International Land Model Benchmark (ILAMB) Common Model Output

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While all models participating in the International Land Model Benchmarking (ILAMB) activity will output their own "native" variables, a common set of variables is needed to facilitate comparison of the model results to each other and to available observational datasets. Model results transmitted to the Earth System Grid (ESG) for redistribution to the community should use common variable names, netCDF long names, Climate and Forecast (CF) Standard Names, and units. Contained in this document are tables of the common output variables proposed for use in ILAMB. Section 1 contains variables requested for the Fifth Climate Model Intercomparison Project (CMIP5), including variables recently added to the Climate and Forecast (CF) Metadata Convention to support carbon cycle model output. Section 2 contains a list of additional variables proposed to support the in-depth analysis proposed for ILAMB. Corrections and suggestions for improvement to this list are solicited from the wider modeling community. Software is available from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) for rewriting model output into netCDF files following the CF Metadata Convention.

1 Variables Defined for CMIP5

The variables requested for CMIP5 are listed in documents contained at http://cmip-pcmdi.llnl.gov/cmip5/output_req.html?submenuheader=2#req_list. Table 1 contains the physical, vegetation, and soil variables requested for CMIP5, and Table 2 contains the biogeochemistry variables requested for CMIP5. The variables contained in this section were extracted from the *standard_output* document dated 5 Jan 2011.

Table 1: Physical, Vegetation, and Soil Variables

	Variable	Long Name	Units	Standard Name	Comment	Priority
1.1	mrsos	Moisture in Upper Portion of Soil Column	kg m^{-2}	moisture_content_of_soil_layer	the mass of water in all phases in a thin surface soil layer.	1
1.2	mrso	Total Soil Moisture Content	kg m^{-2}	soil_moisture_content	the mass per unit area (summed over all soil layers) of water in all phases.	1
1.3	mrfso	Soil Frozen Water Content	kg m^{-2}	soil_frozen_water_content	the mass (summed over all layers) of frozen water.	1
1.4	mrros	Surface Runoff	kg m^{-2} s^{-1}	surface_runoff_flux	the total surface runoff leaving the land portion of the grid cell.	1
1.5	mrro	Total Runoff	kg m^{-2} s^{-1}	runoff_flux	the total runoff (including "drainage" through the base of the soil model) leaving the land portion of the grid cell.	1
1.6	prveg	Precipitation onto Canopy	kg m^{-2} s^{-1}	precipitation_flux_onto_canopy	the precipitation flux that is intercepted by the vegetation canopy (if present in model) before reaching the ground.	2
1.7	evspsblveg	Evaporation from Canopy	kg m^{-2} s^{-1}	water_evaporation_flux_from_canopy	the canopy evaporation + sublimation (if present in model).	1
1.8	evspsblsoi	Water Evaporation from Soil	kg m^{-2} s^{-1}	water_evaporation_flux_from_soil	includes sublimation.	1
1.9	tran	Transpiration	kg m^{-2} s^{-1}	transpiration_flux		1
1.10	mrlsl	Water Content of Soil Layer	kg m^{-2}	moisture_content_of_soil_layer	in each soil layer, the mass of water in all phases, including ice. Reported as "missing" for grid cells occupied entirely by "sea".	1

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	Variable	Long Name	Units	Standard Name	Comment	Priority
1.11	tsl	Temperature of Soil	K	soil_temperature	Temperature of each soil layer. Reported as "missing" for grid cells occupied entirely by "sea".	2
1.12	treeFrac	Tree Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by trees.	1
1.13	grassFrac	Natural Grass Fraction	%	area_fraction	fraction of entire grid cell that is covered by natural grass.	1
1.14	shrubFrac	Shrub Fraction	%	area_fraction	fraction of entire grid cell that is covered by shrub.	1
1.15	cropFrac	Crop Fraction	%	area_fraction	fraction of entire grid cell that is covered by crop.	1
1.16	pastureFrac	Anthropogenic Pasture Fraction	%	area_fraction	fraction of entire grid cell that is covered by anthropogenic pasture.	1
1.17	baresoilFrac	Bare Soil Fraction	%	area_fraction	fraction of entire grid cell that is covered by bare soil.	1
1.18	residualFrac	Fraction of Grid Cell that is Land but Neither Vegetation-Covered nor Bare Soil	%	area_fraction	fraction of entire grid cell that is land and is covered by "non-vegetation" and "non-bare-soil" (e.g., urban, ice, lakes, etc.).	1
1.19	burntArea	Burnt Area Fraction	%	area_fraction	fraction of entire grid cell that is covered by burnt vegetation.	1

