PRODUCT USER MANUAL

For Arctic Ocean Physical and BGC Analysis and Forecasting Products

ARCTIC_ANALYSISFORECAST_PHY_002_001
ARCTIC_ANALYSISFORECAST_BGC_002_004
ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011
ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015
ARCTIC_MULTIYEAR_PHY_002_003
ARCTIC_MULTIYEAR_BGC_002_005

Issue: 5.18

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CHANGE RECORD

Issue	Date	§	Description of Change	Author	Validated By
1.0		All	Creation of the document	Magne Simonsen (met.no), Bruce Hackett (met.no), Laurent Bertino (NERSC)	L. Bertino
2.0	2011-11-18		Update Delivery Mechanism (SUBS and DGF) Update template	L. Crosnier WP17	
2.1	2011-02-24		Time range updated for reanalysis Revised time ranges for real-time products. Added BIO_002_00[45] products.	Laurent Bertino Bruce Hackett	
2.2	2012-07-05		Updated to reflect changes in the production of forecasting products.	Magne Simonsen (met.no), Lars Petter Røed (met.no), Bruce Hackett (met.no)	
2.3	2012-09-28	IV.7 V.2	Updated temporal extent of reanalysis products Updated reanalysis netCDF metadata.	Bruce Hackett (met.no)	
3.0	2013.01.14	IV.7	Updated temporal extent of reanalysis products + surface fluxes	Laurent Bertino	
3.1	2013.01.29	IV.3	Mistake corrected in the output grid description: not an Arakawa C grid SSH does not include inverse barometer effect	Laurent Bertino (NERSC)	
4.0	2014.01.15		Description updated for ensemble mean forecast	Laurent Bertino (NERSC)	L. Crosnier
4.1	2014.05.15	II	Add MFTP download mechanism	Bruce Hackett	L. Crosnier
5.0	2015.01.01	III.3 V.2	Extended physical reanalysis 1991-2013 Removed fy_frac and fy_age variables from physical reanalysis	Laurent Bertino	L. Crosnier
5.1	2015.05.01	all	Change format to fit CMEMS graphical rules	L. Crosnier	L. Crosnier
5.2	2016.01.18	III.1, III.2, III.3, III.4, V.2	Description of new variables bottom temp. and zooplankton added	M. Drivdal, L. Bertino	
5.2	2016.01.25	III.1, III.2, V.2	Description of new dataset: Dataset-topaz4-arc-1hr-myoceanv2-be	M. Drivdal	
5.3	2016.04.26	III.2, V.2	Variable list in new dataset: Dataset-topaz4-arc-1hr-myoceanv2-be Is updated in table 2	M. Drivdal	
5.4	2017.01.18	I.2 III.2 III.5.3 V.2	History of changes update Added Silicate variable Added ice drift in hourly dataset Description of ECOSMO Updated ncdumps	L. Bertino	
5.5	2017.05.31	III.2 V.2	Added ice drift in hourly data set Updated ncdump output	G. Sutherland	
5.6	2017.11.30	V.2	Updated ncdump output for hourly data set Inclusion of year 2016 to PHYS-RAN	G. Sutherland	

				L. Bertino	
5.7	2018.09.12	V.8	Added line on scale factor and offset Inclusion of year 2017 to PHYS-RAN	L. Bertino	
5.8	2019.06		Information on regularly extensions of reanalysis products		
5.9	2019.12	all V	Inclusion of tidal/surge forecasts Removal of NetCDF screendumps	A. Ali	C. Derval
5.10	2020.04	III.4 All V IV.3	Definition of MLP neXtSIM forecast 002_011 Return of all the ncdumps Vector Rotation code	L. Bertino T. Williams L. Bertino L. Bertino	C. Derval
5.11	2020.09	III.5	Assimilation of CS2SMOS in NRT New multiyear PHY product	L. Bertino	
5.12	2021.01	All	New NRT BGC product New multiyear BGC product Missing information about MY PHY product	A. Ali C. Yumruktepe T. Wakamatsu J. Xie L. Bertino	
5.13	2021.09	All	Retirement of old REANALYSIS_PHY_002_003 Larger domain of NRT PHY_ICE Explanation of vertical interpolation algorithm	L. Bertino	C. Derval
5.14	2022.04	I.2 III.5 V.2-3	Assimilation of Sentinel 6a sea level anomaly data in NRT PHY product; general formatting issues. PHY_ICE new variables and monthly datasets MY yearly datasets.	A. Melsom, A. Ali, V.C. Yumruktepe, J. Xie, T. Wakamatsu	C. Derval
5.15	2022.11		Addition of monthly mean datasets in NRT PHT BGC improved assimilation of ocean colour Automatic temporal extension Addition of yearly datasets in MY products		Copernicus Marine Product management
5.16	2023.11	All	Replacement of TOPAZ4 by TOPAZ5 Update of ECOSMO-II Assimilation of SIT in neXtSIM-F Addition of two new variables in 002_011 Corrected a typo in the definition of siconc_my New SIUV inputs in 002_003	L. Bertino, A. Ali, T. Williams, J. Xie	Copernicus Marine Product management
5.17	2023.09	II.5.3	Correction of noise in sea ice thickness, new input of sea ice drift	J. Xie, L. Bertino	Copernicus Marine Product management
5.18	2024.06	III.5. 4	Inclusion of wave terms in tidal forecast	L. Bertino, A. Ali	Copernicus Marine Product management

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GLOSSARY AND ABBREVIATIONS

MFC	Monitoring and Forecasting Centre
NetCDF	Network Common Data Form
CF	Climate Forecast (convention for NetCDF)
SSS	Sea surface salinity.
SSC	Sea surface currents
SSH	Sea surface height
RMS	Root mean square
SDN	SeaDataNet (climatology)
CHL	Chlorophyll
SLA	Sea Level Anomalies
PC	Production Center
PU	Production Unit
Meridional Velocity	West to East component of the horizontal velocity vector (not polar stereographic projection)
Zonal Velocity	South to North component of the horizontal velocity vector (not polar stereographic projection)
FTP	File Transfer Protocol
OpenDAP	Open-Source Project for a Network Data Access Protocol. Protocol to download subset of data from a n-dimensional gridded dataset (ie: 4 dimensions: lon-lat,depth,time)
Subsetter	service tool to download a NetCDF file of a selected geographical box using values of longitude and latitude, and time range
neXtSIM	NeXt generation Sea Ice Model

I. INTRODUCTION

I.1 Summary

This guide describes the data product files from the Arctic Monitoring and Forecasting Centre, what data services are available to access them, and how to use the files and services.

ARCTIC_ANALYSISFORECAST_PHY_002_001 is the nominal product of the Arctic Monitoring and Forecasting Center for ocean physics, and is composed of three-dimensional (3D), daily mean fields of temperature, salinity, sea surface height, zonal velocity, meridional velocity, vertical velocity, sea ice concentration, sea ice thickness, sea ice velocity and sea ice type. Additionally a separate dataset consisting of surface instantaneous (2D) fields with hourly resolution are available in separate daily files. A 6-hourly mean 3D forecasts with 3 days lead time will also be included.
ARCTIC_ANALYSISFORECAST_BGC_002_004 is the nominal product of the Arctic Monitoring and Forecasting Center for ocean biogeochemistry, and is composed of 3D, daily mean fields of nitrate, phosphate, silicate, oxygen, chlorophyll, phytoplankton biomass, primary production, pH, dissolved inorganic carbon, and light attenuation.
ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 is the nominal product for sea ice forecasts of the Arctic MFC. The product is composed of 2-dimensional (2D), hourly averaged fields of sea ice properties (concentration, thickness, ice type, ice age, drift velocity albedo and snow depth on sea ice). It also comes as a monthly average.
ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 is the nominal product of the Arctic Monitoring and Forecasting Center for ocean physics which contains tides, storm surge and wave signals. The product is composed of two-dimensional (2D), quarter-hourly instantaneous fields of sea surface height, and x- and y-velocity components at the sea surface.
ARCTIC_MULTIYEAR_PHY_002_003 is the reanalysis product of the Arctic Monitoring and Forecasting Center, and is composed of 3D, daily (monthly and yearly also) mean fields of temperature, salinity, sea surface height, zonal velocity, meridional velocity, sea ice concentration, sea ice thickness and sea ice velocity.
ARCTIC_MULTIYEAR_BGC_002_005 is a reanalysis product of the Arctic Monitoring and Forecasting Center, and is composed of 3D, monthly mean fields of the biological variables Chl-a, attenuation coefficient, net primary production, phytoplankton biomass, zooplankton biomass, oxygen, nitrate, silicate and phosphate, but not the physical variables that were used to drive the biological model. Daily mean files of the surface (2D) fields are also available as a separate dataset.

I.2 History of changes

- **ARCTIC_ANALYSISFORECAST_PHY_002_001:**
    - Introduction in Nov. 2023
- **ARCTIC_ANALYSIS_FORECAST_BIO_002_004:**
    - On April 19th 2017: replacement of the biogeochemical model NORWECOM by ECOSMO. Inclusion of the silicates variable.
    - May 2021: Superseded by TOPAZ5-ECOSMO, several changes.
    - November 2022: Addition of monthly means.
    - Nov. 2023: addition of coccolithophores compartment.
- **ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011:**
    - Introduction on 7th July 2020
    - Upgrade of sea ice rheology from Maxwell-Elasto-Brittle to Brittle-Bingham-Maxwell on Dec. 2020.
    - Inclusion of Canadian Archipelago in December 2021.
    - November 2022. Assimilate NIC ice charts instead of OSISAF sea ice concentration products.
    - November 2022. Addition of sea ice albedo, ice types
    - November 2022: Monthly means
    - November 2023: Add assimilation of sea ice thickness from CS2-SMOS.
    - November 2023: Addition of sea ice age, young ice type and ridged ice volume fraction
- **ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015:**
    - Introduction on 31st March 2020
    - 18th June 2024: Inclusion of wave terms in ocean surface
- **ARCTIC_MULTIYEAR_PHY_002_003:**
    - December 2020: Time series 1991-2002
    - May 2021: Time series 2002-2012
    - December 2021: Time series completed 1991-2020, automatic updates twice a year (July interim version, December final version)
    - November **2022: 3D daily data; yearly dataset.**
    - Sept 2023: Change of data source for sea ice drift and reprocessed the period 1999-2021, Ocean profile assimilation below ice does not affect sea ice anymore. The goal of both changes was to remove noise in sea ice thickness.
- **ARCTIC_MULTIYEAR_BGC_002_005:**
    - November 2022: Automatic extension until Year-minus-2. Addition of yearly dataset

II DOWNLOAD A PRODUCT

After registration, you will be able to download our data. To assist you, our HelpCenter is available, and more specifically its section about download.

Information on operational issues on products and services can be found on our User Notification Service. If you have any questions, please contact us.

III DESCRIPTION OF THE PRODUCT SPECIFICATION

III.1 General Information (Real-time product)

Product Lines	ARCTIC_ANALYSISFORECAST_PHY_002_001 ARCTIC_ANALYSISFORECAST_BGC_002_004 ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015
Geographical coverage	North of 63°N and ice-covered North Atlantic Ocean.
Variables	ARCTIC_ANALYSISFORECAST_PHY_002_001 • Temperature • Salinity • Sea Surface Height (inverse barometer effect not included) • Horizontal velocity (x- and y- component in polar-stereographic grid) • Vertical Velocity • Sea Ice (Concentration, Thickness, Velocity and Type/classification) • sea_ice_albedo • surface snow thickness • ocean_barotropic_streamfunction • ocean_mixed_layer_thickness • sea_floor_depth_below_sea_level • bottom temperature ARCTIC_ANALYSIS_FORECAST_BIO_002_004 • Nitrate • Phosphate • Silicat • Oxygen • Chlorophyll • Phytoplankton biomass • Primary production • Light attenuation • sea_floor_depth_below_sea_level • zooplankton • pH • dissolved inorganic carbon ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 • Sea Ice (total concentration, thickness, concentration of multi-year ice, concentration of young ice, age, ridged ice fraction and velocity) • Snow depths on sea ice, sea ice albedo

	ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 ● Sea Surface Height (includes tidal elevation) ● Horizontal velocity at the sea surface (also includes tidal signals and Stokes Coriolis Drift*)
Analysis	Yes ARCTIC_ANALYSISFORECAST_PHY_002_001: last two years; ongoing ARCTIC_ANALYSISFORECAST_BGC_002_004: last two years; ongoing ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: from 2018-11-01; ongoing ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: from 2019-03-31; ongoing
Forecast	Yes ARCTIC_ANALYSISFORECAST_PHY_002_001: 10 day forecasts, 10-members average ARCTIC_ANALYSISFORECAST_BGC_002_004: 10 day forecasts, 1 member ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: 9 day forecasts, 1 member ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: 10 day forecasts, 1 member
Available time series	Last 2 years, see above for details per product
Temporal resolution	ARCTIC_ANALYSISFORECAST_PHY_002_001 hourly instantaneous surface fields, 6-hourly average, 24hr average and monthly average 3D fields; ARCTIC_ANALYSISFORECAST_BGC_002_004: 24hr average and monthly average 3D fields; ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 1hr average surface fields ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: quarter-hourly instantaneous surface fields
Target delivery time	ARCTIC_ANALYSISFORECAST_PHY_002_001 and ARCTIC_ANALYSISFORECAST_BGC_002_004: ● Daily 10-day forecast: daily at 0030 UTC ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: ● Daily 9-day forecast: daily at 1100 UTC ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 ● Daily 10-day forecast: daily at 0030 UTC
Delivery mechanism	CMEMS Information System: Subsetter and Copernicus Marine FTP

Horizontal resolution	ARCTIC_ANALYSISFORECAST_PHY_002_001: 6.25 km ARCTIC_ANALYSISFORECAST_BGC_002_004: 6.25 km ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: 3 km ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: 3 km
Number of vertical levels	ARCTIC_ANALYSISFORECAST_PHY_002_001 40 for daily average fields:(0, 2, 4, 6, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2500, 3000, 3500, 4000 meters) Only surface variables otherwise. ARCTIC_ANALYSISFORECAST_BGC_002_004: 40 for daily average fields: (0, 2, 3, 4, 5, 6, 8, 10, 11, 13, 16, 18, 22, 25, 29, 34, 40, 47, 56, 66, 78, 92, 110, 131, 156, 186, 222, 266, 318, 380, 454, 541, 644, 763, 902, 1062, 2000, 3000, 3500, 4000 m)
Format	Netcdf CF1.4

*Table 1: ARC-MFC Real Time products. *: The surface currents are formally "total surface currents" although the standard name is kept as "ocean currents" to avoid disrupting the aggregation server.*

<u>The runtime schedule:</u> ARCTIC_ANALYSISFORECAST_PHY_002_001
The TOPAZ5 Production follows a split temporal scheme: a weekly assimilation/analysis and a daily forecast.
An analysis is produced weekly on Thursdays and is valid for the preceding Monday. It is based on an Ensemble Kalman Filter (EnKF) scheme and utilizes available observations up to the valid date. The analysis is used to initialize a 100-member 7-day ensemble hindcast run performed on the following Monday; the resulting ensemble is used in the EnKF scheme. The mean of the ensemble is calculated and temporally averaged to provide daily mean best estimate fields for the hindcast period (7 days, Monday to Sunday).
A 10-days, 10-members ensemble forecast is produced daily by integrating the 10 first ensemble members forward in time, only the physical forecast is integrated but for performance reasons the biological forecast remains run on member 001 only. The physical dataset consists of ensemble averaged, daily mean fields for the bulletin date (the scheduled production date) and the nine following dates. A new monthly mean dataset has been included. The model is initialized with results from the previous day's model runs, except on Thursdays when the weekly analysis is used for initialization. Thus, the data from the forecast run on Thursdays start three days prior to the bulletin date so that the series length is 13 days, as opposed to 10 days for the other six days of the week. The forecast run is performed in the evening of the bulletin date.
For the calibration of the ensemble forecast method, see:
Melsom A, Counillon F, LaCasce J, Bertino L (2012) Forecasting search areas using ensemble ocean circulation modeling. Ocean Dyn 62(8):1245–1257. doi:10.1007/s10236-012-0561-5

ARCTIC_ANALYSISFORECAST_BGC_002_004
The TOPAZ5 production follows the same split weekly/daily temporal scheme as TOPAZ5 above. Ocean colour data is assimilated once a week on Thursday using the vertical projection algorithm from Ardyna et al. (2013) with updated parameters for the Norwegian and Barents Sea. The model is run every day in the evening, initialized from a restart file from the same day and produces a 10-day forecast. However on Thursdays, due late arrival of ocean color observations, the model is initialized from the restart file from the previous day on which the ocean color data is assimilated. Therefore the product generated on Thursdays contains a 10-day forecast plus 1 day hindcast. A new monthly mean dataset has been included.

ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 (neXtSIM)
A 1-day hindcast and 9-day forecast are produced every day using a single member. neXtSIM is forced with both atmospheric data and ocean data and nudged towards daily sea ice charts and daily (7-day moving window) sea ice thickness observations (when available).

ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 (TOPAZ 6-Tides)
A 10-day forecast is produced every day using a single member. TOPAZ6 is forced with tides, atmospheric data including barometric pressure and wave terms in ocean and is one-way nested into the GLO HR MFC NEMO product.

III.2 Details of datasets (Real Time product)

III.2.1 ARCTIC_ANALYSISFORECAST_PHY_002_001

DATASET	cmems_mod_arc_phy_anfc_6km_detided_PT6H-m cmems_mod_arc_phy_anfc_6km_detided_P1D-m cmems_mod_arc_phy_anfc_6km_detided_P1M-m https://thredds.met.no/thredds/dodsC/topaz/dataset-topaz4-arc-myoceanv2-be.html	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
x and y components of velocity in polar stereographic grid coordinates	m/s m/s	vxo vyo
Vertical velocity	m/s	wo
Sea Surface Height	m	zos
Temperature	degrees_C	thetao

Salinity	1e-3	so
Sea Ice Concentration	1	siconc
Sea Ice Thickness	m	sithick
Sea Ice Velocity Field (x and y components in polar stereographic grid)	m/s	vxsi vysi
sea ice area fraction of first year ice	1	siconc_fy
age of sea ice	day	siage
Surface snow thickness	m	sisnthick
sea ice albedo	1	sialb
ocean_barotropic_streamfunction	m3 s-1	stfbaro
ocean mixed layer thickness	m	mlotst
sea floor depth below sea level	m	model_depth
bottom temperature	degrees_C	bottomT
DATASET	cmems_mod_arc_phy_anfc_6km_detided_PT1H-i	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Surface velocity in x-direction of polar stereographic grid	m/s m/s	vxo vyo

Surface velocity in y-direction of polar stereographic grid		
Sea Surface Height	m	zos
Temperature	degrees_C	thetao
Salinity	1e-3	so
Sea Ice Concentration	1	siconc
Sea Ice Thickness	m	sithick
Surface snow thickness	m	sisnthick
sea floor depth below sea level	m	model_depth
Ice drift x-direction velocity	m/s	vxsi
Ice drift y-direction velocity	m/s	vysi

Table 2: List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSISFORECAST_PHY_002_001

III.2.2 ARCTIC_ANALYSISFORECAST_BGC_002_004

DATASET	cmems_mod_arc_bgc_anfc_ecosmo_P1D-m cmems_mod_arc_bgc_anfc_ecosmo_P1M-m	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Nitrate	mmol m-3	no3
Phosphate	mmol m-3	po4
Oxygen	mmol m-3	o2

Primary production	mg m-3 day-1	nppv
Chlorophyll	mg m-3	chl
Silicate	mmol m-3	si
Phytoplankton biomass	mmol m-3	phyc
Light attenuation	m-1	kd
Model depth	m	model_depth
Zooplankton biomass	mmol m-3	zooc
Sinking mole flux of particulate organic matter	mol m-2 d-1	expc
Dissolved inorganic carbon	mole m-3	dissic
Surface partial pressure of carbon dioxide	Pa	spco2
Sea water ph	1	ph

Table 3 List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSISFORECAST_BGC_002_004

III.2.3 ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

DATASET	cmems_mod_arc_phy_anfc_nextsim_hm cmems_mod_arc_phy_anfc_nextsim_P1M-m	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Sea Ice Concentration	1	siconc
Sea Ice Thickness	m	sithick

Snow thickness	M	sisnthick
Sea ice albedo	1	sialb
Sea ice age	year	siage
Concentration of multi-year ice	1	siconc_my
Concentration of young ice	1	siconc_young
Volume fraction of ridged sea ice	1	si_ridge_ratio
Ice drift x-direction velocity	m/s	vxsi
Ice drift y-direction velocity	m/s	vysi

Table 4: List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

III.2.4 ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

DATASET	dataset-topaz6-arc-15min-3km-be http://thredds.met.no/thredds/catalog/metusers/arildb/catalog.html?dataset=metusers/arildb/dataset-topaz6-arc-15min-3km-be.ncml	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
x and y components of velocity in polar stereographic grid coordinates	m/s m/s	vxo* vyo*
Sea surface height	M	zos

Table 5: List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015. *: Same remark as in Table 1 about total surface currents.

III.3 General Information (Multiyear products)

Product Lines	ARCTIC_MULTIYEAR_PHY_002_003
Geographical coverage	North of 63°N
Variables	Temperature Salinity Sea Surface Height (inverse barometer effect not included) Horizontal velocity (x- and y- component in polar stereographic grid) Sea Ice (Concentration, Thickness, Velocity and Snow depth) ocean_barotropic_streamfunction ocean_mixed_layer_thickness (defined sigma_theta=0.03) bottom temperature sea_floor_depth_below_sea_level
Analysis	Yes
Forecast	No
Available time series	From 1991-01-15 to end of past year
Temporal resolution	Daily, monthly, and yearly average fields
Target delivery time	July and November each year
Delivery mechanism	Copernicus Marine Information System (Subsetter Opendap and FTP)
Horizontal resolution	12.5 km
Number of vertical levels	40 levels (0, 2, 4, 6, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2500, 3000, 3500, 4000 m) for all average fields
Format	Netcdf CF1.4

Table 6 ARC-MFC PHY Multiyear product

Product Lines	ARCTIC_MULTIYEAR_BGC_002_005
Geographical coverage	North of 65°N
Variables	Chl-a Attenuation coefficient Oxygen

	Nitrate Phosphate Silicate Phytoplankton biomass Zooplankton biomass Net primary production sea_floor_depth_below_sea_level
Analysis	Yes
Forecast	No
Available time series	From Jan 2007- to year-minus-2 and regularly updated
Temporal resolution	Daily, Monthly and yearly average fields
Target delivery time	November each year
Delivery mechanism	Copernicus Marine Information System (Subsetter OPENDAP and FTP)
Horizontal resolution	25 km
Number of vertical levels	1 level for Daily and 40 levels for monthly average fields: (0, 2, 3, 4, 5, 6, 8, 10, 11, 13, 16, 18, 22, 25, 29, 34, 40, 47, 56, 66, 78, 92, 110, 131, 156, 186, 222, 266, 318, 380, 454, 541, 644, 763, 902, 1062, 2000, 3000, 3500, 4000 m)
Format	Netcdf CF1.4

Table 7: ARC-MFC BGC Multiyear product

Detailed information on the systems and products are on Copernicus Marine web site: https://data.marine.copernicus.eu/products.

III.4 Details of datasets (Multiyear products)

III.4.1 ARCTIC_MULTIYEAR_PHY_002_003

DATASET	cmems_mod_arc_phy_my_topaz4_P1M or cmems_mod_arc_phy_my_topaz4_P1D-m yearly product: cmems_mod_arc_phy_my_topaz4_P1Y	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE

Zonal Velocity Meridional Velocity	m/s m/s	vxo vyo
Sea Surface Height	m	zos
Temperature	degC	thetao
Salinity	1e-3	so
Sea Ice Concentration	1	siconc
Sea Ice Thickness	m	sithick
Sea Ice Velocity Field (Meridional and Zonal)	m/s	vxsi vysi
Snow thickness	m	sisnthick
Ocean barotropic Stream Function	m^3/s	stfbaro
Ocean mixed layer thickness	m	mlotst
model_depth	m	model_depth
bottom temperature	degC	bottomT

Table 8 List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_MULTIYEAR_ PHY_002_003

III.4.2 ARCTIC_MULTIYEAR_ BGC_002_005

DATASET	cmems_mod_arc_bgc_my_ecosmo_P1D-m and cmems_mod_arc_bgc_my_ecosmo_P1M cmems_mod_arc_bgc_my_ecosmo_P1Y	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Chl-a	mg m^-3	chl

Attenuation coefficient	m^-1	kd
Nitrate	mMol m^-3	no3
Phosphate	mMol m^-3	po4
Silicate	mMol m^-3	si
Phytoplankton biomass	mMolC m^-3	phyc
Oxygen	mMol m^-3	o2
Model depth	m	Model_depth
Primary Production (net)	mg C m^-3 d^-1	nppv
zooplankton	mmol C m-3	zooc

Table 9: List of the variables in the dataset and their names in the NetCDF output files for the ARCTIC_MULTIYEAR_BGC_002_005

III.5 Production System Description

III.5.1 ARCTIC_ANALYSISFORECAST_PHY_002_001

The Arctic MFC physical ocean system is the TOPAZ5 system based on an advanced sequential data assimilation method (the Ensemble Kalman Filter, EnKF) in its deterministic flavour (DEnKF, Sakov and Oke, 2009) and the Hybrid Coordinate Ocean Model (HYCOM version 2.2.98).

III.5.1.1 TOPAZ5 Production Cycle at MET Norway

The model results are produced with the TOPAZ5 ocean data assimilation model system. Presently, TOPAZ5 data assimilation is run weekly on Thursdays to produce an analysis which is valid for the preceding Monday. The following Monday a one-week 100-member ensemble hindcast simulation is run to produce a best estimate for each of the preceding 7 days. Finally, a 10-days, 10-members ensemble forecast is run daily using the most recent analysis, forced by updated and perturbed atmospheric fields. The ensemble mean forecast (cmems_mod_arc_phy_anfc_6km_detided_PT6H-m and cmems_mod_arc_phy_anfc_6km_detided_P1D-m) are delivered to the users and used for the validation. In addition, daily files with hourly resolution of the surface fields (cmems_mod_arc_phy_anfc_6km_detided_PT1H-i) are computed from the ensemble mean

and delivered to the users . A new monthly mean dataset (cmems_mod_arc_phy_anfc_6km_detided_P1M-m) generated from the daily mean best estimates is also delivered.
TOPAZ5 was developed and is maintained by the Nansen Environmental and Remote Sensing Center (NERSC, http://nersc.no/). It is run operationally for CMEMS Arctic MFC production at the Norwegian Meteorological Institute (MET Norway, http://met.no).

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
11							
10							
9							
8							
7							
6	Single						
5	member						
4							
3							
2							
1	10 day FC	10 day FC	10 day FC	10 day FC	10 day FC	10 day FC	10 day FC
0	7 day HC						
-1							
-2				FC uses fresh analysis			
-3	100 member						
-4	EPS			ENKF – Analysis run,			
-5				valid for			
-6				preceding Monday			
-7							
-8							
-9							

Table 10: weekly schedule for the TOPAZ5 system. The vertical axis indicates forecast lead time in days.

III.5.1.2 Observational Data

Observational data are assimilated into the TOPAZ5 system in the weekly analysis. All data are assimilated, but instead of “background check”, the observation error is increased for those observations too far from the model forecast, in order to moderate the impact of their assimilation. Presently the following data are assimilated:

- Altimetric sea level anomaly (SLA) observations from the Jason3, Cryosat2 (since September 2013), Sentinel 3a (since 17th April 2017), Sentinel 3b and Sentinel 6a (since 18th April 2022). From May 2014 the following SLA-products are combined and assimilated:
    1. SEALEVEL_GLO_PHY_L3_NRT_OBSERVATIONS_008_044 (south of 50N)
    2. SEALEVEL_ARC_PHY_L3_NRT_OBSERVATIONS_008_038 (north of 50N)

The SLA-products reference level for mean sea level height was adjusted from a 7-year mean to a 20-year mean – thus the new observations are adjusted before assimilation to compensate for this change (by subtracting an offset of 2cm).

- OSTIA global SST observations.

- OSISAF global sea ice concentration.
- OSISAF global sea ice drift observations.
- *In situ* observations of temperature and salinity profiles from the Arctic In Situ TAC since June 2013 (All profiles).
- Merged ice thickness from CryoSAT2 and SMOS (CS2SMOS) SEAICE_ARC_SEAICE_L3_NRT_OBSERVATIONS_011_014 (in winter only)

III.5.2 ARCTIC_MULTIYEAR_PHY_002_003

The ARC-MFC uses the TOPAZ4 system based on an advanced sequential data assimilation method (the Ensemble Kalman Filter, EnKF) in its deterministic flavour (DEnKF, Sakov and Oke, 2009) and the Hybrid Coordinate Ocean Model (HYCOM version 2.2.37) on the same TOPAZ4 domain as use in NRT (product 002_001a), except with 50 vertical layers. This report describes the Arctic reanalysis product. The variables delivered are all physical variables, including 3D currents, temperatures and salinities, 2D parameters for sea ice, mixed layer depth and sea surface heights. Sea surface temperature and sea surface heights are corrected for bias, with an online bias correction algorithm.

- Production centre name: Arctic Marine Forecasting Centre. ARC-MFC
- Production subsystem name: TOPAZ4b
- Production centre description: Nansen Center, Bergen, Norway. NERSC-BERGEN-NO
  - Name in the catalogue: ARCTIC_MULTIYEAR_PHY_002_003
  - Dataset names
    - Monthly 3D fields cmems_mod_arc_phy_my_topaz4_P1D-m
    - Daily 3D fields cmems_mod_arc_phy_my_topaz4_P1M
    - Yearly 3D fields cmems_mod_arc_phy_my_topaz4_P1Y

III.5.2.1 Assimilated data

Observations that are assimilated by TOPAZ4 include along-track **Sea Level Anomalies** (SLA) from satellite altimeters, **Sea Surface Temperature** (SST) from Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA), **in situ temperature and salinity from hydrographic cruises and moorings**, **ice concentrations (SIC)** from OSI-SAF, the CS2SMOS ice thickness data from seaice.de and Sea Surface Salinity (SSS) from the Barcelona Expert Center, based on the SMOS satellite. The system uses a 7-day assimilation cycle and assimilates the gridded SST and SIC for the day of the analysis; and along-track SLA, ice thickness and in-situ T and S for the week prior to the day of the analysis. A brief overview of observations used in the reanalysis is given in Table 9.
Quality control procedures and preprocessing steps include a range check and horizontal superobing. The details for each observation type follow.

Type	Number	After Superobing	Spacing	Period	CMEMSname
SLA	$9 \cdot 10^4$	$4 \cdot 10^4$	Track	1993-	SEALEVEL_GLO_PHY_L3_REP_OBSERVATIONS_008_062
SST (CCI)	$2 \cdot 10^6$	$2.2 \cdot 10^5$	Gridded	1991--	SST_GLO_SST_L4_REP_OBSERVATIONS_010_011
In-situ T	$3 \cdot 10^4$	$5.\ 10^3$	Point	1991-	INSITU_GLO_TS_REP_OBSERVATIONS_013_001_b
In-situ S	$3 \cdot 10^4$	$5.\ 10^3$	Point	1991-	INSITU_GLO_TS_REP_OBSERVATIONS_013_001_b
Ice conc. (SSM/I)	$9 \cdot 10^4$	$5.\ 10^4$	Gridded	1991-	SEAICE_GLO_SEAICE_L4_REP_OBSERVATIONS_011_009
Ice drift	5.10^3	5.10^3	Gridded	1999-	OSI-455 from OSISAF (DOI:10.15770/EUM_SAF_OSI_0012) , SEAICE_GLO_SEAICE_L4_NRT_OBSERVATIONS_011_001 (after 2019)
Ice thickness	1.10^4	1.10^4	Gridded	2010-	SEAICE_ARC_SEAICE_L3_REP_OBSERVATIONS_011_013
SSS	1.10^4	1.10^4	Gridded	2013-	External (BEC, CSIC)
Total	$\mathbf{2.2 \cdot 10^6}$	$\mathbf{3 \cdot 10^5}$			

Table 11: Overview of assimilated observations per each cycle, average numbers for the cycles during which the observations are present.

