# Latest news about

# *PT VAINT*

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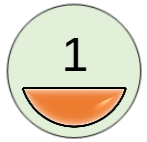
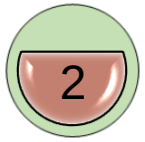
# Relevance of PT VAINT




## COSMO-CLM v5.16

- ✓ Uses the simplified Jarvis-Stewart approach with BATS parametrization for calculations of stomatal resistance
- ✓ Applies highly simplified dependencies, for which the leaf photosynthesis and $CO_2$ uptake cannot be calculated




## COSMO-CLM v5.16

- ✓ Neglects any influence or feedback on the environmental conditions (no connection to the biogeochemical cycle via photosynthesis, no plant growth).
- ✓ Does not consider the influence of atmospheric $CO_2$ concentration

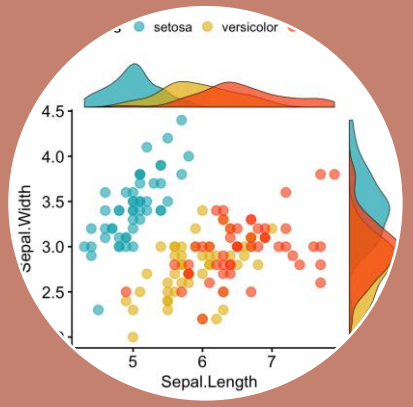

## COSMO-CLM v5.16

- ✓ Uses the phenology cycle based on a 6-year climatology and follows the same sinusoidal fitted curve between its maximum and minimum values

# Project tasks

## Developing the new algorithms for:

- Stomatal resistance
- Leaf photosynthesis
- Two-big leaf
- Leaf area index




## Validating experiment results:

- at stations
- at COSMO-CLM grid

## Writing the documentation and articles:

More information:
https://github.com/users/merajtoelle/projects/

# Model experiments

*COSMO-CLM v5.16* – Regional climate model of the Consortium for Small-Scale Modelling

*CLM 3.5, CLM 4.5* – Community Land Model


**CCLMref**

- ***Jarvis-Stewart*** approach with BATS model parameterization scheme
- Does not consider stomatal regulation and vegetation growth depending on atmospheric $CO_2$ concentrations

**CCLMv3.5**

- ***Ball-Berry*** approach coupled with leaf photosynthesis and calculating separately for sunlit and shaded leaves. (**CLMv3.5**)
- Night-time values of stomatal resistance is equal to 20.000 s $m^{-1}$

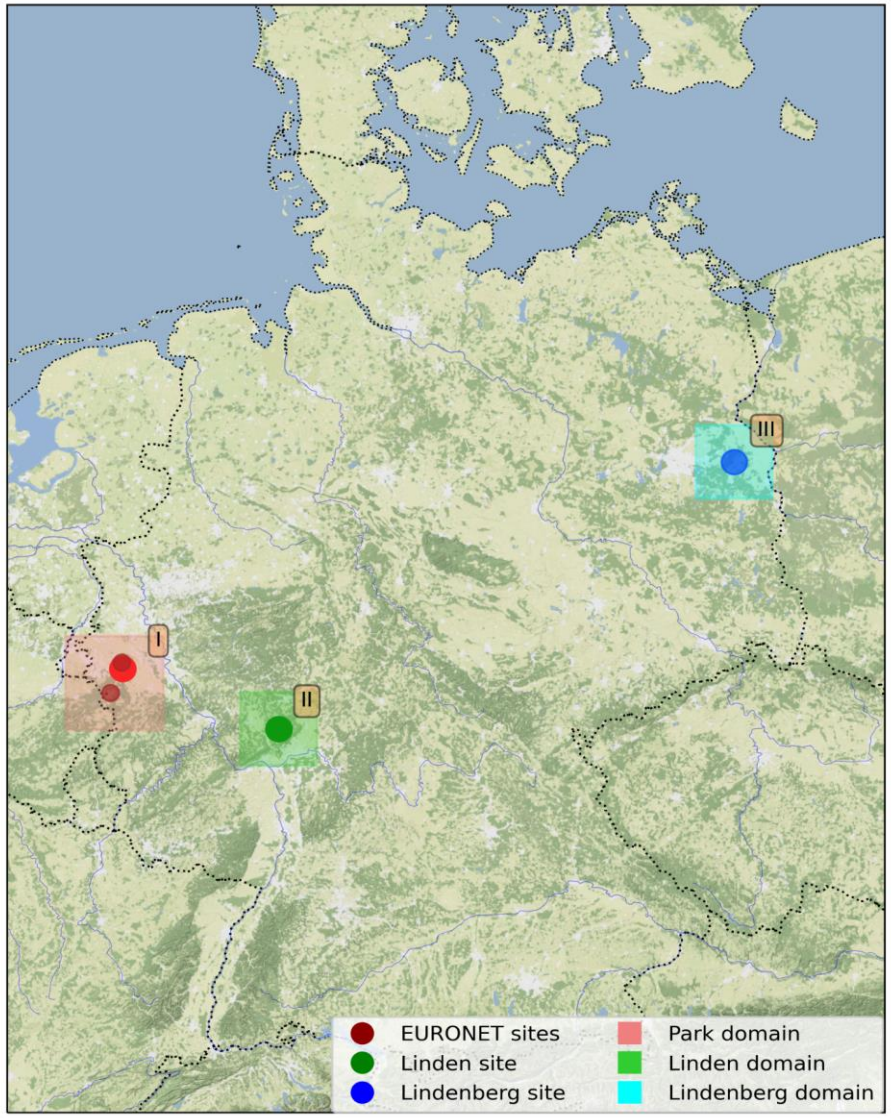
**CCLMv4.5**

- ***Ball-Berry*** approach coupled with leaf photosynthesis and calculating separately for sunlit and shaded leaves. (**CLMv4.5**)
- Night-time values of stomatal resistance is controlling by available soil water

**CCLMv4.5e**

- ***Ball-Berry*** approach coupled with leaf photosynthesis and calculating separately for sunlit and shaded leaves. (**CLMv4.5**)
- Night-time values of stomatal resistance is controlling by available soil water
- Additional changes in calculations of transpiration from dry leaf surfaces

# Research domains




***COSMO-CLM parameters:***

- Time increment: 25 s
- Spatial resolution: 0.0275° ~ 3 km
- Grid size: 25 * 25
- Numbers of vertical atmospheric layers: 50
- Numbers of soil layers: 9

**Verification parameters:**

- AEVAP, $ALHFL_{PL}$, $ALHFL_S$, $ASHFL_S$, $QV_{2M}$, $QV_S$, $T_{2m}$, $T_S$, $T_{max}$
- $T_{min}$, PS, $RELHUM_{2M}$ , ZTRALEAV, ZVERBO, RSTOM

**Data for comparisons:**

- HYRAS, GLEAM datasets ($T_{2m}$, $T_S$, $T_{max}$, $T_{min,}$ AEVAP, ZVERBO)
- EURONET, FLUXNET, TRY
- TERENO, Linden and Lindenberg sites information

- Stomatal resistance, leaf photosynthesis and two-big leaf algorithms

# Stomatal resistance algorithm

## CCLMref

The Jarvis-Stewart approach with BATS model parameterization scheme:

$$g_{st}^{can} = \frac{1}{r_{max}} + \left(\frac{1}{\mathrm{r_{min}}} - \frac{1}{\mathrm{r_{max}}}\right)[\mathrm{F_{rad}F_{wat}F_{tem}F_{hum}}]$$

$\mathrm{F_{rad}}$, $\mathrm{F_{wat}}$, $\mathrm{F_{tem}}$, $\mathrm{F_{hum}}$ – environmental stress functions (photosynthetic active radiation, soil water content, ambient temperature and specific humidity)

$r_{max}$, $r_{min}$ – maximal and minimal stomatal resistance

## CCLMv3.5; CCLMv4.5; CCLMv4.5e

The Ball-Berry approach coupled with processes of leaf photosynthesis

$$g_{st}^{can} = g_{st}^{sun}\mathrm{L^{sun}} + g_{st}^{sha}\mathrm{L^{sha}}$$

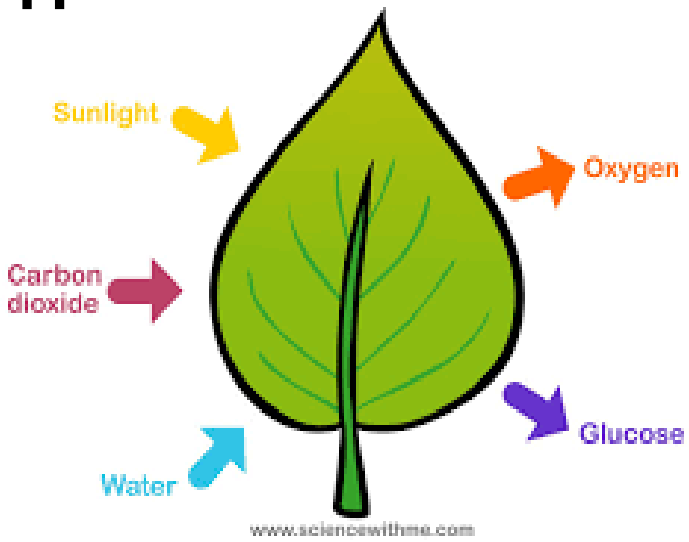
$$g_{st}^{sun,sha} = \frac{1}{r_s^{sun,sha}} = m\frac{A^{sun,sha}e_s}{c_s e_i}P_{atm} + \boldsymbol{bF_{wat}}$$

$\mathrm{r_s^{sun,\,sha}}$, $\mathrm{g_{st}^{sun,\,sha}}$ – stomatal resistance and conductance for sunlit and *shaded* leaves, $\mathrm{A}$ – leaf photosynthesis, $\mathrm{e_s}$, $\mathrm{e_i}$ – vapor pressure at leaf surface and inside the leaf; $\mathrm{c_s}$ – $CO_2$ partial pressure; $\mathrm{m}$, $\mathrm{b}$ – empirical coefficients;

# Leaf photosynthesis algorithm

$$A = A^{sun} L^{sun} + A^{sha} L^{sha}$$

$$A^{sun,\,sha} = min(w_c, w_j, w_e)$$




Leaf photosynthesis algorithm is based on the *Farquhar** and *Collatz** models for $C_3$ and $C_4$ plants and uses sunlit and shaded leaves parameters

$$w_c = \begin{cases} \dfrac{V_{cmax}\,(c_i - \Gamma_*)}{c_i + K_c\,(1 + \dfrac{O_i}{K_0})} \\ \boldsymbol{V_{cmax}} \end{cases} *$$

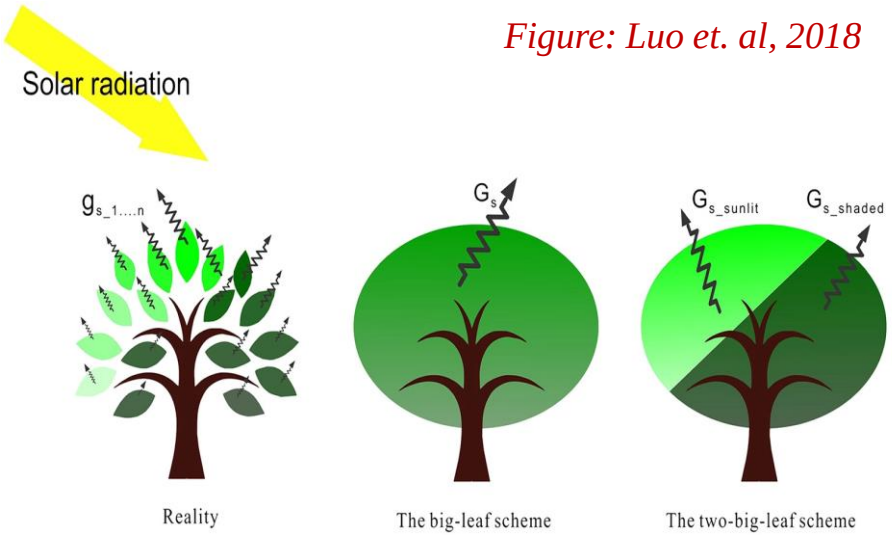
$$w_j = \begin{cases} \dfrac{(c_i - \Gamma_*)\,4.6\,\alpha\,\phi}{c_i + 2\,\Gamma_*} \\ \boldsymbol{4.6\,\alpha\,\phi} \end{cases} *$$

$$w_e = \begin{cases} 0.5\,V_{cmax} \\ \boldsymbol{4000\,V_{cmax}\,\dfrac{c_i}{P_{atm}}} \end{cases} *$$

$V_{cmax}$ – the maximum rate of carboxylation, $K_c$; $K_o$ – the Michaelis–Menten constants for $CO_2$ and $O_2$, $\Gamma_*$ – the $CO_2$ compensation point, $c_i$ – the internal leaf $CO_2$ partial pressure, $O_i$ – the $O_2$ partial pressure, $\alpha$ – the quantum efficiency coefficient, $\phi$ – the absorbed PAR

# Two-big leaves algorithm

*Figure: Luo et. al, 2018*




- Sunlit ($f_{sun}$) and shaded ($f_{sha}$) fraction of canopy:

$$f_{sun} = 1 - \frac{e^{-KL}}{KL} \qquad f_{sha} = 1 - f_{sun}$$

- Sunlit ($L^{sun}$) and shaded ($L^{sha}$) leaf area indices:

$$L^{sun} = f_{sun} L \qquad L^{sha} = f_{sha} L$$

- Sunlit ($\phi^{sun}$) and shaded ($\phi^{sha}$) absorbed photosynthetically active radiation (PAR):

$$\phi^{sun} = \frac{\left(\phi^{\mu}_{dir} + \phi^{\mu}_{dif} f_{sun} + \phi_{dif} f_{sun}\right)\left(\frac{L}{L+S}\right)}{L^{sun}}$$

$$\phi^{sha} = \frac{\left(\phi^{\mu}_{dif} f_{sha} + \phi_{dif} f_{sha}\right)\left(\frac{L}{L+S}\right)}{L^{sha}}$$

