SAND2021-8730PE

Sandia RANS Solutions for the Axisymmetric Transonic Hump

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Sandia Axisymmetric Transonic Hump Workshop
July 27-28, 2021

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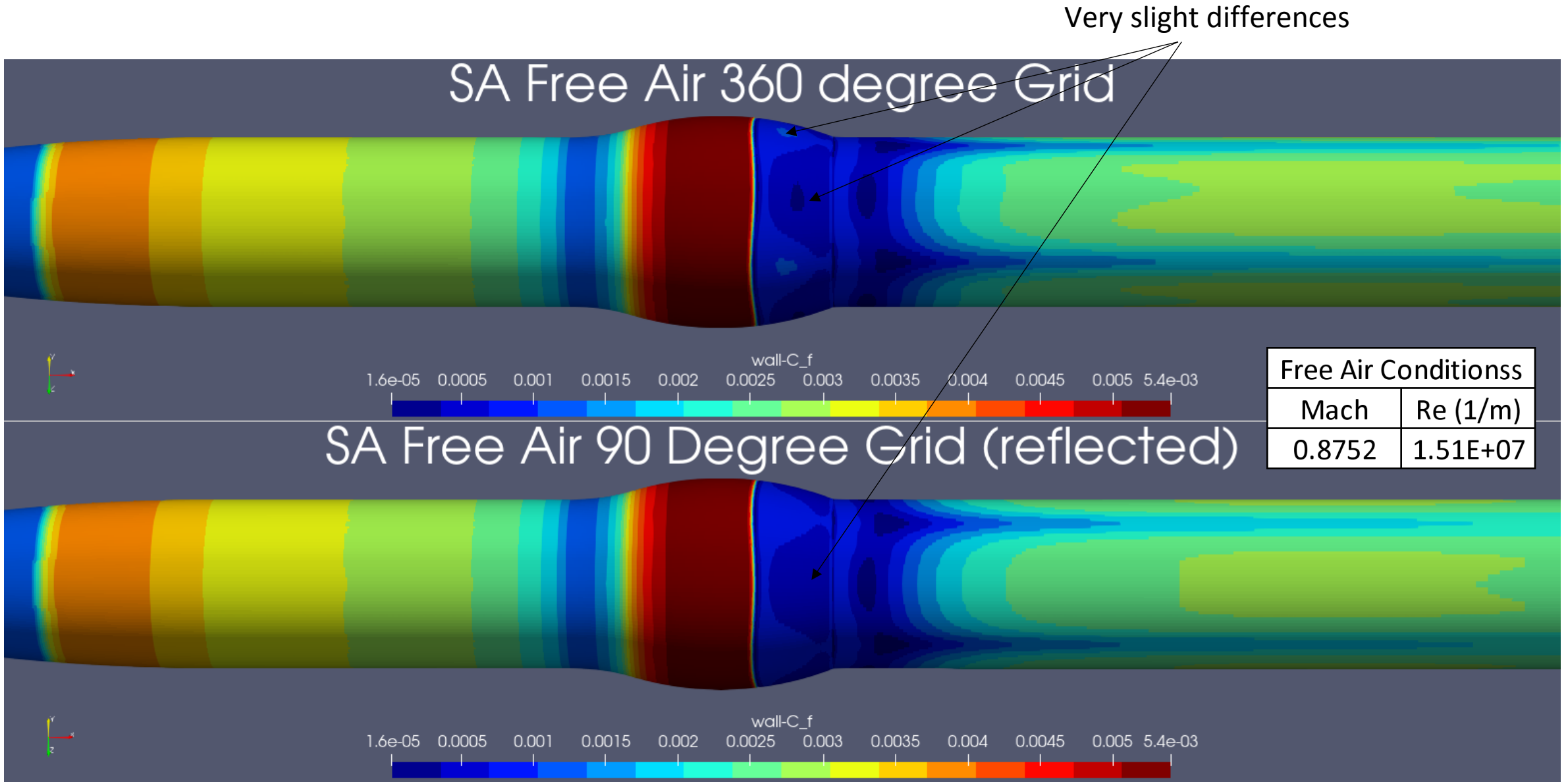
SPARC ATH Simulations

- Solutions obtained using the SPARC code
  - 2nd order, structured grid, finite volume numerical scheme
  - Standard SA and SST-2003 models
- The following plots attempt to show the effects of:
  - Turbulence model; SA and SST – non-axisymmetry?
  - Tunnel walls (in-tunnel solutions compared to free air)
  - Symmetry planes (90° grids vs 180° grids vs 360° grids)
- Some plot titles show (Reflected) – This means the solution is on a 90° or 180° grid and has been reflected/mirrored to appear as a full 360° solution in order to compare with the actual 360° grid solution.

