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

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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.

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.

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.

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 hl for both Dec/Jan and Jul and Gice 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, Gice, has r < 1/e more than half the time for both Dec/Jan and Jul. For Dec/Jan, two budget terms (Rnet and hl) satisfy r < 1/e with a weak majority of times. The last two budget terms (hs and resid) do not even meet that test. For Jul, no budget term except Gice satisfies r < 1/e a majority of times.

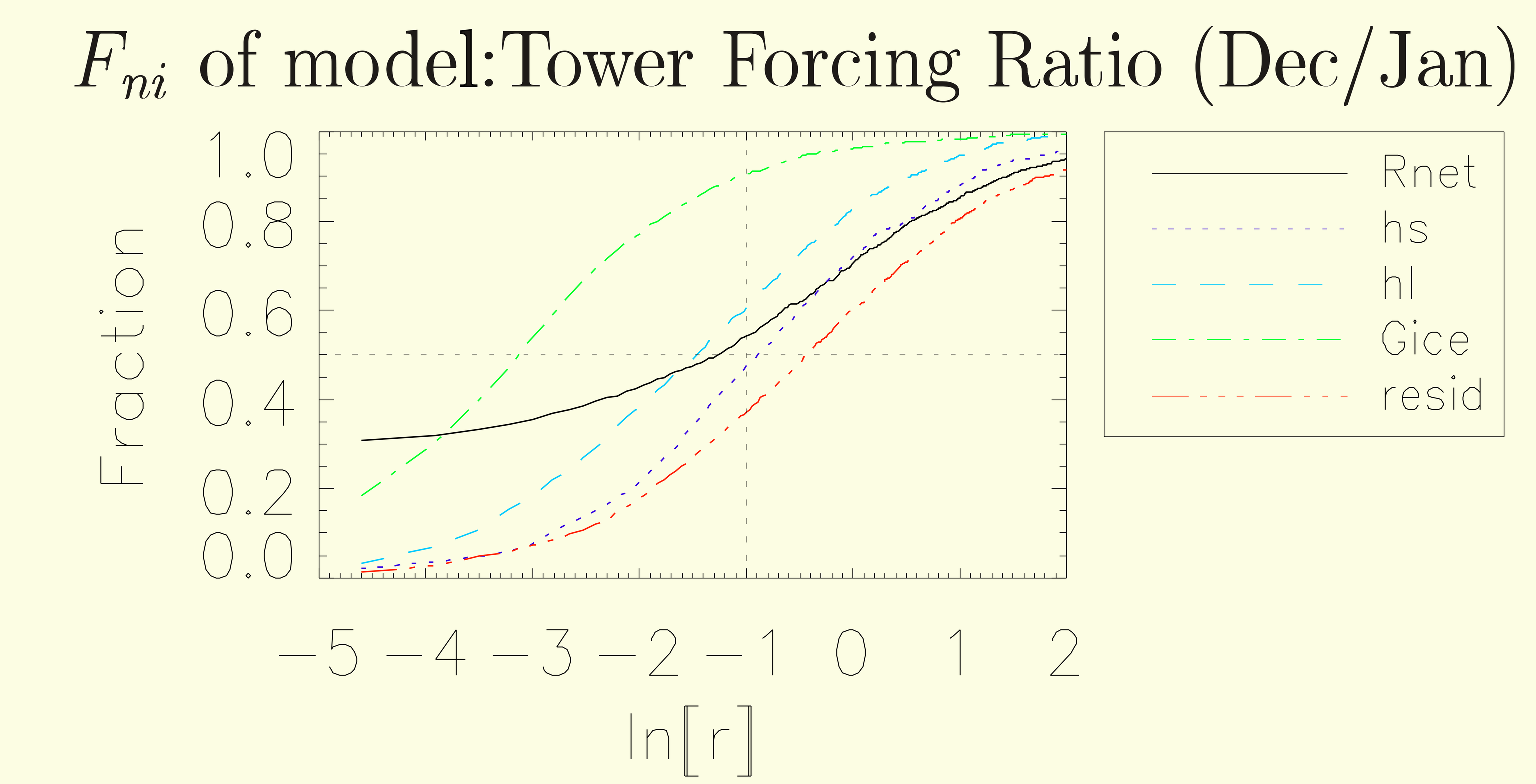

Fig. 1: Non-inclusive cumulative distribution function [F_{ni}(r)] of forcing ratio for each surface energy budget term in Dec/Jan. Rnet is net radiation, hs is sensible heat, hl is latent heat, Gice is ice conduction, and resid is the residual (e.g. heat for melting, etc.).

