GuMNet: Guadarrama Monitoring Network initiative (Madrid, Spain)

18/10/2018

GuMNet Team *

1. The Infrastructure

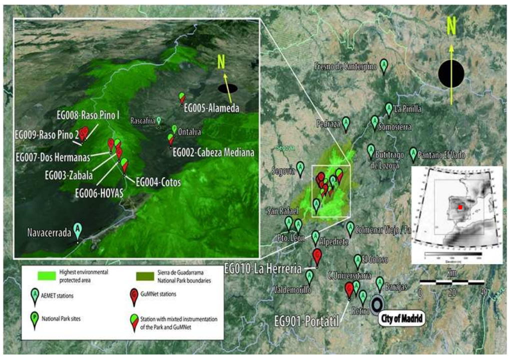


Figure 1. *Spatial distribution of the GuMNet automatic meteorological and subsurface stations across the Sierra de Guadarrama and other meteorological stations in the area. The red-shaded G symbols show the GuMNet stations. The light green-shaded P symbols show earlier Sierra de Guadarrama National Park (SGNP) stations. The light blue-shaded A symbols are referred to the Spanish National Meteorological Agency (AEMet) stations.*

GuMNet (**Guadarrama Monitoring Network**) is a joint initiative to build up a **high mountain meteorological and sub-surface observational infrastructure** in the Sierra de Guadarrama in Madrid, central Spain. The resulting network consists of the following instrumentation: **10 complete WMO standard meteorological stations**, **12 boreholes** for monitoring the **subsurface temperature evolution** (distributed over 6 of the WMO type sites) and **8 trenches** for direct monitoring of **temperature and humidity of the soil** (distributed over 7 stations). Moreover, 2 of the stations include **anemometric instrumentation**, as well as **CO_2 and H_2O vapor flux** trace analyzers and **eddy covariance measurements**. These high altitude locations are within the **Sierra de Guadarrama National Park** (SGNP), an environmentally protected area (Figure 1). The region where the SGNP is settled is characterized by a complex topography and a heterogeneous vegetation cover, offering a variety of different micro-climate setups, such us pine forest, scrub, pastures or bare soil/rock areas.

The GuMNet initiative, funded by the **Moncloa Campus of Excellence**, is supported by research groups with additional infrastructure and the cooperation from the SGNP and the Spanish National meteorological Agency (AEMet) [see *GuMNet Team]. GuMNet is also part of several networks whose efforts are devoted to the investigation and research in high mountain environments, such as the **Mountain Research Initiative (MRI)**, the **Iberian Mountain Research Network (RIIM)** or the **Network for European Mountain Research (NEMOR)**.

All the information about the GuMNet initiative, the facility, the participating institutions, the international partnership with other networks, theses related to the network and requests of available observational data can be found on the initiative website, which can be accessed from the attached QR code or the following link: http://www.ucm.es/gumnet/

2. Observational Data Examples

Thanks to the altitudinal distribution of stations (spanning from 920 to 2.225 m a. s. l.), meteorological and subsurface variables are measured on sites located at different heights so that the high mountain environment of the Sierra de Guadarrama can be monitored (Figures 2, 3, 8 and 9). The recorded data can help observe, amongst other things, the evolution of some phenomena in the lower atmosphere, such as thermal inversions (Figure 4).

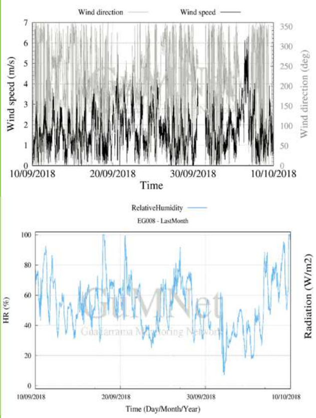


Figure 2. *On the top, wind direction (grey line) and wind speed (black line) at the EG002 - Cabeza Mediana site (1682 m) during September 2018. At the bottom, air humidity at 2 m at the EG008 – Raso del Pino I site (1873 m) during the same period.*

