Quality assessment of a satellite altimetry data product in the Nordic and Kara seas

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1. Overview

Satellite altimetry provides high quality sea surface height data that have been successfully used to study the variability of sea level and surface geostrophic circulation on different spatial and temporal scales. However, the high-latitude regions have traditionally been avoided due to temporally sparse altimetry measurements and sea ice cover. Most of the validation studies have focused on the areas below the polar circles. We examine the quality and performance of a gridded (level-4) satellite altimetry product in the Greenland, Iceland, Norwegian, Barents, and Kara seas. The altimetric sea level in coastal areas is validated using available tide gauge records. Away from the coast the altimetry data are compared to drifter trajectories.

2. Data

- State-of-the-art delayed-time global Maps of Sea Level Anomaly (MSLA) and Absolute Dynamic Topography (MADT) from 14 October 1992 to 31 December 2010, produced by SSALTO/DUACS and distributed by AVISO with support from CNES. Sea surface height measurements above 66°N are provided by either ERS-1/2 or Envisat missions;
- Monthly averaged tide gauge records from the Permanent Service for Mean Sea Level (Figure 1);
- ERA-Interim and ERA-40 sea level pressure are used to correct the tide gauge data for the inverted barometer effect;
- ICE-5G Glacial Isostatic Adjustment model by Peltier [1998, 2004] is used to correct the tide gauge data;
- Surface drifter data (252 drifters) provided by the Global Drifter Program Data Assembly Center of the Atlantic Oceanographic and Meteorological Laboratory (Figure 4). The data are low-pass filtered to remove high-frequency ageostrophic phenomena [Rio and Hernandez, 2004] and corrected for Ekman currents [Rio and Hernandez, 2003].

3. Comparison with tide gauge records

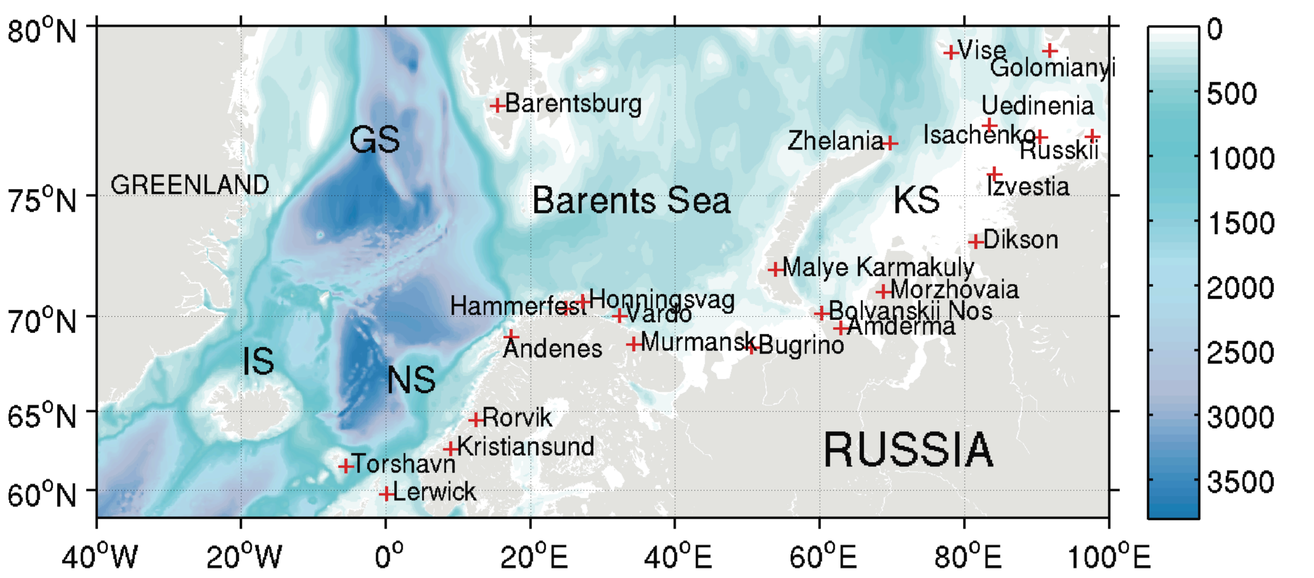

Figure 1. *Map of the study region with bottom topography and the locations of tide gauges. Abbreviations: NS – Norwegian Sea, IS – Icelandic Sea, GS – Greenland Sea, KS – Kara Sea.*

