(Thoughts about) FOSS Solutions for Geospatial Information Processing in Environmental Science and Engineering

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Outline

- Environmental science and engineering
- Free and open source software stack
- Geoinformatica
- Web-based tools

Environmental Science and Engineering: Tasks, goals and topics

- Understanding
- Managing
- Developing solutions for
- Studying
- Planning
- Engineering

- Civil infrastructure
- Environmental change
- Sustainability
- Risks

Environmental Science and Engineering: Subjects of Information

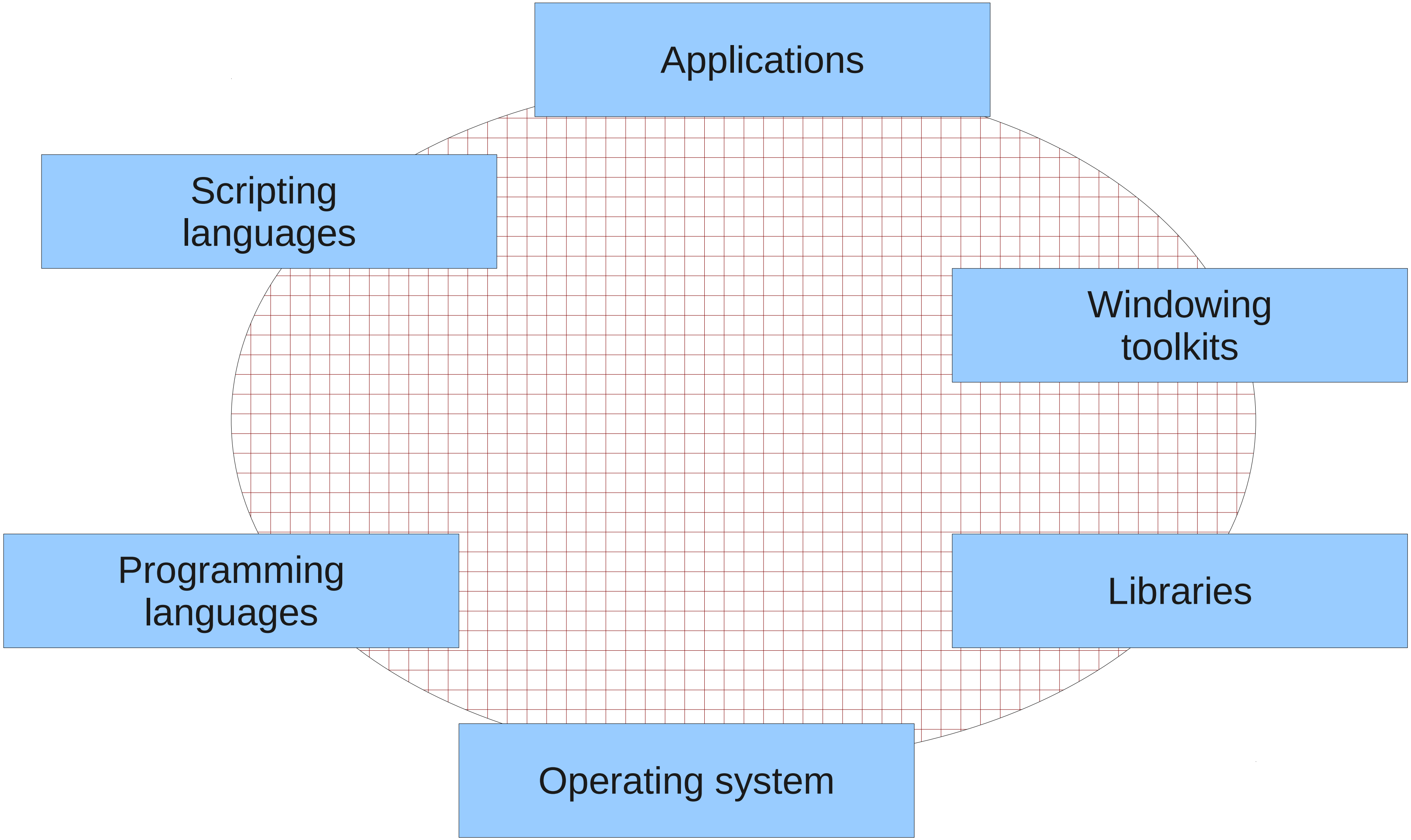
- Processes
  - For example: p in river systems, coastal p, catchment p
  - Physical and biological
  - Positive and negative
- Plans
  - Background materials: assessments, questionnaires, interviews
  - Ideas, drafts
- Engineering structures building and maintenance
  - Metadata, life-cycle
  - Various stake-holders and contractors

