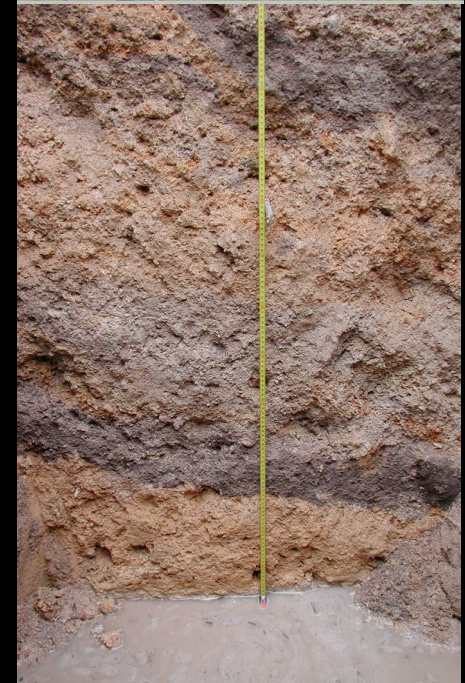


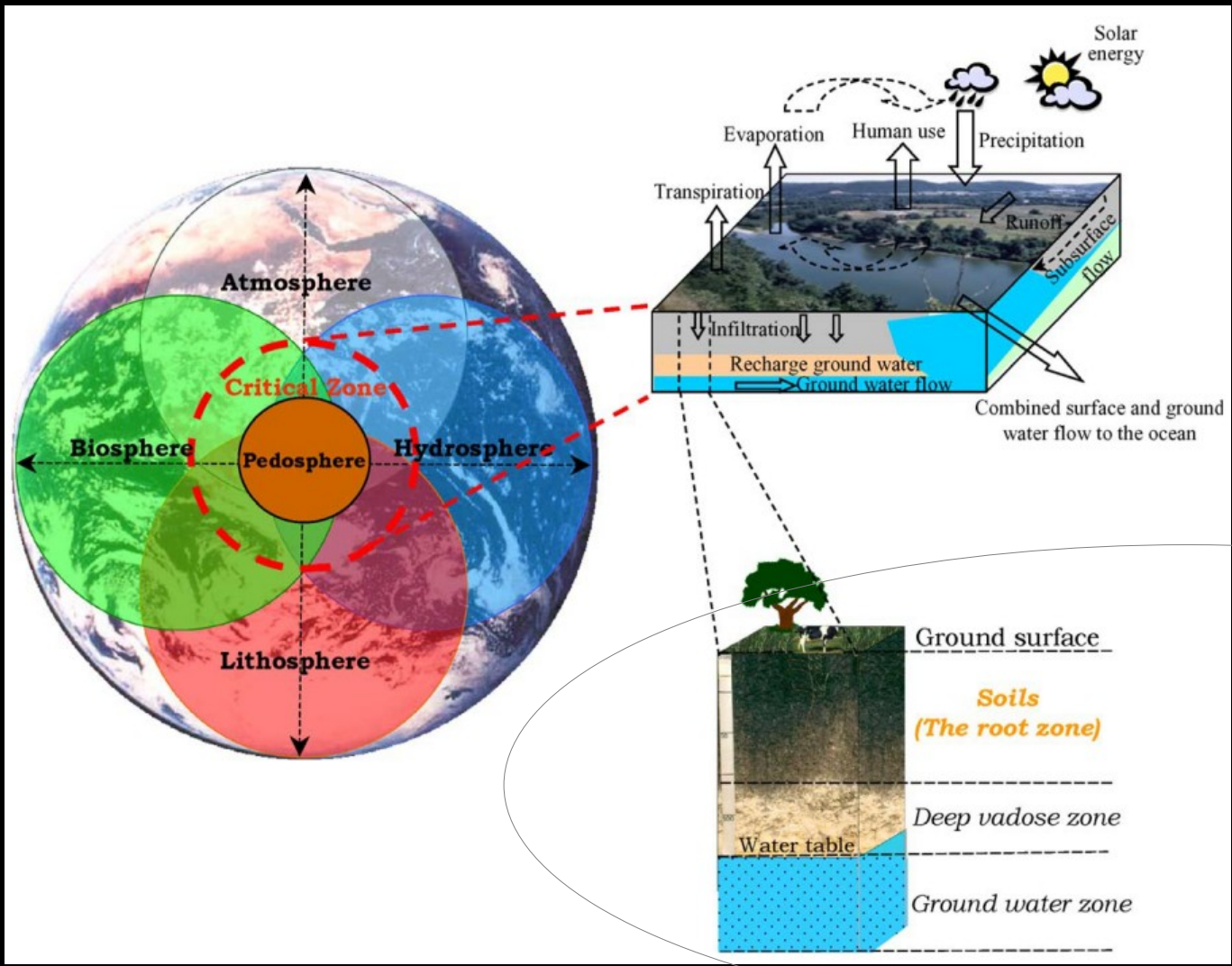
# Presentation of the Virtual Soil (VSoil) project

