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Executive Summary

This ECV Inventory Document (EID) provides a comprehensive overview of the satellite-derived datasets relevant to aerosol-cloud interactions (ACI), compiled within the context of the SATACI project. Building on the scientific framework and requirements outlined in Deliverable D1.1 (Science Requirements Document), this inventory identifies and characterizes Essential Climate Variable (ECV) datasets that are suitable for improving constraints on aerosol–cloud processes and evaluating their radiative impacts.

The datasets included span a range of satellite missions and algorithms, with a focus on high temporal and spatial resolution products derived from both geostationary and polar-orbiting platforms. These datasets cover variables such as Aerosol Optical Depth (AOD), Fine Mode AOD (FMAOD), Dust AOD (DAOD), Cloud Droplet Number Concentration (CDNC), Cloud Optical Depth (COD), Cloud Phase (CPH), and Liquid Water Path (LWP), among others. Each dataset entry documents algorithm names, temporal and spatial resolution and coverage, key variables, availability of pixel-level uncertainties, and references to relevant documentation (PUGs, ATBDs, validation reports, and peer-reviewed literature).
The inventory is organized into activities and scientific studies, reflecting different observational strategies and thematic focuses. Particular attention is given to datasets generated within the ESA Climate Change Initiative (CCI) and Copernicus Climate Change Service (C3S), which provide long-term, consistent records critical for climate model evaluation and ACI research. The inclusion of products from Cloud_cci, CM SAF CLAAS-3, CISAR, ORAC, MODIS, POLDER, and IASI ensures a wide range of aerosol and cloud retrieval approaches are represented.

The datasets have been selected for their relevance to key science questions, and their potential to address existing knowledge gaps identified in recent literature and IPCC assessments. Priority was given to datasets offering well-characterized uncertainties and those enabling pixel-level collocation of aerosol and cloud properties, which is essential for quantifying ACI processes at relevant spatial and temporal scales.

This document serves as a foundational resource to guide the use of satellite data within SATACI for advancing the understanding of aerosol–cloud interactions and assessing the feasibility of new climate indicators related to aerosol-induced cooling effects.

Version	Date	Modified Items/Reason for change
V1.0	2025/04/03	First released version
V1.1	2025/05/09	Add introduction to Section 2.1.1, 2.1.2 and 2.2 to explain the rationale for the selection of the datasets. Added data provider for each dataset and reference to the unique dataset identifier.

1 Definition and abbreviation

This section summarizes the major definitions relevant for the user requirements.

Definition/ abbreviation	Explanation
ACI	Aerosol-Cloud Interactions
ALH	Aerosol Layer Height
AOD	Aerosol Optical Depth: is the vertically normalized atmospheric column integrated aerosol extinction at a certain wavelength or waveband (usually at 550nm, the reference wavelength in modelling). AOD is also often referred to as Aerosol Optical Thickness (AOT).
ATBD	Algorithm Theoretical Basis Document
BIRA	Royal Belgian Institute for Space Aeronomy
C3S	Copernicus Climate Change Service: offers information on climate change and its impacts on many sectors via the Climate Data Store (CDS)
CISAR	Combined Inversion of Surface and Aerosols
CC4CL	Community Cloud retrieval for Climate
CCI	Climate Change Inititative: Generates global, long-term satellite data records of ECVs to track and understand key aspects of Earth's climate system.
CCN	Cloud Condensation Nuclei: subset of atmospheric aerosols on which water vapour condenses for cloud formation.
CER16	Cloud Effective Radius computed from 1.6mm
CER39	Cloud Effective Radius computed from 3.9mm
CDNC	Cloud Droplet Number Concentration
COD	Cloud Optical Depth
CPH	Cloud Phase
CTP	Cloud Top Pressure
CTT	Cloud Top Temperature
DALH	Dust ALH.
DAOD	Dust AOD.
DWD	Deutscher Wetter-Dienst
ECVs	The Essential Climate Variables are geo-physical quantities of the Earth-Atmosphere System that are technically and economically feasible for systematic (climate) observations.
FMAOD	Fine Mode AOD (also AODf) is the part of the total AOD which is contributed by fine mode aerosol particles. This quantity (and its optically defined fraction of the total AOD) depend both on wavelength; usually FMAOD at 550 nm is provided. When AOD at 4 wavelengths is available (e.g. from AERONET or some satellite retrievals), FMAOD can be inferred from it with the SDA algorithm.
FMF	The Fine Mode Fraction is the fraction of the total AOD which is contributed by aerosol particles smaller than 1um in diameter. Due to their smaller size these aerosol particles are referred to as fine-mode aerosol, in contrast to larger or coarse model aerosol

