Stratospheric seasonality and its implications for radiosonde requirements

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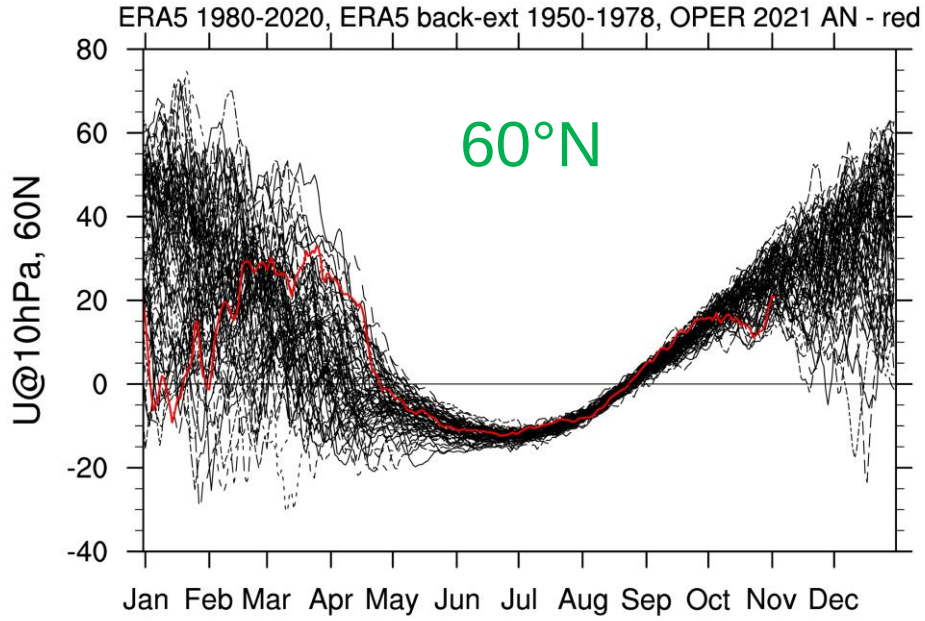
ECMWF

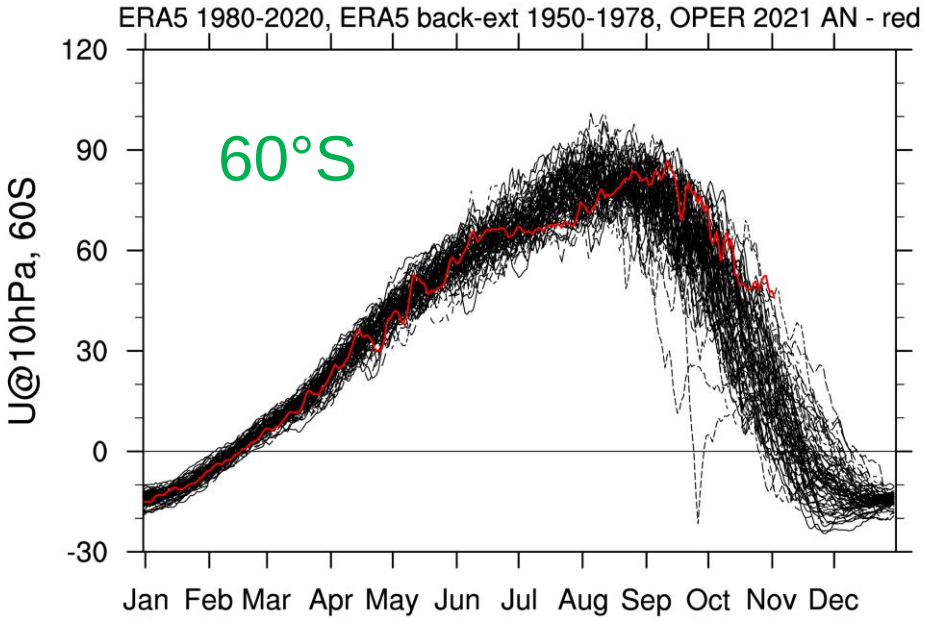
Overview

- Background: WMO (GBON) and EUMETNET requirements
  - In terms of density of observations needed reaching 30 and 10 hPa
- Stratospheric seasonality
  - Very large especially 45-90°N (1/4 of global radiosondes)
  - Not new, but ERA5 reanalyses provide unprecedented detail/confidence
- Estimates of radiosonde impact on global NWP
  - Seasonal cycle and vertical profile
- GBON and current radiosonde reporting
- Summary

