Detecting Linear Kinematic Features in Arctic Sea Ice in a Warmer World Using High Resolution Model Output

European Eddy-Rich ESMs

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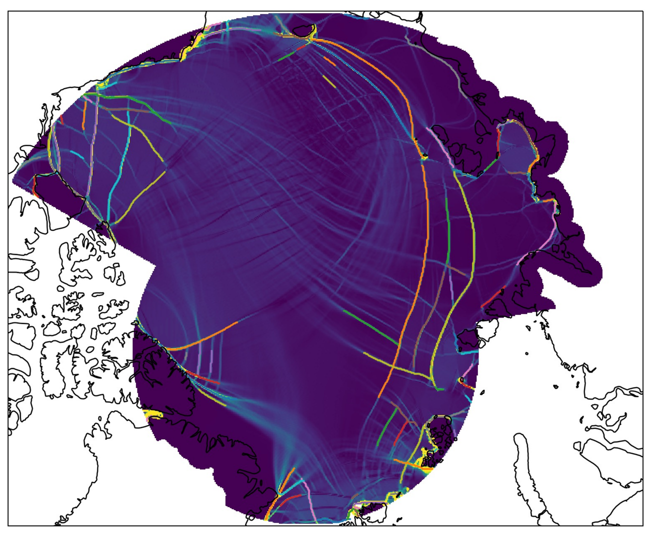
Abstract

Leads and pressure ridges (Linear Kinematic Features, LKFs) are important the sea ice field as they directly affect the heat and momentum exchange between ocean and atmosphere. They therefore influence the development of not only the sea ice cover but also the ocean and the local climate. Vice versa, LKFs are influenced by climate change as the sea ice cover will be affected by changes in atmospheric and oceanic forcing. For creating a climate change signal, the Arctic sea ice cover will be analyzed for LKFs in current climate vs. in a warmer world at the end of the century. For this, the output of the ocean model Fesom, run with a spatial resolution of 1 km, will be used.

Method and Data

The LKF detection algorithm presented by Hutter et al. (2018) searches for regions with larger rates of deformation than their local surroundings by applying a Difference of Gaussian filter, and marks them as LKF pixels. They are then split into segments and reconnected based on orientation, distance and deformation. An example of detected LKFs is shown in Fig. 1. It shows the Arctic ice cover on the 1st of January 2015.

Fig. 1: Detected LKFs in the Arctic sea ice cover. The background is the deformation rate.



The data is taken from Li et al. (2024). The available periods are the time slices 2013-2020 and 2093-2100.The spatial resolution in the Arctic is 1km. The simulated future is the scenario SSP585, leading to an increase in global mean surface temperature of 4K by the end of the century in comparison to the 2010s climate.

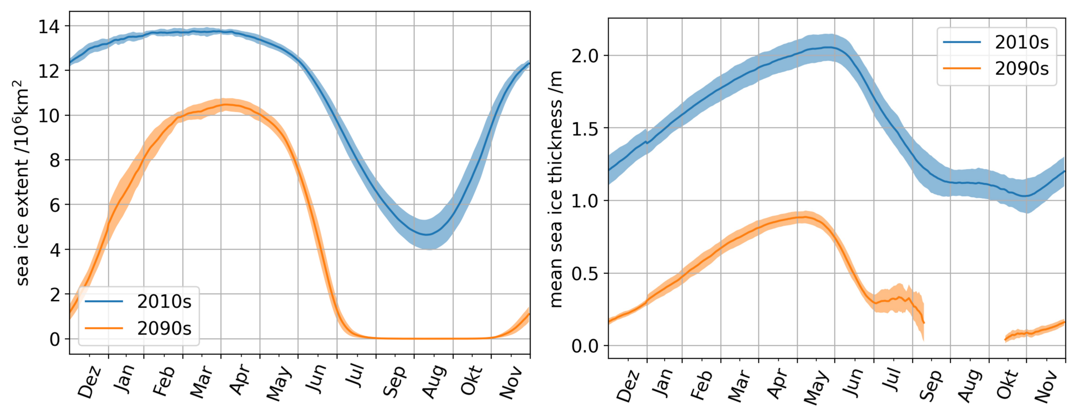


Fig. 2: Arctic sea ice field in a warmer world and in current climate.

