

# Using the VSoil software platform in a forestry context

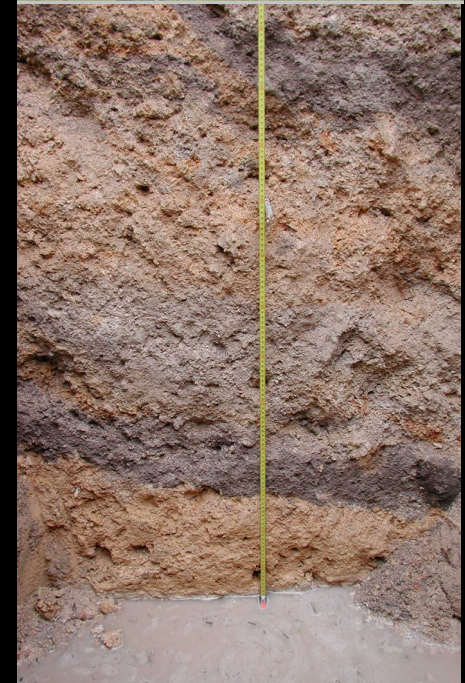
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EMMAH unit, Avignon, 4 mai 2022

Program of the day:

9h – 10h	Presentation of the Virtual Soil project (VSoil)	Nicolas Beudez
10h - 12h	The steps for building a model based on vsoil-forest (model from the VSoilForOAD project)	Manon Martin and Nicolas Beudez
12h - 13h	Lunch break	
13h - 15h	Using the vsoil-forest model	Manon Martin and Nicolas Beudez
15h - 16h	Discussion	

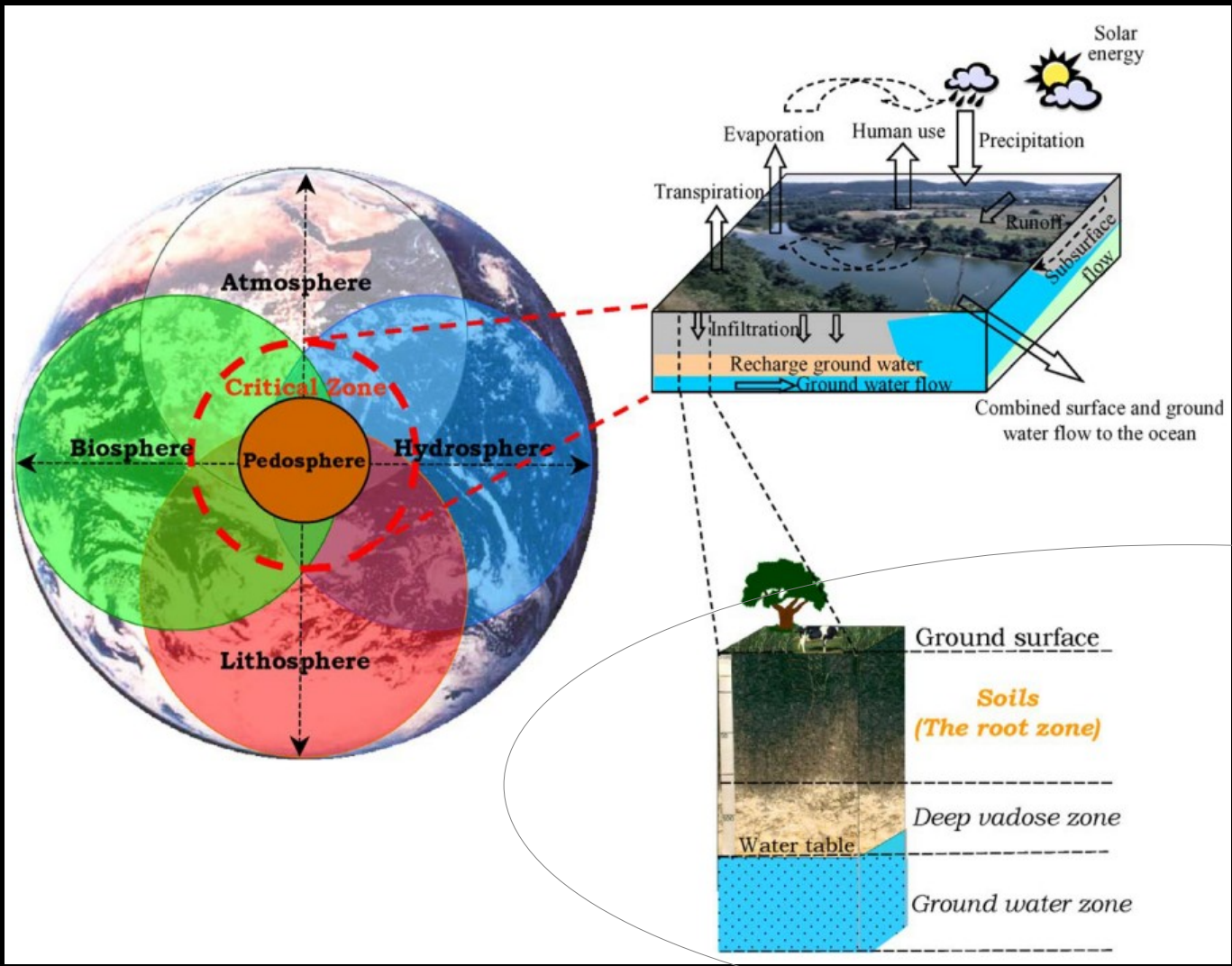
# Presentation of the Virtual Soil (VSoil) project

