Data Descriptor

Areas of Updraft Air Motion in an Idealised Weather Research and Forecasting Model Simulation of Atmospheric Boundary Layer Response to Different Floe Size Distributions

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Abstract

Presented dataset is part of a numerical modelling study focusing on the analysis of the influence of sea ice floe size distribution (FSD) on the horizontal and vertical structure of convection in the atmosphere. The total area and spatial arrangement of the updrafts indicates that the FSD affects the total moisture content and the values of area averaged turbulent fluxes in the model domain. In fact, while convective updrafts occur in every model simulation, their intensity differs with varying FSD due to the changing extent and strength of breeze-like circulation. When the floes are tightly packed in the model domain (simulations with 1000 and 5000 floes) the updrafts are numerous but weaker due to weaker breeze-like circulation. In the simulations with smaller floe numbers (Nf =50 and Nf=100), the opposite situation takes place and the updrafts, while covering a smaller area, are stronger and thus are the values of total moisture and area averaged heat content for the model domain, as described in Wenta and Herman (2019).

Keywords: sea ice; floe size distribution; atmospheric boundary layer

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Specification table (data records)

Subject area	Numerical modeling of ocean/sea ice-atmosphere interactions
More specific subject area	Floe size distribution influence on the atmospheric boundary layer

Type of data	Images
How the data was acquired	Generated with MatLab software from the WRF model output
Data format	tiff
Experimental features	
Data source location	MOST Wiedzy Open Research Catalog, Gdańsk University of Technology, Gdańsk, Poland
Data accessibility	CC BY

Background

Sea ice cover in the Arctic is getting thinner and weaker. In consequence, it is more susceptible to breaking by storms, which accelerate the demise of sea ice (Graham et. al., 2019). Despite increased efforts to increase our knowledge about the changes taking place in the polar regions, many aspects of the response of the atmospheric boundary layer (ABL) to sea ice fragmentation are still poorly understood and require new parameterizations to properly reproduce the conditions in the Arctic (Vihma et.al., 2014). So far, most of the studies have focussed on the ABL modelling and observations over leads (e.g. Alam and Curry, 1995; Andreas and Cash, 1999; Marcq and Weiss, 2012), rarely considering multiple, differently oriented cracks between sea ice floes – typical features of marginal ice zone (MIZ). In a study by Wenta and Herman (2018), the problem of the ABL's response to heterogenous sea ice cover is approached differently. In a set of idealized WRF model simulations, they study the atmospheric response to various floes and leads' spatial and size distributions and demonstrate that the domain-averaged values are sensitive not only to sea ice concentration, but also to subgrid-scale spatial arrangement of ice floes and leads. The results clearly show that the spatial distribution and strength of updraft and downdraft regions associated with convective motion within the ABL are related to the underlying features of the ice cover (distribution of floes and leads). In the follow up study of Wenta and Herman (2019), the differences in area-averaged values of turbulent fluxes, total water vapour and liquid water content are explained based on the fact that floe size distribution (FSD) determines the spatial arrangement and intensity of convective cells, which in turn controls the exchange of heat and moisture.

The presented dataset includes the images and calculated total coverage of updraft areas for a number of WRF model simulations analysed in Wenta and Herman (2019). Analysis of this data allowed us to conclude that the convective updrafts occur in every one of our simulations, but their intensity differs with varying FSD due to the changing extent and strength of breeze-like circulation (Fig. 25.1a).

Methods

The Advanced Research Weather Research and Forecasting (ARW WRF) model is used in an “idealized mode”. In this approach, the model is initialized with a single sounding file consisting of the vertical profiles of potential temperature, water vapour mixing ratio, and the two components of wind velocity. The full air pressure and density, as well as other atmospheric variables, are initialized from that input sounding. The model domain is rectangular, with periodic boundaries in both horizontal directions, dimensions 200 × 200 grid points and a horizontal resolution of 100 m, thus covering an area of 20,000 × 20,000 m. The top boundary is set at 2000 m above the surface, close to the top of the inversion layer separating the ABL from the free atmosphere in the initial sounding. The air column is divided into 61 vertical levels with an exponential thickness distribution, from ~2 m at the surface to ~200 m at the top. Each simulation used in this analysis was performed for 14 h, with a time step of 1 s. The results were stored every 10 min.

In the presented dataset, three different sea ice concentration values are considered: $c=50\%$, $c=70\%$ and $c=90\%$ as in Wenta & Herman (2019). For each ice concentration and two wind speed profiles, the model is launched for a series of simulations with different spatial arrangements of ice floes. Sea ice is represented as round floes with a power-law probability distribution of their radii $P(r) \sim r-\beta$, with an exponent $\beta=1.8$ (values between 1.5 and 2.0 are typically observed in the marginal ice zone). Floe radii range from several tens of metres to over 4 km. The sea ice masks for WRF are obtained by first generating an ensemble of floes with a desired total ice surface area, corresponding to a prescribed c and number of floes Nf; subsequently, these floes are randomly placed within a temporary, very large rectangular domain at a very low ice concentration and without floe overlap, and a DEM model (Herman, 2016) is used to converge the initially loosely packed floe assemblage to obtain a desired ice concentration. A summary of all floe configurations considered is given in Wenta and Herman (2018).

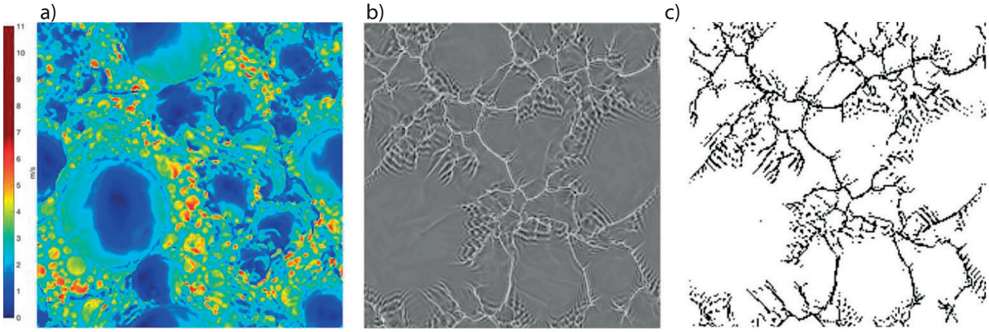

Fig. 25.1. Example of (a) Wind speed (m/s) within model domain for one of the applied FSDs and $c=70\%$. High wind speed is associated with convergence zones related to upward air motions. (b) Grayscale image of upward air motion within the model area. (c) Pixie program output, upward areas marked in black

The study of convective structures within the model domain is based on the analysis of the vertical component of the air motion. In the first step of the analysis, gray-coloured maps of upward air motion areas are generated for every output time step of a given simulation (Fig.25.1b). In the next step, the program called Pixie (https://gitlab.com/seadata-software/pixie) is used to determine the size of updraft areas in every produced image. It is a Python script that applies simple methods of image recognition to distinguish the areas of upward air motion (Fig. 25.1c). It processes every image and counts the pixels for a given colour intensity threshold from 0 (black) to 255 (white). For the presented study, a threshold of 140 has been determined as the most suitable and applied for the whole analysis. Based on the computed number of classified pixels and the number of pixels present in the whole model domain, the total updraft area in km2 and their fractional coverage is computed.

Data Availability

Dataset DOI
10.34808/fwt2-bs21

Dataset License
CC-BY

Acknowledgments

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