Modelling the impact of changing riverine permafrost input on an Arctic coastal ecosystem

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Introduction

Almost half the worlds terrestrially buried carbon is held within the Arctic permafrost. As the climate warms it is likely more of this permafrost carbon will be released into the Arctic rivers which collectively discharge ~11% of global river discharge into the Arctic ocean. At the same time climate change will drive changes in the hydrological cycle which will cause an increase in discharge from these rivers and a change to their seasonal discharge pattern (Peterson et al 2002). These changes in terrestrial carbon input and discharge will have an effect on the coastal ecosystem and possibly the efficacy of the microbial carbon pump. The CACOON project aims to understand these changes through fieldwork and modelling. This poster introduces the modelling work which will use a one way coupled hydrodynamic and lower trophic level ecosystem model to investigate changes to the coastal ecosystem in the Laptev sea from changes in terriginous DOC input. .

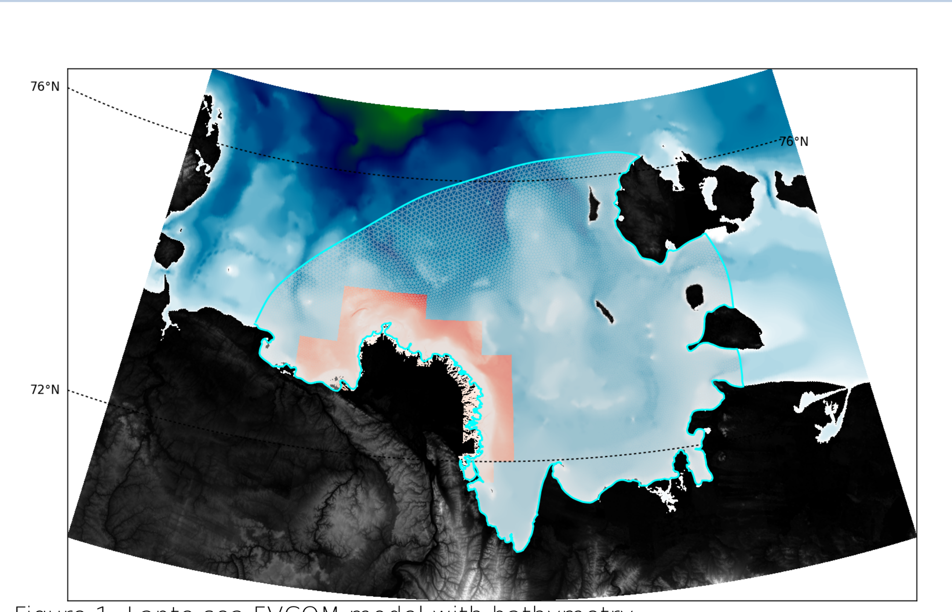
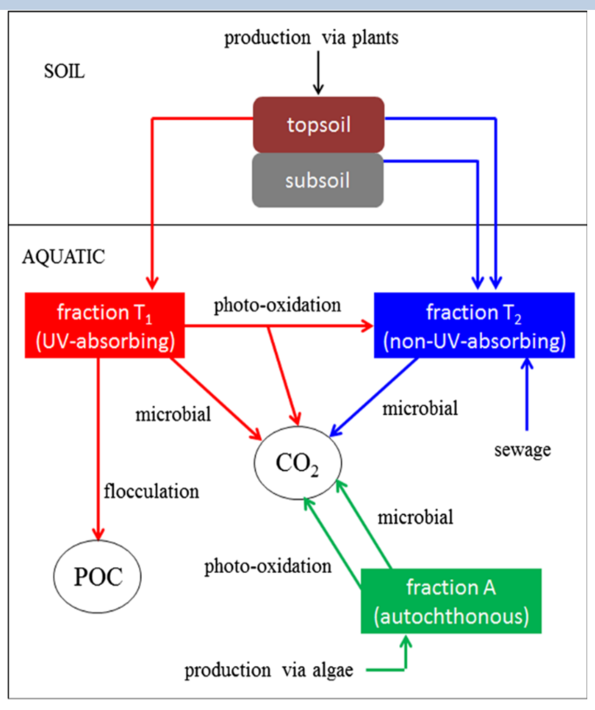


Figure 1: Lapte sea FVCOM model with bathymetry.

Hydrodynamic model (GOTM and FVCOM)

1-D modelling is being done using the General Ocean Turbulence model relaxed to daily forcing from a climatology of temperature, salinity, and surface forcing.

