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Laboratory of Atmospheric Microphysics and Radiation (LAMAR): a set of sensors for the study of extreme meteorological events in the Central Andes of Peru.

Daniel Martinez-Castro, Yamina Silva, Rene Estevan, Jose Luis Flores, Luis Suarez, Aldo Moya, Jairo Valdivia, and Miguel Saavedra

El Perú Primero

Trabajando por un PERÚ LIMPIO, PERÚ NATURAL y PERÚ INCLUSIVO

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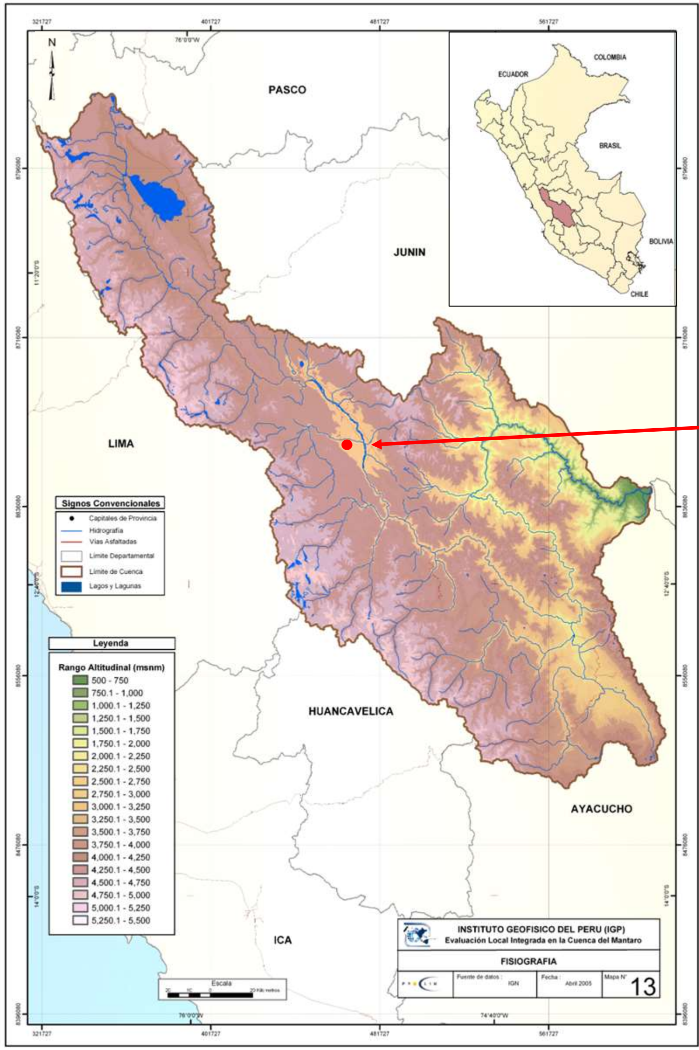
Mantaro Basin



Huancayo Observatory (Founded in 1922)

EL PERÚ PRIMERO

Trabajando por un PERÚ LIMPIO, PERÚ NATURAL y PERÚ INCLUSIVO

IGP, HYO, Huayao Meteo Station and LAMAR

- The Huancayo Observatory (HYO) (12 ° 02'18``, 75 ° 19'22''W, 3350 masl), a few kilometers from the town of Huayao, and not ar from Huancayo City, is the birthplace of the Geophysical Institute of Peru (IGP). It was founded as "Huancayo Magnetic Observatory" in 1922, by the Carnegie Foundation in that place, because of its proximity to the magnetic equator. In 1947, with greater capacity and functions, it became the "Huancayo Geophysical Observatory" and, fifteen years later, together with other scientific institutions, constituted the Geophysical Institute of Peru.

