Ice Prediction Workshop 3 (IPW3) Results: 21-inch NACA 0012 Case

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

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Ice Prediction Workshop 3 (IPW3) Results 21-inch NACA 0012 Case Description

TFG–2

9/23/2026

Soroush Yazdani

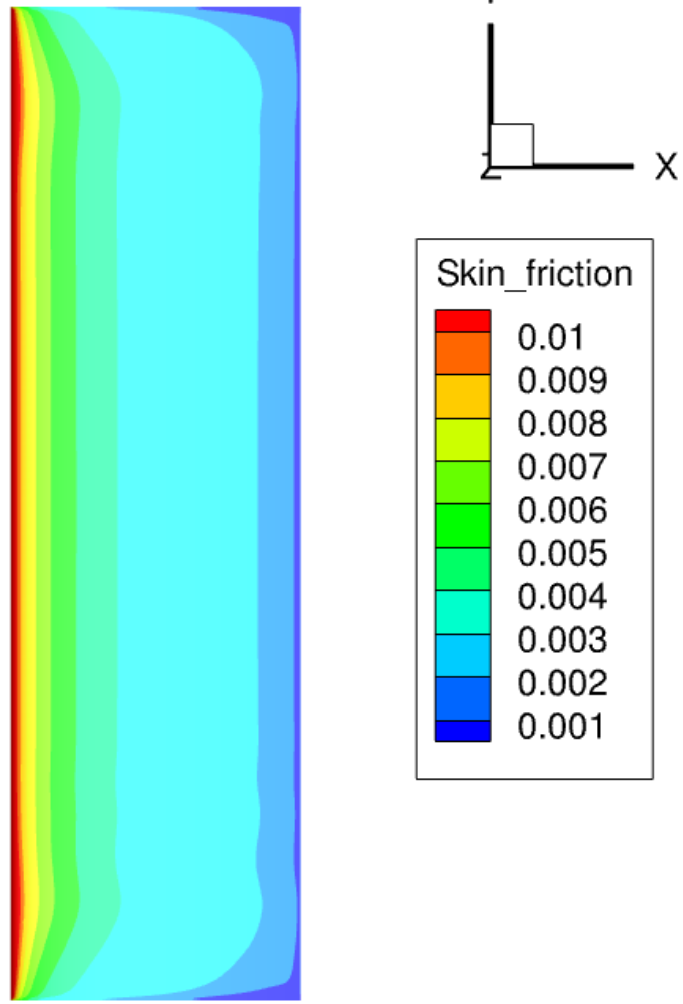
- Presentation covers IPW-3 TFG-2 results for the 21-inch NACA 0012 wing.
- This presentation and the spreadsheet of ice shapes will be provided to the IPW3.
- Ice shapes were generated with two versions of GlennICE (v5.1 and v6.2). Both versions' shapes are shown in this presentation and included in the delivered dataset.

Model / Method	NACA0012	ONERA M6
CFD Model	RANS	N/A – not run
Turbulence Model	SA	N/A – not run
HTC Method	One solution method + Reynolds analogy	N/A – not run
Droplet Formulation	Lagrangian	N/A – not run
Droplet Drag Model	Spherical	N/A – not run
SLD Effects	None	N/A – not run
Thermodynamic Model	Messinger	N/A – not run
Ice Density Model	Constant (450 kg/m³)	N/A – not run
Surface Roughness	Variable – McClain (KS_VAR)	N/A – not run
Geometry Evolution	Extrusion Method	N/A – not run
Ice Accretion Steps	Single-shot (1 layer, 15 bins)	N/A – not run

Roughness permutations run: Variable (McClain, KS_VAR). ONERA M6 was not run for this submission (N/A).

