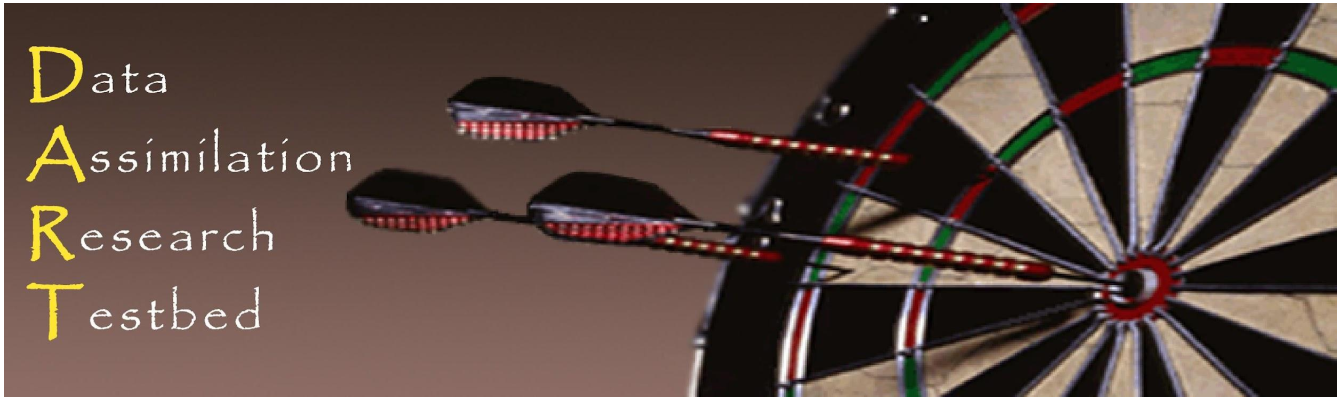


Methods to Estimate Model Parameters within the Data Assimilation Research Testbed (DART)

Brett Raczka[1], Xueli Huo[2], Daniel Hagan[3], Andrew M. Fox[4], Moha Gharamti[1], Kevin Raeder[1], Anthony Holmes[5], Ying Sun[5], Lewis Kunik[2], John Lin[2], Jeffrey Anderson[1]

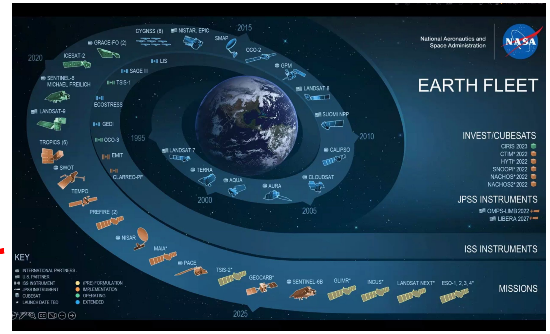
[1]National Center for Atmospheric, [2]University of Utah, [3]Nanjing University of Information Science and Technology [4]NASA Goddard Space Flight Center, [5]Cornell University

CESM Meeting, BGC Working Group
June 14th, 2023

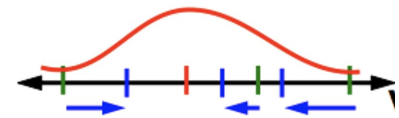
The National Center for Atmospheric Research is sponsored by the National Science Foundation. Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

CLM-DART example w/ aboveground biomass (AGB)

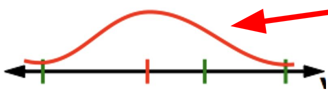
Observation Space



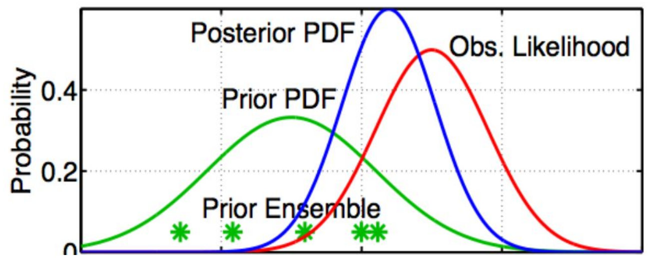
3 Update (posterior)



2 Calculate observed AGB

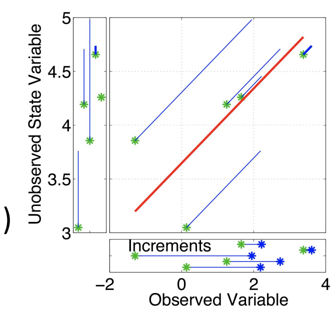


Forward operator: h
Observation estimate = h(deadstemc, livest



4 Apply update to model state (posterior)

(c,n)
:,n)
root(c,n)
Deadcoarseroot(c,n)
Fineroot(c,n)
Litter(c,n)



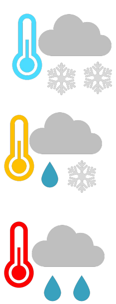
(AGB)

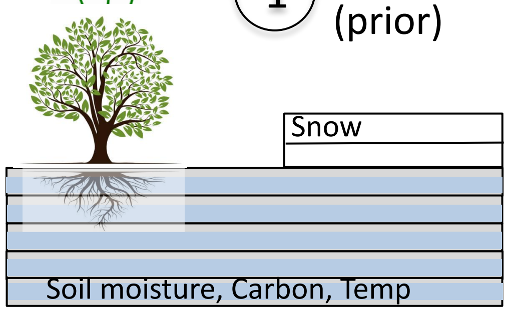
CLM History, restart files

1 Forecast (t_k) (prior)

CAM-DART Reanalysis Ensemble

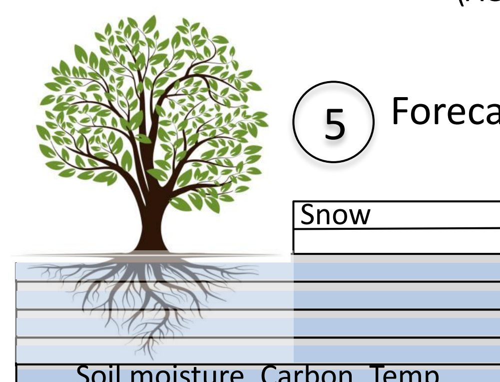
Raeder et al., (2012, 2021)





Model Space

5 Forecast (t_{k+1})

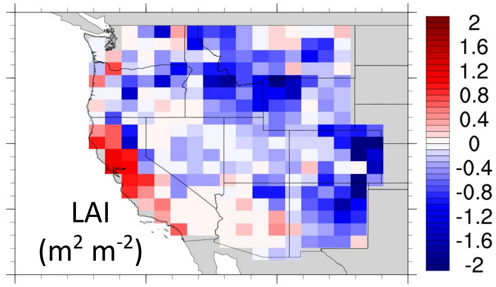


CLM-DART Applications: Carbon Monitoring

Western US

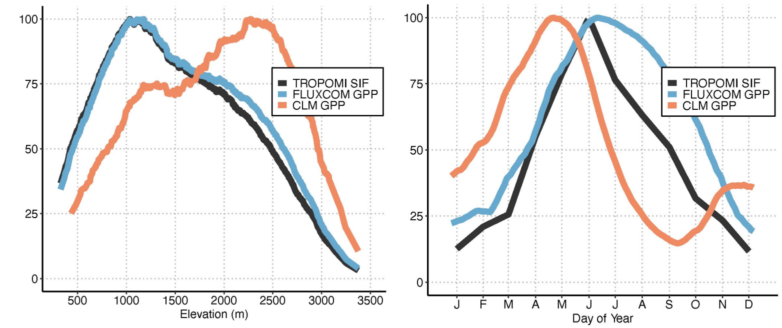
- Biomass
- LAI
- Carbon fluxes

(assimilation – free run)



