Winter ocean heat fluxes under sea ice leads in the Arctic Ocean

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Introduction

Arctic sea ice still declines faster than predicted, mostly due to uncertainties related to :

- internal climate variability (Jahn et al., 2016)
- under-resolved ocean mechanisms (Holloway et al., 2007).

Here we focus on one under-resolved mechanism: heat fluxes coming from underlying ocean.

Near surface area averaged winter ocean heat fluxes are usually **~ 1-2 W/m²,** but fluxes close to **300 W/m²** have been measured locally under ice leads**.**

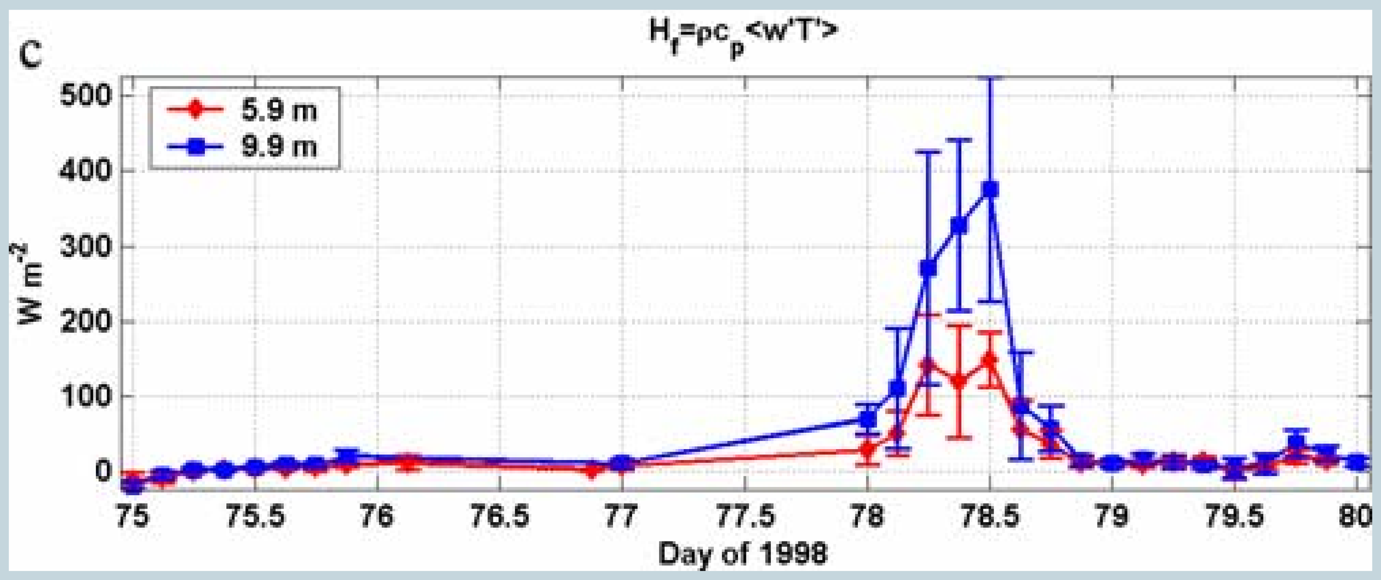


Fig 1 Vertical heat fluxes during the mission SHEBA in 1998. Taking from McPhee et al, 2005.

McPhee et al. (2005) and Slavin et al. (2016) suggest **ice-ocean surface stresses** are strong enough to generate turbulent mixing between the mixed layer(ML) and the Near to surface temperature maximum (NSTM).

