Long-term Monitoring of Greenhouse Gases at the Izaña Atmospheric Observatory

O.E. García[1], E. Sepúlveda[1], E. Cuevas[1], A.J. Gómez-Peláez[1], M. Schneider[2], F. Hase[2], T. Blumenstock[2], A. Redondas[1], and V. Carreño[1].

(1) Izaña Atmospheric Research Centre, State Meteorological Agency of Spain (AEMET), Santa Cruz de Tenerife, Spain.

(2) Institute for Meteorology and Climate Research (IMK-ASF), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

Contact email: ogarciar@aemet.es

Izaña Atmospheric Observatory

The Izaña Atmospheric Observatory (IZO, 28.3ºN, 16.5ºW, 2367 m a.s.l., Tenerife, Spain) is a subtropical high-mountain observatory, run by the Izaña Atmospheric Research Center (IARC, http://izana.aemet.es), belonging to the State Meteorological Agency of Spain (AEMET). The IARC conducts monitoring and research related to atmospheric constituents that are capable of forcing changes in the climate and air quality of the Earth.
IZO is normally above a temperature inversion layer and below the descending branch of the Hadley cell. Consequently, it offers excellent conditions for trace gas and aerosol in situ measurements under "free troposphere" conditions, and for atmospheric observations by remote sensing techniques. The environmental conditions and pristine skies are optimal for calibration and validation activities of both ground-based and space-based sensors.

Regarding greenhouse gases (GHGs), IZO has been a Global WMO-GAW (World Meteorological Organization-Global Atmospheric Watch) station since 1984, recording continuous in-situ concentrations of the main GHGs. In addition, since 1999 total column amounts and low-resolution vertical profiles of many different atmospheric trace gases, GHGs among them, are retrieved by using Fourier Transform Infrared Spectrometer (FTS) in the framework of NDACC (Network for the Detection of Atmospheric Composition Change) and TCCON (Total Carbon Column Observing Network).
In this context, this work gives an overview about the IZO capabilities and activities for monitoring of atmospheric GHGs, especially focusing on the validation of space-based observations.

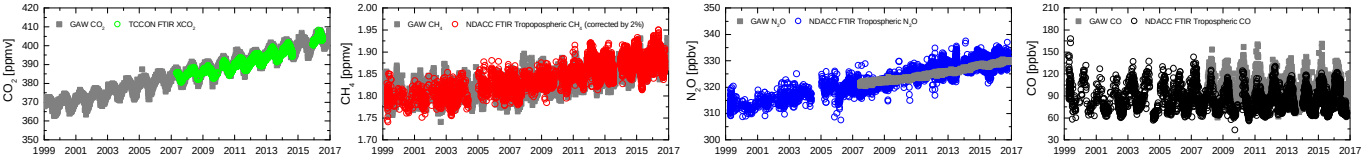
GAW In Situ

Ground-level in situ atmospheric continuous measurements of CO_2 (since 1984), CH_4 (since 1984), CO (since 2008), N_2O (since 2007) and SF_6 (since 2007) have been routinely carried out at IZO as a contribution of AEMET to the WMO-GAW programme (Cuevas et al., 2017, see Table on the right). CO is also monitorised since, although it is not a GHG, it affects the CH_4 cycle. The high quality of these measurements has been externally assessed by (1) periodic audits (2) the participation in WMO Round Robin intercomparisons; and (3) the continuous comparison to simultaneous weekly collected flask samples, within the NOAA/ESRL/GMD CCGG cooperative air sampling network. The expected uncertainties in these IZO continuous measurements are 0.1 ppm for CO_2, 2 ppb for CH_4, 0.2 ppb for N_2O, 2 ppb for CO, and 0.025 ppt for SF_6. Refer to Gómez-Peláez et al. (2012) and Gómez-Peláez et al. (2013) for more details.
Figure below displays the time series of CO_2, CH_4, N_2O and CO as observed by in situ GAW analysers and high-resolution FTS at IZO, showing the high agreement between both datasets.

