases in Indian and Malaysian temperature profiles.
We saw “at 925 hPa there is a bias of about 1 degree relative to the ECMWF background at Indian stations and for Malaysia it is about 2 degrees”. Put low-level rejections into ECMWF data selection.
- See dashed lines on left-hand plots.

NB. We do not regard ECMWF background as “the truth” but it is useful for detecting large/gross errors in radiosonde profiles.
Background errors are larger in boundary layer (BL) than free troposphere, but the data are still useful.

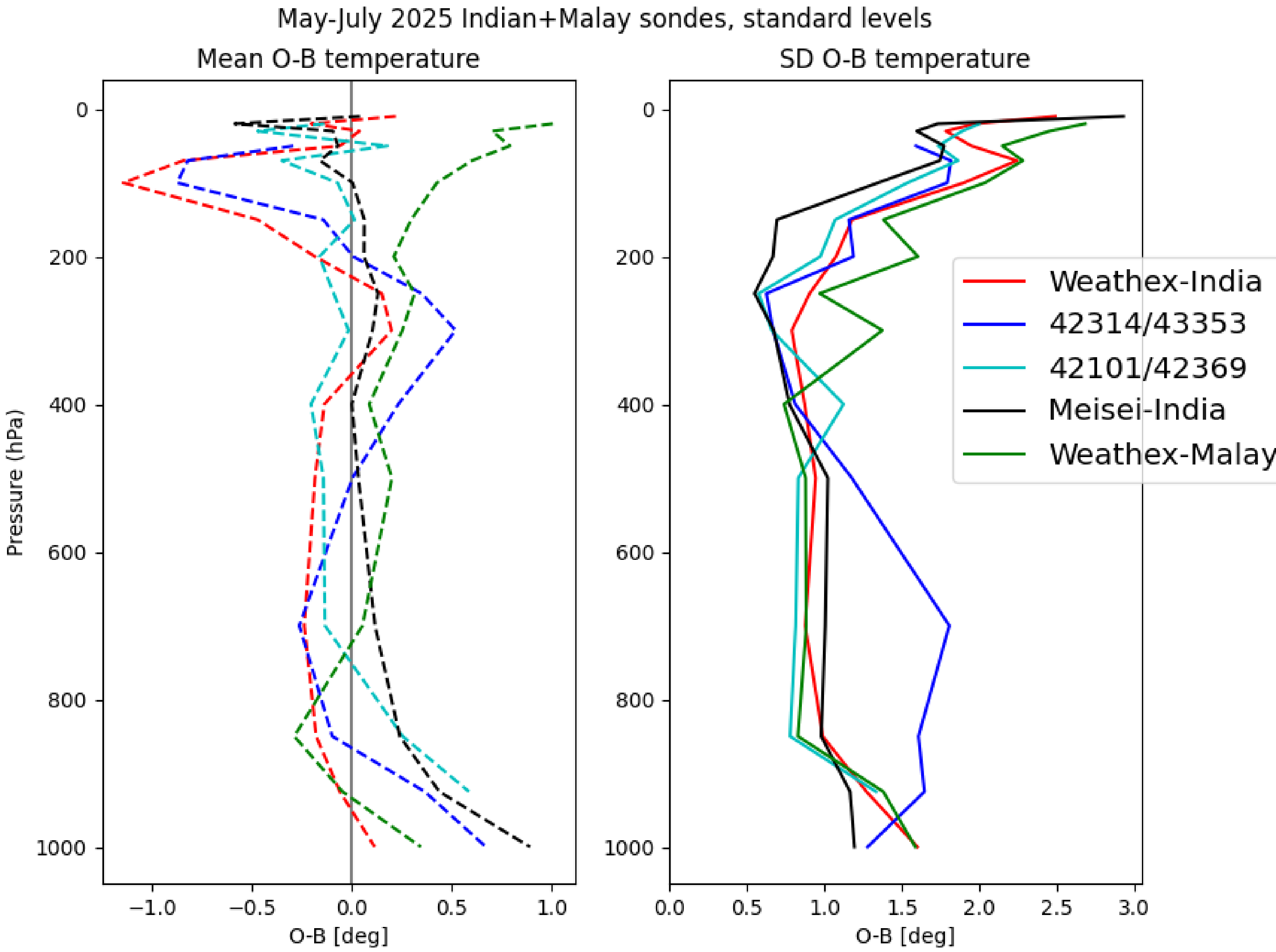
WIGOS Data Quality Monitoring System (WDQMS) had not spotted the problem: the bands (1000-100 hPa) and thresholds were too large.





