The role of soil moisture in water and carbon cycle interactions and modulating feedbacks to weather – an integrated modeling and satellite data approach

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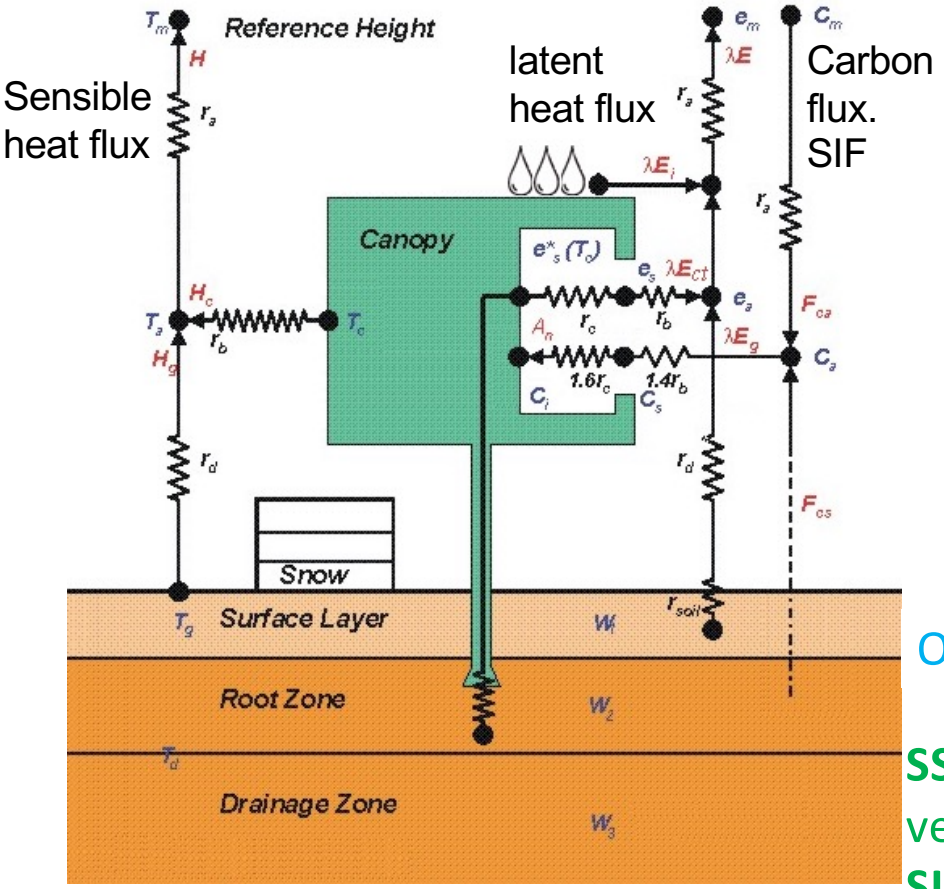
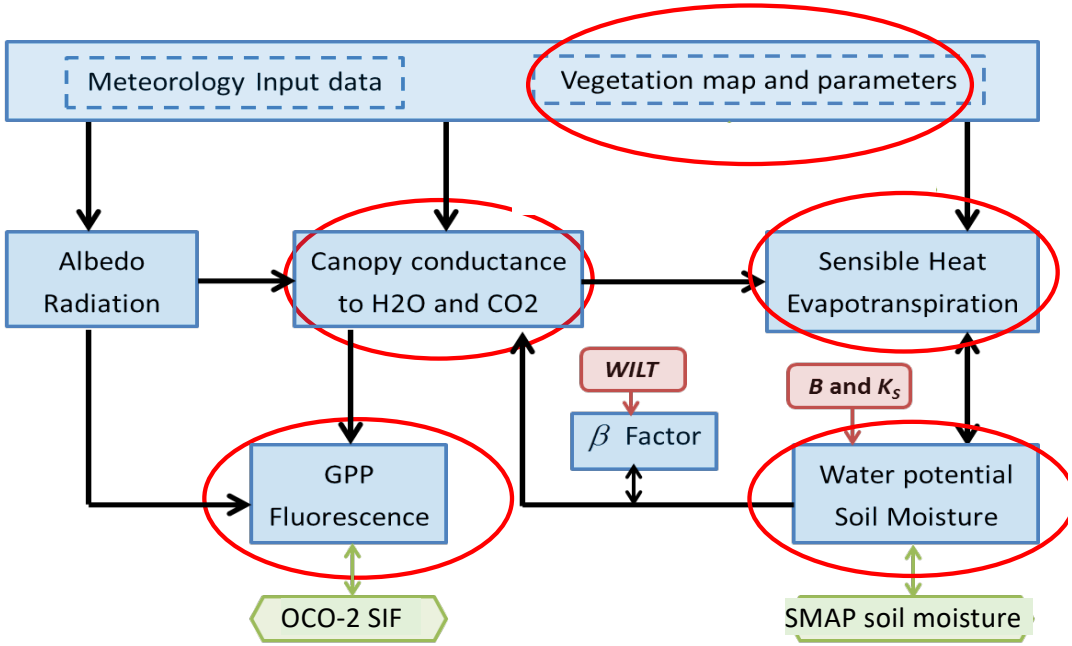
Research Objectives:

This project aims to integrate SMAP soil moisture and other satellite data (mainly OCO-2) in a coupled biophysical/dynamic vegetation model to evaluate and improve land surface model soil moisture and carbon flux estimates, with emphasis on carbon flux sensitivity to moisture deficits and impacts to weather/climate prediction. We will investigate broad-scale relationships between soil moisture and carbon dynamics.

