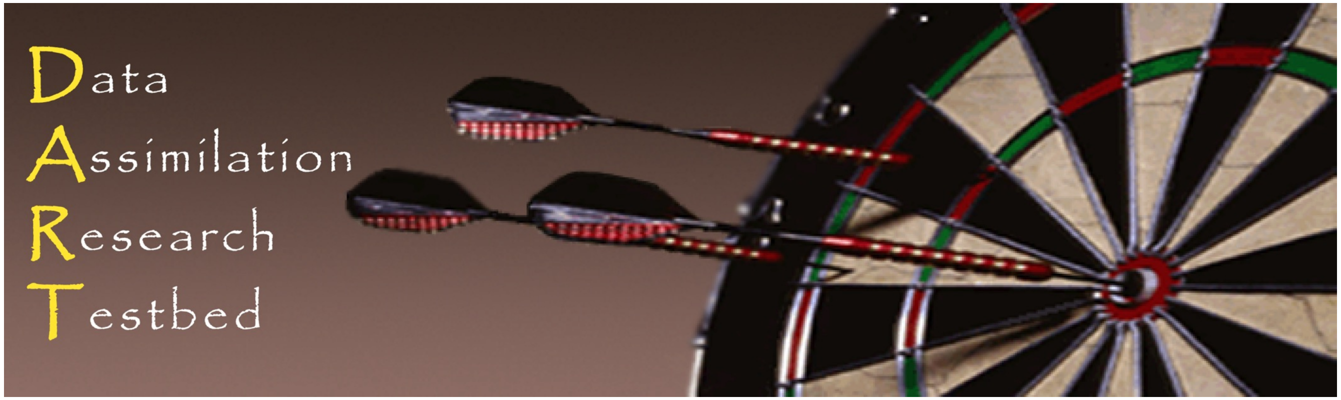
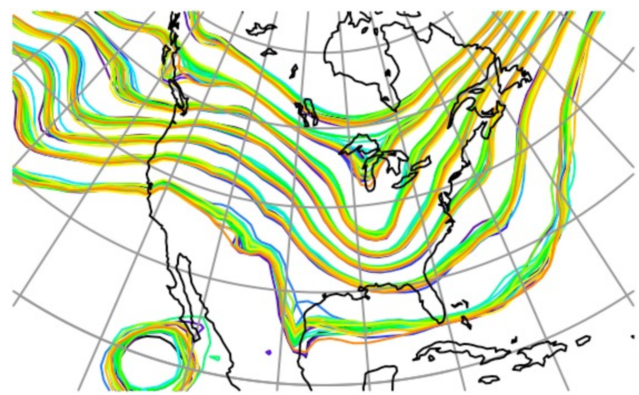


Improving CLM5.0 Biomass and Carbon Exchange across the Western US using Data Assimilation (DART)

Brett Raczka, NCAR, Data Assimilation Research Section (DAReS)

THE UNIVERSITY OF UTAH



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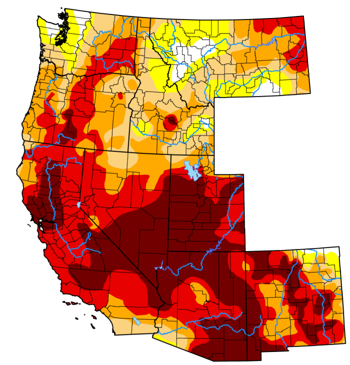
Carbon Monitoring Across Western US

US Drought Monitor, June 10, 2021



- Vulnerable carbon stocks create drastic change to landscape and ecosystem functioning
- Complex terrain challenges traditional carbon monitoring, flux towers, atmospheric inversions

Top-Down Modeling

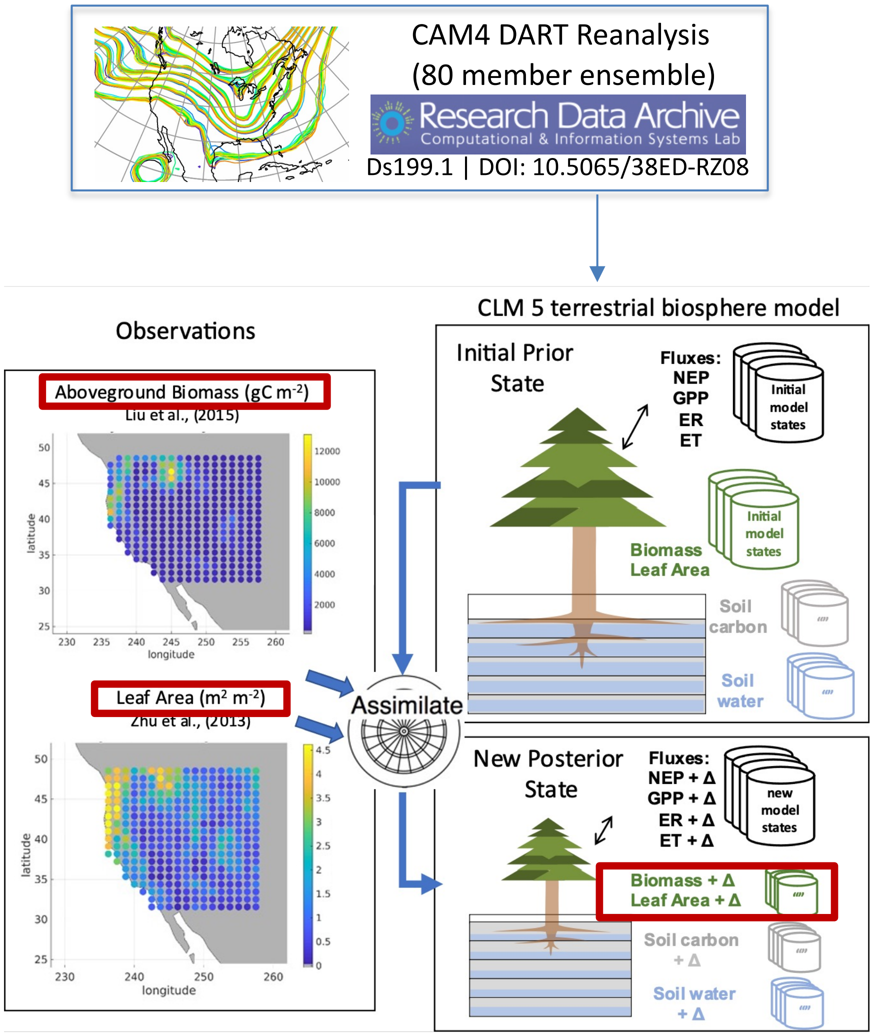
Atmospheric CO_2
↓
Atm. Transport Model
↓
Land carbon exchange

