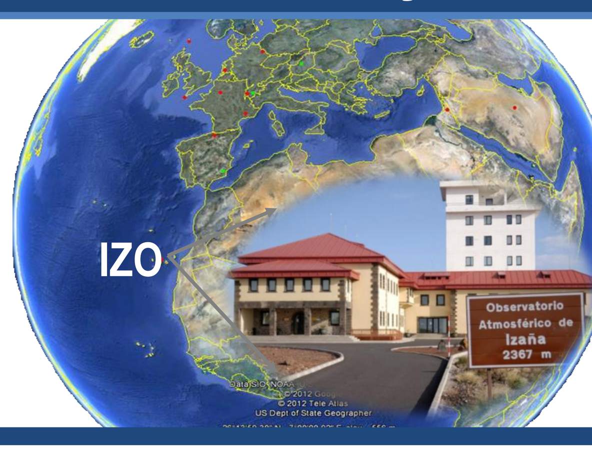
20 years of Fourier Transform Spectrometry at the Izaña Atmospheric Observatory

O. García[1], M. Schneider[2], E. Sepúlveda[1], F. Hase[2], T. Blumenstock[2], E. Cuevas[1], A.J. Gómez-Peláez[1], R.D. García[1,3], E. Reyes[1], R. Ramos[1], A. Redondas[1], V. Carreño[1], S.F. León-Luis[1], P.M. Romero-Campos[1], M. Navarro[4], M. Yela[4]

(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.
(3) Air Liquide España, Delegación Canarias, Candelaria, Spain.
(4) National Institute for Aerospace Tecnology (INTA), Spain.

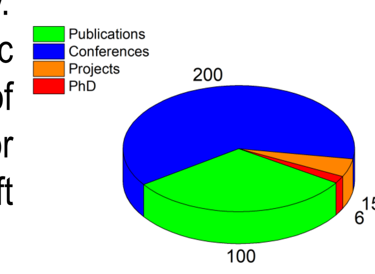
Izaña Atmospheric Observatory and FTS Programme

The Izaña Atmospheric Observatory (IZO, 28.3ºN, 16.5ºW, 2367 m a.s.l., Tenerife) is a subtropical high-mountain observatory, run by the Izaña Atmospheric Research Center (IARC), belonging to the State Meteorological Agency of Spain (AEMET). IZO is normally above a temperature inversion layer and below the descending branch of the Hadley cell. Consequently, it offers excellent conditions for atmospheric observations by in situ and remote sensing techniques under "free troposphere" conditions. Within the IZO's atmospheric research activities, the ground-based FTS (Fourier Transform Infrared Spectrometer) programme started in 1999, in the framework of a collaboration between the IARC-AEMET and the IMK-ASF-KIT (Schneider et al., 2005).



Since1999 two Bruker IFS spectrometers have been installed at IZO: an IFS 120M from 1999 to 2005 and an IFS 120/5HR from 2005 until present. These activities have routinely contributed to NDACC and TCCON since 1999 and 2007, respectively.

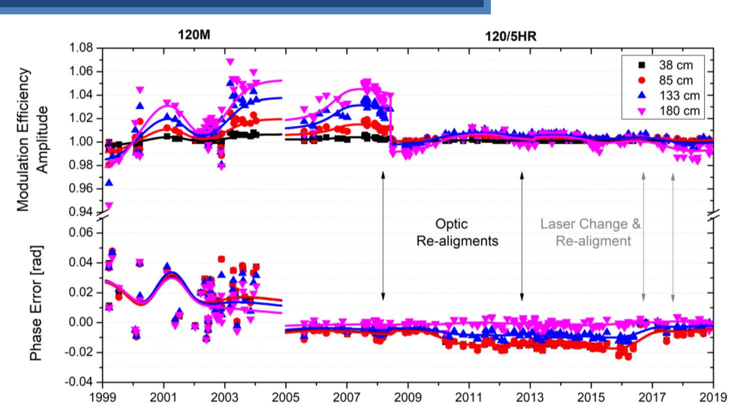
The great potential of the IZO FTS programme for atmospheric composition monitoring is well-recognized. During its 20 years of operation, the IZO FTS observations have been extensively used for many studies on climate research as summarized figure on the left (references at http://izana.aemet.es and https://www.imk-asf.kit.edu).



