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Numerical modelling of land fast ice in the Arctic

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Abstract

Sea ice is regarded as a clear indicator of climate change in the Arctic Ocean. Landfast ice is immobile or nearly immobile sea ice attached to the coast. Its distribution affects heat, moisture, and momentum transfer between the atmosphere and the ocean in coastal areas. Despite the important role of landfast ice in the climate system, landfast ice is not simulated very well by current sea ice models and needs to be parameterized. One parametrization that is successful in shallow marginal seas uses topography information to implement a grounding scheme. Our work aims to develop a parametrization to better represent landfast ice in shallow and deep regions. Coastline features may act as pinning points for sea ice arches leading to landfast ice. For this reason, the better representation of coastline information is thought to enhance the representation of landfast ice. Our work develops a new parametrization in the coarse sea ice model by lateral drag as a function of sea ice thickness, drift velocity, and coastline length. The new parametrization is tested in the 36\,km panarctic sea ice model. Landfast ice simulation in the model run is compared to the landfast ice appearance from the satellite data. With a lateral drag parametrization, the representation of landfast ice improves in deep marginal seas where a grounding scheme fails. A combination of lateral drag

Data and methods

❖ Satelite data
- National Ice Center's Arctic Sea Ice Charts and Climatologies
- 25 km Gridded, biweekly (2001-2007)
- Sea ice volume: Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) developed at APL/PSC

❖ Model data
- Model: regional Arctic configuration of Massachusetts Institute of Technology general circulation model
- 36 km Spatial resolution & 50 layers in the vertical
- viscous-plastic dynamics solver
- Simple zero-layer thermodynamics
- Forcing: European Centre for Medium Range Weather Forecasts ERA renalysis
- Initialisation: temperature and salinity fields from the Polar Science Center Hydrographic Climatology 3.0

Results

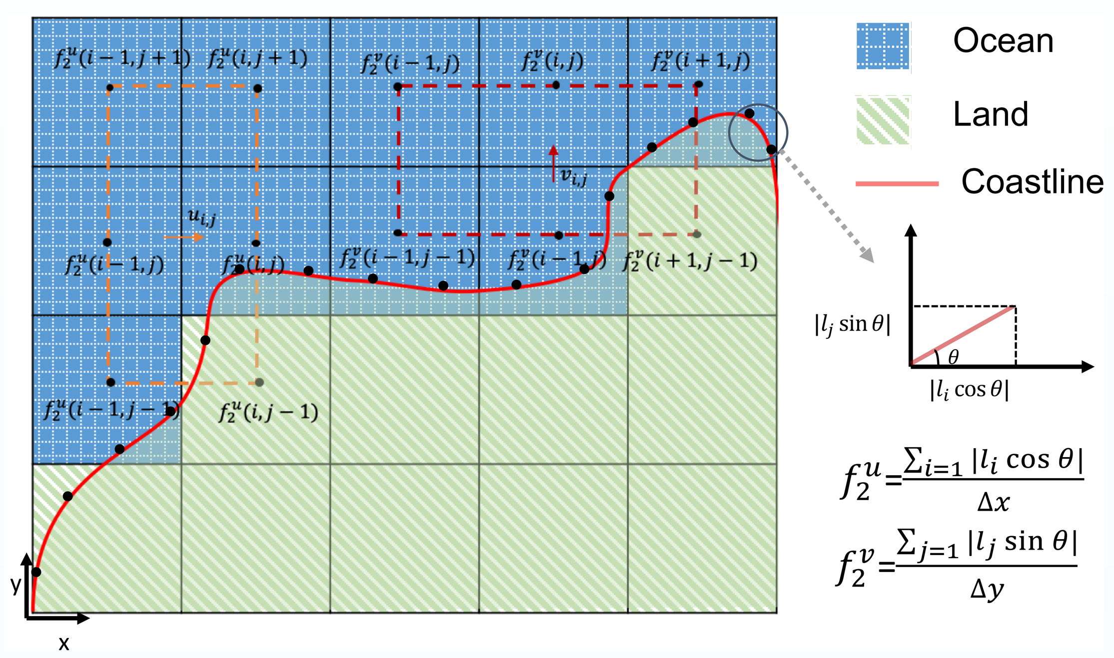

Fig 1. Illustration of form factor in the lateral drag parametrization. Form factor F_2 is the integration of 10 m coastline's projection within unit cell on x/y direction, then normalized over the model grid length.