SA Free Air Grids

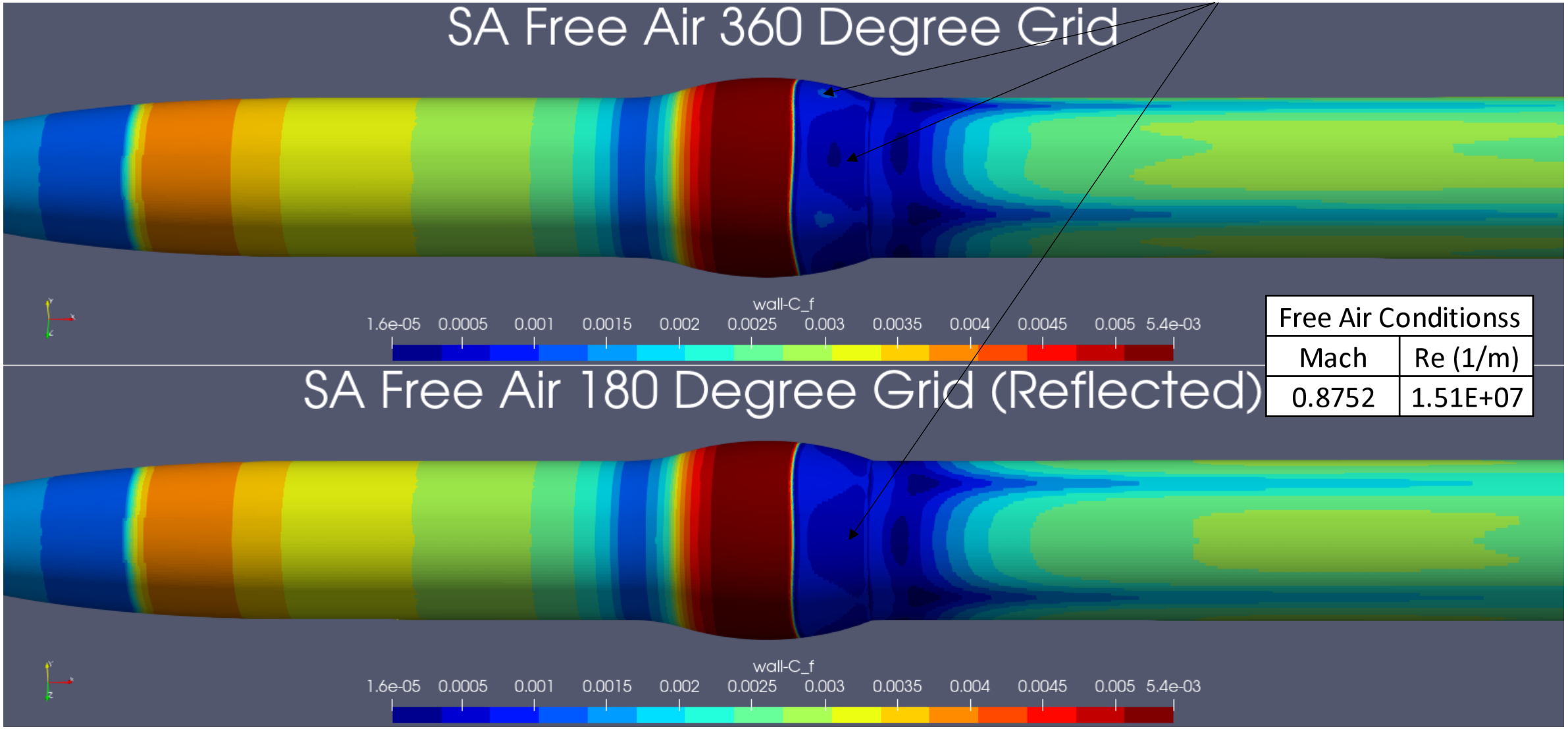
SA Free Air Solutions are not Axisymmetric



