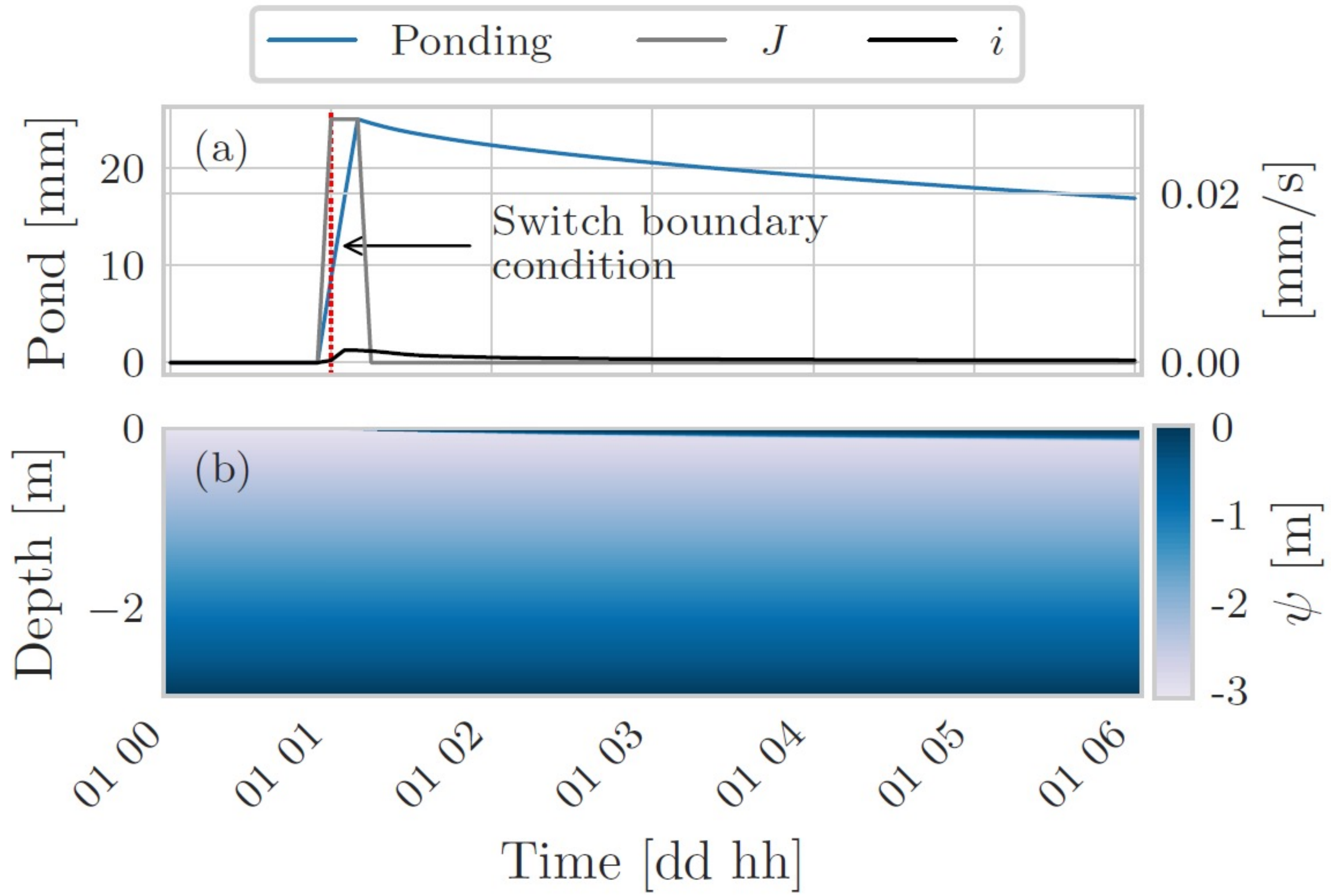
# WHETGEO 1D
# Grid creation

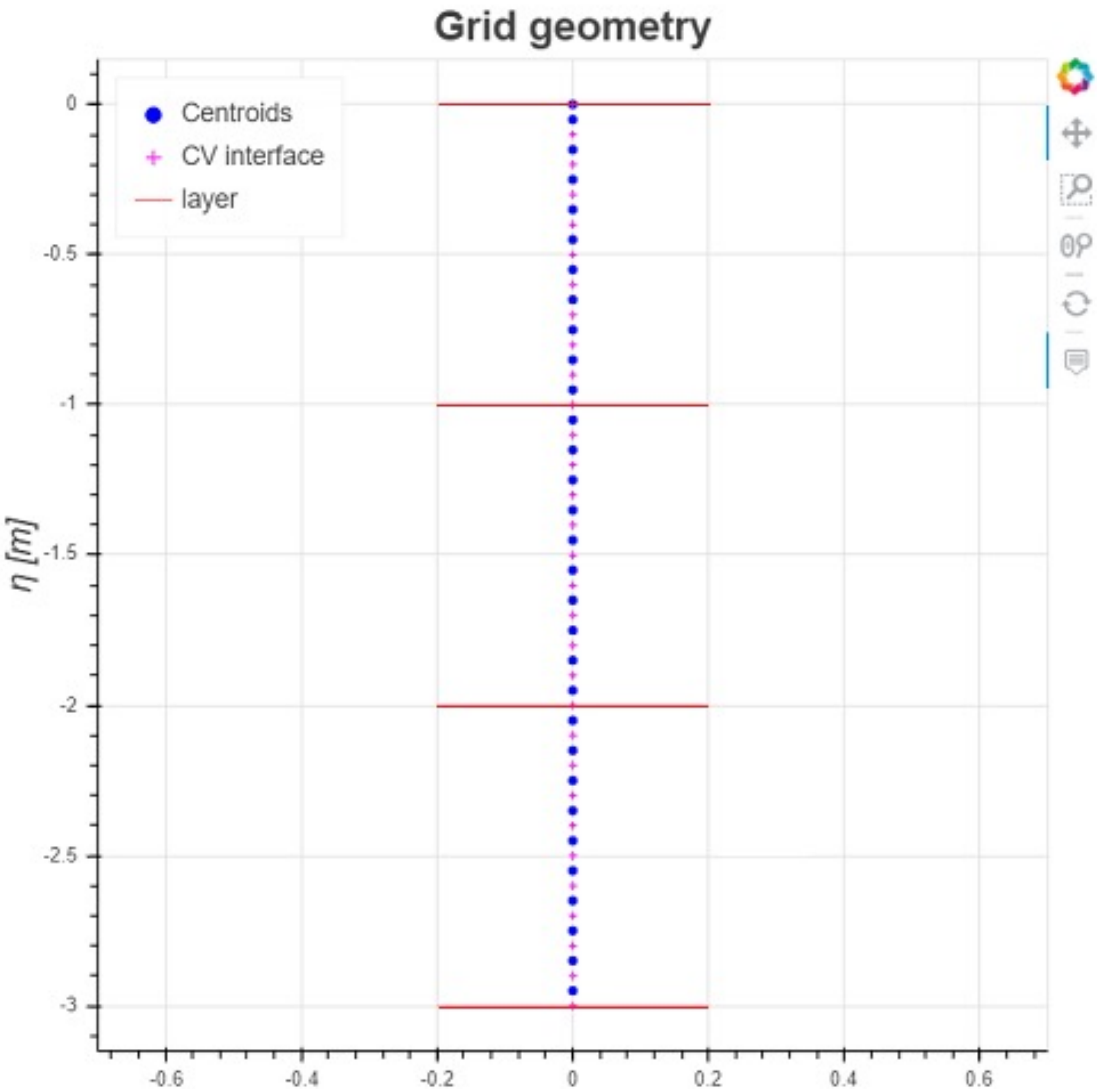
**WHETGEO-1D** model solves the so called mixed - or conservative - formulation of the **Richards' equation**. The novelty regards the use of the nested Newton-Casulli-Zanolli (NCZ) algorithm, (Casulli and Zanolli, 2010) to