LONG-TERM PERFORMANCE

Instrumental Line Shape (ILS) Analysis

At IZO the ILS is routinely monitored about every two months using low-pressure N_2O-cell measurements and the software LINEFIT v14 (Hase, 2012). Figure on the right shows the time series of the IZO ILS Modulation Efficiency Amplitude and Phase Error for the SF filter measurement settings at four optical path differences.

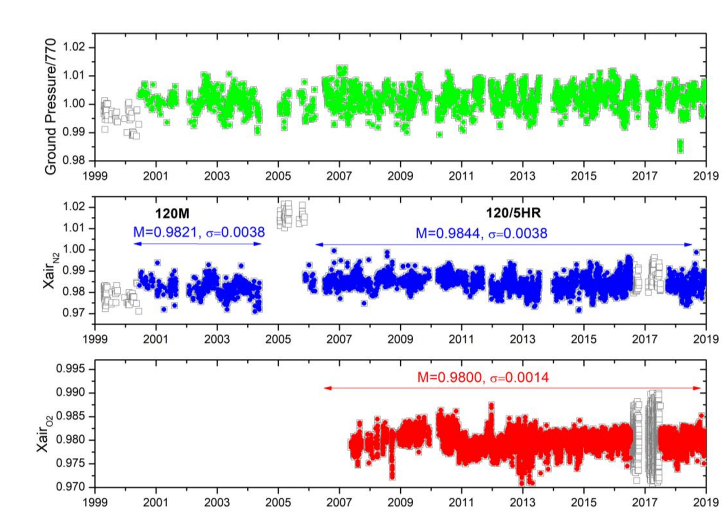


Temporal Stability: X_{air}

The IZO FTS's stability is tested through the column-averaged amount of dry air (X_{air}) parameter (Frey et al., 2019). Figure on the right shows the time series of the IZO ground pressure and the FTS X_{air}, calculated using the nitrogen and oxygen column amounts for the NDACC and TCCON ranges, respectively.

The precision of the IZO FTS records is estimated to be 0.38% and 0.14% for the NDACC and TCCON ranges, respectively.

The periods in grey correspond to instrumental issues on ground pressure records and/or FTS instruments and were ruled out for calculating the mean (M) and standard deviation (σ) statistics displayed on the figure.

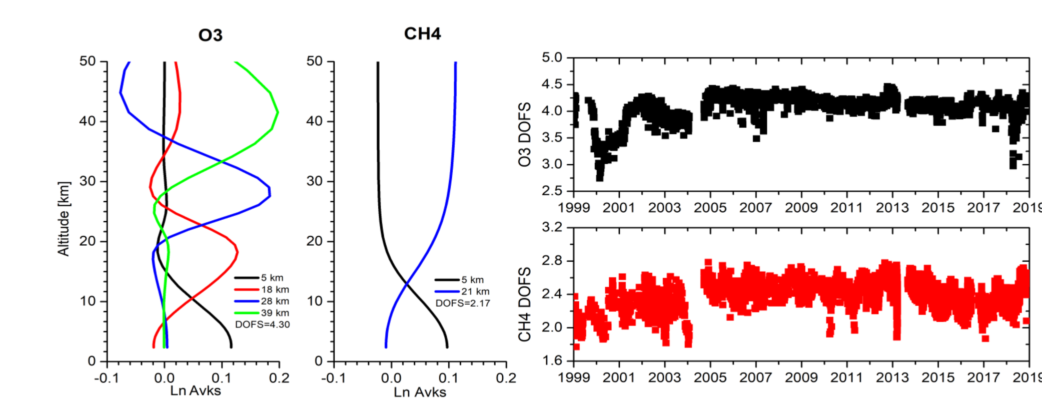


PRODUCTS CHARACTERIZATION

Table on the right gives an overview of the IZO FTS observations performed within the NDACC and TCCON networks. These data correspond to those publicly available at the NDACC and TCCON archive.