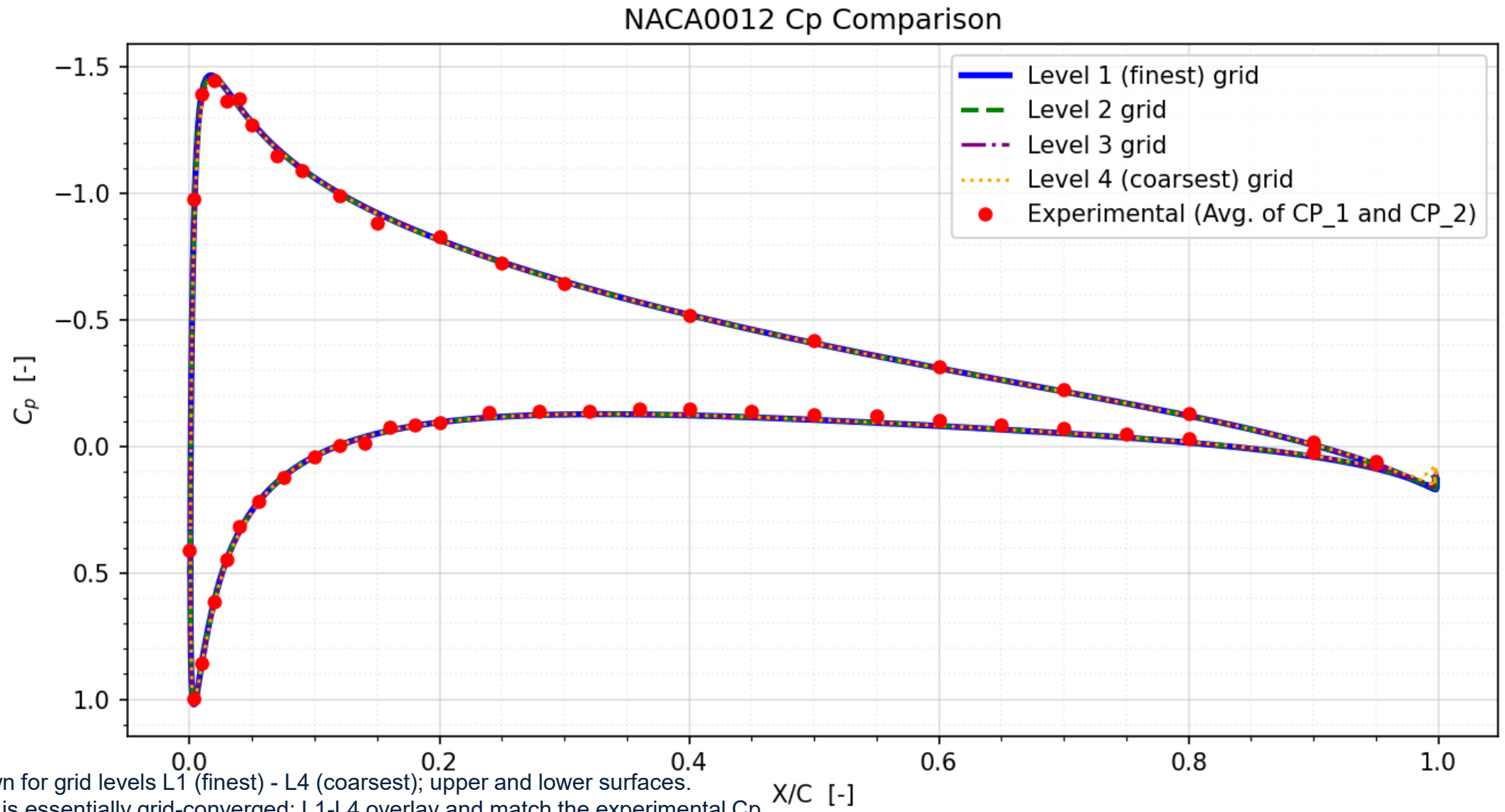
- CFD++ (Version 20.1)

- RANS - steady
- SA turbulence model
- No Slip (Viscous) Walls in the tunnel section
- Committee provided grids used



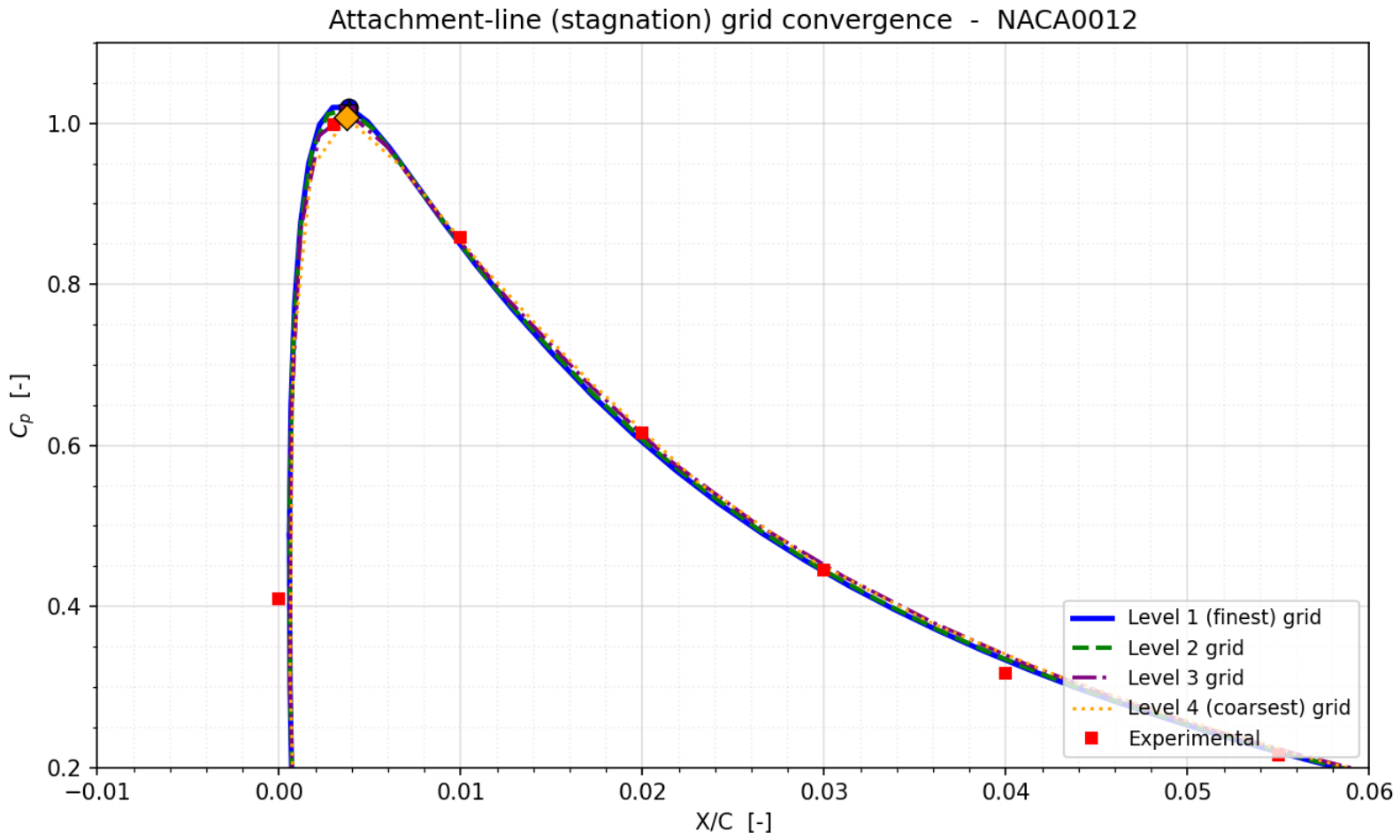
	CL	CD	CM
Lvl 1 (finest)	0.432	0.0113	0.0015

