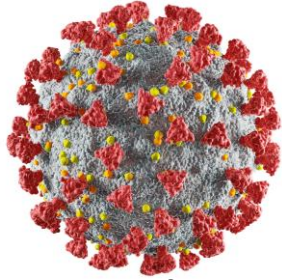


# Aircraft data and COVID-19: impact and mitigation measures at ECMWF

Using ECMWF's Forecasts, 2 June 2021

Bruce Ingleby  
ECMWF

[Bruce.Ingleby@ecmwf.int](mailto:Bruce.Ingleby@ecmwf.int)



# Overview

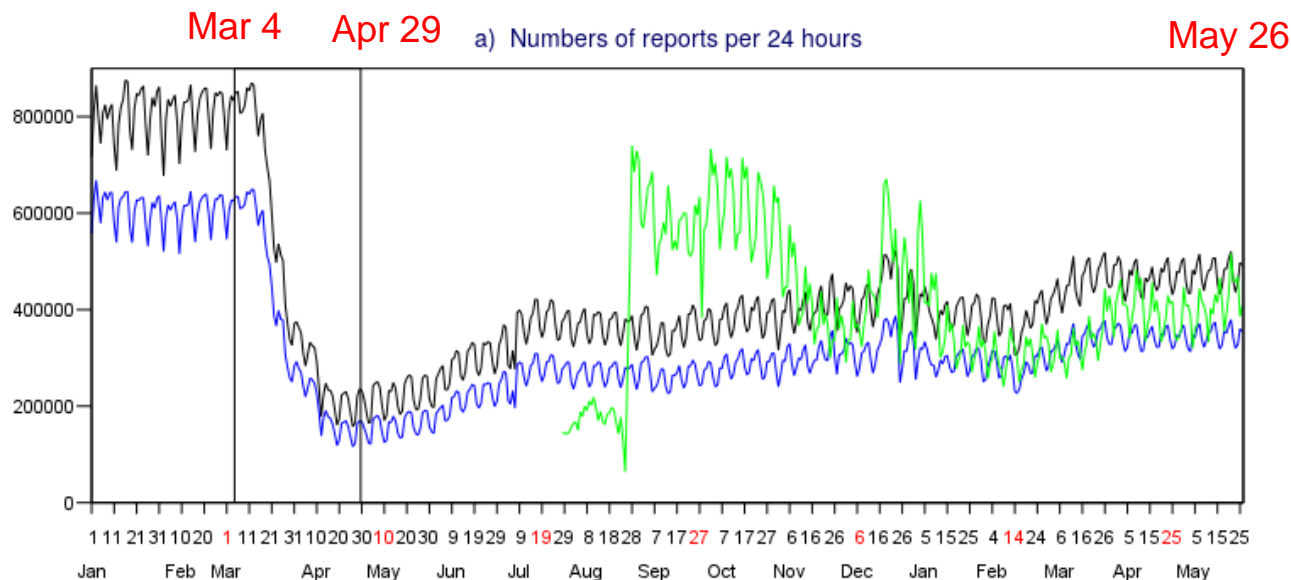
- Impact of Covid-19
  - Drop in aircraft numbers in 2020 due to Covid-19
  - Impact of aircraft data (data denial or OSE)
  - Forecast skill during 2020 (doesn't show a clear drop)
  - Recent papers
- Changes to observation usage, mitigation attempts
  - Use of European Mode-S aircraft data
  - Correction of a wind direction problem
  - Extra satellite data and time series of 'impact'
- Other aircraft issues (bias, gaps)
- Summary
  - Aircraft data are important for global NWP, but not as important as satellite data

## With thanks to

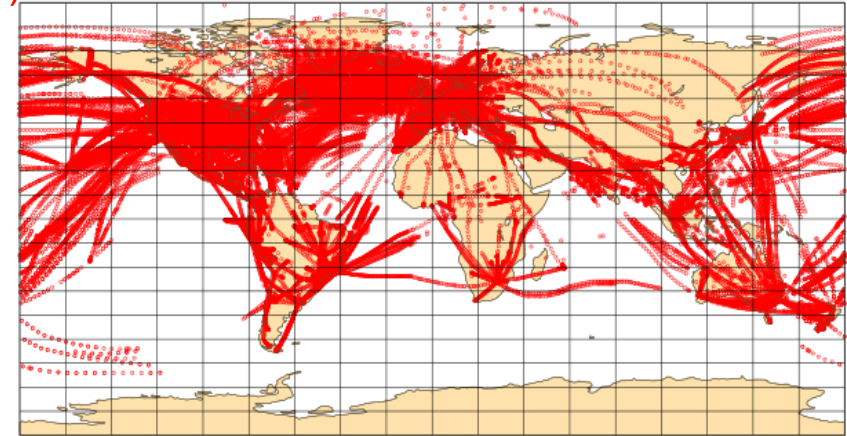
- **ECMWF:** Lars Isaksen, Mohamed Dahoui, Thomas Haiden, Martin Janouscek, Alan Geer, Cristiano Zanna, Marijana Crepulja, Tomas Kral
- **KNMI/EMADDC (NL):** Siebren de Haan, Jan Sondij, Paul de Jong ([Mode-S data](#))
- **Met Office (UK):** Stewart Taylor, Steve Stringer, Brett Candy, John Eyre, Warrant Tennant
- **NOAA/NCEP (US):** Chris Hill, Curtis Marshall, Daryl Kleist
- **BoM (AU):** Fiona Smith, Peter Steinle, Chris Tingwell
- **FLYHT (CA/US):** Meredith Bell ([AFIRS+TAMDAR data](#))
- **NRL (US):** Pat Pauley

# Impact of Covid-19 on aircraft reports

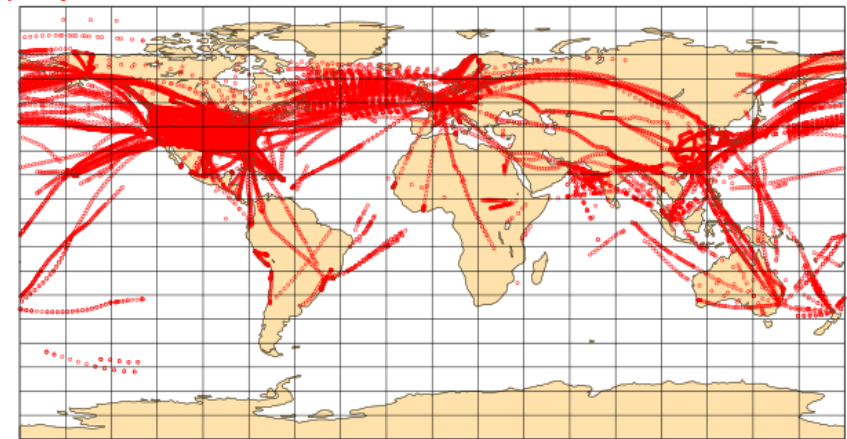
- Mid-March to Mid-April global numbers of AMDAR+AIREP dropped by 75%
- Long-haul very badly hit, cargo less so
- Back to almost 50% by July but ~constant since
- ECMWF started using Mode-S winds over Europe (green line below) – only about 5% of those available
- Recent months: European numbers declining again, numbers in Southern hemisphere increasing



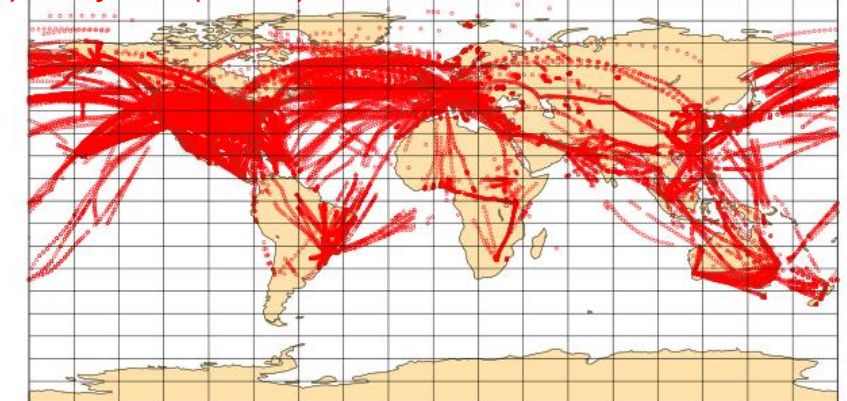
b) March 4 b) 2020-03-04 0900-2100 UTC 325329 reports



