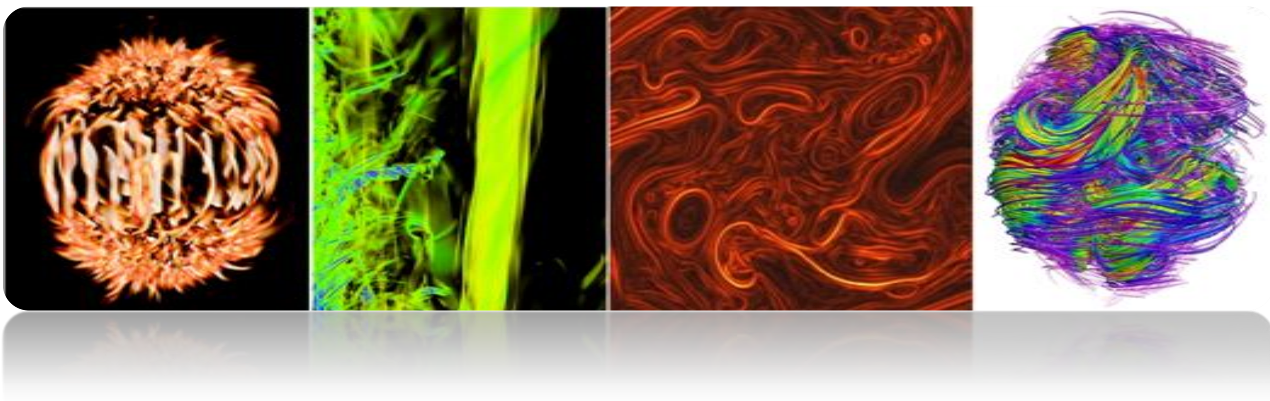

GTP Workshop on Large-Eddy Simulations and MHD Turbulence

May 20 – 23, 2013, NCAR, Boulder, Colorado

Center Green Laboratory 1, Center Auditorium

SCIENTIFIC ORGANIZING COMMITTEE

N. Featherstone (HAO/NCAR and University of Colorado)

M. Miesch (NCAR)

P. Mininni (University of Buenos Aires/NCAR)

A. Petrosyan (Space Res. Inst., Russian Acad. Sci.)

A. Pouquet (NCAR)

J. Toomre (JILA/University of Colorado)

SCHEDULE

Location: Center Green Laboratory 1, Center Auditorium

MONDAY MAY 20

8:20	Bus departs from Best Western Golden Buff to Center Green 1
8:40 - 9:00	Check- in and coffee
9:00 - 9:05	Welcome: Mark Miesch
9:05 - 10:05	Keynote talk: Peter Sullivan "Trends in Large Eddy Simulations of Geophysical Boundary Layers"
10:05 - 10:20	Discussion
10:20 - 10:35	Coffee break
10:35 - 11:35	Keynote talk: Stanislav Boldyrev: "MHD Turbulence: Challenges for SGS"
11:35 - 11:50	Discussion
11:50 - 12:20	Talk W. Matthaeus and J. Herring: “Major Progress in MHF Turbulence: NCAR and Beyond”
12:20 - 1:45	Lunch (not provided)
1:45 - 3:45	**Session 1: SGS Modeling vs. Filtering vs. AMR**, (Leaders M. Miesch & A. Pouquet)
3:45 - 4:00	Coffee break
4:00 - 5:30	Session 1 (cont.)
5:30 - 7:00	Reception – CG1 Lobby
7:05	Bus departs from CG1 back to Golden Buff

TUESDAY MAY 21

8:30	Bus departs from Golden Buff – Coffee
9:00 - 10:30	**Session 2: Anisotropy and Kinetic Effects** (Leaders C. Cambon & F. Jenko)
10:30 - 11:00	Coffee break
11:00 - 12:30	Session 2 (cont.)
12:30 - 2:00	Group Photo and Lunch (not provided)
2:00 - 3:30	**Session 3: Magnetic Reconnection** (Leaders D. Uzdensky & M. Velli)
3:30 - 4:00	Coffee break
4:00 - 5:30	Session 3 (cont.)
5:30 - 6:00	Discussion: Open issues from Sessions 2 and 3
6:05	Bus departs from CG1 to Golden Buff

