Current status of *PT VAINT*

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Why is VAINT important?

Winter temperatures

- Seasonal phenological cycle of summer crops
- Biogeophysical processes

Seasonal phenology

- Energy and water cycle
- Seasonal cycle of the albedo and water availability

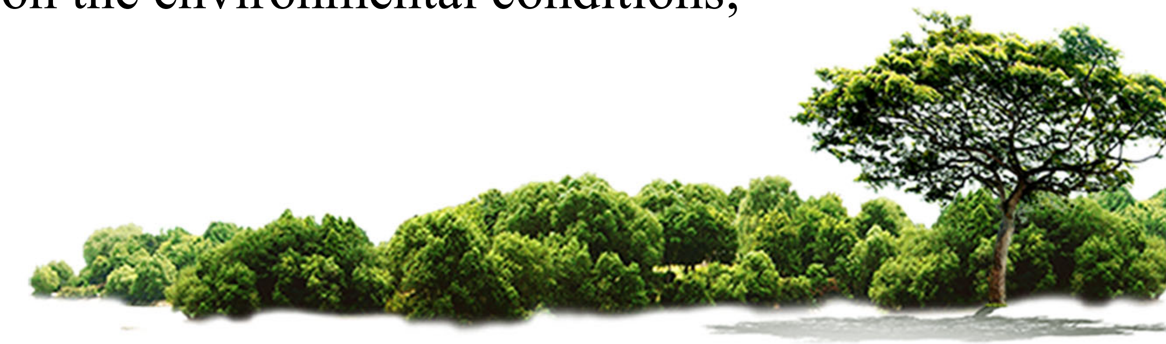
Extreme events

- Increase in frequency
- Increase in the need for modeling

Relevance

COSMO model:

- uses simplified phenology scheme
- is not capable of modelling complex processes
- contains the phenology cycle based on a 6-year climatology
- follows the same sinusoidal fitted curve between its max and min value each year
- neglects any influence or feedback on the environmental conditions;



PT VAINT

SubTask1: Implementation of new photosynthesis/phenology scheme:

a) The canopy photosynthesis and stomatal regulation module (done);

b) The carbon allocation and plant growth module (in progress);

c) The heterotrophic respiration and litter/soil carbon module (in progress);

SubTask2: Validation of new photosynthesis/phenology scheme:

a) Run cosmo_v5.0_clm16 (without changes) and cosmo_v5.0_clm16 (with updates) (in progress);

b) Run cosmo_v5.0.8 (without changes) (in progress);

c) Run cosmo-ccl and cosmo with SubTask1 (b and c) (not started)

SubTask3: Validation of implementation (in progress)

SubTask4: Documentation (in progress)

a) The block schemes for source files (src_terra_multlay and scr_radiation) (done);

https://github.com/users/merajtoelle/projects/1#column-12685832

b) The first version of documentation with new updates (done);

https://github.com/users/merajtoelle/projects/1#column-12685824

Differences in approach

TERRA_ML *vs* **TERRA_ML (updated)**

Stomatal conductance:

- BATS-based
- Empirical **Jarvis-type approach**

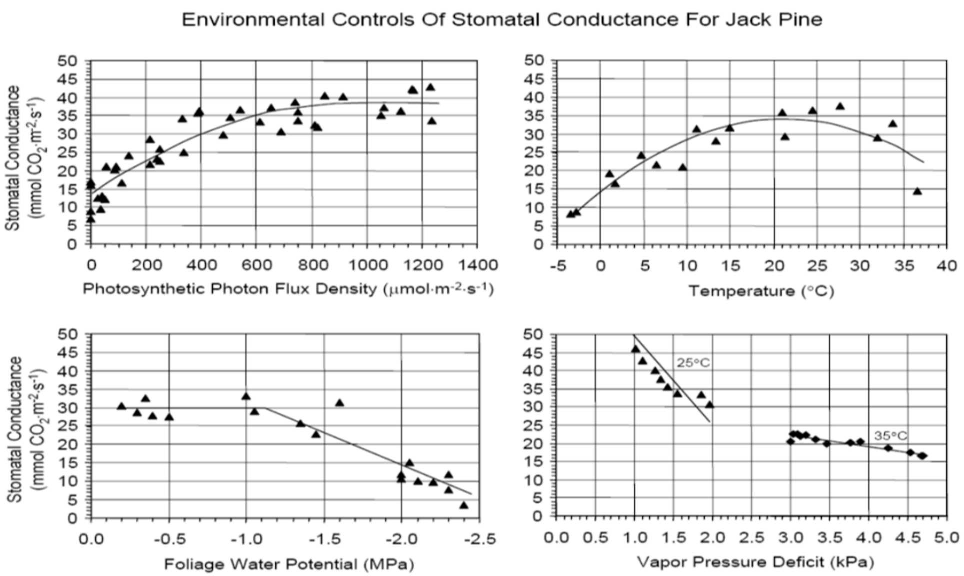


Figure: Bonan, 2002

- "2-leaf" canopy with diffuse/direct light
- **Ball-Berry approach** coupling with photosynthesis

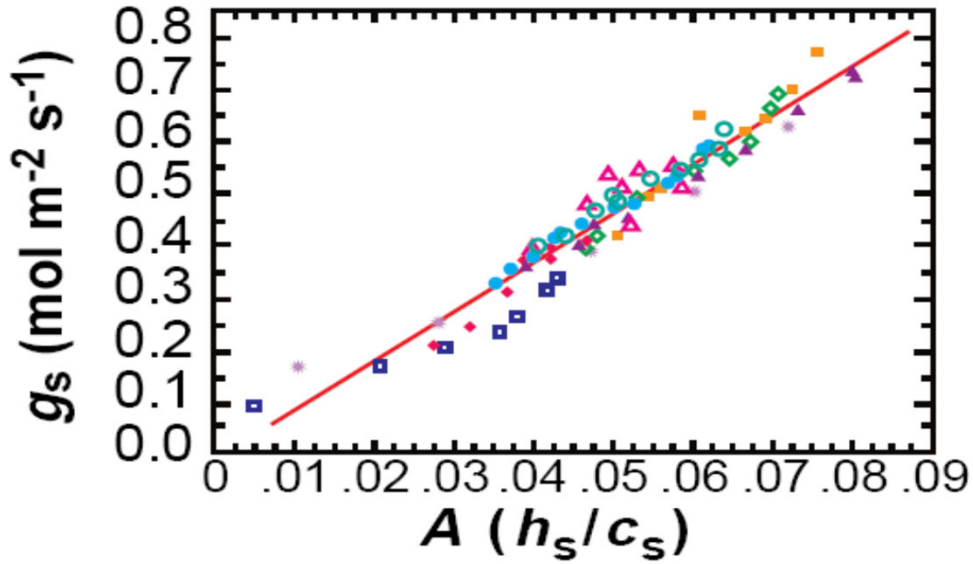


Figure: Sellers et. al, 1997

Differences in approach

TERRA_ML *vs* TERRA_ML (updated)

TERRA_ML

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

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

Where:

- $\mathrm{F_{rad}}$ – the influence on the stomatal resistance of radiation
- $\mathrm{F_{wat}}$ – soil water content
- $\mathrm{F_{tem}}$ – ambient temperature
- $\mathrm{F_{hum}}$ – ambient specific humidity
- r_{max} – maximal stomatal resistance
- $\mathrm{r_{min}}$ – minimal stomatal resistance

TERRA_ML (updated)

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

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

$$g_{st}^{sun} = \frac{1}{r_s^{sun}} = m\frac{A^{sun}e_s}{c_s e_i}P_{atm} + b$$

$$g_{st}^{sha} = \frac{1}{r_s^{sha}} = m\frac{A^{sha}e_s}{c_s e_i}P_{atm} + b$$

Where:

- r_s^{sun} and r_s^{sha} – stomatal resistance for *sun* and *sha* leaves
- g_{st}^{sun} and g_{st}^{sha} – stomatal conductance for *sun* and *sha* leaves
- e_s – the vapor pressure at the leaf surface
- e_i – the saturation vapor pressure inside the leaf at the skin temperature
- c_s – the CO_2 partial pressure at the leaf surface

A – the leaf photosynthesis **b** - is the minimum stomatal conductance; **m** - parameter;

Implemented in COSMO_v5.0_clm16

Photosynthesis:

C3 plants based on Farquhar model (1980) | C4 plants based on Collatz model (1992)

$$w_c = \begin{cases} \dfrac{V_{cmax}\,(c_i - \Gamma_*)}{c_i + K_c\left(1 + \dfrac{O_i}{K_0}\right)}, & for\ C_3\ plants \\ V_{cmax}, & for\ C_4\ plants \end{cases}$$

$$w_j = \begin{cases} \dfrac{(c_i - \Gamma_*)\,4.6\,\alpha\,\phi}{c_i + 2\,\Gamma_*}, & for\ C_3\ plants \\ 4.6\,\alpha\,\phi, & for\ C_4\ plants \end{cases}$$

$$w_e = \begin{cases} 0.5\,V_{cmax}, & for\ C_3\ plants \\ 4000\,V_{cmax}\dfrac{c_i}{P_{atm}}, & for\ C_4\ plants \end{cases}$$

