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SAR revealing hot-spots of internal solitary waves in the Eurasian Arctic

Igor Kozlov*[1], E. Zubkova[1], V. Kudryavtsev[1], A. Zimin[2], A. Myasoedov[1], B. Chapron[3,1]

[1] Satellite Oceanography Laboratory, Russian State Hydrometeorological University, St. Petersburg, Russia [2] Institute of Oceanology RAS, St. Petersburg Branch, St. Petersburg, Russia

*** Corresponding author e-mail: igor.eko@gmail.com** [3] Laboratoire d'Océanographie Spatiale, Ifremer, Brest, France

MOTIVATION

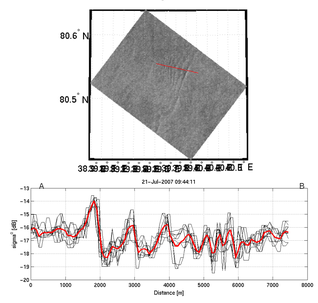
- Internal waves (IWs) are important for dynamics of the Arctic Ocean.
- Recent *in situ* observations indicate enhanced IW-related vertical mixing over rough topography fostering the diffusion of heat from Atlantic water to the Arctic Ocean [1].
- Yet, the locations of enhanced IW activity and mixing still remain unclear.
- In the vicinity of the critical latitude (74.5° N) tidally generated IWs are similar to unsteady lee waves with short spatial and temporal scales and propagate in the form of packets of internal solitary waves (ISW) [2].
- … as those frequently observed by space-borne Synthetic Aperture Radars

DATA and METHODS

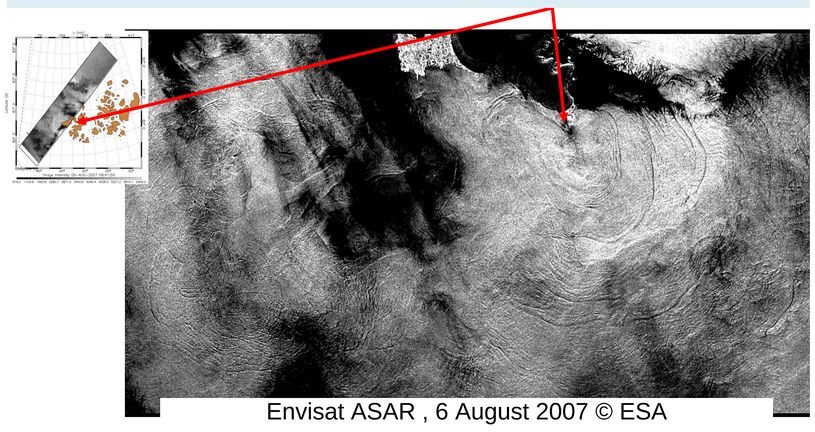
- We analize about 3000 Envisat ASAR images for the north Norwegian, Greenland, Barents, Kara and White seas.
- IW parameters are extracted in semi-automated way from hand-made transects crossing IWs (MATLAB-based code)

List of obtained IW parameters

- IW packet area/ crest length
- Number of waves in packets
- Max/min wavelength in packets
- Average phase speed for consecutive IW packets
- IW propagation direction
- Background NRCS
- Max/Min NRCS modulations by IWs
- Background winds (speed & direction)
- Angle between SAR look & IW direction
- Angle between wind & IW direction
- Depth (IBCAO 2km)
- SAR imaging geometry along the transect



