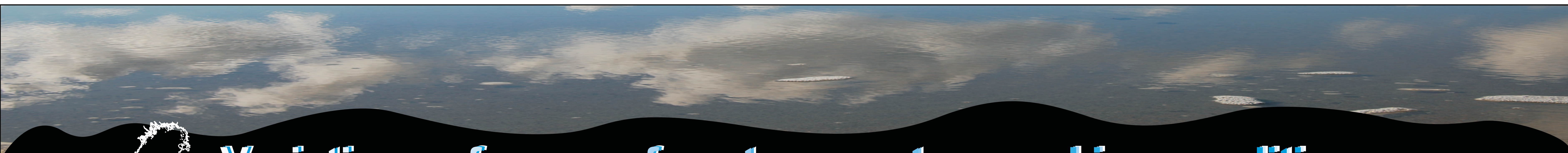

Variations of sea surface temperature and ice conditions in the South-Eastern Baltic over the last decade

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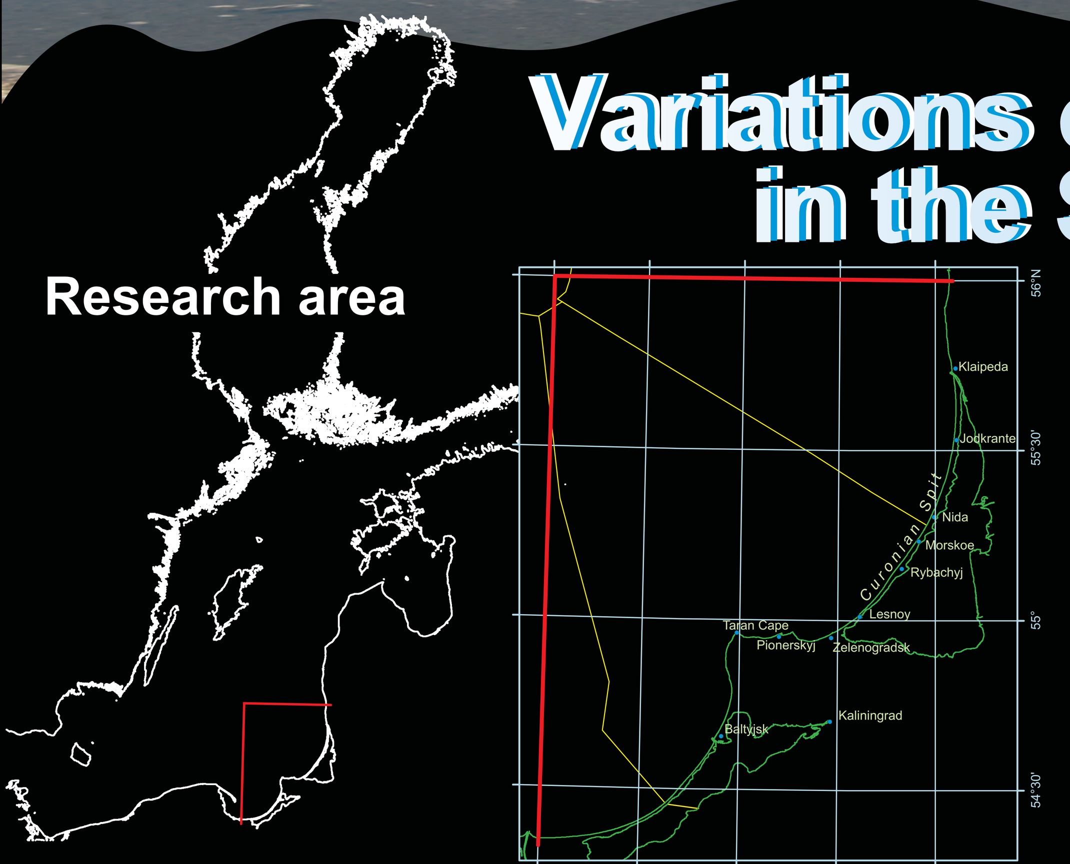
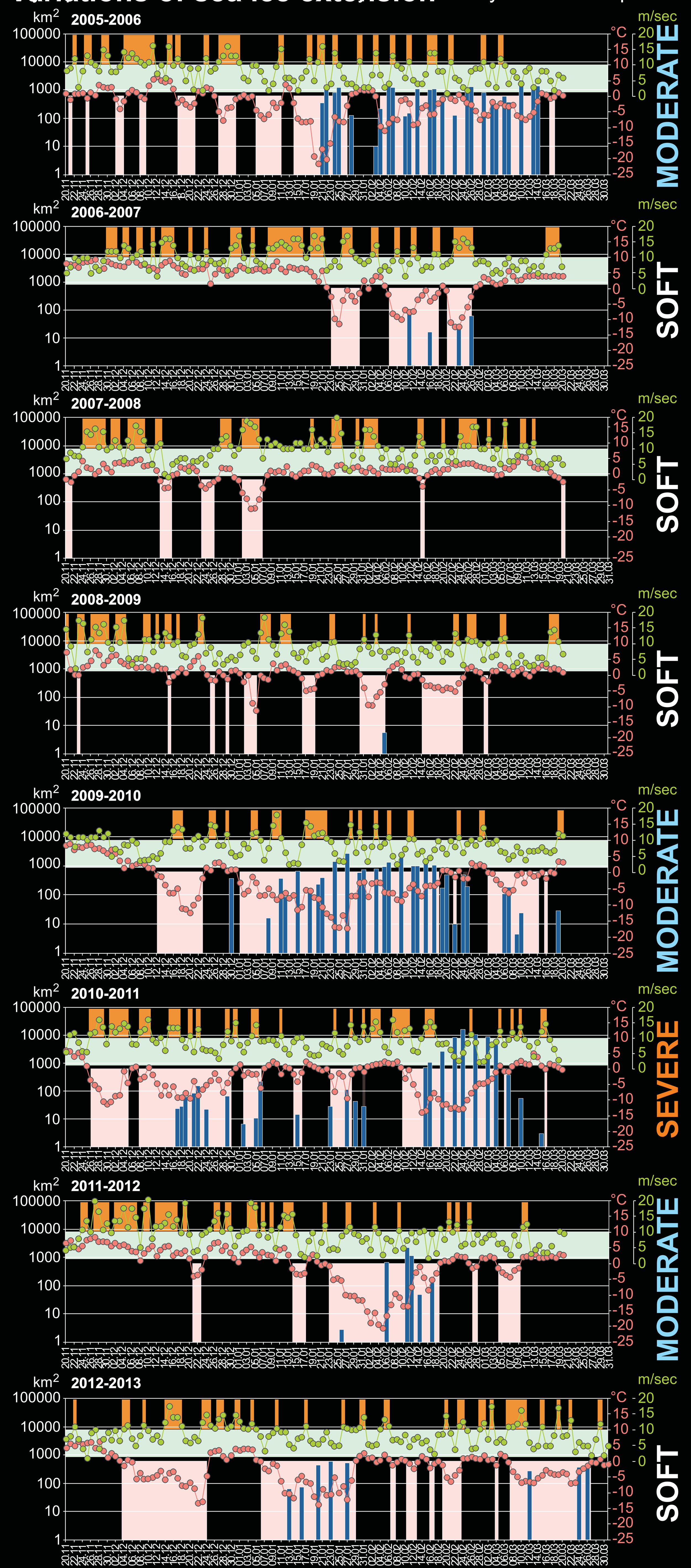
Research area



