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AIRCORE-FR RELEASE 2024

USER DOCUMENTATION

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1. Introduction

The AirCore is an atmospheric sampler that allows the measurement of the vertical profiles (from the surface up to about 30 km of altitude) of atmospheric mixing ratio of greenhouse gases (CO₂, CH₄, CO, N₂O). Initially proposed by NOAA (Tans, 2009; Karion et al., 2010; Membrive et al. 2017), it consists in a long tube of stainless steel placed under a meteorological balloon which, in the ascending phase, empties its air by its open end and is then filled progressively by the atmospheric air during its descent phase. The captured air column is then analyzed using a Picarro CRDS analyzer and finally interpreted in terms of profiles of vertical gas mixing ratio against pressure and altitude using other instruments onboard measuring in particular pressure and/or altitude (electronic board, meteosonde, GPS beacons).

Since 2013, several versions of AirCore have been developed by LMD (CNRS / Ecole Polytechnique / ENS Paris / Sorbonne University) and have then been deployed in partnership with CNES, LSCE (CNRS / CEA / University of Versailles-Saint-Quentin-en-Yvelines), GSMA (CNRS / Université de Reims), OPGC (CNRS / Blaise Pascal University) and CARE-C (The Cyprus Institute), in various places around the globe. Regular launches are organized since 2016 at several stations that form the French AirCore program: Aire-sur-l'Adour (ASA), Traînou (TRN), Reims (MDH). Additional launches are organized during large-scale, multi-instrument field campaigns, such as MAGIC.

The development and deployment of AirCores are carried out in the framework of projects funded by the CNES, CNRS, CEA, Ecole polytechnique, IPSL, the European Union and the University of Reims Champagne-Ardenne.

The present AirCore-FR network dataset comprises all Level 2 gas vertical profiles, along with Level 1 meteosonde and trajectory data, acquired by the French AirCore program from 2014 at all launch sites.

2. Release 2024 main updates

- Reanalysis of all the flights performed over 2014-2023
- Homogenization of the processing version: 14
- Update of the standard gas scales for CO₂: WMO X2019 now (against WMO X2007 before).
- Number of flights with gas profiles retrievals: 235

3. AirCore database description

The files provided in this database, corresponding to the AirCore flights, have the following typical name:

`AC_SSS_YYYYMMDDHHMN_NNN_vVVVV.nc`

with:

SSS: flight station code (refer to array A1 below)

YYYYMMDD: AirCore launch date

HHMN: AirCore launch time (UTC)

NNN: flight number (001 corresponds to the first flight of the year)



VVVV: database release version

E.g.: AC_ASA_202009130834_012_v2024.nc

Site code	Site (City) name	Country
ASA	Aire-sur-l'Adour	France
ASP	Alice Springs	Australia
CYP	Cyprus	Cyprus
KIR	Kiruna	Sweden
MDH	Moulin De la Housse (Reims)	France
TMS	Timmins	Canada
TRN	Traînou	France

Array A1: flight location

Each NetCDF file has the following main structure:

- Global attributes: main information, like contact email, AirCore website address, launch site name and contributors corresponding to the flight considered.
- Flight group: contains general information on the AirCore flight, like launch location and date, longitude, latitude, UTC time at launch or landing, maximum geopotential altitude, the type of AirCore used (e.g., Light, High Resolution), the Picarro analyzer used to measure gas concentrations against time, the AirCore input valve automatic/manual status indicating if the AirCore sample has been preserved at landing or later (the latter case implies the loss of the lower tropospheric part of the vertical gas profiles retrievals) or the delay between landing and the start of the AirCore sample Picarro analysis (the lower this delay, the finer the vertical resolution of the vertical gas profiles retrievals, due to molecular diffusion within AirCore tubes).
- AirCore group: contains the gas vertical profiles against pressure and altitude obtained during the descent of the balloon, as well as the corresponding UTC time, latitude and longitude. The available gases depend on the Picarro used to analyze AirCore sample (possible gases: CO₂, CH₄, CO, N₂O). Note that CO can be measured here either by G2401 Picarro or by G5301 Picarro. In the first case, CO is very noisy. A quality flag has been added to give an indication of uncertainty regarding vertical position of the gas profiles retrievals (uncertainties will be added in next releases). Finally, temperature and relative humidity profiles measured by the meteosonde used on the same flight are also available in this group (but interpolated here).
- Meteosonde group, divided into Ascent and Descent subgroups: contains data (if available) measured by the meteosonde during either ascent or descent of the balloon, that is, UTC time, latitude, longitude,



geopotential altitude, temperature, relative humidity, 3D wind components, as well as empirical pressure computed from meteosonde altitude.

