The role of air-sea ice-ocean interaction processes for Arctic-mid latitude linkages

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1. Motivations

Climate models have deficits in reproducing the atmospheric circulation and sea ice development in the Arctic. The parameterization of surface turbulent fluxes describing air-sea ice-ocean interaction could be a potential reason. The current ones have been estimated based on mid-latitude measurements. One goal of the POLEX project is to use a new suite of surface flux parameterizations [1], which are developed based on the SHEBA expedition data [2]. The impact of the new parameterizations on the regional Arctic circulation as well as on the large scale circulation will be studied.

2. Method

- Implementing the new suite of parameterizations in ECHAM6 with 3 levels of complexity.
- Sensitivity runs of ECHAM-standalone with different parameterizations levels (see table in section 3).
- Ensemble experiments with 10 members for 1996 (representative for high ice cover) and 2007 (representative for low ice cover). Here the plots for 1996 are shown.

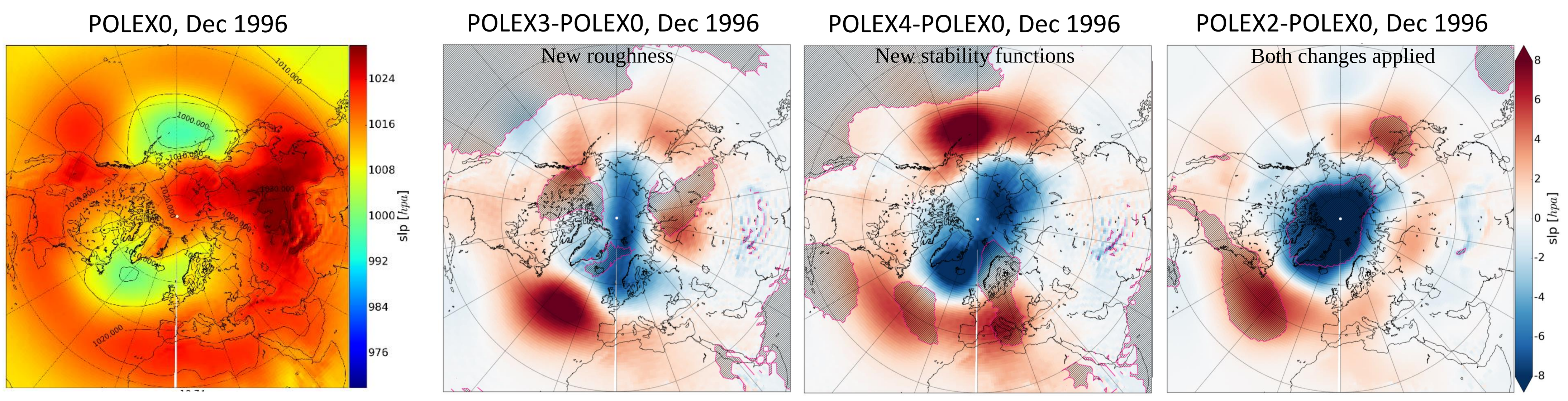

Fig. 1. Ensemble mean sea level pressure in December 1996 of the control run (POLEX0; left) and differences of POLEX3, 4 and 2 to POLEX0 (right). p-values ≤ 0.05 are in black shading.

3. New parameterization

The interaction between atmosphere and sea ice-ocean is determined by fluxes:

Momentum flux: $M = -C_d U^2$ Heat flux: $H = -\rho c_p C_h U\,[\Theta(z) - \Theta_s]$

Heat and Momentum transfer coefficients

Normalized transfer coefficient

$$f_m = \frac{C_d}{C_{dn}}$$

This is what we changed

In ECHAM6, Louis(1979)-type f_m-functions are chosen, which depend on [3]:

- $Ri_{B,i,w}$ Bulk Richardson numbers
- $z_{0,i,w}$ Roughness lengths

f_m-functions are changed only for stable stratification (GL18)[1].

$$f_m = [1 - \frac{1}{ln\, \epsilon_k}(10.29 - 19.5x + 2.18\, ln\frac{(x+0.67)^2}{x^2 - 0.67x + 0.45} + 7.45\, arctan(1.725x - 0.58))]^{-2}$$

$$f_h = {f_m}^{0.5}[1 - \frac{1}{ln\, \epsilon_{t,k}}(2.16 - 2.5\, ln(1 + 3\xi + \xi^2) + 1.12\, ln\frac{\xi + 0.38}{\xi + 2.62})]^{-1}$$

New approach for ξ:

$$\xi = CRi_B + ARi_B{}^{\gamma}, \mathrm{C} = \mathrm{C}(\epsilon, \epsilon_t), \mathrm{A} = \mathrm{A}(\epsilon, \epsilon_t, \gamma)$$

Instead of $\xi = \xi(Ri_B, \epsilon, \epsilon_t)$

Levels differ by the choice of ϵ and ϵ_t, as in the table below:

	$z_{0,i}$	$z_{t,i}$	$f_{m/h}$
POLEX0	0.001 (original)		Louis functions (original)
POLEX3	0.00033	0.000066	
POLEX4	0.001 (original)		GL18 functions
POLEX2	0.00033	0.000066	

