climate change initiative

LONG-LIVED GREENHOUSE GAS
PRODUCTS PERFORMANCES

lolipop
cci

The LOng-LIved greenhouse gas PrOducts Performance (LOLIPOP) CCI+ project

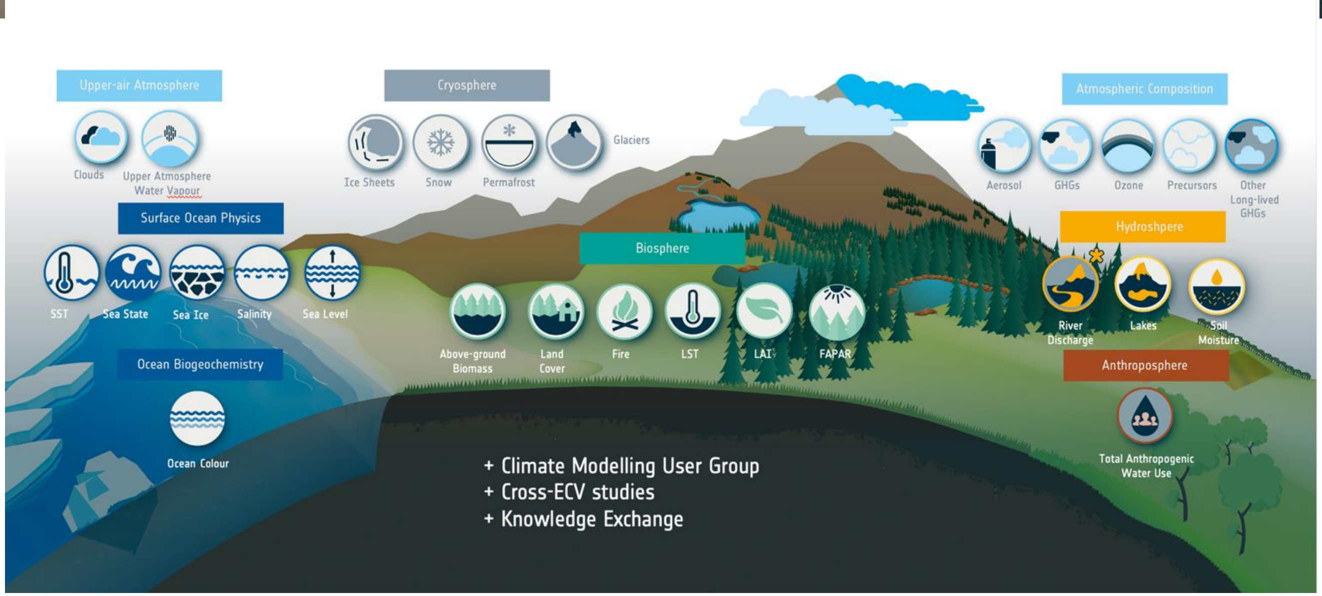
The LOLIPOP team

Rationale

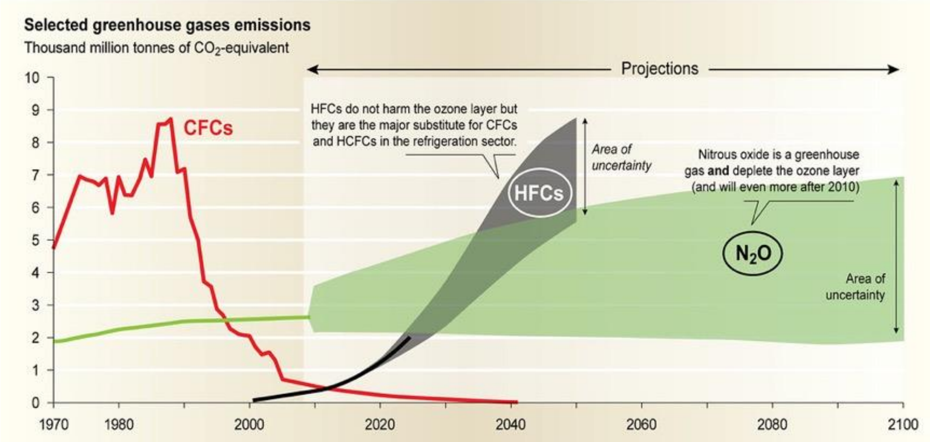
ESA's Climate Change Initiative is already generating robust satellite-based timeseries for the greenhouse gases water vapour, carbon dioxide (CO_2) and methane (CH_4)

