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Analysis of Mars 2020 Entry with Coupled Material Response and CFD

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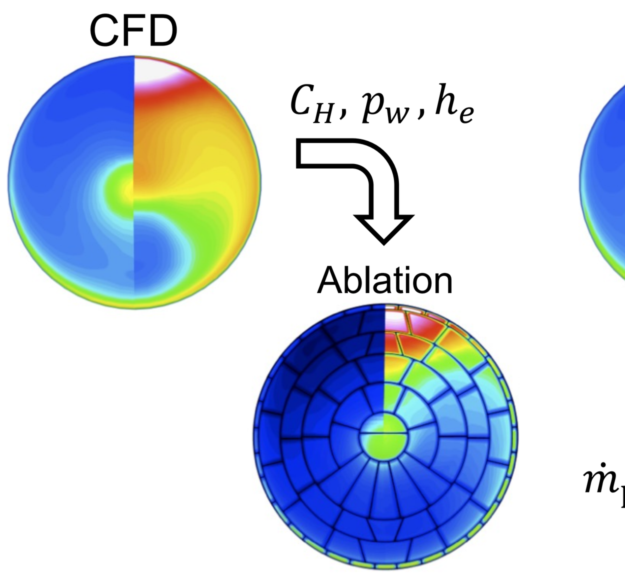
Objective

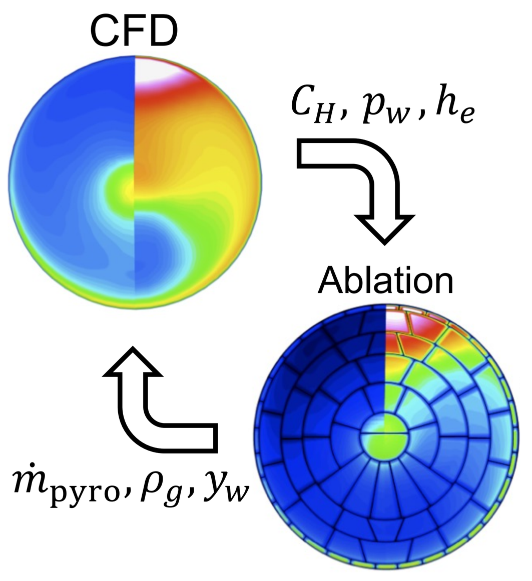
The objective of this work is to showcase and analyze the coupling between the material response and the aerothermal environment in simulating the Mars atmospheric entry of the Mars 2020 in 3D. This work represents an important milestone toward the development of validated predictive capabilities for designing thermal protection systems for planetary probes.

Uncoupled approach



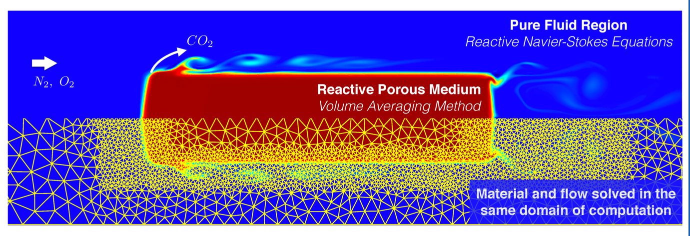
- Uncoupled CFD and MR simulations.
- Approximate methodologies for mass and energy transfer.

Coupled approach

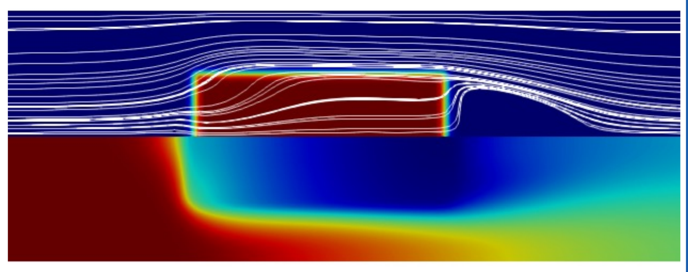


- Simultaneous CFD and MR simulations.
- Direct exchange of information through BCs.

Unified approach



Work by P. Schrooyen



See poster by Bruno Dias

- Unified CFD and MR simulations.
- No need for exchange of information.

