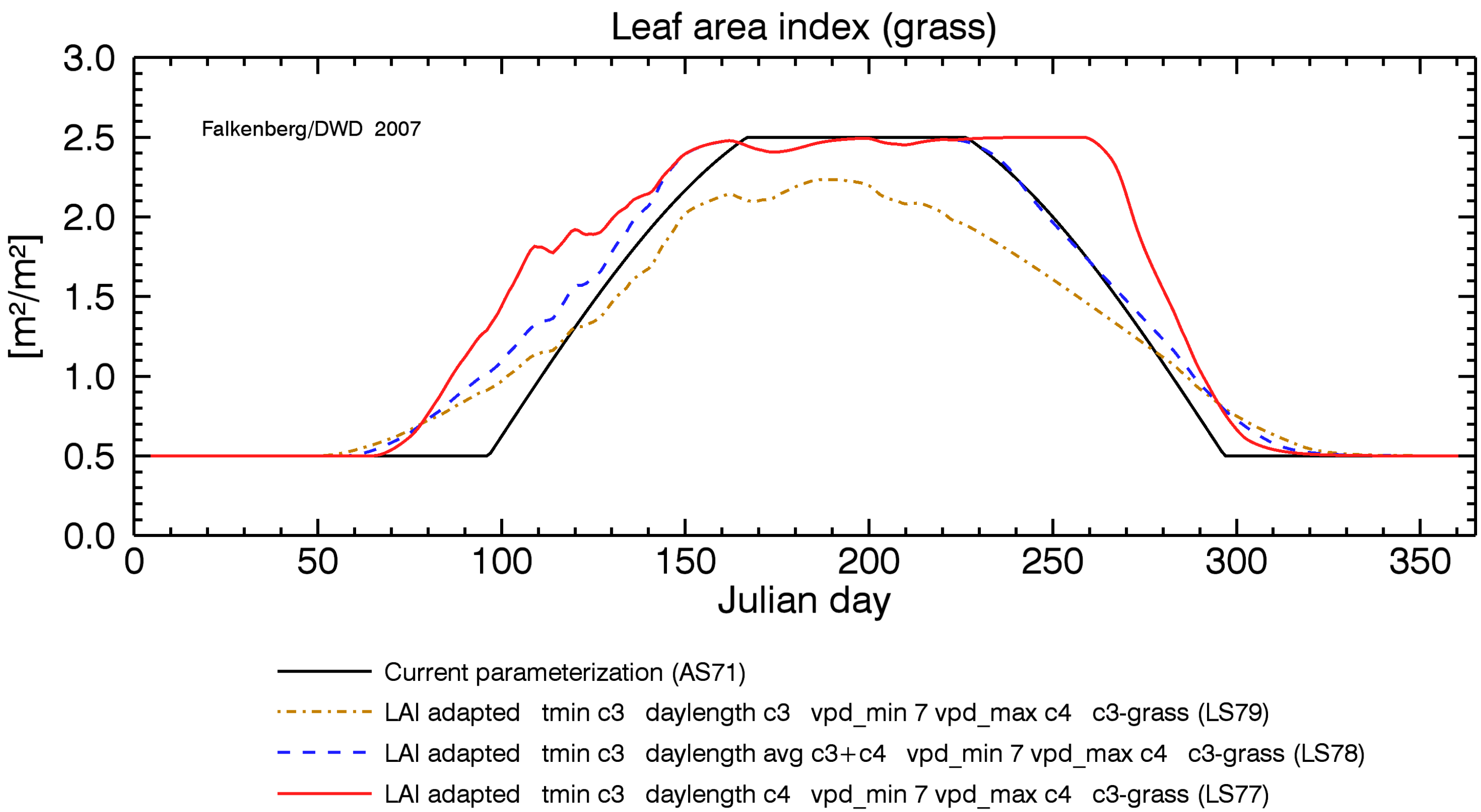
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Optical measurement of Leaf Area Index at Falkenberg site

G. Vogel, U. Rummel and J.-P.Schulz

Three variants



based on Stöckli et al. (2011)

Plant type/Land use type	LAI_Wikipedia	LAImax-GLC2009
farmland (winter)	0,2	
intensively used grassland (summer)	7	
"usual" grassland	1-2	2,5
coniferous forest	5	5
Douglas fir	10-13	
spruce	5-10	
Scots pin	3-4	
European larch tree	2-4	5
deciduous broadleaved forest		6
beech (winter)	0,2	
beech (summer)	6-8	

Motivation

- Several possibilities for assuming the daylength with distinct impact on the LAI development during early spring and in the autumn

- Available information on measured LAI values unsufficient for validating the simulated annual cycles for specific natural surfaces (e.g. grass). Satellite-based data are also not ap-propriated because they often represent area-averages of different plant kinds.

- Decision on performing own mesurements of LAI to check the reliability of the approach under local conditions

- Enlargement of our measurement program at the Boundary layer field site Falkenberg to get LAI data on a weekly basis

Boundary layer site Falkenberg/DWD

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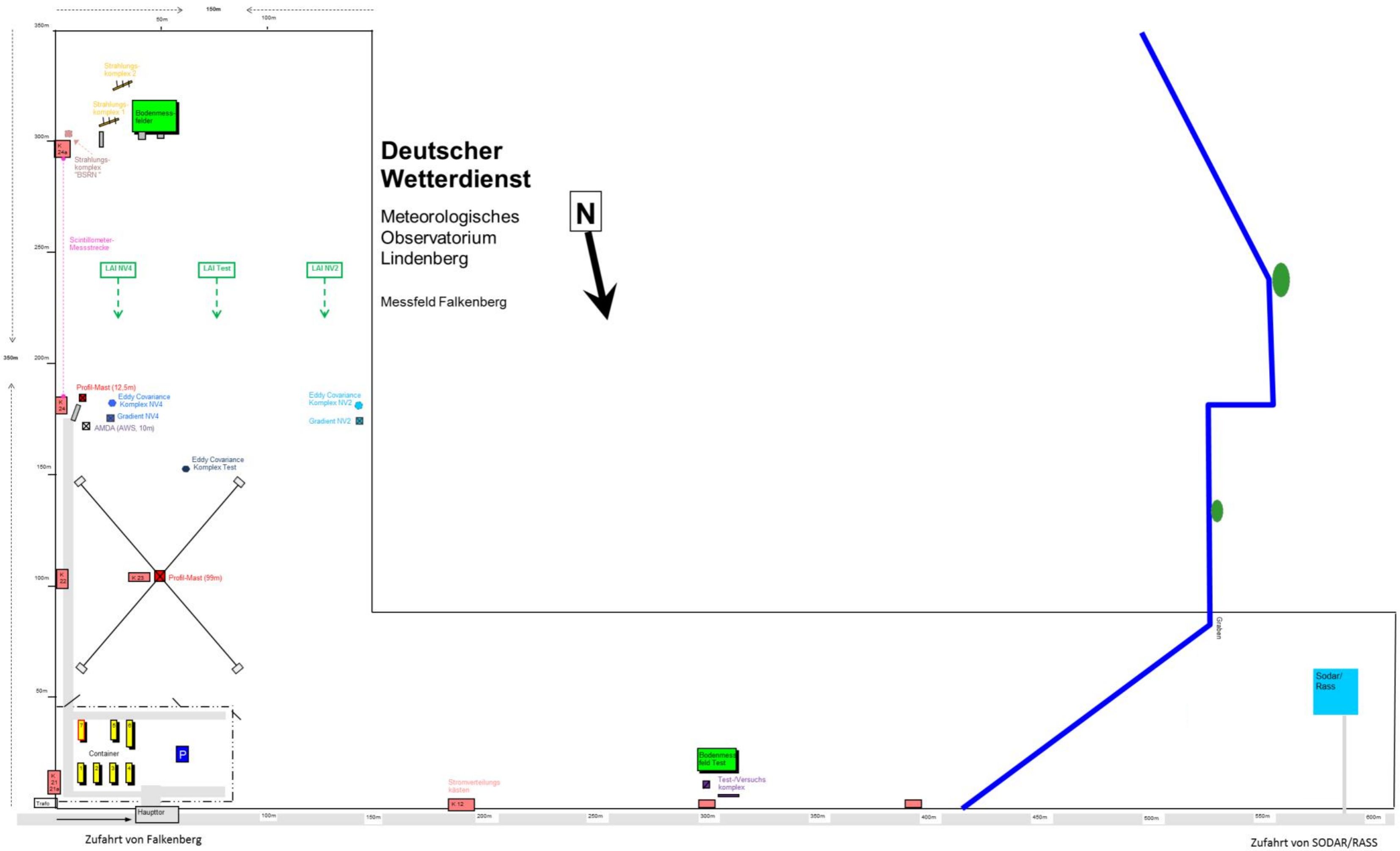
150m
50m
100m
350m
300m
250m
200m
150m
100m
50m
Strahlungs-
komplex 2
Strahlungs-
komplex 1
Bodenmess-
felder
K
24a
Strahlungs-
komplex
"BSRN"
Scintillometer-
Messstrecke
LAI NV4
LAI Test
LAI NV2
Deutscher
Wetterdienst
Meteorologisches
Observatorium
Lindenberg
Messfeld Falkenberg
N
Profil-Mast (12,5m)
K
24
Eddy Covariance
Komplex NV4
Gradient NV4
AMDA (AWS, 10m)
Eddy Covariance
Komplex NV2
Gradient NV2
Eddy Covariance
Komplex Test
K
22
K 23
Profil-Mast (99m)
Container
P
K
21
21a
Trafo
Haupttor
Zufahrt von Falkenberg
Stromverteilungs
kästen
K 12
Bodenmess
feld Test
Test-/Versuchs
komplex
Graben
Sodar/
Rass
200m
250m
300m
350m
400m
450m
500m
550m
600m
Zufahrt von SODAR/RASS

