Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Update on TERRA developments within the CLM-Community

Jan-Peter Schulz

Deutscher Wetterdienst

COSMO WG3b / CLM SOILVEG parallel session

COSMO / CLM / ART User Seminar, 2 - 4 Mar. 2015, Offenbach

Current status

2	Model development (CLM-Community, TERRA)				
2.01	COSMO	N/A	Vertically dependent soil structure, HWSD data set	[CLM] B. Ahrens (Uni Frankfurt	stop
2.02	COSMO	N/A	Soil thermal conductivity dependent on soil moisture	[CLM] JP. Schulz (Uni Frankfur	test
2.03	COSMO	N/A	Carbon cycle	[CLM] B. Ahrens (Uni Frankfurt	stop
2.04	COSMO	N/A	Dynamic vegetation	[CLM] B. Ahrens (Uni Frankfurt	idea
2.05	COSMO	N/A	Urban scheme BEP	[CLM] S. Schubert (PIK)	test
2.06	COSMO	N/A	Urban scheme TEB	[CLM] K. Trusilova (DWD)	finish
2.07	COSMO	5.20	Parameterization of urban effects	[CLM] H. Wouters (KU Leuven)	work
2.08	COSMO	N/A	River routing model	[CLM] J. Volkholz (PIK)	stop
2.09	COSMO	N/A	Soil temperature - lower boundary condition	[CLM] J. Tödter (Uni Frankfur	work

A new leaf phenology for the land surface scheme TERRA of the COSMO atmospheric model

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[2]Deutscher Wetterdienst, Lindenberg
[3]Goethe University Frankfurt

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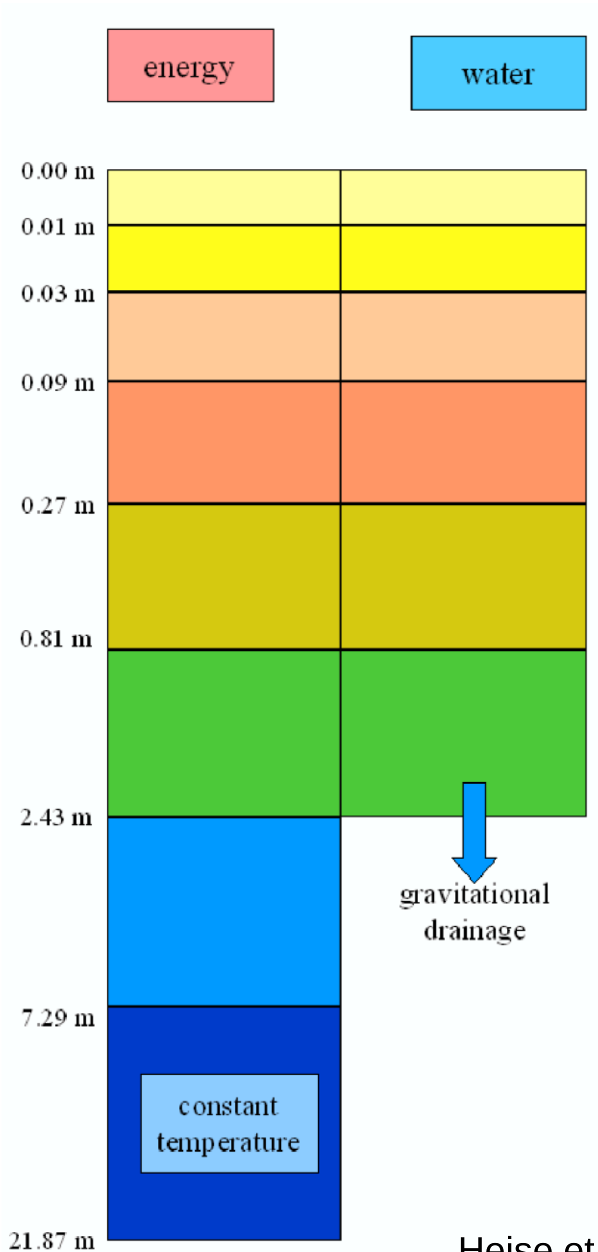
COSMO Phenology Workshop, 1 Dec. 2014, Zürich

Phenology is governed, or limited, by:

- Temperature
- Day length
- Water availability
- ~~NPP (net primary productivity)~~

Two approaches for phenology not depending on NPP adopted from:

- Polcher, J. (1994), *Thèse de doctorat, Univ. Pierre et Marie Curie, Paris*
- Knorr, W., et al. (2010), *J. Geophys. Res.*, **115**, G04017



Heise et al. (2006)

Land surface scheme TERRA

Layers for temperature and soil water content

Experiments:

- Use atmospheric forcing to run TERRA in offline mode
- Here, observed forcing from DWD observatory Lindenberg is used (Falkenberg site)

Phenology determining temperature

$$T(t)=\frac{\int_{-\infty}^{0} T_S(t+\tau)\,e^{\tau/t}\,d\tau}{\int_{-\infty}^{0} e^{\tau/t}\,d\tau}$$

This is equivalent to an exponentially declining memory of the plants for the surface temperature T_S. t is the averaging period for T_S.

Phenology as function of temperature

based on Polcher (1994)

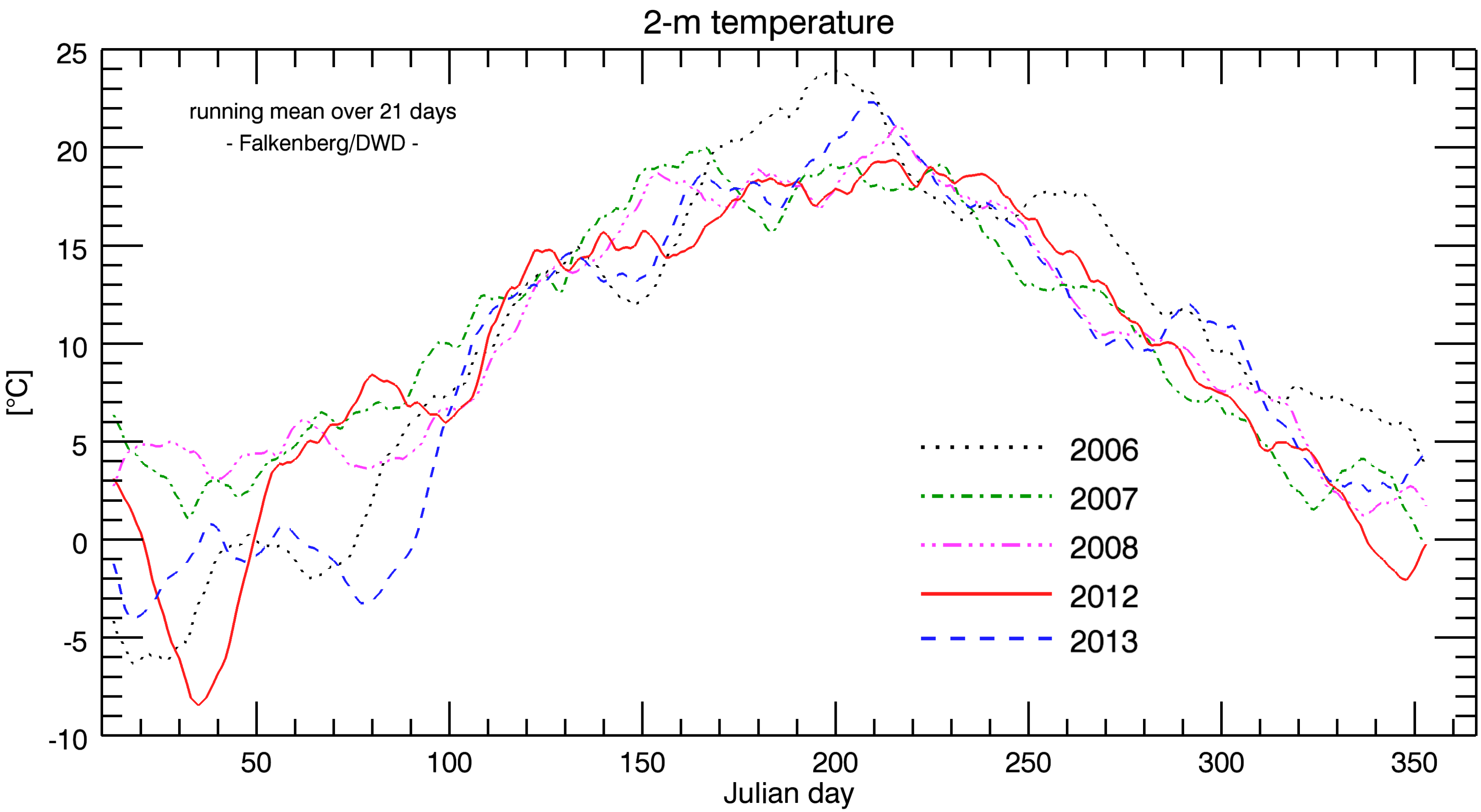
$$
\mathrm{LAI}(t) = \begin{cases} \mathrm{LAI}_{\min} & \text{if } T(t) \le T_1 \\ \mathrm{LAI}_{\min} + \dfrac{T(t) - T_1}{T_2 - T_1}\left(\mathrm{LAI}_{\max} - \mathrm{LAI}_{\min}\right) & \text{if } T_1 < T(t) \le T_2 \\ \mathrm{LAI}_{\max} & \text{if } T_2 < T(t) \end{cases}
$$

