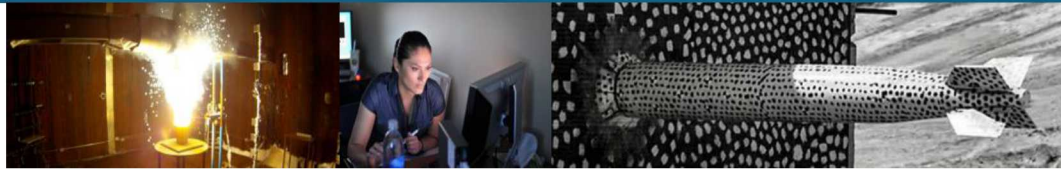




Sandia
National
Laboratories

SAND2019-6701PE

STAR-CTF Temperature Map Update



PRESENTED BY

Lindsay Gilkey



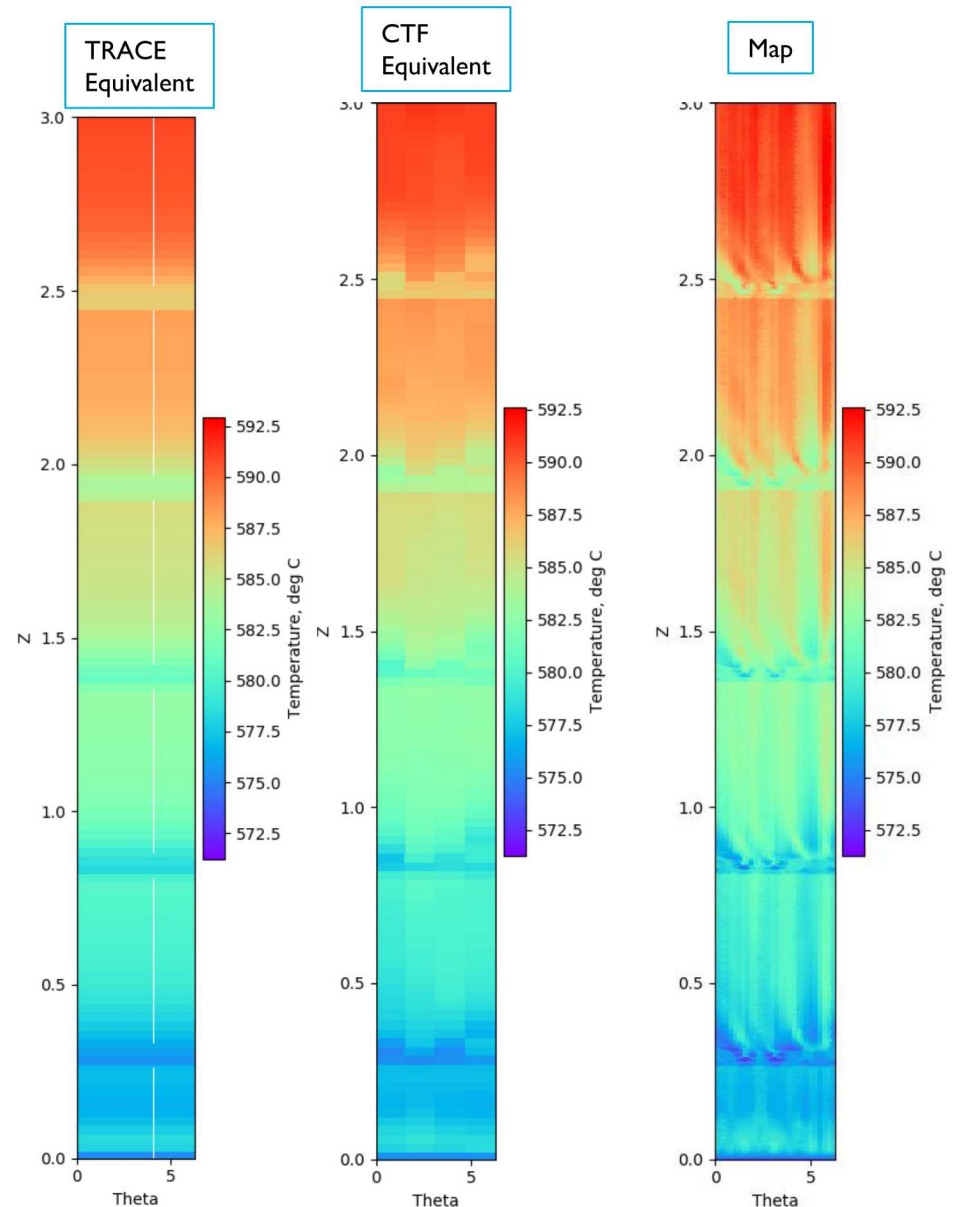
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T-STAR Mapping – 5x5



What information does the STAR mapping give us over just a plot from CTF or TRACE Equivalent?

Example with the WEC 5x5:

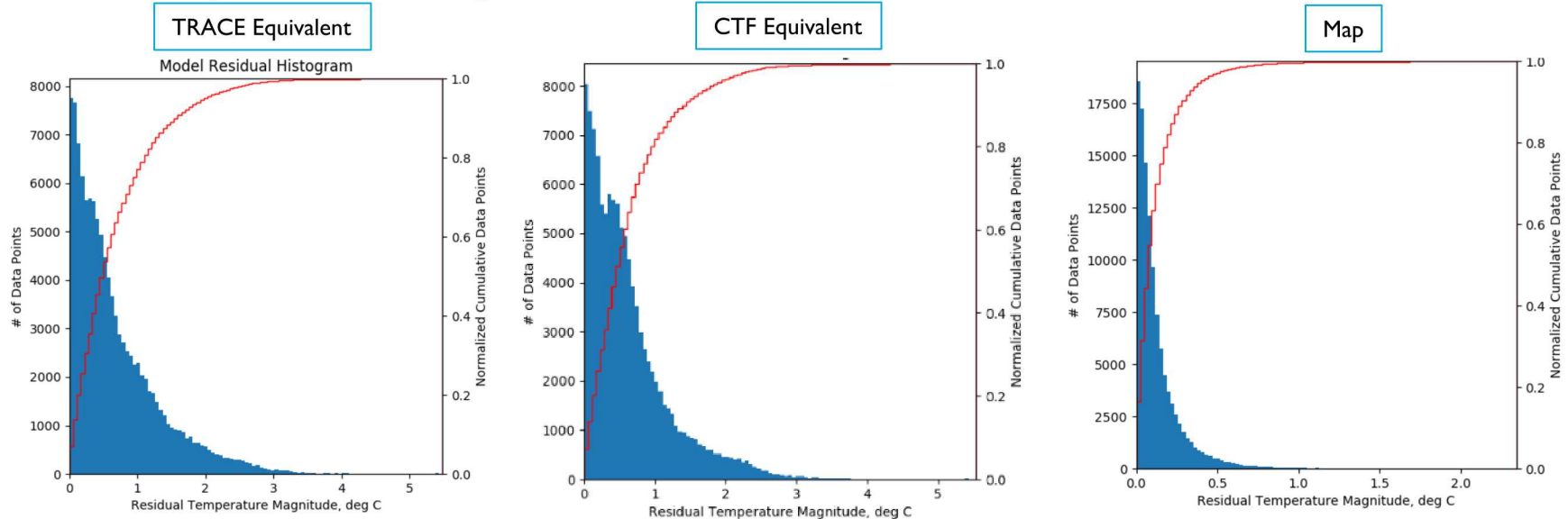


3 T-STAR Mapping – 5x5



What information does the STAR mapping give us over just a plot from CTF or TRACE Equivalent?

Example with the 6x4 grid and Rod 2:

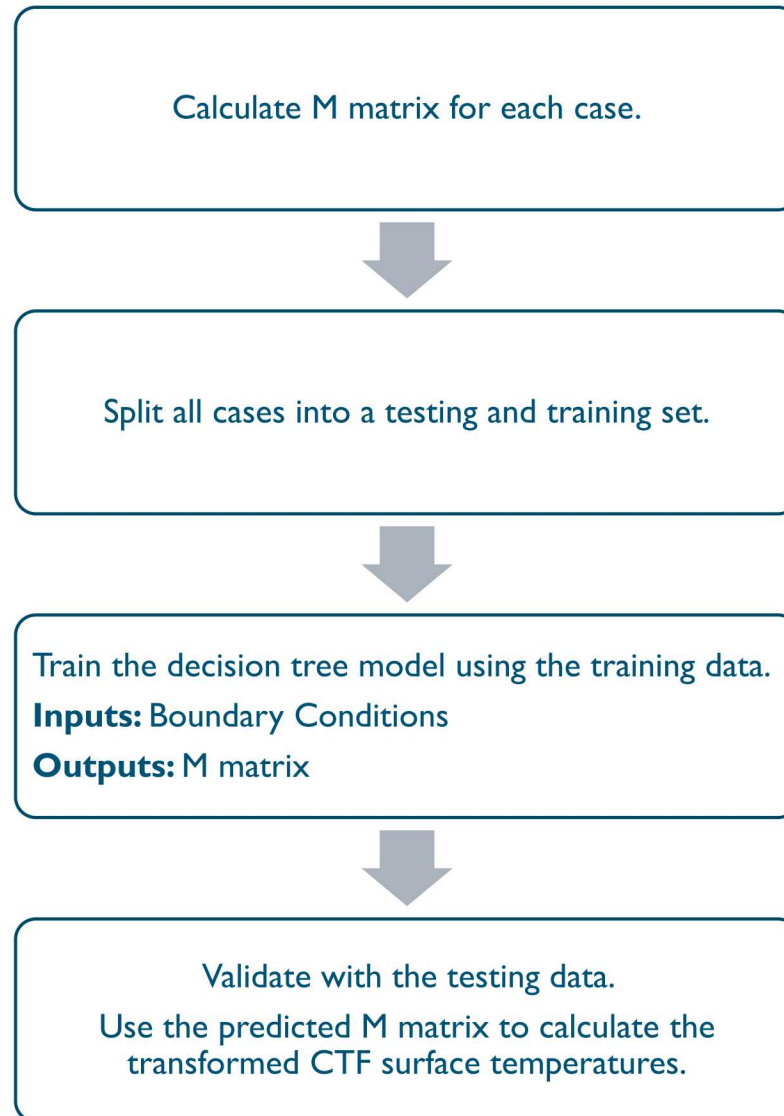


Rod	Type	RMS	L2	Linf
2	TRACE	0.94168	314.6437	5.48341
2	CTF	0.864333	288.7972	5.533348
2	Map	0.172329	57.57975	2.225399



