

AI and Machine Learning for Climate Science and Modeling

Katie Dagon

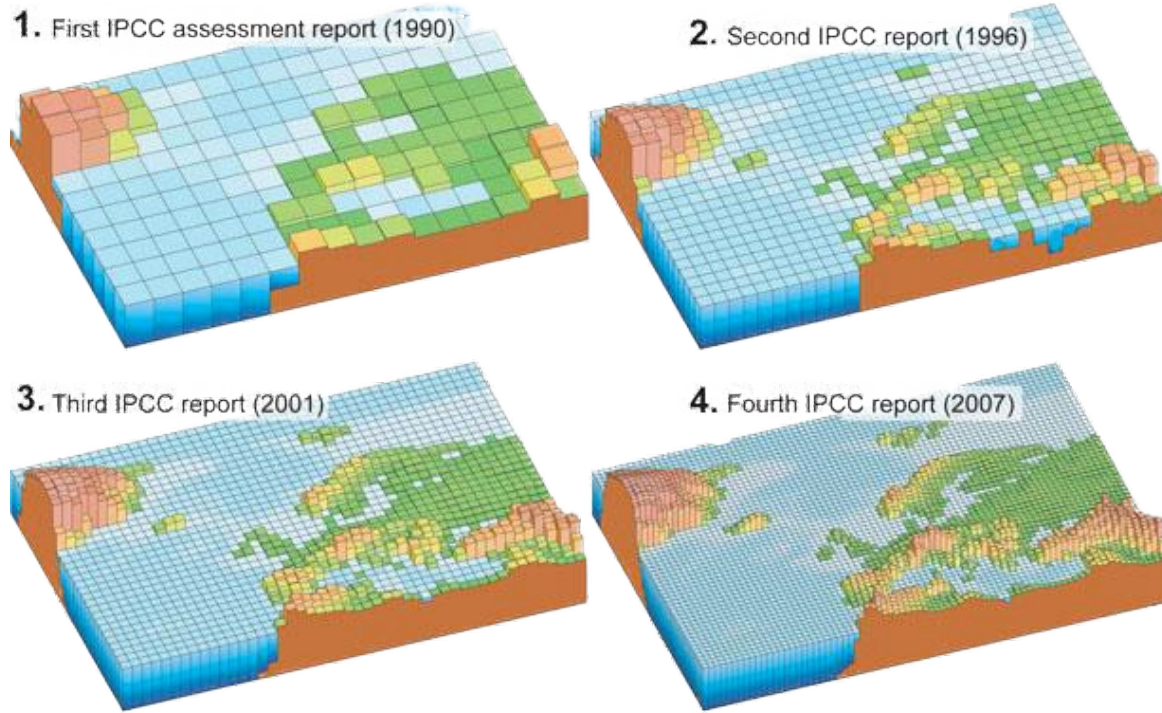
National Center for Atmospheric Research



The Expanding Use of AI in Research Infrastructure Applications
NSF Research Infrastructure Workshop
June 27, 2023



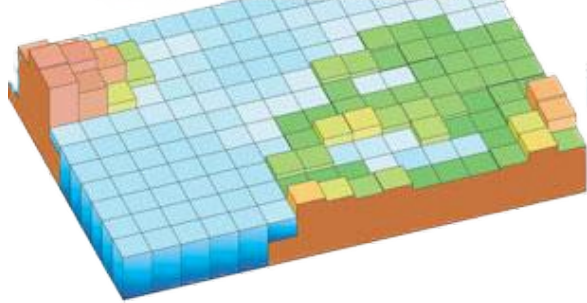
Emerging Paradigms in Earth System Modeling



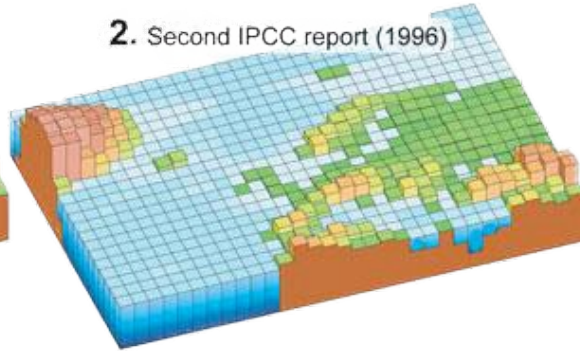
Climate model resolution in recent decades
(National Academies)

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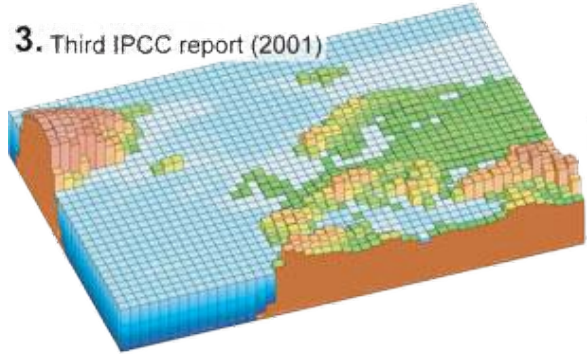
1. First IPCC assessment report (1990)



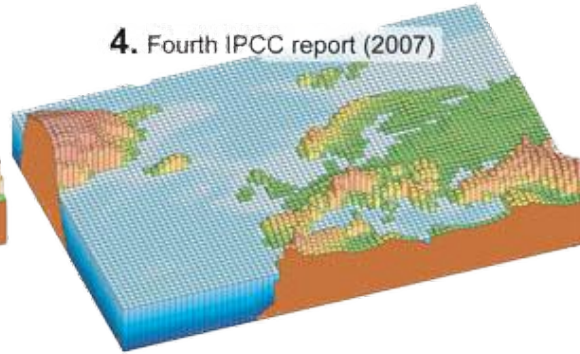
2. Second IPCC report (1996)