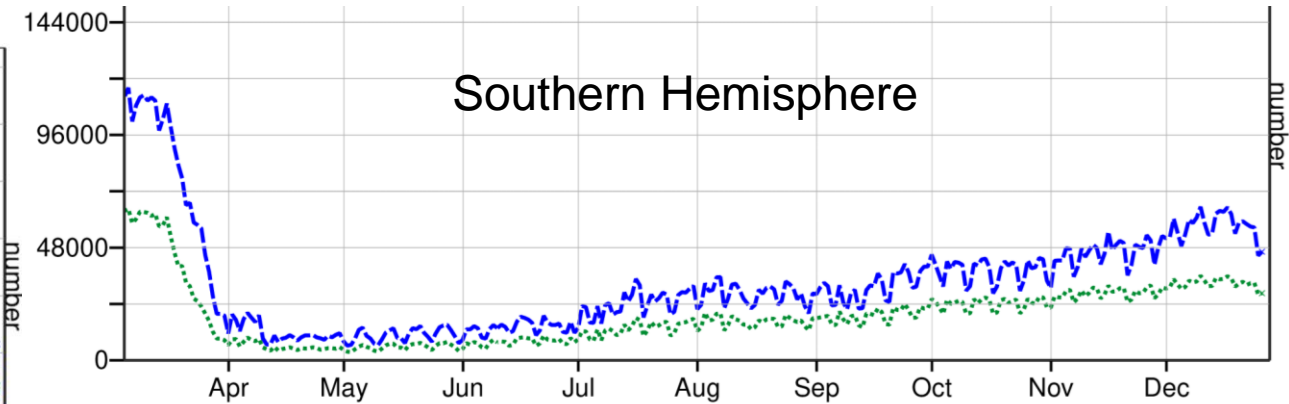
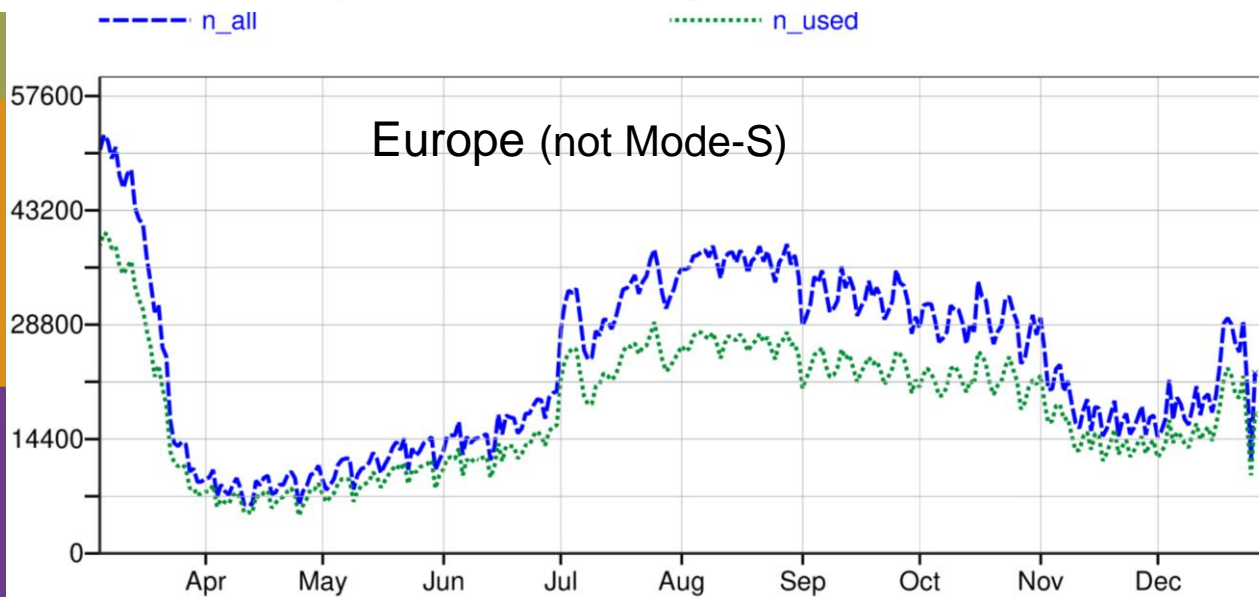
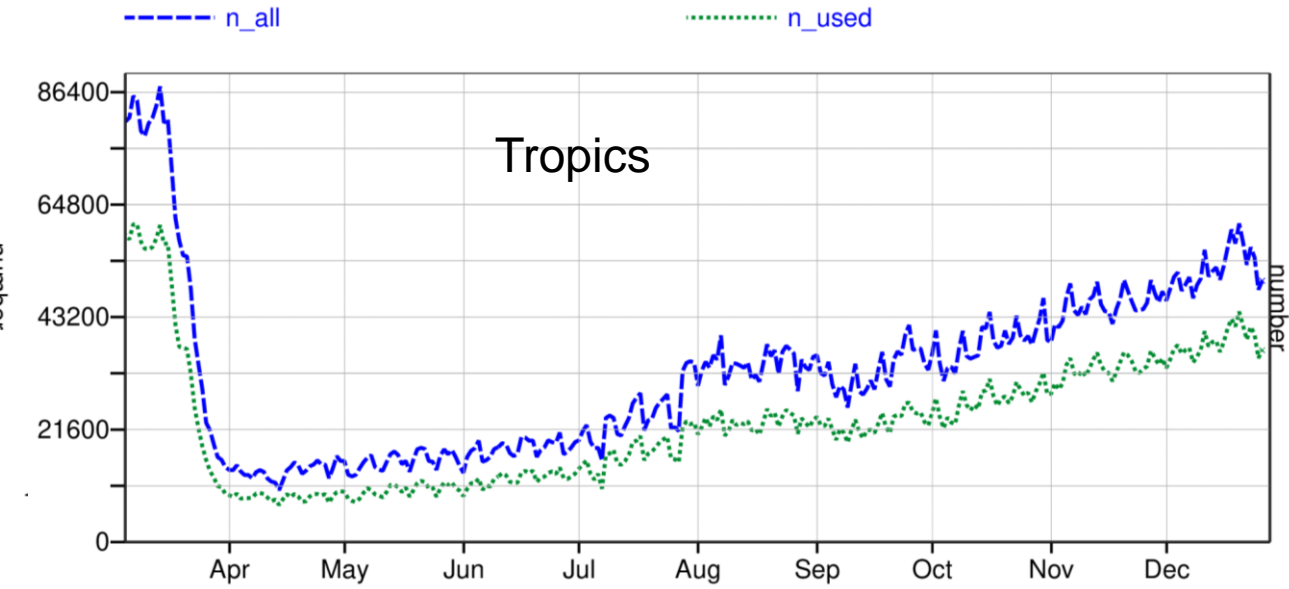
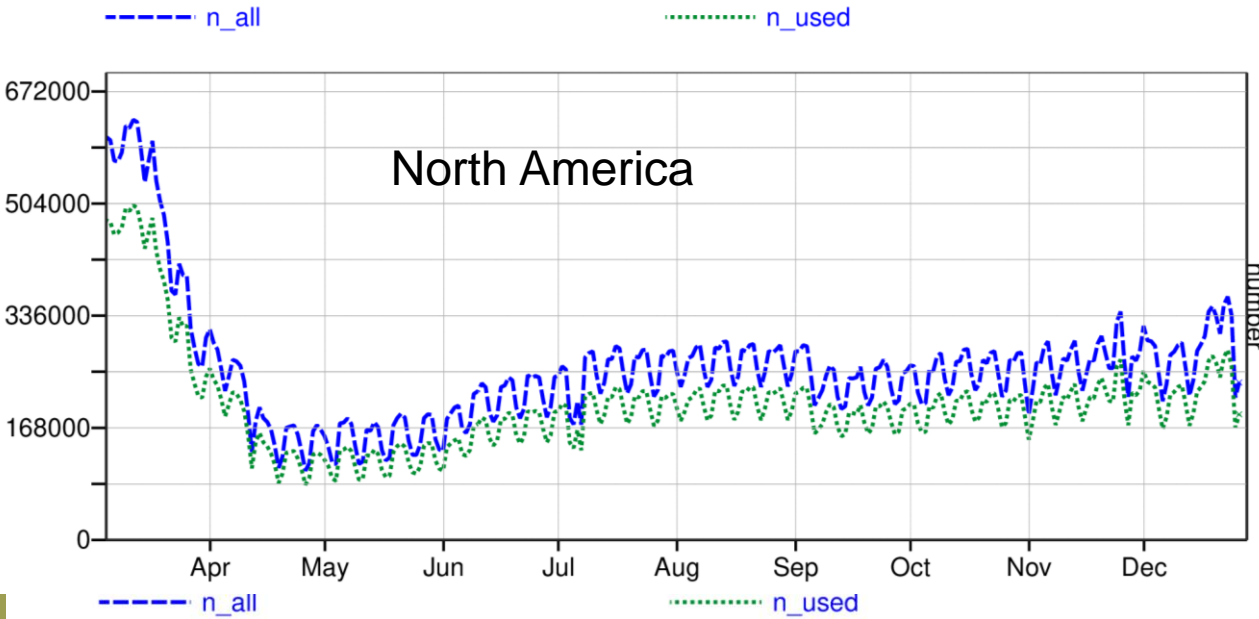
c) April 29 c) 2020-04-29 0900-2100 UTC 89941 reports



