Greenhouse Gas Observation
& Climate-Smart Agriculture

Funded by the
European Comission
under the Horizon2020
Work Programme

January 2019

Africa-Wide Climate System Observations: Data Requirements and Availability

SEACRIFOG Deliverable 4.2

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DOI: 10.13140/RG.2.2.18543.28320

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ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Greenhouse Gas Observation
& Climate-Smart Agriculture

Funded by the European Comission under the Horizon2020 Work Programme

Project: 730995 - Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations (SEACRIFOG)

www.seacrifog.eu

Work package number: WP 4

Work package title: Improving technical harmonisation and data quality in environmental monitoring and experimentation

Deliverable number: D 4.2

Deliverable title: Africa-Wide Climate System Observations: Data Requirements and Availability

[Original title according to project proposal:
'A dataset of current measurement parameters across all systems and the spatial representation of key climatic, land use and GHG data plus a description of best practices.']

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List of Acronyms

AGB	Above Ground Biomass
CCI	[ESA] Climate Change Initiative
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EBV	Essential Biodiversity Variable
EC	Eddy Covariance
ECV	Essential Climate Variable
EFDC	European Fluxes Database Cluster
EO	Earth Observation
EOV	Essential Ocean Variable
ESA	European Space Agency
EU	European Union
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEDI	Global Ecosystem Dynamics Investigation
GEOBON	Group on Earth Observations Biodiversity Observation Network
GHG	Greenhouse Gas
GOOS	Global Ocean Observing System
ICOS	Integrated Carbon Observation System
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
NASA	National Aeronautics and Space Administration
N_2O	Nitrous Oxide
NMVOC	Non-Methane Volatile Organic Compound
NPP	Net Primary Productivity
OSCAR	Observing Systems Capability Analysis and Review Tool
RF	Radiative Forcing
RI	Research Infrastructure
RS	Remote Sensing
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SEACRIFOG	Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations
SMOS	Soil Moisture and Ocean Salinity
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WP	Work Package

Executive Summary

The Earth's climate and environment is undergoing fundamental changes linked to human presence and activity, above all through the emission of greenhouse gases (GHG) and land use/cover change. In the case of the African continent, there are still major observational gaps, resulting in large uncertainties for most of the key variables of climate change, above all the GHG balance. The objective of the 'Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations' (SEACRIFOG) project is to design a continental network of joint EU-African research infrastructures (RIs) for the observation of the climate system on and around the African continent. SEACRIFOG is funded by the European Union (EU) through the Horizon 2020 Programme.

This report constitutes Deliverable 4.2 of the SEACRIFOG project. It was prepared under the lead of the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) as a part of SEACRIFOG Work Package (WP) 4. The SEACRIFOG WP4 is implemented under the lead of the Trinity College Dublin in cooperation with the contributing partner institutions SASSCAL, Uni Research and the University of Bergen.

In line with the SEACRIFOG WP4 objective of improving technical harmonisation and data quality in environmental monitoring and experimentation, this report presents the requirements for observations of the 58 essential variables identified by SEACRIFOG (see Deliverable 4.1) and derived data products. Existing observation infrastructures and data products are then assessed against these requirements in order to identify corresponding gaps and needs.

For most essential variables, global requirements are already defined by initiatives such as the Global Climate Observing System (GCOS). The requirements presented here (see section 2) build on and amended these existing requirements based on expert judgement in the context of the African continent, accounting for current technological and financial feasibility as well as error propagation across climate forcing models which rely on observations of numerous variables.

In order to assess the general availability of relevant data, we considered existing observation infrastructures as a proxy for data availability. We found that long-term and continuous in situ observations and corresponding data products are relatively scarce for Africa and the surrounding oceans. Since the spatial coverage of in situ observations is generally thin and patchy, there are numerous ecoregions which are not yet well understood with regards to their GHG source and sink dynamics as well as other functions relevant to the climate system (see section 3.1 and Annex A3).

About a third of the 58 essential variables can (largely) be observed from space with current technology and future developments in satellite-based earth observation may further increase this number (see section 3.2 and Annex A5). However, in addition to a range of variables which are unlikely to be observable by remote sensing anytime soon (such as biosphere-atmosphere GHG fluxes, tropospheric GHG concentrations as well as stocks such as below-ground biomass and soil carbon), many satellite products also strongly depend on in situ observations for validation and calibration. In order to maximise its impact, it is thus recommended that in the design of new RIs those essential variables be prioritized which cannot

be readily observed from space and/or which require significant enhancement of in situ observations across the African continent and the surrounding oceans.

Table 1 below prioritizes the essential variables according to these considerations. Of the 58 variables identified to be essential in the context of SEACRIFOG, 16 are considered to have a high, 22 a medium and 20 a low RI design priority according to the present assessment.

Table 1: Coarse prioritization of the SEACRIFOG essential variables according to the data and observational design needs arising from the main current and future observation method and the availability of remote sensing (RS) climate data records (CDR). Low design needs apply to variables which are already largely covered by appropriate RS products or which are available otherwise. High design needs are assigned to essential variables which can only be measured in situ or for which enhanced in situ data is critical to complement or produce RS products.

Variable	Domain	RS CDRs available?	Main Obs. Method Current	Main Obs. Method Future	SEACRI-FOG Design Need
Above ground biomass	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Active Fire	Terr.	Y	Remote sensing	Remote sensing	Low
Aerosol properties	Atm.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Albedo	Terr.	Y	Remote sensing	Remote sensing	Low
Area of ploughed land	Terr.		Inventory/in situ	Comb. IS & RS	Medium
Below-Ground Biomass	Terr.		In situ	In situ	High
Biosphere-Atmosphere CH4 flux	Terr.		In situ	In situ	High
Biosphere-Atmosphere CO2 flux (NEE)	Terr.		In situ	In situ	High
Biosphere-Atmosphere N2O flux	Terr.		In situ	In situ	High
Boundary layer height	Atm.		In situ	Comb. IS & RS	Medium
Burnt Area	Terr.	Y	Remote sensing	Remote sensing	Low
Carbon Monoxide (CO)	Atm.	Y	Remote sensing	Remote sensing	Low
Cloud Cover Fraction	Atm.	Y	Remote sensing	Remote sensing	Low
CO2, CH4, N2O emissions by country and IPCC sector	Terr.		Inventory/Census	Inventory/Census	Low
Crop Yield by Type	Terr.		Inventory/Census	Inventory/Census	Medium
Dimethyl Sulfide	Ocn.		In situ	Comb. IS & RS	Medium
Economic Development	Vari-ous		Inventory/Census	Inventory/Census	Low
Evapotranspiration	Terr.		Comb. IS & RS	Comb. IS & RS	High
Extent of inland waters	Terr.	Y	Remote sensing	Remote sensing	Low
Fertilizer application	Terr.		Inventory/in situ	Inventory/in situ	Medium
Fire Fuel Load	Terr.		In situ	Comb. IS & RS	Medium
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Terr.	Y	Remote sensing	Remote sensing	Low
Halocarbons	Atm.		In situ	In situ	Low
Human Population	Terr.		Inventory/Census	Inventory/Census	Low
Infiltration and Runoff	Terr.		In situ	In situ	Medium
Inorganic Carbon	Ocn.		In situ	In situ	High
Irrigation	Terr.		In situ	Remote sensing	Low
Land Cover	Terr.	Y	Remote sensing	Remote sensing	Low
Land Use/Land Use Change	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Litter	Terr.		In situ	In situ	High
Livestock Distribution	Terr.		Inventory/Census	Inventory/Census	Medium
Manure Management	Terr.		Inventory/in situ	Inventory/in situ	High
Marine Nutrients	Ocn.		In situ	Comb. IS & RS	Medium
Net Primary Productivity	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Net Radiation at surface (SW/LW)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Nitrogen Oxides (NOx)	Atm.	Y	Remote sensing	Remote sensing	Low
Nitrous Oxide (Ocean)	Ocn.		In situ	In situ	Medium

Variable	Domain	RS CDRs available?	Main Obs. Method Current	Main Obs. Method Future	SEACRIFOG Design Need
Non-methane hydrocarbons	Atm.		In situ	In situ	Low
Ocean Colour	Ocn.	Y	Remote sensing	Remote sensing	Low
Oxygen	Ocn.		In situ	In situ	Medium
Plant Species Traits	Terr.		In situ	In situ	Medium
Precipitation (surface)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Pressure (surface)	Terr.		In situ	In situ	High
River Discharge	Terr.		In situ	In situ	High
Sea Surface Salinity	Ocn.		Comb. IS & RS	Comb. IS & RS	Low
Sea Surface Temperature	Ocn.	Y	Comb. IS & RS	Comb. IS & RS	Low
Soil Moisture	Terr.	Y	Comb. IS & RS	Remote sensing	Medium
Soil Organic Carbon	Terr.		In situ	In situ	High
Stable Carbon Isotopes	Ocn.		In situ	In situ	Medium
Sulfur Dioxide (SO2)	Atm.	Y	Remote sensing	Remote sensing	Low
Surface Roughness	Terr.		In situ	Comb. IS & RS	Medium
Surface Wind Speed and direction	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Low
Temperature (surface)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric CH4 mixing ratio	Atm.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric CO2 mixing ratio	Atm.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric N2O mixing ratio	Atm.		Comb. IS & RS	Comb. IS & RS	High
Water Vapour (surface)	Terr.		In situ	In situ	High
Wild Herbivore Distribution	Terr.		Inventory/Census	Inventory/Census	Medium

In addition to the above, we compiled an inventory of 142 individual existing data products related to the essential variables (see section 3.3 and Annex A4). The identified data products were assessed against the requirements in order to determine whether the related variables are already covered sufficiently. It turned out that the existing data products under consideration hardly meet the requirements. It needs to be noted, though, that the present efforts constitute only a first step towards a more comprehensive data inventory. Such an inventory could be realized in line with the development of a prototype data infrastructure (in line with SEACRIFOG WP5) to comprehensively capture and administer metadata and data products related to the Africa-wide observation of the climate system. The establishment and operation of such a system will further require an active community of practice, whose members will provide, manage and use the content on a continuous basis.

1 Introduction

1.1 Document Purpose

This report constitutes Deliverable 4.2 of the ‘Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations’ (SEACRIFOG) project funded by the European Union (EU) through the Horizon 2020 Programme. It was prepared in January 2019 under the lead of the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) as a part of SEACRIFOG Work Package (WP) 4. The SEACRIFOG WP4 is implemented under the lead of the Trinity College Dublin in cooperation with the contributing partner institutions SASSCAL, Uni Research and the University of Bergen. The report authors acknowledge the inputs from the contributing SEACRIFOG consortium members, the consulted external experts as well as the wider environmental observation community.

1.2 Background

The Earth’s climate is undergoing fundamental changes linked to human presence and activity, above all through the emission of greenhouse gases linked to fossil fuel combustion as well as land use and land cover change (IPCC, 2014). Observation-based evidence is essential to further our understanding of these phenomena, their causes, interplay, consequences and the role of human activity, with the aim to improve forecasts and develop appropriate mitigation and adaptation responses (Houghton, 2007). As these phenomena take place and can be linked to processes at all spatial scales around the globe, they need to be considered and understood not only locally, but instead require systematic research and long-term observation up to the regional and global level (Karl, et al., 2010).

In the case of the African continent, there are still major observational gaps (ClimDev-Africa, 2013), resulting in major uncertainties for most of the key variables of climate change, above all the continental GHG balance (Valentini, et al., 2014; Williams, et al., 2007; Kim, Thomas, Pelster, Rosenstock, & Sanz-Cobena, 2016). Consequently, at present we are uncertain whether the African continent constitutes a net sink or source of atmospheric GHGs. The ‘Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations’ (SEACRIFOG) project (www.seacrifog.eu) aims to develop a roadmap towards a network of joint EU-African RIs for the systematic long-term in situ observation of anthropogenic GHG emissions across the continent and their links to agricultural production and food security. This network is to be tailored to the African context by ensuring that continent-specific ecosystems and anthropic activities as well as their interactions with the local and global climate system be captured with sufficient accuracy.

The primary focus of the resulting continental observation system will be to determine the anthropogenic and natural contributions to climate forcing across Africa with the same level of accuracy as for the rest of the world. Such a system will make a significant contribution to

- improved quantification of GHG emissions and their attribution to anthropogenic activities and natural processes;
- improved GHG accounting in line with the implementation of the Paris Agreement;
- the refinement of remote sensing products through in situ data;

- the improvement of climate models through the provision of more accurate and spatially explicit input data for more accurate projections

The primary aim of WP4 of the SEACRIFOG project is to ‘improve the technical harmonisation and data quality in environmental monitoring and experimentation’ across operational and future RIs in Africa. The WP4 sub-objectives relevant to this present report include:

- To develop a common set of observational criteria and associated methodologies to monitor climate, land use and their impacts on key biogeochemical cycles.
- To provide guidelines and disseminate best practice guidelines ensuring that the operation of observational networks and associated data collection, quality control and reporting formats can be harmonized across the region and with international research networks.
- To provide information on the key environmental observation criteria required to address the identified gaps in current knowledge and data repositories, in addition to outlining the infrastructure required to obtain such data within atmospheric, terrestrial and marine systems.

This report presents the work done in line with SEACRIFOG Task 4.1 and constitutes Deliverable 4.2 of the SEACRIFOG project. It presents both the requirements for and an assessment of available observations and datasets related to the set of variables which have been identified as being essential to the observation and quantification of anthropogenic climate forcing across Africa and the surrounding oceans. The framework of a corresponding integrated observation system for the major GHGs and non-GHG climate forcing was outlined in SEACRIFOG Deliverable 3.1 [1] The essential variables are described in SEACRIFOG Deliverable 4.1 [2]. Note that these variables are referred to as ‘essential variables’ throughout this document and that they are not to be confused with other sets such as the ‘Essential Climate Variables’ defined by GCOS, even though there is a considerable overlap between these different variable sets.

Section 2 of this report recapitulates the observational requirements for each of the essential variables in terms of spatial and temporal resolution as well as accuracy. Section 3 examines the data availability in terms of spatial and temporal coverage and assesses existing data against the requirements. Corresponding findings are discussed in section 4.

2 Data Requirements

The overall objective of the SEACRIFOG project is the design of a comprehensive pan-African network of research infrastructures to estimate the net climate forcing over the African continent and the surrounding oceans with an accuracy that is comparable to or better than the one achieved for other continents. The overall structure and individual elements of such an observation system are described in SEACRIFOG Deliverable 3.1, aiming to limit the maximum uncertainty of the climate forcing components (both GHG

[1] https://www.seacrifog.eu/fileadmin/seacrifog/Deliverables/SEACRIFOG_D3.1_Report_Final-1.pdf

[2] https://www.seacrifog.eu/fileadmin/seacrifog/Deliverables/2018.08.18_SEACRIFOG_Deliverable_4.1.pdf

and non-GHG) that are currently or projected to become significant for the African continent to ±10% at the continental scale and ±20% at the national and/or 3rd order river basin scale (approx. 500 x 500 km).

More than half (33 out of currently 58) essential variables identified to be relevant in the context of SEACRIFOG are part of the set of the Essential Climate Variables (ECV). For these, global requirements are already defined by GCOS (WMO, 2016). The main requirements considered include spatial and temporal resolution as well as required accuracy (or maximum uncertainty, respectively). The GCOS requirements are for products and thus independent of the observational method. The ECVs include some of the Essential Ocean Variables (EOV), for which observational parameters and requirements are defined under the Framework for Ocean Observing of the Global Ocean Observing System (GOOS). Compatibility goals for the in situ observation of atmospheric variables are further defined by the WMO Global Atmosphere Watch (GAW).

Careful mapping and specification of requirements in order to inform a comprehensive analysis of gaps in observations and data is a crucial part in optimal observation system design (WMO, 2016; European Environment Agency, 2017; Task Team for an Integrated Framework for Sustained Ocean Observing, 2012). Based on and in addition to the above global frameworks, SEACRIFOG Deliverable 3.1 formulated the requirements for observations of individual essential variables identified by the SEACRIFOG consortium and external experts (see Deliverable 4.1). In line with the present work, these requirements were further refined and complemented. These requirements are largely based on expert judgement in the context of the African continent, accounting for error propagation across climate forcing models which rely on observations of numerous variables. Note that there is a partial overlap between the requirements formulated by GCOS, GOOS, GAW and the SEACRIFOG consortium. In case there were various requirements defined for a given variable, the stricter requirement (i.e. the higher resolution or accuracy) was generally adopted. Furthermore, since SEACRIFOG focuses on the design of RIs for in situ observations rather than remote sensing, the requirements for in situ observations are given preference (for example in cases where the GCOS requirements refer to remote sensing based observation, such as for tropospheric GHG concentrations).

The requirements in terms of minimum spatial and temporal resolution as well as maximum uncertainty for each of the 58 essential variables identified in SEACRIFOG Deliverable 4.1 are provided in Table 2. It is these requirements, against which every possibly relevant dataset and -product is assessed in order to determine whether there are particular needs for the respective variable to be taken into account by the observation system being designed by the SEACRIFOG project. If met, these requirements are expected to allow for observation-based estimates of continental climate forcing in Africa at an accuracy as targeted above.

Table 2: Essential variables as identified by SEACRIFOG and respective requirements for observation and data products. Note that uncertainties to ± 1 standard deviation from the actual value in percent, i.e. the percentual margins of a 68% confidence interval.

ID	Variable	Variable Class	Domain	Main Observation Technique	Observation Frequency	Spatial Resolution	Max. Uncertainty	Defined By
1	Above ground biomass	Above ground biomass	Terr.	Combin. IS & RS	1 year	500 m	20 %	GCOS
2	Litter		Terr.	In situ	5 years (resolve seasons)	1 km	10 %	SEACRIFOG
3	Aerosol properties	Aerosol properties	Atm.	Combin. IS & RS	4 h	5 km	10 %	GCOS
4	Area of ploughed land	Agricultural management	Terr.	Inventory/Census	5 years (resolve seasons)	1 ha	20 %	SEACRIFOG
5	Fertilizer application		Terr.	Inventory/Census	1 year	1 country	20 %	SEACRIFOG
6	Irrigation		Terr.	Combin. IS & RS	1 day	100 m	10 %	SEACRIFOG
7	Manure Management		Terr.	Inventory/Census	5 years	1 livestock system	20 %	SEACRIFOG
8	Livestock Distribution	Animal Population	Terr.	Inventory/Census	5 years	20 km	15 %	SEACRIFOG
9	Wild Herbivore Distribution		Terr.	Inventory/Census	5 years	20 km	15 %	SEACRIFOG
10	Below-Ground Biomass	Below-Ground Biomass	Terr.	In situ	5 years	1 km	10 %	SEACRIFOG
11	Biosphere-Atmosphere CH4 flux	Biosphere-Atmosphere GHG flux	Terr.	In situ	1 h	1 site (every major ecoregion)	5 %	SEACRIFOG
12	Biosphere-Atmosphere CO2 flux (NEE)		Terr.	In situ	1 h	1 site (every major ecoregion)	5 %	SEACRIFOG
13	Biosphere-Atmosphere N2O flux		Terr.	In situ	1 h	1 site (every major ecoregion)	5 %	SEACRIFOG
14	Boundary layer height	Boundary layer height	Atm.	Remote sensing	1 h	20 km	20 %	SEACRIFOG
15	Halocarbons	Carbon Dioxide, Methane and other Greenhouse gases	Atm.	In situ	1 week (flask)	1 site	5 %	SEACRIFOG
16	Tropospheric CH4 mixing ratio		Atm.	Combin. IS & RS	1 h	1 site	0.05% (1 ppb)	WMO GAW
17	Tropospheric CO2 mixing ratio		Atm.	Combin. IS & RS	1 h	1 site	0.25% (0.1 ppm)	WMO GAW
18	Tropospheric N2O mixing ratio		Atm.	Combin. IS & RS	1 h	1 site	0.05% (0.1 ppb)	WMO GAW
19	Cloud Cover Fraction	Cloud Properties	Atm.	Remote sensing	1 h	25 km	10 %	SEACRIFOG
20	Crop Yield by Type	Crops	Terr.	Inventory/Census	1 year	1 country	10 %	SEACRIFOG
21	Economic Development	Economic Development	Ocn.	Inventory/Census	1 year	1 country	5 %	SEACRIFOG
22	Net Primary Productivity	Ecosystem Function	Terr.	Combin. IS & RS	1 month	1 km	10 %	SEACRIFOG
23	Active Fire	Fire	Terr.	Remote sensing	1 h	250 m	5 %	GCOS
24	Burnt Area		Terr.	Remote sensing	1 day	30 m	15 %	GCOS
25	Fire Fuel Load		Terr.	In situ	1 year	1 km	15 %	SEACRIFOG
26	Human Population	Human Population	Terr.	Inventory/Census	5 years	20 km	5 %	SEACRIFOG
27	Evapotranspiration	Hydrology	Terr.	In situ	1 day	1 km	10 %	SEACRIFOG
28	Infiltration and Runoff		Terr.	In situ	1 month	1 km	10 %	SEACRIFOG
29	Precipitation (surface)		Terr.	Combin. IS & RS	1 day	1 km	10 %	SEACRIFOG
30	River Discharge		Terr.	In situ	1 day	1 river basin	10 %	GCOS
31	Inorganic Carbon (Ocean)	Inorganic Carbon (Ocean)	Ocn.	In situ	1 month	250 km	10 %	GOOS

