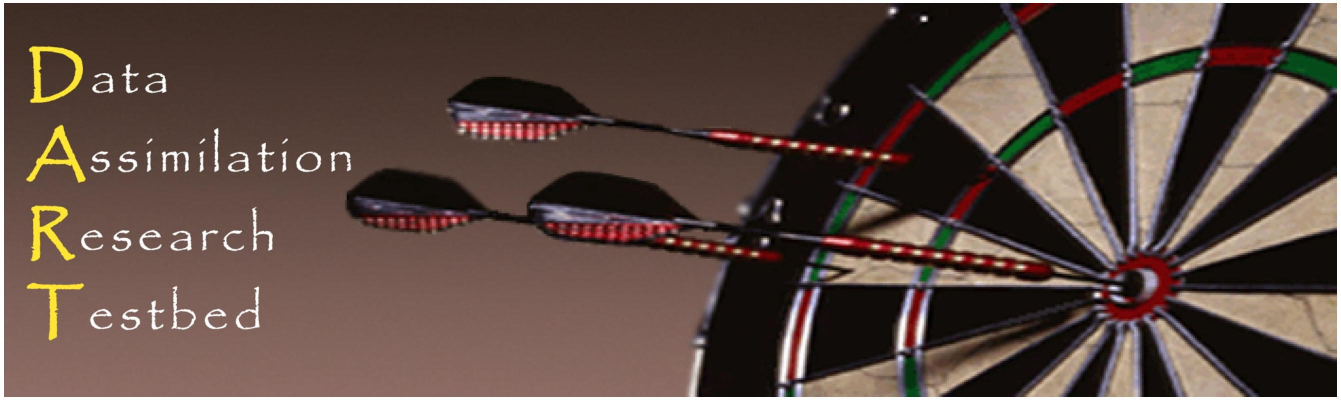
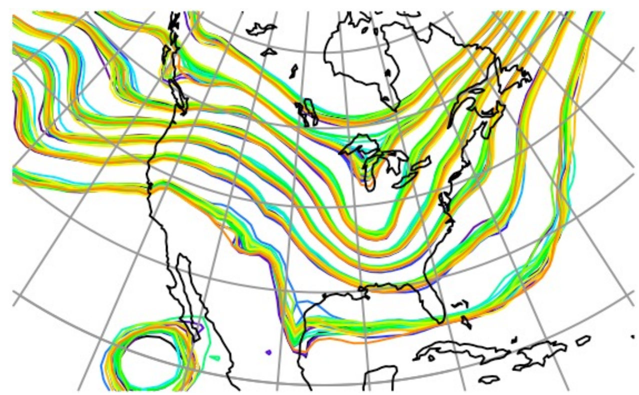


Applying Ensemble Data Assimilation to CLM

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



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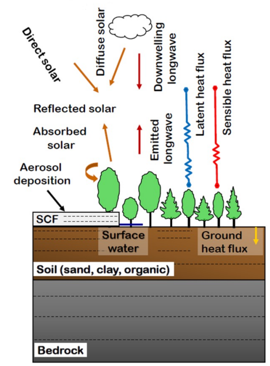
NCAR UCAR | National Center for Atmospheric Research

