About 3D model validation: scientific, technical and institutional considerations

About the official / institutional / administrative validation

- There must be an official “stamp”, if the model(s) must have the same status as geological maps currently have
    - But validating a 3D model is much more complex than validating a map
- It is mandatory to have a careful and thorough peer-review process
- Stakeholders must be part of the peer-review process
- Validate the model against actual uses of the model
- Quite unrealistic to have one single committee validating the entire modeling process (too many specialties involved, potentially spanning over too many different (geological) regions) …
- … but the validation does not need to be done by a “single” committee, it can be split into independent responsibilities:
    - Validation of the input data
        - Delegated to each individual GSO
    - Validation of the geological interpretation / structures
        - Goes along with validating the geometry / topology of the model
        - Again, can be handled on a per-[region/country] base
    - Cross-border harmonization
        - Consensus on cross-border objects and geometries
        - Also applicable in case of “concatenating” independent models
    - …
- How to coordinate these activities across countries at the EU scale to ensure global consistency?
    - Define common workflows / procedures shared among GSOs
    - Necessity of understanding what each GSO does
        - Role of projects such as GSEU, need for a synthesis of at the end of the project

About input data and interpretations validation (QA/QC)

- Can be split on a per-data-type basis: validation must be done by experts, ideally one single person should not have to handle the entire data QA/QC (not always realistic)

- Validate consistency against “indirect” sources of information (those that could not be introduced directly in the modelling): geophysics, …
- Again, need for common QA/QC procedures across countries to ensure a similar global “quality” of the models
- Limitations:
    - This represents an enormous amount of work, so we cannot reprocess every single piece of information on our own: sometimes, we must trust the data we use (typically, when inheriting them from the private sector)
- How to do QA/QC?
    - Ideally: leave some data aside to check the model against them afterward (idea of having training / validation data set in AI)
    - However, we usually have to few data to do so. An alternative: cross-validation (leave-one-out strategy)
    - Validate consistency against “indirect” sources of information (those that could not be introduced directly in the modelling): geophysics, …

About the confidence / trust users can expect from “officially stamped” models

- Always provide “minimal base information”
    - What is the intended purpose of the model?
        - Baseline geological framework? Application-driven model (geothermal, …)?
    - What is the relevant range of scales to use this model?
        - Like the scale of geological maps
- Be as transparent as possible: do not only deliver the model whenever possible:
    - Provide the data that were used to build it,
    - Provide the additional information that was used to interpret, validate, … (e.g., geophysics)
    - Trace hypotheses and interpretations as much as possible
    - This links to FAIR principle
    - Limitation: some of the data we use may not be public / publishable…
- Reproducibility: we must be able to regenerate a model!
    - Role of implicit modeling (as compared to manual modeling)
        - Yet it is very difficult to be fully reproducible
        - Be aware of the “black box” effect that can represent implicit modeling methods
    - Importance of automation
        - QA/QC on entire data sets, less biases (systematic processing of the data)

- Uncertainty quantification as a byproduct: the Graal but…
    - Uncertainties at each step of the workflow (data, interpretation, modeling, …), difficult to propagate
    - Final quantification depends a lot on the method used: comparing uncertainties from one model to another may not be “informative”
    - …
- Provide basic “indicators” about our own confidence in the model
    - May be very simple / well understood ranking systems: traffic lights, 5-stars note, …
    - Can associate indicators to many aspects of the model (confidence in each data source, fitness for use according to specific applications, …)
    - Aim: potential users quickly get an idea of whether the model fits their need

Moving from rare releases to regular updates

- Remember that a model is a living product, not a complete nor a final product. We constantly improve our knowledge and understanding of the subsurface
- Difficulty: the thorough peer-review validation of a geological model is extremely time-consuming
    - We cannot hardly consider providing a yearly release with such a validation process…
- The initial release of the model must follow the entire validation process, but..
- … Subsequent releases may not need it if (new) data were carefully QA/QC and are globally consistent with the current model version
    - Somehow: distinguish major releases with complete peer-review process vs minor releases (that would “just” locally update the geometry) as for software versioning
    - Importance of the automation again! To allow for easy

Some other important ideas

- Validation per the users after the publication of the model:
    - Was the model fit for purpose?
    - Locations where the model does not coincide with the users’ own data and knowledge
    - …
- May be interesting to distinguish 2 categories of models: framework/baseline geological model vs application-driven models (for geothermal, …)
    - Validation workflows and uncertainty / confidence indicators may differ