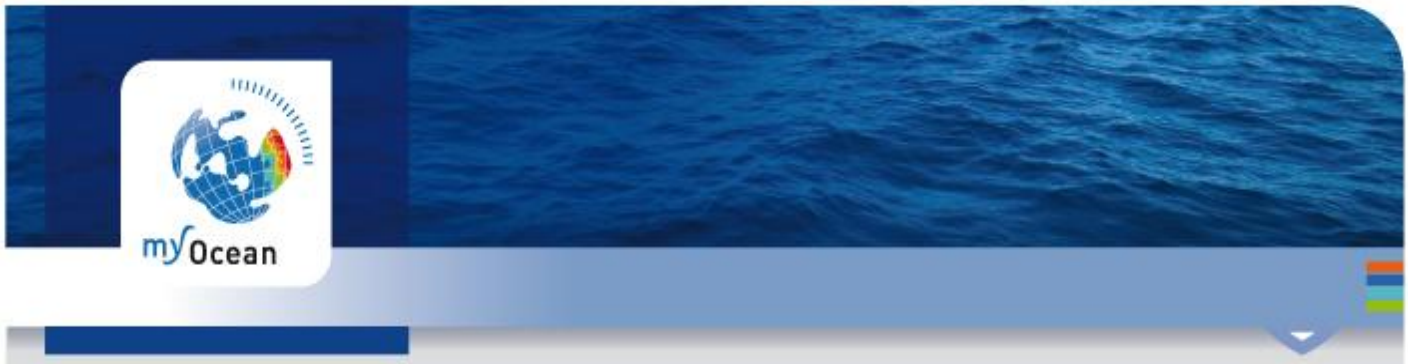

QUALITY INFORMATION DOCUMENT

For Arctic Ocean Physical Analysis and Forecast Product

ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_A

WP leader: ARC MFC, Laurent Bertino, NERSC, Norway **Issue:** 5.1

Contributors: Arne Melsom, Magne Simonsen, Laurent Bertino, Bruce Hackett, Geir Arne Waagbø

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Work programme topic: Pre Operational Marine Service Continuity in transition towards Copernicus.

Duration: 6 Months

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
1.0	8th June 2011	All	First version of document, With copy-paste from ScVR	L. Bertino	
1.1	30th Sept 2011		Removal of links to ScVR	L. Bertino	Bruce Hackett
1.2	05 July 2012	II.1	Revise schedule	G. Waagbø	
1.3	08 April 2013		Revise AATSR validation information	B. Hackett	
1.4	02 Sep 2013	All	New document format. Added reference to Altika data.	G. Waagbø, B. Hackett, A. Melsom	Laurent Bertino
1.5	02 Dec 2013	1.1	Information regarding atmospheric forcing data added.	G.Waagbø	L. Bertino
1.6	15th Jan 2014	3.1, 4.1	Modified for 10-members ensemble mean forecast	L. Bertino	
4.0	13 Mar 2014	All	Updated document format. Revisions due to QuARG review.	A. Melsom, G. A. Waagbø, B. Hackett	L. Bertino
4.1	3 June 2014	1.3, 3.1, 5.1-5.5 5.6	Updated description of assimilated SLA-products, as well as updated validation figures. Removed temporarily section on surface buoy drift until "undrogued"-QC is implemented	G.A.Waagbø	L. Bertino
4.2	12 June 2014	3.2	Change related to assimilation of Hy2a SLA-products.	G.A.Waagbø/ H.Engedahl	
5.0	1st Jan 2015		Updated version numbers	L. Bertino	
5.1	06/03/2015	All	Revision after V5 acceptance		

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I EXECUTIVE SUMMARY

I.1 Products covered by this document

This document covers the following products:

- ARCTIC_ANALYSIS_FORECAST_PHYS_002_001_a, which is the real-time forecast of physical parameters in the Arctic.

The product is produced by the Arctic Monitoring and Forecasting Centre (Arctic MFC) using the TOPAZ4 numerical prediction system, which consists of the following elements:

- Model: Nansen Center's version of HYCOM V2.2.37
- Spatial resolution: horizontal = ~12 km (1/6th to 1/8th deg), vertical = 28 Hybrid z-isopycnal layers.
- Time period for the V3/V4 versions of the product: since January 2012
- Data assimilation: Deterministic version of the Ensemble Kalman Filter (DEnKF) with asynchronous assimilation (ensemble version of the First Guess at Adequate Time FGAT)
- Assimilated data: see below.
- Atmospheric forcing data: Since November 2013, data from ECMWF's HRES (High Resolution) Model are used. The data are on a global regular lat/lon grid (0.125 x 0.125 degrees), and are interpolated to the model grid in a pre-processing step.

The model products are available through the MyOcean Catalogue as daily averages on a 12.5 x 12.5 km grid at 12 depths.

I.2 Summary of the results

Validation of products from the operational forecasts has been performed as an activity of solely comparing model results and observations, in line with the "Class 4" 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, "Class 1-3" 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.

Based on the results provided in Chapter IV, we deem the results from this Arctic MFC product 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).

While no specific model discrepancy has been identified, there is room for improvement of all forecast products. Hence, we will continue the present strategy for improving the quality of products from Arctic MFC. This strategy includes (1) expanding and refining the assimilation

step, (2) improving the performance of the ocean circulation model, and (3) examine if an improvement is possible by application of results from the Global MFC at the open boundaries.

I.3 Estimated Accuracy Numbers

Results that are tabulated below were retrieved on June 3rd 2014.

I.3.1 BIAS

			Forecast	
			Day1	Day6
SST	**Buoys**	Full domain (K)	-0.34	-0.37
		Nordic Seas (K)	-0.27	-0.31
		Barents Sea (K)	-0.39	-0.46
	AATSR / AVHRR	Full domain (K)	-0.14	-0.15
		Nordic Seas (K)	-0.12	-0.11
		Barents Sea (K)	-0.12	-0.11
Sea Ice				
	Edge	Edge length (km)	-130	-134
		Edge position (km)	-7.4	-6.2
	Drift	Arctic Ocean (km/day)	0.012	0.37
		American sector (km/day)	0.96	0.49
		European sector (km/day)	-0.13	0.57
		Asian sector (km/day)	-1.0	-0.44

I.3.2 RMS error

			Forecast	
			Day 1	Day 6
SST	**Buoys**	Full domain (K)	0.86	0.91
		Nordic Seas (K)	0.76	0.80
		Barents Sea (K)	0.70	0.73
	AATSR / AVHRR	Full domain (K)	0.75	0.78
		Nordic Seas (K)	0.70	0.72
		Barents Sea (K)	0.67	0.71
Sea Ice		Concentration (%)	20	22
	Edge	Edge position (km)	47	54
	Drift	Arctic Ocean (km/day)	7.3	8.9
		American sector (km/day)	5.3	6.7
		European sector (km/day)	7.3	9.0
		Asian sector (km/day)	6.9	9.1
SLA		South of 66N (cm)	5.5	5.6
		Nordic Seas south (cm)	3.9	3.8

II EXTERNAL OPERATIONAL PRODUCTS

Validation of the 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 sea surface temperature is also performed using a remote sensing product (originally AATSR, now substituted by AVHRR) which is based on observations from a satellite-borne instrument. The AATSR/AVHRR 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 Arctic MFC ocean model analysis, the AATSR and AVHRR products have much stricter cloud masks than the assimilated product, and thus comes with an increased data quality at the expense of the domain coverage. *Note for document Issue 1.3 and later: The AATSR validation process was stopped in April 2012 upon the failure of Envisat and its data provision. It has been replaced by METOP-A AVHRR as recommended reference instrument.*

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 OSI TAC / OSI-SAF EUMETSAT service. The primary source of data for these ice charts are SAR images. The ice charts are produced daily on week days, and divide 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 Arctic MFC model, so these data constitute a set that is independent from the model results.

III PRODUCTION SUBSYSTEM DESCRIPTION

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.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 is delivered to the users and used for the validation.

TOPAZ4 was developed and is maintained by the Nansen Environmental and Remote Sensing Center (NERSC, http://nersc.no/). It is run operationally for MyOcean 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 member						
5							
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 illustrates the weekly schedule for the TOPAZ system. The vertical axis indicates forecast lead time in days.

III.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, and (since June 2014) Hy2a satellites. From May 2014 the following SLA-products are combined and assimilated:
    - SEALEVEL_GLO_SLA_L3_NRT_OBSERVATIONS_008_017 (south of 50N)
    - SEALEVEL_ARC_SLA_L3_NRT_OBSERVATIONS_008_025 (north of 50N)

These replace the obsolete SLA-products that were assimilated until the end of April 2014 (SEALEVEL_GLO_SLA_L3_NRT_OBSERVATIONS_008_001_a). In the transition to the new SLA-products the 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).

IV VALIDATION FRAMEWORK

Validation of the MyOcean Arctic MFC results for sea surface temperature is performed using data from drifting buoys, which are compiled by the MyOcean In Situ TAC. The buoy data are obtained from the In Situ TAC, 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, so daily model averages are compared to daily averages from buoy observations. Near-surface drift is validated using positional data from the same source of data (i.e., drifting buoys).

