VS-oscilloscope – new parameterization algorithm of process-based tree-ring model

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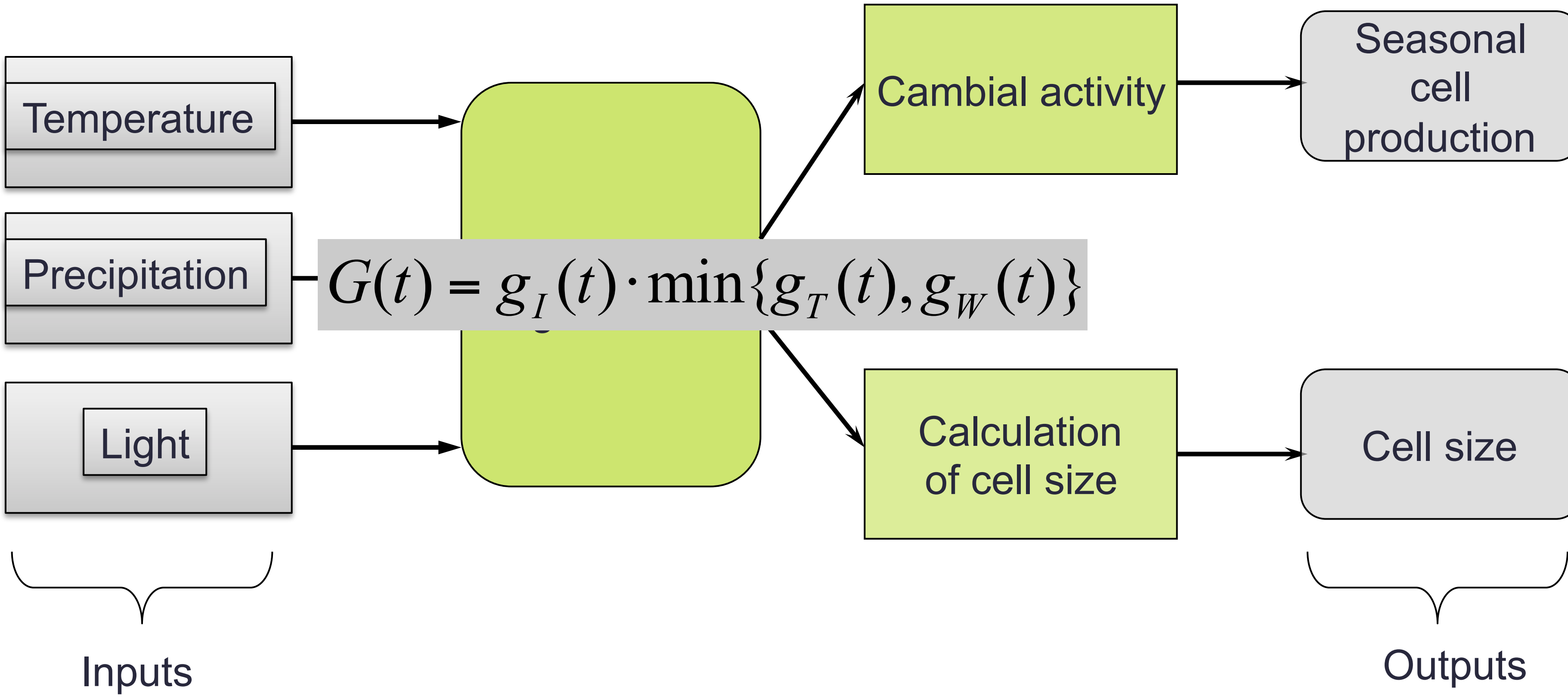
Outline

- VS-modeling
- New visual approach of VS-model parameterization (so-called VS-oscilloscope)
- VS-oscilloscope applications in Siberia, Central Asia, Mediterranean region
- Perspectives

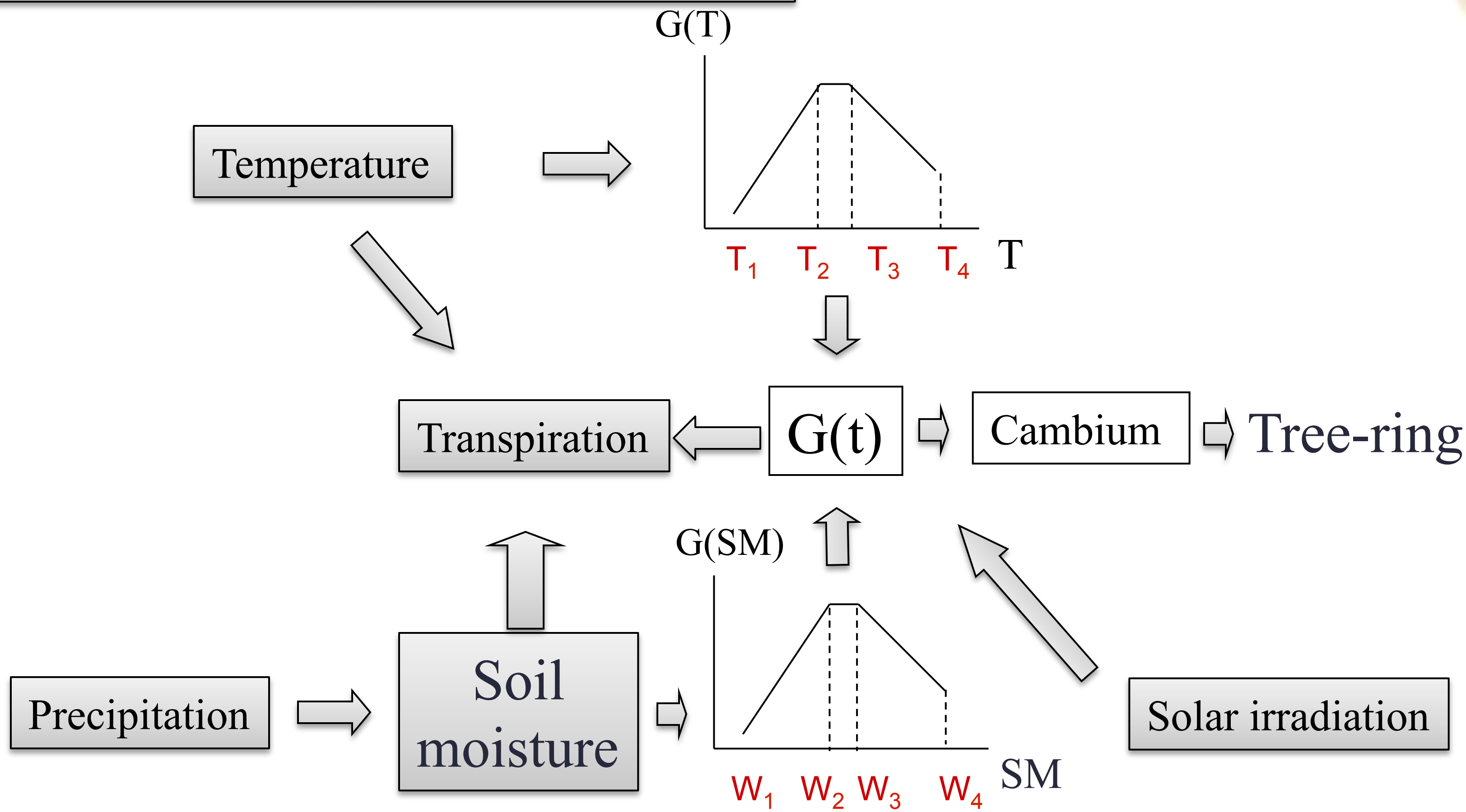
Vaganov-Shashkin (*VS*) simulation model of seasonal tree-ring growth



$$G(t) = g_I(t) \cdot \min\{g_T(t), g_W(t)\}$$

(Vaganov, Hughes, Shaskin, 2006; Anchukaitis et al., 2006; Evans et al., 2006: Touchan et al., 2012)

VS-model parameters



$k_1, k_2, k_3, P_{max}, a_1, a_2$

Totally **42 parameters** are used in VS-model, should be a **reasonably chosen** and **should be re-estimated** for each dendrochronological site.

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Soil moisture estimation

$$W' = {dW}/{dt} = f(P) - Tr - q$$

$$\Delta W = f(P) - Tr - q \;\; (\text{or } \; W_{t+1} = W_t + f(P_t) - Tr_t - q_t)$$

where ***ΔW*** – increment of water infiltration in the soil per time unit (per day),
f(P) –precipitation amount, infiltrated to the soil,
q – soil drainage,
Tr – transpiration.

$$f(P) = \begin{cases} k_1 P, \text{ if } k_1 P \le P_{\max} \\ P_{\max}, \text{ if } k_1 P > P_{\max} \end{cases}$$

where P_{max} - max rate of infiltration water into soil (mm/day),
k_1 – model's parameter (($1 - k_1$) is an interception precip. by crown)

$$Tr = k_2 Gr(t) e^{k_3 T}$$

where k_2, k_3 – model's parameters, ***T*** – temperature.

$$q = rd \circ W$$

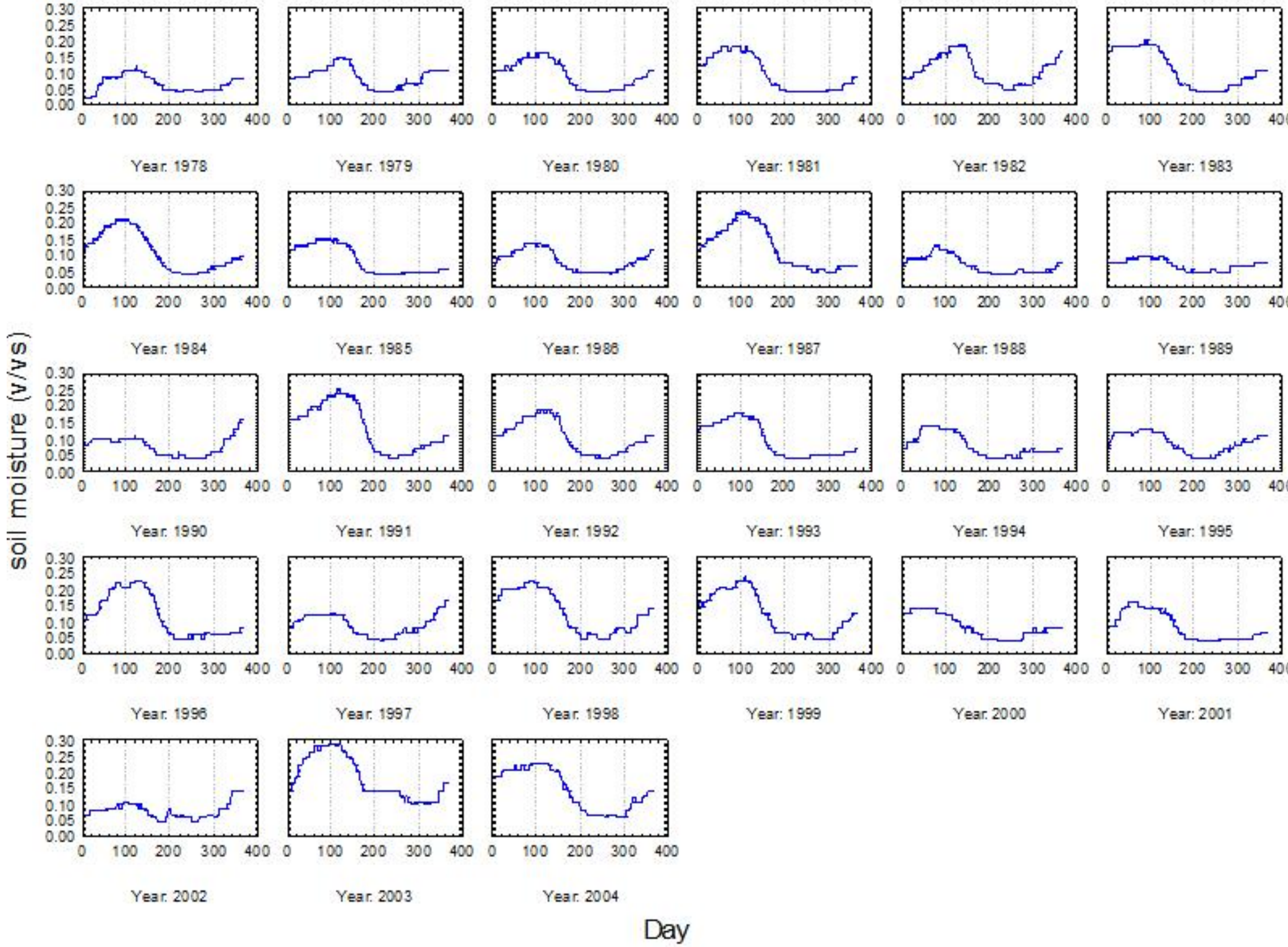
where ***rd*** – the rate of water drainage from the soil.

