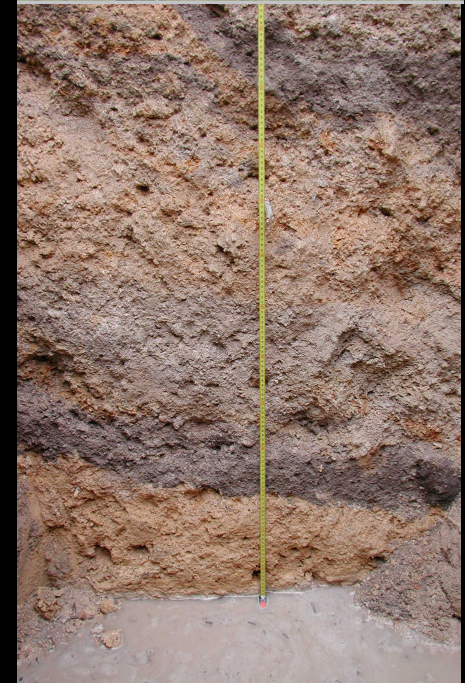


# Presentation of the Virtual Soil (VSoil) project

-  
Workshop IMAE  
Lyon, 4 - 6 April 2023

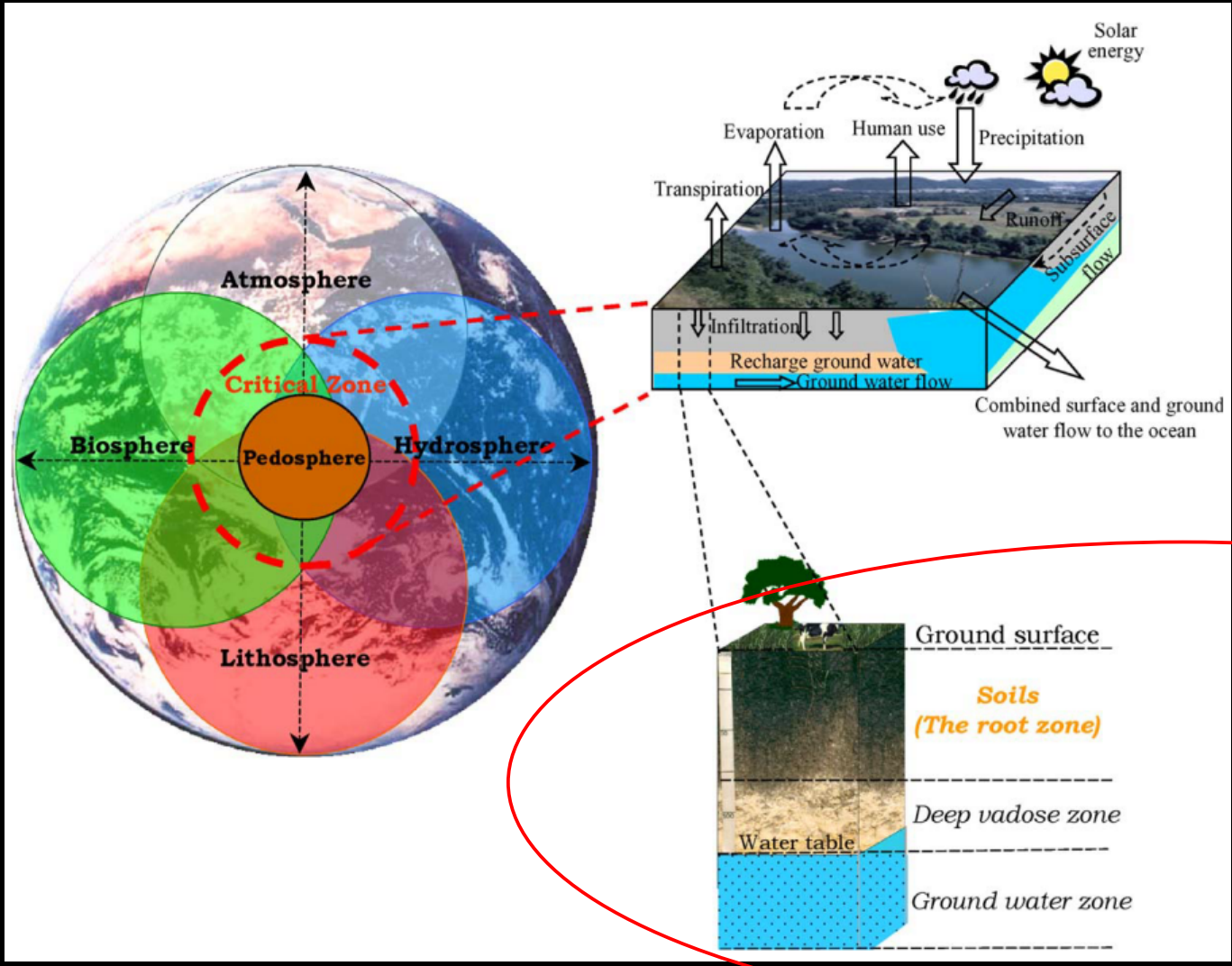
-  
Nicolas Beudez and Nicolas Moitrier



# Context: soil



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.