Cp grid convergence (Y = 36 in) vs. experiment

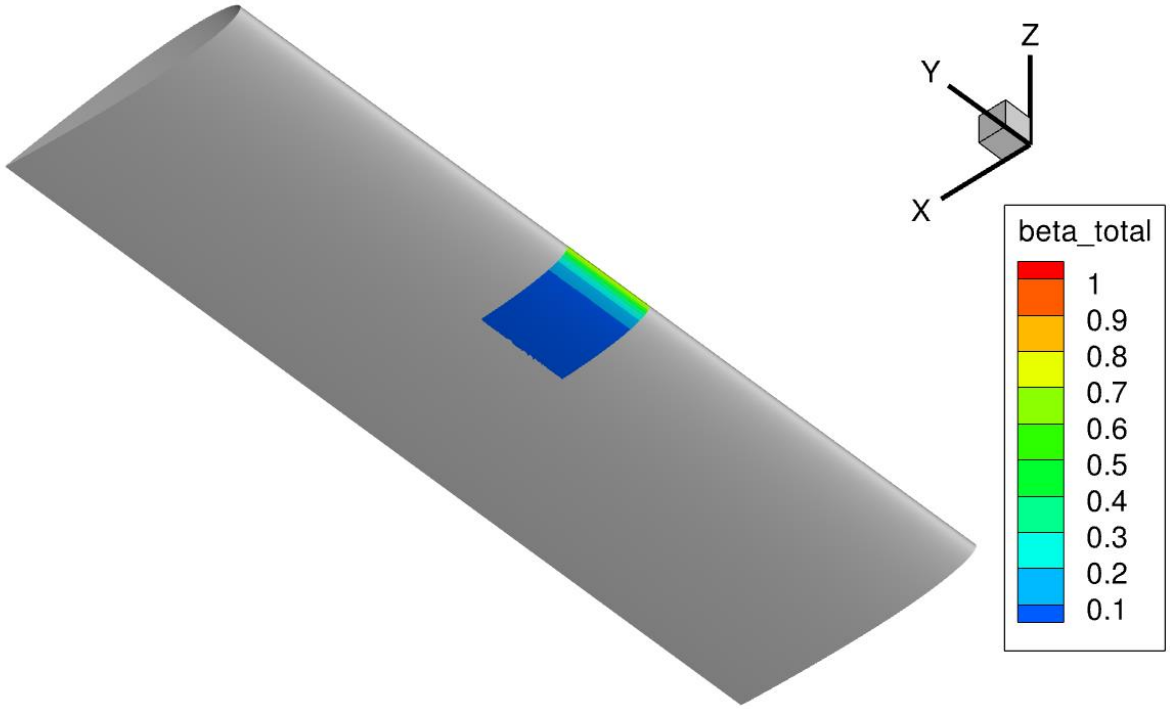


- Cp shown for grid levels L1 (finest) - L4 (coarsest); upper and lower surfaces.
- Solution is essentially grid-converged: L1-L4 overlay and match the experimental Cp.
- Minor scatter near x/c 0.7-0.9 on coarse levels reflects reduced surface-point density.

