CLIMATE-SPACE - THEME II: CROSS-ECV ACTIVITIES

ARCFRESH (ARCTIC FRESHWATER BUDGET)

ECV Inventory Document (EID)

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                                    Nansen Environmental and Remote Sensing Center (NERSC)

                                    Norwegian Research Centre AS (NORCE)

                                    National Physical Laboratory (NPL)

                                    Swedish Meteorological and Hydrological Institute (SMHI)

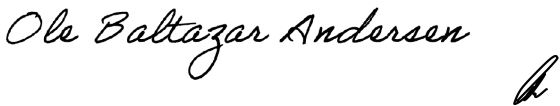   University of Western Brittany (UBO)

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Change Log

Issue	Author	Affected Section	Change	Status
0.5	D. Fantin, S&T	All	Document created	
1.0	J. Wuite	All	V 1.0 consolidated	Released to ESA
1.1	J. Wuite	All	Fixed ESA feedback	Released to ESA

Acronyms and Abbreviations

CCI	Climate Change Initiative
CMEMS	Copernicus Marine Environment Monitoring Services
CPS	Climate Processes Section
CRD	Climate Research Division
DTU	Technical University of Denmark
ECCC	Environment and Climate Change Canada
ECV	Essential Climate Variabke
ENVEO	ENVironmental Earth Observation
EO	Earth Observation
ESA	European Space Agency
FWF	Freshwater flux
GCOS	Global Climate Observing System
GIS	Greenland Ice Sheet
GIS	Greenland Ice Sheet
GRACE	Gravity Recovery and Climate Experiment
IPCC	Intergovernmental Panel on Climate Change
IV	Ice Velocity
METNO	Norwegian Meteorological Institute
MFID	Mass Flux Ice Discharge
NERSC	Nansen Environmental and Remote Sensing Center
NORCE	Norwegian Research Centre
NPL	National Physical Laboratory
OBP	Ocean Bottom Pressure
RCM	RADARSAT Constellation Mission
S1	Sentinel-1
SAR	Synthetic Aperture RADAR

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SEC	Surface Elevation Change
SIM	Sea Ice Motion
SMB	Surface Mass Balance
SMHI	Swedish Meteorological and Hydrological Institute
SoW	Statement-of-Work
SSH	Sea Surface Heights
SSS	Sea Surface Salinity
TBA	To be announced
TOPAZ	Towards an Operational Prediction system of the North Atlantic and the coastal Zone.
UBO	Université de Bretagne-Occidentale

1   Introduction

1.1   Applicable Document

This document contains the ECV Inventory Document (EID) for the ARCFRESH project for CLIMATE-SPACE - THEME II: CROSS-ECV ACTIVITIES, in accordance with the contract [AD1], SoW [AD2] and proposal [AD3-AD10]. It is delivered as part of WP1 on Project definition and requirements analysis. The purpose of this document is to provide a catalogue of all relevant state-of-the-art EO and model-derived datasets that are available for addressing the different components of the FWF. It also provides information on auxiliary EO, in situ, and model data intended to be used in ARCFRESH. These datasets have been developed and generated within ESA-CCI and other existing and ongoing projects. The document lists for each of the datasets information on sensor, spatial and temporal resolution and coverage, availability, uncertainty and responsible partner.

1.2   Document Structure

This document is structured as follows:

- Chapter 1 introduces this document.

- Chapters 2 to 8 describe the ECV datasets for each of the following FWF components: land ice, sea ice, river discharge, P-E, ocean gateways, sea level and ocean bottom pressure, sea surface salinity.

