Analysis of the 2nd Technical Focus Group for the Third Ice Prediction Workshop

Thomas Ozoroski, Karim Zayni

NASA Glenn Research Center; Polytechnique Montréal

Presented 22 September 2026

CC BY-NC-ND 4.0

This work is licensed by the author(s) under a **Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International licence (CC BY-NC-ND 4.0)**. To view a copy of this licence, visit https://creativecommons.org/licenses/by-nc-nd/4.0/.

Suggested citation: Ozoroski, T., Zayni, K. (2026). *Analysis of the 2nd Technical Focus Group for the Third Ice Prediction Workshop*. Presented at the 3rd AIAA Ice Prediction Workshop, online, 22 September 2026.

Cover page added by the IPW3 Organizing Committee for dissemination. The original presentation follows unaltered.

Analysis of the 2nd Technical Focus Group for The Third Ice Prediction Workshop

Thomas Ozoroski, NASA Glenn Research Center

Karim Zayni, Polytechnique Montreal

9/22/2026

Focus of TFG2

Problem:

- Large variations between icing solutions in the workshop
- Multiple routines, grids, methods, workflows
- We have multiple routines working together and error propagates easily
- From the outside, we often seem to be in constant misalignment

Proposed Solution:

- Systematic analysis of the icing workflow to garner consistent results
- Identify first-order drivers of solution misalignment
- Understand impacts of solution inputs on alignment

What Are We Looking For

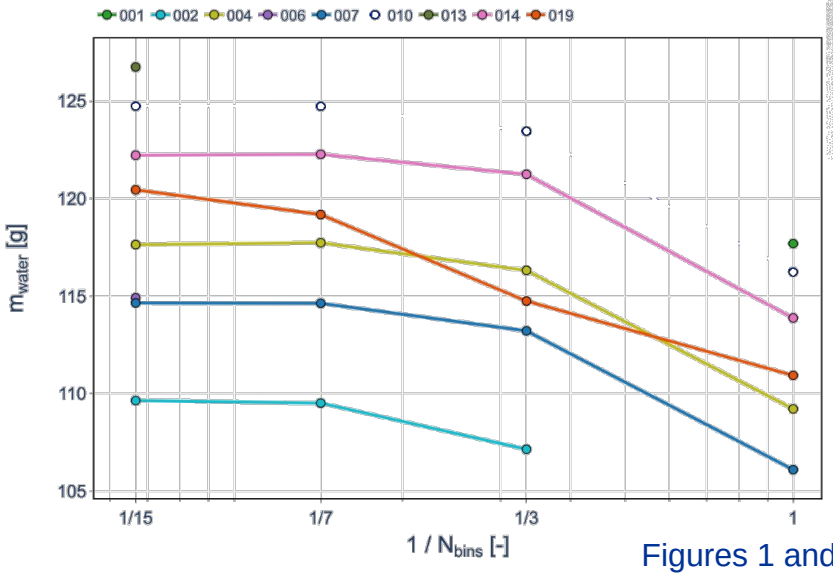
- We are investigating solution convergence based upon a refinement of the grid and the droplet distribution
- The desired result is to see that solutions become unchanging when we increase grid resolution and increase bin size
- We examine this behavior by looking at integrated properties of the solutions and plotting them versus the independent variable
- For this work, a flattening of the output equates to a converged solution
- By doing so, the hope is that we can separate out or trace where the divergence in the solution path is occurring once we get different shapes

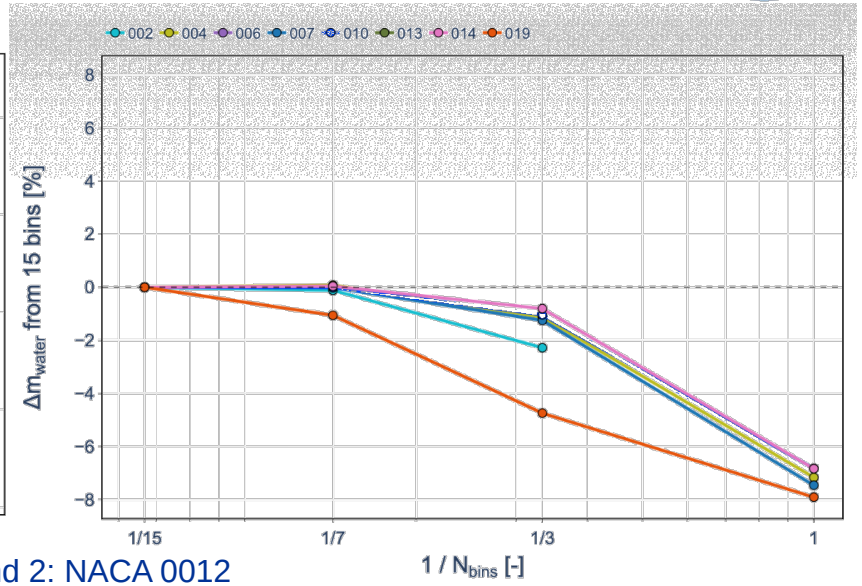
This workshop asked for a ton of data and we received a ton of data. We are only just starting to really digest and process everything. Expect us to be reaching out for information after the workshop as we write the SAE 2027 Summary Paper.

