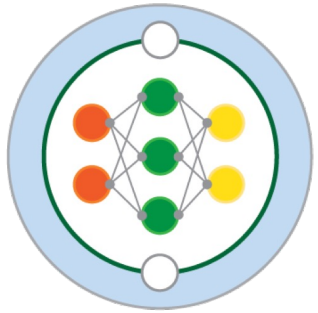
Machine Learning for Climate Modeling: M²LInES and LEAP



LEAP

Galen A. McKinley (Columbia/LDEO)
and
Laure Zanna (NYU)

27th CESM Workshop, 13 June 2022

https://m2lines.github.io

https://leap.columbia.edu/

STC: LEARNING THE EARTH WITH ARTIFICIAL INTELLIGENCE AND PHYSICS

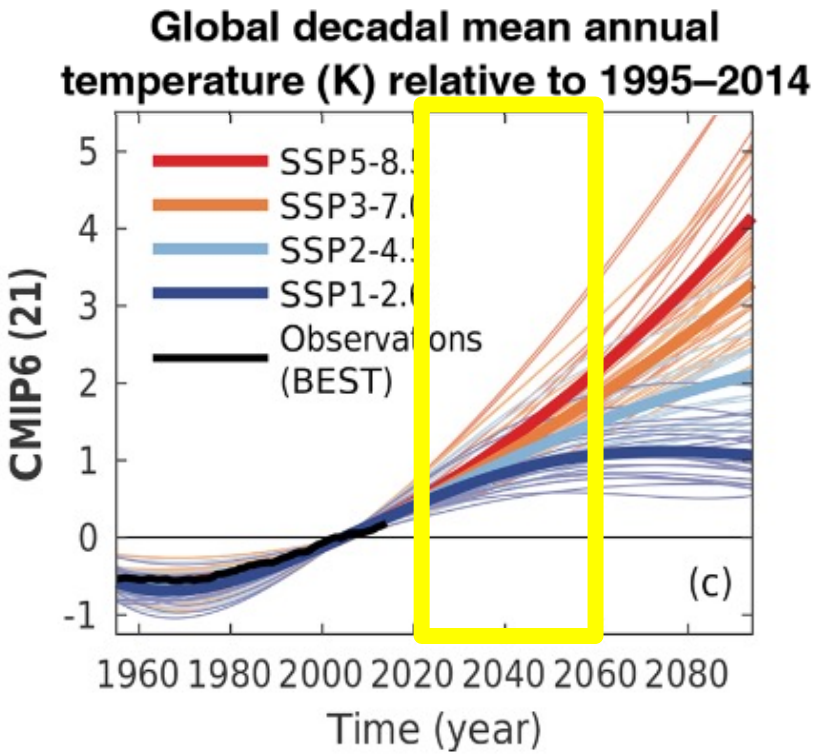
LEAP

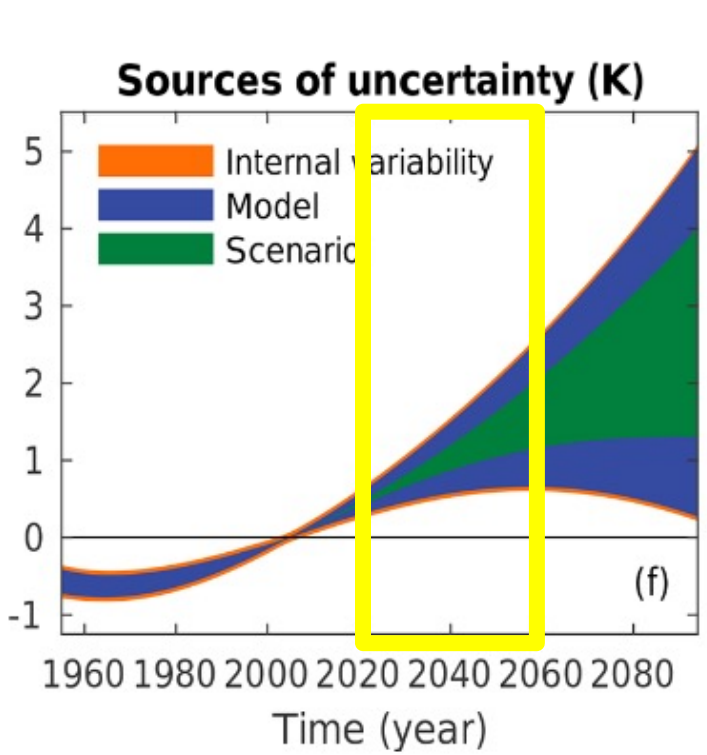
Columbia | NYU | UC Irvine
Teachers College | U. Minnesota

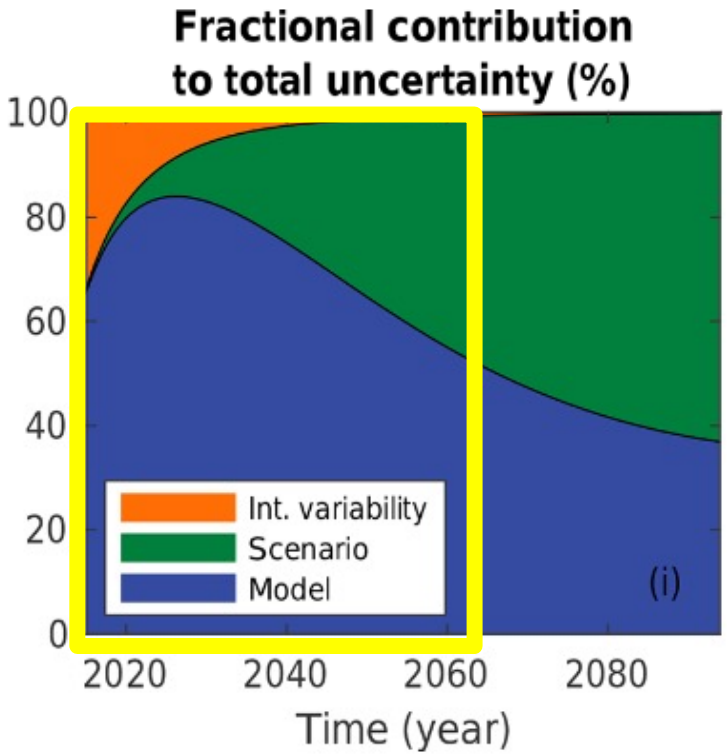
Galen A. McKinley (Columbia/LDEO)
LEAP STC Deputy Director

27th CESM Workshop, 13 June 2022

The coming decades are critical to adaptation. Model structure causes much uncertainty.