U10 hPa @ 60°N, 60°S

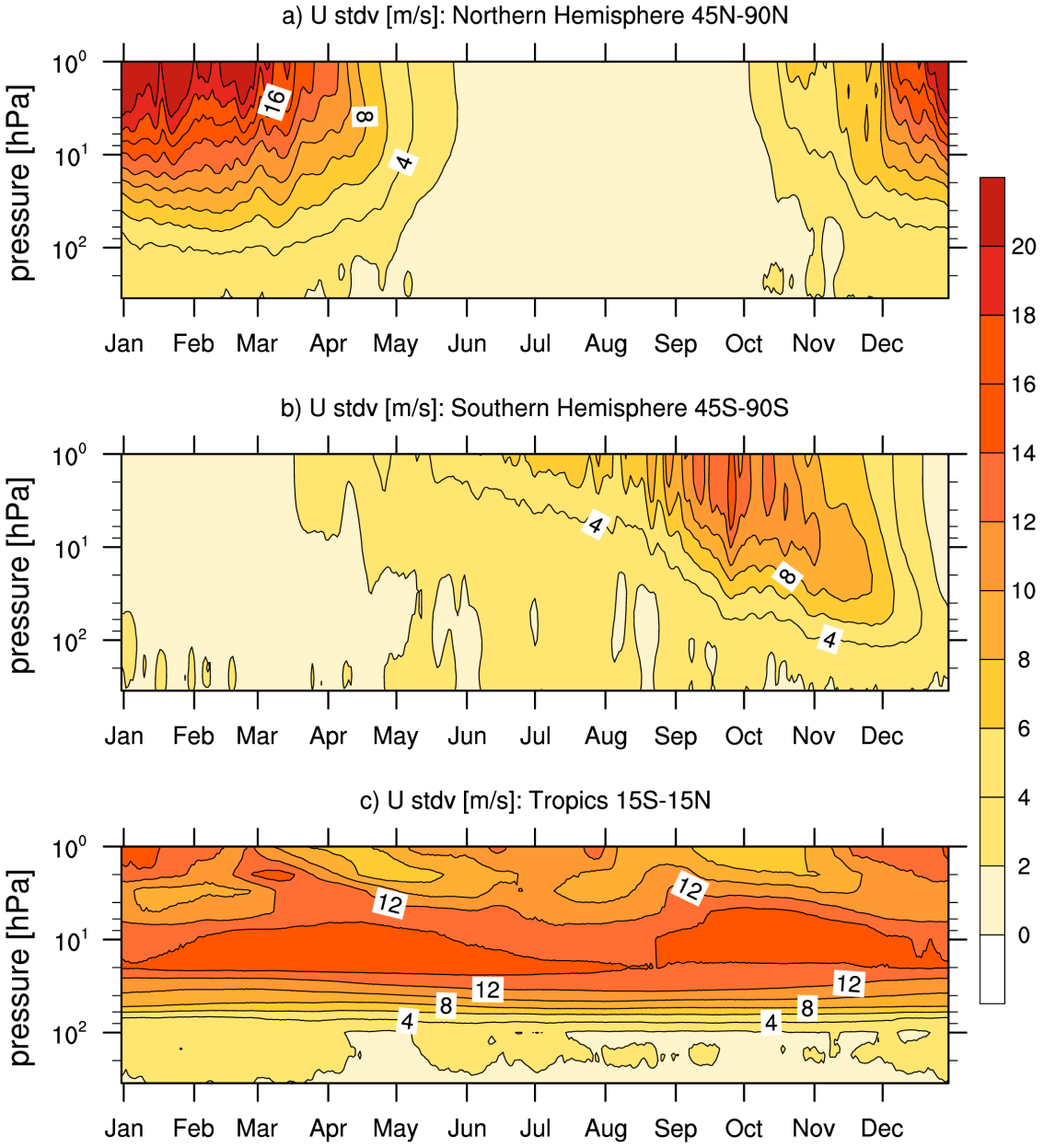
- Different years plotted 1950 to 2021
- Data from ERA5 (Hersbach et al, QJ, 2020)
- Winter: strong polar vortex
- SH vortex stable except when breaking down in Austral spring
- In NH winter planetary waves disturb the polar vortex
- Largest disturbances form stratospheric sudden warmings (SSWs)
- In summer there are about 4 months when nothing much happens – except a few gravity waves