The Arctic ocean surface velocity is projected to increase by the end of the century:

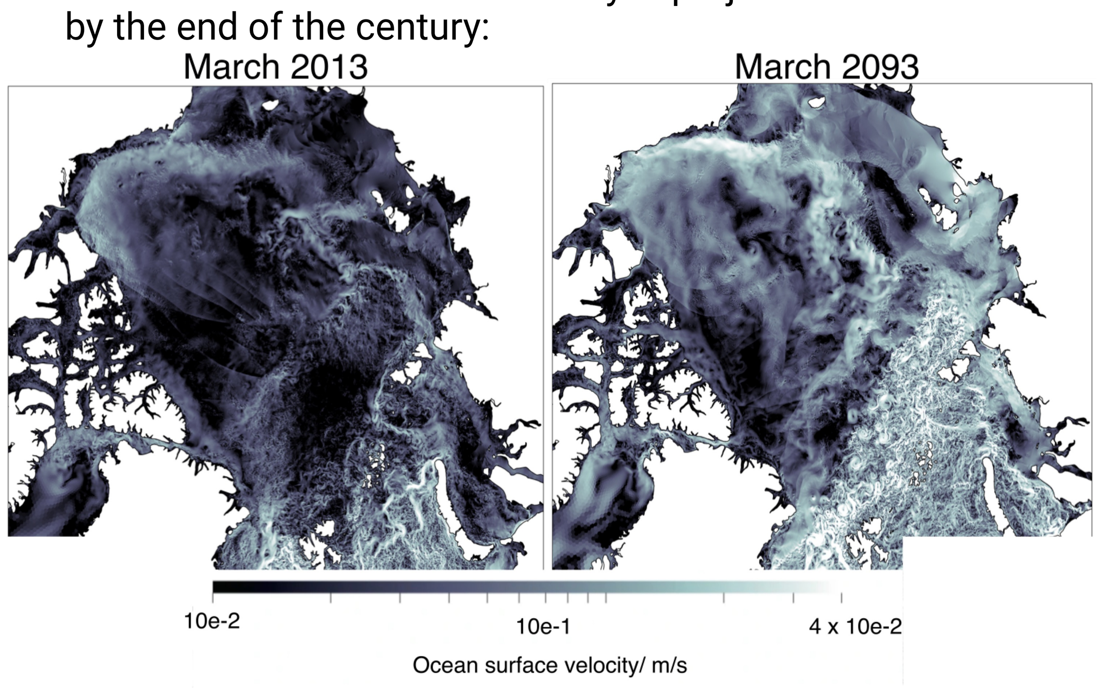


Fig. 3: Snapshots of ocean currents and eddy activity at the surface (Li et al. 2024).

The areas of increased ocean surface velocity (Fig. 2) coincide with the gradients in bottom topography:

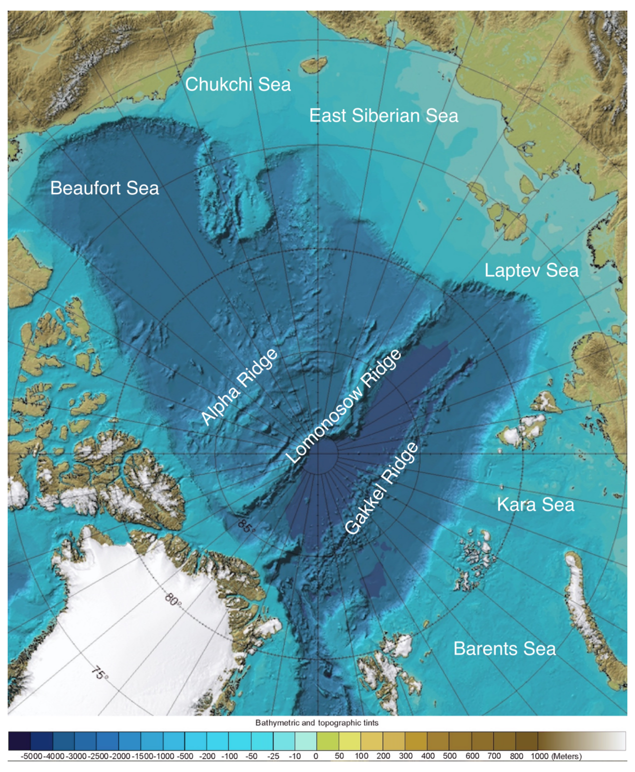


Fig. 4: Arctic bottom topography https://geology.com/articles/arctic-ocean-features/

Statistical Evaluation of Detected LKFs

The sea ice field is weaker by the end of the century which leads to an increase in LKF occurrence. During the freezing phase, the sea ice fields grows stronger, leading to a strong decrease in LKF density.

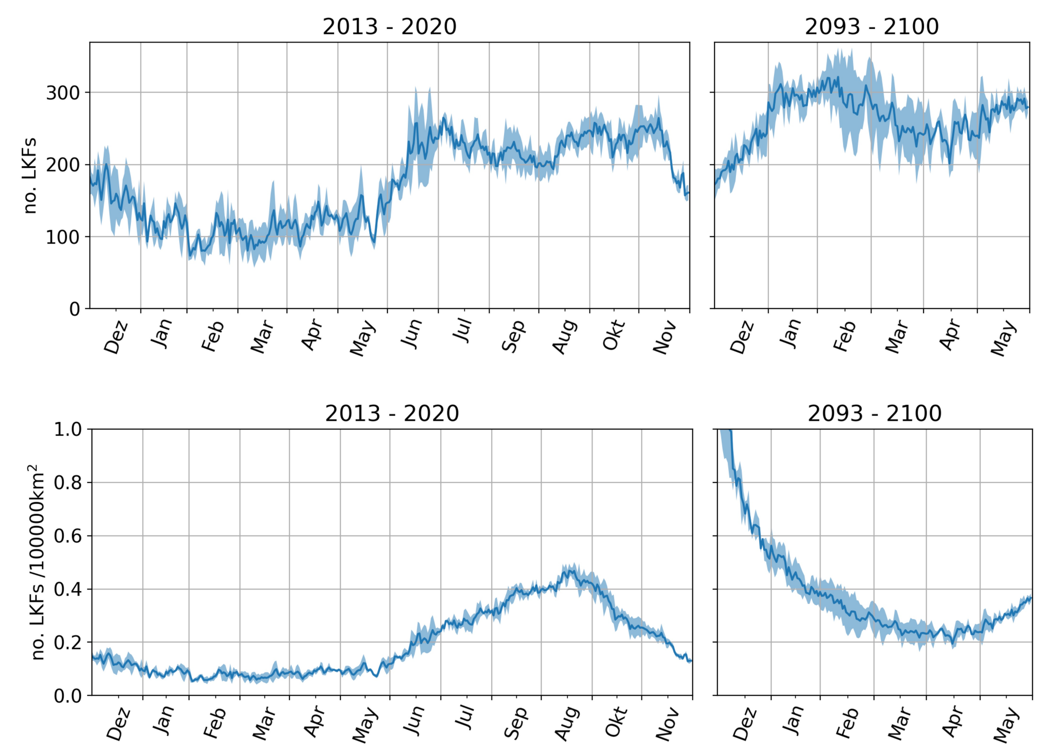


Fig. 5. Number and density of LKFs in current climate vs. in a warmer world.

The total number of LKFs or the mean LKF length alone do not contain any area information. The total LKF length is directly related to the total area of potential air-ice-ocean interaction and is thus a more suitable metric to characterize the LKF field.