Where: w_c, w_j, w_e – the limited rates of carboxylatio, the light and carboxylase

V_{cmax} – the maximum rate of carboxylation

K_c; K_o – the Michaelis–Menten constants for CO_2 and O_2

Γ_* – the CO_2 compensation point

c_i – the internal leaf CO_2 partial pressure

O_i – the O_2 partial pressure

α – the quantum efficiency coefficient

ϕ – the absorbed photosynthetically active radiation

A, A_{sun}, A_{sha} – the leaf photosynthesis; for sunlit and for shaded leaves

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

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

Implemented in COSMO_v5.0_clm16

The maximum rate of carboxylation :

$$V_{cmax} = V_{cmax25}\,(2.4)^{\frac{T_v-25}{10}} f(T_v)\, f(DYL)\, f(N)\, f(F_{wat})$$

Where:
- V_{cmax25} – the maximum rate of carboxylation at 25ºC
- T_v – leaf temperature or skin temperature
- $f(T_v)$ – function of thermal breakdown of metabolic processes
- $f(N)$ – function of nitrogen limitations
- $f(DYL)$ – function of daylength
- $f(F_{wat})$ – function of soil water content

$$V_{cmax25} = N_a F_{LNR} F_{NR} \alpha_{25}$$

Where:
- N_a – the area–based leaf nitrogen concentration
- F_{LNR} – the fraction of leaf nitrogen in Rubisco
- F_{NR} – the mass ratio of total Rubisco molecular mass to nitrogen in Rubisco
- α_{25} – the specific activity of Rubisco

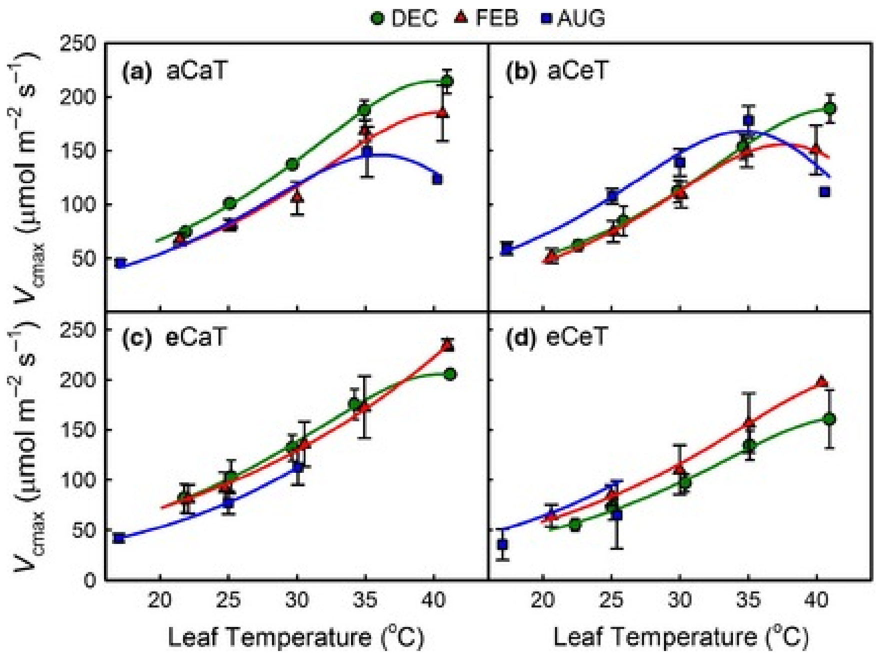


Figure: Crous et. al, 2013

Implemented in COSMO_v5.0_clm16

The area–based leaf nitrogen concentration:

$$N_a = \frac{1}{\mathrm{CN_L\ SLA}}$$

Specific leaf area indices
for sunlit (SLA^{sun}) and shaded (SLA^{sha}) leaves:

$$SLA^{sun} = \frac{\int_0^L SLA(x)e^{-Kx}dx}{L^{sun}} = \frac{-(cSLA_m KL + cSLA_m + cSLA_o K - SLA_m - SLA_o K)}{K^2 L^{sun}}$$

$$SLA^{sha} = \frac{\int_0^L SLA(x)[1 - e^{-Kx}]dx}{L^{sha}} = \frac{L(SLA_o + \frac{SLA_m L}{2}) - SLA^{sun} L^{sun}}{L^{sha}}$$

Where: **$\mathrm{CN_L}$** – the leaf carbon-to-nitrogen ratio

SLA – the specific leaf area indices

L and S – the leaf and stem area indices

SLA_m and SLA_o – the linear slope coefficient and the value for SLA at the top of the canopy

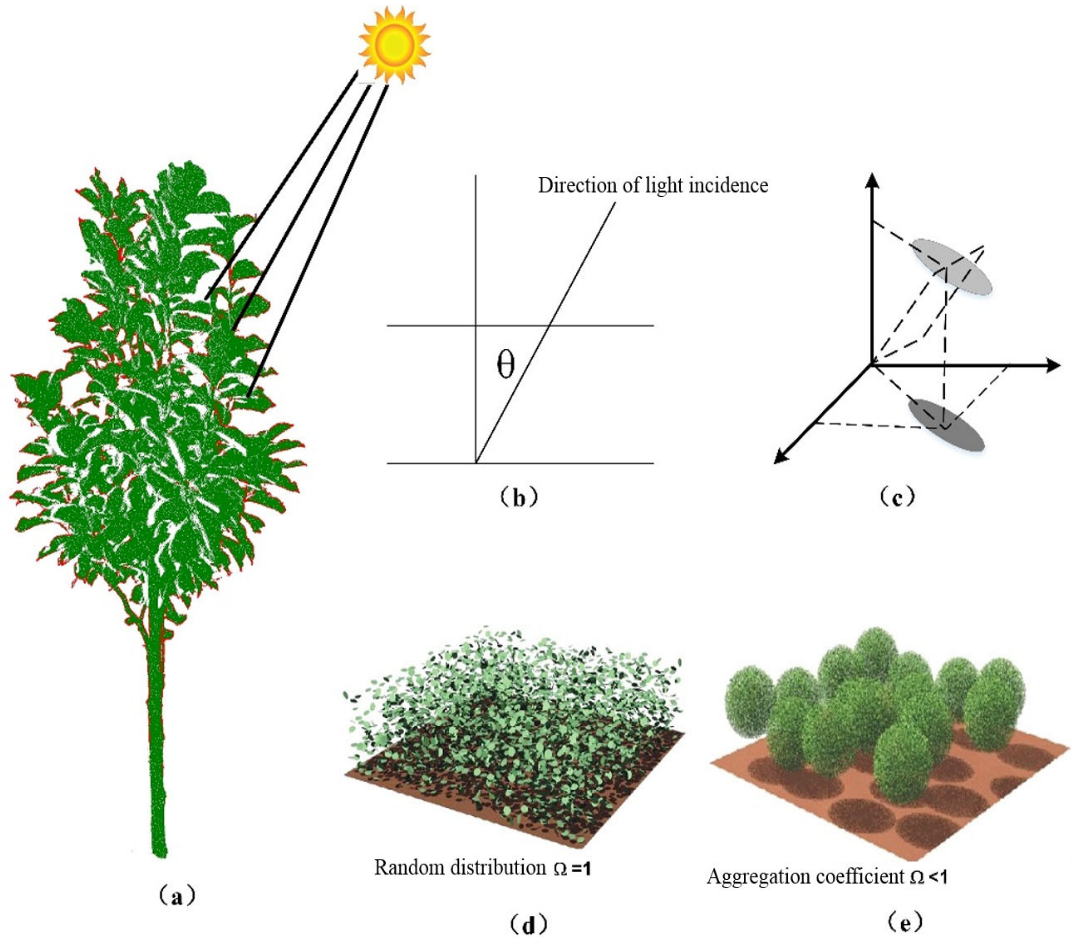


Figure: Chen et. al, 1991

Implemented in COSMO_v5.0_clm16

The new algorithm for "2-leaf" canopy (sunlit and shaded leaves)

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:

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

The light extinction coefficient:

$$K = \frac{G(\mu)}{\mu}$$

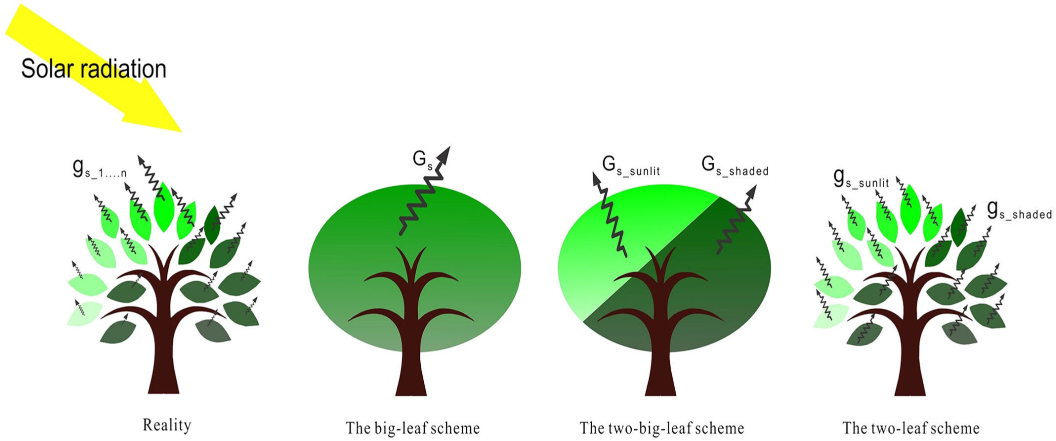


Figure: Luo et. al, 2018

Where: e^{-KL} – the fractional area of sun flecks on a horizontal plane below the leaf area index – L;

K – the light extinction coefficient;

$G(\mu)$ – the relative projected area of leaf and stem elements in the direction $cos^{-1}\mu$;

μ – the cosine of the zenith angle of the incident beam;

Implemented in COSMO_v5.0_clm16

The new algorithm for "2-leaf" canopy (sunlit and shaded leaves)

Sunlit (ϕ^{sun}) and shaded (ϕ^{sha}) absorbed photosynthetically active radiation (PAR):

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

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

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

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

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

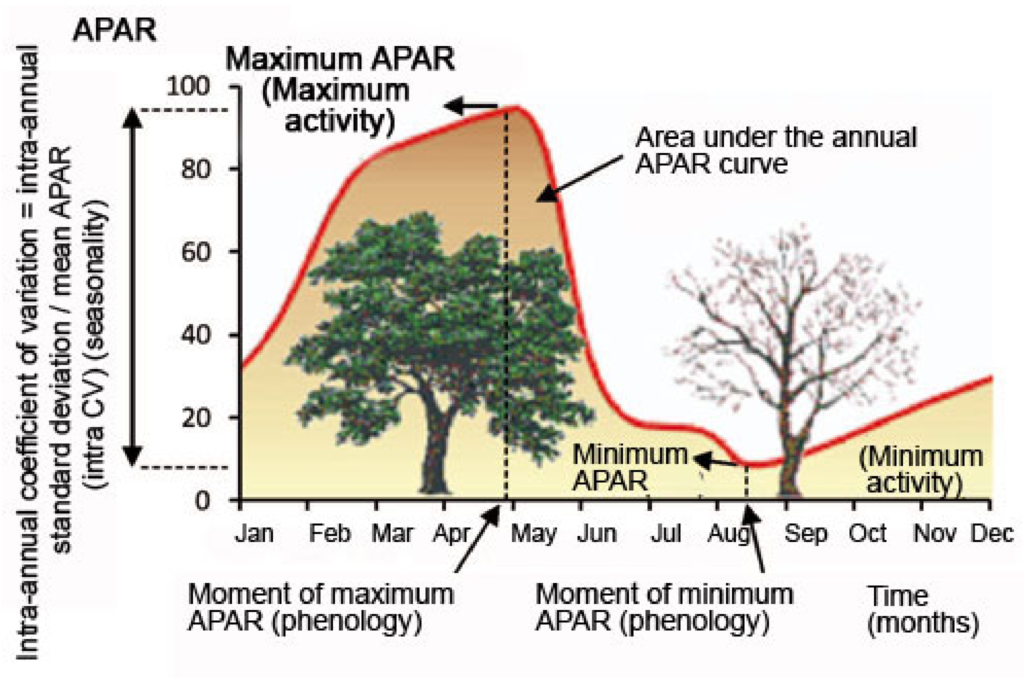
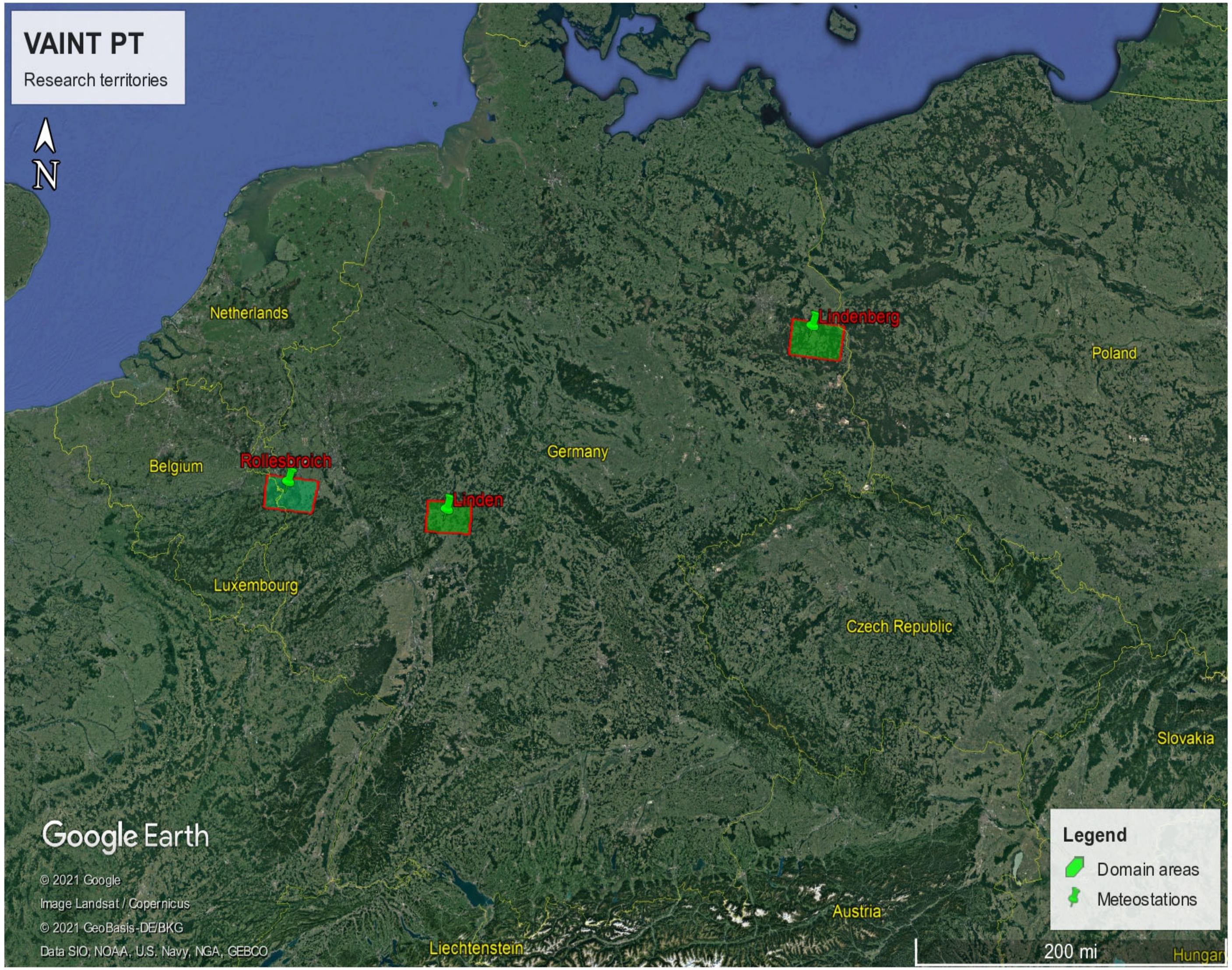


