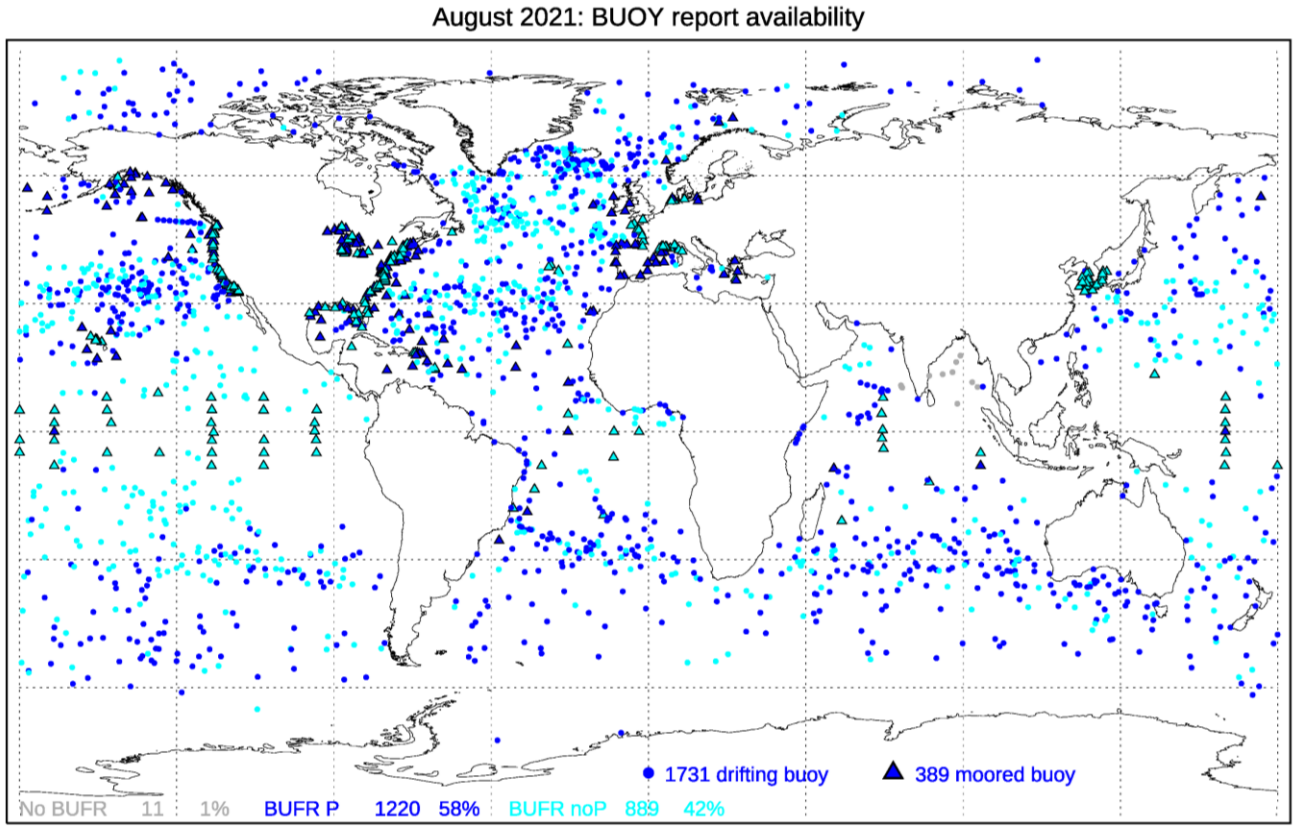
In situ atmospheric observations: status, developments, gap analysis

ECMWF Annual Seminar, 13 September 2021

Bruce Ingleby (ECMWF)

Bruce.Ingleby@ecmwf.int



Overview

- Introduction
  - Use in global NWP, illustrated with ECMWF plots, impact (FSOI)
- Recent developments … and gaps
  - **Aircraft: effect of Covid-19**, use of Mode-S, a direction problem
  - **Radiosonde data:** high-resolution profiles and use of descent data
  - **Surface data**: coverage & frequency
  - **Metadata**, metadata, metadata
- Status
  - Aircraft, Radiosondes and Surface
- References and links

- I will simplify at times for brevity – happy to supply more details later

In situ observations

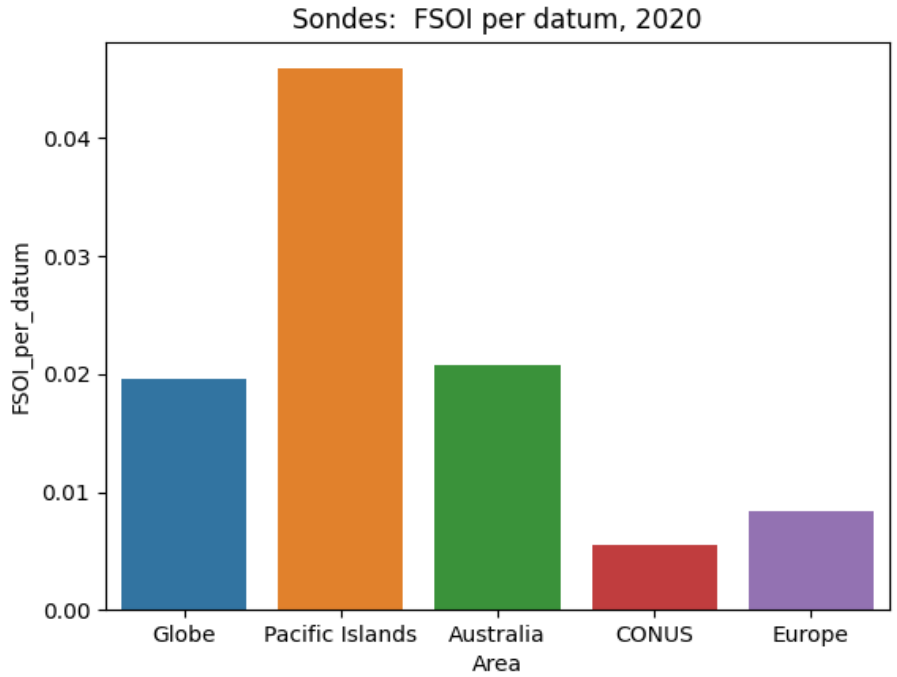
System	Variables, Advantages	Caveats, Notes
Aircraft	Wind, temperature, some humidity Locally high density Low cost	Very uneven distribution T needs bias correction (BC)
Radiosondes	Wind, temperature, humidity High vertical resolution Closest to reference profiles	Low density + gaps Humidity quality mixed in upper troposphere
Surface	Pressure, temperature, humidity, wind, SST, snow depth Locally high density	Sparse over oceans/deserts Local (representation) issues for some variables
GroundGNSS	*Integrated water vapour* *Derived from a time delay*	*Biases, sometimes problems with profile of q increments?* *Used in some global NWP.*

