DEPARTMENT OF EARTH SCIENCES
FACULTY OF SCIENCE
AARHUS UNIVERSITY

Summary of the HyGEM kick-off meeting in Denver 26-27'th of April, 2012

List of participants

HYDROGEOPHYSICS GROUP

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Gianluca Fiandaca	Aarhus University	Italy
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Richard Thomsen	GEUS	Denmark
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Michael Rosenberg Pedersen	Aarhus Vand A/S	Denmark
Per Gisselø	SkyTEM ApS	Denmark
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Aaron Davis	CSIRO	Australia
Andrea Viezolli	Aarhus Geophysics ApS	Italy
Rosemary Knight	Stanford University	USA
Ty Ferré	Arizona University	USA
Jared Abraham	USGS	USA
James Cannia	USGS	USA
Steve Peterson	USGS	USA
Bruce Smith	USGS	USA
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Agenda - Day 1

1. Welcome and introduction – who's who? (Esben Auken)
2. Project overview and the work packages (Anders Vest Christiansen)
3. Presentation of partners/people and key expertise (All)
4. Introduction to the field sites (Aarhus Vand, CSIRO and USGS)
5. Break-out sessions

Ad 1. Welcome and introduction – who's who?

The primary goals of the meeting were pinpointed by Esben Auken (AU) followed by a short presentation round where all participants briefly introduced themselves.

Ad 2. Project overview and the work packages

Anders Vest Christiansen (GEUS) showed a presentation outlining the framework of the project and a detailed walkthrough of the contents of the work packages. The presentation can be found on the website and additionally the information can be found on the website under the heading "Project Description".

Several ideas with regards to WP6 – Dissemination and co-ordination were put forward;

- General agreement that there should be an online "tracker" on the project website of when anything remotely connected to the project is going on e.g. when project participants are giving project related presentations at conferences etc.
- Jim Cannia (USGS) mentioned that we should try to keep track of organizations that are using research/new methodology on a administrative point of view – basically who is using it and is it being used? Would be great if the final output of the project could be tools that can be used for management.
- Rosemary Knight (Stanford University) mentioned that the HyGEM project should establish a relationship with journals where we can make a special issue. The HESS journal was put forward as a good option, since it covers both hydrology and geophysics.
- Rosemary Knight (Stanford University) brought up that it would be interesting to publish not only to see the research that makes it into the publications, but also to see the intermediary steps where a lot of interesting scientific research, ideas and considerations take place. This could be in the form of small informal reports uploaded to the project website or possibly published in journals like Leading Edge, e.g. when fieldwork is carried out a small report could be prepared stating what was measured, how was it done, considerations during the measurements and some results. Could work as a teaser and inspiration to other project participants.

- The project website will get an extra heading concerning dissemination and publications.
- The HyGEM project should host a research workshop in order to profile the project and to disseminate ongoing research. SEG and AGU create joint workshops and could be an option, as well as SAGEEP.

Ad 3. Presentation of partners/people and key expertise
Each partner introduced themselves and those from their organizations who will be working on the project and their key expertizes. Additionally, each partner briefly mentioned their wishes and expectations to the project.

All the partner presentations can be found on the website under the heading "meetings – Kickoff meeting in Denver".

Ad 4. Introduction to the field sites
Aarhus Vand, CSIRO and USGS each gave a brief introduction to the respective field sites they were considering for the HyGEM project. The presentations focused on the challenges, existing field measurements and knowledge of the specific sites. In general the presented field sites are very different with regards to existing knowledge i.e. boreholes, geophysical measurements, existing groundwater models, scale etc.

- The Danish field site is characterized by a high amount of information and already a lot of boreholes, geophysical measurements, chemical data and a groundwater model are available. The field site is small-scale.
- The American field site is characterized by a medium amount of information with a fair amount of geophysical measurements available, some boreholes and an existing groundwater model. The field site is large-scale.
- The Australian field sites are characterized by a low degree of available information. There are no boreholes or measured geophysical data. The field site is very large-scale.

All the field site presentations can be found on the website under the heading "meetings – Kickoff meeting in Denver".

Ad. 5 Break-out sessions
The participants were divided into 4 groups in order to discuss the scientific approaches, the content and a more detailed schedule for the 5 individual work packages.

Agenda - Day 2

1. Breakout sessions continued and summation of discussions
2. Panel discussion with the International advisory board
3. Final details and work assignments.

Ad 1. Breakout-sessions continued and summation of discussions
In the following the key points and decisions from the four breakout sessions are summarized.

Breakout session one – WP 1. Hydrological-geophysical mapping and method development:

The **Danish test site** is decided and will be Kasted.