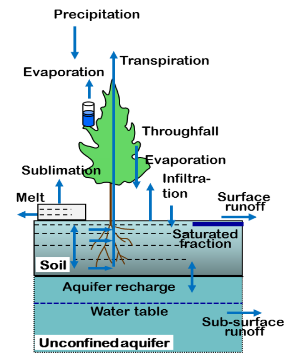
Approaches to reduce CLM uncertainty

CLM-BGC (Biogeochemisty)
- No external constraints
- Prognostic

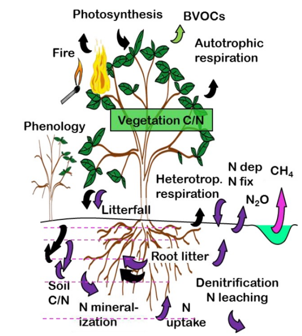
Energy balance



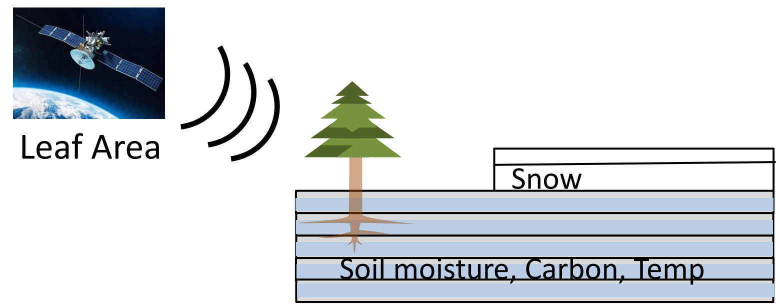
Hydrology



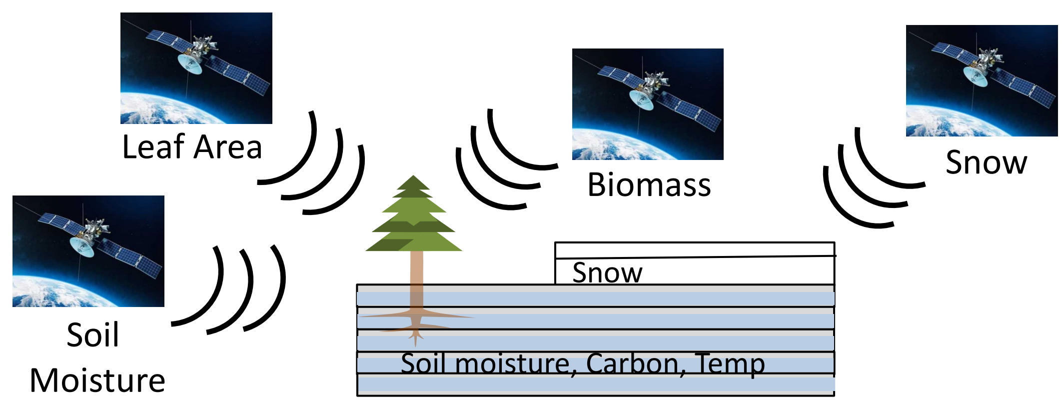
Carbon and nitrogen cycles



CLM-SP (Satellite Phenology)
- Prescribed Leaf Area/Vegetation



CLM-DART
- 'Any' observed land surface property
- Uncertainty estimates