Schematic diagram of vegetation model

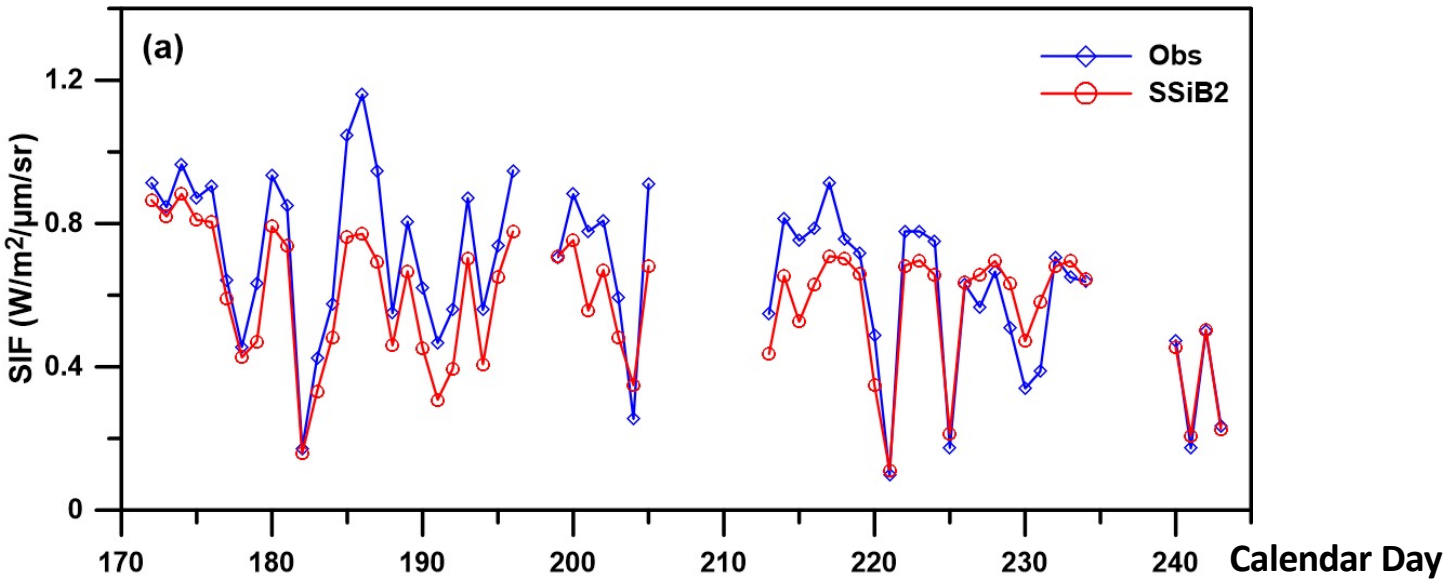




Overview flowchart of the SSiB2 land surface model

SSiB2: A land vegetation model using specifiec vegetation conditions for each plant functional type

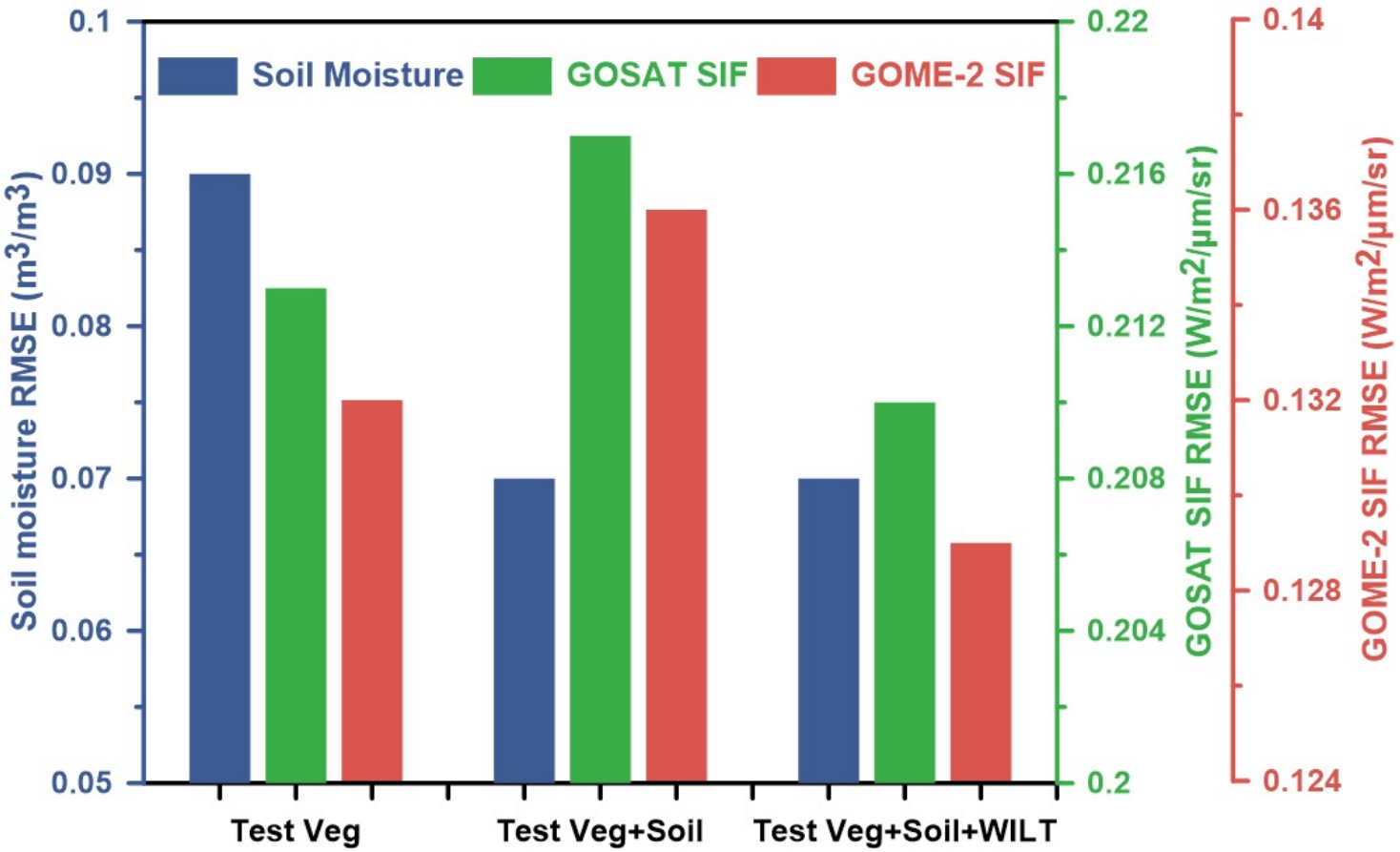
SIF (Solar-induced Chlorophyll Fluorescence) is usec to estimate actual photosynthesis