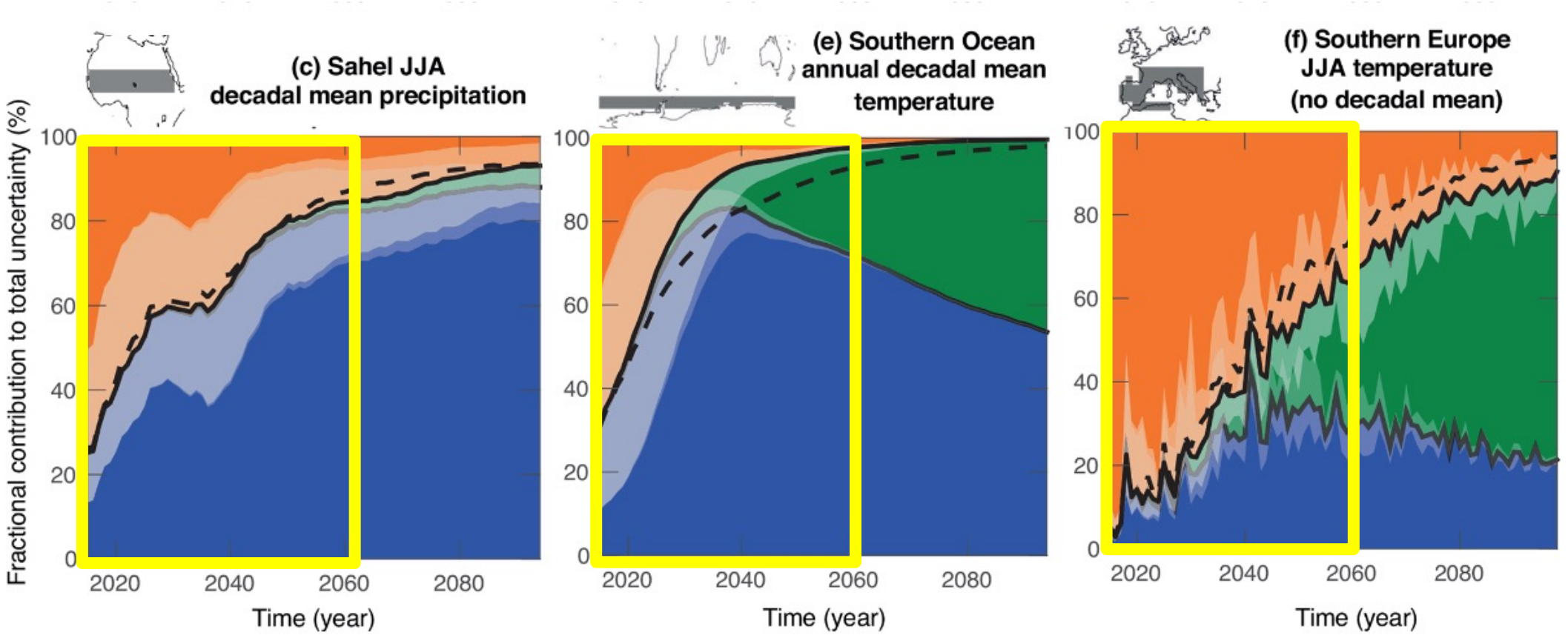






Lehener et al., 2020

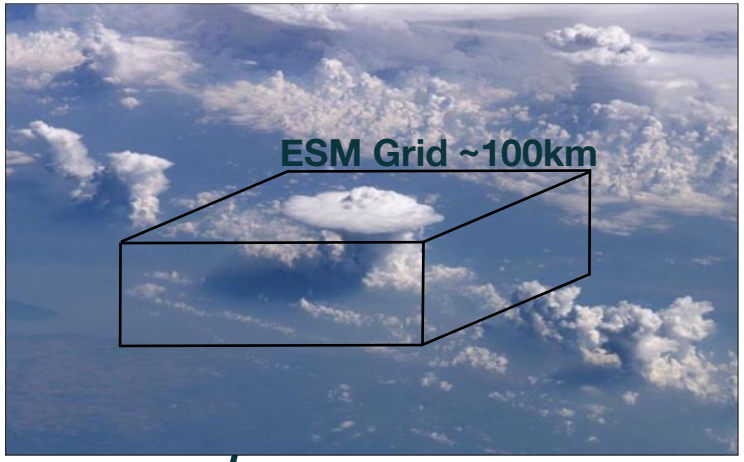
Adaptation will occur locally. Representation of internal variability is connected to model structure.