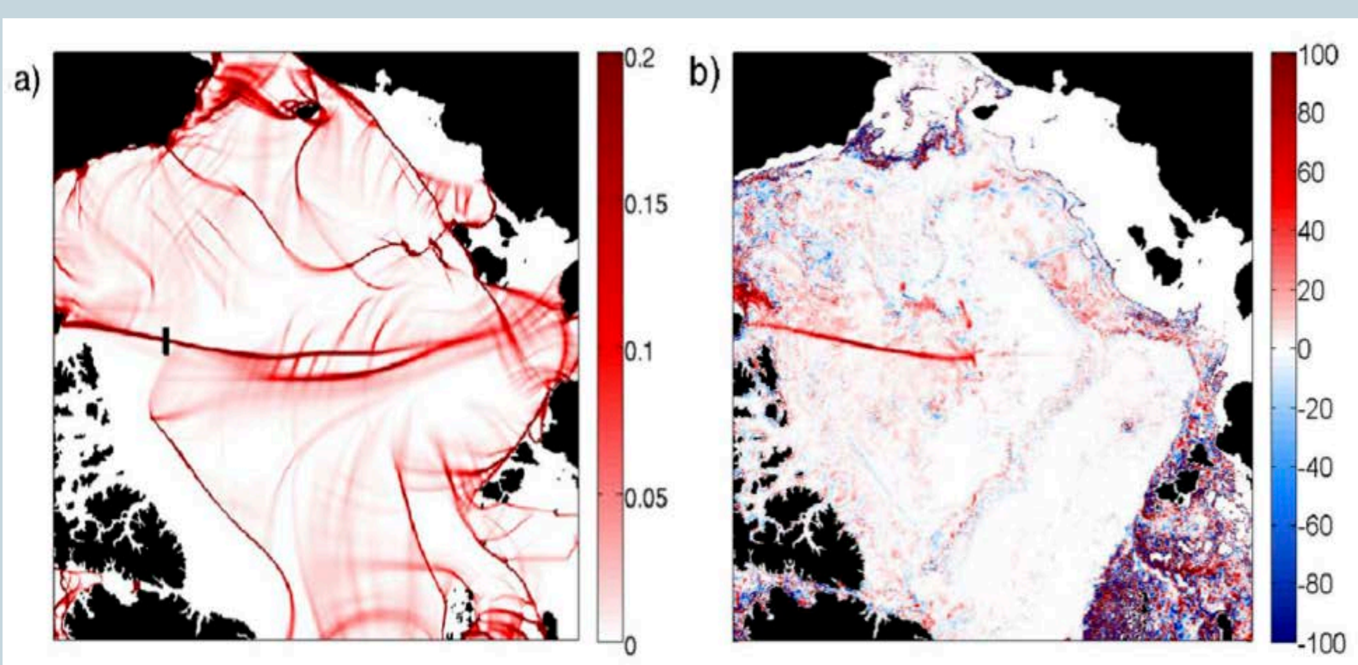


Fig 2 Results from a configuration of the MITgcm showing (a) the shear strain rate (*day*–1) and (b) the vertical advective ocean heat flux at 40 m (bottom of the mixed layer) (W/m2). Taken from Slavin et al. (2015).

Objectives

The main goal of the research is to **understand** and **model** ocean heat fluxes explicitly, without sub-grid scale parameterization.

On a longer term, our goals are:
- Compare those heat fluxes to those predicted by large-scale models.
- Improve sub-grid parameterizations for these mechanisms

Four types of simulations:
1. Forced by a uniform buoyancy flux
2. Forced by a buoyancy flux in a lead
3. Forced by shear in the ice-ocean stress across a lead.
4. Forced by both shear and a surface buoyancy flux across a lead.

Model

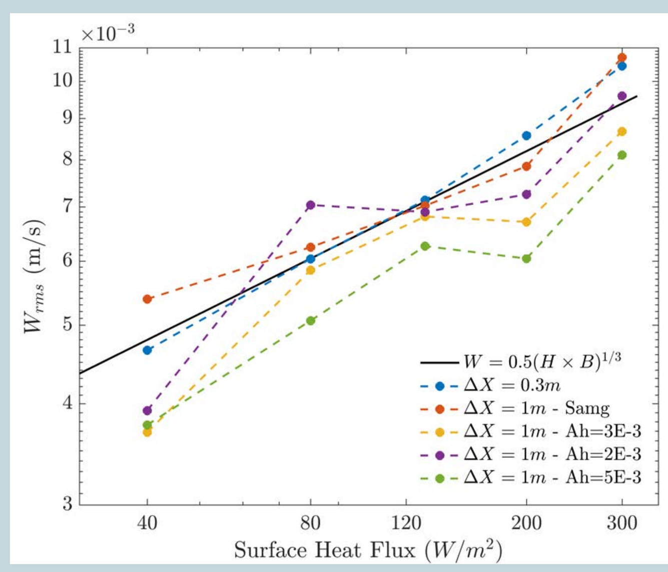
We use a high-resolution configuration of the MITgcm with the following properties:
- $\Delta x = \Delta y = \Delta z = 1$m ; $\Delta t \sim$ 1-4 seconds
- Non-hydrostatic
- Smagorinsky scheme for eddy viscosity
- Realistic T/S profiles of Canadian and Nansen basins
- Sponge layer at the bottom to restore to the profiles
- Ice formation is represented as a salt flux at the surface