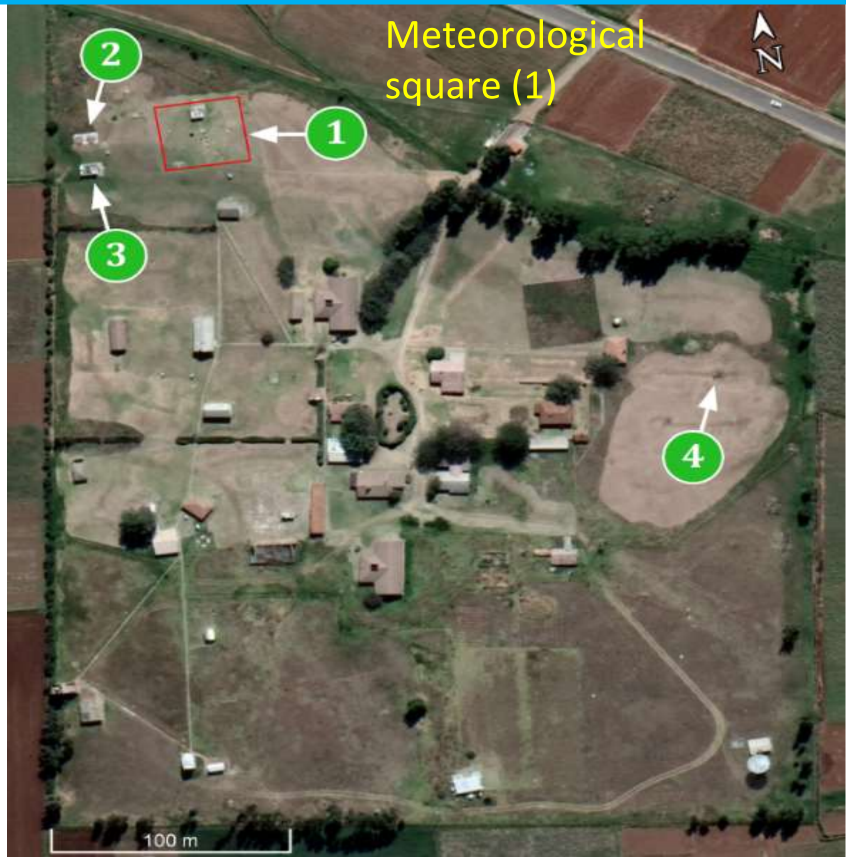
- Since its inception in 1922, this observatory has hosted important geophysical measurements and investigations, among which is the longest series of climatic measurements in the country. This long history makes this information crucial for the study of climate change in Peru, while its quality and diversity in terms of instruments make it useful for a wide variety of studies related to climate.

- The IGP Laboratory of Atmospheric Microphysics and Radiation (LAMAR) is located inside HYO and was conceived in 2015 to improve the understanding of the physical influencing the climate of the Andes, to improve the modeling capacity necessary for developing efficient weather forecasting methods and for the evaluation of the future impacts of climate change, as well as support in the validation of remote sensing techniques. It is based on the long climatic series (1921-present) of the SENAMHI Huayao meteorological station, as well as on sophisticated specialized instruments, such as wind profiler and cloud profiler radars, short and long wave radiometers, a sonic anemometer, disdrometers and different types of raingauges..

Huancayo Observatory (HYO) [12º20´18” S (12.04 S), 75º19´22” W (75.32 W), 3350 masl; UTC-5]

Wind profiler CLAIRE (2)

Radar and radiation sensors (3)



