Summary on cross-topic synergies and perspectives – Water Cycle and water resources

- Address the grand challenges of **climate and environmental changes on water cycle and water resources**
  - **Model Integration and Complexity**: atmospheric and terrestrial systems (hydrology, soil, vegetation, ecosystem), e.g., integrating atmospheric models with hydrological models (surface and groundwater) to predict changes in water availability and distribution,
  - **High Latitudes:** snow/ice changes and feedback on the global water cycle; poleward moisture transport and impact on high latitudes

- Address the grand challenges of **model biases and uncertainty in model predictability across scales**
  - **Model Uncertainty and Biases**: i) strong integration between model developments and process analysis (collaboration with ASR); 2) high-resolution (EAMxx) needs corresponding model developments in cloud microphysics and turbulence besides the resolution advance (many cloud microphysics are strongly scale-dependent and the way of parameterizing them needs to change).
  - **Innovative Technology and AI:** i) Foundational models for improving predictability and UQ. Hybrid model for improving accuracy and computational efficiency; ii) Better integration of available data and enhance process-oriented evaluation or for data assimilation
  - **Metrics, Benchmarks, Credibility, Data**: i) develop testbed and metrics for mesoscale process and storm-scale microphysics and dynamics for CPM/CRM; ii) build database for high-frequency datasets (collaboration with ARM)

- Address the grand challenges of **representing human activities in water cycle**
  - **Urban and Coastal:** human impacts on precipitation (fine-scale urban physics and coastal processes, aerosols, human system decisions)
- Address the grand challenges of **accurate and locally relevant predictions of extreme precipitation for resilience and adaptation**
  - **Extreme Events**: quantify changes of precipitation extremes and the drivers across scales.
  - **Impacts and Resilience:** understanding the socioeconomic impacts of extreme precipitation; engaging stakeholders from various sectors (water, energy, agriculture, industry).

- Address the grand challenges in **water availability and scarcity**
  - **Energy, water, and land system:** i) study changes of surface water availability, including changes in snowpack, glacier melt, and river flows, and groundwater recharge and depletion ii) Water-Energy Nexus: minimize water use in energy production and reduce the energy footprint of water extraction, treatment, and distribution

Cross EESM with ARM/ASR: integration of model development with process-level studies would be extremely helpful to understand the problems and more physical way to address the problem.

Cross EES and BSS: Plant/biology: precipitation-plant--climate interactions - plant function impacts on precipitation and climate impacts on precipitation and plant function.

Cross SC and EERE: There are strong synergies with SETO and WETO in clouds/radiation, precipitation, and wind simulations (they develop physical models and ML/AI models for impact and fast response). They have stakeholders that we need.