

# XC40 Cabin Heatup

## Optimisation

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Anandh PhD Project  
XC40 CabinHeatup at low  
temp

Initial Conditions

- Velocity 50km/hr
- Exterior Temperature -7C
- Cabin Initial Temp -4C
- Temp HVAC 30C
- Heating Time 40mins

Final Results:

Ncpus 920

Avg Cabin Air 24.7C

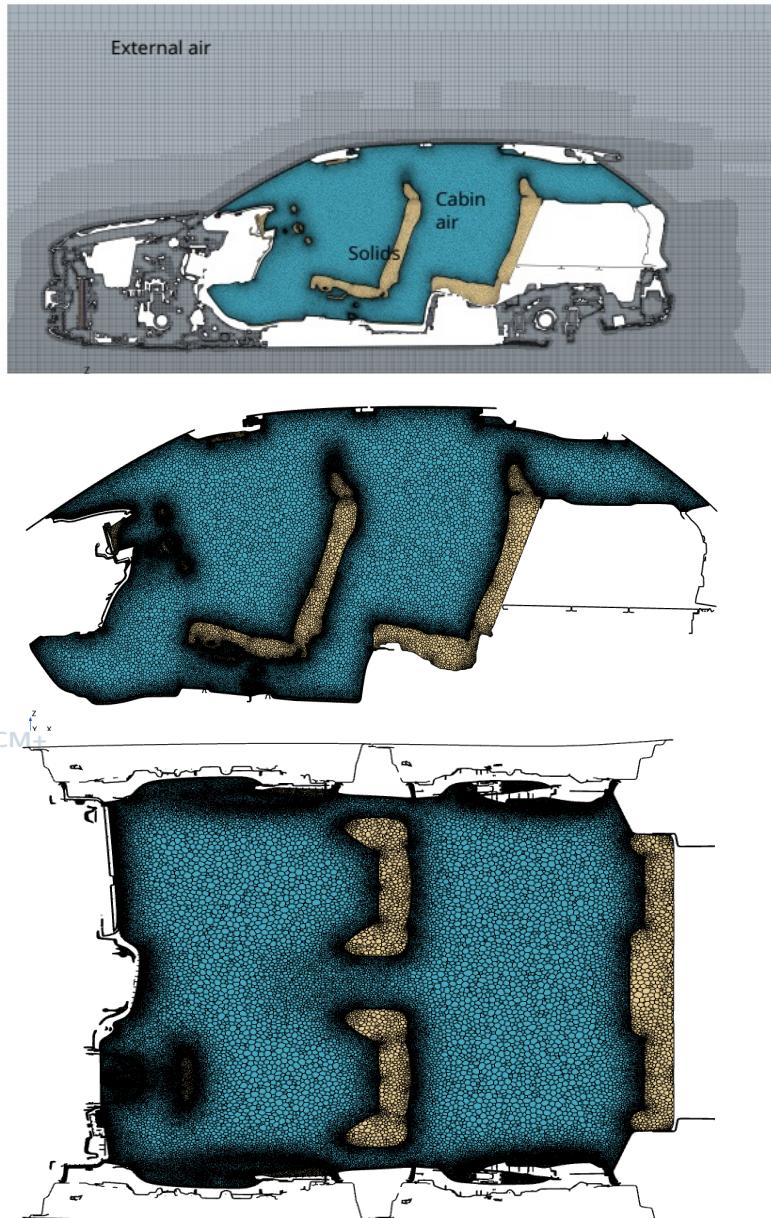
Compt Time 115hr /4.8days

Main Objective

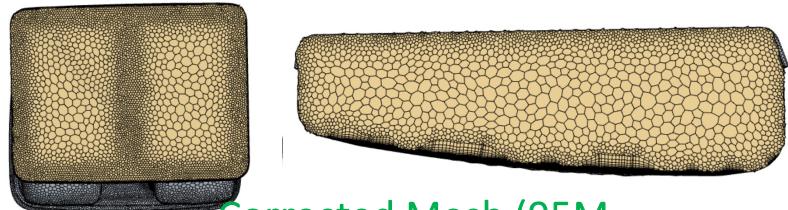
Reduce the time to less than 24hr  
with Temp deviation not more than  
1C (10%)

Parameters Analysed

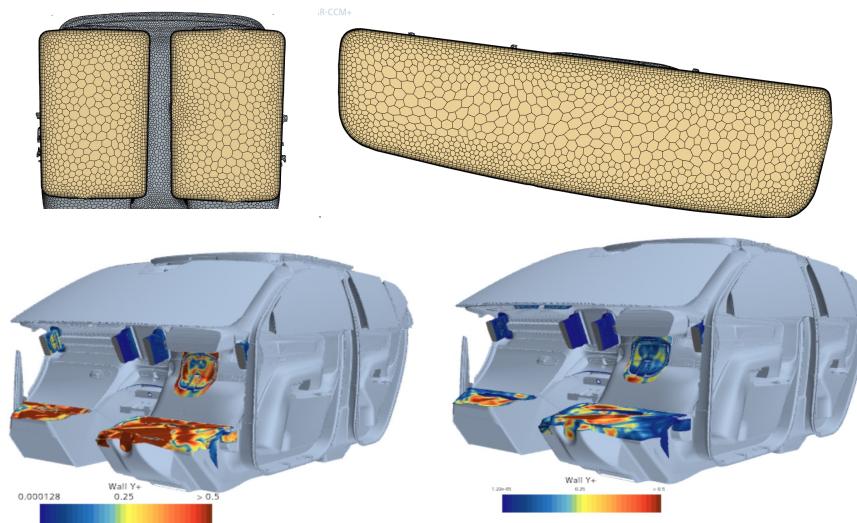
- Timestep (Coarser timestep)
- Sub-iterations
- Mesh Settings
- Trunk effect on energy consumption



## Improvement No 1 Geometry Cleanup

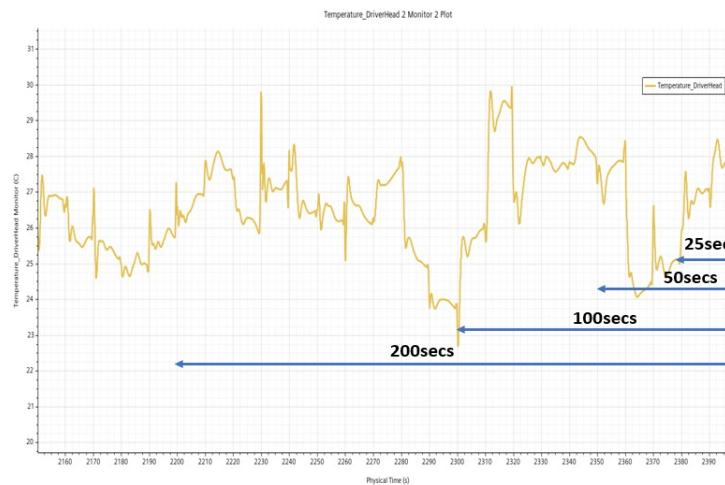


Corrected Mesh (95M Cells)