For northern timberline, plants can use a water from melted soil

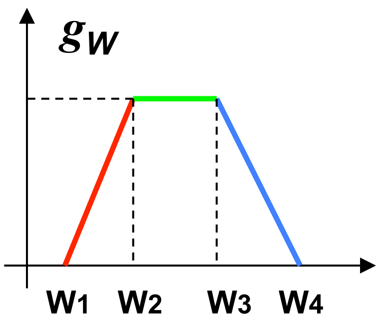
$$l_{t+1} = l_t + a_1 T_t e^{-a_2 l_t}$$

where l_t - melted soil layer
a_1, a_2 – parameters of soil melting.

An example to simulate a soil moisture Mediterranean (Touchan et al., 2012)



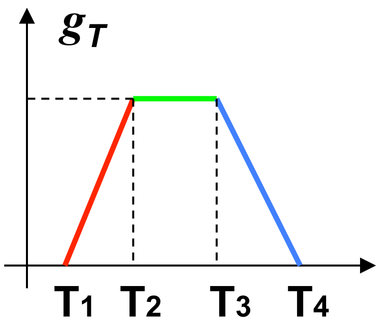
$g_W(t)$ - partial growth rate depending on soil moisture



$$g_W(t) = \begin{cases} 0, \; if \; W(t) < W_1 \; or \; W(t) > W_4 \\ (W(t) - W_1) \big/ (W_2 - W_1), \; if \; W_1 \le W(t) \le W_2 \\ 1, \; if \; W_2 \le W(t) \le W_3 \\ (W_4 - W(t)) \big/ (W_4 - W_3), \; if \; W_3 \le W(t) \le W_4 \end{cases}$$

Finally $$g_W(t) = \frac{l_t}{lr} g_W(t)$$ where ***lr*** - the root depth

$g_T(t)$ **- partial growth rate depending on temperature**



$$g_T(t) = \begin{cases} 0, \; if \; T(t) < T_1 \; or \; T(t) > T_4 \\ (T(t) - T_1) \big/ (T_2 - T_1), \; if \; T_1 \le T(t) \le T_2 \\ 1, \; if \; T_2 \le T(t) \le T_3 \\ (T_4 - T(t)) \big/ (T_4 - T_3), \; if \; T_3 \le T(t) \le T_4 \end{cases}$$

$g_I(t)$ **- partial growth rate depending on solar irradiance**

$$E = E_0(h_s \sin\varphi \sin\theta + \cos\theta \sin h_s)$$ (see Gates, 1980)

$$g_I(t) = E \big/ E_{max}$$

Ln	Module	Par	Min	Max	Default	Parameters description
1	grrt	1	-1,5	6,00	2	T1: min temperature for growth, ºC
2	grrt	2	8	25,00	13	T2: growth rate is max in the range [T2, T3], ºC
3	grrt	3	15	35,00	28	T3: growth rate is max in the range [T2, T3], ºC
4	grrt	4	36	45,00	40	T4: max temperature for growth, ºC
5	grrt	5	0,2	0,50	0,35	Wmax: max soil moisture (field capacity), V/V
6	grrt	6	***	***	***	THE PARAMETER IS RESERVED FOR FUTURE USE
7	grrt	7	5	30,00	20	Tm: sum of temperature to start soil melting, ºC
8	grrt	8	5	15,00	10	a1: coefficient of soil melting, mm/ºC/day
9	grrt	9	0,001	0,01	0,01	a2: coefficient of soil melting, mm^{-1}
10	grrt	10	0,20	0,50	0,30	W0: initial soil moisture, V/V
11	grrt	11	5,00	100,00	40,00	Pmax: max rate of infiltration water into soil, mm/day
*	*	*	*	*	*	* * * * * *
*	*	*	*	*	*	* * * * * *
*	*	*	*	*	*	* * * * * *
40	camb	13	5	16	10	DG2: the max size in G2, μm
41	camb	14	10	16	11	Dm: is the max size in M, μm
42	camb	15	0,0001	1	0,05	: time step in the cambium model, day

Acceptable ranges of parameters

Fragment of parameters list used in VS-model.

Acceptable range of parameters

References

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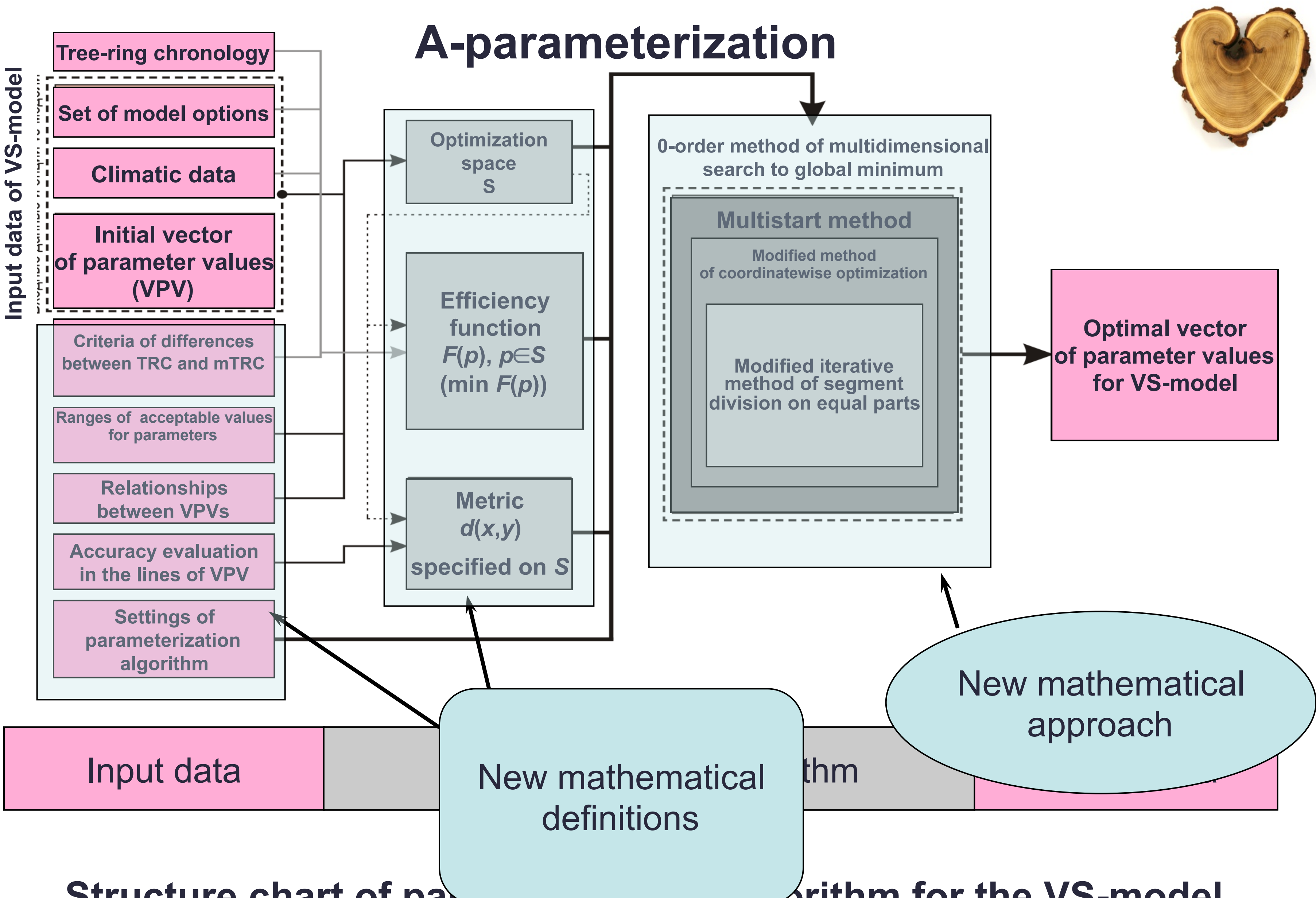
Tasks

- To develop an algorithm which allows to estimate optimal VS-parameters in *automatic mode or semi-automatic mode*

- To apply the algorithm for Siberian boreal forest, Central Asia and Mediterranean region

