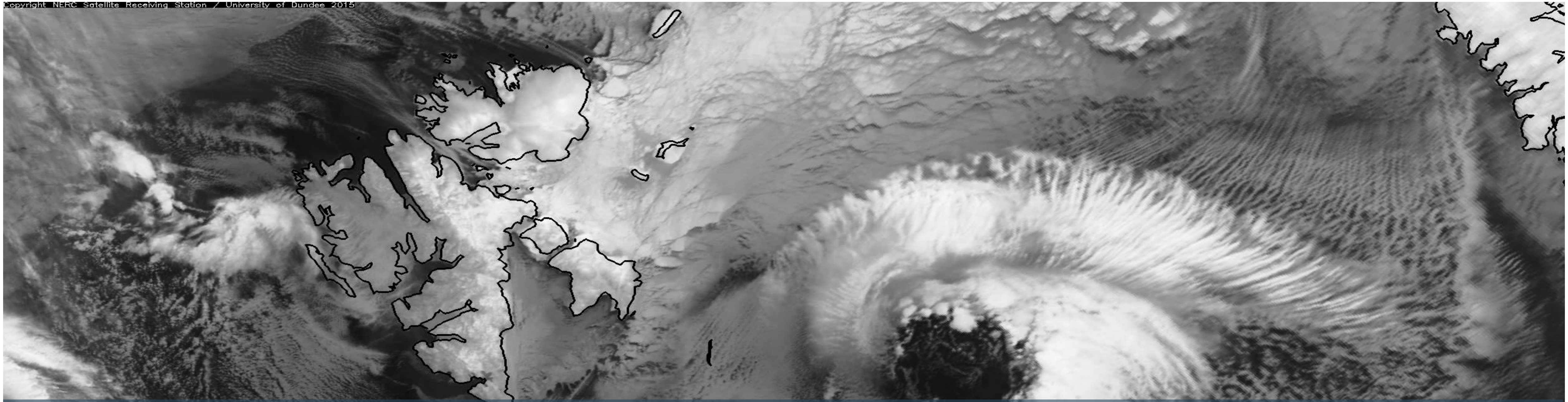

OLIVER GUTJAHR[1] and Carolin Mehlmann[2]

POLAR LOWS IN A GLOBALLY COUPLED STORM AND EDDY RESOLVING (2.5km) CLIMATE MODEL (ICON-Sapphire) – supplementary material (case study 2)

Sharing not permitted

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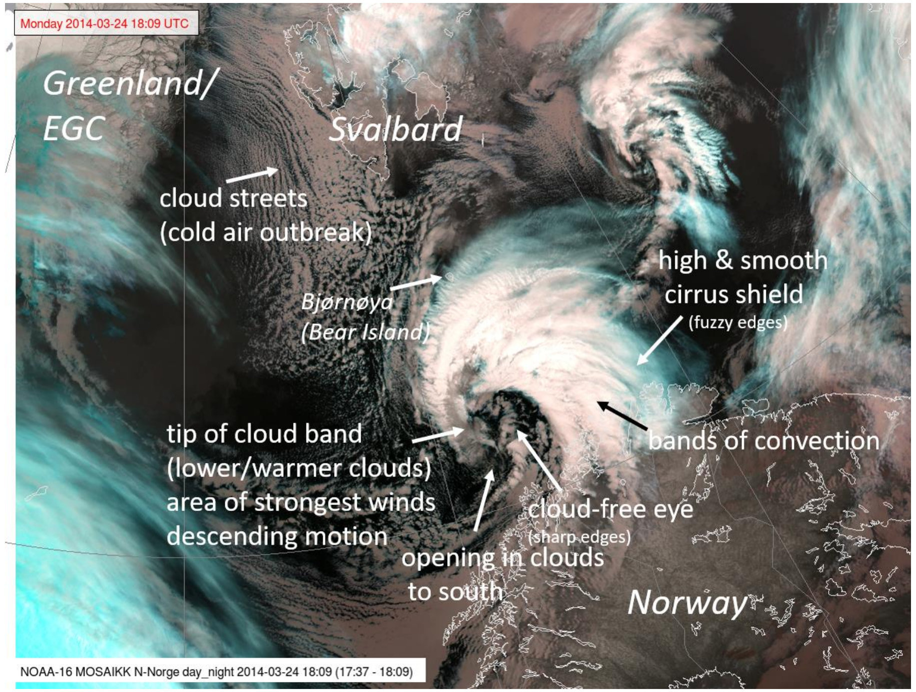
NOAA satellite image of comma-cloud polar low over the Barents Sea east of the Svalbard Archipelago. 1 February 2015. Source: NERC Satellite Receiving Station, Dundee University, Scotland.

