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The TAC to BUFR Migration:

Current Status of BUFR Surface and Upper-Air Observations

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Special thanks to Bruce Ingleby (ECMWF) and Rebecca Stone (NRL/SAIC)

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TAC to BUFR Migration

Why should I care about the way observations are formatted for dissemination?

- Loss of observations as countries stop sending messages in the older formats
- Change in character of radiosonde observations

Talk Outline

- Terminology
- Recent changes in radiosonde data and ongoing issues
- Recent changes in surface data and ongoing issues
- Upcoming change in station identifiers

TAC to BUFR Migration

```
TTAA 56121 72662 99892 12262 27505 00047 ///// ///// 92717 ///// ///// 85430 11263 32026 70018 00058 32553 50563 13557
32078 40729 25560 33077 30931 41356 34104 25052 51159 35120 20195 58557 35127 15374 59362 33588 10628 59368 34058 88181
63356 34622 77207 35129 40716 31313 58208 81109 51515 10164 00009 10194 32034 32054=
```

- **TAC (Traditional Alphanumeric Codes)**
  - TEMP, PILOT radiosonde formats developed for teletype era in 1940's
  - Also includes FM-12 SYNOP (surface data) and FM-42 AMDAR (aircraft data)

```
01010100010101000100000101000001001000000011010100110110001100010011001000110001001000000011011100110010001101100011011000
11001000100000001110010011100100111000001110010011001000100000001100010011001000110010001101100011001000100000001100100011
01110011010100110000001101010010000000110000001100000011000000110100001101110010000000101111001011110010111100101111001011
11001000000010111100101111001011110010111100101111001000000011100100110010001101110011000100110111001000000010111100101111
```

- **BUFR (Binary Universal Form for the Representation of meteorological data)**
  - Approved in 2003 as a replacement for TAC for international exchange
  - TAC distribution originally scheduled to end by November 2014
    - Only a fraction of TAC has ceased to date
    - Migration will take years for completion
    - Cessation of TAC often occurs with little advance notice and insufficient publicity

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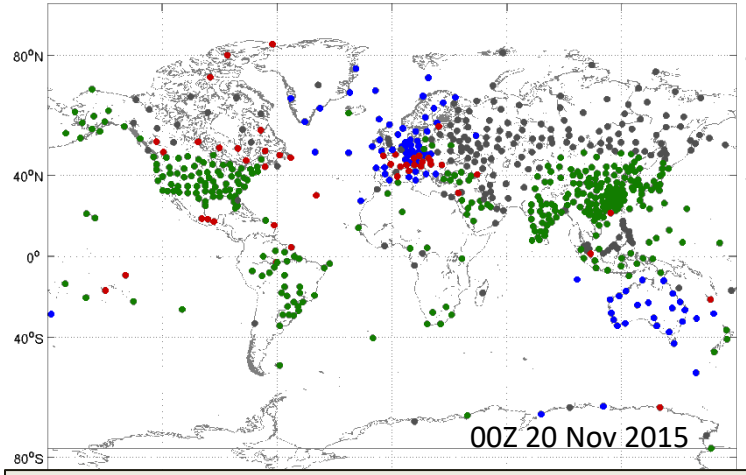
TAC to BUFR Migration—Radiosondes

- **BUFR radiosonde data definitions (Ingleby et al. 2016)**
  - **“Reformatted” BUFR**: TEMP messages converted to BUFR
    - **“Invalid” BUFR**: Each TEMP part placed in a separate BUFR message
    - **“Valid” BUFR**: TEMP parts merged prior to conversion to BUFR
    - Same precision, levels as TEMP messages—typically 50 to 100 levels
    - Station metadata (e.g., latitude, longitude, elevation) from a station list
  - **“Native” BUFR**: ground station data formatted in BUFR
    - Better precision than TEMP, typically 1-2 second data (3500-7000 levels)
    - Station metadata from the ground station
    - Balloon drift time and location offsets included and all variables present at each level
    - Single message used—“valid” BUFR
      - Preliminary message—surface to 100hPa (IUK bulletins)
      - Final message—surface to balloon burst (IUS bulletins)

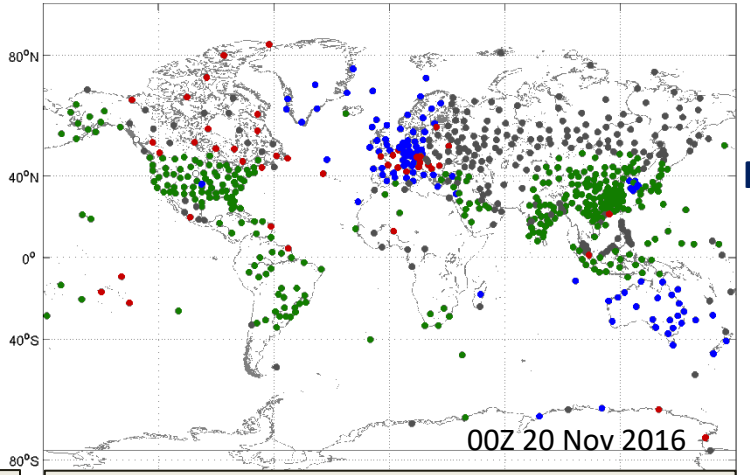
U.S. BUFR Radiosonde Data

- **Types of BUFR produced for U.S. radiosonde data**
  - **"TUABUFR"**: also called "legacy" BUFR
    - Invalid reformatted BUFR—separate message for each TEMP part
    - Station metadata not included
    - No longer placed on GTS but still on NOAAPort
  - **"BMT" BUFR**: bulletins originate at KWBC
    - Valid reformatted BUFR converted using the BUFR Migration Tool
    - Station metadata from a station list that contains errors
    - Significant level winds in PILOT format not converted
  - **"High-resolution"**: also called "RWS Build 3.4.0.1" or "RWS"
    - Valid native BUFR with bulletins originating from individual NWS stations
    - Station metadata from ground station
    - One-second resolution, drift offsets included
    - Enabled by software upgrade at NWS sites using 1680 MHz sondes

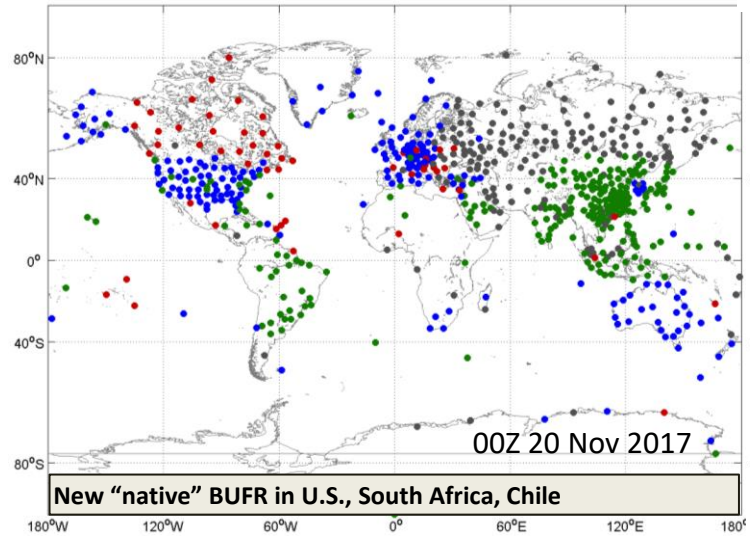
Progress of TAC to BUFR Migration: Native vs. Reformatted BUFR



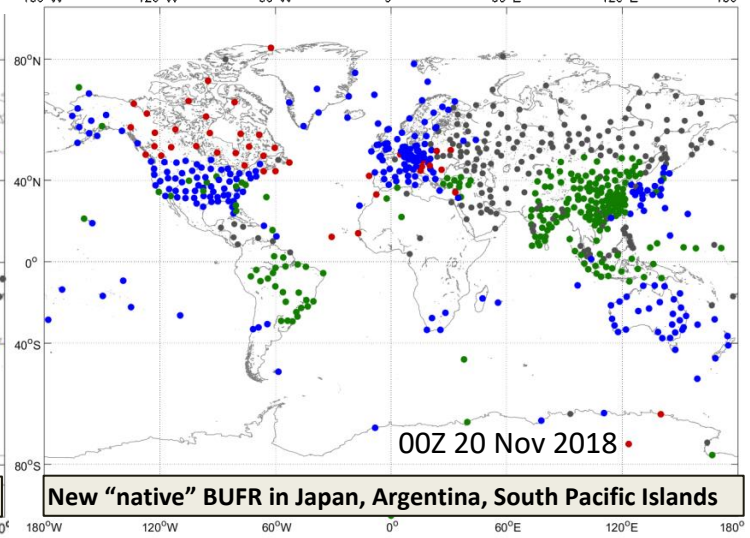
"Native" BUFR in Europe, Canada, Australia, Antarctica, Greenland



