Use of GRUAN measurements and data processing to improve the quality of global radiosounding observing capabilities

Climate Change

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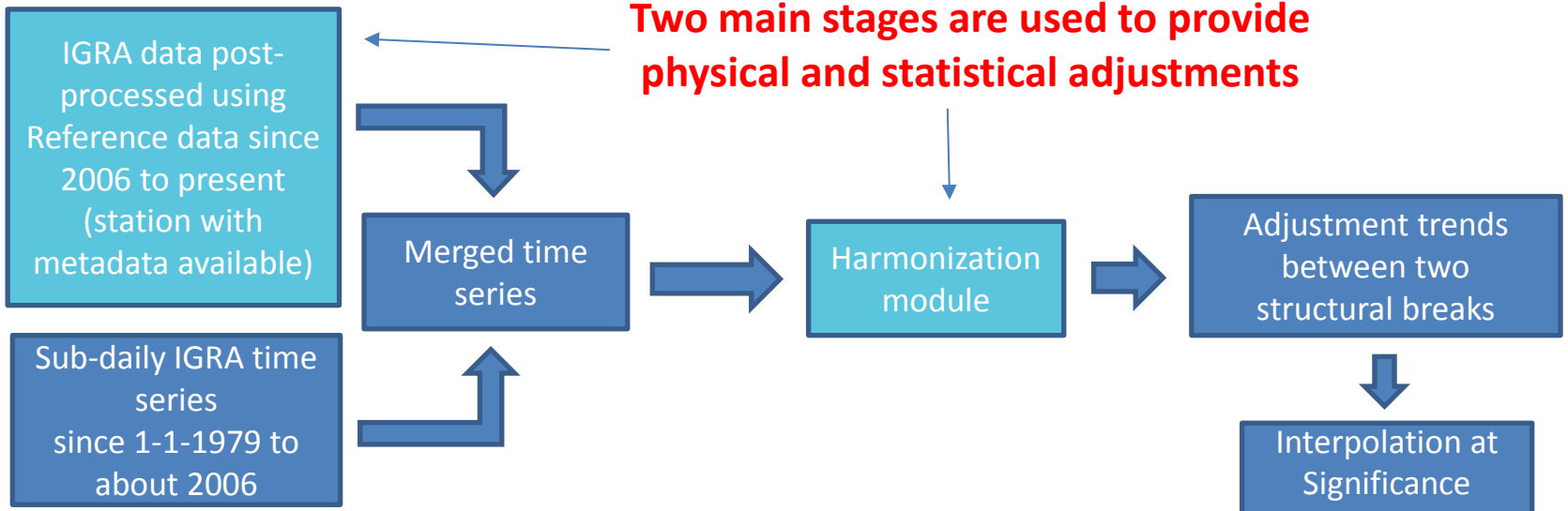
RADIOSOUNDINGS AND HOMOGENIZATION

- 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 on statistical methods or reanalysis data 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).

Radiosounding HARMonization (RHARM) - C3S



- Hybrid approach, data post-processing and homogenizaton method.
- Most recent data are post-processed using GRUAN derived adjustment.
- Historical data are adjusted in their trends backward in time.

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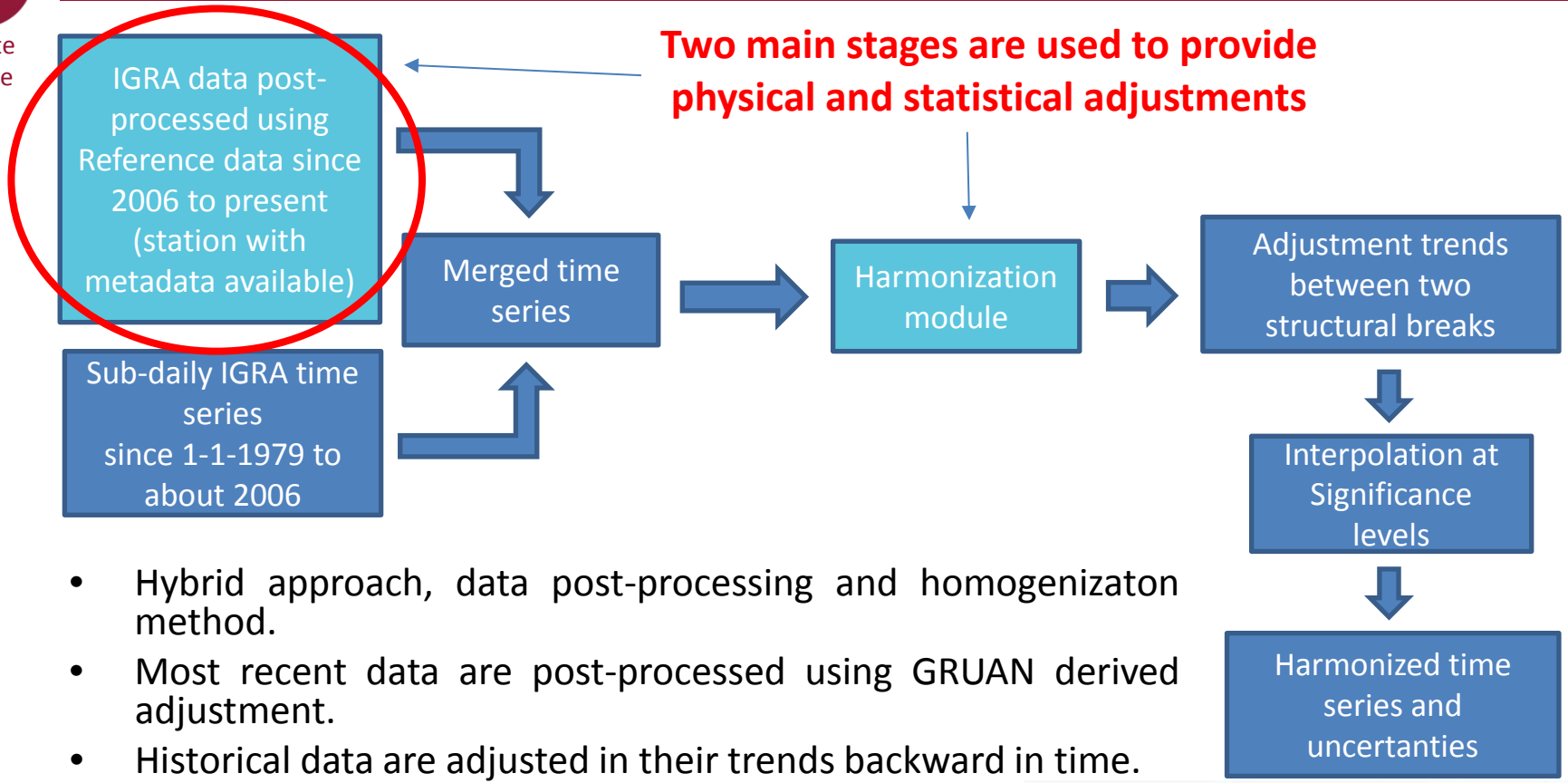