Bin Refinement Convergence

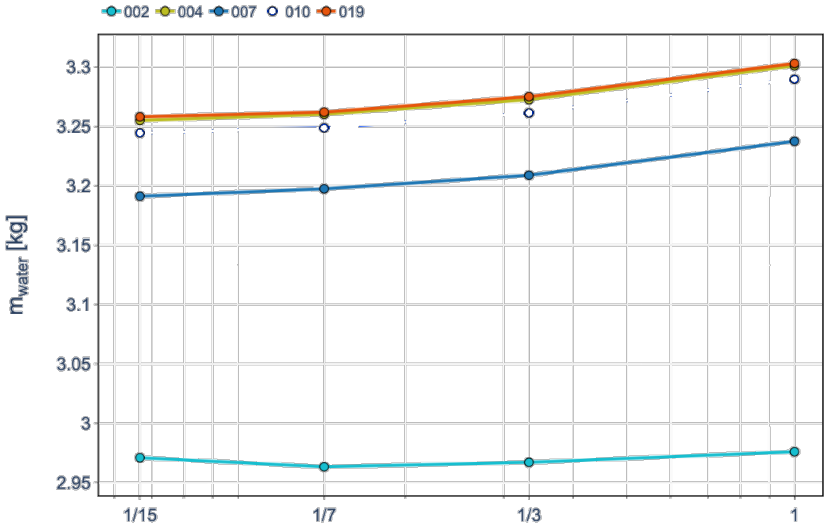
- Both cases show consistent refinement behavior
- In an ideal state, the values of Δm_{water} converges consistently across bins
- Rate of change from bin refinement is well agreed across participants
- The NACA 0012 case does show a spread in the delta for each refinement level
- The ONERA M6 case shows tight alignment with refinement $\%\Delta m_{water}$
- The differences in Δm_{water} convergence trends can likely be attributed to modeling setup

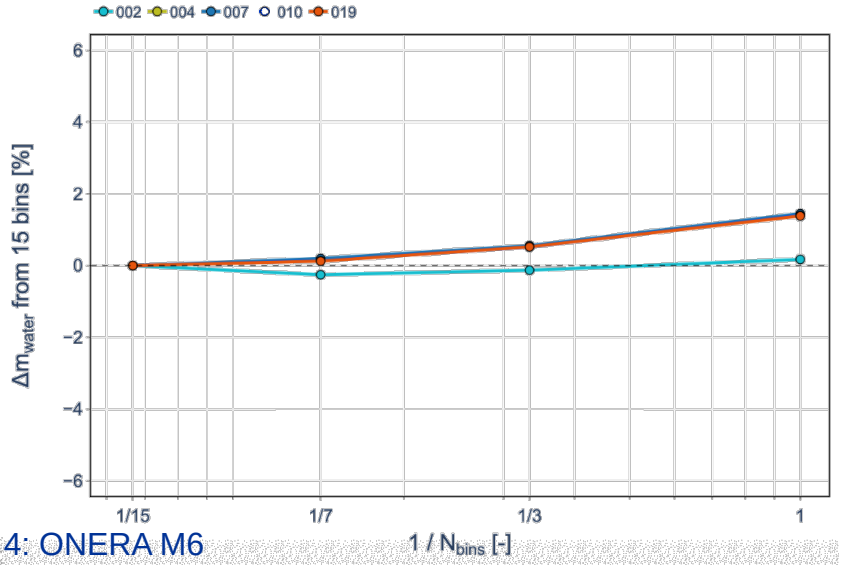
Better agreement on in-tunnel modeling techniques are needed to improve computational alignment





Figures 1 and 2: NACA 0012





Figures 3 and 4: ONERA M6

Grid Convergence

- Limited grid sensitivity on the NACA 0012 cases for 15 Bin distribution
- Increased grid sensitivity seen on ONERA M6 cases, but the coarsest grid is 122K nodes
- We see no clear trend with Lagrangian vs Eulerian methods
  - Likely caused by simplicity of the cases
  - A more complex case could elucidate more discrepancies
- Participant 19 and 4 show strong agreement in ONERA M6 with weaker agreement in NACA 0012
  - Believed to be setup-based discrepancies not code based
- The convergence rates of similar numerical schemes being different remains an open question