New "native" BUFR in New Zealand, South Korea

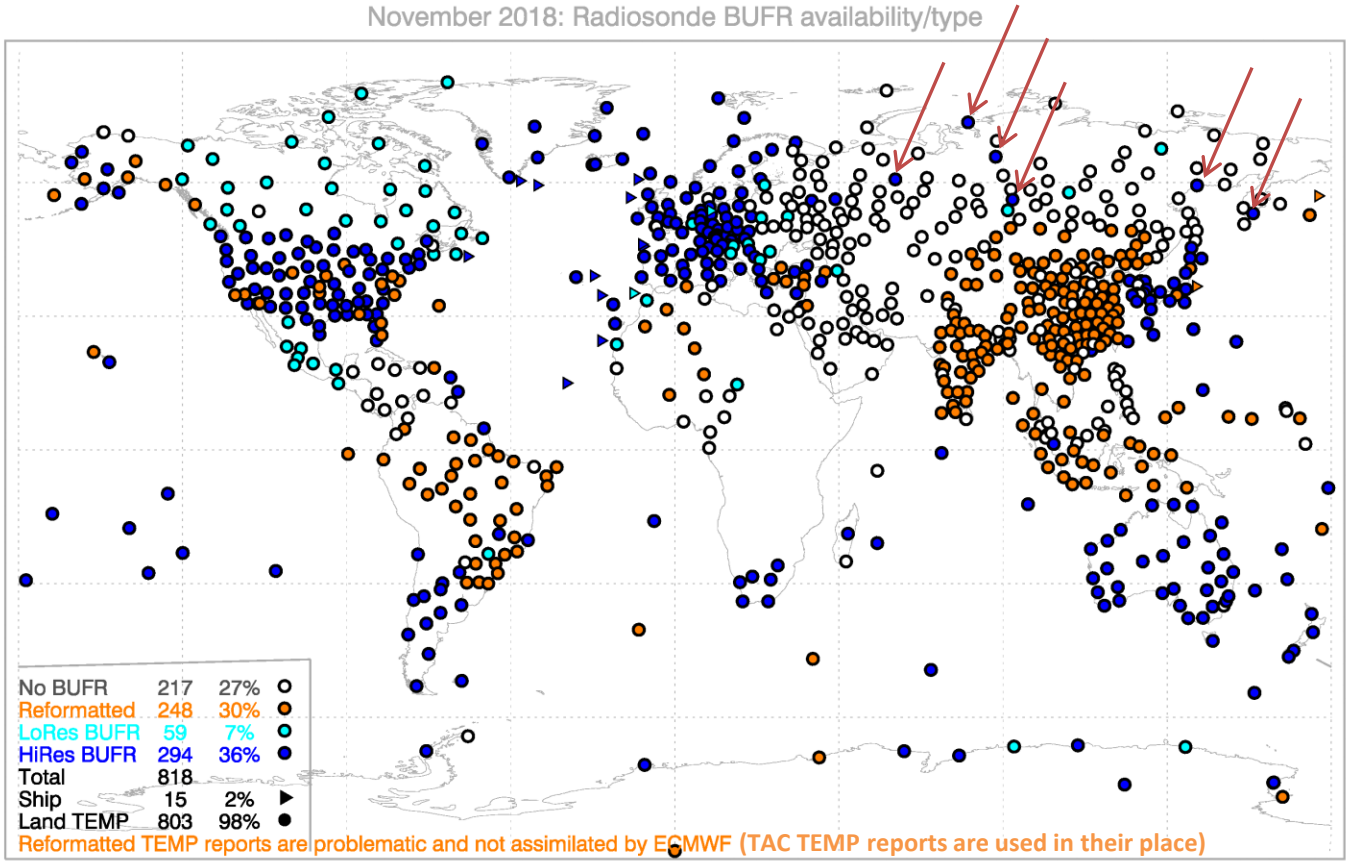


New "native" BUFR in U.S., South Africa, Chile



New "native" BUFR in Japan, Argentina, South Pacific Islands

- Entire RAOB rejected
- Only TAC available
- Reformatted BUFR
- High density native BUFR
- Low density native BUFR

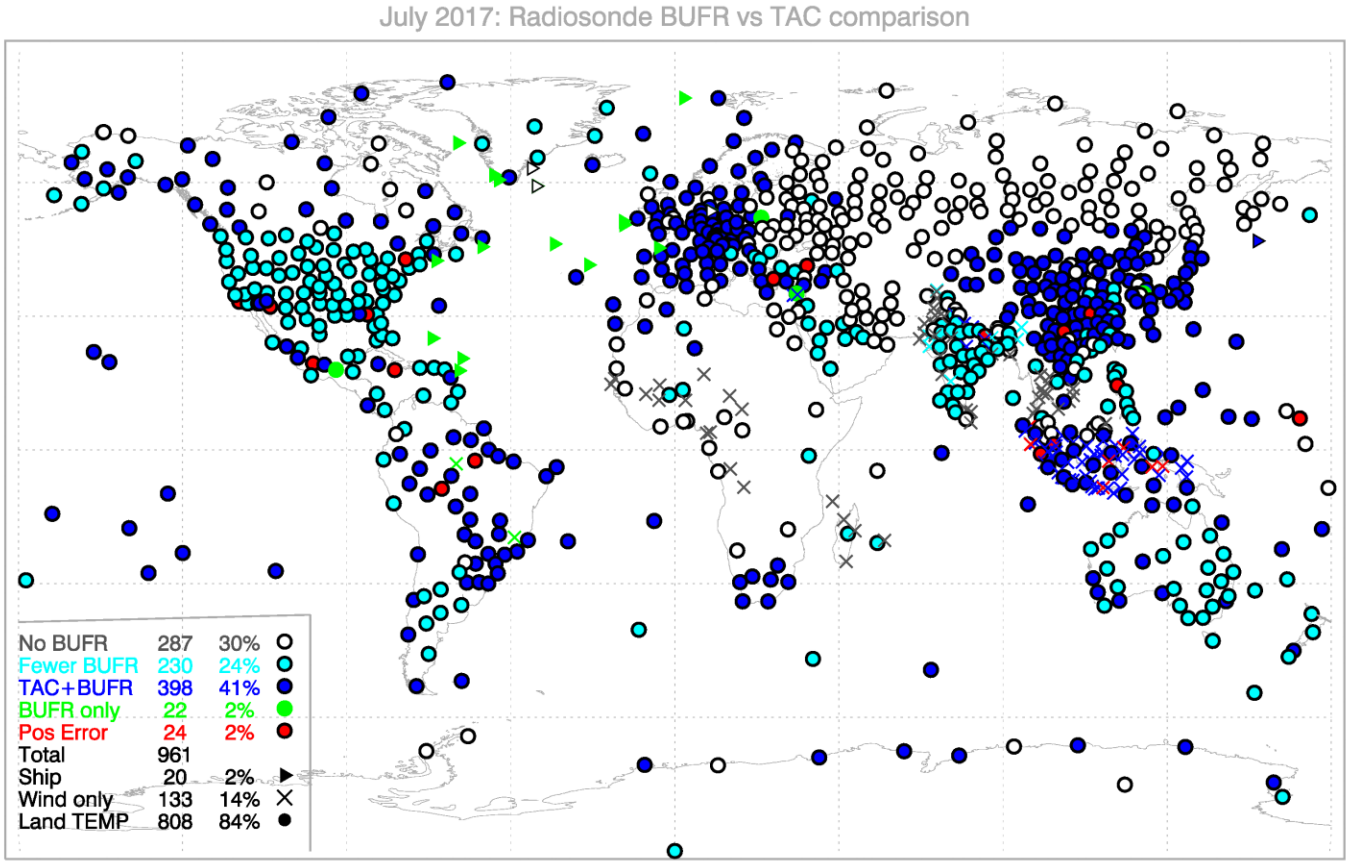


Radiosonde Availability (ECMWF)

New Russian native BUFR indicated by red arrows

Note that as some countries move to native BUFR (blue), some individual stations may switch back and forth between native and reformatted BUFR.

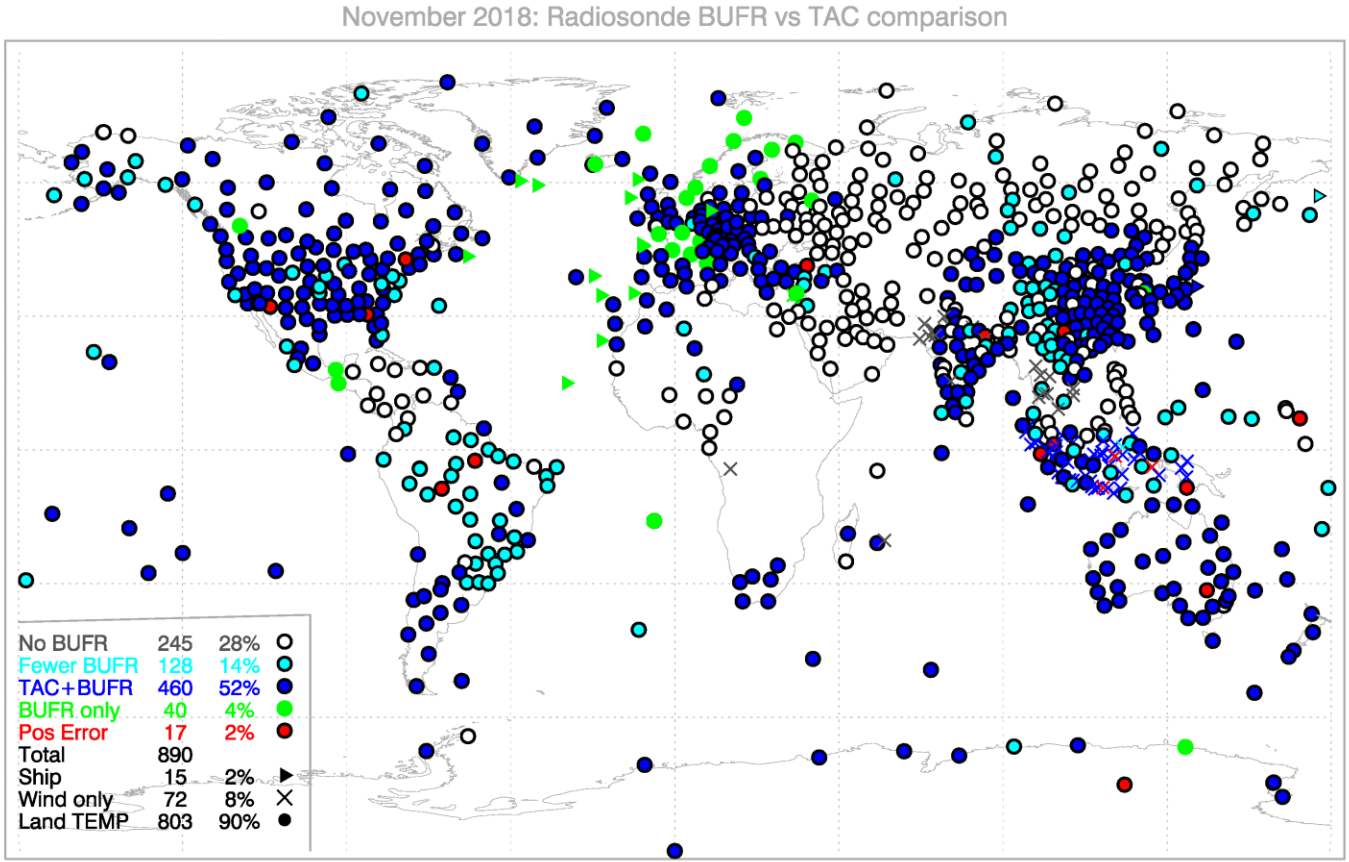
Graphics provided by Bruce Ingleby, ECMWF



Note the increase in countries/stations that provide BUFR data only (green).