Tide Gauge Station	Number of overlapping monthly records	RMS of SLA				RMS of SLA differences		
		ALT	TG	TG-IB	TG-IB-GIA	ALT-TG	ALT-(TG-IB)	ALT-(TG-IB-GIA)
Torshavn	144	5.5	8.0	6.0	5.8	6.9	2.3	2.2
Lerwick	157	6.2	9.6	6.7	6.6	6.2	2.0	2.0
Kristiansund	204	5.9	12.5	9.0	9.0	8.8	4.0	4.0
Rorvik	205	7.0	12.5	8.5	8.6	8.1	3.3	3.2
Andenes	200	6.9	12.3	7.6	7.5	8.0	3.0	3.1
Hammerfest	198	6.1	12.4	7.8	7.8	8.3	3.3	3.3
Honningsvag	200	6.5	11.8	7.1	7.2	7.4	2.9	2.9
Barentsburg	168	4.3	11.7	9.5	9.5	11.3	8.1	8.2
Barentsburg[1]	91	4.3	9.0	6.8	7.0	7.4	4.2	4.3
Vardo	187	6.8	11.8	7.3	7.3	7.6	3.1	3.1
Murmansk	186	6.2	12.0	9.1	9.1	9.1	6.7	6.7
Zhelania	18	4.6	13.8	11.7	11.8	12.2	11.7	11.6
Bolvanskii Nos	12	7.4	14.7	8.3	8.3	6.8	4.9	4.9
Amderma	142	7.9	14.2	11.9	12.0	10.2	9.1	9.2
Amderma[2]	142	7.9	13.0	10.4	10.4	8.1	6.8	6.8
Morzhovaia	5	10.4	21.4	22.4	22.4	17.2	19.6	19.5
Dikson	16	11.6	15.9	13.6	13.6	11.9	11.6	11.6
Izvestia CIK	85	8.0	12.8	9.9	9.9	6.4	5.1	5.1
Isachenko	5	7.1	14.1	10.4	10.4	13.2	9.2	9.2
Uedinenia	8	7.0	15.9	12.6	12.5	8.8	7.1	7.1
Vise	81	4.3	12.7	10.5	10.5	9.3	7.1	7.2
Golomianyi	60	4.1	9.7	6.1	6.1	7.6	5.6	5.6

[1]Only data from 2002 to 2010 are considered.
[2]The 1992-2010 linear trend has been removed from the tide gauge data.

Table 1. *Comparison between the monthly tide gauge records and altimeter MSLA interpolated to the location of tide gauges. The comparison is conducted only for the tide gauges that have overlapping records with altimetry. Abbreviations: ALT – altimeter data, TG – raw tide gauge records, (TG-IB) – tide gauge records corrected for IB, (TG-IB-GIA) – tide gauge records corrected for IB and GIA.*

Tide Gauge Station	Altimetry		Tide Gauge	
	A	φ	A	φ
Torshavn	6	Sep	6	Sep
Lerwick	7	Nov	7	Oct
Kristiansund	7	Nov	10	Nov
Rorvik	8	Nov	9	Nov
Andenes	8	Nov	8	Nov
Hammerfest	7	Nov	8	Nov
Honningsvag	7	Nov	8	Nov
Barentsburg	4	Sep	6	Oct
Vardo	7	Nov	7	Nov
Murmansk	7	Nov	7	Oct
Bugrino[1]	8	Dec	6	Oct
Malye Karmakuly[1]	6	Nov	3	Oct
Zhelania	4	Nov	5	Dec
Bolvanskii Nos	7	Dec	10	Dec
Amderma	10	Nov	11	Oct
Morzhovaya	13	Nov	7	Aug
Dikson	10	Oct	3	Sep
Izvestia CIK	9	Oct	9	Nov
Isachenko[1]	6	Nov	5	Nov
Uedinenia[1]	7	Nov	5	Nov
Russkii[1]	5	Nov	3	Nov
Vise	4	Oct	6	Oct
Golomianyi	2	Nov	3	Nov