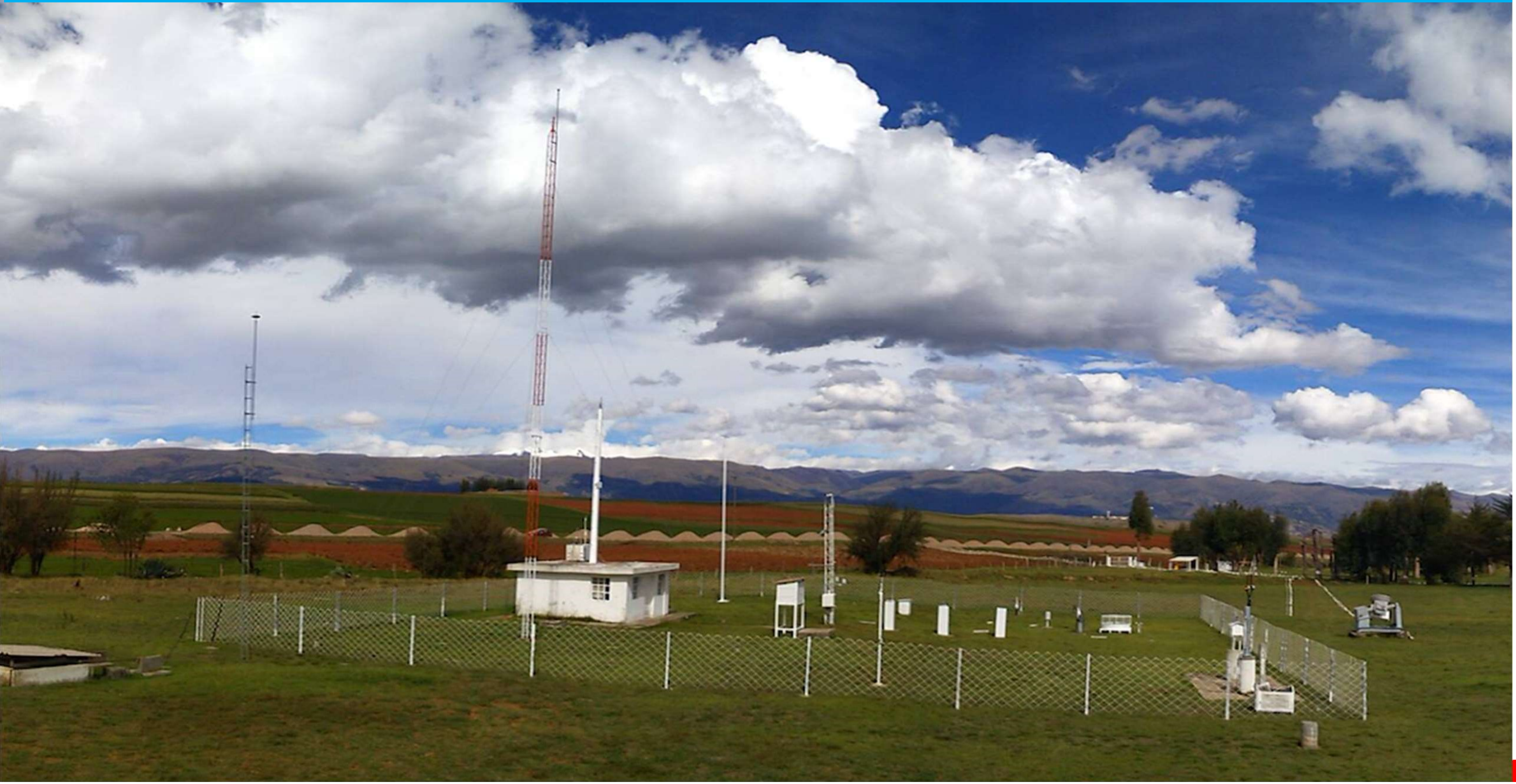
Surface flow complex (4)

Laboratory of Atmospheric Microphysics and Radiation LAMAR

Set of specialized sensors installed in HYO:

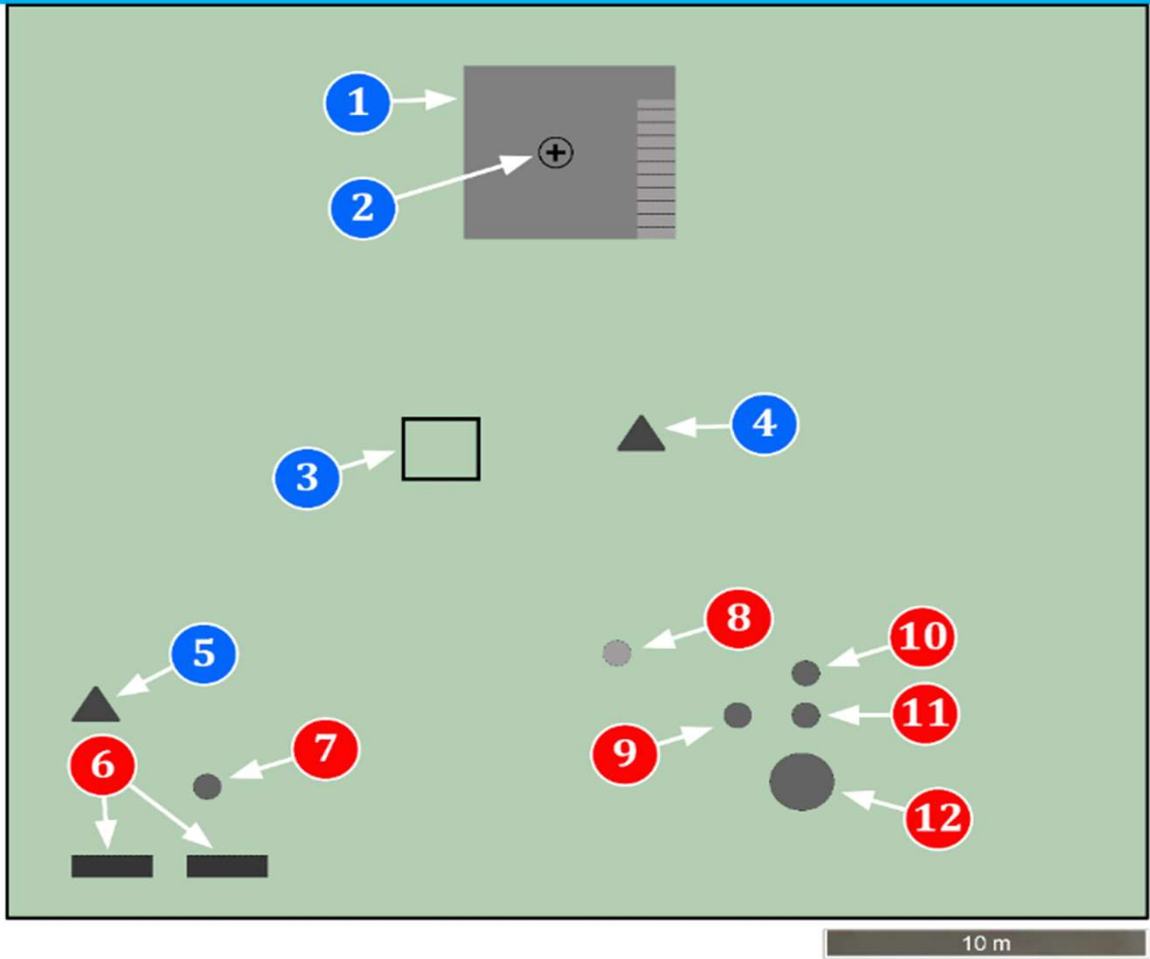
- Measurements of near-surface and low boundary layer turbulent flows (turbulence and gradients subset),
- Measurement of precipitation and its structure (precipitation subset)
- Measurement of aerosols and their interaction with radiation in the atmosphere (radiation subset).
- Upper air soundings

