Temperature response function for soil respiration

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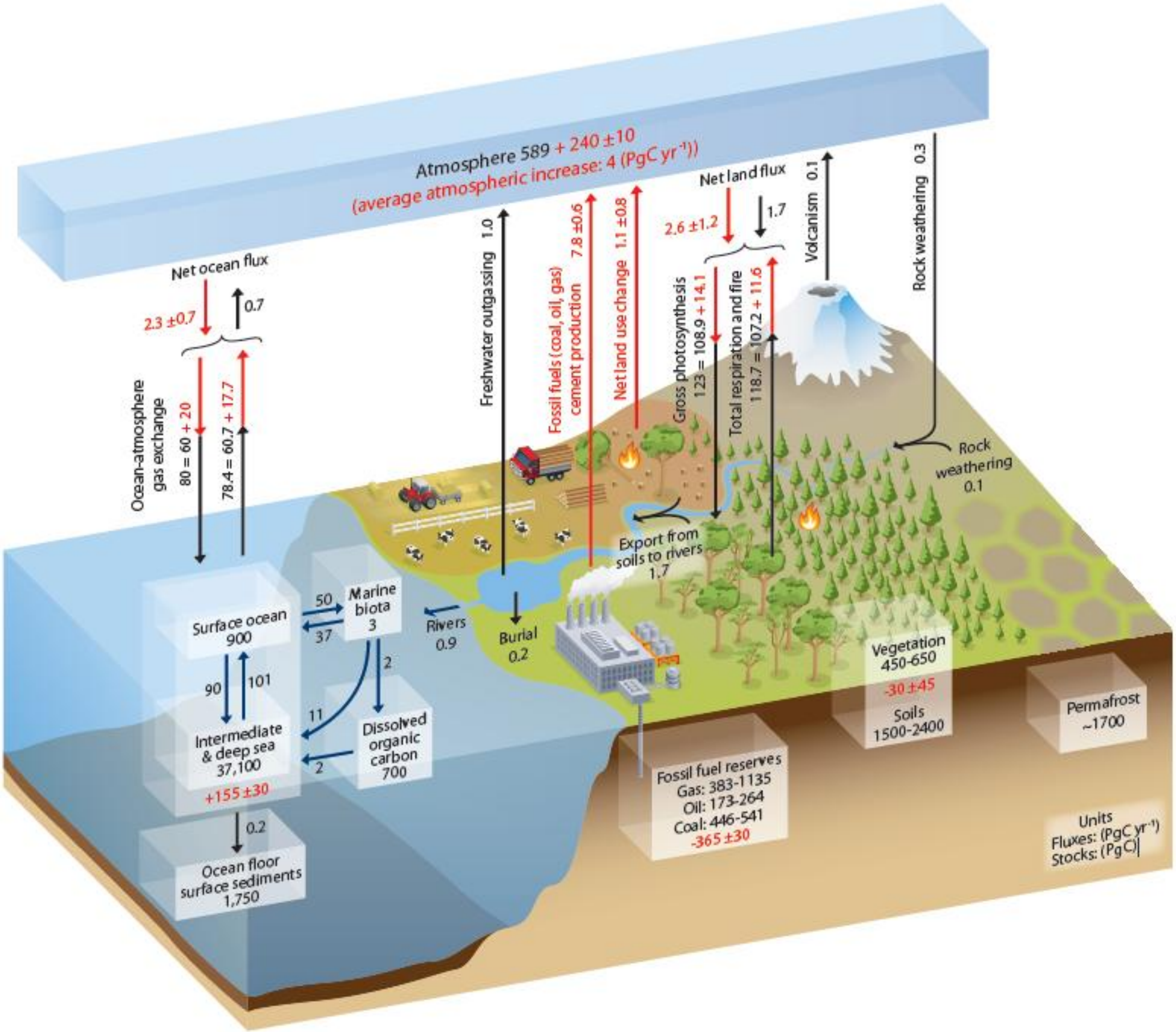
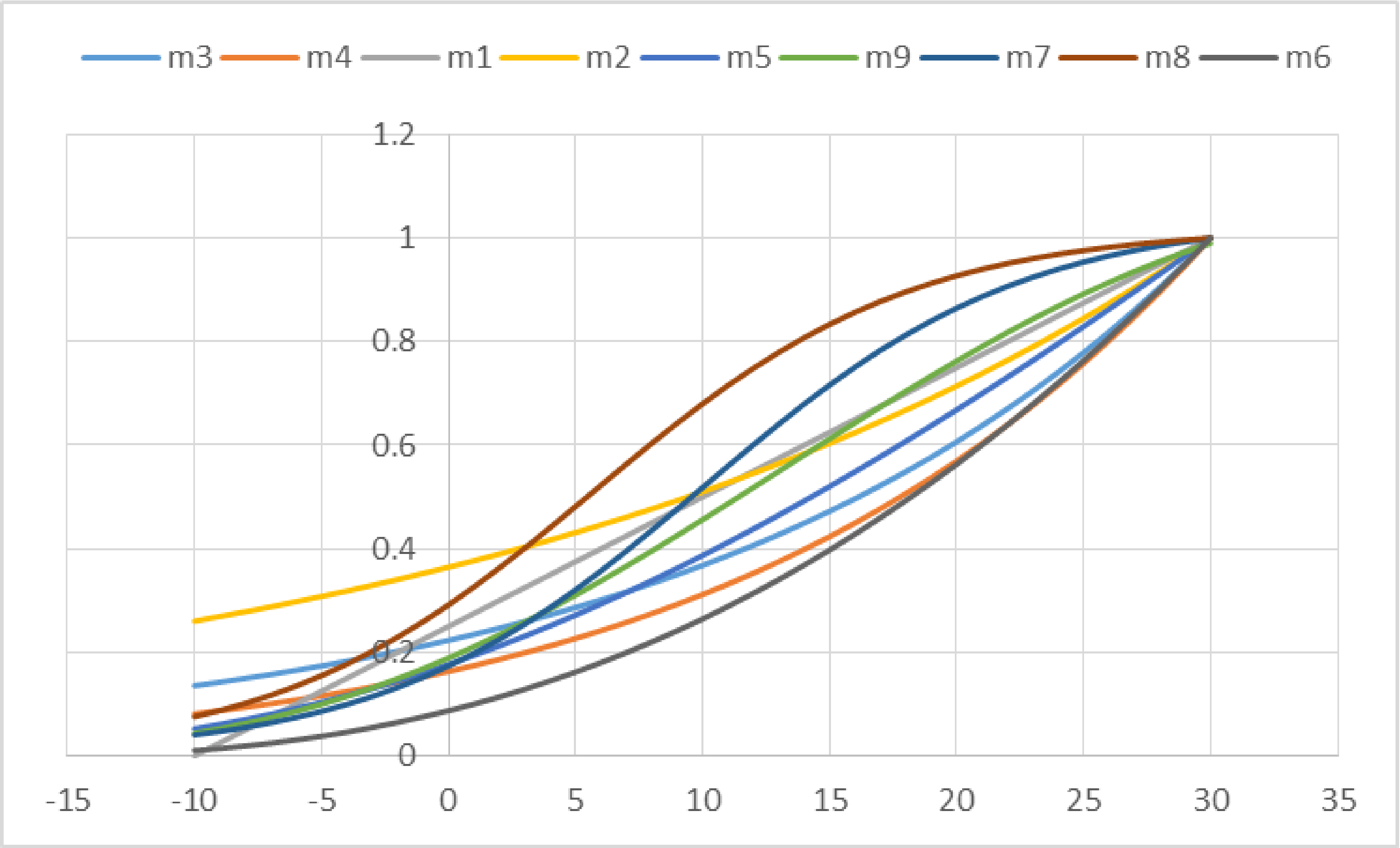
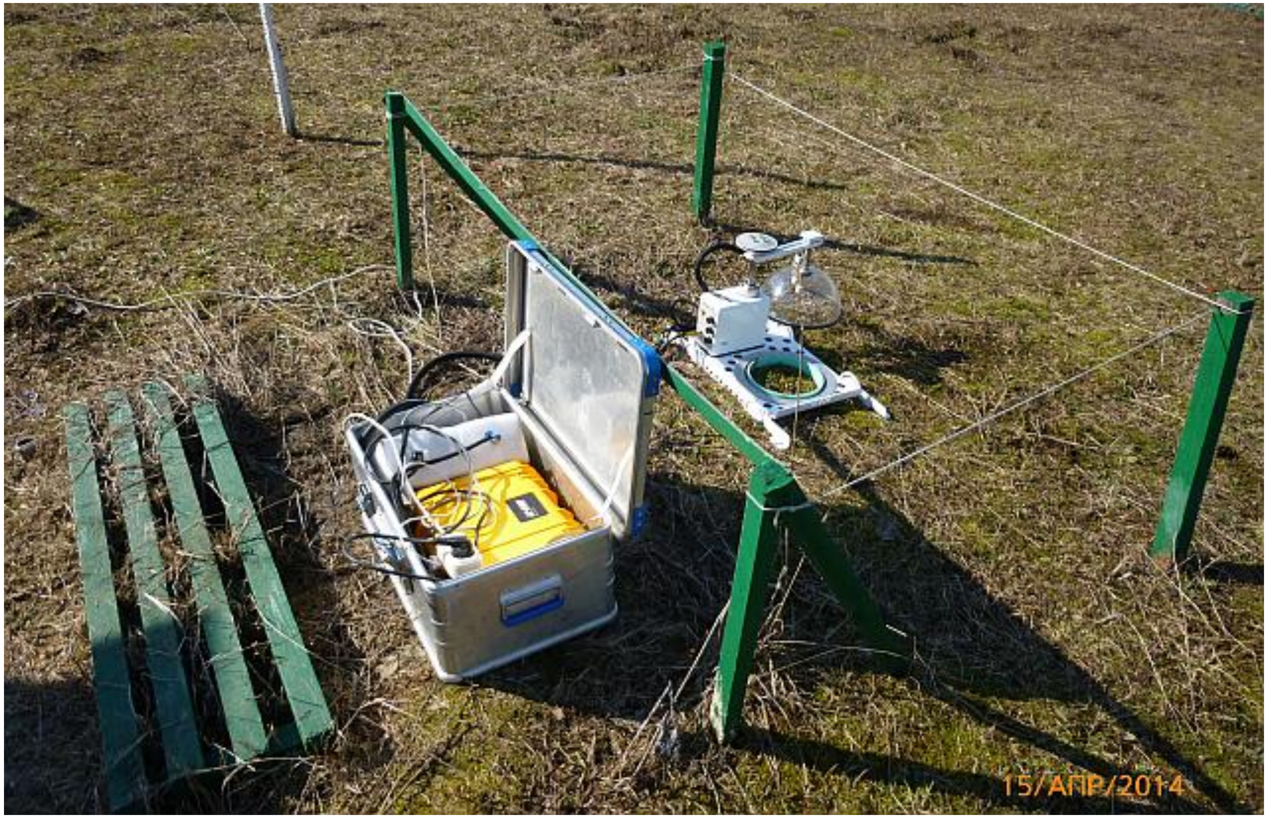

