Beyond static boundaries: Affordable coupling approaches for HARMONIE-AROME

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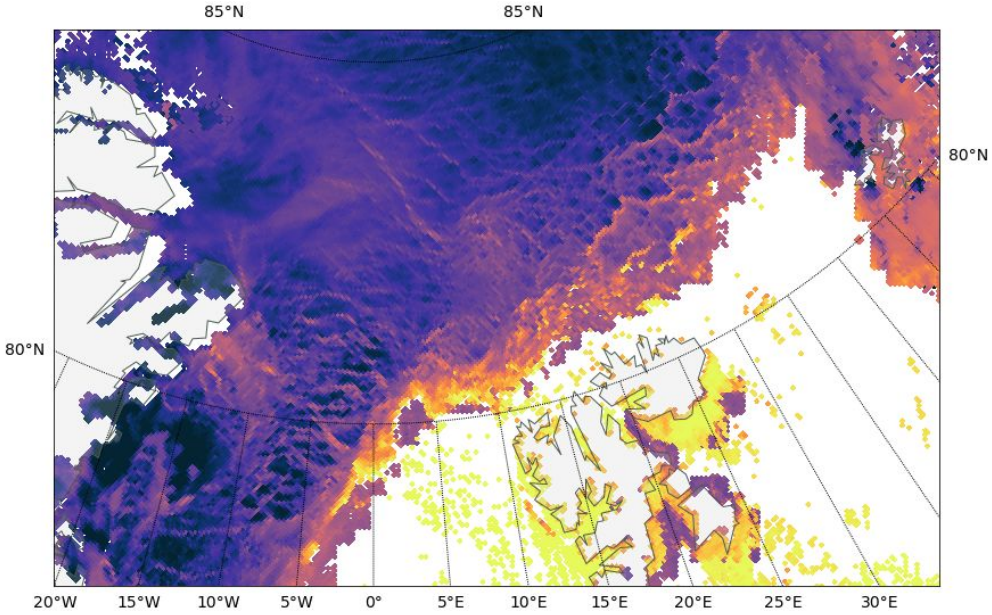
6th ACCORD AWS
Marrakech, Marroko
15.04.2026

Sea ice, a static field?

Hourly surface temperature



- Often treated as a static field, sea ice can evolve rapidly over the course of a day
- Evolution is subject to complex interactions between ice, ocean, and atmosphere
- Accurate physical modelling would require representation of all components
- New socio-economic opportunities, including fishing, exploitation of natural resources, maritime transport, and tourism

People require accurate forecasts in the marginal ice zone!

Sea ice in HARMONIE-AROME

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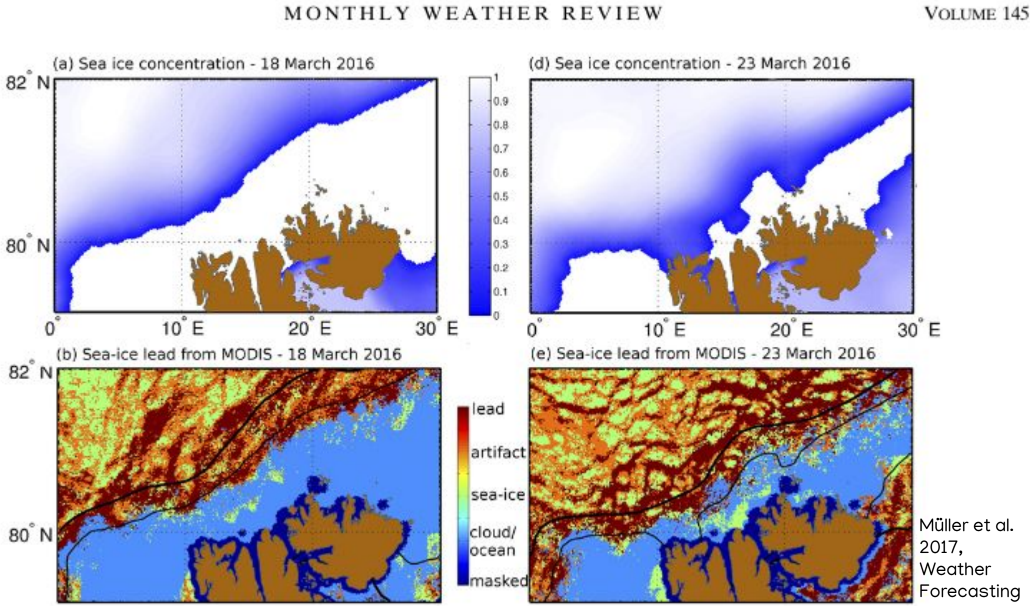
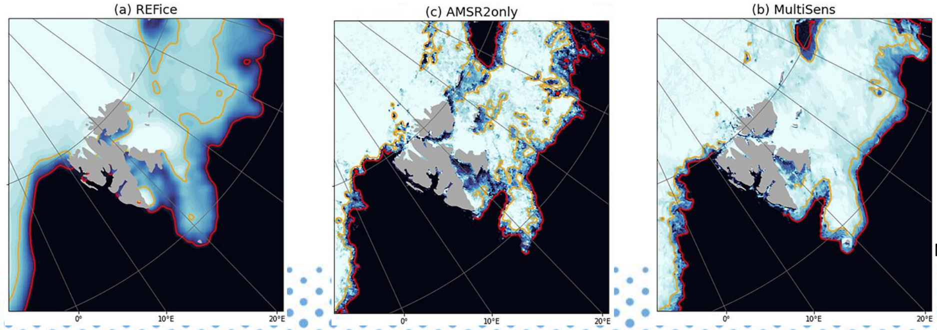
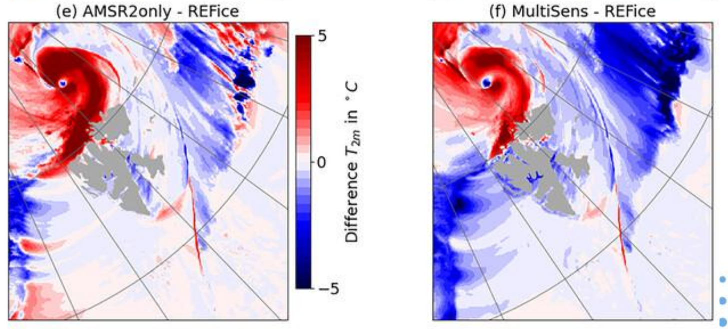
- sea ice is fixed throughout the forecast
- small scale features within the ice are typically absent in input ice concentration
- SIC in HA is controlled by external products
- depending on the chosen product the forecast can change dramatically