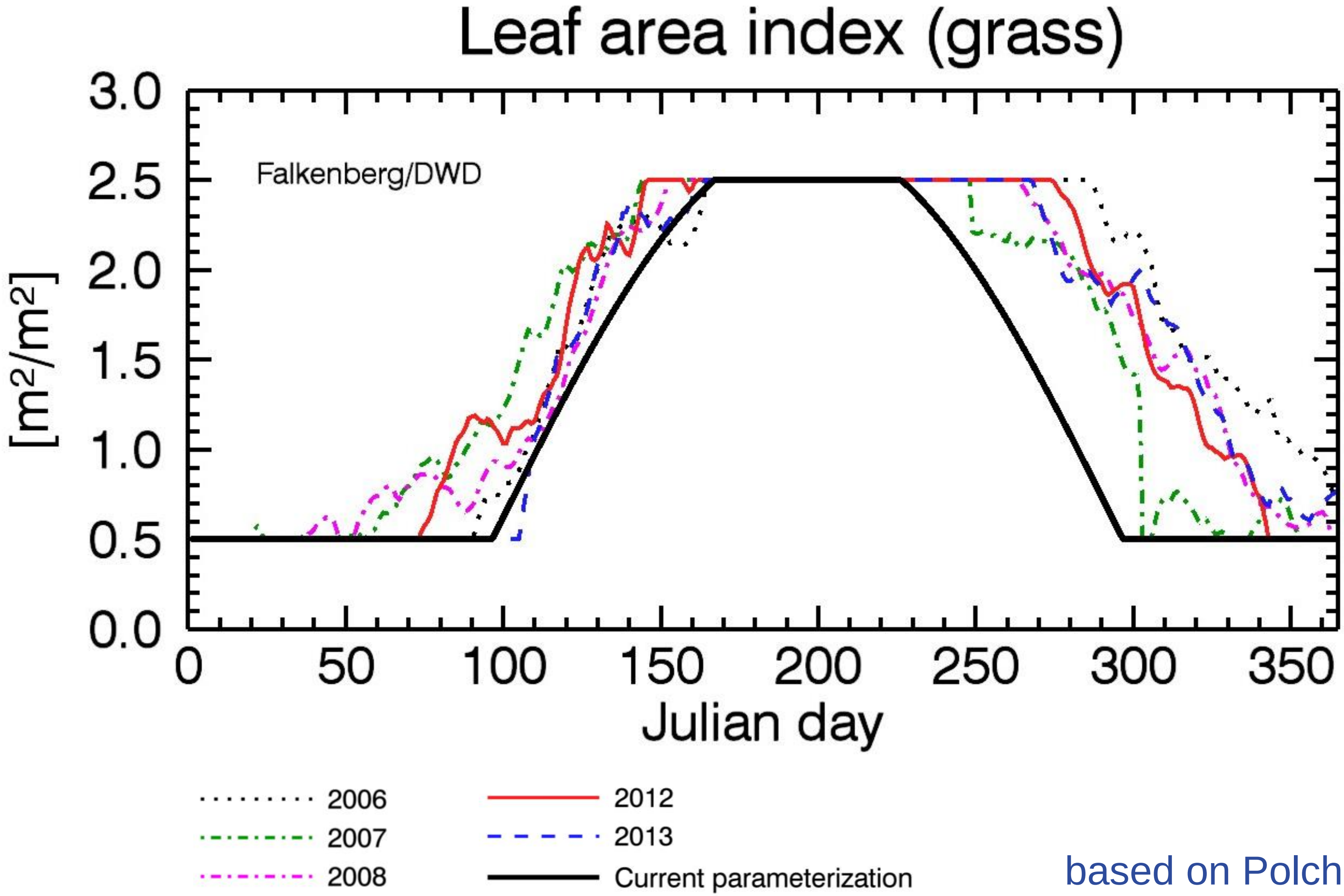
T_1 : minimum limiting temperature

T_2 : maximum limiting temperature

$\mathrm{LAI}_{\min}$, $\mathrm{LAI}_{\max}$: minimum and maximum value of LAI

Inter-annual variability at Lindenberg





based on Polcher (1994)