Raczka et al., (2021)

Normalized GPP & SIF (Southern Sierra)



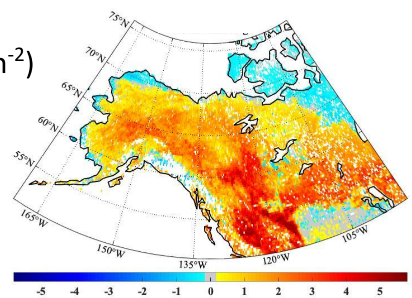
Kunik et al., (in prep)

Arctic

- Biomass
- LAI
- Carbon fluxes
- Energy fluxes
- Canopy Height
- Albedo
- Parameterization

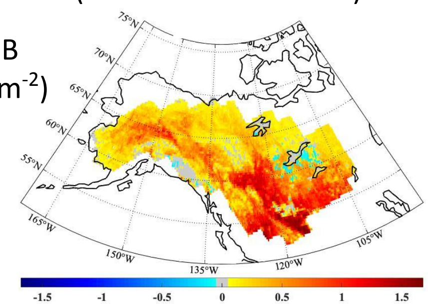
(free run-assimilation)

LAI ($m^2\ m^{-2}$)



(free run-assimilation)

AGB ($kgC\ m^{-2}$)

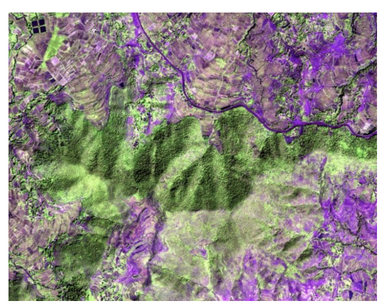


Huo et al., (in prep)

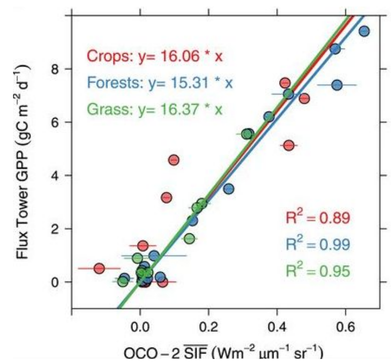
East Africa, Tropics

- Quantifying forest restoration
- Soil carbon modeling
- Solar-Induced Fluorescence

Green = restored forest



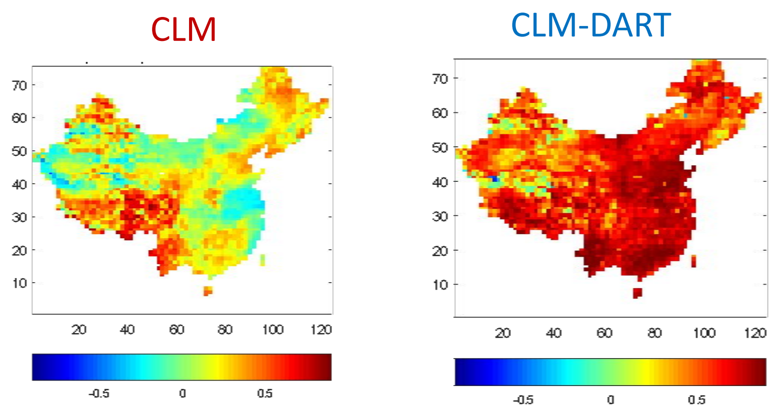
Weira Amba, Ethiopia



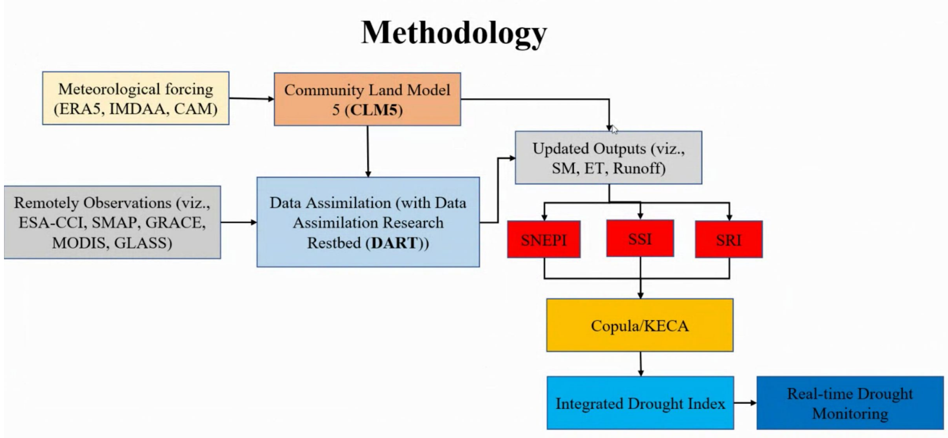
Ying Sun,
Anthony Holmes

CLM-DART Applications: Hydrology, Drought

- Improved Surface Soil Moisture Correlation w/ ERA5 across China using ESA-CCI obs.

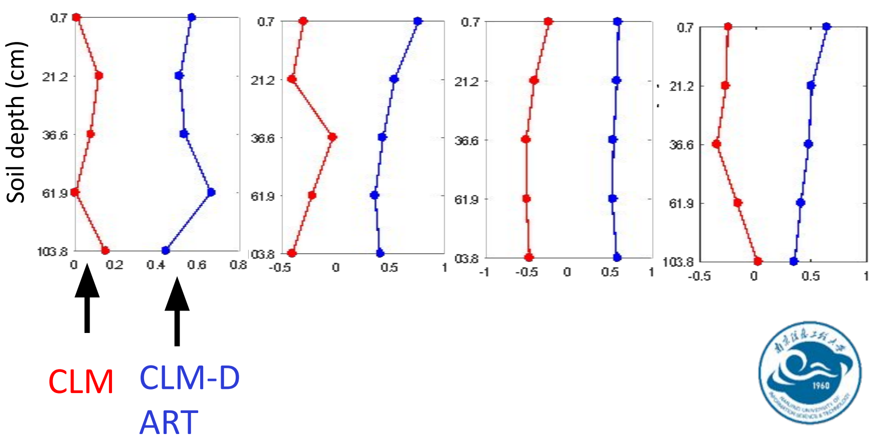


- Drought monitoring system (India) using observations (e.g. soil moisture, leaf area, TWS)



