A new astronomical method to measure the amount of greenhouse gases in the Earth's atmosphere

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Key messages

- CO_2 and CH_4 are critical greenhouse gases driving climate change.
- We propose a new method to measure their abundance using ground-based spectroscopic astronomical observations.
- Preliminary results look promising and would allow us to explore new trends and variations in greenhouse gases abundances.

Introduction

The longest record of direct measurements of carbon dioxide (CO_2) in the atmosphere comes from the Mauna Loa Observatory in Hawaii, which has on going observations since the 1950s (Figure 1). This molecule, along with methane (CH_4), are among what we call greenhouse gases, and their increasing abundance in the atmosphere is the main cause of the global rise in average temperature that drives climate change.

As such, being able to accurately and reliably measure the amount of said gases in the atmosphere is paramount to understand and model climate change, as well as to guide governmental policies for alleviating its impact.

This project proposes a new method to measure the amount of greenhouse gases in the Earth's atmosphere, which uses spectroscopic astronomical observations.

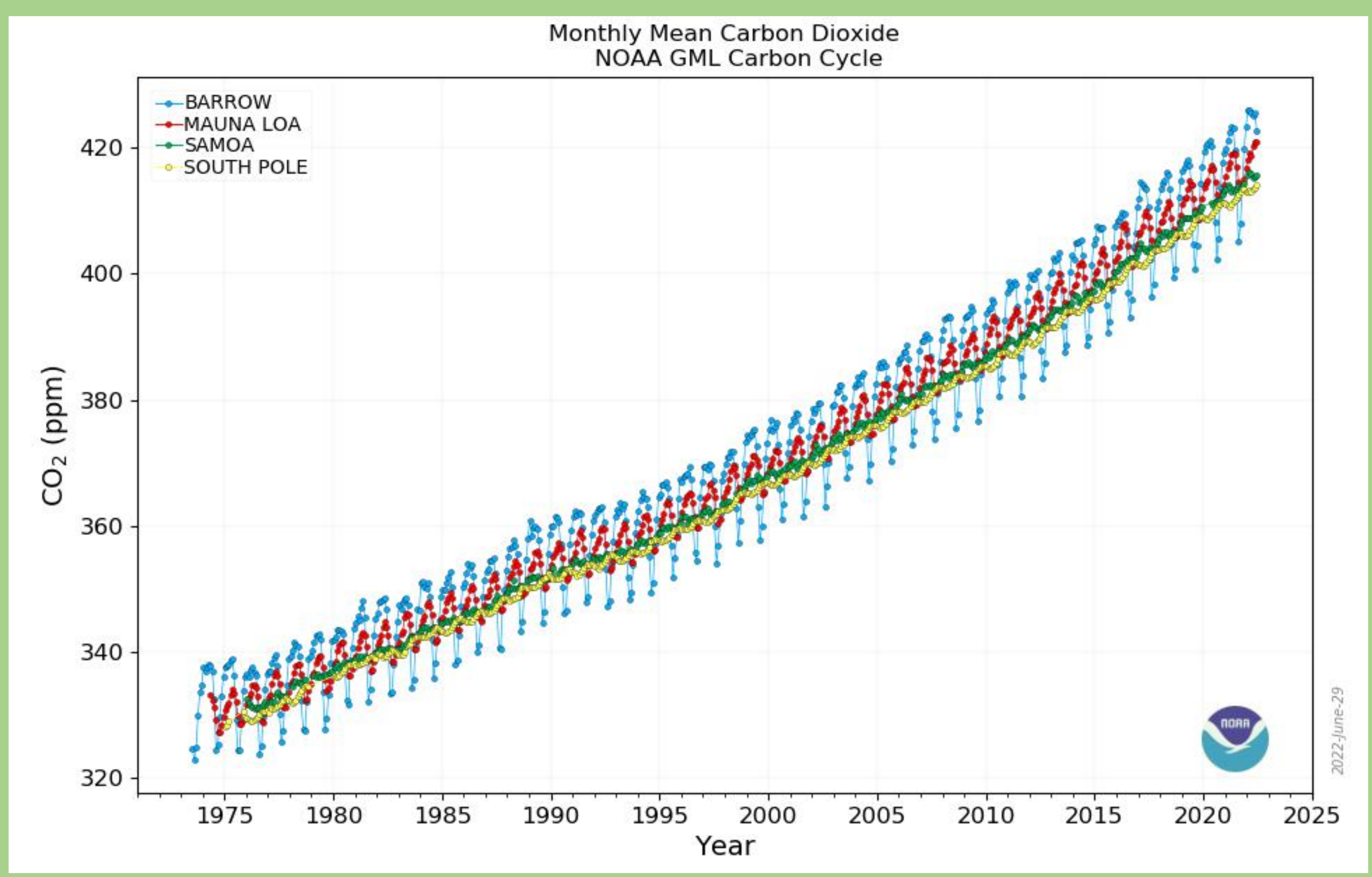

Figure 1: Monthly average of the CO_2 measurements from the four baseline observatories from the Global Monitoring Laboratory (GML). Credit: GML