- Trajectory group: contains complete (if possible) UTC time, latitude, longitude and geopotential altitude data during both ascent and descent of the balloon.

- Availability group: contains information if data from AirCore, meteosonde during ascent, meteosonde during descent and trajectory are available or not. AirCore_fields, Meteosonde_fields, Trajectory_fields subgroups provide information if the physical variables within AirCore, Meteosonde and Trajectory groups respectively are available or not.

Availability group and corresponding subgroups are therefore useful to know which data and variables are available for a given AirCore flight. This is used for instance in the netCDF file reading program described in the following section or within automatic processing chain.

For the complete list of groups/subgroups and variables provided, refer to Annex in the end of the present documentation.

4. NetCDF file reading program

Objective:

Provide user assistance for quick handling of the netCDF file.

1. Visualization of the general architecture and variables available in the different groups
2. Example of quick visualization of the main variables (CO₂, CH₄, CO, N₂O, T, RH) as a function of pressure; this template can then be adapted by users.

Syntax:

- Displaying help : `python aircore_database_read.py`
- 2 execution mode:

Mode 0 = Displaying netCDF file architecture :

`python aircore_database_read.py AC_SSS_YYYYMMDDHHMM_NNN_vVVVV.nc 0`

Mode 1 = Graphical display of the main variables as a function of pressure P :

`python aircore_database_read.py AC_SSS_YYYYMMDDHHMM_NNN_vVVVV.nc 1`

5. Revision history

Main notes:

- Some flights which have not been processed in the previous release have been added as well as 2022 and 2023 flights. All flights below the end of 2023 have therefore been processed in this new release.
- Three flights with bad quality data have been removed: ASA 20190410 #004, ASP 20170404 #001, KIR 20210822 #005.
- The following flights performed at Sodankylä (Finland) have been removed: SDK 20180618 #001, SDK 20180620 #002 and SDK 20180621 #003.
- netCDF file name has been changed: AC_SSS_YYYYMMDD_NNN_V1.nc before against AC_SSS_YYYYMMDDHHMN_NNN_vVVVV.nc now, by adding HHMN UTC hour and minutes at

launch for better launch time identification, easier collocation with other data, and more explicit release version used.

- Homogenization of the processing version: version 14 is now used for all flights, in replacement of version 13 or below before. Old ZPD-balloons flights (i.e., TMS 2014, TMS 2015, KIR 2016, ASP 2017, TMS 2018) have not been reprocessed with version 14, but updated with above improvements.
- Due to homogenization of the processing version, various flights may have been modified, regarding the vertical position of the gas profile retrieval in pressure and altitude.
- Update of the standard gas scales for CO₂: WMO X2019 now against WMO X2007 before.
- Concentrations of several gas tanks used to calibrate Picarro data have been updated by LSCE. Hence, gas concentrations have been updated if necessary.
- Group "Meteosonde" in the netCDF files has been divided into 2 subgroups: "Ascent" and "Descent", and missing values have been added at a given time if no data at that time.
- Variables within group "Trajectory" in the netCDF files have been modified in order to keep undefined latitude/longitude/altitude values with time continuity from balloon take-off to landing.
- Global attributes have been updated.
- Some variables have been added in group "Flight" within the netCDF files: analyzer_SN, carrier_tank, carrier_CO₂, carrier_CH₄, carrier_CO, carrier_N₂O, filling_tank, filling_CO₂, filling_CH₄, filling_CO, filling_N₂O, p_min.
- P variable (empirical pressure computed from meteosonde altitude) has been added in subgroups "Ascent" and "Descent" of group "Meteosonde".
- User documentation has been added.
- Reading program in python has been added.
- Corrections about time variables have been performed for a few flights.
- Profiles from flights TRN 202101201001 #001, TRN 202007240855 #003 and TRN 201711070953 #015 were bugged before. They have been corrected in this new release.
- Altitude variable in group Trajectory of the netCDF files was sometimes bugged, being pressure instead of altitude. This bug has been corrected.
- Pressure and altitude at landing have been updated.
- "recovery_delay" variable (i.e., duration between AirCore landing time and sample analysis start) was sometimes not well computed. This has been corrected.