d) May 26 (2021) d) 2021-05-26 0900-2100 UTC 187896 reports

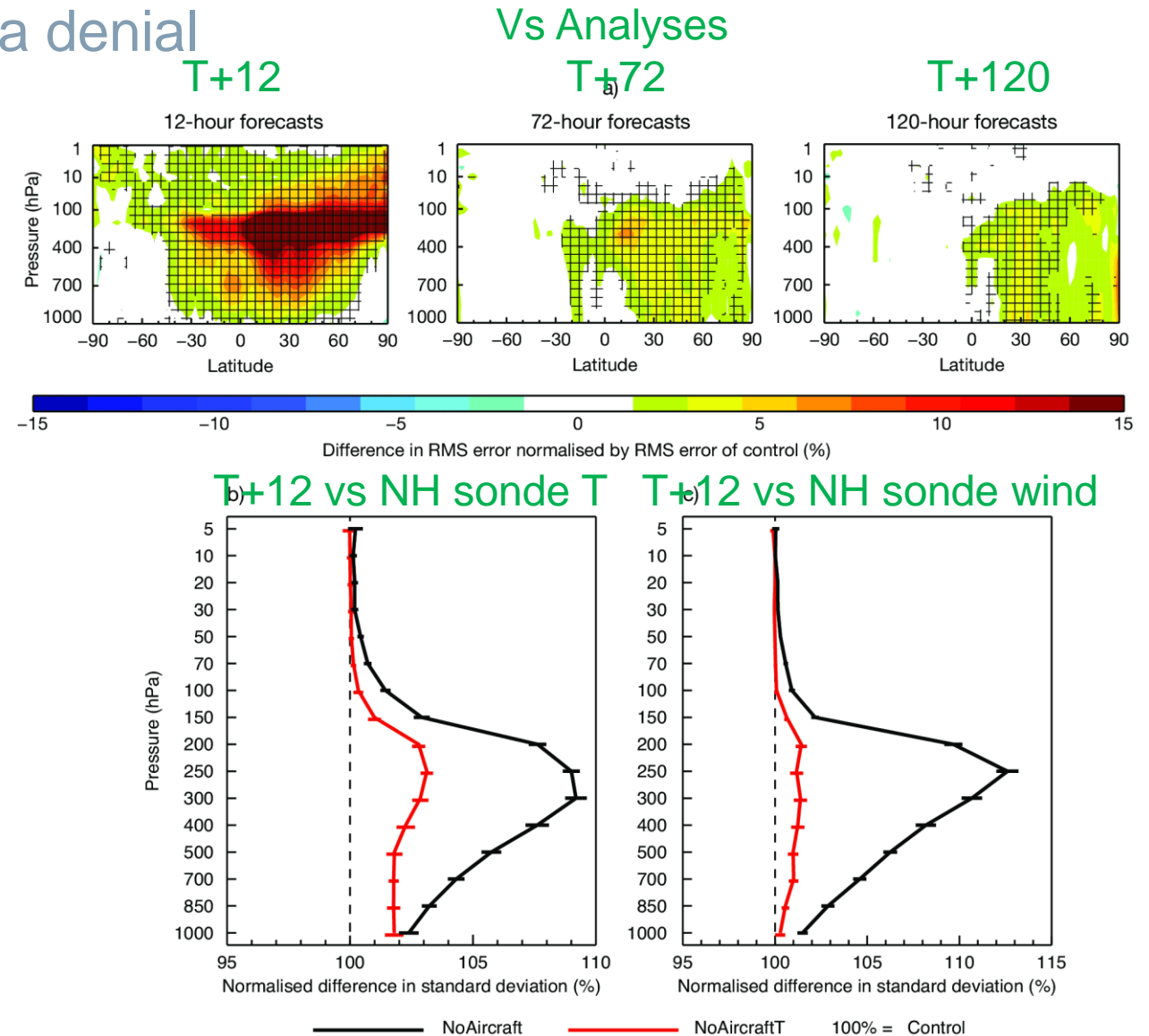


# Aircraft reports by region



# 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(temperature), 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)

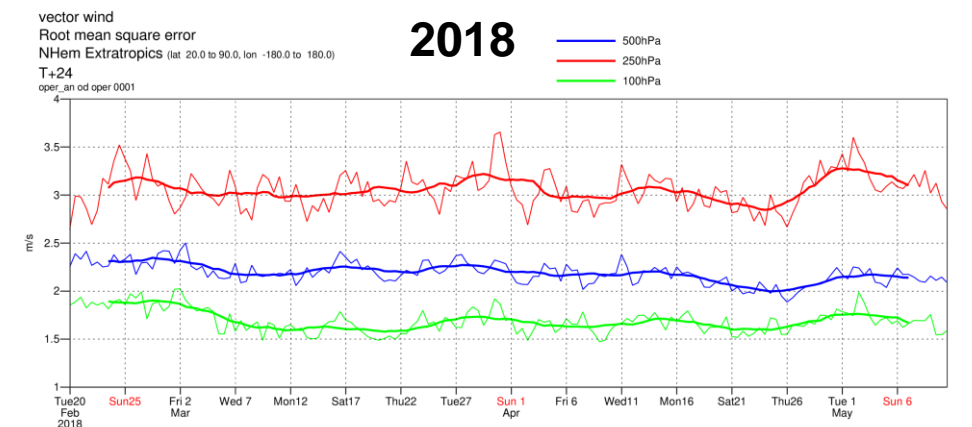
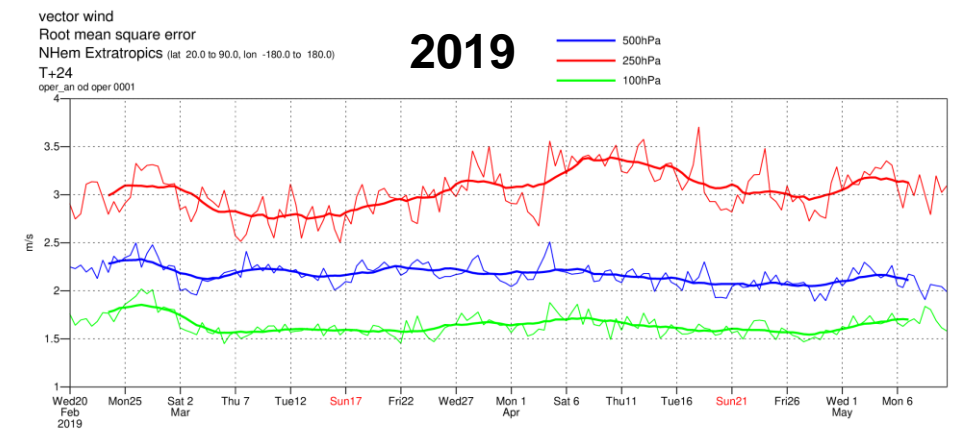
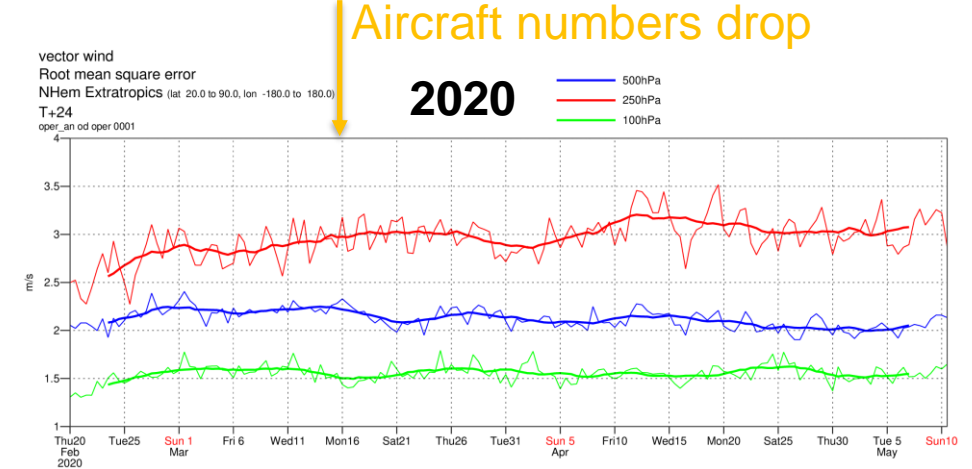




