Project: **1206**

Project title: **High-resolution modeling of the interaction of physical and biogeochemical processes in the Kara Sea**

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In the following we briefly report our main results obtained during the second stage of the project (2022):

1) To successfully tune our regional Kara Sea model, we needed to compare available river discharge data and to find out, the use of which of them can enhance the model results. In our study we considered the following data sources: R-ArcticNet, GRDC, data from (Prange, 2002), AOMIP input river discharge, Global Flood Awareness System (GloFAS), data from (Bryzgalo et al., 2015). In the case of the GloFAS data, we used its raw daily-mean river discharge data and its computed monthly-mean climatological discharge values, with an intention to compare the influence of temporal-averaging of the river runoff upon river plume dynamics in the Kara Sea compared to the impact of more rapid changes in river runoff represented by daily-mean values (Fig. 1 for, e.g., the Ob River).

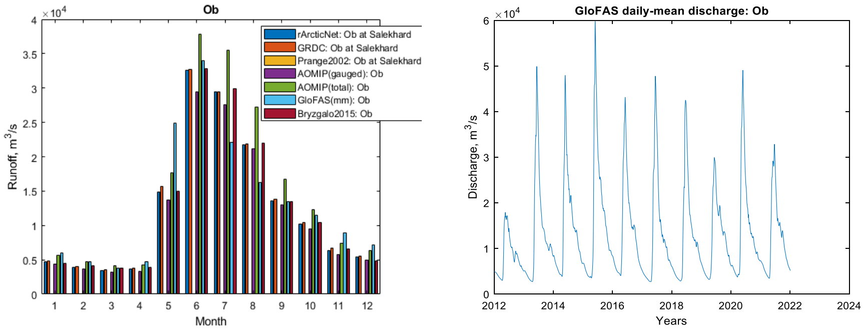
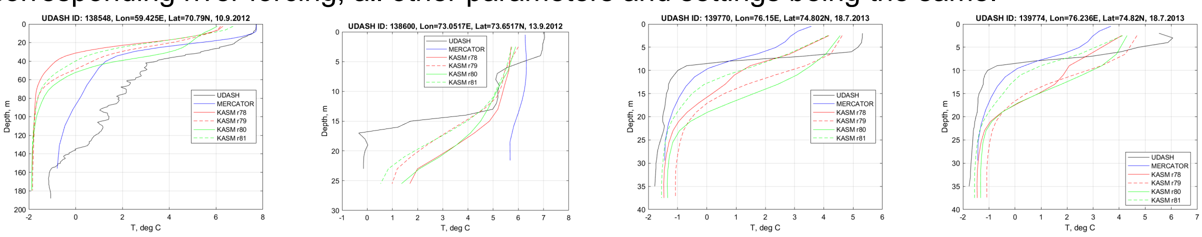


Fig. 1. Left – Climatological monthly-mean river runoff (for the Ob River) as obtained from different sources. Right – Daily-mean river runoff (Ob River) as obtained from the GloFAS.

One of the advantages of the GloFAS data, besides its daily-mean nature, is the ability to extract the river discharge data at the very mouth of the rivers, thus explicitly incorporating all fresh water sources located downflow of the nearest gauges. The difference between the peak Ob discharge based on daily-mean GloFAS data and climatological monthly-mean Ob discharge based on the same data is apparent from Fig. 1. While climatological monthly-mean Ob discharge (reaching its maximum in June) is about 3.3–3.4×10^4 m^3/s, the peak daily-mean Ob discharge reached 6.0×10^4 m^3/s in 2015 and dropped to 3.0×10^4 m^3/s in 2019 and even to 1.9×10^4 m^3/s in 2012, according to the GloFAS archive. Such variability may have significant impact on the thermohaline structure of the Kara Sea, especially in its estuarine regions. This effect has been investigated and comparison with the model results produced with the use of climatological river forcing has been carried out. In total, we carried out four long-term model simulations with different river forcing, namely (Fig, 2): (r78) R-ArcticNet (Ob, Nadym, Pur, Taz, Yenisey) + Prange, 2002 (Pyasina, Taymyra, because both rivers are absent in R-ArcticNet); (r79) the same as (r78), but multiplied by the factor 1.3 to estimate the potential impact of ungauged water flux as proposed in the AOMIP; (r80) GloFAS climatological monthly-mean river discharge; (r81) GloFAS daily-mean river discharge. Each model run was preceded with a 20-year model spin-up with corresponding river forcing, all other parameters and settings being the same.