EMMAH unit, Avignon, 4 mai 2022



# Context: soil

Climate change.  
Changement of use.  
Evolution ?



The soil is at the heart of the **critical zone** of exchange of water and solutes, gases, solids, energy and organisms that extends from the upper canopy to the saturated soil zone.

## Pedon

- Local scale (a few m<sup>2</sup>).
- Soil profile from the surface to the groundwater or bedrock including the root exploration zone.

# Modelling requirements



**Survey** conducted between 2006 and 2008 within the Environment and Agronomy department of INRA

➔ Develop models that **couple mechanisms**:

- at different scales of time and space
- of different natures

➔ key point to understand the functioning and predict the evolution of soils

➔ Models should be developed **easily** et **quickly**: use what is available and / or develop new parts

➔ The development of new models should be accessible to all:  
**coding reduced as much as possible**

# Technical barriers



Difficulties in appropriating the **modelling**:

chain: experiments → model → computer code

➔ **need for support**

**Different computer languages** (Fortran, C, C++, Java, Python, ...) for programming whose lack of standards **restrains the coupling** of existing models

**Lack of assistance and support** for computer programming of simple and complex models

➔ Expectations ⇒ to have a structure that:

- allows to host and share models
- facilitates the development of new models
- allows to analyse the properties of these models

# Objectives



Create a structure to:

- **facilitate** the use of existing tools
- **reuse** and **capitalise** on the existing
- have a **modular modelling** approach
- accept **several representations** of a phenomenon
- **manage the coupling** of mechanisms
- **assist** in the development of new modelling approaches
- **facilitate interactions** between « modellers » and « experimenters »
- **facilitate communication** between scientists from different fields
- **share** and **make** innovations « **immediately** » **usable** for all users of the structure

# The VSoil software platform



VSoil is a **modelling software platform** supported by the INRAE Agroecosystems department and hosted in EMMAH unit on the Avignon site (developed since 2009)

It is a tool to **assist in the development of numerical models** describing the **physical, chemical and biological processes** of the soil in interaction with climate, plants and human actions

VSoil **facilitates the coupling** between these processes and makes it possible to develop complex models from the **assembly of existing or new source codes**

Space for **animation** and **scientific collaboration**

# Basic concepts



The **processes** that take place in the soil can be « described » and knowledge can be shared

Several representations of a process are possible through **modules**

A **model** is an assembly of modules

The modeller / user must be able to **concentrate on his core business:**

- making bricks (the modules)
- assembling the bricks
- analysing the results

**➔** modeller / user should be **relieved** of all tasks that are not its speciality



# Architecture



## From concepts...

Processes



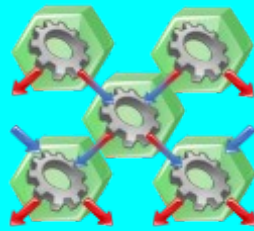
...encoded in modules,



...form skeletons,



...to create models



...and run simulations



vsoil-processes



vsoil-modules



vsoil-models



vsoil-player

...to softwares

# The VSoil software components



## 1) vsoil-processes :



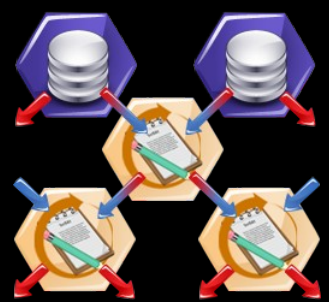
Phenomena are called processes



Some processes are external



Interactions between processes are detected using inputs and outputs



Processes with their inputs and outputs produce graphs: skeletons



demonstration !

