SAR OBSERVATIONS OF INTERNAL WAVES IN THE RUSSIAN ARCTIC SEAS

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ABSTRACT

In this work taking the advantage of high resolution spaceborne synthetic aperture radar (SAR) measurements we present first preliminary results of short-period internal waves (IW) observations in the Barents, Kara and White seas based on ENVISAT ASAR data for summer-autumn months in 2007-2011. Altogether more than 2000 IW packets were identified in about 1400 SAR images. Detailed maps of internal wave's occurrences in the three Arctic seas have helped to identify main sites of regular IW generation.

Index Terms— oceanic internal waves, synthetic aperture radar, Arctic Ocean, Barents Sea, Kara Sea.

1. INTRODUCTION

Internal waves (IWs) are important dynamical features significantly impacting the hydrology of the upper ocean through transferring the energy from tides to turbulent mixing. In the Arctic Ocean they are particularly important for sub-marine navigation and construction, vertical mixing, formation of the water structure and the maintenance of the life activity in marine ecosystems [1].

However, internal waves, and particularly short-period internal waves still remain largely unexplored and poorly investigated in the Arctic Ocean [1, 2]. Major results available in literature typically address low-frequency internal tidal waves and are based on numerical simulations [1, 3] or sparse *in situ* measurements [4, 5, 6]. In turn, spaceborne synthetic aperture radars (SAR) having high spatial resolution and wide coverage proved to be very effective for detection of hot-spots of internal wave activity in the World Ocean (see e.g [7, 8, 9]), as well as in some Arctic seas [2, 10, 11]. In this work taking the advantage of high resolution SAR measurements we present first preliminary results of short-period IWs observations in the Barents, Kara and White seas based on ENVISAT ASAR satellite data for summer-autumn months in 2007-2011.

2. DATA AND METHODS

SAR-based survey of internal waves and their properties in the Arctic seas is based on analysis of ENVISAT ASAR images taken in Wide Swath Mode and Image Mode Precise with spatial resolution of 150 and 30 m correspondingly. Analysis of SAR data and identification of internal waves was done with MATLAB-based code INTERWAVE enabling to calibrate and de-trend the SAR data, and extract informative IW parameters, depth of the normalized radar cross section (NRCS) modulation by IWs, SAR imaging geometry and background wind conditions.

3. RESULTS

Analysis of about 1400 ENVISAT ASAR images helped to identify more than 2000 IW packets in the Barents, Kara and White seas. For the Barents and Kara seas SAR data archive covers the period from June to October 2007, while for the White Sea the dataset covers the period from May to September between 2007-2011.

In general, amount of detected IWs varied significantly throughout extended summer period – IWs were less frequently detected in May-June, then number of observations gradually increased in July, and had a clear maximum in August-September reflecting the general intra-seasonal variability of stratification conditions favorable for IW generation. In second half of October number of observations significantly decreased that, besides changes in stratification could be partially related to higher near-surface winds limiting the ability of SAR to detect sea surface signatures of internal waves. Most internal waves were observed in the form of internal solitary waves (ISWs) with rank-ordered wavelengths in the packets.

Fig. 1 shows results of SAR observations for the Barents Sea including a map of total SAR data coverage (Fig 1, a) and map of leading wave fronts of detected IWs (Fig. 1, b). As seen in Fig. 1 (a) on the mean about 60 SAR frames cover the sea with larger amount of data in the eastern and north-western parts of the sea. In total, analysis of 463 SAR images revealed 904 IW trains. As seen in Fig. 1 (b), the primary regions of IW occurrences in the Barents Sea are located to the north from Svalbard, to the west from the western tip of the Franz-Josef Land archipelago, in the