Why Other Long-lived GHGs?

Nitrous oxide (**N_2O**) and halogenated carbon compounds (**CFCs, HFCs, HCFCs, PFCs**) are considered by GCOS as ECVs. These gases have **long atmospheric lifetimes**, exhibit **significant global warming potentials** and provide a **major contribution to radiative forcing uncertainty estimates**. Nitrous oxide and chlorine-containing OLLGHGs are also the **main sources of anthropogenic ozone depletion** and are regulated internationally under the 1987 UN Montreal Protocol.



HFC AND N_2O: TWO CLIMATE ENEMIES RELATED TO THE OZONE LAYER



Source: A. R. Ravishankara, John S. Daniel, Robert W. Portmann, *Nitrous oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century*, Science, August 2009.

Objective

To assess whether the current set of satellite-based observations is good enough to be used in climate science and services

If **YES** -> the construction of a harmonized and consistent dataset of satellite measurements can go ahead.

If **NO** -> to suggest actions to either improve the quality of satellite measurements of the OLLGHGs) or to develop dedicated satellite missions for their monitoring.

An inventory of the available datasets from limb and nadir satellite measurements has been performed for 11 OLLGHGs. **Based on the outcomes of the literature review, users' needs and satellite products inventory**, a selection of the data to be included in the homogenization and inter-comparison/validation exercise has been performed. **N_2O, SF_6, CFC-11 and CFC-12, (and, additionally, CFC-113, HCFC-22, CF_4, and CCl_4)** retrieved from limb and nadir measurements have been selected for the harmonization and validation exercise. The focus is on the data measured after 2002.

Summary of user needs

Based on the outcomes of the literature review and users' needs survey …

Species of interest	N_2O, CFC-11 and CFC-12			
Application	Evaluation (Chemistry-climate models)	Assimilation (Chemistry-climate models)	Emission inversion (chemistry-transport models)	Input for radiative transfer (weather and climate models)
Data format	Monthly latitude-height climatology/time-varying 3D distribution	individual VMR profiles/high-frequency 3D distribution (~ daily)	High-frequency 3D distribution (~3 hour)/individual VMR profiles	Monthly latitude-height climatology
Horizontal resolution	Few degrees		Around 10 km	Few degrees
Vertical resolution	1-3 km (less in upper atm)		High resolution close to surface	1-3 km
Vertical extension	Troposphere to mesosphere		Surface/lower troposphere	Troposphere and stratosphere
Accuracy	10% (but better at 2-5%), N_2O about 0,1 ppbv			
Additional requirements	Stability over time (no value) and assessment of systematic errors			