Grid	X/C stagnation	Cp max
Level 1 (finest)	0.00384	1.0197
Level 2	0.00381	1.0177
Level 3	0.00378	1.0130
Level 4 (coarsest)	0.00373	1.0071



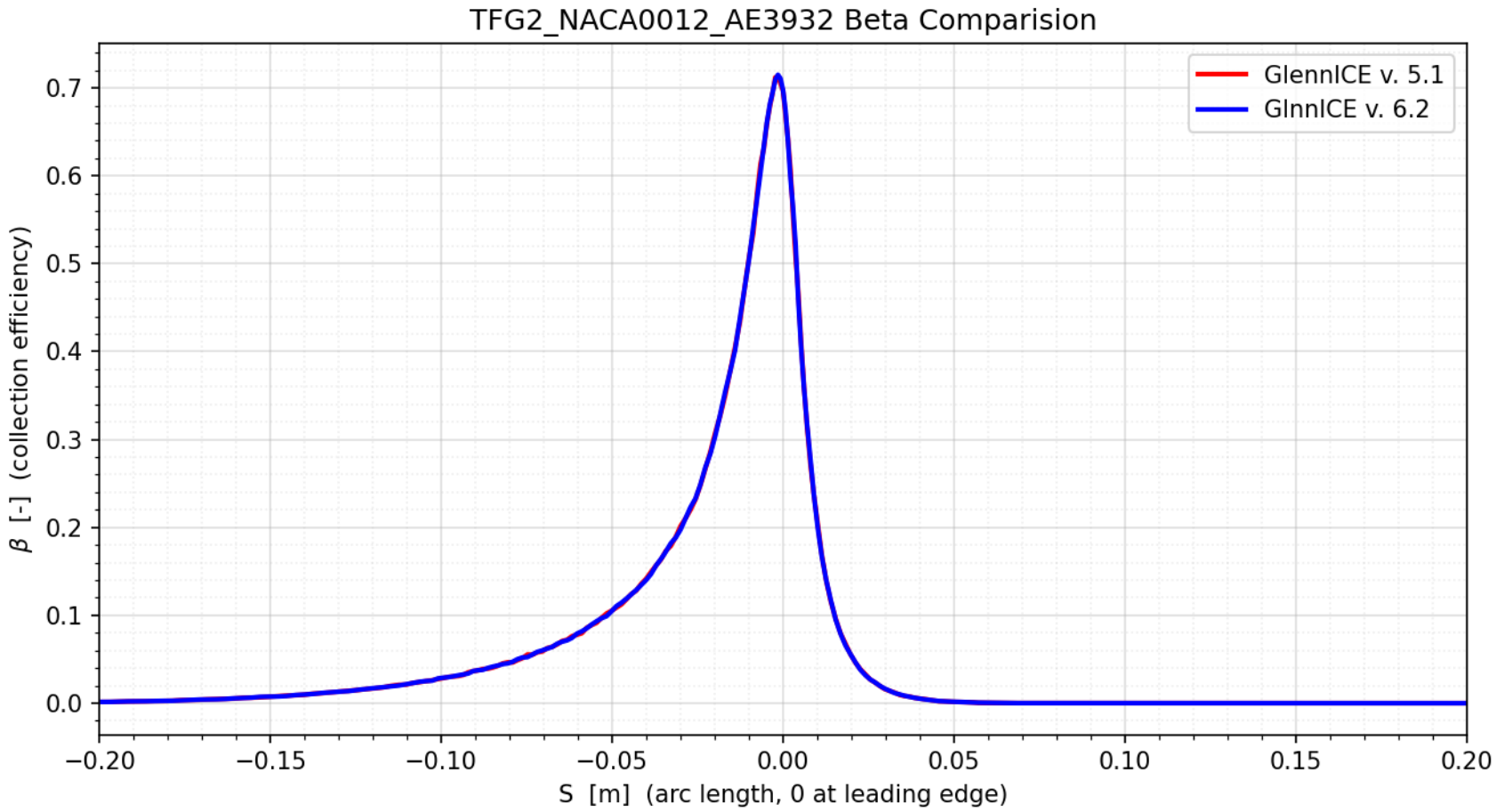
GlennICE (Version 5.1 & 6.2)



- Ice growth on 3D shapes
- Droplet trajectories and collection
- Heat transfer effects
- Surface roughness effects
- Restart runs and output files for visualization

