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C3S_311a_lot3: Results achieved in the Service Year I

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C3S_311a_LOT3: OBJECTIVES

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- To rationalise, harmonise and improve access to open and free observational records and data streams from selected in-situ GCOS-relevant Baseline and Reference observing networks.

Lot3 comprises of 4 work packages:

- WP0 - Management
- WP1 - Access to network data
- WP2 - Data harmonization
- WP3 - Data dissemination

The successful implementation of the proposal will allow:

- The development of consistent quality control algorithms for in situ climate data arising from Baseline and Reference networks at various time scales (hourly, daily, monthly, annually).
- The developments of methods to detect and adjust for inhomogeneities due to issues such as, instrumentation changes, calibration drifts, observing station relocations,
- To provide/quantify uncertainty in a consistent and metrologically rigorous manner.

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PROJECT GENERAL INFORMATION

- Started 1st March 2017 (duration: 4 years)
- Budget, 2.1 MEuros
- 8 sub-contractors
- 4 EU countries + UK represented + WMO
- Variety of expertise including remote sensing experts, statisticians, ICT experts, metrologists, ….
- Redundancy in the specific expertise to minimize the risks.

NUIM	National University of Ireland, Maynooth	IE - Ireland	Public Sector Organisation
BIRA-IASB	Koninklijk Belgisch Instituut voor Ruimte Aeronomie - Institut royal d'Aéronomie Spatiale de Belgique	BE - Belgium	Public Sector Organisation
BKS	BK Scientific GmbH	DE - Germany	Private Sector Organisation
NPL	NPL Management Ltd	UK - United Kingdom	Public Sector Organisation
TUT	Tallinn University of Technology	EE - Estonia	University
UNIBG	Università degli studi di Bergamo	IT - Italy	University
UNIBRE	UNIVERSITÄT BREMEN	DE - Germany	University
WMO	Organisation Météorologique Mondiale	CH - Switzerland	Other

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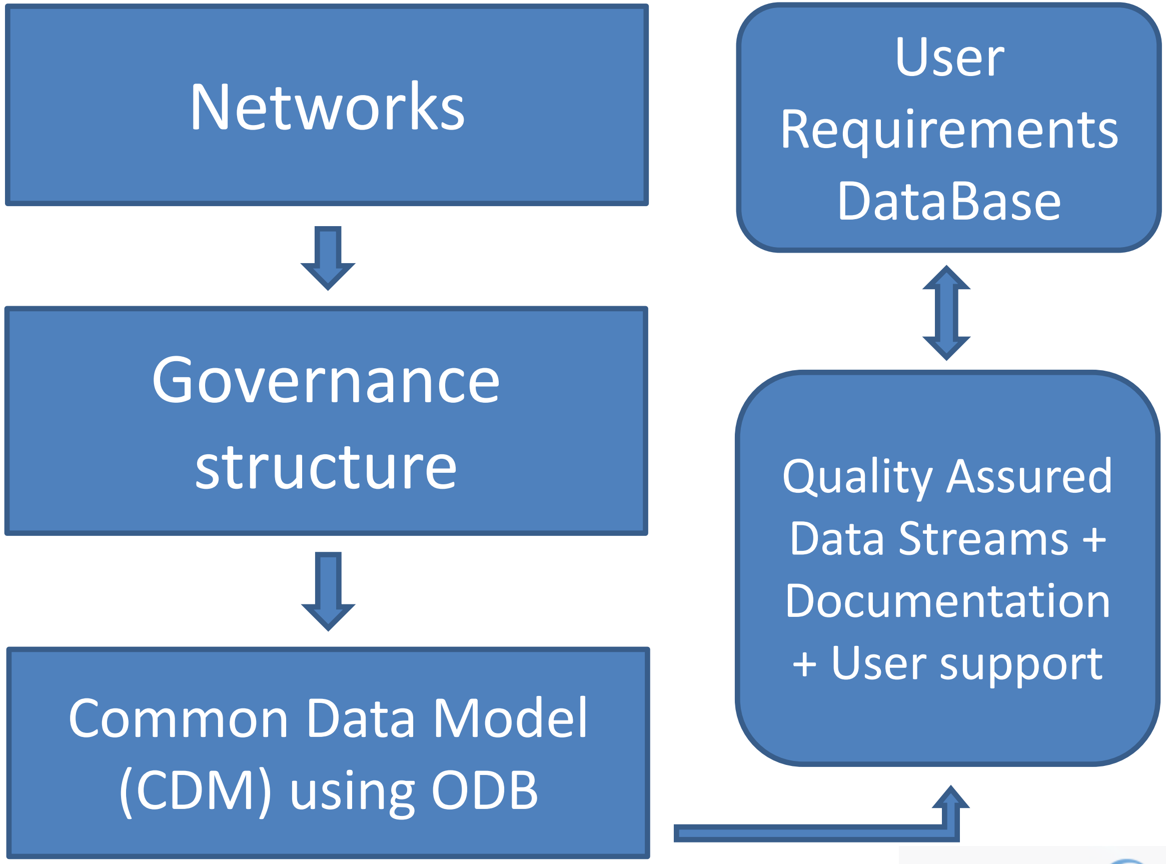
TECHNICAL APPROACH