linearize the nonlinear system resulting from the approximation of the governing equation.



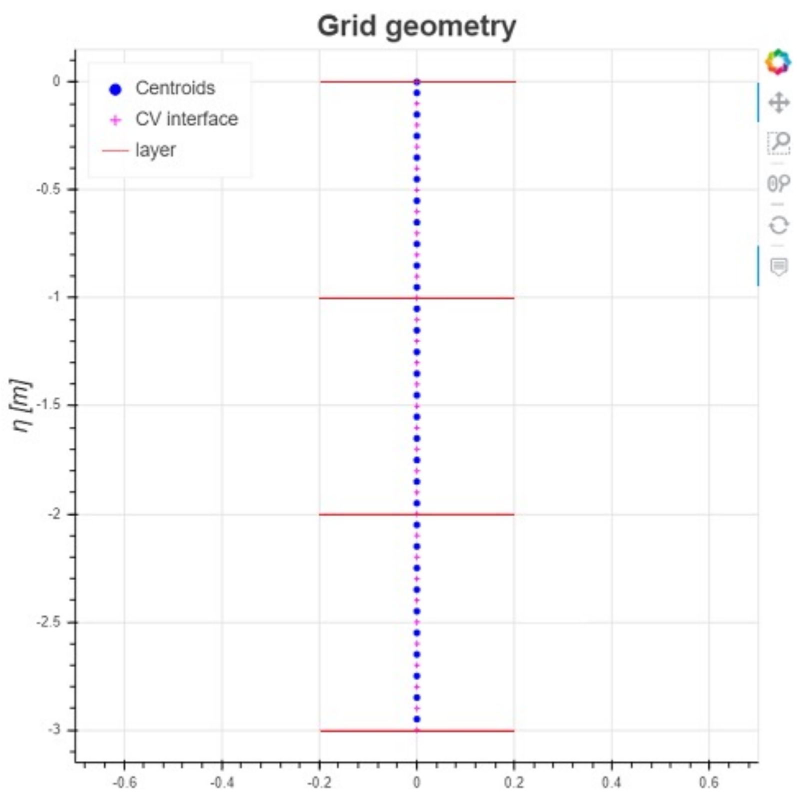

WHETGEO 1D project:

https://github.com/GEOframeOMSProjects/OMS_Project_WHETGEO1D

In order to apply the numerical model it is necessary to define a **grid** on which to calculate the solution.