$\phi^{\mu}_{dir}$ – the portion of the incoming visible waveband direct beam radiation

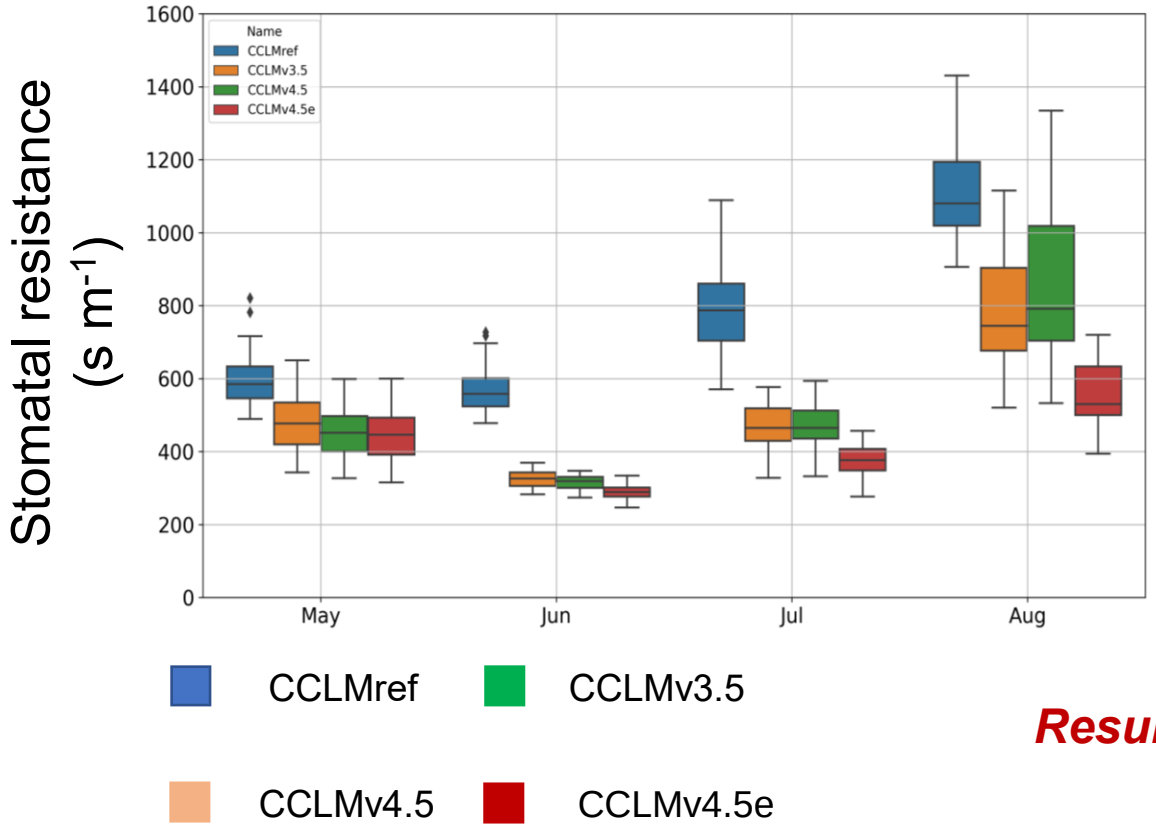
$\phi^{\mu}_{dif}$ – the absorbed visible waveband direct beam radiation

$\phi_{dif}$ – is the incoming visible waveband diffuse radiation

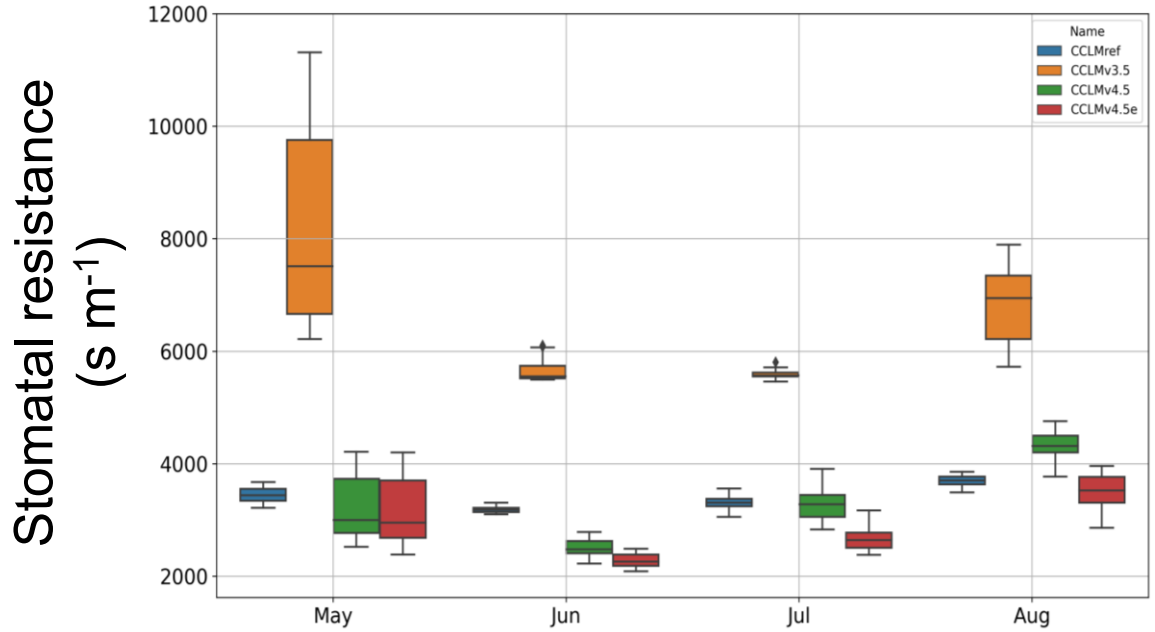
# Evaluation of the new stomatal resistance (*RSTOM*) algorithms at the Parc domain

***Summer months (May – August) from 2010 - 2015***

*Daily day-time values (6 a.m. – 18 p.m.)*




*Daily night-time values (18 p.m. – 6 a.m.)*




CCLMref CCLMv3.5

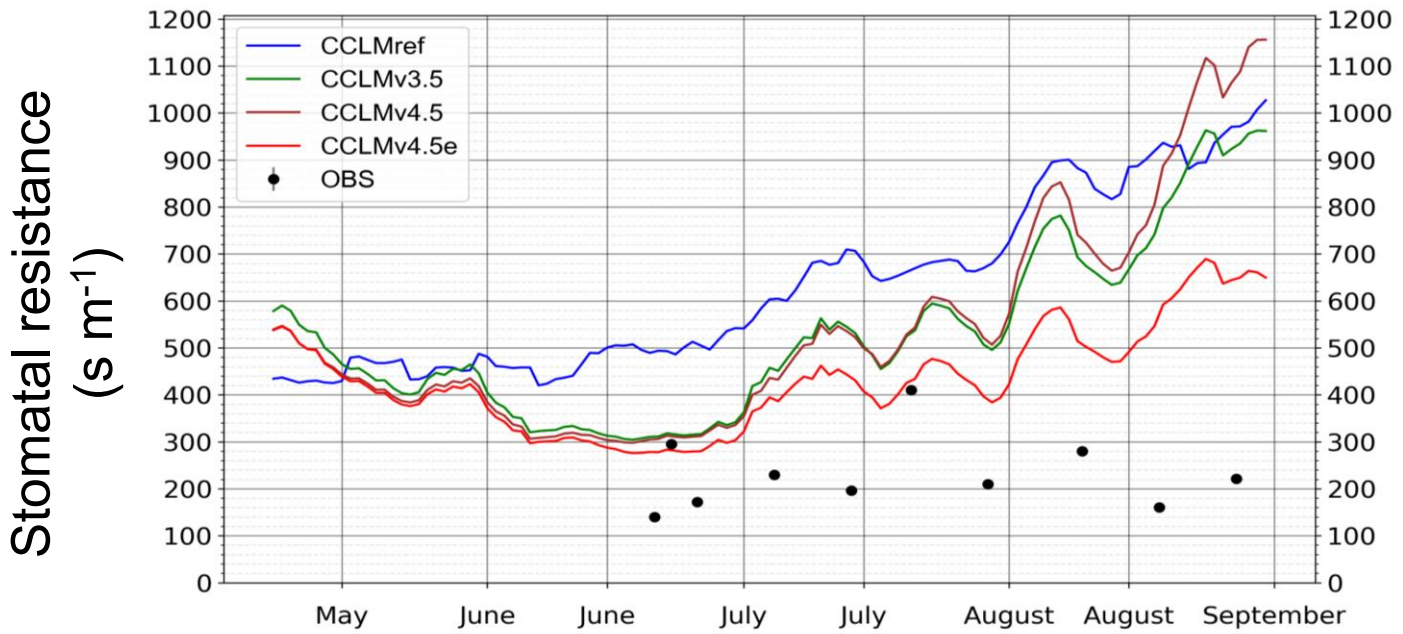
CCLMv4.5 CCLMv4.5e

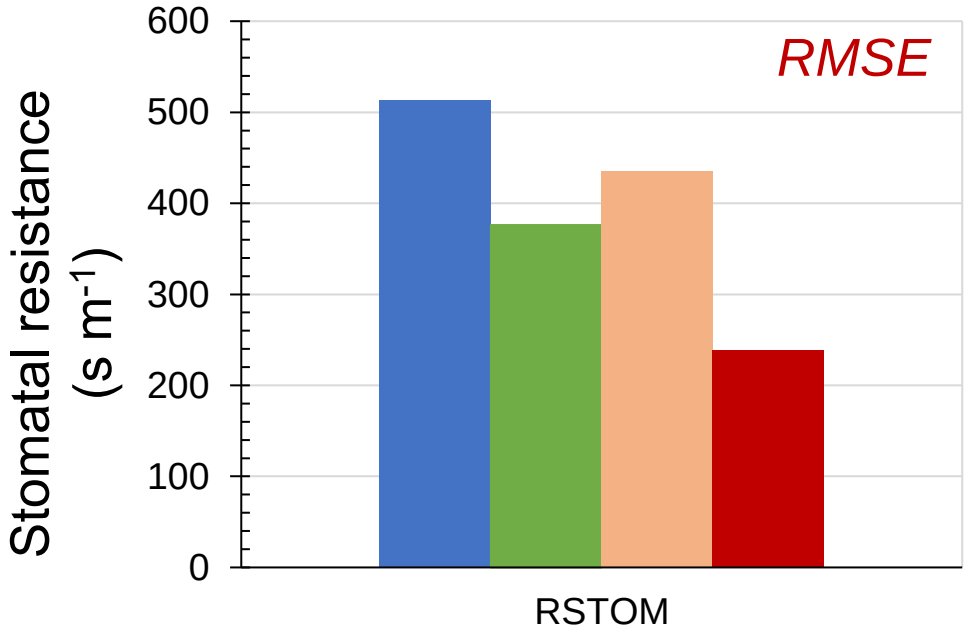
***Results:*** The experimental day-time values of RSTOM are less than the reference COSMO-CLMv5.16. The night-time values of RSTOM of the ***CCLMv3.5*** differ significantly from the other experiments.