## Can we see the impact in 2020?

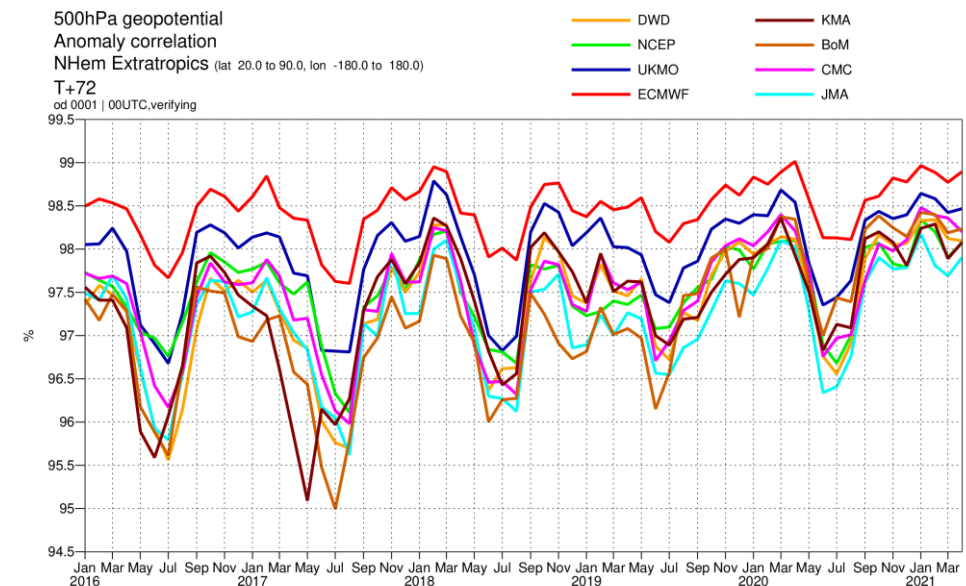
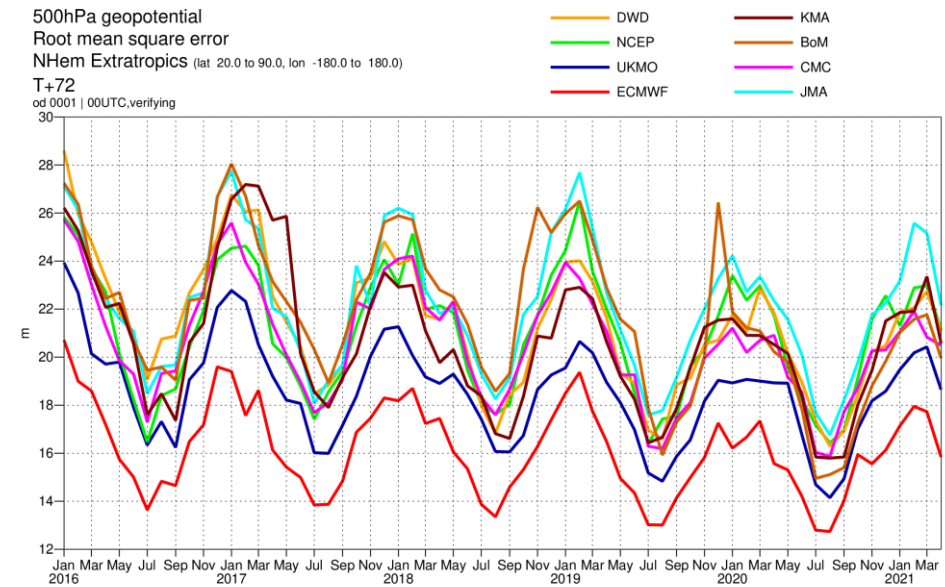
- Not really in verification scores!?
- **T+24 250 hPa NH vector wind rms in red**
- **250 hPa is near jet level**, lower errors at **500 hPa** and **100 hPa**

- Day-to-day noise plus seasonal/annual variations (2019 more predictable in NH?)
- Still a bit surprising
  - Partly due to residual aircraft reports
  - Other factors? – later slides



## Verification scores (2)

- No clear effect on forecast scores
- Show T+72 scores for Z500, 8 NWP centres
- A) Not complete loss – still >25% of AC data
- B) Extra satellite data in 2020: Aeolus winds and radio occultation (COSMIC-2 + Spire)
- C) Other upgrades to forecast system
- D) Year-to-year variations in skill anyway
- E) We don't have a control, with 'normal' aircraft data – sure that that would have been even better
- Ingleby et al (2021, GRL)





## Discussion

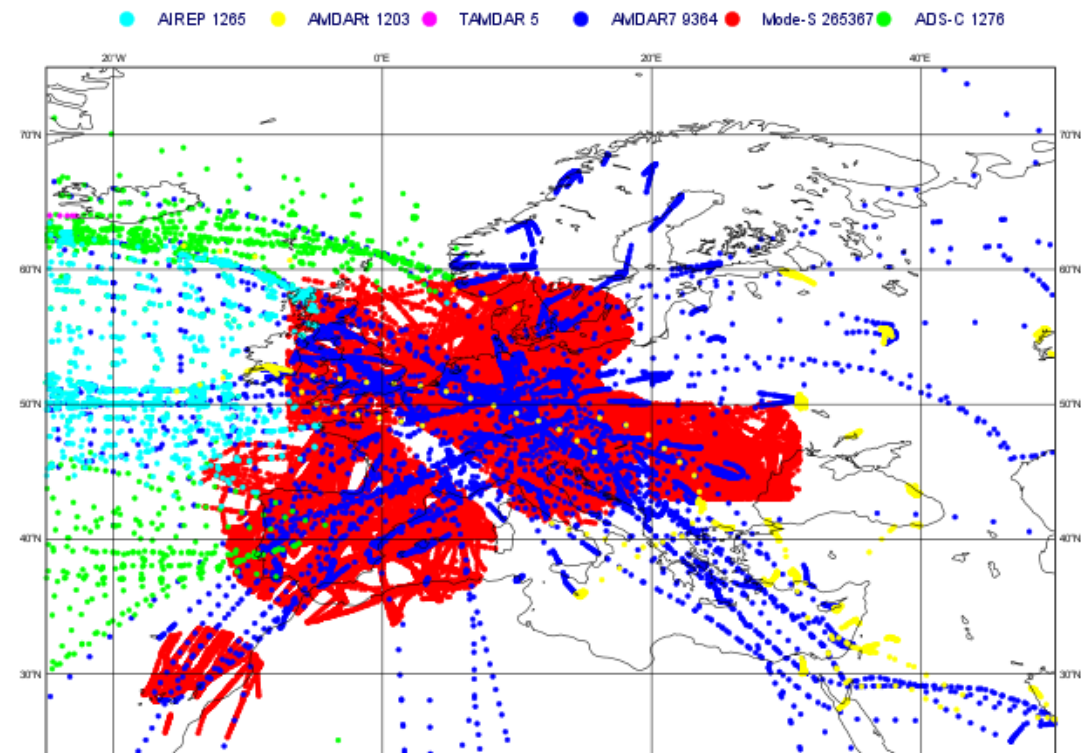
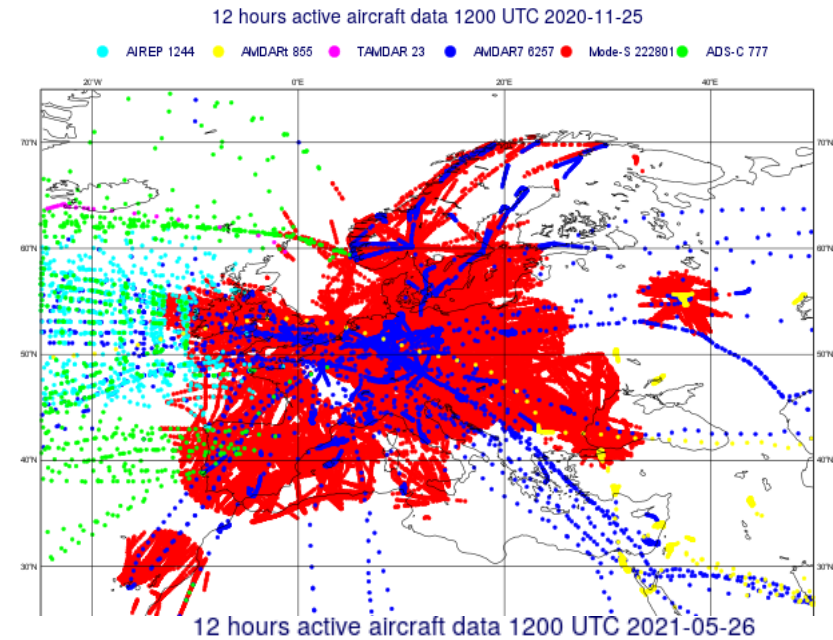
- James & Benjamin (2017, MWR): aircraft data most important data source over North America (Rapid Refresh system)
- James et al (2020, JAMC): 20% of aircraft give >20% of impact of all aircraft
- Chen (2020, GRL) '*COVID-19 pandemic imperils weather forecast*'
- Ingleby et al (2021, GRL): '*The impact of Covid-19 ....: a balanced view*'
  - Authors from ECMWF, Met Office (UK), NCEP (USA), BoM (Australia)
  - Chen's comparison of 2020 with previous years is 'oversimplistic'
  - Importance of satellite data, variations in forecast skill
- Riishojgaard (2020, WMO Bulletin, 69 (2)) '*Impacts of COVID-19 Restrictions*'
  - Minor reductions in surface and radiosonde reports in some regions
- Bauer et al (2015, Nature): '*quiet revolution*' – improvements in global NWP

