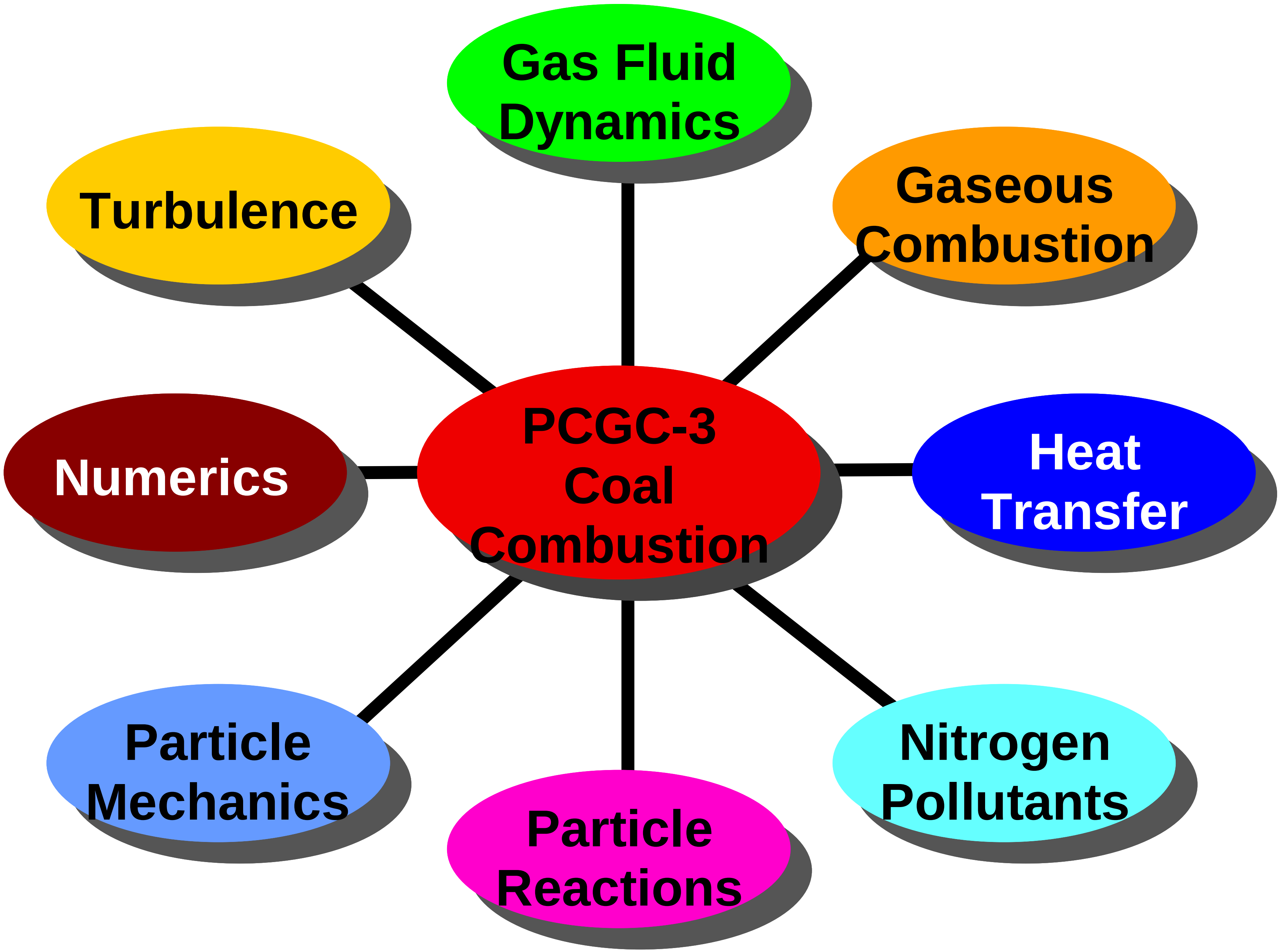
CFD with Combustion

using Fluent


Gas Fluid Dynamics
Turbulence
Gaseous Combustion
Numerics
PCGC-3 Coal Combustion
Heat Transfer
Particle Mechanics
Particle Reactions
Nitrogen Pollutants

General Procedure

- Pick geometry
- Pick variables
  - Turbulent vs laminar
  - Gaseous vs particle-laden
  - Adiabatic?
  - Reacting?
  - Steady-state?
  - Radiation?
- Set up grid system to solve basic equations
  - Cartesian, radial, or spherical?
  - Staggered vs collocated grid
  - "Stair-step" boundary vs. more complicated gridding
    - unstructured mesh, body-fitted coordinates, etc.
  - Finite difference, finite volume, finite element

Goal: Solve all conservation equations for continuum phase as painlessly as possible with one algorithm

$$\frac{\partial(\bar{\rho}\tilde{u}\phi)}{\partial x}+\frac{\partial(\bar{\rho}\tilde{v}\phi)}{\partial y}+\frac{\partial(\bar{\rho}\tilde{w}\phi)}{\partial z}-\frac{\partial}{\partial x}\left(\Gamma_\phi\frac{\partial\phi}{\partial x}\right)-\frac{\partial}{\partial y}\left(\Gamma_\phi\frac{\partial\phi}{\partial y}\right)-\frac{\partial}{\partial z}\left(\Gamma_\phi\frac{\partial\phi}{\partial z}\right)=S_\phi$$