ANNEXE: NetCDF file structure and list of variables

Global attributes	Example
NCPproperties	NetCDF-Fortran 4.5.3
contact	aircore-fr@aeris.fr
website	https://aircore.aeris-data.fr/
Network_name	AirCore-Fr
Station_name	Aire-sur-l'Adour
Station_code	ASA
Station_supervising_PI	Stéphane LOUVEL
Station_PI	Laurent TESSARIOL
Station_AirCore_responsible	Serge CRUZEL
Network_PI	Cyril CREVOISIER
Aircore_manufacturing	Axel GUEDJ
Aircore_processing	Jérôme PERNIN
Contributors	Centre National d'Etudes Spatiales (CNES), Laboratoire de Météorologie Dynamique (LMD)
processing_version	14
standard_gas_scale_version	2
creation	2024-18-10 15:54:47 (UTC)



Group (/Subgroup)	Variable name	Variable description	Unit
Flight	mission	Mission	-
	location	Flight location	-
	launch_date	AirCore launch date	-
	flight_number	Flight number	-
	site_l	Landing site	-
	aircore_id	AirCore ID	-
	aircore_type	AirCore type name	-
	tube1_length	Length of AirCore tube 1	m
	tube1_ext_dia	External diameter of AirCore tube 1	mm
	tube1_width	Width of AirCore tube 1	mm
	tube2_length	Length of AirCore tube 2	m
	tube2_ext_dia	External diameter of AirCore tube 2	mm
	tube2_width	Width of AirCore tube 2	mm
	analyzer	Analyzer type	-
	analyzer_SN	Analyzer serial number	-
	measure_orientation	Part of the gas profiles analyzed first by the Picarro	-
	gas_calibration_scale	Gas calibration scales	-
	carrier_tank	Tank used for pushing the gas sample within AirCore tubes during analysis	-
	carrier_CO2	Calibrated CO2 dry value of the carrier tank	ppm
	carrier_CH4	Calibrated CH4 dry value of the carrier tank	ppb
	carrier_CO	Calibrated CO dry value of the carrier tank	ppb
	carrier_N2O	Calibrated N2O dry value of the carrier tank	ppb
	filling_tank	Tank used for filling AirCore tubes before flight	-
	filling_CO2	Calibrated CO2 dry value of the filling tank	ppm
	filling_CH4	Calibrated CH4 dry value of the filling tank	ppb
	filling_CO	Calibrated CO dry value of the filling tank	ppb
	filling_N2O	Calibrated N2O dry value of the filling tank	ppb
	time_t	UTC time at takeoff	(UTC)
	time_max_altitude	UTC time at maximum altitude	(UTC)
	time_l	UTC time at landing	(UTC)
	valve_status	AirCore input valve closing status manual : closed by the recovery operator auto : closed by electronic board	-
	time_valve_closing	UTC time when AirCore input valve has been closed	-
	time_analysis_start	UTC time at the start of AirCore sample analysis	-
	time_analysis_end	UTC time at the end of AirCore sample analysis	-
	recovery_delay	Duration between AirCore landing time and sample analysis start	-
	lat_t	Latitude at takeoff	degree N
	lon_t	Longitude at takeoff	degree E
	psurf_t	Surface pressure at takeoff	hPa
	alt_t	Surface geopotential altitude at takeoff	km
	p_min	Minimum pressure at top	hPa
	alt_max	Maximum geopotential altitude at top	km
	lat_l	Latitude at landing	degreeN
	lon_l	Longitude at landing	degree E
	psurf_l	Surface pressure at landing	hPa
	alt_l	Surface geopotential altitude at landing	km