WEDNESDAY MAY 22

8:30	Bus departs from Golden Buff to CG1 - Coffee
9:00 - 10:30	**Session 4: Helicity** (Leaders A. Brandenburg & W. Matthaeus)
10:30 - 11:00	Coffee break
11:00 - 12:30	Session 4 (cont.)
12:30 - 2:00	Lunch (not provided)
2:00 - 3:30	**Session 5: Geometry and Boundary Conditions** (Leaders E. King & S. Tobias)
3:30 - 4:00	Coffee break
4:00 - 5:30	Session 5 (cont.)
5:30 - 6:00	Discussion: Open issues from Sessions 4 and 5
6:05	Bus departs from CG1 to Golden Buff

THURSDAY MAY 23

8:30	Bus departs from Golden Buff to CG1 - Coffee
9:00 - 10:30	**Session 6: Applications and the MHD-LES Challenge** (Leaders J. Stone & J. Toomre)
10:30 - 11:00	Coffee break
11:00 - 12:30	Session 6 (cont.)
12:30 - 1:00	Conference summary and future directions (Meeting adjourns for all except SOC & Session Leaders)
1:05	Bus departs from CG1 to Golden Buff
1:00 - 2:00	Lunch
2:00 - 5:00	SOC & Session Leaders: Preparation of white paper on progress and future plans
3:30 - 3:45	Coffee break
5:00	Meeting adjourns

Opening Talks

Date: Monday, May 20 (9:00 a.m. – 12:20 p.m.)

Large-Eddy Simulations: State of the Art

Pierre Sagaut

Time: 9:05 a.m. – 10:05 a.m.

Large-eddy simulation approaches for engineering applications will be surveyed, the emphasis being put on the coupling between LES and adaptive grid refinement. The recent trends will be discussed and illustrated. The possible links with MHD turbulence will be discussed

MHD Turbulence: Challenges for SGS

Stanislav Boldyrev

Time: 10:35 a.m. – 11:35 a.m.

Magnetohydrodynamic turbulence is different from hydrodynamic turbulence of a non-magnetized fluid in fundamental ways. In particular, it becomes progressively more anisotropic and exhibits a tendency to establish local imbalance and self-organization at small scales. We review what is currently known about the physics of strong incompressible MHD turbulence, and discuss the requirements necessary for numerical simulations to reproduce correctly the turbulent cascade.

Major Progress in MHD Turbulence: NCAR and Beyond

W. Matthaeus and J. Herring

Time: 11:50 a.m. – 12:20 p.m.

I. SGS Modeling vs Filtering vs AMR

Date: *Monday, May 20 (1:45 p.m. – 5:30 p.m.)*

Session Leaders: M. Miesch (NCAR, USA miesch@ucar.edu)
P. Sagaut (UPMC, France pierre.sagaut@upmc.fr)

Summary

In this session we will delve into the foundations of LES, reviewing and assessing current strategies for hydrodynamical (HD) and MHD flows. In particular, what is the most reliable and efficient way to capture the dynamics of a turbulent system by only explicitly following a reduced (generally drastically reduced) set of modes or coherent flow structures? The viability of LES rests on the central premise that large scales dominate the turbulent transport and the energy budget so a numerical simulation that captures those scales will provide a realistic depiction of the flow for all practical purposes. Are there classes of flows, particularly for magnetized fluids, where this central premise breaks down? For those flows in which the central premise is justified, is it sufficient to merely filter or otherwise dissipate SGS scales or is it necessary to model the detailed dynamical nature of SGS flows through, for example, self-similar turbulent cascades, coherent structures, or, in the case of MHD, turbulent magnetic reconnection? Is the central premise only justified when SGS flows are dissipative in nature or can upscale transfer (as of of energy and helicity) be reliably and robustly represented in an appropriate SGS model? We will raise these questions here and revisit many of them again in later sessions.

Other topics of discussion include:

• First and foremost, where is the dirty laundry? Where do current LES/SGS strategies for both HD and MHD fail? What are their main weaknesses, both in terms of theoretical justification and practical performance?