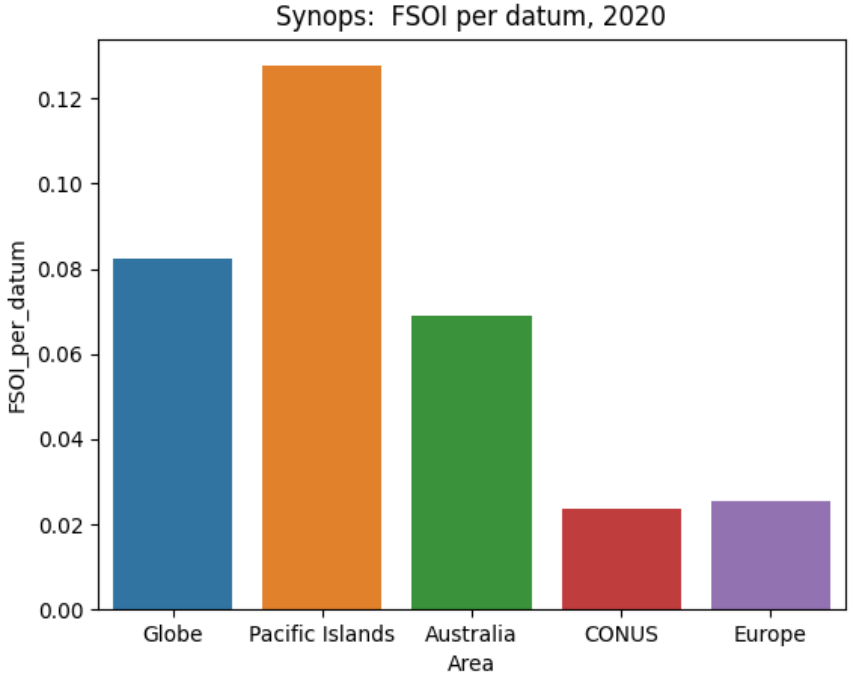
Satellites provide more data on temperature+humidity than wind
Satellite soundings are less useful at low levels over snow/ice

ECMWF

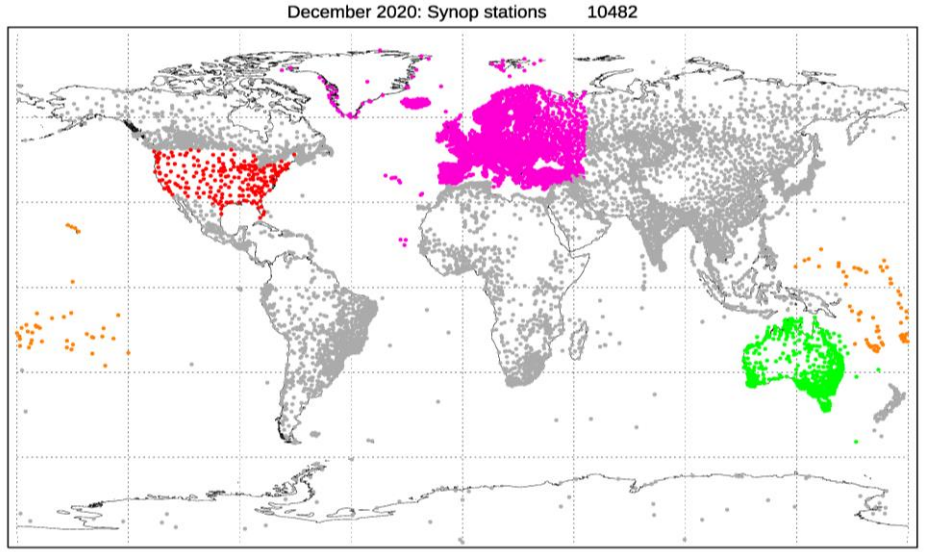
Adapted from Ingleby et al (2021)

More impact per station in data sparse areas:





- ECMWF blog (March 2021) in support of WMO SOFF (Systematic Observations Financing Facility)
- More impact per station/report from scattered islands in the Pacific
- 4 of the radiosondes in the area are maintained by MeteoFrance



ECMWF

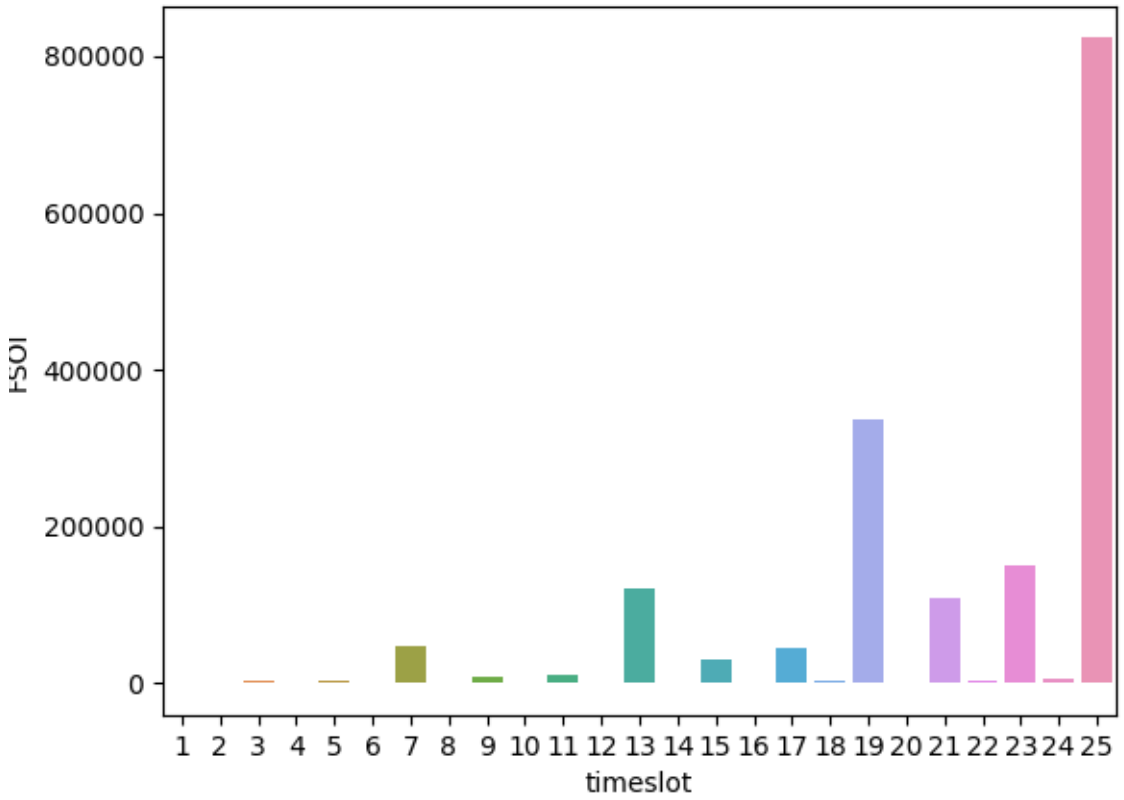
More impact at end of time window – real effect