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Group (/Subgroup)	Variable name	Variable description	Unit
AirCore	time	UTC elapsed time since 00h of launch day	s (UTC)
	lat	Latitude	degree N
	lon	Longitude	degree E
	P	Pressure AirCore profile	hPa
	alt	Geopotential altitude	km
	T	Temperature profile measured by meteosonde (interpolated)	K
	RH	Relative humidity profile measured by meteosonde (interpolated)	%
	CO2	CO2 (carbon dioxide) AirCore profile restituted from Picarro G2301/G2401/G2201i data	ppm
	CH4	CH4 (methane) AirCore profile restituted from Picarro G2301/G2401/G2201i data	ppb
	CO	CO (carbon monoxide) AirCore profile restituted from Picarro G2401 data	ppb
	CO_G53	CO (carbon monoxide) AirCore profile restituted from Picarro G5301 data	ppb
	N2O	N2O (nitrous oxide) AirCore profile restituted from G5301 data	ppb
	quality_flag	quality flag for gas profiles vertical adjustment (compression/dilation and position) with pressure 0 (good quality) 1 (bad quality)	-

Group (/Subgroup)	Variable name	Variable description	Unit
Meteosonde /Ascent	time	UTC elapsed time since 00h of day YYYYMMDD	s (UTC)
	lat	Latitude measured by meteosonde GPS	degree N
	lon	Longitude measured by meteosonde GPS	degree E
	P	Empirical pressure computed from meteosonde GPS altitude	hPa
	alt	Geopotential altitude measured by meteosonde GPS	km
	T	Temperature profile measured by meteosonde	K
	RH	Relative humidity profile measured by meteosonde	%
	DPT	Dew point temperature profile measured by meteosonde	K
	U	Zonal wind component measured by meteosonde	m/s
	V	Meridional wind component measured by meteosonde	m/s
	W	Vertical wind component measured by meteosonde	m/s

Group (/Subgroup)	Variable name	Variable description	Unit
Meteosonde /Descent	time	UTC elapsed time since 00h of day YYYYMMDD	s (UTC)
	lat	Latitude measured by meteosonde GPS	degree N
	lon	Longitude measured by meteosonde GPS	degree E
	P	Empirical pressure computed from meteosonde GPS altitude	hPa
	alt	Geopotential altitude measured by meteosonde GPS	km
	T	Temperature profile measured by meteosonde	K
	RH	Relative humidity profile measured by meteosonde	%
	DPT	Dew point temperature profile measured by meteosonde	K
	U	Zonal wind component measured by meteosonde	m/s
	V	Meridional wind component measured by meteosonde	m/s
	W	Vertical wind component measured by meteosonde	m/s



Group (/Subgroup)	Variable name	Variable description	Unit
Trajectory	time	UTC elapsed time since 00h of day YYYYMMDD	s (UTC)
	lat	Estimated latitude	degree N
	lon	Estimated longitude	degree E
	alt	Estimated geopotential altitude	km

Group (/Subgroup)	Variable name	Variable description	Unit
Availability	AirCore	yes / no	-
	Meteosonde_ascent	yes / no	-
	Meteosonde_descent	yes / no	-
	Trajectory	yes / no	-
Group (/Subgroup)	Variable name	Variable description	Unit
Availability /AirCore_fields	lat	yes / no	-
	lon	yes / no	-
	P	yes / no	-
	alt	yes / no	-
	T	yes / no	-
	RH	yes / no	-
	CO2	yes / no	-
	CH4	yes / no	-
	CO	yes / no	-
	CO_G53	yes / no	-
	N2O	yes / no	-
Group (/Subgroup)	Variable name	Variable description	Unit
Availability/ Meteosonde_fields	lat	yes / no	-
	lon	yes / no	-
	P	yes / no	-
	alt	yes / no	-
	T	yes / no	-
	RH	yes / no	-
	DPT	yes / no	-
	U	yes / no	-
	V	yes / no	-
	W	yes / no	-
sGroup (/Subgroup)	Variable name	Variable description	Unit
Availability /Trajectory_fields	lat	yes / no	-
	lon	yes / no	-
	alt	yes / no	-