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Mantis: A Server Application for Simulating Multi-Century Nitrate and Salt Transport Scenarios in Regional Groundwater Basins

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Abstract

The management of nitrate and salts in groundwater basins needs methods to predict the fate of contaminants through the unsaturated zone and saturated part of the aquifer domain. A number of index and statistical based methods attempt to provide estimations by exploring the relationships between important factors, (e.g. topography, soil, depth to water table etc.) and nitrate and salt concentrations. Other approaches use a physically based methods where the movement of contaminants is simulated through the modeling domain by solving the governing flow and transport equations. The latter are more general but require considerable computational time which makes them inefficient within water management frameworks where hundreds of thousands of scenarios need to be considered. We developed a server application that allows rapid evaluation of nitrate and salt transport scenarios in agricultural groundwater basins. Scenarios are user-defined nitrate and salt loading futures.

The application computes historic, current, and future nitrate and salinity concentrations across features of interests – domestic, urban, and irrigation wells, and stream reaches receiving groundwater. Server data are categorized into spatial data and tabular data. Spatial data are converted to a raster type that allows rapid execution of spatial queries. Typical raster data include unsaturated travel time, groundwater recharge rates, nitrate and salt loading concentration histories etc. Tabular data consist of well data which include the well locations and the well source area in a form of discrete points and relevant stream reaches. For each source point we precalculated the response of a unit input load to the well and the response function is archived in the Mantis as the mean and standard deviation of a lognormal distribution. This architecture results in a robust modeling framework where multi-century transport simulation can be executed within a few seconds. The Mantis framework is applied to the Central Valley groundwater basin to predict future nitrate concentration under different land management scenarios.

Motivation

- Modeling the fate of Nitrate and Salts in groundwater basins is a critical step in groundwater management to predict future responses to current and alternative management practises.
- We present a Server application (Mantis), which simulates multi-century concentration breakthrough curves (BTCs) of Nitrate, Salts etc. as a response of land and crop management scenarios.

Overview of the Method

<u>Preparation Phase</u>

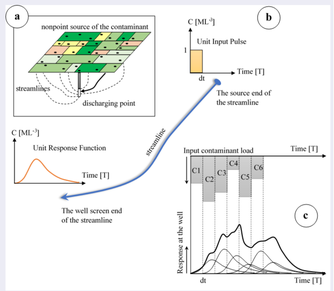
- Simulate steady state flow conditions.
- Identify the links between sources and sinks (Particle tracking).
- Incorporate the dispersion mechanism of transport and calculation of Unit Response Functions.

<u>Simulation Phase</u>

- Convolute Unit Response Functions with loading functions.
- Aggregate results per well.
- Calculate statistics per analysis unit.

<u>Additional Considerations</u>

- Unsaturated travel time: Precalculated Piston Flow Model to estimate the travel time as an additional shift.
- Surface water dilution: Mechanism to account for source mixing



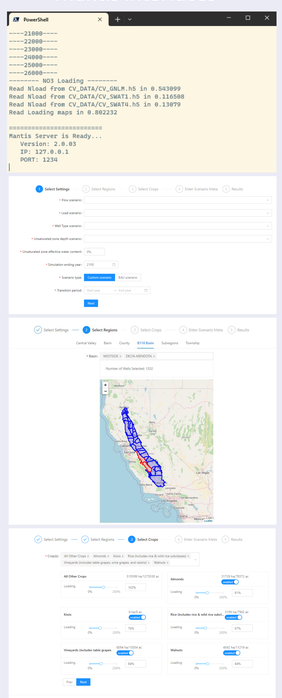
Simulation Phase

- Console Application, that can be run via Matlab, R, Python, etc. or via Web Interface

<u>Required Data</u>

- Select a region (Basin, County, Township etc.).
- Select a transport model.
- Select well type
- (Irrigation, Domestic, monitoring).
- Select an Unsaturated model (Wet, Dry water year and mobile water content.
- Select a Loading scenario Nitrate, Salt.
- Select land use management options.
- Select options about the loading time frame Implementation period and adoption rate.
- Optionally set a depth range.

