

Highlights

SOLPS Tutorials: Introductory documentation to the SOLPS-ITER tokamak edge transport code

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- An open-source, beginner-oriented documentation of the SOLPS-ITER tokamak edge transport code has been created
- The documentation contains step-by-step instructions how to create, run and refine one's first SOLPS-ITER simulation
- External contributions are warmly welcome

SOLPS Tutorials: Introductory documentation to the SOLPS-ITER tokamak edge transport code

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ABSTRACT

SOLPS-ITER, a tokamak edge transport code developed by the ITER Organization, has been until recently lacking documentation aimed toward beginner users. This letter introduces SOLPS-Tutorials, a web-based, open-source collection of step-by-step guides to using SOLPS-ITER with little prior knowledge.

1. Introduction

Nuclear fusion is a candidate for a future energy source which is safe and environmentally clean. [27, Ch. 1] In a fusion reactor, hydrogen isotopes deuterium and tritium fuse at temperatures of roughly 150 million °C in the plasma state of matter. The burning fuel must be confined, which is performed using magnetic fields in a tokamak reactor. The ITER tokamak, currently being built in France, is a test reactor aiming to demonstrate the scientific feasibility of a burning fusion plasma. [21]

A key challenge of tokamak research is plasma-wall interaction, the coexistence of the hot edge plasma and the solid reactor wall. Tokamak edge transport codes have been developed to predict conditions of the burning plasma edge, solving simultaneously for the plasma, neutral particles and their interaction with the plasma-facing components. Transport codes constitute a fortunate compromise between computational speed and physical accuracy, and can be run with varying levels of physics refinement to move along this continuum. They have become indispensable for plasma-wall interaction research, both while interpreting existing tokamak experiments and predicting future plasmas in nuclear reactors. [23]

SOLPS-ITER [28, 2] is a prominent tokamak edge transport code, developed by the ITER Organization. It comprises a suite of coupled codes, such as B2.5, EIRENE [11], DivGeo, Carre and Carre2 or B2plot. The foundation of SOLPS-ITER is the B2.5 code, which solves Braginskii equations for a mix of charged fluids constituting the plasma. [6] Neutrals can be solved either as fluids with B2.5 using Navier-Stokes equations or using more accurate Monte Carlo simulations with EIRENE. The other codes in the suite specify plasma geometry, build grids, visualise simulation results etc. SOLPS-ITER has a history of continual evolution from the B2 code in the 80s [4, 5] until the current SOLPS-ITER, Scrape-Off Layer Plasma Solver for ITER modelling.

Since SOLPS-ITER is a cutting-edge code addressing some of the most burning issues of fusion reactors, its development focuses on refining the code itself, implementing new physics and fixing errors. Recently, the Wide Grids version of SOLPS-ITER has been introduced [13], with the unstructured grid builder GOAT [19, 26], a 9-point-stencil solver which better accommodates non-orthogonal grids [14] and other features. Such new features have usually been documented with an advanced user in mind, one who is familiar with the SOLPS jargon and self-sufficient in troubleshooting. As a result, SOLPS-ITER documentation can be difficult to understand for a beginner. Occasionally, step-by-step guides such as the DivGeo tutorial [12, 1] have been written. Typically, however, learning SOLPS-ITER requires the direct and involved supervision of an expert and cannot be done based on documentation alone.

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Creating a new SOLPS-ITER simulation

This is a narrow grids tutorial (SOLPS-ITER 3.0.x or 3.1.x)

The [wide grids tutorial](#) assumes you're already familiar with this tutorial.

This tutorial will take you through creating a new SOLPS-ITER simulation. The simulation will be as simple as possible: pure deuterium, simple boundary conditions, coupled B2.5+EIRENE. The tutorial will take you through the following steps (see the table of contents on the right):

1. Decide what to model, for example by [scouting a tokamak discharge](#)
2. [Connect to the server](#) where your SOLPS-ITER is installed and [initiate the SOLPS-ITER work environment](#)
3. Create a folder for the new simulation with the usual structure
4. Get the input files: an `.ogr` file containing the wall shape and an `.equ` file containing the equilibrium
5. Create a "simulation geometry" `.dg` file using the DivGeo programme
6. Create the rectangular grid for B2.5 using `carre` and import it into DivGeo for check
7. Create the triangular grid for EIRENE using `triang` and import it into DivGeo for check
8. Procure and edit SOLPS-ITER input files
9. [Run SOLPS-ITER](#)

Alternative resources

This tutorial borrows heavily from the [DivGeo tutorial](#).