# Evaluation of the new stomatal resistance (*RSTOM*) algorithms at the Parc domain

***Summer months (May – August) from 2010 - 2015***

*Daily values at 13:00 p.m.*




CCLMref CCLMv3.5

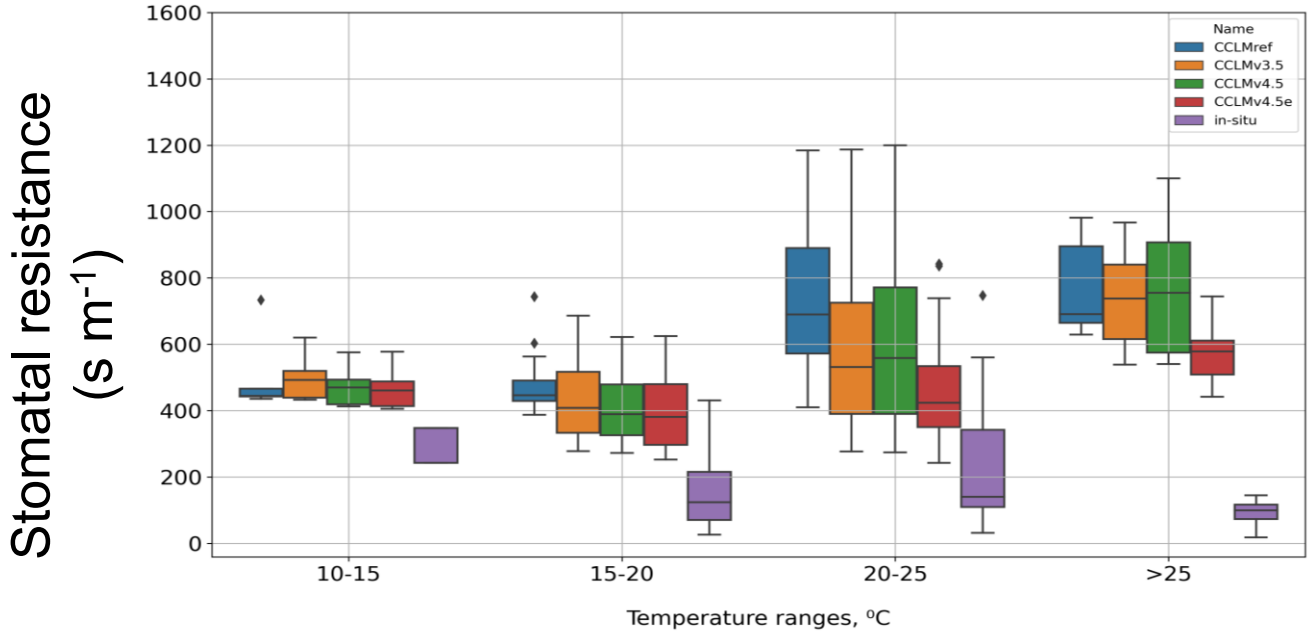
CCLMv4.5 CCLMv4.5e

***Results:*** Refence experiment (**CCLMref**) has the largest values of stomatal resistance at 13:00 p.m.

# Evaluation of the new stomatal resistance (*RSTOM*) algorithms at the Parc domain

***Summer months (May – August) from 2010 - 2015***

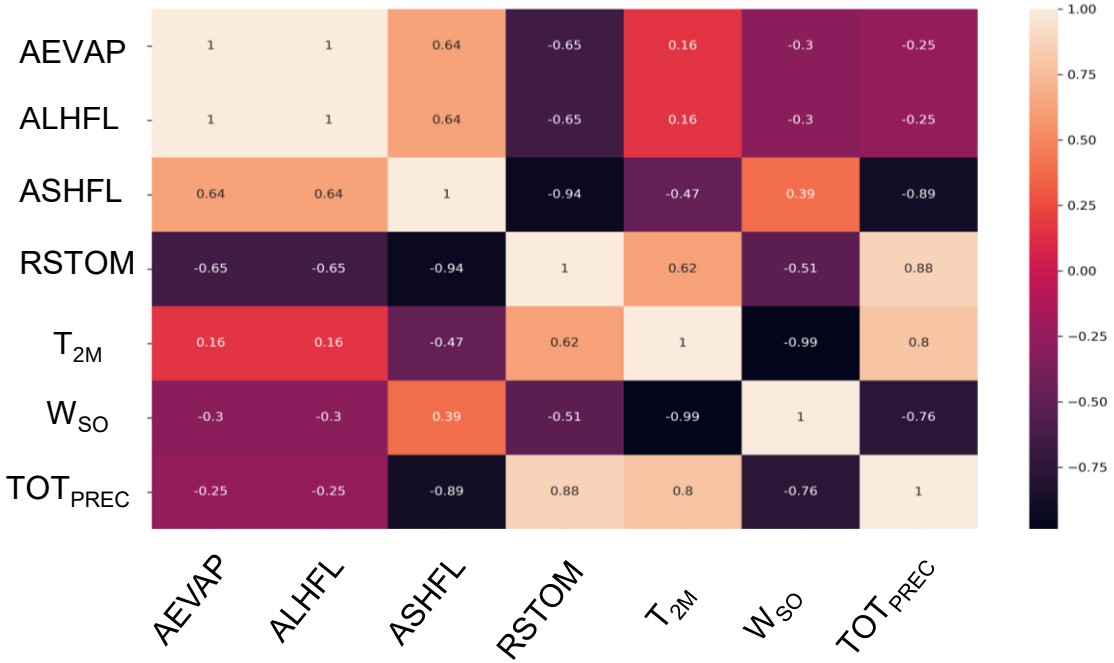
*$T_{2m}$ categories with daily day-time values of RSTOM*




CCLMref CCLMv3.5

CCLMv4.5 CCLMv4.5e

*Correlation heatmap*

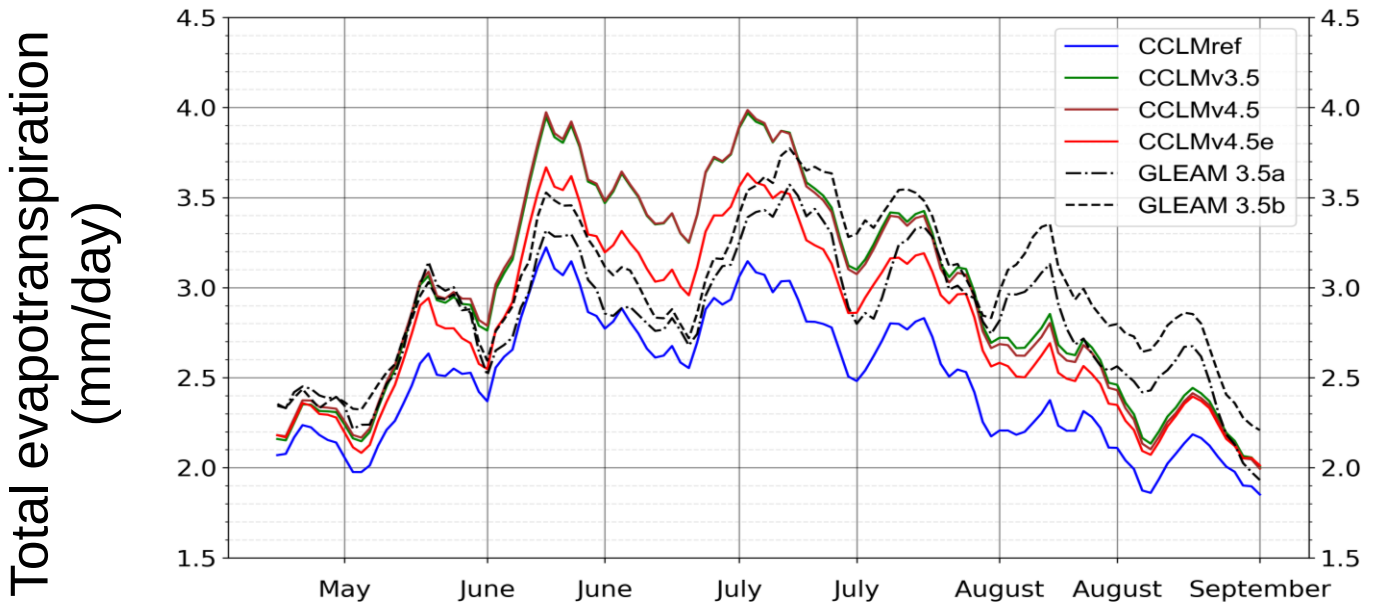


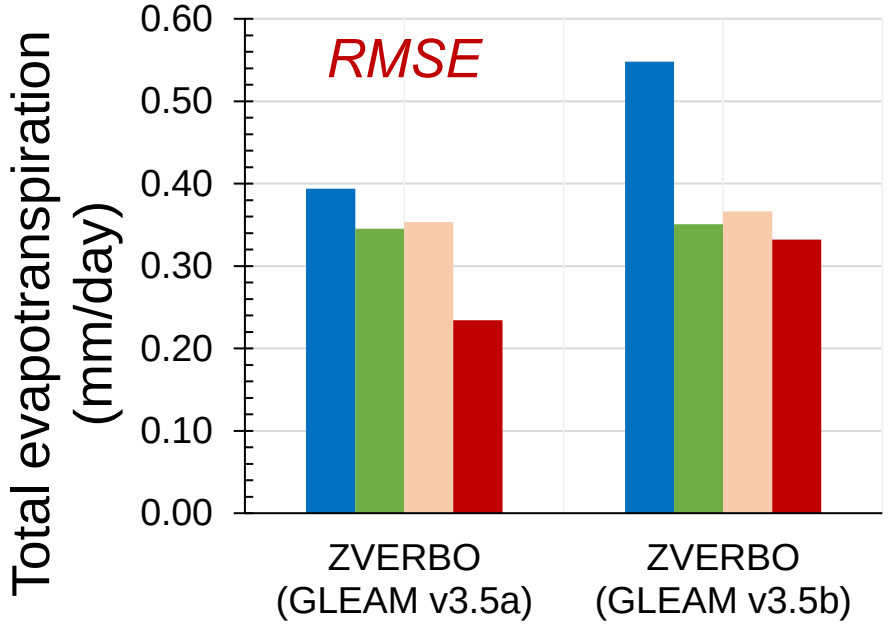

***Results:*** ***CCLMv4.5e*** experiment with the additional changes in the algorithm for calculations of transpiration from dry leaves demonstrates the better accuracy that other experiments.

# Evaluation of the experiments at meteorological stations in Parc domain

***Summer months (May – August) from 2010 - 2015***

Total evapotranspiration (*ZVERBO*)




CCLMref CCLMv3.5

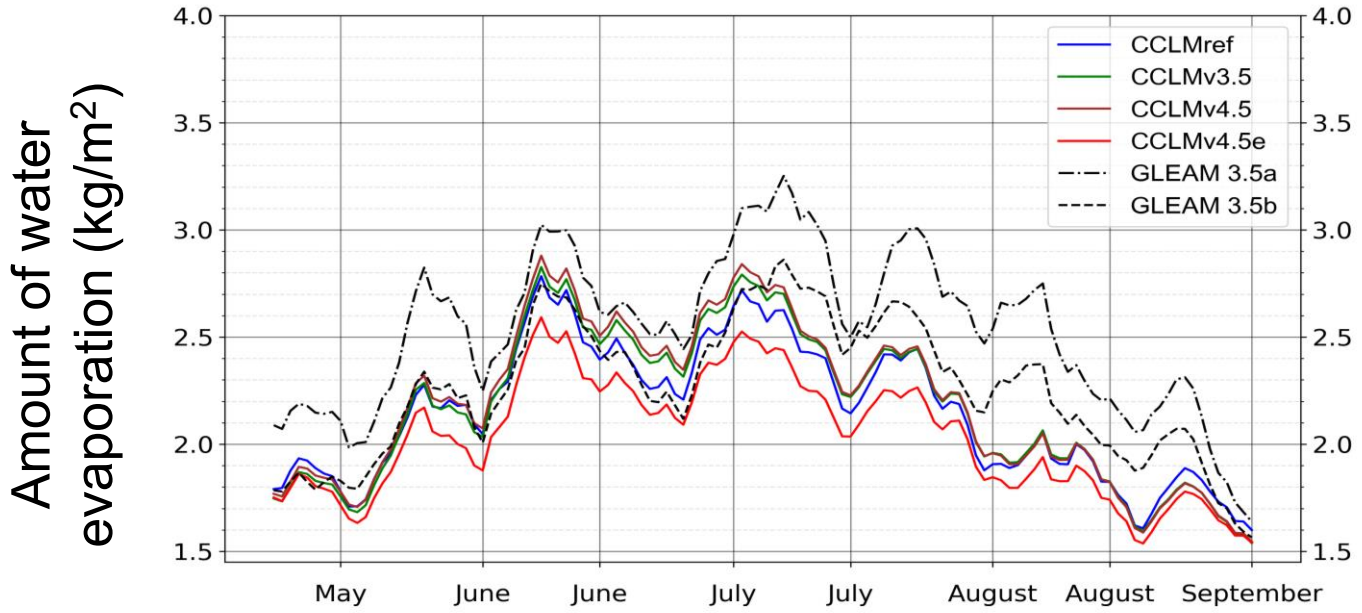
CCLMv4.5 CCLMv4.5e

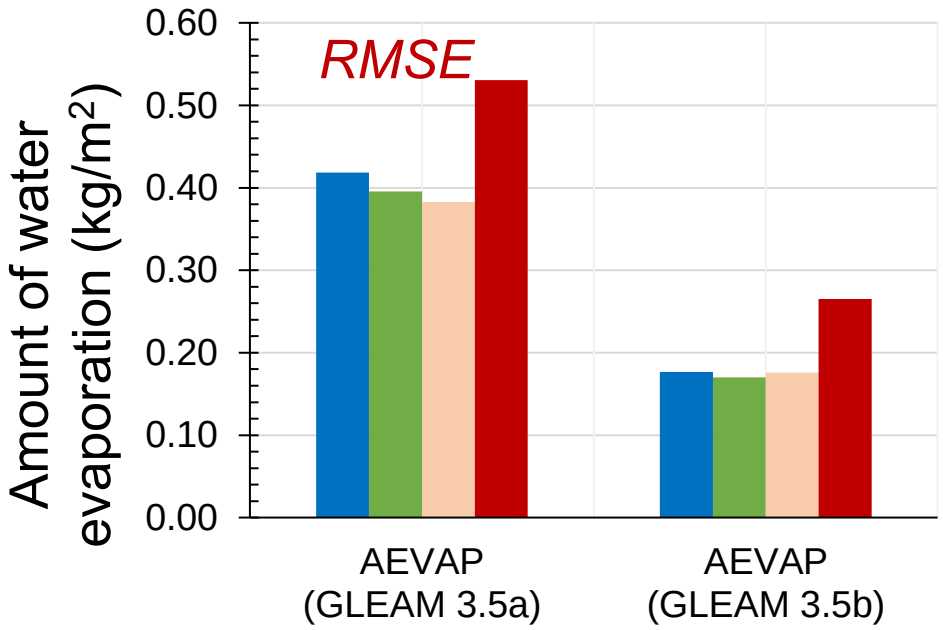
***Results:*** ***CCLMv4.5e*** has the better scores for **ZVERBO** at the meteorological stations in Parc domain (*RMSE = 0.283, r = 0.874*) in comparison with GLEAM data set averaged to the point.