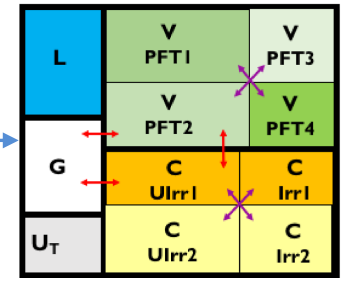
Bottom-Up Modeling

Weather/Climate
↓
Land Surface Model (CLM)
↓
Land carbon exchange

Data Assimilation Research Testbed

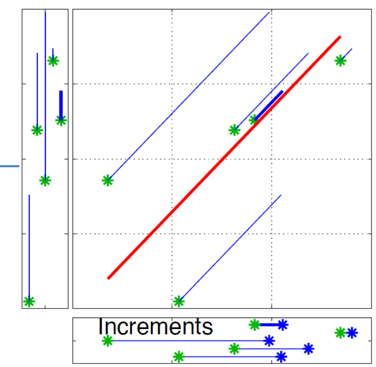
CLM5-DART Overview





Applies update to PFTs and columns in restart file

Unobserved Variables



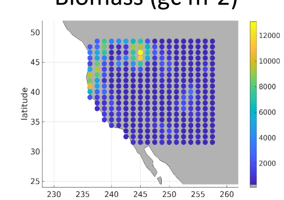
Ensemble estimated Biomass 'observation' (prior state)

Ensemble Adjusted Biomass (posterior state)

'Forward operator'

Live Stem C
Dead Stem C
Leaf C

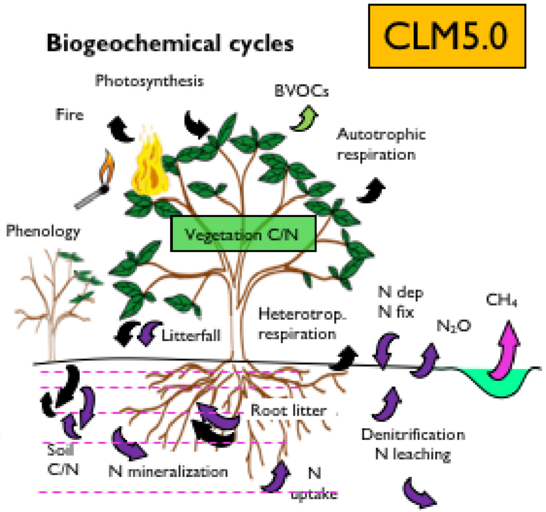
'Observed' Aboveground Biomass (gc m-2)



CLM5-DART Methods/Terminology

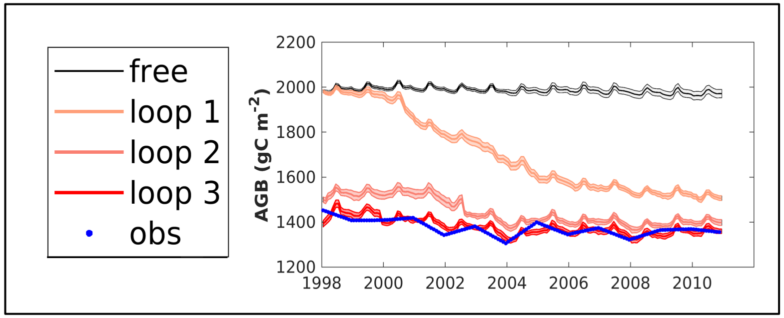
Single Instance Spinup Simulation

- Compset CLM5_BGC_Crop
- 200yr AD spin, 1000yr spin, transient (1850)
- Spatial Resolution (0.95°X1.25°)
- Spinup Meteorological Forcing:
  GRIDMET (Buotte et al., 2019)



Assimilation Run

- 80 ensemble members (CAM4 Reanalysis)
- Assimilation time window: 1998-2011,
  3 cycles (looping)
- Adaptive Inflation



Data
Assimilation
Research
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CLM5-DART Methods/Terminology

- Remotely Sensed 'Observations' (1.25°x0.95°)

Monthly Aboveground Biomass (AGB)

Global Data Sets of Vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g Derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the Period 1981 to 2011

Zhu et al., (2013) ***Remote Sensing***

Monthly Leaf Area Index (LAI)

Recent reversal in loss of global terrestrial biomass

Liu et al., (2015) nature climate change

- Observation Rejection Threshold: 3 sigma

- Spatial Localization:
  Horizontal range: ~100 km

- State Space Localization:
  Select most important variables for carbon cycling

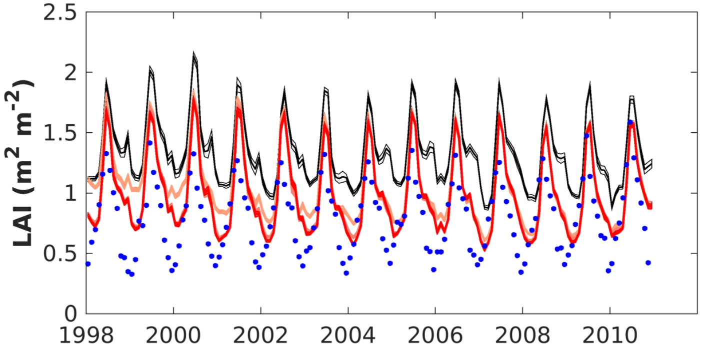
'Standard' Adjusted State Variables (Biomass C, N)