1.3   Applicable Documents

No	Doc. Id	Doc. Title	Date	Issue/ Revision/ Version
AD-1	4000145884/24/I-LR	ESA Contract No. 4000145884/24/I-LR	27/09/2024	NA
AD-2	ESA-EOP-SC-AMT-2023-21	Stetement of Work and Annexes and Appendexes	01/12/2023	1.0
AD-3	DTU-ESA-ARCFRESH-CL-001	ARCFRESH Cover Letter	22/02/2024	1.0
AD-4	DTU-ESA-ARCFRESH-TPROP-001	ARCFRESH Technical Proposal	22/02/2024	1.0
AD-5	DTU-ESA-ARCFRESH-IPROP-001	ARCFRESH Implementation Proposal	22/02/2024	1.0
AD-6	DTU-ESA-ARCFRESH-MPROP-001	ARCFRESH Management Proposal	22/02/2024	1.0
AD-7	DTU-ESA-ARCFRESH-FPROP-001	ARCFRESH Financial Proposal	22/02/2024	1.0
AD-8	DTU-ESA-ARCFRESH-CPROP-001	ARCFRESH Contractual Proposal	22/02/2024	1.0
AD-9	DTU-ESA-ARCFRESH-BF-001	ARCFRESH Background and Facilities	22/02/2024	1.0
AD-10	DTU-ESA-ARCFRESH-CV-001	ARCFRESH Curricula Vitae	22/02/2024	1.0

Note: If not provided, the reference applies to the latest released Issue/Revision/Version

2   Land Ice

This section provides an overview of the main EO and model data sets relevant for addressing the freshwater flux (FWF) contribution from Arctic land ice, which are currently available. The table below lists the main data sets and their specifications. Note that these primarily address the FWF from the Greenland Ice Sheet, as similar data for other land ice masses in the Arctic are either sparse or non-existent. The data sets have mostly been developed and generated within the Greenland Ice Sheet and Glaciers CCI and CCI+ projects, with additional data sets from 4DGreenland, NASA IceBridge and PROMICE, including EO datasets on ice velocity, solid ice discharge, surface elevation change and ice sheet outline and calving front location inventories and model datasets on surface runoff and basal melt fluxes. If additional relevant data sets or updates become available during the project, these will be included for the assessment and scientific analysis.

CCI ECV products							
CCI project	**Sensor**	**CCI dataset**	**Resolution (Temporal/Spatial)**	**Coverage (Temporal/spatial)**	**Availability**	**Uncertainty**	**Responsible**
Greenland Ice Sheet, Glaciers	Altimetry	Surface elevation Changes (SEC)	5 km / annual	1992 - present (Greenland Domain)	ESA CCI	Yes	DTU
	Altimetry	Surface elevation changes (dSEC)	5 km / monthly	2011-present	ESA CCI	Yes	DTU
	S-1 SAR	Ice Velocity	monthly/annual/ multi-annual 100-200m	2015-2023/Greenland Ice Sheet; (Russian and Canadian Arctic; Svalbard)	ESA CCI	Yes	ENVEO
	S-1 SAR IV & ice thickness based on airborne radar sounder	Mass Flux Ice Discharge (MFID)	monthly/200 m (Greenland)	2015-2023/Greenland Ice Sheet	ESA CCI	Yes	ENVEO
	Optical and SAR sensors	Glacier inventories & ice sheet outlines	1-18 yr/10-30m	Greenland. (Russian and Canadian Arctic; Svalbard)	ESA CCI	Yes	ENVEO
Observational non-CCI ECV datasets							

Greenland Ice Sheet ice thickness	IceBridge BedMachine Greenland, Version 5 based on airborne radar sounder ice thickness	NASA IceBridge	N.A./150 m	1993-2021/Greenland Ice Sheet	Open access	Yes	ENVEO
Greenland Ice Sheet runoff	Based on different EO sensors and models	4DGreenland	Monthly 2010-2020	% selected drainage basins in Greenland	Open access	Yes	DTU
Model-derived and reanalysis ECV products							
Greenland Ice Sheet basal melt flux	Modelled	GEUS, PROMICE	Monthly/Greenland Ice Sheet basins scale	2010-2020	Open access	Yes	DTU

3   Sea ice

This section provides an overview of the EO data sets relevant for addressing the freshwater flux (FWF) contribution from sea ice that we plan to use in ARCFRESH. The table below lists information on the specific data sets. We plan to use sea ice drift from Synthetic Aperture Radar (SAR) in recent years, in parallel to the global ice drift product derived from passive microwave (PM) satellite data. While the PM sea ice drift product provides long and consistent time series with complete spatial coverage, SAR ice drift is more accurate, but reliably available only since the launch of the ESA missions Sentinel 1A/B (2014/2016) and the Canadian RadarSat Constellation Mission (2019), and without daily full spatial coverage. However, SAR ice drift will serve as a reference and help to quantify uncertainties in the PM ice drift. If datasets beyond 2020 become available during the project, these will be included for the assessment and scientific analysis.

