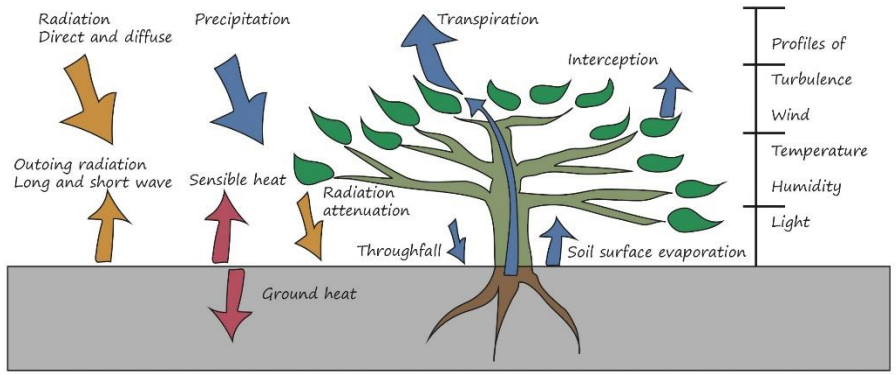
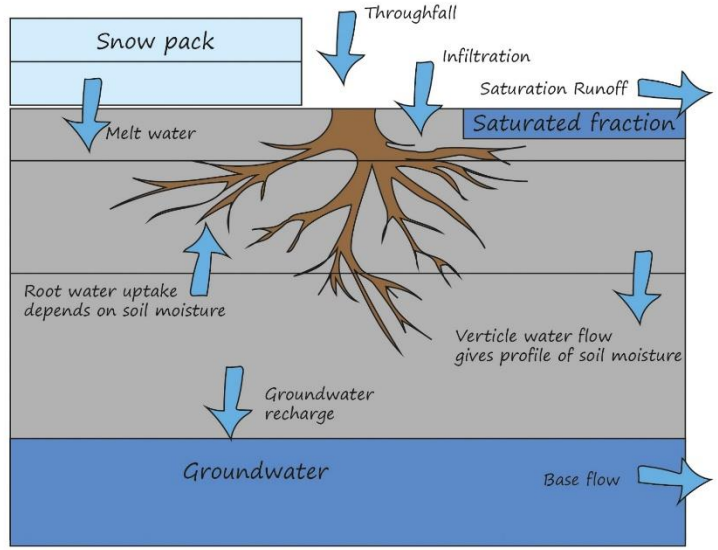
Advances in Land Surface Modeling

Blyth, Arora, Clark, Dadson, de Kauwe, Lawrence, Melton, Pongratz, Turton, Yoshimura, Yuan. https://doi.org/10.1007/s40641-021-00171-5