Free Air Conditionss	
Mach	Re (1/m)
0.8752	1.51E+07

90° (previous slide) and 180 ° look the same

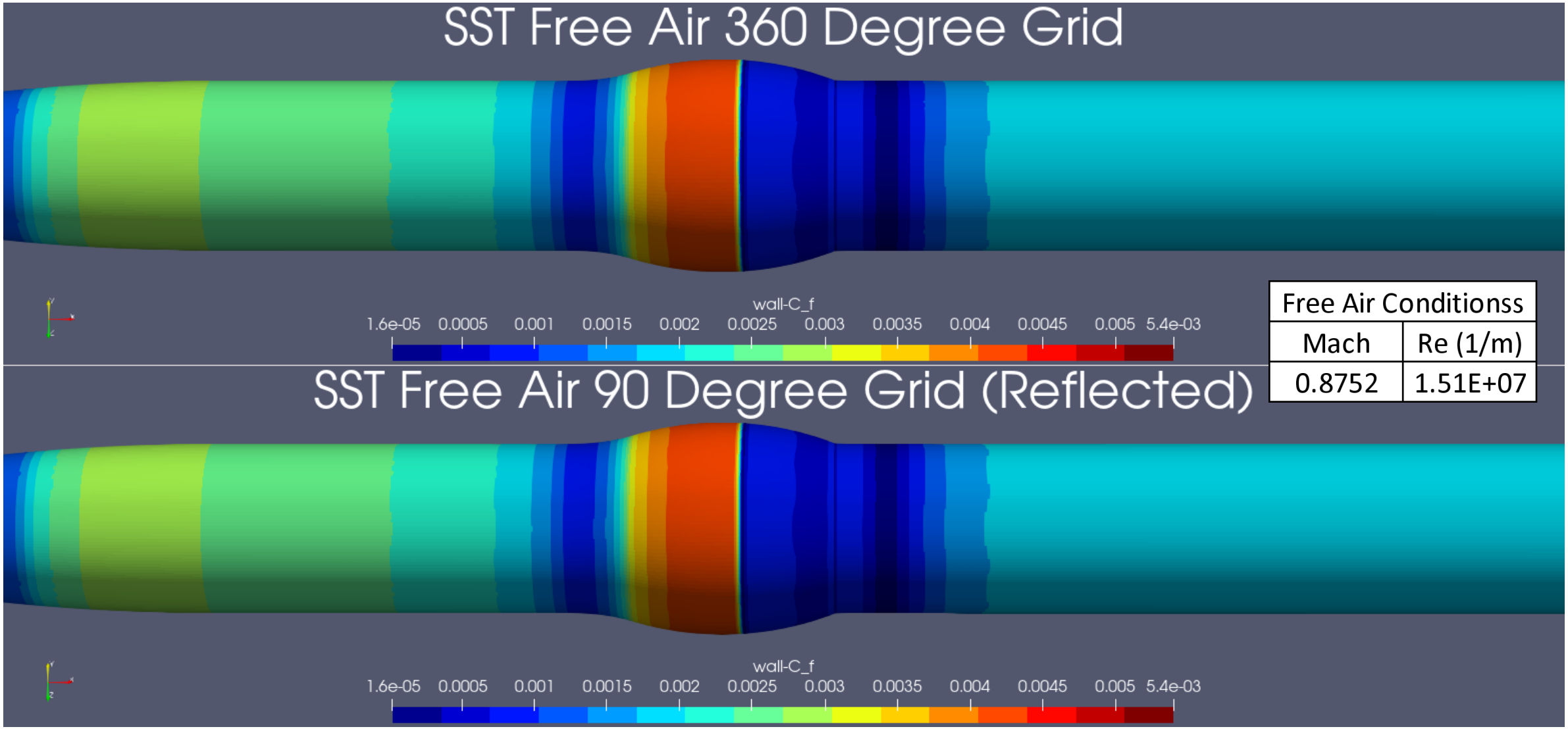
Very slight differences



Free Air Conditionss	
Mach	Re (1/m)
0.8752	1.51E+07

Sparc ATH SST Sims
90°, 180° and 360° grids

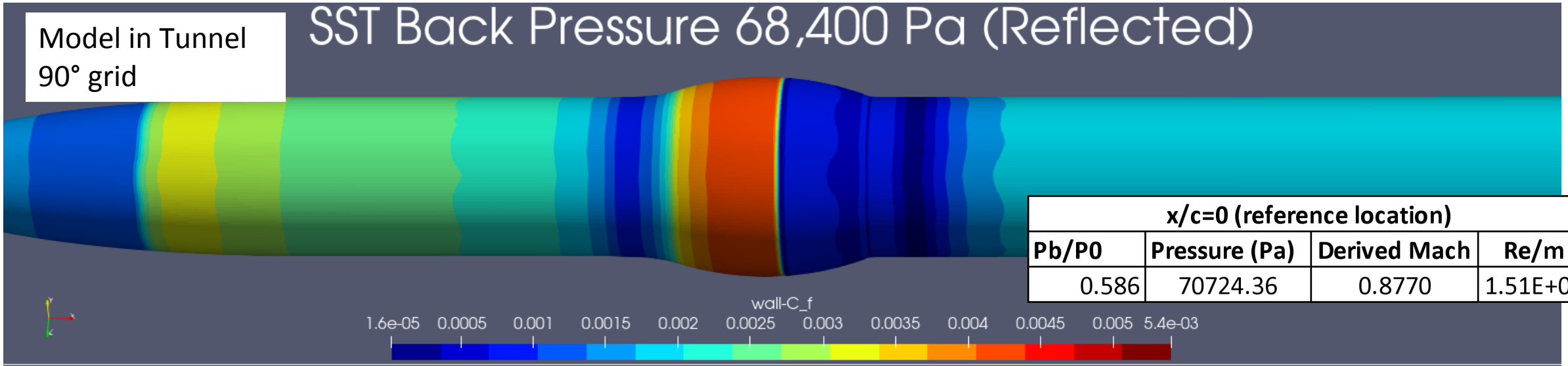
SST Free Air Solutions Show Axisymmetry



Free Air Conditionss	
Mach	Re (1/m)
0.8752	1.51E+07

