Vegetation Atmosphere INTeractions (VAINT)

Evgenii Churiulin[1], Merja Tölle[1],

Juergen Helmert[2] and Jean-Marie Bettems[3]

[1] – Center for Environmental Systems Research, Kassel, Germany

[2] – Deutscher Wetterdienst, Offenbach am Main, Germany

[3] – MeteoSwiss, Zurich, Switzerland

Motivation

1) Changes in the seasonal phenological cycle due to winter of summer crops affect the local climate by changes in the biogeophysical processes;

2) Seasonal phenology of vegetation impacts on the energy and water cycle, and can amplify extreme events by changes of the seasonal cycle of the albedo and water availability;

3) The frequency of extreme events increases and will increase in the near future. Hence, the need for modelling phenology will also increase;

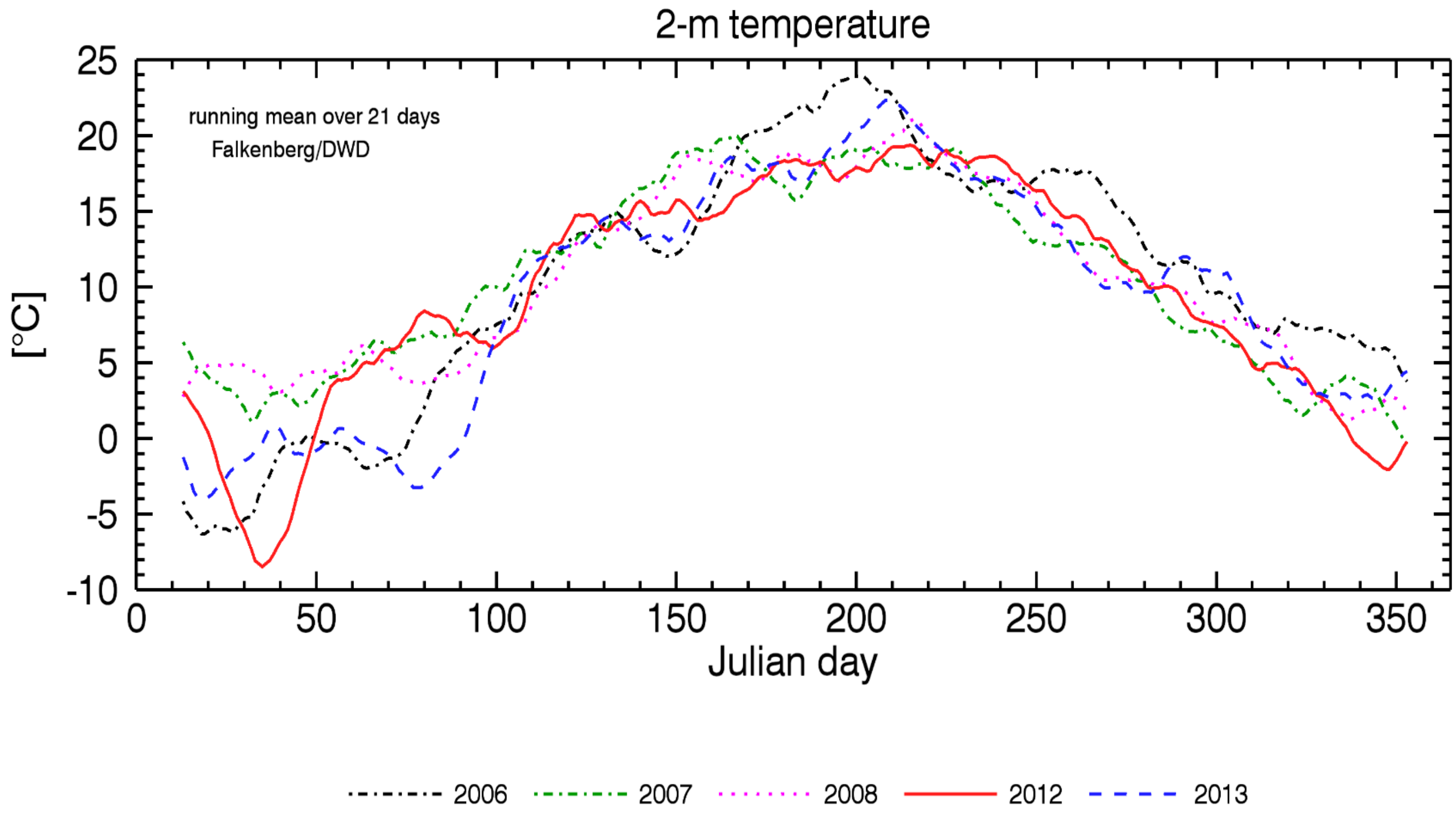
Motivation

4) Forecasting the phenological cycle of vegetation provides valuable information to assist with turbulent flux estimations relevant for boundary layer processes;

