Project

Scientific Validation Report (ScVR) for V1 Real-time Forecasts

WP 05 ï ARC-MFC ï METNO

Reference: MYO-WP05-ScCV-RT-ARC-METNO-OSLO-NO

Project N°: FP7-SPACE-2007-1	**Work programme topic:** SPA.2007.1.1.01 - development of upgraded capabilities for existing GMES fast-track services and related (pre)operational services
Start Date of project :	**Duration**: 36 Months

WP leader: NERSC	**Issue:** V1.0
Contributors : Arne Melsom, Magne Simonsen	
MyOcean version scope : V1	
Approval Date :	**Approver:**
Dissemination level: CO	

DOCUMENT

VERIFICATION AND DISTRIBUTION LIST

	Name	Work Package	Date
Checked By:			
Distribution			

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
1.0		all	First version of document	Arne Melsom, Magne Simonsen	
	1st April (no joke)	II	Added differences between RA and RT systems	Laurent Bertino	

TABLE OF CONTENTS

APPLICABLE AND REFERENCE DOCUMENTS

Applicable Documents

	Ref	Title	Date / Issue
DA 1		Guidelines for the development and validation of pre-operational GMES Fast Track Services	April 2007
DA 2	MYO-MGT-DOW	My Ocean Management: Description of Work	March 2009 6.1

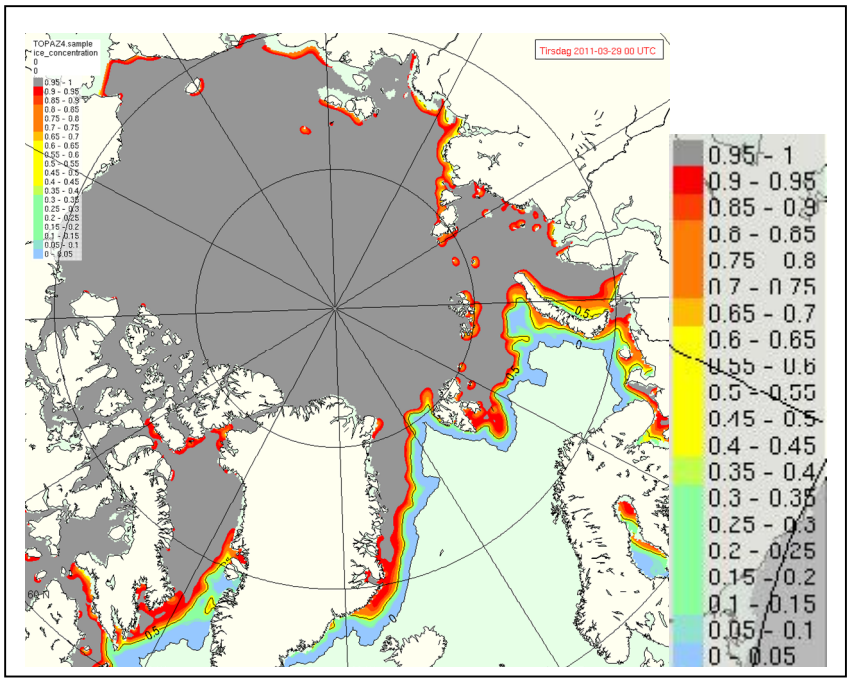
Reference Documents

	Ref	Title	Date / Issue
DR 1	MyO_WP5_ScVP	Scientific Validation Plan (ScVP) for the Arctic Marine Forecast Centre (Arctic MFC) WP05	?/ v0.2
DR 2	met.no Note 12/2010	Validation of sea ice concentration in the myOcean Arctic Monitoring and Forecasting Centre	August 2010/ N/A

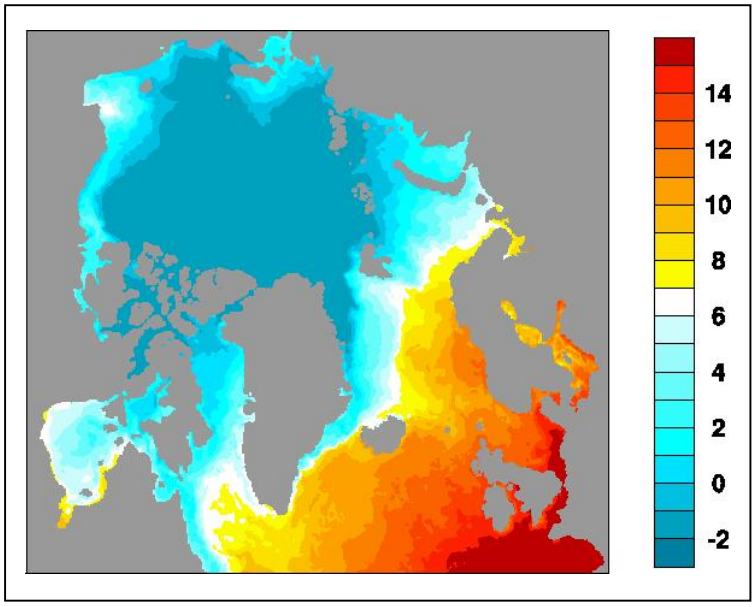
I INTRODUCTION

Our aim is to provide validation results of the V1 real-time forecast system for the first three months of operations after the public transition from V0 to V1 which took place in mid-December 2010. Validation is performed mainly against independent (i.e. non-assimilated) products from MyOcean TACs (SST TAC, SIW TAC, IS TAC).