Müller et al. 2017, Weather Forecasting

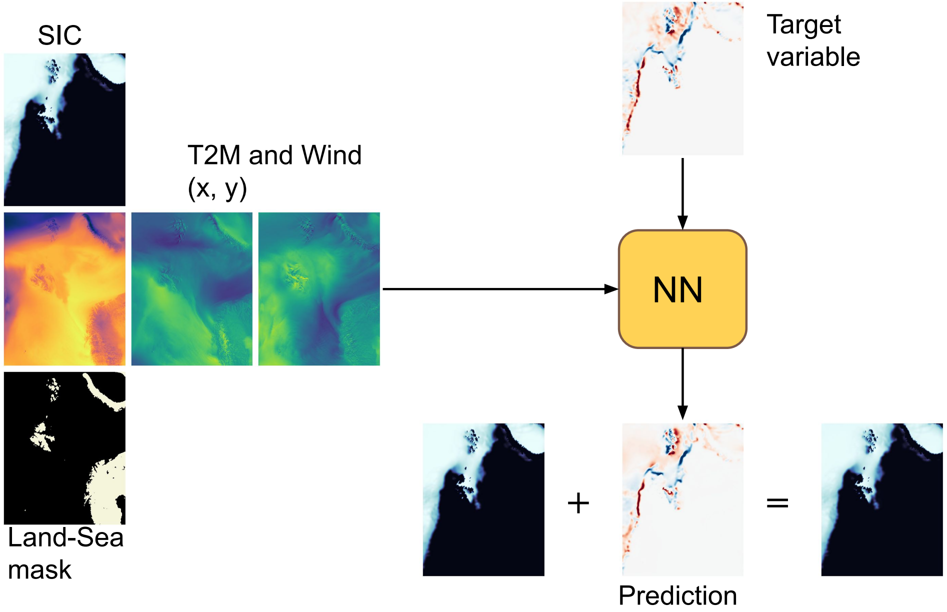


Müller et al. 2023



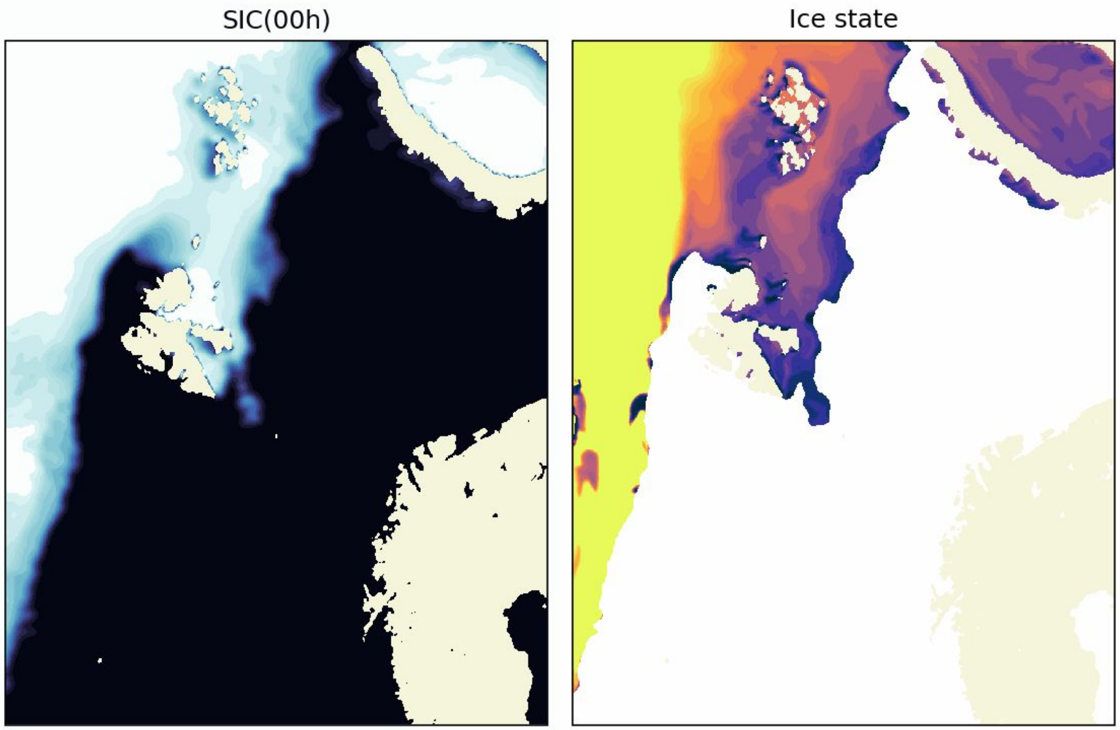
A neural network for sea ice

- **Target variable:**
  - *IFS sea-ice concentration forecast difference at t+6 hours*
- **Predictors:**
  - *IFS sea-ice concentration forecast at t0 hours*
  - *Weather forecasts from AROME-Arctic*
  - *Land - sea mask*
- **Architecture:**
  - *U-ViT (Hoogeboom et al., 2023)*
- **Datasets:**
  - *Training period: 2018/07 - 2022/06*
  - *Validation period: 2022/07 - 2023/06*
  - *Test period: 2023/07 - 2024/06*