32	Extent of inland waters	Land Cover	Terr.	Remote sensing	3 months	20 m	1 %	SEACRIFOG
33	Land Cover		Terr.	Remote sensing	1 year	250 m	15 %	GCOS
34	Land Use/Land Use Change	Land Use/Land Use Change	Terr.	Combin. IS & RS	1 year	1 km	20 %	SEACRIFOG
38	Marine Oxygen	Marine Oxygen	Ocn.	In situ	1 month	100 km (marine biochemical province)	10 %	GOOS
35	Nitrous Oxide (Ocean)	Nitrous Oxide	Ocn.	In situ	1 day	1 km	1 %	GOOS
36	Marine Nutrients	Nutrients	Ocn.	In situ	3 months (seasonal)	100 km (marine biochemical province)	20 %	GOOS
37	Ocean Colour	Ocean Colour	Ocn.	Remote sensing	8 days	1 km	5 %	SEACRIFOG
39	Plant Species Traits	Plant Species Traits	Terr.	In situ	Once off for all common species	All major biomes	10% (determine for 90% of cover)	SEACRIFOG
42	Nitrogen Oxides (NOx)	Precursors	Atm.	Remote sensing	4 h	5 km	20 %	GCOS
43	Non-methane hydrocarbons		Atm.	In situ	1 h	1 site	10 %	WMO GAW
41	Oceanic Dimethyl Sulfide (DMS)		Ocn.	In situ	1 month	10 degrees	10 %	SEACRIFOG
44	Sulfur Dioxide (SO2)		Atm.	Combin. IS & RS	4 h	5 km	30 %	GCOS
40	Tropospheric Carbon Monoxide (CO)		Atm.	Combin. IS & RS	1 h	1 site	1% (1 ppb)	WMO GAW
45	Pressure (surface)	Pressure (surface)	Terr.	In situ	1 h	1 Site	0.01% (0.1 hPa)	GCOS
46	Albedo	Radiation	Terr.	Remote sensing	1 month	300 m	5 %	GCOS / SEACRIFOG
47	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)		Terr.	Remote sensing	8 days	300 m	5 %	SEACRIFOG
48	Net Radiation at surface (SW/LW)		Terr.	Combin. IS & RS	1 month	100 km	0.25% (1 W/m2)	GCOS
49	CO2, CH4, N2O emissions by country and IPCC sector	Reported Anthropogenic Greenhouse Gas Emissions	Terr.	Inventory/Census	1 year	1 country	10 %	SEACRIFOG
50	Sea Surface Salinity	Sea Surface Salinity	Ocn.	Combin. IS & RS	8 days	1 km	1 %	SEACRIFOG
51	Soil Moisture	Soil Properties	Terr.	Combin. IS & RS	1 day	1 km	4% (0.04 m3/m3)	GCOS
52	Soil Organic Carbon		Terr.	In situ	10 years	1 km	5 %	SEACRIFOG
53	Stable Carbon Isotopes	Stable Carbon Isotopes	Ocn.	In situ	3 months (seasonal)	100 km	10 %	GOOS
54	Surface Roughness	Surface Roughness	Terr.	In situ	5 years	1 km	20 %	SEACRIFOG
55	Surface Wind Speed and direction	Surface Wind	Terr.	Combin. IS & RS	3 h	10 km	10% (5 m/s)	GCOS
56	Sea Surface Temperature	Temperature	Ocn.	Combin. IS & RS	1 day	1 km	0.03% (0.1 K)	SEACRIFOG
57	Temperature (surface)		Terr.	Combin. IS & RS	1 h	1 site	0.03% (0.1K)	GCOS
58	Water Vapour (surface)	Water Vapour (surface)	Terr.	In situ	1 h	1 site	1 %	GCOS

3 Data Availability

The present section provides an assessment of the availability of relevant observational data and existing data products for the essential variables identified in line with SEACRIFOG Deliverable 4.1. Subsections 3.1 and 3.1 examine the availability of in situ and remote sensing (RS) observational infrastructure, respectively. This provides an indication on the availability of data for the respective essential variables. Subsection 3.3 presents an assessment of existing datasets and -products which were identified through a non-exhaustive inventory carried out by SEACRIFOG WP4. Besides the spatial and temporal coverage, each item in this inventory was assessed against the requirements presented in section 2.

3.1 In Situ Observations

The coverage of in situ observation has been examined in line with WP3 through the compilation of an inventory of existing and planned observation infrastructure across Africa (publicly accessible at https://seacrifog-tool.sasscal.org/). Based on this in situ observation infrastructure inventory, the observational coverage of the different natural and human-disturbed biomes across Africa was analysed. A corresponding paper was published by the SEACRIFOG project team in Environmental Research Letters (López-Ballesteros, et al., 2018).

Relative to other continents, both the spatial and temporal coverage through in situ observations of relevant meteorological and climate variables is generally low across the African continent, with the exception of Southern Africa (and to a lesser degree parts of West Africa), which by far has the highest density of ground-based in situ observations of all African sub-regions (see Figure 1). Note that, since Figure 1 also contains inactive sites, the actual density of current observations is even considerably lower.

The various in situ networks were linked to the essential variables they observe (or at least some of the sites which are part of that network). Based on these links, the number of in situ observation sites for each essential variable on and around the African continent was determined. A corresponding table listing the number of sites per essential variable and observation network is provided in Annex A1.

It is important to note that the current effort by SEACRIFOG only constitutes a first step and that the compilation of a comprehensive and up-to-date inventory of relevant existing and planned in situ observation infrastructures is a massive and ongoing task which would ideally be addressed continuously by a corresponding community of practice.

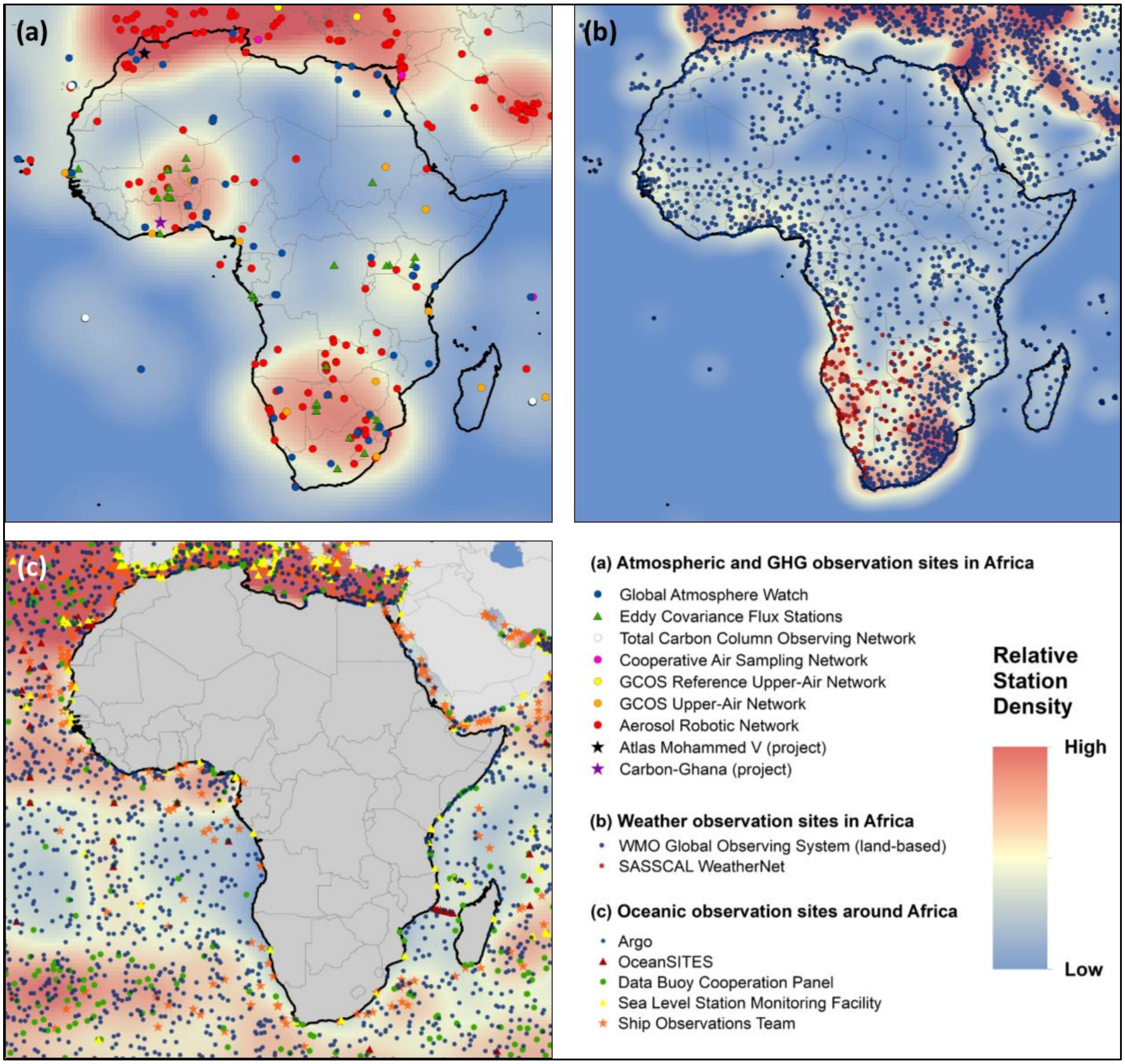

Figure 1 (Published in 2018 by López-Ballesteros et al. (López-Ballesteros, et al., 2018)): Observational sites of selected networks and their relative density for (a) ground-based atmospheric and greenhouse gas, (b) ground-based meteorological and (c) oceanic observation on and around the African continent. The heatmaps are based on kernel density estimations of all stations of the considered networks within a bounding box of 40 to −40 degrees latitude and −50 to 80 degrees longitude. Note that the operational status of each station has not been taken into account since this information was not available for all networks. The major source for the station data for most of the networks is the WMO's OSCAR tool.

In addition to the low site density, the distribution of observations over the variety of the continent's natural biomes (Olson, et al., 2001) is uneven (see Figure 2). Some of the smaller biomes have very limited observations (e.g. mangroves) and, overall, only few stations are located in each biome, particularly for GHG and aerosol observation. For example, considering the significance of tropical and subtropical moist broadleaf forests as a continental and global carbon sink (Valentini, et al., 2014), the density of corresponding stations is very low (on average only one station per more than 130,000 km^2), particular in the central African region.

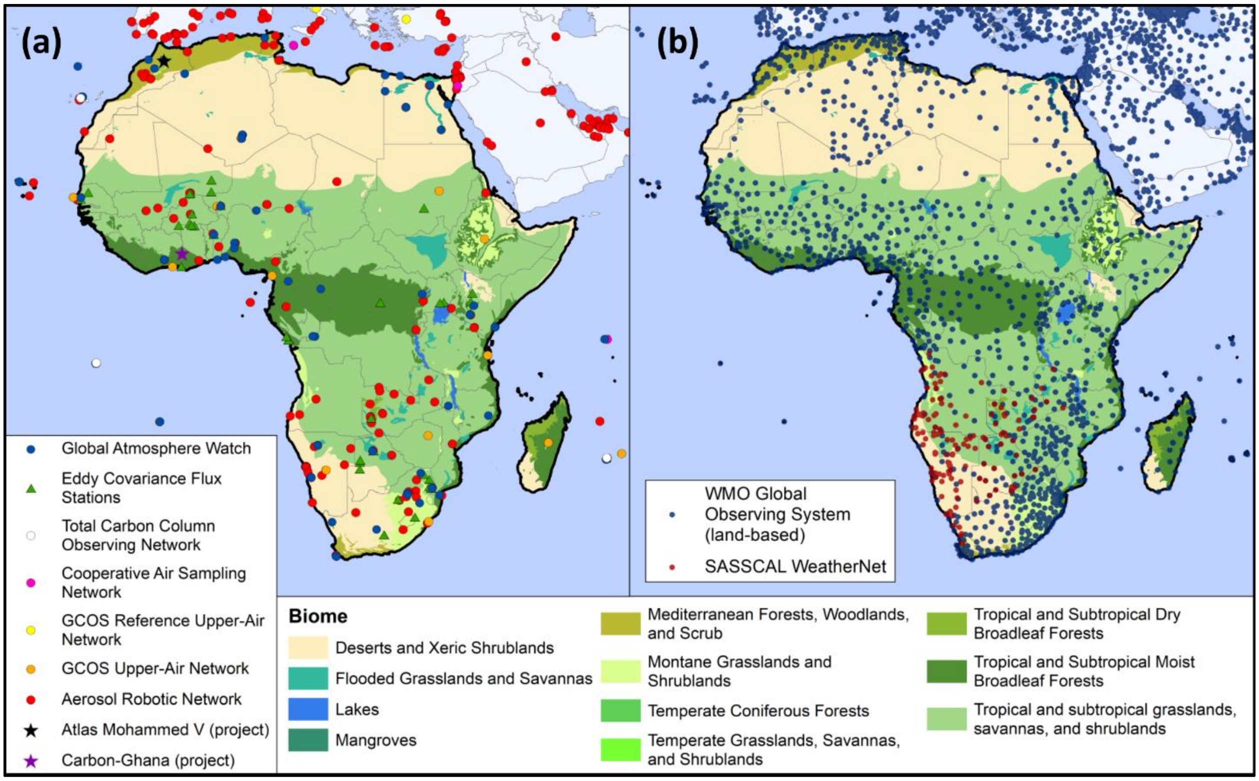

Figure 2 (Published in 2018 by López-Ballesteros et al. (López-Ballesteros, et al., 2018)): Observing stations of selected networks for (a) GHG and aerosols and (b) weather observation against the major biomes (Olson, et al., 2001) of the African continent. The source for the station data for most of the networks is the WMO's OSCAR tool.

With regards to 'anthromes' which classify the terrestrial biosphere according to the degree of their anthropogenic transformation (Ellis, Goldewijk, Siebert, Lightman, & Ramankutty, 2010), spatial analysis yields a positive correlation between station density and the degree of human disturbance for both GHG/aerosol and meteorological observations. In turn, this points towards observational gaps across low- or undisturbed ecosystems, leading to a higher uncertainty regarding their role in the African GHG budget. Detailed tables listing the number and density of ground-based observations for the considered networks per natural and anthropogenic biome across Africa are provided in Annex A2 or in the 2018 ERL publication by the SEACRIFOG team (López-Ballesteros, et al., 2018).

A crucial contribution to the ecosystem-specific quantification of greenhouse gas (GHG) sources and sinks and the understanding of the underlying biogeochemical and biophysical processes is made by ground-based eddy covariance (EC) flux measurements of trace gases. We compiled an inventory of past, current and planned EC towers in Africa based on stations listed under the FLUXNET and the European Fluxes Database Cluster (EFDC) as well as through expert consultations.

As of January 2019, the inventory contains a total of 40 stations in Africa (as a comparison, only the EFDC lists more than 300 stations in Europe). Only eleven of these were found to be operational, with eight of them located in South Africa. Three stations are planned in DR Congo and Kenya. The remainder are either stations with unknown status or inactive stations, most of which were associated with the CarboAfrica project (2006–2010). Figure 3 depicts the location and status of these stations against the major terrestrial biomes and ecoregions in Africa. For a detailed table listing the number of EC stations by terrestrial biome and ecoregion, refer to Annex A3.

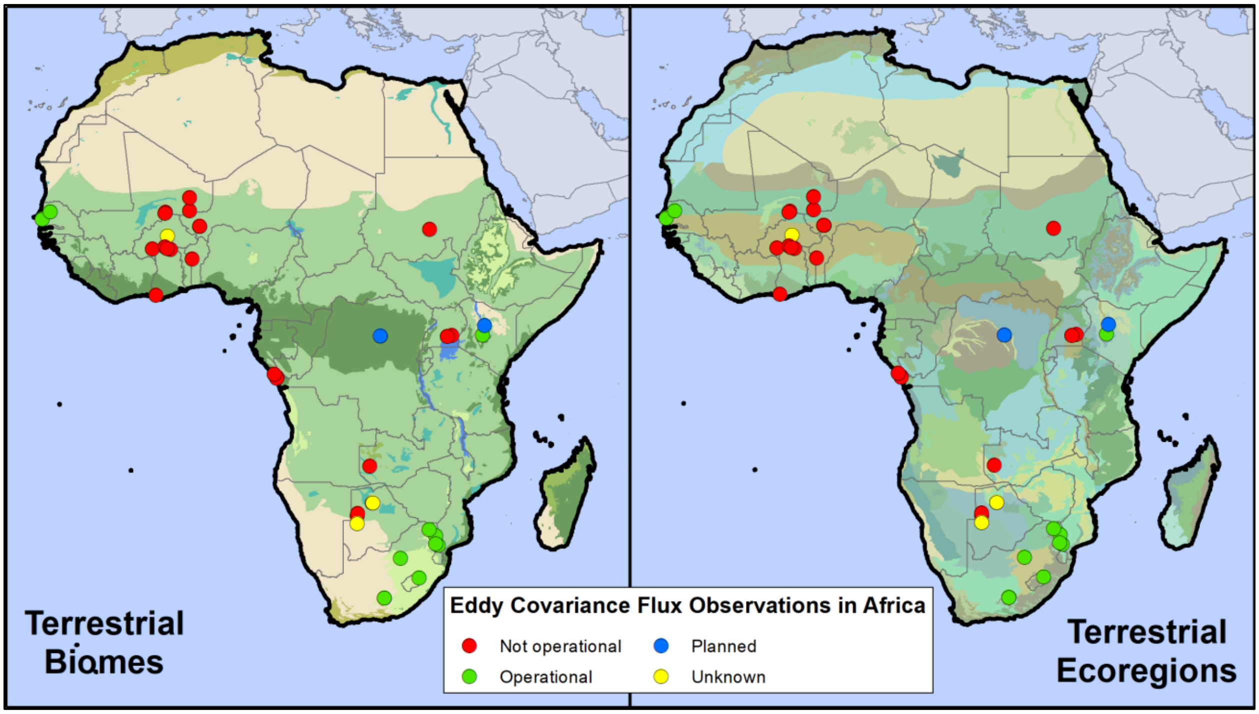

Figure 3: EC flux stations and their status as compiled by the SEACRIFOG consortium against the major African terrestrial biomes (left) and ecoregions (right). See annex A2 for a detailed list of the terrestrial ecoregions within each biome in Africa.

Oceanic in situ measurements are also scarcer in the marine areas surrounding Africa than for other continents. Temperature, salinity and velocity of the upper ocean are routinely measured by Argo, a global array of close to 4,000 free-drifting profiling floats that take measurements of the upper 2000 m of the ocean. Inorganic carbon in form of pCO_2 (partial pressure of CO_2) is measured from Voluntary Observing Ships (VOS) which sail in the Atlantic and in the Indian Ocean, but rarely in the coastal African waters. These measurements are available from the Surface Ocean CO_2 Atlas (SOCAT) database (https://www.socat.info/index.php/data-access/) (Bakker, et al., 2016). Fixed stations and sections are scarce, and a collection is found in the Global Ocean Data Analysis Project (Olsen, et al., 2016), including both historical datasets (e.g. GEOSECS – Geochemical Ocean Sections Program 1970-1980), and newer data. Stations and sections not included in this collection is e.g. the coastal section in western Red Sea collected between 2007 and 2013 (Ali, et al., 2018; Ali E. B., 2017).

3.2 Remote Sensing

The Committee on Earth Observation Satellites (CEOS) maintains a database of earth observation satellites of its member space agencies [3]. As of October 2018 (latest database update at time of writing), the list contains 162 active earth observation missions for non-commercial and non-military use. Of these, 103 are potentially relevant for the African continent and the surrounding oceans, see Annex A5 for the corresponding list (missions not relevant in the SEACRIFOG context, satellites in a geostationary orbit not covering Africa and missions ending in December 2018 were removed).

3.2.1 Space-Based ECV Observation

The GCOS currently specifies 54 ECVs, more than half of which are largely or partially covered by remote sensing data from earth observation satellites. Of the 58 essential variables identified by SEACRIFOG, 33 are ECVs. Of these 33 ECVs, 20 can already largely be measured from space (see Table 3) and more (see section 3.2.2) can partially be derived from satellite observations. The joint CEOS/CGMS Working Group on Climate (WGClimate) is keeping an inventory [4] of existing and planned data products (WGClimate refers to these as climate data records [5]) from space agency sponsored activities. Below table lists the existing and planned RS-based climate data records for the ECVs which are included in the set of essential variables identified by SEACRIFOG. 'Planned' refers to climate data records which are to be delivered as part of an already approved program of an individual or several agencies. A more detailed database, which links ECVs to earth observation missions, instruments and measurements, including respective temporal coverages, is available at http://database.eohandbook.com/measurements/overview.aspx.

Table 3: Existing and planned climate data records for the ECVs which were identified by SEACRIFOG to be essential for observation across the African continent and surrounding oceans. The ECVs listed below are congruent with or directly related to 20 of the SEACRIFOG essential variables. Source: ECV inventory by the CEOS/CGMS Working Group on Climate.

