Summary of the break-out session:
Model linking: experiences, lessons learned, and best practices

Model linking has been a highly discussed and mentioned topic at the entire openmod workshop. It is seen as a useful exercise to improve on the information we can extract and the topics we can cover in our models (see Figure 1). The main goal of the 2-hour long break-out session was to have an open discussion between participants with experience in the field and modelers generally interested in the linking of models. Over the course of the workshop, several benefits of model linking, key challenges, and best practices have been identified:

Main benefits of model linking:

- More complex problems can be addressed without creating complexity issues of integrating everything in one single model (countering a "feature creep" in a single model or framework)
- It can serve as a form of problem decomposition, speeding up the process by keeping functions (and model strengths) separate
- By offering a more holistic approach covering more fields and offering a broader coverage, the real world can be captured in a better way, allowing for more complete analyses and integrated insights

Main barriers / issues faced when linking models:

- Programming languages
- Data matching, data formats, and nomenclature
- Multitude of assumptions that are often not clearly visible
- Aggregation and disaggregation challenges when using models with different granularity
- Complexity compromise: when making the models talk to each other, a common "language"/data format needs to be defined. Simplifying to the lowest denominator might mean that one is not getting the full benefits of each individual tool
- Difficulty in validation
- Coupling with closed models: since the source code and workings of those models are closed, their results are not verifiable, leading to the entire linking results to be "grey" and not replicable except for the institution(s) with access to the closed tool. Also, the workflow becomes unusable after the project lifetime
- No clear definition of terminology, "soft coupling" vs "hard coupling" vs "cascading", "integrated", etc…

Best practices for a successful model linking:

- Have a clear vision on what is to be achieved in the linking exercise, focusing on what each model can provide and needs to be provided to achieve the vision
- Good communication: linking models is most often also linking modellers, so having a good communication structure in place is key
- Use open software and tools :)
- Harmonizing data sets - if possible make sure that all models use the same, single data source
- Offering a good documentation of each other's tools greatly simplifies the process
- Not only version control the models, but also the workflows themselves to ensure compatibility and reproducibility over time
- Ensure consistent assumptions across models
- Make sure that complexity reductions (e.g. aggregations) are reversible by clearly documenting the processes and assumptions
- Convergence is not always necessary, instead other break-up criteria can also be defined – but they should always be defined in advance
- Keep in mind how the introduced constraints, relaxations, or changed assumptions impact the original mathematical problems
- Expect a steep upfront time investment for data and model harmonization before the actual model coupling can take place

For additional information, please refer to the survey results in the Appendix and the Etherpad link with interactive workshop notes (including some links to additional literature on experiences):
https://etherpad.opendev.org/p/r.6bcf29e06ef9a5d4ce3d99ea6e4c8f96

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Appendix: Survey results

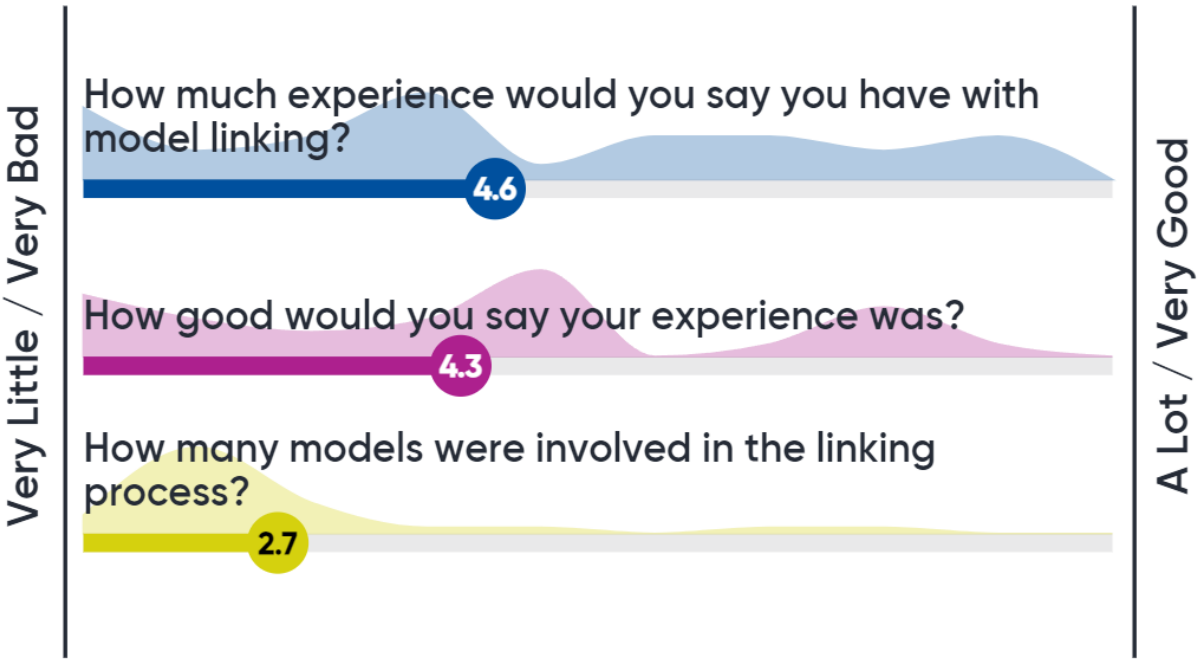

Figure 1: Background information on workshop participants (n=28)