SF_6, CCl_4, HCFC-22, HCFC-134a, CF_4, HCFC-142b, HFC-23, CFC-13			
Evaluation (Chemistry-climate models)	Assimilation (Chemistry-climate models)	Emission inversion (chemistry-transport models)	Assessment of radiative forcing
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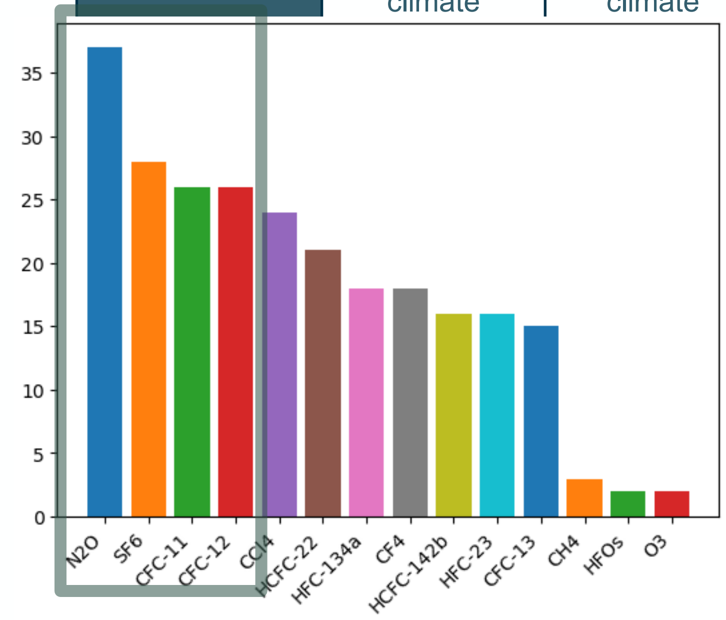


- **N_2O, SF_6, CFC-11** and **CFC-12**, retrieved from both limb and nadir measurements, have been selected for the harmonization and validation exercise
- Main focus on the data measured after 2002

Nadir - Limb satellite datasets harmonization

The N_2O nadir datasets have been harmonized in the format.

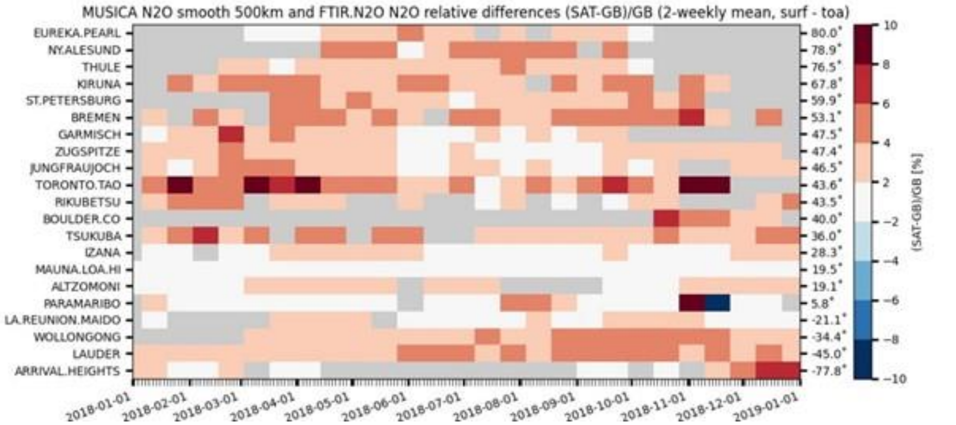
Name and reference	Platform	Time period
TES (Worden et al., 2012)	Aura	2004-08-22 to 2018-01-22
CrIS-CLIMCAPS (Smith at al., 2020)	Suomi-NPP	2015-11-02 to 2021-05-22
AIRS-CLIMCAPS (Smith et al., 2020)	Aqua	2002-08-31 to 2016-09-26
TANSO-FTS-FOCAL (Noël et al., 2022)	GOSAT	2019-2021
IASI-EUMETSAT	MetOp	2009-present
IASI-MUSICA (Schneider et al., 2022)	MetOp	2014-2019
IASI-NOPIR (Vandenbussche et al., 2020)	MetOp	2011-2020
IASI-SOFRID (Barret et al. 2021)	MetOp	2014+2008–2018 @8 NDACC stations
IASI-TN2OR (Chalinel et al., 2022)	MetOp	2011

The limb datasets have been harmonized in the format.