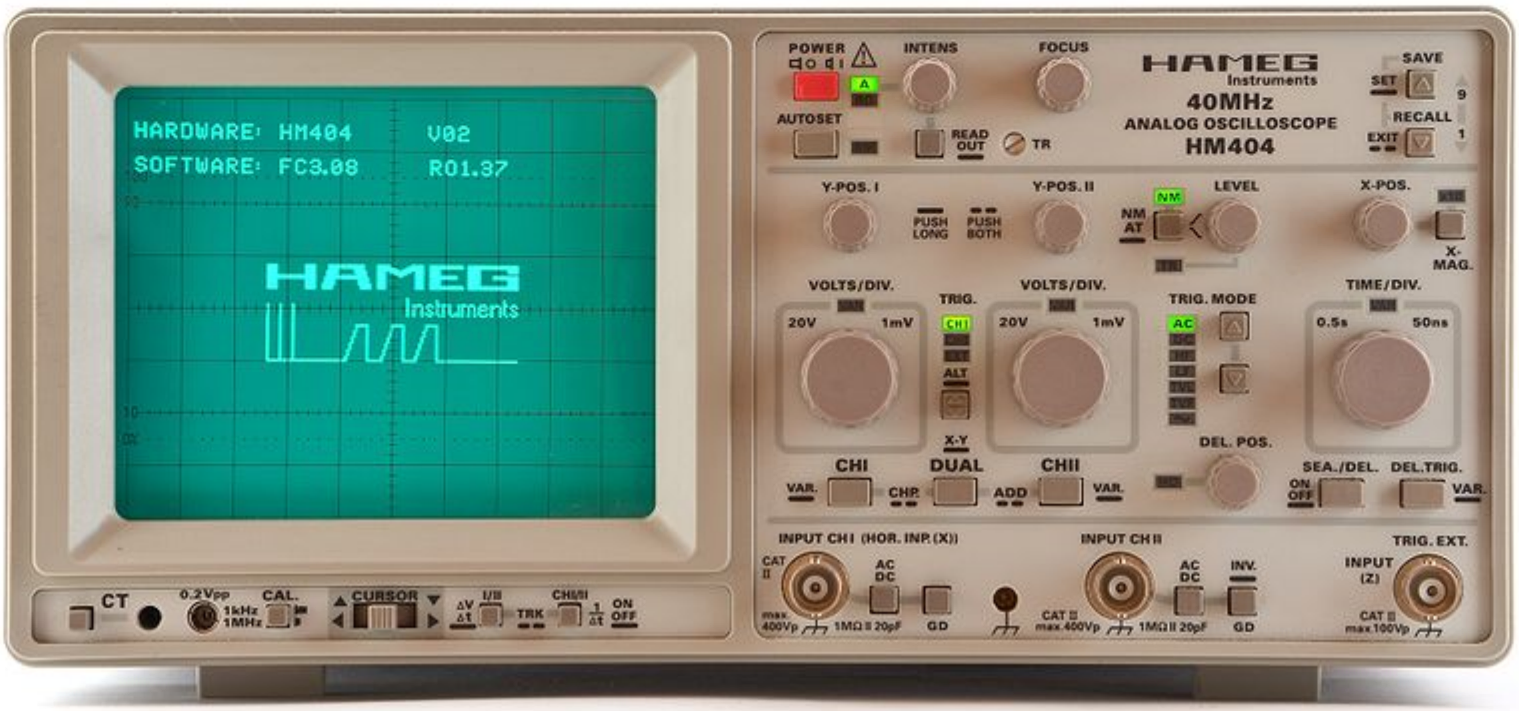
A-parameterization



Structure chart of pa... ...orithm for the VS-model

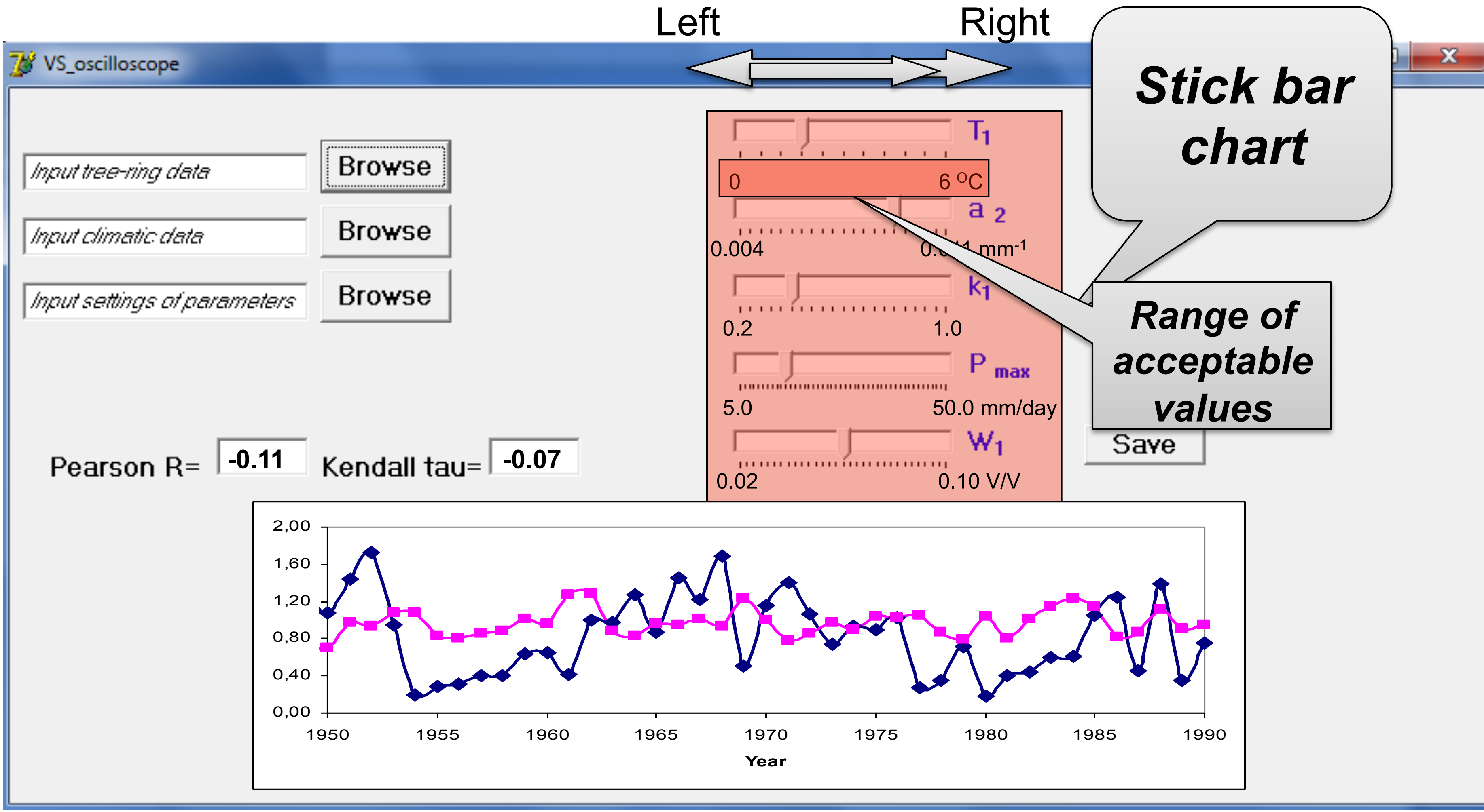
(Ivanovsky, Shishov, 2010)

Physical oscilloscope

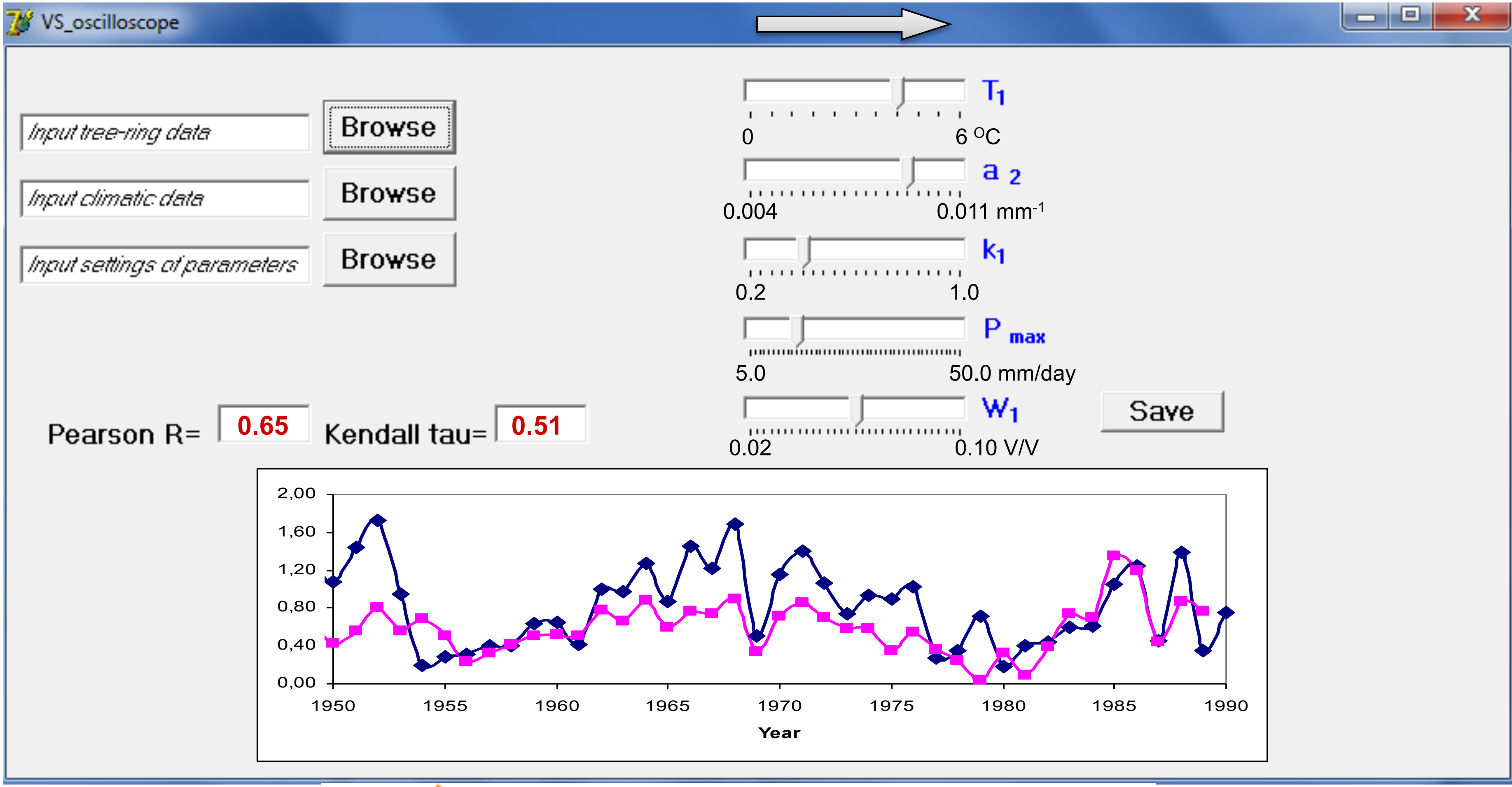


An **oscilloscope** (also known as a **scope**, **CRO**, **DSO** or, an **O-scope**) is a type of *electronic test instrument* that allows observation of constantly varying signal *voltages*, usually as a two-dimensional graph of one or more electrical *potential differences* using the vertical or 'Y' axis, plotted as a function of time, (horizontal or 'x' axis).

VS-oscilloscope – new visual parameterization of *VS*-model (Tychkov, Shishov, 2012)



VS-oscilloscope – new visual parameterization of *VS*-model



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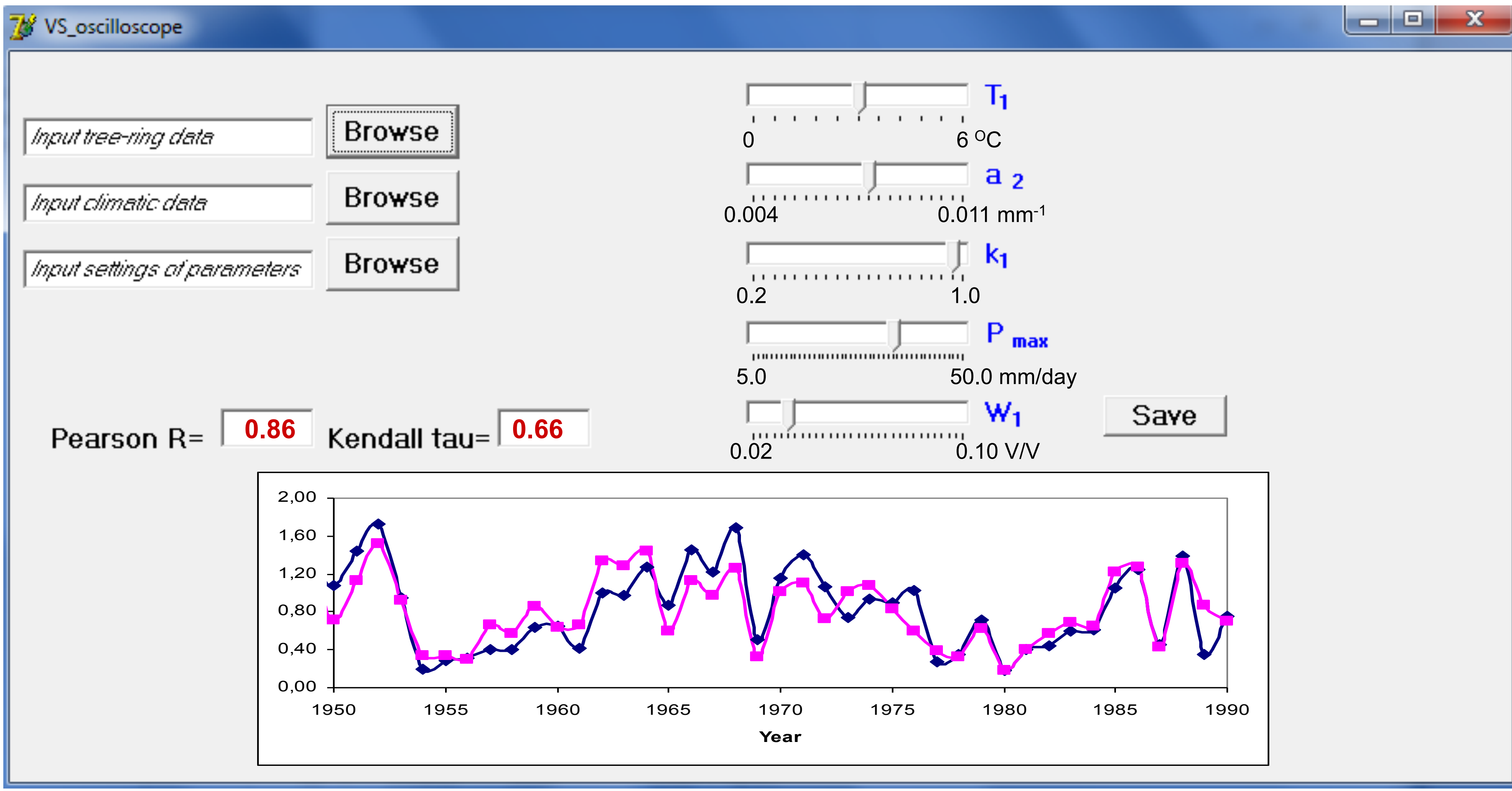
VS-oscilloscope – new visual parameterization of *VS*-model



