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#EUSpace

12th Seminar for Homogenization and Quality Control in Climatological Databases

Comprehensive upper air observation network

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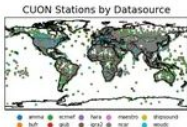
Comprehensive Upper-air Observation Network

Collection of upper-air data, temperature, humidity and wind based on:
radiosondes, pilot balloons, ozon sondes
regular stations, mobile stations & ships

Available now on <https://cds.climate.copernicus.eu/>

From decades long time series to single launches

Metadata & homogeneity adjustments
Desroziers' uncertainty estimates



Comprehensive Upper-air Observation Network from 1901 to present

The Comprehensive Upper-air Observation Network (CUON) dataset is designed to contain all available observations from balloons ascents through the atmosphere. The main geophysical variables are temperature, humidity, and wind speed and wind direction, as functions of atmospheric pressure levels. T...

In-situ observations

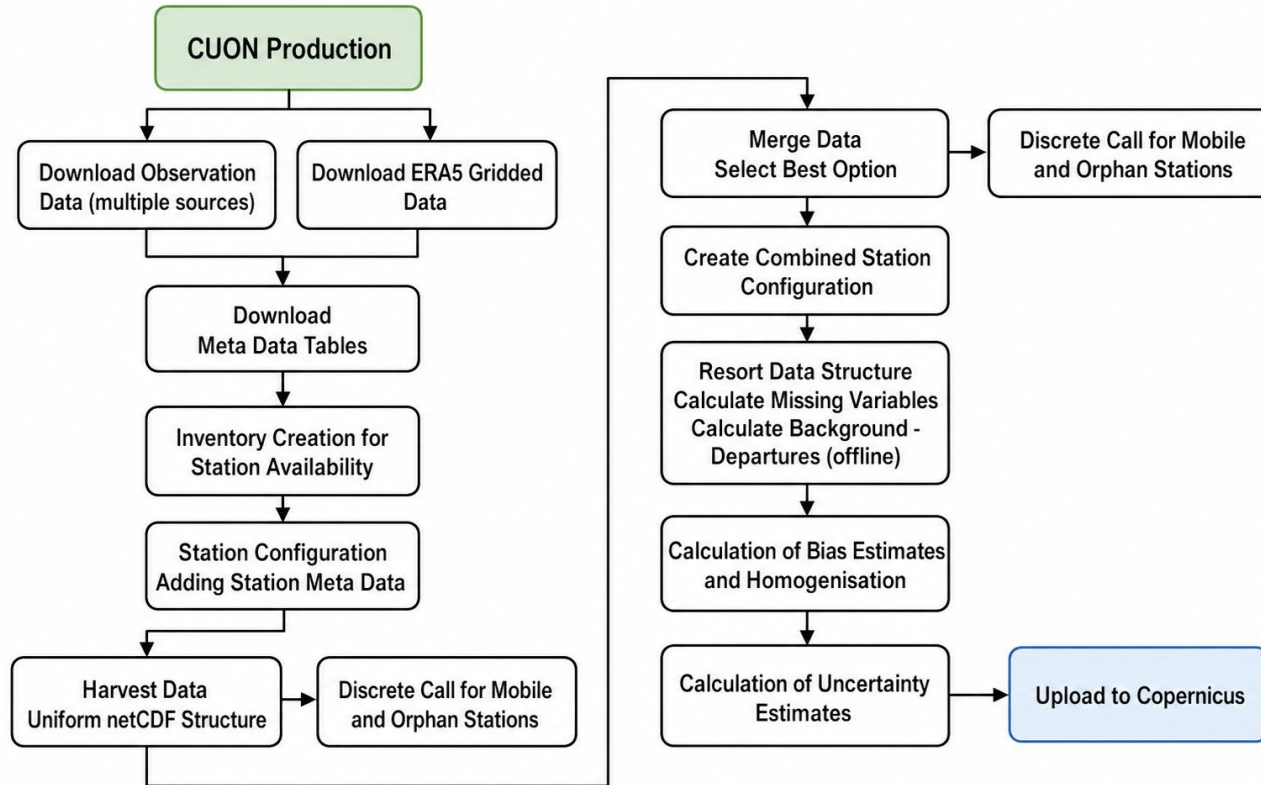
Copernicus C3S

Global

Past

Atmosphere (upper air)