19 February 2015

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30 March 2015

23 April 2015

22 May 2015

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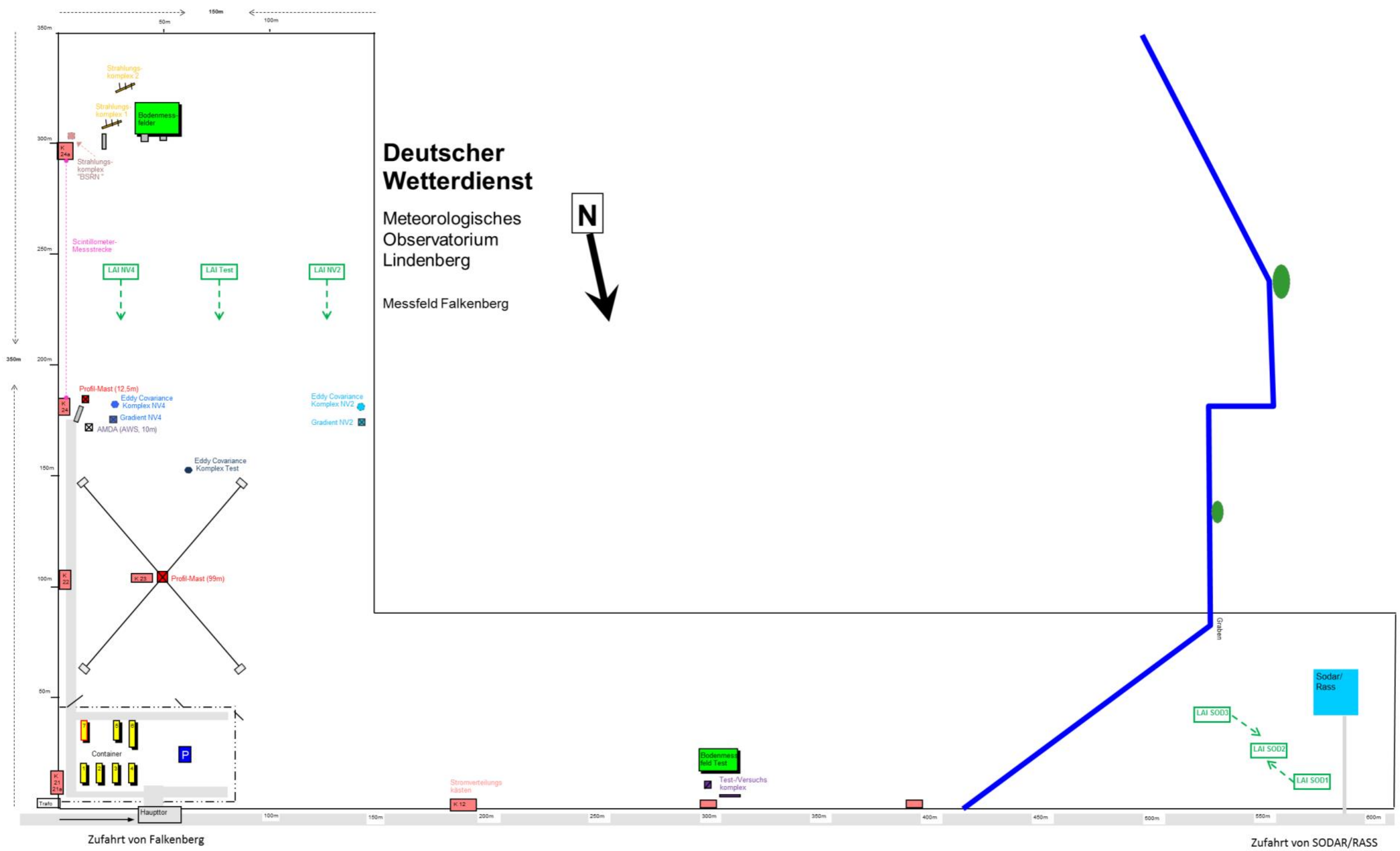
Wetter und Klima aus einer Hand

28 May 2015

Problem

- Due its regular mowning (six times a year) the grass cover at Falkenberg doesn‘t represent natural growth conditions.
- The very low canopy height of the grass cover prevailing around the year strongly impairs the measurement accuracy.
- An additional site (nearby the SODAR site) has been chosen, where the continuous growth process is not disturbed by mowning activities.


Deutscher Wetterdienst
Meteorologisches Observatorium Lindenberg
Messfeld Falkenberg
N
150m
350m
Strahlungs-komplex 2
Strahlungs-komplex 1
Bodenmess-felder
Strahlungs-komplex "BSRN"
Scintillometer-Messstrecke
LAI NV4
LAI Test
LAI NV2
Profil-Mast (12,5m)
Eddy Covariance Komplex NV4
Gradient NV4
AMDA (AWS, 10m)
Eddy Covariance Komplex NV2
Gradient NV2
Eddy Covariance Komplex Test
Profil-Mast (99m)
Container
P
Trafo
Haupttor
Zufahrt von Falkenberg
Stromverteilungs kästen
Bodenmessfeld Test
Test-/Versuchs komplex
Graben
Sodar/ Rass
LAI SOD3
LAI SOD2
LAI SOD1
Zufahrt von SODAR/RASS

SODAR-site

27 May 2015

03 June 2015

SODAR-site

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11 June 2015

Lolium perenne
(Deutsches Weidelgras)

- Species represents c3-grass (vigorous, rapid-growing, easily regenerable, responds well to the water balance)
- Flowering time from may until autumn, canopy height up to 70cm
- Dark green, shiny leaves up to 4mm broad and up to 20cm long
- Grass kind often used for robust lawn retaining its colour for a longer time.

Source: Wikipedia

Measurement device

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LAI-2000

Plant Canopy Analyzer
LI-COR, Inc.

Theoretical basics*

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Assumptions: The foliage is randomly distributed.
The foliage elements are small compared to the area of view of the instrument.

$$T(\theta,\varphi) = \exp\left(-G(\theta,\varphi)\mu S(\theta,\varphi)\right)$$

$$\overline{G}^{\varphi}(\theta)\mu = -\frac{\ln\left(\overline{T}^{\varphi}(\theta)\right)}{\overline{S}^{\varphi}(\theta)} = \overline{K}^{\varphi}(\theta) \qquad LAI = \mu z \qquad \overline{S}^{\varphi}(\theta) = \frac{z}{\cos\theta}$$

$$LAI = 2\int_{0}^{\pi/2} \overline{K}^{\varphi}(\theta)\sin(\theta)d\theta = 2\sum_{i=1}^{5} K_i w_i$$

Θ:	zenith angle
ϕ:	azimuth angle
μ:	foliage density [m²/m³]
G(θ,ϕ):	fraction of foliage projected toward (θ,ϕ)
S(θ,ϕ):	path length through the canopy
T(θ,ϕ):	probability of non-interception of a radiation beam of diffuse sky radiation (<490nm) when passing through the canopy

*Miller; J.B.:A formula for average foliage density, Aust. J. Bot., 15 (1967), 41-44

Measurement of LAI-profile

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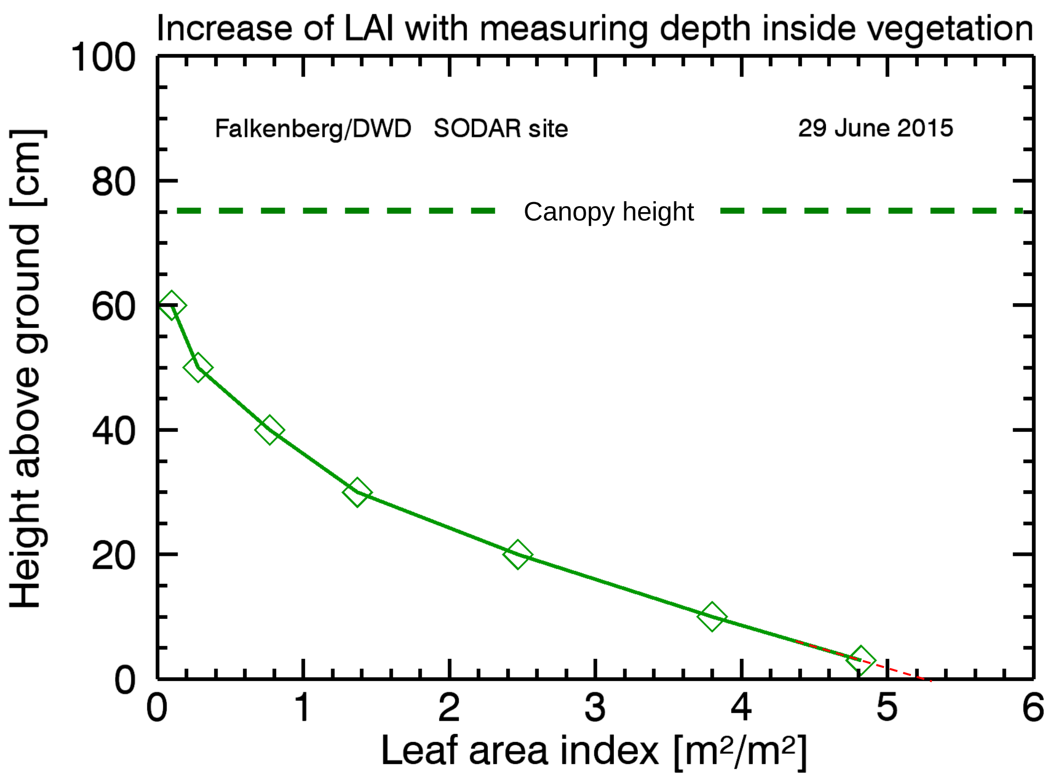