Daily mean SIF over the flux-tower site at Harvard Forest, USA (42.538 °N, 72.171 °W).

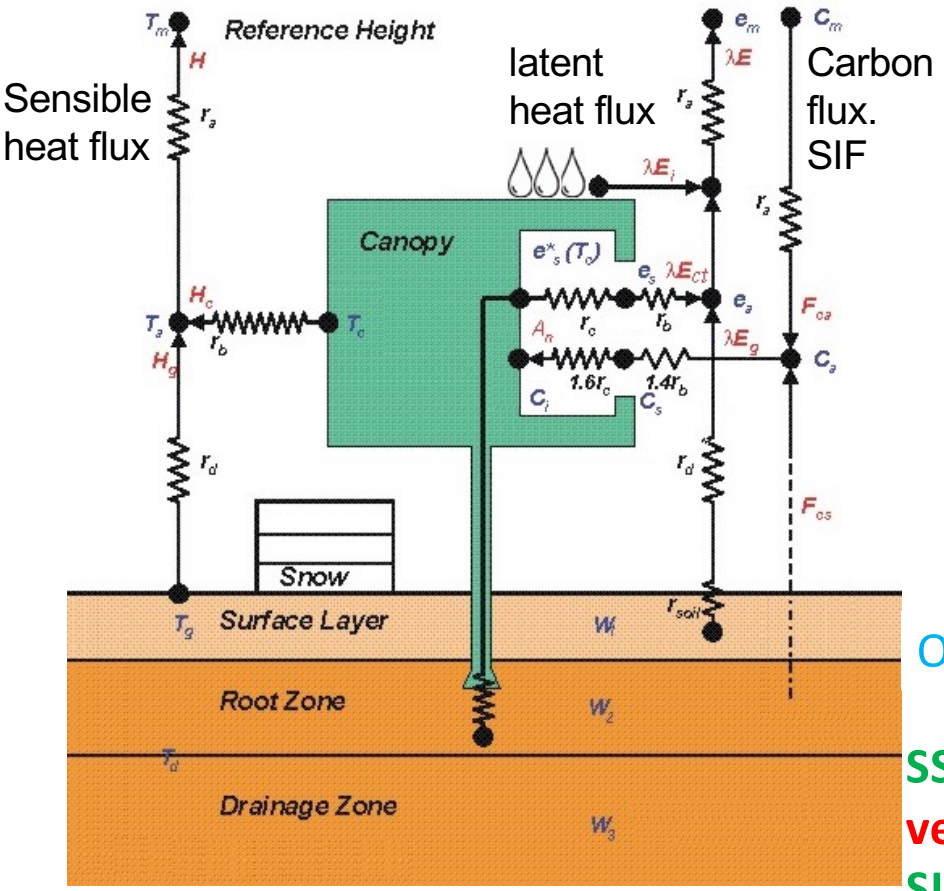
Experimental Design using SSiB2

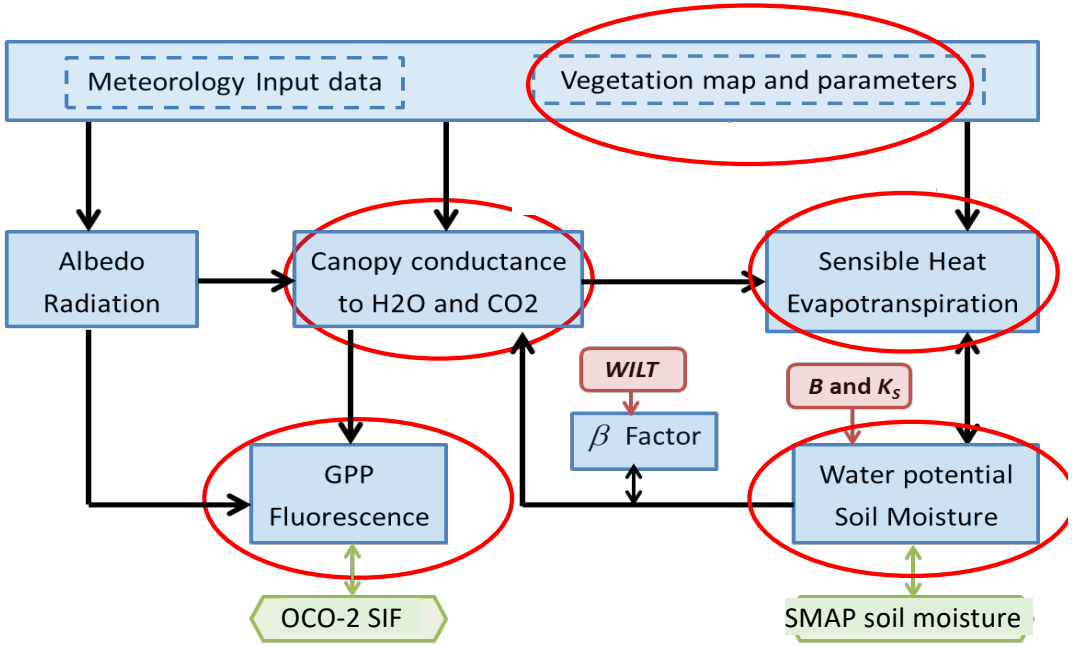
	Experiment Description
CTL	The original LAI, green fraction, and vegetation cover fraction
Test Veg	With modified LAI, Green leaf fraction and cover fraction
Test Veg+Soil	Same as Test Veg, but B parameter and hydraulic conductivity at saturation are modified
Test Veg+Soil+WILT	Same as Test Veg+Soil, but wilting point is modified



Global RMSE of different experiments relative to SMOS soil moisture and GOSAT and GOME-2 SIF

Schematic diagram of vegetation model





Overview flowchart of the SSiB2 land surface model

SSiB2: A land vegetation model **using specified vegetation conditions for each plant functional type**

SIF (Solar-induced Chlorophyll Fluorescence) is used to estimate actual photosynthesis