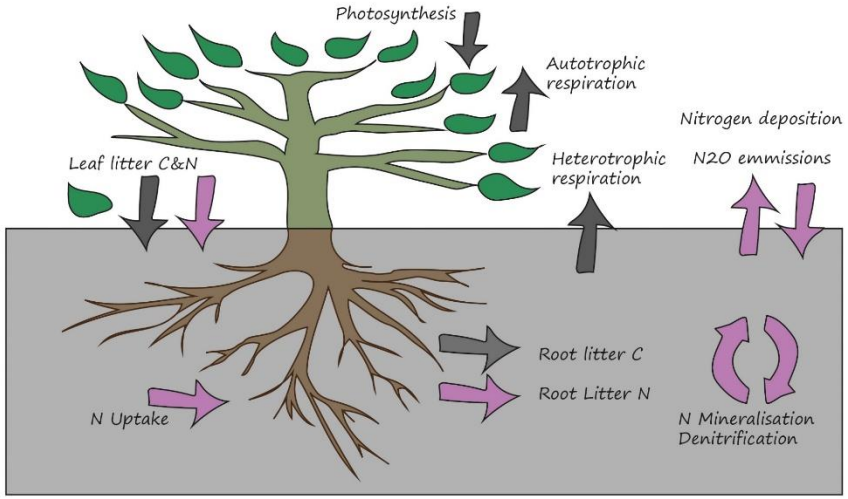
Canopy processes and surface exchange



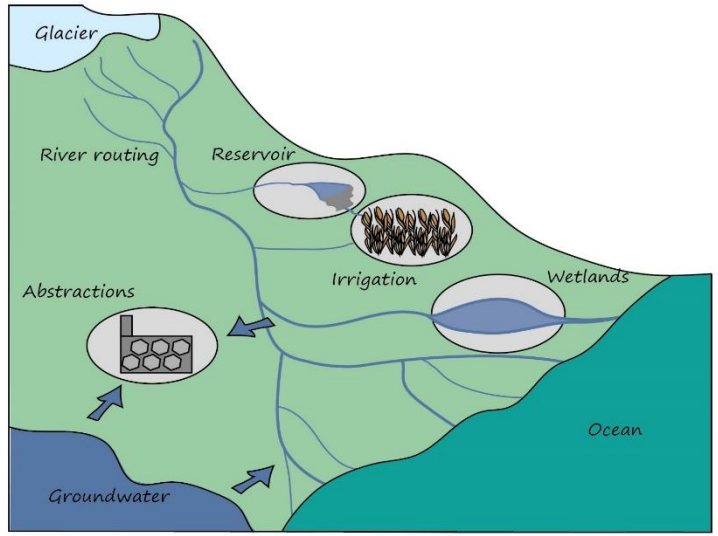
Snow and soil physics



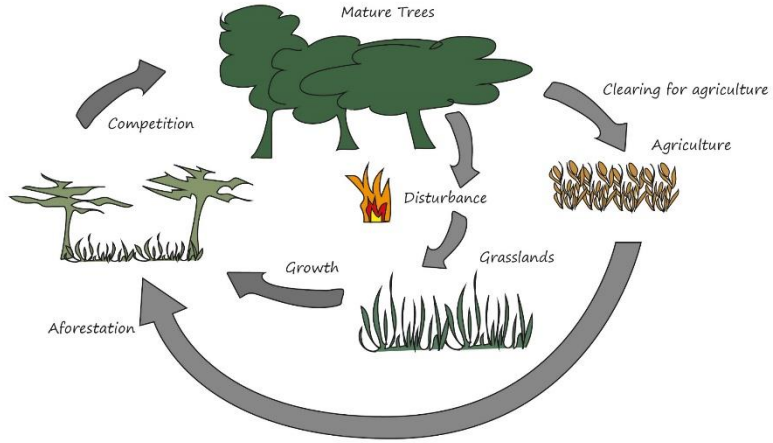
Vegetation physiology and biogeochemistry