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...

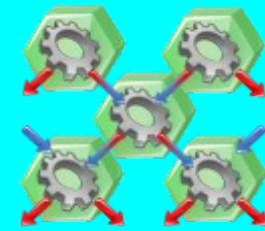
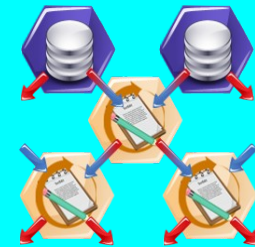
Processes

...encoded in modules,

...form skeletons,

...to create models

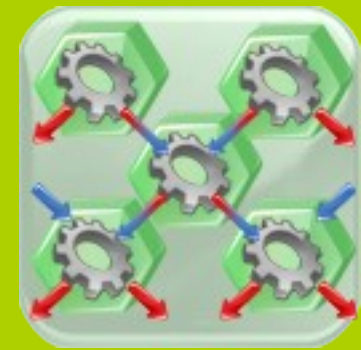
...and run simulations



vsoil-processes



vsoil-modules



vsoil-models



vsoil-player

...to softwares



# The VSoil software components



## 1) vsoil-processes :



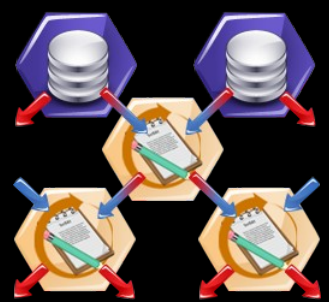
Phenomena are called processes



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++)

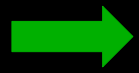
A module is linked to a process



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



demonstration !

**vsoil-modules**

**Parameters**

**Coding assistance**

**Compilation**

**Tests**

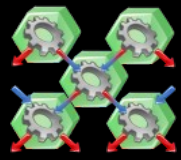
**Graphs**

**Non-invasive  
(standardised languages)**

# The VSoil software components

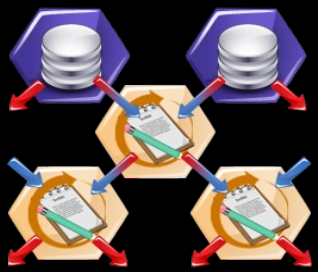


## 3) vsoil-models :

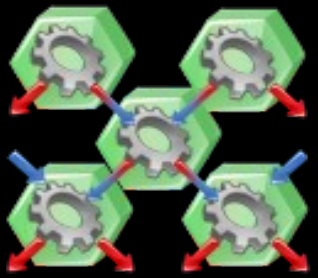


For each process...

... a module is selected



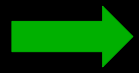
A model is based on a skeleton



A model is an ordered set of modules

**vsoil-models**

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

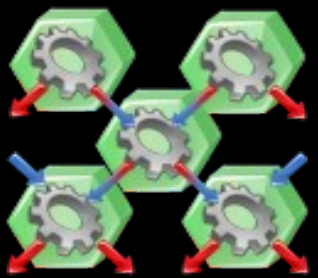


demonstration !