Methodology

Spectroscopic observations from ground-based telescopes are plagued with spectral lines that originate from molecules in the Earth's atmosphere. These are the so-called **telluric lines**. Normally, astronomers want them removed from their analysis, but we aim to study them. For that, we employ the synthetic transmission method, in which a model telluric spectra is generated based on atmospheric profiles (Figure 2), spectral line databases and solving the radiative transfer equation.

This model spectra is then compared to the observational spectra, and an MCMC is run with the abundances of the desired molecules defined as the variables until the best fit is found.

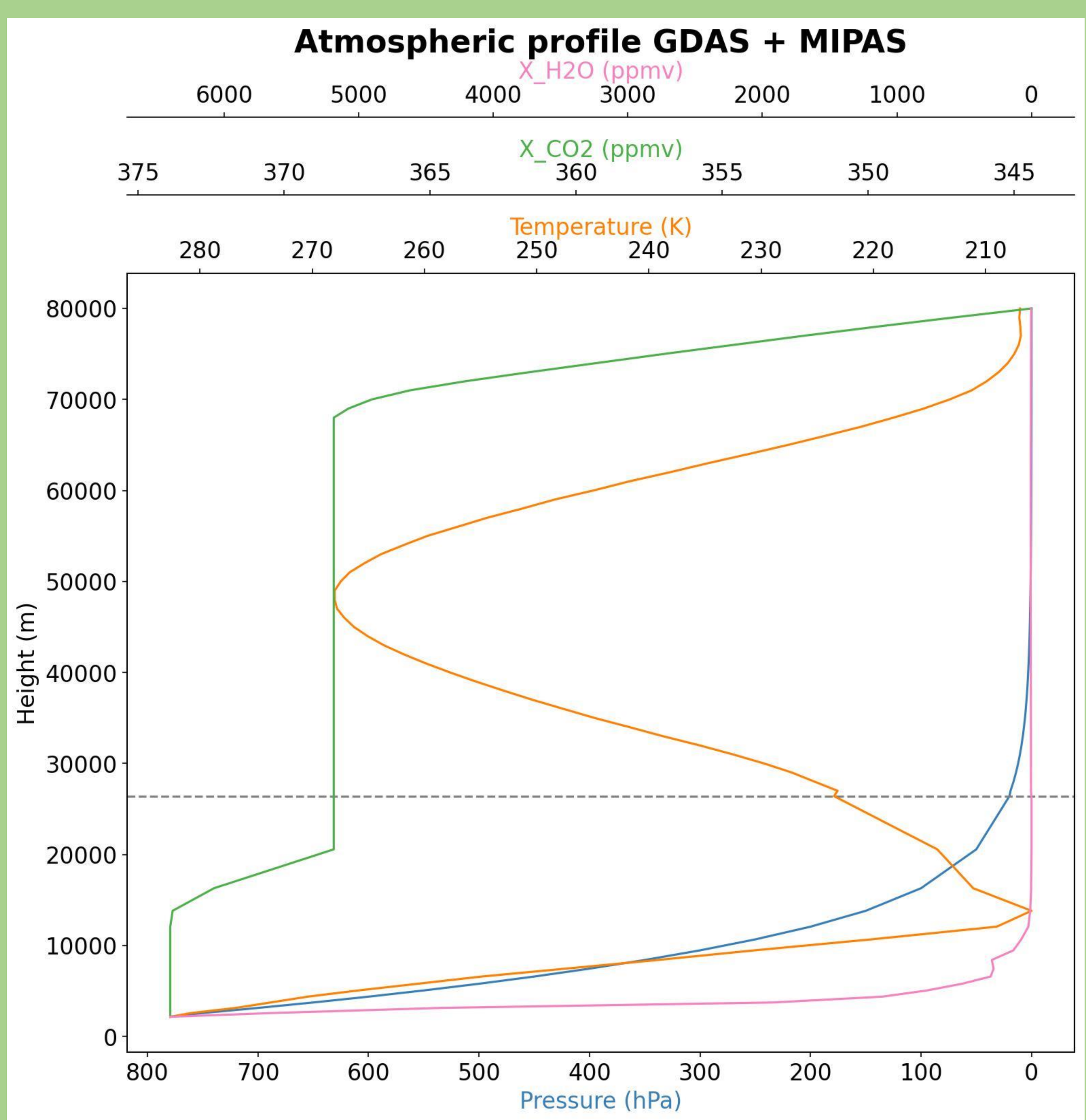

Figure 2: Pressure, temperature and abundances of CO_2 and water as a function of height, obtained by the combination of the MIPAS and GDAS atmospheric profiles.

Preliminary results

Recent observations were taken with the CARMENES instrument at the Calar Alto Observatory and a CO_2 sensor was placed next to the telescope. With that, a time series of the abundance of CO_2 and water was obtained (Figure 3). In both cases, our model overestimated the abundances compared to the sensor values, but our humidity values are in better agreement with the site values. The origin between this offset is still being investigated.

Alongside the astronomical observations, a weather balloon experiment was performed near the observing site, with the intent of obtaining a local temperature-pressure profile. The flight path of the balloon is shown in Figure 4, and in Figure 5 there is a picture of the author with the balloon.