- Context:
- climate change;
  - change of use;
  - evolution.

- 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



A **survey** conducted between 2006 and 2008 within the Environment and Agronomy department of INRA to **identify the needs in terms of soil functioning modelling**. It concluded that:

- scientists want to develop models that **couple mechanisms**:
  - of different natures (water / solutes / gaz / heat transfer, earthworms, particle transport, ...);
  - at different scales of time and space;
- ➔ 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.

# Objectives



Create a structure to:

- **host** and **share** models;
- **assist** in the development of new models;
- **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;
- **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 collaborations**.

# Basic concepts



The **processes** take place in the soil (physical, chemical or biological), can be described (example: water transfer) and have **input / output variables**.

A **module** is a computer representation of a process. Several representations of the same process are possible.

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...

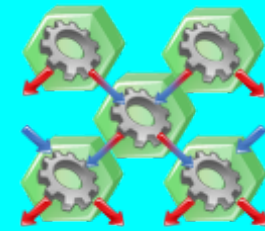
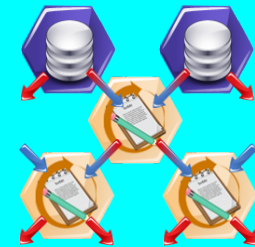
Processes

...encoded in modules,

...form skeletons,

...to create models

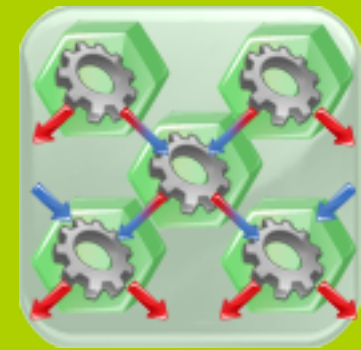
...and run simulations



vsoil-processes



vsoil-modules



vsoil-models



vsoil-player

...to softwares



# The VSoil software components (1/4)



## 1) vsoil-processes:



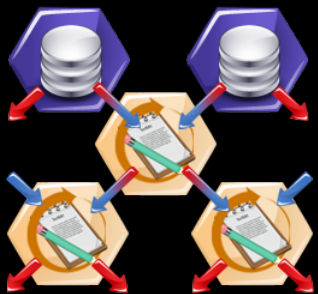
Phenomena are called **processes** (examples: bioturbation, canopy water transfer, evapotranspiration, heat transport and balance, organic matter dynamics, ...).



Some processes are **external**.



Interactions between processes are detected using **inputs** and **outputs**.



Processes with their inputs and outputs produce graphs: **skeletons**.

**vsoil-processes**

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

**58 official processes**

# The VSoil software components (2/4)



## 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**

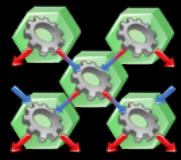
**Standardised languages:  
Fortran / C++**

**141 official modules**

# The VSoil software components (3/4)



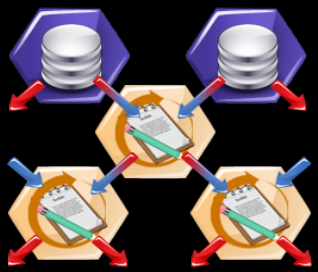
## 3) vsoil-models:



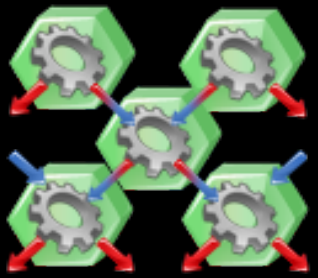
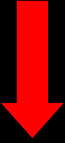
For each process...



... a module is selected.



A **model** is based on a skeleton.



A **model** is an ordered set of modules.