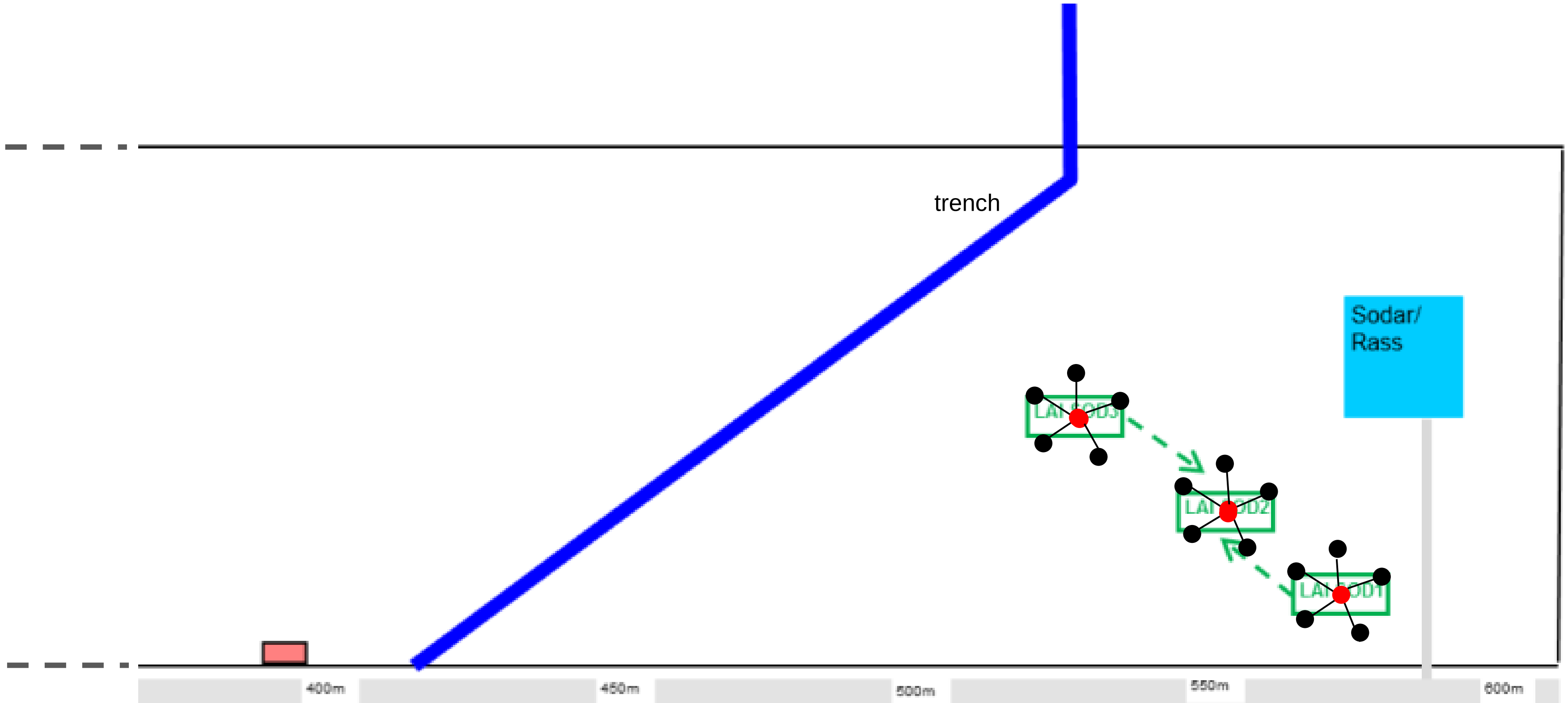
trench
Sodar/
Rass
400m
450m
500m
550m
600m

with LAI_max=6

Deutscher Wetterdienst
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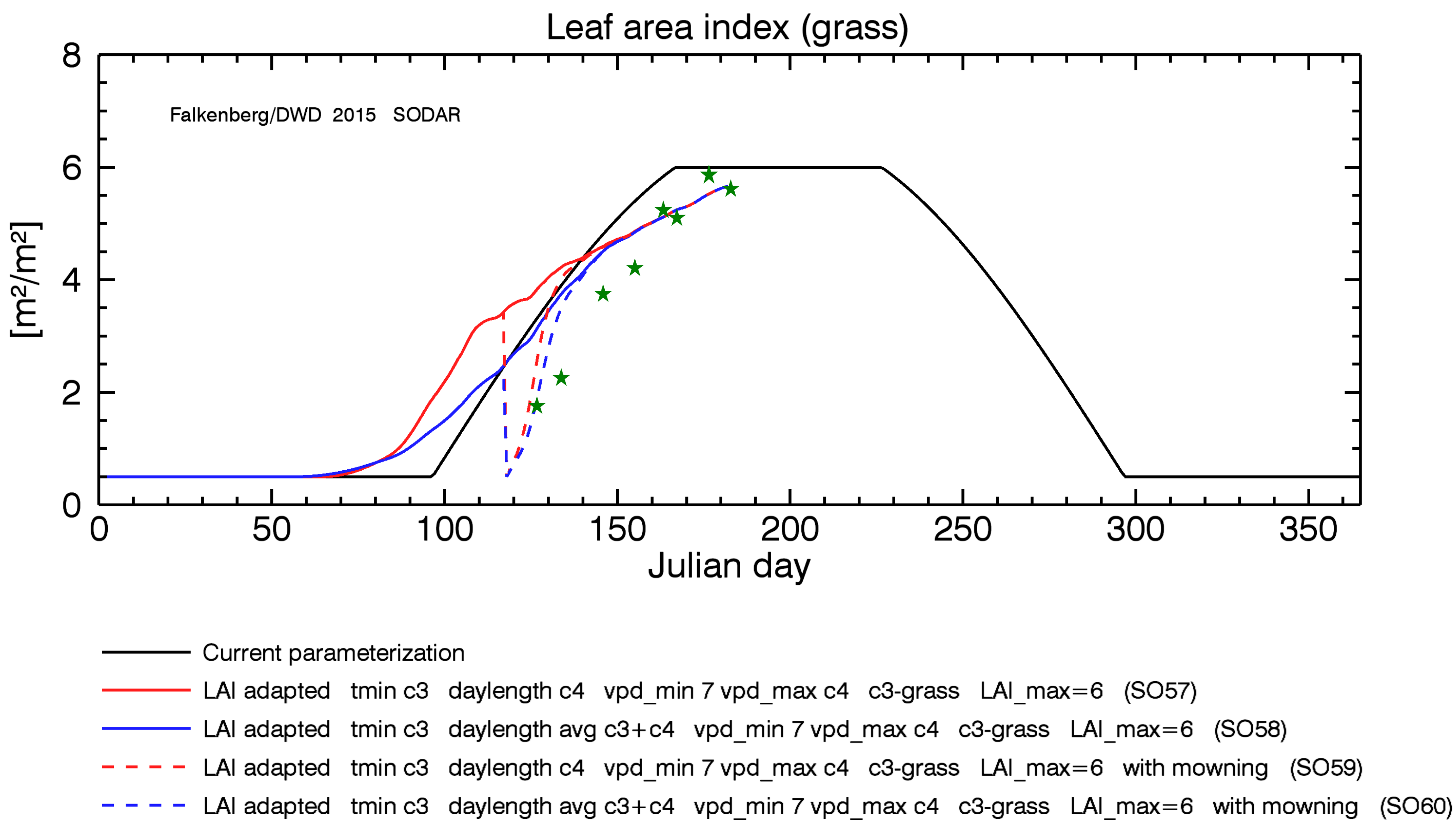
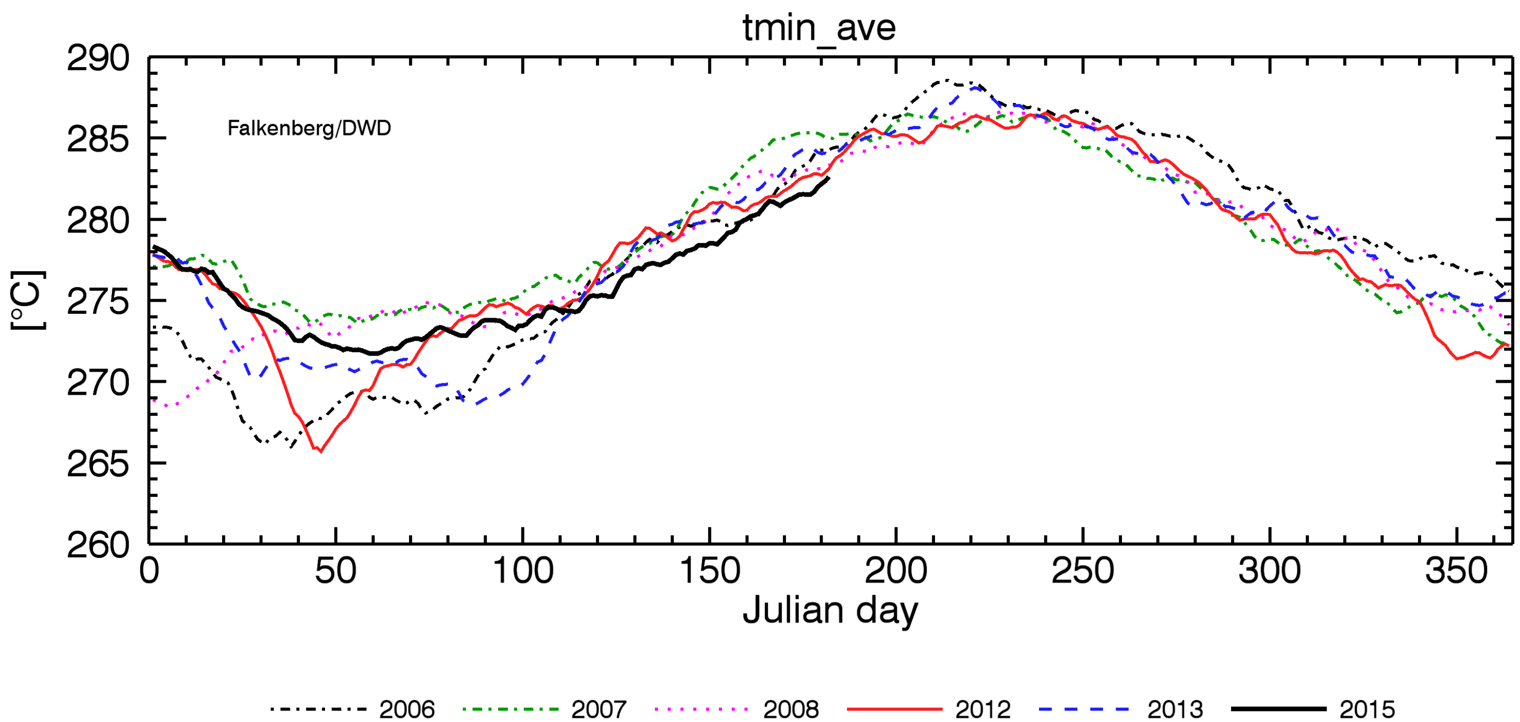
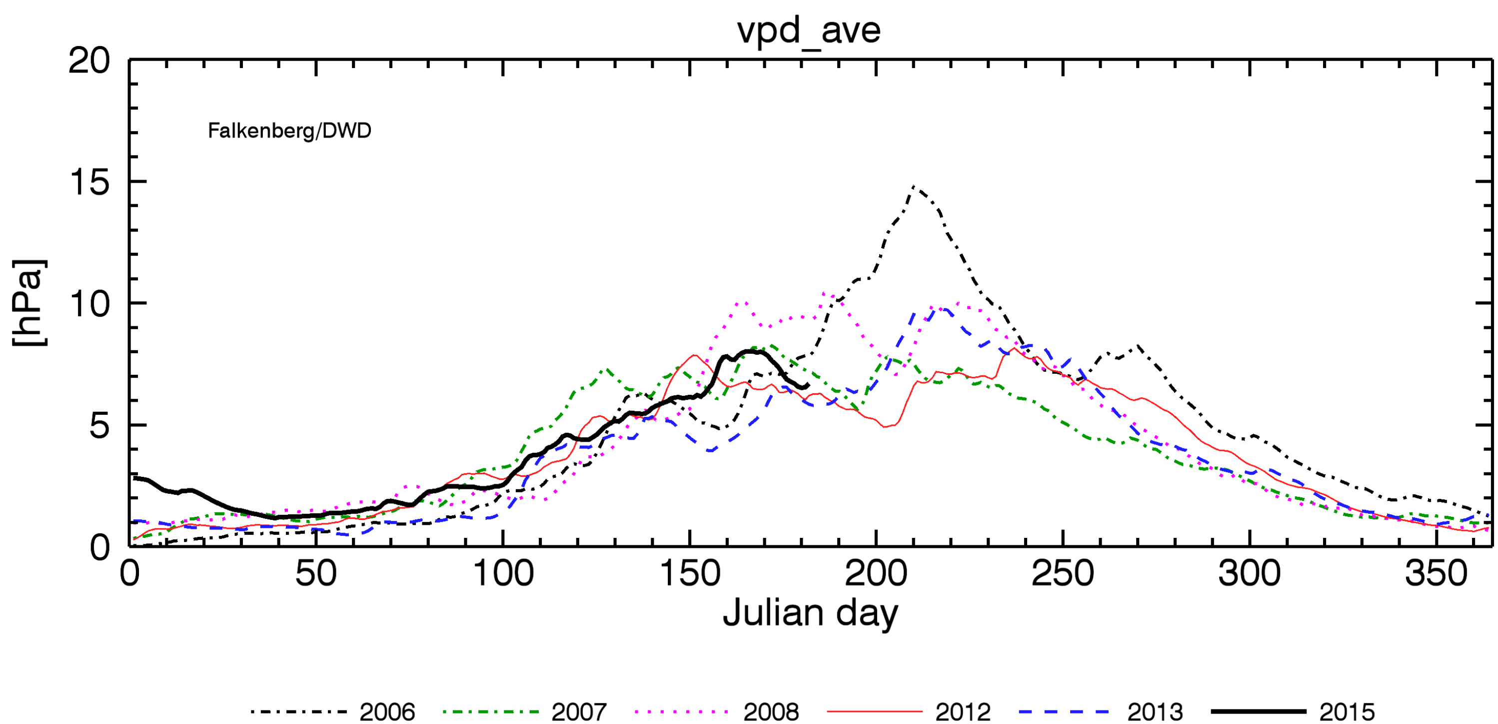
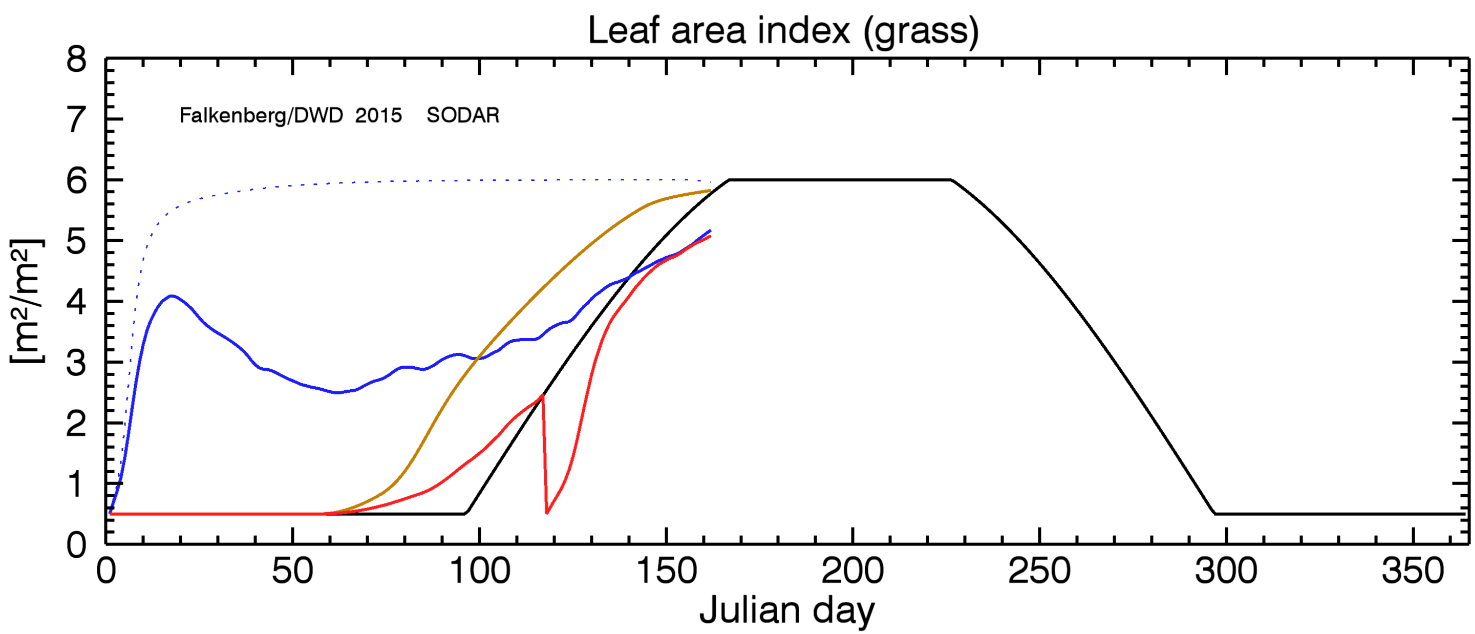