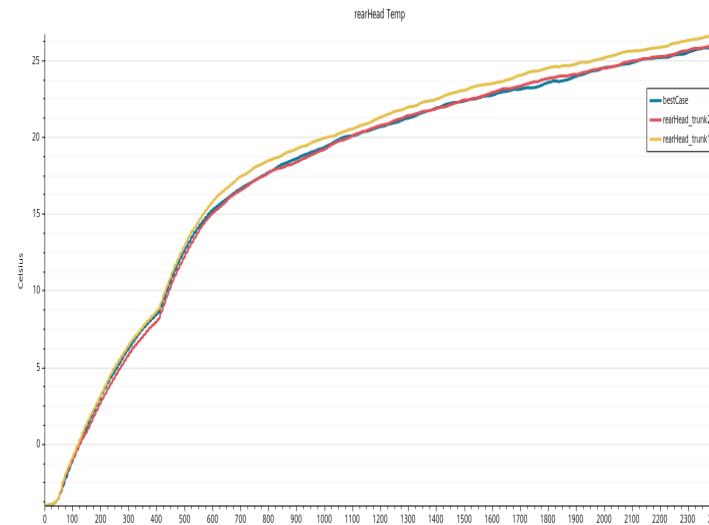


V O L V O

## Improvement No 2 Instant Reports showing higher deviation



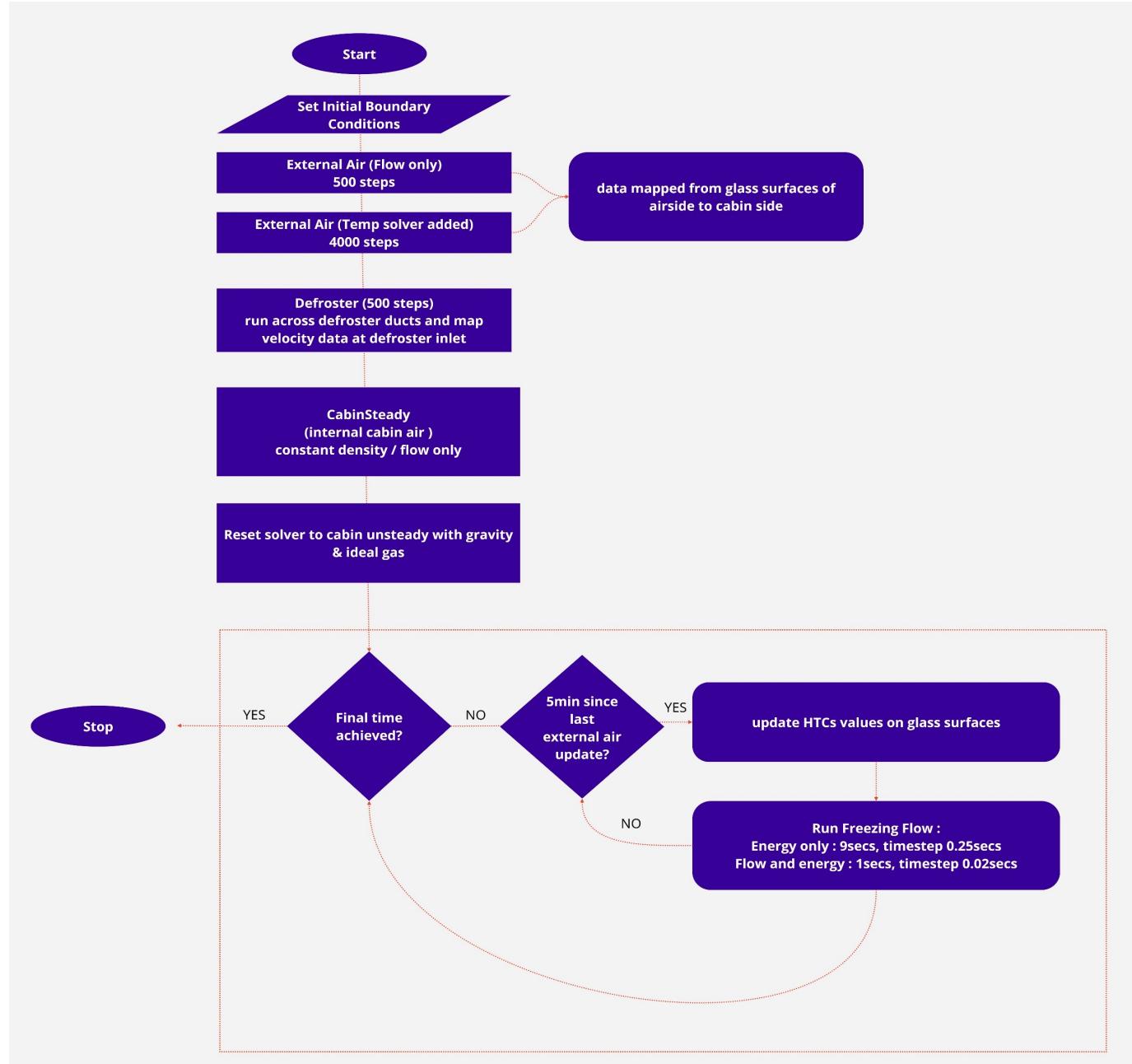
Using Mean 50 secs



## Improvement No 3 Using too small monitor volumes



# Simulation Framework



**v o l v o**

## Timestep Analysis

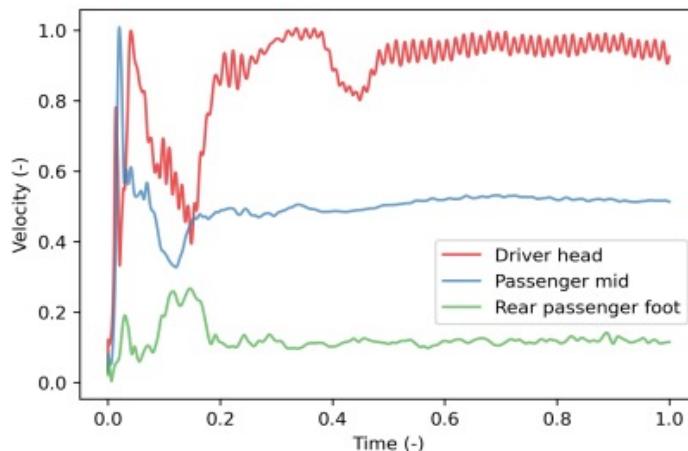
Timestep performed in two steps

**Freeze:** solving only energy transport  
(9sec with timestep 0.25secs)

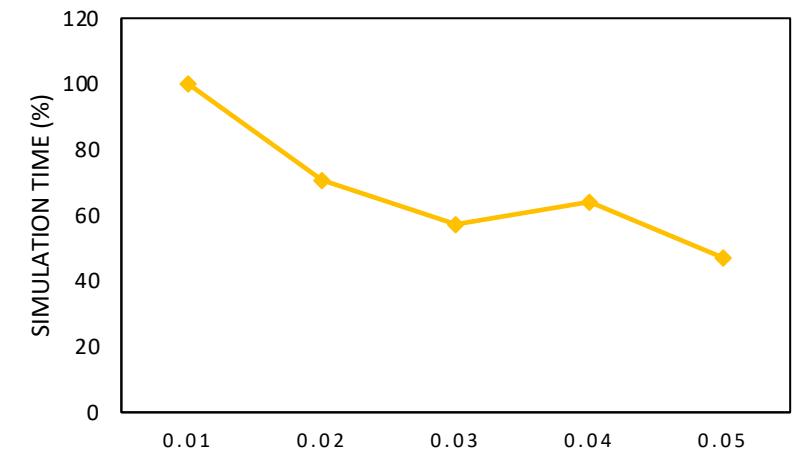
**Unfreeze:** solving all transport eqs  
(1sec with timestep 0.02s)

**Reason:**

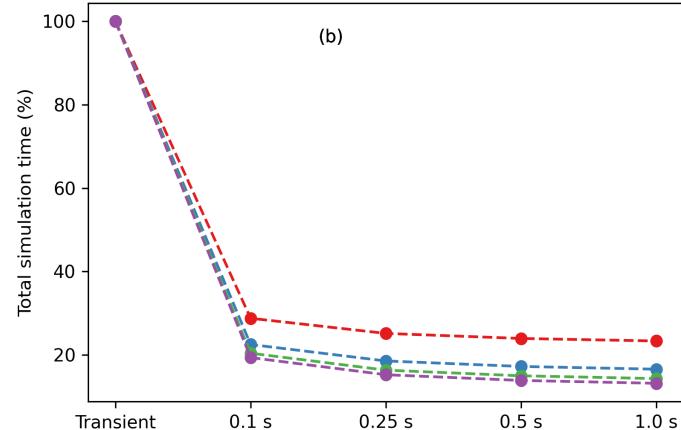
- Flow is locally steady after some time
- To decrease simulation time



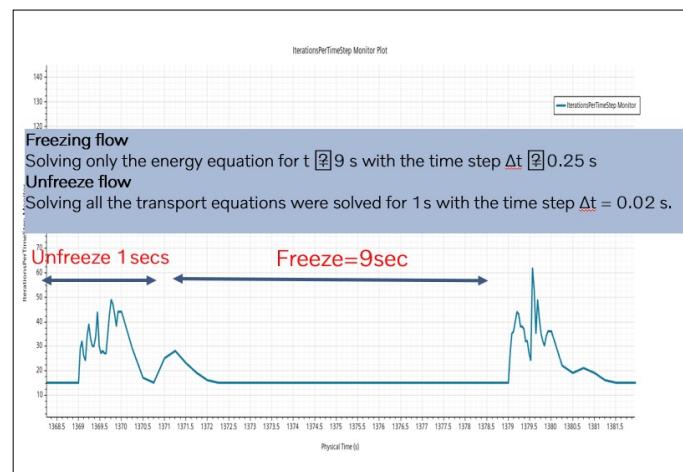
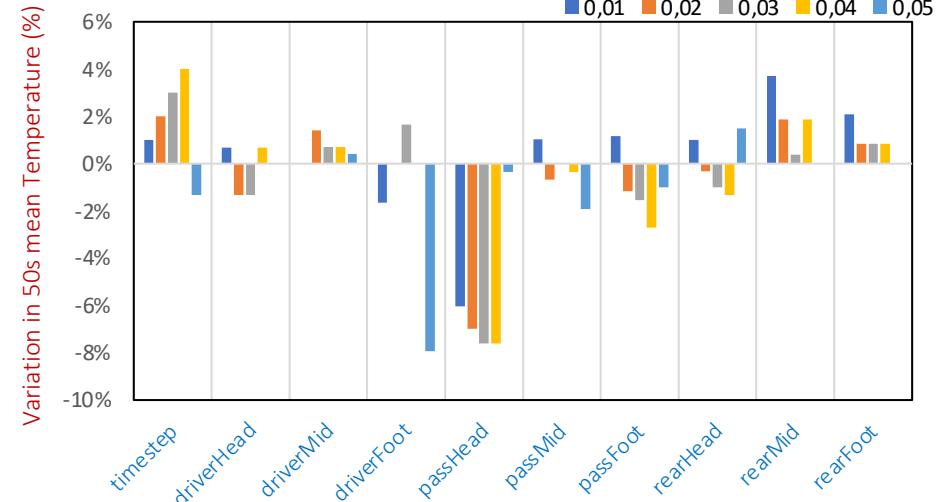
Effect of unfreeze flow timestep on simulation time