Parameter	Present Instrument	Frequency
Greenhouse Gases and Carbon Cycle		
CO_2	NDIR Licor 7000 NDIR Licor 6252 CRDS Picarro G2401	Continuous (30") Continuous (30") Continuous (30")
CH_4	GC-FID Dani 3800 GC-FID Varian 3800 CRDS Picarro G2401	2 samples/hour 4 samples/hour Continuous (30")
N_2O	GC-ECD Varian 3800	4 samples/hour
SF_6	GC-ECD Varian 3800	4 samples/hour
CO	GC-RGD Trace Analytical RGA-3 CRDS Picarro G2401	3 samples/hour Continuous (30")
Fourier Transform Infrared Spectroscopy (FTS)		
GHGs, reactive gases, and related-O_3 substances	Bruker IFS 120/5HR (co-managed with KIT) Bruker EM27/SUN	3 days/week (weather permitting)

FTS

The FTS programme at IZO is the result of the collaboration between the IARC-AEMET and the IMK-ASF-KIT. Within NDACC activities, the IZO high-resolution FTS records direct solar spectra in the middle infrared between 740-4250 cm^{-1} (@0.005 cm^{-1}), while for TCCON the spectral range covers the near infrared from 3500-9000 cm^{-1} (@0.02 cm^{-1}).
By evaluating the measured solar absorption spectra, the FTS systems can derive total column amounts and low-resolution vertical profiles of different atmospheric trace gases with high precision. To do so, two retrieval codes are used at IZO: PROFFIT (Hase et al., 2004) for NDACC products and GFIT (Wunch et al., 2015) for TCCON products. The IZO FTS have routinely contributed to NDACC with C_2H_6, $ClONO_2$, CO, CH4, COF2, HCl, HCN, HF, H_2CO, HNO_3, N_2O, NO_2, NO, O_3 and OCS observations (total column amounts and Volume Mixing Ratio profiles) since 1999, while total column-averaged abundances of CO_2, N_2O, CH_4, HF, CO, H_2O and HDO are measured within TCCON since 2007.
The IZO FTS programme is complemented by a EM27/SUN portable FTS. It measures in the near infrared (@0.5 cm^{-1}), providing total columns of CO_2, CH_4, CO, and H_2O.



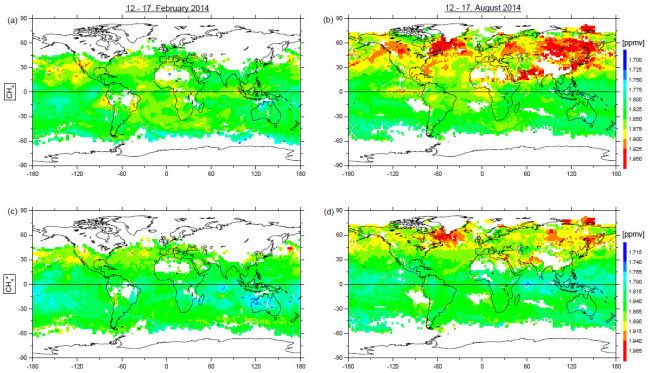
Validation of Space-based Greenhouse Observations

The high-quality IZO data has been extensively applied since many years for the validation of trace gases measured by different satellite instruments (ILAS, MIPAS, ACE-FTS, GOME, OCO-II, TROPOMI, …). Currently, our activities are focused on the IASI sensor through the European projects MUSICA and VALIASI, the German project MOTIV and the Spanish projects NOVIA and INMENSE. By means of these projects the validation of all of IASI operational atmospheric trace gases products is being carried out as well as the developing of the new IASI retrieval strategies.

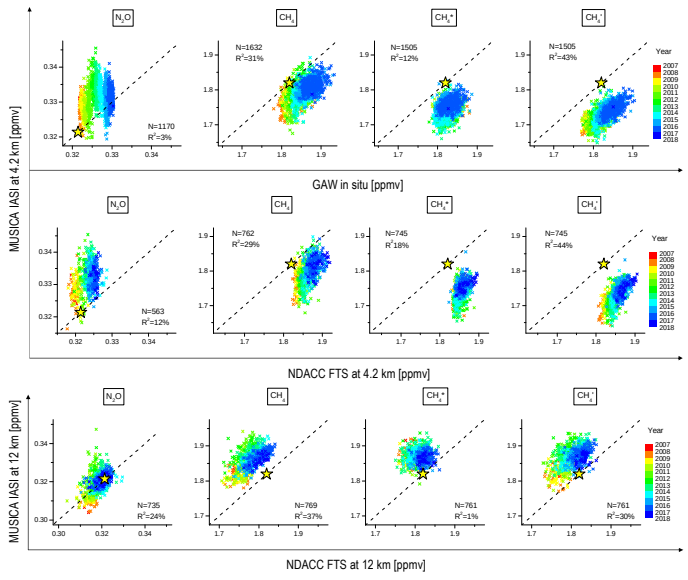
Here, we present an example of the capability of the IZO GHGs observations (GAW in situ and FTS) to validate the CH_4 and N_2O products as generated by the IASI processor developed during the project MUSICA (MUlti-platform remote Sensing of Isotopologues for investigating the Cycle of Atmospheric water, Schneider and Hase, 2011; Wiegele et al., 2014; Schneider et al., 2016). Figures on the right show the global distributions of the MUSICA IASI CH_4 products retrieved at the Upper Troposphere/Lower Stratosphere (ULTS, ~12 km) and averaged for an latitude-longitude area of 2ºx2º (the maps are shown separately for mid February 2014 and mid August 2014).

