EGU General Assembly 2020

EGU2020-6748
https://doi.org/10.5194/egusphere-egu2020-6748
EGU General Assembly 2020

Variability of Lagrangian pathways and coherent structures in the Arctic and its effect on the predictability of MOSAiC drift and material transport

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Lagrangian particle tracking and associated diagnostics may be used to examine advective pathways of material and to identify coherent structures in the flow. Lagrangian coherent structures are material transport barriers and act to separate different flow regimes.

The drift of the International Multidisciplinary Observatory for the Study of Arctic Climate (MOSAiC) expedition onboard R/V Polarstern began in October 2019 and will continue for the full year. Our study has the goals to (i) characterise advective pathways and (ii) examine potential predictability of the MOSAiC drift. Eddies, jets and boundary currents feature large spatiotemporally varying velocity gradients. Since operational ocean forecasts have a limited time horizon (~weeks), we focused on hindcast to examine typical sea ice/ocean circulation scenarios for 2005-15. We applied off-line ARIANE particle tracking in an eddying 1/12 deg. global NEMO sea ice-ocean model to estimate the most likely drift pathways.

Over 10,000 trajectories were initialised in October each year, started at the best estimated MOSAiC location, advected for one year and analysed for key coherent drift structures. The advection and deformation of the initial particle cluster provided information about MOSAiC drift predictability, but also elucidated transport processes of the biogeochemical tracers, such as nutrients and carbon, and spread of pollution and microplastics. We analysed observations from a newly curated dataset of the Arctic to examine various watermass properties, their origin, fate and connectivity.

The MOSAiC surface drift trajectories depend on release time and location, but to leading-order, they are governed by the interannual variability of the wind and of the underlying ocean circulation. Mesoscale flow deformation is linked to a spreading of the cluster of particles and is associated with reduced potential predictability of separation of particles within the cluster (~ 450 km after 12 months). Gyre-scale flow affects the ensemble drift path over long times and influences whether particular coherent structures are encountered by the particles, their location and strength (in terms of velocity magnitude and gradient). Saddle-type structures play a major role in bifurcation of particle trajectories. In the examples studied, saddles north of Nares Strait, near Northern Greenland and Northern Iceland, topologically associated with streamline

connectivity between gyres, coastal boundary currents and inflow/outflow at the Arctic gateways, were significant. On seasonal-interannual scales, the position and strength of the Beaufort Gyre, as well as an anomalous cyclonic gyre in the eastern basin, affected both the ensemble drift path and the coherent flow structures.

The variability of ensemble drift path, cluster deformation and coherent flow structures across the full Arctic basin were often very different from the climatological advective behaviour of Trans-Polar Drift. For estimation of advective pathways and sea ice drift it is important to consider the varying flow from gyre-scale to mesoscale, where velocity gradients are large, and to identify robust Lagrangian measures for steady features.

The study is supported from NE/R012865/1 (APEAR), part of the Changing Arctic Ocean programme, jointly funded by the UKRI Natural Environment Research Council (NERC) and the German Federal Ministry of Education and Research (BMBF).