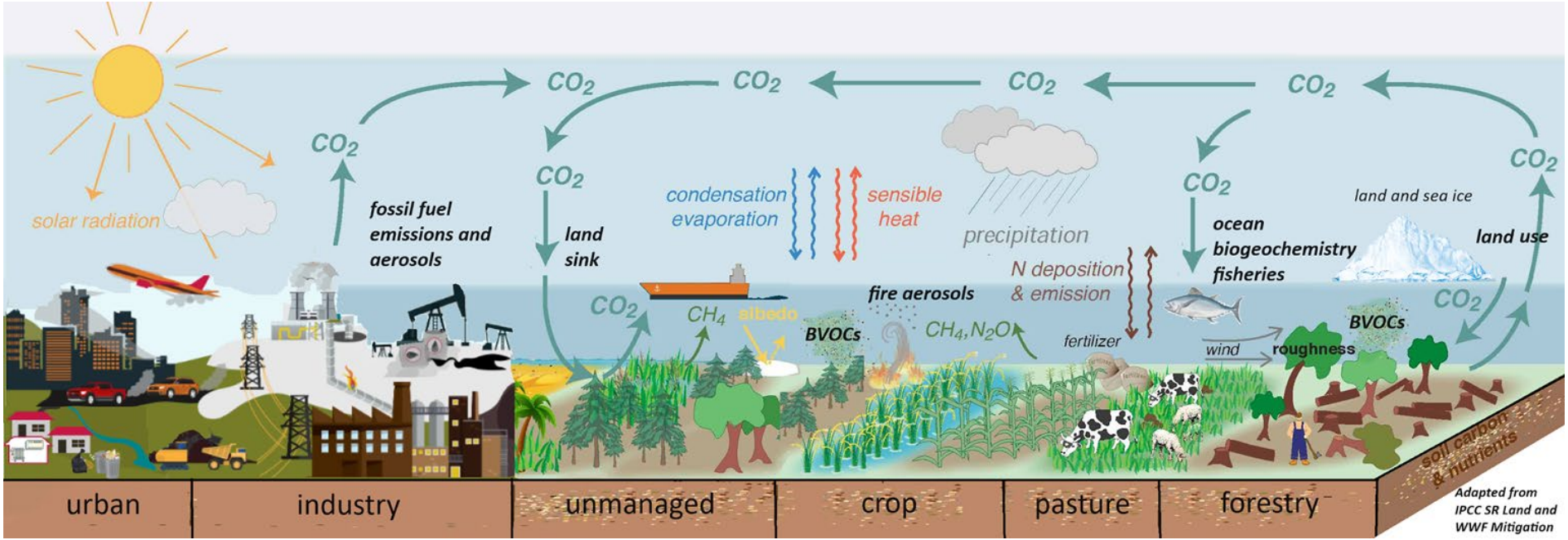
CESM 2.1.5 with emissions and interactive fire and biogenic aerosols for investigating baseline, mitigation, and climate intervention scenarios

June 12 2024

CESM Framework for Impact Assessment and Management



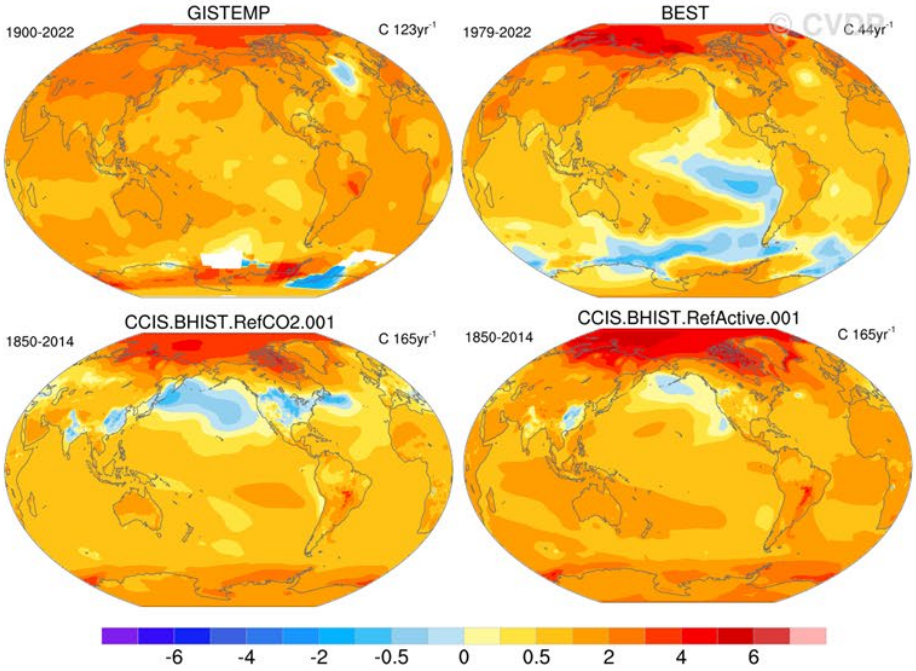
Community Climate Intervention Strategies Ensemble (CCIS Ens):

- CESM 2.1.5 (LENS2 Science) CO2 and Aerosols dynamically modeled.
- CMIP6 Fossil Fuel CO2, Methane, and Aerosol Emissions
- Historical, SSP 1-1.9, SSP 2-4.5 and SSP 3-7.0.
- Active Fire Aerosol Emissions
- Active Biogenic Volatile Organic Compound (BVOC) Emissions
- Marine Coccolithophores in New Ocean BGC – FEISTY Fish Model