We have focussed the present analysis on quantities which are of particular interest to the Arctic region as layed out in the Scientific Validation Plan from WP05. These are sea ice variables, and sea surface temperatures. Snapshots that illustrate model results for these variables are shown below.



Sea ice concentration, fractions in the range 0-1, as shown by the colour bar to the right of the map. Snapshot is for an arbitrary day in March, for a sub-domain of the TOPAZ4 full model domain. Provided for illustrative purposes only.



Sea surface temperature, in °C as shown by the colour bar to the right of the map. Snapshot is for an arbitrary day in March, for a sub-domain of the TOPAZ4 full model domain. Provided for illustrative purposes only.

II DESCRIPTION OF THE REANALYSIS/REPROCESSED ANALYSIS PROJECT

A separate report is provided for the validation of the reanalysis / reprocessed analysis from the ARC MFC, this report is submitted with reference MYO-WP05-ScCV-rea-ARC-NERSC-BERGEN-NO.

Some minor differences should be noted however, as the EnKF system applied in real-time at the time these results were produced did not include the following features of the reanalysis system:

R-factor.

By R-factor we refer to the following modification of the DA scheme. The ensemble update in the EnKF can be considered as a combination of the update of ensemble mean and the update of ensemble anomalies. While the former is defined by matching the first-order terms in the cost function, the latter is defined by matching the second-order terms, and therefore is much more susceptible to suboptimalities. The R-factor approach, instead of trying to ñfixòthe excessive reduction of the ensemble spread after the update by applying ensemble inflation, aims at avoiding the excessive reduction of the ensemble spread in the first instance. It achieves that by increasing the observation error variance during the update of the ensemble anomalies by a factor greater than 1, which is referred to the R-factor.

Adaptive observation pre-screening.

In V1 we increased observation error variance for outliers. However, due to the particular expression used for the updated observation error variance, the magnitude of the increment asymptotically approached zero as the distance between the state and the observation increased to infinity. In the new version the magnitude of the increment in the observation space asymptotically approaches two ensemble spreads, which only limits the impact of outliers on the system state, but does not eliminate it.

Observation error variances.

Based on analysis of innovation statistics, analysis observation impact diagnostics and comparison between model-derived profiles and observed profiles, the following changes in observation error variance have been made:

salinity: 0.01 (RT) -> 0.02 PSU^2 (RA) (0.01 -> 0.2 for Arctic)

temperature: 0.25 (RT) -> 0.5 deg C^2 (RA) (0.25 -> 2.0 for Arctic)

ice drift: 4900 (RT) -> 200 km ^2 (RA)

Bias estimation

Due to discovery of strong seasonal bias in SST and a substantial SSH bias in some regions, bias estimation has been introduced for the last year (2008) of the pilot reanalysis to estimate its possible effect on the performance of the system before starting the main reanalysis.

The above differences are the only differences between the reanalysis and real-time systems. They concern only the assimilation system, but the model system is exactly identical.

III DESCRIPTION OF THE VALIDATION METHODOLOGY

III.1 TOPAZ4 Production Cycle at met.no

The model results are produced with the TOPAZ ocean data assimilation model system. Presently, TOPAZ is run weekly with data assimilation one week prior to the bulletin date, followed by a one-week 100 member ensemble simulation ending on the bulletin date, and finally a 10 day, 10-member forecast. This forecast is re-run every day, forced by updated atmospheric fields. TOPAZ was developed and is maintained by the Nansen Center. (http://nersc.no/)

Product	sim. day	label	Tu_0	We_0	Th_0	Fr_0	Sa_0	Su_0	Mo_1	Tu_1	We_1	Th_1	Fr_1	Sa_1	Su_1	Mo_2	Tu_2	We_2	Th_2	Fr_2	Sa_2
Analysis	**Tu_1**			A																	
Forecast	**Tu_1**	-1		**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	
Ensemble	**We_1**			E	E	E	E	E	E	E											
Forecast	**We_1**	-2		F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	
Forecast	**Th_1**	-3		F	F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	
Forecast	**Fr_1**	-4		F	F	F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**	
Forecast	**Sa_1**	-5		F	F	F	F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	**F**	**F**	
Forecast	**Su_1**	-6		F	F	F	F	F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	**F**	
Forecast	**Mo_2**	-7		F	F	F	F	F	F	F	F	F	F	F	F	**F**	**F**	**F**	**F**	**F**	

In the table, same-date entries on the diagonal are shown using a light blue background colour.

III.2 Observational Data

Validation of the MyOcean Arctic MFC results for sea surface temperature is performed using data from drifting buoys, which are compiled by the MyOcean SST TAC. The buoy data are freely available from ftp://ftp.ifremer.fr/ifremer/cersat/projects/myocean/sst-tac/insitu/data/, operated by IFREMER, with a temporal resolution of approximately 3 hours. These data are converted to daily mean values to conform with the TOPAZ model results prior to the validation, and observations which have questionable quality are disregarded. Note that the analysis is not restricted to night-time data.