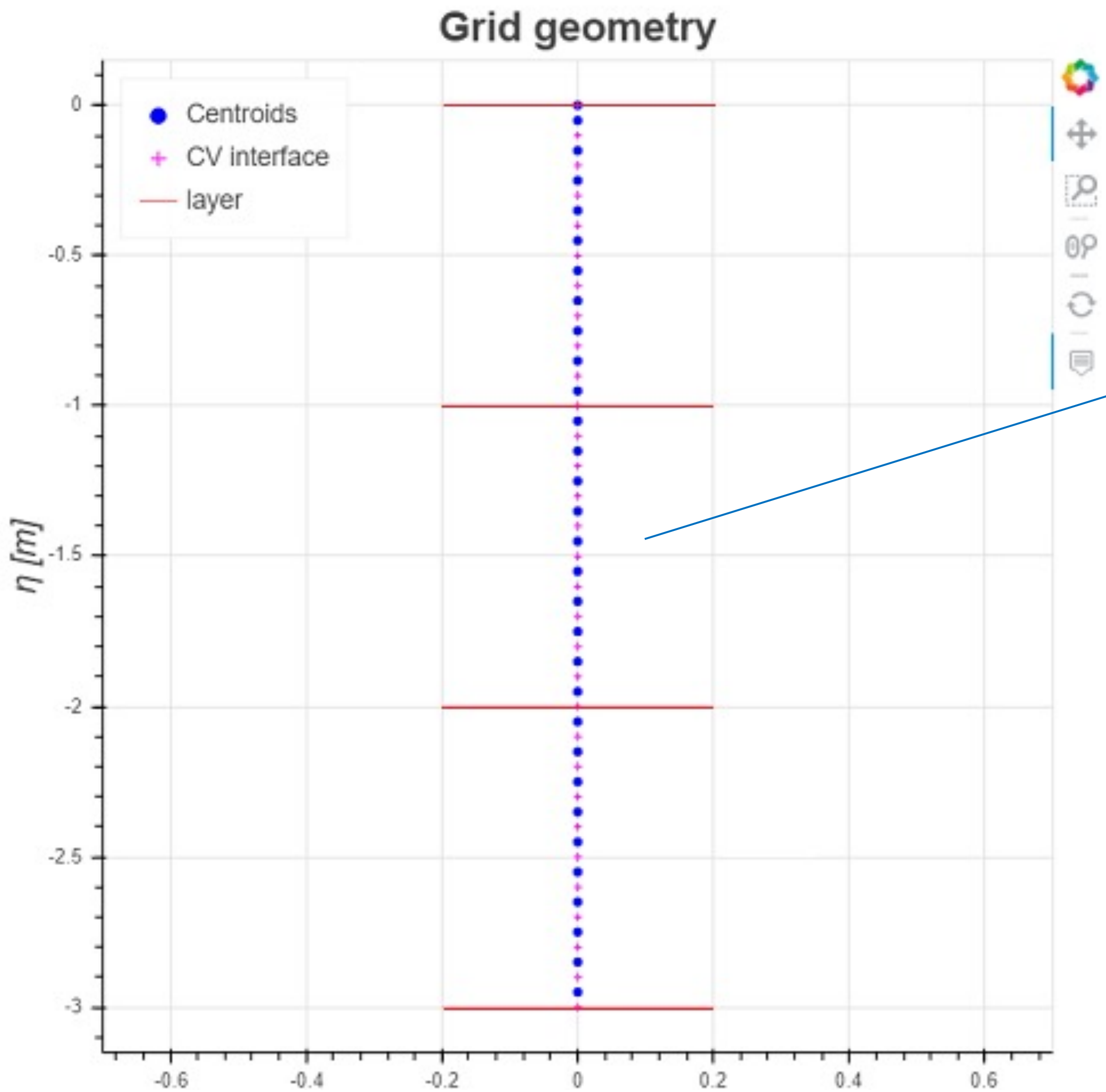
# GRID creation for WHETGEO 1D

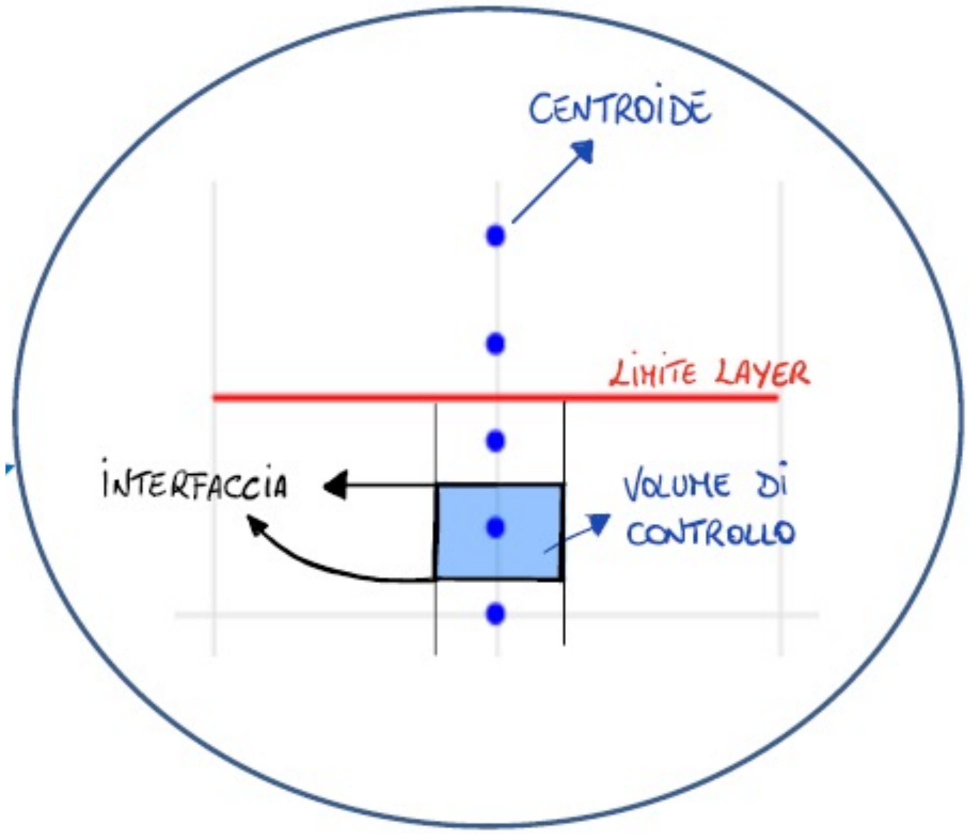



For the column of soil:

- Identify homogeneous **layers** and define their depth
- Determine / hypothesize the **parameters** of the **SWRC**
- Assume an **initial condition** for water **suction**, soil **temperature** (use field measurements, if it is possible).

