U.S. DEPARTMENT OF ENERGY
Office of Science

AI4ESP: Vision for a Machine Learning Framework Enabling End-to-End Earth System Predictability Research

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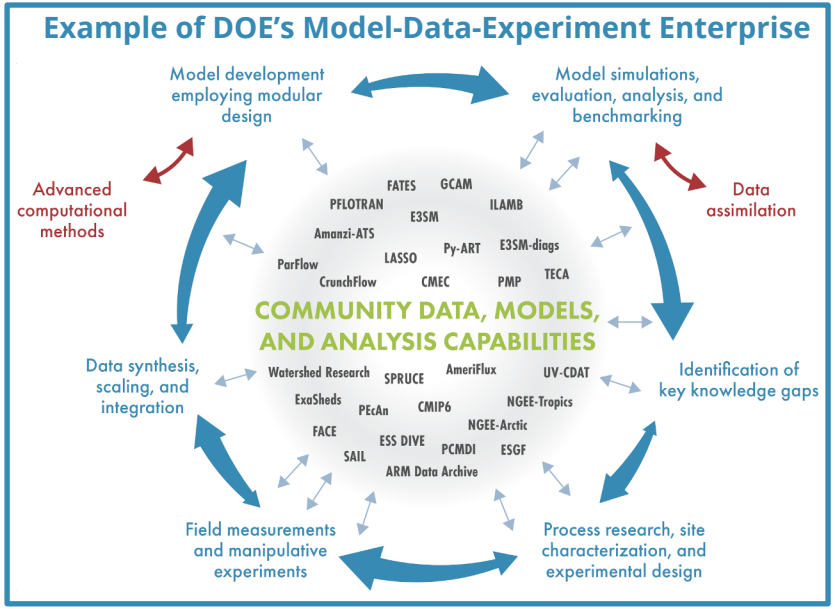
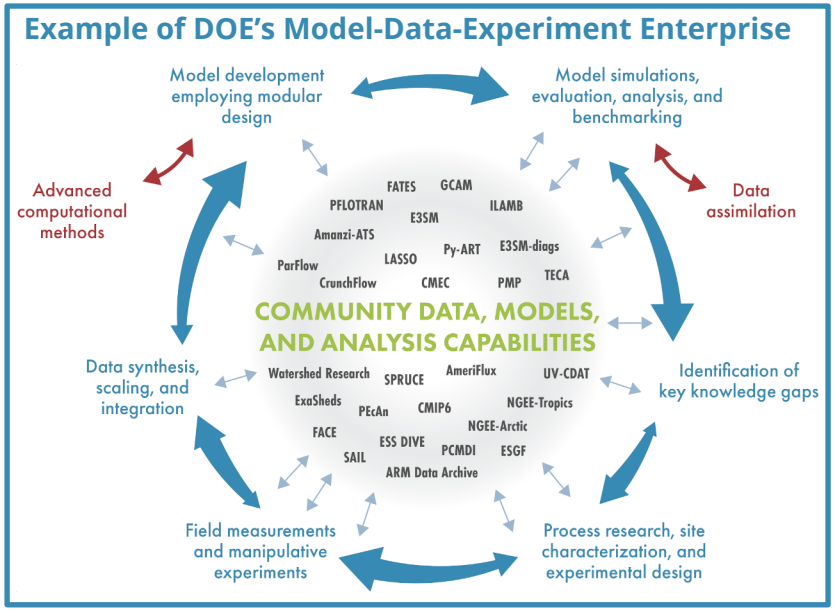
Developing Vision Enabling AI from Obs to Earth System Models

- What does the framework look like that combines DOE's experiment/observation and simulation capabilities to quantify and reduce the uncertainty in high-resolution Earth systems models?
- Goal: Define the paradigm shift required to employ artificial intelligence and machine learning across field, lab, modeling, and analysis activities. Non-incremental advancement built for the future EESSD program needs (5-10yr).
  - Bridge the gap: state-of-the-art in AI/ML research & EESSD program needs
  - Harness Earth System Data including inter-agency resources
  - Harness DOE computing resources, i.e. Exascale
  - Domain-specific machine learning applications



Developing Vision Enabling AI from Obs to Earth System Models

- **AI/ML at every aspect in the wheel** (examples; not exhaustive)
  - Simulation-guided experiment/sampling design
  - Dynamic/responsive AI-controlled measurement systems
  - Edge computing and 5G sensor networks
  - Pattern recognition and process discovery through large data
  - Hybrid process-/machine learning-based coupled Earth system
  - modeling
  - Data-driven multiscale modeling and data–model integration
  - and analytics