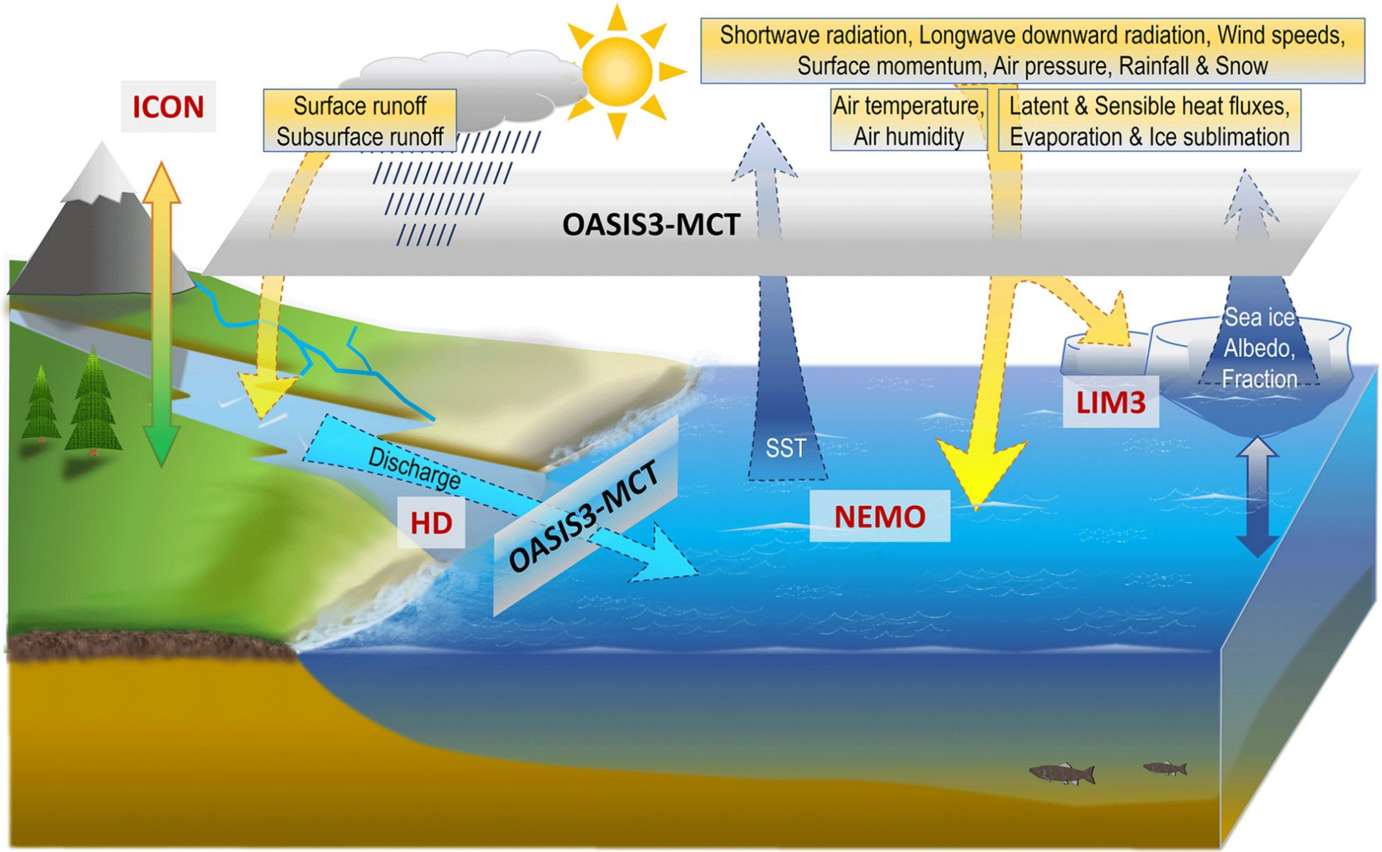


A NN forecast

- The system can run on a CPU for inference
  - One time-step takes ~42sec
  - A full forecast ~ 7m 40sec
- Training-time around 24 hours on a single GPU (H200 tested)
- High resolution fields (2.5km, 928 x 736), each sample uses ~16GB
- Model architecture relatively lightweight (9M params for U-Net, 27M params if U-ViT [4.5M params per ViT block])



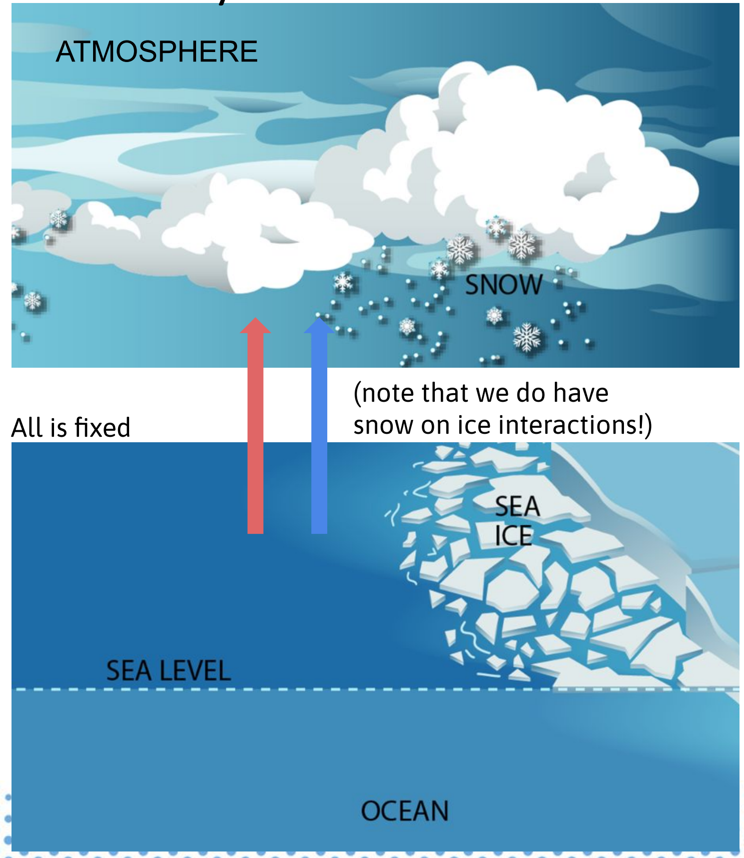
Coupling it to our model: OASIS



Ho-Hagemann, H. T. M., Maurer, V., Poll, S., and Fast, I.: Coupling the regional climate model ICON-CLM v2.6.6 to the Earth system model GCOAST-AHOI v2.0 using OASIS3-MCT v4.0, Geosci. Model Dev., 17, 7815–7834, https://doi.org/10.5194/gmd-17-7815-2024, 2024.

Coupling approach

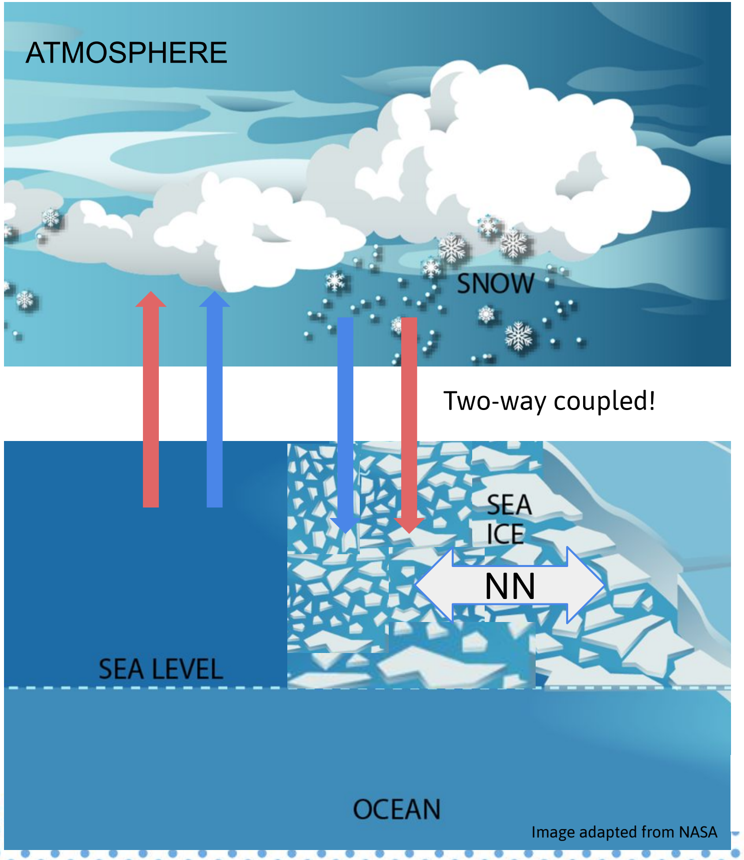
Currently



All is fixed

(note that we do have snow on ice interactions!)

The idea



Two-way coupled!

