Radiosounding HARMonization (RHARM): a new algorithm for the harmonization of temperature, humidity and wind radiosounding time series and estimation of uncertainties

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RADIOSOUNDINGS AND HOMOGENIZATION

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- Long and homogeneously observed time series are an essential source to diagnose the three-dimensional pattern of climate change.
- Global radiosoundings provides a unique information to study the climate variability
- It has long been recognized that the quality of the global radiosounding observations varies for different sensor types and height.
- Several groups have used multiple years of monthly averaged radiosouding measurements (mainly temperature) to construct long-term CDRs (e.g. Durre et al., 2005; Free et al., 2004, 2005; McCarthy et al., 2008; Sherwood et al., 2008; Haimberger et al., 2008; Seidel et al., 2009 2011; Thorne et al., 2012; Haimberger et al., 2012).
- Can we use a **reference data** (**GRUAN**, GCOS Reference Upper-Air Network) to improve the quality of the **global** radiosoundings?

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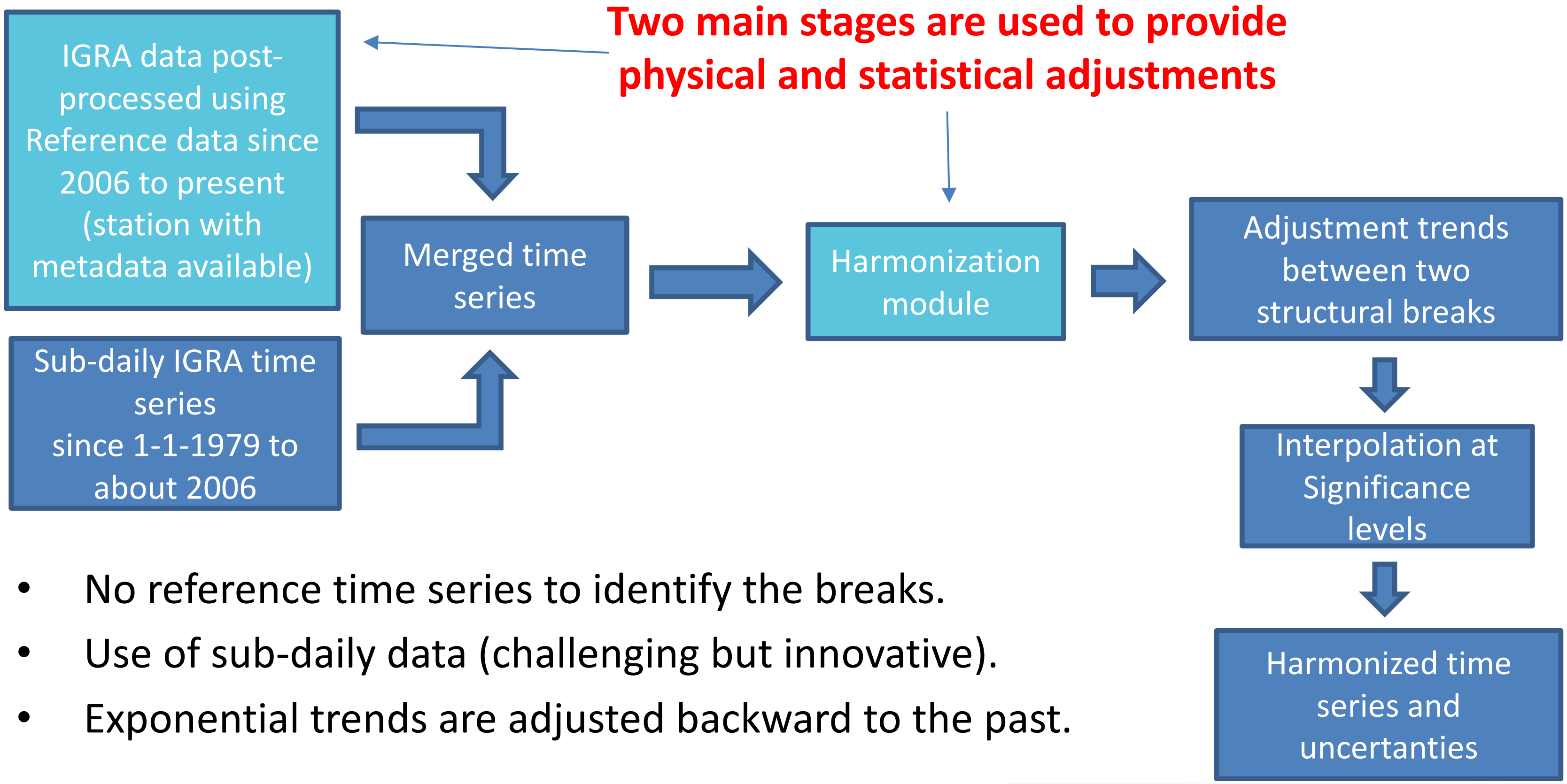
Radiosounding HARMonization (RHARM)



- No reference time series to identify the breaks.
- Use of sub-daily data (challenging but innovative).
- Exponential trends are adjusted backward to the past.