## Changes to ECMWF observation usage in 2020

- **Mid-January started using Aeolus wind data (Business As Usual)**
- **25 March started using COSMIC-2 Radio Occultation (RO) – BAU**
- April-August – extra radiosonde ascents from some European stations
- **13 May to end Sept use of Spire RO data**
- June started use of FLYHT aircraft data (AFIRS+TAMDAR)
- Mid-June started use of German radiosonde descent data
- **27 July started use of European Mode-S aircraft winds**
  - Pan-European ‘test’ product processed by KNMI (NL)
  - Both KNMI and ECMWF accelerated development/implementation
  - Air traffic control messages: De Haan (2011)
  - Wind: similar quality to AMDAR, temperature – more mixed
  - Also included ‘fix’ for ADS-C/AIREP B787 wind direction error

# European coverage including Mode-S

- November 25 (top): 12 hours, used data
- May 26 (bottom): 12 hours
- AMDAR samples small % of flights
- Mode-S samples all flights within range (only 5% of reports used at ECMWF, still too many? Weighting?)
- Over N Atlantic most data provided by ADS-C/AIREP
- In 2<sup>nd</sup> half of 2020 more Mode-S receivers were set up (SE Europe, Norway\*, Moscow\*, \* missing/problems for last few weeks)

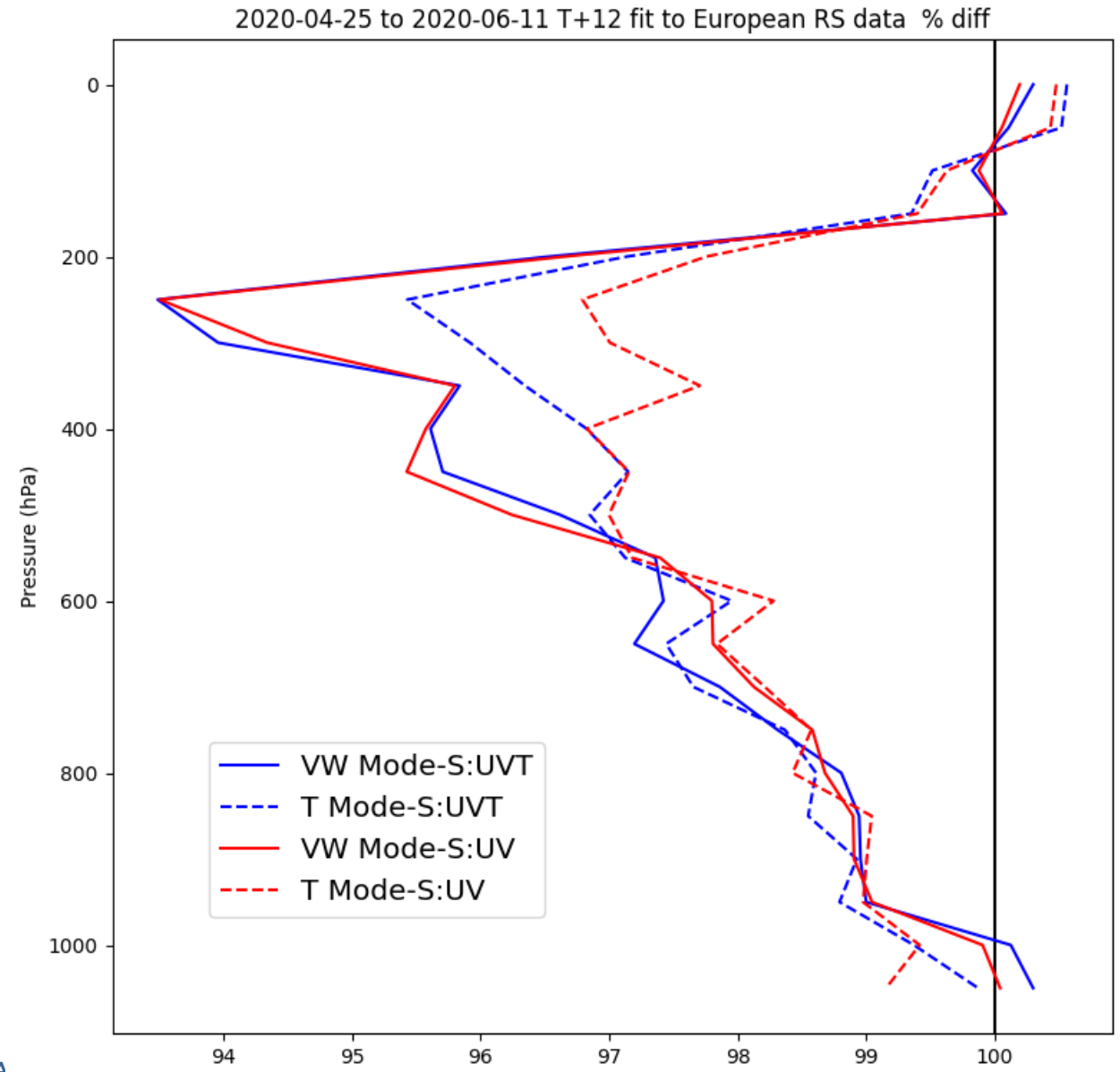


# What is Mode-S?

- Mode-S EHS (De Haan, 2011; Sondij, 2020 EUMETNET/ECMWF workshop)
  - Some ATC systems ping aircraft for additional information
  - All aircraft have to respond (every 4-30 seconds): **very dense data**
  - Mode-S EHS was not designed for meteorological reporting
    - Temperature not included, can be derived from Mach number, but the precision is poor especially at low levels (can be mitigated by clever averaging – De Haan)
    - Aircraft heading (needed for winds) is reported wrt magnetic North\* not true North (correction needed, \*depends on date of aircraft look-up tables)
    - Despite this the wind quality is close to that of AMDAR reports
- Mode-S MRAR
  - These were designed as meteorological reports
  - Only available from limited number of aircraft in South-East Europe