Equation	ϕ	Γ_ϕ	S_ϕ
Continuity	1	0	S_p^m
X Momentum	$\tilde{u}$	μ_e	$-\frac{\partial\bar{p}}{\partial x}+\frac{\partial}{\partial x}\left(\mu_e\frac{\partial\tilde{u}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_e\frac{\partial\tilde{v}}{\partial x}\right)+\frac{\partial}{\partial z}\left(\mu_e\frac{\partial\tilde{w}}{\partial x}\right)+\bar{\rho}g_x-\frac{2}{3}\bar{\rho}\tilde{k}+S_p^u+\tilde{u}S_p^m$
Y Momentum	$\tilde{v}$	μ_e	$-\frac{\partial\bar{p}}{\partial y}+\frac{\partial}{\partial x}\left(\mu_e\frac{\partial\tilde{u}}{\partial y}\right)+\frac{\partial}{\partial y}\left(\mu_e\frac{\partial\tilde{v}}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_e\frac{\partial\tilde{w}}{\partial y}\right)+\bar{\rho}g_y-\frac{2}{3}\bar{\rho}\tilde{k}+S_p^v+\tilde{v}S_p^m$
Z Momentum	$\tilde{w}$	μ_e	$-\frac{\partial\bar{p}}{\partial z}+\frac{\partial}{\partial x}\left(\mu_e\frac{\partial\tilde{u}}{\partial z}\right)+\frac{\partial}{\partial y}\left(\mu_e\frac{\partial\tilde{v}}{\partial z}\right)+\frac{\partial}{\partial z}\left(\mu_e\frac{\partial\tilde{w}}{\partial z}\right)+\bar{\rho}g_z-\frac{2}{3}\bar{\rho}\tilde{k}+S_p^w+\tilde{w}S_p^m$
Turbulent Energy	$\tilde{k}$	$\frac{\mu_e}{\sigma_k}$	$G-\bar{\rho}\tilde{\varepsilon}$
Dissipation Rate	$\tilde{\varepsilon}$	$\frac{\mu_e}{\sigma_\varepsilon}$	$\left(\frac{\tilde{\varepsilon}}{\tilde{k}}\right)(c_1G-c_2\bar{\rho}\tilde{\varepsilon})$
Mixture Fraction	$\tilde{f}$	$\frac{\mu_e}{\sigma_f}$	S_p^f
Mixture Fraction Variance	$\tilde{g}$	$\frac{\mu_e}{\sigma_g}$	$\frac{c_{g1}\mu_e}{\sigma_g}\left[\left(\frac{\partial\tilde{f}}{\partial x}\right)^2+\left(\frac{\partial\tilde{f}}{\partial y}\right)^2+\left(\frac{\partial\tilde{f}}{\partial z}\right)^2\right]-c_{g2}\bar{\rho}\tilde{g}\tilde{\varepsilon}/\tilde{k}$
Coal Gas Mixture Fraction	$\tilde{\eta}$	$\frac{\mu_e}{\sigma_\eta}$	S_p^η
Coal Gas Mixture Fraction Variance	$\tilde{g}_\eta$	$\frac{\mu_e}{\sigma_{g\eta}}$	$c_{g1}\frac{\mu_e}{\sigma_{g\eta}}\left[\left(\frac{\partial\tilde{\eta}}{\partial x}\right)^2+\left(\frac{\partial\tilde{\eta}}{\partial y}\right)^2+\left(\frac{\partial\tilde{\eta}}{\partial z}\right)^2\right]-c_{g2}\bar{\rho}\tilde{g}_\eta\frac{\tilde{\varepsilon}}{\tilde{k}}$
Enthalpy	$\tilde{h}$	$\frac{\mu_e}{\sigma_h}$	$q'_{rg}+\left(\tilde{u}\frac{\partial\bar{p}}{\partial x}+\tilde{v}\frac{\partial\bar{p}}{\partial y}+\tilde{w}\frac{\partial\bar{p}}{\partial z}\right)+S_p^h+\tilde{h}S_p^m$

where:

$$G=\mu_e\left\{2\left[\left(\frac{\partial\tilde{u}}{\partial x}\right)^2+\left(\frac{\partial\tilde{v}}{\partial y}\right)^2+\left(\frac{\partial\tilde{w}}{\partial z}\right)^2\right]+\left(\frac{\partial\tilde{u}}{\partial y}+\frac{\partial\tilde{v}}{\partial x}\right)^2+\left(\frac{\partial\tilde{u}}{\partial z}+\frac{\partial\tilde{w}}{\partial x}\right)^2+\left(\frac{\partial\tilde{v}}{\partial z}+\frac{\partial\tilde{w}}{\partial y}\right)^2\right\}$$