Tackling transience in debris-covered glacier systems

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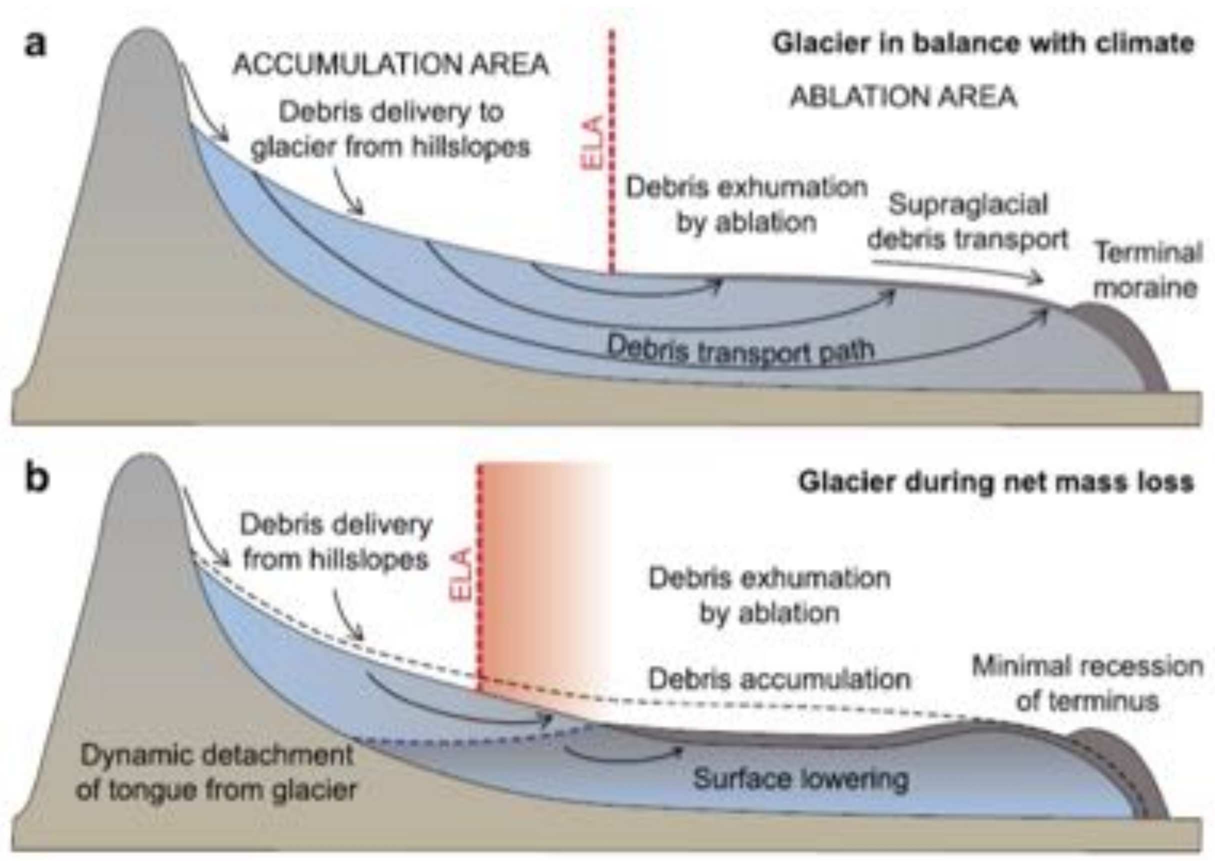
can **debris-covered glaciers** achieve **steady state**?

MOTIVATION

Debris covered glaciers constitute a substantial and increasing proportion of remaining mountain glaciers.

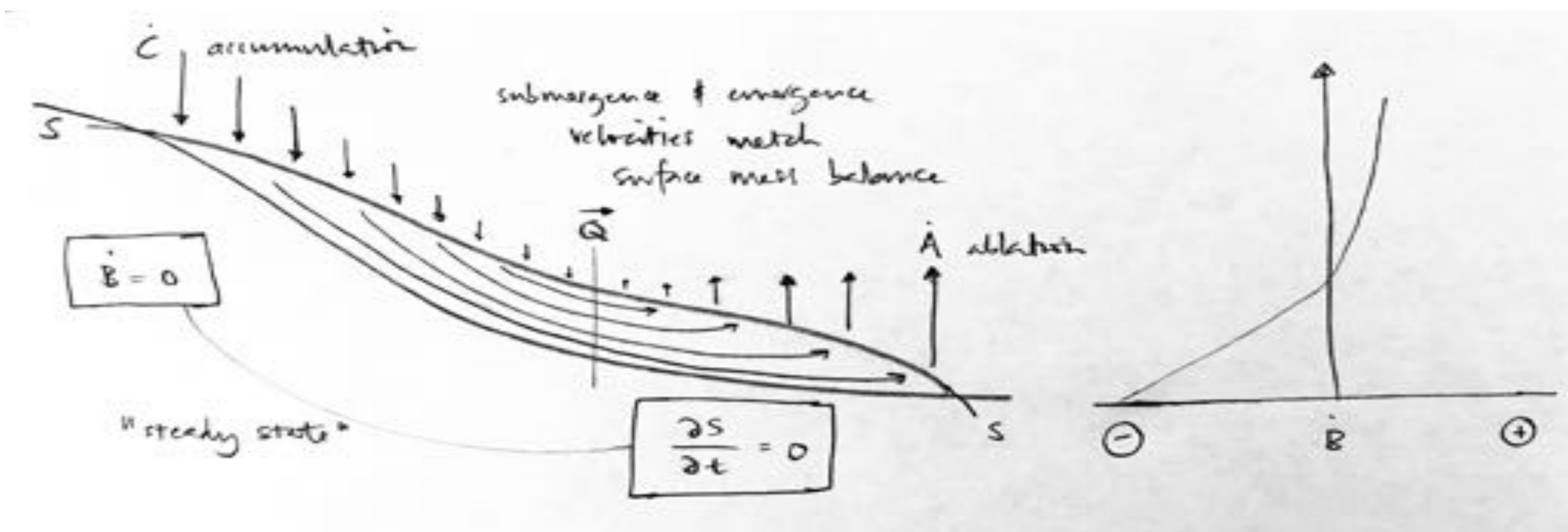
In response to ice loss, they undergo surface lowering instead of retreat, with attendant impacts on ice flow, runoff generation, and hazards:



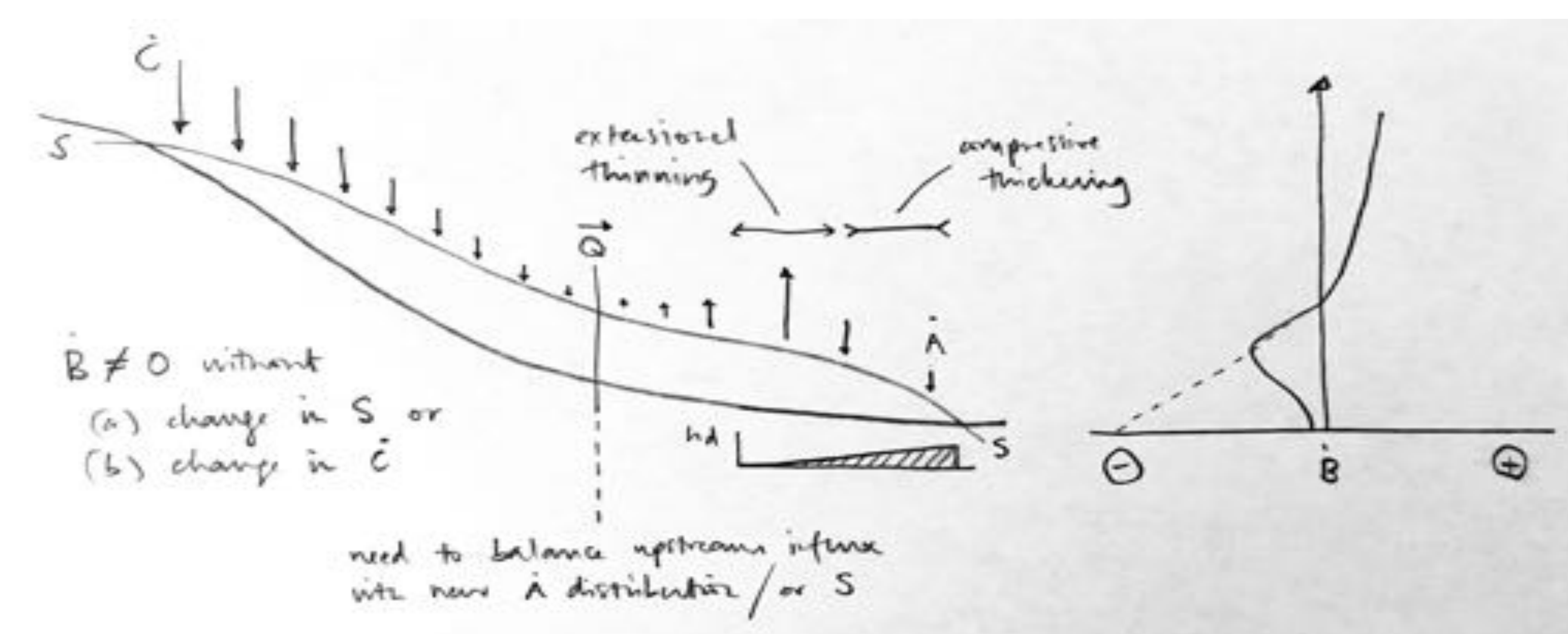
It is therefore expected to be important to include a treatment of debris-covered glaciers in models that project global glacier behavior and runoff.

PROBLEM STATEMENT

Concept of glacier steady state: Balancing accumulation, ice transport and ablation over a constant glacier geometry, underpins understanding and quantification of glacier-climate interaction.



