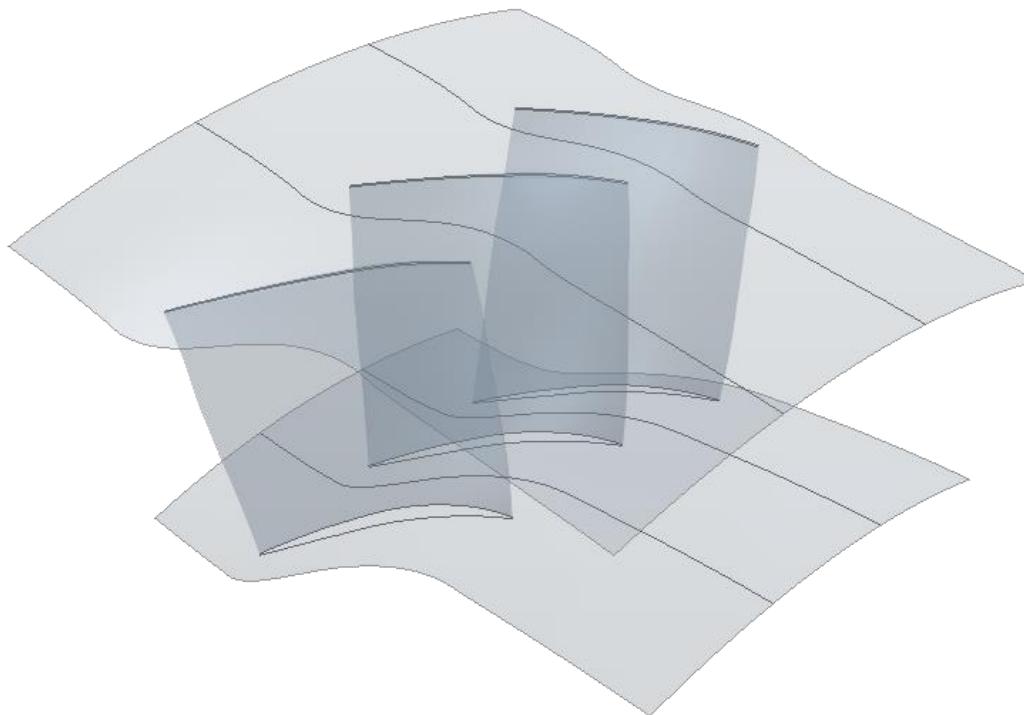


# CFD applied to Turbomachinery

Francesco Romanò

[francesco.romano@ensam.eu](mailto:francesco.romano@ensam.eu)

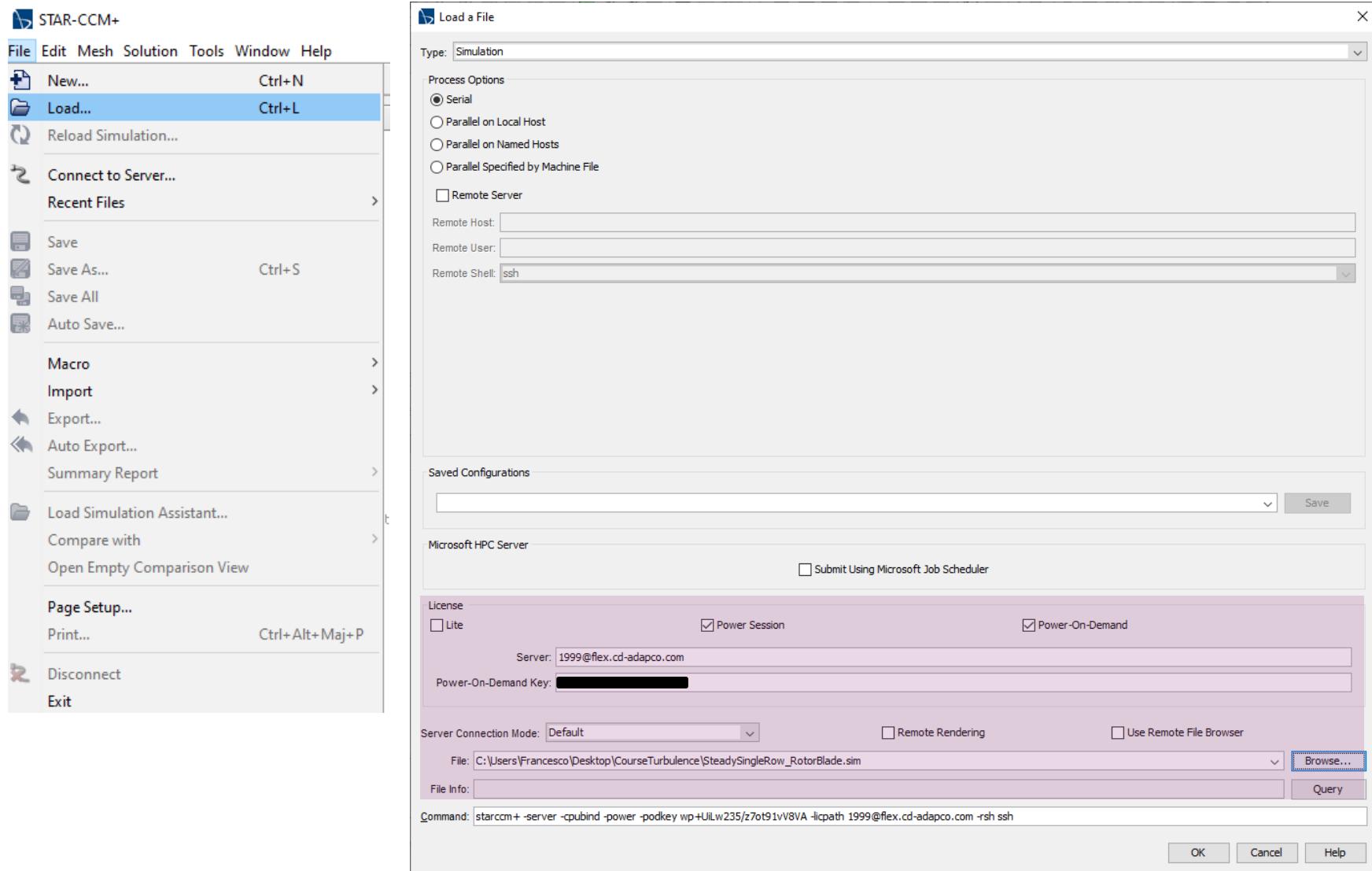
Laboratoire de Mécanique des Fluides Lille, Arts et Métiers Institute of Technology, 59800, Lille, France



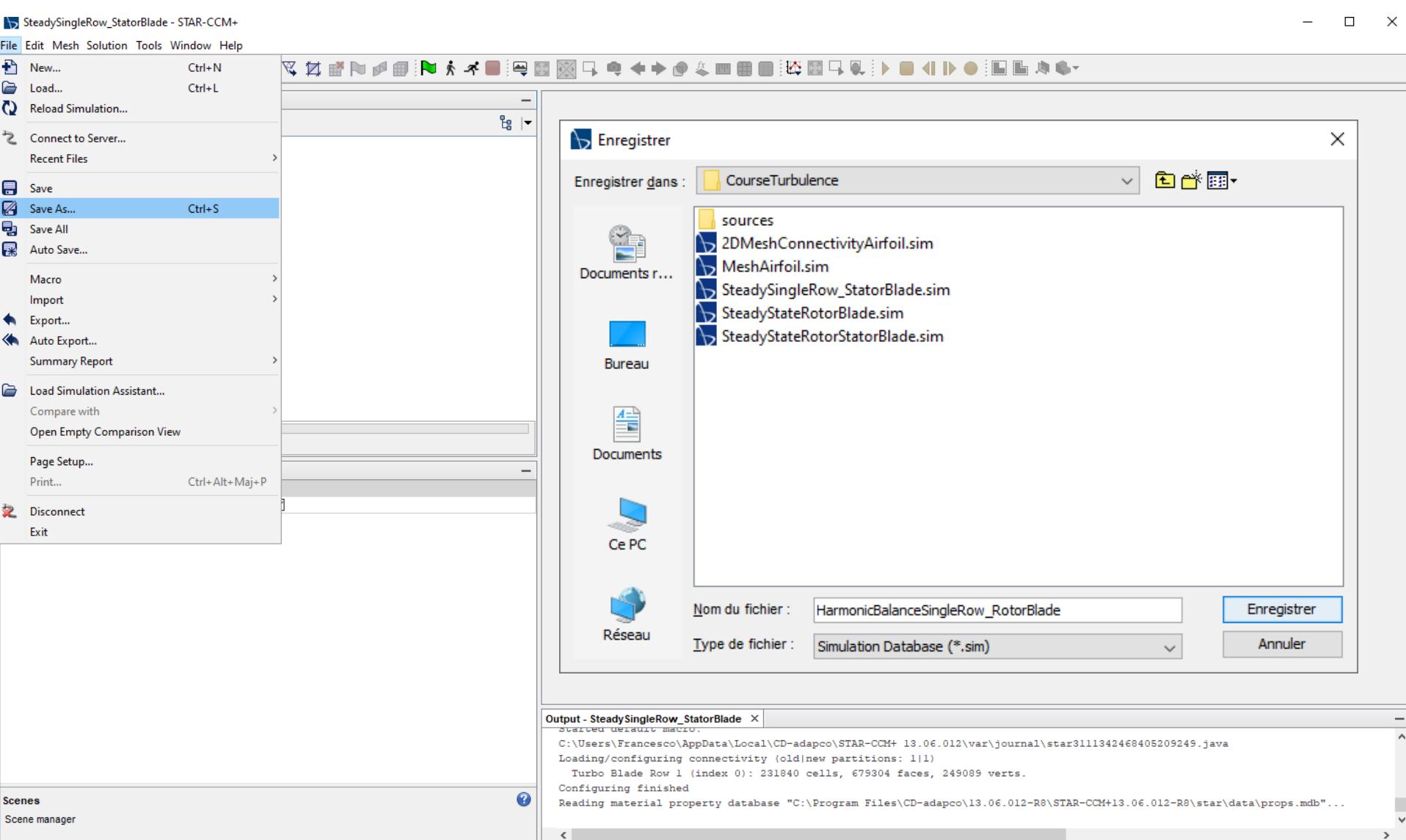
March 17, 2021, International Master of Turbulence



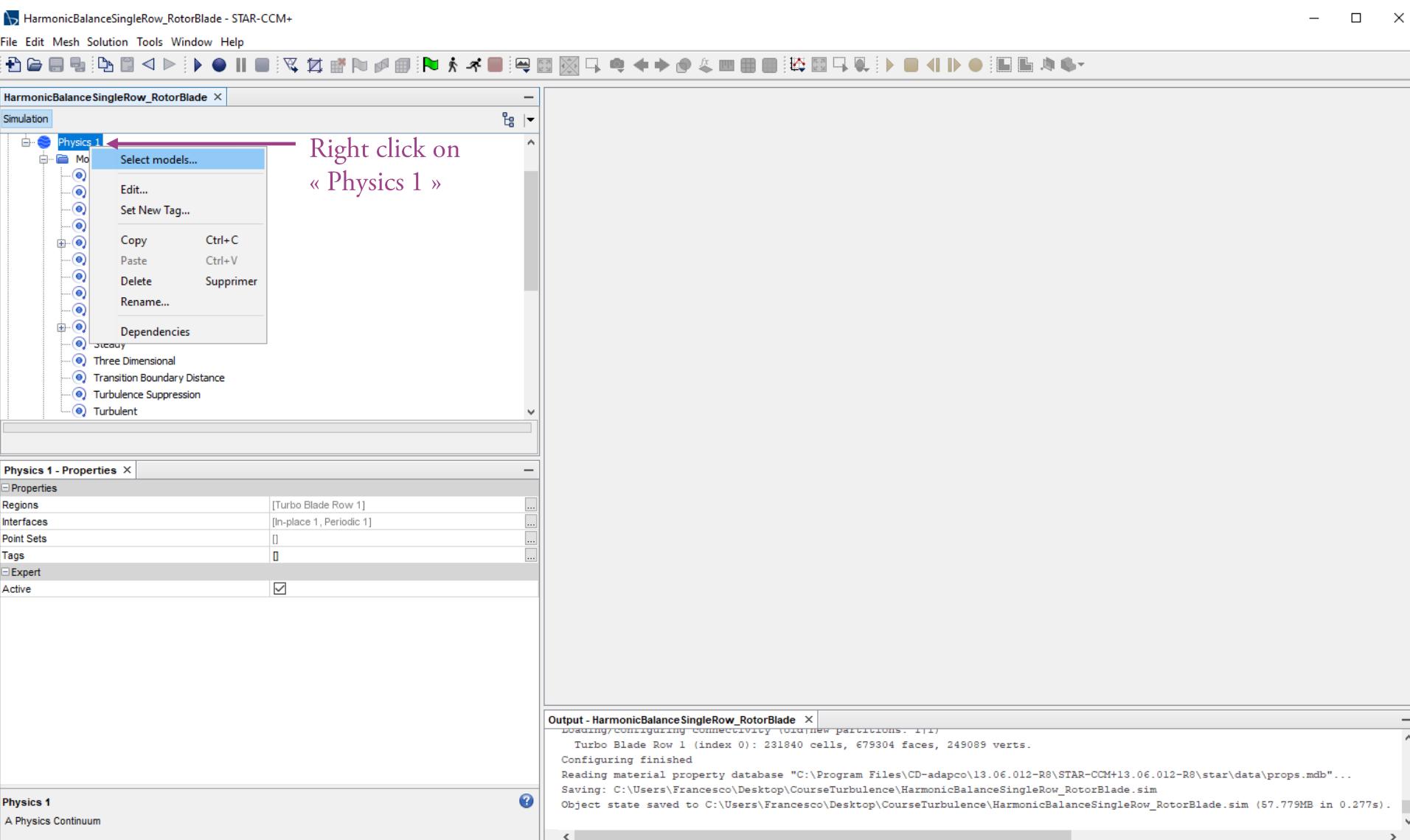
# Harmonic Balance for Rotor Blade in StarCCM+



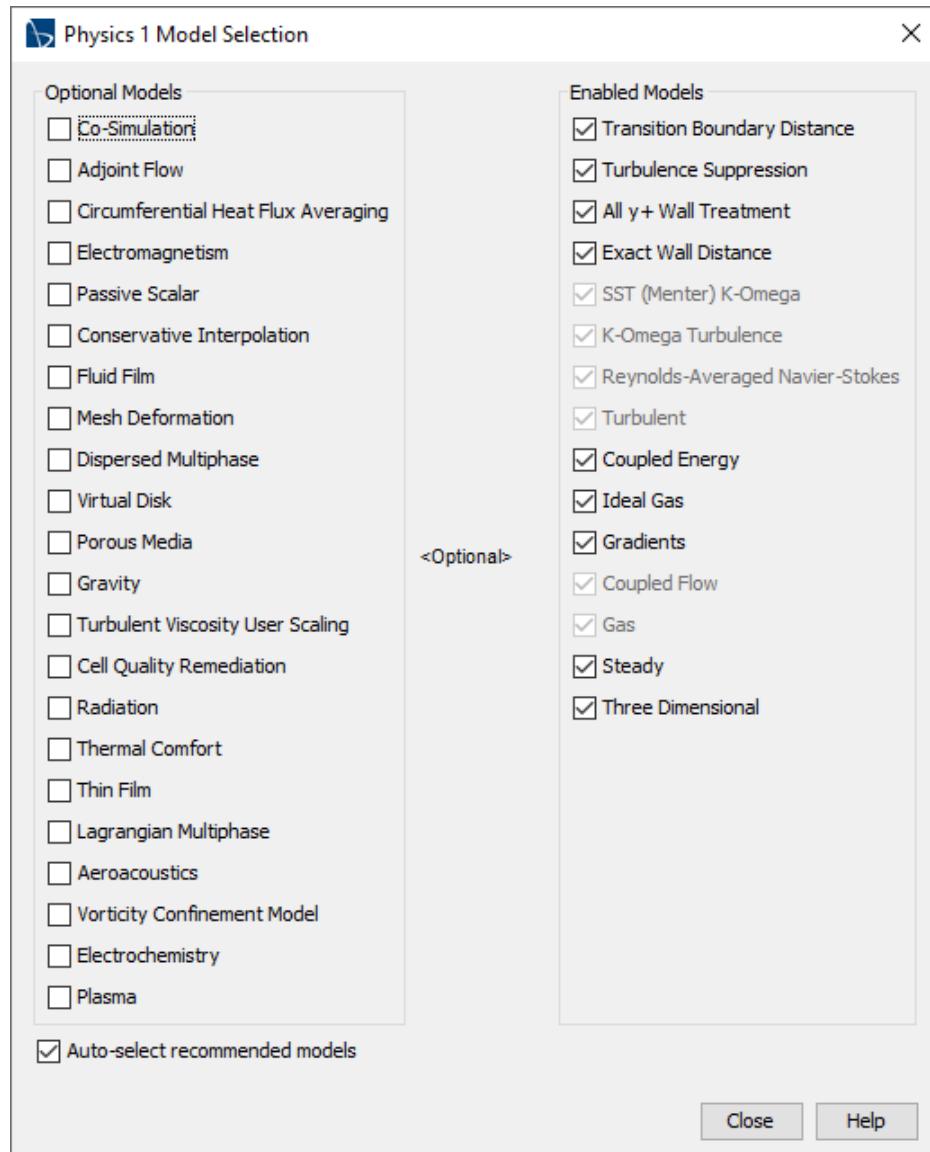
# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+

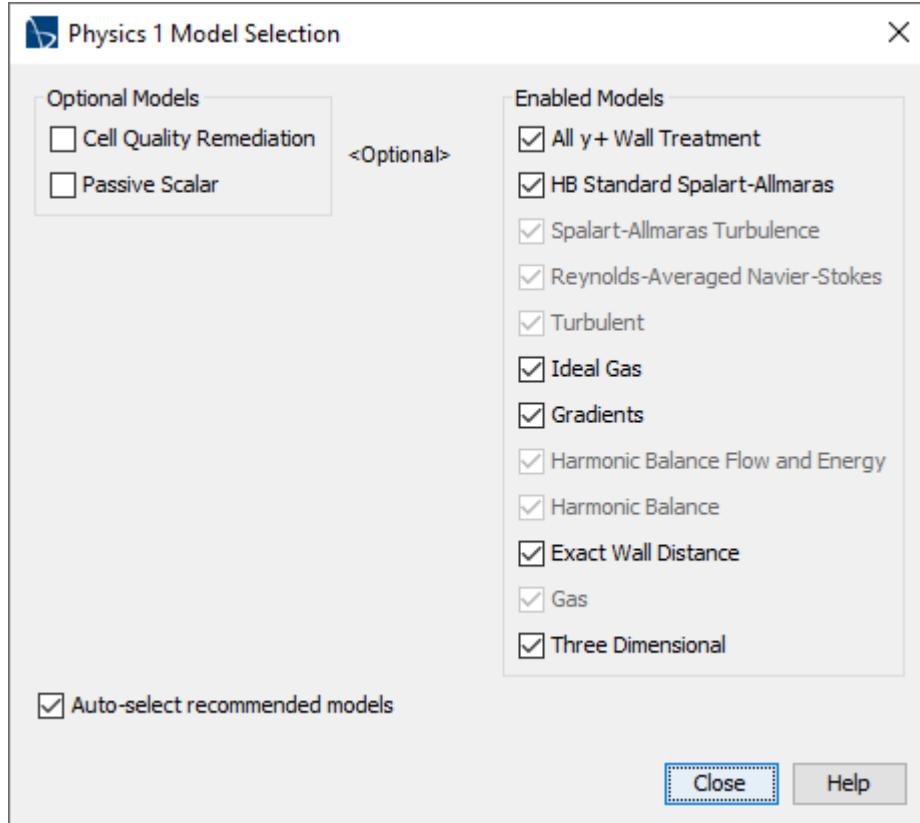


Deactivate:

- Transition Boundary Distance
- Turbulence Suppression
- All y+ Wall Treatment
- SST (Menter) K-Omega
- K-Omega Turbulence
- Reynolds-Averaged Navier-Stokes
- Turbulent
- Coupled Energy
- Ideal Gas
- Gradients
- Coupled Flow
- Gas
- Steady
- Three Dimensional
- Steady



# Harmonic Balance for Rotor Blade in StarCCM+



Activate:

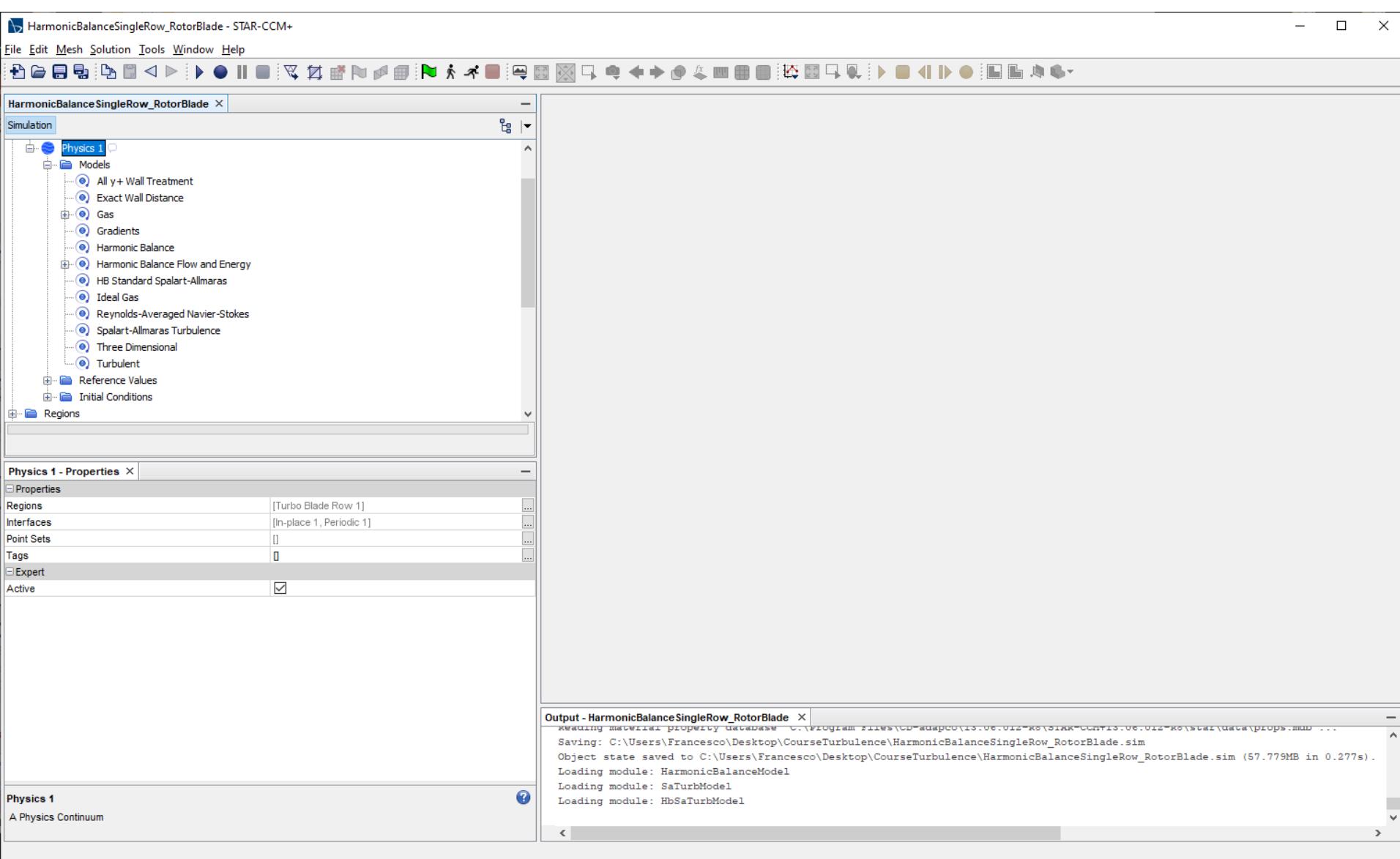
- Harmonic Balance
- Turbulent
- Spalart-Allmaras Turbulence

By « Auto-select recommendend models »:

- HB Standard Spalart-Allmaras
- All  $y+$  Wall Treatment
- Exact Wall Distance

Click « Close »

# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleRow\_RotorBlade - STAR-CCM+ File Edit Mesh Solution Tools Window Help

HarmonicBalanceSingleRow\_RotorBlade X

Simulation

HarmonicBalanceSingleRow\_RotorBlade

- Geometry
- Continua
- Physics 1
  - Models
    - All y+ Wall Treatment
    - Exact Wall Distance
    - Gas
    - Gradients
    - Harmonic Balance
      - Blade Rows
        - New Table
        - Cut-Off Filter
      - Harmonic Balance Flow and Energy
      - HB Standard Spalart-Allmaras
      - Ideal Gas
      - Reynolds-Averaged Navier-Stokes

Right click on « Blade Rows »

Blade Rows - Properties X

Expert

Frequency Compute Option: Consider Only Neighbors

Mode Table Filter Option: Cut-Off

Fictitious Rotation Rate Factor: 0.001

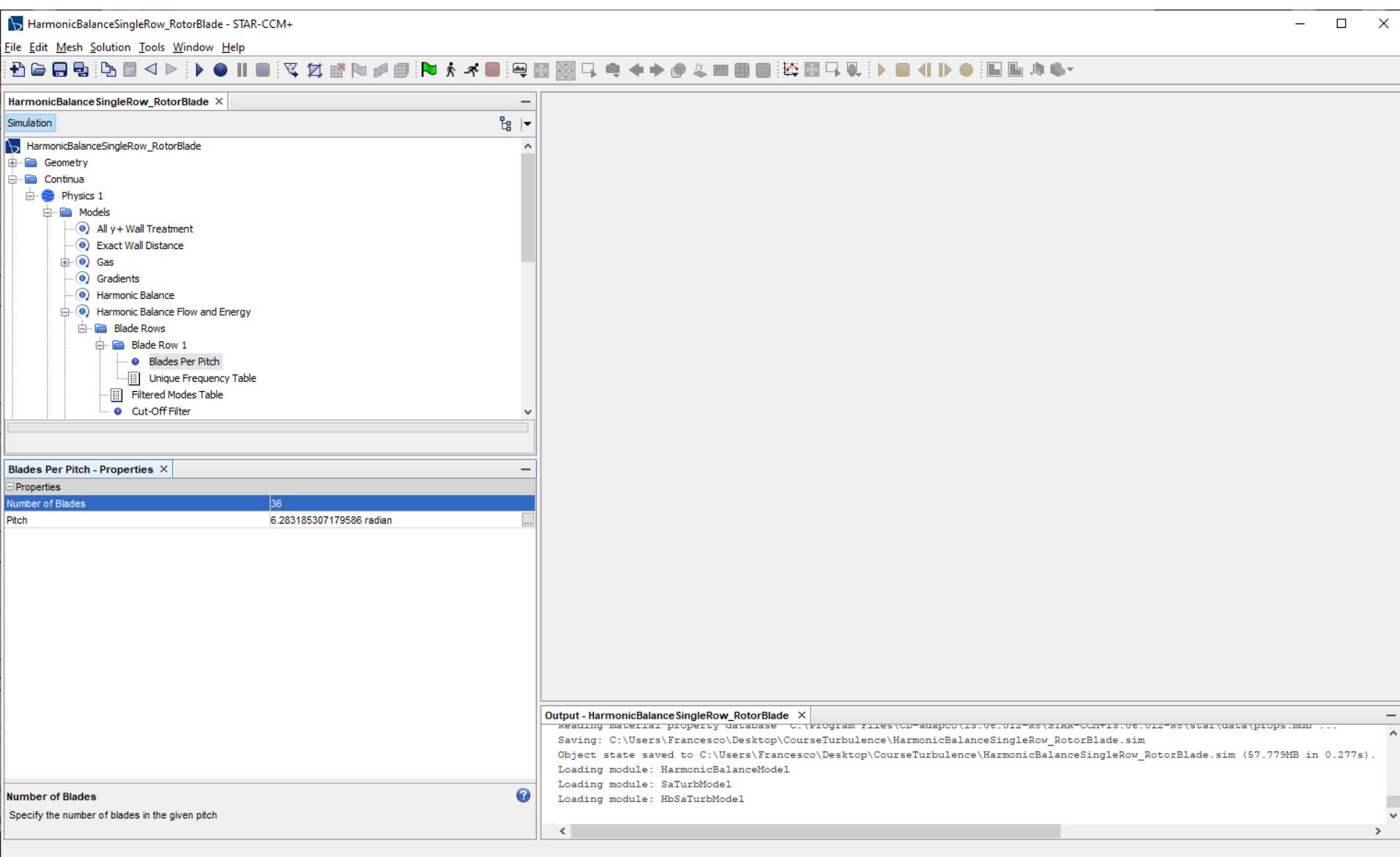
Blade Rows

Blade row manager

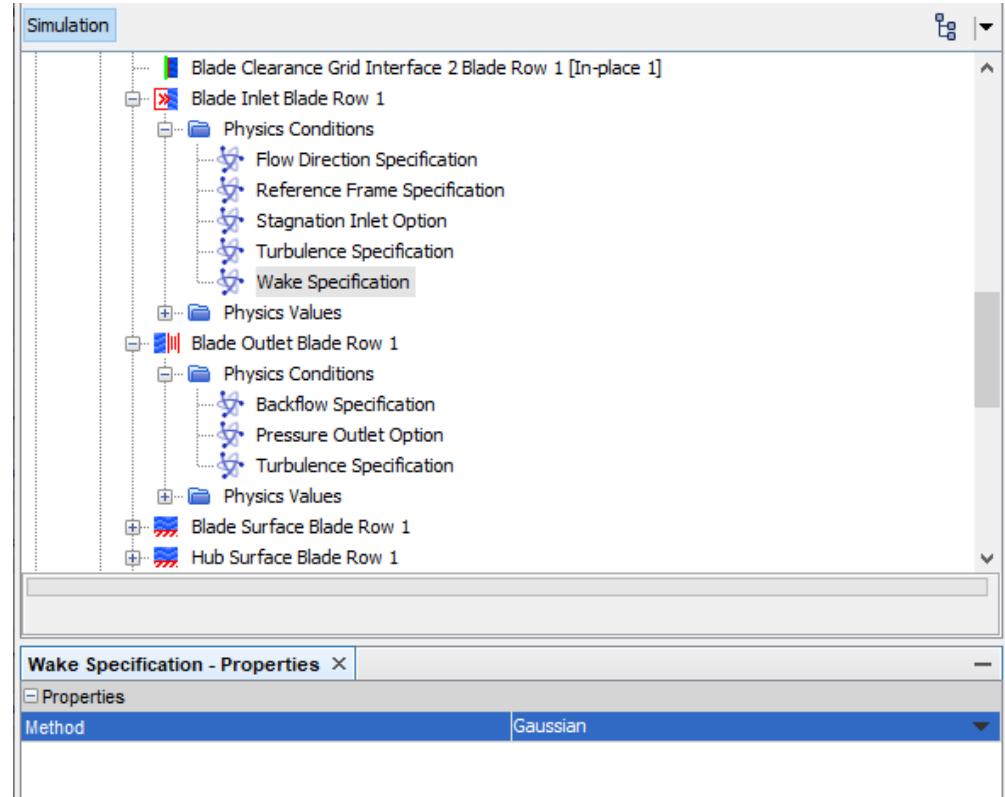
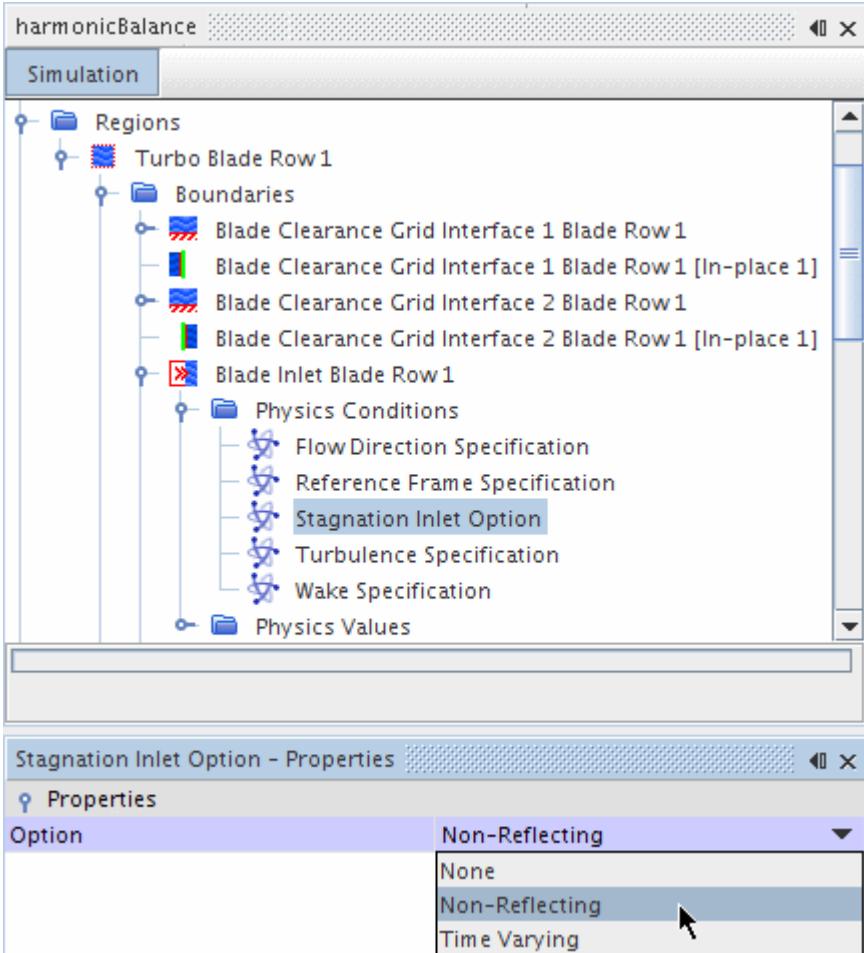
Output - HarmonicBalanceSingleRow\_RotorBlade X

```
Reading material property database C:\Program Files\CD-adapco\15.06.012-R0\STAR-CCM+15.06.012-R0\star\data\props.mdb ...
Saving: C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim
Object state saved to C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim (57.779MB in 0.277s).
Loading module: HarmonicBalanceModel
Loading module: SaTurbModel
Loading module: HbSaTurbModel
```

# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



Wake Specification - Properties X

Properties

Method

Gaussian



# Harmonic Balance for Rotor Blade in StarCCM+

The image shows two side-by-side screenshots of the StarCCM+ software interface, illustrating the setup for a Harmonic Balance simulation of a rotor blade.

**Left Simulation Tree:**

- Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]
- Blade Inlet Blade Row 1
  - Physics Conditions
    - Flow Direction Specification
    - Reference Frame Specification
    - Stagnation Inlet Option
    - Turbulence Specification
    - Wake Specification
  - Physics Values
    - Gaussian Wake
      - Blades Per Pitch
    - Non-Reflecting Mode Specification
    - Supersonic Static Pressure
    - Total Pressure
    - Total Temperature
    - Turbulent Viscosity Ratio
- Blade Outlet Blade Row 1

**Properties Panel for Gaussian Wake:**

Properties	
Rotation Rate	0.0 radian/s
Modes	3
Defect	0.2
Width	0.15

**Right Simulation Tree:**

- Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]
- Blade Inlet Blade Row 1
  - Physics Conditions
    - Flow Direction Specification
    - Reference Frame Specification
    - Stagnation Inlet Option
    - Turbulence Specification
    - Wake Specification
  - Physics Values
    - Gaussian Wake
      - Blades Per Pitch
    - Non-Reflecting Mode Specification
    - Supersonic Static Pressure
    - Total Pressure
    - Total Temperature
    - Turbulent Viscosity Ratio
- Blade Outlet Blade Row 1