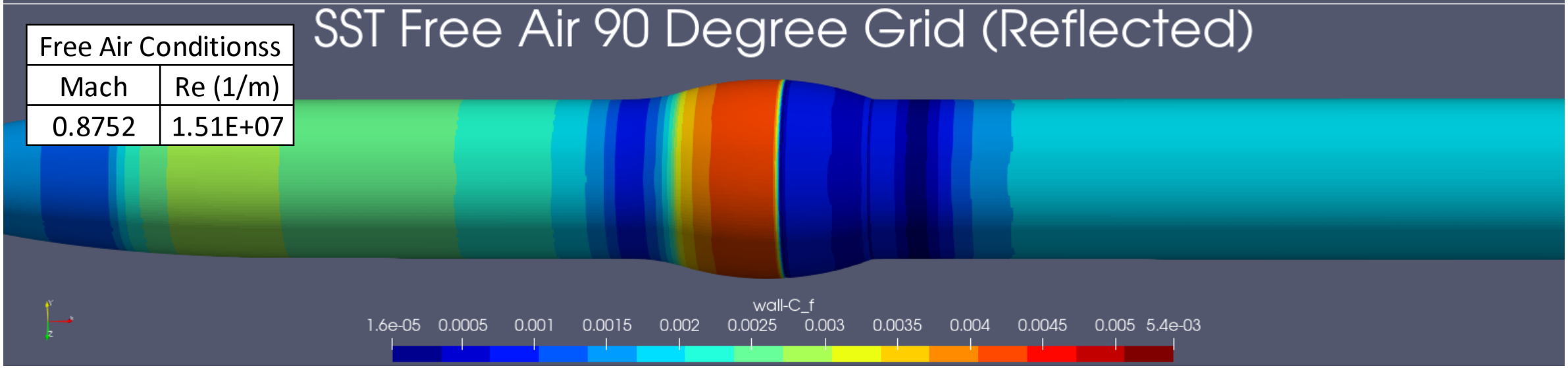
SST: Model in Tunnel vs. Free Air

Model in Tunnel
90° grid



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70724.36	0.8770	1.51E+07

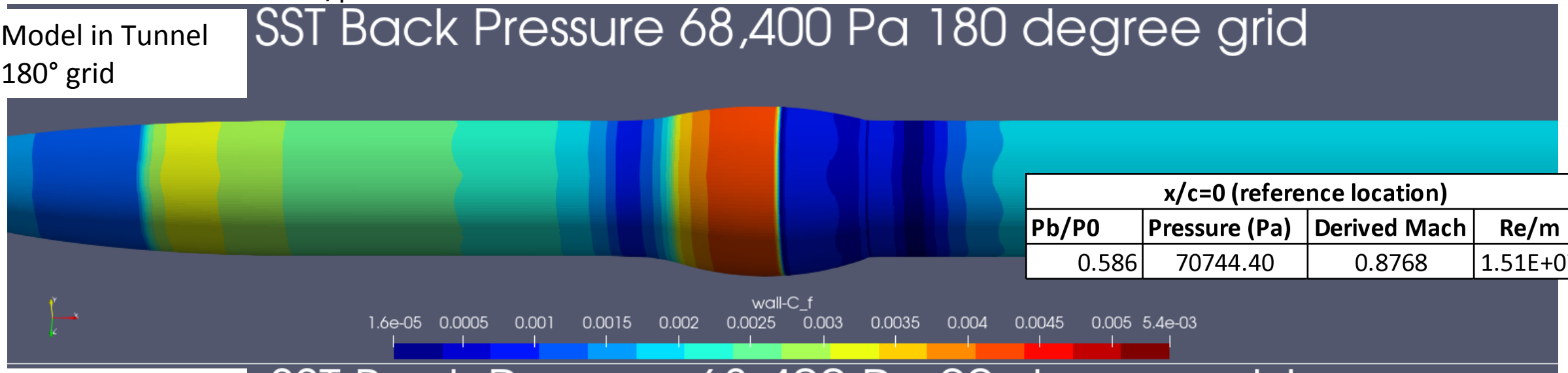
Free Air Conditionss	
Mach	Re (1/m)
0.8752	1.51E+07



Model-in-Tunnel Grids: 90° and 180°

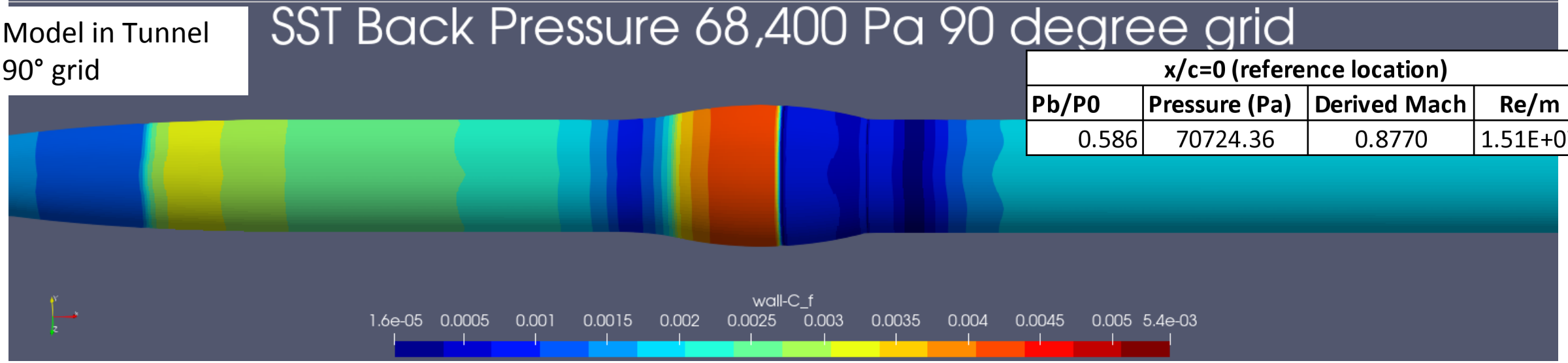
*Neither solution/plot is reflected for better distinction between them

