

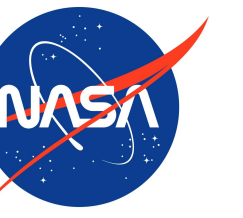


Progress Toward Evaluating Roughness-Resolved Aerothermodynamic Simulations for the Mars Sample Return Earth Entry System

Alireza Mazaheri*, Christopher Jonston*, and Grant Palmer†

*NASA Langley Research Center, Aerothermodynamics Branch, Virginia

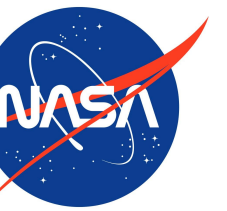
†AMA Inc. @ NASA Ames Research Center, Aerothermodynamics Branch, California



Contents

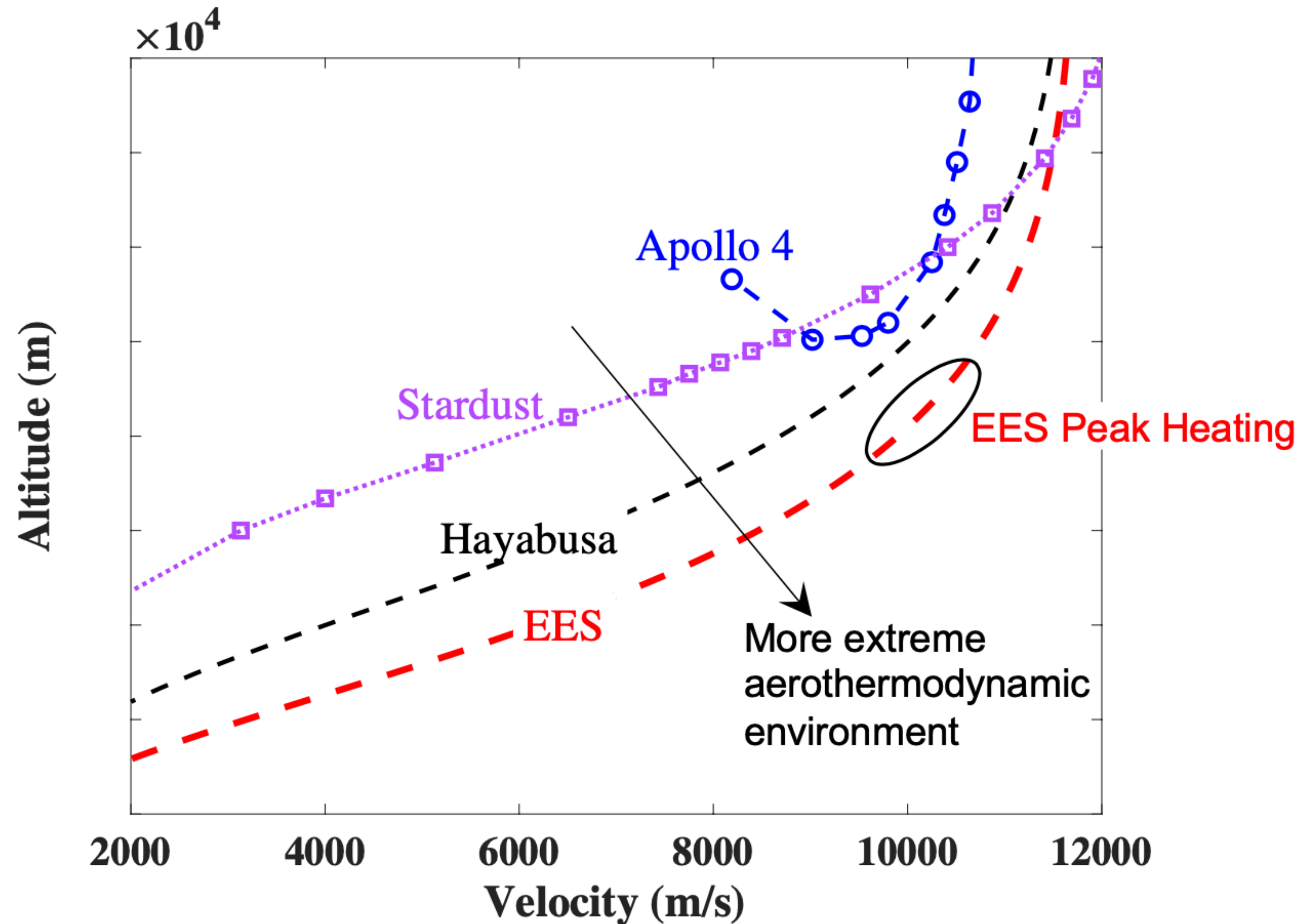
- Mars Sample Return (MSR) Earth Entry System (EES) overview
- Grid resolved roughness CFD procedure
- Verifications & Results
- Heating augmentation evaluation
- Contributions & future work

Earth Entry System (EES) Mission Profile

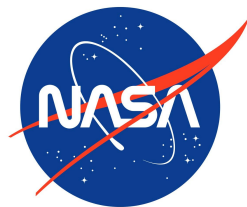


- Steep entry flight-path-angle
- A relatively large size capsule
- Highest peak heat flux of any NASA Earth Entry vehicle