Figure: Cabello et. al, 2011

Research territory

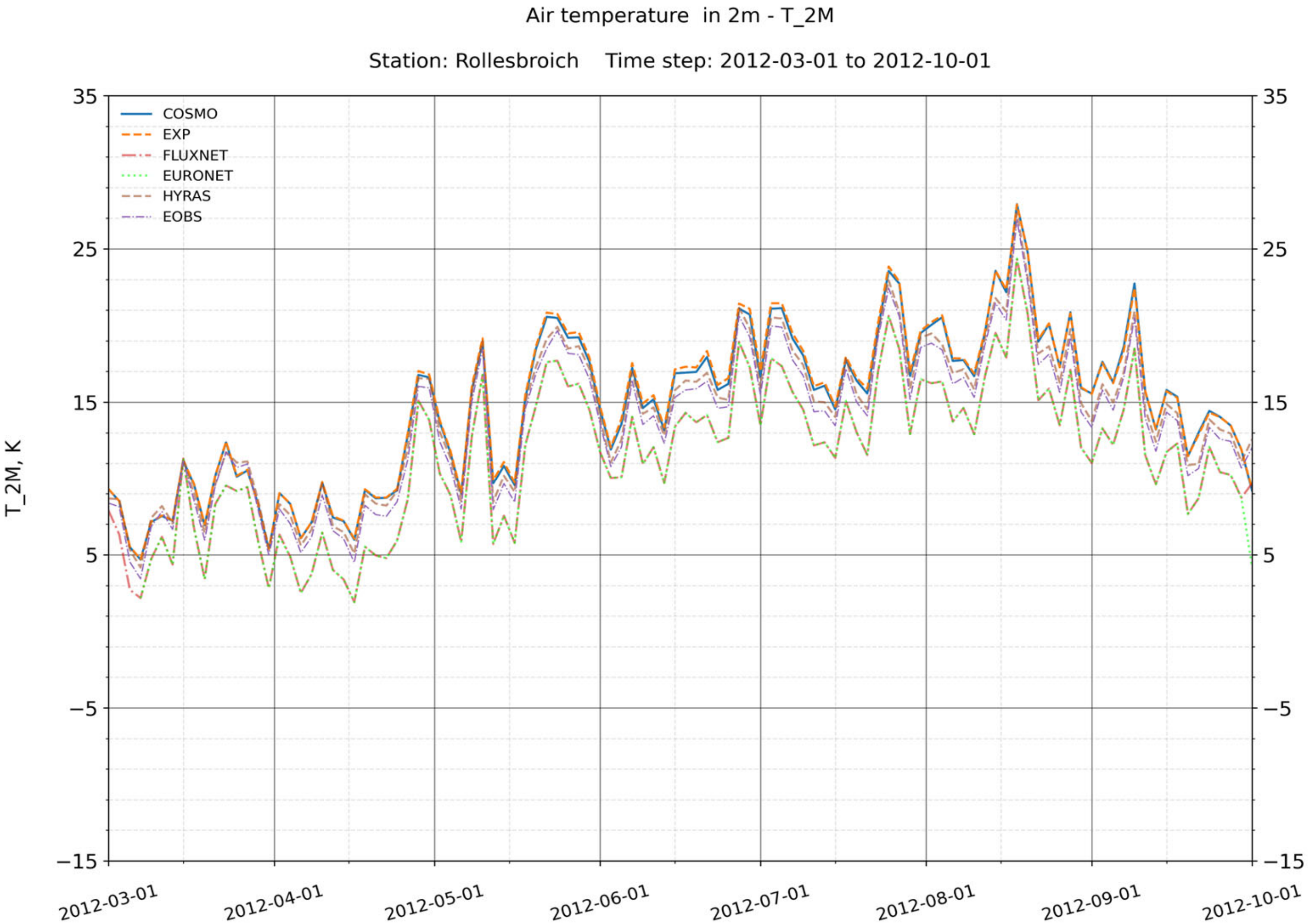


Stations: Rollesbroich
Linden
Lindenberg

Period: 01.01.1999 – 31.12.2015

Data for verification: GLEAM
FLUXNET
EURONET
EOBS
HYRAS

Comparison COSMO_v5.0_clm16
without changes and with updates

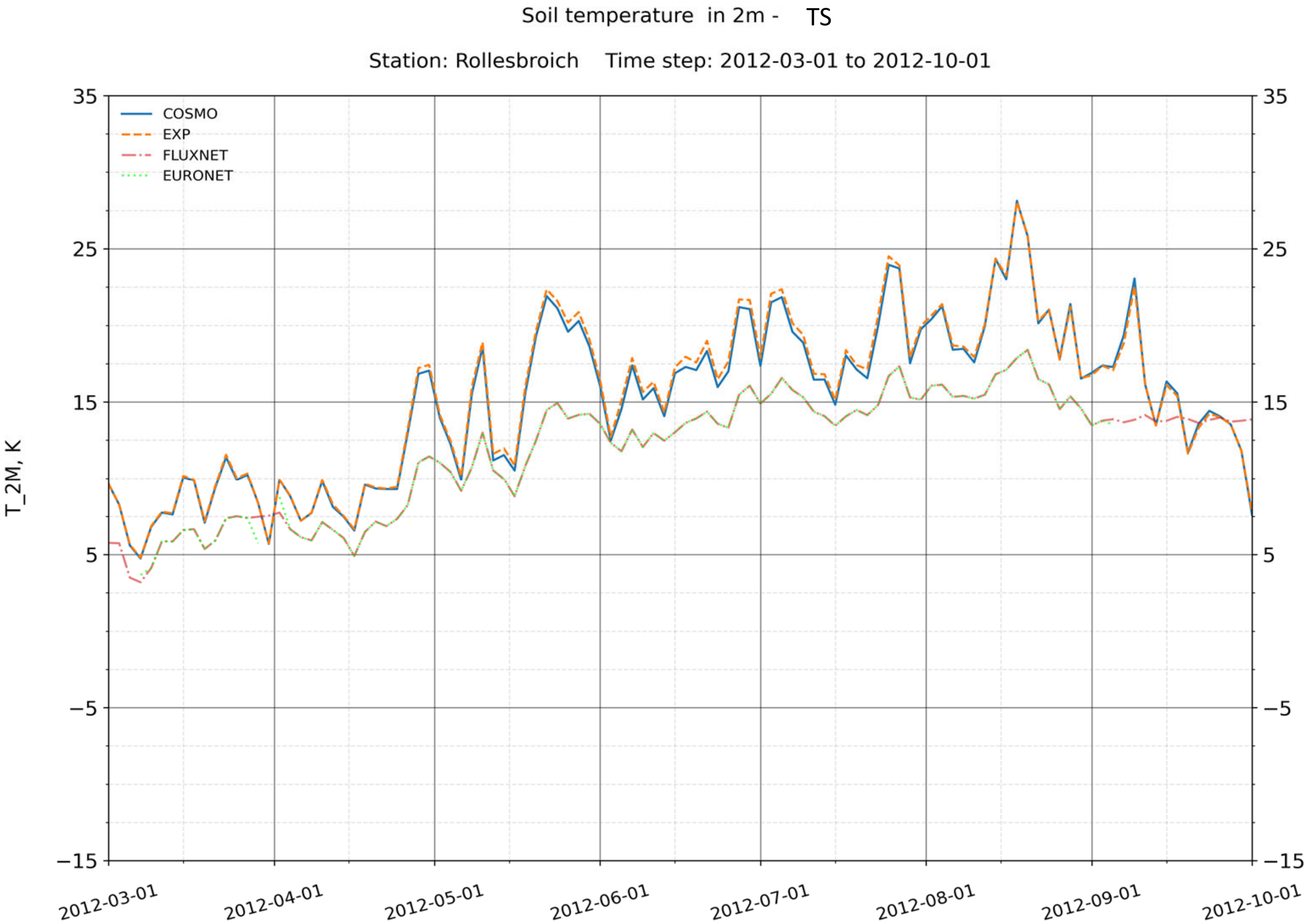


Station: *Rollesbroich*

Parameter: *T2m*

Period: *03.2012 to 10.2012*

Comparison COSMO_v5.0_clm16 without changes and with updates

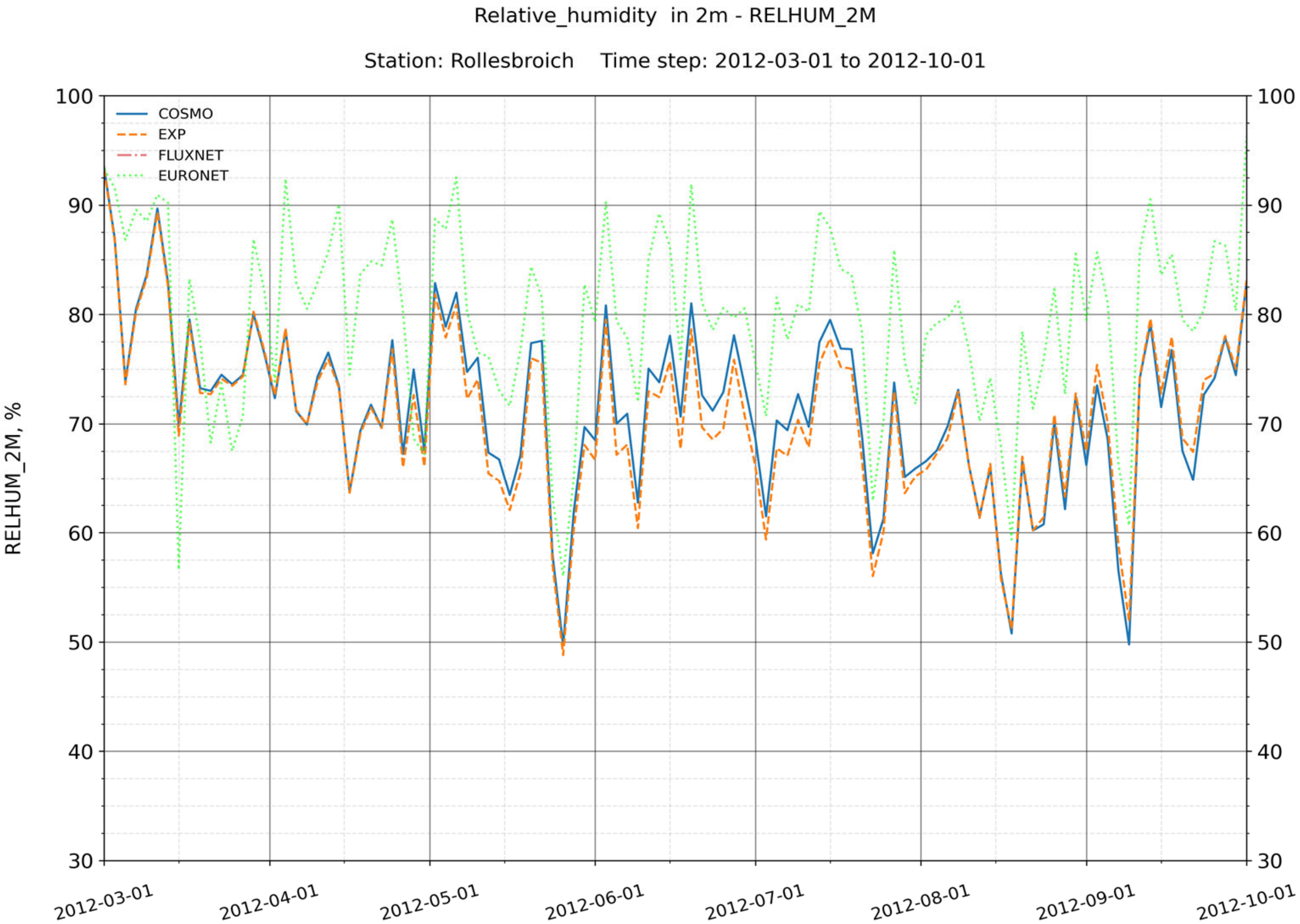


Station: *Rollesbroich*

Parameter: *TS*

Period: *03.2012 to 10.2012*

Comparison COSMO_v5.0_clm16
without changes and with updates

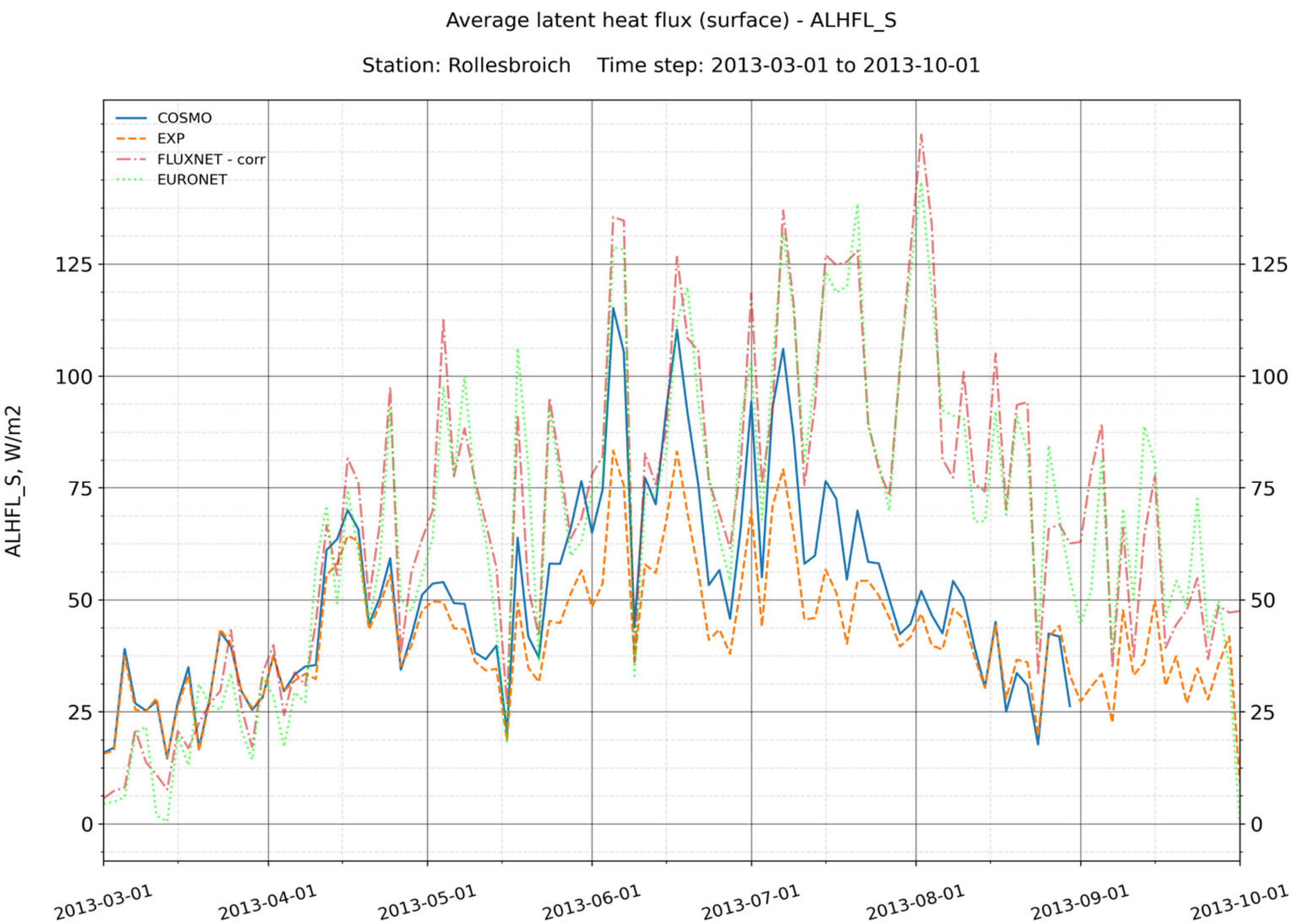


Station: Rollesbroich

Parameter: RELHUM

Period: 03.2012 to 10.2012

Comparison COSMO_v5.0_clm16 without changes and with updates



Station: *Rollesbroich*