5) Knowing the evolution and magnitude of the seasonal LAI and the plant coverage allows for a more realistic estimation of the surface albedo;

The need to improve

Example of annual cycle of leaf area index for grass in the COSMO model



Jan-Peter Schulz et.al., 2015

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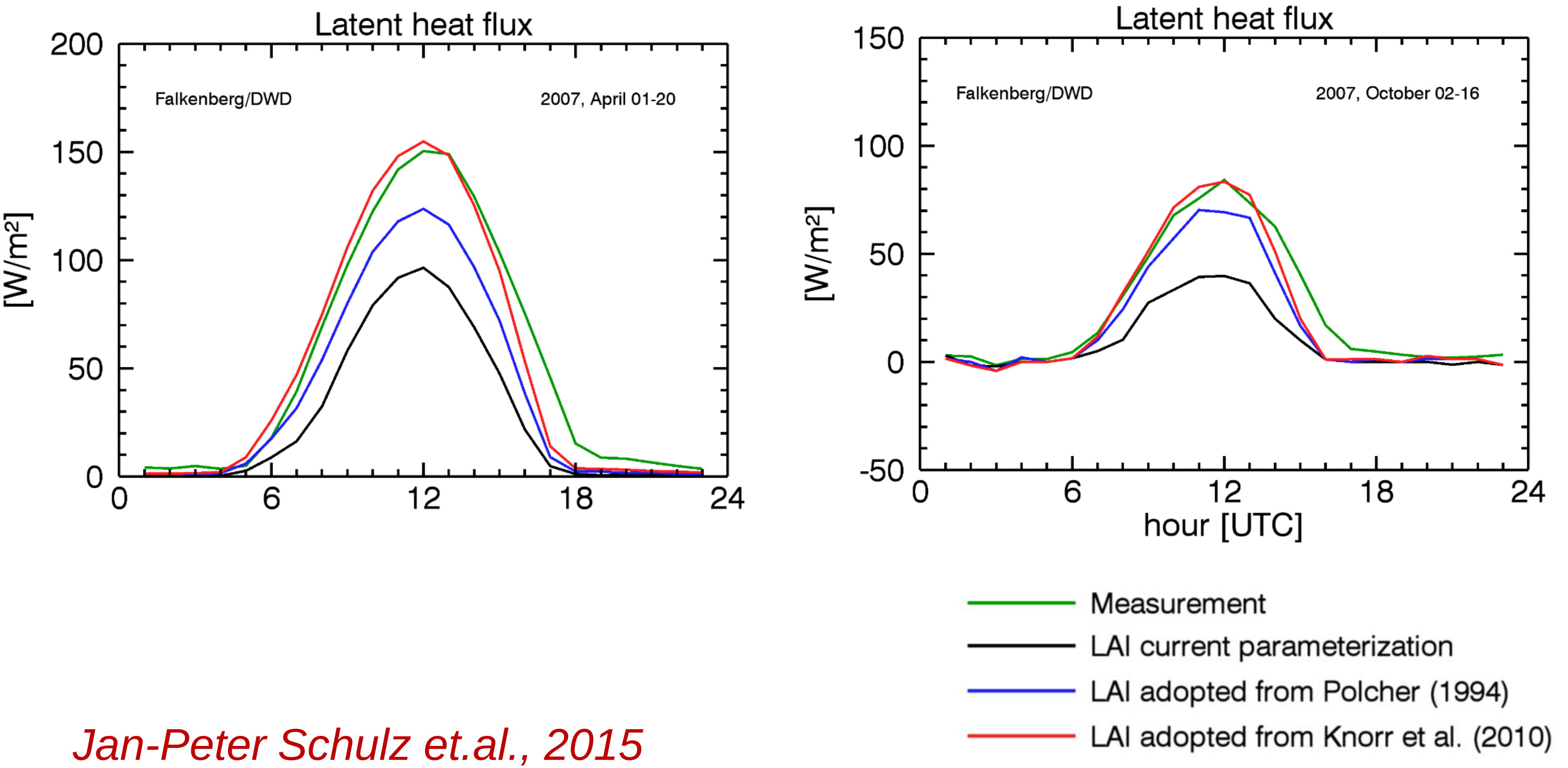