• Where do current LES/SGS closures work best? Are some strategies better than others for certain classes of flows (for example, flows driven by an MHD instability such as MRI verses quasi-kinematic flows such as convective dynamos)?

• Can upscale spectral transfer be handled with any fidelity in a self-similar fashion (magnetic helicity or KE in quasi-2D flows - made so by rotation or a strong guide field) or is the only hope for SGS is to resolve all inhomogeneous (& helical) scales? If only dissipative SGS works reliably, then is there any significant difference between filtering/Implicit LES & classical explicit LES (with SGS modeling)?

•Adaptive Mesh Refinement (AMR) for turbulent flow simulations: where do we stand? Can it accurately and efficiently extend the effective dynamical range (and the Reynolds and magnetic Reynolds numbers) of a simulation? Has this been compellingly demonstrated? How has AMR be used in conjunction with SGS modeling and how should it be used in the future? Are there other ways to optimally exploit computing resources to model turbulent flows, for example, by identifying and modeling coherent structures?

I. SGS Modeling vs Filtering vs AMR

Date: Monday, May 20 (1:45 p.m. – 5:30 p.m.)

Session Leaders: M. Miesch (NCAR, USA miesch@ucar.edu)
P. Sagaut (UPMC, France pierre.sagaut@upmc.fr)

Summary (continued)

• LES for "complex" flows (i.e. more than the classical Richardson cascade at very high Reynolds number): do we perform much better than classical Smagorinsky-type models? The theory is nice, but let's look at the results!

• Can SGS properly handle the intrisically non-local spectral transfer and small-scale anisotropy inherent in MHD? Anisotropies induced by magnetism, rotation, and buoyancy also induce waves; under what conditions can the spectral transfer and spatial transport by waves be adequately captured by LES/SGS?

• Self-organization in MHD and anistropic HD is often linked with the selective dissipation of ideal invariants. Other phenomena such as magnetic cycles in convective dynamos rely on small imbalances between resolved production and dissipation terms. Are these systems sensitive to the LES/SGS approach?

Presenters

• M. Rempel, *"LES simulations of quiet sun magnetism."*

• P. Smolarkiewicz, *"Nonoscillatory forward-in-time differencing for fluids: simulation of global solar dynamo."*

• J.-F. Cossette, *"Thermal signature in global MHD simulations of solar convection."*

• W. Schmidt, *"Adaptively refined LES."*

• A. Petrosyan, *"Subgrid-scale modeling of compressible MHD turbulence."*

• I. Kitiashvili, *"MHD-LES modeling of magnetic self-organization in turbulent solar convection."*

• D. Sondak, *"MHD SGS models derived from VMS formulations."*

• K. Augustson, *"The influence of slope-limited diffusion upon the instability of thermal plumes."*

• O. Vasilyev, *"New paradigm of LES: Dynamic coupling of adaptive mesh refinement and turbulence modeling."*

II. Anisotropy and Kinetic Effects

Date: *Tuesday, May 21 (9:00 a.m. – 12:30 p.m.)*

Session Leaders: C. Cambon (Lyon, France claude.cambone@ec-lyon.fr)
F. Jenko (IPP-MPG, Germany fsj@ipp.mpg.de)

Summary

Anisotropy is an essential feature of MHD flows, especially in the presence of mean magnetic field, rotation and/or buoyancy in density-stratification, from weak to strong density gradients. Breaking isotropy towards axisymmetry, with or without mirror symmetry, is essential in these cases, often until the smallest scales, therefore with possible impact on SGS modeling.

As an important point, the detailed anisotropic structure, statistical two-point description as well as dynamics of key-indicators (e.g. Sagaut and Cambon, monograph, 2008)cannot be disentangled from the one of kinetic helicity, magnetic helicity and cross-helicity.

Even without mean magnetic field, ideal MHD turbulence can be described as an isotropized field, but the problem of a possible anisotropic substructure induced by patches of Alfv'en waves is in the core of a long debate, illustrated by Iroshnikov (1963), Kraichnan (1965), Goldreich and Srhidhar (1995), Bodyrev (many articles), and many other authors.

