

Current status of *PT VAIN*

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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

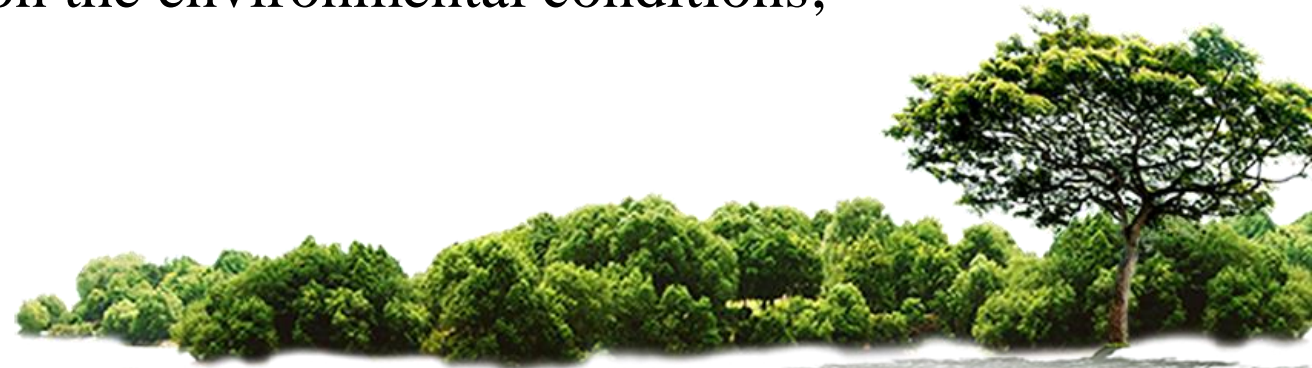
Extreme
events

- Increase in frequency
- Increase in the need for modeling



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;





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**

“2-leaf” canopy with diffuse/direct light

Ball-Berry approach coupling with photosynthesis

Environmental Controls Of Stomatal Conductance For Jack Pine

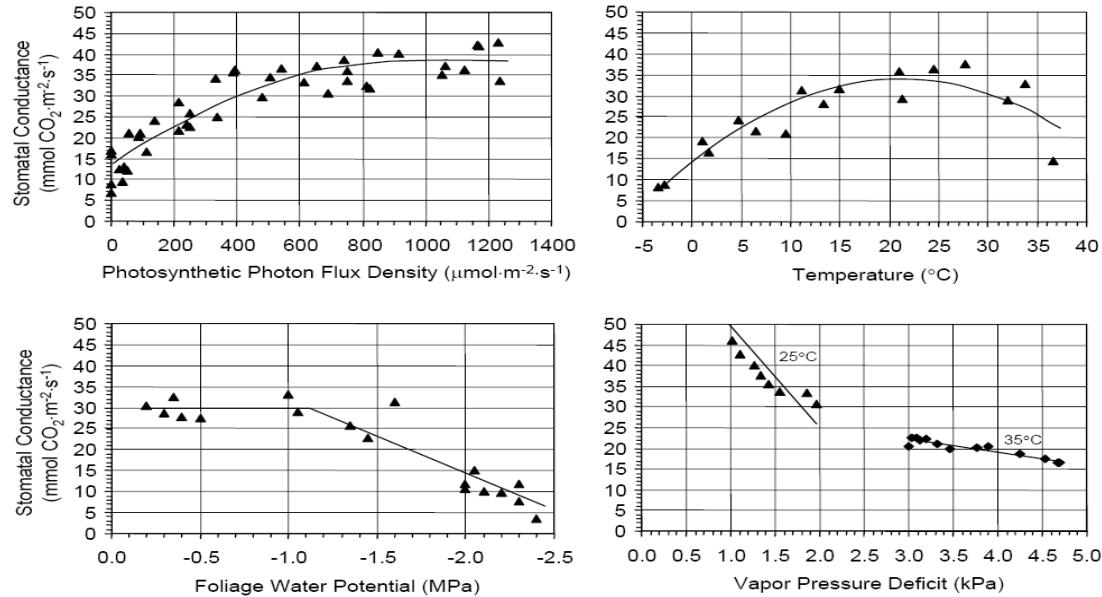


Figure: Bonan, 2002

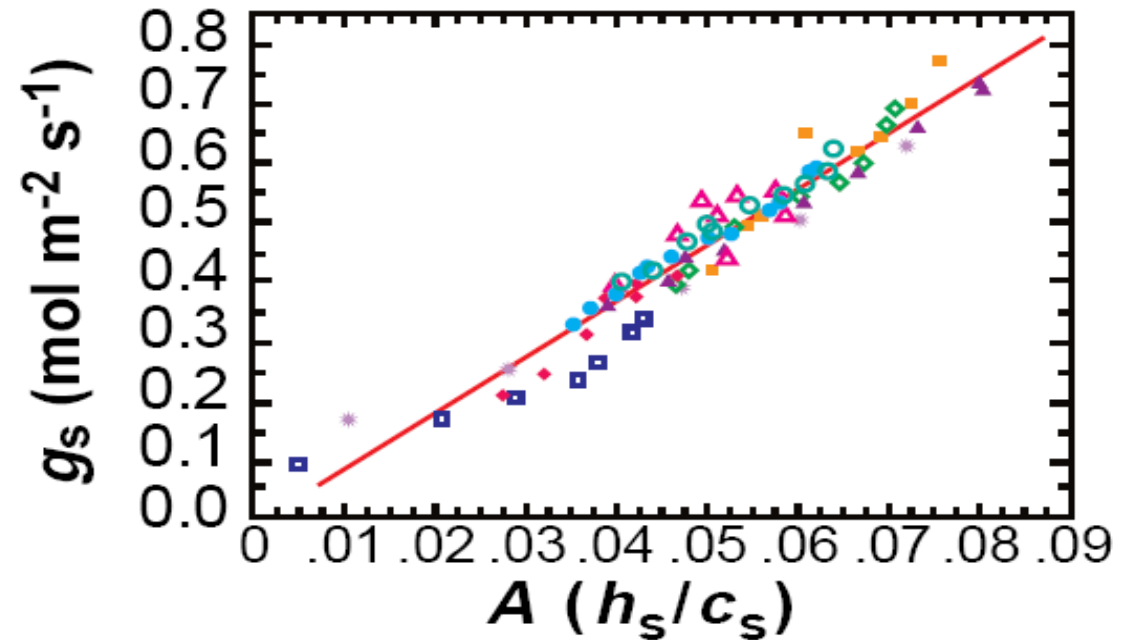


Figure: Sellers et. al, 1997

Differences in approach



TERRA_ML

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

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

Where: F_{rad} – the influence on the stomatal
resistance of radiation

F_{wat} – soil water content

F_{tem} – ambient temperature

F_{hum} – ambient specific humidity

r_{max} – maximal stomatal resistance

r_{min} – minimal stomatal resistance

vs

TERRA_ML (updated)

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

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

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

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

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 CO₂ partial pressure at the leaf surface

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



Photosynthesis:

C3 plants based on **Farquhar model** (1980)

C4 plants based on **Collatz model** (1992)

$$w_c = \begin{cases} \frac{V_{cmax} (c_i - \Gamma_*)}{c_i + K_c (1 + \frac{O_i}{K_o})}, & \text{for } C_3 \text{ plants} \\ V_{cmax} & , \text{for } C_4 \text{ plants} \end{cases} \quad w_j = \begin{cases} \frac{(c_i - \Gamma_*) 4.6 \alpha \phi}{c_i + 2 \Gamma_*}, & \text{for } C_3 \text{ plants} \\ 4.6 \alpha \phi & , \text{for } C_4 \text{ plants} \end{cases} \quad w_e = \begin{cases} 0.5 V_{cmax}, & \text{for } C_3 \text{ plants} \\ 4000 V_{cmax} \frac{c_i}{P_{atm}}, & \text{for } C_4 \text{ plants} \end{cases}$$

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

V_{cmax} – the maximum rate of carboxylation

$K_c; K_o$ – the Michaelis–Menten constants for CO₂ and O₂

Γ_* – the CO₂ compensation point

c_i – the internal leaf CO₂ partial pressure

O_i – the O₂ 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

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

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

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 25°C
 - 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