EXAMPLE : ISW near Franz Josef Land

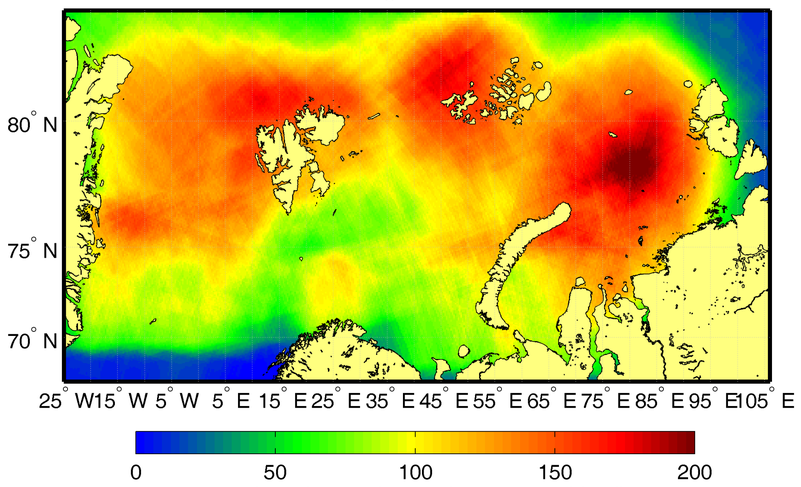


Envisat ASAR , 6 August 2007 © ESA

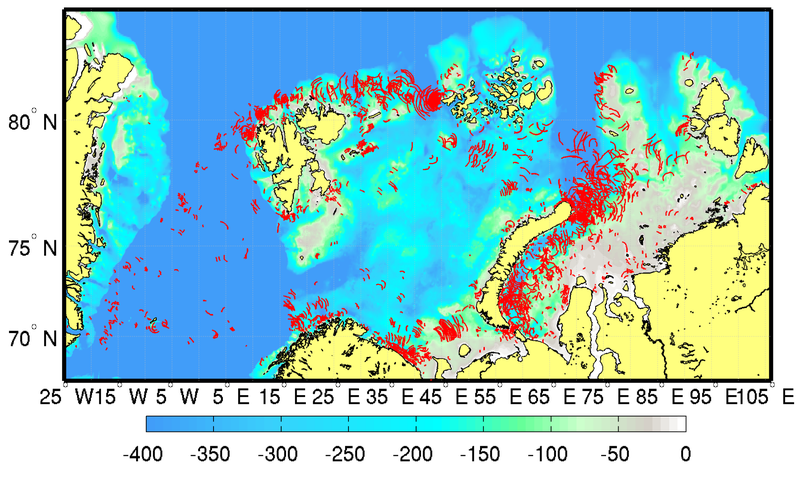
MAIN RESULTS

4290 ISW PACKETS WERE IDENTIFIED IN 2880 ASAR IMAGES

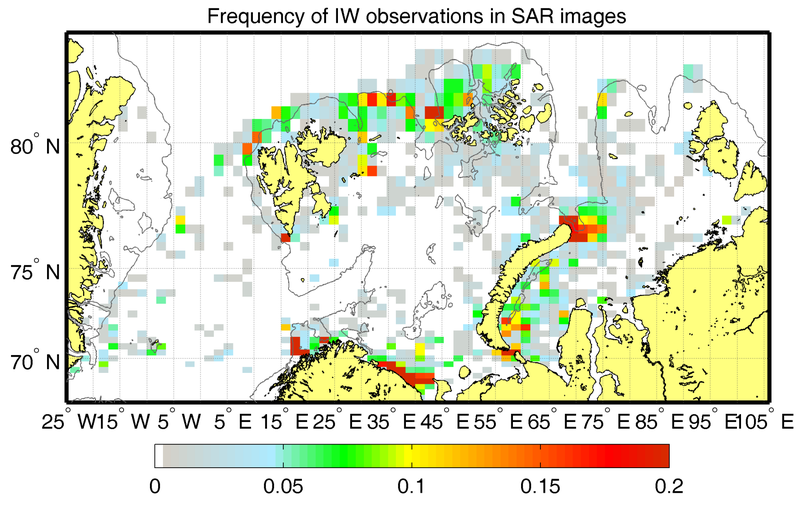
SAR data coverage of the Arctic seas



Spatial distribution of leading wavefronts in the ISW packets



Frequency of IW observations in SAR images



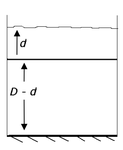
MASS CONTENT OF THE UPPER OCEAN

