PRODUCT USER MANUAL

For Arctic Ocean Physical and Bio Analysis and Forecasting Products

ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a

ARCTIC_ANALYSIS_FORECAST_BIO_002_004

ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

And Physical and Bio Reanalysis Products

ARCTIC_REANALYSIS_PHYS_002_003

ARCTIC_REANALYSIS_BIO_002_005

Issue: 5.10

Contributors : Bruce Hackett (met.no), Laurent Bertino (NERSC), Alfatih Ali (Met.no), Arild Burud (Met.no), Timothy Williams (NERSC)

Approval Date: April 2020

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.	III.1,	Description of new variables bottom	M. Drivdal, L. Bertino	

	18	III.2, III.3, III.4, V.2	temp. and zooplankton added		
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

TABLE OF CONTENTS

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	Protocol to download files
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
Directgetfile	service tool (FTP like) to download a NetCDF file
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_ANALYSIS_FORECAST_PHY_002_001_a 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, 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.

ARCTIC_ANALYSIS_FORECAST_BIO_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, oxygen, chlorophyll, phytoplankton biomass, primary production, 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, drift velocity and snow depth on sea ice).

ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 is the nominal product of the Arctic Monitoring and Forecasting Center for ocean physics which contains tides and storm surge 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_REANALYSIS_PHY_002_003 is the reanalysis product of the Arctic Monitoring and Forecasting Center, and is composed of 3D, monthly mean fields of temperature, salinity, sea surface height, zonal velocity, meridional velocity, sea ice concentration, sea ice thickness and sea ice velocity. Daily mean files of the surface (2D) fields are also available as a separate dataset.

ARCTIC_REANALYSIS_BIO_002_005 is a demonstration 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, nitrate 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_ANALYSIS_FORECAST_PHY_002_001_a:**
  - On June 27th 2017, ice drift is added to hourly dataset
  - On April 13th 2016, hourly surface dataset added. Update of SL data and "buffer time" to accommodate the change until Sept. 13th.
  - On Sept. 13th 2016: Inclusion of Jason 3 instead of Jason 2.
  - On Dec. 1st 2016: Inclusion of Jason 2 in interleaved mode.

- **ARCTIC_ANALYSIS_FORECAST_BIO_002_004:**
  - On April 19th 2017: replacement of the biogeochemical model NORWECOM by ECOSMO. Inclusion of the silicates variable.
- **ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011:**
  - Introduction on 7th July 2020
- **ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015:**
  - Introduction on 31st March 2020
- **ARCTIC_REANALYSIS_PHY_002_003:**
  - **On April 8 2015**, years 2011 2012 2013 are added
  - **On April 8th 2016,** year 2014 is added, daily surface data added
  - **On April 19th 2017:** year 2014 re-processed and year 2015 added.
  - **On 1st December 2017:** years 2014 to 2016 with assimilation of ice thickness.
  - **Since 2018**: **Regular extensions of the time series every year (July: interim version, December final version)**
- **ARCTIC_REANALYSIS_BIO_002_005:**
  - **On April 8th 2016,** daily surface data added

II HOW TO DOWNLOAD A PRODUCT

II.1 Download a product through the Web Portal Subsetter Service

You first need to register. Please find below the registration steps: http://marine.copernicus.eu/web/34-products-and-services-faq.php#1

Once registered, the CMEMS FAQ http://marine.copernicus.eu/web/34-products-and-services-faq.php#3 will guide you on How to download a product through the CMEMS Web Portal Subsetter Service.

II.2 Download a product through the Web Portal Directgetfile Service

You first need to register. Please find below the registration steps: http://marine.copernicus.eu/web/34-products-and-services-faq.php#1

Once registered, the CMEMS FAQ http://marine.copernicus.eu/web/34-products-and-services-faq.php#3 will guide you on How to download a product through the CMEMS Web Portal Directgetfile Service.

II.3 Download a product through the FTP Service

You first need to register. Please find below the registration steps: http://marine.copernicus.eu/web/34-products-and-services-faq.php#1

Once registered, the CMEMS FAQ http://marine.copernicus.eu/web/34-products-and-services-faq.php#3 will guide you on How to download a product through the CMEMS Web Portal FTP Service.

III DESCRIPTION OF THE PRODUCT SPECIFICATION

III.1 General Information (Real-time product)

Product Lines	ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a ARCTIC_ANALYSIS_FORECAST_BIO_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_ANALYSIS_FORECAST_PHY_002_001_a ● 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 Type) ● sea_ice_albedo ● ocean_barotropic_streamfunction ● ocean_mixed_layer_thickness ● sea_floor_depth_below_sea_level ● bottom temperature ARCTIC_ANALYSIS_FORECAST_BIO_002_004 ● Nitrate ● Phosphate ● Oxygen ● Chlorophyll ● Phytoplankton biomass ● Primary production ● Light attenuation ● sea_floor_depth_below_sea_level

	• zooplankton ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 • Sea Ice (Concentration, Thickness and Velocity) • Snow depths on sea ice ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 • Sea Surface Height (includes tidal elevation) • Horizontal velocity at the sea surface (also includes tidal signals)
Analysis	Yes ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a: last two years; ongoing ARCTIC_ANALYSIS_FORECAST_BIO_002_004: from 2011-12-28 ; 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_ANALYSIS_FORECAST_PHY_002_001_a: 10 day forecasts, 10-members average ARCTIC_ANALYSIS_FORECAST_BIO_002_004: 10 day forecasts, 1 member ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: 7 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_ANALYSIS_FORECAST_PHY_002_001_a and ARCTIC_ANALYSIS_FORECAST_BIO_002_004: 24hr average 3D fields; ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a, ARCTIC_ANALYSIS_FORECAST_BIO_002_004 1hr instantaneous surface 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_ANALYSIS_FORECAST_PHY_002_001_a and ARCTIC_ANALYSIS_FORECAST_BIO_002_004: ● Weekly 7-day hindcast: Mondays at 1400 UTC ● Daily 10-day forecast: daily at 0030 UTC ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: ● Daily 7-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: DirectGetFile and Subsetter and CMEMS FTP
Horizontal resolution	ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a: 12.5 km ARCTIC_ANALYSIS_FORECAST_BIO_002_004: 12.5 km ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011: 3 km ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: 3 km
Number of vertical levels	ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a and ARCTIC_ANALYSIS_FORECAST_BIO_002_004: 12 for daily average fields: 5, 30, 50, 100, 200, 400, 700, 1000, 1500, 2000, 2500 and 3000 meters. Only surface variables otherwise.
Format	Netcdf CF1.4

Table 1: ARC-MFC Real Time products

<u>The runtime schedule:</u> ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a and _BIO_002_004 (TOPAZ)

The TOPAZ4 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 ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a consists of ensemble averaged, daily mean fields for the bulletin date (the scheduled production date) and the nine following dates. 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_PHY_ICE_002_011 (neXtSIM)

A 1-day hindcast and 7-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 concentration observations.

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 and atmospheric data including barometric pressure and is one-way nested with GLB-MFC Nemo product.

III.2 Details of datasets (Real Time product)

ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a

DATASET	dataset-topaz4-arc-myoceanv2-be http://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	u v
Sea Surface Height	m	ssh
Temperature	degC	temperature
Salinity	1e-3	salinity

Sea Ice Concentration	1	fice
Sea Ice Thickness	m	hice
Sea Ice Velocity Field (x and y components in polar stereographic grid)	m/s	uice vice
Fraction of First Year Ice	1	fy_frac
First Year Ice Age	day	fy_age
Snow thickness	m	hsnow
albedo	1	sea_ice_albedo
bsfd	m3 s-1	ocean_barotropic_streamfunction
mlp	m	ocean_mixed_layer_thickness
model_depth	m	sea_floor_depth_below_sea_level
bottom temperature	degC	sea_water_potential_temperature_at_sea_floor
DATASET	dataset-topaz4-arc-1hr-myoceanv2-be	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Surface velocity in x-direction of polar stereographic grid Surface velocity in y-direction of polar stereographic grid	m/s m/s	u v
Sea Surface Height	m	ssh
Temperature	degC	temperature
Salinity	1e-3	salinity
Sea Ice Concentration	1	fice
Sea Ice Thickness	m	hice

Snow thickness	m	hsnow
model_depth	m	sea_floor_depth_below_sea_level
Ice drift x-direction velocity	m/s	uice
Ice drift y-direction velocity	m/s	vice

Table 2: List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a

ARCTIC_ANALYSIS_FORECAST_BIO_002_004

DATASET	dataset-topaz4-bio-arc-myoceanv2-be	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Nitrate	mole m-3	nitrat
Phosphate	mole m-3	phosphat
Oxygen	kg m-3	oxygen
Primary production	kg m-2 s-1	pp_depth
Chlorophyll	kg m-3	chla
Silicate	Mole m-3	silicate
Phytoplankton biomass	mole m-3	pbiomass
Light attenuation	m-1	attcoef
Model depth	m	model_depth
Zooplankton biomass	mole m-3	zbiomass

Table 3 List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_ANALYSIS_FORECAST_BIO_002_004

ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

DATASET	*cmems_mod_arc_phy_anfc_nextsim_hm*	
VARIABLE	*UNIT*	*NAME OF VARIABLES IN THE NETCDF FILE*
Sea Ice Concentration	*1*	*siconc*
Sea Ice Thickness	*m*	*sithick*
Snow thickness	*M*	*sisnthick*
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

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

III.3 General Information (Reanalysis products)

Product Lines	ARCTIC_REANALYSIS_PHY_002_003
Geographical coverage	North of 65°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 bottom temperature (only monthly mean) sea_floor_depth_below_sea_level
Analysis	Yes
Forecast	No
Available time series	From 1991-01-15 and regularly updated (see product improvements pages http://marine.copernicus.eu/services-portfolio/product-improvements/).
Temporal resolution	Daily and Monthly average fields
Target delivery time	N/A
Delivery mechanism	CMEMS Information System (Subsetter and Directgetfile and FTP)
Horizontal resolution	12.5 km
Number of vertical levels	1 level for Daily and 12 levels for monthly average fields 5, 30, 50, 100, 200, 400, 700, 1000, 1500, 2000, 2500 and 3000 meters.
Format	Netcdf CF1.4

Table 6 ARC-MFC PHY Reanalysis product

Product Lines	ARCTIC_REANALYSIS_BIO_002_005
Geographical coverage	North of 65°N
Variables	Chl-a Attenuation coefficient Nitrate Phosphate Phytoplankton biomass Oxygen sea_floor_depth_below_sea_level Diatom_mortality_rate Flagellate_mortality_rate Maximum_loss_rate_of_mesozooplankton Maximum_loss_rate_of_microzooplankton
Analysis	Yes
Forecast	No
Available time series	From Jan 2007- and regularly updated (see product improvements pages http://marine.copernicus.eu/services-portfolio/product-improvements/).
Temporal resolution	Daily and Monthly average fields
Target delivery time	N/A
Delivery mechanism	CMEMS Information System (Subsetter and Directgetfile and FTP)
Horizontal resolution	25 km
Number of vertical levels	1 level for Daily and 12 levels for monthly average fields: 5, 30, 50, 100, 200, 400, 700, 1000, 1500, 2000, 2500 and 3000 meters.
Format	Netcdf CF1.4

Table 7: ARC-MFC BIO Reanalysis product

Detailed information on the systems and products are on CMEMS web site: marine.copernicus.eu .