Validation of the MyOcean Arctic MFC results for sea surface temperature is also performed using the AATSR product which is based on observations from a satellite-borne instrument. The AATSR data are available from a password protected ftp site, operated by IFREMER. Although these data are included in one of the observational products that are assimilated in the ARC-MFC ocean model analysis, the AATSR product has a much stricter cloud mask than the assimilated product, and thus comes with an increased data quality at the expense of the domain coverage.

The validation of sea ice concentration and sea ice edge position is performed based on ice charts for the Arctic Ocean that are available from the MyOcean SIW TAC. The primary source of data for these ice charts are SAR images. The ice charts are produced daily on week days, and divides the domain into regions with a discrete set of sea ice classes, as defined by WMO. The data are freely available from http://thredds.met.no/thredds/catalog/myocean/siw-tac/siw-metno-svalbard/catalog.html. SAR

data are presently not included in the analysis and initialization of the ARC-MFC model, so these data constitute a set that is independent from the model results.

III.3 Model results

TOPAZ results are available as an aggregated ñbest estimatesò product from http://thredds.met.no/thredds/myocean/ARC-MFC/myoceanv1-class1-arctic.html?dataset=dataset-topaz4-arc-myocean-be, and as a list of separate forecasts from the production cycle with weekly updated bulletin dates from http://thredds.met.no/thredds/myocean/ARC-MFC/myoceanv1-class1-arctic.html. The ñbest estimateò product is a collection of daily means from the 100-member ensemble model, supplemented by results from the forecast for future dates which the 100-member ensemble does not yet cover.

Presently, the model results that are validated are

- sea surface temperature
- sea ice concentration
- position of the sea ice edge.

For the validation of sea surface temperature, model results for ocean temperature at the 5 meter level are used.

III.4 Validation products

The validation products are listed here:

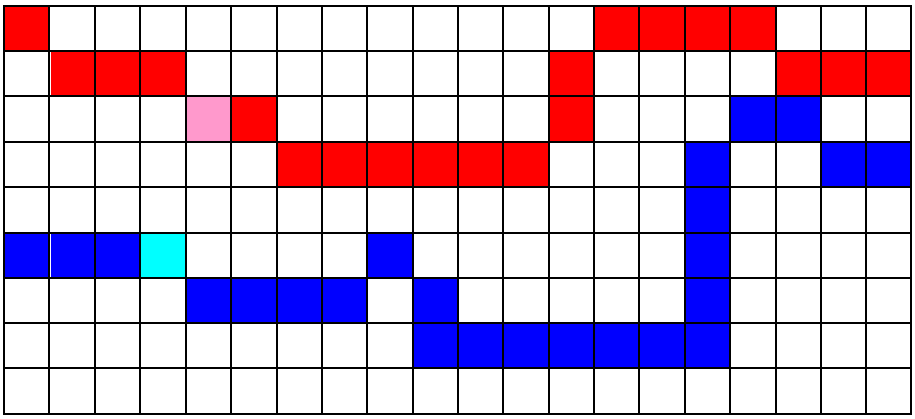
- Sea Surface Temperature - buoys
  - Number of observations
  - Bias
  - RMS error
  - Daily trend
  - Weekly trend
- Sea Surface Temperature – satellites (AATSR)
  - Number of observations
  - Bias
  - RMS error
  - Daily trend

- Sea Ice
  - RMS error of sea ice edge distance
  - RMS error of sea ice concentration
  - Ice Classes Area
    - Four ice classes:
      - Very open drift ice
      - Open drift ice
      - Close drift ice
      - Very close drift ice
  - Verifying number of grid points where ice class is matching

Arctic MFC validation results are updated weekly, presently late on Thursdays. Results are displayed on-line at http://myocean.met.no/ARC-MFC/Validation/index.html. Note that the validation software is re-run for each weekly bulletin after two weeks, in order to incorporate observations that span the entire forecast period. Bias always refers to results when observational values are subtracted from model results, so e.g. a positive bias in SST occurs when model output is warmer than the corresponding observations.

The algorithm for validation of sea ice concentration is described in detail in a report that is available from the web site mentioned above (to be specific, it may be downloaded e.g. from http://myocean.met.no/ARC-MFC/V1Validation/SeaIceConcentration/SICvalNote.pdf).

The algorithm for computing the RMS distance between the model ice edge and the observed ice edge is an extension of the methods used to validate sea ice concentration. The ice edge is here defined as the boundary between ice classes Very Open Drift Ice (VODI) and Open Drift Ice (ODI). In practice, the edge is identified by those grids which belong to class ODI and has at least one neighbour (up, down, left or right) belonging to class VODI. An illustration of how the identified grids may line up are displayed below, with one product (e.g. observations) represented by the red grids, and the other represented by the blue grids.



Then, for each grid belonging to the model sea ice edge, e.g. the light blue grid above, the closest grid belonging to the observed edge grids is found, in our example this is the light red grid. The distance between the observed and modeled sea ice edge is then taken to be the distance between the centres of these two grids.