**vsoil-processes**

- Open lists of variables and processes
- Guide for naming variables
- Tool for exploring content
- Automatic creation of skeletons
- Provide information for coding and assembly of modules

# The VSoil software components



## 2) vsoil-modules :



A module corresponds to a modelling, a numerical method, ...



It is a computer code (Fortran, C++)

A module is linked to a process



Several modules may be available for a process



A module uses some of the inputs of its process and must produce at least one output

**vsoil-modules**

**Parameters**

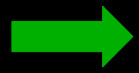
**Coding assistance**

**Compilation**

**Tests**

**Graphs**

**Non-invasive  
(standardised languages)**

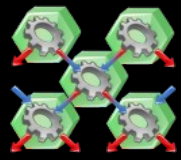


demonstration !

# The VSoil software components

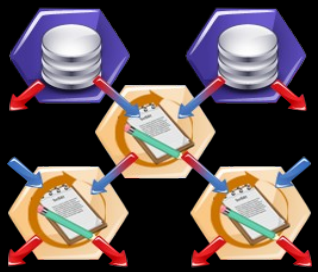


## 3) vsoil-models :

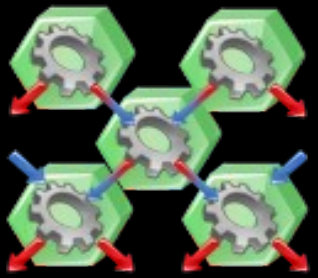


For each process...

... a module is selected

A blue rounded rectangle containing text and two icons. The top icon is a clipboard with a pencil and four arrows (two blue, two red). The bottom icon is a green gear with four arrows (two blue, two red).

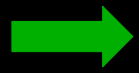
A model is based on a skeleton



A model is an ordered set of modules

**vsoil-models**

- Module selection
- Generation of the main
- Generation of the GUI
- Execution
- Visualization
- Backup
- Modification

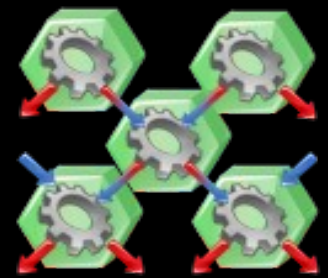
A green rounded rectangle containing a list of vsoil-models components.

demonstration !

# The VSoil software components



4) vsoil-player :

