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Multiphysics Simulation of Infrared Signature of an Ice Cube

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Abstract

This poster presents the Multiphysics numerical methodologies used to simulate the Infrared (IR) signature of an ice cube when taken out of the cold environment (-28 °C) and allowed to warm at room temperature conditions by means of natural convection. The ice cube is chosen to simplify the geometry. The cubical geometry can be discretized simply and hence allows easy application of Multiphysics simulation tools. The aim of this work is to validate the various numerical methodologies.

In order to model the behaviour, a 3D transient heat equation is solved using three different methodologies. In the first part of the work, the finite difference method is used to discretize the heat equation and solved using an FTCS (Forward-Time Central-Space) method in MATLAB® software. Then the same problem is modelled using the spectral method where the domain is discretized non-linearly for the appropriate solution. In the final part of the work, the problem is modelled in ANSYS® Multiphysics software. The results obtained through all methodologies are found in close agreement.

This proves that Multiphysics tools can be employed to model thermal behaviour and hence predict IR profile. Further work will be carried out to compare with the experimental results.

Heat Equation

Heat Equation

$$\rho c \frac{\partial T}{\partial t} = \dot{q} + \frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right)$$

where ρ is density of the medium $\left(\frac{Kg}{m^3}\right)$,

c is specific heat capacity $\left(\frac{J}{kg.K}\right)$,

$\dot{q}$ is volumetric energy generation term $\left(\frac{W}{m^3}\right)$,

k is coefficient of thermal conduction $\left(\frac{W}{m.K}\right)$,

T is temperature (K),

x refers to spatial position (m) and

t is time (s).

Spatial expansion of Heat Equation (no source term)

$$\frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

where x, y and z refer to spatial positions (m) in three dimensions and α is the thermal diffusivity term $\left(\frac{m^3}{s}\right)$ as given below,

$$\alpha = \frac{k}{\rho c}$$

Convective Boundary Condition

$$-k \frac{\partial T_s}{\partial x} = h(T_\infty - T_s)$$

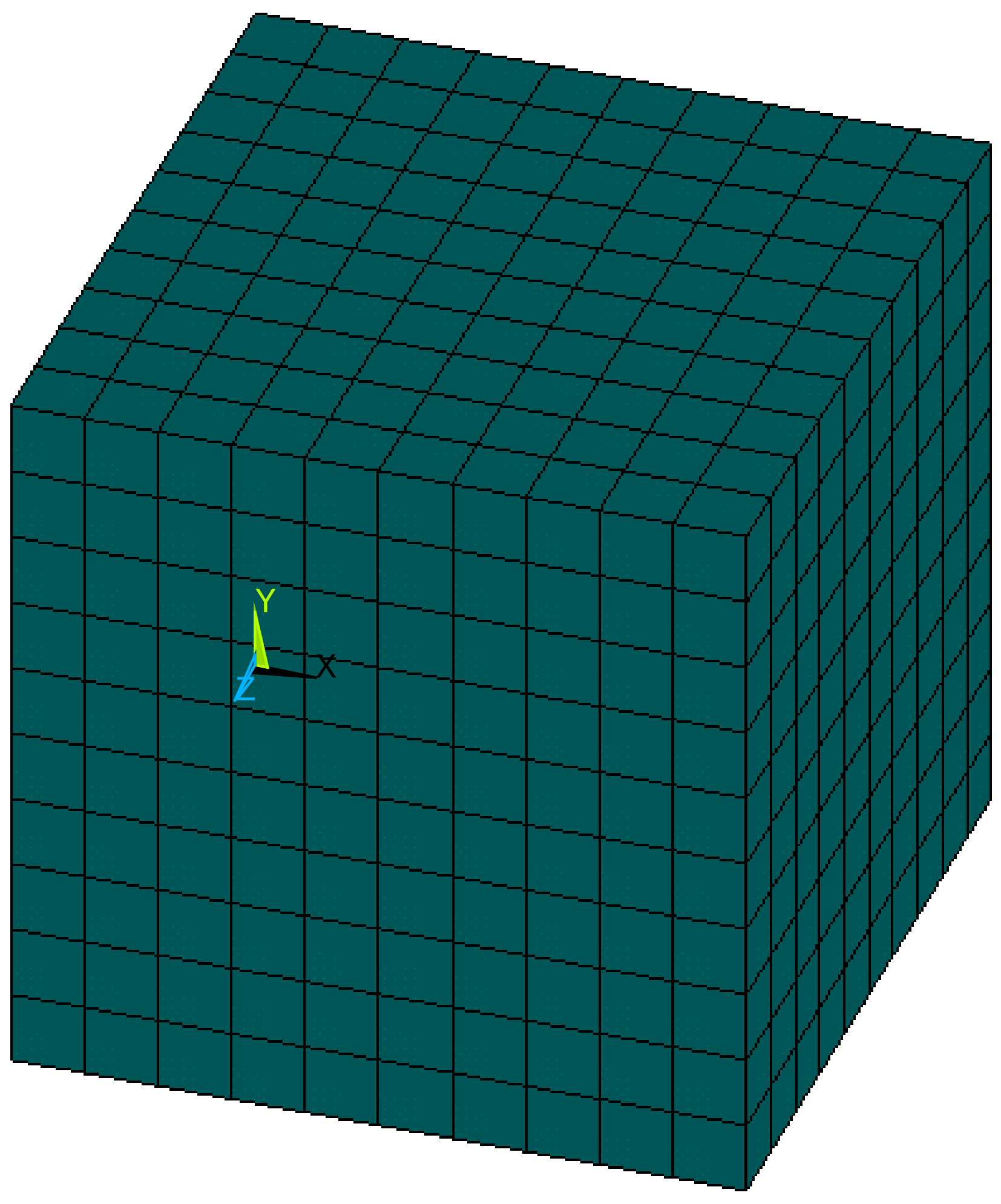
where T_s is the surface temperature (K),