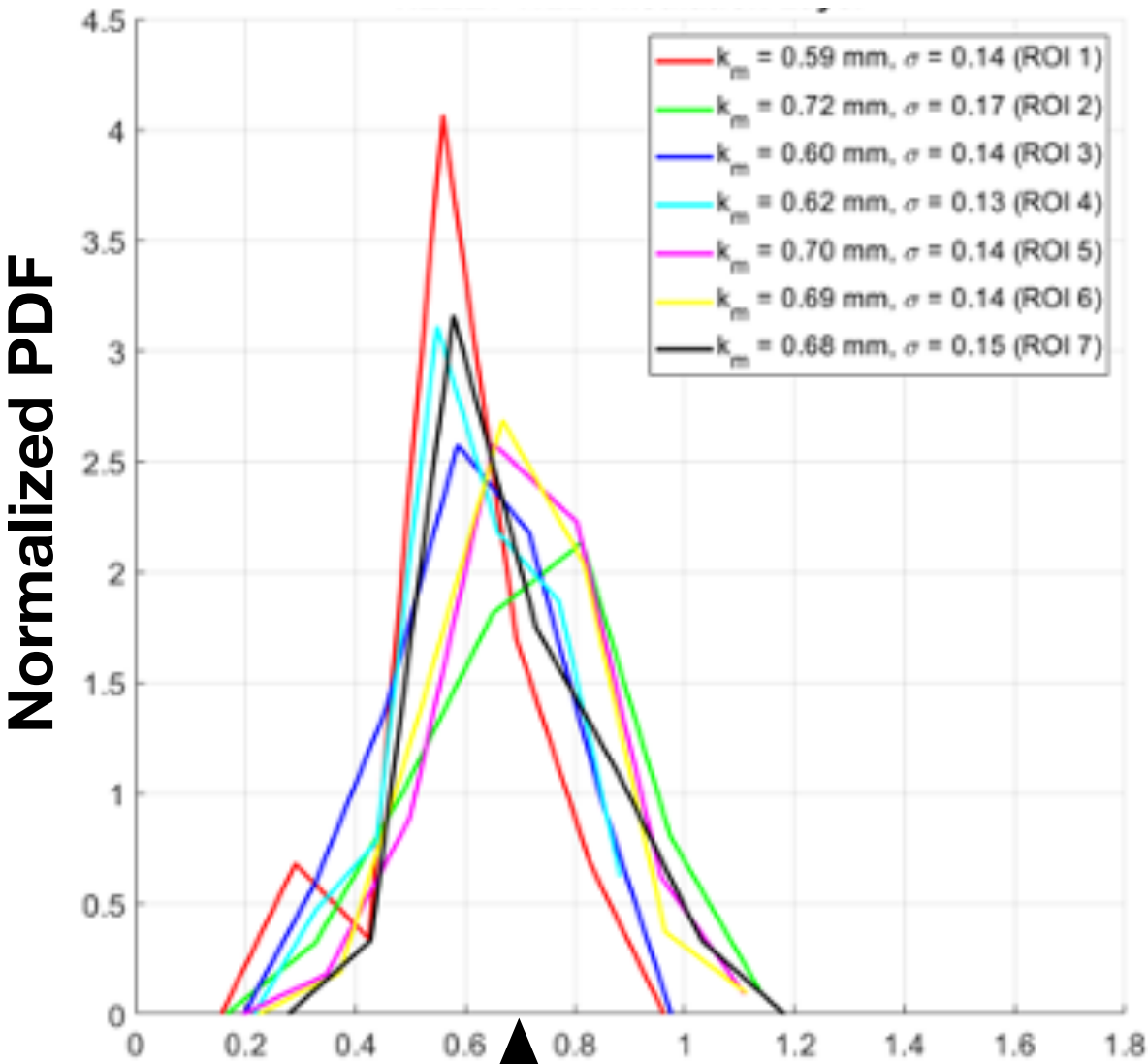
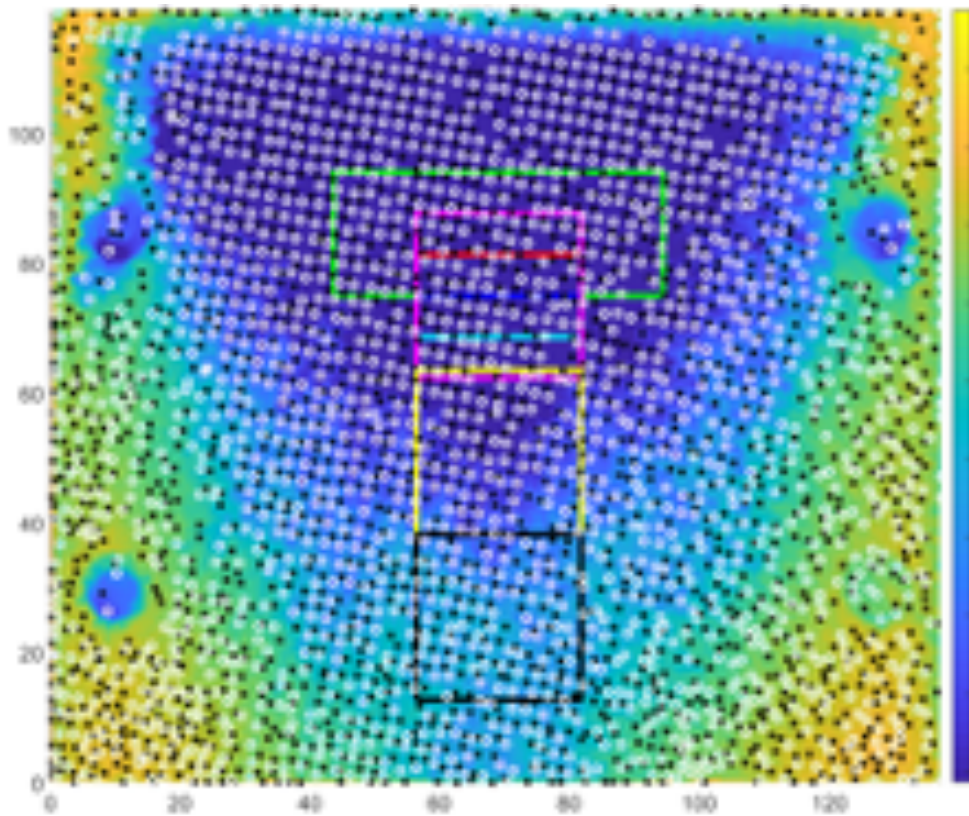
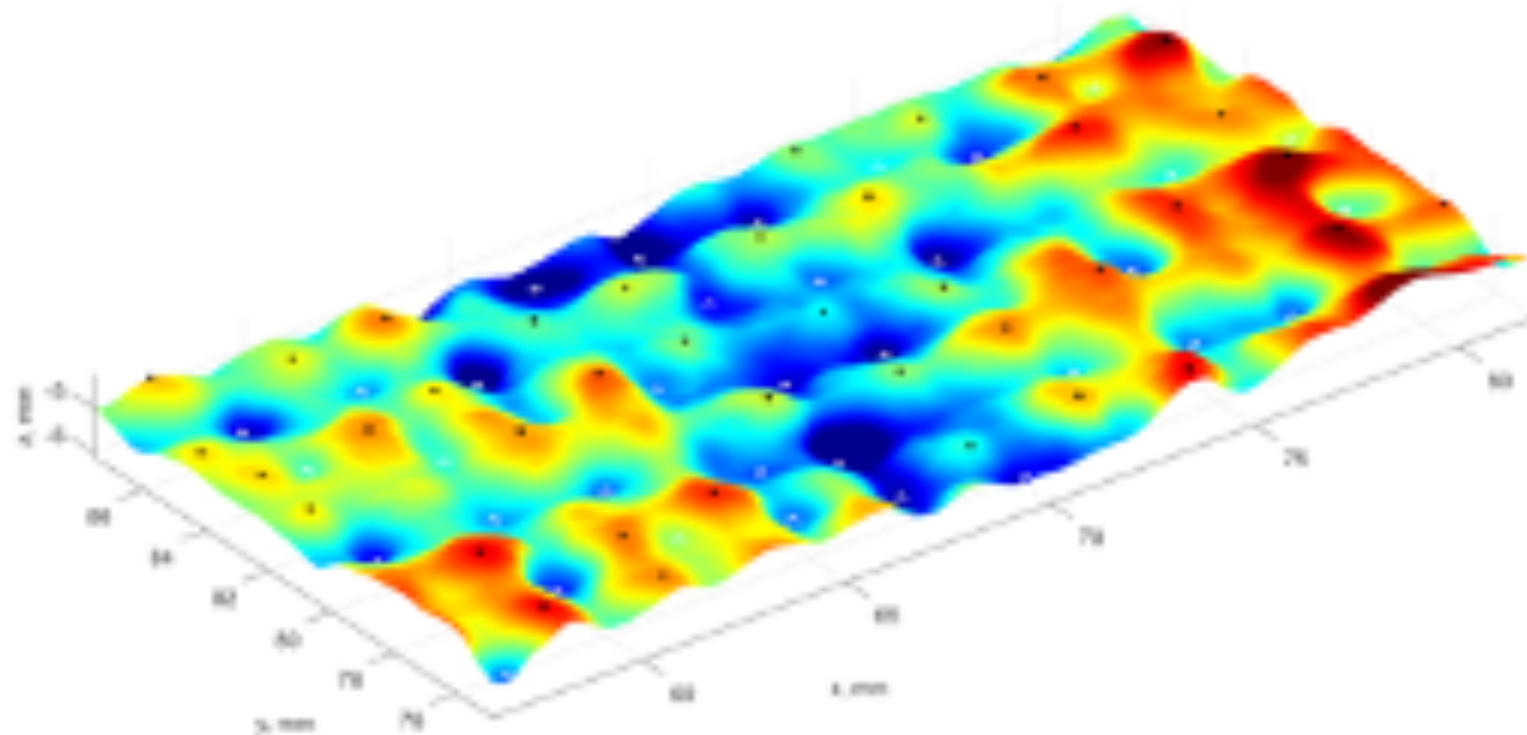
➡ Unprecedented turbulence & roughness