**vsoil-models**

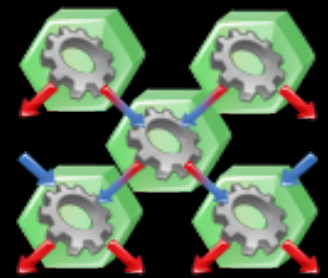
- Module selection
- Generation of the main
- Generation of the GUI
- Execution
- Visualisation
- Backup
- Modification

20 official models

# The VSoil software components (4/4)



## 4) vsoil-player:



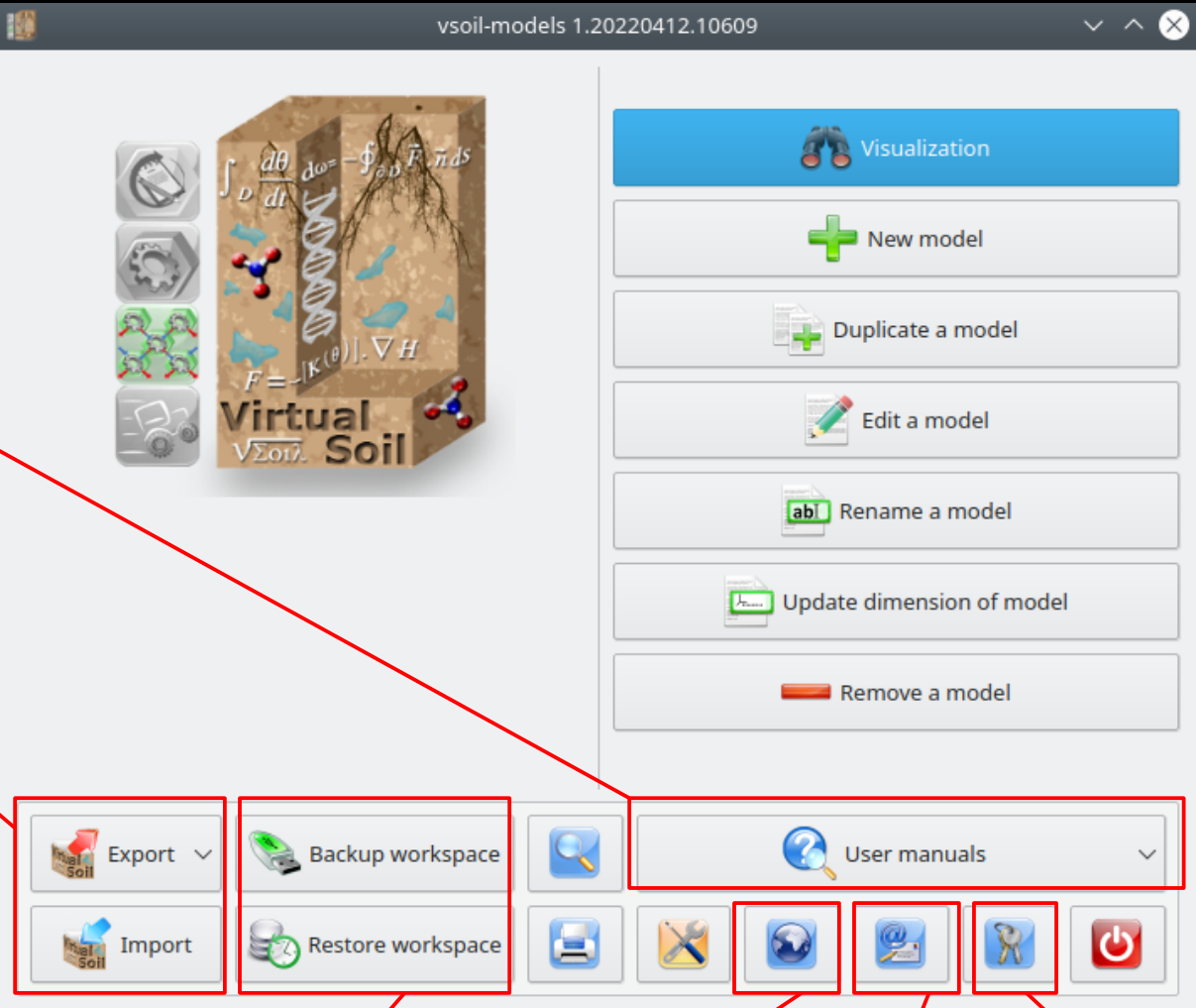
A model already built.