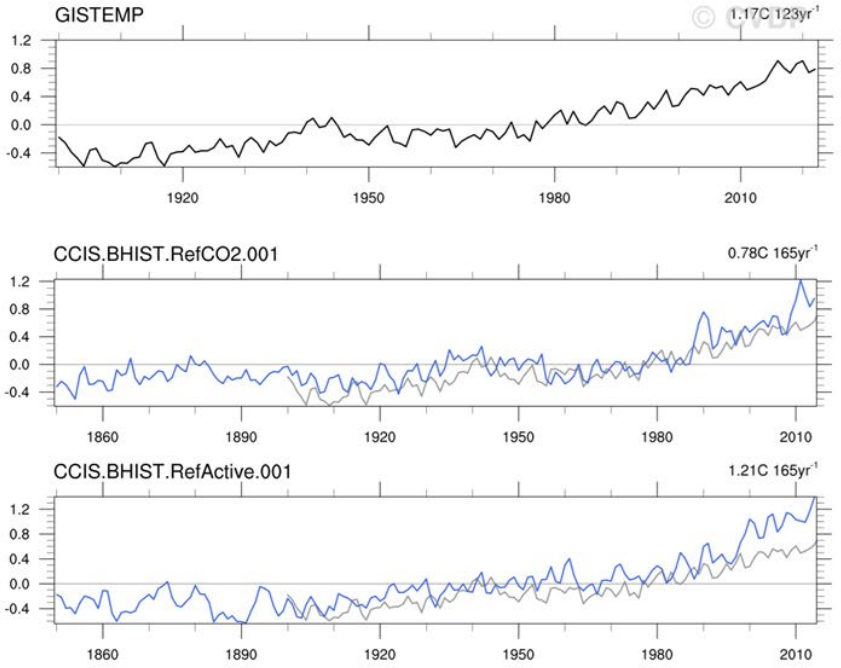
- **Atmosphere SRM:** Stratospheric Aerosol Injection (SAI) -- Marine Cloud Brightening (MCB)
- **Land CDR:** Re/Afforestation -- Bio Energy and Carbon Capture and Storage (BECCS) -- Direct Air Capture (DAC with CCS)
- **Ocean CDR:** Enhanced Alkalinity -- Macroalgae (Kelp) with Biomass Sinking -- Electrochemical CO2 removal from sea water

CESM Framework Historical Surface Temperature Evaluation

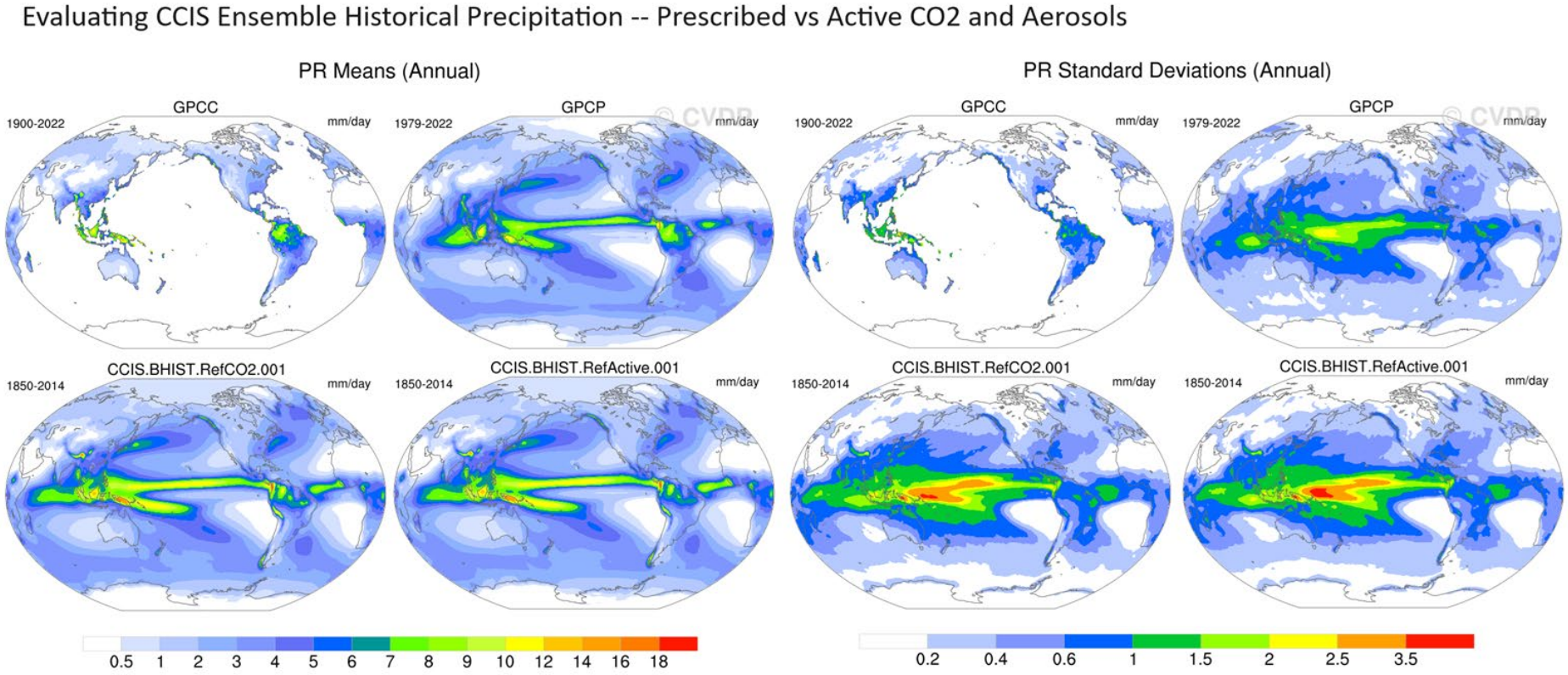
Evaluating CCIS Ensemble Historical Temperature
Prescribed vs Active CO2 and Aerosols