**Properties Panel for Blades Per Pitch:**

Properties	
Number of Blades	48
Pitch	6.283185307179586 radian

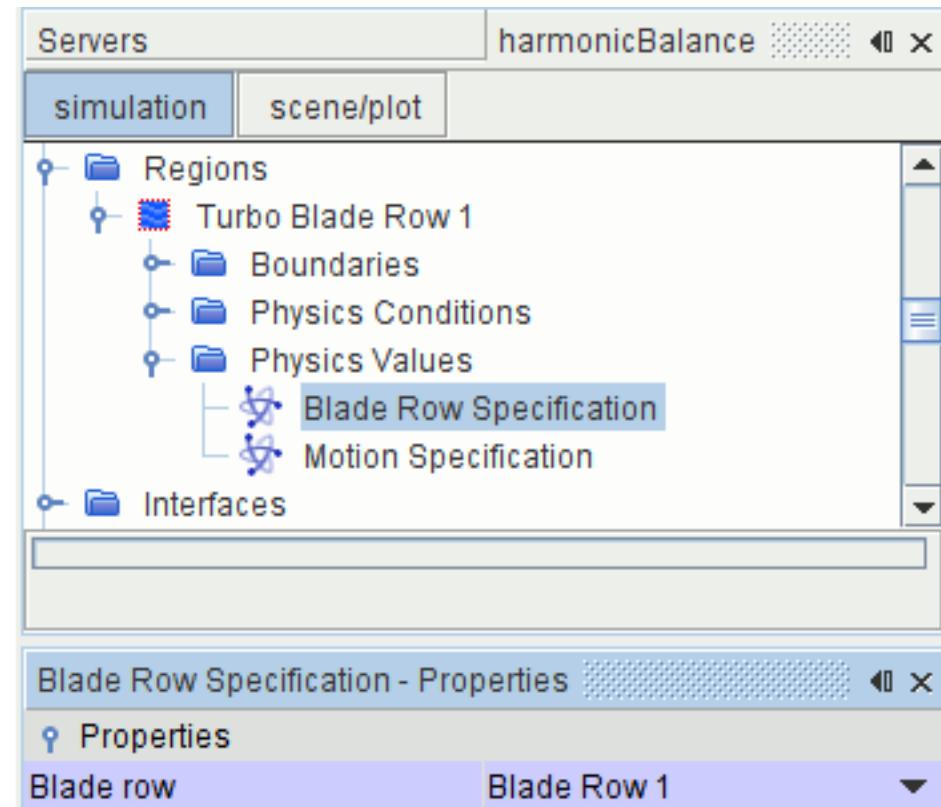
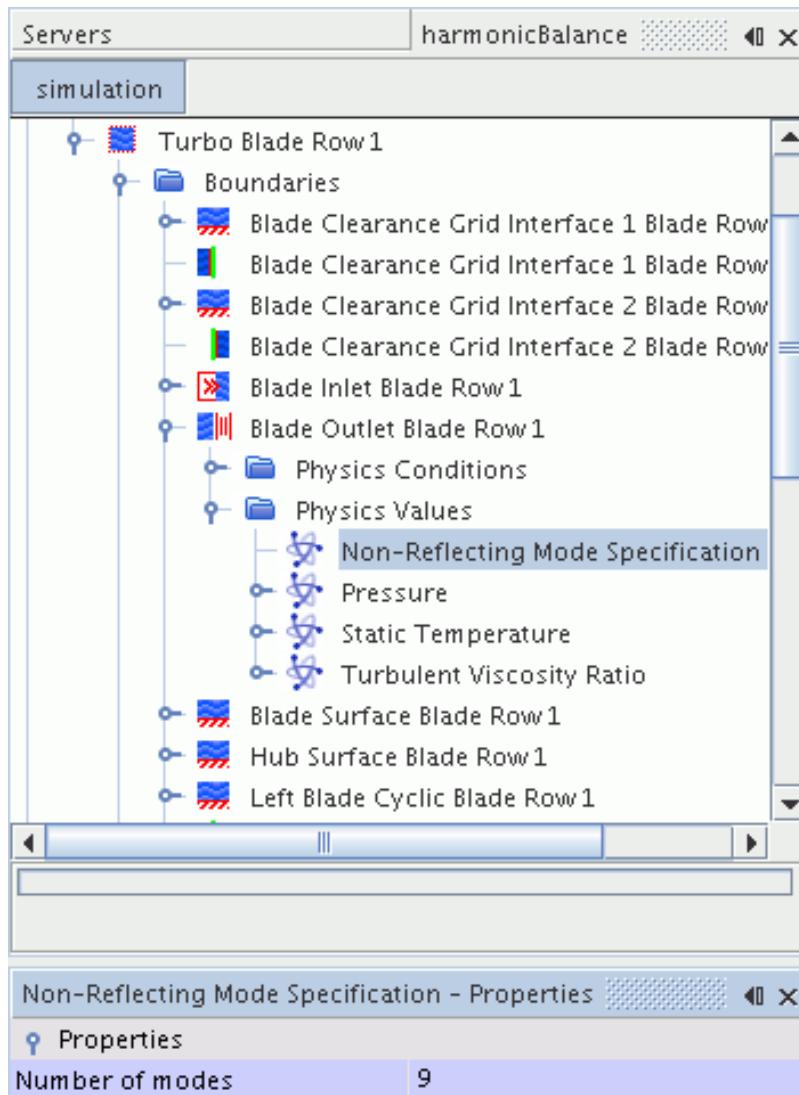


# Harmonic Balance for Rotor Blade in StarCCM+

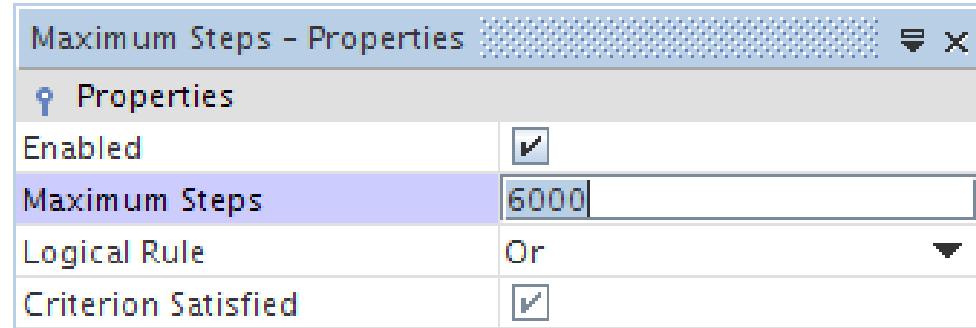
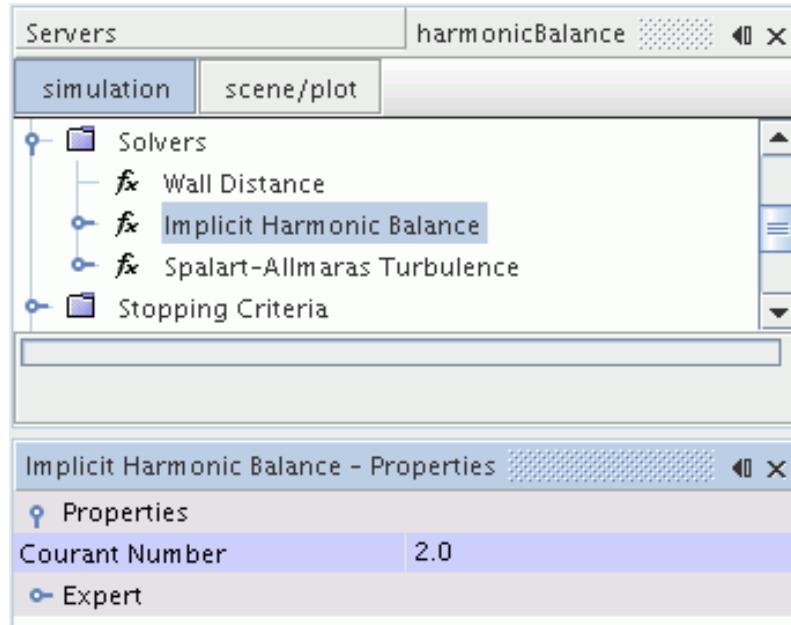
The screenshot displays the StarCCM+ software interface for setting up a Harmonic Balance simulation. The main window shows the project tree under the 'simulation' tab, specifically for the 'Regions' section. It lists 'Turbo Blade Row 1' and its sub-components: 'Boundaries' (containing 'Blade Clearance Grid Interface 1 Blade Row 1', 'Blade Clearance Grid Interface 1 Blade Row 1 [In-place 1]', 'Blade Clearance Grid Interface 2 Blade Row 1', 'Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]', 'Blade Inlet Blade Row 1', and 'Blade Outlet Blade Row 1'), 'Physics Conditions' (containing 'Backflow Specification', 'Pressure Outlet Option', 'Turbulence Specification', and 'Wake Specification'), and 'Physics Values' (containing 'Gaussian Wake', 'Non-Reflecting Mode Specification', and 'Supersonic Static Pressure'). A context menu is open over the 'Non-Reflecting Mode Specification' item.

A secondary window titled 'Pressure Outlet Option - Properties' is open, showing the 'Properties' tab with a dropdown menu for 'Option'. The menu items are: Non-Reflecting (selected), None, Non-Reflecting, Target Mass Flow, and Time Varying. A mouse cursor is hovering over the 'Non-Reflecting' option in the list.

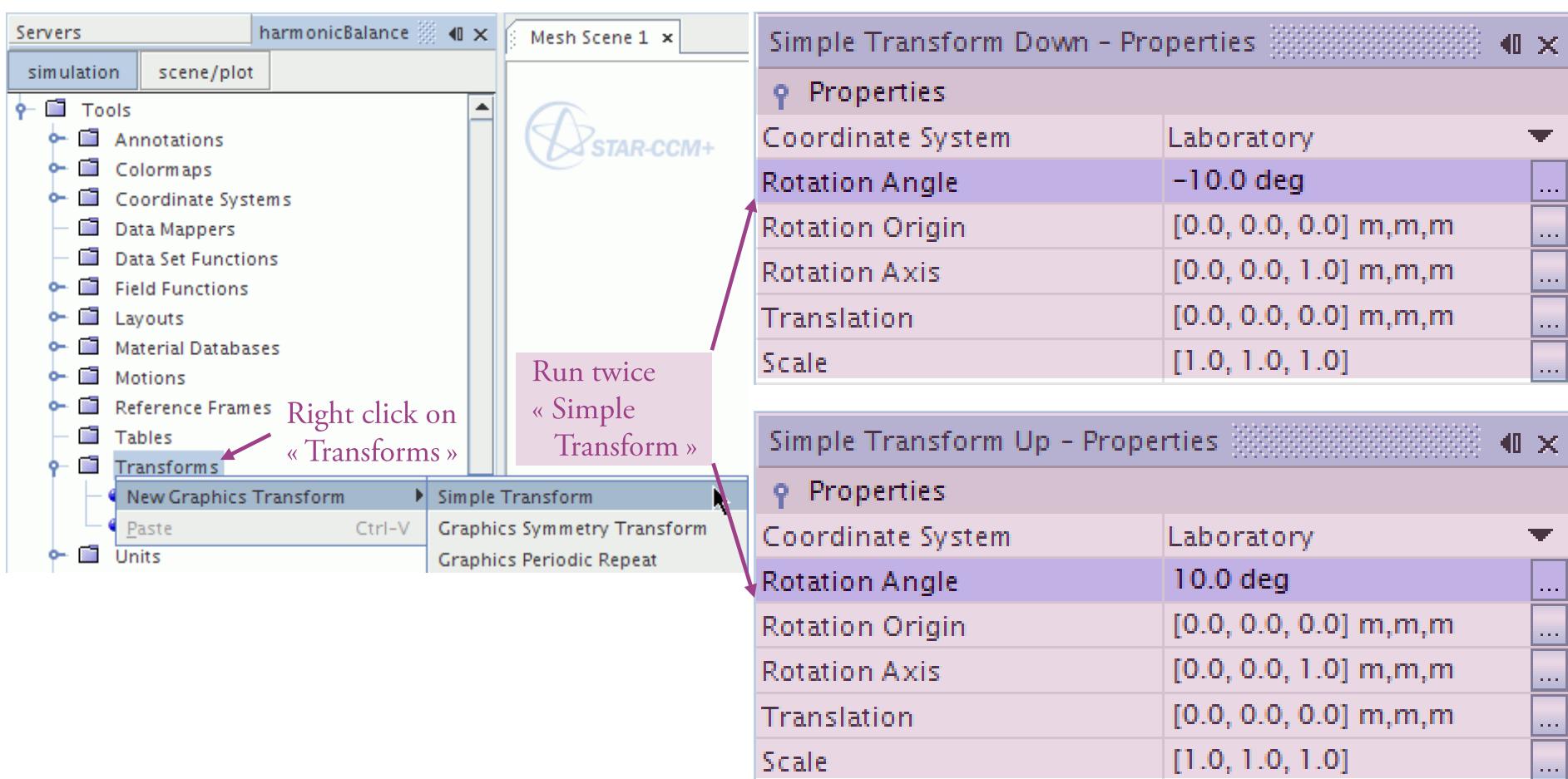
# Harmonic Balance for Rotor Blade in StarCCM+



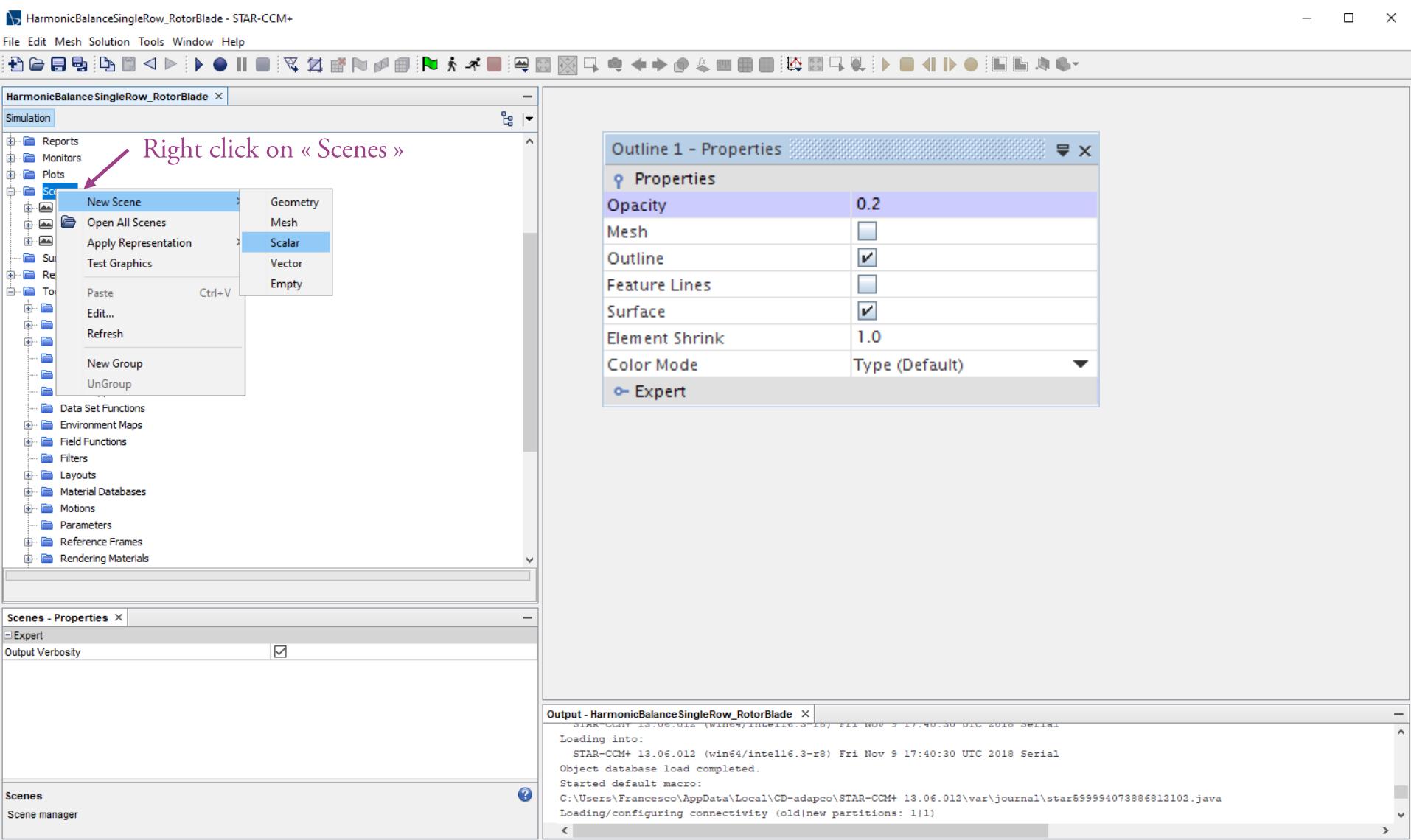
# Harmonic Balance for Rotor Blade in StarCCM+



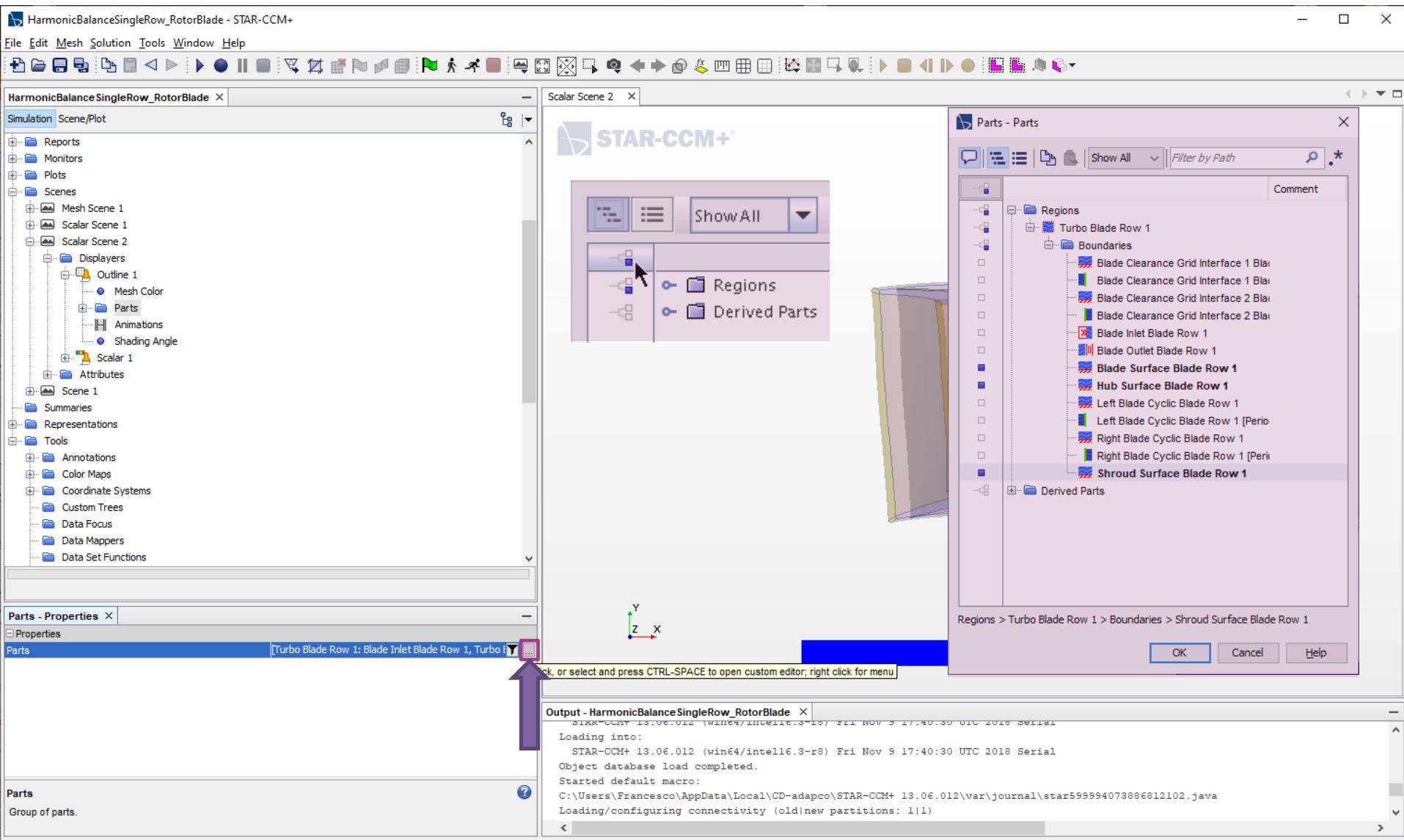
# Harmonic Balance for Rotor Blade in StarCCM+



