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Early spring SST distribution in the Baltic Sea: in search of the coldest water

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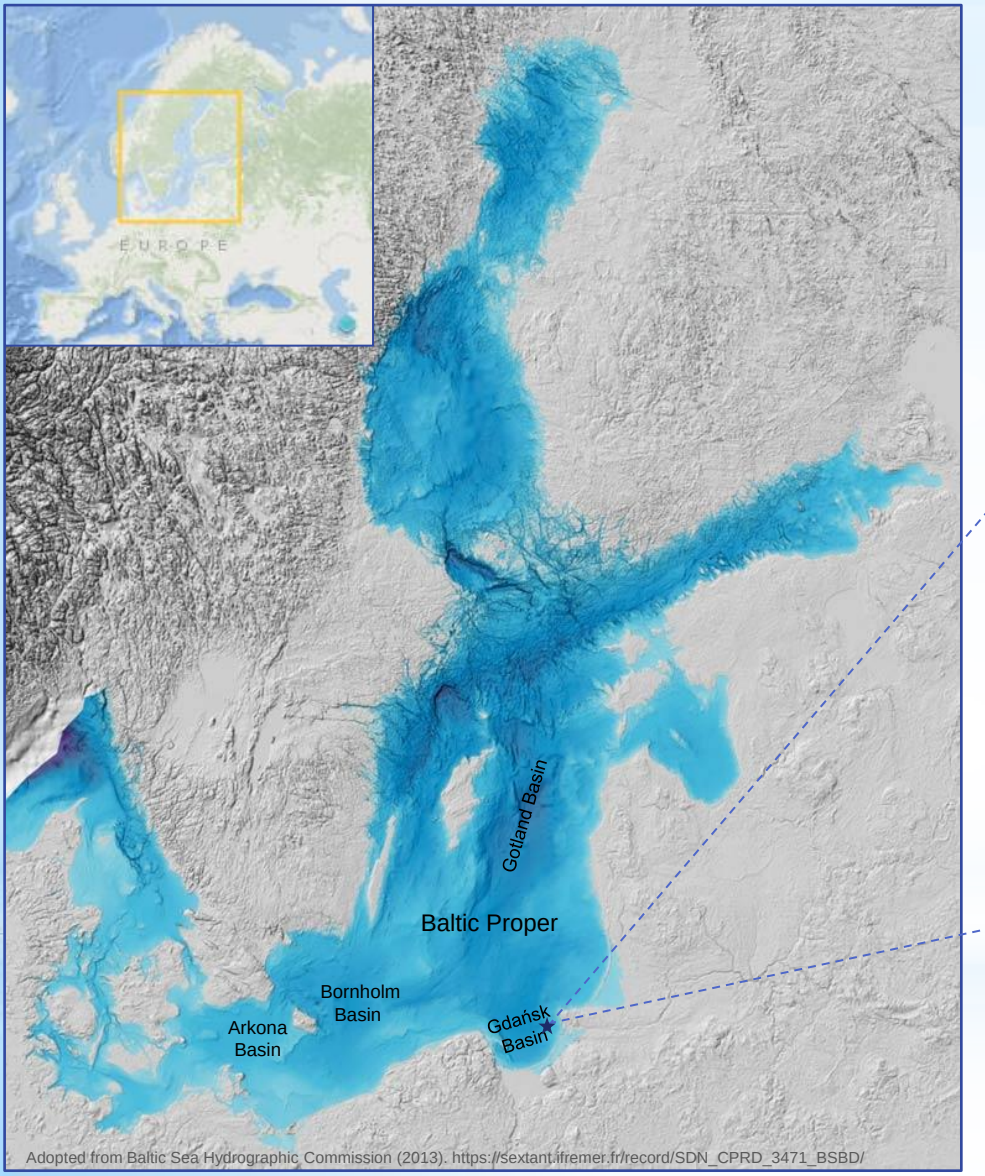