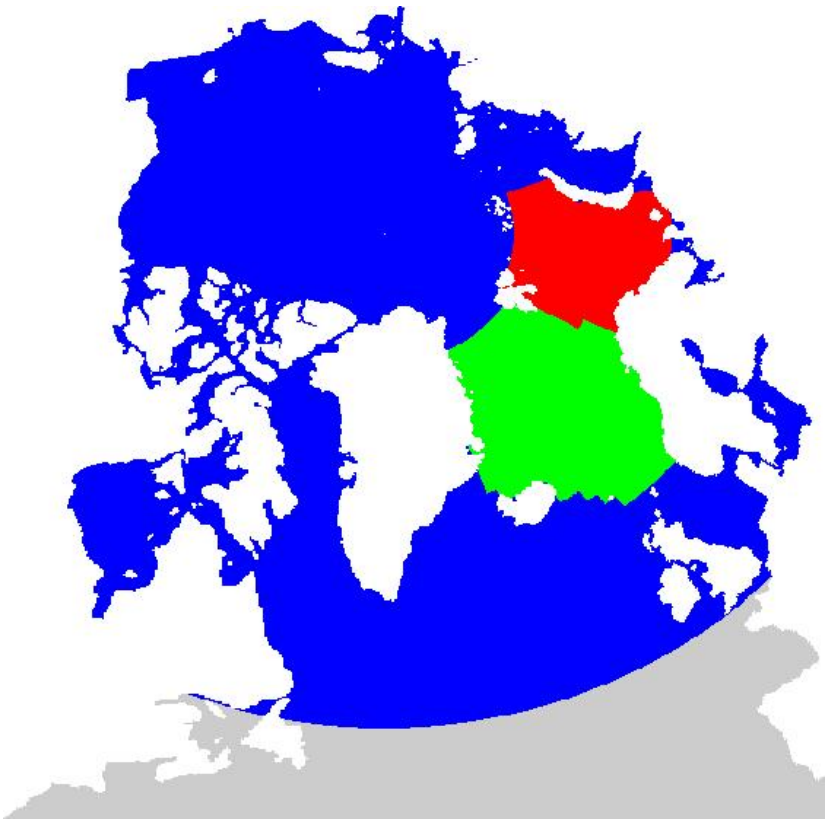
III.5 Period

Results from the V1 products have been validated since 2010-10-27. These product achieved operational status on 2010-12-15, and were preceded by validation of the V0 ARC MFC model (from mid-January 2010 to mid-March 2011).

III.6 Regions

The ocean circulation model used in myOcean's Arctic MFC covers the Arctic Ocean, the North Atlantic Ocean and adjacent ocean regions. The northern part is depicted in the figure below. Validation of sea surface temperature from model results is performed for three domains:

- an extended domain indicated by the blue, green and red regions in the figure
- the Nordic Seas, shown as the green region
- the Barents Sea, depicted in red



IV VALIDATION RESULTS

The figures in this chapter are time series of selected validation quantities, with bulletin dates provided on the x-axis. Lines labeled ñD+0ô(full lines in most of the time series) are validation of the daily mean from first the 24 hours after the data assimilation/model re-initialization, whereas ñD+6ô(dashed lines) refers to the daily mean centered at a date that lags the ñD+0ôcurve by 6 days. Results from the ñbest estimateòproduct are displayed by green lines, whereas results from the ñforecastòproduct are shown as blue lines. More details on the definitions of the ñbest estimateò and ñforecastò products are provided in Chapter III.3 (and Chapter III.1).

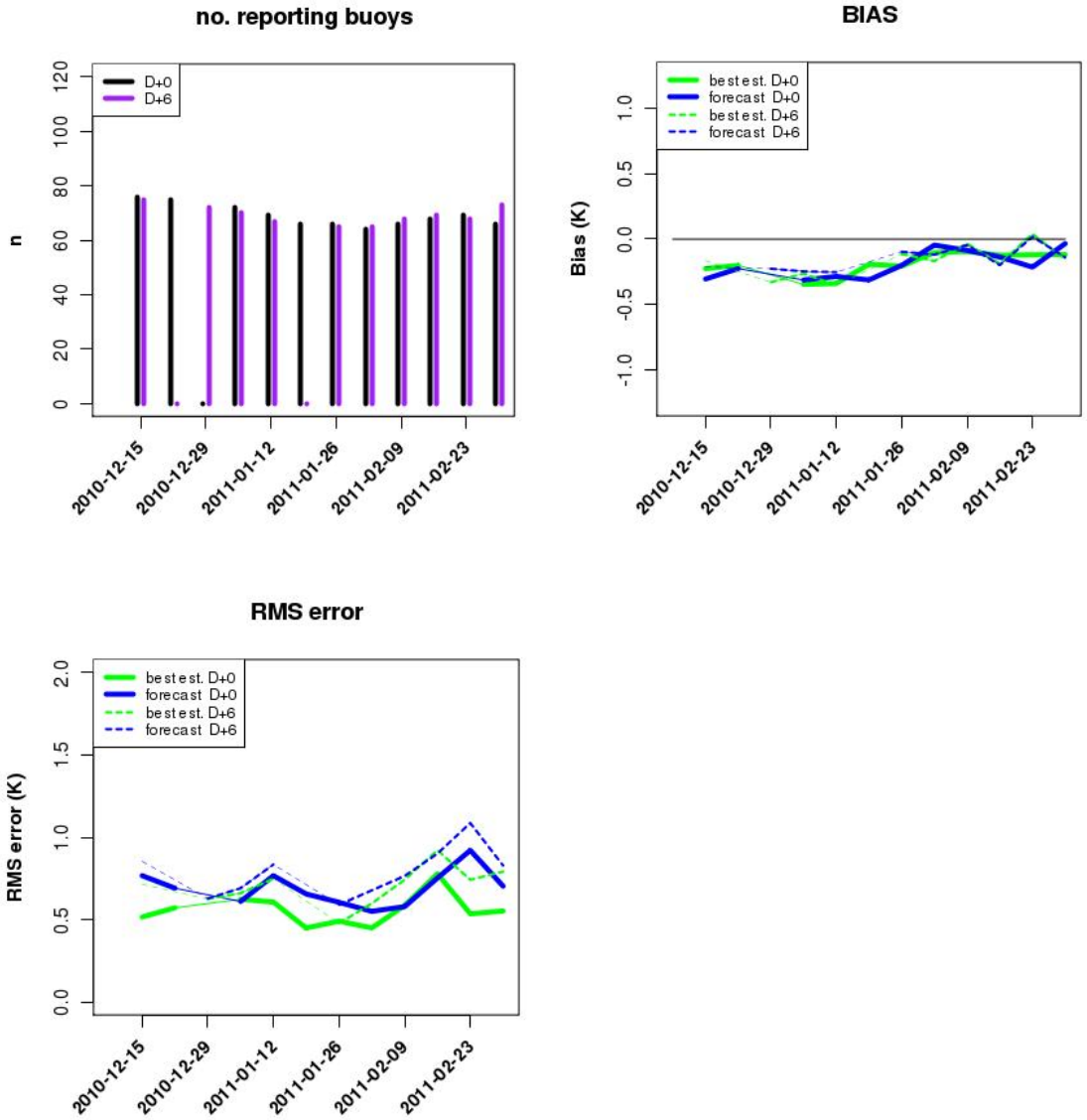
In some of the figures lines are thin in parts of the full time series. Thin lines are used to bridge curves when validation results are not available from one or more intermediate bulletin dates due to lack of observations.