Effect of freeze flow timestep on simulation time

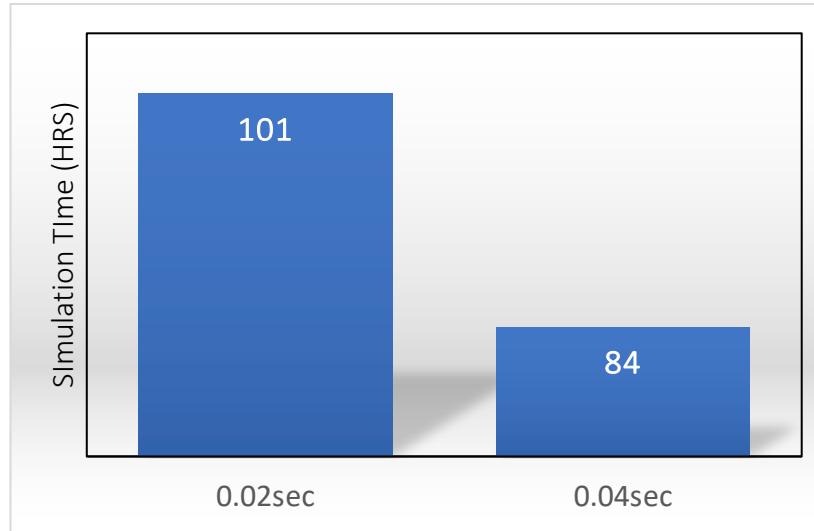


Deviation in Monitor Voll Temp vs unfreezeFlowTimestep



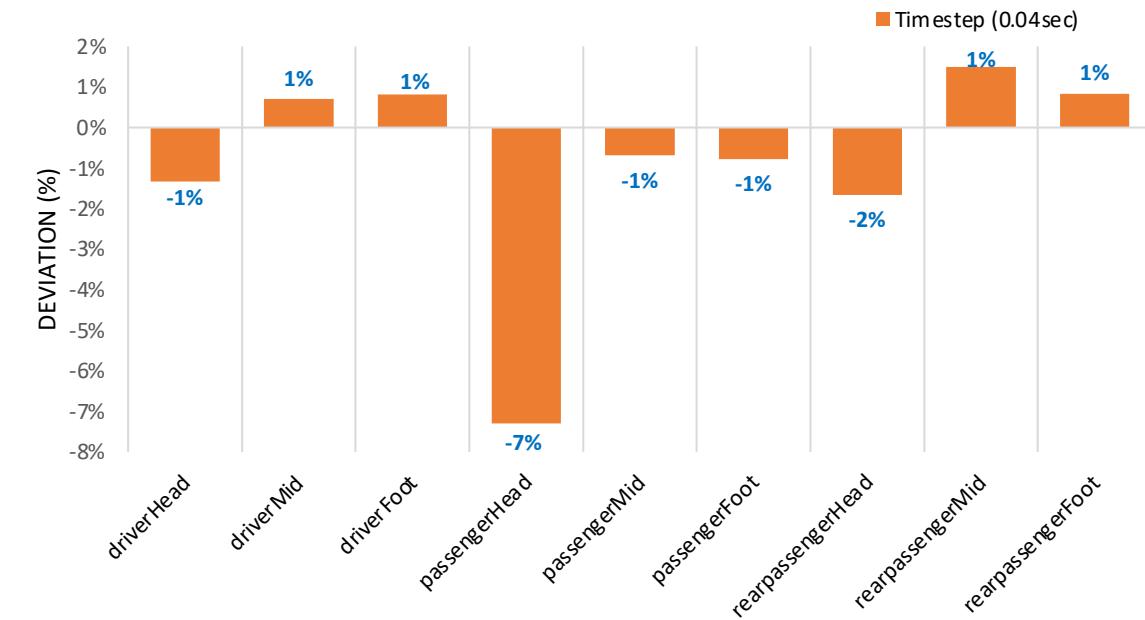
# Results: Timestep Analysis

Reduction in Simulation time due to using large timestep (0.02 ->0.04)

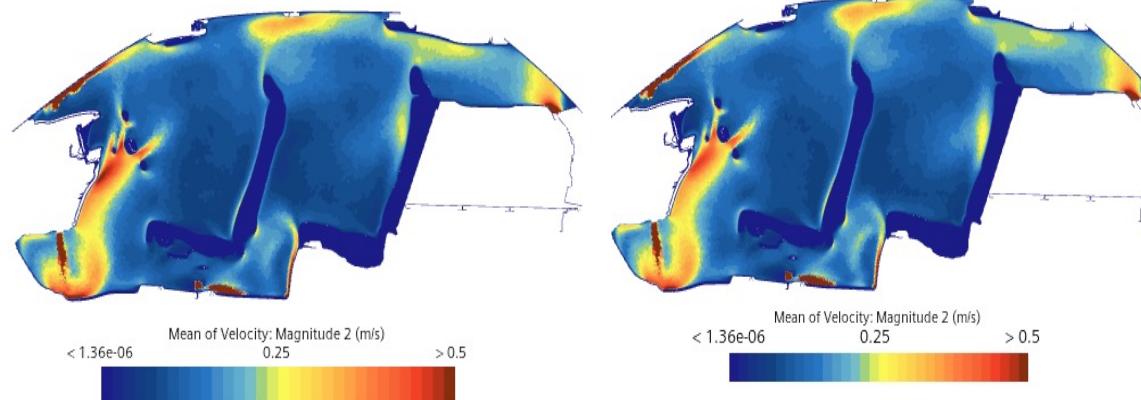


v o l v o

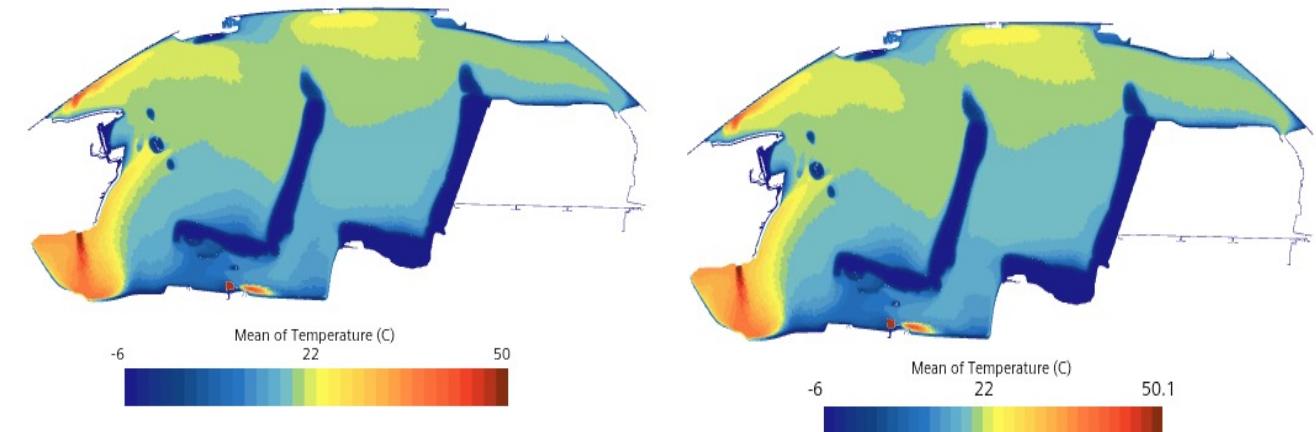
Deviation in Normalised Mean Temperature of working model after timestep study



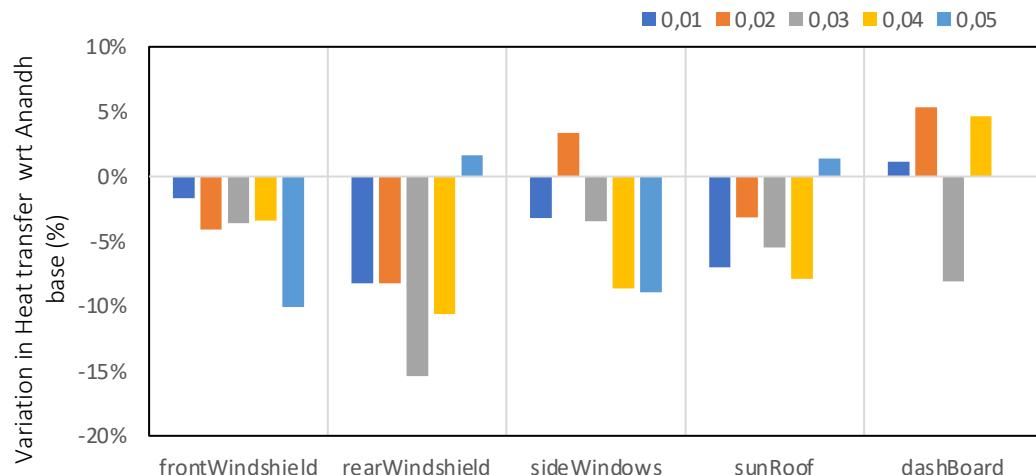
Comparison of Mean Velocity (AnandhBaseCase vs afterTimestepStudy)



Comparison of Mean Temperature (AnandhBaseCase vs afterTimestepStudy)



## Heat Transfer of Glass Surface vs UnfreezeFlowTimestep



unfreezeFlowTimestep@0.01sec

Heat Transfer Coefficient

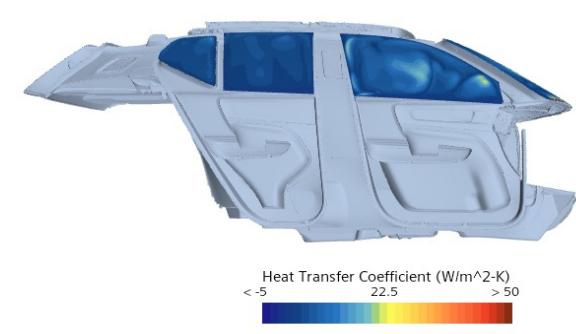


Heat Transfer Coefficient ( $\text{W/m}^2\text{-K}$ )

<-5 22.5 >50

unfreezeFlowTimestep@0.05sec

Heat Transfer Coefficient

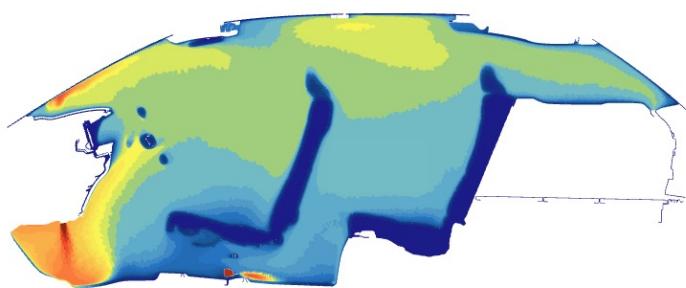


Heat Transfer Coefficient ( $\text{W/m}^2\text{-K}$ )

<-5 22.5 >50

unfreezeFlowTimestep  
@0.01sec

50 sec MeanTemp

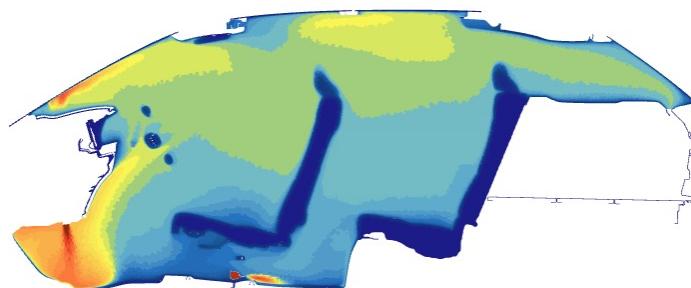


Mean of Temperature ( $^\circ\text{C}$ )