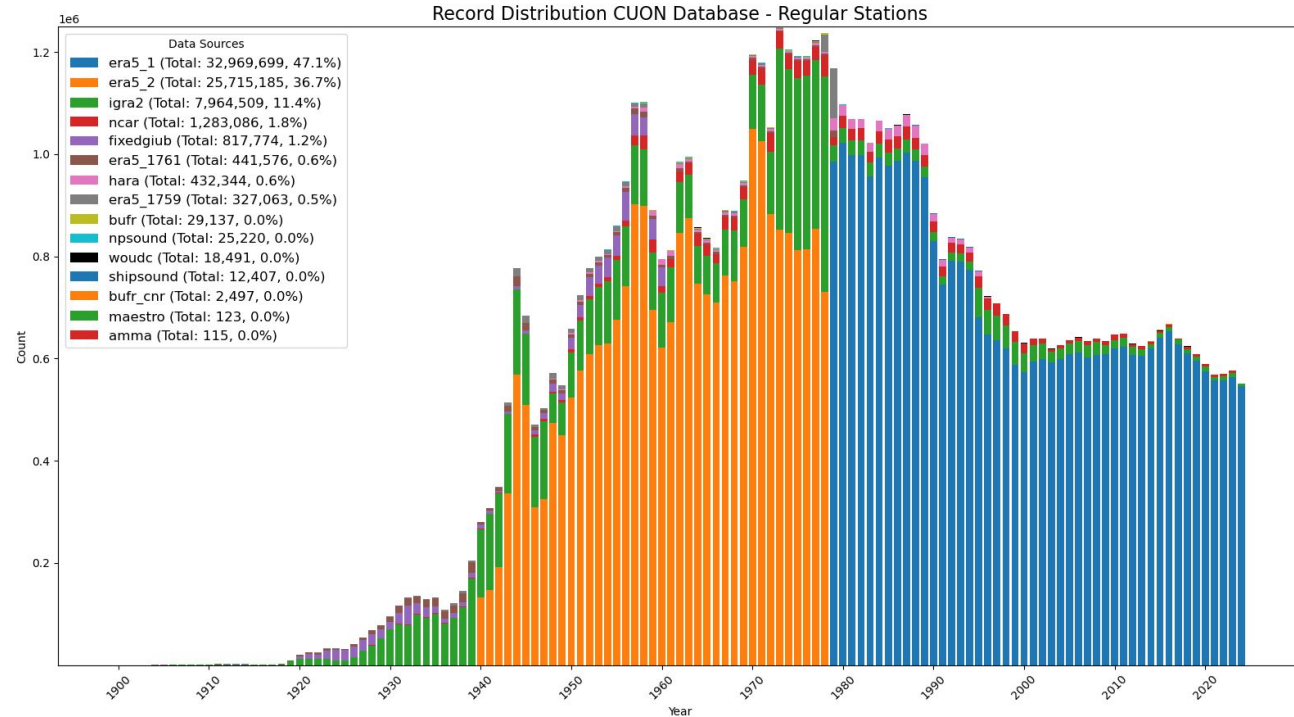
CUON production pipeline



Data Sources

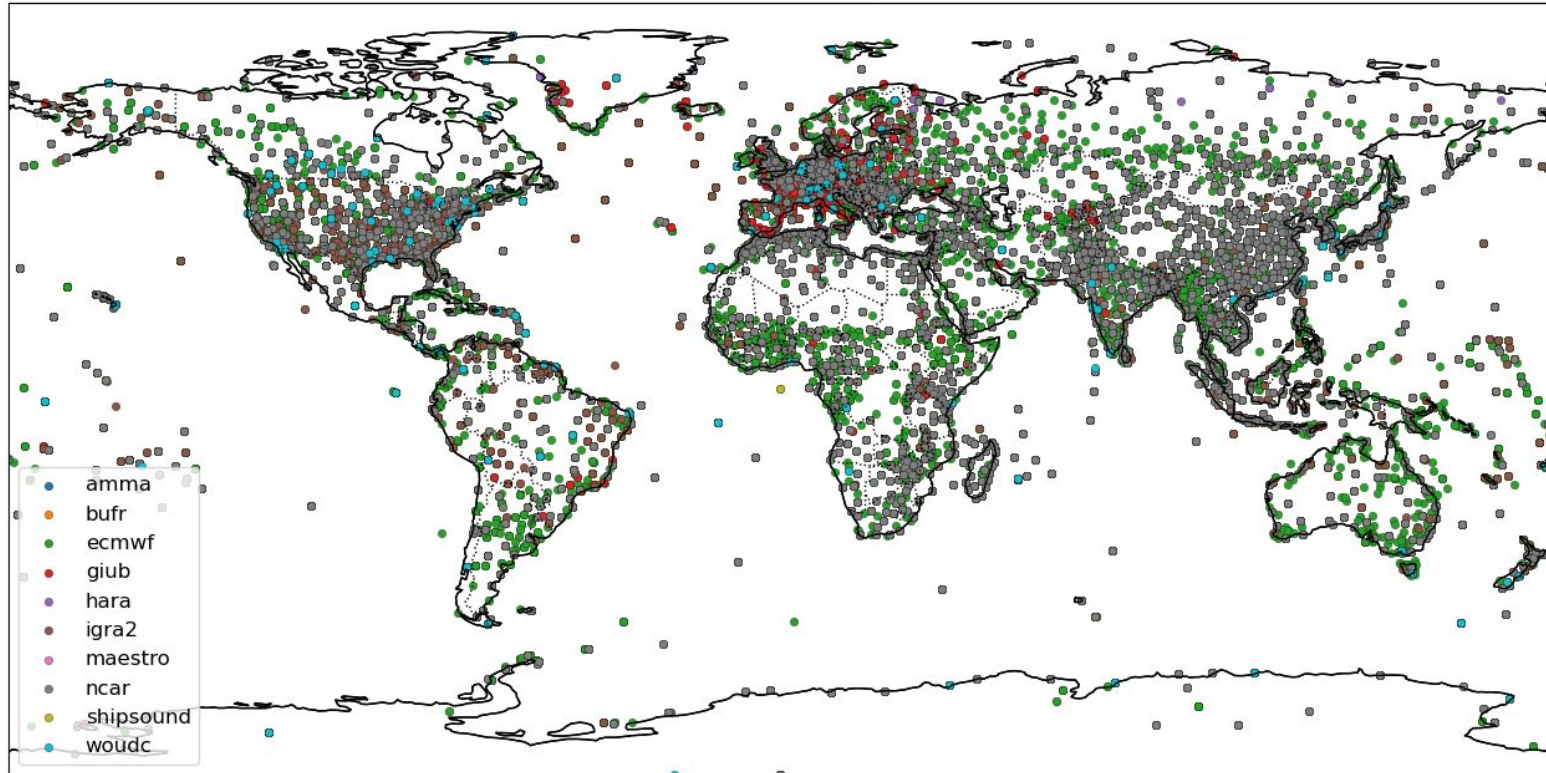
Majority of observations based on ERA5 (ECMWF) collection and igra v2 (NOAA).

~5% of records from other sources
-> ~2.5 million records



Global Coverage

CUON Identified Stations by Datasource



Merging Selection

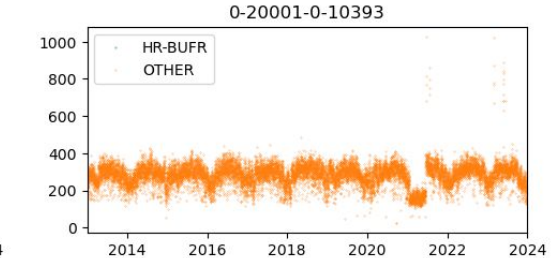
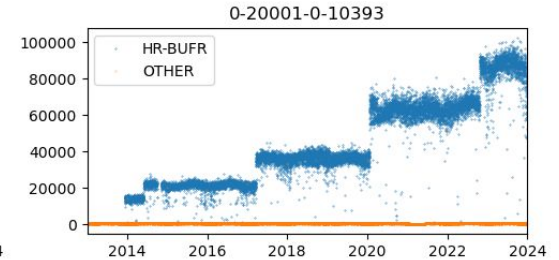
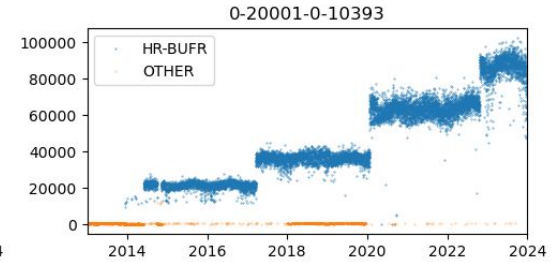
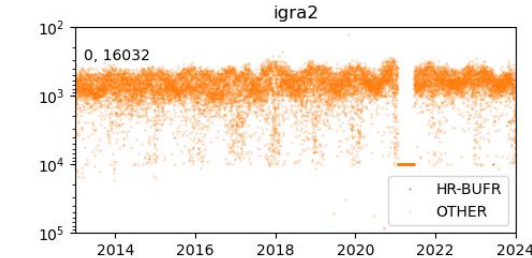
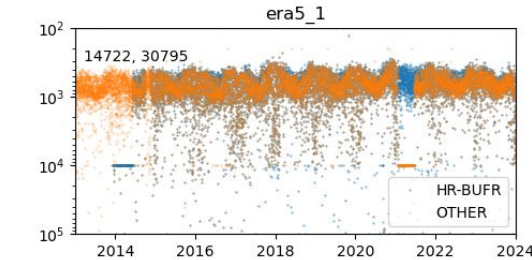
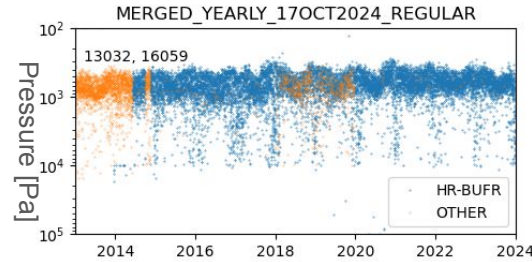
Priority list based on metadata

- Highest reaching observation
- Observation resolution
- Available variables

Production of ~ 3.5TB of data

Stored as station-wise time series.

Lindenberg

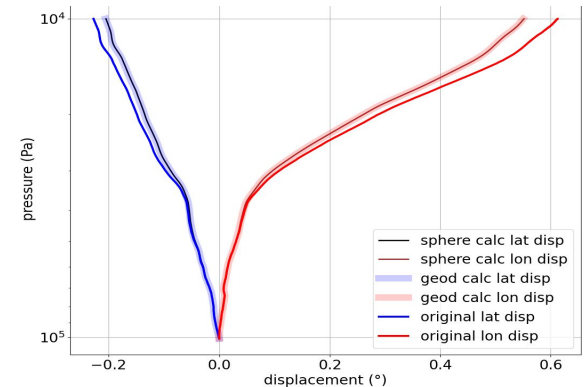
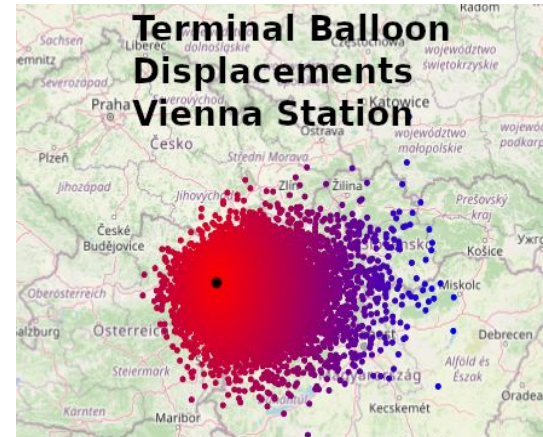


Balloon Drift

Representation errors due to assumed vertical ascent and nominal launch time.