Materials and methods

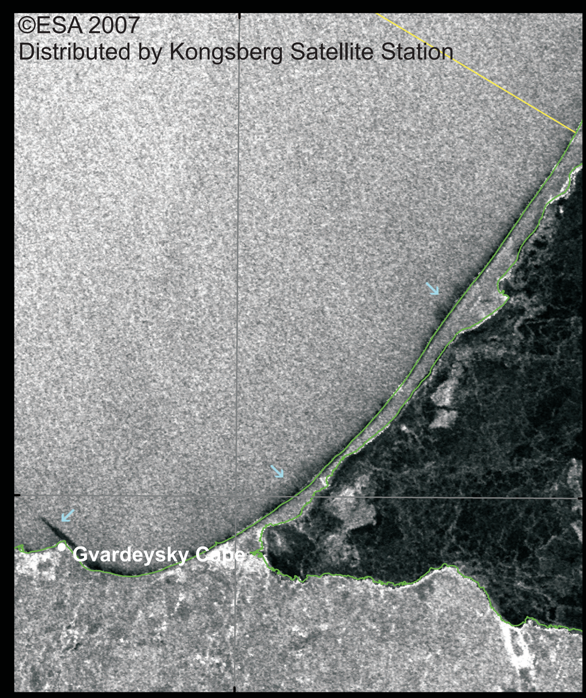
- Sea ice fields were observed from ENVISAT (ESA), RADARSAT-1 (CSA), and RADARSAT-2 (MDA) satellite radar imagery for 2005-2013. The satellite data is distributed by Kongsberg Satellite Services (KSAT, Norway) (www.ksat.no);
- The area of sea ice coverage was calculated with ArcGIS 9.2 software;
- SST evaluation was based on radiometer MODIS (TERRA, AQUA) satellite data for 2003-2012 (822 images);
- Air temperature and wind speed were obtained from Autonomous Hydrometeorological station (AHMS) installed on offshore ice-resistant fixed platform (OIFP) D-6 at a distance of 22 km from the Curonian Spit shore;
- Indicator of the severity of climate was defined as the sum of mean monthly air temperatures anomalies (T) from December to March. The limits of winter's type temperatures were taken as in equation: $T=T\pm\frac{1}{2}\sigma$. Severe winters are the winters with $T\leq 4.8$ C, mild winters meet the conditions $-4.7\leq T\geq 3.1$ °C, and soft winters are the winters with $T\geq 3.2$ °C;
- Synoptical situations was estimated by surface analysis of the maps of

Variations of sea ice extension

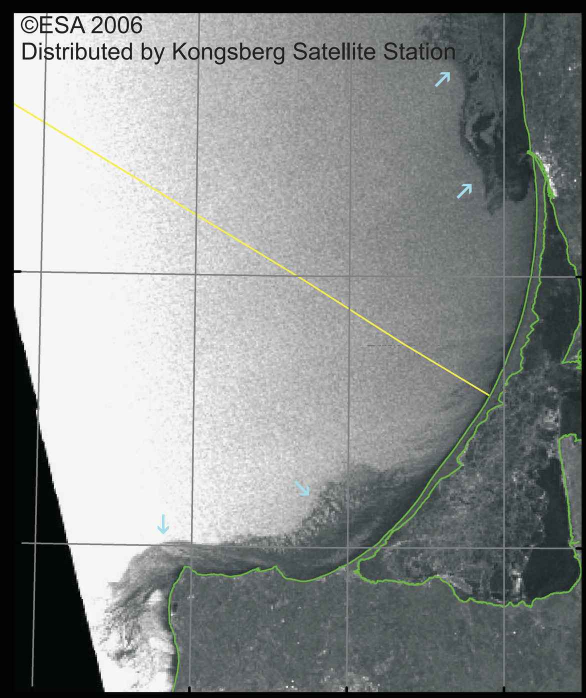


Legend:
1 – ice area, km²;
2 – air temperature in Klaipeda, °C;
3 – mean daily wind speed by AHMS data on D-6, m/sec;
4 – mean daily air temperature in Klaipeda < 0 °C;
5 – mean daily wind speed by AHMS data on D-6 from 2 to 10 m/sec;