✂ **TODO:** Eventually, we would like to merge this tutorial with the DivGeo tutorial.

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SOLPS-ITER dry run

Figure 1: Beginning of the *Creating a new SOLPS-ITER simulation* tutorial, as rendered by ReadtheDocs.

SOLPS Tutorials [17] is an open-source, online documentation package for SOLPS trainees with only basic knowledge of tokamak edge plasma physics. Written predominantly in the form of step-by-step tutorials, it covers one's first SOLPS-ITER simulation, several of the code's advanced features, and useful supplementary information. Its goal is to take its reader from a complete beginner to a moderately experienced SOLPS-ITER user ready to tackle the particular topic of their tokamak edge transport research task. This letter provides an overview of SOLPS Tutorials for students and teachers looking for SOLPS-related educational materials.

2. Contents of SOLPS Tutorials

SOLPS Tutorials are best viewed through their ReadtheDocs webpage [18], shown in figure 1. On the left, the navigation bar lists all available tutorials. On the right, sections of the current tutorial are charted. In the center, the current tutorial is displayed. Importantly, the search bar on the upper right allows for looking up keywords across the entire documentation.

SOLPS Tutorials are split into three groups: My first SOLPS-ITER simulation, Feature blog and Supplementary material.

2.1. My first SOLPS-ITER simulation

My first SOLPS-ITER simulation is a sequential list of tutorials which guides the reader through installing SOLPS-ITER, setting up a simple "narrow grids" SOLPS-ITER simulation and tuning its input parameters until the desired plasma solution is achieved.

Installing SOLPS-ITER. A collection of two current and two legacy tutorials.

- **SOLPS-ITER codebase.** The first step to working with SOLPS-ITER is to download its source code, compile it, and get in touch with the user community. This tutorial explains how to access SOLPS-ITER, where to install it, and how to do it on a properly configured site such as the EUROfusion Gateway [9]. Additionally, it describes how to initiate the SOLPS-ITER work environment, how to update SOLPS-ITER when a new version is released, and how to work with the Git version control system.
- **Installing SOLPS-ITER in a container.** Container installations simplify and, in the best case, circumvent the problem of installing SOLPS-ITER. To that end, this tutorial uses the `solps-container` package. [15].
- **Installing SOLPS-ITER at COMPASS (Soroban) and Installing SOLPS-ITER at IT4I (Karolina, Barbora).** Manual installation of SOLPS-ITER outside of a properly configured site is complicated due to software dependencies. These legacy tutorials describe SOLPS-ITER installation at the Soroban server of the Institute of Plasma Physics of the Czech Academy of Sciences (IPP CAS) and the IT4Innovations computational cluster. [8] Although they have been superseded by the more convenient container installations, they are kept as references for users performing their own installation of SOLPS-ITER.

Creating a new SOLPS-ITER simulations. Any SOLPS-ITER run must begin with specifying the plasma and wall geometry and setting up input files. Leaning heavily on the DivGeo tutorial [1], this tutorial takes the reader through creating a folder for the new simulation, procuring descriptions of the tokamak wall outline and the magnetic equilibrium, preparing the simulation geometry with DivGeo, creating the B2.5 grid with Carre and the EIRENE grid with Triang, and preparing the basic input files.

Running SOLPS-ITER. Once a simulation is set up, it must be run repeatedly until convergence is achieved, that is, the solution is physically sound and no longer evolves with subsequent iterations. This tutorial shows how to launch the simulation using the `b2run` command or submission scripts, set its duration, restart it, interrupt it, and branch it out into several similar runs. It explains how to monitor a simulation in progress and gives an overview of convergence criteria.

Processing SOLPS-ITER output. Once a simulation has converged, its output must be post-processed and analysed. This tutorial describes the basics of select built-in SOLPS post-processing tools: the B2plot programme, the `2d_profiles` command, and EIRENE tallies. It further lists publicly available post-processing tools, such as the SOLPS GUI [20], Quixote [22], Aurora [25], Cherab [7] and ERO2.0 [24]. Lastly, since SOLPS-ITER parallel transport is projected on the poloidal direction, it explains converting between poloidal, parallel and perpendicular fluxes and flux densities.