Jan-Peter Schulz et.al., 2015

Relevance

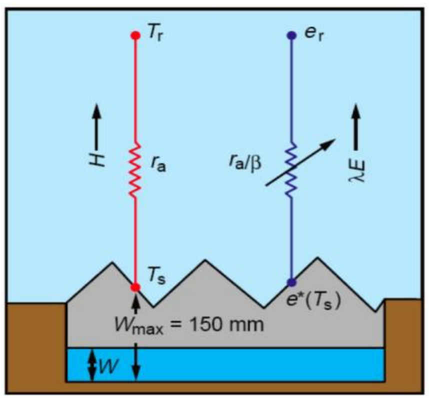
1) COSMO model use simplified phenology scheme, which are in general not capable to model the complex processes of the growing season in spring, the evolution of LAI, plant coverage and the senescence in autumn;

2) COSMO model contains the phenology cycle is based on a 6-year climatology. Cycle follows the same sinusoidal fitted curve between its max and min value each year while neglecting any influence, feedback on the environmental conditions;

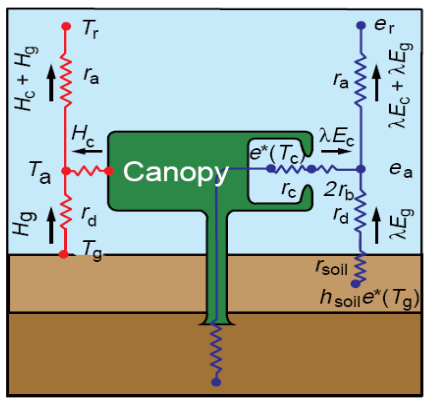
Evolution of land surface modelling

1st generation LSM:	2nd generation LSM:	3rd generation LSM:	Vegetation dynamics
★ “bucket model”	★ “Big-leaf” approach	★ Photosynthesis	(biogeography)
★ No explicit treatment of vegetation	★ Stomatal conductance	★ Carbon cycle	

1970 — 1980 — 1990



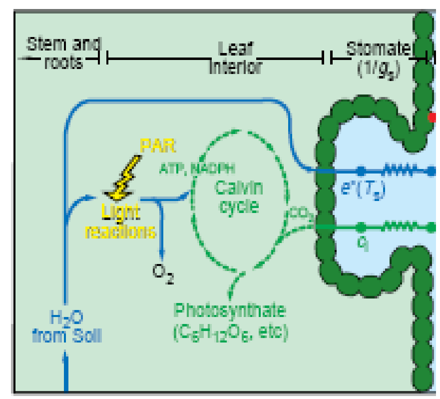
Bucket model:
Manabe, 1969



BATS:
Dickinson, 1984

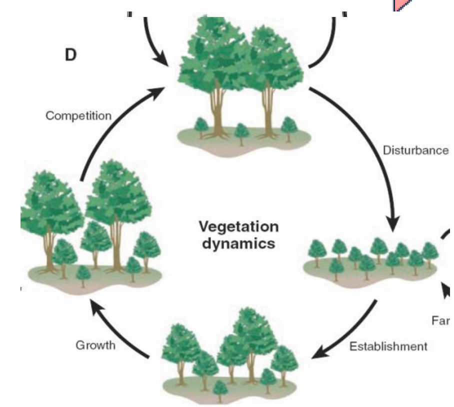
SIB:
Sellers et al., 1986

TERRA-ML



SiB2:
Sellers et. al, 1992

LSM:
Bonan, 1995



IBIS:
Foley et al., 1996

CLM

Seller et. al. (1997) classification

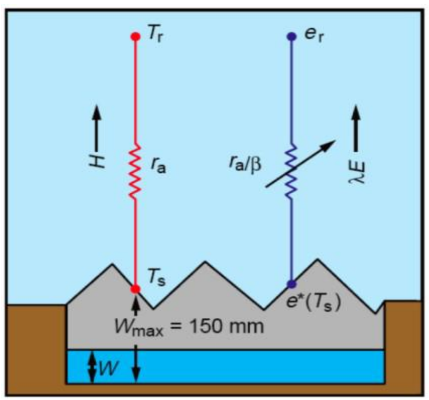
Evolution of land surface modelling

Vertical discretization

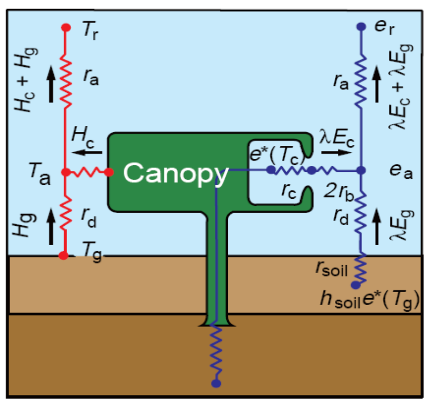
no canopy layer — "Big-leaf approach" — "2-leaf" approach — Multi-layer canopy