Atmosphere 589 + 240 ±10
(average atmospheric increase: 4 (PgC yr⁻¹))
Net ocean flux
2.3 ±0.7
0.7
Ocean-atmosphere gas exchange
80 = 60 + 20
78.4 = 60.7 + 17.7
Freshwater outgassing 1.0
Fossil fuels (coal, oil, gas) cement production 7.8 ±0.6
Net land use change 1.1 ±0.8
Net land flux
2.6 ±1.2
1.7
Gross photosynthesis 123 = 108.9 + 14.1
Total respiration and fire 118.7 = 107.2 + 11.6
Volcanism 0.1
Rock weathering 0.3
Rock weathering 0.1
Export from soils to rivers 1.7
Marine biota 3
50
37
Surface ocean 900
Rivers 0.9
Burial 0.2
90
101
2
11
Intermediate & deep sea 37,100
+155 ±30
Dissolved organic carbon 700
2
0.2
Ocean floor surface sediments 1,750
Vegetation 450-650
-30 ±45
Soils 1500-2400
Permafrost ~1700
Fossil fuel reserves
Gas: 383-1135
Oil: 173-264
Coal: 446-541
-365 ±30
Units
Fluxes: (PgC yr⁻¹)
Stocks: (PgC)

Temperature response functions of soil respiration (*SR*). *k*, *r*, *p* – model parameters, T_1 – temperature (°C),

T_{ref} = 10 °C, T_K = 273.15 °C, T_0 = –46.02 °C, T_g =40 °C, R_g = 8.31 J mol^{-1} K^{-1}.

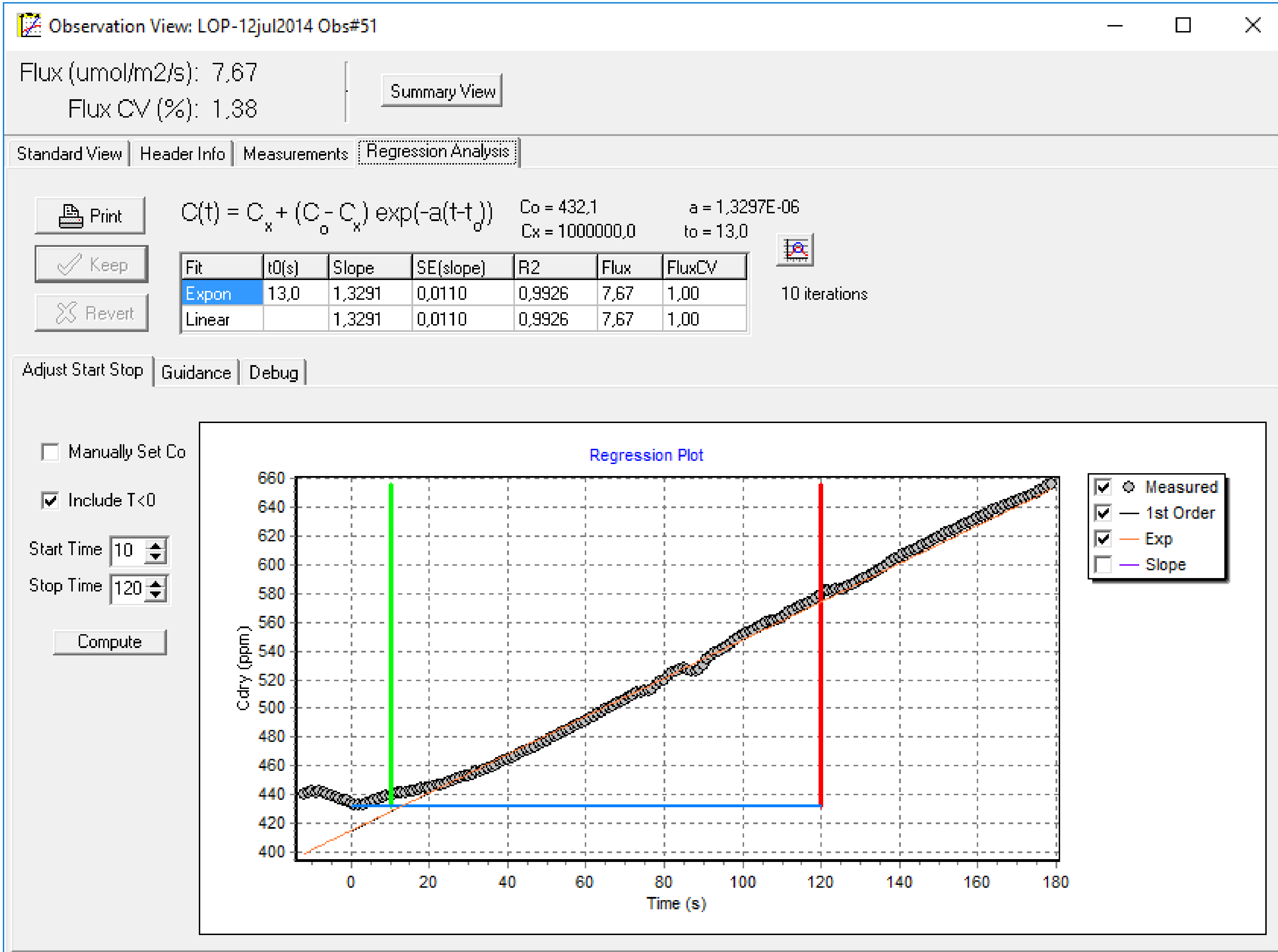
Model	Equation	Reference
1. Linear	$SR = r + k \cdot T_1$	[Wang et al., 2002; Mahadevan et al., 2008, Kur al., 2011]
2. Q_{10}	$SR = r \cdot k^{(T_1 - T_{ref})/10}$	[van't Hoff 1898, Bond-Lamberty et al., 2011]
3. Exponential	$SR = r \cdot \exp[k \cdot T_1]$	[van't Hoff 1898, Bond-Lamberty et al., 2011]
4. Arrhenius	$SR = r \cdot \exp\left[-\frac{k}{R_g \cdot (T_1 + T_K)}\right]$	[Lloyd and Taylor, 1994; Fang and Moncrieff, 2(
5. Lloyd&Taylor	$SR = r \cdot \exp\left[k\left(\frac{1}{T_{ref} - T_0} - \frac{1}{T_1 - T_0}\right)\right]$	[Lloyd and Taylor, 1994; Reichstein et al., 2005]
6. Power	$SR = r \cdot \lvert T_1 - p \rvert^k$	[Fang and Moncrieff, 2001]
7. Logistic	$SR = \frac{r}{1 + p \cdot \exp[-k \cdot T_1]}$	[Richards, 1959; Rodeghiero and Cescatti, 2005]
8. Sigmoid	$SR = \frac{r}{p + k^{-(T_1 - T_{ref})/10}}$	[Jenkinson, 1990; Fang and Moncrieff, 2001]
9. Gamma	$SR = (T_1 + T_g)^r \cdot \exp[p - k \cdot (T_1 + T_g)]$	[Khomik et al., 2009; Bond-Lamberty et al., 201