Meteorological square



Meteorological squre. Distribution of sensors

1.Office
2. Anemometer and wnd direction sensor
3. Manual Meteorological station
4,5.. Automátic meteorologiocal station



6. Parsive-2 disdrometers
7. Automatic weight raingauge
8. Rainfall collector for composition
9. Pluviograph
10. Automatic tipping bucket raingauge
11. Manual raingauge
12. Evaporimeter

Disdrometers, raingauge and automatic meteorological station

Technical characteristics. Disdrometer Parsivel^2 OTT

Optical sensor laser diode

Wavelength: 780 nm
Output power: 0.5 mW
Beam size: 180 x 30 mm
Measurement Surface: 54 cm^2
Recognition of Edge events
Measurement range:
Drops: 0.2-5 mm
Solid: 0.2- 25 mm
Particle speed: 0.2- 20 m/s
Visibility: 100- 5000 m
Rain rate: 0.001- 1200 mm/h
Accuracy: 5% (liquid): 20% (solid)

Parsivel^2 working principle

- The Parsivel^2 disdrometer is used to measure all types of precipitation, providing continuous and accurate information on the sizes and speeds of the precipitating particles. The technology used in these instruments allows classification into 32 different sizes, as well as their respective speeds. It measures liquid and solid particles, ranging from fine drizzle to heavy rain, snow and hail. From the original data it is possible to determine the type, amount, intensity and kinetic energy of the precipitation. As additional information, it calculatesintegral parameters od the particle spectra as visibility during precipitation and equivalent radar reflectivity.

- Its operating principle consists of a laser beam of constant power that goes from a transmitter to a receiver. The precipitation particles pass through the measurement volume of the beam, partially shielding it, so that when a particle passes, a decrease in the signal received by the receiver occurs, which magnitude is related with the particle size. Simultaneously, the time taken by the particle within the measurement volume is detected, estimating the fall rate.

Ka band Radar MIRA 35-C

Frecuency: 34.85GHz
Wavelenth: 8.6 mm
Space resolution: 30 m
Temporal resolution: 6s,
Beam width: 0.6º

MIRA- 35C RADAR WORKING PRINCIPLE

- MIRA-35c is a compact and low-energy-consuming magnetron-based pulsed Ka-Band Doppler radar with very high sensitivity. It is designed to detect atmospheric clouds and fog, transmitting a linear polarised signal while receiving co- and cross-polarised signals simultaneously to detect Doppler spectra of reflectivity and linear de-polarisation ratio (LDR).
- The reflectivity is used to determine the density of cloud constituents, and LDR helps to identify the target type. The radar components of the MIRA-35c are installed in a weatherproof outdoor enclosure with dimensions of 45cm/55cm/50cm. This enclosure hosts the transmitter, the receiver and the MicroBlaze-based signal processor board, and also supports the radar antenna.