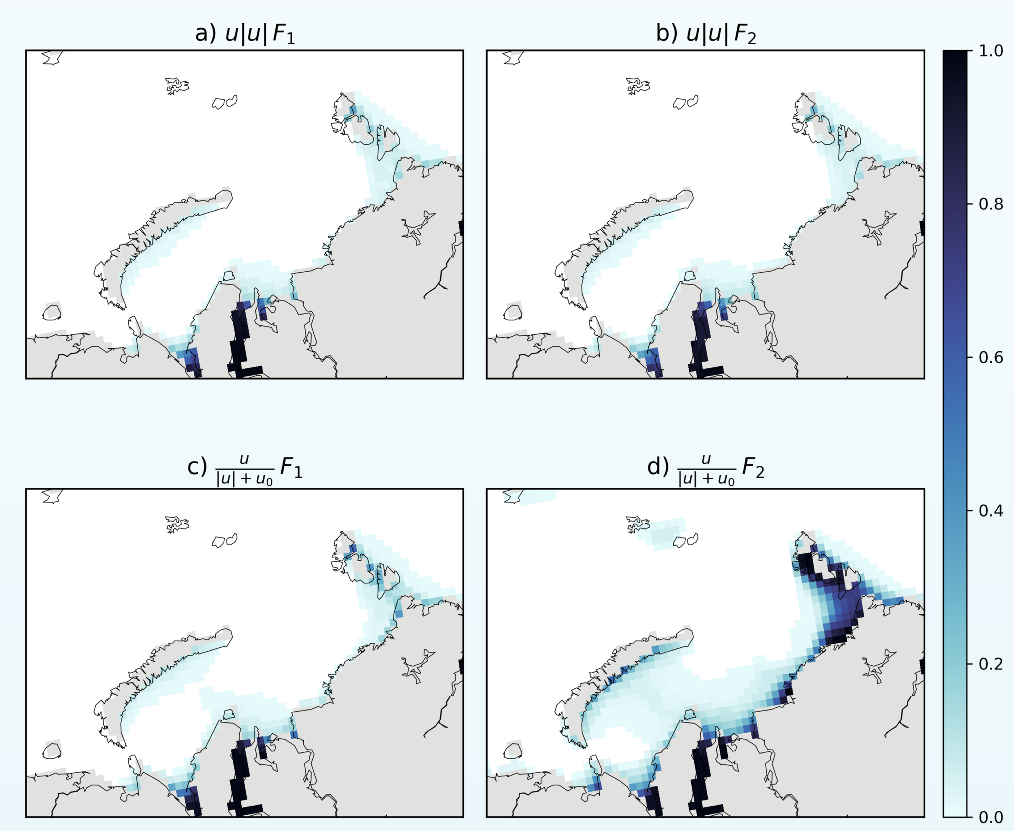

Fig. 2 Landfast ice frequency from January to May from year 2001 to 2007 in the Kara Sea with different lateral drag equations, a) quadratic correlation with simple coast factor lateral drag $C_q = 10^{-2} m\, s^{-2}$, b)quadratic correlation with normalized coastline length $C_q = 10^{-2} m\, s^{-2}$,c)static correlation with simple coast factor$C_s = 5{\times}10^{-5} m\, s^{-2}$, d)static correlation with normalized coastline length $C_s = 5{\times}10^{-5} m\, s^{-2}$. The colorbar states landfast ice frequency, the darker the more landfast ice.

