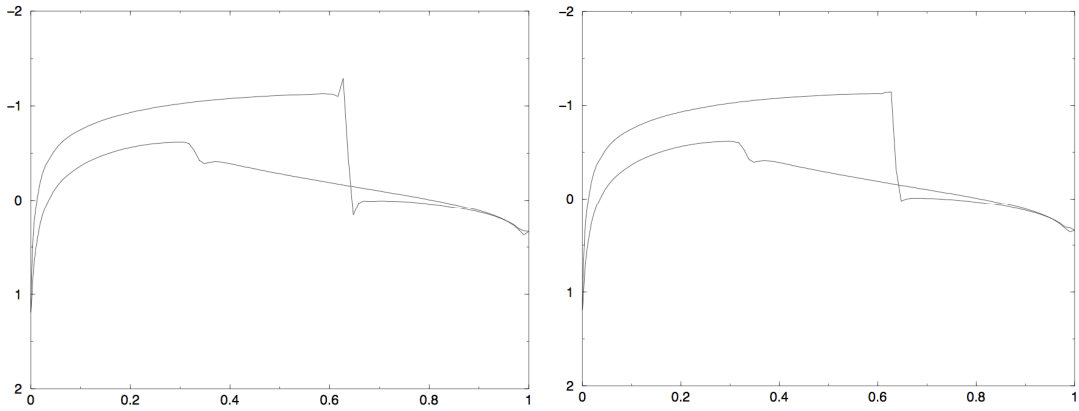
Discussion of Flux Limiters

While the plots that can be viewed through the Euler Solver Emulator interface do not use flux limiters, and as such give overshoots and undershoots on the Cp plots near a shock, a brief discussion of flux limiters and their effects seemed appropriate.

Effectively, a flux limiter does exactly what it would purport to do: it limits massive changes in gradients between cells, which is especially useful at discontinuities (such as shocks). By simply limiting the gradient applied to the second order extrapolation (and thusly limiting the flux between control volumes), a smoother Cp plot can be achieved. Figures 1 and 2 show a Cp plot at Mach 0.8, angle of attack 1.25° without and with a limiter, respectively. Figure 3 shows the two plots superimposed to accentuate the smoothing effect a limiter has on a transonic shock.



Figures 1 and 2: Cp Plot on NACA 0012 without flux limiters and with flux limiters, respectively. Note that the top of the airfoil is the uppermost plot, and the y-axis has been inverted based on convention. There is a strong shock atop the airfoil and a weak shock developing on the bottom of the airfoil.

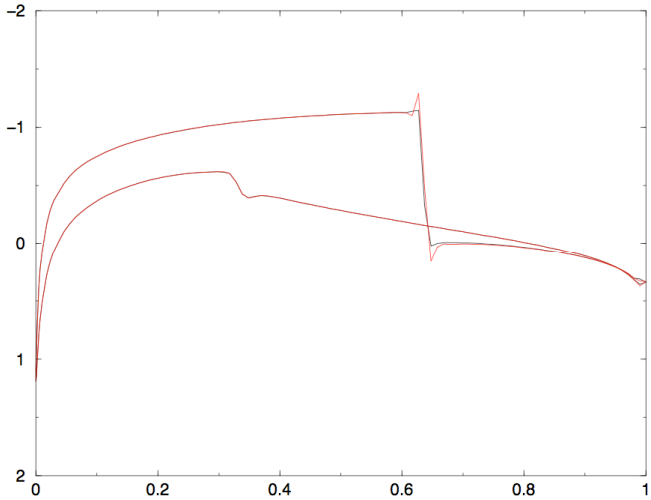


Figure 3: Superimposed Figures 1 and 2 to help visualize the significant smoothing effect of a flux limiter. Note that the top of the airfoil is the uppermost plot, and the y-axis has been inverted based on convention. There is a strong shock atop the airfoil and a weak shock developing on the bottom of the airfoil.

The drawback to using flux limiters is that it causes convergence to stall out (Figure 4 shows the RMS error without and with a limiter, respectively), and thus it seemed imprudent to use this technique in generating such a massive array of cases. However, for someone who is used to seeing the experimental Cp plot on a wing, it is instructive to understand where the overshoots and undershoots come from and that they must be ignored in determining the actual physics occurring on the wing.

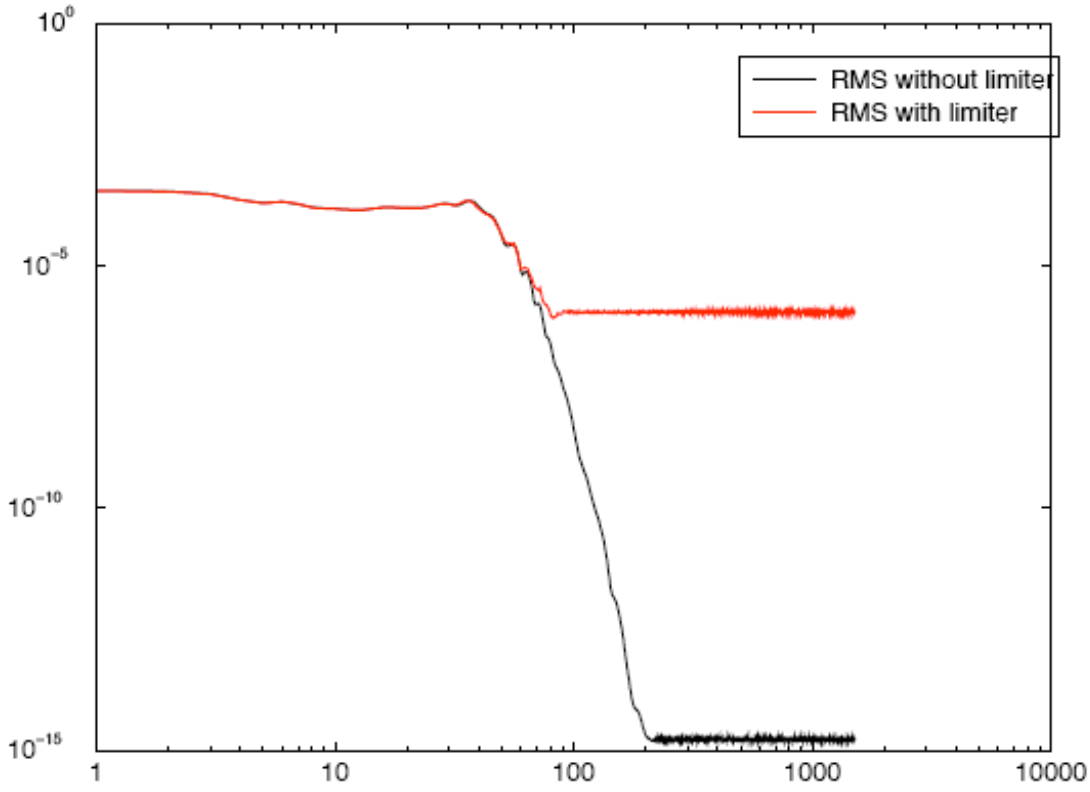


Figure 4: RMS Error for an identical solver run (CFL=200, PTITER=100, ITERATIONS = 1500, ORDER = 2, MACH = 0.8, ALPHA = 1.25) without and with flux limiters.

While the goal of this short piece is not to discuss this concept in full detail, the flux limiting method implemented was the "Minmod" limiter of Timothy Barth and Dennis Jespersen (NASA Ames) detailed in their paper "The Design and Application of Upwind Schemes on Unstructured Meshes", published in the Proceedings of the 27th Aerospace Sciences Meeting (AIAA-89-0366).