m3
m4
m1
m2
m5
m9
m7
m8
m6
1.2
1
0.8
0.6
0.4
0.2
0
-15
-10
-5
0
5
10
15
20
25
30
35

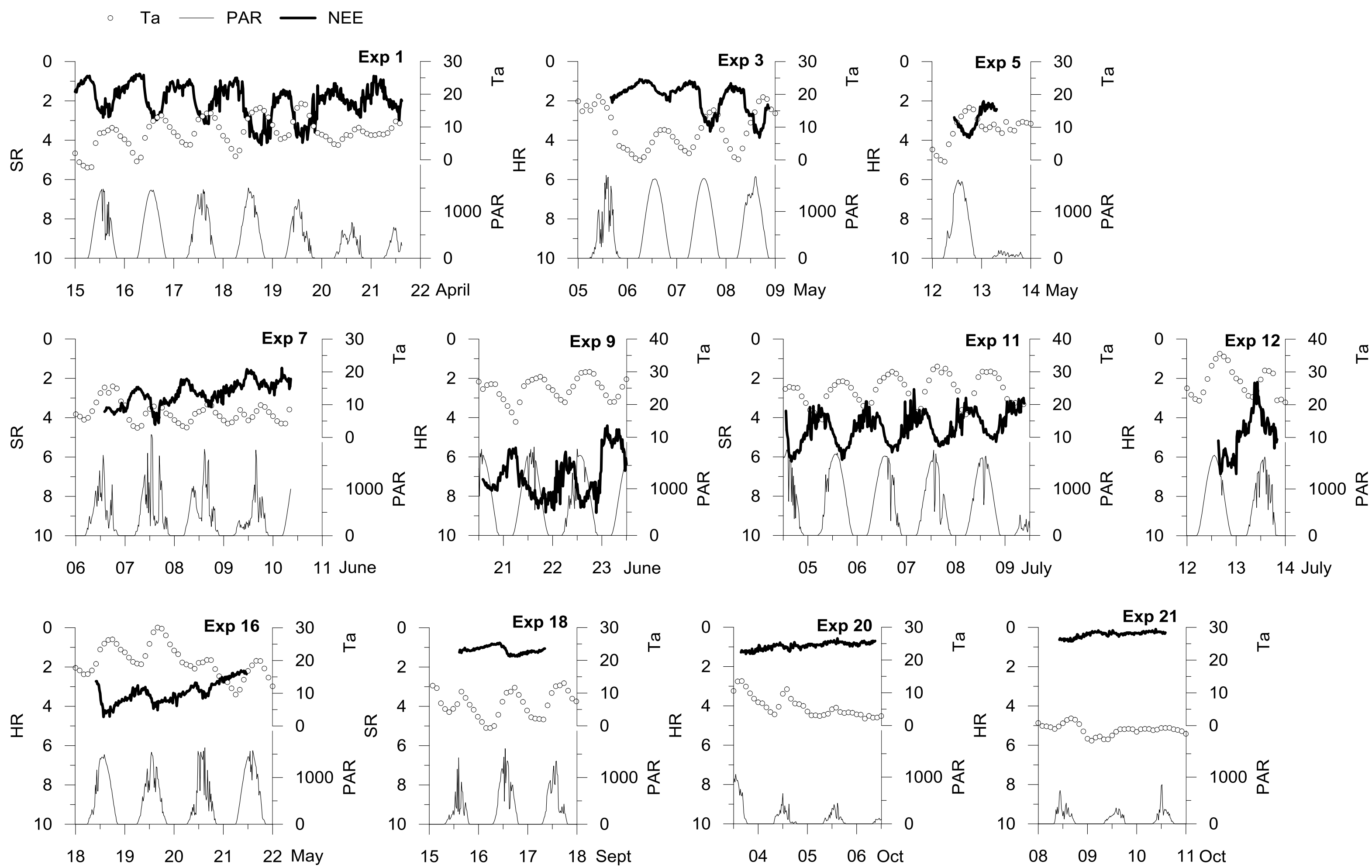


LI-8100a - Automated Soil CO2 Flux System with clear long-term chamber installed at Lower Observation Point (IMCES).