# Evaluation of the experiments at meteorological stations in Parc domain

***Summer months (May – August) from 2010 - 2015***

Amount of water evaporation (*AEVAP*)



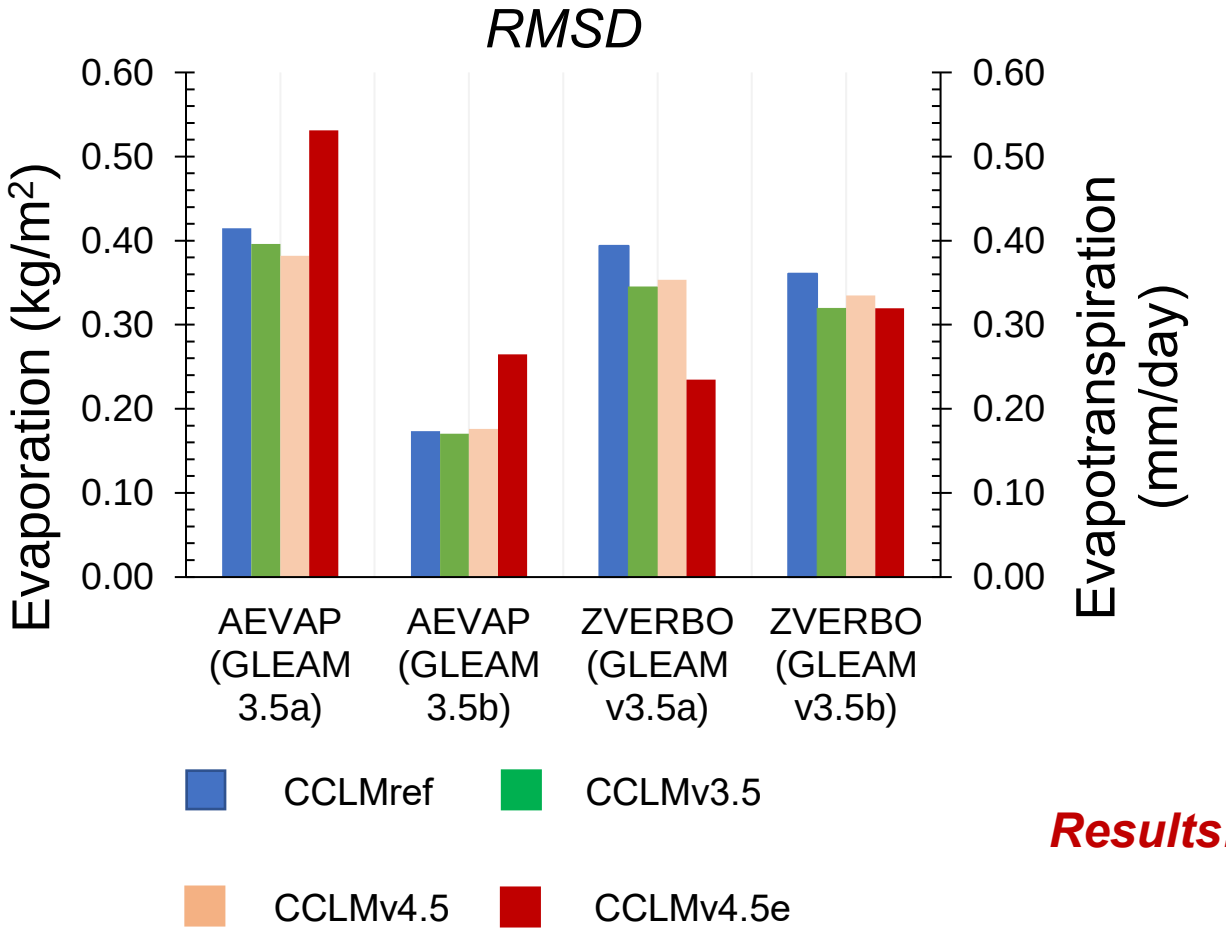

CCLMref CCLMv3.5

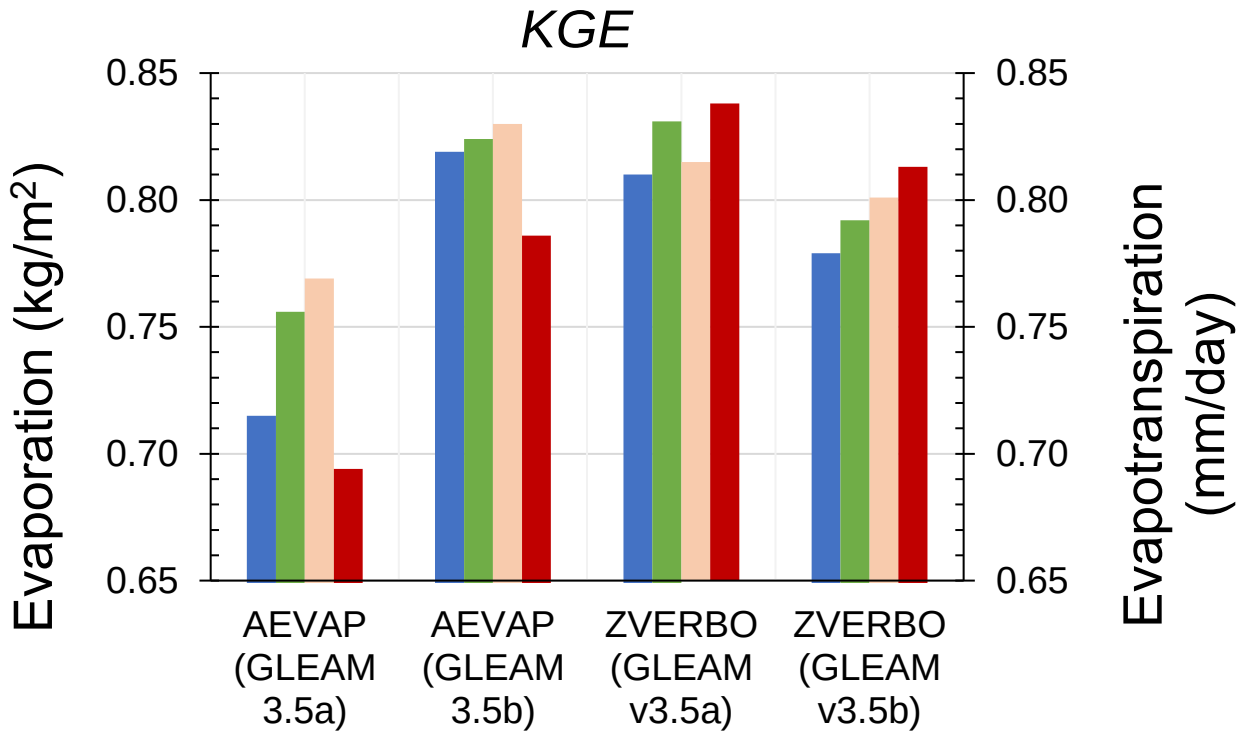
CCLMv4.5 CCLMv4.5e

***Results:*** ***CCLMv4.5*** has the better scores for **AEVAP** at the meteorological stations in Parc domain (*RMSE = 0.279, r = 0.882*) in comparison with GLEAM data set averaged to the point.

# Evaluation of the experiments presenting at COSMO-CLM model grid (Parc domain)

***Summer months (May – August) from 2010 - 2015***

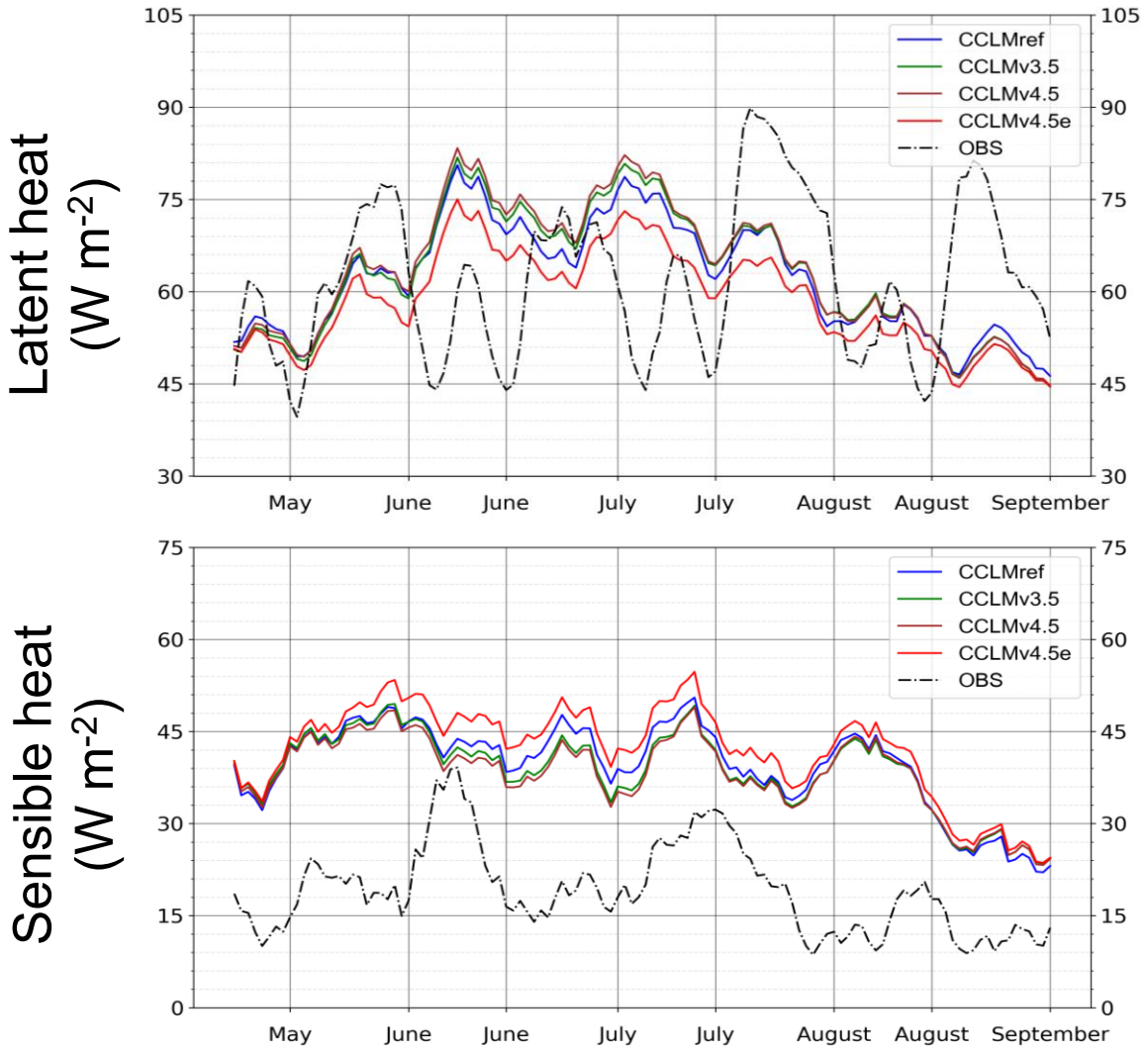


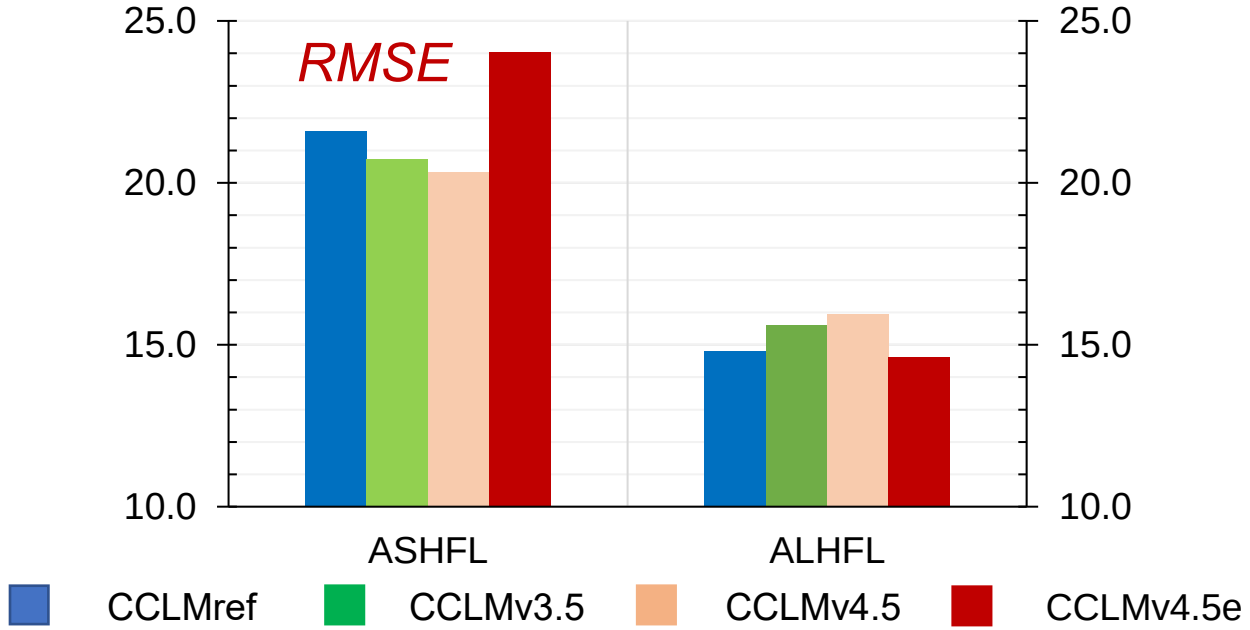




***Results:*** ***CCLMv4.5*** (*RMSD = 0.279, KGE = 0.80*) has more accurate results than the other experiments for ***AEVAP*** parameter, the ***CCLMv4.5e*** (*RMSD = 0.277, KGE = 0.82*) for ***ZVERBO*** parameter