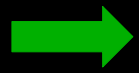


A model already built



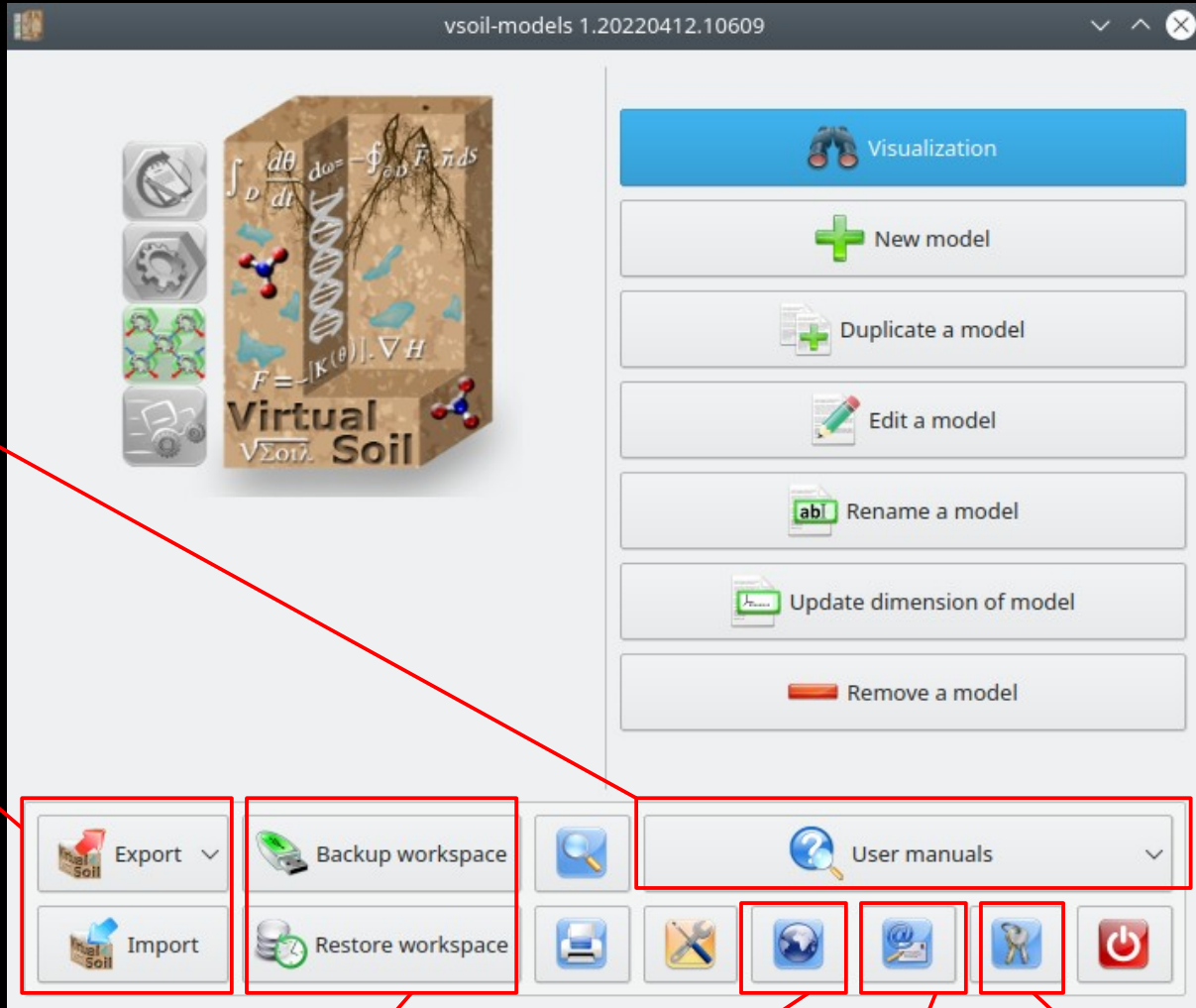
Simulations, visualisation of results, ...

- vsoil-player**
- Use available models**
- Run simulations**
- Archive simulations**
- View saved results**
- Compare simulation results**
- Perform sensitivity analysis and parameter estimation**



demonstration !

# A collaborative tool



online documentations (softwares and tutorials)

exchange of « user » objects

backup and restoration

access to the website

contact and support

licence and charter

# Advantages of VSoil



## 1) Ability to run calculations on remote servers:

- « vsoil-calcul » Linux server : Ubuntu 20.04, 56 cores, RAM 92 Go
- compatible clusters

activation of remote connection

The screenshot shows the VSoil software interface. At the top, there is a toolbar with various icons. Below it, a menu bar includes 'Model information', 'Modules selection', 'Ordering', 'Model generation', 'Initialization', 'Run', and 'Plots'. A status bar at the top indicates 'Model successfully compiled on local host (20.209 s)'. The main window is divided into a left sidebar with a tree view of model components, a central console displaying compilation logs, and a right sidebar with a progress bar. A 'Connect to remote host' dialog box is open in the foreground, with a red box highlighting the 'Connect to remote host' icon in the toolbar. The dialog box has the following fields: 'Host' (vsoil-calcul@Avignon (147.100.9.5)), 'Port' (22), 'login' (nbeudez), 'Password' (masked with dots), 'Scheduler' (none), and 'Environment'. There is a checkbox for 'Enable remote connection' and another for 'Run in Singularity container'. Below these fields is a table of 'Remote tools' with columns for 'Tools' and 'command'. The table lists tools like 'os-release', 'hostnamectl', 'uname', 'lscpu', 'free', 'c++', 'gfortran', 'gprof', 'make', and 'rscrip'. At the bottom of the dialog, there are buttons for 'Check remote tools' and 'Close'. The console in the background shows the output of the compilation process, including the command 'vsoil tool sed found' and 'Checking vsoil tool awk'.