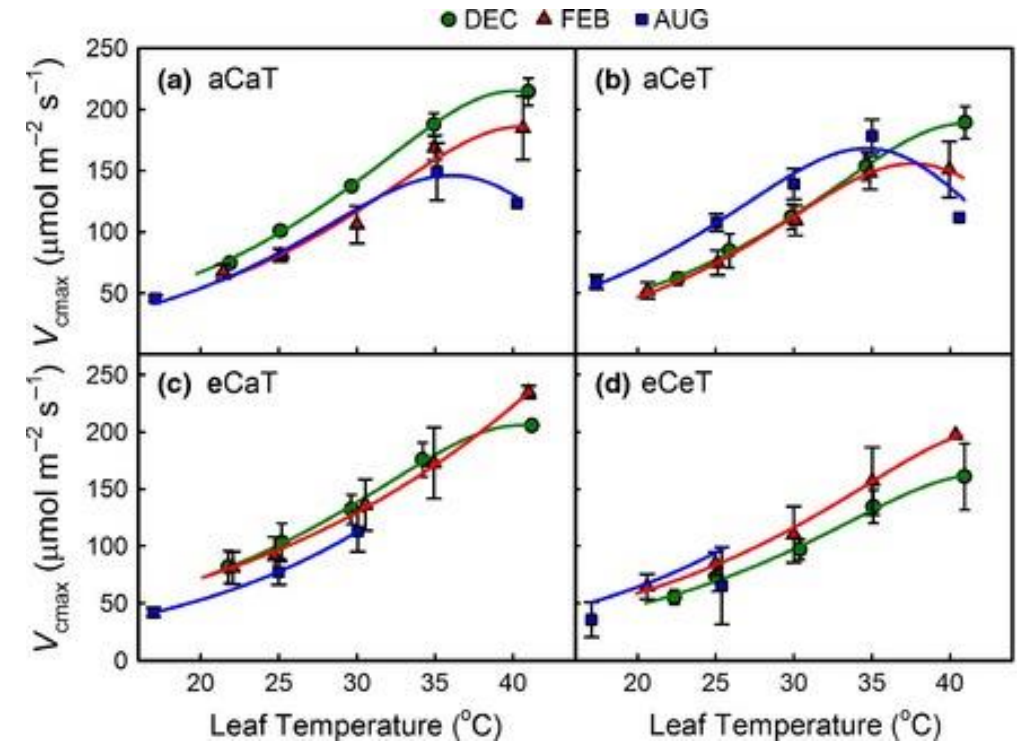


Figure: Crous et. al, 2013



The area-based leaf nitrogen concentration:

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

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: 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

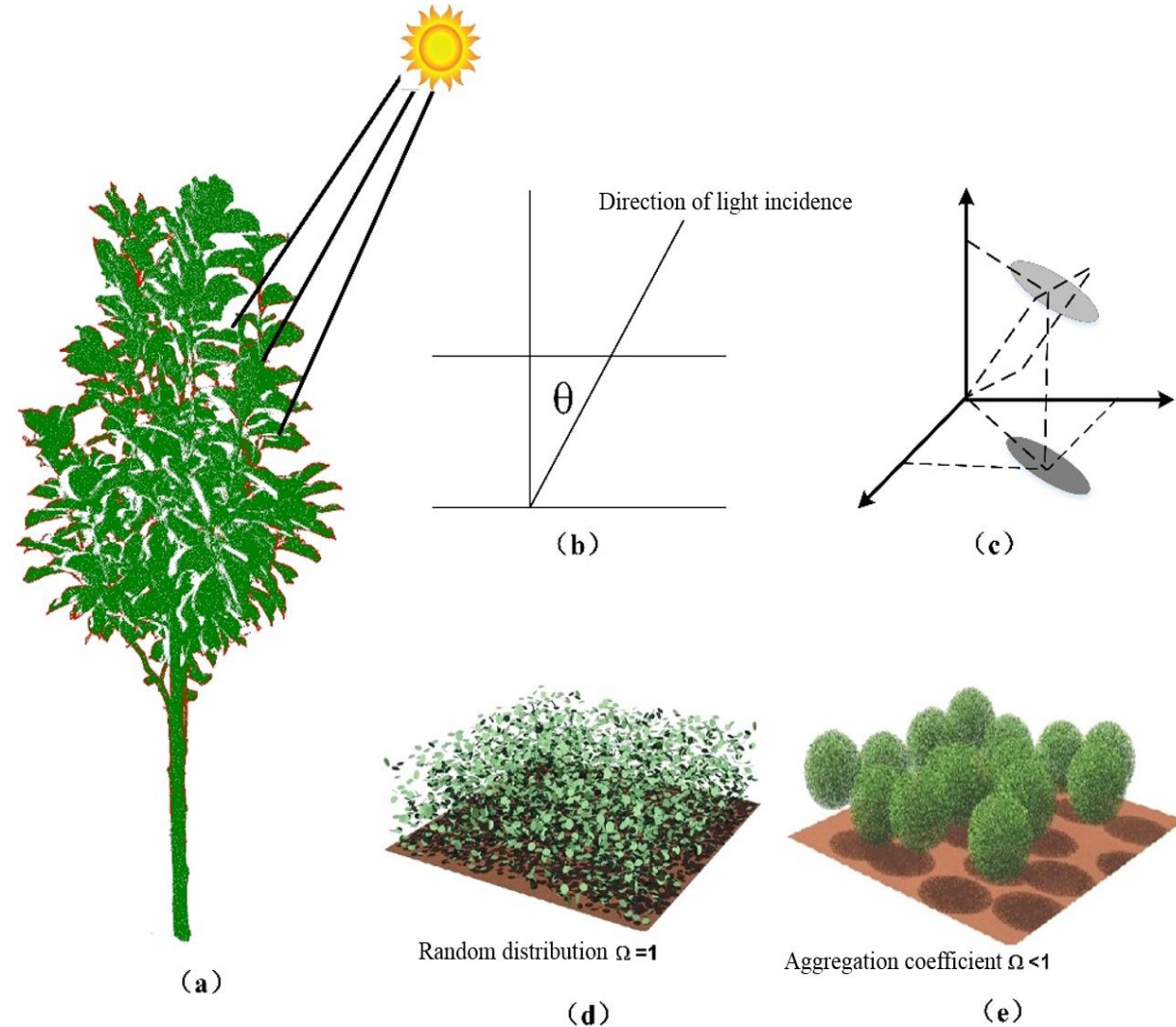


Figure: Chen et. al, 1991

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:

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

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

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

The light extinction coefficient:

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

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;

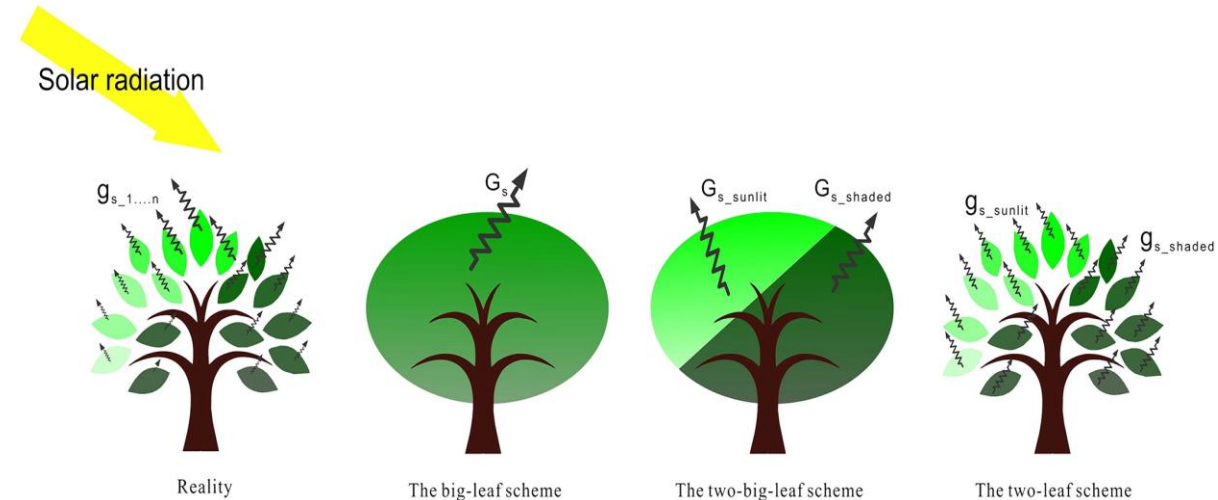


Figure: Luo et. al, 2018

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):

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

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

- Where:
- ϕ_{dir}^{μ} – the portion of the incoming visible waveband direct beam radiation
 - ϕ_{dif}^{μ} – the absorbed visible waveband direct beam radiation;
 - ϕ_{dif} – is the incoming visible waveband diffuse radiation;