Phenology as function of temperature

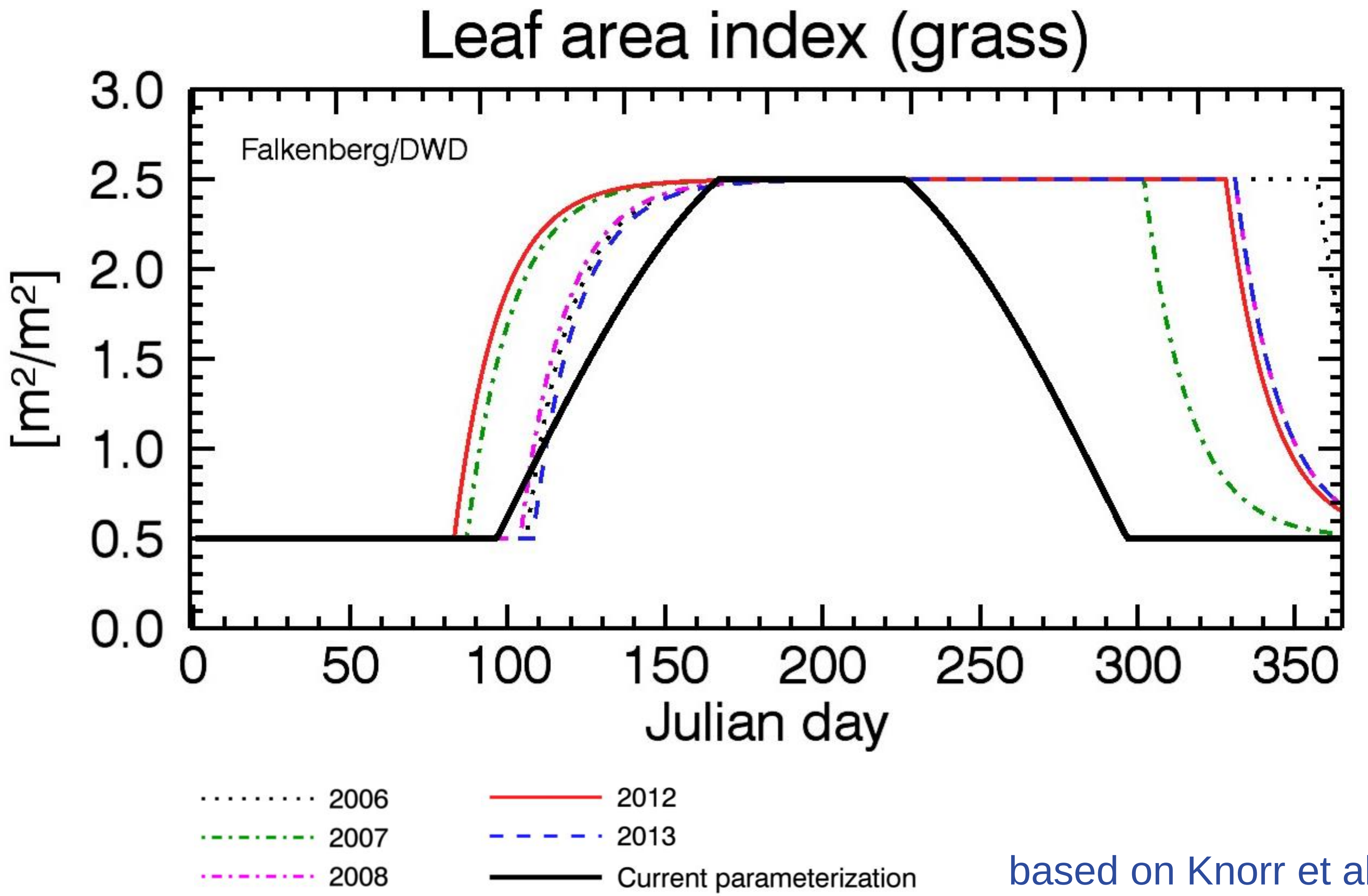
based on Knorr et al. (2010)

$$\frac{d\mathrm{LAI}(t)}{dt} = \begin{cases} k_{grow}(\mathrm{LAI}_{max} - \mathrm{LAI}(t)) & \text{if } T(t) \geq T_{on/off} \\ k_{shed}(\mathrm{LAI}_{min} - \mathrm{LAI}(t)) & \text{else} \end{cases}$$

$T_{on/off}$: leaf onset and offset temperature

k_{grow} , k_{shed} : growth rate and shedding rate

LAI_{max} , LAI_{min} : maximum and minimum value of LAI



based on Knorr et al. (2010)

Phenological Data Assimilation

A gap-free Leaf-Area Index Climate Data Record

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This Rutishauser[3], Scott Denning[2]
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[2]Colorado State University, Fort Collins CO, USA
[3]Oeschger Center, University of Bern, Bern, Switzerland

NASA NEWS (NASA Energy and Water Cycle Study), Grant NNG06CG42G

The GSI diagnostic phenology model

The GSI model was developed based on the insight that also the state of vegetation on the global scale can be determined by only 3 climatic driving states:

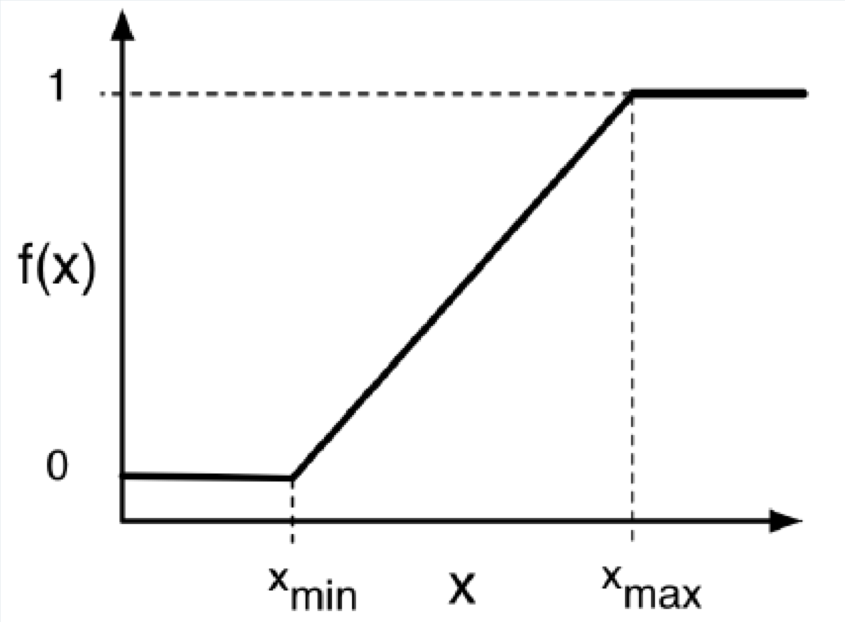
- Temperature T (air temperature)
- Radiation R (daylength or global radiation)
- Water W (vapor pressure deficit)

$$\mathrm{GSI} = f(T) \cdot f(R) \cdot f(M)$$

$$f(T) = \frac{T - T_{min}}{T_{max} - T_{min}}$$

$$f(R) = \frac{R - R_{min}}{R_{max} - R_{min}}$$

$$f(W) = 1 - \frac{W - W_{min}}{W_{max} - W_{min}}$$



Growing Season Index (GSI)
Jolly et al. (2005)

From diagnostic to prognostic phenology

Steady-state GSI:

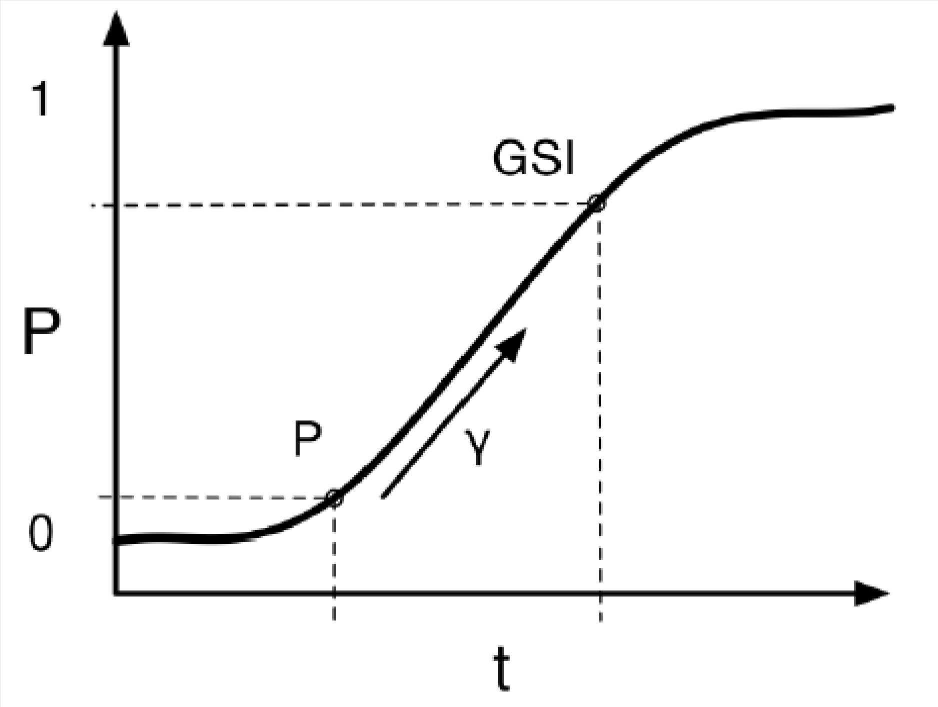
$$\mathrm{GSI} = f(T) \cdot f(R) \cdot f(M)$$