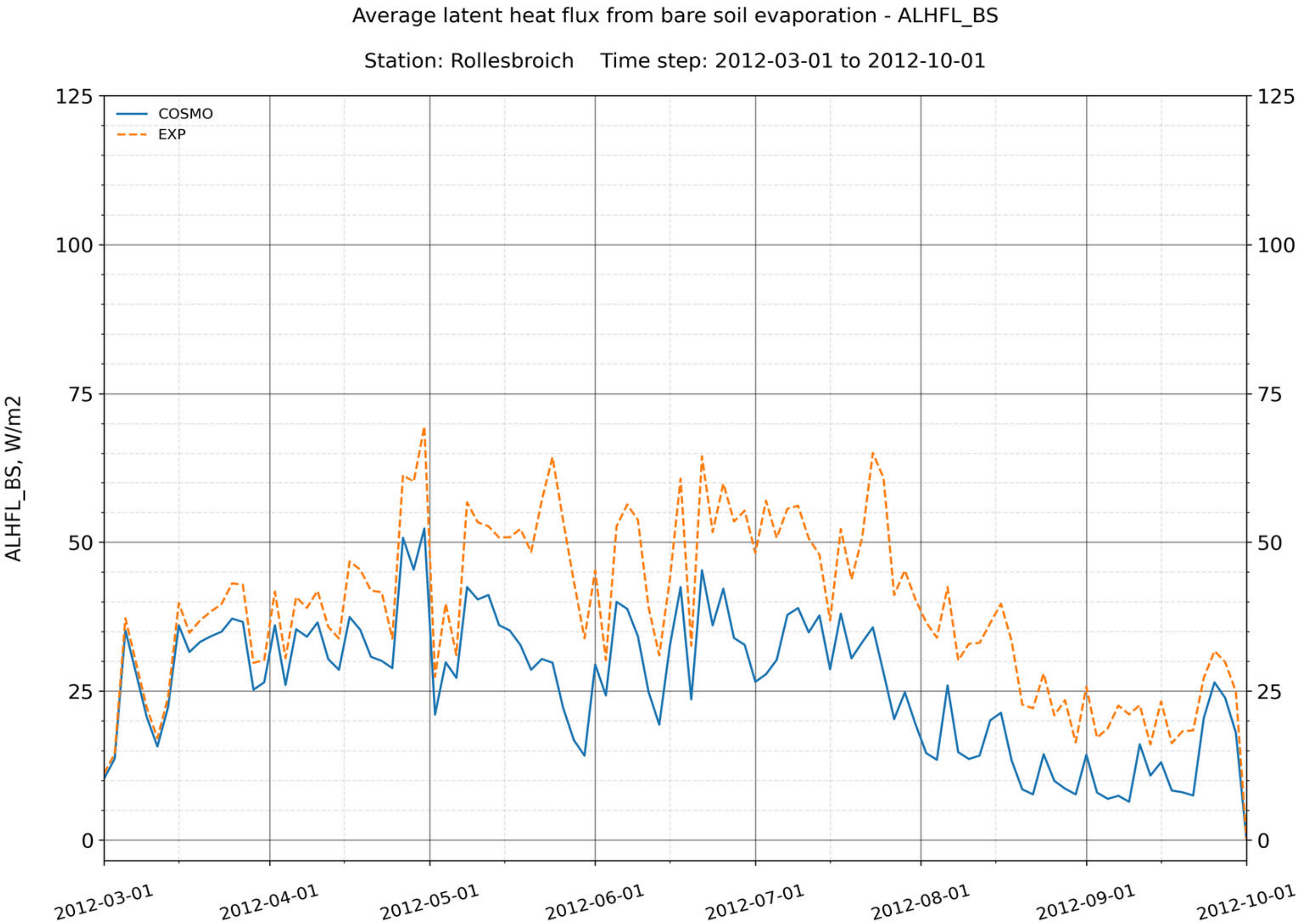
Parameter: *ALHFL_S*

Period: *03.2013 to 10.2013*

Mode1: *Daily*

Mode2: *Monthly*

Comparison COSMO_v5.0_clm16 without changes and with updates

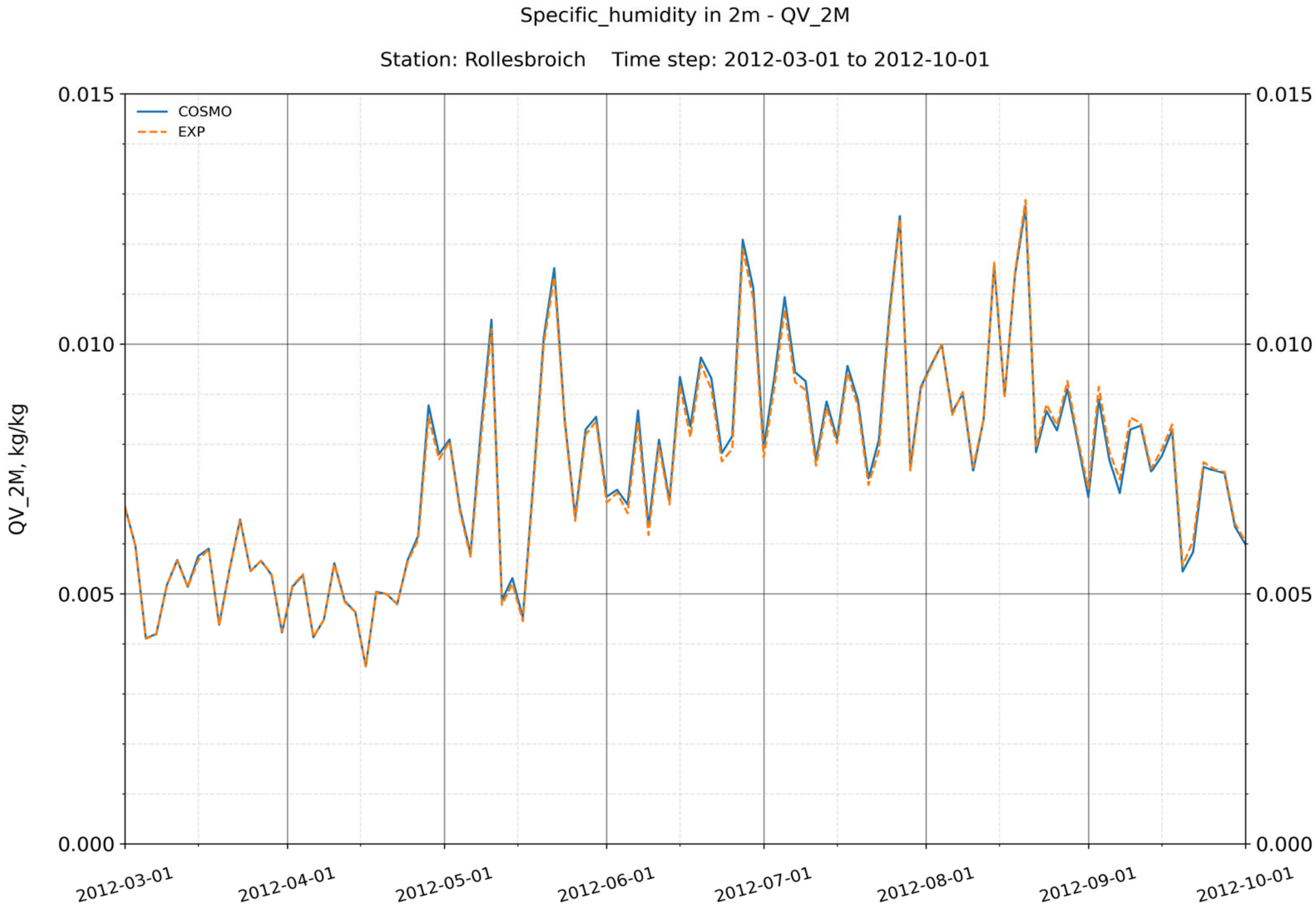


Station: Rollesbroich

Parameter: ALHFL_BS

Period: 03.2012 to 10.2012

Comparison COSMO_v5.0_clm16 without changes and with updates

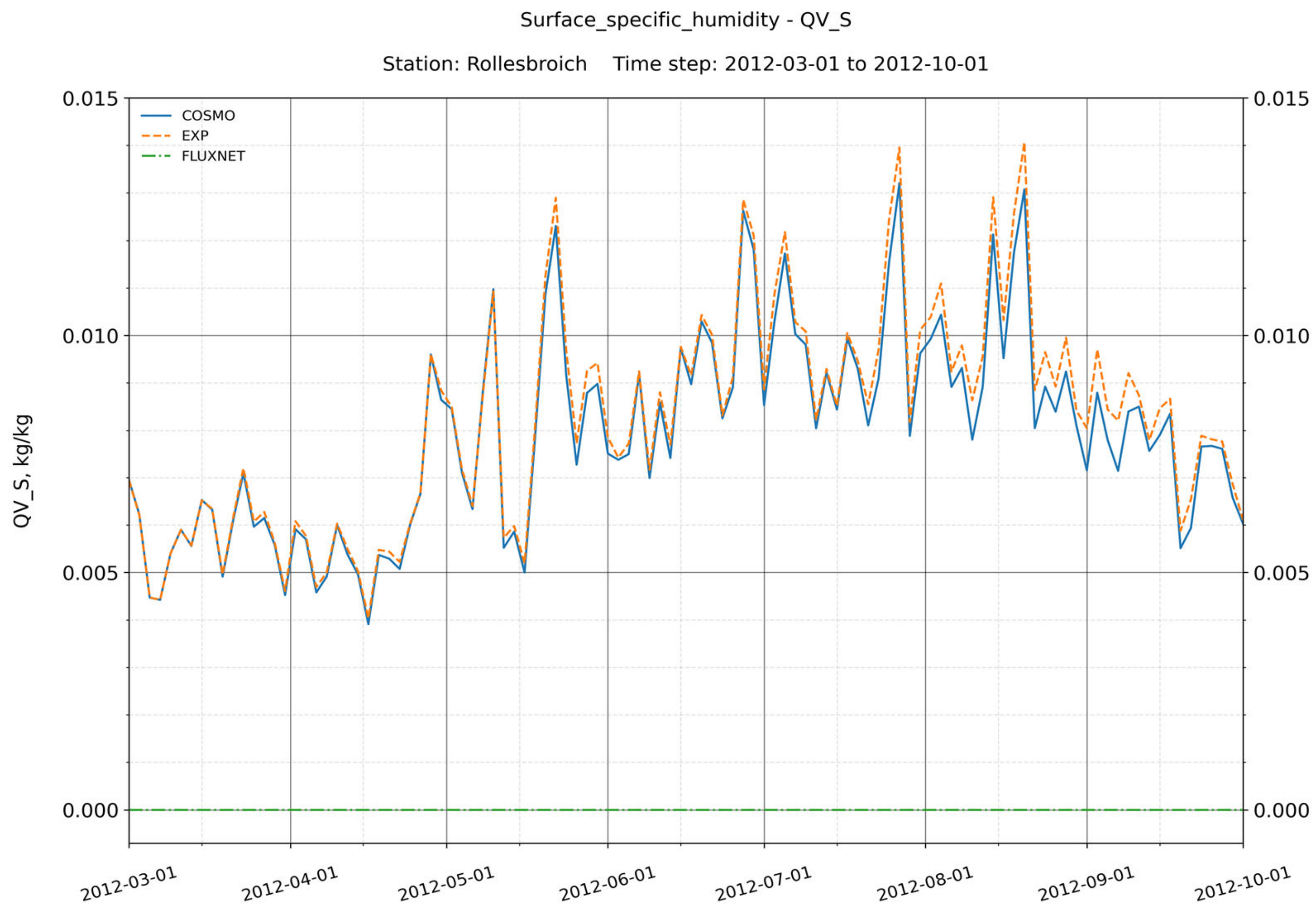


Station: *Rollesbroich*

Parameter: *QV_2M*

Period: *03.2012 to 10.2012*

Comparison COSMO_v5.0_clm16 without changes and with updates

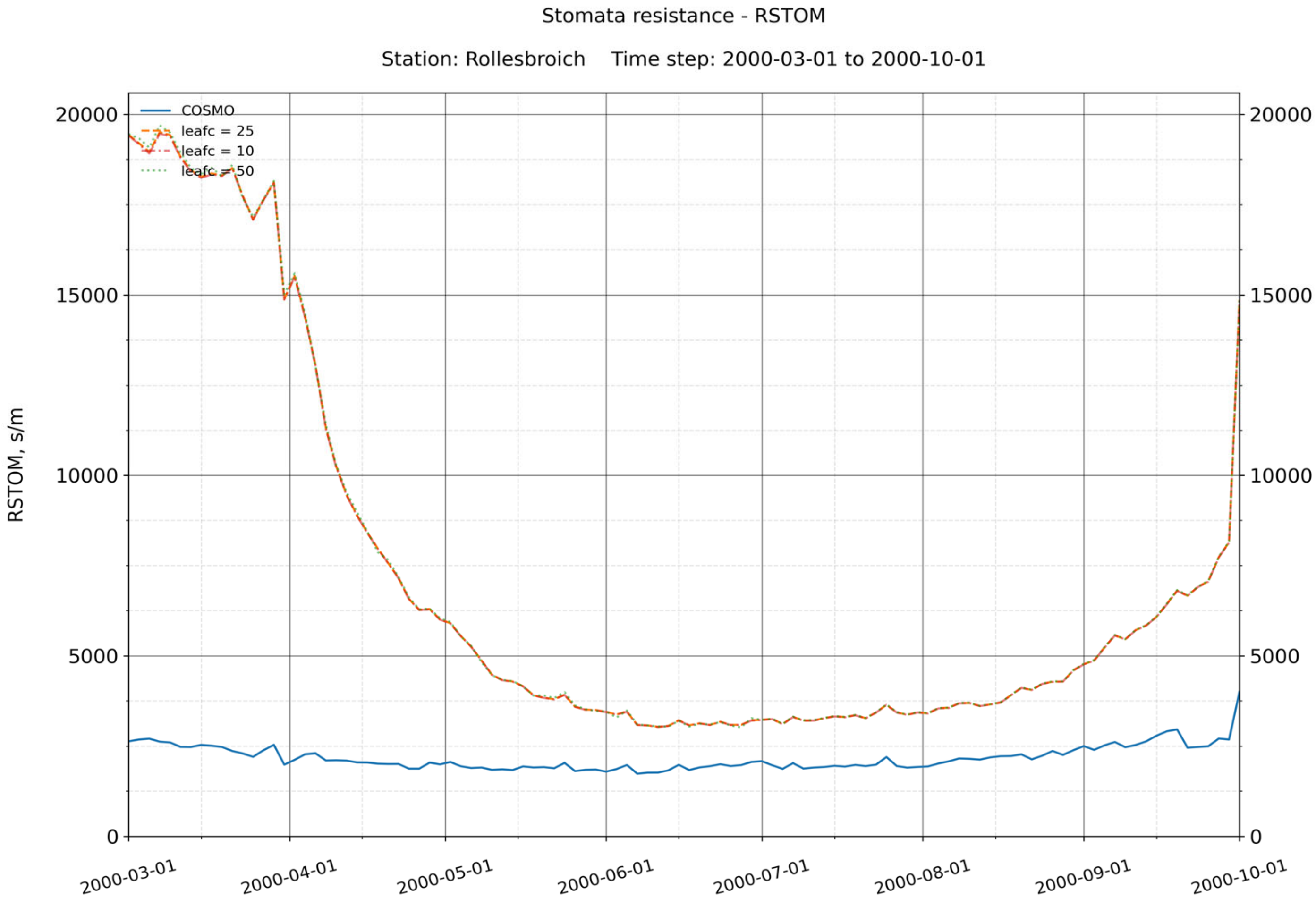


Station: Rollesbroich

Parameter: QV_S

Period: 03.2012 to 10.2012

Comparison COSMO_v5.0_clm16
without changes and with updates



Station: *Rollesbroich*

Parameter: *RSTOM*

Period: *03.2012 to 10.2012*

Final Summary:

1) Continue work on VAINT PT;