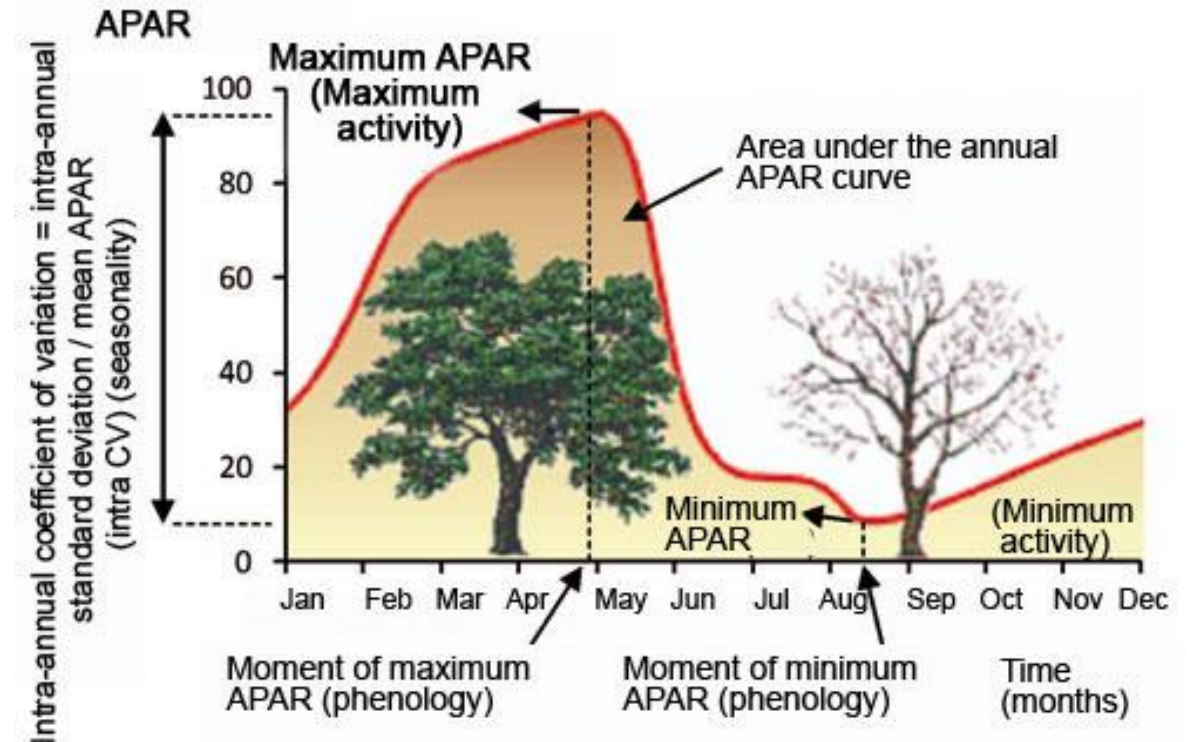
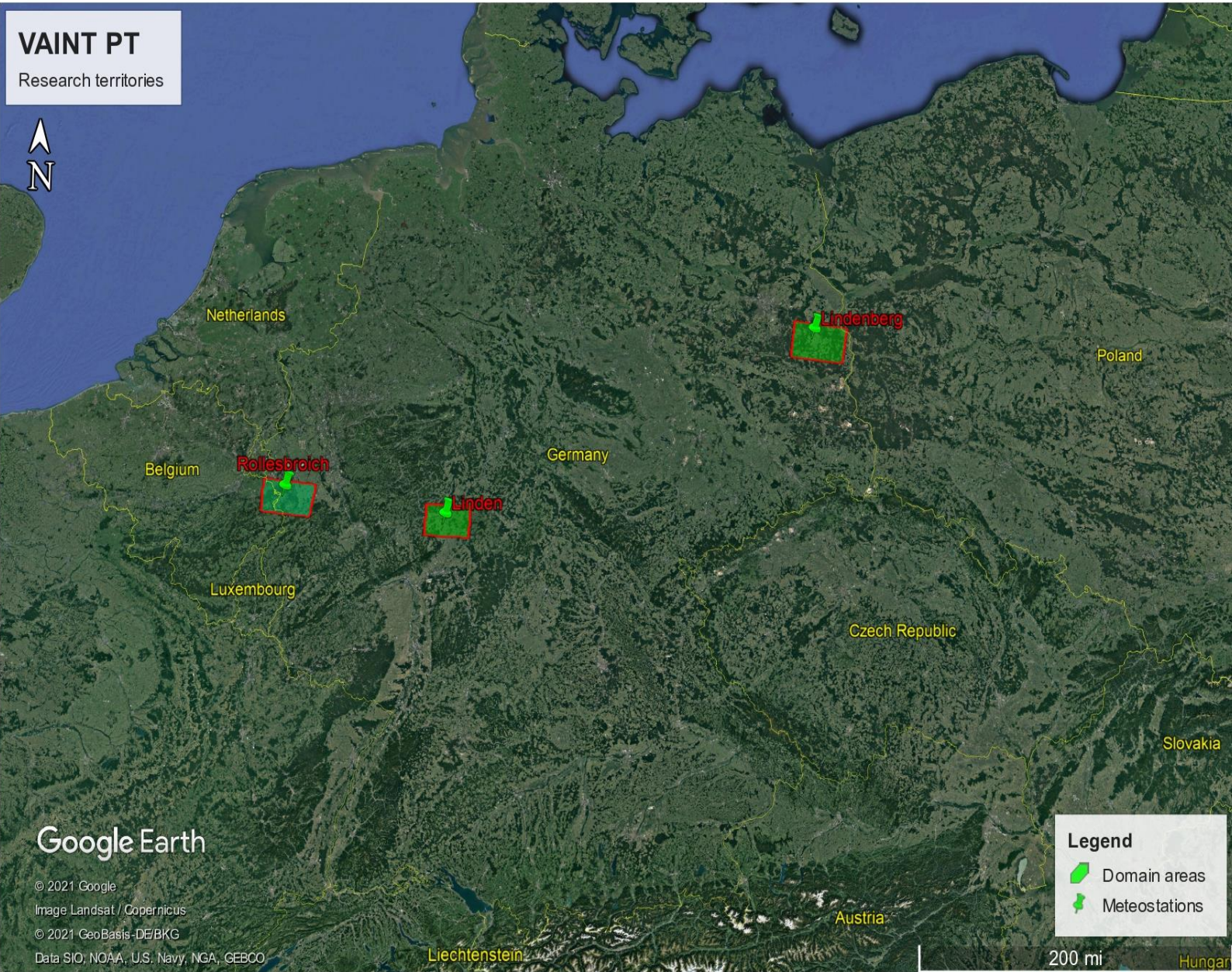