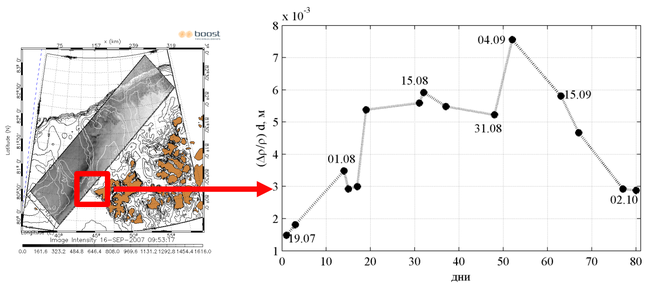
Estimation of mass content of the upper ocean layer from SAR observations of IW kinematics

Using dispersion relation for lower baroclinic mode $c^2 = \frac{g\rho}{k\rho\coth(kd) + k(\rho_2 - \rho)\coth(k(D-d))}$ (1),

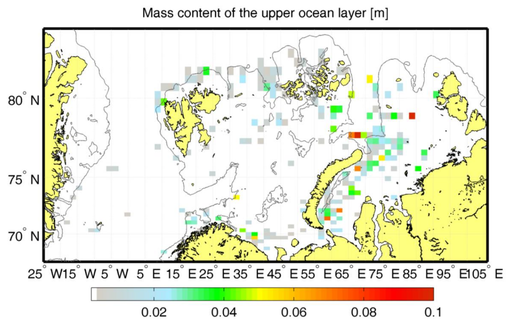
assuming $kd \ll 1$ $c^2 = \frac{g\rho d}{k(\rho_2 - \rho)\coth(k(D-d))}$ (2),

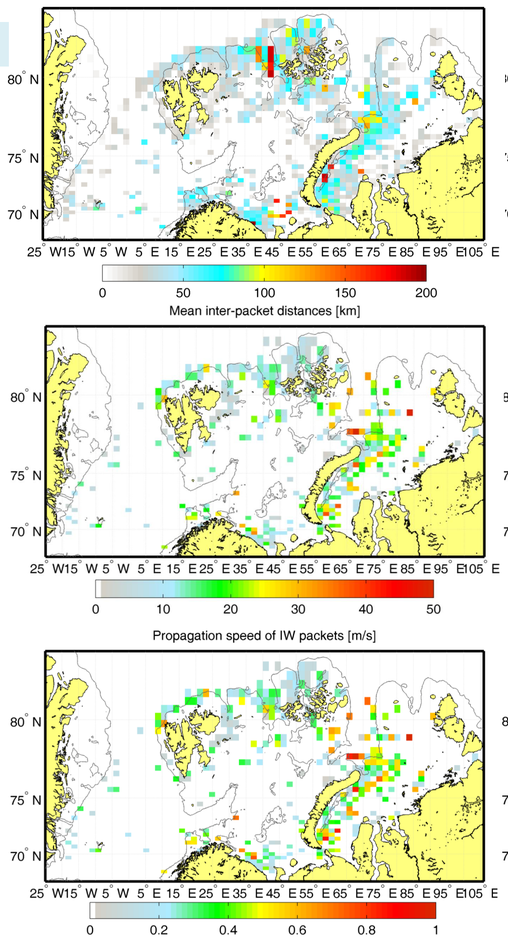
and $\coth k(D-d) \sim 1$ $d\frac{\Delta\rho}{\rho} = \frac{c^2}{g}$ (3).