For IPW3 these values has been

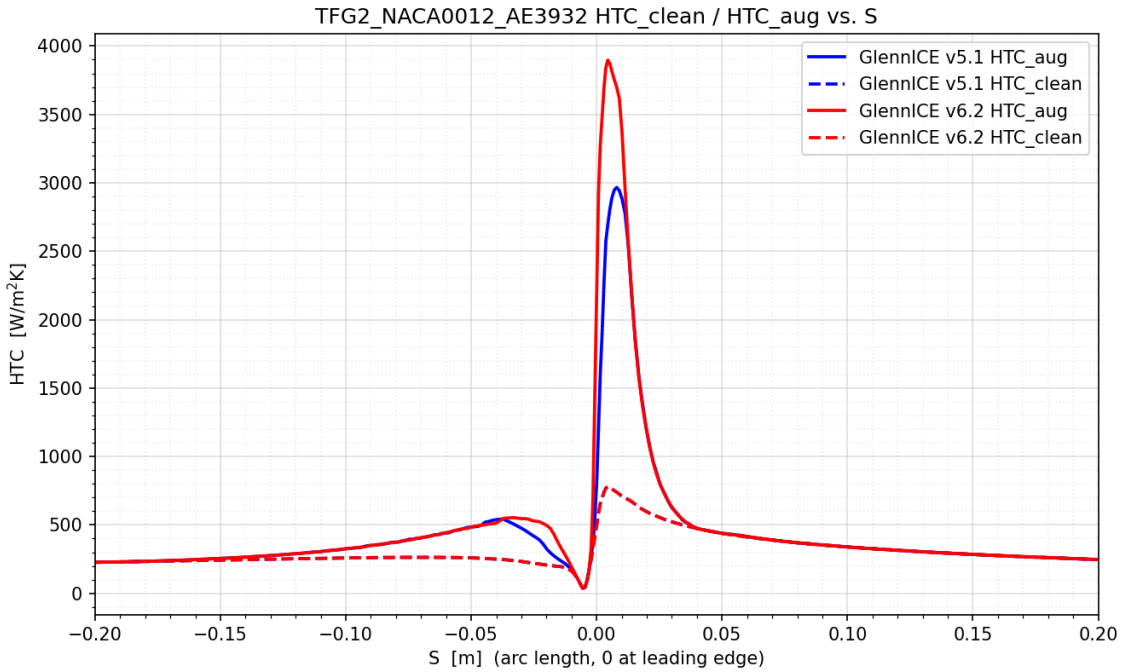
- The McClain roughness value was used for this exercise
- Ice density constant 450 kg/m^3
- Below is the report of the GlennICE input file
  - AUGMENTATION_TYPE = 'McClain_roughness'
  - TURBULENT_HTC_AUGMENTATION = 1
  - IDEAL_RIME_LIMIT = 0.004