Figure: Cabello et. al, 2011

Research territory



Stations: Rollesbroich
Linden
Lindenberg

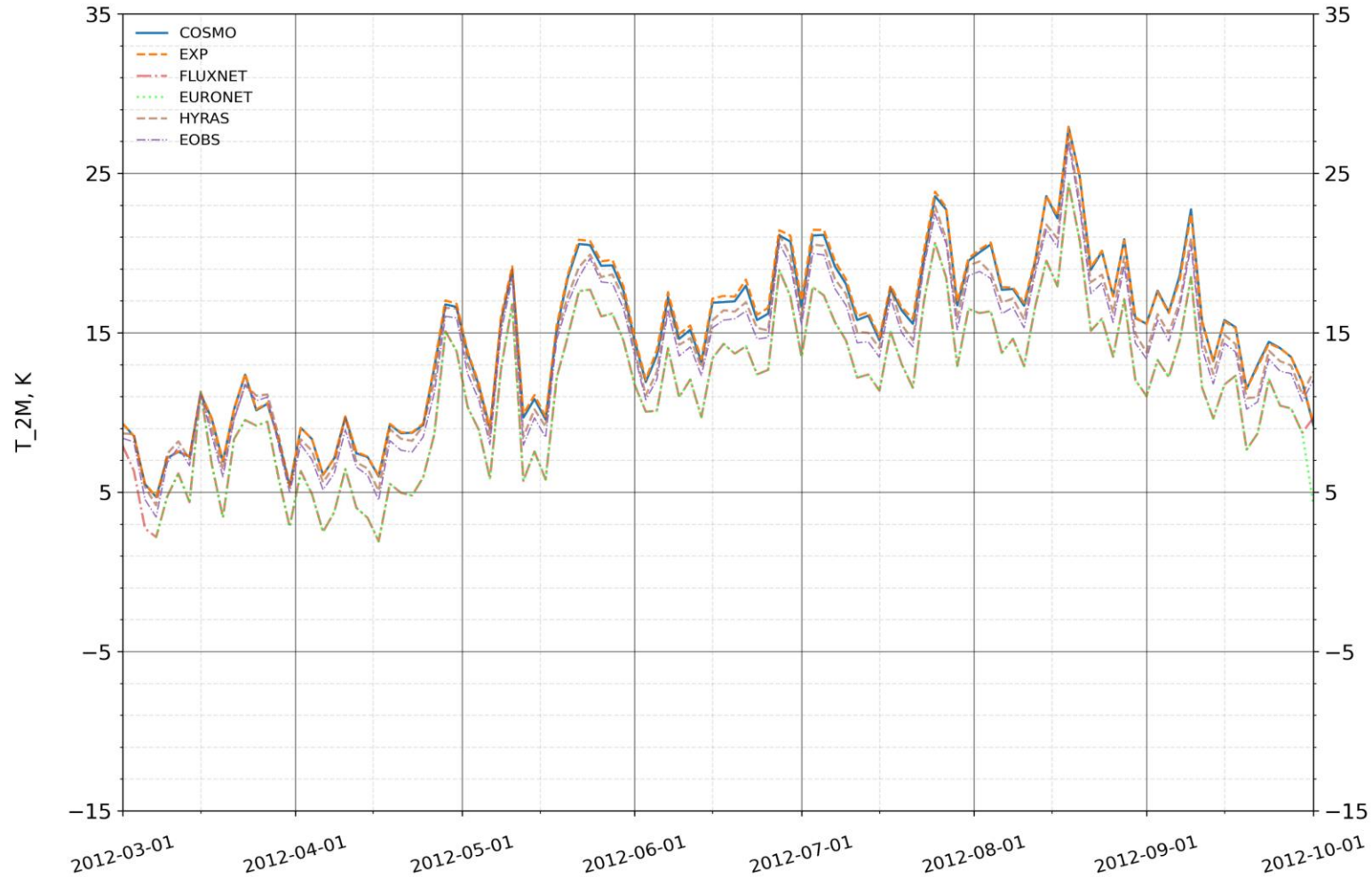
Period: 01.01.1999 – 31.12.2015

Data for verification: GLEAM
FLUXNET
EURONET
EOBS
HYRAS

Comparison COSMO_v5.0_clm16 without changes and with updates

Air temperature in 2m - T_2M

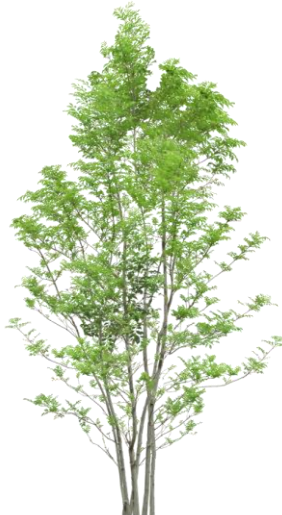
Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: T2m

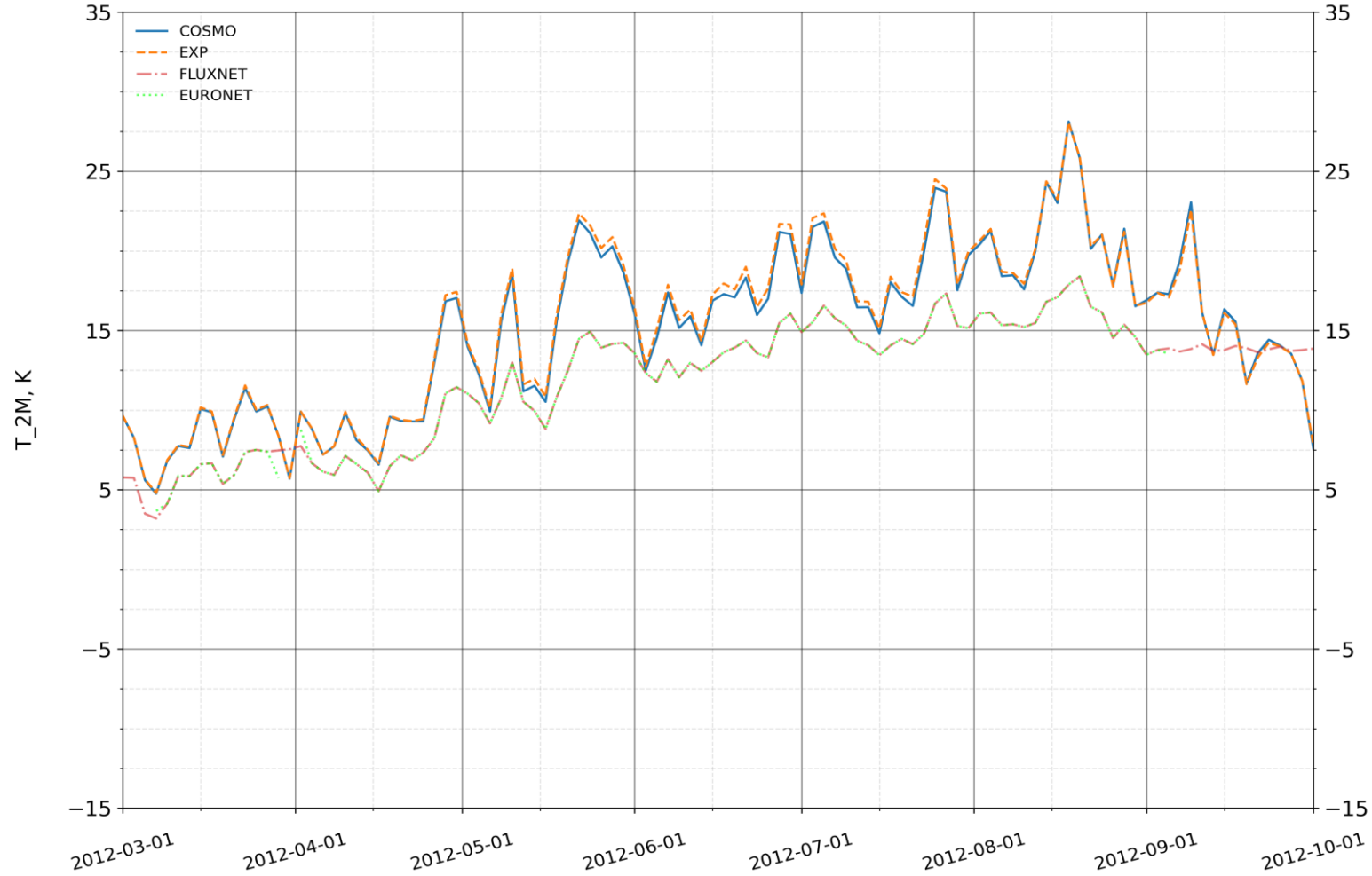
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Soil temperature in 2m - TS

Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: TS

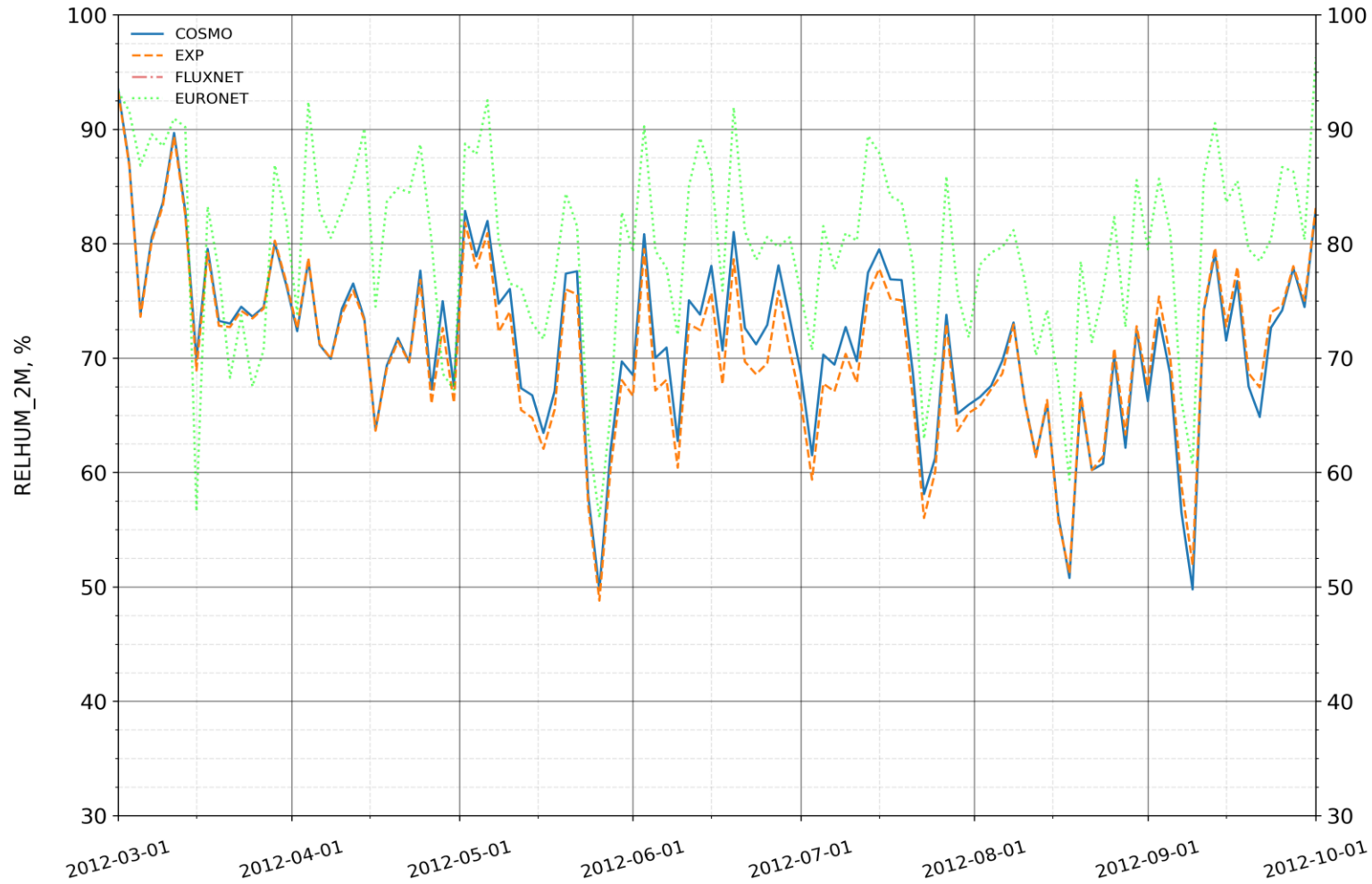
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Relative_humidity in 2m - RELHUM_2M