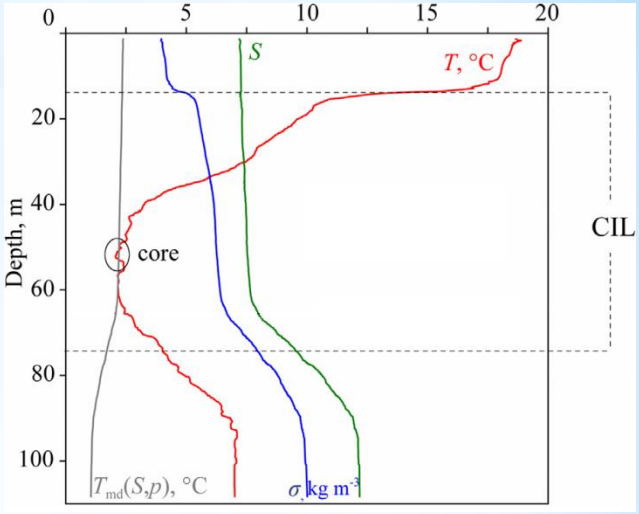
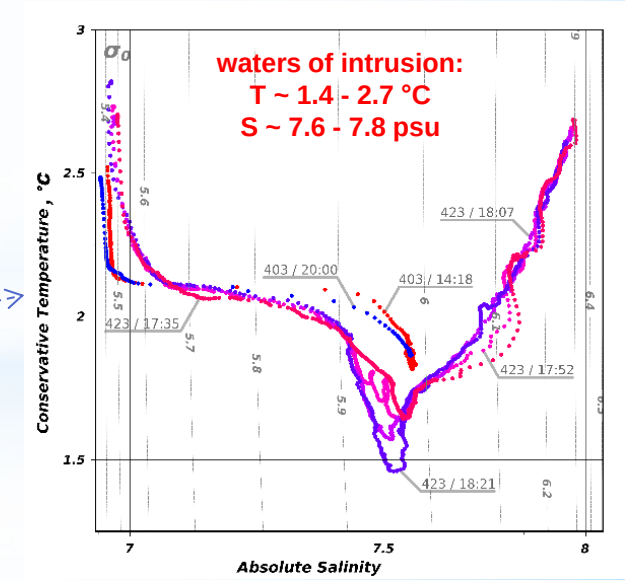
The Cold Intermediate Layer (CIL) is the most typical feature of the vertical thermohaline structure of the Baltic Sea for most of a year