TAS Trends (Annual)

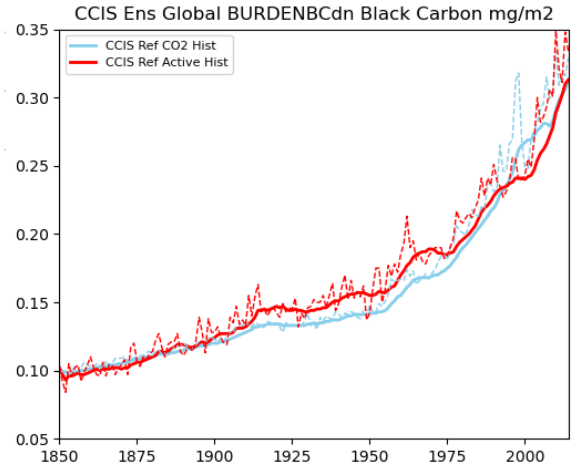


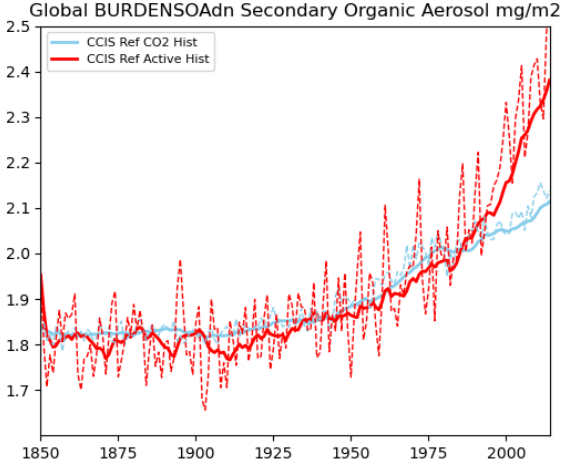
CESM Framework Precipitation Evaluation

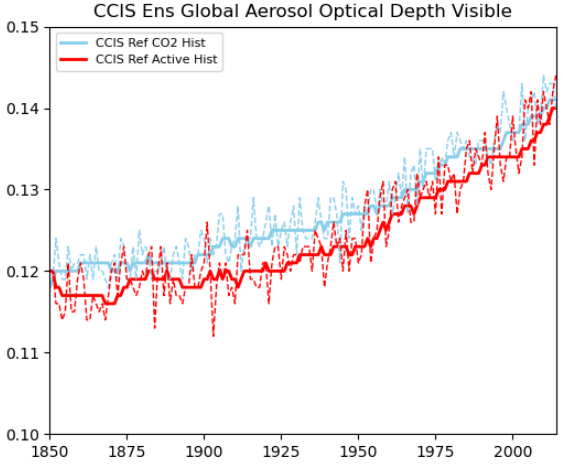


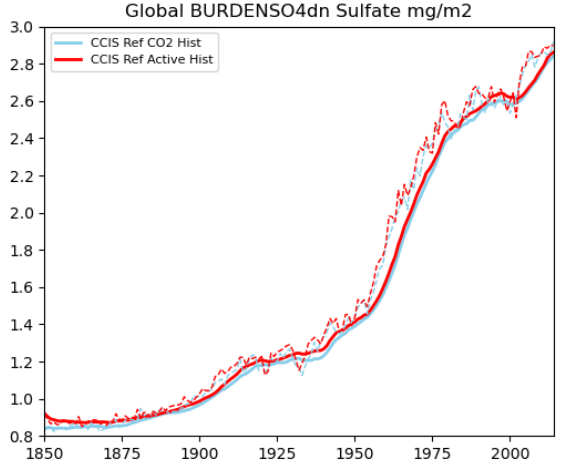
CESM Framework Historical Active Aerosol Evaluation

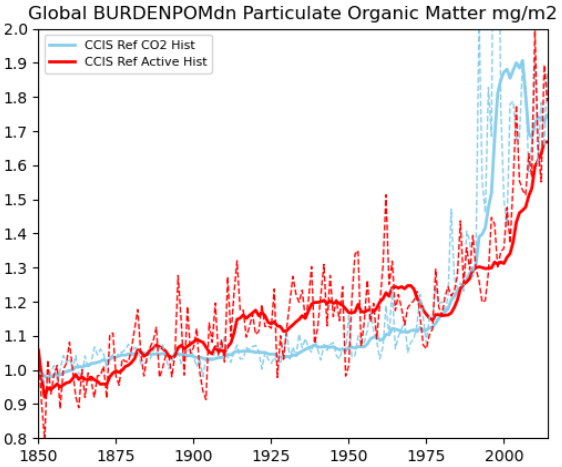
Evaluating CCIS Ensemble Historical Fire and BVOC Aerosol Burdens – Prescribed vs Active CO2 and Aerosols. Active Emission Factors Tuned for Fire and MEGAN to target CMIP6 values