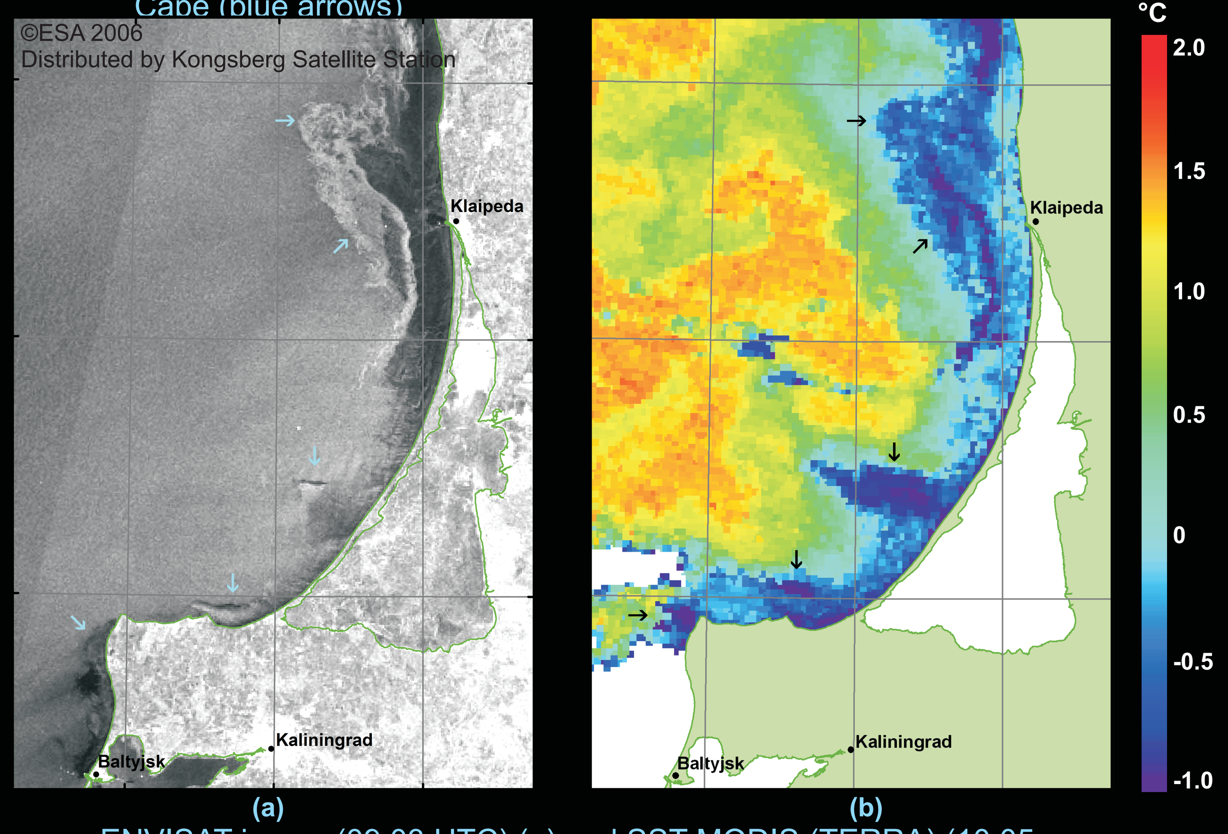
Correlation of the sea ice coverage area with air temperature and wind speed



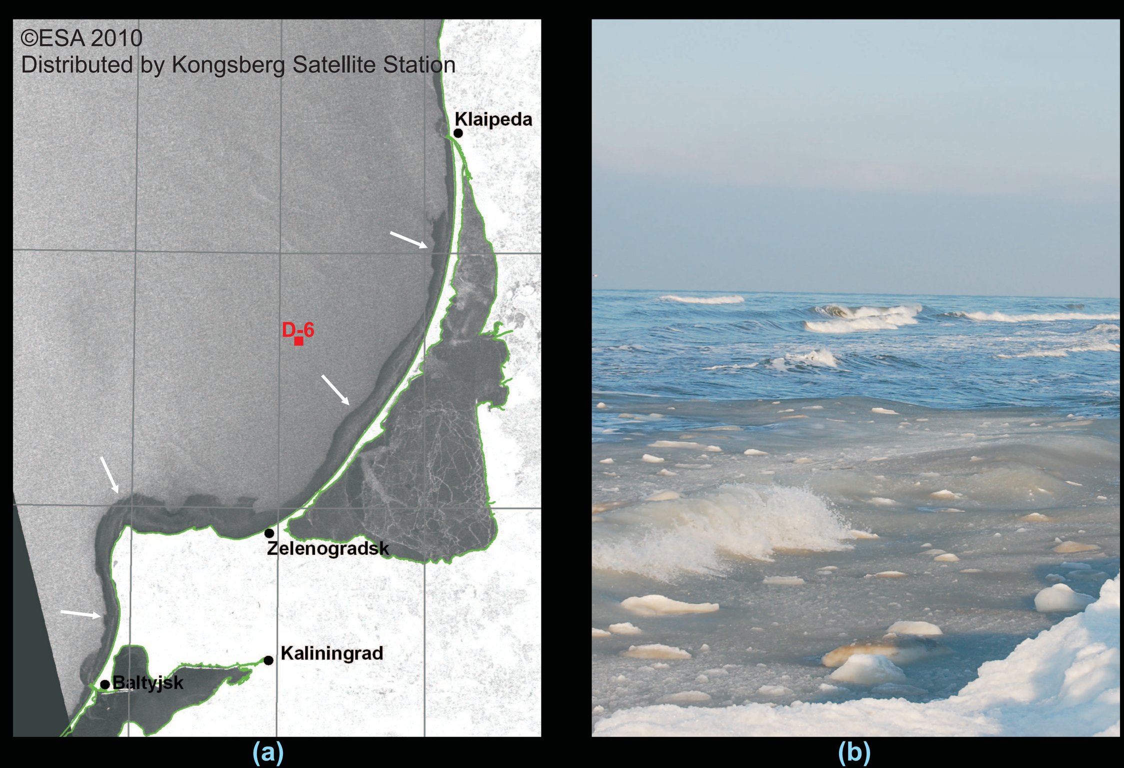
ENVISAT image from 26.02.2007 (09:08 UTC). Fast ice was observed along the Curonian Spit shore up to Gvardeysky Cape (blue arrows)