Typical summer CTD profiles in the Baltic Proper (July 2006, The Gdansk Basin). Figure is adapted from Chubarenko and Stepanova, 2018.



Typical spring intrusion activity of cold and saline waters in the intermediate layers of the Gdansk Basin, April 2013 (figure is adapted from Chubarenko and Stepanova, 2018)

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Hypotheses of formation of CIL waters in the Baltic Sea

The coldest waters are formed:

1) at the beginning of spring warming in the Arkona and Bornholm basins. CIL results from advection of Arkona-Bornholm waters in the intermediate layers and further lateral water-exchange within the Baltic Proper (Chubarenko and Stepanova, 2018);
2) in the centers of mesoscale vortexes (similar to those in the Black Sea (Stanev et al., 2003);
3) in the convergence zones of alongshore fronts and penetrate into intermediate layers while cooling over shelves (as in the Mediterranean Sea) (Stommel, 1979).

Where and when do the coldest Baltic waters occur ?

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Where and when do the coldest Baltic waters occur?

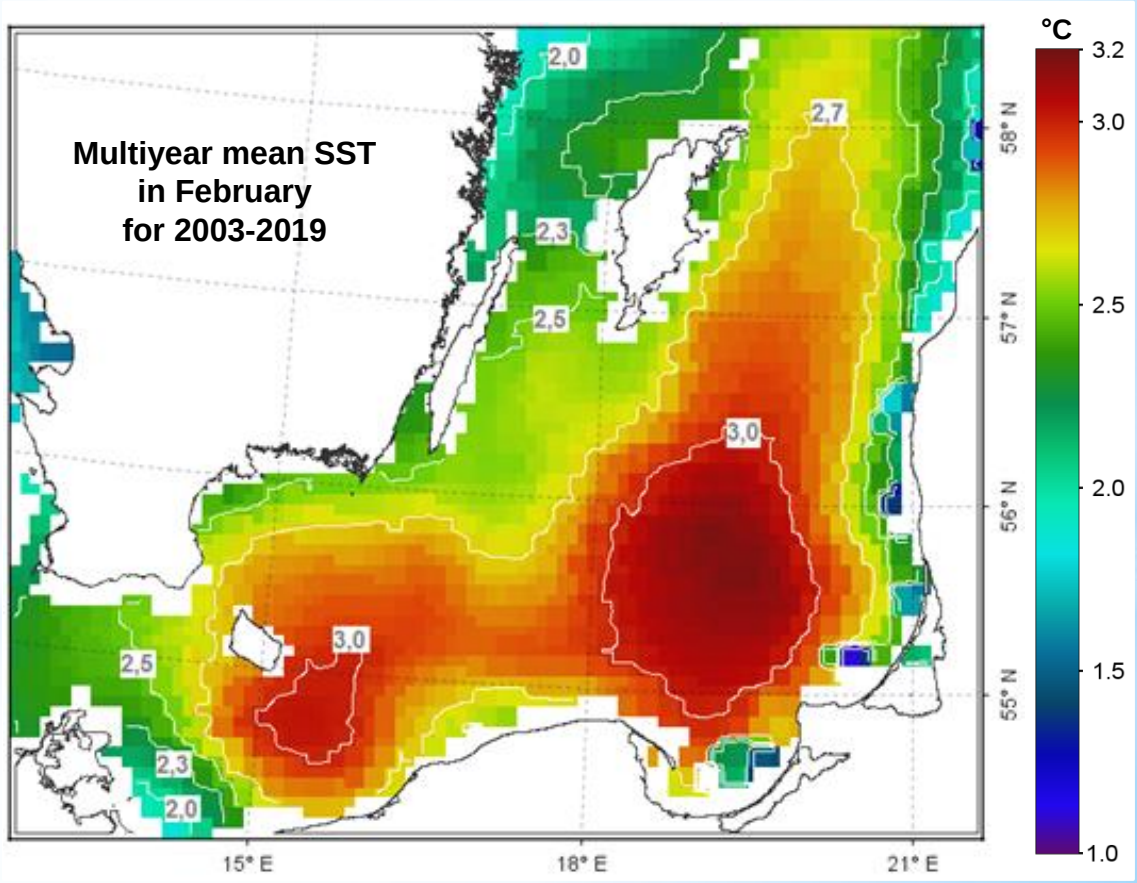
Data and methodology

We analyzed multiyear averages of sea surface temperature (SST) in the Baltic Sea Proper for the period from February to the beginning of April 2003-2019. Long-term averaging of SST is generated from combined infrared (MODIS/Terra, Aqua and VIIRS/Suomi-NPP) and microwave (AMSR-E/Aqua, AMSR-2/GCOM-W1 and WindSat/Coriolis) satellite SST daily (Level 2) imagery. Spatial resolution is 9 km.

Satellite data are distributed by OceanColor Web (https://oceancolor.gsfc.nasa.gov) and Earth microwave data center "Remote Sensing Systems" (http://remss.com/measurements/sea-surface-temperature).

Results

- The coldest surface waters (0-2.5 °C, below the temperature of maximum density (Tmd)) are observed in February above shallows and along the shoreline. February is the coldest month in the Baltic Proper, when the surface heat balance is negative and the two-layered winter-time vertical mixing occurs (Feistel et al., 2008; Leppäranta and Myrberg, 2008).