-6 22 50

unfreezeFlowTimestep  
@0.05sec

50 sec MeanTemp

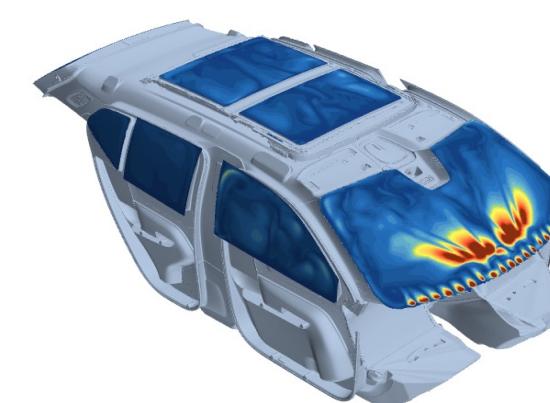


Mean of Temperature ( $^\circ\text{C}$ )

-6 22 50

unfreezeFlowTimestep@0.01sec

Heat Transfer Coefficient

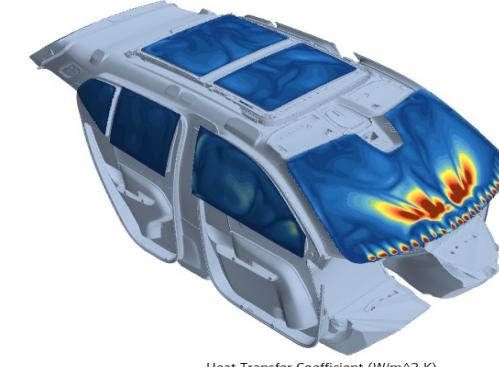


Heat Transfer Coefficient ( $\text{W/m}^2\text{-K}$ )

<-5 22.5 >50

unfreezeFlowTimestep@0.05sec

Heat Transfer Coefficient

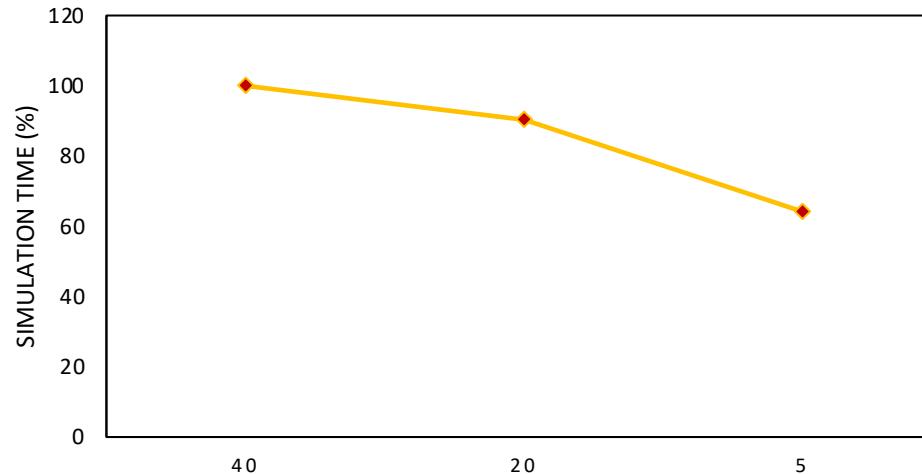


Heat Transfer Coefficient ( $\text{W/m}^2\text{-K}$ )

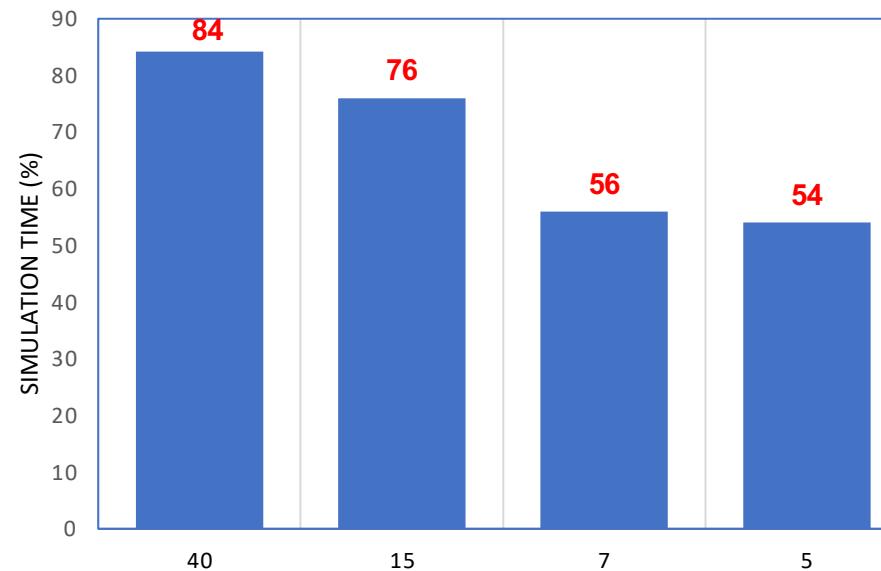
<-5 22.5 >50

# Results: Iteration Analysis

Effect of subiteration on reducing Simulation Time

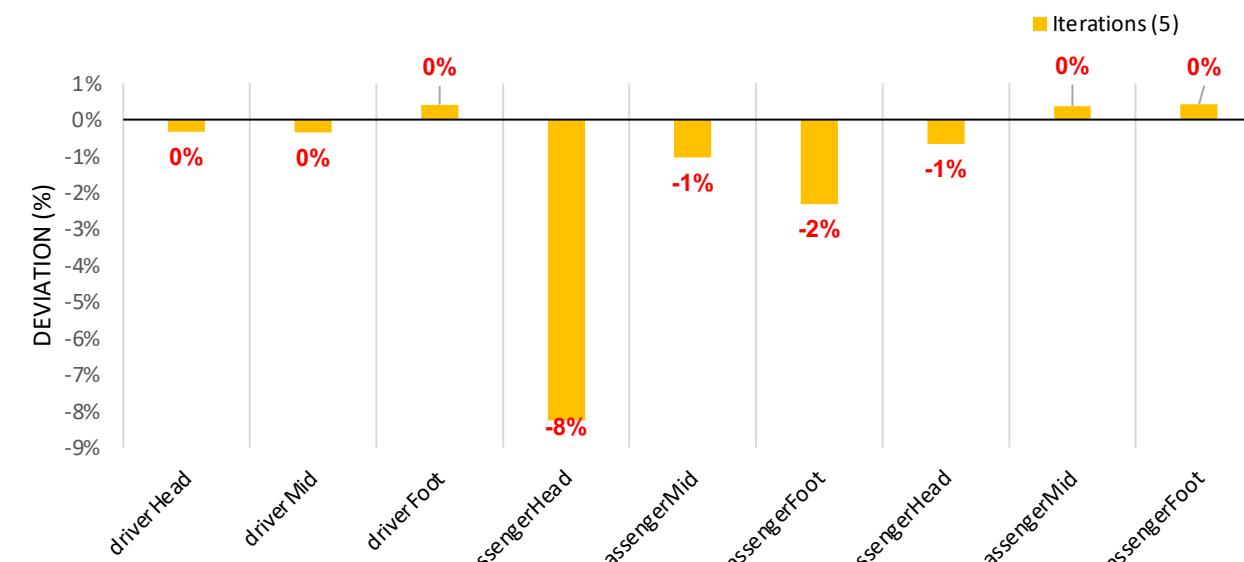


Reduction in Simulation time due to decreasing sub-iterations (40 -> 5)

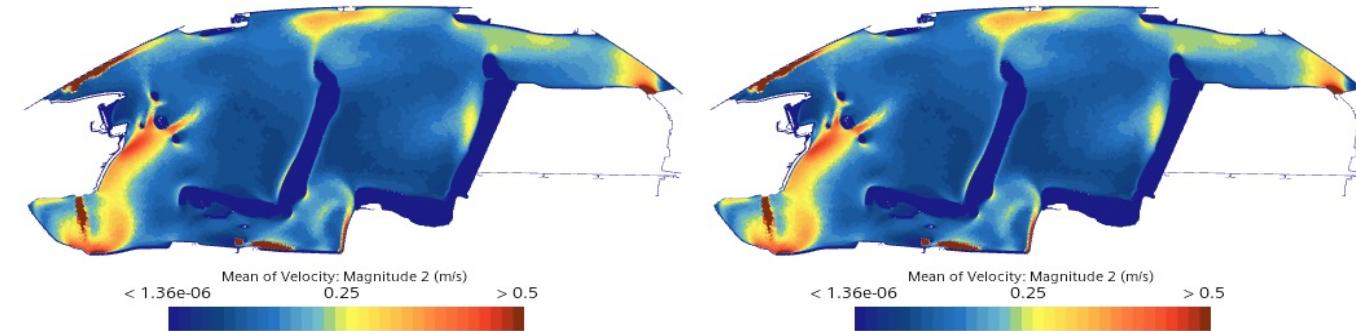


**v o l v o**

Deviation in Normalised Mean Temperature of working model after iterations study



Comparison of Mean Temperature (AnandhBaseCase vs afteriterationStudy)



# Mesh Study Final Results

**V O L V O**

Try changing different mesh parameters

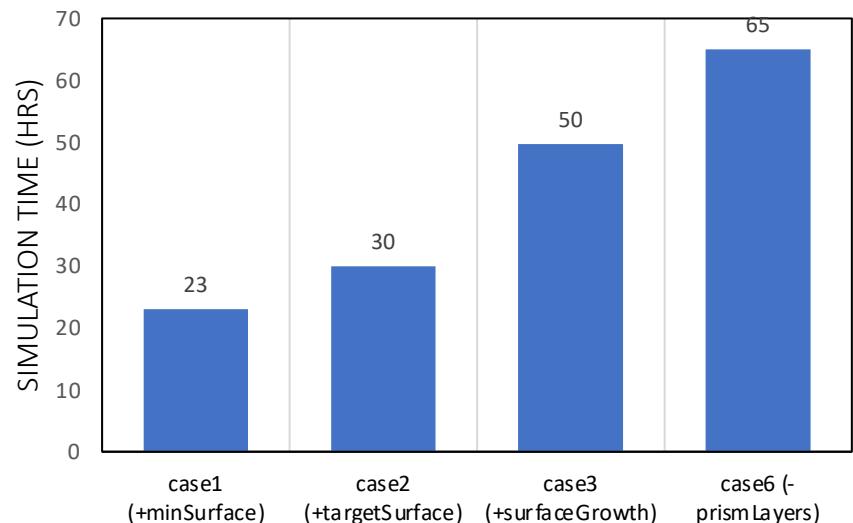
Higher Surface Growth Rate  
(1.2 => 1.5)