	particles. Although microphysicallydefined the quantity is wavelength dependent, as smaller aerosol contribute stronger at smaller wavelengths in the visible spectral regions, Usually, the mid-visible wavelength of 550nm is assumed as reference wavelength.
IMS	Infrared and Microwave Sounding
INPs	Ice Nucleating Particles
LMD	Laboratoire de Météorologie Dynamique
ML	Machine Learning
NN	Neural Network
ORAC	Optimal Retrieval of Aerosol and Cloud
PQAR	Product Quality Assessment Report
PUG	Product User Guide
RAL	Rutherford Appleton Laboratory
SSA	The Single Scattering Albedo quantifies the fraction of the attenuation (or extinction) due to scattering at a certain wavelength (usually at 550nm)
ULB	Université Libre de Bruxelles
VAL	Validation Report

2 ECVs Dataset

The following sections provide a structured inventory of satellite-based datasets relevant to the study of aerosol–cloud interactions (ACI). These datasets are grouped by the SATACI thematic activities and scientific studies. Information is presented in a harmonized tabular format to facilitate comparison across sources, and to support dataset selection for subsequent scientific analyses within the SATACI framework.

For each dataset, the following information are listed: dataset name, algorithm, data provider, temporal and spatial characteristics, available geophysical variables, uncertainty quantification, and documentation sources. Emphasis is placed on products with high spatial/temporal resolution and robust uncertainty characterization, given their importance for resolving sub-grid scale processes and enabling meaningful statistical relationships between aerosol and cloud properties.

This inventory represents the starting point of the SATACI project, and it might be updated following the fitness-for-purpose exercise.

2.1 Activity I: ACI analyses from satellite data

2.1.1 Analysis on aerosols indirect effect on liquid clouds

The dataset selection for the Scientific Study I on the aerosol indirect effect on liquid clouds aims to identify complementary strengths for analysing ACI at varied spatial and temporal resolutions. In particular, this study aims at evaluating the impact of the temporal scale, while relying on previous efforts to expand the retrieval of aerosols in the vicinity of clouds. This study will use mostly two different state-of-the-art inversion algorithms for joint retrieval of aerosols and clouds from satellite observations, both partially developed and exploited in past or current CCI projects: CISAR and ORAC. CISAR delivers joint aerosol-cloud retrievals, improving the spatial coverage of the aerosol product; however, while the aerosol product has been extensively validated (Luffarelli and Govaerts, 2019, Luffarelli et al., 2022), the cloud optical depth is retrieved with mid confidence. The inclusion of ORAC ensures consistency with other ESA CCI efforts, provides an additional aerosol dataset and derives cloud properties with high confidence (Thomas et al., 2009; McGarragh et al., 2018). The two algorithms are applied to MSG/SEVIRI observations to retrieve aerosol and cloud properties. To complement the resulting datasets, the CM SAF CLAAS-3, is included in the analysis, providing mature, validated cloud microphysical parameters, including effective radii and CDNC proxies. Collectively, these datasets enable robust statistical analyses necessary for quantifying aerosol indirect effects and deriving key susceptibility metrics, aligning with the scientific objectives laid out in the Science Requirement Document (SRD).