"bucket hydrology" — *2-layer hydrology* — *Multi-layer hydrology*

1970 — 1980 — 1990 — 2000 — 2010



Bucket model:
Manabe, 1969



BATS:
Dickinson, 1984

SIB:
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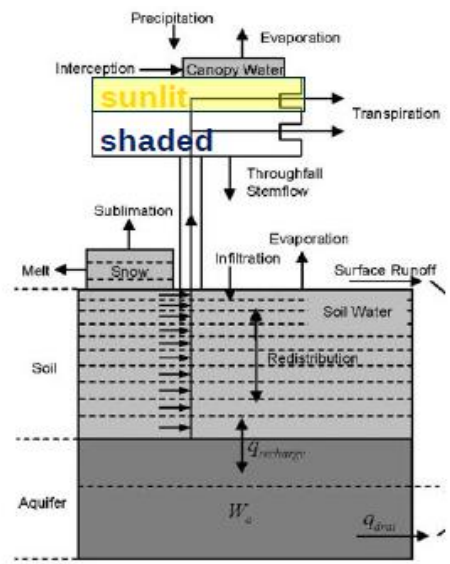
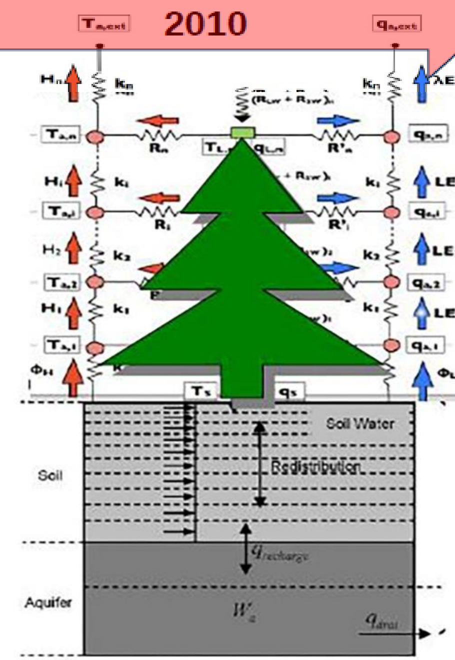


CLM3:
Oleson et al, 1984



CLM 4.5:
Oleson et al, 2013

ORCHIDEE:
Ryder et al, 2013

Edouard Davin, 2013 – Introduction to the CLM

Parameterization of the surface fluxes

$$E_b + \sum_{k=1}^{ke_{soil,hy}} T_{r_k} + E_i + E_{snow} = -(F^3_{q^v})_{sfc}$$