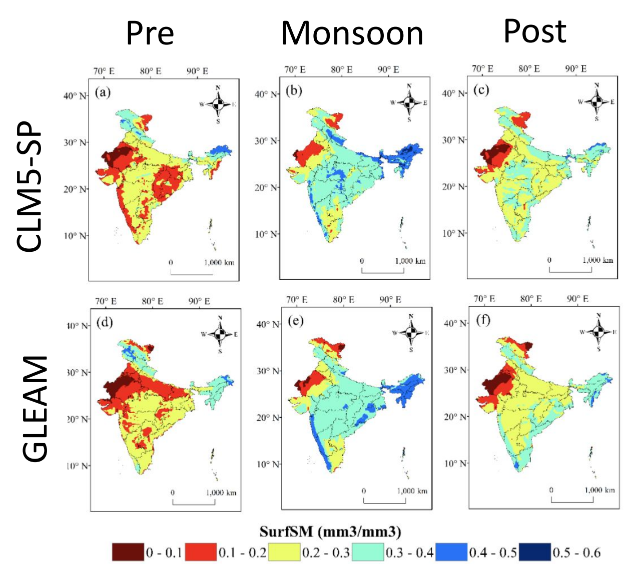
- Improved Sub-Surface SM Correlation (1-100 cm)

4 different sites



D. Hagan et al, (in prep)

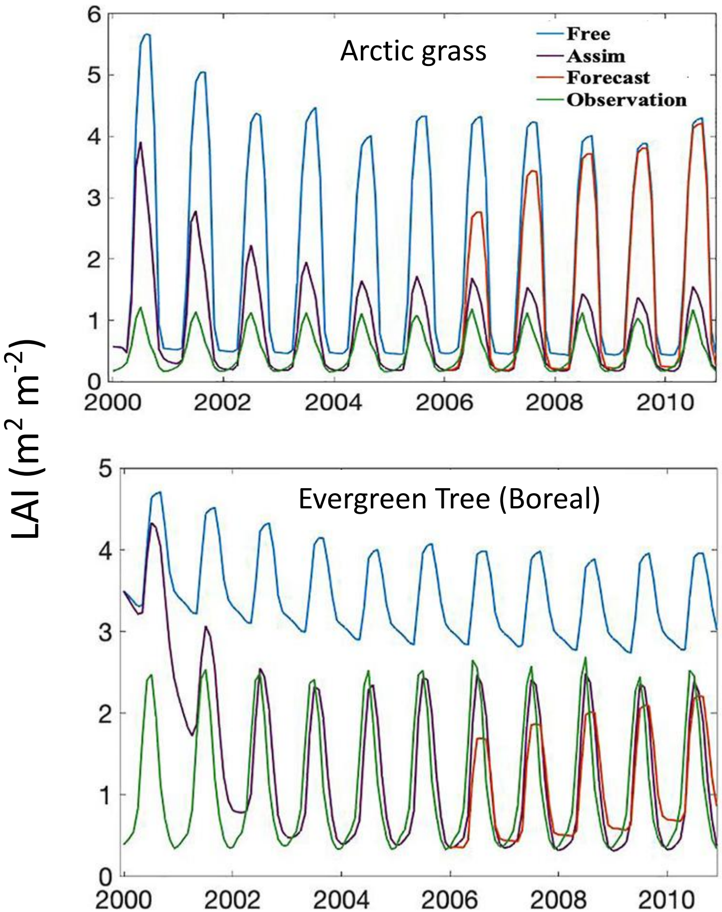
- CLM-SP Simulations of surface soil moisture against GLEAM validation data



D.C. Naik
Danya
C.T.

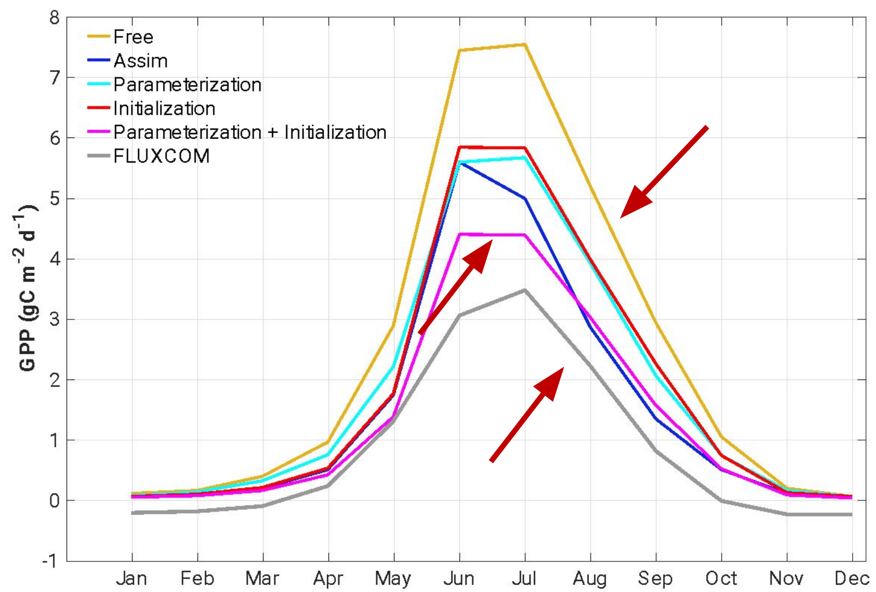
Limitations of updating model 'states' only

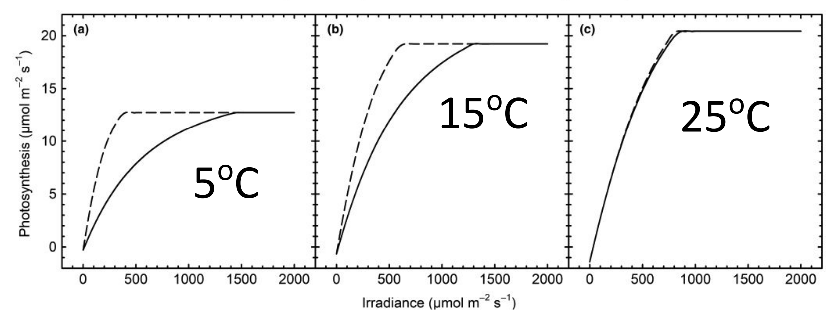
- Global CLM LAI forecasts approach free run



Fox et al., (2022)

- Seasonal cycle of CLM simulated GPP for Arctic domain





Huo et al., (in prep)

- 'State' updates resolve initial condition errors, but not model error. 'Parameter' updates can bring more resilient forecast improvement

Parameter Estimation w/ Ensemble DA

Contents lists available at ScienceDirect
Journal of Marine Systems
journal homepage: www.elsevier.com/locate/jmarsys

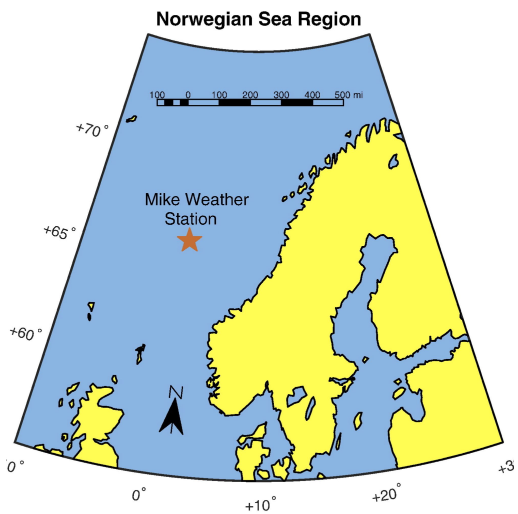
Online tuning of ocean biogeochemical model parameters using ensemble estimation techniques: Application to a one-dimensional model in the North Atlantic