Validation of the MyOcean Arctic MFC results for sea surface temperature is also performed against satellite data from the currently identified reference instrument. Up to April 2012, this was the Envisat AATSR product. 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 Arctic 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. *Note for Issue 1.3 and later: The AATSR validation process was stopped in April 2012 upon the failure of Envisat and its data provision. From May 2013, the reference instrument is the AVHRR flying on the METOP-A satellite; all validation for 2013 was reprocessed using this data set.*

The validation of sea ice concentration and sea ice edge position is performed based on ice charts for the Arctic Ocean that are obtained from the MyOcean OSI TAC: SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_002. The primary source of data for these ice charts are SAR images. The ice charts are produced daily on week days, and divide the domain into regions with a discrete set of sea ice classes, as defined by WMO. SAR data are presently not included in the analysis and initialization of the Arctic MFC model, so these data constitute a set that is independent from the model results. The unavailability of observational data from this product on Saturdays, Sundays and holidays implies that no validation can be performed for these days.

The validation of Arctic sea ice drift is performed against global satellite observations obtained from the MyOcean OSI TAC: SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_006. The ice drift data are based on a pattern recognition algorithm which is applied to observations from Synthetic Aperture Radar (SAR) imagery.

The validation of sea level anomaly forecasts is performed using the SLA data from a single altimeter: currently JASON-2, which flies in a non-sun-synchronous orbit at an inclination of 66° to Earth's equator. The data are obtained from the MyOcean SL TAC.

Our aim is to provide validation results of the present real-time forecast system. Validation is performed against independent (i.e. non-assimilated) products from MyOcean TACs, when a relevant observational product exists (OSI TAC, IS TAC), as described above.

We have focused the present analysis on quantities which are of particular interest to the Arctic region. These are sea ice variables, and sea surface temperature and sea level anomalies, but note that other variables such as temperature/salinity profiles, sea level and near-surface trajectories are also included in our validation of the product. Snapshots that illustrate model results for sea ice 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.

The product data are validated against two SST observational products (in situ and satellite), independent sea ice concentration and edge observations from the Svalbard region, satellite Arctic sea ice drift observations, SLA observations from a single altimeter and near-surface drift against positional data from drifting buoys. Validation metrics are calculated for each daily forecast horizon: Day 1 forecast to Day 10 forecast. Results are published at http://myocean.met.no/ARC-MFC/V2Validation/index.html with weekly updates.

IV.1 Model results

TOPAZ results are available as an aggregated “best estimates” product from the MyOcean data portal using the SUBSETTER download vehicle, and as a list of separate forecasts from the production cycle with weekly updated bulletin dates using the GetFile vehicle. The “best estimate” product is the average of daily means from the 100-member ensemble model, followed by the ensemble average from the 10-members ensemble forecast for future dates.

Presently, the model results that are validated are

- ✓ sea surface temperature
- ✓ sea ice concentration
- ✓ position of the sea ice edge
- ✓ sea ice drift
- ✓ temperature and salinity profiles, averaged in selected layers as specified by the MyOcean PQCV-WG for joint use across MFCs
- ✓ sea surface elevation

- ✓ near-surface drift.

For the validation of sea surface temperature and near-surface drift, model results for ocean temperature and velocity at the 5 meter level are used.

IV.2 Validation products

The validation products are listed here:

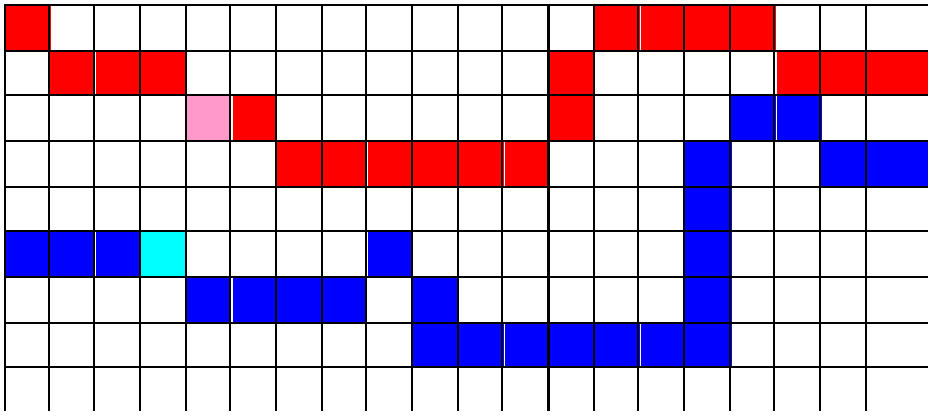
- Sea Surface Temperature - buoys
  1. Number of observations
  2. Bias
  3. RMS error
- Sea Surface Temperature – satellites (AATSR, AVHRR)
  1. Number of observations
  2. Bias
  3. RMS error

- Sea Ice
    1. RMS error of sea ice edge distance
    2. RMS error of sea ice concentration
    3. Ice Classes Area; four ice classes:
        1. Very open drift ice
        2. Open drift ice
        3. Close drift ice
        4. Very close drift ice
    4. Confusion matrix with match-up of sea ice
    5. Number of ice drift trajectories
    6. Ice drift distance
    7. RMS error of drift
- Sea level anomaly
    1. Number of observations
    2. RMS error
- Temperature and salinity profiles
    1. Number of profiles
    2. 5 depth intervals
    3. Bias of temperature and salinity in each layer
    4. RMS error of temperature and salinity in each layer
- Near-surface drift
    1. Number of profiles
    2. Bias of 24h drift distance
    3. RMS of separation of trajectories after 24h drift

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.



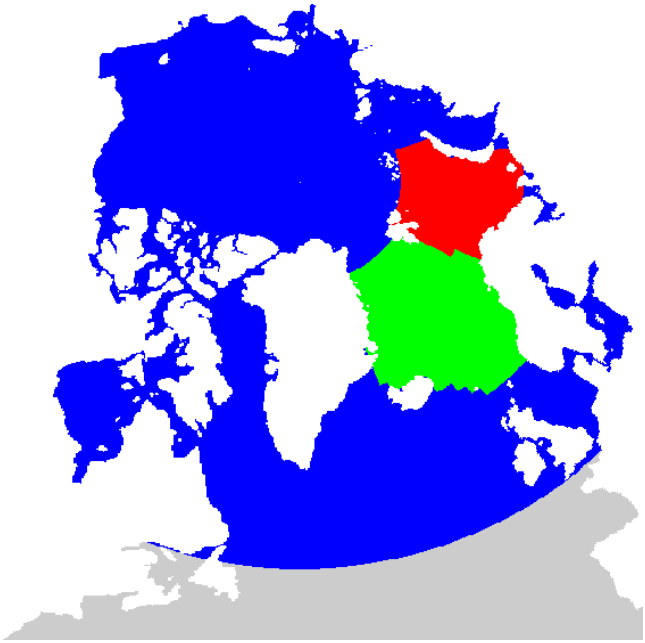
Then, for each grid belonging to the model sea ice edge, e.g. the light blue grid above, the closest grid belonging to the observed edge grids is found, in our example this is the light red grid. The distance between the observed and modeled sea ice edge is then taken to be the distance between the centres of these two grids. Furthermore, in this document we present validation results for the bias of the ice edge position. A positive bias means that the modeled sea ice edge is on the open ocean side of the observed edge. Note that this metric can be interpreted as a proxy for sea ice extent.

IV.3 Period

Results from the ARC MFC product have been validated since 2011-12-21. These products achieved operational status on 2011-12-16.

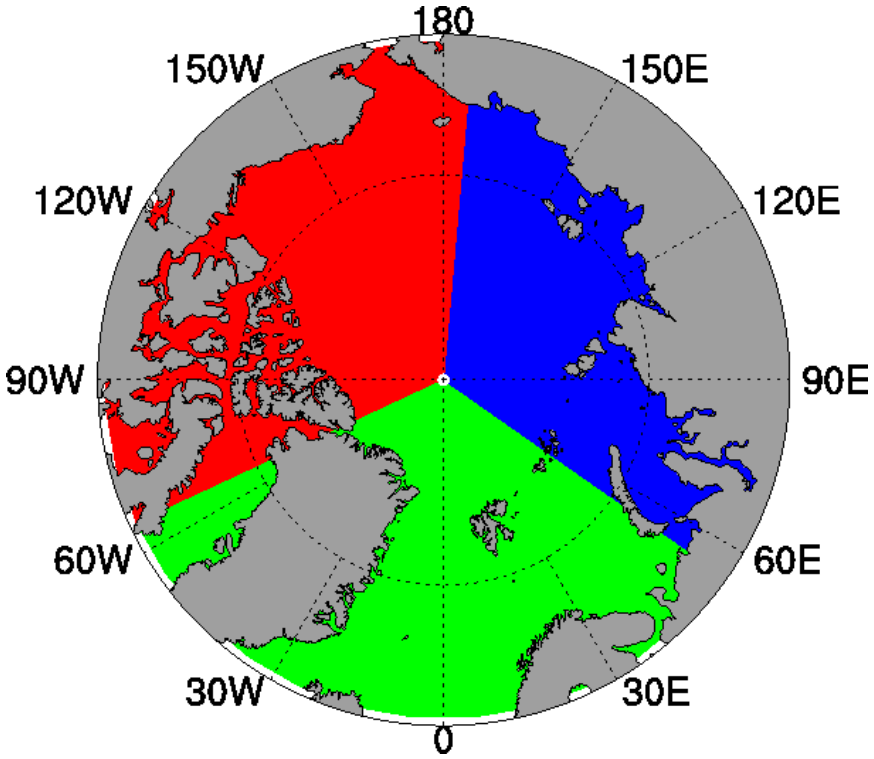
The ocean circulation model used in MyOcean's Arctic MFC covers the Arctic Ocean, the North Atlantic Ocean and adjacent ocean regions. The northern part is depicted in the figure below. Validation of sea surface temperature from model results is performed for three domains:

- 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



For the ice drift validation, the Arctic has been divided into 3 sectors as shown on the map below:

- 65 °W – 55 °E (European, Green)
- 55 °E – 175 °E (Asian, Blue)
- 175 °E – 65 °W (American, Red)



Regions for which validation is performed for the various products are displayed on http://myocean.met.no/ARC-MFC/V2Validation/regions.