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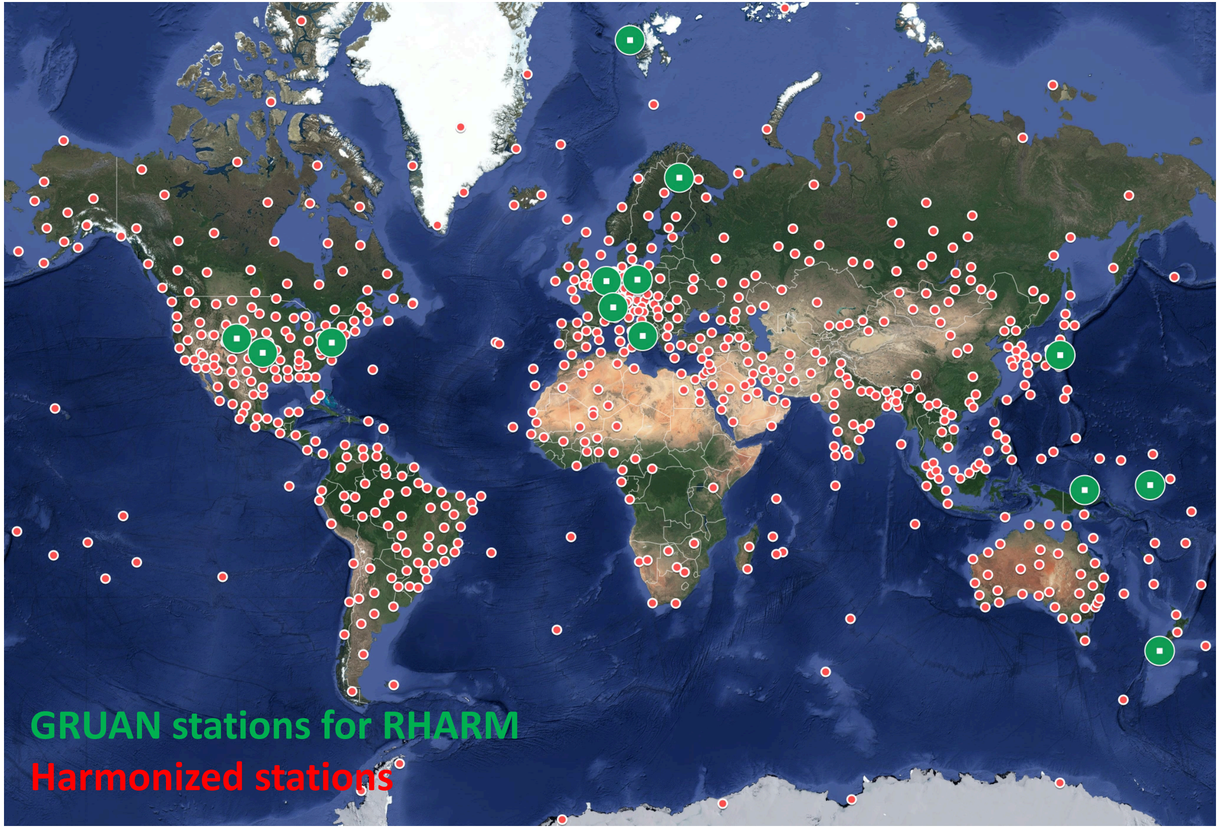
DATA SOURCE



Global distribution of **GRUAN** Reference station used in RHARM (green large dots) and the subset of IGRA stations harmonized using the RHARM within C3S (red dots).

IGRA= about 1200 stations
More than 15 millions of radiosoundings.

GRUAN=18 stations

IGRA harminozed = 656 stations
More than 8 millions of radiosoundings.

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GRUAN-LIKE POST PROCESSING

- Temperature
  - Radiation correction (RTM model) only for RS92/RS41 Vaisala sondes based on GRUAN-like data processing (Dirksen et al. 2014).
  - Additional bias adjustment (comparison at GRUAN stations) only for RS92/RS41 Vaisala sondes
  - WMO/CIMO 2010 intercomparison dataset (Nash et al. 2011) to extend the bias adjustment to other sonde types

- Relative Humidity
  - Radiation correction (RTM model) only for RS92/RS41 Vaisala sondes based on GRUAN-like data processing.
  - Time-lag correction (comparison at GRUAN stations) only for RS92/RS41 Vaisala sondes
  - WMO/CIMO 2010 intercomparison dataset to extend the bias adjustment to other sonde types

- Wind
  - Separation in the vectorial components, zonal and meridional
  - Bias adjustment (comparison at GRUAN stations) only for RS92/RS41 Vaisala sondes
  - WMO/CIMO 2010 intercomparison to extend the bias adjustment to other sonde types
  - Recombination in wind speed and direction.