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From Fortran to Python

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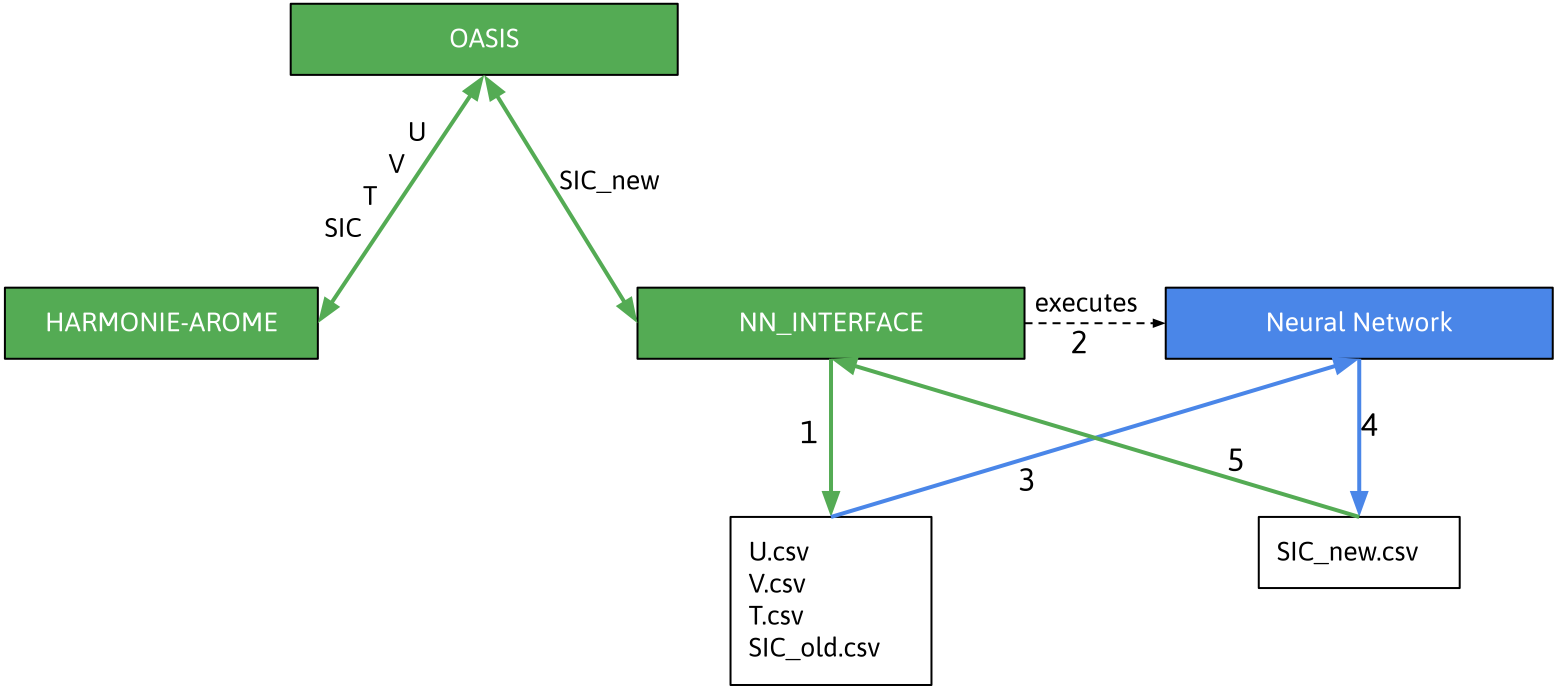