Figure 1: NACA 0012

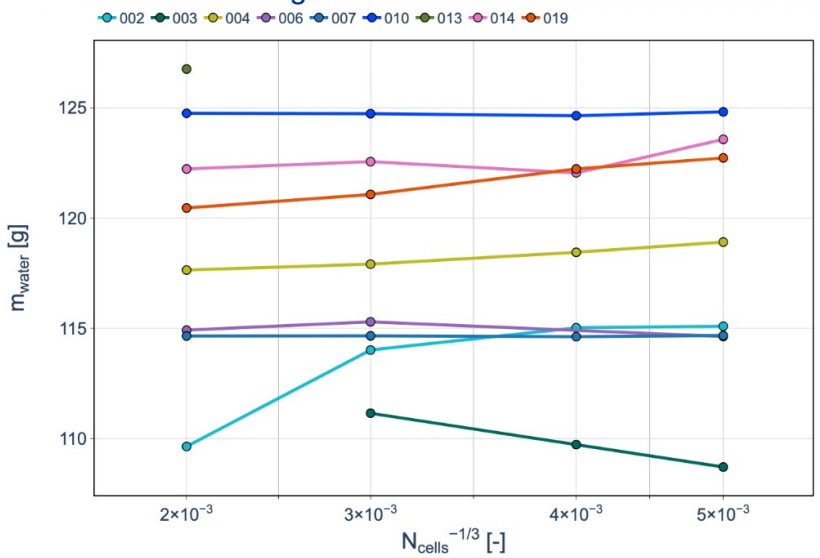
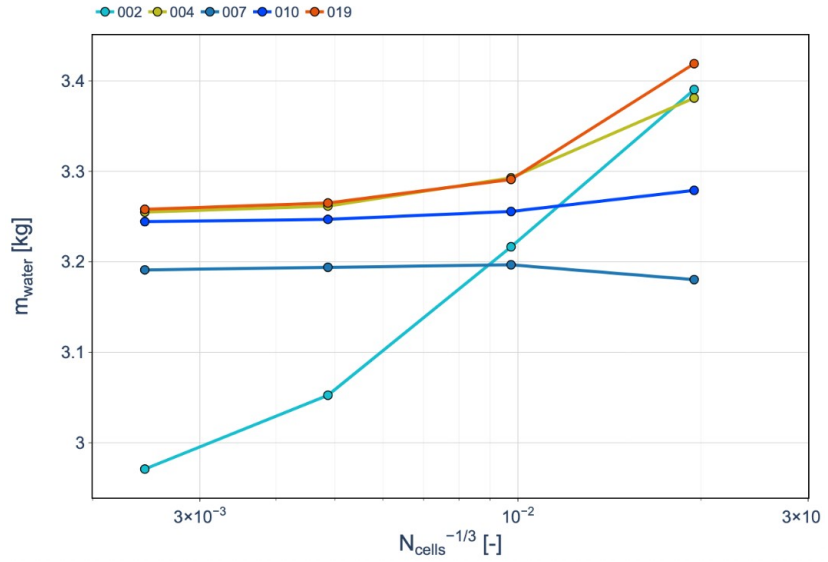
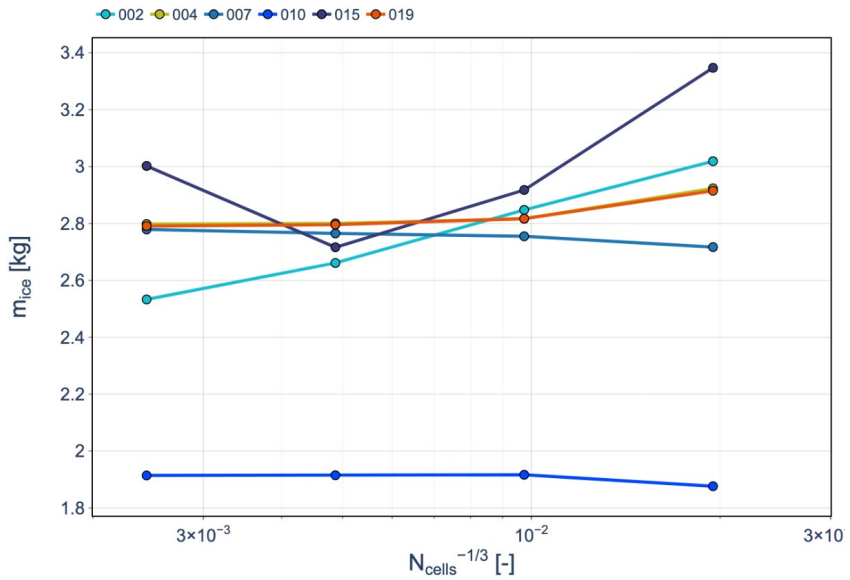