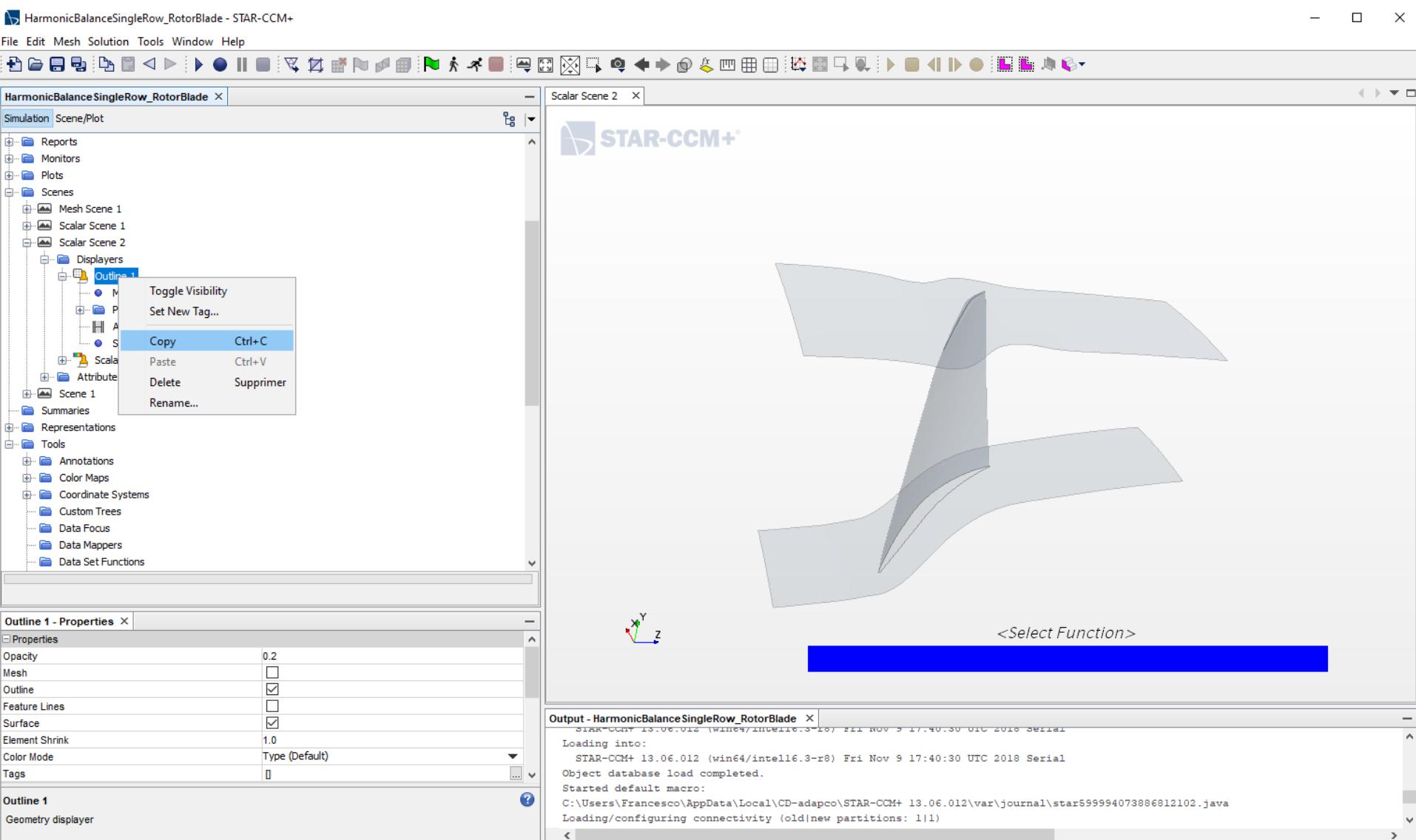
# Harmonic Balance for Rotor Blade in StarCCM+



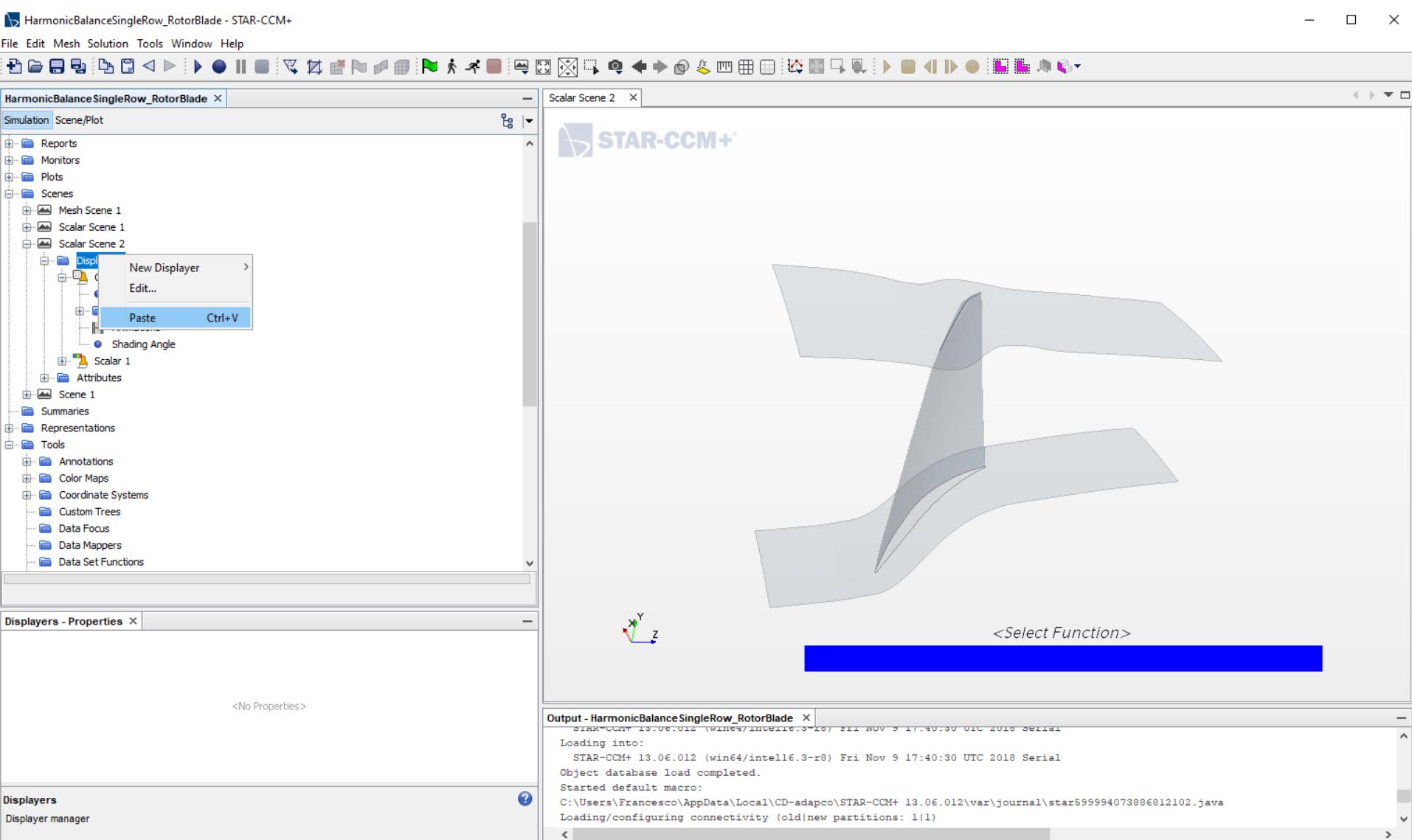
# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



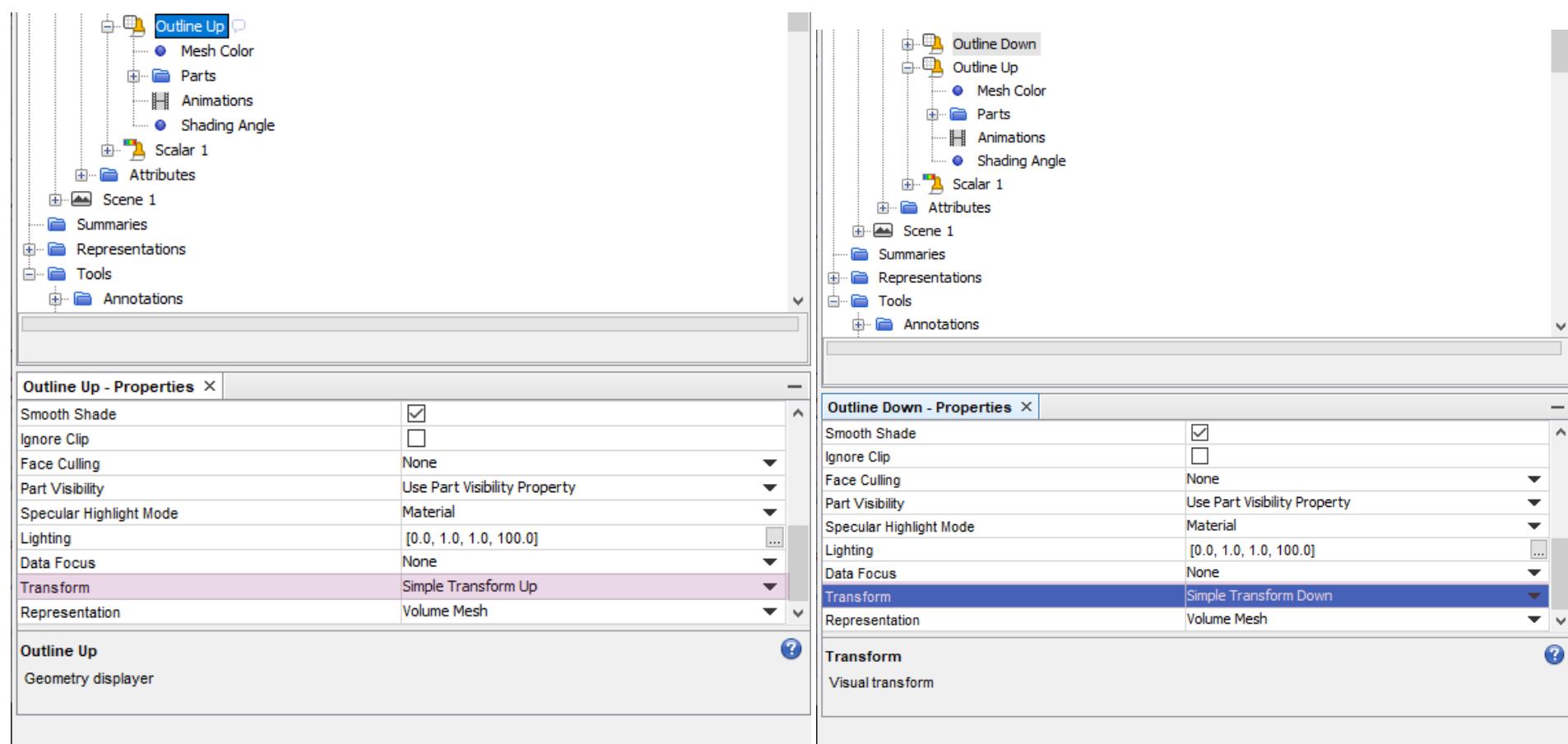
# Harmonic Balance for Rotor Blade in StarCCM+



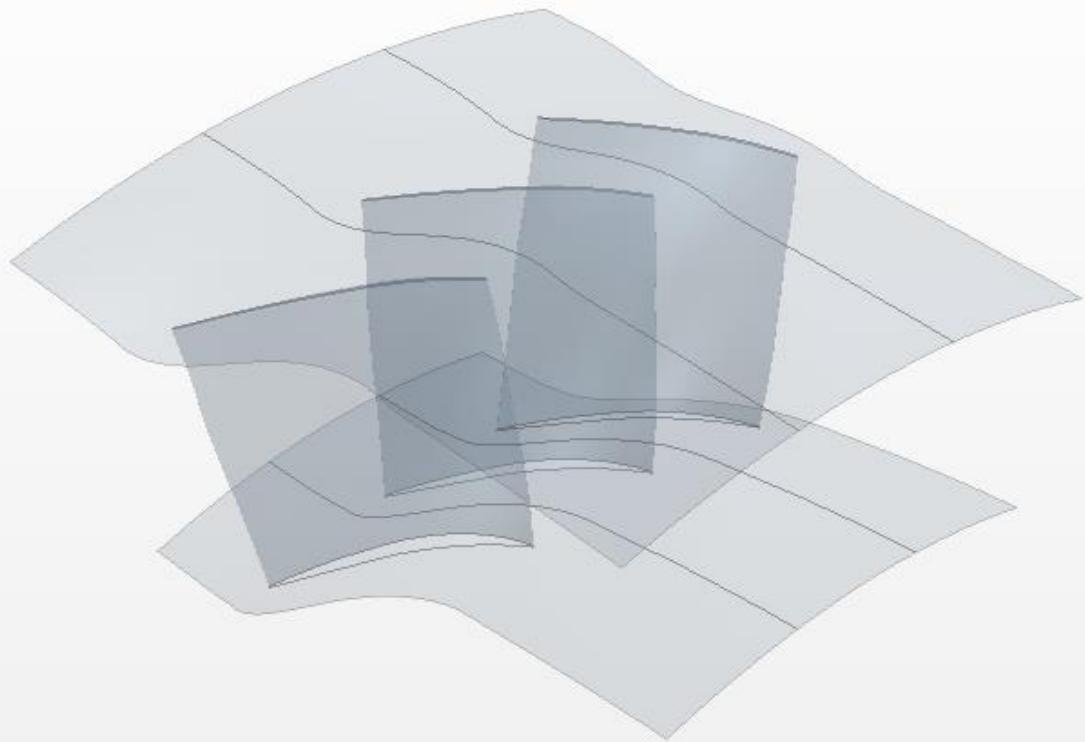
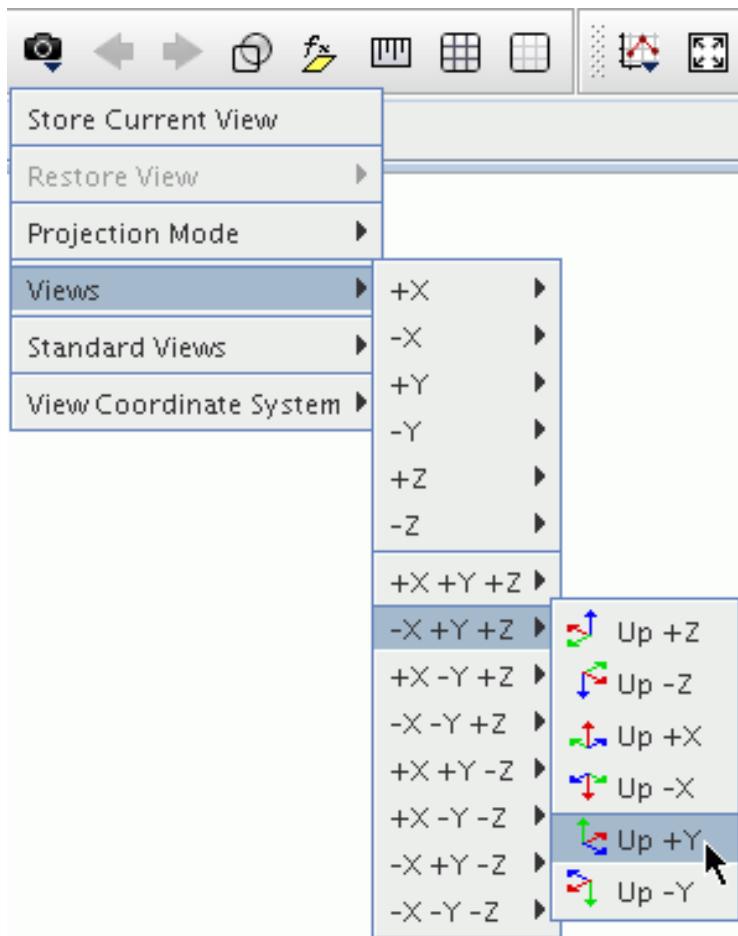
Repeat the copy-paste operation twice such to have 3 outlines



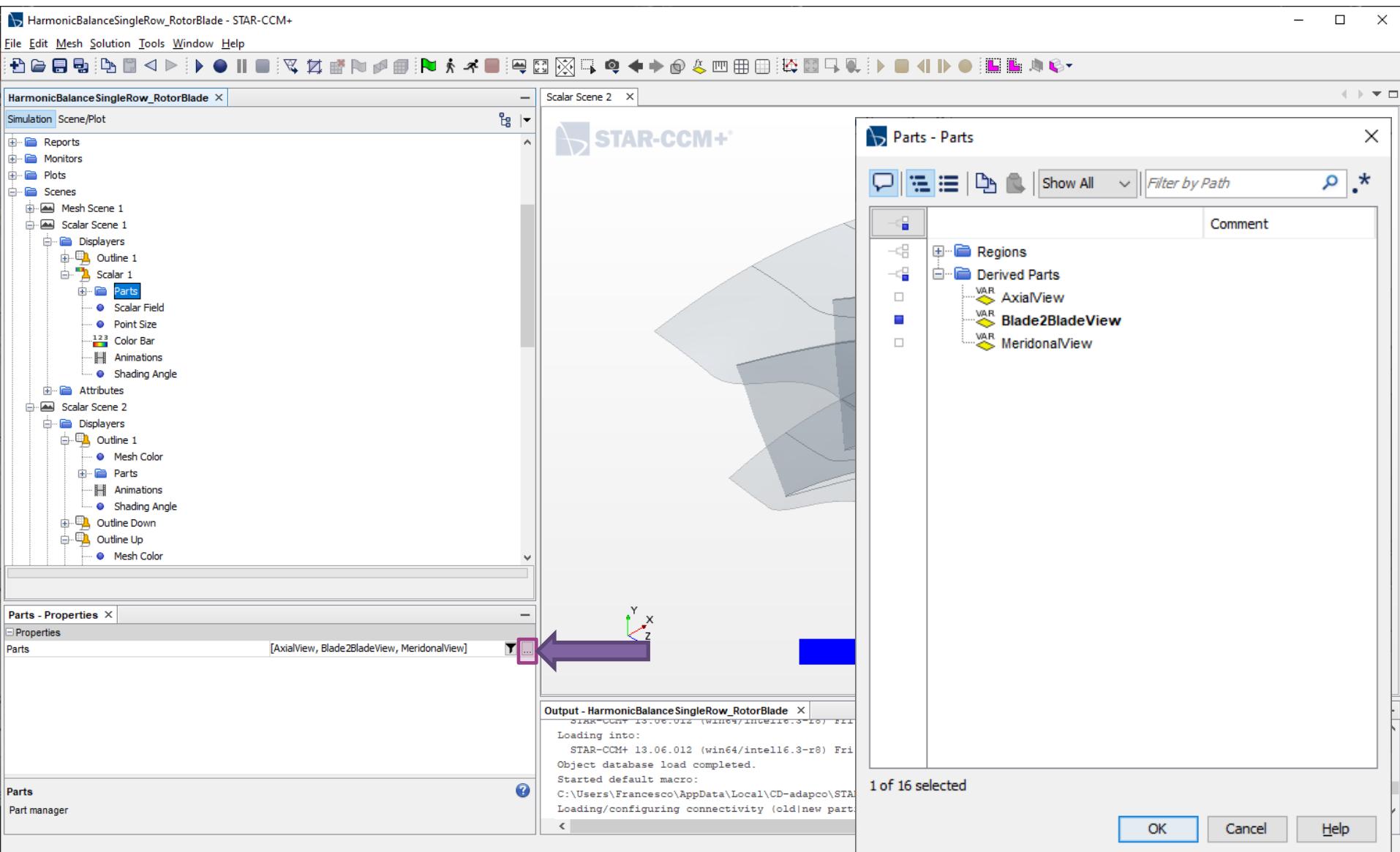
# Harmonic Balance for Rotor Blade in StarCCM+