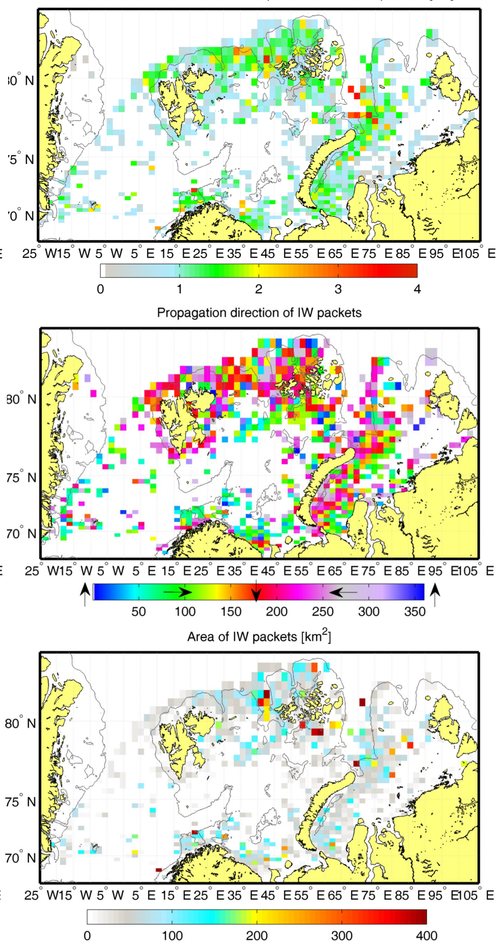




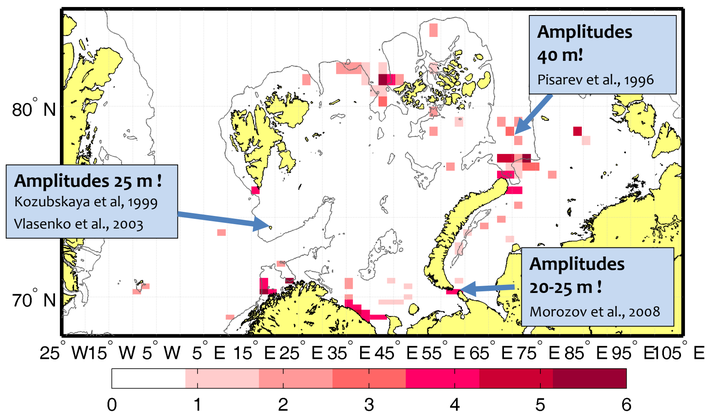
Mass content of the upper ocean layer [m]







Maximum observed inter-soliton separations in the IW packets [km]

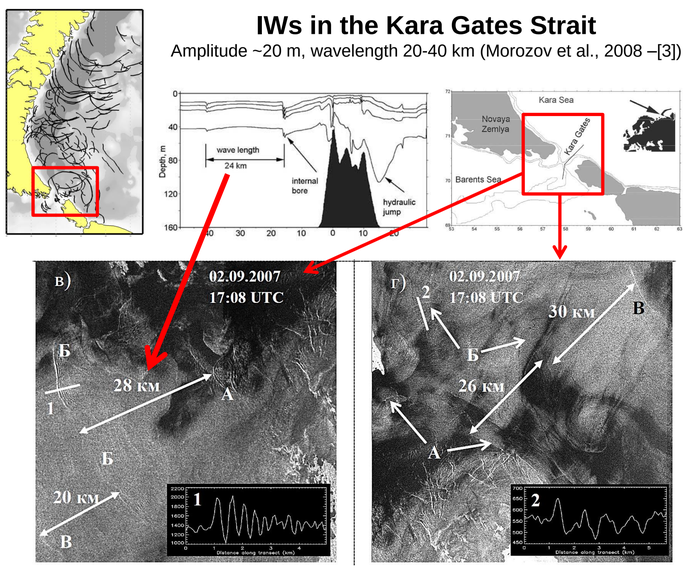


1: Leading front length >100 km
2: Inter-soliton distance > 2 km
3: Inter-packet distance > 40 km (>1 m/s phase speed)
4: Observational frequency >0.2
>4 – sum of indexes from 1 to 4

KARA SEA

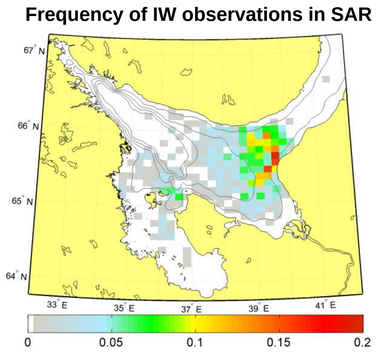
IWs in the Kara Gates Strait

Amplitude ~20 m, wavelength 20-40 km (Morozov et al., 2008 –[3])