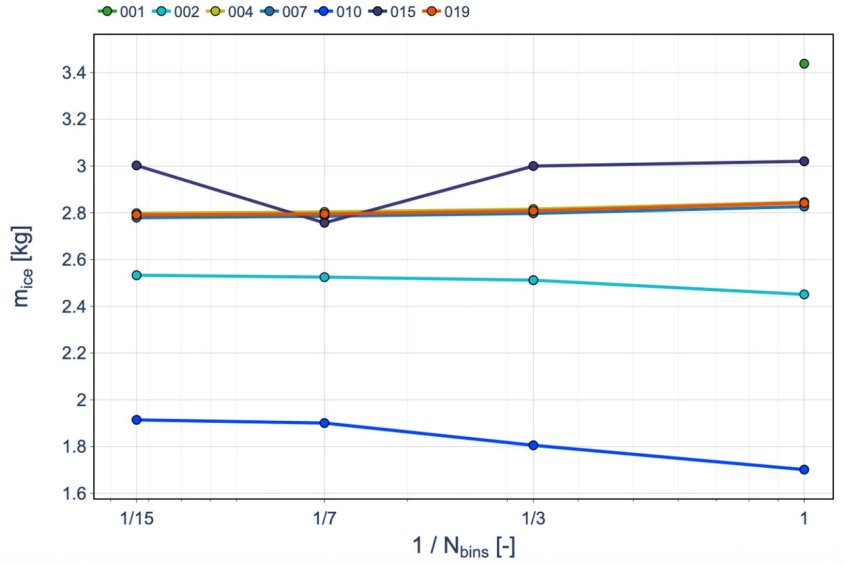
Figure 2: ONERA M6



ONERA M6 1 [mm] Ice Mass Convergence

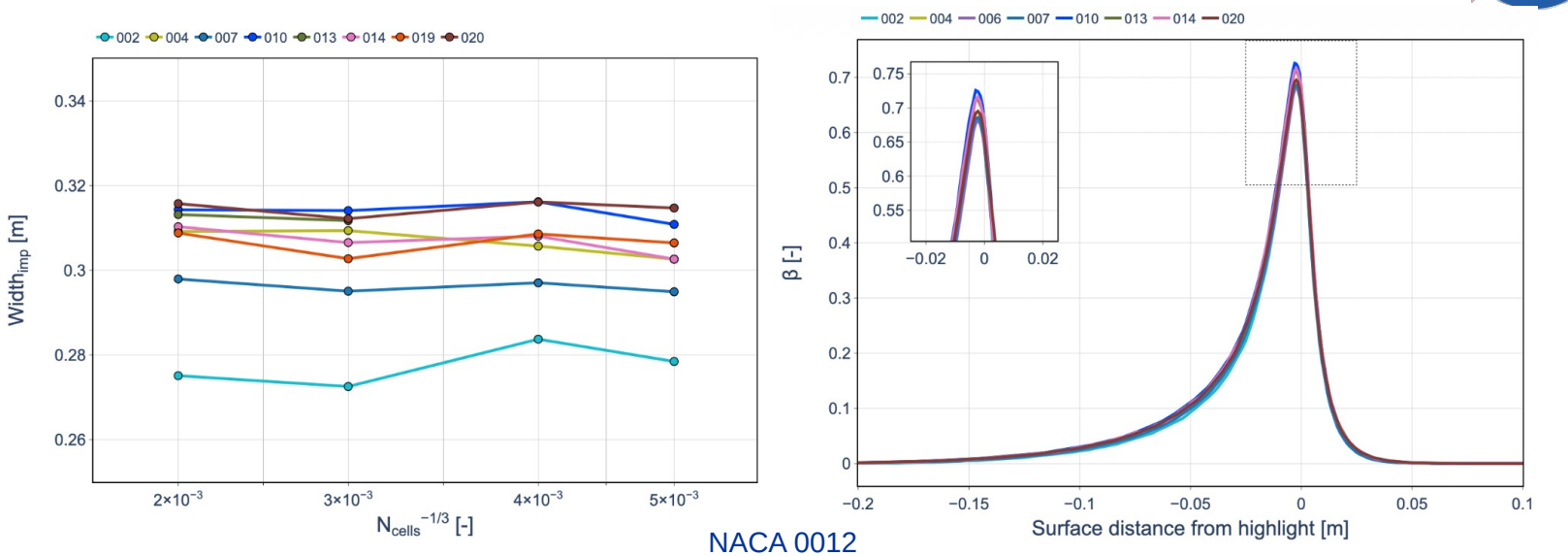
- Using the 15-bin solution vs grid size and Level 1 solutions vs Bin size
- Great agreement in ice mass is seen between participants 004, 007, and 019
- Participants 004 and 019 trend together well for grid refinement
- All three are Eulerian based tools
- For the NACA 0012, we did not see this level of agreement between these three participants



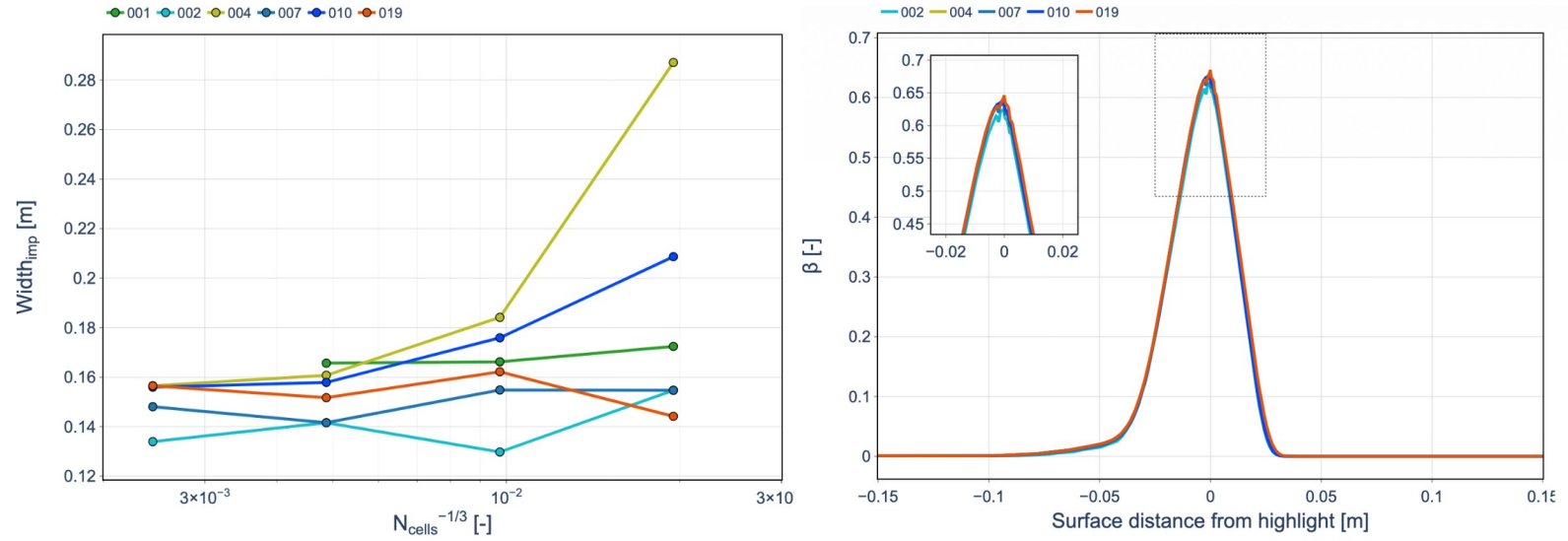


Impingement Agreement

- Impingement looks well aligned over the range of solutions provided
- Impingement limits were well agreed upon between participants
- The location of maximum impingement was not converged
- Impingement width agreement was excellent on the ONERA M6 between participants 004, 010, and 019
- The impingement width was well grouped for the NACA 0012



