

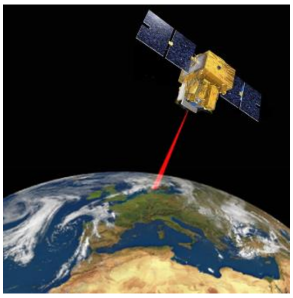


THE HALO-CoMet 2.0 ARCTIC MISSION

CoMet 2.0 Arctic aims to learn more about the distribution and temporal variation of the two most important anthropogenically-influenced greenhouse gases, carbon dioxide (CO_2) and methane (CH_4) in the Arctic. Aircraft-based instruments using both remote sensing and in-situ techniques will carry out measurements of these trace gases and tracers related to their emissions. The results will help to better understand the global methane and carbon cycle. This mission makes use of the German research aircraft HALO.

Scientific rationale

Carbon dioxide (CO_2) and methane (CH_4) have been recognized by the International Panel of Climate Change (IPCC) as the most important of the Earth's greenhouse gases which are directly modified by human activities and which are the main contributors to global warming.

In order to reliably predict the climate of our planet, and to help inform political conventions on greenhouse gas emissions such as the Paris Agreement of 2015, adequate knowledge of both natural and anthropogenic sources of these greenhouse gases (GHG) and their feedbacks is needed. Despite the recognized importance of this issue, our current understanding about sources and sinks of CO_2 and CH_4 is still inadequate. This is particularly true for the Arctic, where large wetlands and permafrost areas constitute the most relevant but least quantified ecosystems for the global carbon budget.

The Arctic is warming twice as fast as the global average, making climate change's polar effects more intense than anywhere else in the world. The Arctic accounts for half of the organic carbon stored in soils, and rising temperatures and thawing permafrost threaten its stability. The release of CO_2 and CH_4 from thawing permafrost will amplify global warming and further accelerate permafrost degradation. Fires in boreal forests and tundra peatlands are direct sources of CH_4 and CO_2 and also accelerate the thawing of permafrost, leading to the release of carbon. There is increasing, but divergent, evidence that a changing climate in the modern period has already shifted these ecosystems from net sinks of carbon to net sources, or will do so in the near future. The high-latitude natural sources also overlap with geologic CH_4 sources (e.g. natural gas seeps in the Mackenzie delta), as well as anthropogenic sources from fossil fuel excavation in e.g. Alaska or Alberta, making the separation of natural vs. anthropogenic signals difficult.

Two methodologies are used to infer GHG emissions in order to understand the global carbon budget: The bottom-up approach assesses emissions by aggregating inventories fed by data about fuel consumption, local activity data, and vegetation models. In contrast, the top-down approach is based on atmospheric measurements and inverse modelling. While the latter offers the potential to verify reported emissions with independent measurements, the two approaches still disagree to a degree that prevents accurate budgeting of the major greenhouse gases and fails to fully explain recent atmospheric trends.

Three prerequisites are required to optimally apply the top-down methodology: First, the atmosphere must be measured at high spatial and temporal resolution via networks of ground-based stations and aircraft. Second, remote sensing is necessary, from satellites to give global coverage, from the ground to calibrate the satellite data, and from aircraft to bridge the scales. Third, modelling is needed, to synthesize the results and convert the concentration measurements to surface fluxes.

Thus, the overarching goal of the CoMet 2.0 mission is to provide relevant measurements from Arctic regions using a suite of scientific instrumentation onboard the German research aircraft HALO to support state-of-the-art Earth system models. At the same time, CoMet intends to support and improve current and future satellite missions, which struggle to make high-quality measurements given the low sun elevation and adverse cloud conditions in the Arctic.

CoMet 2.0 is a sequel to CoMet 1.0, which was successfully carried out in Europe in 2018 and concentrated on anthropogenic emissions and instrument tests. CoMet 2.0 shall now transfer the methodologies developed during the first mission to the Arctic region. The mission has undergone scientific review by an international advisory board under the auspices of the German Research Foundation (DFG).

Timing and location of CoMet 2.0

CoMet 2.0 Arctic is foreseen for a six-week intensive operation period from **August to mid-September 2022** targeting boreal wetlands and permafrost areas in the **Alaskan and Canadian Arctic**. The exact location of the campaign base is still to be defined. A total of 120 flight hours, including transfer flights from Germany, are planned, enabling approximately 11-13 scientific flights on site.