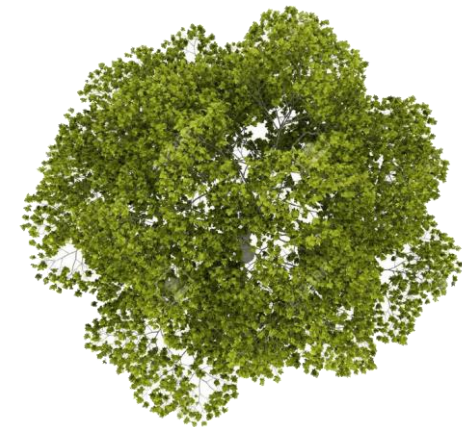
Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: RELHUM

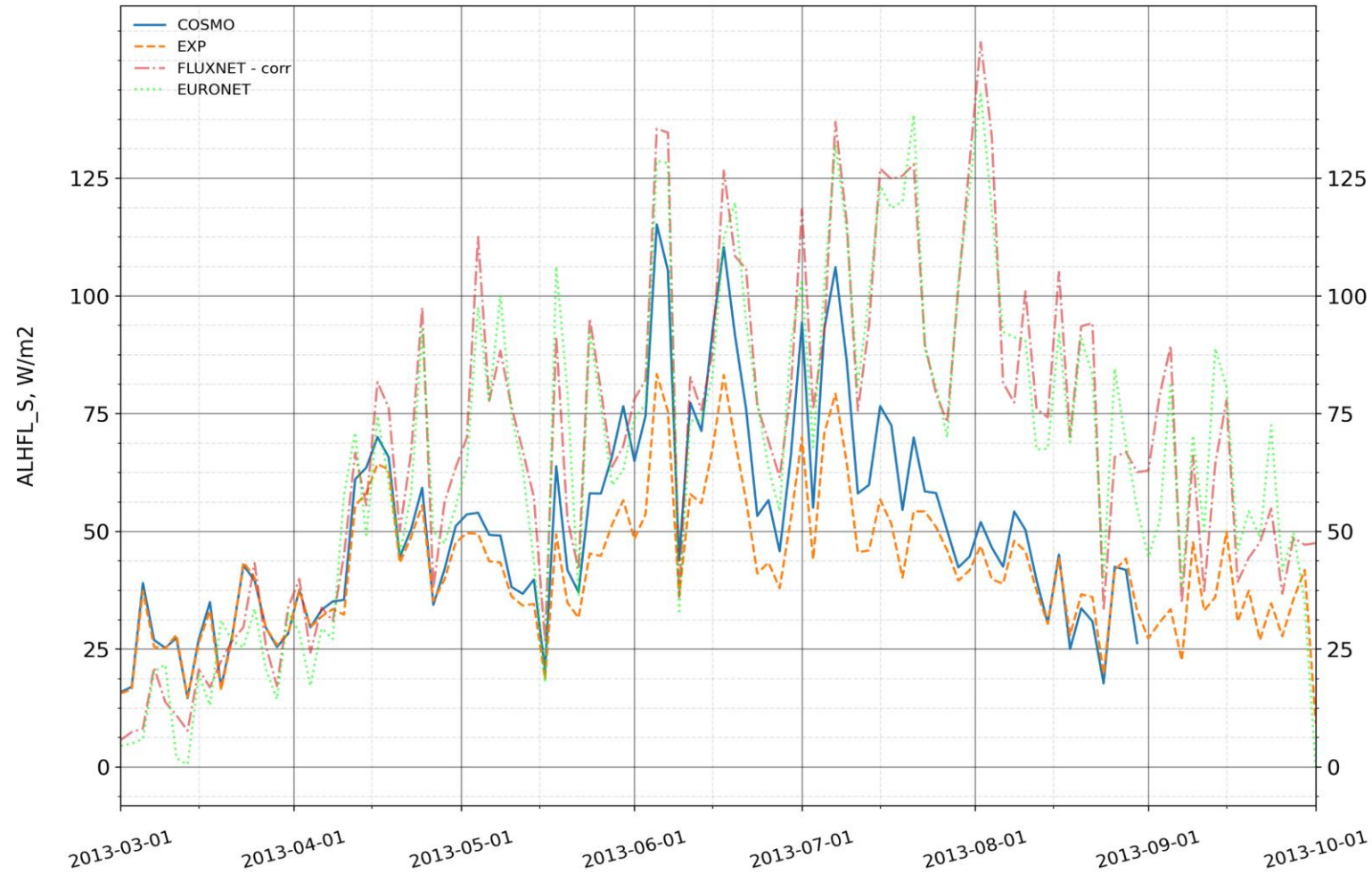
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Average latent heat flux (surface) - ALHFL_S

Station: Rollesbroich Time step: 2013-03-01 to 2013-10-01



Station: Rollesbroich

Parameter: ALHFL_S

Period: 03.2013 to 10.2013

Mode1: Daily

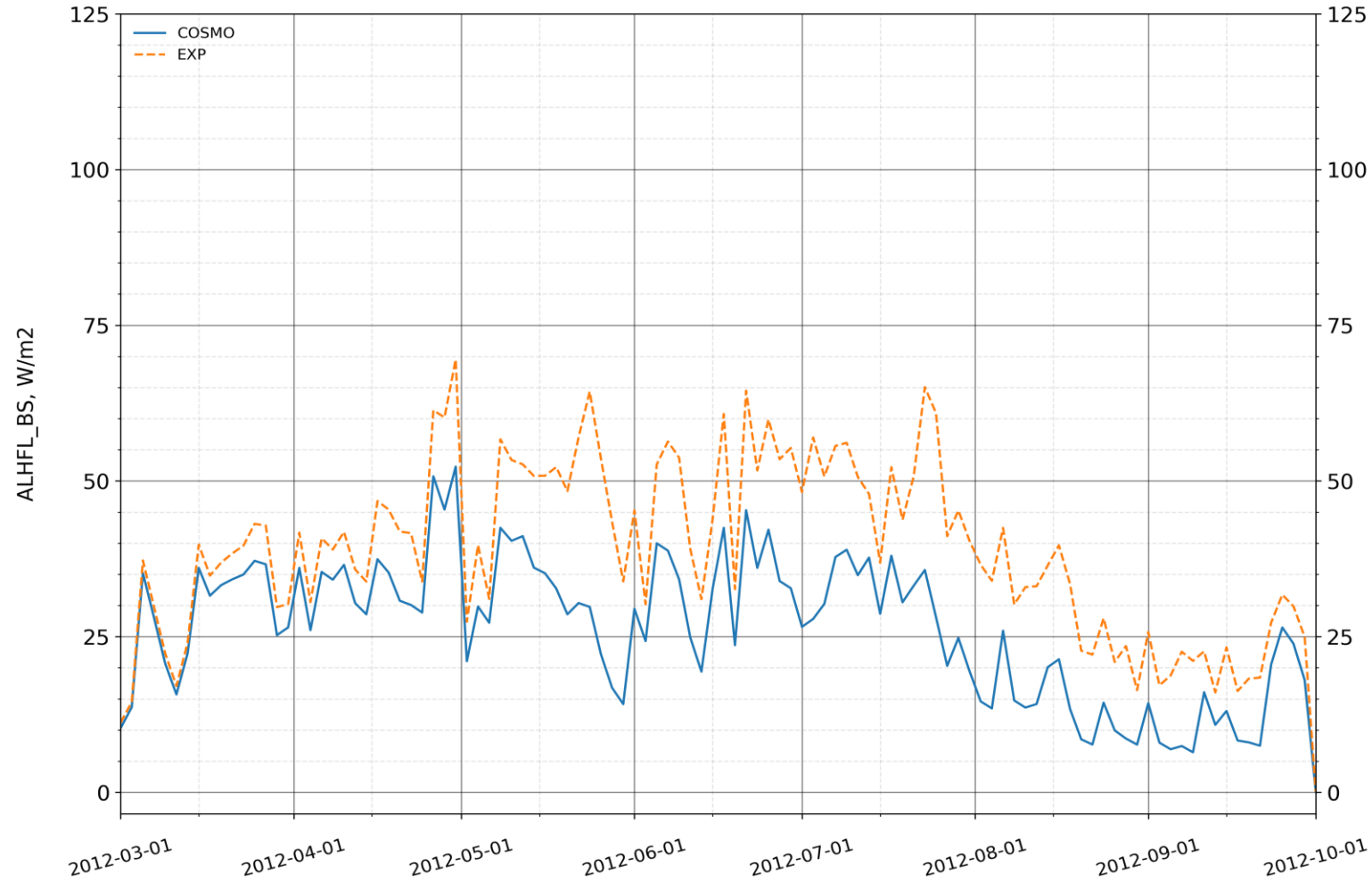
Mode2: Monthly



Comparison COSMO_v5.0_clm16 without changes and with updates

Average latent heat flux from bare soil evaporation - ALHFL_BS

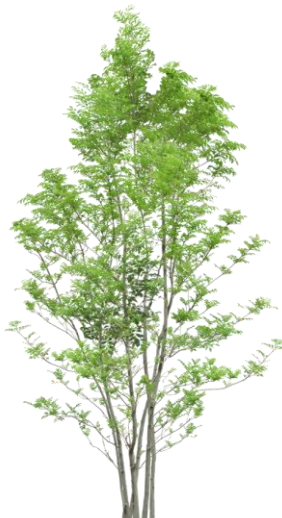
Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: ALHFL_BS