Uncertainties are available for each processing step.

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IGRA vs GRUAN

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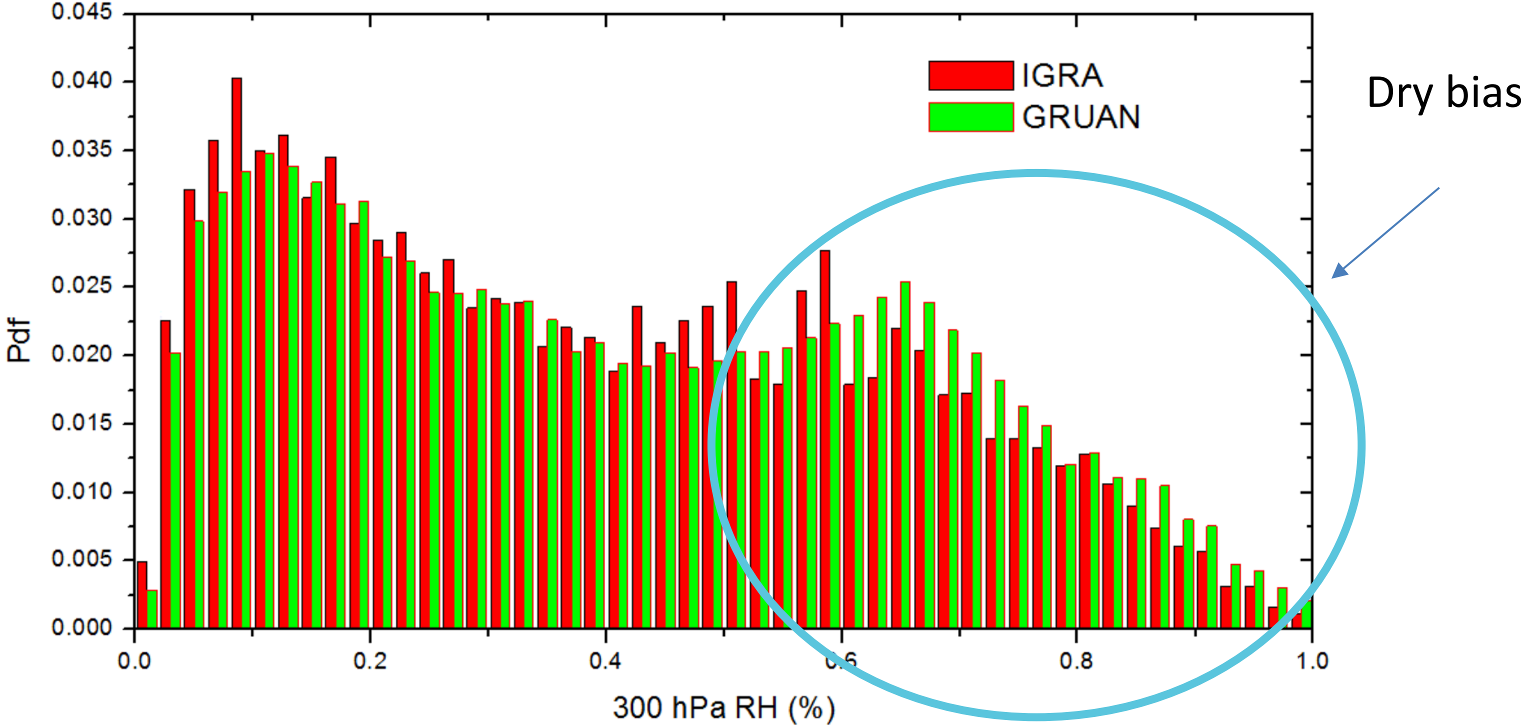
Lindenberg, Germany, WMO ID 10393 , RS92/RS41 Night and Day, 2006-2018