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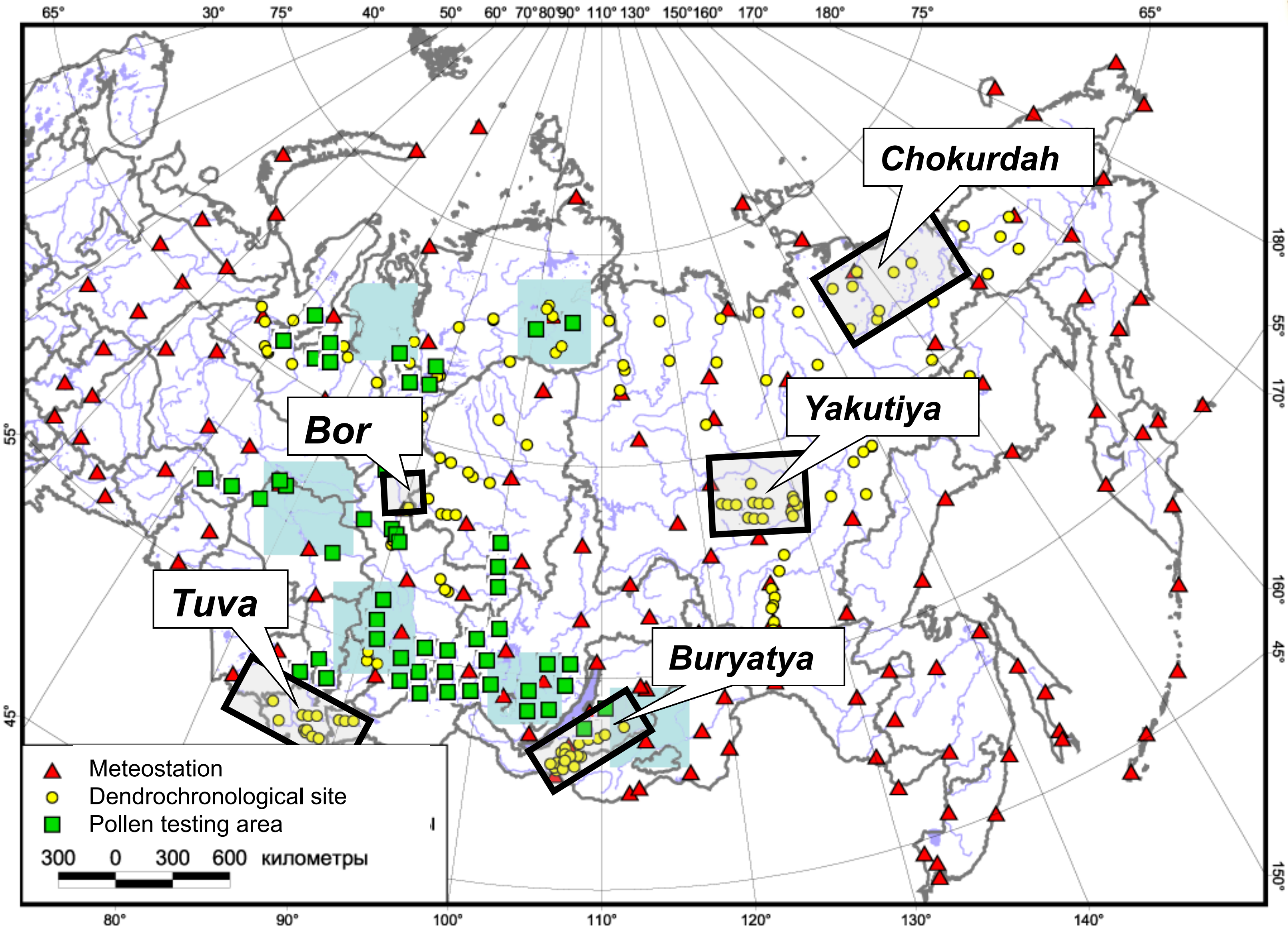
Temperature-sensitive regions

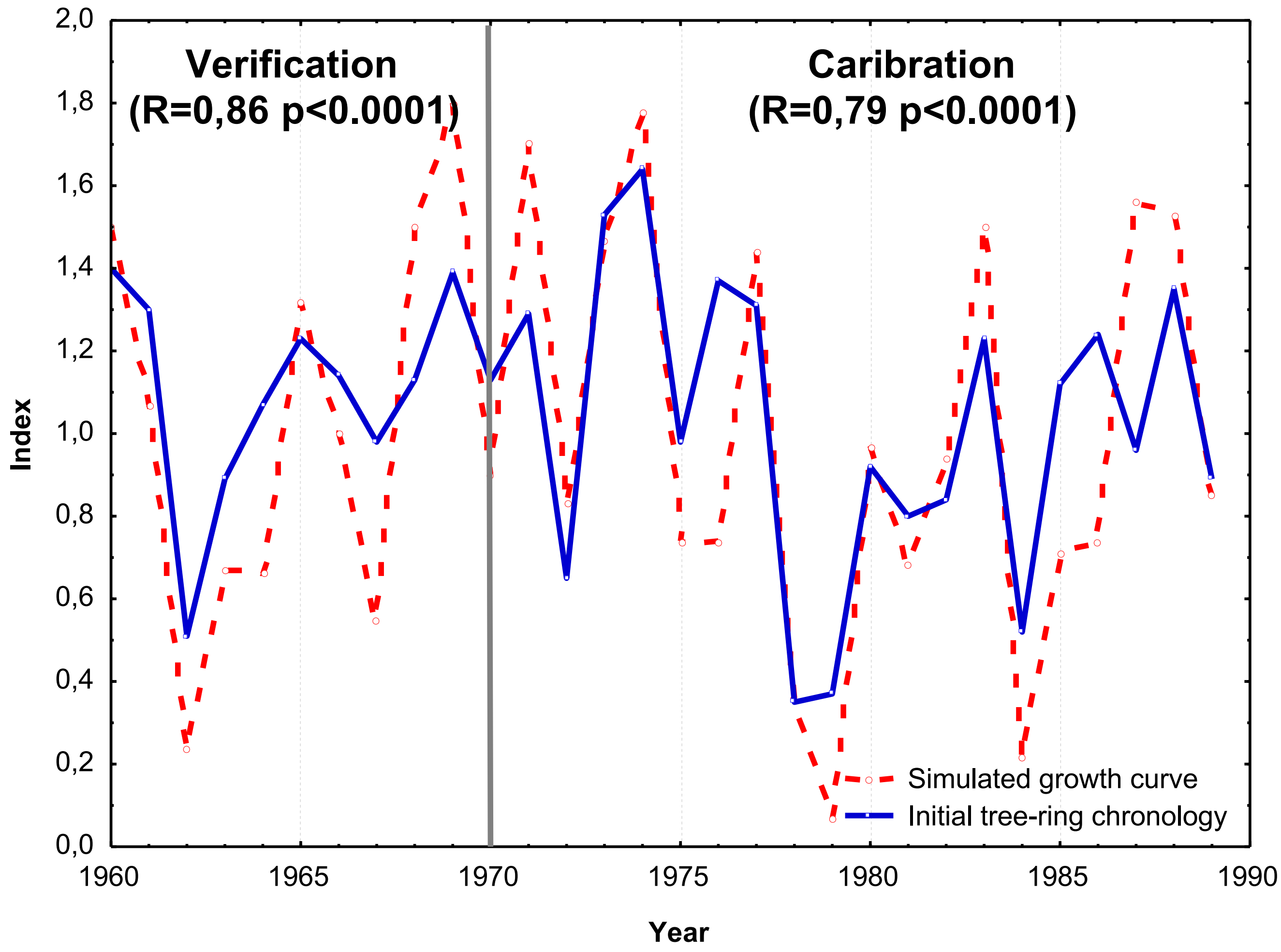


340 dendrochronological sites and 140 meteostations used in *VS*-model parameterization


VS-modeling
1000 км
500 мил.

Timberline and glacier. Taymir peninsula, Russia. July 2007

Taymir peninsula



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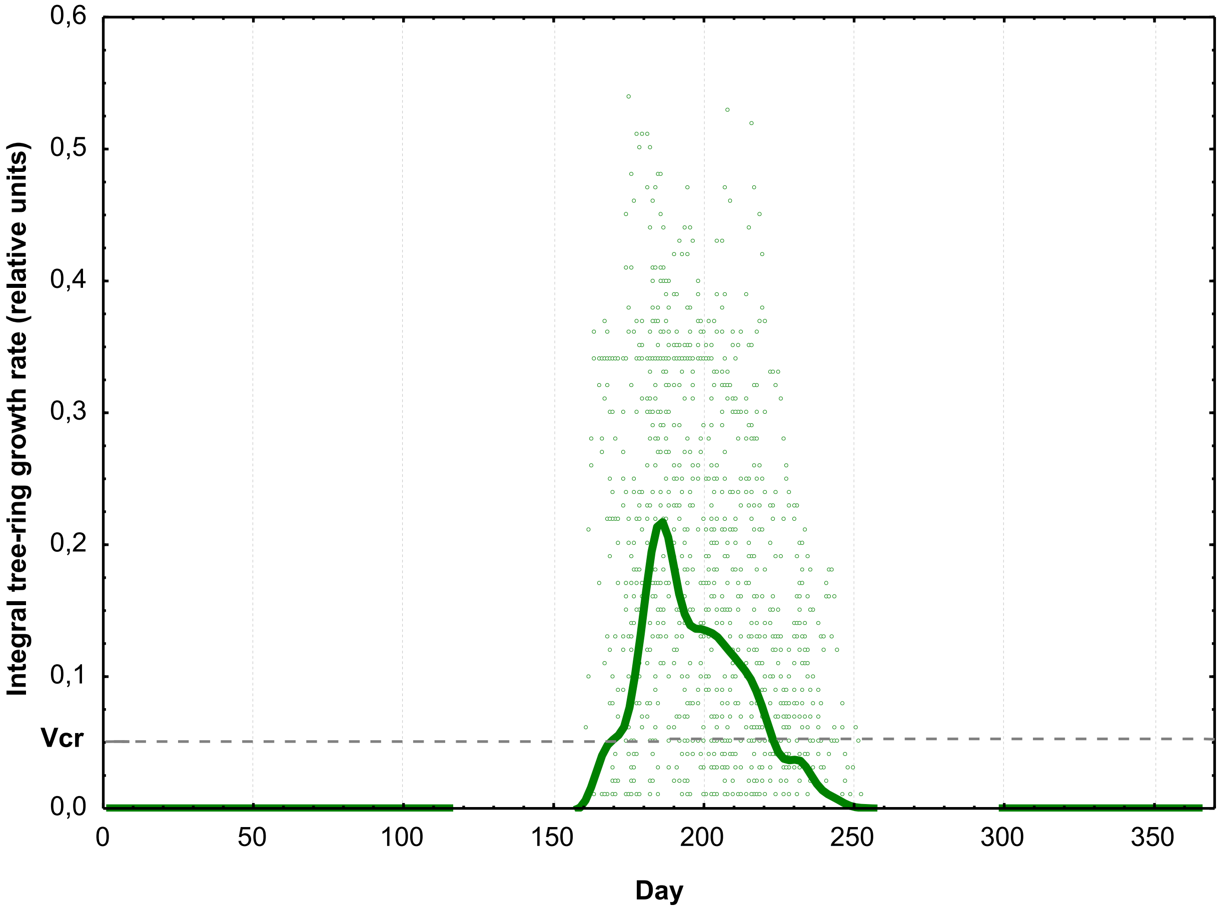
Taymir peninsula

Parameter	Description (Units)	Value
T_{min}	Minimum temperature for tree growth (°C)	8
$Topt_1$	Lower end of range of optimal temperatures (°C)	21
$Topt_2$	Upper end of range of optimal temperatures (°C)	27
T_{max}	Maximum temperature for tree growth (°C)	31
W_{min}	Minimum soil moisture for tree growth, relative to saturated soil (v/vs)	0,02
$Wopt_1$	Lower end of range of optimal soil moistures (v/vs)	0,23
$Wopt_2$	Upper end of range of optimal soil moistures (v/vs)	0,33
W_{max}	Maximum soil moisture for tree growth (v/vs)	0,90
W_0	Initial soil moisture (v/vs)	0,09
W_w	Minimum soil moisture (wilting point)	0,07
T_{beg}	Temperature sum for initiation of growth (°C)	100
t_{beg}	Time period for temperature sum (days)	10
l_r	Depth of root system (mm)	2000
P_{max}	Maximum daily precipitation for saturated soil (mm/day)	40
C_1	Fraction of precip. penetrating soil (not caught by crown) (rel. unit)	0.75
C_2	First coefficient for calculation of transpiration (mm/day)	0.45
C_3	Second coefficient for calculation of transpiration (mm/day)	0.20
Λ	Coefficient for water drainage from soil (rel.unit)	0.00
t_c	Cambial model time step (days)	1.00
V_{cr}	Minimum cambial cell growth rate (no units)	0.07
D_0	Initial cambial cell size (μm)	4.000
D_{cr}	Cell size at which mitotic cycle begins (μm)	8.000
V_m	Growth rate during mitotic cycle (μm/day)	1.000
D_m	Cambial cell size at which mitosis occurs (μm)	10.00