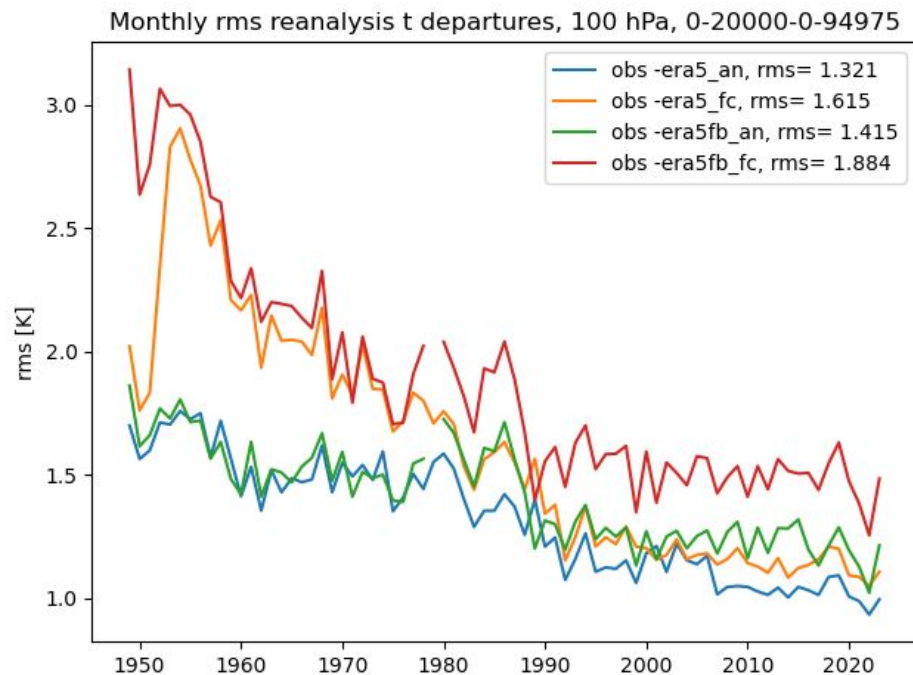
- For non-GPS sondes and TEMPs (< ~ 2014)
- Significant drifts up to several 100 km
- Potentially large representation errors
- Drift modeled from observed winds
- Early data with few levels has similar quality
- Assuming 5m/s ascent speed -> adding timestamps to each observation

Voggenberger et al. 2024, GMD



Balloon Drift

- Bg departures with new balloon positions from archived gridded data
- Obs-bg with drift considered < than station obs-bg at most places



$$\text{obs-bg} = \mathbf{y} - \mathbf{H}\mathbf{x}_b$$

Red: obs-bg archived in ERA5

Orange: obs-bg calculated offline,
with accurate balloon position

Green: obs-an archived in ERA5

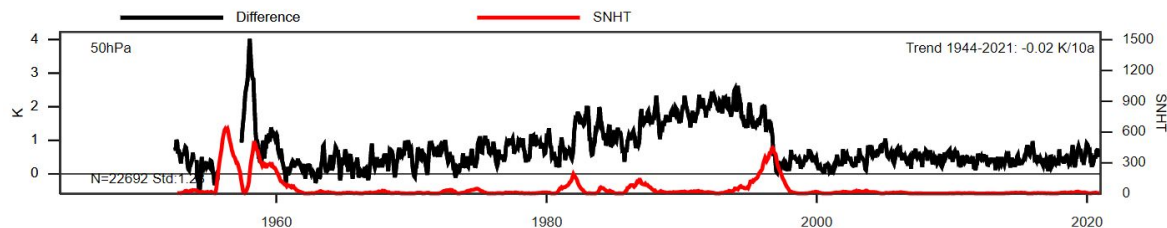
Blue: obs-an calculated offline

>30% improvement 1990 onward at high levels at some stations with large balloon drift (Hobart, Tasmania)

Temperature Adjustments

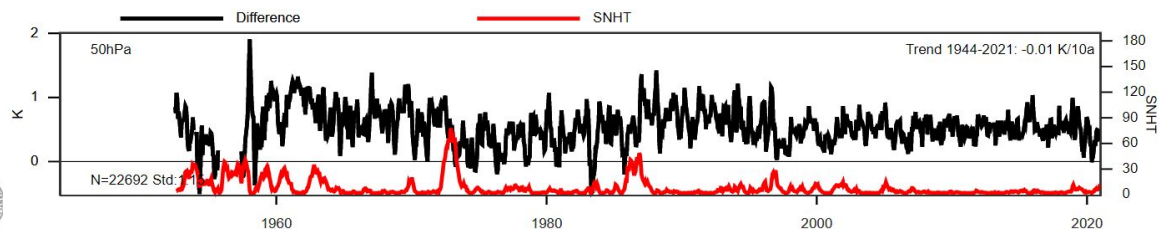
- RAOBCORE-RICH method (Haimberger et al. 2012)
 - RAOBCORE uses ERA5 as reference for break detection/adjustments
 - RICH uses neighbouring radiosondes as reference for adjustments
- Quantile matching the bias on different pressure levels

Background departures, 011035 , 48.25N, 16.37E, 12h, exp01



obs-bg, Vienna 12GMT

bgdep - RICH-obs24-adjustment, 011035 , 48.25N, 16.37E, 12h, exp01



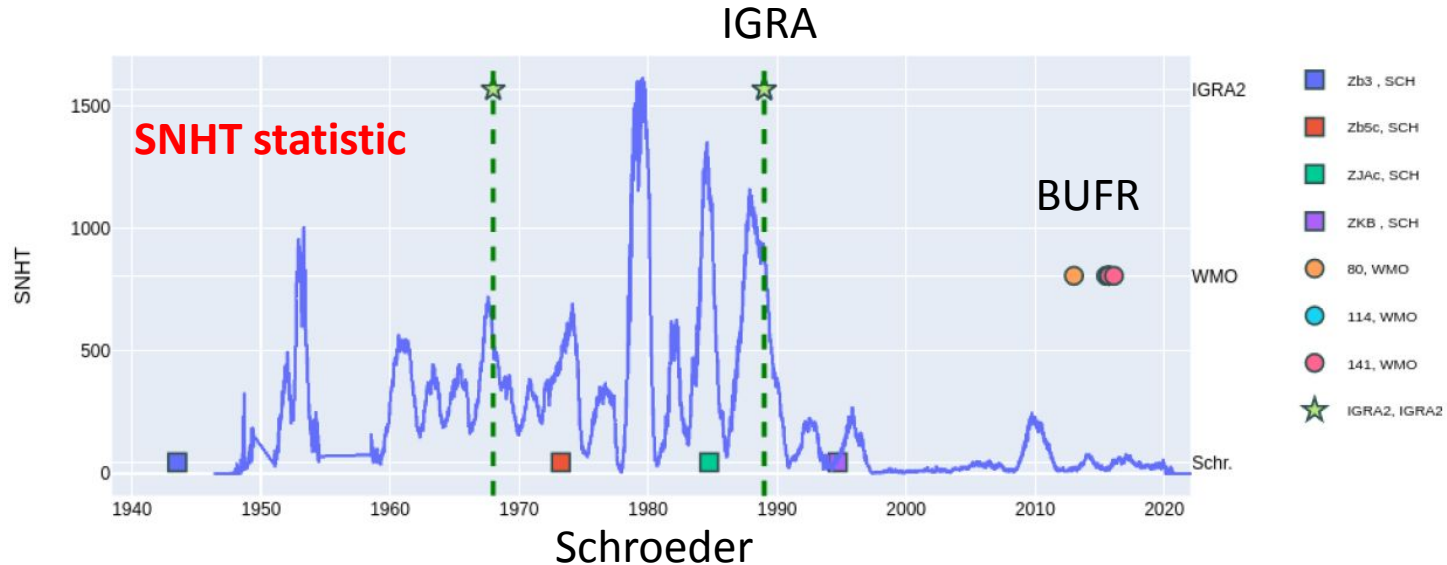
RICH-adjusted obs-bg

Break detection

Metadata from IGRA, S. Schroeder (TAMU) and WMO BUFR codes
Complementary, incomplete, SNHT statistics help finding time of breaks