III.4 Details of datasets (Reanalysis products)

ARCTIC_REANALYSIS_PHY_002_003

DATASET	dataset-arc-nersc-bergen-no-myocean-rv2	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Zonal Velocity Meridional Velocity	m/s m/s	u v
Sea Surface Height	m	ssh
Temperature	degC	temperature
Salinity	1e-3	Salinity
Sea Ice Concentration	1	fice
Sea Ice Thickness	m	hice
Sea Ice Velocity Field (Meridional and Zonal)	m/s	uice vice
Snow thickness	m	hsnow
Ocean barotropic Stream Function	m^3/s	bsfd
Ocean mixed layer thickness	m	mlp*
model_depth	m	sea_floor_depth_below_sea_level
bottom temperature	degC	sea_water_potential_temperature_at_sea_floor

Table 8 List of variables in datasets and their names and units in the NetCDF output files for the ARCTIC_REANALYSIS_PHY_002_003

*: Note that the long name attribute contains a mistake: "long_name: Defined by a delta of sigma (density) » should be equal to 0.03 instead of 0.05, and is consistent with the NRT product.

ARCTIC_REANALYSIS *BIO_002*_005

DATASET	dataset-arc-nersc-bergen-no-myocean-brv2	
VARIABLE	UNIT	NAME OF VARIABLES IN THE NETCDF FILE
Chl-a	kg m^3	Chla
Attenuation coefficient	m^-1	Attcoef
Nitrate	Mol N m^-3	Nitrat
Phosphate	Mol P m^-3	Phosphat
Phytoplankton biomass	Mol N m^-3	Pbiomass
Oxygen	Kg m^-3	Oxygen
Model depth	m	Model_depth
CCD	d-1	Diatom_mortality_rate
CCF	d-1	Flagellate_mortality_rate
MU2	d-1	Maximum_loss_rate_of_mesozooplankton
MU3	d-1	Maximum_loss_rate_of_microzooplankton
zooplankton	mole m-3	mole_concentration_of_zooplankton_in_sea_ water_expressed_as_nitrogen

Table 9: List of the variables in the dataset and their names in the NetCDF output files for the ARCTIC_REANALYSIS_ BIO_002_005

III.5 Production System Description

III.5.1 ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a

The Arctic MFC V3/V4 nominal system is 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). The V2, V3, V4 and V5 systems have been upgraded successively but there has not been any cold restart or “double diffusion” of parallel production chains.

III.5.1.1 TOPAZ4 Production Cycle at MET Norway

The model results are produced with the TOPAZ4 ocean data assimilation model system. Presently, TOPAZ4 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 (dataset-topaz4-arc-myoceanv2-be) is delivered to the users and used for the validation. In addition, daily files with hourly resolution of the surface fields (dataset-topaz4-arc-1hr-myoceanv2-be) are delivered from a single member.

TOPAZ4 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							

The table 10 illustrates the weekly schedule for the TOPAZ system. The vertical axis indicates forecast lead time in days.

III.5.1.2 Observational Data

Observational data are assimilated into the TOPAZ 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 Jason2, Cryosat, (since September 2013) AltiKa, (since June 2014) Hy2a satellites and Sentinel 3a (since 17th April 2017). 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).

III.5.2 ARCTIC_REANALYSIS_PHY_002_003

The ARC-MFC V3 nominal system is the TOPAZ 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). This report describes the 27-years Arctic reanalysis product in the period 1991-2018 included. 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: TOPAZ4
- Production centre description: Nansen Center, Bergen, Norway. NERSC-BERGEN-NO
  - Name in the catalogue: ARCTIC_REANALYSIS_PHY_002_003
  - Dataset name dataset-ran-arc-day-myoceanv2-be and dataset-ran-arc-myoceanv2-be for monthly means

III.5.2.1 <u>Assimilated data</u>

Observations that are assimilated by TOPAZ4 include along-track **Sea Level Anomalies** (SLA) from satellite altimeters, **Sea Surface Temperature** (SST) from NOAA and then the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA), **in situ temperature and salinity from hydrographic cruises and moorings**, **ice concentrations (ICEC)** from OSI-SAF, the CS2SMOS ice thickness data from seaice.de. The system uses a 7-day assimilation cycle, and assimilates the gridded SST and ICEC 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	1993-2018	SEALEVEL_GLO_PHY_L3_REP_OBSERVATIONS_008_045
SST (Reynolds)	$6{\cdot}10^3$	$6{\cdot}10^3$	Gridded	1990-1998	Ext.
SST (OSTIA)	$2{\cdot}10^6$	$2.2 \cdot 10^5$	Gridded	1998-2007	SST_GLO_SST_L4_REP_OBSERVATIONS_010_011
“”	“”	“”	“”	2008-2018	SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001
In-situ T	$3{\cdot}10^4$	$5.\ 10^3$	Point	1991-2017	INSITU_GLO_TS_REP_OBSERVATIONS_013_001_b
In-situ S	$3{\cdot}10^4$	$5.\ 10^3$	Point	1991-2017	
Ice conc. (SSM/I)	$9 \cdot 10^4$	$5.\ 10^4$	Gridded	1990-2018	SEAICE_GLO_SEAICE_L4_REP_OBSERVATIONS_011_009
Ice drift	5.10^3	5.10^3	Gridded	2002-2018	Ext. (Ifremer)
Ice thickness	1.10^4	1.10^4	Gridded	2014-2018	Ext. (AWI, seaice.de)
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-SLA-L3-RAN-OBSERVATIONS-008-045) from 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 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 snap-shots 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 (followed by its NRT counterpart after 2008). The

data set was included from June 1998 at horizontal resolution of approximately 6km (though the spatial scales evident in OSTIA tend to be significantly coarser than 6 km), 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. Prior to June 1998, TOPAZ4 uses version 2 of the Reynolds SST product [Reynolds and Smith, 1994] from the National Climatic Data Center (NCDC), which has a resolution of approximately 100 km.

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 **ICEC** data is obtained from SSM/I at the OSI-TAC (OSI-SAF data SEAICE_GLO_SEAICE_L4_REP_OBSERVATIONS_011_009, followed by its NRT counterpart after 2010). It is computed with the OSI-SAF sea ice concentration algorithm. The gridded data is available from 1979 to 2017 and was assimilated since 1990, at a resolution of 25 km. The spatial coverage is almost complete. TOPAZ4 assimilates the ICEC 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 ICEC.

The **sea ice drift** product is provided by CERSAT, Ifremer [Ezraty et al., 2006] SEAICE_ARC_SEAICE_L3_REP_OBSERVATIONS_011_010 until 2016, followed by the OSI SAF NRT product SEAICE_GLO_SEAICE_L4_NRT_OBSERVATIONS_011_001. The Lagrangian drift data is obtained at a resolution of 35 km by a pattern recognition algorithm from QuickSCAT, AMSR-E and SSM/I images. It is avail- able from October to April inclusive and does not provide information close to the ice edge. The 3-day drift has been chosen as a compromise: long enough to average out some random errors in the composites that are computed over shorter periods and 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 October 2002 but the data is unavailable during summer due to loss of patterns where melting occurs. The provider accuracy estimate of 7 km/3 days is overestimated by a factor 2 to account for representation error. Because the sea ice drift data is Lagrangian, the corresponding observation operator is nonlinear. The model equivalent 3-days drift is computed for each ensemble member and each grid cell of the satellite data product. The initial positions are advected 3 days forward using model daily averaged ice velocities and a 2nd order Runge-Kutta method. The final displacements are computed on the observation grid. To the best of our knowledge, assimilation of ice drift in TOPAZ represents the first example of assimilating Lagrangian data in a realistic ocean model.

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) from Oct 2014 to April 2017.

III.5.2.2 The Model:

TOPAZ4 uses version 2.2.18 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 TOPAZ4 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 28 hybrid layers with carefully chosen reference potential densities of 0.1, 0.2, 0.3, 0.4, 0.5, 24.05, 24.96, 25.68, 26.05, 26.30, 26.60, 26.83, 27.03, 27.20, 27.33, 27.46, 27.55, 27.66, 27.74, 27.82, 27.90, 27.97, 28.01, 28.04, 28.07, 28.09, 28.11, 28.13 1. 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 3 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 that combines the World Atlas of 2005 [WOA05, Locarnini et al., 2006; Antonov et al., 2006] with version 3.0 of the Polar Science Center Hydrographic Climatology [PHC, Steele et al., 2001]. 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 ERA- interim [Simmons et al., 2007] that has a resolution of 0.25◦. The atmospheric fields from ERA-interim 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). 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 mean SSH is computed over the period 1993-1999 and used to assimilate altimeter observations (See Figure 3).
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

TOPAZ4 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.
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. Each of these states is used to produce five initial states by perturbing the layer and ice thickness by 10% with the decorrelation length scale of 50km. The perturbation of layer thickness also has vertical decorrelation distance of three layers. 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 and in the following publication:

Xie, J., Bertino, L., Counillon, F., Lisæter, K. A., and Sakov, P.: Quality assessment of the TOPAZ4 reanalysis in the Arctic over the period 1991–2013, *Ocean Sci*., 13, 123-144, https://doi.org/10.5194/os-13-123-2017, 2017.

III.5.3 ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

neXtSIM is a stand-alone sea-ice model which can use winds and currents from a variety of atmospheric and oceanic models(hindcasts or forecasts). Its dynamical core is the Maxwell-elasto-brittle (MEB) rheology (Dansereau et al., 2016). 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 resolution of about 10 km.

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_ANALYSIS_FORECAST_PHY_002_001_a (TOPAZ4) near-surface (30 m) ocean velocity andthe mixed layer depth (MLD) directly in the model, while the temperature and salinity in the model’s slab ocean are relaxed towards the TOPAZ4 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 TOPAZ4.

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 7 days to provide a forecast. Sea ice concentrations from the SI TAC SEAICE_GLO_SEAICE_L4_NRT_OBSERVATIONS_011_001 / OSI SAF product (a combination of SSMI/I and AMSR-2 products) are assimilated on a daily basis.

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 Discuss., https://doi.org/10.5194/tc-2019-154, in review, 2019.

Other references:

Dansereau, V., Weiss, J., Saramito, P., and Lattes, P.: A Maxwell elasto-brittle rheology for sea ice modelling, The Cryosphere, 10, 1339–1359, 2016.

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, 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_ANALYSIS_FORECAST_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.

III.5.5 ARCTIC_ANALYSIS_FORECAST_BIO_002_004

The biogeochemical forecast is produced by a corresponding module in the full ARC forecast model. Thus, the ARC-PHYS results and the ARC-BIO results become available from the same model runs.