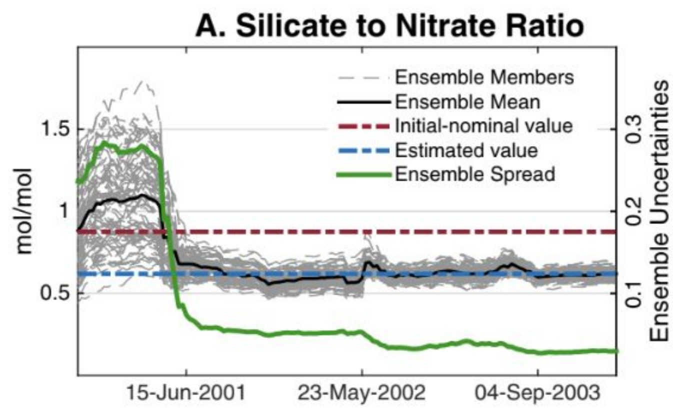
M.E. Gharamti[*,a,c], A. Samuelsen[a], L. Bertino[a], E. Simon[b], A. Korosov[a], U. Daewel[a]

- Using EnKF to estimate biogeochemical parameters with chlorophyll observations in a 1-D ocean model 'state augmentation'

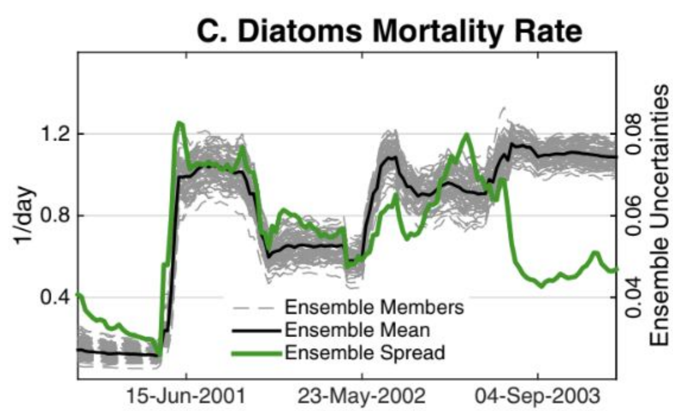
Norwegian Ecological Model
(estimated parameters)

Name	Symbol	Unit	Nominal value
1. Diatom temperature dependence	a2	1/°C	0.063
2. Flagellate temperature dependence	a4	1/°C	0.063
3. Nitrate to silicate ratio	N-Si-ratio	mol/mol	0.875
4. Diatoms mortality rate	cc3-dia	1/day	0.14
5. Flagellate mortality rate	cc3-fla	1/day	0.14
6. Sinking rate of detritus	srdet	m/day	−3
7. Sinking rate of biogenic silica	srsis	m/day	−3
8. Loss-rate of micro-zooplankton	mju2	1/day	0.2
9. Loss-rate of meso-zooplankton	mju3	1/day	0.2





- Parameter convergence

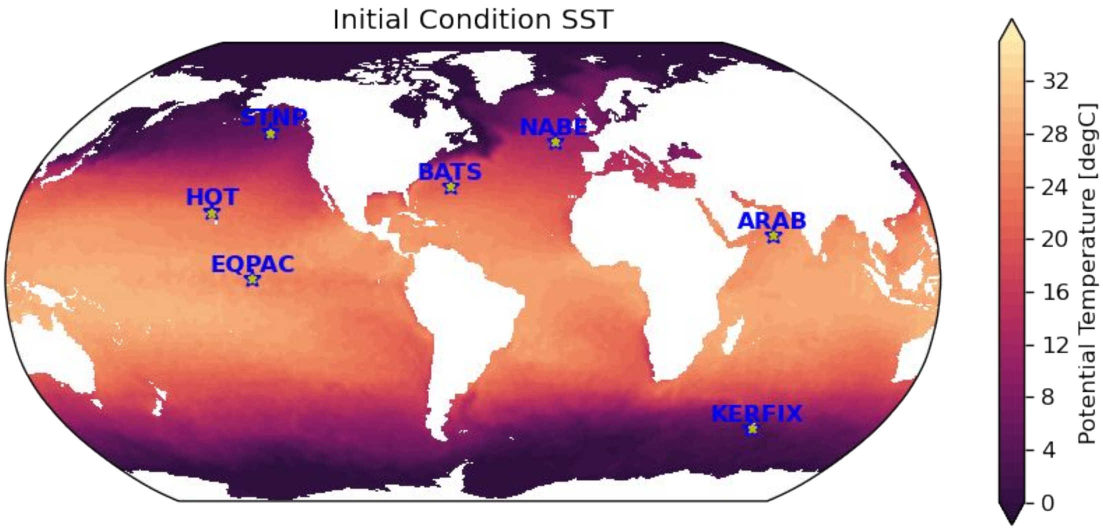


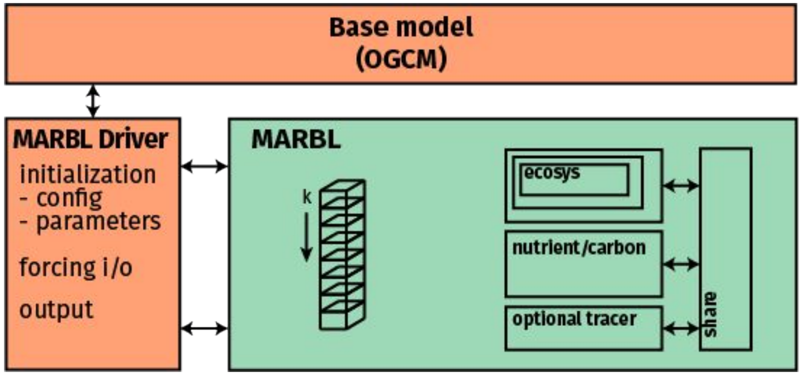
- No convergence, temporally evolvi

Ocean parameter estimation: MARBL-MOM6

Project Goals:

- Compare 1-D column MOM6/MARBL to data at BATS, HOT, etc.
- Estimate BGC parameters (e.g. nutrient uptake, productivity, predation) using the ensemble Kalman filter
- Evaluate parameters for global simulations