# Advantages of VSoil



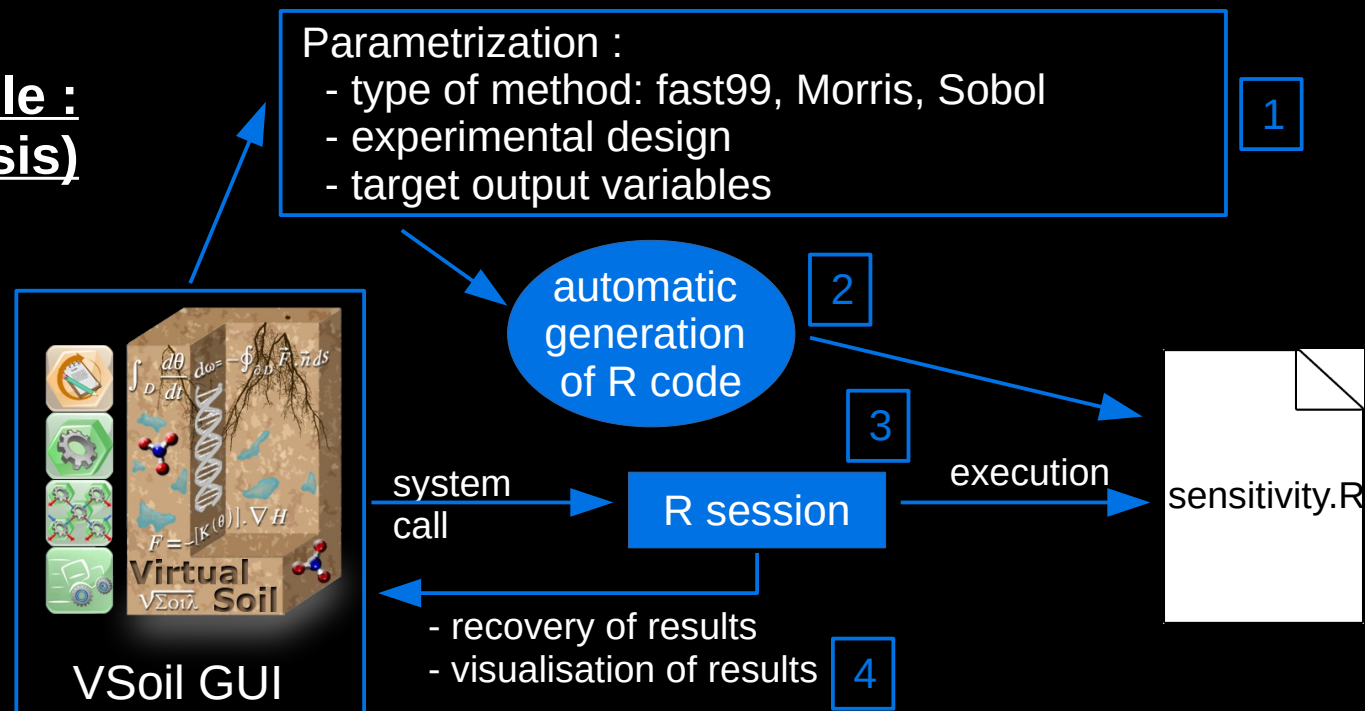
## 2) Model exploration tools: VSoil models interfaced to dedicated R packages

⇒ several methods of **sensitivity analysis**: fast99, Morris, Sobol

⇒ different algorithms for **parameter estimation**:

- Levenberg-Marquardt
- SCE-UA (Shuffle Complex Evolution – Uncertainty Analysis)
- DREAM (Differential Evolution Adaptive Metropolis)
- DREAMzs (Differential Evolution Adaptive Metropolis)