- Aarhus Vand will set up a meeting with AU, GEUS, AAG and SkyTEM to make a detailed list of existing data (boreholes, geophysics, chemical etc.) to get an overview of the quality and make a detailed plan for fieldwork.
  There is already a lot of TEM, PACES, borehole, and chemical data at the site as well as an existing groundwater model. It is important to ensure that the boreholes have the specs for downhole MRS.
- Alectia will go through the existing groundwater model and, if needed, refine it, and come with suggestions for new field measurements.
- New downhole and surface MRS measurements will be carried out (AU/USGS), as well as a new SkyTEM survey (SkyTEM). The downhole MRS will be performed from October 2012 and onwards in suitable boreholes. The SkyTEM survey will be executed in early 2013 and processed and modeled (uncoupled and sounding based) by summer 2013 (Aarhus Geophysics). We aim at making an adaptive survey, so surface MRS will be carried out after, based on the SkyTEM results.
- A suitable test-reference site for MRS measurements will be sought. Numis, Javelin and VISTA CLARA surface NMR will be deployed and tested here. GEUS is working on moving the SkyTEM test site to a new area a.s.a.p., and the site could coincide with the MRS site.

The **American test site** is decided and will be Western Nebraska.

- USGS will need to make a detailed list of existing data (boreholes, geophysics, chemical etc.) to distribute between project partners.
- The area is covered by 10.000 line km of AEM data from different systems at different spacing's. Quite a lot of boreholes and some MRS measurements. There is an existing groundwater model.
- 32 surface and 32 downhole MRS soundings are to be acquired in the fall of 2012 (USGS).

- A number of test holes and monitoring wells will be put down in august 2012 (USGS).
- USGS will take care of all activities in the US, but AU will send a PhD and possibly the NUMIS instrument in the fall of 2012 to participate in the acquisition of the new MRS data.
- Nikolaj Foged (AU) might run a SSV model for the Nebraska field site. USGS will send the data packet or Nikolaj will be at USGS in August/September.

Additional information is needed from the Australians (CSIRO) in order to decide if the sites are suitable. The information needed is planned geophysical and hydrological measurements and existing data in the areas (boreholes, geophysics, groundwater models etc.).

SkyTEM is experimenting with damped receivers in order to increase the signal to noise ratio, while maintaining the very near surface resolution. They expect that the method developments will be ready for the field campaign in early 2013. AU will set up a meeting with SkyTEM to discuss instrument developments.

AU will work on field procedures to alleviate noise (e.g. multiple Rx, star pattern layouts) and try new processing techniques for increasing the S/N ratio.

Breakout-session two – WP2. Voxel inversion of geophysical data proved hydrological integration:

- A template for a typical mesh that is used for groundwater models is needed in order to proceed. We are most likely moving towards OC3 meshes, since they are easy to import and visualize.
- The mesh will be created to handle 3D forward responses.
- The methodology should be as general as possible, but the pitfall is that with generality comes complexity. Need to draw a line and put some limitations e.g. only invert for parameters where there are a clear petrophysical correlation.
- The work package leader will set up a meeting with Gianluca Fiandaca (Aarhus University) to make a detailed plan with milestones for the work package.

Breakout-session three – WP3. Analysis of hydrological, lithological and geophysical relationships:

- The data will be;
    - Existing resistivity data measured on samples – in field from auger drilling or in lab on tubes.

    - Database exercise: GERDA (geophysical database)/Jupiter (borehole database)
    - Additional data: get clay content on samples by XRD/XRF measurements giving the element distribution for the sample.
    - Hydrological data: yields from pump test reported to Jupiter.
    - Measurements of K in lab on samples from e.g. KUPA project (contact Bo Vangsø Iversen)
- Complications:
    - Different support volumes (vertically: loss of resolution with depth in geophysical models. Horizontally: borehole points observation, geophysics increasing footprint with depth)
    - Water quality influences on resistivity of the aquifers.
    - Boreholes: variation in quality may lose thin clay layers due to the drilling method.
- Classification problem:
    - How many classes can we discriminate between?
    - Overlapping resistivity/equal resistivity intervals.
    - Better discrimination adding water quality (TDS variations).
    - E.g. “ml” very distinct resistivity intervals for a specific till unit – not to be separated in the lithological log in the database.
    - The null space (thin layers in lithological logs not resolved in geophysical models)
    - Different types of clays, silts – different resistivities.
    - Scale – how large areas can belong to the same class – local/regional.

For Denmark the resistivity variations are mainly driven by changes in clay content and for clay-free deposits.
For Nebraska the resistivity variations are mainly driven by variations in grain size and compaction.

- Methods:
    - Form probability clouds for different formations/lithologies.
    - Make histograms and variograms for the different classes.
    - What does the probability function look like (for resistivity of a given formation)?
    - How do we form the resistivity 3D space – using the correlation with the log.