- The NDACC products (total columns and vertical profiles) are retrieved by analyzing the measured mid-infrared spectra (740-4250 cm^{-1}, @0.005 cm^{-1}) with the retrieval code PROFFIT (Hase et al., 2004).
- The TCCON products, given as total column-averaged abundances, are obtained from the measured near-infrared spectra (3500-9000 cm^{-1}, @0.02 cm^{-1}) using the GFIT algorithm (Wunch et al., 2011).

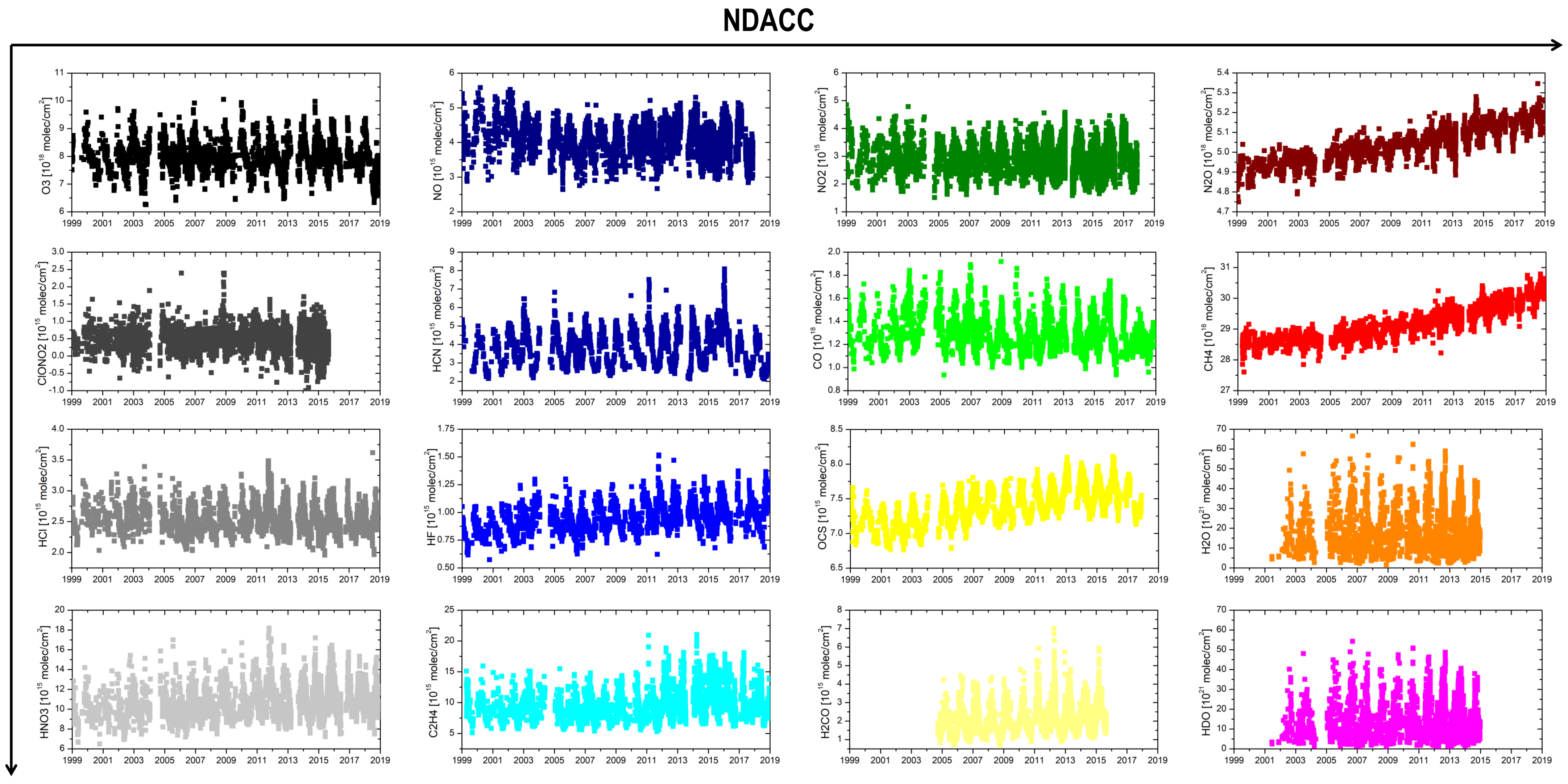
Example of the NDACC O3 and CH4 vertical information given by the averaging kernels and DOFS.