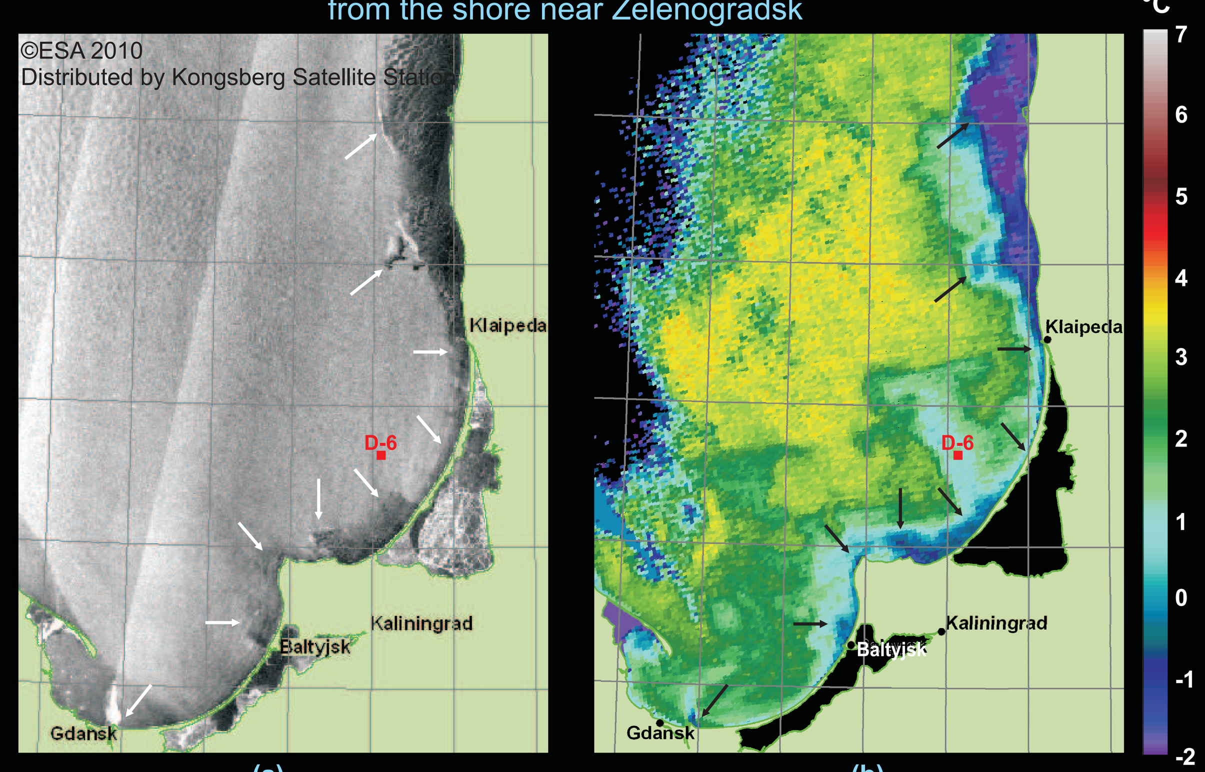
ENVISAT image from 22.01.2006 (20:05 UTC). Extension of ice fields is shown by blue arrows