Name	Algorithm	Data Provider	Temporal coverage, resolution	Spatial coverage, resolution	Relevant available Variables	Pixel-level uncertainties	Documentation/References
CM SAF CLAAS-3 V003	PPS, CPP	Eumetsat	2004-today, 15 minutes	MSG disk SEVIRI pixel	$CER16_{liq}$, $CER39_{liq}$, CDNC	yes	PUG, ATBD, VAL, Benas et al. (2023)
CISAR/SEVIRI v1.0.0	CISAR	Rayference	2020, hourly	Subset of MSG disk (North Africa/South Europe), 10 km	Spectral AOD, FMAOD, COD	yes	PUG, ATBD/VAL (available on request)
ORAC/SEVIRI (internal)	ORAC	Rutherford Appleton Laboratory (RAL)	2020, 15 minutes	Subset of MSG disk (North Africa/South Europe), native resolution	AOD, COD, CER, CTP, CTH	yes	Thomas et al., 2009; McGarragh et al., 2018

* must be calculated from existing variables

2.1.2 Dust impact on cloud glaciation temperature

For the scientific study II, potential candidate datasets have to include the variables necessary for conducting this study; these are primarily the cloud properties CTT and CPH as well as the aerosol variables DAOD and DALH. Furthermore, associated uncertainties should be available as far as possible to properly quantify the uncertainty in the statistical results of this study which also guide the interpretation and conclusions.

Considering the fast development of clouds and cloud structures, high temporal resolution of cloud observations are required, motivating the utilization of geostationary observations. This, together with the aim of covering multiple cloud regimes and climate zones as well as including Europe, leads to the conclusion that SEVIRI-based cloud datasets remain as candidate datasets for this study. SEVIRI has not only been in mature operational service from 2004 onwards, but also has the temporal, spatial and spectral characteristics to allow the retrieval of cloud products suitable for this study. With this in mind, SEVIRI-based cloud products from Cloud_cci and CM SAF were selected, also supported by the comprehensive documentation being available for both sources. Cloud_cci is listed twice as there are two products for CTT, one is based on neural networks (implemented in the preprocessing of the Cloud_cci CC4CL processing package), and one being the result of the optimal estimation approach in CC4CL.

The temporal variability of aerosol concentration is slower than for clouds. Thus it is justified to select dust aerosol information available from polar orbiting IR sounders, at the cost of decreased temporal resolution (compared to geostationary sensors). E.g. IASI has been used quite extensively as basis for dust aerosol retrievals, with products available directly from RAL (IMS scheme) and the Climate Data Store of C3S, with the latter products being based on developments made in CCI.

A strong asset of all data products mentioned above is, that the SATACI consortium has a comprehensive expertise in how they were developed and implemented, as well as their strengths and weaknesses, which is important for their application.

All datasets and their key facts are listed in Table below.

Name	Algorithm	Data Provider	Temporal coverage, resolution	Spatial coverage, resolution	Relevant available Variables	Pixel-level uncertainties	Documents/ References
Cloud_cci+ SEVIRI	SEVIRI_ML	DWD	2019, 15 minutes	MSG disk SEVIRI pixel	CPH, CTT	yes	Philipp et al (in prep)
Cloud_cci+ SEVIRI	CC4CL/ORAC	DWD	2019, 15 minutes	MSG disk SEVIRI pixel	CTT	yes	PUG, ATBD, VAL
CM SAF CLAAS-3	PPS, CPP	CM SAF	2004 -present, 15 minutes	MSG disk SEVIRI pixel	CPH, CTT	CTT: yes, CPH: no	PUG, ATBD, VAL, Benas et al. (2023)
IMS scheme	CC4CL/ORAC	RAL	2007 – today, 4 retrievals per day	Global, 12 km	DAOD, DALH	yes	Sellitto et al. (2024)
C3S DAOD	Multiple algorithms and products	C3S CDC	2007-2022, Daily, Monthly	Global, 1x1 degrees	DAOD, DALH	yes	PUG, ATBD, PQAR

* must be calculated from existing variables

2.2 Activity II: Feasibility study for a new aerosol-cloud climate indicator

For the climate indicator one needs operational long-term records to allow following climate changes in the 5-year intervals of the Global Stocktake. These should have sufficient historic basis (at least 30 years) and assured continuation. This makes data records from the C3S and the CM-SAF priority candidates. Furthermore, the long record consistency is essential. As there are still issues between record parts from different similar instruments in the C3S aerosol records in this regard (AATSR vs. SLSTR AOD bias and overall Fine Mode AOD bias) and MODIS as the best established dataset for the period (2000 – current) will be the aerosol baseline for operational continuation with CS3 / CM-SAF data . Also, POLDER with a potentially higher information content on aerosol properties will serve as an additional aerosol reference dataset.