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NETWORKS AND DATASETS

According to the Service Contract 1, Lot3 must facilitate access to data from the following networks:

- Surface Temperature: USCRN, RBSN, GSN, RBCN;
- Temperature/humidity/wind (profiles): GRUAN, GUAN, RAOB;
- Ozone (concentration, columns and profiles): NDACC, SHADOZ, GAW Networks;
- CO, CO2, CH4 (concentration, columns and profiles): TCCON, GAW networks;
- Integrated water vapour (from GNSS zenith tropospheric delay only): IGS, EUREF, all international GNSS networks.

According to the following timeline:

Service year I (03/2017-02/2018): in-situ sounding temperature and humidity profile;

Service year II (01/2018-12/2018): column and profile ozone data products, surface temperature, in-situ sounding wind profile;

Service year III (01/2019-12/2019): column and profile CH_4, CO_2 and CO;

Service year IV (01/2020-12/2020): integrated water vapour from GNSS.

Updated on yearly basis.

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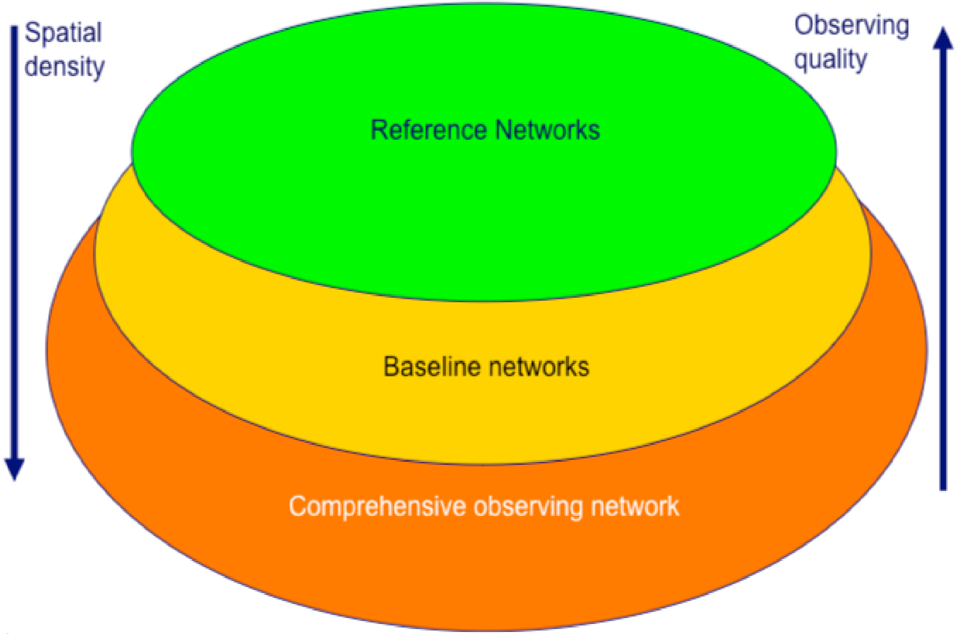
Reference vs Baseline



Proposed tiers in a system of systems approach elaborated within GAIA-CLIM H2020 project is adopted in C3S 311a Lot3.

Thorne, P. W. et al., "Making better sense of the mosaic of environmental measurement networks: a system-of-systems approach and quantitative assessment", Geosci. Instrum. Method. Data Syst., 6, 453-472, https://doi.org/10.5194/gi-6-453-2017, 2017.

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WORK PACKAGES

- WP0 - Management
- WP1 - Access to network data

Reference and Global radiosonde data are routinely ingested into the CNR data management facility adopting a Common Data Model (based on CF and WIGOS conventions). Estalishing a governance for running the service permanently

- WP2 - Data harmonization

Implementation of a statistical model to detect changes and physical issues in the time series. Correction for T and RH radiation biases applied to all the global data radiosonde data. Uncertainty provision.

- WP3 - Data dissemination

Define service specification. Provision of ancillary products. Support to the users.

WORK PROGRESS

Service year I (03/2017-02/2018)

Access to in-situ sounding temperature and humidity profile from Reference and Baseline radiosoundings networks and time series harmonization

SERVICE YEAR I: RATIONALE

Several groups have used multiple years of RAOB temperature measurements to construct long-term CDRs (Durre et al., 2005; Free et al., 2004, 2005; Sherwood et al., 2008; Haimberger et al., 2008, 2011; Thorne et al., 2011; Seidel et al., 2009).

- It has long been recognized that the quality of the global radiosounding observations varies for different sensor types and height.

- How we can use a **reference network** to improve the quality of the **baseline** radiosounding capability?