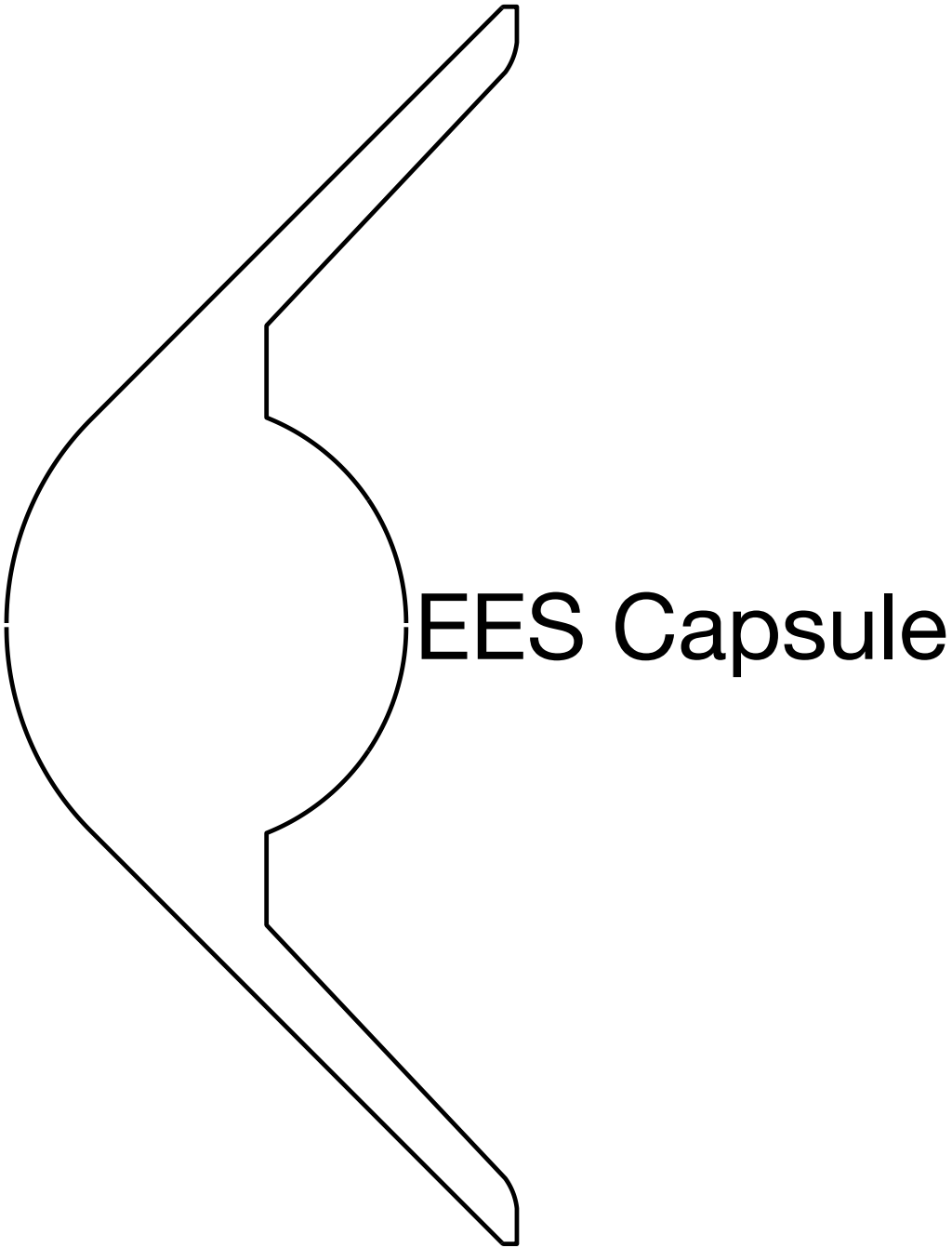
Post Arc-Jet Scan of the EES TPS Surface Roughness



EES TPS: 3D Medium Density Carbon Phenolic (3MDCP)