Furthermore, understanding the reliability of the records is important. This shall be achieved by using the uncertainties provided within the C3S datasets and by evaluating the spread of records between several datasets obtained from the same sensor but with different algorithms (C3S individual datasets and uncertainty-weighted ensemble dataset for ATSR / SLSTR, IASI). Also, associations on aerosol-cloud interactions (e.g. FM-AOD vs. CDNC) shall be assessed on the basis of comparing / averaging various data pairs to reduce the overall uncertainties in statistical analyses.

Aerosol-cloud effect studies will be based on associations between best proxy retrievals for aerosol (e.g. FM-AOD/DAOD) and clouds (e.g. CDNC, CRE/CREI, CAL/CAI, CLWP/CIWP) globally and (for more detail) for different enviromental stratifications (e.g. existing conditions, cloud types of climate zones).

Name	Algorithm	Data Provider	Temporal coverage, resolution	Spatial coverage, resolution	Relevant available Variables	Pixel-level uncertainties	Documents/ References
C3S/CCI Dual view	SU, ADV, ORAC + ensemble	Swansea University (SU), Finnish Meteorological Institute (FMI-ADV), RAL (ORAC), German Aerospace Center (DLR-ensemble)	1995-2012 (CCI) 1995-2023 (C3S) monthly (daily)	Global, 1deg	AOD, FMAOD	yes	PUGS, ATBD, PQAR, for 3 algorithms, available through the [C3S website]().
MODIS Atmosphere L3 Global C6.1	Dark target	NASA	2000-2022, monthly	Global, 1deg	AOD, FMAOD	no	Levy et al., ATM, 2013 Pu et al, ACP 2020
C3S/CCI IASI	4 algorithms + ensemble	Université Libre de Bruxelles (ULB), Laboratoire de Météorologie Dynamique (LMD), DLR, Royal Belgian Institute for Space	2007-2022, monthly (daily)	Global, 1deg	DAOD, DALH	yes	PUGS, ATBD, PQAR, for 4 algorithms

		Aeronomy (BIRA),					
POLDER	GRASP	GRASP	2006-2012, monthly (daily)	Global, 1deg	AOD, FMAOD, SSA	yes	PUGS, ATBD, PQAR, Dubovik et al., 2014
CM SAF CLAAS-3	PPS, CPP	Eumetsat	2004 -today, 15 min	MSG disk, SEVIRI pixel	COD, LWP, cloud cover, CDNC	yes	PUG, ATBD, VAL, Benas et al. (2023)
Cloud_cci+ SEVIRI	CC4CL/ORAC	DWD, RAL	2019	MSG disk	COD, LWP, cloud cover, CDNC*	CER39: yes, CDNC: no	PUG, ATBD, VAL
L3 MCD06 COSP Cloud Properties		NASA	2000-2022		COD, LWP, cloud cover, CDNC	no	
C3S/CCI ATSR/SLSTR	CC4CL/ORAC	DWD, RAL	1997-2023, monthly (daily)	Global, 0.5 (0.1) deg	COD^{DL}, LWP^{DL}, cloud cover, CDNC*	yes	PUG, ATBD, VAL, PQAR

* must be calculated from existing variables.
**^{DL} = under daylight conditions;

3 Summary

The datasets presented in this inventory represent a foundational element of the SATACI project's data landscape. They reflect both the heritage of previous ESA and Copernicus initiatives and the evolving capabilities of satellite Earth observation in supporting climate science. Together, they provide a robust empirical basis for future work on quantifying aerosol–cloud interactions, assessing regional and global radiative forcing effects, and informing the design of new climate indicators grounded in observational evidence.

To ensure continued relevance, this inventory might be updated periodically in response to new dataset releases, algorithm improvements, and user feedback obtained during the fitness-for-purpose exercise.

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