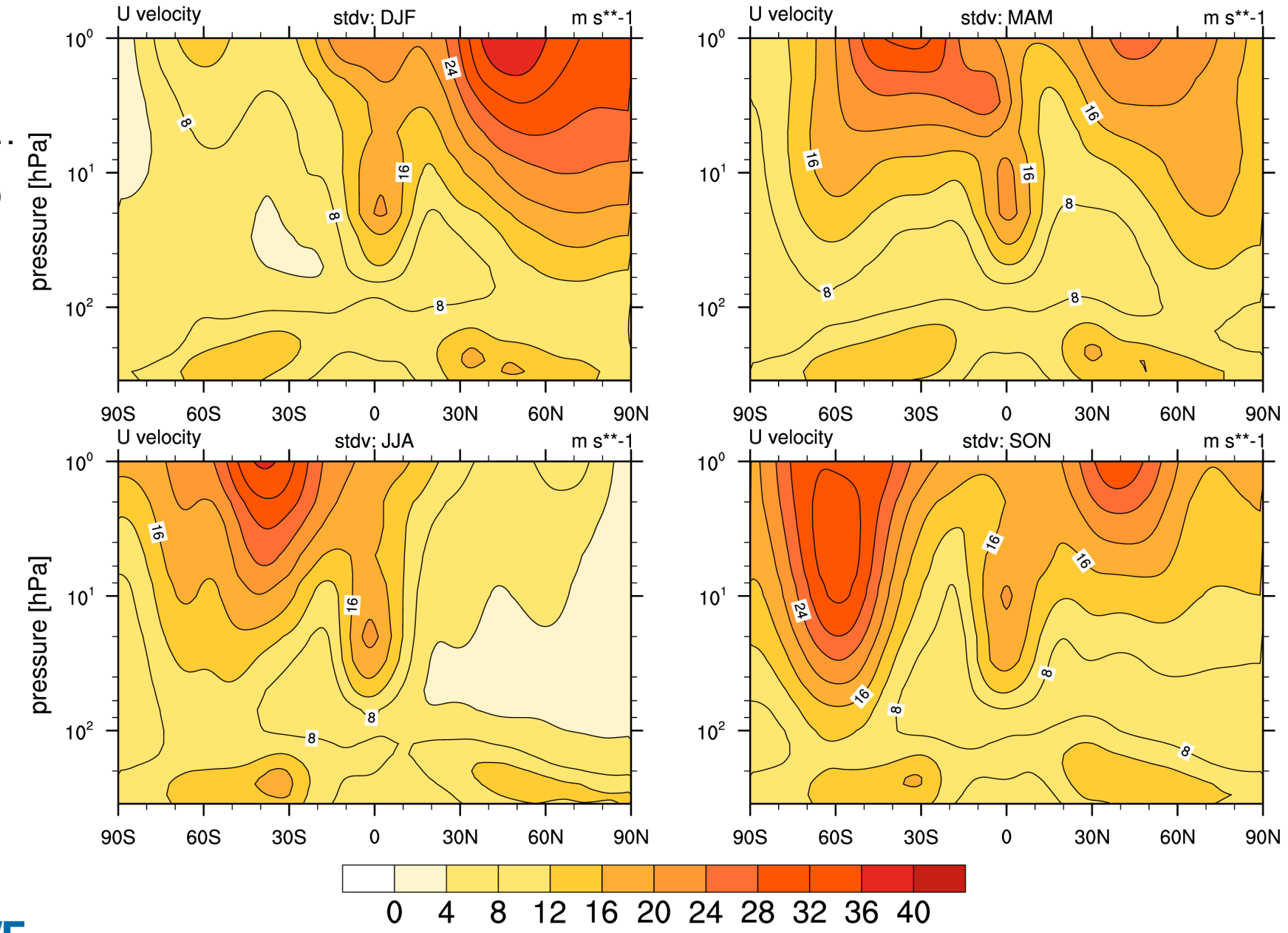
ERA5 U variability 1979-2020

- Seasonal cycle removed first
- Then standard deviation calculated
- Some downwards propagation, visible in SH
- Evidence for stratospheric influence on tropospheric developments is mainly limited to (NH DJMF) winter and (SH ONDJ) spring
- Temperature variability is qualitatively similar (not shown)



SD vs latitude

- Plots by ‘season’ DJF…
- At 1 hPa enhanced SD closer to equator: ~ 25° cutoff



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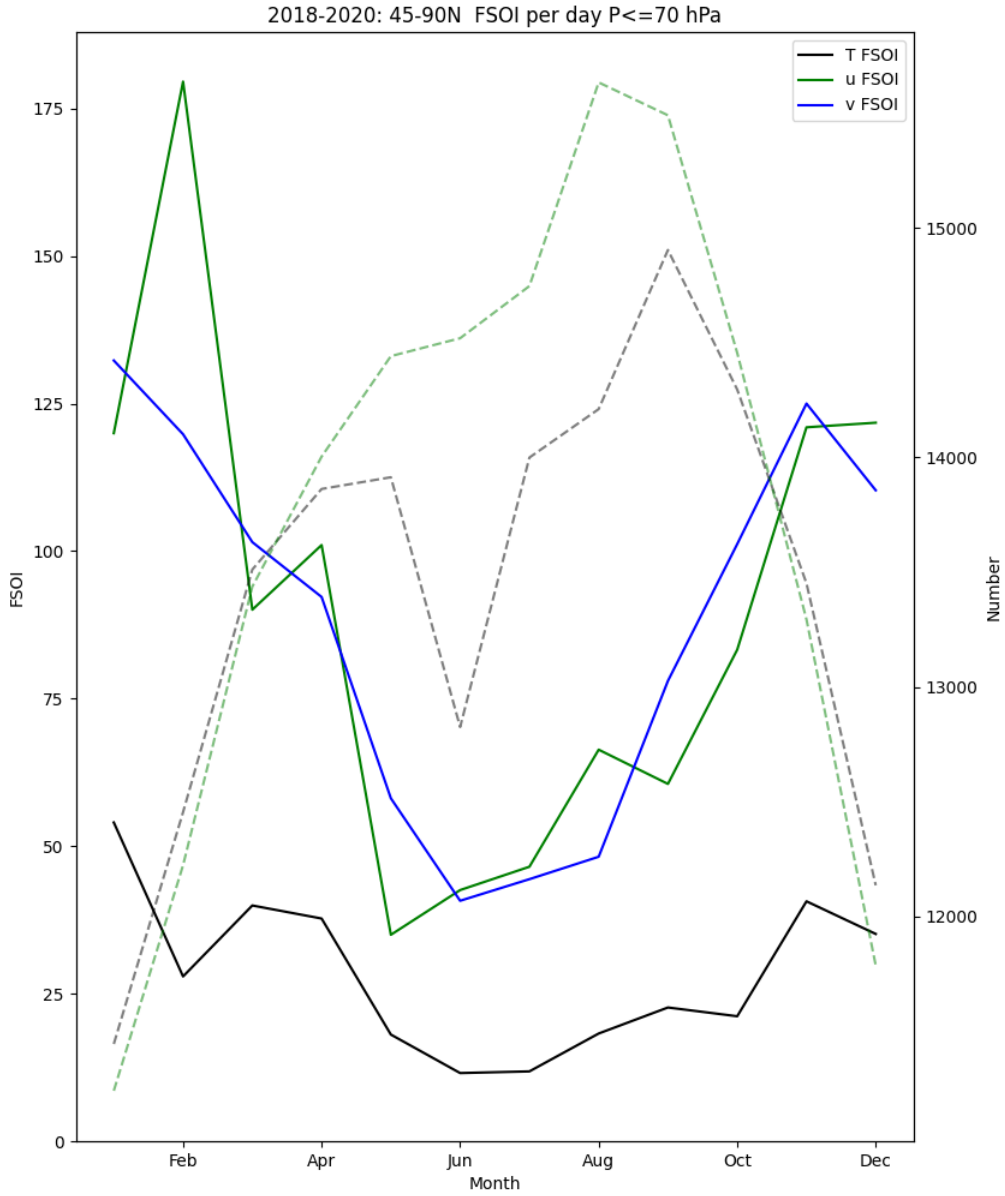
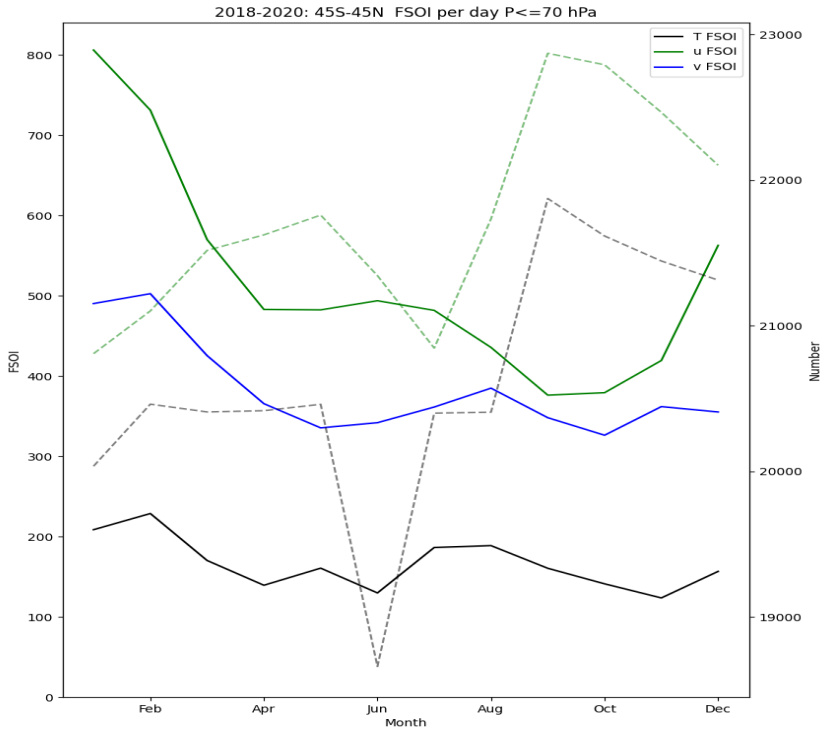
Annual cycle of radiosonde impact 45-90N, 70-0 hPa