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DATA SOURCE: IGRA

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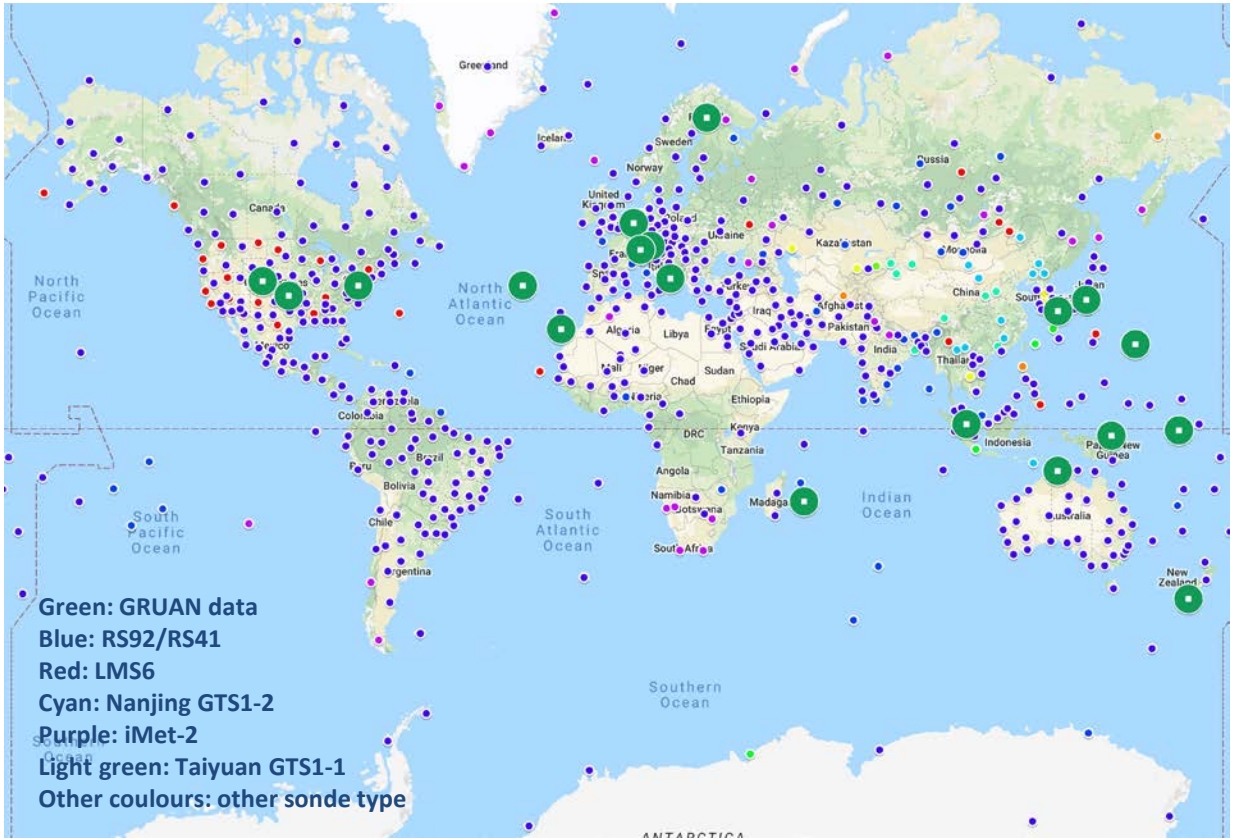
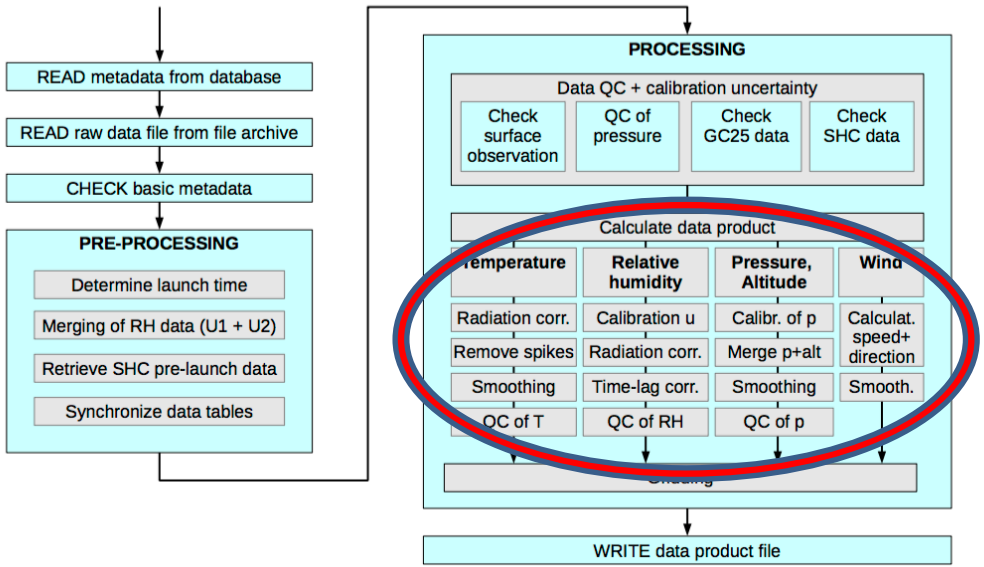