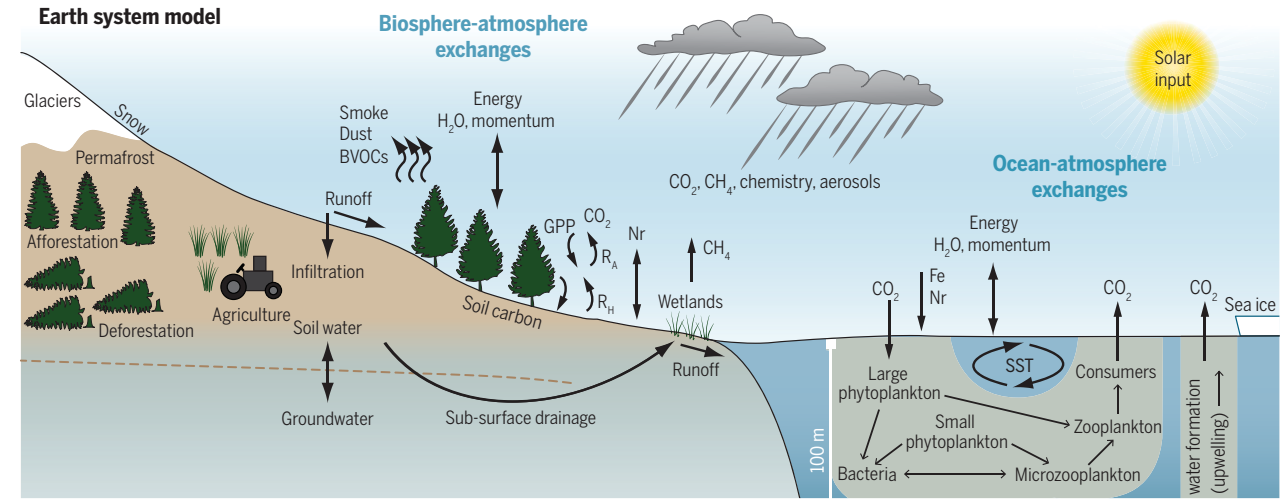
3. Third IPCC report (2001)



4. Fourth IPCC report (2007)



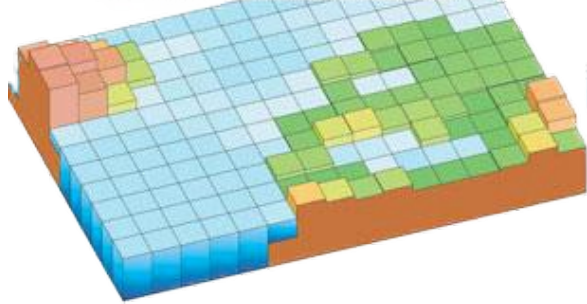
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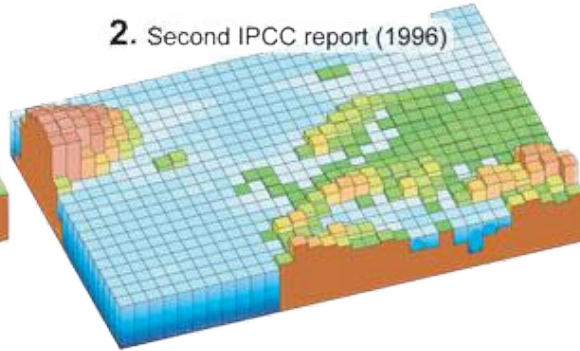
Earth system model complexity (Bonan & Doney 2018)