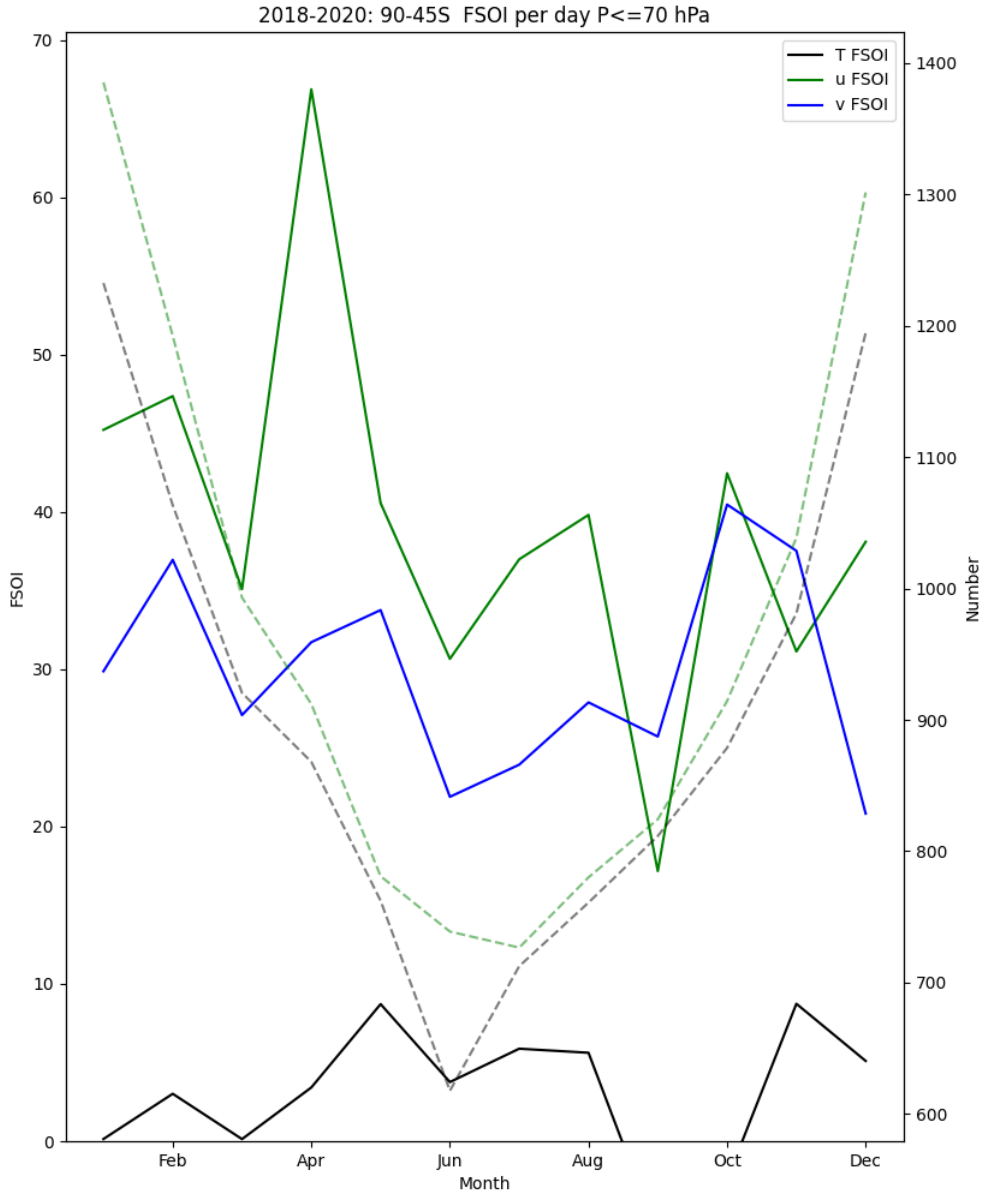
- Forecast Sensitivity to Observation Impact (FSOI) – estimate of the importance of data in reducing errors in T+24 h forecasts (doesn't account for anchoring in bias correction)
- Radiosonde FSOI for different variables: 3 years
- Wind (U,V) FSOI > temperature FSOI
- Larger values Nov-April <u>despite</u> lower observation numbers (dashed)
  - Balloons burst at lower altitudes in winter ☹
  - Especially DJF
  - Could use larger balloons then (cost)
- Somewhat noisy plots …
- Upper level data in NDJF 'worth' about 2.5* the data in MJJA by this measure!