Low level temperature biases from Weathex II

- Initial Weathex response was to deny that there was a bias problem
- I pointed to the use of B in observation monitoring – inc. TECO 2022 preprint
- Weathex made a software 'fix', just fn(T) to make it fit ECMWF background better ☹
- I think they may have over-corrected the data, see red Weathex-India vs black Meisei-India (O-B on left – dashed)
- In parallel I ran an experiment (winter 24/25) removing all Weathex and Meteosis temperature and humidity (not just low levels) results better – implemented July 2025.
- I told IMD/Weathex/Turkiye – Weathex very unhappy.



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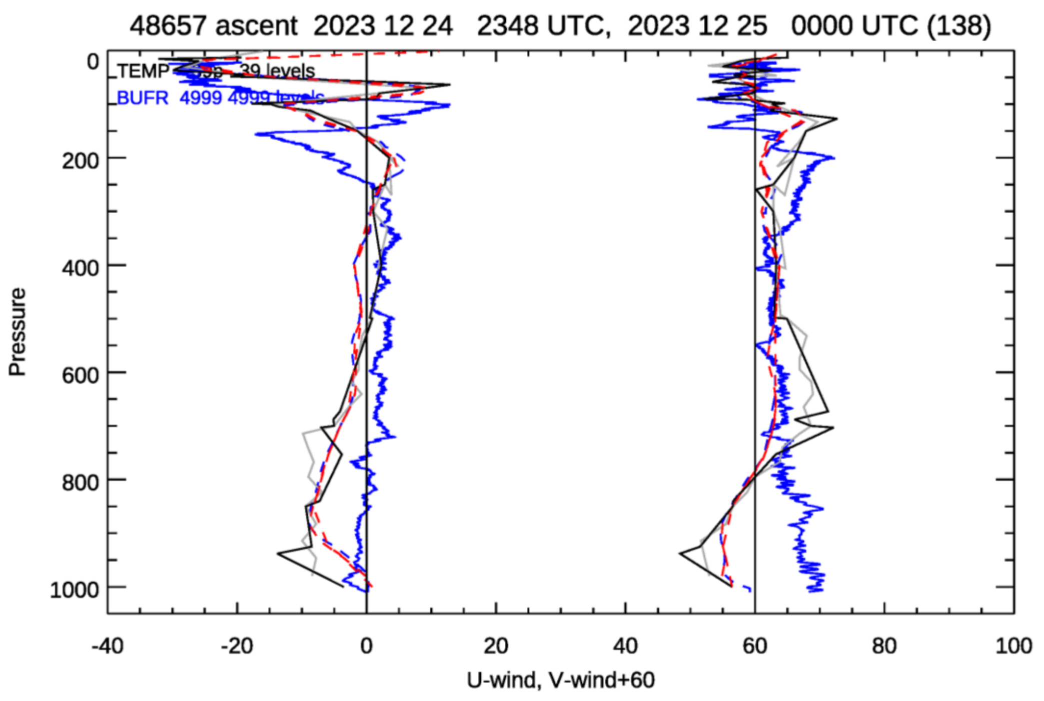
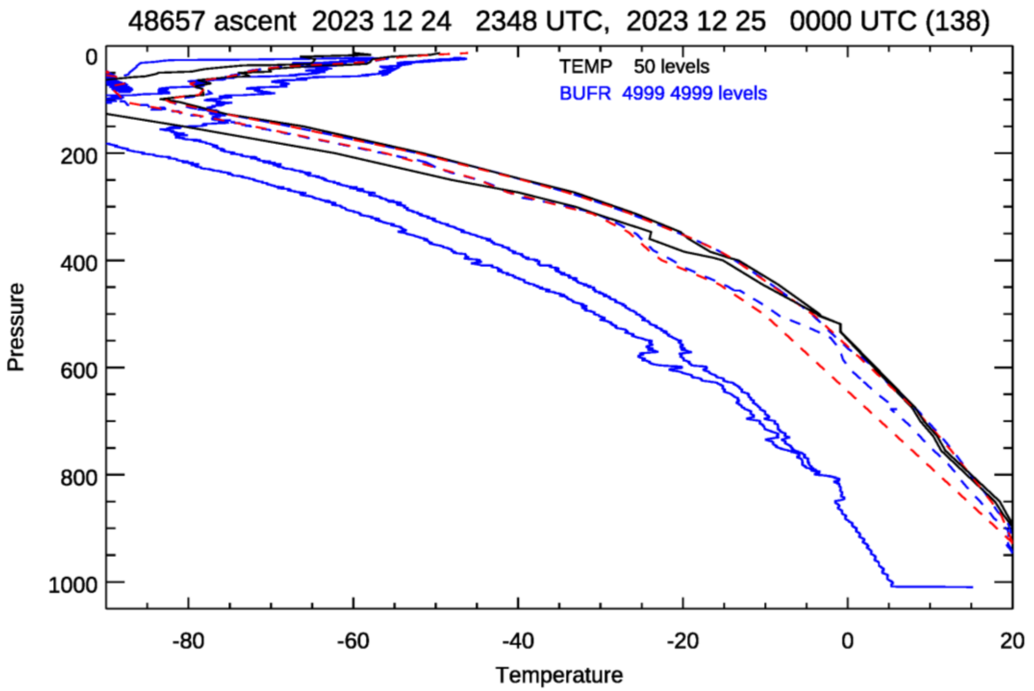
Weathex: linked temperature/pressure issues