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**

# A collaborative tool



online documentations (softwares and tutorials)

exchange of « user » objects

backup and restoration

access to the website

contact and support

license and charter

# Advantages of VSoil (1/3)



## 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. A dialog box titled "Connect to remote host" is open, with the "Enable remote connection" checkbox checked. The host is set to "vsoil-calcul@Avignon (147.100.9.5)", the port is "22", the login is "nbeudez", and the password is masked with dots. The scheduler is set to "none". Below the form 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, there is a "vsoil tool sed found" section and a "Checking vsoil tool awk" section. The awk section shows the command `/usr/bin/test -x /usr/bin/awk && /usr/bin/awk -W version` and the output: "GNU Awk 5.0.1, API: 2.0 (GNU MPFR 4.0.2, GNU MP 6.2.0) Copyright (C) 1989, 1991-2019 Free Software Foundation." There are "Check remote tools" and "Close" buttons at the bottom right of the dialog.

# Advantages of VSoil (2/3)



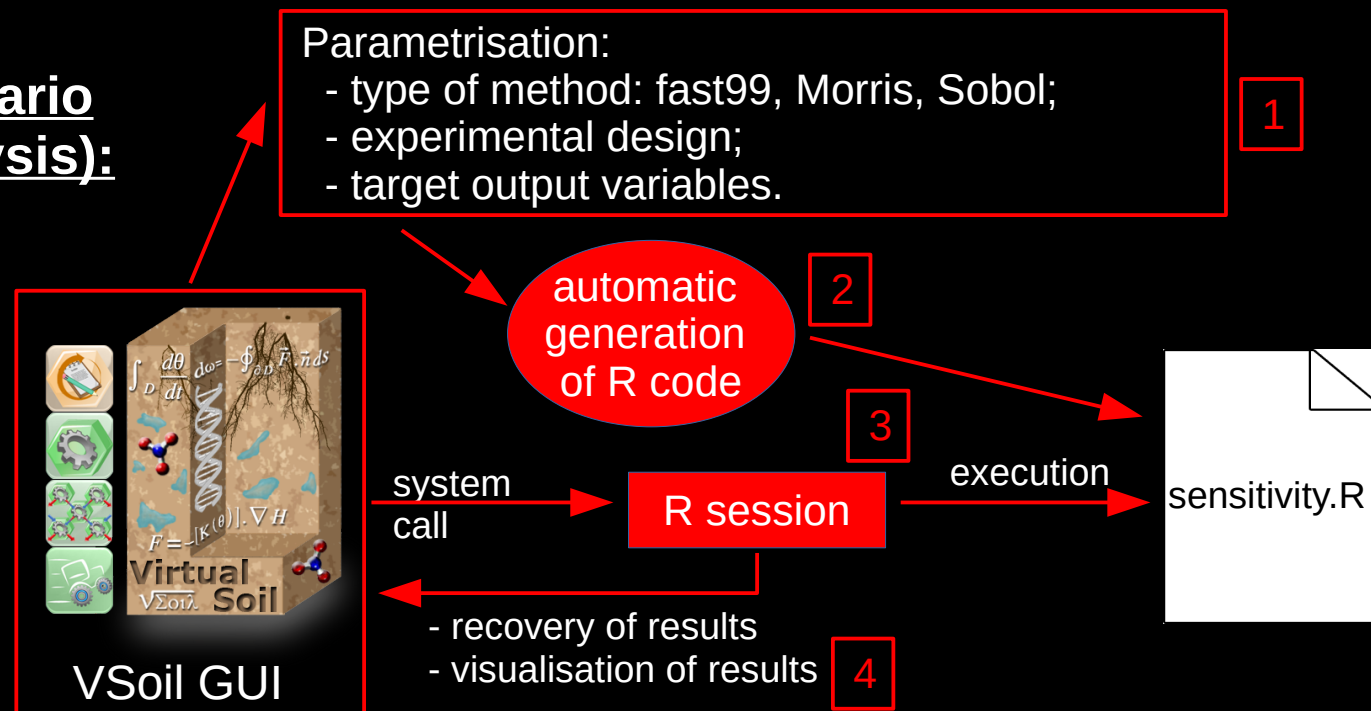
## 2) **Model exploration** tools: VSoil models interfaced to dedicated **R packages**

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

⇒ different algorithms for **parameter estimation**:

- Levenberg-Marquardt (*minpack.lm*);
- SCE-UA (Shuffle Complex Evolution – Uncertainty Analysis) (*rtop*);
- DREAM (Differential Evolution Adaptive Metropolis) (*dream*);
- DREAMzs (Differential Evolution Adaptive Metropolis) (*BayesianTools*).