CCI ECV products							
CCI project	**Sensor**	**CCI dataset**	**Resolution (Temporal/ Spatial)**	**Coverage (Temporal/spatial)**	**Availability**	**Uncertainty**	**Responsible**
Sea Ice	Altimetry (CryoSat-2, Envisat, Sentinel 3)	sea ice thickness, drift-aware sea ice thickness, snow depth is retrieved from a climatology based on W99 and AMSR-2 snow depth	Monthly, Daily (drift aware) 25 km	up to 81.4N (2002- 2010), up to 88N (2011-present), No data from May - September	ESA CCI	Error propagation	NORCE
	Microwave radiometry	sea ice concentration	Daily 12.5 km	Northern Hemisphere 1978-present	ESA CCI	Yes	METNO
Observational non-CCI ECV datasets							
Sea ice	Microwave radiometry	OSISAF sea ice drift	Daily, 75km	1991-2020 Northern Hemisphere	OSISAF/open access	Yes	METNO
Sea ice	SAR (Sentinel 1A/B, RCM)	SAR sea ice drift from ECCC	At the gates	2016-	ECCC	No	ECCC
Sea ice	Altimetry (CryoSat-2)	Summer sea ice thickness from Landy et al., 2022	80 km	2011-2020 Northern Hemisphere	Open access	Yes	UiT

4   River Discharge

This section provides an overview of the data sets relevant for addressing the freshwater flux (FWF) contribution from river discharge in ARCFRESH. The table below lists information on the specific data sets.

CCI ECV products							
CCI project	**Sensor**	**CCI dataset**	**Resolution (Temporal/Spatial)**	**Coverage (Temporal/spatial)**	**Availability**	**Uncertainty**	**Responsible**
River Discharge (to be published)	Altimetry	River discharge	Unknown	Selected river basins (Lena, Ob, Mackenzie, Collville)	ESA CCI	No	ESA
Snow Water Equivalent	Passive Microwave data + in-situ data	Snow	0.10° x 0.10°	Northern Hemisphere, mountains, permanent snow and ice areas, water masked, 1979 - 2022, daily	ESA CCI	Yes, Standard deviation	ENVEO
Snow Cover Extent	Optical satellite data	Snow	0.05° x 0.05° (1982 - 2022) 0.01° x 0.01° (2000 - 2022)	Global land areas, permanent snow and ice areas, clouds and (polar) night, water masked, 1982 - 2022, daily	ESA CCI	Yes, Unbiased RMSE	ENVEO
Observational non-CCI ECV datasets							
River discharge	In-situ stations	Arctic HYCOS	Daily/Monthly, 420+ stations each representing the FWF through a given	The combined station network represent about 60% of the FWF to the Arctic Ocean	Open access from most countries, variable latency time (from real	No	All national hydrological services around the Arctic
Model-derived ECV datasets							
River discharge	Modelled Arctic-HYPE v3, v4	SMHI	Daily, catchment based	Regional arctic, 1979-now	Open access	No	SMHI

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5   Precipitation-Evaporation

This section provides an overview of the data sets relevant for addressing the freshwater flux (FWF) contribution from precipitation and evaporation in ARCFRESH. The table below lists information on the specific data sets. We plan to use precipitation and evaporation together with their uncertainty estimate from ERA5 (reanalysis). While EO data sets are also available, the consistency of evaporation and precipitation in ERA5 is a key factor for closing the FWF. Additionally, EO data sets of precipitation in the Arctic are often affected by biases or large uncertainties. If additional relevant data sets or updates become available during the project, these can be included (like, for instance, the GIRAFE data set).