White Paper Call - Organization

Focused Topic: Extreme Water Cycle
Focal Areas

- **Data acquisition and assimilation** enabled by machine learning, AI, and advanced methods including experimental/network design/optimization, unsupervised learning (including deep learning), and hardware-related efforts involving AI (e.g., edge computing)
- **Predictive modeling through the use of AI** techniques and AI-derived model components; the use of AI and other tools to design a prediction system comprising of a hierarchy of models (e.g., AI driven model/component/parameterization selection)
- **Insight gleaned from complex data** (both observed and simulated) using AI, big data analytics, and other advanced methods, including explainable AI and physics- or knowledge-guided AI

AI4ESP

Artificial Intelligence for Earth System Predictability

A multi-lab initiative working with the Earth and Environmental Systems Science Division (EESSD) of the Office of Biological and Environmental Research (BER) to develop a new paradigm for Earth system predictability focused on enabling artificial intelligence across field, lab, modeling, and analysis activities.

White papers were solicited for development and application of AI methods in areas relevant to EESSD research with an emphasis on quantifying and improving Earth system predictability, particularly related to the integrative water cycle and extreme events. Submitted white papers will be used to inform the design of three sequential workshops (conducted in 2021-2022) focused on answering the question:

ML with AI4ESP Papers

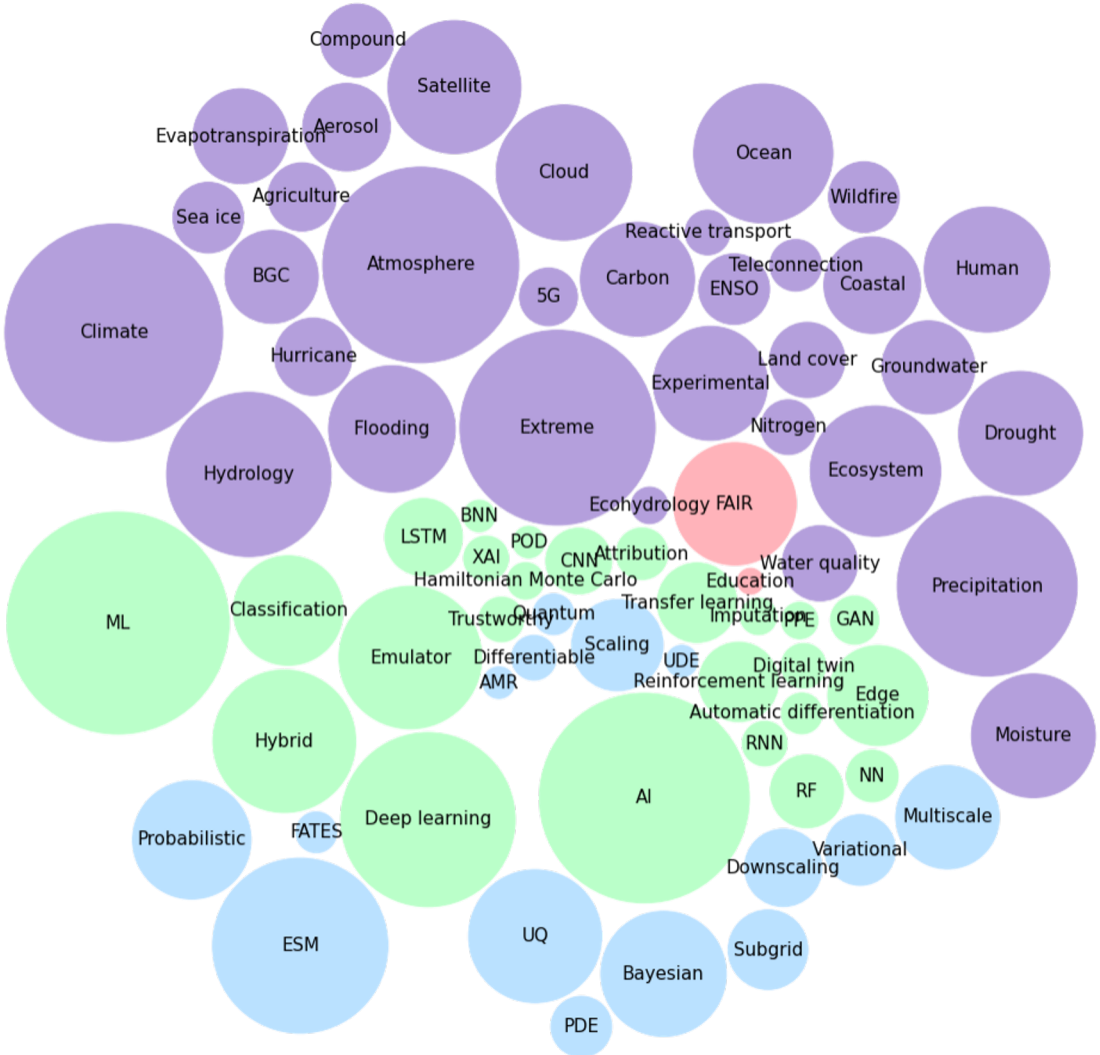
- 155 papers
- Area of circles = # occurrence
- Multiple occurrences in 1 paper = 1