NACA 0012



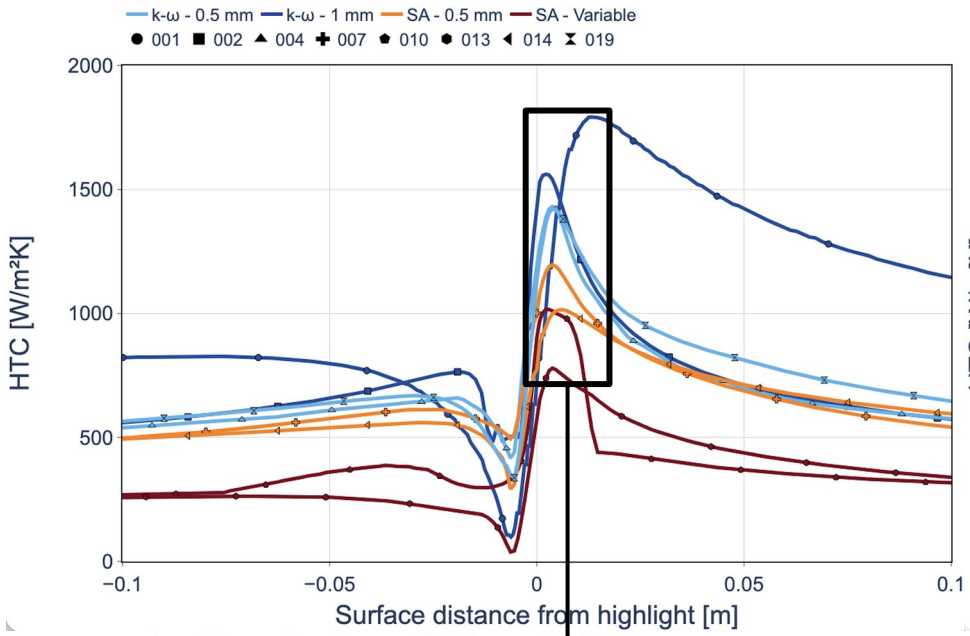
ONERA M6

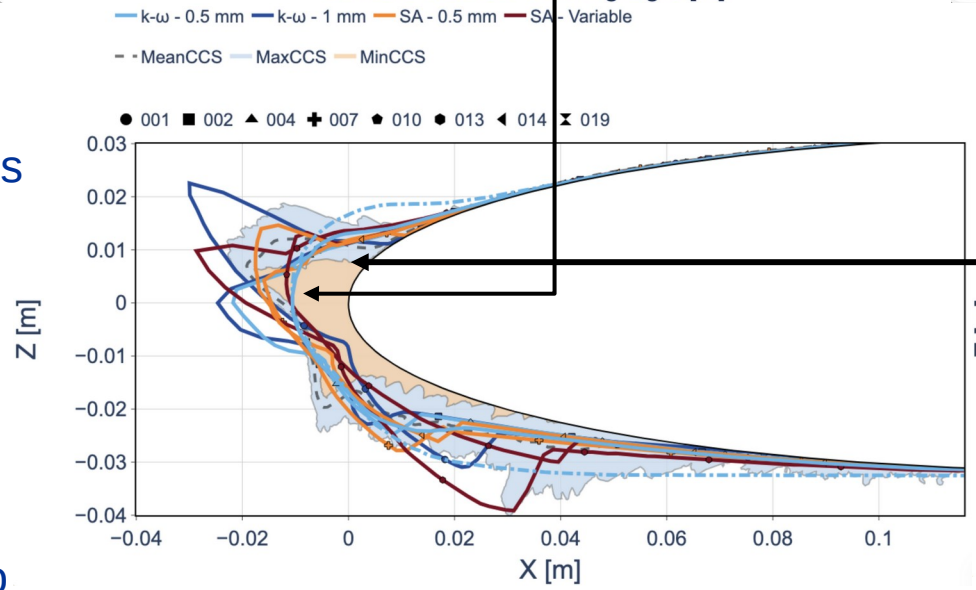
HTC Agreements and Disagreements

- We see upper surface enhancement agreement across participants
- Lower surface enhancement sees more spread
- AE3933 shows strong agreement across cases
- There exists an inconsistency in the value of HTC is being computed for similar roughness values
- There exists discrepancies in the path to computing HTC

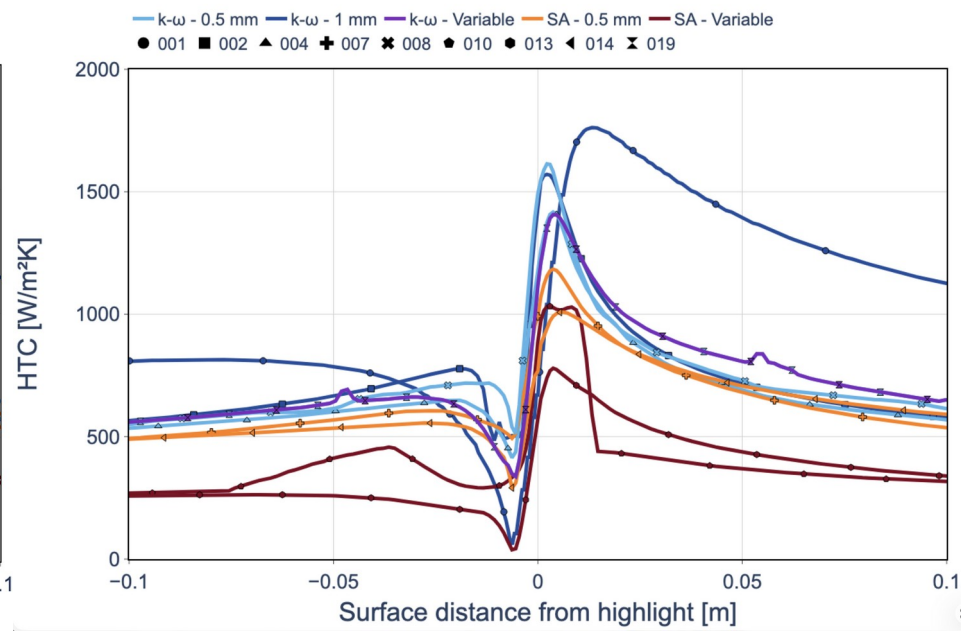
Agreement of ice shapes is favorable, while density and extrusion methods continue to play a strong role