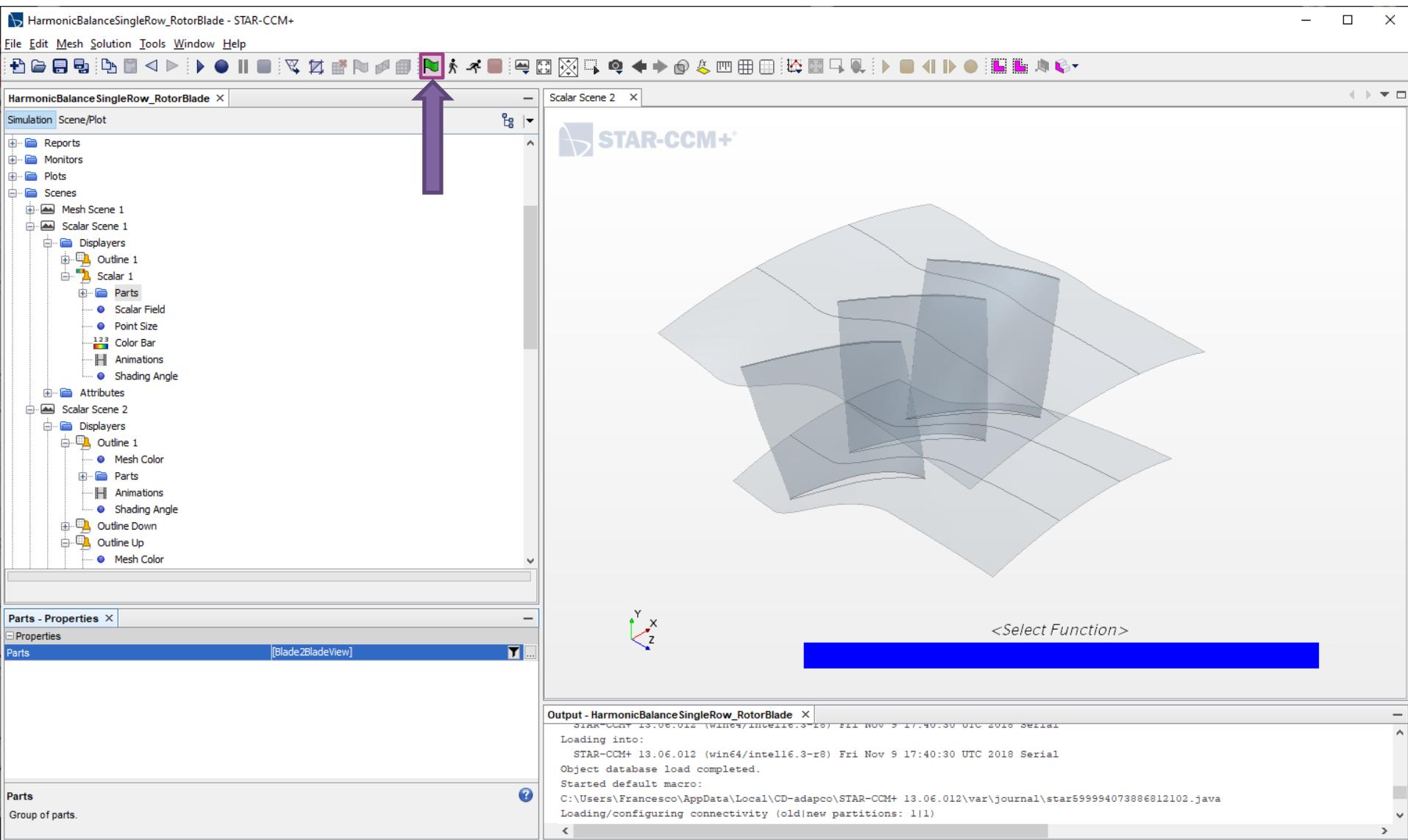
# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+

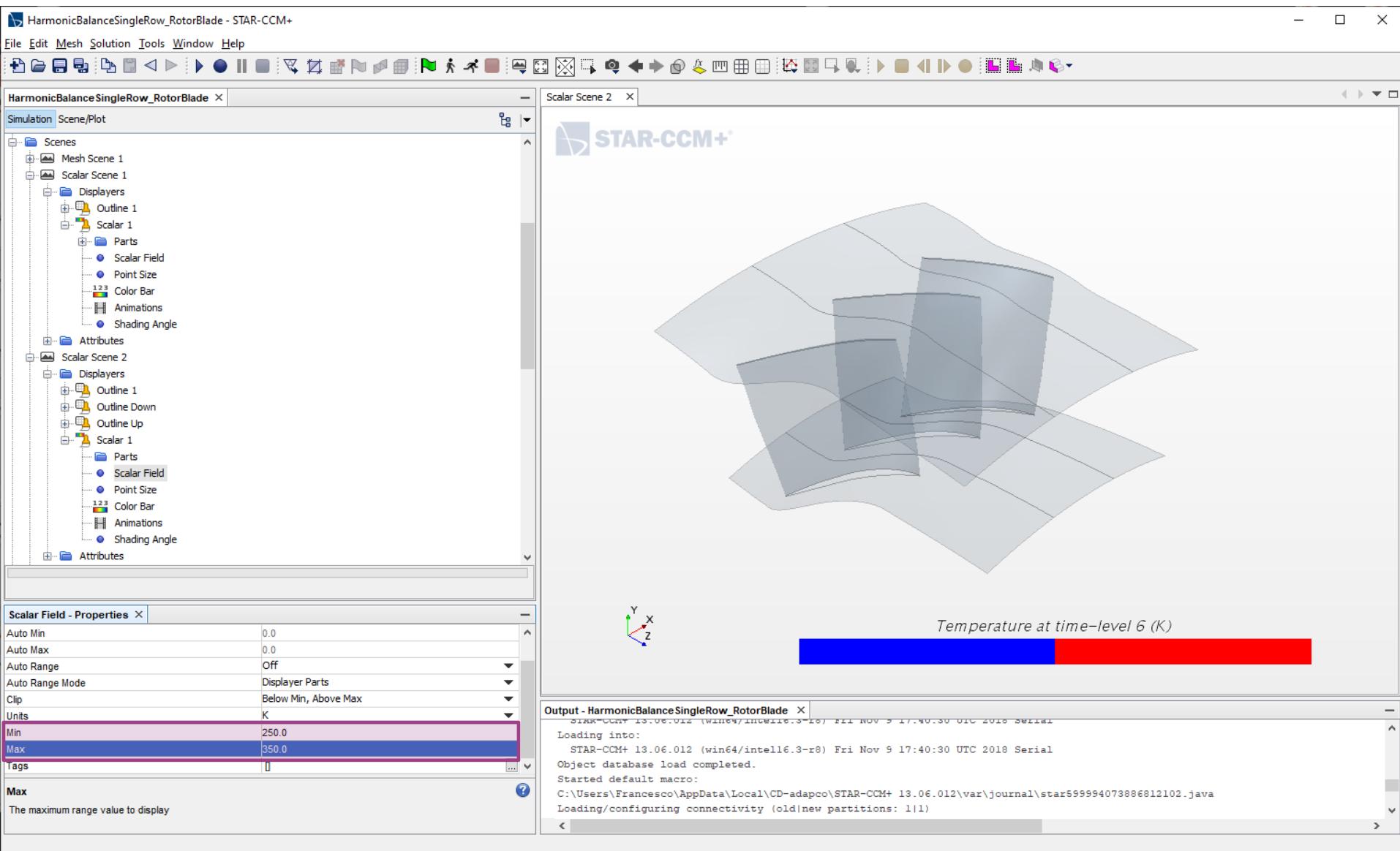


# Harmonic Balance for Rotor Blade in StarCCM+

The screenshot shows the StarCCM+ software interface with the following components:

- Top Bar:** HarmonicBalanceSingleRow\_RotorBlade - STAR-CCM+. File Edit Mesh Solution Tools Window Help.
- Toolbar:** Standard icons for file operations, meshing, solution, and tools.
- Left Panel:** Simulation tree titled "HarmonicBalanceSingleRow\_RotorBlade". It includes sections for Scenes, Mesh Scene 1, Scalar Scene 1 (with Displacers, Scalar 1, and Attributes), and Scalar Scene 2 (with Displacers, Outline 1, Outline Down, Outline Up, Scalar 1, and Attributes).
- Scalar Field - Properties Panel:** Shows settings for a Scalar Field: Function (<Select Function>), Auto Min (0.0), Auto Max (0.0), Auto Range (Min and Max Values), Auto Range Mode (Display Parts: Below Min, Above Max), Units (None), and Min (0.0). A large purple arrow points from this panel towards the "Scalar Field" node in the tree.
- Scalar Field - Function Dialog:** A list of available scalar fields. The "fx<sub>s</sub> Temperature at time-level 6" option is highlighted with a red box and selected. Other options include fx<sub>s</sub> Grid Flux, fx<sub>s</sub> BCB\_dTheta, fx<sub>s</sub> Boundary Circumferential Bin Coordinate, fx<sub>s</sub> Boundary Circumferential Bin Index, fx<sub>s</sub> Boundary Circumferential Bin Spatial Modes, fx<sub>s</sub> Boundary Circumferential Bin Theta, Density, Effective Viscosity, Entropy, Frequency, fx<sub>s</sub> Fundamental Frequency, Mass Flow Rate, Mass Flux, Mass Imbalance, Modified Diffusivity, Pressure, Relative Velocity, Specific Heat, Temperature (Fourier Mode, Time Function, Time Level 000, 001, 002, 003, 004, 005, 006), fx<sub>s</sub> Temperature at time-level 6, fx<sub>s</sub> Temperature Level 6 Phase Lagged Down, fx<sub>s</sub> Temperature Level 6 Phase Lagged Up, and Total Enthalpy.
- Bottom Buttons:** OK, Cancel, Help.

# Harmonic Balance for Rotor Blade in StarCCM+

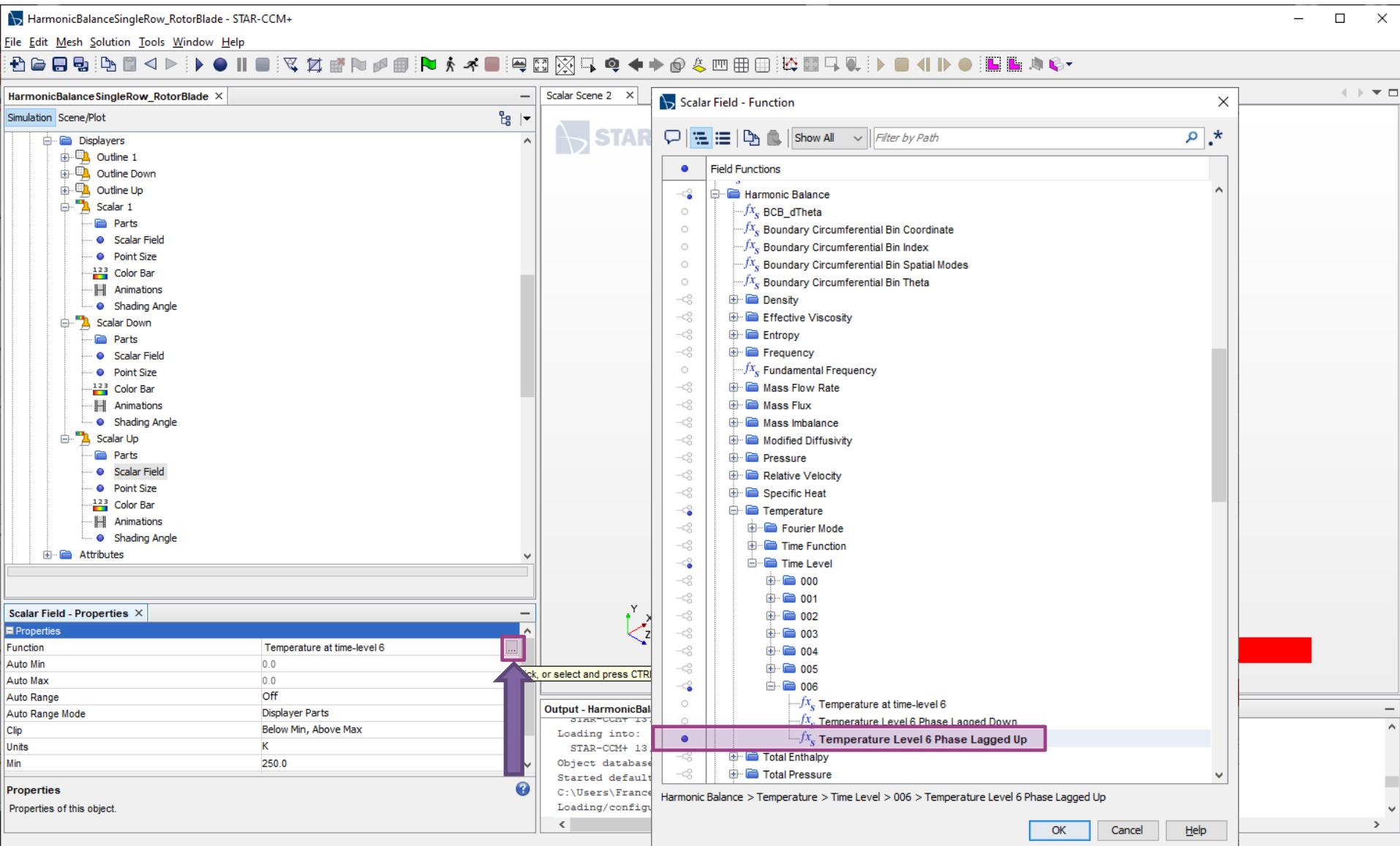


Copy-paste « Scalar 1 » twice as done for the Outline Dpliers

CFD applied to Turbomachinery

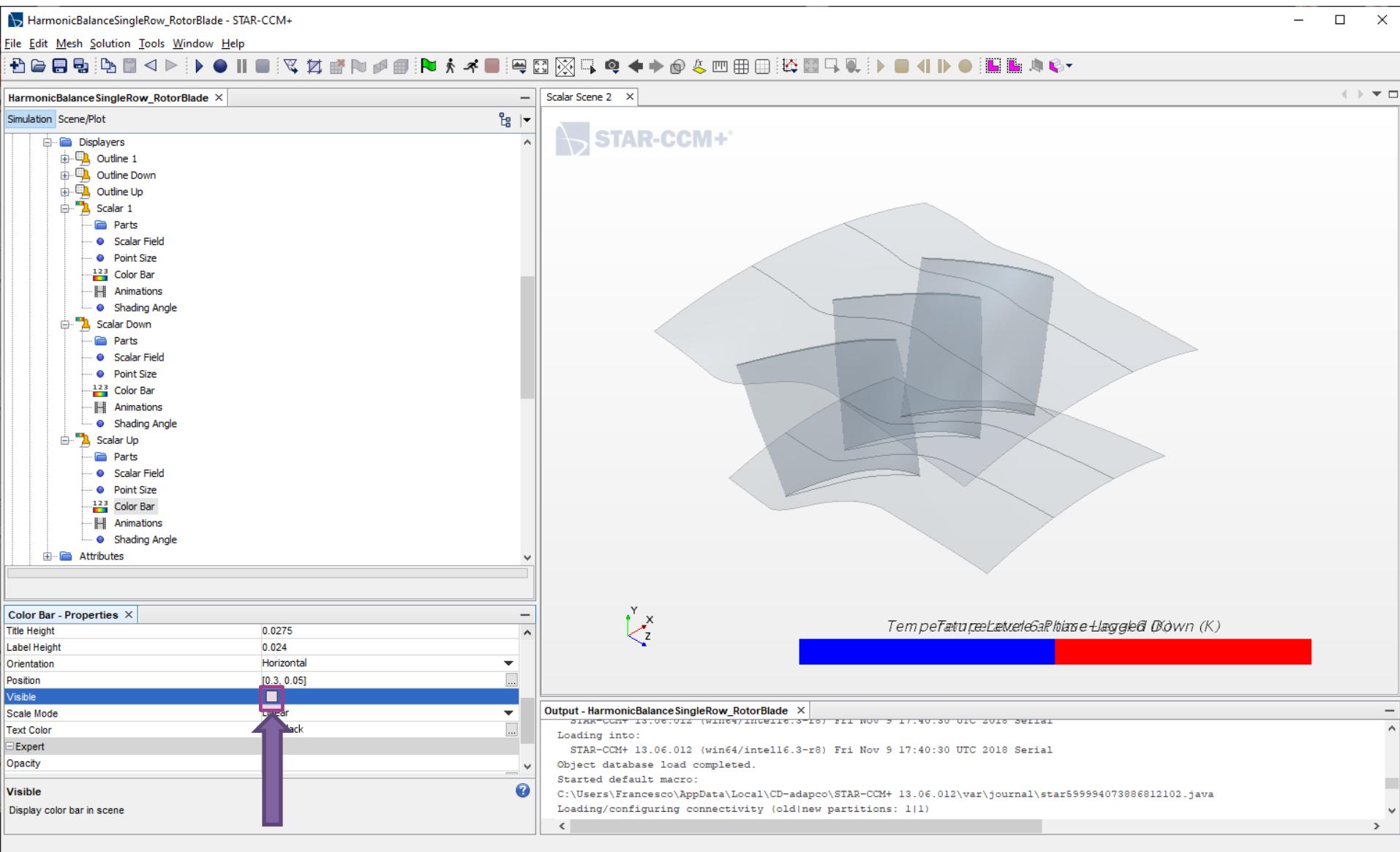


# Harmonic Balance for Rotor Blade in StarCCM+



Change the Scalar Function of « Scalar Down » to « Temperature Level 6 Phase Lagged Down »