Model in Tunnel 180° grid



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70744.40	0.8768	1.51E+07

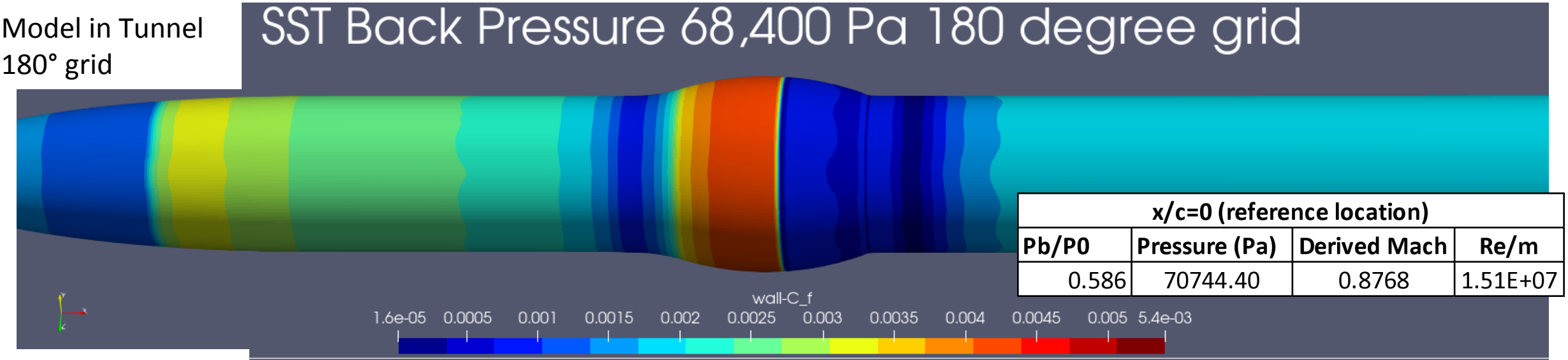
Model in Tunnel 90° grid



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70724.36	0.8770	1.51E+07

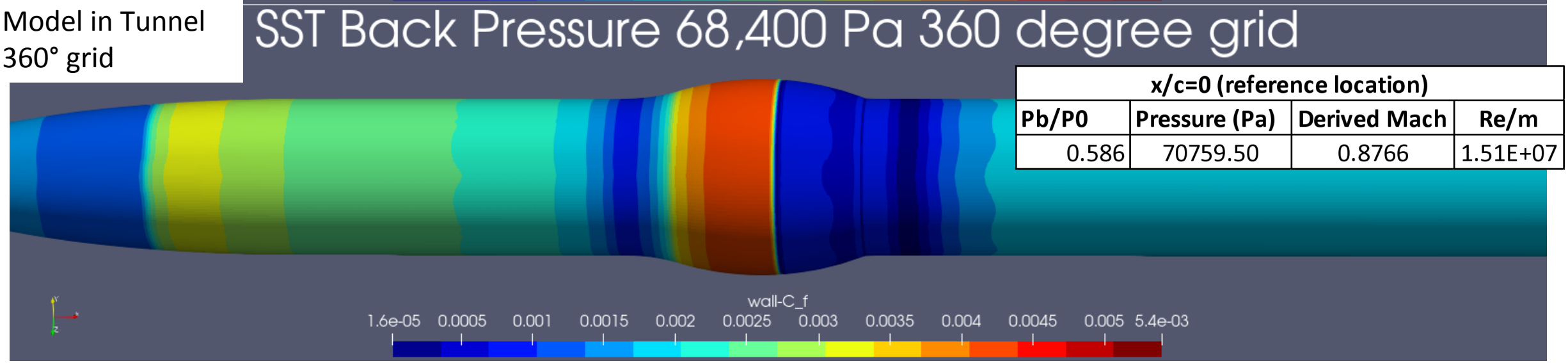
Model-in-Tunnel Grids: 360° and 180°

Model in Tunnel 180° grid



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70744.40	0.8768	1.51E+07

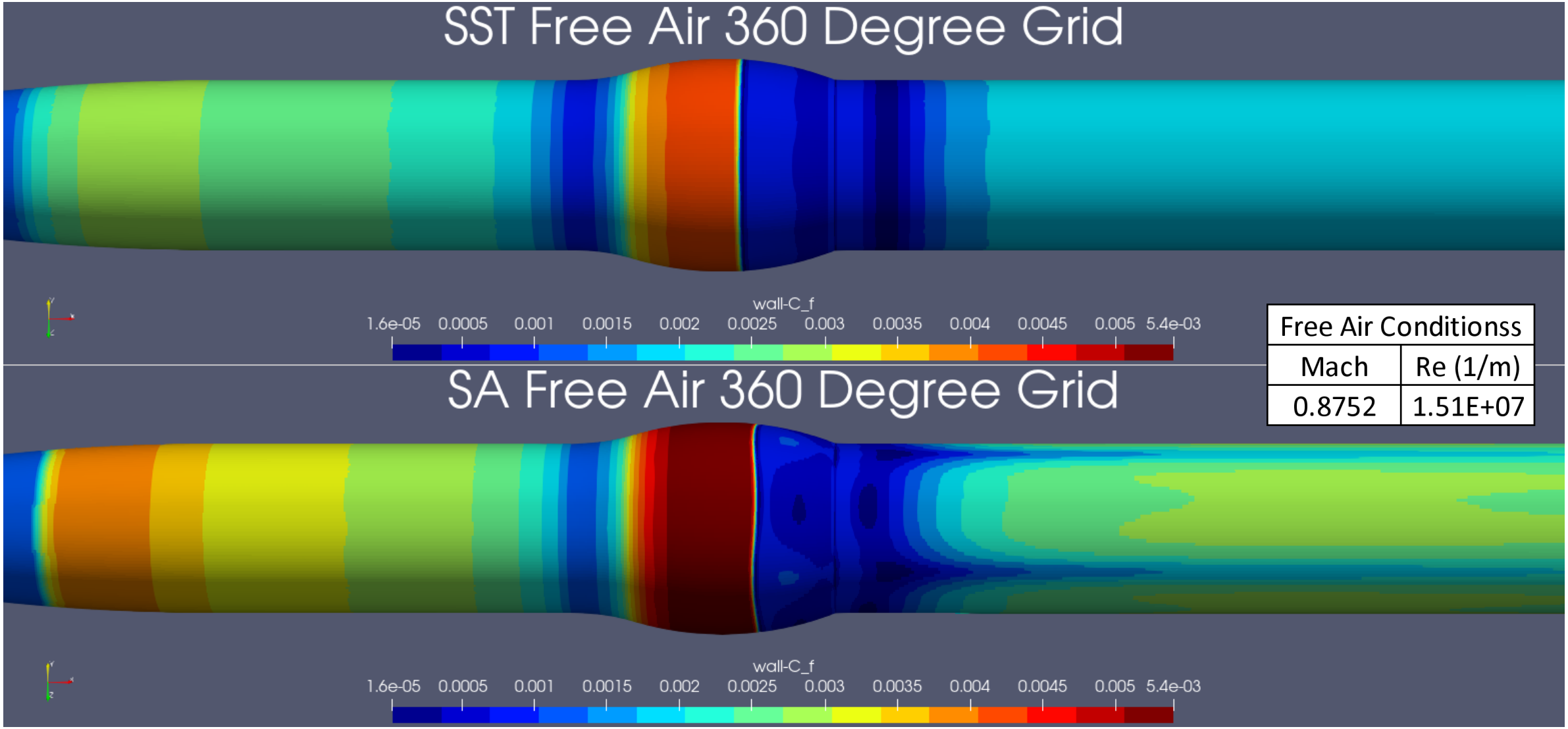
Model in Tunnel 360° grid



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70759.50	0.8766	1.51E+07

Sparc ATH SA and **SST** Sims
Free air grid
360° grid