Water bodies

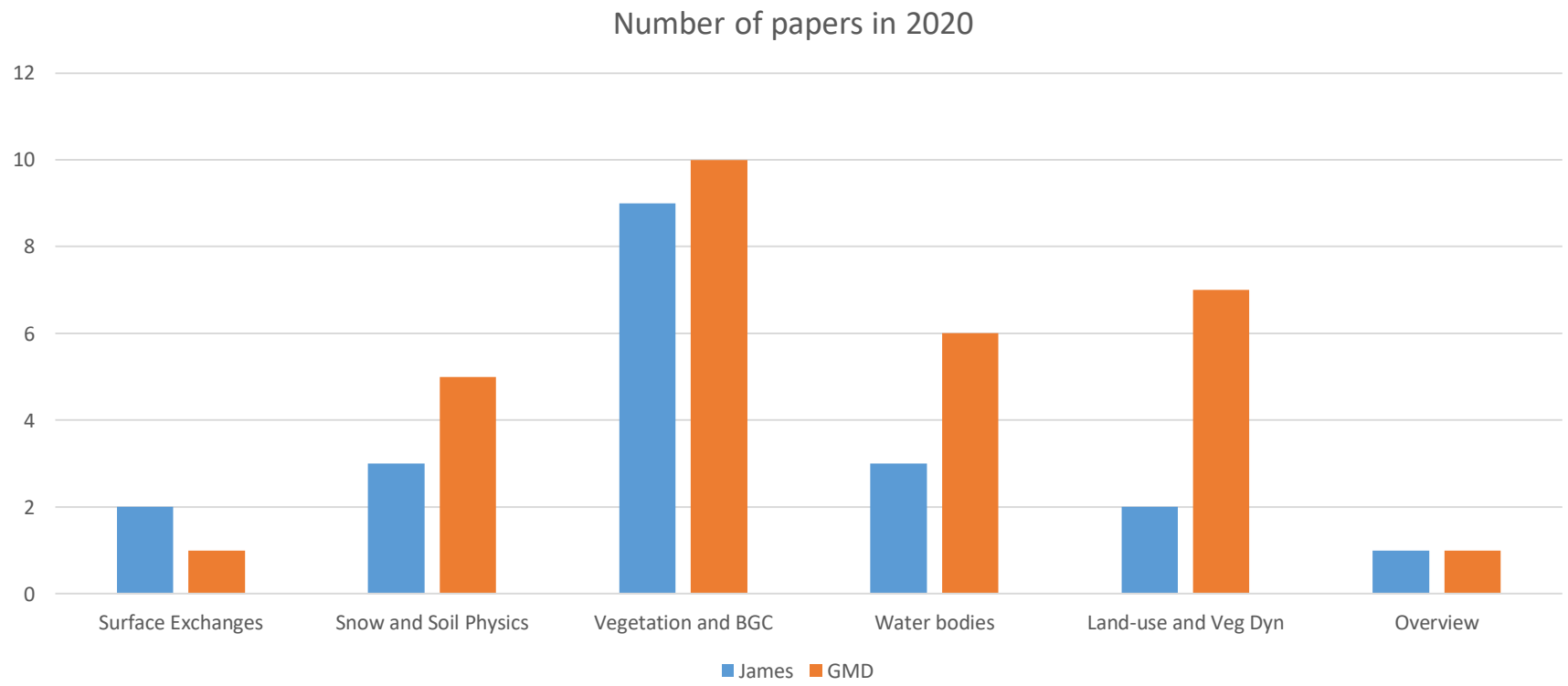


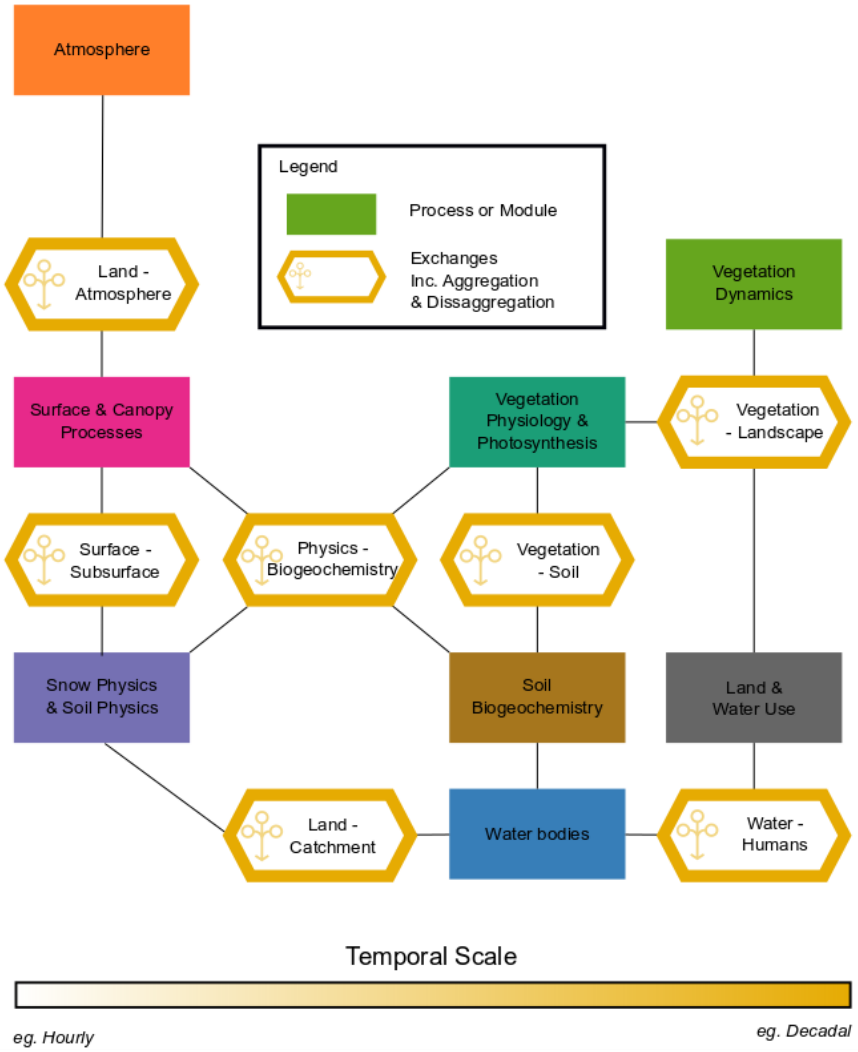
Land-use and vegetation dynamics



Model development papers in 2020

- GMD (Geoscientific Model Development): EGU.
- JAMES (Journal for Advances in Modelling Earth Systems). AGU





Schematic of Land Surface Model showing Components (Process or Module) and the Exchanges between components across temporal scales (Hourly to Decadal).

Land Surface Model Exchange developments for Pre 2000, Recent Advances and Future Directions.