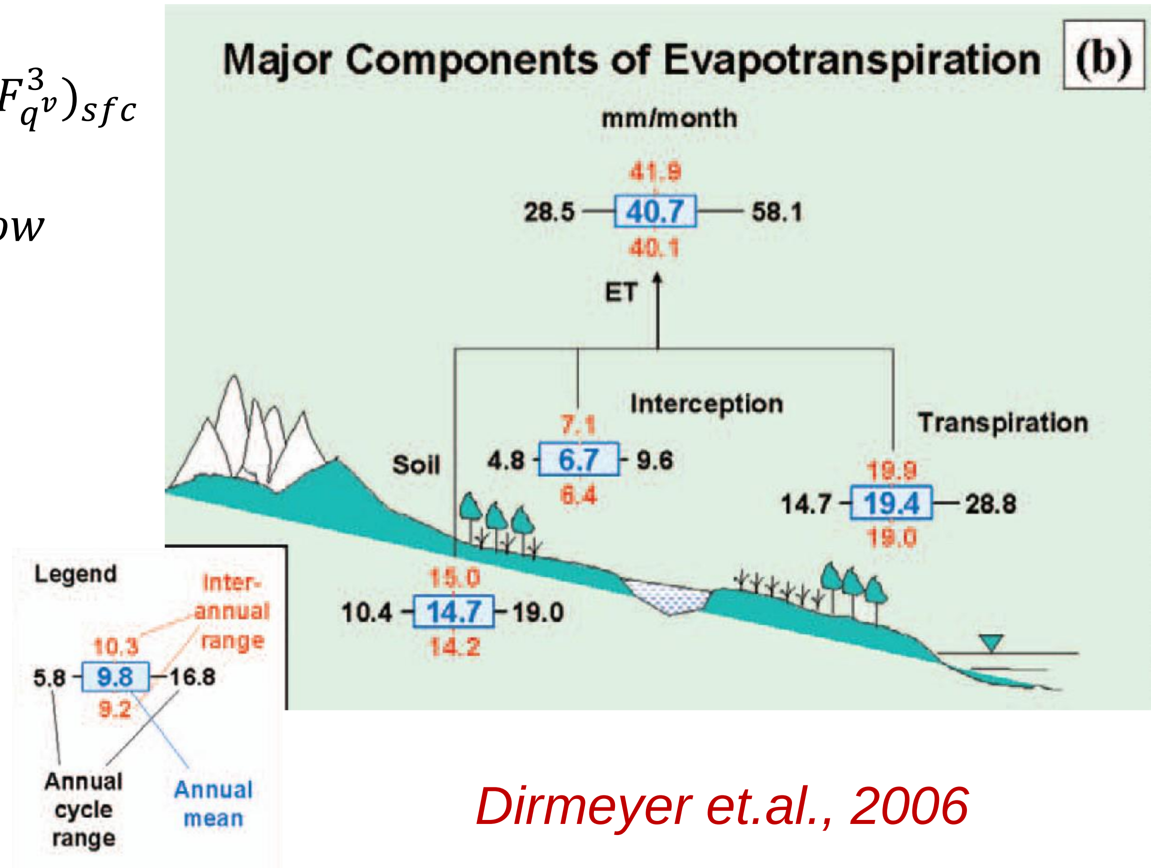
E_{snow} – *evaporation from snow*

E_b – *evaporation from soil*

T_{r_k} – *plant transpiration*

E_i – *interception*

Biological processes play a major role in controlling evapotranspiration



Dirmeyer et.al., 2006

2^{nd} generation Biophysical models (TERRA_ML)

Stomatal behavior represented based on empirical relations (Jarvis et. al., 1976)

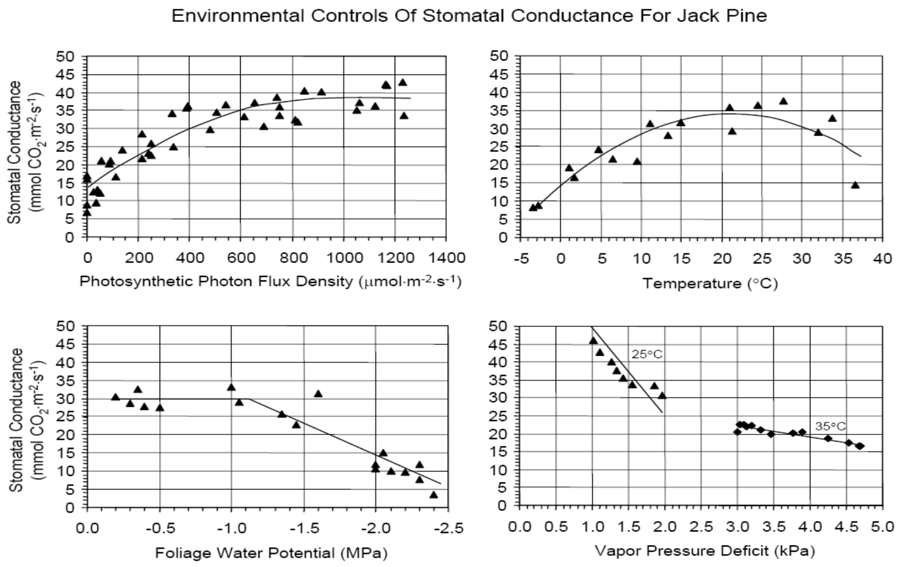


Figure: Bonan, 2002

3^{rd} generation Photosynthesis models (CLM)

Stomatal conductance explicitly related to photosynthetic assimilation model using Ball-Berry approach (Collatz et. al., 1991)