We are comparing the uncoupled and coupled approaches for Mars entry conditions

Mars 2020 Supercomputer Runtime and Usage

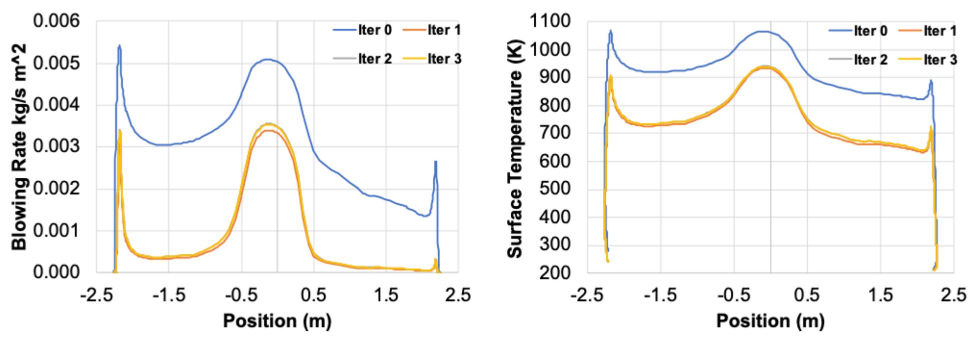
Restart Capability implemented in PATO

- Do not compute entire trajectory for each iteration.
- Cut down on simulation time by over half.

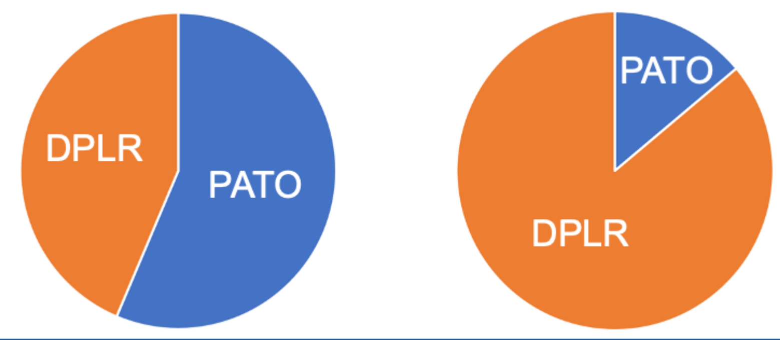
Massive Mars 2020 Coupled Simulations

Resources:	600 processors (Haswell)
Without Restart:	30 days
With Restart:	14 days
3D Refined Grid:	9M (DPLR) & 1M (PATO)