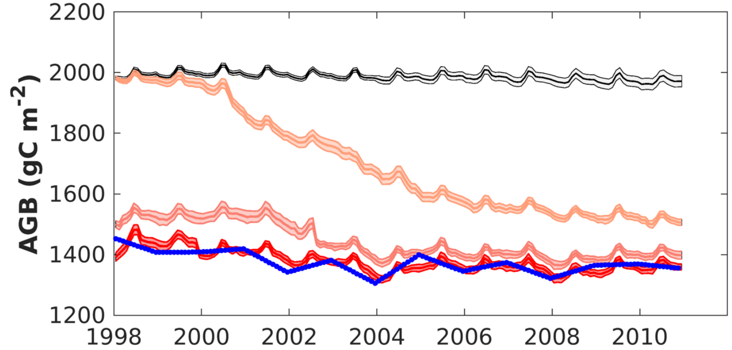
Leaf carbon	Leaf nitrogen
Live stem carbon	Fine root nitrogen
Dead stem carbon	Live coarse root nitrogen
Leaf area index	Dead coarse root nitrogen
Fine root carbon	Live stem nitrogen
Live coarse root carbon	Dead stem nitrogen
Dead coarse root carbon	

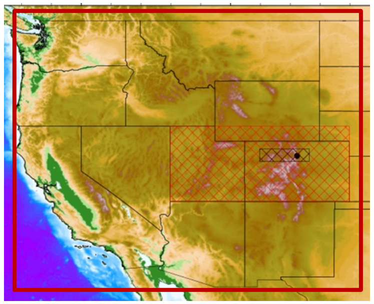
Data Assimilation Research Testbed

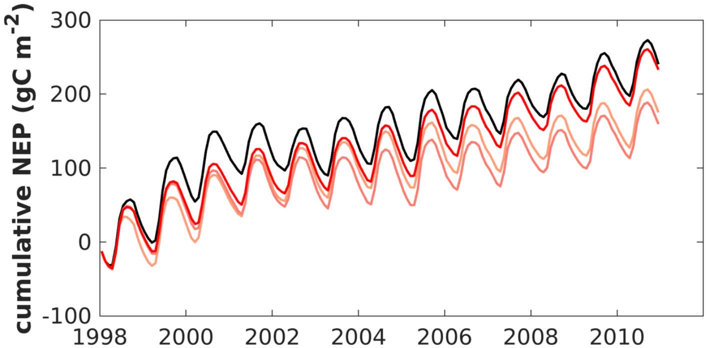
Observations reduce biomass/leaf area, net carbon flux steady

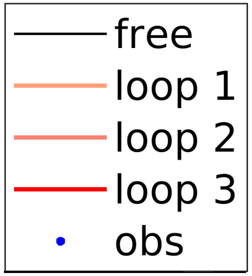
- 31 and 27 % reduction in AGB and LAI respectively











Simulation Name	AGB (kgC m^{-2})	LAI (m m^{-2})	GPP (gC m^{-2} month^{-1})	ER (gC m^{-2} month^{-1})	NEP (gC m^{-2} month^{-1})
Free	1.98	1.31	48.18	47.18	1.00
CLM5-DART	1.36	0.96	38.49	37.21	1.28

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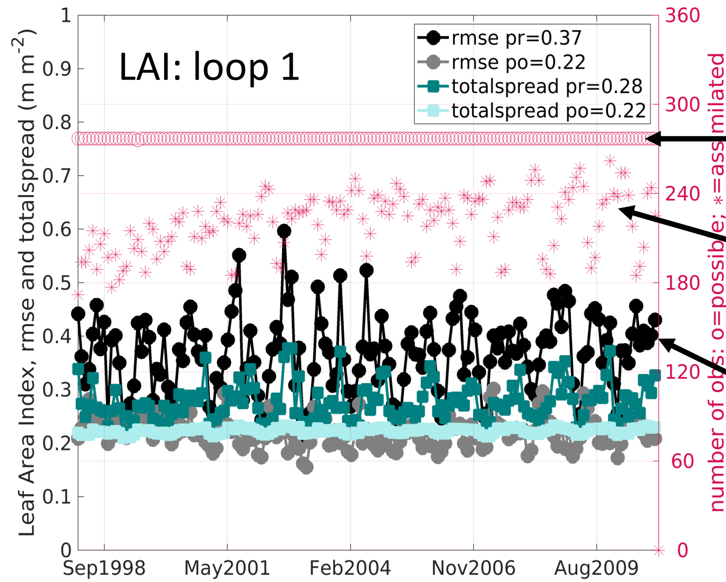
Diagnostics of LAI/AGB observation acceptance and RMSE