Two approaches to determining the “M” multiplier matrix to transform the CTF surface temperatures to match the STAR surface temperatures (averaged to match the approximate resolution of the CTF grid):

1. Using a decision tree based approach. Based on the BCs (inlet temperature, velocity, power), use the decision tree to predict the M multiplier matrix.
2. Using a calibrated set of constants approach. Based on the BCs (inlet temperature, velocity, power), use the calibrated constants to calculate the M multiplier matrix.



T-AVG Mapping – Approach I



Goal: Want to transform TSTAR to TCTF based on BCs.

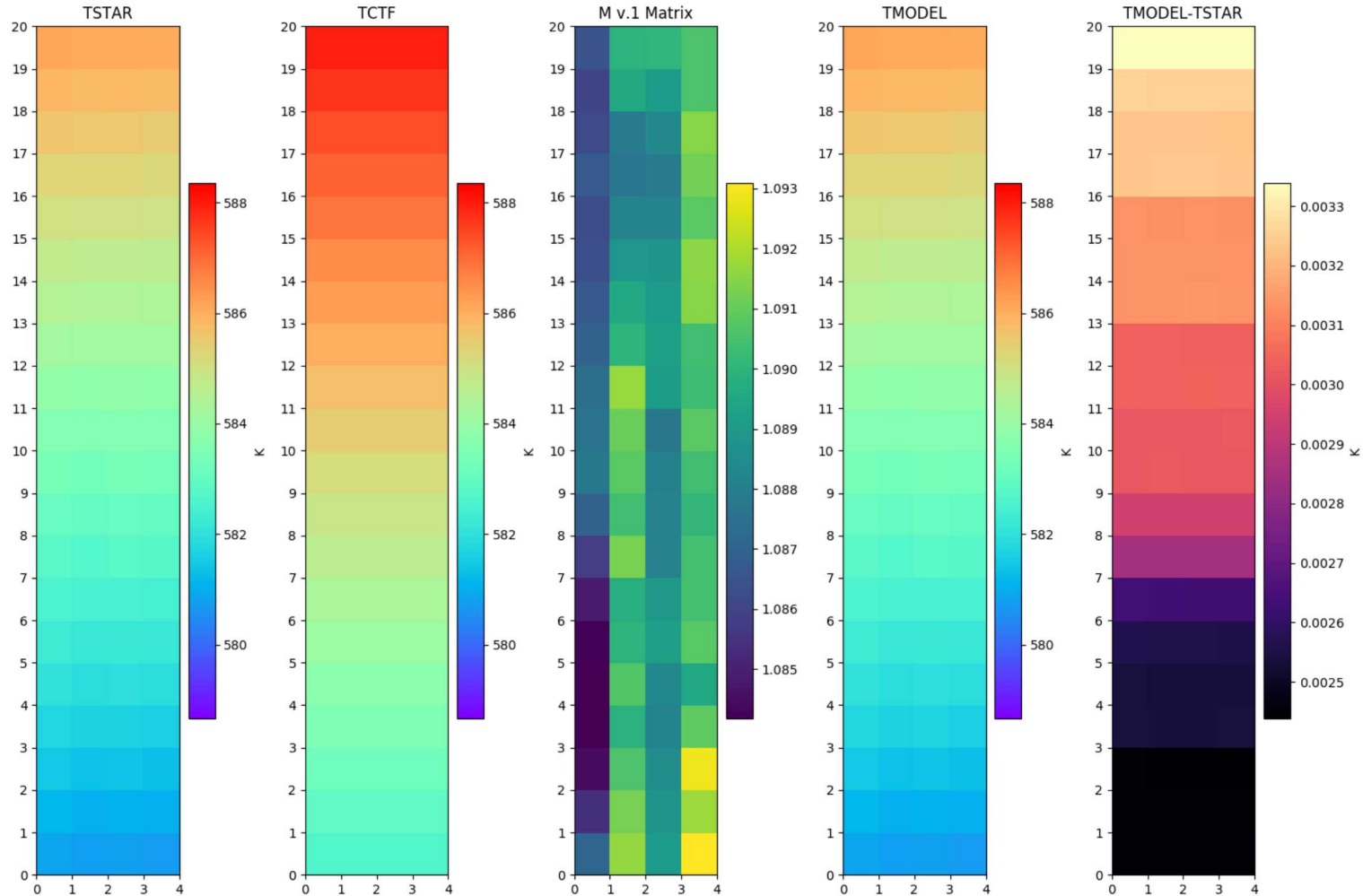


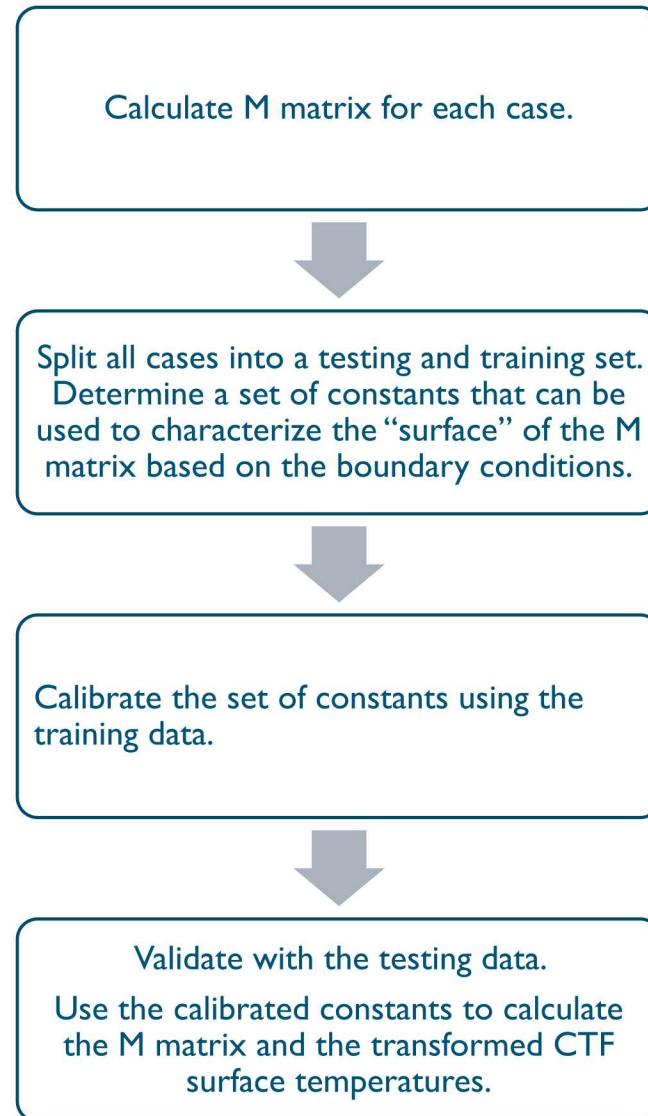
Predict M
Matrix with
trained model.



Use M Matrix to solve for
TMODEL which will
minimize Tmodel - TSTAR.

Axis = Level Index





T-AVG Mapping – Approach 2



Goal: Want to transform TSTAR to TCTF based on BCs.