# Validating experiment results

## Sensible and latent heat fluxes (*ASHFL, ALHFL*)

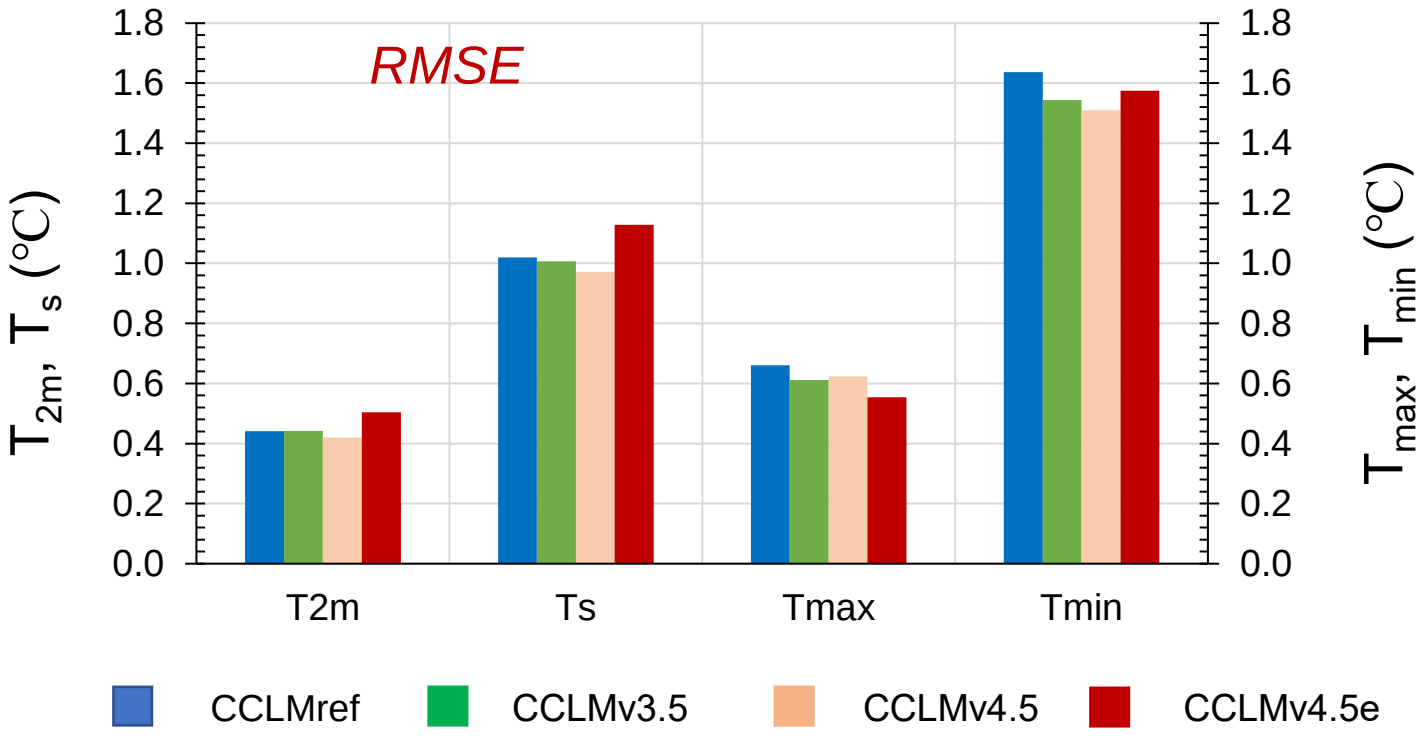


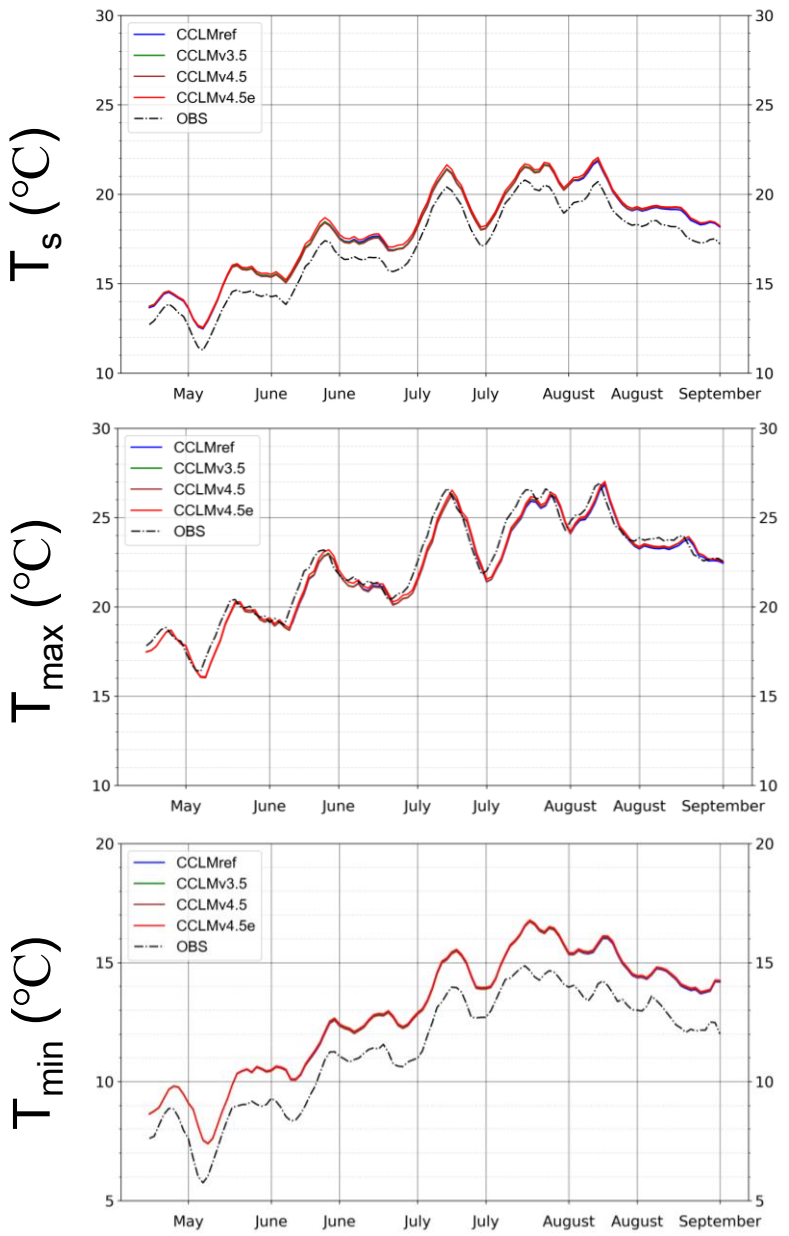




***Results:*** ***CCLMv3.5*** and ***CCLMv4.5*** are better representing changes in sensible heat flux, however worse representing changes in latent heat. ***CCLMv4.5e*** shows opposite results.

# Validating experiment results

## Air near-surface, maximum and minimum temperatures ($T_s$, $T_{max}$, $T_{min}$)




***Results:*** There are no significant changes in simulations of air temperatures (near-surface, maximum and minimum)

# Leaf area index algorithm

# Leaf area index algorithm

## CCLMv4.5 + LAI algorithm from ISBA-A-gs (SURFEX)

The Calvet approach calculating leaf area index depending on leaf photosynthesis

$$LAI = \frac{B}{\alpha_B}$$

Photosynthetic active biomass

$$B(t + \Delta t) = B(t) + \Delta \boldsymbol{B}^{+} - \Delta \boldsymbol{B}^{-}$$

Growth of biomass based on the accumulated net $CO_2$ assimilation

$$\Delta \boldsymbol{B}^{+} = \frac{M_C}{P_C M_{CO_2}} \boldsymbol{A_{nI,\,day}} \Delta t$$

Mortality of biomass due to soil moisture stress, diseases and senescence

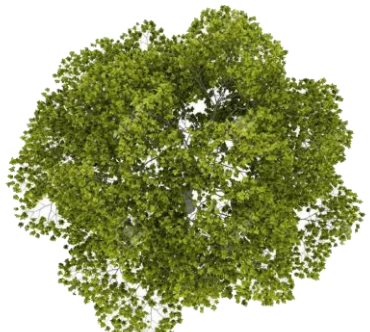
$$\Delta \boldsymbol{B}^{-} = B\left(1 - \exp\left(-\frac{\Delta t}{\boldsymbol{\tau}}\right)\right)$$

Maximum effective life expectancy

$$\boldsymbol{\tau}(t) = \tau_M \frac{\boldsymbol{A_{nfm}}(t)}{\boldsymbol{A_{n,max}}}$$

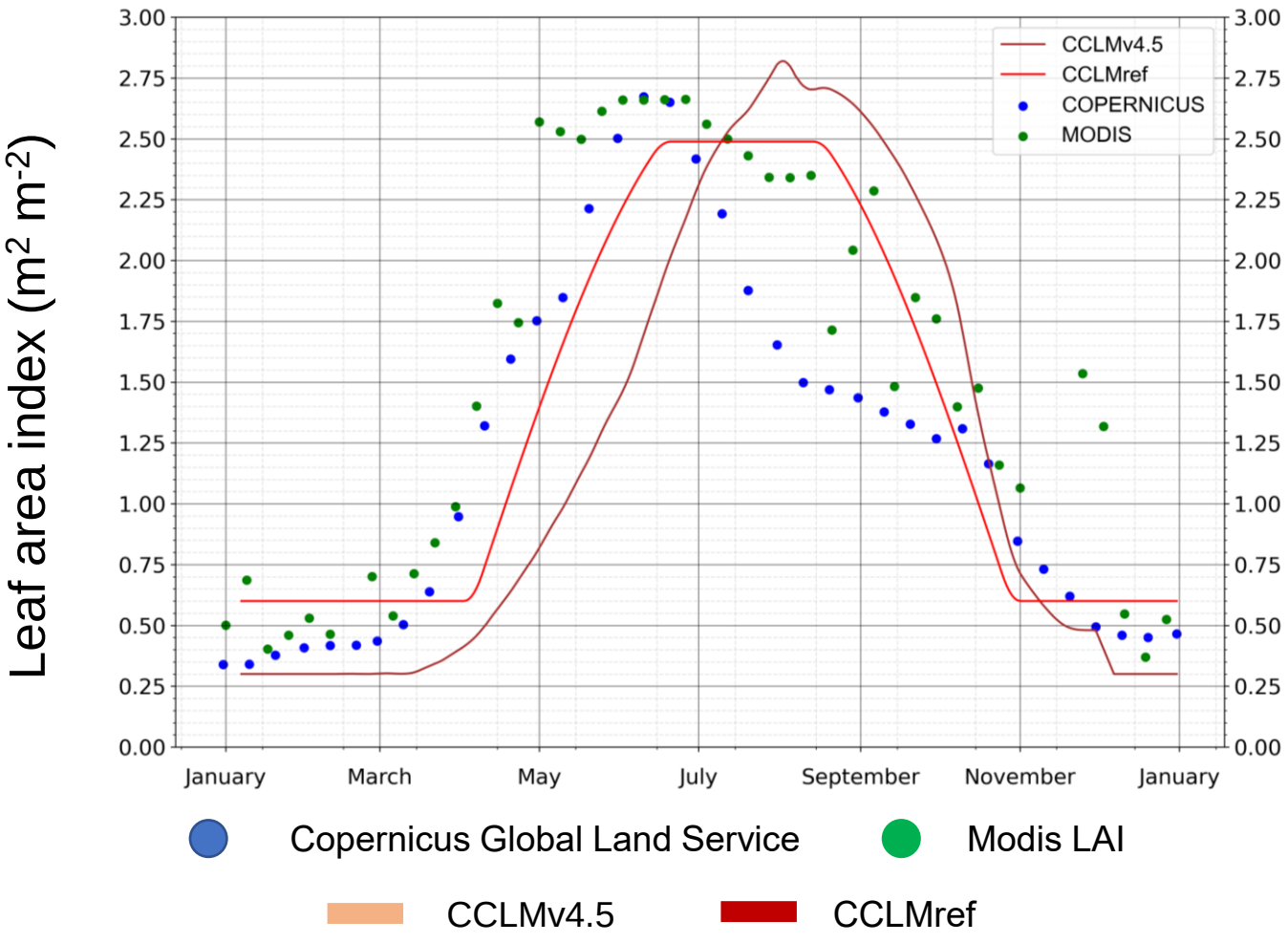
Ratio of biomass

$$\alpha_B = 0.06$$

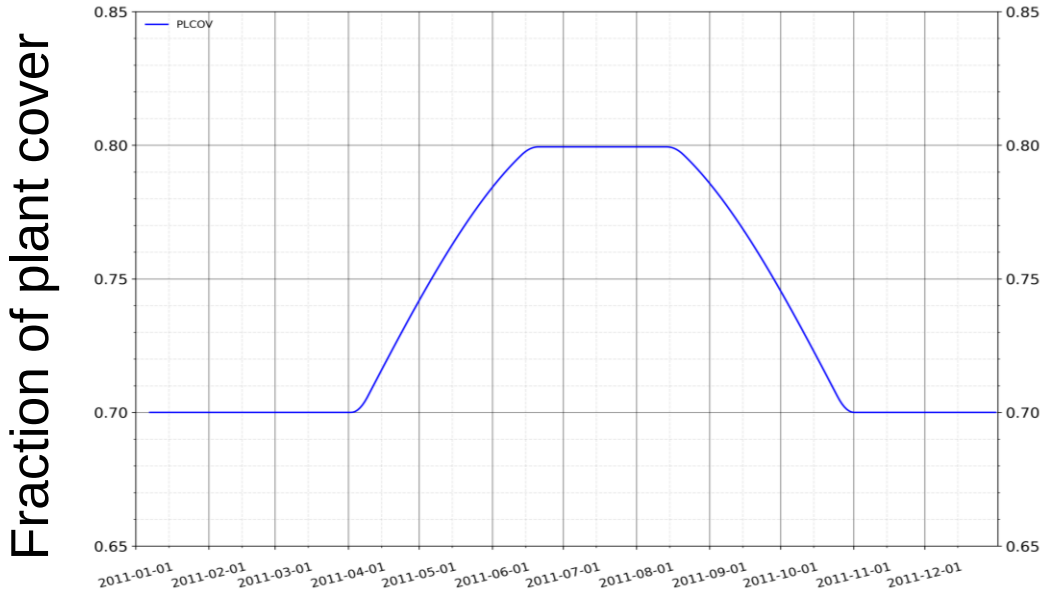


# First experiment results

## Research year - **2011**




Similar for *CCLMref, CCLMv4.5*

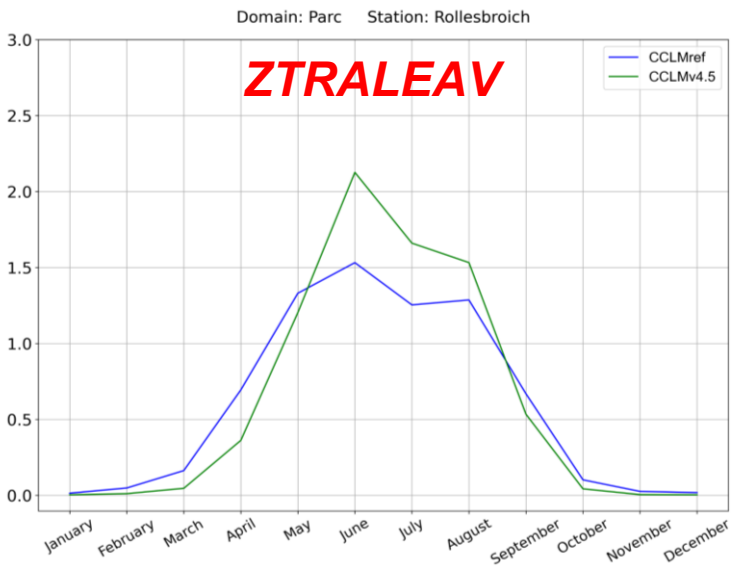



***Results:*** Algorithm for calculations of leaf area indexes based on biomass evolution has been implemented in COSMO-CLM v5.16 based on the CCLMv4.5 experiment. The next step is related to the modernization of PLCOV parameter.