Month-to-Month Variability in TAC vs. BUFR Radiosonde Availability (ECMWF)

Graphics provided by Bruce Ingleby, ECMWF



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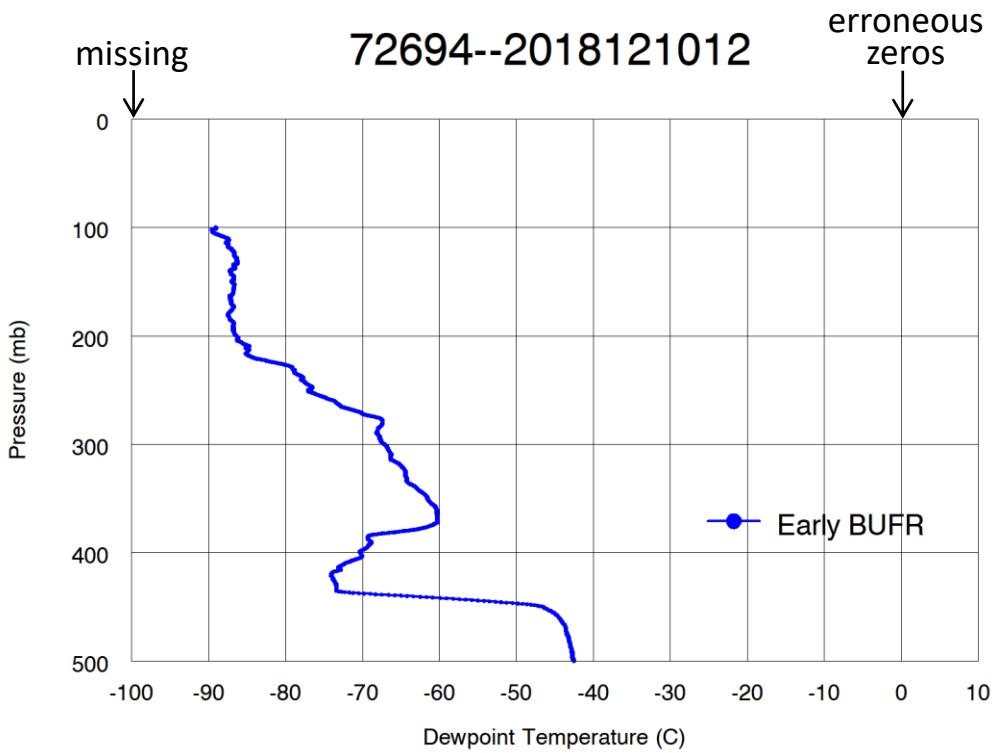
U.S. BUFR Radiosonde Error Example



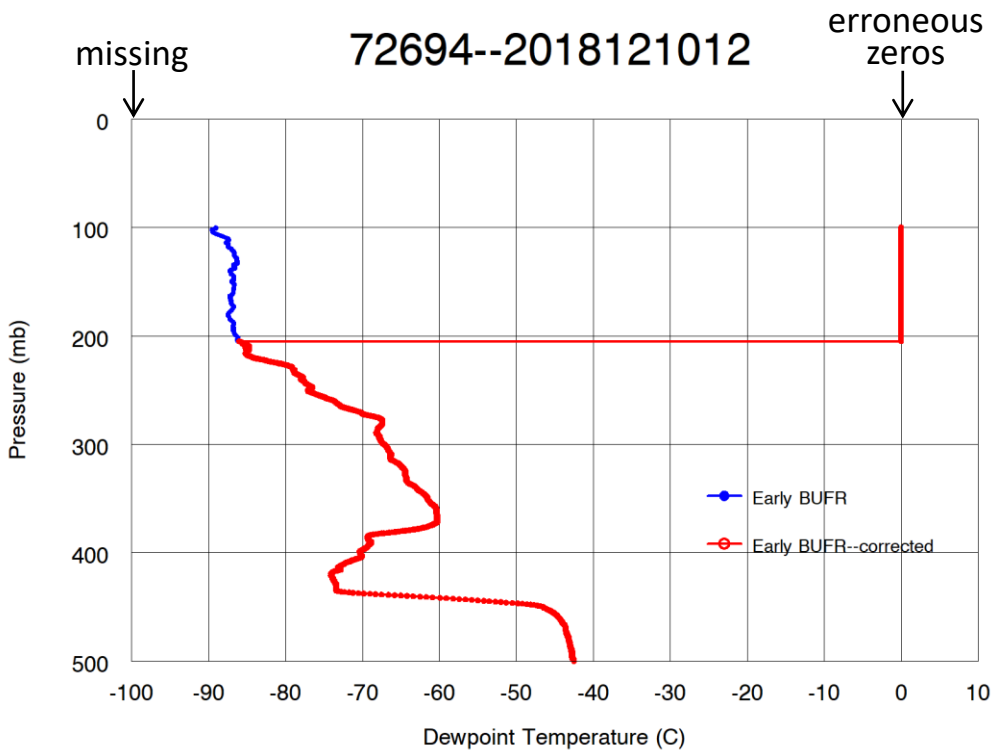
Native BUFR from 72694 (Salem, OR)
Early BUFR message—up to 100mb

Early BUFR message with correction
- **Operator marks data for rejection**
- **Rejected data have T_d = 0°C (should be set to "missing")**

Late BUFR message—full sounding
Late BUFR message with correction
- **T_d = 0°C persists from previous**
- **No difference in correction**

TAC message with correction
- **Rejected dewpoints marked missing**

U.S. BUFR Radiosonde Error Example



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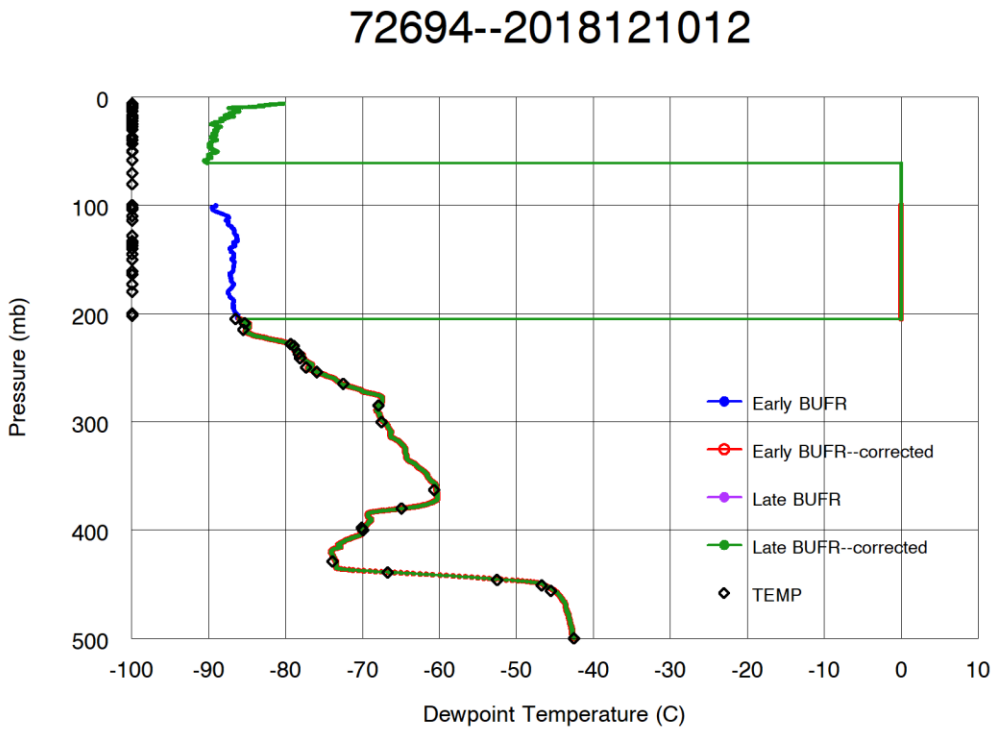