I G R A A D J U S T E D v s G R U A N

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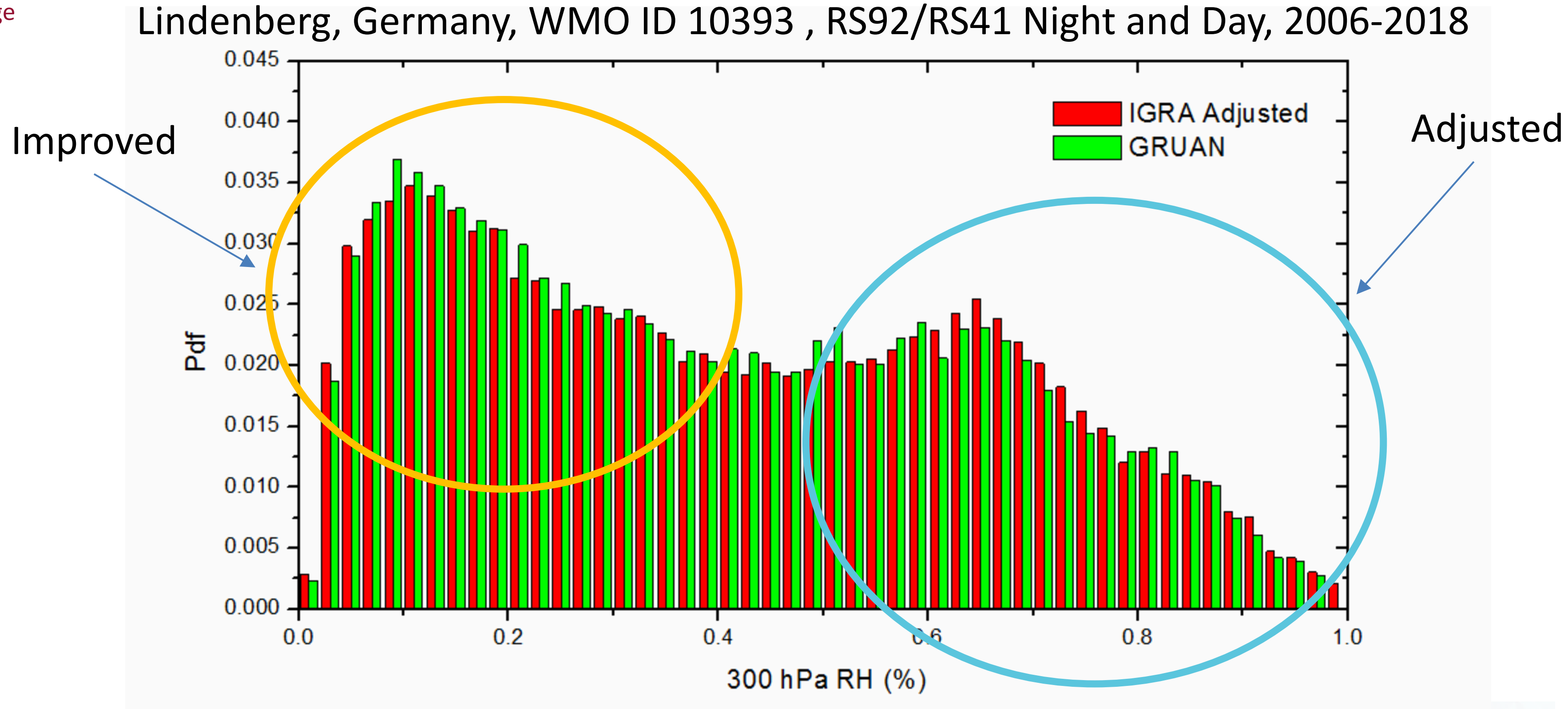

HARMONIZATION MODULE

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The Harmonization Module enables the detection of breaks and the adjustment of systematic effects.

- Stations are harmonized only if metadata are available (e.g. radiosonde type).
- Night and day measurements are separated (00 UTC and 12 UTC launches only).
- Under normal distribution assumption for x, it is used an additive model:

$$x(p,t) = Tr(p,t) + \boldsymbol{S(p,t)} + \boldsymbol{\varepsilon(p,t)}$$

- Tr is the unknown climate trend
- S is the seasonal signal (used to detect breaks in RH and wind time series)
- $\varepsilon \sim N(0, \sigma^2)$ are the residuals (used to detect breaks in temperature time series)

- Profiles are harmonized at all the mandatory pressure levels (1000 hPa -10 hPa)
- Data harmonization extended at significant levels by interpolation.
- Uncertainties are provided at all levels.