Table 1 Metrics and status of validation activity

Name of metric	Model output	Supporting observations	Class	Metrics	Status
SST vs. buoys	On model output grid (12.5 km, top 5 m layer)	SST from drifting buoys	4	Bias and RMS error	Routine on myocean.met.no MyOcean web
SST vs. AATSR and AVHRR	Same as above	High-quality satellite data from OSI TAC	4	Same as above	Routine on myocean.met.no
Ice concentration	On model output grid	Digitized SAR-based ice charts from OSI TAC	4	RMS error	Routine on myocean.met.no
Sea ice edge	On model output	Same as above	4	RMS error	Routine on myocean.met.

position	grid				no
Sea ice drift	On model output grid	SAR-based displacement calculations	4	RMS error	Routine on myocean.met.no
Sea level anomaly	On model output grid	Single altimeter SLA data (Jason-2)	4	RMS error	Routine on myocean.met.no
Temp. and salinity profiles	On model output grid, vertically averaged over 5 layers	Quality-controlled data from IS TAC	4	Bias and RMS error	Routine on myocean.met.no

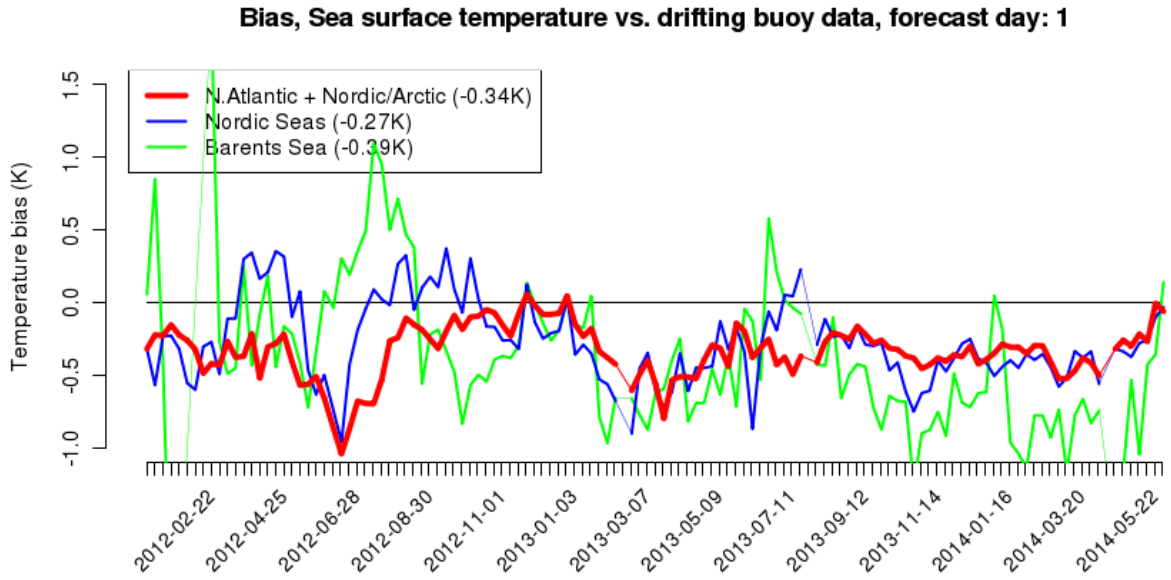
V VALIDATION RESULTS

The full set of operational validation products is maintained and accessible on the web pages found under http://myocean.met.no/ARC-MFC/V2Validation/index.html. The figures in this chapter are representative samples of time series of selected validation quantities, with bulletin dates provided on the x-axis. Subsections labeled 'Day 1 forecast' are validation of the daily mean from first the 24 hours after the data assimilation/model re-initialization, whereas 'Day 6 forecast' refers to the daily mean centered at a date that lags Day 1 by 5 days.

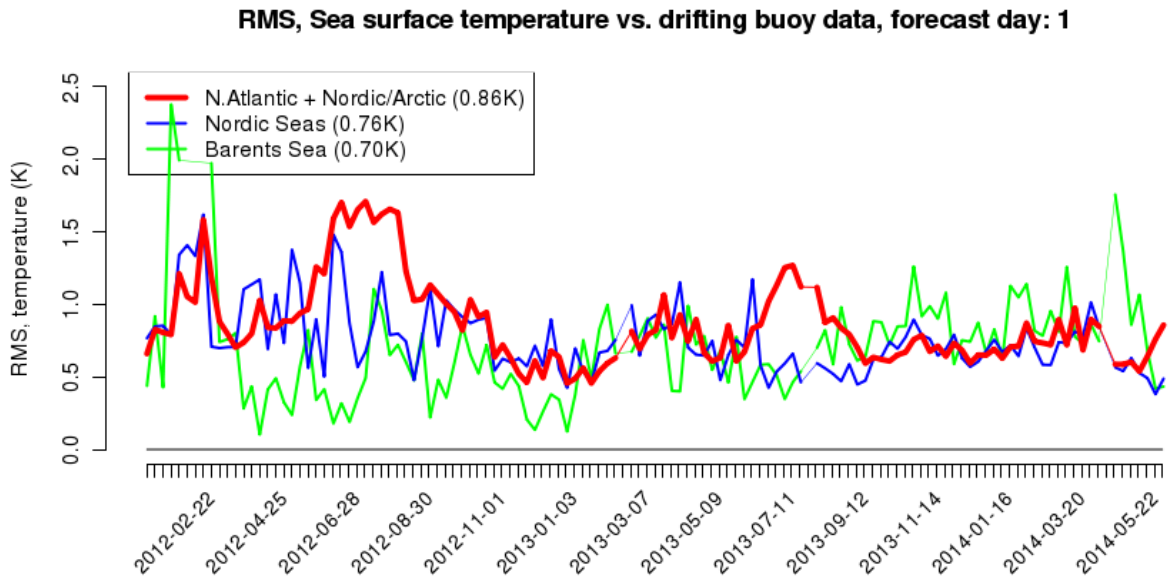
In some of the figures lines are thin in parts of the full time series. Thin lines are used to bridge curves when validation results are not available from one or more intermediate bulletin dates due to lack of observations.