project	_Sensor_	_dataset_	_Resolution_ _(Temporal/Spatial)_	_Coverage_ _(Temporal/spatial)_	_Availability_	_Uncertainty_	_Responsible_
Observational non-CCI ECV datasets							
Precipitation	Infrared and microwave + rain gauges	GPCP v1.3	Daily, 1.0°	October 1996 to present, global	Open access	Monthly	GPCP/CDS
Precipitation	Infrared and microwave	GIRAFE	Daily, 1.0°	2002-2022, global (sea-ice free areas)	Open access	Yes	CDS/CMSAF
Precipitation	Microwave radiometry	COBRA	Daily, 1.0°	2000-2017, global	Open access	No	CDS
Evaporation	Based on different EO sensors + reanalysis	OAFlux V3	Daily, 1.0°	1985-2022	Open access	Yes	WHOI
Precipitation - Evaporation	Microwave radiometry	HOAPS V4.0	6-hourly, 0.5°	Jul 1987–Dec 2014, global (80°S to 80°N)	Open access	Yes	CMSAF
Model derived and reanalysis ECV datasets							
Precipitation - Evaporation	Modelled ERA5	ECMWF	Hourly, 0.25°	Global, 1940–now	Open access	Relative only	ECMWF
Precipitation - Evaporation	Modelled CARRA	C3S/CDS	Hourly, 2.5km	Regional arctic, 1990-now	Open access	No	METNo

6   Ocean gateways

This section provides an overview of the observational datasets related to Arctic Ocean gateways that will be used in ARCFRESH. The table below lists the available datasets. The ocean gateways, including the Bering Strait and Fram Strait, are key locations for monitoring exchanges of freshwater between the Arctic Ocean and surrounding basins. To estimate the flux across a gateway, we need to determine the slope of the dynamic ocean topography derived from altimetry (Jason-1/2/3, Sentinel-6, and Sentinel-3) and estimate the salinity content, for which we will use in situ data from the Fram Strait Arctic Outflow Observatory. During the project, we will also investigate the potential use of satellite-derived sea surface salinity data as a proxy for the ocean column-integrated salinity.

CCI ECV products							
CCI project	**_Sensor_**	**_CCI dataset_**	**_Resolution (Temporal/Spatial)_**	**_Coverage (Temporal/spatial)_**	**_Availability_**	**_Uncertainty_**	**_Responsible_**
None							
Observational non-CCI ECV datasets							
Sea Level	Altimetry (Jason 1-3/Sentinel-6MF)	Along track altimetry from Radar Altimeter Database System (RADS)	10 days / 7 km	Jason 1-3 /Sentinel-6: 2001 - present	open access	Range uncertainty (~3 cm)	DTU
Sea Level	SAR Altimetry	Along track altimetry from Sentinel-3	27 days / 300 meter (along track)	Sentinel 3: 2016 - present	Open access	Range uncertainty (~3 cm)	DTU
Salinity	Moorings and CTD	Fram Strait Arctic Outflow Observatory	monthly/ ~10 km (across strait) / 10 m (depth	2003-present	Open access	No	NPI / AWI

7   Sea Level and Ocean Bottom Pressure

This section provides an overview of the observational datasets related to sea level and ocean bottom pressure that will be used in ARCFRESH to validate the Arctic freshwater budget inferred from flux estimates into and out of the Arctic Ocean. We will use high-latitude sea level anomaly products developed under the ESA CCI Sea Level project, including both gridded and along-track datasets from multiple satellite missions (e.g., Envisat, Saral, the Jason series, and CryoSat-2). These products cover much of the Arctic Ocean up to 88°N and include corrections specifically optimized for high-latitude performance. Monthly ocean bottom pressure fields from the GRACE and GRACE-FO missions will be used to account for mass-driven changes in ocean water content. Observational datasets from the Radar Altimeter Database System (RADS) and enhanced CryoSat-2 products from the ESA CryoTempo project will complement the CCI datasets. Updated versions and extended time coverage will be incorporated into ARCFRESH as they become available during the project.