DATA AND METADATA PROVIDED IN YEAR I

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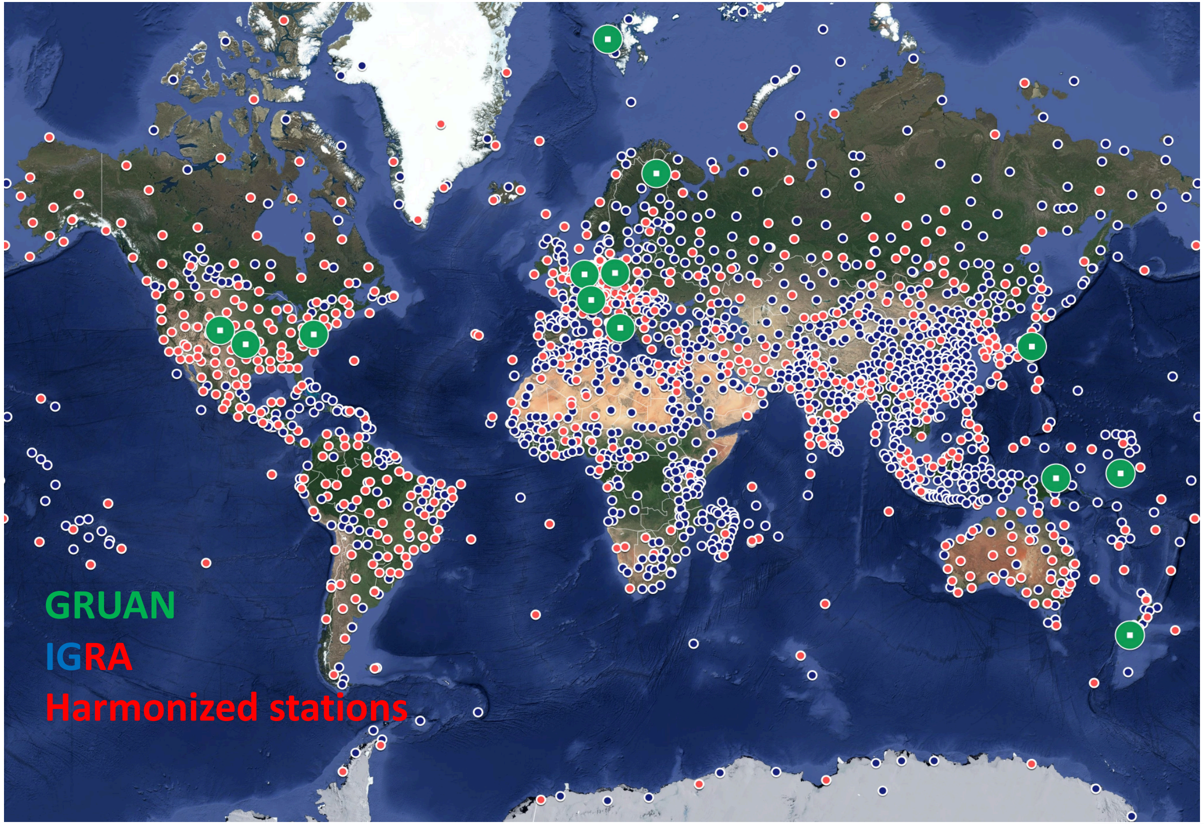


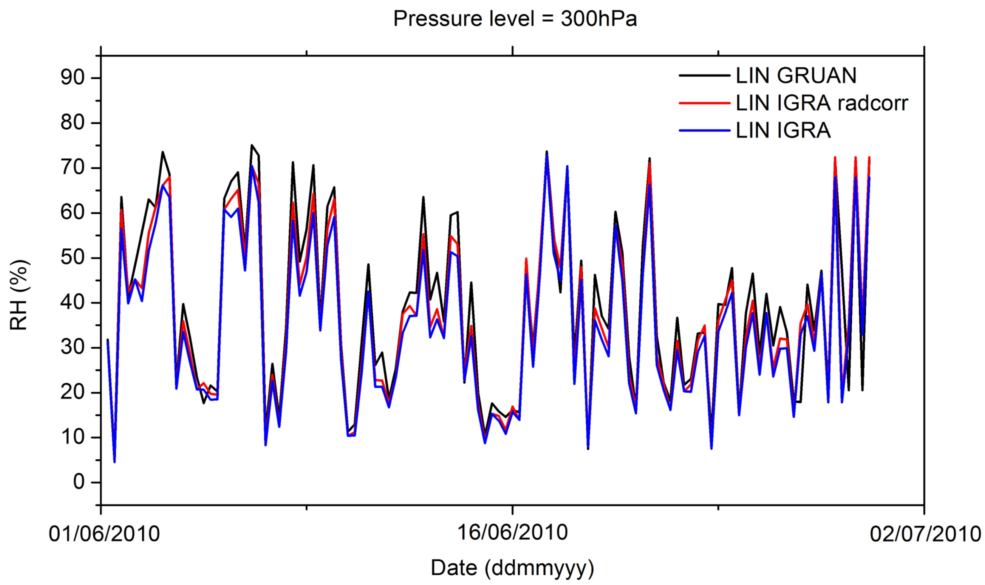
Global distribution of **GRUAN** Reference station (green large dots), **IGRA** baseline radiosounding stations (red and blue dots), and subset of IGRA stations harmonized using RHARM approach developed within C3S 311a Lot3 contract (red dots).