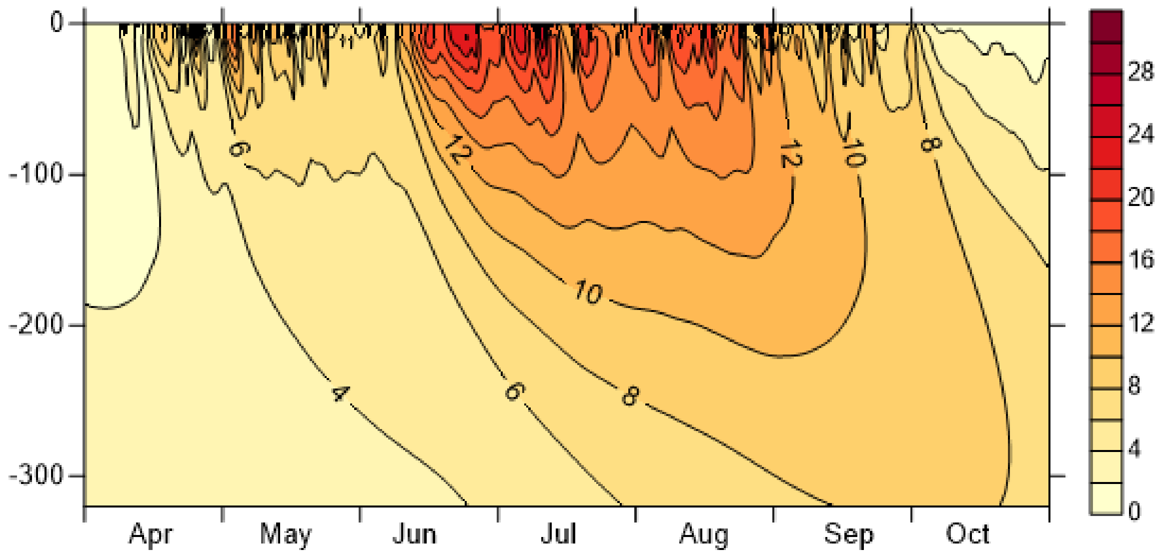
Bare soil site

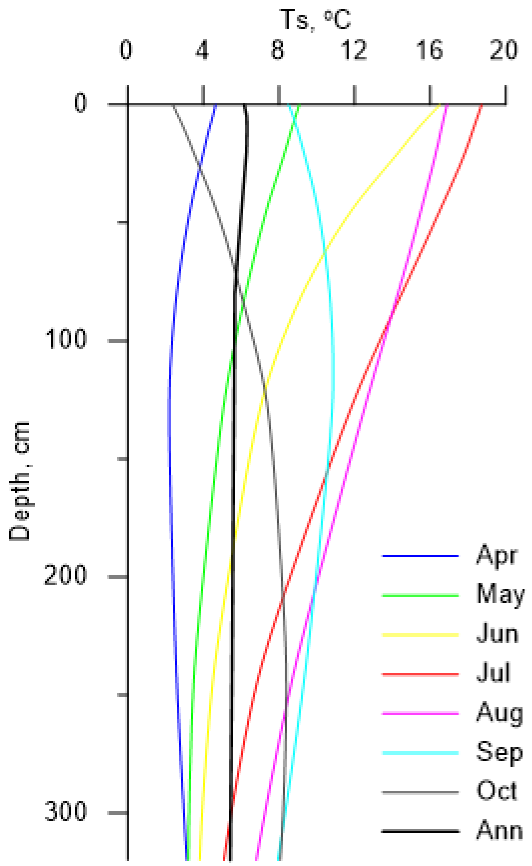

Observation View: LOP-12jul2014 Obs#51
Flux (umol/m2/s): 7,67
Flux CV (%): 1,38
Summary View
Standard View
Header Info
Measurements
Regression Analysis
Print
Keep
Revert
C(t) = Cx + (Co - Cx) exp(-a(t-to))
Co = 432,1
Cx = 1000000,0
a = 1,3297E-06
to = 13,0
Fit | t0(s) | Slope | SE(slope) | R2 | Flux | FluxCV
Expon | 13,0 | 1,3291 | 0,0110 | 0,9926 | 7,67 | 1,00
Linear | | 1,3291 | 0,0110 | 0,9926 | 7,67 | 1,00
10 iterations
Adjust Start Stop
Guidance
Debug
Manually Set Co
Include T<0
Start Time 10
Stop Time 120
Compute
Regression Plot
Cdry (ppm)
Time (s)
Measured
1st Order
Exp
Slope

Variations of CO_2 fluxes (SR, μmol m^{-2} s^{-1}), air temperature (Ta, °C), and photosynthetically active radiation (PAR, μmol m^{-2} s^{-1}) during experiments. Note that SR axis descends.



Soil temperature





Model optimization - *fminsearch*

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(O_i - M_i\right)^2}$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}\left(O_i - M_i\right)^2}{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)^2}; \quad R^2 = \left(\frac{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)\left(M_i - \overline{M}\right)}{\sqrt{\sum_{i=1}^{n}\left(O_i - \overline{O}\right)^2}\sqrt{\sum_{i=1}^{n}\left(M_i - \overline{M}\right)^2}}\right)^2;$$

To determine the model goodness the Nash–Sutcliffe coefficient (NSE) (Nash and Sutcliffe, 1970), root mean squared error (RMSE), the coefficient of determination (R^2) were used.

O – observed, M - modelled

Temperature response functions of soil respiration (*SR*).

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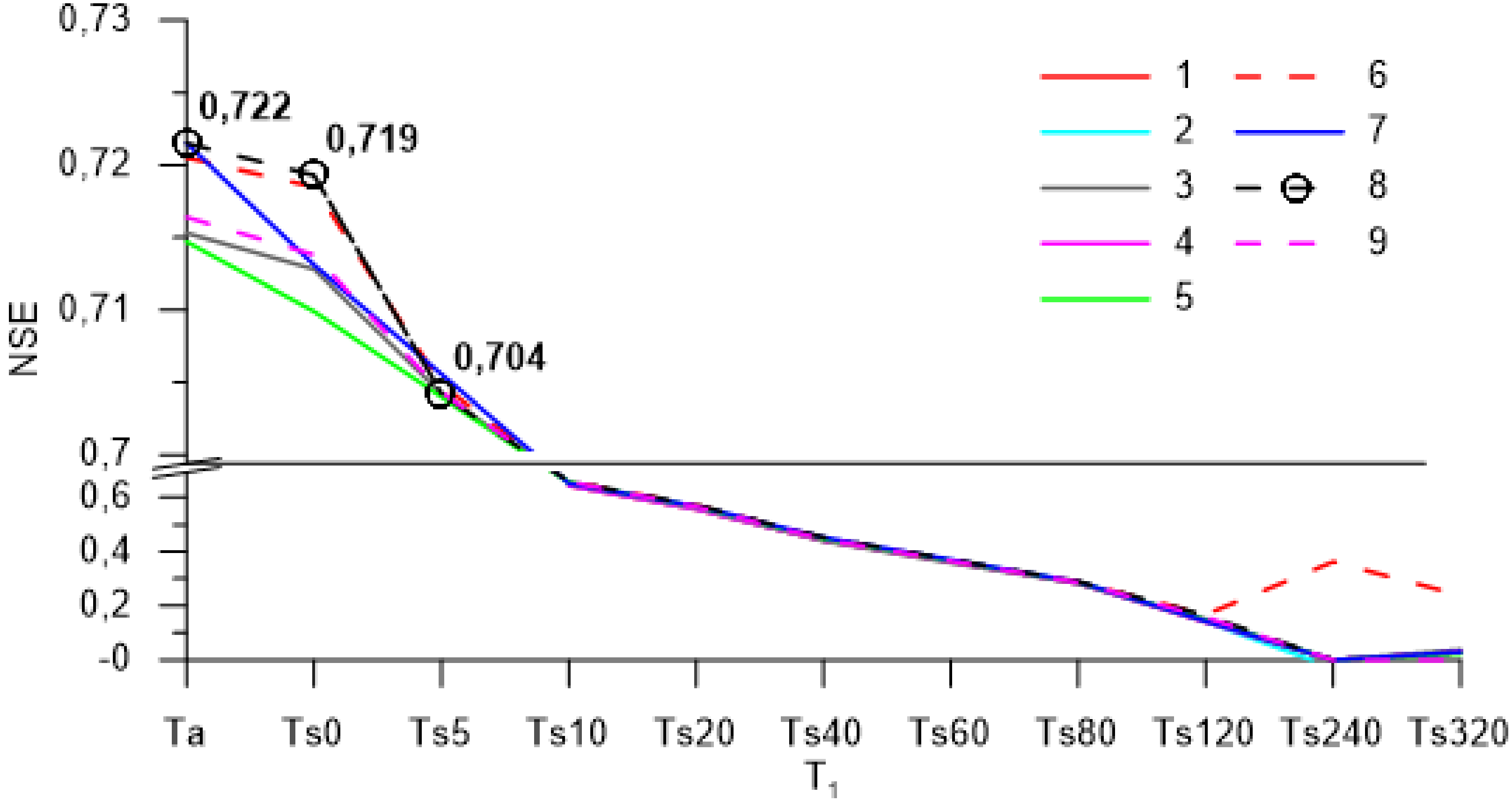
k, r, p – model parameters

T_1 – temperature (°C)

Controlling temperature (T_1)