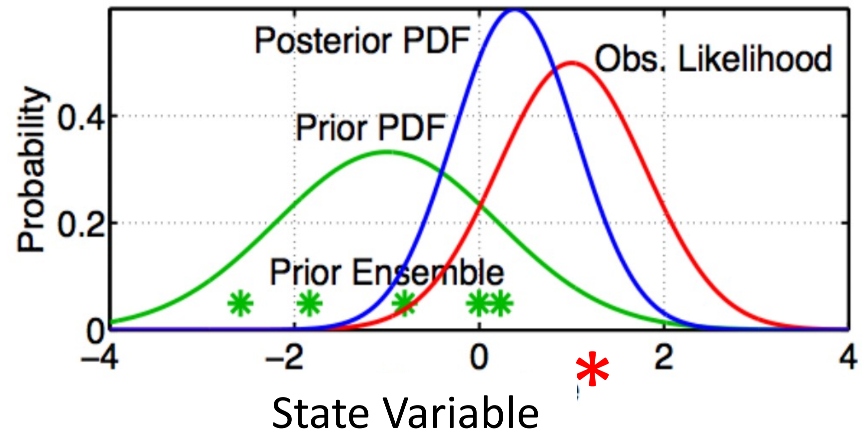
Data Assimilation Research Testbed

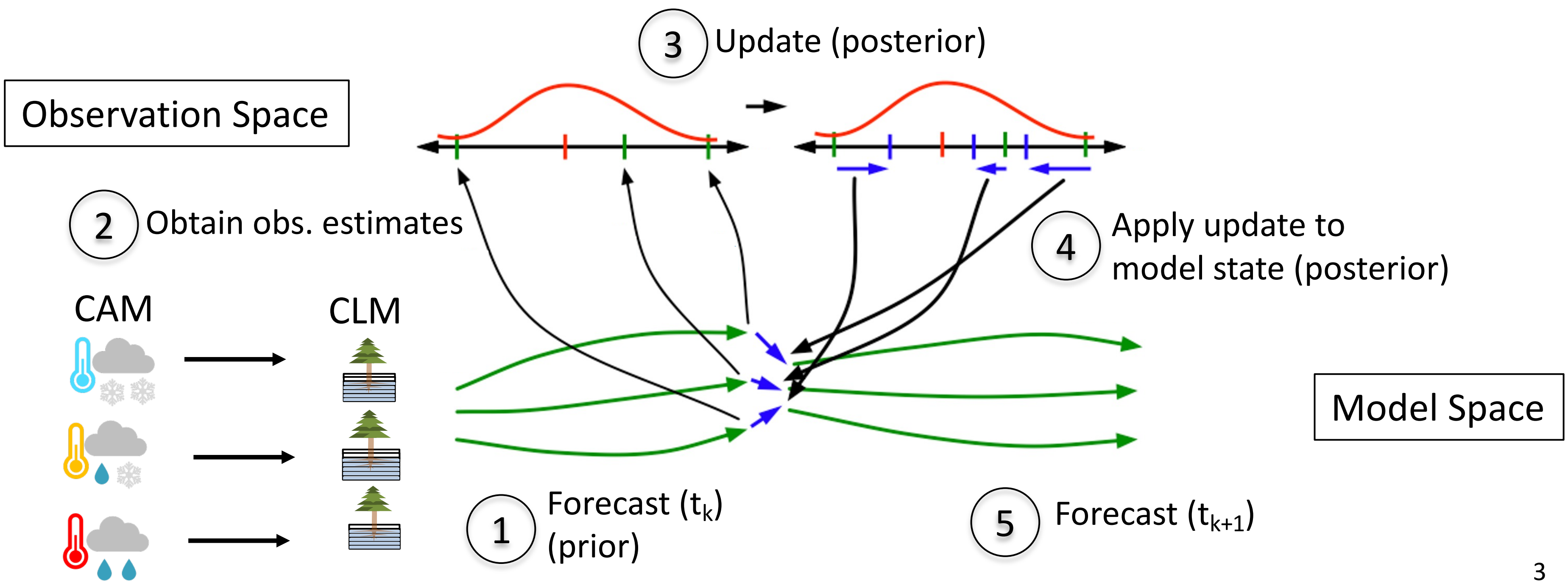
Overview of CLM-DART

- Bayesian Approach

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

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



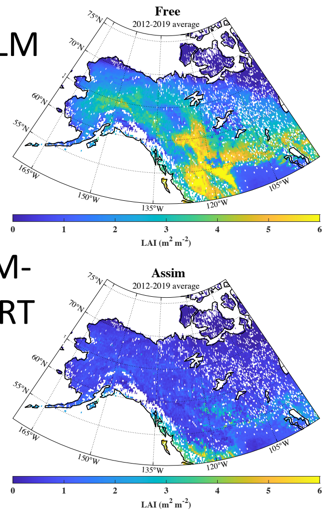


CLM-DART Applications

Leaf Area/ Biomass (Arctic)

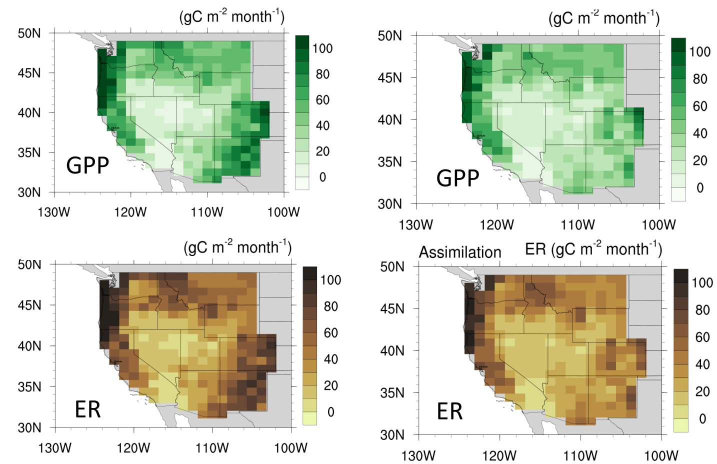
CLM

CLM-DART



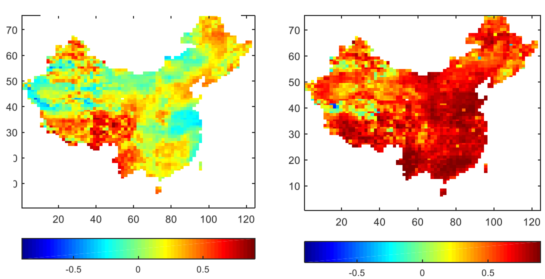
X. Huo et al, (in prep)