Domain **ECV**	Existing	Planned
Atmosphere		
Aerosol Properties	**34**	**13**
Carbon Dioxide; Methane and other Greenhouse Gases	**32**	**28**
Cloud Properties	**100**	**82**
Earth Radiation Budget	**74**	**53**
Precipitation	**11**	**4**
Precursors supporting the Ozone and Aerosol ECVs	**10**	**12**
Surface Wind Speed and Direction	**16**	**8**
Water Vapour	**59**	**35**
Land		
Albedo	**21**	**13**
FAPAR	**2**	**3**
Fire Disturbance	**3**	**9**
LAI	**2**	**3**

[3] http://database.eohandbook.com/

[4] http://climatemonitoring.info/ecvinventory/

[5] WGClimate provides the following definition of a Climate Data Record: 'In view of the relatively slow dynamics of climate change, observations of ECVs have to be accurate, well-calibrated and homogeneous, to generate time-series than span decades; these data records are referred to as Climate Data Records (CDRs).'

Domain ECV	Existing	Planned
Lakes		**3**
Land Cover	**1**	**1**
Land-Surface Temperature	**10**	**18**
Soil Moisture	**4**	**24**
Ocean		
Ocean Colour	**8**	**8**
Sea Surface Temperature	**16**	**17**

3.2.2 Future EO Capabilities

In addition to current missions, the CEOS database further lists some 160 civil earth observation satellite missions to be launched over the next 15 years to measure components of the climate system. With the increasing number and coverage of satellites and advances in instrumentation technology, the applications and contributions of remote sensing to the systematic global measurement of the following essential variables can be expected to further increase significantly:

- **Above ground biomass (AGB)**
  ESA's Climate Change Initiative (CCI) Biomass project aims to develop an above ground biomass product at 500 m to 1 km spatial resolution with a relative error of less than 20% where AGB exceeds 50 Mg ha^{-1} based on spatial data from past, current and future EO missions. The recently launched Global Ecosystem Dynamics Investigation (GEDI) lidar as well as future approved missions, notably ESA's BIOMASS (planned launch 2022) and the NASA–ISRO Synthetic Aperture Radar (NISAR, planned launch 2021) mission, are expected to further increase the resolution and accuracy of forest AGB products.
- **Soil moisture / irrigation**
  ESA's Soil Moisture CCI project aims to produce the most complete and most consistent global soil moisture data record based on active and passive microwave sensors. While the required resolution and accuracy could not be achieved in the past, current products[6] from ESA's Soil Moisture and Ocean Salinity (SMOS) mission are getting closer (accuracy of 0.04 m^3m^{-3} at a spatial resolution of 35-50 km and a temporal sampling of 1-3 days) for surface soil moisture estimates. According to CEOS, around 16 future missions with instrumentation relevant for soil moisture measurement are currently approved, with launch dates between now and 2030.
  Approaches for RS-based observation of irrigation are under development. A recently presented approach based on satellite soil moisture products (Brocca, et al., 2018) is able to quantify irrigation over dry summer sites, with satisfactory performance from satellite data with retrieval errors lower than ~0.04 m^3/m^3 and revisit times shorter than 3 days.
- **Sea surface salinity**
  ESA's current SMOS mission is the first one to provide satellite-based global ocean salinity estimates. It aims at an accuracy of 0.1 practical salinity scale units for a 10 - 30 day average for an open ocean area of 200 km x 200 km. There are currently no further dedicated missions planned for remotely-sensed sea surface salinity.

[6] http://www.catds.fr/Products/Available-products-from-CEC-SM/L4-Land-research-products

- **Surface Roughness**
  NASA's GEDI lidar instrument as well as ESA's upcoming BIOMASS mission (2022) aim to drastically improve vegetation canopy height and cover observations, thus significantly enhancing the ability to extrapolate surface roughness from in situ measurements.
- **Water Runoff and River Discharge**
  NASA's Surface Water and Ocean Topography (SWOT) mission (planned launch 2021) aims to provide global runoff data at sufficiently fine spatial scales (all terrestrial water bodies with surface area > 250 m^2 and rivers with width > 100 m) to improve the knowledge of water balance on land.
- **Net Primary Productivity**
  Net primary productivity (NPP) can be extrapolated using remote sensing. The MODIS annual NPP 1 km product is validated using EC flux tower measurements that are compared to a sample of the MODIS product located around each tower.

3.3 Existing Datasets and -Products

While the previous subsections focused on the availability of observation infrastructure, the present subsection considers existing individual datasets and-products which were identified to be directly related to one or more essential variables and which were thus included in a data product inventory compiled by the SEACRIFOG consortium. Note that this inventory is far from exhaustive and will remain subject to continuous updates. As for observation infrastructure (see section 3.1), the compilation of a comprehensive and up-to-date inventory of relevant datasets and -products is a massive and ongoing task which would ideally be addressed continuously by a corresponding community of practice.

With regards to terminology, in the context of the present report, the terms 'dataset' and 'data product' are both used to refer to entries in this data inventory. A 'data product' here refers to an individual item, independent of the processing level [7]. The term 'dataset', in line with ESA's definition, refers to a group of products presenting similar characteristics from a user point of view i.e. a series of products presenting physical consistency and interoperability. Other inventory entries could rather be described as 'collections' of data products (e.g. the Memento database on marine CH_4 and N_2O observations).

[7] Various levels of processing range from raw data to fully referenced and modelled ready-to-use data. At higher levels, the data are generally converted into more useful parameters and formats. For example, the data processing levels of NASA's Earth Observing System Data and Information System (EOSDIS) for EO-based products range from Level 0 (raw unprocessed) to Level 4 (model output, e.g., variables derived from multiple measurements). Level 3 are typically variables mapped on uniform space-time grid scales, usually with some completeness and consistency.

3.3.1 Data Product Inventory

For each of the 58 environmental variables identified to be essential for the quantification of climate forcing across the African continent and the surrounding oceans (see SEACRIFOG Deliverables 3.1 and 4.1), existing datasets or -products were identified and corresponding metadata was collected through literature and internet research as well as consultations with the SEACRIFOG consortium partners and the wider environmental observation community. Relevant datasets or -products can be derived from data from in situ or remote observations, combinations thereof, inventories and statistical datasets or modelled data. Metadata on existing data products was collected according to the metadata fields presented in Table 4. Each data product is linked to one or more essential variables. For each essential variable, this allows for an assessment of spatial and temporal data coverage.

Table 4: Metadata fields used for the inventory of existing datasets.

Field	Description
dpid	Data product/dataset ID
dptitle	Data product/dataset title
dppubyear	Data product/dataset year of publication
dptype	Data product/dataset type (Options: Geospatial - Raster, Geospatial - Vector, Time Series, Cross-sectional data, Other)
dptype2	Data product/dataset observation/source type (Options: In situ, Remote, Combination in situ & remote, Model)
dpkeywords	Data product/dataset keywords
dpabstract	Data product/dataset abstract/description
dpprovider	Data product/dataset provider
dpauthor	Data product/dataset author(s)/authoring institution
dpcontact	Data product/dataset contact
dpcovspatial	Data product/dataset spatial coverage (bounding box in decimal degrees)
dpcovtempstart	Data product/dataset temporal coverage - start date
dpcovtempend	Data product/dataset temporal coverage - end date
dpresspatial	Data product/dataset spatial resolution - value
dpresspatialunit	Data product/dataset spatial resolution - unit
dprestemp	Data product/dataset temporal resolution - value
dprestempunit	Data product/dataset temporal resolution - unit
dpuncertainty	Data product/dataset uncertainty/error - value
dpuncertaintyunit	Data product/dataset uncertainty/error - unit
dpdoi	Data product/dataset DOI
dplicense	Data product/dataset license information
dpurldownload	Data product/dataset download URL
dpfileformat	Data product/dataset download file format
dpfilesize	Data product/dataset download file size - value (of individual file in case of dataset series)
dpfilesizeunit	Data product/dataset download file size - unit
dpurlinfo	Data product/dataset further information URL

For each of the essential variables, requirements in terms of spatial and temporal resolution as well as maximum uncertainty/error were formulated (see section 2) and the datasets were assessed against these requirements.

Metadata on relevant data products was stored in a PostgreSQL database which was fed through a custom-built frontend called the "SEACRIFOG Collaborative Inventory Tool" based on a web-based app written in R using the 'Shiny' package (see Figure 4). The tool is publicly accessible at https://seacrifog-tool.sasscal.org. As of the time of writing this report, the database contained metadata on 142 items.

Analysis of the set of metadata and production of tables and figures was carried out using custom-written R scripts. Furthermore, the database contains metadata on relevant observation infrastructure (both in situ and remote sensing) and – where available – corresponding observation site information.

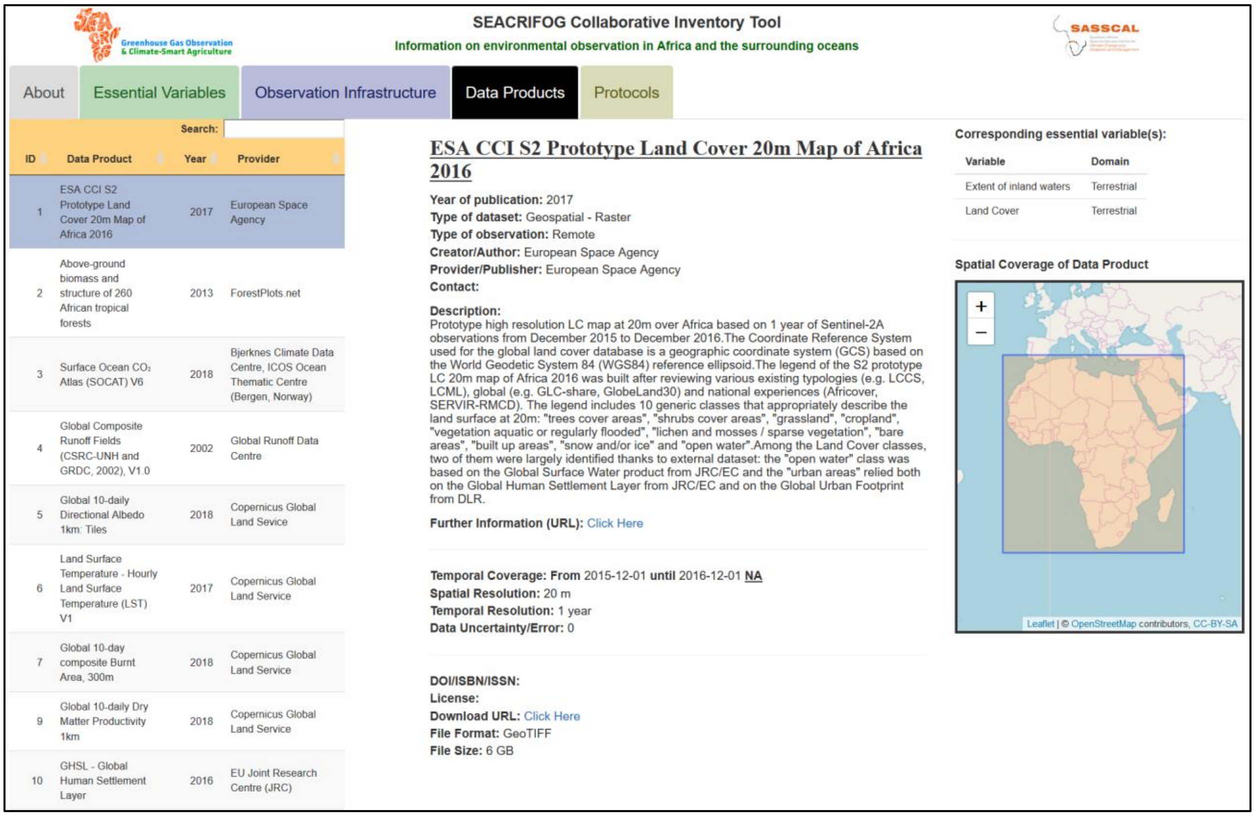

Figure 4: Screenshot of the tab "Data Products" of the SEACRIFOG Collaborative Inventory Tool (Version 3.1) which serves as a frontend for both data entry and access/visualization.

Figure 5 visualizes the number of datasets/-products per observation category for each essential variable as captured in the SEACRIFOG Inventory Tool database. More detailed information on each data product is available at https://seacrifog-tool.sasscal.org.

Only about a quarter of these data products are in situ data. In general, it appears that Africa-specific in situ datasets and -products are not only rare, but also hard to access publicly.

Datasets and -products (partially) based on RS are more readily available (often at high processing levels) and accessible via the various space agencies' data portals. Most of these products have global coverage and thus high interoperability. However, the accuracy of these products often varies spatially according to the quantity as well as spatial and temporal coverage of complementary in situ observations, which – again – are generally relatively scarce across Africa. A detailed spatial assessment of the accuracy of RS-based products could help to identify gaps and needs of such complementary in situ observations.

The same is true for many modelled products, the accuracy of which generally also depends on the quantity and quality of complementary data from in situ observations.

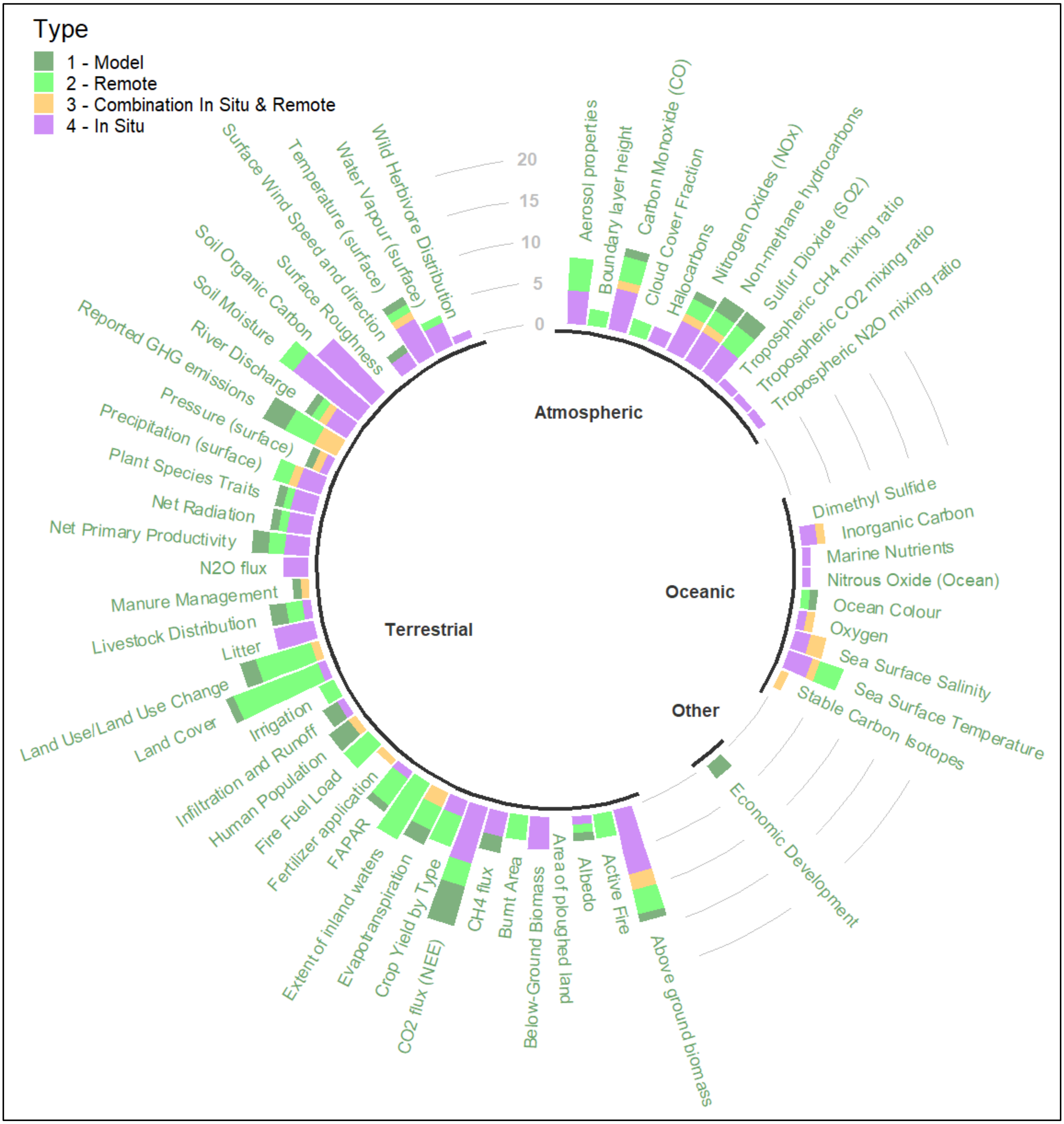

Figure 5: Number of datasets/-products per observation type for each essential variable as captured in the SEACRIFOG Inventory Tool database as of January 2019.

Table 5 provides an overview of the number of datasets/-products per observation category as captured in the SEACRIFOG Inventory Tool database as of January 2019.

Table 5: Number of datasets/-products per observation type as captured in the SEACRIFOG Inventory Tool database (Jan. 2019)

Observation category	#	Description
In Situ	36	The majority of the terrestrial in situ datasets specific to Africa are from • SAFARI 2000 project, covering Southern Africa from 1999 to 2001, studying linkages between land and atmosphere processes • Several individual grassland sites covering different periods, primarily measuring NPP and biomass Items in this category are limited, since Africa-specific in situ datasets appear not only to be generally rare, but also hard to access.
Remote	59	Mainly global products covering the last 10 to 20 years. This category is far from being exhausted (see sections 3.2.1 and 0), more work is required to identify the various RS-based products, preferably level 3 or 4 products. The distinction between the categories “Remote” and “Combination In Situ & Remote” is often ambiguous.
Combination In Situ & Remote	21	The majority of the datasets in this category are 250m Africa Soil Grids from the Africa Soil Information Service (AfSIS). Data products in this category cover periods between 10 up to 50 years.
Model	26	Mainly global gridded model-based estimates on essential variables, typically covering several decades.
Grand Total	**142**	

3.3.2 Spatial Coverage

The spatial coverage of each data product was captured as the minimal bounding box (containing all observation sites in case of in situ datasets) in decimal degrees. Based on the respective bounding box size, the data products were classified into the distinct spatial domains as presented in Figure 6. Visualizations of the bounding boxes of each data product (as well as all data products related to a given variable) are available at [https://seacrifog-tool.sasscal.org.](https://seacrifog-tool.sasscal.org)

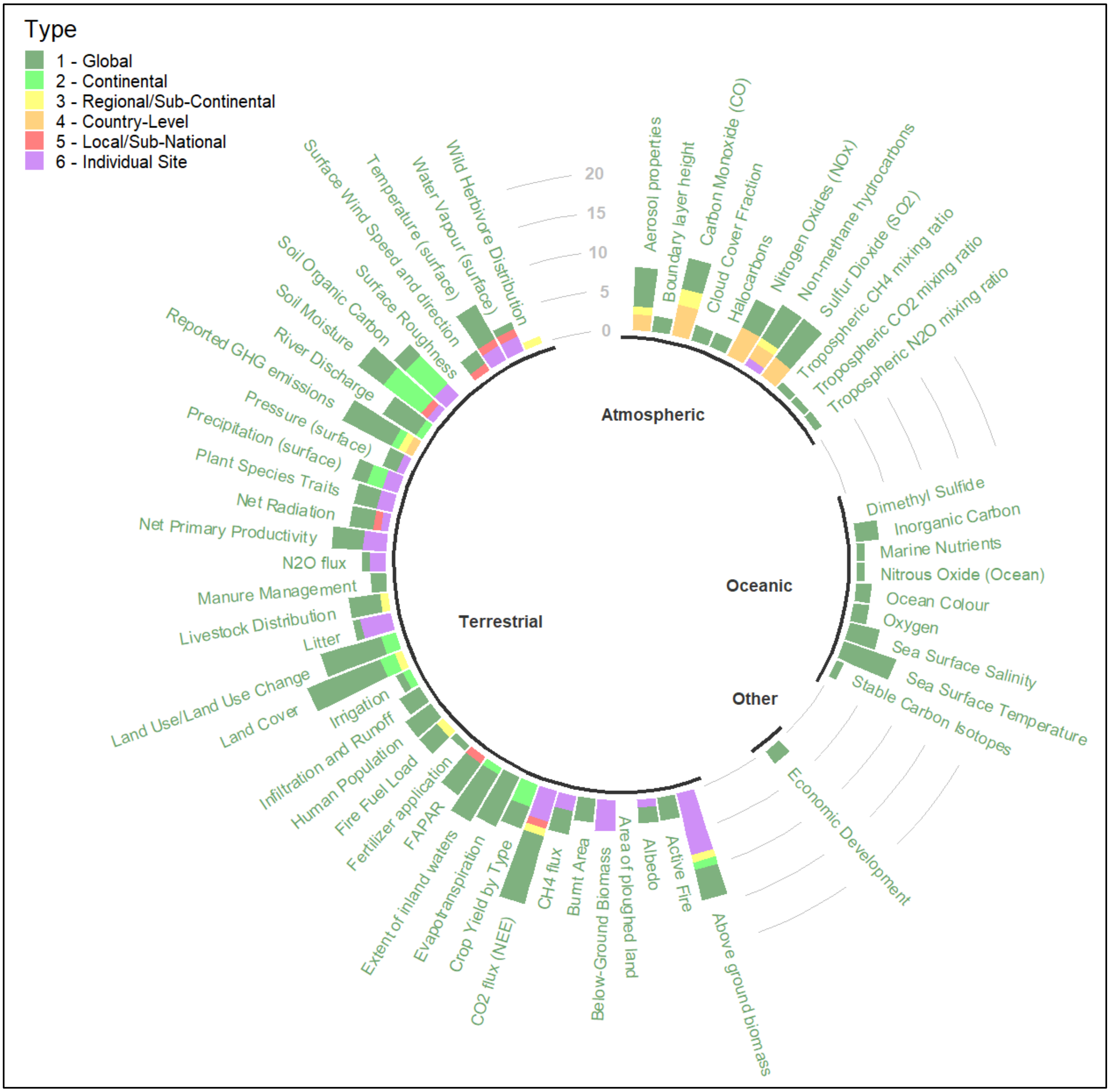

Figure 6: Number of datasets/-products per spatial domain for each essential variable as captured in the SEACRIFOG Inventory Tool database as of January 2019.