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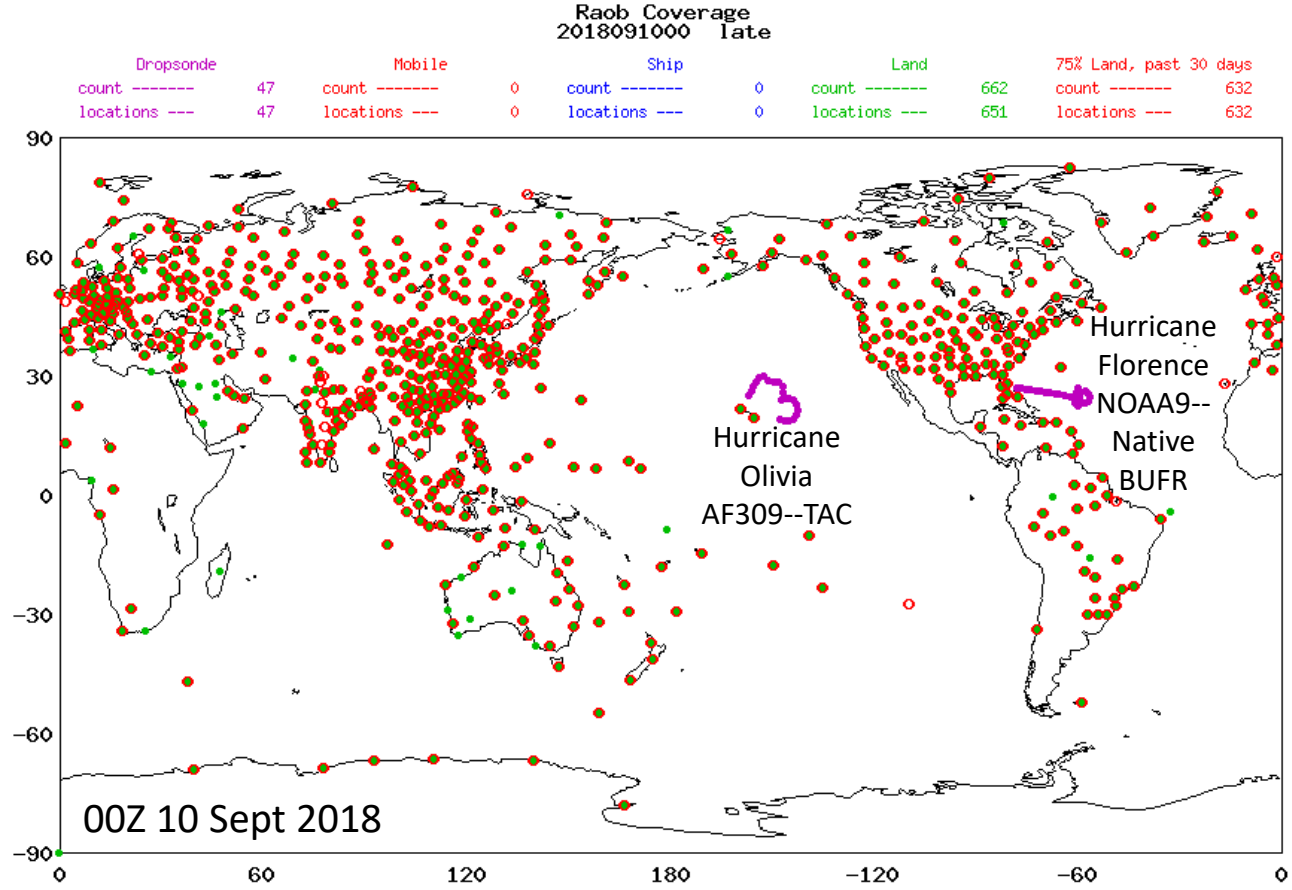
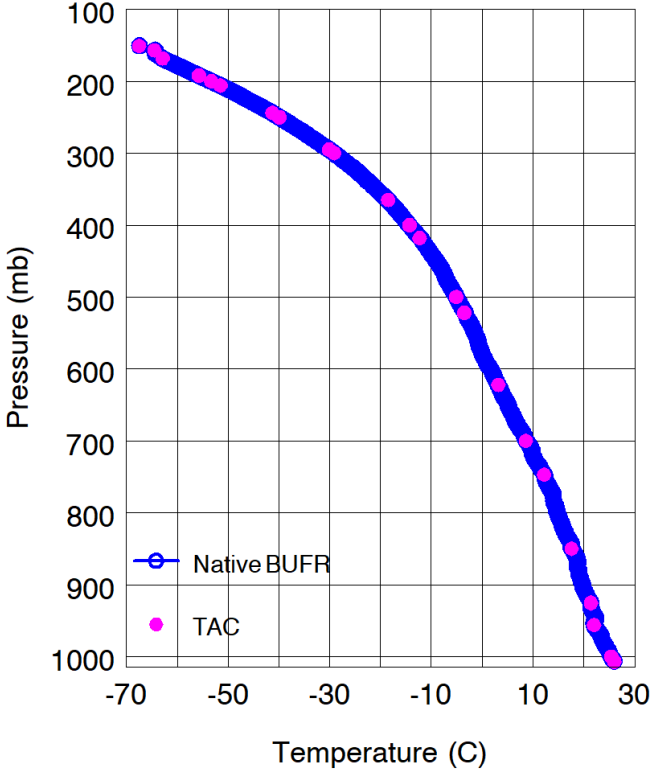
U.S. BUFR Dropsonde Data

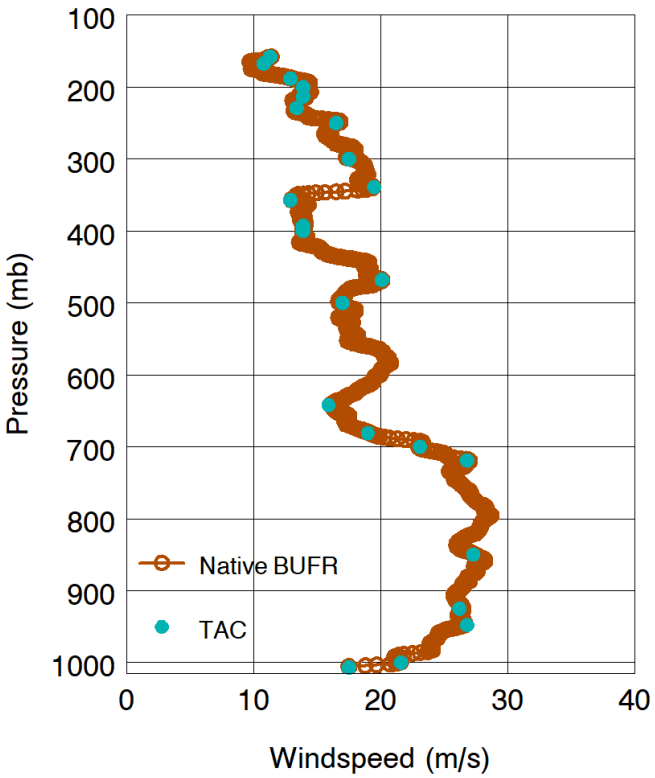


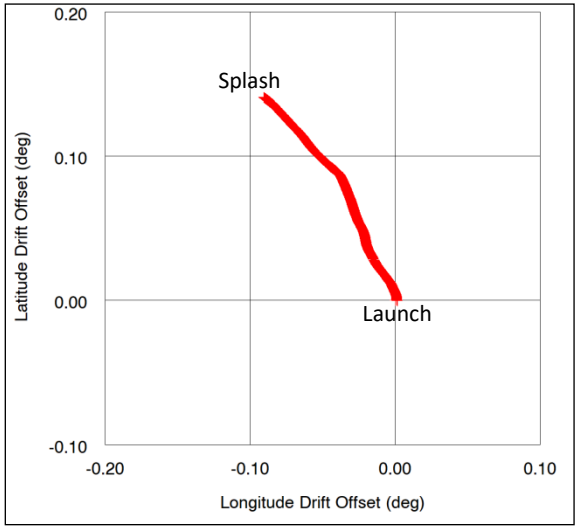
Real-time native BUFR dropsonde data were available for the first time during the 2018 hurricane season (NOAA aircraft only).

U.S. BUFR Dropsonde Data

Dropsonde from NOAA9 (G-IV) flying Hurricane Florence







- Launch: 2138Z 9 Sept 2018
  - –at 24.84°N, 55.98°W
- Splash: 2154Z 9 Sept 2018
  - –at 24.98°N, 56.07°W
- TAC has 37 levels
- BUFR has 955 levels (1 sec resolution)
  - –GPS drift included
  - –Thinned to 105 (wind) levels

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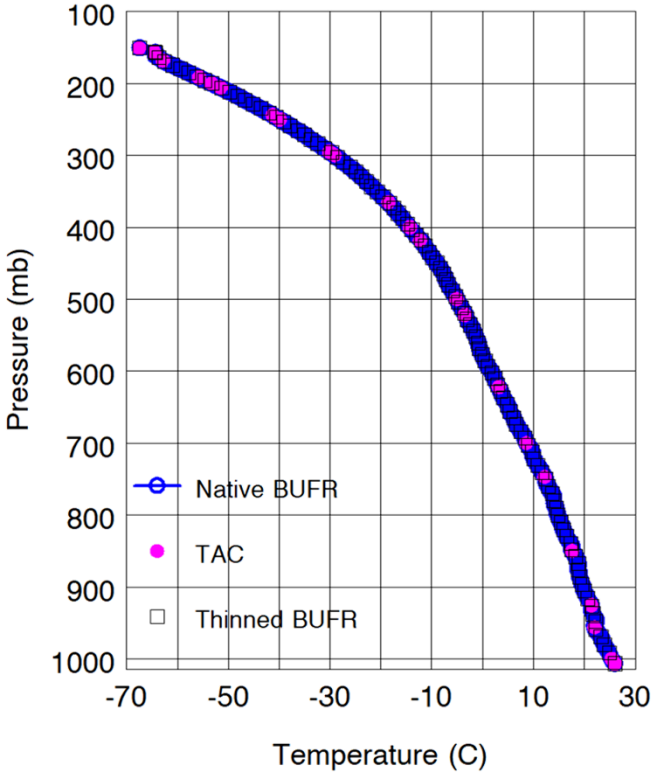