In many applications of MHD turbulence, one would like to know how the energy is converted into heat or energetic particles at the tail of the cascade. Examples include the solar wind and hot accretion flows. To address this question on an ab initio basis, one has to resort to a kinetic treatment. Given that the dynamics at the relevant scales largely falls into the regime of gyrokinetic theory (a reduced version of kinetics for low frequency phenomena in magnetized systems), one may study some issues with greatly reduced effort. One main goal is to discuss our present understanding of the dissipative processes in MHD turbulence and how to represent them in LES-type models.

• Role of the anisotropic substructure for predicting power laws of isotropized spectra.

• Relevance of DNS and LES in periodic cubic boxes, from isotropy to strong anisotropy, with respect to computations in explicitly bounded, e.g. spherical, domains.

• Relevance of statistical theory of homogeneous turbulence, towards very high Reynolds numbers, as generalized EDQNM, from isotropy to strong anisotropy.

• Anisotropy and dynamics, with Alfv'en, inertial and internal gravity waves combined together and with turbulence, in rotating stratified MHD,

- Role of Hall effects on the local structures such as the enstrophy density and the current density,

II. Anisotropy and Kinetic Effects

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Session Leaders: C. Cambon (Lyon, France claude.cambone@ec-lyon.fr)
F. Jenko (IPP-MPG, Germany fsj@ipp.mpg.de)

Presenters

- J. Shebalin, *"Anisotropy in ideal MHD turbulence due to rotation and/or a mean magnetic field."*
- A. Pouquet, *"Structures, anisotropy, and helical couplings in stratified turbulence, with and without rotation."*
- P. Sagaut, *"Anisotropy in DNS and LES, SGS modeling, present challenges."*
- H. Miura, *"DNS of Hall and non-Hall MHD turbulence."*
- C. Cambon, *"Two-point description and dynamics in strongly anisotropic homogeneous turbulence, in rotating, stratified and MHD flows."*
- J. Stone, *"Kinetic effects in diffuse astrophysical plasmas."*
- W. Daughton, *"Anisotropy, agyrotropy, and dissipation in fully kinetic turbulence."*
- W. Matthaeus, *"How anisotropic can you get: models and observations."*
- L. Bettarini, *"Towards a subgrid model for turbulent astrophysical/fusion plasmas: first steps within European CHARM network."*
- F. Jenko, *"What happens at the tail of the MHD cascade and how to model it."*

III. Magnetic Reconnection

Date: *Tuesday, May 22 (2:00 p.m. – 5:30 p.m.)*

Session Leaders:

D. Uzdensky (Univ. Colorado, USA uzdensky@colorado.edu)

M. Velli (JPL/Cal Tech, USA mvelli@jpl.nasa.gov)

Summary

In laminar reconnection models, which are much better understood than models of turbulent reconnection, there are two outstanding questions: where does reconnection occur, and how rapidly? The first question addresses issues of magnetic topology, and the second deals with dynamics. Issues of dynamics are often controlled by the mechanisms that break field lines, and their influence on the reconnection rate, be it quasi-steady or impulsive. Our understanding of turbulent reconnection is much less developed, and it is not even always clear what the important questions are. Here is a partial list of important questions, some of which are beginning to be addressed in the literature and will be discussed in the Workshop:

- How do we define reconnection rate in a turbulent system, especially in 3D?

- What is the role of magnetic topology in defining preferred sites of reconnection in a turbulent system? Is reconnection distinguishable from diffusion in such a system?

- What are the diagnostics of fast reconnection? Is fast reconnection necessarily associated with current sheets, and are they the dominant sites of dissipation and intermittency?

- Is enhanced diffusion the primary outcome of MHD turbulence? How does enhanced diffusion comport with constraints imposed by global conservation laws, such as energy, magnetic helicity, and cross helicity? (For example, what do self-consistent mean-field dynamo theories teach us?)

- Can the subtleties of small-scale reconnection in LES of MHD turbulence be reliably captured by SGS modeling or filtering? Can such modeling substitute for plasma kinetic effects? What about eddy noise?

- What lessons can be learned from comparative studies of LES in HD, MHD, extended MHD or fully kinetic models?

