SPARCS: Scale dependent Parametrization of processes in the atmospheric boundary layer over ARCtic Sea ice

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Main goal of SPARCS:

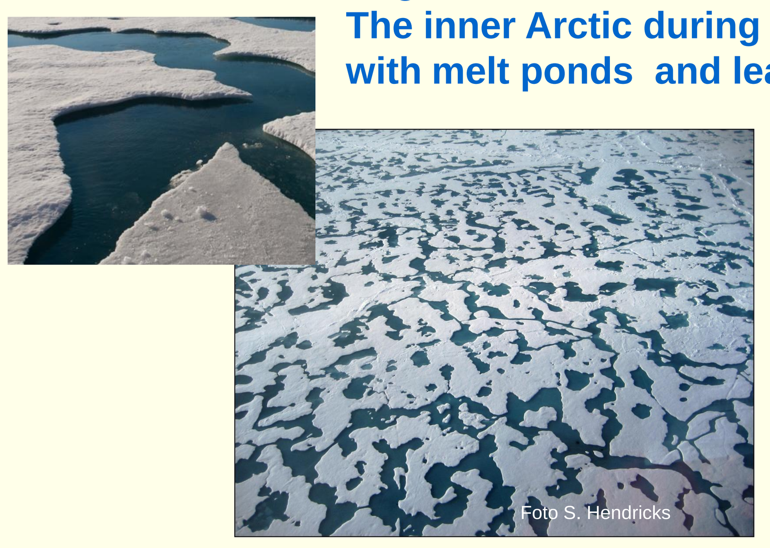
Parametrization of near-surface transport of momentum and energy over different sea ice regimes for climate models as ECHAM6. The focus is on regimes with an open water fraction (leads, melt ponds).

Main achievement in 2014:

Development of a stability dependent parametrization of transfer coefficients for momentum and heat over polar sea ice to be used in climate models (Lüpkes and Gryanik, 2015)

Regime I
The marginal sea ice zone with drifting floes

Regime II
The inner Arctic during summer with melt ponds and leads



Edges of floes, leads, and melt ponds influence the atmospheric flow over sea ice and thus the transport processes of momentum and heat near the surface. The edge impact on the drag coefficients has been parametrized during SPARCS/MiKlip by distinguishing coefficients for skin drag ($C_{d,i}$; $C_{d,w}$) (i= ice, w = water) and form drag C_{df} (Lüpkes et al., 2012, 2013; Lüpkes and Gryanik, 2015) so that the drag coefficients over an ice/water mixture is given by

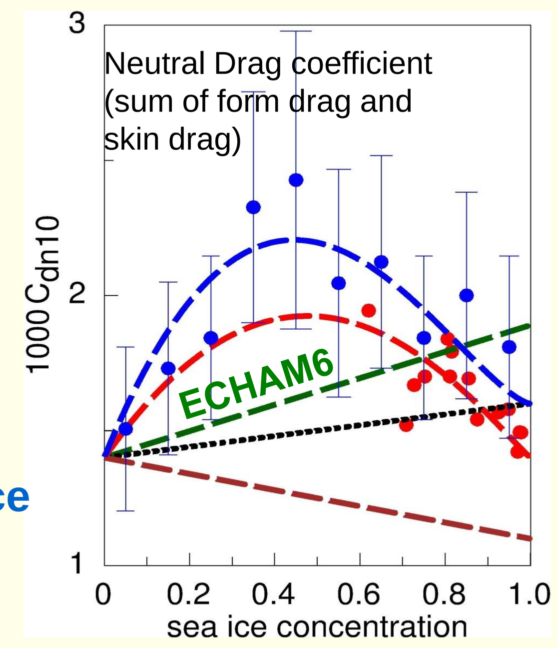
$$C_d = (1 - A)\, C_{d,w} + A\, C_{d,i} + C_{d,f}$$

For neutral conditions the form drag coefficient C_{dnf} was derived on the basis of a theoretical model and in-situ turbulence measurements as a function of sea ice concentration A as

$$C_{dnf} = C_{e10}\left[\frac{\ln(10/z_0)}{\ln(z_p/z_0)}\right] A\,(1 - A)^{\beta}$$

Z_p = first grid level
Z_0 = roughness length

The resulting 10 m drag coefficients (blue, red) are shown in the right figure for different ice regimes together with observations (Andreas et al., 2010; Hartmann et al., 1994, Mai et al., 1996) and C_{dn10} from present climate models (e.g. ECHAM6).

