Groundwater

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FREEWAT, a Free and Open Source, GIS-Integrated, Hydrological Modeling Platform

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Introduction

The FREEWAT modeling platform (www.freewat.eu) is an open source and public domain GIS integrated modeling environment, developed as a plugin of the well-known, free, and open source GIS desktop software QGIS (QGIS Development Team 2017). It is conceived as a canvas, where several simulation codes, related to the hydrological cycle, hydrogeochemical, or economic-social processes, are integrated in a unique GIS project. It combines the power of QGIS with data analysis tailored toward hydrological and hydrogeological data and with numerical simulations for both water quantity and quality. FREEWAT takes advantage of the capabilities of GIS geoprocessing and postprocessing tools for spatial data analysis and connects them to numerical simulation software. FREEWAT is expected to enhance stakeholders' capabilities in dealing with water resources management issues, as required by the Water FrameWork Directive in Europe, and similar regulations all around the world (such as the Sustainable Groundwater Management Act in California). The FREEWAT platform is implemented in the framework of the FREEWAT HORIZON 2020 project financed by the EU Commission, aiming at promoting water resource management by simplifying the application of the Water Framework Directive and other EU water-related Directives (Rossetto et al. 2015). The FREEWAT approach aims at creating a common, self-sustaining environment where stakeholders address water-related issues by making use of free and readily applicable Information and Communication Technology tools.

The platform includes both database management tools for pre- and postprocessing different types of data and modeling tools for the simulation of the complete hydrological cycle using open source numerical codes, mainly belonging to the USGS MODFLOW family. In particular, it integrates:

- MODFLOW-2005 (Harbaugh 2005) (with the main packages included, such as WEL, MNW2, CHD, RIV, DRN, EVT, UZF, SFR2, and LAK) (Figure 1a).
- MT3DMS (packages ADV, DSP, SSM), for solute transport in groundwater flow systems, including the UZT Package of the recent MT3D-USGS (Bedekar et al. 2016), for taking into account contaminant fate in the unsaturated zone.
- SEAWAT (Langevin et al. 2007) for the simulation of viscosity and density dependent flow (an example of a seawater intrusion simulation is showed in Figure 1b).
- MODFLOW-OWHM (Hanson et al. 2014), to simulate water management, and to include the specific computation of water demand coming from rural environments and crop acreages.
- Analysis of hydrochemical and hydrogeological data (Figure 2a and 2b).
- Time series processing to support advanced model calibration.
- Sensitivity analysis and parameter estimation, applying UCODE-2014 (Poeter et al. 2014).

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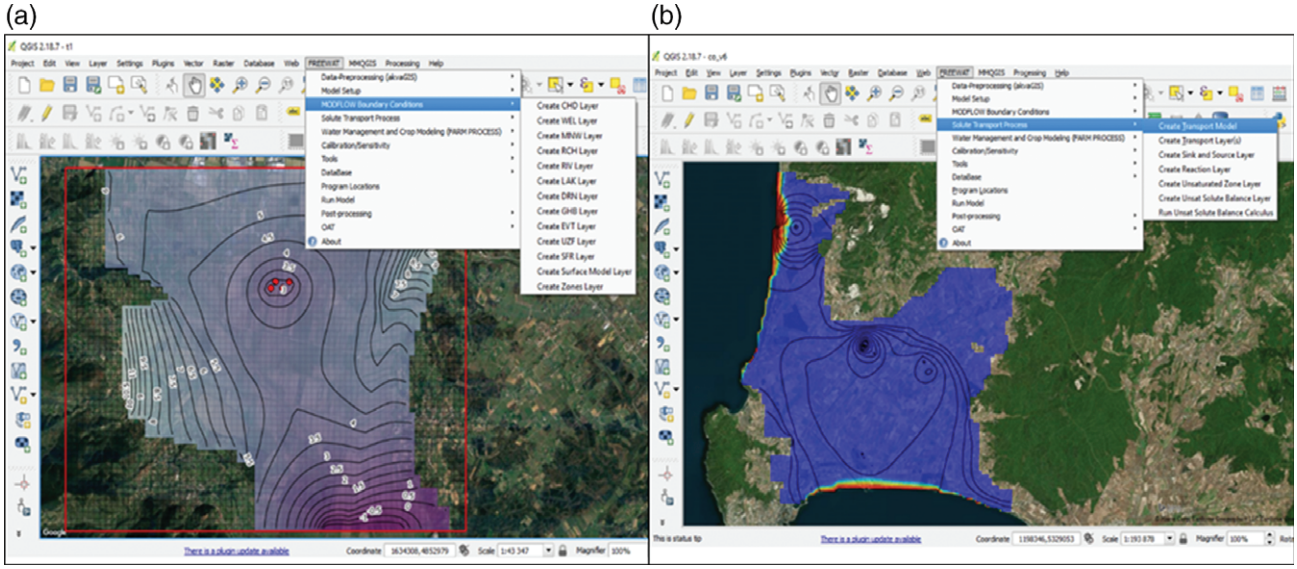

Figure 1. Example of FREEWAT application to simulate groundwater flow with MODFLOW (a) and seawater intrusion with SEAWAT (b).