GRUAN DATA PROCESSING

To harmonize the most recent radiosonde baseline radiosoundings, the GRUAN Data Processing (GDP) has been taken as the model, though GDP can be applied only if raw data are available.



Flow chart of the GRUAN Data processing (Dirksen et al., 2014 AMT).

Look-up table used in GRUAN and based on the Streamer RTM (Key and Schweiger, 1998) for radiation correction are applied to IGRA data.

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IGRA DATA 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.
  - Additional bias correction (static, 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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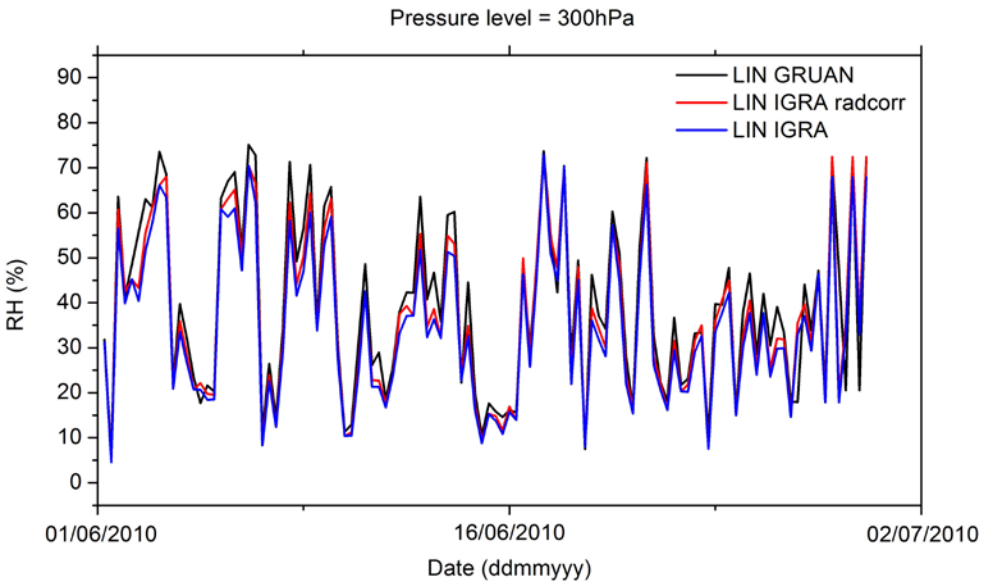
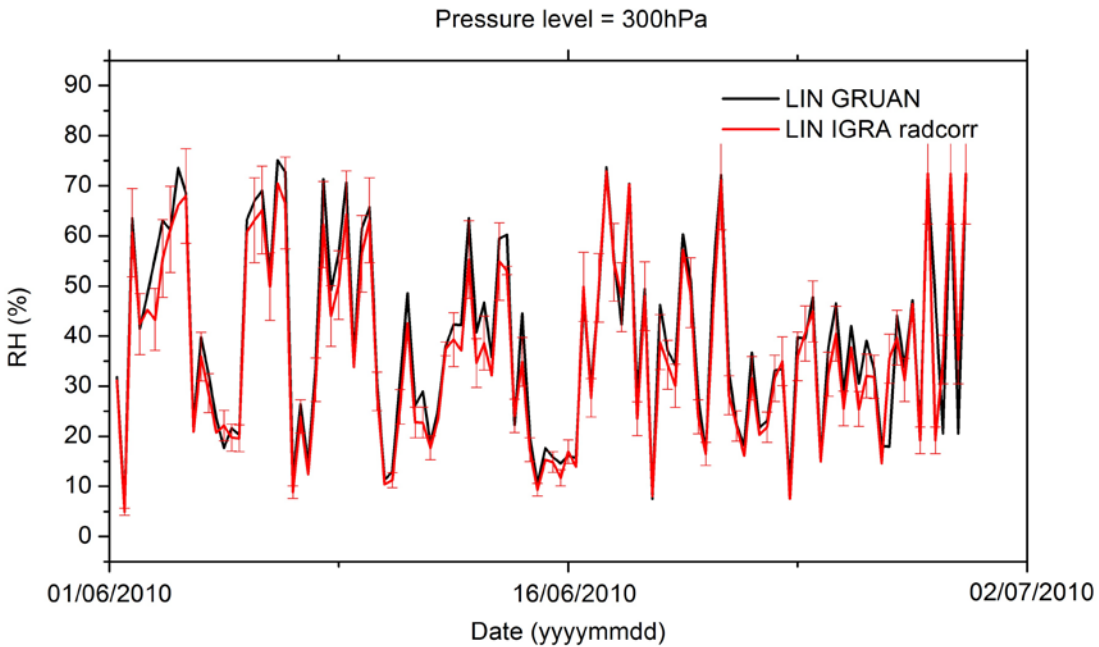
ADJUSTMENT: RADIATION CORRECTION

Comparison of the time series of the relative humidity at 300 hPa measured with the radiosondes launches in Lindenberg in June 2010 and processed using the manufacturer software (blue), processed applying the GRUAN radiation correction (red) and applying the full GRUAN data processing on the raw high-resolution data.



