GRUAN activities at CIAO observatory

Marco Rosoldi, Fabrizio Marra, Ilaria Gandolfi, Gessica Cosimato, Canio Colangelo, Aldo Giunta, Simone Gagliardi and Fabio Madonna

Routine Activities

CIAO Observatory

The CNR-IMAA Atmospheric Observatory (CIAO) is a long-standing, comprehensive facility equipped with several types of advanced sensors for atmospheric observation, including ground based remote sensing for profiling of aerosols, clouds, meteorological variables and trace gases (lidar, radar, microwave radiometer, FTIR), in-situ laboratory for near surface measurements of aerosols and greenhouse gases and radiosounding systems for profiling meteorological variables through the troposphere and stratosphere. The main scientific goals of CIAO are improving the knowledge of atmospheric processes and their role in meteorology and climate, as well as providing quality assured measurements for satellite calibration/validation and model evaluation. CIAO is part of European research infrastructures ACTRIS and ICOS and of the global networks GALION and GRUAN.

Manual Launches

Upper-air sounding activities at CIAO

Balloon-borne measurements of atmospheric temperature, pressure, humidity, and wind (speed and direction) throughout the troposphere and stratosphere are routinely carried out at CIAO using two **VAISALA MW41 radiosounding systems,** one **manual** and the second equipped with an **automatic launcher (VAISALA AS15)**. CIAO is also equipped with a mobile VAISALA MW41 system for measurement campaigns and three **Standard Humidity Chambers** (**SHCs**) to carry out manufacturer-independent pre-launch ground checks, following the GRUAN operating procedures

The autosonde system enables fully automated, remotely supervised operations, allowing for up to **24 consecutive launches** without human intervention. It can also be programmed to perform **backup soundings** in case of launch anomalies or technical faults, ensuring data continuity.

VAISALA AS15 automatic launcher

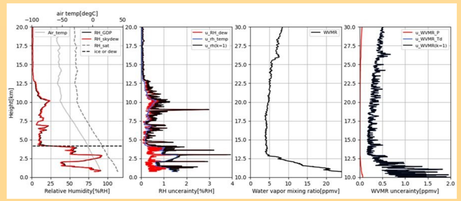
Since 2015, CIAO is an officially certified site of the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN; www.gruan.org). As part of this global reference network, the observatory contributes to the GRUAN data archive providing data from up to 3 weekly radiosoundings. Whenever possible, radiosondes are launched within ±3 hours of the GNSS-RO or LEO satellite relevant overpasses provided by the GRUAN Lead Center. Occasionally, additional launches are performed targeted to the calibration and validation of ground-based and satellite remote sensing observations.

Research Activities

Chilled mirror hygrometers

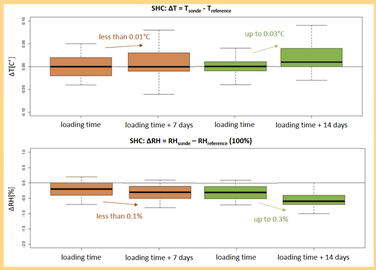
Meisei Skydew chilled mirror hygrometers, connected to Vaisala RS41, are currently launched at CIAO for accurate stratospheric water vapor measurements.

In the Skydew, a mirror is electronically cooled using a **two-stage Peltier device** to saturate the adjacent air with water vapor and maintain equilibrium between water vapor and the condensate (liquid water or ice) formed on the mirror surface. The mirror temperature, measured by **Pt100 sensor** located between the mirror and the cold side of the Peltier, corresponds to the air dew or frost point temperature. From this, water vapor concentration can be derived using the **Clausius-Clapeyron equation**. Light from an IR LED is transmitted to the mirror via an optical fiber, and the intensity of the backscattered light is monitored to detect condensate formation. The system regulates the amount of condensate to maintain equilibrium with water vapor by adjusting the cooling current through the Peltier device.



GRUAN water vapor profiles with related uncertainties (Sugidachi et al., AMT, 2025) for the nighttime launch of 06/05/2025 at 19:25 UTC.

SHC GC Experiment in autolauncher



Statistical analysis (box and whisker plots) of SHC GCs results for the automatic launcher at CIAO.

Laboratory tests at CIAO, in collaboration with other GRUAN stations equipped with autolauncher, aim to develop procedures and recommendations for routinely performing the SHC GCs in automatic launchers within GRUAN, improving traceability and calibration uncertainty quantification of their measurements.

Assuming SHC GCs are performed before loading radiosondes into autolauncher, the stability of the checks with respect to the sondes' storage time in launchers is evaluated, i.e., whether and to what extent the checks results remain valid at launch time after storage, typically less than 2 weeks.