Emerging Paradigms in Earth System Modeling

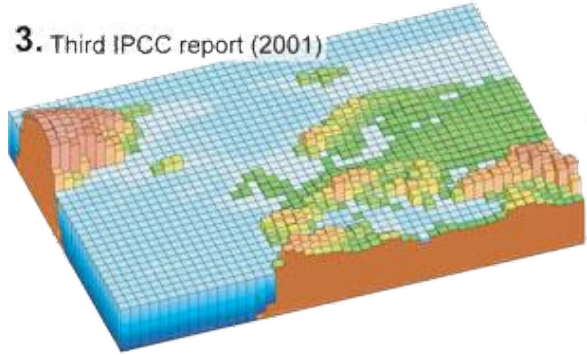
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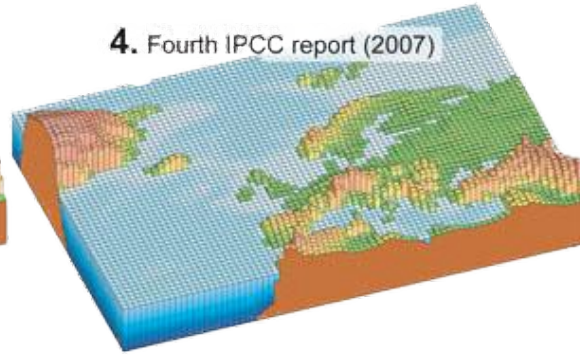
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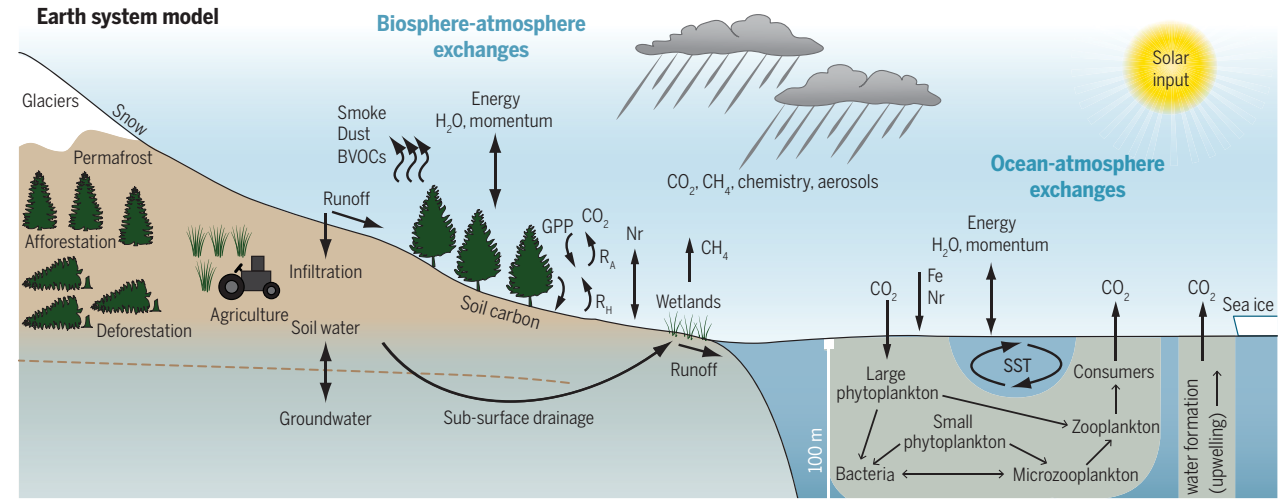
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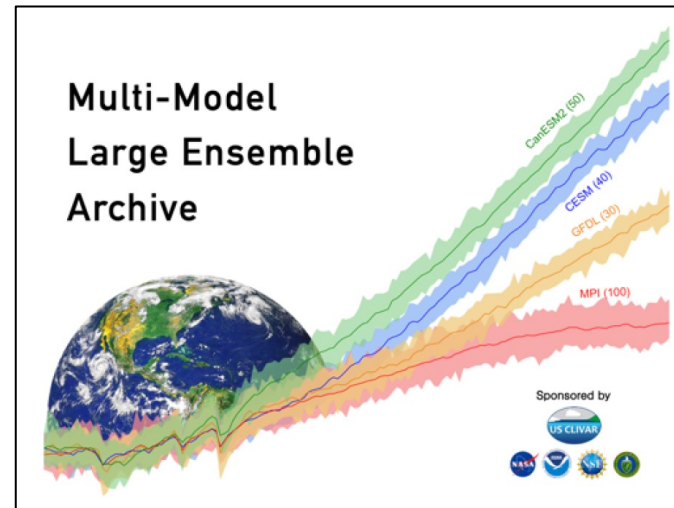
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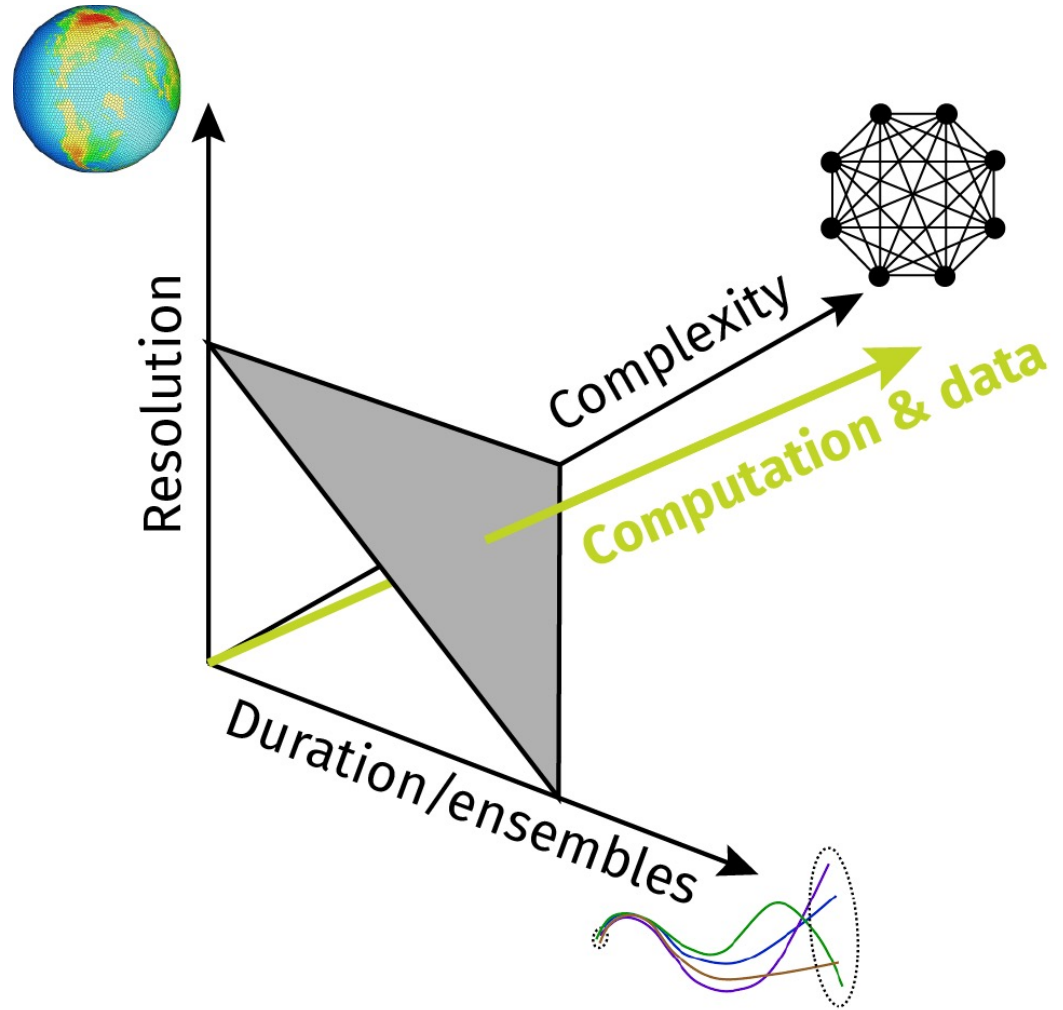