based on Stöckli et al. (2011)


tmin_ave
Falkenberg/DWD
[°C]
290
285
280
275
270
265
260
0
50
100
150
200
250
300
350
Julian day
2006
2007
2008
2012
2013
2015

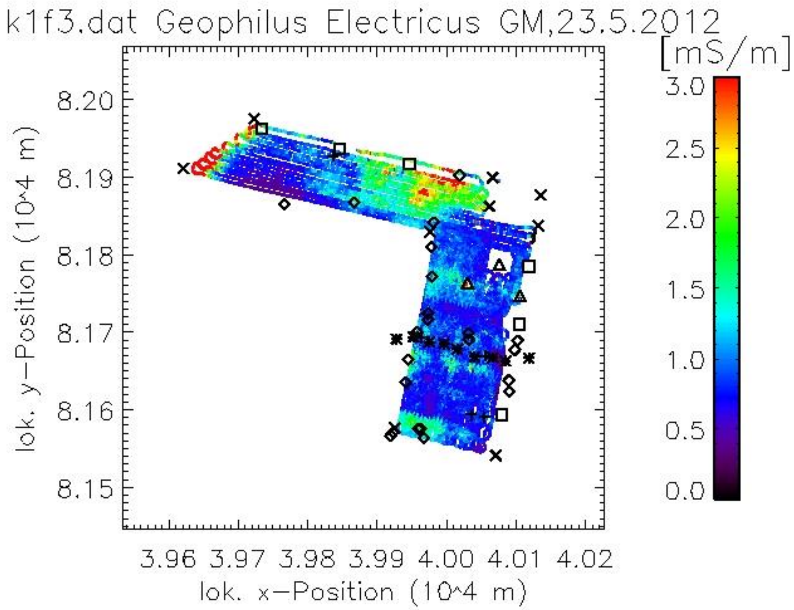

vpd_ave
Falkenberg/DWD
[hPa]
20
15
10
5
0
0
50
100
150
200
250
300
350
Julian day
2006
2007
2008
2012
2013
2015

with LAI_max=5

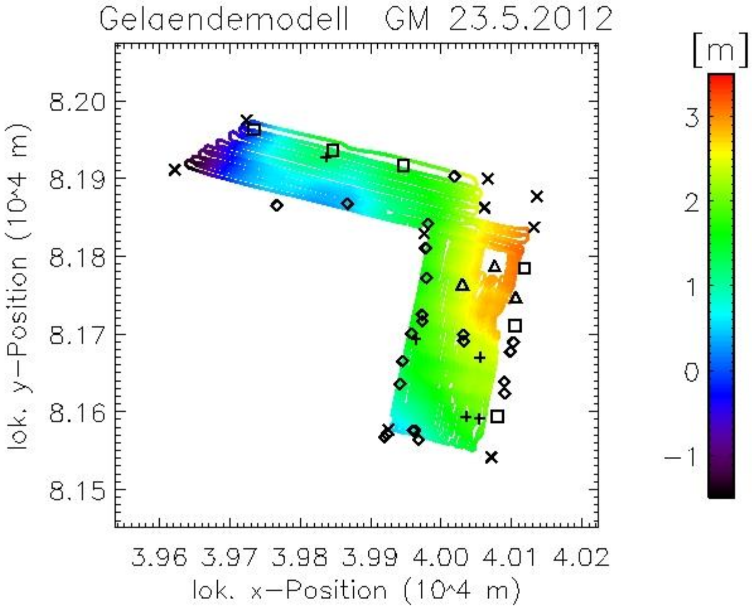


Current parameterization
LAI adapted tmin c3
LAI adapted daylength (avg c3+c4)
LAI adapted vpd (vpd_min 7 vpd_max c4)
LAI adapted all stress factors (tmin daylength vpd)

based on Stöckli et al. (2011)