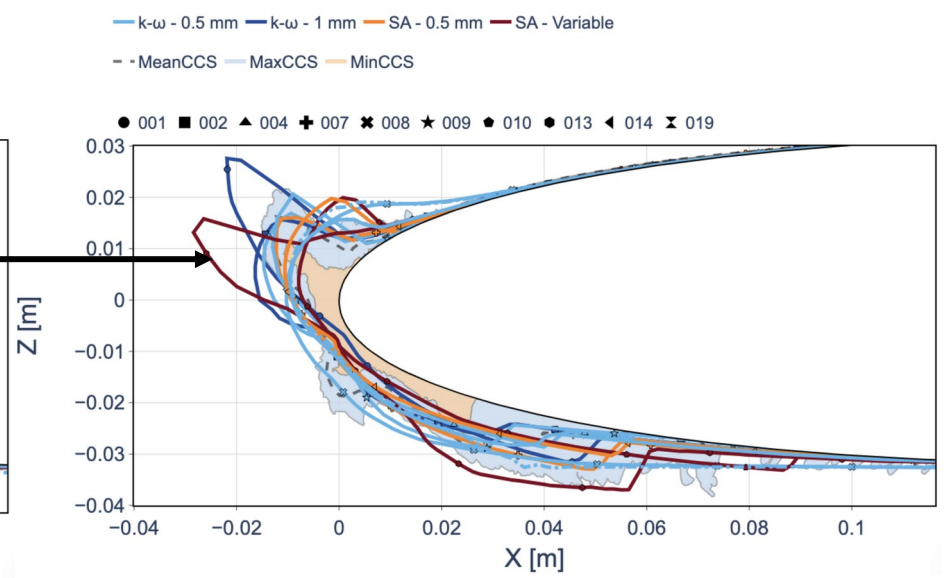
AE3932



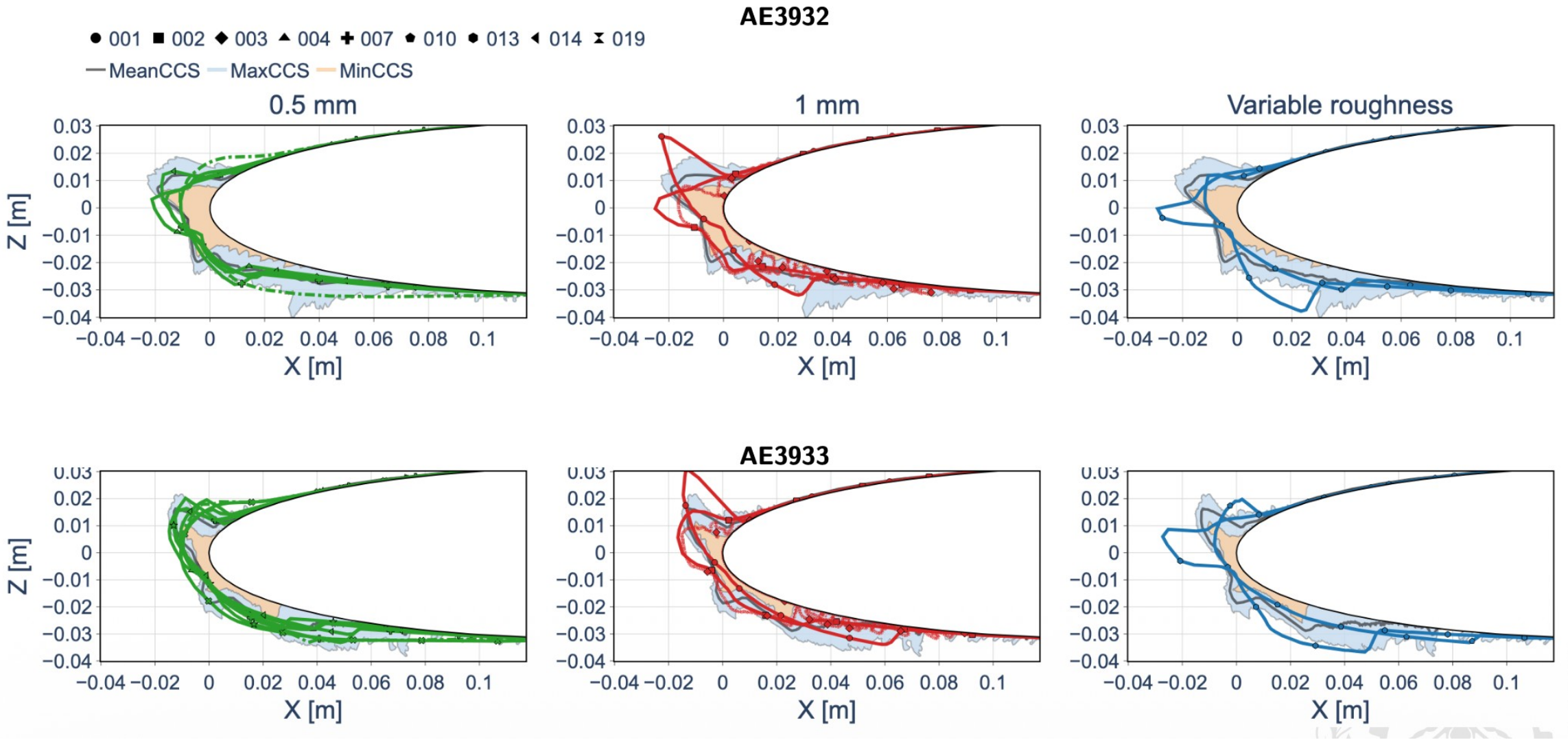


AE3933



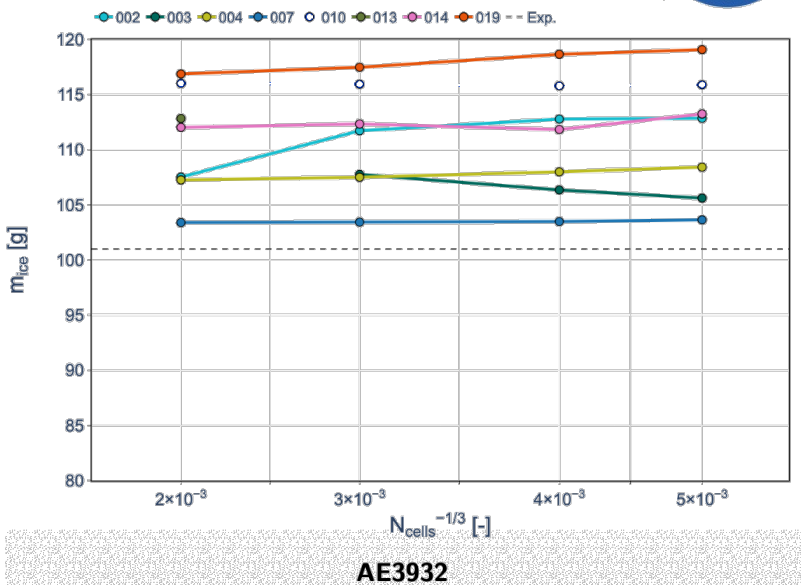


Continued Agreement in Ice Shapes for AE3933 over AE3932

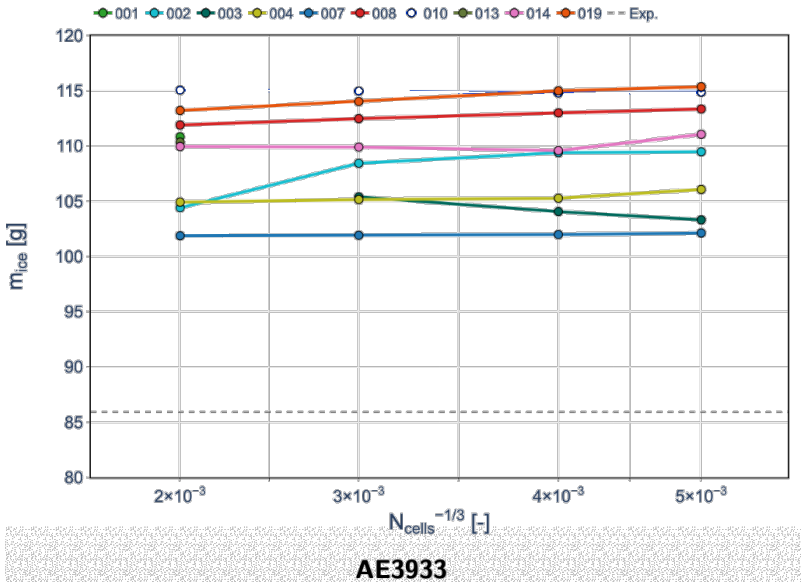


Temperature Changes on NACA 0012 Mass

- This was the first time we really asked for mass as a primary response for comparison
- We see only a small decrease in mass experienced by all participants
- Experimental change in mass of the experiment was around 15%
- We know these solutions to be converged and that the evaporation alone is driving the change
- A few things remain open from this analysis:
  - Is there something we are incorrectly modeling
  - Should we be considering splashing
  - What do more unsteady accretion workflows produce
  - Are the codes overpredicting runback
  - Can we adjust experimental practices to inform misalignment
  - Is there significant shedding during the accretion