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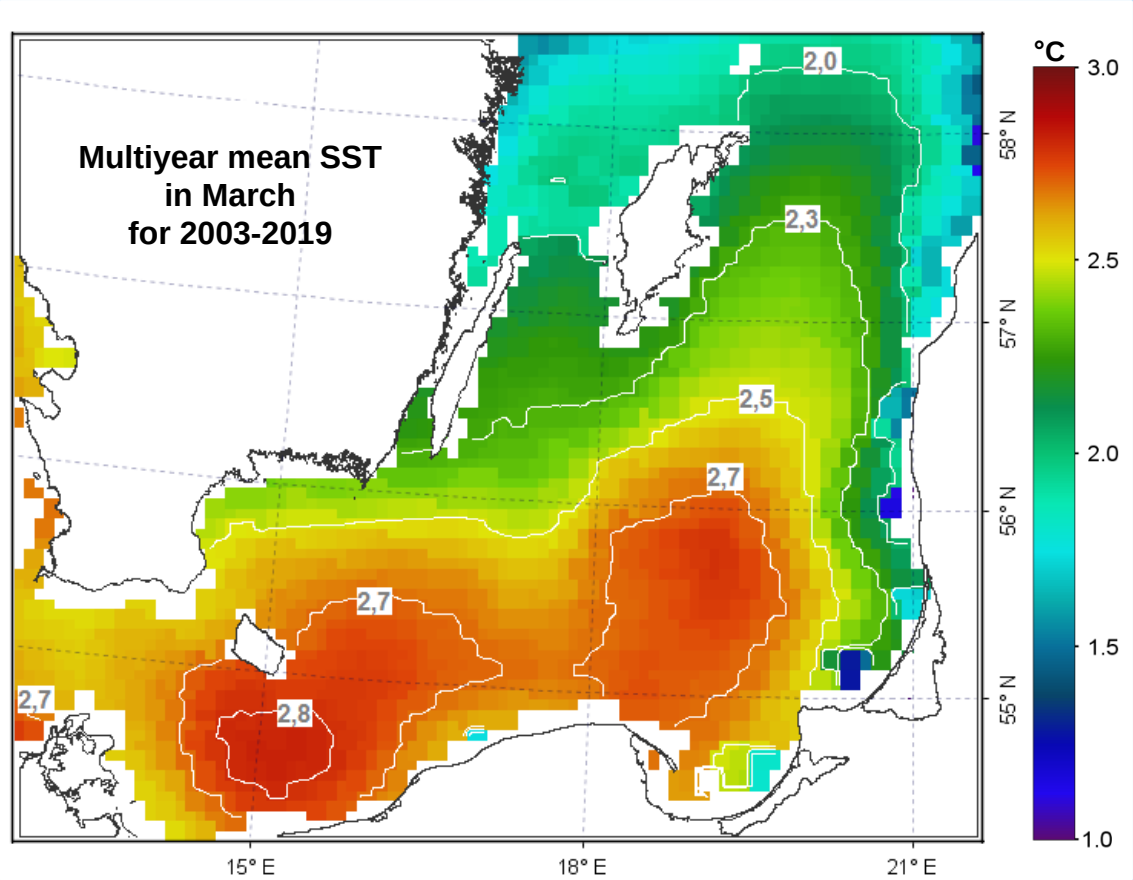
Where and when do the coldest Baltic waters occur?

- SST cools down to the minimum values in March. Convective mixing in March reaches much larger depths and even the bottom above shallow areas (Chubarenko and Demchenko, 2010).
- However the coldest waters of Arkona and Bornholm basins, that were observed in February, have completely washed out in March. The surface water has warmed up to 2.7-2.9 °C. Following Chubarenko, Stepanova, 2018 surface waters of 7.6-7.8 psu (and temperature of 2-2.5 °C according to our result) disappear in the Arkona-Bornholm area and then are replaced by warm waters of central Bornholm area.