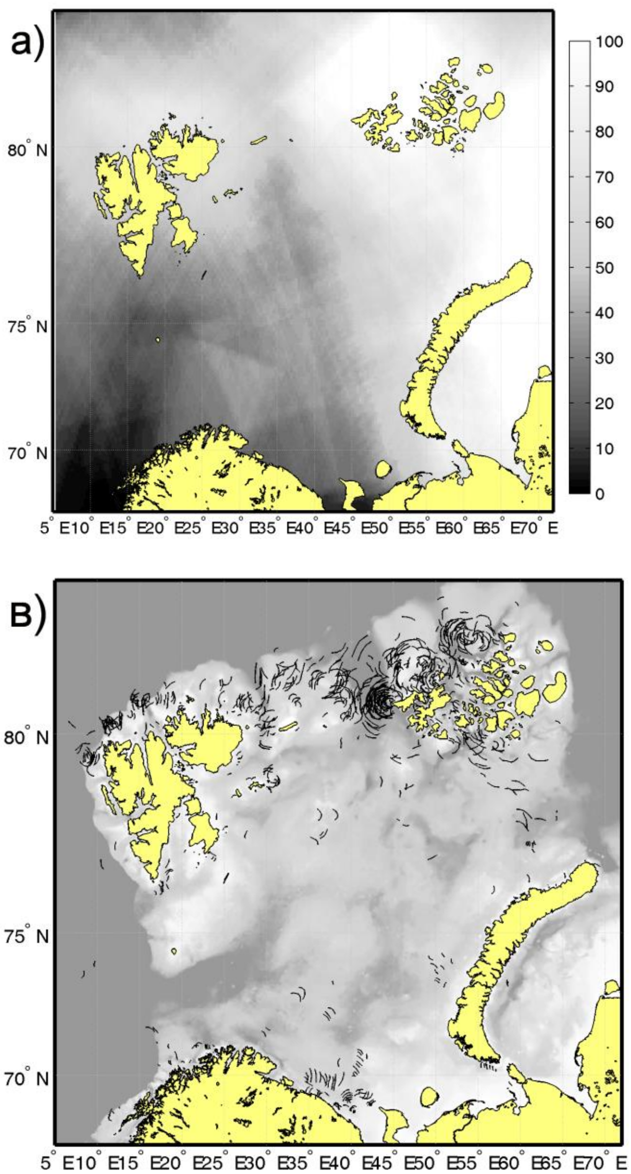

Figure 1. ENVISAT ASAR observations of short-period internal waves in the Barents Sea in June-October 2007. a) Map of total SAR data coverage, b) distribution map of internal wave locations.

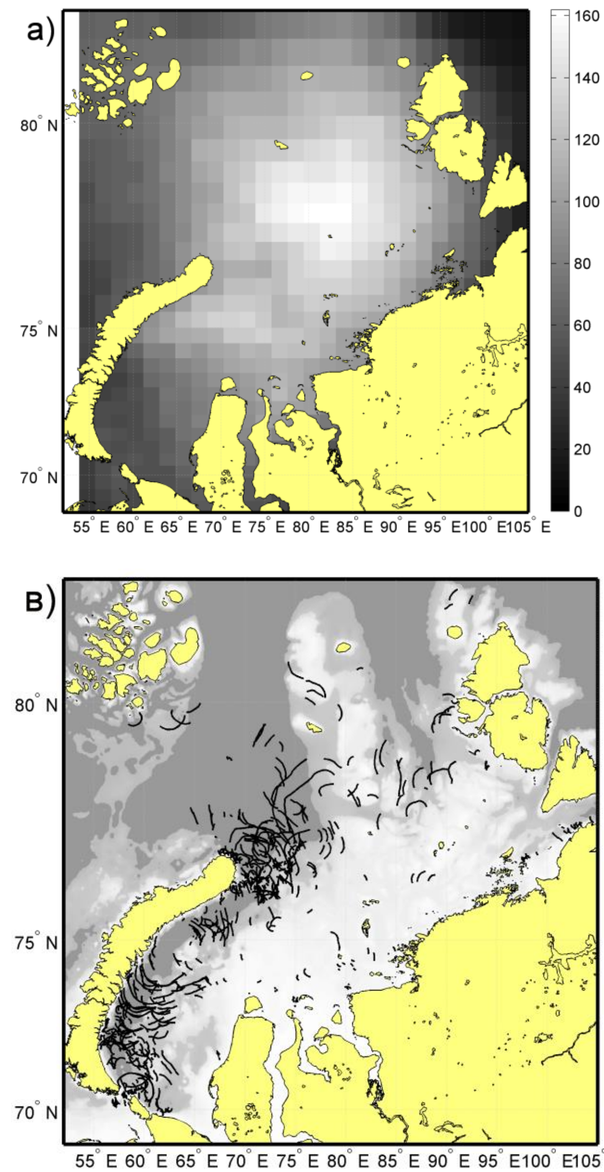

Figure 2. ENVISAT ASAR observations of short-period internal waves in the Kara Sea in June-October 2007. a) Map of total SAR data coverage, b) distribution map of internal wave locations.

vicinity of the northern Norwegian coast, and in the southern part of the Barents Sea close to the Voronka of the White Sea.