However, a significant difference between the two sets of results arises from the assimilation step: presently, assimilation is only carried out for variables in the ARC-PHYS system. Furthermore, the ARC-BIO system is less mature in the sense that less tuning has been performed in order to optimize this system's performance. Hence, the ARC-BIO system is presently classified as being in an experimental mode.

Brief overview of the system:

The Core System for the Arctic MFC is the TOPAZ data assimilation system, which includes assimilation of observations of physical variables for the ocean and the sea ice, by application of the Ensemble Kalman Filter. Subsequent to the production of initial conditions from the assimilation mode, 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 (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.

Assimilation is performed in a weekly cycle, while model forecasts are updated on a daily basis. The assimilation is performed three days after the last observation comes in, on Thursdays. Consequently, the Thursday model simulation is performed as a 3-day hindcast. For the other days of the week, the model simulations are performed as 1 day hindcasts, using updated atmospheric forcing fields.

A detailed explanation is provided in Table 10.

		Valid day																
		Su	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	A*	F	F	F	F	F	F	F	F	F						
	Tu		A	A*	F	F	F	F	F	F	F	F	F					
	We			A	A*	F	F	F	F	F	F	F	F	F				
	Th		P	A	A	A*	F	F	F	F	F	F	F	F	F			
	Fr					A	A*	F	F	F	F	F	F	F	F	F		
	Sa						A	A*	F	F	F	F	F	F	F	F	F	
	Su							A	A*	F	F	F	F	F	F	F	F	F

Table 12: The weekly production cycle at the ARC-MFC. 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. There is presently no assimilation of biogeochemical variables.**

The ECOSMO II model 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

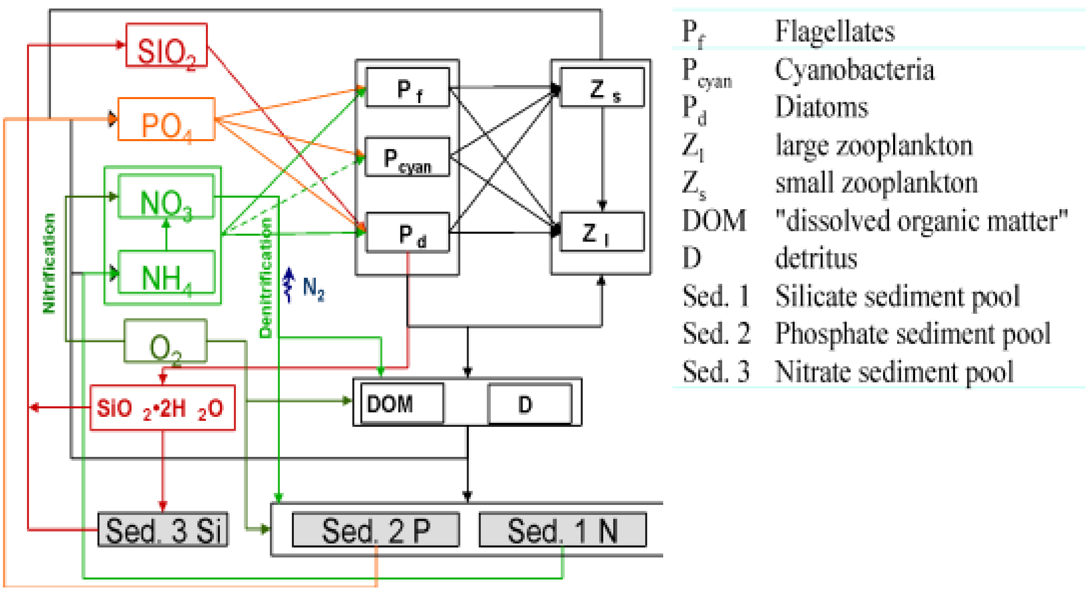

Figure 1: Overview over the components of ECOSMO and how they interact with each other.

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 ARCTIC_REANALYSIS_BIO_002_005

The ARC-MFC V3 nominal system is the TOPAZ 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) coupled to the NORWegian ECOsystem Model from IMR (NORWECOM). The dataset delivered in CMEMS contains only the biological variables: 3D attenuation coefficient, nutrients (phosphate, nitrate and oxygen, but not the silicates), total phytoplankton biomass concentration, Chlorophyll-a, zooplankton.

The NORWECOM (The NORWEgian ECOlogical Model Sytem, Aksnes et al., 1995; Skogen and Søiland, 1998) model is coupled online to the physical HYCOM model it uses the HYCOM routines for advection of tracers and has the same time-step as the physical model.

The current version of this model includes two classes of phytoplankton (diatom and flagellates), two classes of zooplankton (meso- and microzooplankton) derived with the same formulation from the model ECOHAM4 [Pätsch et al., 2009], several types of nutrients (inorganic nitrogen, phosphorus and silicon) and detritus (nitrogen, phosphorus), biogenic silica, and oxygen, so that the ecosystem state vector is made of 11 variables. The chlorophyll-a concentration (CHLA) is computed from the model diatom and flagellates concentrations (DIA and FLA) by the equation CHLA=(DIA+FLA)/11. The constant conversion factor 11 is added to obtain the chlorophyll concentration in mg/m3, the standard unit of data produced from satellite, from the phytoplankton. The interactions between the different components of the model are highlighted in Figure 1.

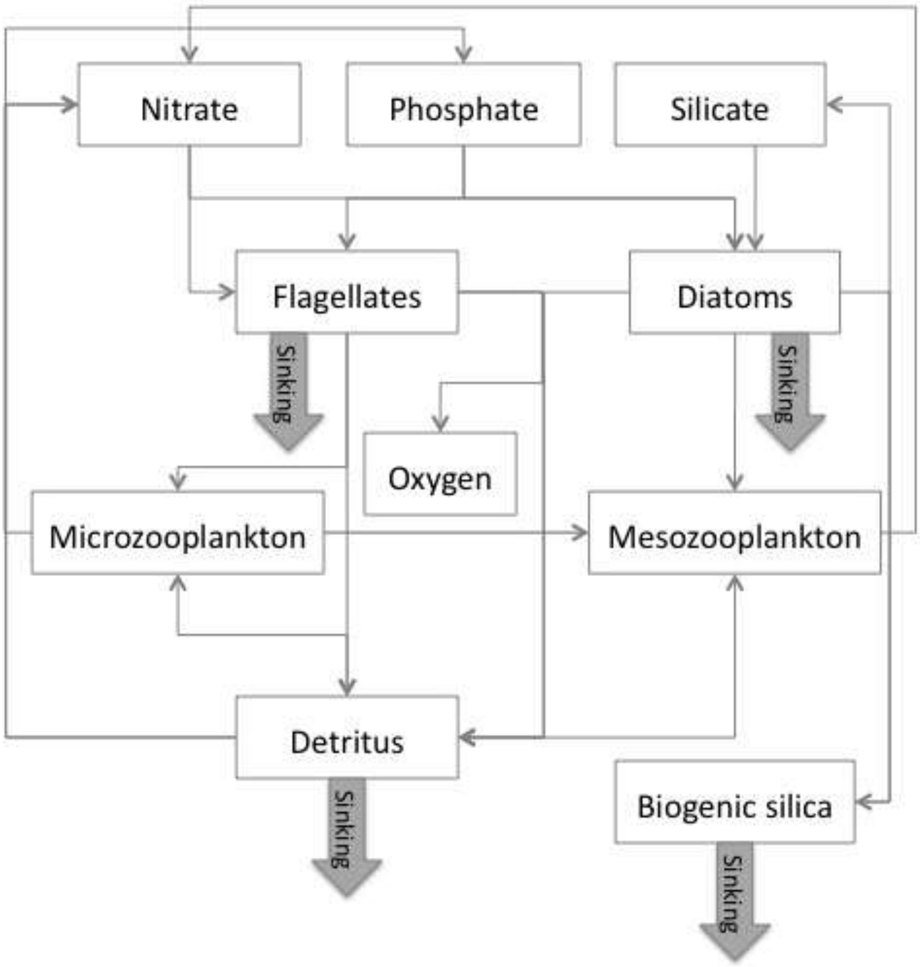

Figure 2: Overview over the components of NORWECOM and how they interact with each other.

III.5.6.1 Assimilated data

Observations that are assimilated by TOPAZ4 include GlobColour 8-days averaged **Chl-a maps** (Chl), along-track **Sea Level Anomalies** (SLA) from satellite altimeters, **Sea Surface Temperature** (SST) from NOAA, **ice concentrations (ICEC)** from OSI-SAF. The system uses a weekly assimilation cycle, and assimilates the gridded Chl, SST and ICEC for the day of the analysis; and along-track SLA for the week prior to the day of the analysis. A brief overview of observations used in the reanalysis is given in Table 1.

Quality control procedures and preprocessing steps include a range check and horizontal superobing. The details for each observation type follow.

Type	Number	After Superobing	Period	CMEMS name	Spacing type
Chl	$2.5\text{-}7{\cdot}10^4$	$0.5\text{-}1{\cdot}10^4$	2008-2010	Retired OC product	Gridded
SLA	$9{\cdot}10^4$	$2{\cdot}10^4$	2007-present	SEALEVEL_GLO_PHY_L3_REP_OBSERVATIONS_008_045	Track
SST (Reynolds)	$2{\cdot}10^6$	$2\ 10^4$	2007-2010	Ext.	Gridded
Ice conc. (SSM/I)	$9 \cdot 10^4$	$6.\ 10^3$	2007-present	SEAICE_GLO_SEAICE_L4_REP_OBSERVATIONS_011_009	Gridded
Total	$\mathbf{2.2 \cdot 10^6}$	$\mathbf{3{\cdot}10^5}$			

Table 13 Overview of assimilated observations per each cycle, average numbers for the cycles during which the observations are present.

- The ocean colour data used for assimilation are the GlobColour GSM-derived CHL1 products obtained from MERIS, MODIS and SeaWiFS intruments. They correspond to the 8-day averaged chlorophyll-a concentration for case 1 water. Their spatial coverage varies strongly with seasons resulting in the absence of observations for the Arctic ocean in winter. The observation error is assumed log-normally distributed and are log-transformed before assimilation. The standard deviation of the these log-transformed observations is specified to 0.35, meaning an observation error equaling 35% of the observation values on average [Gregg and Casey, 2004]. Observations in water shallower than 300m are not assimilated in the first 6 months of 2008 in order to prevent the over assimilation of observations with poor quality. From 1 July 2008, all the data located both in water deeper than 10 m and at least 50 km away from the coast are assimilated.

- The altimetry data used for assimilation are **the along- track SLA** from TOPEX/Poséidon, JASON-1, JASON-2, ENVISAT provided by the SL-TAC from January 2007 to 2010. These data are geophysically corrected for tides, inverse barometer, tropospheric, and ionospheric signals [Le Traon and Ogor, 1998; Dorandeu and Le Traon, 1999]. 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.

- TOPAZ4 uses version 2 of the Reynolds **SST** product [Reynolds and Smith, 1994] from the National Climatic Data Center (NCDC), which has a resolution of approximately 100 km.