Impact of an evolving sea ice

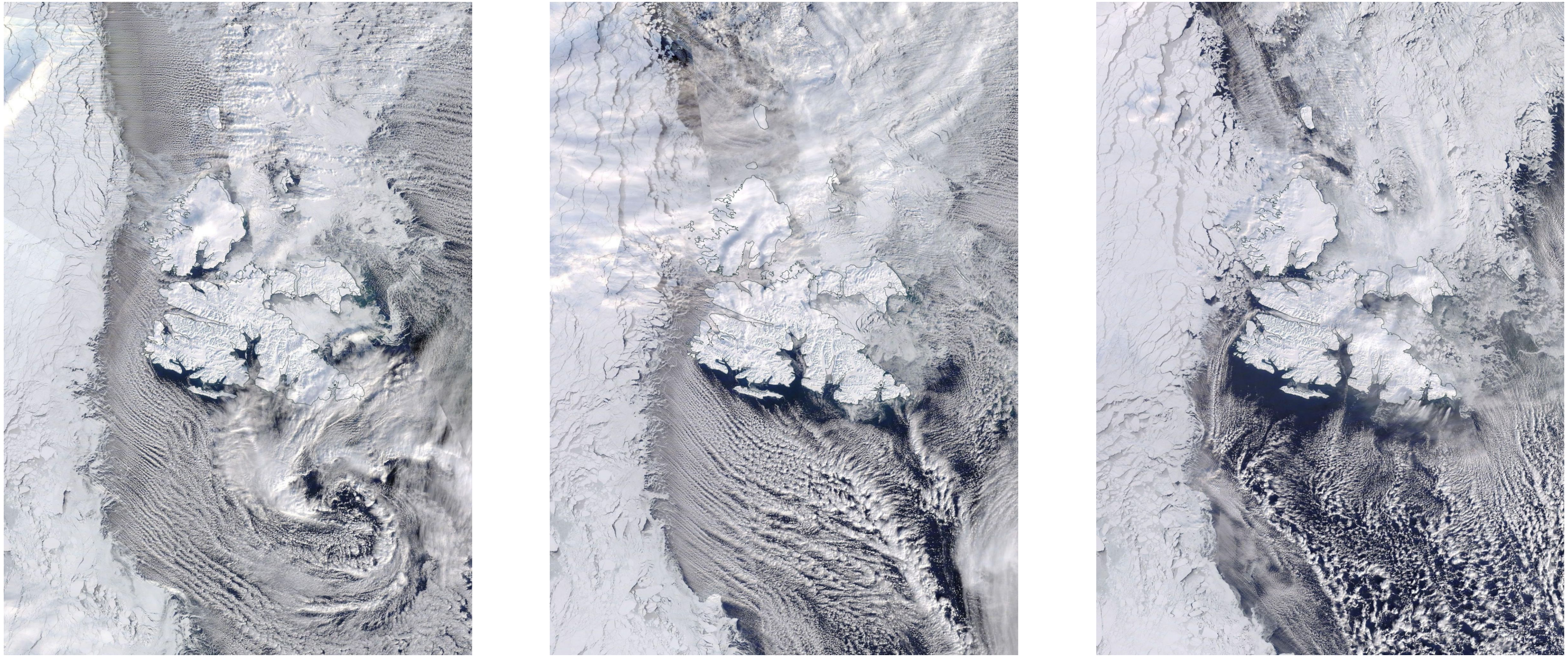

image source: NASA worldview

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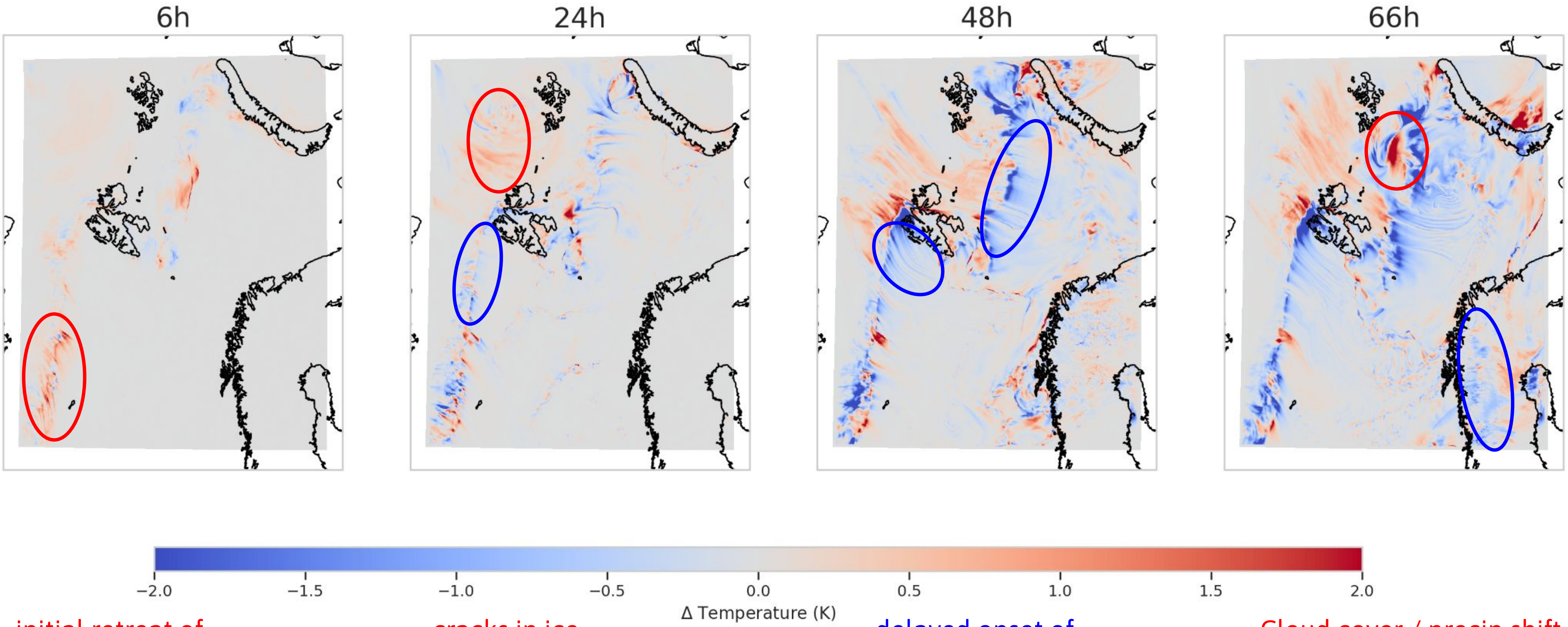
Impacts on atm. temperatures



initial retreat of sea ice

cracks in ice

shift in ice edge

delayed onset of heat fluxes

Cloud cover / precip shift

change in cloud cover

Cross-sections through the PBL

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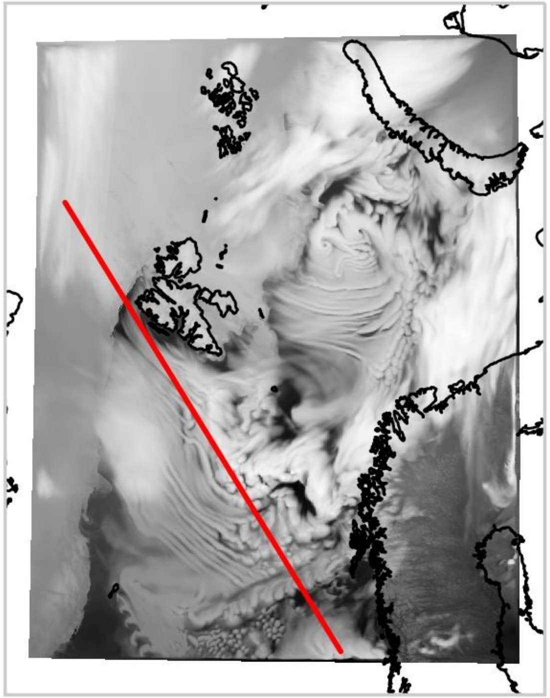
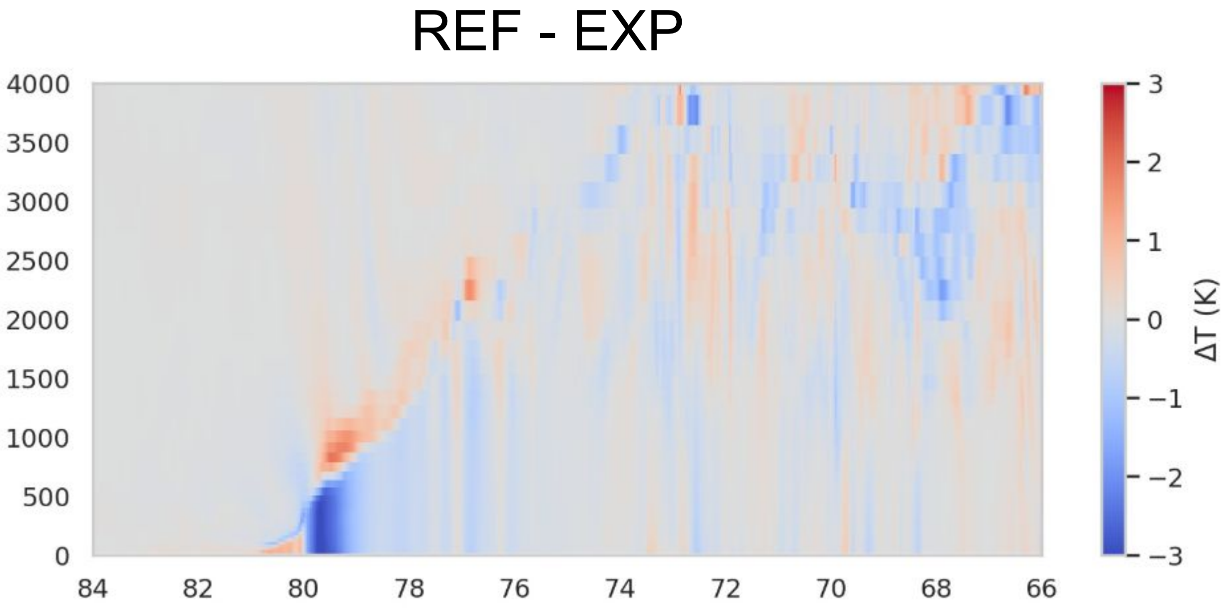
REF



EXP

Downstream impacts



Shallower and colder boundary layer due to delayed onset of heat fluxes.

Reverses downstream due to stronger gradients (fixed SST).

Result is more pronounced convection (higher PBL).