The term ñTOPAZò here refers to the real-time assimilation and model system operated by the Arctic MFC.

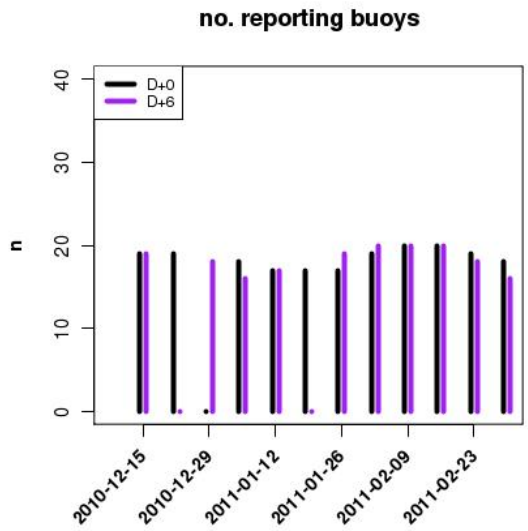
IV.1 Validation *vs*. SST observations from drifting buoys

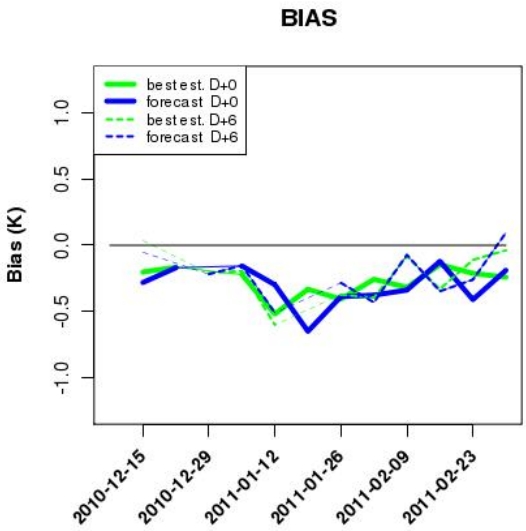
The validation *vs*. drifting buoy data was stopped in mid-March due to a disruption in the data delivery from the SST TAC. At the time of writing (2010-03-27), the most recent drifting buoy data are observations from 2010-03-13.