LSM Component	Basic Description	Pre 2000	Recent Advances	Future Directions
Surface & Canopy Processes	Physics of the surface affecting exchange of the momentum, water, energy and carbon.	Turbulent exchange of momentum, heat, water and carbon. Beer's law for radiation attenuation through canopy.	Multiple canopy layers for radiation attenuation.	Multiple canopy layers for energy, water and carbon exchanges. Microclimate within vegetation canopy.
Snow Physics & Soil Physics	Transfer of energy, heat and water vertically through the medium of snow or soil.	Darcy-Richards equation. Soil freezing included. Single snow layer.	Deeper soil layers for Permafrost. Organic soils included. Multiple snow layers.	Flows of water across the grid. Soil tiles for heterogeneity of soils.
Water bodies	Water that is stored and flows across the landscape, such as rivers, lakes, wetlands, glaciers and groundwater.	Riverflow routed.	Inundation, wetlands and groundwater.	Nutrients and water quality. Representation of hillslope-scale dynamics including interaction with river network and groundwater.
Vegetation Physiology & Photosynthesis	Plant processes that affect the uptake and allocation of the net carbon into roots, shoots and leaves.	Photosynthesis linked to transpiration. Phenology included. Carbon uptake affects plant growth.	Introduce dynamic nitrogen cycle to affect photosynthesis.	Slow acclimation of plants to temperature.
Soil Biogeochemistry	Soil carbon processes and its interaction with the nitrogen cycle.	Single carbon store with respiration linked to moisture and temperature.	Multi-layered soil carbon. Linked nitrogen and soil carbon.	More nutrients such as phosphorus. Acclimation of soil carbon respiration to temperature changes.
Vegetation Dynamics	Land cover changes due to competition and disturbance including fire and mortality.	Vegetation competition based on height.	Mortality due to fire, pests and drought. Age-classes of forests introduced.	Vegetation distribution linked landscape heterogeneity through soil tiles.
Land & Water Use	How humans alter the vegetation and water distribution.	Agriculture defined as a land-cover type	Different crop-types included.	Link to other models for food and water use. Irrigation dynamic with water need and available.

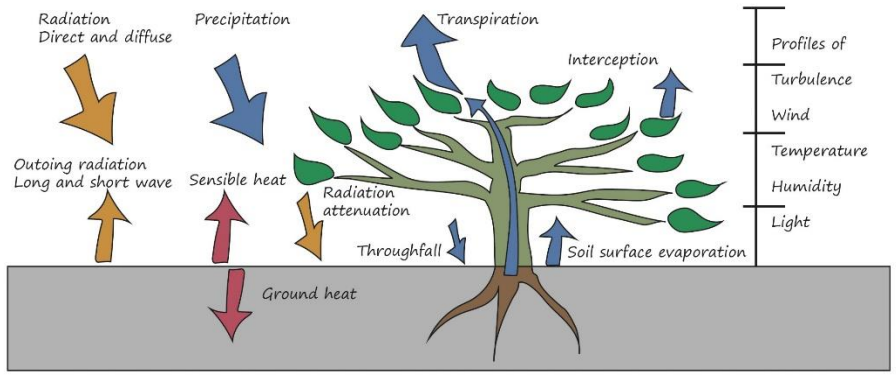
Land Surface Model Component development for Pre 2000, Recent Advances and Future Directions.

LSM Exchange	Basic Description	Pre 2000	Recent Advances	Future Directions
Land - Atmosphere	Exchanges between the land and the atmosphere; involves aggregation of the land fluxes and disaggregation of the meteorological variables.	Rainfall intensity distribution accounted for. Tiled representation of vegetation.	Improved description and more tiles. Direct and diffuse short-wave radiation available.	Exchange scheme is flexible to match a range of model grid sizes.
Surface - Subsurface	Exchange of water and heat between the surface and soils below ground and the snow-pack.	Rainfall-runoff model based on statistical distribution of soil moisture.	Rainfall-runoff model includes topography and groundwater.	Tiled soils will include explicit description of soil heterogeneity.
Physics - Biogeochemistry	Temperature and moisture affect the plant and soil processes. Changes in structure affects the physics.	Moisture and temperature affect biological systems such as photosynthesis and respiration. Light levels affect photosynthesis. Changes to plants structure affect roughness length.	Soil moisture and temperature at deeper layers affect soil carbon.	Distribution of leaf temperatures through the canopy to affect photosynthesis. Roots respond to groundwater level. Changes to the soil hydraulic properties from changes in carbon content.
Vegetation - Soil	The movement of carbon and nitrogen between the plants and soil is through leaf-litter and nutrient uptake by the plants.	Carbon from leaf litter transferred to soils.	Nitrogen in the leaves transferred to soils. Nutrient levels in soils taken up by plants.	More information about nutrient content of leaf litter. Improved representation of plant nutrient uptake.
Vegetation - Landscape	Vegetation competition and the agriculture affect the land-cover.	Dynamic vegetation model informs tile fractions. Agriculture fraction fixed.	More tiles used to describe age-classes.	Age classes inform forestry and land-use tiles. Agriculture tiles dynamic with land-use and climate. Better description of heterogeneity to interpret land-use decisions.
Land - Catchment	Overland runoff flows laterally over large catchments. At certain hotspots, the water flows back onto the land.	Water is routed to the sea.	Inundation and irrigation can interact with the energy and water cycle.	Groundwater, river and wetland systems are fully integrated with modelled hillslope-scale soil hydrology and with energy and nutrient cycles.
Water - Humans	Anthropogenic control of water flow to and from rivers through abstractions but also transfers.	Water from the land supplies the rivers.	Irrigation and other anthropogenic water uses.	Humans will direct changes to the water abstractions, the water use and transfers.