Shemya, Alaska

Sensors Time Series - 0-20000-0-70414

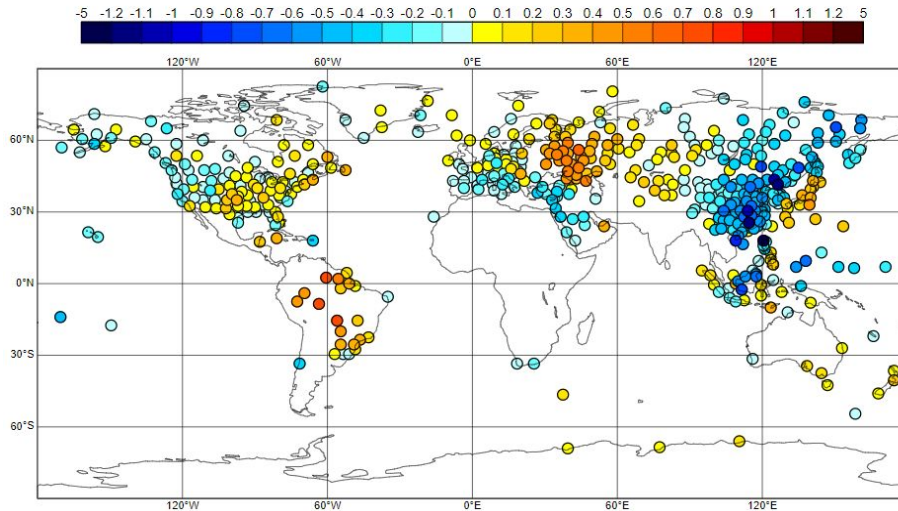


12GMT-00GMT differences

- Some 12GMT-00GMT differences still large in 2018-2019
- Large radiation errors in the 1970s

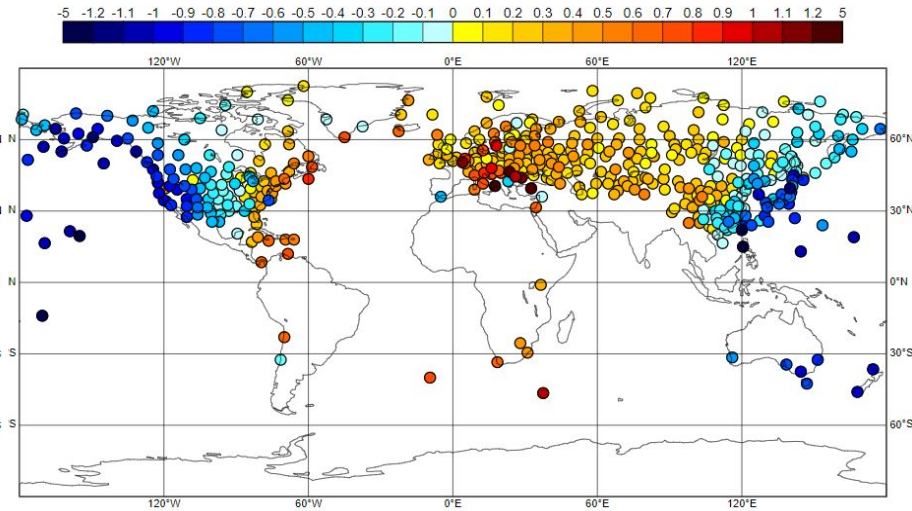
2018-2019

Temperature Difference [K], tm, 12h-00h, exp02, 2018-2019, 100 hPa
508 Stations, Cost: 453.31, 1.0



1970-1979

Temperature Difference [K], tm, 12h-00h, exp02, 1970-1979, 100 hPa
492 Stations, Cost: 1092.68, 1.0

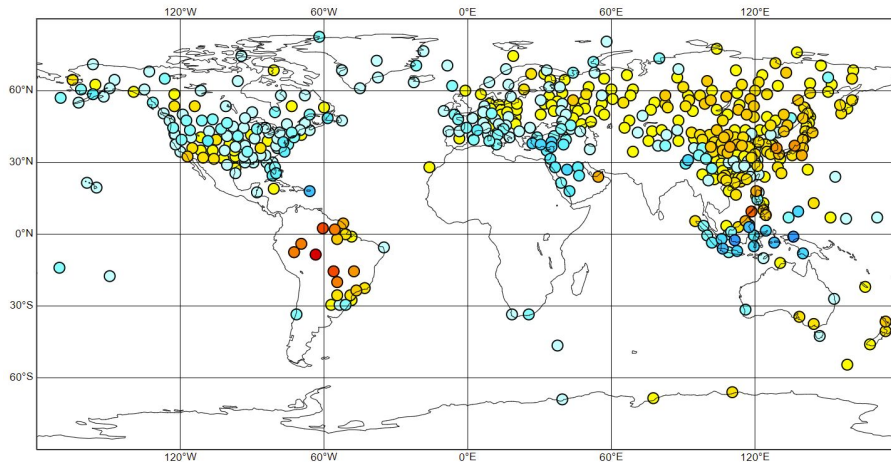
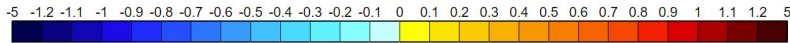


12GMT-00GMT differences

- Most recent parts of time series unadjusted for trusted radiosondes, others adjusted by comparing obs-bg with obs-bg of trusted sondes
- Positive Effect sustained back to 1960s and 1970s

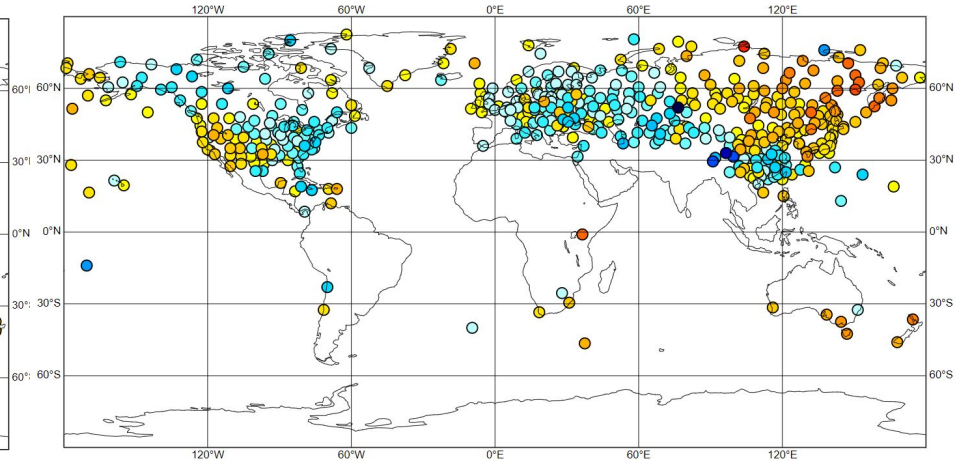
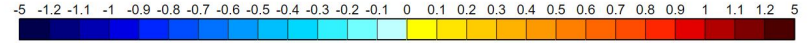
2018-2019