Increase Min Surface/Target  
(1mm => 4mm, 4mm => 8mm)

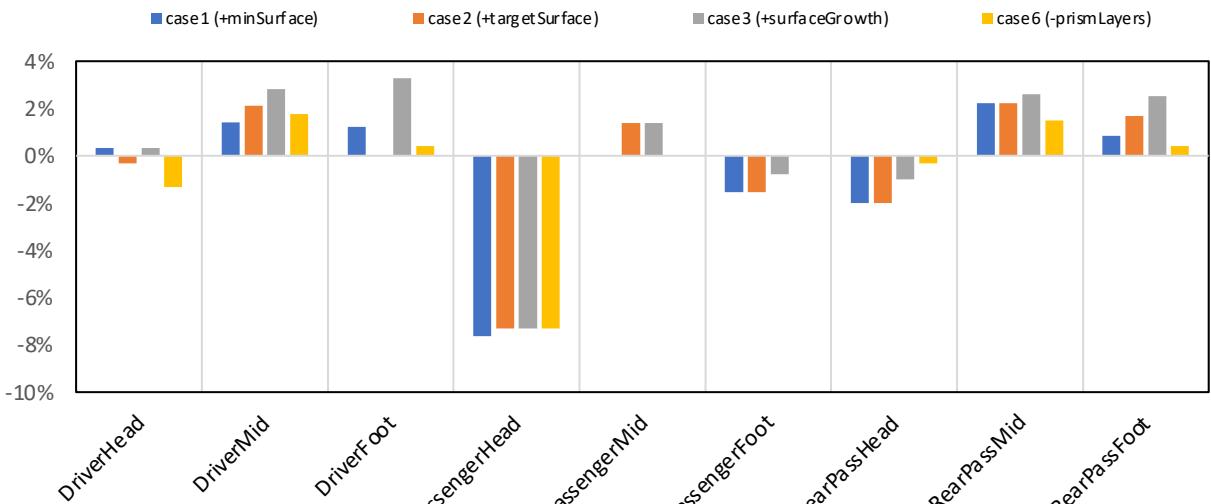
Higher Volume Growth  
(1.2 => 1.3)

Higher Tet size  
(16mm => 32mm)

Lower Prism Layers  
(10 => 6)

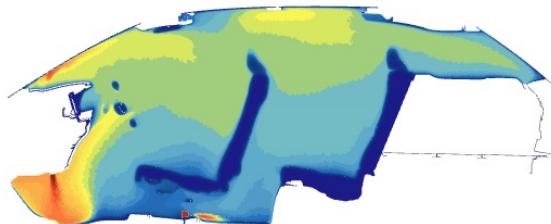


Normalised Mean Temperature w.r.t Anandh base mesh (115 Hrs)

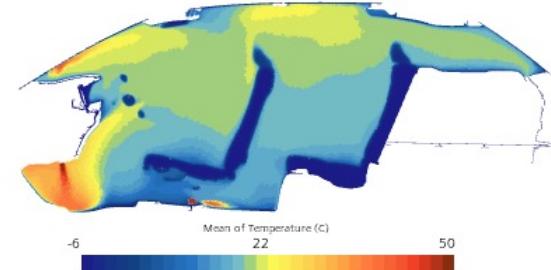


50sec Mean Temp (C)

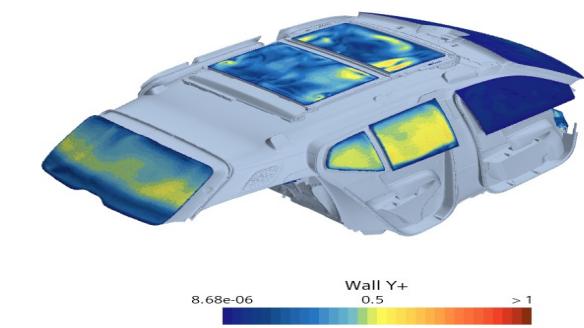
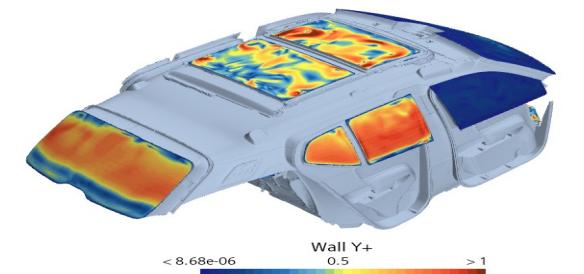
Anandh  
StartingCase  
(115Hours)



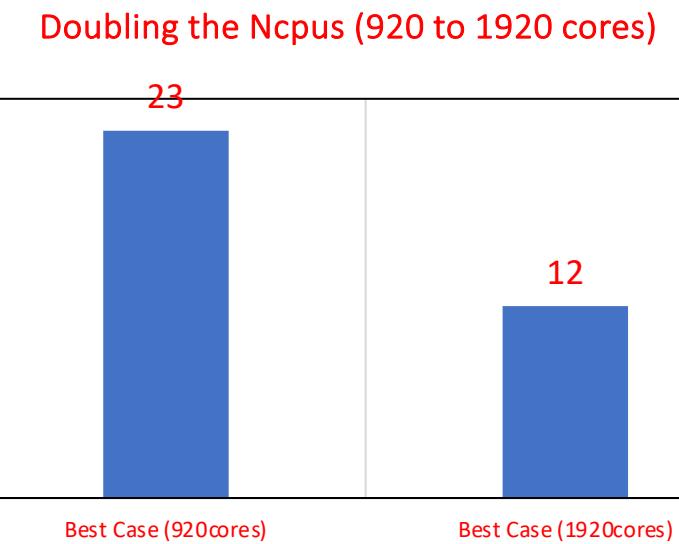
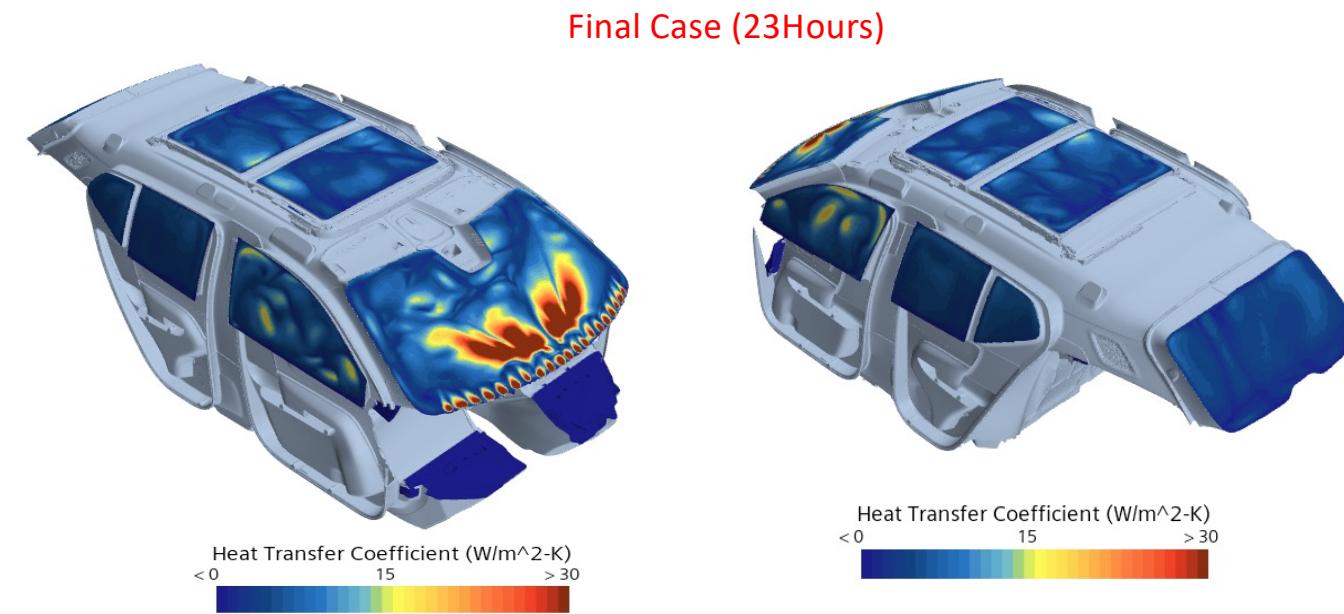
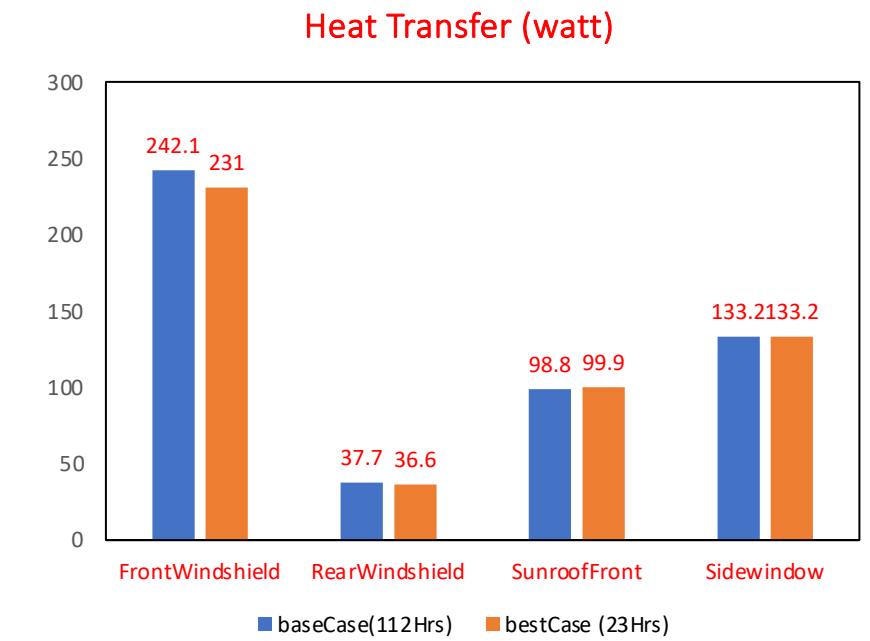
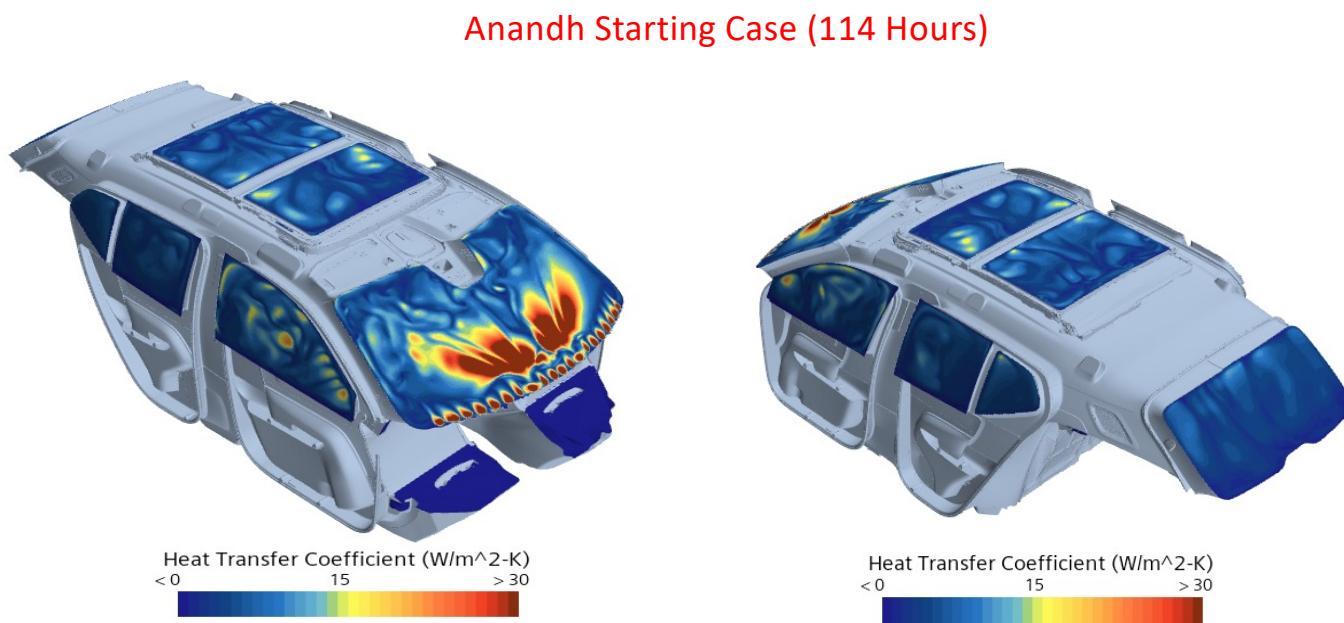
Best Case  
(23Hours)