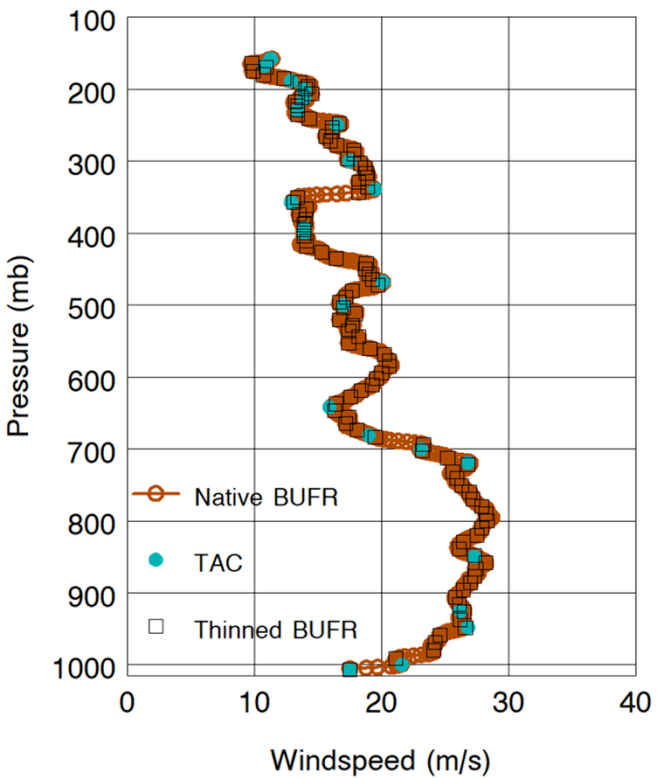

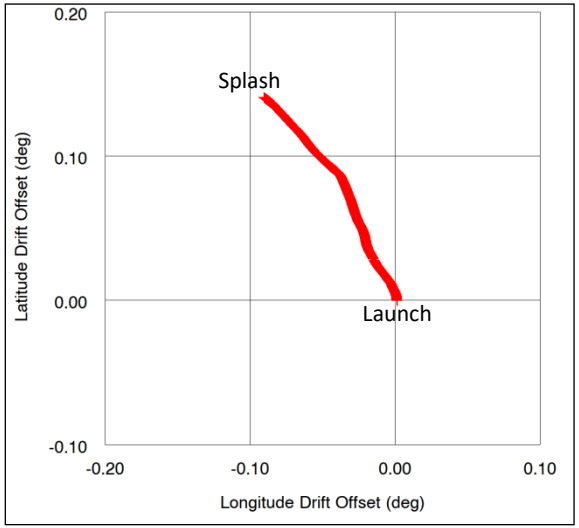

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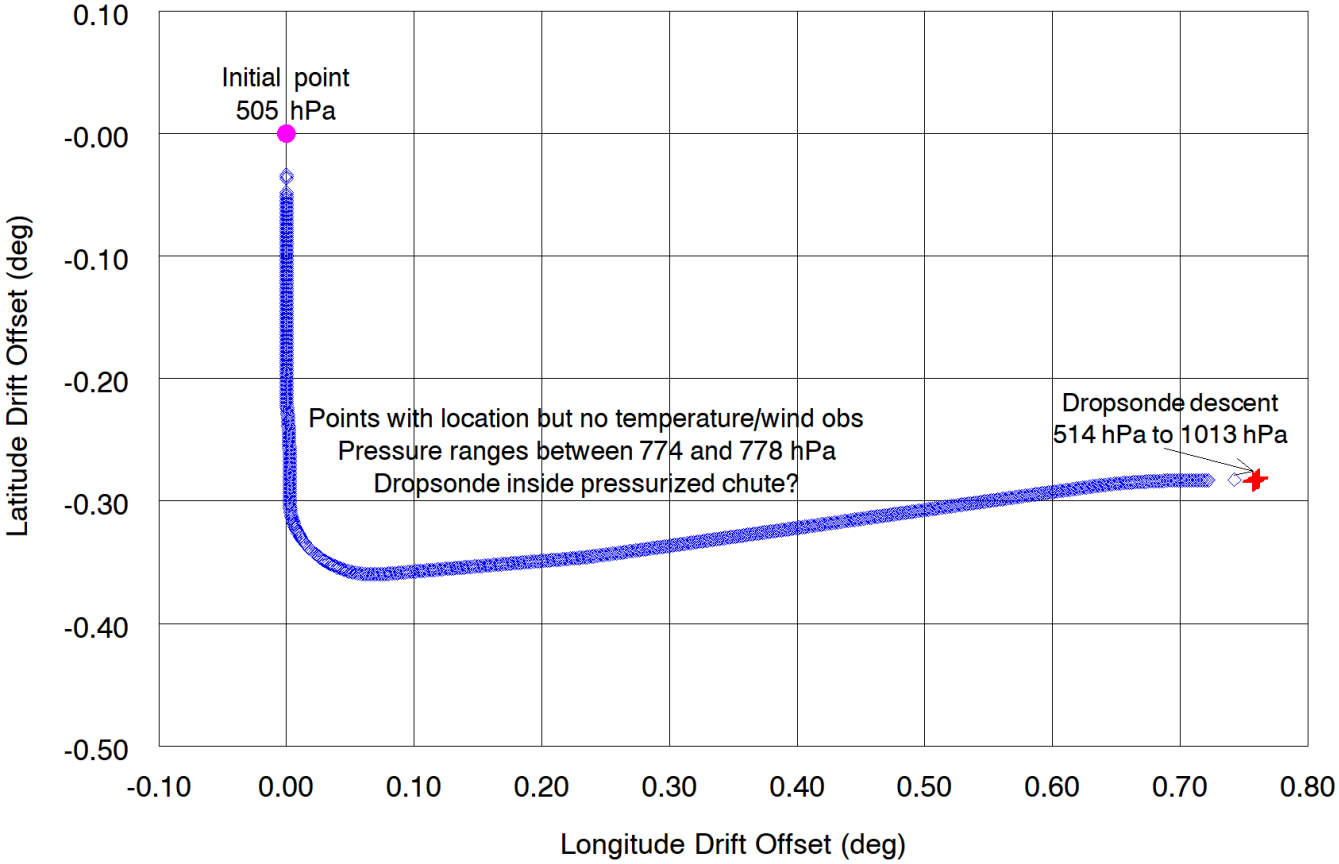
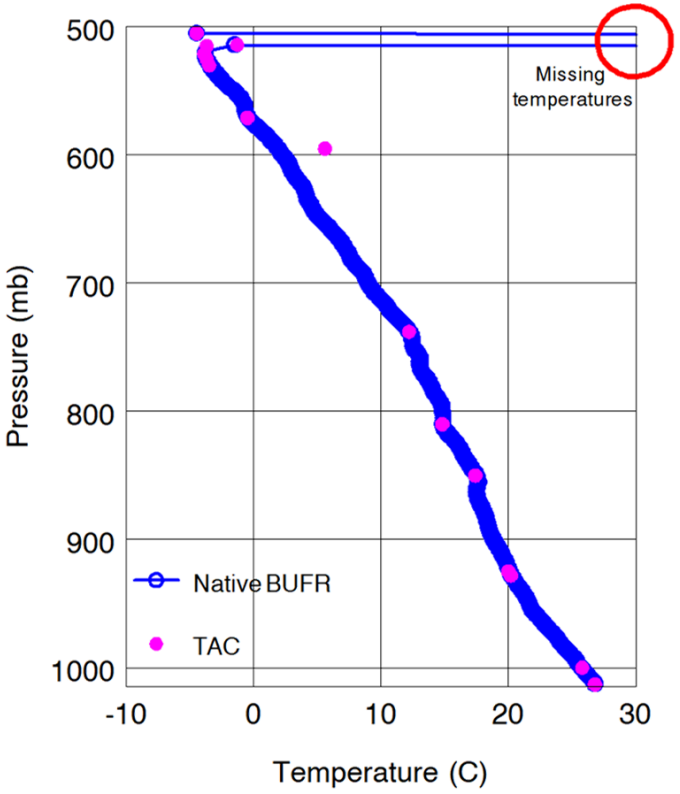
U.S. BUFR Dropsonde Error Example

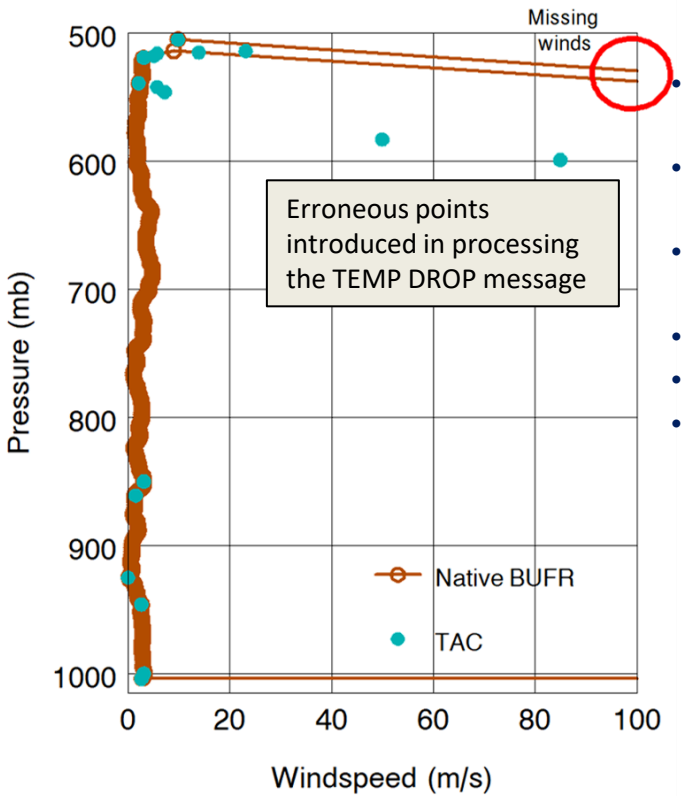


Dropsonde from NOAA2 flying TS Gordon

- Launch: 2118Z 3 Sept 2018
  - –at 25.78°N, 84.0°W
- Splash: 2137Z 3 Sept 2018
  - –at 25.50°N, 83.24°W
- BUFR has 1112 “levels” (1 sec resolution)
  - –Thinned to 31 (wind) levels
- TAC has 27 levels
- GPS drift provided with the BUFR
- “Early launch detect” problem