The altimetry data used for assimilation are **the along- track SLA (SEALEVEL_GLO_PHY_L3_MY_008_062**) from Sentinel-6A, Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2 provided by Collecte Localisation Satellites from September 1992 to 2017. These data are geophysically corrected for tides, inverse barometer, tropospheric, and ionospheric signals [Le Traon and Ogor, 1998; Dorandeu and Le Traon, 1999]. The mean sea surface heights are referenced to the CNES-LEGOS Mean Dynamic Topography from Rio et al. 2018. The oceanographic signal is less accurate near the coast because of pollution by land and in shallow waters due to inaccuracies of the global tidal model that is used to de-alias the along-track altimeter observations. Therefore, we only retain data located both in water deeper than 200 m and at least 50 km away from the coast. The observation error is a combination of instrumental and representation error, where the instrumental error is set as recommended by the provider (3 or 4cm depending on the satellite), and the representation error accounts for sub-grid variability of observations. Little is known about the latter and we assume that this error is larger in the more dynamical areas [Oke and Sakov, 2008]. Thus, a proxy based on the model variance for the

period 1993-1999 scaled by a factor of 0.7 is used. The observations are assimilated asynchronously [Sakov et al., 2010] by using daily snapshots of the ensemble SLA fields.
The **SST** data assimilated is from OSTIA [OSTIA Stark et al., 2007], a CMEMS product SST_GLO_SST_L4_REP_OBSERVATIONS_010_011 The data set was included from June 1991 at horizontal resolution of approximately 6km, and is free of diurnal variation. It is a foundation SST product that combines data from infrared sensors (AVHRR and AATSR), microwave sensors (AMSR-E and TMI), and in situ data from ships and surface drifting buoys. From the initial data set, the values retained include those that are within a realistic range (i.e. ∈ [-1.9, 45]◦ C) and away from the ice edge (mask provided with OSTIA data). The observation error estimated by the provider is purposely overestimated by a factor 2.5 to account for the representation error.

Temperature (T) and salinity (S) profiles from research cruises that are assimilated from January 1991 to 2017 were from the Coriolis data centre at Ifremer: INSITU_GLO_TS_REP_OBSERVATIONS_013_001_b. Unlike SLA data, in situ temperature and salinity data are not assimilated asynchronously but are instead assumed to correspond to the analysis time, even though they spanned the week preceding the analysis time. Profiles of T and S are checked for hydrostatic stability, and observations within each profile are superobed vertically to retain a maximum of one super-observation per layer, based on the layer structure of the first ensemble member. The forecast at each observation for each ensemble member is calculated by linearly interpolating between the adjacent layers of each member to the depth of the observation. The scientific cruise data from the World Ocean Atlas [WOA05 Levitus et al., 2005, WOA09], ICES, IOPAS, IMR, AARI, Ocean Weather Station Mike, NABOS, NPI, North Pole Environment Observatory, the TRACTOR project, MMBI, LOGS are also assimilated after being manually quality checked (A. Korablev and A. Smirnov, pers. 20ocal.). A total of 3.000.000 observations are assimilated.

The **SIC** data is obtained from SSM/I at the Sea Ice TAC (OSI-SAF data SEAICE_GLO_SEAICE_L4_REP_OBSERVATIONS_011_009). It is computed with the OSI-SAF ESA CCI sea ice concentration algorithm. The gridded data was assimilated since 1991, at a resolution of 25 km. The spatial coverage is almost complete. TOPAZ4 assimilates the SIC data on the day of each analysis. The observation error standard deviation is set to 10% at the start of the reanalysis and is increased to account for larger errors near the ice edge and to reduce over-fitting at these locations. The error variance is: $\sigma^2_{obs} = 0.01 + (0.5 - |0.5 - c|)^2$, where c is the observed SIC.

The **sea ice drift (SIUV)** product is provided by OSI-455 from OSISAF (10.15770/EUM_SAF_OSI_0012; daily product); After 2019 the SEAICE_GLO_SEAICE_L4_NRT_OBSERVATIONS_011_001 (METNO-GLO-SEAICE_DRIFT-NORTH-L4-NRT-OBS; 2-days product) . The Lagrangian drift data is obtained at a resolution of 75 km by a continuous cross-correlation algorithm from passive microwave satellite data (AMSR-E, SSM/I, SSMIS, and AMSR2). It is available year-round but does not provide information close to the ice edge. The 1-day drift is short enough to avoid severe loss of data near the coast that occurs in the composites computed over longer periods.

The data is available from 1991 to 2020 but we only used it in the winter months since 1999. The provider specified an averaged uncertainty (24 hours displacement in both vector components) of about 2.5 km per day. We increased the observation error to 7 km per day to account for representation error. Because the sea ice drift data is Lagrangian, the corresponding observation operator is nonlinear. The model equivalent 1-day drift is computed for each ensemble member and each grid cell of the satellite data productThe initial positions are advected 24 hours forward, using the daily averages for interpolation of the ice velocities and a 2nd order Runge-Kutta method for the Lagrangian trajectories. The final displacements are computed on the observations grid.

The **ice thickness** product is the weekly merged CS2SMOS dataset from AWI (Ricker et al. 2017), combining thin sea ice measurements from the ESA SMOS mission to the thick sea ice retrievals from another ESA mission CryoSAT2. The merged product is assembled on a weekly basis and contains mapping errors as uncertainty estimates. An additional uncertainty has therefore been added to account for retrieval errors increasing linearly as a function of thickness. Sea ice thickness is only available in Winter (end of October to early April).

The **Sea Surface Salinity** is the 9-days averaged Level-4 SMOS product from BEC, CSIC developed as part of the ESA Arctic+Salinity project (Version 3.1). An uncertainty is provided as part of the dataset and exaggerated in areas of fresh water following Xie et al. (2019). The OSSE using the SSS product in Xie et al. (2023) in the Arctic shows that the biases and the root-mean-squared differences (RMSD) of SSS are reduced by 10 % up to 50 % depending on areas, and the Arctic freshwater content (FWC) and its seasonal cycle are modified by the assimilation of the SSS products. The observation error variance is increased as a decreasing function of salinity $\sigma^2_{obs} = \max\{\sigma^2_{int}, [0.6+1/(1+\exp((sss-16)/5))]^2\}$, where σ^2_{int} is the instrumental error variance specified by the data provider.

III.5.2.2 The Model

TOPAZ4 uses version 2.2.37 of HYCOM. In our implementation of HYCOM, the vertical coordinate is isopycnal in the stratified open ocean and z-coordinates in the unstratified surface mixed layer. Isopycnal layers permit high resolution in areas of strong density gradients and better conservation of tracers and potential vorticity; and z-layers are well suited to regions where surface mixing is important. To realistically simulate the circulation in the Arctic region, an ocean model requires a particularly accurate representation of the dense overflow and the surface mixed layer to isolate the warm Atlantic inflow from the sea ice. In our opinion, this makes HYCOM a suitable model for the North Atlantic and Arctic region that spans the stratified open ocean, a wide continental shelf, regions of steep topography, and extensive sea ice. HYCOM also permits sigma coordinates that can be beneficial in coastal regions, however we have not adopted this option here.
The TOPAZ4b implementation of HYCOM uses: the tracer and continuity equation solved with the second order flux corrected transport [FCT2, Iskandarani et al., 2005; Zalesak, 1979]; the turbulent mixing sub-model from the Goddard Institute for Space Studies [Canuto et al., 2002]; the vertical remapping for fixed and non-isopycnal coordinate layers with the Weighted Essentially Non-Oscillatory (WENO) piecewise parabolic scheme; the short wave radiation penetration with varying exponential decay depending on the Jerlov water type [Halliwell,

2004]; and biharmonic viscosity.

The model is coupled to a one thickness category sea ice model with elastic-viscous-plastic (EVP) rheology [Hunke and Dukowicz, 1997]; its thermodynamics are described in Drange et al. [1996] with a correction of heat fluxes for sub- grid scale ice thickness heterogeneities following Fichefet and Morales Maqueda [1997]. The sea ice strength is set to 27500 $N.m^{-2}$. The advection of ice tracers (concentration, ice thickness, snow depth, first year ice fraction and ice age) is calculated using a 3rd order WENO scheme [Jiang and Shu, 1996], with a 2nd order Runge-Kutta time discretisation. The coupling (exchange of stress, heat, salinity) with the ocean is done on the HYCOM Arakawa C-grid every 3 hours.
The model domain covers the North Atlantic and Arctic basins (see Figure 2), with the horizontal model grid created by a conformal mapping with the poles shifted to the opposite side of the globe to achieve a quasi-homogeneous grid size [Bentsen et al., 1999]. The grid has 880 × 800 horizontal grid points, with approximately 12-16 km grid spacing in the whole domain. This is eddy-permitting resolution for low and middle latitudes, but is too coarse to properly resolve all of the mesoscale variability in the Arctic, where the Rossby radius is as small as 1-2 km.

The model uses 50 hybrid layers. The top five target densities are purposely low to force them to remain z-coordinates. The minimum z-level thickness of the top layer is 2 m, while the maximum z-layer thickness is 450 m, to resolve the deep mixed layer in the Sub-Polar Gyre and Nordic Seas. The model bathymetry is interpolated from the General Bathymetric Chart of the Oceans database (GEBCO) at 1-minute resolution.
The model is initialized in 1973 using climatology from the World Atlas of 2018 [WOA18, Locarnini et al., 2006; Antonov et al., 2006]. At the lateral boundaries, model fields are relaxed towards the same monthly climatology. The model includes an additional barotropic inflow of 0.7 Sv through the Bering Strait, representing the inflow of Pacific water, with seasonal variations [Ness et al. 2010]. This inflow is balanced by an outflow at the southern boundary of the domain in the Atlantic Ocean.

Forcing: For the reanalysis experiment presented in this paper, TOPAZ is forced at the ocean surface with fluxes derived from 6-hourly atmospheric fluxes from ERA5 that has a resolution of 0.25◦. The atmospheric fields from ERA5 include: precipitation, dew point temperature, total cloud cover, air temperature at 2 m, sea level pressure, wind speed at 10 m and long wave radiation at the sea surface. The incoming shortwave radiation is computed every 3h from synoptic cloud fields, and the wind stress is derived from 10 m winds, estimated as in Large and Pond [1981]. The surface fluxes are forced with a bulk formula parameterisation [Kara, 2000].

The value of river discharge is poorly known because the observation array for river flows is sparse. A monthly climatological discharge is estimated by applying the run-off estimates from ERA-interim to the Total Runoff Integrating Pathways [TRIP, Oki and Sud, 1998] over the 20-year reanalysis period (1989-2009). The mass loss from the Greenland Ice Sheet has been included using a linear regression on the ESA GrIS CCI gravity data and distributed onto 30 terminal glaciers around Greenland. Rivers in HYCOM are treated as a negative salinity flux with an additional mass exchange.

The remaining inaccuracies in **the evaporation and run-off** are constrained using relaxation towards climatology. However, relaxation can have a detrimental impact on some regions – particularly where strong fronts occur and/or they are misplaced (e.g., Gulf Stream). In such places the water mass distribution is bimodal, and the relaxation towards an average estimate reduces the sharpness of fronts. To avoid this problem, relaxation is only activated when the difference between the climatology and the model is less than 0.5 PSU (Mats Bentsen, BCCR, pers. comm.).

The diagnosed model SSH is the steric height anomaly that varies due to barotropic pressure mode, deviations in temperature and salinity, and does not include the inverse barometer effect (atmospheric effect).

The model code is publicly available. It can be accessed from https://svn.nersc.no/repos/hycom or browsed at https://svn.nersc.no/hycom/browser.

III.5.2.3 Data assimilation

TOPAZ4b has transitioned from using the traditional "perturbed observations" EnKF scheme [Burgers et al., 1998] to the "deterministic EnKF", or DEnKF, that was developed by Sakov and Oke [2008a]. In the case of "weak" DA, when the increments are much smaller than the ensemble spread, the DEnKF is asymptotically equivalent to the symmetric right multiplied ensemble square root filter (ESRF) [Sakov and Oke, 2008b], commonly known as the ETKF [Bishop et al., 2001]. In the case of "strong" DA the DEnKF yields smaller increments than the ESRF – a characteristic that can be interpreted as adaptive inflation, aimed at increasing the robustness of the system.

Similar to TOPAZ3, TOPAZ4 uses a simple, non-adaptive, distance-based localization method known as "local analysis" [Evensen, 2003; Sakov and Bertino, 2011]. With this method, a local analysis is computed for one horizontal grid point at a time, using observations from a spatial window around it. In contrast to TOPAZ3, TOPAZ4 uses smooth localization (rather than a box-car type localization) that yields spatially continuous analyses. The smoothing is implemented by multiplying local ensemble anomalies, or perturbations, by a quasi-Gaussian, isotropic, distance dependent localization function [Gaspari and Cohn, 1999]..

The localization radius, beyond which the ensemble-based covariance between two points is artificially reduced to zero, is uniform in space and is set to 300 km. This corresponds to an e1/2-folding radius of about 90 km. The localisation radius is larger for in situ profiles than satellite data (600 km rather than 90 km effective radius)

During each analysis step, TOPAZ calculates a 100×100 local ensemble transform matrix (ETM, called X5 in Evensen 2003) for each of the 880 × 800 horizontal model grid cells. The matrix inversion involved in the calculation of each local ETM is performed either in ensemble or observation space (whichever is smaller), depending on whether the number of locally assimilated observations is greater or smaller than the ensemble size. This 880 × 800 array of ETMs is then used for updating each horizontal model field (about 150 fields total).

The analysis is performed in the model grid space. The instances of negative layer thickness or ice concentration, should they occur, are corrected in a post-processing procedure. The next cycle is restarted from the analysis in a straightforward manner; without using incremental update or nudging.

The DA code is publicly available. It can be accessed from https://svn.nersc.no/repos/enkf or browsed at https://svn.nersc.no/enkf/browser.

III.5.2.4 History of the reanalysis

The initial ensemble is generated so that it contains variability both in the interior of the ocean and at surface. The initial ensemble is generated from 20 model snapshots taken from a long model run at a similar time of the year. The initial ensemble is integrated for 40 days to damp instabilities that result from the perturbations.
After generating the initial ensemble the DA system is spun up during a period of 1 year, for the calendar year of 1990. In order to limit the impact from an abrupt start of DA, the observation error variance is at first purposely overestimated and gradually decreased to the realistic level over a period of one year, starting from a factor of 8 and reducing to 1 at the end of the year 1990 for an official start of the reanalysis in 1991.
The assimilation cycle is weekly, similarly to the real-time system, but more observations are assimilated in delayed mode. More information about changes of product quality can be found in the QuID.
In the second half of 2004, the impact of T/S profiles assimilation on sea ice was removed, thereby "decoupling" partially the sea ice and ocean data assimilation. This was intended to avoid the appearance of noise in the sea ice thickness when Ice-tethered profilers (ITPs) are introduced in the Arctic.
References:

Xie, J., Raj, R. P., Bertino, L., Samuelsen, A., & Wakamatsu, T. (2019). Evaluation of Arctic Ocean surface salinities from the Soil Moisture and Ocean Salinity (SMOS) mission against a regional reanalysis and in situ data. Ocean Science, 15, 1191–1206,. https://doi.org/10.5194/os-2018-163

Xie, J., Raj, R. P., Bertino, L., Martínez, J., Gabarró, C., and Catany, R.: Assimilation of sea surface salinities from SMOS in an Arctic coupled ocean and sea ice reanalysis, Ocean Sci., 19, 269–287, https://doi.org/10.5194/os-19-269-2023 , 2023.

III.5.3 ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

neXtSIM is a stand-alone sea-ice model that can use winds and currents from a variety of atmospheric and oceanic models (hindcasts or forecasts). Its dynamical core is the Brittle-Bingham-Maxwell (BBM) rheology. The dynamical equations are solved with a finite element method on a Lagrangian (moving) triangular mesh. The code is a parallelised C++ code (used by Rampal et al., 2019, and presented by Samaké et al., 2017). The domain is a pan-Arctic one, with a mesh size of about 10 km (corresponding to about 7 km square grid resolution).
There is also a thermodynamic component of the code and beneath the ice is a slab ocean with three variables: temperature, salinity and thickness. The temperature and salinity are modified by the heat and salinity fluxes determined by the thermodynamical model as ice melts and freezes and as the model interacts with the atmosphere. The thermodynamical model is a three-category model (detailed in Rampal et al., 2019, Appendix A): open water, newly-formed ice (treated as one ice layer and one snow layer; Semtner, 1976) and older ice (treated as two ice layers and a snow layer; Winton, 2000).
Ocean forcing: To force neXtSIM, we use the ARCTIC_ANALYSISFORECAST_PHY_002_001 (TOPAZ5) near-surface (30 m) ocean

velocity and the mixed layer depth (MLD) directly in the model, while the temperature and salinity in the model's slab ocean are relaxed towards the TOPAZ5 sea surface (3 m) temperature (SST) and salinity (SSS) (respectively) over a time scale of about a month. The thickness of the slab ocean is the MLD from TOPAZ5.