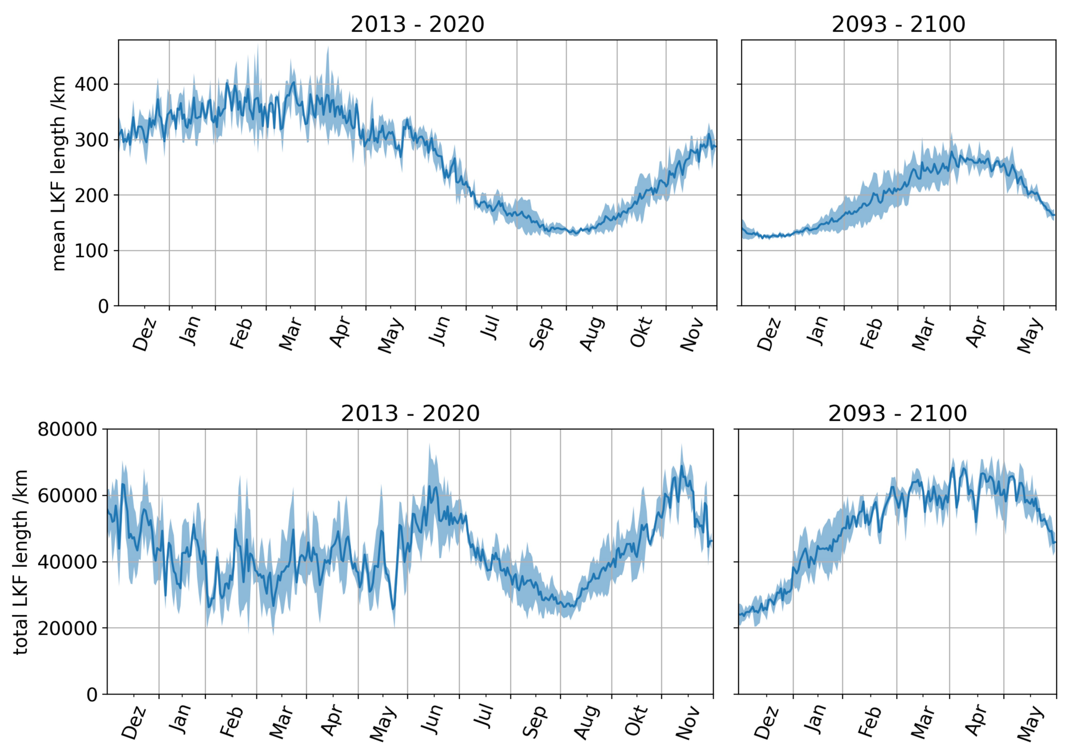


Fig. 6. Number and density of LKFs in current climate vs. in a warmer world.

Spatial Distribution of LKFs

In the 2010s, the only regions with an increased LKF occurrence are along coastlines and in front of islands. In these regions, the closed boundary leads to an increase in internal ice stress, leading to more ice deformation and LKF formation.