### Scenario (example : sensitivity analysis)

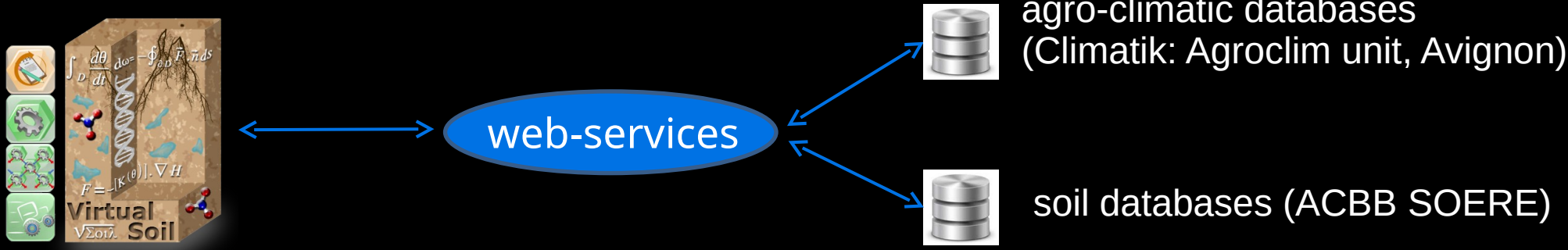




# Advantages of VSoil



## 3) Connections to databases




SOERE: Long-term Observation and Experimentation System for Environmental Research (« Système d’Observation et d’Expérimentation sur le long terme pour la Recherche en Environnement »)


ACBB: Agro-ecosystem, Bio-geochemical Cycle and Biodiversity (« Agro-écosystème, Cycle Bio-géochimique et Biodiversité »)

# Resources

Website: <https://www6.inrae.fr/vsoil/>



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 INRAE

The project

The software platform

Project life [Home page](#)

Download

Documentation

Contact

## Welcome to the VSoil project!

VSoil is a **modelling software platform** supported by the "**Agroécosystèmes**" division of **INRAE** and developed and hosted by **EMMAH laboratory**. It is a tool to **help develop numerical models** describing the **physical, chemical and biological processes of the soil** in interaction with the **climate, plants and anthropic actions**. By **facilitating the coupling between these processes**, the platform makes it possible to **develop complex models from assemblies of existing or new codes**.

You can find below all the **news about the VSoil project**: new stable versions of VSoil software suite, new collaborations (projects, thesis, ...), ...

Look also at the left of this page to access more informations about the VSoil project: description of the **project** and the **software platform**, informations about the **project life**, procedures to **download** the VSoil software suite (on Linux and Windows), access to **documentations** of the VSoil software suite (including some tutorials) and how to **contact** us.

### News

**03/03/2022 - Manon Martin (INRAE, EMMAH, Avignon) developed several modules as part of the VSoilForOAD project**

**Manon Martin** recently **developed several modules** that have been integrated to the model she is developing for the **VSoilForOAD project**: (1) a **C++ module** that implements the "**climate**" process and **reads climatic data from different sources**: SAFRAN, Météo-France or local data, (2) a **C++ module** that implements the "**evapotranspiration**" process and has the capacity to **read hourly PET (potential evapotranspiration) data** or **calculate PET values from climatic data** using the ASCE standardized Penman-Monteith formulation, (3) a **Fortran module** that implements the "**crop development**" process and calculates a **leaf area index** profile (using read or calculated **phenological dates**) and **root lengths**, and (4) a **C++ module** that implements the **new created "soil practicability" process** and that calculates several **soil saturation** and **soil practicability indexes**. Moreover, the **Sobol sensitivity analysis method** (from "sensitivity" R package) was added in the list of R sensitivity analysis methods available in VSoil in order Manon can run sensitivity analysis with **experimental design built with both continuous and discrete parameters** (an example of discrete parameter is the origin of climatic data: SAFRAN, Météo-France or local).