- Many Synops only report 3-hourly ☹
- WIGOS encouraging hourly data

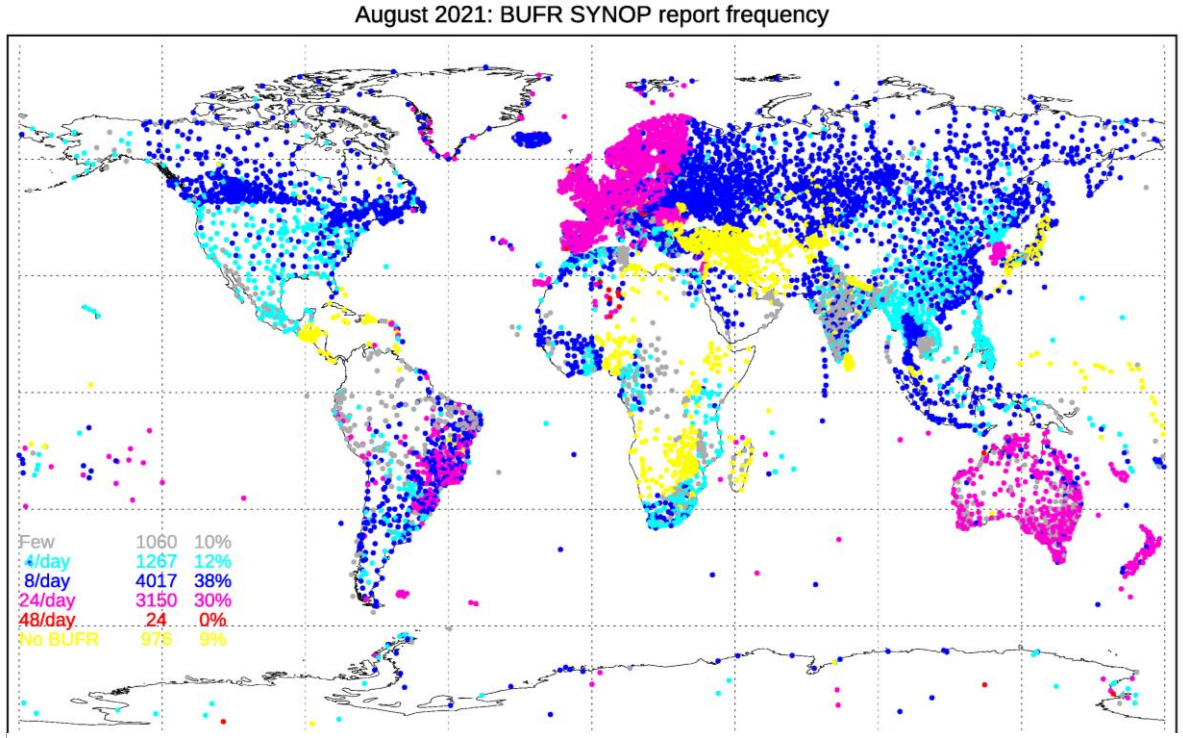
- Radiosondes mainly 3h into window
=> lower FSOI

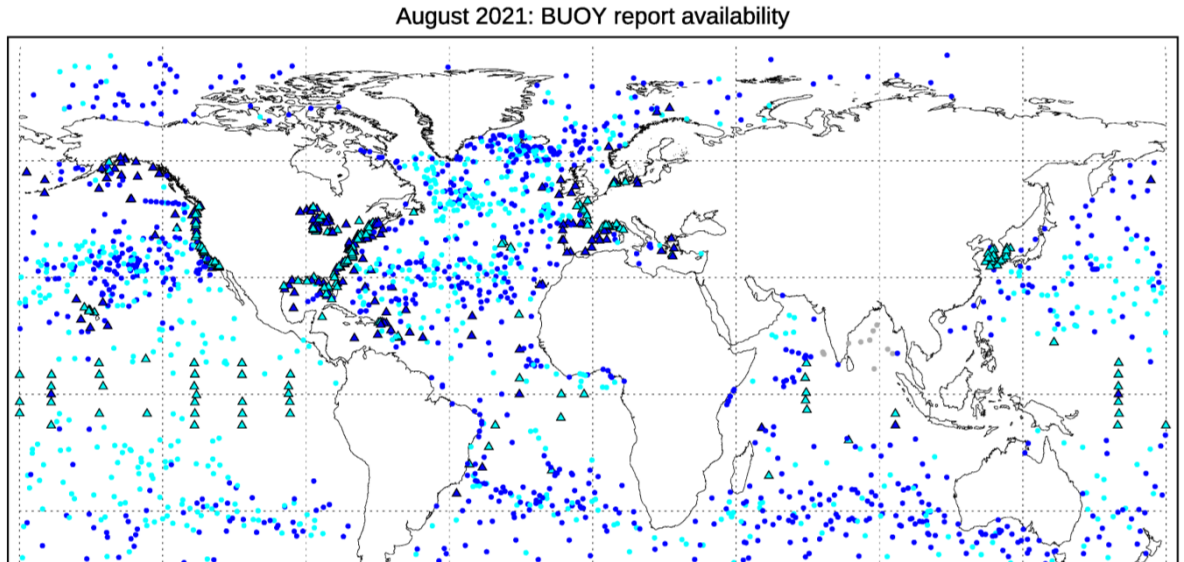
- Drifting buoys have very high FSOI per pressure report (data sparse areas)
- But only 58% of drifters have a pressure sensor ☹