Prognostic state P:

$$P = f(\mathrm{LAI})$$

Deviation of P from "potential" GSI:

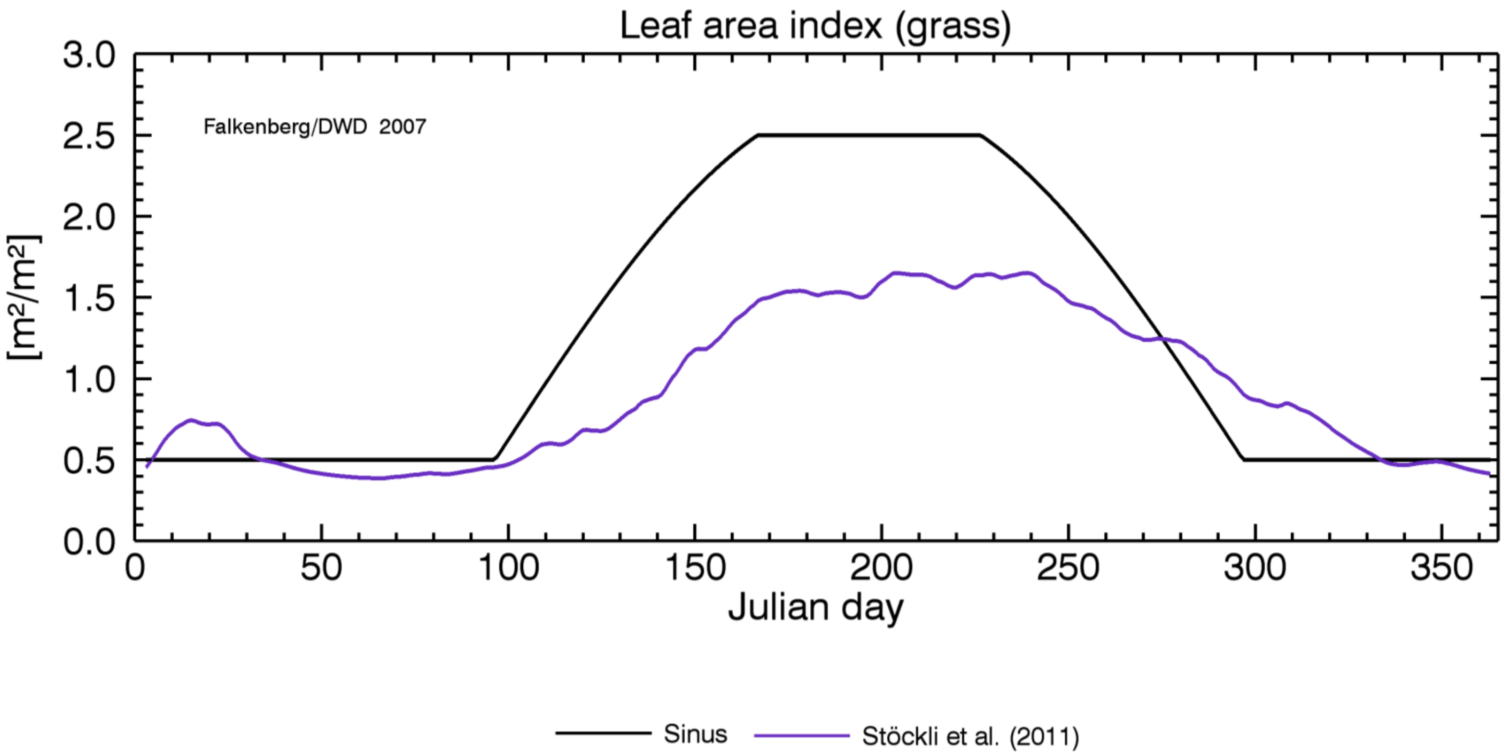
$$\frac{\partial \mathrm{GSI}}{\partial t} = \mathrm{GSI} - P$$

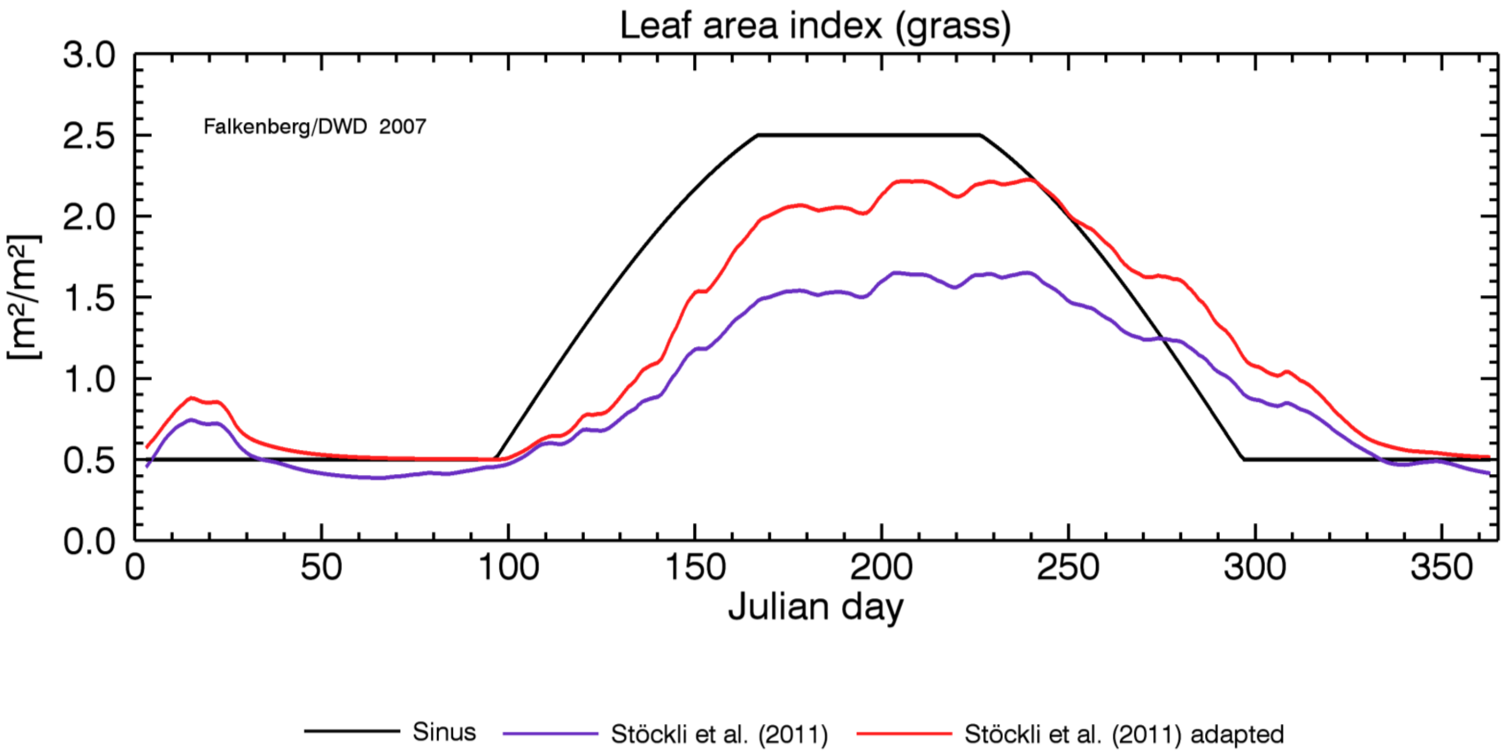


Modify LAI at each time step towards diagnostic GSI by logistic growth and defined growth rate:

$$\frac{\partial \mathrm{LAI}}{\partial t} = \gamma \cdot \frac{\partial \mathrm{GSI}}{\partial t} \cdot P(1-P) \qquad \gamma = \begin{cases} \gamma_g & \text{if } \partial \mathrm{GSI} \geq 0 \\ \gamma_d & \text{if } \partial \mathrm{GSI} < 0 \end{cases} .$$

