The Cryosphere Discuss.,
doi:10.5194/tc-2017-6-AC1, 2017


The Cryosphere Discussions
Open Access
EGU



# *Interactive comment on* "Reply to "Basal buoyancy and fast-moving glaciers: in defense of analytic force balance" by C. J. van der Veen (2016)" *by* Terence J. Hughes

**T. Hughes**

terry.hughes@maine.edu

Received and published: 28 February 2017

Cornelis van der Veen has responded to my reply to his note in The Cryosphere [Van der Veen, 2016]. I am pleased to address his concerns. First, a minor point: The version of his paper I saw had only open parentheses ) associated with his equations, not closed parentheses(). But as I stated, that did not prevent me–or anyone else familiar with these equations–from closing the parentheses with ( in the conventional way. The flawed version was sent to me by my colleague, Professor James Fastook at the University of Maine. I don't know where he got it. I now see the version published in The Cryosphere is free from this defect.

Van der Veen's Figure 2 still confuses me. It compares a "driving stress" with a "gra-



Printer-friendly version

Discussion paper

dient in longitudinal stress", "basal drag", and "lateral drag" but no dimensions are provided for numbers on the vertical axis. From the numbers, I assume the units are stresses, kilo-Pascals to be specific. But a "gradient" in kilo-Pascals needs units of length along flow. To me that's comparing apples and oranges. So his Figure 2 demonstrates nothing.

Van der Veen's Figure 3 does not represent my geometrical force balance because his lines AF and BE are not parallel. I can only assume he doesn't understand the geometrical force balance.

Van der Veen's Figure 4(a) is a vertical force balance, even though his horizontal arrows create the impression he wants it to be a horizontal force balance. However, forgetting the arrows, Figure 4(a) will not allow horizontal flow either on a flat ice shelf with no ice thickness gradient or down the flanks of an ice divide where the surface slope is zero. His Figure 4(b) with arrows and with a surface slope is correct.

Van der Veen does not seem to recognize that my floating fraction "phi" of ice along an ice stream is based on the vertical force balance, a body force, as quantified by Newton's second law of motion: force (of gravity) is mass (of ice) times acceleration (of gravity). I will make this unmistakably clear when I revise my version now available for interactive discussion.

Van der Veen does not have to "defend" the analytic approach to the force balance. I freely admit my geometric approach will never replace integrating the Navier-Stokes equations in the analytic force balance for serious modelers of ice-sheet dynamics. My approach is for students, primarily glacial geologists, who understand simple geometry but lack an adequate understanding of calculus.

I do maintain that the geometric force balance allows a deeper insight into the role of basal water under an ice stream that is deep enough to remove contact with the bed for some significant floating fraction of ice that generally increases downstream, and becomes complete ice-bed uncoupling for a freely-floating ice shelf.

Contrary to what Van der Veen states,I have never stated nor would I state that Van der Veen's treatment of the force balance "is wrong or seriously flawed" (his words). On the contrary, I stated "Cornelis van der Veen understands ice dynamics as well as anyone..." My point then and now is none of us has a complete understanding of the force balance in glaciology, or of any other aspect of glaciology for that matter. Glaciology is not "settled science" unlike climate science–as we are repeatedly told.

More than most, my career in glaciology has been marked by challenging conventional thinking. I mentioned three other examples in addition to the geometrical force balance: (1) the "pulling power" of ice streams, (2) the possibility of thermal convection in polar ice sheets, (3) former ice sheets can be reconstructed from the bottom up using glacial geology more reliably than from the top down using the mass balance. There are many others. All have been published in refereed journals, with the assistance of reviewers who are worth their weight in gold.

Terence J. Hughes Fort Pierre, South Dakota 28 February 2017

---

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2017-6, 2017.