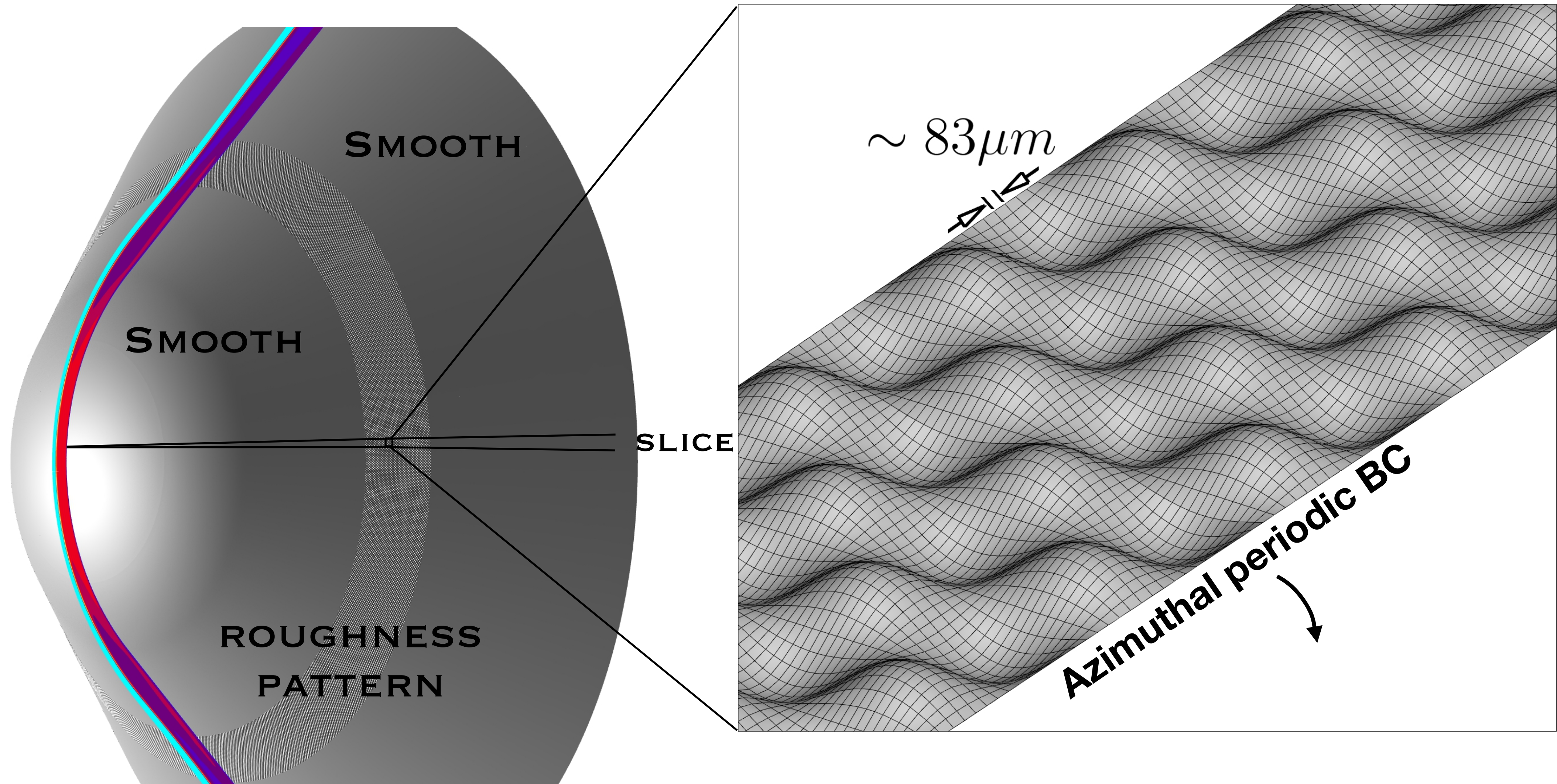
nominal value:
 ≈ 0.7 mm



Toward Grid-Resolved Roughness CFD