Temperature Difference [K], tmcrr, 12h-00h, exp02, 2018-2019, 100 hPa
508 Stations, Cost: 121.64, 1.0



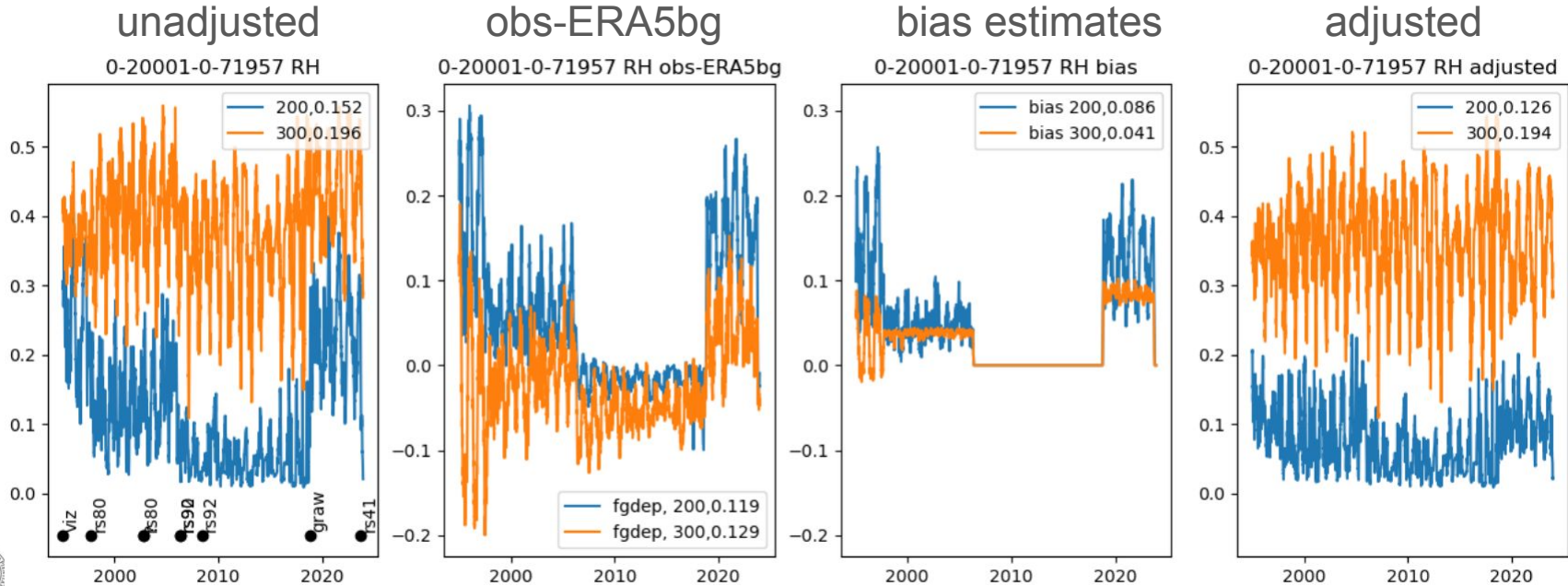
1970-1979

Temperature Difference [K], rio24, 12h-00h, exp01, 1970-1979, 100 hPa
492 Stations, Cost: 427.83, 1.0



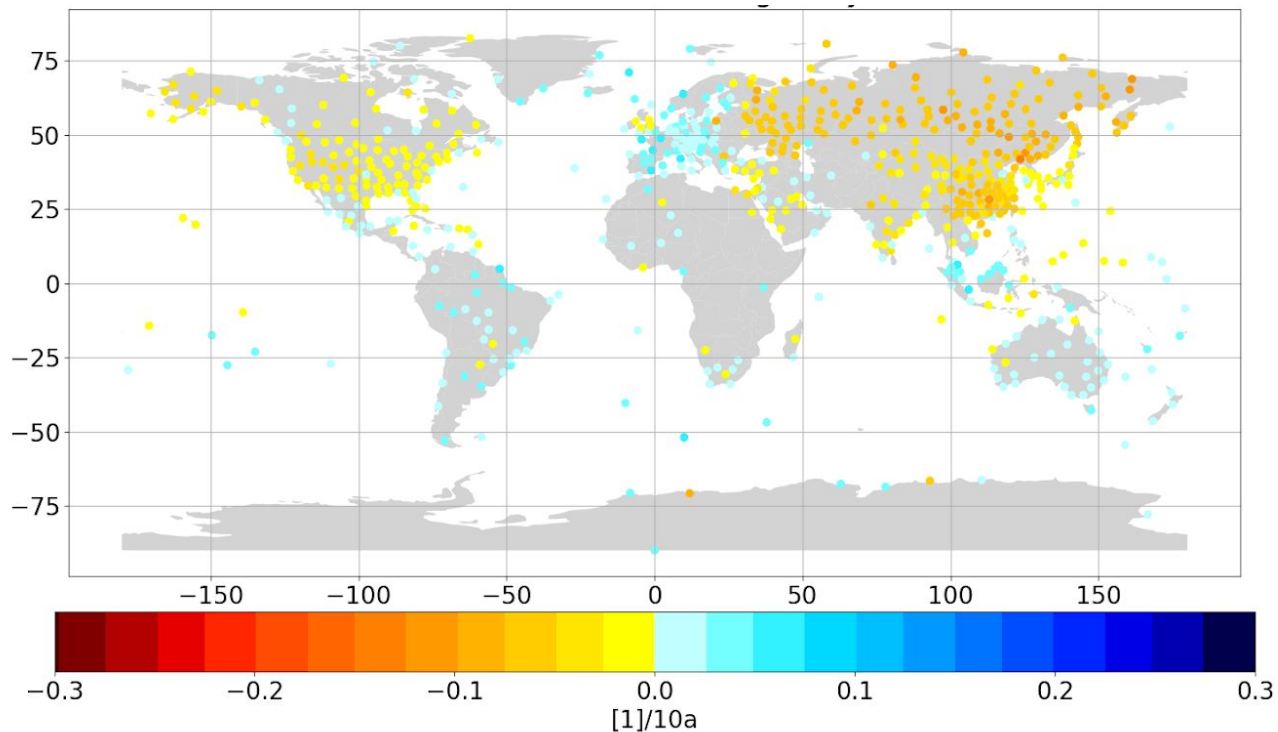
Humidity Adjustments

- Large biases in high altitude humidities, even from recent sensors
- Trusted sondes + SNHT + quantile matching for adjustments
- Less very moist values after adjustments