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

V.1.1 Day 1 forecast

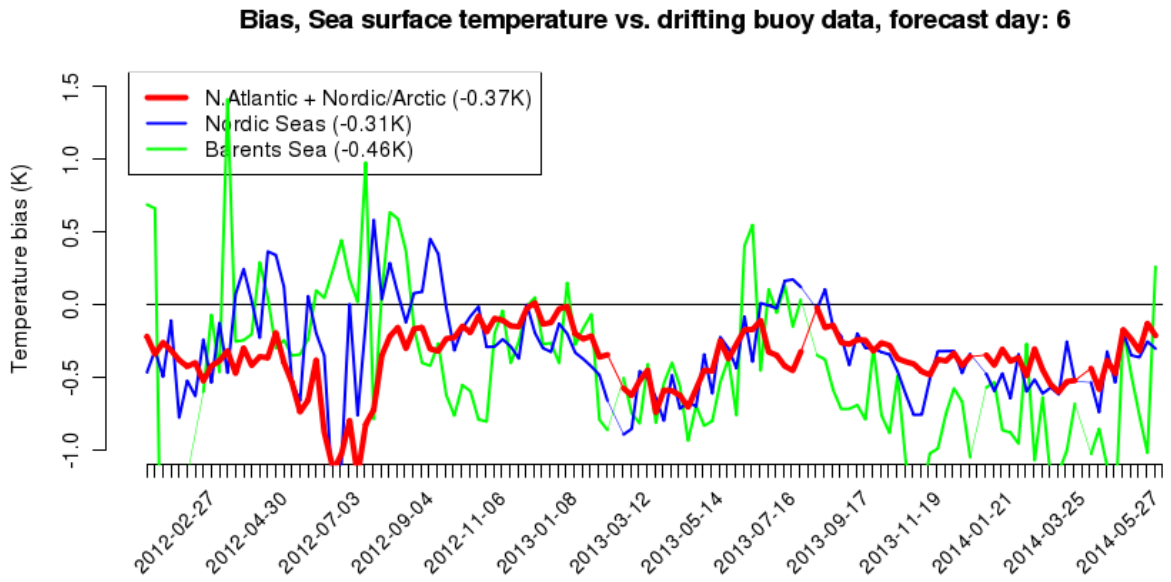


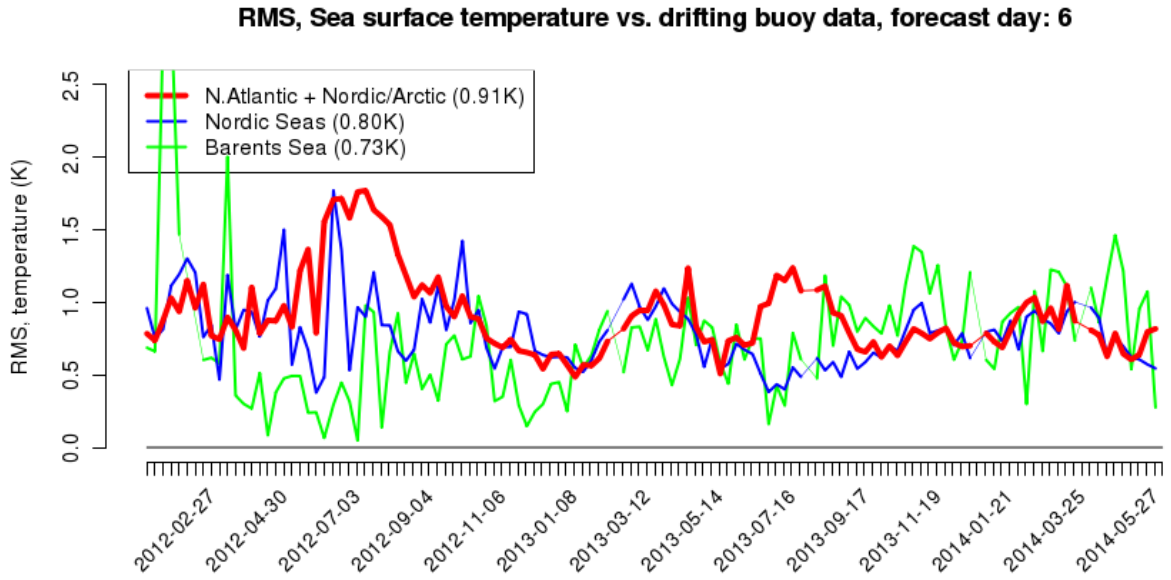
V3.1 changes: HYCOM update from NERSC. Changed perturbation of atmospheric forcing fields



The relatively large bias and RMS values that were present during some periods in 2011 and 2012 have not appeared since. From 2013 on, model values that are averaged in the observation space are consistently within 0.5K of the observations, and RMS values are about 1K or lower. The exception is the Barents Sea, where the cold bias is somewhat more pronounced.

V.1.2 Day 6 forecast



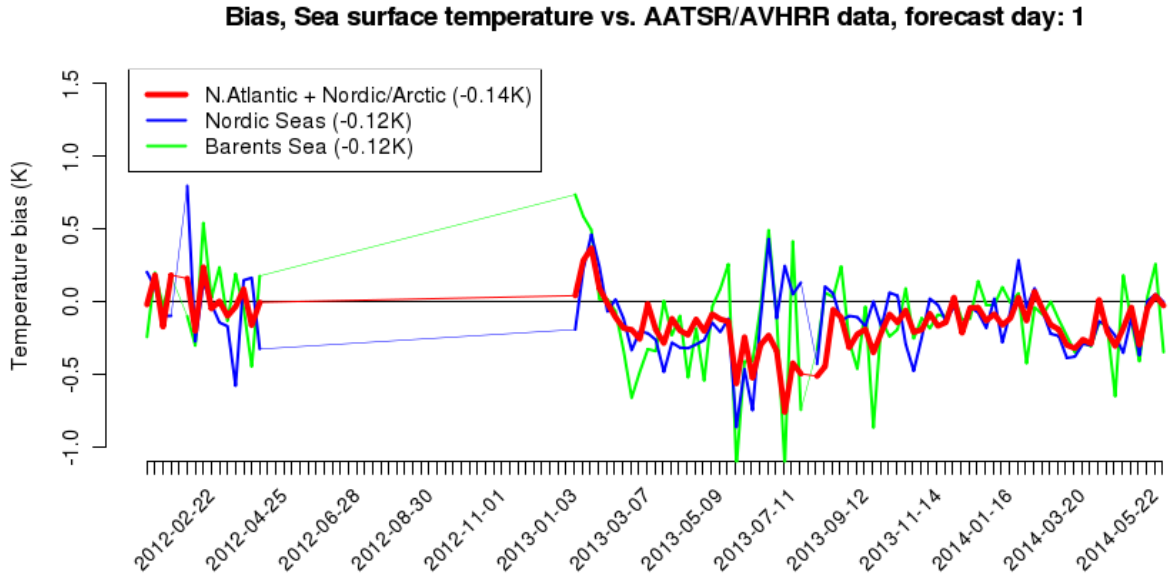


We find that the deterioration in the forecast accuracy from forecast day 1 to forecast day 6 is very small, as e.g. the bias increases from -0.34K to -0.37K for the largest domain.

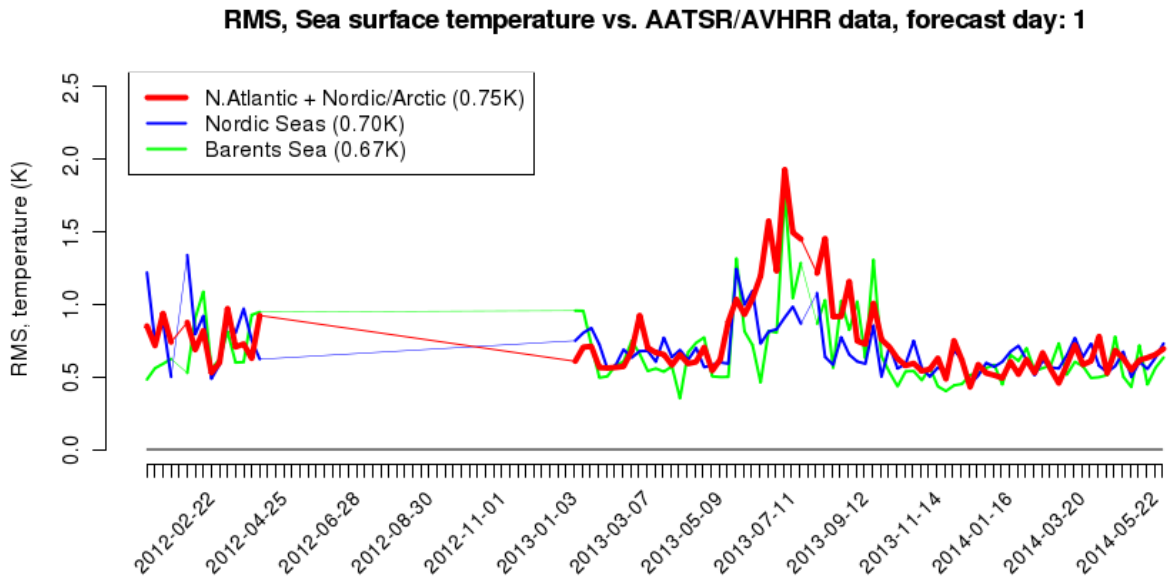
V.2 Validation of SST *vs*. the AATSR and AVHRR satellite-based products

V.2.1 Day 1 forecast

Note that the time series has been interrupted in April 2012 after the loss of ENVISAT. The validation production was restarted in May 2013 when a new reference dataset for SST was recommended by OSI