Atmospheric forcing: We use ECMWF IFS forecast of the 10-m wind velocity, the 2-m air and dew point temperatures (the latter is used to determine the specific humidity of air for the latent heat flux calculation), the mean sea level pressure, the long- and short-wave downwelling radiation, and the total precipitation (this becomes snow if the temperature is below 0◦C).

Data Assimilation: The assimilation is performed before each forecast run using a data insertion method — an updated variable is calculated as a function of the forecast variable and observations. The simulation is then restarted using the updated variable and the model is run for 10 days to provide a forecast. Ice charts from the National Ice Center (United States of America) (the daily Arctic Marginal Ice Zone chart: https://usicecenter.gov/Catalog/ArcticMizChart)are assimilated on a daily basis. When available (October-April), daily (with a 7-day moving window) sea ice thickness observations from CS2-SMOS are also assimilated.

For more details on the present model setup, see

Williams, T., Korosov, A., Rampal, P., and Ólason, E.: Presentation and evaluation of the Arctic sea ice forecasting system neXtSIM-F, The Cryosphere, 15, 3207–3227, https://doi.org/10.5194/tc-15-3207-2021, 2021.

Other references:

Rampal, P., Dansereau, V., Olason, E., Bouillon, S., Williams, T., Korosov, A., and Samaké, A.: On the multi-fractal scaling properties of sea ice deformation, The Cryosphere, 13, 2457–2474, https://doi.org/10.5194/tc-13-2457-2019, 2019.

Samaké, A., Rampal, P., Bouillon, S., and Ólason, E.: Parallel implementation of a Lagrangian-based model on an adaptive mesh in C++: Application to sea-ice, J. Comp. Phys., 350, 84–96, https://doi.org/10.1016/j.jcp.2017.08.055, 2017

Winton, M.: A Reformulated Three-Layer Sea Ice Model, J. Atmos. Ocean Tech., 17, 525–531, 2000.

III.5.4 ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

The ARC-MFC tide product is generated by TOPAZ6 which is stand-alone system based on HYCOM (version 2.2.98) coupled with the Community sea Ice Code CICE version 5.1. TOPAZ6 is forced with atmospheric forcing from ECMWF including barometric pressure, the wave terms from the 3km WAM forecasts ARCTIC_ANALYSIS_FORECAST_WAV_002_014, as well as tidal lateral boundary conditions from FES2014 dataset (on a 1/16°x1/16° grid). FES2014 was developed by Noveltis, Legos and CLS and distributed by Aviso+, with support from Cnes (https://www.aviso.altimetry.fr/)". In addition TOPAZ6 is using 3D daily fields from the GLB-MFC (non-tidal) product GLOBAL_ANALYSISFORECAST_PHY_001_024, hence it is one-way nested with the global NEMO model. No data assimilation is involved in TOPAZ6.

The horizontal resolution is 3km with 50 hybrid layers in the vertical. However, the product includes only the surface velocities and sea surface elevation recorded at every 15 minutes and projected on stereographic grid.

The product (dataset-topaz6-arc-15min-3km-be) containing 10-day forecasts is delivered to the users every day.

Reference for the wave terms in HYCOM:

Ali, A., Christensen, K. H., Breivik, Ø., Malila, M., Raj, R. P., Bertino, L., Chassignet, E. and Bakhoday-Paskyabi, M. (2019). A comparison of Langmuir turbulence parameterizations and key wave effects in a numerical model of the North Atlantic and Arctic Oceans. *Ocean Modelling*, *137*, 76–97. https://doi.org/10.1016/j.ocemod.2019.02.005

III.5.5 ARCTIC_ANALYSISFORECAST_BGC_002_004

The biogeochemical forecast is temporarily produced by a separate ARC forecast model. Thus, the PHY_002_001_a results and the BGC_002_004 results become available from different model runs.
The BGC product comes from the TOPAZ5 coupled physical-ecosystem model. The numerical ocean circulation model HYCOM (coupled to a dynamic -thermodynamic sea ice model) is integrated forward in time, forced with atmospheric fields from the ECMWF weather forecast model.
ECOSMO II(CHL) (Yumruktepe et al, 2022) contains 16 variables: nitrate, ammonium, phosphate, silicate, diatoms, flagellates, cyanobacteria, micro- and meso-zooplankton, particular and dissolved organic matter, opal and oxygen with explicit prognostic chlorophyll for each phytoplankton. Yumruktepe et al. (2022) provide the parameter set that is tuned for the Artic region. In its recent iteration, ECOSMO II(CHL) received 4 additional state variables (not published), coccolithophores, its chlorophyll-a component, CaCO3 and variable detritus sinking speed respectively. It received a change to its light limitation on growth such that the growth is now directly related to chlorophyll-a concentration (Yumruktepe et al., 2023). ECOSMO II(CHL) parameters were further tuned for the Nordic Seas using chlorophyll-a and oxygen from BGC-Argo buoys. River nutrients were derived from output from the GlobalNEWS model (Seitzinger et al., 2005). At the model lateral boundaries nutrients (nitrate, silicate and phosphate) are nested to the GLO BGC PISCES model through a linearly decreasing effect, otherwise the ECOSMO model variables develop freely. ECOSMO II(CHL) includes an explicit sediment biogeochemistry module which exchanges nutrients, organic matter, oxygen and CaCO3 with the water column. An explicit carbon chemistry module is also included in ECOSMO II(CHL). Horizontally variable annual atmospheric deposition of nitrogen was taken from the EMEP model. Atmospheric deposition of phosphate was resolved using the N:P ratio given in Okin et al. (2011).
Assimilation of ocean colour is performed in a weekly cycle, while model forecasts are updated on a daily basis. The assimilation is performed one day after the satellite observation acquisition, on Thursdays. The ocean colour chlorophyll-a is projected down to 200 meters using the approach of Ardyna et al. (2013) with a further regional parameter modification at the Norwegian and Barents Sea, and the model chlorophyll-a (phytoplankton biomass is modified accordingly) is nudged towards the projected profiles. Consequently, the Thursday model simulation is performed as a one-day hindcast plus 10 days forecast. For the other days of the week, the model simulations are performed such that the first day is using analysed atmospheric forcing fields. A detailed explanation is provided in Table 12.

		Valid day															
		Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu
B u ld la ey t i n	Mo	A*	F	F	F	F	F	F	F	F	F						
	Tu		A*	F	F	F	F	F	F	F	F	F					
	We			A*	F	F	F	F	F	F	F	F	F				
	Th			P	A*	F	F	F	F	F	F	F	F	F			
	Fr					A*	F	F	F	F	F	F	F	F	F		
	Sa						A*	F	F	F	F	F	F	F	F	F	
	Su							A*	F	F	F	F	F	F	F	F	F

Table 12: The weekly production cycle of the ARCTIC_ANALYSISFORECAST_BGC_002_004 product. In the table, "Bulletin day" refers to the day when a forecast is produced, and "Valid day" refers to days for which forecasts are available (as daily mean values). Further 'A' indicates simulation with analysed atmospheric forcing fields,
'A' (on the bulletin day) refers to a mix of analysed atmospheric forcing (up to and including 12 UTC) and forecasts, 'F' corresponds to production using atmospheric forecasts, and 'P' refers to assimilation of the physical state of the model.*

The ECOSMO II(CHL) model is coupled online to the physical HYCOM model using the FABM coupler. It uses the HYCOM facility for advection of tracers and has the same time-step as the physical model. The interactions between the different components of the model are highlighted in Figure 1. The FABM coupler enables the development of HYCOM and ECOSMO code separately and effectively test the ECOSMO model to be tested in 1D prior to its integration to 3D HYCOM framework.

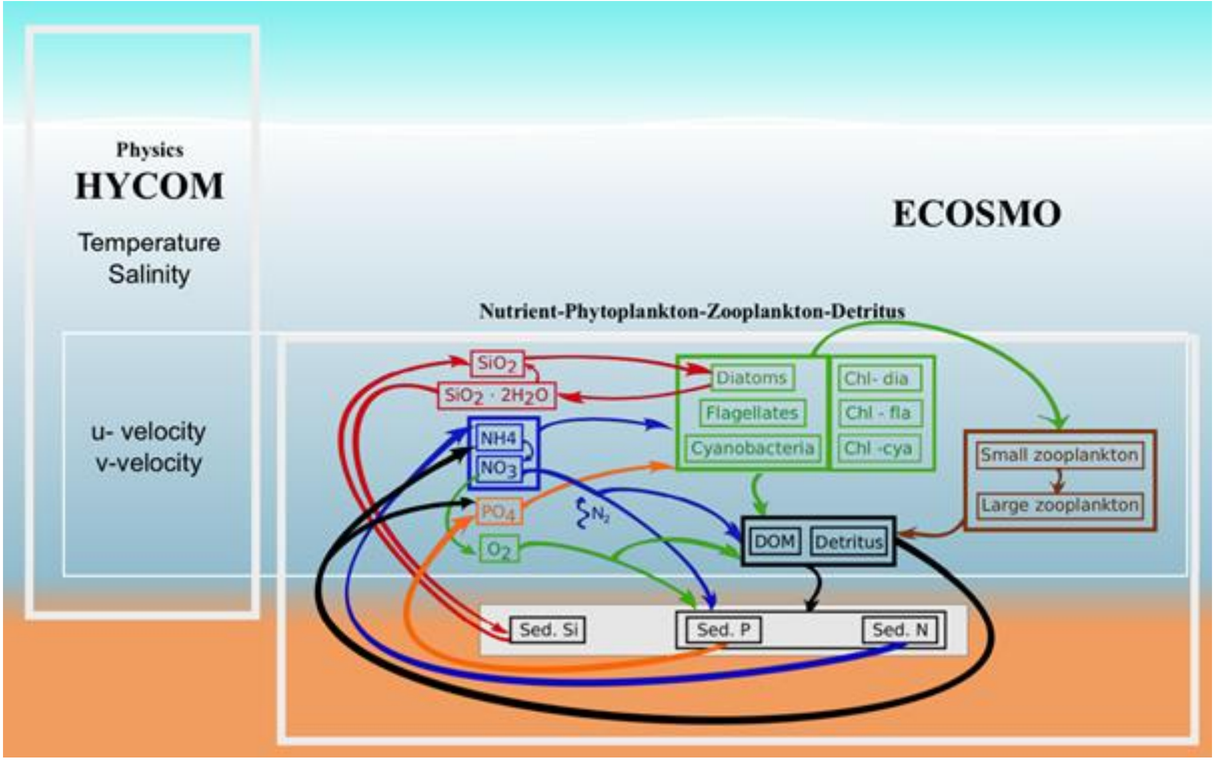

Figure 1: Overview over the components of ECOSMO and how they interact with each other after Yumruktepe et al. (2022).

Reference:

Ardyna, M., Babin, M., Gosselin, M., Devred, E., Bélanger, S., Matsuoka, A., and Tremblay, J.-É.: Parameterization of vertical chlorophyll a in the Arctic Ocean: impact of the subsurface chlorophyll maximum on regional, seasonal, and annual primary production estimates, Biogeosciences, 10, 4383–4404, https://doi.org/10.5194/bg-10-4383-2013, 2013.

Okin, G. S., et al. (2011), Impacts of atmospheric nutrient deposition on marine productivity: Roles of nitrogen, phosphorus, and iron, Global Biogeochem. Cycles, 25, GB2022, doi:10.1029/2010GB003858

Yumruktepe, V. Ç., Samuelsen, A., and Daewel, U.: ECOSMO II(CHL): a marine biogeochemical model for the North Atlantic and the Arctic, Geosci. Model Dev., 15, 3901–3921, https://doi.org/10.5194/gmd-15-3901-2022, 2022.

Yumruktepe, V. Ç., Mousing, E. A., Tjiputra, J., and Samuelsen, A.: An along-track biogeochemical Argo modelling framework, a case study of model improvements for the Nordic Seas, Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2023-25, in review, 2023.

III.5.6 ARCTIC_MULTIYEAR_BGC_002_005

The Biogeochemical (BGC) reanalysis system was developed based on the HYCOM-EVP-ECOSMO II ocean-ice-biogeochemical coupled model. The ocean model is based on HYCOM 2.2.37 and its configuration is the 50 km North Atlantic - Arctic domain, NA2a0.80. In our implementation of HYCOM, the vertical coordinate is isopycnal in the stratified open ocean and z-coordinates in the unstratified surface mixed layer. Isopycnal layers permit high resolution in areas of strong density gradients and better conservation of tracers and potential vorticity; and z-layers are well suited to regions where surface mixing is important. The data assimilation system for the joint parameter-state estimate is based on the TOPAZ ensemble Kalman filter system (EnKF) used in a one-lag smoother (EnKS).

ECOSMO II (Daewel and Schrum, 2013) contains 13 variables: nitrate, ammonium, phosphate, silicate, diatoms, flagellates, cyanobacteria, micro- and meso-zooplankton, particular and dissolved organic matter, opal and oxygen. In addition chlorophyll was included as prognostic variable in the model rather than just diagnosing it from the phytoplankton biomass, following the formulation in Bagniewski et al. (2011). This adds three additional tracers. Compared to the model presented in Daewel and Schrum (2013), some tuning of the model parameters connected to phytoplankton growth and zooplankton grazers has been done since the model was coupled to HYCOM. River nutrients were derived from output from the GlobalNEWS model (Seitzinger et al., 2005). At the model lateral boundaries nutrients are relaxed towards climatological values, otherwise the ECOSMO model variables develop freely. ECOSMO is coupled online to the physical HYCOM model; it uses the HYCOM facility for advection of tracers and has the same time-step as the physical model. The interactions between the different components of the model are highlighted in Figure 1.

III.5.6.1 Assimilated data

In the 3D reanalysis system, assimilated data are in-situ biogeochemical data: Nitrate, Phosphate, Silicate and satellite chlorophyll-a (Chl-a) data. Sources of the in-situ data are: 1. Institute of Marine Research nutrient data, 2. GLODAPv2_2019 (Olsen et al., 2019), 3. ICES oceanographic database and 4. CLIVAR. All in-situ data are quality controlled and duplication of data from multiple data source are merged through TOPAZ preprocessor. The satellite Chl-a data are ESA Ocean Color CCI (OC-CCI) ver 4.2 product ([rvw1] Sathyendranath et al., 2020). Specific OC-CCI product we use here are the global, 8 day composite with 4 km horizontal resolution. The satellite Chl-a data are assumed to be sampled from the ocean surface. In-situ biogeochemical data are temporally binned at the nearest OC-CCI 8 daily date. All data are pre-processed to be compatible with TOPAZ model resolution before they are assimilated. A brief overview of observations used in the reanalysis is given in Table 13.

Quality control procedures and preprocessing steps include a range check and horizontal superobing.

Variable	Number (2007)	CMEMS Product ID	Source	Spacing Type
Surface Chl-a	181.658	OCEANCOLOUR_GLO_CHL_L4_ REP_OBSERVATIONS_009_093	ESA OC-CCI	Gridded (4 km x 4 km) 8 days frequency

In-situ Nutrients: NO3 PO3 SiO3	 620 650 647		Merged: ICES, IMR GLODAPv2_2019 CLIVAR	In situ (lat,lon,depth)

Table 13 List of observations assimilated to ARC MFC BGO reanalysis system. Example of number of observations from 2007.

III.5.6.2 The Model

ARCTIC_MULTIYEAR_BGC_002_005 uses version 2.2.37 of HYCOM.
The implementation of HYCOM and coupling to sea ice: See section III.2.2

Coverage model: The model domain covers the North Atlantic and Arctic basins (see Figure 3), with the horizontal model grid created by a conformal mapping with the poles shifted to the opposite side of the globe to achieve a quasi-homogeneous grid size [Bentsen et al., 1999]. The grid 216*144 horizontal grid points, with approximately 50 km grid spacing in the whole domain. This is too coarse to permit or resolve the mesoscale variability in the Arctic, where the Rossby radius is as small as 1-2 km.