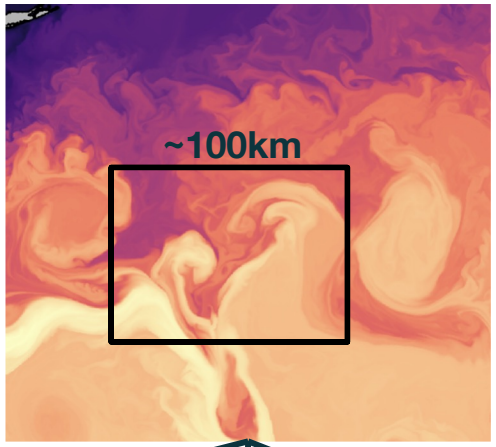
Lehener et al., 2020

Model Structure = Parameterizations and parameters

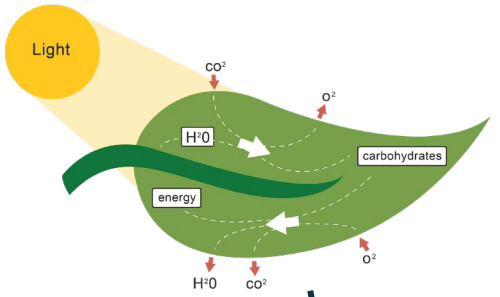
Clouds



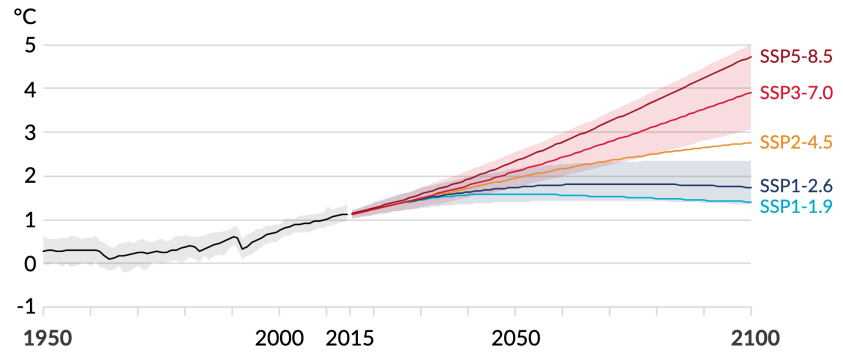
Ocean Eddies

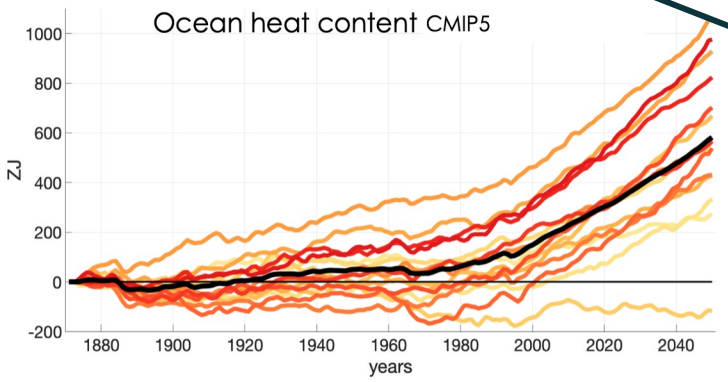


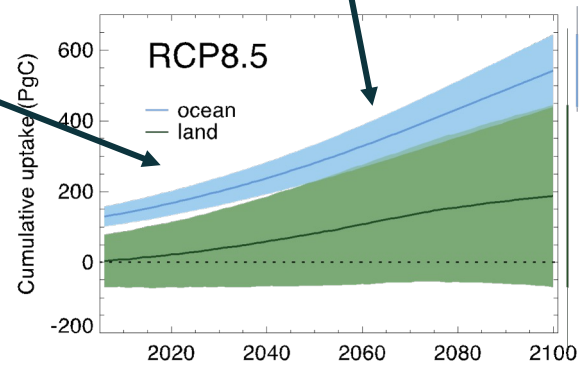
Photosynthesis



a) Global surface temperature change relative to 1850-1900





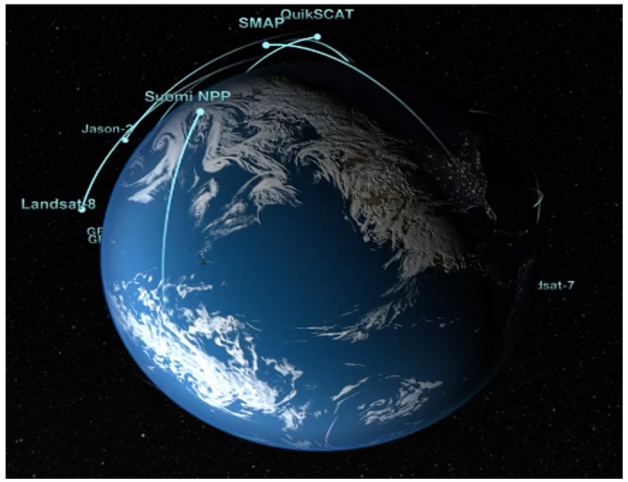


Newsom, Zanna et al., 2020 *Geo Res Letters*; Bronselaer + Zanna, 2020 *Nature*; Friedlingstein et al. 2006 *J Climate*