Carbon Exchange (Western U.S)



Raczka et al, (2021)

Soil Moisture (China)



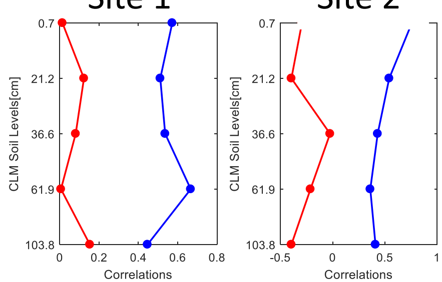
Correlations (R) w/ ERA5 reanalysis

surface

Sub-surface

CLM

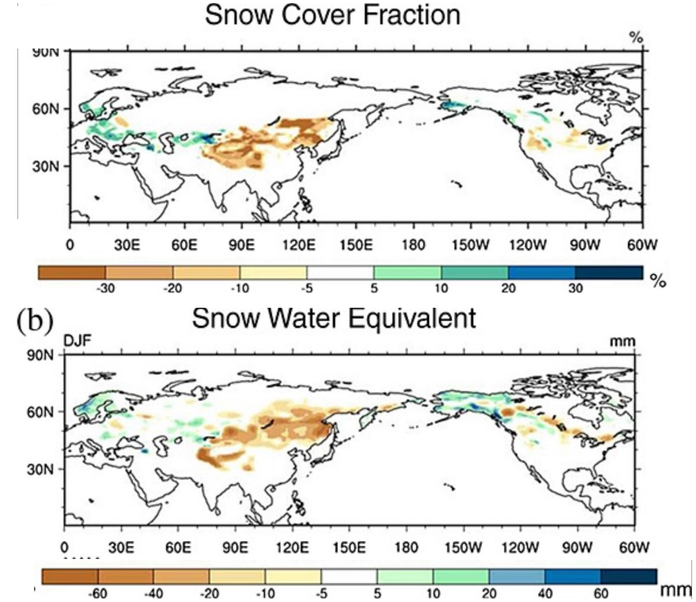
CLM-DART



D. Hagan et al, (in prep)

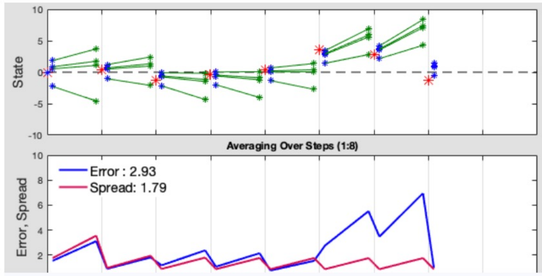
Snow (Global)

CLM minus (CLM-DART)



Zhang et al., 2014

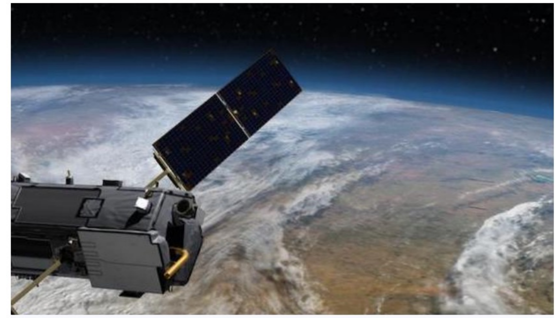
DART Tutorials



MATLAB

DART LAB

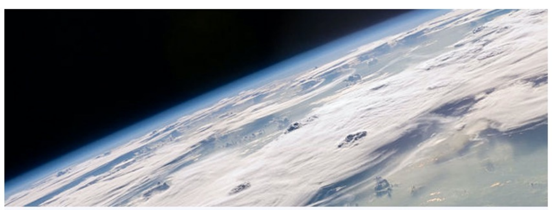
An introduction to Data Assimilation using MATLAB DART_LAB is a MATLAB®-based tutorial to demonstrate the principles of ensemble data assimilation. The DART_LAB tutorial begins at a more introductory level than the materials in the tutorial directory, and includes hands-on exercises. ...