SSiB4/TRIFFID: A land vegetation model with dynamic vegetation

CFS: global climate model

WRF: Regional Climate model

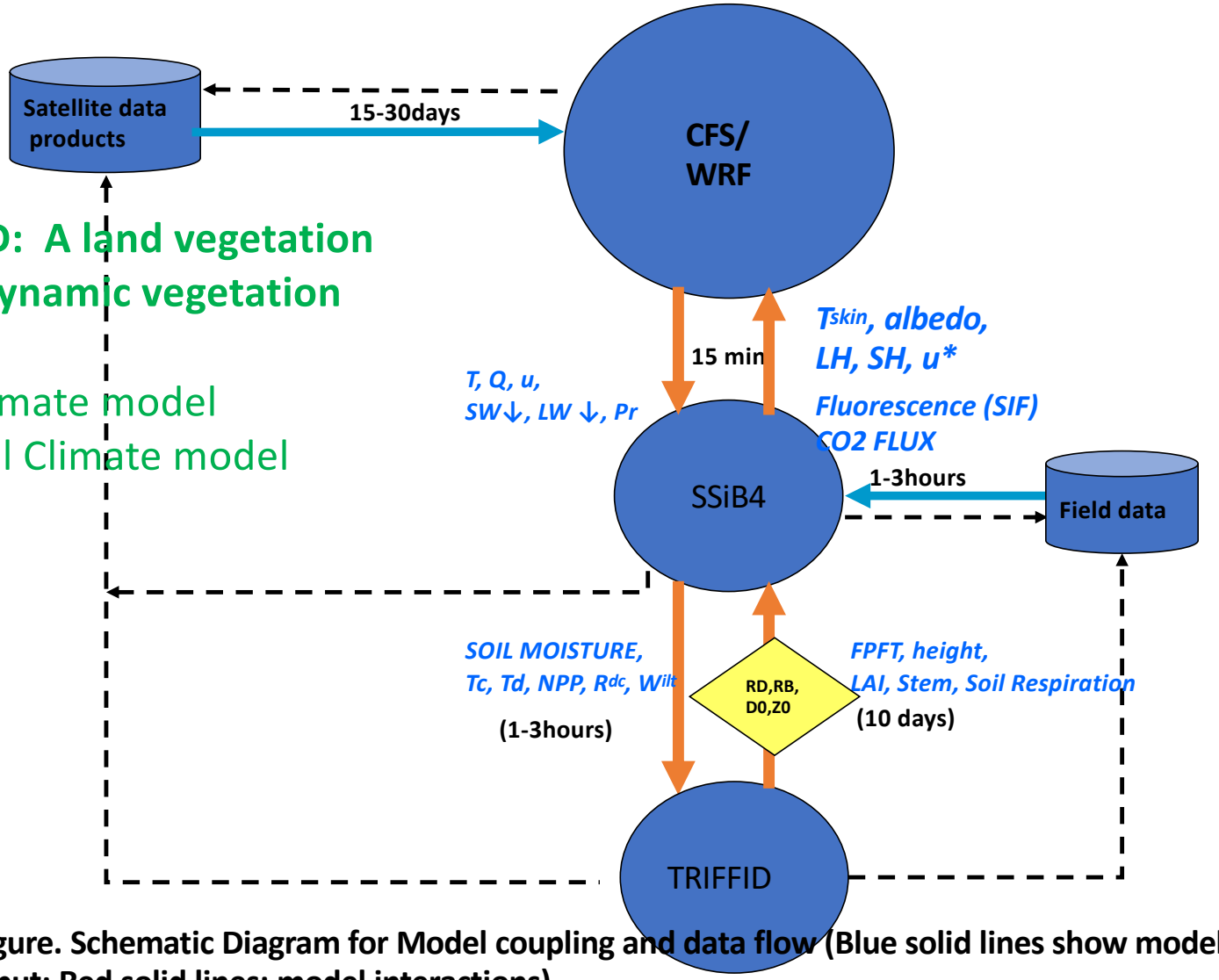
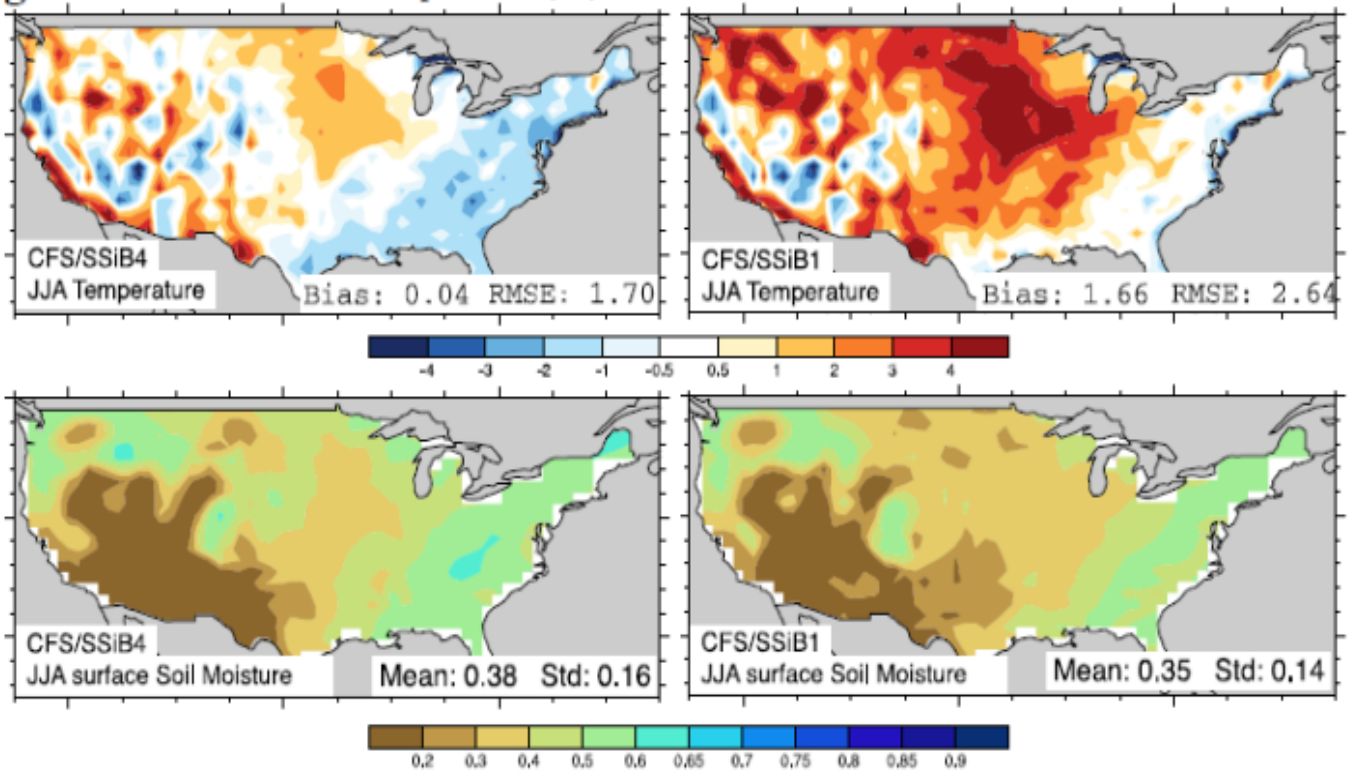


Figure. Schematic Diagram for Model coupling and data flow (Blue solid lines show model input; Red solid lines: model interactions).

Figure CFS/SSiB JJA Temperature (°C) bias and surface soil moisture over America for 1979-2009