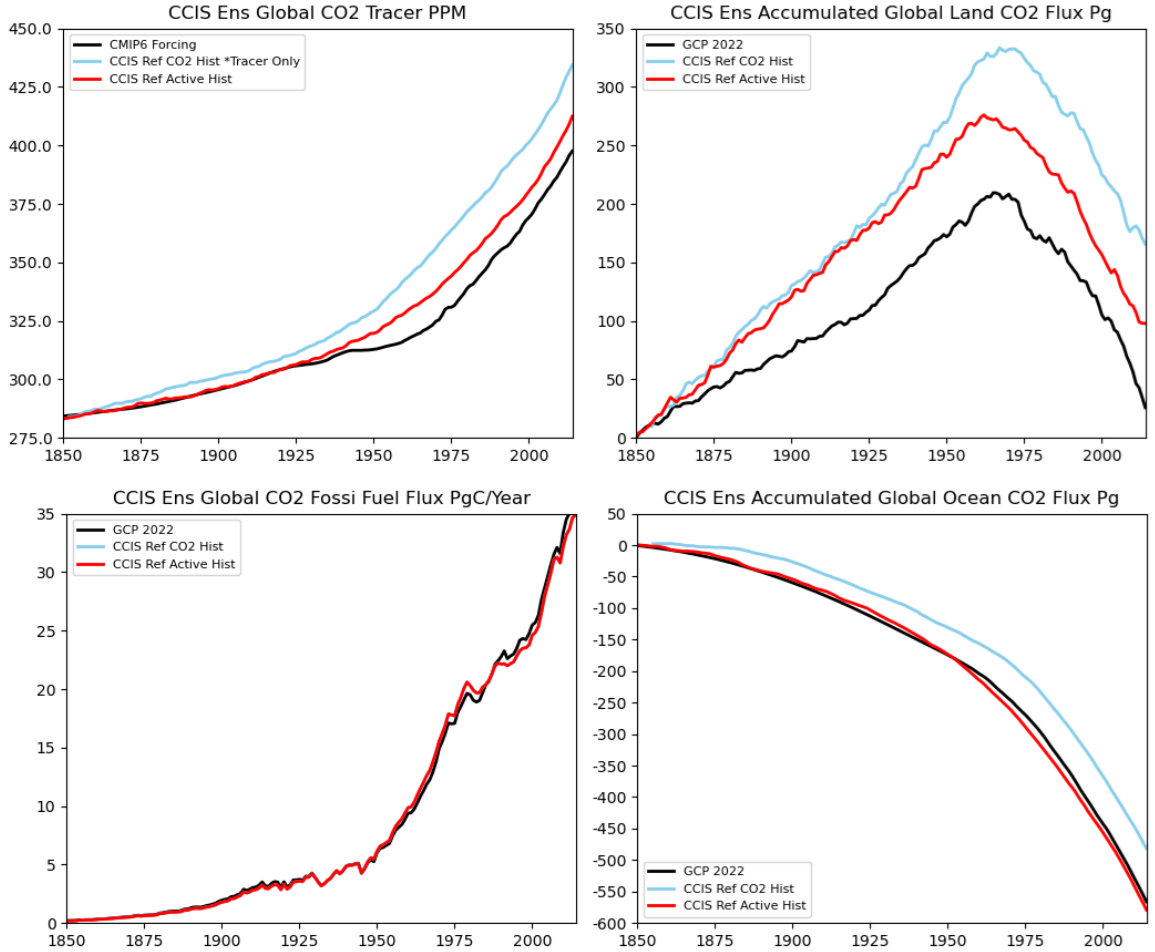






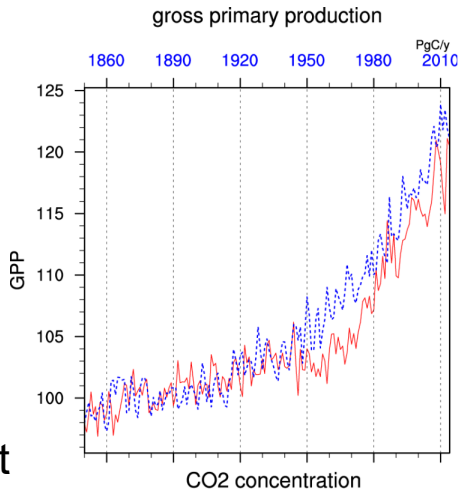
CESM Framework and Global Carbon Cycle

Evaluating CCIS Ensemble Historical Carbon Cycle – Prescribed vs Active CO2 and Aerosols compared to the Global Carbon Project (2022)