Annual cycle: 45-90S, 70-0 hPa

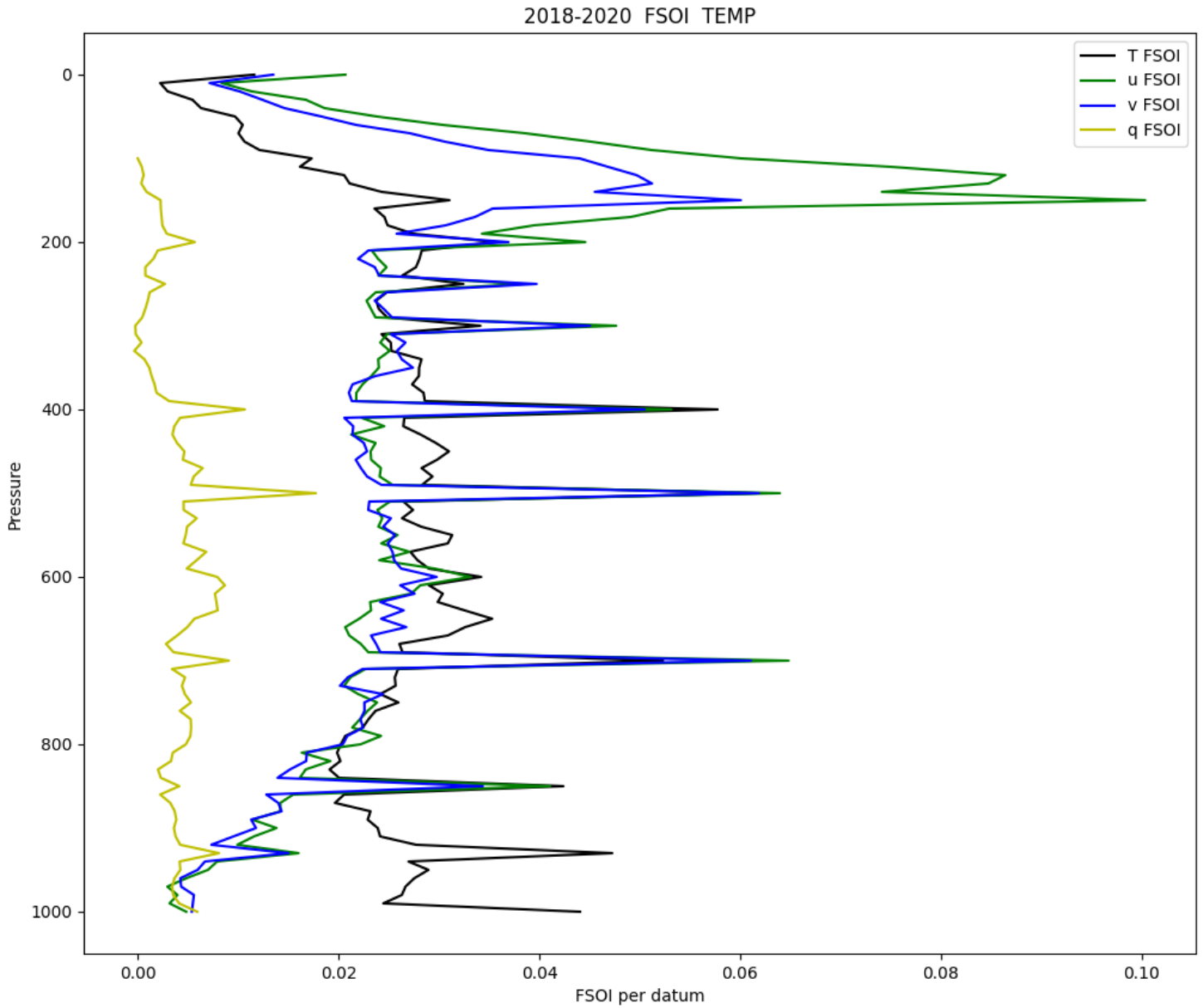
- Noisy plot, no clear annual cycle
  - Except in number of reports
- Much smaller sample size
- RS temperatures apparently detrimental in some months
- 45S-45N: max in Jan (below)