- The **ICEC** data is obtained from SSM/I at the SIW-TAC (OSI-SAF data). It is computed with the ARTIST sea ice concentration algorithm. The gridded data is available from 1979, before the beginning of the reanalysis at a resolution of 25 km. The spatial coverage is almost complete. TOPAZ4 assimilates the ICEC 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 ICEC.

III.5.6.2 <u>The Model:</u>

TOPAZ4 uses version 2.2.37 of HYCOM.
The TOPAZ4 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 1), 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- interim [Simmons et al., 2007] that has a resolution of 0.5 deg◦. The atmospheric fields from ERA-interim 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

see section III.2.3, only differences are detailed below.

The localisation radius, beyond which the ensemble-based covariance between two points is reduced to zero, is uniform in space and is set to 300 km for the assimilation of physical data and 200 km for the assimilation of ocean colour data.

During each analysis step, coarse-TOPAZ4 calculates a 100×100 local ensemble transform matrix (ETM, called X5 in Evensen 2003) for each of the 216 × 144 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 216 × 144 array of ETMs is then used for updating each horizontal model field.

The analysis is performed in the model grid space and divides into two steps. In a first step, the physical data (SST, TSLA and ice concentration) are assimilated in the physical component (HYCOM) of the coupled model. In this first step, the biological component is not included in the analysis state vector. The instances of negative layer thickness or ice concentration, should they occur, are corrected in a post-processing procedure. The mass balance is also corrected to account for vertical updates of isopycnals during analysis. However, biological tracers being defined as concentrations, changes in layer thickness might lead to changes in the amount of substance, due to changes in volume that are not compensated by changes in concentrations of the species. In order to insure the conservation of the amount of species for each tracer at each horizontal grid point (conservation in the water column), a vertical remapping of the tracer is also performed. This remapping uses the WENO interpolations that are already embedded in HYCOM. In the second step, surface chlorophyll concentrations data are assimilated in the biological component (NORWECOM) of the coupled model. It means that the dynamics of the physical ocean is not corrected by the assimilation of biological data. Biological state variables and parameters are log-transformed prior to assimilation in order to prevent issues arising from the positiveness of the variables [Simon and Bertino, 2012].

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.5.6.4 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 one model snapshot taken from a long model (20-year simulation) that corresponds to 1 September 2006. This state is used to produce 100 initial states by perturbing the layer and ice thickness by 10% with the decorrelation length scale of 50km. The perturbation of layer thickness also has vertical decorrelation distance of three layers. The initial ensemble is integrated for 3 months to damp instabilities that result from the perturbations.

After generating the initial ensemble the DA system is spun up with assimilation of physical variables only during a period of 1 year, for the calendar year of 2007. The assimilation of Chl data starts on 1st January 2008. The observation error is multiplied by a factor 8 during the first two months to prevent an over-assimilation of the observations due to strong model bias. This factor is divided by two every month and reaches the value one in April 2008.

The assimilation cycle is weekly, similarly to the real-time system. These cycles follow the availability of the physical observations – daily products – and the date of the analysis is used to define which 8-day averaged chlorophyll data set is assimilated in the biological analysis.

The EnKF estimates also biological parameters of the NORWECOM model, varying pixel by pixel. At the end of 2009, these parameter values are frozen and no longer updated for the last year of the reanalysis.

IV NOMENCLATURE OF FILES

The nomenclature of the downloaded files differs on the basis of the chosen download mechanism **Subsetter** or **Directgetfile** or **CMEMS FTP** service.

IV.1 Nomenclature of files when downloaded through the CMEMS Web Portal Subsetter Service

Files nomenclature when downloaded through the CMEMS Web Portal Subsetter is based on product dataset name and a numerical reference related to the request date on the MIS.

The scheme is: **datasetname_nnnnnn.nc**

where :

.datasetname is a character string within one of the following :

- dataset-topaz4-arc-myoceanv2-be (for real time physics product)
- cmems_mod_arc_phy_anfc_nextsim_hm (for stand-alone sea ice forecast product)
- dataset-topaz6-arc-15min-3km-be (for stand-alone ocean-tide forecast product)
- dataset-topaz4-bio-arc-myoceanv2-be (for real time bio product)
- dataset-ran-arc-myoceanv2-be (for phys reanalysis product)
- dataset-bio-ran-arc-myoceanv2-be(for bio reanalysis product)

. nnnnnn: 6 digit integer corresponding to the current time (download time) in milliseconds since January 1, 1970 midnight UTC.

.nc: standard NetCDF filename extension.

Example:

dataset-topaz4-arc-myoceanv2-be_435283.nc

IV.2 Nomenclature of files when downloaded through the CMEMS Web Portal Directgetfile or CMEMS FTP Service

The nomenclature used for the ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a product is:

[VDATE]_dm-metno-MODEL-topaz4-ARC-b[BDATE]-fv02.0.nc

where

[BDATE]: YYYYMMDD is the bulletin date

[VDATE]: YYYYMMDD is the forecast valid date

The nomenclature used for the ARCTIC_ANALYSIS_FORECAST_BIO_002_004 product is:

[VDATE]_dm-metno-MODEL-topaz4_norwecom2-ARC-b[BDATE]-fv02.0.nc

where

[BDATE]: YYYYMMDD is the bulletin date

[VDATE]: YYYYMMDD is the forecast valid date

The nomenclature used for the ARCTIC_ANALYSIS_FORECAST_PHY_002_011 product is:

[VDATE]_*hr-nersc-MODEL-nextsimf-ARC-b[BDATE]-fv00.0.nc*

where

[BDATE]: YYYYMMDD is the bulletin date

[VDATE]: YYYYMMDD is the forecast valid date

The nomenclature used for the ARCTIC_REANALYSIS_PHY_002_003 product is:

topaz_V4_myocean_arctic_grid1to8_da_class1_[VDATE].nc

where

[VDATE]: YYYYMM15 is the reanalysis valid date (middle of the month)

There is no bulletin date for the reanalysis.

The nomenclature used for the ARCTIC_REANALYSIS_BIO_002_005 products is:

YYYYMMDD_mm-NERSC-MODEL-TOPAZ4BIO-ARC-RAN-fv02.nc

where

[DATE]: YYYYMMDD is the valid field date (monthly averages, DD is at the middle of the month)

IV.3 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:

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 " ;

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.

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

IV.4 Domain coverage

The three products

ARCTIC_ANALYSIS_FORECAST_PHY_002_001_a,
ARCTIC_ANALYSIS_FORECAST_BIO_002_004
ARCTIC_REANALYSIS_PHY_002_003
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_REANALYSIS_BIO_002_005 product has twice coarser horizontal resolution (25 km) but otherwise the same vertical resolution.

ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011

ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

is released on a regular polar-stereographic grid, with a horizontal grid step of 3 km (see Figures 4 and 5)

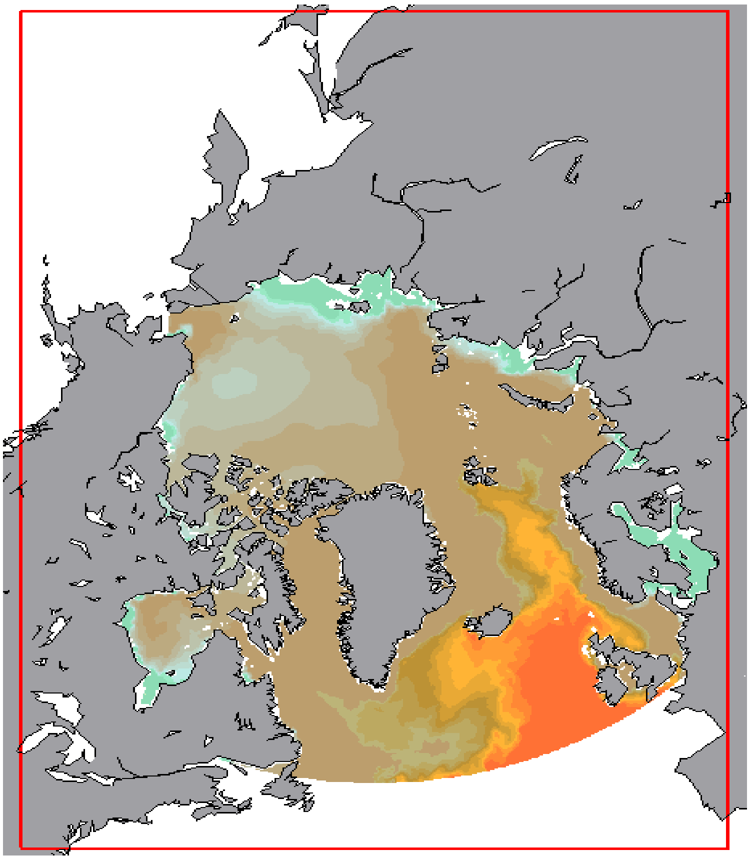

Figure 3: Spatial coverage of the ARC-MFC Arctic products, masked below 50N

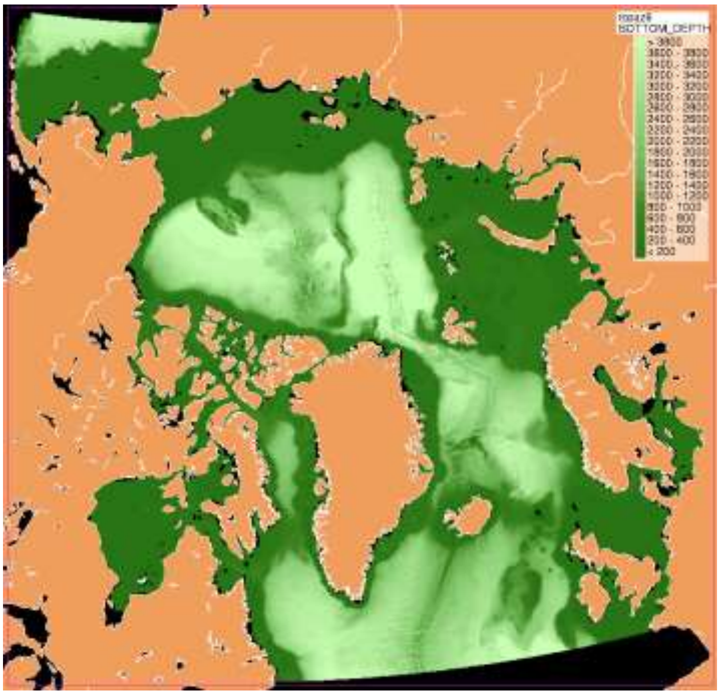

Figure 4: Spatial coverage of the ARC-MFC ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 product, note the inclusion of the Bering Sea.