The four problems of information system development

- The presentation problem
  - Map
- The interaction problem
  - Display, mouse, keyboard
- The modeling problem
  - Data models and algorithms
- The development problem
  - Software tools

- Processes, plans and life-cycles
- Risks, sustainability criteria

The software stack



Operating system

- The main choices: Linux-based, Win32-based, Darwin-based
- Which distribution?
- For software development there are several choices, including Gnu for Windows
- Portability is useful: It is often easy to deploy to Win32 platform and users may prefer it
- Development (especially integration) is often much easier on Linux-based systems

Programming languages

- C or C++? A part of the modeling community prefers FORTRAN
  - Doesn't really matter if the result is a shared library
- I make an important distinction between programming languages and scripting languages (which are high-level PLs in fact!)
  - In my mind Java attempts to be both
- Some PLs are platform specific or make up their own platform (C#, Java)
  - This is always problematic

Libraries

- Should be easy to compile, focus on one task, have a clean and stable interface, and in general do what they are supposed to do and do it fast
- When within libraries: different data models are a hurdle, but not a show-stopper
  - Also, things may get complicated when you get closer to OS (memory, error handling, threads,...)
    - An occasional library developer should not have to deal with these – one solution is to develop within an existing library (GDAL for example) or use a utility library (GLib for example)
- Occasionally we need to use proprietary ones
- A general principle of mine is to always use libraries through a scripting language foreign function interface