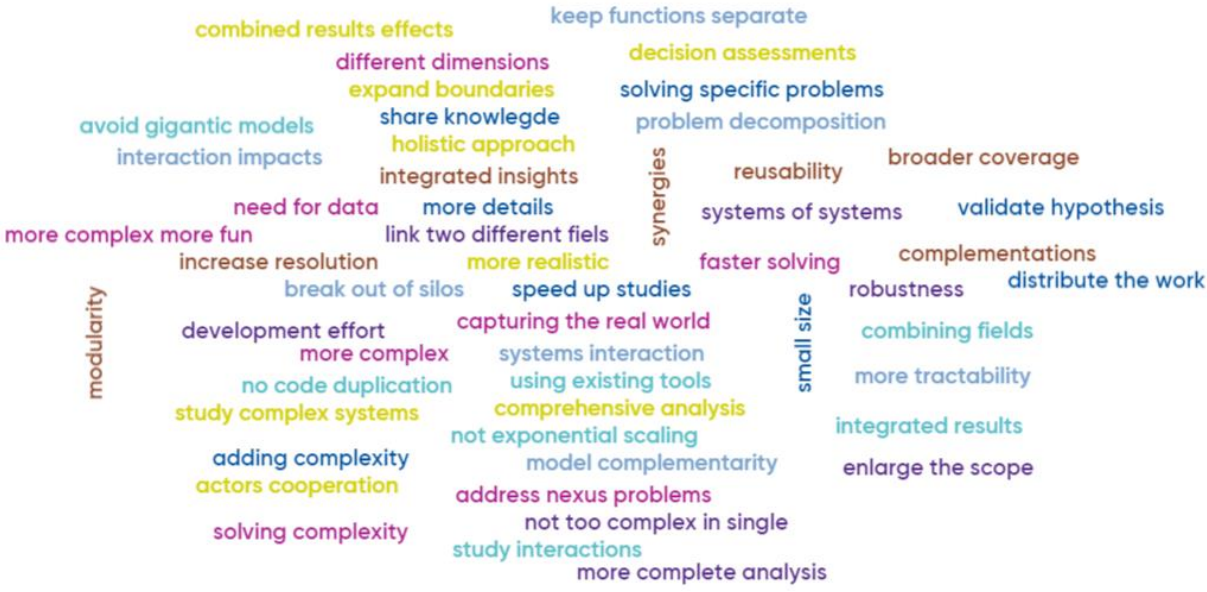

Figure 2: Answers to the question: "What are, in your opinion, benefits of model linking?" (n=25)

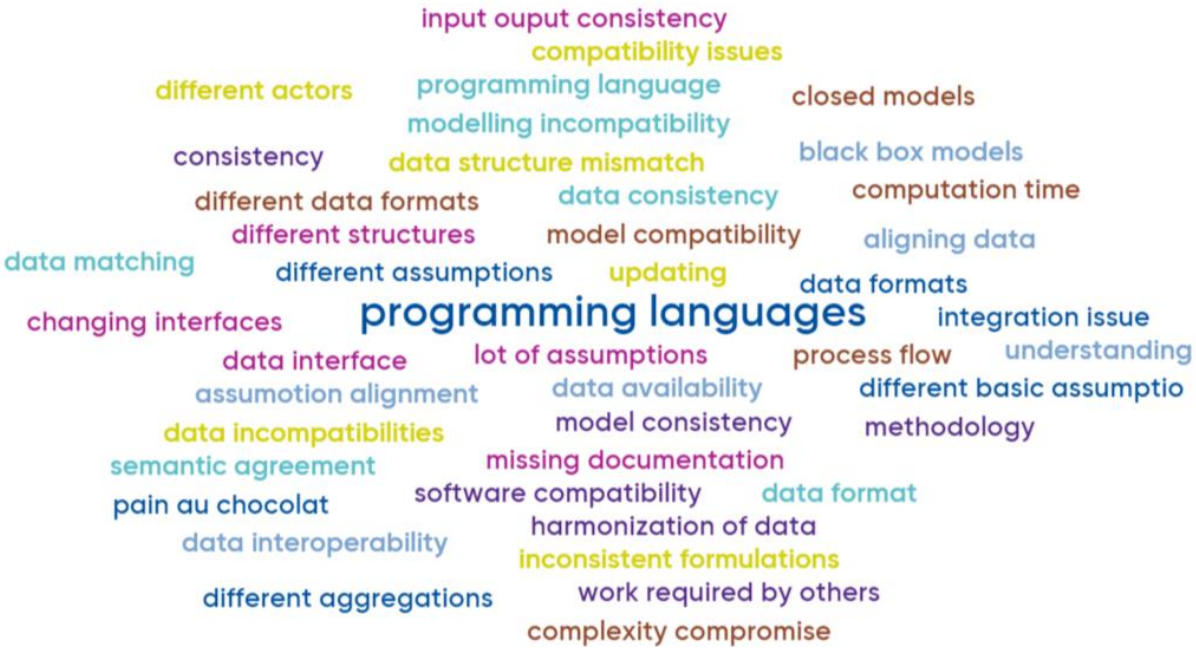

Figure 3: Answers to the question: "What barriers have you faced when performing model coupling?" (n=21)