# Impact of Mode-S: T+12 fit to European radiosondes

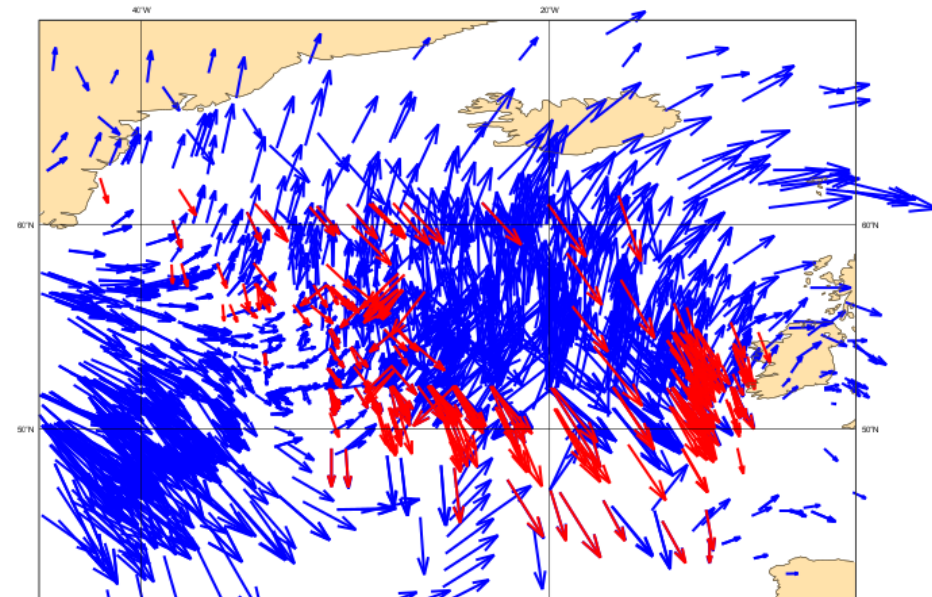
- As expected the impact is larger (more positive) over Europe
- Larger than seen in earlier LAM tests – partly because Mode-S is being used over a wider area
- Verification against analyses is ~neutral
- Minor bias effects and/or analysis increments outside an area with very dense observations??
- Biggest impact on winds at cruise level and less impact of T data – as seen for all aircraft data on hemispheric scale



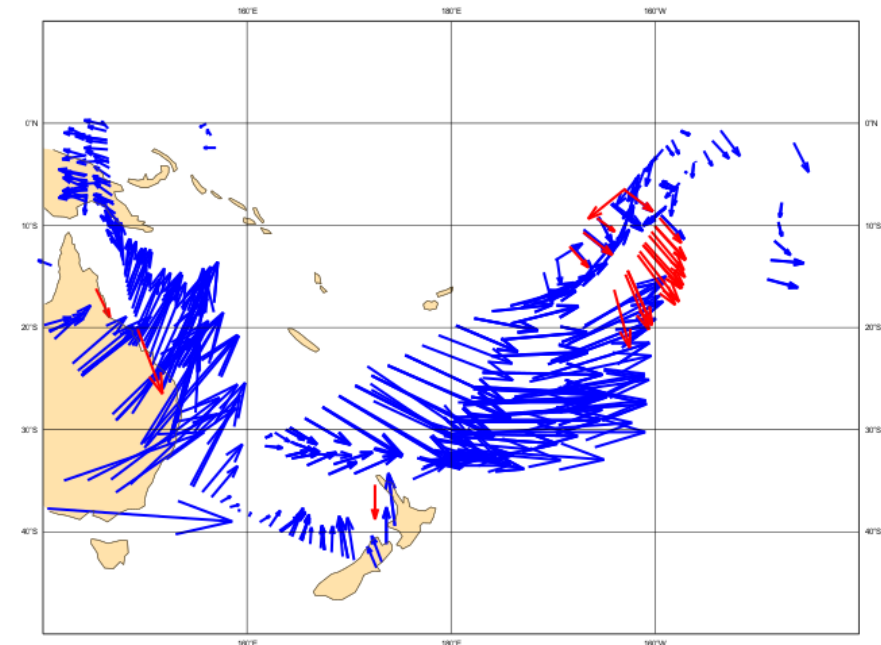


## B787 wind problem

- Quasi-intermittent problem with wind direction (sign of  $v$ ) for a subset of B787 winds! Winds from ADS-C/AIREP from certain directions (details from C Hill, NOAA). Nasty, frustrating QC problem 😞 😞
- 2018 rejected wind from known B787s (550+ identifiers) – throws out good data too
- No metadata on aircraft type in reports: 😞 😞 we now know type for a subset of aircraft
- Simple “correction” of  $v$ -winds (AIREP and ADS-C) implemented in 2020 - imperfect
- 90% of bad winds in North Atlantic – but little impact there – lots of good winds too
- More impact in South Pacific: fewer flights