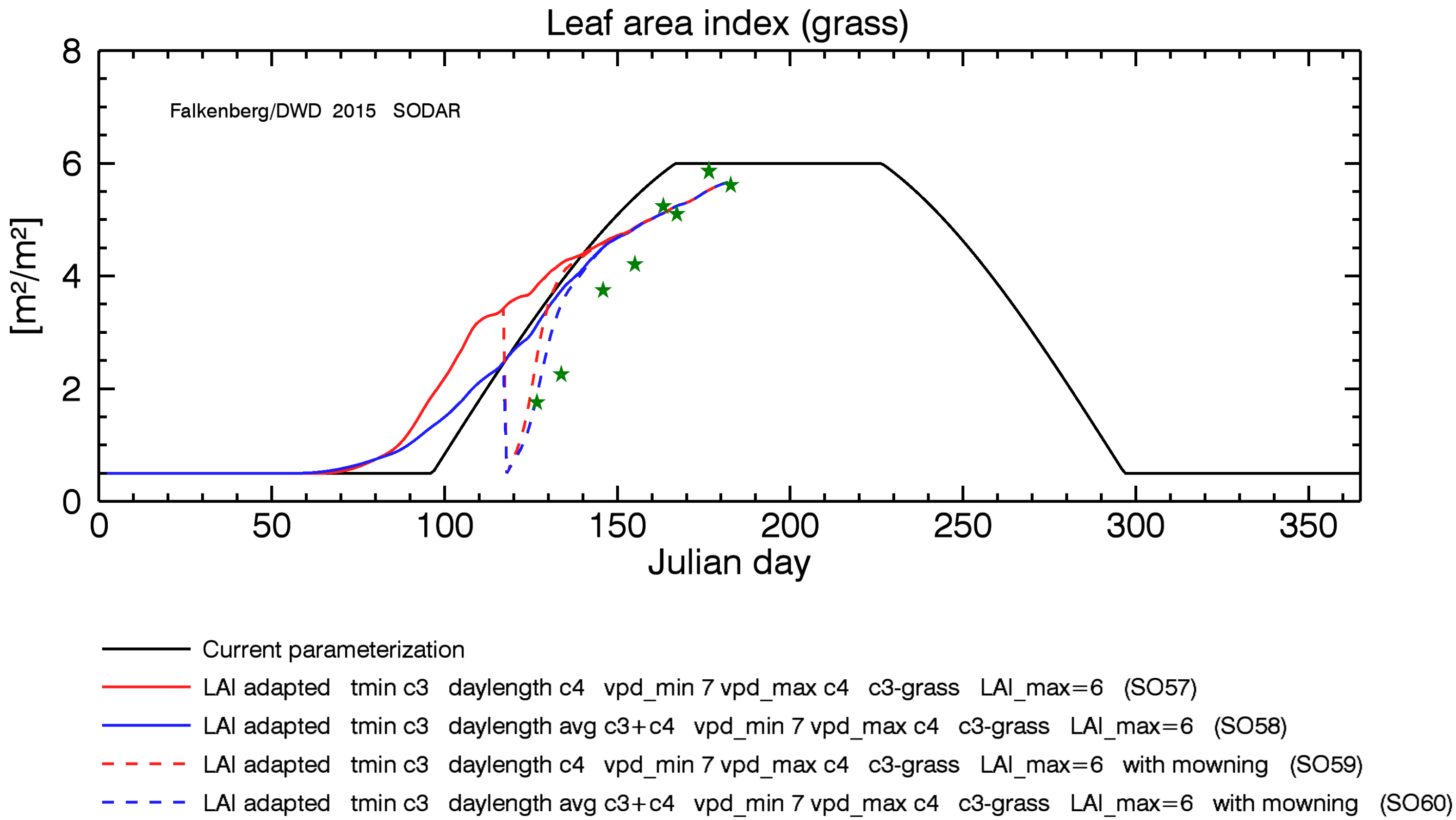


Distribution of electric soil conductivity



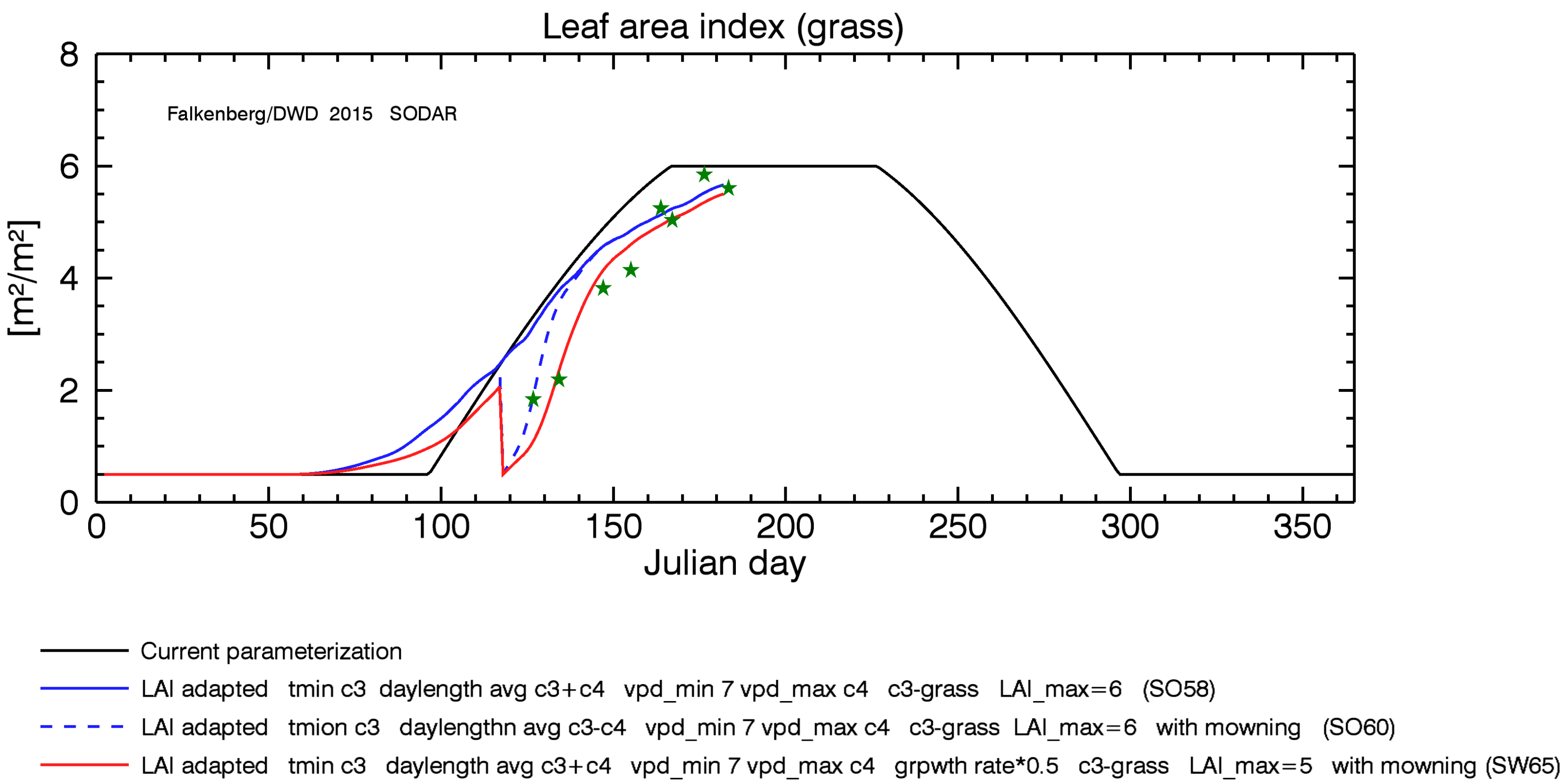
Relative topography of Falkenberg site

with LAI_max=6



based on Stöckli et al. (2011)

with LAI_max=6 and halved growth rate



based on Stöckli et al. (2011)

We saw:

- For an optimal fit to the LAI measurements over natural grass cover the parameterization needs a reliable maximum value. Such a value should exclude, however, any temperature stress. Therefore, long-term mea-surements are required over several years.

- First offline studies yield already encouraging results during spring and summer.

- The mowning at end of April enabled to measure the LAI over the whole growth phase. This shows: the approach is fairly diagnostically dominated and the growth rate somewhat overestimated.

- The decision which daylength produces the most realistic LAI cycle can only be made, however, if the mea-surement data from the coming au-tumn and next spring will be available.