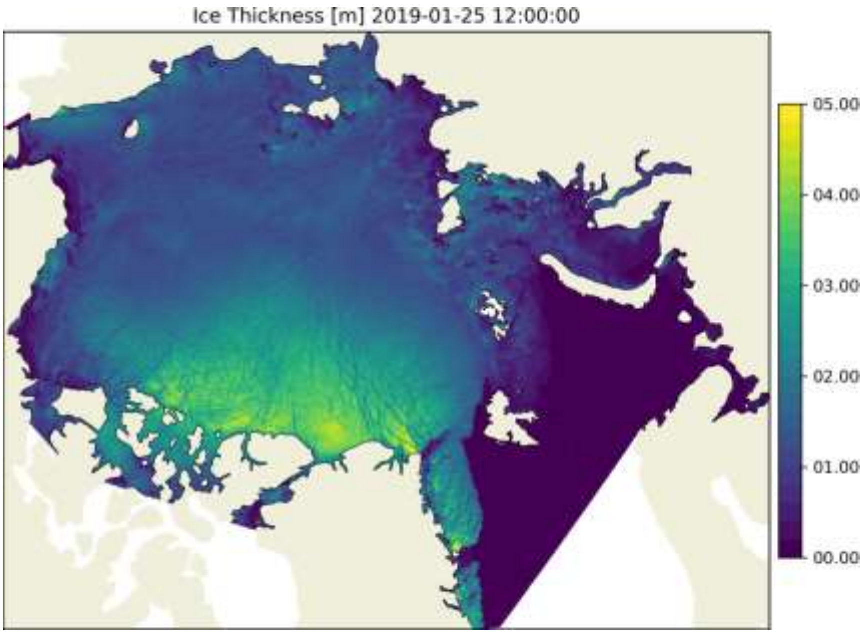

Figure 5: Sea Ice thickness chart showing the spatial coverage of the ARC-MFC ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 product, note the exclusion of Baffin Bay, the Canadian Achipelago and Hudson Bay.

IV.5 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).

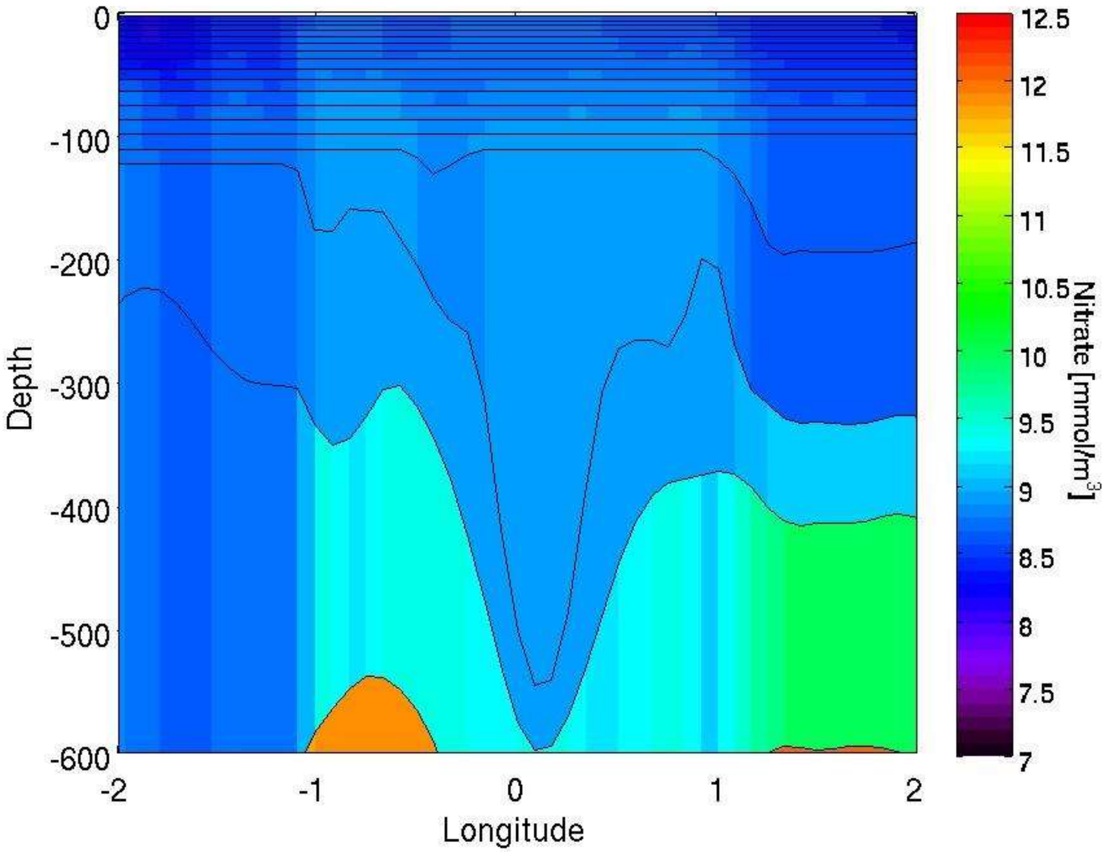

Figure 6 Vertical section of nitrates and vertical levels. Shading indicates concentrations, thin lines indicate layer interfaces. The coordinates revert from isopycnal to z-levels in the mixed layer.

The ARCTIC products are interpolated to 12 unevenly (Levitus) spaced vertical levels: 5, 30, 50, 100, 200, 400, 700, 1000, 1500, 2000, 2500 and 3000 meters.

IV.6 Update Time

ARCTIC_ANALYSIS_FORECAST_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 of the following day. The weekly analysis is not distributed.

ARCTIC_ANALYSIS_FORECAST_BIO_002_004 products: The forecast fields are updated as for ARCTIC_ANALYSIS_FORECAST_PHY_002_001. There is no corresponding 7-day hindcast for this product.

ARCTIC_REANALYSIS_PHY_002_003 is updated twice a year (interim and final update).

ARCTIC_REANALYSIS_BIO_002_005 products: The reanalysis is produced once.

ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015: a 10-day forecast is updated in the evening and is available by 0030 UTC of the following day

IV.7 Temporal extent of analysis and forecast stored on delivery mechanism

ARCTIC_ANALYSIS_FORECAST_PHY_002_001 and ARCTIC_ANALYSIS_FORECAST_BIO_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.

An archive of analyses since 19 October 2011 (physics) and 28 December 2011 (bio) is available. 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_REANALYSIS_PHY_002_003 products temporal coverage: 20 years from January 1991 until December 2017 included.

ARCTIC_REANALYSIS_BIO_002_005 products temporal coverage: Four years 2007-2010; in 2007 only the physical variables have been assimilated and in 2008 the ocean colour data have also been assimilated.

IV.8 Other information: mean centre of Products, land mask value, missing value

ARCTIC_ANALYSIS_FORECAST_PHY_002_001 and ARCTIC_ANALYSIS_FORECAST_BIO_002_004 products: forecast and the analysis are 24hr mean fields centered at 12:00 UTC.

ARCTIC_REANALYSIS_PHY_002_003 and ARCTIC_REANALYSIS_BIO_002_005 the monthly values are centered at the middle of the month.

The NetCDF3 format is used with short integer coding for best compression, using an offset and scale factor as shown below:

Real_Value = (Display_Value X scale_factor) + add_offset

Fill values / missing values: -32767s, land values '-'

V FILE FORMAT

V.1 NetCDF

The products are stored using the NetCDF format.

NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The netCDF libraries define a machine-independent format for representing scientific data.

Please see Unidata netCDF pages (http://www.unidata.ucar.edu/software/netcdf/) for more information, and to retrieve netCDF software package.

NetCDF data format is:

* Self-Describing. A netCDF file includes information about the data it contains.

* Architecture-independent. A netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.

* Direct-access. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.

* Appendable. Data can be appended to a netCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a netCDF dataset can be changed, though this sometimes causes the dataset to be copied.

* Sharable. One writer and multiple readers may simultaneously access the same netCDF file.

The products are compliant with the NetCDF Climate and Forecast Convention CF-1.4 (see http://cf-pcmdi.llnl.gov/).

The ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011 and ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015 products are distributed in netCDF4 format.

V.2 Structure and semantic of netCDF maps files

V.2.1 Output from an ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a product:

The model output files contain some additional fields in addition to the variables mentioned earlier. An example output NetCDF file header for dataset-topaz4-arc-myoeanv2-be is inserted below, with the additional fields in italic fonts.

```
netcdf \20170529_dm-metno-MODEL-topaz4-ARC-b20170529-fv02.0 {
dimensions:
	x = 609 ;
	y = 881 ;
	depth = 12 ;
	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:false_easting = 0. ;
		stereographic:false_northing = 0. ;
	double time(time) ;
		time:units = "hour since 1950-1-1T00:00:00Z" ;
		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" ;
    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 temperature(time, depth, y, x) ;
        temperature:_FillValue = -32767s ;
        temperature:missing_value = -32767s ;
        temperature:add_offset = 23.5 ;
        temperature:scale_factor = 0.000808839239385893 ;
        temperature:units = "Celsius" ;
        temperature:standard_name = "sea_water_potential_temperature" ;
        temperature:grid_mapping = "stereographic" ;
        temperature:coordinates = "longitude latitude" ;
        temperature:cell_methods = "area: mean" ;
    short salinity(time, depth, y, x) ;
        salinity:_FillValue = -32767s ;
        salinity:missing_value = -32767s ;
        salinity:add_offset = 22.5 ;
```

```
		salinity:scale_factor = 0.000686750297591796 ;
		salinity:units = "1e-3" ;
		salinity:standard_name = "sea_water_salinity" ;
		salinity:grid_mapping = "stereographic" ;
		salinity:coordinates = "longitude latitude" ;
		salinity:cell_methods = "area: mean" ;
	short u(time, depth, y, x) ;
		u:_FillValue = -32767s ;
		u:missing_value = -32767s ;
		u:add_offset = 0. ;
		u:scale_factor = 9.15667063455728e-05 ;
		u:units = "m s-1" ;
		u:standard_name = "x_sea_water_velocity" ;
		u:grid_mapping = "stereographic" ;
		u:coordinates = "longitude latitude" ;
		u:cell_methods = "area: mean" ;
	short v(time, depth, y, x) ;
		v:_FillValue = -32767s ;
		v:missing_value = -32767s ;
		v:add_offset = 0. ;
		v:scale_factor = 9.15667063455728e-05 ;
		v:units = "m s-1" ;
		v:standard_name = "y_sea_water_velocity" ;
		v:grid_mapping = "stereographic" ;
		v:coordinates = "longitude latitude" ;
		v:cell_methods = "area: mean" ;
	short mlp(time, y, x) ;
		mlp:_FillValue = -32767s ;
		mlp:missing_value = -32767s ;
		mlp:add_offset = 2500. ;
		mlp:scale_factor = 0.0763055886213106 ;
```

```
        mlp:units = "m" ;
        mlp:standard_name = "ocean_mixed_layer_thickness" ;
        mlp:grid_mapping = "stereographic" ;
        mlp:coordinates = "longitude latitude" ;
        mlp:cell_methods = "area: mean" ;
float ssh(time, y, x) ;
        ssh:_FillValue = -1.e+14f ;
        ssh:missing_value = -1.e+14f ;
        ssh:units = "m" ;
        ssh:standard_name = "sea_surface_elevation" ;
        ssh:grid_mapping = "stereographic" ;
        ssh:coordinates = "longitude latitude" ;
        ssh:cell_methods = "area: mean" ;
short bsfd(time, y, x) ;
        bsfd:_FillValue = -32767s ;
        bsfd:missing_value = -32767s ;
        bsfd:add_offset = 0. ;
        bsfd:scale_factor = 305222.354485243 ;
        bsfd:units = "m3 s-1" ;
        bsfd:standard_name = "ocean_barotropic_streamfunction" ;
        bsfd:grid_mapping = "stereographic" ;
        bsfd:coordinates = "longitude latitude" ;
        bsfd:cell_methods = "area: mean" ;
short fice(time, y, x) ;
        fice:_FillValue = -32767s ;
        fice:missing_value = -32767s ;
        fice:add_offset = 0.5 ;
        fice:scale_factor = 1.52611177242621e-05 ;
        fice:units = "1" ;
        fice:standard_name = "sea_ice_area_fraction" ;
        fice:grid_mapping = "stereographic" ;
```

```
        fice:coordinates = "longitude latitude" ;
        fice:cell_methods = "area: mean" ;
short hice(time, y, x) ;
        hice:_FillValue = -32767s ;
        hice:missing_value = -32767s ;
        hice:add_offset = 10. ;
        hice:scale_factor = 0.000305222354485242 ;
        hice:units = "m" ;
        hice:standard_name = "sea_ice_thickness" ;
        hice:grid_mapping = "stereographic" ;
        hice:coordinates = "longitude latitude" ;
        hice:cell_methods = "area: mean where sea_ice" ;
short uice(time, y, x) ;
        uice:_FillValue = -32767s ;
        uice:missing_value = -32767s ;
        uice:add_offset = 0. ;
        uice:scale_factor = 9.15667063455728e-05 ;
        uice:units = "m s-1" ;
        uice:standard_name = "sea_ice_x_velocity" ;
        uice:grid_mapping = "stereographic" ;
        uice:coordinates = "longitude latitude" ;
        uice:cell_methods = "area: mean where sea_ice" ;
short vice(time, y, x) ;
        vice:_FillValue = -32767s ;
        vice:missing_value = -32767s ;
        vice:add_offset = 0. ;
        vice:scale_factor = 9.15667063455728e-05 ;
        vice:units = "m s-1" ;
        vice:standard_name = "sea_ice_y_velocity" ;
        vice:grid_mapping = "stereographic" ;
        vice:coordinates = "longitude latitude" ;
```

```
        vice:cell_methods = "area: mean where sea_ice" ;
short hsnow(time, y, x) ;
        hsnow:_FillValue = -32767s ;
        hsnow:missing_value = -32767s ;
        hsnow:add_offset = 1.5 ;
        hsnow:scale_factor = 4.57833531727864e-05 ;
        hsnow:units = "m" ;
        hsnow:standard_name = "surface_snow_thickness" ;
        hsnow:grid_mapping = "stereographic" ;
        hsnow:coordinates = "longitude latitude" ;
        hsnow:cell_methods = "area: mean where sea_ice" ;
short fy_frac(time, y, x) ;
        fy_frac:_FillValue = -32767s ;
        fy_frac:missing_value = -32767s ;
        fy_frac:add_offset = 0.5 ;
        fy_frac:scale_factor = 1.52611177242621e-05 ;
        fy_frac:units = "1" ;
        fy_frac:long_name = "fraction_of_first_year_ice" ;
        fy_frac:grid_mapping = "stereographic" ;
        fy_frac:coordinates = "longitude latitude" ;
        fy_frac:cell_methods = "area: mean" ;
short fy_age(time, y, x) ;
        fy_age:_FillValue = -32767s ;
        fy_age:missing_value = -32767s ;
        fy_age:add_offset = 182.5 ;
        fy_age:scale_factor = 0.00557030796935568 ;
        fy_age:units = "day" ;
        fy_age:long_name = "age_of_first_year_ice" ;
        fy_age:grid_mapping = "stereographic" ;
        fy_age:coordinates = "longitude latitude" ;
        fy_age:cell_methods = "area: mean" ;
```

```
short albedo(time, y, x) ;
        albedo:_FillValue = -32767s ;
        albedo:missing_value = -32767s ;
        albedo:add_offset = 0.5 ;
        albedo:scale_factor = 1.52611177242621e-05 ;
        albedo:units = "1" ;
        albedo:standard_name = "sea_ice_albedo" ;
        albedo:grid_mapping = "stereographic" ;
        albedo:coordinates = "longitude latitude" ;
        albedo:cell_methods = "area: mean" ;
short btemp(time, y, x) ;
        btemp:_FillValue = -32767s ;
        btemp:missing_value = -32767s ;
        btemp:add_offset = 23.5 ;
        btemp:scale_factor = 0.000808839239385893 ;
        btemp:units = "Celsius" ;
        btemp:standard_name = "sea_water_potential_temperature_at_sea_floor" ;
        btemp:long_name = "Sea floor potential temperature" ;
        btemp:grid_mapping = "stereographic" ;
        btemp:coordinates = "longitude latitude" ;
        btemp:cell_methods = "area: mean" ;

// global attributes:
        :title = "Arctic Ocean Physics Analysis and Forecast, 12.5km daily mean (dataset-topaz4-arc-myoceanv2-be)" ;
        :institution = "MET Norway, Henrik Mohns plass 1, N-0313 Oslo, Norway" ;
        :history = "20170529:Created by program hyc2proj, version V0.3" ;
        :source = "NERSC-HYCOM model fields" ;
        :references = "http://marine.copernicus.eu" ;
        :field_type = "Files based on file type nersc_daily" ;
        :Conventions = "CF-1.4" ;
```

```
                :field_date = "2017-05-29" ;
                :bulletin_date = "2017-05-29" ;
                :bulletin_type = "Forecast" ;
                :Forecast_range = "10 days" ;
}
```

The same output from a sample file of dataset-topaz4-arc-1hr-myoeanv2-be:

```
netcdf \20171107_hr-metno-MODEL-topaz4-ARC-b20171107-fv02.0 {
dimensions:
        x = 609 ;
        y = 881 ;
        time = UNLIMITED ; // (24 currently)
variables:
        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" ;
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "forecast time" ;
                time:units = "hours since 1950-01-01 00:00:00" ;
                time:calendar = "standard" ;
        short model_depth(y, x) ;
                model_depth:standard_name = "sea_floor_depth_below_sea_level" ;
                model_depth:units = "meter" ;
```

```
        model_depth:coordinates = "longitude latitude" ;
        model_depth:add_offset = 5000.5 ;
        model_depth:scale_factor = 0.152626438360346 ;
        model_depth:_FillValue = -32767s ;
        model_depth:missing_value = -32767s ;
        model_depth:cell_methods = "area: mean" ;
short salinity(time, y, x) ;
        salinity:standard_name = "sea_water_salinity" ;
        salinity:units = "1e-3" ;
        salinity:coordinates = "longitude latitude" ;
        salinity:add_offset = 22.5 ;
        salinity:scale_factor = 0.000686750297591796 ;
        salinity:_FillValue = -32767s ;
        salinity:missing_value = -32767s ;
        salinity:cell_methods = "area: mean" ;
short temperature(time, y, x) ;
        temperature:standard_name = "sea_water_potential_temperature" ;
        temperature:units = "Celsius" ;
        temperature:coordinates = "longitude latitude" ;
        temperature:add_offset = 23.5 ;
        temperature:scale_factor = 0.000808839239385893 ;
        temperature:_FillValue = -32767s ;
        temperature:missing_value = -32767s ;
        temperature:cell_methods = "area: mean" ;
short fice(time, y, x) ;
        fice:standard_name = "sea_ice_area_fraction" ;
        fice:units = "1" ;
        fice:coordinates = "longitude latitude" ;
        fice:add_offset = 0.5 ;
        fice:scale_factor = 1.52611177242621e-05 ;
        fice:_FillValue = -32767s ;
```

```
        fice:missing_value = -32767s ;
        fice:cell_methods = "area: mean" ;
short hice(time, y, x) ;
        hice:standard_name = "sea_ice_thickness" ;
        hice:units = "m" ;
        hice:coordinates = "longitude latitude" ;
        hice:add_offset = 10. ;
        hice:scale_factor = 0.000305222354485242 ;
        hice:_FillValue = -32767s ;
        hice:missing_value = -32767s ;
        hice:cell_methods = "area: mean where sea_ice" ;
short hsnow(time, y, x) ;
        hsnow:standard_name = "surface_snow_thickness" ;
        hsnow:units = "m" ;
        hsnow:coordinates = "longitude latitude" ;
        hsnow:add_offset = 1.5 ;
        hsnow:scale_factor = 4.57833531727864e-05 ;
        hsnow:_FillValue = -32767s ;
        hsnow:missing_value = -32767s ;
        hsnow:cell_methods = "area: mean where sea_ice" ;
short uice(time, y, x) ;
        uice:standard_name = "sea_ice_x_velocity" ;
        uice:units = "m s-1" ;
        uice:coordinates = "longitude latitude" ;
        uice:add_offset = 0. ;
        uice:scale_factor = 9.15667063455728e-05 ;
        uice:_FillValue = -32767s ;
        uice:missing_value = -32767s ;
        uice:cell_methods = "area: mean where sea_ice" ;
short vice(time, y, x) ;
        vice:standard_name = "sea_ice_y_velocity" ;
```

```
        vice:units = "m s-1" ;
        vice:coordinates = "longitude latitude" ;
        vice:add_offset = 0. ;
        vice:scale_factor = 9.15667063455728e-05 ;
        vice:_FillValue = -32767s ;
        vice:missing_value = -32767s ;
        vice:cell_methods = "area: mean where sea_ice" ;
float ssh(time, y, x) ;
        ssh:standard_name = "sea_surface_elevation" ;
        ssh:units = "m" ;
        ssh:coordinates = "longitude latitude" ;
        ssh:_FillValue = -1.e+14f ;
        ssh:missing_value = -1.e+14f ;
        ssh:cell_methods = "area: mean" ;
float u(time, y, x) ;
        u:coordinates = "longitude latitude" ;
        u:_FillValue = -32767.f ;
        u:missing_value = -32767.f ;
        u:standard_name = "x_sea_water_velocity" ;
        u:units = "m s-1" ;
        u:grid_mapping = "stereographic" ;
        u:cell_methods = "area:mean" ;
float v(time, y, x) ;
        v:coordinates = "longitude latitude" ;
        v:_FillValue = -32767.f ;
        v:missing_value = -32767.f ;
        v:standard_name = "y_sea_water_velocity" ;
        v:units = "m s-1" ;
        v:grid_mapping = "stereographic" ;
        v:cell_methods = "area:mean" ;
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:false_easting = 0. ;
                stereographic:false_northing = 0. ;
        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" ;

// global attributes:
                :CDI = "Climate Data Interface version 1.6.7 (https://code.zmaw.de/projects/cdi)" ;
                :Conventions = "CF-1.4" ;
                :title = "Arctic Ocean Physics Analysis and Forecast, 12.5km hourly instantaneous (dataset-topaz4-arc-1hr-myoceanv2-be)" ;
                :references = "http://marine.copernicus.eu" ;
                :field_type = "Files based on file type archs" ;
                :field_date = "2017-11-07" ;
                :bulletin_date = "2017-11-07" ;
                :CDO = "Climate Data Operators version 1.6.7 (https://code.zmaw.de/projects/cdo)" ;
                :NCO = "4.4.7" ;
                :bulletin_type = "Forecast" ;
                :Forecast_range = "10 days" ;
}
```