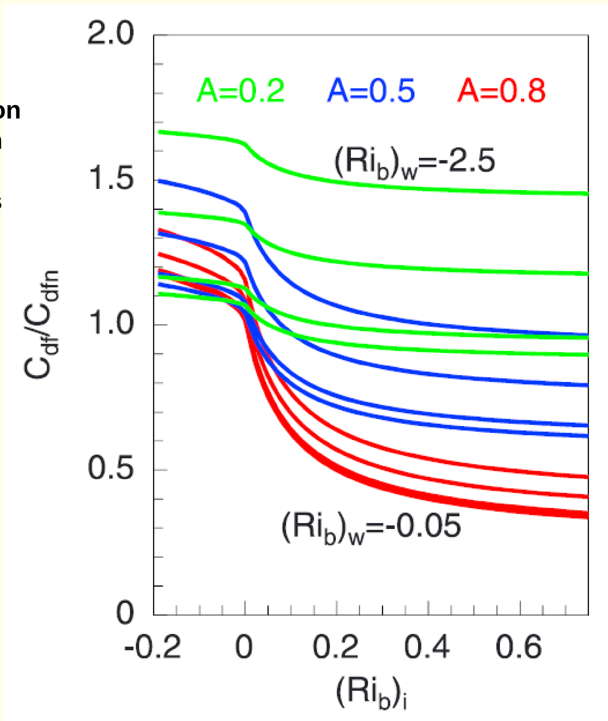


More complex parametrization levels include also other sea ice characteristics as freeboard and floe/pond parameters.

In general, C_{df} depends on both the stability over water ($f_{m,w}$) and ice ($f_{m,i}$). Thus Lüpkes and Gryanik (2015) propose the approach

$$C_{df} = C_{dnf}\,[f_{m,w}\,(1 - A) + f_{m,i}\,A]$$

The Figure shows the stability correction for Cdf as a function of the bulk Richardson numbers over water and ice and of the sea ice coencentration A

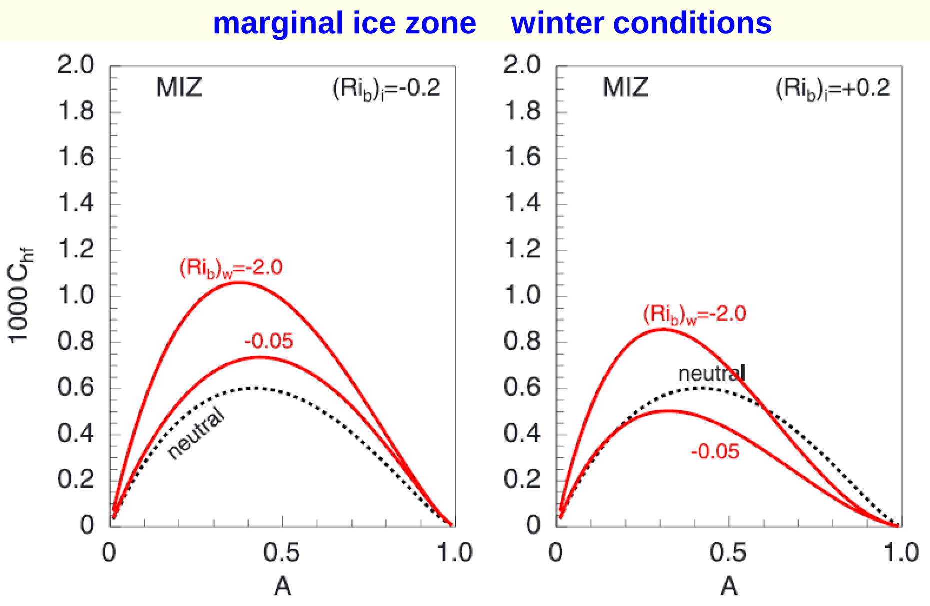


A similar approach was obtained for heat transfer. The edge generated heat flux was derived as