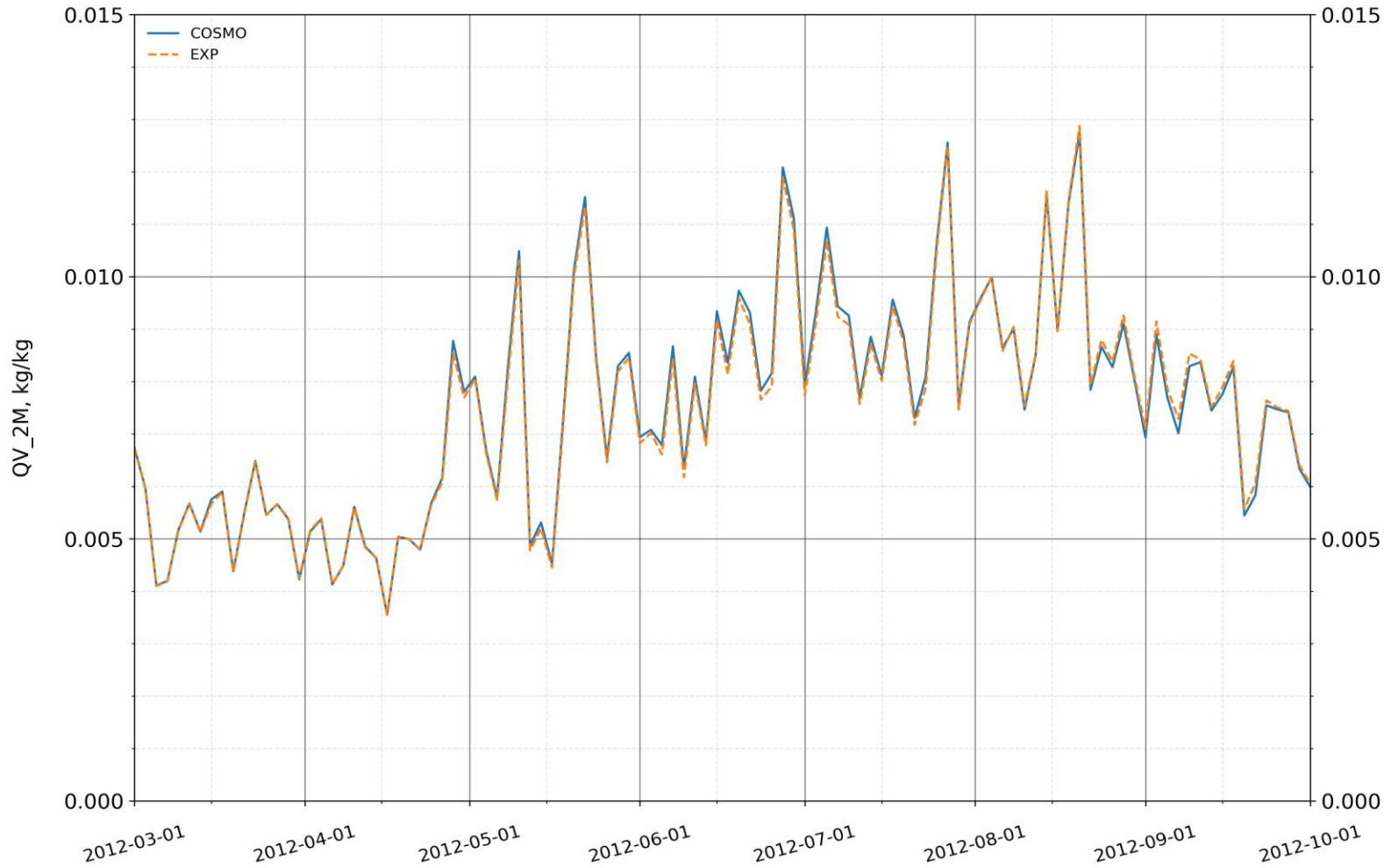
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Specific_humidity in 2m - QV_2M

Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: QV_2M

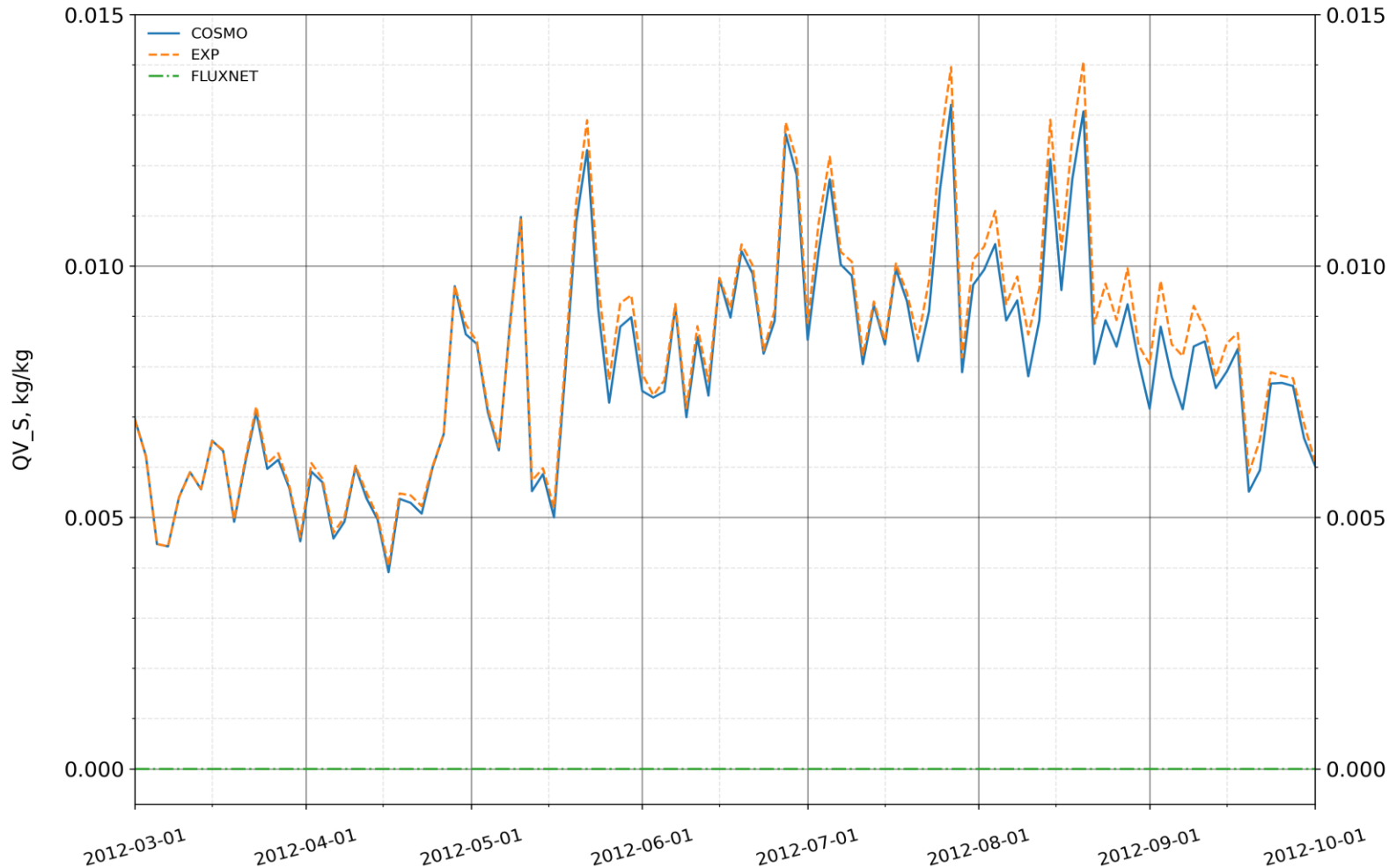
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Surface_specific_humidity - QV_S