libral

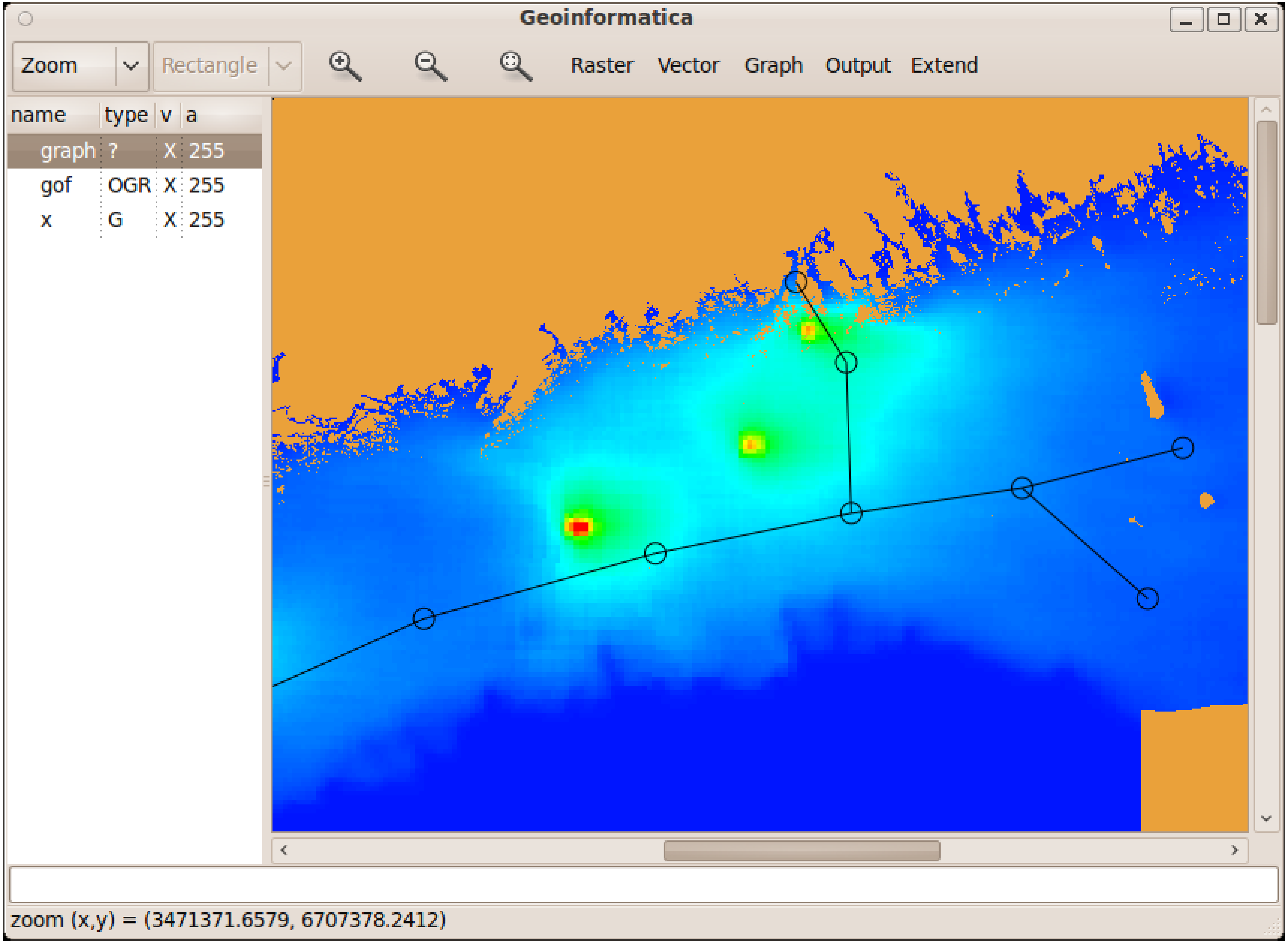
- A C library I've been developing (and using as a research/learning tool...) for raster algebra
  - Simple in-memory rasters → really fast algorithms
  - A back-end for Perl extension for raster algebra
  - Code for rendering rasters and vector data (coming from OGR) on GDK-pixbufs and/or Cairo surfaces has crept in
  - Interoperates with GDAL rasters (very simple to convert a libral raster to an OGR memory raster)
    - Perl rasters can polymorphically be libral or GDAL rasters → interesting possibilities for raster algebra
  - Interoperates (well, one way currently) with PDL (Perl Data Language) → easy to bring in data supported by PDL

Scripting languages

- Surprisingly many: Perl, Python, Ruby are well-known all-purpose ones, but there are several more specialized ones: R, The-Matlab-like-one-Octave-uses, Postscript, ... and even more more specialized ones: SQL, Glade, The-MILP-language-I-whipped-up, …
  - The concept of little languages or minilanguages is well-known
- Benefits: division of labor, domain-specificness, fewer lines of code
- Problems: complexities of mixtures, debugging, challenges to intellect

Windowing toolkits

- Needed when you are required to deliver an application with a new graphical user interface
- I use GTK+, which is a part of GNOME, the alternative is Qt (used by Quantum GIS for example)
  - GNOME is the default in Linux-based distributions that I use
  - gtk-perl is alive and well


Geoinformatica
Zoom
Rectangle
Raster
Vector
Graph
Output
Extend
name type v a
graph ? X 255
gof OGR X 255
x G X 255
zoom (x,y) = (3471371.6579, 6707378.2412)