Model Tuning

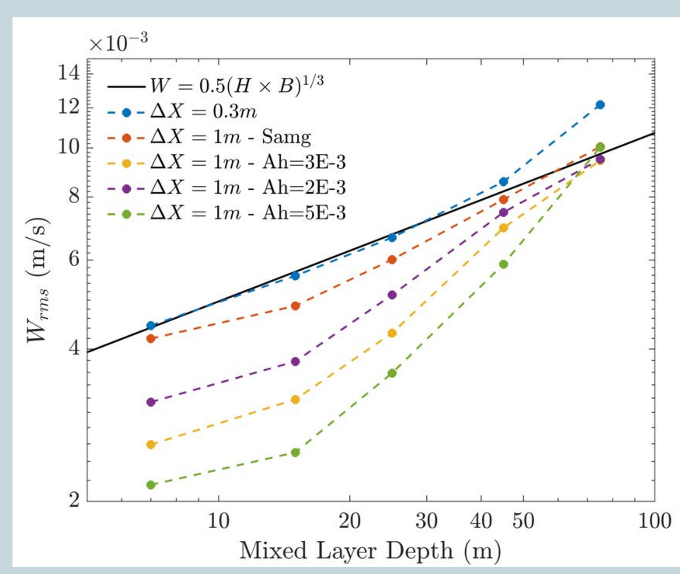
Root mean square of vertical velocities (Wrms) theory predict (Klinger et Marshall, 1995):