V.2.2 Output from an ARCTIC_ANALYSIS_FORECAST_BIO_002_004 sample file:

```
netcdf \20170530_dm-metno-MODEL-topaz4_ecosmo-ARC-b20170530-fv02.0 {
dimensions:
        x = 609 ;
        y = 881 ;
        depth = 12 ;
        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:false_easting = 0. ;
                stereographic:false_northing = 0. ;
        double time(time) ;
                time:units = "hour since 1950-1-1T00:00:00Z" ;
                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" ;
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 pp_depth(time, y, x) ;
        pp_depth:_FillValue = -32767s ;
        pp_depth:missing_value = -32767s ;
        pp_depth:add_offset = 5.e-08 ;
        pp_depth:scale_factor = 1.52611177242621e-12 ;
        pp_depth:units = "kg m-2 s-1" ;
        pp_depth:standard_name = "gross_primary_productivity_of_carbon" ;
        pp_depth:grid_mapping = "stereographic" ;
        pp_depth:coordinates = "longitude latitude" ;
        pp_depth:cell_methods = "area: mean" ;
short chla(time, depth, y, x) ;
        chla:_FillValue = -32767s ;
        chla:missing_value = -32767s ;
```

chla:add_offset = 5.e-05 ;

chla:scale_factor = 1.52611177242621e-09 ;

chla:units = "kg m-3" ;

chla:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water" ;

chla:grid_mapping = "stereographic" ;

chla:coordinates = "longitude latitude" ;

chla:cell_methods = "area: mean" ;

short attcoef(time, depth, y, x) ;

attcoef:_FillValue = -32767s ;

attcoef:missing_value = -32767s ;

attcoef:add_offset = 0.25 ;

attcoef:scale_factor = 7.63055886213106e-06 ;

attcoef:units = "m-1" ;

attcoef:standard_name = "volume_attenuation_coefficient_of_downwelling_radiative_flux_in_sea_water" ;

attcoef:grid_mapping = "stereographic" ;

attcoef:coordinates = "longitude latitude" ;

attcoef:cell_methods = "area: mean" ;

short nitrat(time, depth, y, x) ;

nitrat:_FillValue = -32767s ;

nitrat:missing_value = -32767s ;

nitrat:add_offset = 0.025 ;

nitrat:scale_factor = 7.63055886213106e-07 ;

nitrat:units = "mole m-3" ;

nitrat:standard_name = "mole_concentration_of_nitrate_in_sea_water" ;

nitrat:grid_mapping = "stereographic" ;

nitrat:coordinates = "longitude latitude" ;

nitrat:cell_methods = "area: mean" ;

short phosphat(time, depth, y, x) ;

phosphat:_FillValue = -32767s ;

phosphat:missing_value = -32767s ;

phosphat:add_offset = 0.005 ;

phosphat:scale_factor = 1.52611177242621e-07 ;

phosphat:units = "mole m-3" ;

phosphat:standard_name = "mole_concentration_of_phosphate_in_sea_water" ;

phosphat:grid_mapping = "stereographic" ;

phosphat:coordinates = "longitude latitude" ;

phosphat:cell_methods = "area: mean" ;

short pbiomass(time, depth, y, x) ;

pbiomass:_FillValue = -32767s ;

pbiomass:missing_value = -32767s ;

pbiomass:add_offset = 0.005 ;

pbiomass:scale_factor = 1.52611177242621e-07 ;

pbiomass:units = "mole m-3" ;

pbiomass:standard_name = "mole_concentration_of_phytoplankton_expressed_as_nitrogen_in_sea_water" ;

pbiomass:grid_mapping = "stereographic" ;

pbiomass:coordinates = "longitude latitude" ;

pbiomass:cell_methods = "area: mean" ;

short zbiomass(time, depth, y, x) ;

zbiomass:_FillValue = -32767s ;

zbiomass:missing_value = -32767s ;

zbiomass:add_offset = 0.005 ;

zbiomass:scale_factor = 1.52611177242621e-07 ;

zbiomass:units = "mole m-3" ;

zbiomass:standard_name = "mole_concentration_of_zooplankton_expressed_as_nitrogen_in_sea_water" ;

zbiomass:grid_mapping = "stereographic" ;

zbiomass:coordinates = "longitude latitude" ;

zbiomass:cell_methods = "area: mean" ;

short oxygen(time, depth, y, x) ;

oxygen:_FillValue = -32767s ;

oxygen:missing_value = -32767s ;

```
            oxygen:add_offset = 0.025 ;
            oxygen:scale_factor = 7.63055886213106e-07 ;
            oxygen:units = "kg m-3" ;
            oxygen:standard_name = "mass_concentration_of_oxygen_in_sea_water" ;
            oxygen:grid_mapping = "stereographic" ;
            oxygen:coordinates = "longitude latitude" ;
            oxygen:cell_methods = "area: mean" ;
      short silicate(time, depth, y, x) ;
            silicate:_FillValue = -32767s ;
            silicate:missing_value = -32767s ;
            silicate:add_offset = 0.05 ;
            silicate:scale_factor = 1.52611177242621e-06 ;
            silicate:units = "mole m-3" ;
            silicate:standard_name = "mole_concentration_of_silicate_in_sea_water" ;
            silicate:grid_mapping = "stereographic" ;
            silicate:coordinates = "longitude latitude" ;
            silicate:cell_methods = "area: mean" ;

// global attributes:
            :title = "Arctic Ocean Biogeochemistry Analysis and Forecast, 12.5km daily mean (dataset-topaz4-bio-arc-myoceanv2-be)" ;
            :institution = "MET Norway, Henrik Mohns plass 1, N-0313 Oslo, Norway" ;
            :history = "20170530:Created by program hyc2proj, version V0.3" ;
            :source = "NERSC-HYCOM model fields" ;
            :references = "http://marine.copernicus.eu" ;
            :field_type = "Files based on file type nersc_daily" ;
            :Conventions = "CF-1.4" ;
            :field_date = "2017-05-30" ;
            :bulletin_date = "2017-05-30" ;
            :bulletin_type = "Forecast" ;
            :Forecast_range = "10 days" ;
```

}

V.2.3 Output of the ARCTIC_ANALYSISFORECAST_PHY_ICE_002_011:

```
netcdf \20190321_hr-nersc-MODEL-nextsimf-ARC-b20190314-fv00.0 {
dimensions:
	time = UNLIMITED ; // (24 currently)
	nv = 2 ;
	y = 2367 ;
	x = 2467 ;
variables:
	byte projection_stereo ;
		projection_stereo:latitude_of_projection_origin = 90. ;
		projection_stereo:longitude_of_projection_origin = -45. ;
		projection_stereo:straight_vertical_longitude_from_pole = -45. ;
		projection_stereo:semi_major_axis = 6378273. ;
		projection_stereo:semi_minor_axis = 6378273. ;
		projection_stereo:scale_factor_at_projection_origin = 1. ;
		projection_stereo:grid_mapping_name = "polar_stereographic" ;
		projection_stereo:false_northing = 0. ;
		projection_stereo:false_easting = 0. ;
		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 " ;
	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:bounds = "time_bnds" ;
	double time_bnds(time, nv) ;
		time_bnds:units = "days since 1900-01-01 00:00:00" ;
```

```
        time_bnds:calendar = "standard" ;
    double y(y) ;
        y:standard_name = "projection_y_coordinate" ;
        y:units = "m" ;
        y:axis = "Y" ;
    double x(x) ;
        x:standard_name = "projection_x_coordinate" ;
        x:units = "m" ;
        x:axis = "X" ;
    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" ;
    float siconc(time, y, x) ;
        siconc:standard_name = "sea_ice_area_fraction" ;
        siconc:long_name = "Sea Ice Concentration" ;
        siconc:units = "1" ;
        siconc:cell_methods = "time: mean (interval: 1 hours) area: mean" ;
        siconc:_FillValue = -1.e+14f ;
        siconc:grid_mapping = "projection_stereo" ;
    float sithick(time, y, x) ;
        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:_FillValue = -1.e+14f ;
        sithick:grid_mapping = "projection_stereo" ;
```

```
        float sisnthick(time, y, x) ;
                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:_FillValue = -1.e+14f ;
                sisnthick:grid_mapping = "projection_stereo" ;
        float vxsi(time, y, x) ;
                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:_FillValue = -1.e+14f ;
                vxsi:grid_mapping = "projection_stereo" ;
        float vysi(time, y, x) ;
                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:_FillValue = -1.e+14f ;
                vysi:grid_mapping = "projection_stereo" ;

// global attributes:
                :Conventions = "CF-1.6" ;
                :institution = "NERSC, Thormoehlens gate 47, N-5006 Bergen, Norway" ;
                :source = "neXtSIM model fields" ;
                :email = "nextsimf@nersc.no" ;
                :title = "neXtSIM-F sea ice forecast, 3.5 km hourly averaged fields" ;
                :field_type = "Files based on file type moorings" ;
                :bulletin_type = "Forecast" ;
                :forecast_range = "7 days" ;
```

```
                :field_date = "2019-03-21" ;
                :bulletin_date = "2019-03-14" ;
                :history = "cmems_postproc.py /cluster/work/users/timill/nextsimf_forecasts/ma10km_cmems_forecast.AssimConc.extended_all/20190314 config-files/cmems_pp.cfg n 20190314 8" ;
}
```

V.2.4 Output of the ARCTIC_ANALYSISFORECAST_PHY_TIDE_002_015

```
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_REANALYSIS_PHYS_002_003 product:

```
netcdf topaz_V4_cmems_arctic_grid1to8_da_class1_20181231 {
dimensions:
        x = 609 ;
        y = 881 ;
        depth = 12 ;
        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:false_easting = 0. ;
                stereographic:false_northing = 0. ;
        double time(time) ;
                time:units = "hour since 1950-1-1T00:00:00Z" ;
                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" ;
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 temperature(time, depth, y, x) ;
        temperature:_FillValue = -32767s ;
        temperature:missing_value = -32767s ;
        temperature:add_offset = 23.5 ;
        temperature:scale_factor = 0.000808839239385893 ;
        temperature:units = "Celsius" ;
```