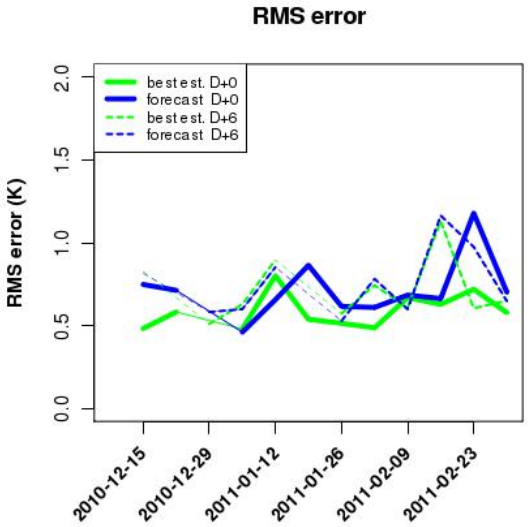
IV.1.1 Full domain



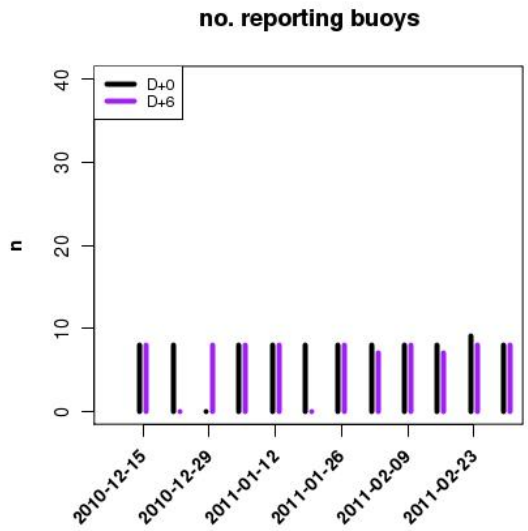
IV.1.2 Nordic Seas domain

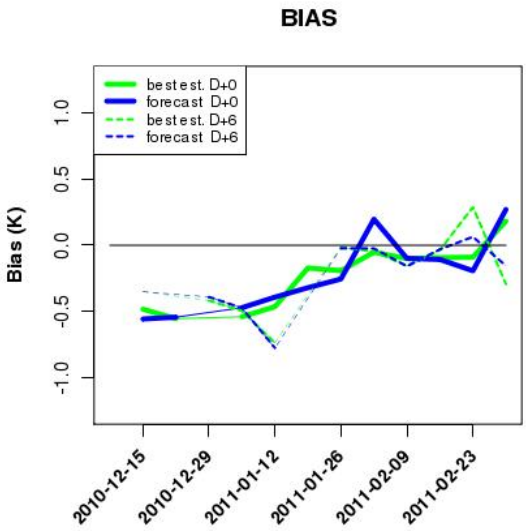


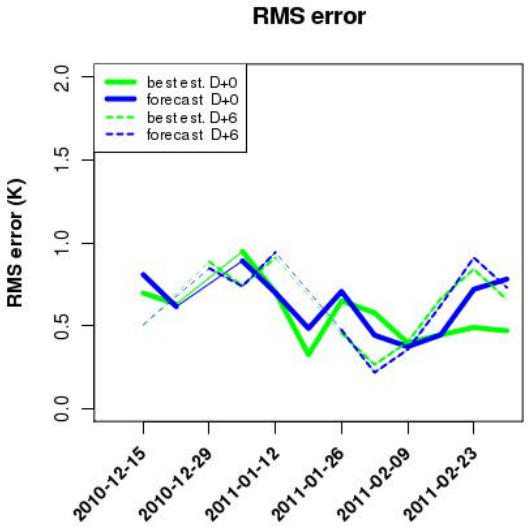




IV.1.3 Barents Sea domain

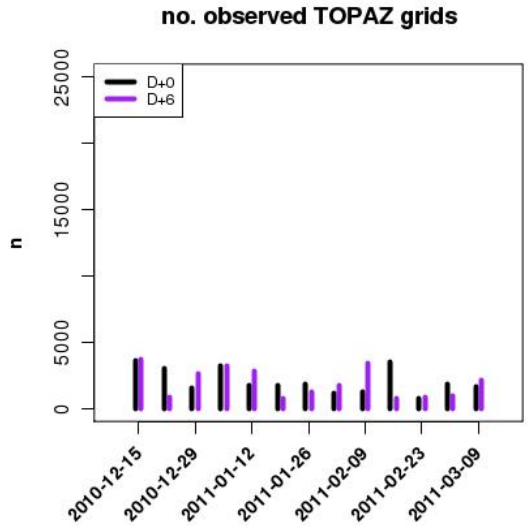


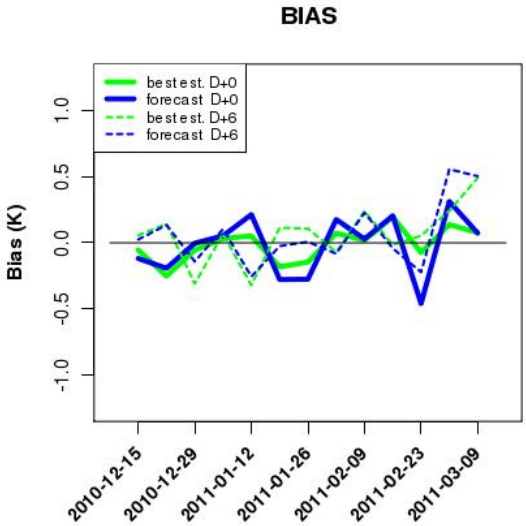


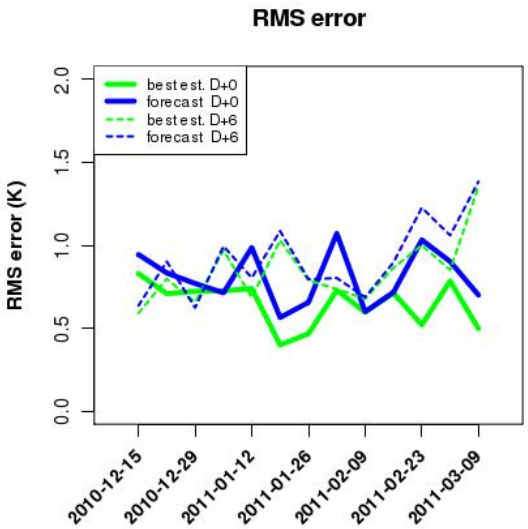


IV.2 Validation of SST *vs*. the AATSR satellite based product

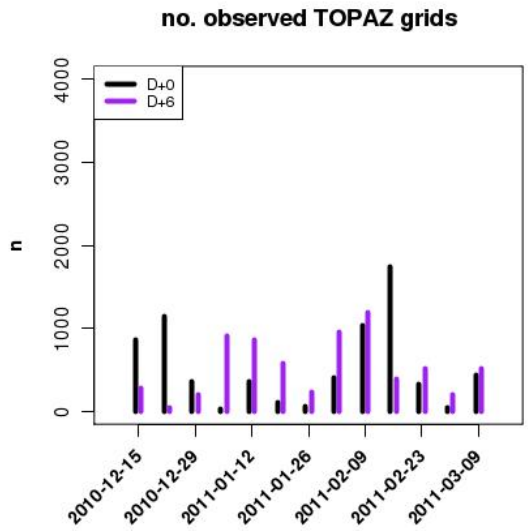
IV.2.1 Full domain

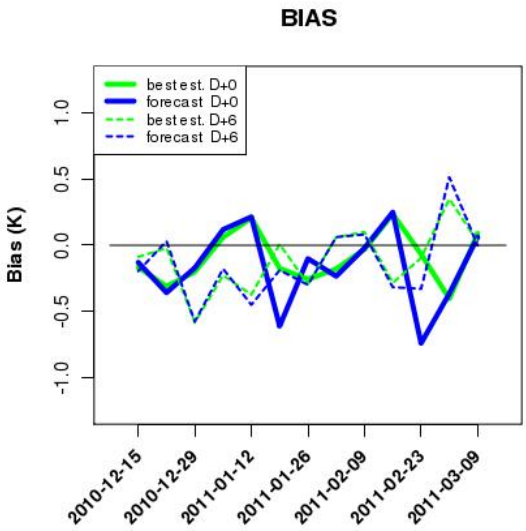


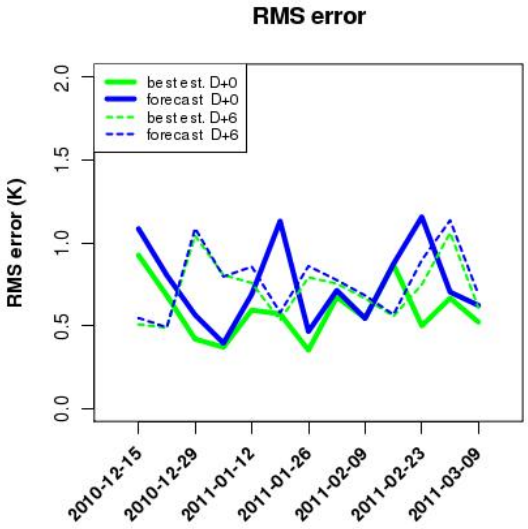




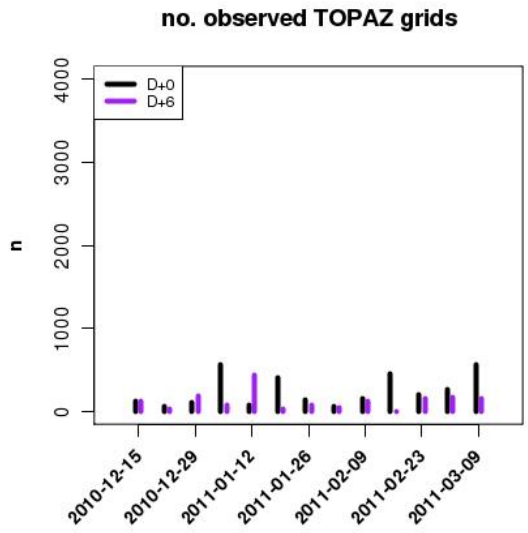
IV.2.2 Nordic Seas domain

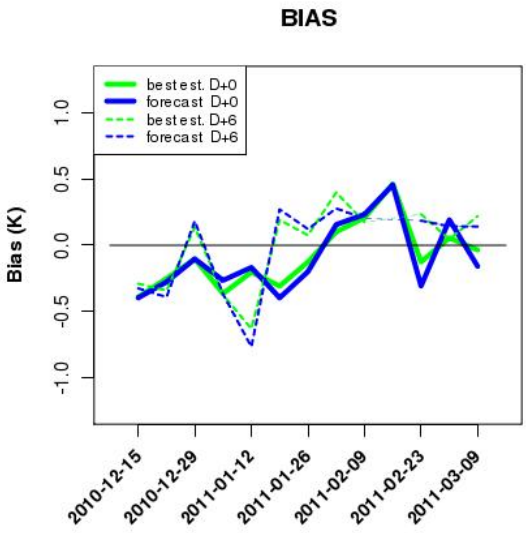


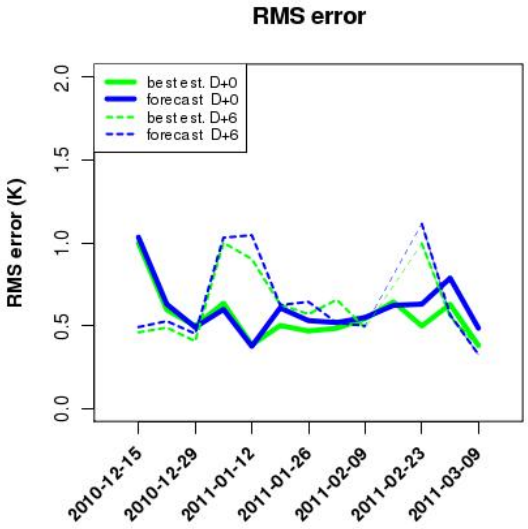




IV.2.3 Barents Sea domain

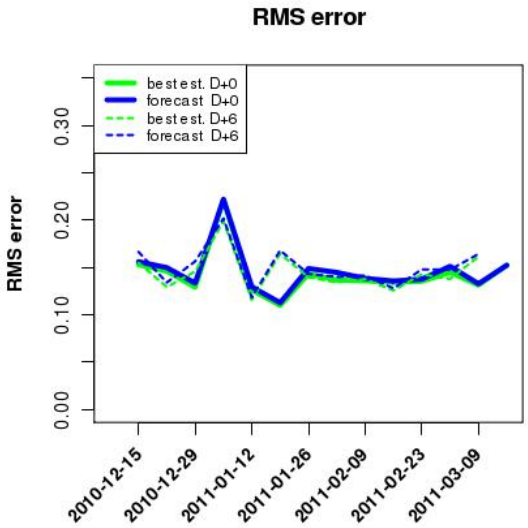




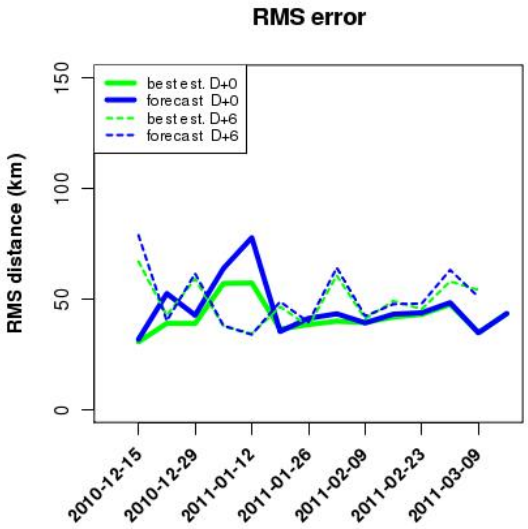


IV.3 Validation of sea ice concentration and position of ice edge *vs*. ice chart data

IV.3.1 Ice Concentration



IV.3.2 Ice Edge



IV.4 Tables

IV.4.1 BIAS

			Forecast		Best Estimate	
			D+0	D+6	D+0	D+6
SST	**Buoys**	Full domain	-0,196	-0,152	-0,188	-0,173
		Nordic Seas	-0,307	-0,223	-0,274	-0,230