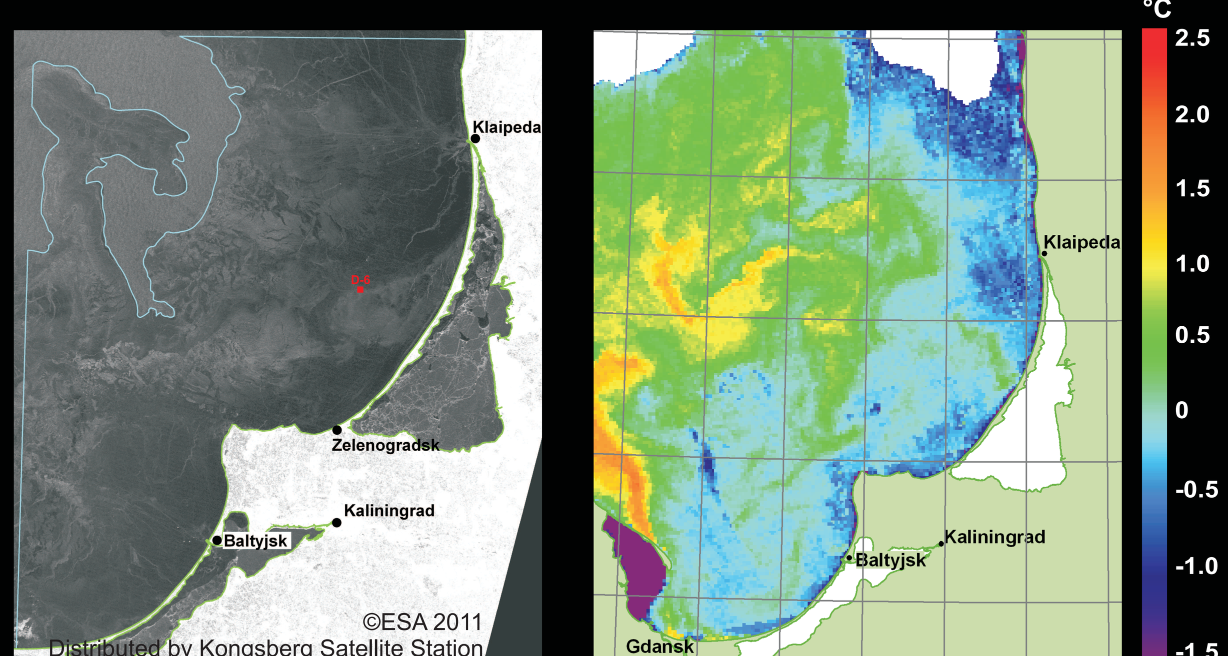
ENVISAT image (09:03 UTC) (a) and SST MODIS (TERRA) (10:05



Grease ice spreading on 31.01.2010. a) Radar image from ENVISAT (20:05 UTC). Grease ice along the shore is shown by blue arrows. b) Picture taken from the shore near Zelenogradsk



Radar image from ENVISAT (24.01.2010, 09:00 UTC) (a) and SST by MODIS (AQUA) (23.01.2010, 12:00 UTC) (b). Sea ice spreading is shown by arrows