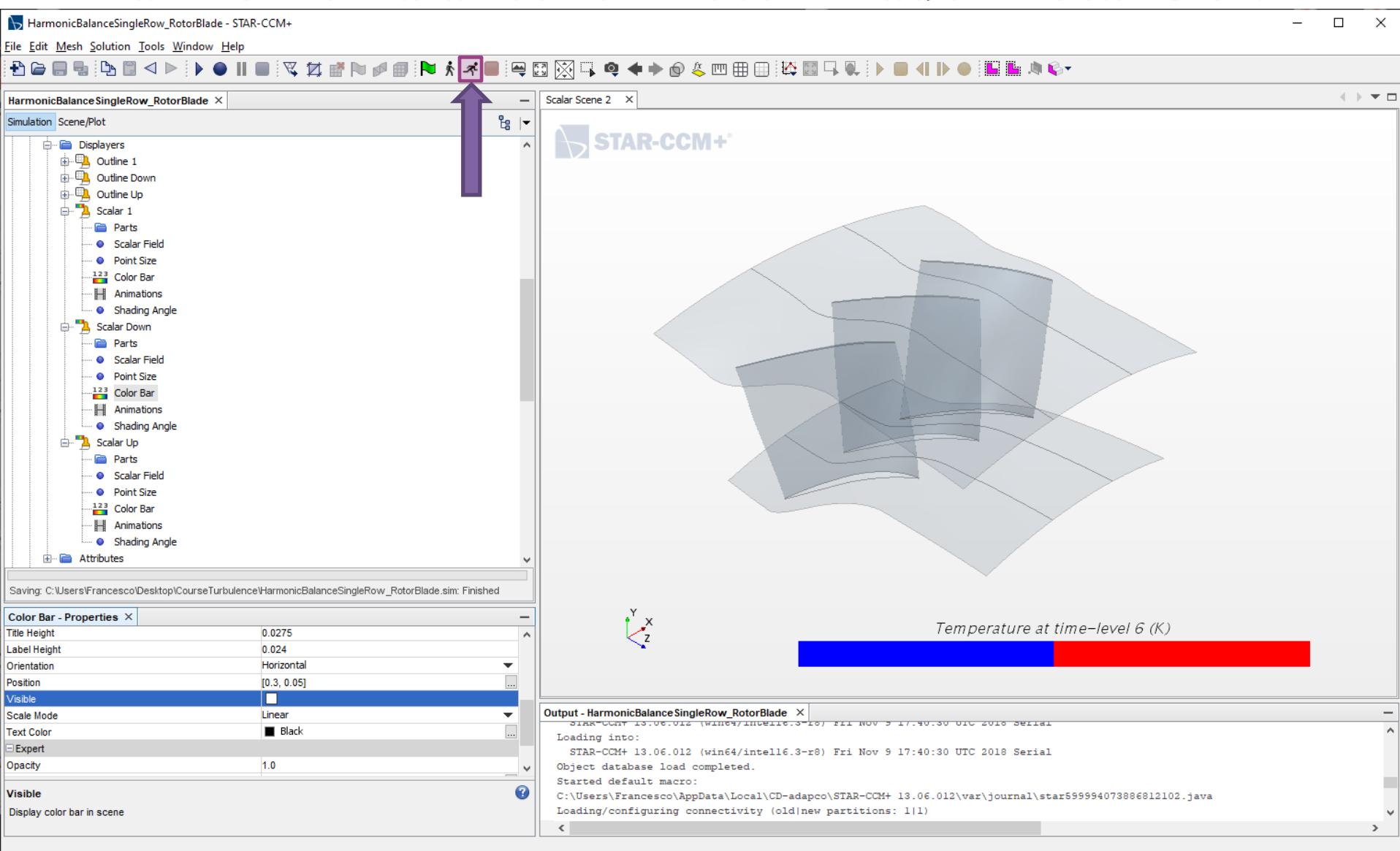
# Harmonic Balance for Rotor Blade in StarCCM+



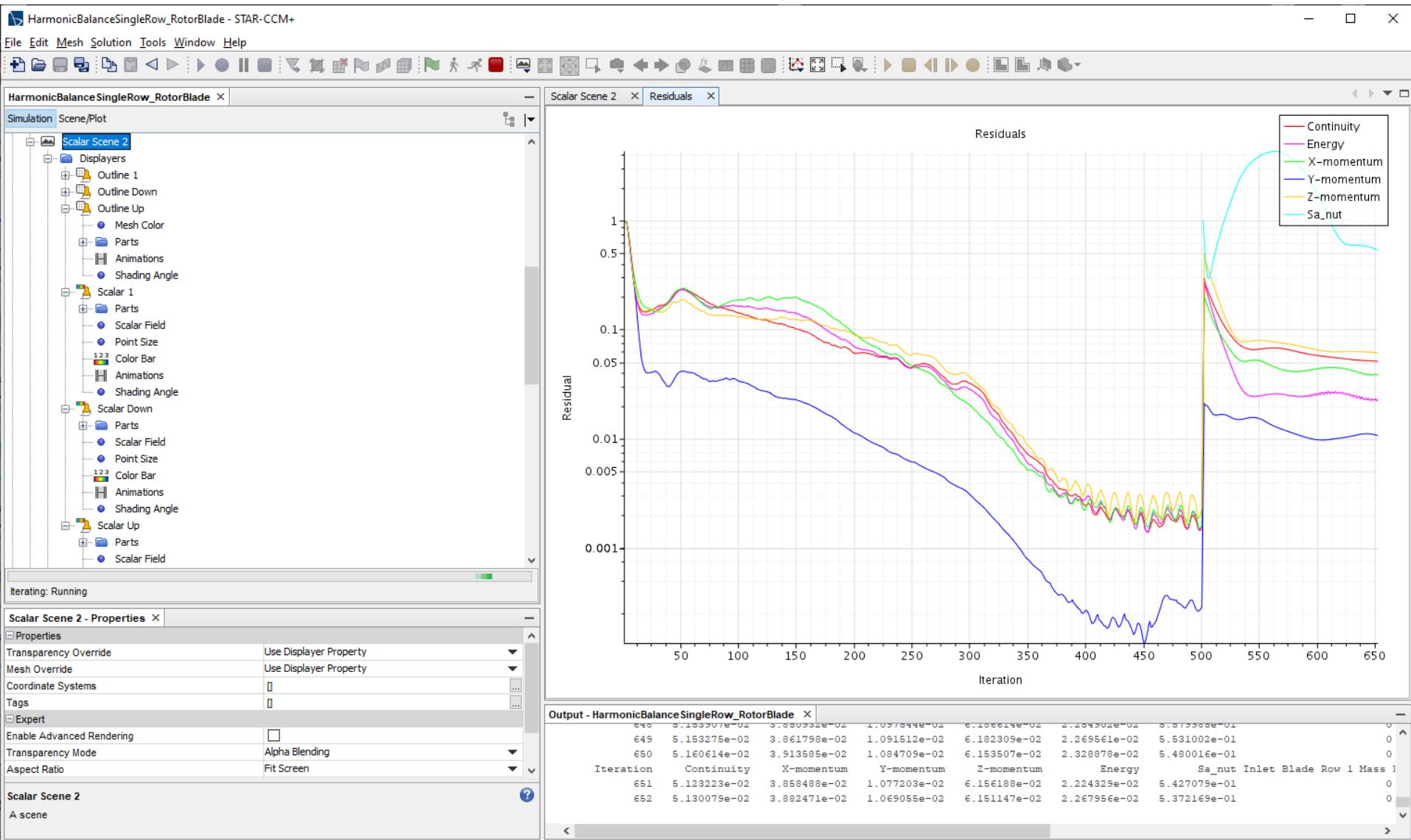
Deselect « Visible » for « Scalar Down » and « Scalar Up »



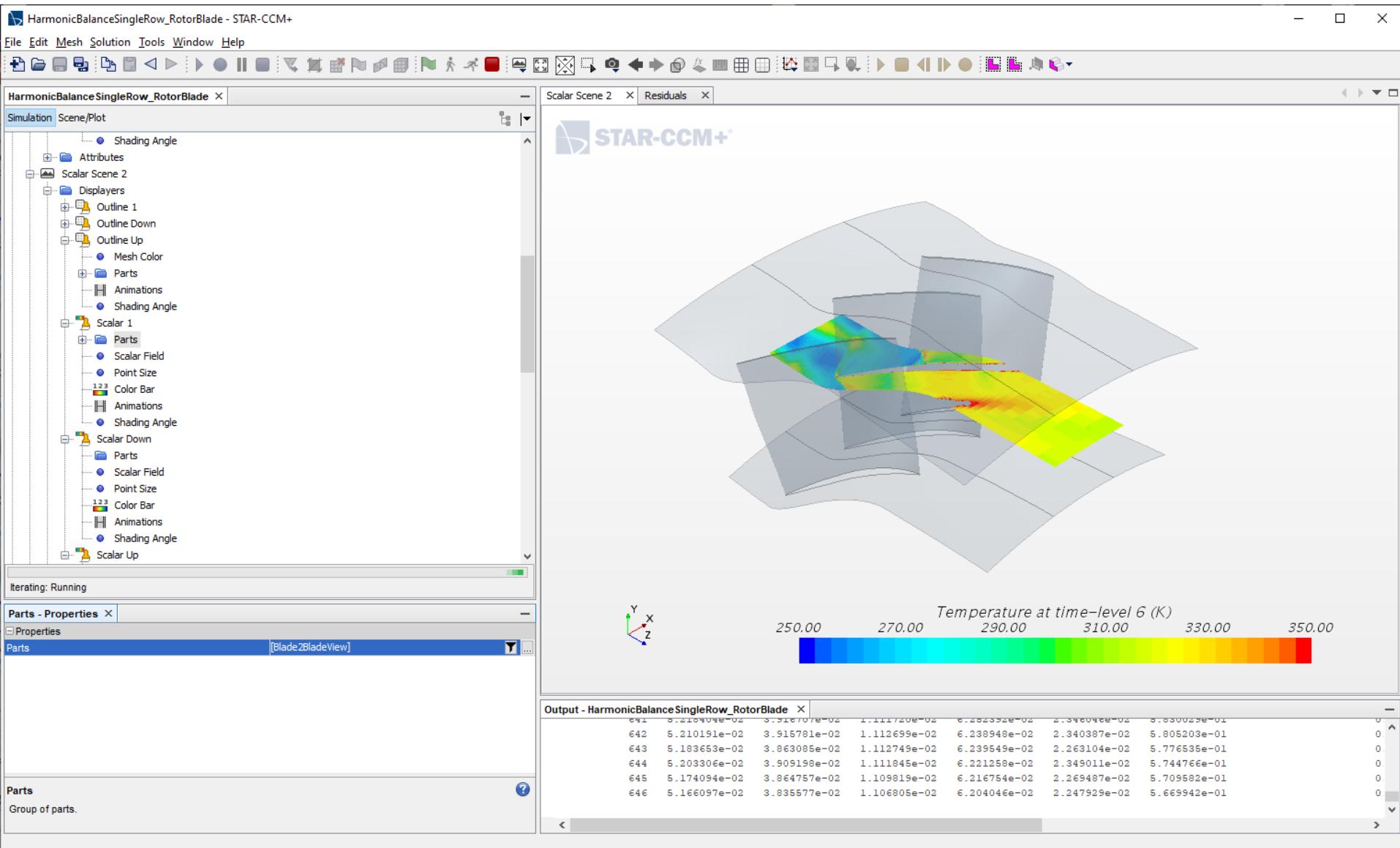
# Harmonic Balance for Rotor Blade in StarCCM+



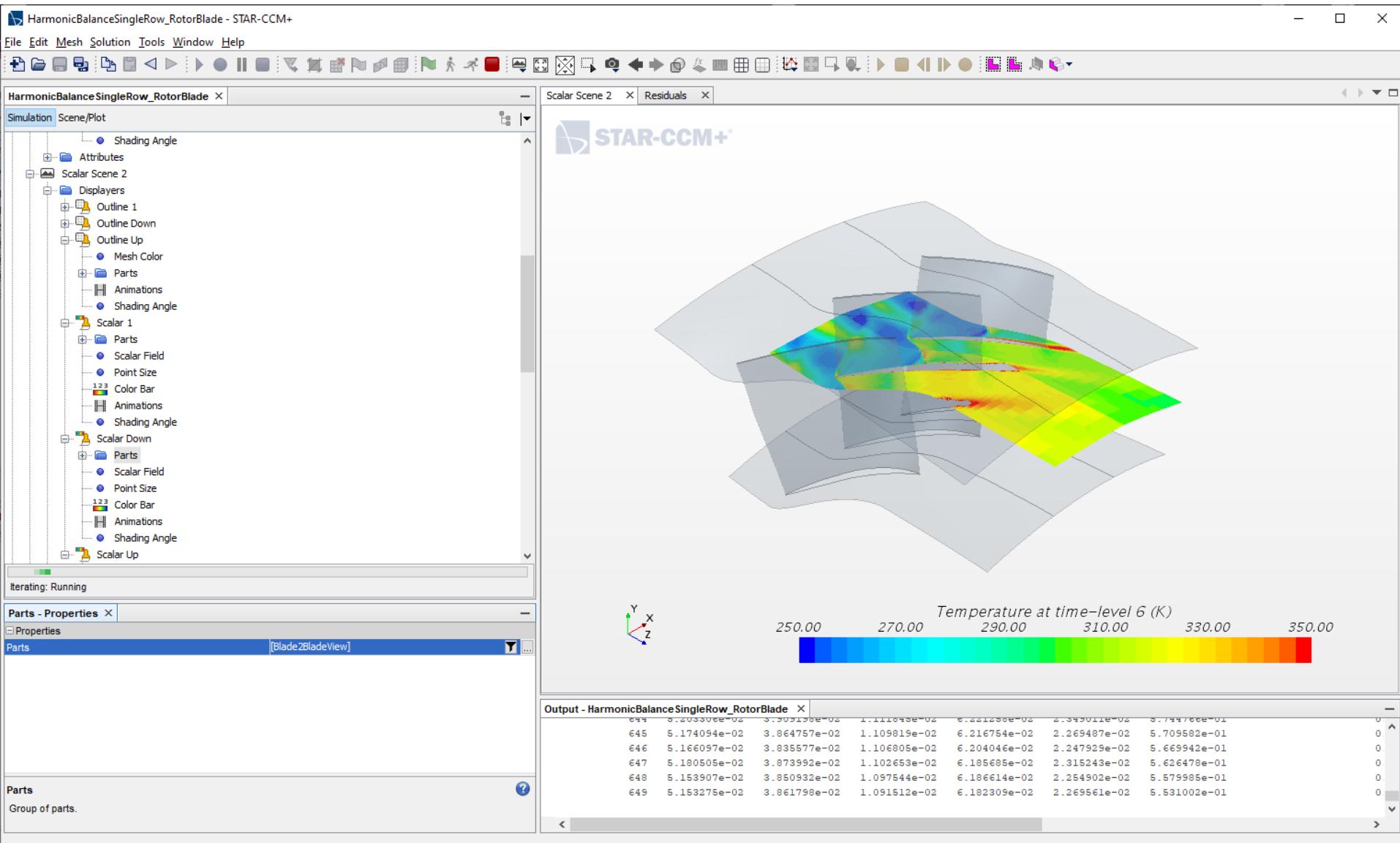
# Harmonic Balance for Rotor Blade in StarCCM+



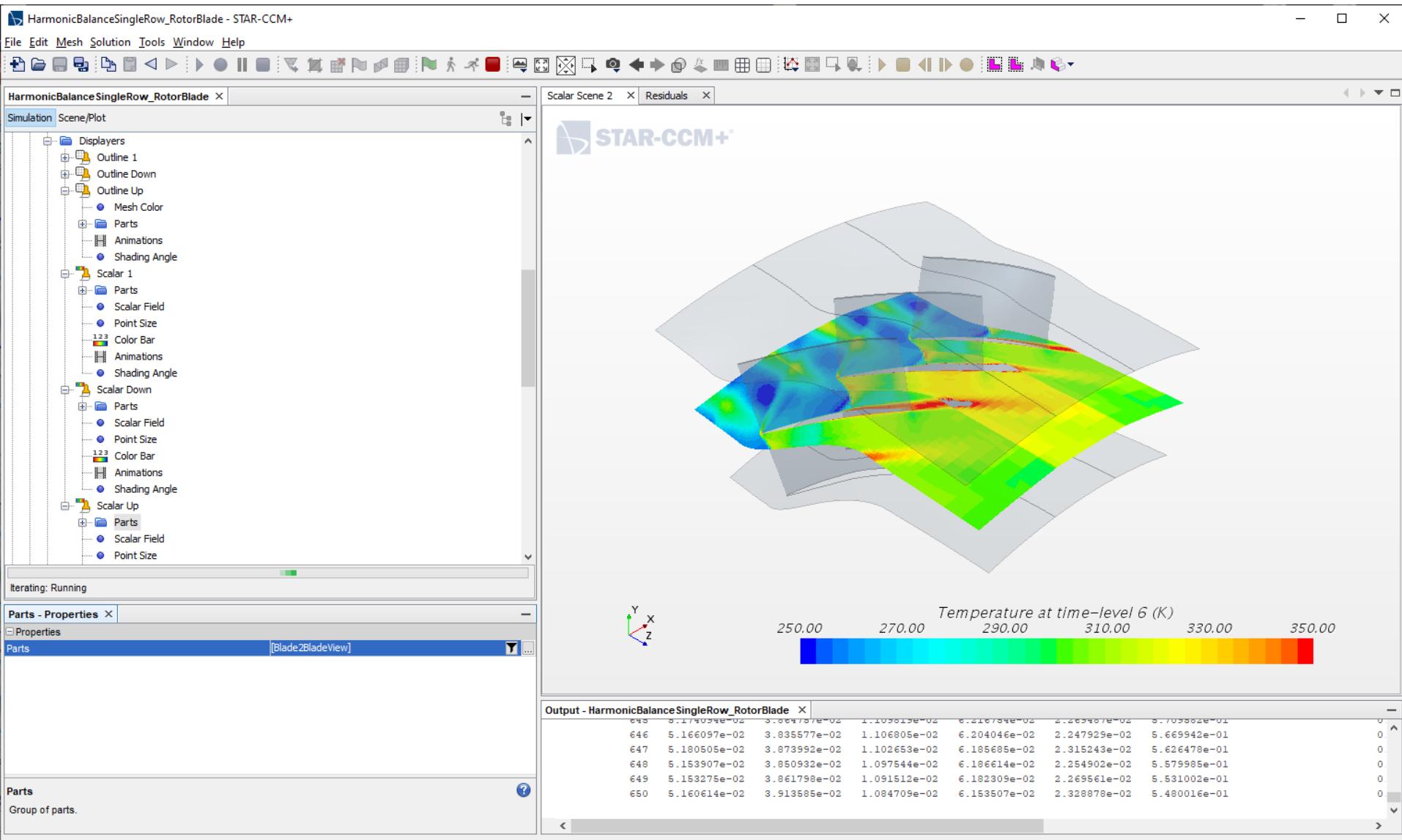
# Harmonic Balance for Rotor Blade in StarCCM+