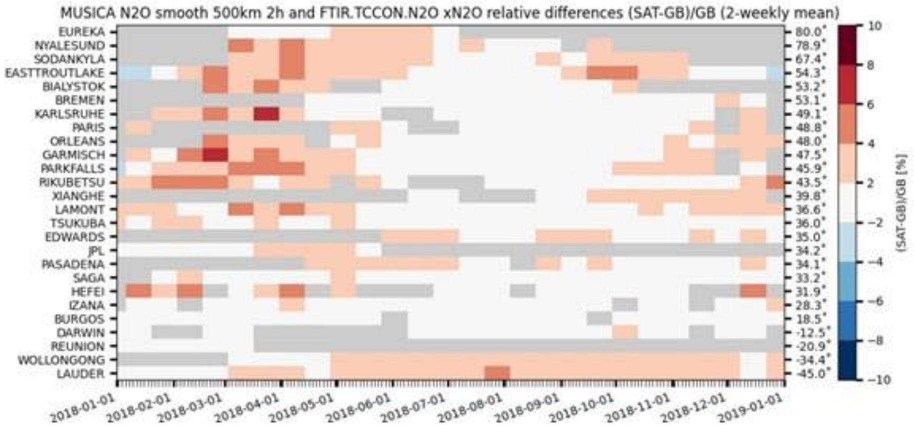
Name and reference	Platform	Gases	Time period
ACE-FTS (Bernath et al., 2005)	SCISAT	N_2O, CFC-11, CFC-12, SF_6	Feb 2004-present
HIRDLS (Gille et al., 2008)	Aura	N_2O, CFC-11, CFC-12	Jan 2005-Mar 2008
MIPAS (Fischer et al., 2008)	Envisat	N_2O, CFC-11, CFC-12 IMK-IAA only: SF_6	Jul 2002-April 2012
MLS (Waters et al., 2006)	Aura	N_2O	Aug 2004-present
SMR (Murtagh et al., 2002)	Odin	N_2O	Jan 2002-Sep 2022

In addition, **CRISTA-1/2 L2 products** harmonization is now ongoing. CRISTA was an infrared telescope instrument designed for applications on space shuttle missions (one week of operation in Nov 1994 and Aug 1997). A couple of the L2 products (N_2O, CFC-11) are of interest for LOLIPOP.

Nadir – Limb Intercomparison/validation results examples

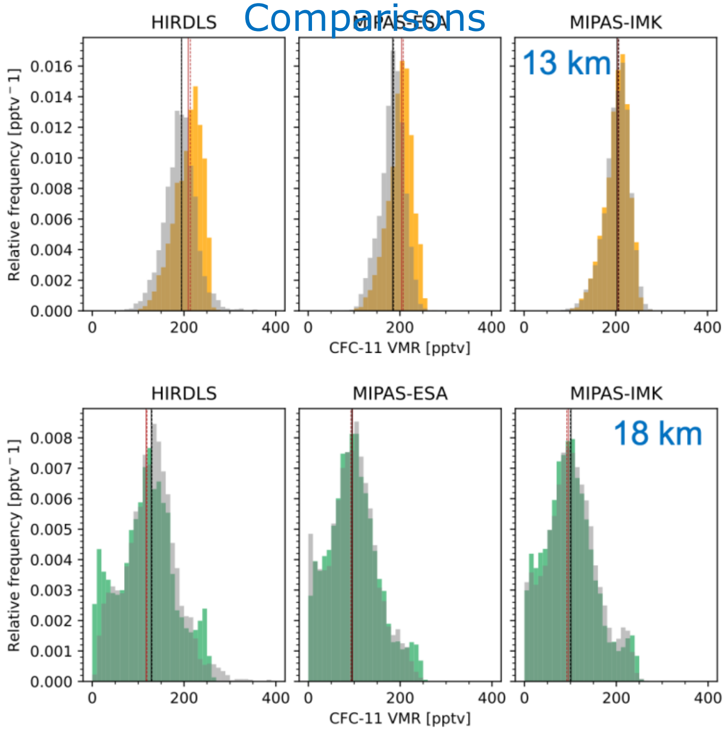


Bi-weekly median IASI-MUSICA N_2O total column concentration relative biases with respect NDACC per station