SSiB4/TRIFFID: A land vegetation model with dynamic vegetation

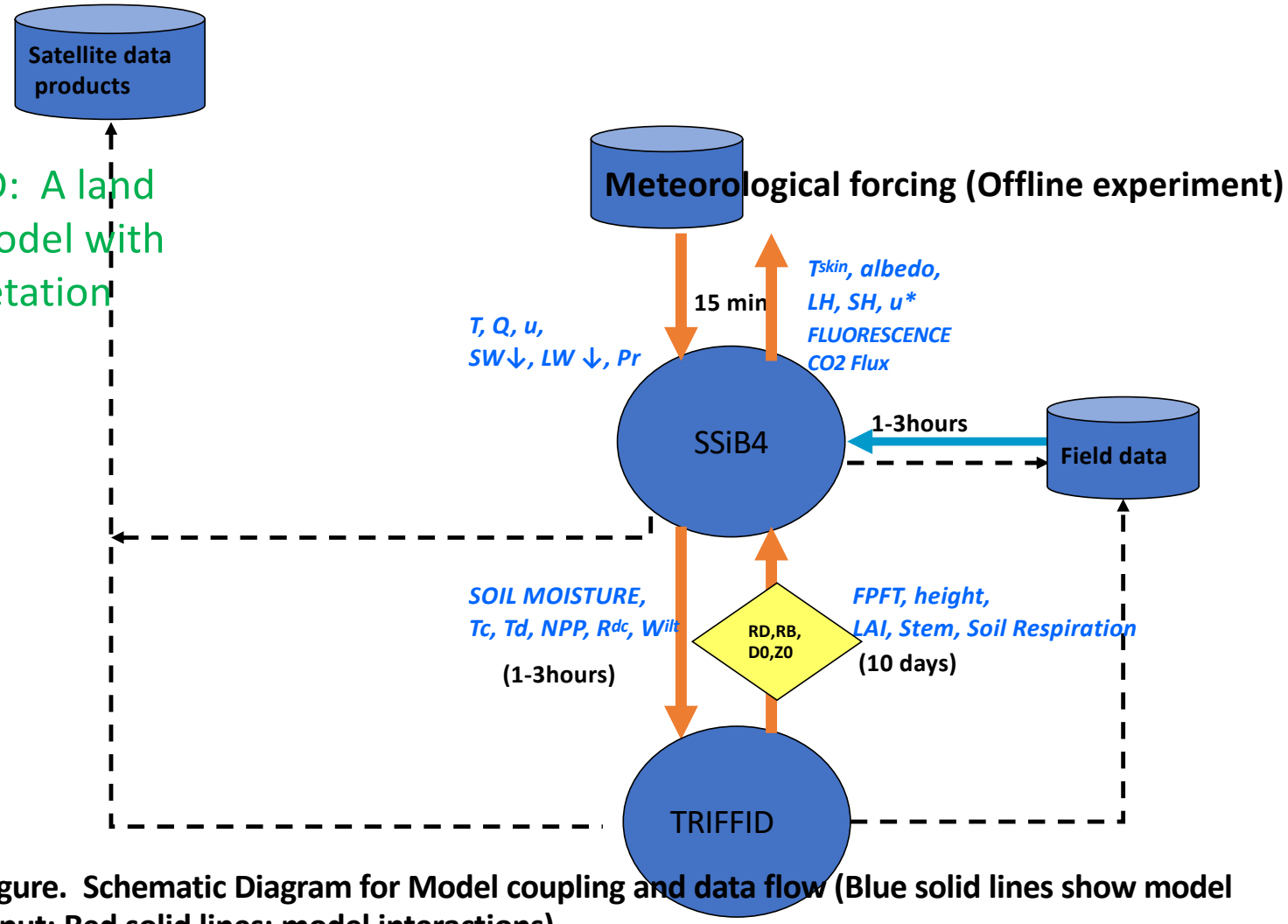
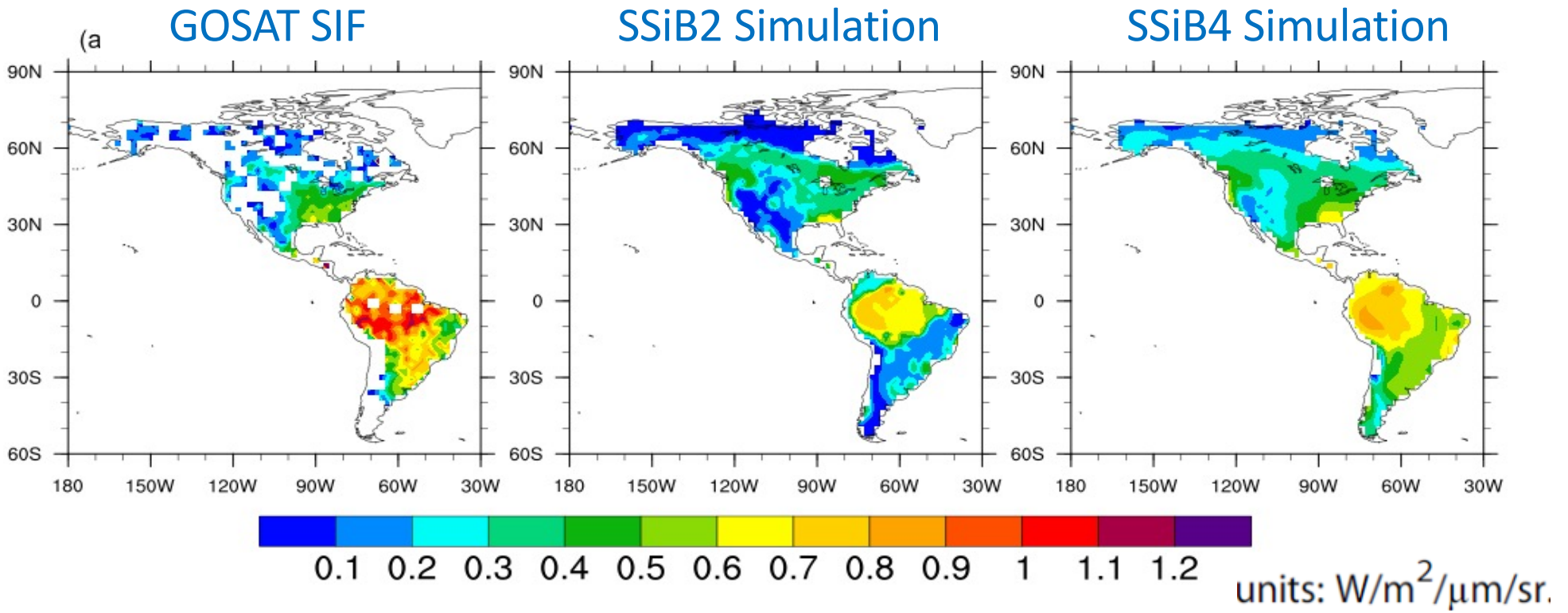