3-d Modelling is using FVCOM (Chen et al 2003), a finite volume hydrodynamic model running on a triangular unstructured grid, particularly suited to coastal and estuarine modelling. For the implementation in the Laptev sea boundary forcing is from the CMEMS Topaz model, with tidal adjustments from TPXO9. Surface forcing comes from ECMWF ERA5 reanalysis data. The Lena river input is modelled from gauge data and observations from the ArcticGRO dataset (Holmes et al 2018). A simple sea ice model developed by Akvaplan-NIVA is used to adjust surface heating, freshwater input and surface wind stress in the presence of ice. Ice cover and ice thickness is taken from satellite observations from the AMSR2 and Cryosat2 products. For the future climate scenario a 'climatology' run will be made to removing the sea ice and with adjusting the river discharge in line with the projections from climate models (Nohara et al 2006)



Ecosystem model (ERSEM + TDOC)

The ERSEM ecosystem model is a variable stochiometry model of the lower trophic levels. It includes a full bacteria model with carbon cycling. A new set of equations to represent terrestrial DOM classes after Anderson et al (2019) has recently been added. TDOC is modelled through 2 state variables, photo-labile and non-photo-labile TDOC. These will allow us to represent the carbon input from terrestrial permafrost both in present day and adjust them for future climate scenarios. Initial parameterisations are from literature but incubation experiments are being undertaken in CACOON to reparameterise the model for this domain.

The 1-D model model will receive climatological boundary conditions and the 3-d model will have exterior boundaries provided by a pan-Arctic ROMS-ERSEM model run by NIVA.

Figure 2 (Left adapted from Anderson et al 2019) Schematic of new TDOC model, a version of which has been implemented in ERSEM

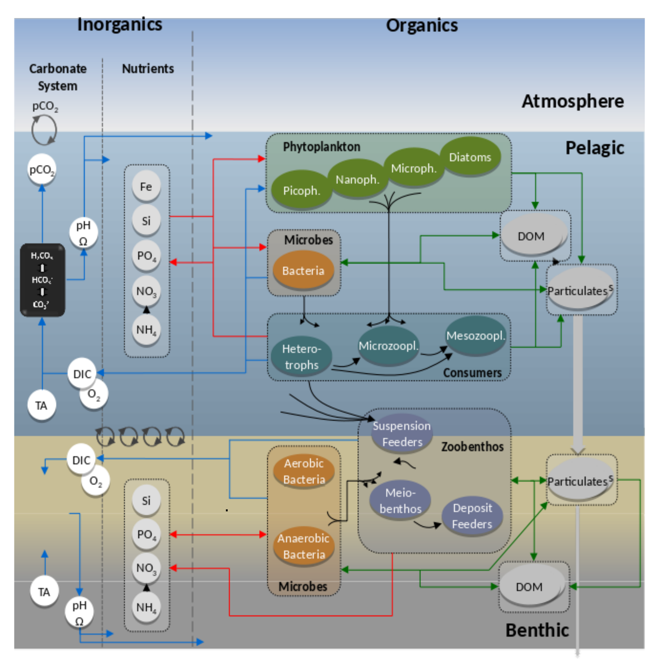


Figure 3(Right) Scjhematic of ERSEM model (Butenshon et al 2016).

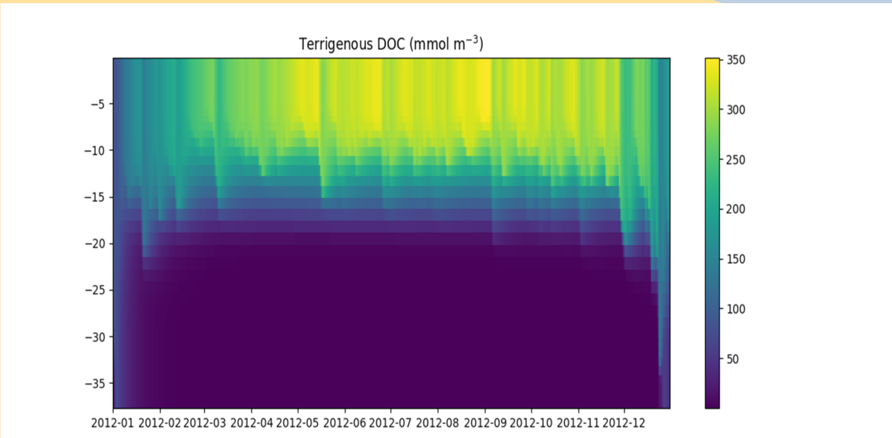


Figure 5 Total TDOC in the 1-d model. input is based on a river climatology.