$$Wrms = (H \times B)^{1/3}$$

in function of B



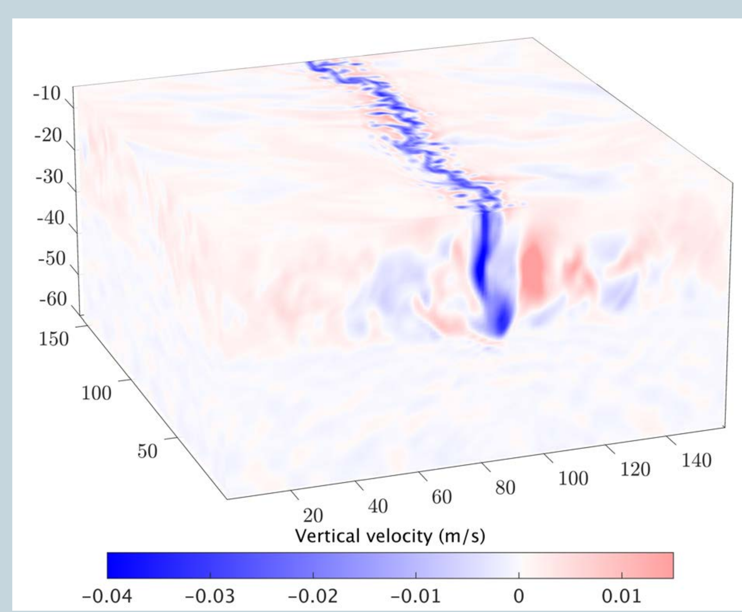
in function of H



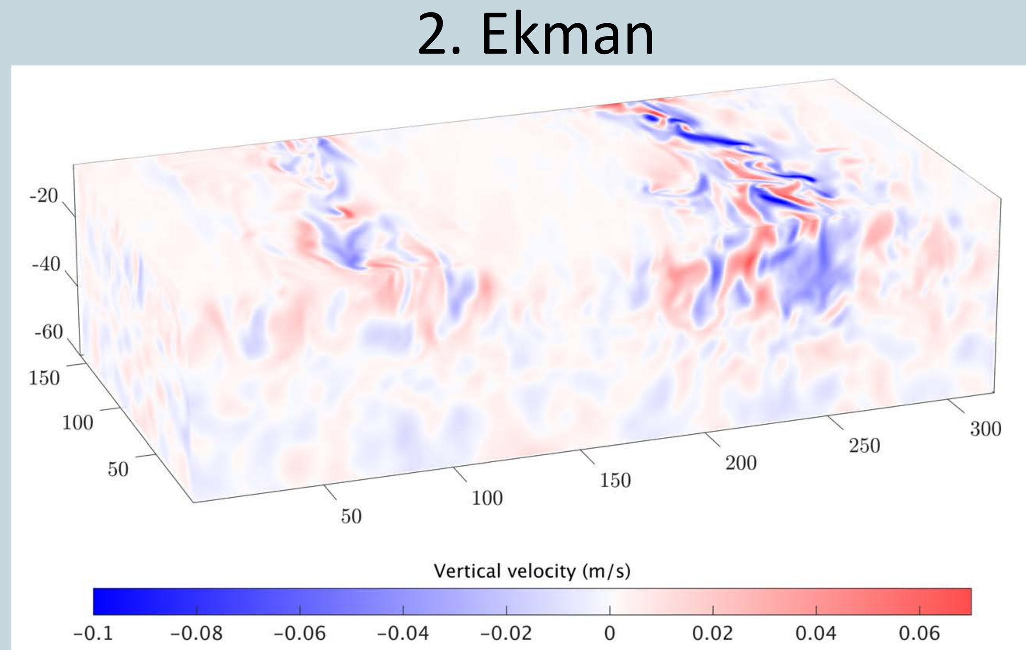
Vertical velocities

1. Salt Flux

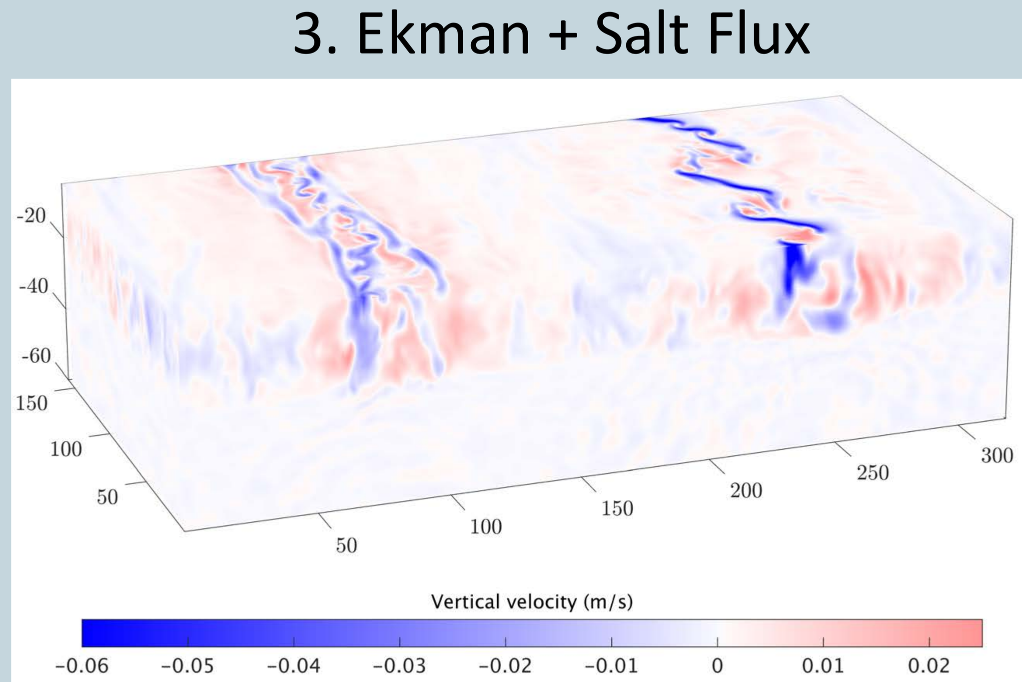
- Snapshots of vertical velocities for different types of surface fluxes
- Fluxes of momentum yield stronger velocities.
- Effects are non-additive