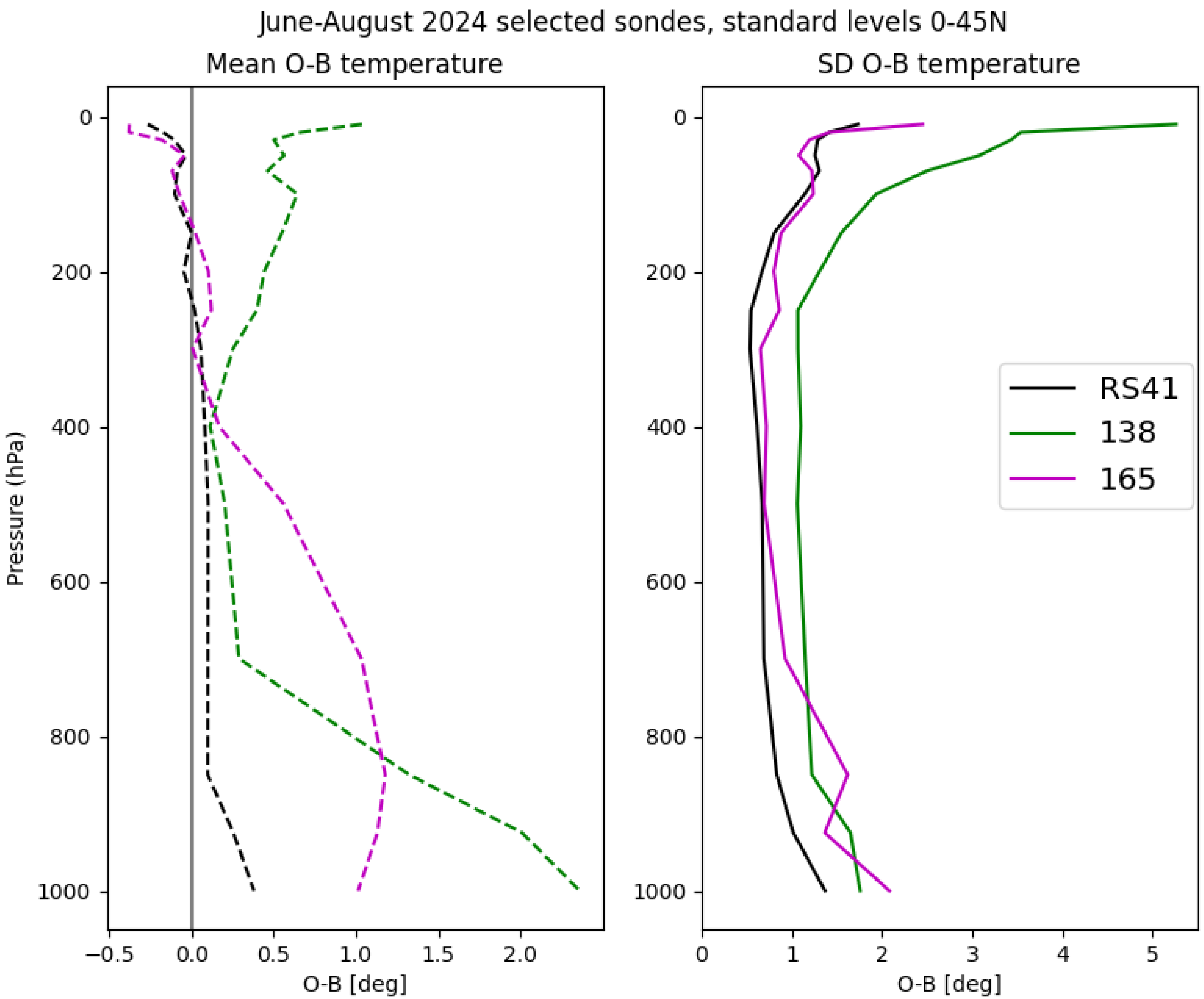
- There are occasional wind profiles (top) where the maxima and minima are offset in the vertical relative to the background
- These appear to be linked to very large temperature errors (below)
- I think the bad temperatures are being used in a hydrostatic calculation: hence giving bad pressures ☹