6-power, 7-logistic, 8-sigmoid

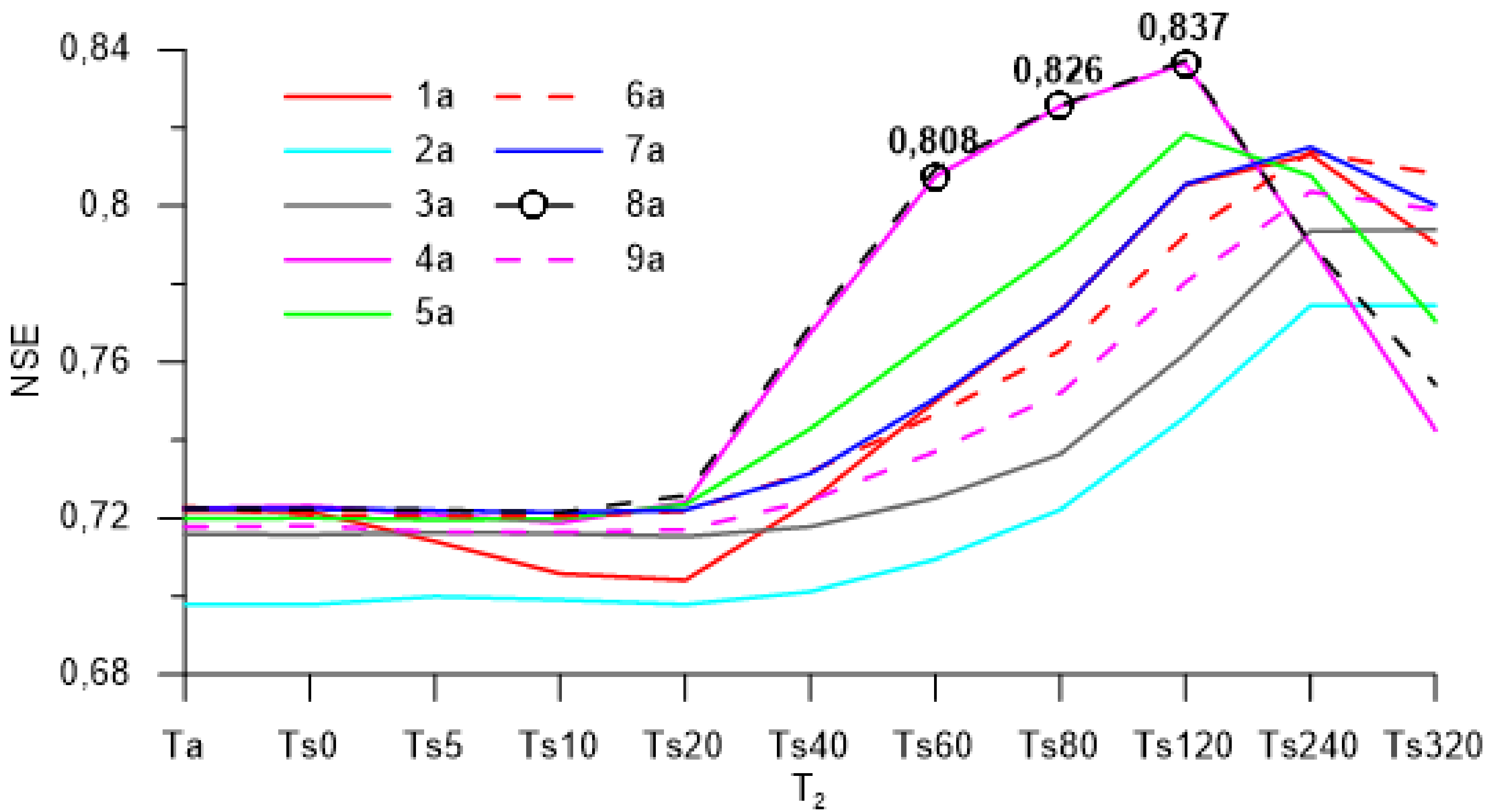
Model modification - Case A

$$k = k_0 + k_1 \cdot T_2$$

Model - 3A

$$SR = r \cdot \exp\left[(k_0 + k_1 \cdot T_2) \cdot T_1\right]$$

Controlling temperature for modification «A»



4-Arrhenius, 8-sigmoid

Model modification – case B

$$k = k_0 + k_1 \cdot T_2$$

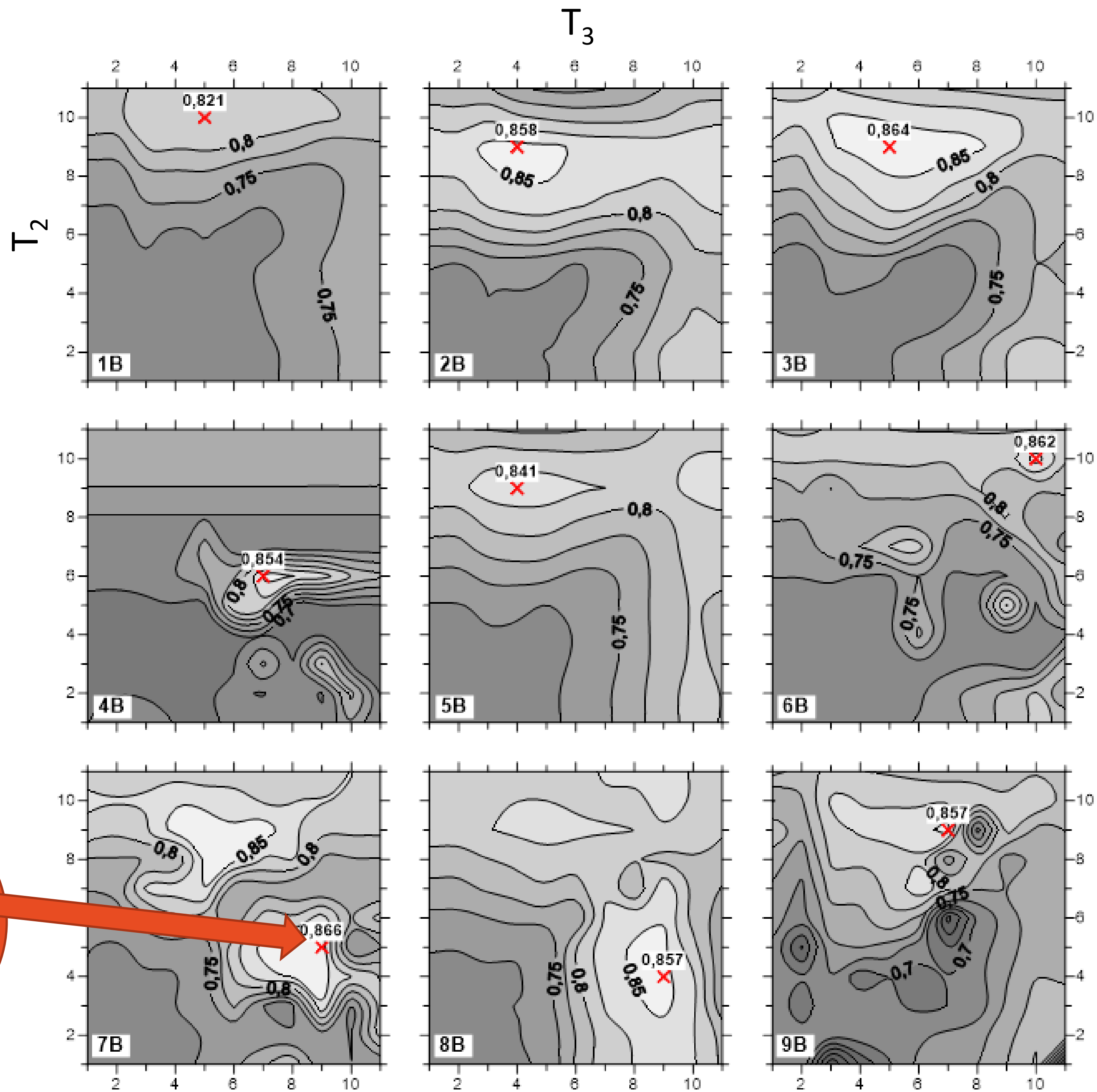
$$r = r_0 + r_1 \cdot T_3$$

Model – 3B

$$SR = (r_0 + r_1 \cdot T_3) \cdot \exp\left[(k_0 + k_1 \cdot T_2) \cdot T_1\right]$$

Controlling temperatures for models «B» - NSE

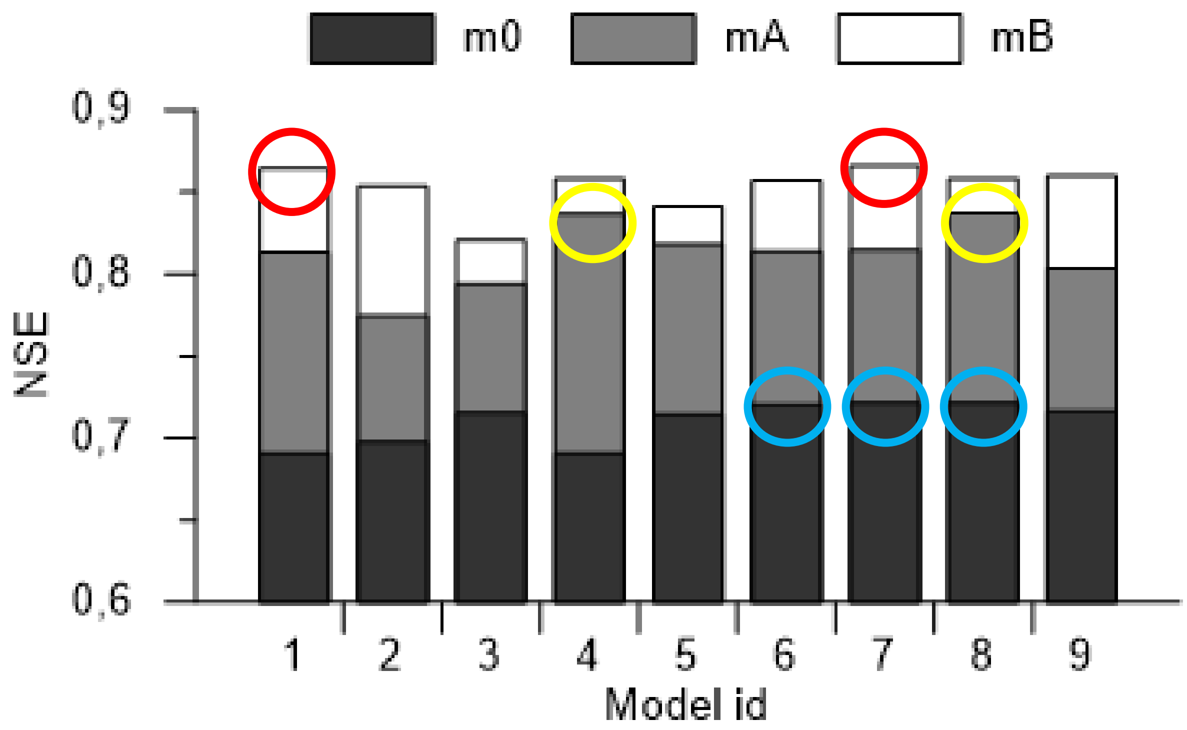
N – depth
1 – Ta
2 - 0
3 - 5
4 - 10
5 - 20
6 - 40
7 - 60
8 - 80
9 - 120
10 - 240
11 - 320