ML/AI methods

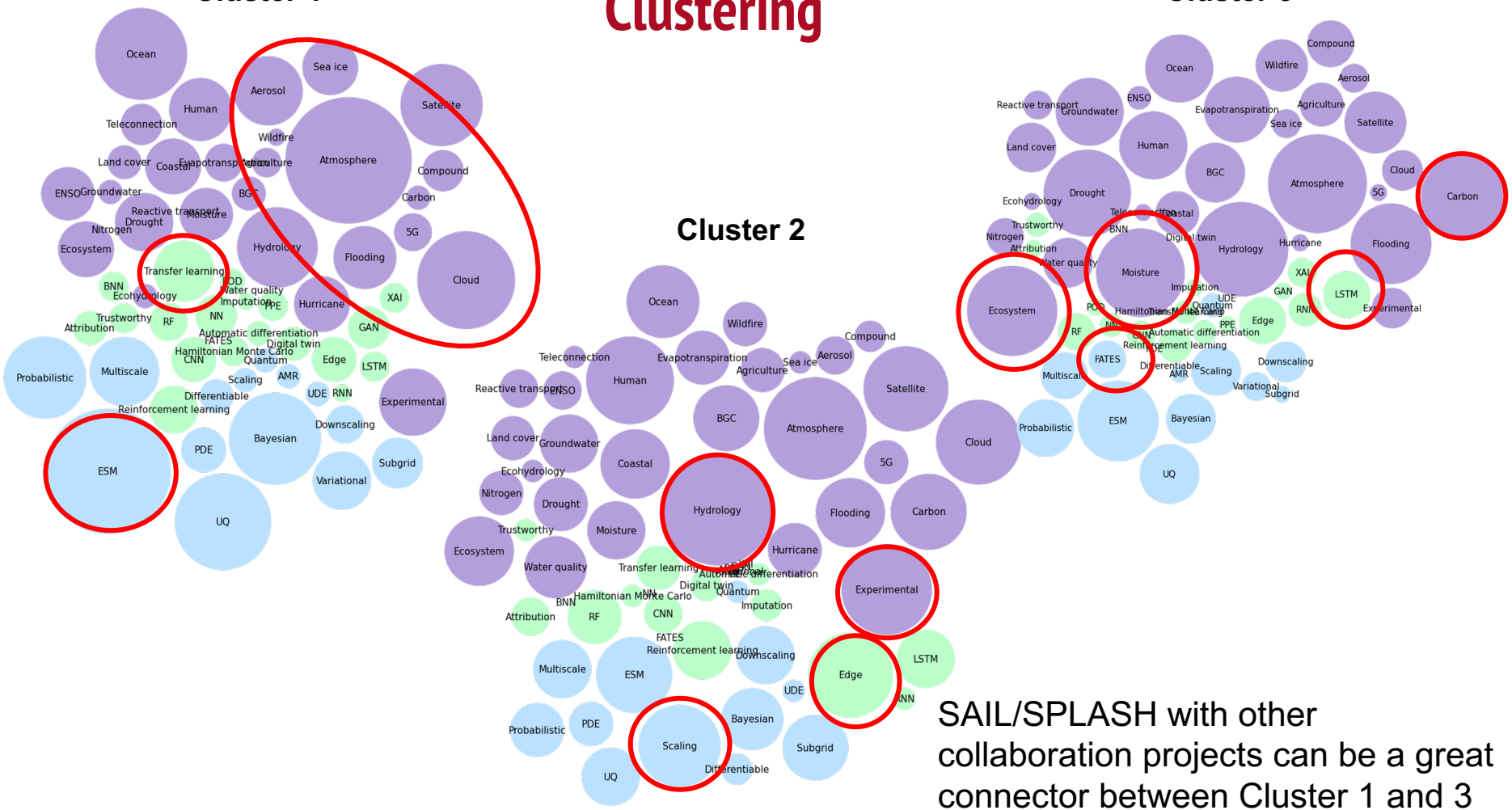
Domain Science

Math/Model

Others



Clustering

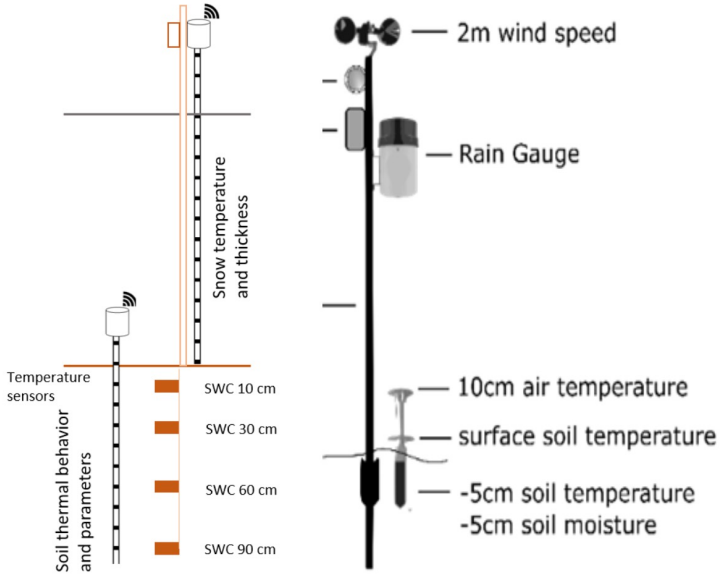


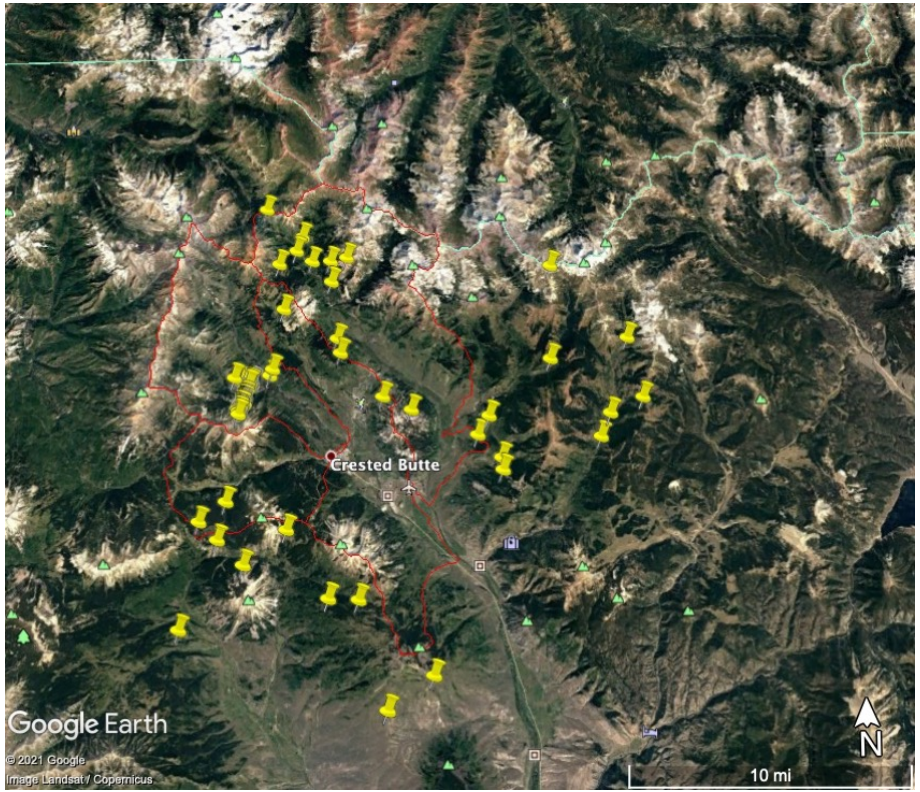
SAIL/SPLASH with other collaboration projects can be a great connector between Cluster 1 and 3

Timeline

- The white papers are available at AI4ESP.org
- Workshop in October
  - Organized based on focal areas
  - Breakout sessions: cross-cut (focal areas) and “silo” (focal areas > domain science)
  - Workshop report → New direction in BER-EESSD

ML-guided Monitoring Network in SFA





Gaussian mixture models (Watershed Zonation) to capture the co-variability among NASA ASO, topography, Landsat-based plants' drought sensitivity: ~120 locations

….. **Connecting Cluster 1 and Cluster 3**