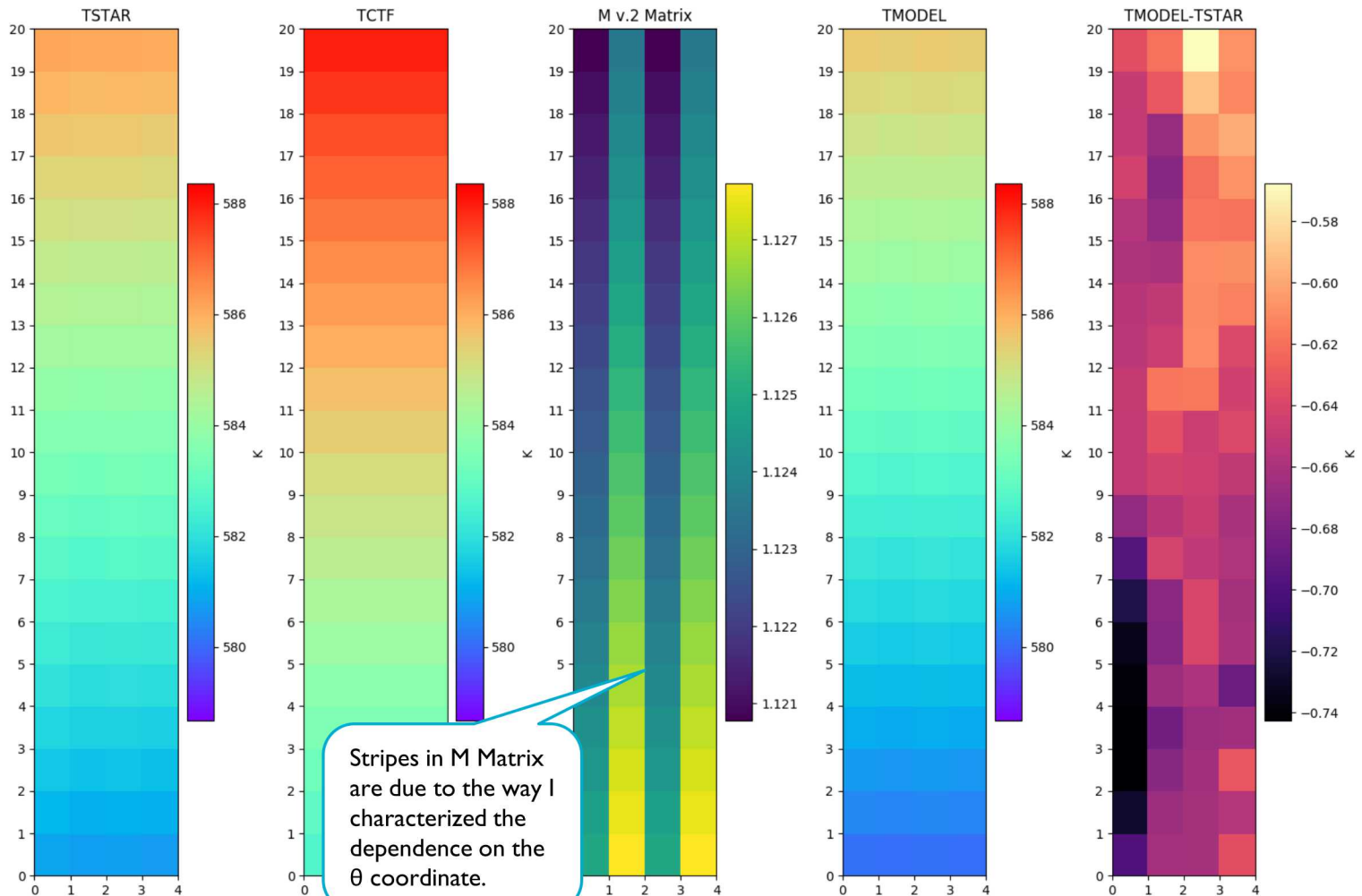


Calculate M Matrix after calibrating its constants.



Use M Matrix to solve for TMODEL which will minimize Tmodel - TSTAR.

Axis = Level Index

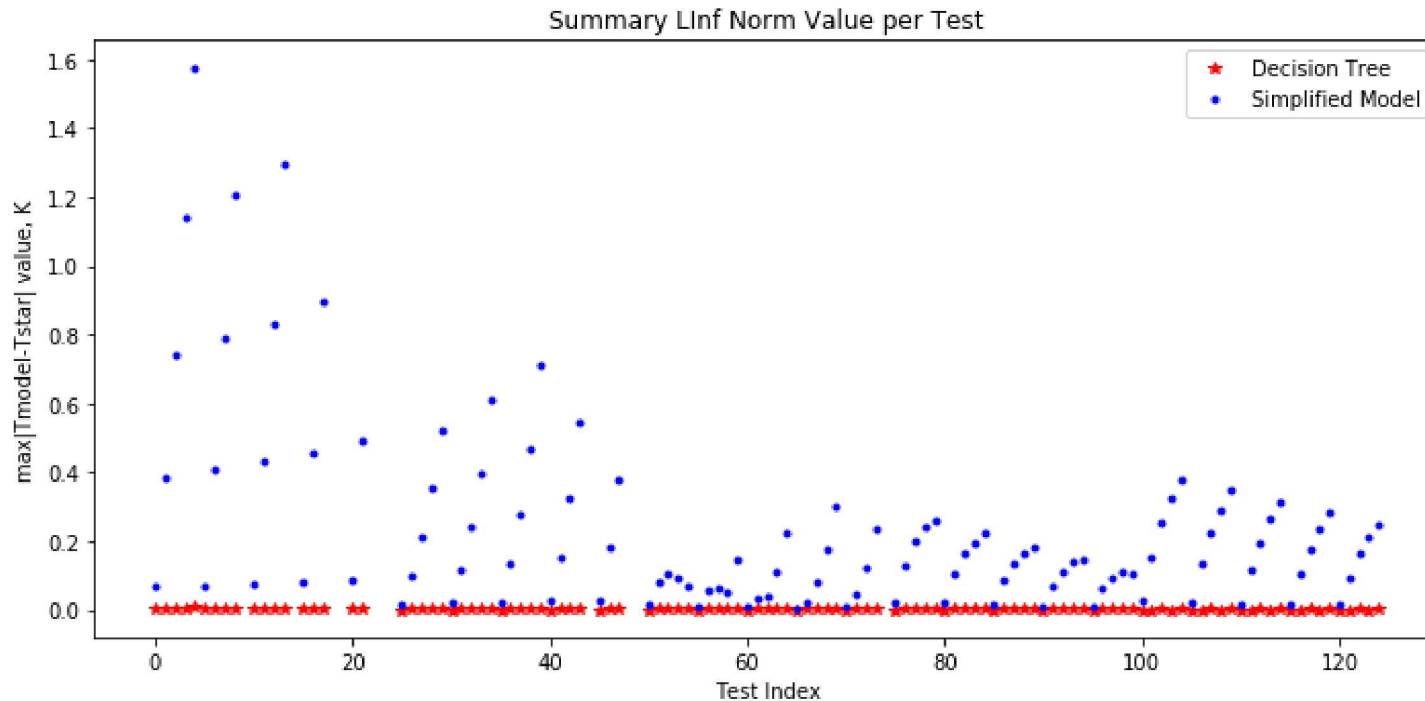


T-AVG Mapping – Comparing Approaches



For this simple case, the decision tree (Approach 1) performs better (max residual temperatures are less than 0.1 K for the tested boundary conditions). However the “simplified model” (Approach 2) has a maximum residual temperature for 1.6 K for the tested boundary conditions, which is very low considering the range of temperatures and the uncertainty of the simulated data.

Our initial thought is that Approach 2 is likely more predictive than Approach 1, which requires a very large set of training data to be able to adequately fill in the decision tree.





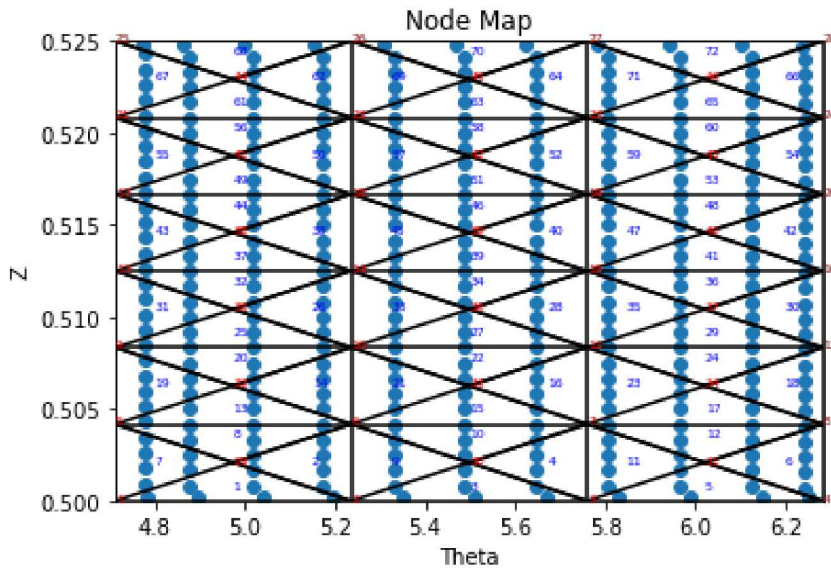
The T-STAR mapping is performed by the following steps:

1. The CTF mesh is projected onto the STAR data. An average temperature is calculated per cell of the CTF mesh. This is used to transform the STAR data into an averaged and fluctuating quantity: $T_i = \bar{T} + T_i'$
2. The mapping script splits the STAR data into a submesh.
3. Each element of the submesh is composed of three nodes. These nodes define a plane, which can then be used to determine element temperature fluctuation, T_i' , as a function of coordinate.
4. The node heights are calibrated using Dakota or Python such that their summed value is equal to zero.
5. This process is performed per CTF cell.
6. This can then be used to train a decision tree that uses the simulation boundary conditions and CTF cell index as the inputs and the node heights as the outputs.