All this information must be placed in **files .csv**




The grid consists of:

**Layer** → Soil layer

**Control volumes**

Control volume **centroids**

**Interface** between control volumes

The computational grid is created by a **Notebook**

***WHETGEO1D_RichardsCoupled_Computational_grid.ipynb***

It needs as **input** of **3 file .cvs** with the soil column characteristics:

- Geometry of the soil column (*grid_input_file_name.csv*)
- Initial conditions (*ic_input_file_name.csv*)
- SWRC parameters (*parameter_input_file_name.csv*)

**grid_input_file_name.csv**

_grid_Richards_coupled_(

Delimiter: ,

| | Type | eta | K | equationStateID | parameterID |
|---|---|---|---|---|---|
| 1 | L | 0 | 30 | 1 | 1 |
| 2 | L | -1 | 20 | 1 | 2 |
| 3 | L | -2 | 10 | 1 | 3 |
| 4 | L | -3 | nan | nan | nan |

## Type

**L:** identifies a layer. The first and last row must always be layers (L).

**M:** identifies a suction measurement point. This point must belong to the computation domain both because it is to be used to reconstruct the initial suction profile and to validate the calculated solution.

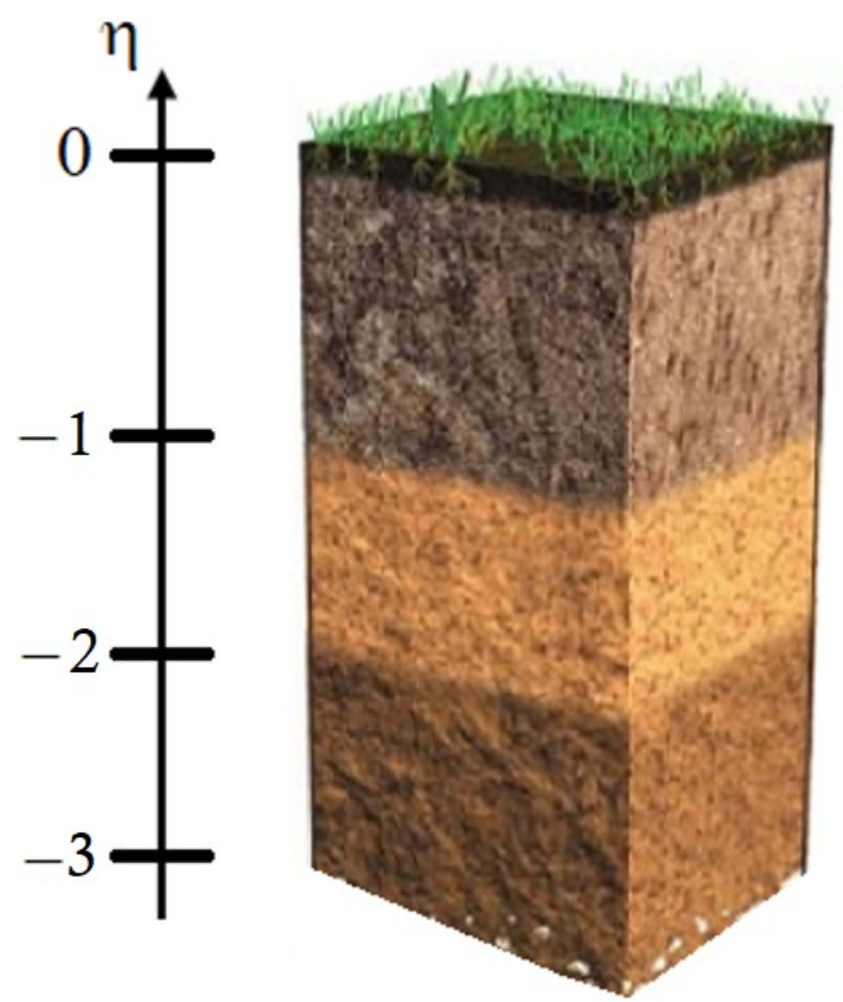
**grid_input_file_name.csv**

**eta:** is the upward positive vertical coordinate with origin fixed to the surface [$m$]

_grid_Richards_coupled_(

Delimiter: ,

| | Type | eta |
|---|---|---|
| 1 | L | 0 |
| 2 | L | -1 |
| 3 | L | -2 |
| 4 | L | -3 |