Simulations require 1 to 3 iterations to converge

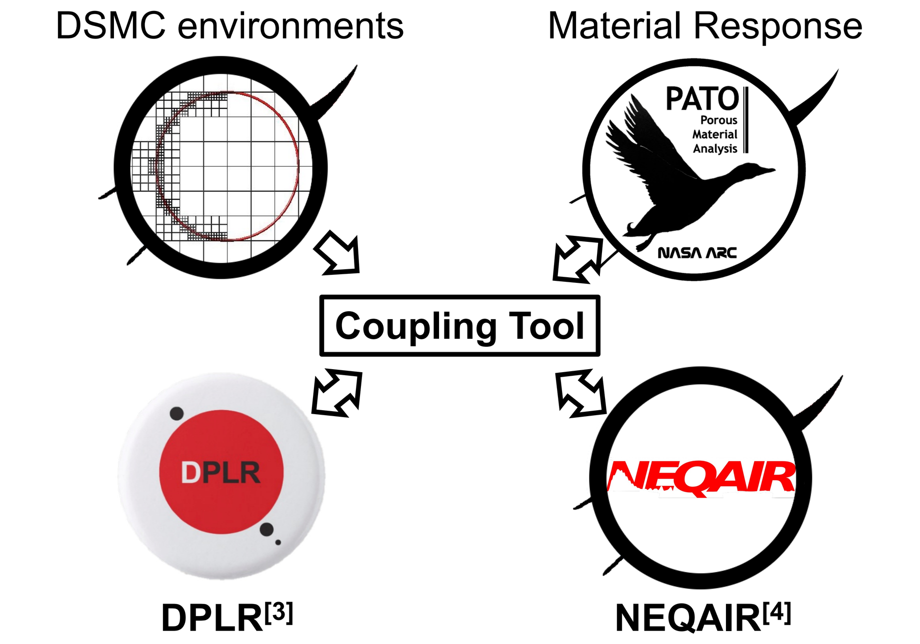


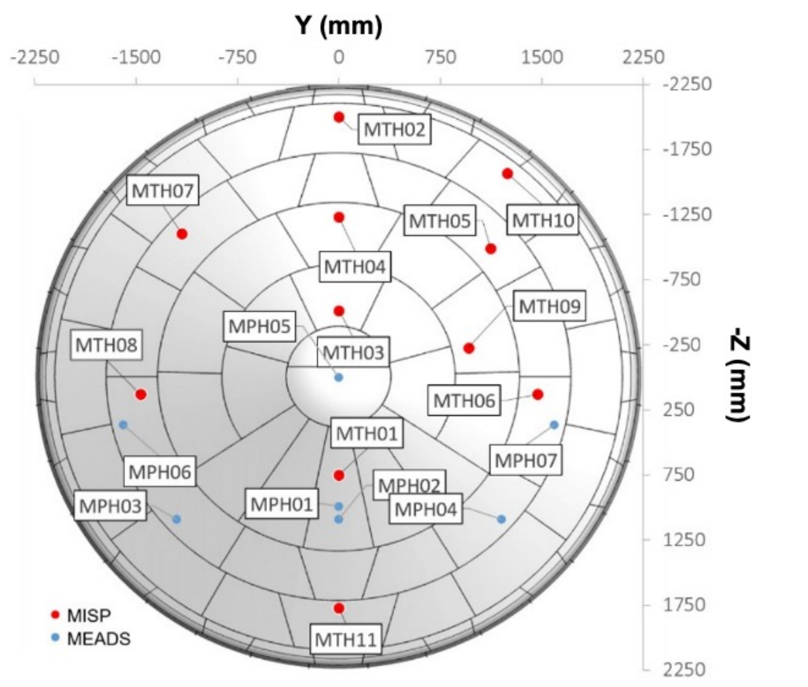
Computing time for each code



Coupling Tool

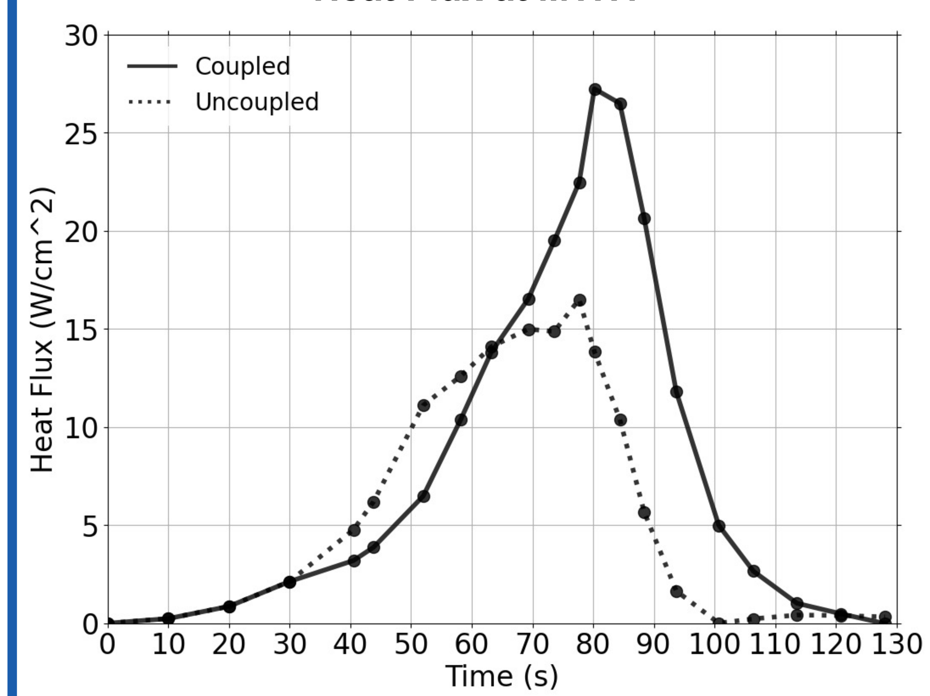
Interfaces and automates the interaction between NASA tools