All the data and metadata will be provided to C3S users using a Common Data Model developed within C3S 311a contract family complian with **ECWMF ODB, ISO, WIGOS, CF convention**.

ADJUSTMENT AND UNCERTAINTIES- GRUAN

The approach, named RHARM, is based on two steps

First step: Physical harmonization using GRUAN data processing and WMO intercomparison data. Calculation of measurement uncertainties.



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.

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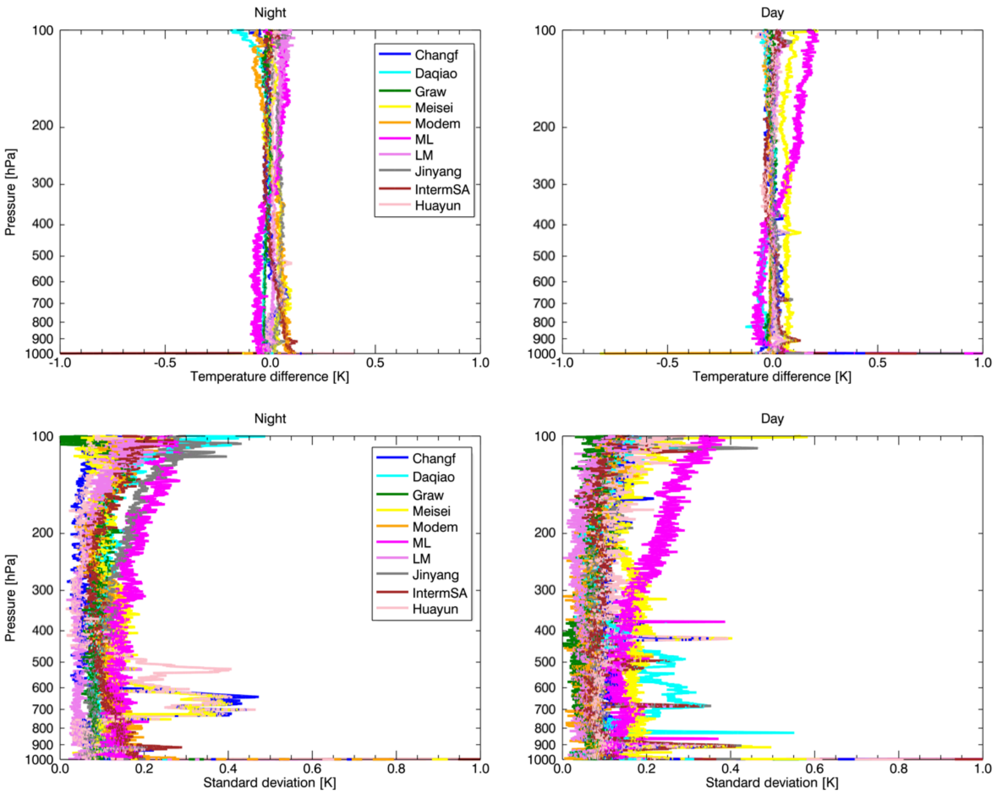
ADJUSTMENT AND UNCERTAINTIES - WMO



Each historical time series of T or RH available at a single radiosounding station flying radiosondes other than VAISALA is adjusted using the information inferred from the 2010 WMO/CIMO radiosonde intercomparison dataset (Nash et al. 2010)

ADJUSTMENT AND UNCERTAINTIES

Second step: estimation of uncertainties, identification of breaks and adjustment for historical data back to 1979 (only for station having metadata since 2000).

Using GRUAN residuals to estimate the uncertainty for the IGRA stations → Using Cumulative summing method (CUMSUM) to estimate breaks → Tuning the thresholds of the CUMSUM using data harmonized in the step 1

To extend the benefit of the data harmonization to the stations where no metadata exists, the kriging technique will be applied.

RADIOSONDE HARMONIZATION: RHARM

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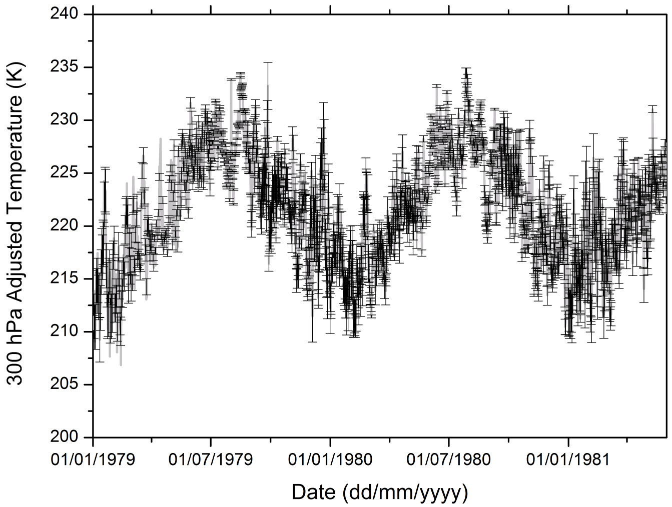