SYNOP FSOI within ECMWF 12 h window



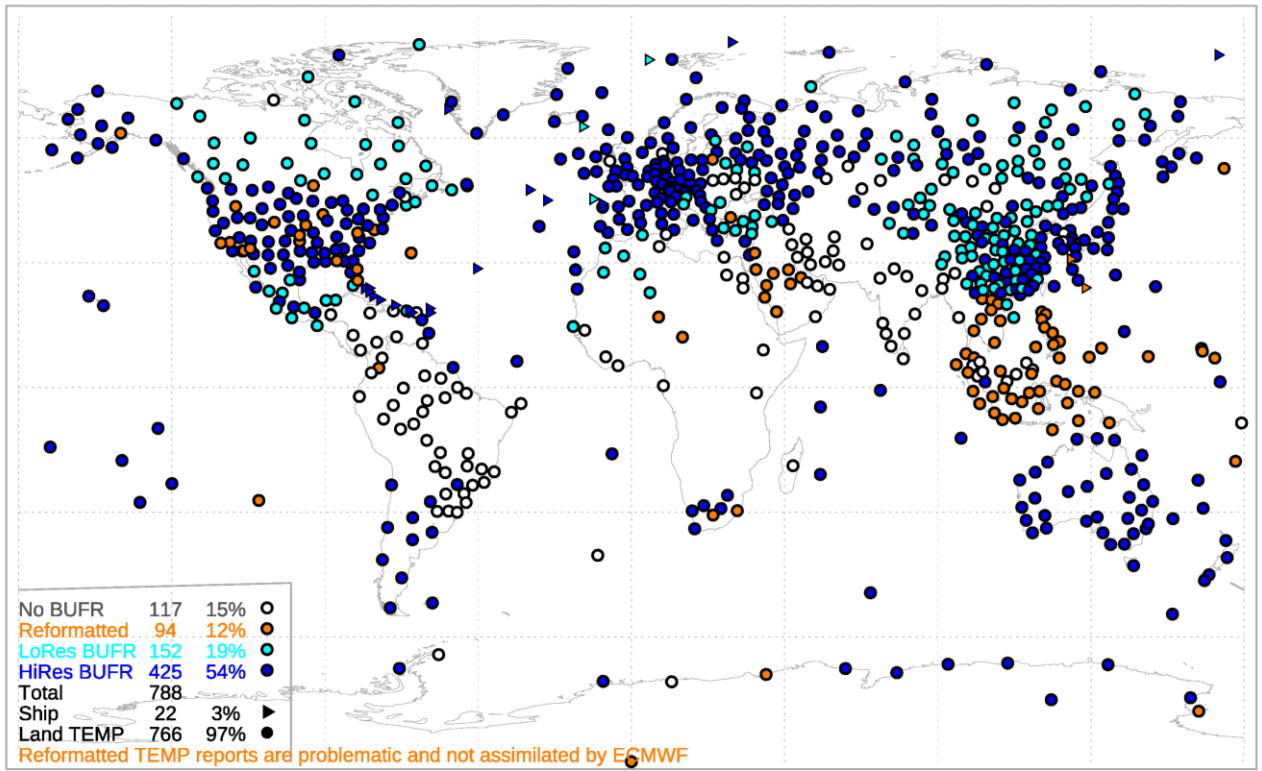
Gaps, migration to BUFR and high resolution/frequency





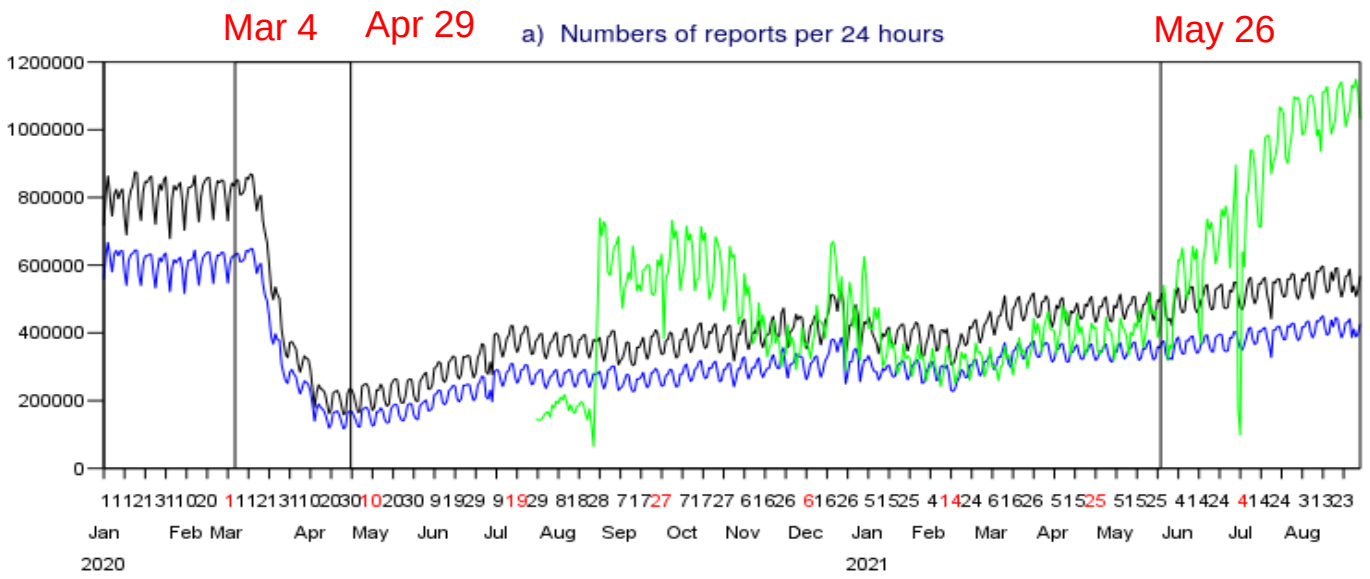
- 10% of SYNOPs and 28% of TEMPs don't send good BUFR ☹
- 30% of SYNOPs report hourly – mainly Europe+Australia
- 54% of TEMPs provide HiRes (China improved recently)
- Only 58% of BUOYs (1220) provide pressure