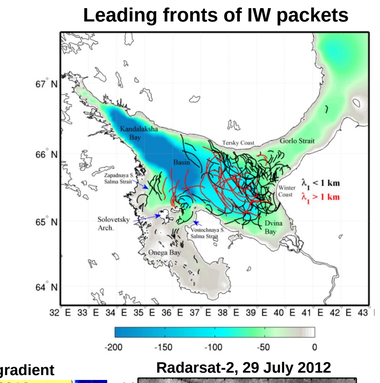


WHITE SEA

Frequency of IW observations in SAR

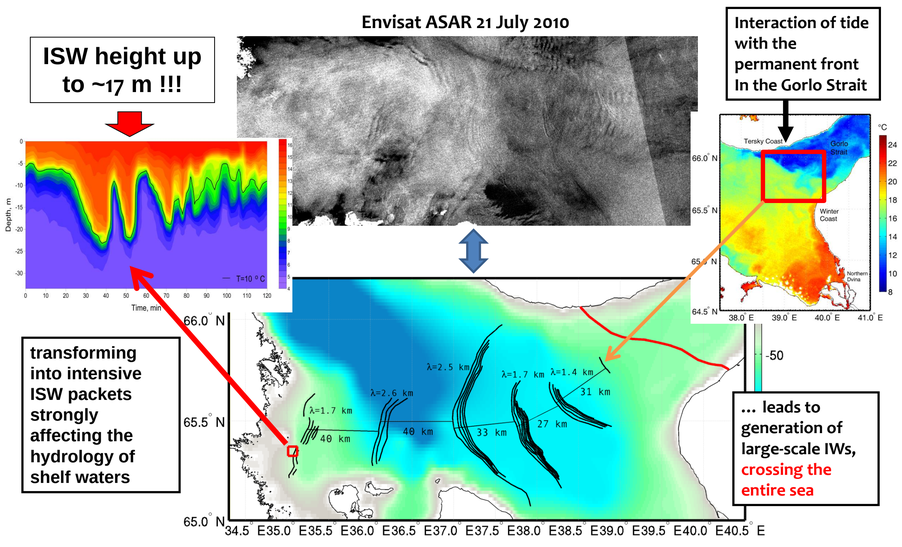


Leading fronts of IW packets

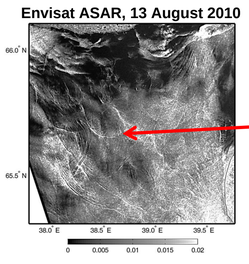


Large-scale nonlinear internal waves in the White Sea

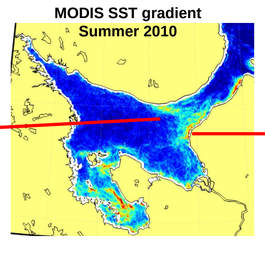
Kozlov et al., Remote Sensing of Environment, 2014, doi:10.1016/j.rse.2014.02.017 – ref [4]



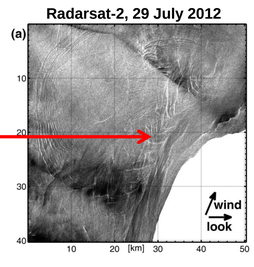
Envisat ASAR, 13 August 2010



MODIS SST gradient Summer 2010



Radarsat-2, 29 July 2012



KEY RESULTS

- We present a first account on the ISW activity in the seasonally ice-free Arctic seas using high resolution space-borne SAR images
- Analysis of 2880 Envisat ASAR images taken in June-October 2007-2011 revealed 4290 ISW packets.
- Hot-spots of ISW activity in the selected Arctic seas have been identified.
- Most frequently ISWs are found over the steepest continental slope regions.
- Detailed spatial and kinematic ISW properties were obtained.
- Regions with large-scale nonlinear ISW packets (wavelengths of 2-5 km and crest lengths >200 km) were identified.

ACKNOWLEDGEMENT

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