MOTIVATION

What are polar lows?

Polar lows (PLs) are the most intense cyclones of the polar mesoscale cyclone (PMC) family, with subsynoptic scales of less than 1000 km and near-surface wind speeds of more than 15 m/s, forming over high-latitude maritime environments poleward of the polar front zone.
[after Heinemann and Claude (1997)]

Why are polar lows important?



A mature polar low off the coast of Finnmark in Northern Norway from late March in 2014. Illustration: MET-Norway/NOAA (modified)

- Danger to shipping/air traffic, coastal communities and offshore installations
  → forecasting with atmosphere-only models (formation processes)
- Effect on ocean/sea ice and climate?
  → coupled global models needed
  → **Problem: kilometer-scale resolution required for atmosphere, ocean and sea ice to capture PLs**

ICON-SAPPHIRE 2.5KM GLOBALLY COUPLED CONFIGURATION (ICON2.5)

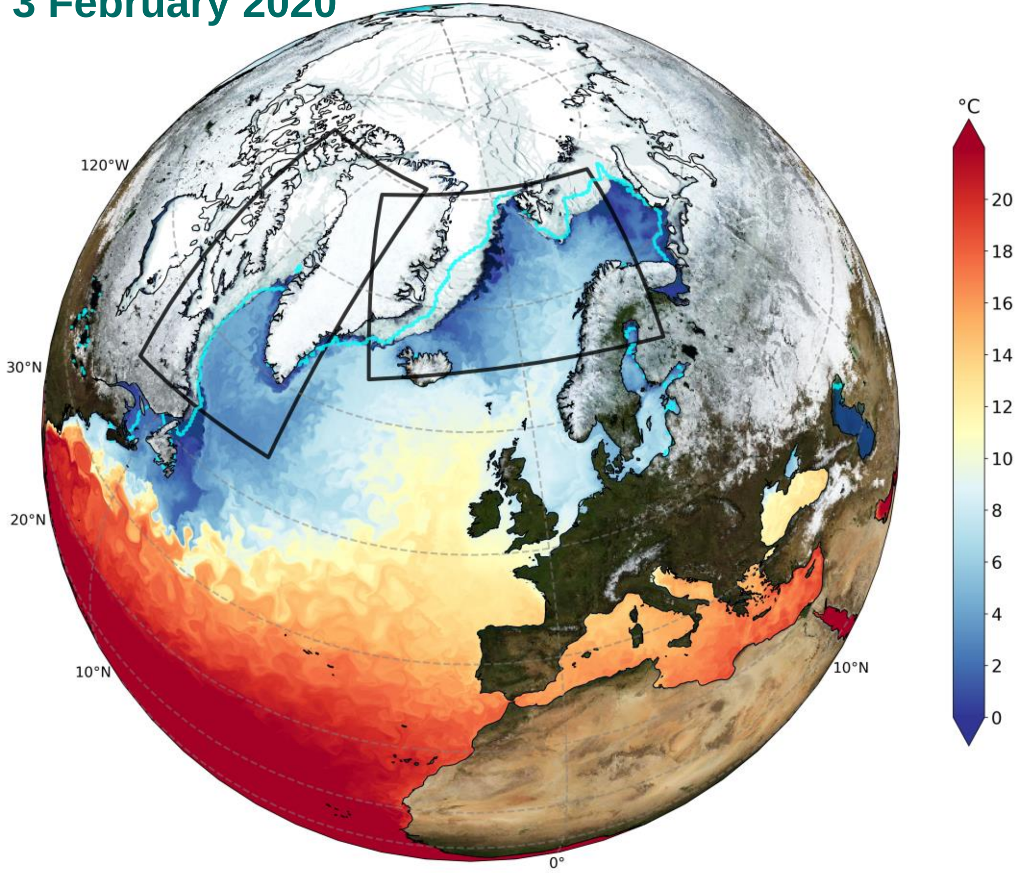
Parameter	ICON2.5
horizontal resolution	r2b10 (2.5 km)
# vertical levels (atm/oce)	90/112
Δ z-levels (oce)	6 to 53 2m
Δt (atm/oce)	20 s/80 s
coupling frequency	12 min
simulation period	2020-01-20 to 2020-03-31 (71 d)
output volume	$\sim$ 340 TB (135 TB/month)
output frequency	2d-atm. (30 min), 3d-atm. (1d),
	2d-oce (1h,3h), 3d-oce <200 m (3h), 3d-oce (1d)

