

On The Evaluation of the Role of Large-Scale Control in Arctic Surface Heat Flux Parameterizations

Johnny Wei-Bing Lin

CIRES/University of Colorado, Boulder and Computation Institute, University of Chicago

Abstract

Arctic surface energy budget parameterizations are evaluated as parameterizations (i.e. which exhibit large-scale control) using a quasi-equilibrium framework. While the parameterizations for a few terms in the surface energy budget (ice conduction and latent heat) exhibit evidence of large-scale control, other terms (net radiation and sensible heat) do not, suggesting that these parameterizations fundamentally misrepresent the connection between small- and large-scales.

It can be shown that for such a parameterized atmospheric variable A :

- (1) The ratio of the small-scale timescale to the parameterization timescale should be much less than one,
- (2) The ratio of parameterized forcing to small-scale forcing should be much less than one.

We test whether parameterizations for Arctic surface fluxes meet these two criteria.

Parameterization and Large-Scale Control

The parameterization problem can be simply stated: How do we represent sub-grid physics in terms of grid-scale variables? A parameterization does not represent actual physical phenomena, however, but the collective effects of the physical phenomena of interest upon large-scale variables, and vice versa. Strictly speaking, a parameterization is not even necessarily a representation of the ensemble average of the physical phenomena, for that would assume *a priori* that the small and large-scales communicate with each other through the ensemble average.

Parameterization is ultimately a scale-interaction or scale-relationships problem as opposed to a physics description problem. The key variables within the parameterization are fundamentally not the coefficients within the parameterization algorithm but the large-scale variables, which are the only prognostic variables in the system. Thus, a parameterization must exhibit large-scale control. If it does not, it is no better from a model standpoint than a stochastic representation of the sub-grid quantities.

The Quasi-Equilibrium Framework For Understanding Large-Scale Control

But how to define and measure large-scale control? Arakawa and Schubert (1974), in their development of a cumulus convection parameterization, articulate a “quasi-equilibrium” relationship between sub-grid effects and large-scale effects. Under this assumption, a parameterized atmospheric variable A (which in Arakawa and Schubert is the cloud work function) is forced by large-scale and sub-grid processes such that A follows a sequence of quasi-equilibria, with the timescale of A approximately the timescale of the large-scale and small-scale processes acting to restore A around this quasi-equilibrium state.

Data

We test parameterizations from the ECMWF reanalysis model (“model”). Local hourly average point-observations taken at the ASFG Tower (“Tower”) during SHEBA are assumed to approximate the forcing by the small-scale contribution. Two periods are examined: “Dec/Jan” [1 Dec 1997 (0Z) to 30 Jan 1998 (3Z)]; and “Jul”, [28 Jun 1998 (1Z) to 6 Aug 1998 (2Z)].

Budget Term	Dec/Jan		Jul	
	τ_{model}	τ_{Tower}	τ_{model}	τ_{Tower}
R_{net}	30 hrs	25 hrs	2 days	6 days
h_s	30 hrs	15 hrs	15 hrs	10 hrs
h_l	30 hrs–12 days	10 hrs	15 hrs	5 hrs
G_{ice}	8 days	40 hrs	3 days	3 days
$resid$	30 hrs	15 hrs	5 hrs	5 days

Table 1: Timescale for surface energy budget terms (see Fig. 1 caption for budget term abbreviation key).

Results

Table 1 shows the timescales of each surface energy budget term, based upon the e -folding time of the autocorrelation coefficient for each term. Only h_l for both Dec/Jan and Jul and G_{ice} for Dec/Jan meets criteria (1).

From Fig. 1 and 2 we can see how often criteria (2) is true. Only one of the surface energy budget terms, G_{ice} , has $r < 1/e$ more than half the time for both Dec/Jan and Jul. For Dec/Jan, two budget terms (R_{net} and h_l) satisfy $r < 1/e$ with a weak majority of times. The last two budget terms (h_s and $resid$) do not even meet that test. For Jul, no budget term except G_{ice} satisfies $r < 1/e$ a majority of times.