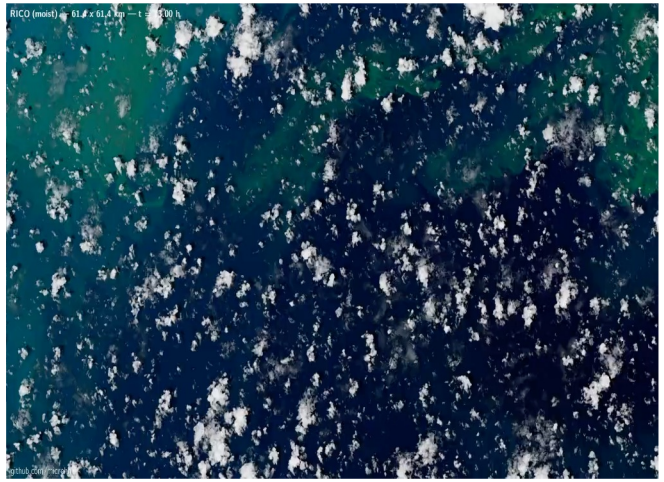
LEAP

Big data and machine learning create an opportunity

Massive data from satellites and autonomous sensing



High-resolution process-resolving simulations

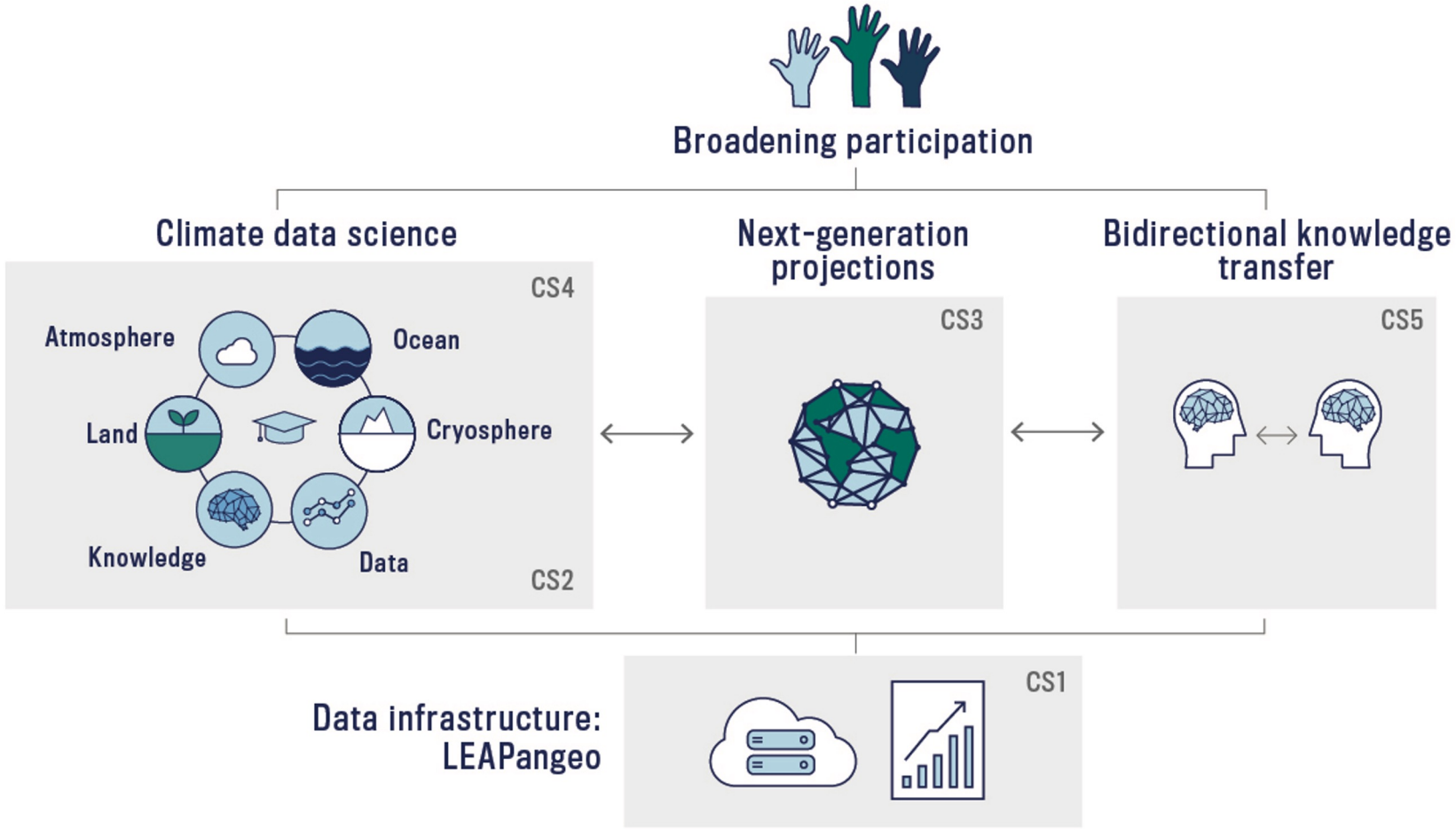


Machine Learning

LEAP will **harness data** + **advance ML** to improve climate projections.

LEAP

Mission: **LEAP's mission is to increase the reliability, utility, and reach of climate projections through the integration of climate and data science.**



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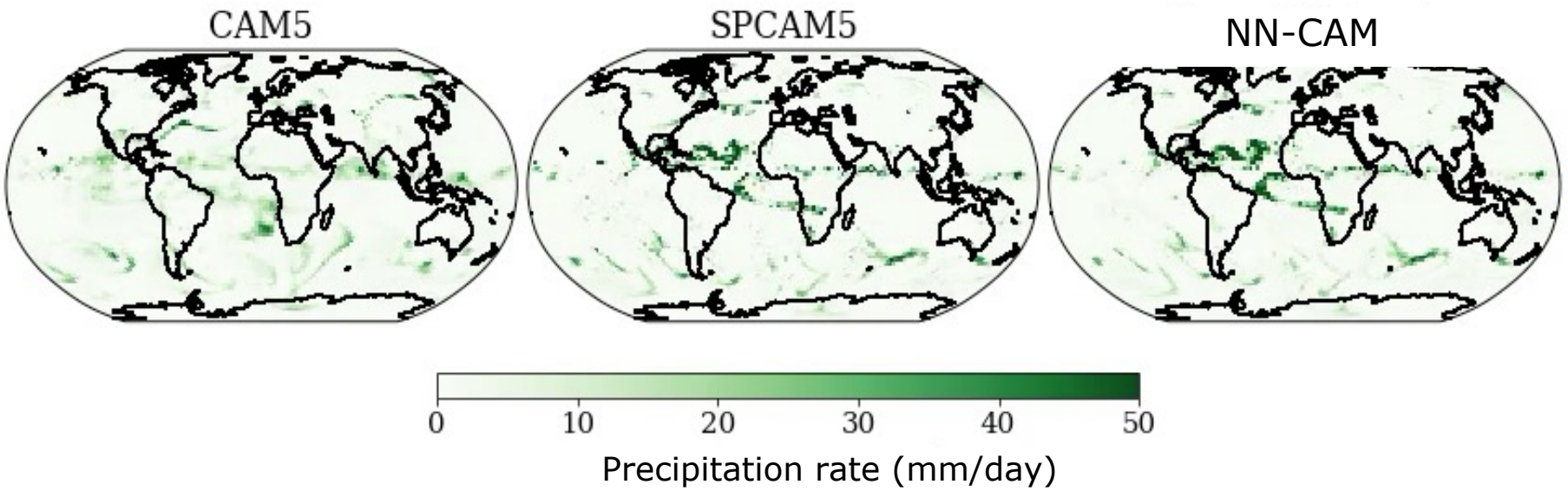
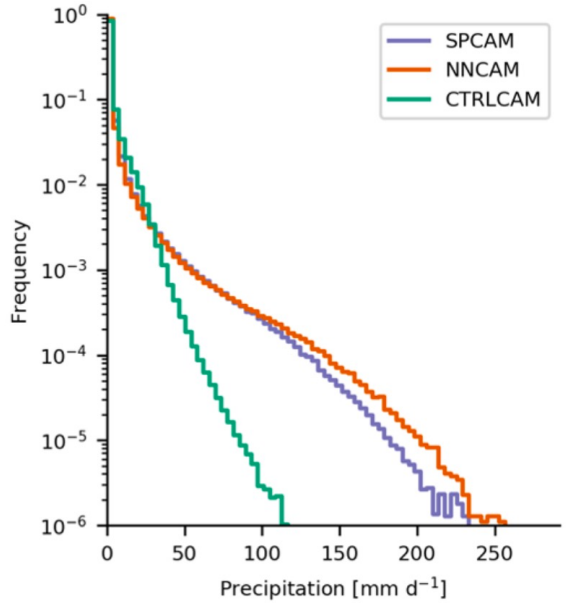
Research Objective 1.1: **Improve parameterizations**

Accelerate CESM development with novel parameterizations enabled by ML and growing datasets