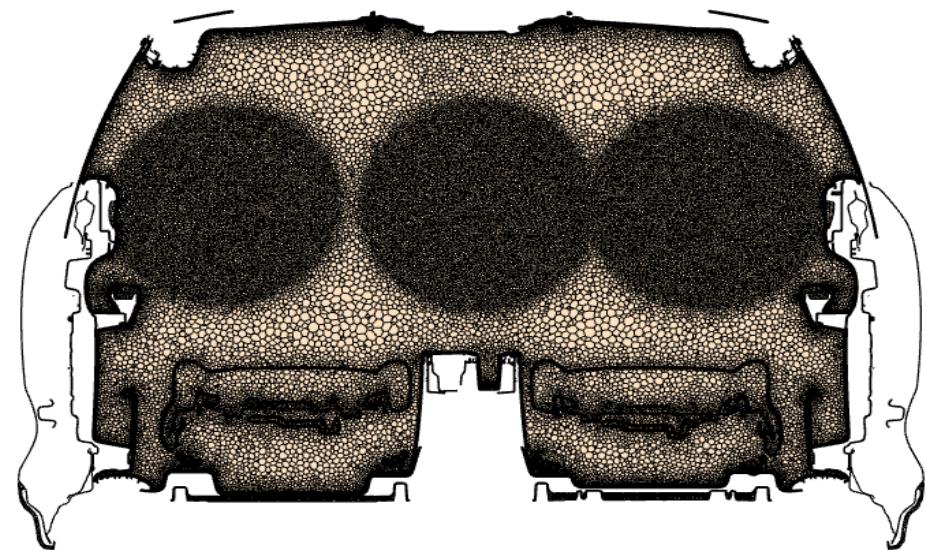
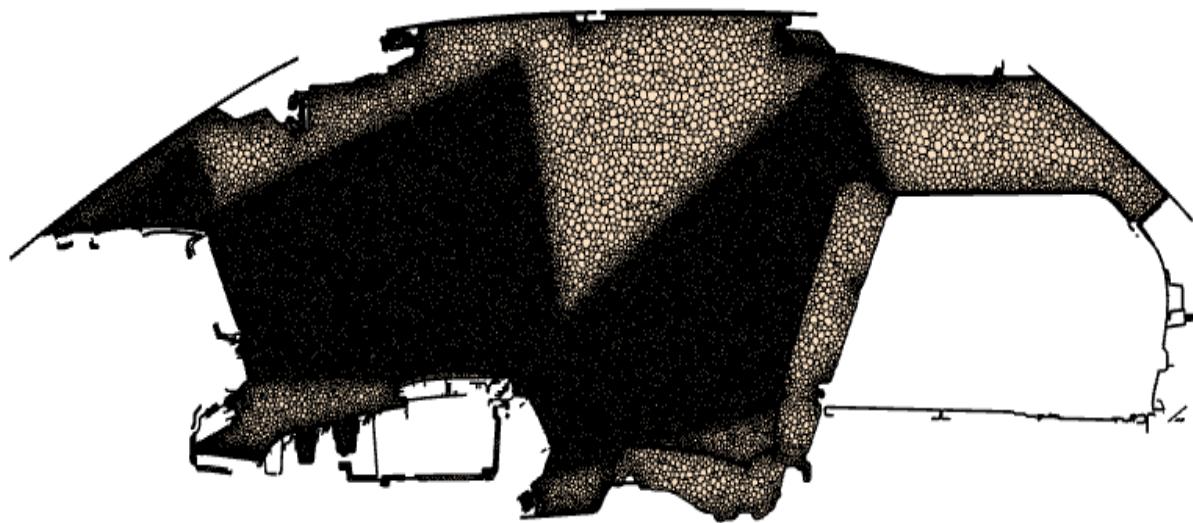
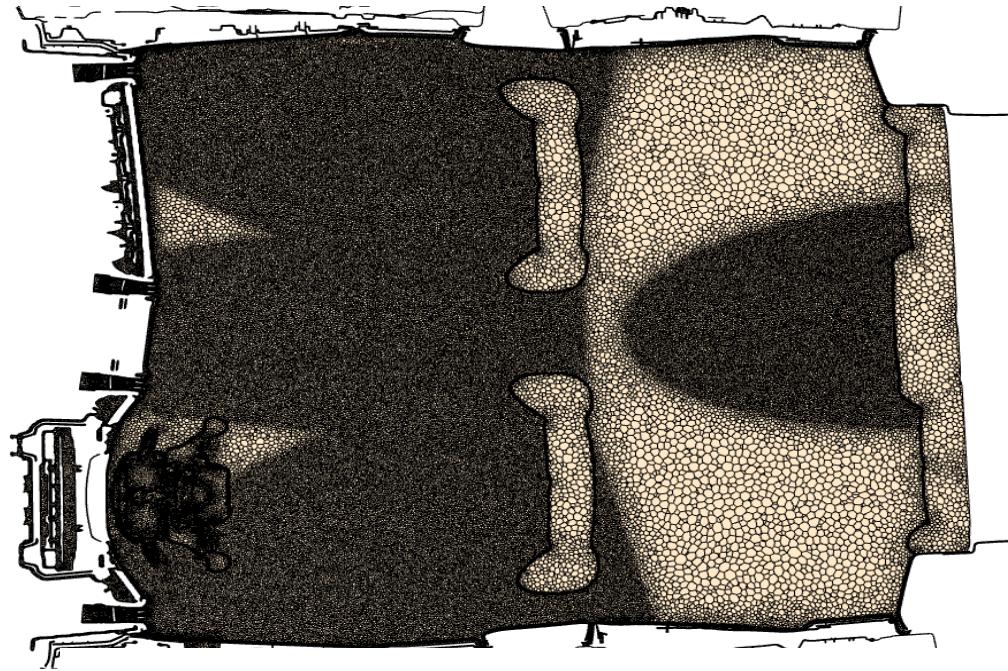
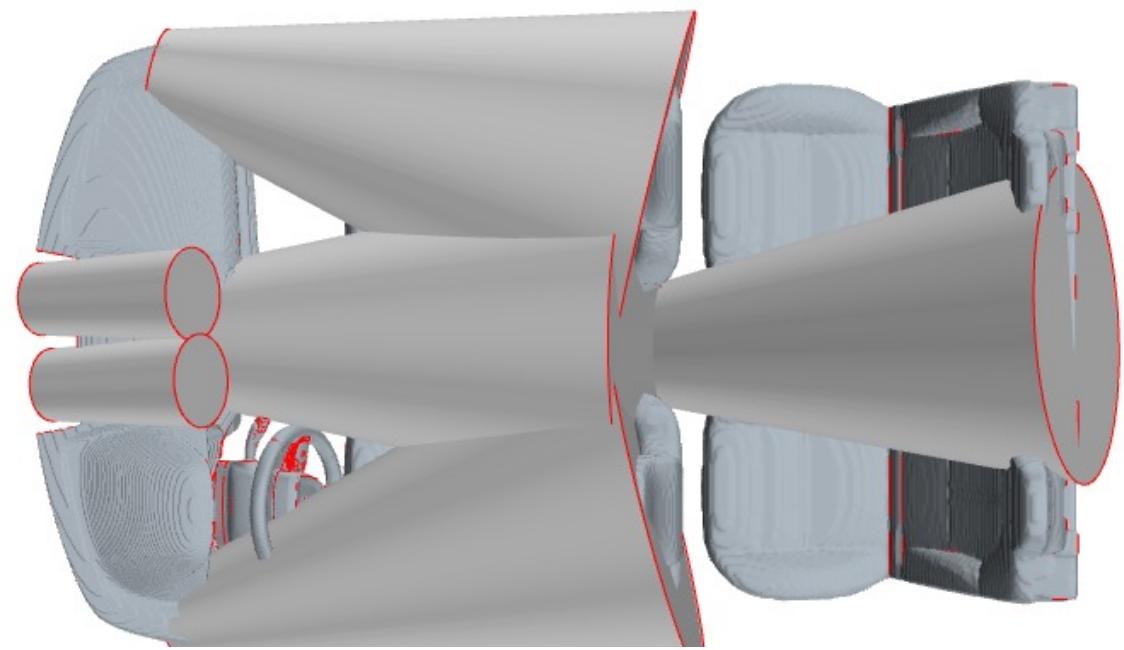
Wall Y+