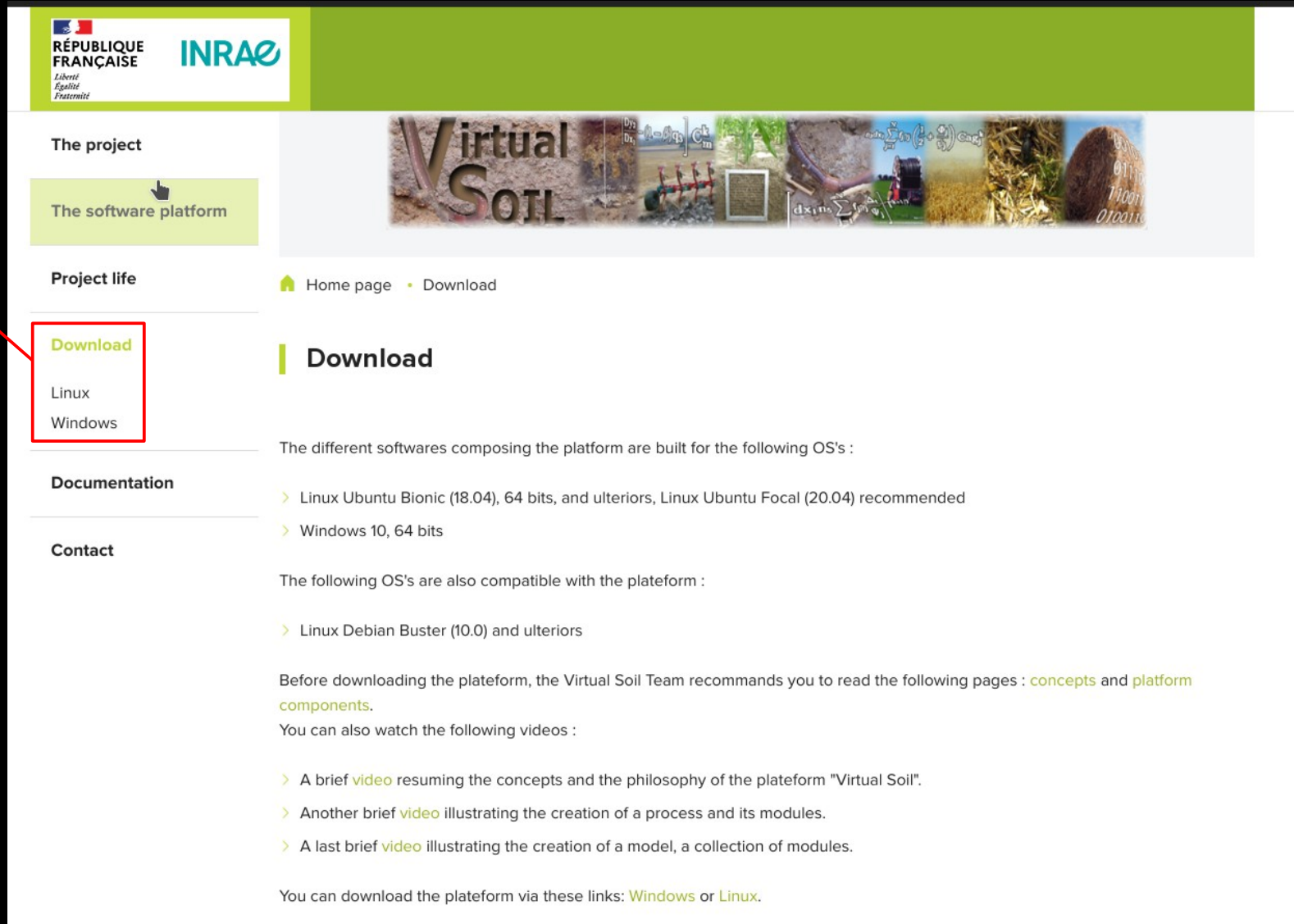
news

# Resources

Website: <https://www6.inrae.fr/vsoil/>



download



The screenshot shows the website for 'Virtual Soil' on the INRAE platform. The header features the INRAE logo and the French Republic emblem. The main navigation menu includes 'The project', 'The software platform', 'Project life', 'Documentation', and 'Contact'. The 'Project life' section is expanded to show 'Download', 'Linux', and 'Windows'. The 'Download' page content includes a breadcrumb trail 'Home page > Download', a heading 'Download', and text stating that the software is built for Linux Ubuntu Bionic (18.04), Linux Ubuntu Focal (20.04), and Windows 10 (64 bits). It also lists compatible Linux distributions like Debian Buster (10.0) and provides links to 'concepts' and 'platform components' pages. A list of videos is provided, and the page concludes with download links for 'Windows' and 'Linux'.

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**The project**

**The software platform**

**Project life** [Home page](#) • [Download](#)

**Download**

Linux  
Windows

**Documentation**

**Contact**

The different softwares composing the platform are built for the following OS's :

- > Linux Ubuntu Bionic (18.04), 64 bits, and ulteriors, Linux Ubuntu Focal (20.04) recommended
- > Windows 10, 64 bits

The following OS's are also compatible with the platform :

- > Linux Debian Buster (10.0) and ulteriors

Before downloading the plateform, the Virtual Soil Team recommands you to read the following pages : [concepts](#) and [platform components](#).