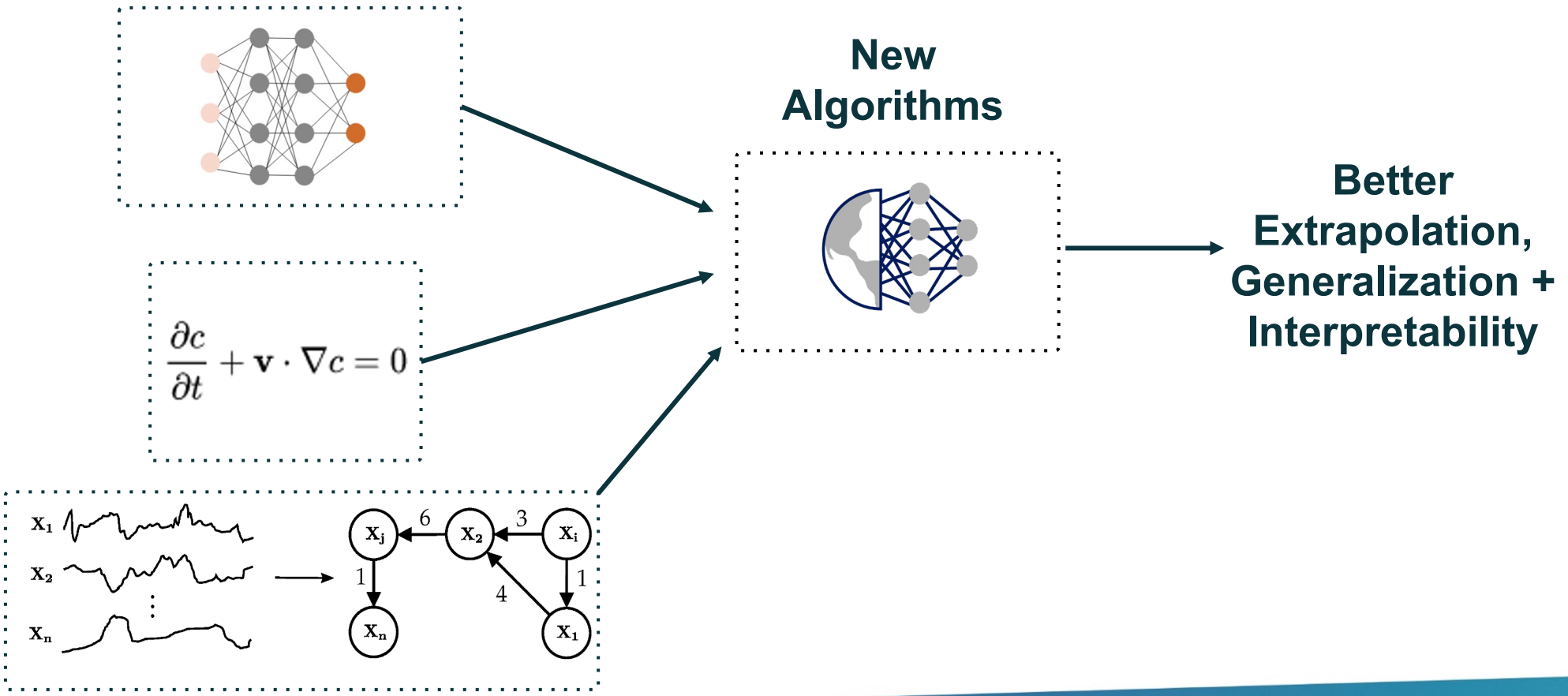


Gentine, Pritchard et al. 2018, *GRl*; Rasp, Pritchard and Gentine 2018 *PNAS*, Mooers, Pritchard et al. 2021

LEAP

Research Objective 1.2: **Enhance ML with physics**

Create new ML algorithms that respect physics and discover causal relationships

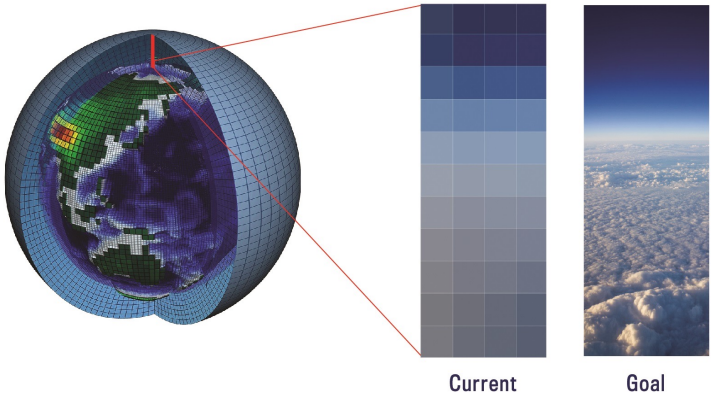


Research Objective 1.3: **Automatically calibrate ESMs**

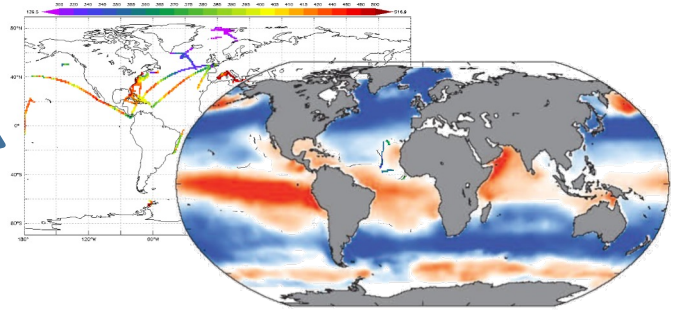
Establish systematic ML-based methodology for calibration of Earth System Model parameters