[1]Tide gauge records prior to 1992 are used

Table 2. *Comparison of amplitudes (cm) and phases (months of the annual maxima) of the seasonal cycle estimated from the altimetry and tide gauge data.*

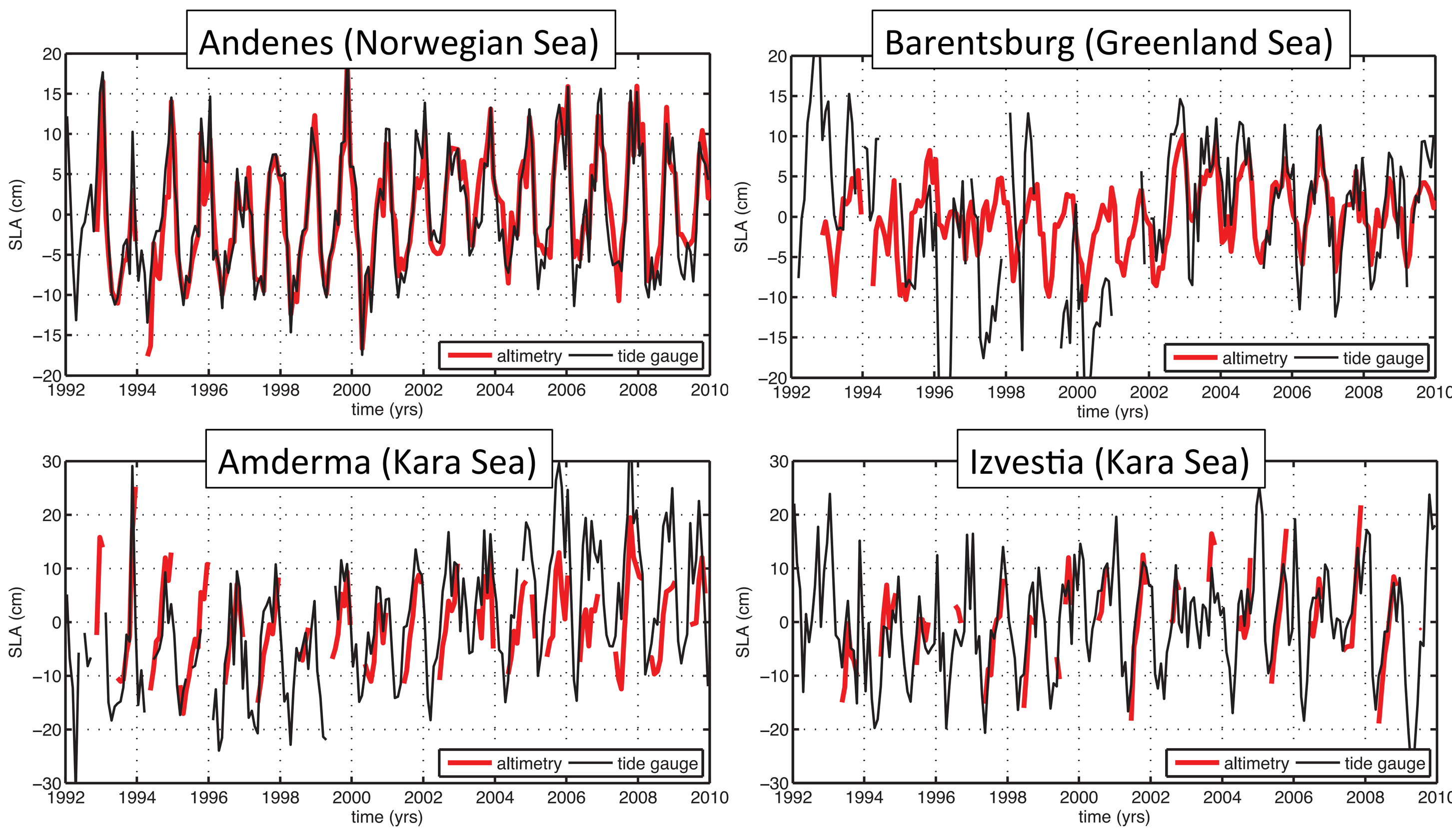

Figure 2. *Sea level anomaly (cm) from the records of four tide gauges (black curves) and from the MSLA interpolated to the locations of the tide gauges (red curves).*