T_∞ is the surrounding temperature (K) and

h is convective heat transfer coefficient $\left(\frac{W}{m^2.K}\right)$

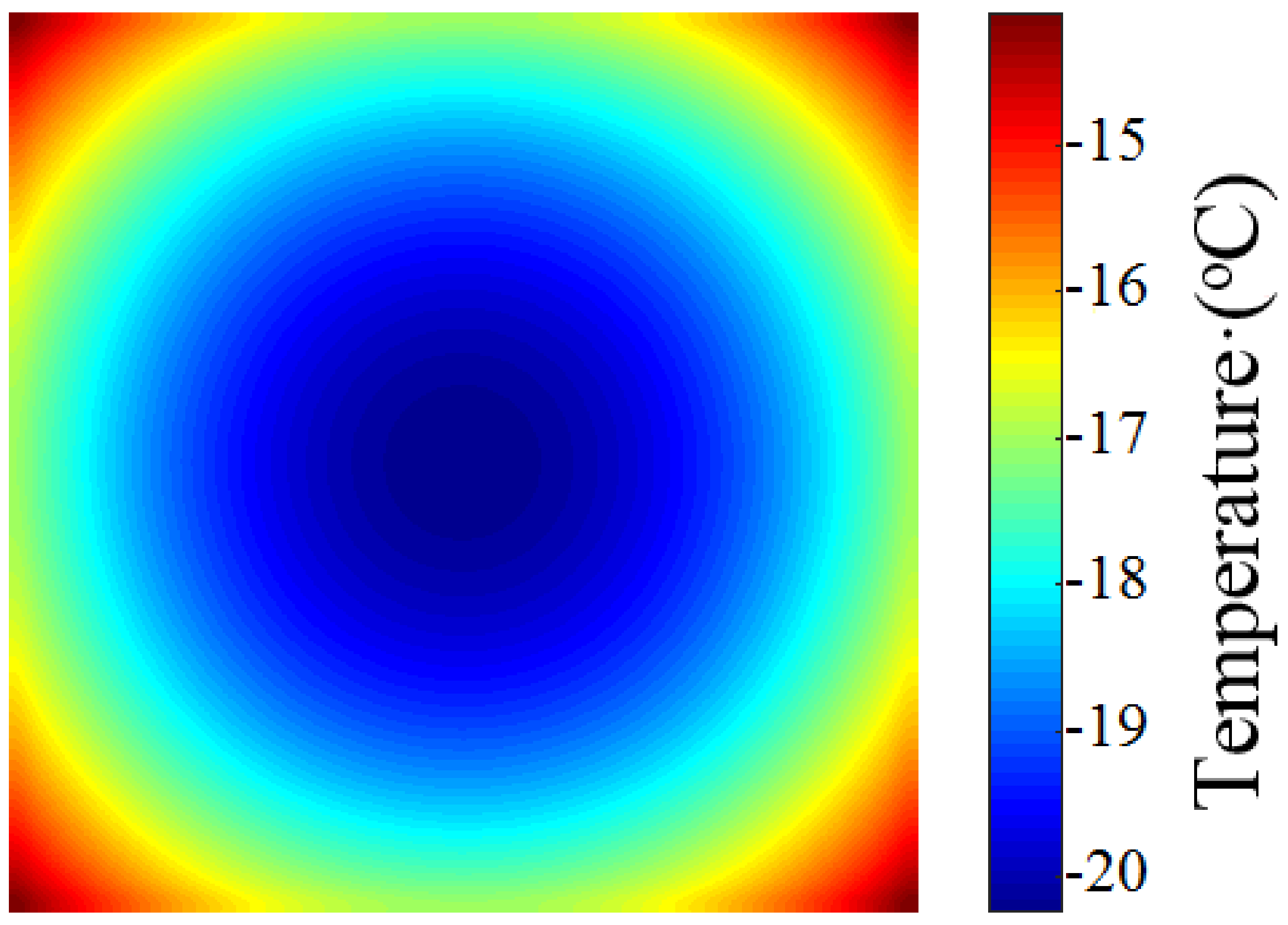
Numerical Results

Discretized Domain (15 X 15 X 15 cm)