Lower surface

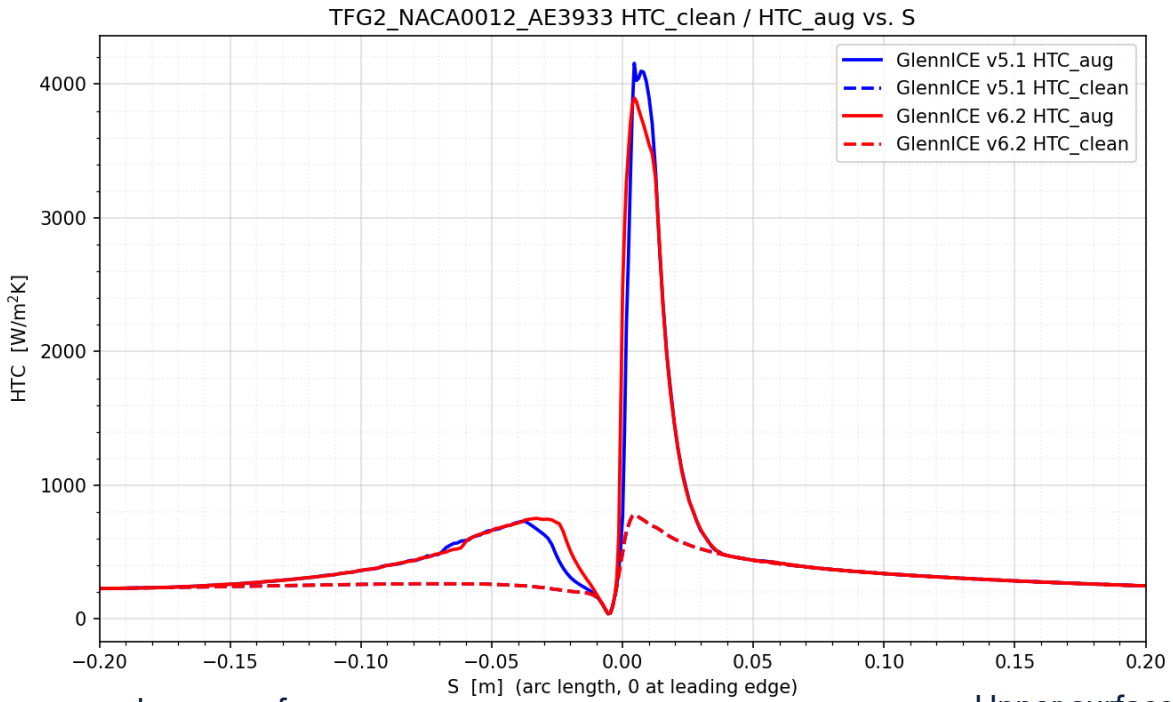
Upper surface

HTC/HTC_Clean comparison



Lower surface

Upper surface



Lower surface

Upper surface

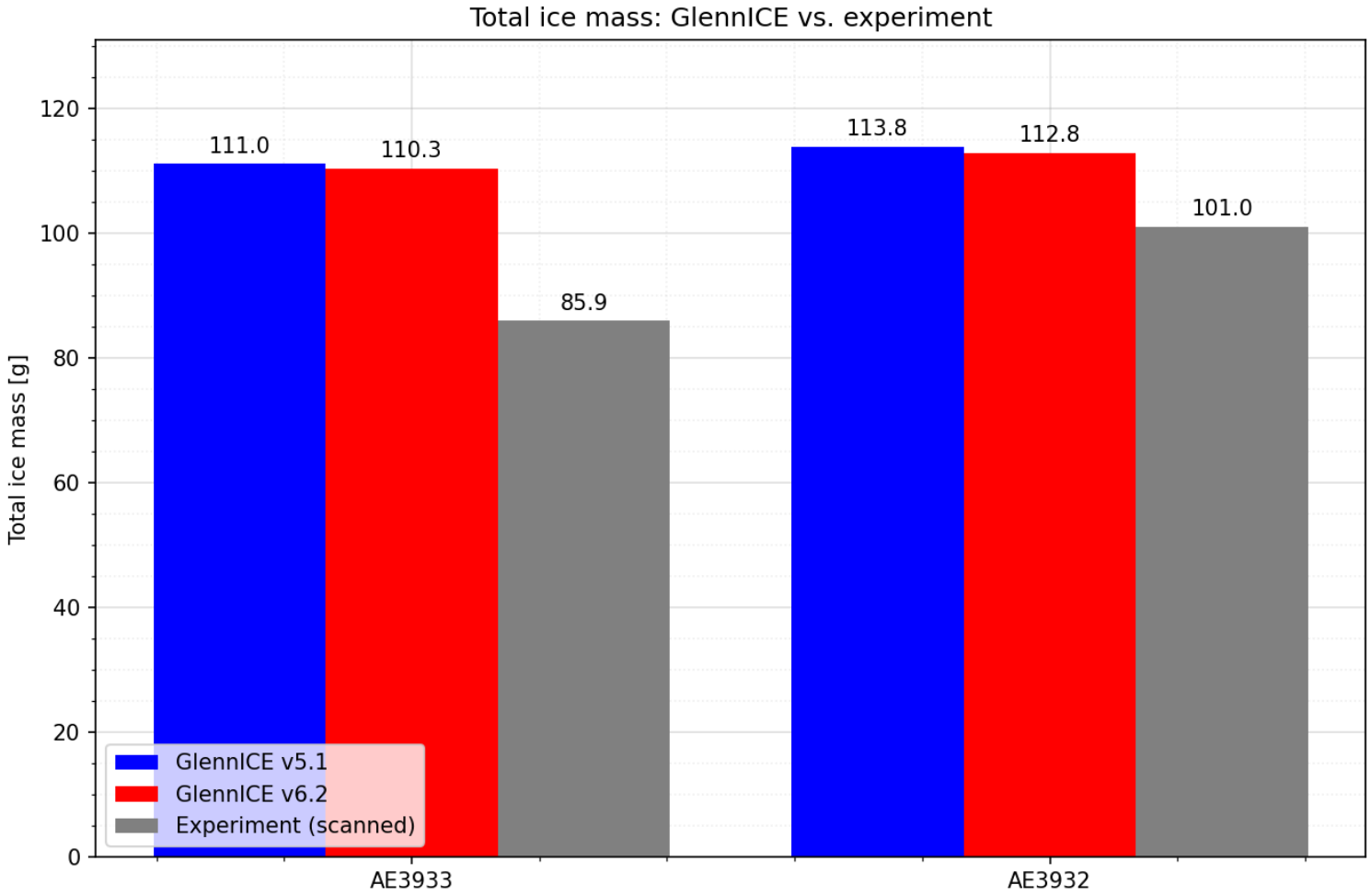
GlennICE version 6.2	AE3933	AE3932
Ice mass (g)	110.35	112.84
Water mass in (g)	124.1	126.76
Ice density (kg/m^3)	450	450
Ice Volume (in^3)	15.0	15.3

GlennICE version 5.1	AE3933	AE3932
Ice mass (g)	111.05	113.85
Water mass in (g)	124.1	124.1
Ice density (kg/m^3)	450	450
Ice Volume (in^3)	15.1	15.4

