Machine learning is a useful tool to predict & understand sea-ice motion in the Arctic.

Lauren Hoffman **lahoffma@eng.ucsd.edu**

Matthew Mazloff, Sarah Gille, Donata Giglio, Cecelia Bitz, Patrick Heimbach

MOTIVATION

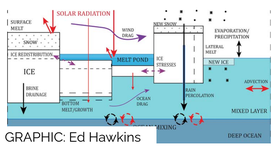
In a changing Arctic, machine learning can be used to **predict** and **understand** sea-ice motion.

Predictability

Increased maritime activity in an ice-free Arctic requires predictability of ice motion and positioning.

Machine learning models can be used to predict sea-ice dynamics and are more computationally efficient than traditional physics-based models.

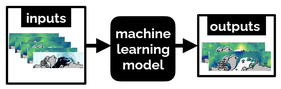
Physics-based Models



GRAPHIC: Ed Hawkins

A Multi-scale & multi-phase problem: Mass, momentum and energy balances between the ice, air, and ocean at different length and time scales.

Machine Learning Models

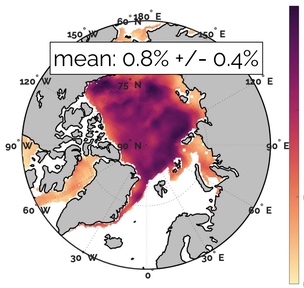


Data-driven learning: Draws information from data & learns patterns without constraints of physics.

Machine learning can also teach us about emergent behavior we have not yet recognized.

Understanding changes in sea-ice motion

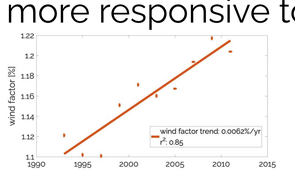
The response of the ice to the dynamic mechanisms that drive it's motion is changing as it melts.



Ice motion is largely dependent on wind speed.

wind factor: ratio of sea-ice speed to wind speed

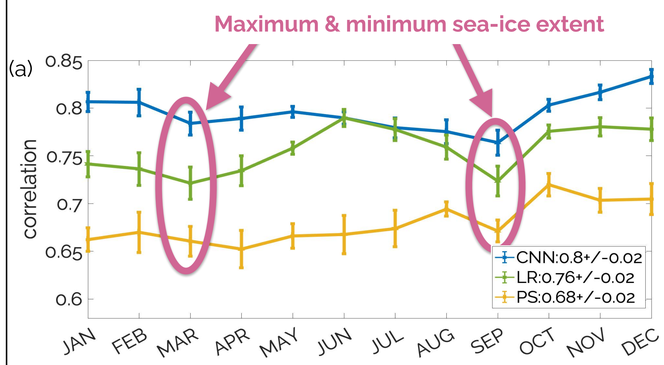
As the ice melts it is becoming more responsive to wind forcing.



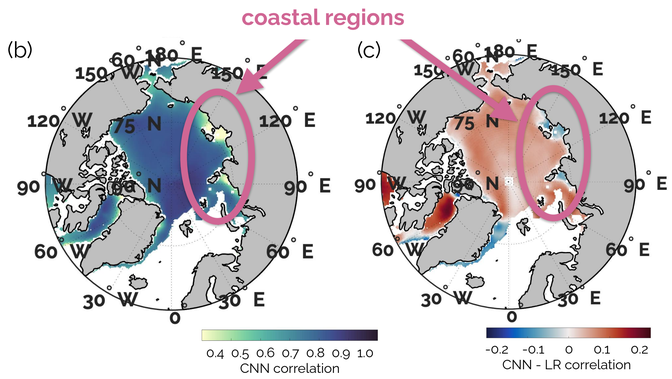
The **wind factor is increasing!**

Predictability & model comparisons:

Machine learning models can make skillful one-day predictions of sea-ice motion, with a few caveats.