Specific humidity shows similar behavior

strong impact on graupel

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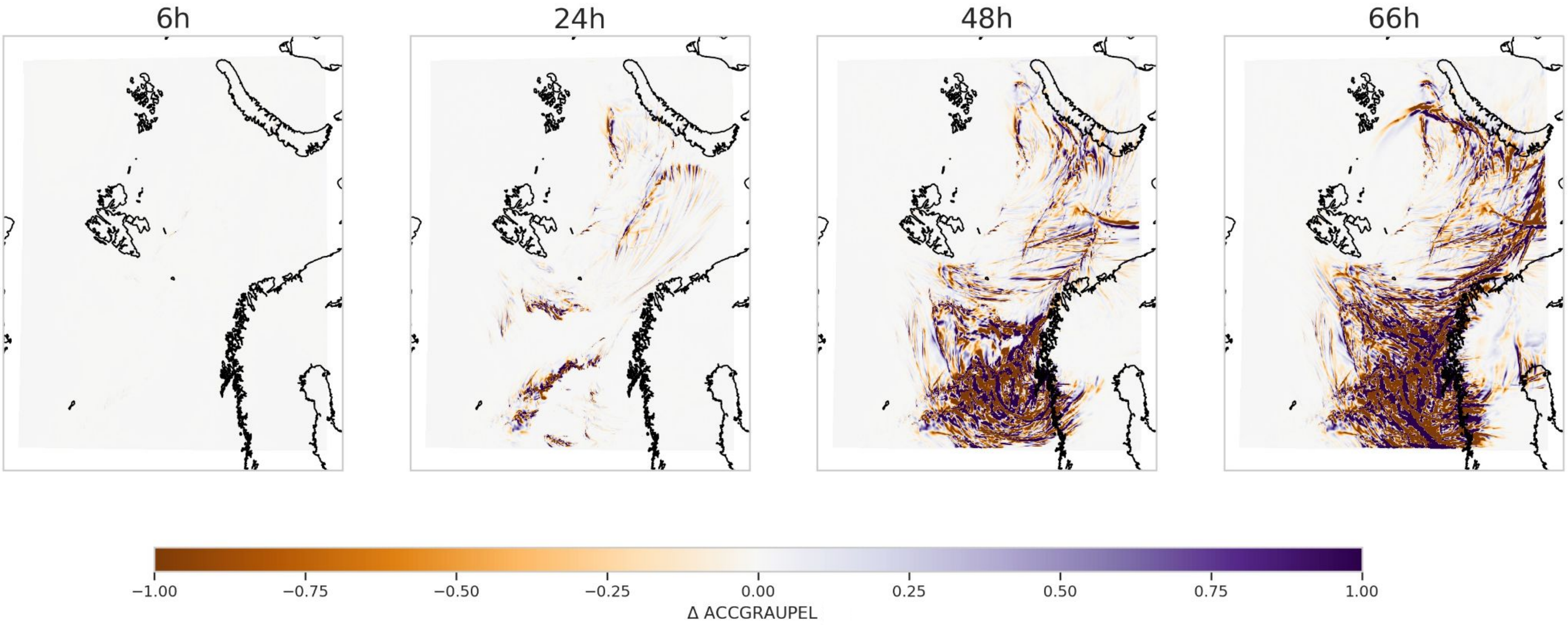
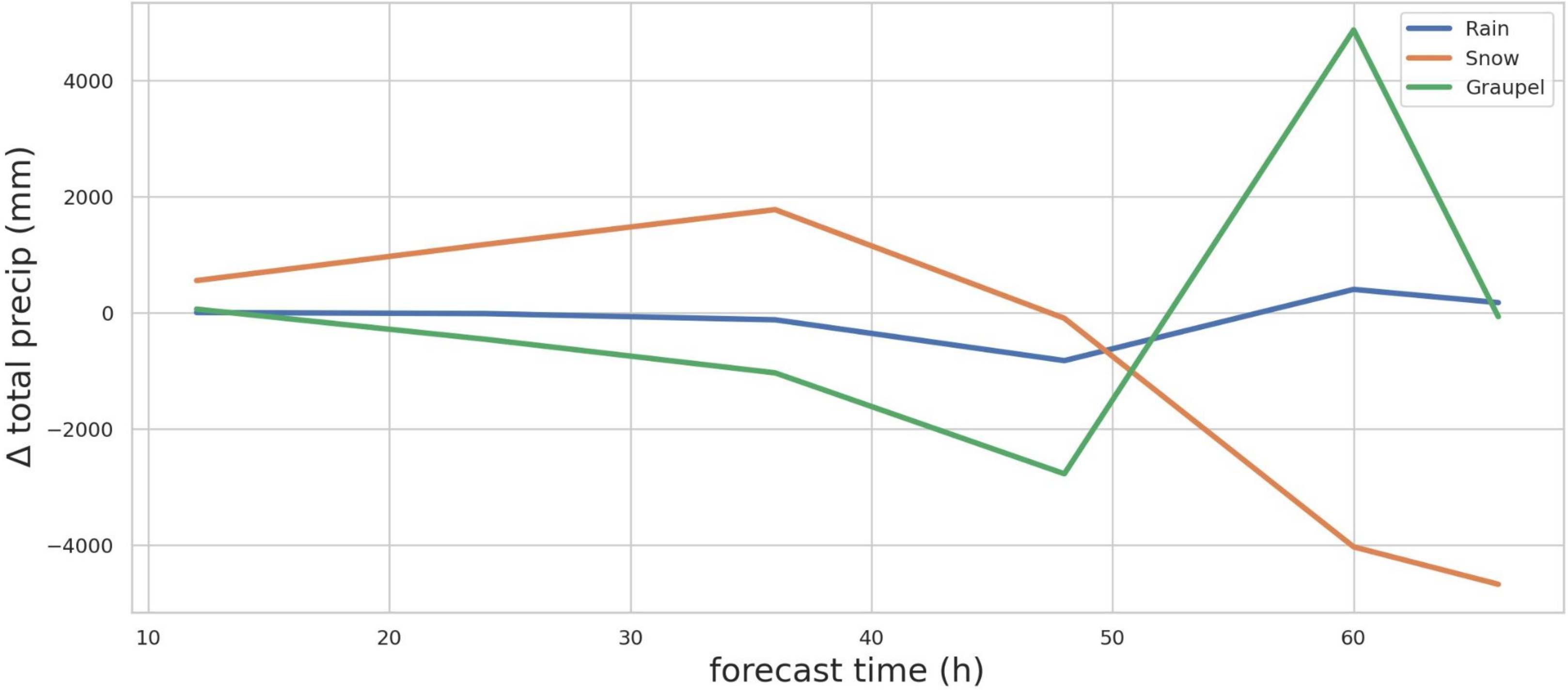


