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Interactive comment on "Ground based measurements of immersion-freezing in the eastern Mediterranean" *by* K. Ardon-Dryer and Z. Levin

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Summary:

This manuscript has examined the immersion freezing potential of air sampled in the eastern Mediterranean region. Specifically, they collected 19 filter samples at Tel Aviv University in Tel Aviv, Israel. This region receives characteristic air masses, with previous studies showing that air from the northwest contains largely sea salt aerosol and anthropogenic pollution, with little influence from dust. Air masses originating from the southwest contain Saharan dust and marine aerosol, with much smaller anthropogenic influence. Concomitant measurements of total particle concentrations (0.11 to 3 μm) and daily averaged PM10 and PM2.5 mass concentrations were also obtained. Fil-

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ter samples were immersed in water and agitated in a sonicator. Immersion freezing experiments on this suspension was determined using the FRankfurt Ice-nuclei Deposition Freezing Experiment-Tel Aviv University (FRDIGE-TAU) chamber. Freezing nuclei (FN) concentrations were estimated using a cumulative nucleus spectrum modified from Vali et al., (1971); this approach was validated using montmorillonite. Immersion freezing was observed from -12 to -29 °C, corresponding to FN concentrations from 0.33 to 211 L-1 air. FN concentrations were also determined for "dusty" and "clean" conditions, which were defined by PM10 loadings and back trajectories. Interestingly, there was only a small increase in FN concentrations during "dusty" conditions in comparison to "clean" conditions. The authors' suggest that this is because atmosphere in Tel Aviv always contains dust particles, even in the absence of dust storms.

Overall, this work provides a nice addition to the current literature of ground-based studies of immersion freezing and helps constrain the specific problem of ice nucleation on atmospheric particles. I do, however, have several general comments that may enhance the utility of this manuscript, as well as several minor comments that would increase its clarity.

General Comments:

[1] Several instances in the paper compare either initial freezing, 50% frozen fraction, or overall activation fraction curves in the FRIDGE-TAU experiments to previous studies on ice nucleation of montmorillonite, biological particles, soot, and biomass burning. While FN concentrations have been normalized per liter of air, special care must be taken when comparing freezing temperatures between experimental methods, especially when comparing freezing temperatures in laboratory experiments. For example, the reviews by Hoose and Mohler (2012) and Murray et al. (2012) have shown that normalization by particle surface area does lead to a convergence between different methods for immersion freezing. Thus, if possible, an estimation of the surface area loading would be appreciated. In theory, this should be possible by using particle number mass concentrations (Maynard, 2003). Furthermore, this analysis would allow

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direct comparison of these results to previous laboratory studies on well characterized dust sources in the immersion mode. This last step would allow the authors' better evidence to support their claim that dust particles are the IN responsible for ice nucleation on both "dusty" and "clean" days.

[2] The Lag Ba Omer festival that provides an interesting case study for a type of biomass burning aerosol; however, the authors may be overgeneralizing their results. As noted in the text, the work by Petters et al (2009) indicates that both the fuel type and burning conditions alter FN concentrations from biomass burning aerosol. Although the type of wood and fire intensity was mentioned, it might be instructive to provide more details about the fuel type and the normal combustion conditions of the bonfires. Also, interestingly, initial freezing temperatures for the 1 May 2010_23 Lag Ba Omer experiments were lower than the average "clean" day initial freezing temperatures, which could point to a coating mechanism at these warmer temperatures. This should also be discussed.

[3] Finally, the FN concentration discussion could be greatly enhanced by an analysis of the temperature error associated with the FRIDGE-TAU chamber for immersion freezing. One easy way to do this would be to report the experimental error determined by the days where two frozen fraction curves were obtained by cutting the filter in half. This would give more credence to the montmorillonite data as well as the "dusty" vs "clean" days.

Specific Comments:

Page 472, line 23: It may be more useful to cite the review of Hoose and Möehler (2012) here instead of listing these citations. If the citations are kept, it may be more useful to state what type of IN were examined in each study (i.e., dust, soot, etc.).

Page 473, line 4: Perhaps the author could be more specific about why these studies have "contributed a lot to our understanding of IN distributions in different parts of the world?"

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Page 475, line 20: Could you provide an estimate how much the total number concentration is underestimated for ignoring particles smaller than 110 nm and greater than 3 μm in this region. Alternatively, you could be more explicit that you are likely calculating activated fractions for particles $\geq$ 110 nm?

Page 476, line 26: The consistency of these results, however, was not reported. See general comment [3].

Page 478, line 9: Here is one instance where surface area estimations would be useful to compare between experimental methods. See general comment [1].

Page 478, line 26: Is it valid to remove these points from your analyses? While some temperatures in your experiments overlap with the temperatures at which some particles froze during blank/pure water experiments, the frozen fractions are much different. As you mention, the average shift is small, only 0.18 $^{\circ}$C, but it will greatly affect the results for some of the colder frozen fraction curves.

Page 479, line 3: This entire paragraph is another instance where surface area estimations would be useful compare between experiment methods. See general comment [1].

Page 479, line 19: As mentioned in general comment [2], the type of burning fuel will influence FN concentrations. Thus, the comparison to the study in the Amazon by Prenni et al. (2009) may not be valid and the conclusion "particles from biomass burning are not a likely source of effective ice nuclei" may be overstated.

Page 479, line 25: As mentioned in general comment [2], it would be helpful to expand upon the type of construction wood and the bonfire combustion conditions.

Page 482, line 5: Here is another example of why an estimation of the temperature error associated with FRIDGE-TAU immersion freezing experiments may be important.

Page 482, line 7: Again, surface area estimations would be useful to compare between experimental methods. See general comment [1].

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Page 482, line 12: How were these elemental compositions determined?

Page 483, line 2: This statement could be greatly enhanced by an estimation of the surface area. If an estimate can be provided, then the freezing results from both dusty and clean days can be directly compared to previous laboratory studies on dust proxies (Murray et al., 2012).

Technical Corrections:

Page 472, line 1: "Nuclei" should be "nuclei"

Page 472, line 2: Please define FRIDGE-TAU before using the acronym

Page 472, line 6-7: "Immersion-Freezing Nuclei" should be "Immersion-freezing nuclei"

Page 472, line 11: "Dusty" should be "dusty"

Page 472, line 15: There should be a comma after importance

Page 473, line 16: The word "articles" in this sentence is misleading. Perhaps "studies" or "field studies?"

Page 473, line 22: There should be a semicolon after years

Page 475, line 17: There should be a comma after Lag Ba Omer

Page 476, line 7-8: There should be a comma after "chamber" in line 7 and after the end parenthesis in line 8

Page 477, line 1: "immersion-Freezing Nuclei" should be "immersion-freezing nuclei"

Page 477, line 21: In both cases, "Montmorillonite" should be "montmorillonite"

Page 479, line 22: "wildfire" should be "wildfires"

Page 480, line 4: "Freeze" should be "froze"

Page 481, line 1: As before, the word "publications" in this sentence is misleading.

Perhaps “studies?”

Page 481, line 26: Delete the word “they”

Page 482, line 11: There should be a comma after the end parenthesis

Page 482, line 26: There should be a comma after “common” and “Europe”

Fig. 1: The size bar in the Google map is hard to read. Also, the red dot in the legend appears to be on the map, which could be confusing to the reader

Fig. 6: “immersion-Freezing Nuclei” should be “immersion-freezing nuclei”

Fig. 10: “Freezing Nuclei Concentration” should be “Freezing nuclei concentration,” and “Activation Fraction” should be “activation fraction”

References:

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