

The Life Cycle of Ice Streams

T. Hughes

Department of Earth Sciences and Climate Change Institute

University of Maine, Orono, ME 04469

Ice streams have life cycles that proceed through inception, growth, mature, declining, and terminal stages controlled by basal buoyancy factor ϕ_B equal to the product of ice-bed uncoupling factor ϕ beneath ice streams and ice-shelf unbuttressing factor ϕ_O beyond ice streams, where ϕ_B , ϕ , and ϕ_O all decrease from one to zero as resistance to gravitational motion of ice increases. Table 1 shows how ϕ_B decreases as ϕ decreases with increased ice-bed coupling in stages 1 through 5 and ϕ_O decreases with increased ice-shelf buttressing in stages A through E. Any path can be taken from 1A to 5E, including temporary reversals, with an ice stream shutting down for either full coupling ($\phi = 0$) or full buttressing ($\phi_O = 0$). At stage 5E, a marine ice sheet has been downdrawn close to sea level, its ice streams have shut down, and its ice shelves are vulnerable to catastrophic disintegration, with calving bays migrating up stagnant ice streams to carve out the collapsed accumulation zone of the ice sheet, removing the ice sheet from Earth's climate system and opening the possibility for rapid climate change. For the West Antarctic Ice Sheet, ice streams entering Ross and Ronne-Filchner Ice Shelves are in stages 4D, 4E, and 5D, and in Pine Island Bay, Pine Island Glacier is in stage 2B and Thwaites Glacier is in stage 2A.

Table 1: A Life-Cycle Classification for Ice Streams, modified from Hughes (1992).

← Increasing ice-bed coupling	Stages in life cycle					Stage	ϕ_B during life cycle				
	1A	1B	1C	1D	1E	Inception	1	3/4	1/2	1/4	0
2A	2B	2C	2D	2E	Growth	3/4	9/16	3/8	3/16	0	
3A	3B	3C	3D	3E	Mature	1/2	3/8	1/4	1/8	0	
4A	4B	4C	4D	4E	Declining	1/4	3/16	1/8	1/16	0	
5A	5B	5C	5D	5E	Terminal	0	0	0	0	0	
Increasing ice-shelf buttressing →											
<p>Basal buoyancy factor $\phi_B = \phi \phi_O$ decreases from 1A to 5E defined as:</p> <p>Increasing ice-bed coupling beneath an ice stream</p> <ol style="list-style-type: none"> 1. No coupling along entire length ($\phi = 1$). 2. Coupling slowly increasing upstream. 3. Coupling steadily increasing upstream. 4. Coupling rapidly increasing upstream. 5. Full coupling along entire length ($\phi = 0$). <p>Increasing ice-shelf buttressing beyond the ice stream</p> <ol style="list-style-type: none"> A. No ice shelf or a freely floating ice shelf ($\phi_O = 1$). B. Weak buttressing by a confined and pinned ice shelf. C. Moderate buttressing by a confined and pinned ice shelf. D. Strong buttressing by a confined and pinned ice shelf. E. Full buttressing by a fully confined ice shelf or an ice lobe ($\phi_O = 0$). 											