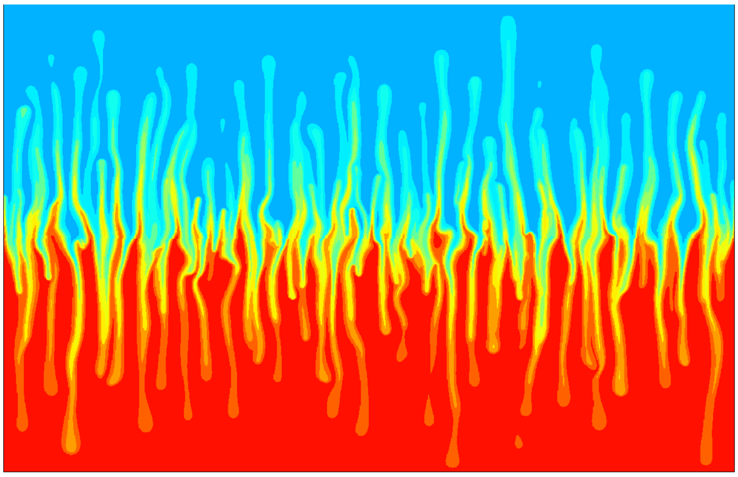
FEFLOW

Modelling saltwater intrusion and other density-dependent processes

Variable density flow is of increasing concern in groundwater hydrology, where fluid density varies in space and time as a function of pressure, temperature and concentrations of multiple species. FEFLOW is adopted worldwide to simulate variable density groundwater flow phenomena. As thoroughly documented and published, FEFLOW has been benchmarked over the entire spectrum of variable density groundwater flow in 2D and 3D applications.

APPLICATIONS

- Seawater intrusion
- Fresh/saline water interfaces and saltwater upconing in coastal aquifers
- Heat and thermohaline fluid flow in geothermal systems
- Design of subsurface heat extraction and energy storage systems
- Subterranean groundwater discharge
- Dense contaminant plume migration and buoyant plume effects
- Density driven transport in the vadose zone
- Transport of salts due to agricultural practices
- Flow through salt formations in high level radioactive waste disposal sites
- Diagenetic processes in sedimentary basins
- Multidiffusive and multispecies solute displacements



Variable-density multidiffusive fingering convection phenomena.

BENEFITS

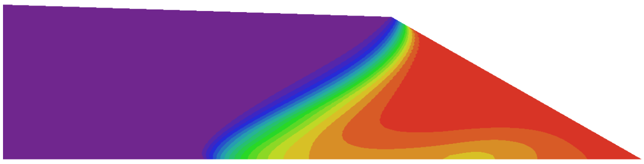
- Coupled density dependent simulation for varying concentrations and/or temperature
- Linear relation of density versus concentration
- Linear or nonlinear relation of density versus temperature
- Predefined or user defined relation of viscosity vs. concentration and temperature
- Different relations of density versus concentration for each species in (reactive) multispecies simulations
- Variable density flow in both porous and fissured media
- Saturated and unsaturated conditions

FEATURES

- Finite element method for 3D, or for one of various options in 2D (vertical, horizontal with projected gravity, axisymmetric)
- Flexible, unstructured meshing
- Automatic, adaptive time stepping
- Oberbeck-Boussinesq and extended Oberbeck-Boussinesq approximation
- Picard and Newton iteration schemes
- Various upwind techniques
- Sparse matrix PCG type and algebraic multigrid solvers appropriate for large equation systems
- Parallel computing

SALTWATER INTRUSION/UPCONING

Saltwater intrusion in combination with upconing effects at pumping wells threatens the water supply for both domestic use and irrigation in many coastal areas. FEFLOW is used in projects all over the world to optimise groundwater extraction and avoid further saltwater intrusion.



Density-driven saltwater intrusion process in a coastal aquifer.

FRESHWATER STORAGE IN SALINE AQUIFERS

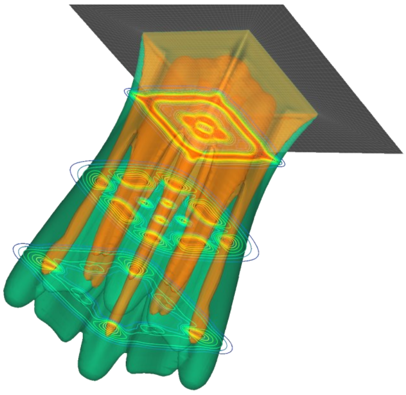
In areas with low and only seasonal freshwater availability, so-called aquifer storage and recovery (ASR) techniques are applied. Hereby freshwater is injected into a saline aquifer in the wet season and recovered in the dry season.

FEFLOW is used to, for example, predict the amount of freshwater that can be recovered versus the amount of water that is lost by mixing and lateral groundwater flow.

DISPOSAL OF SALINE WATER

Highly saline brines such as remnants of salt mining or cavern construction in salt domes are often injected back into deep aquifers.

FEFLOW is used to simulate the migration of the brine and to predict a possible endangerment of upper aquifers and rivers.



Computed salinity isosurfaces of the 3D Elder problem.

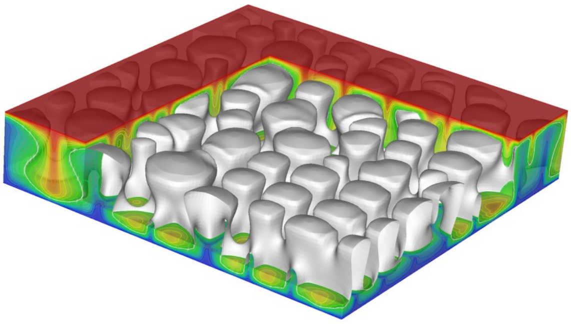
GEOTHERMAL POWER PRODUCTION

Using geothermal energy for heating/cooling purposes or power production affects the temperature of the aquifer. FEFLOW is used to check the feasibility of technical systems, to provide data for the approval procedure and to obtain information about, for example, the environmental impact. Variable density groundwater modelling is required in case of high temperature gradients within the system.

EASE OF USE

FEFLOW's comprehensive preprocessing and postprocessing capabilities include specific features for variable density groundwater flow modelling:

- Convenient input of all density relationships
- Appropriate boundary conditions (conversion between saltwater head and freshwater head, boundary constraints applied to the seaside boundary in saltwater intrusion modelling)
- Expression editor and fast code interpreter to handle user specified relationships



Computed temperature isosurfaces of the 3D Elder problem.

OPEN PROGRAMMING INTERFACE

A large number of parameters can easily be accessed and modified during a simulation via the FEFLOW interface manager (IFM). Typical applications include the implementation of additional or alternative dependency relations for fluid density, the control of boundary conditions and the coupling to external procedures. For example, one freely available IFM plugin replaces the implementation of the equation of state for fluid density by a more comprehensive approach, which extends the applicability to very deep hot aquifers.

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