4. Discussion

- Changing the surface parameterizations affects almost all surface field variables like SLP. The magnitude of the effect depends on the background state and on the considered month (Fig. 1).
- For experiments with the original stability functions by Louis et al. (1979) (POLEX0 and 3) we cannot reproduce the observed structure of Hs/U10 as a function temperature gradient with a minimum at T10-Ts = 2°K (Fig. 2a). However, the new stability functions used in GL18[1] in POLEX4 and 2 simulate $\frac{SHF}{V}$ as a function of ΔT closer to observation. For a temperature difference larger than 2°K the magnitude of the heat fluxes decrease with increasing stability. Reference equation: $C_h \sim \frac{SHF}{V.\Delta T}$.
- ECHAM6.3 overestimate the cloud over sea ice [4,5]. It is consistent with our result shown in Fig. 3. Showing a larger area affected by clouds than in the SHEBA observations. However, the well-known two states of the winter Arctic boundary layer, namely clear sky and cloudy (e.g. Stramler et al., 2011) are reproduced independent on the used closure.

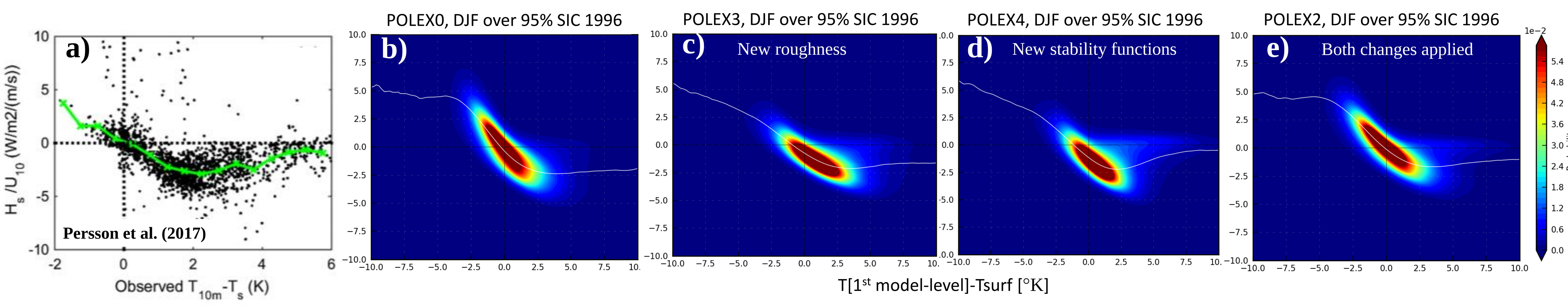

Fig. 2. a) Sensible heat flux normalized by 10 m wind as a function of the surface layer vertical temp. gradient in SHEBA, green line is bin-averaged values [6]. **b,c,d,e)** Bivariate PDFs of December, January, February temperature gradient (1st model level temperature – surface temperature) and sensible heat flux normalized by 1st model level wind in ECHAM with different parameterization .

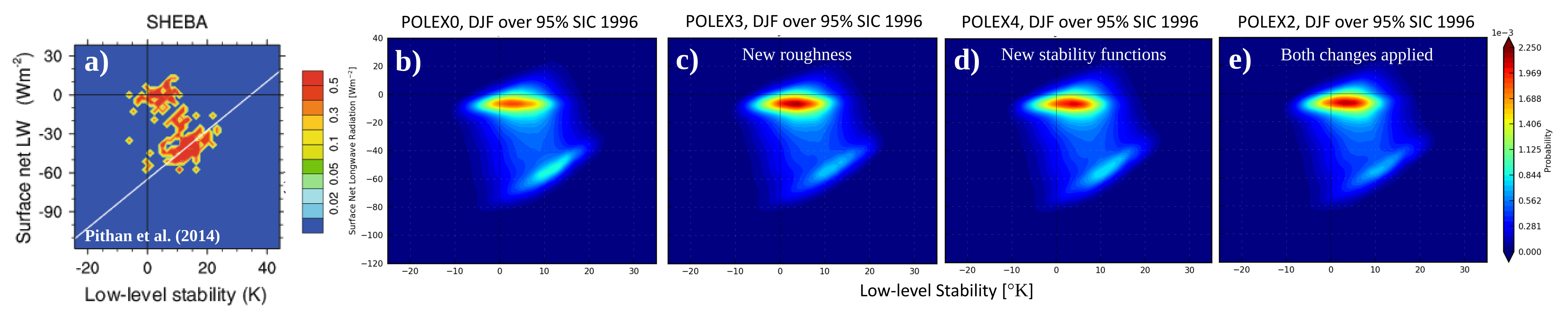

Fig. 3. Bivariate PDFs of December, January, February low-level stability and surface net longwave radiation in SHEBA observation [4] and ECHAM with different parameterization .

5. Outlooks

- Studying the sensitivity of the heat budget with a simplified model
- Implementing a more advanced version of the new parameterization (variable roughness length)
- Coupled model sensitivity runs with AWI-CM
- Comparing results with regional model (HIRHAM)

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