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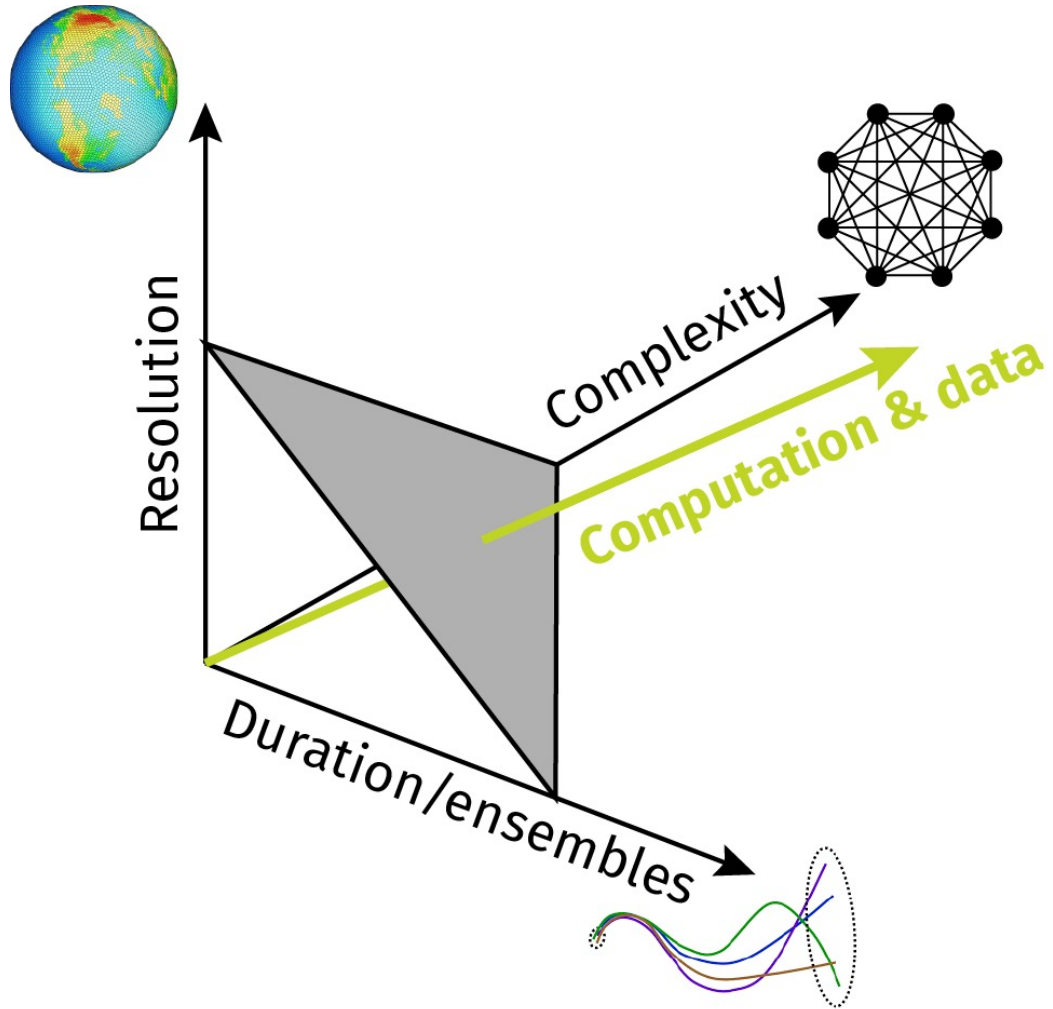


Large ensembles sampling internal variability and model uncertainty (US CLIVAR)

High Performance Computing

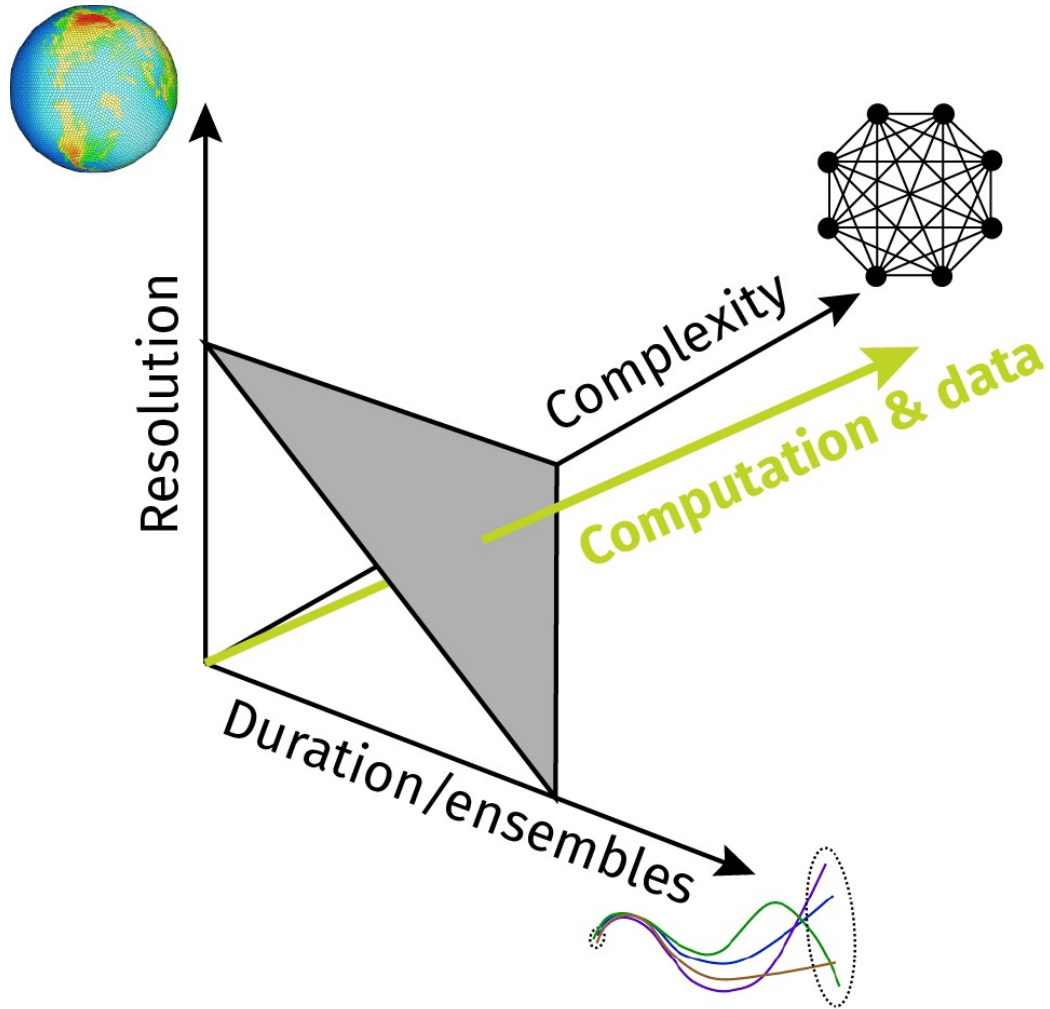


High Performance Computing



Cheyenne & Derecho Supercomputers
(Images: NCAR CISL; Hardware specs: Brian Vanderwende)

High Performance Computing



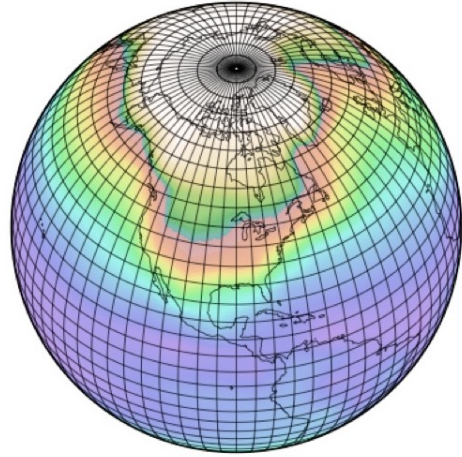
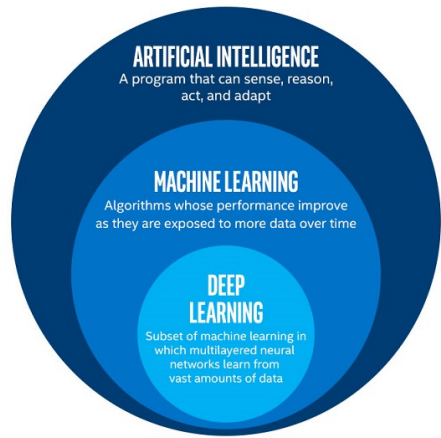
No GPU capability; Separate analysis cluster has 64 V100 GPUs across 10 nodes, with plans for 28 A100 GPUs across 7 nodes.