Adjusting SOLPS-ITER input. Once the plasma solution has been understood, the modeller tweaks the simulation inputs in a feedback loop to achieve the desired results. This tutorial categorises SOLPS-ITER inputs as either switches or boundary conditions, and outlines the text files which contain their values. It charts the most important SOLPS inputs and sketches their effect on the plasma solution. Finally, it discusses the fidelity one should expect of SOLPS-ITER and the concept of overfitting.

Following through with the *My first SOLPS-ITER simulation* tutorial sequence yields a simple SOLPS-ITER simulation which can be used as a springboard for a more complicated model.

2.2. Feature blog

The *Feature blog* is a collection of independent tutorials introducing advanced physics features of SOLPS-ITER and delving deeper into selected aspects of tokamak edge transport modelling. Once the reader has implemented all features relevant to their line of research, they have become a moderately experienced SOLPS-ITER user capable of self-sufficient work with the rest of the documentation.

Diffusion coefficients. Tokamak transport codes do not describe cross-field transport self-consistently; rather, they presume so-called anomalous diffusion and require diffusion coefficients as input parameters. This tutorial shows how to implement radial profiles of diffusion coefficients in SOLPS-ITER simulations of the tokamak H-mode, discusses where radially constant diffusivities are appropriate in L-mode, and advises how to choose diffusivity values.

Gas puffing and pumping. In most tokamak experiments, plasma density is controlled by puffing gas into the edge plasma and removing it via vacuum pumps. Emulating these processes lends SOLPS-ITER simulations credibility and facilitates self-consistent particle balance. This tutorial introduces the concept of particle sources, sinks and balance and shows how to implement gas pumping and puffing. Finally, automatic density adjustment via feedback schemes is explained.

Impurities. Deuterium is typically the primary component of tokamak plasmas, but impurities can appear as a result of poor vacuum chamber conditioning, plasma-wall interaction, or deliberate impurity seeding. Including these impurities in a SOLPS-ITER simulation is crucial particularly in detachment studies. This tutorial discusses which impurities to model in the edge plasma and how to set up impurity seeding and carbon impurity sputtering from the plasma-facing components.

Drifts. Electrostatic drifts, particularly the diamagnetic drift and the $E \times B$ drift, affect the tokamak edge plasma by redistributing divertor target particles and changing plasma flows. This tutorial shows how to enable drifts, lists drift-compatible boundary conditions and provides trouble-shooting tips.

Wide grids. The recently developed Wide Grids version of SOLPS-ITER allows simulating the edge plasma up to the first wall, improved fluid neutrals treatment, estimating diffusion coefficients self-consistently using the $\kappa - \epsilon$ model, and automatically tuning input parameters using algorithmic differentiation. This tutorial guides the reader through setting up a Wide Grids simulations using DivGeo, Carre2 and Triang, with additional tips for handling simulation divergence.

Magnetic equilibrium reconstructions. In the tokamak edge plasma, plasma transport parallel to the magnetic field is orders of magnitude faster than cross-field transport. Transport codes exploit this by building their plasma grids aligned to the magnetic field, separating the two kinds of transport. Unfortunately, magnetic equilibrium reconstructions, which are used as basis for building field-aligned grids, are often imprecise. This tutorial provides suggestions how to deal with the ensuing grid errors.

Energy fluxes deep dive. The physics and nomenclature of plasma, neutral, radiation, and other energy fluxes in SOLPS-ITER is complicated. This tutorial breaks energy fluxes down into components and shows how they are calculated and used in the code.

Interpretative simulations of COMPASS. Interpretative simulations are ones aiming to reproduce experimental results as closely as possible. On the example of the COMPASS tokamak [16], this tutorial describes how to pick a discharge to model with SOLPS-ITER, compile relevant diagnostic measurements, ascertain their quality, procure a good magnetic equilibrium reconstruction and match simulation results to experimental measurements.

In the future, the *Feature blog* will cover more topics.

2.3. Supplementary material

The third and final group of tutorials, titled *Supplementary material*, covers know-how which supports the reader in using SOLPS efficiently.

SOLPS-ITER user wisdom. Over time, as one uses SOLPS-ITER and interacts with its community, one acquires basic orientation in what is what and who is who. This tutorial collects the most important of this meta-information, offering pointers where to find solutions to one's problems, a guide to the SOLPS-ITER manual [10], a dictionary of SOLPS-related terms, and links to other sources of SOLPS-ITER documentation.