Earth System Model

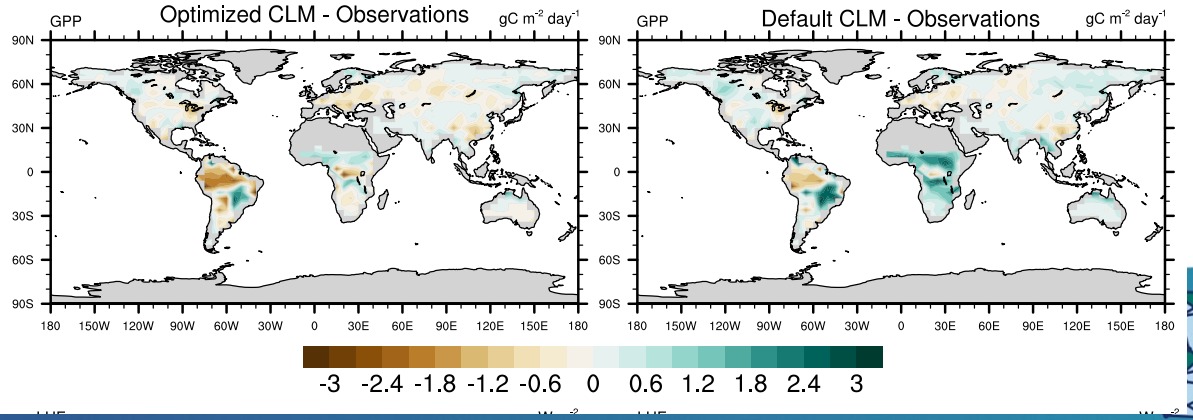
Data-driven parameterizations



Metrics: Datasets and approaches

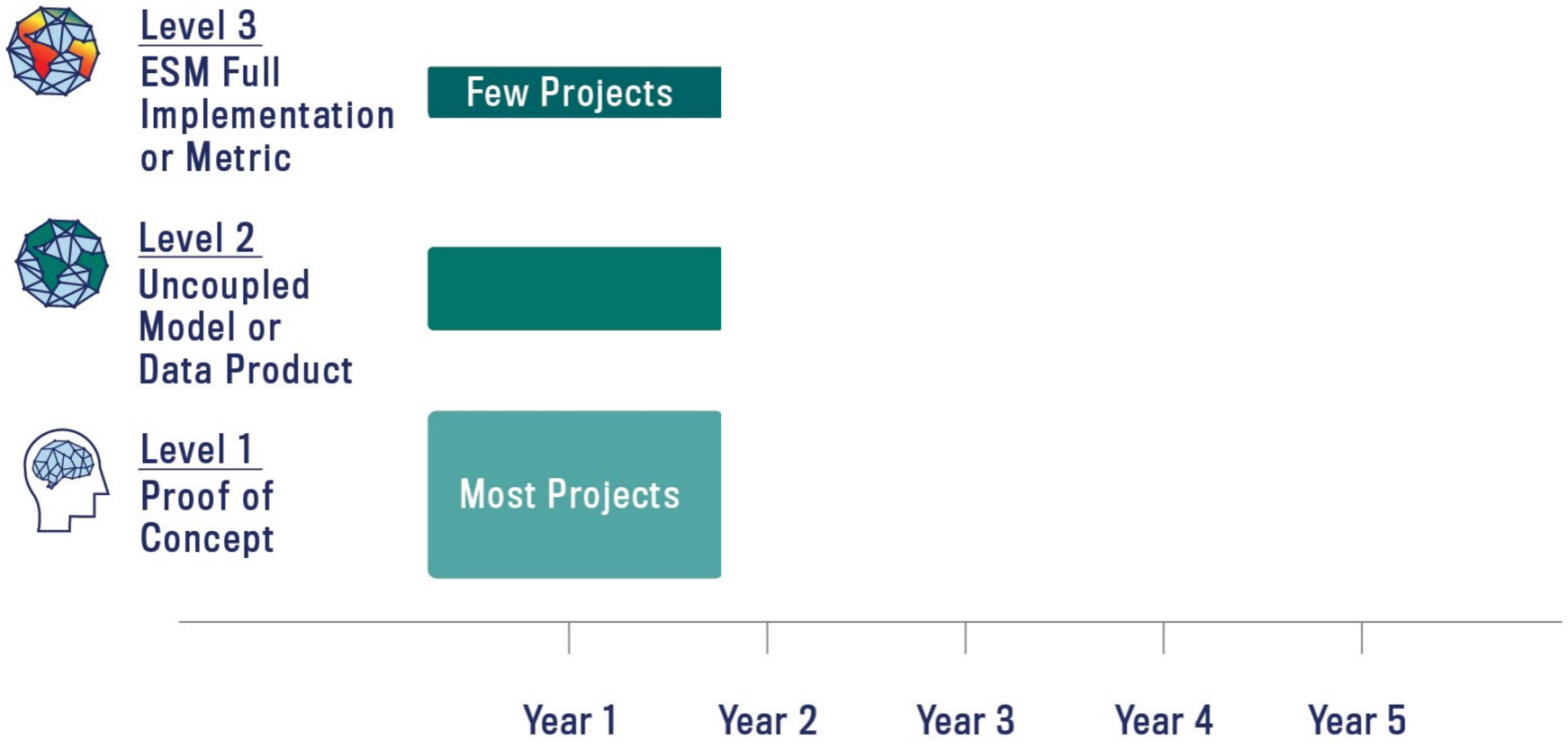


Parameter estimation



Dagon et al., 2020

LEAP research is structured to **progress from proof of concept to CESM implementation**



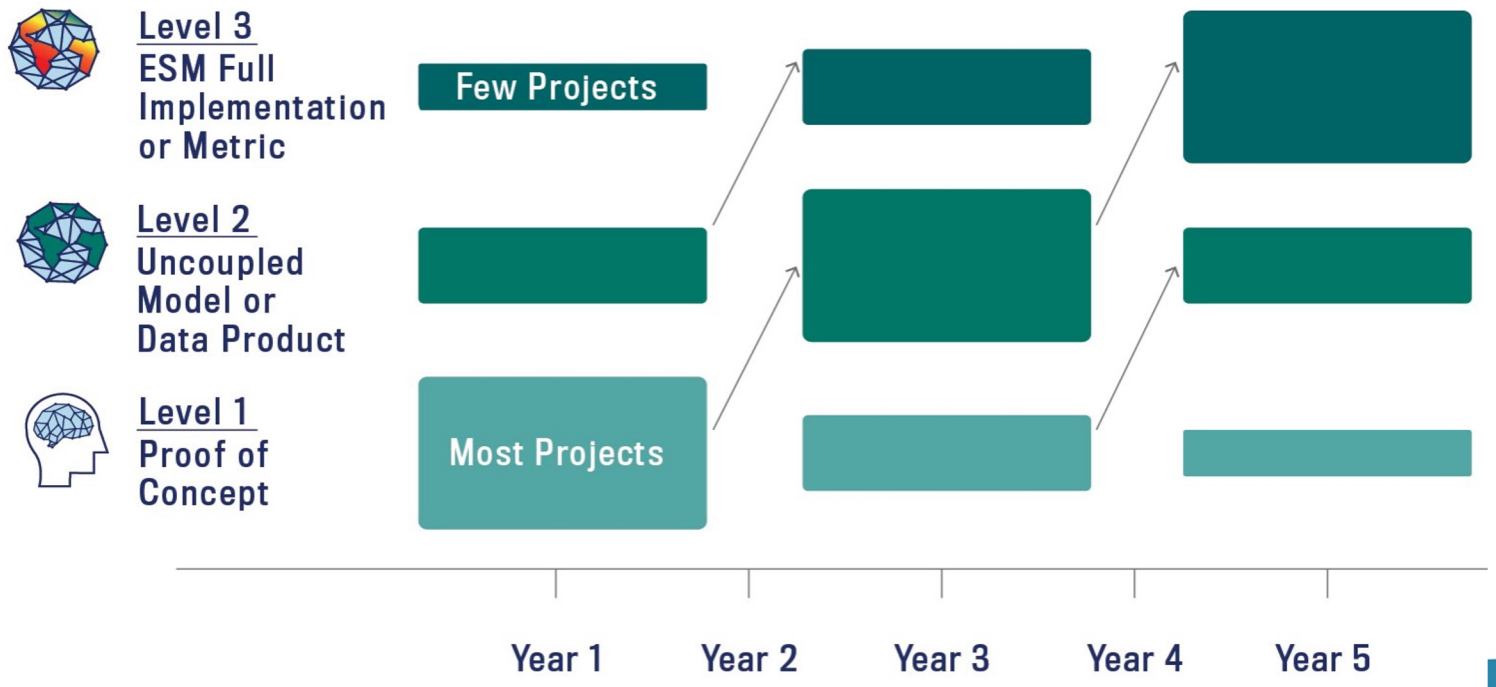
14 LEAP research projects selected in Year 1