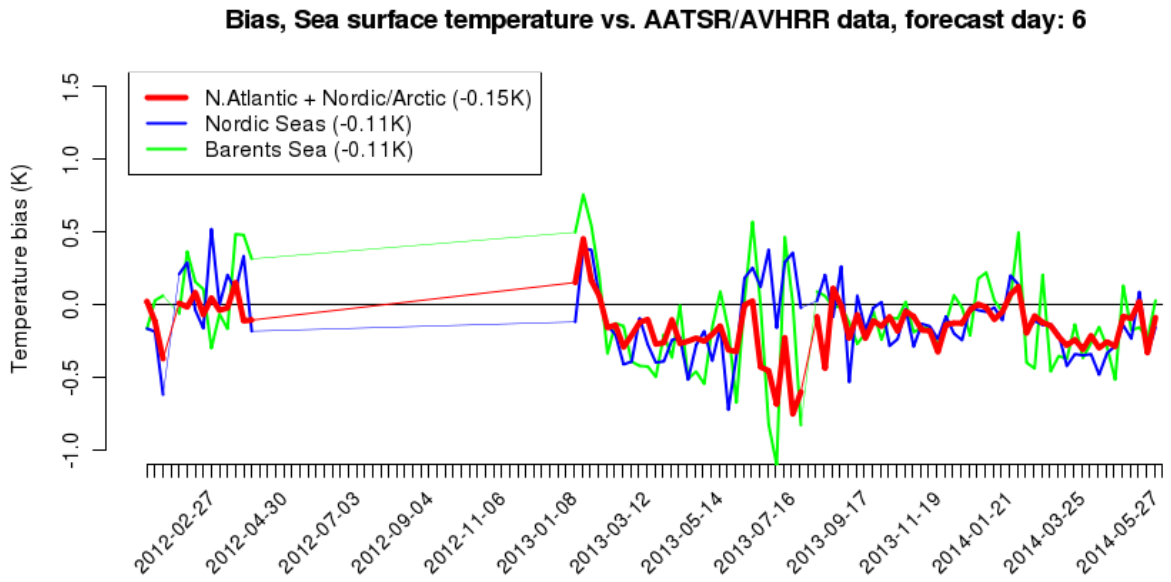


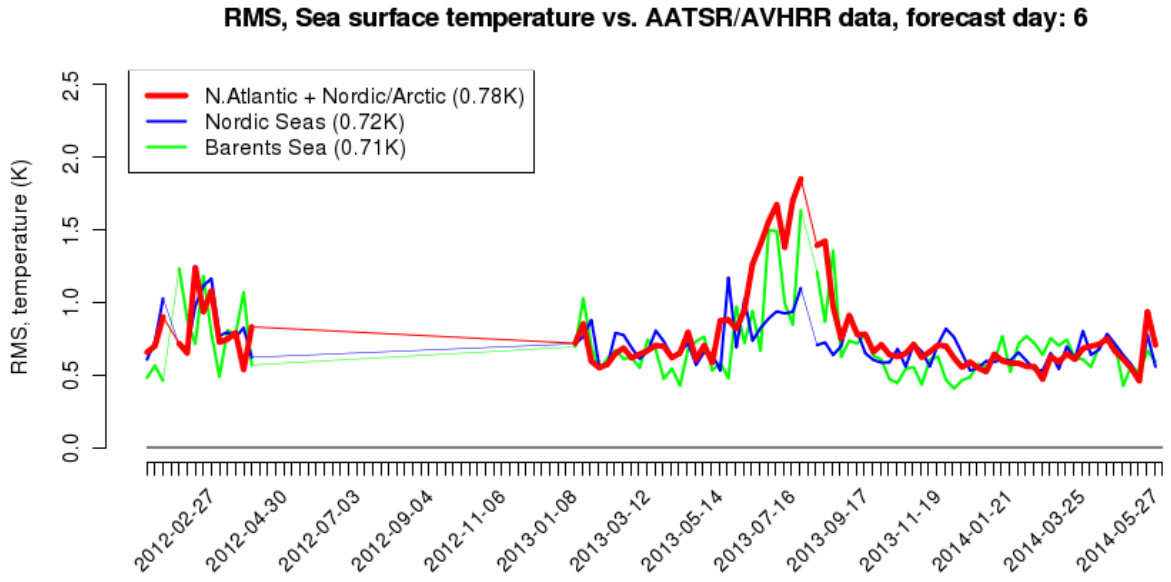
TAC. The validation was then processed for all earlier bulletins in 2013.



We find that the validation using the remote sensing data indicates an even higher quality than the validation based on buoy observations. In this context, it is worth pointing out that (a) the data coverage of the remote sensing product is much higher than that of the buoy data, and (b) these remote se nsing data are used in the model's assimilation system, so the present validation is not performed with independent data.

V.2.2 Day 6 forecast



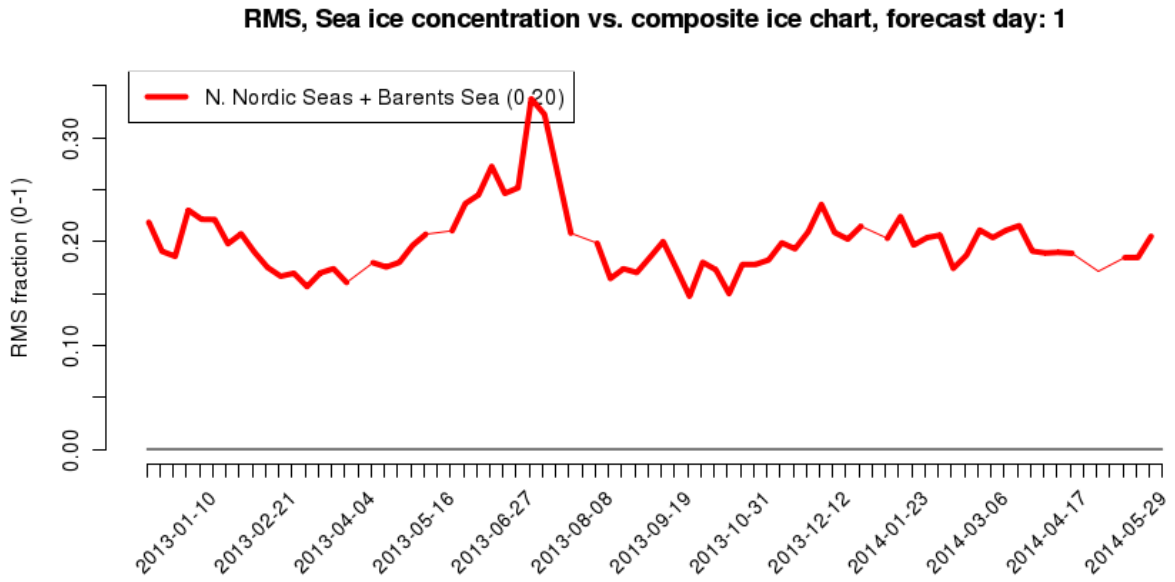


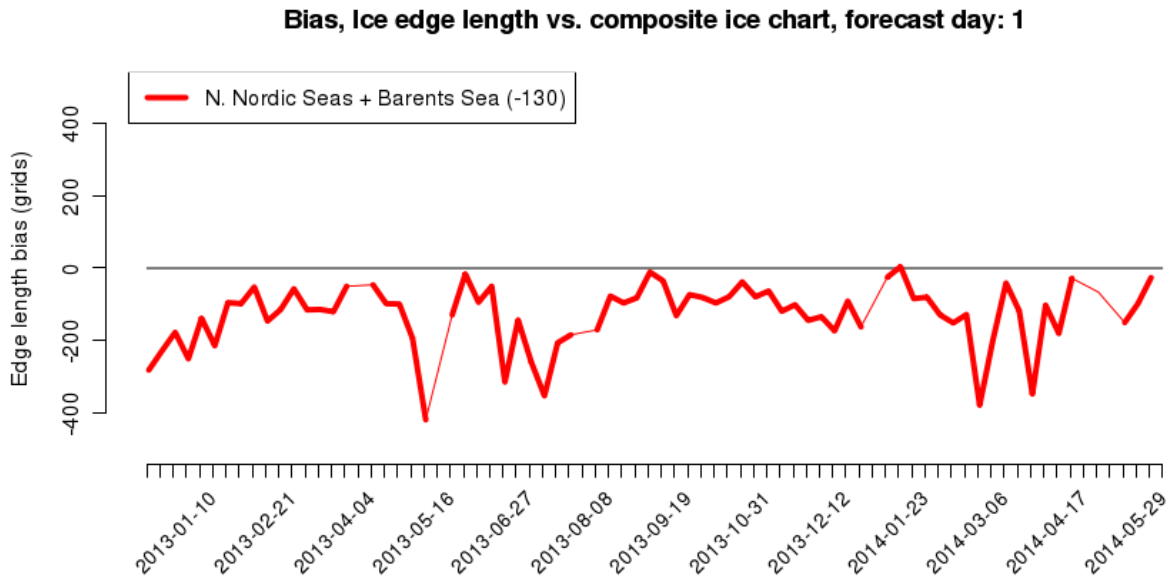
Here also, we find that the deterioration in the forecast accuracy from forecast day 1 to forecast day 6 is very small.

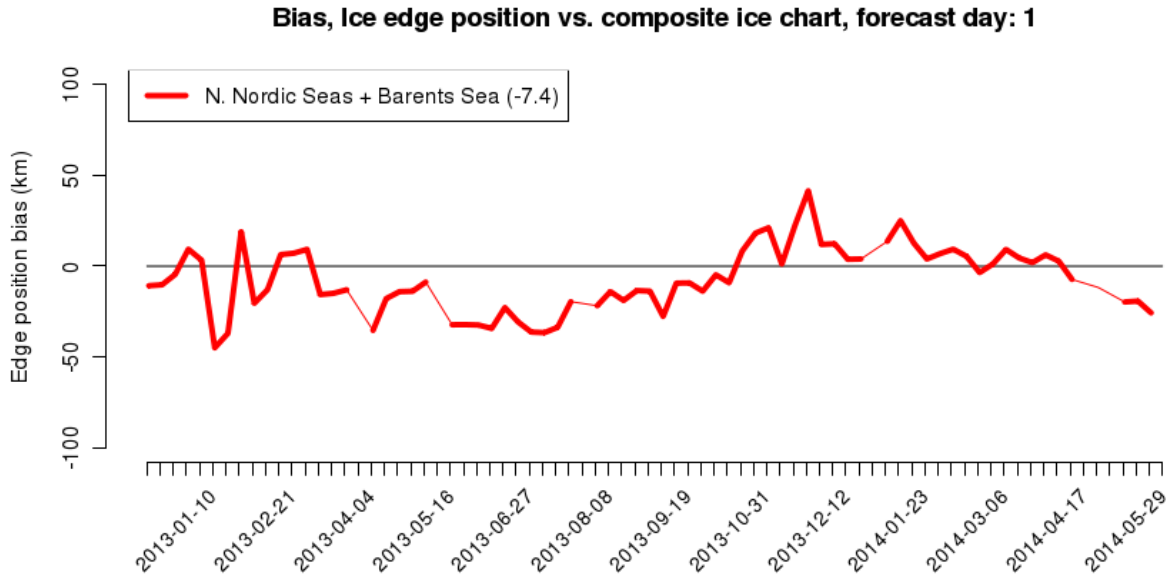
V.3 Validation of sea ice concentration and position of ice edge *vs*. ice chart data