Taymir peninsula



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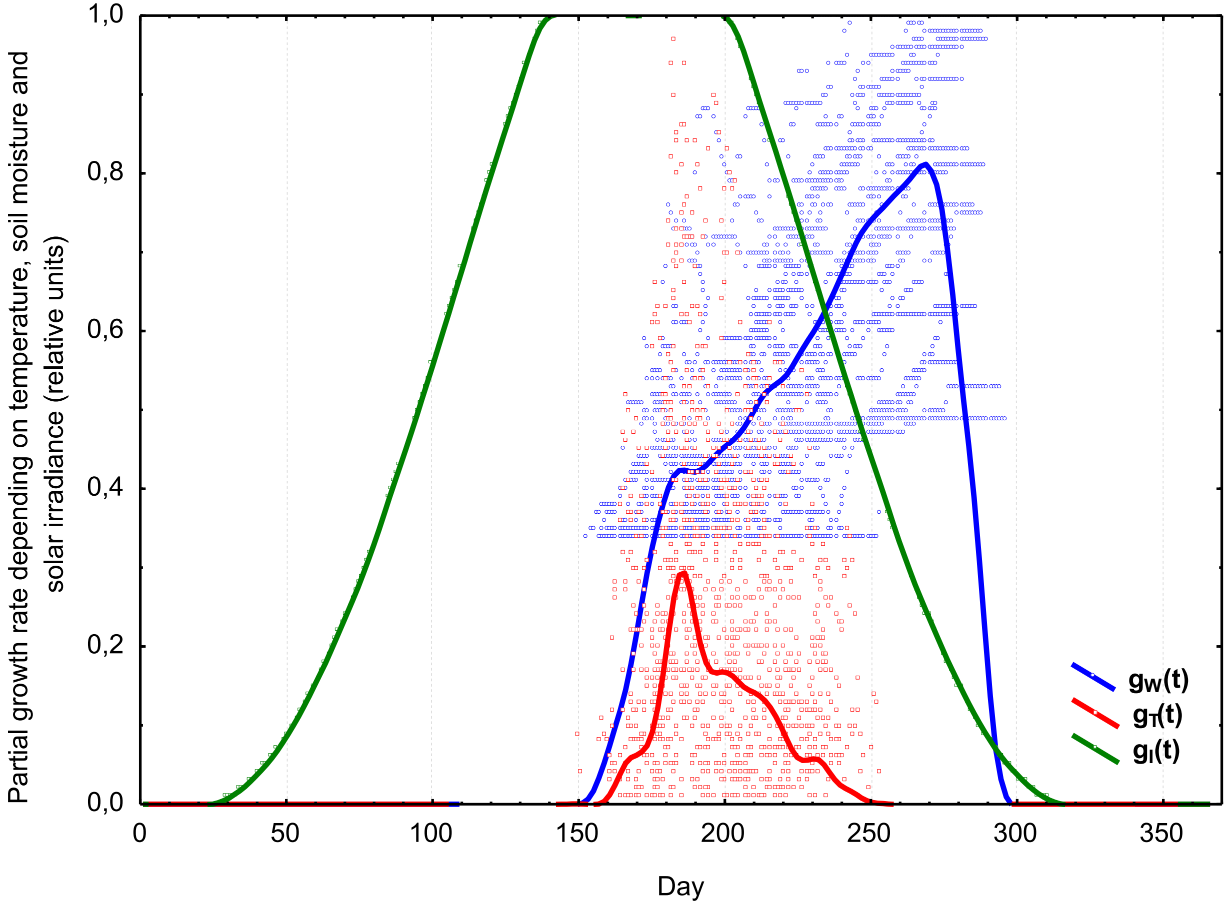
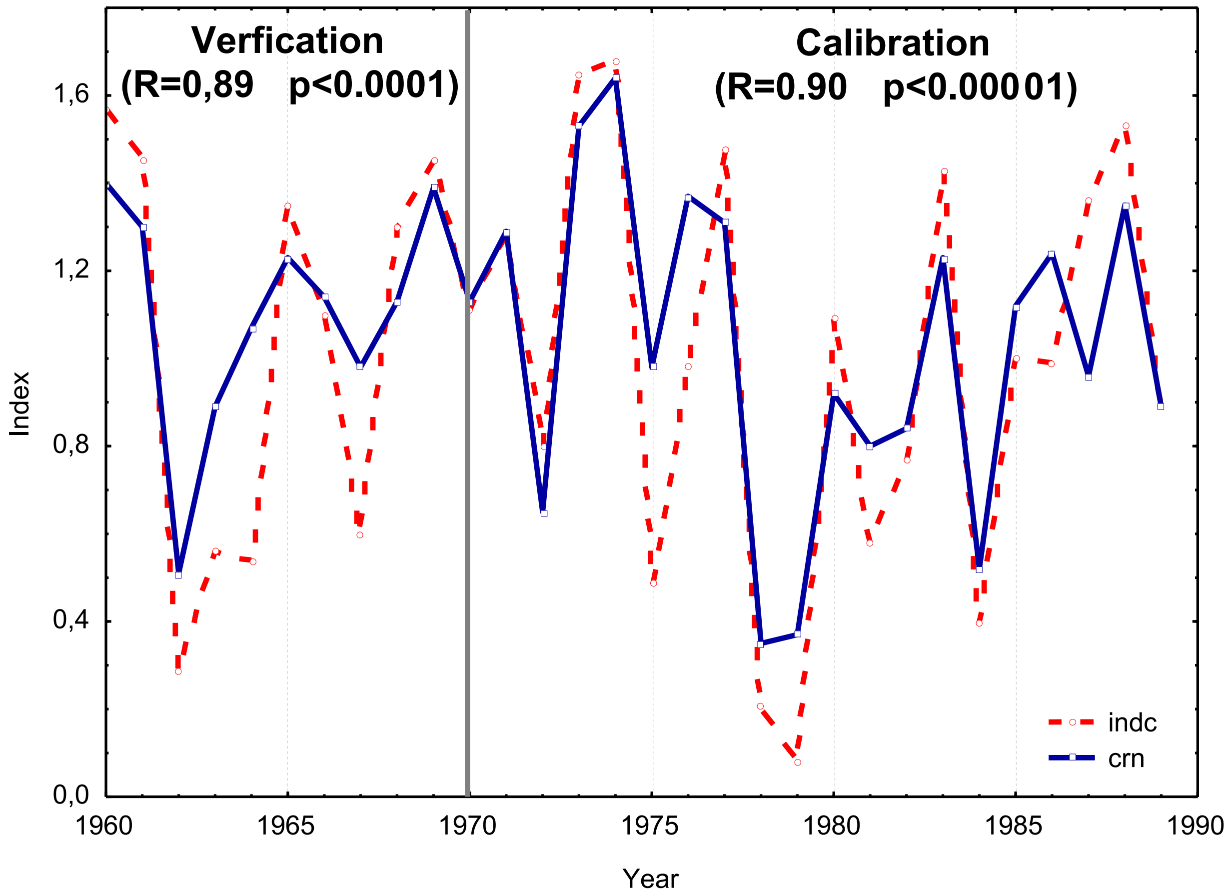
Taymir peninsula



Temperature, indicated by the VS model to have limited growth in 100% of the growing-season days.
Average duration of growth season - 45 days(±6 days). Average date of season's start is the middle of June

Unreasonable VS-parameters

Taymir peninsula *(Unreasonable parameters)*



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Taymir peninsula (Unreasonable parameters)

Parameter	Description (Units)	Value
T_{min}	Minimum temperature for tree growth (°C)	8
$Topt_1$	Lower end of range of optimal temperatures (°C)	21
$Topt_2$	Upper end of range of optimal temperatures (°C)	26
T_{max}	Maximum temperature for tree growth (°C)	31
W_{min}	Minimum soil moisture for tree growth, relative to saturated soil (v/vs)	0,03
$Wopt_1$	Lower end of range of optimal soil moistures (v/vs)	0,23
$Wopt_2$	Upper end of range of optimal soil moistures (v/vs)	0,38
W_{max}	Maximum soil moisture for tree growth (v/vs)	0,90
W_0	Initial soil moisture (v/vs)	0,09
W_w	Minimum soil moisture (wilting point)	0,07
T_{beg}	Temperature sum for initiation of growth (°C)	100
t_{beg}	Time period for temperature sum (days)	10
l_r	Depth of root system (mm)	400
P_{max}	Maximum daily precipitation for saturated soil (mm/day)	40
C_1	Fraction of precip. penetrating soil (not caught by crown) (rel. unit)	0.71
C_2	First coefficient for calculation of transpiration (mm/day)	8.30 (0,45)
C_3	Second coefficient for calculation of transpiration (mm/day)	0.34 (0,20)
Λ	Coefficient for water drainage from soil (rel.unit)	0.00
t_c	Cambial model time step (days)	1.00
V_{cr}	Minimum cambial cell growth rate (no units)	0.025
D_0	Initial cambial cell size (μm)	4.000
D_{cr}	Cell size at which mitotic cycle begins (μm)	8.000
V_m	Growth rate during mitotic cycle (μm/day)	1.000
D_m	Cambial cell size at which mitosis occurs (μm)	10.00