# The VSoil software components



4) vsoil-player : 

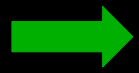


A model already built

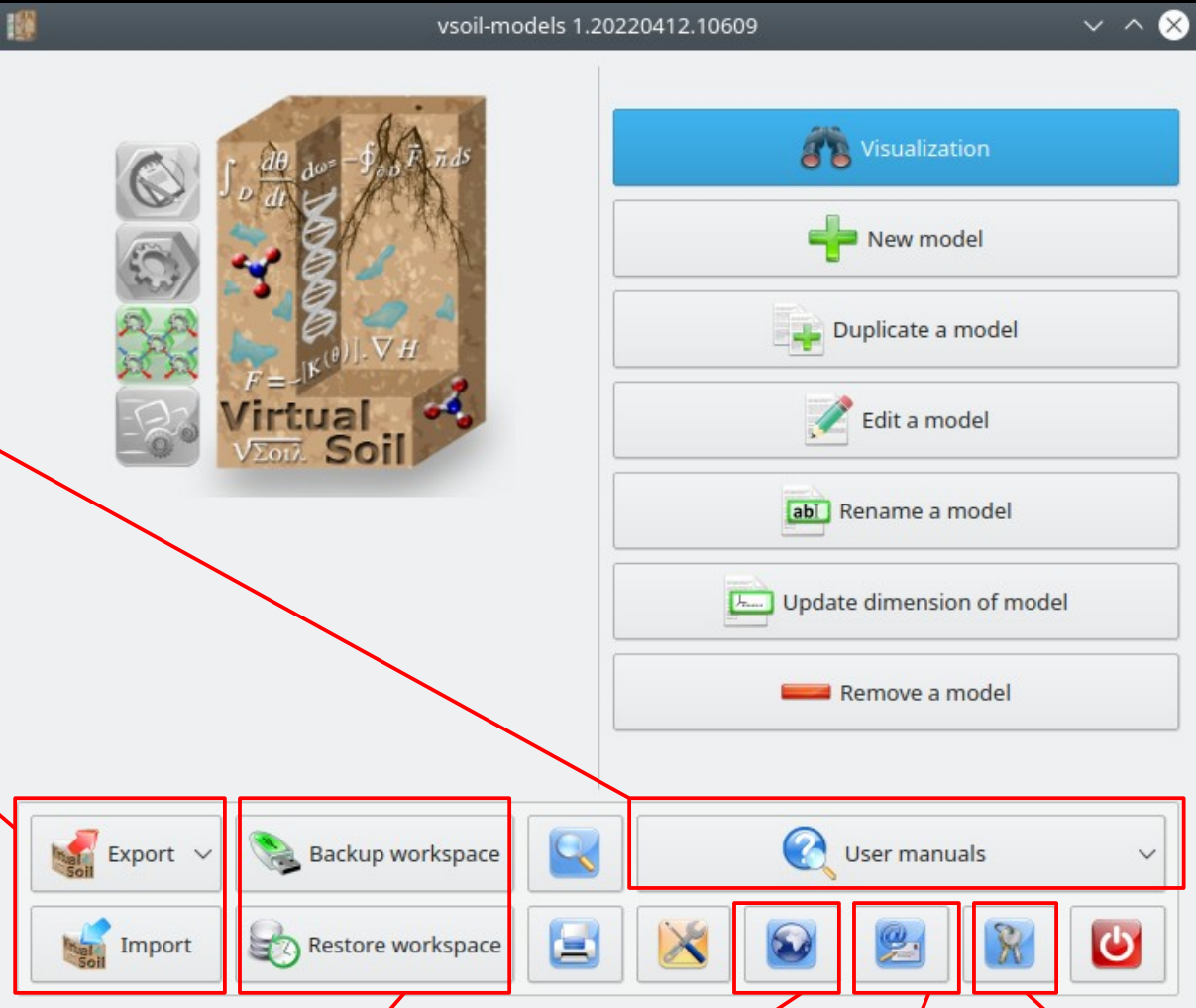


Simulations, visualisation of results, ...