The HALO aircraft

The High Altitude and LOng Range Research Aircraft (HALO), callsign D-ADLR, is a research platform for atmospheric and Earth system research, operated by the German Aerospace Center (DLR) on behalf of a consortium consisting of the German Research Foundation (DFG), the Max Planck Society, the German Aerospace Center, Forschungszentrum Jülich, the Karlsruhe Institute of Technology, the German Research Centre for Geosciences, and the Leibniz Institute for Tropospheric Research. HALO-supported research focusses on questions at the interface between Earth system processes and human activity using integrated and system-oriented approaches. It also enables scientists to develop high-technology sensors and new instruments and deploy them in atmospheric and geoscience research.

Originally a standard Gulfstream G550 twin-engine jet aircraft, the aircraft has been significantly modified to make it suitable for scientific use. HALO has a maximum range of about 10 000 km or > 10-h endurance, a ceiling altitude of 14.5 km and is able to carry a scientific payload of up to 3000 kg.

Scientific instrumentation

For the CoMet 2.0 mission, HALO will be equipped with a suite of sophisticated instruments measuring the carbon dioxide and methane columns between the aircraft and the ground using remote sensing, as well as in-situ instruments that collect air samples at flight level. Furthermore, instruments to provide detailed information about the standard meteorological parameters (pressure, wind, humidity) will also be on board. In order to link those in-flight data to profiles, the launch of small meteorological sondes is foreseen.

The payload is exclusively dedicated to atmospheric measurement. The following table gives an overview on the instruments onboard the aircraft during CoMet and their measurement parameters.

Scientific instrument acronym	Description	Measurement parameters	Institution
CHARM-F	Active Remote Sensing (Lidar)	CO_2 and CH_4 columns	DLR IPA
MAMAP2D	Imaging NIR spectrometer	CO_2 and CH_4 columns	IUP-UB
HALO_JIG	Cavity-Ring-Down Spectroscopy	CO_2, CH_4, H_2O, CO	MPI-BGC
HALO_JAS	Collection of atmospheric air samples	^{2}H, ^{13}C, and ^{18}O isotopes (in CO_2, CH_4, N_2O, CO)	MPI-BGC
MIRACLE	Laser Spectrometer	CH_4, CO_2, C_2H_6, $^{13}C(CH_4)$	DLR IPA
specMACS (tbd)	Hyperspectral imaging	Land surface properties, clouds, aerosol	LMU Munich
BAHAMAS	HALO basic data acquisition system	Pressure, temperature, humidity, aircraft attitude data	DLR FX
SHARC	Laser Spectrometer	Water vapour	DLR FX
Dropsonde	Meteorological mini-sondes	Pressure, temperature, humidity, wind profiles	DLR IPA
FOKAL (tbd)	Frequency Comb	Frequency reference for CHARM-F	DLR IPA

German consortium

CoMet 2.0 has been scientifically approved by the German Research Foundation (DFG) and is jointly conducted by the following scientific institutions:

- DLR-IPA: German Aerospace Center (DLR)
  Institute of Atmospheric Physics, Oberpfaffenhofen (Germany) http://www.dlr.de/ipa/
- IUP-UB: Institute of Environmental Physics, University of Bremen, Bremen (Germany) http://www.iup.uni-bremen.de
- MPI-BGC: Max Planck Institute for Biogeochemistry Jena (Germany) http://www.bgc-jena.mpg.de/
- DLR-FX: German Aerospace Center (DLR),
  Flight Experiments, Oberpfaffenhofen (Germany) http://www.dlr.de/fb/

International cooperation

CoMet 2.0 will be coordinated in conjunction with the Arctic-Boreal Vulnerability Experiment (ABoVE) which is a NASA Terrestrial Ecology Program field campaign conducted in Alaska and Western Canada. ABoVE is a large-scale study of environmental change and its implications for social-ecological systems focused on gaining a better understanding of the vulnerability and resilience of Arctic and boreal ecosystems to environmental change and providing the scientific basis for informed decision-making to guide societal responses from local to international levels. Both missions, ABoVE and CoMet 2.0, are linked through the transatlantic initiative AMPAC (Arctic Methane and Permafrost Challenge) that has recently been inaugurated by the US and European Space Agencies, NASA and ESA.

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