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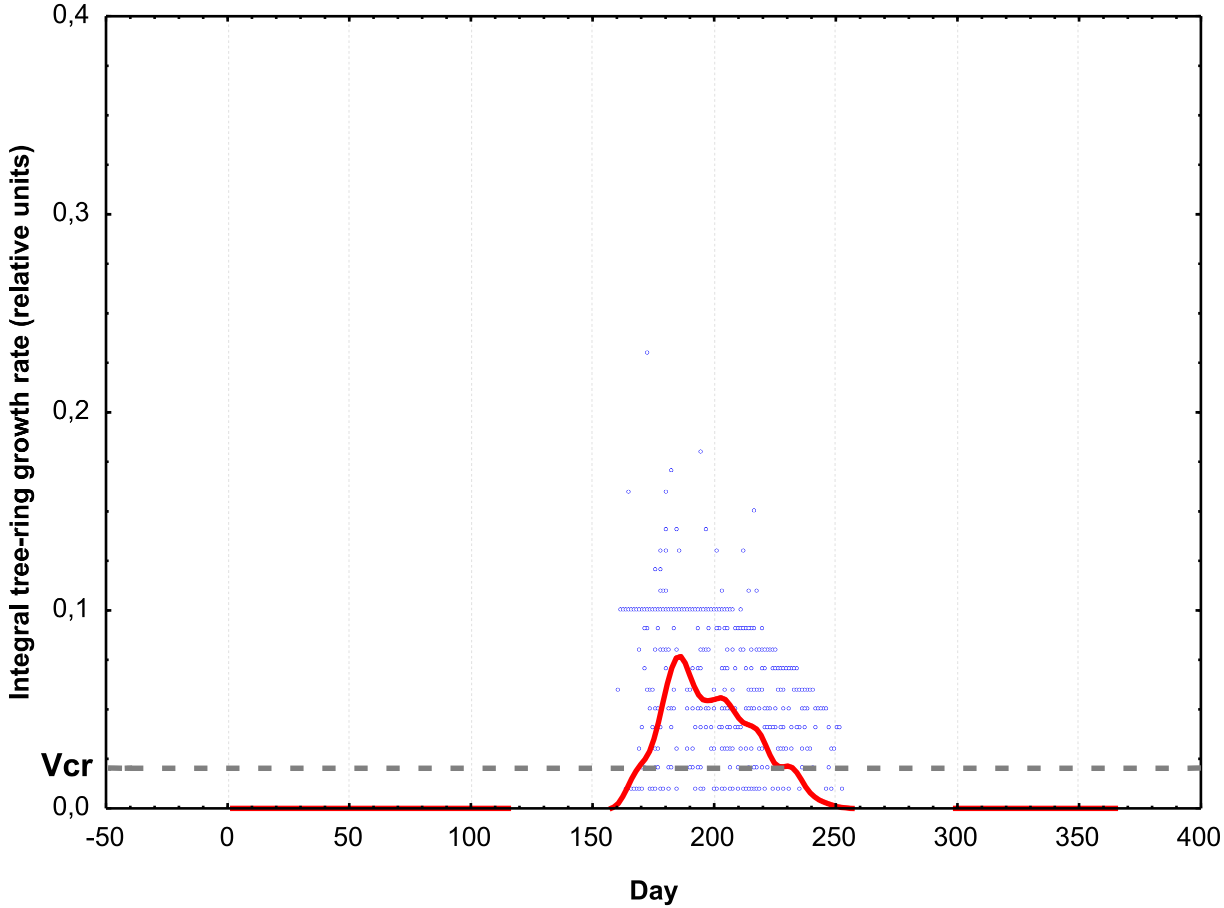
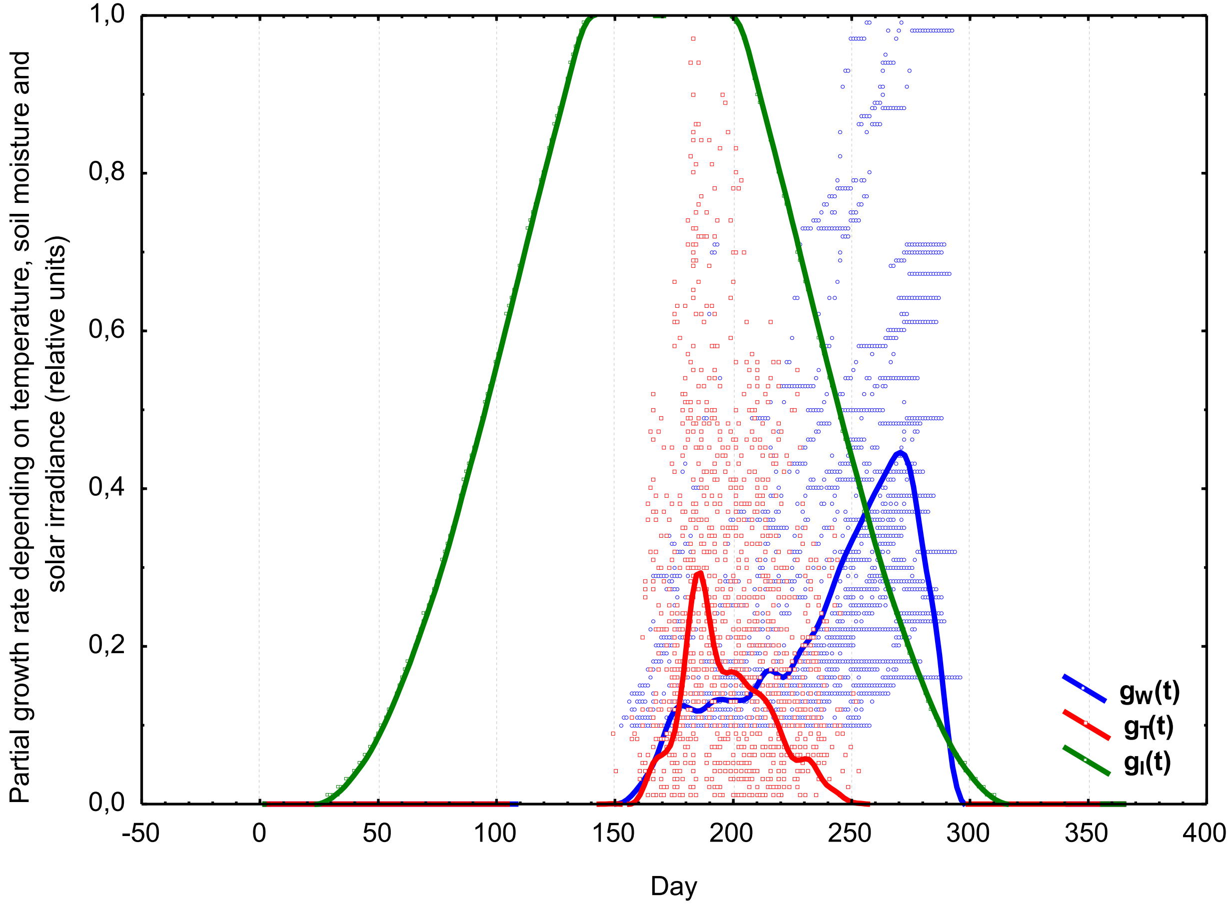
Taymir peninsula *(Unreasonable parameters)*



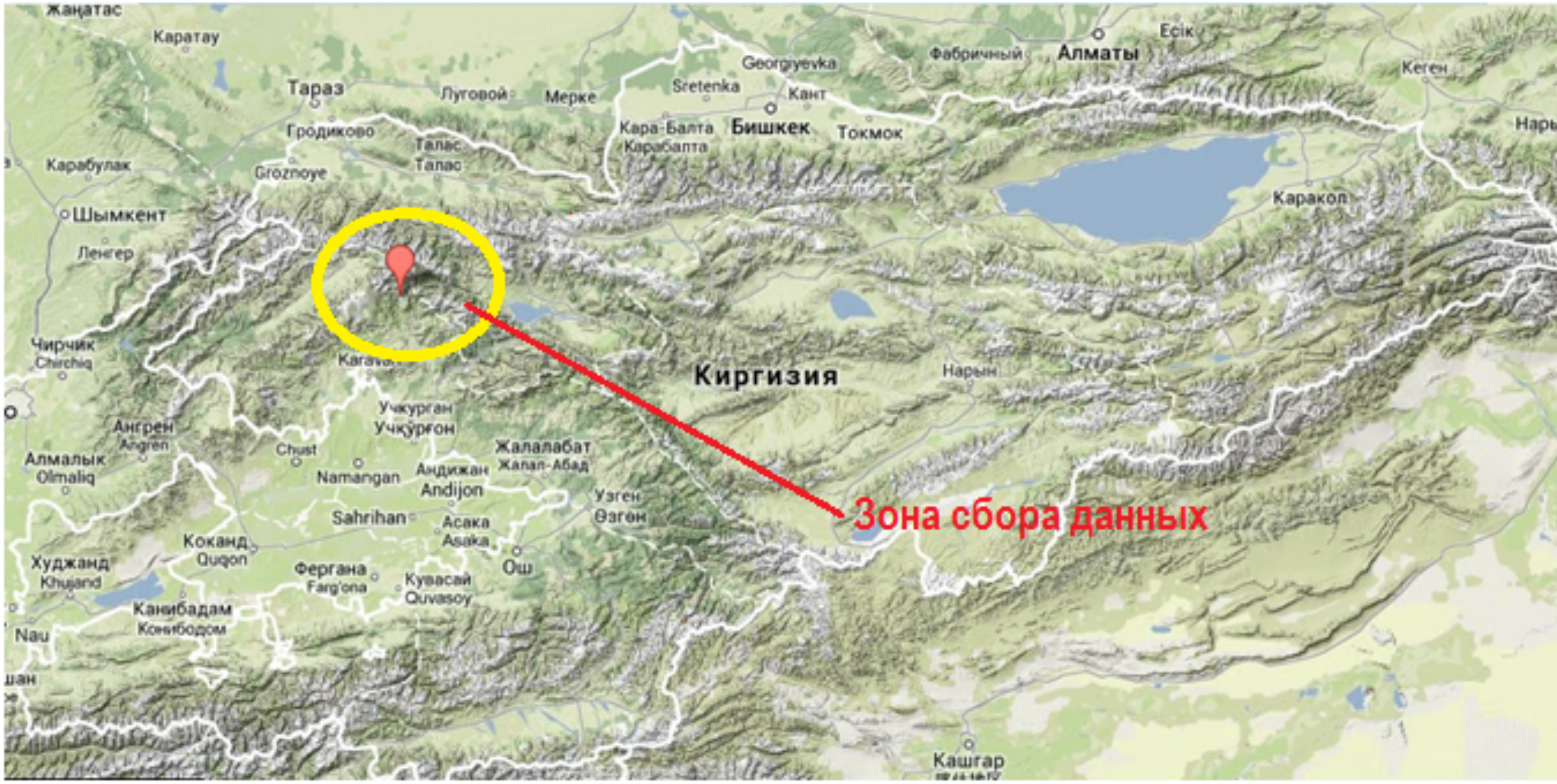
Taymir peninsula *(Unreasonable parameters)*



Precipitation, indicated by the VS model to have limited growth in 50% of the growing-season days.

Average duration of growth season - 45 days(±6 days). Average date of season's start is the middle of June