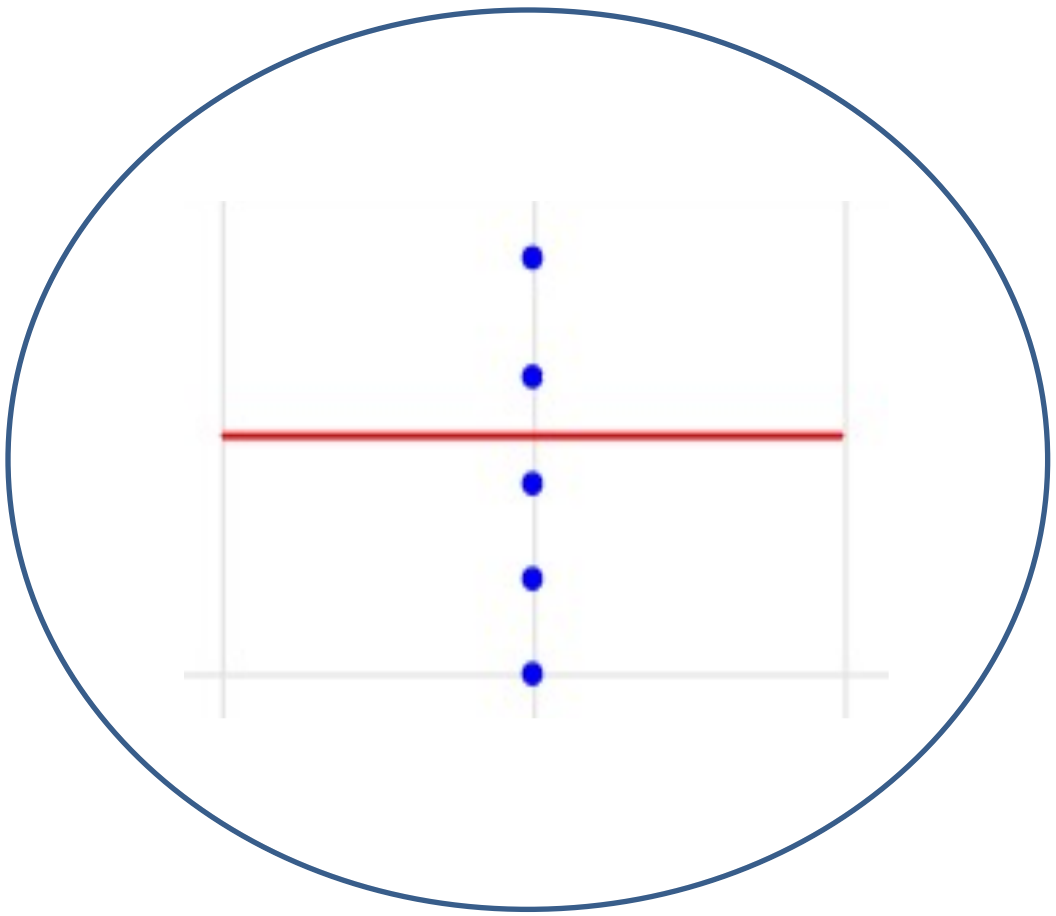


**grid_input_file_name.csv**

_grid_Richards_coupled_(

Delimiter: ,

| | Type | K |
|---|---|---|
| 1 | L | 30 |
| 2 | L | 20 |
| 3 | L | 10 |
| 4 | L | nan |



**K**: number of control volumes in which the layer is to be discretized

**grid_input_file_name.csv**

_grid_Richards_coupled_(

Delimiter: ,

| | Type | parameterID |
|---|---|---|
| 1 | L | 1 |
| 2 | L | 2 |
| 3 | L | 3 |
| 4 | L | nan |

**parameterID:** number refers to the set of parameter chosen in the *parameter_input_file_name.csv* file

# Grid creation for WHETGEO 1D

**ic_input_file_name.csv**

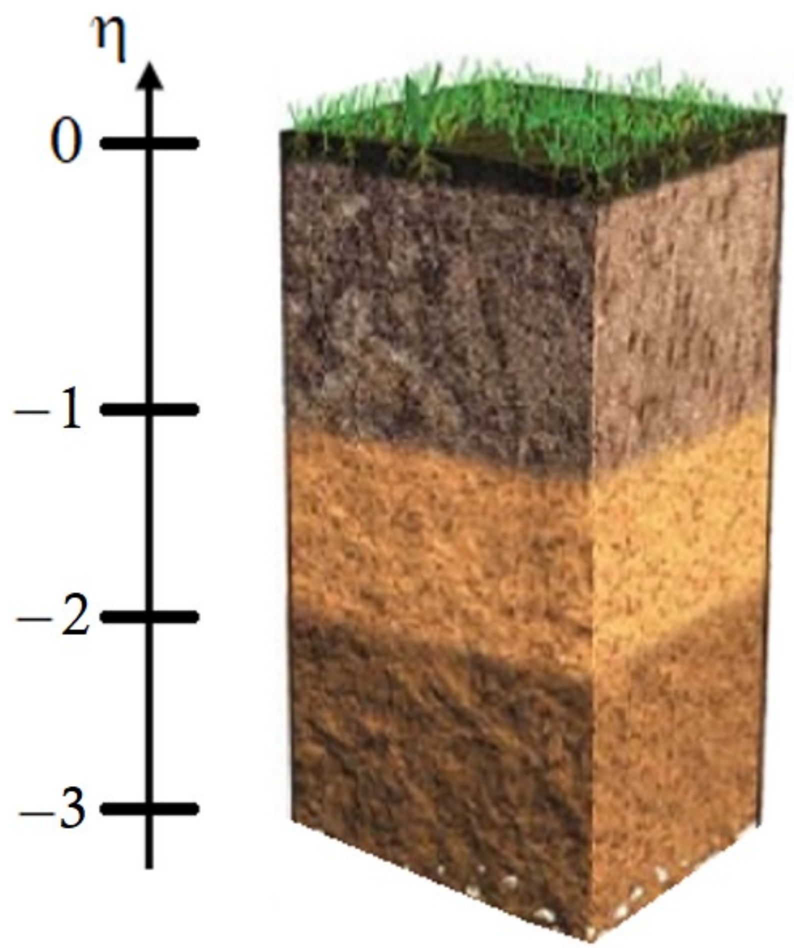
_ic.csv

Delimiter: ,

| | eta | Psi0 | T0 |
|---|---|---|---|
| 1 | -0.0 | -3.0 | 273.15 |
| 2 | -3.0 | 0.0 | 273.15 |
| 3 | | | |

**Psi0:** In this column you must enter the value of the initial condition for the suction.

**T0:** In this column you must enter the value of the initial condition for the soil temperature.



**parameter_input_file_name.csv**

The SWRC parametrization implemented are:

- **Van Genuchten**
- **Brooks - Corey**
- **Kosugi**
- **Romano**

**parameter_input_file_name.csv**

# Van Genuchten

$$\theta(\psi) = \begin{cases} \theta_r + (\theta_s - \theta_r)[1 + (|\alpha\psi|)^n]^{-m} & \text{if } \psi < 0 \\ \theta_s + \rho g(\alpha_{ss} + \theta_s \beta_{ss})\psi & \text{otherwise} \end{cases}$$

| Symbol | Physical quantity | Unit | Input |
|---|---|---|---|
| $\theta_r$ | residual water content | [-] | thetaR |
| $\theta_s$ | water content at saturation | [-] | thetaS |
| $\alpha$ | Van Genuchten parameter | [$m^{-1}$] | alpha |
| $n$ | Van Genuchten parameter ($> 1$) | [-] | n |
| $m = 1 - \frac{1}{n}$ | Van Genuchten parameter | [-] | not required |
| $\alpha_{ss}$ | matrix compressibility | [] | alphaSpecificStorage |
| $\beta ss$ | water compressibility | [] | betaSpecificStorage |
| $K_s$ | saturated hydraulic conductivity | [$m\ s^{-1}$] | Ks |