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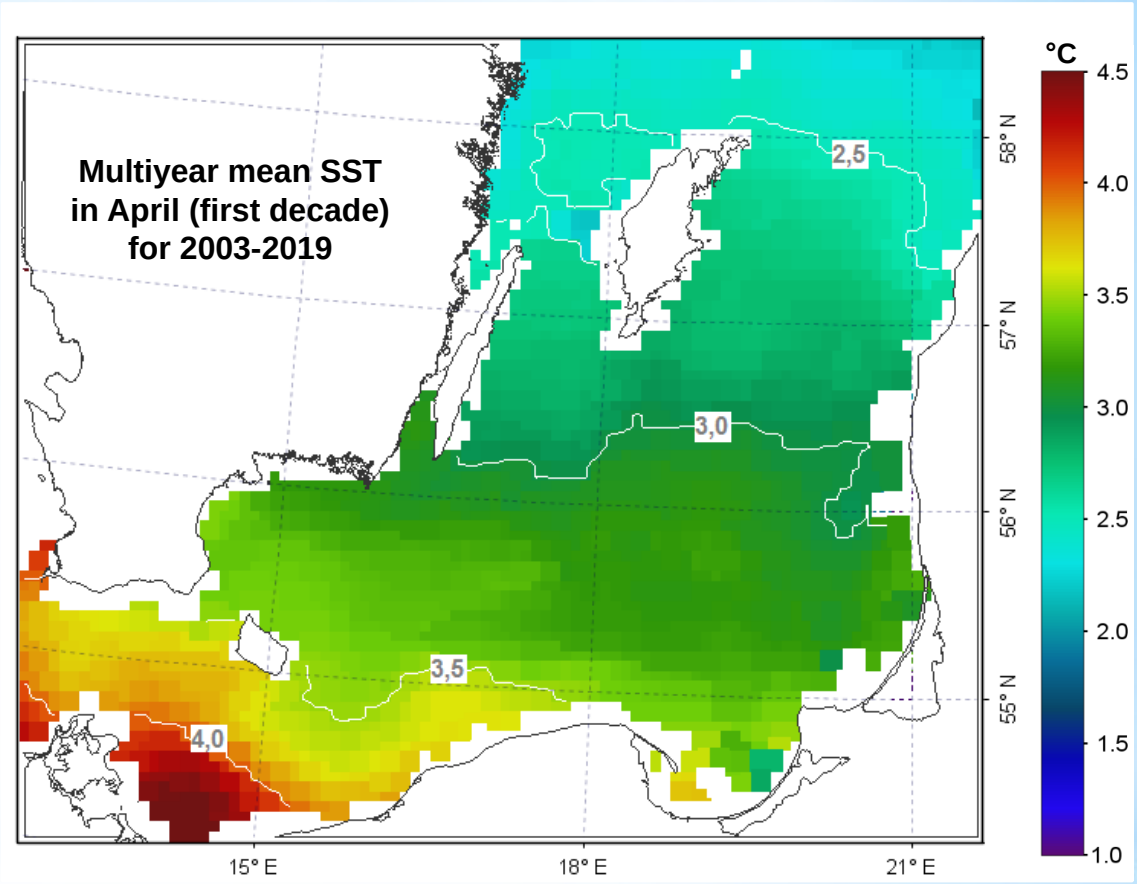
Where and when do the coldest Baltic waters occur?

- Heating of surface waters is recoded from the end of March to the beginning of April.
- Abrupt and quick re-structuring of thermal field is clearly visible during the first decade of April, especially evident in the Arkona and Bornholm basins. SST crosses over the Tmd in the Baltic Proper (except the northern part of the sea). Isotherms demonstrate latitudinal shifting in the south-north direction, SST is increasing downstream.

Winter-time vertical mixing has completely ceased to this moment and three-layered summer-time vertical stratification and formation of the CIL have been established in the Baltic Proper (Stepanova, 2015; Stepanova, 2017; Chubarenko et al., 2017).



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Conclusions

- ✓ Multiyear mean SST maps (for February, March, April 2003-2019) indicate rather quick, abrupt re-structuring of thermal field in late March - early April, especially evident in the Arkona and Bornholm basins. This supports the idea that seasonal transfer from two-layered winter-time vertical water stratification to the summer-time three-layered stratification is driven in the Baltic Sea not by the direct heat fluxes through the surface, but rather by the large-scale north-south water exchange (Chubarenko and Stepanova, 2018).
- ✓ The gradual warming of waters from south to north direction is clearly seen with long-term averaging.
- ✓ Stable vortexes and frontal zones are not observed under multiyear SST averaging. Location of coastal fronts is rather changeable, they persist for a few weeks in winter-time.

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