2) Validation of new photosynthesis algorithm;

3) Implementation new modules for carbon allocation, plant growth, heterotrophic respiration and litter/soil;

4) Validation of new modules;

5) Update documentation + articles;

UNI KASSEL VERSITÄT

Our contacts:

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

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Wilhelmshöher Allee 47, 34117 Kassel

Email: evgenychur@uni-kassel.de

Special acknowledgements to
Marina Shatunova

Discussion questions:

Do you need the new parameters for the COSMO community?

* ***sfldir_par*** – direct component of photosynthetic active radiation flux at the ground;
* ***sfldifd_par*** – diffuse downward component of photosynthetic active radiation flux at the ground;
* ***sfldifu_par*** – diffuse upward component of photosynthetic active radiation flux at the ground;
* ***cos_zen_ang*** – cosine of solar zenith angle;
* ***ztraleav*** – transpiration rate of dry leaves;
* ***ztrang*** – transpiration contribution by the different layers;
* ***ztrangs*** – total transpiration ;
* ***zverbo*** – total evapotranspiration;

Accumulated values:

*asfldir_par; *asfldifd_par; *asfldifu_par; *aztraleav; *aztrang; *aztrangs; *azverbo;

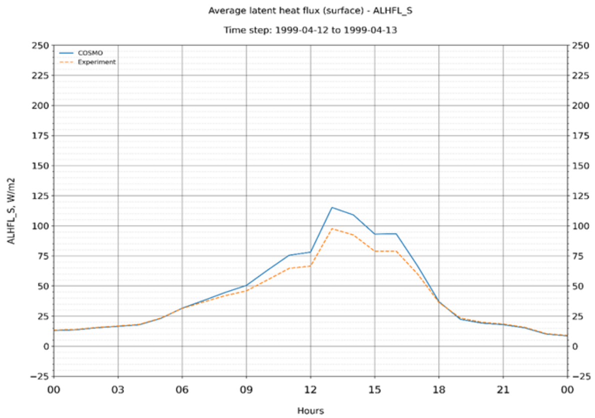
Discussion questions:

Why the ***EVATRA_SUM*** and ***TRA*** in src_setup_wartab are incorrect?

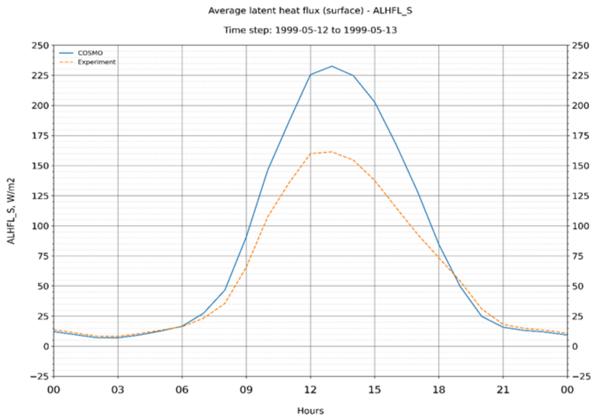
Can be that in COSMO we are using (soil water content function), but in CLM (soil water potential)?

Do you have in COSMO (TERRA-ML) a tuning parameters which are related to stomatal regulation, latent heat?

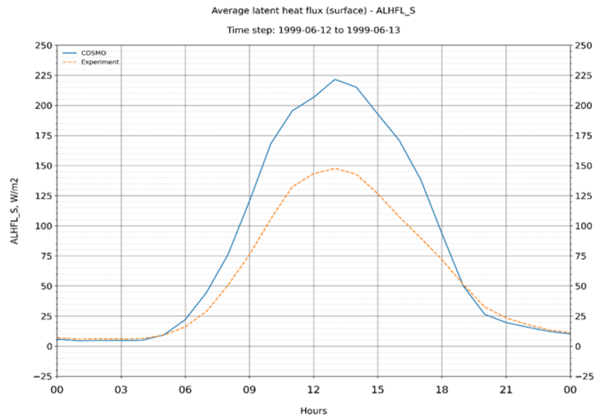
Comparison COSMO_v5.0_clm16
without changes and with updates