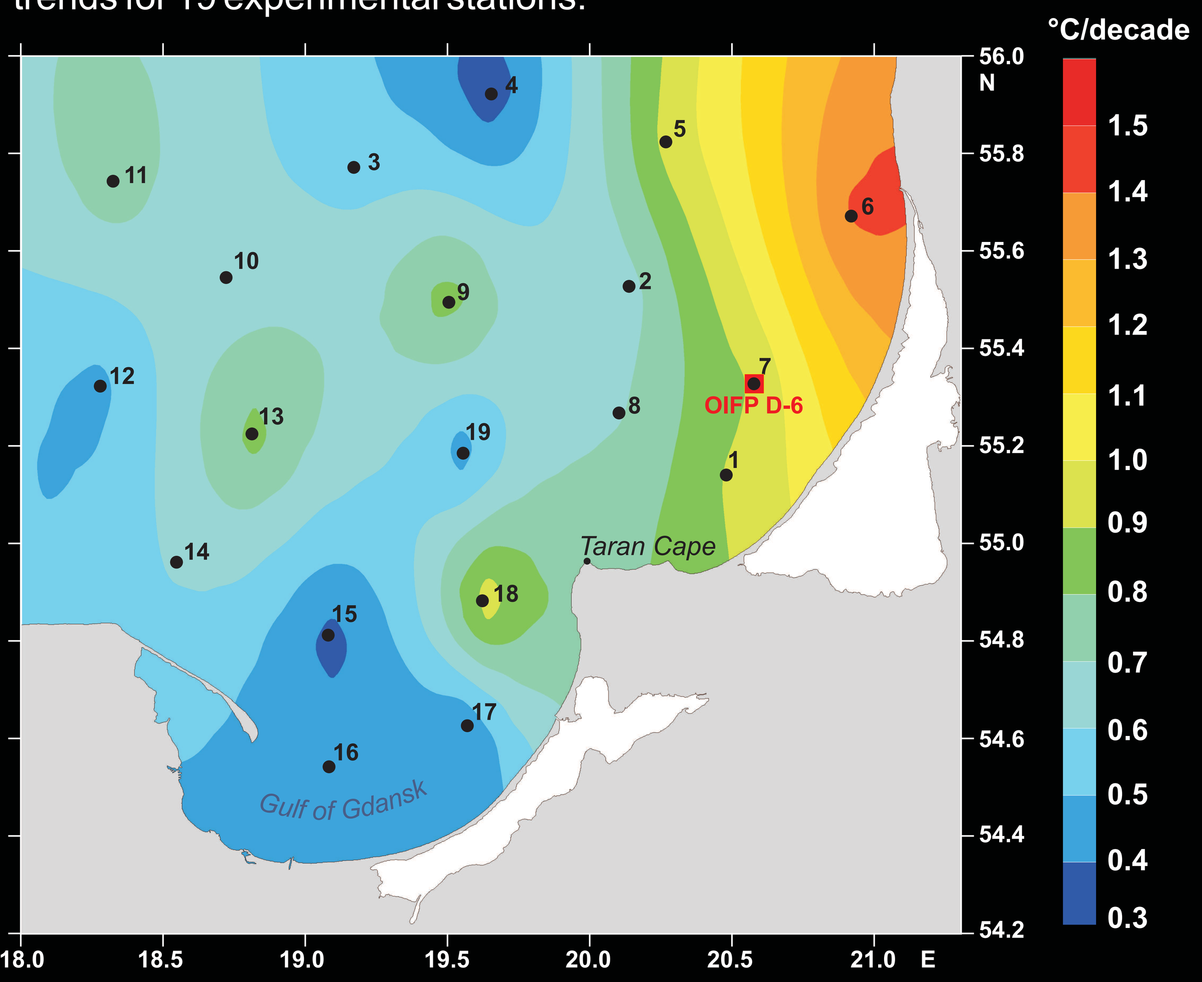


Spreading of sea ice by ENVISAT, 24.02.2011 (09:12 UTC) (blue line)