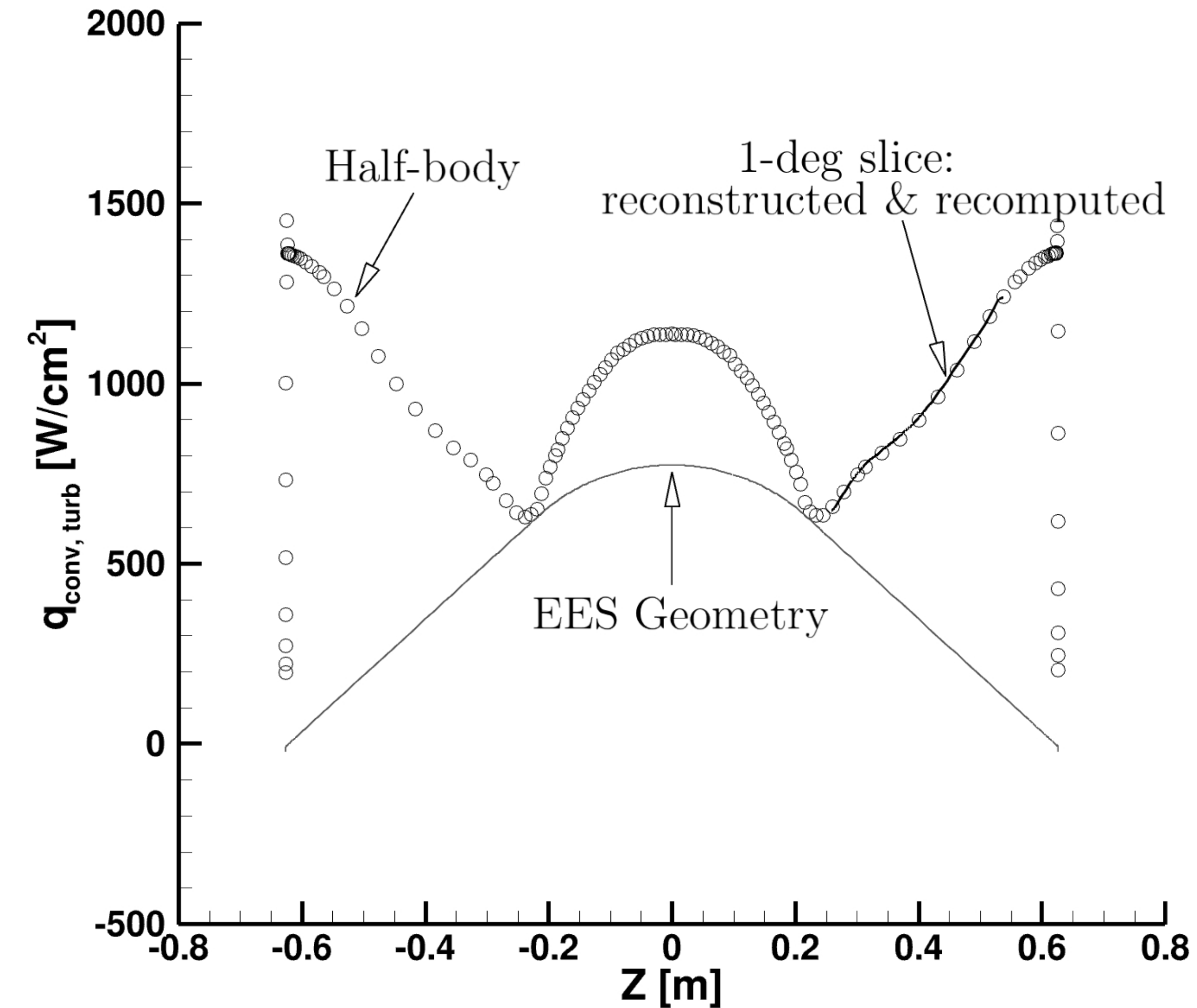
1.65B cells

4.5M cells

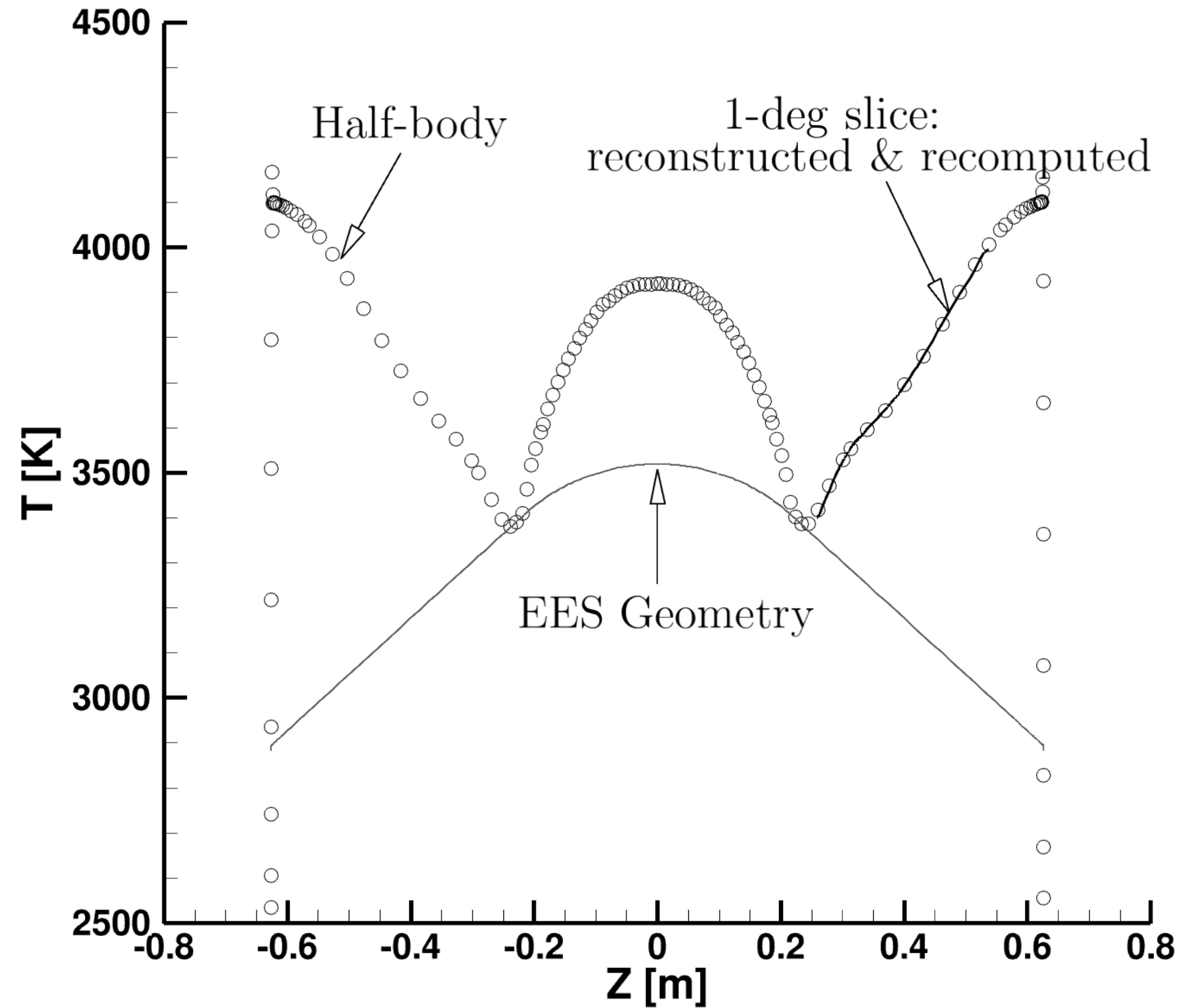