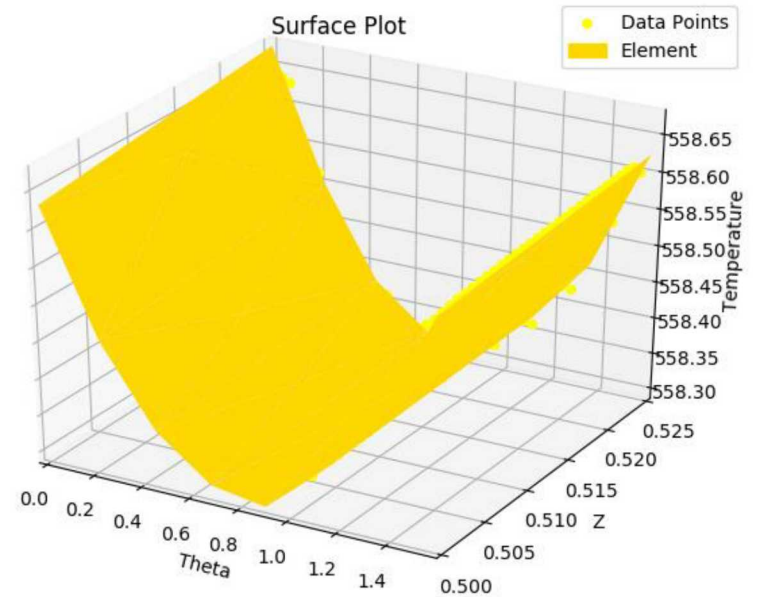
T-STAR Mapping – Single CTF cell

Example for a single CTF cell projected onto the STAR data:

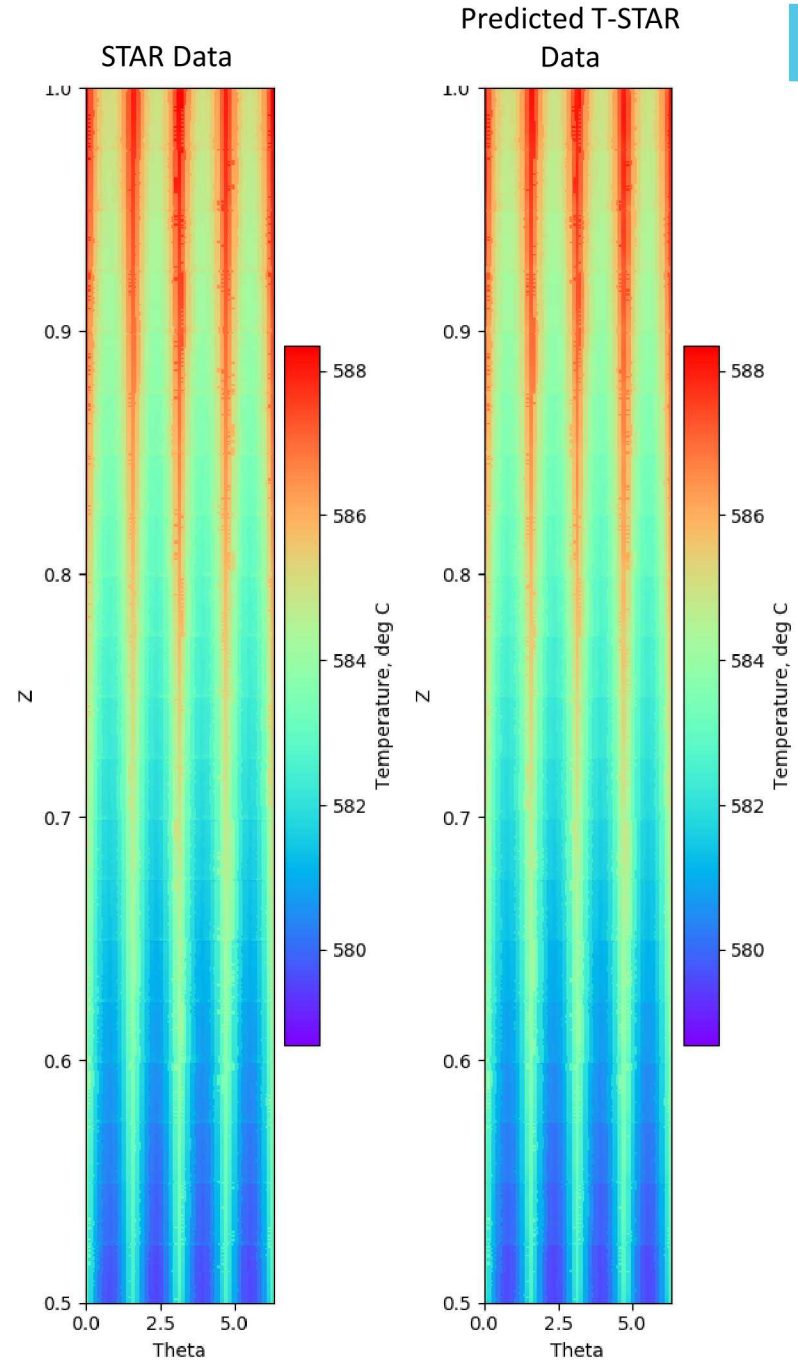
Mapping submesh. Blue dots represent STAR data points.



3D representation of the T-STAR map, using absolute temperatures.



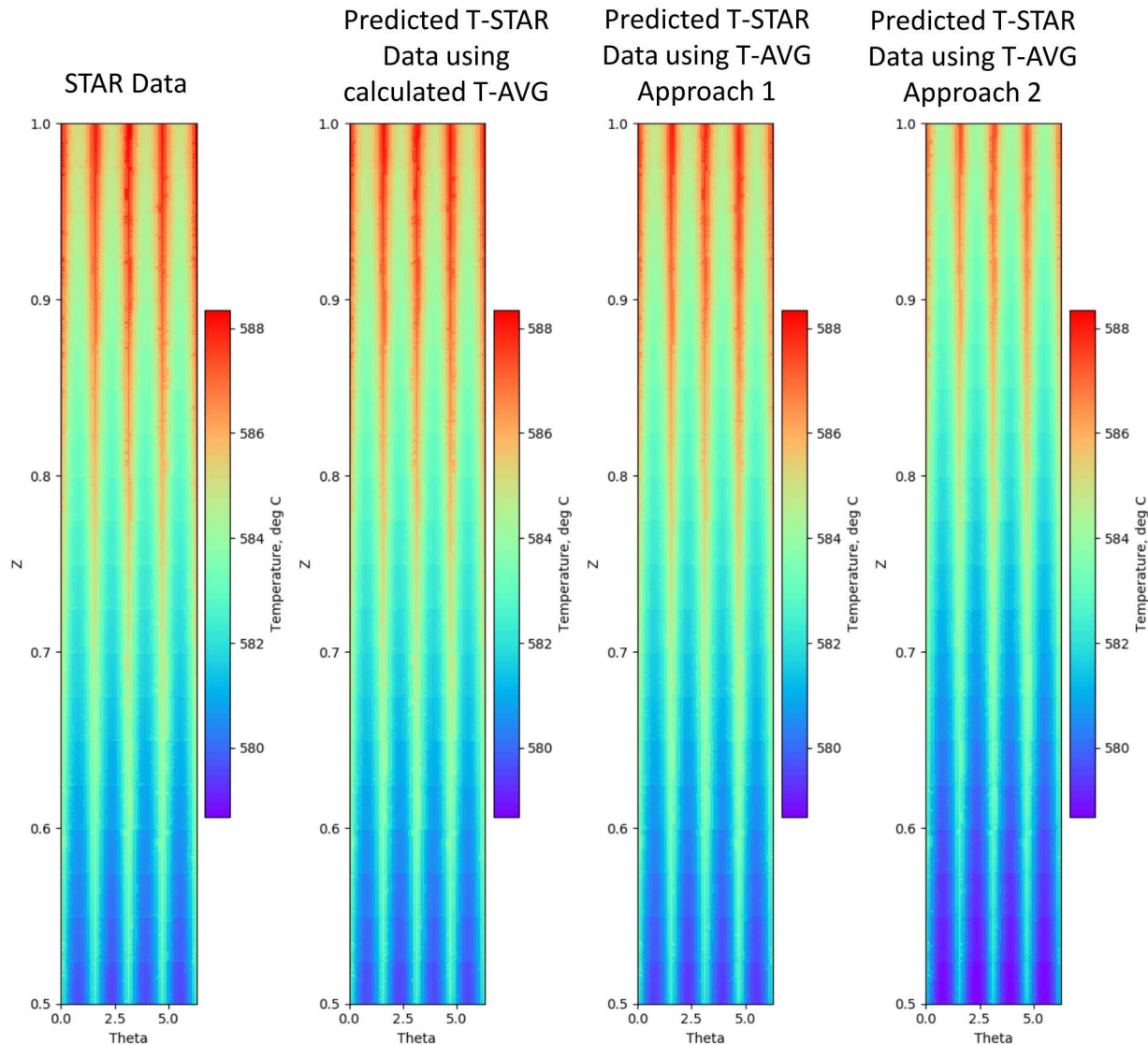
I repeated the process of the previous slide on every CTF cell for all cases and used this to train a decision tree for predicting T_i' as a function of CTF cell index and simulation boundary conditions.



T-STAR Mapping – Single Rod Continued



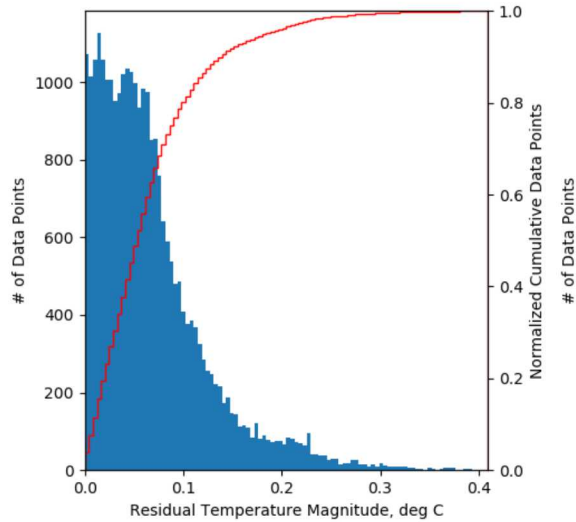
What if we use the M matrix to predict the T-AVG values instead of calculating this value directly from the data?



