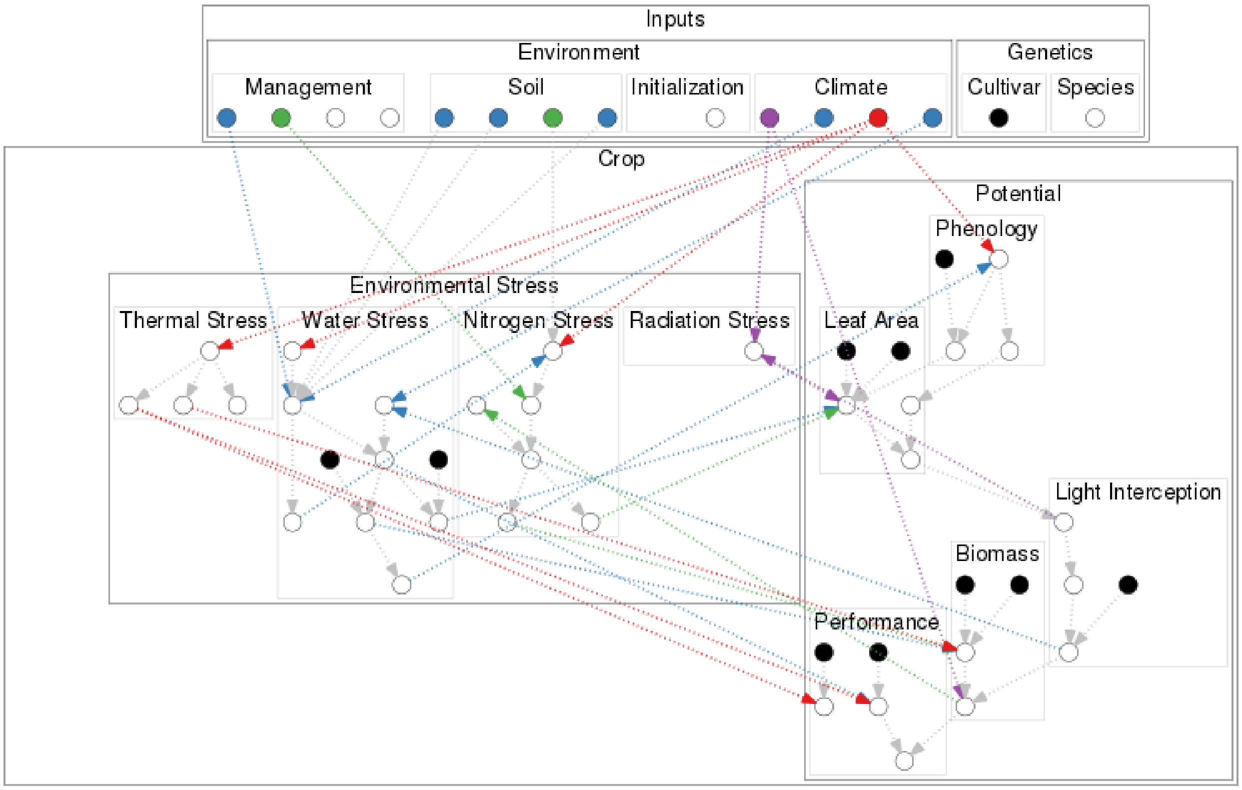
Documentation for the SUNFLO crop model

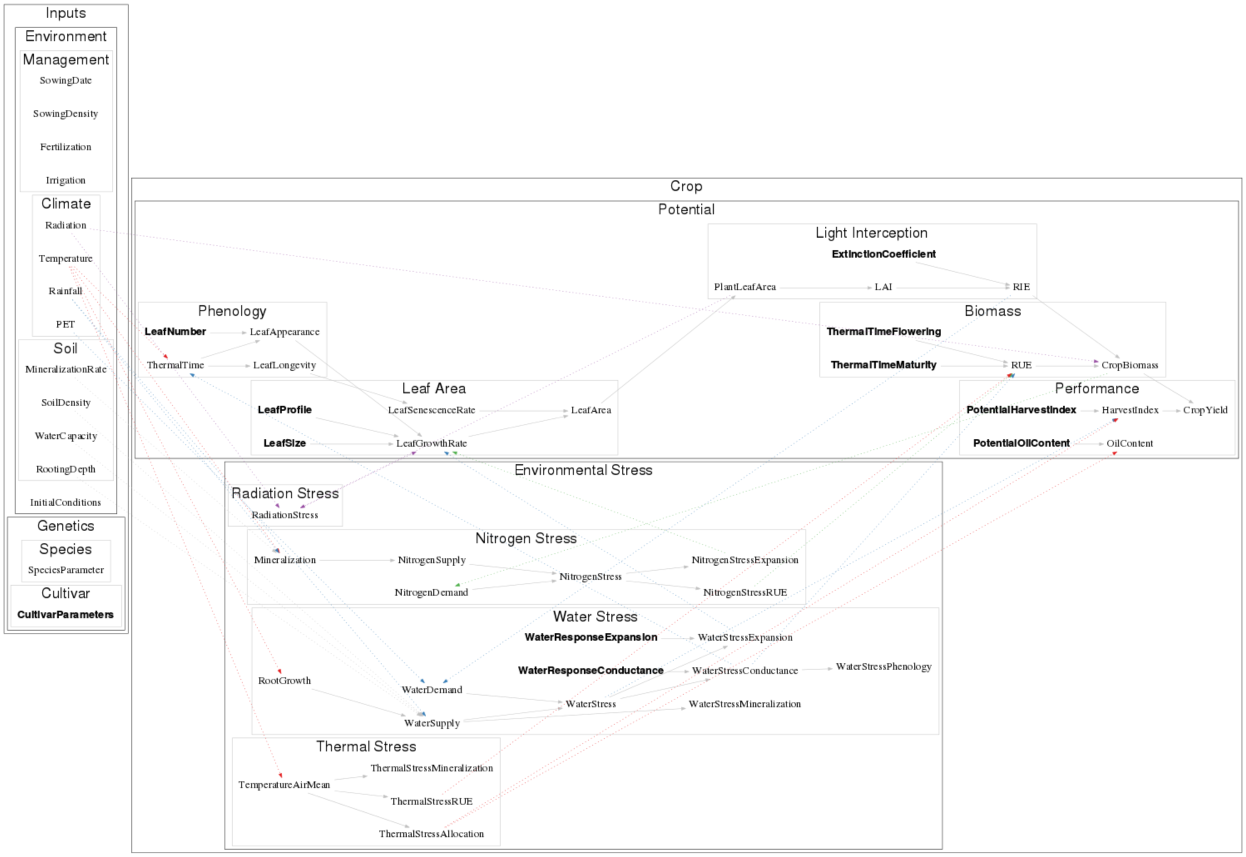
Contents

Model structure

Modules



Variables



Inputs

Environment

Climate

label	description	unit
TemperatureAirMin	Minimum air temperature	°C
TemperatureAirMax	Maximum air temperature	°C
Radiation	Global incident radiation	MJ.m-2
PET	Reference evapotranspiration	mm
Rainfall	Rainfall	mm

Soil

Management

Genetics

Species

Cultivar

Crop potential growth

Phenology

Inputs

label	description	value	unit	reference
ThermalTimeVegetative	Temperature sum to floral initiation	482	°Cd	(J. Lecoeur et al. 2011)
ThermalTimeFlowering	Temperature sum from emergence to the beginning of flowering	836	°Cd	(J. Lecoeur et al. 2011)
ThermalTimeSenescence	Temperature sum from emergence to the beginning of grain filling	1083	°Cd	(J. Lecoeur et al. 2011)
ThermalTimeMaturity	Temperature sum from emergence to seed physiological maturity	1673	°Cd	(J. Lecoeur et al. 2011)
SowingDepth	Sowing depth	30	mm	
Germination	Temperature sum from sowing to germination	86.2	°Cd	(Villalobos et al. 1996)
ElongationRate	Reciprocal of hypocotyl elongation rate	1.19	°Cd/mm	(Villalobos et al. 1996)

