A NEW FORMULATION OF f_k FOR THE PANS MODEL***

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DES vs. PANS

DES

$$C^k = P^k + D^k - \psi\varepsilon$$

$$C^\varepsilon = C_{\varepsilon 1}\frac{\varepsilon}{k}P^k + D^\varepsilon - C_{\varepsilon 2}\frac{\varepsilon^2}{k}$$

$$\psi = \max\left(1, \frac{k^{3/2}/\varepsilon}{C_{DES}\Delta_{max}}\right)$$

PANS

$$C^k = P^k + D^k - \varepsilon$$

$$C^\varepsilon = C_{\varepsilon 1}\frac{\varepsilon}{k}P^k + D^\varepsilon - C^*_{\varepsilon 2}\frac{\varepsilon^2}{k}$$

$$C^*_{\varepsilon 2} = C_{\varepsilon 1} + \frac{f_k}{f_\varepsilon}(C_{\varepsilon 2} - C_{\varepsilon 1})$$

$$f_{k,obs} = \frac{k_{model}}{k_{model} + k_{res}}, \quad f_\varepsilon \simeq 1$$

DES vs. PANS

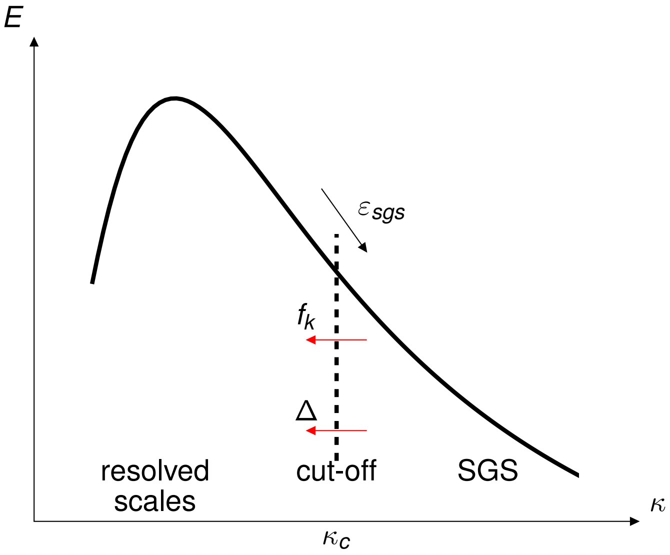

FIGURE: Spectrum of velocity.

DES AND PANS I

$$C^k - D^k \simeq C^\varepsilon - D^\varepsilon \simeq 0, \quad \gamma = \frac{P^k}{Sk}, \quad S = (2\bar{s}_{ij}\bar{s}_{ij})^{1/2}, \quad T = \frac{k}{\varepsilon}$$

$$\psi = \max\left(1, \frac{k^{3/2}/\varepsilon}{C_{DES}\Delta_{max}}\right), C^*_{\varepsilon 2} = C_{\varepsilon 1} + \frac{f_k}{f_\varepsilon}(C_{\varepsilon 2} - C_{\varepsilon 1})$$

- PANS

$$TP^\varepsilon - P^k = TC^*_{\varepsilon 2}\frac{\varepsilon^2}{k} - \varepsilon \Rightarrow$$

$$\gamma(C_{\varepsilon 1} - 1)Sk = (C^*_{\varepsilon 2} - 1)\varepsilon$$

Differentiation yields:

$$\frac{\delta\gamma}{\gamma} + \frac{\delta S}{S} + \frac{\delta k}{k} = \frac{\delta C^*_{\varepsilon 2}\varepsilon}{(C_{\varepsilon 1} - 1)\gamma Sk}$$

$$= \frac{\delta C^*_{\varepsilon 2}}{C^*_{\varepsilon 2} - 1}$$

- DES

$$TP^\varepsilon - P^k = TC_{\varepsilon 2}\frac{\varepsilon^2}{k} - \psi\varepsilon \Rightarrow$$

$$\gamma(C_{\varepsilon 1} - 1)Sk = (C_{\varepsilon 2} - \psi)\varepsilon$$

Differentiation yields:

$$\frac{\delta\gamma}{\gamma} + \frac{\delta S}{S} + \frac{\delta k}{k} = -\frac{\delta\psi\varepsilon}{(C_{\varepsilon 1} - 1)Sk\gamma}$$

$$= -\frac{\delta\psi}{C_{\varepsilon 2} - \psi}$$

DES and PANS II

- $$\frac{dC^*_{\varepsilon 2}}{C^*_{\varepsilon 2}-1}=\frac{-d\psi}{C_{\varepsilon 2}-\psi}$$

Integrate from RANS ($C_{\varepsilon 2}$ and $\psi = 1$) to LES ($C^*_{\varepsilon 2}$ and ψ) conditions

$$\int_{C_{\varepsilon 2}}^{C^*_{\varepsilon 2}}\frac{dC^*_{\varepsilon 2}}{C^*_{\varepsilon 2}-1}=\int_1^{\psi}-\frac{d\psi}{C_{\varepsilon 2}-\psi}\Rightarrow$$
$$\ln\left(\frac{C^*_{\varepsilon 2}-1}{C_{\varepsilon 2}-1}\right)=\ln\left(\frac{C_{\varepsilon 2}-\psi}{C_{\varepsilon 2}-1}\right)$$

- By using the expression for $C^*_{\varepsilon 2}$ with requirement $0 < f_k \le 1$ we get

$$f_k=\max\left[0,\min\left(1,1-\frac{\psi-1}{C_{\varepsilon 2}-C_{\varepsilon 1}}\right)\right],\quad \psi=\max\left(1,\frac{k^{3/2}/\varepsilon}{C_{DES}\Delta_{max}}\right),$$

CONCLUSIONS

- We have validated the new PANS in channel flow, hill flow and hump flow
- It gives much better results than the old PANS model
- It gives very similar results to the DES model
- Advantage of the new PANS model vs. the DES model
  - The PANS model is based on a rigorous derivation whereas DES is based on an ad-hoc modification of RANS models
- More recent work: a new model – IDD-PANS – which is a PANS model that mimics the IDDES model [2]

References I

[1] L. Davidson and C. Friess.
A new formulation of f_k for the PANS model.
Journal of Turbulence, pages 1–15, 2019.

[2] C. Friess and L. Davidson.
A formulation of PANS able to mimic IDDES (submitted).
International Journal of Heat and Fluid Flow, 2020.