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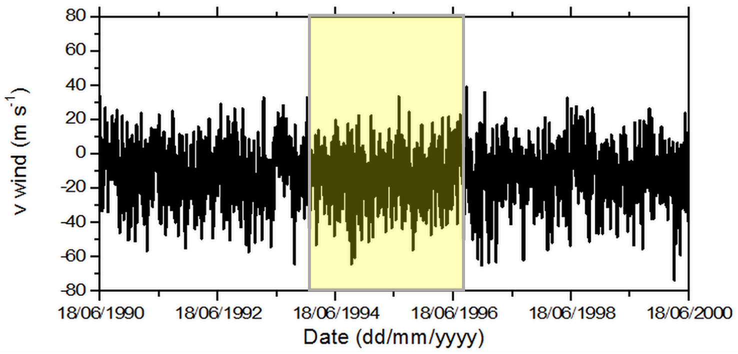
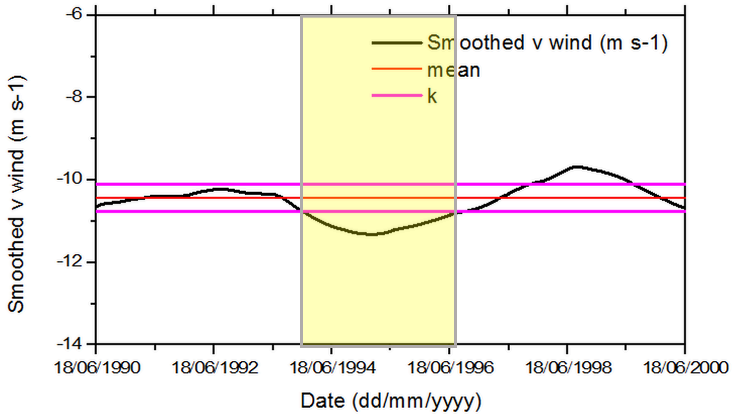
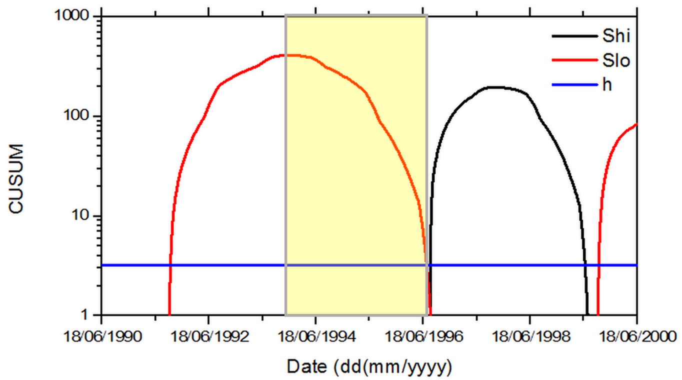
CUSUM DETECTION OF BREAKS







- LOWESS is used to model seasonality and trend and calculate residuals.
- RHARM automatic break identification is based on the Cumulative SUMming (CUSUM) approach (Aue et al., 2014).
- Isolated outliers are removed using the Median Absolute Deviation (MAD) test (only for temperature).

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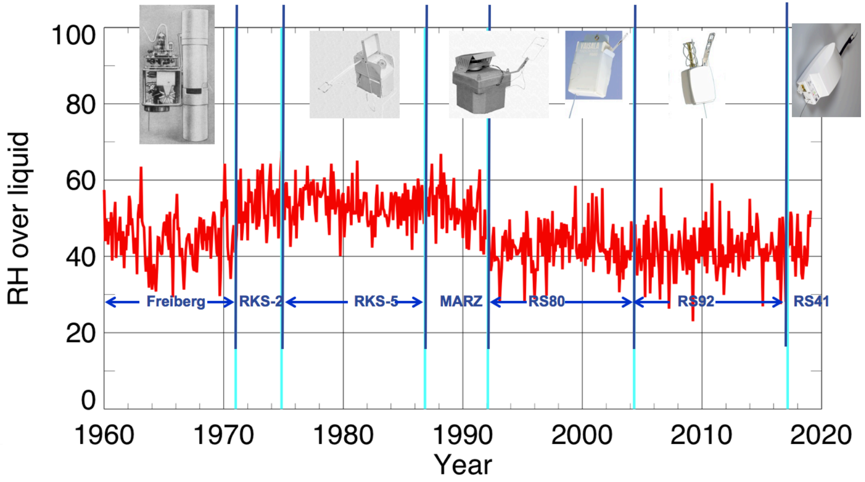
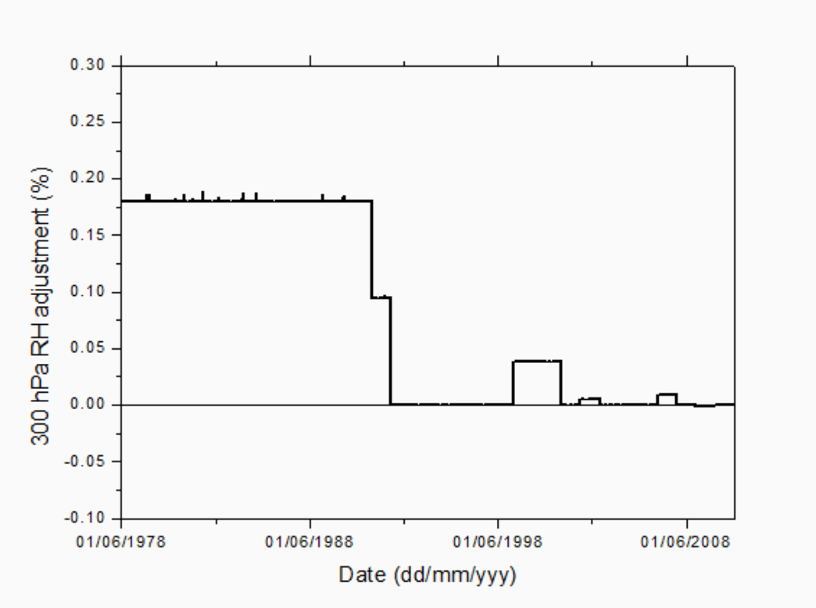
RH ADJUSTMENT: AN EXAMPLE