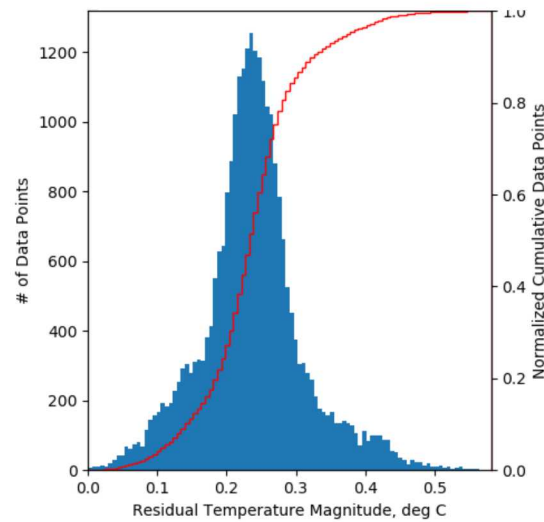
T-STAR Mapping – Single Rod Continued



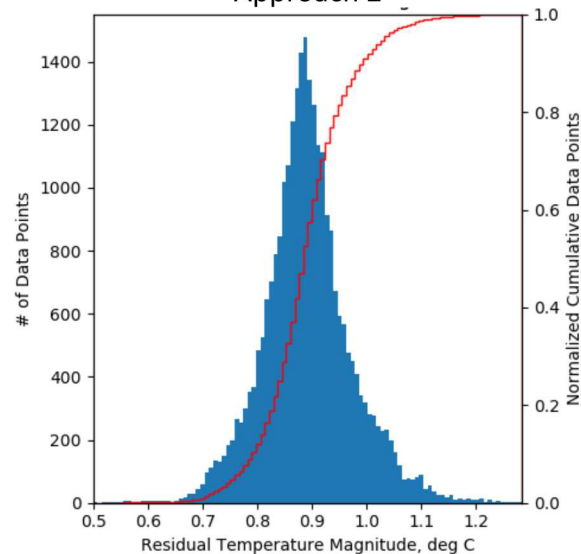
Predicted T-STAR Data using
calculated T-AVG



Predicted T-STAR Data using T-
AVG Approach 1



Predicted T-STAR Data using T-AVG
Approach 2

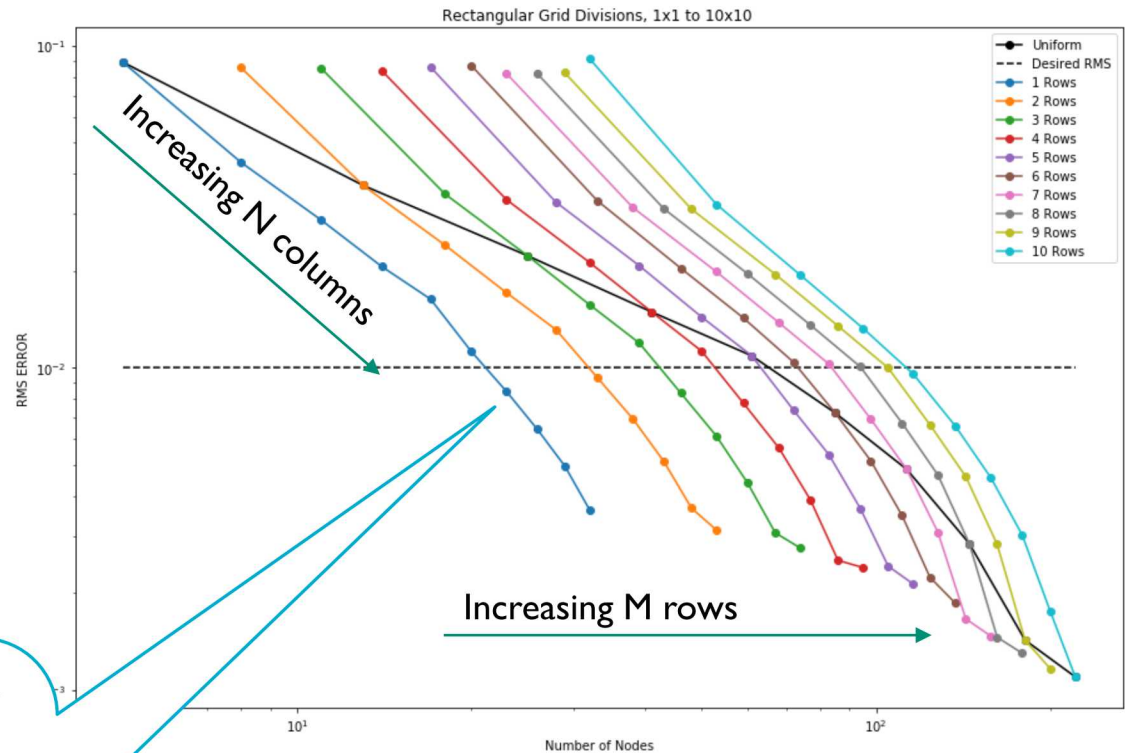
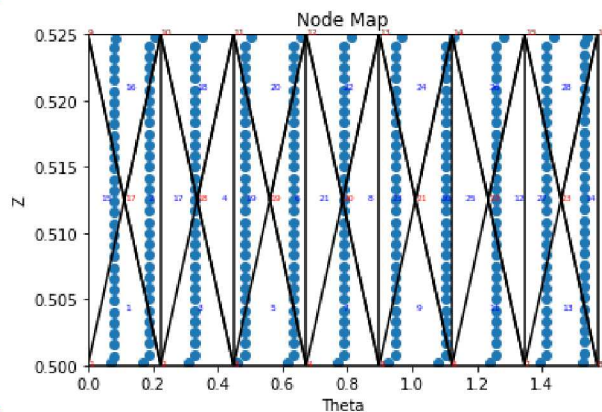
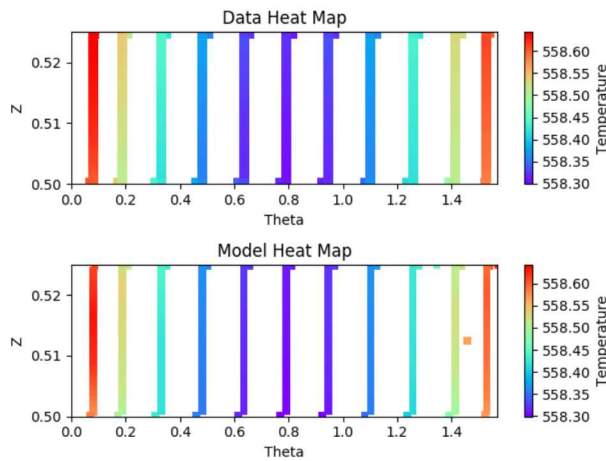


T-STAR Mapping – Single Rod Grid Convergence



A 1x7 grid configuration is adequate to capture the surface temperature such that the RMS error is less than $1e-2$.

Example using a 1x7 submesh.