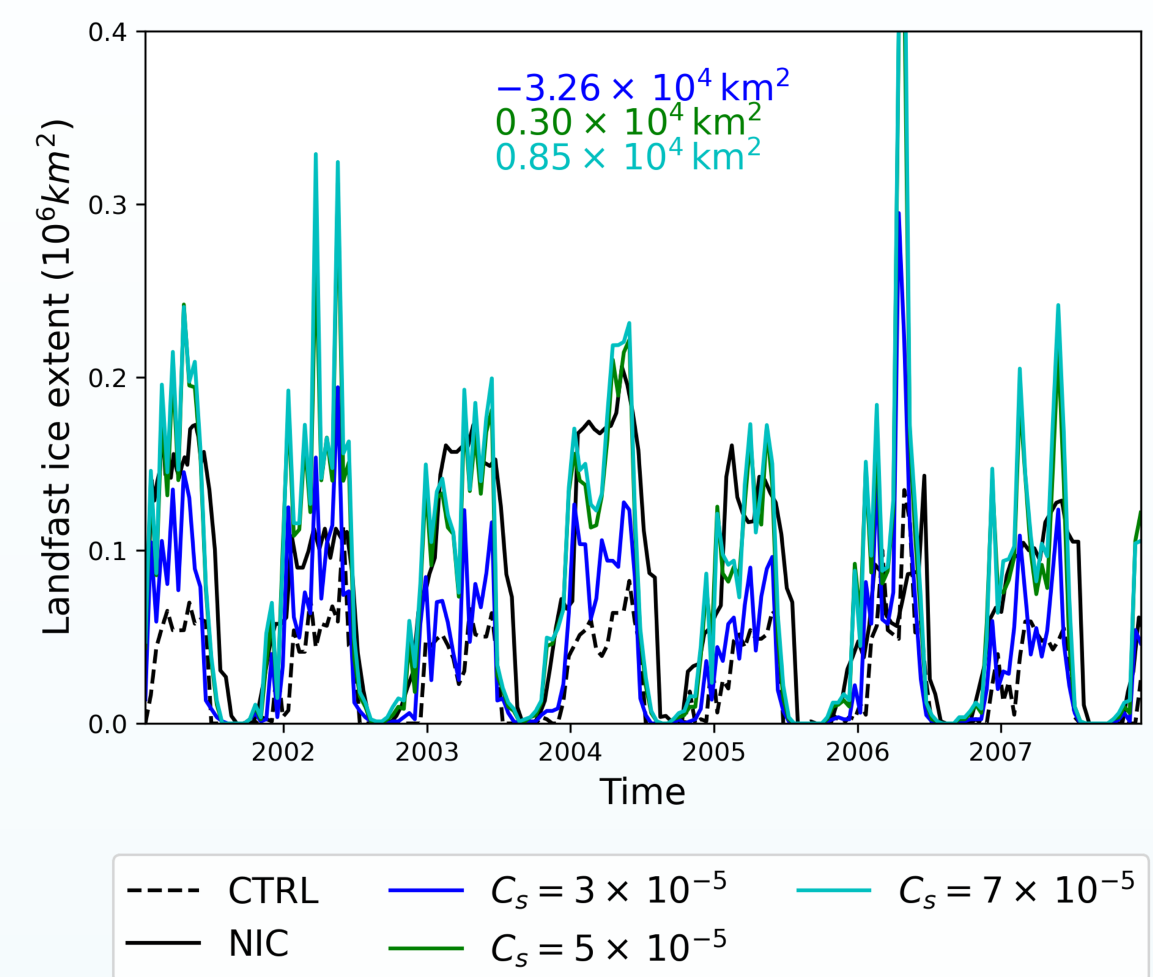

Fig. 3 Sensitivity of lateral drag coefficient in the lateral drag parametrization.
Landfast ice extent in the Kara Sea, blue line: LD with $C_s = 3{\times}10^{-5} m\, s^{-2}$ green line: LD with $C_s = 5{\times}10^{-5} m\, s^{-2}$, cyan line: LD with $C_s = 3{\times}10^{-5} m\, s^{-2}$, black line: from NIC data set, black dashed line: CTRL. The numbers state the mean difference from 2001 to 2007 of landfast ice extent in four regions between LD and observation