Stockli et al. (2008,2011)


Leaf area index (grass)
Falkenberg/DWD 2007
[m²/m²]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
300
350
Julian day
Sinus
Stöckli et al. (2011)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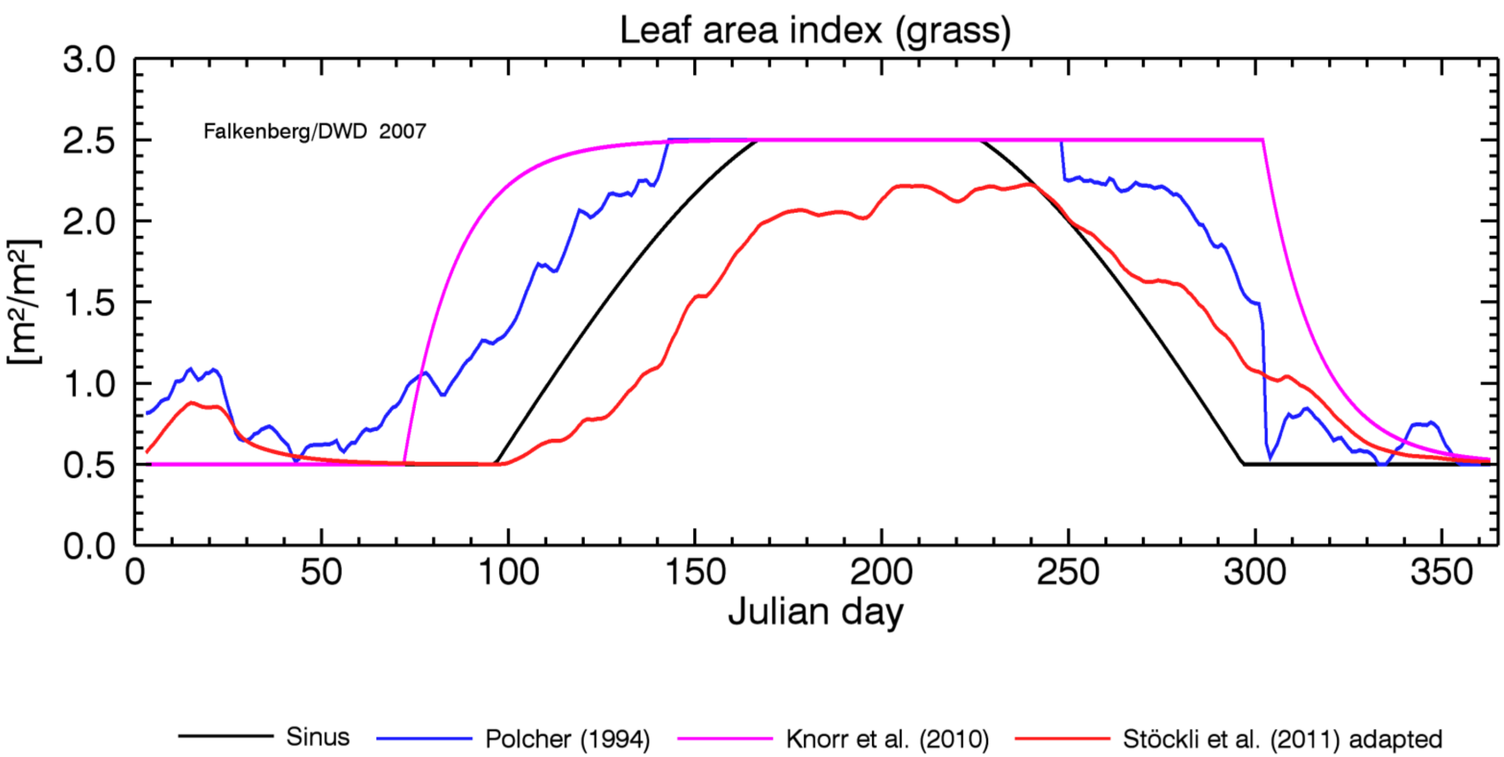
Sinus
Stöckli et al. (2011)
Stöckli et al. (2011) adapted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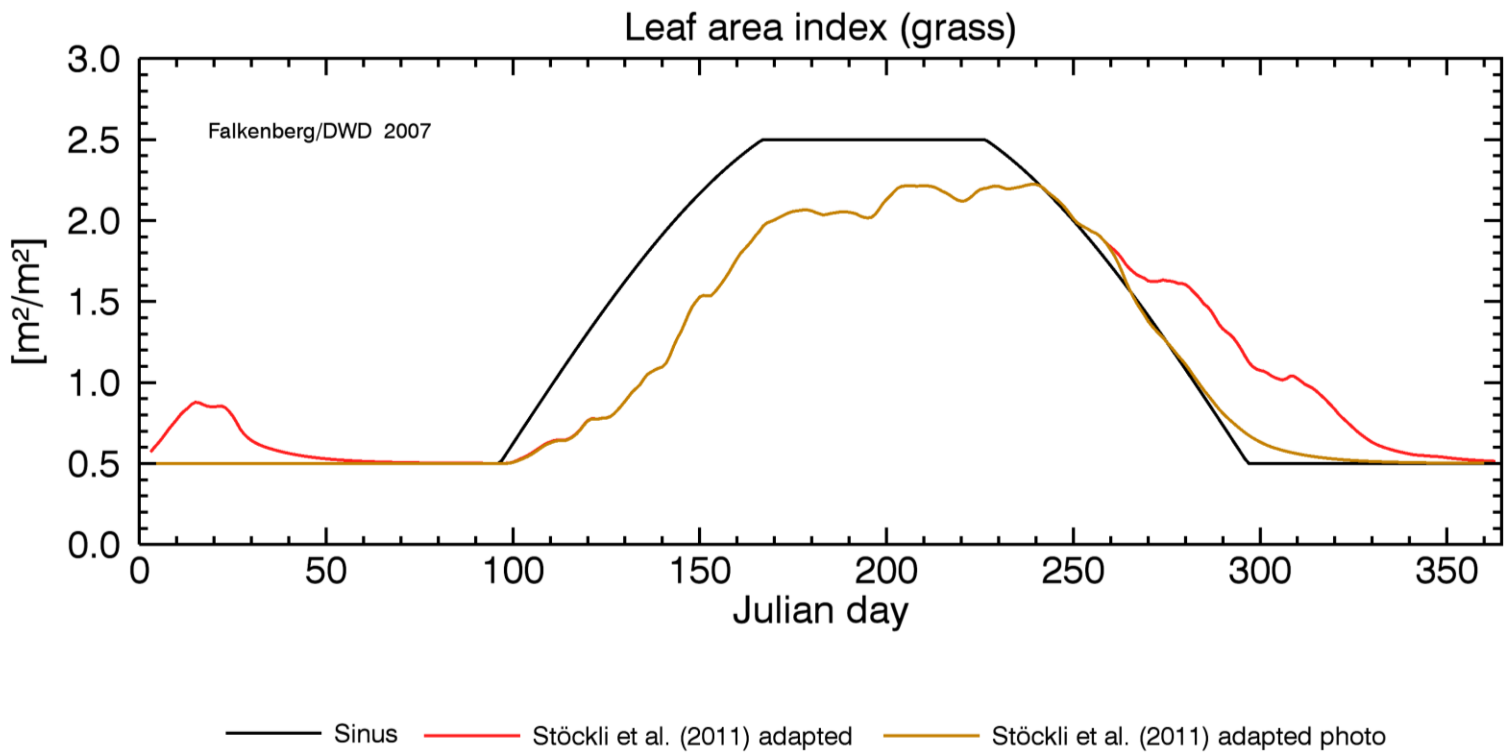
Julian day
Sinus
Polcher (1994)
Knorr et al. (2010)
Stöckli et al. (2011) adapted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Falkenberg/DWD 2007
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Julian day
Sinus
Stöckli et al. (2011) adapted
Stöckli et al. (2011) adapted photo