Geoinformatica

- A stack of GDAL, libral, Perl, GTK+, gtk-perl
- Statistics of the Perl part (not counting external Perl modules and GDAL Perl):
  - ~19 500 lines of code, of which
  - ~3 900 lines is comments
  - 800 subroutines (= average 20 lines per sub)
  - 19 dialogs (stored in Glade XML files)
  - 40 source code files
  - 5 major classes, 61 in all
  - Start-up time ~3 seconds (the first time, 2nd time is faster)
  - The main program is 250 lines, which sets up a vanilla application

Applications

- A program, which interacts with the user, who wishes to accomplish a task
  - Input-output program
    - A small program written in a scripting language, often by the user or a more generic program that is controlled by switches
    - Task is well-structured
  - Graphical program
    - Task-oriented, with a as-simple-as-possible GUI, or a generic one, with as large set of functionalities as possible
    - Task often not so well-structured, typically providing decision support or a platform for explorative research
    - May also be used for structured tasks

Geoinformatica as a research platform

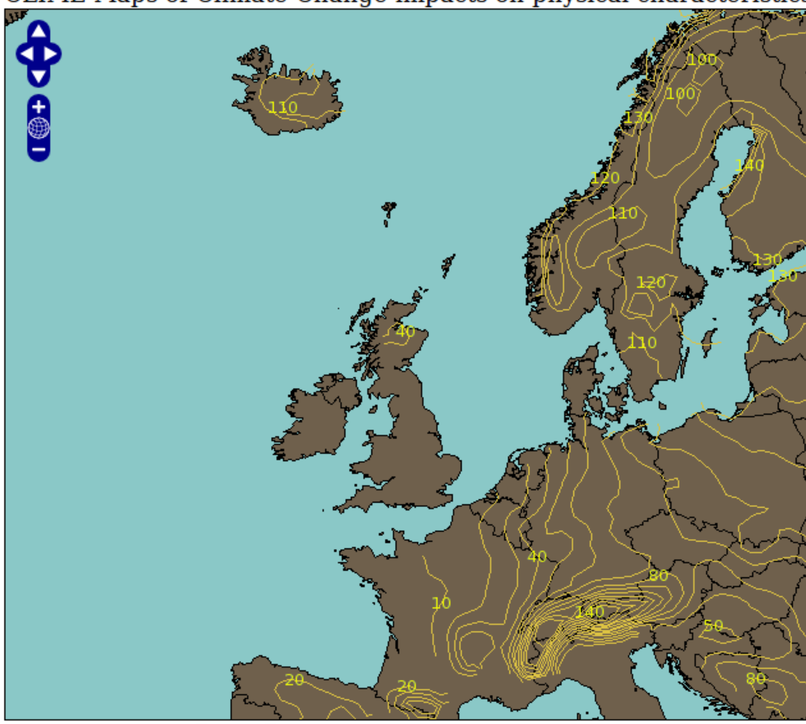
- An optimized set of tools (for myself), with very good basic functionality provided by packages (which are free)
- It is possible to deliver good solutions implemented as good graphical applications
  - Examples: soil database management tool, oil spill risk assessment tool
- Really interesting simulation modeling applications still to be developed
- Looking forward to study planning with complex features and geospatial design (civil engineering, landscape design)

The web

- Remote servers will be increasingly used as data sources and data processing services
- Typically data will enter the system through data access libraries. For example GDAL can already be compiled to access WMS and WCS.
- Scripting languages are powerful tools to implement those services. For example I've implemented a simple WMS server for research purposes with Perl equipped with appropriate modules (there is no WMS module as such) with < 300 lines of code.

Deploying information about environmental change using the Web

CLIME Maps of Climate Change impacts on physical characteristics of lakes



IPCC Scenario: A2 B2
Lake type: small and shallow small and deep large and shallow

- Regions whose lakes may start experiencing ice-free winters more...
- Shortening of the duration of ice cover [days] more...
- Becoming earlier of the timing of ice-off [days] more...
- Increase in summer temperature of lake surface water [degrees C] more...

The climate variable map page depicts the input data used for these projection

Regional climate model data courtesy of the Prudence project.

