

# Subgrid turbulence model implemented in xAMC

BERND NOACK

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## 1 POD Model

Starting point: 3-mode mean-field model of the cylinder wake (Noack+ 2003 JFM).

## 2 Subgrid turbulence model

The dynamic turbulence model introduces 2 new states:  $a_4$  which corrects the eddy viscosities determined from an energy flow analysis and  $a_5$  which monitors the ratio of the amplitude of the Galerkin model and the correct one.

$$\dot{a}_1 = f_1 + \nu_{T,1} l_{11}^\nu a_1 a_4 \quad (1)$$

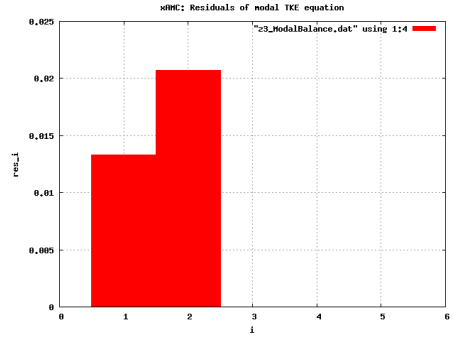
$$\dot{a}_2 = f_2 + \nu_{T,2} l_{22}^\nu a_2 a_4 \quad (2)$$

$$\dot{a}_3 = f_3 + \nu_{T,3} l_{33}^\nu a_3 a_4 \quad (3)$$

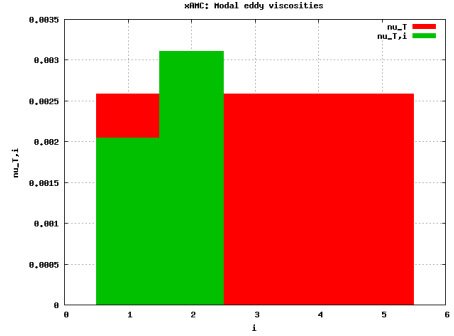
$$\dot{a}_4 = 0.1(a_5 - 1) \quad (4)$$

$$a_5 = \frac{\sqrt{a_1^2 + a_2^2}}{\sqrt{\lambda_1 + \lambda_2}} \quad (5)$$

$$f_i = c_i + \sum_{j=1}^3 l_{ij} a_j + \sum_{j,k=1}^3 q_{ijk} a_j a_k \quad (6)$$



- Execute `x3_EddyViscosity.sh` to determine the global / model eddy viscosities from consistent with the energy flow residuals (see below).



- Execute `x3_TurbulenceModel.sh` and choose one of currently 10 options.

## 3 Implementation in xAMC

- Execute `x3_ModalBalance.sh` to determine the modal energy flow residuals (see below)

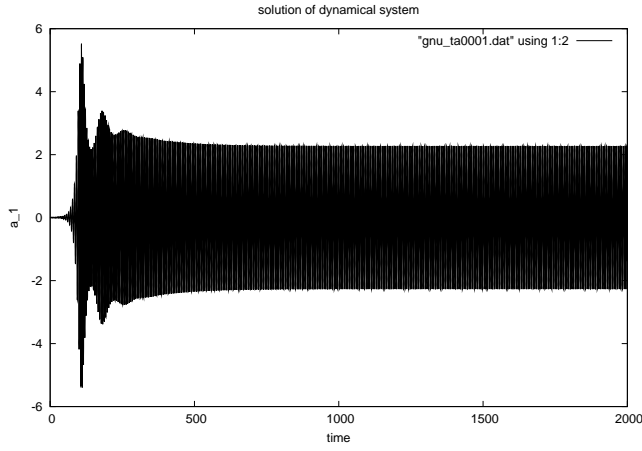


Figure 1: Evolution of mode amplitude 1.

## 4 Sample trajectory

See Figures 1–5. Note how the turbulence model accelerates the transient towards the final fluctuation level:  $a_4$  becomes negative.