F_{ni} of model: Tower Forcing Ratio (Dec/Jan)

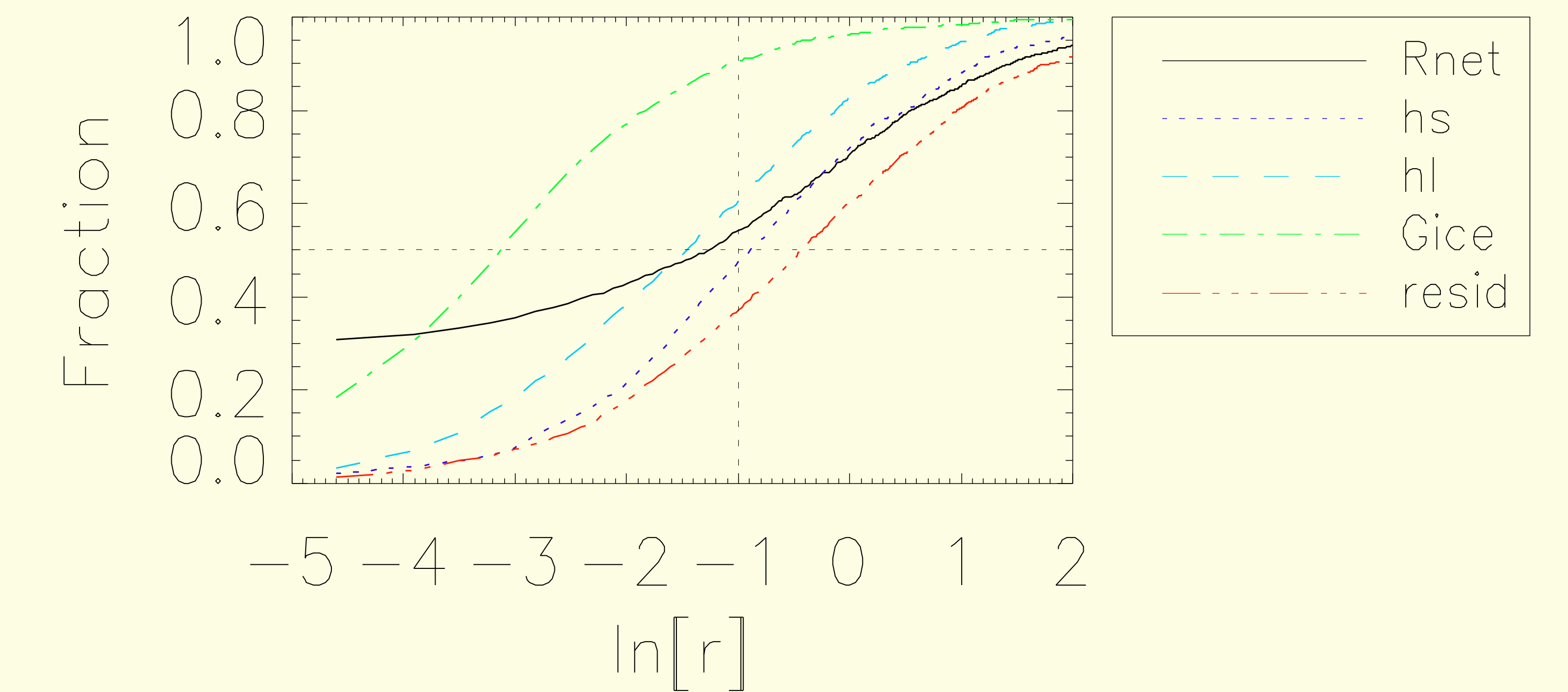


Fig. 1: Non-inclusive cumulative distribution function [$F_{ni}(r)$] of forcing ratio for each surface energy budget term in Dec/Jan. R_{net} is net radiation, h_s is sensible heat, h_l is latent heat, G_{ice} is ice conduction, and $resid$ is the residual (e.g. heat for melting, etc.).

