Do you need or like to work with:

- complex geology?
- conceptual modeling?
- statistical analysis?
- original TOUGH2 files format?

GMS → TOUGH2 → GMS

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Scope

- **In some instances there is the need to:**
  - use TOUGH2 in complex geological systems, with both surface and underground geological data from geophysical techniques and boreholes; amount of data may increase in time and the geological model have to be updated;
  - test different conceptual models or elaborate on specific ones;
  - change grid sizes or orientations, cell spacing and distribution;
  - visualize input and output data in 3D;
  - use standard statistical analysis on output data.

- **IN THESE CASES TOUGH2 MAY BE FOUND TO BE A NIGHTMARE!**

PARTICULARLY FOR BEGINNERS!

One possible solution

- Use Groundwater Modeling System (GMS™) as a TOUGH2 pre- and post-processor < http://www.aquaveo.com>

- **Preprocessing:**
    - Build a:
        - 3D Geologic Model;
        - Conceptual Model;
        - 2D and 3D scatter-point sets (observations);
        - grid.
    - Exchange data between these four categories.

- **Postprocessing:**
    - Visualize model output variables with geology, in space (3D) and time (movies).
    - Analyze output variables with statistical package.

GMS – TOUGH2 simulations workflow

- Create a model;
- Interpolate the model to a MODFLOW grid and run it in "steady state";
- Save the GMS-MODFLOW model as original modflow file format;

- Use the Fortran code TMT2 (Translating MODFLOW to TOUGH2 – downloadable for free from the TOUGH2 webpage) to generate MESH (with ELEME and CONNE blocks) and INCON files;

- Use the MESH and INCON files to solve your TOUGH2 problem;

- Use the Fortran code TT2M (Translating TOUGH2 to MODFLOW – only a preliminary version available – ask me), or any other self-made code, to generate 3D scatter point data sets of the values of TOUGH2 output variables at each grid-block center);

- Read the 3D scatter point data set into GMS;
- Interpolate the 3D scatter point data set to the grid;
- Analyze results with visualization and statistical analysis tools.

3D Geologic model

http://www.xmswiki.com/xms/GMS:GMS

- **Build your 3D geologic model through:**
  - **materials (lithological units);**
  - **tins (2D geologic surfaces);**
  - **boreholes (used to make stratigraphic horizons);**
  - **cross sections – this is the way you may implement faults;**
  - **solids (rock “bodies” of specific lithologies).**

- **Save the geologic model and change it whenever you need without interfering with the rest of the model.**

Conceptual model

http://www.xmswiki.com/xms/GMS:Map_Module

- **Build your conceptual model through:**
  - **map module, with tools that are a GIS-based, abstract, simplified description of natural systems;**
  - **coverages, that contain all information needed to be transferred to specific grid volumes;**
  - **frame of model grid.**

- **Build many different conceptual models to test different thesis.**

2D and 3D scatter-point sets

http://www.xmswiki.com/xms/GMS:2D_Scatter_Point_Module
http://www.xmswiki.com/xms/GMS:3D_Scatter_Point_Module

- **Observational point data are represented by**
  - **2D scatter point data sets, i.e., values of a variable with (x, y) coordinates;**
  - **3D scatter point data sets, i.e., values of a variable with (x, y, z) coordinates.**

- **3D scatter point data sets are the format to import the TOUGH2 output data.**

Grid

http://www.xmswiki.com/xms/GMS:3D_Grid_Module

- **Build your model grid by making a MODFLOW-like grid (a rectangular structured grid)**

- **This is perhaps the weak part of the process:**
  - **only this type of grid is allowed;**
  - **only one grid per model is allowed.**

Example of 3D visualization of results for a TOUGH2 injection model

Temperature distribution in model before injection

Distribution of induced earthquakes during injection