e.g.: Lindenberg 8km (0:00 UT)



Courtesy of GRUAN LC (Dr. R. Dirksen)



RH ADJUSTMENT: AN EXAMPLE

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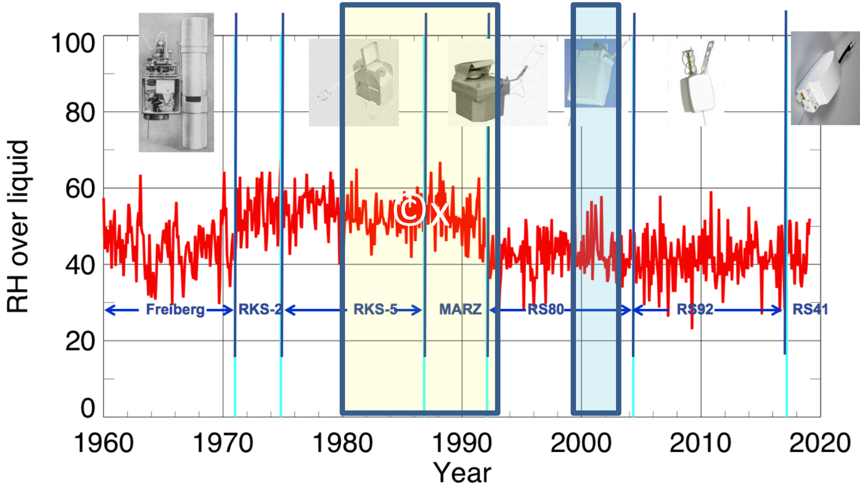

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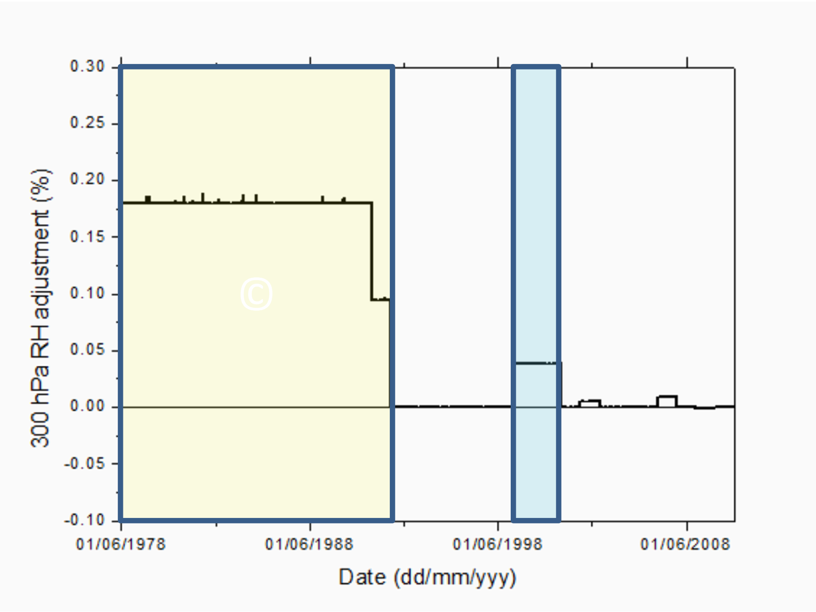