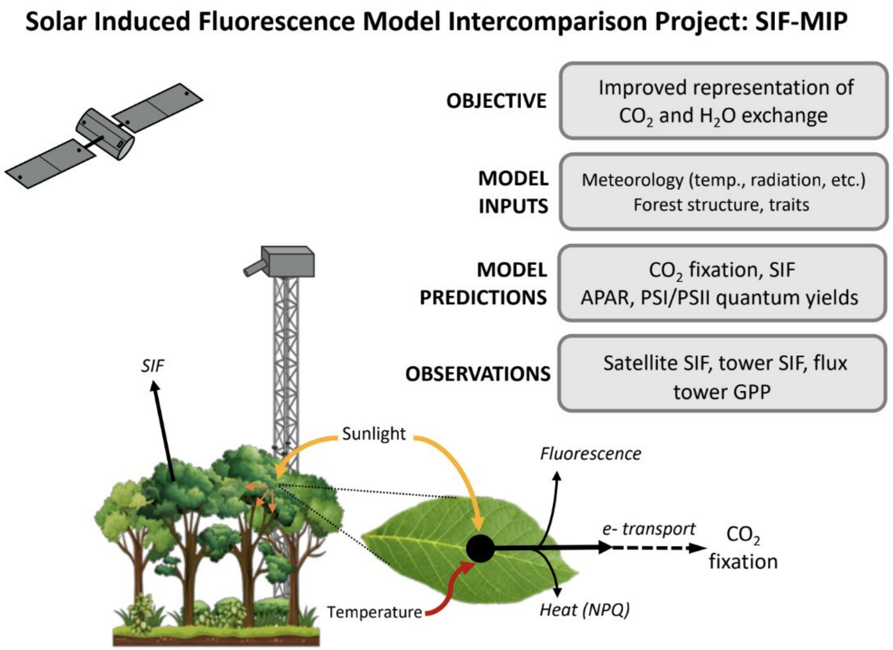


Robin Armstrong (SIParCS student)

with Mike Levy, Kristen Krumhardt, Helen Kershaw, Alper Altuntas, Keith Lindsay, Moha Gharamti, Matt Long, and Dan Amrhein

Land parameter estimation: SIF-MIP2

- Leveraging strong SIF-GPP relationship to estimate photosynthetic parameters

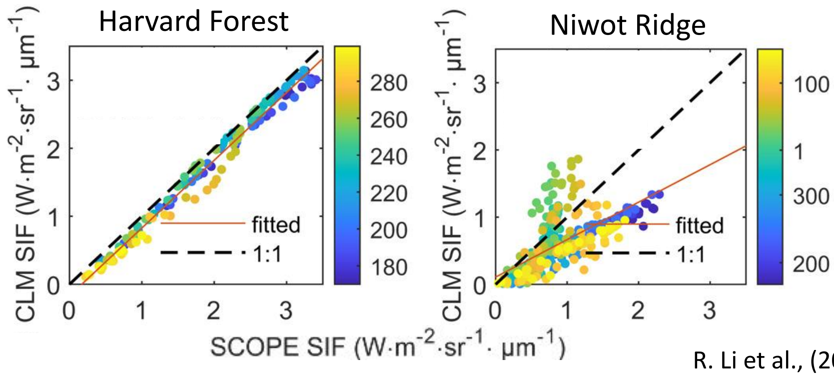


Provided by N. Parazoo

- Group 1: Free simulations (~10 models)
  Sites: Alaska □ Florida

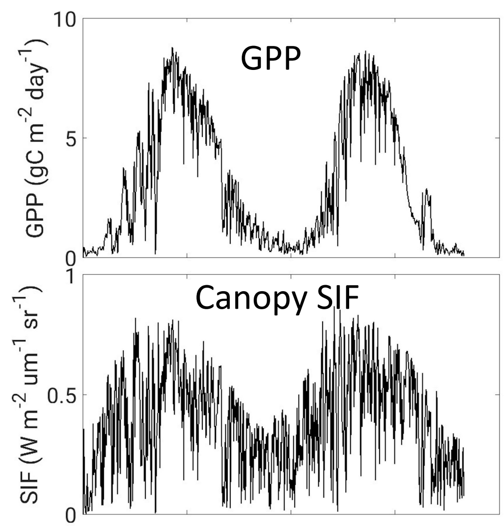
- Group 2: Data Assimilation
  (ORCHIDAS, CLM-DART, CARDAMOM)

1) Create SIF forward operator (leaf to canopy)



R. Li et al., (2022)

2) CLM performance (SIF-MIP2)

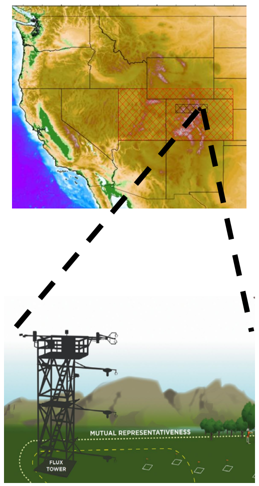


Niwot Ridge,
Years: 2017-18

Site Level PE Methods: Met Forcing

Apply CAM6 ensemble to a site:

1) Use site level met to remove bias
2) Maintain ensemble spread and temporal variation



CAM6 Met Reanalysis (1x1 degree)

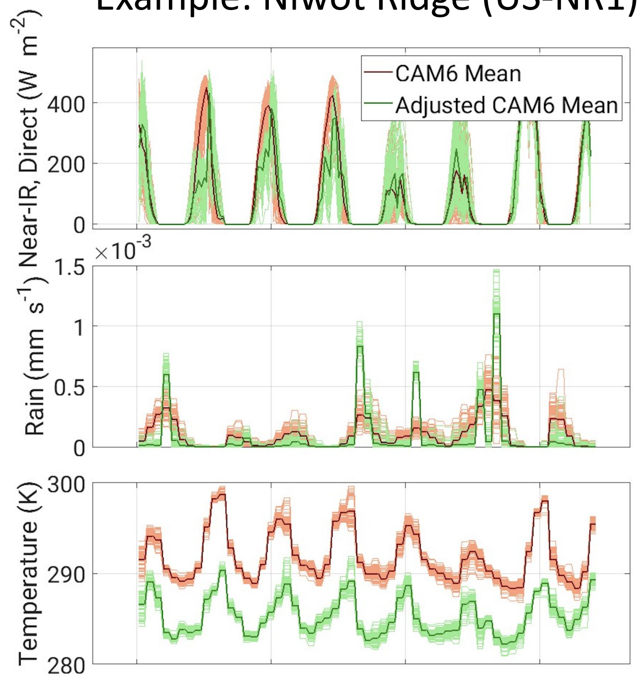
↓

$$X_{i,scaled} = X_i + (\bar{X}_{scaled} - \bar{X}) \;;\; i = 1,2,\ldots,80$$

↓

Site Level Met Reanalysis (1 km^2)

Example: Niwot Ridge (US-NR1)

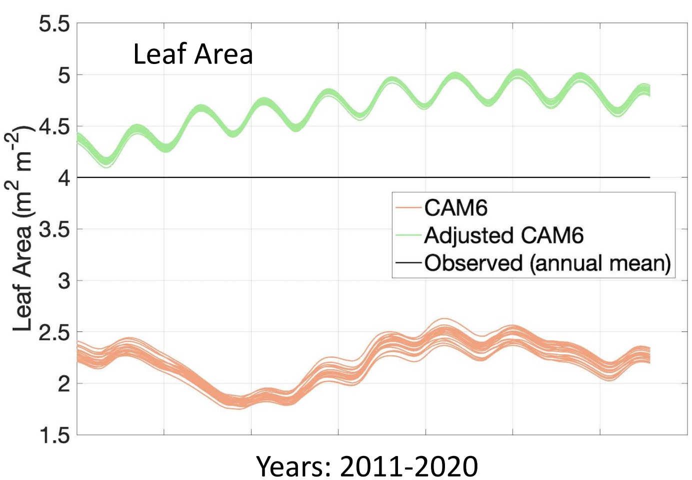


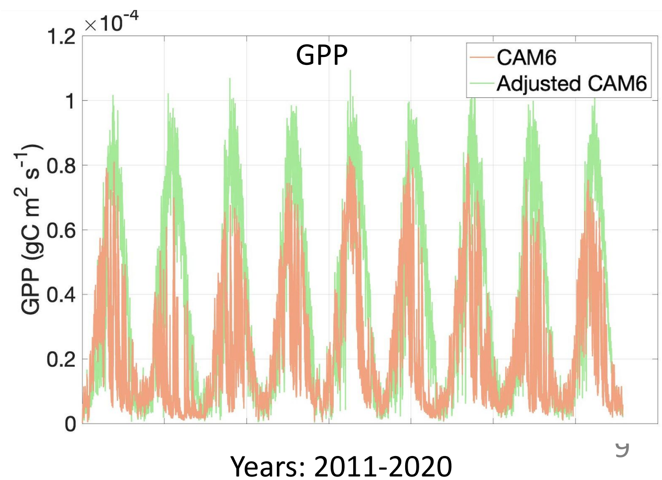
--> more clouds

--> wetter

--> cooler

Minimizes prior state variable biases (free simulations)