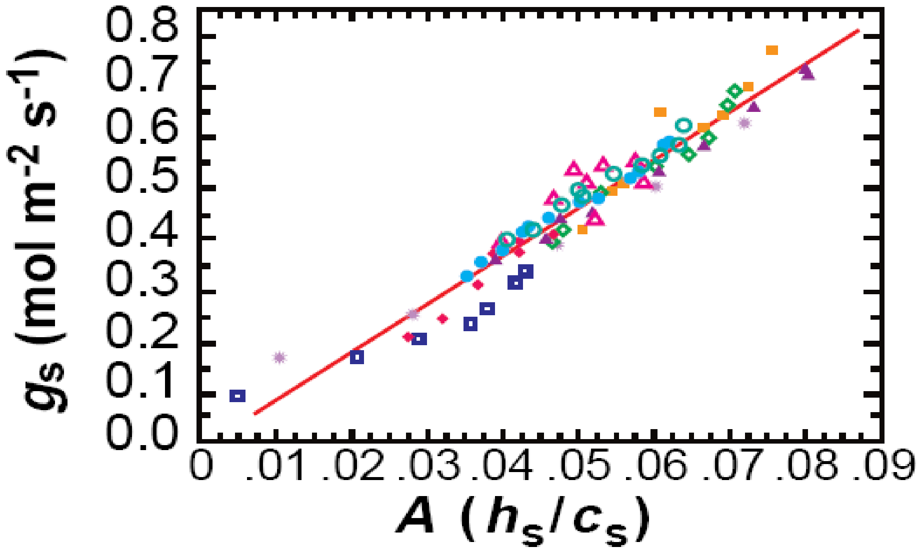
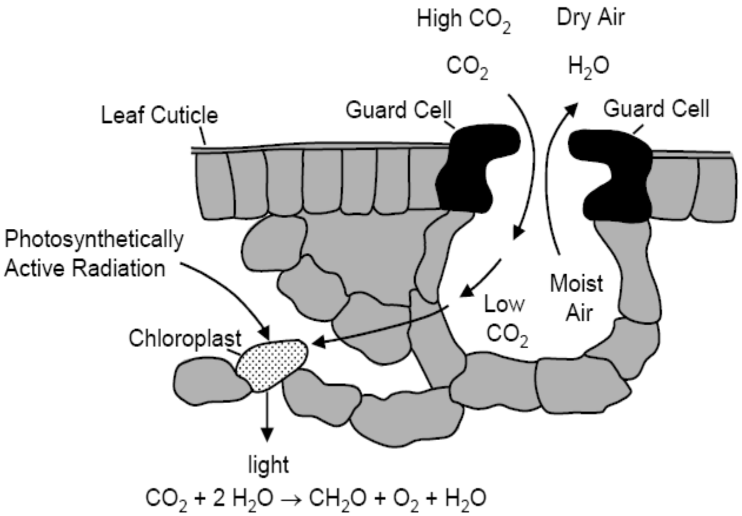


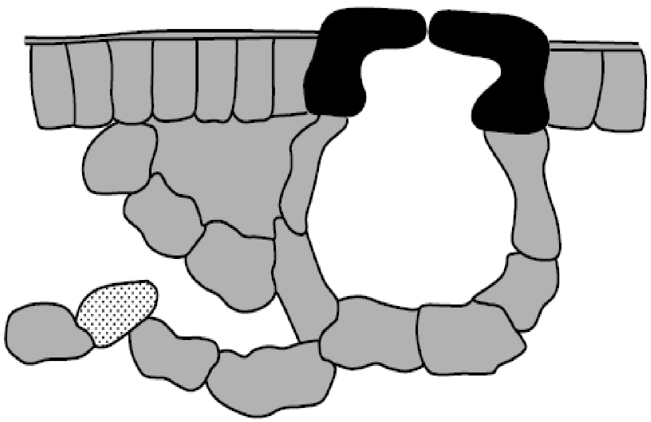
Figure: Sellers et. al, 1997

Limitation of 2nd generation LSMs

Vegetation explicitly represented in 2nd generation LSMs but...

Stomatal conductance is calculated empirically without considering the actual process controlling stomatal functioning



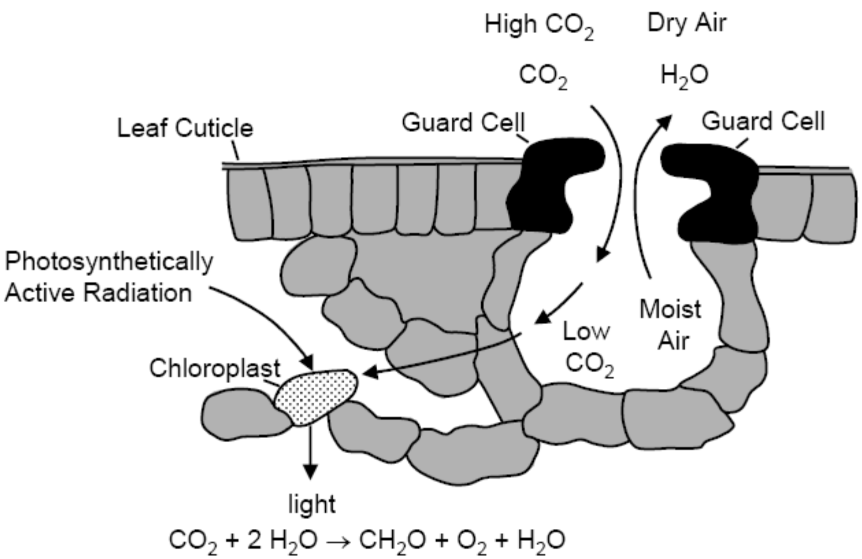


Maximization of water use efficiency (photosynthesis/water)