Conclusions

- With the current parameterization TERRA can not account for the inter-annual variability of the phenology.
- Two approaches based on Polcher (1994) and Knorr et al. (2010) for simulating the seasonal cycle of phenology as function of temperature were implemented.
- The first one improves the simulations, the second one even gets very close to the observations of latent heat flux.
- The approach by Knorr et al. (2010) appears to be favourable due to the use of the concept of growth and shedding rates.
- The next steps are the extension of the scheme to more vegetation types, e.g. trees (deciduous and evergreen), and the implementation into the three-dimensional coupled model code.

Conclusions

- With the current parameterization TERRA can not account for the inter-annual variability of the phenology.
- Two approaches based on Polcher (1994) and Knorr et al. (2010) for simulating the seasonal cycle of phenology as function of temperature were implemented.
- In addition, the approach by Stöckli et al. (2008, 2011) was implemented, including functions of temperature, but also of day length and water availability.
- It combines the concepts of threshold values (Polcher 1994) and of growth and decay rates (Knorr et al. 2010).
- The next steps are the inclusion of the full 35 plant functional types, and the implementation into the three-dimensional coupled model code.

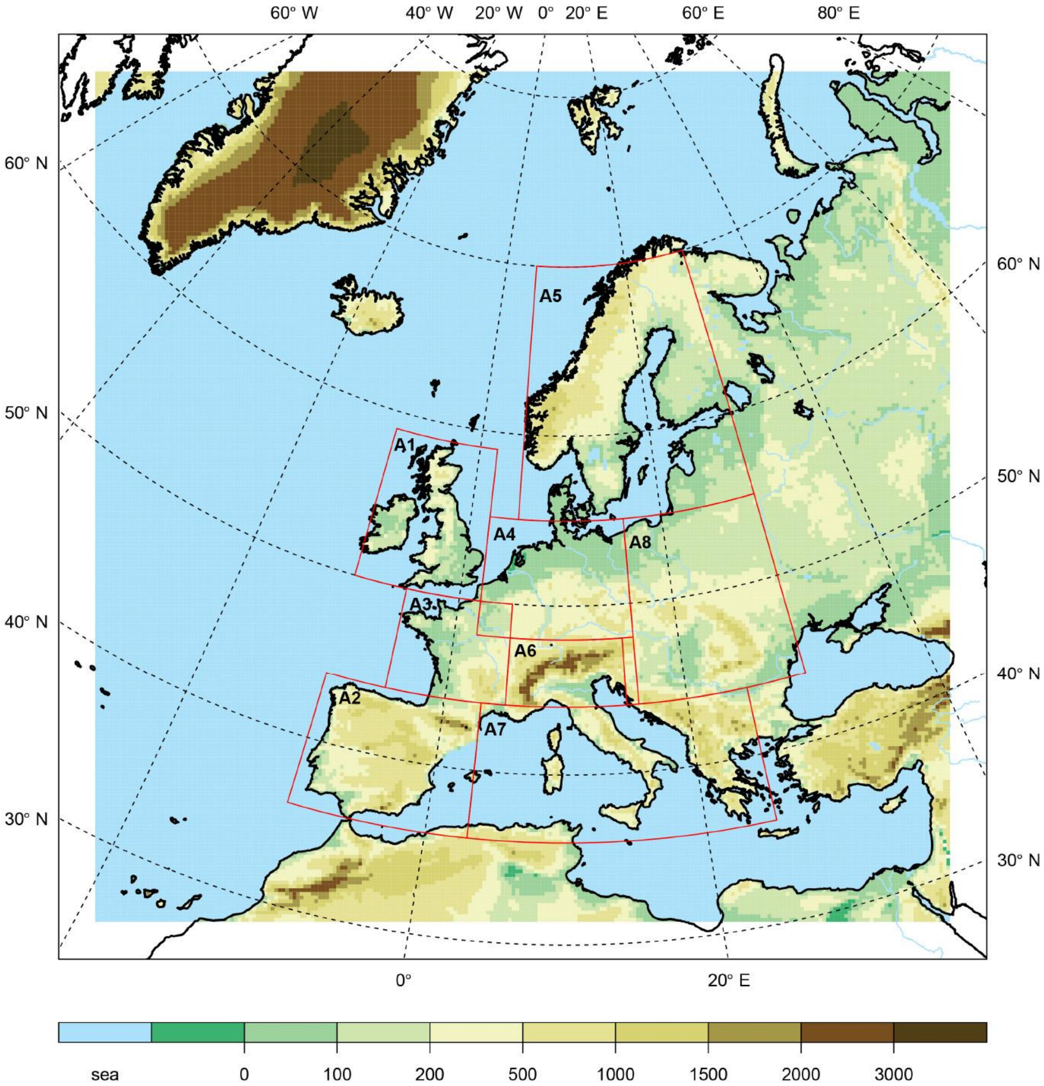
WG EVAL: Coordinated Evaluation Project

Aim of this WG task is to carry out a coordinated parameter testing of the new reunified version COSMO5.0-CLM and give a recommendation on the parameters to the users. We would like to end in an evaluated community version including an evaluation report.

For most of the simulations the following facts have been defined:

- **domain:** CORDEX-EU
- **simulation period:** 1979-2010 (currently only until 2000)
- **evaluation period:** 1981-2010 (1981 - 2000)

Reference simulation for all tests is CON502, done by Klaus Keuler.