Library. To orient one's research in a productive direction, it is important to know the relevant works of scientific literature. This collection of articles includes official SOLPS-ITER manuals, annotated SOLPS input files, main SOLPS publications, historic evolution of B2/SOLPS, transport code physics, heat flux limiting, implementation and numerics details, and academic theses.

Remote access. SOLPS-ITER is typically run at high-performance computational clusters, which necessitates familiarity with methods of secure remote access. This tutorial explains the basics of using the VPN and SSH protocols and describes specific configurations of servers run by IPP Prague, IPP Garching and HPC Cineca. Additionally, it covers transferring SOLPS-ITER simulations between servers or installations.

Common pitfalls. Some issues with SOLPS-ITER simulations are encountered often enough to warrant tutorials of their own. This tutorial covers the danger of timestamps (causing SOLPS-ITER to ignore input files), divergence (simulation crashes and unphysical results) and speed-up recipes for faster SOLPS-ITER run times.

Questions and answers. Occasionally, highly specific information is best understood in the form of questions and answers rather than as part of a tutorial. This collection includes Q&A related to B2plot, input files and boundary conditions, post-processing SOLPS-ITER results, running SOLPS-ITER, physics of SOLPS-ITER, and other miscellaneous items.

B2.5 switches. SOLPS-ITER uses hundreds of switches and boundary conditions, which are documented in the `b2input.xml` file and reprinted in the SOLPS-ITER manual. This viewport renders the file contents in a more readable manner with a built-in search function, and covers several SOLPS-ITER releases for convenience.



Figure 2: Logo of SOLPS Tutorials: a supra-luminal unicorn.

3. Contributions to further development

The SOLPS Tutorials documentation was developed under the auspices of the Institute of Plasma Physics of the Czech Academy of Sciences. To expand and improve the documentation, the project was transferred to an open GitHub repository [17] of the ITER Organization in September 2026. We would like to invite members of the SOLPS-ITER community to contribute, be it in the form of corrections, revisions or new tutorials. As the SOLPS-ITER code itself has recently become open-source [3], high-quality, public documentation is more important than ever.

Guidelines to contributing to SOLPS Tutorials are provided in the *Contribute* tutorial. The source code of the tutorials are simple text files written in the Markdown mark-up language, supplied by Markdown extensions for setting LaTeX maths, code blocks and text boxes. Contributions are submitted and reviewed as GitHub pull requests for the SOLPS-Tutorials repository. [17] Once the changes are merged into the master branch, the documentation webpage is automatically built with the MkDocs documentation tool. The *B2.5 switches* viewport is compiled separately using Python scripts. Finally, the project is hosted on ReadtheDocs as a static webpage. [18]

The vision of SOLPS Tutorials is to remain oriented toward beginners. It does not aim to replace nor paraphrase the existing documentation, only to provide the basic motivation and first steps which facilitate moving on to more specialised resources. For this reason, we do not anticipate fundamental changes in the *My first SOLPS-ITER simulation* tutorial group, unless the Wide Grids version becomes universally preferred. In contrast, substantial expansions and refinements are expected in the *Feature blog*, *Library* and *Common pitfalls*. If the reader finds coverage of a certain topic lacking, they are warmly encouraged to write a tutorial about it. Vast technical expertise is not required; preference is given to clarity of writing and careful explanations of each new concept.

If the reader has found SOLPS Tutorials helpful in their work, we would appreciate an acknowledgment in the following form: *This work was facilitated by SOLPS Tutorials, introductory documentation to the SOLPS-ITER tokamak edge transport code [Hromasova 2026]*.

CRedit authorship contribution statement

Kateřina Hromasová: Conceptualization, visualization, validation, investigation, writing - original draft. **Jan Hečko:** Conceptualization, methodology, software, investigation, writing - review & editing. **Aleš Podolník:** Visualization, writing - review & editing. **Xavier Bonnin:** Validation, writing - review & editing. **Irina Borodkina:** Investigation. **David Coster:** Supervision. **Lukáš Kripner:** Software, writing - review & editing. **Jakub Seidl:** Software, supervision. **Oleg Shyshkin:** Investigation. **Daniel Švorc:** Software, investigation. **Matěj Tomeš:** Software. **David Tskhakaya:** Supervision, funding acquisition. **Sven Wiesen:** Supervision. **COMPASS team:** Resources, project administration, funding acquisition.

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