Breakout-session four – WP4/5. Coupled three-dimensional hydrological and hydrogeophysical modeling. Hydrological and geophysical test-bench modeling:

- Most participants seemed to agree that the coupled approach is the preferred way to go if it is practically possible.

- Stochastic method challenging (either infinite # runs, or "calibration").
    - Geophysics could be used to select between stochastically generated geological realizations.
    - Or be used as information in the production of realization(s).
- Field sites:
    - The Danish field site– go home and do: good overview of the existing data; consider the important purpose(s) of modeling (i.e. model predictions) and prioritize them – near surface gw/sw interaction; is a sufficient model available or should one be developed for the project; collect additional data aimed at improving the model's ability to predict; make long-time well-controlled pumping test to test model's ability to predict; age data?
    - The Australian field site: select site with good hydrological and geophysical data sets; describe these data carefully; sufficient model available?; prediction(s) of interest?; data available to test model's ability to predict?; who will carry out the study of coupled modeling?
    - The American field site: Steve Petersen recommended the site to be a 1500 sq. miles catchment. Airborne EM has been used to determine aquifer base (geometry); resistivities for aquifer have not yet been used; 1D gw. model to simulate dynamic stream flow to manage gw pumping; age data probably available for upper part of catchment; hor. res. approx. 450 m; transient run takes 1,5 hour; less than 1000 model pilot point parameters optimized using regularization; NW area has the most data; should this be the focus area used to develop test model?

- The test bench is the best way of comparing methods of coupled modeling.
- Design test models corresponding to the selected field cases and their relevant prediction(s).
    - The Danish: some further development from the presented synthetic example.
        - A brief report should be prepared describing the thoughts behind the constructed test model; can be used as inspiration for the Australian/American.
    - The Australian: build from above characterization of field site and prediction(s).
    - The American: build from above characterization of field site and prediction(s).
- Water quality is important but difficult to simulate.
    - Mainly used as "prediction" and not as calibration data?

    - Should “age” be the “quality” prediction?
    - To simulate quality we require porosity; how can 3D porosity be informed in practice?
- Consider relationships between K and ρ that could be included in the testing
    - Log(K) vs. Log(ρ) with contamination
    - Different versions developed from Archie’s law.
    - K vs. porosity relationship.
    - Salinity influence? (Distribution can either be simulated or assumed.)
    - Vadose zone will not be included.
- Additional testing:
    - Run blind tests, “buy” data piece by piece.
    - This analysis of “which data are most important” can probably be made much easier and more objectively by analysis of linear model prediction uncertainty. This is part of ongoing MSc study.
- Scan for available free software. Most necessary software probably available:
    - TPROGS, MFLAB, Gaussian sim, MODFLOW, EM1DINV, TEMDDD, PEST ….?
- AU will set up a meeting with Peter Bauer (DTU) and Steen Christensen to define the roles for the various partners within this work package and settle on PhDs.

Ad 2. Panel discussion with the International advisory board

- Good organization and mixture of people, everything covered with aspects of what we want to do. Good definition of work packages.
- Important to simplify because the project is quite big. Essential to keep track of where in the workflow we simplify, because we will need to simplify in order to move forward. Track when we simplify, to see where we could develop again due to simplification.
- Involvement of end-users is a key element.
- Build a universal test model that can be adapted by users. It should produce virtual scenarios that are (not) related to real sites.
- Groundwater age (and other transport predictions) should be included in the test bed.

Ad 3. Final details and actions!

- The **project management** group will draft a final plan and get feedback from the work package leaders to make a detailed schedule with milestones for the individual work packages.
- The **project management** group will make a version of the cooperation agreement and pass it to project partners.

- The **project management** group will send out short monthly reports to know where everybody is in the project (In the beginning the reports will come out every second month). The first monthly report is scheduled to the 1 of July, 2012.
- The **project management** group will update the website with a dissemination and publication section.
- The **Workpackage leaders** will have to give monthly updates on the progress and upcoming activities in the individual workpackages.
- **AU** will set up a meeting with Gianluca Fiandaca to define milestones and a detailed content for workpackage 2.
- **AU** will set up a meeting with Peter Bauer (DTU) and Steen Christensen to discuss the partners' roles in the project and decide on PhDs.
- **AU** will set up a meeting with SkyTEM to discuss instrument developments within the HyGEM project.
- **AU** will set up a meeting with TNO (Not present at the kick-off meeting) to define their role in work package 1.
- **Aarhus Vand** will set up a meeting with AU, GEUS, AAG and SkyTEM to make a detailed list of existing data (boreholes, geophysics, chemical etc.) to get an overview of the quality and make a detailed plan for fieldwork.
- **USGS** will need to make a detailed list of existing data (boreholes, geophysics, chemical etc.) to distribute between project partners.