III. Magnetic Reconnection

Date: *Tuesday, May 21 (2:00 p.m. – 5:30 p.m.)*
Session Leaders:

D. Uzdensky (Univ. Colorado, USA uzdensky@colorado.edu)
M. Velli (JPL/Cal Tech, USA mvelli@jpl.nasa.gov)

Presenters

- A. Pouquet, *"Is there a path from ideal structures to reconnection?"*
- N. Yokoi, *"Self-consistent turbulence modeling on magnetic reconnection."*
- W. Schmidt, *"Kinetic and MHD approaches to turbulent reconnection."*
- W. Matthaeus, *"Multiple islands and acceleration in a turbulent reconnection environment."*
- J. Stone, *"Turbulent reconnection driven by the MRI."*
- D. Uzdensky, *"Reconnection in MHD turbulence: statistics of current sheets and intermittency of energy dissipation."*
- W. Daughton, *"New insights from large-scale kinetic studies."*
- G. Eyink, *"Turbulent reconnection, flux-Freezing, and coarse-graining."*
- M. Velli, *"Fast tearing of quasi-singular current sheets: reconnection in the ideal limit."*
- J.-F. Cossette, *"Relaxing ideal magneto-fluids: Eulerian vs. semi-Lagrangian approaches."*

IV. Helicity

Date: *Wednesday, May 22 (9:00 a.m. - 12:30 p.m.)*

Session Leaders: A. Brandenburg (Nordita, Sweden brandenb@nordita.org)
W. Matthaeus (Univ Deleware, USA whm@udel.edu)

Summary

Helicities, including magnetic, kinetic, and cross helicity are crucial ingredients of large-scale dynamos and determine their nonlinear evolution. They also influence the nature and strength of spectral transfer in turbulence, and therefore may influence construction of turbulence models. To develop hydromagnetic LES/SGS models, we need to understand how magnetic helicity affects turbulence at larger magnetic Reynolds numbers. This session will explore the evidence for influence of helicities on turbulence, review what is known about helicity effects in modeling, and discuss how this knowledge may impact future developments in LES/SGS models. Topics of discussion include:

- What are the influences on spectral transfer and modeling due to multiple ideal invariants including in some cases, helicities?

- What is the interplay between anisotropy and helicities? In rotating cases? In mean field cases?

- What is the relationship between helicities and intermittency/higher order statistics?

- How do helicities influence the relative amounts of local and nonlocal spectral transfer?

- How can one model the spontaneous formation of helical patches? Is this needed?

- When/how can selective dissipation of multiple invariants impact modeling?

- If there is a multiplicity of preferred final states of decay, how can this be built into turbulence models?

- How important are magnetic helicity fluxes for the dynamo? Are they important in other related problems?

- What difficulties are known and what solutions are available to deal with helicities in modeling driving and decay of MHD, and how do these carry over to LES models?

- What are good tests for LES/SGSmodels that are sensitive to helicity?

IV. Helicity

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Session Leaders: A. Brandenburg (Nordita, Sweden brandenb@nordita.org)
W. Matthaeus (Univ Deleware, USA whm@udel.edu)

Presenters

- A. Brandenburg, *TBD*
- A. Pouquet, *TBD*
- F. Cattaneo, *TBD*
- N. Brummel, *TBD*
- N. Yokoi, *"Sub-grid scale model with structure effects incorporated through the helicity."*
- J. Shebalin, *"Rotation and helicity in MHD turbulence."*
- E. Blackman, *"Astrophysical implications."*
- H. Aluie, *"Reconciling the cascade picture in physical and Fourier space: Issues of locality, helicity, and compressibility."*

V. Geometry and Boundary Conditions

Date: *Wednesday, May 22 (2:00 p.m. - 5:30 p.m.)*

Session Leaders: E. King (Univ California, Berkeley, USA eric.king@berkeley.edu)
S. Tobias (Univ. Leeds, UK smt@maths.leeds.ac.uk)

Summary

A prominent goal for LES modeling and the successful treatment of sub-grid scales is the indenfication of universal behavior in small scale dynamics. In this session, we aim to address this goal by exploring how the small scale dynamics are influenced by the large scales. In particular, we would like to ask: I.) when do geometry and boundary conditions directly influence the small scales, and how might this be parameterized; and II.) when do geometry and boundary conditions influence the small scales via the dynamics of the large scales (such as through conservation laws)? Some additional questions that should be addressed:

- What differences for LES closures must be addressed between cartesian and spherical geometries?