LAI : steady acceptance rate (90%) seasonal dependence, RMSE steady

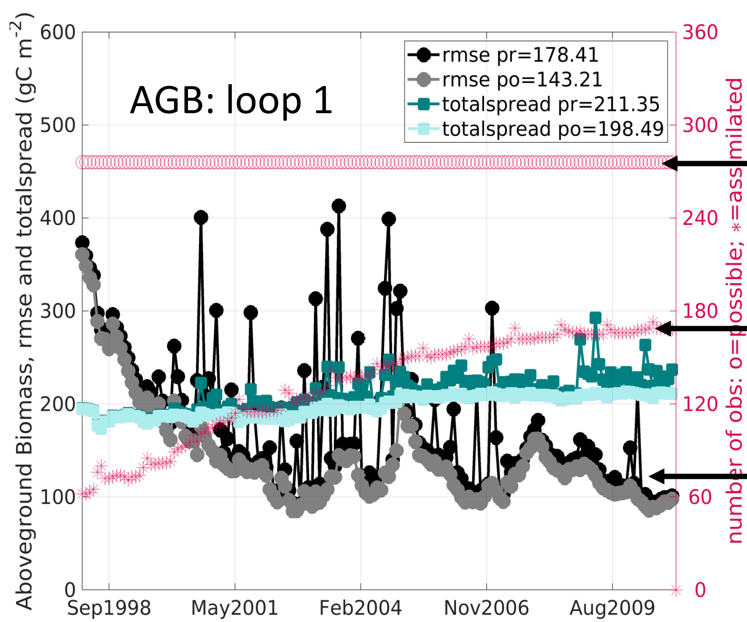


Observations possible

Observations assimilated

Prior RMSE

AGB : increasing acceptance rate (75%), decreasing RMSE



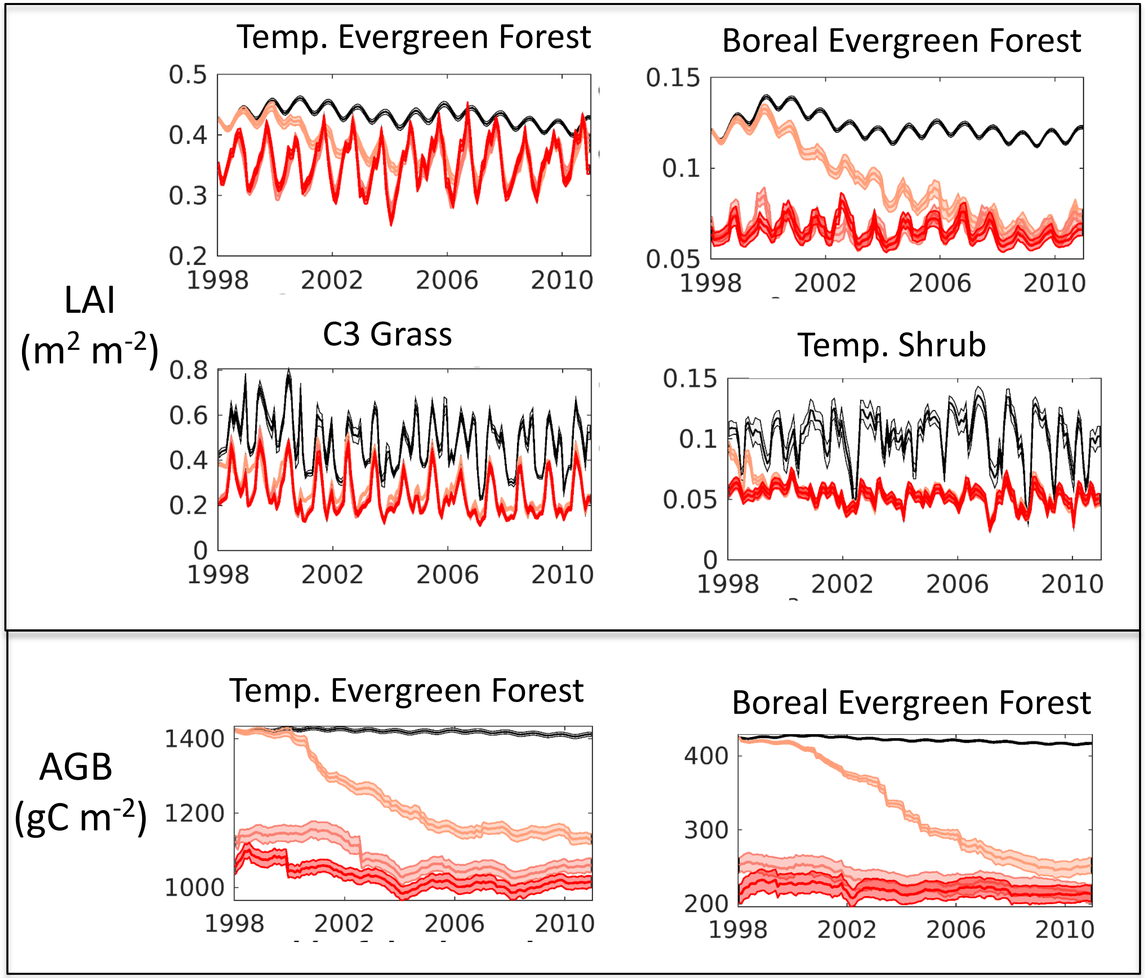
Observations possible

Observations assimilated

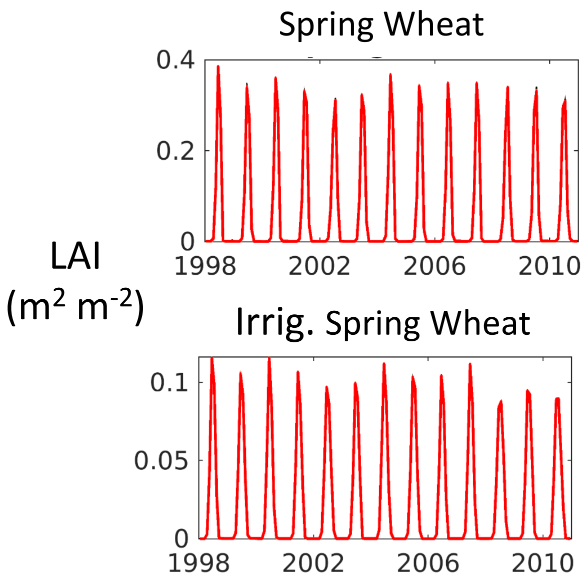
Prior RMSE

Data Assimilation Research Testbed

Behavior for dominant PFTs within domain



- Crops have much smaller adjustments than natural vegetation