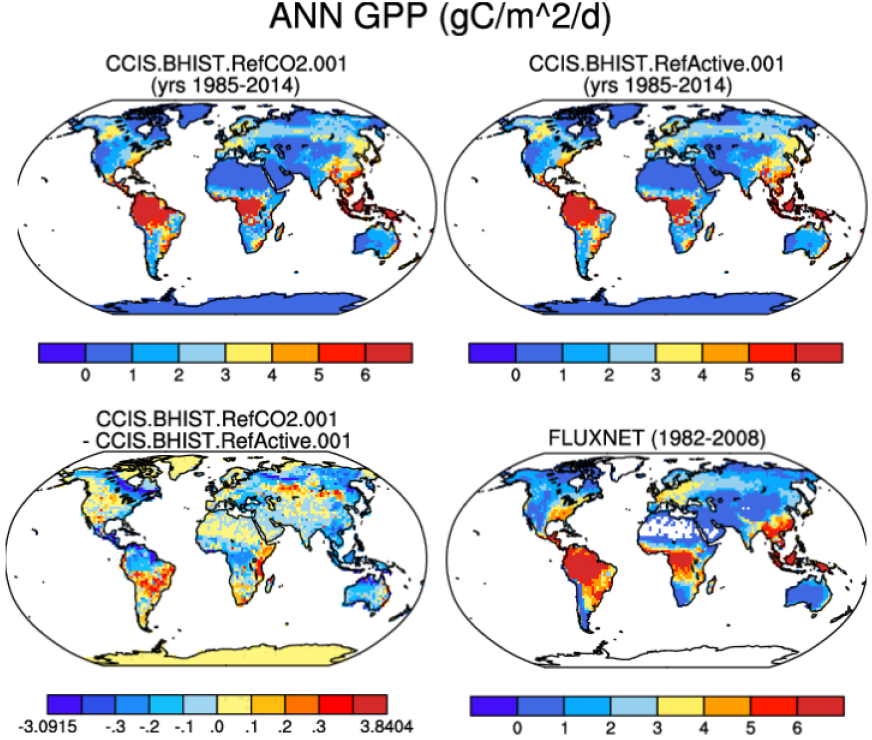
Evaluating CCIS Ensemble Historical Carbon Cycle – Prescribed vs Active CO2 and Aerosols compared to the Global Carbon Project (2022)

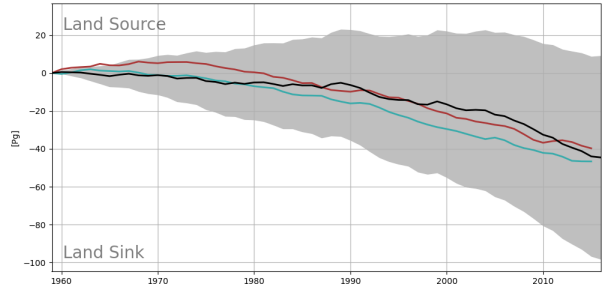
* Note Colors are swapped from previous plots



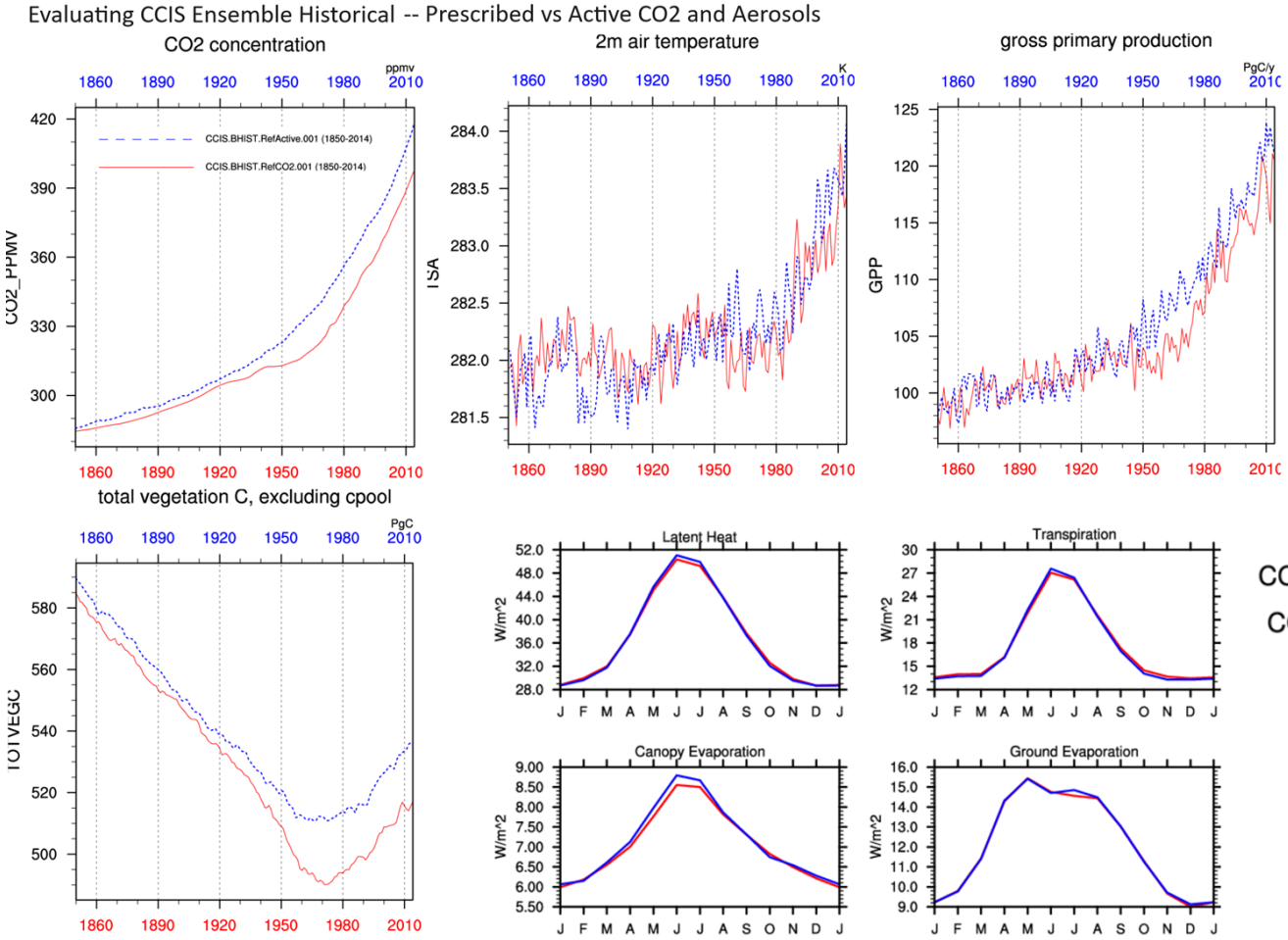
CCIS.BHIST.RefActive.001 (yrs 1985-2014)