see more details in Hohenegger et al. (2023)

We focus on two case studies:

- Iceland/Greenland Sea (see presentation)
- Labrador Sea (**supplementary material**)

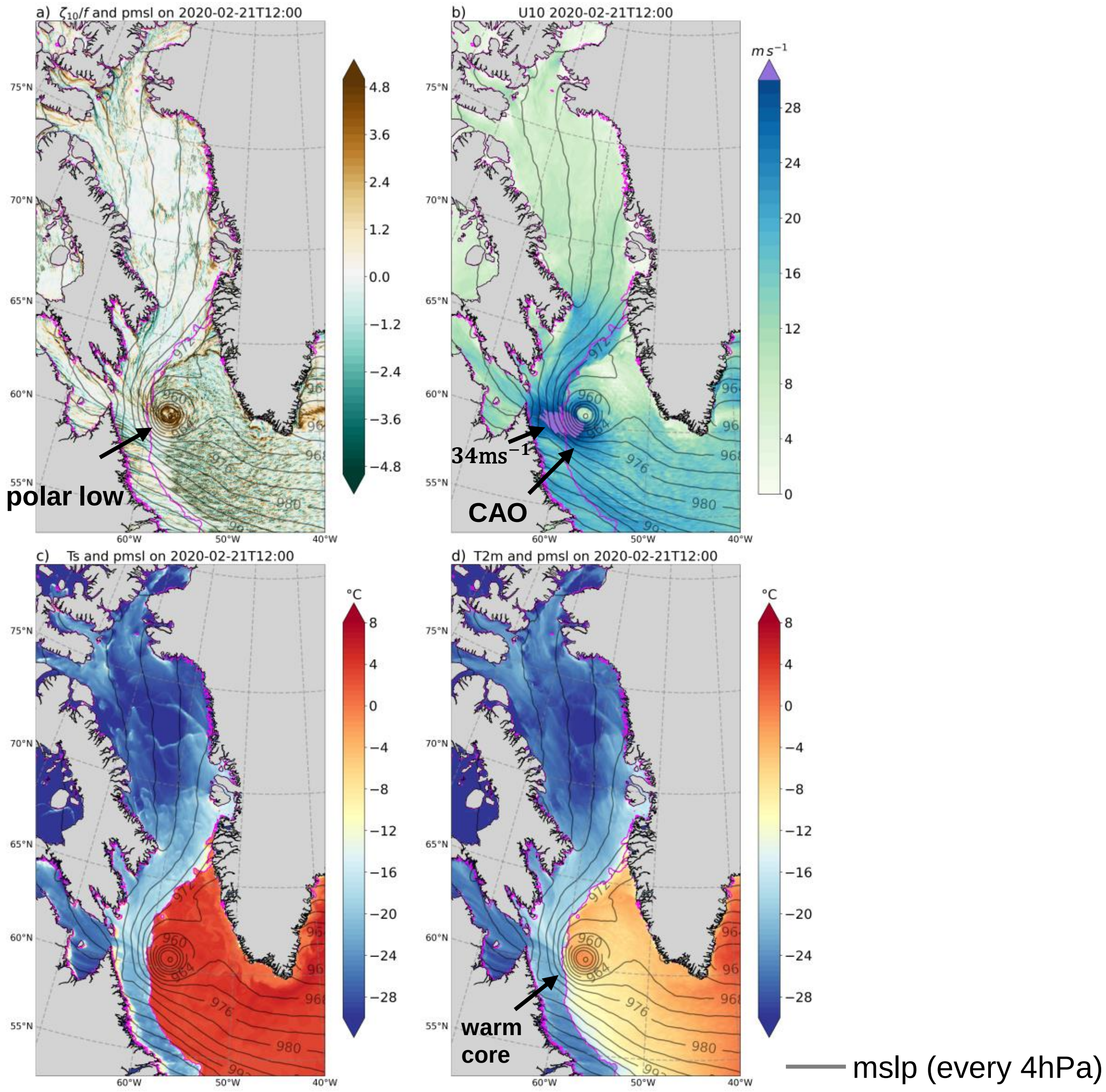
ICON2.5 snapshot (SST and sea ice concentration) 3 February 2020