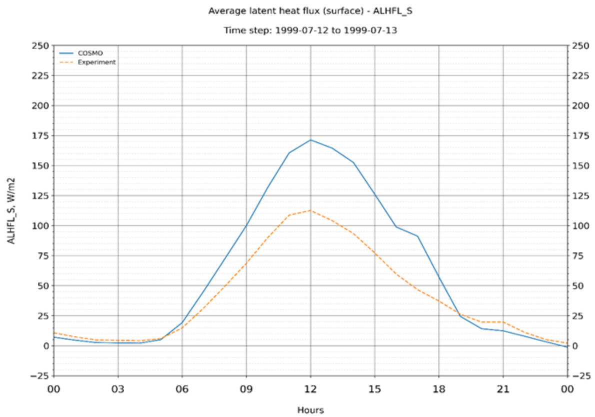
Date: 12.04.1999



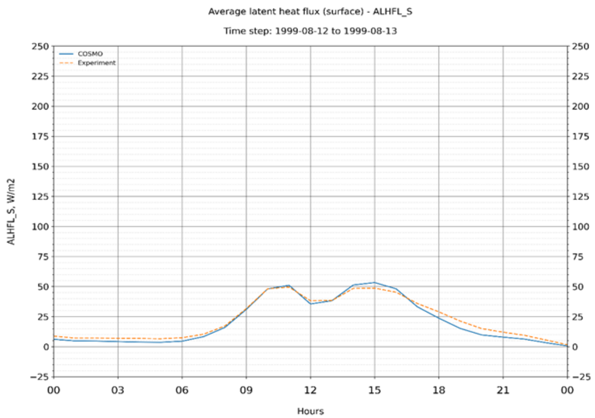
Date: 12.05.1999



Date: 12.06.1999



Date: 12.07.1999



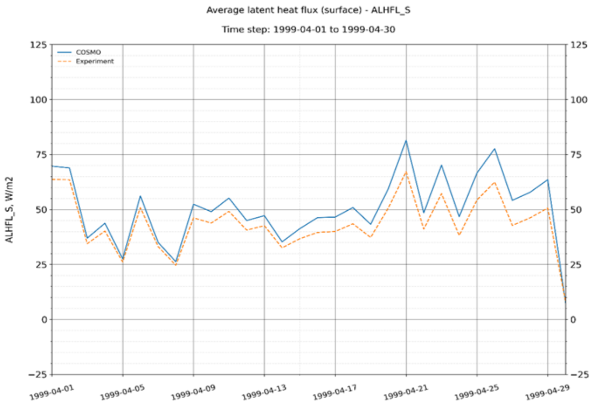
Date: 12.08.1999

Station: Rollesbroich

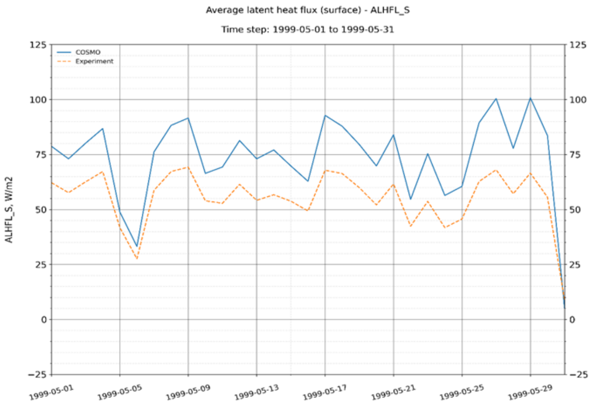
Parameter: ALHFL_S

Return

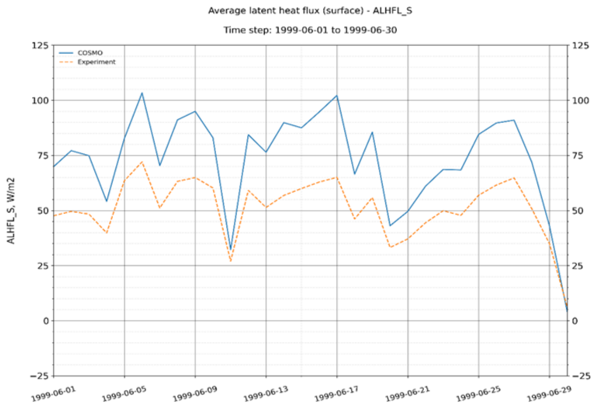
Comparison COSMO_v5.0_clm16 without changes and with updates



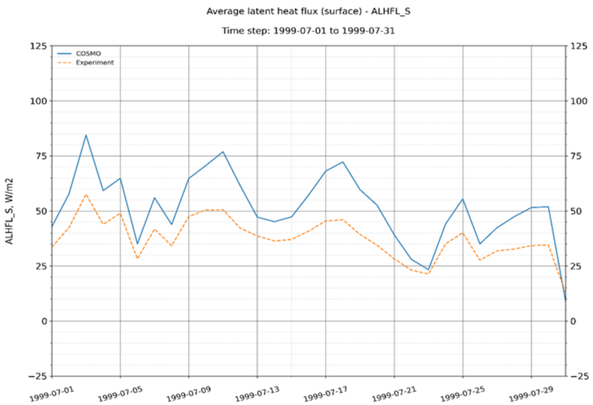
Period: 04.1999 to 05.1999



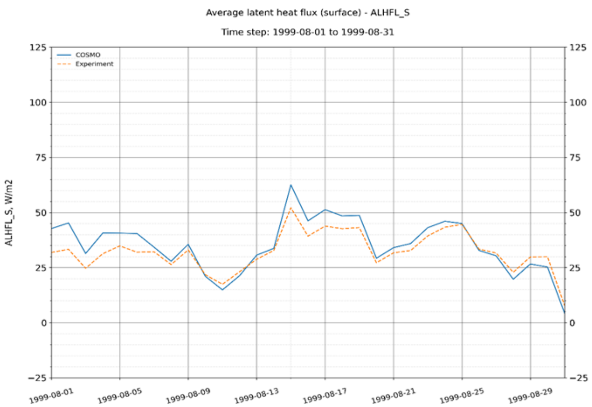
Period: 05.1999 to 06.1999



Period: 06.1999 to 07.1999



Period: 07.1999 to 08.1999



Period: 08.1999 to 09.1999

Station: Rollesbroich

Parameter: ALHFL_S

Return

Preparatory work with COSMO_v5.0_clm16

Have been added changes in next src_files:

data_fields **src_allocation** **src_setup_vartad**	The **15 new global data parameters** have been added: **7 for src_radiation** and **8 for srs_soil_multlay**
near_surface	The **7 accumulation parameters** have been added**:** **3 for src_radiation** and **4 for src_soil_multlay**
io_metadata	The additional option for CASE(111) has been added
src_gridpoints	The 3 additional parameters have been added
organize_data	The 3 additional parameters have been added
data_constance	The 5 additional constant values have been added

Preparatory work with COSMO_v5.0_clm16

Have been added changes in next src_files:

src_radiation The 4 additional parameters:

sfldir_par - direct component of photosynthetic active radiation flux at the ground;

sfldifd_par - diffuse downward component of photosynthetic active radiation flux at the ground;

sfldifu_par - diffuse upward component of photosynthetic active radiation flux at the ground;

cos_zen_ang - cosine of solar zenith angle;

src_soil_multlay The 4 local parameters have been changed on 4 global parameters and 2 outside modules have been implemented: **src_phenology** and **data_phenology**

ztraleav - transpiration rate of dry leaves;

ztrang - transpiration contribution by the different layers;

ztrangs - total transpiration ;

zverbo - total evapotranspiration;

Preparatory work with COSMO_v5.0_clm16

Have been implemented in COSMO_CLM:

data_phenology The module contains:

- **new constant values** for C3 and C4 PFTs
- **new parameters** for canopy photosynthesis
- **new parameters** for stomatal conductance

src_phenology The module contains 4 new subroutine:

- **get_stomatal_grid** – create a grid with PFT values instead of Land Use Class
- **get_sun_data** – calculate of daylength and solar declination angel
- **get_stomatal_data** – calculate of 2-leaf canopy parameters with diffuse/direct light
- **stomata** – calculate stomatal regulation and photosynthesis parameters

CESR_project The separate project which are applying for ***PT VAINT*** statistical analysis and data visualization;

Possible reasons:

Not parameterized parameters:

leafc: 30 [kgC/m2]
forc_hgt_u: 30 [m]

Not balance in experiment runs:

Calculated experiment only for 2012 and 2013 years

New stomatal regulation algorithm:

Need different tuning parameters

Errors in new algorithms:

Errors in dimensions;

Errors in adaptation COSMO data to CLM data;

Errors in PFT grid

Differences between the models:

	TERRA-ML	Veg3D	JS-BACH	LPJmL	CARAIB	CLM v3.5
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)	YES / Big leaf concept (shaded and sunlit leaves)
Turbulent fluxes	Surface temperature	Vegetation temperature	Vegetation temperature	Vegetation temperature	Vegetation temperature	Vegetation temperature
Vegetation parameters	Weighted average	Dominant	Tile approach	Tile approach	Tile approach	Tile approach
Radiation	Albedo constant	Albedo depends on vegetation	Albedo depends on vegetation	Albedo depends on vegetation	Albedo depends on vegetation	Albedo depends on vegetation
PFT	NO		YES	YES	YES	YES
Documentation	YES		YES	YES / NO	YES / NO	YES
Programming language	Fortran 90		C++		Fortran 77	Fortran 90

Our decision:

We have been applying a Community Land Model (CLM 3.5 – 4.0) as the main example for the new implementations in TERRA-ML