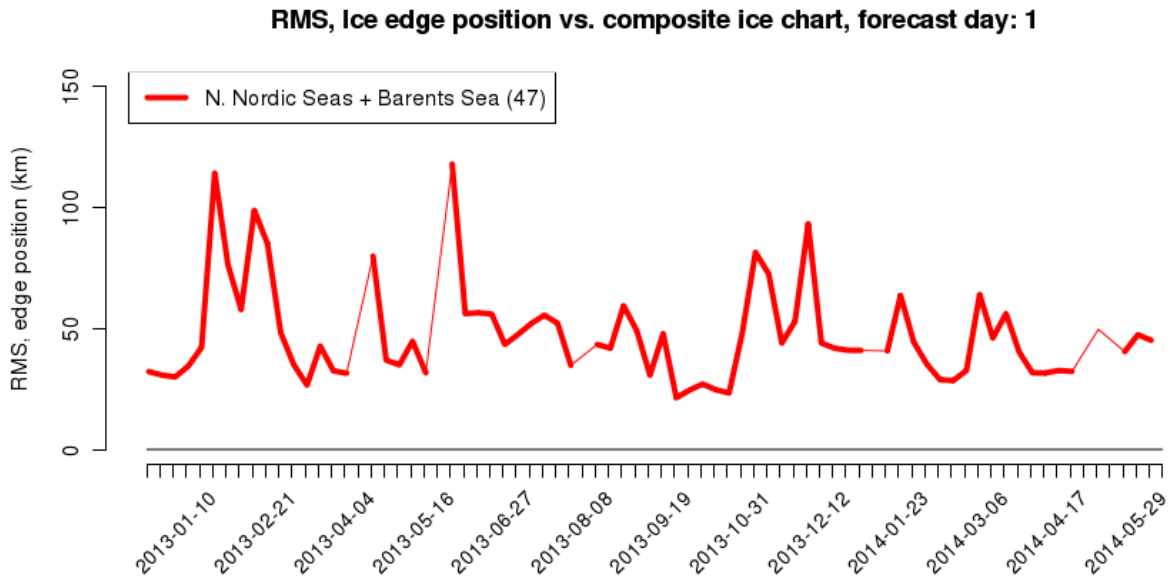
The figures below rely on the metrics defined in Section 2. The RMS for sea ice fraction are complemented by a perhaps more intuitive error in distance from the ice edge.

V.3.1 Day 1 forecast



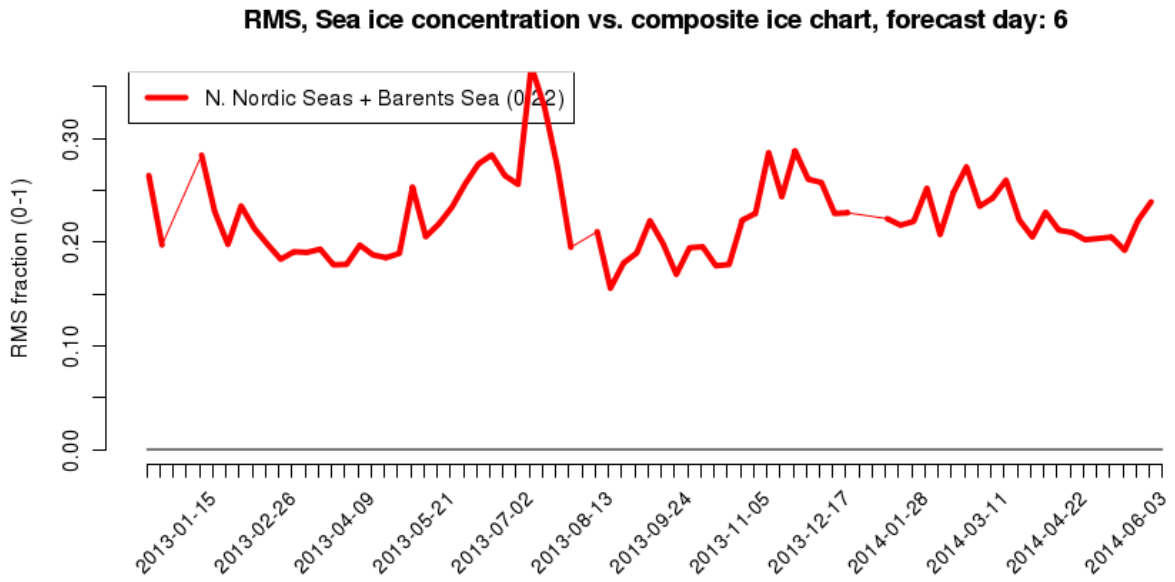

Bias, Ice edge length vs. composite ice chart, forecast day: 1
N. Nordic Seas + Barents Sea (-130)
Edge length bias (grids)
400
200
0
-200
-400
2013-01-10
2013-02-21
2013-04-04
2013-05-16
2013-06-27
2013-08-08
2013-09-19
2013-10-31
2013-12-12
2014-01-23
2014-03-06
2014-04-17
2014-05-29

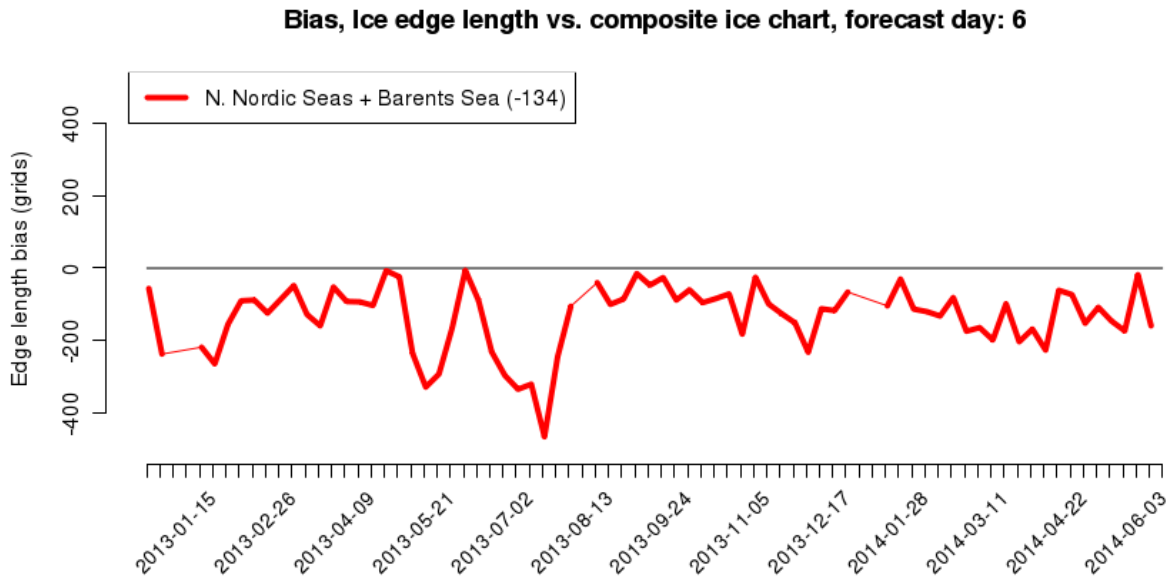

Bias, Ice edge position vs. composite ice chart, forecast day: 1
N. Nordic Seas + Barents Sea (-7.4)
Edge position bias (km)
100
50
0
-50
-100
2013-01-10
2013-02-21
2013-04-04
2013-05-16
2013-06-27
2013-08-08
2013-09-19
2013-10-31
2013-12-12
2014-01-23
2014-03-06
2014-04-17
2014-05-29

