The ATEMO device: a compact solution for earth monitoring

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Abstract. In today's context, where climate change is increasingly topical and of global interest, the ATEMO (Atmospheric Technologies for Earth Monitoring and Observation) project proposes a multi-purpose solution, which can be integrated on board drones or stratospheric balloons, to provide a framework for environmental assessment in areas of interest. Specifically, ATEMO, equipped with a set of cameras and sensors, aims to enrich data on air pollution, light pollution and vegetation health with high spatial resolution and rapid deployment.

Introduction

In environmental protection, monitoring activities are crucial for determining preventive strategies or large-scale solutions; particular interest is arisen regarding Earth observation from space [1]. However, due to low spatial and, mainly, temporal resolution of such instrumentation, information about an area or site of interest is often not sufficient and may need to be validated by other measurement and analysis methods.

The ATEMO project therefore aims to increase knowledge on environmental issues with the development of a versatile device that can be used in various contexts and environments, from the analysis of atmospheric composition, through the detection of substances and pollutants such as VOCs (Volatile Organic Compounds), NO_x (Oxides of Nitrogen), SO_x (Oxides of Sulphur), CO_2 (Carbon Dioxide), O_3 (Ozone), to the determination of ground-based light sources and their characterisation. Furthermore, in order to understand how these factors may influence ecosystems, ATEMO also aims to determine ground vegetation indices (e.g. the NDVI - Normalized Difference Vegetation Index). The ultimate goals are comparing these data with the ones obtained from satellites [2] and to look for a correlation between the various investigated parameters. In fact, while the influence of air pollutants and night lighting on ecosystems, plants and humans is already known [3], recent studies suggested that the combined effect of light and air pollution leads to the formation of harmful and worsening reaction by-products [4] of the already critical situation.

In the remainder of this paper, the ATEMO device will be introduced, and the main design solutions will be described: the selected solution allows compactness and integrability on different vehicles (drones, tethered balloons and stratospheric balloons). Last, the tests campaign planned to validate the device functional requirements will be briefly introduced.

Design of ATEMO experiment

Due to the desired versatility of ATEMO, the device is strictly constrained in both mass and size. The device has a weight of 2.5 kg, a base of 17 cm x 17 cm and a height of 25 cm; as shown in Fig. 1, the instrument consists of an external aluminium frame to which are attached 3D-printed

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components that guarantee both the safe integration of the various sensors and cameras and their easy attachment and removal in the event of a change of setup. In fact, one of ATEMO's main strengths is its modularity and scalability, which allows it to best adapt its physical and measurement characteristics to the application context.

Regarding the sensing part of the device, ATEMO is equipped with two cameras (one monochrome and one colour) Basler ace 2 both with Sony's IMX546, an 8MP square CMOS sensor with a wide relative response spectrum (from approximately 400 nm to 1000 nm). In addition, a FLIR typology Vue Pro R thermal imaging camera is mounted on board. There are also several sensors for temperature, pressure, humidity, detection of O_3, CO_2 and other substances, a GPS tracking system and an SQM-L (Sky Quality Meter - L type), a sensor that allows to measure the brightness of the night sky in magnitudes per square arc second.

The two cameras are used for two main purposes: the estimation of vegetation indices during the day and the analysis of light sources at night. For the two cases, the setup of the cameras obviously slightly changes in function of the required the light filtering. In the case of the vegetation analysis, the colour camera is equipped with a triple-band filter (475, 550 and 850 nm) and the monochrome camera with a band-pass filter (735 nm), both of which are designed to reproduce indices already calculated by means of Planet satellites [5]. In the night-time application, however, the two cameras are used with a filtering solution similar to that of the MINLU experiment [6], another project conducted by our research group. In order to easily switch filters, a filter wheel driven by a stepper motor has been chosen; its attachment points can be seen in Fig.1, at the centre of the camera compartment in the view from below.

The cameras field of view (FOV) is another additional key point to consider. In fact, the choice of optics is made according to the host vehicle; in the case of integration on drones or balloons tethered at a height of 50-100 m, optics with large apertures are used, while in the case of stratospheric balloons, optics with much narrower apertures are favoured.

Figure 1: On the left: the complete assembled experiment. On the right the main components: the SQM with its 3D-printed baffled and the cameras at the bottom.

The system is controlled by a Raspberry Pi 3, programmed with Python, which, thanks to a 20000 mAh lithium battery, acquires data from on-board instrumentation and manages electrical and electronic systems for more than 6 hours. ATEMO's power consumption is in the range between 6 W and 14 W, depending on the sampling frequency and the subsystems in use.

For a correct interpretation of the data provided by ATEMO, a calibration using a commercial spectrometer (Black Comet C-SR-14) was necessary; the on-board cameras were characterised in the various filtering configurations since the input information is affected by the transmission of the optics, the filter, and the response of the CMOS sensor. Using a selection of known sources and the spectrometer, the response function of the system was thus defined, making the collected results consistent and comparable with those of other measurement systems (e.g., satellites).

It shall be underlined that the current design choices may be affected by the experimental activities planned in the next years and briefly introduced in the following section; thanks to its modularity, it is expected to easily adapt ATEMO with only minor modifications to the bus.

Test programme

Several test campaigns have been planned over the next three years to verify the functioning of ATEMO. These campaigns retrace previous experiments already conducted by the research group, but with a more compact configuration that encompasses them all.

This summer (2023), some experiments have already begun in collaboration with the Department of Agronomy, Food, Natural Resources, Animals, and the Environment (DAFNAE) of the University of Padova. The aim is to evaluate the effects of differential irrigation of soybean fields in order to understand whether it is possible to obtain abundant harvests with a considerable saving of water. In this situation, the experiment is integrated aboard a tethered balloon and stationed for a day at the same location at a height of 50 metres (Fig. 2).

Of course, this is only one of the possible configurations in which ATEMO will be involved in measurement campaigns. In the coming months, in fact, other collaborations will be launched, e.g. with the Chilean PUCV (Pontificia Universidad Católica de Valparaíso) University for the determination of light pollution.

Figure 2: In the first two photos, on the left, the release phase, on the right, the tethered balloon at an altitude of 50 metres.

Conclusions

In this paper, the ATEMO device for Earth monitoring has been presented. To date, the device is in the early stages of testing; the different application cases will be investigated in the next months. Functional and operational tests will be consequently performed by the research team, which has an excellent knowledge of drone flights [7], stratospheric balloons [8] and the assessment of air [9] and light pollution [10].

In conclusion, ATEMO is promising for its potential to provide a global environmental image of an area of interest, thus proving useful in a variety of fields, from atmospheric monitoring in populated areas to precision agriculture and in the verification of satellite data.

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