Abstract Submitted
for the DFD19 Meeting of
The American Physical Society

Optimal interpretation of measurements for enhanced-fidelity prediction of hypersonic boundary layer transition[1] DAVID BUCHTA, TAMER ZAKI, Johns Hopkins University — High-speed boundary-layer transition is extremely sensitive to the freestream disturbances which are often uncertain, thus compromising the accuracy of model predictions. To enhance the fidelity of simulations, we directly infuse them with measurements data. Our methodology is general and can be adopted with any simulation technique, e.g. parabolized stability equations or direct numerical simulations. An ensemble variational (EnVar) optimization is performed, whereby we determine the upstream flow that optimally reproduces the measurements. The cost functional can account for our relative confidence in the model and the measurements, and judicious choice of the ensemble members improves convergence and reduces the prediction uncertainty. We demonstrate our data-augmented simulations for boundary-layer transition at Mach 4.5. Without prior knowledge of the freestream condition and using only wall measurements from an independent computation (true flow), all the relevant inflow disturbances are identified, and their amplitudes and phases are accurately predicted. We can then evaluate the entire flow field, beyond the original limited wall measurements. Our predicted flow compares favorably to the true unknown state, and discrepancies are analyzed in detail.

[1]This work was supported by the Air Force Office of Scientific Research (FA9550-19-1-0230)

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Date submitted: 31 Jul 2019 Electronic form version 1.4