Vertical grid: See section III.2.2
Initialization: See section III.2.2

Atmospheric forcing: For the reanalysis experiment presented in this document, TOPAZ is forced at the ocean surface with fluxes derived from 6-hourly reanalysed atmospheric fluxes from ERA-5 [Dee et al., 2016] that has a resolution of 0.5 deg◦. The atmospheric fields from ERA-5 include: precipitation, dew point temperature, total cloud cover, air temperature at 2 m, sea level pressure, wind speed at 10 m and long wave radiation at the sea surface. The incoming short wave radiation is computed every 3h from synoptic cloud fields, and the wind stress is derived from 10 m winds, estimated as in Large and Pond [1981]. The surface fluxes are forced with a bulk formula parametrisation [Kara, 2000].

The value of river discharge See section III.2.2
The diagnosed model SSH: See section III.2.2

The model code is publicly available. It can be accessed from https://svn.nersc.no/repos/hycom or browsed at https://svn.nersc.no/hycom/browser.

III.5.6.3 Data assimilation

In the reanalysis system, 8 days composite surface Chlorophyll data from ESA OC-CCI and in-situ nutrients (Nitrate, Silicate and Phosphate) from IMR, ICES and GLODAPv2 datasets are assimilated into HYCOM-CICE-ECOSMOII, ice-ocean-biogeochemistry coupled ocean circulation model, at every reanalysis cycle with an 8 day assimilation window. The assimilation system is a one-lag ensemble Kalman smoother (EnKS) with joint state and parameter estimation.

III.5.6.4 History of the reanalysis

The reanalysis production is conducted independently year by year following a deterministic spin-run from 2000 January 1st and a one year ensemble spin-up run starting from January 1st the year before.
The EnKF estimates also scalar biological parameters of the ECOSMO model,

IV NOMENCLATURE OF FILES

Information about how the data if named can be found in this article (chapter "Files Nomenclature and Format") : [Article | Copernicus Marine Help Center]

The ARC MFC products have been set up through different phases of Copernicus Marine and the file and dataset naming conventions have changed in the meantime. As a result, the tables 14 and 15 below provide a summary of the different files that can be found on the CMEMS server to this date.

Table 14: Near Real Time products

Product Name	*Dataset Name*	*File Name*
ARCTIC_ANALYSIS_FORECASTPHYS_002_001	*cmems_mod_arc_phy_anfc_6km_detided_PT1H-i*	*20210113_hr-metno-MODEL-topaz5-ARC-b20210111-fv02.0.nc*
	cmems_mod_arc_phy_anfc_6km_detided_P1D-m	*20200101_dm-metno-MODEL-topaz5-ARC-b20200106-fv02.0.nc*
	cmems_mod_arc_phy_anfc_6km_detided_PT6H-m	*20200101_6hm-metno-MODEL-topaz5-ARC-b20200106-fv02.0.nc*
	cmems_mod_arc_phy_anfc_6km_detided_P1M-m	*202109_mm-metno-MODEL-topaz5-ARC-fv02.0.nc*
ARCTIC_ANALYSISFORECAST_BGC_002_004	*cmems_mod_arc_bgc_anfc_ecosmo_P1D-m*	*20210120_dm-metno-MODEL-topaz5_ecosmo-ARC-b20210111-fv02.0.nc*
	cmems_mod_arc_bgc_anfc_ecosmo_P1M-m	*202109_mm-metno-MODEL-topaz5_ecosmo-ARC-fv02.0.nc*
ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011	*cmems_mod_arc_phy_anfc_nextsim_hm*	*20190321_hr-nersc-MODEL-nextsimf-ARC-b20190314-fv00.0*
	cmems_mod_arc_phy_anfc_nextsim_P1M-m	*202201_mm-nersc-MODEL-nextsimf-ARC-fv00.0.nc*
ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015	*dataset-topaz6-arc-15min-3km-be*	*20191214_qhr-metno-MODEL-topaz6-tide-ARC-b20191205-fv02.0.nc*

Table 15: Multiyear products

Product Name	*Dataset Name*	*File Name*
ARCTIC_MULTIYEAR_PHY_002_003	*cmems_mod_arc_phy_my_topaz4_P1D-m*	*19930716_dm-12km-NERSC-MODEL-TOPAZ4B-ARC-RAN.fv2.0.nc*
	cmems_mod_arc_phy_my_topaz4_P1M	*19950115_mm-12km-NERSC-MODEL-TOPAZ4B-ARC-RAN.fv2.0.nc*
	cmems_mod_arc_phy_my_topaz4_P1Y	*19910101_ym-12km-NERSC-MODEL-TOPAZ4B-ARC-RAN.fv2.0.nc*
ARCTIC_MULTIYEAR_BGC_002_005	*cmems_mod_arc_bgc_my_ecosmo_P1D-m*	*20070330_dm-25km-NERSC-MODEL-ECOSMO-ARC-RAN-fv2.0.nc*
	cmems_mod_arc_bgc_my_ecosmo_P1M	*20070315_mm-25km-NERSC-MODEL-ECOSMO-ARC-RAN-fv2.0.nc*

IV.1 Grid

All products are interpolated onto the same polar stereographic output grid, although at different resolutions. HYCOM uses a staggered Arakawa C grid but all variables are defined at the center of the output grid cell after interpolation.
The same projection is used for all Arctic MFC grids on a spherical Earth, following this definition under the proj4 projection library: (Beware, this is not the WGS84 ellipsoid reference).
projection_stereo:proj4 = "+units=m +proj=stere +a=6378273.0 +b=6378273.0 +lon_0=-45.0 +lat_0=90.0 +lat_ts=90.0 +ellps=sphere" ;
This polar stereographic projection also defines the reference direction of vectors (current and sea ice velocity), which should therefore be rotated if the data is reprojected to a Lat-Long or any other grid.
In ArcGIS and QGIS softwares, the x- and y- coordinates units should be converted from 100 km to meters.

A simple code (in Matlab) is provided below that can easily be ported to any programming language:

```
nx=size(lon,1);
ny=size(lon,2);
radian=pi/180.;
dlon_ip1=(lon(2:nx,:)-lon(1:nx-1,:)).*cos( radian*.5*(lat(2:nx,:)+lat(1:nx-1,:)) );
dlat_ip1=lat(2:nx,:)-lat(1:nx-1,:);
dlon_ip1(nx,:)=dlon_ip1(nx-1,:);
dlat_ip1(nx,:)=dlat_ip1(nx-1,:);
theta_ip1=atan2(dlat_ip1,dlon_ip1); % Angle displacement with constant latitude
lines
theta_jp1=theta_ip1+90*radian;
%%rotated Easterly and Northerly components
```

```
tmpu=u.*cos(theta_ip1) + v.*cos(theta_jp1);
tmpv=u.*sin(theta_ip1) + v.*sin(theta_jp1);
```

IV.2 Domain coverage

The products
ARCTIC_MULTIYEAR_PHY_002_003 (40 vertical output levels)
are released on a regular polar-stereographic grid, with a horizontal grid step of 12.5 km (see Figure 3). The ARC-MFC area of responsibility, north of 65° N, is well included into the output domain. The ARCTIC_MULTIYEAR_BGC_002_005 product has twice coarser horizontal resolution (25 km) but otherwise the same vertical resolution.
ARCTIC_ANALYSISFORECAST_PHY_002_001, (40 vertical output levels)
and ANALYSISFORECAST_BGC_002_004 have twice the horizontal resolution (6.25km).
ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 and
ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015
are released on a regular polar-stereographic grid, with a horizontal grid step of 3 km (see Figures 4 and 5)

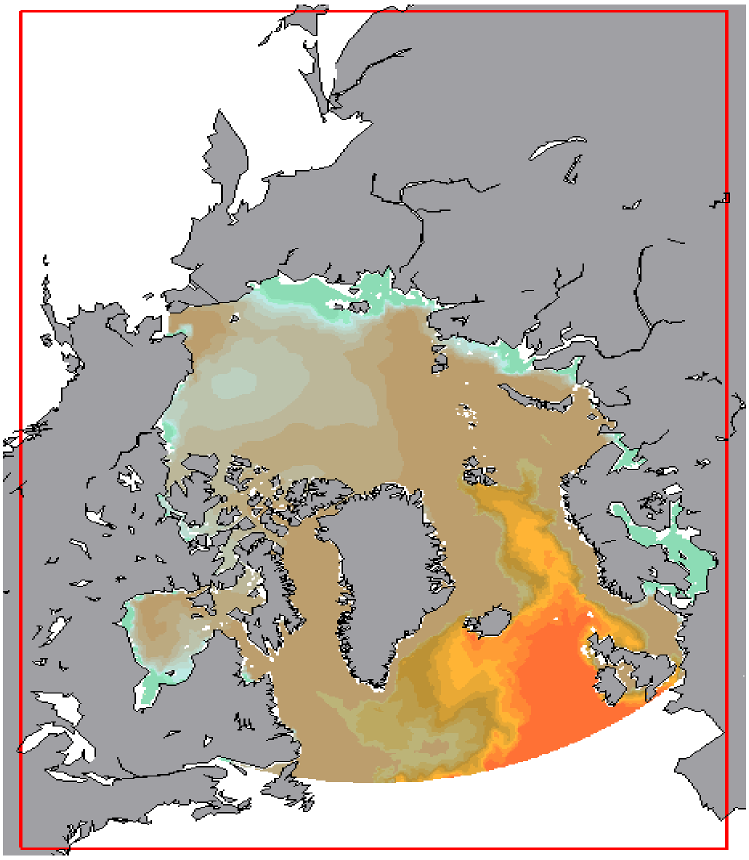

Figure 3: Spatial coverage of the Arctic MULTIYEAR_PHY TOPAZ4b product, masked below 50N

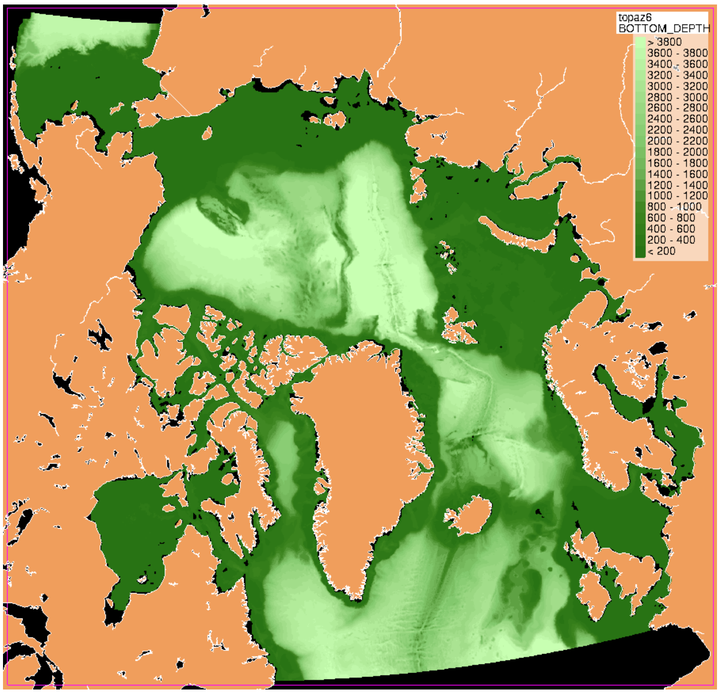

Figure 4: Spatial coverage of the other ARC-MFC products, note the inclusion of the Bering Sea.

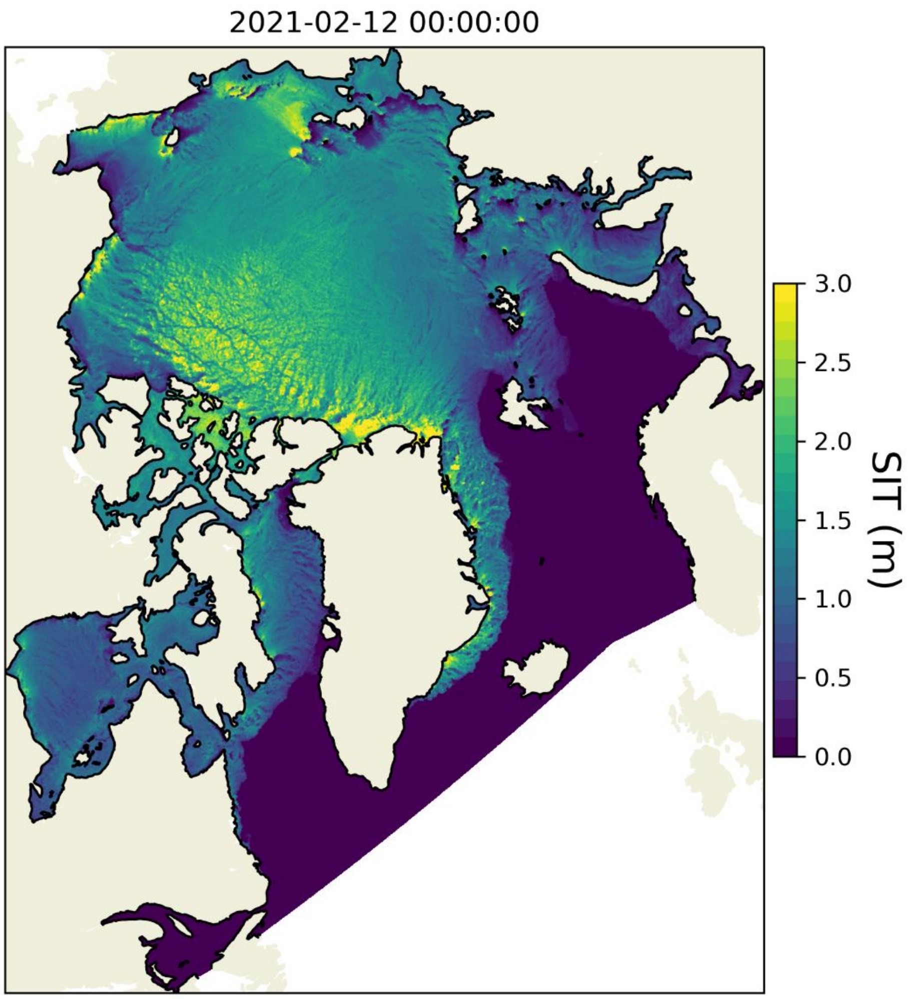

Figure 5: Sea Ice thickness chart showing the spatial coverage of the ARC-MFC ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 product, note the inclusion of Baffin Bay, the Canadian Archipelago and Hudson Bay.

IV.3 Vertical Levels

All ARCTIC ocean products – except the sea ice product - are computed on a hybrid vertical coordinate. This is a combination of isopycnal (constant density levels) in the open, stratified ocean, terrain-following coordinates in shallow coastal areas and z-levels in the mixed layer or unstratified deep ocean. See figure below (http://www.hycom.org/hycom/overview).

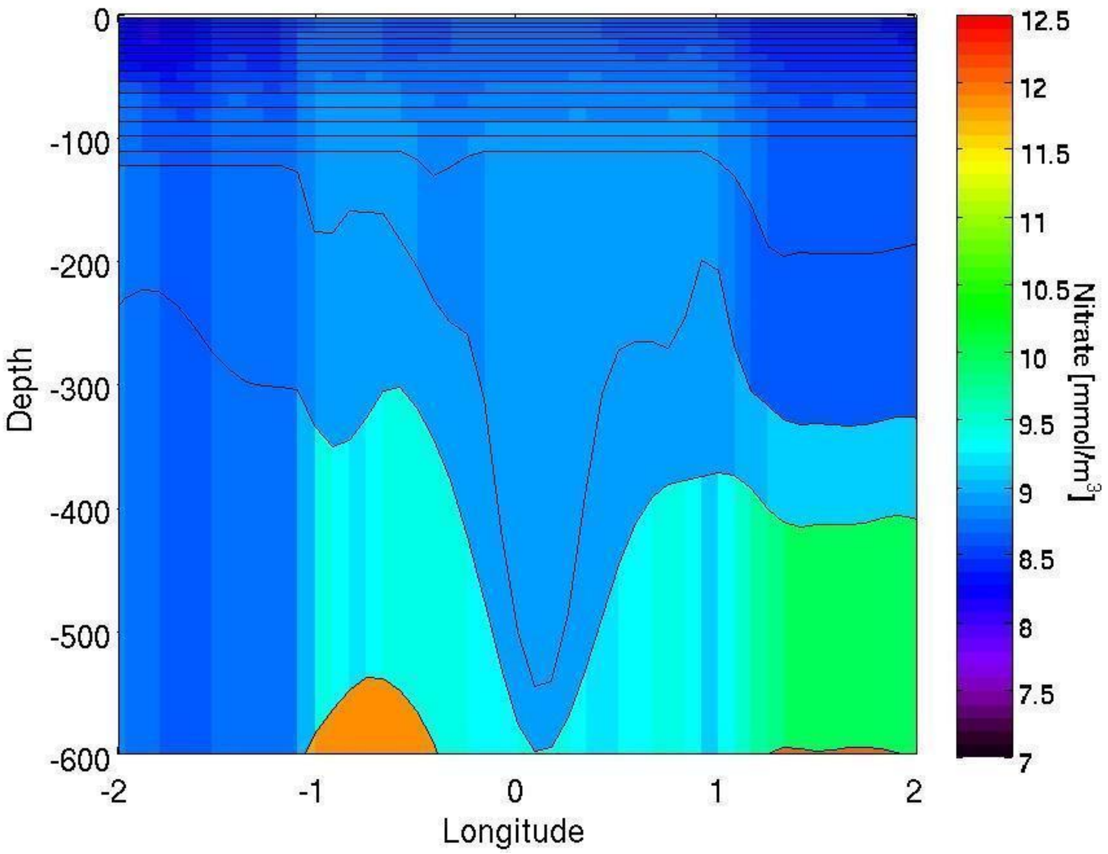

Figure 6 Vertical section of nitrates and vertical levels. Shading indicates concentrations, thin lines indicate layer interfaces. The coordinates revert from isopycnal to z-levels in the mixed layer.