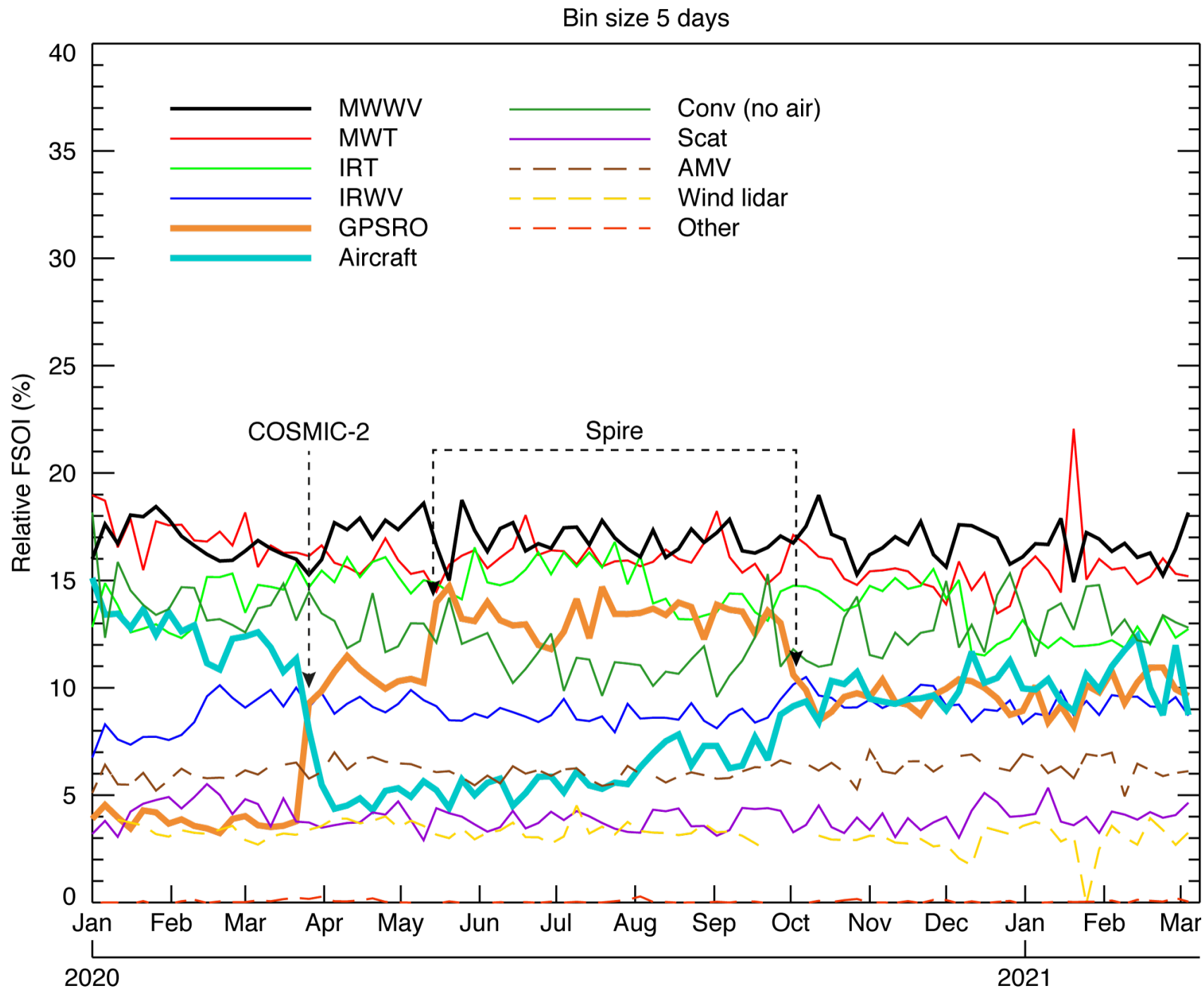


SH2020090712, aircraft winds, 175-225 hPa

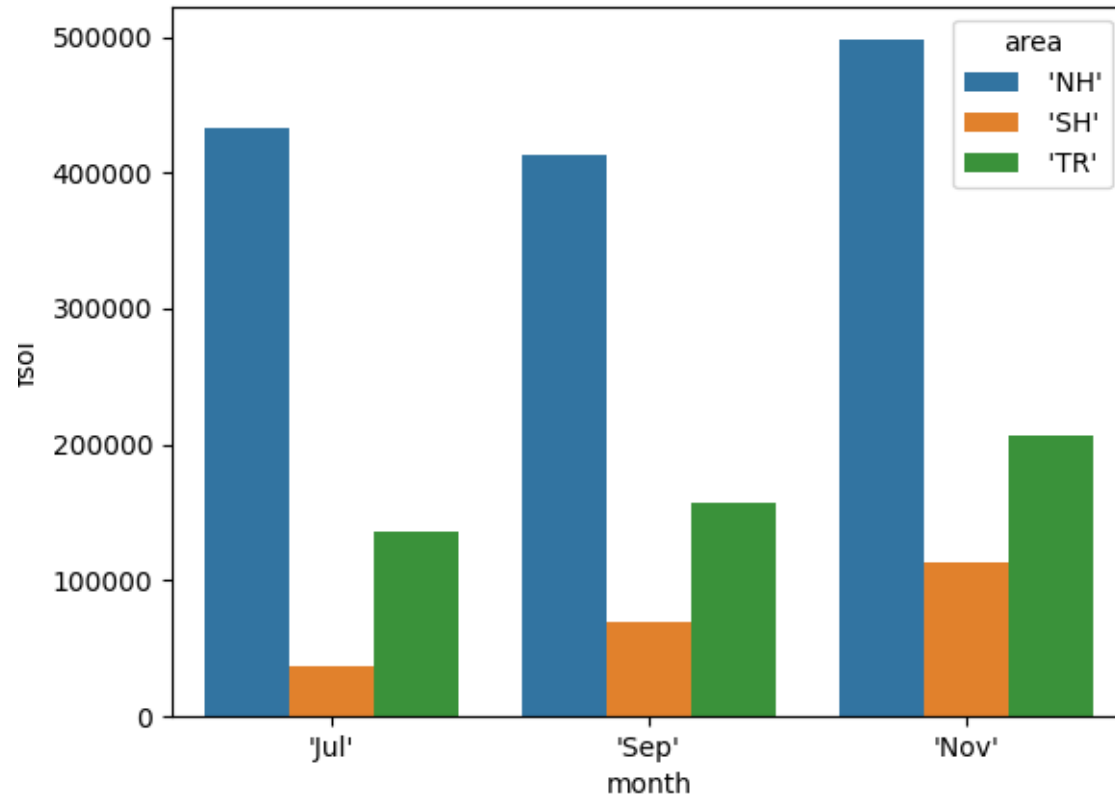


# FSOI % for 2020/21

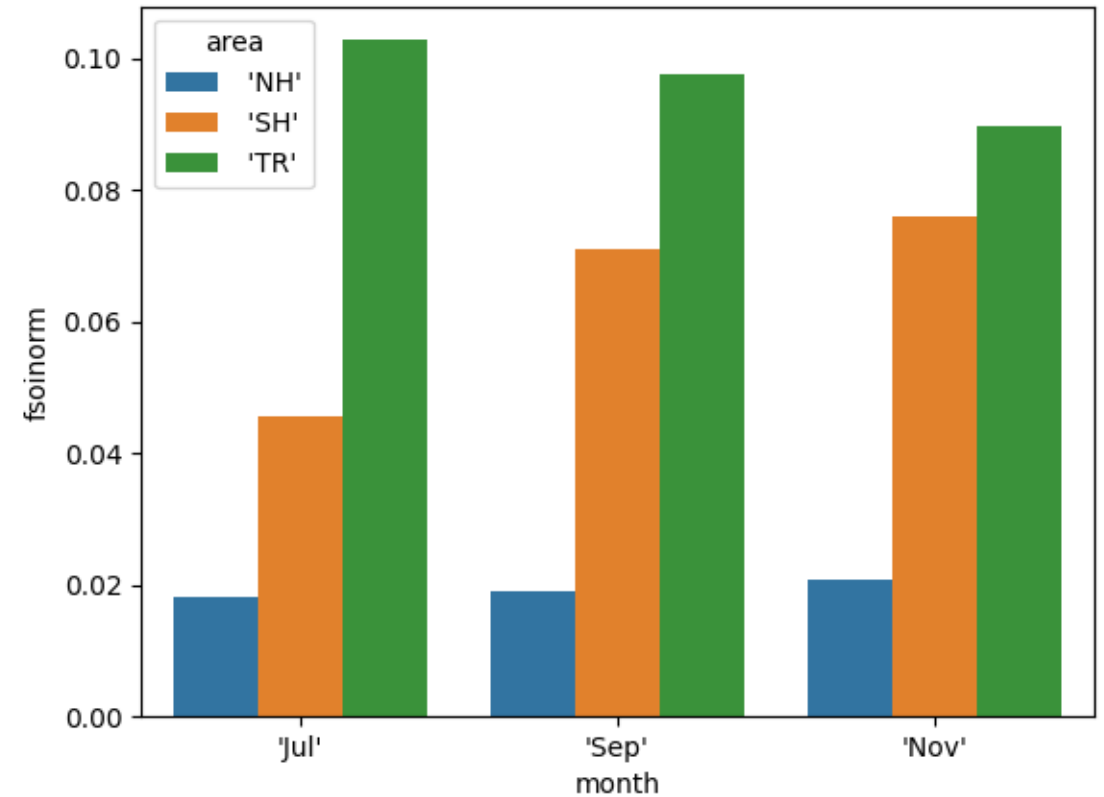
- Forecast sensitivity to observation impact: estimate of how important obs subsets are for T+24 forecast
- RO: steps from start of COSMIC-2+Spire, Spire stopped end Sept
- Aircraft: drop in Mar/Apr then ~level
- Recent increase: seasonal or SH? (next)
- Aeolus: ~3% (gaps)