Verification

Surface heating

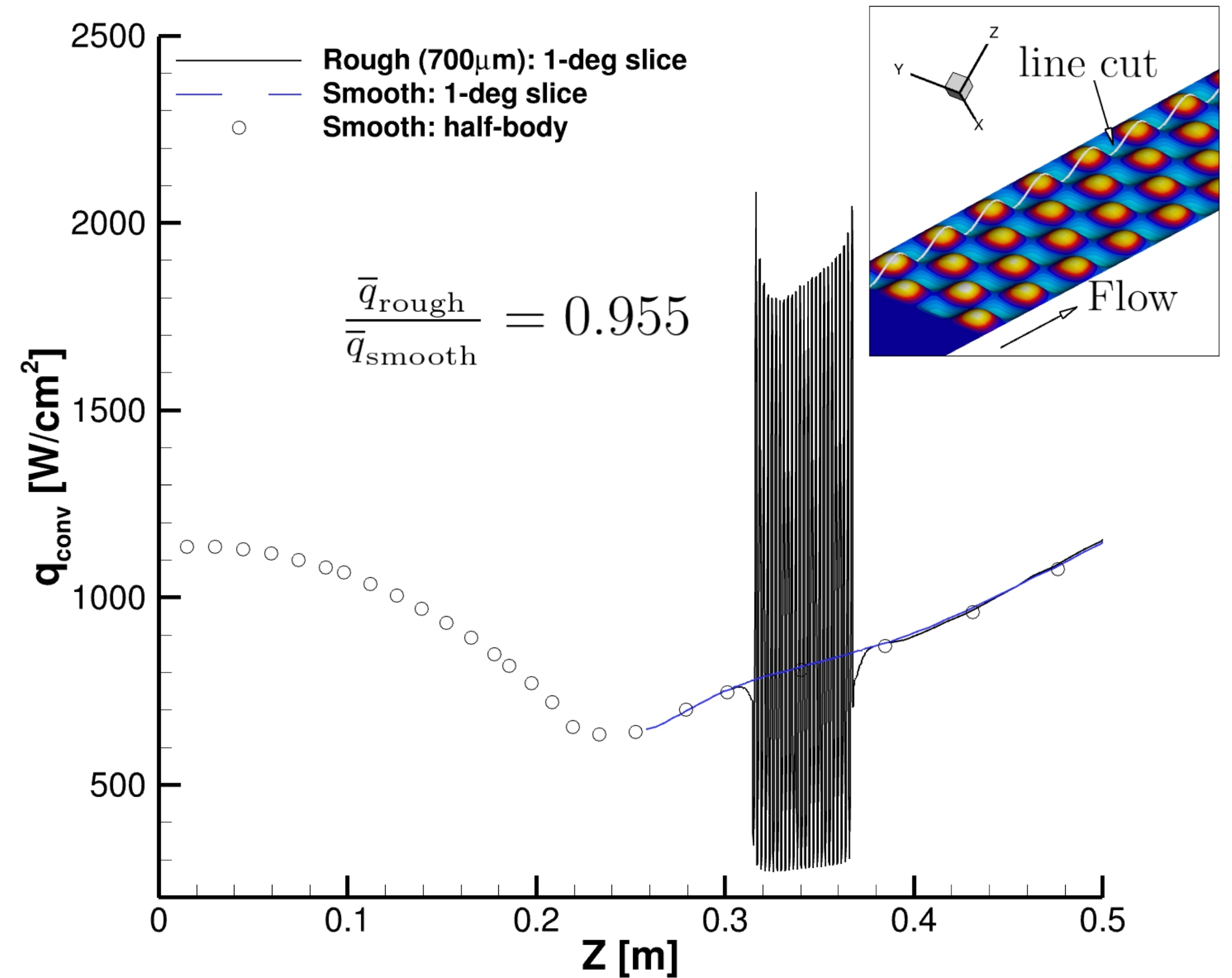
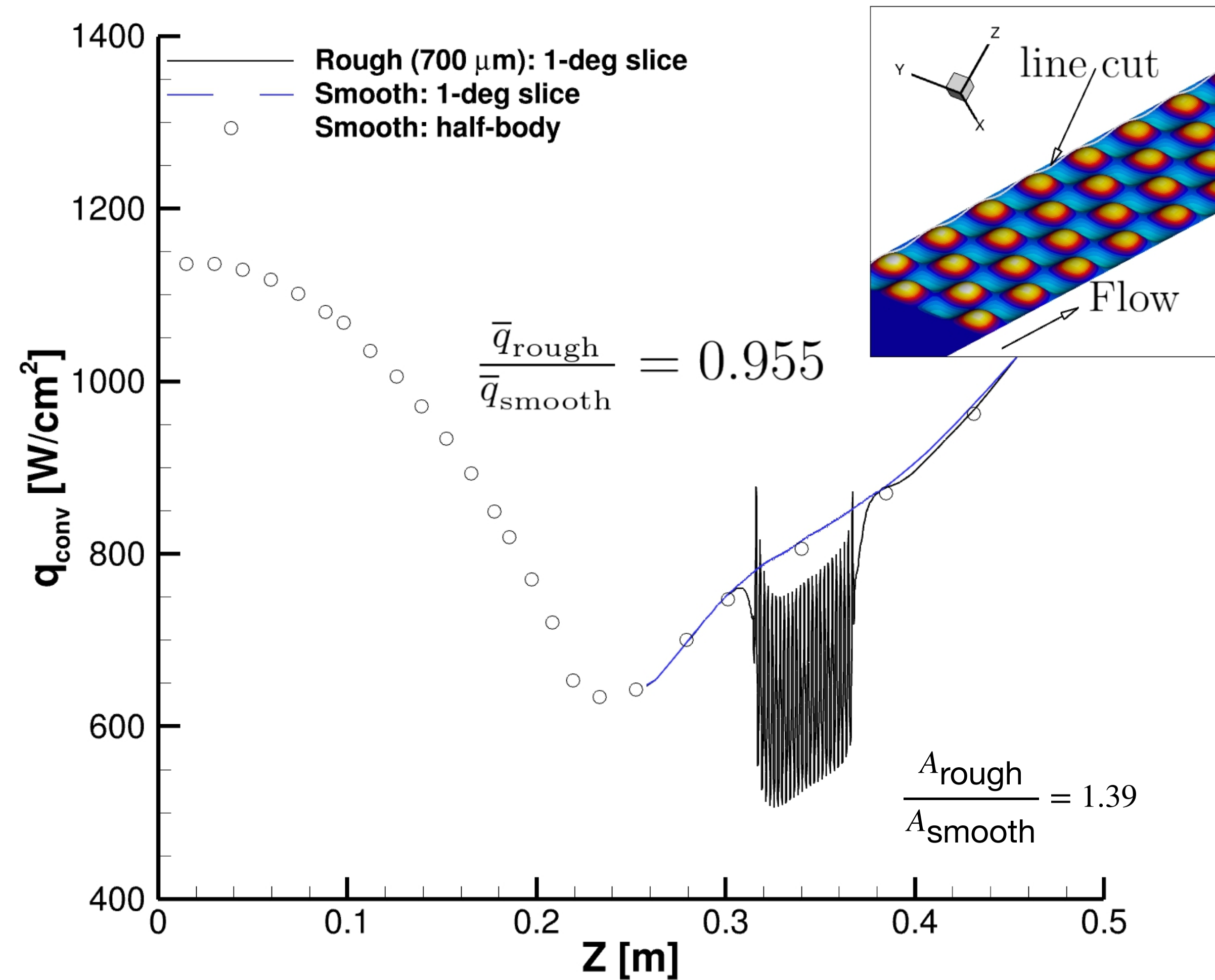