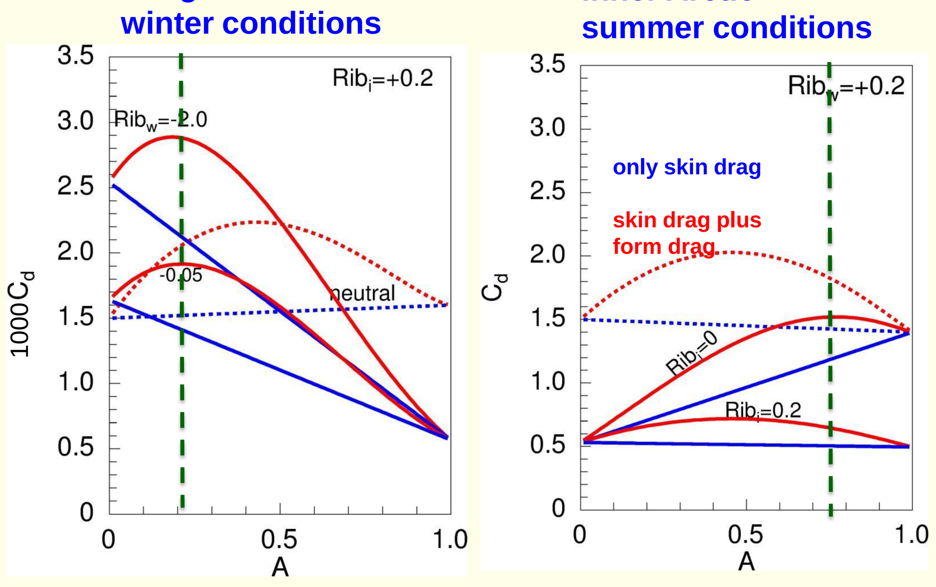
$$C_{hf} = C_{hnf,w}\, f_{h,w}\,(1 - A) + C_{hnf,i}\, f_{h,i}\, A$$