Table 2: Biogeochemical Variables

	Variable	Long Name	Units	Standard Name	Comment	Priority
2.1	cLitter	Carbon Mass in Litter Pool	kg m^{-2}	litter_carbon_content		1
2.2	cSoil	Carbon Mass in Soil Pool	kg m^{-2}	soil_carbon_content		1
2.3	cProduct	Carbon Mass in Products of Land Use Change	kg m^{-2}	carbon_content_of_products_of_anthropogenic_land_use_change		1
2.4	lai	Leaf Area Index	1	leaf_area_index	a ratio obtained by dividing the total upper leaf surface area of vegetation by the (horizontal) surface area of the land on which it grows.	1
2.5	gpp	Carbon Mass Flux out of Atmosphere due to Gross Primary Production on Land	kg m^{-2} s^{-1}	gross_primary_productivity_of_carbon		1
2.6	ra	Carbon Mass Flux into Atmosphere due to Autotrophic (Plant) Respiration on Land	kg m^{-2} s^{-1}	plant_respiration_carbon_flux		1
2.7	npp	Carbon Mass Flux out of Atmosphere due to Net Primary Production on Land	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon		1
2.8	rh	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration on Land	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux		1
2.9	fFire	Carbon Mass Flux into Atmosphere due to CO_2 Emission from Fire	kg m^{-2} s^{-1}	surface_upward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_emission_from_fires_excluding_anthropogenic_land_use_change	CO_2 emissions (expressed as a carbon mass flux) from natural fires + human ignition fires as calculated by the fire module of the DGVM, but excluding any CO_2 flux from fire included in fLuc.	1

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	Variable	Long Name	Units	Standard Name	Comment	Priority
2.10	fGrazing	Carbon Mass Flux into Atmosphere due to Grazing on Land	kg m^{-2} s^{-1}	surface_upward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_emission_from_grazing		1
2.11	fHarvest	Carbon Mass Flux into Atmosphere due to Crop Harvesting	kg m^{-2} s^{-1}	surface_upward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_emission_from_crop_harvesting		1
2.12	fLuc	Net Carbon Mass Flux into Atmosphere due to Land Use Change	kg m^{-2} s^{-1}	surface_net_upward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_emission_from_anthropogenic_land_use_change	human changes to land (excluding forest regrowth) accounting possibly for different time-scales related to fate of the wood, for example.	1
2.13	nbp	Carbon Mass Flux out of Atmosphere due to Net Biospheric Production on Land	kg m^{-2} s^{-1}	surface_net_downward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_all_land_processes	This is the net mass flux of carbon between land and atmosphere calculated as photosynthesis MINUS the sum of plant and soil respiration, carbonfluxes from fire, harvest, grazing and land use change. Positive flux is into the land.	1
2.14	fVegLitter	Total Carbon Mass Flux from Vegetation to Litter	kg m^{-2} s^{-1}	litter_carbon_flux		1
2.15	fLitterSoil	Total Carbon Mass Flux from Litter to Soil	kg m^{-2} s^{-1}	carbon_mass_flux_into_soil_from_litter		1
2.16	fVegSoil	Total Carbon Mass Flux from Vegetation Directly to Soil	kg m^{-2} s^{-1}	carbon_mass_flux_into_soil_from_vegetation_excluding_litter	In some models part of carbon (e.g., root exudate) can go directly into the soil pool without entering litter.	1
2.17	cLeaf	Carbon Mass in Leaves	kg m^{-2}	leaf_carbon_content		2
2.18	cWood	Carbon Mass in Wood	kg m^{-2}	wood_carbon_content	including sapwood and hardwood.	2
2.19	cRoot	Carbon Mass in Roots	kg m^{-2}	root_carbon_content	including fine and coarse roots.	2
2.20	cMisc	Carbon Mass in Other Living Compartments on Land	kg m^{-2}	miscellaneous_living_matter_carbon_content	e.g., labile, fruits, reserves, etc.	2