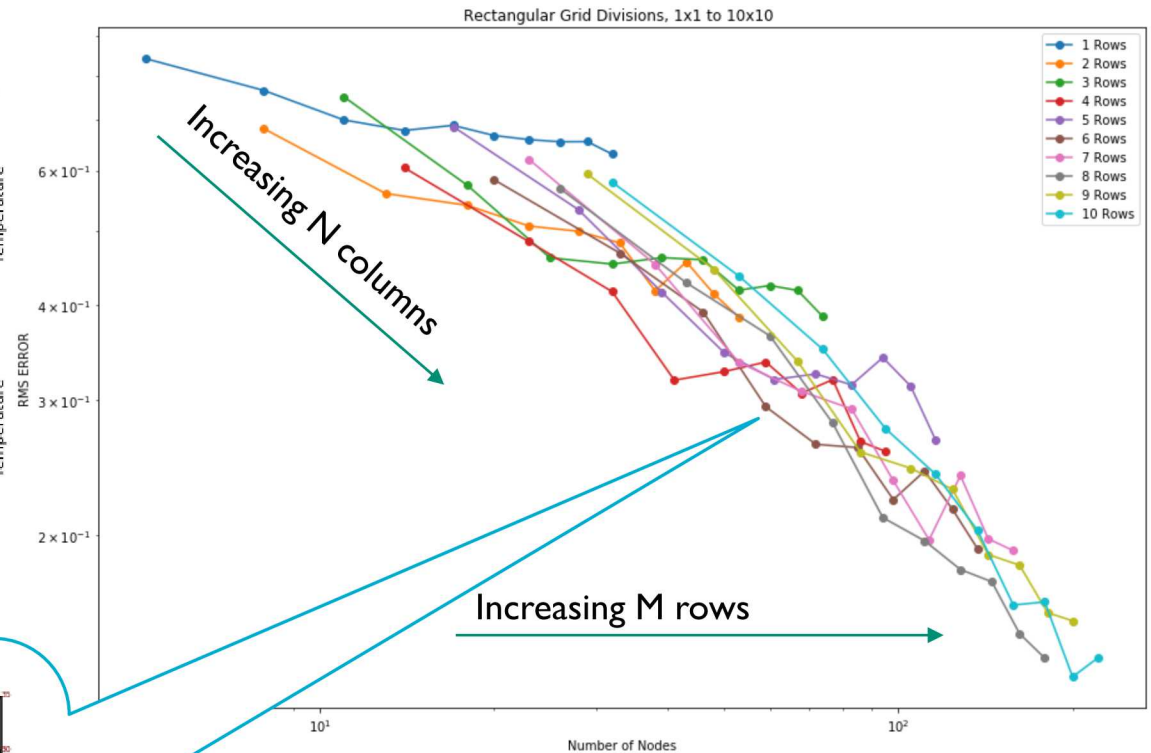
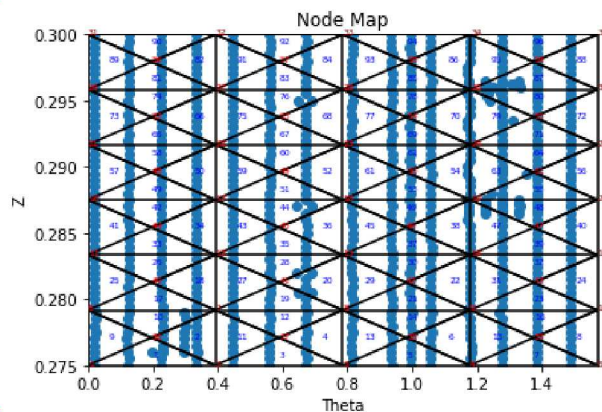
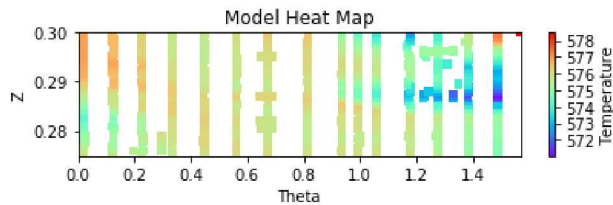
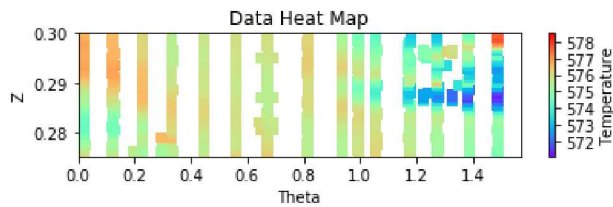


T-STAR Mapping – 5x5 Rod Grid Convergence



For more complex surface temperature (such as a cell from the WEC 5x5), grid convergence is not as straight-forward, and a more refined submesh is required.

Example using a 6x4 submesh.

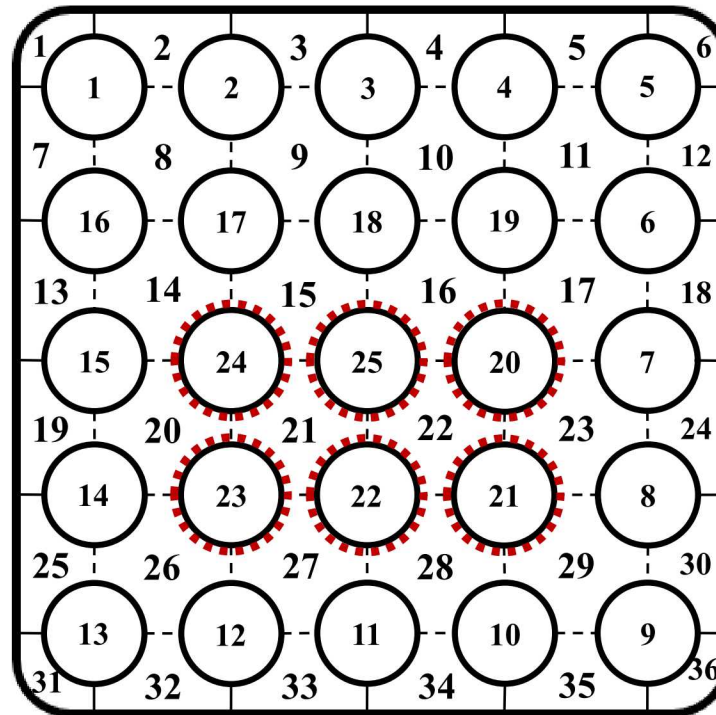


T-STAR Mapping – 5x5



Ideally, we would want to be able to characterize a given rod in a way that is entirely decoupled from an x,y coordinate.

As a proof of concept that this is possible, let's break down the WEC 5x5 and its spacer grid.



T-STAR Mapping – 5x5

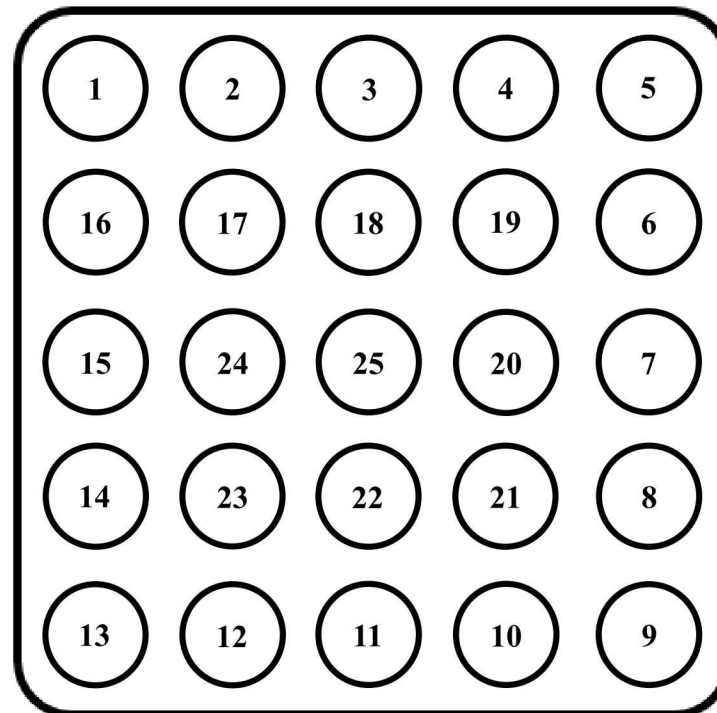


If we can neglect the dimples and springs in the spacer grid, we can assume that rod surface temperature is dominated by the vane orientation (not shown).

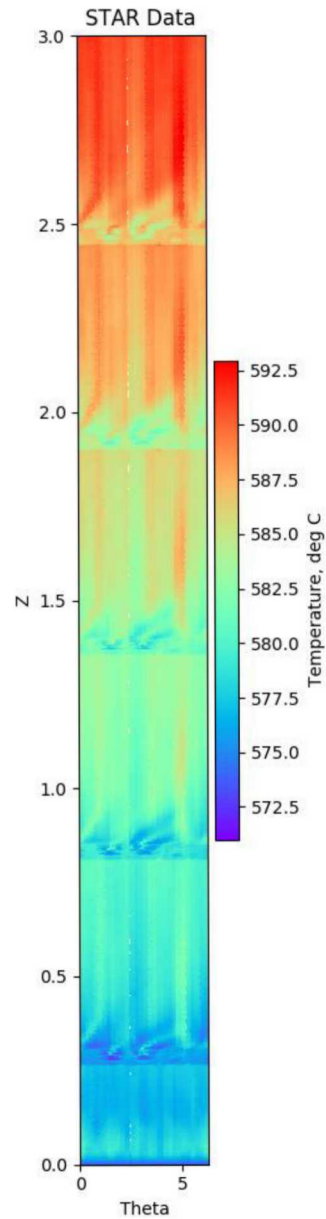
If this is true, we can break up the spacer grid into groups. An example grouping might be:

- Side, corner, middle
- Vane orientation

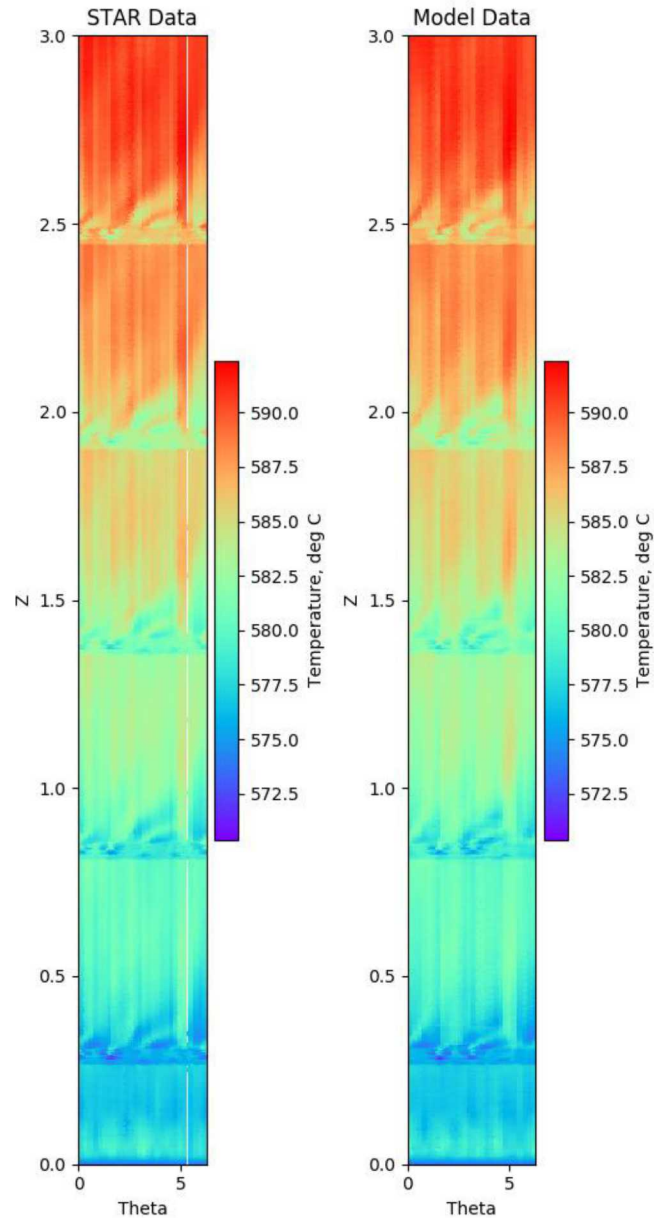
Can we guess what rods have a surface temperature pattern that is close to rod 2?