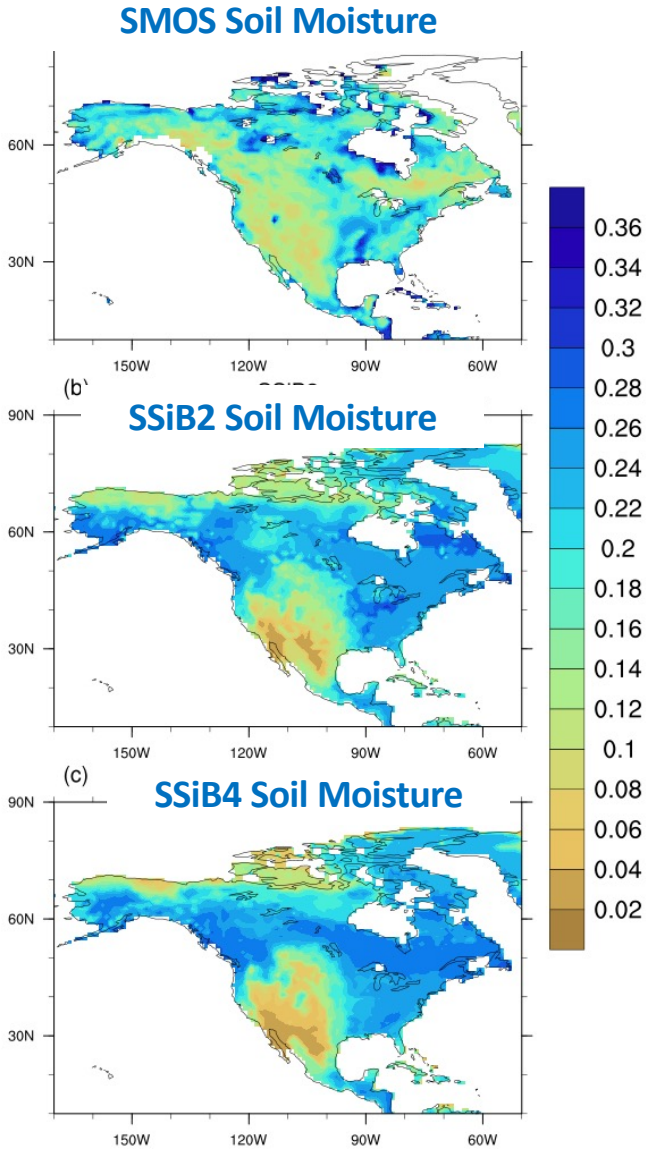
Figure. Schematic Diagram for Model coupling and data flow (Blue solid lines show model input; Red solid lines: model interactions)

Figure 1. Schematic Diagram to show the generation of initial conditions for SSiB4/TRIFFID for transient simulation