Data
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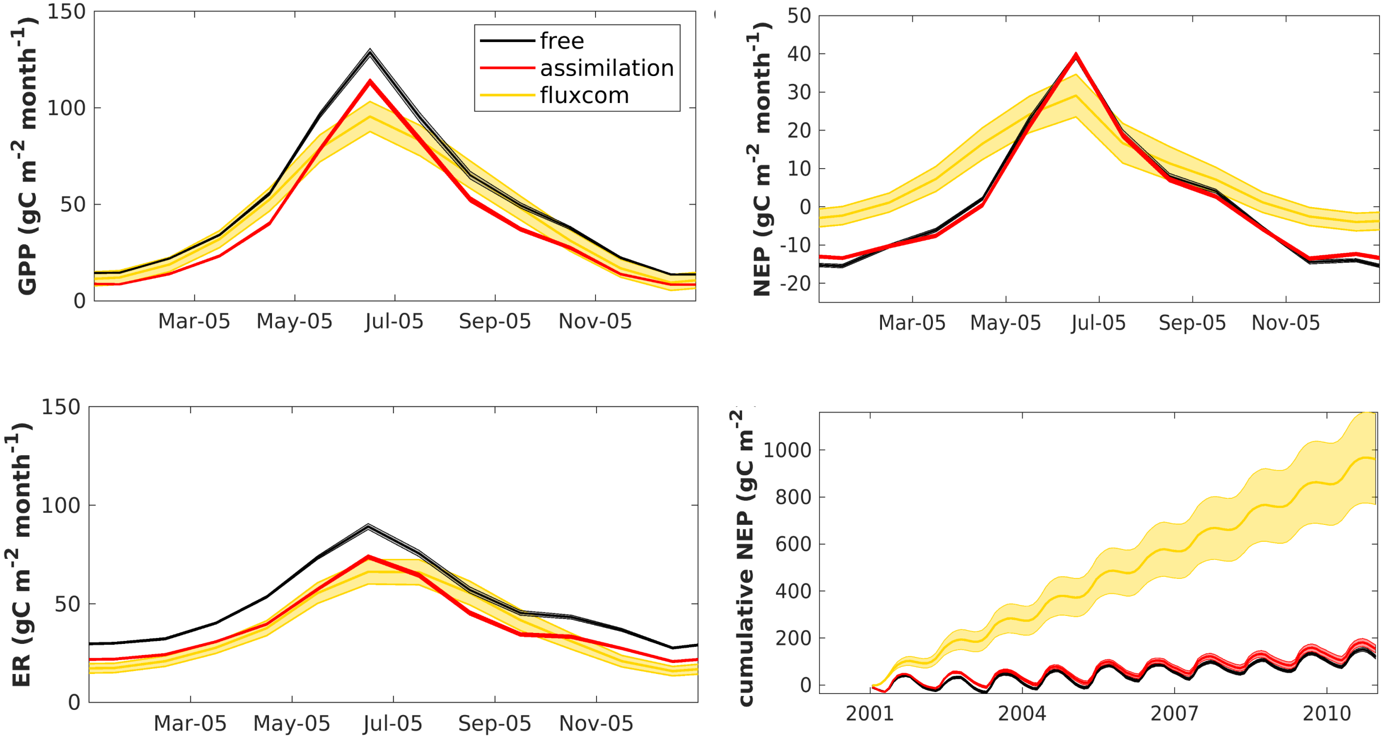
CLM5-DART simulates weak carbon sink compared to FLUXCOM

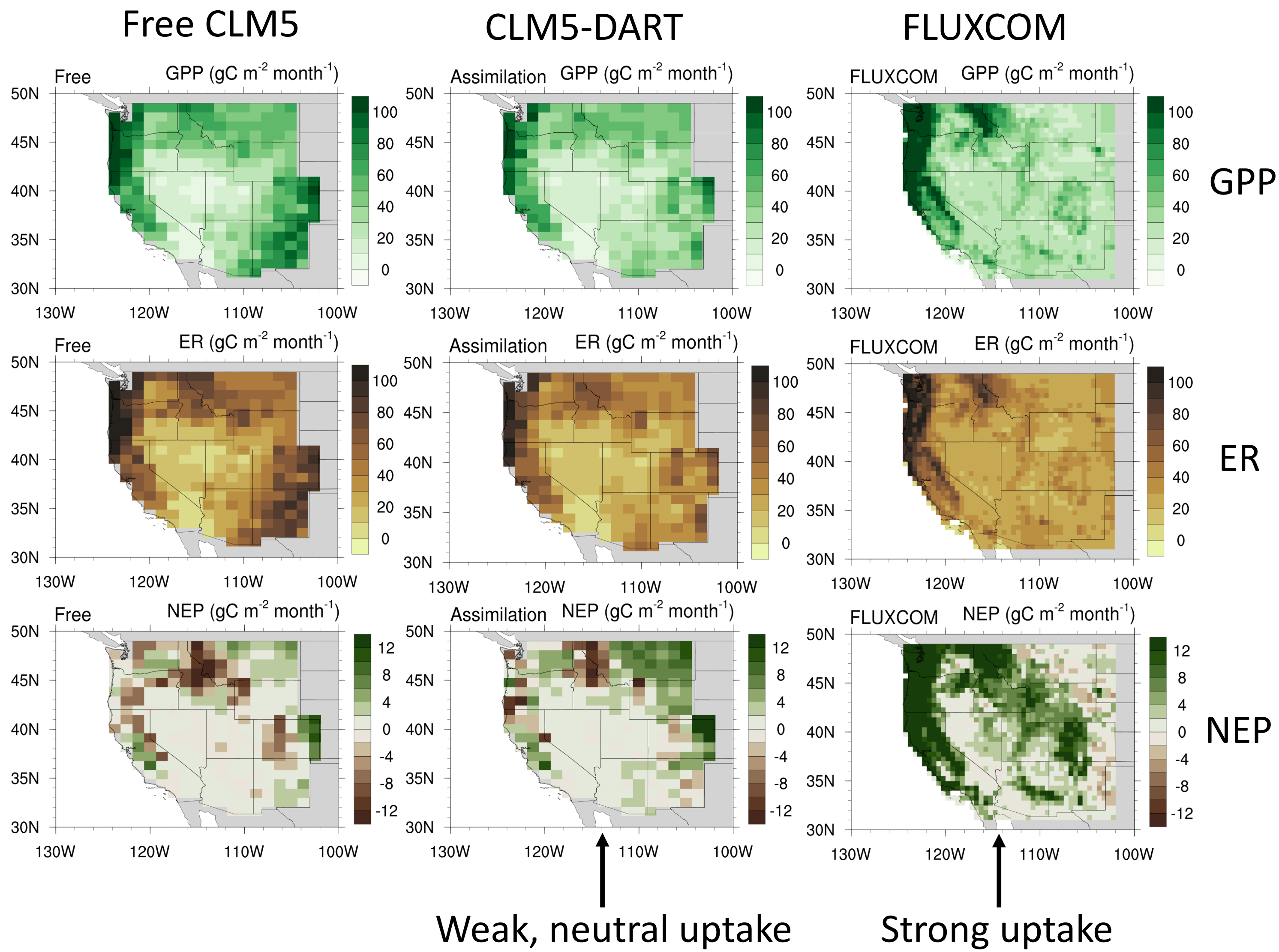
- CLM5-DART (red) reduces biomass states create offsetting reductions in GPP and ER compared to free run
- FLUXCOM (yellow): Machine learning approach that uses flux tower data, satellite data and meteorology as explanatory variables for carbon cycling data product Jung et al., (2020).