total precipitation changes



Contrasted against LWP/IWP

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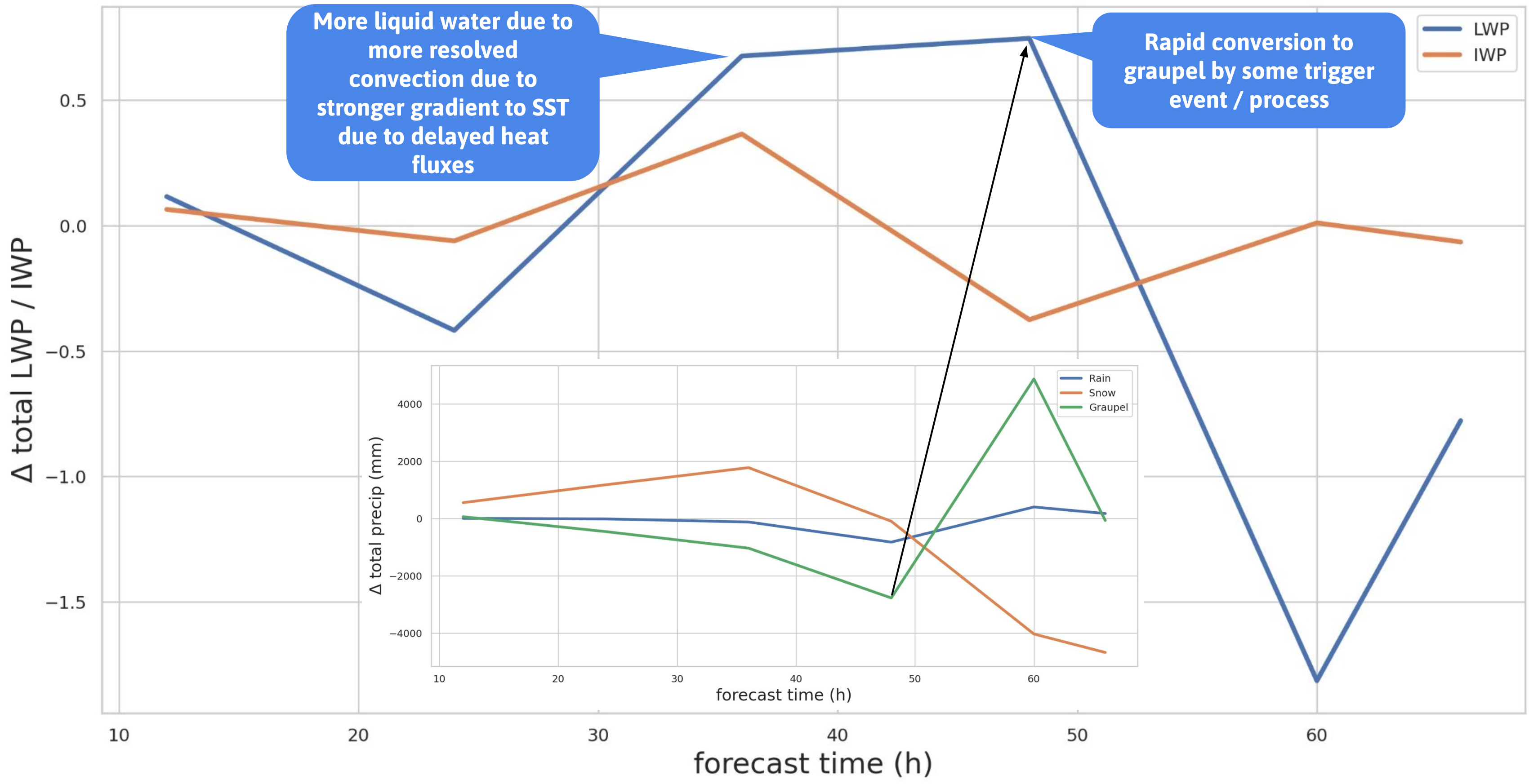
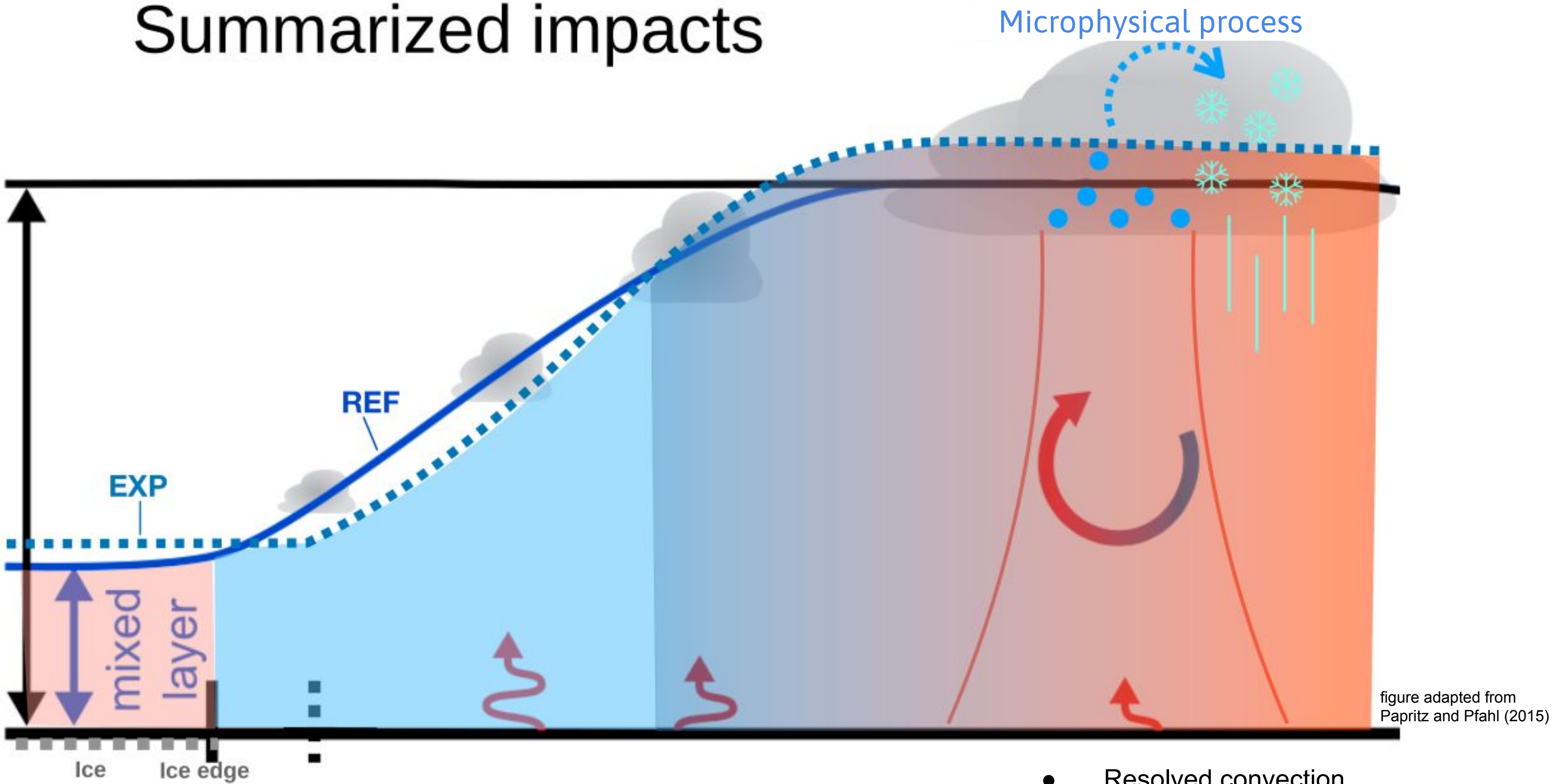