Emergence

$$Emergence = Germination + ElongationRate \cdot SowingDepth$$

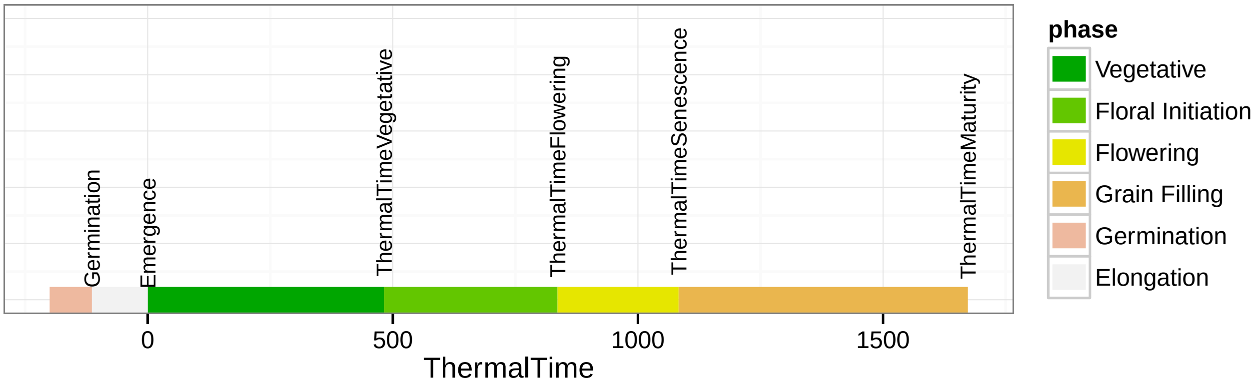
with : $Germination = 86$, Thermal time for germination (°C.d) (Casadebaig et al. 2011) ; $ElongationRate = 1.19$, Hypocotyl elongation rate (°Cd/mm) (Villalobos et al. 1996) ; $SowingDepth = 30$, Sowing depth (mm).

ThermalTime

$$ThermalTime_d = \begin{cases} \int_0^d (T_m - T_b) \cdot (1 + WaterStressPhenology) \cdot dt & \text{if } T_m > T_b \\ 0 & \text{else} \end{cases}$$

with : T_m, Daily mean air temperature (°C); $T_b = 4.8$, Basal temperature (°C) see (Granier and Tardieu 1998); $ThermalStressPhenology$ Water stress effect on plant heating

PhenoStages



LeafAppearance

LeafLongevity

Leaf Area

LeafProfile

LeafGrowthRate, LeafSenescenceRate, LeafArea

Light interception

LAI

RIE

Biomass production

RUE

CropBiomass (Monteith 1977)

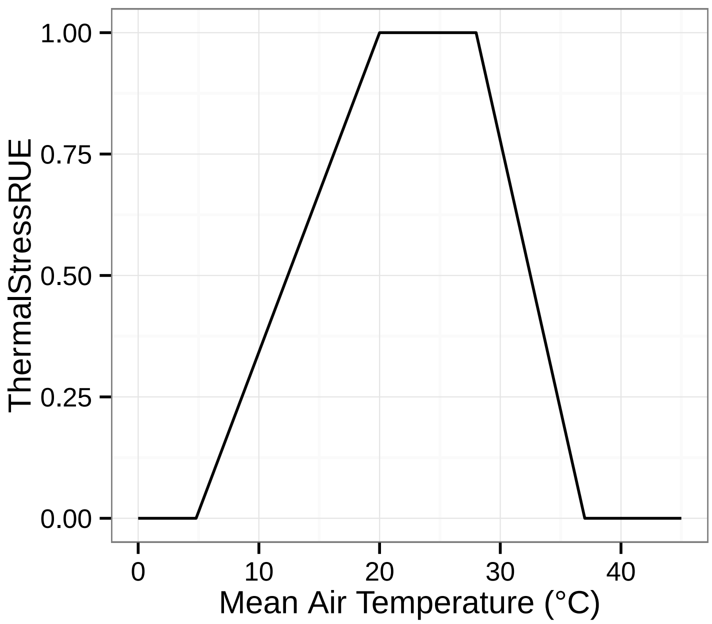
$$dCropBiomass = 0.48 \cdot Radiation \cdot RIE \cdot RUE \cdot dt$$

