Turbulence radiation interactions

in channel flows with various optical depths

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Radiative modifications of turbulent heat transfer

- **Indirect:** No need for modeling
- **Direct:** Reduction of temperature fluctuations which cause an additional dissipation; Need modeling

What happens in a radiative flow? (JFM)
Emission term reduces θ' proportional to $\theta', \overline{\theta}$
Absorption term increases θ' proportional to $\theta', \overline{\theta}, \kappa$ and temperature length scale (structure optical thickness)
Consequence $\rightarrow$ Pr_t increases with τ until a maximum, and then decreases. Difficult to model.
This since $\overline{Q_r'\theta'} = 0$ for both $\tau = 0$ and $\tau \rightarrow \infty$ but for two different reasons.

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temperature variance equation

Better to model the temperature variance equation

$$0 = \underbrace{-2\overline{v'\theta'}\frac{\partial\overline{\theta}}{\partial y}}_{\mathcal{P}_\theta} \underbrace{+\frac{\partial}{\partial y}\left(\frac{1}{RePr}\frac{\partial\overline{\theta'^2}}{\partial y} - \overline{v'\theta'^2}\right)}_{\phi_m+\mathcal{T}_\theta} \underbrace{-\frac{2}{RePr}\overline{\left(\frac{\partial\theta'}{\partial x_j}\right)^2}}_{\epsilon_m} \underbrace{-\frac{2}{RePrPl}\overline{Q_r'\theta'}}_{\mathcal{R}} \tag{1}$$

Where $\overline{Q_r'\theta'} \approx \overline{\kappa}_P(\overline{E_m'\theta'} - \overline{G'\theta'})$

Model:

$$E_m' = f_1(\overline{\theta})\theta' \rightarrow \overline{E_m'\theta'} = f_1(\overline{\theta})\overline{\theta'^2} \tag{2}$$

$$G' = f_2(\overline{\kappa}_P)f_1(\overline{\theta})\theta' \rightarrow \overline{G'\theta'} = f_2(\overline{\kappa}_P)f_1(\overline{\theta})\overline{\theta'^2} \tag{3}$$

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where from the expansion of E'_m and linearization:

$$f_1(\overline{\theta}) = \frac{1}{RePrPl}\left(\frac{16}{T_0^4}\overline{\theta}^3 + \frac{48}{T_0^3}\overline{\theta}^2\frac{48}{T_0^2}\overline{\theta} + \frac{16}{T_0}\right) \tag{4}$$

and from consideration on $G(\kappa)$:

$$f_2(\overline{\kappa}_P) = \frac{\overline{\kappa}_P}{c_{r2}} atan\left(\frac{c_{r2}}{\overline{\kappa}_P}\right) \tag{5}$$

In addition, direct modification of temperature time scales leads to:

$$\alpha_t = C_\lambda f_\lambda k\sqrt{\frac{k}{\epsilon}\frac{\overline{\theta'^2}}{\epsilon_\theta + c_{r1}\overline{Q'_r\theta'}}} \tag{6}$$

Only two constants to define:

$$c_{r1} = 0.5 \quad c_{r2} = 7.0 \text{ probably representation of temperature lenght scales} \tag{7}$$