

# <sup>1</sup> Tutorials for the GRASS geocomputation engine

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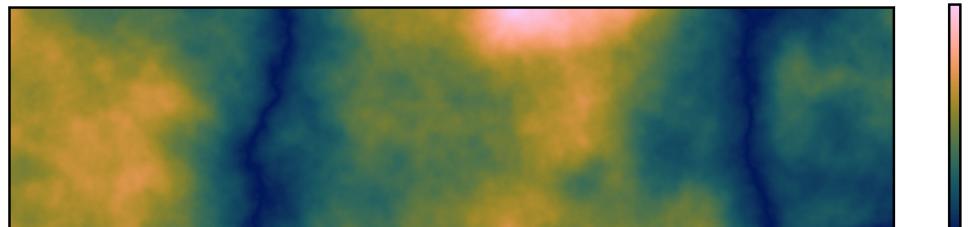
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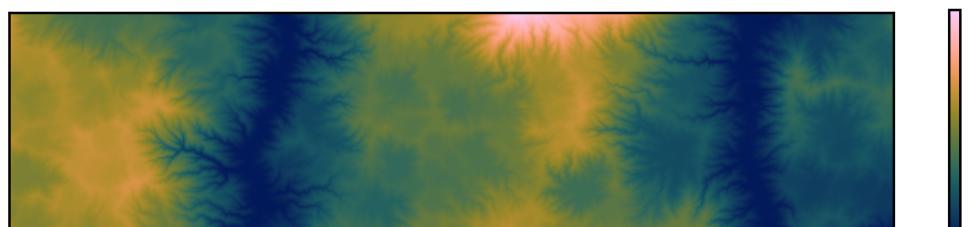
## <sup>6</sup> Summary

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 & Mítášová, 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 of individual processing tools, tutorials were needed to introduce the many ways to interface with the tools and combine them into computational workflows ([Figure 1](#)). 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 are built with Quarto and are 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.

Fractal terrain generated with GRASS



Fractal terrain eroded with LandLab



**Figure 1:** [Tutorial](#) on using GRASS, NumPy, and LandLab for Scientific Modeling. This tutorial demonstrates a seamless workflow for scientific modeling in Python, showing how gridded data can be passed as arrays between GRASS, NumPy ([Harris et al., 2020](#)), and Landlab ([Barnhart et al., 2020](#)).

## 20 Statement of Need

21 As GRASS has grown from its roots as a geographic information system (Westervelt, 2004), it  
22 has evolved into a geocomputational engine with many interfaces. As an engine, it can be  
23 integrated in geospatial data science pipelines using shell scripting, application programming  
24 interfaces, tangible interfaces (Petrášová et al., 2018), computational notebooks (Haedrich  
25 et al., 2023), cloud computing environments (Neteler et al., 2019; White et al., 2023), or  
26 high performance computing environments. While GRASS is well documented with books, a  
27 user manual, developer manuals, and a wiki, it lacked official tutorials. Over the years, the  
28 community developed many tutorials across different platforms, but as these are independently  
29 maintained, many have become outdated and obsolete. The current roadmap for GRASS  
30 – established in 2024 – calls for official new tutorials to encourage community growth and  
31 demonstrate integrations in data science pipelines.

32 The design and implementation of the new official tutorials for GRASS was based on experience  
33 teaching university courses and conference workshops using open educational resources. Over  
34 the last decade, the GRASS community has developed many open educational resources,  
35 experimenting with delivery via web documents, computational notebooks, and cloud computing  
36 services. Online tutorials for GRASS have been built from source in HTML (Petráš et al., 2015),  
37 built from Markdown with a static site generator (Harmon, 2020), included Jupyter notebooks  
38 (Haedrich et al., 2023), and used cloud computing services such as Binder (Petrášová & Petráš,  
39 2019), Whole Tale (Andrej, 2023b), and Google Colab (Andrej, 2023a). Petráš et al. (2015)  
40 used a modular structure with tabs to teach the core interfaces for GRASS – the GUI, CLI,  
41 and Python API – separating explanatory text introducing geospatial concepts from software  
42 specific text for each interface. This scaffolding helps learners to focus on concepts, while  
43 building their skills with increasingly complex interfaces. Haedrich et al. (2023) developed  
44 a GRASS–Jupyter integration to incorporate more scripting into a graduate-level course on  
45 Geospatial Computing and Simulation. The package extends the existing GRASS Python APIs  
46 with data visualization and management tools for the Jupyter environment. The new course  
47 materials include Jupyter Notebooks that combine tutorials and assignments, allowing students  
48 to write and modify code, interact with examples, and explain their reasoning in markdown,  
49 all within a single document. Based on these experiences, our design principles for the new  
50 tutorials include teaching geospatial concepts discretely from software specifics to encourage  
51 spatial thinking, supporting live coding to encourage computational thinking, and using an  
52 open source publishing system to build documents from plain text tracked with version control.