20% compute power from GPUs; 328 A100 GPUs across 82 nodes, equiv. 67% Cheyenne performance, plus above analysis cluster.

Cheyenne & Derecho Supercomputers
(Images: NCAR CISL; Hardware specs: Brian Vanderwende)

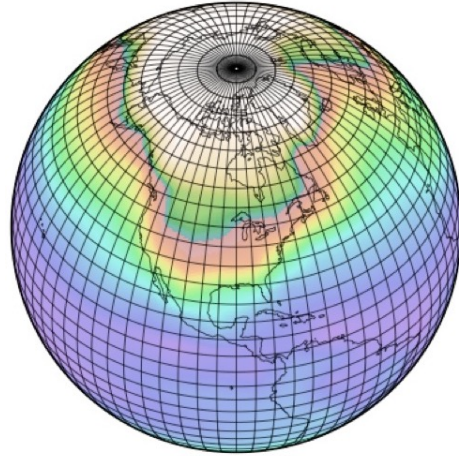
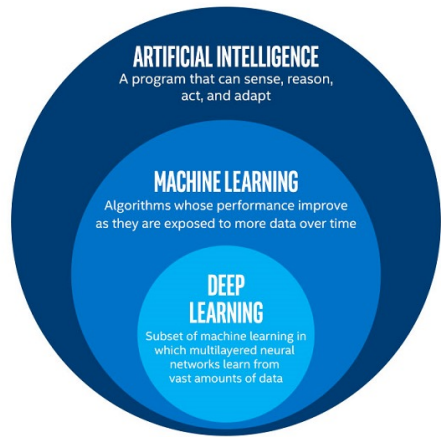
AI/ML for Climate Science and Modeling



Current research topics:

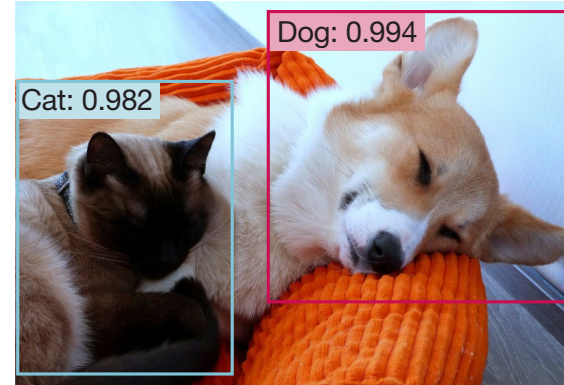
- Emulation of climate models for parameter calibration and **uncertainty quantification**

AI/ML for Climate Science and Modeling



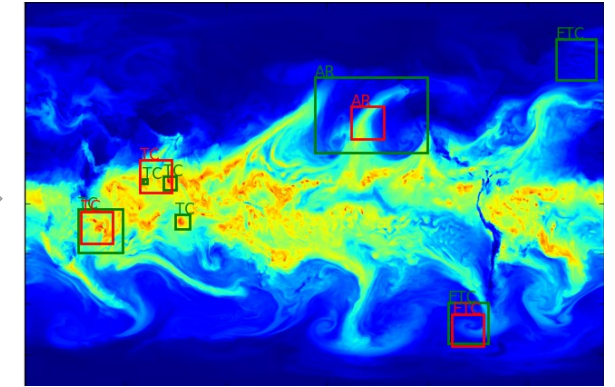
Machine learning tasks

a Object classification and localization



Earth science tasks

Pattern classification

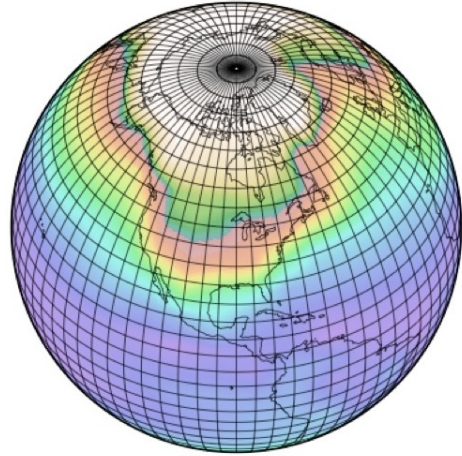
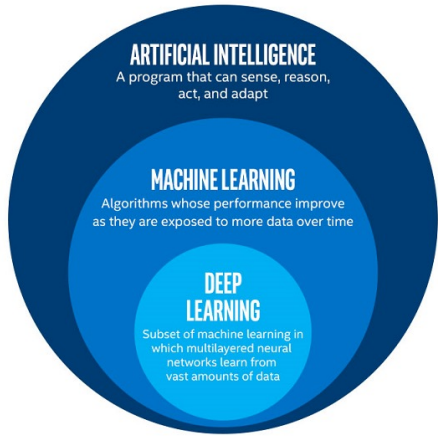


Current research topics:

- Emulation of climate models for parameter calibration and **uncertainty quantification**
- Segmentation models for detection and understanding **extreme weather events**

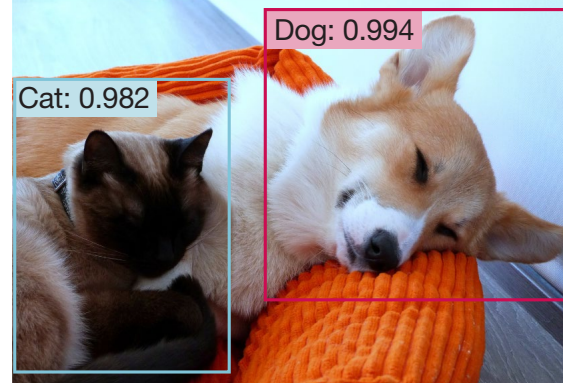
Reichstein et al. (2019)