- When are the boundary conditions unimportant?

- What is the influence of magnetic field, rotation, and/or stratification? How do these anisotropic effects link small and large scales?

- In convective turbulence, where is kinetic energy injected? Should the buoyancy force do significant work in the SGS?

- In dynamos, how is field generation (alpha-effect) distributed in real and spectral space? When can upscale magnetic energy transport be ignored?

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Session Leaders: E. King (Univ California, Berkeley, USA eric.king@berkeley.edu)
S. Tobias (Univ. Leeds, UK smt@maths.leeds.ac.uk)

Presenters

- S. Boldyrev, *TBD*
- K. Julien, *"Asymptotic approaches to rotationally constrained convective flows. The role of spatial anisotropy."*
- B. Kosovic, *"Large-eddy simulations of stably stratified atmospheric boundary layers."*
- N. Nelson, *"Buoyant magnetic loops enabled by Lorentz force suppression of SGS diffusion."*
- S. Tobias, *"Anisotropy and boundary condition effects in calculations of turbulent diffusivities in convection."*
- M. Rast, "*A mixed Eulerian-Lagrangian scalar transport model."*
- M. Calkins, *"Some thoughts on when geometry is important for rapidly rotating convection."*
- A. Strugarek, *"Magnetic energy transfers on a sphere: cascades vs non-local transfers."*
- J. Shebalin, *"Ideal MHD turbulence in Cartesian and spherical geometries."*

VI. Applications and the MHD LES Challenge

Date: *Thursday, May 23 (9:00 a.m. - 12:30 p.m.)*

Session Leaders:

J. Stone (Princeton Univ., USA jstone@astro.princeton.edu)
J. Toomre (Univ. Colorado/JILA, USA jtoomre@lcd.colorado.edu)

Summary

This session will focus on our current understanding of how sensitive are the results of various widely-studied astrophysical MHD problems to the treatment of SGS, using four specific applications as examples. These are (1) solar convection and the dynamo, (2) the magneto-rotational instability (MRI) and MHD turbulence in accretion disks, (3) supersonic MHD turbulence in the interstellar medium (ISM), and (4) MHD turbulence in the solar wind. There will be one review speaker for each topic, and each speaker will be asked to briefly review the latest research results in their topic, with most of their time spent on addressing how SGS are commonly modeled in their area, what is the evidence that modeling the SGS directly is important, and the challenges to, and/or importance of, developing LES approaches for their area.

Following the four review talks, there will be a variety of short contributions to stimulate discussion of whether a benchmark test problem can be devised to compare different approaches for modeling the SGS as implemented in different codes and/or mathematical approximations. Due to the wide variety of physics that could be important in astrophysical plasmas in different regimes (e.g. compressibility, anisotropic transport coefficients, and other kinetic effects), no one benchmark problem may serve the needs of every topical area. Nonetheless there may be subgroups who can find common ground on which to build further tests. For example, a variety of groups are studying dynamo action in spherical shells using similar but different codes and approaches, and a benchmark problem in this regime may be both feasible and worthwhile. Similarly, it is now possible to study turbulent reconnection in astrophysical accretion disks using a variety of approximations, from single fluid MHD to gyrokinetics to hybrid PIC, and there are potential test problems that can be pursued in this application area. The discussion will hopefully reveal and develop more such examples.

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Session Leaders:

J. Stone (Princeton Univ., USA jstone@astro.princeton.edu)
J. Toomre (Univ. Colorado/JILA, USA jtoomre@lcd.colorado.edu)

Presenters

- A.S. Brun, *"Getting starspots in stellar dynamos: the role of sub-grid scale models in global simulations."*

- W. Schmidt, *"Supersonic MHD turbulence."*

- G. Lesur, *"The magneto-rotational instability."*

- M. Velli, *"MHD turbulence in the solar wind."*

- Y. Fan, *"A convective dynamo simulation of a cyclic solar dynamo with FSAM."*