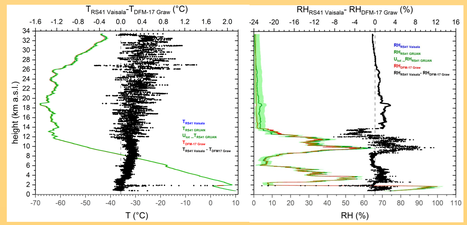
At each site involved in the experiment, SHC GCs performed twice on a sample of 60 radiosondes:

- 30 radiosondes: SHC GCs at loading time and after 7 days;
- 30 radiosondes: SHC GCs at loading time and after 14 days.

The radiosondes were kept in the launcher between the 1° and 2° SHC check, simulating routine automatic launches between loading and launch.

RS41 and DFM-17 dual launches

New GRUAN data products (GDPs) are currently under development for the GRAW DFM-17 radiosonde model. At CIAO, systematic RS41-DFM-17 dual launches (both daytime and nighttime) are performed for contributing to characterize the differences between RS41 and DFM-17, considering both manufacturers' data products (MDPs) and GDPs. This characterization is essential for validating and intercomparing GDPs from the two radiosonde models and for homogenizing their respective measurements. The latter is relevant within GRUAN for using DFM-17 radiosondes as an alternative or replacement for RS41, and outside GRUAN for any climatological study or dataset based on measurements from these different radiosonde models.



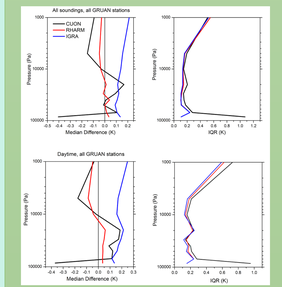
Profiles of temperature (left) and relative humidity (right) and related MDPs differences for a daytime dual launch performed at CIAO on 19/12/2024 at noon.

Projects

Copernicus Climate Change Service (C3S) contracts

The site team is involved in a new **Copernicus C3S contract** to deliver an updated version of the harmonized GRUAN dataset, which will include processing of Vaisala RS41 radiosondes. Currently, the C3S Climate Data Store provides access to GDP version 2, covering Vaisala RS92 and Meisei RS-11G radiosonde data from 17 stations for the period 2006-2020.

Moreover, the version 2 of RHARM (Radiosonde HARMonization) dataset, based on a novel algorithm designed and implemented by the site team using GRUAN GPDs and the related algorithms, was released in September 2025.



Median difference (left plots) and the related interquartile ranges (right plots) of the CUON, RHARM and IGRA dataset to GRUAN. Top panels are referred to all the GRUAN measurements available from all the active stations providing the RS92 GDP product. Bottom plots are referred to the daytime measurements only.

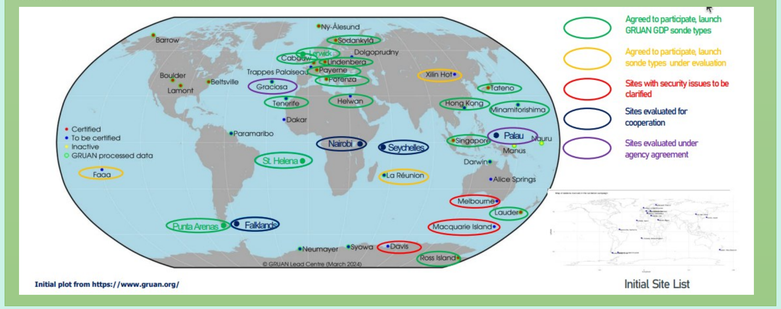
The comparison shows the capability of RHARM to adjust most of the difference between the IGRA and GRUAN profiles, with a residual difference smaller than -0.05 K on average at pressures lower than 200 hPa, and near-zero above the same pressure. During daytime, a residual bias smaller than 0.05 K is found at pressure higher than 200 hPa, while the bias is negative and smaller than -0.08 K at lower pressures. For CUON, differences are generally up to 0.19 K at pressure higher 200 hPa and up to -0.17 K elsewhere.

EUMETSAT Radiosondes Validation Support for Earth-Observing Satellites (EUMETRAVES)

Since 15th October 2025, the site team is leading the EUMETSAT scientific contract **EUMETRAVES** aimed at setting up a globally coordinated service for providing radiosondes reference measurements (GDPs) targeted to support **EUMETSAT Polar System – Second Generation (EPS-SG)** calibration/validation (Cal/Val) and monitoring activities.

To this end, EUMETRAVES will coordinate dedicated **radiosounding campaigns** providing **fiducial reference measurements** based on GRUAN procedures and processing algorithms, forming the scientific backbone of this effort and providing uncertainty-characterized upper-air data for satellite Cal/Val. Within the project, the site team will act as the operational lead, managing communication with GRUAN and non-GRUAN stations involved in the service and coordinating targeted launches during satellite overpasses, in close collaboration with EUMETSAT.

Initiated in 2022 within the GRUAN Working Group and Task Team Satellites, EUMETRAVES also extends support to other EPS-SG and MTG missions and aligns with Satellite Application Facility for Numerical Weather Prediction (NWP-SAF) recommendations to strengthen sustained in-situ reference networks.



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