1d Model initial results

Run with climatology of TDOC reflecting lena river discharge and maximum value from remote sensing. Three model scenarios reflecting increased TDOC input.

3 scenarios/simulations:

Model 1: TDOC max concentration ~350 μM
Model 2: model1+30%
Model 3: model1+50%

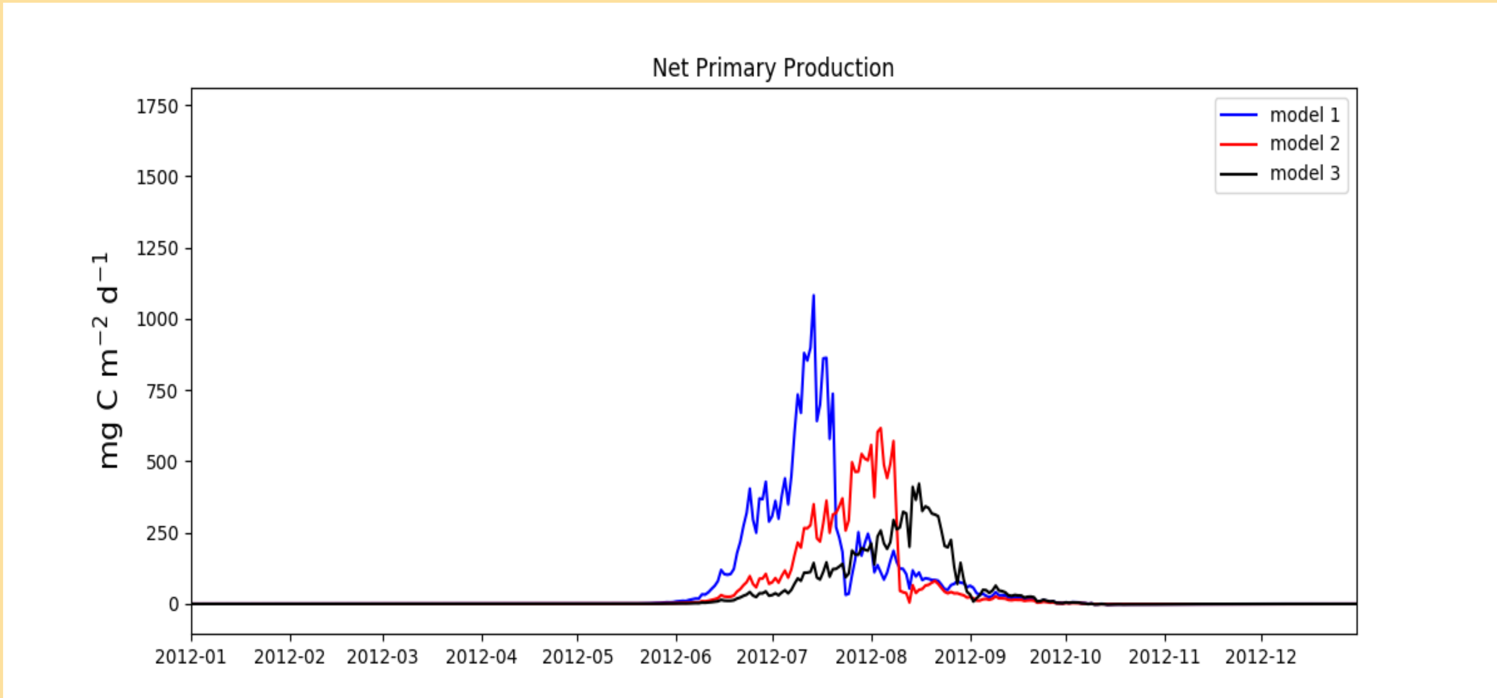
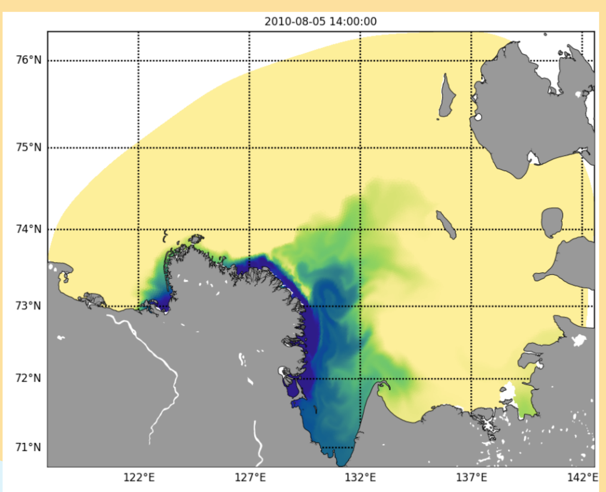