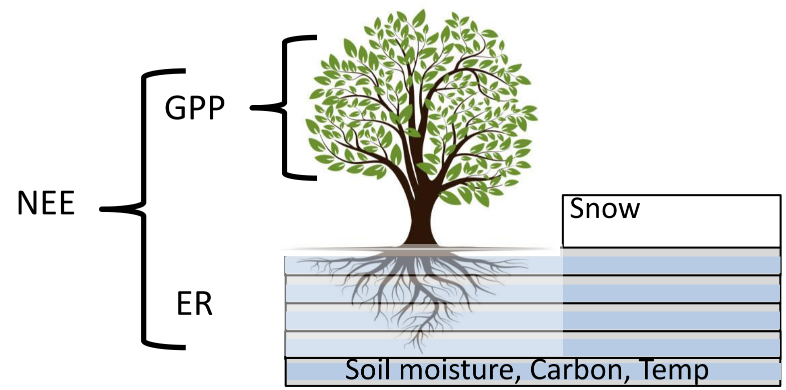
Data Assimilation Research Testbed

Site Level PE Methods: Flux Tower Network

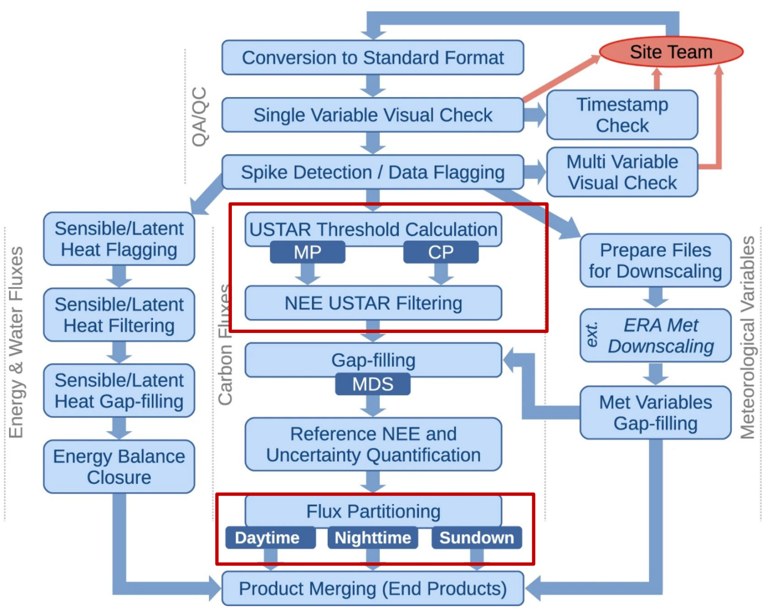
DART software (in development) queries: ‘Ameriflux Fullset formatted carbon & energy flux data’

1) Gap-filled
2) Partitioned fluxes (NEE, GPP, ER)
3) Hourly □ Monthly temporal resolution
4) Multiple uncertainty estimates

- Partitioned fluxes allow for targeted adjusted of related states/parameters (localization)



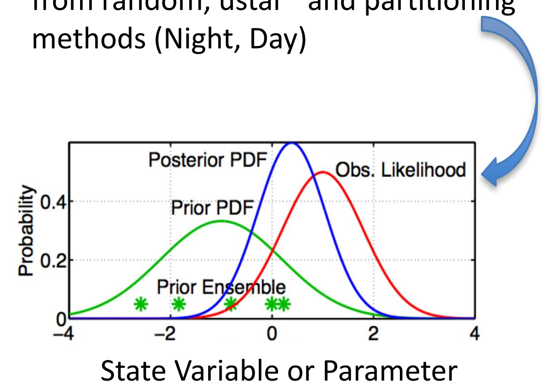
‘Oneflux’ Processing Overview



Pastorello et al., (2020)

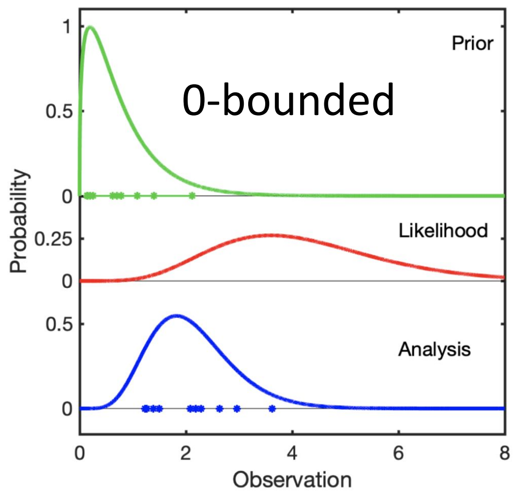
- Having multiple temporal resolutions potentially could reduce contributions from random uncertainty

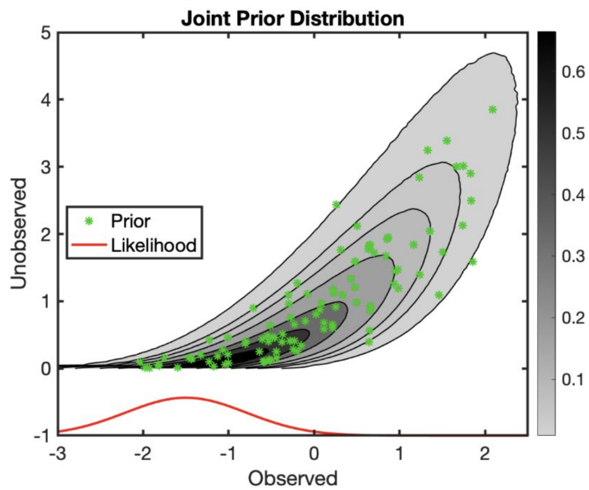
- Flux uncertainty includes contributions from random, ustar* and partitioning methods (Night, Day)