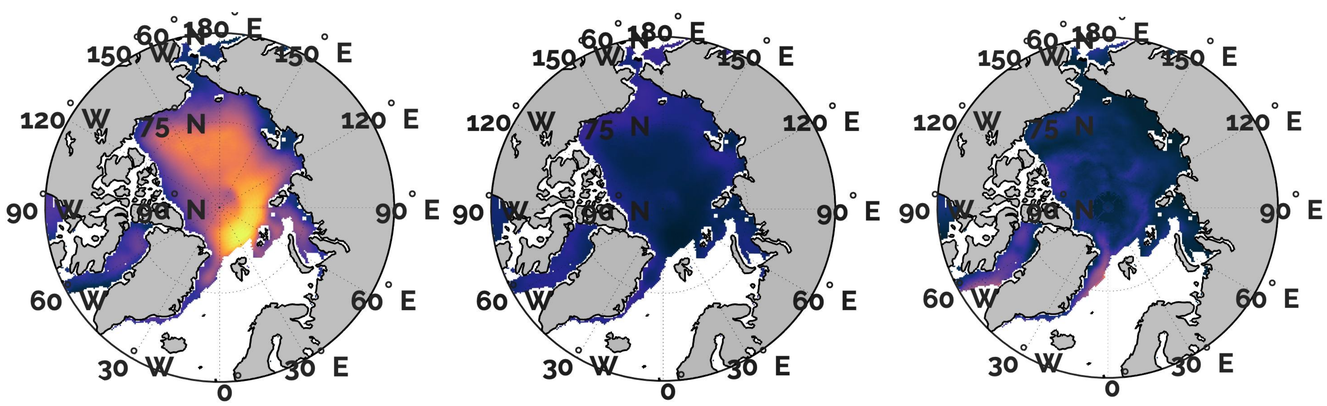
(a) A convolutional neural network (CNN) outperforms conventional linear regression (LR) and persistence (PS) models. Model skill tends to decrease during months of minimum and maximum sea-ice extent.



(b) The correlation between the model prediction and observations is lower in coastal regions.
(c) The CNN largely outperforms the LR model (red), except for in some coastal regions (blue) .

Understanding sea-ice motion:

Machine learning methods help gain insight into the behavior of sea-ice motion and confirm historical results that wind velocity has the largest relevance in determining sea-ice velocity.



wind velocity | sea-ice velocity | sea-ice concentration

Normalized Linear Regression Parameter Magnitude

DATA & METHODS

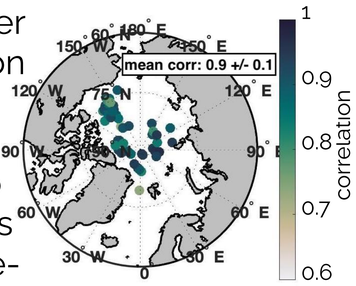
A convolutional neural network (CNN) is compared to conventional linear regression (LR) and persistence (PS) models.

Models make one-day predictions of sea-ice velocity from inputs of:

Input Variable	Dataset
Present-day Wind Velocity	Japanese 55-year Reanalysis
Previous-day Sea-Ice Velocity	Polar Pathfinder Daily Ice Motion
Previous-day Sea-Ice Concentration	Nimbus-7 Passive Microwave

Satellite Data Validation

The use of the Polar Pathfinder Daily Ice Motion product is validated by comparison to measurements from in situ Ice-Tethered Profilers.

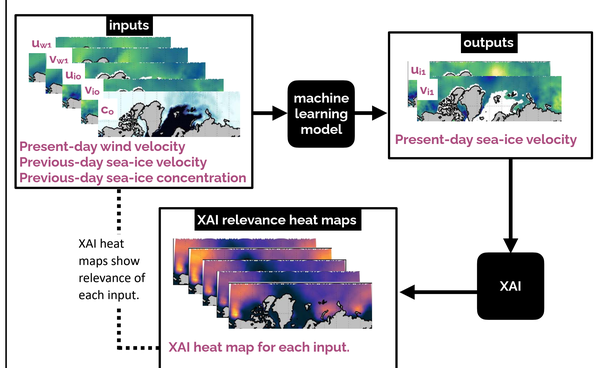


Data Acknowledgements

- Ice motion and ice concentration data were made available by the National Snow and Ice Data Center Distributed Active Archive Center.
- Ice-Tethered Profiler data were made available by the Ice-Tethered Profiler Program based at Woods Hole Oceanographic Institution.
- Wind velocity data are provided from the Japanese 55-year Reanalysis (JRA-55) project carried out by the Japan Meteorological Agency (JMA). This dataset was also collected and provided under the Data Integration and Analysis System (DIAS), which was developed and operated by a project supported by the Ministry of Education, Culture, Sports, Science and Technology.

FUTURE WORK

Explainable AI (XAI) methods will be applied to understand trends in the changing relationship between wind speed and sea-ice speed.



Office of Naval Research ONR Science & Technology · SCRIPPS INSTITUTION OF OCEANOGRAPHY · UC San Diego JACOBS SCHOOL OF ENGINEERING