Rotational Mixing due to Meridional Circulation

If a star is rotating, meridional circulation ensues, driven by latitudinal temperature gradients along lines of longitude. Such temperature gradients arise when $\nabla F_{rad} \neq 0$ on equipotential surfaces, and this occurs when a star is rotating and $\Omega \neq 0$. While the theory of such mixing is not simple, a back-of-the-envelope understanding is straightforward. One finds that the characteristic mixing timescale is:

$$t_{mix} \sim 0.45 \left(\frac{GM^2}{RL}\right)\left(\frac{GM}{\Omega^2 R^3}\right) , \tag{1}$$

where the first term is the Kelvin-Helmholtz time and the second term is the square of the ratio of the surface Keplerian frequency to the actual frequency. The closer the rotational frequency is to the Keplerian frequency, the shorter is t_{mix} and the more important is meridional mixing. Therefore, one compares the stellar evolutionary time with t_{mix} to determine whether meridional circulation is relevant. It turns out that it is not important for solar-mass stars, but since early-type stars are more rapidly rotating, it can be important for O, B, and, sometimes, for A type stars. Hence, meridional mixing might effect the evolution of massive stars and would somehow need to be included in simulations of their evolution.