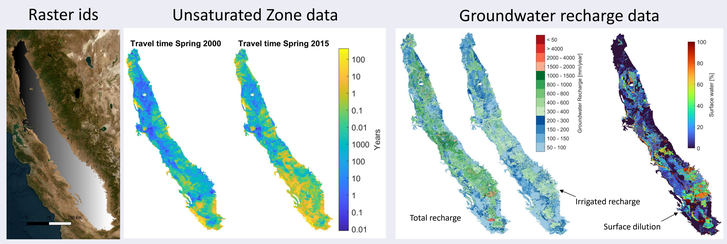
Mantis interfaces

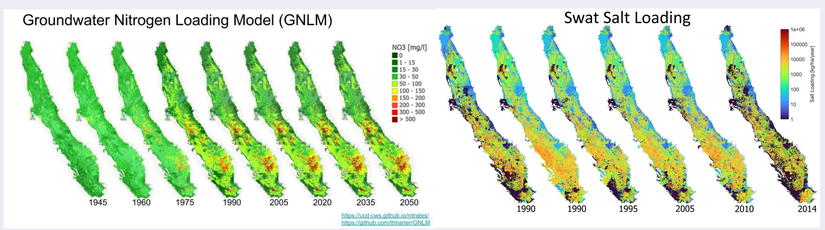


Mantis Server Efficiency

- Define a raster grid where all the information aggregated as linear matrix

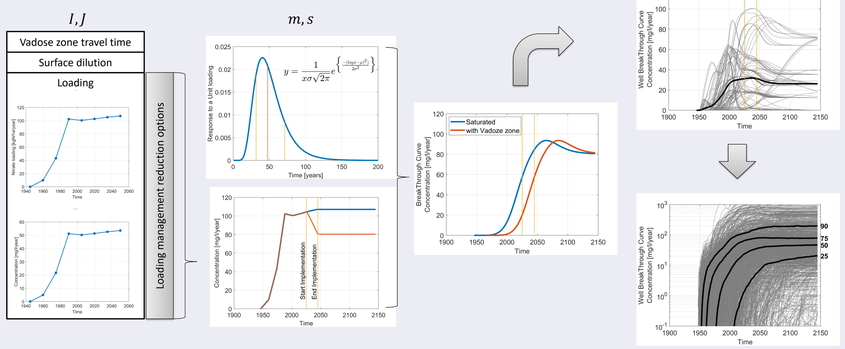
<u>Raster Data</u>





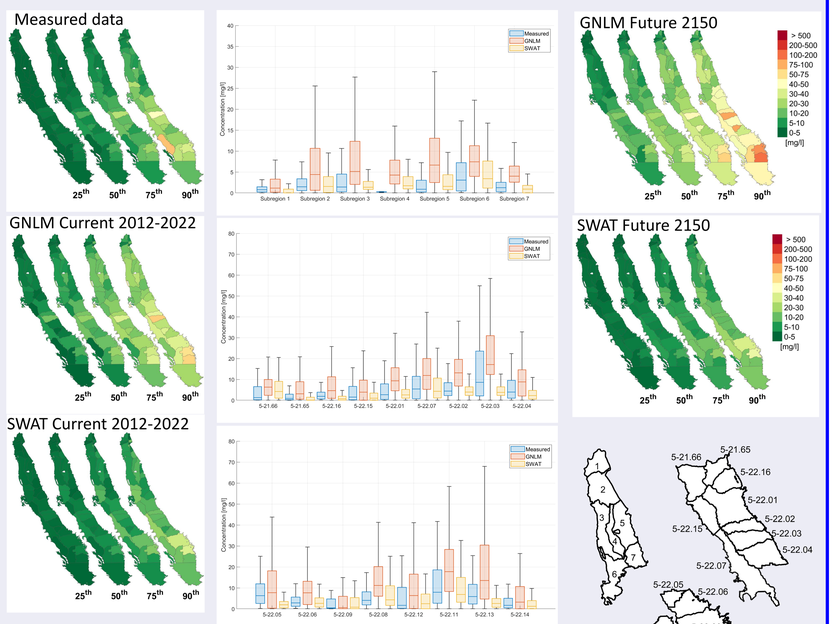
<u>Tabular Data</u>

- Well info: Well coordinates (XY), Depth (D), Screen length(SL), Source area orientation (SA)
- Streamline info: Row (I), Column (J) of Source, Lognormal distribution parameters Mean (m), standard deviation (s), Flow contribution weight (w), Surface Source (r), Extend of Source area (n)

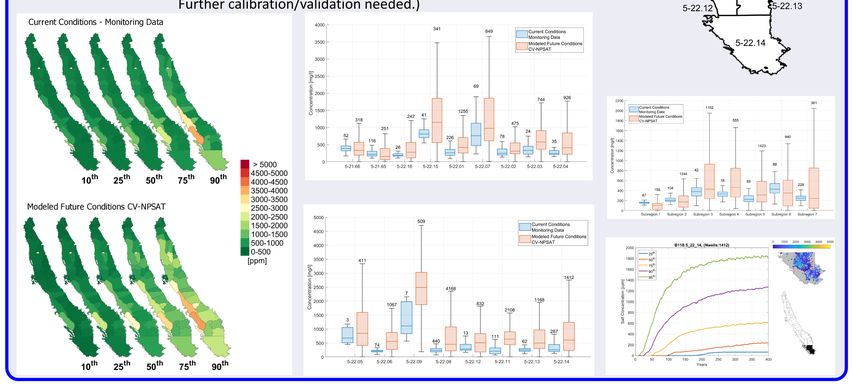


Results

<u>Nitrate simulation</u>



<u>Salt simulation</u> (Initial salinity simulations demonstrating model linkage. Further calibration/validation needed.)



Conclusions – Next steps

- We developed a server – client application for the simulation of non-point source pollution in agricultural groundwater basins.
- We provide a web interface https://npsat-dev.lawr.ucdavis.edu/ and a command line interface https://github.com/giorgk/Mantis via MATLAB, R, Python API etc.
- Future research will focus on further calibration and validation of the model in Central Valley as well as developing NPSAT models in other groundwater basins.
- Next versions will allow simulations of loading with feedback loop such as salts and tracers

References

1) MPEP TEAM (PlanTierra LLC, Formation Environmental LLC, Ken Cassman, Sid Davis) 2019. Assessment of Management Practice Performance in the Central Valley Using the Soil and Water Assessment Tool. Prepared for Southern San Joaquin Valley MPEP Committee, 499 p.

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