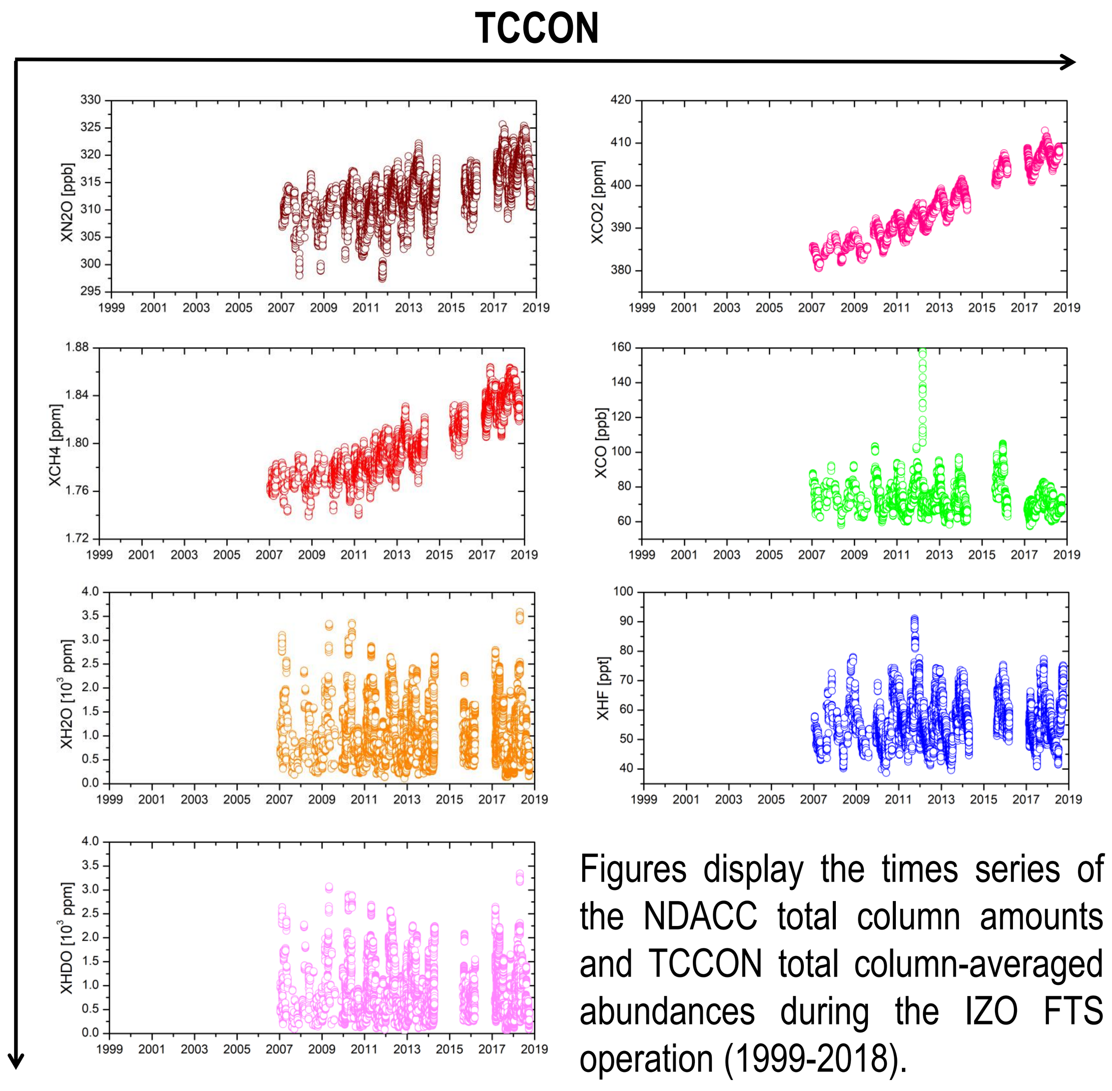


	Gas	N spectra	DOFS (1σ)	Ran Unc [%] (1σ)	Sys Unc [%] (1σ)
NDACC	O_3	5629	4.12 (0.20)	1.79 (0.15)	2.17 (0.03)
	$ClONO_2$	4140	1.0 (0.0)*	104 (1786)	93 (1578)
	HCl	11495	2.02 (0.14)	1.88 (0.43)	5.08 (0.15)
	HNO_3	5729	2.18 (0. 36)	2.17 (0.51)	2.47 (0.24)
	NO	4695	1.49 (0.27)	3.76 (1.03)	4.56 (0.23)
	HCN	3711	2.13 (0.14)	11.70 (2.31)	16.09 (1.80)
	HF	3953	1.74 (0.13)	1.38 (0.28)	5.10 (0.07)
	C_2H_6	11495	1.49 (0.15)	1.81 (0.39)	5.44 (0.17)
	NO_2	11065	1.0 (0.0)*	7.50 (2.06)	11.64 (0.64)
	CO	5056	3.07 (0.12)	0.51 (0.06)	2.11 (0.03)
	OCS	4695	2.24 (0.15)	0.94 (0.13)	3.37 (0.23)
	H_2CO	11202	1.0 (0.0)*	52 (19)	54 (18)
	N_2O	11495	2.85 (0.18)	0.44 (0.04)	2. 33 (0.06)
	CH_4	11495	2.41 (0.15)	0.56 (0.10)	3.23 (0.06)
	H_2O	9350	2.08 (0.11)	0.15 (0.09)	0.25 (0.10)
	HDO	9350	2.17(0.11)	0.08 (0.03)	0.63 (0.36)
TCCON	XCO_2	38464	1.0 (0.0)*	0.11 (0.13)	-
	XCH_4			0.12 (0.14)	-
	XN_2O			0.22 (0.15)	-
	XCO			0.51 (0.23)	-
	XHF			1.70 (0.83)	-
	XH_2O			1.20 (0.69)	-
	XHDO			1.62 (0.97)	-

DOFS: Degrees of Freedom, Ran Unc: Random Uncertainties and Sys Unc: Systematic uncertainties, (*) Scale Retrieval.

NDACC and TCCON IZO FTS TIME SERIES





Figures display the times series of the NDACC total column amounts and TCCON total column-averaged abundances during the IZO FTS operation (1999-2018).

