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My co-authors and I would like to express our gratitude to the reviewers for their constructive feedback and suggestions for strengthening our research. The changes we have made to the attached file in response to such feedback and suggestions have been highlighted in blue to facilitate their identification. I would also like to offer my apologies for the length of time it took us to prepare this response.

Reviewer #1

In general this is an interesting contribution to the problem of black ice forecasting where where a system dynamics modelling is used, rather than a more traditional physcial based model that solves the energy and mass balances.

1. Generally, the paper is well-written, but the I recommend moving section 4.1 from the discussion to the method.

- Thanks for your insightful comment. As mentioned, Section 4.1 of the Manuscript has been moved to Section 2.4, the latter part of Section 2.3, along with Figure 9. I have modified the Discussion section so that only validation and discussion of results are handled. And I have made Sections 4.1~4.4 by stepping up Sections 4.2 and 4.2.1~4.2.4 one step at a time. The new paragraph in Section 2.4 has been amended as follows.

Lines 397-405(existing section 4.1) → Lines 281-296(new section 2.4)

2.4 Black ice multi-sensor configuration and model validation
In this paper, sensor validation was performed on the model's point where black ice was predicted to occur. To determine the generation of black ice at the prediction point of the model, a black ice multi-sensor—that connects several sensors with the control board—was configured, as shown in (Figure 9→Figure 4). The Multi-sensor consisted of a round force (FSR402), 400 water pressure (gravity: analog water pressure sensor), ultrasonic (W238), and temperature/humidity (SHT30). The round force sensor was buried in the floor, and it detected the pressure of the black ice generated from the upper part. The water pressure sensor had a principle similar to that of the round force sensor, and it detected the pressure of moisture that entered the upper part and was frozen inside. In the case of the ultrasonic sensor, the area where the ultrasonic wave was emitted faced the floor; when black ice was generated, a height difference (default of 8 cm) was detected. Finally, the temperature/humidity 405 sensor had a sensing part facing the ground, and the interval was ~ 2 cm.

2. The use of the unit for the amount of black ice is confusing. The paper both uses g/m^2

and g/m^3. To me only g/m^2 makes sense and this the most common way to express the amount of snow/ice contaminations on roads.

- Thank you for pointing this out. As a result of an additional investigation of previous studies, these studies generally expressed the amount of ice on the road surface and road moisture in g/m^2. The monitoring method of black ice generation belongs to the two-dimensional view from top to bottom, so it is correct to change the unit to g/m^2. I have unified the unit of black ice generation to g/m^2 and added a description of the unit. The following References have been added to the Manuscript.

Lines 661

➢ Lysbakken, K. and Norem, H.: The Amount of Salt on Road Surfaces after Salt Application, Surface Transportation Weather and Snow Removal and Ice Control Technology, 85, 2008.
  ➔ This is a study on the road surface condition, and the amount of water is expressed in g/m^2.

Lines 665

➢ Nilssen, K.: Ice melting capacity of deicing chemicals in cold temperatures, 2017.
  ➔ This is a study on road surface conditions and ice melting, and the unit of g/m^2 was used for the thin ice layer.

Lines 680

➢ Schulson, E.: Sliding heavy stones to the Forbidden City on ice, Proceedings of the National Academy of Sciences, 110, 19978-19979, 2013.
  ➔ The thickness of the ice was converted into g/m^2 and explained.

3. The amount of predicted black ice (presuming the correct unit is g/m^2) seems unrealistically high, for the predictions made at 18th and 19th of December. (50 000 g/m^2 equals 50 mm of black ice) Whether the predicted predicted amounts are high, low, realistic/unrealistic are not sufficiently discussed.

- Thank you for this comment. The amount of black ice generated from the 17th to the 19th ((b) 17th: 52,021 g/m^2, (c) 18th: 26,067 g/m^2, and (d) 19th: 9,770 g/m^2) is the sum of the black ice generation for 14 hours, so it looks unrealistic. The table for the amount of black ice generated per hour during the sensing period is as follows. Although the amount of black ice generated per hour is in a realistic range (for example, 7286.524 g/m^2 is 7.3 mm), the result value (Total value in the table below) looks unrealistic when the figures for 14 hours are combined.

	16th (g/m^2)	17th (g/m^2)	18th (g/m^2)	19th (g/m^2)
AM 0	0	0	0	0
AM 1	4.703768	0	0	42.19465
AM 2	13.43411	0	0	75.57897
AM 3	27.35065	0	0	125.5276

AM 4	40.34503	0	0	149.5643
AM 5	70.43864	0	1483.693	266.8406
AM 6	71.22914	0	1907.632	472.6097
AM 7	71.22914	0	2260.974	755.2013
AM 8	71.22914	7286.524	2595.929	755.2013
AM 9	71.22914	7850.426	2910.015	755.2013
AM 10	0	8408.506	3278.66	2059
AM 11	0	9156.224	3876.928	1826.048
AM 12	0	9443.289	3876.928	1476.62
PM 13	0	9876.263	3876.928	1010.715
Total	441	52021.23	26067.69	9,770

Although it is stated that 50000 g/m^2 (50 mm) occurred during the 14 hours of each day, the average is 3,571 g/m^2 (3.571 mm). The sum of the amount of black ice generated for each hour for 14 hours does not realistically reflect the trend of the amount of black ice generated. To compensate for the unrealistic value, I changed the black ice generation value for 14 hours to an average value and corrected the relevant parts of the result.