# Final Results

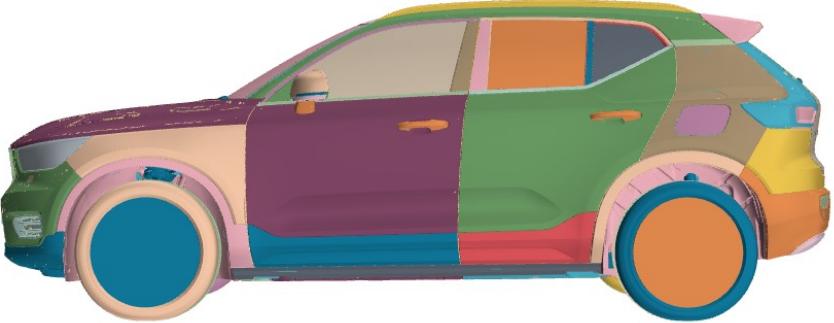


# Refinement Study

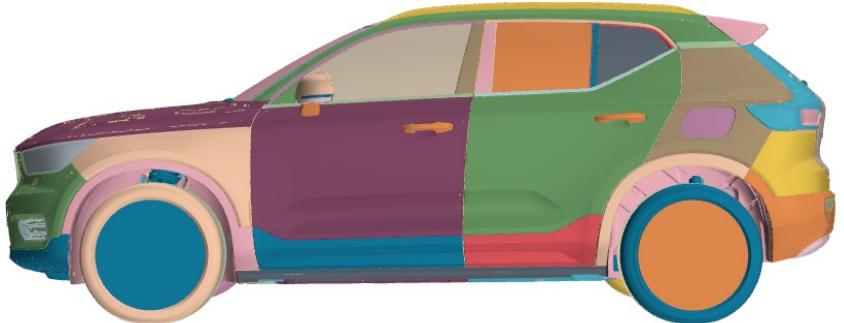


# Effect of Trunk on Energy Consumption

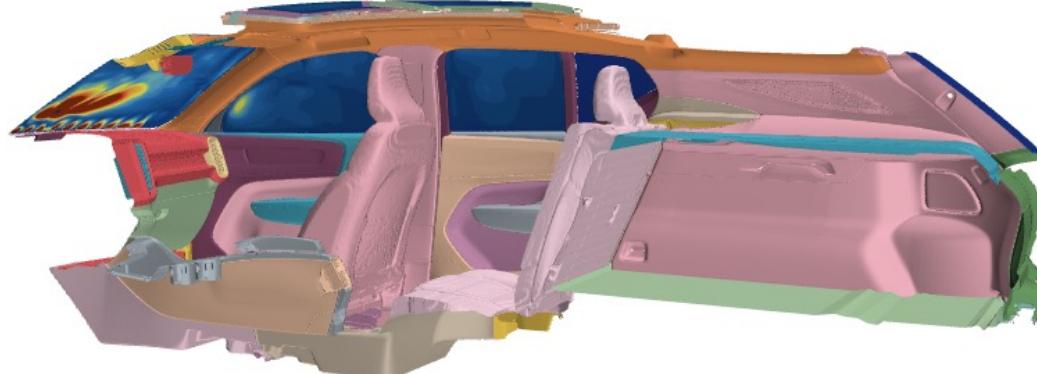
Case1 -  
w\_LuggageCover  
Position of outlets  
changed



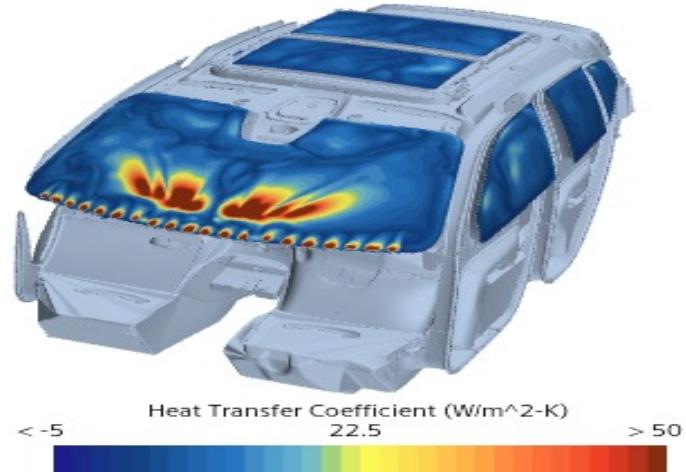
Case2 –  
w/o\_LuggageCover  
Position of outlets  
changed



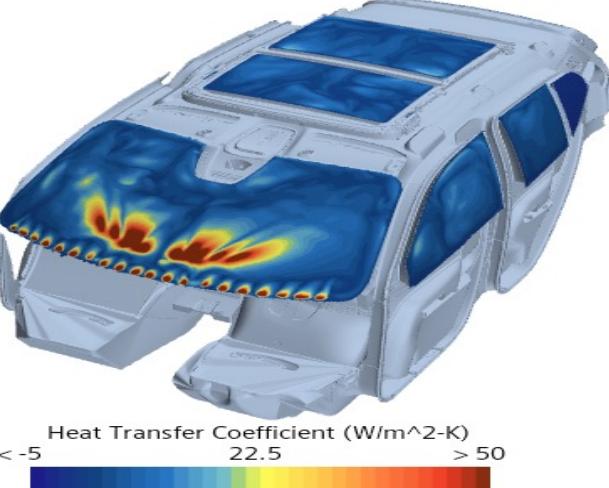
Case3 – morphed  
Length increased from 16  
to 68cm