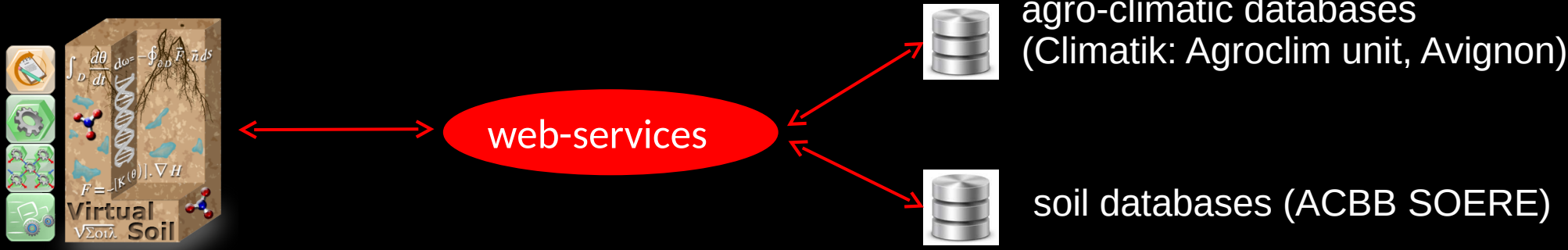
### Example of scenario (sensitivity analysis):



# Advantages of VSoil (3/3)



## 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 »)



# Examples of realisations using VSoil



1) **OC VGEN model**: to simulate the soil carbon dynamics over long periods of time with the aim of moving towards a model of soil evolution in response to anthropogenic actions and climate change.

*Saba Keyvansokouhi, Sophie Cornu (CEREGE, Aix-en-Provence), 2019*

2) **ForestOAD model**: to predict the humidity of a layer of soil on the surface according to weather predictions in order to optimise forestry machine operations and avoid problems of soil degradation and compaction. This model will be used in a **decision-making tool for forestry professionals** (work in progress).



*Manon Martin, Mostafa Moradzadeh (EMMAH, Avignon), since 2016*

3) **MIPP (2015-2017) and RIPP-Viti (since 2020) projects**: modelling of pesticide fate at the landscape scale to aid decision making

⇒ **communication** between:

- **OpenFLUID**: works on transfers at the level of the catchment area;
- **VSoil**: builds a local model;
- **FIDES**: simulates the air transport of molecules.

# Resources (1/3)

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



**RÉPUBLIQUE FRANÇAISE** **INRAE**  
*Liberté  
Égalité  
Fraternité*

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

- > **Mostafa Moradzadeh** (INRAE, EMMAH, Avignon) joined the VSoil project as a **new modeler**. He works on the **VSoilForOAD project** since April 2022 until the end of April 2023 in replacement of **Manon Martin** who found a new job. Mostafa more precisely carries out some **sensitivity analysis** in order to identify the relative influence of some parameters of the model developed in this project (climatic, soil, vegetation, phenological and mulch parameters, and boundary conditions) on a set of model outputs produced by the module implementing the **"soil praticability" process** (saturation index, praticability index and drying slope). To do that, two methods implementing the **Monte Carlo estimation of the Sobol' indices**, named *soboljansen* and *soboSalt* (from "sensitivity" R package), were added in the list of R sensitivity analysis methods available in VSoil.  
25/08/2022

news

# Resources (2/3)

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



download

The screenshot shows the website interface for Virtual Soil. At the top left is the logo for the République Française and INRAE. The main navigation menu includes 'The project', 'The software platform', 'Project life', 'Documentation', and 'Contact'. Under 'Project life', there are links for 'Home page' and 'Download'. The 'Download' link is highlighted with a red box, and a red arrow points from the word 'download' on the left to this box. The 'Download' section contains the following text:

**Download**

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

- > Linux Ubuntu Bionic (18.04), 64 bits, and ulteriores, 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 ulteriores

Before downloading the plateforme, the Virtual Soil Team recommends 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 plateforme "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 plateforme via these links: [Windows](#) or [Linux](#).

# Resources (3/3)

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

Download

Documentation

Contact

## 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.

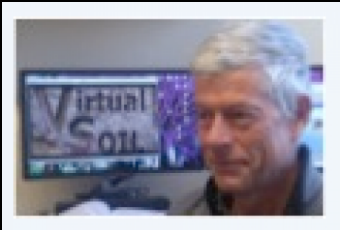
You can access data from the **SOERE ACBB** database through the connection to a web service. This functionality is described in the [connection to SOERE ACBB user manual](#).

# The VSoil team

## Team members:



**Stéphane Ruy**  
(research fellow – scientific leader of the project)



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

try to « replace » François !



**Nicolas Beudez**  
(design engineer – scientific computing)

- scientific team:

- 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**