RADIATION CORRECTION: UNCERTAINTY

Radiation correction is always provided along with its estimated uncertainty (red vertical bars)



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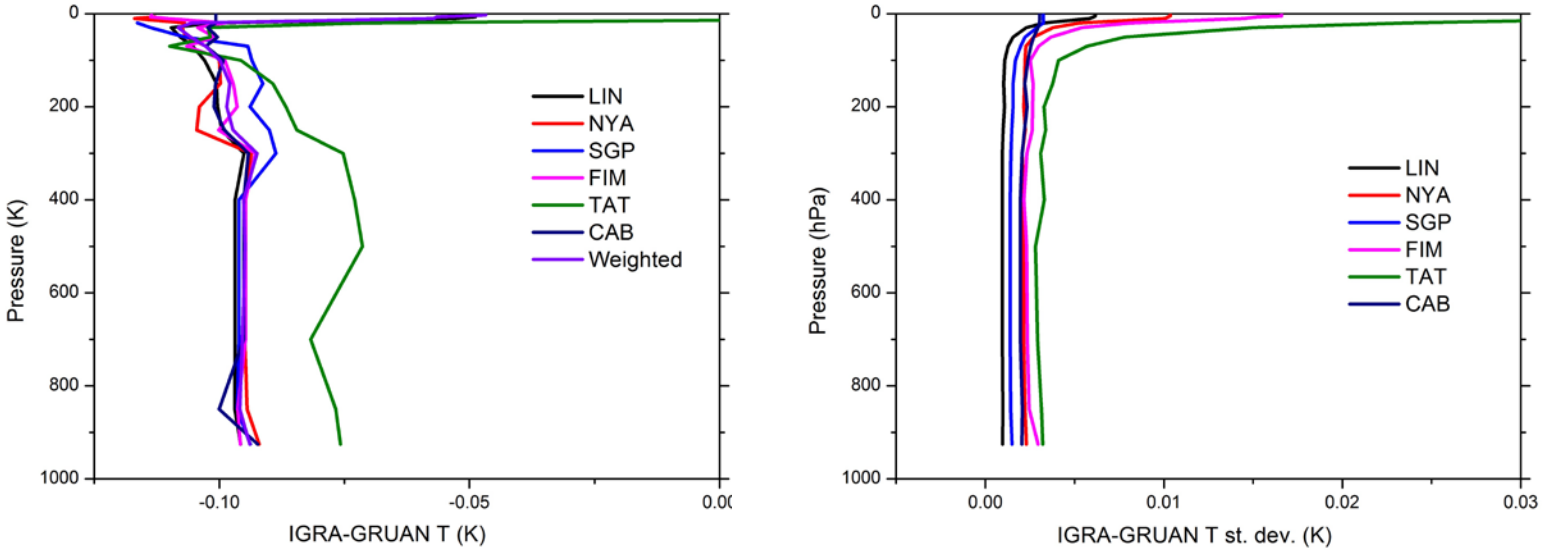
IGRA vs GRUAN T DIFFERENCES: NIGHT

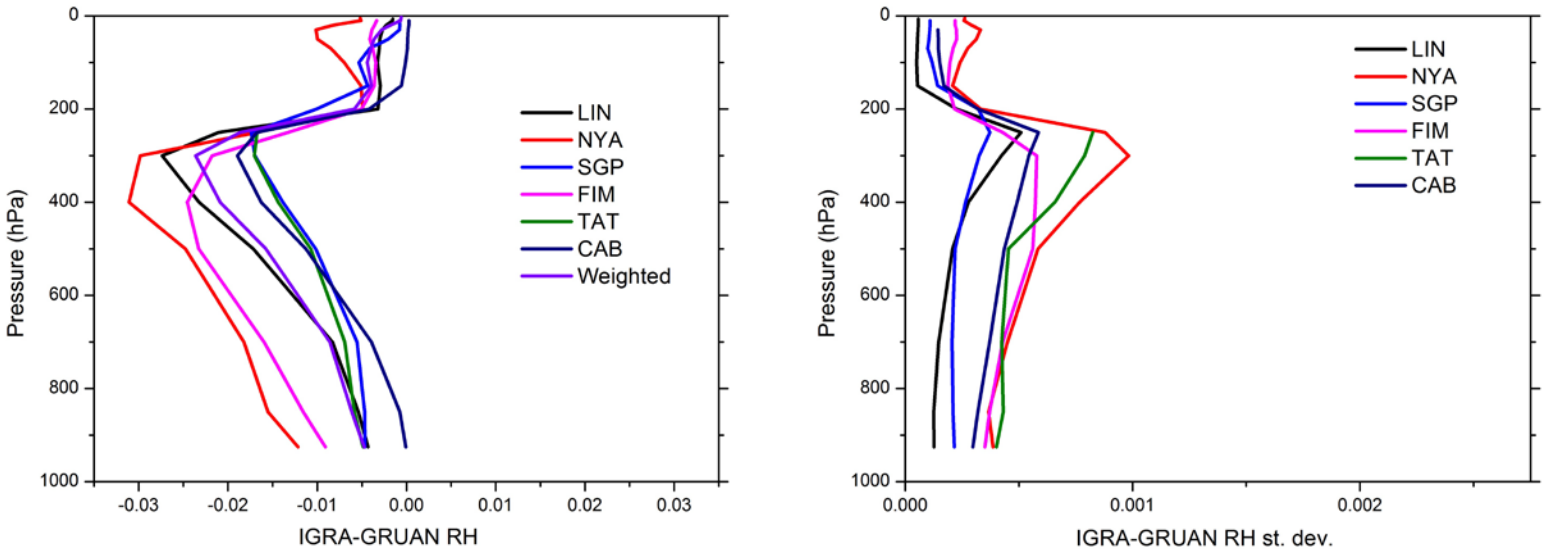
2006-2016 Night time observations only



- Standard deviations of the difference between GRUAN Data Processing and IGRA data at six stations are very small, also compared with the other corrections (e.g. radiation).
- Outliers have been also investigated to assess their relevance.
- Levels above 10 hPa, due to the smaller number of data available, must be handled with care.