$$C_{hnf,k} = \frac{C_{dnf,k}}{1 + \sqrt{C_{dnf,k}/C_\alpha}}$$

Edge-related heat transfer coefficient

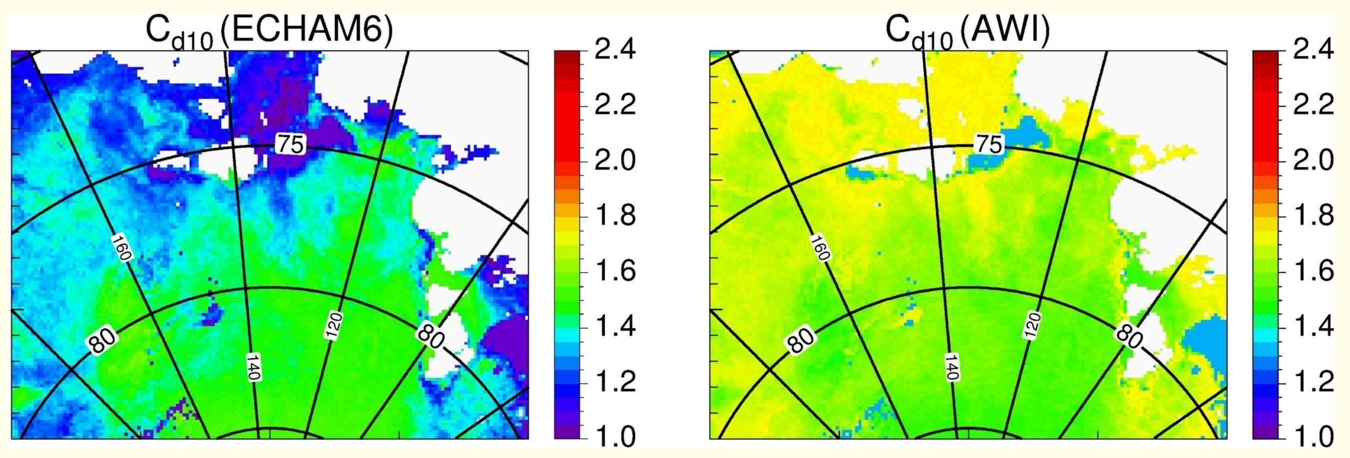


Sum of skin drag and form drag coefficient

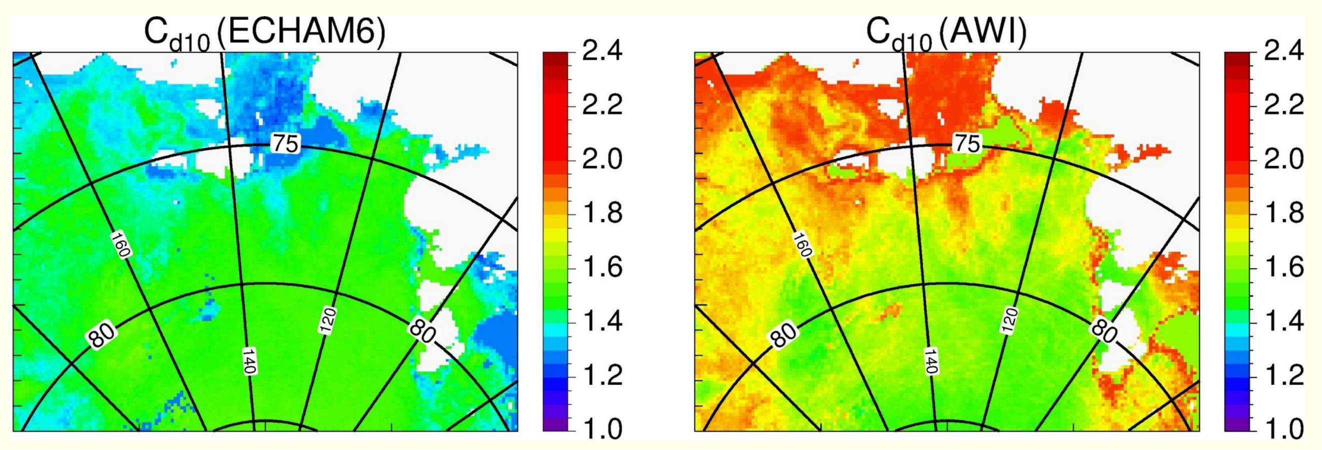


The stability impact on the drag coefficients is demonstrated for idealized atmospheric forcing using satellite data of sea ice concentration and melt pond concentration (Rösel et al., 2012). The figures below are valid for summer. The upper pair shows a case with prescribed slight warm-air advection, the lower one shows a case with slight cold-air advection. The AWI scheme (new parametrization) results in higher values in regions with many melt ponds and leads.

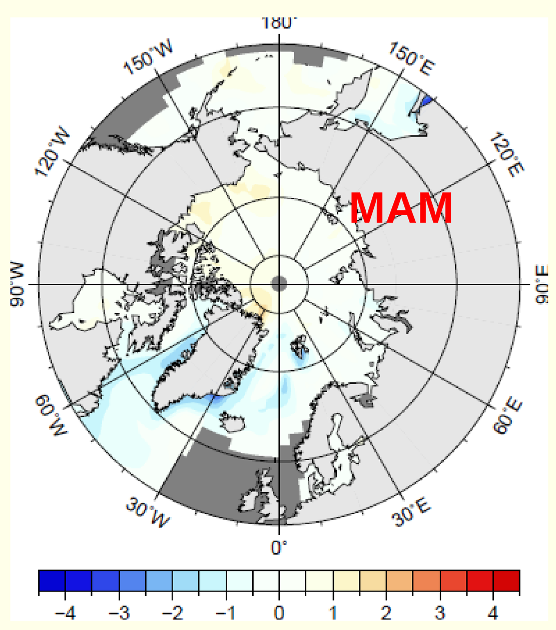
warm-air advection



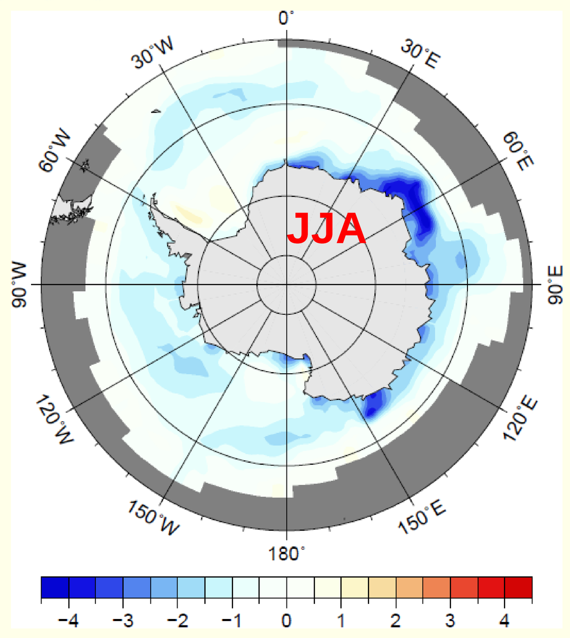
cold-air advection

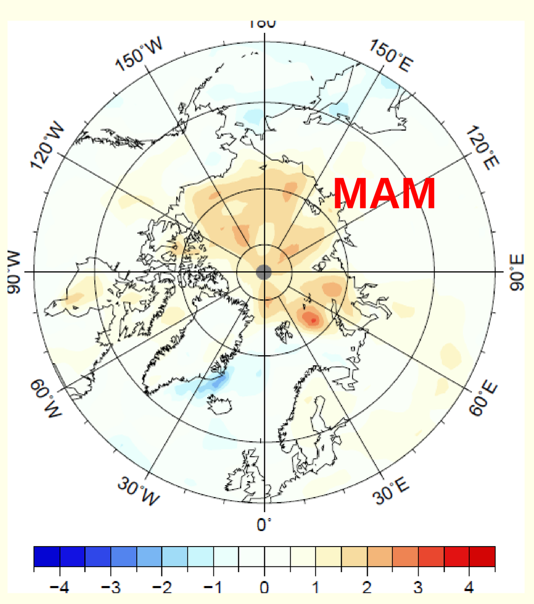


A prototype of the new parametrization has been used in ECHAM6/FESOM (Project TORUS). Normalized differences (new – old) are shown below for the ensemble average over 10 runs over 20 years.
The number +-2 represents the 95 % significance level.