Edouard Davin, 2013 – Introduction to the CLM

Stomatal functioning

Stomata open



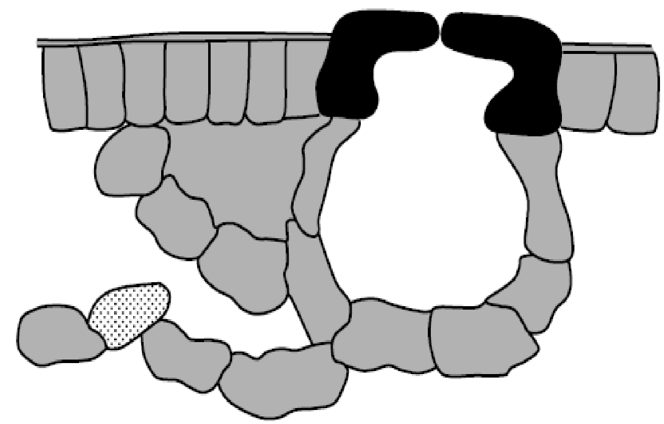
High light levels | Moist leaf

Warm temperature | Moist air

Moderate CO_2

High leaf nitrogen

Stomata close (smaller pore opening)



Low light levels | Dry leaf

Cold temperature | Dry air

High CO_2

Low leaf nitrogen

Comparison

TERRA_ML vs ***New scheme***

Surface temperature and energy balance

TERRA_ML	New scheme
Single interface with one temperature (***t_g***) and bulk density	Distinguishes temperature and energy fluxes for canopy (***tv***) and ground (***tg***)

Radiation fluxes

TERRA_ML	New scheme
Fluxes based on grid scale albedo and temperature	Albedo dependences from vegetation
Technically in src_radiation	

Comparison

TERRA_ML vs *New scheme*

Stomatal conductance

TERRA_ML	*New scheme*
• BATS-based	• Ball-Berry approach
• Empirical Jarvis-type approach	• Coupling with photosynthesis
	• "2-leaf" canopy with diffuse/direct light

Subgrid-scale heterogeneity

TERRA_ML	*New scheme*
• Only accounts for partial coverage of snow	• Tile approach
• Tile approach in ICON-TERRA	• Vegetation types adapted for ICON

Individual Sub-Tasks 1

Implementation of three new modules in current photosynthesis/phenology scheme of COSMO/ICON code

1) The canopy photosynthesis and stomatal regulation;

2) Carbon allocation and plant growth;

3) Autotrophic/Heterotrophic respiration and litter/soil carbon dynamics;

*The new modules will be implemented in a way to minimize the additional computational time introduced by these new parameterizations

Individual Sub-Tasks 2

Quantification of impact on implemented parameterizations

*Impact of new scheme on the albedo and on evapotranspiration/latent heat flux will be quantified

**The start from a specific date need to be accounted for NWP applications, and the necessary predictions to be written out and read in each time step

Individual Sub-Tasks 3

Validation of implementation of new photosynthesis/phenology scheme

Sub-Task 3 includes verification of prognostic and diagnostic parameters affected by the photosynthesis/phenology scheme.

*Especially, the diagnostic parameters such as the 2m air temperature will be affected by an improved photosynthesis/phenology scheme.

**Adjustments to such diagnostics will be made if required.

Individual Sub-Tasks 4

Documentation of new photosynthesis/phenology scheme

In the final phase 4 required documentations in forms of internal works reports (COSMO consortium) as well as scientific publications for peer-reviewed journals will be prepared.

Our contacts:

GitHub page: https://github.com/users/merajtoelle/projects/1

Address: Center for Environmental Systems Research
Wilhelmshöher Allee 47, 34117 Kassel

Email: evgenychur@gmail.com

Background

- Vegetation dynamics are prescribed in lookup tables or in gridded maps with effective plant properties for each raster cell.
- As a consequence, the development of the leaf area index (LAI), for example, is the same in each year.
- The dynamics are “frozen” and hence do not depend on the prevailing weather conditions.
- Errors in turbulent fluxes resulting from this coarseness translate into changes in regional air and surface temperature, evolution of the atmospheric boundary layer, and spatial distribution of rainfall.
- In general, a warmer climate will accelerate vegetation development…