Fortran

The DART tutorial

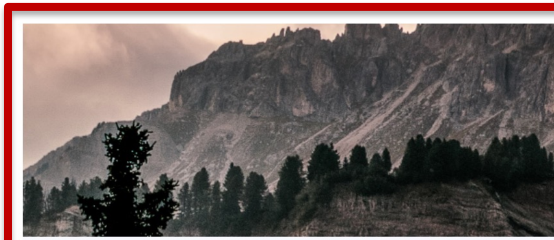
The DART Tutorial is intended to aid in the understanding of ensemble data assimilation theory and consists of step-by-step concepts and companion exercises with DART. ...



Fortran

WRF-DART tutorial

Overview The WRF-DART tutorial steps through a WRF-DART experiment. The experiment covers the continental United States and uses a 50 member ensemble initialized from NCEP's Global Forecast System (GFS) initial conditions at 2017/04/27 00:00 UTC. ...



Fortran

CLM5-DART Tutorial

The CLM5-DART tutorial provides a detailed description of the download, setup, executation and diagnostic steps required for a simple global assimilation run using CLM5. It is intended to be performed after the completion of the more general DART tutorial which covers the fundamental concepts of the Ensemble Kalman Filter used within DART. ...

https://dart.ucar.edu/tutorials/

CLM5-DART Tutorial

Downloading, setup, run, diagnostic steps:

- Step 1: Download CLM5
- Adding CLM5 SourceMods
- Compiling CLM5
- Step 2: Download DART
- Step 3: Navigating DART Scripts
- Step 4: Compiling DART
- Step 5: Setting up the atmospheric forcing
- Step 6: Setting up the initial conditions for land earth system properties
- **Step 7: Setting up the observations to be assimilated**
- Step 8: Setting up the DART and CLM states
- Step 9: Set the spatial localization
- Step 10: Set the Inflation
- Step 11: Complete the Assimilation Setup
- Step 12: Execute the Assimilation Run
- Step 13: Diagnose the Assimilation Run

Instructions, script examples, and definitions:

In this tutorial we have several observation types that are to be assimilated, including `SOIL_TEMPERATURE`, `MODIS_SNOWCOVER_FRAC`, `MODIS_LEAF_AREA_INDEX` and `BIOMASS`. To enable the assimilation of these observations types they must be included within the `&obs_kind_nml` within the `input.nml` file as:

```
&obs_kind_nml
  assimilate_these_obs_types = 'SOIL_TEMPERATURE',
                               'MODIS_SNOWCOVER_FRAC',
                               'MODIS_LEAF_AREA_INDEX',
                               'BIOMASS',
  evaluate_these_obs_types   = 'null'
  /
```

Observation Sequence File Variable	Description
observation sequence number	The chronological order of the observation within the observation sequence file. This determines the order in which the observation is assimilated by DART for a given time step.
observation value	The actual observation value that the DART `filter` step uses to update the CLM model. This is derived from the true observation value generated from CLM model output with uncertainty added.
true observation value	The observation generated from CLM output. In this case the observation was generated as part of a perfect model experiment (OSSE; Observing System Simulation Experiment), thus the 'true' value is known.
observation quality control	The quality control value provided from the data provider. This can be used as a filter in which to exclude low quality observations from the assimilation.