For the majority of the essential variables, data products with global coverage are available. However, most of these do not meet the specified requirements (see section 3.3.4). Africa-specific datasets at the continental, sub-continental and national level are generally not available or harder to access.

3.3.3 Temporal Coverage

Figure 7 presents the number of datasets/-products per timespan covered for each essential variable as captured in the SEACRIFOG Inventory Tool database.

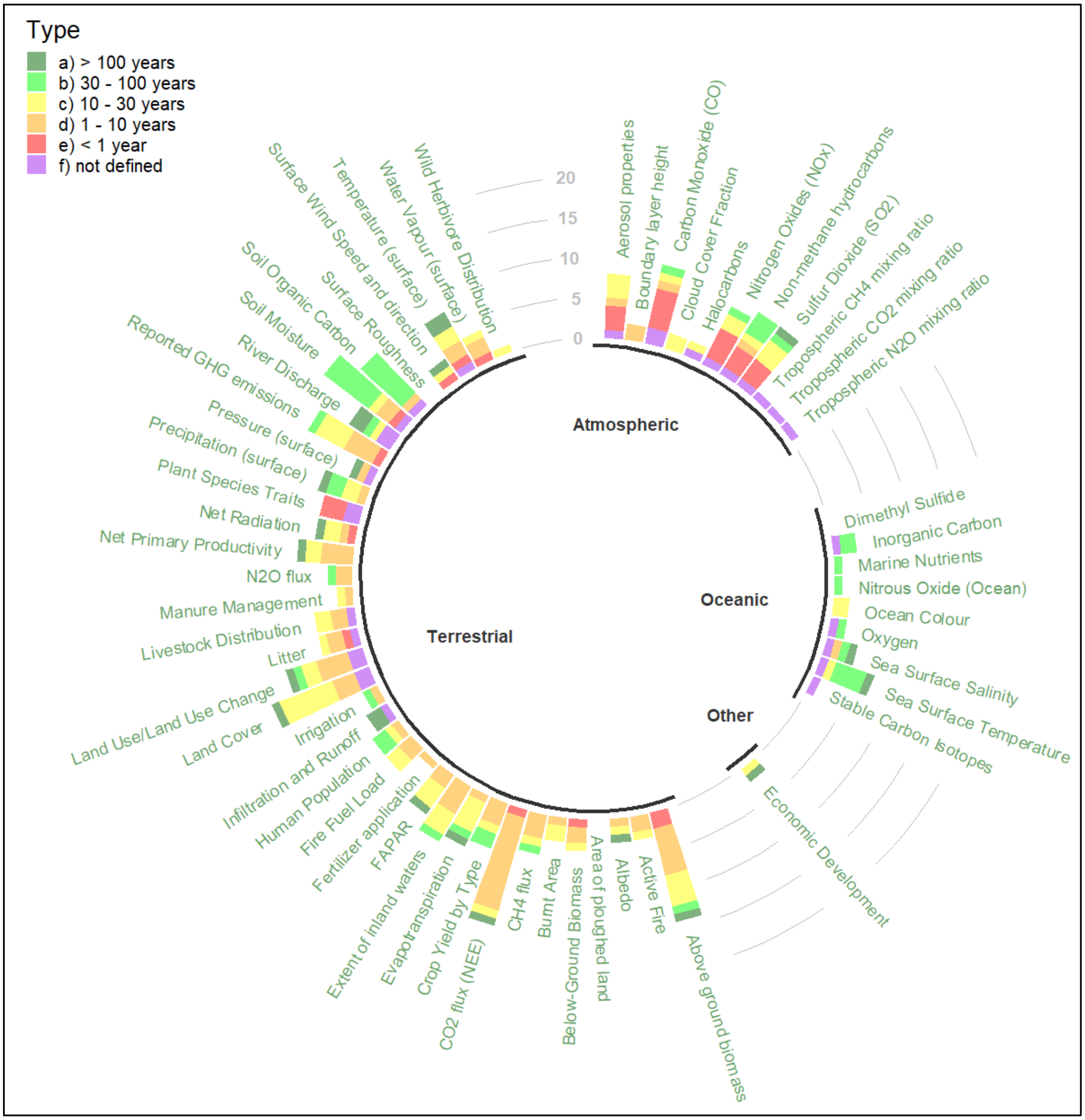

Figure 7: Number of datasets/-products per timespan covered for each essential variable as captured in the SEACRIFOG Inventory Tool database as of January 2019.

3.3.4 Assessment against Requirements

Finally, the captured datasets/-products were assessed against the requirements (see section 2) in terms of spatial and temporal resolution.

Table 6: Number of datasets/-products per essential variable meeting the variable-specific requirements as presented in section 2. Note that this analysis is based on the data inventory in line with the SEACRIFOG Collaborative Inventory Tool, which is work-in-progress and non-exhaustive. Furthermore, the table contains datasets across different spatial and temporal domains.

Variable	Domain	# Data Products	# of Data Products which meet requirements for		
			Spat. Res.	Temp. Res.	Spat. & Temp. Res.
Above ground biomass	Terrestrial	14	2	9	0
Active Fire	Terrestrial	3	0	0	0
Aerosol properties	Atmospheric	8	5	1	0
Albedo	Terrestrial	3	0	3	0
Below-Ground Biomass	Terrestrial	4	0	3	0
Biosphere-Atmosphere CH4 flux	Terrestrial	5	0	0	0
Biosphere-Atmosphere CO2 flux (NEE)	Terrestrial	15	0	4	0
Biosphere-Atmosphere N2O flux	Terrestrial	3	0	0	0
Boundary layer height	Atmospheric	2	1	0	0
Burnt Area	Terrestrial	3	0	0	0
Cloud Cover Fraction	Atmospheric	2	1	0	0
CO2, CH4, N2O emissions by country and IPCC sector	Terrestrial	10	9	8	8
Crop Yield by Type	Terrestrial	6	6	4	4
Economic Development	Various	2	2	0	0
Evapotranspiration	Terrestrial	7	5	1	0
Extent of inland waters	Terrestrial	8	2	4	1
Fertilizer application	Terrestrial	1	1	0	0
Fire Fuel Load	Terrestrial	4	4	4	4
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Terrestrial	6	2	4	2
Halocarbons	Atmospheric	2	0	0	0
Human Population	Terrestrial	4	3	1	1
Infiltration and Runoff	Terrestrial	3	0	2	0
Inorganic Carbon (Ocean)	Oceanic	3	2	0	0
Irrigation	Terrestrial	2	1	0	0
Land Cover	Terrestrial	13	4	9	3
Land Use/Land Use Change	Terrestrial	10	8	5	4
Litter	Terrestrial	5	0	3	0
Livestock Distribution	Terrestrial	5	4	2	2
Manure Management	Terrestrial	2	2	1	1
Marine Nutrients	Oceanic	1	0	0	0
Marine Oxygen	Oceanic	2	0	0	0
Net Primary Productivity	Terrestrial	7	2	5	1
Net Radiation at surface (SW/LW)	Terrestrial	5	0	4	0
Nitrogen Oxides (NOx)	Atmospheric	8	1	2	0
Nitrous Oxide (Ocean)	Oceanic	1	0	0	0
Non-methane hydrocarbons	Atmospheric	9	0	0	0
Ocean Colour	Oceanic	2	0	2	0
Plant Species Traits	Terrestrial	5	1	0	0
Precipitation (surface)	Terrestrial	6	0	3	0
Pressure (surface)	Terrestrial	3	0	1	0
River Discharge	Terrestrial	6	0	1	0
Sea Surface Salinity	Oceanic	4	0	0	0
Sea Surface Temperature	Oceanic	7	0	2	0
Soil Moisture	Terrestrial	12	7	3	0

Variable	Domain	# Data Products	# of Data Products which meet requirements for Spat. Res.	Temp. Res.	Spat. & Temp. Res.
Soil Organic Carbon	Terrestrial	9	6	2	0
Stable Carbon Isotopes	Oceanic	1	0	0	0
Sulfur Dioxide (SO2)	Atmospheric	9	1	2	0
Surface Wind Speed and direction	Terrestrial	3	0	1	0
Temperature (surface)	Terrestrial	8	0	3	0
Tropospheric Carbon Monoxide (CO)	Atmospheric	10	0	2	0
Tropospheric CH4 mixing ratio	Atmospheric	1	0	0	0
Tropospheric CO2 mixing ratio	Atmospheric	1	0	0	0
Tropospheric N2O mixing ratio	Atmospheric	1	0	0	0
Water Vapour (surface)	Terrestrial	4	0	2	0
Wild Herbivore Distribution	Terrestrial	1	0	0	0
Grand Total		**281**	**82**	**103**	**31**

While for most variables there are data products which either meet the requirements for spatial or temporal resolution, both conditions are met by the identified data products for only 11 out of the 58 variables. The only variable for which a single data product has been identified which meets all criteria including accuracy is “Extent of inland waters”, which can readily be observed from space.

For the vast majority of data products, the uncertainty is not indicated in the metadata and/or cannot easily be inferred from the actual dataset. For remote sensing products which strongly rely on calibrations from in situ observations, the uncertainty can vary significantly across the globe if observations are distributed heterogeneously. A systematic assessment of individual datasets against the accuracy requirements thus constitutes a major task.

For more detail, Table 12 in Annex A4 provides a disaggregated view of the data products associated with each essential variable including their respective spatial and temporal coverage.

4 Discussion

4.1 Data Gaps and Needs

In line with this report, we assessed the availability of both in situ and remote sensing observational infrastructure as well as existing data products related to the essential variables for climate system observations on and around the African continent.

We found that terrestrial in situ datasets and -products are relatively scarce for Africa, particularly those that are long-term and continuous in nature. The spatial coverage of in situ observations is thin and patchy. There is a need to cover the different biomes and ecosystems more homogeneously, particularly those areas with potentially important GHG source/sink dynamics and rather low human disturbance (see Annex A2). While the sub-regions of Central and East Africa appear to be severely understudied in general, there are numerous ecoregions which appear to be understudied (see Annex A3).

Some of the essential variables identified in line with SEACRIFOG are already largely covered by remote sensing technology or can be expected to be observable from space in the near to mid future. Given the global, periodic, quasi non-invasive and standardized character of satellite remote sensing measures, remotely sensed variables can be considered as 'low hanging fruits', meaning they are easier to generate than non-remotely sensed variables, which have to be assembled from disparate and local sources of information. The (largely) remotely sensed essential variables include active fire and burnt area, surface albedo and net radiation, cloud cover, extent of inland waters, FAPAR, land cover, ocean colour (and ocean chlorophyll content), sea surface temperature, precipitation and wind at surface. Accordingly, these variables have a rather low priority with regards to SEACRIFOG's observation RI design, since it is expected that they will require little effort in terms of additional in situ observations as compared to other variables in order to be measured at sufficient accuracy.

Despite the rapid advances made in EO technology, however, note that the need for long term systematic in situ observation will be no means be obliterated. In situ observations will always be indispensable to calibrate, validate and complement remote sensing technology in order to deliver accurate products for most variables. For example, various services of the Copernicus network note that 'variance in spatial or time coverage of in situ land and atmospheric observations is an issue that collectively cuts across Copernicus services. The key factor being that data coverage often jumps at national land borders, which can relate to a step change in the actual density or reporting frequency of observations, or alternatively be due to data accessibility and data policy issues. These issues can result in inconsistency within products that span nations and potentially introduce errors where the step changes are not understood by users. For example, resolution and confidence in a product may be assumed to be consistent across borders, where this may not be actually the case, resulting in poor decisions being made because based upon false assumptions' (European Environment Agency, 2017). Further work is thus necessary to assess the uncertainty of existing data products against the corresponding requirements, particularly in order to determine the possible need for further in situ observations in Africa to enhance the applicability and accuracy of existing or planned remote sensing products for the continent.

Variables which are measured by other means than in situ observation or remote sensing, such as human population and economic development, are considered as essential, yet 'ancillary' variables. This means that the SEACRIFOG project takes them into account in the observation network and data infrastructure design, but does not envisage their direct measurement by that network. In other words, SEACRIFOG-designed RIs will unlikely actively capture these variables, which thus have a low design priority.

In order to maximise its impact, the SEACRIFOG design tasks should focus on essential variables which cannot be readily observed from space currently or in the near to mid future and/or which require significant enhancement of in situ observations across the African continent and the surrounding oceans. Such design primarily refers to the determination of optimal number, location, methods and harmonization of existing and additional long-term/periodic observations of a given variable (to be addressed by WP3 for the major GHGs) required for the production of datasets and -products which meet the requirements specified in section 2. These variables include CO_2, CH_4 and N_2O biosphere–atmosphere fluxes as well as tropospheric mixing ratios, below ground biomass, soil organic carbon and litter, evapotranspiration, water vapour, river discharge, marine inorganic carbon, manure management as well as air temperature and pressure at surface.

Table 7 below provides a coarse classification of the essential variables according to the above considerations. Of the 58 variables identified to be essential in the context of SEACRIFOG, 16 are considered to have a high, 22 a medium and 20 a low RI design priority according to the present assessment.

Table 7: Coarse prioritization of the SEACRIFOG essential variables according to the data and observational design needs arising from the main current and future observation method and the availability of remote sensing records. Low design needs apply to variables which are already largely covered by appropriate RS products or which are available otherwise. High design needs are assigned to essential variables which can only be measured in situ or for which enhanced in situ data is critical to complement or produce RS products.

Variable	Domain	RS CDRs available?	Main Obs. Method Current	Main Obs. Method Future	SEACRIFOG Design Need
Above ground biomass	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Active Fire	Terr.	Y	Remote sensing	Remote sensing	Low
Aerosol properties	Atm.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Albedo	Terr.	Y	Remote sensing	Remote sensing	Low
Area of ploughed land	Terr.		Inventory/in situ	Comb. IS & RS	Medium
Below-Ground Biomass	Terr.		In situ	In situ	High
Biosphere-Atmosphere CH4 flux	Terr.		In situ	In situ	High
Biosphere-Atmosphere CO2 flux (NEE)	Terr.		In situ	In situ	High
Biosphere-Atmosphere N2O flux	Terr.		In situ	In situ	High
Boundary layer height	Atm.		In situ	Comb. IS & RS	Medium
Burnt Area	Terr.	Y	Remote sensing	Remote sensing	Low
Carbon Monoxide (CO)	Atm.	Y	Remote sensing	Remote sensing	Low
Cloud Cover Fraction	Atm.	Y	Remote sensing	Remote sensing	Low
CO2, CH4, N2O emissions by country and IPCC sector	Terr.		Inventory/Census	Inventory/Census	Low
Crop Yield by Type	Terr.		Inventory/Census	Inventory/Census	Medium
Dimethyl Sulfide	Ocn.		In situ	Comb. IS & RS	Medium
Economic Development	Various		Inventory/Census	Inventory/Census	Low
Evapotranspiration	Terr.		Comb. IS & RS	Comb. IS & RS	High
Extent of inland waters	Terr.	Y	Remote sensing	Remote sensing	Low
Fertilizer application	Terr.		Inventory/in situ	Inventory/in situ	Medium
Fire Fuel Load	Terr.		In situ	Comb. IS & RS	Medium
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Terr.	Y	Remote sensing	Remote sensing	Low
Halocarbons	Atm.		In situ	In situ	Low
Human Population	Terr.		Inventory/Census	Inventory/Census	Low
Infiltration and Runoff	Terr.		In situ	In situ	Medium
Inorganic Carbon	Ocn.		In situ	In situ	High
Irrigation	Terr.		In situ	Remote sensing	Low
Land Cover	Terr.	Y	Remote sensing	Remote sensing	Low
Land Use/Land Use Change	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Litter	Terr.		In situ	In situ	High
Livestock Distribution	Terr.		Inventory/Census	Inventory/Census	Medium
Manure Management	Terr.		Inventory/in situ	Inventory/in situ	High
Marine Nutrients	Ocn.		In situ	Comb. IS & RS	Medium
Net Primary Productivity	Terr.		Comb. IS & RS	Comb. IS & RS	Medium
Net Radiation at surface (SW/LW)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Nitrogen Oxides (NOx)	Atm.	Y	Remote sensing	Remote sensing	Low
Nitrous Oxide (Ocean)	Ocn.		In situ	In situ	Medium
Non-methane hydrocarbons	Atm.		In situ	In situ	Low

Variable	Domain	RS CDRs available?	Main Obs. Method Current	Main Obs. Method Future	SEACRI-FOG Design Need
Ocean Colour	Ocn.	Y	Remote sensing	Remote sensing	Low
Oxygen	Ocn.		In situ	In situ	Medium
Plant Species Traits	Terr.		In situ	In situ	Medium
Precipitation (surface)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Medium
Pressure (surface)	Terr.		In situ	In situ	High
River Discharge	Terr.		In situ	In situ	High
Sea Surface Salinity	Ocn.		Comb. IS & RS	Comb. IS & RS	Low
Sea Surface Temperature	Ocn.	Y	Comb. IS & RS	Comb. IS & RS	Low
Soil Moisture	Terr.	Y	Comb. IS & RS	Remote sensing	Medium
Soil Organic Carbon	Terr.		In situ	In situ	High
Stable Carbon Isotopes	Ocn.		In situ	In situ	Medium
Sulfur Dioxide (SO2)	Atm.	Y	Remote sensing	Remote sensing	Low
Surface Roughness	Terr.		In situ	Comb. IS & RS	Medium
Surface Wind Speed and direction	Terr.	Y	Comb. IS & RS	Comb. IS & RS	Low
Temperature (surface)	Terr.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric CH4 mixing ratio	Atm.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric CO2 mixing ratio	Atm.	Y	Comb. IS & RS	Comb. IS & RS	High
Tropospheric N2O mixing ratio	Atm.		Comb. IS & RS	Comb. IS & RS	High
Water Vapour (surface)	Terr.		In situ	In situ	High
Wild Herbivore Distribution	Terr.		Inventory/Census	Inventory/Census	Medium

4.2 Towards a Comprehensive Data Inventory

An important objective of SEACRIFOG is to maximise the interoperability of the observation network to be designed by SEACRIFOG as well as to ensure data access and sharing through the prototype development of a corresponding African e-infrastructure (WP5). The latter could include the development of a comprehensive inventory and corresponding data infrastructure to host metadata on existing and planned climate data records (and possibly actual datasets), both remote sensing and in situ, for the set of variables which was identified to be essential for constraining the climate forcing across the African continent and surrounding oceans. A first iteration of such a system has been made in line with the present (non- exhaustive) data product inventory and the SEACRIFOG Collaborative Inventory Tool. It was developed with the main intent to facilitate the collective input and participation by SEACRIFOG consortium members and to store and access the work across various SEACRIFOG work packages in a structured way.

A fully fledged data infrastructure for the compilation of a comprehensive inventory of relevant observation infrastructures (and corresponding instrumentation), data products and supporting protocols will on one hand require further software development, particularly with regards to automatization and more powerful functionality for search and analysis. Even more, the sustainable operation of such a data infrastructure will require an active community of practice, whose members will provide and manage the content of such a system on a continuous basis.

Possible further developments/functionality to be included in prototype e-infrastructure include:

- Metadata import/export (currently manual data product entry)
- Add table of active/planned satellites/space-borne instruments (and corresponding instruments) and link each variable to relevant satellites (and corresponding instruments)
- For each known/planned long term in situ observation site: Capture instrumentation and variables measured + temporal coverage for each variable, link to the respective variables
- Functionality to edit individual observation sites
- Visualize temporal coverage of existing/planned data products linked to each variable (see CEOS ECV Inventory)
- Detailed assessment of the uncertainty of individual data products, particularly uncertainty over/around Africa of RS-based products.

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Appendix

A1 In Situ Observation Sites in Africa per Essential Variable

Table 8: Number of in situ observation sites per essential variable in Africa (i.e. within the following bounding box (decimal degrees): North: 40; West: -26; East: 64; South: -40) for all in situ observation networks with site information contained in the SEACRIFOG observation infrastructure inventory (https://seacrifog-tool.sasscal.org) as of January 2019. Note that below figures refer to all sites independent of their operational status. Further note that no assessment of instrumentation at the individual site level was made, meaning that not necessarily all sites of a given network actually measure the respective variable. Consequently, the actual number of currently operational sites is lower than the figures provided.