Problem with Turkish temperatures in lower troposphere

- In August 2024 looking at impact (FSOI) diagnostics I came to suspect a problem at Turkish stations
- They use new Meteosis radiosonde (165)
- The problem was notified to Turkiye and WDQMS – not resolved, data rejected at ECMWF
- Is this related to GPS spoofing or not?



Summary

- WindBorne data looks generally good (Q about humidity), data on GTS monitored operationally since May 2025
- Impact is mixed, ~ neutral (also seen with other smallish subsets)
- Possible use of GPS altitude as vertical coordinate for aircraft and some radiosonde profiles in future

- Weathex radiosondes (used in India and Malaysia): a catalogue of errors noted since early 2023, some fixed. Low level temperatures overcorrected? without clear explanation.
  - Hypothesis that ‘bad’ temperatures are more damaging to NWP in the tropics than the extratropics
- On positive side India now uses Meisei radiosondes at 12 stations
- Turkish (Meteosis) temperatures too high in lower troposphere
- <u>Monitoring is needed</u>: difficult choices on which subsets to monitor
  - Large subsets – can miss problems, Small subsets – too many false alarms.

Summary of radiosonde usage in countries discussed

- Turkiye
  - Q1/Q2 2022 Graw DFM-17 (154), from ~2022-09 Meteosis MTS-01 (165)
- Malaysia
  - 2022-04 to 2023-04 Graw DFM-17 (154), then Weathex WXR-301D (138)
- India
  - TAC reporting of RS type is often wrong, and BUFR reporting is patchy ☹
  - 2022 Some Graw DFM-9 (17), a few Weathex (reporting as 21 JinYang)!
  - 2023 Graw being replaced by Weathex WXR-301D (138, eventually)
  - 2024-09 11 stations using Meisei iMS-100 (135), 27 using Weathex, 4 using new Indian types
- Slightly simplified for presentation