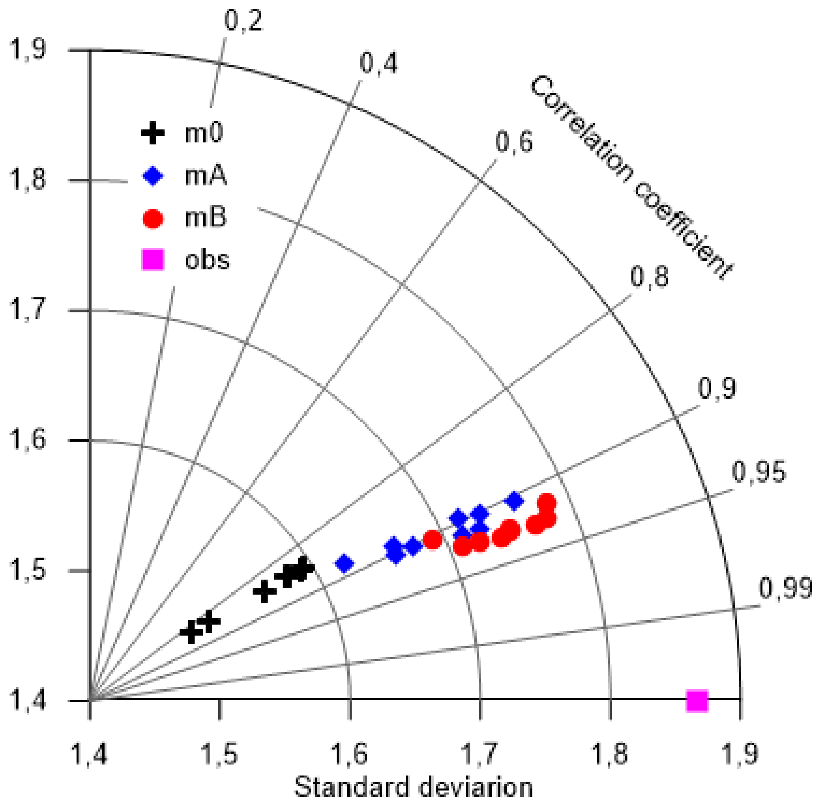
Model 7B
T_1 = Tair
T_2 = T20
T_3 = T120

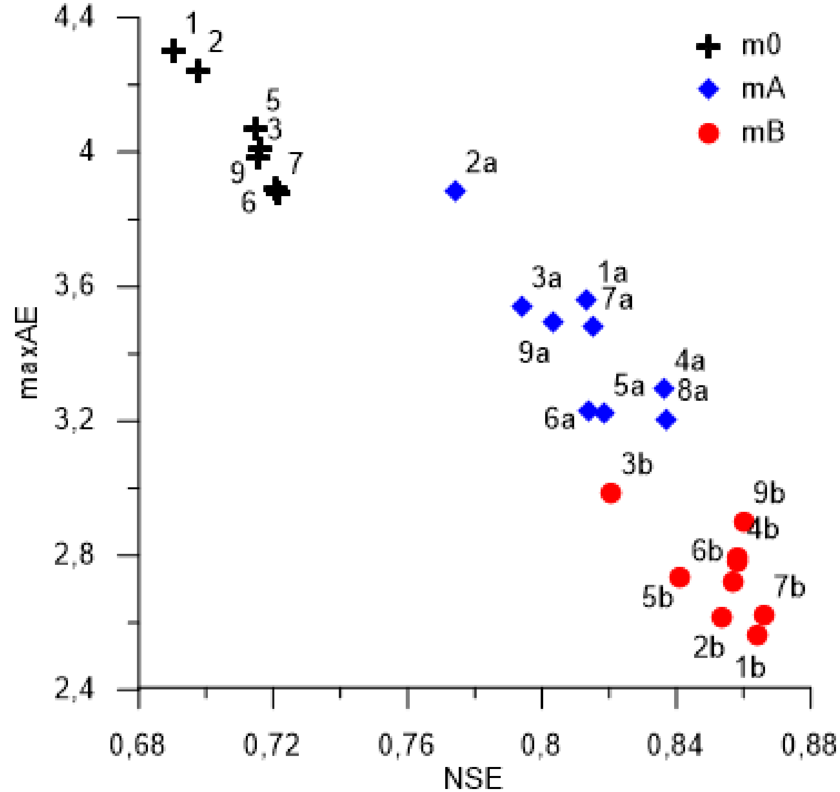
Model performance comparision

- **1. Linear**
- **2. Q10**
- **3. Exponential**
- **4. Arrhenius**
- **5. Lloyd&Taylor**
- **6. Power**
- **7. Logistic**
- **8. Sigmoid**
- **9. Gamma**