Raingauges

Pluviograph

Weight raingauge

Tipping bucket

Manual

Evaporimeter

The Class A Tank Evaporimeter is used to measure effective evaporation, that is, the amount of water that a liquid mass loses in the open air through its surface due to evaporation, during a certain period of time . This tank has a diameter of 121 cm and a depth of 25.5 cm. It is placed on a wooden platform, 15 cm above ground. The water level in the tank is kept between 5 and 7.5 cm from the edge.

Precipitation measurements

Instrument	Measurement principle	Measured variable	Digital/Manual
Parsivel Disdrometer	Optical Laser scattering	Size and fall speed of precipitation particles	Digital
OTT Pluvio^2 S Raingauge	Weight cell	Precipitation volume and rate	Digital
Pluviograph	Weighting of rainfall and recording on paper	Accumulated rainfall volume as a function of time	Manual (record on paper)
Raingauge	Tipping bucket	Accumulated rainfall volume as a function of time	Digital
Raingauge	Accumulation of rainfall water	Accumulated rainfall volume in a period of time	Manual
Evaporimeter	Evaporation of rainfall water	Effective Evaporation	Manual

Wind and rain profiler CLAIRE

- CLear AIr and Rainfall Estimations (CLAIRE):
- Estimates winds, turbulence, and rainfall
- Four Yagi-Uda antenna phased arrays, one for transmission and three for reception, arranged in a quasimonostatic system.
- f=445-MHz
- Sensitive to both clear-air and precipitation echoes.

CLAIRE Working principle

- CLAIRE provides tropospheric winds, turbulence, and rainfall estimations. It consists of four Yagi-Uda antenna phased arrays, one for transmission and three for reception, arranged in a quasimonostatic system. The 445-MHz CLAIRE system is sensitive to both clear-air and precipitation echoes. The aim is to separate the two types of echoes through spectral analysis and process them independently. For the wind and turbulence measurements, Spaced Antenna technique is applied, while precipitation measurements are obtained by analyzing the corresponding radar reflectivity factor (Ze).

Wind profiler BLTR

Frecuency: 49.92 GHz
Wavelenth: 6 m
Space resolution: 75 m
Temporal resolution: 32 s
Phase array antenna (Rx)
Nyquist velocity: 11.74 m/s
Beam width: 19.79º

BLTR working principle

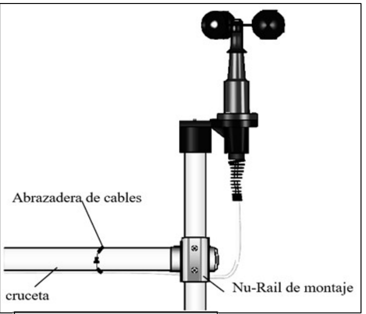
- **The Boundary Layer and Troposphere Radar (BLTR) was manufactured by Genesis Software Pty Ltd. It is a 49.92 MHz (λ = 6.0 m). It is a monostatic wind profiler radar consisting of three antenna arrays. The BLTR operates using the Spaced Antenna (SA) Technique \citep{briggs1984analysis}, which provides the three wind components (zonal, meridional and vertical) with a vertical resolution of 75 m. Due to its operational frequency, it is mainly sensitive to Bragg scatter mechanisms, but after further processing by spectral analysis, precipitation echoes were detected during convective precipitation events when large raindrops are observed. Echoes from clear-air are processed independently in the spectral domain in order to obtain the true vertical wind component.**

Surface flow measurement complex

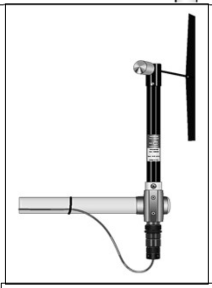
- **The flow complex is a set of sensors to estimate the different energy flows such as sensible heat (H) and latent heat (LE). Furthermore, it is possible to measure gas flows such as carbon dioxide (CO2), water vapor (H2O), methane (NH4) among other trace gases.**

- **The sonic anemometer measures wind speed in its three dimensions (u, v, w), and the krypton hygrometer quantifies the fluctuations of water vapor. Both instruments measure at a frequency of 10 Hz.**