CCIS.BHIST.RefCO2.001 (yrs 1985-2014)





Research Accomplishments: ESM Framework and Toolkit

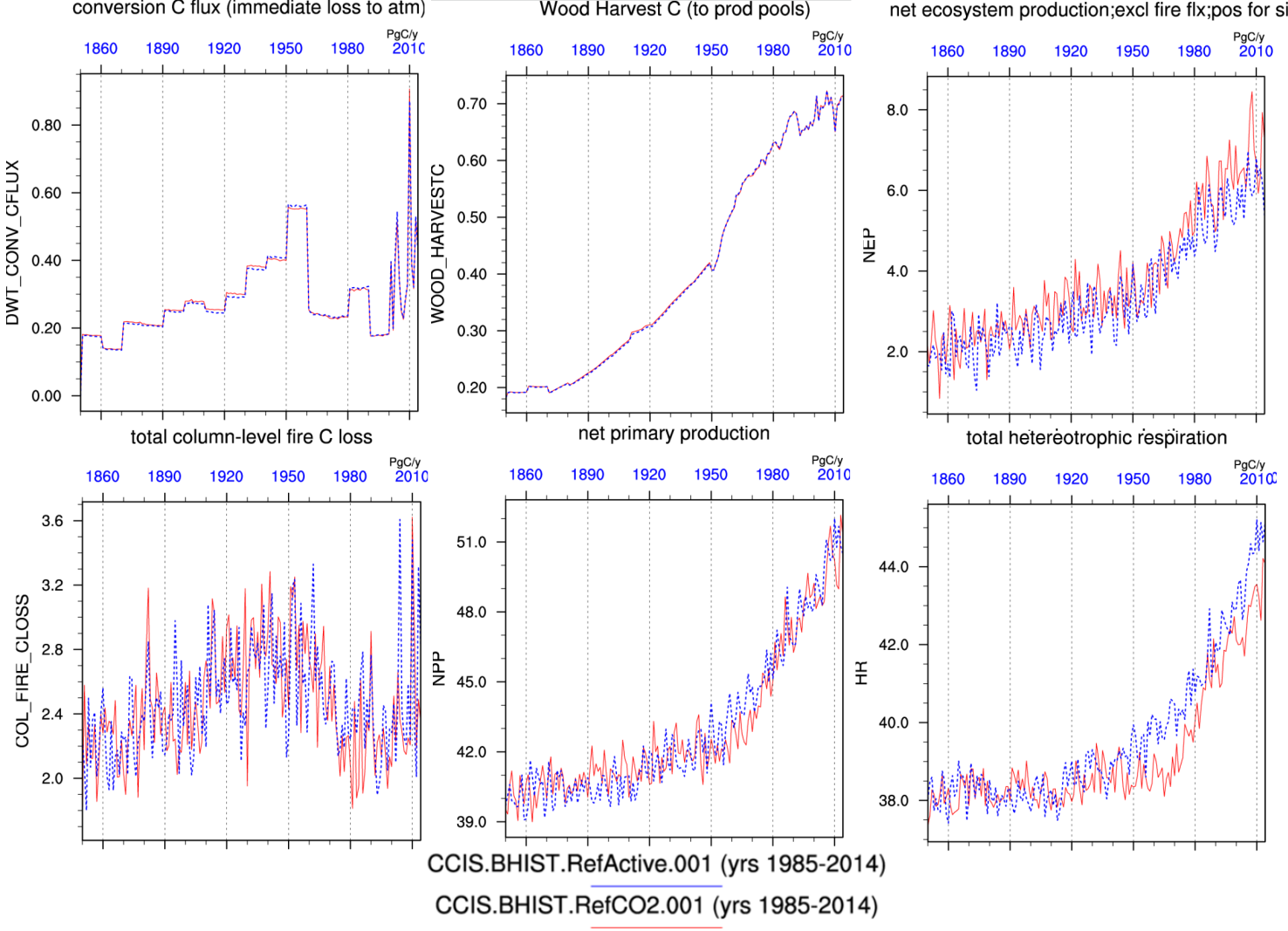


CCIS.BHIST.RefActive.001 (yrs 1985-2014)

CCIS.BHIST.RefCO2.001 (yrs 1985-2014)

