

Laboratory study of frazil ice accumulation under wave conditions
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This is a description of a laboratory study of the formation of frazil ice under the influence of waves. The authors have recorded the time evolution of ice thickness and measured frazil and water salinities, and air and water temperatures. From these data they have derived the solid ice fraction in the frazil ice, in relation to the properties of the wave field. The paper reports initial and maximum frazil ice solid fractions and describes the processes that lead to the formation of a pancake ice cover.

The authors are to be congratulated on successfully carrying out these experiments. They are difficult experiments with much inherent variability. The data have been extensively analysed and substantial conclusions have been drawn from the experimental evidence. The abstract is accurate and the paper is worthy of publication. However I do have a number of comments in relation to language and presentation. I list these below.

General Comments:

Section 2.1, Page 1840: What is the accuracy of the CTD? In order to decide whether or not the water becomes supercooled, the accuracy of the calibration of the salinity and temperature measurements are needed. Please quote errors in the water salinity and temperature measurements.

Maus and De la Rosa (2011): Details of the derivation of equations and the discussion depend on this paper. At the time of submission this was under review. Unless Maus and De la Rosa is now in press then I suggest that some dependence between the papers be removed, particularly in section 5 where the dependence reduces the impact of the discussion. Depending on status, throughout the manuscript it should say Maus and De la Rosa (under review).

Fig 6c: This is referred to on p. 1852, line 23 but I did not have a Fig 6c in the version of the paper that I have. Please correct.

Section 5.1: I felt section 5.1 was longer than it needed to be. Perhaps the comparison could be put in a table? The authors need to emphasise the point of section 5.1 because some of the background information regarding the difference between in situ and drained samples seems to be the subject of Maus and De la Rosa (under review).

Section 5: I suggest that the authors could increase the impact of their paper by reducing the length of the discussion. Some material is repeated, some is given in detail that would be better delivered in a table, while some is very dependent on Maus and De la Rosa (under review) and might be better described in their follow-up paper. In particular I wonder about the necessity of including sections 5.5 and 5.6, both of which seem to conclude that more measurements are necessary.

Specific and technical comments:

Page 1839; Line 26: Replace “less” with “lesser”

Page 1840; Line 4: Replace “placed stationary” with “placed at fixed locations”

Page 1840; Line 11: You cannot use an “approximation” to derive a temperature to 1 mK precision. Please round the temperature to a number of decimal figures that is appropriate to the approximation used.

Page 1840; Line 16: I do not understand “Two thermistor chains of platinum resistance thermometer (Pico Pt-100) sensors”, since a thermistor and a platinum resistance thermometer are different types of temperature sensors. Do you mean “Two temperature chains of platinum resistance thermometer (Pico Pt-100) sensors”?

Page 1840; Line 17: I don’t know what you mean by “covered air temperatures” Do you mean that air temperatures were measured up to 16 cm above the ice?

Page 1840; Line 26: Insert “temperature” before “sensors”

Page 1840; Line 26: Insert “frazil” before “ice”

Page 1842; Line 9: In order to make statements about supercooling we need to be told the accuracy of the temperature and salinity measurements. Please quote these.

Page 1843; Line 2: I think you mean “perfectly insulated” on all sides but the upper surface?

Page 1843; Eqn 1: This assumes uniform properties throughout the tank, in particular the rate of change of temperature in the water. Please comment on assumptions.

Page 1843; Line 8 & 9: Were C_{pw} and ρ_w calculated from the salinity of the water? Please explain.

Page 1843; Line 23: Does Q_s become 0 when Q_i becomes non zero?

Page 1844; Line 4: “We see that the along-tank ice thickness distribution becomes approximately uniform with time, for all experiments in tank A, and experiments E2, E3 and E4 in tank B.” I don’t think I am reading Fig 3 correctly because E1(A) does not look any more uniform with time than E1(B). However it is difficult to tell because we are not told the times of the measurements (see comment on Fig 3). Please clarify.

Page 1844; Line 8: “Ice accumulation at the end of the tanks only noticeably occurred during experiments E1 and E3 after 5 h of freezing.” Again I don’t think I am reading Fig

3 correctly because there seems to be ice accumulation at the end of the tank in E2(B) early in this experiment. Please clarify.

Page 1844; Line 16: Where is the time dependence in these functions? Is there a physical explanation for choosing these forms?

Page 1844; Line 25: h_2 is not an exponential function. I assume you mean expression 2? Does h_2 have an exponential time dependence? Please clarify how time enters your fit.

Page 1847; Line 13: I felt that this comment should also be in the figure caption of Fig 5. "Note that all salinities in E4 that started with a 2gkg-1 higher salinity, are shown normalised by 33/35.38."

Page 1848; Line 3: "The first group (not shown) presents two peaks in.." I assume that this is the difference between the dark bars and the light bars? Thus I would not agree that this group is not shown.

Page 1848; Lines 8 & 9: Replace "show if" with "examine whether". Insert "show before "how". Put brackets around Sect 4.1 and Sect 4.2.