30 m - Gradient tower



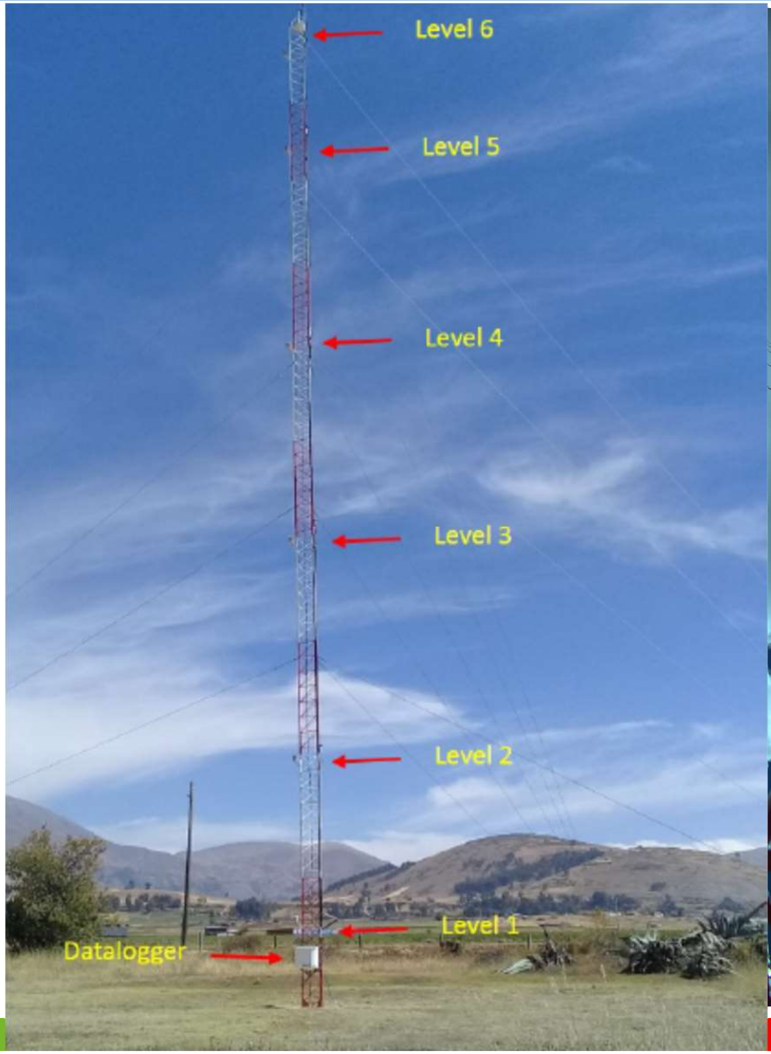
Anemometer
03101 – Campbell Scientific

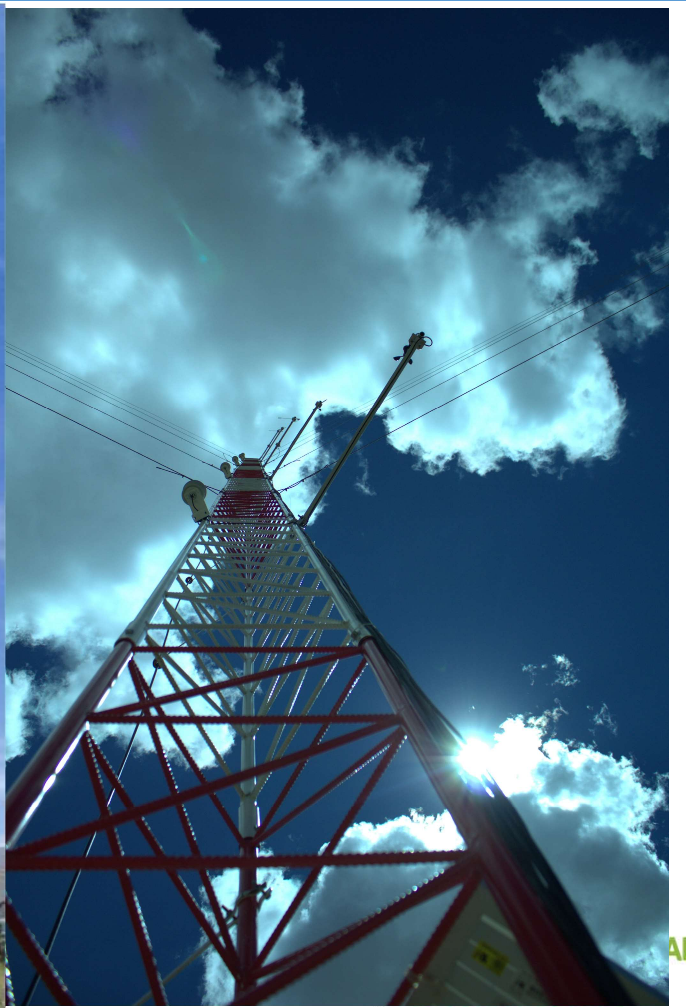


Wind direction sensor
024A – Met One

Temperature and humidity sensor
HMP60 Campbell Scientific

Heat flux plate HFP01
Campbell Scientific





IMG_7372.CR2

30 m - Gradient tower

- **A set of meteorological sensors were installed in a gradient tower of 30 m high since 2018. Temperature and relative humidity was measured by the HMP60 probe of Campbell Scientific. This sensor measures temperature for the range of -40 to 60ºC with an accuracy of 0.6ºC, and relative humidity for the range of 0 to 100% RH with an accuracy of 3% over 0 to 90% and 5% over 90 to 100%. The 03002 Wind Sentry Set of Campbell Scientific measures both wind speed and direction. It consists of a 3-cup anemometer and a wind vane mounted on a small crossarm. The 03002 measures wind speed for the range of 0 to 50 m/s with an accuracy of 0.5 m/s. The wind vane measures wind direction for the range of 0 to 360º. The HFP01 soil heat flux plate outputs a voltage signal that is proportional to the heat flux of the surrounding medium (soil). Its measurement range is _2000 m^2 with an accuracy within –15% to +5% in most common soils.**

Radiation Complex

Sky Camera
Image of the celestial vault with information about the present cloudiness..

CIMEL CE-318 Solar Photometer
Spectral measurement of solar and sky irradiance, to determine the Aerosol Optical Depth (AOD) and Angstrom Coefficient. Part of NASA-AERONET. Uses 8 wavelengths (340, 380, 440, 500, 675, 870, 1020, 1640 nm). Automatic sun-tracking. Precision: 0.003°.

BSRN Station. (Baseline Solar Radiation Network). Measurement of Surface short wave and long wave solar radiation.

Instrument	Model	spectral range (µm)	Sensitivity (µV/W/m^2)	Net irradiance limits (W/m^2)
Pyrgeometer	CGR4	4.5 a 42.0	5 a 15	-250 a + 250