The PHY product ANALYSISFORECAST-PHY-002-001 (daily dataset) and MULTIYEAR-PHY-002-003 products are interpolated to 40 unevenly spaced vertical levels: .(0, 2, 4, 6, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2500, 3000, 3500, 4000 meters)
The BGC products ANALYSISFORECAST_BGC_002_004, and MULTIYEAR_ BGC monthly datasets are interpolated to 40 levels: 0, 2, 3, 4, 5, 6, 8, 10, 11, 13, 16, 18, 22, 25, 29, 34, 40, 47, 56, 66, 78, 92, 110, 131, 156, 186, 222, 266, 318, 380, 454, 541, 644, 763, 902, 1062, 2000, 3000, 3500, 4000 m.
The vertical interpolation method from hybrid layers to fixed levels is a cubic spline honouring the following constraints:

- Conservation of the mean value in each layer
- Continuity and derivability of the value at each layer interface
- Vertical derivatives at the uppermost and lowermost model layers.

The model isopycnic layers can become thin at the bottom of the water column (called *outcropping* of the layers) and are removed from the interpolation, resulting in a few bottom grid cells being masked intermittently as land cells. If this issue turns out problematic, for example for downscaling, a turnaround is to apply the masked values constantly to the pixels where the flickering occurs. We will provide a definitive fix to this issue in a future upgrade of the system.
The bottom temperature is interpolated vertically at 10 meters above the seabed. As a result, it will appear discontinuous at the transition between two isopycnic layers.

IV.4 Update Time

ARCTIC_ANALYSISFORECAST_PHY_002_001 products:
The weekly 7-day hindcast (best estimate) is updated on Mondays and is available by 1400 UTC. The daily 10-day forecast is updated in the evening and is available by 0030 UTC the following day. The weekly analysis is not distributed.
ARCTIC_ANALYSISFORECAST_BGC_002_004 products: The forecast fields are updated daily. There is no corresponding 7-day hindcast for this product.
ARCTIC_MULTIYEAR_PHY_002_003 is updated twice a year (interim and final update).
ARCTIC_MULTIYEAR_BGC_002_005 products: The reanalysis is updated once a year.
ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: a 10-day forecast is updated in the evening and is available by 0030 UTC the following day
ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 a 9-day forecast is available the following day at 9:30 UTC

IV.5 Temporal extent of analysis and forecast stored on delivery mechanism

ARCTIC_ANALYSISFORECAST_PHY_002_001 and
ARCTIC_ANALYSISFORECAST_BGC_002_004 products temporal coverage:
For the daily forecast, the temporal extent is 10 days starting on the bulletin date, except Thursdays when the extent is 13 days starting three days prior to the bulletin date. For the weekly 7-day hindcast provided on Mondays, the temporal extent is 7 days starting on the previous Monday.
The bulletin date is the date at which the production run is scheduled. In the case of the weekly 7-day hindcast, it corresponds to the day after the end of the time period of the data. In the case of the daily forecast, it corresponds to the start of the time period of the data, except for Thursdays where the data start three days earlier than the bulletin date.
The data older than 2 years are automatically removed from the server. There is currently no data assimilation in the biogeochemical model, so the past archive of bio-variables consists of forecast fields. All daily 10-day forecasts are maintained on the dissemination facilities for three months, after which only one forecast per week is retained. All weekly 7-day hindcasts are maintained. Thus, there is always a continuous time series of previous 7-day hindcasts and

the latest forecast available; this is the Best Estimate dataset provided via OPeNDAP/SUBSETTER.
ARCTIC_MULTIYEAR_PHY_002_003 products temporal coverage: from January 1991 until December in Year-minus-1 included.
ARCTIC_MULTIYEAR_BGC_002_005 products temporal coverage: 2007- Year-minus-2 included

IV.6 Other information: mean centre of Products, land mask value, missing value

ARCTIC_ANALYSISFORECAST_PHY_002_001 and ARCTIC_ANALYSISFORECAST_BGC_002_004 products: forecast and the analysis are 24hr mean fields centered at 12:00 UTC.
All files are using the NetCDF4 format without offset nor scale factors.
The monthly values are centered at the middle of the month.

V FILE FORMAT

V.1 NetCDF

The products are stored using the NetCDF format.
To know more about the NetCDF format, please follow this link: [What is the format of Copernicus Marine products ? NetCDF]

V.2 Structure and semantic of netCDF maps files

V.2.1 Output from ARCTIC_ANALYSISFORECAST_PHY_002_001

Sample file:

```
netcdf \20230523_dm-metno-MODEL-topaz5-ARC-b20230514-fv02.0 {
dimensions:
	x = 1185 ;
	y = 1137 ;
	depth = 40 ;
	time = UNLIMITED ; // (1 currently)
variables:
	int stereographic ;
		stereographic:grid_mapping_name = "polar_stereographic" ;
		stereographic:latitude_of_projection_origin = 90. ;
		stereographic:longitude_of_projection_origin = -45. ;
		stereographic:scale_factor_at_projection_origin = 1. ;
		stereographic:straight_vertical_longitude_from_pole = -45. ;
		stereographic:earth_radius = 6378273. ;
		stereographic:proj4 = "+proj=stere +lon_0=-45 +lat_0=90 +k=1 +R=6378273 
+no_defs" ;
		stereographic:false_easting = 0. ;
		stereographic:false_northing = 0. ;
	double time(time) ;
		time:units = "seconds since 1970-1-1T00:00:00Z" ;
		time:long_name = "forecast time" ;
	float x(x) ;
		x:axis = "X" ;
		x:standard_name = "projection_x_coordinate" ;
		x:units = "100  km" ;
	float longitude(y, x) ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
	float y(y) ;
		y:standard_name = "projection_y_coordinate" ;
```

```
        y:axis = "Y" ;
        y:units = "100  km" ;
float latitude(y, x) ;
        latitude:standard_name = "latitude" ;
        latitude:units = "degrees_north" ;
float depth(depth) ;
        depth:long_name = "depth" ;
        depth:units = "m" ;
        depth:standard_name = "depth" ;
        depth:positive = "down" ;
        depth:axis = "Z" ;
float model_depth(y, x) ;
        model_depth:_FillValue = -1.e+14f ;
        model_depth:missing_value = -1.e+14f ;
        model_depth:units = "meter" ;
        model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
        model_depth:grid_mapping = "stereographic" ;
        model_depth:coordinates = "longitude latitude" ;
        model_depth:cell_methods = "area: mean" ;
float so(time, depth, y, x) ;
        so:_FillValue = -1.e+14f ;
        so:missing_value = -1.e+14f ;
        so:units = "1e-3" ;
        so:standard_name = "sea_water_salinity" ;
        so:grid_mapping = "stereographic" ;
        so:coordinates = "longitude latitude" ;
        so:cell_methods = "area: mean" ;
float thetao(time, depth, y, x) ;
        thetao:_FillValue = -1.e+14f ;
        thetao:missing_value = -1.e+14f ;
        thetao:units = "degrees_C" ;
        thetao:standard_name = "sea_water_potential_temperature" ;
        thetao:grid_mapping = "stereographic" ;
        thetao:coordinates = "longitude latitude" ;
        thetao:cell_methods = "area: mean" ;
float vxo(time, depth, y, x) ;
        vxo:_FillValue = -1.e+14f ;
        vxo:missing_value = -1.e+14f ;
        vxo:units = "m s-1" ;
        vxo:standard_name = "sea_water_x_velocity" ;
        vxo:grid_mapping = "stereographic" ;
        vxo:coordinates = "longitude latitude" ;
        vxo:cell_methods = "area: mean" ;
float vyo(time, depth, y, x) ;
        vyo:_FillValue = -1.e+14f ;
```

```
		vyo:missing_value = -1.e+14f ;
		vyo:units = "m s-1" ;
		vyo:standard_name = "sea_water_y_velocity" ;
		vyo:grid_mapping = "stereographic" ;
		vyo:coordinates = "longitude latitude" ;
		vyo:cell_methods = "area: mean" ;
	float wo(time, depth, y, x) ;
		wo:_FillValue = -1.e+14f ;
		wo:missing_value = -1.e+14f ;
		wo:units = "m s-1" ;
		wo:standard_name = "upward_sea_water_velocity" ;
		wo:grid_mapping = "stereographic" ;
		wo:coordinates = "longitude latitude" ;
		wo:cell_methods = "area: mean" ;
	float bottomT(time, y, x) ;
		bottomT:_FillValue = -1.e+14f ;
		bottomT:missing_value = -1.e+14f ;
		bottomT:units = "degrees_C" ;
		bottomT:standard_name = "sea_water_potential_temperature_at_sea_floor" ;
		bottomT:long_name = "Sea floor potential temperature" ;
		bottomT:grid_mapping = "stereographic" ;
		bottomT:coordinates = "longitude latitude" ;
		bottomT:cell_methods = "area: mean" ;
	float stfbaro(time, y, x) ;
		stfbaro:_FillValue = -1.e+14f ;
		stfbaro:missing_value = -1.e+14f ;
		stfbaro:units = "m3 s-1" ;
		stfbaro:standard_name = "ocean_barotropic_streamfunction" ;
		stfbaro:grid_mapping = "stereographic" ;
		stfbaro:coordinates = "longitude latitude" ;
		stfbaro:cell_methods = "area: mean" ;
	float mlotst(time, y, x) ;
		mlotst:_FillValue = -1.e+14f ;
		mlotst:missing_value = -1.e+14f ;
		mlotst:units = "m" ;
		mlotst:standard_name =
"ocean_mixed_layer_thickness_defined_by_sigma_theta" ;
		mlotst:grid_mapping = "stereographic" ;
		mlotst:coordinates = "longitude latitude" ;
		mlotst:cell_methods = "area: mean" ;
	float zos(time, y, x) ;
		zos:_FillValue = -1.e+14f ;
		zos:missing_value = -1.e+14f ;
		zos:units = "m" ;
		zos:standard_name = "sea_surface_height_above_geoid" ;
```

```
		zos:grid_mapping = "stereographic" ;
		zos:coordinates = "longitude latitude" ;
		zos:cell_methods = "area: mean" ;
	float sithick(time, y, x) ;
		sithick:_FillValue = -1.e+14f ;
		sithick:missing_value = -1.e+14f ;
		sithick:units = "m" ;
		sithick:standard_name = "sea_ice_thickness" ;
		sithick:grid_mapping = "stereographic" ;
		sithick:coordinates = "longitude latitude" ;
		sithick:cell_methods = "area: mean where sea_ice" ;
	float siconc(time, y, x) ;
		siconc:_FillValue = -1.e+14f ;
		siconc:missing_value = -1.e+14f ;
		siconc:units = "1" ;
		siconc:standard_name = "sea_ice_area_fraction" ;
		siconc:grid_mapping = "stereographic" ;
		siconc:coordinates = "longitude latitude" ;
		siconc:cell_methods = "area: mean" ;
	float vxsi(time, y, x) ;
		vxsi:_FillValue = -1.e+14f ;
		vxsi:missing_value = -1.e+14f ;
		vxsi:units = "m s-1" ;
		vxsi:standard_name = "sea_ice_x_velocity" ;
		vxsi:grid_mapping = "stereographic" ;
		vxsi:coordinates = "longitude latitude" ;
		vxsi:cell_methods = "area: mean where sea_ice" ;
	float vysi(time, y, x) ;
		vysi:_FillValue = -1.e+14f ;
		vysi:missing_value = -1.e+14f ;
		vysi:units = "m s-1" ;
		vysi:standard_name = "sea_ice_y_velocity" ;
		vysi:grid_mapping = "stereographic" ;
		vysi:coordinates = "longitude latitude" ;
		vysi:cell_methods = "area: mean where sea_ice" ;
	float sisnthick(time, y, x) ;
		sisnthick:_FillValue = -1.e+14f ;
		sisnthick:missing_value = -1.e+14f ;
		sisnthick:units = "m" ;
		sisnthick:standard_name = "surface_snow_thickness" ;
		sisnthick:grid_mapping = "stereographic" ;
		sisnthick:coordinates = "longitude latitude" ;
		sisnthick:cell_methods = "area: mean where sea_ice" ;
	float siage(time, y, x) ;
		siage:_FillValue = -1.e+14f ;
```

```
			siage:missing_value = -1.e+14f ;
			siage:units = "day" ;
			siage:standard_name = "age_of_sea_ice" ;
			siage:grid_mapping = "stereographic" ;
			siage:coordinates = "longitude latitude" ;
			siage:cell_methods = "area: mean" ;
		float siconc_fy(time, y, x) ;
			siconc_fy:_FillValue = -1.e+14f ;
			siconc_fy:missing_value = -1.e+14f ;
			siconc_fy:units = "1" ;
			siconc_fy:standard_name = "sea_ice_classification" ;
			siconc_fy:long_name = "sea ice area fraction of first year ice" ;
			siconc_fy:grid_mapping = "stereographic" ;
			siconc_fy:coordinates = "longitude latitude" ;
			siconc_fy:cell_methods = "area: mean" ;
		float sialb(time, y, x) ;
			sialb:_FillValue = -1.e+14f ;
			sialb:missing_value = -1.e+14f ;
			sialb:units = "1" ;
			sialb:standard_name = "sea_ice_albedo" ;
			sialb:grid_mapping = "stereographic" ;
			sialb:coordinates = "longitude latitude" ;
			sialb:cell_methods = "area: mean" ;

// global attributes:
:title = "Arctic Ocean Physics Reanalysis" ;
:institution = "Met Norway, Henrik Mohns plass 1, 0313 Oslo,  Norway" ;
:references = "https://marine.copernicus.eu/" ;
:source = "NERSC-HYCOM model fields" ;
:contact = "<servicedesk.cmems@mercator-ocean.eu>" ;
:credit = "E.U. Copernicus Marine Service Information (CMEMS)" ;
:conventions = "CF-1.4" ;
:field_date = "2023-05-29T12:00:00Z" ;
:bulletin_date = "2023-05-29T12:00:00Z" ;
}
```