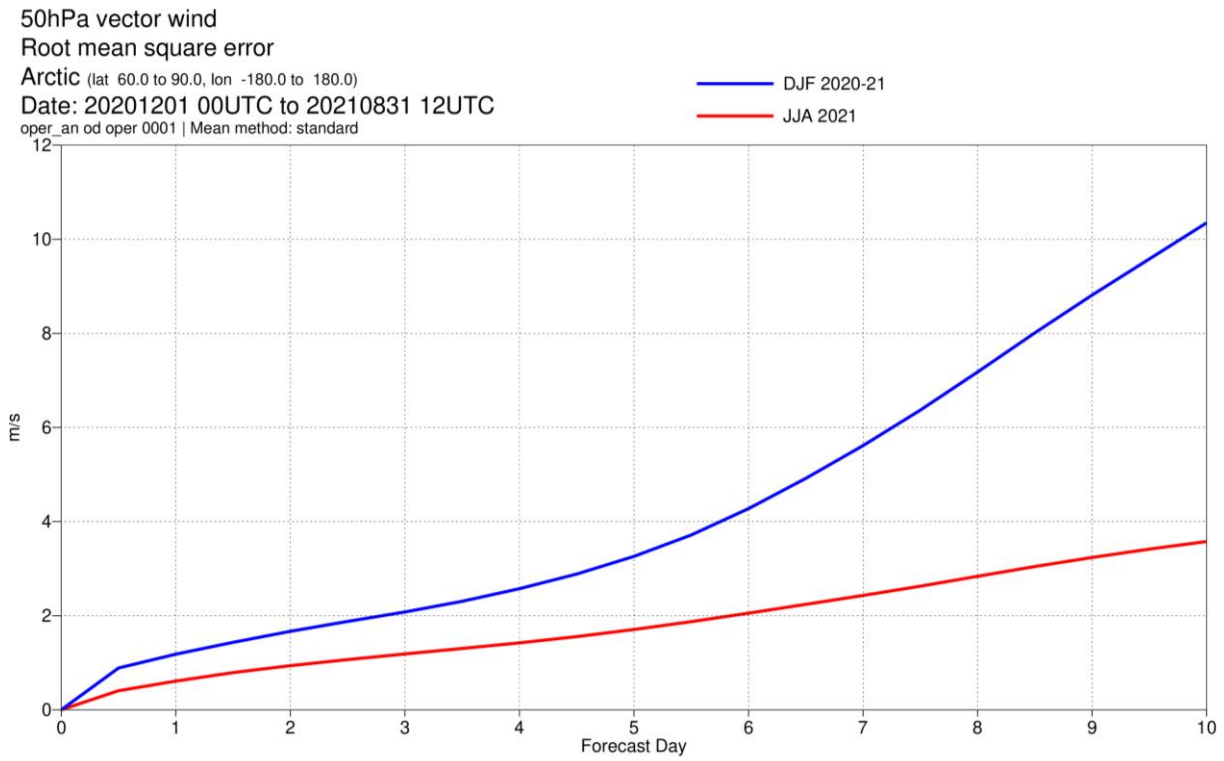
Global profiles of FSOI in 10 hPa intervals

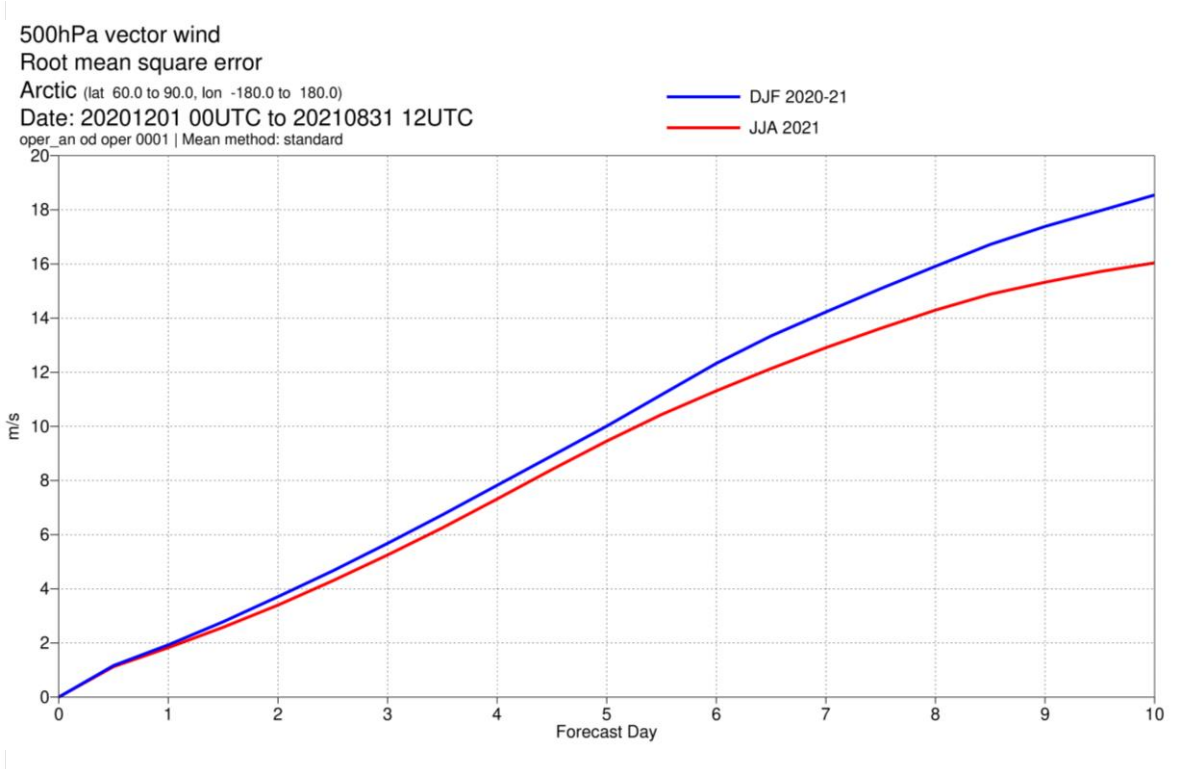
- FSOI per datum shown
- Still has maxima at standard levels from LoRes reports
- Wind maximum at 150-100 hPa is a tropical feature
- At low levels temperature dominates FSOI at high levels wind dominates
- Difficult to pick a level above which we “don’t want” observations
- However horizontal length scales increase with height in stratosphere (eg Ingleby, 2001, QJ) so reasonable to have lower density obs at 10 hPa than 30 hPa



