Main questions

1. **How do atmospheric processes control emergent climate behaviours relevant to sensitivity?**

   Examples: Charney climate sensitivity, hydrologic or extreme precipitation changes, emergent constraints appearing in GCMs.

2. **What can model-observation climate discrepancies ("enigmas") tell us about atmospheric processes?**

   Examples: mid-Holocene Saharan greening, humid hothouse climates/dry cold climates, evident anomalous hydrological cycle changes, tropical widening, lapse rate change, haitus, polar amplification.

1. **How do atmospheric processes control emergent climate behaviours relevant to climate/hydrological sensitivity?**

Processes: cloud radiative effects, convection (e.g., entrainment, lower tropospheric mixing), PBL, microphysics.

Emergent behaviours: cloud feedback, hydrologic or extreme precipitation responses to warming, emergent constraints appearing in GCMs, organisation of convection.

Strategies/subquestions:

1. What physical mechanisms and processes underlie either the robust model (GCM, CRM/LES) responses or biases, or their inter-model spread; and are they credible?
2. Determine more rigorously what quantities/processes/trends are key to observe better.
3. Understand/assess outlier/extreme behaviour in models. Try to build credible models with exotic/extreme sensitivities to see if it can be done.
4. Can we find, explain, and test the physical basis/hypotheses of emergent constraints between observable and desired quantities? Can we reconcile different approaches?

Methodologies/approaches: model hierarchies, hypothesis testing, process diagnostics (tendencies), SPOOKIE, PPE, targeted sensitivity tests, use of fine-scale models to test hypotheses or localised GCM responses

2. **What can systematic model-observation climate discrepancies tell us about wrong or missing atmospheric processes?**

Discrepancies: mid-Holocene Saharan greening, humid hothouse climates/dry cold climates, evident anomalous hydrological cycle changes, tropical widening, tropical lapse rate trends, warming "hiatus"/decadal variation, polar amplification in past climates

Atmospheric processes and mechanisms: clouds, microphysics, circulation, convection, land-atmosphere interaction; model biases (e.g. midlevel cloud, southern ocean bias)

Strategies/subquestions:

1. Which of these discrepancies are confidently established (vs. proxy/observation errors or natural variability)?
2. Which are possibly attributable to atmospheric process errors?
3. What can be done to resolve these discrepancies?

Methodologies/approaches: seek hypotheses on process representations, violent sensitivity experiments, proxy representation of missing/erroneous processes, test much higher resolution or higher-top models, ensemble/SPOOKIE analyses, idealized experiments or forcings (e.g. bogus heat/moisture sources/sinks)

Science questions

- How do atmospheric processes control emergent behaviours?
    - Examples: climate sensitivity, hydrologic or extreme precipitation changes, emergent constraints appearing in GCMs.
- What can important model-data climate discrepancies tell us about atmospheric processes?
    - Examples: mid-Holocene Saharan greening, humid hothouse climates/dry cold climates, evident anomalous hydrological cycle changes, tropical widening, lapse rate change, haitus, polar amplification.

Science questions

- Can atmospheric process errors account for "enigmas" (observations suggesting a major gap in basic understanding) such as mid-Holocene Saharan greening, humid hothouse climates/dry cold climates, evident anomalous hydrological cycle changes, tropical widening, lapse rate change, haitus, polar amplification, etc.?

- -> confirm robustly observed, seek new model ingredients that fix the problem, ...

Science questions

- What physical mechanisms and processes underlie either the robust model (GCM, CRM/LES) responses, biases, or the inter-model spread of responses, and are they credible?

  - -> examine multimodel ensemble, SPOOKIE, ...

Science questions

- Can we find, explain, and test the physical basis of emergent constraints between observable and desired quantities? Can we reconcile different approaches?

    - Establish credible bounds by seeking models with extreme sensitivities

Science questions

- Can we use our enhanced understanding to identify the most useful observations?

- How sensitive is extreme precipitation to global temperature?

- Is the physics of aggregation represented properly in GCMs? Is the MJO a basic test of convective organisation? Relevant to global sensitivity as well as A1&A2.

Other questions

- Do we use GCMs to address feedbacks? Need framework going beyond GCMs?
- Can we learn lessons from CGILS about how to use LES or test GCM low-cloud behaviour?
- Is there a way of gaining more resources, or credibility, for participation in idealised experiment inter-comparisons that are useful for developing understanding?
- How to ensure that what we learn is relevant and useful for model development.
- How to gain more resources and effort toward model development in atmospheric processes.

What would success look like in 10 yrs?

- Have multiple emergent constraints backed by tested physical mechanisms
- New questions!
- Consensus on main sources of model spread in key responses
- Have identified which model failures are significant
- Findings are leading to model improvements