- 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. A red box highlights the 'Remote connection' icon. Below the toolbar, there are tabs for 'Model information', 'Modules selection', 'Ordering', 'Model generation', 'Initialization', 'Run', and 'Plots'. The 'Run' tab is active, showing a progress bar and a message: 'Model successfully compiled on local host (20.209 s)'. A dialog box titled 'Connect to remote host' is open, with the following fields: Host (vsoil-calcul@Avignon (147.100.9.5)), Port (22), login (nbeudez), Password (masked with dots), Scheduler (none), and Environment (empty). There is a checkbox for 'Enable remote connection' which is checked. Below the fields is a table of remote tools:

Remote tools	command
Tools	
os-release	/etc/os-release
hostnamectl	/usr/bin/hostnamectl
uname	/bin/uname
lscpu	/usr/bin/lscpu
free	/usr/bin/free
c++	/usr/bin/c++
gfortran	/usr/bin/gfortran
gprof	/usr/bin/gprof
make	/usr/bin/make
rscrip	/usr/bin/rscrip

At the bottom of the dialog box, there is a 'Check remote tools' button and a 'Close' button. The background shows a list of modules on the left and a log window on the right with text like 'documentation generation done in 0.372s', 'code sources generation done in 0.631s', and 'Platform common fortran sources compilation'.

# Advantages of VSoil



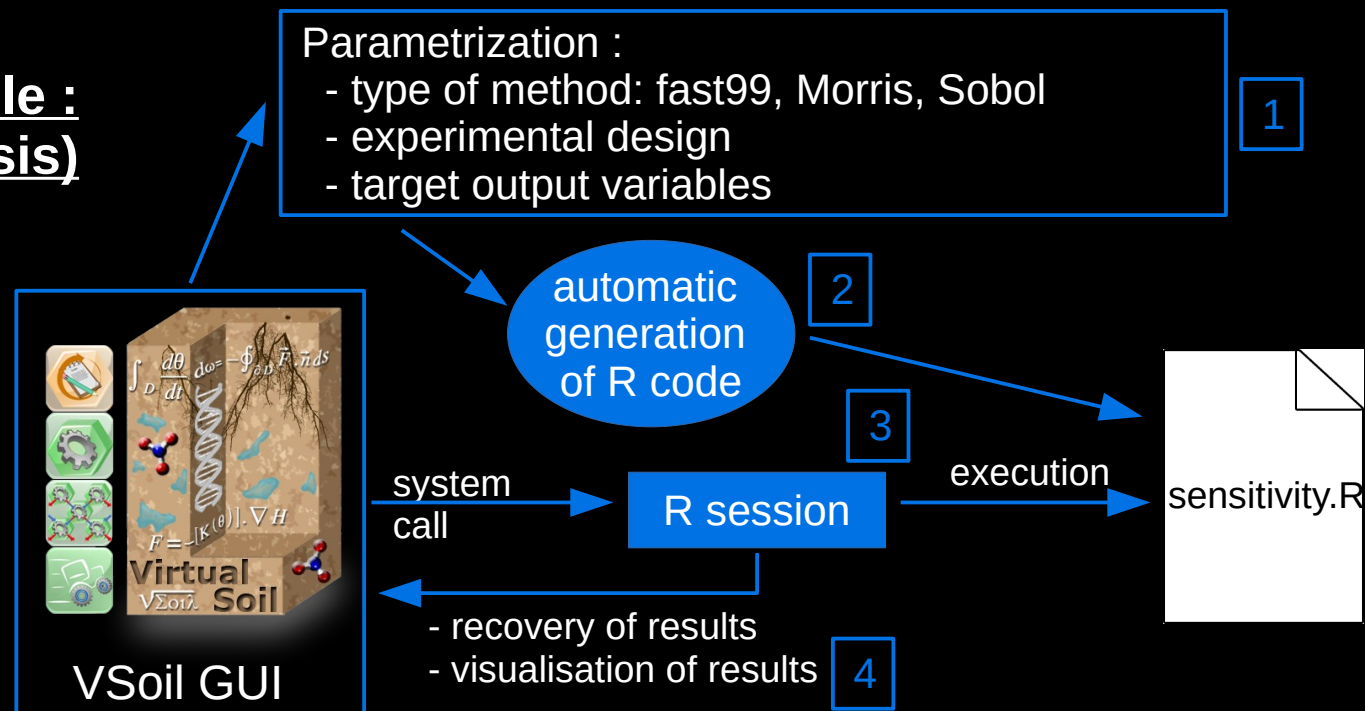
## 2) Model exploration tools: VSoil models interfaced to dedicated R packages