V.2.2 Output from ARCTIC_ANALYSISFORECAST_BGC_002_004

Sample file: netcdf \20210120_dm-metno-MODEL-topaz5_ecosmo-ARC-b20210111-fv02.0 {

```
dimensions:
   x = 1185 ;
   y = 1137 ;
   depth = 40 ;
   time = UNLIMITED ; // (1 currently)
variables:
```

```
    int stereographic ;
            stereographic:grid_mapping_name = "polar_stereographic" ;
            stereographic:latitude_of_projection_origin = 90. ;
            stereographic:longitude_of_projection_origin = -45. ;
            stereographic:scale_factor_at_projection_origin = 1. ;
            stereographic:straight_vertical_longitude_from_pole = -45. ;
            stereographic:earth_radius = 6378273. ;
            stereographic:proj4 = "+proj=stere +lon_0=-45 +lat_0=90 +k=1 +R=6378273
+no_defs" ;
            stereographic:false_easting = 0. ;
            stereographic:false_northing = 0. ;
    double time(time) ;
            time:units = "seconds since 1970-1-1T00:00:00Z" ;
            time:long_name = "forecast time" ;
    float x(x) ;
            x:axis = "X" ;
            x:standard_name = "projection_x_coordinate" ;
            x:units = "100  km" ;
    float longitude(y, x) ;
            longitude:standard_name = "longitude" ;
            longitude:units = "degrees_east" ;
    float y(y) ;
            y:standard_name = "projection_y_coordinate" ;
            y:axis = "Y" ;
            y:units = "100  km" ;
    float latitude(y, x) ;
            latitude:standard_name = "latitude" ;
            latitude:units = "degrees_north" ;
    float depth(depth) ;
            depth:long_name = "depth" ;
            depth:units = "m" ;
            depth:standard_name = "depth" ;
            depth:positive = "down" ;
            depth:axis = "Z" ;
    float model_depth(y, x) ;
            model_depth:_FillValue = -1.e+14f ;
            model_depth:missing_value = -1.e+14f ;
            model_depth:units = "meter" ;
            model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
            model_depth:grid_mapping = "stereographic" ;
            model_depth:coordinates = "longitude latitude" ;
            model_depth:cell_methods = "area: mean" ;
    float nppv(time, depth, y, x) ;
            nppv:_FillValue = -1.e+14f ;
            nppv:missing_value = -1.e+14f ;
```

```
		nppv:units = "mg m-3 day-1" ;
		nppv:standard_name = 
"net_primary_production_of_biomass_expressed_as_carbon_per_unit_volume_in_sea_water" ;
		nppv:grid_mapping = "stereographic" ;
		nppv:coordinates = "longitude latitude" ;
		nppv:cell_methods = "area: mean" ;
	float chl(time, depth, y, x) ;
		chl:_FillValue = -1.e+14f ;
		chl:missing_value = -1.e+14f ;
		chl:units = "mg m-3" ;
		chl:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water" ;
		chl:grid_mapping = "stereographic" ;
		chl:coordinates = "longitude latitude" ;
		chl:cell_methods = "area: mean" ;
	float kd(time, depth, y, x) ;
		kd:_FillValue = -1.e+14f ;
		kd:missing_value = -1.e+14f ;
		kd:units = "m-1" ;
		kd:standard_name = 
"volume_attenuation_coefficient_of_downwelling_radiative_flux_in_sea_water" ;
		kd:grid_mapping = "stereographic" ;
		kd:coordinates = "longitude latitude" ;
		kd:cell_methods = "area: mean" ;
	float no3(time, depth, y, x) ;
		no3:_FillValue = -1.e+14f ;
		no3:missing_value = -1.e+14f ;
		no3:units = "mmol m-3" ;
		no3:standard_name = "mole_concentration_of_nitrate_in_sea_water" ;
		no3:grid_mapping = "stereographic" ;
		no3:coordinates = "longitude latitude" ;
		no3:cell_methods = "area: mean" ;
	float po4(time, depth, y, x) ;
		po4:_FillValue = -1.e+14f ;
		po4:missing_value = -1.e+14f ;
		po4:units = "mmol m-3" ;
		po4:standard_name = "mole_concentration_of_phosphate_in_sea_water" ;
		po4:grid_mapping = "stereographic" ;
		po4:coordinates = "longitude latitude" ;
		po4:cell_methods = "area: mean" ;
	float phyc(time, depth, y, x) ;
		phyc:_FillValue = -1.e+14f ;
		phyc:missing_value = -1.e+14f ;
		phyc:units = "mmol m-3" ;
		phyc:standard_name = 
"mole_concentration_of_phytoplankton_expressed_as_carbon_in_sea_water" ;
```

```
		phyc:grid_mapping = "stereographic" ;
		phyc:coordinates = "longitude latitude" ;
		phyc:cell_methods = "area: mean" ;
	float zooc(time, depth, y, x) ;
		zooc:_FillValue = -1.e+14f ;
		zooc:missing_value = -1.e+14f ;
		zooc:units = "mmol m-3" ;
		zooc:standard_name =
"mole_concentration_of_zooplankton_expressed_as_carbon_in_sea_water" ;
		zooc:grid_mapping = "stereographic" ;
		zooc:coordinates = "longitude latitude" ;
		zooc:cell_methods = "area: mean" ;
	float o2(time, depth, y, x) ;
		o2:_FillValue = -1.e+14f ;
		o2:missing_value = -1.e+14f ;
		o2:units = "mmol m-3" ;
		o2:standard_name =
"mole_concentration_of_dissolved_molecular_oxygen_in_sea_water" ;
		o2:grid_mapping = "stereographic" ;
		o2:coordinates = "longitude latitude" ;
		o2:cell_methods = "area: mean" ;
	float si(time, depth, y, x) ;
		si:_FillValue = -1.e+14f ;
		si:missing_value = -1.e+14f ;
		si:units = "mmol m-3" ;
		si:standard_name = "mole_concentration_of_silicate_in_sea_water" ;
		si:grid_mapping = "stereographic" ;
		si:coordinates = "longitude latitude" ;
		si:cell_methods = "area: mean" ;
	float expc(time, depth, y, x) ;
		expc:_FillValue = -1.e+14f ;
		expc:missing_value = -1.e+14f ;
		expc:units = "mol m-2 d-1" ;
		expc:standard_name =
"sinking_mole_flux_of_particulate_organic_matter_expressed_as_carbon_in_sea_water" ;
		expc:grid_mapping = "stereographic" ;
		expc:coordinates = "longitude latitude" ;
		expc:cell_methods = "area: mean" ;
	float ph(time, depth, y, x) ;
		ph:_FillValue = -1.e+14f ;
		ph:missing_value = -1.e+14f ;
		ph:units = "1" ;
		ph:standard_name = "sea_water_ph_reported_on_total_scale" ;
		ph:grid_mapping = "stereographic" ;
		ph:coordinates = "longitude latitude" ;
```

```
		ph:cell_methods = "area: mean" ;
	float dissic(time, depth, y, x) ;
		dissic:_FillValue = -1.e+14f ;
		dissic:missing_value = -1.e+14f ;
		dissic:units = "mole m-3" ;
		dissic:standard_name =
"mole_concentration_of_dissolved_inorganic_carbon_in_sea_water" ;
		dissic:grid_mapping = "stereographic" ;
		dissic:coordinates = "longitude latitude" ;
		dissic:cell_methods = "area: mean" ;
	float spco2(time, depth, y, x) ;
		spco2:_FillValue = -1.e+14f ;
		spco2:missing_value = -1.e+14f ;
		spco2:units = "Pa" ;
		spco2:standard_name = "surface_partial_pressure_of_carbon_dioxide_in_sea_water" ;
		spco2:grid_mapping = "stereographic" ;
		spco2:coordinates = "longitude latitude" ;
		spco2:cell_methods = "area: mean" ;

// global attributes:
		;
		 :institution = "Met Norway, Henrik Mohns plass 1, 0313 Oslo,  Norway" ;

		:source = "NERSC-HYCOM model fields" ;

		  :references = "https://marine.copernicus.eu/" ;
		:
		:conventions = "CF-1.4" ;
		 :contact = "<servicedesk.cmems@mercator-ocean.eu>" ;
		 :credit = "E.U. Copernicus Marine Service Information (CMEMS)" ;
		:field_date = "2021-01-20T12:00:00Z" ;
		:bulletin_date = "2021-01-11" ;
		:title = "Arctic Ocean Biogeochemistry Analysis and Forecast, 6.25 km daily mean" ;
		:bulletin_type = "Forecast" ;
		:Forecast_range = "10 days" ;
}
```

V.2.3 Output from ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

Sample file:

```
netcdf netcdf \20220201_hr-nersc-MODEL-nextsimf-ARC-b20220201-fv00.0 {
dimensions:
	time = UNLIMITED ; // (24 currently)
	x = 2467 ;
	y = 2367 ;
	nv = 2 ;
```

```
variables:
        inbyte stereographic ;
                stereographic:grid_mapping_name = "polar_stereographic" ;
                stereographic:latitude_of_projection_origin = 90. ;
                stereographic:longitude_of_projection_origin = -45. ;
                stereographic:scale_factor_at_projection_origin = 1. ;
                stereographic:straight_vertical_longitude_from_pole = -45. ;
                stereographic: semi_major_axis = 6378273. ;
                stereographic: semi_minor_axis = 6378273. ;
                stereographic:proj4 = "+proj=stere +lat_0=90 +lat_ts=90 +lon_0=-45 +x_0=0
+y_0=0 +R=6378273 +ellps=sphere +units=m +no_defs" ;
                stereographic:false_easting = 0. ;
                stereographic:false_northing = 0. ;
        double x(x) ;
                x:standard_name = "projection_x_coordinate" ;
                x:units = "m" ;
                x:axis = "X" ;
        double y(y) ;
                y:standard_name = "projection_y_coordinate" ;
                y:units = "m" ;
                y:axis = "Y" ;
        double longitude(y, x) ;
                longitude:standard_name = "longitude" ;
                longitude:long_name = "longitude" ;
                longitude:units = "degrees_east" ;
        double latitude(y, x) ;
                latitude:standard_name = "latitude" ;
                latitude:long_name = "latitude" ;
                latitude:units = "degrees_north" ;
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "simulation time" ;
                time:units = "days since 1900-01-01 00:00:00" ;
                time:calendar = "standard" ;
                time:axis = "T" ;
                time:bounds = "time_bnds" ;
        double time_bnds(time,nv) ;
                time_bnds: units = "days since 1900-01-01 00:00:00" ;
        double siconc(y,x) ;
                siconc:standard_name = "sea_ice_area_fraction" ;
                siconc:long_name = "Sea Ice Concentration" ;
                siconc:units = "1" ;
                siconc:_FillValue = "-100000000376832." ;
                siconc:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
                siconc:grid_mapping = "stereographic" ;
```

```
double sithick(time, y, x) ;
        sithick:_FillValue = -100000000376832. ;
        sithick:standard_name = "sea_ice_thickness" ;
        sithick:long_name = "Sea Ice Thickness" ;
        sithick:units = "m" ;
        sithick:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
        sithick:grid_mapping = "stereographic" ;
double sisnthick(time, y, x) ;
        sisnthick:_FillValue = -100000000376832. ;
        sisnthick:standard_name = "surface_snow_thickness" ;
        sisnthick:long_name = "Surface Snow Thickness" ;
        sisnthick:units = "m" ;
        sisnthick:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
        sisnthick:grid_mapping = "stereographic" ;
double vxsi(time, y, x) ;
        vxsi:_FillValue = -100000000376832. ;
        vxsi:standard_name = "sea_ice_x_velocity" ;
        vxsi:long_name = "Sea Ice X Velocity" ;
        vxsi:units = "m s-1" ;
        vxsi:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
        vxsi:grid_mapping = "stereographic" ;
double vysi(time, y, x) ;
        vysi:_FillValue = -100000000376832. ;
        vysi:standard_name = "sea_ice_y_velocity" ;
        vysi:long_name = "Sea Ice Y Velocity" ;
        vysi:units = "m s-1" ;
        vysi:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
        vysi:grid_mapping = "stereographic" ;
double sialb(time, y, x) ;
        sialb:_FillValue = -100000000376832. ;
        sialb:standard_name = "sea_ice_albedo" ;
        sialb:long_name = "Sea Ice Albedo" ;
        sialb:units = "1" ;
        sialb:cell_methods = "time: mean (interval: 1 hours) area: mean where sea_ice" ;
        sialb:grid_mapping = "stereographic" ;
double si_ridge_ratio(time, y, x) ;
        si_ridge_ratio:_FillValue = -100000000376832. ;
        si_ridge_ratio:standard_name = "sea_ice_volume_fraction_of_ridged_ice" ;
        si_ridge_ratio:long_name = "Sea Ice Volume Fraction of Ridged Ice" ;
        si_ridge_ratio:units = "1" ;
        si_ridge_ratio:cell_methods = "time: mean (interval: 1 hours) area: mean where
sea_ice" ;
        si_ridge_ratio:grid_mapping = "stereographic" ;
double siage(time, y, x) ;
        siage:_FillValue = -100000000376832. ;
```

```
		siage:standard_name = "age_of_sea_ice" ;
		siage:long_name = "Age of Sea Ice" ;
		siage:units = "years" ;
		siage:cell_methods = "time: mean (interval: 1 hours) area: mean where sea_ice"
	;
		siage:grid_mapping = "stereographic" ;
	double siconc_my(time, y, x) ;
		siconc_my:_FillValue = -100000000376832. ;
		siconc_my:standard_name = "sea_ice_classification" ;
		siconc_my:long_name = "Sea Ice Area Fraction of Multi-year Ice" ;
		siconc_my:units = "1" ;
		siconc_my:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
		siconc_my:grid_mapping = "stereographic" ;
	double siconc_young(time, y, x) ;
		siconc_young:_FillValue = -100000000376832. ;
		siconc_young:standard_name = "sea_ice_classification" ;
		siconc_young:long_name = "Sea Ice Area Fraction of Young Ice" ;
		siconc_young:units = "1" ;
		siconc_young:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
		siconc_young:grid_mapping = "stereographic" ;



	// global attributes:
		:Conventions = "CF-1.6" ;
		:institution = "NERSC, Jahnebakken 3, N-5007 Bergen, Norway" ;
		:source = "neXtSIM model fields" ;
		:email = "nextsimf@nersc.no" ;
		:title = "neXtSIM-F sea ice forecast, 3 km hourly-averaged fields
	(cmems_mod_arc_phy_anfc_nextsim_hm)" ;
		:field_type = "Files based on file type moorings" ;
		:bulletin_type = "Forecast" ;
		:forecast_range = "9 days" ;
		:field_date = "2022-02-01" ;
		:bulletin_date = "2022-02-01" ;
}
```

V.2.4 Output from ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

Sample file: netcdf \20200401_qhr-metno-MODEL-topaz6-tide-ARC-b20200401-fv02.0 {

```
dimensions:
	time = UNLIMITED ; // (96 currently)
	x = 2467 ;
	y = 2367 ;
variables:
	double time(time) ;
```

```
            time:standard_name = "time" ;
            time:long_name = "forecast time" ;
            time:units = "seconds since 1970-1-1T00:00:00Z" ;
            time:calendar = "standard" ;
            time:axis = "T" ;
      float longitude(y, x) ;
            longitude:standard_name = "longitude" ;
            longitude:long_name = "longitude" ;
            longitude:units = "degrees_east" ;
            longitude:_CoordinateAxisType = "Lon" ;
      float latitude(y, x) ;
            latitude:standard_name = "latitude" ;
            latitude:long_name = "latitude" ;
            latitude:units = "degrees_north" ;
            latitude:_CoordinateAxisType = "Lat" ;
      float x(x) ;
            x:standard_name = "projection_x_coordinate" ;
            x:units = "100  km" ;
            x:axis = "X" ;
      float y(y) ;
            y:standard_name = "projection_y_coordinate" ;
            y:units = "100  km" ;
            y:axis = "Y" ;
      int stereographic ;
            stereographic:grid_mapping_name = "polar_stereographic" ;
            stereographic:latitude_of_projection_origin = 90. ;
            stereographic:longitude_of_projection_origin = -45. ;
            stereographic:scale_factor_at_projection_origin = 1. ;
            stereographic:straight_vertical_longitude_from_pole = -45. ;
            stereographic:earth_redius = 6378273. ;
            stereographic:proj4 = "+proj=stere +lon_0=-45 +lat_0=90 +k=1 +R=6378273
+no_defs" ;
            stereographic:false_easting = 0. ;
            stereographic:false_northing = 0. ;
      float model_depth(y, x) ;
            model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
            model_depth:units = "meter" ;
            model_depth:grid_mapping = "stereographic" ;
            model_depth:coordinates = "latitude longitude" ;
            model_depth:_FillValue = -1.e+14f ;
            model_depth:missing_value = -1.e+14f ;
            model_depth:cell_methods = "area: mean" ;
      float vxo(time, y, x) ;
            vxo:standard_name = "sea_water_x_velocity" ;
            vxo:units = "m s-1" ;
```

```
                vxo:grid_mapping = "stereographic" ;
                vxo:coordinates = "latitude longitude" ;
                vxo:_FillValue = -1.e+14f ;
                vxo:missing_value = -1.e+14f ;
                vxo:cell_methods = "area: mean" ;
        float vyo(time, y, x) ;
                vyo:standard_name = "sea_water_y_velocity" ;
                vyo:units = "m s-1" ;
                vyo:grid_mapping = "stereographic" ;
                vyo:coordinates = "latitude longitude" ;
                vyo:_FillValue = -1.e+14f ;
                vyo:missing_value = -1.e+14f ;
                vyo:cell_methods = "area: mean" ;
        float zos(time, y, x) ;
                zos:standard_name = "sea_surface_height_above_geoid" ;
                zos:units = "m" ;
                zos:grid_mapping = "stereographic" ;
                zos:coordinates = "latitude longitude" ;
                zos:_FillValue = -1.e+14f ;
                zos:missing_value = -1.e+14f ;
                zos:cell_methods = "area: mean" ;

// global attributes:
                :CDI = "Climate Data Interface version 1.9.2 (http://mpimet.mpg.de/cdi)" ;
                :history = "20200401:Created by program hyc2proj, version V0.3" ;
                :source = "NERSC-HYCOM model fields" ;
                :institution = "NERSC, Thormoehlens gate 47, N-5006 Bergen, Norway" ;
                :Conventions = "CF-1.4" ;
                :references = "http://topaz.nersc.no" ;
                :field_type = "Files based on file type archs" ;
                :field_date = "2020-04-01T00:00:00Z" ;
                :CDO = "Climate Data Operators version 1.9.2 (http://mpimet.mpg.de/cdo)" ;
                :bulletin_date = "2020-04-01" ;
                :title = "Arctic Ocean Physics Analysis and Forecast, 3 km quarter-hourly
instantaneous (dataset-topaz6-tide-arc-qhr-myoceanv2-be)" ;
                :bulletin_type = "Forecast" ;
                :Forecast_range = "10 days" ;
}
```