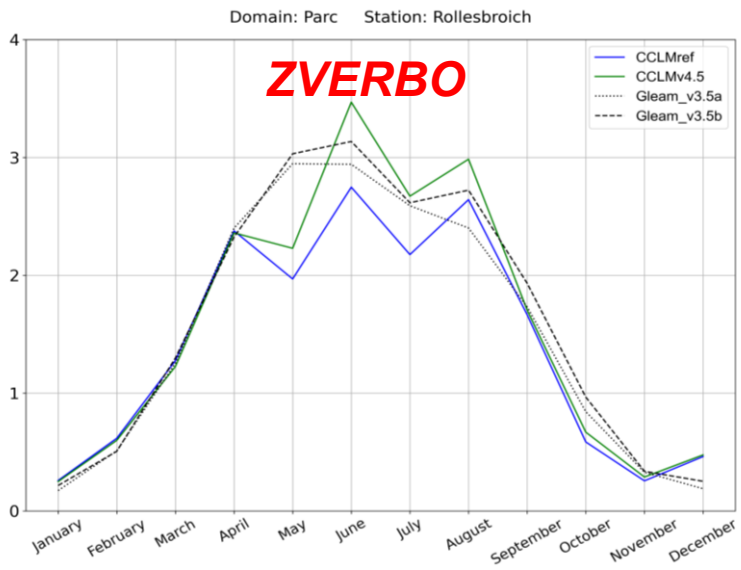
# Annual cycles for the experiment CCLMv4.5 from 01.2011 to 12.2011

First experiment results

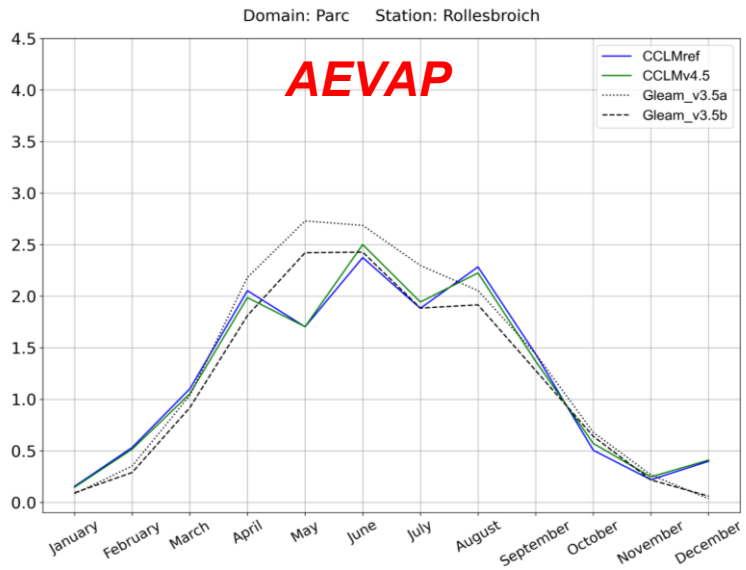
Transpiration from dry leave surface (mm day$^{-1}$)




Total evapotranspiration (mm day$^{-1}$)




Amount of water evaporation (kg m$^{-2}$)




CCLMref

CCLMv4.5

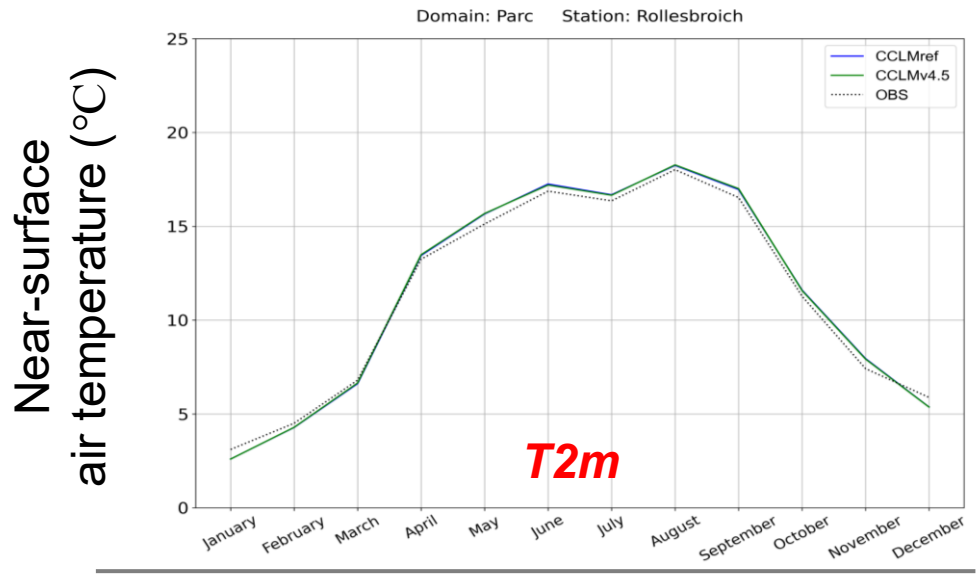
GLEAM v3.5a

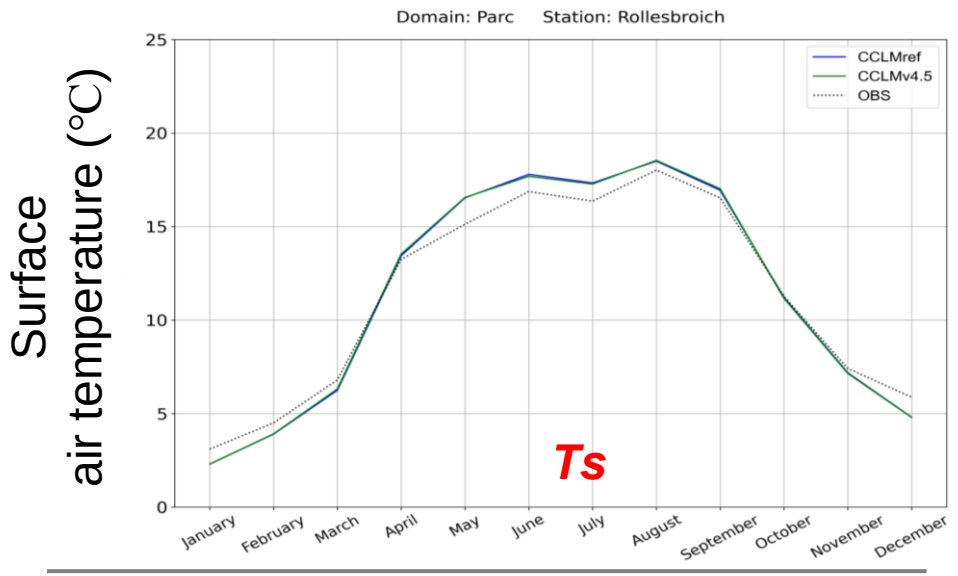
GLEAM v3.5b

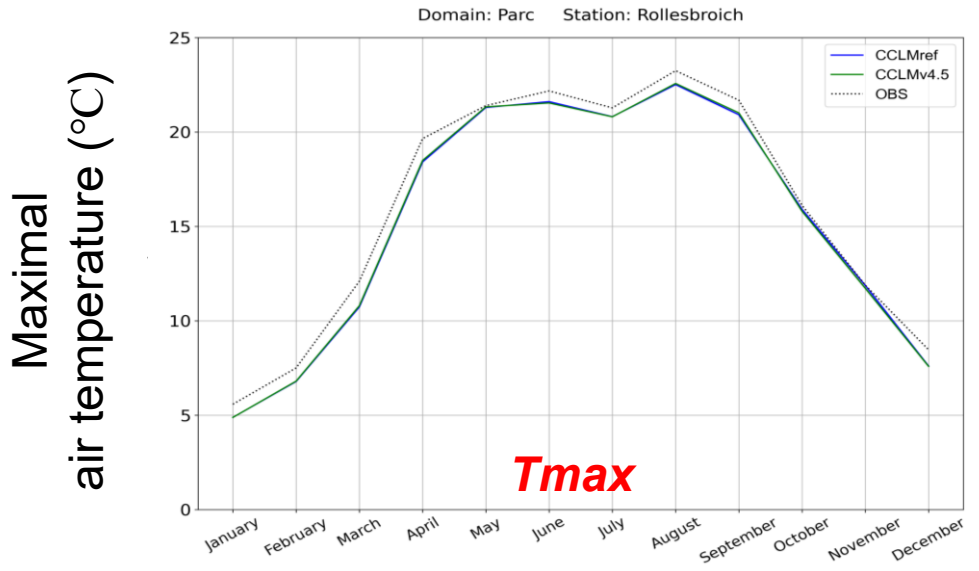
***Results:*** The accuracy of the CCLMv4.5 experiment slightly increasing after implementation of the algorithm for LAI calculations depending on biomass evolution.

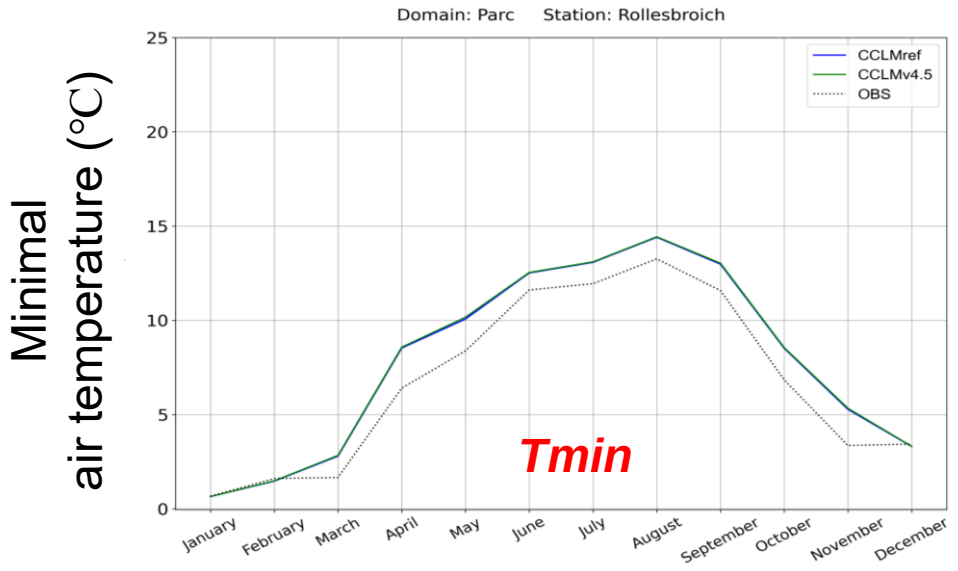
# Annual cycles for the experiment CCLMv4.5 from 01.2011 to 12.2011

