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# ***Interactive comment on “Technical Note: On the use of the mushy-layer Rayleigh number for the interpretation of sea-ice-core data” by M. Vancoppenolle et al.***

**Anonymous Referee #3**

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Calculated critical Rayleigh numbers appeared in the sea ice literature prior to a theoretical analysis of the sea ice system marked by depth-dependent permeability and temperature-dependent physical properties. As a result, past authors have interpreted the Rayleigh number differently and used various parameters. As this impedes inter-comparability, this study provides an empirical attempt to put sea ice Rayleigh number calculations on a more consistent footing. The missing theoretical basis leads to an ad-hoc trial-and-error approach in this work devoid of theoretical insight. Also, only case examples are calculated and it is not stated whether there are any circumstances under which conclusion may be different. While the lack of deeper insight is a shortcoming for publication in a scientific journal I think this work makes a valuable contribution

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nonetheless. However, the presentation appears to be a bit too sloppy in parts where some handwavy comments or half-truths should be backed up with references and qualified, respectively.

I think theoretical clarification should be presented on whether the thermal conductivity should be that of the fluid or that of the solid or a mixture. Also, the meaning of a Rayleigh number “at” a particular depth defies my imagination and should be elaborated on.

Tests were performed based on salinity datasets that are either not published or still in press. This may have impeded the peer review process.

3210

(Abstract) Where in the manuscript is the uncertainty due to brine loss quantified? Where is brine loss quantified?

Where does Untersteiner (1968) say that brine convection (in the sense used in this publication) desalinates sea ice? Isn't he commenting on gravity drainage of levitated sea ice?

Under what circumstances can convection be described by a Rayleigh number of the given form? Reference?

3211

Interpretation of the Rayleigh number: there should be references that can be added here, in particular since the development of this ratio is a bit more sophisticated than the interpretations suggest. It is not mentioned why this "interpretation" paragraph is useful. The authors return to this briefly in the context of thermal diffusivity where it turns out that the former interpretation seems to imply that the diffusivity is that of sea ice while the latter seems to imply that it is that of brine. Shouldn't there be a right and wrong answer here? This little pearl of science should be elaborated on.

"If the diffusive time scale is shorter than the advective time scale" sounds like the critical Rayleigh number is 1.

What is the reference for the in-situ measurements? Are there many studies out there to back up this claim?

Full-depth desalination due to Rayleigh number: how does flushing fit in here as described by Untersteiner (1968)?

Permeability  $P_i$  depends on  $T$  and  $S$  indirectly at best. It depends on the structure of the pore network.  $T$  and  $S$  specify average porosity. What about air?

"Ice core derived  $R_a$  has been provided" apparently only by studies the current group of authors has co-authored. Or are there independent groups that could be mentioned?

3212

Apart from errors in  $S$  and  $T$ : errors in  $P_i$  due to unknowns in the pore network, maybe? Are we talking about FYI only? Arctic and/or Antarctic? Granular ice?

These days sea ice salinity is the result of a conductivity measurement rather than a mass measurement. I believe nobody has measured mass fractions to determine salinity for decades. I would like to refer to the pertinent UNESCO documents and strongly advise that gkg-1 not be used as a sea ice salinity unit in The Cryosphere. According to the UNESCO documents salinity is unitless.

3213

"often a simpler": references?

3214

It is implicitly assumed here that sea ice permeability is only a function of porosity. It should be acknowledged that it is not and why. What kind of ice do the parameterizations relate to: newly formed ice? Ice late in the growth season? How does this matter

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for the pore structure?

3215

"a marked permeability increase exists": what does "marked" mean? A break in slope on a log-log plot??? (trick question)

What is the "Rayleigh number for a certain level"? The Rayleigh number as I know it describes an entire system with a specific domain configuration and well-defined boundary conditions. Talking about a Rayleigh number at certain level simply does not seem to make sense. This should be clarified in the introduction when the Rayleigh number is thoroughly introduced.

Based on what theoretical basis should the harmonic mean be the relevant quantity? How should anisotropy of permeability be dealt with?

"usually": references?

"z": early formulations of the Rayleigh number... I think insights should be added here (or in the introduction) on the nature of the Rayleigh number, see comment above. Wettlaufer may have had a very good reason to do as he did.

3216

The fundamentally different interpretations of kappa merit, imho, a thorough introduction to the concept of Rayleigh number in the introduction. Are all approaches presented of equal scientific value?

Is "heat diffusivity" the same as "thermal diffusivity"?

3217

Unfortunately, there is absolutely no scientific insight in the presented recommendation. Could this be changed if only to acknowledge that this is a scientific journal? Also, it would be much appreciated if a theoretical basis would be provided explaining

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whether thermal diffusivity should be that of ice, sea ice, or brine.

3218

"close to the freezing point" of what?

3219

what is a "0.5 underestimation"?

"This type of error": what type of error?

Temperature varies strongly at sub-daily time scales? Close to the ice–ocean interface???

3220

"are also important" for what?

"weak evidence of the basal winter permeable layer". Petrich, Karlsson, Eicken (2013) have recently discussed porosity of the winter permeable layer. Is that related to the matter discussed here?

3221

After reading this manuscript I get the impression that the nature of the Rayleigh number is a bigger unknown than brine properties at low temperatures.

As an aside, could the authors recommend a reasonable salinity sampling interval at the ice–water interface in the light of brine loss at different times of the year?

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