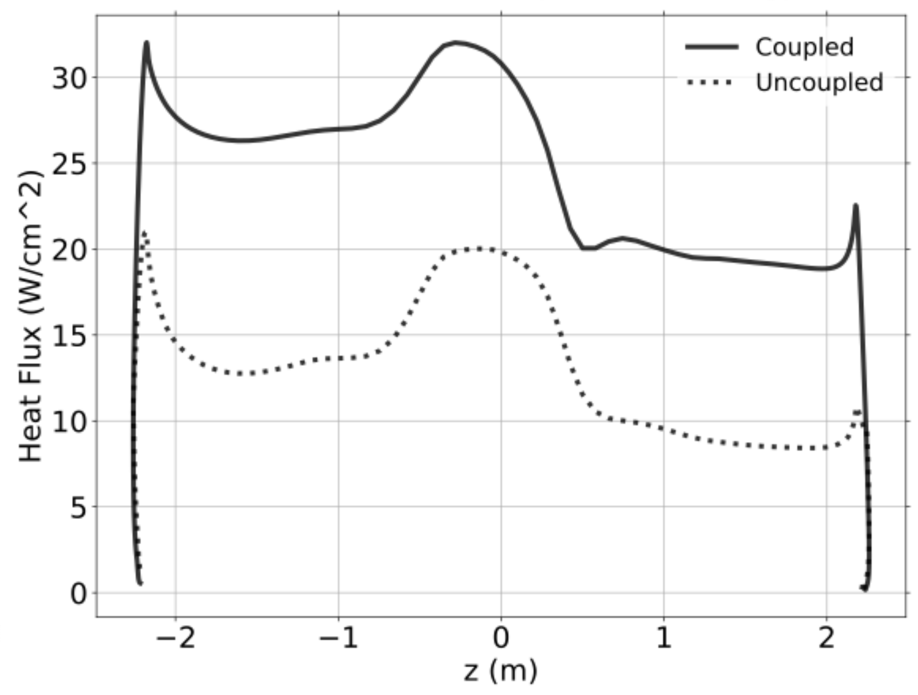




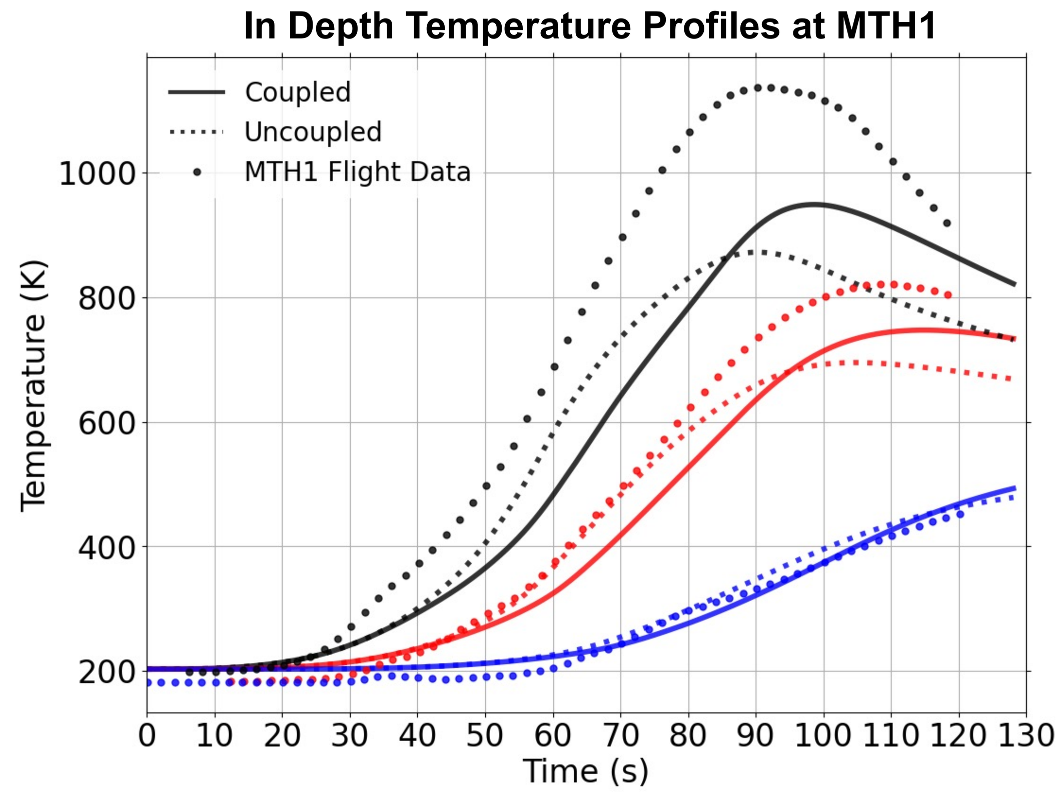
MEDLI2 Plug Layout on Mars 2020 Heatshield