```
        temperature:standard_name = "sea_water_potential_temperature" ;
        temperature:grid_mapping = "stereographic" ;
        temperature:coordinates = "longitude latitude" ;
        temperature:cell_methods = "area: mean" ;
short salinity(time, depth, y, x) ;
        salinity:_FillValue = -32767s ;
        salinity:missing_value = -32767s ;
        salinity:add_offset = 22.5 ;
        salinity:scale_factor = 0.000686750297591796 ;
        salinity:units = "1e-3" ;
        salinity:standard_name = "sea_water_salinity" ;
        salinity:grid_mapping = "stereographic" ;
        salinity:coordinates = "longitude latitude" ;
        salinity:cell_methods = "area: mean" ;
short u(time, depth, y, x) ;
        u:_FillValue = -32767s ;
        u:missing_value = -32767s ;
        u:add_offset = 0. ;
        u:scale_factor = 9.15667063455727e-05 ;
        u:units = "m s-1" ;
        u:standard_name = "x_sea_water_velocity" ;
        u:grid_mapping = "stereographic" ;
        u:coordinates = "longitude latitude" ;
        u:cell_methods = "area: mean" ;
short v(time, depth, y, x) ;
        v:_FillValue = -32767s ;
        v:missing_value = -32767s ;
        v:add_offset = 0. ;
        v:scale_factor = 9.15667063455727e-05 ;
        v:units = "m s-1" ;
        v:standard_name = "y_sea_water_velocity" ;
```

```
                v:grid_mapping = "stereographic" ;
                v:coordinates = "longitude latitude" ;
                v:cell_methods = "area: mean" ;
        float ssh(time, y, x) ;
                ssh:_FillValue = -1.e+14f ;
                ssh:missing_value = -1.e+14f ;
                ssh:units = "m" ;
                ssh:standard_name = "sea_surface_elevation" ;
                ssh:grid_mapping = "stereographic" ;
                ssh:coordinates = "longitude latitude" ;
                ssh:cell_methods = "area: mean" ;
        short bsfd(time, y, x) ;
                bsfd:_FillValue = -32767s ;
                bsfd:missing_value = -32767s ;
                bsfd:add_offset = 0. ;
                bsfd:scale_factor = 305222.354485242 ;
                bsfd:units = "m3 s-1" ;
                bsfd:standard_name = "ocean_barotropic_streamfunction" ;
                bsfd:grid_mapping = "stereographic" ;
                bsfd:coordinates = "longitude latitude" ;
                bsfd:cell_methods = "area: mean" ;
        short mlp(time, y, x) ;
                mlp:_FillValue = -32767s ;
                mlp:missing_value = -32767s ;
                mlp:add_offset = 2500. ;
                mlp:scale_factor = 0.0763055886213106 ;
                mlp:units = "m" ;
                mlp:standard_name = "ocean_mixed_layer_thickness" ;
                mlp:grid_mapping = "stereographic" ;
                mlp:coordinates = "longitude latitude" ;
                mlp:cell_methods = "area: mean" ;
```

```
		mlp:long_name = "Defined by a delta of sigma(density) = 0.05." ; *
	short fice(time, y, x) ;
		fice:_FillValue = -32767s ;
		fice:missing_value = -32767s ;
		fice:add_offset = 0.5 ;
		fice:scale_factor = 1.52611177242621e-05 ;
		fice:units = "1" ;
		fice:standard_name = "sea_ice_area_fraction" ;
		fice:grid_mapping = "stereographic" ;
		fice:coordinates = "longitude latitude" ;
		fice:cell_methods = "area: mean" ;
	short hice(time, y, x) ;
		hice:_FillValue = -32767s ;
		hice:missing_value = -32767s ;
		hice:add_offset = 10. ;
		hice:scale_factor = 0.000305222354485242 ;
		hice:units = "m" ;
		hice:standard_name = "sea_ice_thickness" ;
		hice:grid_mapping = "stereographic" ;
		hice:coordinates = "longitude latitude" ;
		hice:cell_methods = "area: mean where sea_ice" ;
	short hsnow(time, y, x) ;
		hsnow:_FillValue = -32767s ;
		hsnow:missing_value = -32767s ;
		hsnow:add_offset = 1.5 ;
		hsnow:scale_factor = 4.57833531727864e-05 ;
		hsnow:units = "m" ;
		hsnow:standard_name = "surface_snow_thickness" ;
		hsnow:grid_mapping = "stereographic" ;
		hsnow:coordinates = "longitude latitude" ;
		hsnow:cell_methods = "area: mean where sea_ice" ;
```

```
short uice(time, y, x) ;
        uice:_FillValue = -32767s ;
        uice:missing_value = -32767s ;
        uice:add_offset = 0. ;
        uice:scale_factor = 9.15667063455727e-05 ;
        uice:units = "m s-1" ;
        uice:standard_name = "sea_ice_x_velocity" ;
        uice:grid_mapping = "stereographic" ;
        uice:coordinates = "longitude latitude" ;
        uice:cell_methods = "area: mean where sea_ice" ;
short vice(time, y, x) ;
        vice:_FillValue = -32767s ;
        vice:missing_value = -32767s ;
        vice:add_offset = 0. ;
        vice:scale_factor = 9.15667063455727e-05 ;
        vice:units = "m s-1" ;
        vice:standard_name = "sea_ice_y_velocity" ;
        vice:grid_mapping = "stereographic" ;
        vice:coordinates = "longitude latitude" ;
        vice:cell_methods = "area: mean where sea_ice" ;
short btemp(time, y, x) ;
        btemp:_FillValue = -32767s ;
        btemp:missing_value = -32767s ;
        btemp:add_offset = 23.5 ;
        btemp:scale_factor = 0.000808839239385893 ;
        btemp:units = "Celsius" ;
        btemp:standard_name = "sea_water_potential_temperature_at_sea_floor" ;
        btemp:long_name = "Sea floor potential temperature" ;
        btemp:grid_mapping = "stereographic" ;
        btemp:coordinates = "longitude latitude" ;
        btemp:cell_methods = "area: mean" ;
```

// global attributes:

:title = "Arctic Ocean Physics Reanalysis, daily surface fields" ;

:institution = "NERSC, Thormoehlens gate 47, N-5006 Bergen, Norway" ;

:history = "20190502: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 = "2018-12-31" ;

:bulletin_date = "2018-12-26" ;

:version = "Interim" ;}

*: Note that this MLD attribute is a typo, the real value of the delta-density for MLD calculation is 0.03 as in the NRT product

V.2.6 Output for ARCTIC_REANALYSIS_BIO_002_005 product:

netcdf \20070115_mm-NERSC-MODEL-TOPAZ4BIO-ARC-RAN-fv02 {

dimensions:

x = 305 ;

y = 432 ;

depth = 12 ;

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:false_easting = 0. ;

```
        stereographic:false_northing = 0. ;
    double time(time) ;
        time:units = "hour since 1950-1-1T00:00:00Z" ;
        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" ;
    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 attcoef(time, depth, y, x) ;
        attcoef:_FillValue = -32767s ;
        attcoef:missing_value = -32767s ;
        attcoef:add_offset = 0.25 ;
        attcoef:scale_factor = 7.63055886213106e-06 ;
        attcoef:units = "m-1" ;
        attcoef:standard_name =
"volume_attenuation_coefficient_of_downwelling_radiative_flux_in_sea_water" ;
        attcoef:grid_mapping = "stereographic" ;
        attcoef:coordinates = "longitude latitude" ;
        attcoef:cell_methods = "area: mean" ;
    short chla(time, depth, y, x) ;
        chla:_FillValue = -32767s ;
        chla:missing_value = -32767s ;
        chla:add_offset = 5.e-05 ;
        chla:scale_factor = 1.52611177242621e-09 ;
        chla:units = "kg m-3" ;
        chla:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water" ;
        chla:grid_mapping = "stereographic" ;
        chla:coordinates = "longitude latitude" ;
        chla:cell_methods = "area: mean" ;
    short nitrat(time, depth, y, x) ;
        nitrat:_FillValue = -32767s ;
        nitrat:missing_value = -32767s ;
        nitrat:add_offset = 0.025 ;
        nitrat:scale_factor = 7.63055886213106e-07 ;
        nitrat:units = "mole m-3" ;
        nitrat:standard_name = "mole_concentration_of_nitrate_in_sea_water" ;
```

```
		nitrat:grid_mapping = "stereographic" ;
		nitrat:coordinates = "longitude latitude" ;
		nitrat:cell_methods = "area: mean" ;
	short phosphat(time, depth, y, x) ;
		phosphat:_FillValue = -32767s ;
		phosphat:missing_value = -32767s ;
		phosphat:add_offset = 0.005 ;
		phosphat:scale_factor = 1.52611177242621e-07 ;
		phosphat:units = "mole m-3" ;
		phosphat:standard_name = "mole_concentration_of_phosphate_in_sea_water" ;
		phosphat:grid_mapping = "stereographic" ;
		phosphat:coordinates = "longitude latitude" ;
		phosphat:cell_methods = "area: mean" ;
	short oxygen(time, depth, y, x) ;
		oxygen:_FillValue = -32767s ;
		oxygen:missing_value = -32767s ;
		oxygen:add_offset = 0.025 ;
		oxygen:scale_factor = 7.63055886213106e-07 ;
		oxygen:units = "kg m-3" ;
		oxygen:standard_name = "mass_concentration_of_oxygen_in_sea_water" ;
		oxygen:grid_mapping = "stereographic" ;
		oxygen:coordinates = "longitude latitude" ;
		oxygen:cell_methods = "area: mean" ;
	short pbiomass(time, depth, y, x) ;
		pbiomass:_FillValue = -32767s ;
		pbiomass:missing_value = -32767s ;
		pbiomass:add_offset = 0.005 ;
		pbiomass:scale_factor = 1.52611177242621e-07 ;
		pbiomass:units = "mole m-3" ;
		pbiomass:standard_name =
"mole_concentration_of_phytoplankton_in_sea_water_expressed_as_nitrogen" ;
```

```
        pbiomass:grid_mapping = "stereographic" ;
        pbiomass:coordinates = "longitude latitude" ;
        pbiomass:cell_methods = "area: mean" ;
    short zbiomass(time, depth, y, x) ;
        zbiomass:_FillValue = -32767s ;
        zbiomass:missing_value = -32767s ;
        zbiomass:add_offset = 0.005 ;
        zbiomass:scale_factor = 1.52611177242621e-07 ;
        zbiomass:units = "mole m-3" ;
        zbiomass:standard_name =
"mole_concentration_of_zooplankton_in_sea_water_expressed_as_nitrogen" ;
        zbiomass:grid_mapping = "stereographic" ;
        zbiomass:coordinates = "longitude latitude" ;
        zbiomass:cell_methods = "area: mean" ;

// global attributes:
        :title = "MyOcean Arctic bio pilot reanalysis TOPAZ4(2007-2010)" ;
        :institution = "NERSC, Thormoehlens gate 47, N-5006 Bergen, Norway" ;
        :history = "20151201: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 = "2007-02-00" ;
        :bulletin_date = "2007-02-00" ;
}
```

V.3 Reader software

NetCDF data can be browsed and used through a number of software packages, including:

- ✔ ncBrowse: http://www.epic.noaa.gov/java/ncBrowse/,
- ✔ NetCDF Operator (NCO): http://nco.sourceforge.net/
- ✔ IDL, Matlab, Panoply, GMT…