AI/ML for Climate Science and Modeling



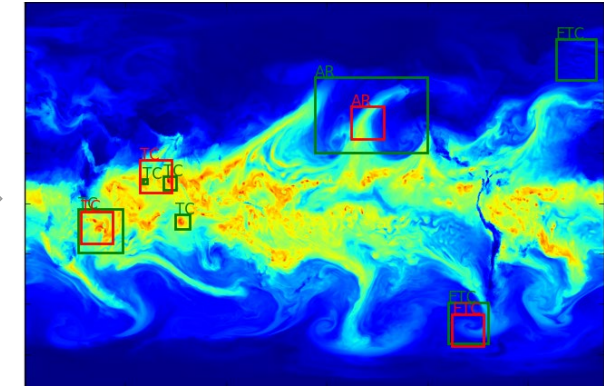
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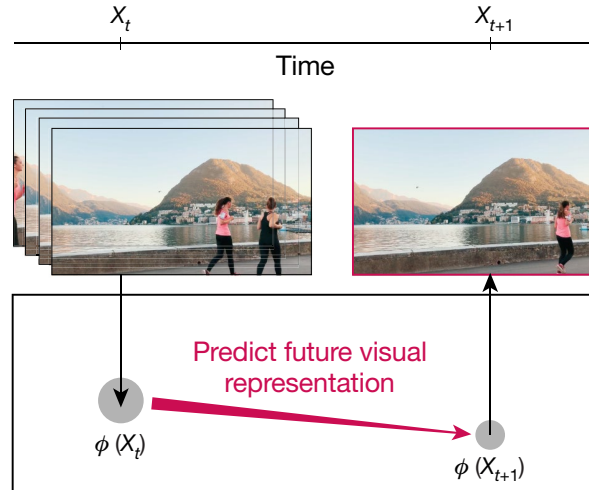
Pattern classification



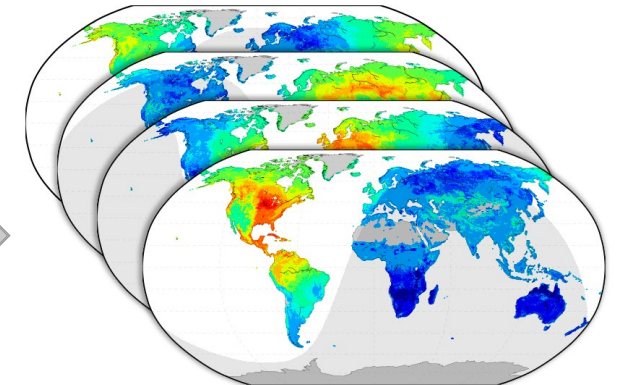
Current research topics:

- Emulation of climate models for parameter calibration and **uncertainty quantification**
- Segmentation models for detection and understanding **extreme weather events**
- Bias correcting climate models for **subseasonal prediction**

c Video prediction



Short-term forecasting



Reichstein et al. (2019)

Emerging Paradigms of Earth System Data Science

Domain science

Water



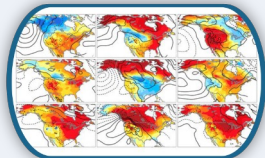
Weather



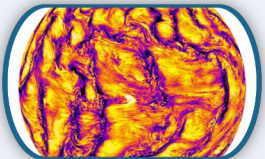
Air Quality



Climate



**Sun+Space
Weather**



Emerging Paradigms of Earth System Data Science

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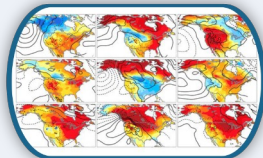
Weather



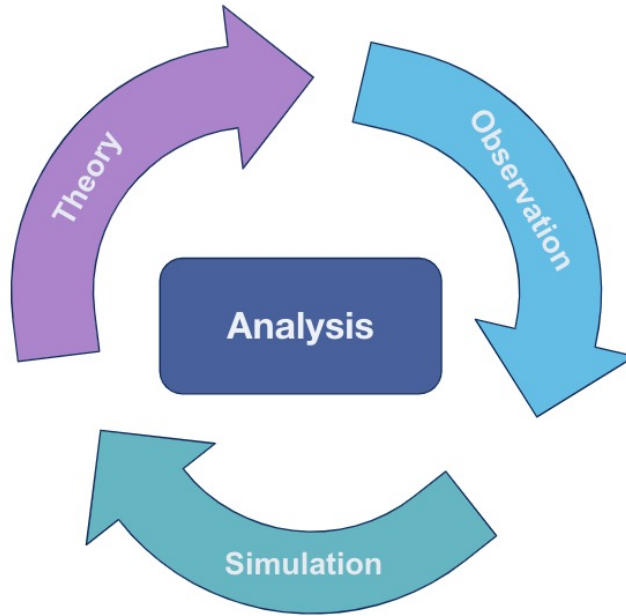
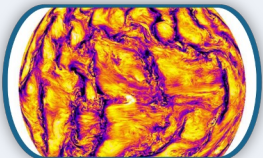
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Weather**



Different goals, same means

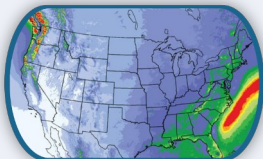
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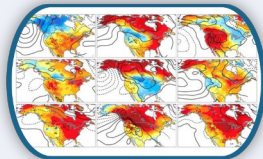
Weather



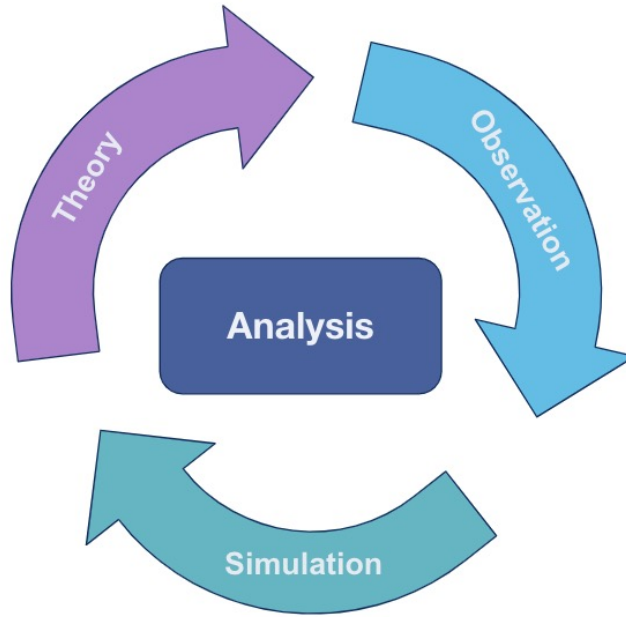
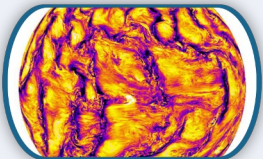
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Climate



