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Tutorials for the GRASS geocomputation engine

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Summary

This collection of tutorials is an introduction to the GRASS geospatial processing engine. GRASS is an open source computational engine for spatiotemporal data management, analysis, modeling, and simulation (GRASS Development Team et al., 2025; Neteler & Mitášová, 2008). As an engine that can be integrated in data science pipelines with shell scripting, Python, R, Jupyter, and Colab, there are many ways to use GRASS. While GRASS already had extensive documentation, tutorials were needed to introduce the many ways to interface with GRASS. These open education tutorials - which cover integrations, core features, and disciplinary applications - were developed as part of an effort to grow the GRASS community. The tutorials were built with Quarto and deployed as webpages paired with Jupyter computational notebooks. The tutorials are available at https://grass-tutorials.osgeo.org under both the GNU Free Documentation License v1.2 or later and the Creative Commons Attribution-ShareAlike 4.0 International License.

Statement of Need

As GRASS has grown from its roots as a desktop geographic information system (Westervelt, 2004), it has evolved into a geocomputational engine with many interfaces. As an engine, it can be integrated in geospatial data science pipelines using shell scripting, application programming interfaces, tangible interfaces (Petrášová et al., 2018), computational notebooks (**?**), cloud computing environments (**?**), or high performance computing environments. While GRASS is well documented with user and developer manuals, it lacked official tutorials. Over the years, the community developed many tutorials, but as these are independently maintained, many have become outdated and obsolete. The current roadmap for GRASS – established in 2024 – calls for official new tutorials to encourage community growth and demonstrate integrations in data science pipelines.

- Growing the GRASS ecosystem
    - GRASS has extensive documentation, but lacked official tutorials
        - Manual pages, api documentation, programming manual, etc.
        - Community developed tutorials
            - Not maintained by GRASS Dev Team
    - Current GRASS roadmap calls for new tutorials
        - Encourage community growth
        - Demonstrate integration into data science pipelines
    - Introduction to GRASS as geospatial engine
        - Examples of how to interface with engine needed
            - GUI, CLI, Py, R, Cloud, Jupyter, etc.
    - Implementation based on teaching experiences
        - HTML: NCSU Geospatial Modeling (GIS/MEAS 582) (Petráš et al., 2015)

- HTML: NCSU UAS Mapping and Analysis (GIS/MEAS 584)
- Jupyter: NCSU Geospatial Computing and Simulation (GIS714) (Haedrich et al., 2023)

Description

Learning Objectives

These tutorials were developed to teach the fundamentals of geoprocessing with GRASS, integrations of GRASS into data science pipelines, and disciplinary applications of GRASS. The tutorials were designed for self-study by learners of all levels, integration into courses, and deployment in workshops.

Instructional Design

The tutorials were designed to teach a computational approach to thinking about spatiotemporal phenomena through different interfaces to the GRASS engine. Drawing on the education benefits of computational notebooks (Barba et al., 2022), the tutorials were designed as modules for reuse and remixing, as worked examples to reduce cognitive load, as interactive lessons for active learning and engagement, as scaffolded prose and code to structure learning, and as computable content to teach computational thinking. The tutorials introduce geocomputational concepts through worked examples that synthesize prose explanations, graphics, and runnable code. The tutorials, which range from introductory to advanced, have a modular design for reuse and remixing so that learners can choose their own course of study and teachers can select modules for their lesson plans. The tutorials build in complexity from introductory to core to disciplinary modules. A set of getting started tutorials introduce different ways to interface with the GRASS engine. The core tutorials cover important concepts such as geovisualization, map algebra, geospatial modeling, and the temporal framework. Disciplinary tutorials demonstrate applications for GRASS in domains such as climatology, ecology, hydrology, geomorphology. The disciplinary tutorials build engagement by working through applications in the learner's domain and thus motivate further exploration. Throughout the tutorials, different ways to interface with GRASS are presented as tabs in code blocks, so that learners can work their way through the same tutorial repeatedly using increasingly challenging interfaces – building proficiency first with the graphical user interface (GUI), then with the command line interface (CLI), and finally with the Python application programming interface (API).