AE3932

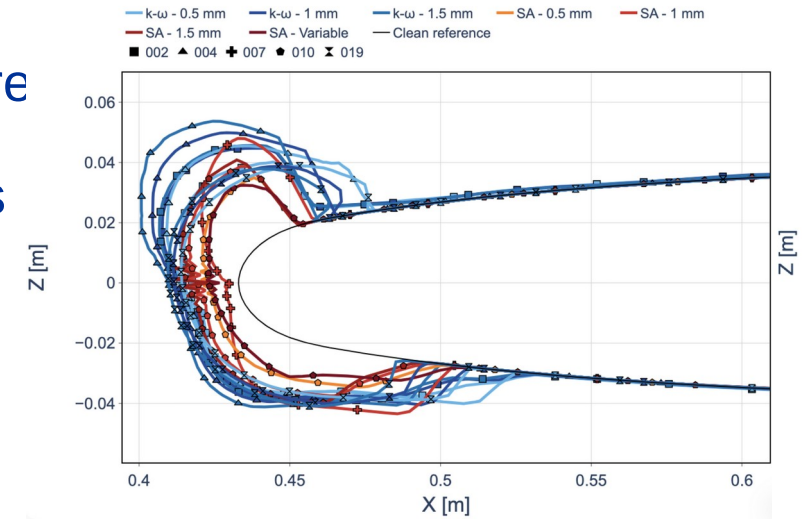


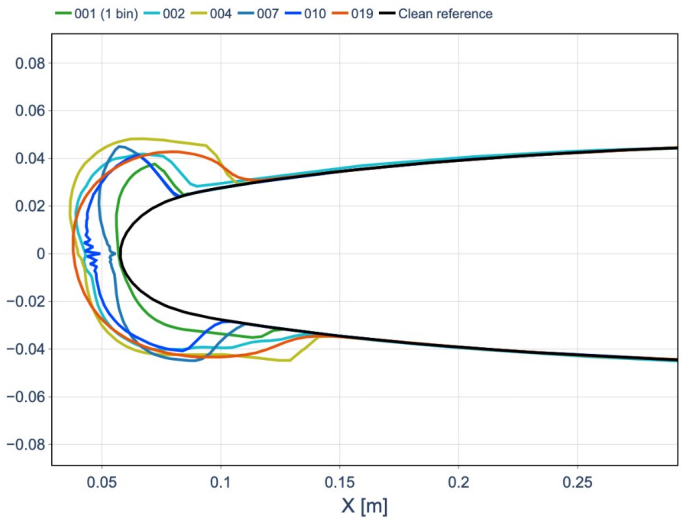
AE3933

ONERAM6 Ice Shapes

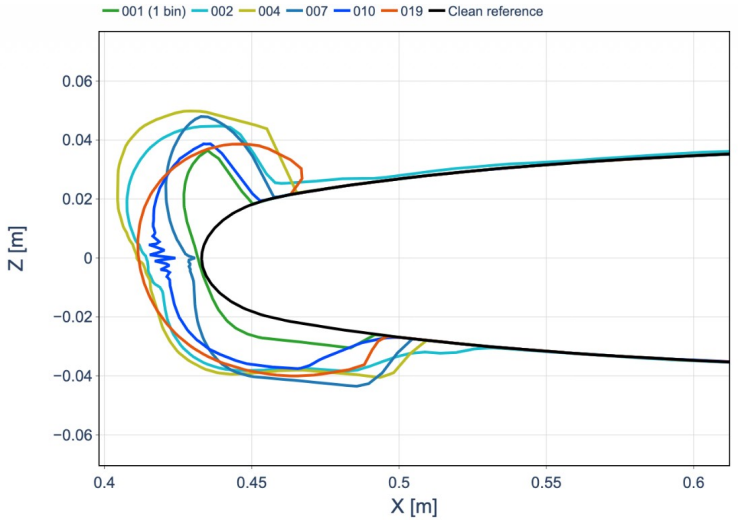
- Density and roughness height were held constant
- Results that had consistent values of ice mass have different shapes
- We see 2-eqn models typically generating larger shapes than 1-eqn
- Across all solutions, we can actually recover rather similar shapes

Ice shape discrepancies seem to be driven by a misalignment in the computed value of HTC that a given roughness height produces and the method in which the shape is grown

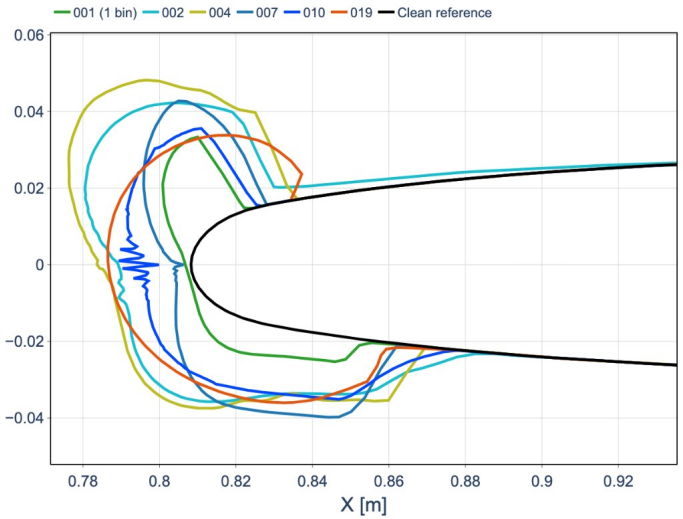




$y = 0.10$ m



$y = 0.75$ m



$y = 1.40$ m

High-Level Takeaways

- Agreement between solutions is possible
  - Difficulties in alignment for in-tunnel simulations
- Solutions were robust against grid refinement for these cases
  - Robustness on more complicated cases remains open
- Convergence of bin sizes was incredibly well behaved
  - Every participant trended consistently
  - This should be examined for large drop configurations
- The method to refine the IRT distribution was seen to be numerically sound
  - What is the right distribution for tunnel evaluation remains open
  - What is necessary to replicate remains open
- The warmer NACA 0012 case saw improved solution grouping compared to the colder case
  - Likely relates to the amount of water being frozen by the available amount of heat convection
- The ONERA M6 ice shapes exhibited good agreement
  - HTC vs roughness height misalignment
  - Extrusion methodology impacts
  - If we are after code agreement, this is a good setup for doing so
- The discrepancies in computed and experimental ice mass remain unclear
  - Are the models missing something
  - Is the experimental data incomplete
  - How do unsteady evaluations compare to these data
- A highly systematic set of cases has been generated that will allow for the evaluation of codes going forward
- Now that we have a process to establish uncertainty in our computational solutions, it is likely we should compare this to our experimental solutions.
  - Uncertainty quantification applied to icing

Acknowledgements

- I’d like to thank Mateusz Pawłucki from Collins Aerospace Poland for his work generating the NACA 0012 grid family
- I’d like to thank Karim Zayni for all his hard work getting our new GitHub website up and running along with the generation of all the wonderful plots
- I’d like to thank all of our participants who provided data for the workshop
- I’d like to thank the organizing committee for the leadership
- I’d like to thank AIAA for hosting