Seasonality in verification (linked to variability)

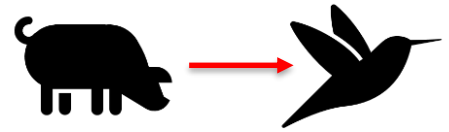
- At 50 hPa (left) forecast errors are much less in JJA than DJF
- Much smaller difference at 500 hPa (right)
- These stats are for 60-90N – standard verification area





GBON requirement: 100 m vertical res, 30/10 hPa density

"Geneva, 20 October 2021 (WMO) - The World Meteorological Congress has approved three sweeping initiatives", one of them was the Global Basic Observing Network (GBON). ☺☺
Enhanced reporting should be in place by January 2023.
See https://public.wmo.int/en/media/press-release/wmo-overhauls-data-exchange-policy



3.2.2.12 Members shall maintain the continuous operation of a set of upper-air stations/platforms over land that observe, at a minimum, temperature, humidity and horizontal wind, with a vertical resolution of 100 m or higher, twice a day or better, up to a level of 30 hPa or higher, twice a day or better to the extent possible, located such that GBON has a horizontal resolution of 500 kilometres or higher for these observations. to the extent possible.

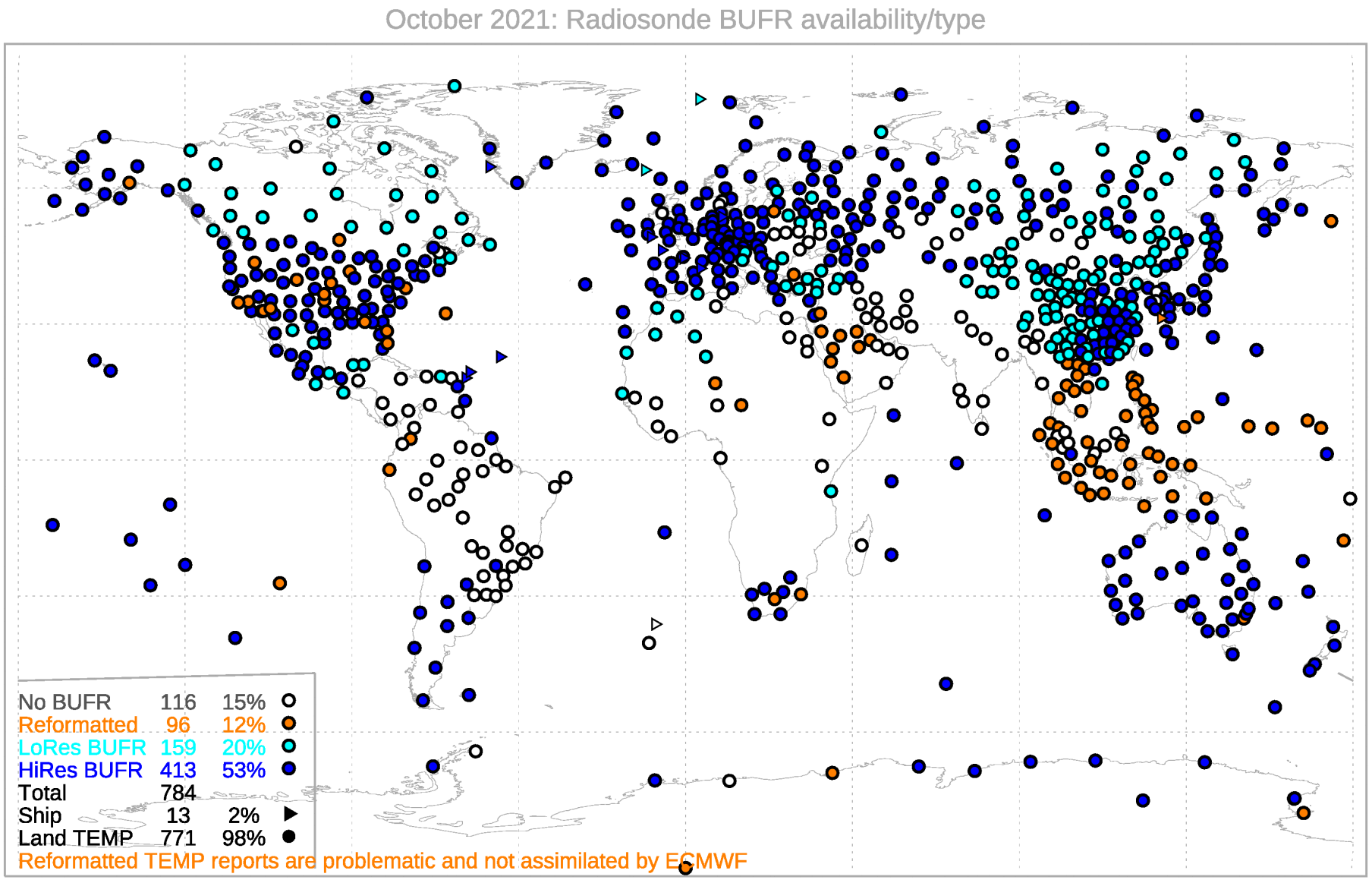
Notes:
1. Radiosonde systems currently provide the primary means for collecting such observations.
2. A vertical resolution of 100 m or higher means that observations are spaced and reported not more than 100 m apart in the vertical on average.
3. Upper-air observations obtained over remote/isolated islands have particularly high impact on Global NWP skill, and continued operation of these stations/platforms are of high priority for GBON.