	Atmosphere	Ocean	Land	Ice	ML
 Level 3 ESM Full Implementation or Metric	**Warm Rain** / Gettelman, Gagne, Morrison (NCAR), van Lier-Walqui (NASA-GISS), Zheng (Columbia) --- **Superparameterization emulation** / Pritchard (UCI), Bachman (NCAR), Gentine (Columbia)				
 Level 2 Uncoupled Model or Data Product	**Systematic Calibration** / Elsaesser, van Lier-Walqui (NASA GISS), Gettelman, Lawrence, Dagon (NCAR)	**Air-sea CO_2 metrics** / McKinley, Zheng (Columbia), Long (NCAR)	**CLM Parameter Estimation** / Lawrence, Dagon, Kennedy (NCAR), Gentine (Columbia)		
 Level 1 Proof of Concept	3 projects	1	2	1	2

Implementation will be facilitated by engaging with **CESM Working groups** and hiring a **LEAP Integration Engineer,** resident at NCAR

https://leap.columbia.edu/opportunities/

Integration engineer is currently being recruited,
also several postdoc positions

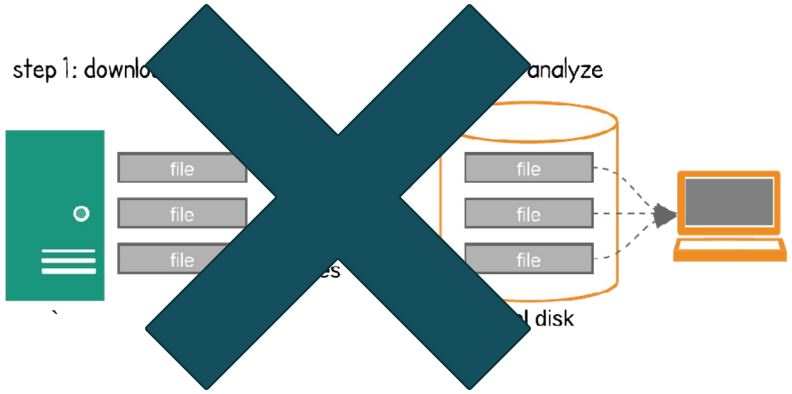


LEAP

LEAP-Pangeo: **A modern data infrastructure to support research and knowledge transfer**

Extending Pangeo (https://pangeo.io) into LEAP-Pangeo: an open-cloud computing platform for research and outreach.

Standard approach: Download Model

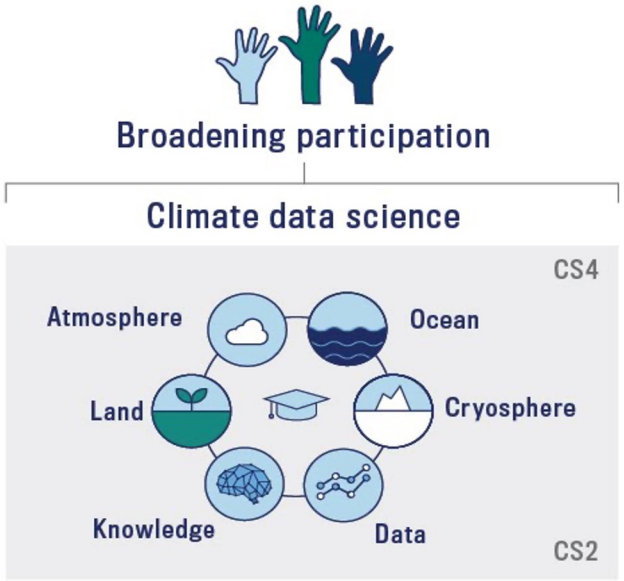


Education: **Inclusively Train Climate Data Scientists**

Training in climate and ML for the next generation of model developers

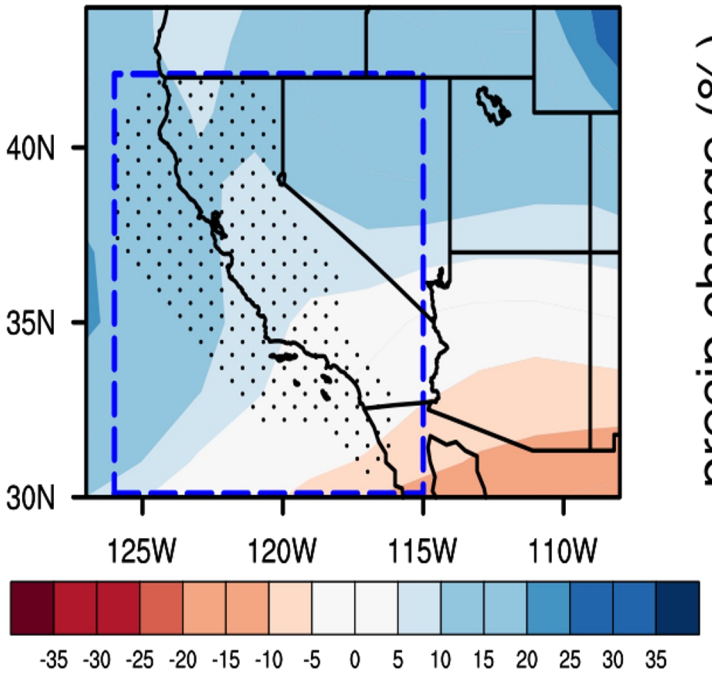
Forge a new **climate data science** discipline via convergence between education + research