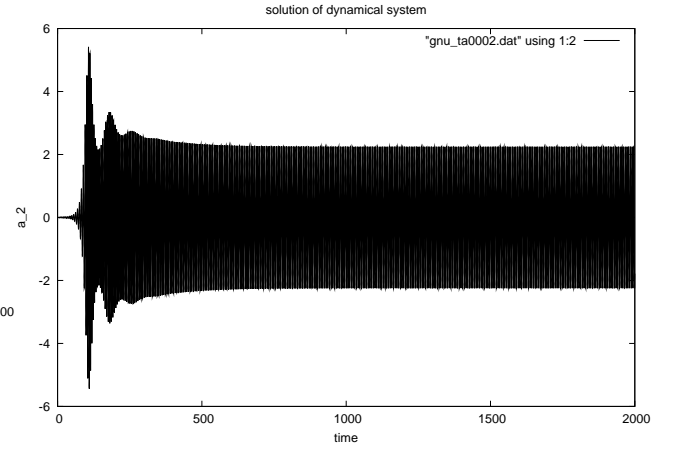


Figure 2: Evolution of mode amplitude 2.

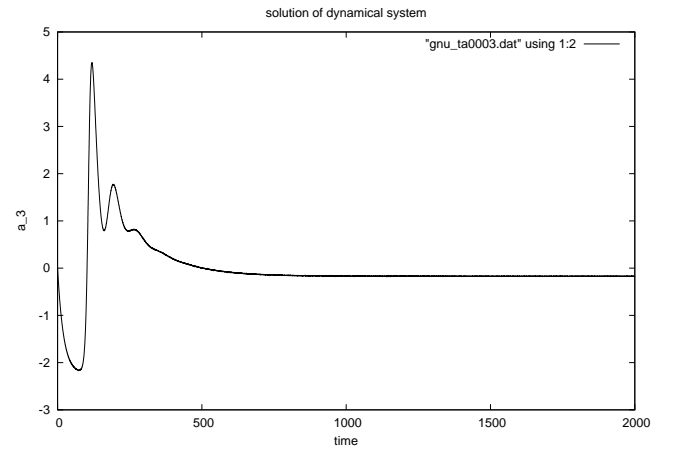


Figure 3: Evolution of mode amplitude 3.

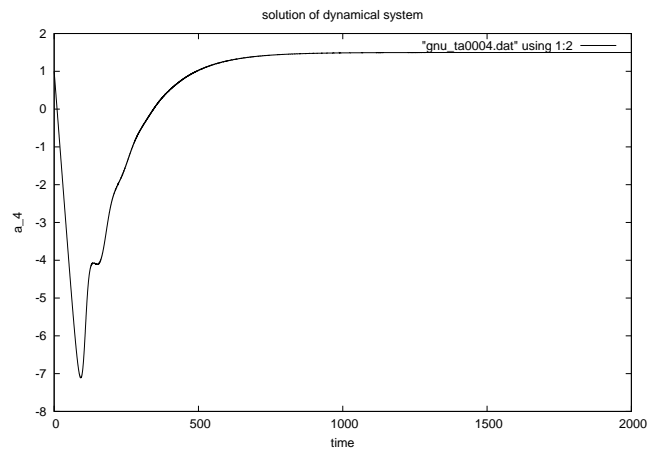


Figure 4: Evolution of mode amplitude 4.

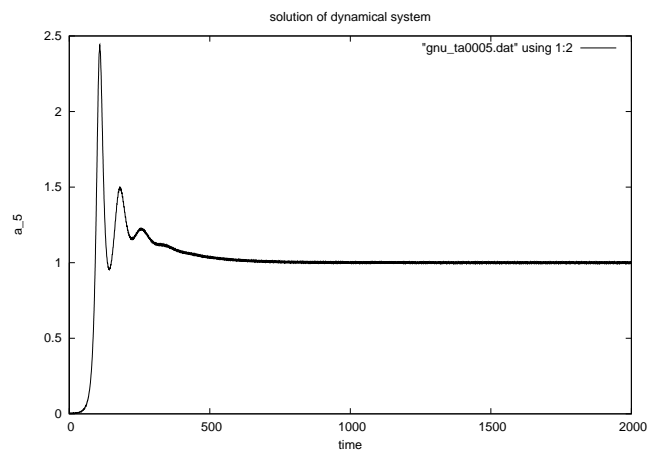


Figure 5: Evolution of mode amplitude 5.