Survey of 12 land surface models

- CABLE: Community Atmosphere-Biosphere Land Exchange model (Australia)
- CLASSIC: Canadian LAnd Aurface Scheme Including biogeochemical Cycles (Canada)
- CLM: Community Land Model (USA)
- CoLM: Common Land Model (China)
- ELM: E3SM Land Model (USA)
- G/LM: Global Land Model (USA)
- ISBA: Interaction Sol-Biosphère-Atmosphère (France)
- JSBACH: Joined-up Simulation of the Biosphere-Atmosphere-Climate and Hydrosphere (Germany)
- JULES: Joint UK Land Environment Simulator (UK)
- Matsiro: (Japan)
- Orchidee: (France)
- TESSEL: Tiled ECMWF Scheme for Surface Exchanges of Land (Europe).

Canopy processes and surface exchange



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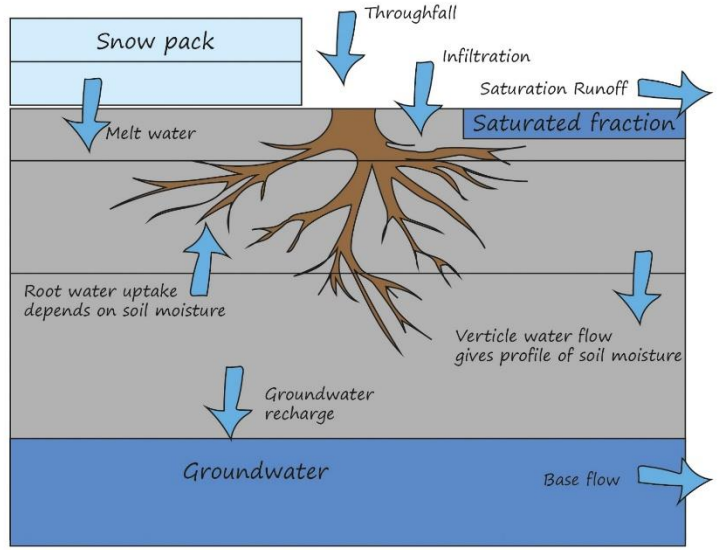