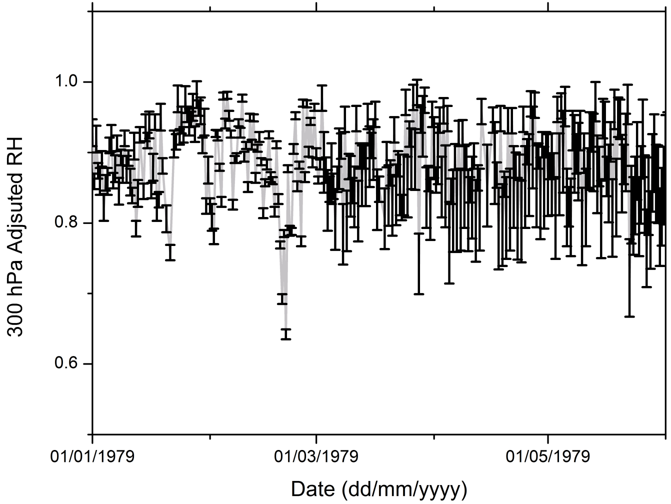

Left panel, temperature time series for the Sodankyla station with the uncertainties calculated using RHARM for the period from 01/01/1979 to 01/06/1981. Right panel, same as left panel but for relative humidity and in the period from 01/01/1979 to 01/07/1979. A smaller number of points has been used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

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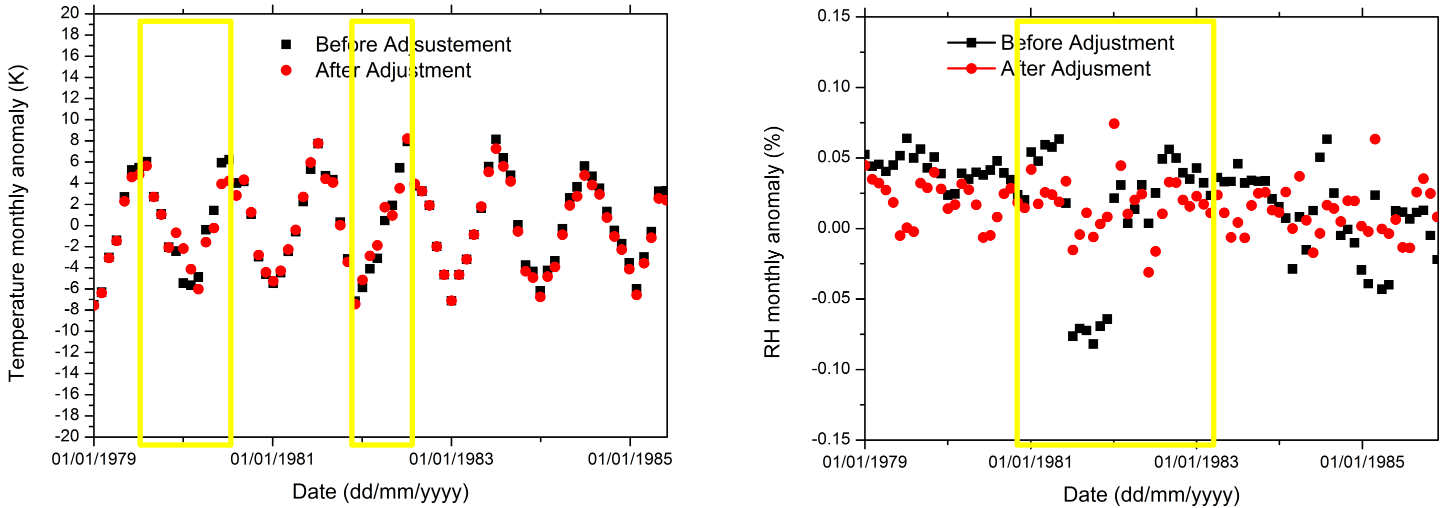

Temperature (left panel) and relative humidify (right panel) monthly anomalies before and after the application of RHARM algorithm, calculated at 300 hPa for Sodankyla station are reported for the period from 01/01/1979 to 01/06/1985.

Major changes are within the yeallow boxes

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ENSEMBLE OF DATASETS

Acknowledging the importance to provide the C3S users with the best ensemble of the available harmonization datasets of radiosounding temperature and humidity profiles, C3S 311a Lot3 will also make available a few already existing harmonized radiosonde datasets provided by several institutions and groups over the last decade.

C3S 311a Lot3 will initially focus on the following datasets:

- Radiosonde Atmospheric Temperature Products for Assessing Climate (RATPAC) by NOAA;
- RAdiosonde OBservation COrrection using REanalyses (RAOBCORE) and Radiosonde Innovation Composite Homogenization (RICH), by the University of Wien and part of the current input data stream of ERA5 reanalysis;
- HadAT2, Hadley Centre's radiosonde temperature product v2, by MetOffice.