Variable	Domain	Network Title	Number of Sites in Africa
Aerosol properties	Atmospheric	Aerosol Robotic Network	215
		Atlas Mohammed V (MARSU project)	1
		Global Atmosphere Watch	53
		Network for the Detection of Atmospheric Composition Change	3
		TOTAL	**272**
Albedo	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
Biosphere-Atmosphere CH4 flux	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
Biosphere-Atmosphere CO2 flux (NEE)	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
Biosphere-Atmosphere N2O flux	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
Boundary layer height	Atmospheric	Eddy Covariance Flux Station Inventory for Africa	40
Evapotranspiration	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
		South African Environmental Observation Network	130
		TOTAL	**170**
Halocarbons	Atmospheric	Network for the Detection of Atmospheric Composition Change	3
Infiltration and Runoff	Terrestrial	South African Environmental Observation Network	130
Inorganic Carbon (Ocean)	Oceanic	Argo	1559
		OceanSITES	46
		TOTAL	**1605**
Land Cover	Terrestrial	SASSCAL ObservationNet	54
Marine Nutrients	Oceanic	Argo	1559
		OceanSITES	46
		TOTAL	**1605**
Marine Oxygen	Oceanic	Argo	1559
		OceanSITES	46
		TOTAL	**1605**
Net Radiation at surface (SW/LW)	Terrestrial	Baseline Surface Radiation Network	7
		Eddy Covariance Flux Station Inventory for Africa	40
		Global Atmosphere Watch	53
		OceanSITES	46
		South African Environmental Observation Network	130
		TOTAL	**276**
Nitrogen Oxides (NOx)	Atmospheric	Atlas Mohammed V (MARSU project)	1
		Global Atmosphere Watch	53

		TOTAL	**54**
Nitrous Oxide (Ocean)	Oceanic	Argo	1559
Non-methane hydrocarbons	Atmospheric	Cooperative Air Sampling Network	8
		Global Atmosphere Watch	53
		TOTAL	**61**
Ocean Colour	Oceanic	OceanSITES	46
Plant Species Traits	Terrestrial	SASSCAL ObservationNet	54
Precipitation (surface)	Terrestrial	Atlas Mohammed V (MARSU project)	1
		Eddy Covariance Flux Station Inventory for Africa	40
		GCOS Surface Network	137
		Global Observing System	1288
		OceanSITES	46
		SASSCAL ObservationNet	54
		SASSCAL Weathernet	154
		Ship Observations Team	383
		South African Environmental Observation Network	130
		TOTAL	**2233**
Pressure (surface)	Terrestrial	Baseline Surface Radiation Network	7
		Data Buoy Cooperation Panel	357
		Eddy Covariance Flux Station Inventory for Africa	40
		GCOS Surface Network	137
		Global Atmosphere Watch	53
		Global Observing System	1288
		OceanSITES	46
		SASSCAL Weathernet	154
		Ship Observations Team	383
		South African Environmental Observation Network	130
		TOTAL	**2595**
River Discharge	Terrestrial	Global Terrestrial Network for River Discharge	17
		South African Environmental Observation Network	130
		TOTAL	**147**
Sea Surface Salinity	Oceanic	Argo	1559
		OceanSITES	46
		Ship Observations Team	383
		TOTAL	**1988**
Sea Surface Temperature	Oceanic	Argo	1559
		Data Buoy Cooperation Panel	357
		OceanSITES	46
		Ship Observations Team	383
		South African Environmental Observation Network	130
		TOTAL	**2475**
Soil Moisture	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
		SASSCAL Weathernet	154
		South African Environmental Observation Network	130

		TOTAL	**324**
Soil Organic Carbon	Terrestrial	SASSCAL ObservationNet	54
Sulfur Dioxide (SO2)	Atmospheric	Global Atmosphere Watch	53
Surface Roughness	Terrestrial	Eddy Covariance Flux Station Inventory for Africa	40
Surface Wind Speed and direction	Terrestrial	Atlas Mohammed V (MARSU project)	1
		Data Buoy Cooperation Panel	357
		Eddy Covariance Flux Station Inventory for Africa	40
		OceanSITES	46
		SASSCAL Weathernet	154
		Ship Observations Team	383
		South African Environmental Observation Network	130
		TOTAL	**1111**
Temperature (surface)	Terrestrial	Atlas Mohammed V (MARSU project)	1
		Baseline Surface Radiation Network	7
		Data Buoy Cooperation Panel	357
		Eddy Covariance Flux Station Inventory for Africa	40
		GCOS Surface Network	137
		Global Atmosphere Watch	53
		Global Observing System	1288
		SASSCAL ObservationNet	54
		SASSCAL Weathernet	154
		Ship Observations Team	383
		South African Environmental Observation Network	130
		TOTAL	**2604**
Tropospheric Carbon Monoxide (CO)	Atmospheric	Cooperative Air Sampling Network	8
		Global Atmosphere Watch	53
		Network for the Detection of Atmospheric Composition Change	3
		Total Carbon Column Observing Network	3
		TOTAL	**67**
Tropospheric CH4 mixing ratio	Atmospheric	Cooperative Air Sampling Network	8
		Global Atmosphere Watch	53
		Total Carbon Column Observing Network	3
		TOTAL	**64**
Tropospheric CO2 mixing ratio	Atmospheric	Cooperative Air Sampling Network	8
		Global Atmosphere Watch	53
		Total Carbon Column Observing Network	3
		TOTAL	**64**
Tropospheric N2O mixing ratio	Atmospheric	Cooperative Air Sampling Network	8
		Global Atmosphere Watch	53
		Total Carbon Column Observing Network	3
		TOTAL	**64**
Water Vapour (surface)	Terrestrial	SASSCAL Weathernet	154
		South African Environmental Observation Network	130
		TOTAL	**284**

A2 In Situ Observation Densities for African Biomes and Anthromes

Table 9: Number of stations and station density (per 10,000 km²) per biome (Olson, et al., 2001) on the African continent for the networks considered in Figure 2 (a) and (b).

Biome	Area (sqkm)	GHG/Aerosol Stations	GHG Station Density	Weather Stations	Weather Station Density
Temperate Coniferous Forests	21,764	2	0.92	5	2.30
Montane Grasslands and Shrublands	857,684	19	0.22	110	1.28
Flooded Grasslands and Savannas	553,912	10	0.18	42	0.76
Mediterranean Forests, Woodlands, and Scrub	842,758	14	0.17	145	1.72
Mangroves	66,626	1	0.15	14	2.10
Tropical and Subtropical Dry Broadleaf Forests	191,222	2	0.10	10	0.52
Tropical and Subtropical Moist Broadleaf Forests	3,455,531	26	0.08	168	0.49
Tropical and subtropical grasslands, savannas, and shrublands	13,948,474	96	0.07	560	0.40
Lakes	154,730	1	0.06		0.00
Deserts and Xeric Shrublands	9,780,796	44	0.04	274	0.28

Table 10: Number of stations and station density (per 10,000 km²) per anthrome (Ellis, Goldewijk, Siebert, Lightman, & Ramankutty, 2010) for the networks considered in Figure 2 (a) and (b).

Anthrome	Area (sqkm)	GHG/Aerosol Stations	GHG Station Density	Weather Stations	Weather Station Density
DENSE SETTLEMENTS	**181,091**	**32**	**1.767**	**180**	**9.94**
Urban	40,570	28	6.90	117	28.84
Mixed settlements	140,521	4	0.28	63	4.48
VILLAGES	**1,127,592**	**37**	**0.33**	**319**	**2.83**
Rice villages	478		0.00		0.00
Irrigated villages	76,039	3	0.39	37	4.87
Rainfed villages	751,622	22	0.29	132	1.76
Pastoral villages	299,453	12	0.40	150	5.01
CROPLANDS	**3,176,498**	**38**	**0.12**	**159**	**0.50**
Residential irrigated cropland	74,285	3	0.40	20	2.69
Residential rainfed croplands	2,247,851	22	0.10	125	0.56
Populated croplands	704,914	5	0.07	8	0.11
Remote croplands	149,448	8	0.54	6	0.40
RANGELANDS	**11,745,700**	**60**	**0.05**	**429**	**0.37**
Residential rangelands	3,987,659	22	0.06	238	0.60
Populated rangelands	5,260,394	26	0.05	124	0.24
Remote rangelands	2,497,647	12	0.05	67	0.27
SEMINATURAL	**6,151,580**	**31**	**0.05**	**147**	**0.24**
Residential woodlands	1,611,084	8	0.05	56	0.35
Populated woodlands	2,279,254	5	0.02	32	0.14
Remote woodlands	459,980	1	0.02	6	0.13
Inhabited treeless and barren	1,801,261	17	0.09	53	0.29
WILDLANDS	**7,360,073**	**15**	**0.02**	**84**	**0.11**
Wild woodlands	352,377	3	0.09	5	0.14
Wild treeless and barren lands	7,007,695	12	0.02	79	0.11

A3 List of EC Flux Observations per Terrestrial Ecoregion in Africa

Table 11: List of terrestrial biomes and ecoregions in Africa according to Olson et al. (Olson, et al., 2001) and the respective number of EC flux towers based on the inventory compiled by SEACRIFOG.

Biome Terrestrial Ecosystem	No More Operational	Currently Operational	Planned	Status Unknown	Total
Deserts and Xeric Shrublands	**0**	**2**	**0**	**1**	**3**
Aldabra Island Xeric Scrub	0	0	0	0	0
Arabian Desert And East Sahero-Arabian Xeric Shrublands	0	0	0	0	0
Atlantic Coastal Desert	0	0	0	0	0
East Saharan Montane Xeric Woodlands	0	0	0	0	0
Eritrean Coastal Desert	0	0	0	0	0
Ethiopian Xeric Grasslands And Shrublands	0	0	0	0	0
Hobyo Grasslands And Shrublands	0	0	0	0	0
Kalahari Xeric Savanna	0	0	0	1	1
Kaokoveld Desert	0	0	0	0	0
Madagascar Spiny Thickets	0	0	0	0	0
Madagascar Succulent Woodlands	0	0	0	0	0
Masai Xeric Grasslands And Shrublands	0	0	0	0	0
Mesopotamian Shrub Desert	0	0	0	0	0
Nama Karoo	0	2	0	0	2
Namib Desert	0	0	0	0	0
Namibian Savanna Woodlands	0	0	0	0	0
North Saharan Steppe And Woodlands	0	0	0	0	0
Red Sea Coastal Desert	0	0	0	0	0
Red Sea Nubo-Sindian Tropical Desert And Semi-Desert	0	0	0	0	0
Sahara Desert	0	0	0	0	0
Somali Montane Xeric Woodlands	0	0	0	0	0
South Saharan Steppe And Woodlands	0	0	0	0	0
Succulent Karoo	0	0	0	0	0
Tibesti-Jebel Uweinat Montane Xeric Woodlands	0	0	0	0	0
West Saharan Montane Xeric Woodlands	0	0	0	0	0
Flooded Grasslands and Savannas	**1**	**0**	**0**	**0**	**1**
East African Halophytics	0	0	0	0	0
Etosha Pan Halophytics	0	0	0	0	0
Inner Niger Delta Flooded Savanna	0	0	0	0	0
Lake Chad Flooded Savanna	0	0	0	0	0
Nile Delta Flooded Savanna	0	0	0	0	0
Saharan Flooded Grasslands	0	0	0	0	0
Saharan Halophytics	0	0	0	0	0
Zambezian Coastal Flooded Savanna	0	0	0	0	0
Zambezian Flooded Grasslands	1	0	0	0	1
Zambezian Halophytics	0	0	0	0	0

Biome Terrestrial Ecosystem	No More Operational	Currently Operational	Planned	Status Unknown	Total
Inland Water	**1**	**0**	**0**	**0**	**1**
Lake: Afrotropic	1	0	0	0	1
Mangroves	**0**	**0**	**0**	**0**	**0**
Central African Mangroves	0	0	0	0	0
East African Mangroves	0	0	0	0	0
Guinean Mangroves	0	0	0	0	0
Madagascar Mangroves	0	0	0	0	0
Southern Africa Mangroves	0	0	0	0	0
Mediterranean Forests, Woodlands and Scrub	**0**	**0**	**0**	**0**	**0**
Albany Thickets	0	0	0	0	0
Lowland Fynbos And Renosterveld	0	0	0	0	0
Mediterranean Acacia-Argania Dry Woodlands And Succulent Thickets	0	0	0	0	0
Mediterranean Dry Woodlands And Steppe	0	0	0	0	0
Mediterranean Woodlands And Forests	0	0	0	0	0
Montane Fynbos And Renosterveld	0	0	0	0	0
Montane Grasslands and Shrublands	**0**	**2**	**0**	**0**	**2**
Angolan Montane Forest-Grassland Mosaic	0	0	0	0	0
Angolan Scarp Savanna And Woodlands	0	0	0	0	0
Drakensberg Alti-Montane Grasslands And Woodlands	0	0	0	0	0
Drakensberg Montane Grasslands, Woodlands And Forests	0	1	0	0	1
East African Montane Moorlands	0	0	0	0	0
Eastern Zimbabwe Montane Forest-Grassland Mosaic	0	0	0	0	0
Ethiopian Montane Grasslands And Woodlands	0	0	0	0	0
Ethiopian Montane Moorlands	0	0	0	0	0
Highveld Grasslands	0	1	0	0	1
Jos Plateau Forest-Grassland Mosaic	0	0	0	0	0
Madagascar Ericoid Thickets	0	0	0	0	0
Maputaland-Pondoland Bushland And Thickets	0	0	0	0	0
Mediterranean High Atlas Juniper Steppe	0	0	0	0	0
Ruwenzori-Virunga Montane Moorlands	0	0	0	0	0
South Malawi Montane Forest-Grassland Mosaic	0	0	0	0	0
Southern Rift Montane Forest-Grassland Mosaic	0	0	0	0	0
Temperate Conifer Forests	**0**	**0**	**0**	**0**	**0**
Mediterranean Conifer And Mixed Forests	0	0	0	0	0
Temperate Grasslands, Savannas and Shrublands	**0**	**0**	**0**	**0**	**0**
Tristan Da Cunha-Gough Islands Shrub And Grasslands	0	0	0	0	0
Tropical and Subtropical Dry Broadleaf Forests	**0**	**0**	**0**	**0**	**0**
Cape Verde Islands Dry Forests	0	0	0	0	0
Madagascar Dry Deciduous Forests	0	0	0	0	0
Zambezian Cryptosepalum Dry Forests	0	0	0	0	0
Tropical and Subtropical Grasslands, Savannas and Shrublands	**20**	**7**	**1**	**2**	**30**

Biome Terrestrial Ecosystem	No More Operational	Currently Operational	Planned	Status Unknown	Total
Angolan Miombo Woodlands	0	0	0	0	0
Angolan Mopane Woodlands	0	0	0	0	0
Ascension Scrub And Grasslands	0	0	0	0	0
Central Zambezian Miombo Woodlands	0	0	0	0	0
East Sudanian Savanna	0	0	0	0	0
Eastern Miombo Woodlands	0	0	0	0	0
Guinean Forest-Savanna Mosaic	0	0	0	0	0
Itigi-Sumbu Thicket	0	0	0	0	0
Kalahari Acacia-Baikiaea Woodlands	2	0	0	0	2
Mandara Plateau Mosaic	0	0	0	0	0
Northern Acacia-Commiphora Bushlands And Thickets	0	1	1	0	2
Northern Congolian Forest-Savanna Mosaic	0	0	0	0	0
Sahelian Acacia Savanna	5	1	0	0	6
Serengeti Volcanic Grasslands	0	0	0	0	0
Somali Acacia-Commiphora Bushlands And Thickets	0	0	0	0	0
Southern Acacia-Commiphora Bushlands And Thickets	0	0	0	0	0
Southern Africa Bushveld	0	1	0	0	1
Southern Congolian Forest-Savanna Mosaic	0	0	0	0	0
Southern Miombo Woodlands	0	0	0	0	0
St. Helena Scrub And Woodlands	0	0	0	0	0
Victoria Basin Forest-Savanna Mosaic	1	0	0	0	1
West Sudanian Savanna	8	1	0	1	10
Western Congolian Forest-Savanna Mosaic	3	0	0	0	3
Western Zambezian Grasslands	0	0	0	0	0
Zambezian And Mopane Woodlands	1	3	0	1	5
Zambezian Baikiaea Woodlands	0	0	0	0	0
Tropical and Subtropical Moist Broadleaf Forests	**1**	**0**	**2**	**0**	**3**
Albertine Rift Montane Forests	0	0	0	0	0
Atlantic Equatorial Coastal Forests	0	0	0	0	0
Cameroonian Highlands Forests	0	0	0	0	0
Central Congolian Lowland Forests	0	0	2	0	2
Comoros Forests	0	0	0	0	0
Cross-Niger Transition Forests	0	0	0	0	0
Cross-Sanaga-Bioko Coastal Forests	0	0	0	0	0
East African Montane Forests	0	0	0	0	0
Eastern Arc Forests	0	0	0	0	0
Eastern Congolian Swamp Forests	0	0	0	0	0
Eastern Guinean Forests	1	0	0	0	1
Ethiopian Montane Forests	0	0	0	0	0
Granitic Seychelles Forests	0	0	0	0	0
Guinean Montane Forests	0	0	0	0	0

Biome Terrestrial Ecosystem	No More Operational	Currently Operational	Planned	Status Unknown	Total
Knysna-Amatole Montane Forests	0	0	0	0	0
Kwazulu-Cape Coastal Forest Mosaic	0	0	0	0	0
Madagascar Lowland Forests	0	0	0	0	0
Madagascar Subhumid Forests	0	0	0	0	0
Maputaland Coastal Forest Mosaic	0	0	0	0	0
Mascarene Forests	0	0	0	0	0
Mount Cameroon And Bioko Montane Forests	0	0	0	0	0
Niger Delta Swamp Forests	0	0	0	0	0
Nigerian Lowland Forests	0	0	0	0	0
Northeastern Congolian Lowland Forests	0	0	0	0	0
Northern Zanzibar-Inhambane Coastal Forest Mosaic	0	0	0	0	0
Northwestern Congolian Lowland Forests	0	0	0	0	0
Sao Tome And Principe Moist Lowland Forests	0	0	0	0	0
Southern Zanzibar-Inhambane Coastal Forest Mosaic	0	0	0	0	0
Western Congolian Swamp Forests	0	0	0	0	0
Western Guinean Lowland Forests	0	0	0	0	0
Tundra	**0**	**0**	**0**	**0**	**0**
Southern Indian Ocean Islands Tundra	0	0	0	0	0
Grand Total	**23**	**11**	**3**	**3**	**40**

A4 Data Product Inventory: Assessment Table

Table 12: Datasets/-products linked to each essential variable as stored in the SEACRIFOG Collaborative Inventory Tool database as of January 2019. For more detailed metainformation on each dataset/-product, refer to the web-based tool at https://seacrifog-tool.sasscal.org/.