August 2021: radiosondes

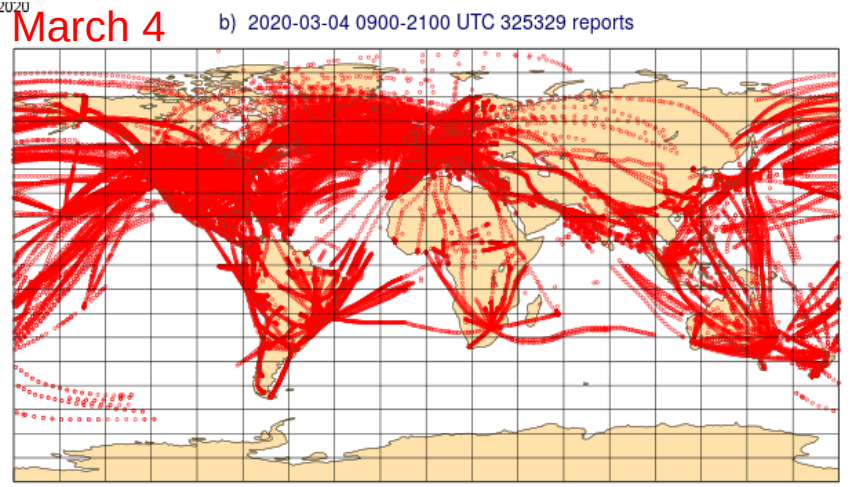


Impact of Covid-19 on aircraft reports

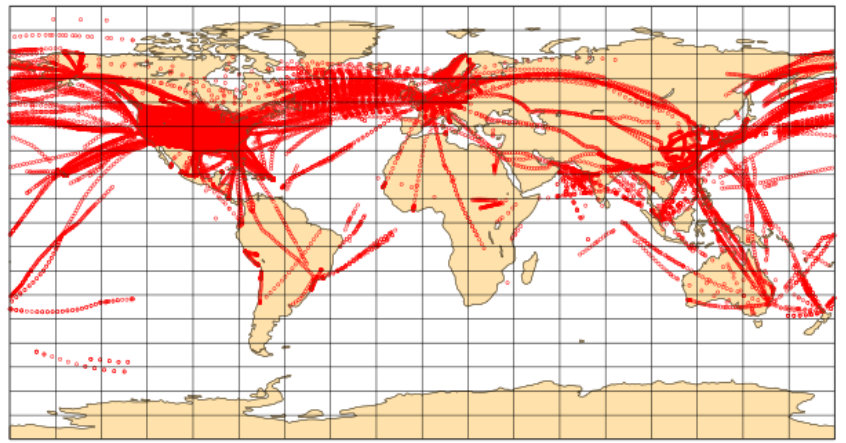
- Mid-March to Mid-April 2020 global numbers of AMDAR+AIREP dropped by 75%
- Long-haul very badly hit, cargo less so
- Back to almost 50% by July 2020, slight increase since
- ECMWF started using Mode-S winds over Europe (green line below) – only about 5% of those available
- Regional numbers have fluctuated (very few in SH in April 2020), increase in Europe in last few months



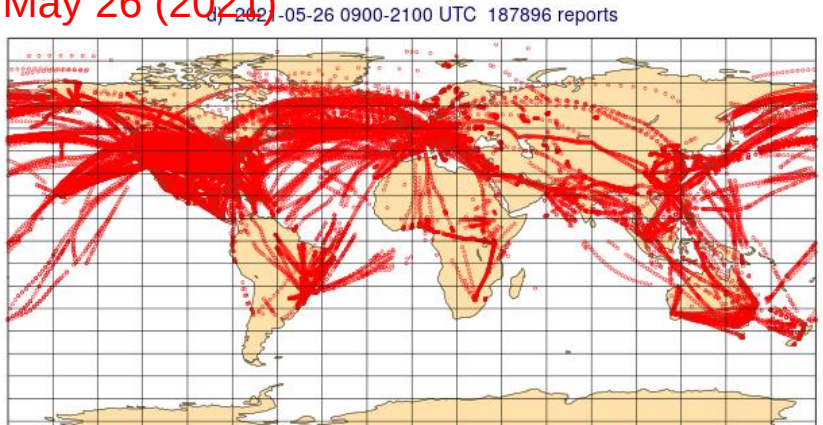
b) March 4



c) April 29



d) May 26 (2021)



Impact from aircraft data denial

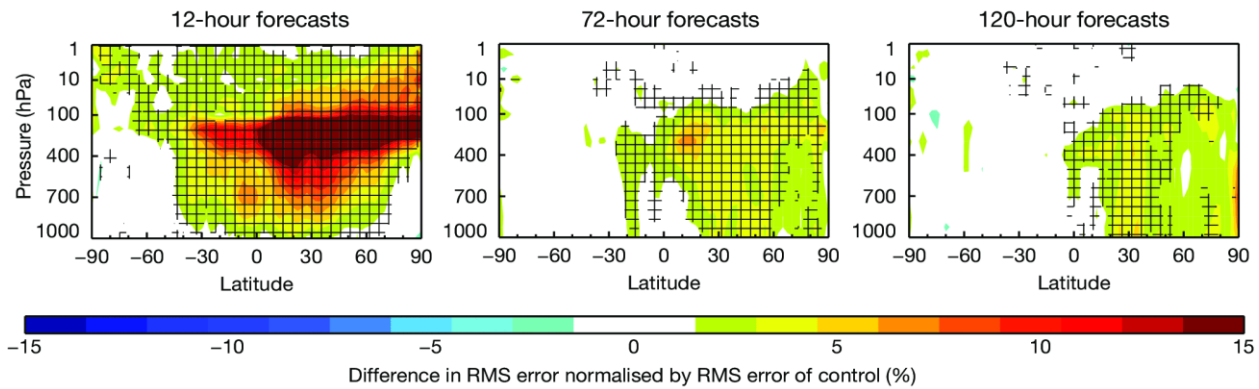
- OSE: Observing System Experiment
- ECMWF IFS, 3 months in 2019
- Control – all data
- NoAircraft: top plot and black line in b,c)
- NoAircraftT(emperature), red line in b,c)

- Biggest impact is ~250 hPa in NH almost 10% worse vs sonde T, 13% vs sonde wind
- Most of the impact (even on T) comes from the aircraft winds

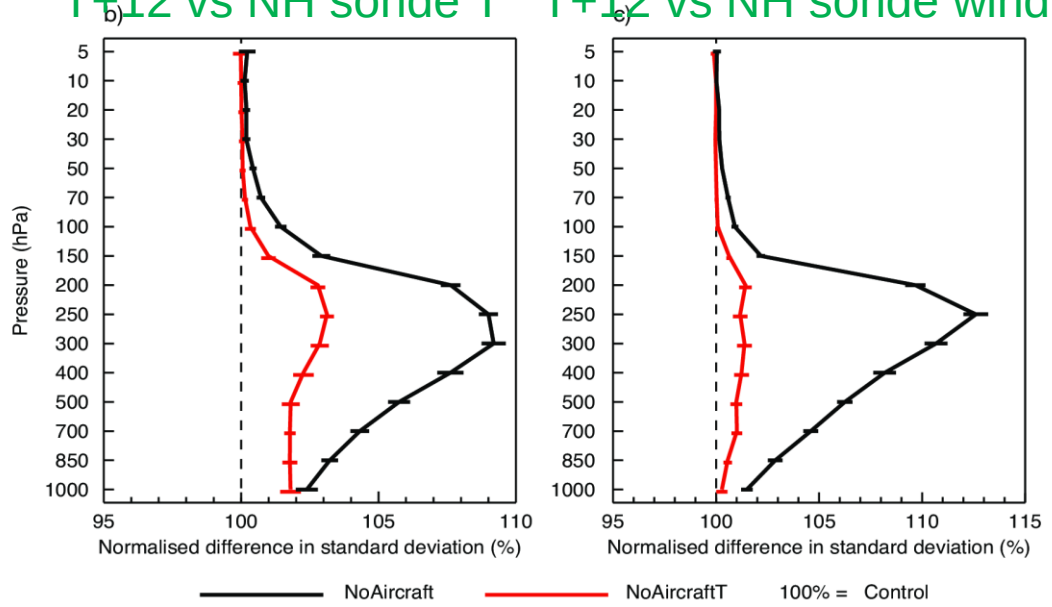
- Ingleby et al (2021, GRL)