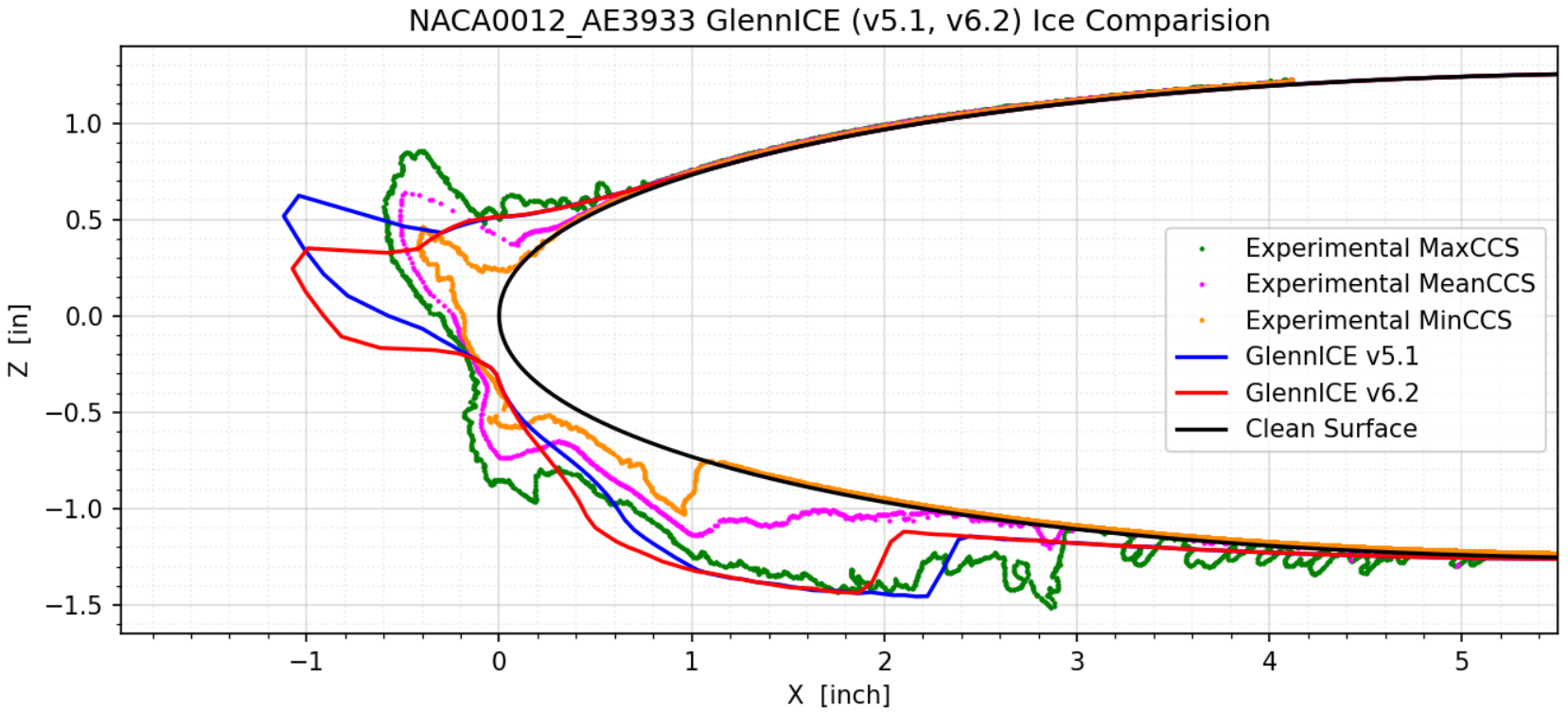
From Experiment

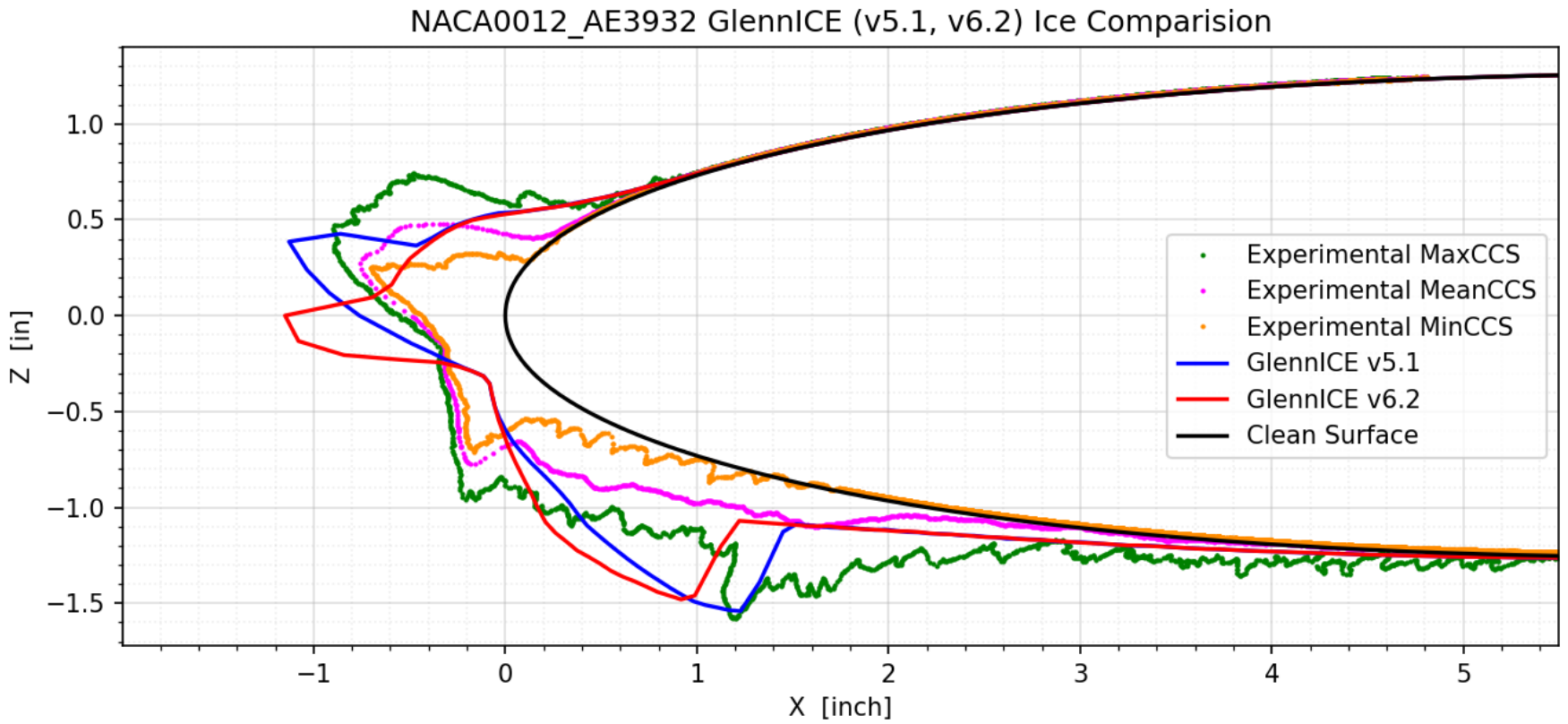
Run	Scanned Ice Volume (in^3)	MaxCCS Bulk Volume (in^3)	MeanCCS Bulk Volume (in^3)	MinCCS Bulk Volume (in^3)
AE3932	10.12	20.79360	10.49296	5.02496
AE3933	7.58	17.01280	8.51664	3.66856

Total ice mass vs. experiment



- GlennICE v5.1 and v6.2 total ice mass compared with laser-scanned experimental mass.
- Both versions over-predict mass vs. experiment (AE3933: ~110-111 g vs 85.9 g; AE3932: ~113-114 g vs 101.0 g).
- Experimental values are scanned bulk masses (E00 dataset / ice-properties workbook).


NACA0012_AE3933 GlennICE (v5.1, v6.2) Ice Comparision
Z [in]
X [inch]
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1
0
1
2
3
4
5
Experimental MaxCCS
Experimental MeanCCS
Experimental MinCCS
GlennICE v5.1
GlennICE v6.2
Clean Surface


NACA0012_AE3932 GlennICE (v5.1, v6.2) Ice Comparision
Z [in]
X [inch]
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1
0
1
2
3
4
5
Experimental MaxCCS
Experimental MeanCCS
Experimental MinCCS
GlennICE v5.1
GlennICE v6.2
Clean Surface

- Two GlennICE versions (v5.1 and v6.2) were run for the 21-in NACA 0012 at two icing conditions (AE3932, AE3933); both shape sets are delivered to the IPW3.
- Aerodynamics are grid-converged: Cp over grid levels L1-L4 overlays and matches experiment; the attachment-line (stagnation) location and peak Cp are essentially grid-independent (X/C ~ 0.0038, Cp_max ~ 1.02).
- Collection efficiency and HTC/HTC_clean distributions are consistent between the two solver versions along the surface.
- Ice shapes from both versions fall within the experimental Max/Min CCS envelope; version differences appear mainly at the leading-edge horns.
- Total ice mass is over-predicted vs. experiment for both versions (AE3933: ~110-111 g vs 85.9 g; AE3932: ~113-114 g vs 101.0 g).
- Icing was run single-shot at the finest mesh only (15 bins); coarser-mesh icing and multiple drop distributions were not run for this submission.
- Next steps: assess the mass over-prediction (density / freezing-fraction assumptions) and, if resources allow, icing grid-convergence and drop-distribution sensitivity.

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