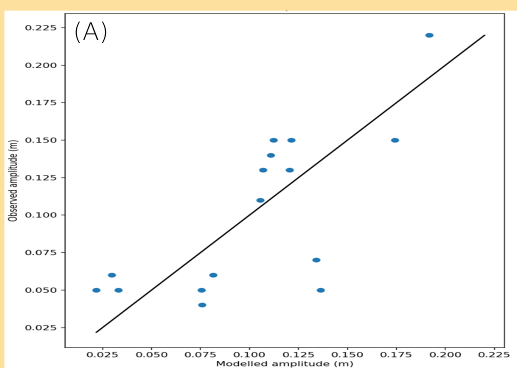
Figure 5 Net primary production under the three differnt TDOC inputs

Increased TDOC remarkably affect planktonic ecosystem by:

- Enhanced light limitation
- Reducing PP
- Delaying phytoplankton bloom
- Increasing bacterial production and respiration

However does not include effect of sea ice changes (which will reduce light limitation), changes in timing of river discharge, or changes in quality of TDOC.





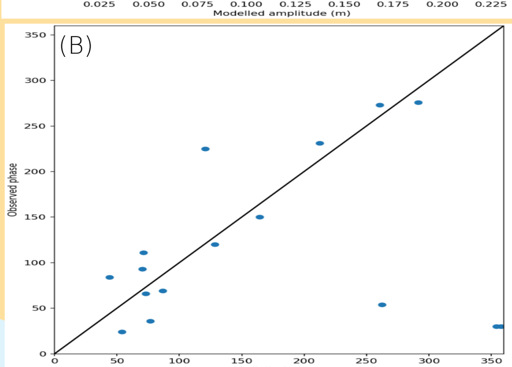


Figure 6 3d physics running showing (above) the river plume in the model mid-August and right comparison of the (A) M2 and (b) S2 tidal constituents between the model and the tidal gauges summarised in Fofanova et al 2014

3d Model validation and plans

Validation of 3d model physics has been promising, however problems with offline coupling mean the full ERSEM model hasn't been run yet. Experiments to look at relative transport and residence time of coastal versus riverine sediment are being undertaken; river inputs constant concentration calculated from load estimate in Charkin et al 2011. Coastal inputs are at each coast segment using an average carbon input per km (from Gunter et al 2013) which is then adjusted from TOC to bulk, and spread throughout the ice free period for each segment.

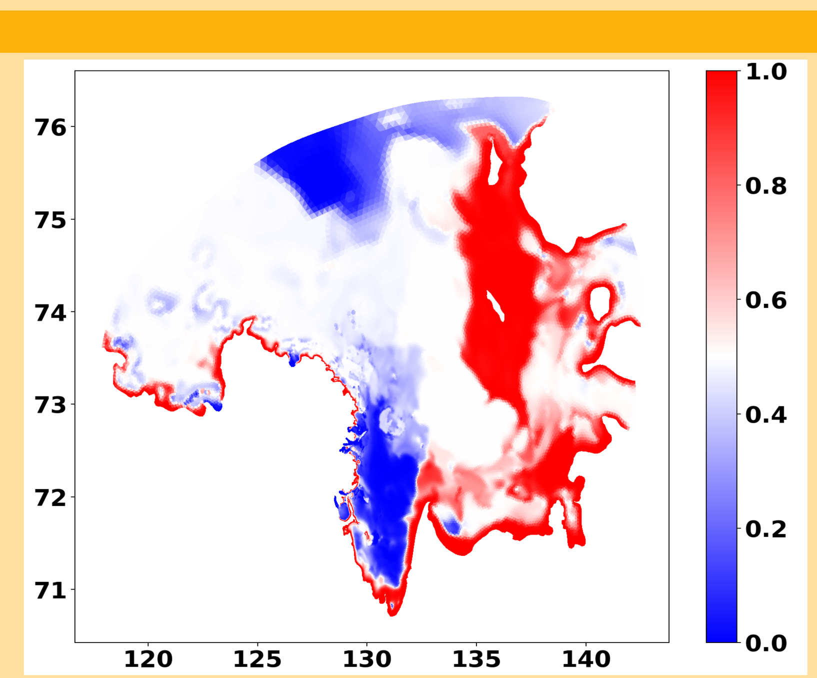


Figure 7 Sediment transport experiments showing relative contribution at bed from coastal (red) or river (blue) sediments.Due to the offline coupling issues this has been run online so has not yet been run long enough to get equilibrium

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