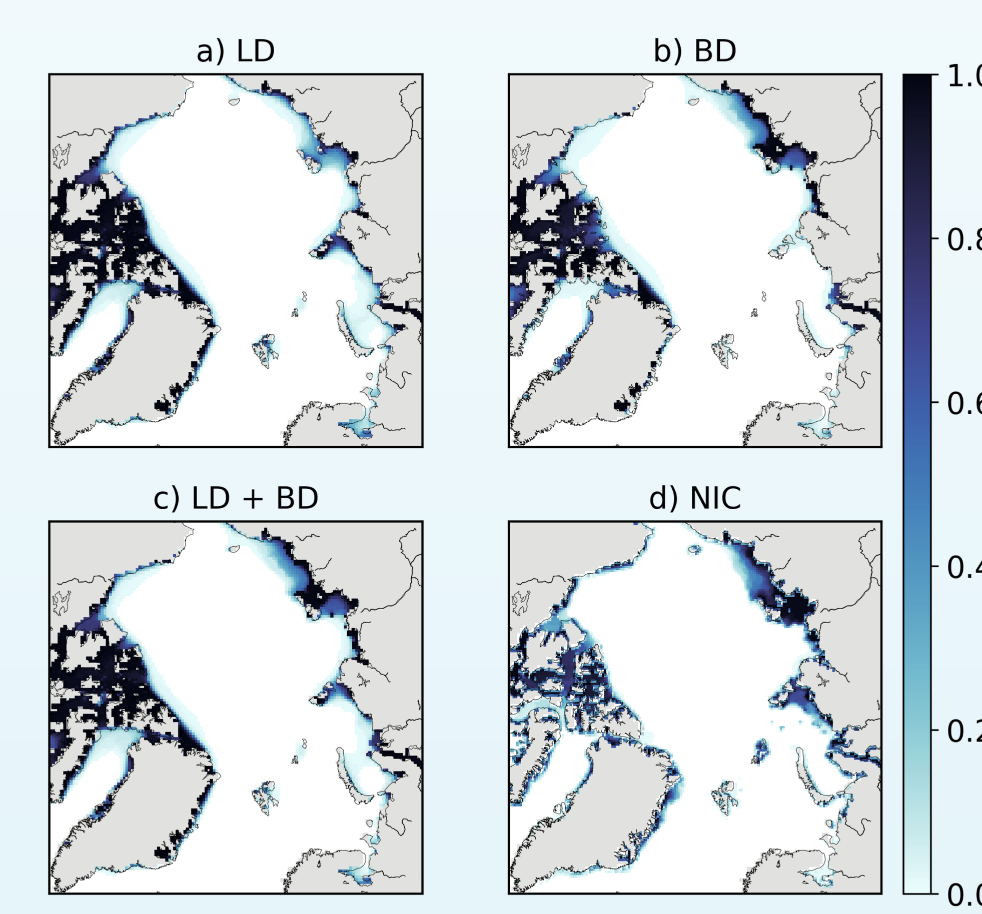

Fig. 4 Map of landfast ice frequency in the Arctic from January to May from 2001 to 2007.
a) model with lateral drag parametrization, b) model with basal drag parametrization, c) model with both lateral and basal drag parametrization, d) NIC satellite data.