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Above ground biomass	Terr.	500 m	1 year	20 %	Above-ground biomass and structure of 260 African tropical forests	Cross-sectional Data	In Situ	Regional/Sub-Continental	2013-01 until 2013-12			
					Global 10-daily Dry Matter Productivity 1km	Geospatial - Raster	Remote	Global	2014-01 until present		X	
					Fraction of Green Vegetation Cover 1km V2	Geospatial - Raster	Remote	Global	1999-01 until present		X	
					Normalized Difference Vegetation Index (NDVI), V2.2, 1km	Geospatial - Raster	Remote	Global	1998-04 until present		X	
					NPP Grassland: Nylsvley, South Africa, 1974-1989, R1	Time series	In Situ	Individual Site	1974-10 until 1977-09		X	
					NPP Grassland: NPP Grassland: Towoomba, South Africa, 1949-1990, R1	Time series	In Situ	Individual Site	1950-01 until 1981-12		X	
					NPP Grassland: Nairobi, Kenya, 1984-1994, R1	Time series	In Situ	Individual Site	1984-07 until 1994-11		X	
					NPP Grassland: Olokemeji, Nigeria, 1956-1964, R1	Time series	In Situ	Individual Site	1956-01 until 1964-11		X	
					NPP Tropical Forest: Kade, Ghana, 1957-1972, R1	Time series	In Situ	Individual Site	1957-01 until 1957-01			
					CMS: Estimated Deforested Area Biomass, Tropical America, Africa, and Asia, 2000	Geospatial - Raster	Comb. IS & RS	Continental	2000-01 until 2012-12	X		
					CMS: Aboveground Biomass for Mangrove Forest, Zambezi River Delta, Mozambique	Geospatial - Raster	Comb. IS & RS	Individual Site	2012-09 until 2013-10	X		
					AfriSAR: Mondah Forest Tree Species, Biophysical, and Biomass Data, Gabon, 2016	Cross-sectional Data	In Situ	Individual Site	2016-03 until 2016-03			
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12		X	
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12		X	
Litter	Terr.	1 km	3 months	10 %	NPP Grassland: Nylsvley, South Africa, 1974-1989, R1	Time series	In Situ	Individual Site	1974-10 until 1977-09		X	
					NPP Grassland: Nairobi, Kenya, 1984-1994, R1	Time series	In Situ	Individual Site	1984-07 until 1994-11		X	
					NPP Tropical Forest: Kade, Ghana, 1957-1972, R1	Time series	In Situ	Individual Site	1957-01 until 1957-01			
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12		X	
					A Global Database of Litterfall Mass and Litter Pool Carbon and Nutrients	Other	In Situ	Global				
Aerosol properties	Atm.	5 km	4 h	10 %	NASA Ocean Color Web	Geospatial - Raster	Remote	Global	2002-07 until present	X		

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
					MCD19A2: MODIS/Terra and Aqua MAIAC Land Aerosol Optical Depth Daily L2G 1 km SIN Grid V006	Geospatial - Raster	Remote	Global	2000-02 until present	X		
					Global Annual PM2.5 Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD) with GWR, v1 (1998â€Šâ€“â€Š2016)	Geospatial - Raster	Remote	Global	1998-01 until 2016-12	X		
					SAFARI 2000 C-130 Aerosol and Meteorological Data, Dry Season 2000	Geospatial - Raster	In Situ	Regional/Sub-Continental	2000-09 until 2000-09			
					SAFARI 2000 CV-580 Aerosol and Cloud Data, Dry Season 2000 (CARG)	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09	X		
					SAFARI 2000 JRA Aerocommander Trace Gas, Aerosol, and CCN Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					GLAS/ICESat L2 Global Planetary Boundary Layer and Elevated Aerosol Layer Heights (HDF5), Version 33	Geospatial - Raster	Remote	Global	2003-02 until 2009-10	X		
					World Data Centre for Aerosols (WDCA)	Other	In Situ	Global				
Fertilizer application	Terr.	1 country	1 year	20 %	Global Fertilizer and Manure, v1	Geospatial - Raster	Comb. IS & RS	Global	1994-01 until 2001-12	X		
Irrigation	Terr.	100 m	1 day	10 %	Global Surface Water	Geospatial - Raster	Remote	Global	1984-01 until 2015-12	X		
					Irrigated Cropland area (ha)	Geospatial - Raster	Remote	Continental	2000-01 until 2000-12			
Manure Management	Terr.	1 livestock system	5 years	20 %	Global Fertilizer and Manure, v1	Geospatial - Raster	Comb. IS & RS	Global	1994-01 until 2001-12	X		
					CMS: Global Carbon Fluxes Associated with Livestock Feed and Emissions, 2000-2013	Geospatial - Raster	Model	Global	2000-01 until 2013-12	X	X	X
Livestock Distribution	Terr.	20 km	5 years	15 %	Gridded Livestock of the World (GLW)	Geospatial - Raster	Model	Global	2005-01 until 2007-12	X	X	X
					Global rangeland mask	Geospatial - Raster	Remote	Global		X		
					Characteristics of African Savanna Biomes for Determining Woody Cover	Cross-sectional Data	In Situ	Regional/Sub-Continental	1981-01 until 2003-12			
					CMS: Global Carbon Fluxes Associated with Livestock Feed and Emissions, 2000-2013	Geospatial - Raster	Model	Global	2000-01 until 2013-12	X	X	X
					Pastures, v1 (2000)	Geospatial - Raster	Remote	Global	2000-01 until 2000-12	X		
Wild Herbivore Distribution	Terr.	20 km	5 years	15 %	Characteristics of African Savanna Biomes for Determining Woody Cover	Cross-sectional Data	In Situ	Regional/Sub-Continental	1981-01 until 2003-12			
Below-Ground Biomass	Terr.	1 km	5 years	10 %	NPP Grassland: Nylsvley, South Africa, 1974-1989, R1	Time series	In Situ	Individual Site	1974-10 until 1977-09		X	
					NPP Grassland: Nairobi, Kenya, 1984-1994, R1	Time series	In Situ	Individual Site	1984-07 until 1994-11		X	
					NPP Tropical Forest: Kade, Ghana, 1957-1972, R1	Time series	In Situ	Individual Site	1957-01 until 1957-01			
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12		X	

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Biosphere-Atmosphere CH4 flux	Terr.	1 site	1 h	5 %	MarinE MethanE and NiTrous Oxide (MEMENTO) database	Other	In Situ	Global	1960-01 until present			
					CMS: Global 0.5-deg Wetland Methane Emissions and Uncertainty (WetCHARTs v1.0)	Geospatial - Raster	Model	Global	2001-01 until 2015-12			
					CMS: Carbon Fluxes from Global Agricultural Production and Consumption, 2005-2011	Geospatial - Raster	Model	Global	2005-01 until 2011-12			
					Annual CO2, CH4 and N2O emissions from 59 plots, across different vegetation types, field types and land classes in western Kenya	Time series	In Situ	Individual Site	2013-08 until 2014-08			
					Annual CO2, CH4 and N2O emissions from different maize farming techniques in the highlands of Tanzania	Time series	In Situ	Individual Site	2012-01 until 2014-12			
Biosphere-Atmosphere CO2 flux (NEE)	Terr.	1 site	1 h	5 %	FLUXNET2015 Dataset	Geospatial - Raster	In Situ	Global	1989-01 until 2015-12		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			
					SAFARI 2000 Monthly and Annual CO2 Emissions from Soil, 0.5 Degree Grid	Geospatial - Raster	Model	Regional/Sub-Continental	1995-01 until 1995-12			
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					CMS: Carbon Fluxes from Global Agricultural Production and Consumption, 2005-2011	Geospatial - Raster	Model	Global	2005-01 until 2011-12			
					ISLSCP II Atmospheric Carbon Dioxide Consumption by Continental Erosion	Geospatial - Raster	Model	Global	1986-01 until 1995-12			
					CMS: Modeled Net Ecosystem Exchange at 3-hourly Time Steps, 2004-2010	Geospatial - Raster	In Situ	Global	2004-01 until 2010-12			
					SiB3 Modeled Global 1-degree Hourly Biosphere-Atmosphere Carbon Flux, 1998-2006	Geospatial - Raster	Model	Global	1998-01 until 2006-12		X	
					CMSFluxFire: Carbon Monitoring System Carbon Flux for Fire L4 V1	Geospatial - Raster	Remote	Global	2010-01 until 2013-01			
					CMSFluxNEE: Carbon Monitoring System Flux from the Net Ecosystem Exchange L4 V1	Geospatial - Raster	Remote	Global	2010-01 until 2013-01			
					CMSFluxOcean: Carbon Monitoring System Flux for Ocean Carbon L4 V1	Geospatial - Raster	Remote	Global	2010-01 until 2013-01			
					Annual CO2, CH4 and N2O emissions from 59 plots, across different vegetation types, field types and land classes in western Kenya	Time series	In Situ	Individual Site	2013-08 until 2014-08			
					Annual CO2, CH4 and N2O emissions from different maize farming techniques in the highlands of Tanzania	Time series	In Situ	Individual Site	2012-01 until 2014-12			
					CO2 and other GHG fluxes from charcoal production in Zambia	Time series	In Situ	Individual Site	2007-09 until 2009-07		X	

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Biosphere-Atmosphere N2O flux	Terr.	1 site	1 h	5 %	MarinE MethanE and NiTrous Oxide (MEMENTO) database	Other	In Situ	Global	1960-01 until present			
					Annual CO2, CH4 and N2O emissions from 59 plots, across different vegetation types, field types and land classes in western Kenya	Time series	In Situ	Individual Site	2013-08 until 2014-08			
					Annual CO2, CH4 and N2O emissions from different maize farming techniques in the highlands of Tanzania	Time series	In Situ	Individual Site	2012-01 until 2014-12			
Boundary layer height	Atm.	20 km	1 h	20 %	GPSROZPBLS: GPS Radio Occultation Boundary Layer Depth Seasonal L3 V1	Geospatial - Raster	Remote	Global	2006-06 until 2015-12			
					GLAS/ICESat L2 Global Planetary Boundary Layer and Elevated Aerosol Layer Heights (HDF5), Version 33	Geospatial - Raster	Remote	Global	2003-02 until 2009-10	X		
Halocarbons	Atm.	1 site	1 week	5 %	Halocarbons in the Ocean and Atmosphere (HalOcAt) database	Other	In Situ	Global	1989-01 until 2011-12			
					World Data Centre for Greenhouse Gases (WDCGG)	Other	In Situ	Global				
Tropospheric CH4 mixing ratio	Atm.	1 site	1 h	1 ppb	World Data Centre for Greenhouse Gases (WDCGG)	Other	In Situ	Global				
Tropospheric CO2 mixing ratio	Atm.	1 site	1 h	0.1 ppm	World Data Centre for Greenhouse Gases (WDCGG)	Other	In Situ	Global				
Tropospheric N2O mixing ratio	Atm.	1 site	1 h	0.1 ppb	World Data Centre for Greenhouse Gases (WDCGG)	Other	In Situ	Global				
Cloud Cover Fraction	Atm.	2.5 km	1 h	10 %	Global 1-km Cloud Cover	Geospatial - Raster	Remote	Global	2000-01 until 2015-12	X		
					MODIS Cloud Parameters	Geospatial - Raster	Remote	Global	2000-02 until present			
Crop Yield by Type	Terr.	1 country	1 year	10 %	Global 10-daily Dry Matter Productivity 1km	Geospatial - Raster	Remote	Global	2014-01 until present	X	X	X
					Africa SoilGrids - Root zone texture	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					Africa SoilGrids - Root zone depth (cm)	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					Vegetation Condition Index V1, 1km	Geospatial - Raster	Remote	Global	2013-01 until present	X	X	X
					Normalized Difference Vegetation Index (NDVI), V2.2, 1km	Geospatial - Raster	Remote	Global	1998-04 until present	X	X	X
					GFSAD30AFCE: Global Food Security-support Analysis Data (GFSAD) Cropland Extent 2015 Africa 30 m V001	Geospatial - Raster	Remote	Continental	2015-01 until 2015-12	X	X	X
Economic Development	Various	1 country	1 year	5 %	Global Gridded Geographically Based Economic Data (G-Econ), v4 (1990, 1995, 2000, 2005)	Geospatial - Raster	Model	Global	1990-01 until 2005-12	X		

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
					Socioeconomic Downscaled Projections	Geospatial - Raster	Model	Global	1990-01 until 2100-12	X		
Net Primary Productivity	Terr.	1 km	1 month	10 %	Global 10-daily Dry Matter Productivity 1km	Geospatial - Raster	Remote	Global	2014-01 until present	X	X	X
					Terra/MODIS Net Primary Production Yearly L4 Global 1km	Geospatial - Raster	Remote	Global	2000-01 until 2010-12	X		
					NPP Grassland: Nylsvley, South Africa, 1974-1989, R1	Time series	In Situ	Individual Site	1974-10 until 1977-09		X	
					NPP Grassland: Nairobi, Kenya, 1984-1994, R1	Time series	In Situ	Individual Site	1984-07 until 1994-11		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12		X	
					CMS: Carbon Fluxes from Global Agricultural Production and Consumption, 2005-2011	Geospatial - Raster	Model	Global	2005-01 until 2011-12			
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12		X	
Active Fire	Terr.	250 m	1 h	5 %	MOD14A1: MODIS/Terra Thermal Anomalies & Fire Daily L3 Global 1km V006	Geospatial - Raster	Remote	Global	2000-02 until present			
					VNP14: VIIRS/NPP Thermal Anomalies/Fire 6-Min L2 Swath 750 m V001	Geospatial - Raster	Remote	Global	2012-01 until present			
					CMSFluxFire: Carbon Monitoring System Carbon Flux for Fire L4 V1	Geospatial - Raster	Remote	Global	2010-01 until 2013-01			
Burnt Area	Terr.	30 m	1 day	15 %	Global 10-day composite Burnt Area, 300m	Geospatial - Raster	Remote	Global	2014-04 until present			
					MCD64A1: MODIS/Terra and Aqua Burned Area Monthly L3 Global 500 m SIN Grid V006	Geospatial - Raster	Remote	Global	2000-11 until present			
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12			
Fire Fuel Load	Terr.	1 km	1 year	15 %	Vegetation Condition Index V1, 1km	Geospatial - Raster	Remote	Global	2013-01 until present	X	X	X
					Normalized Difference Vegetation Index (NDVI), V2.2, 1km	Geospatial - Raster	Remote	Global	1998-04 until present	X	X	X
					MOD44B: MODIS/Terra Vegetation Continuous Fields Yearly L3 Global 250 m SIN Grid V006	Geospatial - Raster	Remote	Global	2000-03 until 2017-03	X	X	X
					SAFARI 2000 Modeled Fuel Load in Southern Africa, 1999-2000	Geospatial - Raster	Remote	Regional/Sub-Continental	1999-09 until 2000-08	X	X	X
Human Population	Terr.	20 km	5 years	5 %	GHSL - Global Human Settlement Layer	Geospatial - Raster	Comb. IS & RS	Global	1975-01 until 2015-12	X		
					Gridded Population of the World (GPW), v4	Geospatial - Raster	Model	Global	2000-01 until 2020-12	X	X	X
					Global Population Projection Grids Based on SSPs, v1 (2010â€Šâ€“â€Š2100)	Geospatial - Raster	Model	Global	2010-01 until 2100-12	X		
					Anthropogenic Biomes of the World, v2 (2000)	Geospatial - Raster	Model	Global	2000-01 until 2000-12			

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Evapotranspiration	Terr.	1 km	1 day	10 %	Leaf Area Index 1km, V2	Geospatial - Raster	Remote	Global	1999-01 until present	X		
					VNP15A2H: VIIRS/S-NPP Leaf Area Index/FPAR 8-Day L4 Global 500 m SIN Grid V001	Geospatial - Raster	Remote	Global	2012-01 until present	X		
					MCD15A3H: MODIS/Terra+Aqua Leaf Area Index/FPAR 4-Day L4 Global 500 m SIN Grid V006	Geospatial - Raster	Remote	Global	2002-07 until present	X		
					MOD16A2: MODIS/Terra Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid V006	Geospatial - Raster	Comb. IS & RS	Global	2001-01 until present	X		
					MYD16A2: MODIS/Aqua Net Evapotranspiration 8-Day L4 Global 500 m SIN Grid V006	Geospatial - Raster	Comb. IS & RS	Global	2002-07 until present	X		
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			
					GLEAM Evaporation parameters V3	Geospatial - Raster	Model	Global	1980-01 until 2017-12		X	
Infiltration and Runoff	Terr.	1 km	1 month	10 %	Global Composite Runoff Fields (CSRC-UNH and GRDC, 2002), V1.0	Geospatial - Raster	Model	Global				
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12		X	
					Global Runoff Data Base	Time series	In Situ	Global	1869-01 until present		X	
Precipitation (surface)	Terr.	1 km	1 day	10 %	CHIRPS v2	Geospatial - Raster	Comb. IS & RS	Global	1981-01 until present			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					Spatio-temporal Characteristics of Rainfall in Africa, 0.25 degrees, from 1998-2012	Geospatial - Raster	Remote	Continental	1998-01 until 2012-12			
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12			
					Global Historical Climatology Network - Daily (GHCN-Daily), Version 3	Time series	In Situ	Global	1880-01 until present		X	
					TAMSAT V3.0	Geospatial - Raster	Remote	Continental	1983-01 until present		X	
River Discharge	Terr.	1 river basin	1 day	10 %	Global Composite Runoff Fields (CSRC-UNH and GRDC, 2002), V1.0	Geospatial - Raster	Model	Global				
					Water Level - Rivers, V2	Time series	Remote	Global	2002-05 until present			
					ISLSCP II Global River Fluxes of Carbon and Sediments to the Oceans	Geospatial - Raster	Comb. IS & RS	Global	1947-01 until 1998-12			
					Global River Discharge, 1807-1991, V[ersion]. 1.1 (RivDIS)	Time series	In Situ	Global	1807-01 until 1991-09			
					Long-Term Statistics and Annual Characteristics of GRDC Timeseries Data (GRDC, 2018)	Other	In Situ	Continental				
					Global Runoff Data Base	Time series	In Situ	Global	1869-01 until present		X	

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Inorganic Carbon (Ocean)	Ocn.	250 km	1 month	10 %	Surface Ocean COâ,, Atlas (SOCAT) V6	Geospatial - Raster	In Situ	Global	1957-01 until 2017-12	X		
					GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12	X		
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
Extent of inland waters	Terr.	20 m	3 months	1 %	ESA CCI S2 Prototype Land Cover 20m Map of Africa 2016	Geospatial - Raster	Remote	Continental	2015-12 until 2016-12	X		
					Water Bodies V1, 300m	Geospatial - Raster	Remote	Global	2014-01 until present		X	
					Water Level - Lakes, V2	Time series	Remote	Global	1992-09 until present		X	
					Water Level - Rivers, V2	Time series	Remote	Global	2002-05 until present		X	
					MOD44W: MODIS/Terra Land Water Mask Derived from MODIS and SRTM L3 Yearly Global 250 m SIN Grid V006	Geospatial - Raster	Remote	Global	2000-01 until 2015-12			
					Global Surface Water	Geospatial - Raster	Remote	Global	1984-01 until 2015-12	X	X	X
					Tropical and Subtropical Wetlands Distribution version 2	Geospatial - Raster	Remote	Global	2011-01 until 2017-12			
					Global Reservoir and Dam (GRanD), v1	Geospatial - Vector	Remote	Global	2011-01 until 2011-12			
Land Cover	Terr.	250 m	1 year	15 %	ESA CCI S2 Prototype Land Cover 20m Map of Africa 2016	Geospatial - Raster	Remote	Continental	2015-12 until 2016-12	X	X	X
					Fraction of Green Vegetation Cover 1km V2	Geospatial - Raster	Remote	Global	1999-01 until present		X	
					Dynamic land cover 100m, 2005	Geospatial - Raster	Remote	Continental	2014-10 until 2016-03	X	X	X
					Top Of Canopy Reflectances	Geospatial - Raster	Remote	Global	1999-01 until present		X	
					Normalized Difference Vegetation Index (NDVI), V2.2, 1km	Geospatial - Raster	Remote	Global	1998-04 until present		X	
					Land Cover Type Yearly L3 Global 500 m SIN Grid	Geospatial - Raster	Remote	Global	2001-01 until 2013-12		X	
					MCD12Q1: MODIS/Terra and Aqua Combined Land Cover Type Yearly Global 500 m SIN Grid V006	Geospatial - Raster	Remote	Global	2001-01 until 2017-12		X	
					MOD44B: MODIS/Terra Vegetation Continuous Fields Yearly L3 Global 250 m SIN Grid V006	Geospatial - Raster	Remote	Global	2000-03 until 2017-03	X	X	X
					Global crop mask	Geospatial - Raster	Remote	Global				
					Global rangeland mask	Geospatial - Raster	Remote	Global				
					Tropical and Subtropical Wetlands Distribution version 2	Geospatial - Raster	Remote	Global	2011-01 until 2017-12	X		
					Characteristics of African Savanna Biomes for Determining Woody Cover	Cross-sectional Data	In Situ	Regional/Sub-Continental	1981-01 until 2003-12			

Appendix

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
					Harmonized Global Land Use for Years 1500 -2100, V1	Geospatial - Raster	Model	Global	1500-01 until 2100-12		X	
Land Use/Land Use Change	Terr.	1 km	1 year	20 %	GHSL - Global Human Settlement Layer	Geospatial - Raster	Comb. IS & RS	Global	1975-01 until 2015-12	X		
					Fraction of Green Vegetation Cover 1km V2	Geospatial - Raster	Remote	Global	1999-01 until present	X	X	X
					Dynamic land cover 100m, 2005	Geospatial - Raster	Remote	Continental	2014-10 until 2016-03	X	X	X
					Top Of Canopy Reflectances	Geospatial - Raster	Remote	Global	1999-01 until present	X	X	X
					GFSAD30AFCE: Global Food Security-support Analysis Data (GFSAD) Cropland Extent 2015 Africa 30 m V001	Geospatial - Raster	Remote	Continental	2015-01 until 2015-12	X	X	X
					Global crop mask	Geospatial - Raster	Remote	Global		X		
					Global rangeland mask	Geospatial - Raster	Remote	Global		X		
					Harmonized Global Land Use for Years 1500 -2100, V1	Geospatial - Raster	Model	Global	1500-01 until 2100-12		X	
					Anthropogenic Biomes of the World, v2 (2000)	Geospatial - Raster	Model	Global	2000-01 until 2000-12			
					Pastures, v1 (2000)	Geospatial - Raster	Remote	Global	2000-01 until 2000-12	X		
Marine Oxygen	Ocn.	1 km	1 month	10 %	GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12			
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
Nitrous Oxide (Ocean)	Ocn.	1 km	1 day	1 %	MarinE MethanE and NiTrous Oxide (MEMENTO) database	Other	In Situ	Global	1960-01 until present			
Marine Nutrients	Ocn.	100 km	3 months	20 %	GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12			
Ocean Colour	Ocn.	1 km	8 days	5 %	NASA Ocean Color Web	Geospatial - Raster	Remote	Global	2002-07 until present		X	
					NASA Ocean Biogeochemical Model assimilating satellite chlorophyll data global daily VR2017	Geospatial - Raster	Model	Global	1998-01 until 2015-12		X	
Plant Species Traits	Terr.	1 biome			SAFARI 2000 Leaf-Level VOC Emissions, Maun, Botswana, Wet Season 2001	Cross-sectional Data	In Situ	Individual Site	2001-02 until 2001-02			
					AfriSAR: Mondah Forest Tree Species, Biophysical, and Biomass Data, Gabon, 2016	Cross-sectional Data	In Situ	Individual Site	2016-03 until 2016-03			
					ISLSCP II C4 Vegetation Percentage	Geospatial - Raster	Model	Global	1995-02 until 1995-07	X		
					CMS: GLAS LiDAR-derived Global Estimates of Forest Canopy Height, 2004-2008	Geospatial - Vector	Remote	Global				
					A Global Data Set of Leaf Photosynthetic Rates, Leaf N and P, and Specific Leaf Area	Other	In Situ	Global				
Nitrogen Oxides (NOx)	Atm.	5 km	4 h	20 %	Global Air Pollutant Emissions EDGAR v4.3.2	Time series	Model	Global	1970-01 until 2012-12			