Humidity Adjustments

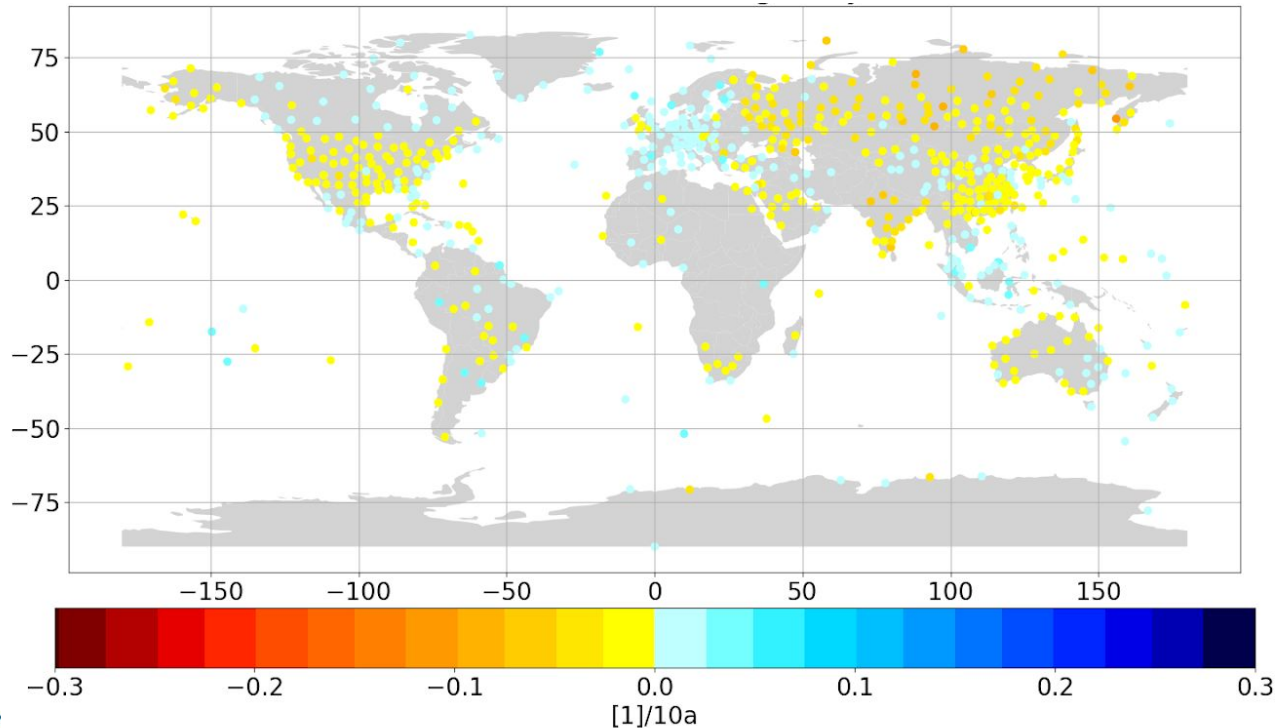
- 300 hPa relative humidity trends
- Heterogen at a high layer



RH Trends
1994-2023

Humidity Adjustments

- At 300 hPa much reduced drying trends over FSU, China, US
- Better agreement with satellite data though comparison is challenging

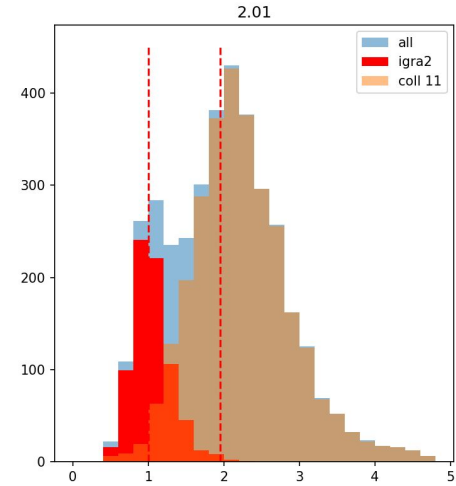
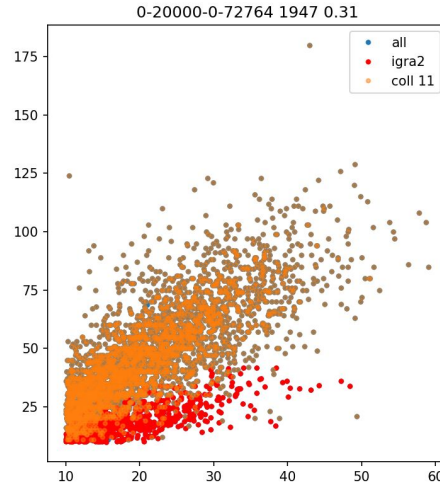


Wind Adjustments

Unmarked wind speed units, m/s & knots in different sources or even mixed.

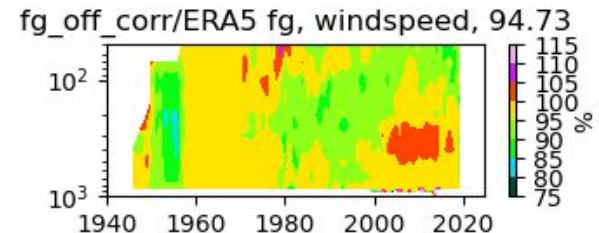
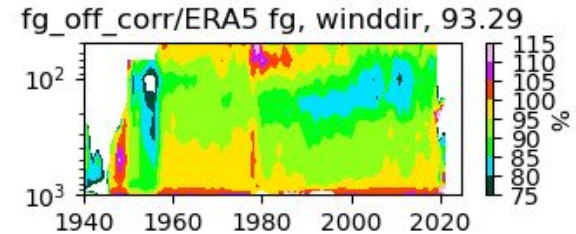
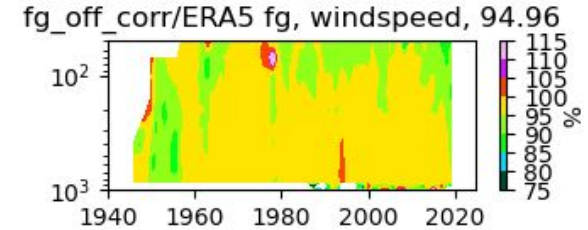
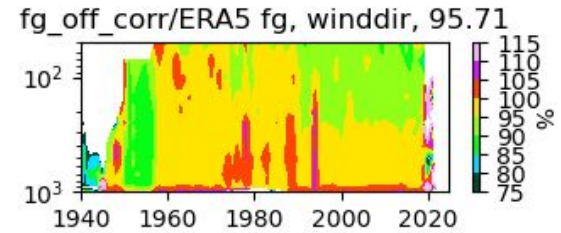
- observed wind speeds versus ERA5 bg wind speeds (left)
- histograms of ratios of observed wind speeds vs ERA5 bg wind speeds (right).

Pilot balloons: Quite many in early times and over Southern Hemisphere, but inaccurate z-p conversion via standard atmosphere.



PILOT Wind Adjustments

- Australian pilot sondes
- Yellow, green & blues reduce the difference to reanalysis
- Top with balloon drift & bias adjustments
- Bottom with balloon drift, bias adjustments & z to p conversion
- Meta data improves wind more than break detection