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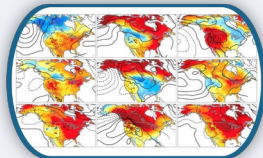
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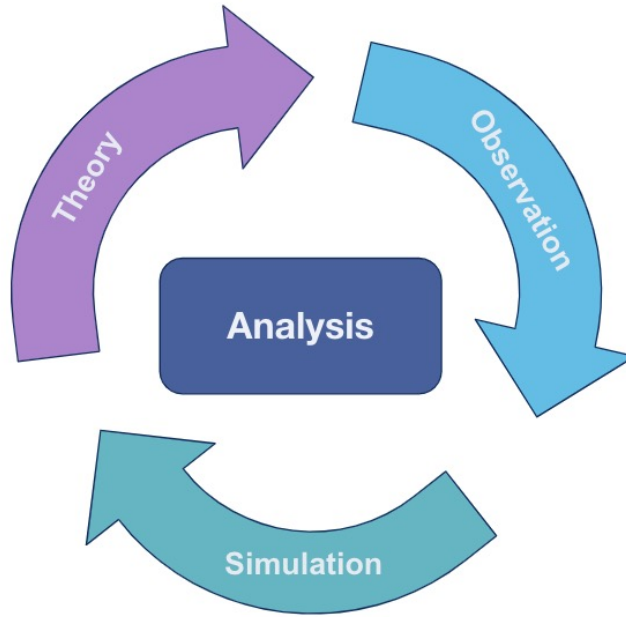
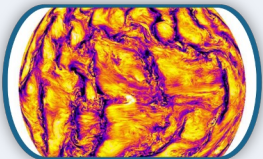
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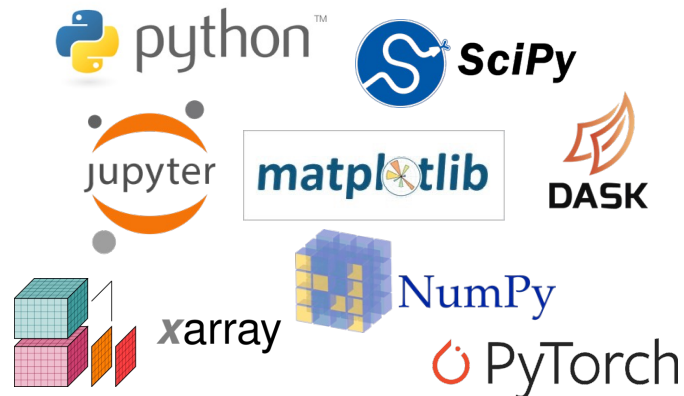
Climate