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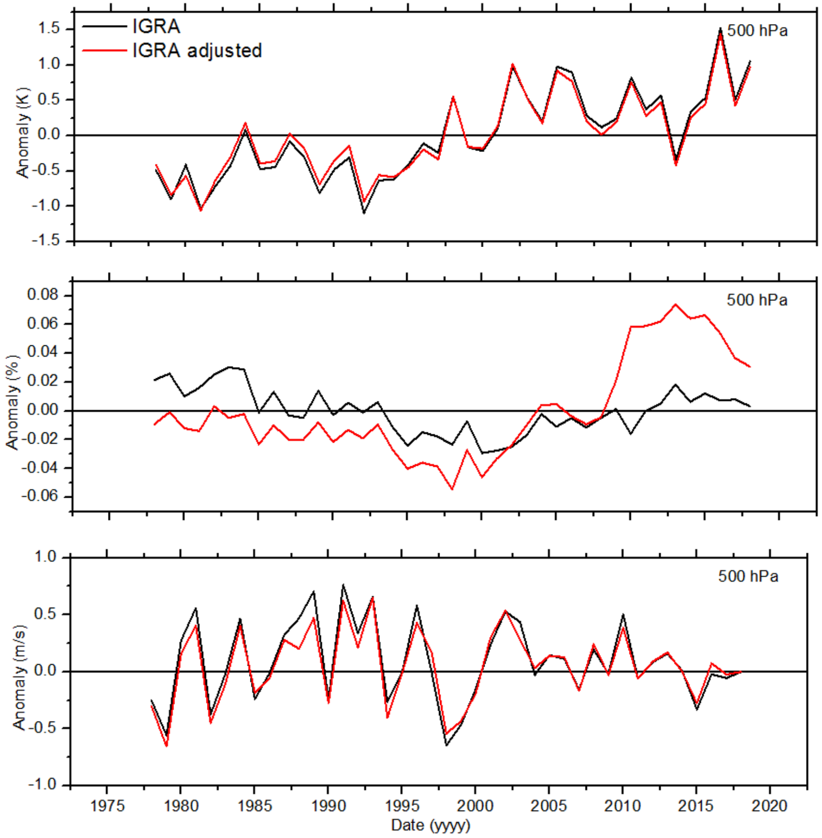
NORTH POLE: 500 hPa YEARLY ANOMALIES



Temperature

Relative Humidity

Wind Speed

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ADJUSTEMENTS: VERTICAL CORRELATION

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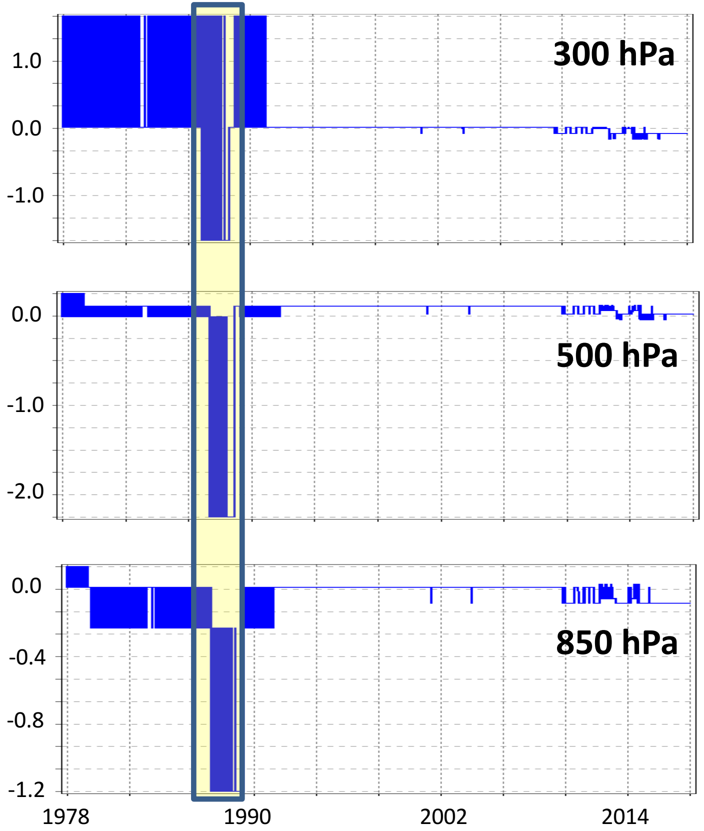
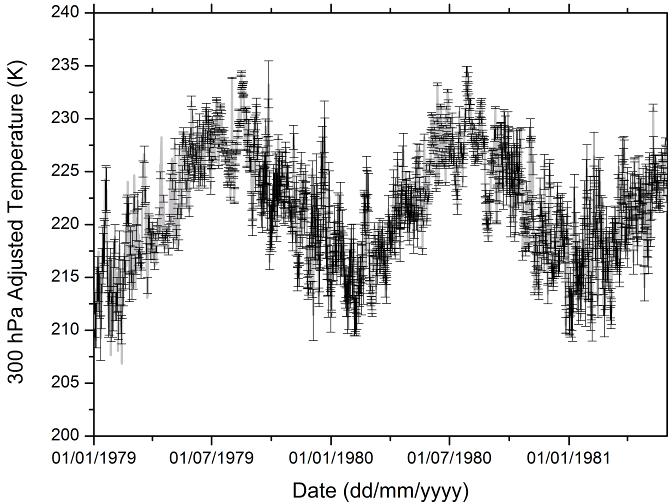
Mersa Matruh, Egypt, WMO ID 62306, 1978-2018, T adjustment 850-300 hPa