You can also watch the following videos :

- > A brief [video](#) resuming the concepts and the philosophy of the plateform "Virtual Soil".
- > Another brief [video](#) illustrating the creation of a process and its modules.
- > A last brief [video](#) illustrating the creation of a model, a collection of modules.

You can download the plateform via these links: [Windows](#) or [Linux](#).

# Resources

Website: <https://www6.inrae.fr/vsoil/>



documentations of the different softwares:

- vsoil-processes
- vsoil-modules
- vsoil-models
- vsoil-player

tutorials for creating modules

other documentations:  
connection to databases

A screenshot of the VSoil website's documentation page. The page has a sidebar on the left with 'Download', 'Documentation', and 'Contact' links. The main content area is titled 'Documentation' and contains several sections. Red boxes and arrows highlight specific parts: 'Documentation of VSoil softwares', 'Tutorials of modules creation', and 'Other VSoil documentations'. The text in the 'Documentation of VSoil softwares' section lists user manuals for vsoil-processes, vsoil-modules, vsoil-models, and vsoil-player. The 'Tutorials of modules creation' section lists four tutorials: root water uptake, simple denitrification, mulch decomposition, and variation of organic matter. The 'Other VSoil documentations' section mentions a connection to the SOERE ACBB database.

**Download**

**Documentation**

**Contact**

You can find in this section the documentations (PDF format) relative to the 4 softwares composing the VSoil software suite as well as tutorials illustrating modules creation. All these documentations are intended to be written in english. Some of them are still written in french and are currently being translated.

> **Documentation of VSoil softwares**

Documentation of **vsoil-processes** software: [vsoil-processes user manual](#)

Documentation of **vsoil-modules** software: [vsoil-modules user manual](#)

Documentation of **vsoil-models** software: [vsoil-models user manual](#)

Documentation of **vsoil-player** software: [vsoil-player user manual](#)

The functionalities allowing to **compile a module/model, configure it, run it and display the results of a simulation** are the same in *vsoil-modules*, *vsoil-models* and *vsoil-player* softwares. These functionalities are described in the [model usage user manual](#).

It is possible to **import or export one or more variables, processes, modules and models** from each of the 4 VSoil softwares. These functionalities are described in the [import/export user manual](#).

The different softwares of VSoil platform have a set of **common features** accessible from the toolbar of the main window of each software. These features are described in the [common toolbar user manual](#).

When **two variables** A and B calculated by two different modules MA and MB are **coupled** (it means that variable A is calculated using variable B and variable B is calculated using variable A), one has the choice between linearization (module MA is executed first and variable A is then used to calculate variable B in module MB) and iterations between modules. The VSoil platform can perform **iterations between these two modules**. This functionality is documented in the [user manual for iterations between modules](#).

> **Tutorials of modules creation**

A set of 4 tutorials has been written in order to illustrate through concrete examples the creation of modules in the VSoil platform. These tutorials are presented below classified by increasing order of complexity.

Tutorial 1 : [creation of a module for root water uptake](#)

Tutorial 2 : [creation of a module for simple denitrification](#)

Tutorial 3 : [creation of a module for mulch decomposition](#)

Tutorial 4 : [creation of a module for variation of organic matter in soil](#)

> **Other VSoil documentations**

This section presents some documentations relative to specific functionalities available in VSoil softwares.

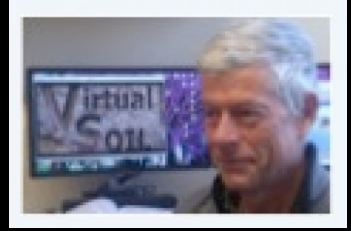
You can access data from the [SOERE ACBB](#) database through the connection to a web service. This functionality is described in the [connection to SOERE ACBB user manual](#).

# The VSoil team



Team members:

- scientific team:



François Lafolie  
(research fellow – scientific leader of the project)



Nicolas Beudez  
(design engineer – scientific computing)

- development team:



Nicolas Moitrier  
(research engineer – IT project manager)



Nathalie Moitrier  
(design engineer – software engineering)



Cédric Nougier  
(design engineer – software engineering)

To contact us:

- [vsoil@inrae.fr](mailto:vsoil@inrae.fr) → scientific team
- [vsoil-support@inrae.fr](mailto:vsoil-support@inrae.fr) → development team

- Discord server



**Thank you for your attention**