15% sea ice concentration (OSI-450a; Lavergne et al., 2019)

NASA's blue marble image over land retrieved from https://neo.gsfc.nasa.gov/view.php?datasetId=BlueMarbleNG-TB

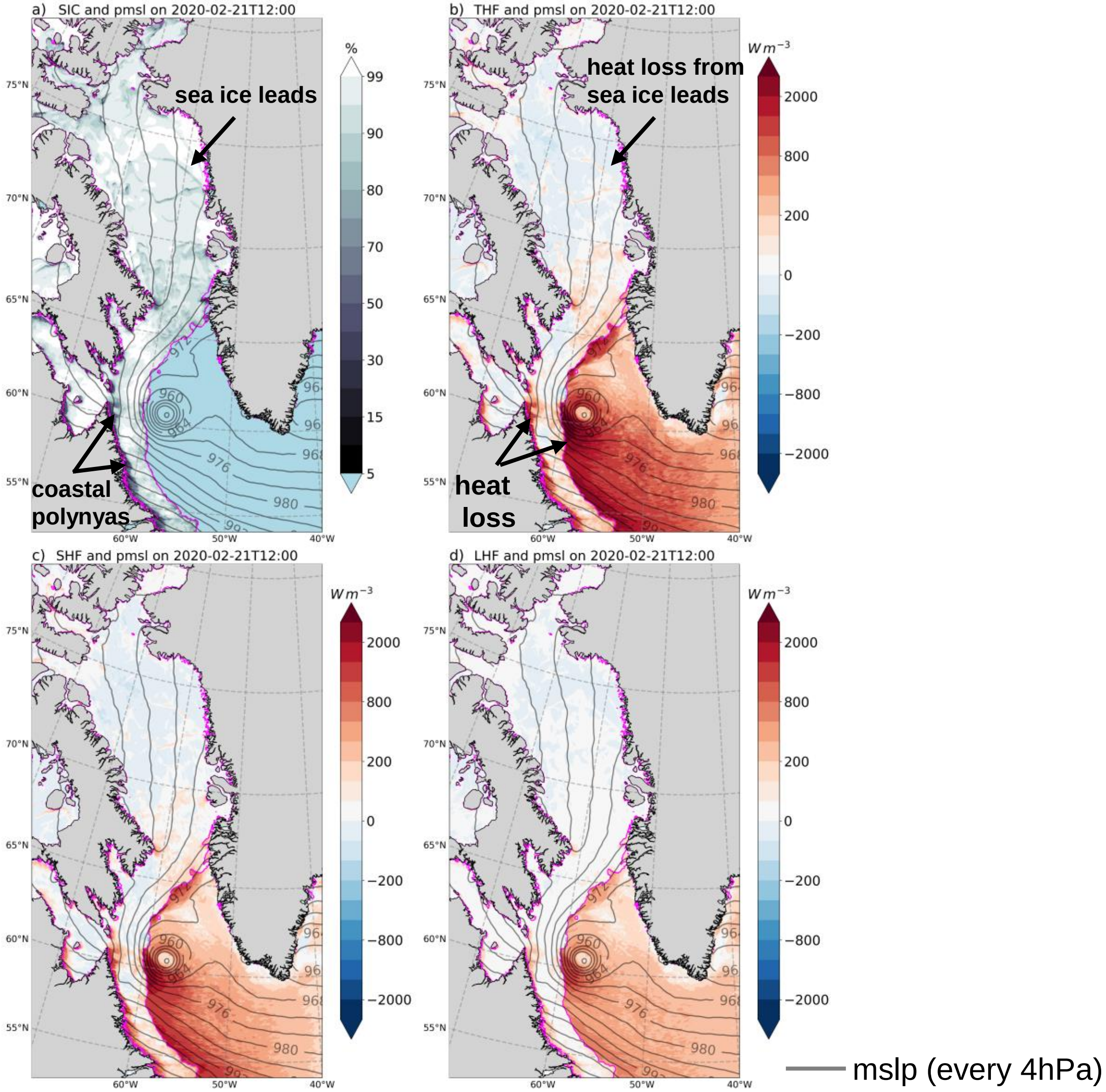
CASE STUDY: POLAR LOW OVER LABRADOR SEA



PL forms at sea ice edge in Labrador Sea on 21 February 2020

- PL formed from CAO off coast from Labrador, is steered northward and rapidly intensifies at sea ice edge
- PL reaches mature stage within 24 hours (core pressure of 944 hPa) with a warm core
  - ➢ Hurricane force winds (up to 34 ms^{-1} at sea ice edge)
  - ➢ Strong cold air outbreak (CAO) south of PL core
- PL moves east south of Cape Farewell into Irminger Sea within next 24 hour and merges with lee cyclone

