Parametrization of Turbulent Fluxes over Leads in Sea Ice in a Non-Eddy-Resolving Small-Scale Atmosphere Model

Janosch Michaelis(1), Christof Lüpkes(1), Xu Zhou(2), Michya Gryshaka (2), and Vladimir M. Gryanik(1,2)

(1) Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
(2) Institute for Meteorology and Climatology, Hannover, Germany
(3) A. M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow, Russia

1. Motivation and Objectives

In our study, we focus on the convection generated over polar sea ice leads (Figure 1) and its influence on atmospheric boundary layer (ABL) characteristics.

During winter, large temperature differences occur between the lead surface and the near-surface atmospheric flow.

→ Strong convective plumes
→ Internal boundary layer (IBL) over lead
→ Complex processes in the entire ABL (Fig. 2)
→ Strong local and large scale impact [9,11,12]

The convection strongly depends on both meteorological and the lead geometry [13,14], where the governing processes act on small atmospheric scales.

Based on [6] ("L08"), we propose a new parametrization for the flow over a lead accounting for the lead width for a non-eddy-resolving small-scale model.

2. Methods

Non-eddy-resolving model "METRAS" [9,10]

- Grid: 200 m horizontally, 20 m vertically
- Parametrization of sub-grid scale turbulence needed
- All relevant turbulent scales are resolved

Turbulence parametrization (see 4.)

3. Model setup

Initial conditions:
- Scenario represents measured springtime conditions in the polar ocean regions observed during several campaigns [13,14]
- U, L and T∞ are varied

4. Turbulence parametrization

For parametrizing sub-grid scale turbulence, local or non-local closures are applied in non-eddy-resolving models. For the heat flux \( w'\theta' \), they are written as follows:

Local approach
\[ w'\theta' = -K_h \frac{\partial \theta}{\partial z} \] (1)

Non-local approach
\[ w'\theta' = -K_h \left( \frac{\partial \theta}{\partial z} - \Gamma \right) \] (2)

Characteristics of our parametrization:
- Non-gradient heat transport
- Horizontal inhomogeneities
- Variable lead width

Main idea (approach by L08 [6]):
- Basis: Non-local approach (2)
- Inside the plume at P1 and P2 (Fig. 4), \( K_h \) and \( \Gamma \) depend on mean lead surface conditions.
- Decay of turbulence due to lateral entrainment and dissipation over downstream sea ice
- Scaling of \( K_h \) and \( \Gamma \) with IBL height and lead surface buoyancy flux
- New modified and extended approach ("New")

5. Results

LES ("reference")
- Sensible heat flux \( (W/m^2) \)
- METRAS: Local closure
- METRAS: New closure

Horizontal wind speed (ms⁻¹)

6. Conclusions & Outlook

We developed a new non-local parametrization for the turbulent fluxes over leads that accounts for the lead geometry (width L). It is applicable in plume-resolving but non-eddy-resolving atmosphere models.

Results obtained with our new parametrization agree well with time-averaged LES results for different L and various atmospheric conditions.

Our approach can be applied for sensitivity studies on the impact of leads on larger scales to derive parametrizations for climate and weather prediction models.

References


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Contact: janosch.michaelis@awi.de