

## ***Interactive comment on “Review article: the false–bottom ice” by D. V. Alexandrov et al.***

### **Anonymous Referee #1**

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In this contribution, the authors review the relevance of false bottoms that form in summer underneath sea ice and present some approaches to modelling them.

While the topic of false bottoms is interesting and certainly deserves more attention, in particular from an observational point of view, I do not believe that a review article on this rather narrow topic is necessary: Just by reading, for example, Martin and Kauffmann (1974), Eicken (1994) and Notz et al (2003), the vast majority of insights provided by this review can be obtained. In addition, some of the physical description of false-bottom physics in this review paper is erroneous, and its correction would move the contents of this paper even closer to that of the three references just mentioned. I therefore suggest to keep this paper in the discussion stage rather than moving it into The Cryosphere.

Detailed comments:

C3061

p.5660

I.7: The increasing relevance of false bottoms "in the era of global warming and climate change" is unclear. What's the difference between global warming and climate change?

I.21: This "present-day" estimate of false bottom-coverage stems from 1965, when the Arctic sea-ice cover was substantially different from what it is today.

p.5661

First two paragraphs of the introduction: The introduction deals a lot with the importance of heat fluxes from the ocean into the atmosphere. However, false bottoms only very indirectly change those heat fluxes: The formation of an underwater-melt pond might increase the phase-equilibrium temperature at the bottom of the ice from, say,  $-1.5^{\circ}\text{C}$  to around  $0^{\circ}\text{C}$ , which then in turn very slightly changes the heat flux from the ice to the atmosphere. Large-scale weather patterns that form the focus of the introduction will most likely not be influenced by the existence of false bottoms.

I.12ff: The relevance of winter heat fluxes from leads for this topic is unclear.

I.22ff: I don't believe that much of the meltwater penetrates through the ice matrix. It would immediately refreeze upon entering the ice matrix, forming impermeable layers in the ice.

I.26: Why is there an upper limit of  $+1^{\circ}\text{C}$  and a lower limit of  $-1^{\circ}\text{C}$  for the temperature range in which the density of brackish water decreases upon cooling?

p.5662:

I.1: The density does not decrease by a cooling from  $0$  to  $-1^{\circ}\text{C}$ , instead such cooling increases the density.

I.2: Supercooling does not specifically produce a density inversion, this term simply describes the fact that the local temperature is below the local freezing temperature.

C3062

There's no magic about the density of supercooled water.

I.5: Ice crystals have a lower density than water, which is why they float to the top. This is independent of any density inversions in the surrounding water column.

I.16ff: Who considers these manuscripts as the classical interpretation of the subject?

I.20: Lyons et al. (1971, not 1951) describe the accumulation of ice crystals underneath an ice shelf. This mechanism is according to our modern understanding mostly related to the depression of the sea-water freezing temperature with depth rather than to the mechanisms that cause the formation of a false bottom.

p.5663:

I.1: This is not a present-day estimate. Today's sea-ice cover consists mostly of first-year ice, which has a much smoother topography compared to multi-year ice.

I.8: How is the reflectance of a thin ice cover decreased by false bottom formation?

I.12: The general assumption is that, both thick and thin ice melt at a similar rate. This equality of melt rates is related to the fact that the heat flux through the ice is low in summer, and hence almost equal in thin ice and thick ice.

I.19: The C-shape profile in Eicken(1994) is shown for normal sea ice, not for a false bottom.

I.23ff: Not sure what is meant by "phase transition layer". Independent of this terminology, there is no fundamental difference between the growth in the presence of false bottoms compared to their absence. Any kind of sea ice is mushy (i.e., by definition consists of several phases (liquid ice, solid brine, gas) and several components (salt and water). It is therefore unclear why the term mushy layer is only used to refer to the false bottoms in this contribution. Indeed, these false bottoms are probably the least-mushy part of sea ice, since they consist mostly of freshwater ice.

p.5666:

C3063

I.1: What does the term "previously" refer to here? Are there any estimates of false bottom coverage from before 1965 that are lower than the estimates in this paragraph?

I.23ff: To first order, the water in under-ice cavities will almost be fresh. Hence, the ice that forms there is much less representative of a typical "mushy layer" than is sea ice itself.

I.27: The lower boundary of a false bottom cannot warm because of a heat flux through the ice, it must remain in phase equilibrium with the underlying water. It might warm because of phase changes which decrease the salinity of that underlying water, though.

p.5667

I.25: I doubt that there is supercooled water around ice crystals. Supercooled water can only survive in the absence of nucleation sites. Assuming that the underice cavity is filled with fresh water and ice crystals, the theory of Notz et al. (2003) remains valid: The existence of some ice crystals in the cavity will barely effect the growth of the false bottom. It seems unnecessary in the light of the low salinity of the under-water cavity to use full mushy-layer theory to study the evolution of false bottom. (Compare, for example, Figure 10 d of Notz et al with Fig 4 c in the present contribution. The two are almost identical.)

p.5668:

I.8: This is a very unlikely case study. It would require that fresh water had only just collected in an under ice cavity (i.e. recent surface temperature well above freezing), but that the ice surface has on the other hand been cold for so long to allow for a significant heat flux through the ice to grow ice from the bottom of the ice downward. I can barely think of weather conditions that would allow for such scenario.

I.5669:

I.14 until p.5670, I.20: Most of this discussion has already been given by Notz et al. (2003)

C3064

p.5670

l.21: I do not see why suddenly the brine salinity changes. Because of phase-equilibrium considerations, the brine salinity is only determined by local temperature.

p.5671:

l.14: Solar radiation divergence is of order 100-200 W/m<sup>2</sup>, not around 10 W/m<sup>2</sup> as suggested here.

p.5672

l.7ff: See comment on Lyons et al. (1971) above

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Interactive comment on The Cryosphere Discuss., 7, 5659, 2013.