Vs Analyses

T+12 T+72 T+120



T+12 vs NH sonde T T+12 vs NH sonde wind



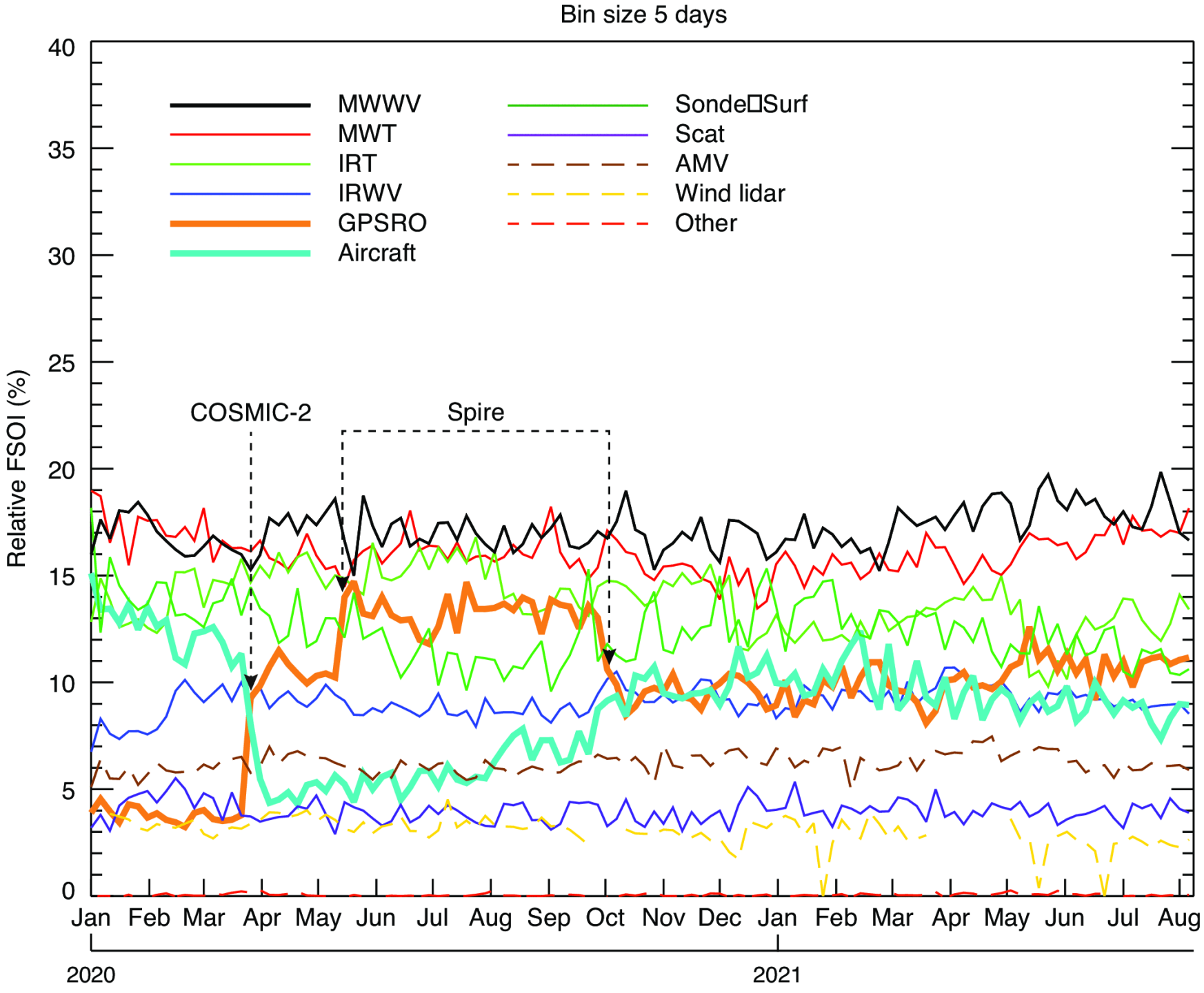
FSOI % for 2020/21

- Forecast sensitivity to observation impact: estimate of how important obs subsets are for T+24 forecast

- RO: steps from start of COSMIC-2+Spire, Spire stopped end Sept

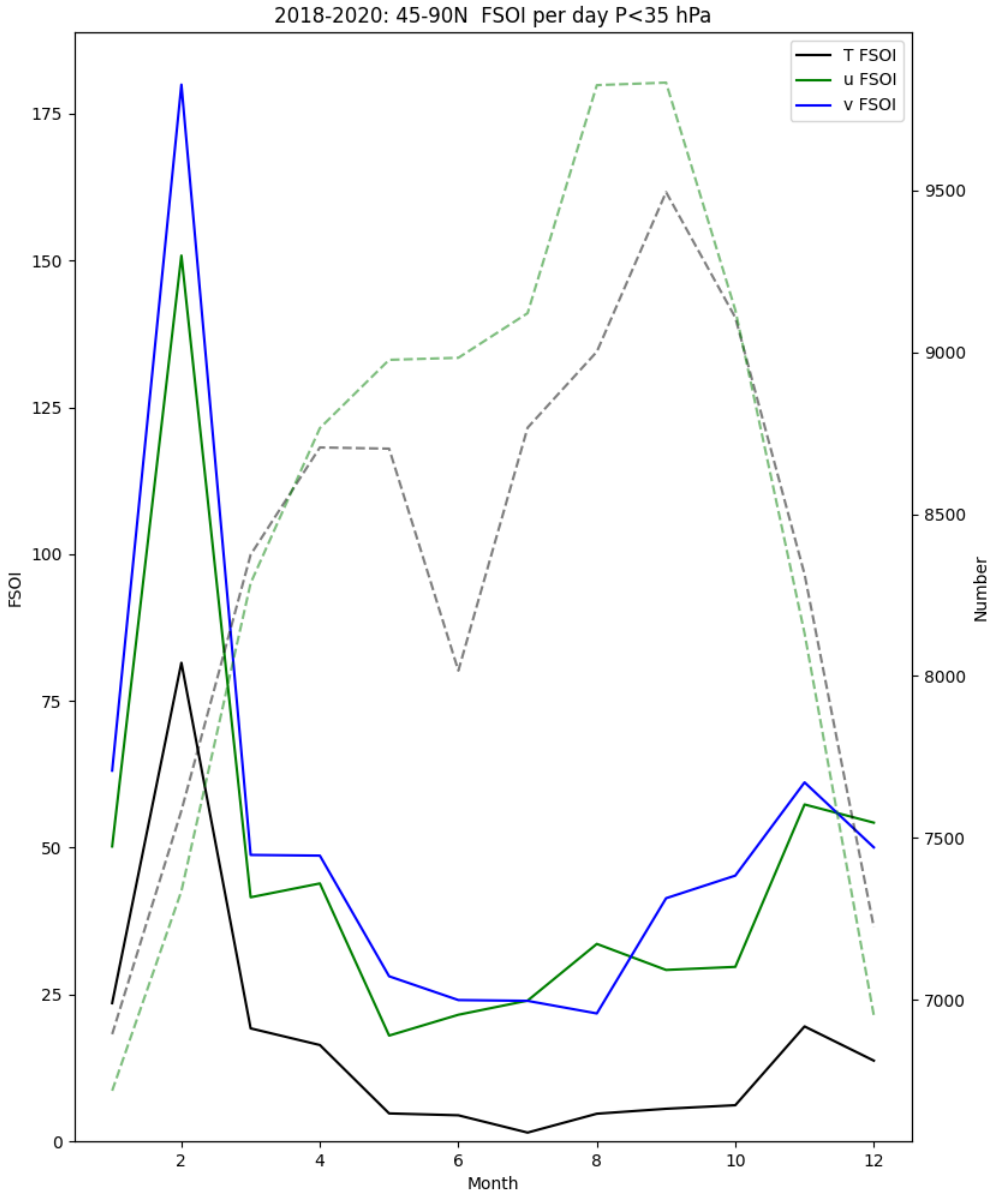
- Aircraft: drop in Mar/Apr then ~level
- Then increase (SH+)
- 2021: seasonal cycle?