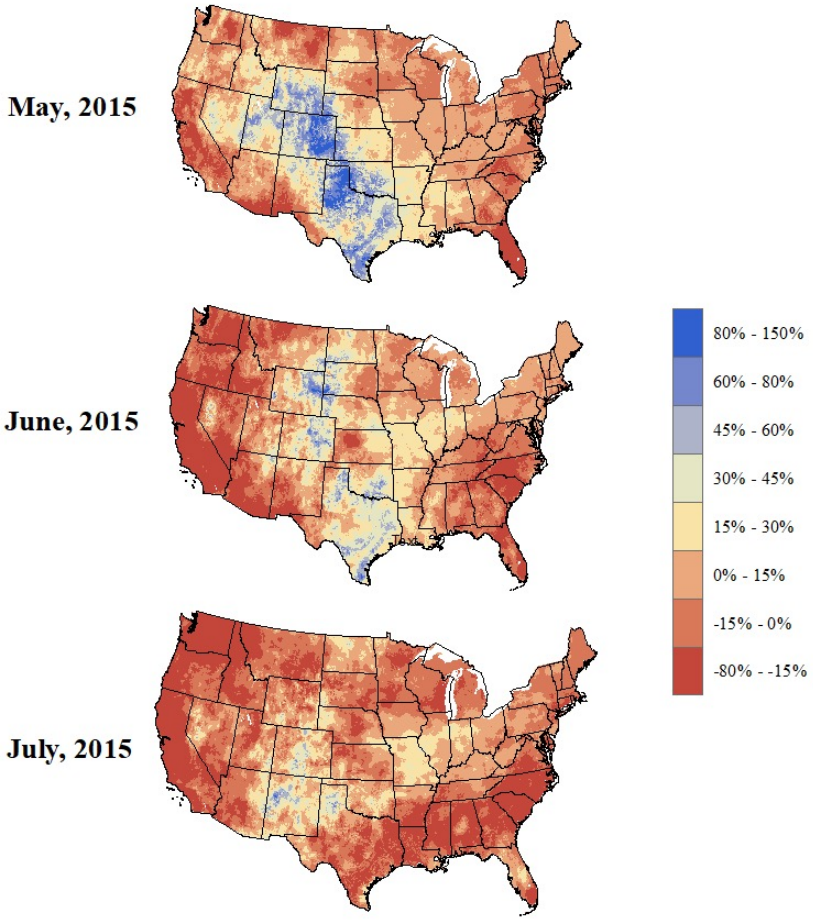
Satellite Products

Dataset Name	Level	Temporal Coverage:	Resolution	Variables
SMAP	L3 Enhanced Global Daily 9 km EASE-Grid Soil Moisture, V4	31 March 2015 - Dec. 2020	9 km; 1 Day	Soil Moisture (water content)
	L4 Global 3-hourly 9 km EASE-Grid Surface Soil Moisture V5	31 March 2015 - Dec. 2020	9 km; 3-hourly	Soil Moisture (water content /wetness)
SMOS	L2 1 Day Surfaced Soil Moisture (Reprocessed)	2010 - May 2015	30 - 50m; daily	Soil moisture (water content)
	L2 1 Day Surfaced Soil Moisture (Operational)	May 2015 - Dec 2020	30 - 50m; daily	Soil Moisture (water content)
	L3 Polarised Brightness Temperature (Repro & opera)	April 2015 - June 2021	30 - 50m; monthly	Soil Moisture (water content)
CCI	L3	Nov 1978 - Dec 2020	0.25 deg.; Daily	Soil Moisture (Water Content)
GOSAT	L3	Apr 2009 - Dec 2018	2 degree; Monthly	SIF
GOME-2	L3	Feb 2007 – Mar 2019	0.5 degree; Monthly	SIF
OCO-2	L2	Sep 2014 – Jun 2021	1 degree; daily	SIF

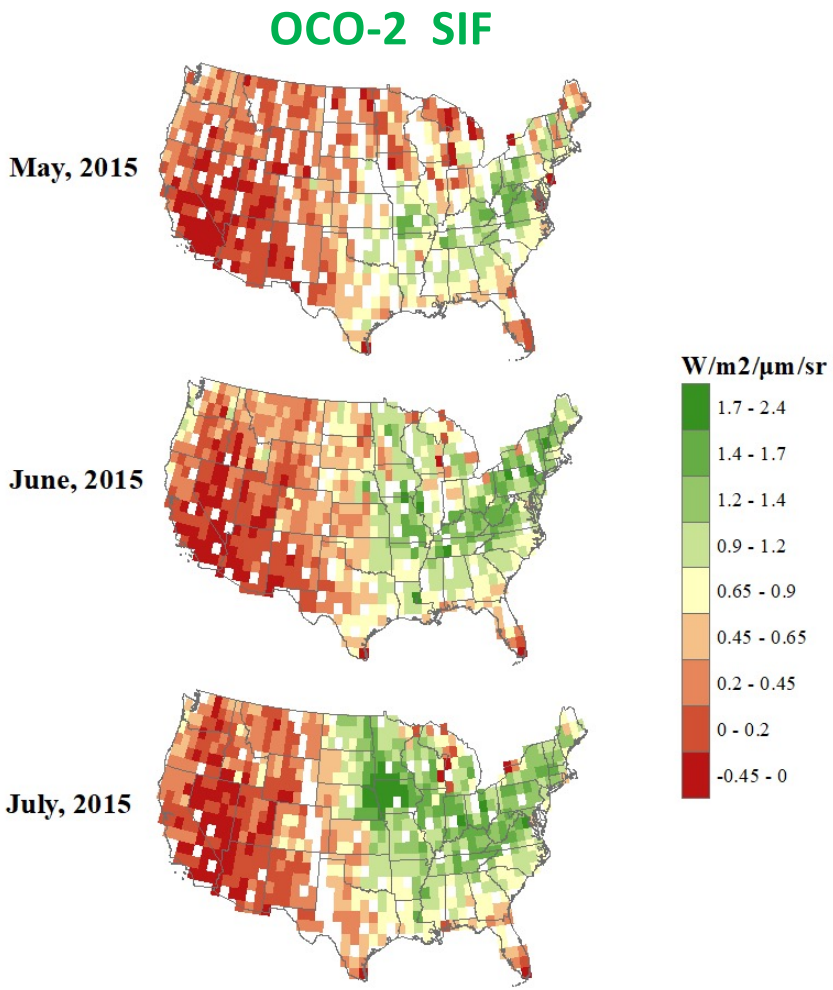

(a
GOSAT SIF
SSiB2 Simulation
SSiB4 Simulation
90N
60N
30N
0
30S
60S
180
150W
120W
90W
60W
30W
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2
units: W/m2/μm/sr.


SMOS Soil Moisture
60N
30N
150W
120W
90W
60W
(b)
SSiB2 Soil Moisture
90N
60N
30N
150W
120W
90W
60W
(c)
SSiB4 Soil Moisture
90N
60N
30N
150W
120W
90W
60W
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02

SMAP Soil Wetness



The spatial change (%) of SMAP soil moisture compared to the multiyear mean (Apr., 2015–Dec.,2018) over United States



The spatial difference (W/m2/µm/sr) of OCO-2 SIF compared to the multiyear mean (Jan.,2015–Sep.,2018) over United States