Lines 382-390(before correction) → Lines 399-406(after correction)

Figure (8→9) shows the simulation results of the amount and location of black ice predicted by the system dynamics modelling in GIS (Esri). The results of simulating the amount and location of black ice in units of 1 m^2 were exaggerated using the buffer function in GIS. Figure (8→9) (a)–(d) shows the predicted location and generated amount of black ice between December 16–19. 385 The raster information of each black ice map was the ~~sum~~ average of the black ice generated from 00:00 AM to 13:00 PM on the selected day. The maximum amount black ice formed during the 14-h period was ~~(a) 441 g/m^3, (b) 52,021 g/m^3, (c) 26,067 g/m^3, and (d) 9,770 g/m^3~~ (a) 31.5 g/m^2, (b) 3715.79 g/m^2, (c) 1861.93 g/m^2, and (d) 697.86 g/m^2, respectively, for each scenario date and the total amount of black ice generated, i.e. the ~~sum~~ average of all scenarios, was ~~88,300~~ 1,576.79 g/m^2 [Figure (8→9) (e)]. The days with the highest amount of black ice were December 16 and 17, when freezing rain and snow occurred, respectively (Figure (8→9) (b) and (c), respectively), and it was found that road moisture was 390 higher and road temperature was lower than on the other days.

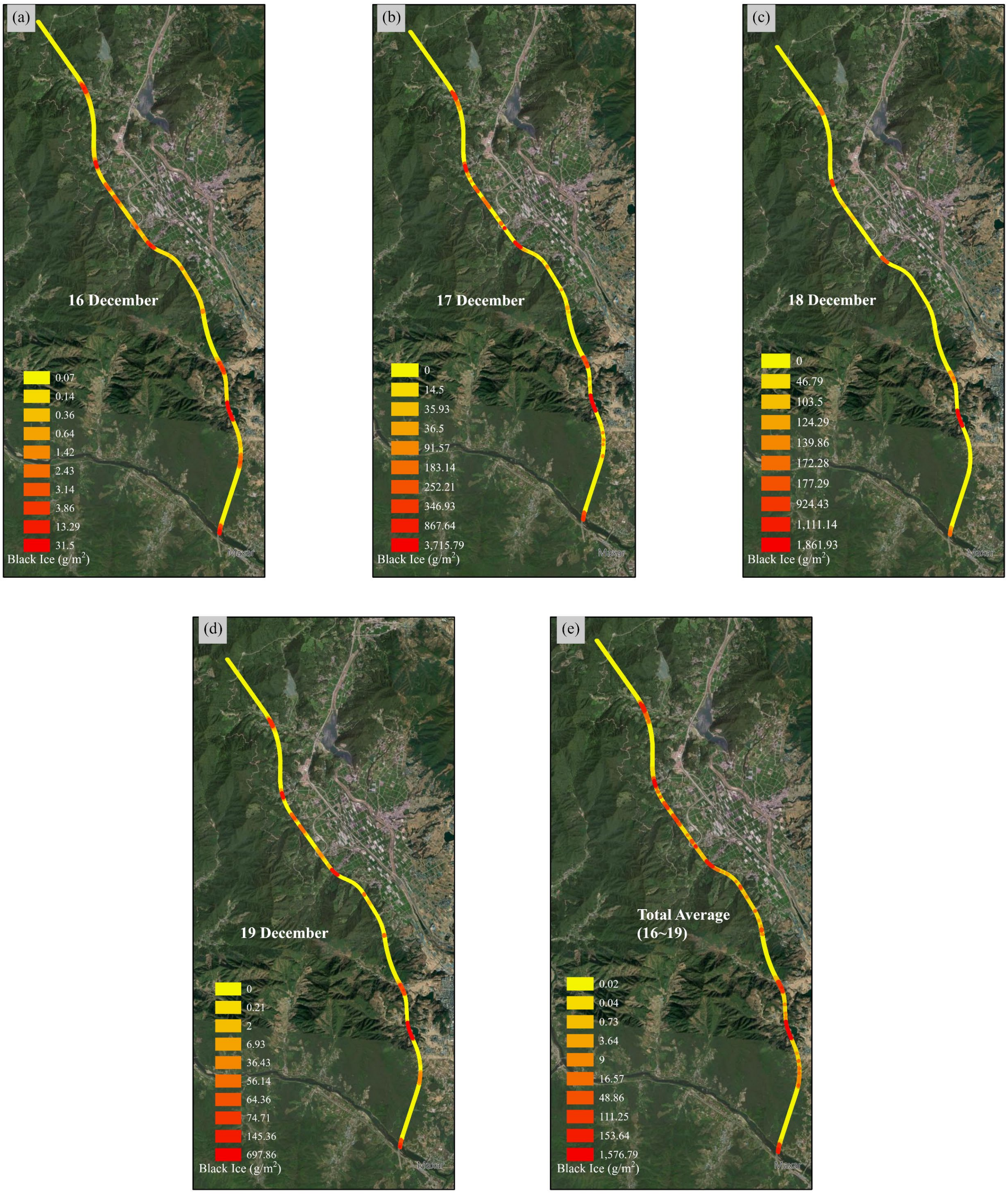

Figure *(8→9)*: Simulation of black ice occurrence prediction results of system dynamics in units of 1 m2 on GIS.

(a), (b), (c), and (d) show the amount and location of black ice from December 16–19. (e) The average of the amount and location of black ice from December 16–19. (Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.)