2. Ekman



3. Ekman + Salt Flux

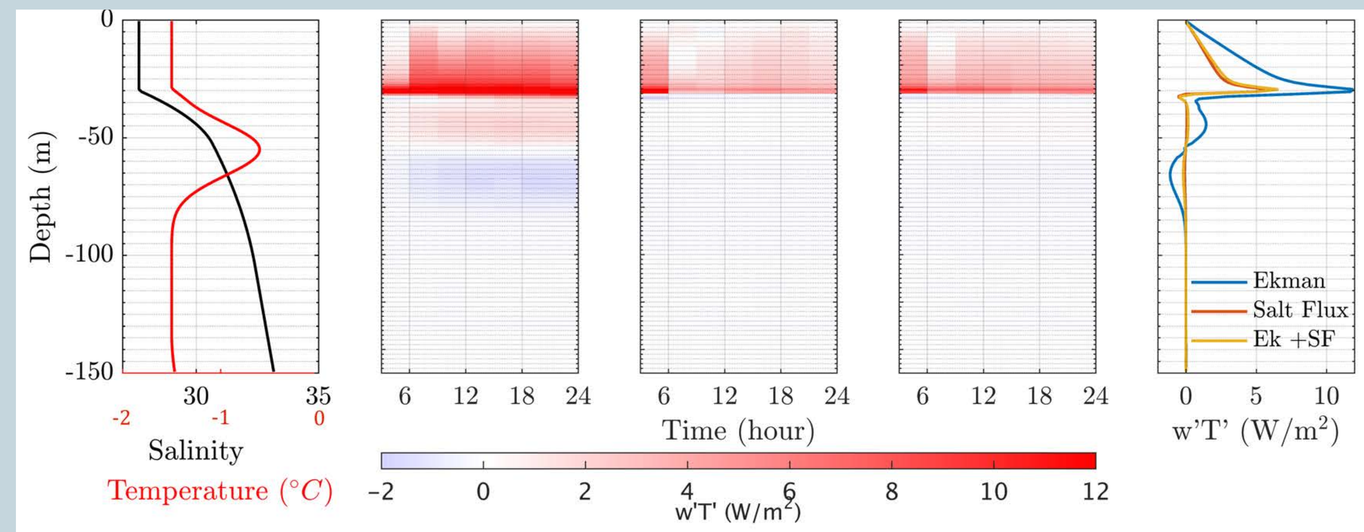


Heat Fluxes

- In the Canadian Basin heat comes from the Near Surface Temperature Maximum(NSTM)
- In the Nansen Basin, heat fluxes are weaker due to the absence of NTSM
- Heat fluxes are stronger with Ekman alone than combined fluxes

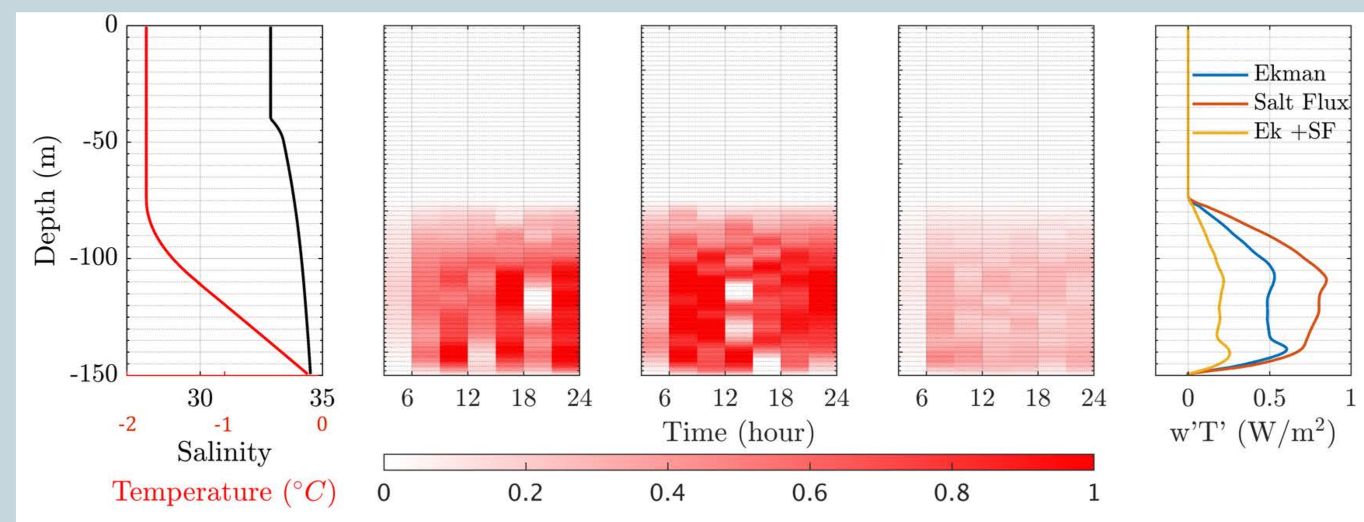
Canadian Basin

TS Profile | Ekman | Salt Flux | Ek + SF | HF



Nansen Basin

TS Profile | Ekman | Salt Flux | Ek + SF | HF



Conclusion

- We studied the effects of two types of surface fluxes occurring over sea ice leads during winter: Ekman pumping and brine rejection.
- Results show that both types of forcing lead to heat fluxes of similar amplitude
- Their combined effects are not additive.
- Heat fluxes and vertical velocities are in agreement with observed values under sea ice leads (Morison and al, 1992; Morison and McPhee, 1998 ;McPhee and al, 2005).
- Yet, we did not measure heat fluxes as strong as those measured on the SHEBA mission

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