- Aeolus: ~3% (gaps)



Seasonal cycle of radiosonde impact in stratosphere (poster)

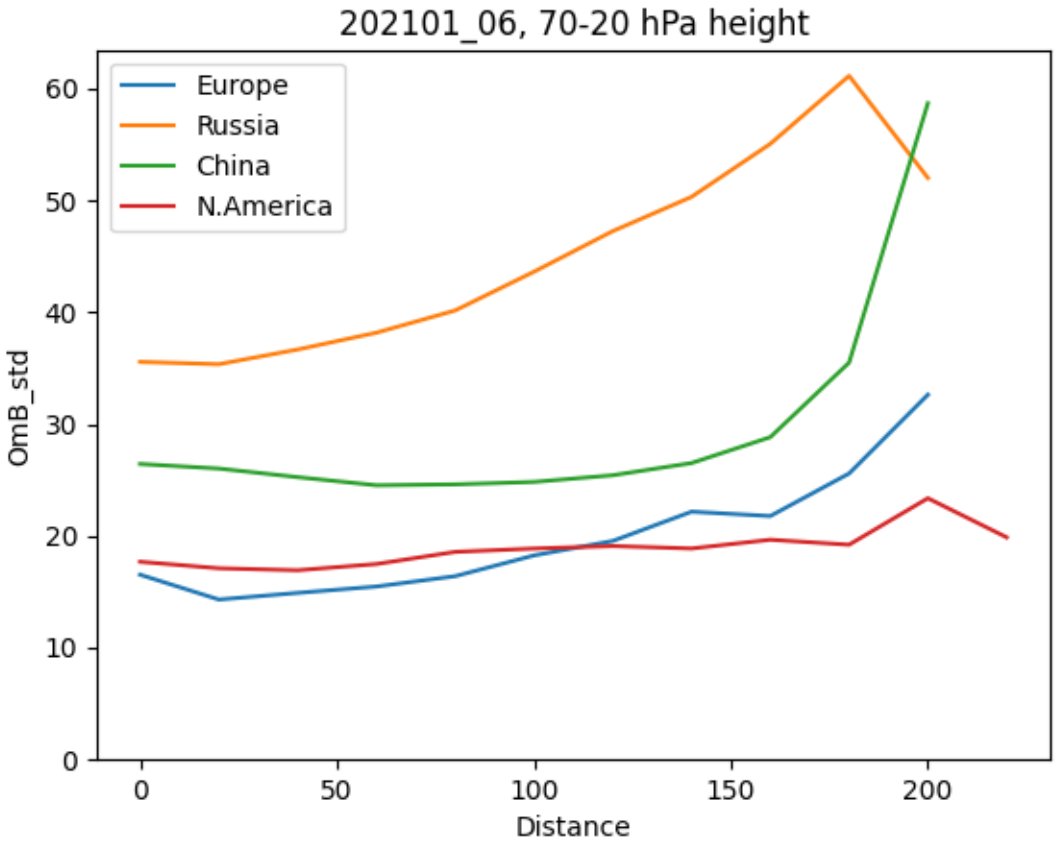
- Radiosonde FSOI 45-90N for pressure <35 hPa
- Most of the impact comes from wind: u and v
- Nothing much happens in summer!
- Main impact in winter, especially associated with sudden warming/vortex splitting
- Fewer data points in winter (dashed lines) – balloons burst earlier ☹
- Case for using larger balloons in winter



ECMWF

Radiosondes: GNSS vs radar

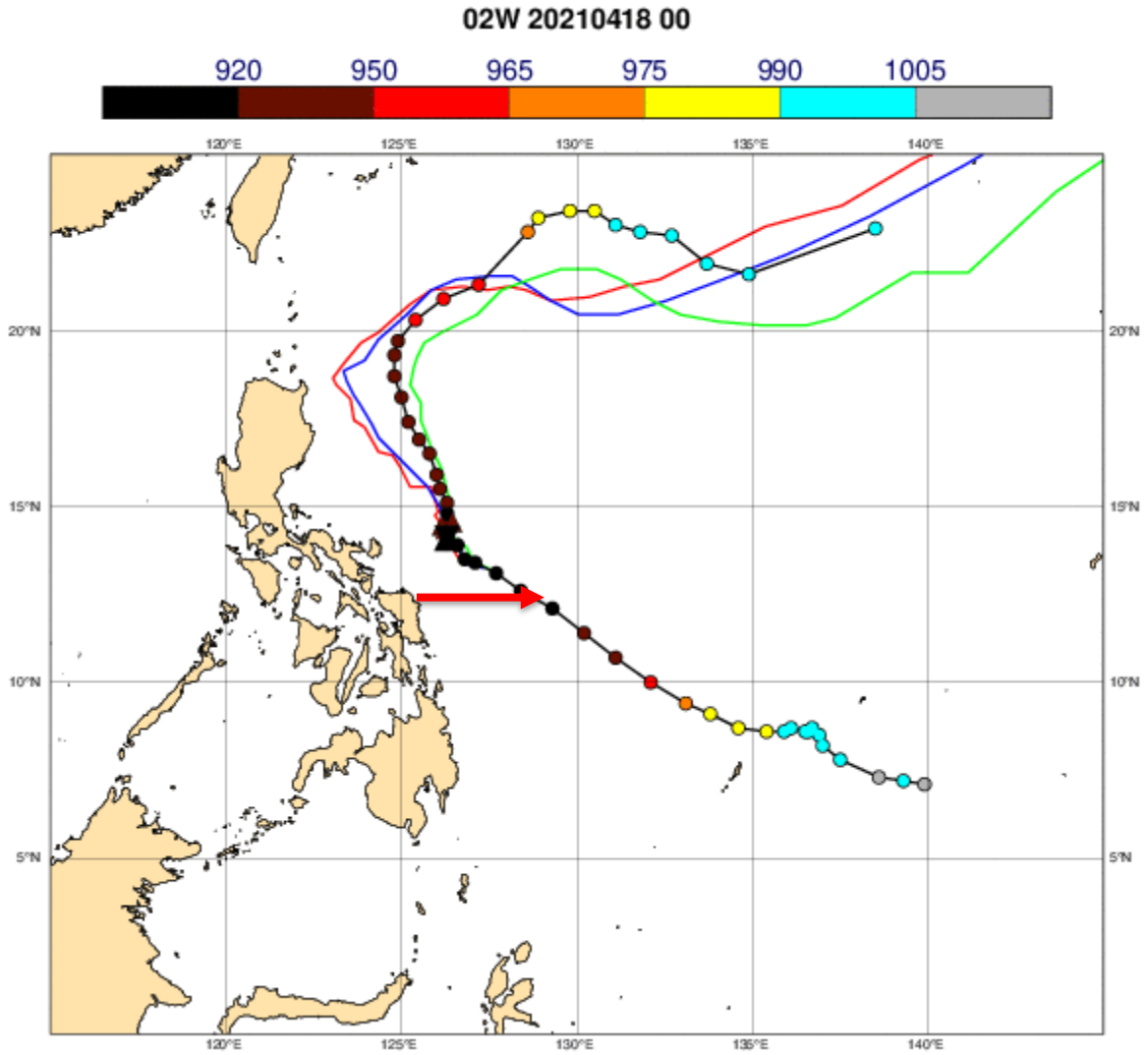
- Plot shows fit of stratospheric heights to model vs the distance drifted (km)
- Many radiosondes now use GNSS for position+wind finding (OK with or without a pressure sensor) ☺
- China uses radar + P sensor – OK ☺
- Russia uses radar without P sensor – not good especially at large distance (low radar 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