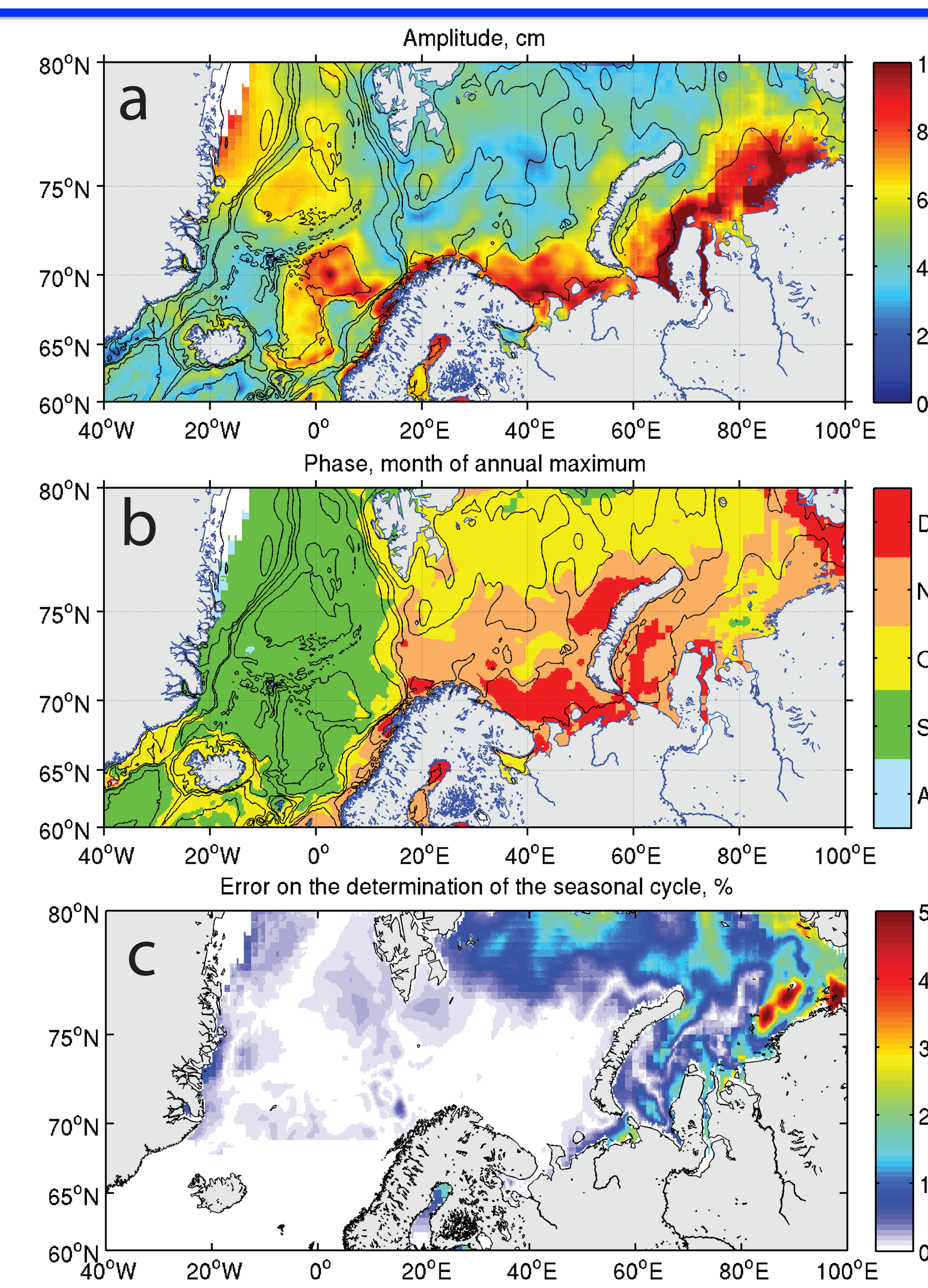

Figure 3. *(a) Amplitude (cm) of the seasonal cycle. (b) Phase of the seasonal cycle (month of the annual maximum). (c) Error (%) on the determination of the seasonal cycle.*

- Altimetry data are robust in most coastal areas of the region (Table 1, Figure 2)
- IB has a prominent effect on the variability of sea level, while the impact of the GIA correction is found negligible (Table 1)
- The seasonal cycle of sea level is well observed by altimetry (Table 2). In most places, the difference between the annual phases does not exceed 1 month.