## Total (-)FSOI by region



## FSOI/datum by region

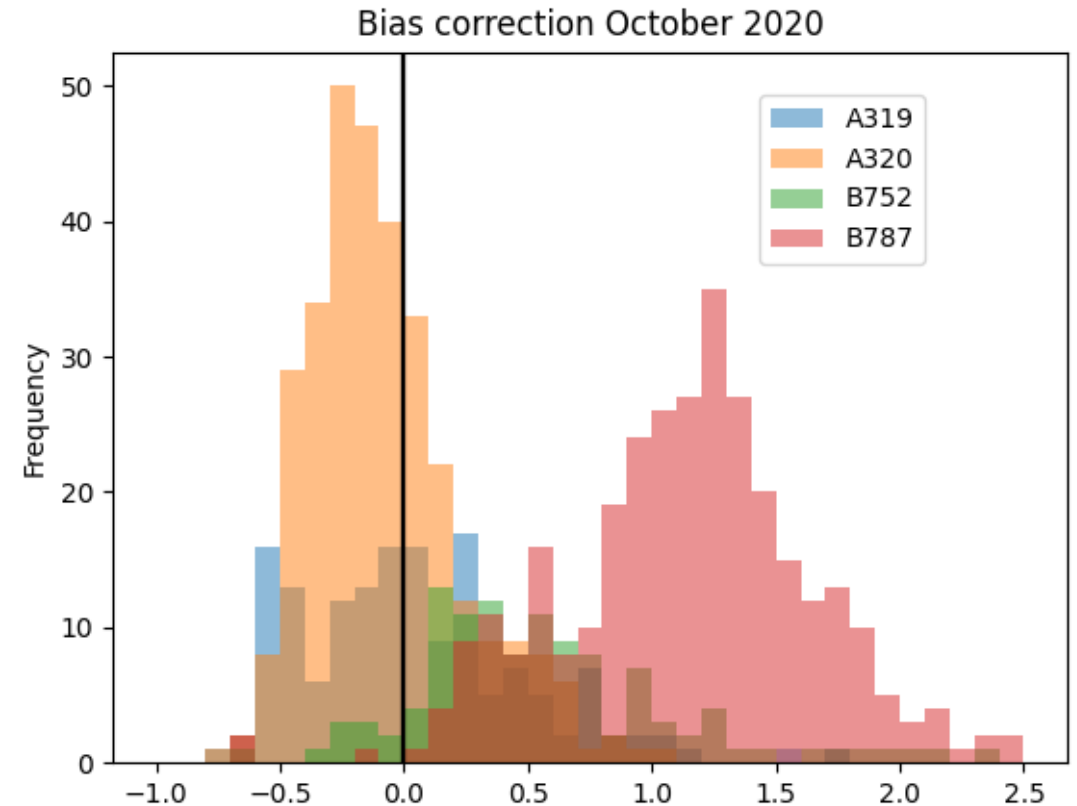


- **More impact per report in data sparse areas**
- Wind data particularly important in the tropics
- **Recovery in tropics + southern hemisphere has disproportionate impact**
- Mode-S (not included in figures): 12.5% of FSOI from ~50% of aircraft obs

*See poster on  
'Estimates of  
radiosonde and aircraft  
impact and their  
implications'*

# Aircraft temperature biases

- Ballish and Kumar (BAMS, 2008), Petersen (BAMS, 2016), Zhu et al (MWR, 2015): aircraft biased warm by 0.3-1.0K on average
- ECMWF use of VarBC to “correct” the data: Isaksen et al (2012, Newsletter)
- Correction methods are imperfect!
- Our knowledge of metadata is very patchy 😞
- Better if the bias can be removed at source. De Haan et al (2021, AMTD) may help with this.

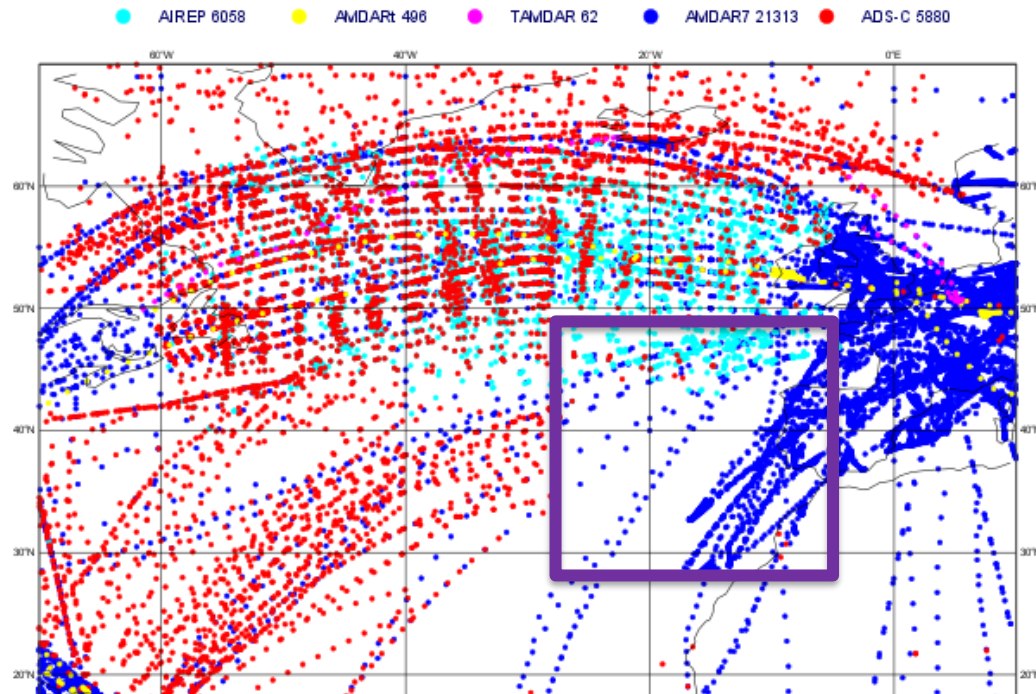


\*Type information is incomplete but comes from either a) US/EU AMDAR programs or b) ESoWC 2019 study (with M Chan, M Dahoui) matching flightradar24 to AMDAR tracks. NOT used in ECMWF VarBC, which uses aircraft identifier, ascent rate and O-B.

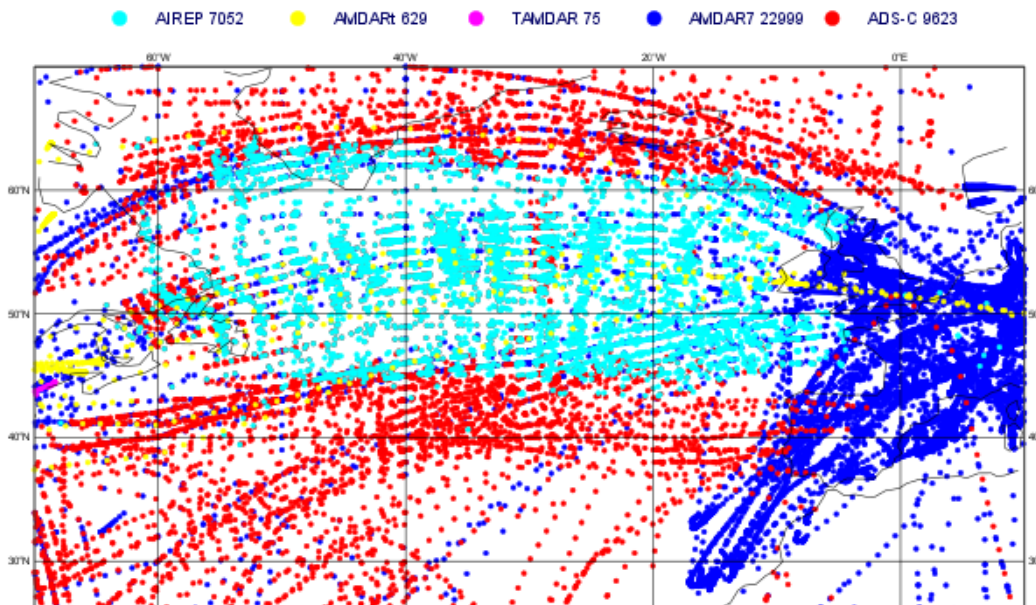
**Bias is linked to aircraft type** (Drüe et al, 2008: even if the details aren't clear)



Aircraft data 2020-10-01



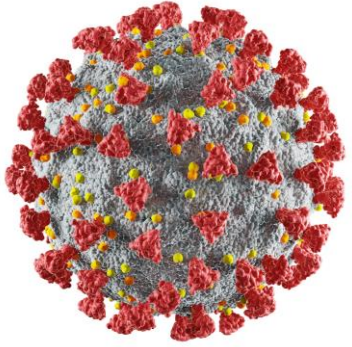
Aircraft data 2020-10-03



## A gap in the North Atlantic

- ~3 years ago we noticed a gap in N Atlantic west of Europe
- Tracks started/stopped 30-40°W
- **AMDAR** problem? No: **ADS-C** problem.
  - At that time ADS-C was treated as AMDAR
- Spoke to EUMETNET, Steve Stringer
- 'Santa Maria' flight information region
- Steve spoke to NavPortugal – outcome unclear
- Early October 2020 we started getting **ADS-C** from that region 🕶️
- Only 26 more Air Navigation Service Providers to go! (40 provide met information)





## Summary

- Covid-19 reduced the number of aircraft reports by 75% for ~2months
  - Partial recovery to ~50% of pre-Covid levels
  - Autumn/Fall 2020: European reports decreasing, S Hem. reports increasing
- Aircraft data are valuable for NWP, biggest impact is on wind at ~250 hPa
  - Winds give more impact than temperatures
  - More impact in NH where most reports are
- Cannot see a decrease in forecast quality in 2020 (multiple centres):
  - Satellite data more important – some increases 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 – more metadata would be helpful
- Use of **Mode-S aircraft winds** at ECMWF, more data here than in 2019!