F_{ni} of model: Tower Forcing Ratio (Jul)

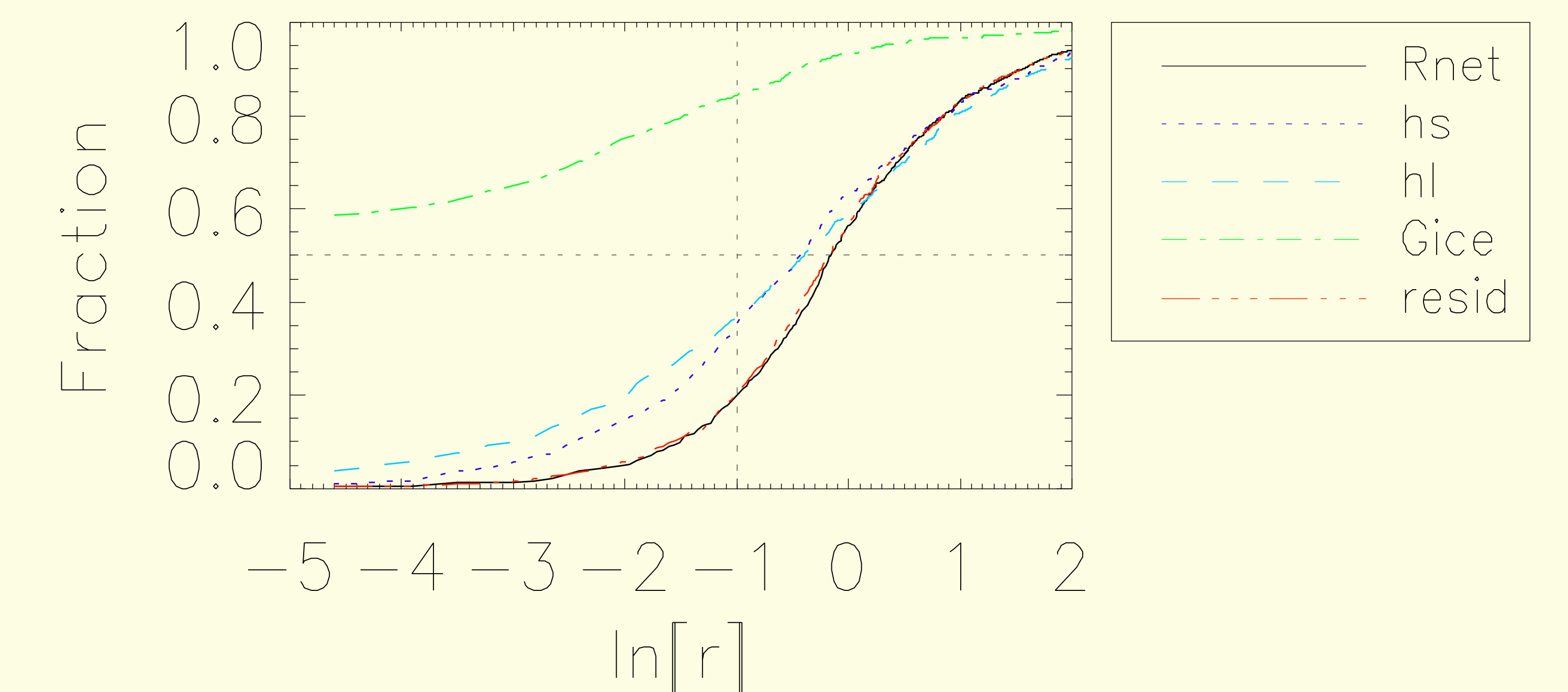


Fig. 2: Same as Fig. 1, but for Jul.

Reference, Acknowledgments, Contact Information

Arakawa, A. and W. H. Schubert, 1974: Interaction of a cumulus cloud ensemble with the large-scale environment. Part I. *J. Atmos. Sci.*, **31**, 674-701.

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Contact information: Johnny Wei-Bing Lin, jlin@atmos.ucla.edu, <http://www.johnny-lin.com/>.