U.S. BUFR Dropsonde Error Example





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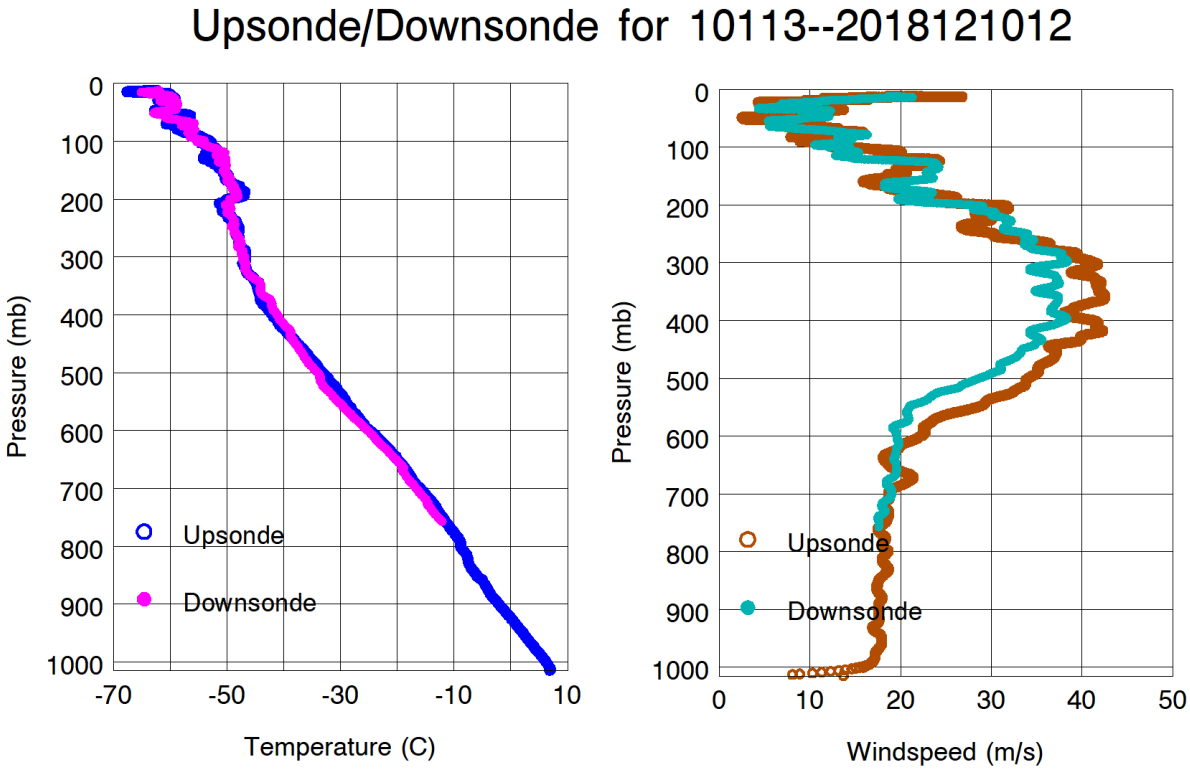
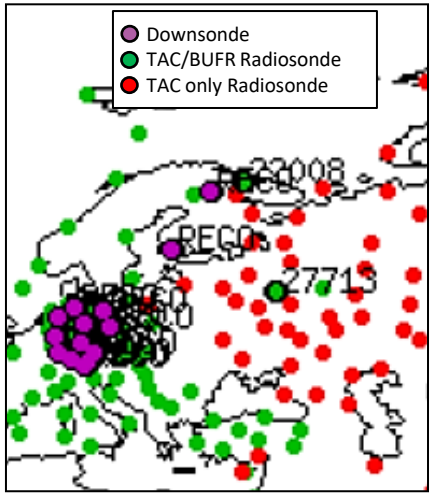
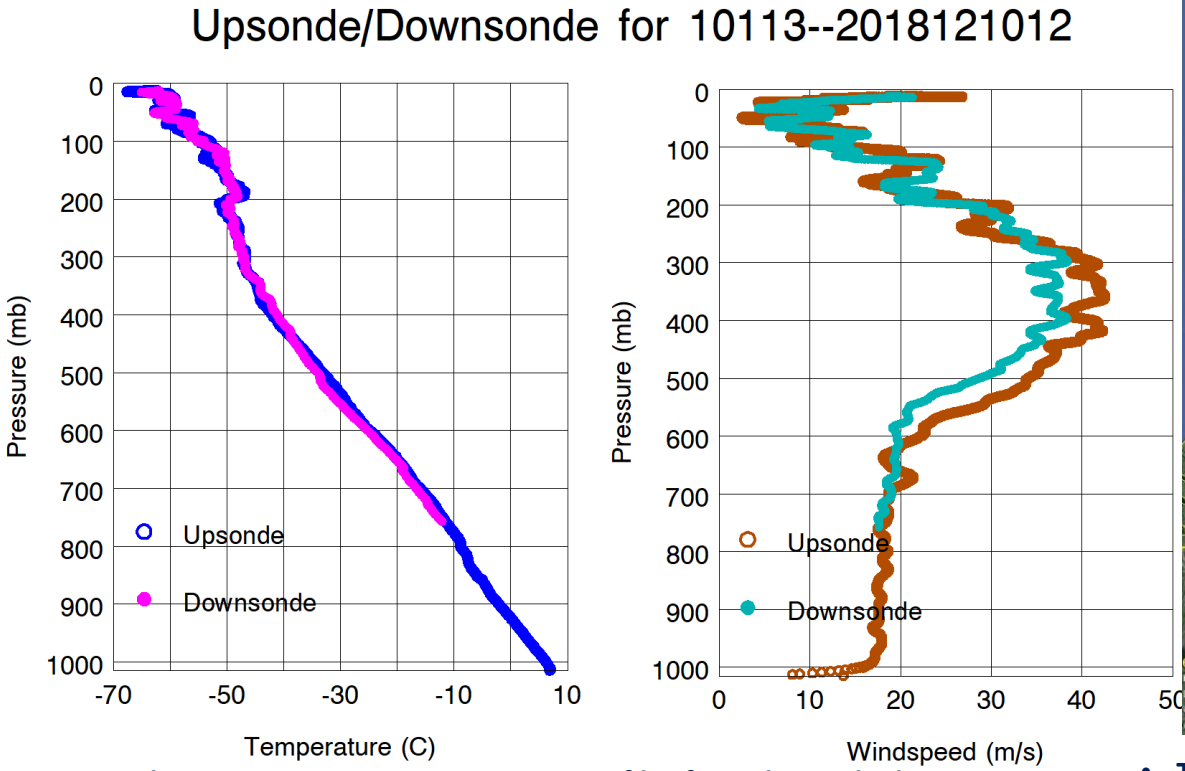
BUFR Downsonde Data

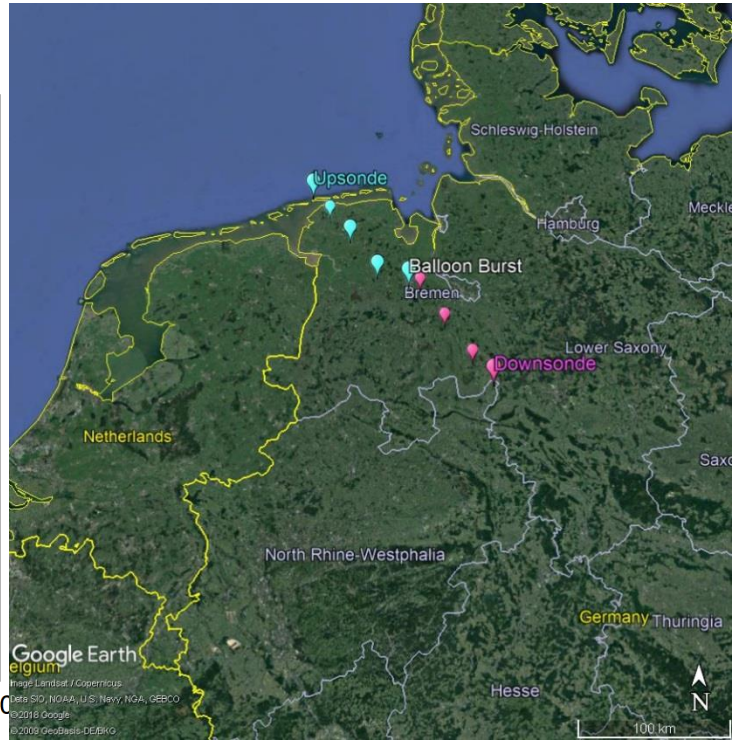




- **Vaisala RS41 systems can generate BUFR files for radiosonde descent**
- **Dropsonde template used for "downsondes"**
- **Downsonde data available for Germany (6 hourly) and Finland (12 hourly)**

BUFR Downsonde Data



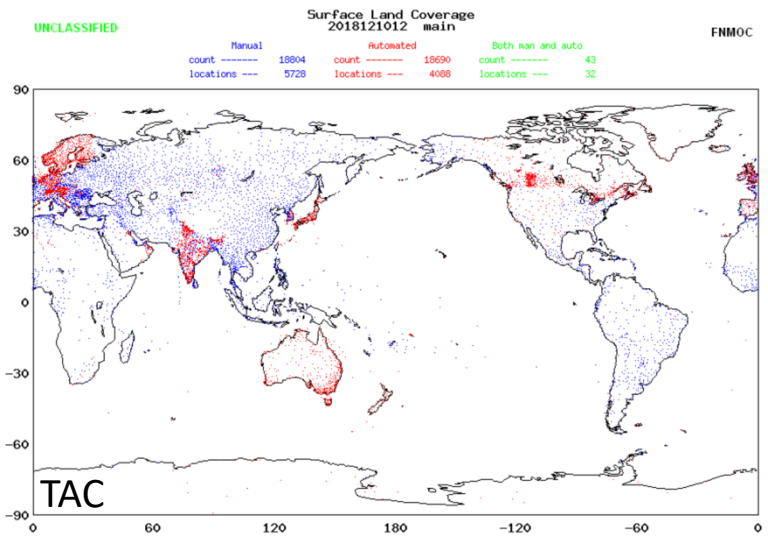


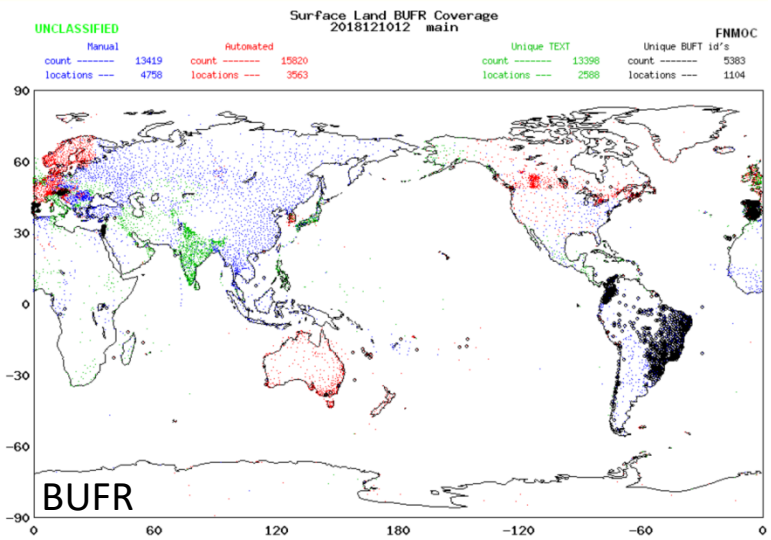
- Vaisala RS41 systems can generate BUFR files for radiosonde descent
- Dropsonde template used for “downsondes”
- Downsonde data available for Germany (6 hourly) and Finland (12 hourly)