Bi-weekly median IASI-MUSICA XN_2O dry air mole fraction relative biases with respect TCCON per station

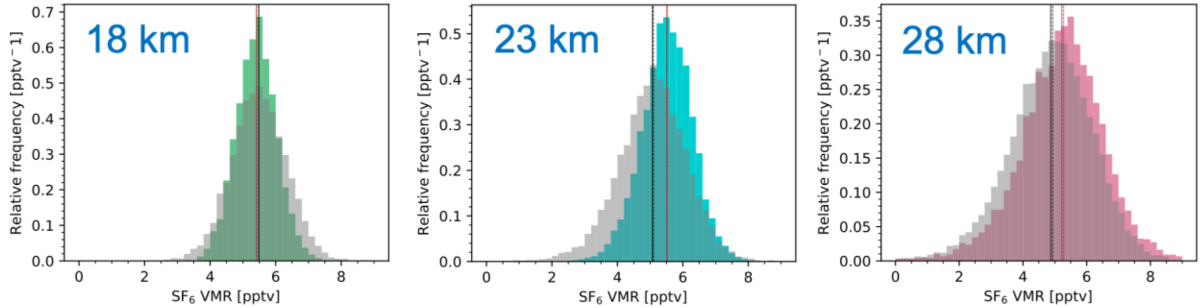
ACE-FTS v5.2 CFC-11 Comparisons



Probability density functions used to compare global coincident measurements at selected altitudes

- ACE-FTS v5.2 shown in colour
- Mean and median indicated by vertical lines.

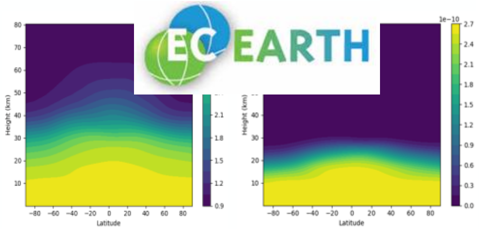
ACE-FTS v5.2 and MIPAS IMK SF_6 Comparisons



today's presentations

User case studies

Sensitivity of historical climate model simulations to the OLLGHG climatology

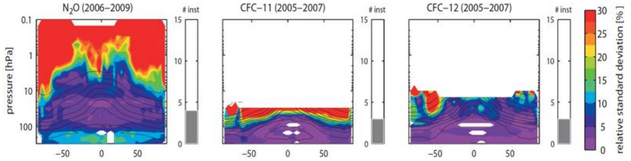


N2O climatology in EC-Earth and CFC-11 climatology used also for CFC-12 and other minor GHGs

Evaluate the sensitivity of the simulated climate to changes in the distribution of minor GHGs

Implement an updated climatology of GHGs in the EC-Earth climate model

Study of the radiative forcing of OLLGHG

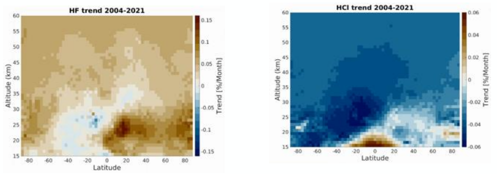


Uncertainties in key OLLGHGs as derived from satellite

Estimate the RF of long-lived GHGs using an off-line radiative transfer model, SOCRATES

Quantify uncertainties in RF due to uncertainties and distributions of OLLGHGs.

Monitoring of stratospheric chlorine levels and their impacts on ozone recovery

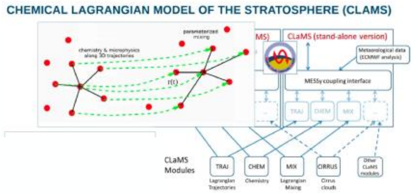


A first look at trends from ML-TOMCAT

Compare ACE-FTS, ML-TOMCAT chlorine datasets to better understand biases in the models.