Sun+Space Weather

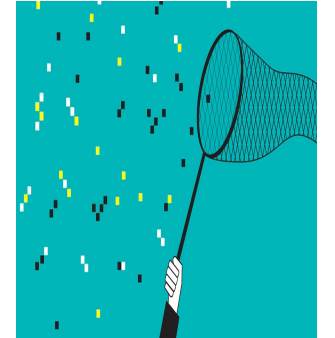


Different goals, same means



Challenges

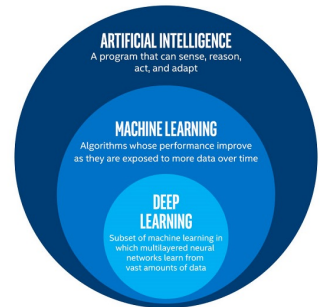
Data wrangling



Limited sharing and reuse



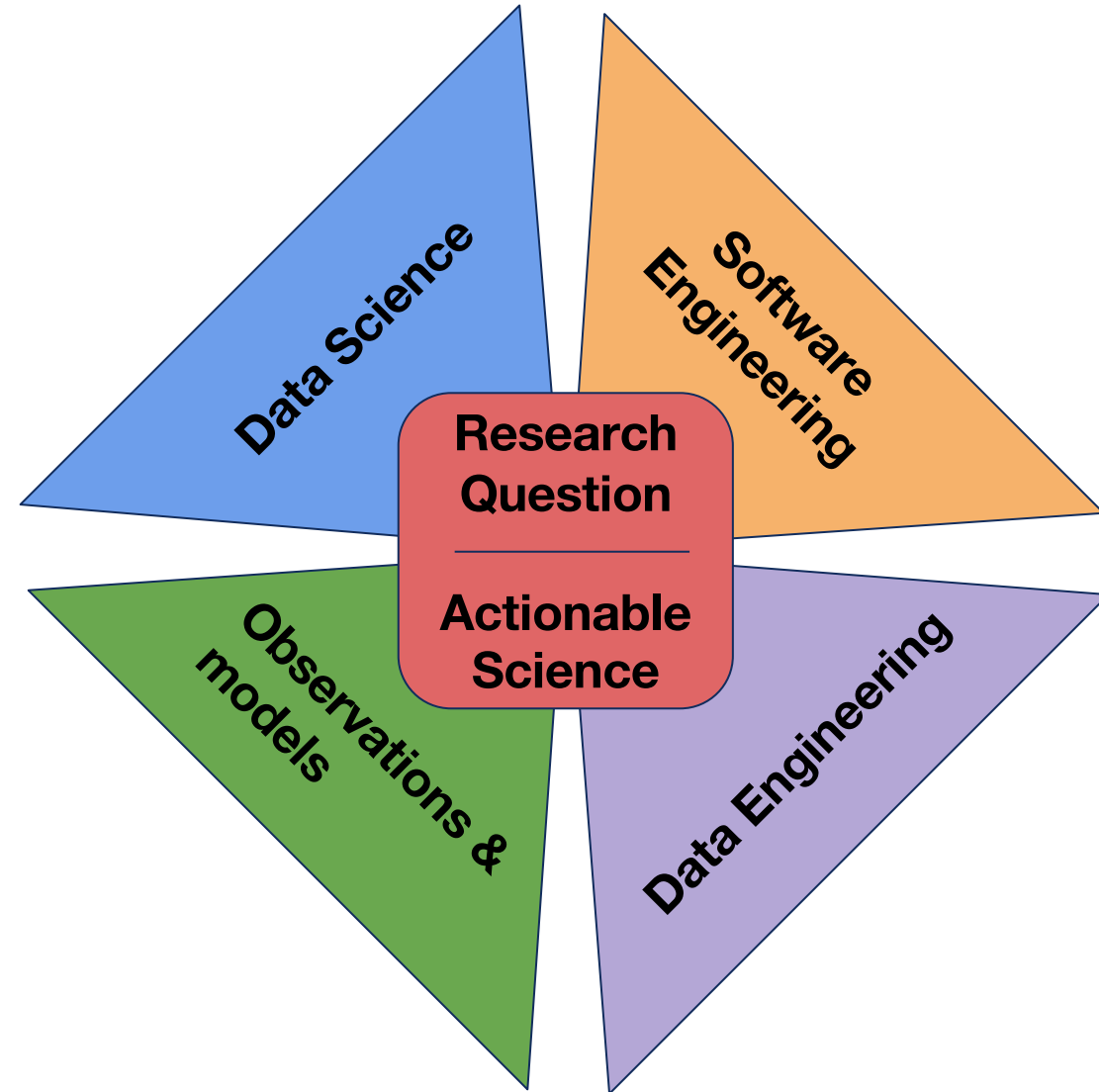
AI/ML



NCAR/UCAR Earth System Data Science (ESDS) Initiative

Vision

Profoundly **increase the effectiveness** of the NCAR/UCAR workforce by promoting deeper **collaboration centered on analytics** and transforming how geoscientists **synthesize and extract information** from large, diverse datasets.



Website

<https://ncar.github.io/esds/>

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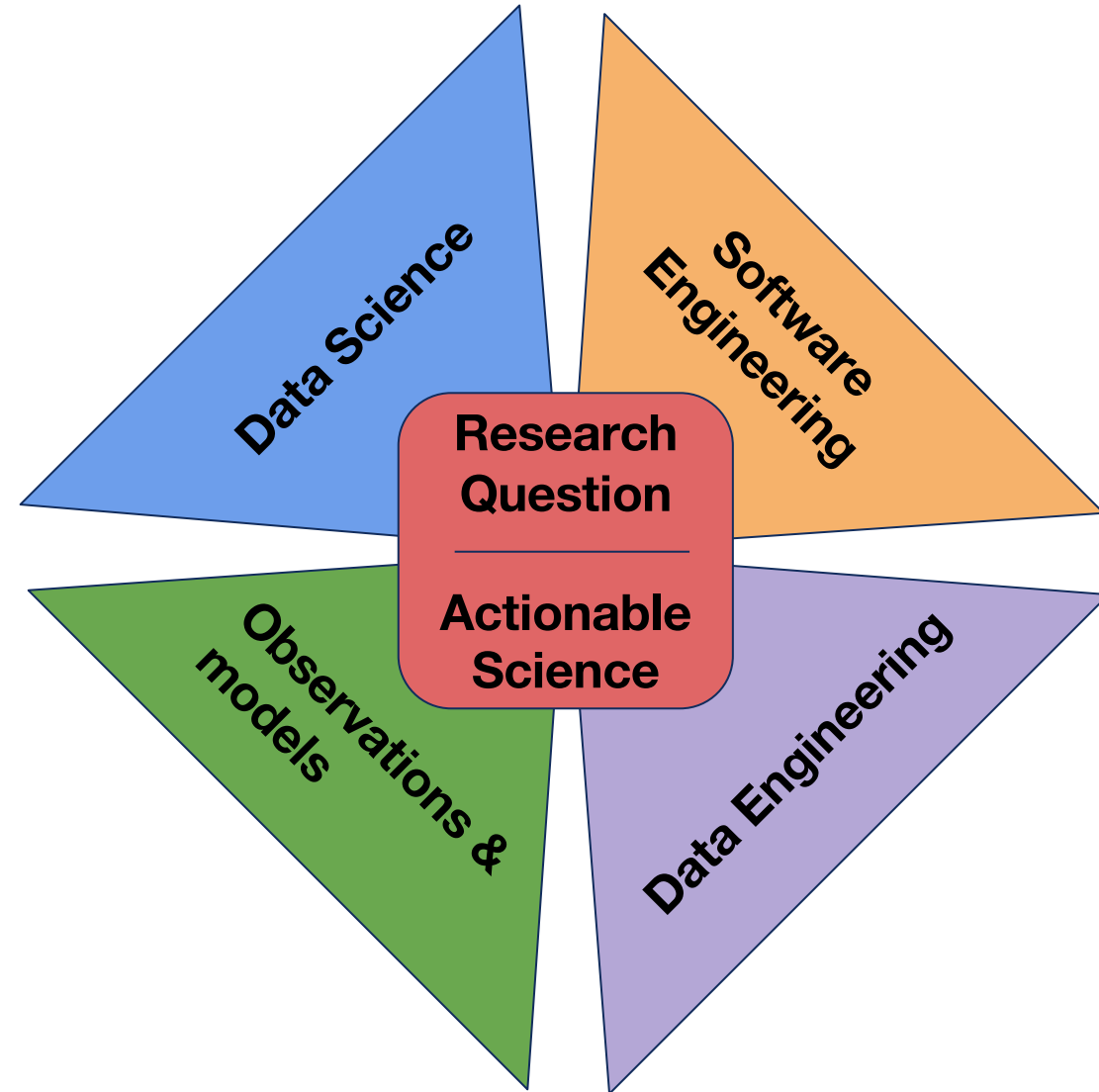
Approach

Cultivate a **community of practice** centered on the development and application of scalable analysis workflows:

- Core software development and computing
- Training and education
- **Community building:** regular meetings, blog posts, analysis “office hours”, asynchronous discussion forum

Website

<https://ncar.github.io/esds/>



Challenges and Opportunities

Core Development

- Create and share **analysis workflows** for AI/ML tasks.
- Democratize access to **diverse data sources**.

Training and Education

- Broaden participation through **Earth data science education**.
- Facilitate **entry points** for domain scientists to explore AI/ML, and AI/ML experts to explore Earth science applications.
- Provide training on how to best **leverage research infrastructure** (e.g., GPU hackathons, cloud computing).

Community Building

- Encourage **open science and development contributions** and reward them like scientific publications.
- Fund interdisciplinary research and **science-software partnerships**.



LEAP



docker



Thanks!



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