Surface temperature



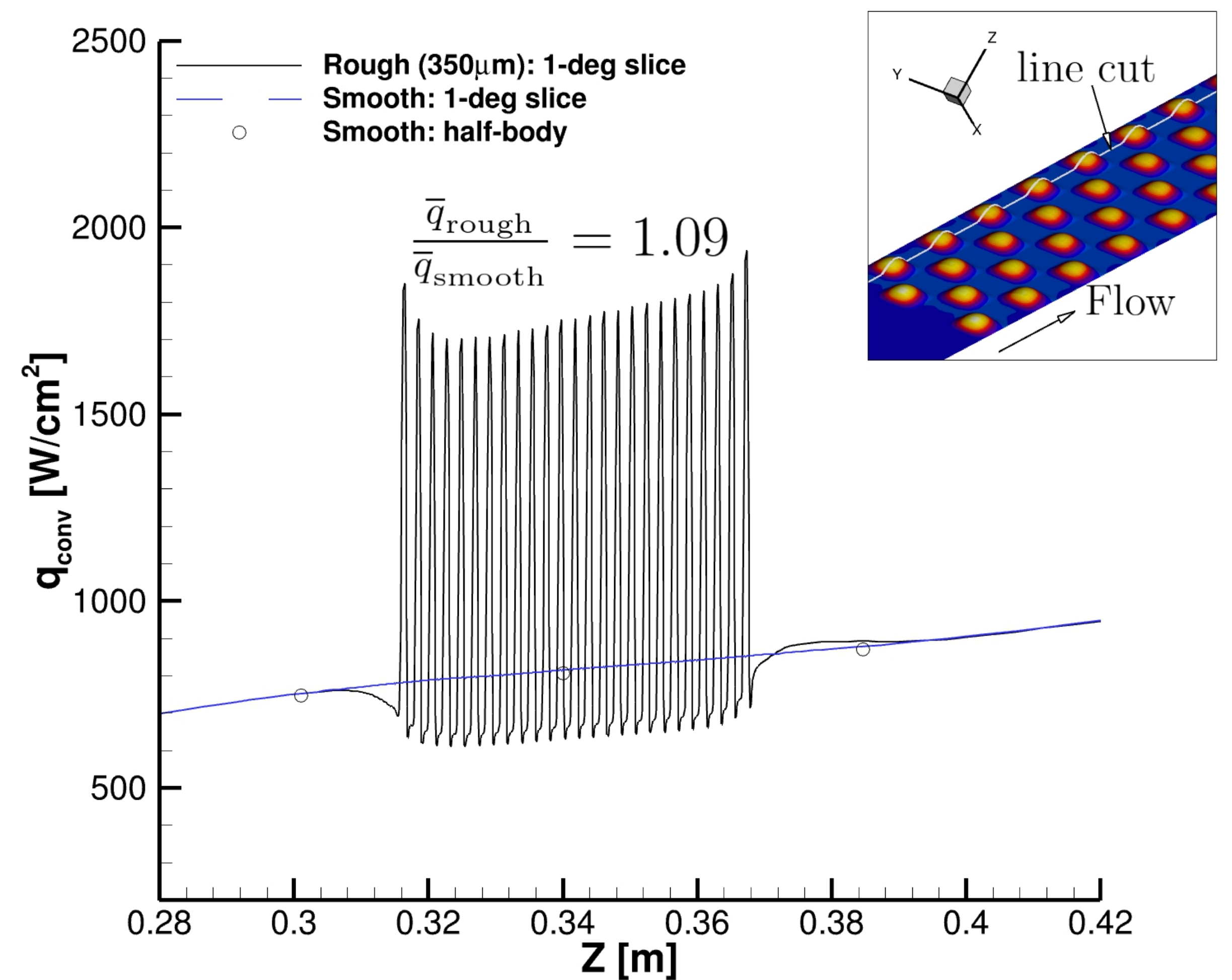
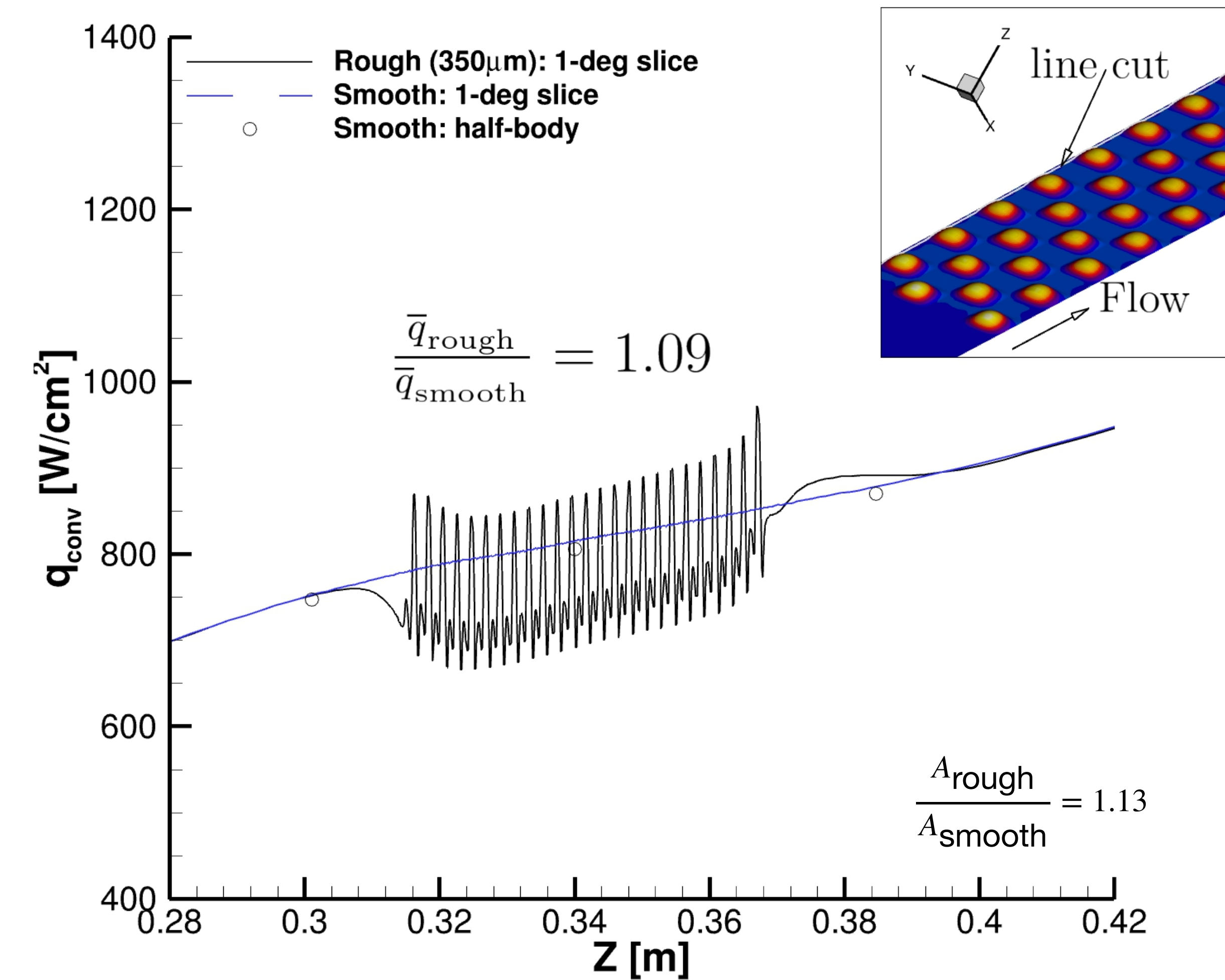
Results

0.7 mm peak-to-valley height

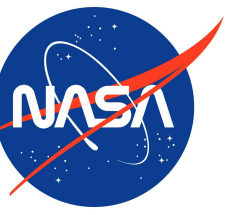


Results

0.35 mm bump (no-valley)



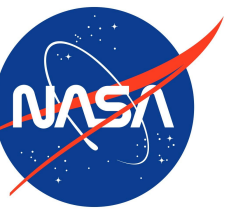
Smooth Surface Heating Augmentation Factor



Augmentation Factor : $\left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right)$

$$\leftarrow k^+ \approx 35$$

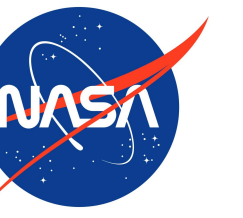
Smooth Surface Heating Augmentation Factor



Augmentation Factor : $\left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right) \quad \leftarrow k^+ \approx 35$

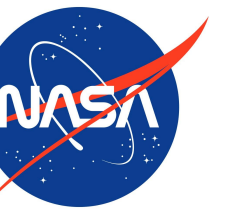
Rough to smooth surface area ratio: $\left(\frac{A_{\text{rough}}^{(0.7mm)}}{A_{\text{smooth}}} = 1.39 \right)$

Smooth Surface Heating Augmentation Factor



$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right) \times \left(\frac{A_{\text{rough}}^{(0.7mm)}}{A_{\text{smooth}}} = 1.39 \right) = 1.33 \quad \leftarrow k^+ \approx 35$$