Calculate trends in chlorine OLLGHGs and implications for stratospheric O_3.

CLaMS stratospheric circulation estimates



Stratospheric circulation changes form observed changes in OLLGHGs

Evaluating uncertainties in stratospheric circulation changes on OLLGHGs

The atmospheric lifetimes of OLLGHGs

Due to the importance of lifetimes of trace gases in the atmosphere to predict future abundances, infer emissions estimate, calculate global warming potentials.

We propose to determine the stratospheric lifetimes of some key species using ACE-FTS.

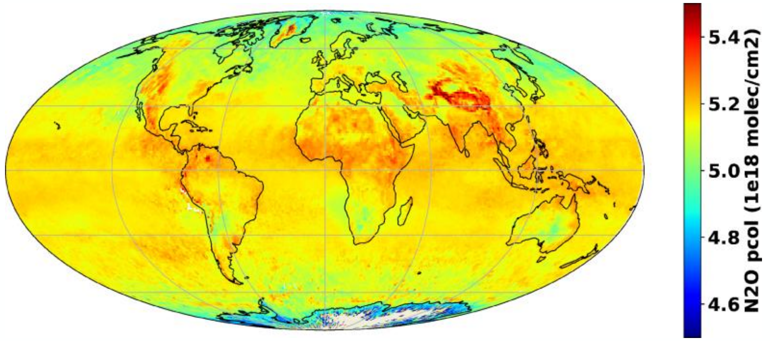
today’s presentations

Development or improvement of OLLGHGs satellite products

Exploring the possibility of using nadir looking satellite instruments for measuring OLLGHGs time series

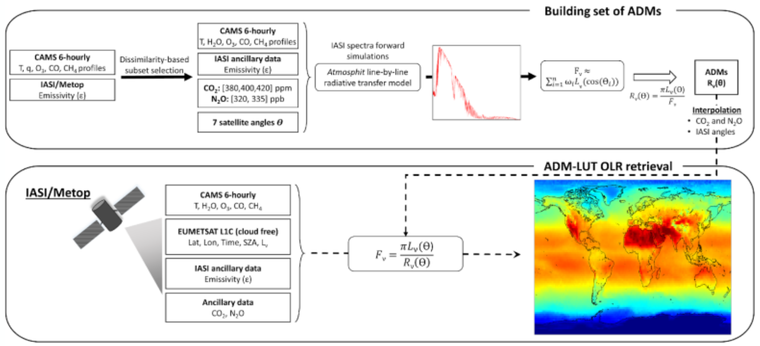
IASI can be exploited to obtain time series of N_2O and of other GHGs.
upgrade the forward and retrieval models **sigma-IASI/F2N and delta-IASI/F2N to retrieve OLLGHGs from IASI-like measurements**.

Consistent and improved N_2O profiles from IASI



Improve the NOPIR retrieval
Reprocess IASI-A and IASI-C time series using **consistent** EUMETSAT IASI CDR.

SR-OLR dataset and RFs of long-lived halogenated compounds from IASI



Update SR-OLR dataset 2008 to 2025
Derive the radiative forcing of gases from changes in SR-OLR.