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	Variable	Long Name	Units	Standard Name	Comment	Priority
2.21	cCwd	Carbon Mass in Coarse Woody Debris	kg m^{-2}	wood_debris_carbon_content		2
2.22	cLitterAbove	Carbon Mass in Above-Ground Litter	kg m^{-2}	surface_litter_carbon_content		2
2.23	cLitterBelow	Carbon Mass in Below-Ground Litter	kg m^{-2}	subsurface_litter_carbon_content		2
2.24	cSoilFast	Carbon Mass in Fast Soil Pool	kg m^{-2}	fast_soil_pool_carbon_content	fast is meant as lifetime of less than 10 years for reference climate conditions (20°C, no water limitations).	2
2.25	cSoilMedium	Carbon Mass in Medium Soil Pool	kg m^{-2}	medium_soil_pool_carbon_content	medium is meant as lifetime of more than than 10 years and less than 100 years for reference climate conditions (20°C, no water limitations)	2
2.26	cSoilSlow	Carbon Mass in Slow Soil Pool	kg m^{-2}	slow_soil_pool_carbon_content	fast is meant as lifetime of more than 100 years for reference climate conditions (20°C, no water limitations)	2
2.27	landCoverFrac	Plant Functional Type Grid Fraction	%	area_fraction	The categories may differ from model to model, depending on their PFT definitions. This may include natural PFTs, anthropogenic PFTs, bare soil, lakes, urban areas, etc. Sum of all should equal the fraction of the grid-cell that is land.	2

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	Variable	Long Name	Units	Standard Name	Comment	Priority
2.28	treeFracPrimDec	Total Primary Deciduous Tree Fraction	%	area_fraction	This is the fraction of the entire grid cell that is covered by "total primary deciduous trees."	2
2.29	treeFracPrimEver	Total Primary Evergreen Tree Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by primary evergreen trees.	2
2.30	treeFracSecDec	Total Secondary Deciduous Tree Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by secondary deciduous trees.	2
2.31	treeFracSecEver	Total Secondary Evergreen Tree Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by secondary evergreen trees.	2
2.32	c3PftFrac	Total C3 PFT Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by C_3 PFTs (including grass, crops, and trees).	2
2.33	c4PftFrac	Total C4 PFT Cover Fraction	%	area_fraction	fraction of entire grid cell that is covered by C_4 PFTs (including grass and crops).	2
2.34	rGrowth	Carbon Mass Flux into Atmosphere due to Growth Autotrophic Respiration on Land	kg m^{-2} s^{-1}	surface_upward_carbon_mass_flux_due_to_plant_respiration_for_biomass_growth		2
2.35	rMaint	Carbon Mass Flux into Atmosphere due to Maintenance Autotrophic Respiration on Land	kg m^{-2} s^{-1}	surface_upward_carbon_mass_flux_due_to_plant_respiration_for_biomass_maintenance		2
2.36	nppLeaf	Carbon Mass Flux due to NPP Allocation to Leaf	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_leaves	This is the rate of carbon uptake by leaves due to NPP	2
2.37	nppWood	Carbon Mass Flux due to NPP Allocation to Wood	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_wood	This is the rate of carbon uptake by wood due to NPP	2

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	Variable	Long Name	Units	Standard Name	Comment	Priority
2.38	nppRoot	Carbon Mass Flux due to NPP Allocation to Roots	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_roots	This is the rate of carbon uptake by roots due to NPP	2
2.39	nep	Net Carbon Mass Flux out of Atmophere due to Net Ecosystem Productivity on Land.	kg m^{-2} s^{-1}	surface_net_downward_mass_flux_of_carbon_dioxide_expressed_as_carbon_due_to_all_land_processes_excluding_anthropogenic_land_use_change	Natural flux of CO_2 (expressed as a mass flux of carbon) from the atmosphere to the land calculated as the difference between uptake associated will photosynthesis and the release of CO_2 from the sum of plant and soil respiration and fire. Positive flux is into the land. emissions from natural fires + human ignition fires as calculated by the fire module of the DGVM, but excluding any CO_2 flux from fire included in fLuc.	1