## 53 Description

### 54 Learning Objectives

55 This collection of tutorials was designed to teach geocomputational thinking using the GRASS  
56 geoprocessing engine. To introduce computational approaches (National Research Council,  
57 2010; Weintrop et al., 2016) to thinking about space and time, the tutorials cover the  
58 fundamentals of geoprocessing with GRASS, integrations of GRASS into data science pipelines,  
59 and disciplinary applications of GRASS. The tutorials were designed for self-study by learners  
60 of all levels, integration into courses, and deployment in workshops.

### 61 Instructional Design

62 In order to teach a computational approach to thinking about spatiotemporal phenomena  
63 through different interfaces to the GRASS engine, the tutorials were designed:

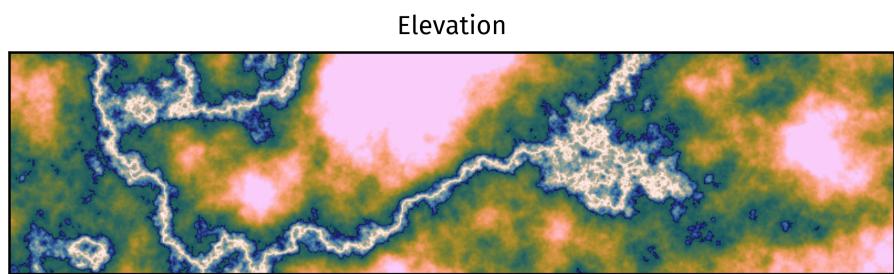
- 64     ■ as modules for reuse and remixing,
- 65     ■ as worked examples to reduce cognitive load,
- 66     ■ as interactive lessons for active learning and engagement,

67       ■ as scaffolded prose and code to structure learning,  
 68       ■ and as computable content to teach computational thinking.

69 Drawing on the education benefits of computational notebooks (Barba et al., 2022), the  
 70 tutorials introduce geocomputational concepts through worked examples that synthesize prose  
 71 explanations, graphics, and executable code. The tutorials, which range from introductory  
 72 to advanced, have a modular design for reuse and remixing so that learners can choose their  
 73 own course of study and teachers can select modules for their lesson plans. The tutorials  
 74 build in complexity from introductory to core to disciplinary modules. A set of “Getting  
 75 Started” tutorials introduce different ways to interface with the GRASS engine. The core  
 76 tutorials cover important concepts such as geovisualization, map algebra (Figure 2), geospatial  
 77 modeling, and the temporal framework. Disciplinary tutorials demonstrate applications for  
 78 GRASS in domains such as climatology, ecology, hydrology, geomorphology. The disciplinary  
 79 tutorials build engagement by working through applications in the learner’s domain and thus  
 80 motivate further exploration. Throughout the tutorials, different ways to interface with GRASS  
 81 are presented as tabs in code blocks, so that learners can work their way through the same  
 82 tutorial repeatedly using increasingly challenging interfaces – building proficiency first with the  
 83 graphical user interface (GUI), then with the command line interface (CLI), and finally with  
 84 the Python or R application programming interfaces (API).

## 85 Implementation

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



**Figure 2:** Tutorial introducing the basics of map algebra in GRASS. This This tutorial demonstrates local algebraic operations using the raster map calculator, focal operations using nearest neighbors analysis, zonal operations using conditional statements with the raster map calculator, and global operations using raster metadata.

## 101 Content

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

**Table 1:** Official GRASS tutorials

| Modules      | Tutorials  | Level        | Lang.   |
|--------------|--|--------------|---------|
| Core         | 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      |
|              | 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      |
| Disciplinary | 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 |
|              | Basic earthworks                                       | Beginner     | En      |
|              | Gully modeling   | Beginner     | En      |
|              | Coastal infrastructure                                 | Beginner     | En      |
|              | Terrain synthesis                                      | Intermediate | En      |

**Table 2:** Community contributed tutorials

| Modules      | Tutorials   | No. | Level                   | Lang. |
|--------------|---|-----|-------------------------|-------|
| 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                   | Lang.   |
|--------------|--|-----|-------------------------|---------|
| Disciplinary | Geoprocessamento com GRASS GIS                             | 1   | Beginner - Intermediate | Pt      |
|              | Tutoriales de GRASS GIS en grasswiki                       | 4   | Beginner - Intermediate | Es      |
|              | GISMentors   | 30  | Beginner - Advanced     | En & Cs |
|              | Deforestation study using GRASS GIS                        | 1   | Beginner                | En      |
|              | Teledetección, OBIA y series de tiempo                     | 5   | Beginner - Advanced.    | Es      |
|              | GIS for designers  | 12  | Beginner - Intermediate | En      |
|              | GRASS GIS for environmental monitoring and disease ecology | 2   | Beginner - Intermediate | En      |
|              | Processing lidar and UAV point clouds                      | 1   | Beginner - Intermediate | En      |
|              | Physically-based hydrologic modeling using 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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