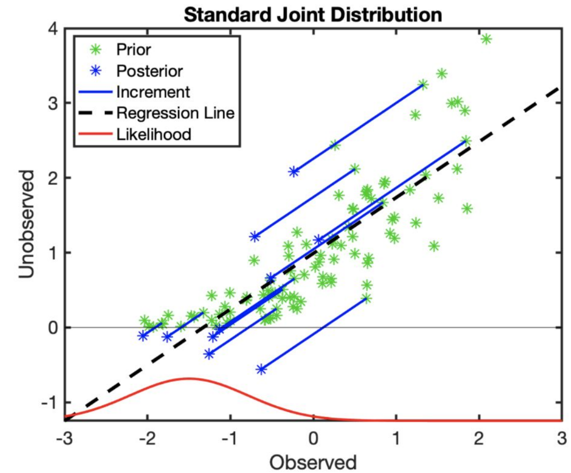


Site Level PE Methods: Bounded Quantities

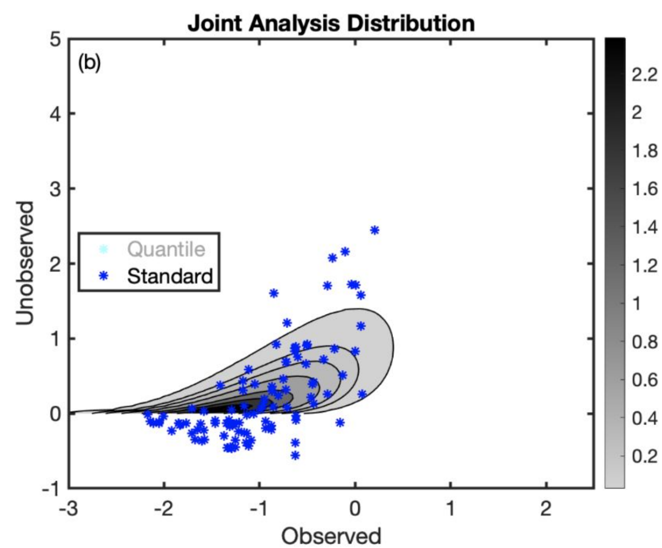
- What if the physical quantity or parameter being updated is bounded?





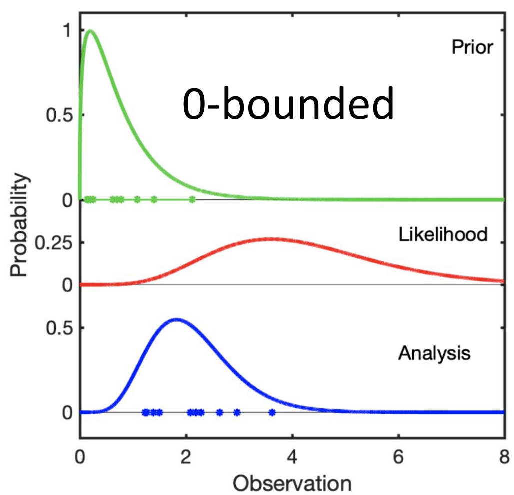


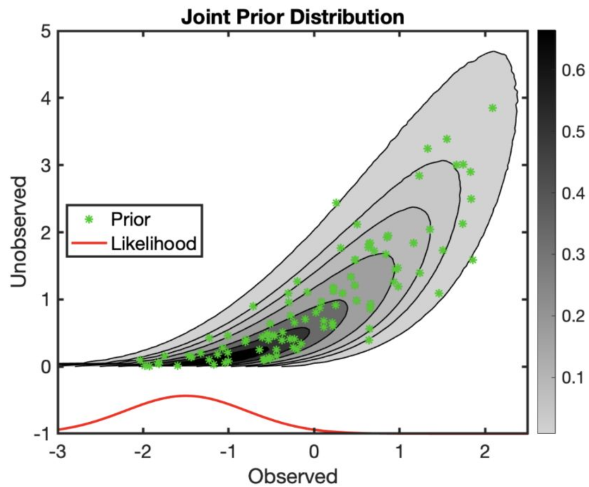
- ’Standard’ linear regression updates do not respect bounds, have trouble with non-linear relationships.

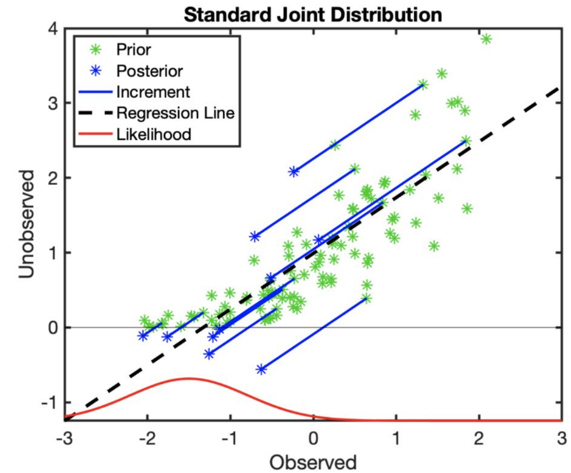


Site Level PE Methods: Bounded Quantities

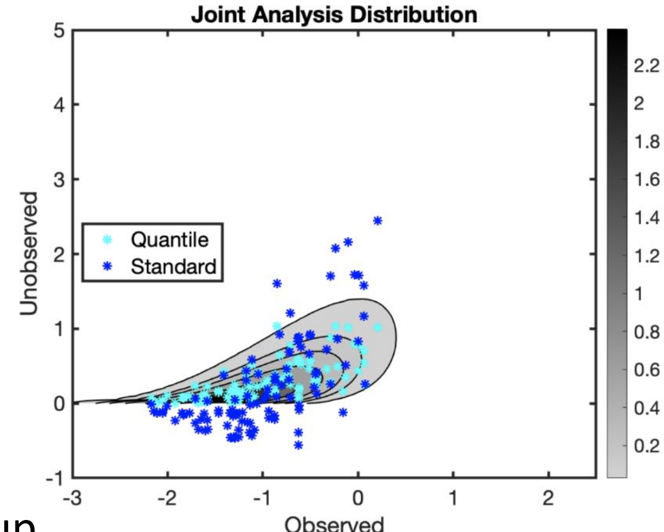
- What if the physical quantity or parameter being updated is bounded?







- However, a probit-transformed quantile regression filter *does* respect both bounds and non-linear relationships

