2D Transport Tutorial Part 3b: Post-Processing and Visualization

1. Overview

This tutorial focuses on post-processing techniques to enhance the interpretation of the numerical simulations performed in previous steps. We will use a Streamlit-based web application to visualize the analytical solution and import that output into ModelMuse to compare with numerical results.

2. Using the Streamlit App for Analytical Visualization

Access the Streamlit application titled: **2D Solute Transport: Continuous Source in Uniform 1D Flow**. The app plots the analytical solution in a format resembling numerical output from ModelMuse.

Steps

- Launch the app using the provided link.
- Input the same parameters as used in your numerical model.
- Take a screenshot of the resulting plot once the visualization appears.

Parameters to Use

- Source concentration: `1 g/m`^{3}
- Source width Y: `100 m`
- Longitudinal dispersivity α_x: `10 m`
- Specific discharge q: `0.432 m/day`
- Porosity n: `0.25`
- Dispersivity ratio α_x/α_y: `10`
- Time: `1000 days`

- Under `Adjust Plot` set
  - `Max Conc of plot (g/m`^{3}`)`, set the value to `1`
  - Set `Max extension in x direction` to `2100`
  - Set `Max extension in y direction` to `550`
  - Toggle the switch next to `Show isolines instead of contour`

3. Importing the Analytical Image into ModelMuse

ModelMuse supports image import and alignment, which we will use to compare the analytical and numerical outcomes.

Geo-referencing Strategy

To overlay the analytical image onto the numerical model domain in ModelMuse, we must align two reference points (anchor points) between image coordinates and model coordinates.

- **Bottom-Left Anchor Point:** Map the image point $(0, -550)$ to the model coordinate $(400, -1100)$.
  - The image spans vertically from $y = -550$ to $y = 550$, but only ticks spaced at 200 units are visible. The bottom line, just below the -400 tick, corresponds to $y = -550$.
  - In the model, the top is at $y = 0$ and each of the 11 rows is 100 m high. So, the bottom is at $y = -1100$.
  - The image's $x = 0$ is mapped to $x = 400$ in the model to align with the source location, which sits in column 4 (centered at 350 m, adjusted to 400 m for clarity).
- **Top-Right Anchor Point:** Map the image point $(2100, 550)$ to the model coordinate $(2500, 0)$.
  - The image has a horizontal extent from $x = 0$ to $x = 2100$. Since the image origin is placed at $x = 400$ in the model, the far-right edge aligns at $x = 400 + 2100 = 2500$.
  - Vertically, the image top at $y = 550$ is aligned to the model's top at $y = 0$.

Anchor Points for Geo-referencing

Anchor Point	Image Coordinates (x, y)	Model Coordinates (x, y)
Bottom-Left	$(0, -550)$	$(400, -1100)$
Top-Right	$(2100, 550)$	$(2500, 0)$

Import Steps in ModelMuse

1. Open your existing model in ModelMuse.
2. Go to `File > Import > Image`.
3. Click `Select Image` and navigate to the screenshot you saved earlier.
4. Click the point on the bottom-left corner of the image and enter $(x = 400, y = -1100)$.
5. Click the top-right corner and enter $(x = 2500, y = 0)$.
6. Press `OK` to place the image.
7. Optional: Hide grid lines by toggling the `Show/Hide 2D Grid Lines` icon.

4. Visualizing User-Defined Datasets in ModelMuse

Overlaying Saved Results

1. Click `Data Visualization` (colored icon in the second row).
2. If `MODPATH Pathlines` is enabled, uncheck `Show Pathlines`.
3. Press `OK`.

We disable the pathlines in this step because our focus is on comparing concentration distributions. Displaying pathlines alongside contours can introduce visual clutter. In the following step, we will import the concentration dataset and generate a contour grid for direct comparison with the analytical image

Comparing Analytical and Numerical Results

1. Go to `Data Visualization`.
2. Select `Contour Data > User Defined > 3D Data`.
3. Choose the relevant dataset (e.g., `FD_Coarse`).
4. Click `Apply`, then `Close`.

Tip: Use these overlays to identify where the numerical solution deviates from the analytical benchmark.

5. Save Your Work

After completing the steps above:

- Press `Ctrl + S` to save your model setup.

6. Breakthrough Curve Comparison

Up to this point, we have relied on visual comparison—overlaying the analytical image (from the Streamlit app) on the numerical model domain and displaying concentration contours. This provided a useful qualitative sense of how closely the numerical solution matches the analytical benchmark.

However, the Streamlit app also offers a powerful feature: the ability to extract concentration values at user-defined observation points.

Exporting Analytical Observation Data

To enable direct, point-wise comparison:

- Within the Streamlit app, define observation points at the same distances from the source as used in your numerical model.
- Once configured, download the resulting CSV file containing the computed concentration values at those locations over time.

Organizing the Data in Excel

- Open the provided Excel sheet and paste the downloaded CSV data into the designated section for analytical results.
- Next, open the `.MTO` file generated by your numerical simulation. This file contains time series data of solute concentration at observation points as computed by the transport model.
- Copy this numerical dataset and paste it into the corresponding section in the same Excel sheet.

Comparing the Results

With both datasets placed in the same sheet:

- Use the pre-configured plots to visualize how the numerical and analytical concentration curves overlap.
- This side-by-side comparison allows for quantitative validation and can help identify discrepancies due to discretization, boundary effects, or model assumptions.

7. What's Next

In the next step, we will explore grid refinement. Large deviations from the analytical solution can often be attributed to coarse discretization. By refining the grid, we aim to observe how spatial resolution influences numerical accuracy.