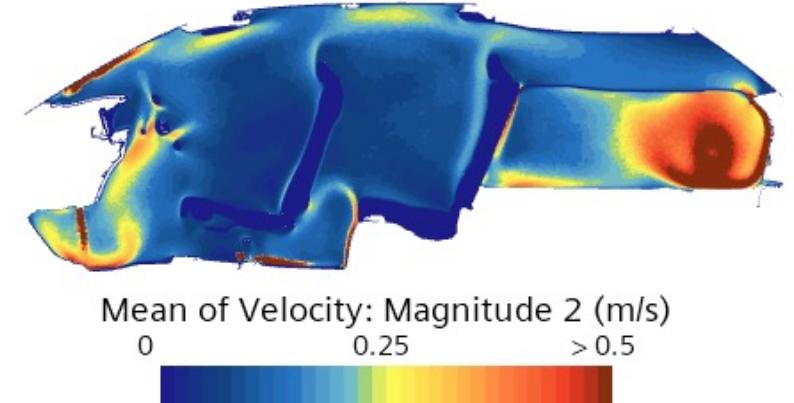
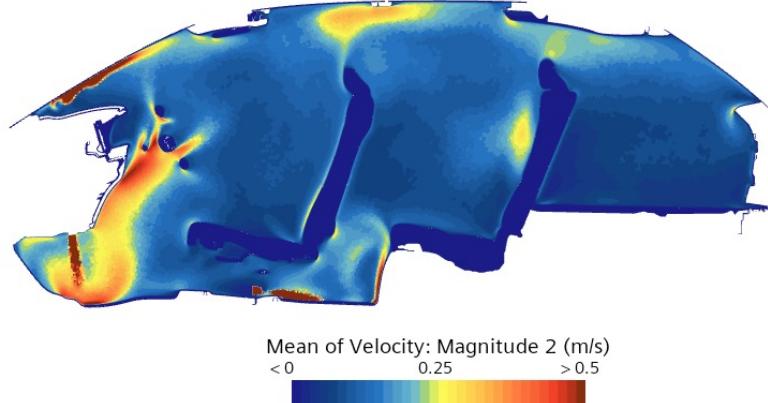
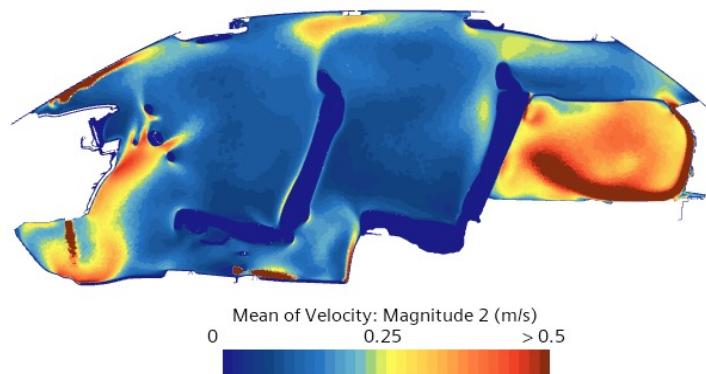
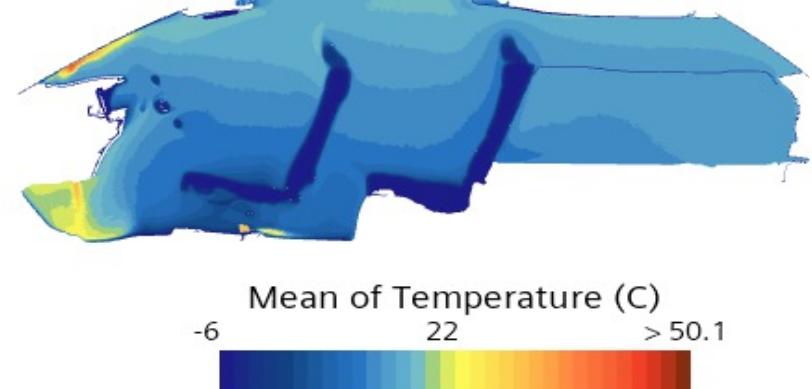
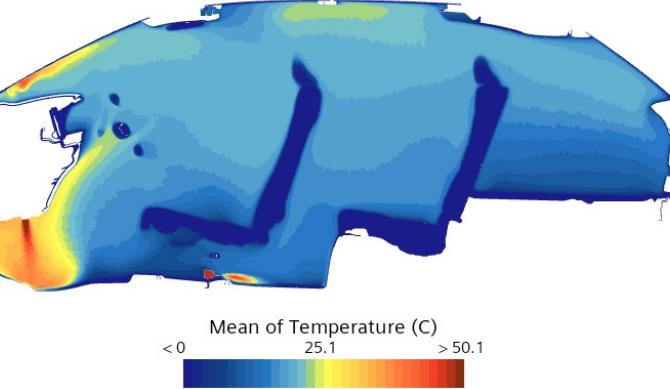
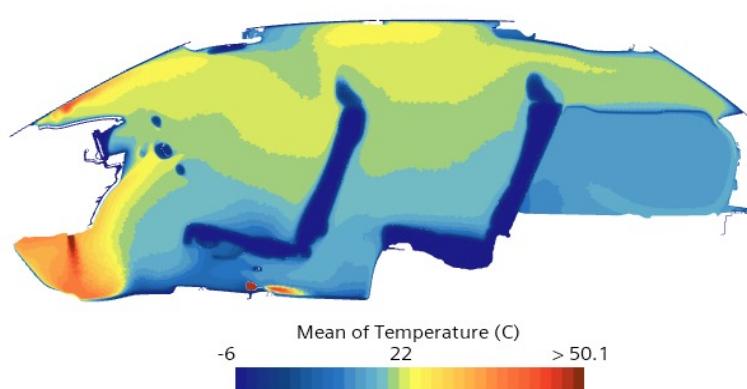
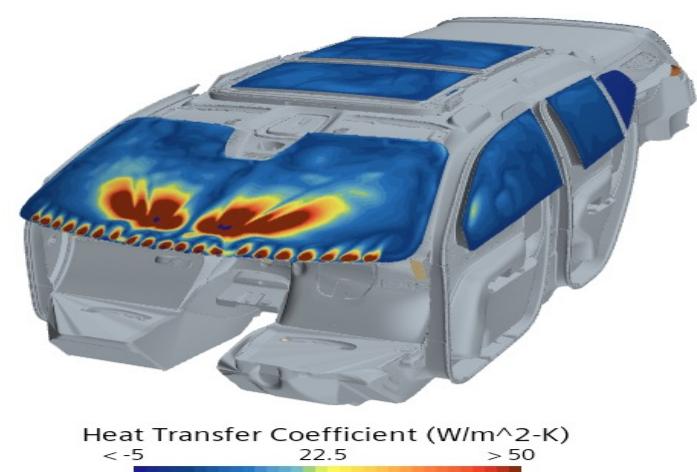
withLuggageCover



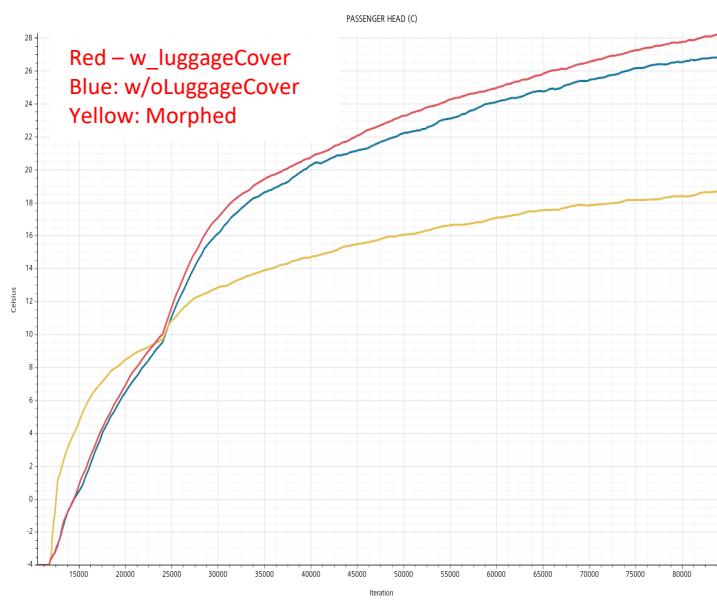
Without LuggageCover



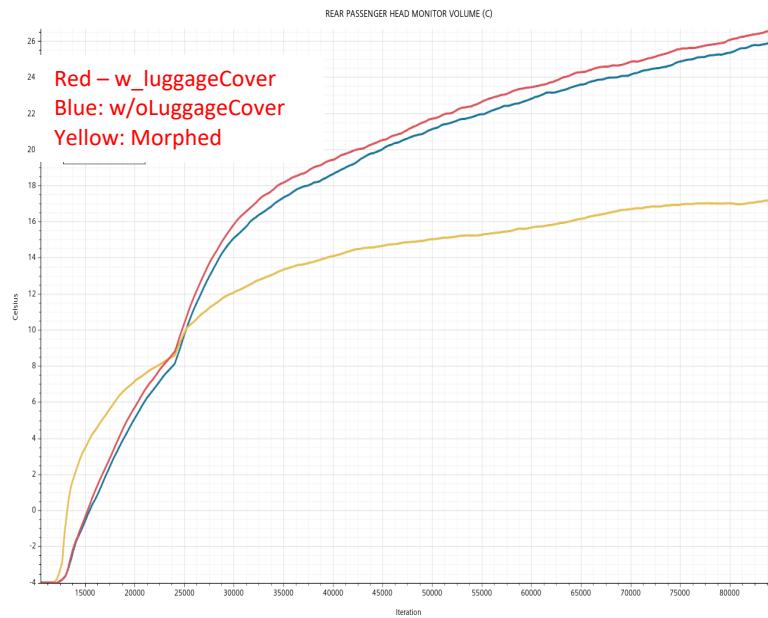
trunkMorphed



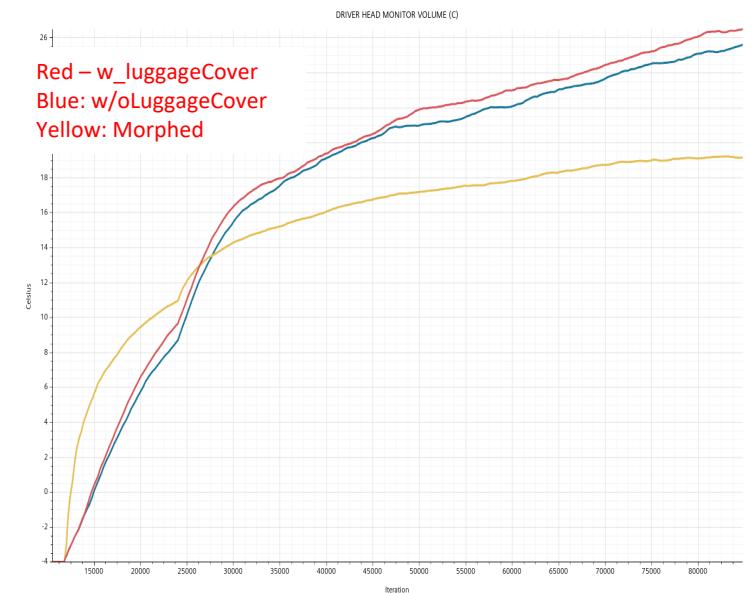
### Passenger Head Comparison (all three cases)



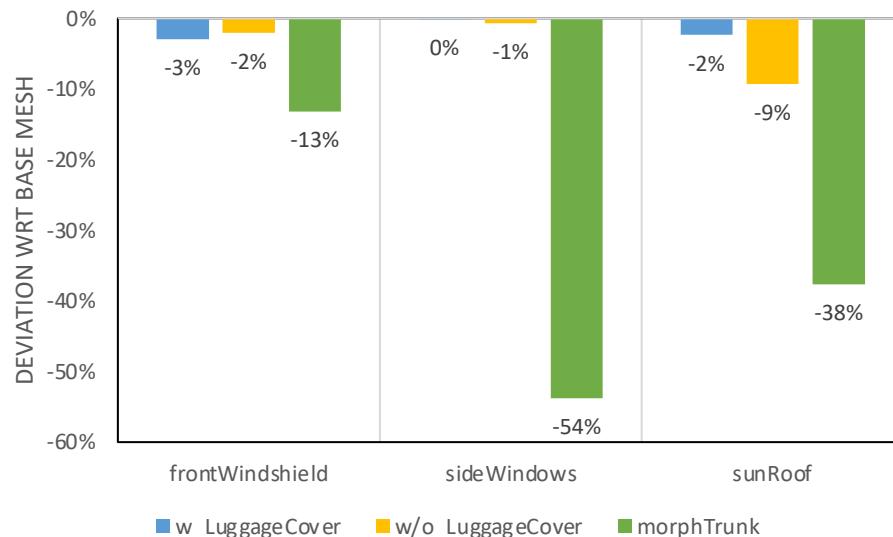
### RearPassengerHead Comparison (all three cases)



### Driver Head Comparison (all three cases)



### Heattransfer (Watt) wrt to Base Mesh (Anandh Starting Case)



### Deviation in 50sec Mean Temperature wrt base Mesh (AnandhStartingCase)