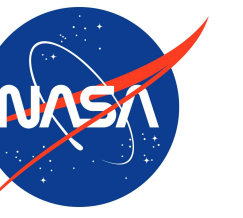
Smooth Surface Heating Augmentation Factor



$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right) \times \left(\frac{A_{\text{rough}}^{(0.7mm)}}{A_{\text{smooth}}} = 1.39 \right) = 1.33 \quad \leftarrow k^+ \approx 35$$

$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.35mm)}}{\bar{q}_{\text{smooth}}} = 1.09 \right) \quad \leftarrow k^+ \approx 17$$

Smooth Surface Heating Augmentation Factor

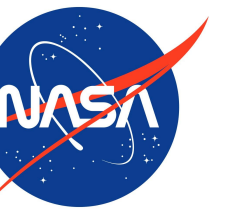


$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right) \times \left(\frac{A_{\text{rough}}^{(0.7mm)}}{A_{\text{smooth}}} = 1.39 \right) = 1.33 \quad \leftarrow k^+ \approx 35$$

$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.35mm)}}{\bar{q}_{\text{smooth}}} = 1.09 \right) \quad \leftarrow k^+ \approx 17$$

$$\text{Rough to smooth surface area ratio: } \left(\frac{A_{\text{rough}}^{(0.35mm)}}{A_{\text{smooth}}} = 1.13 \right)$$

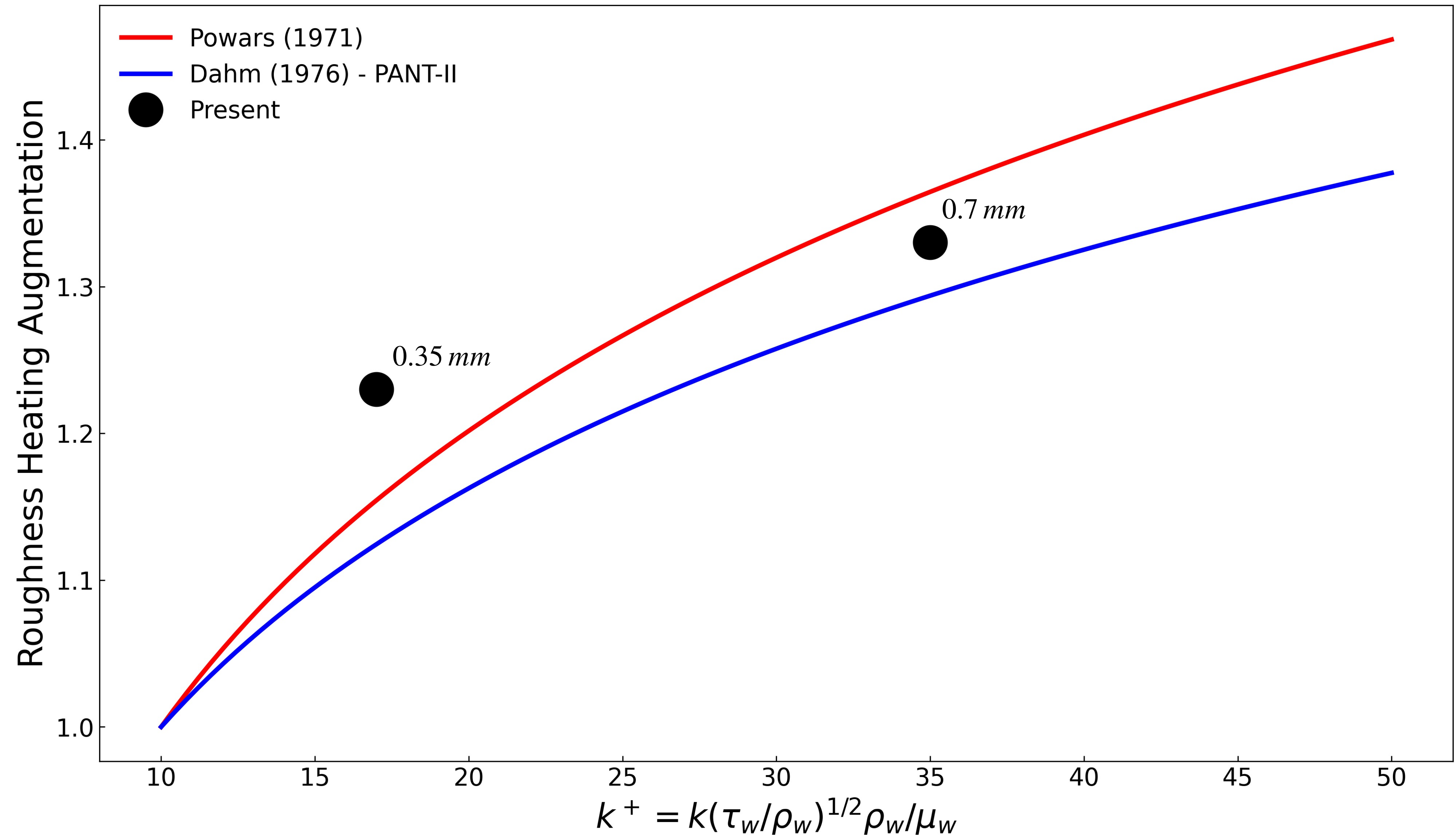
Smooth Surface Heating Augmentation Factor



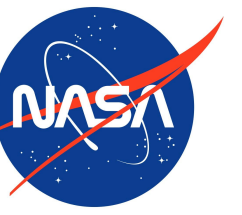
$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.7mm)}}{\bar{q}_{\text{smooth}}} = 0.955 \right) \times \left(\frac{A_{\text{rough}}^{(0.7mm)}}{A_{\text{smooth}}} = 1.39 \right) = 1.33 \quad \leftarrow k^+ \approx 35$$

$$\text{Augmentation Factor : } \left(\frac{\bar{q}_{\text{rough}}^{(0.35mm)}}{\bar{q}_{\text{smooth}}} = 1.09 \right) \times \left(\frac{A_{\text{rough}}^{(0.35mm)}}{A_{\text{smooth}}} = 1.13 \right) = 1.23 \quad \leftarrow k^+ \approx 17$$

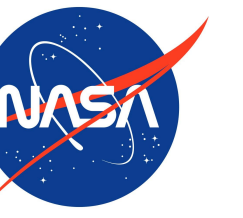
Heating Augmentation Factor



Contributions & Future Work



- Developed a non-coplanar periodic boundary condition and a reconstruction procedure to enable grid resolved roughness CFD
- Presented a proper process in evaluating augmentation factor for the flight project
- Discussed that the k^+ —type correlations are inadequate in accounting for roughness characteristics.
- Future work is to investigate transition onset through probability stability equation (PSE) with DNS-like simulations.



Backup

Results

0.7 mm bump (no valley)