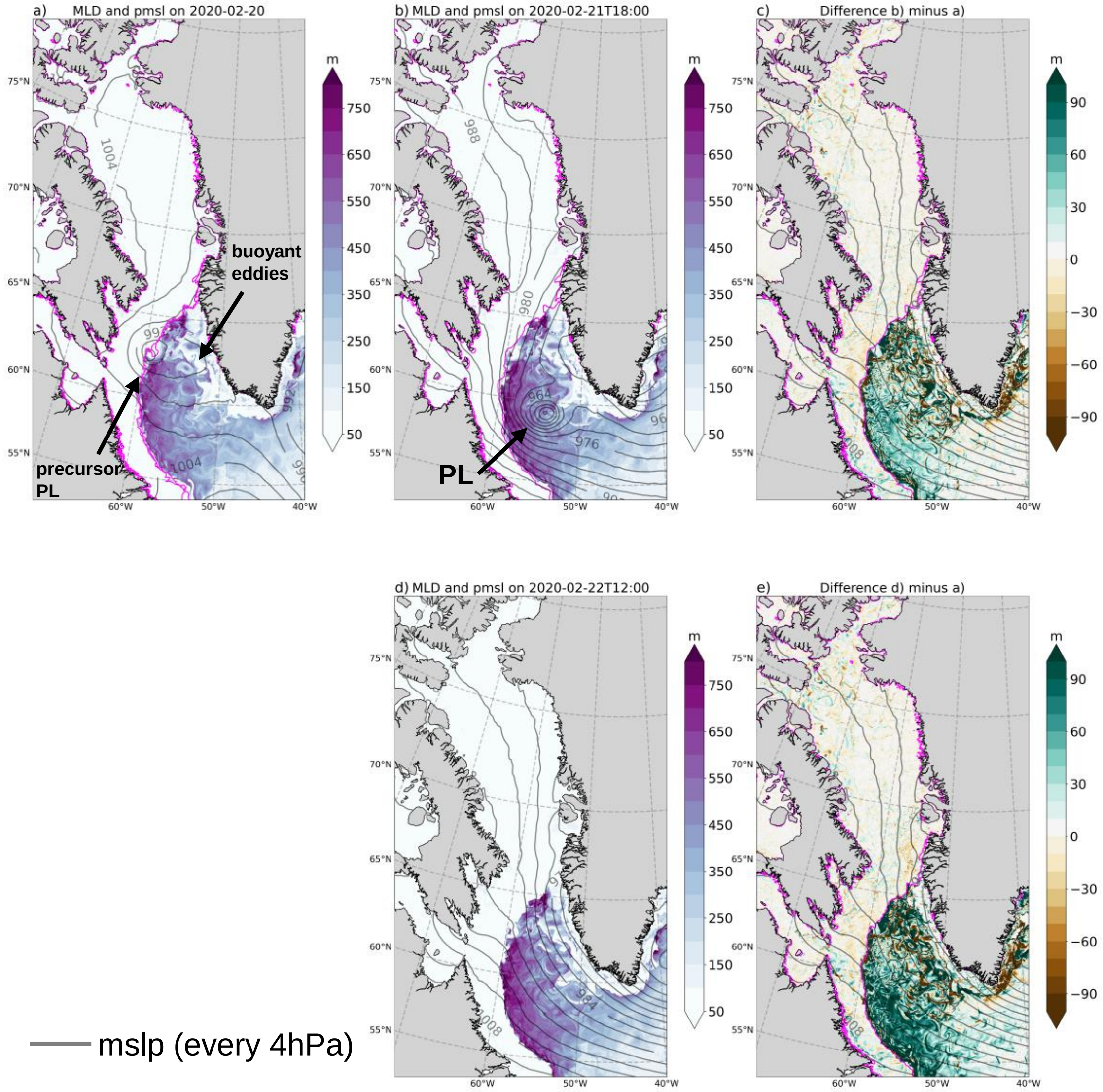
CASE STUDY: POLAR LOW OVER LABRADOR SEA



Strong heat fluxes at sea ice edge and from leads and polynyas

- Coastal polynyas form along coat of Labrador and Baffin Island. Sea ice leads form over Baffin Bay due to northward winds
- Strong total turbulent heat flux (THF, $> 3000\ \mathrm{Wm}^{-2}$) at sea ice edge during CAO
  - ➢ ~ 200 to $1000\ \mathrm{Wm}^{-2}$ from coastal polynyas
  - ➢ $\sim 200\ \mathrm{Wm}^{-2}$ from sea ice leads
- Sensible heat flux (SHF) dominates latent heat flux (LHF)
- Direct cooling of boundary current