4. Comparison with surface drifters

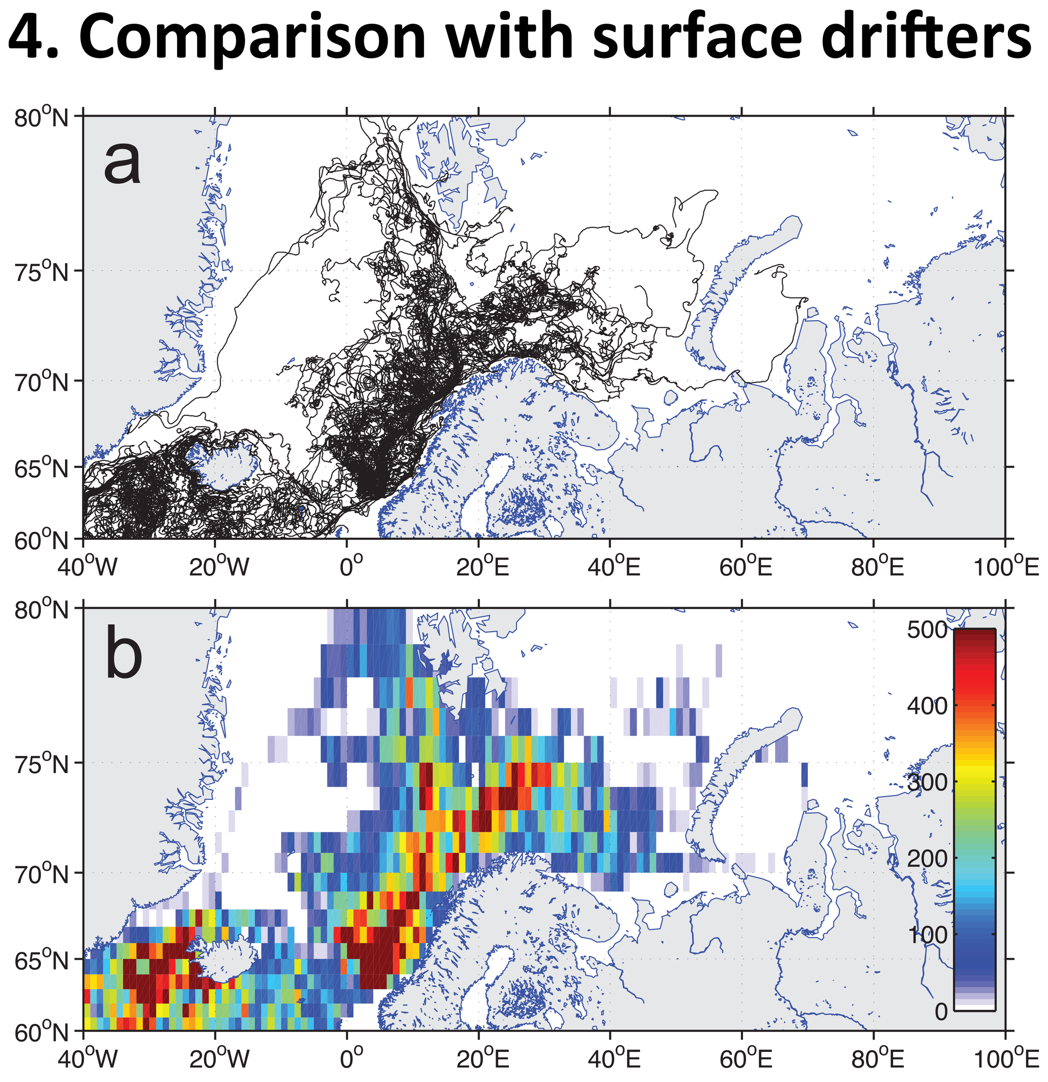

Figure 4. *(a) The trajectories of 252 surface drifters present in the region from January 1993 to December 2010. (b) The number of drifter records in 1°×1° bins.*