pyranometer	CMP21	0.285 a 2.8	7 a 14	Max. 4000
Pyrheliometer	CHP1	0.2 a 4.0	7 a 14	Max. 4000

The CIMEL CE-318 Solar Photometer

- **The CIMEL CE-318 Solar Photometer** performs AOD and Angstrom Coefficient measurements at 8 wavelengths (340, 380, 440, 500, 675, 870, 1020, 1640 nm). It works automatically and completely autonomously, following the sun and positioning the instrument for its measurements with an accuracy of 0.003 °. Measurements are made from sunrise to sunset at varying intervals depending on the scenario being performed.

- The main measurements that this instrument performs are:

- Direct measurement of the sun: tracking and positioning of the sun and sequence of measurements in different spectral bands.

- Sky measurements: positioning of the instrument in the main plane or the plane and sequence of measurements in different spectral bands.

- Night measurements of the moon: periodic monitoring of the moon and sequence of measurements in different spectral bands

BSRN (Baseline Solar Radiation Network) station

- The BSRN (Baseline Solar Radiation Network) station has the function of measuring solar radiation on the surface, both short and long wave, with high quality standards. These measurements are made with the objective of monitoring the background conditions, supplying data for the evaluation and validation of solar flux measurements from satellite platforms, and producing observations data to compare with climate models and the development of local and regional climatologies.

- This station performs measurements of Global Horizontal Irradiance (GHI), Diffuse Horizontal Irradiance (DHI), Direct Normal Irradiance (DNI), Reflected Ground Irradiance (GRI), Global Long Wave Horizontal Irradiance (GHLI) and Long Wave Reflected Terrestrial Irradiance (GRLI). These measurements are made every one minute, from sunrise to sunset.