IGRA vs GRUAN RH DIFFERENCES: NIGHT

2006-2016 Night time observations only



- Average differences due to time-lag effects and calibration of the measurements sensors.

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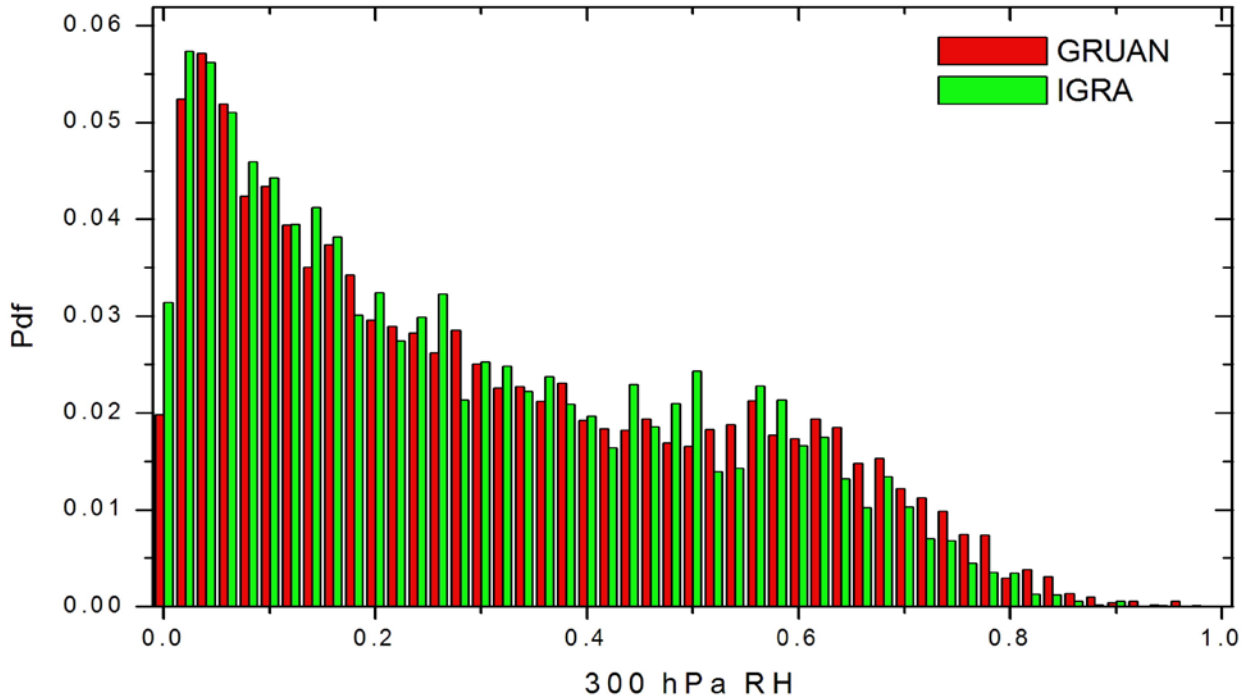
All GRUAN station, RS92/RS41 Night and Day, 2009-2018



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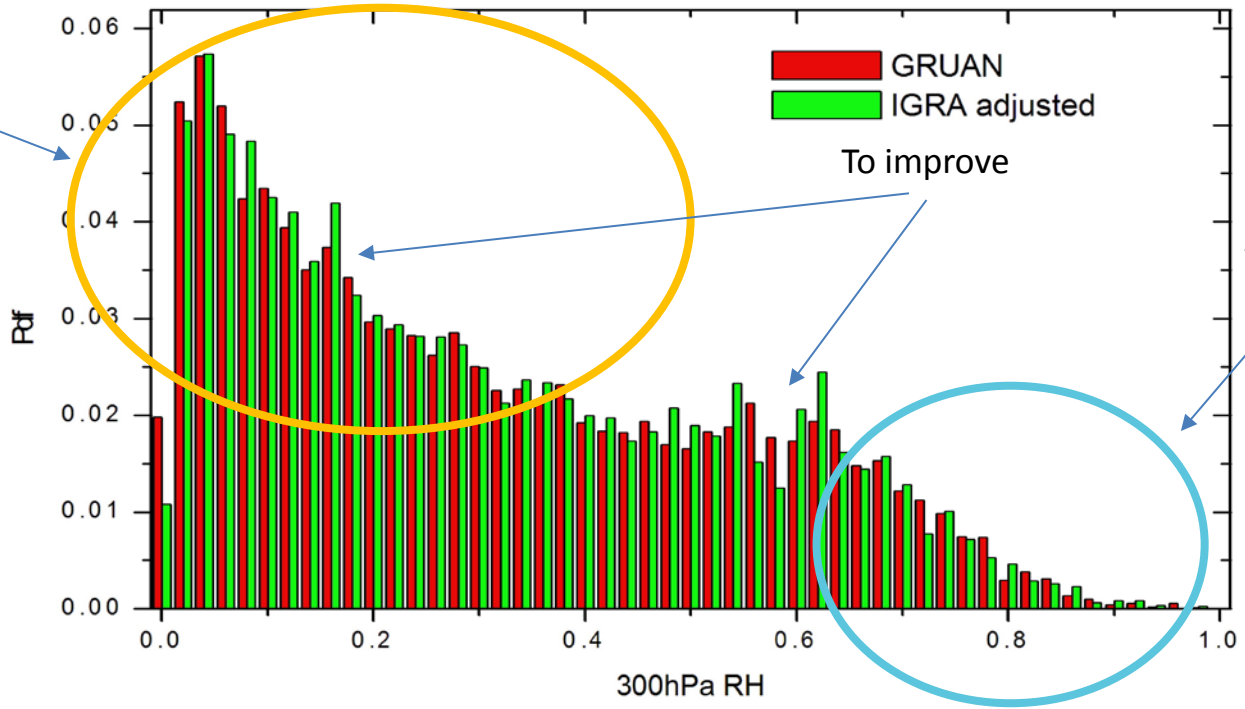
All GRUAN station, RS92/RS41 Night and Day, 2009-2018