Crop performance

Environmental factors limiting crop production

Thermal stress

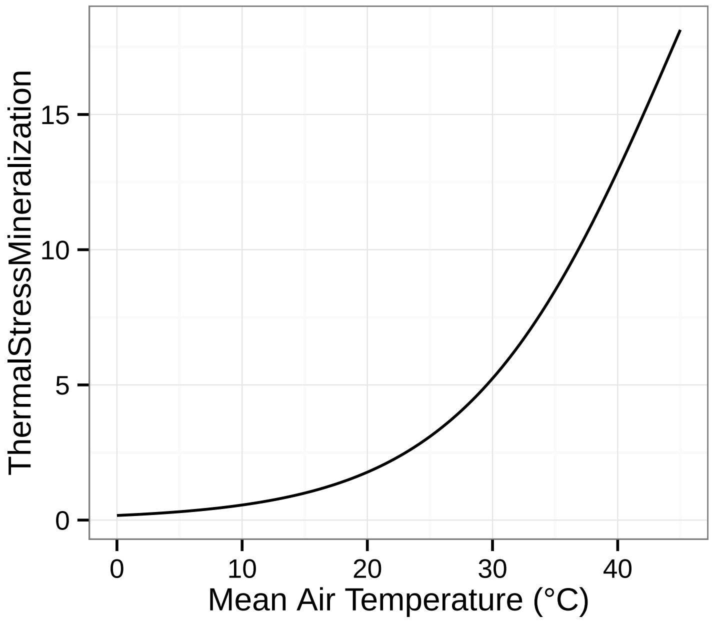
ThermalStressRUE (Villalobos et al. 1996)



$$ThermalStressRUE = \begin{cases} T_m \cdot \frac{1}{T_{ol} - T_b} - \frac{T_b}{T_{ol} - T_b} & \text{if } T_b < T_m < T_{ol} \\ 1 & \text{if } T_{ol} < T_m < T_{ou} \\ T_m \cdot \frac{1}{T_{ou} - tc} - \frac{tc}{T_{ou} - tc} & \text{if } T_{ou} < T_m < tc \\ 0 & \text{else} \end{cases}$$

with $T_b = 4.8$, base temperature (°C); $T_{ol} = 20$, optimal lower temperature (°C); $T_{ou} = 28$, optimal upper temperature (°C); $T_c = 37$, critical temperature (°C)

ThermalStressMineralization (Valé, Mary, and Justes 2007)



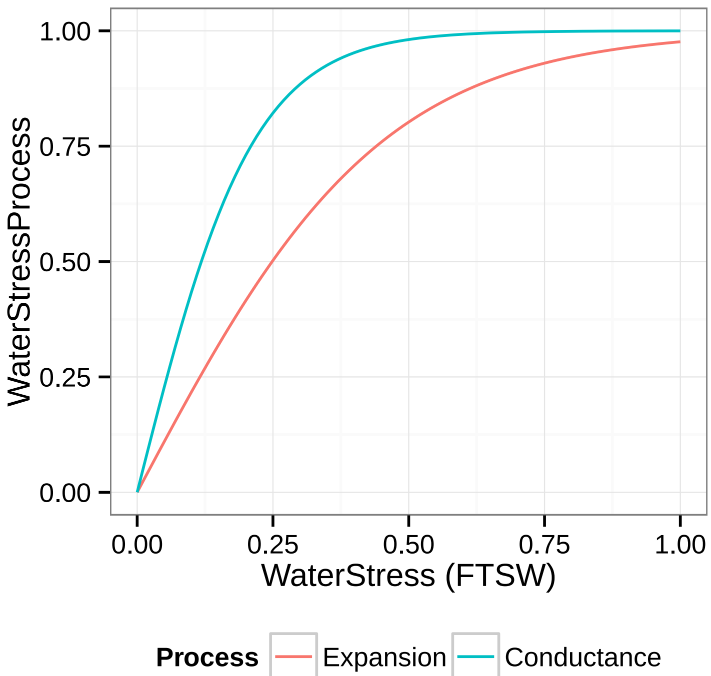
$$ThermalStressMineralization = \frac{T_c}{1 + (T_c - 1) \cdot exp^{(-0.119 \cdot (T_m - T_b))}}$$

with $T_b = 15$, base temperature (°C); $T_c = 36$, critical temperature (°C)