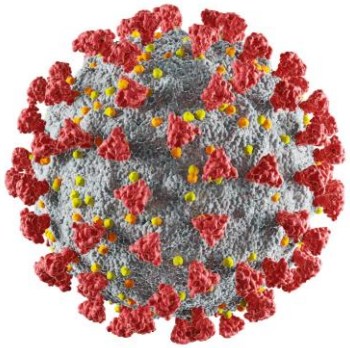
Metadata: crucial but often underappreciated

- Even getting latitude/longitude/height correct for fixed stations can be a headache
- Wrong heights – Pstn biases

- Track of TC Surigae, April 2021
- Operational forecast (red) track too far W
- Forecast excluding Synop from 98546 (green)
- Catarman airport: 124.6°E but typo in 2019 moved it to 128.6°E in OSCAR/surface
  - Correct location in BUFR reports – but OSCAR/surface usually more reliable



Status – Aircraft data (also see WCRP-WWRP presentation)



- Covid-19 reduced the number of aircraft reports by 75% for ~2months
  - Then partial recovery to ~50% of pre-Covid levels, fluctuations by region
- Aircraft data are valuable for NWP, biggest impact is on wind at ~250 hPa
  - Winds give more impact than temperatures, more impact in NH
- Cannot see a decrease in forecast quality in 2020 (multiple centres):
  - Satellite data more important (increased in 2020). Aircraft data didn't drop to zero
  - Day-to-day and year-to-year variations in forecast skill complicate the picture
- B787 wind problem – very frustrating issue - partially corrected at ECMWF now
- Aircraft temperature biases – need **metadata** (aircraft type & airline)
- Anonymisation and multiple identifiers complicate matters ☹
- Use of **Mode-S aircraft winds** over Europe at ECMWF – very dense
- WMO link to ICAO (WICAP) should increase AMDAR coverage
- Possible future use of GNSS altitudes from aircraft

Status – Radiosonde data

- Reported profiles include some filtering/corrections (Dirksen et al, 2014)
- GNSS winds: good quality and high resolution
  - Pendulum motion needs more attention
- Radar: occasional wind problems, poor heights without P sensor (Russia)
- Migration to HiRes BUFR reports still incomplete ...
- Use of radiosonde drift positions improves (O-B) at upper levels
- Recent work on radiosonde descent data (Ingleby et al, 2021, AMTD)
- Radiosondes under financial (and Covid) pressure …
- Next WMO radiosonde intercomparison in Germany in 2022

- **Important** for: **assimilation** (anchor obs), **verification**, **diagnostic studies**
- North of 45N stratospheric data more important in winter than summer

Status – Surface data

- Main variable used is **surface pressure** (PS); verification of T, pptn etc
- Some stations need PS bias correction (wrong Zstn?)
- Good **metadata** important (surface and radiosondes)
- Use of other variables in global NWP (Ingleby, 2015; Met Office)
  - Benefit from using T and RH, but use of Synop winds ~ neutral

- Migration to BUFR 90% complete
- WIGOS station identifiers just starting – messy.
- 'Easy wins': **Hourly Synops! Put P sensors on all buoys!**
- Extra stations: SEE-MHEWS (SE Europe), Mistral (Italy), TAHMO (Africa)
- Crowd-sourced data: WOW and NetAtmo (Randriamampianina, Friday)
- Global NWP: want to fill in the gaps in data sparse areas

Recent references

- Bormann et al (2019, EC TM 839): '*Global observing system experiments in the ECMWF assimilation system*.'
- de Haan et al (2021, AMTD): '*Characterizing and correcting the warm bias observed in AMDAR temperature observations*'
- Dirksen et al (2014, AMT): '*Reference upper air data: GRUAN … RS92 radiosonde*'
- Ingleby (2015, QJRMS): '*Global assimilation of … surface stations*' (at UKMO)
- Ingleby et al (2016, BAMS): '*Progress toward High-Resolution, Real-Time Radiosonde Reports*.'
- Ingleby (2017, EC TM 807): '*An assessment of different radiosonde types 2015/2016*.'
- Ingleby and Isaksen (2018, ASL): '*Drifting buoy pressures: Impact on NWP*.'
- Ingleby et al (2019, EC TM 855): '*Evaluation and impact of aircraft humidity data in ECMWF's NWP system*.'
- Ingleby et al (2021, GRL): '*The impact of Covid-19 on weather forecasts: a balanced view*'
- Ingleby et al (2021, AMTD): '*On the quality of RS41 radiosonde descent data*'
- James & Benjamin (2017, MWR): '*OSEs with Rapid Refresh system*'
- James et al (2020, JAMC): '*Commercial aircraft-based observations for NWP: Global coverage, data impacts, and COVID-19*'
- Lawrence et al (2019, QJRMS): '*Use and impact of Arctic observations in the ECMWF NWP system*.'
- Pauley and Ingleby (2021, book chapter, in press): '*Assimilation of in situ observations*'
- Zhu et al (2015, MWR): '*Variational Correction of Aircraft Temperature Bias in the NCEP's GSI Analysis System*.'
- 2020 Workshop: Aircraft weather observations and their use - https://events.ecmwf.int/event/168/
- BUFR migration maps/links: https://confluence.ecmwf.int/display/TCBUF/Data+availability