Turbulence Database from Direct Numerical Simulations

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Background and Motivation

The motion of turbulent flows is **one the unsolved problems of classical physics** and is of both fundamental and practical importance. Turbulent flows exhibits many anomalies that are not well understood and of interest for a large research community. Due to this complexity turbulent flows are **difficult to attack by rigorous analytic theories**. In turbulence unknown statistical quantities emerge for which no governing equation exists.

A solution of turbulent flows can be obtained by numerical methods. **Direct Numerical Simulation (DNS)** solves the governing equations. It does not relay on turbulence models, since all relevant scales are numerically resolved. DNS allows to simulate turbulent flows at sufficiently **high Reynolds numbers** with at the same time high resolution of the fine-scales. For high Reynolds number flows it is customary to solve the Navier-Stokes equation in a periodic box by means of a **pseudo-spectral approach**.

Over the past years DNS of turbulent flows has been conducted at the supercomputer JUQUEEN. The present simulations belong to the **most comprehensive work of its kind** and are unique in the sense that the small scales are resolved with a higher accuracy compared to that reported in literature.

Motivated by the obtained results new questions arise so that a continuously analysis of the data can be possible.
With the development of a data sharing concept of a highly resolved DNS results based on a turbulence database our principal intention is to **simplify the access and further post-processing by different research groups world-wide**.

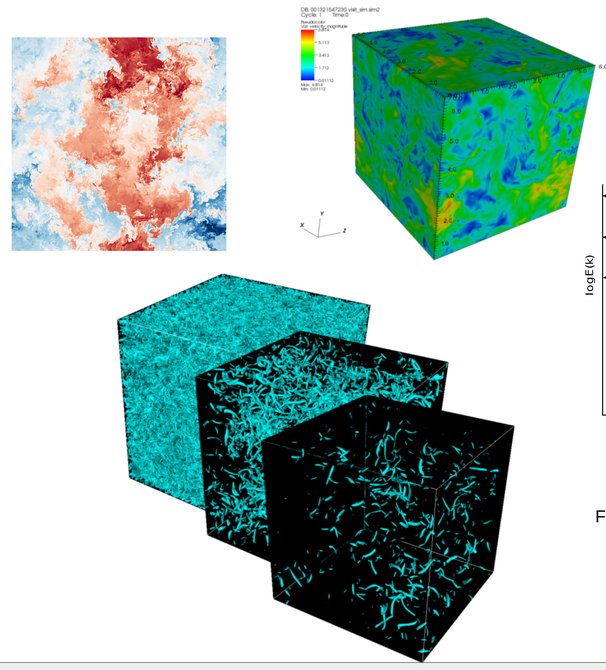
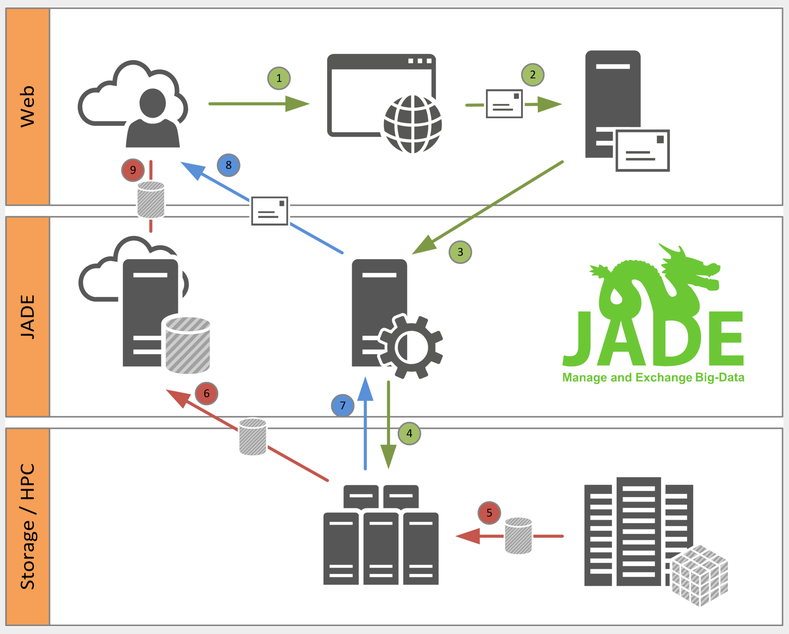


Fig. 1: Energy spectrum

Cloud Data Access for Highly Resolved Turbulence Simulation Data

- **easy to manage**
  => use established standards (Email, HTTP, SSH)
- **easy to add new functionality**
  => decouple web interface and data extraction from request management
  => allow domain experts to manage web interface and data analytics tool on their own
- **easy to adopt to different scenarios**
  => combination of existing infrastructure
  => independent of research domain



- **easy to extend on high loads**
  => multiple web interfaces possible
  => multiple data access server possible
  currently JUDAC, JURECA, JUQUEEN
  => multiple storage server possible
  => independent of storage server location

Outlook

- **on demand big data processing**
  => forward data post-processing requests to supercomputer JURECA

Request Pipeline : User > 1 > Website > 2 > Mail-Server > 3 > Management Server > 4 > Data Access Server
Response Pipeline : Data Access Server > 7 > Management Server > 8 > User
Data Pipeline : Storage > 5 > Data Access Server > 6 > Data Web Server > 9 > User

Request Management

- management of **request pipeline**
- receiving new request **via email**
- **scheduling** requests depending on load on different data access server
- **resource management** (multiple data access server)
- extendible to **different communication protocols**
- **monitoring** pipelines
- written in **Python**

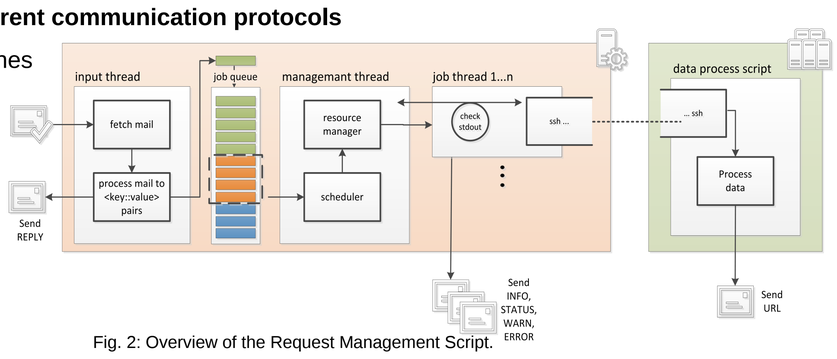


Fig. 2: Overview of the Request Management Script.

Direct Numerical Simulations

- stored in **HDF5 file format**
- N^3 denotes the **number of grid points,** which increases rapidly with the Reynolds number (Re)
- each case contains of **multiple data sets** (M)
- stored components are **velocity field**, **passive scalar** (4 fields required for restart)
- current data base size is **87.2 TiB**

	R0	R1	R2	R3	R4	R5	R6
N^3	512^3	1024^3	1024^3	2048^3	2048^3	4096^3	4096^3
Re_λ	88	119	184	215	331	529	754
file size (GB)	8	64	64	512	512	4096	4096
M	189	62	61	10	10	6	11
data size (TB)	1.5	3.88	3.81	5	5	24	44

Tab. 1: Overview of the conducted DNS.

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