2 Additional Variables Proposed for ILAMB

In order to support the in-depth biogeochemical, hydrological, and energy diagnostics proposed for ILAMB, additional variables—beyond those requested for CMIP5—are needed. These variables provide additional insights into model behavior by 1) requesting additional quantities available in some models, 2) splitting out individual components of pools or fluxes requested as totals for CMIP5, or 3) representing quantities that are measured or provided by specific observational data sets. For example, the net rate of nitrogen mineralization in soil and the total biogenic volatile organic compound flux are available in some models and will influence net primary production. Separately reporting fine versus coarse root carbon pools and fluxes as well as above- and below-ground net primary production may be useful in understanding model allocation, particularly if coarse root carbon is reported as wood carbon by some models. Additional fluxes are required to close the carbon budgets for some individual pools, either the total loss or the total accumulation fluxes. In addition, reporting litter and soil carbon content within 30 and 100 cm depths will simplify comparison with databases of soil measurements that are conventionally reported at these depths. Table 3 contains a list of physical, vegetation, and soil variables that may be requested for ILAMB. Table 4 contains a list of biogeochemistry variables that may be requested for ILAMB. Comments and suggestions are solicited regarding the utility of these variables for model-data comparison.

Table 3: Physical, Vegetation, and Soil Variables

	Variable	Long Name	Units	Standard Name	Comment	Priority
3.1	mrls30	Water Content of Soil to 30 cm	kg m^{-2}	`moisture_content_of_soil_layer`	the mass of water in all phases, including ice.	2
3.2	mrls100	Water Content of Soil to 100 cm	kg m^{-2}	`moisture_content_of_soil_layer`	the mass of water in all phases, including ice.	2

Table 4: Biogeochemical Variables

	Variable	Long Name	Units	Standard Name	Comment	Priority
4.1	cBioAbove	Carbon Mass in Above-Ground Biomass	kg m^{-2}	surface_biomass_carbon_content	This may be the sum of cLitterAbove (Table 2) and cLiveBioAbove.	2
4.2	cBioBelow	Carbon Mass in Below-Ground Biomass	kg m^{-2}	subsurface_biomass_carbon_content	This may be the sum of cLitterBelow (Table 2) and cLiveBioBelow.	2
4.3	cLiveBioAbove	Carbon Mass in Above-Ground Live Biomass	kg m^{-2}	surface_live_biomass_carbon_content.		2
4.4	cLiveBioBelow	Carbon Mass in Below-Ground Live Biomass	kg m^{-2}	subsurface_live_biomass_carbon_content.		2
4.5	nppAbove	Carbon Mass Flux due to NPP Allocation to Above-Ground Live Biomass	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_surface_live_biomass	This may be the sum of nppLeaf and nppWood (Table 2).	2
4.6	nppBelow	Carbon Mass Flux due to NPP Allocation to Below-Ground Live Biomass	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_subsurface_live_biomass	This may be equivalent to nppRoot (Table 2).	2
4.7	bvoc	Volatile Organic Compound Mass Flux into Atmosphere due to Emission from Biomass	kg m^{-2} s^{-1}	plant_volatile_organic_compound_flux		2
4.8	bco	Carbon Monoxide Mass Flux into Atmosphere due to Emission from Biomass	kg m^{-2} s^{-1}	plant_carbon_monoxide_flux		2
4.9	rhCwd	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Coarse Woody Debris	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_wood_debris		2

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	Variable	Long Name	Units	Standard Name	Comment	Priority
4.10	fVegCwd	Total Carbon Mass Flux from Vegetation to Coarse Woody Debris	kg m^{-2} s^{-1}	wood_debris_carbon_flux		2
4.11	cRLitter	Carbon Mass in Root Litter	kg m^{-2}	root_litter_carbon_content	including fine and coarse root litter.	3
4.12	rhRLitter	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Root Litter	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_root_litter	including fine and coarse root litter.	3
4.13	fRootRLitter	Total Carbon Mass Flux from Roots to Root Litter	kg m^{-2} s^{-1}	root_litter_carbon_flux	including fine and coarse roots.	3
4.14	cFRoot	Carbon Mass in Fine Roots	kg m^{-2}	fine_root_carbon_content		3
4.15	nppFRoot	Carbon Mass Flux due to NPP Allocation to Fine Roots	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_fine_roots		3
4.16	cFRLitter	Carbon Mass in Fine Root Litter	kg m^{-2}	fine_root_litter_carbon_content		3
4.17	rhFRLitter	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Fine Root Litter	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_fine_root_litter		3
4.18	fFRootFRLitter	Total Carbon Mass Flux from Fine Roots to Fine Root Litter	kg m^{-2} s^{-1}	fine_root_litter_carbon_flux		3
4.19	cCRoot	Carbon Mass in Coarse Roots	kg m^{-2}	coarse_root_carbon_content		3
4.20	nppCRoot	Carbon Mass Flux due to NPP Allocation to Coarse Roots	kg m^{-2} s^{-1}	net_primary_productivity_of_carbon_accumulated_in_coarse_roots		3
4.21	cCRLitter	Carbon Mass in Coarse Root Litter	kg m^{-2}	coarse_root_litter_carbon_content		3
4.22	rhCRLitter	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Coarse Root Litter	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_coarse_root_litter		3