Results of SAR observations for the Kara Sea are shown on Fig. 2. The data coverage for the Kara Sea is better than that of the Barents Sea, - 598 SAR frames in total with about 100 SAR observations per grid cell (Fig. 2, a), and 701 case of IW detection. As seen, central and north-eastern parts of the sea are covered somewhat better than e.g. its south-western part. However, the latter region, particularly over the southern part of Novaya Zemlya Trough, is one of the key regions for IW activity (see Fig. 2, b). Internal waves were also regularly observed from both sides of the Kara Gates Strait, in the strait itself, and in the vicinity of Cape Zhelaniya. Notably, very small amount of IW occurrences was found in shallow sea areas close to Ob and Yenisei estuaries. Large-scale nonlinear IW packets with wavelengths of 2-5 km and crest lengths >200 km were periodically observed north-east to Cape Zhelaniya over the southern part of Svyataya Anna Trough. More details about characteristics of short-period IWs in the Kara Sea may be found in [12].

In the White Sea (Fig. 3) analysis of 292 SAR images revealed 502 IW occurrences. The primary region of IW

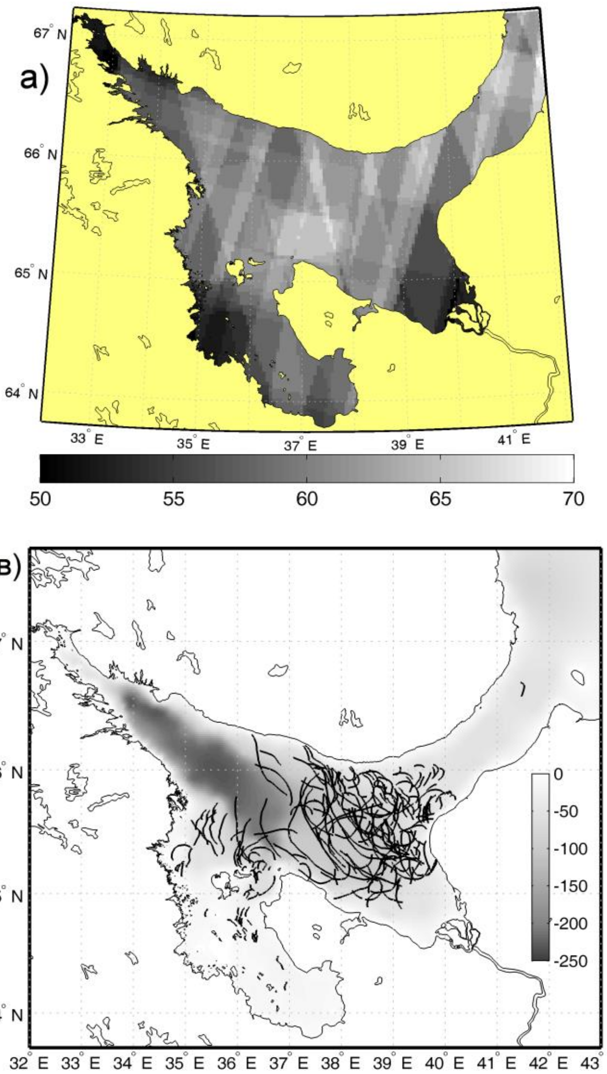

Figure 3. ENVISAT ASAR observations of short-period internal waves in the White Sea in May-September 2007-2011. a) Map of total SAR data coverage, b) distribution map of internal wave locations.

activity is the southwestern Gorlo Strait in the north-eastern part of the sea (see Fig. 3, b). IW packets emerging from this area were regularly observed to reach crest lengths up to 200 km and propagate few hundred kilometers from their origin towards the western sea shelf [2]. IWs were also regularly observed north from the Solovetsky archipelago and in the Dvina Bay. More details on short-period IWs in the White Sea may be found in [2].

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