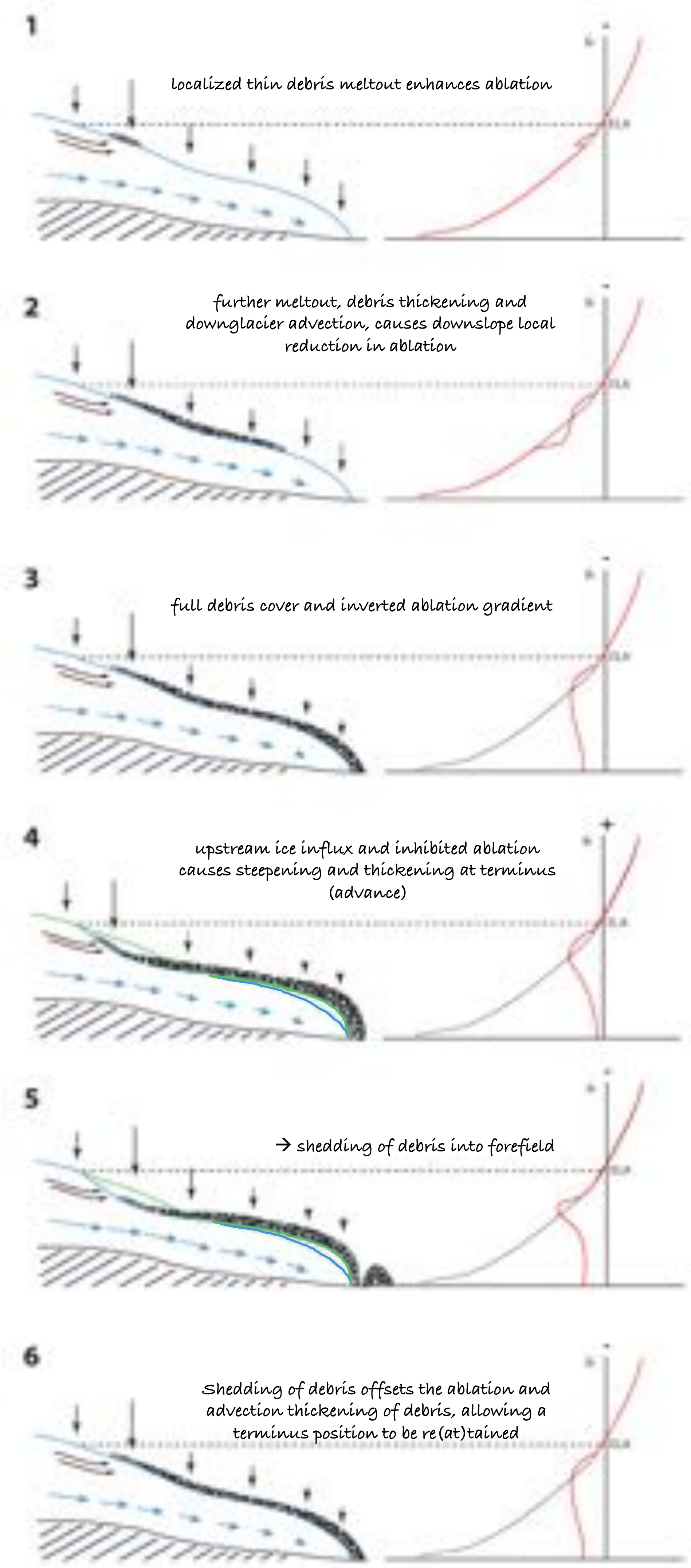
Debris → time-dependent feedback on surface ablation that evolves partially independently of climate forcing: Debris thickness increases non-linearly with cumulative melt out, then governs subsequent ablation and melt-out. Konrad & Humpries (2000) suggest debris-covered glaciers advance indefinitely in steady-state climate. But, forced by constant supply of >1m of surface debris at ELA. So, what is a more realistic scenario?



How will debris thickness distribution evolve over time?
Will system tend towards uniform debris thickness?
What is the pattern and pace of glacier geometry adjustment?
Is terminus stagnation a necessary result in any mass change state?

OSCILLATING EQUILIBRIUM?

Potential of lagged interplay of kinematic wave propagation and frontal steepening causing shedding of debris?



DISCUSSION AND IMPLICATIONS

The thoughts collected in this poster leave key question unresolved, but we hope to stimulate discussion and can highlight some key points:

1. Including a treatment of debris in global models of glacier change requires some (simplified) representation of the long-term co-evolution of debris cover and glacier geometry with climate.

2. Impact of surface debris dependent on time varying debris cover extent, and thickness, that is only partially climatically forced. Relevant timescales of debris cover extent and thickness change remain poorly constrained.

3. Steady-state for debris-covered glaciers does not look the same as for clean ice glaciers. This affects how global glacier models can be optimized for debris-covered glaciers.

4. More needs to be known about debris supply and evacuation from debris-covered glaciers. In particular how it might change in both time, and with glacier geometry.

5. Stagnant glacier tongues hemmed in behind latero-terminal moraines whose crestlines are above present day glacier surfaces are a special problem to glacier modelling. Relict features no longer connected to climatic mass change and ice flux balance, but do still provide meltwater runoff and influence glacier buttressing and advance conditions.