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12			
					Global 3-Year Running Mean Ground-Level NO2 Grids from GOME, SCIAMACHY and GOME-2, v1 (1996â€Šâ€“â€Š2012)	Geospatial - Raster	Remote	Global	1996-01 until 2012-12			
					SAFARI 2000 Fire Emission Data, Dry Season 2000	Cross-sectional Data	Comb. IS & RS	Country	2000-08 until 2000-09			
					SAFARI 2000 CV-580 Aerosol and Cloud Data, Dry Season 2000 (CARG)	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09	X		
					SAFARI 2000 JRA Aerocommander Trace Gas, Aerosol, and CCN Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					SAFARI 2000 JRB Aerocommander Trace Gas and Aerosol Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					World Data Centre for Aerosols (WDCA)	Other	In Situ	Global				
Non-methane hydrocarbons	Atm.	1 site	1 h	10 %	GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12			
					Global Air Pollutant Emissions EDGAR v4.3.2	Time series	Model	Global	1970-01 until 2012-12			
					Global speciated NMVOC Emissions: EDGAR v4.3.2_VOC_spec (January 2017)	Time series	Model	Global	1970-01 until 2012-12			
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12			
					SAFARI 2000 1-Degree Estimates of Burned Biomass, Area, and Emissions, 2000	Geospatial - Raster	Remote	Regional/Sub-Continental	2000-01 until 2000-12			
					SAFARI 2000 Leaf-Level VOC Emissions, Maun, Botswana, Wet Season 2001	Cross-sectional Data	In Situ	Individual Site	2001-02 until 2001-02			
					SAFARI 2000 Fire Emission Data, Dry Season 2000	Cross-sectional Data	Comb. IS & RS	Country	2000-08 until 2000-09			
					SAFARI 2000 CV-580 Aerosol and Cloud Data, Dry Season 2000 (CARG)	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09			
					World Data Centre for Aerosols (WDCA)	Other	In Situ	Global				
Sulfur Dioxide (SO2)	Atm.	5 km	4 h	30 %	Multi-Satellite Air Quality Sulfur Dioxide (SO2) Database Long-Term L4 Global V1	Geospatial - Vector	Remote	Global	2005-01 until 2017-12			
					Global Air Pollutant Emissions EDGAR v4.3.2	Time series	Model	Global	1970-01 until 2012-12			
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12			
					Historical Anthropogenic Sulfur Dioxide Emissions by Source Category, v2.86 (1850â€Šâ€“â€Š2005)	Geospatial - Raster	Model	Global	1850-01 until 2005-12			
					SAFARI 2000 CV-580 Aerosol and Cloud Data, Dry Season 2000 (CARG)	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09	X		
					SAFARI 2000 JRA Aerocommander Trace Gas, Aerosol, and CCN Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					SAFARI 2000 JRB Aerocommander Trace Gas and Aerosol Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	

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					OMSO2e: OMI/Aura Sulfur Dioxide (SO2) Total Column L3 1 day Best Pixel in 0.25 degree x 0.25 degree V3	Geospatial - Raster	Remote	Global	2004-10 until present			
					World Data Centre for Aerosols (WDCA)	Other	In Situ	Global				
Tropospheric Carbon Monoxide (CO)	Atm.	1 site	1 h	1 ppb	Global Air Pollutant Emissions EDGAR v4.3.2	Time series	Model	Global	1970-01 until 2012-12			
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12			
					SAFARI 2000 1-Degree Estimates of Burned Biomass, Area, and Emissions, 2000	Geospatial - Raster	Remote	Regional/Sub-Continental	2000-01 until 2000-12			
					SAFARI 2000 Emissions Estimates, MODIS Burned Area Product, Dry Season 2000	Geospatial - Raster	Remote	Regional/Sub-Continental	2000-09 until 2000-09			
					SAFARI 2000 Fire Emission Data, Dry Season 2000	Cross-sectional Data	Comb. IS & RS	Country	2000-08 until 2000-09			
					SAFARI 2000 CV-580 Aerosol and Cloud Data, Dry Season 2000 (CARG)	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09			
					SAFARI 2000 JRA Aerocommander Trace Gas, Aerosol, and CCN Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					SAFARI 2000 JRB Aerocommander Trace Gas and Aerosol Data, Dry Season 2000	Cross-sectional Data	In Situ	Country	2000-08 until 2000-09		X	
					World Data Centre for Greenhouse Gases (WDCGG)	Other	In Situ	Global				
					World Data Centre for Aerosols (WDCA)	Other	In Situ	Global				
Pressure (surface)	Terr.	1 Site	1 h	0.1 hPa	NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
Albedo	Terr.	300 m	1 month	5 %	Global 10-daily Directional Albedo 1km: Tiles	Geospatial - Raster	Remote	Global	1998-12 until present		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12		X	
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Terr.	300 m	8 days	5 %	FAPAR 1km V2	Geospatial - Raster	Remote	Global	1999-01 until present		X	
					Normalized Difference Vegetation Index (NDVI), V2.2, 1km	Geospatial - Raster	Remote	Global	1998-04 until present		X	
					VNP15A2H: VIIRS/S-NPP Leaf Area Index/FPAR 8-Day L4 Global 500 m SIN Grid V001	Geospatial - Raster	Remote	Global	2012-01 until present	X	X	X
					MCD15A3H: MODIS/Terra+Aqua Leaf Area Index/FPAR 4-Day L4 Global 500 m SIN Grid V006	Geospatial - Raster	Remote	Global	2002-07 until present	X	X	X
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
					SAFARI 2000 FPAR TRAC Data for Mongu, Zambia, 1999-2002	Time series	In Situ	Local/Sub-National	1999-08 until 2002-02			
Net Radiation at surface (SW/LW)	Terr.	100 km	1 month	1 W/m2	MCD18A1: MODIS/Terra and Aqua Downward Shortwave Radiation Daily 3-Hourly L3 Global 5 km V006	Geospatial - Raster	Remote	Global	2001-01 until present		X	
					FLUXNET2015 Dataset	Geospatial - Raster	In Situ	Global	1989-01 until 2015-12		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12		X	
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
CO2, CH4, N2O emissions by country and IPCC sector	Terr.	1 country	1 year	10 %	EDGARâ€™s Global Fossil CO2 Emissions from 1990 to 2016 (EDGARv4.3.2_FT2016 dataset)	Time series	Model	Global	1990-01 until 2016-12	X	X	X
					EDGARâ€™s Global Greenhouse Gas Emissions from 1970 to 2012 (EDGARv4.3.2 dataset)	Time series	Model	Global	1970-01 until 2012-12	X	X	X
					Global Fire Emissions Database inventory (GFED4)	Geospatial - Raster	Remote	Global	1997-01 until 2016-12	X	X	X
					Fossil fuel data assimilation system (FFDAS) dataset	Geospatial - Raster	Comb. IS & RS	Global	1997-01 until 2010-12	X	X	X
					SAFARI 2000 1-Degree Estimates of Burned Biomass, Area, and Emissions, 2000	Geospatial - Raster	Remote	Regional/Sub-Continental	2000-01 until 2000-12	X	X	X
					CMS: Estimated Deforested Area Biomass, Tropical America, Africa, and Asia, 2000	Geospatial - Raster	Comb. IS & RS	Continental	2000-01 until 2012-12	X		
					SAFARI 2000 Fire Emission Data, Dry Season 2000	Cross-sectional Data	Comb. IS & RS	Country	2000-08 until 2000-09			
					CMS: Carbon Fluxes from Global Agricultural Production and Consumption, 2005-2011	Geospatial - Raster	Model	Global	2005-01 until 2011-12	X	X	X
					CMSFluxFire: Carbon Monitoring System Carbon Flux for Fire L4 V1	Geospatial - Raster	Remote	Global	2010-01 until 2013-01	X	X	X
					CMSFluxMISC: Carbon Monitoring System Flux for Shipping, Aviation, and Chemical Sources L4 V1	Geospatial - Raster	Remote	Global	2000-01 until 2001-01	X	X	X
Sea Surface Salinity	Ocn.	1 km	8 days	1 %	GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12			
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
					WOHP (World Ocean Hydrographic Profiles) V1.0	Other	In Situ	Global	1804-01 until 2010-12			
					Sea surface salinity (SSS) from SMOS	Geospatial - Raster	Comb. IS & RS	Global	2010-07 until 2016-12			
Soil Moisture	Terr.	1 km	1 day	0.04 m3/m3	Africa SoilGrids - Bulk density (BD)	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		
					Africa SoilGrids - Texture	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		

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					Africa SoilGrids - Depth to bedrock	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		
					Africa SoilGrids - Root zone moisture content at saturation (v%)	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					Africa SoilGrids - Root zone texture	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					Africa SoilGrids - Root zone depth (cm)	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					SoilGrids250m - Derived available soil water capacity (volumetric fraction) with FC = pF 2.5	Geospatial - Raster	In Situ	Global	1950-01 until 2015-12	X		
					IPCC default soil classes (Tier I)	Geospatial - Raster	In Situ	Global				
					Soil Water Index V3	Geospatial - Raster	Remote	Global	2007-01 until present		X	
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					SMAP/Sentinel-1 L2 Radiometer/Radar 30-Second Scene 3 km EASE-Grid Soil Moisture, Version 2	Geospatial - Raster	Remote	Global	2015-03 until present		X	
Soil Organic Carbon	Terr.	1 km	10 years	5 %	Africa SoilGrids - Bulk density (BD)	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		
					Africa SoilGrids - Soil organic carbon (SOC)	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		
					Africa SoilGrids nutrients - Total Nitrogen (N)	Geospatial - Raster	In Situ	Continental	1980-01 until 2016-12	X		
					Africa SoilGrids - Texture	Geospatial - Raster	In Situ	Continental	1960-01 until 2015-12	X		
					Africa SoilGrids - Root zone texture	Geospatial - Raster	In Situ	Continental	1950-01 until 2015-12	X		
					SoilGrids250m - Soil organic carbon content (fine earth fraction)	Geospatial - Raster	In Situ	Global	1950-01 until 2015-12	X		
					IPCC default soil classes (Tier I)	Geospatial - Raster	In Situ	Global				
					NPP Grassland: NPP Grassland: Towoomba, South Africa, 1949-1990, R1	Time series	In Situ	Individual Site	1950-01 until 1981-12		X	
					Annual CO2, CH4 and N2O emissions from 59 plots, across different vegetation types, field types and land classes in western Kenya	Time series	In Situ	Individual Site	2013-08 until 2014-08		X	
Stable Carbon Isotopes	Ocn.	100 km	3 months	10 %	WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
Surface Wind Speed and direction	Terr.	10 km	3 h	0.5 m/s	FLUXNET2015 Dataset	Geospatial - Raster	In Situ	Global	1989-01 until 2015-12		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			

Appendix

Variable Name	Variable Domain	Required Spatial Res.	Required Temp. Res.	Required Max. Uncertainty	Dataproduct Title	Data Type	Observation Type	Spatial Coverage	Temporal Coverage	Spat. Res. Sufficient	Temp. Res. Sufficient	S. & T. Res. Sufficient
Sea Surface Temperature	Ocn.	1 km	1 day	0.1 K	Surface Ocean COâ,, Atlas (SOCAT) V6	Geospatial - Raster	In Situ	Global	1957-01 until 2017-12			
					GLODAP calibrated open ocean data product of inorganic and carbon-relevant variables	Geospatial - Raster	In Situ	Global	1972-01 until 2013-12			
					NASA Ocean Color Web	Geospatial - Raster	Remote	Global	2002-07 until present		X	
					Long Term Stewardship and Reanalysis Facility (LTSRF) for the Group for High Resolution SST (GHRSST)	Geospatial - Raster	Remote	Global	1981-09 until present			
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
					WOHP (World Ocean Hydrographic Profiles) V1.0	Other	In Situ	Global	1804-01 until 2010-12			
					Sea surface temperature (Reynolds-SST)	Geospatial - Raster	Remote	Global	1981-09 until 2018-08		X	
Temperature (surface)	Terr.	1 site	1 h	0.1 K	Land Surface Temperature - Hourly Land Surface Temperature (LST) V1	Geospatial - Raster	Remote	Global	2010-10 until present		X	
					FLUXNET2015 Dataset	Geospatial - Raster	In Situ	Global	1989-01 until 2015-12		X	
					NACP MsTMIP: Global 0.5-degree Model Outputs in Standard Format, Version 1.0	Geospatial - Raster	Model	Global	1900-01 until 2010-12			
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					NPP Grassland: Lamto, Ivory Coast, 1965-1987, R1	Time series	In Situ	Individual Site	1969-01 until 1990-12			
					WORLD OCEAN DATABASE (WOD) 2018	Other	Comb. IS & RS	Global				
					Global Historical Climatology Network - Daily (GHCN-Daily), Version 3	Time series	In Situ	Global	1880-01 until present			
Water Vapour (surface)	Terr.	1 site	1 h	1 %	MCD19A2: MODIS/Terra and Aqua MAIAC Land Aerosol Optical Depth Daily L2G 1 km SIN Grid V006	Geospatial - Raster	Remote	Global	2000-02 until present			
					SAFARI 2000 Kalahari Transect CO2, Water Vapor, and Heat Flux, Wet Season 2000	Time series	In Situ	Local/Sub-National	2000-03 until 2000-03			
					SAFARI 2000 Meteorological and Flux Tower Measurements in Maun, Botswana, 2000	Time series	In Situ	Individual Site	2000-02 until 2000-09		X	
					CO2 and other GHG fluxes from charcoal production in Zambia	Time series	In Situ	Individual Site	2007-09 until 2009-07		X	

A5 CEOS List of Active Earth Observation Satellites

Table 13: List of 103 active EO satellites in space with relevance for the African continent as of January 2019 according to CEOS. Satellites in a geostationary orbit not covering the African continent were removed from the list. Source: CEOS Database (http://database.eohandbook.com/).

Mission Name	Mission Agencies	Launch Date	EOL Date	Applications	Instruments
ADM-Aeolus	ESA	22.08.2018	01.08.2022	Will provide wind profile measurements for global 3D wind field products used for study of atmospheric dynamics, including global transport of energy, water, aerosols, and chemicals.	ALADIN
ALOS-2	JAXA	24.05.2014	01.05.2019	Environmental monitoring, disaster monitoring, civil planning, agriculture and forestry, Earth resources, land surface.	CIRC, PALSAR-2 (ALOS-2)
Aqua	NASA, JAXA, INPE	04.05.2002	01.09.2020	6-year nominal mission life, currently in extended operations. Atmospheric dynamics/water and energy cycles, cloud formation, precipitation and radiative properties, air/sea fluxes of energy and moisture, sea ice extent and heat exchange with the atmosphere.	AIRS, AMSR-E, AMSU-A, CERES, HSB, MODIS
Aura	NASA, NSO, FMI, NIVR, UKSA	15.07.2004	01.09.2020	3-year nominal mission life, currently in extended operations. Measurements of aerosol and cloud properties for climate predictions, using a 3 channel lidar and passive instruments in formation with CloudSat for coincident observations of radiative fluxes and atmospheric state.	HiRDLS, MLS (EOS-Aura), OMI, TES
BJ-2	NRSCC, 21AT	11.07.2015	01.07.2022	High-resolution domestic mapping. Operational monitoring applications including urban planning and intelligent management. Constellation of three satellites spaced 120 degrees apart.	MSI (BJ-2), PAN (BJ-2)
CALIPSO	NASA, CNES	28.04.2006	01.09.2020	3-year nominal mission life, currently in extended operations. Measurements of aerosol and cloud properties for climate predictions, using a 3 channel lidar and passive instruments in formation with Aqua and CloudSat for coincident observations of radiative fluxes and atmospheric state.	CALIOP, IIR, WFC
CARTOSAT-1	ISRO	05.05.2005	01.06.2019	High precision large-scale cartographic mapping of 1:10000 scale and thematic applications (with merged XS data) at 1:4000 scales.	PAN (Cartosat-1)
CARTOSAT-2A	ISRO	28.04.2008	01.04.2019	High precision large-scale cartographic mapping of 1:10000 scale and thematic applications (with merged XS data) at 1:4000 scales.	PAN (Cartosat-2A/2B)
CARTOSAT-2B	ISRO	12.07.2010	01.07.2019	High precision large-scale cartographic mapping of 1:10000 scale and thematic applications (with merged XS data) at 1:4000 scales.	PAN (Cartosat-2A/2B)
CARTOSAT-2E	ISRO	23.06.2017	01.06.2022	High precision large-scale cartographic mapping and thematic applications with MX data at 1:4000 scales.	HRMX, PAN (Cartosat-2C/2E)
CBERS-4	INPE, CRESDA	06.12.2014	01.12.2019	Earth resources, environmental monitoring, land surface.	DCS , IRS, MUX, PAN (CBERS), WFI-2
CloudSat	NASA, DoD (USA), CSA	28.04.2006	01.09.2020	22-month nominal mission life, currently in extended operations. CloudSat uses advanced radar to "slice" through clouds to see their vertical structure, providing a completely new observational capability from space. First use of active 94 GHz radar from space to study clouds on global basis.	CPR (CloudSat)
COSMIC-1 FM1	NOAA, NSPO, UCAR	14.04.2006	01.09.2019	Meteorology, ionosphere and climate.	GOX, TIP
CryoSat-2	ESA	08.04.2010	01.12.2019	To determine fluctuations in the mass of the Earth's major land and marine ice fields.	DORIS-NG, Laser Reflectors (ESA), SIRAL
CSES	CNSA, ASI	02.02.2018	01.12.2023	Monitoring of electromagnetic field and waves, plasma and particle perturbations of the atmosphere, ionosphere and magnetosphere; and the study of their correlations with the occurrence of seismic events. Study of solar-terrestrial interactions and phenomena of solar physics; study of cosmic ray solar modulation.	HEPD
CYGNSS	NASA, NOAA	15.12.2016	01.01.2020	To understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation and convective dynamics in the inner core of a Tropical Cyclone (TC)	DDMI (CYGNSS)
DESIS-on-ISS	DLR	29.06.2018	01.12.2019	DESIS detects changes in the land surface, oceans and atmosphere; it will contribute to the development of effective measures to protect the environment and climate and allows scientists to detect changes in ecosystems and to make statements on the condition of forests and agricultural land. Among other things, its purpose is to secure and improve the global cultivation of food.	DESIS
Diademe 1&2	CNES	15.02.1967	01.12.2050	Geodetic measurements using satellite laser ranging.	RRA
DMC3	UKSA	10.07.2015	01.12.2022	A constellation of 3 high resolution optical imaging satellites for land use monitoring, urban planning, crop monitoring and pollution monitoring	VHRI-100