| CCI ECV products							
CCI project	*Sensor*	*CCI dataset*	*Resolution (Temporal/Spatial)*	*Coverage (Temporal/spatial)*	*Availability*	*Uncertainty*	*Responsible*
Sea Level	Altimetry	High Latitude Sea Level Anomalies from satellite altimetry (by DTU/TUM)	weekly 0.25x0.50 deg	08/1991 - 04/2017 65N - 88N	ESA CCI	Yes	DTU
	Altimetry	Sea level ESA CCI FCDR v2.0	6 km, various time (ungridded)	01/1993 -12/2015	ESA CCI	Yes	DTU
	Altimetry	High latitude sea level anomalies from Envisat and Saral	Weekly 0.25x0.75 deg	03/2003-03/2012 + 06/2013-09/2016 50N-81.5N	ESA CCI	No	DTU
Sea Level Budget	Altimetry	High Latitude Sea Level Anomalies from satellite altimetry	weekly 0.25x0.50 deg	08/1991 - 09/2019 65N - 88N	ESA CCI	Yes	DTU
	GRACE and GRACE-FO	Ocean Bottom Pressure	Monthly 0.50 deg	04/2002 – 06/2017 + 07/2018 – present global	TU GRAZ	No	DTU
Observational non-CCI ECV datasets							
Sea Surface Heights	Radar Altimetry	Radar Altimetry Database System	along-track	1992 - present / up to 88N	Open access	Yes (Range uncertainty)	DTU

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		(RADS)					
Sea surface heights	Radar Altimetry	CryoTempo enhanced Polar Ocean CryoSat-2 dataset	Along-track (250 meters)	2011 - present / Polar regions up to 88N	ESA CryoTempo	Yes	DTU
Ocean Bottom Pressure	GRACE and GRACE-FO	NASA Goddard Space Flight Center /Jet Propulsion Laboratory	~Monthly/ ~300 km	06/2002 to 06/2017 07/2018 - present / 88S - 88N	Open access	Yes	DTU

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8 Sea surface salinity

This section provides an overview of the EO data sets relevant for addressing the freshwater flux (FWF) contribution from sea ice that we plan to use in ARCFRESH. The table below lists information on the specific data sets. We plan to use Sea Surface Salinity derived from L-Band radiometric satellite measurements. The CCI+SSS product is an L4 product developed in the framework of the ESA CCI+SSS project (Boutin et al., 2021). The CCI+SSS product is a merged product from ESA SMOS (2010-now), NASA Aquarius (2010-2015), and NASA SMAP (2015-now) missions. It has been specifically tailored to improve the accuracy of SSS in the high latitudes. The CCI+SSS latest version (v5.6) covers the period 2010-2022. As the CCI+SSS project is still running, an updated version and extended time coverage will be available during the ARCFRESH project. The SMOS Arctic CEC product (v2, 2010-2023) will also be tested. Sea ice contamination and low SST sensitivity correction have been specifically implemented for the Arctic basin (Supply et al., 2020).

CCI ECV products							
CCI project	*Sensor*	*CCI dataset*	*Resolution (Temporal/Spatial)*	*Coverage (Temporal/spatial)*	*Availability*	*Uncertainty*	*Responsible*
Sea Surface Salinity	SMOS, SMAP, Aquarius L-Band microwave	Sea Surface Salinity	~Monthly, ´~45 km	2010-2022	ESA CCI	0.5 pss	UBO
Observational non-CCI ECV datasets							
Sea Surface Salinity	SMOS Band microwave	CEC CATDS SMOS LOCEAN	~8days, ~45 km	2010-2023	open access	0.5-1.0 pss	UBO

9   References

Boutin et al., 2021: Satellite-based time-series of sea surface salinity designed for ocean and climate studies. Journal of Geophysical Research.doi:10.1029/2021JC017676

Supply, A., J. Boutin, J.-L. Vergely, N. Kolodziejczyk, G. Reverdin, N. Reul and A. Tarasenko, 2020: A new methodology to derive SMOS Sea Surface Salinity in the Arctic Ocean. Remote Sensing of Environment. https://doi.org/10.1016/j.rse.2020.112027.