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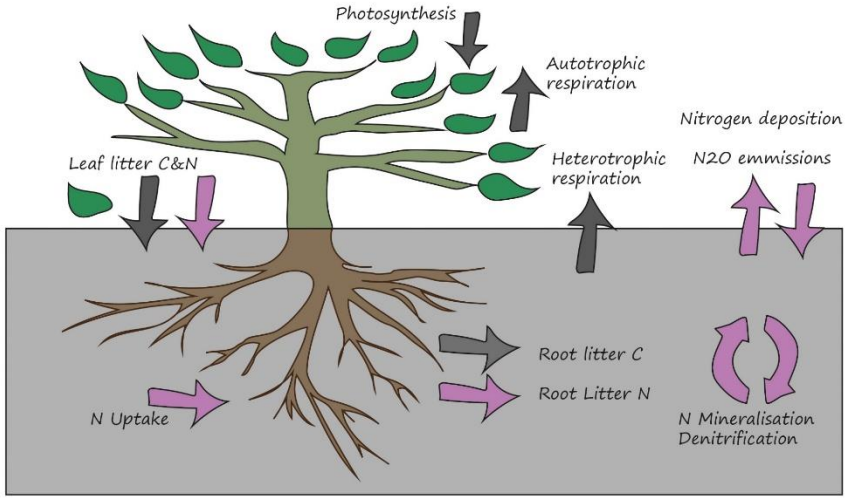
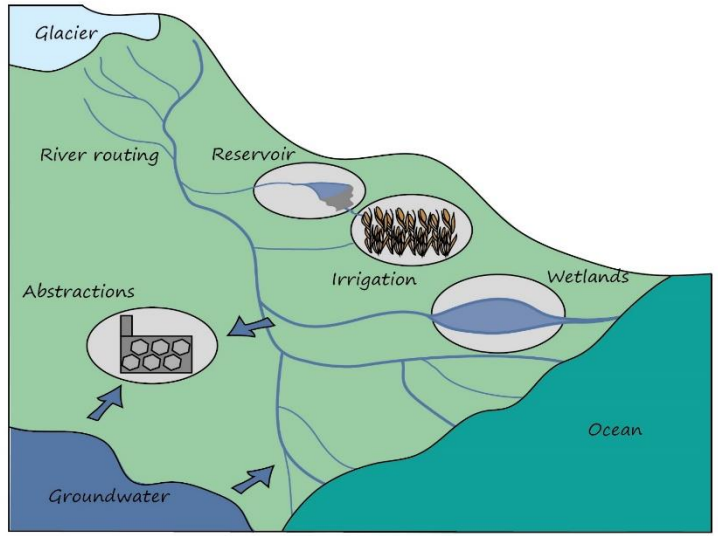
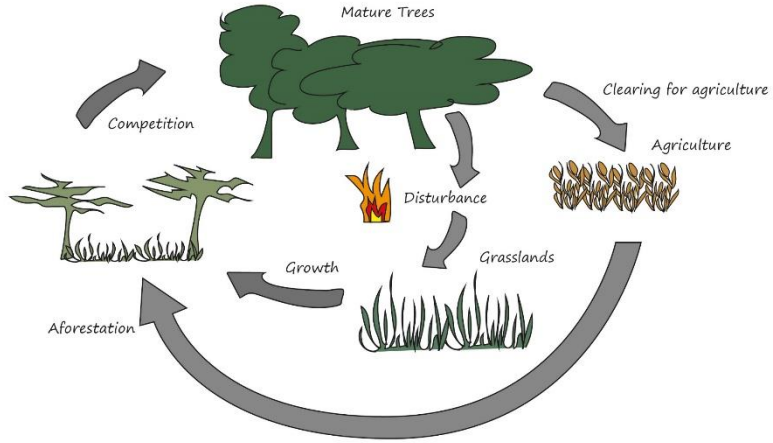


Water bodies



Land-use and vegetation dynamics



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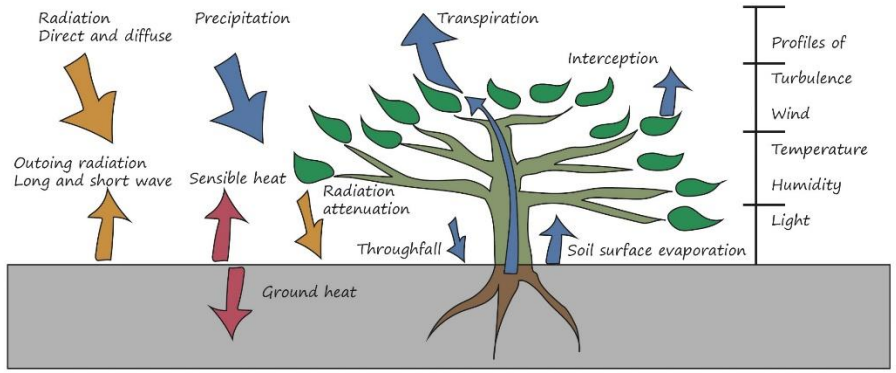
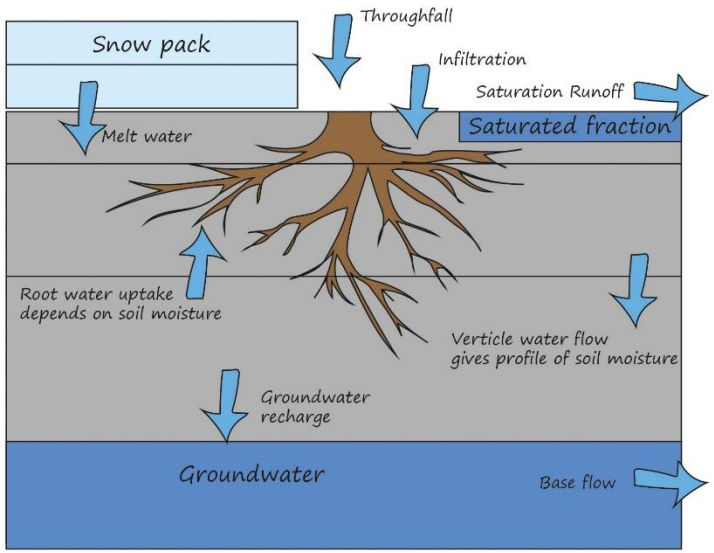