Implementation

This collection of tutorials was published using Quarto as web documents paired with computational notebooks. To reach a broad audience, the tutorials are published as web documents for immediate, easy access via web browsers. When appropriate, the web documents are accompanied by computational notebooks for the sake of interactivity, engagement, and geocomputational thinking. The tutorials – which are built and deployed using the Quarto scientific publishing system (Allaire et al., 2025) – are written in Markdown with YAML frontmatter. Tutorials are composed in Markdown for human-readable source code, efficient version control, executable code blocks for different interfaces, rendering in multiple formats, and reproducibility. As this open education project aims to teach different ways to interface with GRASS, executable code for multiple relevant interfaces such as the GUI, CLI, Python, or R can be included in tutorials as tabsets. Once tutorials have been written, they are reviewed by the GRASS Development Team, rendered as web documents and Jupyter notebooks, and deployed to an Open Source Geospatial Foundation website. The source code for the tutorials is built in the GitHub repository https://github.com/OSGeo/grass-tutorials and deployed to the website https://grass-tutorials.osgeo.org using GitHub Actions.

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Contents / Tutorials

This official collection of tutorials is maintained by the GRASS Development Team as part of the documentation for the GRASS geocomputational engine (Table 1). This ensures that tutorials undergo rigorous review, tutorials are maintained and updated as GRASS evolves, and issues are promptly addressed. The website also includes a curated collection of community contributed tutorials that are hosted on external websites and maintained by their creators (Table 2).

Table 1: Official GRASS tutorials

Modules	Tutorials	Level	Language
Integrations	Get started with GRASS GUI	Beginner	En
	Get started with GRASS & Python in Jupyter Notebooks	Beginner	En
	Get started with GRASS in Google Colab	Beginner	En
	Get started with GRASS in Jupyter Notebooks on Windows	Beginner	En
	Get started with GRASS & R: the rgrass package	Advanced	En
Core	Basics of map algebra	Beginner	En
	Making plots with GRASS	Beginner	En
	Visualizing and modeling terrain from DEMs in GRASS	Beginner	En & Pt
	Introduction to remote sensing with GRASS	Beginner	En
	Quick comparison: R and Python GRASS interfaces	Intermediate	En
	Introduction to time series in GRASS	Intermediate	En
	Temporal subset, import and export	Intermediate	En
	Temporal aggregations	Advanced	En
	Temporal algebra	Advanced	En
	Temporal accumulation	Advanced	En
	Temporal gap-filling	Advanced	En
	Temporal query with vector data	Advanced	En
	Modeling Movement in GRASS	Advanced	En & Pt
Disciplinary	Basic earthworks	Beginner	En
	Gully modeling	Beginner	En
	Coastal infrastructure	Beginner	En
	Terrain synthesis	Intermediate	En
	Procedural noise	Intermediate	En
	Hydro-flattening a Digital Elevation Model	Intermediate	En

Table 2: Community contributed tutorials

Modules	Tutorials	No.	Level	Language
Integrations	Unleash the power of GRASS GIS	5	Beginner - Advanced	En
	GRASS for Remote Sensing data processing with Jupyter Notebooks	1	Advanced	En
Core	NCSU Geospatial Modeling and Analysis Course	13	Beginner - Intermediate	En

Modules	Tutorials	No.	Level	Language
	Geoprocessamento com GRASS GIS	1	Beginner - Intermediate	Pt
	Tutoriales de GRASS GIS en grasswiki	4	Beginner - Intermediate	Es
	GISMentors	30	Beginner - Advanced	En & Cs
Disciplinary	Deforestation study using GRASS GIS	1	Beginner	En
	Teledetección, OBIA y series de tiempo	5	Beginner - Intermediate	Es
	GIS for Designers	12	Beginner - Intermediate	En
	GRASS GIS for environmental monitoring and disease ecology applications	2	Beginner - Intermediate	En
	Processing lidar and UAV point clouds	1	Beginner - Intermediate	En
	Physically-based hydrologic modeling using GRASS GIS r.topmodel	1	Intermediate	En
	Spatio-temporal data handling and visualization	1	Intermediate	En
	Ecodiv.earth tutorials	16	Beginner - Advanced	En
	Urban growth modeling with FUTURES	1	Advanced	En

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