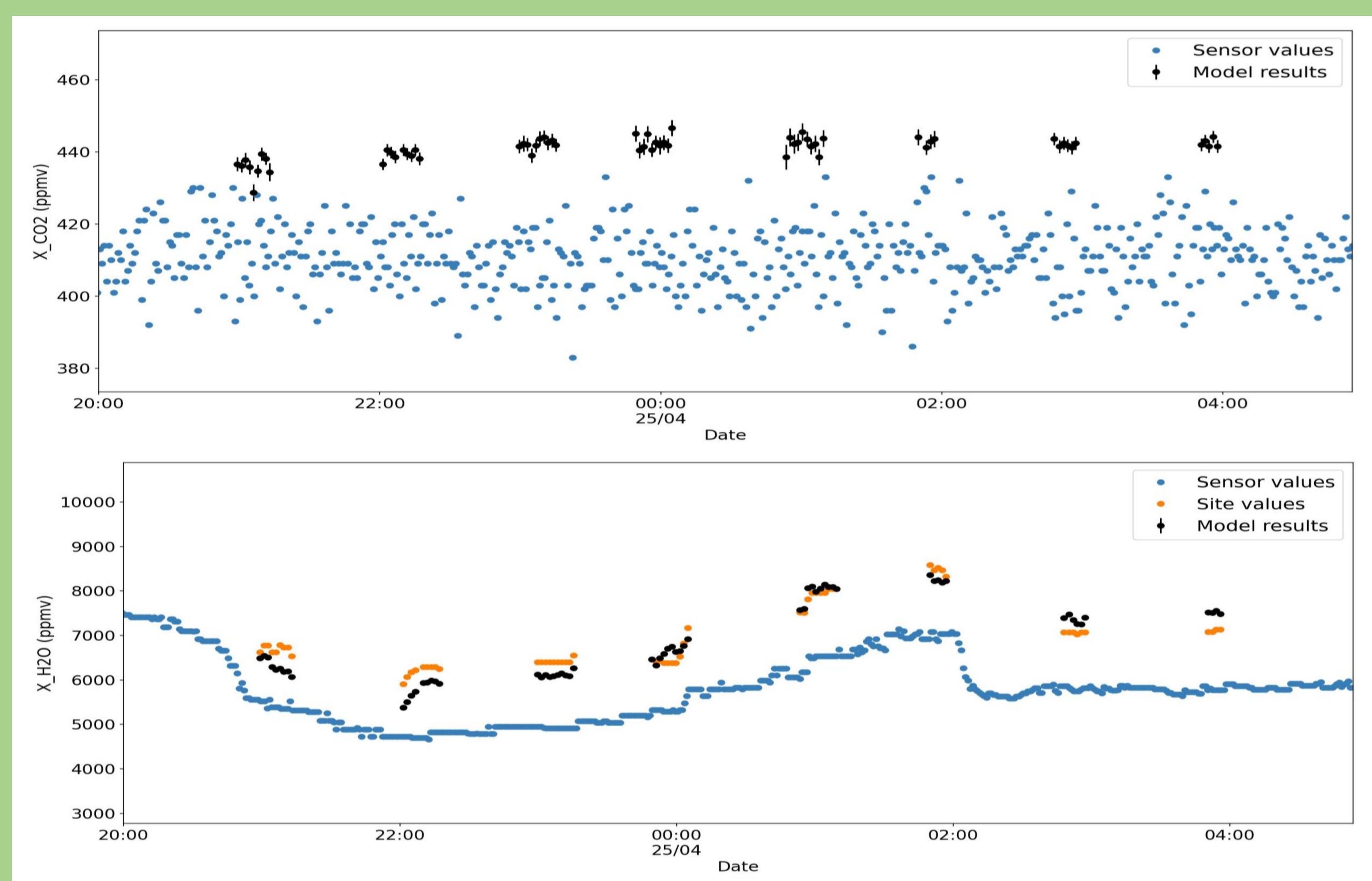

Figure 3: time evolution of the CO_2 (top) and H_2O (bottom) abundances. Sensor values come from the CO_2 sensor placed near the telescope, whereas site values are obtained from the FITS