ICAO z to p conversion

accurate z to p conversion

Conclusion

CUON

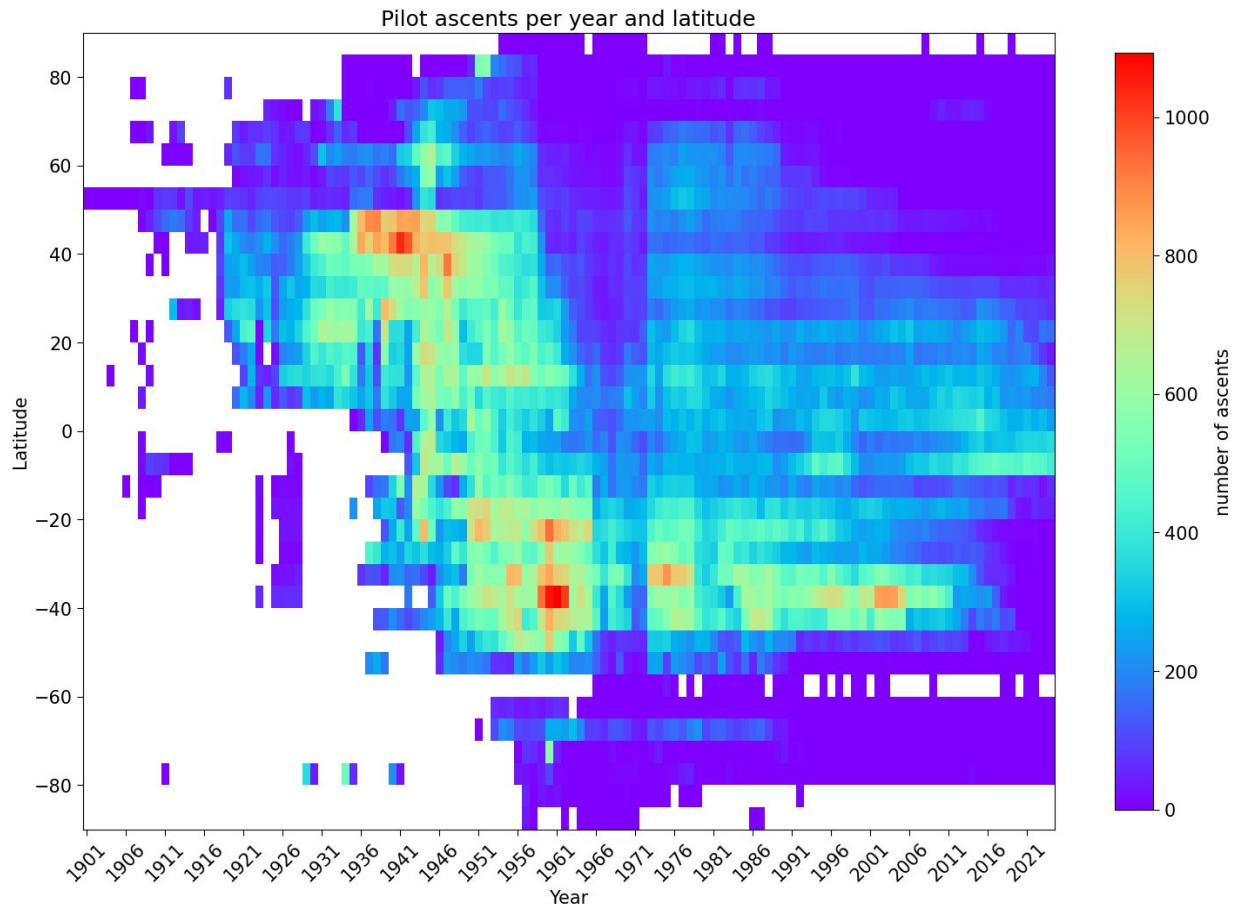
- Comprehensive data set, contains observation values, obs-bg departures and adjustments separately
- Annual updates of adjustments & meta data

ERA6

- Uses CUON data including improved positions, timing & adjustments
- RICH adjustments -> neighbouring stations

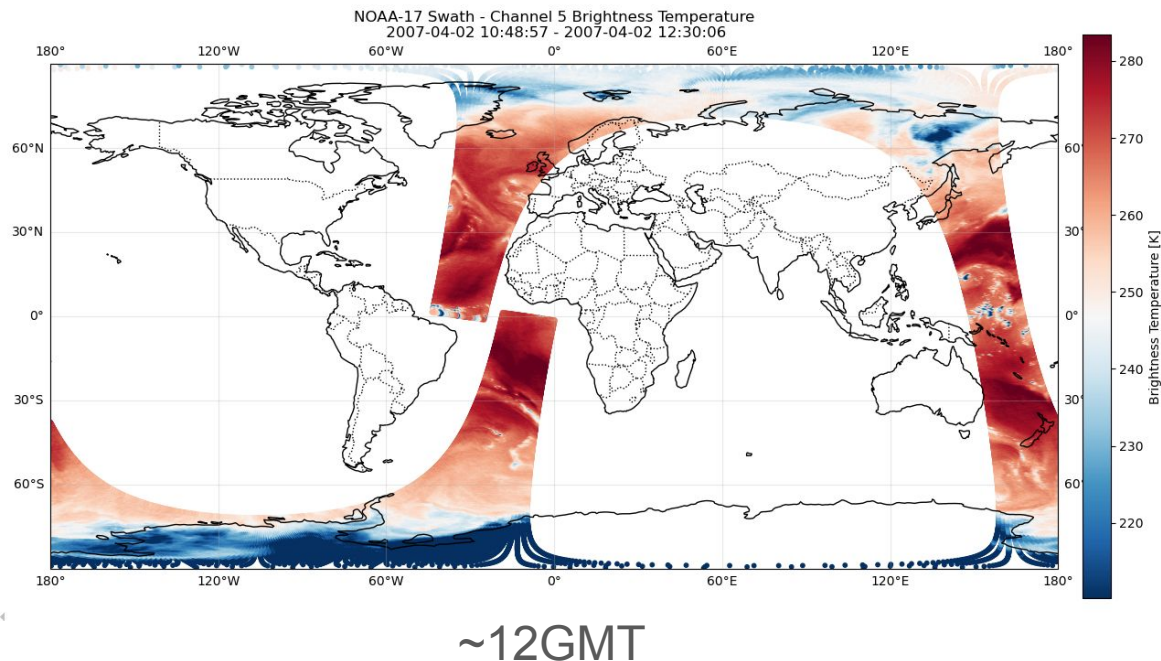
Reanalysis Background Departures useful for finding issues in observation