Central Asia



12 dendrochronological sites (4 species, different altitudes) and 1 meteostation

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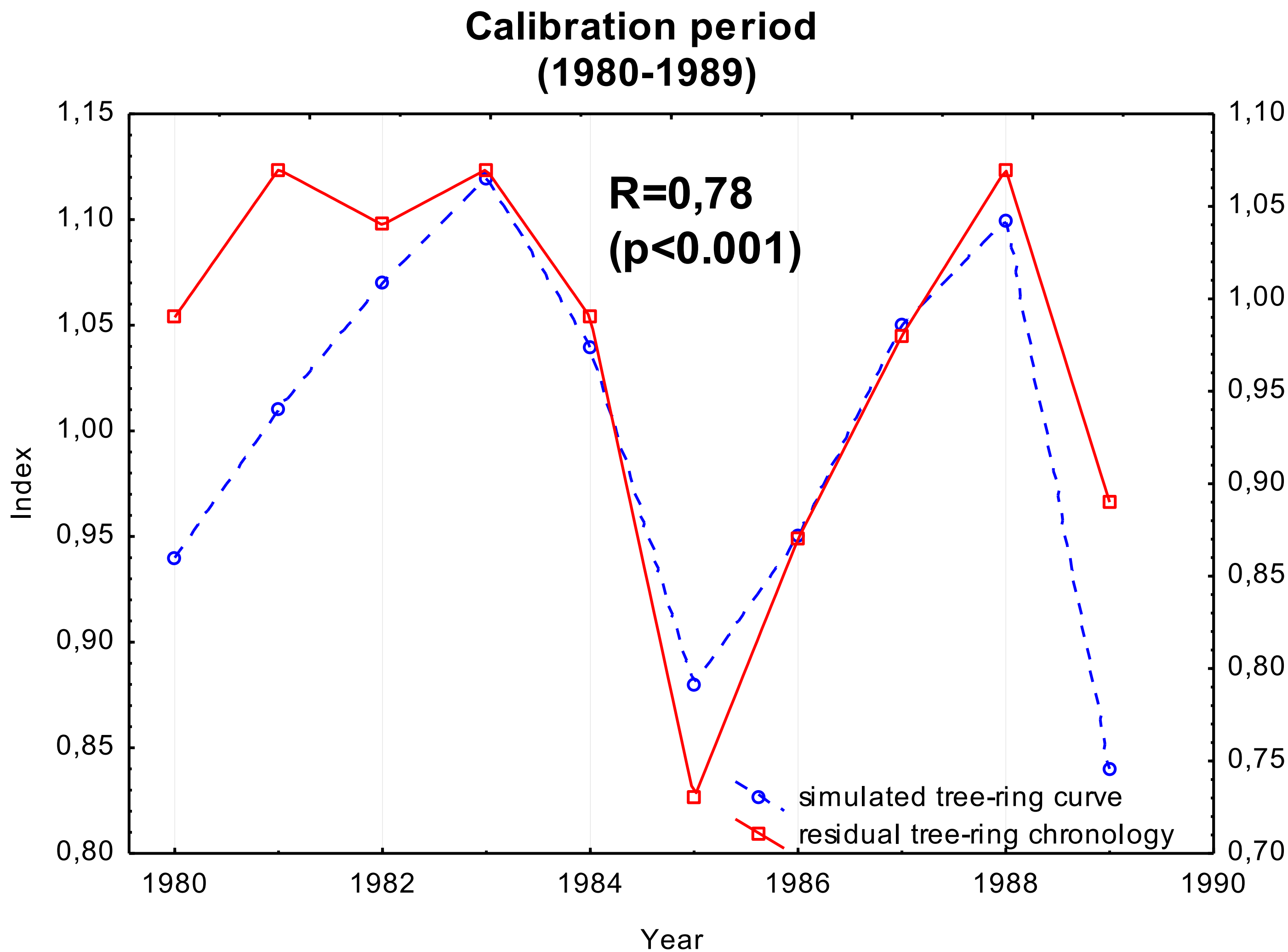
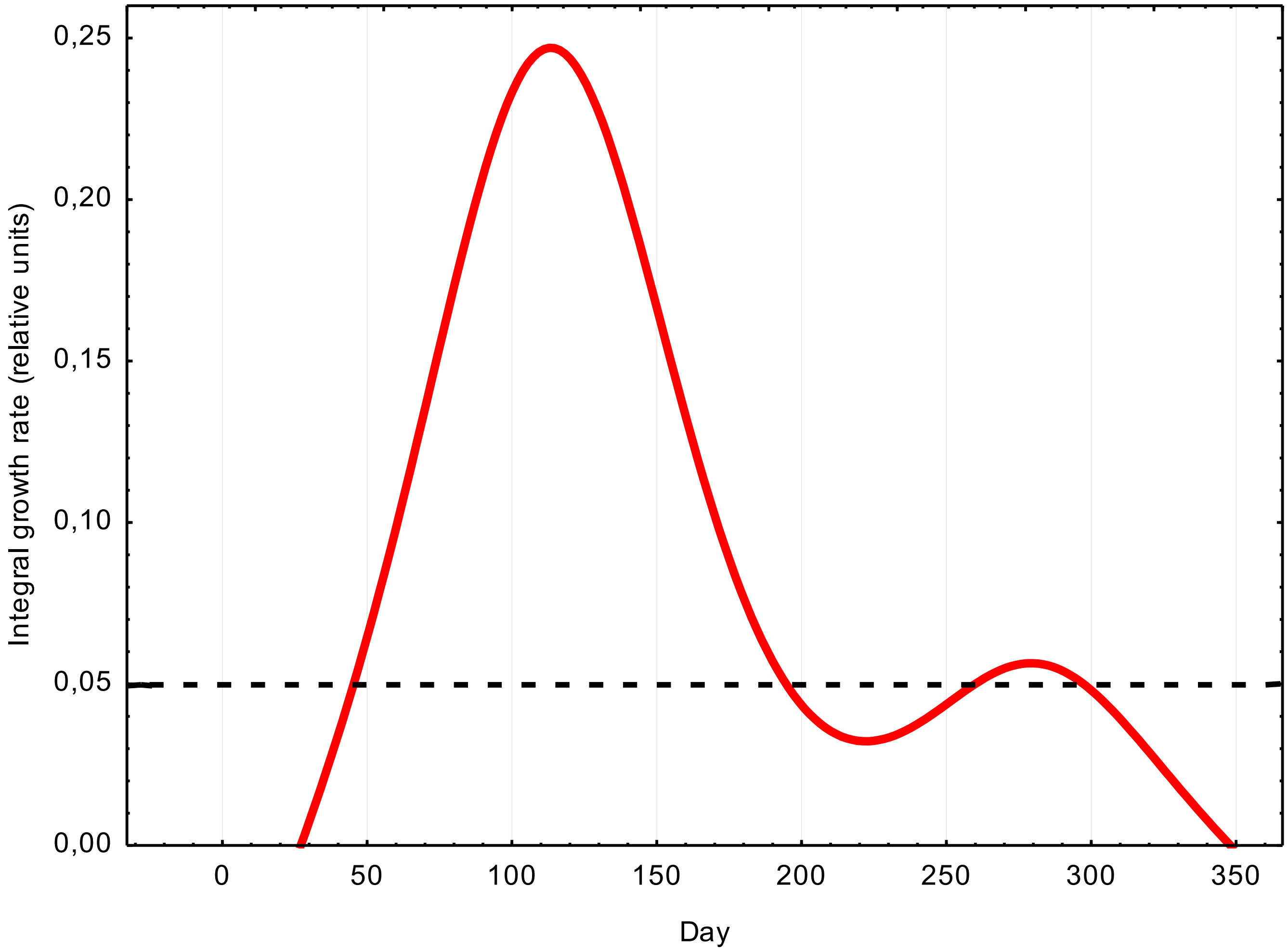
Central Asia

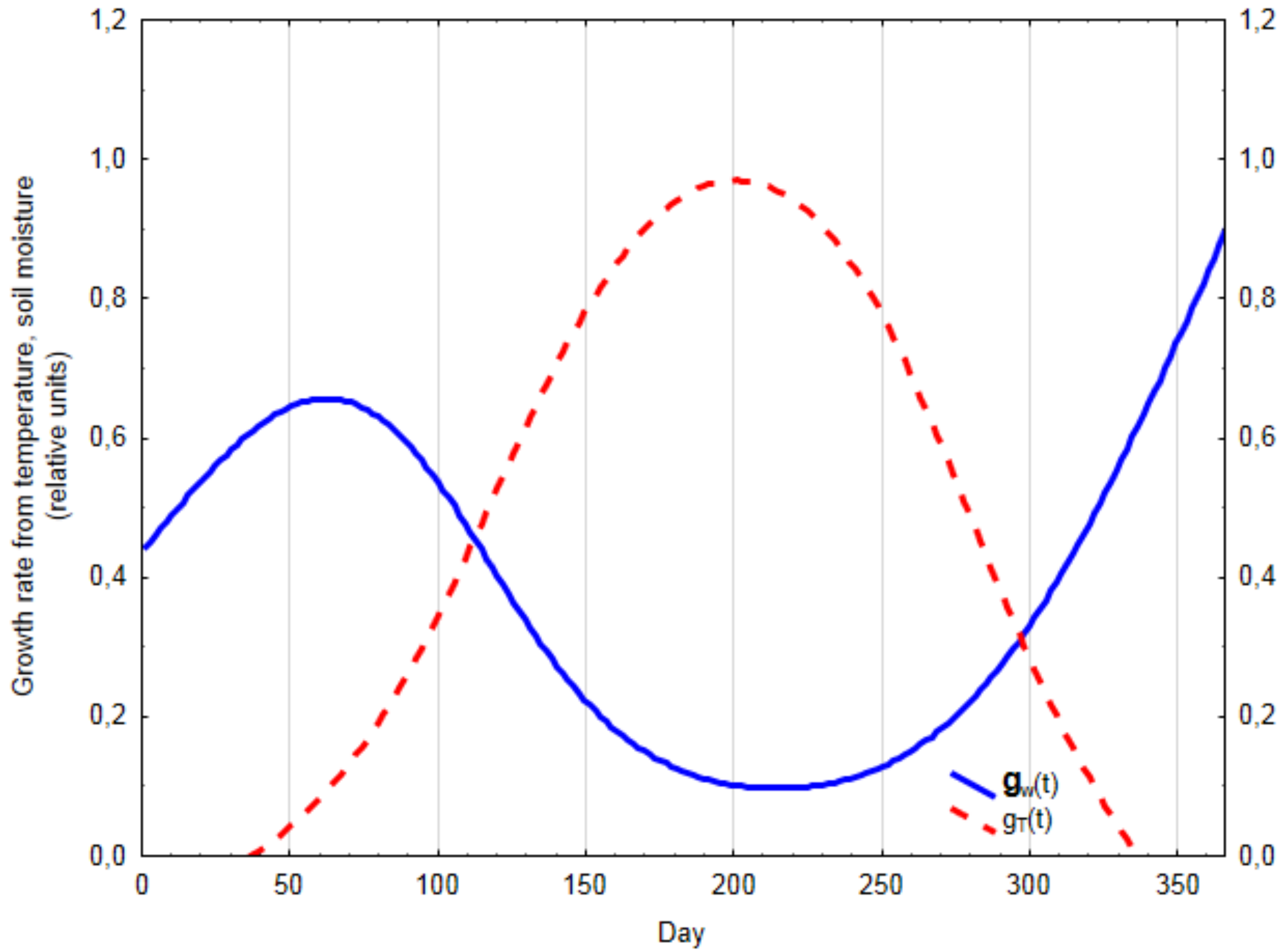
***Fir (Abies semenovii Fedtsch)* (Altitude 2360 m a.s.l.)**



Central Asia



Central Asia



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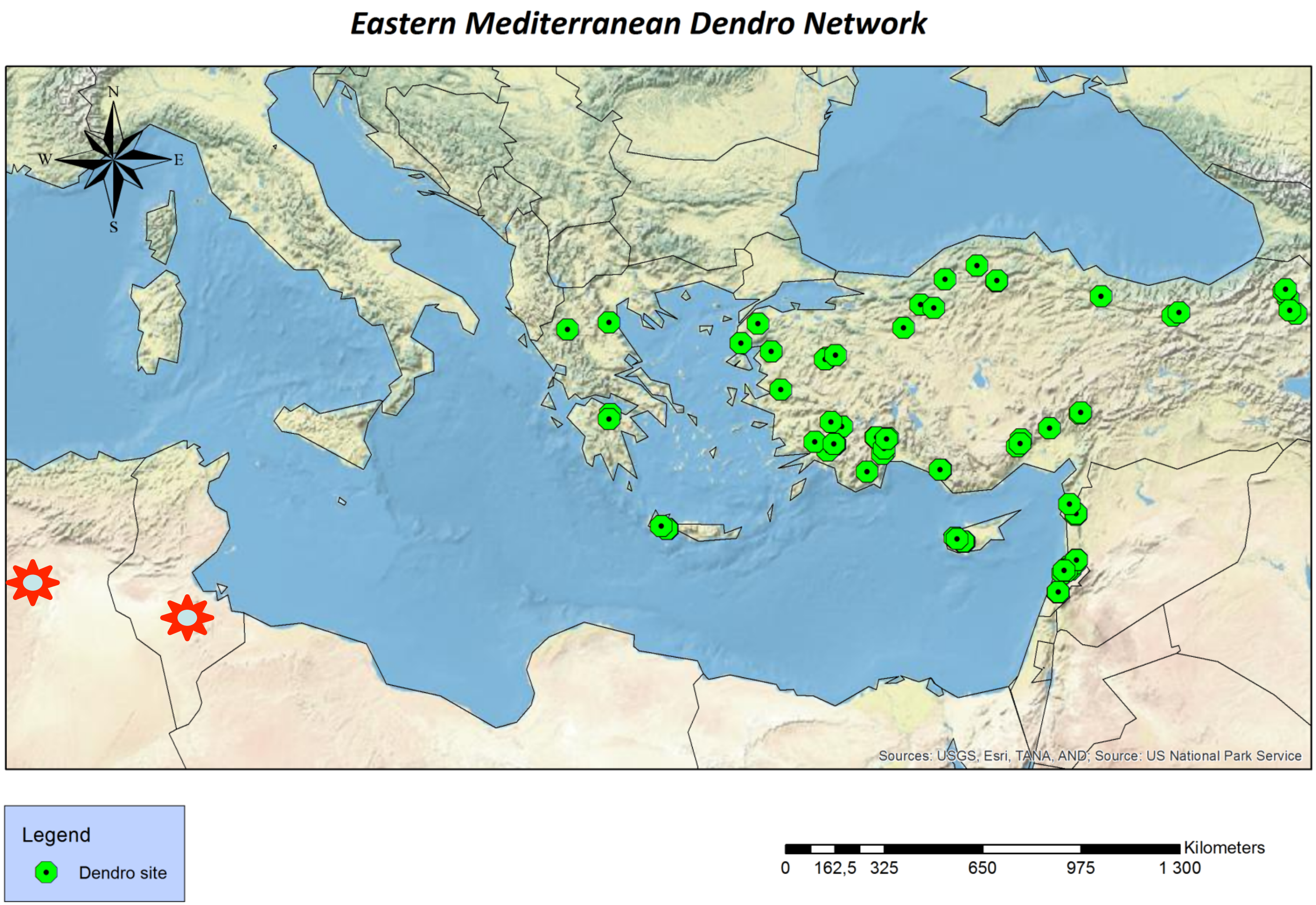
Mediterranean region