files' headers, which come from the observatory's weather station.

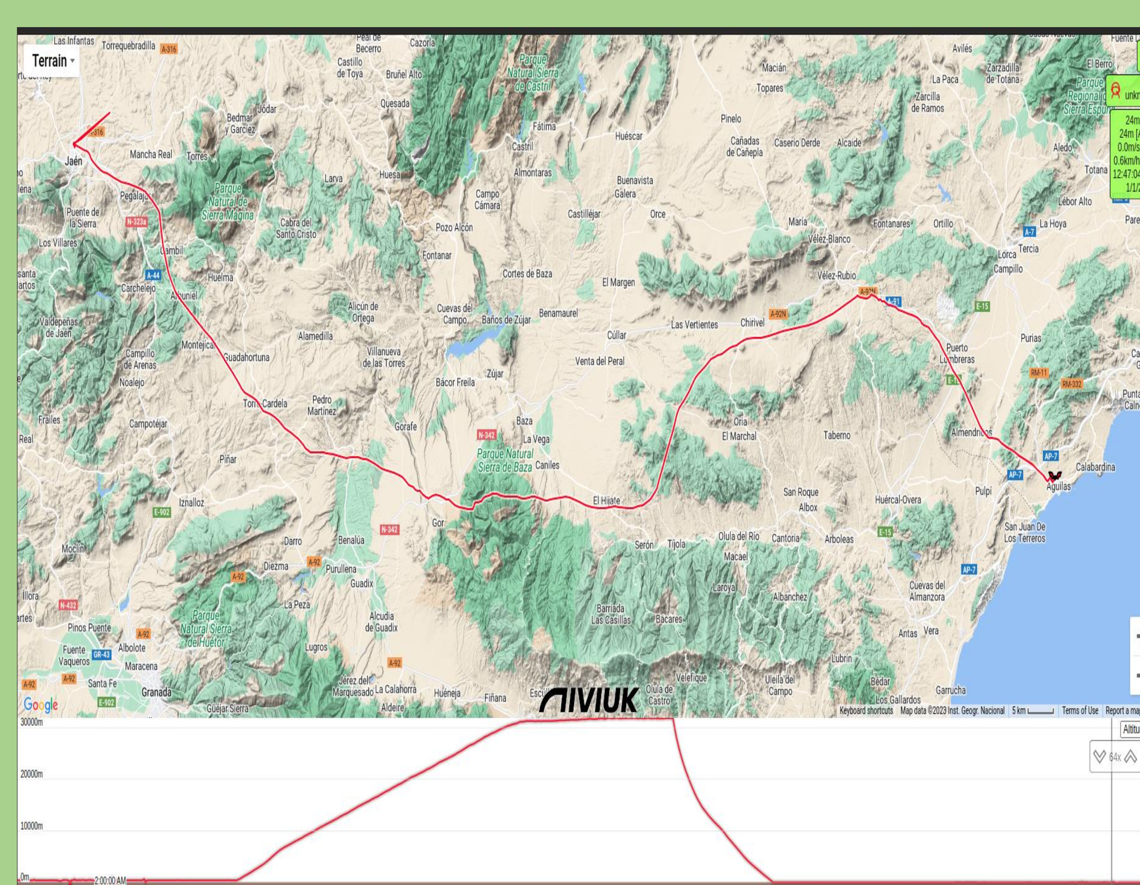

Figure 4: flight path of the weather balloon made with FlyXC. Figure 5.

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