Results

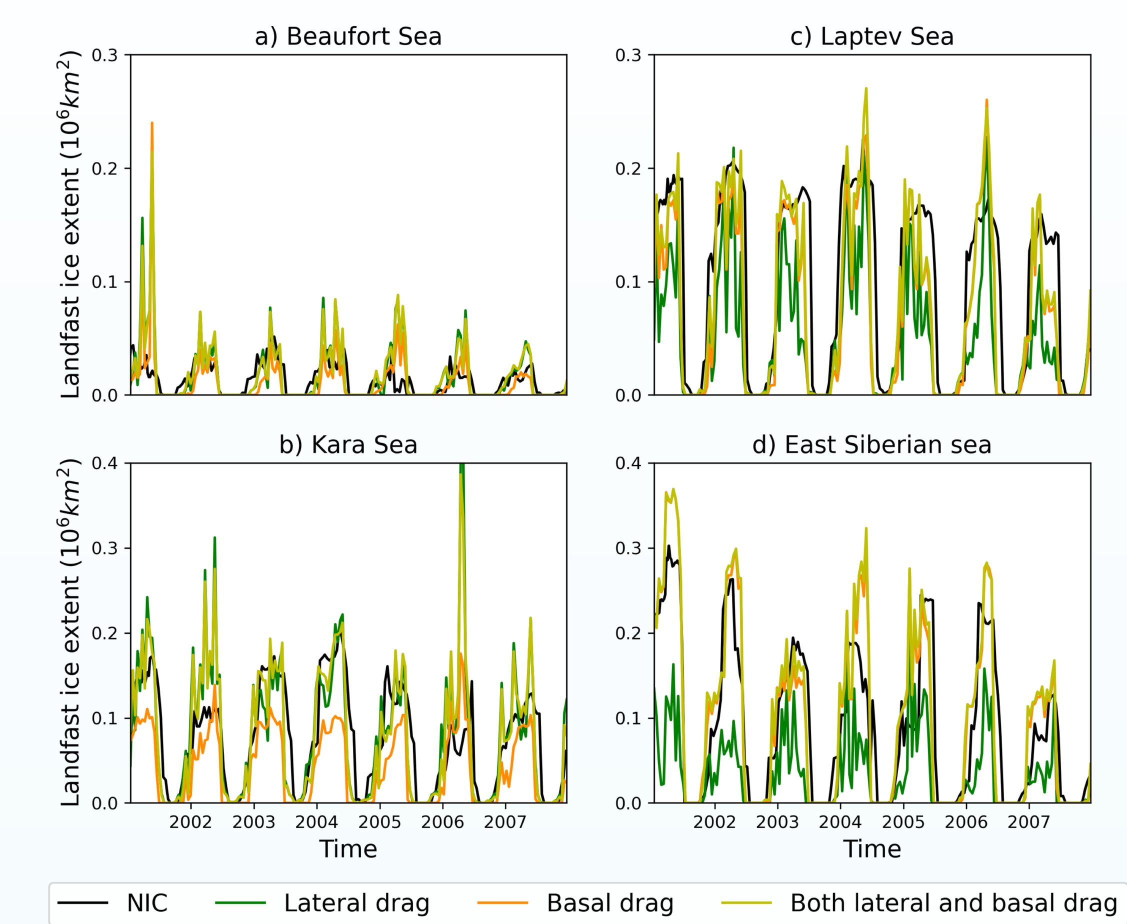

Fig. 5 Time series of landfast ice extent in four regions: a) Beaufort Sea, b) Kara Sea, c) Laptev Sea and d) East Siberian Sea. The black line is from NIC data set, the green line stands for LD, orange line stands for BD, olive line is LD\,+\,BD.

Conclusions

❖ In coarser resolution sea ice models, lateral drag parametrization improves landfast ice simulation in the Kara Sea.
❖ The static friction most suits for the lateral drag between the coast and sea ice.
❖ The combination of lateral drag and basal drag parametrization better simulates landfast ice in the Arctic region.

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Acknowledgements

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