NOCOS DT
NORDIC CRYOSPHERE DIGITAL TWIN

LEVERAGING DIGITAL TWIN OPPORTUNITIES FOR KEY SEA-ICE IMPACT SECTORS IN THE NORDIC AND BALTIC CONTEXT

Case studies towards cryosphere digital twin applications

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Nordic Cryosphere Digital Twin

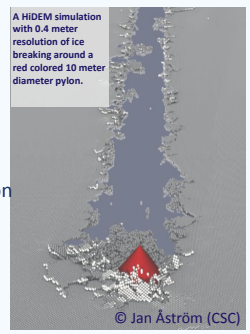
NOCOS DT is a digital twin project focusing on sea ice in the Arctic, Nordic and Baltic regions. It ties to Destination Earth, a project ultimately aiming at creating a digital model of the whole world, and especially to its Climate Change Adaptation Digital Twin. The project aims to explore and pilot the digital twin technology and showcase how it could be leveraged for key sea-ice impact sectors.

NOCOS DT at the UN Climate Change Conference (COP29)
Meet us during our panel discussion *Global and regional approaches to cryosphere and related climate challenges* at the Nordic Council of Ministers' pavillion on Saturday November 16 at 13:15–14:00.

High Resolution Discrete Element Model (HiDEM)

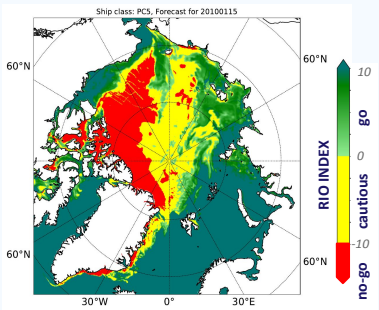
- Simulates fracture of brittle materials
- ~10 000 km² sea ice at below 10 m resolution
- 0.4 m ice resolution for pylon simulation ➡
- Reproduce observed floe size distributions
- Reproduce observed fracture patterns and ice motion

Recent publications:
➢ A large-scale high-resolution numerical model for sea-ice fragmentation dynamics, ***The Cryosphere*, 18 (5), 2024**
➢ High resolution fracture dynamics simulation of pack-ice and drift-ice formation during sea ice break up events using the HiDEM2.0 code, ***Geophys. Res. Lett.*, accepted September 2024.**



Risk Index Outcome (RIO)

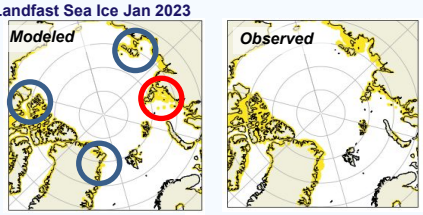
- RIO is based on ice concentration, ice thickness and the ship polar class
- Advanced RIO calculation method: include sea ice salinity or ice age data for thick ice – Determine the POLARIS ice type with precision
- Usage:
  - ➢ Voyage planning
  - ➢ Real-time decision making



Arctic RIO index generated using DMI HYCOM-CICE data
© Xinfang Zhang (FMI)

Landfast Sea Ice (LFSI)

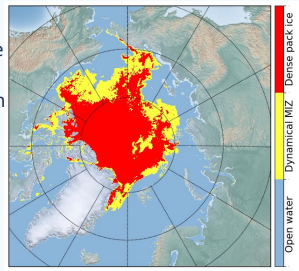
- It is hard to simulate realistic LFSI
- LFSI is defined as ice that does not move despite being forced by wind and ocean
- This is caused by anchor points that lock the sea ice
- Landfast sea ice is used to travel on, including the construction of ice roads
- LFSI is important for fisheries as local communities fish from here ⬇️
- LFSI reduction is expected with climate change



Further information on used data:
Ponsoni et al., Greenlandic sea ice products with a focus on an updated operational forecast system, ***Frontiers in Marine Science*, 2023**

Marginal Ice Zone (MIZ)

- MIZ is a transition region from open water to dense pack ice that is affected by open ocean processes. It is a dynamic zone under strong interactions between the atmosphere, ocean, sea ice and waves
- MIZ is also an area much more navigable than the inner dense pack ice
- Traditional MIZ is defined solely based on sea ice concentration between 0.1 and 0.8
- Dynamical MIZ can be parameterized using sea ice concentration and thickness (Wang et al., 2024)

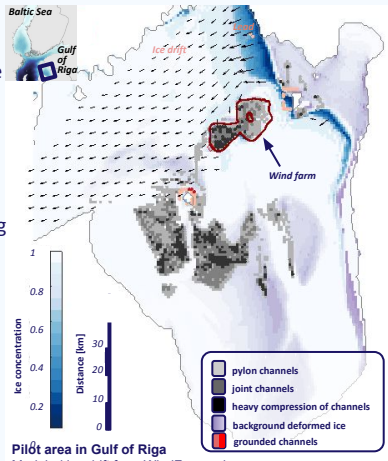


Dynamical MIZ from NorHAPS (Wang et al., 2023) model simulations of Arctic sea ice for 15/08/2022, © Keguang Wang (MET Norway)

Further information:
➢ **Wang et al.** Local analytical optimal nudging for assimilating AMSR2 sea ice concentration in a high-resolution pan-Arctic coupled ocean (HYCOM 2.2.98) and sea ice (CICE 5.1.2) model, ***The Cryosphere*, 2023**
➢ **Wang et al.** Multisensor data fusion of operational sea ice observations, ***Frontiers in Marine Science*, 2024**

Sea Ice Ridging

- Ridging poses Navigational Challenge: Ice ridges obstruct winter navigation and relevant information is crucial for ship routing
- Engineering Concern for offshore constructions: ridges pose risks for offshore structures (construction, planning and operations), requiring robust designs
- Gulf of Riga as target area for DT demo: assessing the potential impacts on offshore windfarm development and related ship traffic (including wintertime servicing of the wind farm)
- Ridged ice quantified from local DT results by implementing Lagrangian Particle Model and interpreting sea ice state and sea ice drift data

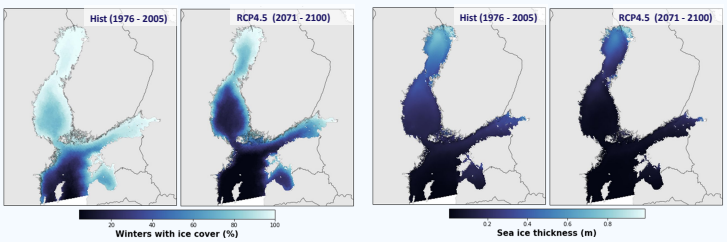


Pilot area in Gulf of Riga
Modeled ice drift from WindFarm pylons
© Rivo Uiboupin and Ilja Maljutenko (TalTech)

Marine Spatial Planning (MSP)

- In the Baltic Sea, the impact of climate change on marine ecosystems, including changes in sea ice, are larger than all other anthropogenic impacts together (Wåhlström et al., 2022)
- It is therefore important to gather valuable information about sea ice changes due to climate change in formats useful for MSP developers
- We will provide an efficient Python framework for data aggregation, processing and visualization of the Climate DT data once available

Further information:
➢ **Wåhlström et al.** Projected climate change impact on a coastal sea—As significant as all current pressures combined. ***Global change biology*, *28*(17), 2022**



Examples of maps that can be delivered by the framework using outputs from a high-resolution ocean model, forced by CMIP5 models for emission scenario RCP4.5. For example, in these results it is shown that large parts of the Baltic Sea will have less years with ice cover, while some parts will preserve both the cover and thickness of the ice © Linn Carlstedt (SMHI)

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