GuMNet: A high-altitude monitoring network in The Guadarrama mountain range (Spain)

GuMNet Team *

http://www.ucm.es/gumnet/

1. Infrastructure:

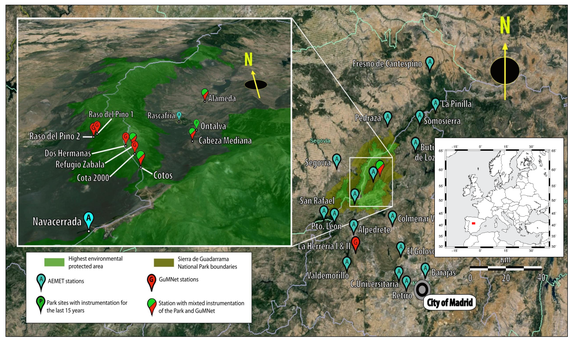


Fig. 1. Spatial distribution of GuMNet automatic weather stations across The Guadarrama mountain range and other meteorological stations in the area.

GuMNet (**Guadarrama Monitoring Network**) is a joint initiative to build up an **observational meteorological and sub-surface infrastructure** in The Guadarrama mountain range, central Spain. The resulting network consists of the following instrumentation:

- **10 complete WMO standard meteorological stations**.
- **15 experimental boreholes** for monitoring the **subsurface temperature evolution**, distributed over the 8 WMO-type sites & **8 trenches** for direct monitoring of **temperature and humidity of the soil**, at each station.
- **2 anemometric stations** including an WMO standard setup, as well as **CO_2 and H_2O vapor flux** trace analyzers and **eddy covariance measurements** .

These high-altitude locations are within the **National Park Sierra de Guadarrama** (PNSG), an environmentally protected area (Figure 1). The GuMNet initiative will be complemented with locations endorsed by the **Spanish National Meteorological Agency** (AEMET, see blue icons). GuMNet builds upon a network of 5 sites (green icons) including meteorological instrumentation within the PNSG that have been operational over 10 to 15 years. 4 of these sites have been updated and extended with new meteorological instrumentation and also incorporated soil and subsurface monitoring infrastructure (green/red icons). This region is characterized by a complex topography and heterogeneous vegetation cover offering a variety of different microclimate setups, e.g. pine forest, scrub, pastures, or bare soil/rock areas. The GuMNet initiative is supported by research groups and funded by the **Moncloa Campus of Excellence** with additional infrastructure and collaboration support by the PNSG and AEMET (see *GuMNet team). The goal of GuMNet is to create a meeting point to develop educational and research synergies between diverse institutions and research groups of wide range of disciplines.

2. Surface & subsurface observations

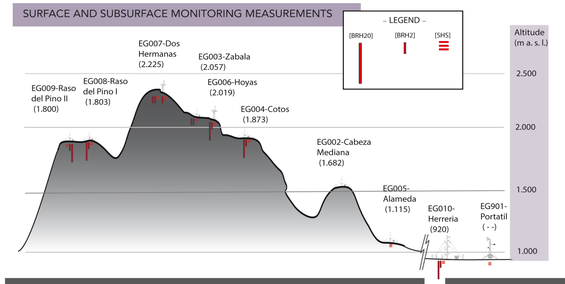


Fig. 2. Altitude distribution of GuMNet automatic weather stations including the surface and subsurface infrastructure over the Peñalara orography. Note the coverage on North and South sides above 1.500 m a.s.l. GuMNet also provides two valley sites and a portable station.

MONITORING BOREHOLES: Temperature [BRH20, BRH2]

The majority of GuMNet sites include subsurface-temperature monitoring infrastructure. Boreholes are drilled and shaped casings installed to easily place and replace temperature sensors at **14 different depths** at each station. This is done at two monitored **experimental boreholes of 2-m (BRH2) and 20-m depth (BRH20).**

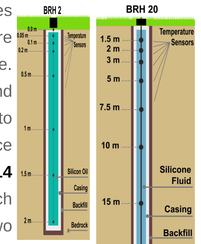


*Fig. 3.Scheme of the 20 m **(BRH20)** and 2 m **(BRH2)** borehole showing the casing of PVC and silicone oil filling where 8 temperature sensors (pt1000) are immersed at different depths in each. Note that the density of measurement points is higher close to the surface to improve the resolution of the subsurface temperature evolution.*

Fig. 4. The Core Rock extracted during borehole drilling.

TRENCHES: Temperature and humidity [SHS]

Trenches (SHS) are dug in the first layers (1-2 m) of sediment to introduce **temperature and humidity sensors**. This allows to determine and document the soil horizons at each site.

Fig. 5. Once the spectroscopy analysis is done, a set of samples are taken in order to make subsequent analysis in the laboratory.

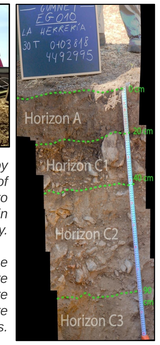


Fig. 6. Before covering the trench, soil horizons are determined and temperature and humidity sensors are placed at different depths.

3. Eddy covariance CO_2 fluxes

EG010-La Herreria is a fixed anemometric tower with wind-speed (VV) and air-temperature (TA) sensors at three different heights. This configuration is complemented with an in-situ **open-path mid-infrared absorption gas analyzer** integrated with a three dimensional **sonic anemometer** (CO_2+AS3). Likewise, the station includes the standard WMO meteorological sensors, the two experimental boreholes (BRH20, BRH2) and a trench (SHS).