V.2.5 Output from ARCTIC_MULTIYEAR_PHY_002_003

Sample file: netcdf 20001201_dm-12km-NERSC-MODEL-TOPAZ4B-ARC-RAN.fv2.0.nc {

```
dimensions:
   time = UNLIMITED;   // (1 currently)
   depth = 40;
   x = 609;
```

```
 y = 881;
variables:
double time(time) ;
        time:long_name = "forecast time" ;
        time:units = "hour since 1950-1-1T00:00:00Z" ;
 float bottomT(time, y, x) ;
        bottomT:_FillValue = -1.e+12f ;
        bottomT:cell_methods = "area: mean" ;
        bottomT:coordinates = "longitude latitude" ;
        bottomT:grid_mapping = "stereographic" ;
        bottomT:long_name = "Sea floor potential temperature" ;
        bottomT:missing_value = -1.e+12f ;
        bottomT:standard_name = "sea_water_potential_temperature_at_sea_floor" ;
        bottomT:units = "degrees_C" ;
 float depth(depth) ;
        depth:long_name = "depth" ;
        depth:units = "m" ;
        depth:standard_name = "depth" ;
        depth:positive = "down" ;
        depth:axis = "Z" ;
 float latitude(y, x) ;
        latitude:standard_name = "latitude" ;
        latitude:units = "degrees_north" ;
 float longitude(y, x) ;
        longitude:standard_name = "longitude" ;
        longitude:units = "degrees_east" ;
 float mlotst(time, y, x) ;
        mlotst:_FillValue = -1.e+12f ;
        mlotst:cell_methods = "area: mean" ;
        mlotst:coordinates = "longitude latitude" ;
        mlotst:grid_mapping = "stereographic" ;
        mlotst:missing_value = -1.e+12f ;
        mlotst:standard_name = "ocean_mixed_layer_thickness_defined_by_sigma_theta" ;
        mlotst:units = "m" ;
  float model_depth(y, x) ;
        model_depth:_FillValue = -1.e+12f ;
        model_depth:cell_methods = "area: mean" ;
        model_depth:coordinates = "longitude latitude" ;
        model_depth:grid_mapping = "stereographic" ;
        model_depth:missing_value = -1.e+12f ;
        model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
        model_depth:units = "meter" ;
  float siconc(time, y, x) ;
        siconc:_FillValue = -1.e+12f ;
        siconc:cell_methods = "area: mean" ;
```

```
        siconc:coordinates = "longitude latitude" ;
        siconc:grid_mapping = "stereographic" ;
        siconc:missing_value = -1.e+12f ;
        siconc:standard_name = "sea_ice_area_fraction" ;
        siconc:units = "1" ;
 float sithick(time, y, x) ;
        sithick:_FillValue = -1.e+12f ;
        sithick:cell_methods = "area: mean where sea_ice" ;
        sithick:coordinates = "longitude latitude" ;
        sithick:grid_mapping = "stereographic" ;
        sithick:missing_value = -1.e+12f ;
        sithick:standard_name = "sea_ice_thickness" ;
        sithick:units = "m" ;
    float so(time, depth, y, x) ;
        so:_FillValue = -1.e+12f ;
        so:cell_methods = "area: mean" ;
        so:coordinates = "longitude latitude" ;
        so:grid_mapping = "stereographic" ;
        so:long_name = "Salinity" ;
        so:missing_value = -1.e+12f ;
        so:standard_name = "sea_water_salinity" ;
        so:units = "1e-3" ;
    int stereographic ;
        stereographic:grid_mapping_name = "polar_stereographic" ;
        stereographic:latitude_of_projection_origin = 90. ;
        stereographic:longitude_of_projection_origin = -45. ;
        stereographic:scale_factor_at_projection_origin = 1. ;
        stereographic:straight_vertical_longitude_from_pole = -45. ;
        stereographic:earth_radius = 6378273. ;
        stereographic:proj4 = "+proj=stere +lon_0=-45 +lat_0=90 +k=1 +R=6378273
+no_defs" ;
        stereographic:false_easting = 0. ;
        stereographic:false_northing = 0. ;

float stfbaro(time, y, x) ;
        stfbaro:_FillValue = -1.e+12f ;
        stfbaro:cell_methods = "area: mean" ;
        stfbaro:coordinates = "longitude latitude" ;
        stfbaro:grid_mapping = "stereographic" ;
        stfbaro:missing_value = -1.e+12f ;
        stfbaro:standard_name = "ocean_barotropic_streamfunction" ;
        stfbaro:units = "m3 s-1" ;
    float thetao(time, depth, y, x) ;
        thetao:_FillValue = -1.e+12f ;
        thetao:cell_methods = "area: mean" ;
```

```
        thetao:coordinates = "longitude latitude" ;
        thetao:grid_mapping = "stereographic" ;
        thetao:long_name = "Sea Temperature" ;
        thetao:missing_value = -1.e+12f ;
        thetao:standard_name = "sea_water_potential_temperature" ;
        thetao:units = "degrees_C" ;
    float vxo(time, depth, y, x) ;
        vxo:_FillValue = -1.e+12f ;
        vxo:cell_methods = "area: mean" ;
        vxo:coordinates = "longitude latitude" ;
        vxo:grid_mapping = "stereographic" ;
        vxo:missing_value = -1.e+12f ;
        vxo:standard_name = "sea_water_x_velocity" ;
        vxo:units = "m s-1" ;
 float vxsi(time, y, x) ;
        vxsi:_FillValue = -1.e+12f ;
        vxsi:cell_methods = "area: mean where sea_ice" ;
        vxsi:coordinates = "longitude latitude" ;
        vxsi:grid_mapping = "stereographic" ;
        vxsi:missing_value = -1.e+12f ;
        vxsi:standard_name = "sea_ice_x_velocity" ;
        vxsi:units = "m s-1" ;
    float vyo(time, depth, y, x) ;
        vyo:_FillValue = -1.e+12f ;
        vyo:cell_methods = "area: mean" ;
        vyo:coordinates = "longitude latitude" ;
        vyo:grid_mapping = "stereographic" ;
        vyo:missing_value = -1.e+12f ;
        vyo:standard_name = "sea_water_y_velocity" ;
        vyo:units = "m s-1" ;
    float vysi(time, y, x) ;
        vysi:_FillValue = -1.e+12f ;
        vysi:cell_methods = "area: mean where sea_ice" ;
        vysi:coordinates = "longitude latitude" ;
        vysi:grid_mapping = "stereographic" ;
        vysi:missing_value = -1.e+12f ;
        vysi:standard_name = "sea_ice_y_velocity" ;
        vysi:units = "m s-1" ;

float x(x) ;
        x:axis = "X" ;
        x:standard_name = "projection_x_coordinate" ;
        x:units = "100  km" ;
    float y(y) ;
        y:standard_name = "projection_y_coordinate" ;
```

```
            y:axis = "Y" ;
            y:units = "100  km" ;
        float zos(time, y, x) ;
            zos:_FillValue = -1.e+12f ;
            zos:cell_methods = "area: mean" ;
            zos:coordinates = "longitude latitude" ;
            zos:grid_mapping = "stereographic" ;
            zos:long_name = "Sea surface height" ;
            zos:missing_value = -1.e+12f ;
            zos:standard_name = "sea_surface_height_above_geoid" ;
            zos:units = "m" ;
 // global attributes:
:title = "Arctic Ocean Physics Reanalysis" ;
:creator_institution = "NERSC, Jahnebakken 3, N-5007 Bergen, Norway" ;
 :history = "20201202:Created by program hyc2proj, version V0.3";
 :source = "NERSC-HYCOM model fields";
 :references = "http://topaz.nersc.no";
 :field_type = "Files based on file type nersc_daily";
 :Conventions = "CF-1.4";
 :field_date = "2000-12-01";
 :version = "v4b";
 }
```

V.2.6 Output from ARCTIC_MULTIYEAR_BGC_002_005

Sample file: netcdf \20070101_dm-25km-NERSC-MODEL-ECOSMO-ARC-RAN-fv2.0{dimensions:

```
        time = UNLIMITED ; // (1 currently)
        x = 297 ;
        y = 285 ;
        depth = 1 ;
variables:
        double time(time) ;
                time:long_name = "forecast time" ;
                time:units = "hour since 1950-1-1T00:00:00Z" ;
        int stereographic ;
                stereographic:grid_mapping_name = "polar_stereographic" ;
                stereographic:latitude_of_projection_origin = 90. ;
                stereographic:longitude_of_projection_origin = -45. ;
                stereographic:scale_factor_at_projection_origin = 1. ;
                stereographic:straight_vertical_longitude_from_pole = -45. ;
                stereographic:earth_radius = 6378273. ;
                stereographic:proj4 = "+proj=stere +lon_0=-45 +lat_0=90 +k=1 +R=6378273
+no_defs" ;
                stereographic:false_easting = 0. ;
                stereographic:false_northing = 0. ;
        float x(x) ;
```

```
		x:axis = "X" ;
		x:standard_name = "projection_x_coordinate" ;
		x:units = "100  km" ;
	float longitude(y, x) ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
	float y(y) ;
		y:standard_name = "projection_y_coordinate" ;
		y:axis = "Y" ;
		y:units = "100  km" ;
	float latitude(y, x) ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
	float depth(depth) ;
		depth:long_name = "depth" ;
		depth:units = "m" ;
		depth:standard_name = "depth" ;
		depth:positive = "down" ;
		depth:axis = "Z" ;
	short model_depth(y, x) ;
		model_depth:_FillValue = -32767s ;
		model_depth:missing_value = -32767s ;
		model_depth:add_offset = 5000.5 ;
		model_depth:scale_factor = 0.152626438360346 ;
		model_depth:units = "meter" ;
		model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
		model_depth:grid_mapping = "stereographic" ;
		model_depth:coordinates = "longitude latitude" ;
		model_depth:cell_methods = "area: mean" ;
	short chl(time, depth, y, x) ;
		chl:_FillValue = -32767s ;
		chl:missing_value = -32767s ;
		chl:add_offset = 50. ;
		chl:scale_factor = 0.00152611177242621 ;
		chl:units = "mg m-3" ;
		chl:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water" ;
		chl:grid_mapping = "stereographic" ;
		chl:coordinates = "longitude latitude" ;
		chl:cell_methods = "area: mean" ;
	short phyc(time, depth, y, x) ;
		phyc:_FillValue = -32767s ;
		phyc:missing_value = -32767s ;
		phyc:add_offset = 50. ;
		phyc:scale_factor = 0.00152611177242621 ;
		phyc:units = "mmol m-3" ;
```

```
		phyc:standard_name = 
	"mole_concentration_of_phytoplankton_expressed_as_carbon_in_sea_water" ;
		phyc:grid_mapping = "stereographic" ;
		phyc:coordinates = "longitude latitude" ;
		phyc:cell_methods = "area: mean" ;
	short zooc(time, depth, y, x) ;
		zooc:_FillValue = -32767s ;
		zooc:missing_value = -32767s ;
		zooc:add_offset = 50. ;
		zooc:scale_factor = 0.00152611177242621 ;
		zooc:units = "mmol m-3" ;
		zooc:standard_name = 
	"mole_concentration_of_zooplankton_expressed_as_carbon_in_sea_water" ;
		zooc:grid_mapping = "stereographic" ;
		zooc:coordinates = "longitude latitude" ;
		zooc:cell_methods = "area: mean" ;
	float o2(time, depth, y, x) ;
		o2:_FillValue = -1.e+14f ;
		o2:missing_value = -1.e+14f ;
		o2:units = "mmol m-3" ;
		o2:standard_name = 
	"mole_concentration_of_dissolved_molecular_oxygen_in_sea_water" ;
		o2:grid_mapping = "stereographic" ;
		o2:coordinates = "longitude latitude" ;
		o2:cell_methods = "area: mean" ;
	short no3(time, depth, y, x) ;
		no3:_FillValue = -32767s ;
		no3:missing_value = -32767s ;
		no3:add_offset = 17.5 ;
		no3:scale_factor = 0.000534139120349174 ;
		no3:units = "mmol m-3" ;
		no3:standard_name = "mole_concentration_of_nitrate_in_sea_water" ;
		no3:grid_mapping = "stereographic" ;
		no3:coordinates = "longitude latitude" ;
		no3:cell_methods = "area: mean" ;
	short po4(time, depth, y, x) ;
		po4:_FillValue = -32767s ;
		po4:missing_value = -32767s ;
		po4:add_offset = 1. ;
		po4:scale_factor = 3.05222354485242e-05 ;
		po4:units = "mmol m-3" ;
		po4:standard_name = "mole_concentration_of_phosphate_in_sea_water" ;
		po4:grid_mapping = "stereographic" ;
		po4:coordinates = "longitude latitude" ;
		po4:cell_methods = "area: mean" ;
```

```
        short si(time, depth, y, x) ;
                si:_FillValue = -32767s ;
                si:missing_value = -32767s ;
                si:add_offset = 17.5 ;
                si:scale_factor = 0.000534139120349174 ;
                si:units = "mmol m-3" ;
                si:standard_name = "mole_concentration_of_silicate_in_sea_water" ;
                si:grid_mapping = "stereographic" ;
                si:coordinates = "longitude latitude" ;
                si:cell_methods = "area: mean" ;
        short kd(time, depth, y, x) ;
                kd:_FillValue = -32767s ;
                kd:missing_value = -32767s ;
                kd:add_offset = 0.25 ;
                kd:scale_factor = 7.63055886213106e-06 ;
                kd:units = "m-1" ;
                kd:standard_name =
"volume_attenuation_coefficient_of_downwelling_radiative_flux_in_sea_water" ;
                kd:grid_mapping = "stereographic" ;
                kd:coordinates = "longitude latitude" ;
                kd:cell_methods = "area: mean" ;
        short nppv(time, depth, y, x) ;
                nppv:_FillValue = -32767s ;
                nppv:missing_value = -32767s ;
                nppv:add_offset = 100. ;
                nppv:scale_factor = 0.00305222354485243 ;
                nppv:units = "mg m-3 day-1" ;
                nppv:standard_name =
"net_primary_production_of_biomass_expressed_as_carbon_per_unit_volume_in_sea_water" ;
                nppv:grid_mapping = "stereographic" ;
                nppv:coordinates = "longitude latitude" ;
                nppv:cell_methods = "area: mean" ;

// global attributes:
                :title = "Arctic Ocean Biogeochemistry Reanalysis, 25km surface daily mean" ;
                :institution = "NERSC, Jahnebakken 3, 5006 Bergen, Norway" ;
                :source = "NERSC-HYCOM model fields" ;
                :references = "http://topaz.nersc.no" ;
                :field_type = "Files based on file type nersc_daily" ;
                :Conventions = "CF-1.4" ;
                :field_date = "2007-01-01" ;
                :NCO = "netCDF Operators version 4.7.9 (Homepage = http://nco.sf.net, Code =
http://github.com/nco/nco)" ;
                :history = "Created by program hyc2proj, version V0.3" ;
}
```

II. VI REFERENCE

I.1. VI.1 QUID

https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-ARC-QUID-002-001a.pdf
https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-ARC-QUID-002-004.pdf
https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-ARC-QUID-002-011.pdf
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https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-ARC-QUID-002-005.pdf