Richards_VG.csv

Delimiter: ,

| | thetaS | thetaR | n | alpha | alphaSpecificStorage | betaSpecificStorage | Ks |
|---|---|---|---|---|---|---|---|
| 1 | #1 Sand | Bonan 2018 Tab 8.3 | | | | | |
| 2 | 0.43 | 0.045 | 2.68 | 14.5 | 0.0 | 0.0 | 8.25e-05 |
| 3 | #2 Loamy sand | Bonan 2018 Tab 8.3 | | | | | |
| 4 | 0.41 | 0.057 | 2.28 | 12.4 | 0.0 | 0.0 | 4.0528e-05 |
| 5 | #3 Sandy loam | Bonan 2018 Tab 8.3 | | | | | |
| 6 | 0.41 | 0.065 | 1.89 | 7.5 | 0.0 | 0.0 | 1.2278e-05 |

**parameter_input_file_name.csv**

# Brooks - Corey

$$\theta(\psi) = \begin{cases} \theta_r + (\theta_s - \theta_r)\left(\dfrac{\psi_D}{\psi}\right)^n & \text{if } \psi < \psi_D \\ \theta_s + \rho g(\alpha_{ss} + \theta_s \beta_{ss})\psi & \text{otherwise} \end{cases}$$

| Symbol | Physical quantity | Unit | Input |
|---|---|---|---|
| $\theta_r$ | residual water content | [-] | thetaR |
| $\theta_s$ | water content at saturation | [-] | thetaS |
| $\psi_D$ | Brooks and Corey parameter | [m] | psiD |
| $n$ | Brooks and Corey parameter | [-] | n |
| $\alpha_{ss}$ | matrix compressibility | [] | alphaSpecificStorage |
| $\beta ss$ | water compressibility | [] | betaSpecificStorage |
| $K_s$ | saturated hydraulic conductivity | [m $s^{-1}$] | Ks |

Richards_BC.csv

Delimiter: ,

| | thetaS | thetaR | n | psiD | alphaSpecificStorage | betaSpecificStorage | Ks |
|---|---|---|---|---|---|---|---|
| 1 | #sand | | | | | | |
| 2 | 0.36689 | 0.05385 | 2.54723 | -0.334 | 0.0 | 0.0 | 5.40583E-05 |
| 3 | #clay | | | | | | |
| 4 | 0.46291 | 0.06707 | 1.65275 | -2.247 | 0.0 | 0.0 | 5.18521E-06 |
| 5 | #silt | | | | | | |
| 6 | 0.48664 | 0.13335 | 1.34174 | -1.397 | 0.0 | 0.0 | 9.73284E-07 |

**parameter_input_file_name.csv**

# Kosugi

$$\theta(\psi) = \begin{cases} \dfrac{\theta_s - \theta_r}{(2\pi)^{1/2}\sigma(-\psi)} \exp\left\{ -\dfrac{[\ln(\psi/\psi_m)]^2}{2\sigma^2} \right\} & \text{if } \psi < \psi_D \\ \theta_s + \rho g(\alpha_{ss} + \theta_s \beta_{ss})\psi & \text{otherwise} \end{cases}$$

| Symbol | Physical quantity | Unit | Input |
|---|---|---|---|
| $\theta_r$ | residual water content | [-] | thetaR |
| $\theta_s$ | water content at saturation | [-] | thetaS |
| $\psi_m$ | median value | [m] | psiMedian |
| $\sigma$ | dimensionless parameter | [-] | sigma |
| $\alpha_{ss}$ | matrix compressibility | [] | alphaSpecificStorage |
| $\beta ss$ | water compressibility | [] | betaSpecificStorage |
| $K_s$ | saturated hydraulic conductivity | [m $s^{-1}$] | Ks |

Richards_Kosugi.csv

Delimiter: ,

| | thetaS | thetaR | psiMedian | sigma | alphaSpecificStorage | betaSpecificStorage | Ks |
|---|---|---|---|---|---|---|---|
| 1 | #loam | | | | | | |
| 2 | 0.42 | 0.09 | -4.9 | 0.98 | 0.0 | 0.0 | 1.19444E-06 |
| 3 | #sandy-loam | | | | | | |
| 4 | 0.41 | 0.27 | -2.63 | 1.79 | 0.0 | 0.0 | 8.3611E-06 |
| 5 | #silt | | | | | | |
| 6 | 0.38 | 0.01 | -2.63 | 2.74 | 0.0 | 0.0 | 4.4444e-05 |

**parameter_input_file_name.csv**

# Romano

$$\theta(\psi) = \begin{cases} \theta_r + (\theta_s - \theta_r)\left\{ w \left\{ \frac{1}{2}\left[ \frac{\ln(\psi/\psi_{m1})}{\sigma_1\sqrt{2}} \right] \right\} + (1-w)\left\{ \frac{1}{2}\left[ \frac{\ln(\psi/\psi_{m2})}{\sigma_2\sqrt{2}} \right] \right\} \right\} & \text{if } \psi < \psi_D \\ \theta_s + \rho g(\alpha_{ss} + \theta_s \beta_{ss})\psi & \text{otherwise} \end{cases}$$

| Symbol | Physical quantity | Unit | Input |
|---|---|---|---|
| $\theta_r$ | residual water content | [-] | thetaR |
| $\theta_s$ | water content at saturation | [-] | thetaS |
| $w$ | weighting factor | [-] | w |
| $\psi_{m1}$ | median value of water suction texture | [m] | h1 |
| $\psi_{m2}$ | median value of water suction structure | [m] | h2 |
| $\sigma_1$ | standard deviation texture | [-] | sigma1 |
| $\sigma_2$ | standard deviation structure | [-] | sigma2 |
| $\alpha_{ss}$ | matrix compressibility | [] | alphaSpecificStorage |
| $\beta ss$ | water compressibility | [] | betaSpecificStorage |
| $K_s$ | saturated hydraulic conductivity | [m $s^{-1}$] | Ks |