Dilemma

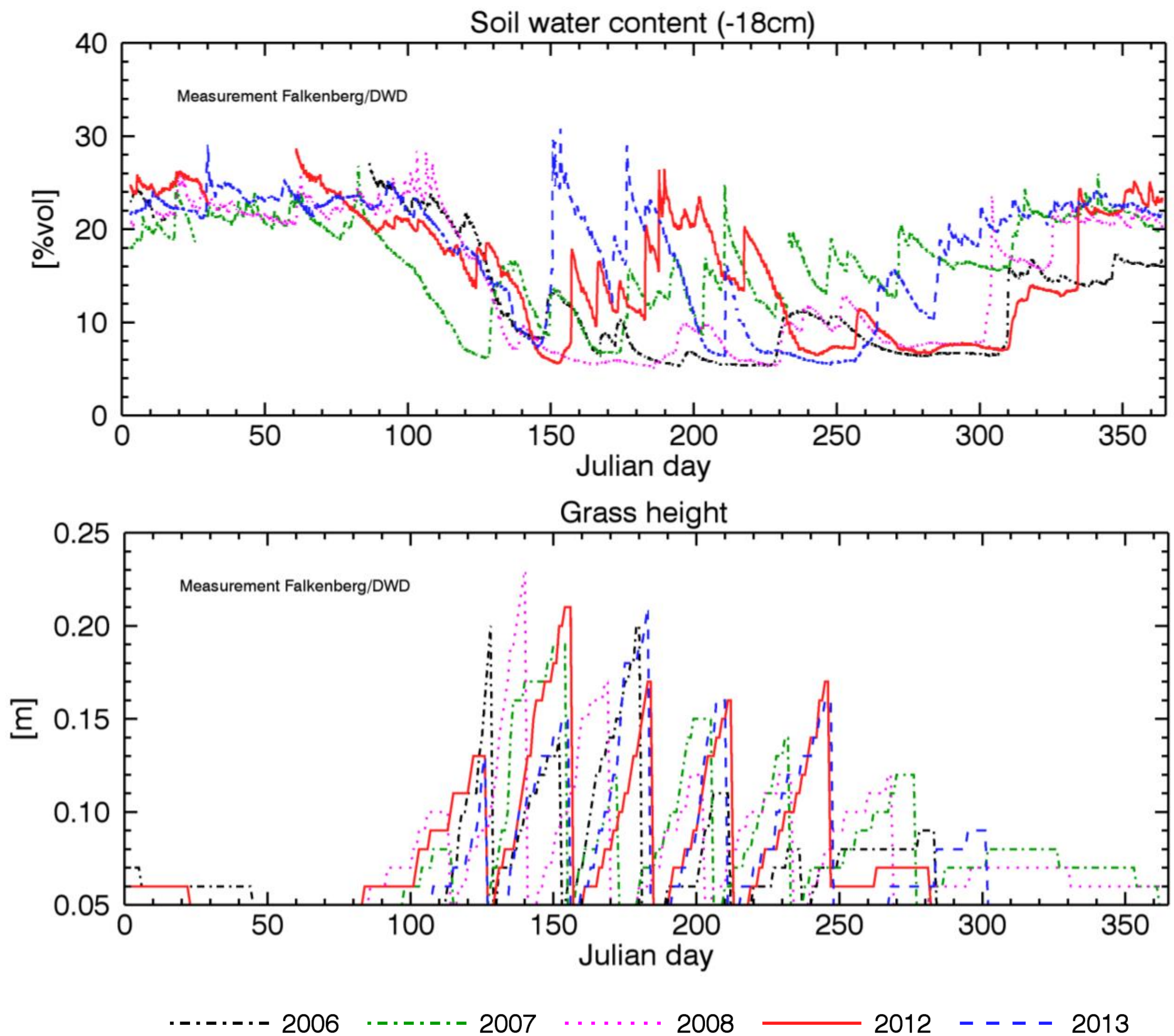
- **On the one hand**, a lot of measurements carried out at the Falkenberg site is used for manifold forcing and validation purposes, but the LAI cannot be measured continuously, because the canopy height is often too low. It is, however, needed in various parameterizations.

- **On the other hand,** an additional measurement program has been set up to measure the annual cycle of the LAI at SODAR site, but no other meteoro-locical quantities are available from here.

- **Conclusion**: use the SODAR-site measurements for estimating the needed LAI time series at the Falkenberg site.

Fotunately,

weekly measurements of the grass canopy height available from the Falken-berg site over the last 10 years


Soil water content (-18cm)
Measurement Falkenberg/DWD
[%vol]
40
30
20
10
0
0
50
100
150
200
250
300
350
Julian day
Grass height
Measurement Falkenberg/DWD
[m]
0.25
0.20
0.15
0.10
0.05
Julian day
2006
2007
2008
2012
2013

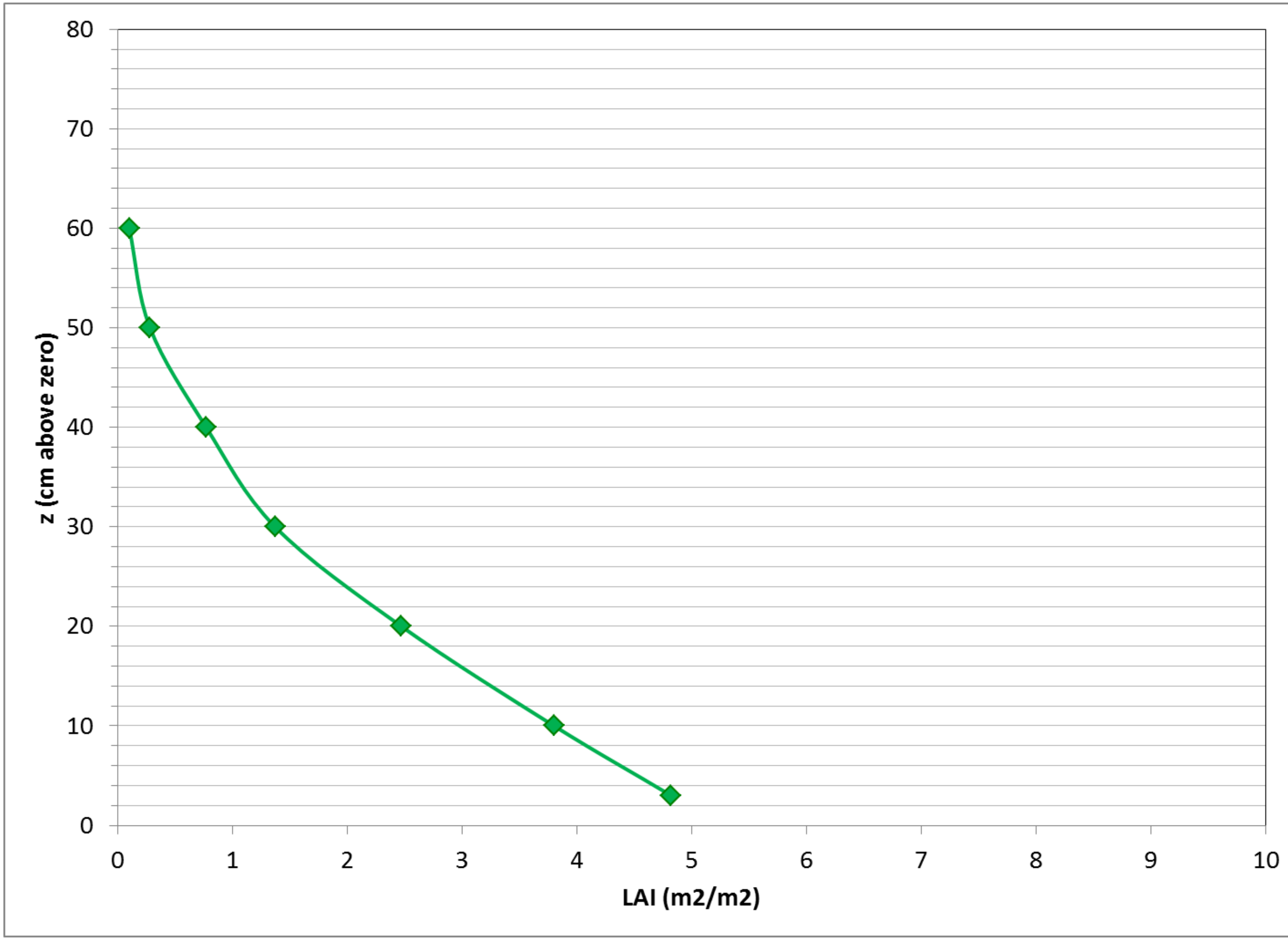
How to do this?

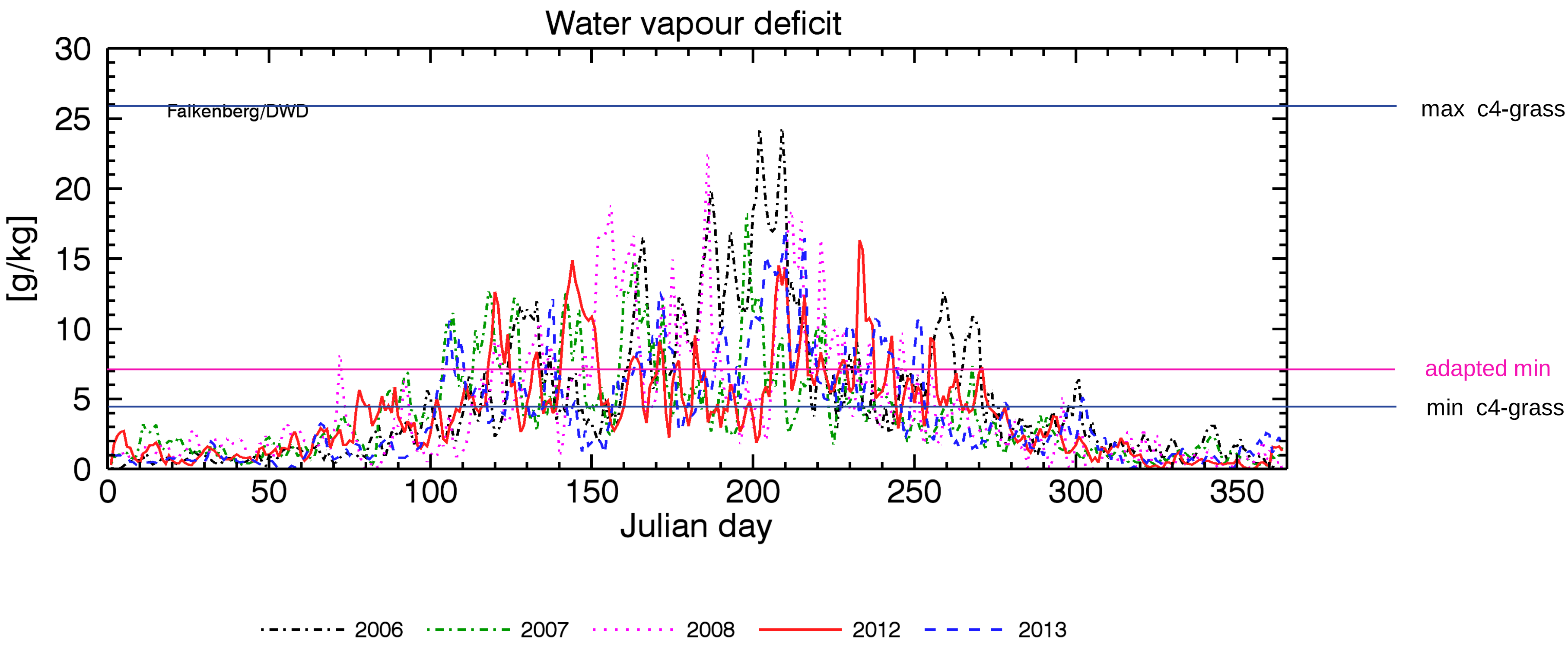
- Measure the canopy height at SODAR site (first measurements already have been taken)
- Try to establish regression relationships between LAI and h as soon as the data basis will enable any statistitcal treatment (after some years).
- Applicate this relationship to estimate the LAI time series over the last 10 years for use in offline validation studies instead to parameterize them with a lot of uncertainties (e.g. growth also depends on temperature and soil moisture).
- Accuracy and consistency checks by comparisions with measured LAI values (if larger canopy height are obtained shortly before mowning), photosynthetically active radiation data and CO_2-fluxes as well