- Difference due to disturbance history?
- Need more adjusted variables in CLM5-DART?

CLM5-DART simulates weak carbon sink compared to FLUXCOM

1998-2011 Average Fluxes

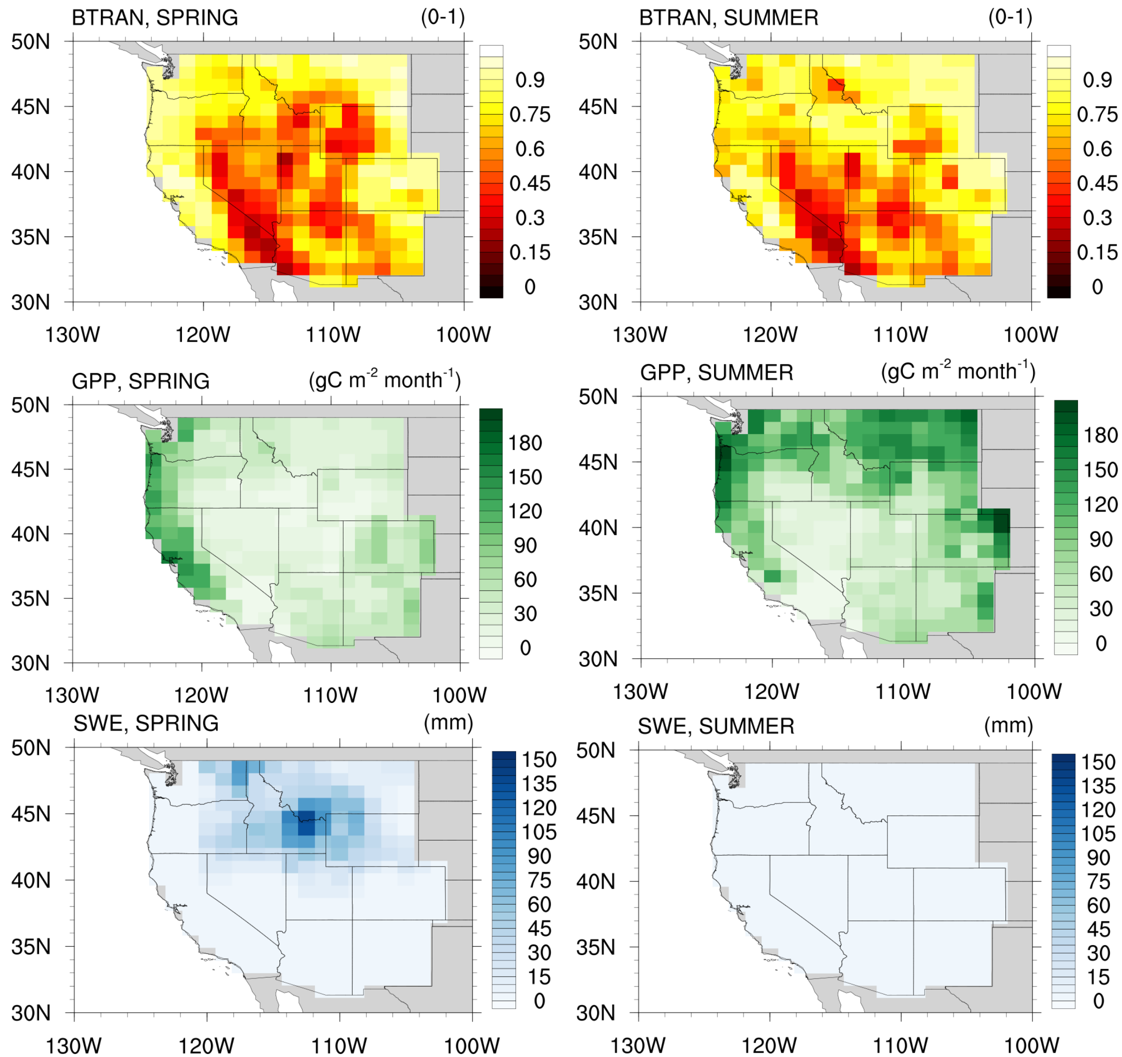


Water limitation shapes carbon uptake pattern

- Soil moisture limitation and GPP highly correlated (spring: R=0.64; summer: R=0.67)

- Simulated snow has low bias

Spring (1998-2011) Summer (1998-2011)