SST and SA C_f Compared



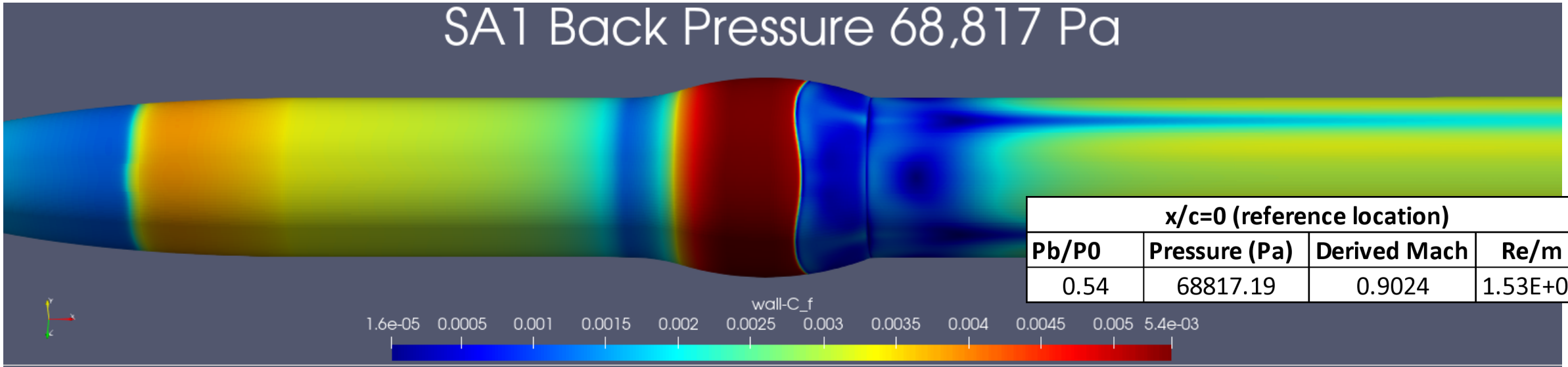
Free Air Conditionss	
Mach	Re (1/m)
0.8752	1.51E+07

Sparc ATH SA Sims
Tunnel grid
90° grid

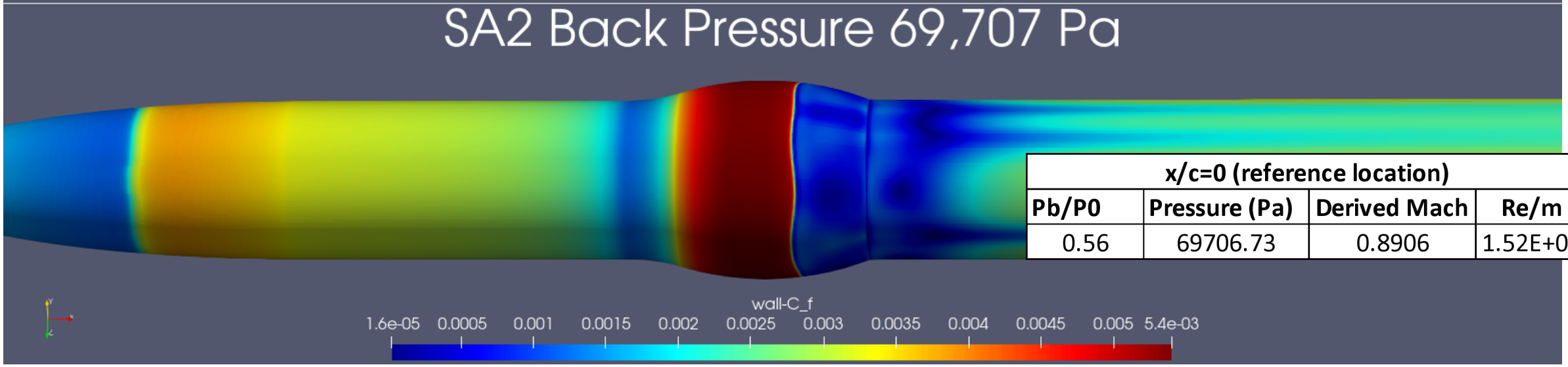
Model-in-tunnel grids: SA Back Pressure Variations

						x/c=0	x/c=0	
Turbulence Model	**Case Name**	**P0 (Pa)**	**T0 (K)**	**Pb/P0**	**Pb (Pa)**	**pressure**	**derived Mach**	**Re/m**
Spalart-Allmaras	SA1	116700	318	0.54	63018	68817.19	0.902	15265796
Spalart-Allmaras	SA2	116700	318	0.56	65352	69706.73	0.891	15187704
Spalart-Allmaras	SA3	116700	318	0.58	67686	70965.90	0.874	15071730
Spalart-Allmaras	SA4	116700	318	0.6	70020	72649.10	0.852	14906631