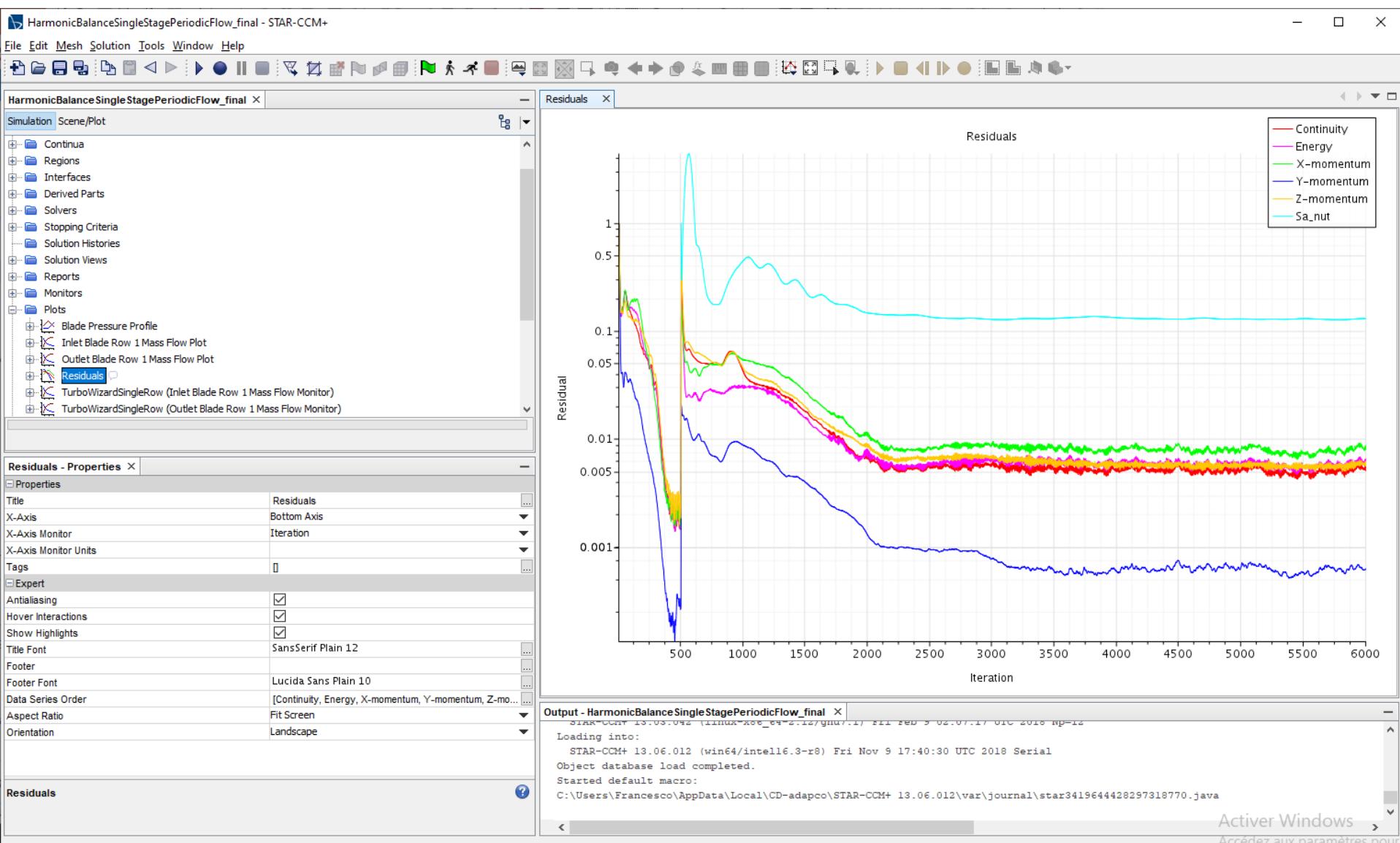
# Harmonic Balance for Rotor Blade in StarCCM+



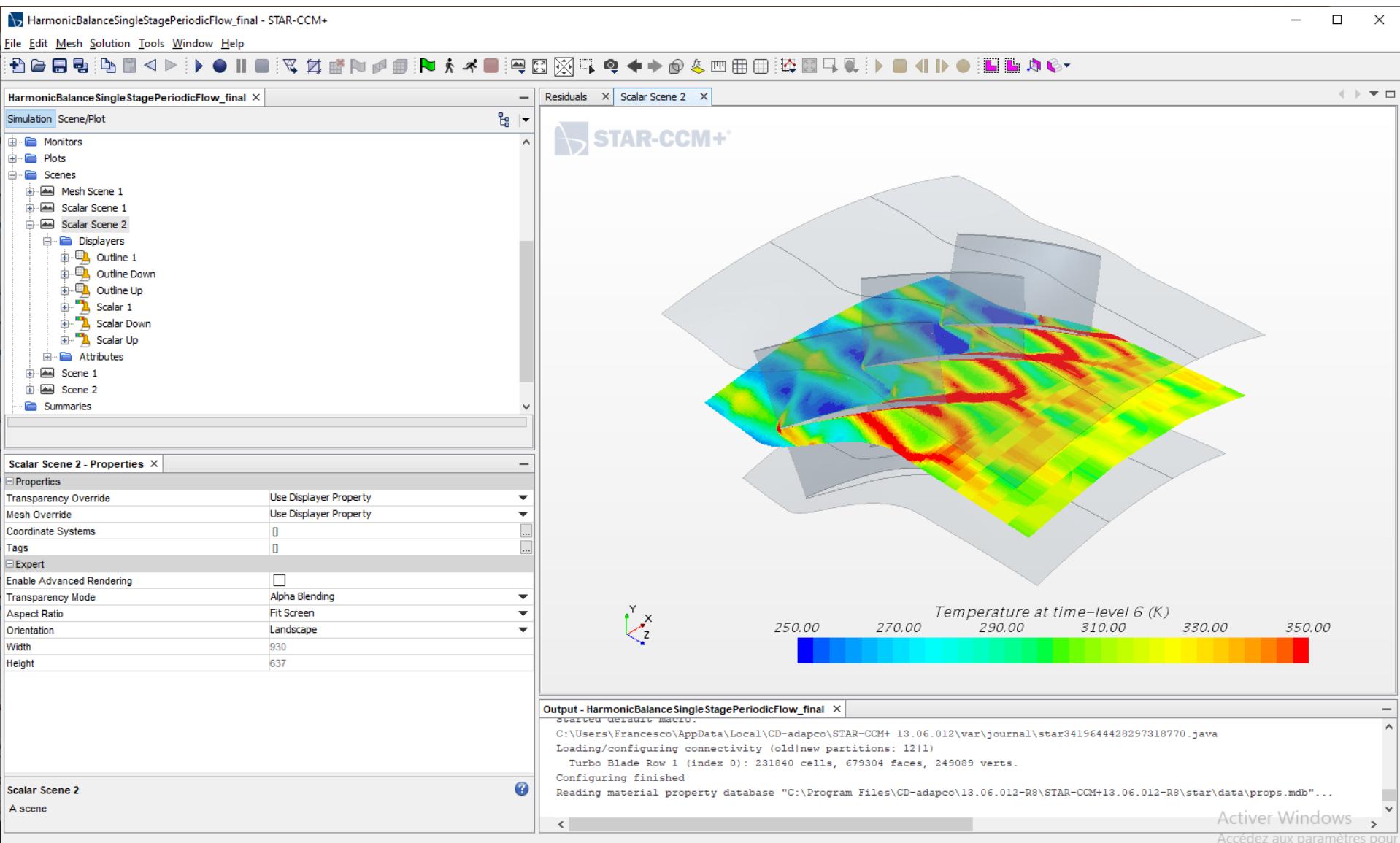
# Harmonic Balance for Rotor Blade in StarCCM+



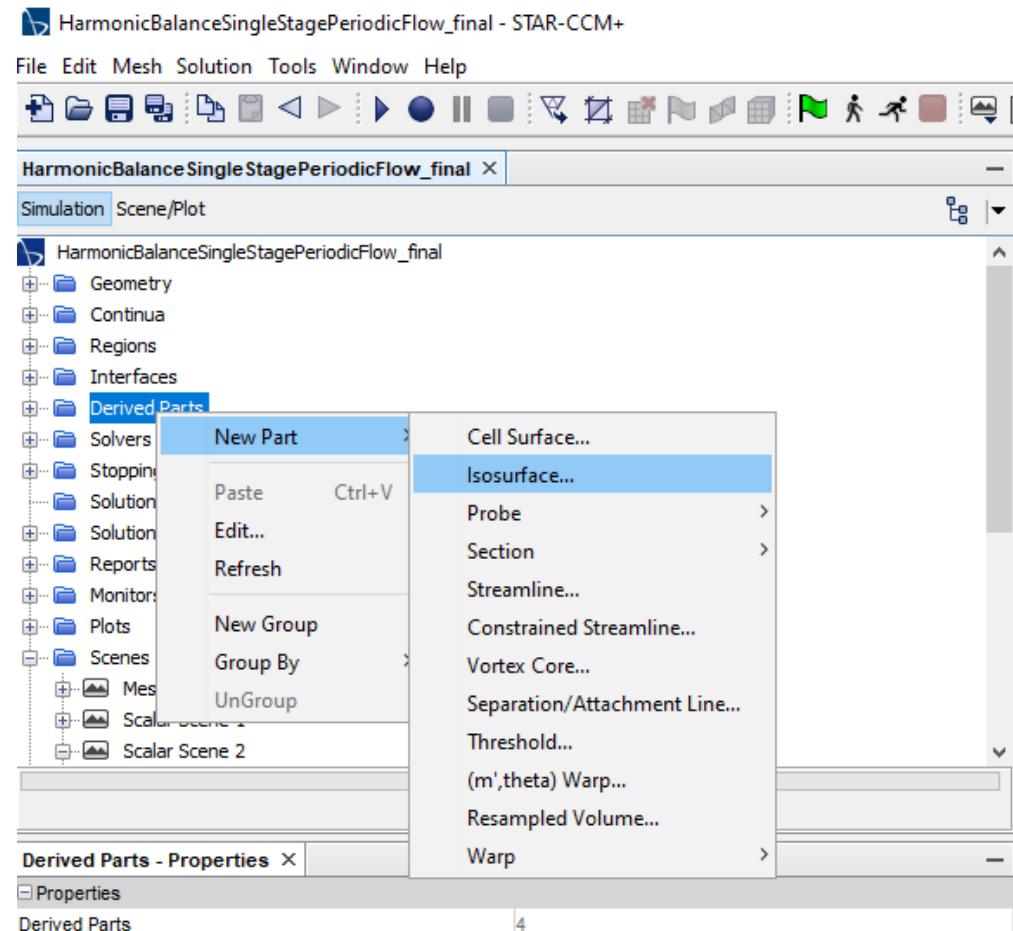
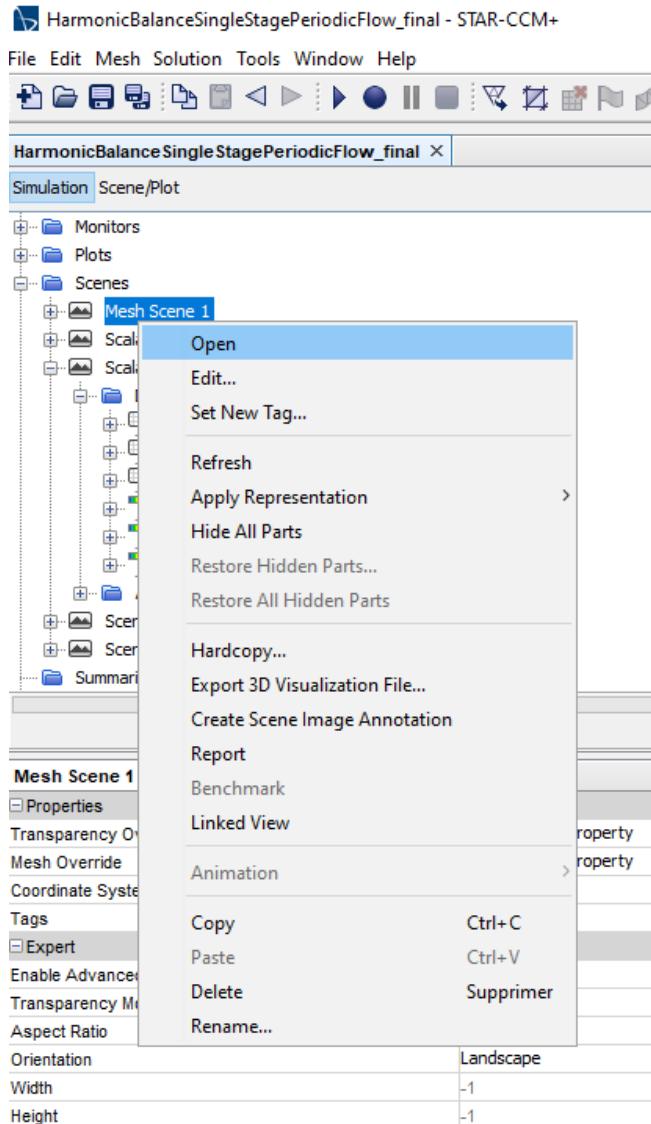
# Harmonic Balance for Rotor Blade in StarCCM+



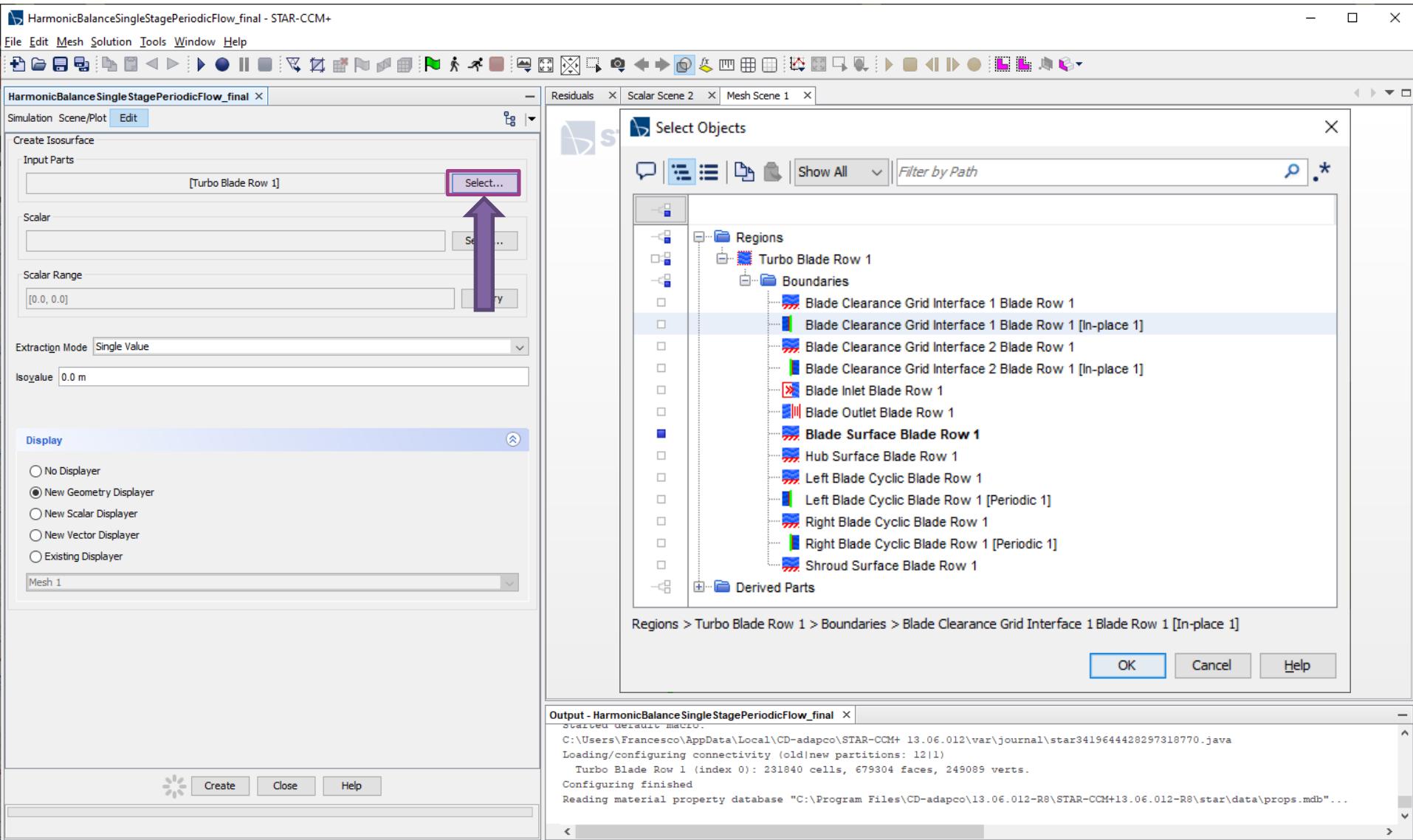
# Harmonic Balance for Rotor Blade in StarCCM+



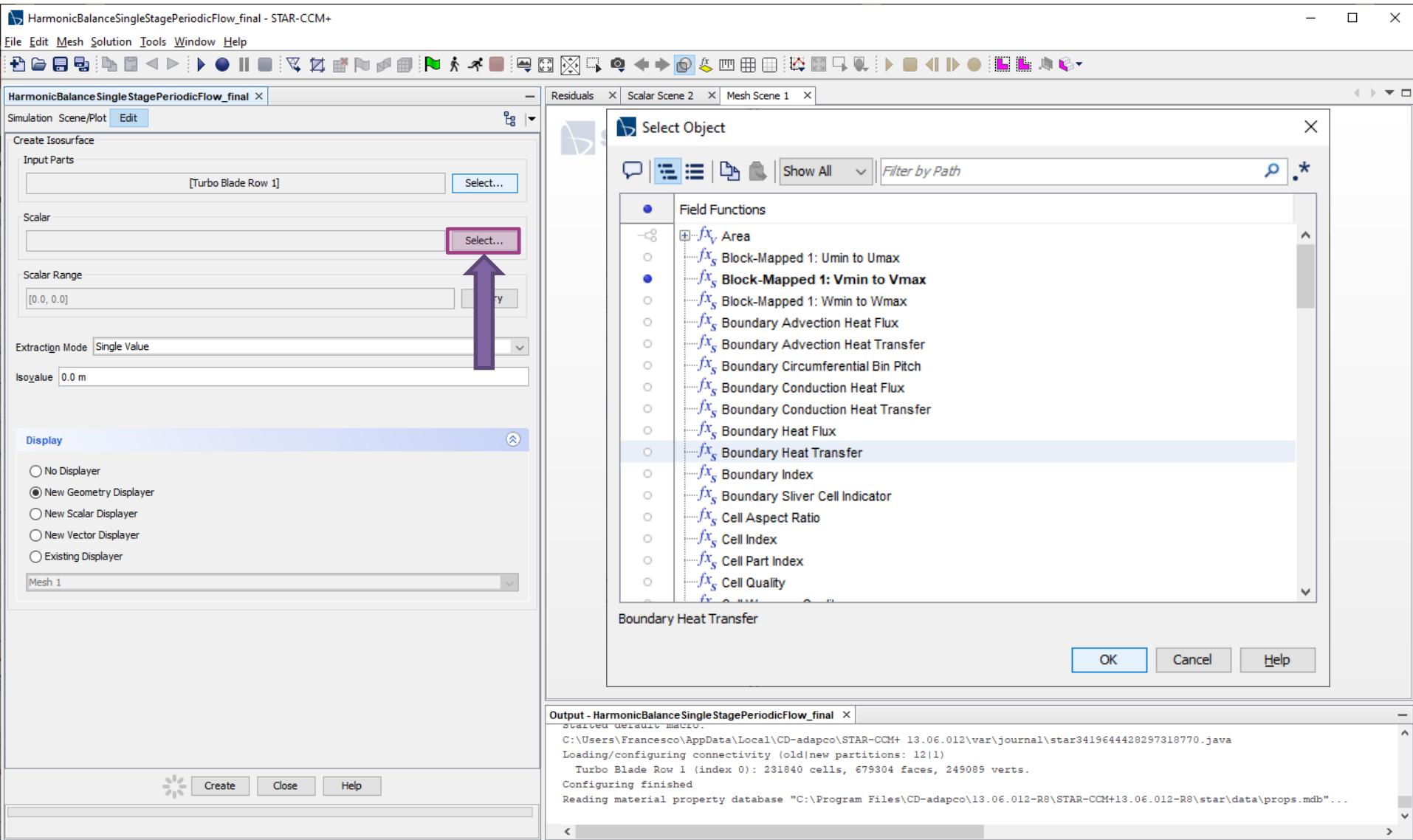
# Harmonic Balance for Rotor Blade in StarCCM+