SST by MODIS-TERRA, 28.02.2011

Decadal SST variations

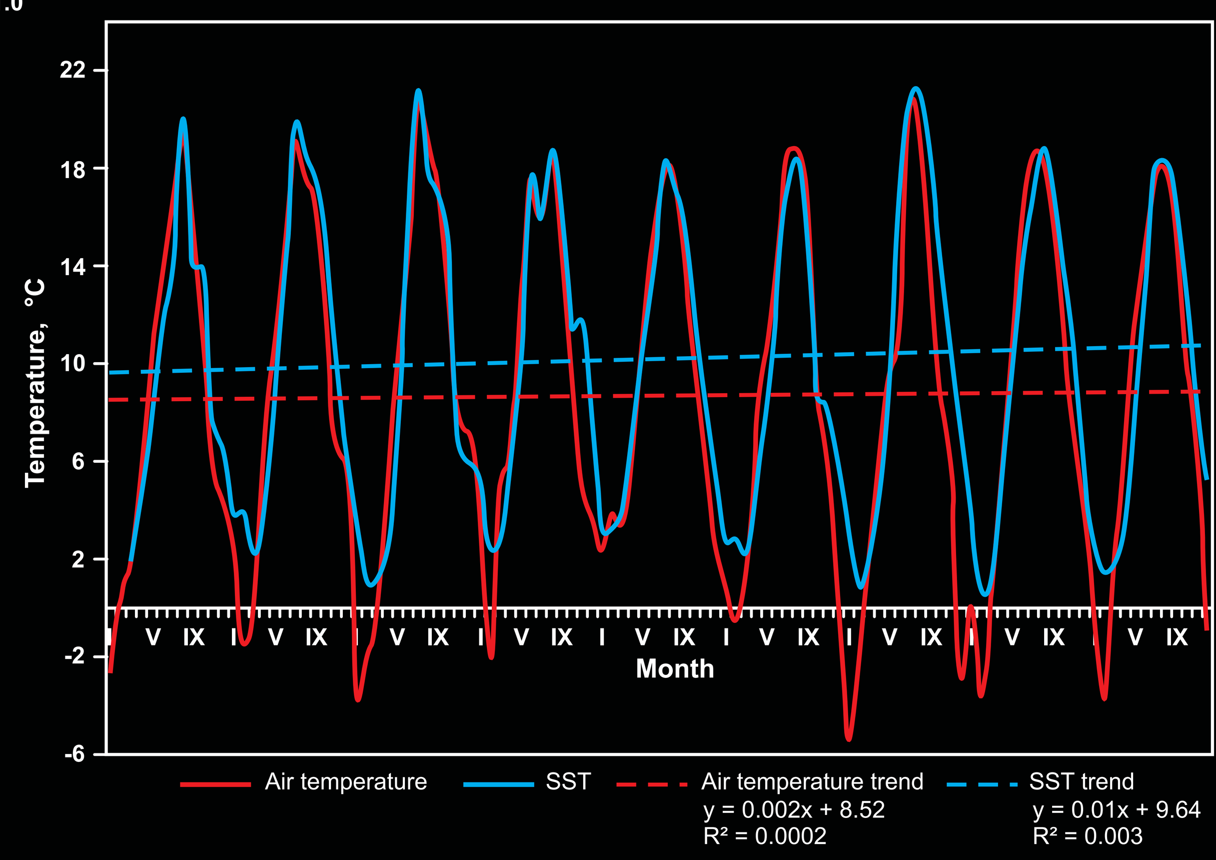
Recent SST change was evaluated according to linear decadal trends for 19 experimental stations:



Decadal trends of SST from MODIS satellite data (2003-2012)

- The average linear trend of SST for the South-Eastern Baltic accounts for 0.7±0.3 °C/decade;
- SST increase is estimated at a rate of 0.5±0.4 °C/decade in spring, and maximum increase was detected in summer 1.1±0.4 °C/decade. Cold period perform negative SST trends: -0.4±0.6 °C/decade in winter and

SST and air temperature interactions



Interannual variations of air temperature from OIFP D-6 and SST from station 7 for 2004-2012

- Linear trend of air temperature change in the South-Eastern Baltic is estimated at a rate of 0.02 °C for 2004-2012 ;
- A strong correlation is found between air temperature and SST change: number of pairs = 87, $R^2 = 0.91$, bias = 1.33 °C, RMSE = 1.73 °C;
- Seasonal change of air temperature coincide the SST seasonal

CONCLUSIONS

1. Within a short time period from 2005 to 2013 winters of various ice formation types, ice spreading, and ice fields stability were observed. According to the character of ice formation processes different types of winters were detected. There were three soft winters during the studied period: 2006-2007, 2007-2008, and 2008-2009. Mild winters were observed in 2005-2006, 2009-2010, 2011-2012, and 2012-2013. Only one winter of 2010-2011 fitted the severe conditions.

2. Sea ice was formed within 5-7 days of air temperatures below 0 °C and absence of vertical mixing of surface waters. Sea ice formation is associated with the establishment of anticyclonic conditions when significant decrease of air temperature is observed, and light winds of eastern rhumbs are prevailed. The active processes of ice formation was not observed under the domination of west transfer and cyclonic conditions.

3. SST increase was estimated at a rate of 0.7±0.3 °C/decade.

4. A coincidence of air temperature and SST seasonal change was revealed. Positive SST and air temperature annual trends were caused by intensive increase in warm period (summer and spring).

5. The observed SST increase in the region was spatially

The research was conducted in the frame of NATO SfP 984359