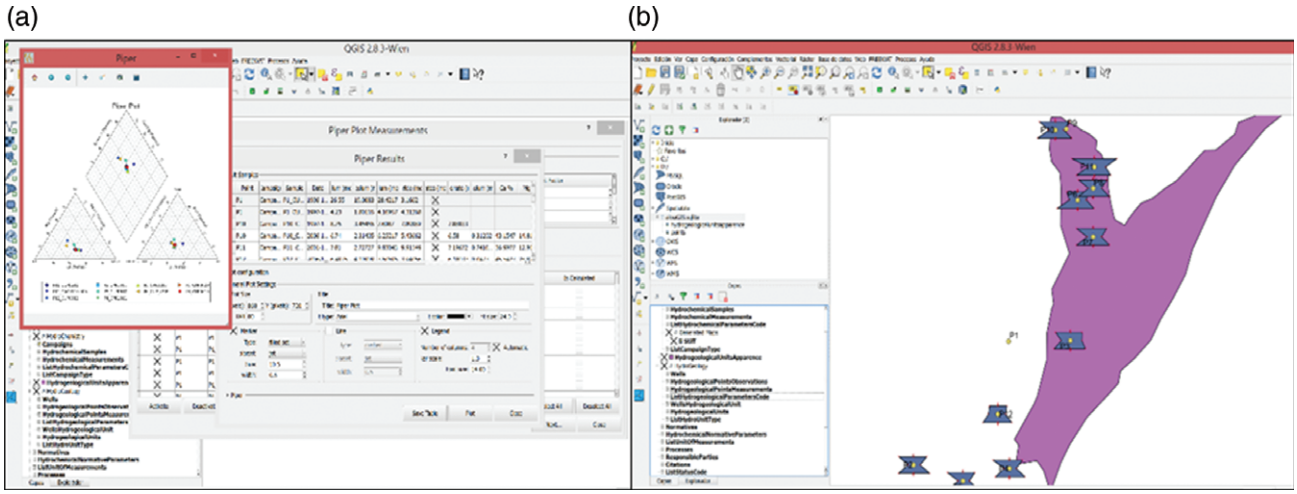

Figure 2. Example of hydrochemical and hydrogeological data analysis in FREEWAT: (a) Piper diagram to understand the hydrochemistry of the water and (b) Stiff diagram to investigate the spatial variation of the composition of the aquifer ions.

For most of the capabilities included, the FREEWAT platform relies on FloPy (Bakker et al. 2016), a Python library allowing to prepare scripts for writing inputs, running and postprocessing MODFLOW, MT3D, SEAWAT, and other MODFLOW-related groundwater programs. Data management and sharing are based on Spatialite Database, whose usage is fully integrated in QGIS: FREEWAT's Users can share their models by sharing a simple SQLite file where all the model information is stored.

The open-source characteristic of the project has significant advantages:

- It is expected to enhance the FREEWAT applications among a variety of stakeholders interested in both data management and analysis and numerical applications.
- It will facilitate data and model sharing across different computing platforms.
- More funds can be redirected to create tailored applications.
- As an open-source initiative, FREEWAT aims at creating a community of developers, at integrating new capabilities, and at maintaining a very lively and innovative environment.

The FREEWAT platform has been successfully applied to 14 selected case studies, these being among the core activities included in the corresponding FREEWAT EU H2020 project (Rossetto et al. 2015). Each case study addresses a specific water management issue:

- nine case studies (in Greece, Italy, Romania, Estonia, Germany, Malta, Czech Republic, Slovenia, and Switzerland) are specifically referred to the application

of the EU Water Framework Directive and other water-related Directives;
- five case studies (in Italy, Spain, Turkey, Ukraine, and Africa) are related to application in rural management, including the application of the EU Nitrates Directive and of the greening aspects of the Common Agricultural Policy.

Partners running the case studies, as well as the growing number of users in Europe and around the world, are providing feedback and suggestions to the FREEWAT Developers: this enhances ongoing improvements of the platform, increasing its stability, capabilities, and usability.

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Authors' Note

The authors do not have any conflicts of interest or financial disclosures to report.

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