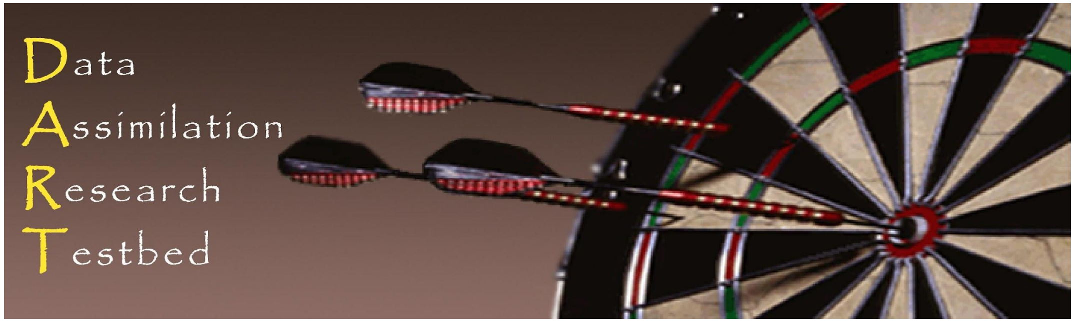


Jeffrey Anderson
Parameter Estimation Cross-Working Group

Summary

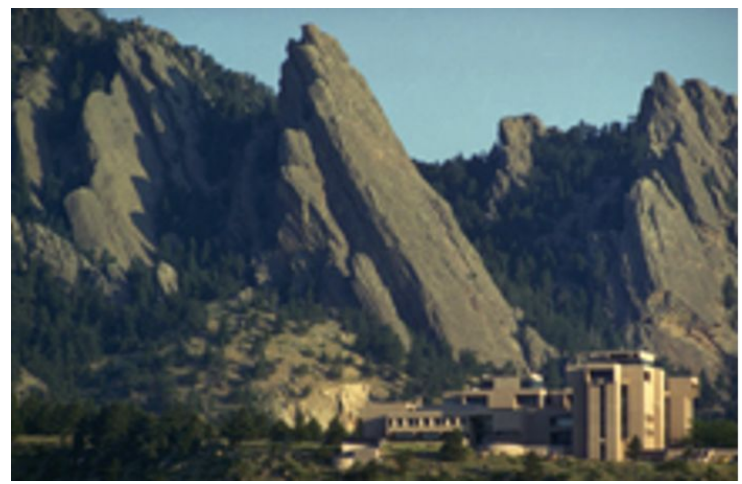
- CESM-DART state updates can be applied to the land surface to improve forecasting skill related to carbon cycling, hydrology, and seasonal atmospheric forecasting
- Forecasting skill is limited when updating model states only, updating parameters can bring additional improvements
- Site level parameter estimation work currently underway for both ocean and land site level applications for CESM
- New Quantile Conserving Filter in DART is promising to address non-linear and non-gaussian applications within parameter estimation

For more information:



Thank You !

Questions ?



CISL
Computational & Information Sy

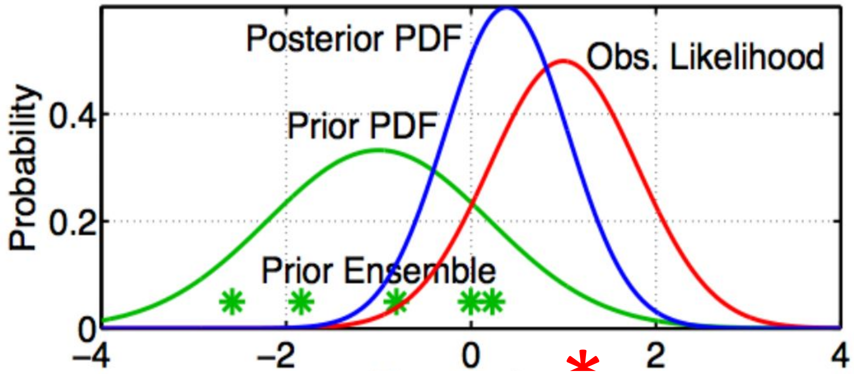
We would like to acknowledge high-performance computing support from Cheyenne (doi:10.5065/D6RX99HX) provided by NCAR's Computational and Information Systems Laboratory, sponsored by the National Science Foundation.

CLM-DART Methodology

- Bayesian Approach

Posterior ~ **Prior** · **Observation Likelihood**

'Analysis' 'Update'	CLM generated forecast	Earth System Observations
		e.g. satellite, surface data



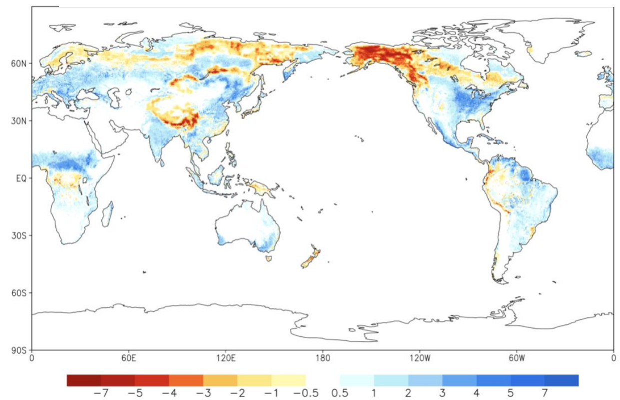
State Variable or Parameter

Data Assimilation Research Testbed

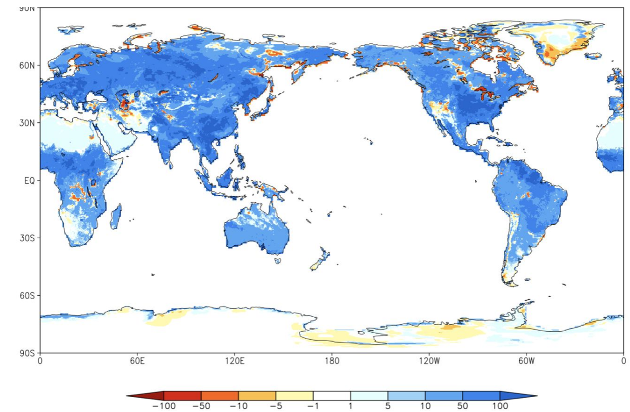
CLM-DART Applications: Seasonal Forecasting

<u>Objective</u>: Use CLM and observations of LAI, AGB, snow and soil moisture to initialize the land surface (LDAS-SPREADS) for seasonal atmospheric forecasts

LAI (m^2 m^{-2}), (obs – open loop)



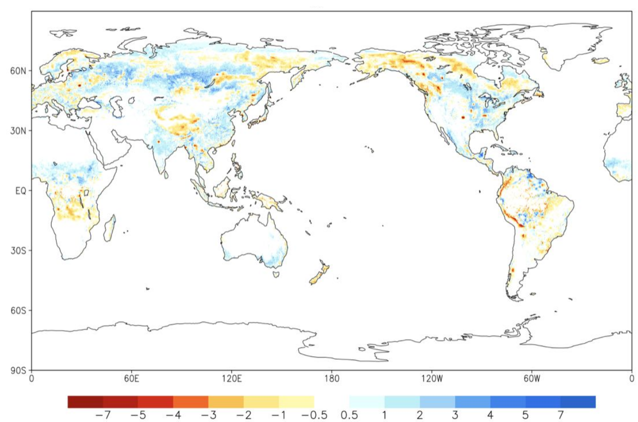
Latent Heat (W m^{-2}), (ERA5 – open loop)



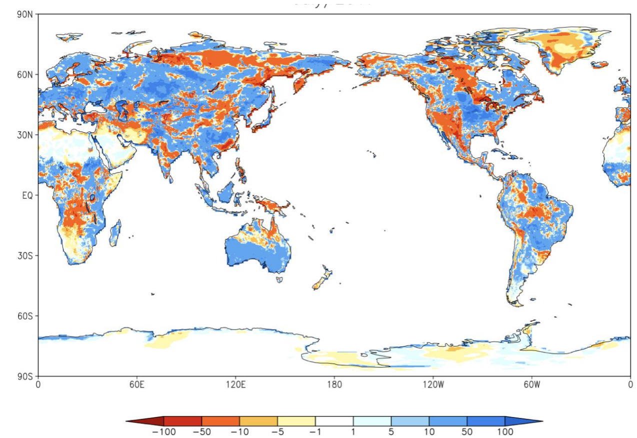
- Assimilation of LAI observation product (GLASS) shifts LAI and latent heat flux distributions

- cesm2.2 vs. cesm2.3

LAI (m^2 m^{-2}), (obs – assimilation)



Latent Heat (W m^{-2}), (ERA5 – assimilation)



cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

Provided by Luis Gustavo Goncalves