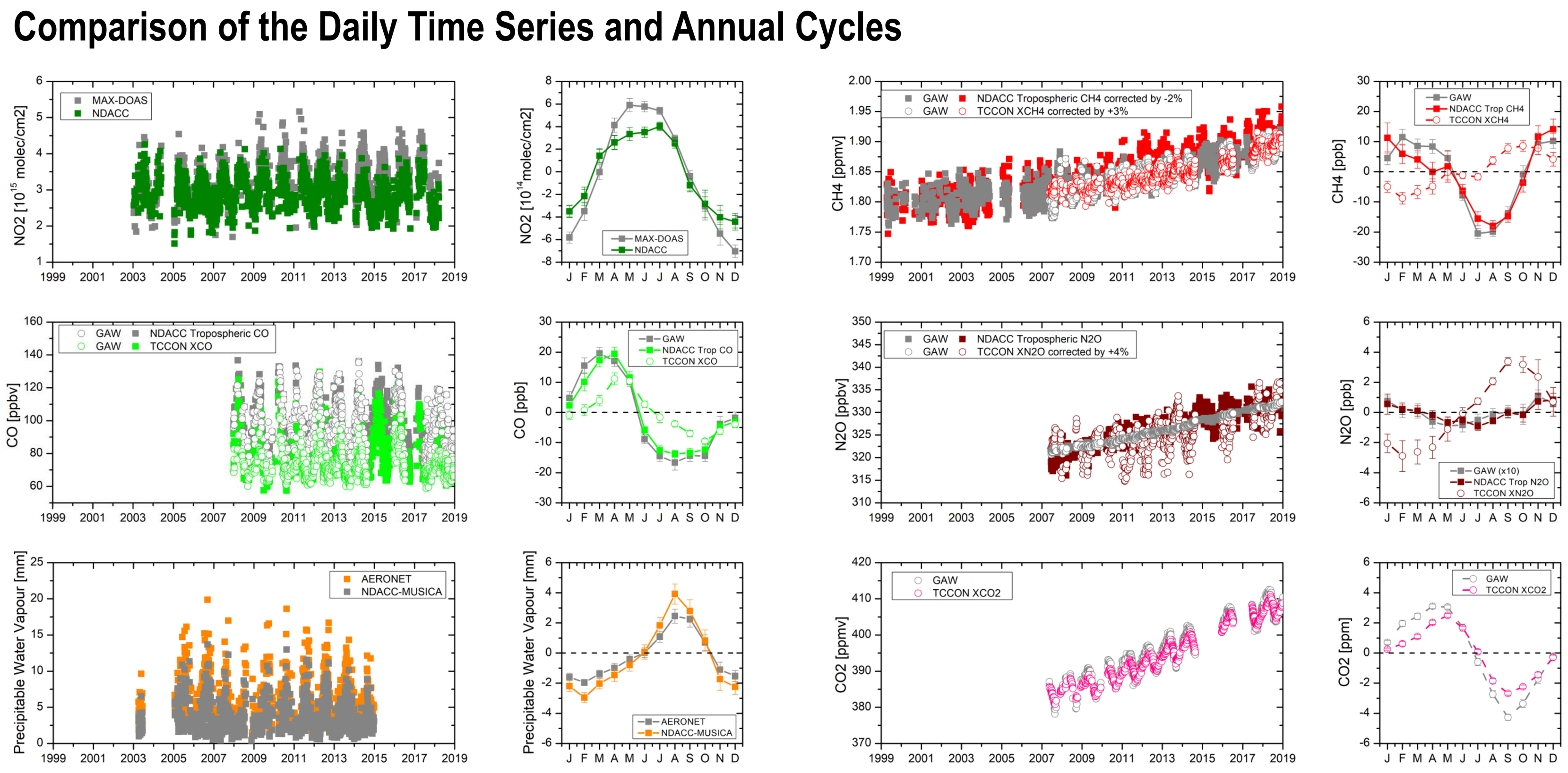
COMPARISON WITH INDEPENDENT IZO OBSERVATIONS

IZO Atmospheric Trace Gases Observations

At IZO other high-quality measurement techniques for monitoring atmospheric trace gases are available (Cuevas et al., 2017). By using those data a documentation of the quality and long-term consistency of the IZO FTS products is presented here.