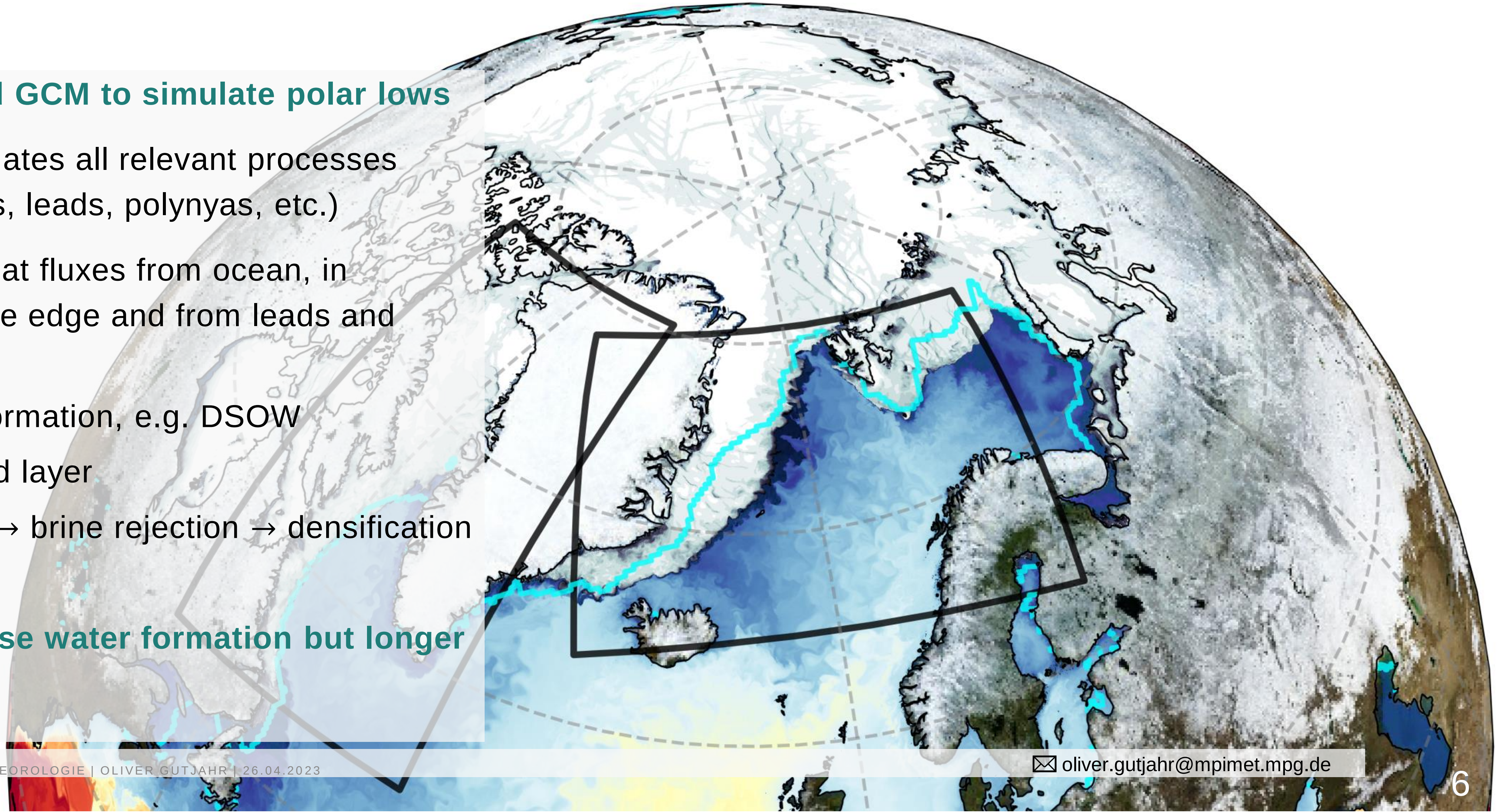
CASE STUDY: POLAR LOW OVER LABRADOR SEA



Deepening of mixed layer in response to PL

- Mixed layer depth (MLD) up to 800 m along sea ice edge on 20 Feb 2020, a precursor PL was present
- Buoyant mesoscale eddies shed from West Greenland Current and inhibit deep MLDs
- During mature stage of PL (12-18UTC, 21 Feb 2020), the MLD deepened by ~50m over open ocean, more along sea ice edge
- A day later, the MLD deepened by >100m along sea ice edge and over open ocean after PL moved into Irminger Sea

CONCLUSIONS



First globally coupled GCM to simulate polar lows

- ICON-Sapphire simulates all relevant processes (mesocyclones, BLFs, leads, polynyas, etc.)
- PLs induce strong heat fluxes from ocean, in particular near sea ice edge and from leads and polynyas:
  - ➢ Water mass transformation, e.g. DSOW
  - ➢ Deepening of mixed layer
  - ➢ New ice formation → brine rejection → densification of shelf water

➢ PLs may affect dense water formation but longer simulations needed

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