⇒ 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)

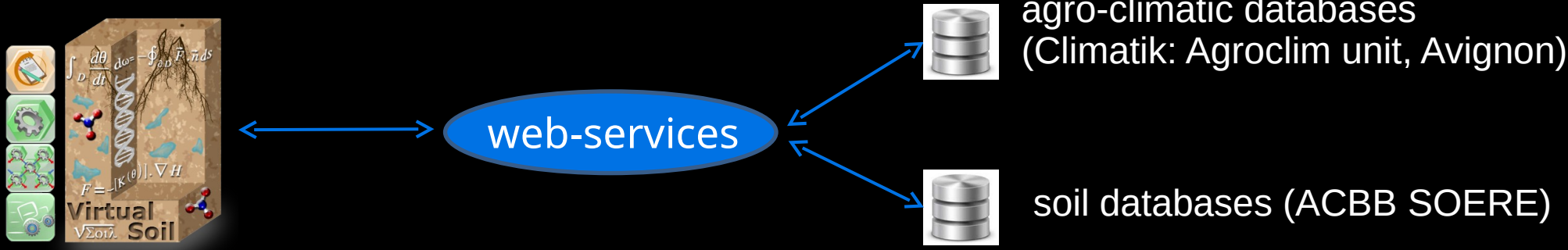
### Scenario (example : sensitivity analysis)



# 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/>



 **RÉPUBLIQUE FRANÇAISE**  
Liberté  
Égalité  
Fraternité

**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 Virtual Soil website interface. At the top left is the logo for the République Française and INRAE. Below it is a navigation menu with 'The project', 'The software platform', 'Project life', 'Download', 'Documentation', and 'Contact'. The 'Download' menu item is highlighted with a red box, and a red arrow points from the word 'download' on the left to this box. The main content area is titled 'Download' and contains text about the software's compatibility with various operating systems (Linux Ubuntu Bionic, Linux Ubuntu Focal, Windows 10, Linux Debian Buster) and links to documentation and videos. At the bottom, it provides links to download the platform for 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

The screenshot shows the 'Documentation' section of the VSoil website. The page has a sidebar 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 describes the documentation for four software components: vsoil-processes, vsoil-modules, vsoil-models, and vsoil-player. It also discusses common features, coupled variables, and tutorials for creating modules. Finally, it mentions other documentations related to specific functionalities and database connections.

**Download**

**Documentation**

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.

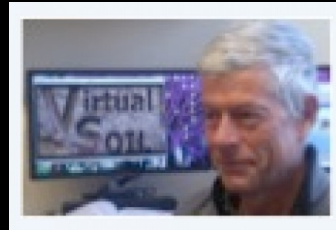
You can access data from the **SOERE ACBB** database through the connection to a web service. This functionality is described in the [connection to SOERE ACBB user manual](#).

# 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 Nouguié  
(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**