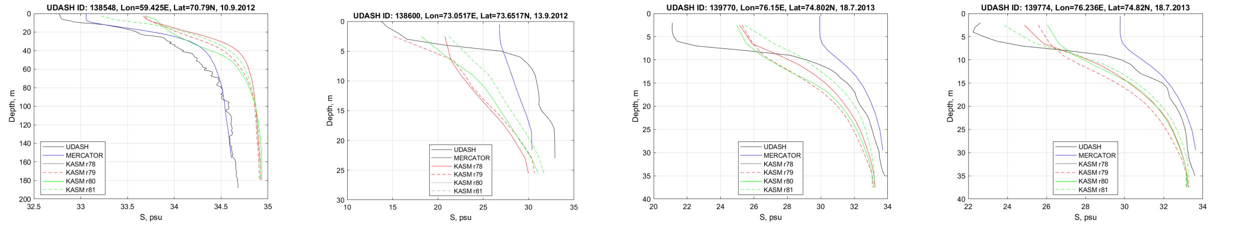


Fig. 2. Vertical profiles of water temperature and salinity. UDASH – in-situ T,S-profiles, MERCATOR – ocean reanalysis, r78–r81 – KASM results with various river forcing.

From Fig. 2 it follows that the use of the GloFAS daily-mean river forcing enhances the model results compared to the other three simulations where the climatological monthly-mean values of river discharge were used. The benefits include the sharper modeled thermocline and halocline, both in a better agreement with the observed ones than in other experiments.

2) The explicit inclusion of tidal dynamics in the KASM leads to the appearing of oscillations clearly visible in frontal zone motions. Still, no other significant benefits from taking into account the tidal motions explicitly in KASM have been achieved, notwithstanding the fact that our model results of tides simulation are in satisfactory agreement (Fig. 3) with those provided by an inverse tidal model AOTIM or those simulated by a regional tidal model specifically tuned for the Kara Sea (e.g., Kagan and Timofeev, 2017), though KASM solution underestimates the tidal amplitudes along the southern coasts of the Kara Sea in very shallow regions (Gulf of Ob, Baydarata Bay, etc.). As our simulations have shown, a use of a well-calibrated KASM setup with specific values of background turbulent viscosity and diffusivity is advantageous in terms of closeness of model results to observational data (Fig. 2) and computational economy compared to taking into account the tidal motions explicitly when only a daily-mean model output is of interest.

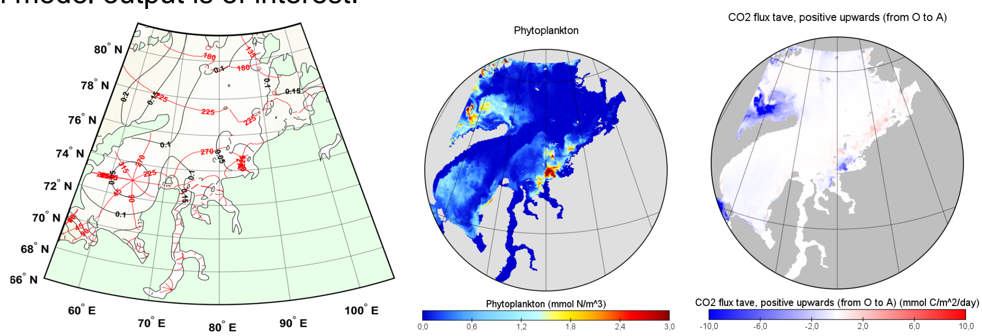


Fig. 3. Left – Co-tidal chart of the M_2 constituent as modeled with KASM. Red lines – phase (degrees), black lines – amplitudes (m). Middle – Modeled phytoplankton concentration in the upper layer on 2012-05-20. Right – Modeled CO_2 flux between the ocean and the atmosphere on 2012-05-20.

3) A number of coupled physical-biogeochemical KASM runs were carried out to calibrate the biogeochemical module of KASM. Although the biogeochemical model is rather simple compared to other multi-phytoplankton and multi-nutrients models such as BFM, PlankTOM or ERSEM, but according to previous studies, it captures the main features of phytoplankton bloom in Arctic marginal seas, provided it has been thoroughly tuned and verified. It also incorporates a carbon cycle sub-model allowing to investigate the fluxes of CO_2 in the Kara Sea, which is especially interesting due to a gradual decrease of sea ice cover area in the Arctic. The main tuning parameters in this bgc-model are the initial slope of P-I curve, detritus sinking velocity, light attenuation due to water and phytoplankton (self-shading), and maximum growth rate of phytoplankton. Currently, we have adopted the values of main model parameters and parameterizations implemented in our previous studies, but additional calibration is still required to fully tune this biogeochemical module to the conditions of the Kara Sea only. Among potential improvements planned for the nearest future is the addition of a benthic sub-model in order to more accurately deal with nutrient flux on the continental shelf. An example of the modeled phytoplankton concentration in the surface layer and the estimated CO_2 flux between the ocean and the atmosphere is presented in Fig. 3. The zones of increased CO_2 flux directed from the atmosphere into the water coincide with the zones of increased primary production due to assimilation of carbon from the water for phytoplankton growth.