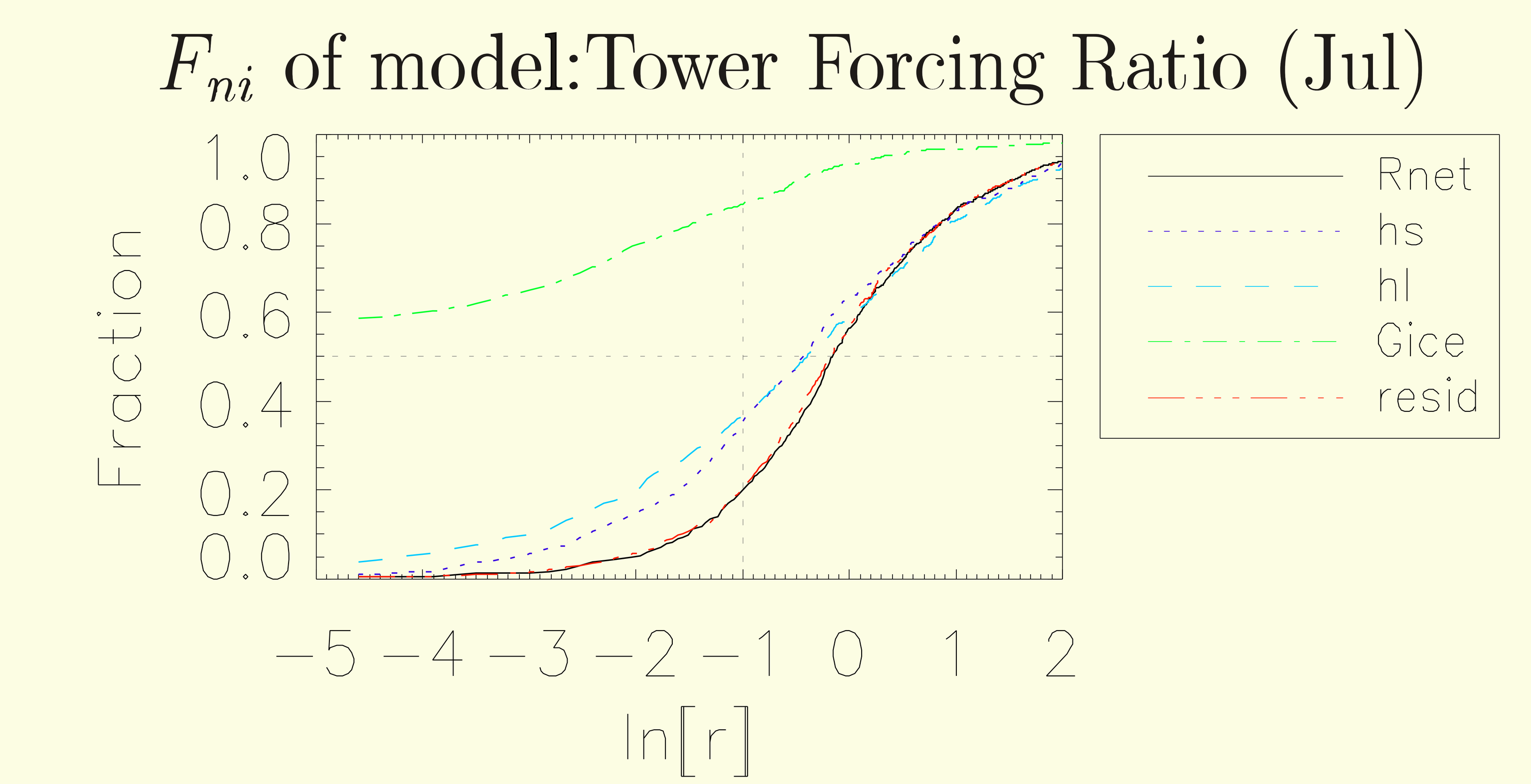

Fig. 2: Same as Fig. 1, but for Jul.

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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