- Not containerized, assumes you have Cheyenne account or ported CLM and DART to your local HPC

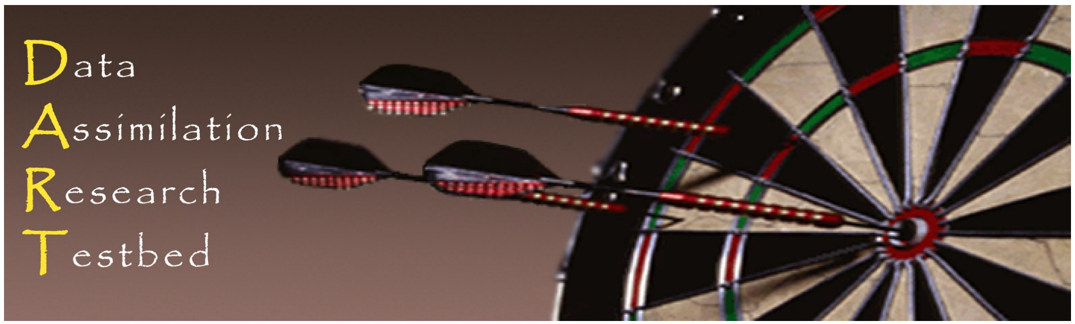
Data
Assimilation
Research
Testbed

For more information:

CAM GCOM CAM-Chem FESOM ROMS WRF

GITM CABLE WRF-Hydro WACCM

CLM



POP

AM2

BGRID

SQG

https://dart.ucar.edu

https://docs.dart.ucar.edu

dart@ucar.edu

COAMPS NOAH

NCOMMAS PE2LYR

MITgcm_ocean COAMPS_nest

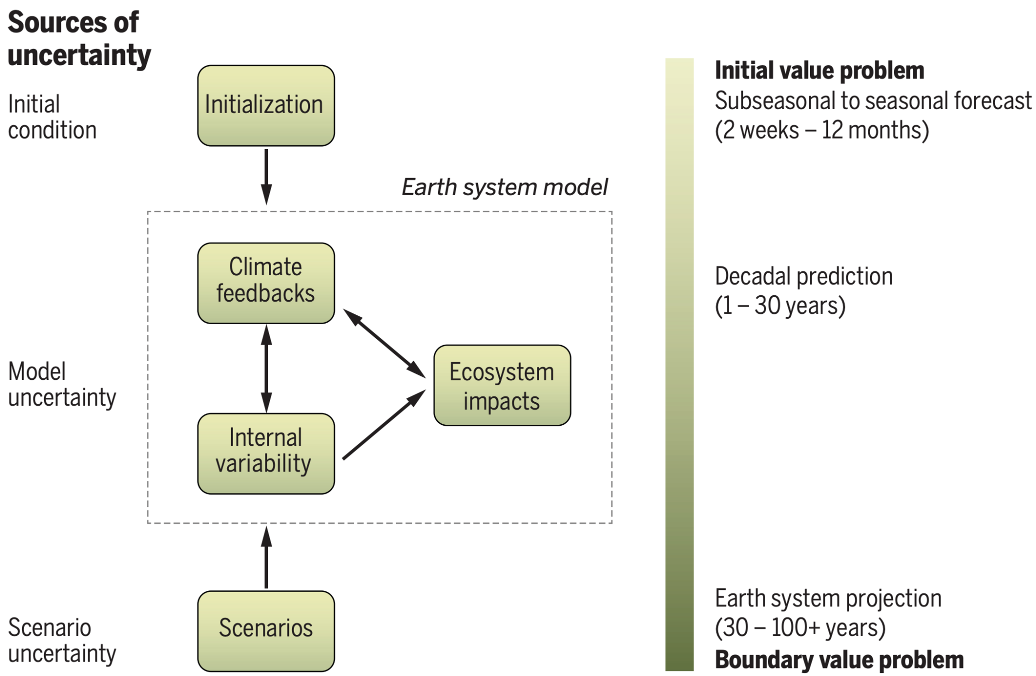
WRF-Chem NAAPS TIEGCM MPAS_ATM

MPAS_OCN WACCM-X PBL_1d NOAH-MP

CISL Computational & Information Systems Lab

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.

Data Assimilation minimizes uncertainty



Climate, ecosystems, and planetary futures: The challenge to predict life in Earth system models

Gordon B. Bonan[1*] and Scott C. Doney[2*]

REVIEW SUMMARY

EARTH SYSTEMS

Sources of CTSM Uncertainty:

Initial Conditions:
- Leaf Area/Biomass
- Soil Carbon

Model Structure:
- Model mechanisms
- parameter settings

Boundary Condition:
- Meteorology data