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ADJUSTMENT – CIMO INTERCOMPARISON

The previous adjustment can be applied only to RS92 sondes. But using the 2010 WMO/CIMO RS intercomparison dataset, it is possible to extend the adjustment to several other modern radiosonde types.

Abbrev.	Name	WMO radiosonde code
RS92	VAISALA RS92	14, 79, 80, 81
Graw	DMF-09 Graw	17
Modem	M10, Modem	57
LM	LMS6	11, 82
Meisei	Meisei	30
JinYang	JinYang	21
IntermSA	iMet-2 InterMet	97, 98, 99
Daqiao	Nanjing GTS1-2/GFE(L) (China)	33
Huayun	Taiyuan GTS1-1/GFE(L) (China)	31
Changf	Beijing Changfeng CF-06 (China)	45
ML	Meteolabor	26

List of the operational radiosondes involved in the 2010 WMO/CIMO intercomparison. Please note that also RS92 and RS41 are included in the list. Adjustments have been calculated using the RS92 sondes as the reference. The table also allows to identifies how many station are reporting the “radiosonde type” code in the metadata and how many station can be harmonized using RHARM

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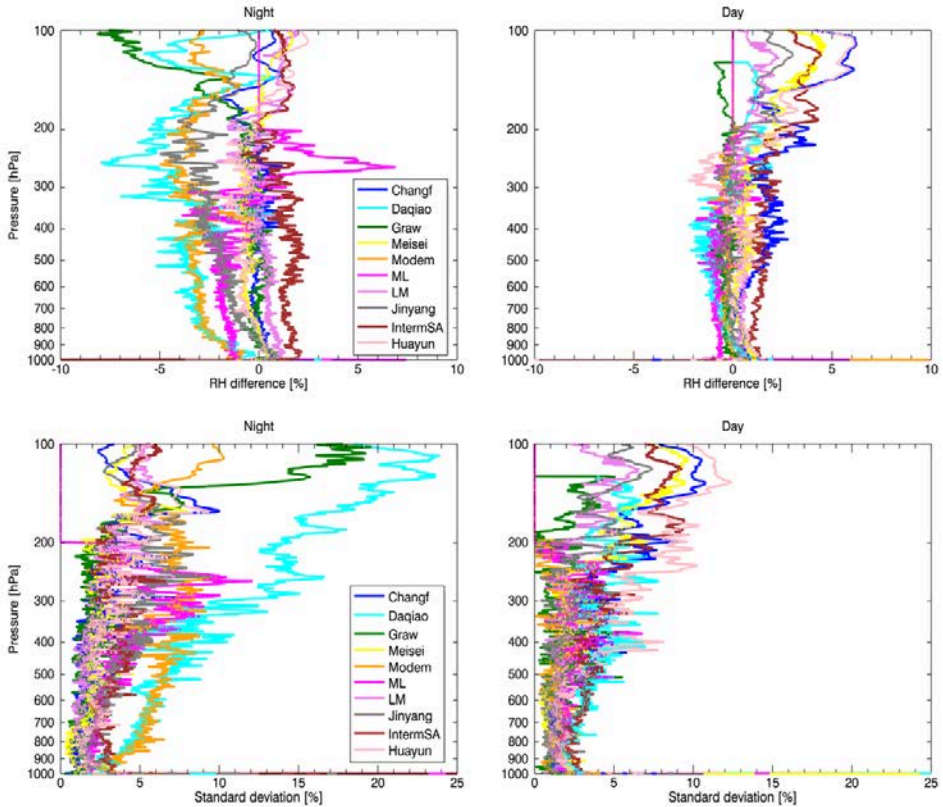
WMO-CIMO INTERCOMPARISON DATA: RH



Upper panels, night time and daytime profiles of the mean differences between RS92 relative humidity profiles and the profiles measured by each of the radiosonde types listed in Table 1; lower panels, profiles of the standard deviation of the mean reported in the upper panels.

UNCERTAINTY ESTIMATION

GRUAN is also helpful in the tuning of error model…..

Model uncertainty is actually the deviation of a calculated value from the true value, which is unknown.