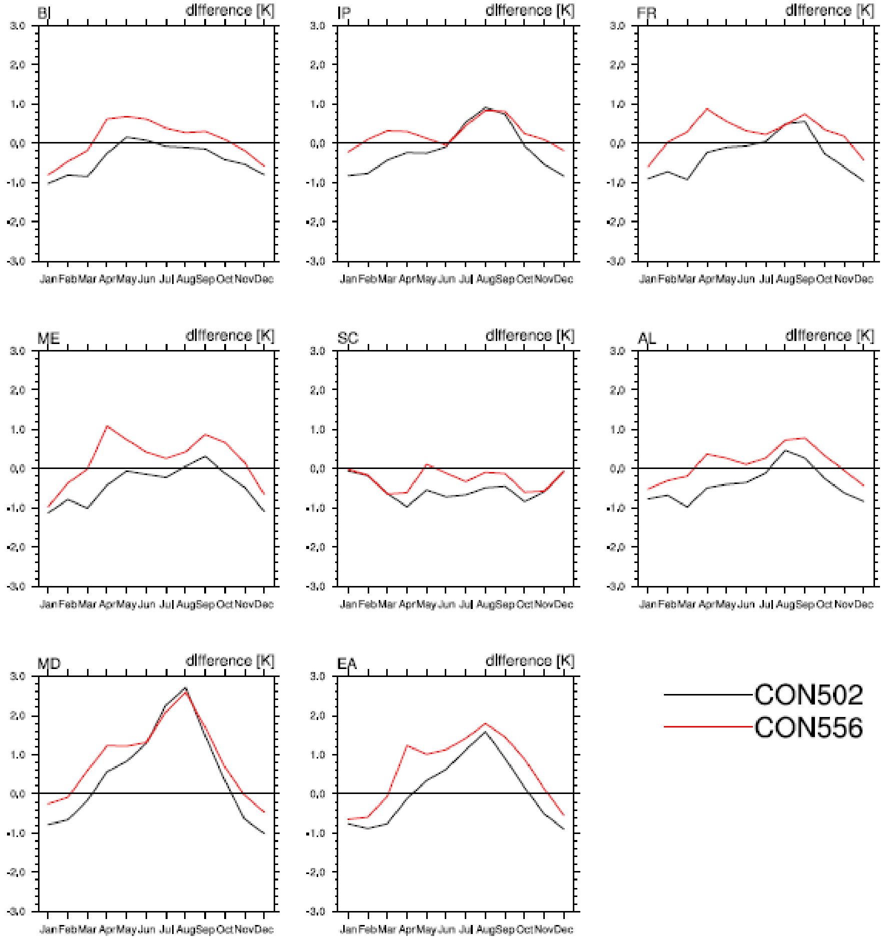
Parameter test:

Bare soil evaporation:

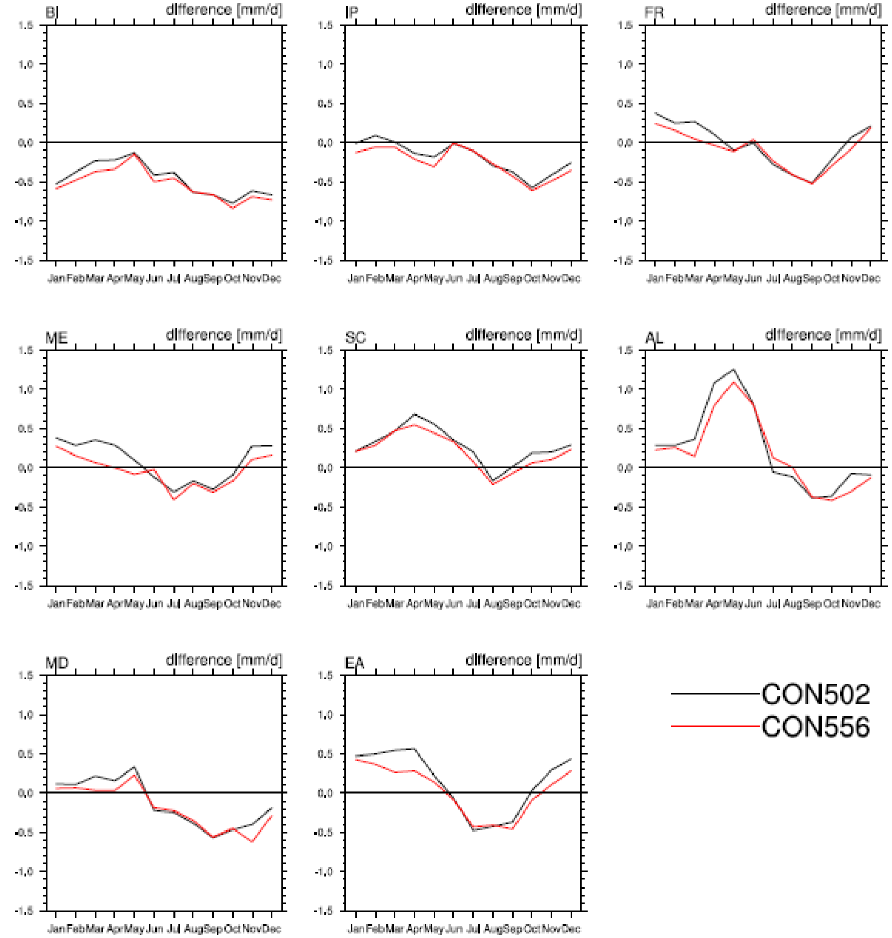
- Replace BATS by ISBA
- This reduces the bare soil evaporation

Geyer et al. (2014)

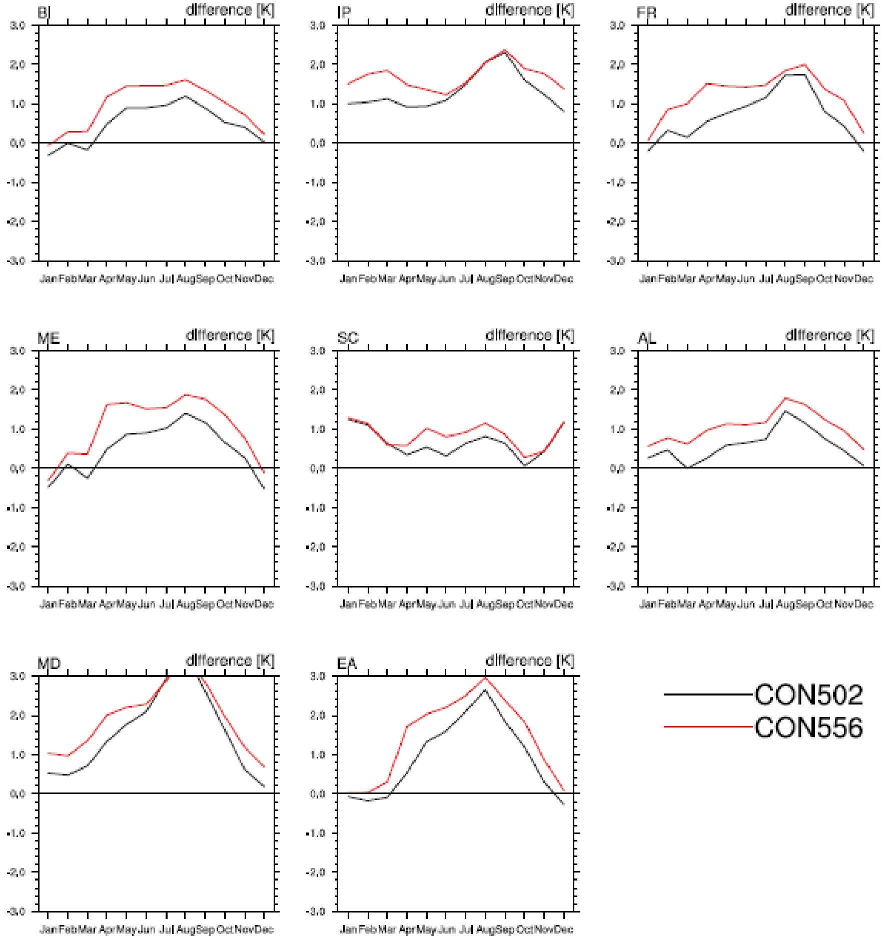
BIAS CCLM - EOBS (T_2M)



