# **S6 Appendix. Properties of the modified Z-function**

Z- functions were designed to regulate a quantity between a minimum, a normal (steady state) and a maximum value in dependence on TPO. In the original form, it reads as follows:

$Z\left(X,y\_{min},y\_{nor},y\_{max},b\_{Y}\right)=y\_{max}-\left(y\_{max}-y\_{min}\right)∙exp\left(-ln\left(\frac{y\_{max}-y\_{min}}{y\_{max}-y\_{nor}}\right)∙X^{b\_{Y}}\right)= $

$ y\_{max}-\left(y\_{max}-y\_{min}\right)∙\left(\frac{y\_{max}-y\_{nor}}{y\_{max}-y\_{min}}\right)^{X^{b\_{Y}}}$, (S.6.3)

where X is the relative TPO concentration. The parameter bY defines the steepness of the Z-function and is therefore called sensitivity parameter. This function is however numerically instable for high values of the sensitivity parameter, which can occur in cases of strong feedbacks. We stabilize our Z-functions in the present paper using a limiting parameter $Lim\_{sig}$ of the steepness of the function. In detail:

$Z\left(X,y\_{min},y\_{nor},y\_{max},b\_{Y},Lim\_{sig}\right)=$

$y\_{max}-\left(y\_{max}-y\_{min}\right)∙exp\left(-ln\left(\frac{y\_{max}-y\_{min}}{y\_{max}-y\_{nor}}\right)∙Trans\_{tanh}\left(X^{b\_{Y}},Lim\_{sig}\right)\right)= $

$ y\_{max}-\left(y\_{max}-y\_{min}\right)∙\left(\frac{y\_{max}-y\_{nor}}{y\_{max}-y\_{min}}\right)^{Trans\_{tanh}\left(X^{b\_{Y}},Lim\_{sig}\right)} $ (S.6.4)

$Trans\_{tanh}\left(X^{b\_{Y}},Lim\_{sig}\right)=exp\left(Lim\_{sig}∙tanh\left(\frac{ln\left(X^{b\_{Y}}\right)}{Lim\_{sig}}\right)\right)=exp\left(Lim\_{sig}∙tanh\left(\frac{b\_{Y}∙ln\left(X\right)}{Lim\_{sig}}\right)\right)$. (S.6.5)

The hyperbolic tangent transformation $Trans\_{tanh}$ of *Xby* is an approximation of *Xby* for small parameters *bY* and values of X close to 1 (see S.6.6), but is limited by exp(*Limsig*) for large values of X. Since the parameter $Lim\_{sig}$ was poorly identifiable, we fixed it to 7.

$\begin{matrix}\begin{matrix}\frac{dTrans\_{tanh}\left(Y,Lim\_{sig}\right)}{dY}= \\= Lim\_{sig}∙exp\left(Lim\_{sig}∙tanh\left(\frac{ln\left(Y\right)}{Lim\_{sig}}\right)\right)∙\frac{1}{Lim\_{sig}∙Y∙cosh\left(\frac{ln\left(Y\right)}{Lim\_{sig}}\right)^{2}}=\end{matrix}\\=exp\left(Lim\_{sig}∙tanh\left(\frac{ln\left(Y\right)}{Lim\_{sig}}\right)\right)∙\frac{1}{Y∙cosh\left(\frac{ln\left(Y\right)}{Lim\_{sig}}\right)^{2}} \\\left.\frac{dTrans\_{tanh}\left(Y,Lim\_{sig}\right)}{dY}\right|\_{Y=1}=1 \end{matrix} $. (S.6.6)

Fig 1 shows comparisons of original and modified Z-function for three settings of the sensitivity parameter *bY*. Parameters *ymin, ynor* and *ymax* are set to 0, 1, 10, respectively. A difference between former and novel Z-function can only be detected for large values of the regulation function. Modified Z-functions with very high by can be considered as smoothed step functions in a neighborhood of the steady state of TPO.

As can be seen from the formula (S.6.4), the modified Z-function has a smaller range compared to the original Z-function. However, due to our setting of the parameter *Limsig*, the difference is without practical relevance.

Fig 1: Comparison of original and modified Z-function. Relative TPO is between 0 and 5. Sensitivity parameter b takes values 1, 3 and 6, respectively. *ymin, ynor* and *ymax* are set to 0, 1, 10, respectively. The functions start to be different near the upper limit of their range.