Mars 2020 Coupled and Uncoupled Cases

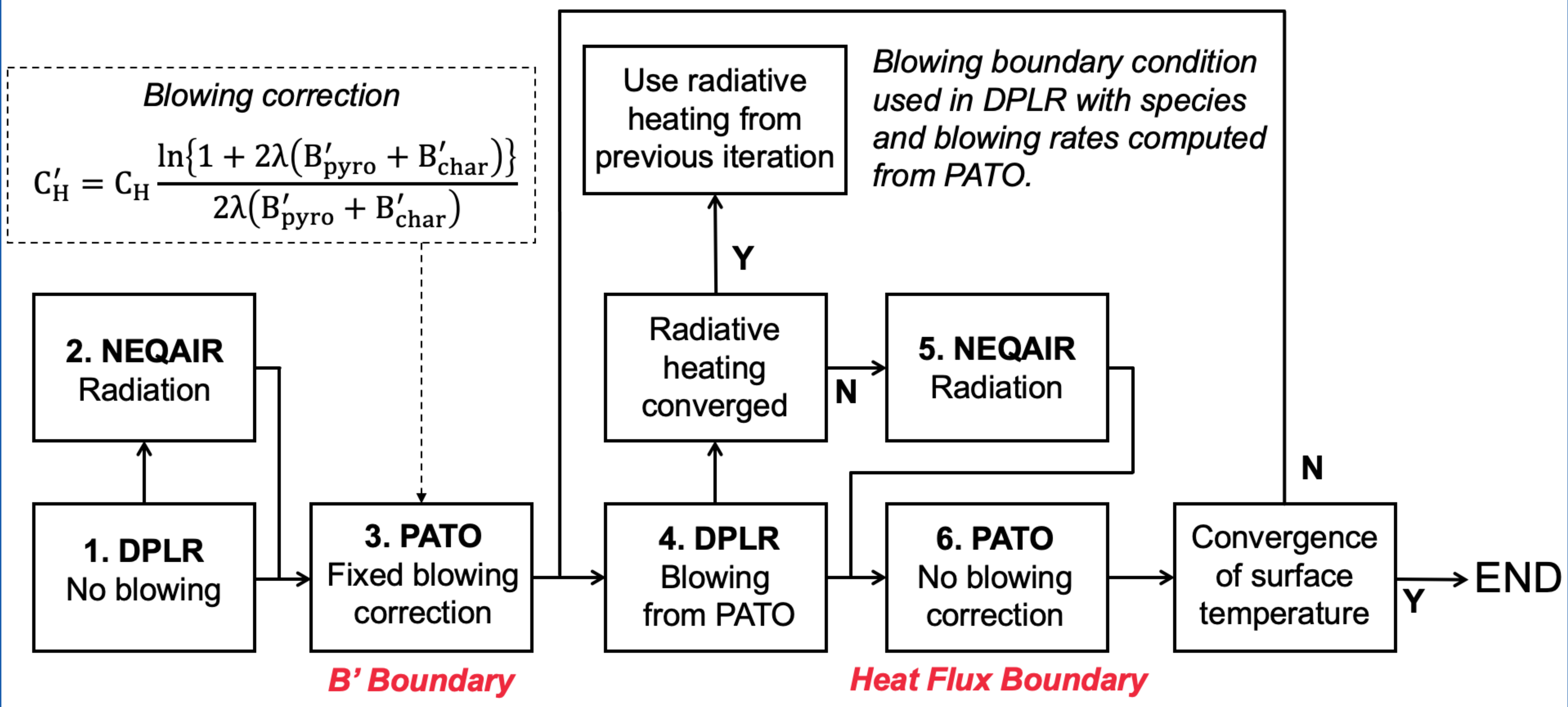




- Flow assumed to be laminar and did not include radiation or recession.
- Underpredicting flight data. Radiation accounts for some of the underprediction, but not all.
- Similar trends as with previous study on MSL.