Soil moisture limitation

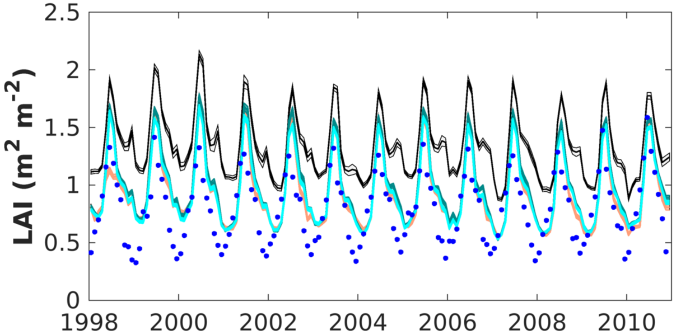
GPP

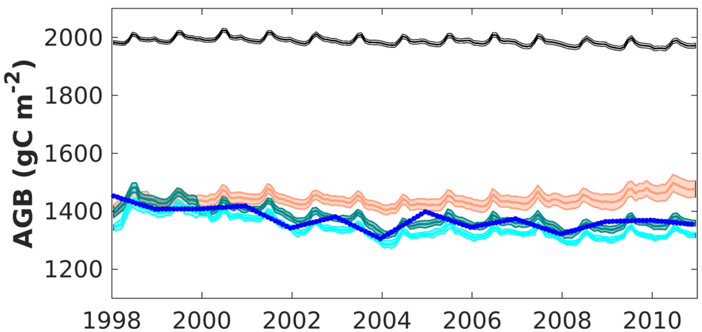
Snow water equivalent

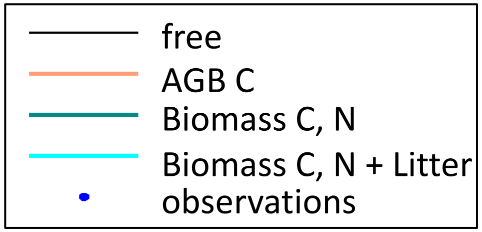
Data Assimilation Research Testbed

Impact of adjusted variables (loop 3 only)

Adjusted variables

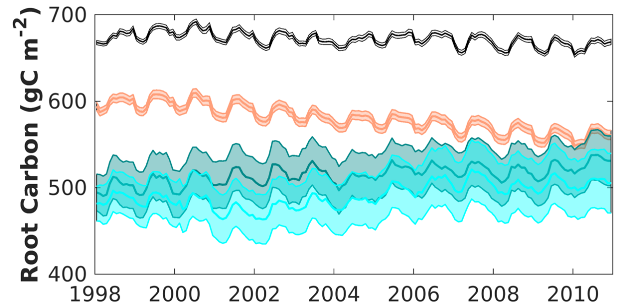


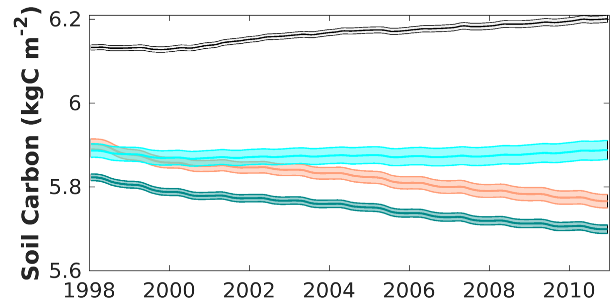




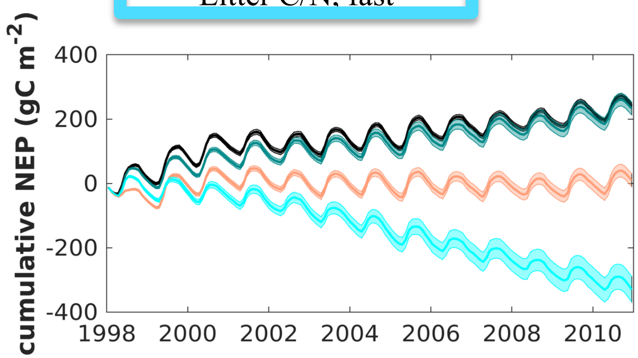
Leaf C
Live stem C
Dead stem C
Leaf area index
Fine root C
Live coarse root C
Dead coarse root C
Leaf N
Fine root N
Live coarse root N
Dead coarse root N
Live stem N
Dead stem N
Litter C/N, slow
Litter C/N, medium
Litter C/N, fast

Other variables





- Net land carbon uptake (cumulative NEP) is near neutral for all assimilation runs

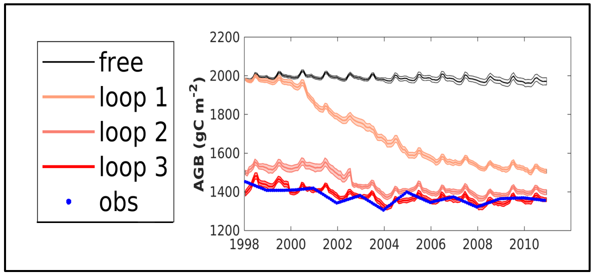


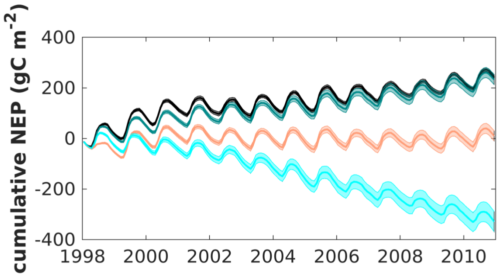
- Would flux behavior change if soil carbon was directly adjusted?