Other existing datasets may be added. Given that this effort was not planned in the SC1, the Lead Contractor fixed the final delivery date for these additional datasets by end of 2018.

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Service year IV (01/2020-12/2020)

Access to GNSS data from international networks and harmonization of integrated water vapour time series

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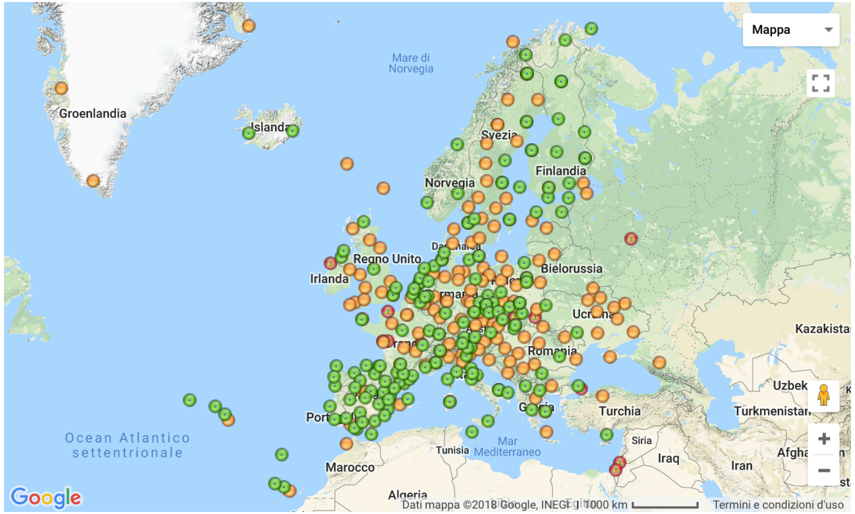
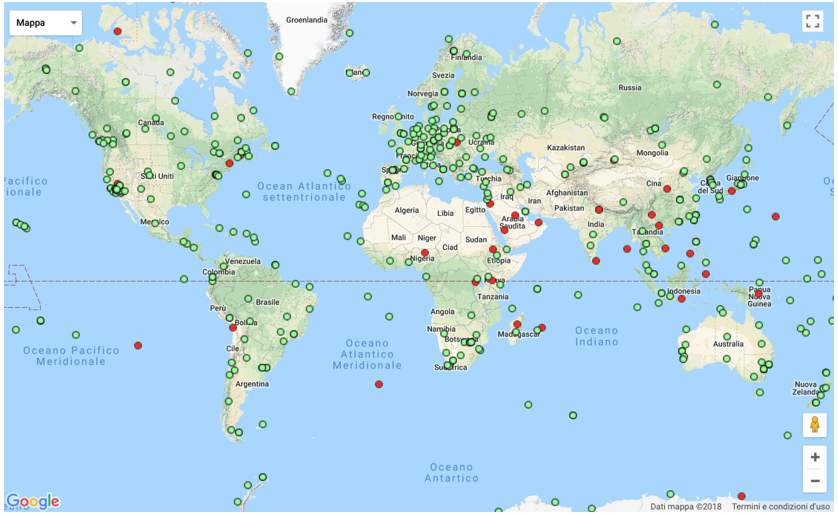
EUREF AND IGS

Facilitate access to the data from international GNSS networks and harmonize IPW retrieval with estimation of uncertainties.



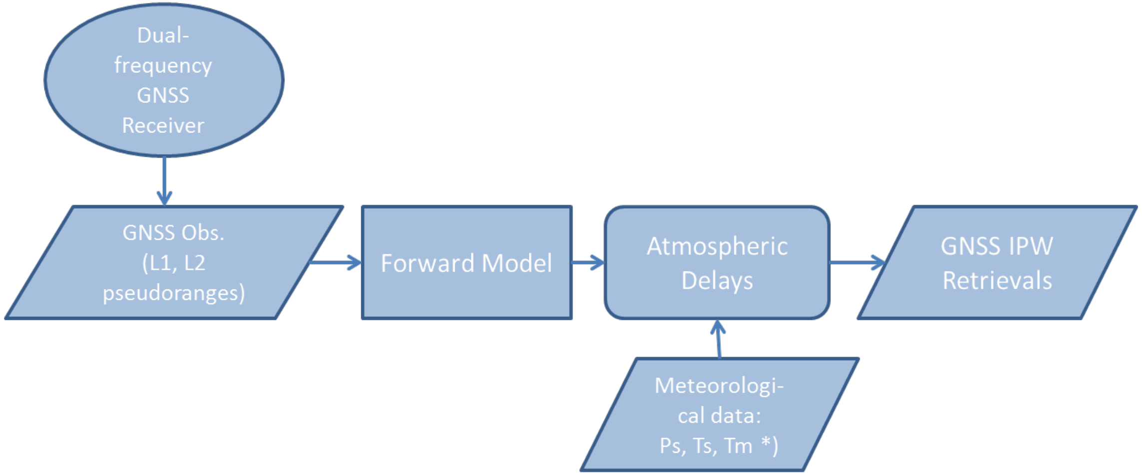
EUREF GNSS Permanent Network



International GNSS Initiative

GNSS IPW TRACEABILITY DIAGRAM

GNSS IPW Measurement: Main Chain



Ps – surface pressure
Ts – surface temperature
Tm – mid-temperature of the atmosphere

«Forward model» ≡ standard GNSS data processing software (Bernese, ...)