ThermalStressAllocation

Water stress

WaterStressExpansion, WaterStressConductance



$$WaterStressProcess = -1 + \frac{2}{1 + exp^{(a \cdot WaterStress)}}$$

with $a \in [-15.6; -2.3]$, genotype-dependant response parameter

WaterStressPhenology

$$WaterStressPhenology = a \cdot (1 - WaterStressConductance)$$

with $a = 0.1$, scaling parameter for water-stress plant heating

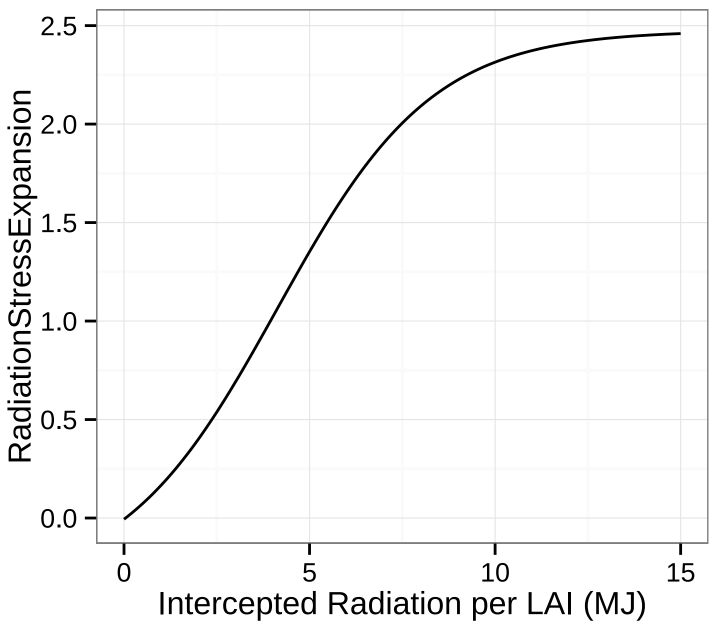
WaterStressMineralization

$$WaterStressMineralization = 1 - (1 - y_0) \cdot (1 - RelativeWaterContent_{layer1})$$

Nitrogen stress

Radiation stress

RadiationStressExpansion (Rey 2003)



$$RadiationStressExpansion = s \cdot a + \frac{b}{1 + exp^{(\frac{c - IPAR/LAI}{d})}}$$

with $s = 2.5$, scaling parameter for density effect; $a = -0.14$; $b = 1.13$; $c = 4.13$; $d = 2.09$

References

Casadebaig, Pierre, Lydie Guilioni, Jeremie Lecoeur, Angélique Christophe, Luc Champolivier, and Philippe Debaeke. 2011. "SUNFLO, a Model to Simulate Genotype-Specific Performance of the Sunflower Crop in Contrasting Environments." *Agricultural and Forest Meteorology* 151: 163–178. doi:10.1016/j.agrformet.2010.09.012.

Granier, C., and F. Tardieu. 1998. "Is Thermal Time Adequate for Expressing the Effects of Temperature on Sunflower Leaf Development?" *Plant, Cell & Environment* 21 (7): 695–703.

Lecoeur, Jérémie, Richard Poiré-Lassus, Angélique Christophe, Benoit Pallas, Pierre Casadebaig, Philippe Debaeke, Felicity Vear, and Lydie Guilioni. 2011. "Quantifying Physiological Determinants of Genetic Variation for Yield Potential in Sunflower. SUNFLO: a Model-Based Analysis." *Functional Plant Biology* 38 (3): 246–259. doi:10.1071/fp09189.

Monteith, J. L. 1977. "Climate and the Efficiency of Crop Production in Britain." *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 281 (November): 277–294.

Rey, Hervé. 2003. "Utilisation de La Modélisation 3D Pour L'analyse Et La Simulation Du Développement Et de La Croissance Végétative d'une Plante de Tournesol En Conditions Environnementales Fluctuantes (Température Et Rayonnement)." PhD thesis, Ecole Nationale Supérieure Agronomique de Montpellier, spécialité sciences agronomiques, CIRAD-AMAP / INRA - LEPSE.

Valé, M., B. Mary, and E. Justes. 2007. “Irrigation Practices May Affect Denitrification More Than Nitrogen Mineralization in Warm Climatic Conditions.” *Biology and Fertility of Soils* 43 (6): 641–651.

Villalobos, F.J., A.J. Hall, J.T. Ritchie, and F. Orgaz. 1996. “OILCROP-SUN: a Development, Growth and Yield Model of the Sunflower Crop.” *Agronomy Journal* 88: 403–415.