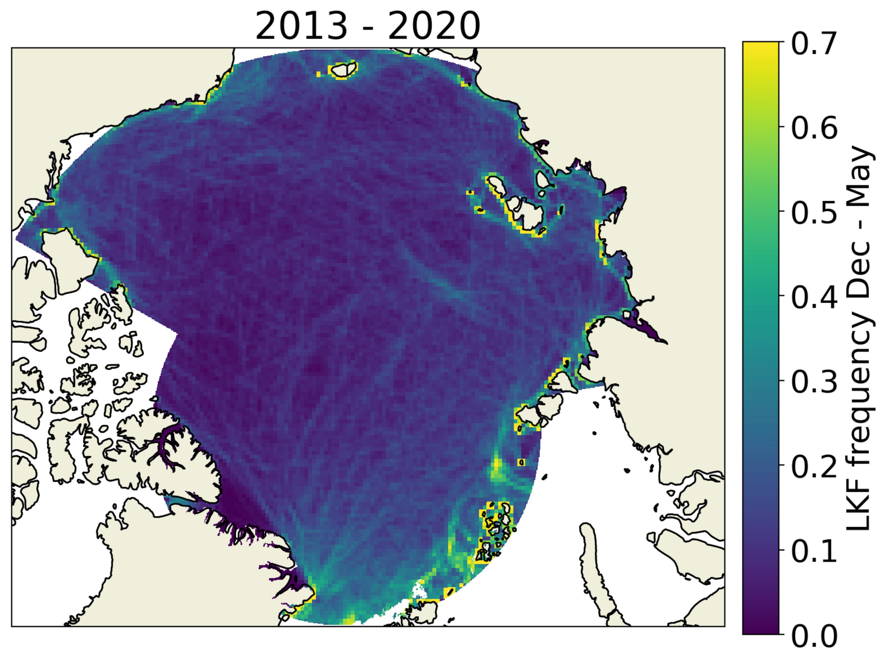


Fig. 7: Frequency of LKF occurrence per 25 km x 25 km grid box.

In the 2090s, more regions of increased LKF formation emerge. A high LKF frequency can be found above the shelf break in front of the Laptev, East Siberian and Chukchi Sea. In this region, two effects come together (that most probably positively effect each other): a weaker sea ice field and and an increased ocean surface velocity. The effect of the Lomonosow Ridge can also be seen with weaker intensity in the LKF occurrence. The region above the Gakkel Ridge shows the highest LKF frequency but the high deformation rates here are most probably mainly due to it being directly at the ice edge.

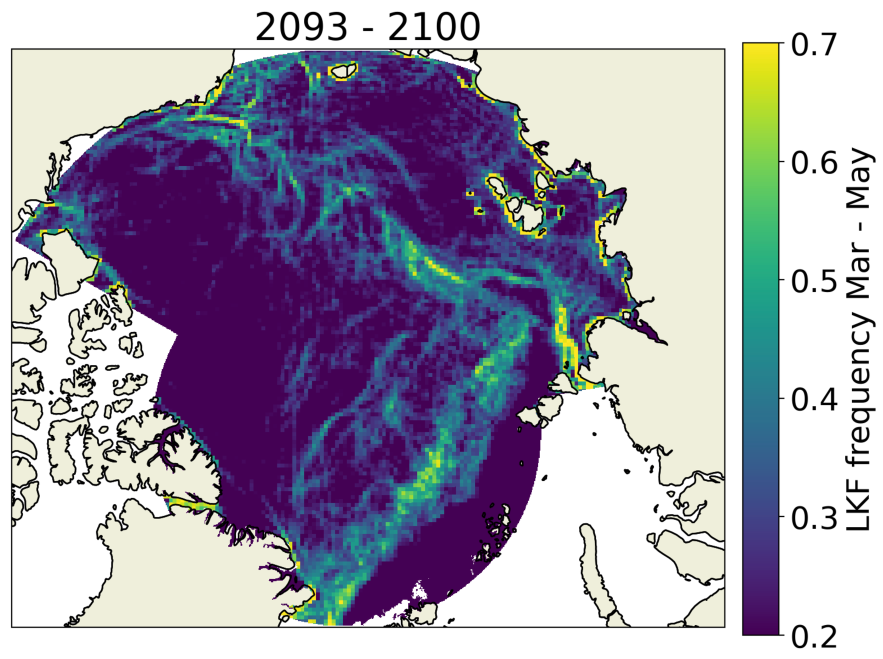


Fig. 8: Frequency of LKF per 25 km x 25 km grid box. The growing phase in December and January is omitted as the ice concentration is too low for it to be considered pack ice (the LKF frequency field looks very noisy here).

References:

Hutter, N., Zampieri, L., and Losch, M. (2019). Leads and ridges in arctic sea ice from rgps data and a new tracking algorithm. The Cryosphere, 13(2):627–645.

Li, X., Wang, Q., Danilov, S., Koldunov, N., Liu, C., M¨uller, V., Sidorenko, D., and Jung, T. (2024). Eddy activity in the arctic ocean projected to surge in a warming world. NatureClimate Change, pages 1–7.

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