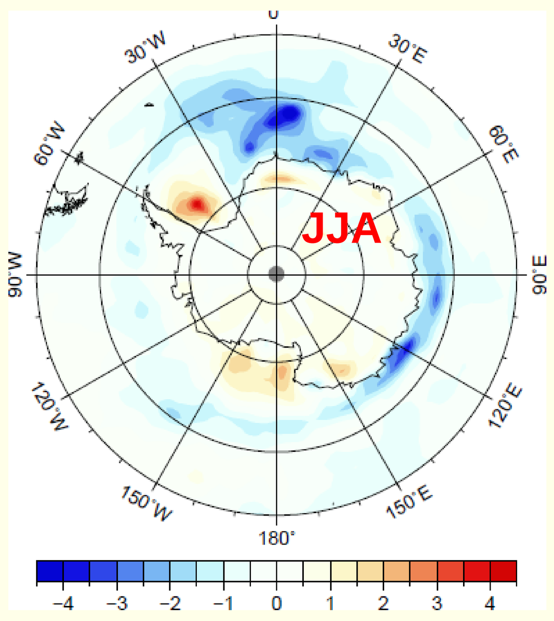


sea ice concentration (normalized difference)





wind speed (normalized difference)



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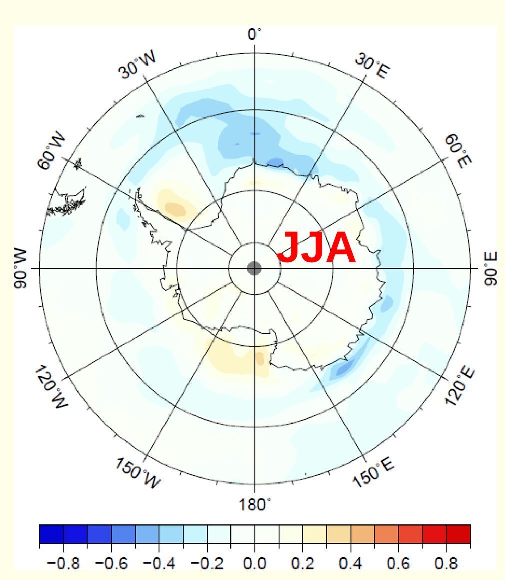
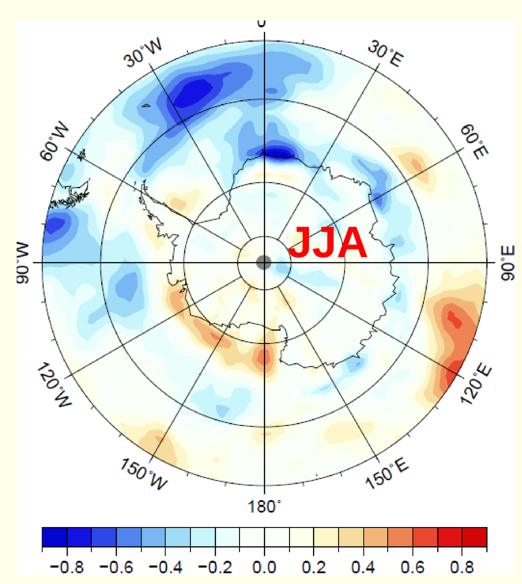
ensemble mean



wind speed difference in m/s

1 ensemble member



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Summary of Results

A hierarchy of parametrizations for the transfer coefficients over sea ice has been developed. The scheme with lowest complexity (presented here) can be easily used in climate models including ECHAM6.

It has been shown that the sea ice morphology has a large impact on the transfer of momentum and heat. A new stability correction is proposed for the transfer coefficients (C_{df}, C_{hf}) accounting for the impact of ice edges.

Results obtained with the new scheme (still simplified for this test) in ECHAM6/FESOM shows a moderate impact on the ensemble average, but a large impact on individual ensemble members so that the scatter of results increases.