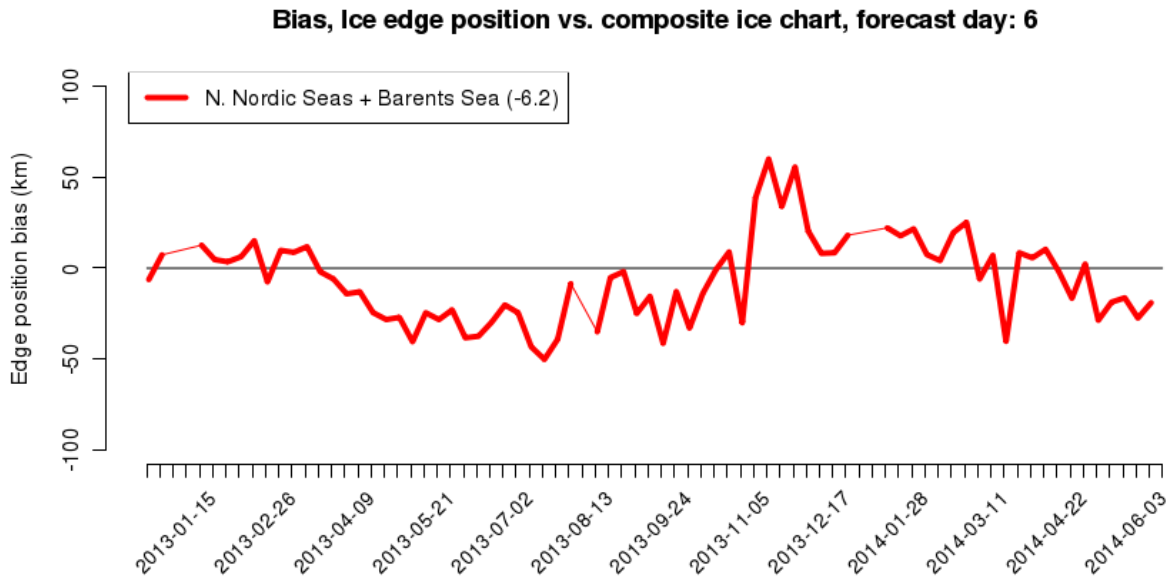


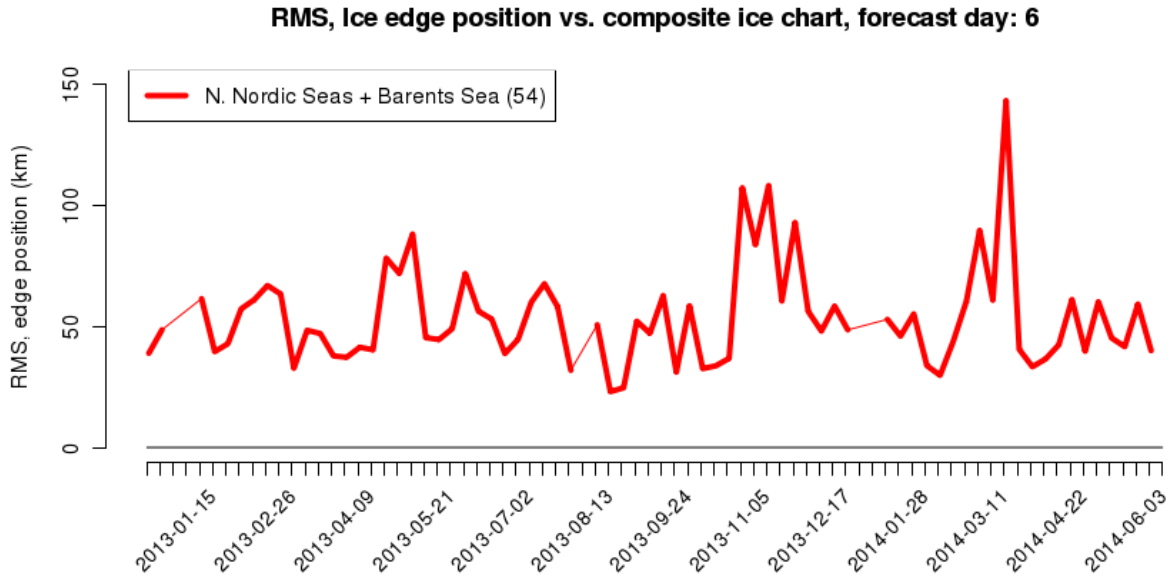
With a few exceptions, biases are nearly constant. This also holds for the RMS of the sea ice concentration. One main episode where this is not the case, is the large RMS values for sea ice concentration that occurred during the summer of 2013. This issue, and the volatility of the early time series for RMS of the ice edge position, have improved in the later part of the validation period.

V.3.2 Day 6 forecast


RMS, Sea ice concentration vs. composite ice chart, forecast day: 6
N. Nordic Seas + Barents Sea (0.22)
RMS fraction (0-1)
0.00
0.10
0.20
0.30
2013-01-15
2013-02-26
2013-04-09
2013-05-21
2013-07-02
2013-08-13
2013-09-24
2013-11-05
2013-12-17
2014-01-28
2014-03-11
2014-04-22
2014-06-03


Bias, Ice edge length vs. composite ice chart, forecast day: 6
N. Nordic Seas + Barents Sea (-134)
Edge length bias (grids)
-400
-200
0
200
400
2013-01-15
2013-02-26
2013-04-09
2013-05-21
2013-07-02
2013-08-13
2013-09-24
2013-11-05
2013-12-17
2014-01-28
2014-03-11
2014-04-22
2014-06-03



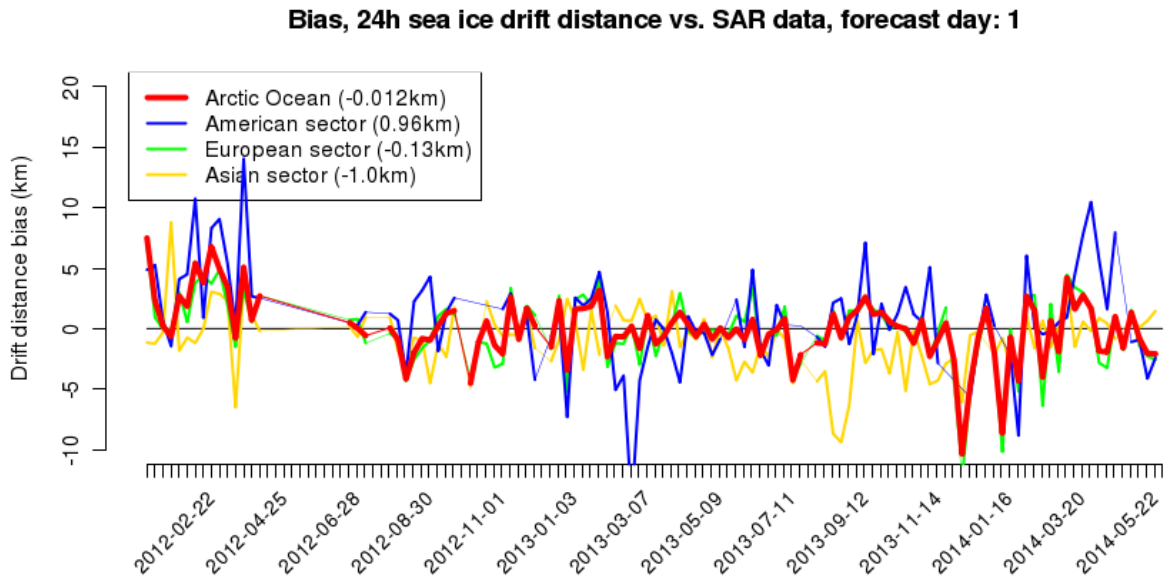


We find that the deterioration in the forecast accuracy from forecast day 1 to forecast day 6 is very small.

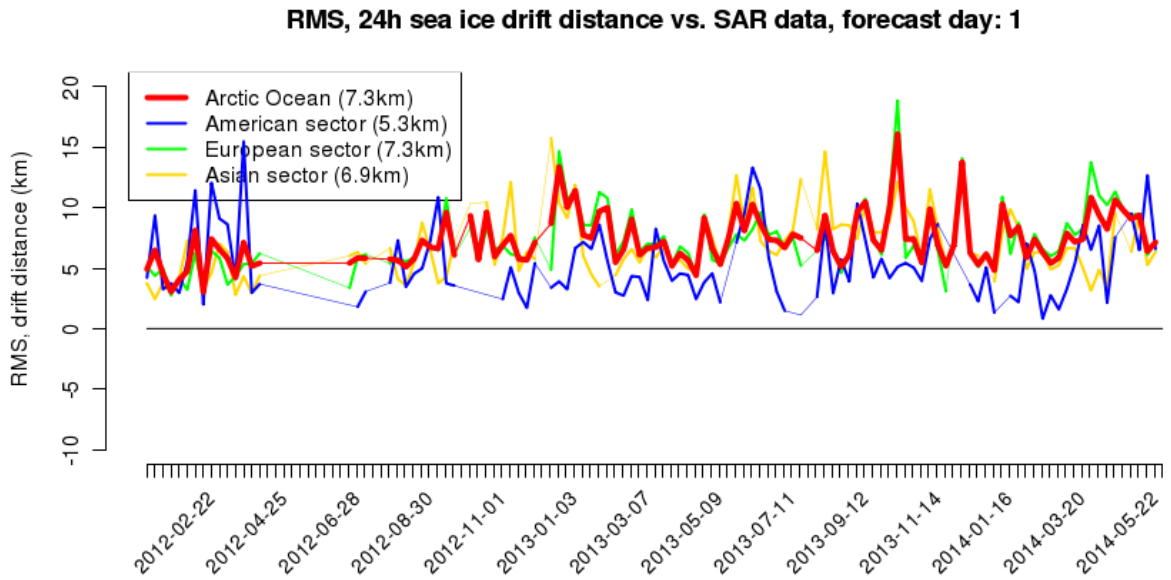
V.4 Validation of sea ice drift *vs.* satellite-derived observations

The SAR satellite sea ice drifts have a resolution of about 10km, which is roughly the same as the model resolution (8 to 15 km depending on the location). For a complete discussion of the scale-dependence of sea ice drift statistics, see Rampal et al. (2008).