Richards_Romano.csv

Delimiter: ,

| | thetaS | thetaR | w | sigma1 | sigma2 | h1 | h2 | alphaSpecificStorage | betaSpecificStorage | Ks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | #loam | | | | | | | | | |
| 2 | 0.39 | 0.02 | 0.4 | 0.2 | 0.8 | -10.25 | -1.4 | 0.0 | 0.0 | 0.0000981 |
| 3 | #sandy-loam | | | | | | | | | |
| 4 | 0.2 | 0.04 | 0.5 | 0.4 | 0.9 | -1.25 | -0.04 | 0.0 | 0.0 | 0.0000981 |
| 5 | #silt | | | | | | | | | |
| 6 | 0.5 | 0.01 | 0.45 | 0.3 | 0.8 | -2.3 | -0.5 | 0.0 | 0.0 | 0.000006 |

Create all the input.csv files

run the **notebook**

***WHETGEO1D_RichardsCoupled_Computational_grid.ipynb***

**Notebook** *WHETGEO1D_RichardsCoupled_Computational_grid.ipynb*

# Create the grid for WHETGEO 1D Richards coupled with shallow water

```
-Author: Niccolò Tubini and Riccardo Rigon
-License: this work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License
```

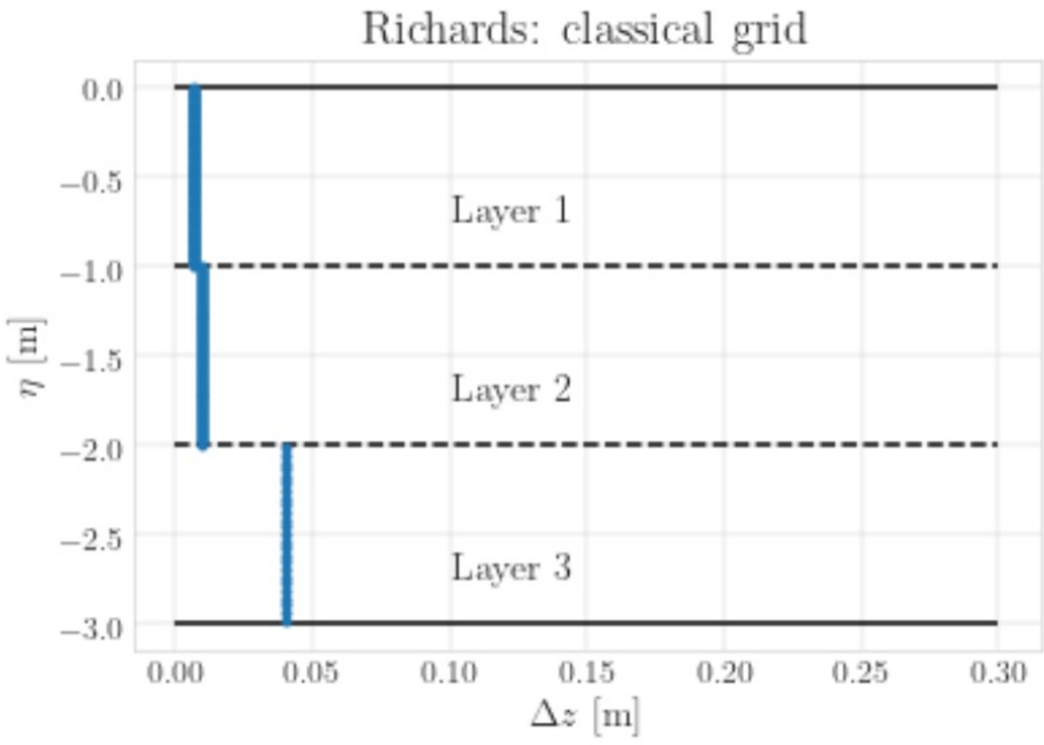
---

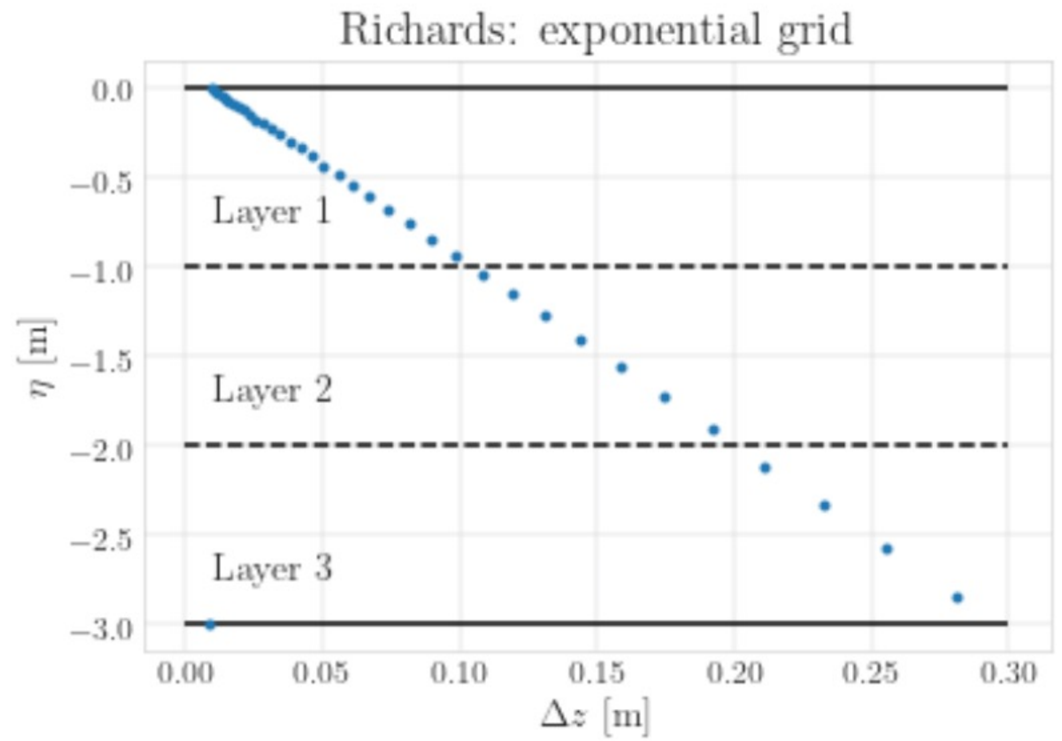
```
grid_input_file_name = project_path + "/data/Grid_input/_grid_Richards_coupled.csv"

ic_input_file_name = project_path + "/data/Grid_input/_ic.csv"

parameter_input_file_name = project_path + "/data/Grid_input/Richards_VG.csv"

dictionary_input_file_name = project_path + "/data/Grid_input/dictionary.csv"

grid_type = 'classical'
```