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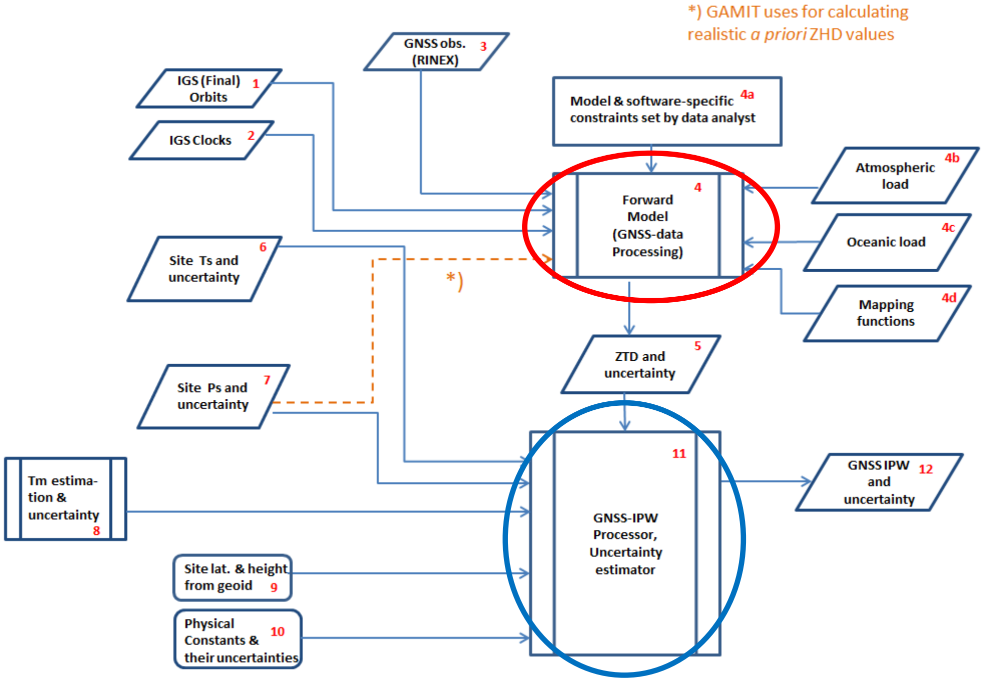
GNSS IPW TRACEABILITY DIAGRAM



Product traceability chain for GNSS-IPW technique with standard GNSS data processing software and dedicated software package for IPW derivation and uncertainty estimation

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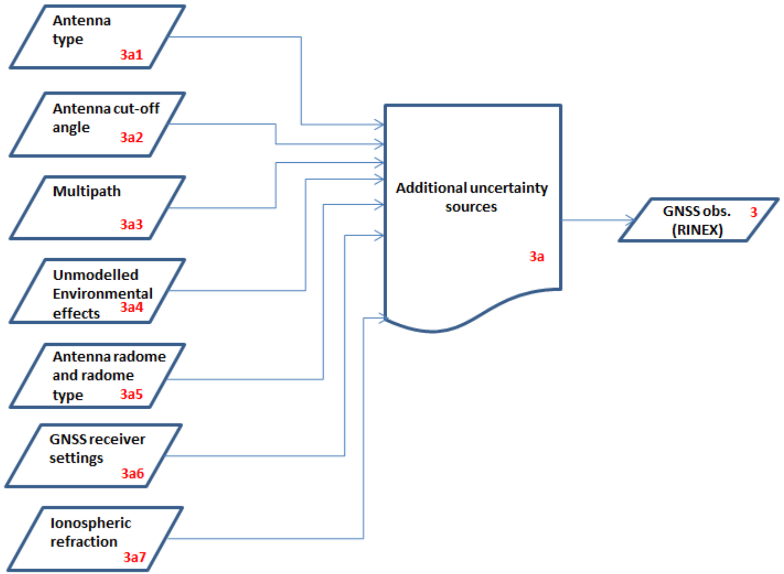
GNSS IPW TRACEABILITY DIAGRAM



Additional details on the GNSS observations' term in the product traceability chain

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GNSS IPW RETRIEVAL

- GNSS IPW process is the same for any data analysis centre: «standard GNSS data processing software»
- Some big data analysis centres may use also their own in-house developed software (for example, GFZ uses their own EPOS8 for both IGS and GRUAN data processing).
- «The GNSS-IPW and uncertainty estimator» - this additional software package is usually developed by the data analysis centre (or by data analyst) according to the local needs and motivation. Nothing standard or commercial is available.
- Details in the processing can be different (i.e., how to get the meteorological data, how to get the mean temperature of the atmosphere, how to interpret formal errors, etc.).
- The main issue is the transparency of the full processing chain – including the GNSS data processing itself – for getting Zenith Total Delays and their uncertainties (formal errors).