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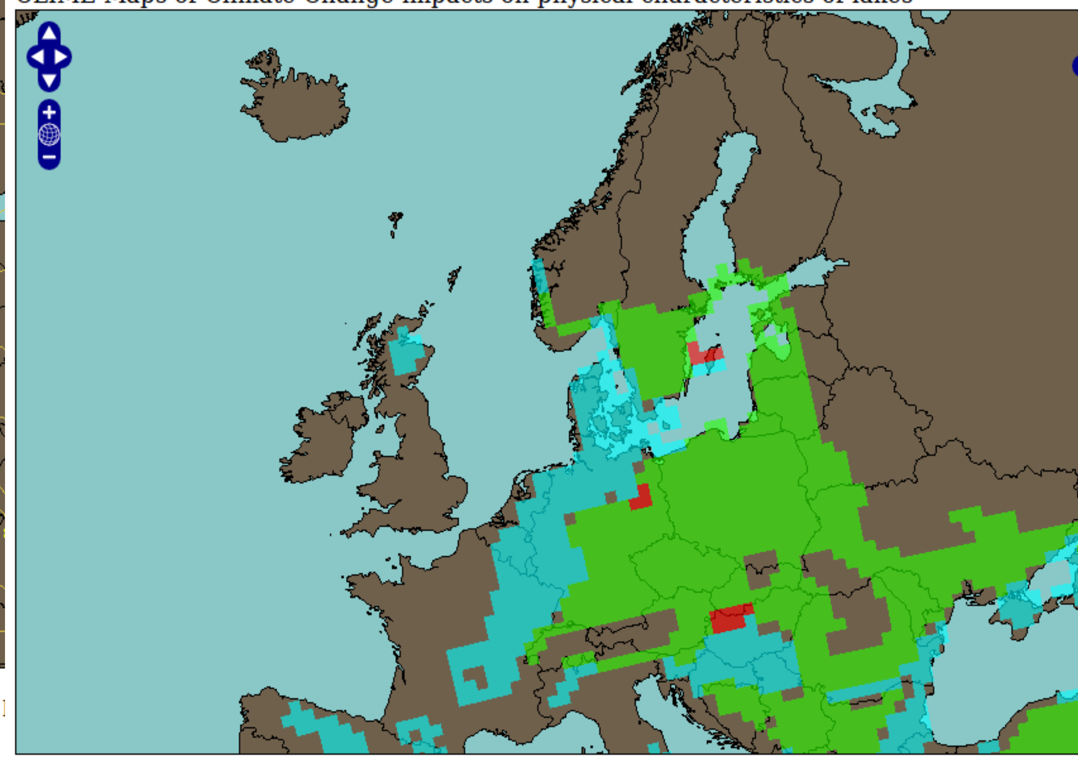

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Regional climate model data courtesy of the Prudence project.

More interaction ...

CLIME lake analyst for the selected lake/location

Location is [53° 33′ 12″ N, 14° 44′ 36″ W]
The model is SMHI HC (grid is SMHI)
closest CLIME lake is 'Müggelsee'
closest GLRIP lake is 'Nehmitzsee' (ice duration data from 29 years)
closest lake with a Wikipedia entry that has been added to the database is [Dąbie Lake]

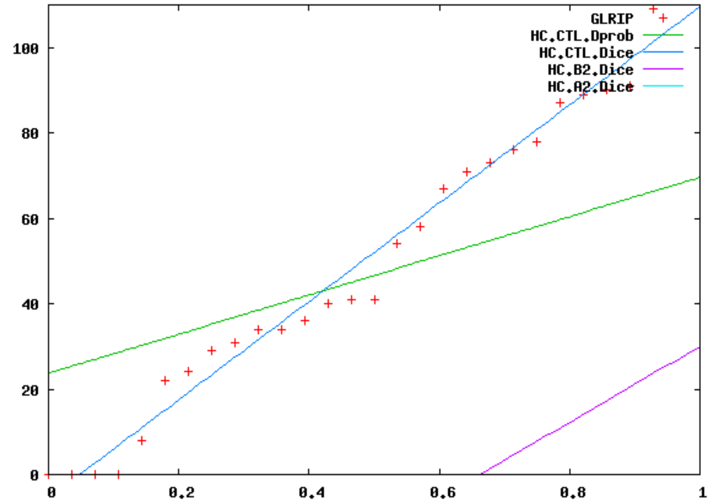


Figure The number of below-zero days and duration of ice cover vs. its cumulative probability. The unit of x-axis is probability and that of the y-axis is days. The climate data i from cell (41,51) of the grid.