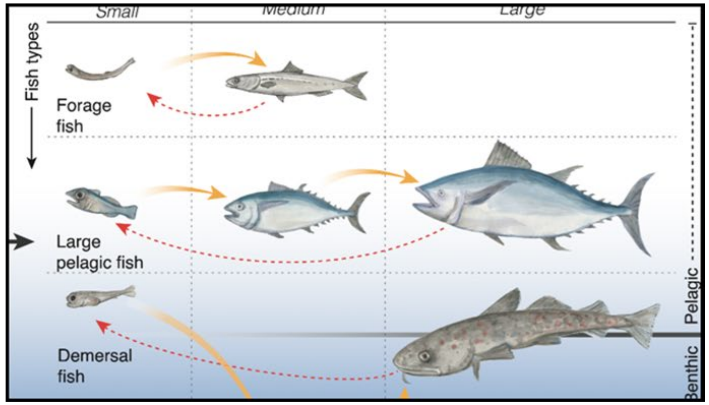
* Note Colors are swapped from previous plots

Evaluating CCIS Ensemble Historical Carbon Cycle – Prescribed vs Active CO2 and Aerosols compared to the Global Carbon Project (2022)

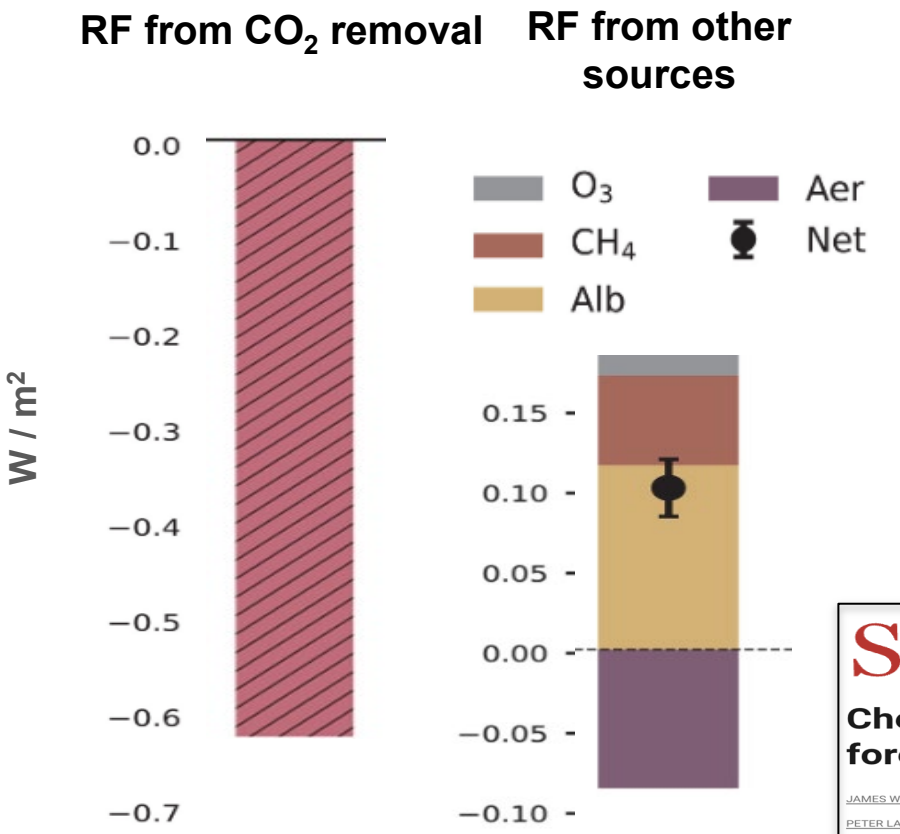


Research Accomplishments: CESM Embedded Impacts

- Agricultural Yield (CLM Crop)
- Fisheries Modeling (MARBL-> FEISTY)
- Urban Climate (CLM Urban) and Human Health
- Wildland and Crop Fires
- Water Availability and Irrigation Demand
- Wood Production
- Ecosystem Health



Earth System response to reforestation is complex



Full understanding of impacts of reforestation requires ESM

In CESM2 experiments, the direct radiative forcing (RF) from CO_2 removal is offset by changes in albedo and BVOC emissions and their impact on ozone, methane, and aerosol burdens

Science

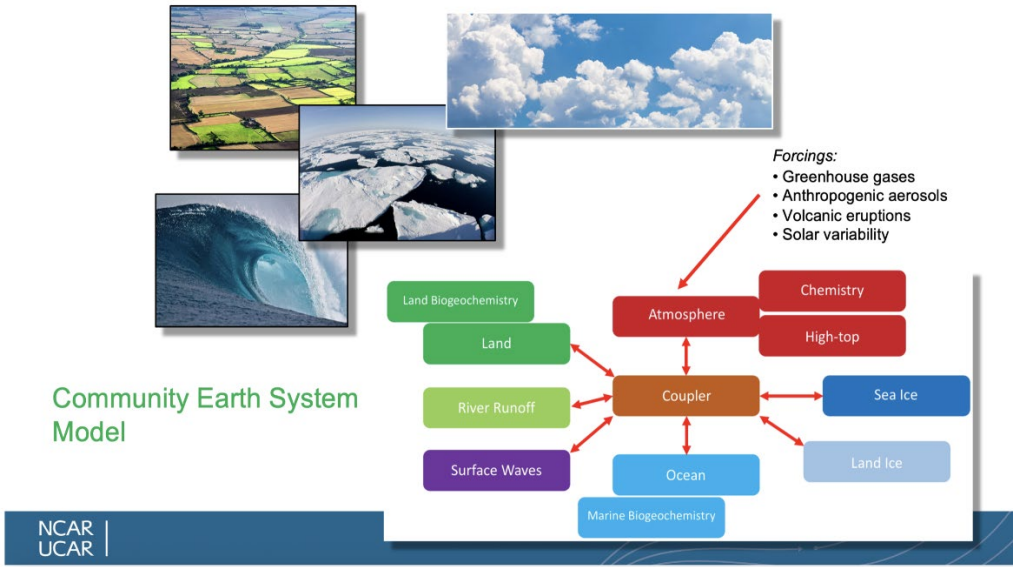
Chemistry-albedo feedbacks offset up to a third of forestation's CO_2 removal benefits