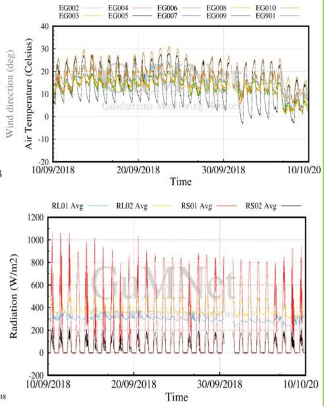
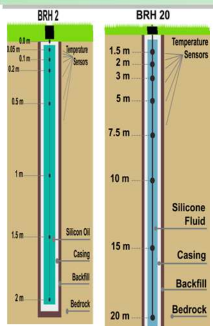


Figure 3. *On the top, air temperature at 2 m on some sites during September 2018. Note the thermal inversion on cloudless days. At the bottom, the 4-component radiation measured al EG006 – Hoyas (2019 m) during September 2018. Note the short wave radiation peak that produces the thermal inversion.*

3. Subsurface Observations



Most of the GuMNet sites include subsurface temperature monitoring instrumentation. Boreholes are drilled and cylinder-shaped casings installed to easily place and replace temperature sensors at **16 different depths** at each station, distributed in two monitored **boreholes of 2 (BRH2) and 20 meters depth (BRH20)**, respectively (Figure 6).

Figure 6. *Scheme of the 20 m **(BRH20)** and 2 m **(BRH2)** boreholes showing the casing of PVC and silicone oil filling where 8 temperature sensors (pt1000) are immersed at different depths in each borehole. The density of measurement points is higher close to the surface to improve the resolution of the subsurface temperature.*

Figure 7. ***Soil horizons*** *in one of the trenches located at EG010-La Herrería station.*

Trenches (SHS) are dug in the first layers (1 – 2 m) of sediment to introduce temperature, humidity and electrical conductivity sensors. This allows to establish and document the soil horizons at each site (Figure 7).

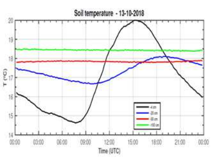


Figure 8. *Time series of temperatures in the trenches located at the EG010-Herrería site on October 13, 2018.*

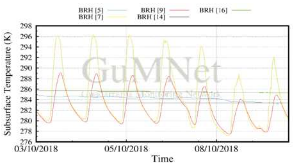


Figure 9. *Time series of temperatures in thee boreholes located at the EG008-Raso del Pino I site for the period October 03-10, 2018.*

4. Atmosphere Observations

The standard WMO GuMNet station includes: 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) especially designed for snow measurements. A GPRS connection is established between all the remote stations and a central server. This configuration allows the download of the recorded data once a day and to verify the health status of the instrumentation, hence **minimizing the loss of data,** like after a snowstorm (Figure 10).

Figure 11. *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 minimal impact without perimeter security fence. A single mast houses all the atmospheric instrumentation. Since it is located in an area of high accumulation of snow during the winter season, the mast is configured to be over the snow cover and high visible to avoid ski activities.*

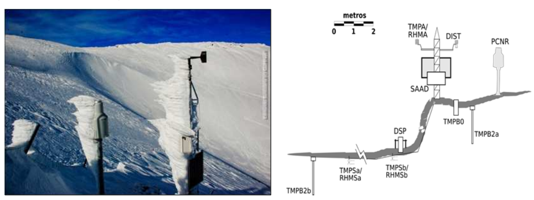


Figure 10. *EG007-Dos Hermanas automatic weather station after a snowstorm. The stations is anchored in the wall of the glacier circus of Peñalara at 2.225 m.a.s.l. It has standard atmospheric instrumentation. The subsurface instrumentation consists of three temperature monitoring boreholes, one of them 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. Eddy Covariance CO_2 Flux

EG010-La Herrería (Figure 12) **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** (CO2+AS3). Likewise, the station includes the standard WMO meteorological sensors, two boreholes (BRH20, BRH2) and two trenches (SHS).