- Higher heating at peak with coupled cases.
- Lower heating initially.



Coupling Methodology

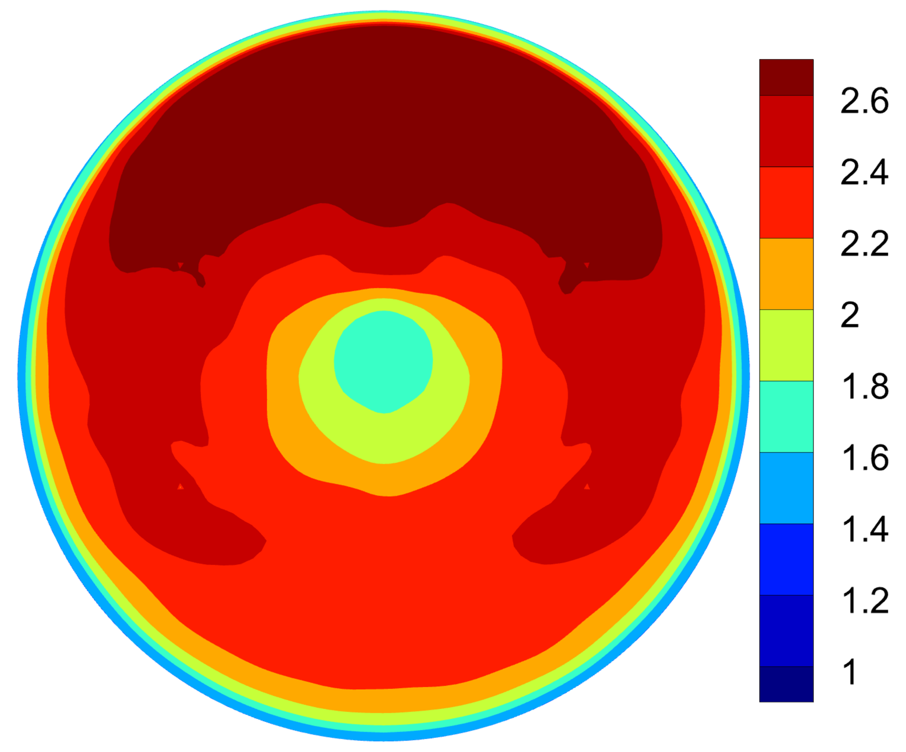


Conclusions

- Significant differences in heating between coupled and uncoupled cases
- Underpredicting flight data. Adding radiation and char blowing could possibly alleviate discrepancies.