JAMES WEBER, JAMES A. KING, NATHAN LUKE ABRAHAM, DANIEL P. GROSVENOR, CHRISTOPHER J. SMITH, YOUNGSUB MATTHEW SHIN, PETER LAWRENCE, STEPHANIE ROE, DAVID J. BEERLING, AND MARIA VAL MARTIN Authors Info & Affiliations

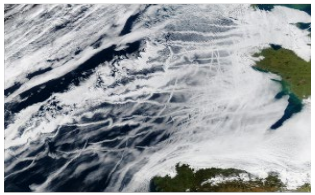
Modeling Tools for SAI and MCB Projections

State of the Art Earth System Models are required to simulate the full impact of Stratospheric Aerosol Intervention and Marine Cloud Brightening Approaches (WACCM)

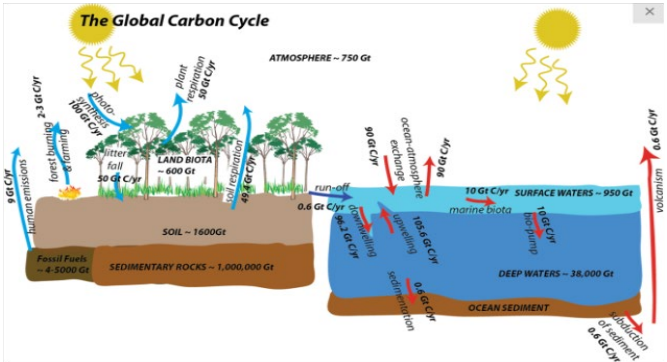
- Complex process in both troposphere and stratosphere are needed, aerosol microphysics, cloud-aerosol and chemistry
- Coupling for land and ocean carbon cycle, sea-ice model, land model
- Modeling across scales: actional science application to address water, food, and health
- Evaluation: observational lab and field experiments, and observing system, satellites (for ship tracks, volcanic eruptions, etc)



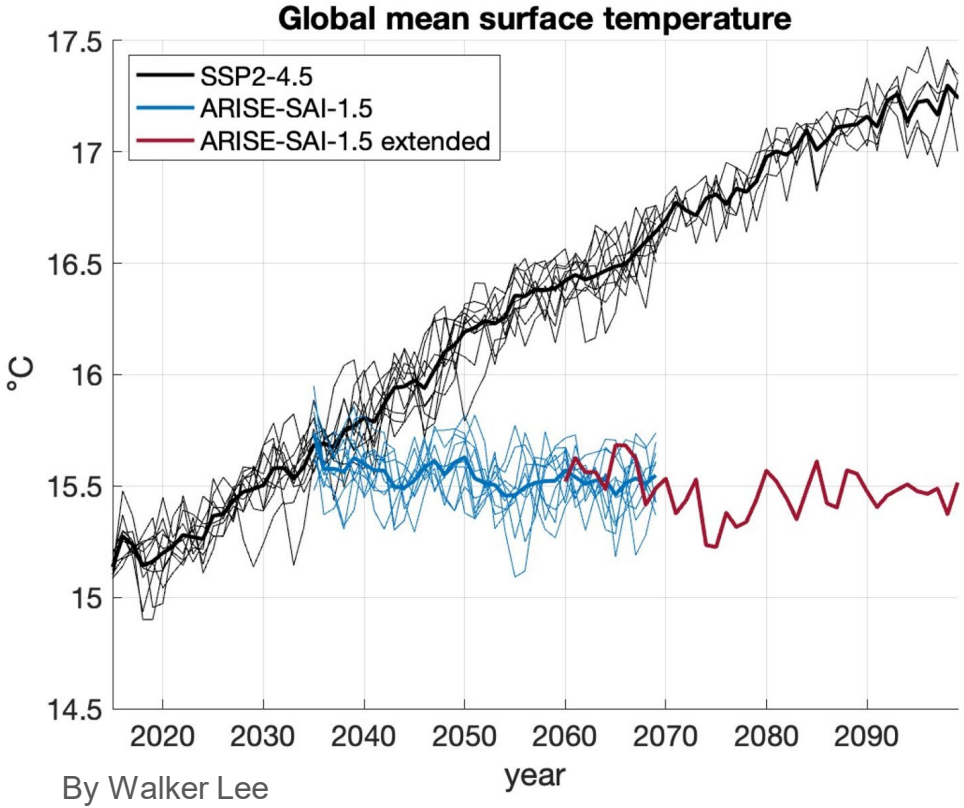
Volcanoes



Ship Tracks



Stratospheric Aerosol Intervention Scenarios



By Walker Lee

Assessing Responses and Impacts of Solar climate intervention on the Earth system (**ARISE**) SAI and MBC (Richter et al., 2022): 10-member ensemble using CESM2(WACCM6)

- Start: 2035
- Goal: Keep surface temperature at 1.5C above Pre-Industrial Conditions
- Extension of the ARISE dataset from 2070 -2100 conditions
- Used as maximum plausible SAI scenario
- Results are used for combined CDR / SAI studies in the next phase of the project

Thank you – Questions?