A complementary **twin portable station, EG901-La Herrería/Portátil** (Figure 13) 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.

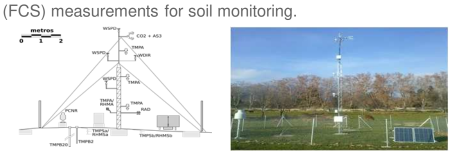


Figure 12. *Station scheme on the left, a picture on the right. EG010- La Herrería automatic weather station is located in the municipality of El Escorial at 920 m.a.s.l. Atmospheric instrumentation have been design to study boundary layer evolution and CO2 fluxes.*

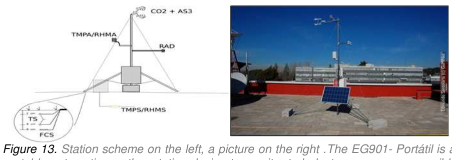


Figure 13. *Station scheme on the left, a picture on the right .The EG901- Portátil is a portable automatic weather station design to monitor turbulent processes responsible for soil respiration and gas exchange, such as turbulence CO2 and H2O vapor fluxes, take place in this range.*

6. Modeling at the Sierra de Guadarrama

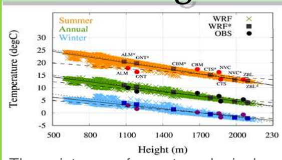


Figure 14. *Distribution of the vertical temperature gradients for the observations (squares), WRF (crosses) and WRF* (circles). Annual temperatures are shown in grey for the observations, dark-green for WRF and light-green for WRF*. Winter temperatures are in light-blue for the observations, dark-blue for WRF and purple for WRF*. Summer temperatures are shown in dark-red for the observations, red for WRF and brown for WRF*. Linear fit for every dataset is shown in matching colors.*

The existence of a meteorological and subsurface/soil database like GuMNet in the Sierra de Guadarrama has permitted the comparison between observational data and simulated data in order to evaluate the capability of a **high resolution (1 Km) WRF model simulation** during the period 2000 - 2015 (Figures 14, 15 and 16). As far as air temperature is concerned, this comparison proved the WRF model to be an improvement over ERA Interim and representative of the observations, which led to a first analysis of **temperature variability** in this region (Figure 17).

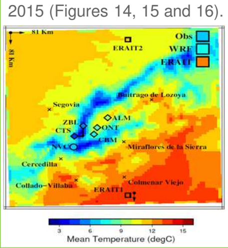


Figure 15. *Mean temperature in the Sierra de Guadarrama for the period 2000 to 2014. The coloured field represents the WRF simulated data, the diamonds and circle are the SGNP stations, the little squares are the ERA Interim co-located grid points and the cross symbols are reference locations. The map shows a very dominant orography and a high consistency between the simulations and the observations. The regional averages (squares at the right top corner) show the same consistency between every datasets.*

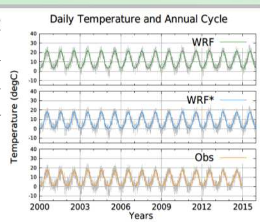


Figure 16. *Time series of the regional average of the daily temperatures (grey) and the annual cycle of the entire WRF simulation (green), the simulated data at the stations sites (blue) and the observational data (orange) for the period 2000 – 2015. As observed, the simulated data have the same behaviour as the observational data.*

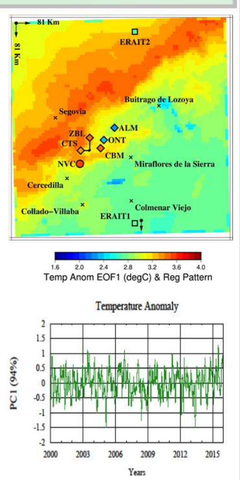


Figure 17. *On the top, temporal evolution of the first Principal Component (PC1) for the annual daily temperature anomaly of the WF simulated data. At the bottom, map of the first empirical orthogonal function (EOF1) for the annual daily temperature of the WRF simulated data.*

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