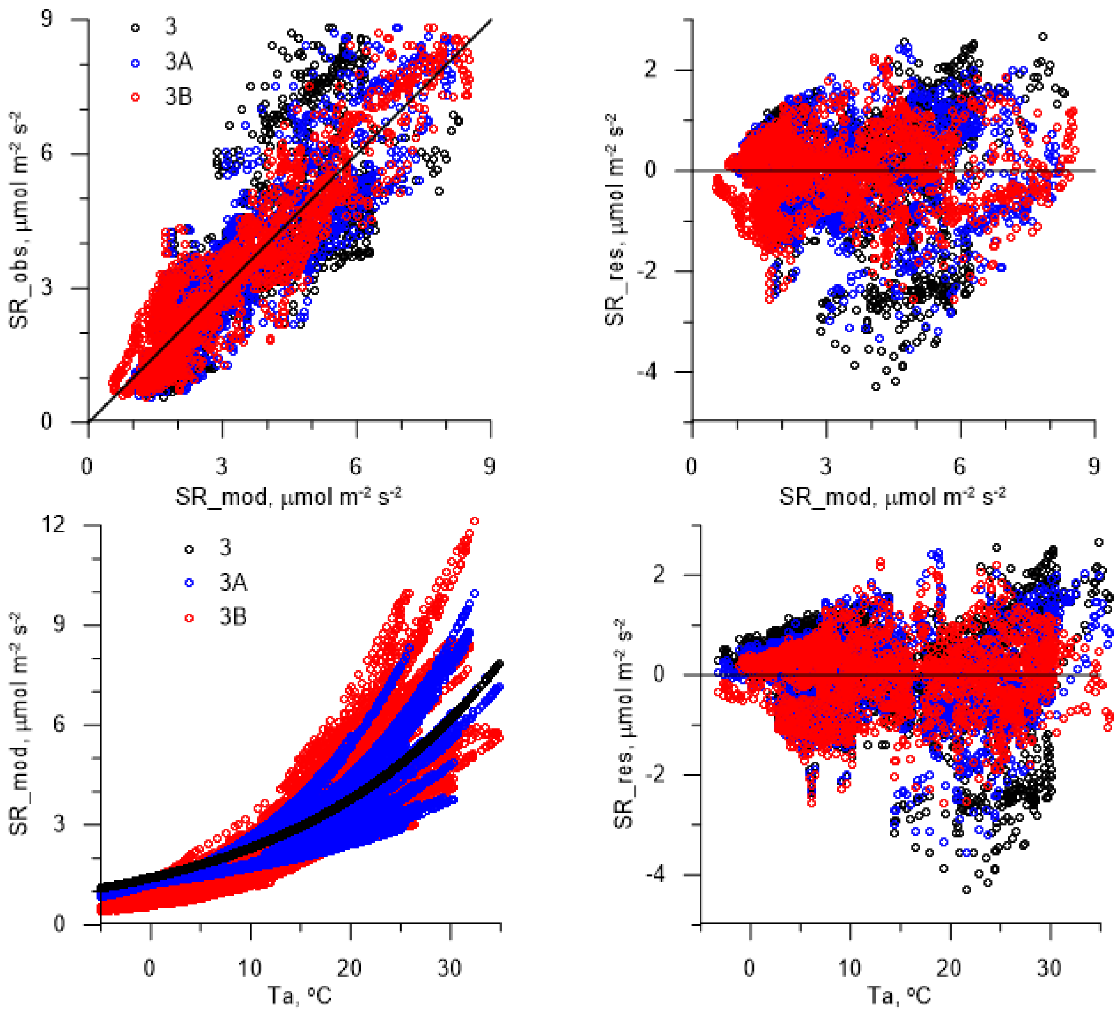
Model performance comparison





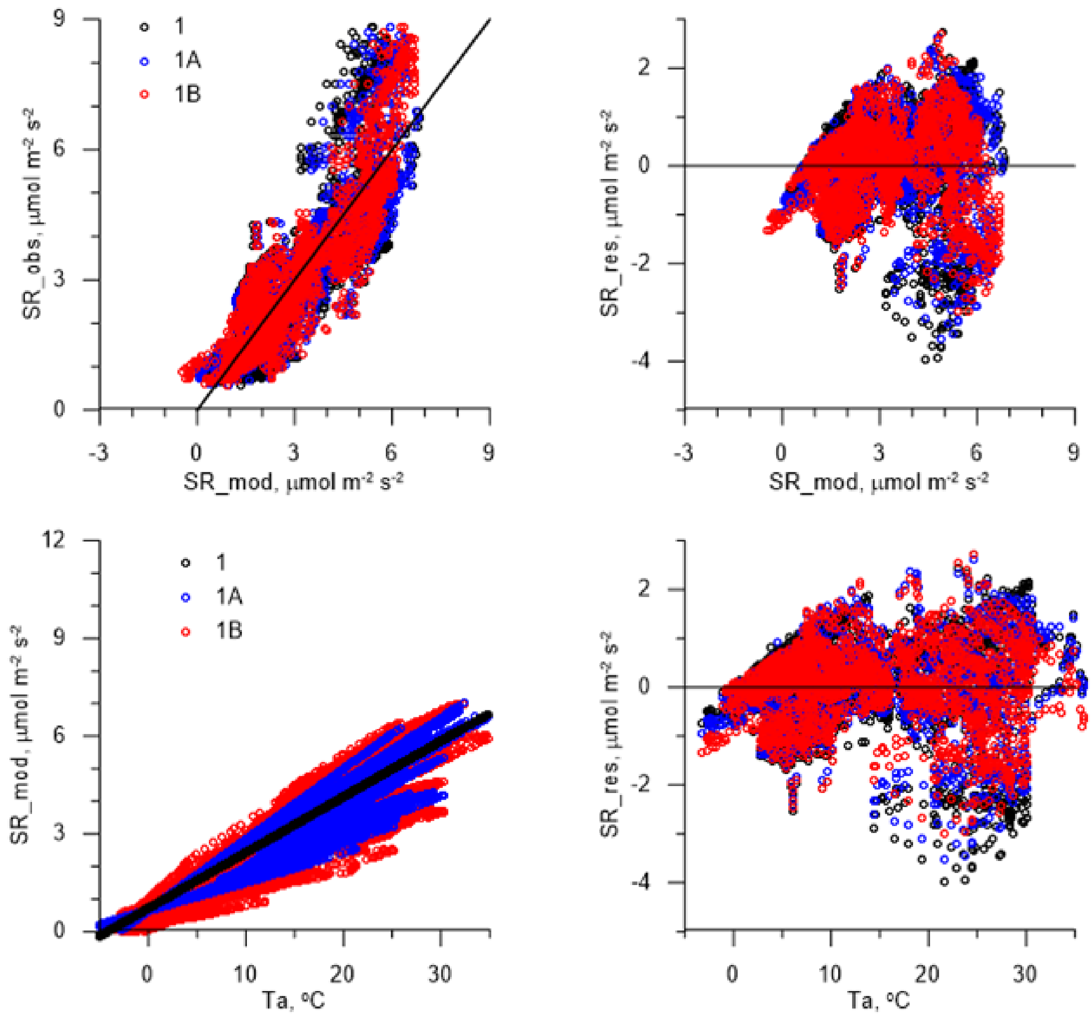
Results – model 3 (exponential)

$$R = r \cdot \exp\left[k \cdot T_1\right]$$



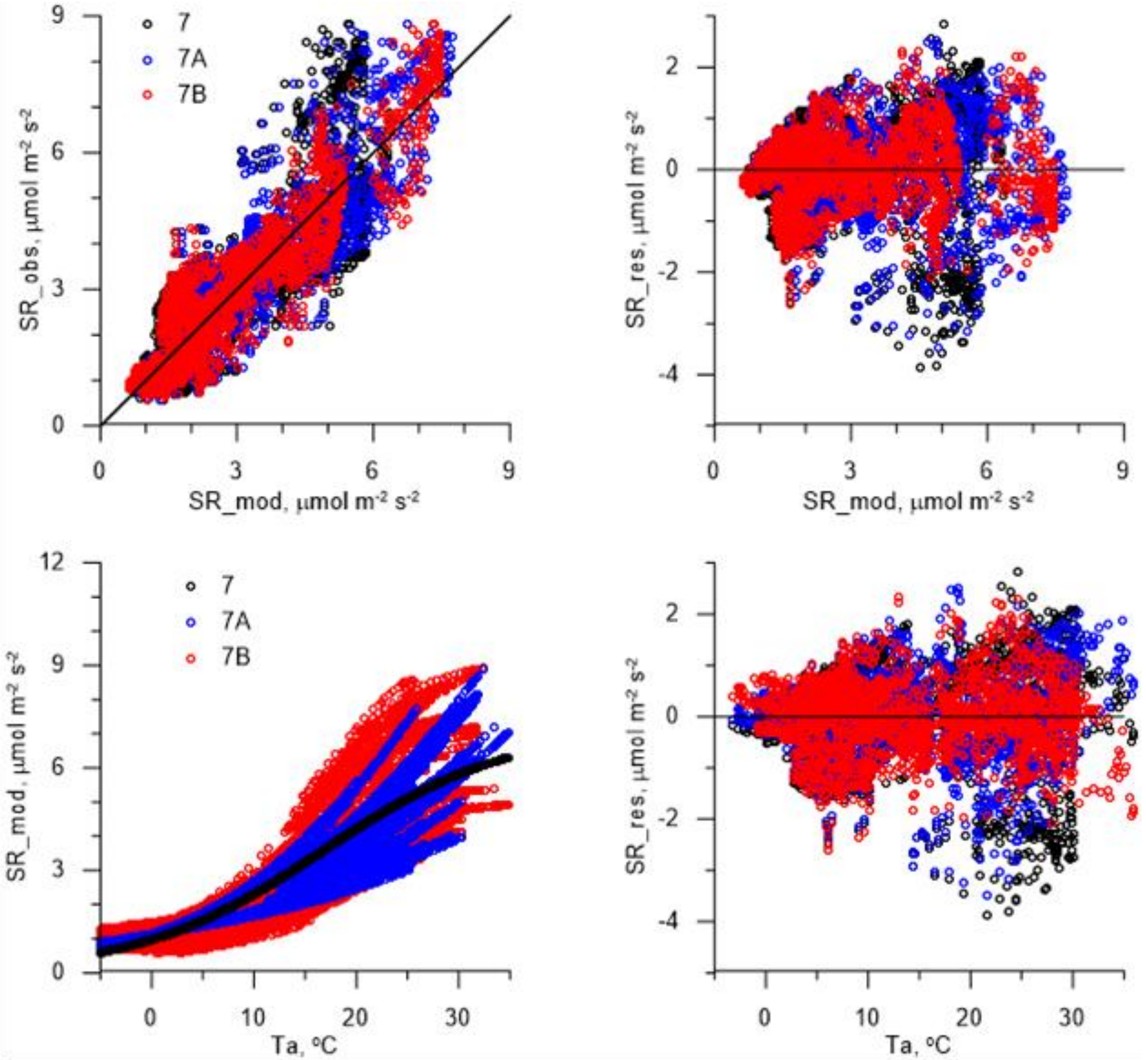
Results – model 1 (linear)