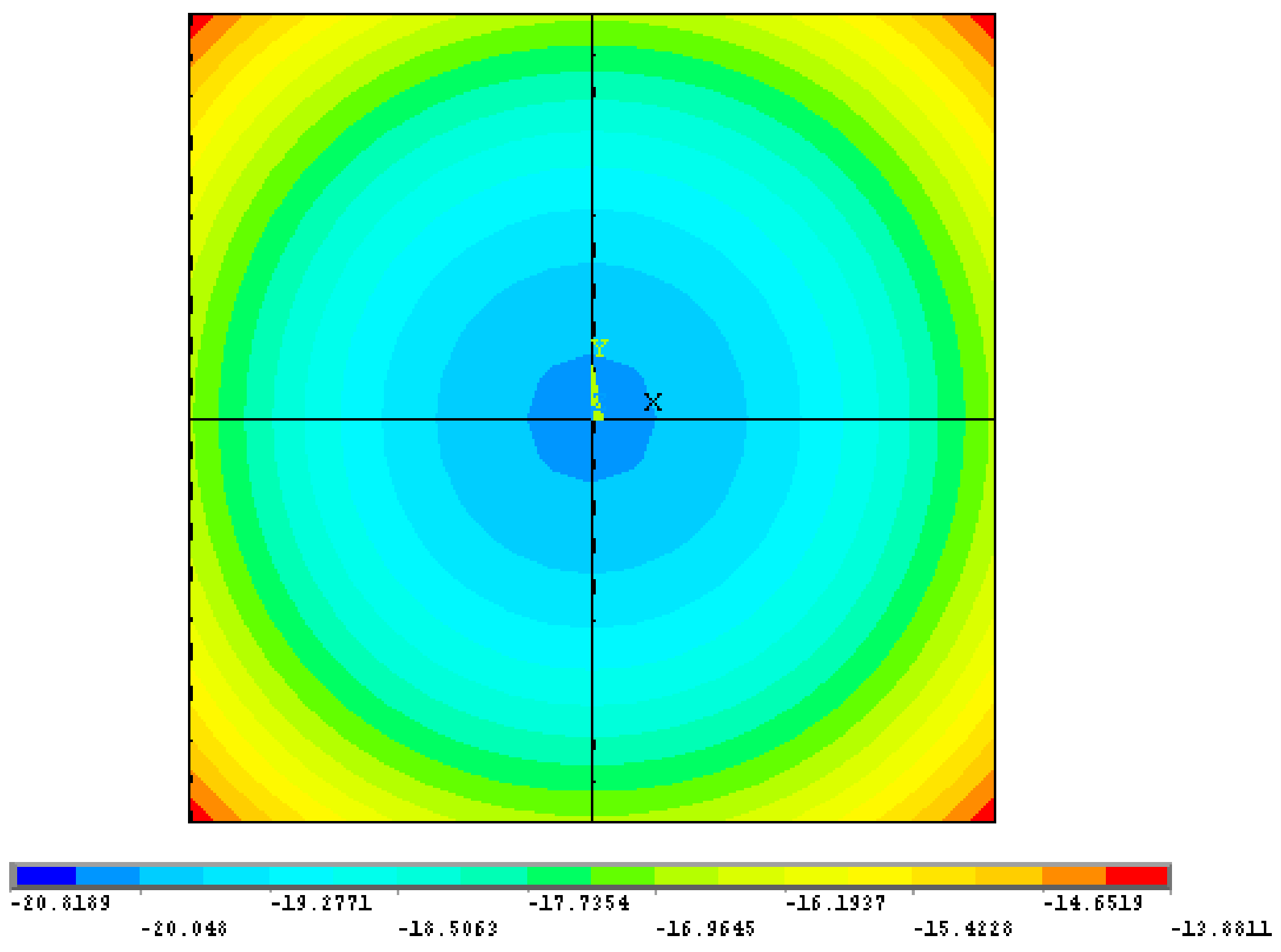
Surface Temp. Profile (FTCS & Spectral Method – MATLAB®)

Warm up time of 1500s



Surface Temp. Profile (ANSYS®)

Warm up time of 1500s



Conclusion

The results from three different numerical methodologies FTCS (Forward-Time Central-Space) method, Spectral method and ANSYS® Multiphysics are found in good agreement. This proves that Multiphysics tools can be employed to model thermal behaviour and hence predict IR profile.

Recommendation

It is recommended to conduct the experiment and compare with the given results. This will validate the presented numerical modelling methodologies and the underlying principles of heat transfer.

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