LES of Turbulent Flows: Project #2

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Overview

1. Overview of Project #2

Class project description

- The class project will be to conduct your own *a priori* study of SGS models
- The minimum requirement will be to examine two SGS models
- You will submit the assignment in the form of a short report (4-5 pages max including references and figures) and a short (15 minutes including questions) presentation

Class project description

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Class project description

- Two datasets will be made available to the class (through email)
- One is wind tunnel PIV data over a rough wall and the other is from DNS of decaying isotropic turbulence
- You do not have to use this data!

Class project description

- One option: You are free to use a dataset from the Johns Hopkins Turbulence Database (`http://turbulence.pha.jhu.edu`)
- They have channel flow, forced isotropic turbulence, forced magnetohydrodynamic (MHD) turbulence, and buoyancy-driven turbulence
- I'll give a brief demo of this now
- I can help if you run into issues here

Class project description

- If you have your own dataset that you would like to use instead you are free to do so
- Please check with me before getting into your analysis. This will ensure your data is proper for an *a priori* study and that you have a sound plan for data reduction
- Also contact me if you wish to use other data but are unsure of a source
- Don't feel confined to the limited description given here and contact me if you want to do something based on your research topic but are unsure of how to proceed

Class project description

The report should contain the following components (or equivalent)

- A brief introduction explaining the general idea of LES and the goal of your study. You don't have to show all the LES equations but you must include at least a description of the LES methodology, i.e., scale separation using a low-pass filter and what the closure problem is (i.e., the SGS stress term that must be modeled)

Class project description

The report should contain the following components (or equivalent)

- A description of the two models you have chosen to evaluate including at least their general basis, any key assumptions they make and any interesting model coefficients etc. that they use

Class project description

The report should contain the following components (or equivalent)

- A short description of the data set you are using. This is especially important if you aren't using the provided data. This doesn't have to be long.
- If you are using the provided data you still need to give a description but it can be short and focus on the relevant details.

Class project description

The report should contain the following components (or equivalent)

- Citing a reference does not completely get you off the hook from describing the data but your data description can be as short as a few sentences.
- The requirement is that a reader doesn't have to check the reference just to know what type of flow and what technique the data was generated/collected from/with

Class project description

The report should contain the following components (or equivalent)

- Key results (statistical) from your study
- A summary of the major finding from your study. It is fine if these are similar results to what has been found previously or are not completely conclusive. Still, your summary should demonstrate knowledge of the models you tested and their strengths and limitations
- Any references you used in your report

Class project description

- Your report should give as a minimum the following statistics.
- Note: you are encouraged to calculate other relevant SGS statistics depending on your application/interests and the models that you choose to study.
- Feel free to talk to me about this as you go. What is listed here are minimum requirements

Class project description

Your report should give as a minimum the following statistics

- Average SGS dissipation rate $\langle \Pi^{\Delta} \rangle$ calculated from the data and $\langle \Pi^{\Delta,M} \rangle$ calculated from each tested model using the filtered data
- Standard deviation of the locally calculated values of Π^{Δ} and $\Pi^{\Delta,M}$ along with the probability density functions of Π^{Δ}

Class project description

Your report should give as a minimum the following statistics

- Correlation coefficients for as many of the components of the SGS stress tensor as you can calculate from your data. That is calculate

$$\rho\left(\tau_{ij}^{\Delta}, \tau_{ij}^{\Delta,M}\right) = \frac{cov\left(\tau_{ij}^{\Delta}, \tau_{ij}^{\Delta,M}\right)}{\sigma_{\tau_{ij}^{\Delta}}\sigma_{\tau_{ij}^{\Delta,M}}}$$

Class project description

Your report should give as a minimum the following statistics

- Model coefficients for the models you choose to study calculated based on matching the average SGS dissipation rates between the actual data and the model

$$\langle \Pi^{\Delta} \rangle = \langle \Pi^{\Delta,M} \rangle.$$

- You can also calculate local model coefficients but this is not required

Class project description

Procedurally, you will calculate your statistics as follows (specific examples are for the constant coefficient Smagorinsky model)

- After selecting your data (and doing any needed data quality control) you will first need to separate your data into resolved and SGS components by calculating $\tilde{u}_i$ and $\widetilde{u_i u_j}$ where the tilde ($\tilde{}$) is a filter at scale Δ.
- Note, calculating $\widetilde{u_i u_j}$ means filtering the product $u_i u_j$. Use one of the common filters discussed in class (and that you used in homework #2) that is appropriate for the model you are testing

Class project description

Procedurally, you will calculate your statistics as follows (specific examples are for the constant coefficient Smagorinsky model)

- Calculate the exact SGS stress tensor $\tau_{ij}^{\Delta} = \widetilde{u_i u_j} - \tilde{u}_i \tilde{u}_j$
- Calculate the filtered strain rate tensor (or as many components are you can from your data, for incomplete data you may need to make approximations):

$$\tilde{S}_{ij} = \frac{1}{2} \left(\frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial \tilde{u}_j}{\partial x_i} \right)$$

Class project description

Procedurally, you will calculate your statistics as follows (specific examples are for the constant coefficient Smagorinsky model)

- calculate the modeled stress tensor $\tau_{ij}^{\Delta,M}$ from each of your models using the filtered strain rate tensor $\tilde{S}_{ij}$ and, if needed for the model, the filtered velocity $\tilde{u}_i$
- Calculate the exact and modeled SGS dissipation (recall $\langle \Pi^{\Delta} \rangle = -\langle \tau_{ij}^{\Delta} \tilde{S}_{ij} \rangle$)
- Calculate the correlation coefficients $\rho\left(\tau_{ij}^{\Delta}, \tau_{ij}^{\Delta,M}\right)$

Class project description

Procedurally, you will calculate your statistics as follows (specific examples are for the constant coefficient Smagorinsky model)

- Calculate any model coefficients based on matching the average modeled and exact SGS dissipation. For example, with the Smagorinsky model:

$$\langle \Pi^{\Delta} \rangle = \langle \Pi^{\Delta,M} \rangle \;\Rightarrow\; C_S = -\frac{\langle \tau_{ij}^{\Delta} \tilde{S}_{ij} \rangle}{\langle 2\Delta^2 |\tilde{S}| \tilde{S}_{ij} \tilde{S}_{ij} \rangle}$$