$$R = r + k \cdot T_1$$

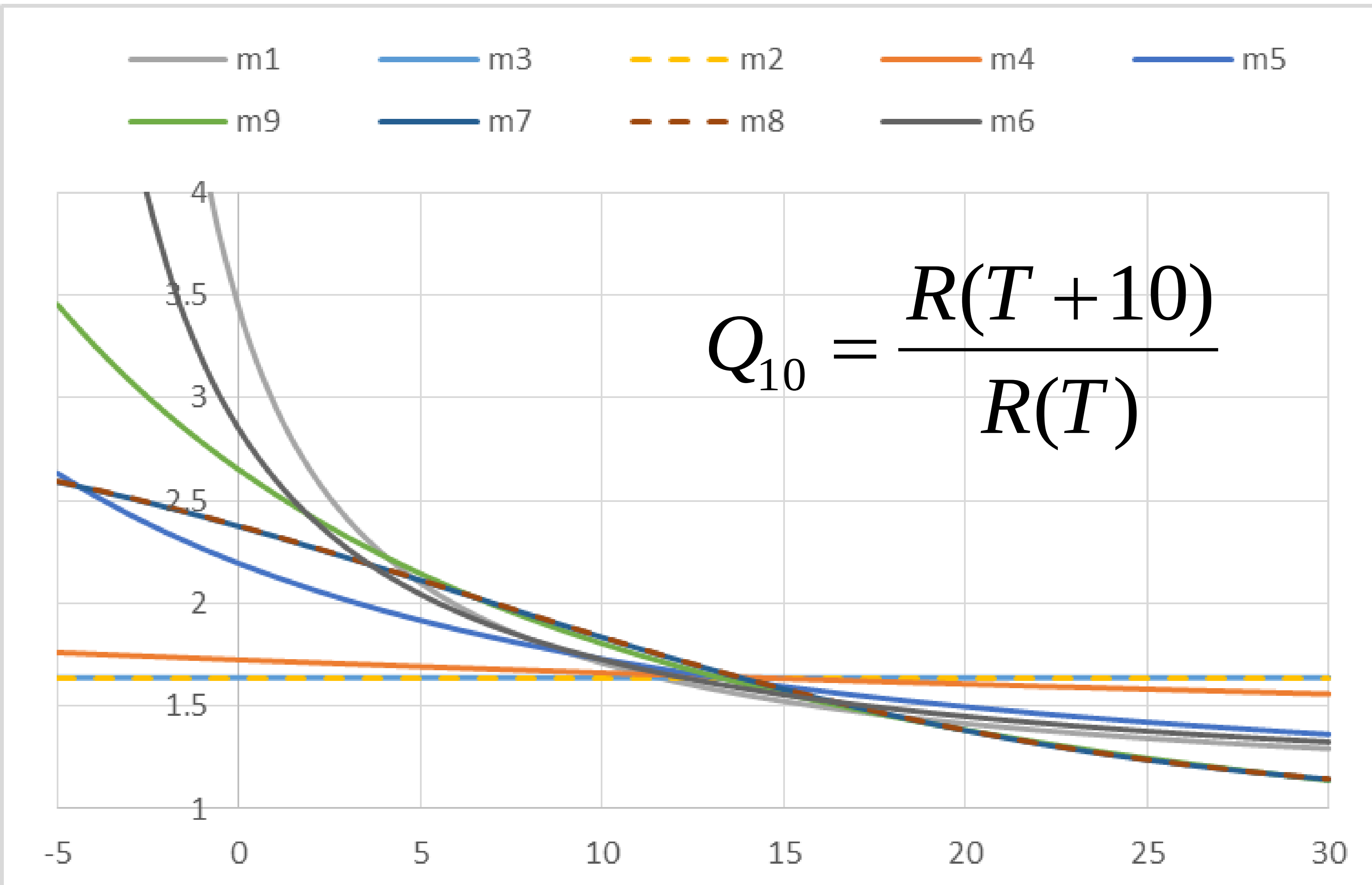


Results – model 7 (logistic)

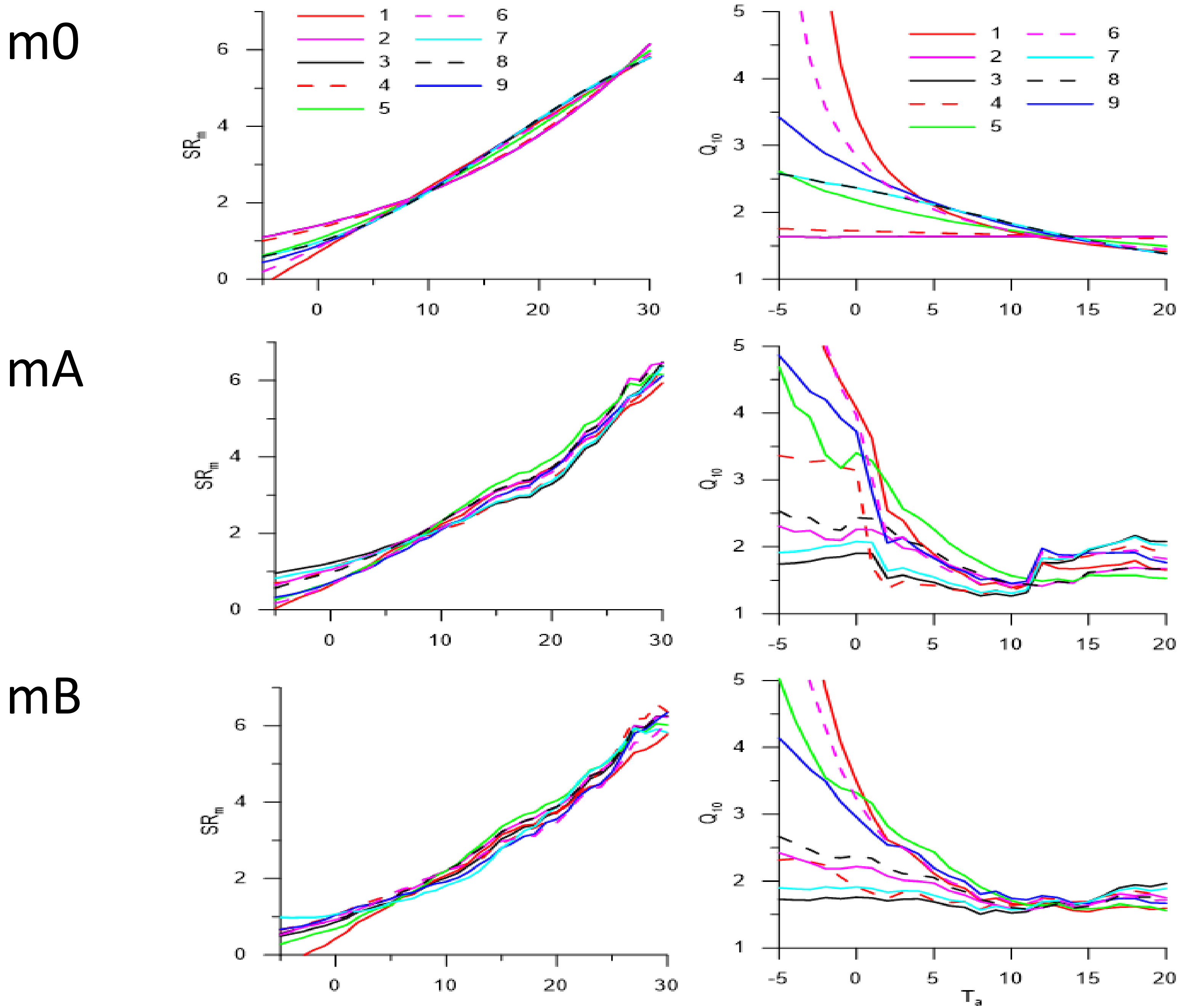
$$R = \frac{r}{1 + p \cdot \exp\left[-k \cdot T_1\right]}$$



Temperature sensitivity coefficient



$$Q_{10} = \frac{R(T+10)}{R(T)}$$


m0
mA
mB
1
2
3
4
5
6
7
8
9
SR$_m$
Q$_{10}$
T$_a$
0
2
4
6
10
20
30
-5
5
15
1
3

The best soil respiration model

$$\mathrm{SR} = \frac{r_0 + r_1 \cdot T_3}{1 + p \cdot exp[-(k_0 + k_1 \cdot T_2) \cdot T_a]}$$

Model 7B
T_1 = Tair
T_2 = T20
T_3 = T120

Спасибо за внимание!