		Barents Sea	-0,224	-0,232	-0,232	-0,225
	AATSR	Full domain	-0,021	0,060	-0,014	0,061
		Nordic Seas	-0,160	-0,142	-0,092	-0,109
		Barents Sea	-0,095	-0,027	-0,083	-0,013

IV.4.2 RMS error

			Forecast		Best Estimate	
			D+0	D+6	D+0	D+6
SST	**Buoys**	Full domain	0,691	0,785	0,559	0,702
		Nordic Seas	0,717	0,754	0,589	0,717
		Barents Sea	0,632	0,633	0,574	0,631
	ATTSR	Full domain	0,806	0,915	0,648	0,846
		Nordic Seas	0,749	0,765	0,590	0,716
		Barents Sea	0,604	0,652	0,557	0,626
Sea Ice		Edge distance	45,7	50,5	41,9	48,7
		Concentration	0,146	0,151	0,143	0,145

V VALIDATION TECHNICAL SUMMARY

V.1 Reanalysis/Reprocessed Analysis framework

This report is limited to validation based on observations and model results from the real-time forecast system in WP05. A separate report is provided for the validation of the reanalysis / reprocessed analysis from the ARC MFC, this report is submitted with reference MYO-WP05-ScCV-rea-ARC-NERSC-BERGEN-NO.

V.2 Validation task

Validation of products from the operational forecasts has been performed as an activity of solely comparing model results and observations, in line with the ñClass 4ò definition in MyOcean. The rational for this choice is that users who work with forecasts are expected to have a focus of the variability on time scales from hours to one or two weeks. In such a context, comparison with e.g. climatology is of less interest. Thus, ñClass 1-3ò metrics are left to the reanalysis. The list of variables which will undergo validation will be expanded according to the Scientific Validation Plan for the Arctic MFC.

V.3 Validation summary

Based on the results provided in Chapter IV, we deem the results from the Arctic MFC to be of a satisfactory quality. Improvements *vs*. the V0 products from the Arctic MFC have been reported earlier (see also http://myocean.met.no/ARC-MFC/Validation/V0toV1). The main challenge we face is to include an improved description of conditions in the marginal ice zone (MIZ). The present product has a tendency of exhibiting a too narrow MIZ. Further, it would also be useful to reduce the RMS error of the SST product.

Target quality measures such as ñexpected accuracy levelò was not defined for forecast products in the Scientific Validation Plan for the Arctic MFC.