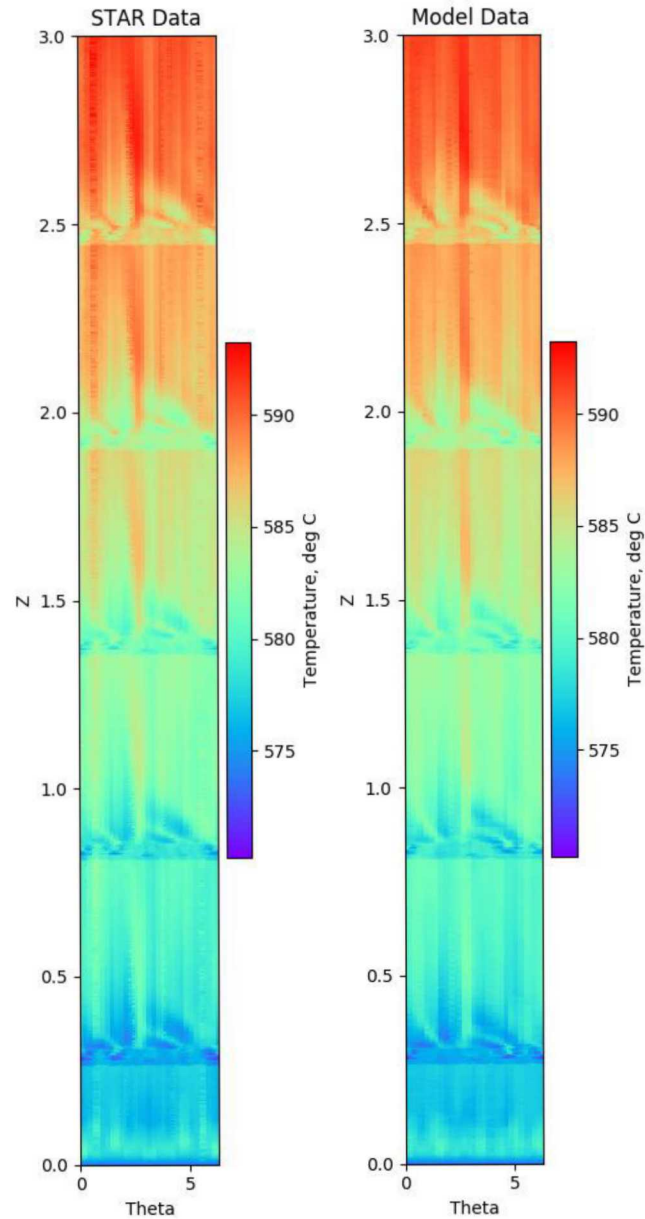
T-STAR Mapping – 5x5, Rod 2 Map



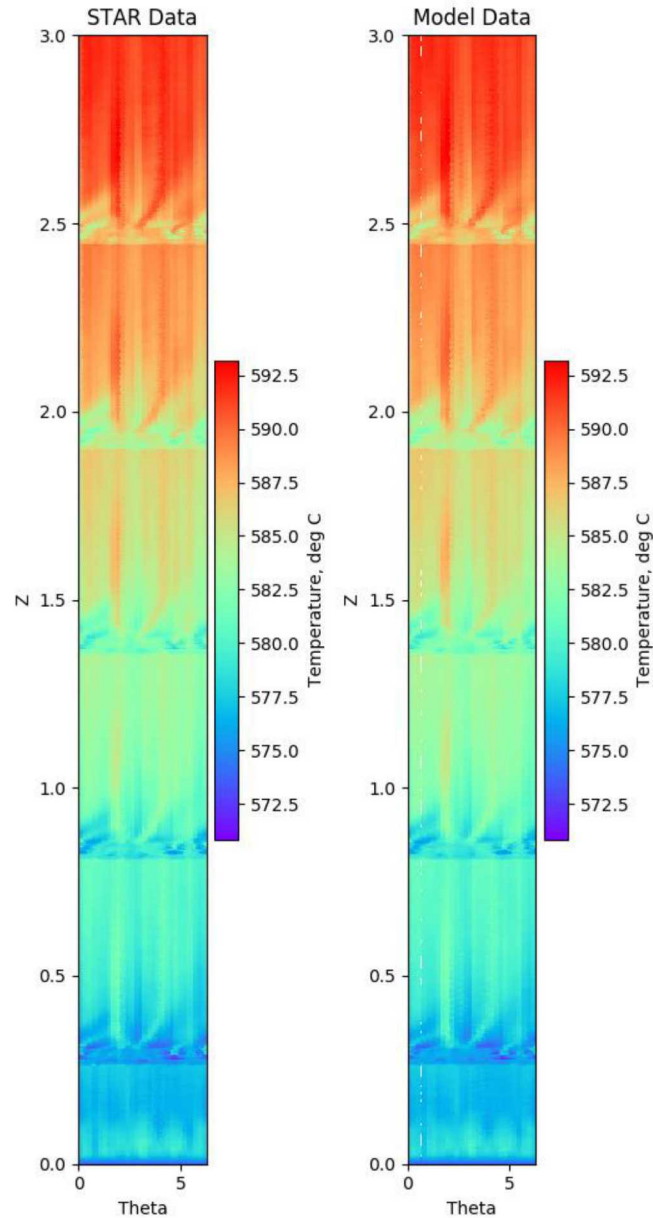
T-STAR Mapping – 5x5, Rod 2 Map Applied to Rod 4



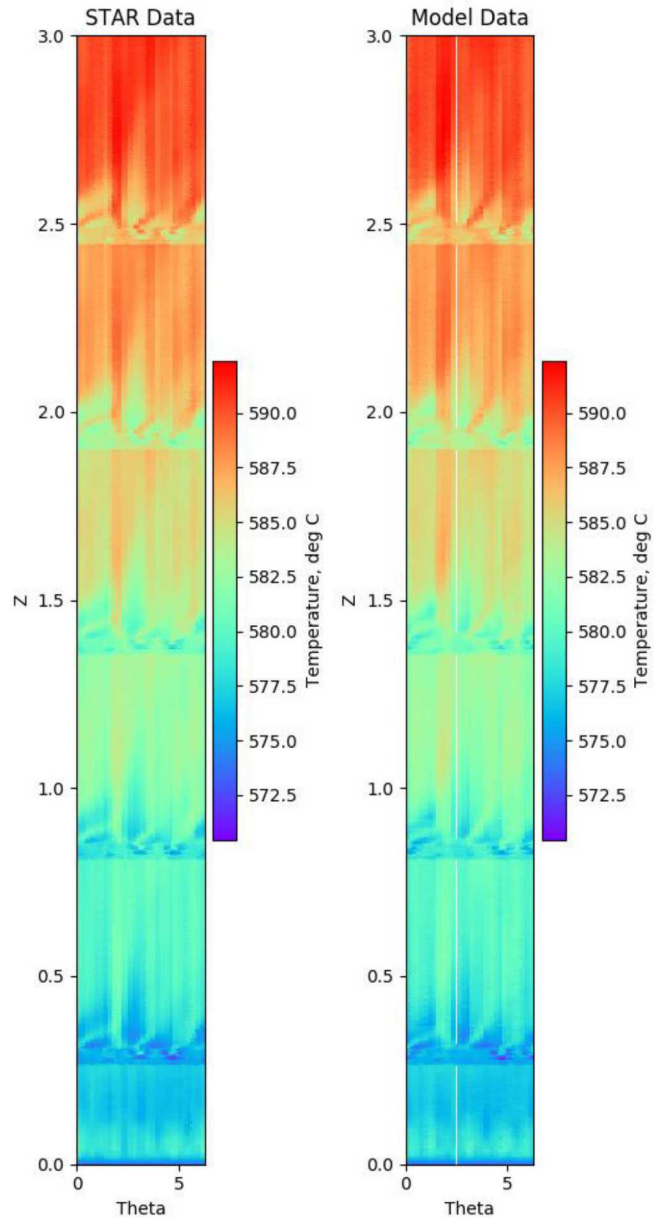
T-STAR Mapping – 5x5, Rod 2 Map Applied to Rod 7