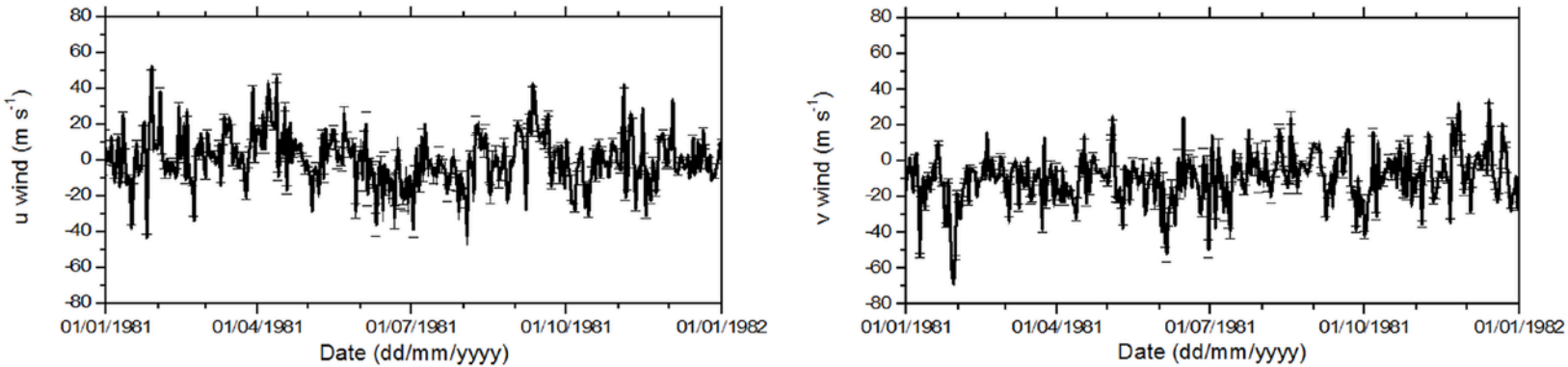
For RHARM apporach, we use the deviation of calculated value from the observation (e.g. residuals) as an estimation of the uncertainty, i.e:

$$\varepsilon_t = x_t - q_t \quad t = 1,2, \dots \dots, T$$

where x_t = measurement; q_t = modelled value; t=time index, and T=length of the time record.

In order to tune (“constraint”) the model and obtain a reliable estimation of the uncertainty, the model is forced in the “GRUAN period” to match the GRUAN uncertainty.

UNCERTAINTIES: USING REFERENCE AS CONS



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.

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CONCLUSIONS

- The use of a adjustments inferrerd by GDP and GRUAN data is a solution to improve the quality of baseline radiosoundings.
- Using other “golden” datasets like WMO intercomparisons allows to extend the adjustement to other radiosonde types (see back-up slides).
- Reference data can be also used to tune uncertainty models for historical data. New data GRUAN products may be used to adjust different sonde types.

A peer-reviewed paper is in advanced preparation stage and should be submitted in few weeks.

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This work was done on behalf of the European Union's Copernicus Climate Change Service implemented by ECMWF.
Use of data as stated in the Copernicus licence agreement is acknowledged.

Thanks to the GRUAN Lead Center for sharing the LUT of the Streamer RTM

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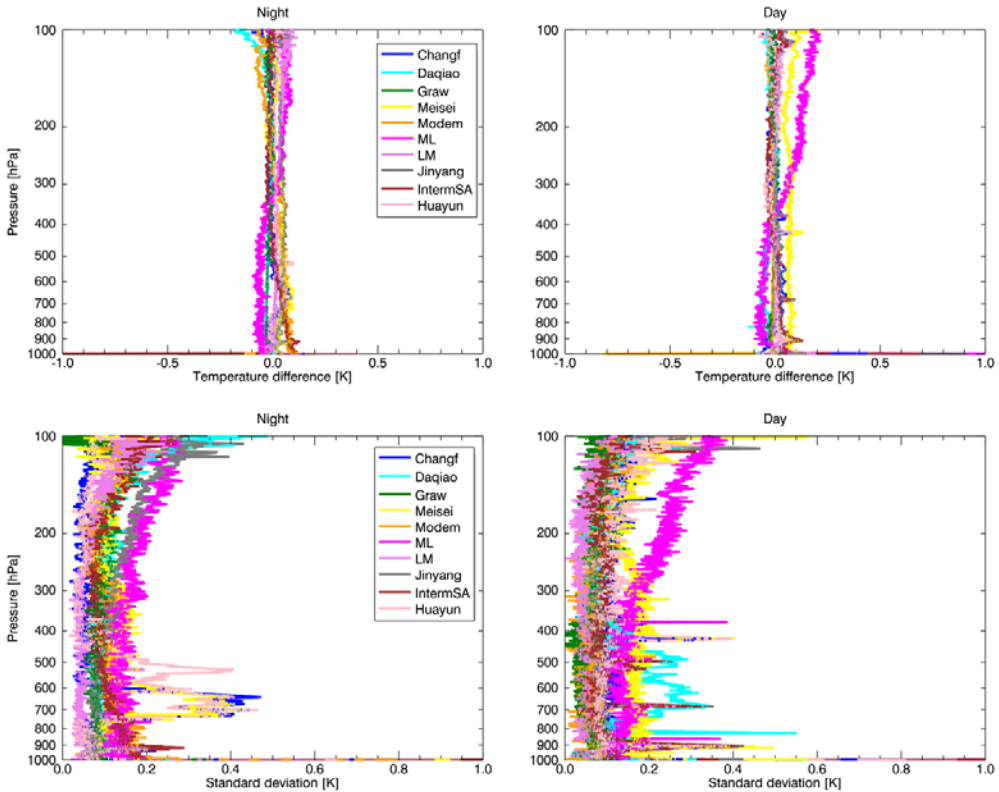
WMO-CIMO INTERCOMPARISON DATA: T



Upper panels, night time and daytime profiles of the mean differences between RS92 temperature profiles and the profiles measured by each of the radiosonde type listed in table 1; lower panels, profiles of the standard deviation of the mean reported in the upper panels.