Development or improvement of OLLGHGs satellite products

The spectroscopy of OLLGHGs

Bernath et al., JQSRT, 2020

CFC-113

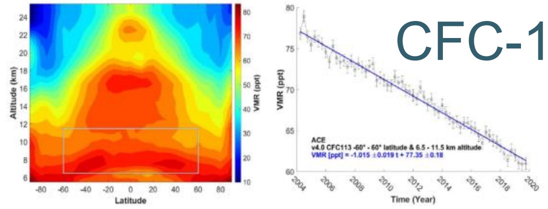
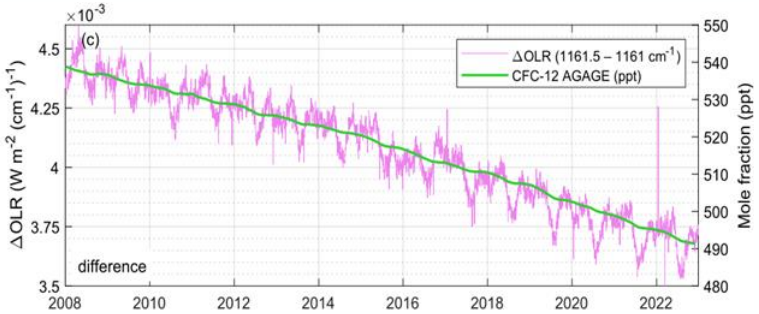


Fig. 3. CFC-113 (CCl_2FCClF_2) altitude-latitude distribution (left), and trends from ACE-FTS (right). The ACE-FTS VMR trend values are the average of data from 60°S to 60°N latitude and 6.5 to 11.5 km in altitude.

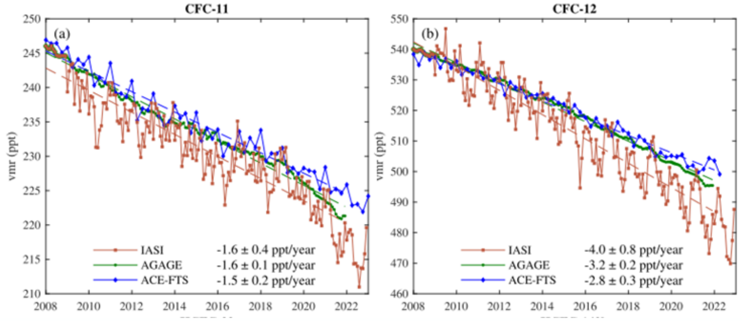
Absorption cross sections for CFC-113 and HCFC-142b from previous laboratory measurements.
Investigate the absorption cross sections of SF_6 and CF_4.
Identify the sources of spectroscopic data and microwindows in LOLIPOP dataset.

Study of N2O OLR trends and of the breakpoints in the time series of halogenated compound concentrations



Trends in the concentration of halogenated compounds and SOLR.
Computation of MetOp-A IASI OLR trends in N_2O bands
Quantification of the contribution of N_2O trends.

IASI time series extension to Tropics and Southern hemisphere and over land



Update time series from 2008 to 2025
Expand coverage to the tropics and the southern mid-latitudes for both land and oceans regions separately.

The LOLIPOP team

Scientific and Project Coordination:

CNR-ISAC: Elisa Castelli is the Science Leader supported by the former Science Leader Bianca Maria Dinelli

Serco Italia: Massimo Cardaci is the Project Manager supported by Gabriele Brizzi and Massimo Valeri

Retrieval team:

- **CNR-IFAC:** Piera Raspollini, Marco Gai, Samuele Del Bianco
- **UniBas:** Guido Masiello, Giuliano Liuzzi
- **LATMOS-SU:** Cathy Clerbaux, Maya George
- **SQUARES-ULB:** Pierre Coheur, Lieven Clarisse, Simon Whitburn
- **BIRA-IASB:** Sophie Vandenbusshe

Validation team:

- **BIRA-IASB:** Bart Dils, Corinne Vigouroux
- **UoT:** Kaley Walker, Laura Saunders
- **KIT-IMK:** Gabriele Stiller

Climate team:

- **FZJ:** Michaela Hegglin, Reinhold Spang, Felix Ploeger
- **NCEO:** Martyn Chipperfield, Jeremy Harrison, Antonio Giovanni Bruno
- **CNR-ISAC:** Federico Fabiano, Alessandro Montanarini

ESA Contacts: Simon Pinnock, Claire Macintosh

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