90 degree quadrants, reflected

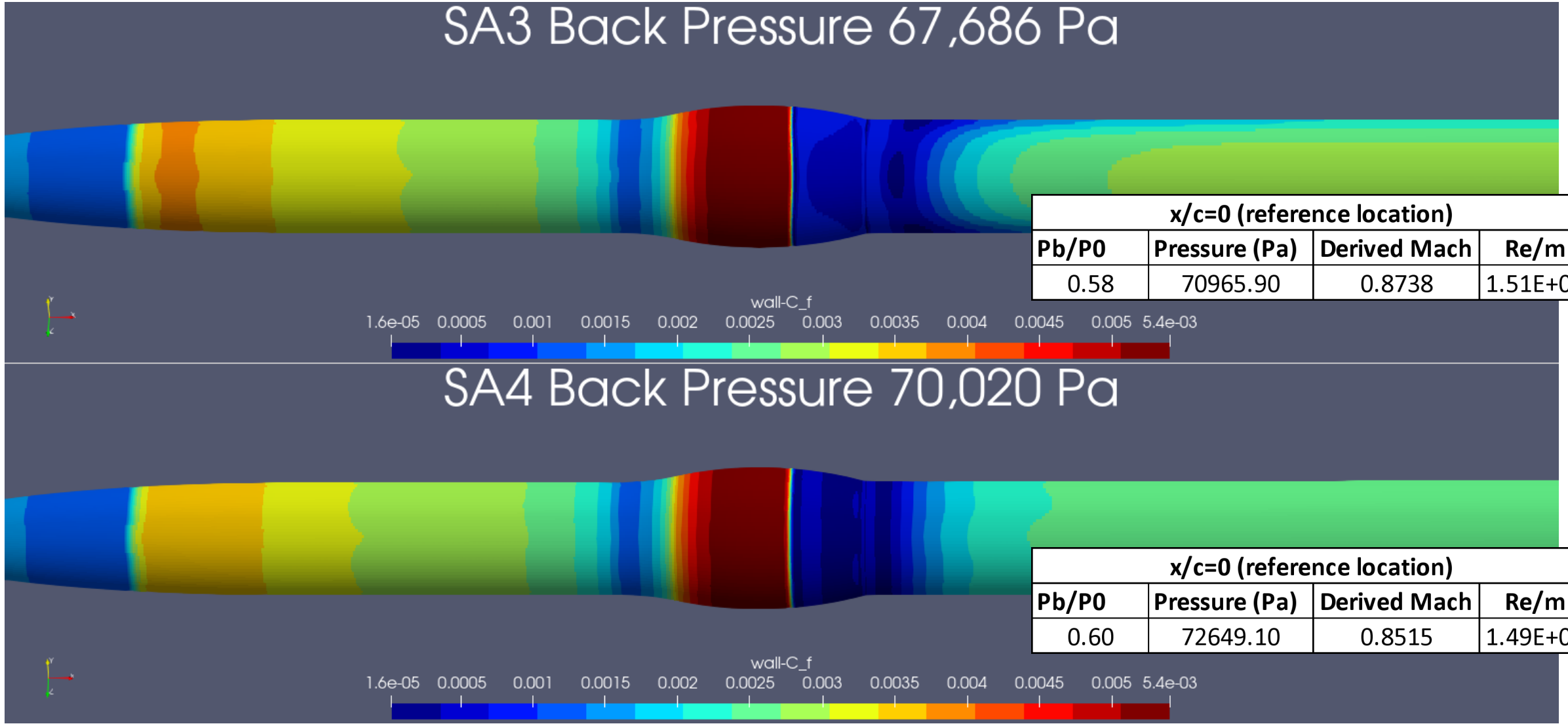


x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.54	68817.19	0.9024	1.53E+07



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.56	69706.73	0.8906	1.52E+07

90 degree quadrants, reflected



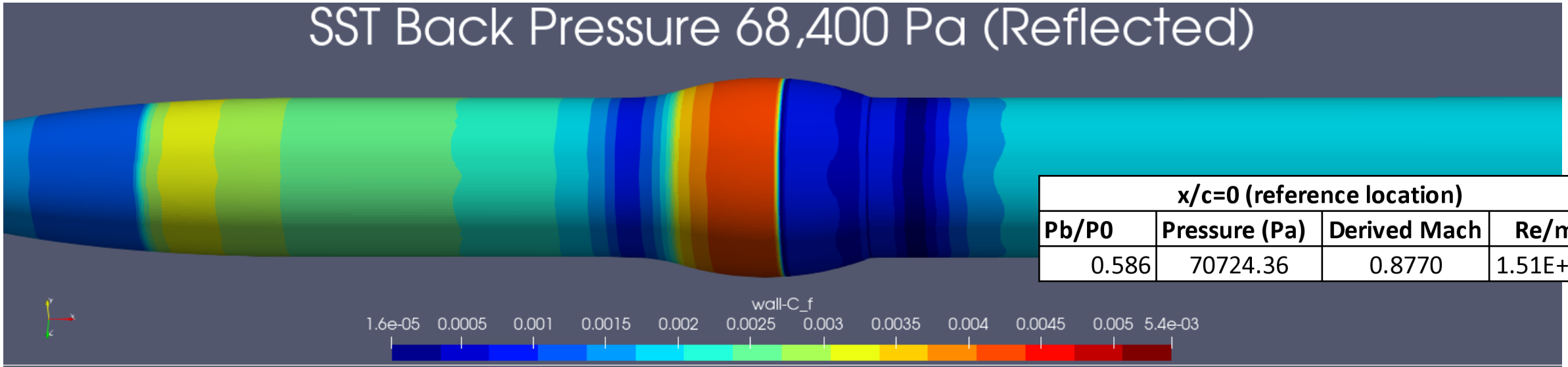
x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.58	70965.90	0.8738	1.51E+07

x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.60	72649.10	0.8515	1.49E+07

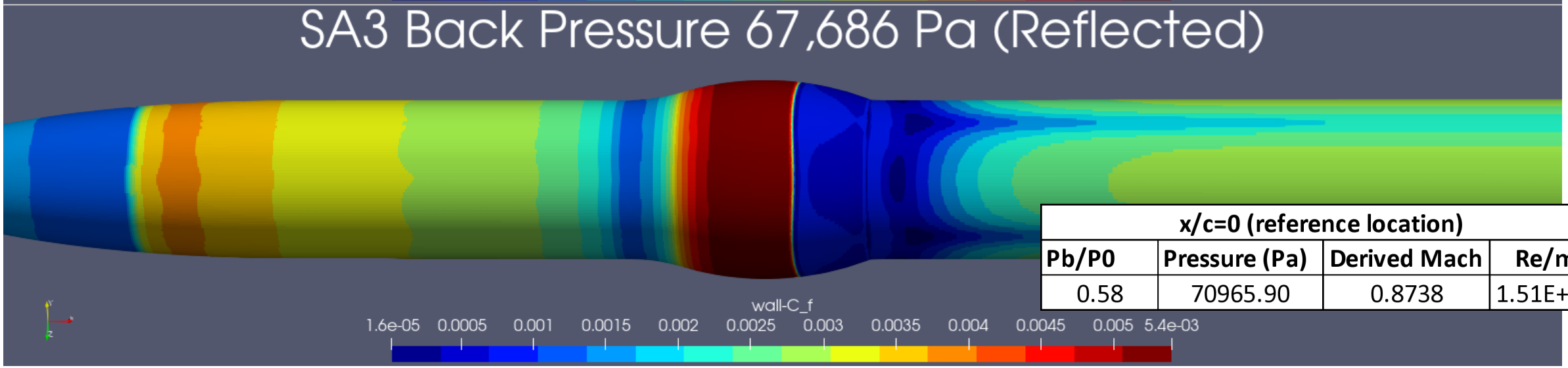
Model-in-tunnel grids
SA and SST with predictions ~Mach 0.875 at x/c=0

						x/c=0	x/c=0			
Case Name	**Turbulence Model**	**P0 (Pa)**	**T0 (K)**	**Pb/P0**	**Pb (Pa)**	**pressure**	**derived Mach**	**T**	**mu**	**Re/m**
SA3	Spalart-Allmaras	116700	318	0.58	67686	70965.90	0.874	275.871	1.73E-05	1.5072E+07
SST1	SST	116700	318	0.5861	68400	70724.36	0.877	275.603	1.73E-05	1.5094E+07