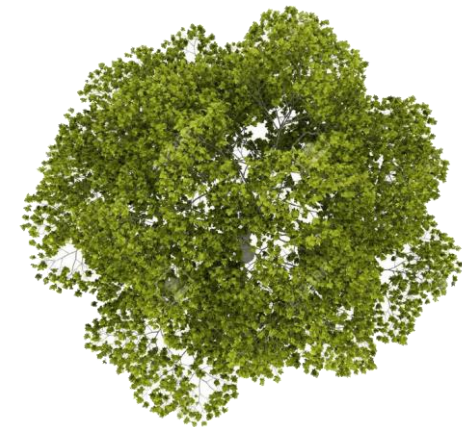
Station: Rollesbroich Time step: 2012-03-01 to 2012-10-01



Station: Rollesbroich

Parameter: QV_S

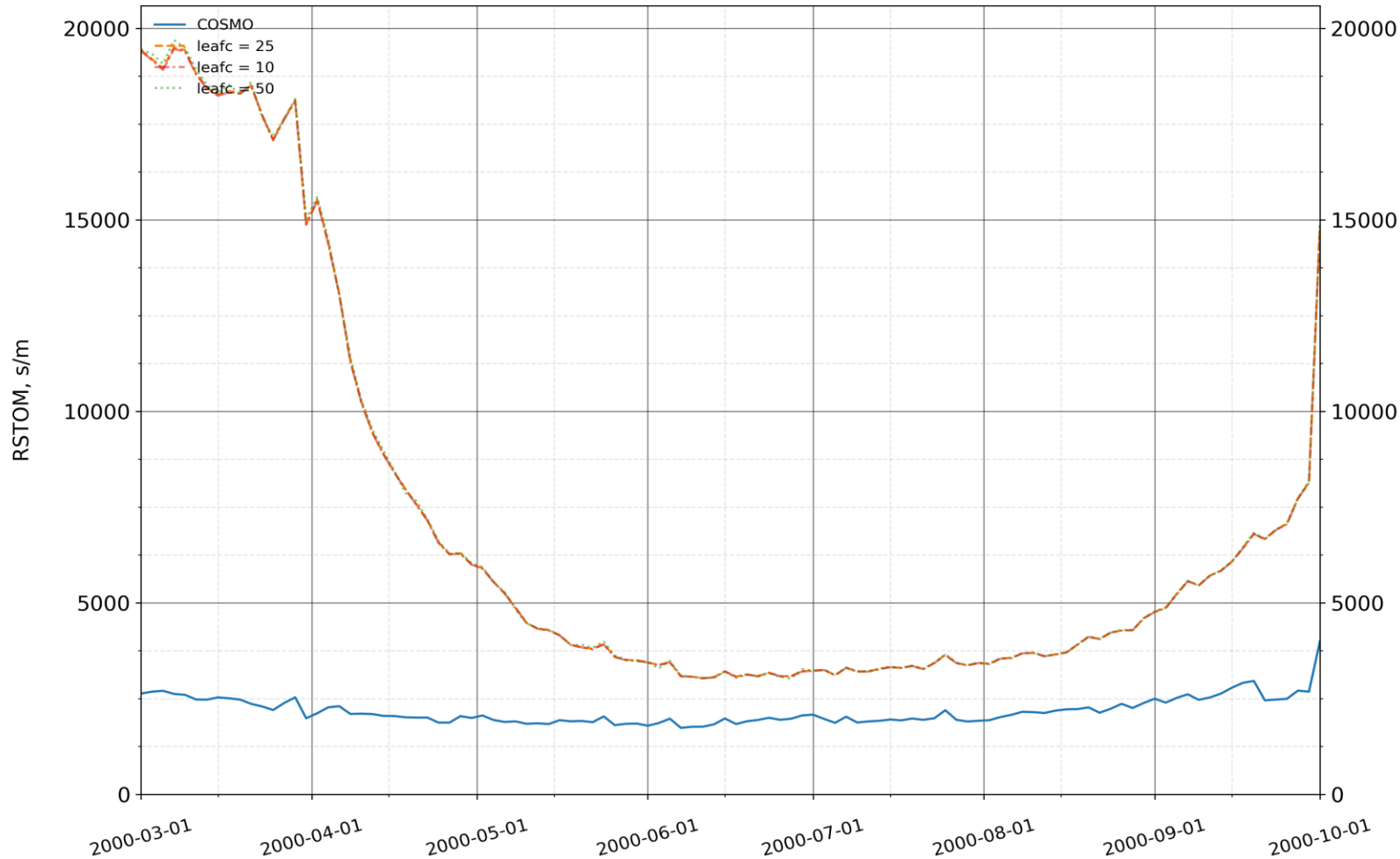
Period: 03.2012 to 10.2012



Comparison COSMO_v5.0_clm16 without changes and with updates

Stomata resistance - RSTOM

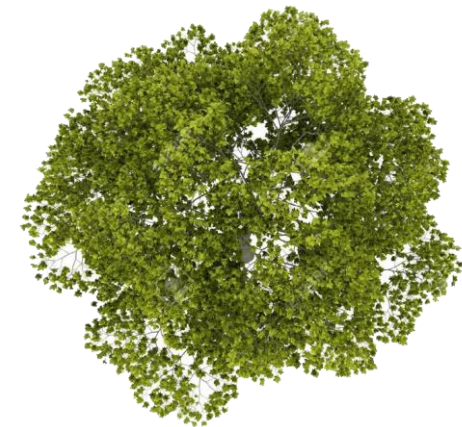
Station: Rollesbroich Time step: 2000-03-01 to 2000-10-01



Station: Rollesbroich

Parameter: RSTOM

Period: 03.2012 to 10.2012



Final Summary:

- 1) Continue work on VAIN T 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;



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?

- * *sfl_dir_par* – direct component of photosynthetic active radiation flux at the ground;
- * *sfl_difd_par* – diffuse downward component of photosynthetic active radiation flux at the ground;
- * *sfl_difu_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:

**asfl_dir_par*; **asfl_difd_par*; **asfl_difu_par*; **aztraleav*; **aztrang*; **aztrangs*; **azverbo*;

Discussion questions:

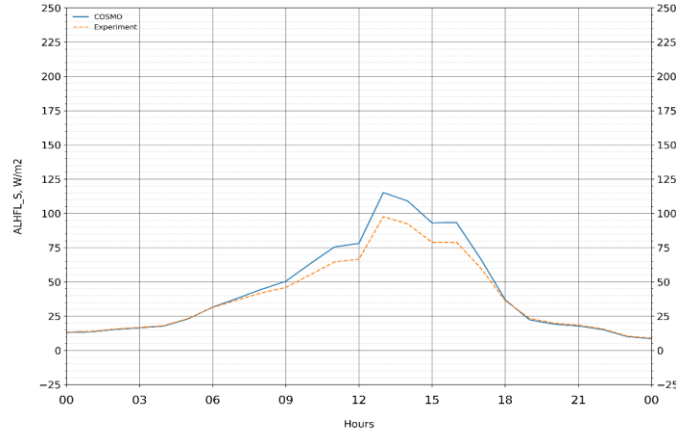
Why the ***EVATRA_SUM*** and ***TRA*** in src_setup_wartab are incorrect?

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?

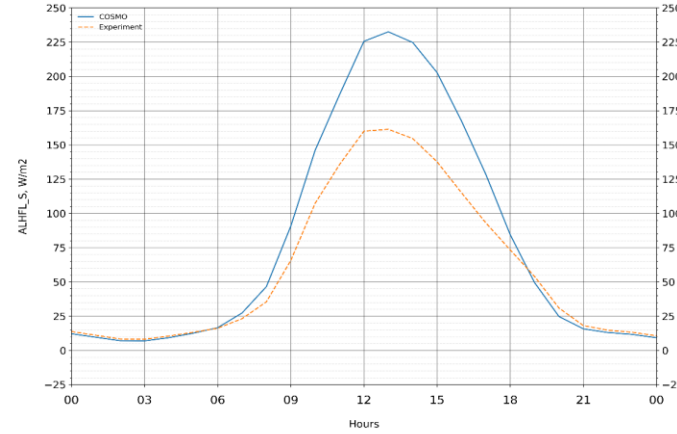
Comparison COSMO_v5.0_clm16 without changes and with updates