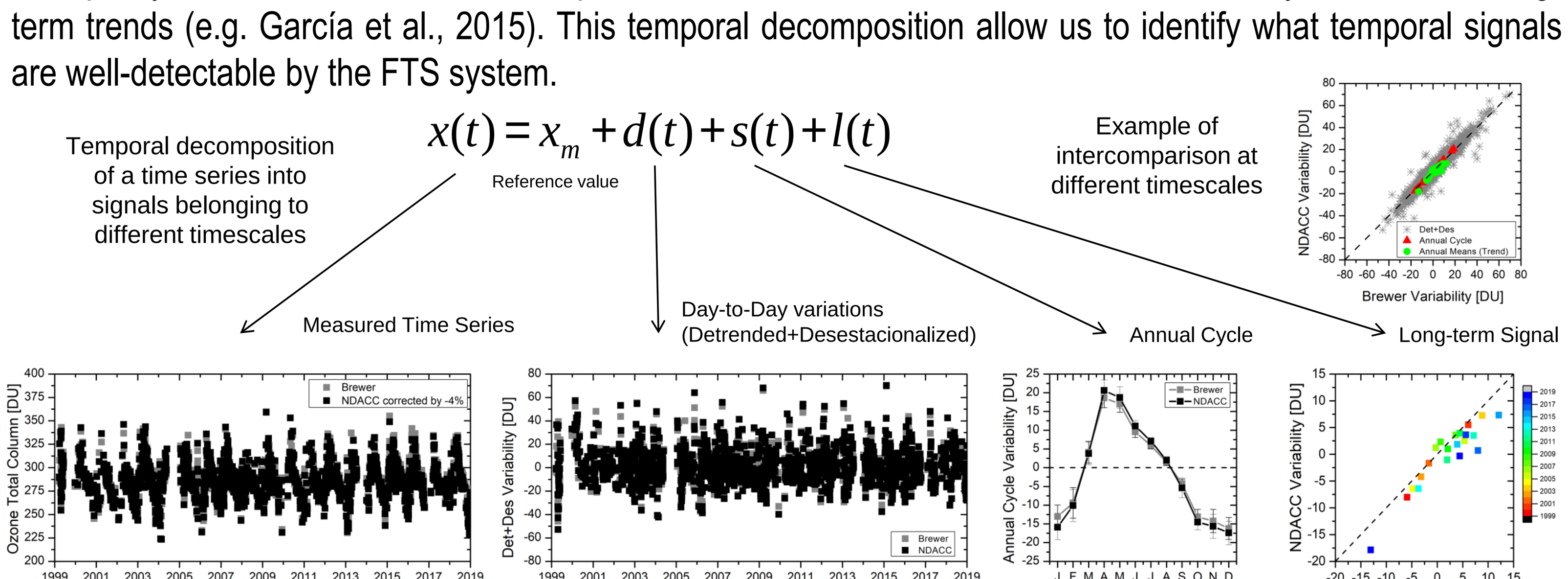
- Ground-level Greenhouse and Carbon Cycle Gases: Continuous measurements of CO_2 (since 1984), CH_4 (since 1984), and N_2O (since 2007) have been routinely carried out in the framework of the WMO-GAW programme. CO (since 2008) is also monitorized since it affects the CH_4 cycle.
- Nitrogen Dioxide Total Columns (TC): NO_2 TC are acquired with MAX-DOAS technique since 2003, contributing to NDACC network since 2010.
- Ozone Total Columns: Ozone TC observations are routinely performed with Brewer spectrometers since 1991, contributing to NDACC network since 2001.
- Water Vapour Total Columns: Water vapour TC measurements are taken at IZO by many different measurement techniques. Here, we only use those obtained from CIMEL sunphotometers within AERONET.