V.4.1 Day 1 forecast

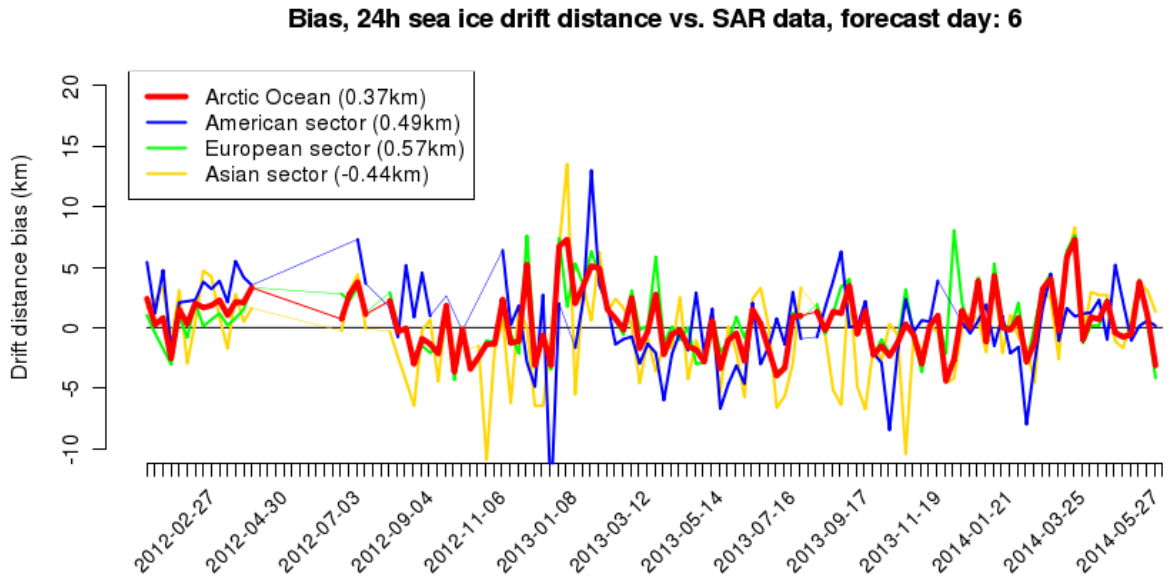


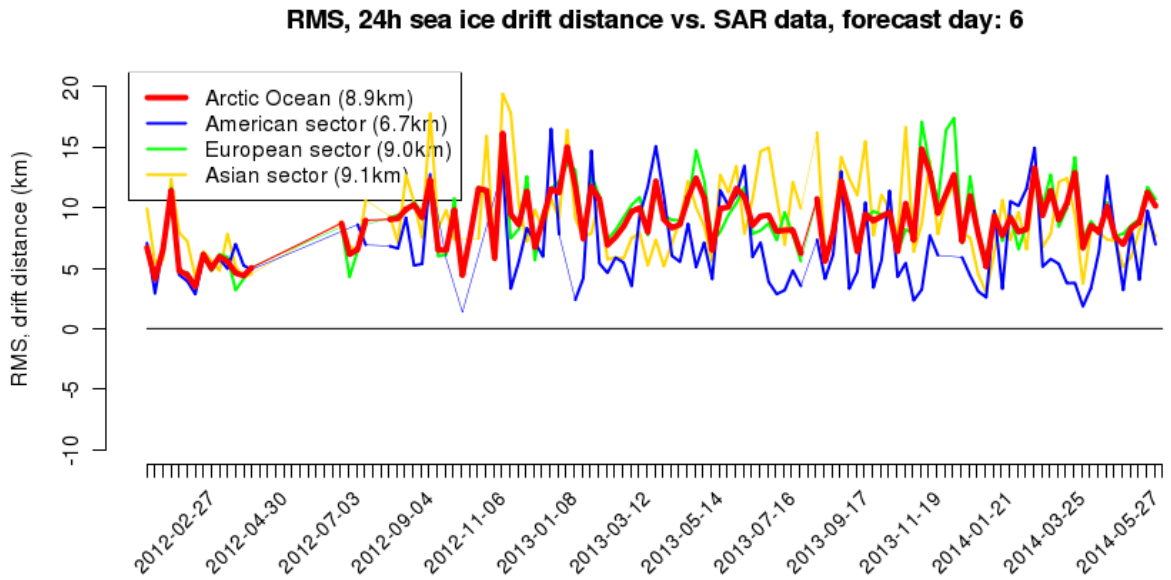
All drifts are calculated as 24 hours drift, based on the daily mean sea ice drift parameter. The American, European and Asian sectors correspond to 175°E - 65°W, 65°W - 55°E, and 55°E - 175°E, respectively.



Although these validation results are indicative of a stable quality, we note that there is a degree of fluctuations in the validation results. This can in part be attributed to periods when the data coverage is low.

V.4.2 Day 6 forecast



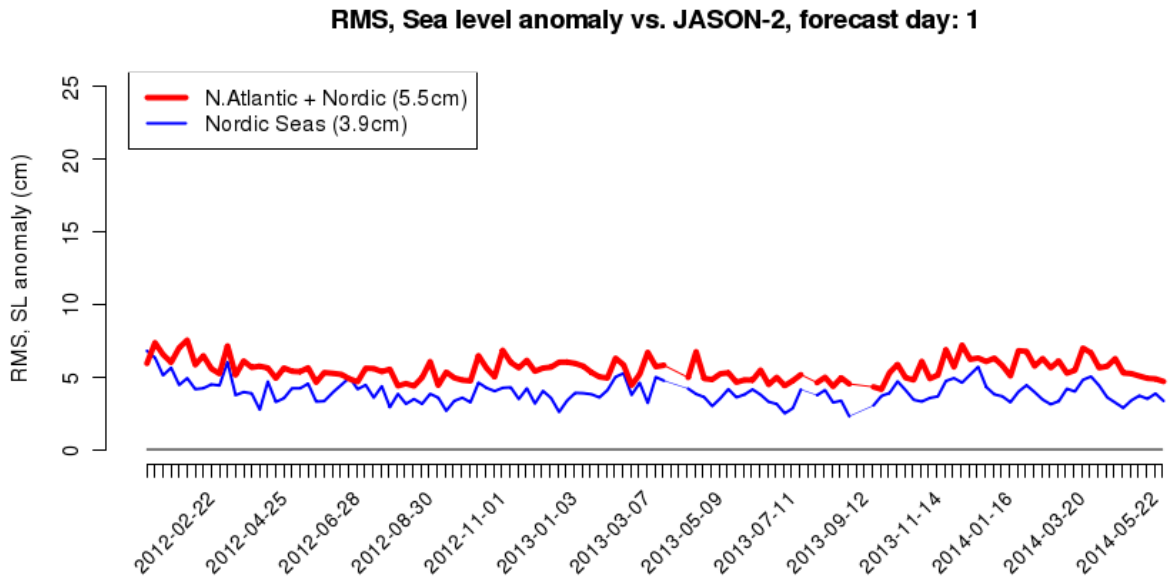


While the deterioration from forecast day 1 to forecast day 6 is moderate, it is somewhat higher for sea ice drift than for other variables. This results likely reflects the high dependency of the quality on the wind forcing, which as most meteorological products have a fater drop in quality than ocean forecasts due to the shorter memory of the atmosphere.

V.5 Validation of sea level anomaly vs. Jason-2 altimeter data

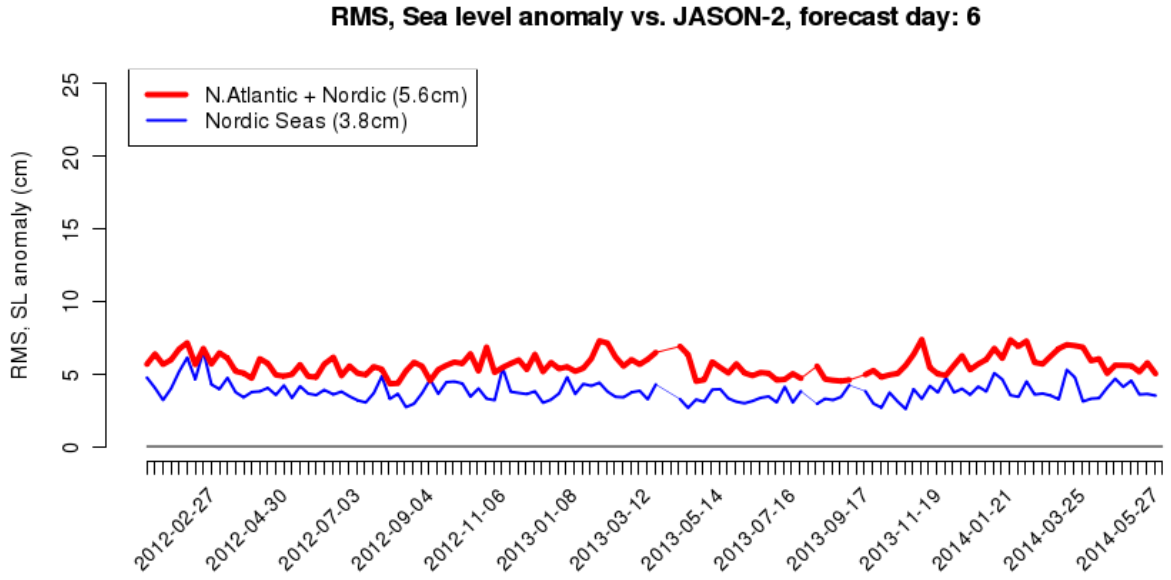
The Jason-2 satellite tracks are limited to the South of 66N. See the maps of the areas North Atlantic and Nordic Seas on the following link: http://myocean.met.no/ARC-MFC/V2Validation/regions/

V.5.1 Day 1 forecast



Validation results for sea level anomaly shows a remarkably constant product quality. Note that the Jason-2 data are assimilated by the model, so these are not independent data.

V.5.2 Day 6 forecast



Sea level anomalies are an integral measure of the temperature and salinity variability in the ocean. Due to the high ocean inertia, it is therefor not surprising that the validations of sea level anomalies indicates close to no quality loss from the day 1 forecast of sea level anomalies to the day 6 forecast.

V.6 Validation *vs.* positional data from drifting buoys

Section temporarily removed until a correction for undrogued buoys is implemented (Lumpkin et al., J Atmox Ocean Tech 2013 p. 353-)