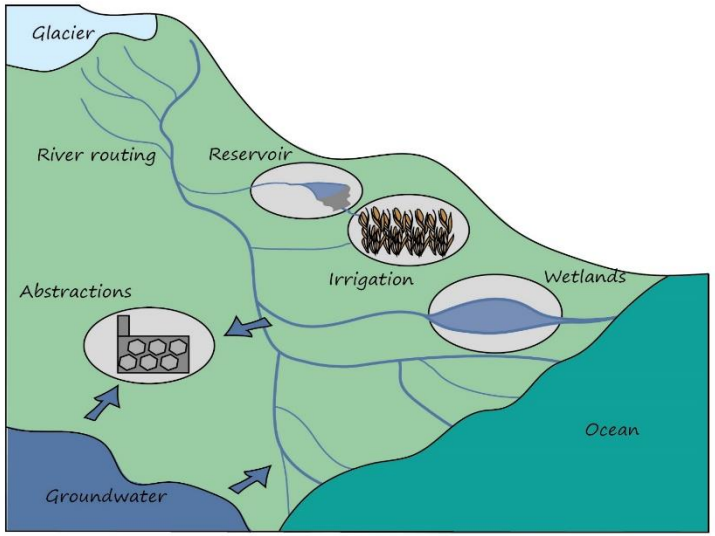
	CABLE	CLASSIC	CLM	CoLM	ELM	G/LM	ISBA	JSBACH	JULES	Matsiro	Orchidee	TESSEL
Tiles												
Separate surface T within a tile								N	N		N	
Vertical layers for radiation	N	N	CM1	CO10		Y		N	JU6	N	Y	T8
Vertical layers for water and heat	N	N	CM1	N		Y		N	N	N	N (OR3)	N

Snow and soil physics



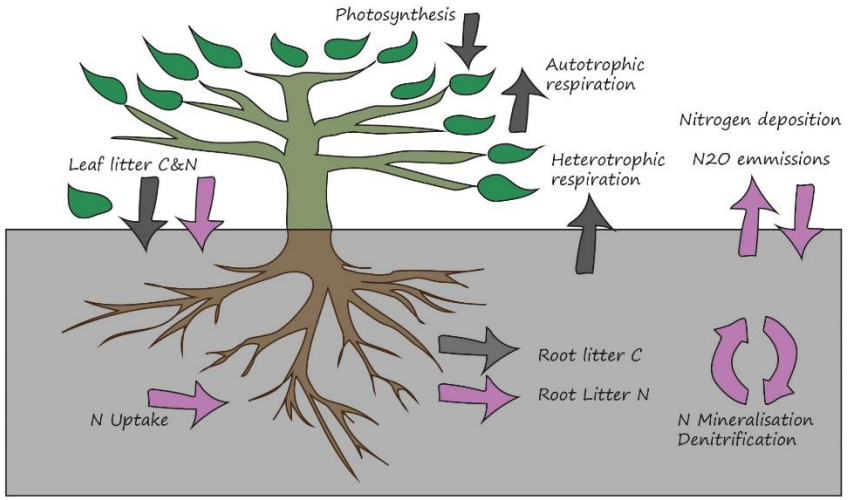
	CABLE	CLASSIC	CLM	CoLM	ELM	G/LM	ISBA	JSBACH	JULES	Matsiro	Orchidee	TESSEL
Darcy-Richards	Ca5	CL8		N		LM1 LM5		Y	JU1		Y	T12
Rainfall-runoff generation	Ca1	CL6		N		LM5		N	JU1	MA1		T2 T10 T11
Deep soil layers (>4m)	Ca5 Ca1	CL7		N		LM1, LM5		JS4	JU2 JU10		Y	N
Organic soils	Y	CL10 CL11	CM10	CO4 CO6		LM7		JS11		N	Y	T2
Ponding and/or other	Y	CL8	CM20 CM8	CO7		LM1 LM5		N	N	N		T13
Lateral flow in-grid/ hillslopes	N	N	CM21	N		LM1 LM7		N	N	N	In prep	N
Layered snow	Ca5	N	CM7	CO1 CO2		LM5		N	JU1		OR5	T1 T7