A complementary **twin portable station, EG901-Portátil** is also operational for comparison purposes at this site or for use in intensive measurement campaigns elsewhere. It includes subsurface sensors: temperature (TS), humidity (SHS) and heat-flux (FCS) measurements for soil monitoring.

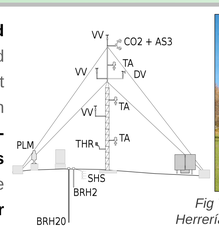
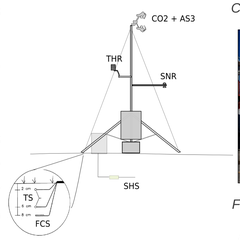


Fig 7. (left scheme, right picture) EG010- La Herrería automatic weather station is located in the municipality of El Escorial at 920 m a.s.l. Atmospheric instrumentation has been installed in order to study the boundary-layer evolution and CO_2, H_2O and other turbulent fluxes .



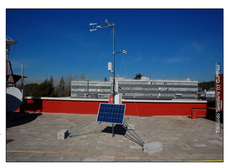


Fig 8. (left scheme, right picture) The EG901- Portátil is a portable automatic weather station design to monitor CO_2, H_2O and other turbulent fluxes as well.

4. Atmosphere observations.

The standard WMO GuMNet station includes also: an **alpine-wind monitor** (DVV), an **air temperature and humidity** sensor (THR), **ultrasonic snow-height** sensor (SAN), a **4 component net radiation** sensor (SNR) and **a rain gauge** (PLM) specially designed for snow measurements. A GPRS connection is established between all the remote stations and a central server. This configuration allows to download the recorded data once a day and to verify the health status of the instrumentation, hence **minimizing the loss of data,** e.g. after a snowstorm (Fig 9).

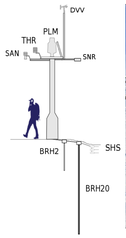


Fig 10. EG006-Hoyas automatic weather station is located in the cirque valley of Peñalara at 2.019 m a.s.l. Abounding in tall grass and wetlands the design of the station aims to minimalize the impact on the environment without the perimeter security fence. A single mast houses all atmospheric instrumentation. Since it is located in an area of high snow accumulation during the winter season, the mast is configured to be over the snow cover and highly visible for ski activities.

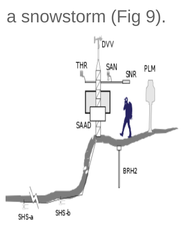
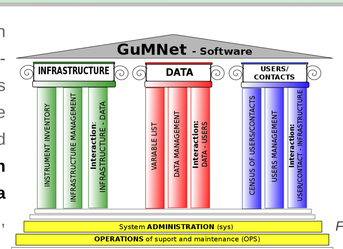


Fig 9. EG007-Dos Hermanas automatic weather station after a snowstorm. The station is anchored in the wall of the glacier cirque of Peñalara at 2.225 m a.s.l. It has standard atmospheric instrumentation. The subsurface instrumentation consists of three temperature-monitoring boreholes, one of them designed for skin-temperature measurements. Besides, two trenches measure temperature and humidity near the station, and another one is located 30 m downslope, below an area where snow tends to accumulate until the summer.

5. Software management system

The different parts of the GuMNet infrastructure and the communication system are wrapped up under a **software-management tool**. The GuMNet-Software will help to track and maintain instrumentation, as well as **managing data observations and data-users** in order to register all the interactions that may be **relevant to facilitate data interpretation** and management of the system. The aim of GuMNet is to **serve as a high mountain laboratory by providing the users of the Guadarrama mountains with high quality data and derived products** for research, teaching and leisure of the Guadarrama mountains.



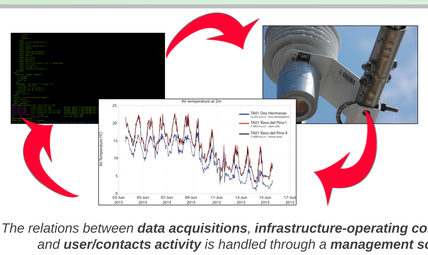


*Fig 11. The relations between **data acquisitions**, **infrastructure-operating conditions** and **user/contacts activity** is handled through a **management software** .*

* 6. GuMNet team (institutions and research groups)

- **PalMA** (UCM), *Paleoclimate Modeling and Analysis*
- **MicroVAR** (UCM), *Micrometeorology and climate Variability*
- **GFAM** (UCM), *Geografía Física de Alta Montaña*
- **CEI** (UCM, UPM), *Campus de Excelencia Internacional*
- **PDC** (UCM), Plataforma de Divulgación Científica
- **CPD** (UCM), *Centro de Procesamiento de Datos*
- **CEIGRAM** (UPM), *Centro de Estudios e Investigación para la Gestion de Riesgos Agrarios y Medioambientales*
- *Departamento* ***Energías Renovables*** (CIEMAT)
- *Departamento* ***Medio Ambiente*** (CIEMAT)
- **IGEO** (UCM-CSIC), *Instituto de Geociencias*
- **AEMET,** *Agencia Estatal de Meteorología*

PNSG, *Parque Nacional Sierra de Guadarrama*
PN, *Patrimonio Nacional*
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