GRUAN-GNSS vs GNSS data processing

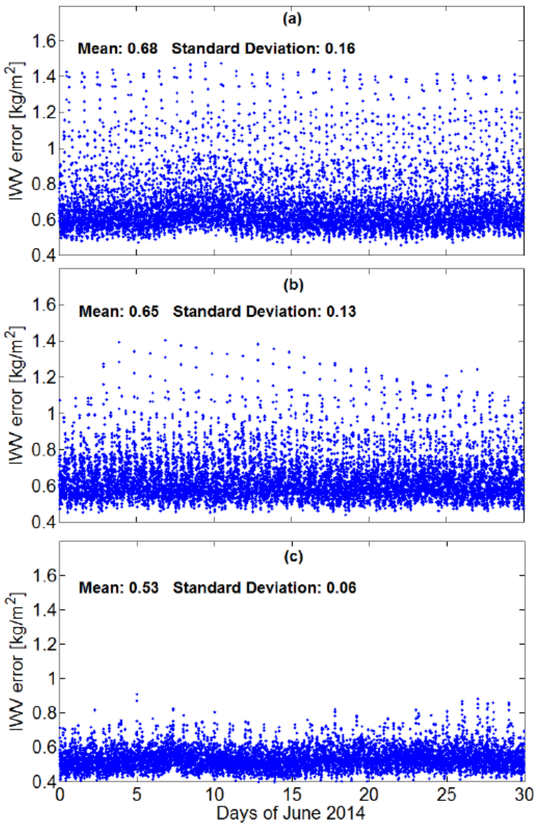
- GRUAN GNSS data processing (GFZ) should be currently the only exception, following not only the best practices, but also performing full analysis for GNSS-IPW uncertainty estimation (published by T. Ning, et al., 2016).

So, what is the difference, GRUAN-GNSS data processing ←→ «conventional» GNSS data processing?

Both relying on the same principles ...

- The first thing that is not implemented anywhere (except GFZ) is the calculation of additional orbital errors contributing to the ZTD uncertainty (theoretical analysis given by J.Dousha 2010).
- Complete analysis of total uncertainty of the GNSS-IPW (i.e., including all known components contributing to the final uncertainty. If using ZTD uncertainties just obtained from the GNSS data processing software, these are usually underestimated by a factor of 2...3.
- The key issue is, that ZTD uncertainty contributes around 75% to the total IPW uncertainty. Using downscaled (=unrealistic) ZTD uncertainties leads to remarkable underestimation of IPW uncertainties.

EXAMPLE OF GRUAN IPW WITH UNCERTAINTY



The estimated total IWV uncertainty for the month of June 2014 and for three GRUAN sites: (a) LDB0, (b) LDRZ, and (c) NYA2 (Ning et al., 2016).

Formula to retrieve uncertainty:

$$\sigma_V = \sqrt{\left(\frac{\sigma_{ZTD}}{Q}\right)^2 + \left(\frac{2.2767\sigma_{P_0}}{f(\lambda, H)Q}\right)^2 + \left(\frac{P_0\sigma_c}{f(\lambda, H)Q}\right)^2 + \left(V\frac{\sigma_Q}{Q}\right)^2}$$

More details in Ning et al., 2016 AMT

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GNSS RETRIEVAL FOR C3S

The goal for C3S (BARON) regarding GNSS IPW: using non-GRUAN GNSS-data (from national and International geodetic and meteorological networks) – implementing GRUAN-like processing. While possibly not implementing additional orbital errors modeling, then at least with following full data processing transparency and IPW uncertainty budget according to T. Ning etal.

Giving access to the data:

- From GRUAN (shared by GRUAN LC) – GNSS IPW time series + complete uncertainty analysis? This is re-routing th euser to GRUAN share point.
- Access to reanalysis data (EUREF, ...)? EGVAP and different COST actions, different research institutions – needs negotiation for getting access etc.

If BARON calculates IPW from data based on IGS/EUREF tropospheric product, it may again need some negotiation to enable the «GRUAN-like processing» with known exceptions.

The key issue is – how to get information about the initial data (the GNSS tropospheric product) – how the data was processed (outliers' screening, software constraints, etc.) in common practice not shared. The same with meteorological data (surface presure and temperature at the site).

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S U M M A R Y

- C3S 311a Lot3 contract is going to provide access to original and harmonized time series of radiosoundings temperature and humidity profile from Reference and Baseline networks.
- C3S 311a Lot3 will provide the C3S users with the best ensemble of the available harmonization datasets of radiosounding temperature and humidity profiles from a few different harmonization approaches.
- In the harmonization the goal is to show also the importance of “Reference datasets” from GRUAN and WMO-CIMO radiosonde intercomparisons
- In 2020, C3S 311a Lot3 will work to facilitate the access to GNSS data from international networks (IGS, EUREF, ..) and to harmonize the retrieval of integrated water vapour using the GRUAN GNSS data processing.

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QUESTIONS?