- ERA5 & JRA3Q
- ERA6 in the future

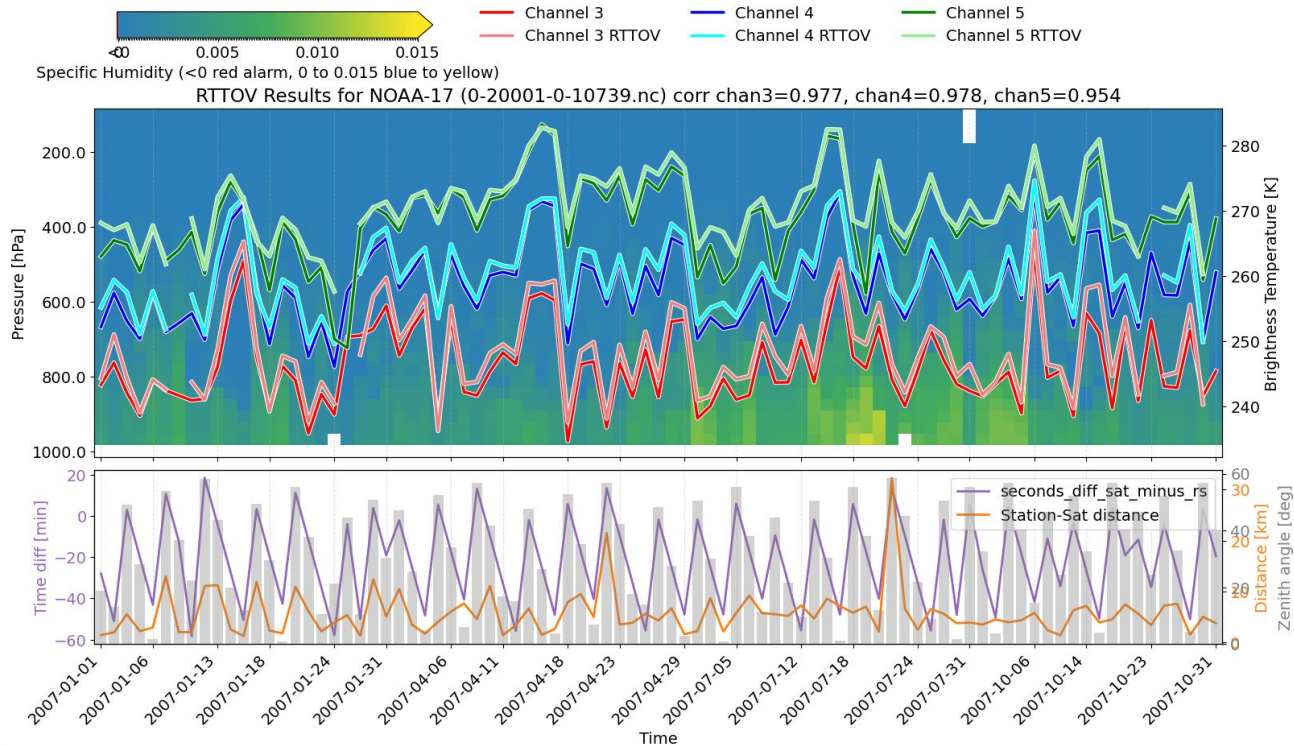


Humidity Adjustments & Satellite Comparison

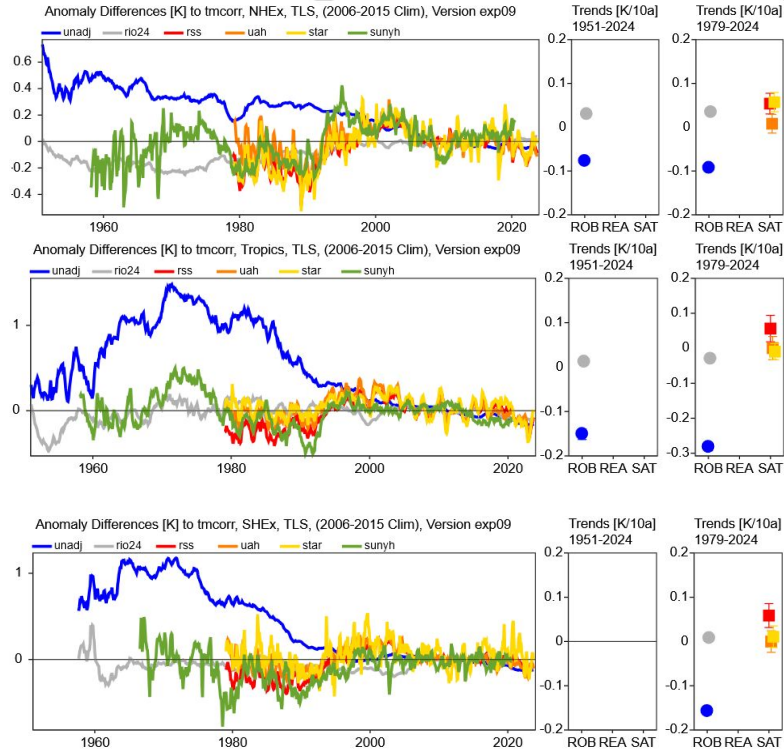
- EUMETSAT MW humidity, T. Hanschmann, V. John
- Used Channels 3,4,5; NOAA 17 (18,19, METOP MHS)
- Ascent vs Pixel within <1h, <25km distance
- RTTOV14, high sensitivity to missing data
- EUMETSAT provided test data for 2007
- Complete dataset 1993-2025



Humidity Adjustments & Satellite Comparison



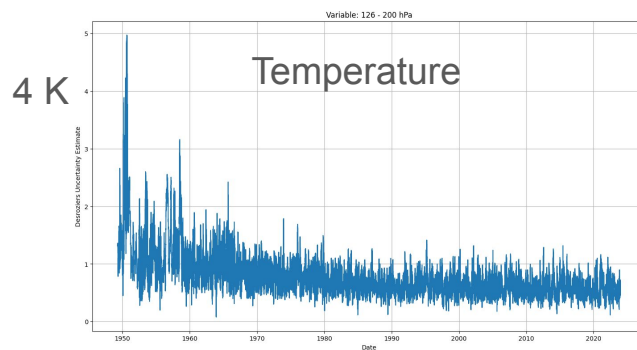
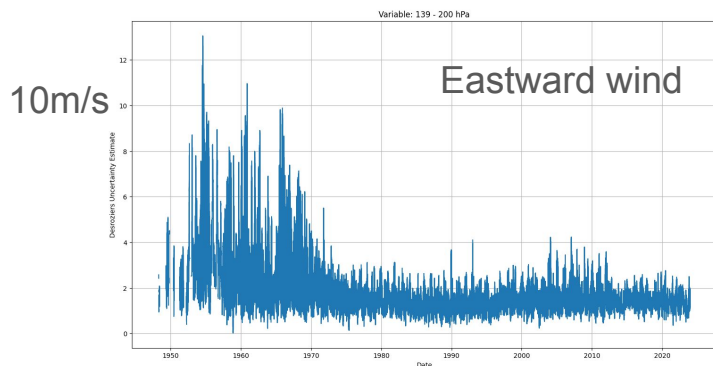
Comparison to other Homogenized Brightness Temperatures



- Anomaly differences with respect to RAOBCORE adjusted radiosondes.
- Blue=unadjusted, grey=RICH adjusted (used in ERA6)
- Yellow-Red=MSU TLS products
- Green=Zhang et al. 2021 (adjusted radiosondes)

Uncertainty Estimates

- Desroziers (2005) estimates calculated for all parameters (u,v,T,rh,q,Td)
 - 30 day average, example shown below for station Vienna
 - Calculated from available obs-bg, obs-an before homogeneity adjustments
 - Considered estimate for random (measurement+representation) error



Uncertainty Estimates - Desroziers

$\mathbf{dO-B}$ be the observation minus background departure and $\mathbf{dO-A}$ the observation minus analysis departure. We then define the error cross covariance matrix \mathbf{R} as the time-average:

$$E[\mathbf{d}_a^0(\mathbf{d}_b^0)^T] = \mathbf{R}$$

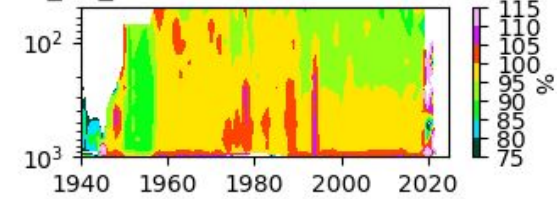
Only the diagonal values are usually interpreted as expectations of observation errors.

Where the expectation value is calculated over an arbitrary time range (we use time window of 1,2,3 and 6 months). We note that the value of the cross covariance thus depends on the chosen time window. For each pressure level, the quantities $\mathbf{dO-B}$ and $\mathbf{dO-A}$ are available and the estimate of the error can be calculated from the time averages. Note that the result is valid if $\mathbf{dO-A}$ and $\mathbf{dO-B}$ are unbiased. However, results with biased departures did not differ much from the ones obtained with bias corrected data (Waller et al., 2016).

PILOT Wind Adjustments

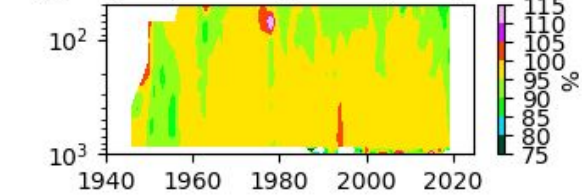
- SNHT for detecting shifts in observed wind direction
- Offline calculated obs-bg standard deviation for wind direction and wind speed smaller compared to archived obs-bg (ratio <100%)
- Improvement due to **wind drift** estimation (upper panels) additionally due to **accurate z-p conversion** (lower panels).

fg_off_corr/ERA5 fg, winddir, 95.71

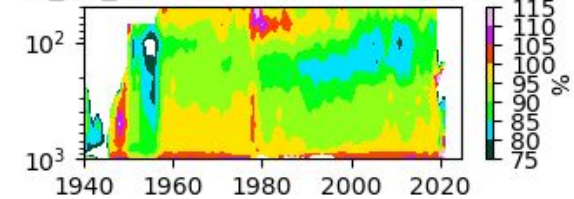


Balloon drift
ICAO z to p conversion

fg_off_corr/ERA5 fg, windspeed, 94.96



fg_off_corr/ERA5 fg, winddir, 93.29



accurate z to p conversion

fg_off_corr/ERA5 fg, windspeed, 94.73