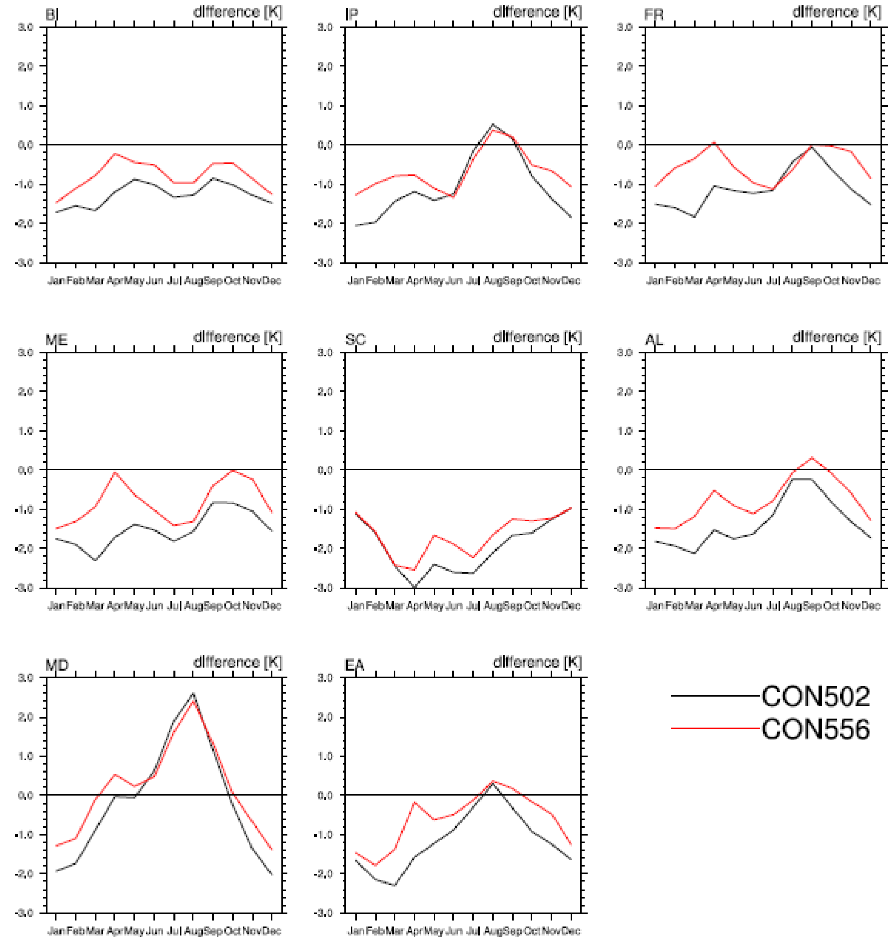
BIAS CCLM - EOBS (TOT_PREC)

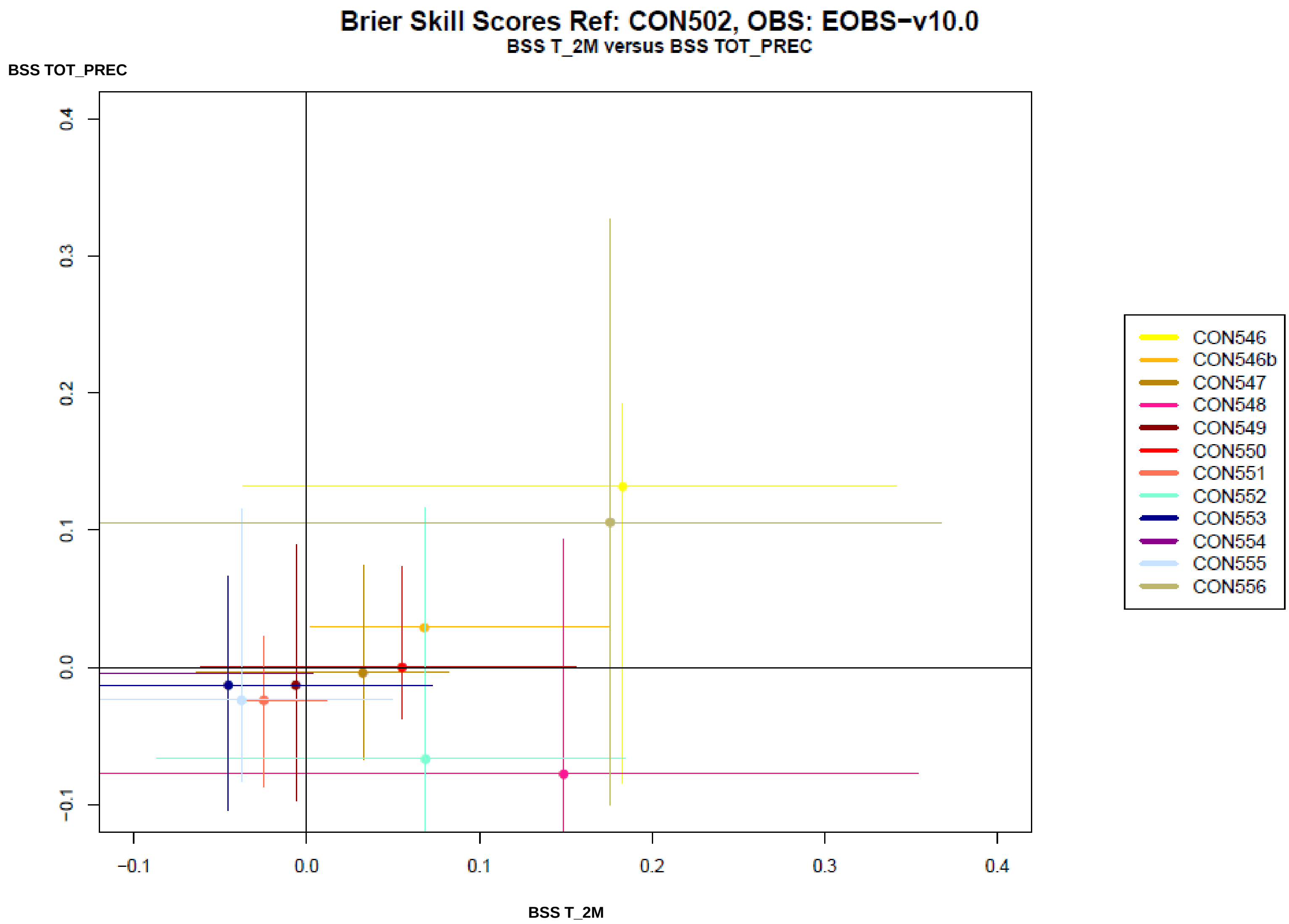


BIAS CCLM - EOBS (TMIN_2M)



BIAS CCLM - EOBS (TMAX_2M)




Brier Skill Scores Ref: CON502, OBS: EOBS−v10.0
BSS T_2M versus BSS TOT_PREC
BSS TOT_PREC
0.4
0.3
0.2
0.1
0.0
−0.1
−0.1
0.0
0.1
0.2
0.3
0.4
BSS T_2M
CON546
CON546b
CON547
CON548
CON549
CON550
CON551
CON552
CON553
CON554
CON555
CON556

Conclusions

In the experiment the parameterisation for the bare soil evaporation was changed from BATS to ISBA. This reduces the bare soil evaporation.

- 2-m temperature and total precipitation are improved on average over European domains.
- Cold and wet biases mainly in spring are reduced.
- Cold bias of maximum 2-m temperature is reduced, but warm bias of minimum 2-m temperature is enhanced.