Mission Name	Mission Agencies	Launch Date	EOL Date	Applications	Instruments
DMSP F-14	NOAA, USAF	04.04.1997	01.01.2026	The long-term meteorological programme of the US Department of Defense (DoD) - with the objective to collect and disseminate worldwide atmospheric, oceanographic, solar-geophyscial, and cloud cover data on a daily basis. Tactical use only; on-board tape recorders failed; special sensor microwave instrument no longer operational; no longer provides global data.	OLS, SSB/X-2, SSI/ES-2, SSJ/4, SSM, SSM/I, SSM/T-1, SSM/T-2
DMSP F-15	NOAA, USAF	12.12.1999	01.01.2026	The long-term meteorological programme of the US Department of Defense (DoD) - with the objective to collect and disseminate worldwide cloud cover data on a daily basis. (Primary operational satellite).	OLS, SSI/ES-2, SSJ/4, SSM, SSM/I, SSM/T-1, SSM/T-2
DMSP F-16	NOAA, USAF	18.10.2003	01.01.2026	The long-term meteorological programme of the US Department of Defense (DoD) - with the objective to collect and disseminate worldwide cloud cover data on a daily basis.	OLS, SSI/ES-3, SSJ/5, SSM, SSM/IS, SSULI, SSUSI
DMSP F-17	NOAA, USAF	04.11.2006	01.01.2026	The long-term meteorological programme of the US Department of Defense (DoD) - with the objective to collect and disseminate worldwide cloud cover data on a daily basis.	OLS, SSI/ES-3, SSM, SSM/IS, SSULI, SSUSI
DMSP F-18	NOAA, USAF	18.10.2009	01.01.2026	The long-term meteorological programme of the US Department of Defense (DoD) - with the objective to collect and disseminate worldwide cloud cover data on a daily basis.	OLS, SSI/ES-3, SSM, SSM/IS, SSULI, SSUSI
DSCOVR	NOAA, USAF, NASA	11.02.2015	01.02.2020	Measure a combination of solar phenomena and earth science measurements. Provides 15 min warning for solar storms (CME) events. Provides full disk Earth observations at 10 wavelengths with 2-4 hour cadence. This mission is positioned at the Earth-Sun L-1 point.	EPIC, ES, FC, NISTAR, PHA, PlasMag
ECOSTRESS-on-ISS	NASA, USGS	29.06.2018	01.08.2019	Uses a high-resolution thermal infrared radiometer to measure plant evapotranspiration, the loss of water from growing leaves and evaporation from the soil. These data will reveal how ecosystems change with climate and provide a critical link between the water cycle and effectiveness of plant growth, both natural and agricultural.	ECOSTRESS
ePOP on CAS-SIOPE	CSA, MDA	29.09.2013	01.04.2024	The ePOP probe observes the Earth's ionosphere, where space meets the upper atmosphere. The instruments are used in conjunction with other satellite-based and ground-based instruments to analyze radio wave propagation in the ionosphere, measure the densities of ionized particles, and observe the aurora from space, all as they respond to space weather. The orbit is 450 km to 1500 km. Note: MDA is the owner and University of Calgary is the operator.	CER, FAI, GAP, IRM, MGF, NMS, RRI, SEI
FY-3B	NSMC-CMA, NRSCC	05.11.2010	01.12.2019	Meteorology and environmental monitoring; data collection and redistribution. (Experimental pre-cursor to FY-3C).	ERM, IRAS, MERSI, MWHS, MWRI, MWTS, SEM, SIM, TOU/SBUS, VIRR
FY-3C	NSMC-CMA, NRSCC	23.09.2013	01.12.2019	Meteorology and environmental monitoring; data collection and redistribution. (Operational follow-on to FY-3B). FY-3C suffered a problem on May 30th 2015 and has recovered gradually over time. At present, 10 of 12 onboard instruments are back in operation.	ERM, GNOS, IRAS, MERSI, MWHS-2, MWRI, MWTS-2, SES, SIM-2, TOU/SBUS, VIRR
FY-3D	NSMC-CMA, NRSCC	15.11.2017	01.12.2022	Meteorology and environmental monitoring; data collection and redistribution.	ASI, GAS, GNOS, HIRAS, MERSI-2, MWHS-2, MWRI, MWTS-2, SES, WAI
GCOM-C	JAXA	23.12.2017	01.12.2022	Understanding of climate change mechanism.	SGLI
GF-2	CRESDA	19.08.2014	01.08.2019	Earth resources, environmental monitoring, land surface.	MUX (GF-2), PAN (GF-2)
GF-3	CRESDA	10.08.2016	01.08.2024	Earth resources, environmental monitoring, land surface.	C-SAR
GPM Core	NASA, JAXA	27.02.2014	01.09.2020	3-year nominal mission life, 5-year goal. Study of global precipitation, evaporation, and the water cycle. The mission comprises a primary spacecraft with active and passive microwave instruments, and a number of â€˜constellation spacecraft' with passive microwave instruments.	DPR, GMI
GRACE-FO	NASA, GFZ	22.05.2018	01.05.2023	5-year nominal mission life, Extremely high precision gravity measurements for use in construction of gravity field models. GRACE-FO will consists of two satellites (A, B) serving one mission in the same manner as the original GRACE mission	GRACE instrument, LRI, MWI
HY-1C	NSOAS, CAST	07.09.2018	01.12.2020	Detecting ocean colour and sea surface temperature.	COCTS, CZI
ICESat-2	NASA	15.09.2018	01.12.2021	3-year nominal mission life, 5-year goal. Continue the assessment of polar ice changes and measure vegetation canopy heights, allowing estimates of biomass and carbon in aboveground vegetation in conjunction with related missions, and allow measurements of solid earth properties.	ATLAS
Jason-3	EUMETSAT, NOAA, CNES, NASA	17.01.2016	01.12.2021	3-year nominal mission lifetime, 5-year extended lifetime. Physical oceanography, geodesy/gravity, climate monitoring, marine meteorology.	AMR, DORIS-NG, GPSP, LRA, POSEIDON-3B Altimeter
JPSS-1	NOAA, EUMETSAT, NASA	18.11.2017	01.09.2024	Meteorological, climatic, terrestrial, oceanographic, and solar-geophysical applications; global and regional environmental monitoring, search and rescue, data collection.	ATMS, CERES, CrIS, OMPS, VIIRS

Appendix

Mission Name	Mission Agencies	Launch Date	EOL Date	Applications	Instruments
Kanopus-V	ROSKOSMOS, ROSHYDROMET	22.07.2012	01.07.2019	Disaster monitoring, forest fire detection, land surface, environmental monitoring.	MSS, PSS
Kanopus-V N3	ROSKOSMOS, ROSHYDROMET	01.02.2018	01.02.2023	Disaster monitoring, forest fire detection, land surface, environmental monitoring.	MSS, MSU-IK-SR, PSS
Kanopus-V N4	ROSKOSMOS, ROSHYDROMET	01.02.2018	01.02.2023	Disaster monitoring, forest fire detection, land surface, environmental monitoring.	MSS, MSU-IK-SR, PSS
Kanopus-V-IR	ROSKOSMOS, ROSHYDROMET	14.07.2017	01.07.2022	Disaster monitoring, forest fire detection, land surface, environmental monitoring.	MSS, MSU-IK-SR, PSS
KOMPSAT-3	KARI, ASTRIUM	18.05.2012	01.12.2020	Cartography, land use and planning, disaster monitoring.	AEISS
KOMPSAT-3A	KARI	26.03.2015	01.03.2019	Cartography, land use and planning, disaster monitoring.	AEISS-A
KOMPSAT-5	KARI, TAS-i	22.08.2013	01.08.2020	Cartography, land use and planning, disaster monitoring.	COSI
LAGEOS-1	NASA, ASI	04.05.1976	01.05.2052	Geodesy, crustal motion and gravity field measurements by laser ranging.	LRA (LAGEOS)
LAGEOS-2	ASI, NASA	22.10.1992	01.10.2052	Geodesy, crustal motion and gravity field measurements by laser ranging.	LRA (LAGEOS)
Landsat 7	USGS, NASA	15.04.1999	01.07.2021	5-year nominal mission life, currently in extended operations. Earth resources, land surface, environmental monitoring, agriculture and forestry, disaster monitoring and assessment, ice and snow cover. The LST will be allowed to drift below the mission specification towards end of mission life.	ETM+
Landsat 8	USGS, NASA	11.02.2013	01.05.2023	10-year nominal mission life. Earth resources, land surface, environmental monitoring, agriculture and forestry, disaster monitoring and assessment, ice and snow cover.	OLI, TIRS
LARES	ASI	13.02.2012	01.02.2052	Scientific objectives are the measurement of the dragging of inertial frames due to the Earth's angular momentum, or Lense-Thirring effect, and a high precision test of the Earth's gravitomagnetic field with accuracy of the order of a few percent. Gravitomagnetic field and dragging of inertial frames are predictions of Einstein's theory of General Relativity. In addition, LARES will allow other measurements in geodesy and geodynamics.	LCCRA
LIS-on-ISS	NASA	19.02.2017	01.05.2019	Spare LIS unit from the TRMM mission. NASA selected the LIS spare hardware to fly to the space station in order to take advantage of the orbiting laboratory’s high inclination. Will monitor global lightning for Earth science studies, provide cross-sensor calibration and validation with other space-borne instruments, and ground-based lightning networks. LIS will also supply real-time lightning data over data-sparse regions, such as oceans, to support operational weather forecasting and warning.	LIS
MEGHA-TROPIQUES	CNES, ISRO	12.10.2011	01.12.2020	Study of the inter-tropical zone and its convective systems (water and energy cycles).	MADRAS, ROSA, SAPHIR, ScaRaB
Meteor-M N2	ROSKOSMOS, ROSHYDROMET	08.07.2014	01.07.2019	Hydrometeorology, climatology, heliogeophysics, Earth resources and environmental monitoring.	DCS , GGAK-M, IKFS-2, KMSS, MSU-MR, MTVZA, Severjanin
Meteosat-10	EUMETSAT, ESA	05.07.2012	01.09.2030	Meteorology, climatology, atmospheric dynamics/water and energy cycles. Meteosat 1-7 are first generation. Meteosat 8-11 are second generation and known as MSG in the development phase.	GERB, MSG Comms, SEVIRI
Meteosat-11	EUMETSAT, ESA	15.07.2015	01.12.2033	Meteorology, climatology, atmospheric dynamics/water and energy cycles. Meteosat 1-7 are first generation. Meteosat 8-11 are second generation and known as MSG in the development phase.	GERB, MSG Comms, SEVIRI
Meteosat-8	EUMETSAT, ESA	28.08.2002	01.06.2020	Meteorology, climatology, atmospheric dynamics/water and energy cycles. Meteosat 1-7 are first generation. Meteosat 8-11 are second generation and known as MSG in the development phase.	GERB, MSG Comms, SEVIRI
Meteosat-9	EUMETSAT, ESA	22.12.2005	01.10.2024	Meteorology, climatology, atmospheric dynamics/water and energy cycles. Meteosat 1-7 are first generation. Meteosat 8-11 are second generation and known as MSG in the development phase.	GERB, MSG Comms, SEVIRI
Metop-A	EUMETSAT, NOAA, CNES, ESA	19.10.2006	01.12.2021	Meteorology, climatology. Metop-A is in a drifting LST orbit since August 2017 and LTAN is drifting from the original 09:30 to expected 07:30 by end-of-life.	AMSU-A, ARGOS, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, S&R (NOAA), SEM (POES)
Metop-B	EUMETSAT, NOAA, CNES, ESA	17.09.2012	01.09.2024	Meteorology, climatology. Due to a hardware problem on the Metop-B satellite, the A-DCS3 instrument is only supporting an ARGOS-2 service.	AMSU-A, ARGOS, ASCAT, AVHRR/3, GOME-2, GRAS, HIRS/4, IASI, MHS, S&R (NOAA), SEM (POES)
NOAA-18	NOAA	20.05.2005	01.12.2019	Meteorology, agriculture and forestry, environmental monitoring, climatology, physical oceanography, volcanic eruption monitoring, ice and snow cover, total ozone studies, space environment, solar flux analysis, search and	AMSU-A, ARGOS, AVHRR/3, HIRS/4, MHS, NOAA Comms,

Mission Name	Mission Agencies	Launch Date	EOL Date	Applications	Instruments
				rescue. The EOL date is based on a reliability and health & status analysis; the date shown is at the 60% confidence level.	S&R (NOAA), SBUV/2, SEM (POES)
NOAA-19	NOAA	04.02.2009	01.07.2021	Meteorology, agriculture and forestry, environmental monitoring, climatology, physical oceanography, volcanic eruption monitoring, ice and snow cover, total ozone studies, space environment, solar flux analysis, search and rescue. The EOL date is based on a reliability and health & status analysis; the date shown is at the 60% confidence level.	AMSU-A, ARGOS-3, ARGOS-4, AVHRR/3, HIRS/4, LRIT, MHS, NOAA Comms, S&R (NOAA), SBUV/2, SEM (POES)
OCO-2	NASA	02.07.2014	01.09.2020	High resolution carbon dioxide measurements to characterize sources and sinks on regional scales and quantify their variability over the seasonal cycle.	Spectrometer (OCO-2)
OSTM (Jason-2)	NASA, NOAA, EU-METSAT	20.06.2008	01.10.2019	3-year nominal mission life. Physical oceanography, geodesy/gravity, climate monitoring, marine meteorology. Long-Repeat Orbit geodetic mission phase from July 2016 to December 2019.	AMR, DORIS-NG, GPSP, LRA, POSEIDON-3
PAZ	HISDESAT, CDTI, INTA	22.02.2018	01.02.2023	Security, land use, urban management, environmental monitoring, risk management.	Paz SAR-X
Pleiades 1A	CNES	17.12.2011	01.12.2019	Cartography, land use, risk, agriculture and forestry, civil planning and mapping, digital terrain models, defence.	HiRI
Pleiades 1B	CNES	02.12.2012	01.12.2020	Cartography, land use, risk, agriculture and forestry, civil planning and mapping, digital terrain models, defence.	HiRI
PROBA-V	ESA, BELSPO	07.05.2013	01.12.2019	The PROBA-V missionâ€™s main multispectral imager extends the 15-year dataset of Spot-4 & Spot-5â€™s Vegetation instrument, delivering global coverage every two days for uses including climate impact assessments, surface water resource management, agricultural monitoring, and food security estimates.	Vegetation
RADARSAT-2	CSA, MDA	14.12.2007	01.04.2019	Environmental monitoring, physical oceanography, ice and snow, land surface. Note: Ownership of RADARSAT-2 has been transferred to MDA Corporation. CSA investment in the project is paid back with the data generated by the satellite since it entered operations.	SAR (RADARSAT-2)
RapidEye	DLR	29.08.2008	01.08.2019	System of 5 satellites for cartography, land surface, digital terrain models, disaster management, environmental monitoring.	MSI
RESOURCE-SAT-2	ISRO	20.04.2011	01.04.2020	Natural resources management, agricultural applications, forestry, etc.	AWiFS, LISS-III (Resourcesat), LISS-IV
RESOURCE-SAT-2A	ISRO	07.12.2016	01.11.2021	Natural resources management, agricultural applications, forestry, etc.	AWiFS, LISS-III (Resourcesat), LISS-IV
Resurs-P N1	ROSKOSMOS, ROSHYDROMET	25.06.2013	01.06.2019	Earth resources, environmental and disaster monitoring, cartography.	Geoton-L1 (2), GSA (1), SHMSA-SR, SHMSA-VR
Resurs-P N3	ROSKOSMOS	13.03.2016	01.03.2021	Earth resources, environmental and disaster monitoring, cartography.	Geoton-L1 (2), GSA (1), SHMSA-SR, SHMSA-VR
SAGE-III-on-ISS	NASA	19.02.2017	01.03.2020	1-year design life, 3 year goal. Refurbishment of the SAGE-III instrument and of a hexapod pointing platform, and accommodation studies. This mission flies on the ISS. Objective is to monitor the vertical distribution of aerosols, ozone, and other trace gases in the Earth's stratosphere and troposphere to enhance our understanding of ozone recovery and climate change processes in the upper atmosphere.	SAGE-III
SARAL	CNES, ISRO	25.02.2012	01.12.2019	This will provide precise, repetitive global measurements of sea surface height, significant wave heights and wind speed.	AltiKa, ARGOS
SCATSAT-1	ISRO	26.09.2016	01.08.2021	Observe the sea roughness, wind velocity vector	Scatterometer (Scatsat-1)
SCISAT-1	CSA, ESA, NASA	12.08.2003	01.03.2019	The SCISAT satellite has been in continuous spaceflight operation since 2003. It now measures over sixty (60) atmospheric species at still one of the world's highest vertical resolutions possible, and includes ozone, methane, and multiple CFCs. Many of these species are measured by no other instrument or satellite world-wide, making Canada the sole provider of these datasets globally. As of 2015, the objectives of the mission are to validate data used in: Environment Canada's Air Quality Health Index, retrieve winds for forecasting, and retrieve chemical information from operational meteorological instruments. Additional objectives are to assess the quality of model predictions for: EC's UV forecasting system, atmospheric carbon transport, and climate-chemistry process studies.	ACE-FTS, MAESTRO
Sentinel-1 A	ESA, COM	03.04.2014	01.01.2021	Providing continuity of C-band SAR data for operational applications notably in the following areas: monitoring of sea ice zones and the arctic environment, surveillance of marine environment, monitoring of land surface motion risks and mapping in support of humanitarian aid in crisis situations.	C-Band SAR

Appendix

Mission Name	Mission Agencies	Launch Date	EOL Date	Applications	Instruments
Sentinel-1 B	ESA, COM	25.04.2016	01.04.2023	Providing continuity of C-band SAR data for operational applications notably in the following areas: monitoring of sea ice zones and the arctic environment, surveillance of marine environment, monitoring of land surface motion risks and mapping in support of humanitarian aid in crisis situations.	C-Band SAR
Sentinel-2 A	ESA, COM	22.06.2015	01.05.2022	Supporting land monitoring related services, including: generation of generic land cover maps, risk mapping and fast images for disaster relief, generation of leaf coverage leaf chlorophyll content and leaf water content.	MSI (Sentinel-2)
Sentinel-2 B	ESA, COM	06.03.2017	01.03.2024	Supporting land monitoring related services, including: generation of generic land cover maps, risk mapping and fast images for disaster relief, generation of leaf coverage leaf chlorophyll content and leaf water content.	MSI (Sentinel-2)
Sentinel-3 A	ESA, EUMETSAT, COM	16.02.2016	01.01.2023	Supporting global land and ocean monitoring services, in particular: sea/land colour data and surface temperature; sea surface and land ice topography; coastal zones, inland water and sea ice topography; vegetation products.	OLCI, SLSTR, SRAL
Sentinel-3 B	ESA, EUMETSAT, COM	25.04.2018	01.11.2025	Supporting global land and ocean monitoring services, in particular: sea/land colour data and surface temperature; sea surface and land ice topography; coastal zones, inland water and sea ice topography; vegetation products.	OLCI, SLSTR, SRAL
Sentinel-5 precursor	ESA, COM, NSO	13.10.2017	01.10.2024	Supporting global atmospheric composition and air quality monitoring services.	UVNS (Sentinel-5 precursor)
SMAP	NASA, CSA	31.01.2015	01.09.2020	3-year nominal mission life. Global soil moisture and freeze-thaw state mapping.	L-band Radar (SMAP), L-band Radiometer (SMAP)
SMOS	ESA, CDTI, CNES	02.11.2009	01.12.2019	Overall objectives are to provide global observations of two crucial variables for modelling the weather and climate, soil moisture and ocean salinity. It will also monitor the vegetation water content, snow cover and ice structure.	MIRAS (SMOS)
SORCE	NASA	25.01.2003	01.12.2019	5-year nominal mission life, currently in extended operations. Continues the precise, long-term measurements of total solar irradiance at UV and VNIR wavelengths. Daily measurements of solar UV. Precise measurements of visible solar irradiance for climate studies.	SIM, SOLSTICE, TIM, XPS
SSTL S1-4	UKSA	16.09.2018	01.01.2026	A high resolution optical imaging satellites for land use monitoring, urban planning, crop monitoring and pollution monitoring	VHRI-100
STARLETTE	CNES	06.02.1975	01.12.2050	Geodesy/gravity study of the Earth's gravitational field and its temporal variations.	Laser Reflectors
STELLA	CNES	30.09.1993	01.12.2050	Geodesy/gravity study of the Earth's gravitational field and its temporal variations.	Laser Reflectors
Suomi NPP	NASA, NOAA	28.10.2011	01.09.2020	5-year nominal mission life. Operational polar weather and climate measurements.	ATMS, CERES, CrIS, OMPS, OMPS-L, VIIRS
Swarm	ESA, CNES, CSA	22.11.2013	01.12.2019	A three-satellite constellation that is providing the best ever survey of the geomagnetic field and its temporal evolution to gain new insights into improving our knowledge of the Earth's interior and climate. Canada contributes the electric field instrument that is required to correctly separate the measured magnetic field into its different sources.	ACC, ASM, EFI, GPS Receiver (Swarm), Laser Reflectors (ESA), STR, VFM
TanDEM-X	DLR	21.06.2010	01.12.2020	Cartography, land surface, civil planning and mapping, digital terrain models, environmental monitoring.	X-Band SAR
TanSat	NRSCC, NSMC-CMA	21.12.2016	01.12.2019	the carbon dioxide (CO2) monitoring	ACGS, CAPI
TCTE	NOAA, NASA	19.11.2013	01.12.2019	Hosted on USAF STPSat-3 spacecraft	TIM
TDS-1	UKSA, ESA	08.07.2014	01.01.2019	A satellite to demonstrate a number of UK developed payloads. SGR-ReSI paylaod demonstrates GNSS Reflectometry for ocean winds and other applications	SGR-ReSI
Terra	NASA, METI, CSA	18.12.1999	01.09.2020	6-year nominal mission life, currently in extended operations. Atmospheric dynamics/water and energy cycles, atmospheric chemistry, physical and radiative properties of clouds, air-land exchanges of energy, carbon and water, vertical profiles of CO and methane vulcanology.	ASTER, CERES, MISR, MODIS, MOPITT
TerraSAR-X	DLR	15.06.2007	01.12.2020	Cartography, land surface, civil planning and mapping, digital terrain models, environmental monitoring.	GPSRO (Terra-SAR), X-Band SAR
TSIS-1-on-ISS	NASA	17.12.2017	01.03.2023	Continue solar irradiance record	TSIS-1
UK-DMC2	UKSA	29.07.2009	01.12.2019	Wide area, medium resolution optical imaging for mapping, crop monitoring, environmental resource and disaster management.	SLIM-6-22
VENUS	CNES, ISA	02.08.2017	01.12.2020	Vegetation, agriculture monitoring, water management.	VSC
ZY-3-02	CRESDA	30.05.2016	01.05.2021	Earth resources, land surface,stereo mapping	CCD (ZY-1-02C and ZY-3), MUX (ZY-3-02)