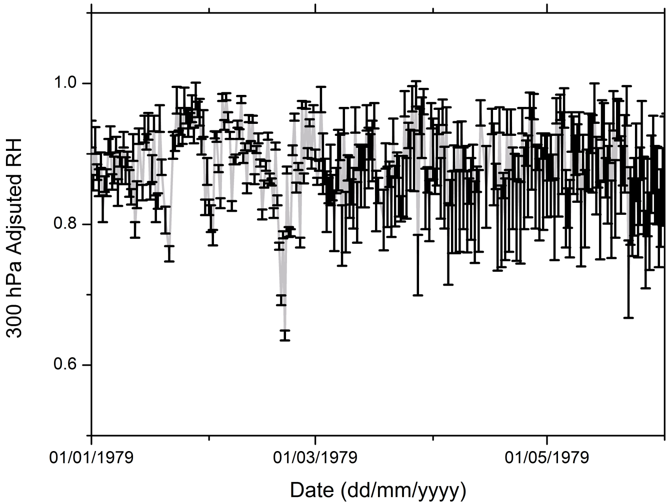


- Vertical correlation of the breaks bas been also investigated.
- Correlation in breaks along the entire vertical profiles (i.e. ground calibration bias) at several sites.
- Correlation for radiation or time lag biases studied in specific vertical regions (e.g above 500 hPa for radiation bias).

UNCERTAINTIES: T AND RH

Uncertainties are calculated from monthly averaged residuals of LOWESS calculated on a smoothing window selected in order to match the GRUAN measurement uncertainties.





Left panel, temperature time series for the Sodankyla station with the uncertainties calculated using RHARM for the period from 01/01/1979 to 01/06/1981. Right panel, same as left panel but for relative humidity and in the period from 01/01/1979 to 01/07/1979. A smaller number of points has been used for relative humidity to increase the clarify of the plot.

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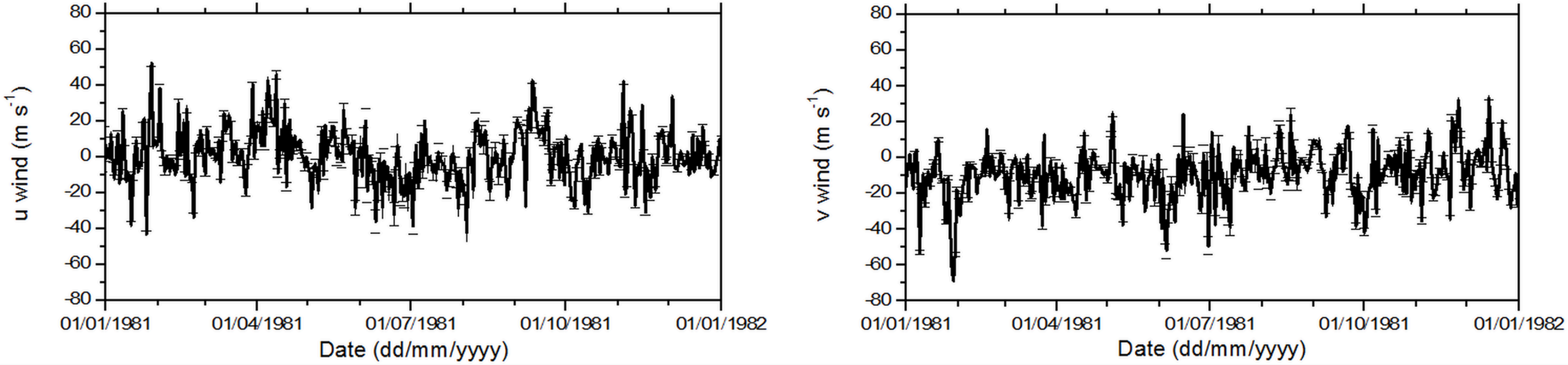
UNCERTAINTIES: WIND



Top panel, zonal wind component (u) time series at 300 hPa (only night time) for the Sodankyla station with the uncertainties calculated using RHARM for the period from 01/01/1980 to 01/01/1982. Bottom panel, same as top panel but for meridional zonal component (v). The vertical bar is the random uncertainty quantified using a statistical method.

OUTLOOK

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- RHARM dataset will become soon available in Copernicus Cimate Data Store (likely in May-June 2019).
- Consider autocorrelation and higher-order moments .
- Improve timely detection of the change (+/- 90 days).
- Extension of GRUAN data processing to other sonde types.
- Two papers in preparation to describe the two main stages of RHARM algorithm.
- Work on a second version of the algorithm using the ERA5 as the reference time series and compare with RHARM.

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Use of data as stated in the Copernicus licence agreement is acknowledged.