Conclusions

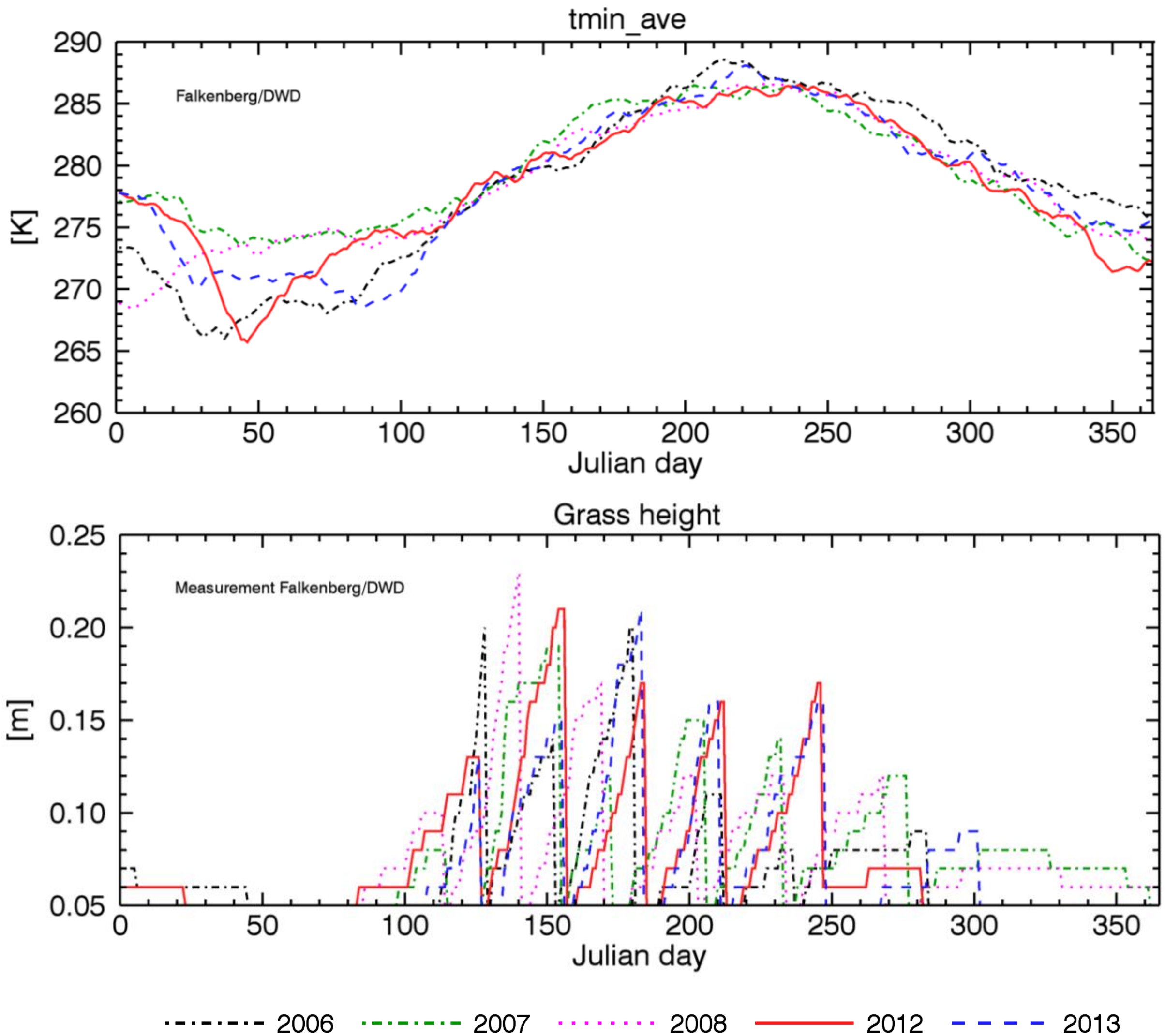
- LAI represents an important quantity for simulating transpiration, shading and prescribing the plant cover as well
- Current parameterization (sinus approach) unappropriate (no plant-specific approximation as needed e.g. for tile approach, no dependency on pre-ceding weather development, no separate stress factors)
- Stöckli approach well appropriate to simulate the annual cycle of LAI for grass cover under natural growth conditions
- A local-referred parameter tuning against in-situ measurements will only possible if a sufficiently large data base is available in future


Thank you for your attention!


80
70
60
50
40
30
20
10
0
z (cm above zero)
0
1
2
3
4
5
6
7
8
9
10
LAI (m2/m2)



based on Stöckli et al. (2011) adapted LAI daylength vpd c3-grass


tmin_ave
Falkenberg/DWD
[K]
290
285
280
275
270
265
260
0
50
100
150
200
250
300
350
Julian day
Grass height
Measurement Falkenberg/DWD
[m]
0.25
0.20
0.15
0.10
0.05
0
50
100
150
200
250
300
350
Julian day
2006
2007
2008
2012
2013

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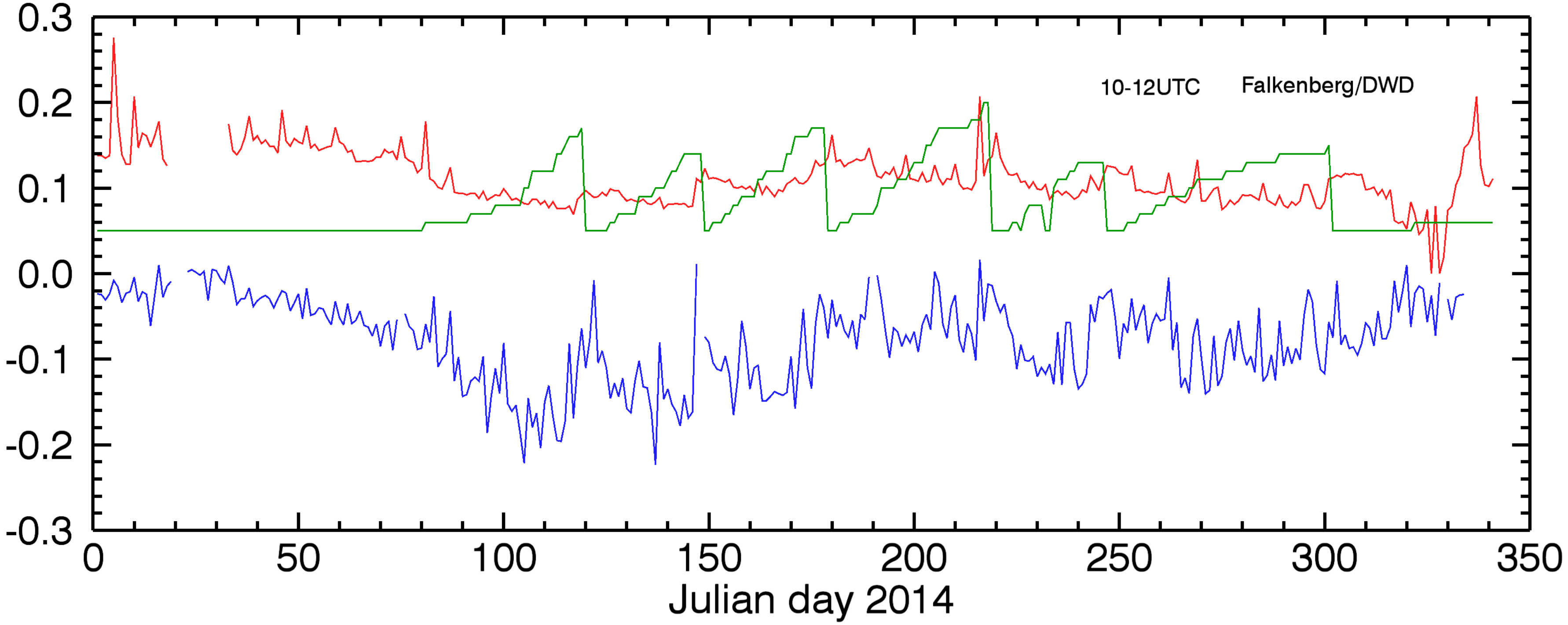
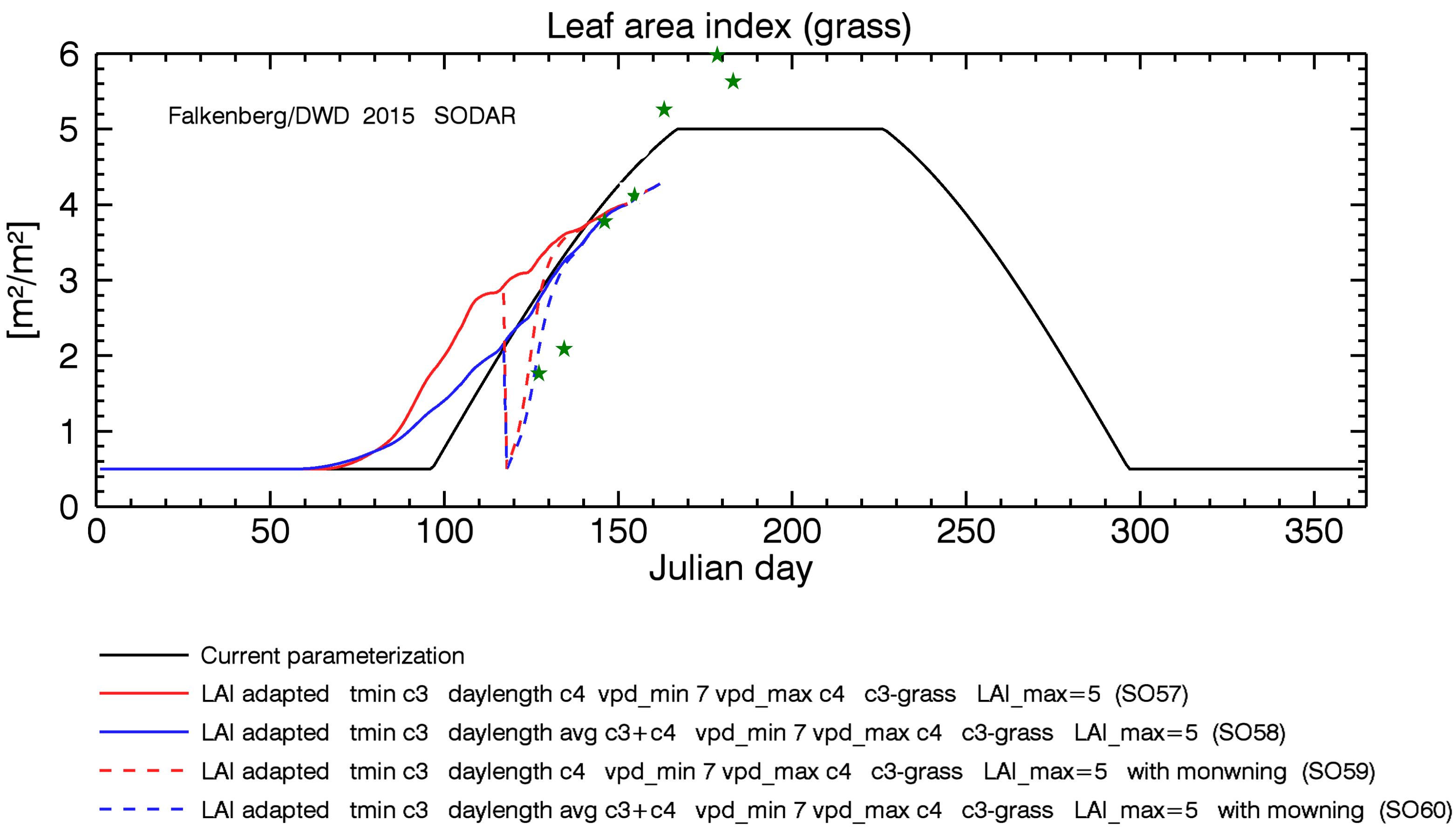
->analog für 2015 mit LAI