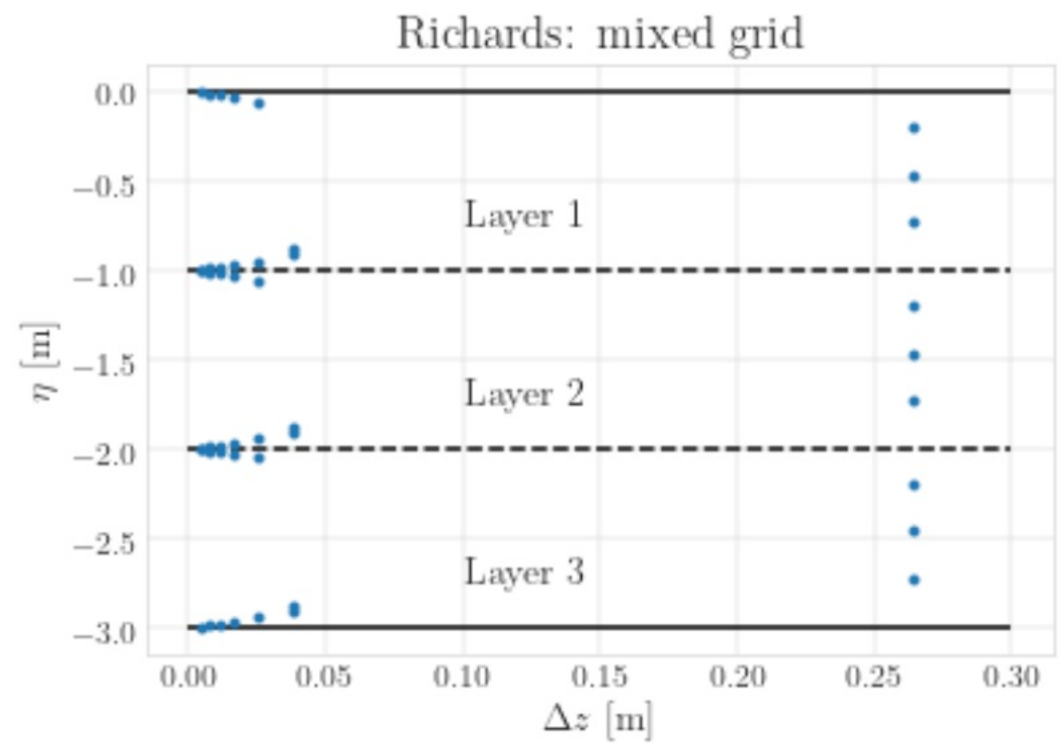
**Notebook** *WHETGEO1D_RichardsCoupled_Computational_grid.ipynb*

**grid_type**: string defining how to discretize the 1D domain. You can choose among:

> `classical`
>
> `exponential`
>
> `mixed`



**Notebook** *WHETGEO1D_RichardsCoupled_Computational_grid.ipynb*

**dz_min**: thickness of the first layer (for `exponential` and `mixed`)

**dz_max**: larger thickness of the grid (for `mixed`)

**b**: growth rate (for `exponential` and `mixed`)

**psi_interp_model**: string defining the type of the 1D interpolation function used to define the initial condition for water suction

> https://docs.scipy.org/doc/scipy/reference/generated/scipy.interpolate.interp1d.html#scipy.interpolate.interp1d

**T_interp_model**: string defining the type of the 1D interpolation function used to define the initial condition for temperature

> https://docs.scipy.org/doc/scipy/reference/generated/scipy.interpolate.interp1d.html#scipy.interpolate.interp1d

**water_ponding_0**: double [m] defining the water suction at soil surface. If it is larger than $0$ means that there is water ponding.

**T_water_ponding_0**: double [K] defining the temperature at soil surface.

```
dz_min = 0.005

dz_max = 0.1

b = 0.1

psi_interp_model = "linear"

T_interp_model = "linear"

water_ponding_0 = -3.0

T_water_ponding_0 = 273.15
```

**Notebook** *WHETGEO1D_RichardsCoupled_Computational_grid.ipynb*

```
output_file_name =  project_path + "/data/Grid_NetCDF/Richards_coupled_VG2.nc"

output_title = '''Computational grid to solve the Richards' equation with the surface
                    boundary condition defined coupling with the shallow water.
                  '''
output_summary = '''

Type,eta,K,equationStateID,parameterID
L,0,150,1,1
L,-1,50,1,2
L,-2,10,1,3
L,-3,nan,nan,nan

eta,Psi0,T0
-0.0,-3.0,273.15
-3.0,0.0,273.15

water_ponding_0 = -3.0

T_water_ponding_0 = 273.15

'''

output_date = ''

output_institution = 'GEOframe'
```

Ulrici, 2000 ?

**WHETGEO 1D**
Author: Niccolò Tubini
Executables: WHETGEO-1D v0.98

For more general information regarding the use of GEOframe programs and models, please see:
GEOframe essentials
GEOframe Winter School