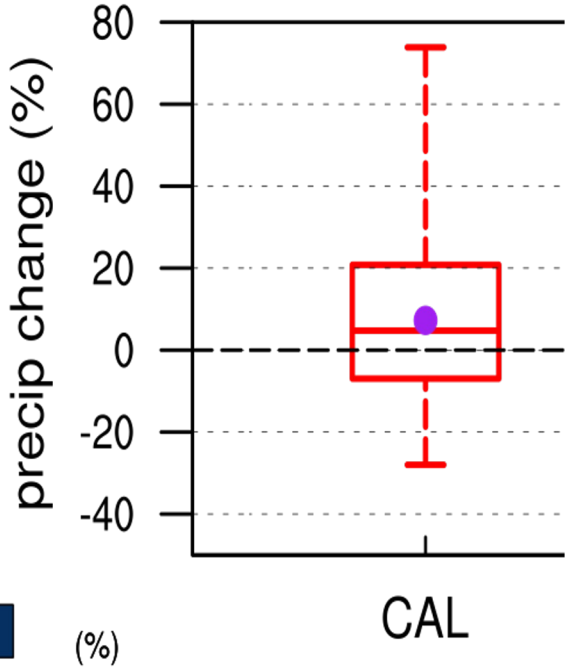
- Research-integrated transdisciplinary curricula
- Opportunities from K-12 to graduate
- Increase representation of URMs in climate data science through post-baccalaureate Bridge programs and partnerships (e.g., SOARS)

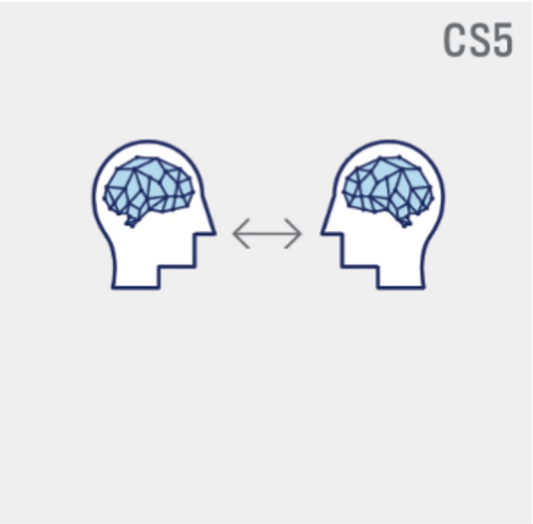


Knowledge Transfer: **Opening lines of communication with corporations and the public sector**

- **Challenge:** Better climate modeling will not improve adaption decisions
- **Solution:** Bi-directional, regular communication between scientists, corporations, and the public sector







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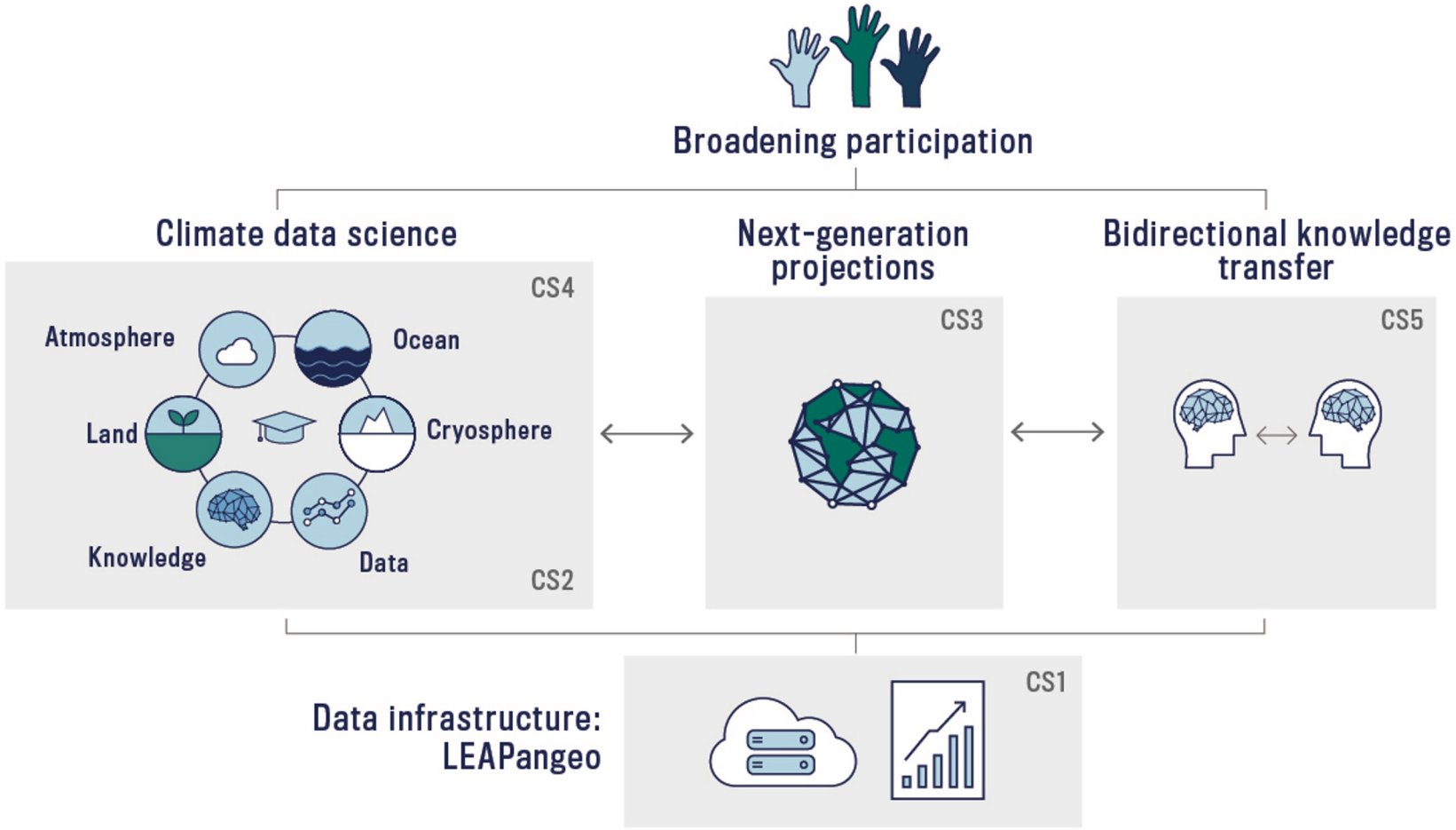

NSF STC 2021-2026

Thank You

https://galenmckinley.github.io

@OceanCarbon