Comparison of the Daily Time Series and Annual Cycles



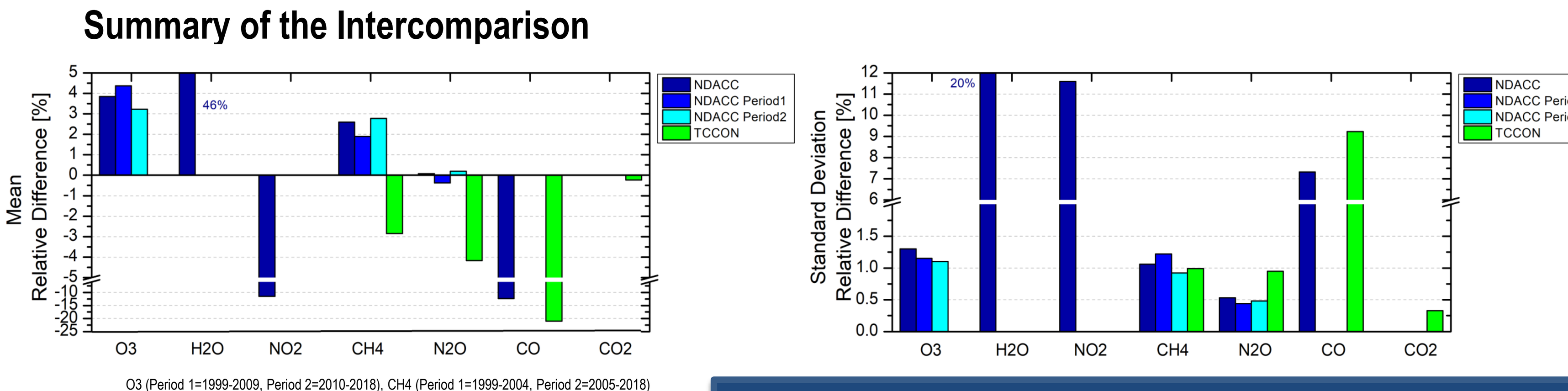
Comparison Strategy

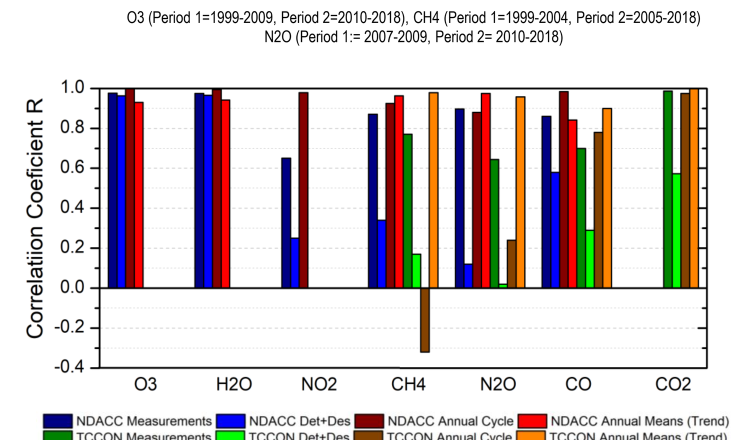
- The quality assessment of the IZO FTS products is addressed at different time scales: daily, annual, and long-term trends (e.g. García et al., 2015). This temporal decomposition allow us to identify what temporal signals are well-detectable by the FTS system.



- The NDACC tropospheric concentrations are obtained as the mean of the retrieved VMR profles between IZO altitude (2.37 km a.s.l.) and the middle troposphere (5.6 km a.s.l.).
- The relative differences are computed with respect to the independent IZO observations: $\mathrm{RD}\,[\%] = \frac{(\mathrm{FTS}-\mathrm{IZO})}{\mathrm{IZO}}$

Summary of the Intercomparison





After 20 years of operation, the IZO FTS programme has demonstrated a great value for atmospheric composition research.
The FTS instruments have been very stable and well-characterized during these 20 years.
By comparing to other independent IZO records, the IZO FTS observations have documented high quality and long-term consistency.

ACKNOWLEDGEMENTS

This work has strongly benefit from funding by the European Research Council under FP7/(2007-2013)/ERC Grant agreement nº256961 (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.
Frey et al., AMT, 2019.
García et al., AMT, 2015.
Hase, AMT, 2012.
Hase et al., JQSRT, 2004.
Schneider et al., ACP, 2005.
Wunch et al., PTRS, 2011.