# Reply anonymous reviewer #2

The paper introduces a new portable Fourier Transform Spectrometer (FTS) with a higher resolution than other commercially available portable FTS instruments. The characteristics of the instruments are described in detail and methods for spectral and radiometric calibration are implemented. The information content to retrieve the vertical profile information of $CO_2$ and $CH_4$ and the associated errors are explained and compared to two other FTS instruments that are widely used within the remote sensing community. The optimized number of channels to retrieve $CO_2$ and $CH_4$ are carried out at the end.
The work presented in the manuscript is within the scope of AMT. The text sometimes becomes unclear and hard to follow. I suggest reviewing the transitions between topics and fleshing out when a new topic is introduced to make it easier for the readers to follow along.

We thank the anonymous reviewer for his careful reading of our manuscript. After thorough consideration, we are providing an improved manuscript that reflects his insightful suggestions and comments with a slightly modified title as follows: **Instrumental characteristics and potential Greenhouse gases measurement capabilities of the Compact High-spectral Resolution Infrared Spectrometer: CHRIS.** As recommended, this revised manuscript benefits from clearer transitions between topics and rewriting some of sentences/sections, as well as further calculation results and figures that will be discussed in details in the following answers.

Below we respond to the questions and comments of the reviewer in detail, with reviewer comments in a different color.

1- The MAGIC campaign has been brought up a few times in the manuscript, however, it's unclear when exactly that campaign took place? How many days of measurement are available from each instrument involved?

The MAGIC campaigns are annual campaigns held at different locations in France (see **Fig. 1**), with the collaboration of different French laboratories: LMD, GSMA, LERMA, LSCE, and the LOA. In the future, these campaigns will be organized once or twice a year: once in France and once at the stratospheric balloon release sites (Kiruna, Sweden and Timmins, Canada). Up until now, there are about ten days of data available for each instrument involved during the last two campaigns. The objective is the monitoring of the emission of GHG, mainly $CO_2$ and $CH_4$, and to provide regular mobile data for the validation of the current and future space missions, like Merlin, Microcarb and IASI-NG.

We want to point out again that CHRIS is an instrumental prototype, and that MAGIC offers the ideal framework to its characterization, which motivated the first part of the manuscript. The potential capabilities to measure greenhouse gases are presented in the second part of the manuscript through an exhaustive information content study and a comparison with two other commercial FTIR: the EM27/SUN and the IFS125HR. However, the context of these campaigns and the scientific analysis of the measurements made by CHRIS and the inter-comparisons with the different instruments involved, will be detailed in an upcoming paper. Some extra details on MAGIC are mentioned in the revised manuscript.

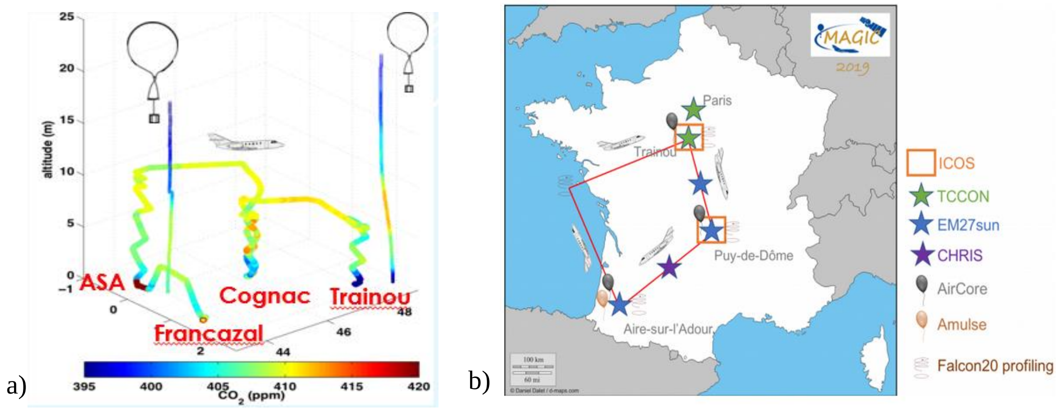


**Fig 1:** $CO_2$ vertical concentration and instrument deployment for the MAGIC campaigns: a) 2018 and b) 2019

2- The title of the manuscript suggests "greenhouse gas measurement capabilities" of the instrument are discussed in the paper. However, the main focus of the paper is on the information that could be obtained for the vertical profiles of $CO_2$ and $CH_4$ and there's no presentation of retrieved column values. Given that two other instruments (125-HR and EM27/SUN) were measuring at the same time as CHRIS, comparison of $CO_2$ and $CH_4$ column values between the three instruments could be proving the "greenhouse gas measurement capabilities" of CHRIS. GGG could easily be used perform the retrievals.