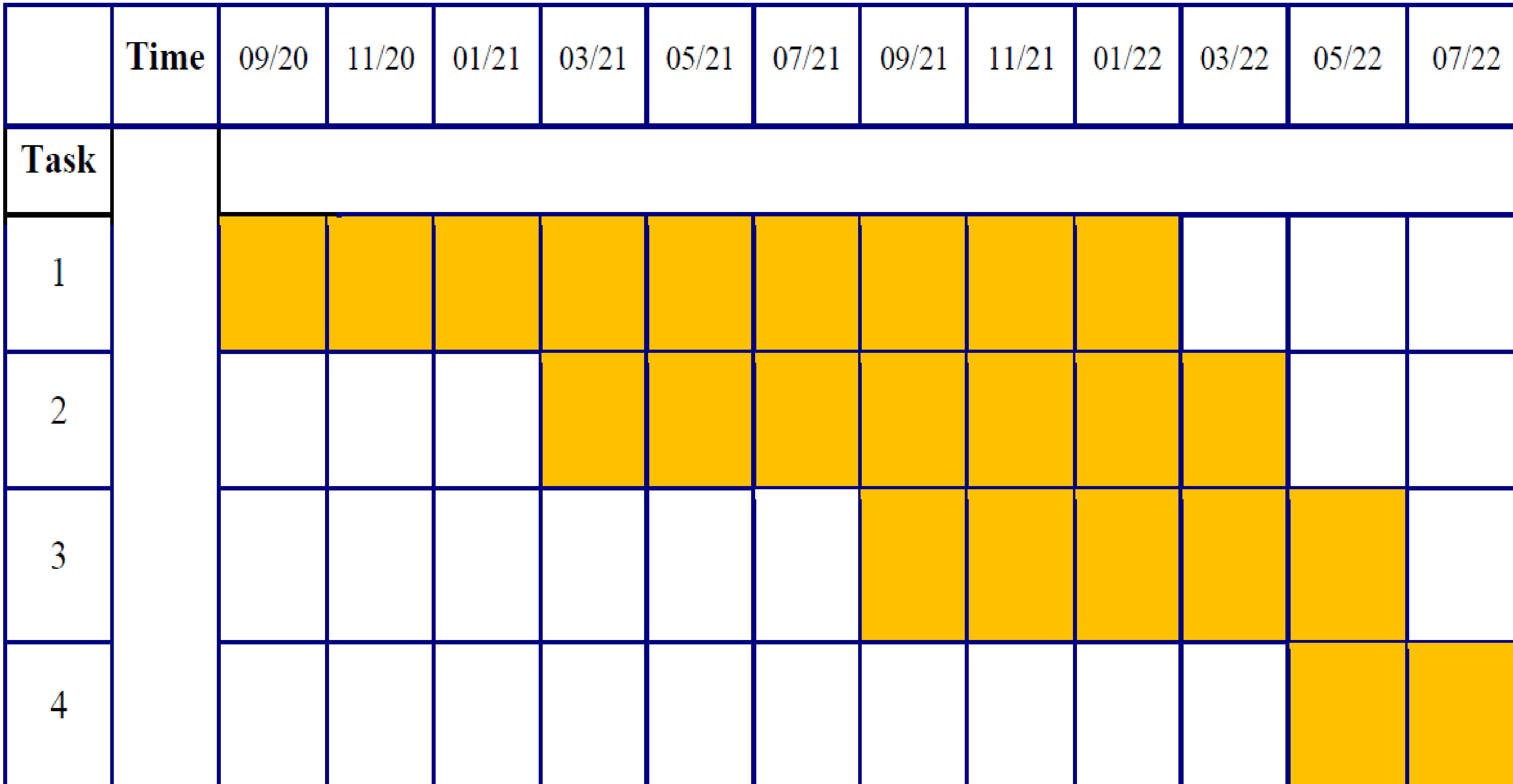
Differences between the models

	TERRA-ML	Veg3D	JS-BACH	LPJmL	Caraib
Vegetation layer	NO / Vegetation parameters	YES / Big leaf concept	YES / Big leaf concept	YES / Big leaf concept	YES / Big leaf concept (shaded and sunlit leaves)
Turbulent fluxes	Surface temperature	Vegetation temperature	Vegetation temperature	Vegetation temperature	Vegetation temperature
Vegetation parameters	Weighted average	Dominant			
Radiation	Albedo constant	Albedo depends on vegetation			

Modifications in TERRA

- modify…
- Add photosynthesis, respiration, allocation, and phenology

Gantt chart


Time
09/20
11/20
01/21
03/21
05/21
07/21
09/21
11/21
01/22
03/22
05/22
07/22
Task
1
2
3
4

FTEs summary

	Institution	CESR	MeteoSwiss	DWD
Task				
1		1.39	0.005	0.005
2		0.29	0.005	0.005
3		0.19	0.005	0.005
4		0.09	0.005	0.005
Total FTEs		1.96	0.02	0.02

****Total of 2 FTEs over 2 years***