90 degree grids, reflected



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.586	70724.36	0.8770	1.51E+07



x/c=0 (reference location)			
Pb/P0	**Pressure (Pa)**	**Derived Mach**	**Re/m**
0.58	70965.90	0.8738	1.51E+07

Sparc ATH: More SA Sims
Tunnel grid
90° grid
Reynolds Number Studies

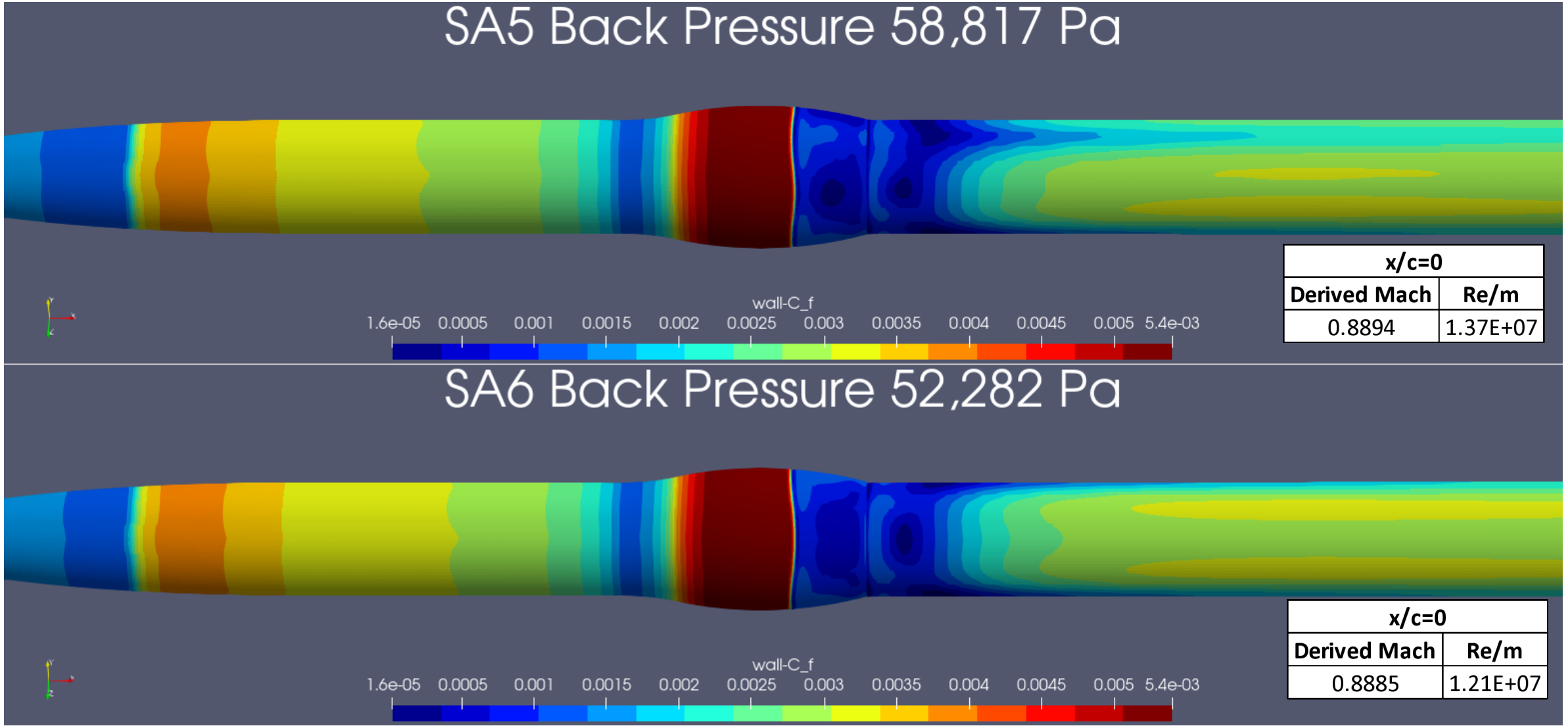
Reynolds Number Calculated using Reference Conditions Derived from Pressure at x/c=0

						x/c=0	x/c=0		Percent
Turbulence Model	**Case Name**	**P0 (Pa)**	**T0 (K)**	**Pb/P0**	**Pb (Pa)**	**pressure**	**derived Mach**	**Re/m**	**Change Re/m**
Spalart-Allmaras	SA5	105030	318	0.56	58817	62816	0.889	13661740	8.92%
Spalart-Allmaras	SA6	93360	318	0.56	52282	55888	0.889	12139160	19.07%
Spalart-Allmaras	SA7	81690	318	0.56	45746	48922	0.888	10619945	29.20%
Spalart-Allmaras	SA8	128370	318	0.56	71887	76681	0.891	16706143	-11.37%

		Reference Values (x/c=0) SI Units:				
Turbulence Model	**Case Name**	**T**	**mu**	**U**	**rho**	**q**
Spalart-Allmaras	SA5	274.56	1.7235E-05	295.43	0.79702	34781
Spalart-Allmaras	SA6	274.64	1.7239E-05	295.18	0.70893	30886
Spalart-Allmaras	SA7	274.67	1.7240E-05	295.07	0.62049	27013
Spalart-Allmaras	SA8	274.47	1.7230E-05	295.76	0.97328	42567

Previous slides showed results with a Reynolds number 1.5e7 per meter
These four SA solutions result in Reynolds number variation of about -11% to 29%
Each calculated value of C_f, for SA5 through SA8, has a unique **dynamic pressure** calculated after extracting pressure at x/c=0

90 degree grids



90 degree grids