The comparison studies demonstrate that the MUSICA IASI data capture signals well that are larger than 1-2%, like the latitudinal gradients, the long-term increase and the seasonal cycles in the UTLS region. The MUSICA IASI CH_4 data offer a better sensitivity than N_2O data. While for the latter the sensitivity is mainly limited to the UTLS region, for CH_4 we are able to proof that at low latitudes the MUSICA IASI processor can detect variations that take place in the free troposphere independently from the variations in the UTLS region (see figures below). This validation exercise is also extented to two a posteriori corrected CH4 products (CH4* and CH4'), based on the a posteriori calculated logarithmic scale difference of the CH_4 and N_2O retrieval estimates. Refer to García et al. (2017) for more details.

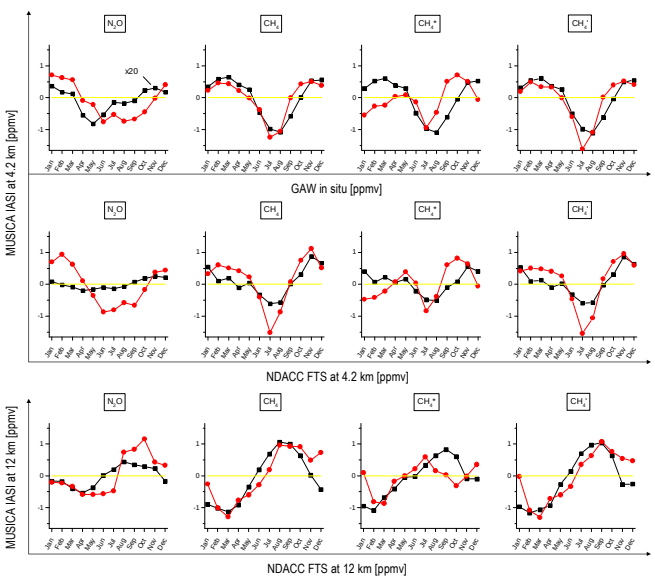
Global distribution of MUSICA IASI CH4 products at UTLS (12 km)



Comparison of daily observations



Seasonal cycle relative to long-term background [%]



ACKNOWLEDGEMENTS

This work has strongly benefit from funding by the European Research Council under FP7/(2007-2013)/ERC Grant agreement n°256961 (project MUSICA), by the Deutsche Forschungsgemeinschaft for the project MOTIV (Geschaftszeichen SCHN 1126/2-1), by the Ministerio de Economía y Competitividad from Spain trough the projects CGL2012-37505 (project NOVIA) and CGL2016-80688-P (project INMENSE), by the Ministerio de Educación, Cultura y Deporte (Programa "Jose Castillejo", CAS14/00282), and by EUMETSAT under its Fellowship Programme (project VALIASI).

REFERENCES

Cuevas et al., WMO/GAW Report No.236, 2017.
García et al., ATMD, 2017.
Gómez-Peláez et al., WMO/GAW Report No. 206, 2012.
Gómez-Peláez et al., ATM, 2013.
Hase et al., JQSRT, 2004.
Schneider and Hase, ACP, 2011.
Schneider et al., AMT, 2016.
Wiegele et al., AMT, 2014.
Wunch et al., http://doi.org/10.14291/TCCON.GGG2014.DOCUMENTATION.R0/1221662, 2015.