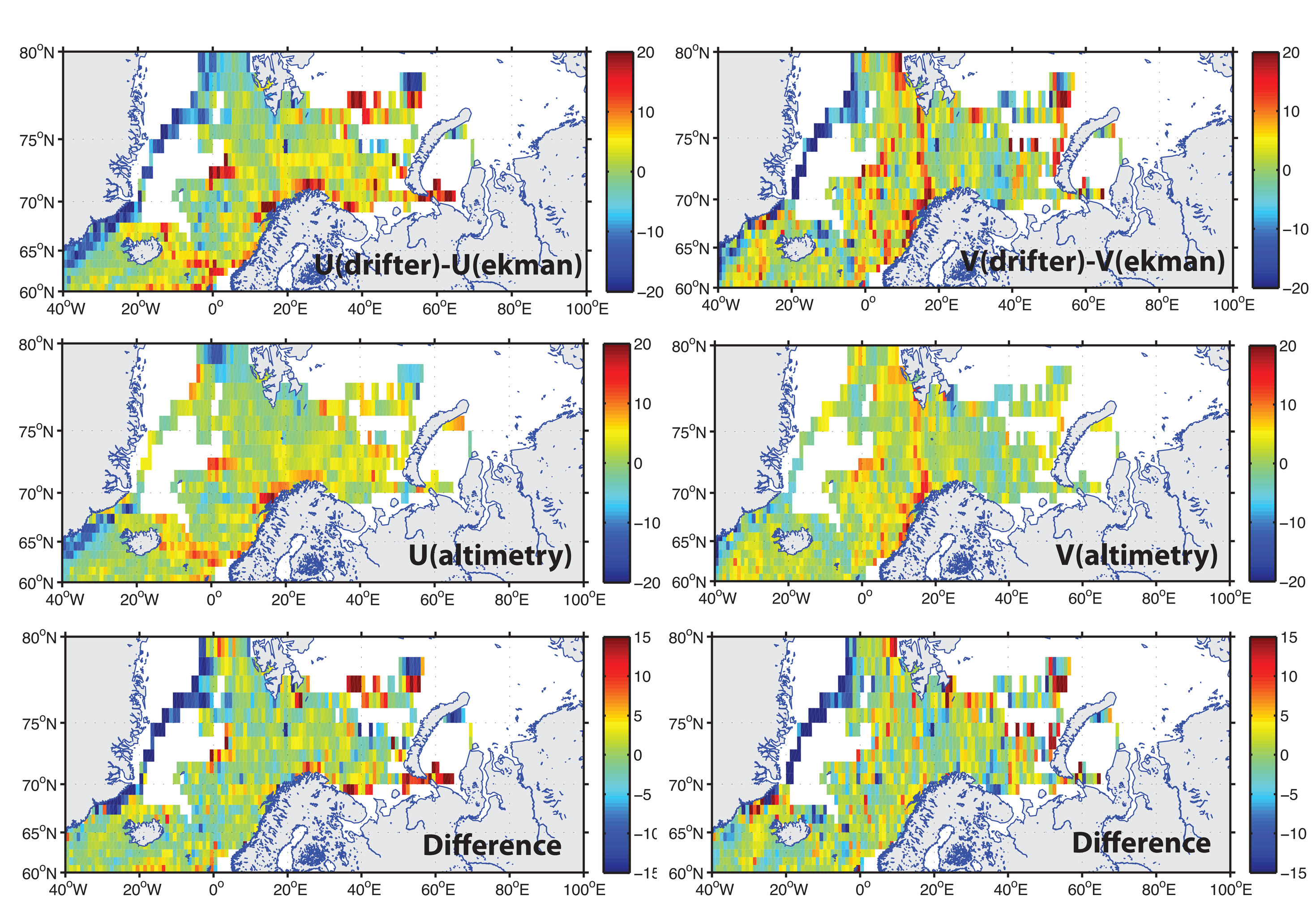

Figure 5.
The time mean U and V components of the drifter (top) and altimetry (middle) velocities averaged over 1°×1° bins, and the difference between them (bottom). The drifter velocities were corrected for Ekman currents. The altimetry data were interpolated at the trajectories of drifters.