First experiment results



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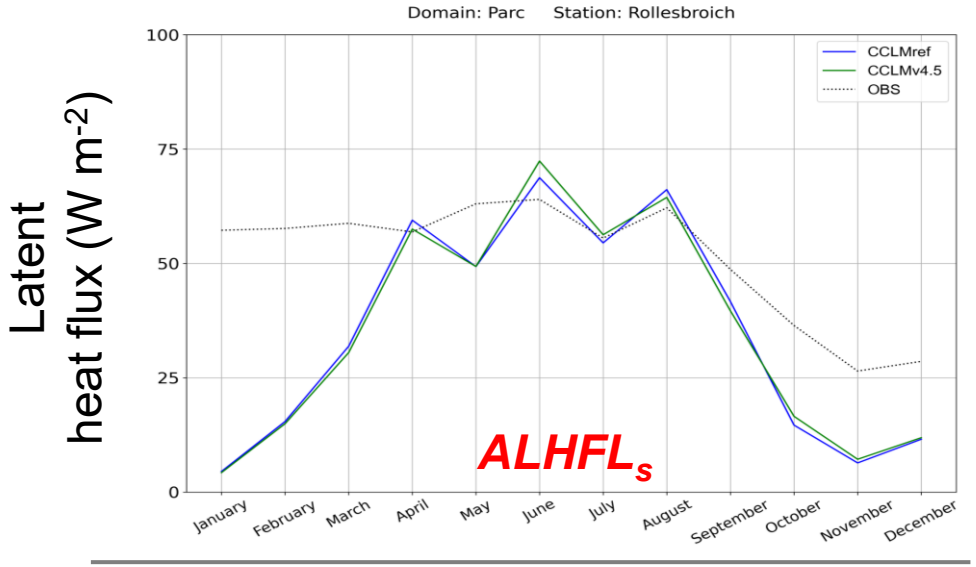
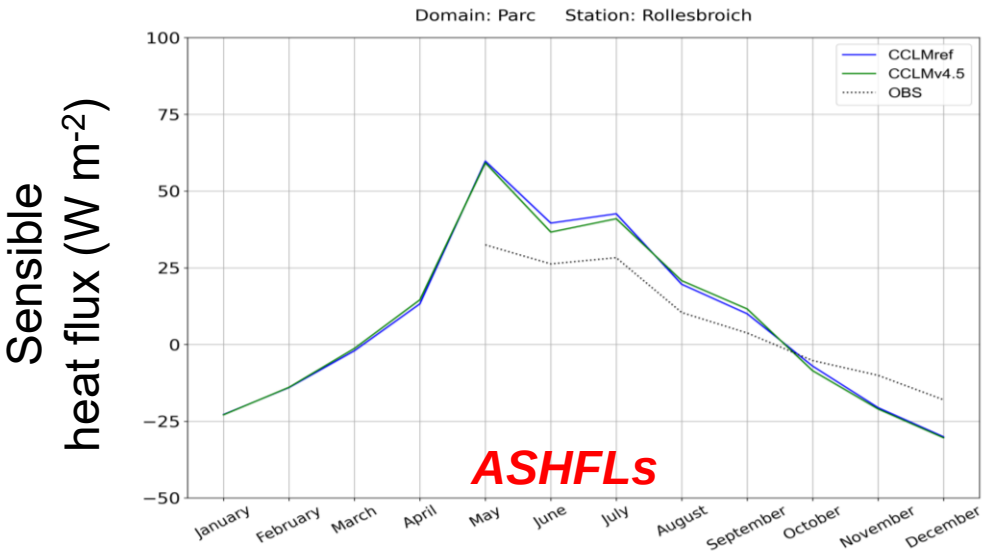
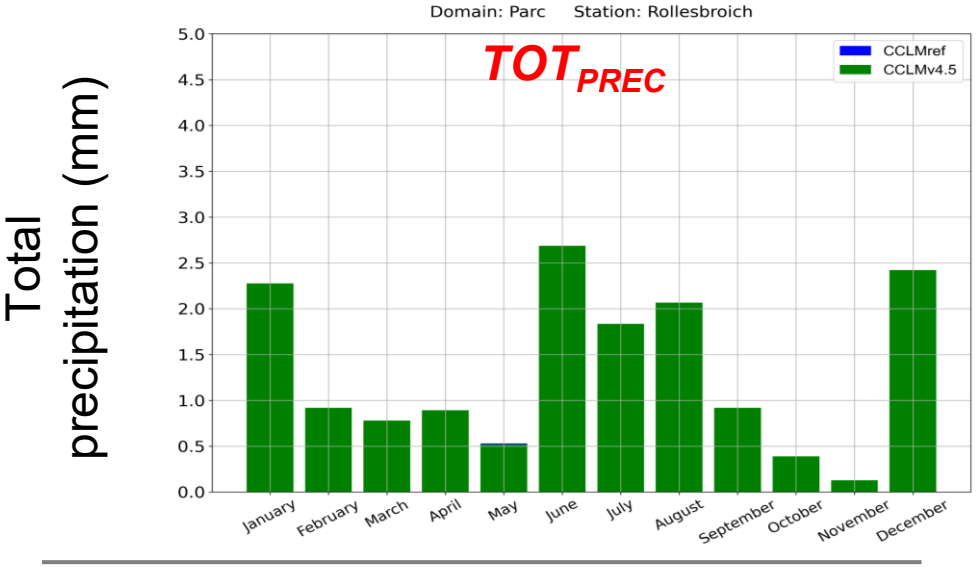
First experiment results






CCLMref CCLMv4.5 OBS

# Conclusions

| In COSMO-CLM v5.16, the new vegetation algorithms have been implemented | Validation of the new algorithms have been done | The documentation for the updates have been written |
|---|---|---|
| ❖ Stomatal resistance<br>❖ Leaf photosynthesis<br>❖ Two-big leaf<br>❖ LAI changes depending on biomass | ❖ in the exceptional warm summer 2013<br>❖ in the period 2010 – 2015<br>❖ In 2010 – 2011 for LAI | ❖ Code (*https://github.com/EvgenyChur/PT-VAINT*);<br>❖ Documentation (https://github.com/EvgenyChur/Doc_version1); |

The experiment CCLMv4.5 for stomatal resistance shows the results, representing changes in stomatal resistance better than the reference experiment. The algorithm CCLMv4.5 was used as a background for the development of the new algorithm for calculations leaf area indexes depending on biomass evolution. The LAI algorithm was implemented in COSMO-CLMv5.16 and we are working on the validation of the experiment results

*Implementation the CCLMv4.5 algorithm into COSMO-CLM v6.0*

# Our contacts: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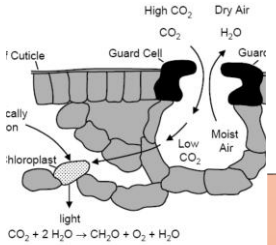
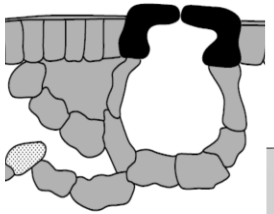
# Plant stomata behavior



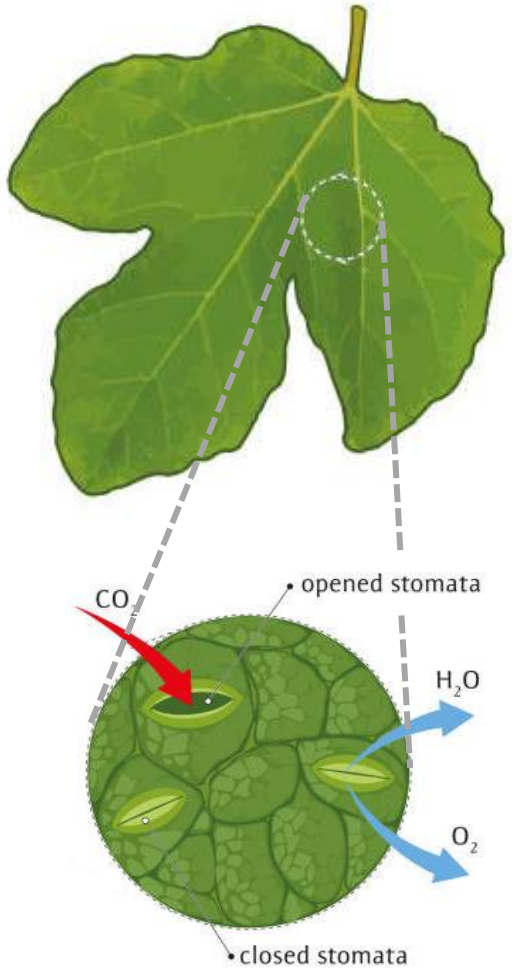

## Stomata open

- High light level
- High leaf nitrogen
- Moderate $CO_2$
- Moist leaf
- Moist air
- Warm temperature



## Stomata close

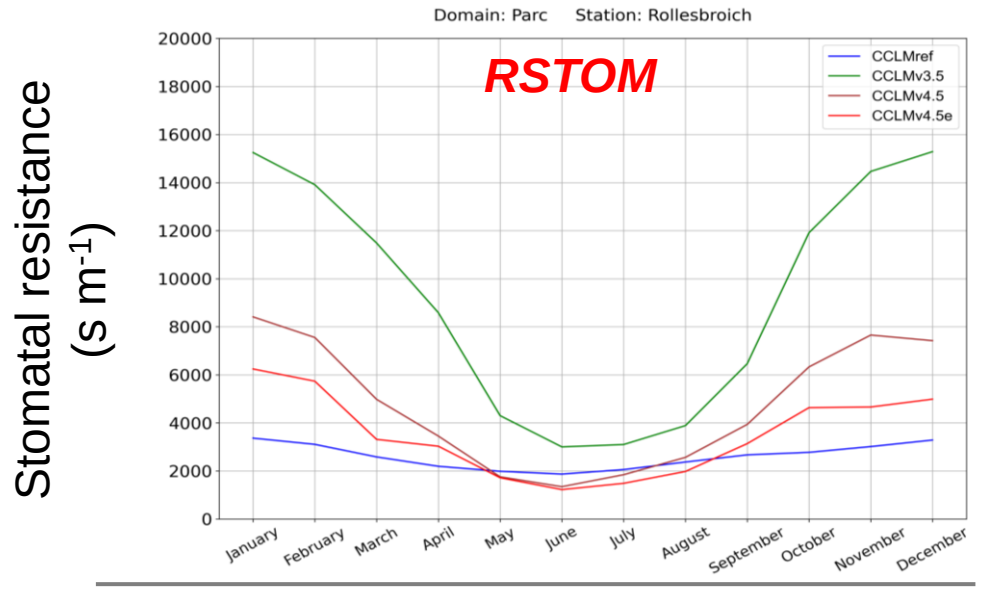
- Low light level
- Low leaf nitrogen
- High CO2
- Dry leaf
- Dry air
- Cold temperature

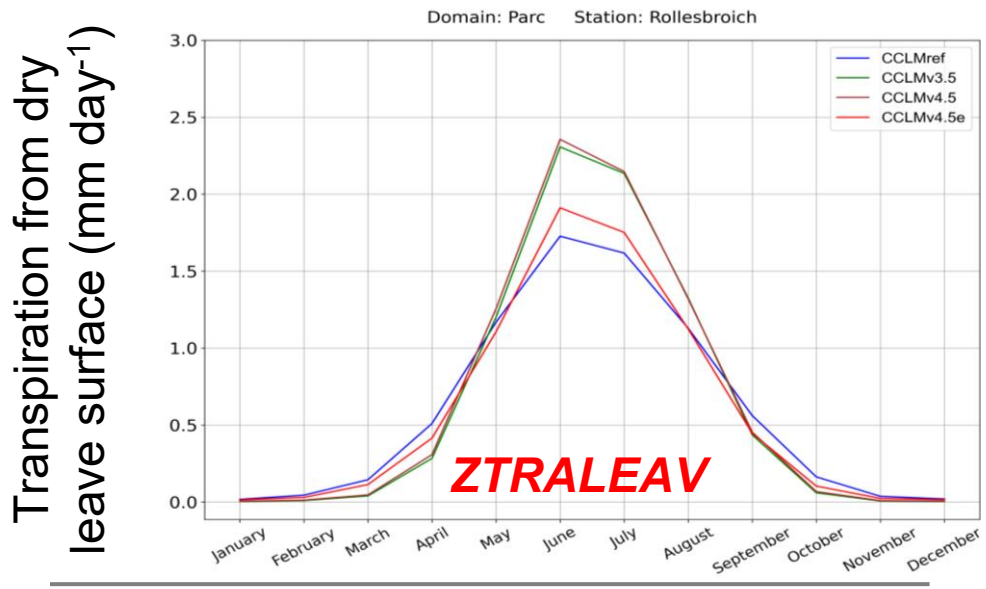


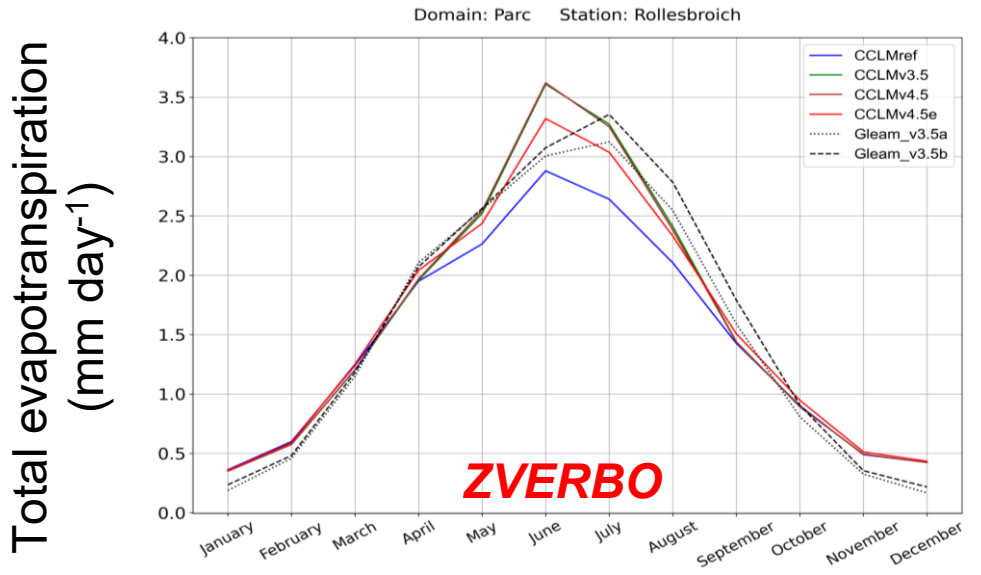

↓ Stomatal resistance ↑ Plant transpiration ↑ Amount of water evaporation ↑ Latent heat flux ↓ Sensible heat flux ↓ Air temperatures ↑ Surface moisture ($1^{st}$ level)

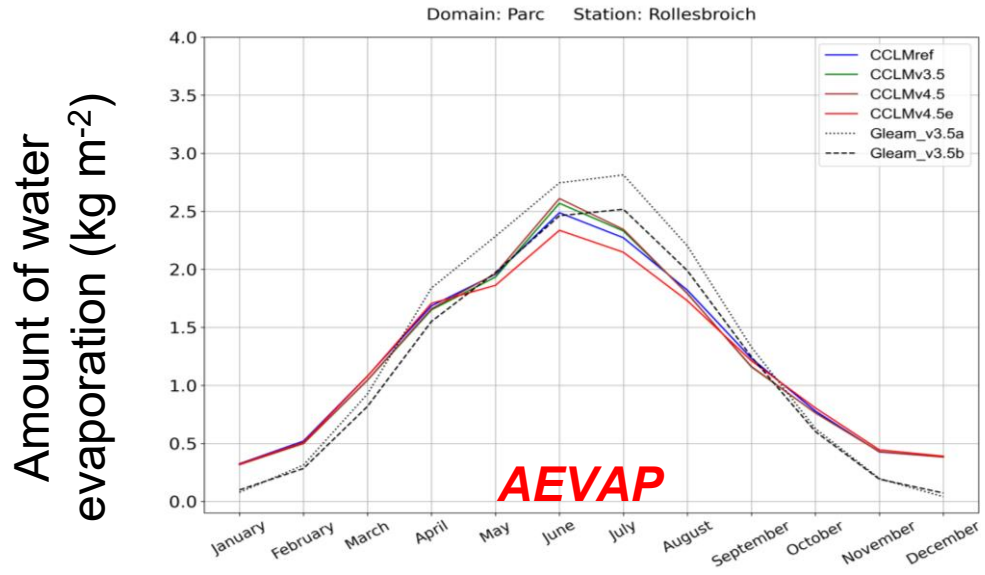
# Annual cycles of COSMO-CLM parameters (after stomatal resistance algorithms)