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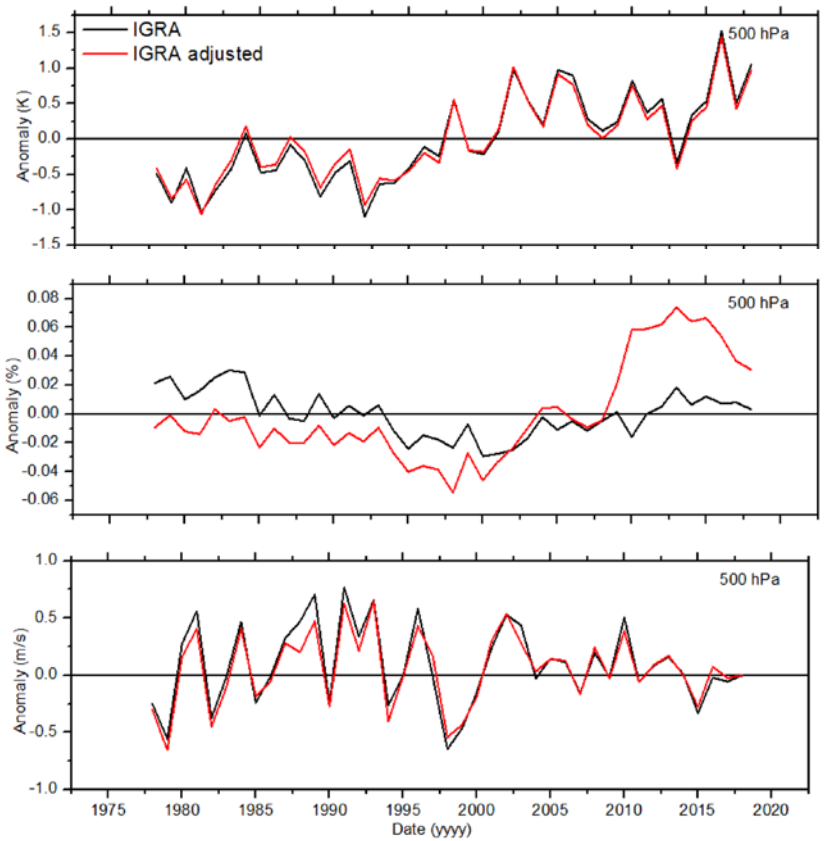
NORTH POLE: 500 hPa YEARLY ANOMALIES



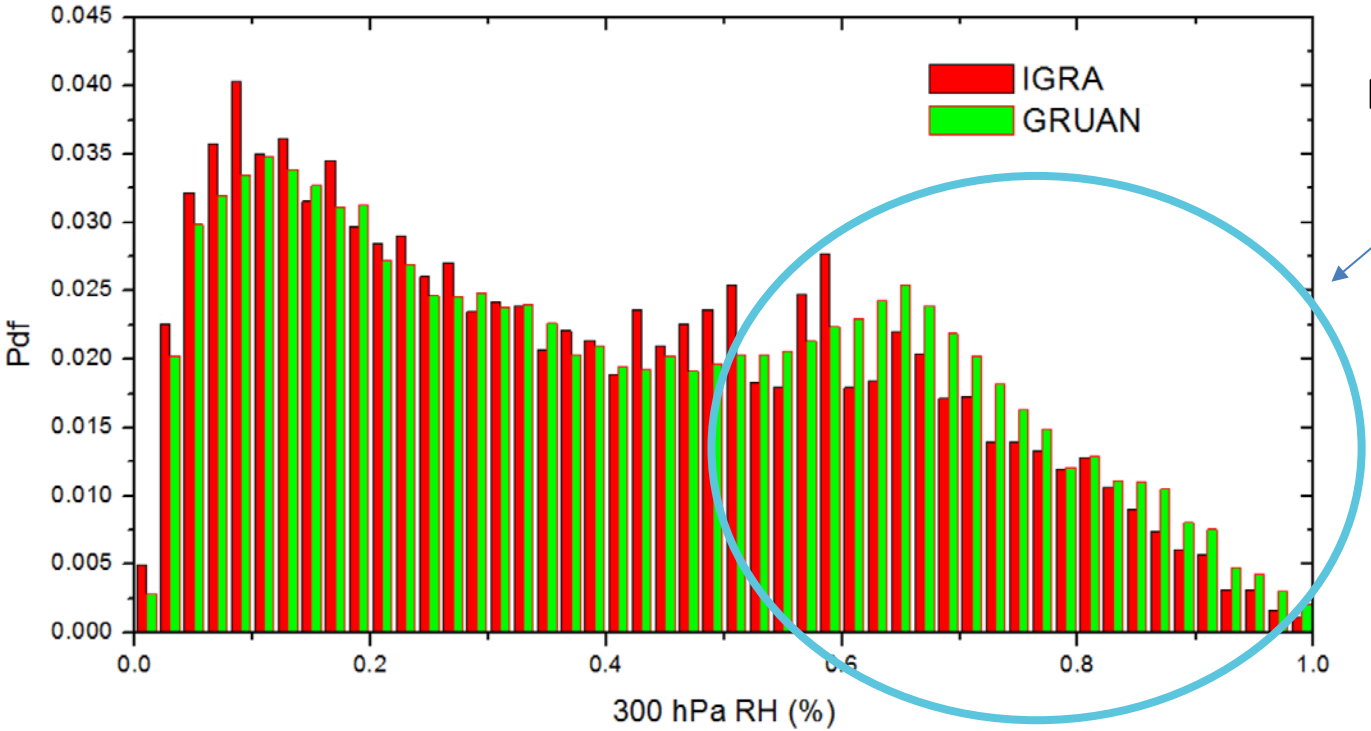
Temperature

Relative Humidity

Wind Speed

IGRA vs GRUAN

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



Dry bias

IGRA ADJUSTED vs GRUAN

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