Introduction to BOUT++

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The University of York

Lawrence Livermore National Laboratory
The BOUT++ code

- Plasma fluid simulation framework\(^1\)
- Solves an arbitrary number of fluid equations in curvilinear coordinates
- Finite difference with implicit or explicit timestepping. Methods can be changed at run-time, and include 4th-order Central differencing, Arakawa, and 3rd-order WENO.
- Written in C++, open source (LGPL)\(^2\)

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\(^1\) B.D. Dudson et. al. Comp. Phys. Comm. 180 (2009), pp. 1467-1480
\(^2\) Available at [http://github.com/bendudson/BOUT](http://github.com/bendudson/BOUT)
What is BOUT++

- Framework for writing fluid / plasma simulations in curvilinear geometry
- Finite-difference code, variety of numerical methods and time-integration solvers
- Written from scratch in C++, borrowing some ideas from the original BOUT code
- Intended to be quite modular, enabling fast testing of numerical methods
- Can evolve any number of equations, with equations appearing in a readable form
- Primarily designed and tested with reduced plasma fluid models in mind
What isn’t BOUT++

- Not a general parallel simulation library. Better tools such as PETSc exist for that.
- Not a magic bullet. It doesn’t automate the process of choosing an appropriate numerical scheme, just makes it easier to implement and test different ones.
- Not suitable for every problem. The numerical methods currently implemented are quite general, but cannot cover all problems.
Overall aims

- Started with the aim of simulating ELMs. Appropriate physics model not known. Wanted to make the code easy to change.
- Large codes often hard to understand, so wanted to isolate the model-specific code into a small number of lines.
- Still hard to understand whole code, but clearer what problem is being solved.

Now becoming more widely used, and aim is to build a community to use and develop the code further.

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- Promising results for turbulence and ELM simulations. Xu will talk more about this next...
- For typical ELM simulations the code scales well to a few thousand cores
Work in progress

- Coupling to the PETSc library for time-stepping working and under development
- Gyro-fluid extensions (gyro-averaging operators) working and being tested
- Pre-processing routines to prepare equilibria functional, but needs improvement
- Test cases: many example problems, and some unit tests. More needed to allow regular regression testing
- Documentation. Quite extensive manuals, but lags behind code
Future developments

- Preconditioning methods, including physics-based
- More advanced numerical methods, both differencing and time-integration
- Improved handling of highly non-uniform meshes
- Additional differential operators to model effects like Landau damping
- Coupling to external databases or codes to model things like atomic physics, fuelling and interactions with core and walls
- Better visualisation tools, in languages other than IDL
- Use of external libraries (e.g. PETSc, hypre) for linear and nonlinear solvers
- Scalability beyond 10,000 cores
Access to BOUT++

The BOUT++ code is open source, and publicly available at github.com

http://github.com/bendudson/BOUT

For this workshop, we have created a “stable” version 1.0, which may be updated with bugfixes, but no new features

http://github.com/bendudson/BOUT-1.0

Anyone can download a copy, but to make changes you will need to set up an account and SSH keys on github. Sean Farley will cover this after coffee...
Why use Git?

- Git was written by Linus Torvalds with Linux development in mind, so can easily handle very large collaborations and complicated merging.
- Doesn’t enforce any particular way of working, and doesn’t have the concept of a “central” server - all copies of the code are equivalent.
- A particular copy of BOUT++ is only “the” version by consent (or diktat).

This can seem strange coming from SVN, but makes it easier to work independently on features, then merge changes together afterwards.
⇒ Hopefully a help, rather than a hinderance to collaboration.
Use of BOUT++

Contributing:

- BOUT++ is under the LGPL license, so code which uses it can be proprietary. Modifications to the BOUT++ library do come under the LGPL.
- You’re free to take and modify BOUT++ for any purpose.
- We would appreciate it if you contributed back improvements you make to the code.
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Support:
- We’re happy to help, but our time is limited
- One aim of this workshop is to get a group of people comfortable with using BOUT++ and (eventually) help support each other
- There is a BOUT++ development mailing list. Please let me know if you’d like to join it
BOUT++ is a fluid simulation framework designed with plasma edge simulations in mind.

Less general than libraries like PETSc, still very flexible for plasma applications.

A tool to speed up development of new plasma models and numerical methods.
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Not perfect...
I look forward to working with you to improve it