- Total drift = 190 km from launch to last ob in descent
- Ascent took 88 minutes, descent took 36 minutes
- Descent ends at 757mb, approx. 2200 m AGL

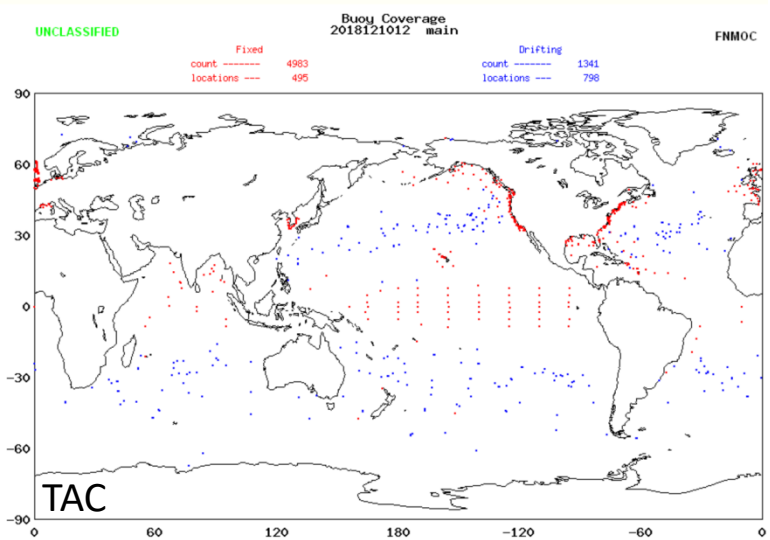
TAC to BUFR Migration—Surface Data

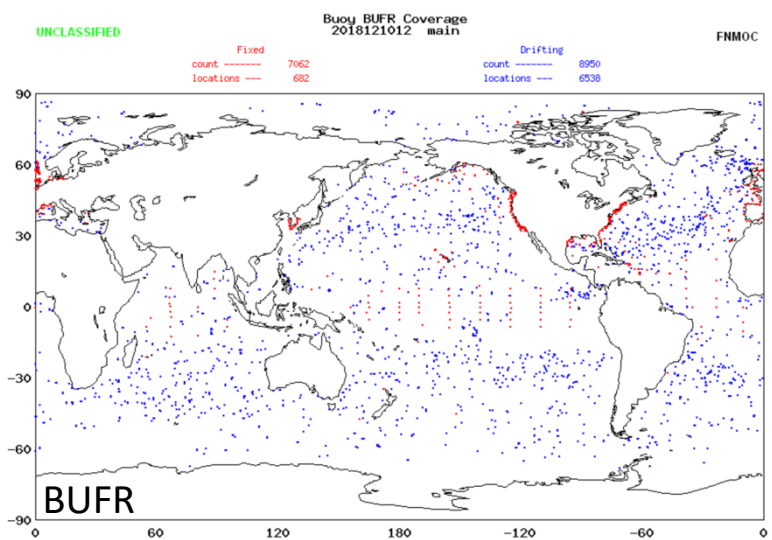
- **BUFR surface data definitions (following Ingleby et al. 2016)**
  - **“Reformatted” BUFR**: SYNOP messages converted to BUFR
    - The BMT (BUFR Migration Tool) can convert SYNOP to BUFR
    - Station metadata (e.g., latitude, longitude, elevation) from a station list
    - U.S. BUFR SYNOP are generated by the BMT
  - **“Native” BUFR**: surface data directly formatted in BUFR
    - No fundamental difference in character compared to reformatted BUFR
    - Difficult to tell which BUFR obs are native vs. reformatted





Surface Land Data
Unique BUFR—black
Unique TAC—green
(on right plot)

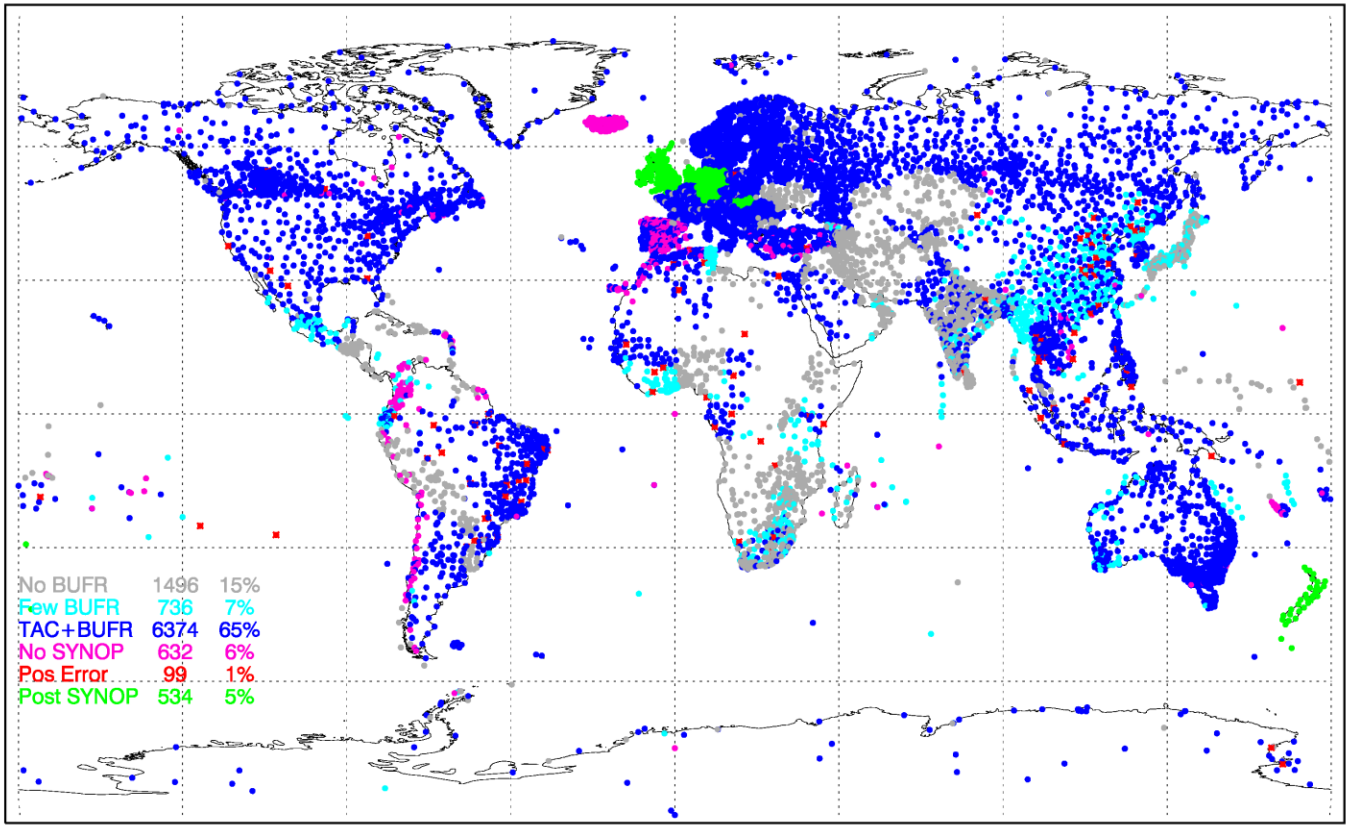




Buoy Data
Unique TAC not shown

Significantly fewer buoy observations still available in TAC

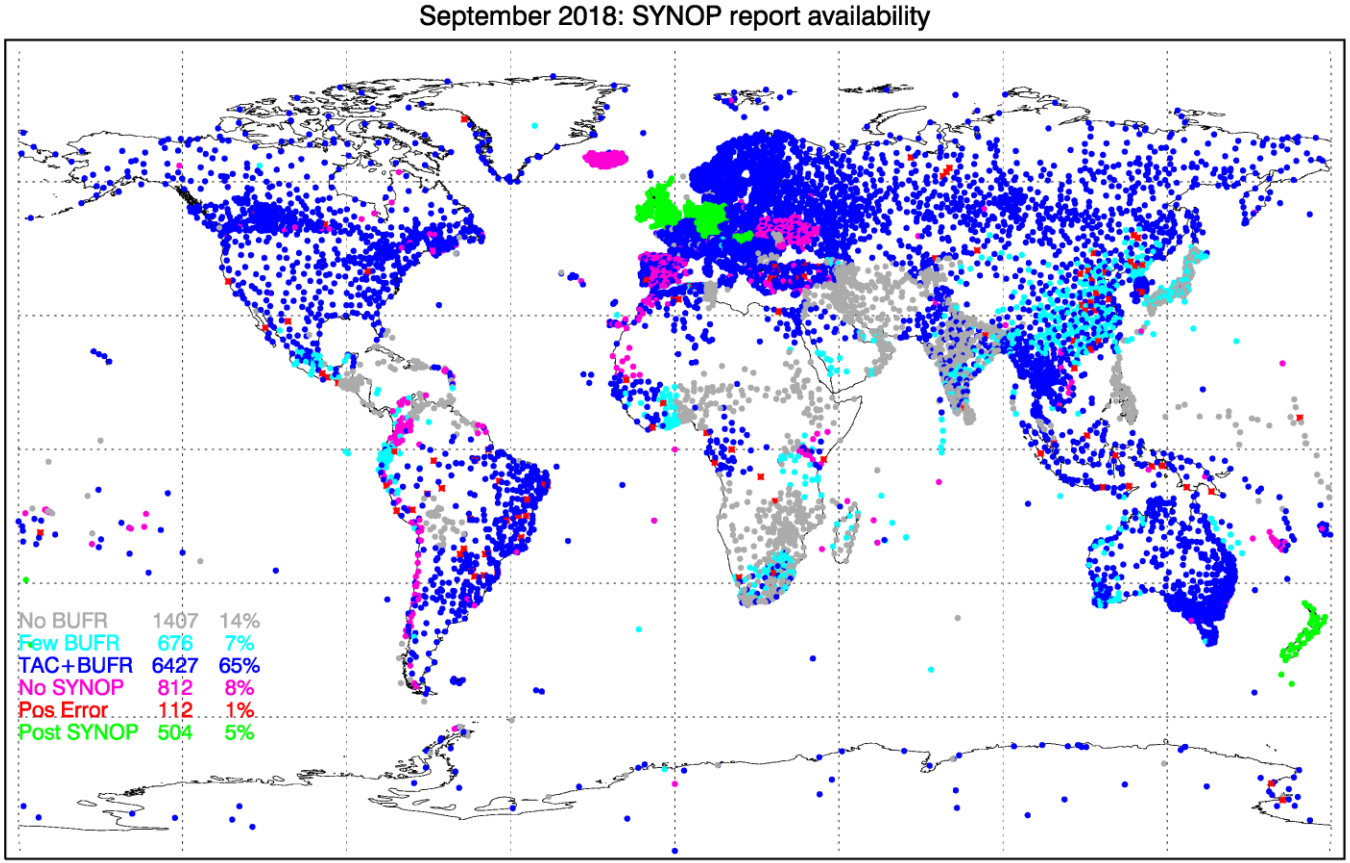
July 2017: SYNOP report availability



Variability in TAC vs. BUFR SYNOP Availability (ECMWF)