Indeed, we agree that the objective of this paper is the investigation of the potential capabilities of this instrument to measure the greenhouse gases, hence the adjustment of the title. The real capacities of this instrument and the preliminary results of the retrieval process is the main objective of the work that had just begun on CHRIS, within the framework of MAGIC. The latter is processed alongside different types of instruments: the ground-based commercial instruments like the IFS125HR from TCCON and the EM27/SUN; but also a methane lidar, the Aircore and the Amulse, and will therefore be the subject of the upcoming paper. However, we will use for these retrievals the radiative transfer model ARAHMIS, which has the particularity to apply the retrieval of absolute radiances on different spectral regions simultaneously, including the thermal band.

3- In section, 2.2.1 it is mentioned that 50, 100 spectra are coadded for $CO_2$ and $CH_4$ measurements. My calculations using the laser frequency and scanner velocity suggests a single scan time of about 0.7 s. Can you confirm this number? If that's the case, caoadding 100 spectra is still fast enough not to worry about changes in the atmosphere and also stability of the laser.

Indeed, for the covered spectral domain, one recorded interferogram consists of 99527 points with a scanner velocity of 120 KHz, which corresponds to a scan time of 0.83 s. After several tests on the scan velocity and the scan number, we found that the best compromise to measure $CO_2$ and $CH_4$ is a scan speed of 120 KHz and a scan number of 100. With this protocol, the total time required to record a spectrum is 83 s, which is low in comparison to the variability of these gases in the atmosphere. Furthermore, a scan velocity of 120 KHz was chosen as a compromise between two important features: the elimination of the ghost signal, which appears at scan velocities below 80 KHz that result from the vibrations of the compressor of the closed-cycle stirling cooler, and the increase of the detector non-linearity at a velocity of 160 KHz. Note that the spectral parameters are adjustable at each retrieval and for each spectrum in the radiative transfer model ARAHMIS.

4- Although $H_2O$ absorption lines are present in almost all spectral windows, water vapour mole fractions are not retrieved in the analysis. Is it because of the certain meteorological conditions in Izaña that leads to stable water vapour values? Bringing some evidence to prove that's the case would be helpful.

One of the main objectives of the acquisition of CHRIS is the validation of the space instruments, like TANSO-fts/ GOSAT, which has similar spectral bands. Since this information content study has to be easily compared to measurements from space instruments, we considered variability for the water vapor profile as derived from the IASI level 2 products provided by EUMETSAT (Herbin et al. 2013, De Wachter et al. 2017). However, we agree that the impact of water is huge, and in the work that had just begun on the $CO_2$ retrieval, $H_2O$ is part of the retrieved state vector. This information is mentioned in the revised manuscript.

5- In section 3.1, it is mentioned the apriori profiles (I am guessing of $CO_2$ and $CH_4$), temperature and humidity are used for the analysis. Could you please specify where these information are obtained from?

During campaigns, the a priori profiles for the temperature, pressure and water vapor are derived from the radiosondes located both spatially and temporally near our instrument. Otherwise, we take, when available, the radiosondes data located as close as possible to our measurement point. The $CO_2$ and $CH_4$ a priori profiles are interpolated from the available satellite instruments Level 2 profiles and/or NDACC/TCCON a priori profiles.

6- Page 13, the last paragraph, you mention that calculation of $X_G$ using $O_2$ column values done by EM27/SUNs allows comparisons with satellite data and it's not possible for CHRIS. This statement contradicts the point made earlier in the introduction where you suggest CHRIS could be used for satellite validation. In fact, retrieval of $X_G$ values are possible for CHRIS if surface pressure and water vapour measurements are used as described by Wunch et al., 2010.

Indeed, this part of the manuscript might be confusing, and we agree that the retrieval of $X_G$ values is possible for CHRIS if the formula in Wunch et al. 2010 is used. During the MAGIC campaigns, we have access to the balloons and radiosondes data (temperature, surface pressure, $H_2O$ vmr, etc…); so for these particular campaigns, $X_G$ values will be calculated for CHRIS and the results will be compared with the other instruments involved, especially the IFS125HR of the TCCON network and the EM27/SUN, and this will be the subject of the upcoming paper. However, what we want to point out is the fact that the two equations to calculate $X_G$ are not strictly similar since the EM27/SUN can measure $O_2$ column to calculate the DMFs, which eliminates the systematic errors due to the measurements which will not be possible for us, since the $O_2$ band is not detected by CHRIS. This paragraph is rewritten in the revised manuscript to eliminate any ambiguity.