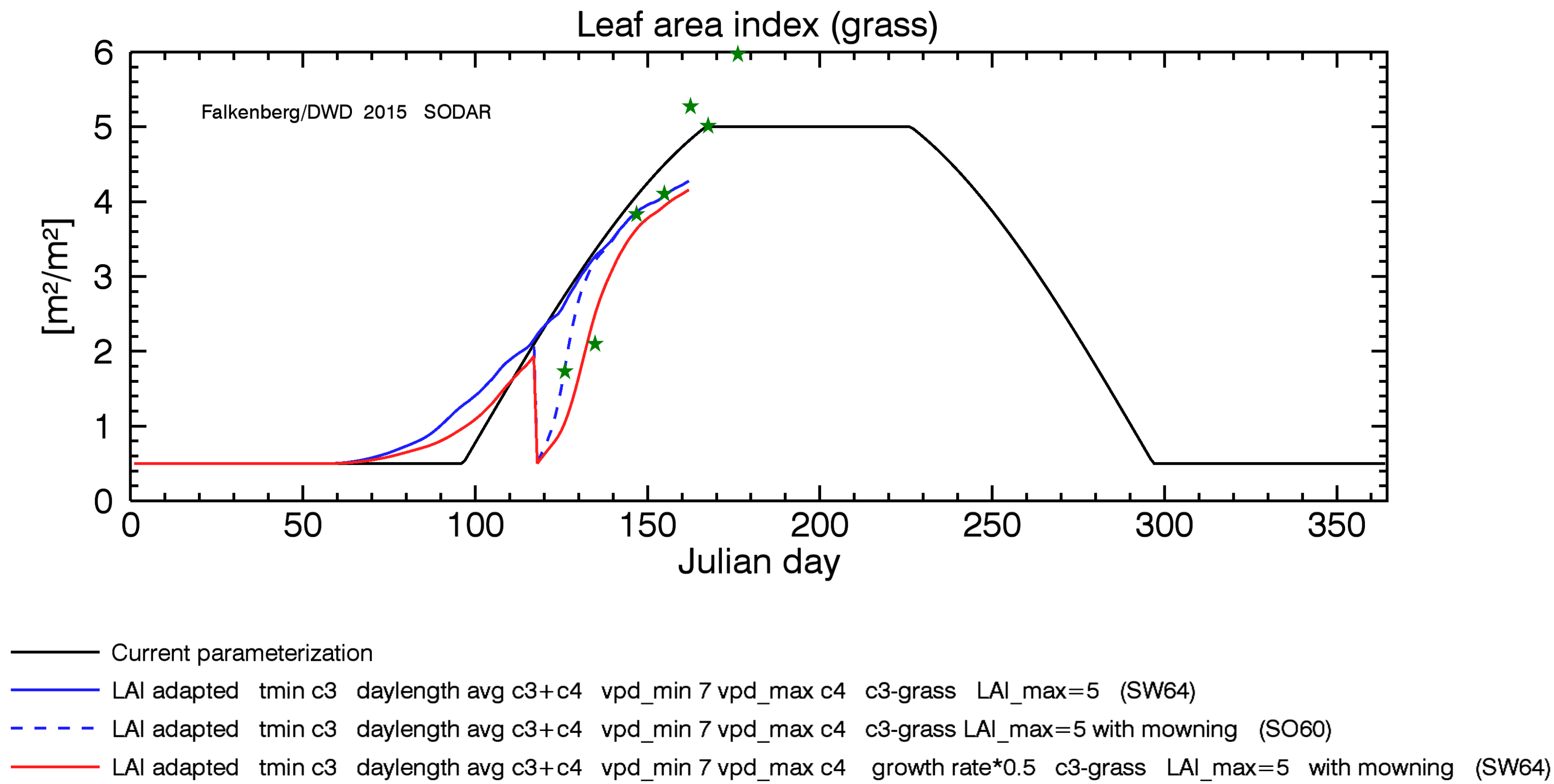


with LAI_max=5

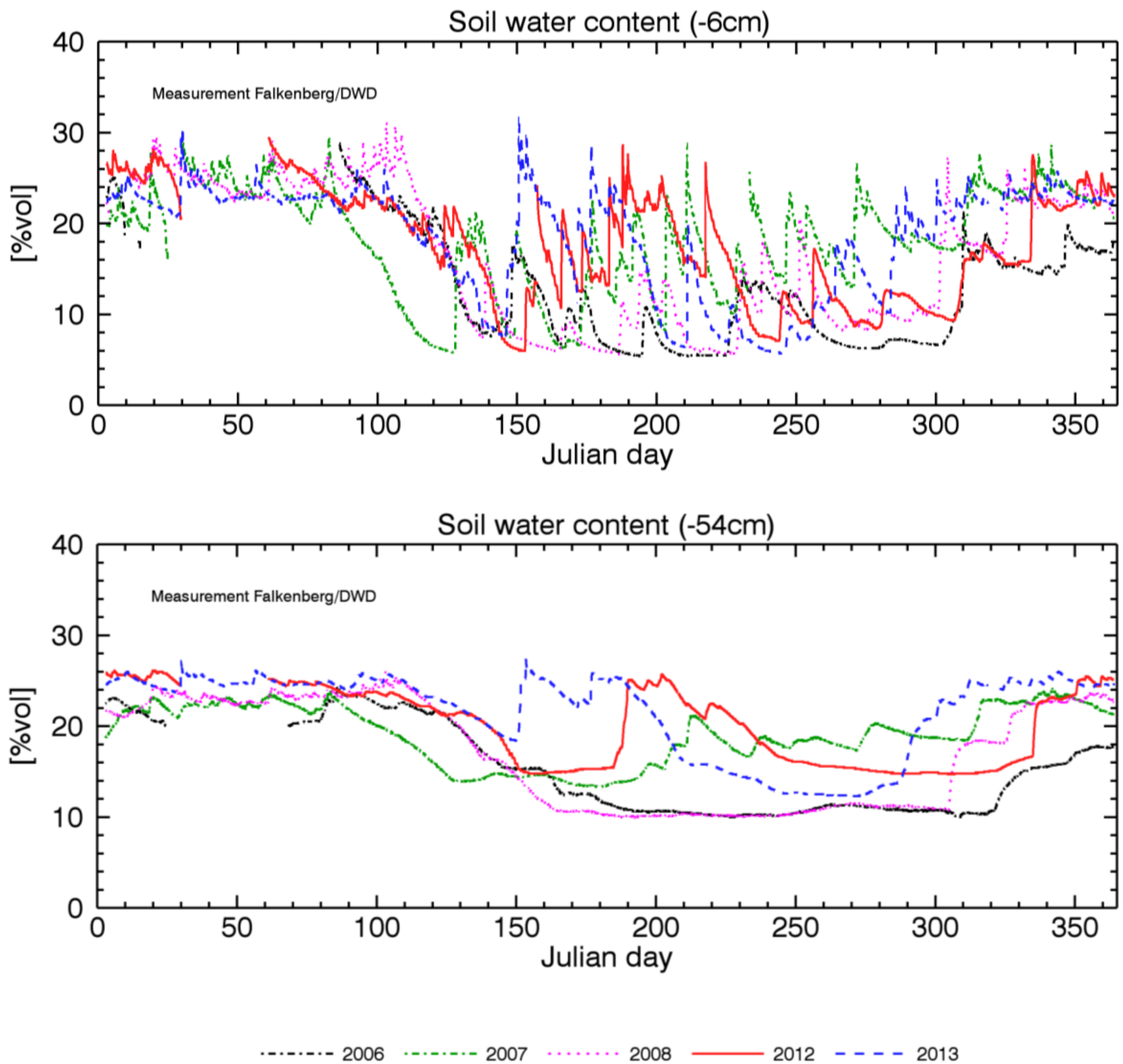


based on Stöckli et al. (2011)

with LAI_max=5 and halved growth rate



based on Stöckli et al.(2011)


Soil water content (-6cm)
Measurement Falkenberg/DWD
[%vol]
Julian day
Soil water content (-54cm)
Measurement Falkenberg/DWD
[%vol]
Julian day
2006
2007
2008
2012
2013

29 Januay 2015 Radiation site

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

19 March 2015