Additional materials:



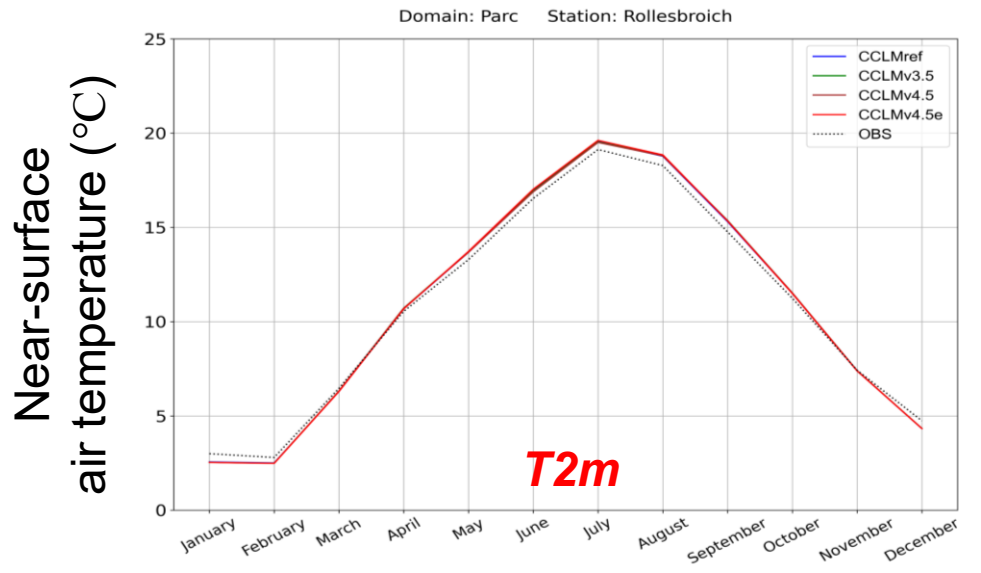



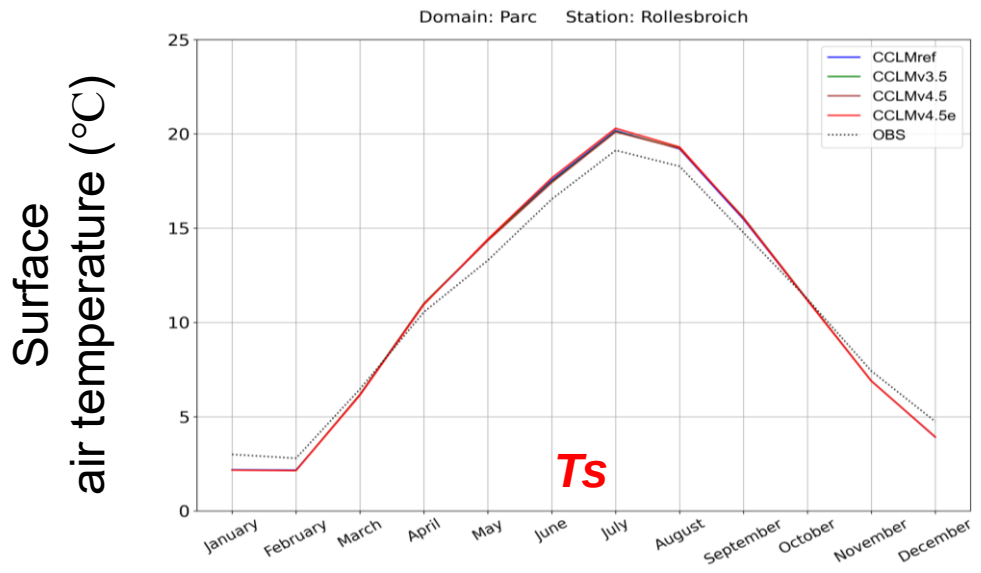



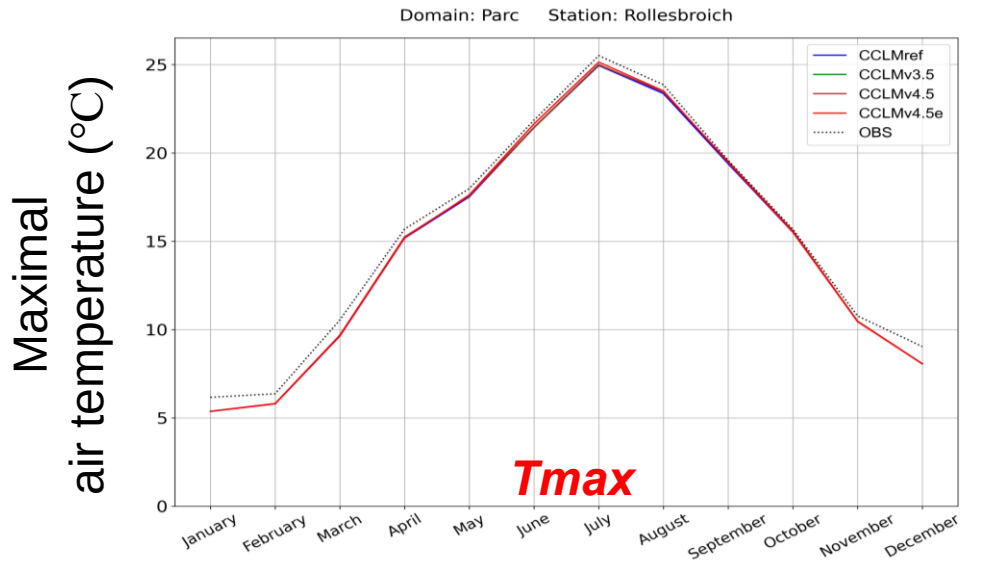

CCLMref CCLMv3.5 GLEAM v3.5a
CCLMv4.5e CCLMv4.5 GLEAM v3.5b

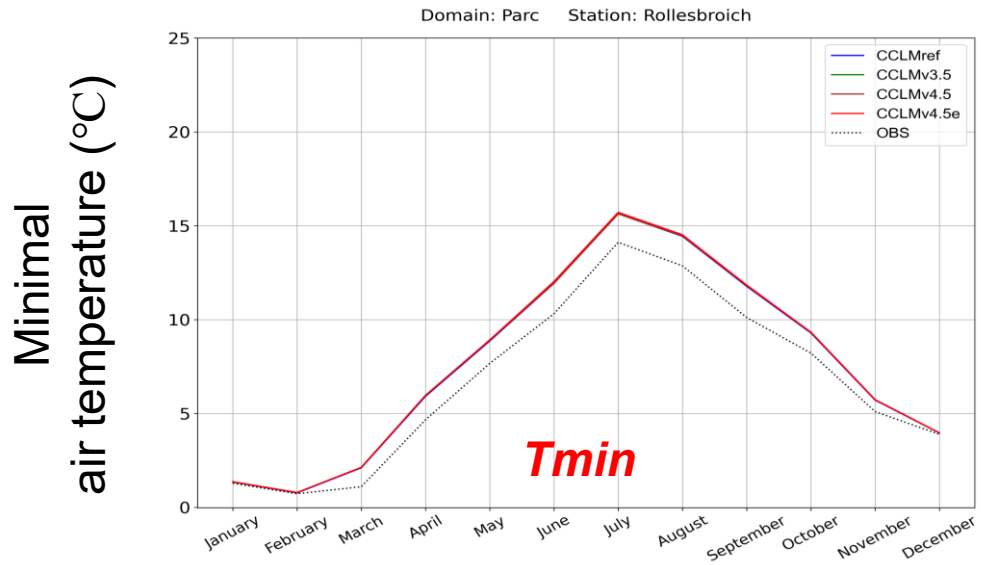
# Annual cycles of COSMO-CLM parameters (after stomatal resistance algorithms)

Additional materials:



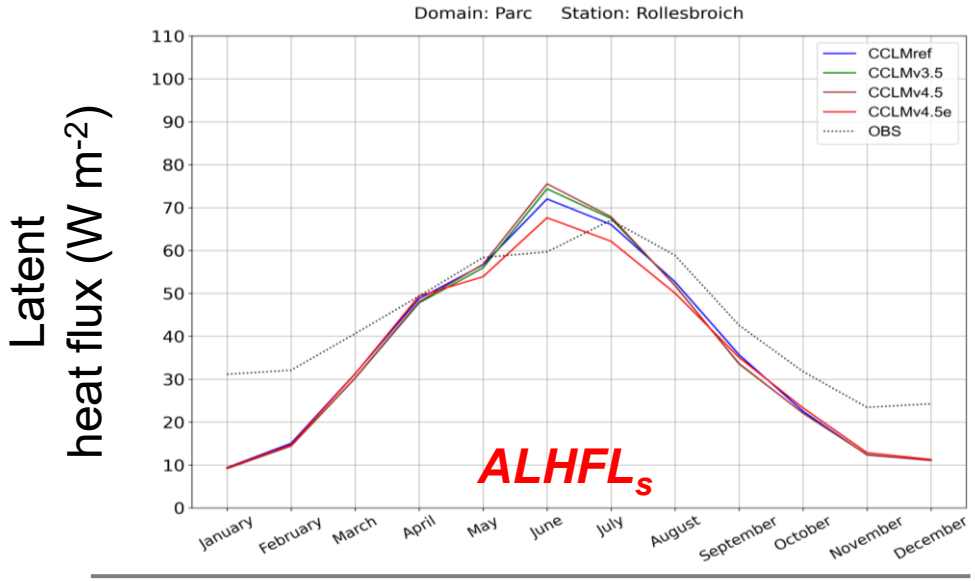



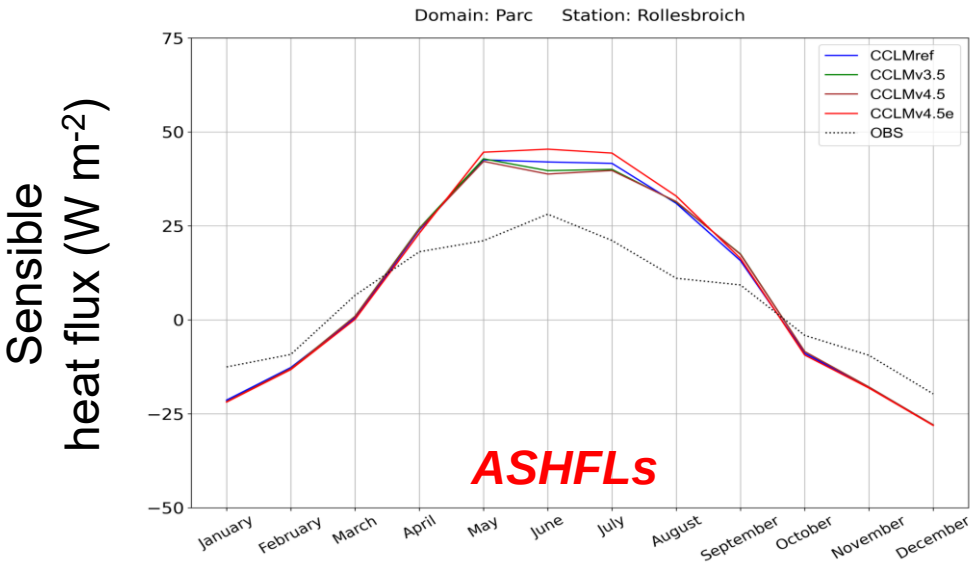



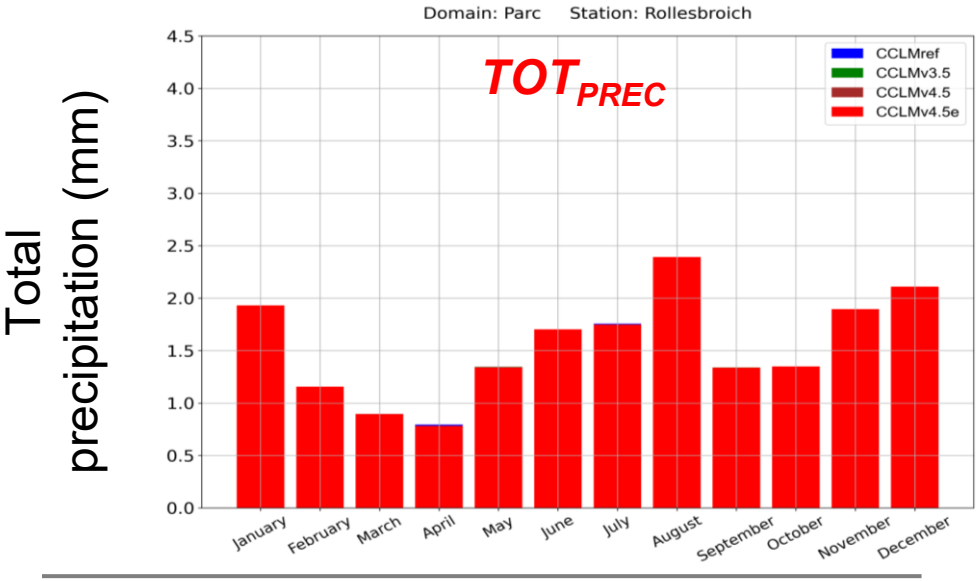



# Annual cycles of COSMO-CLM parameters (after stomatal resistance algorithms)

Additional materials:






CCLMref CCLMv3.5 CCLMv4.5 CCLMv4.5e OBS