Water bodies



	CABLE	CLASSIC	CLM	CoLM	ELM	G/LM	ISBA	JSBACH	JULES	Matsiro	Orchidee	TESSEL
River routing	N	CL2	CM13	CO3		LM5		N	JU9	MA1 MA2 MA3 MA4 MA10 MA11	Y	Y
Wetlands and inundation	N	CL1	CM20 CM16 CM17	CO3		LM7		N	JU3	MA1 MA2 MA8 MA10	N	Y
Irrigation	Ca2	N	CM12 CM22	N		In prep		JS1	Y	MA3 MA4 MA6	Y	Y
Groundwater	Ca1	N	CM14 CM19	CO3		LM5		N	N	MA3 MA4 MA5 MA7	N	Y

Vegetation physiology and biogeochemistry



	CABLE	CLASSIC	CLM	CoLM	ELM	G/LM	ISBA	JSBACH	JULES	Matsiro	Orchidee	TESSEL
Photosynthesis responds to environment	Y	Y	Y	Y	Y	Y	Y	Y	Y	MA3 MA4	Y	Y
Allocation of carbon to roots, stems and leaves.	Y	Y	Y	Y	Y	Y	Y	Y	Y	MA3	Y	N
Plants acclimatise to temperature and soil moisture	Y	N	Y	Y	N	N	N	Y	JU13	N	N	N
Soil carbon model	Ca7	Y	CM9	N	Y	LM8	Y	JS3 JS6 JS9	JU4	MA3	Y	N
Nitrogen cycle linked to carbon cycle	Ca7	N	CM5	N	Y	LM2 LM3 LM8	N	JS2	JU16	MA3	OR4	N

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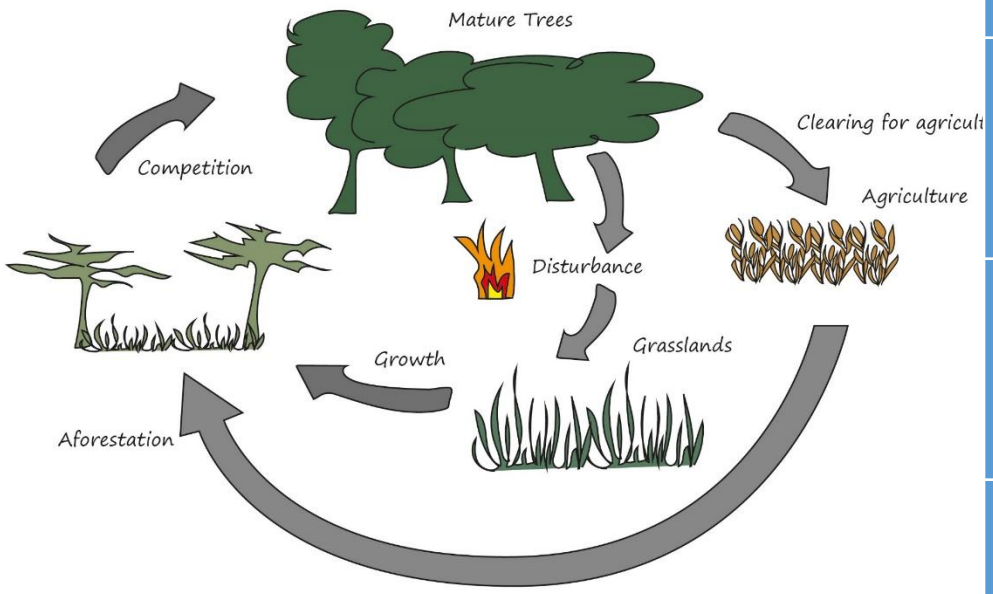

	CABLE	CLASSIC	CLM	CoLM	ELM	G/LM	ISBA	JSBACH	JULES	Matsiro	Orchidee	TESSEL
Different crop types	N	N	CM4 CM3	N		N		N	JU11 JU12	MA3 MA4	Y	T5
Land use and land cover change	Ca4	CL4	Y	N		Y		JS6 JS7 JS8 JS10	JU7	MA4	OR2	N
Competition between PFTs	Y	CL9	Y	Y	Y	Y	N	Y	JU8 JU15	N	Y	N
Water use and transfers of water between grid cells	N	N	N	N	N	N	N	N	N	MA3	N	N

This is just the beginning…..

Where are we going next?

How do we get there?

Can we help each other to achieve our goals?

Thanks for listening.