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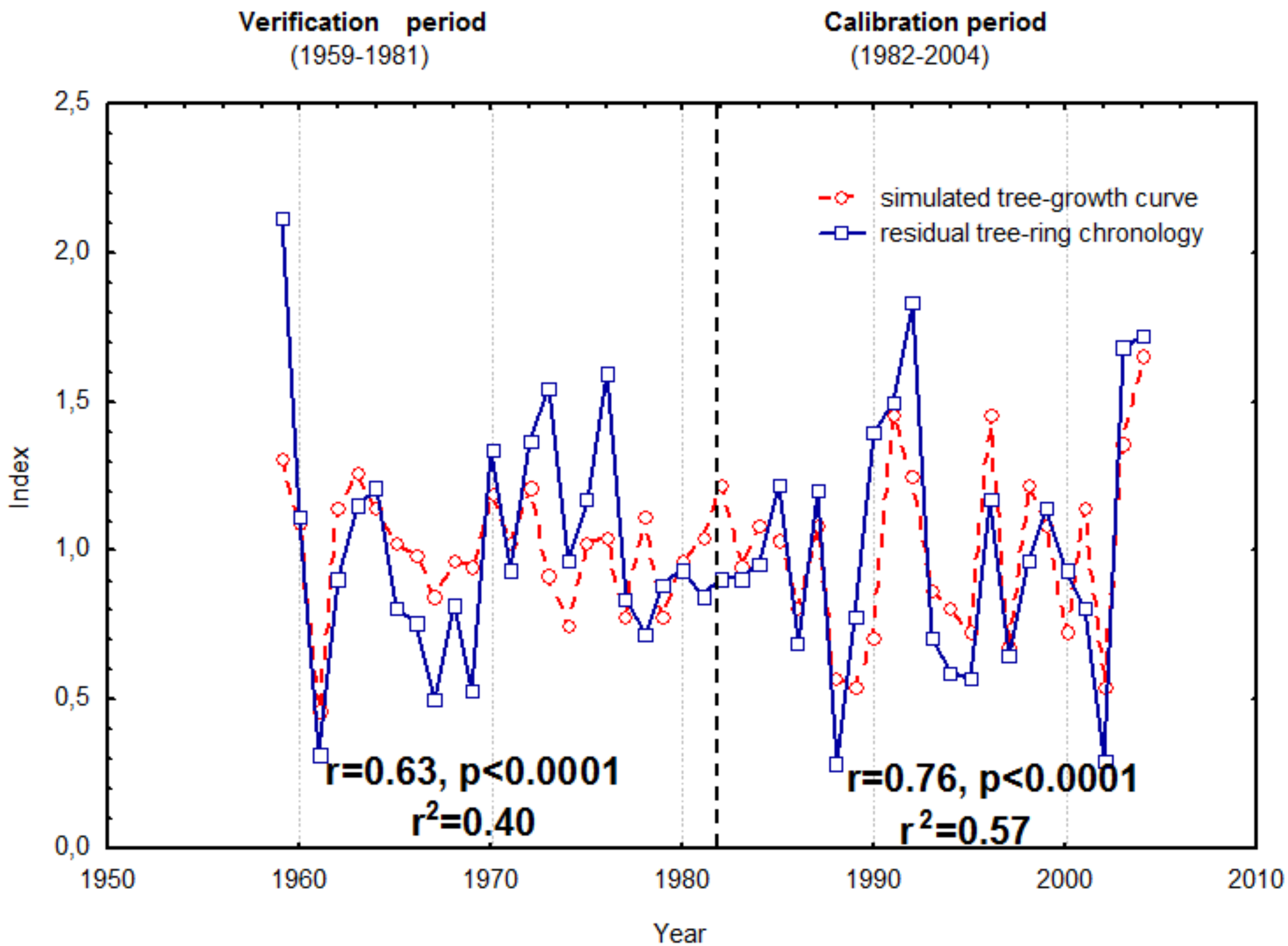
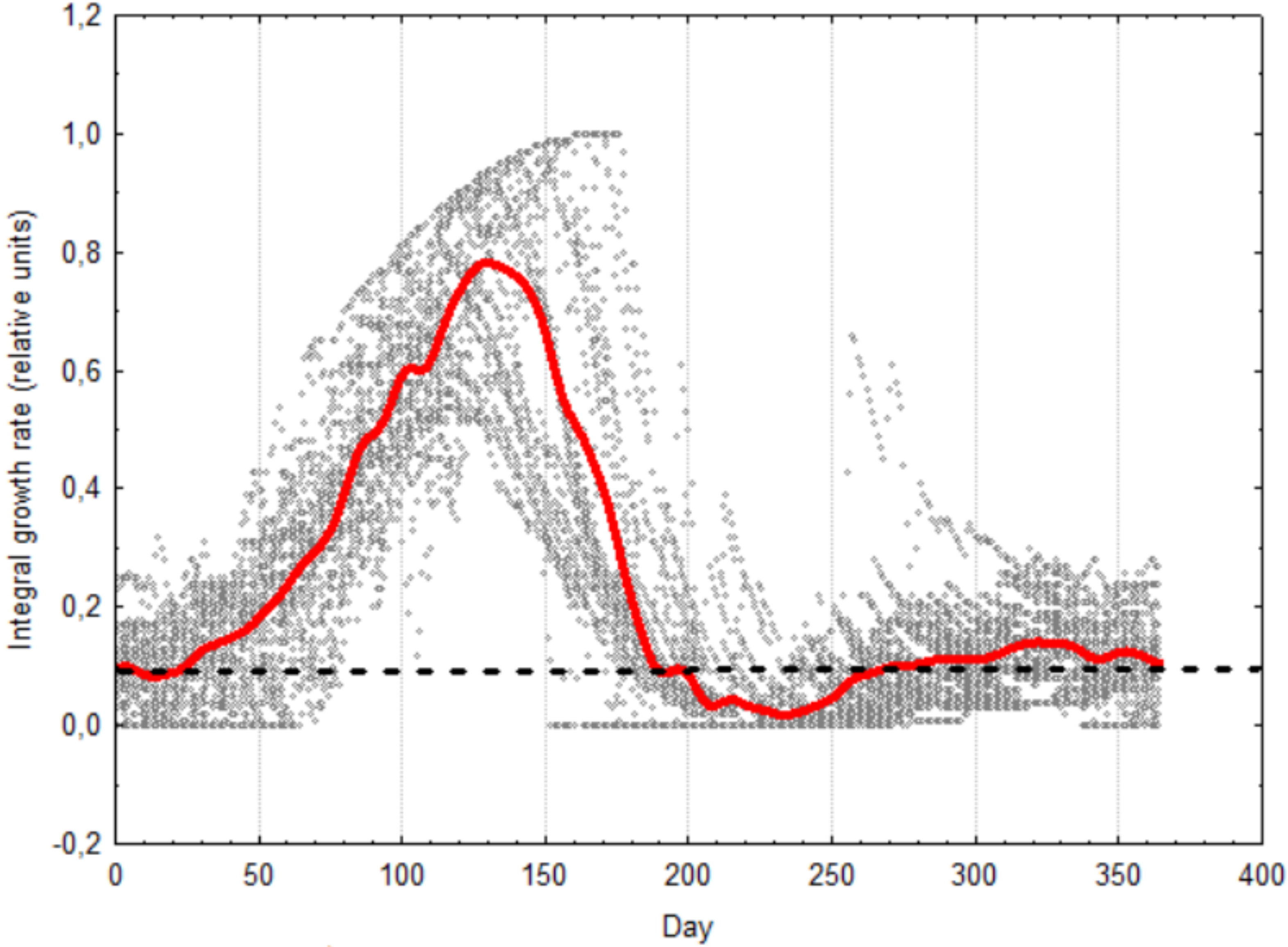
Tunisia



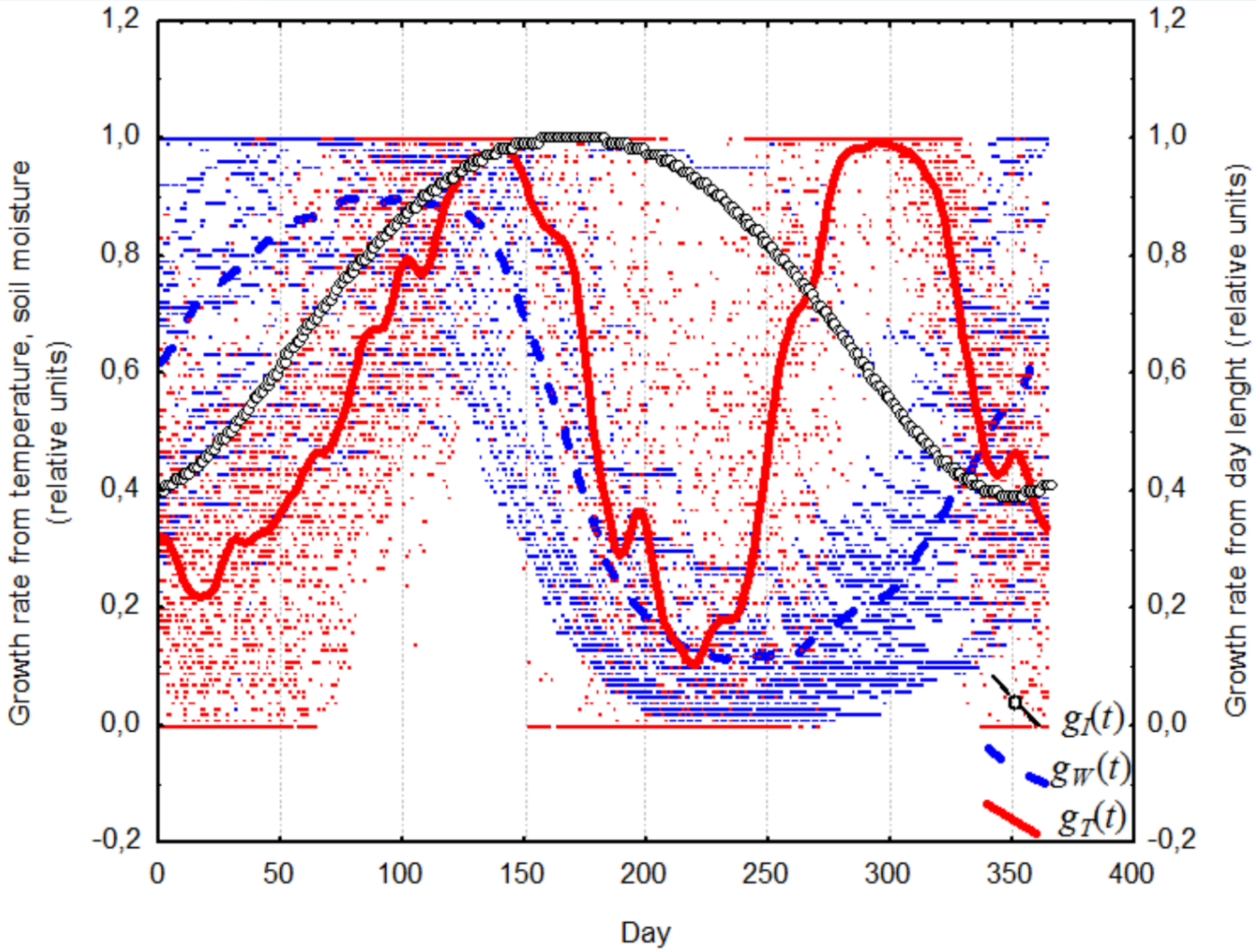
Touchan et al., 2012

Tunisia



1,2
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
Integral growth rate (relative units)
0
50
100
150
200
250
300
350
400
Day

Tunisia



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Conclusions

•New visual approach of ***VS***-model parameterization (so-called ***VS***-oscilloscope) is developed which allows to simulate tree-ring growth and can be used by individual researchers and students.

• Seasonal tree-ring growth features (growing season duration, start date of growing season, number of days in growing season controlling by specific climate factor, etc.) were obtained for different regions: Siberia, Central Asia and Mediterranean Africa.

•Bi-modal growth patterns are obtained in Central Asia and Mediterranean Africa. These patterns should be verify by natural field studies.

Perspectives

➢**VS- Growth Evolution Neural Network (fully automatic parameterization algorithm based on specific genetic IT-approach)**

➢**Multiyear natural field studies (*in specific region*), including:**

- **Seasonal observation of cell dynamics**
- **Cell dimension measurements**

Our partners:

(University of Barcelona, Spain; INRA Orlean, France; University of Arizona, USA; Mediterranean modeling center, Aix-an-Provance, France**)**

Thank you very much to be patient during the oral talk!