At the 2023 MERGE Annual Meeting our members discussed the following points and identified some associated knowledge gaps in the scope of the three focus topics of the meeting.

Machine learning

General Points:

- Machine learning is weak in the following areas:
    - Limited capacity to extrapolate
    - Active exploration or areas where we lack data
    - Feedback between data acquisition and modelling
    - Causality, but there are recent ML methods that can test for causality.

- Machine learning is here to stay and has been underestimated.
- Generalisation of physical model building: machine learning has a capacity to do this automatically, but there are cases where this doesn't work.
- Machine learning can be used for sensitivity analyses. Constraints can be included as penalty terms in the model
- Data knowledge is very important!
- Many are already using different AI pathways/technologies in their research or are planning to apply them, from Random Forest to Deep Learning.
- AI and ML methods are simply tools; the important part are the data and topical knowledge. Compare to statistical methods used in RA4. So perhaps ML/climate activities should be brought in under the RA4 umbrella?

- **Other ideas and activities discussed were:**
    - The need for workshops, seminars and hackathons, very hands-on, for junior researches, actually doing research.
    - A mapping exercise to identify ongoing MERGE ML/AI activity
    - AI Lund has a drop-in where very few people how show up. Should we coordinate a MERGE show up?
    - Establish a competence centre for AI & climate support?
    - There are some related COMPUTE courses. Sometimes the level is too high and too mathematical. Can ClimBEco and COMPUTE create courses that fill this gap?
    - Can RA4 build a reference library somewhere on the MERGE homepage?
    - Ask around in the ML groups and see what exists and what could be added as tutorials on the MERGE webpage. Here RA4 knows who to ask to create/collect tutorials.
    - PyTorch standardized packages and examples: MERGE RA4 could be tasked to collect and list as introduction at some suitable point

Linking small and large models

General Points:

- Concerns were raised about computational time (regional & global models), and about time scales relevant to different processes in coupled models
- One challenge is that it is not always easy to tell beforehand which small-scale process or parameterization is relevant also for large scale models. Here a 1-D column model could

be helpful to quickly test even complicated parameterizations and compare against simplified process descriptions and observations.

- There is a broad range of expertise in MERGE on various aspects related to this topic: box models, development of parameterizations/lookup tables for large-scale models, process-based models, field studies for development of parameterizations and validiation,1-D column models, feedback loops, machine learning, and regional models, vegetation models, large scale models (stand-alone or coupled)
- This expertise should be better exploited! MERGE should:
  o Set up a list with contact information to MERGE researchers, with suitable tags that make it easy to identify somebody that can help you with your model related questions
  o Create an on-line user forum or similar for discussions among MERGE partners on models, parameterizations and feedbacks. The discussions should be saved in a searchable archive in case somebody else has the same question(s) a year later.
  o Publish factsheets that explain relevant processes (for climate or ecosystem services) and how they are modelled (in different types of models?)
  o Arrange workshops (with a process focus) bringing "non-specialist" in simplified way to the research frontier
  o Make a list of groups (database on who is doing what)
  o Create an action group to initiate activities linking models
  o Arrange a webinar or seminar on different "processes" or/and methods to do this

Humans and society in the climate system

General points:
- Social Climate Models (SCMs) could eventually replace IAMs. It's important to have a coupling to society and some kind of human boundary.
- Emission-driven ESMs will be more standard in CMIP7
- It is claimed that SCMs, by superseding the SSP framework, could eventually reduce the uncertainties in future climate projections – do we believe this?
- If so, it would be good if MERGE was well placed to contribute to the development and analysis of SCMs in future
- But do the models gain credibility by adding more layers of complexity? Also, more freedom in the models makes simulations more difficult to compare, as opposed to standard scenario-driven simulations.
- There has been a lot of progress in the more quantitative aspects of the social sciences in recent years. It might be advisable to begin with more modest, tractable questions as we learn to work with SCMs, or to start with simple things like forest management or urbanization.
- Based on existing studies - what are the parameters that lead to the greatest uncertainty in SCMs? What real-world processes do they represent?
- ESMs consume enormous resources – better to learn from simpler SCMs that include simplified climate models and/or regional approaches to better understand the dynamics of the systems.
- How should MERGE cooperate with social scientists? Is this something they ask for? BECC and ClimBEco connect us with other fields increasing our understanding of things outside the physical climate system. Also, we should link up with the profile areas to analyse the behavioural response aspects and parameterizations in SCMs (e.g. Miljöpsykologi).

MERGE members are encouraged to seek funding for SPs that relate to items above and/or to the following additional ideas:

- o Detailed descriptions of climate extremes and how these influence people and ecosystems (e.g. crop yields) in a SCM, but also how wildfires and BVOC emissions influence air quality – all of which could influence the Cognition and Behavioural Response aspects detailed in Beckage et al.
- o Funded SCM-related ideas are encouraged to include a **high-level workshop or seminar** with international speakers to explore the potential of SCMs and for MERGE contributions to them. It would instructive to hear descriptions of, and concrete results from working SCMs. Note that MERGE researchers already collaborate with Brian Beckage (LPJ-GUESS applications).
- o Mathematicians could apply dynamical systems theory to analyse simpler SCMs
- o The creation of an Action Group to initiate activities linking models, including webinars or seminars
- o Projects in which heuristic/empirical parameterizations, components or models are identified as candidates to be replaced with neural networks instead since these will be faster and can include some amount of physics, e.g. in LPJ-GUESS and aerosol models
- o Projects in which SMHI data or ICOS data are used in a ML setting.