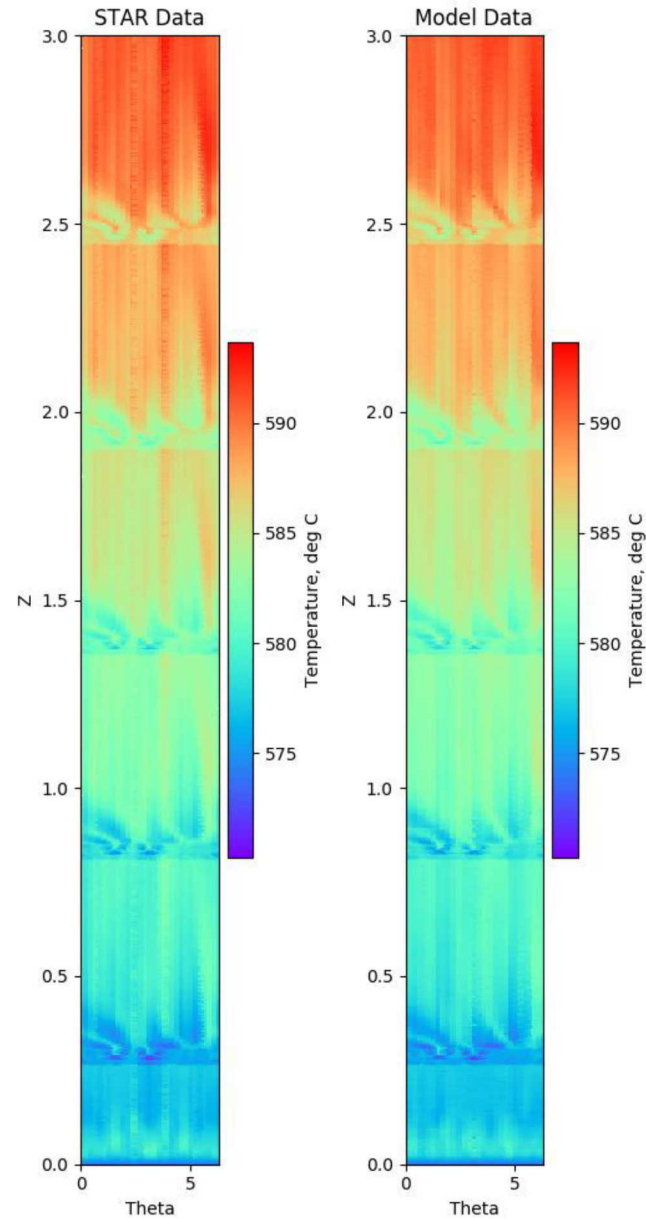
T-STAR Mapping – 5x5, Rod 2 Map Applied to Rod 10



T-STAR Mapping – 5x5, Rod 2 Map Applied to Rod 12

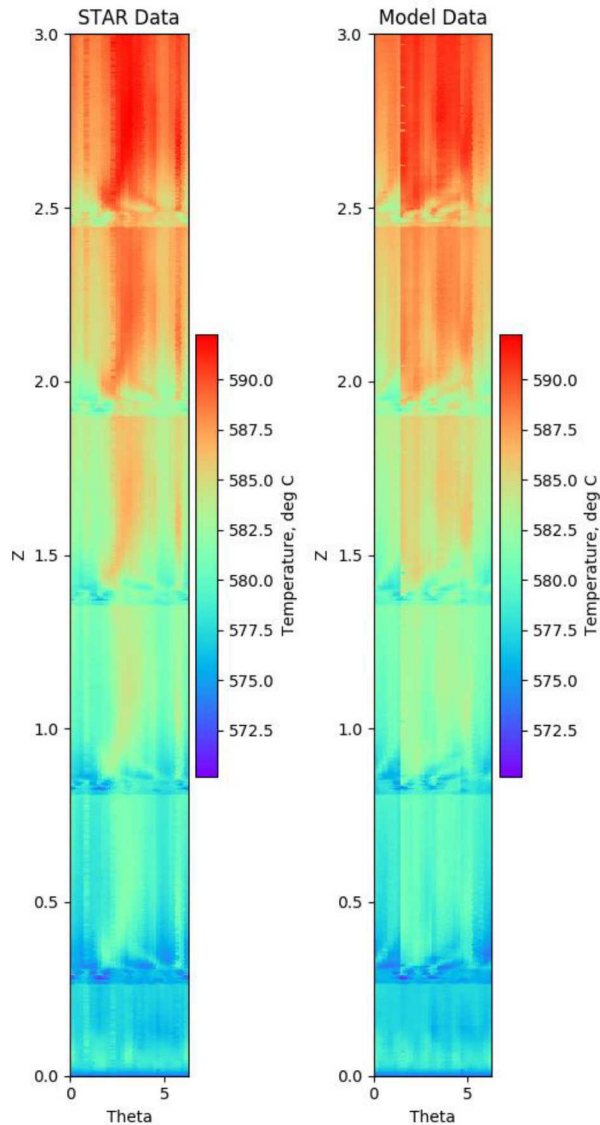


T-STAR Mapping – 5x5, Rod 2 Map Applied to Rod 15

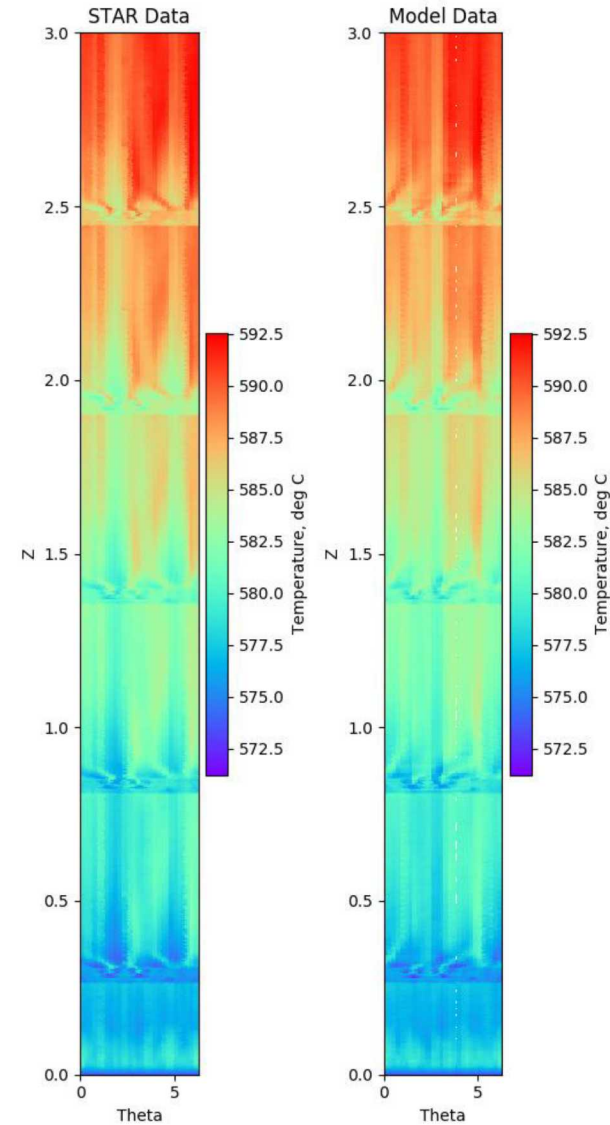




ROD 3



ROD 17



T-STAR Mapping – 5x5, Rod 2 Map



Rod	Map Applied		Rod 2 Map Applied		* Custom Rod 2 Map	
	RMS	Linf	RMS	Linf	RMS	Linf
1	0.19823	2.343958	1.141108	4.744129		
2	0.172329	2.225399	0.172329	2.225399		
3	0.208593	2.646449	1.288335	6.242694		
4	0.178669	2.132788	0.770235	4.223475	0.770235	4.223475
5	0.173143	2.400026	1.160799	5.92467		
6	0.157844	2.131388	0.897903	4.747625		
7	0.217959	2.427428	1.165238	4.897953	0.823172	4.382206
8	0.164716	2.248632	0.934386	4.624299		
9	0.198973	2.409345	1.205954	5.176735		
10	0.173001	2.154434	1.021843	5.436081	0.231407	2.30942
11	0.209379	2.44513	1.391029	5.485755		
12	0.173398	2.173862	0.945979	5.615884	0.761019	3.719099
13	0.170552	2.440409	1.181084	5.830939		
14	0.157814	2.038165	0.900519	4.595267		
15	0.212727	2.207818	1.0985	5.181452	0.710646	3.117945
16	0.160618	2.163088	0.809045	3.64881		
17	0.169353	2.048544	1.376439	5.481364		
18	0.189675	2.1088	0.915477	3.98174		
19	0.183811	1.948787	1.326886	5.463215		
20	0.227425	2.408523	1.132746	5.010781		
21	0.203578	2.535352	1.689609	6.232945		
22	0.229959	2.252158	1.16984	5.804589		
23	0.223033	2.423066	1.645716	7.399258		
24	0.225782	2.385948	0.979588	4.793683		
25	0.263433	2.568954	1.741809	6.479002		

T-STAR Mapping – 5x5, Rod 2 Map



Rod	Map Applied		Rod 2 Map Applied		* Custom Rod 2 Map	
	RMS	Linf	RMS	Linf	RMS	Linf
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5	0.173143	2.400026	1.160799	5.92467		
6	0.157844	2.131388	0.897903	4.747625		
7	0.217959	2.427428	1.165238	4.897953	0.823172	4.382206
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