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Some papers bound to LAMAR

- **Villalobos-Puma, E., Martinez-Castro, D., Flores-Rojas, J. L., Saavedra-Huanca, M., & Silva-Vidal, Y. (2019).** *Diurnal Cycle of Raindrops Size Distribution in a Valley of the Peruvian Central Andes*. **Atmosphere, 11(1). https://doi.org/10.3390/atmos11010038**

- **Martínez-Castro D., Kumar S, Flores Rojas J. L., Moya-Álvarez A.,. Valdivia-Prado J. M, Villalobos-Puma E., Del Castillo-Velarde C., Silva-Vidal Y, 2019:** *The impact of microphysics parameterization in the simulation of two convective rainfall events over the Central Andes of Perú using WRF-ARW*. **Valdivia-Prado J. M, Villalobos-Puma E., Del Castillo-Velarde C., Silva-Vidal Y, 2019: Atmosphere, 10, 442; https://www.mdpi.com/2073-4433/10/8/442. doi:10.3390/atmos10080442**

- **Valdivia Jairo M. , Kevin Contreras, Daniel Martinez-Castro, Elver Villalobos-Puma, Luis F. Suarez-Salas, y Yamina Silva (2020):** *Dataset on raindrop size distribution, raindrop fall velocity and precipitation data measured by disdrometers and rain gauges over Peruvian central Andes (12.0_S)*

- **Flores-Rojas José Luis, Joan Cuxart, Manuel Piñas-Laura, Stephany Callañaupa, Luis Suárez-Salas, Shailendra Kumar, Aldo S. Moya-Alvarez and Yamina Silva (2019):** *Seasonal and Diurnal Cycles of Surface Boundary Layer and Energy Balance in the Central Andes of Perú, Mantaro Valley.* **Atmosphere 2019, 10, 779; doi:10.3390/atmos10120779**

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- **Estevan, R., Martínez-Castro, D., Suarez-Salas, L., Moya, A., Silva, Y. (2019*).*** *First two and a half years of aerosol measurements with an AERONET sunphotometer at the Huancayo Observatory, Peru*. Atmospheric Environment: X, Volume 3, 100037. doi: 10.1016/j.aeaoa.2019.100037.
- **Moya-Álvarez, A. S., Estevan, R., Kumar, S., Rojas, J. L. F., Ticse, J. J., Martínez-Castro, D., & Silva, Y. (2020)**. *Influence of PBL parameterization schemes in WRF_ARW model on short - range precipitation's forecasts in the complex orography of Peruvian Central Andes*. Atmospheric Research, 233, 104708. https://doi.org/https://doi.org/10.1016/j.atmosres.2019.104708
- **Valdivia, J.M., Contreras, K., Martinez-Castro, D., Villalobos-Puma, E., Suarez-Salas, L.F. and Silva, Y. 2020**: *Dataset on raindrop size distribution, raindrop fall velocity and precipitation data measured by disdrometers and rain gauges over Peruvian central Andes* (12.0°S). Data in Brief • April 2020. https://doi.org/10.1016/j.dib.2020.105215
- **Kumar, S.; Castillo-Velarde, C.D.; Valdivia Prado, J.M.; Flores Rojas, J.L.; Callañaupa Gutierrez, S.M.; Moya Alvarez, A.S.; Martine-Castro, D.; Silva, Y., 2020**: *Rainfall Characteristics in the Mantaro Basin over Tropical Andes from a Vertically Pointed Profile Rain Radar and In-Situ Field Campaign.* Atmosphere 2020, 11, 248
- **Moya-Álvarez A. S., Martínez-Castro D., Kumar S., Flores Rojas J. L., Estevan R., Saavedra-Huanca M., Silva Y.,, 2020:** *Statistical characterization of vertical meteorological profiles obtained with the WRF-ARW model on the central Andes of Peru and its relationship with the occurrence of precipitation on the region*, Atmospheric Research, 239. https://doi.org/10.1016/j.atmosres.2020.104915.

WELCOME TO HUANCAYO!

- The Geophysical Institute of Peru (IGP) offers its LAMAR installations and facilities to the international geophysical and meteorological community to develop joint research projects aimed at improving the understanding and insight in the physical and dynamical processes linked to the energy and water balance, and particularly to the development of extreme meteorological events in the complex orograpic condtions of the Central Andes of Peru.

- The site is accessible from the neighboring towns and cities and includesinternal basic housing facilities and internet access for developing field measurement campaigns and experiments.

Landscape in the Observatory



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ciencia para avanzar.

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