Summarized impacts



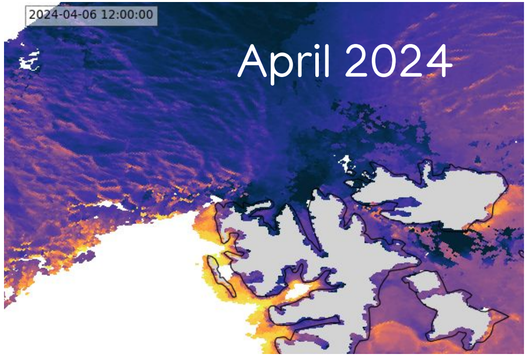
- Break-up of ice
- Heat fluxes
- Warmer/deeper PBL

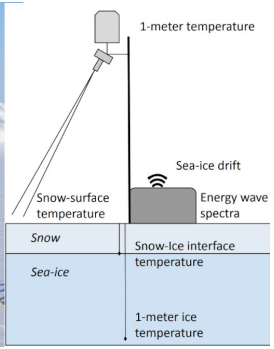
- Shift in sea ice extent
- Delayed heat fluxes
- Colder shallower PBL

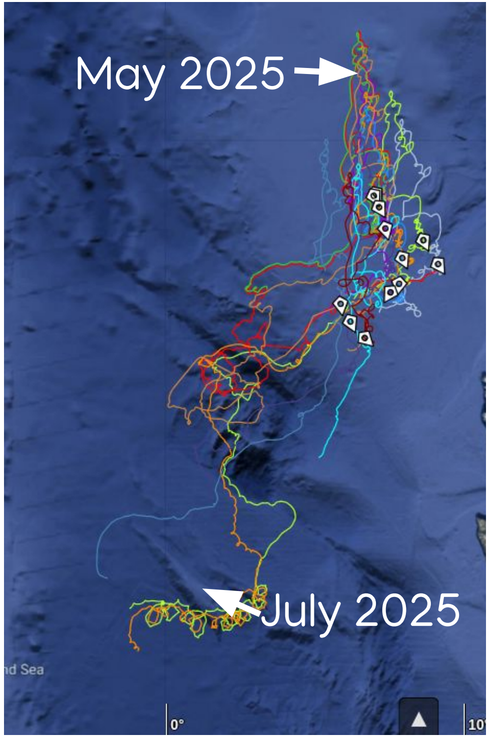
- Stronger gradient
- Stronger convection
- Warmer/deeper PBL

- Resolved convection
- More cloud water
- Rapid transformation to ice
- Shift in precipitation

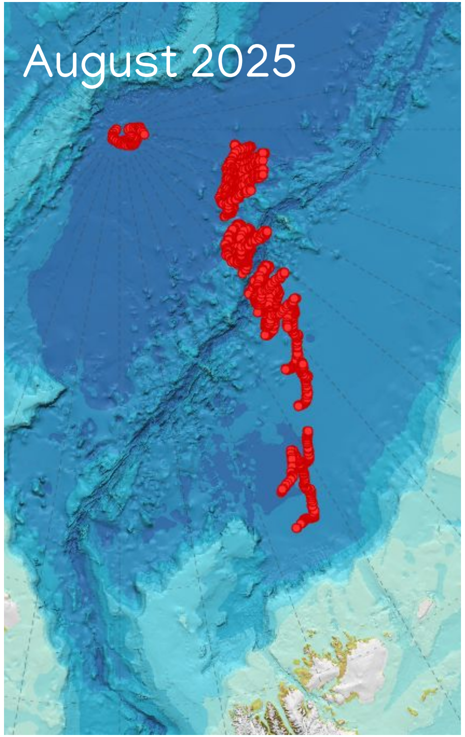
Planned validation: SvalMIZ campaign







https://odl.bzh/GyGURNvb



https://openmetbuoy-arctic.com/campaigns.html

Many potential applications for coupling

I. drag over ocean

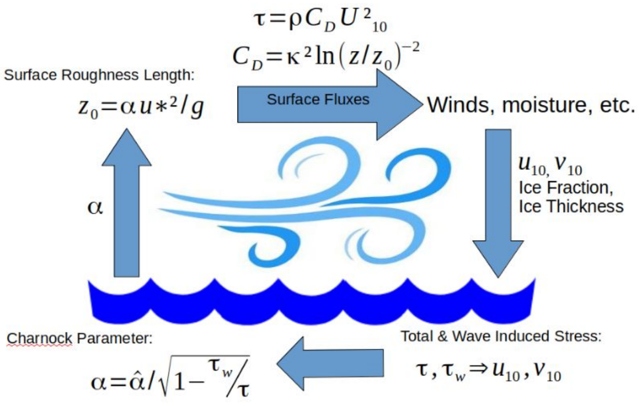
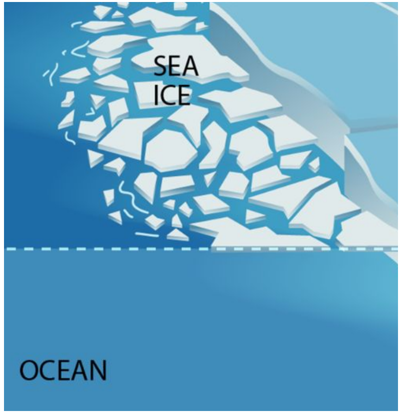
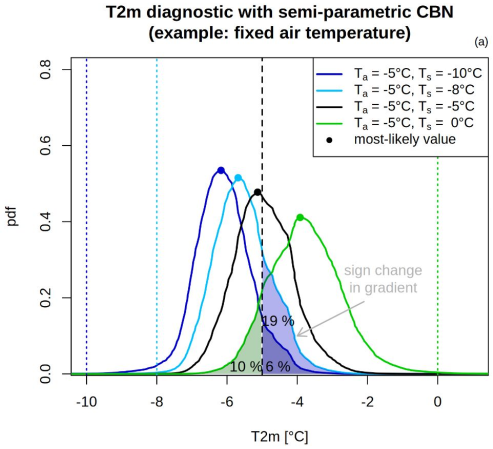


Figure 1 from Thomas et al. 2021

II. evolving sea ice



III. fluxes and T2M



Mack et al. 2026 (in review)

Conclusions

- Coupling capabilities of H-A deserve more attention
- Coupling to an external field allows to probe the model's sensitivity and can guide developments
- NN can help to save computational resources (compared to physical model)!
- Working setup regarding coupling to a changing sea ice concentration
    - Domain-wide effects on temperature, moisture, clouds, precipitation
    - The model is sensitive to moving sea ice -> thorough validation is planned
    - Various complex interplays to consider
    - Sea ice concentration can change notably during a 66h forecast, our model should reflect that