Average latent heat flux (surface) - ALHFL_S
Time step: 1999-04-12 to 1999-04-13



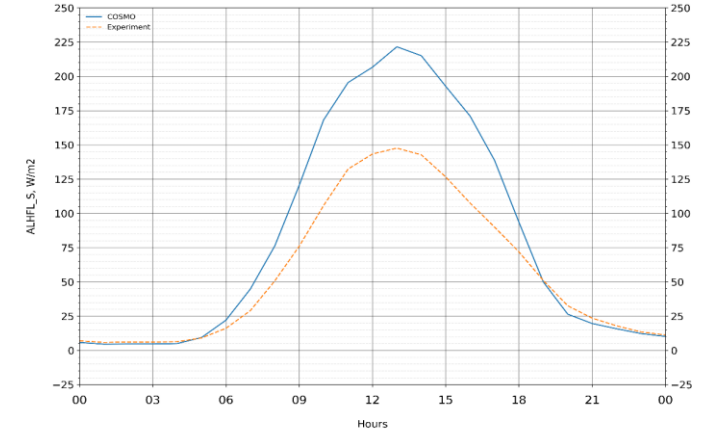
Date: 12.04.1999

Average latent heat flux (surface) - ALHFL_S
Time step: 1999-05-12 to 1999-05-13



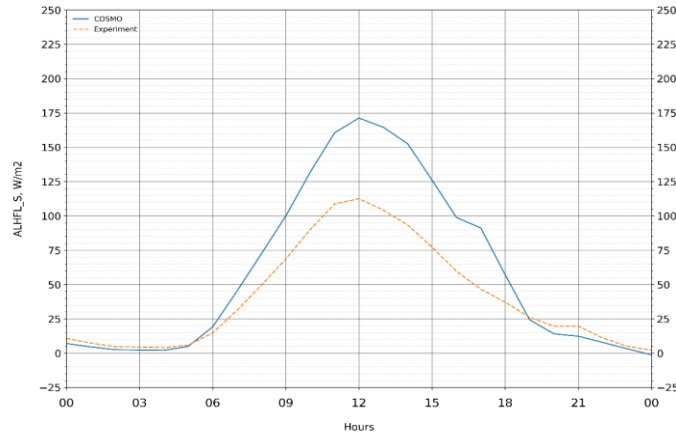
Date: 12.05.1999

Average latent heat flux (surface) - ALHFL_S
Time step: 1999-06-12 to 1999-06-13



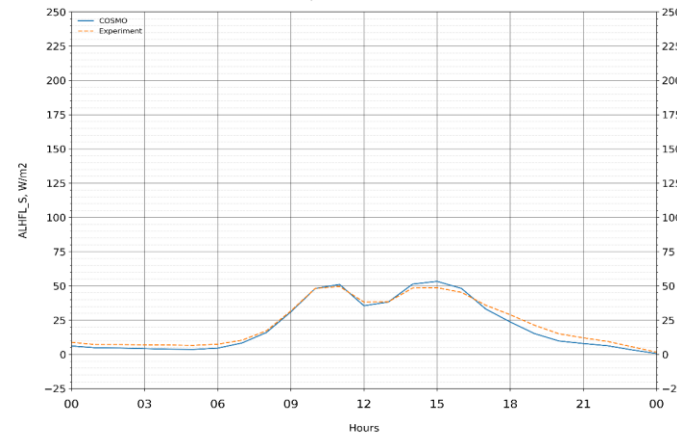
Date: 12.06.1999

Average latent heat flux (surface) - ALHFL_S
Time step: 1999-07-12 to 1999-07-13



Date: 12.07.1999

Average latent heat flux (surface) - ALHFL_S
Time step: 1999-08-12 to 1999-08-13

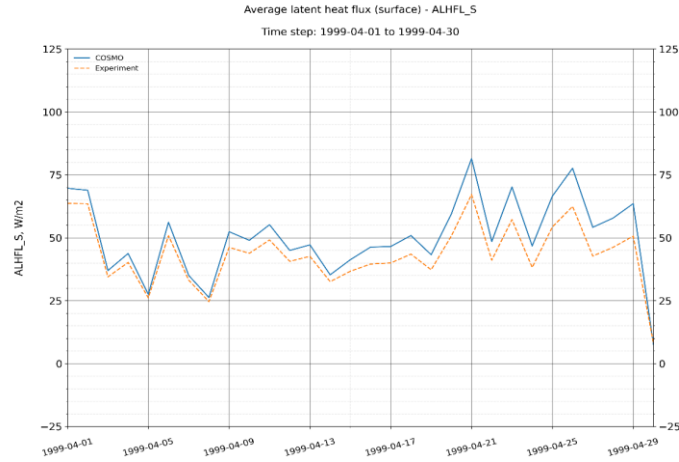


Date: 12.08.1999

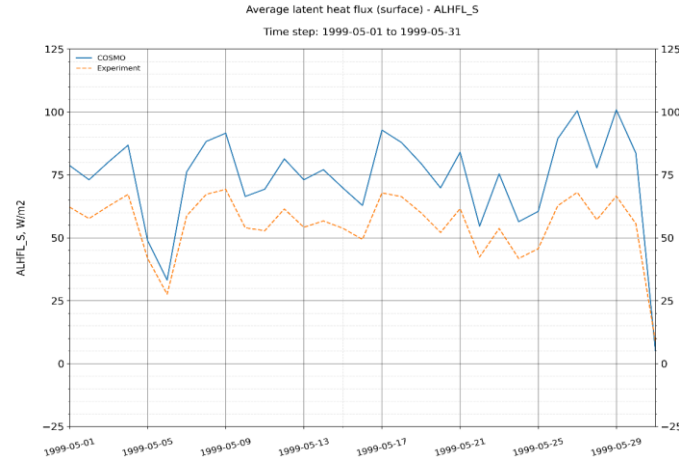
Station: Rollesbroich

Parameter: ALHFL_S

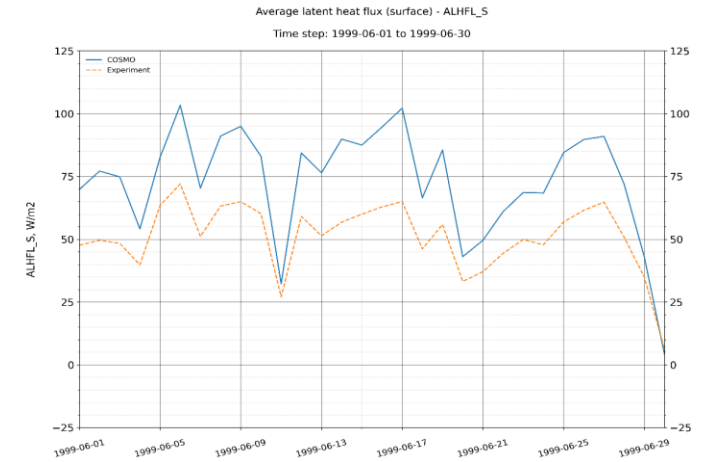
Comparison COSMO_v5.0_clm16 without changes and with updates



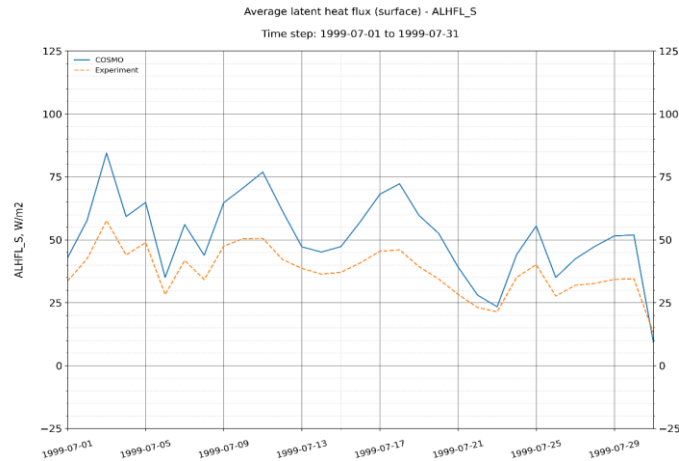
Period: 04.1999 to 05.1999



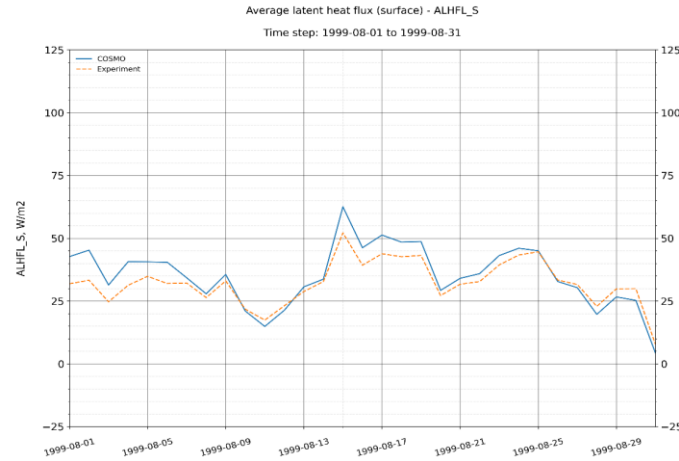
Period: 05.1999 to 06.1999



Period: 06.1999 to 07.1999



Period: 07.1999 to 08.1999



Period: 08.1999 to 09.1999

Station: Rollesbroich
Parameter: ALHFL_S

Preparatory work with COSMO_v5.0_clm16

Have been added changes in next src_files:

data_fields

The **15 new global data parameters** have been added:

src_allocation

7 for src_radiation and **8 for srs_soil_multlay**

src_setup_vartad

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





Have been added changes in next src_files:

src_radiation The 4 additional parameters:

sflidir_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;



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