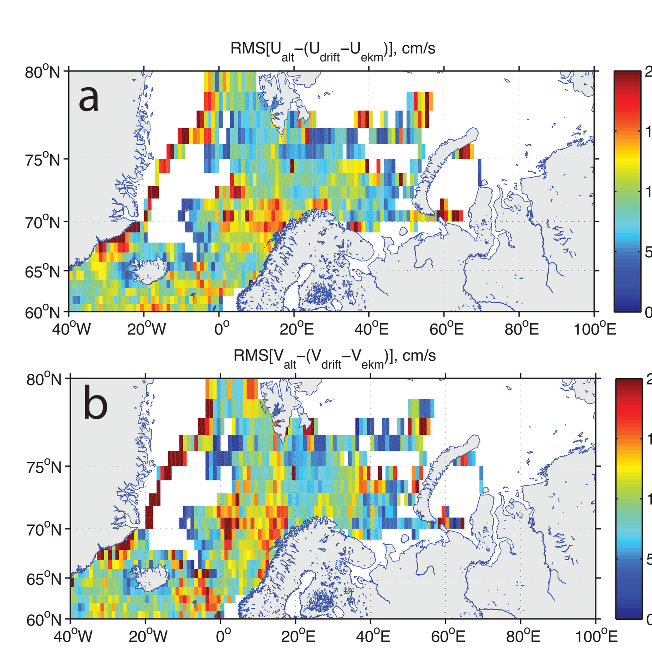

Figure 6. *The RMS of the differences (cm/s) between the altimetry and drifter U (a) and V (b) velocity components computed over 1°×1° bins. The altimetry data were interpolated at the trajectories of drifters. The drifter velocities were corrected for Ekman currents.*

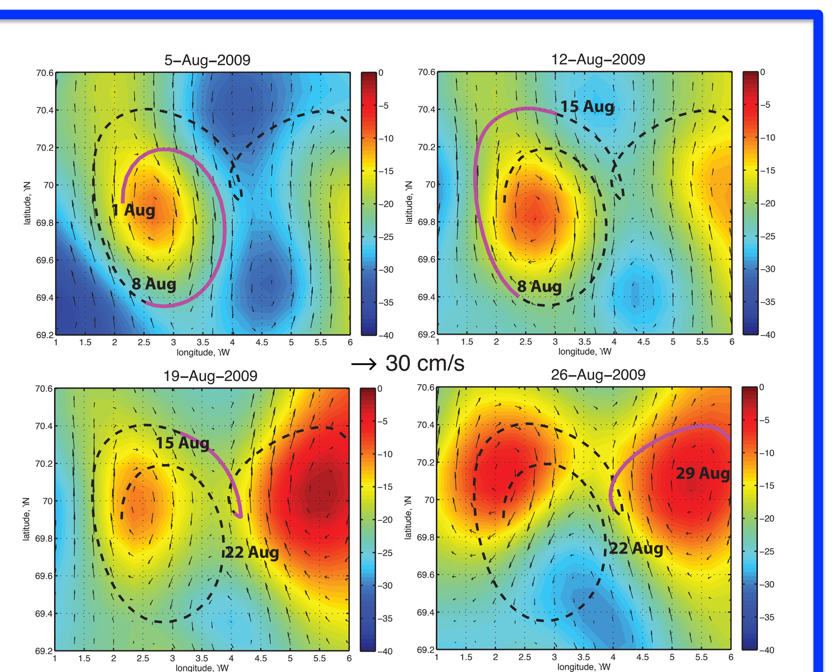

Figure 7. *The MADTs (cm), the altimetry geostrophic velocities, and the trajectory of the surface drifter SD63945 from 1 August 2009 to 29 August 2009 in the Norwegian Sea. The trajectories, corresponding to the weeks approximately centered at the times of the MADT are highlighted by magenta.*

- Compared to drifters, altimetry appears to underestimate the velocities (Figure 5)
- The RMS differences between the drifter and altimetry velocities are comparable to earlier studies that focused on the lower latitude regions of the World Ocean (Figure 6)
- The drifter trajectories are in a good agreement with altimetric sea surface topography and its mesoscale variability (Figure 7)

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