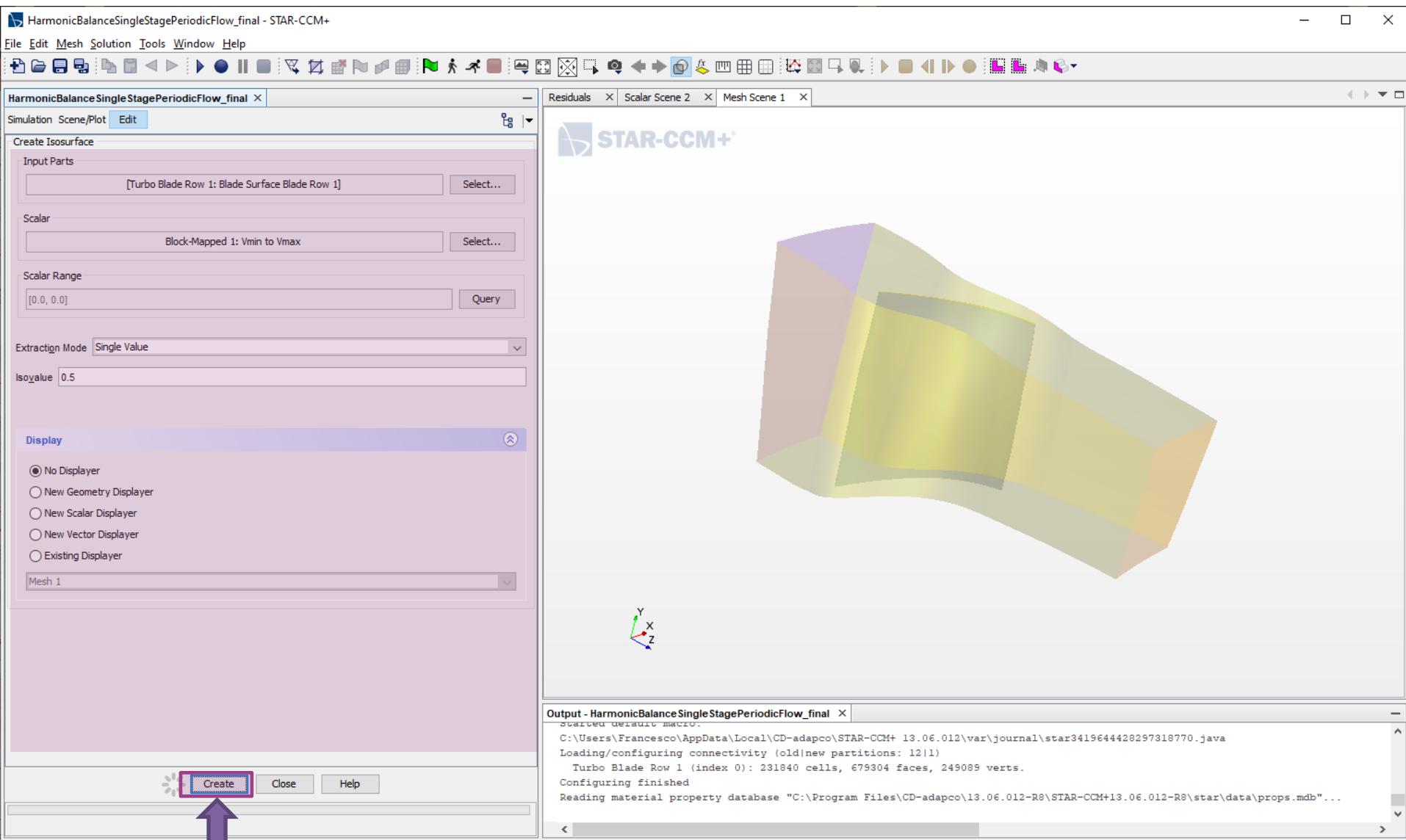
# Harmonic Balance for Rotor Blade in StarCCM+



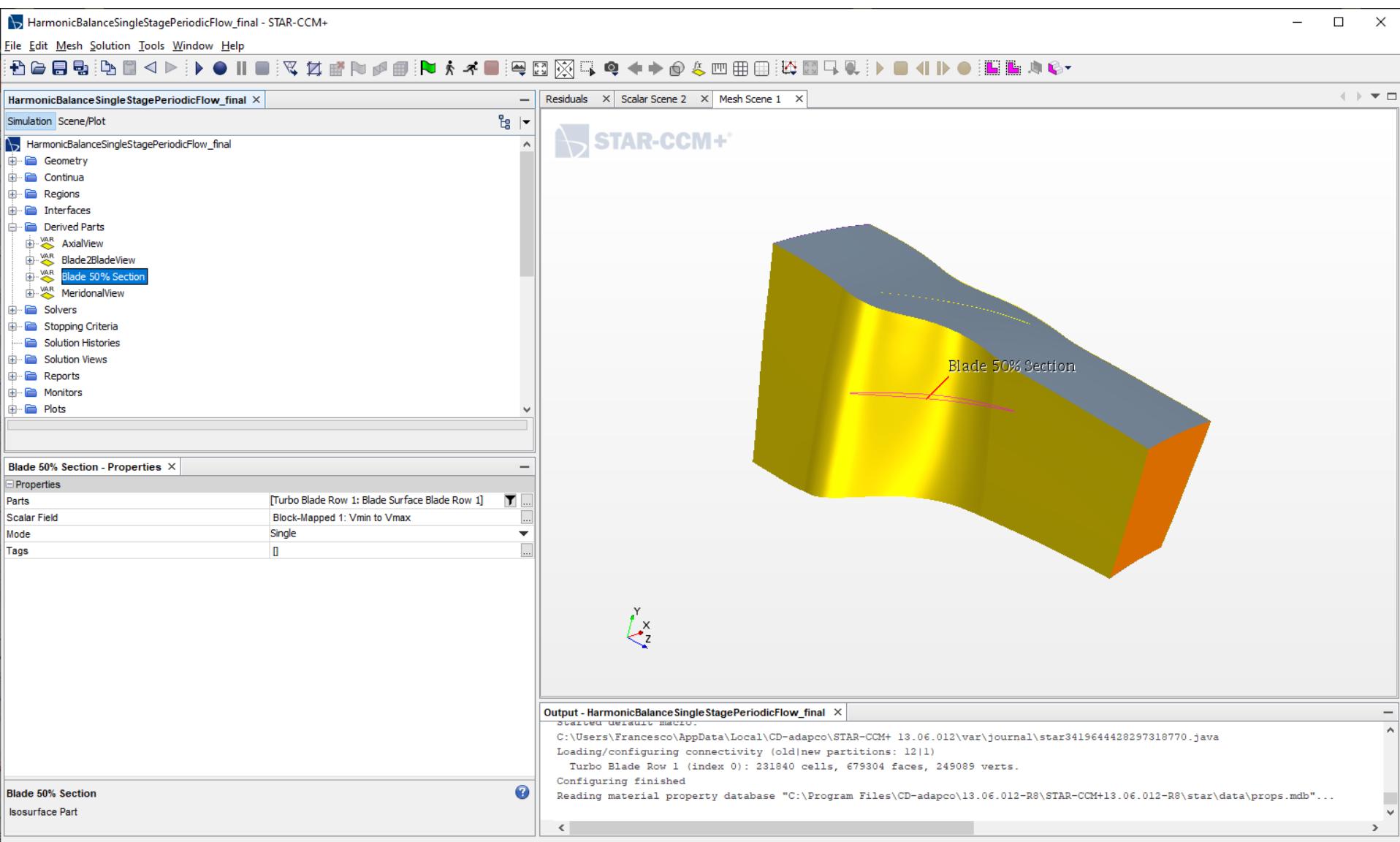
# Harmonic Balance for Rotor Blade in StarCCM+



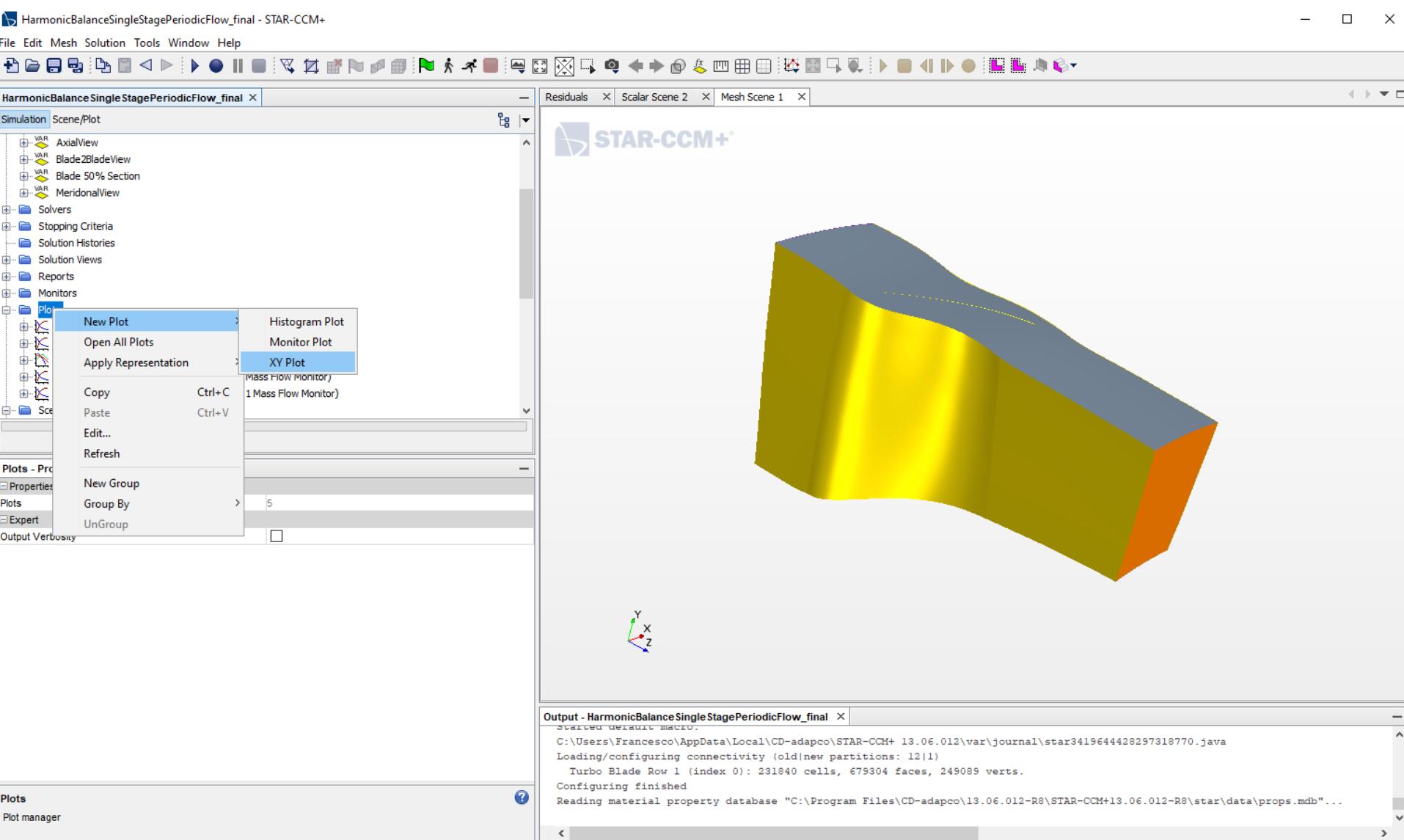
# Harmonic Balance for Rotor Blade in StarCCM+



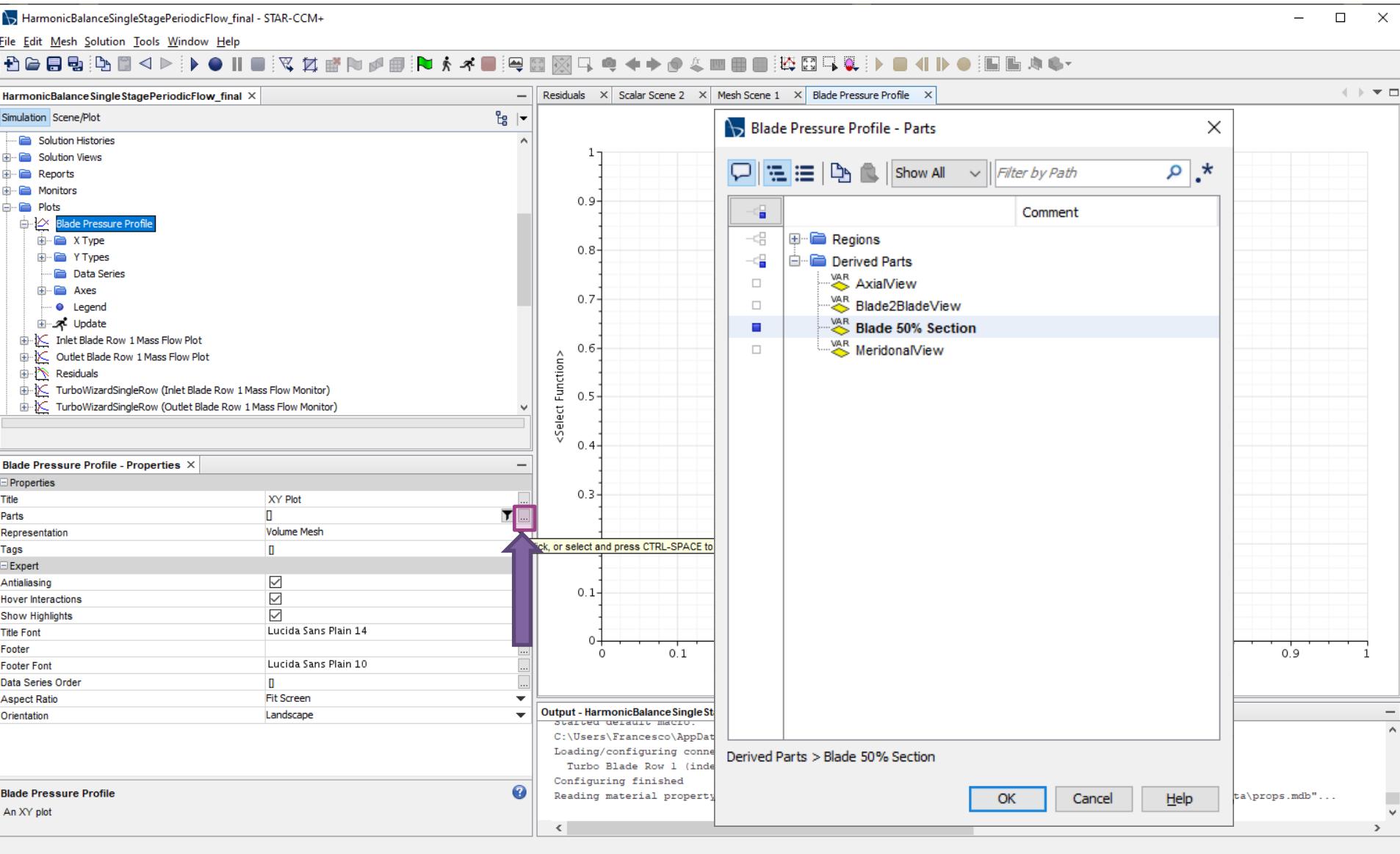
# Harmonic Balance for Rotor Blade in StarCCM+



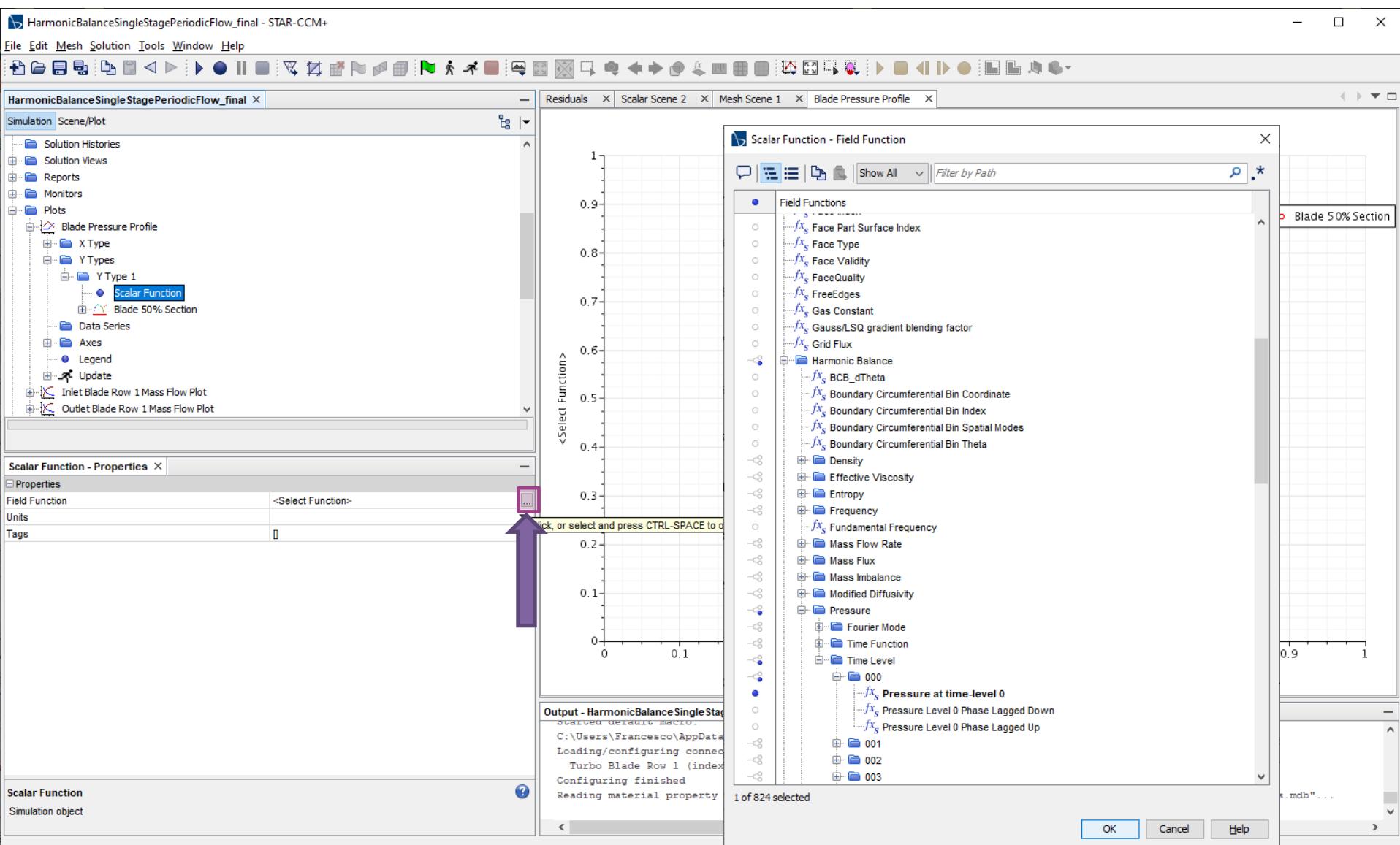
# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+



# Harmonic Balance for Rotor Blade in StarCCM+