"No SYNOP" (magenta) means only BUFR is available for the indicated station
"Post SYNOP" (green) means that country has notified the end of TAC
See https://confluence.ecmwf.int/display/TCBUF/Data+availability

Graphics provided by Bruce Ingleby, ECMWF



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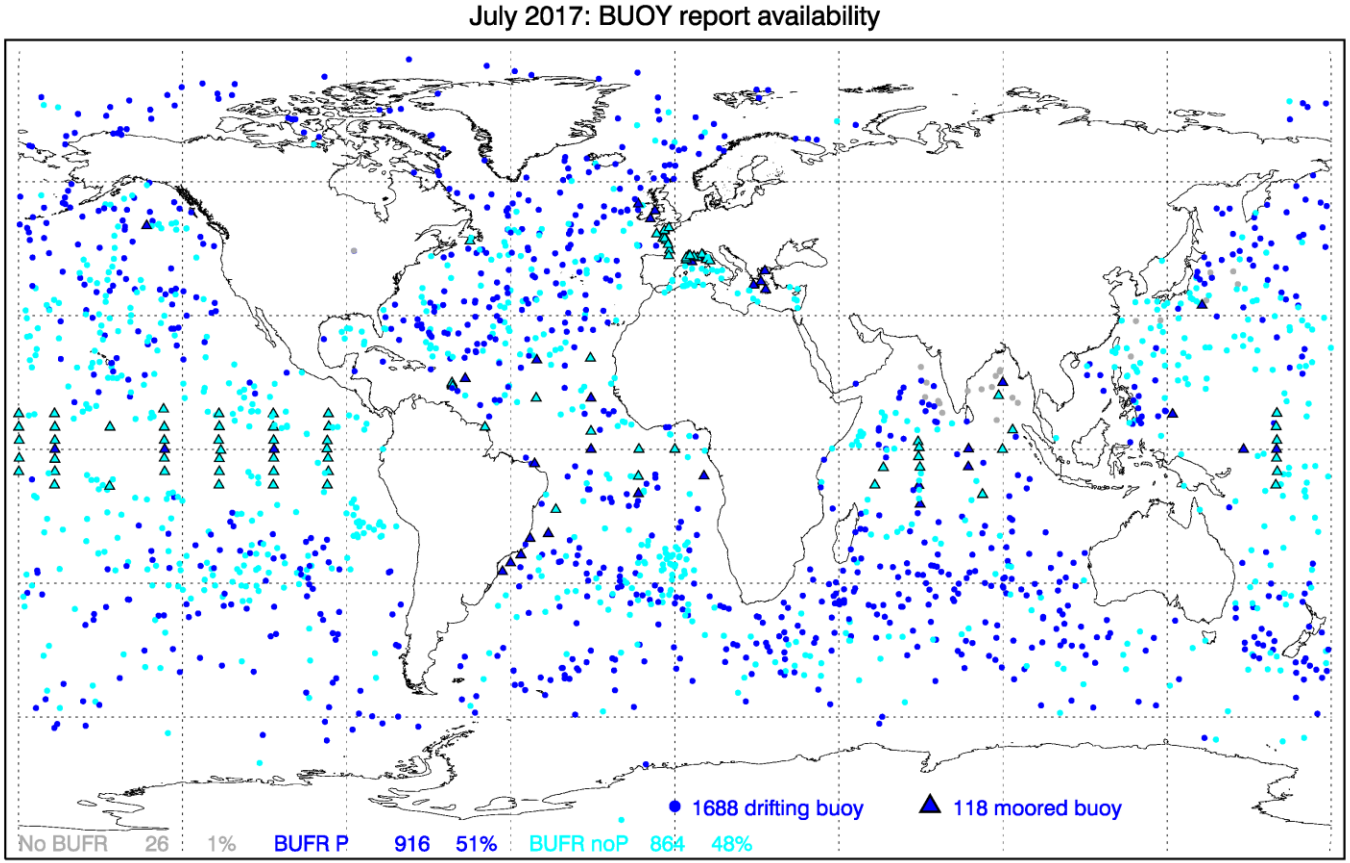

Variability in TAC vs. BUFR BUOY Availability (ECMWF)

About half of the buoys are deployed to measure SST and currents and lack pressure obs
Very few TAC buoy obs are available—the migration to BUFR is essentially complete
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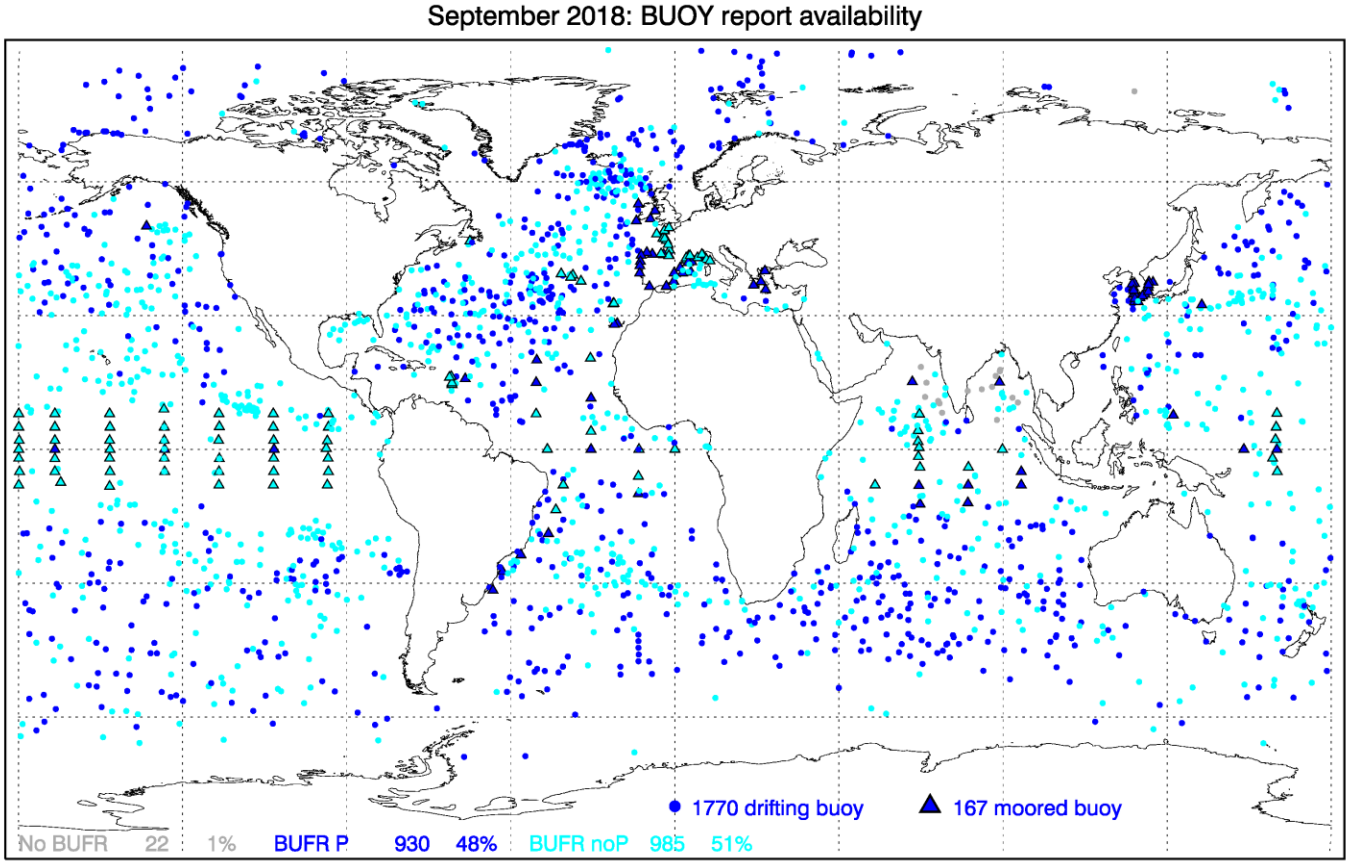

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TAC to BUFR Migration

- **The TAC to BUFR Migration is progressing.**
  - **Native BUFR radiosonde obs are more widely available (including U.S.).**
    - High-resolution (1-2 sec) data with balloon drift reported
    - Native BUFR dropsonde and downsonde data now available
  - **Some countries have ceased distribution of TAC radiosonde and surface obs.**
    - More of a factor for surface data at present
  - **The migration is essentially complete for buoy data.**
    - NDBC recently started sending BUFR and plans to stop sending TAC in May 2019.
  - **Errors in station metadata (lat, lon, elevation) are present in reformatted obs.**
    - Corrections don't happen quickly, so a check against a local station list is recommended.
- **The next big problem—transition to WIGOS station identifiers**
  - **Current TEMP/SYNOP WMO identifiers are five-digit numbers (e.g., 72662).**
  - **WIGOS identifiers use up to 30 characters (e.g., 0-20001-0-72662).**

Questions?