Future Work:

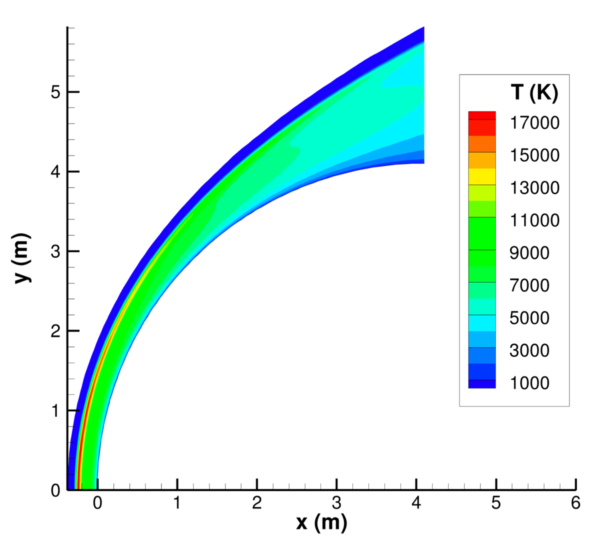
- Efforts have been made to create a coupling process which includes char blowing/recession [6].
  - ***See poster by Georgios Bellas Chatzigeorgis and talk by Brett Cruden***
- A Mars 2020 coupled case which includes radiation is currently being run.
- Using comparison between coupled and uncoupled cases to create new blowing correction models.

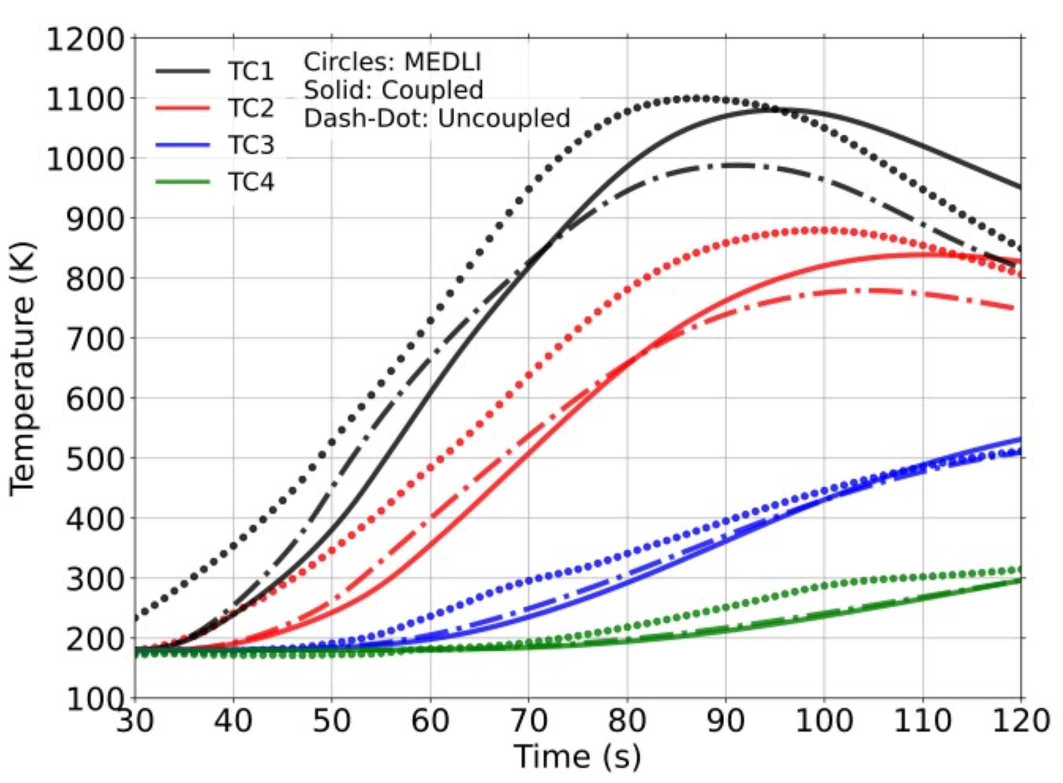


Ratio of Coupled and Uncoupled Heat Flux at 80.2s

Sphere Case for MSL

- 2D axisymmetric sphere case with environments from MSL MISP1 [5].
- Includes radiative heating.
- No DSMC or char blowing/recession.
- Good agreement with flight data.





References

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[3] M.J. Wright *et al.* (2009), DPLR Code User Manual: Acadia-Version 4.01.1.
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[5] J.M Thornton *et al.* (2023), AIAA SCITECH 2023 Forum.
[6] B.A. Cruden *et al.* (2023), AIAA AVIATION 2023 Forum.