3.2.2.13 Members should operate networks of upper air stations/platforms providing horizontal resolutions of 200 km or higher.
3.2.2.14 Members should operate a subset of the selected GBON upper-air observing stations/platforms that observe temperature, humidity and horizontal wind up to 10 hPa or higher, at least once per day, located such that, where geographical constraints allow, GBON has a horizontal resolution of 1000 kilometres or higher, for these observations.
3.2.2.15 Members shall operate a set of upper-air stations/platforms that observe temperature, humidity and horizontal wind, with a vertical resolution of 100 m or higher, twice a day or better, up to 30 hPa or higher, located such that, where opportunity exists, GBON has a horizontal resolution of 1000 kilometres or higher over the marine areas of their jurisdictions, for all these observations.

Archive of UA BUFR data (HiRes + LoRes) available at
https://www.ncei.noaa.gov/data/ecmwf-global-upper-air-bufr/

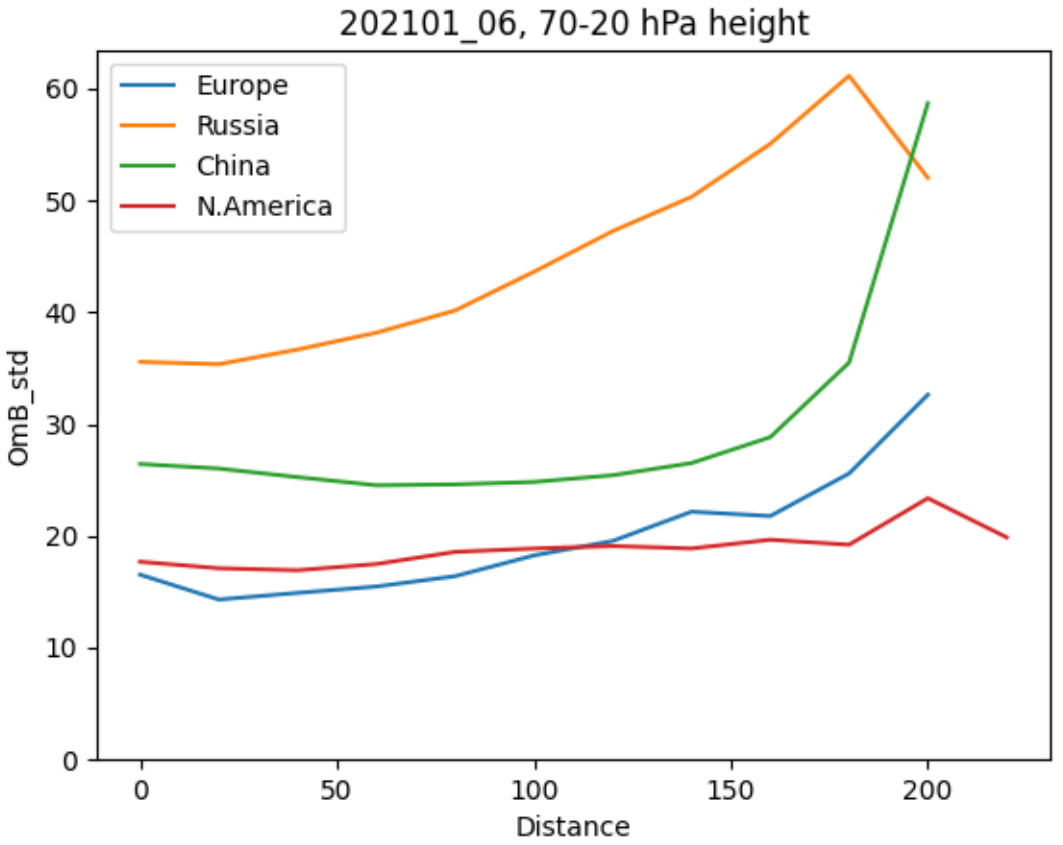
Status of global radiosonde network Oct 2021

- 73% of stations send native BUFR ☺ ☺
- Mostly HiRes but Canada and China send MediumRes
- 27% send no BUFR ☹ or reformatted TEMP ☹
- Big gaps in Africa and over oceans
- Large reduction in soundings from India (Covid)



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 MRZ-N1 GNSS radiosondes – small sample so far
  - Problems clearest for height – used for verification but not assimilation



Summary

- In the Northern extratropics the stratosphere is very active in extended winter (Nov-Apr), it is very quiet in summer (May-Aug)
- Stratospheric radiosonde data (esp. winds) have much more impact in winter
- Balloons burst earlier in winter – less data then ☹
- Can use larger balloons in winter to counteract this (e.g. Sodankyla)
  - Should this be encouraged more widely?
  - EUMETNET guidance emphasises higher density of obs in winter
- Should Summer balloon size be reduced to ‘pay for’ Winter increase?
  - NMSs would have to write to DG WMO if they miss Summer GBON targets!
  - What is the way forward on this?
- Intend to submit a short paper on this topic next year