Page 1848; Line 10: I suggest introducing this paragraph with a sentence from p. 1849 "In laboratory conditions, with relatively constant air ventilation and radiation, the heat flux leading to ice growth may be approximated by the empirical growth law $\dot{h} = \alpha_a(\alpha_a - \alpha_s)$, where α_a is the air temperature at a fixed reference level above the ice, and α_s the ice or water surface temperature." In fact you might consider inserting the first paragraph of p. 1849 at the start of the section on Equivalent ice thickness.

Page 1848; Line 12: Please comment on the fact that the equivalent ice thickness varies linearly with time. Is this to be expected?

Page 1848; Line 23: "We may consider the difference between the mean water and air temperatures as an indicator of the possible changes observed in α_i , derived from the procedure explained above, we see a small decrease in α_i ." is not a sentence. Please amend.

Page 1849; Line 21: Insert "et al" after "Wadhams"

Page 1850; Line 13: Replace "considerably" with "considerable"

Page 1851; Line 6: This does not appear consistent with E1(A) in Fig 3 which seems to get thicker as you go further from the wave paddle? Please clarify.

Page 1851; Line 22: Please define $\bar{v}_{S(t)}$ and v_{S0} when they first appear. The latter is defined on p. 1852.

Page 1852; Line 25: Insert “,” after “fall”

Page 1852; Line 27: There are too many significant figures in the error. That is, I suggest 0.27 ± 0.03 . I also then suggest replacing “a slightly higher estimate than” with “within error of”

Page 1853; Line 15: Remove “already”

Page 1853; Line 16: There is no E5. Please correct.

Page 1854; Line 7: Replace “Once” with “once”

Page 1854; Line 13: Replace “further increase in thickness remained rather uniform over the tank” with “thickness increased uniformly over the tank”

Page 1854; Line 20: Replace “Experiments” with “experiments”

Page 1854; Line 26: Please give the error in 0.01 K measurement.

Page 1855; Line 13: Remove “already”

Page 1856; Line 1: Replace “we report here” with “here we report”

Page 1856; Line 21: Replace “also Onstott et al. (1998)” with “Onstott et al. (1998) also”

Page 1857; Line 6: Insert “ice” after “low”

Page 1857; Line 23: I did not understand the sentence after “i.e.”

Page 1857; Line 27: Replace “it” with “this”

Page 1859; Line 1: Replace “evens out” with “becomes uniform”

Page 1859; Line 11: Insert “of” after “height”

Page 1859; Line 24: Will turbulence not also act to keep frazil in suspension?

Page 1860; Line 14 to 1861; Line 9: Here you are describing the time dependence of the solid fraction. However Fig 6 is the data for all times (I assume). Do you have enough data to be able to examine the time dependence?

Page 1861; Line 26: Replace “considerable” with “a considerable amount of”

Page 1863; Line 5: Replace “identified” with “identified”

Page 1863; Line 20: Replace “the top, we used in our earlier study of the second phase of E2 (De la Rosa et al., 2011) additional infrared surface temperature observations to distinguish between pancake and frazil/grease ice.” with “the top, in our earlier study of the second phase of E2 (De la Rosa et al., 2011) we used additional infrared surface temperature observations to distinguish between pancake and frazil/grease ice.”

Page 1863; Line 25: Replace “to” with “at”

Page 1864; Line 6: Replace “periodical” with “periodic”

Page 1864; Line 16: “appears to scale”? Do you mean “appears to scale linearly”?

Page 1864; Line 25: Again I am not sure what you mean by “scale”?

Page 1865; Line 15: Replace “The question from which levels the heat lost through the surface is derived,” with “The question of the depths from which heat is lost through the surface”

Page 1865; Line 21: Why does the tank receive this heat through the bottom and sides? Please explain.

Page 1867; Line 3: Why is heat entering the tank at the surface? I thought it would be leaving. Please explain.

Page 1868; Line 23: Replace “emphasize” with recommend”

Page 1868; Line 19 on: It is a pity that the first paragraph of your conclusion depends on the not-yet-published paper.

Page 1869; Line 1: Please modify the statement about supercooling once consideration has been given to the error in this measurement.

Pages 1869 & 1870: I found the conclusions drawn from your observations regarding the relations between solid fraction and thickness very interesting.

Table 1: I think many of the quantities on Table 1 are quoted to too many decimal places. I doubt that freezing point is known to 10 mK given that it is “approximated” from Maus (2007). I doubt that wave height is known to $\pm 10 \mu\text{m}$. Please think carefully about the error in the quantities you have measured.

Fig 1: Are the temperature sensors thermistors or platinum resistance thermometers.

Fig 3: Generally thickness increases with time, but clearly not always. Could the symbols be colour-coded so that the times could be identified?

Fig 4: It is difficult to distinguish between the blue colours in this figure.

Fig 5: I think that a capital V_s has been used on the axes when lower case v_s is used in the text. There is something wrong with the caption. It does not mention (c).

Fig 6: I assume that this histogram is for data collected at all times. Do you have enough data to consider the time dependence? Could some sort of shading be used to include time information in the plot? Because of the different ice conditions at the start of the experiments, this may not be possible.

Fig 8: Q_s is not marked on either axis of the figure. Is the mean a spatial or temporal average?

Fig 9: Replace “meaned” with “averaged”.

Fig 10: I was confused by the caption since I was expecting wave height to be one of the axes. I suggest you replace “against” with “by”