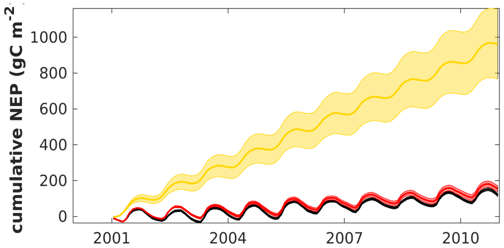
Data Assimilation Research Testbed

Key Points

- Assimilating observations of biomass and leaf area reduced simulated biomass and projects a weak land carbon sink across the Western US.
- The estimate of carbon uptake was robust across various assimilation setup settings.
- Our estimate of carbon exchange contrasts with an independent FLUXCOM estimate that shows a significant carbon sink in the Western US.
- Water cycle observations should be used to complement biomass observations to improve the spatial pattern of modeled carbon fluxes







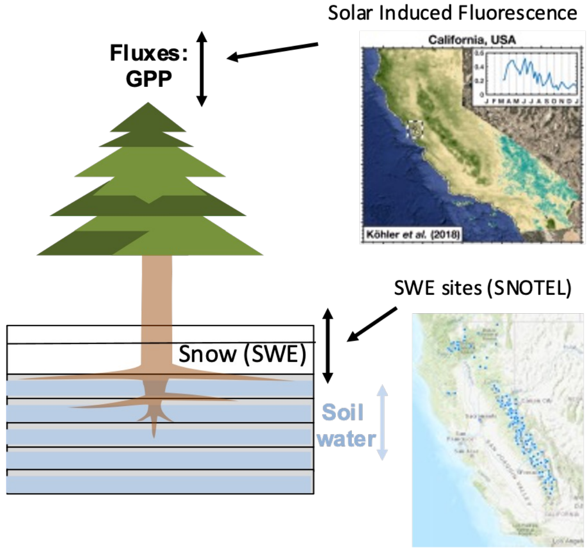
Improving CLM5.0 Biomass and Carbon Exchange across the Western US Using a Data Assimilation System

Brett Raczka, Tim Hoar, Henrique Duarte, Andy Fox, Jeff Anderson, David Bowling John Lin
**Accepted; JAMES

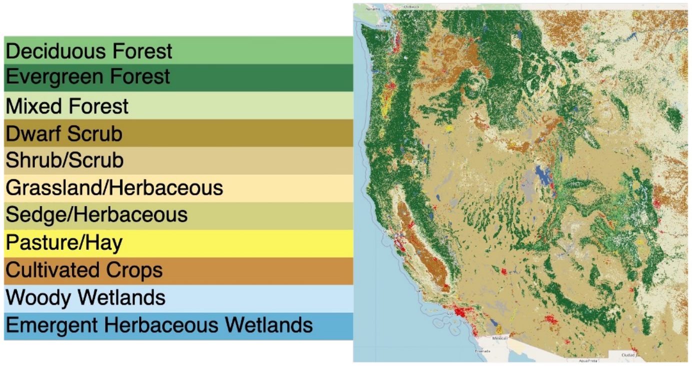
Data Assimilation Research Testbed

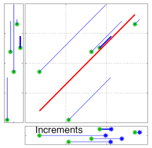
Future Directions

Additional data streams help constrain carbon cycling



Using high res land cover maps for improved forward operators (PFT specific).





Finer Spatial Resolution?

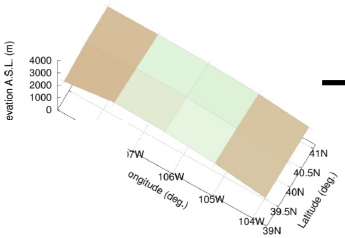
Atmosphere:

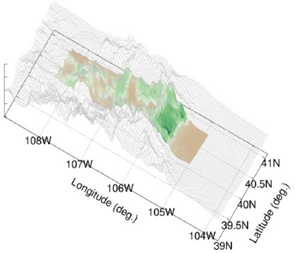
CAM4 Reanalysis (~2°) → CAM6 Reanalysis (~1°)

Ds199.1 | DOI: 10.5065/38ED-RZ08

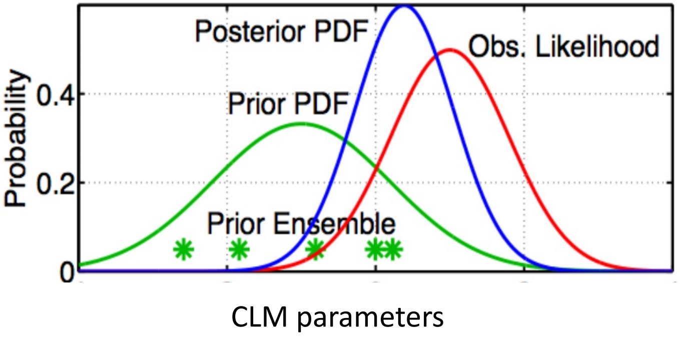
Ds345.0 | DOI: 10.5065/JG1E-8525

Land surface:





Parameter Estimation



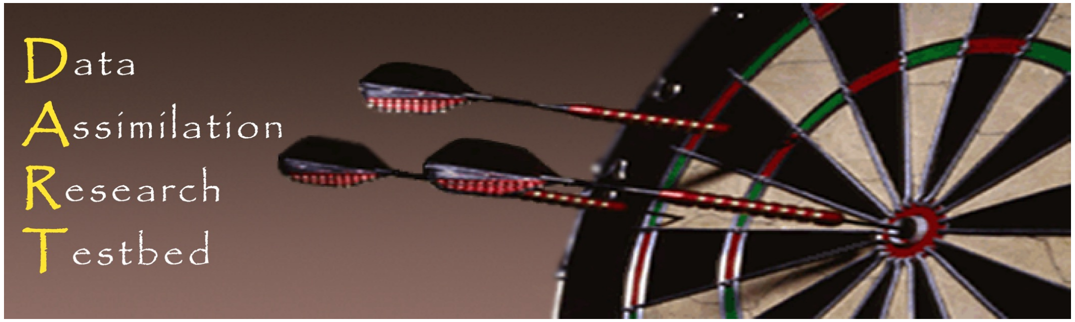
For more information:

CAM GCOM CAM-Chem FESOM ROMS WRF

GITM CABLE WRF-Hydro WACCM

CLM

AM2



POP

BGRID

SQG

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COAMPS NOAH

NCOMMAS PE2LYR

MITgcm_ocean WRF-Chem COAMPS_nest

NAAPS

WACCM-X

CISL
Computational & Information Systems Lab

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