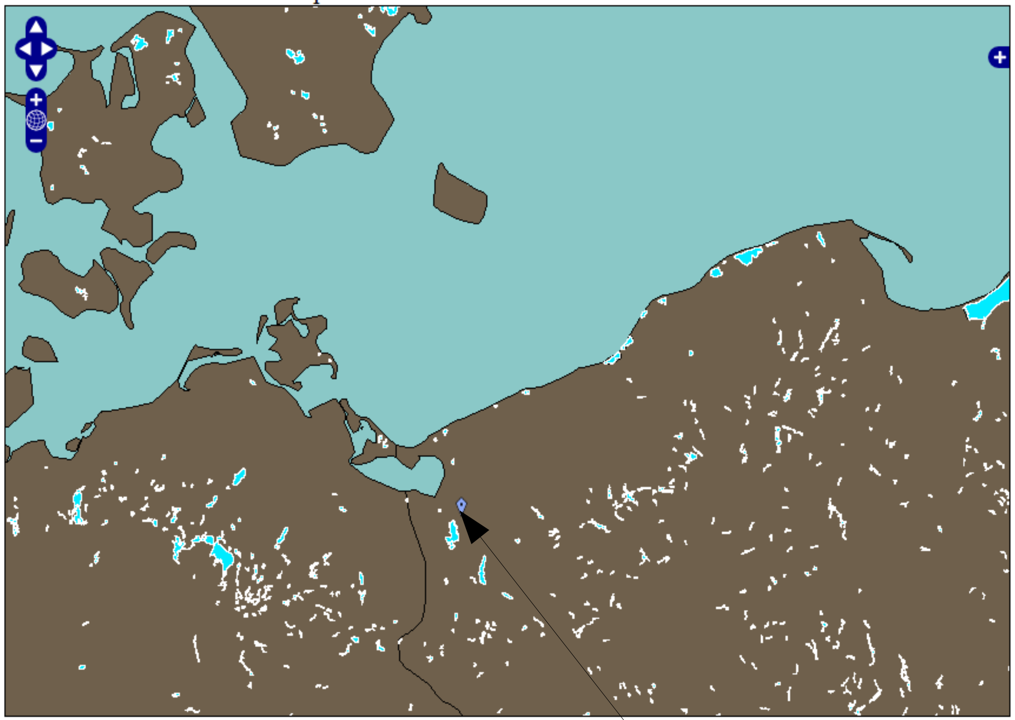
c = D^-_{prob}/D_{ice} = 2.50840014634213

df = how many days to have ice cover = 25.9039369835667

change c and df

use c and df from closest GLRIP lake

CLIME Climate Variable Maps



Model	Scenario	Variable
○ HadRM	○ A2	○ D^-_{prob}
○ SMHI MPI	○ B2	○ theta
◉ SMHI HC	◉ Control	○ T_summer

[Back to the impacts map page.]

A single click on the map opens the ice cover duration analysis page.

Regional climate model data courtesy of the [Prudence project].

Selected location

The software stack used for the climate change on lake ice study

Presentation
Interaction
Modeling
Development

- OpenLayers viewer
- WMS server (DIY)
- Analytical tools (DIY, Gnuplot)
- Data management (PostGIS)
- Geospatial computations (GEOS, GDAL)
- Spatial extrapolation of the geophysical model (GDAL+Perl)
- The geophysical model (Octave)

Thank You!

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