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	Variable	Long Name	Units	Standard Name	Comment	Priority
4.23	fCRootCRLitter	Total Carbon Mass Flux from Coarse Roots to Coarse Root Litter	kg m^{-2} s^{-1}	coarse_root_litter_carbon_flux		3
4.24	raLeaf	Carbon Mass Flux into Atmosphere due to Autotrophic (Plant) Respiration from Leaves	kg m^{-2} s^{-1}	plant_respiration_carbon_flux_from_leaves		2
4.25	fLeafLitter	Total Carbon Mass Flux from Leaves to Litter	kg m^{-2} s^{-1}	litter_carbon_flux		2
4.26	cLLitter	Carbon Mass in Leaf Litter	kg m^{-2}	leaf_litter_carbon_content		3
4.27	rhLLitter	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Leaf Litter	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_leaf_litter		3
4.28	fLeafLLitter	Total Carbon Mass Flux from Leaves to Leaf Litter	kg m^{-2} s^{-1}	leaf_litter_carbon_flux		3
4.29	fLLitterSoil	Total Carbon Mass Flux from Leaf Litter to Soil	kg m^{-2} s^{-1}	carbon_mass_flux_into_soil_from_leaf_litter		2
4.30	rhLitter	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Litter	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_litter		2
4.31	nnmin	Net Nitrogen Mineralization in Soil	kg m^{-2} s^{-1}	net_mineralization_of_nitrogen		2
4.32	rhSoil	Carbon Mass Flux into Atmosphere due to Heterotrophic Respiration from Soil	kg m^{-2} s^{-1}	heterotrophic_respiration_carbon_flux_from_soil		2
4.33	cSoil30	Carbon Mass in Soil Pool in top 30 cm	kg m^{-2}	soil_carbon_content		3
4.34	cSoil100	Carbon Mass in Soil Pool in top 100 cm	kg m^{-2}	soil_carbon_content		3

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	Variable	Long Name	Units	Standard Name	Comment	Priority
4.35	cSoilFast30	Carbon Mass in Fast Soil Pool in top 30 cm	kg m^{-2}	fast_soil_pool_carbon_content	fast is meant as lifetime of less than 10 years for reference climate conditions (20°C, no water limitations).	3
4.36	cSoilFast100	Carbon Mass in Fast Soil Pool in top 100 cm	kg m^{-2}	fast_soil_pool_carbon_content	fast is meant as lifetime of less than 10 years for reference climate conditions (20°C, no water limitations).	3
4.37	cSoilMedium30	Carbon Mass in Medium Soil Pool in top 30 cm	kg m^{-2}	medium_soil_pool_carbon_content	medium is meant as lifetime of more than than 10 years and less than 100 years for reference climate conditions (20°C, no water limitations)	3
4.38	cSoilMedium100	Carbon Mass in Medium Soil Pool in top 100 cm	kg m^{-2}	medium_soil_pool_carbon_content	medium is meant as lifetime of more than than 10 years and less than 100 years for reference climate conditions (20°C, no water limitations)	3
4.39	cSoilSlow30	Carbon Mass in Slow Soil Pool in top 30 cm	kg m^{-2}	slow_soil_pool_carbon_content	fast is meant as lifetime of more than 100 years for reference climate conditions (20°C, no water limitations)	3
4.40	cSoilSlow100	Carbon Mass in Slow Soil Pool in top 100 cm	kg m^{-2}	slow_soil_pool_carbon_content	fast is meant as lifetime of more than 100 years for reference climate conditions (20°C, no water limitations)	3