A software component for simulation of the impacts of weather extremes on agricultural production

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10/09/2015

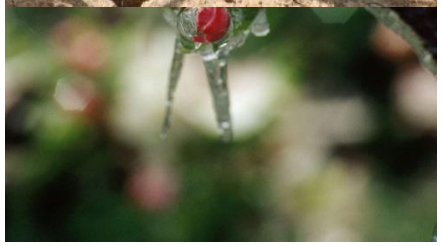
Outline

- **Why** a software component for extreme events?
- **The modelling approaches** for estimating the impact of extremes and…
- **…their implementation** according to the BioMA component-based architecture
- **The software component** *MODEXTREME*

Extreme events

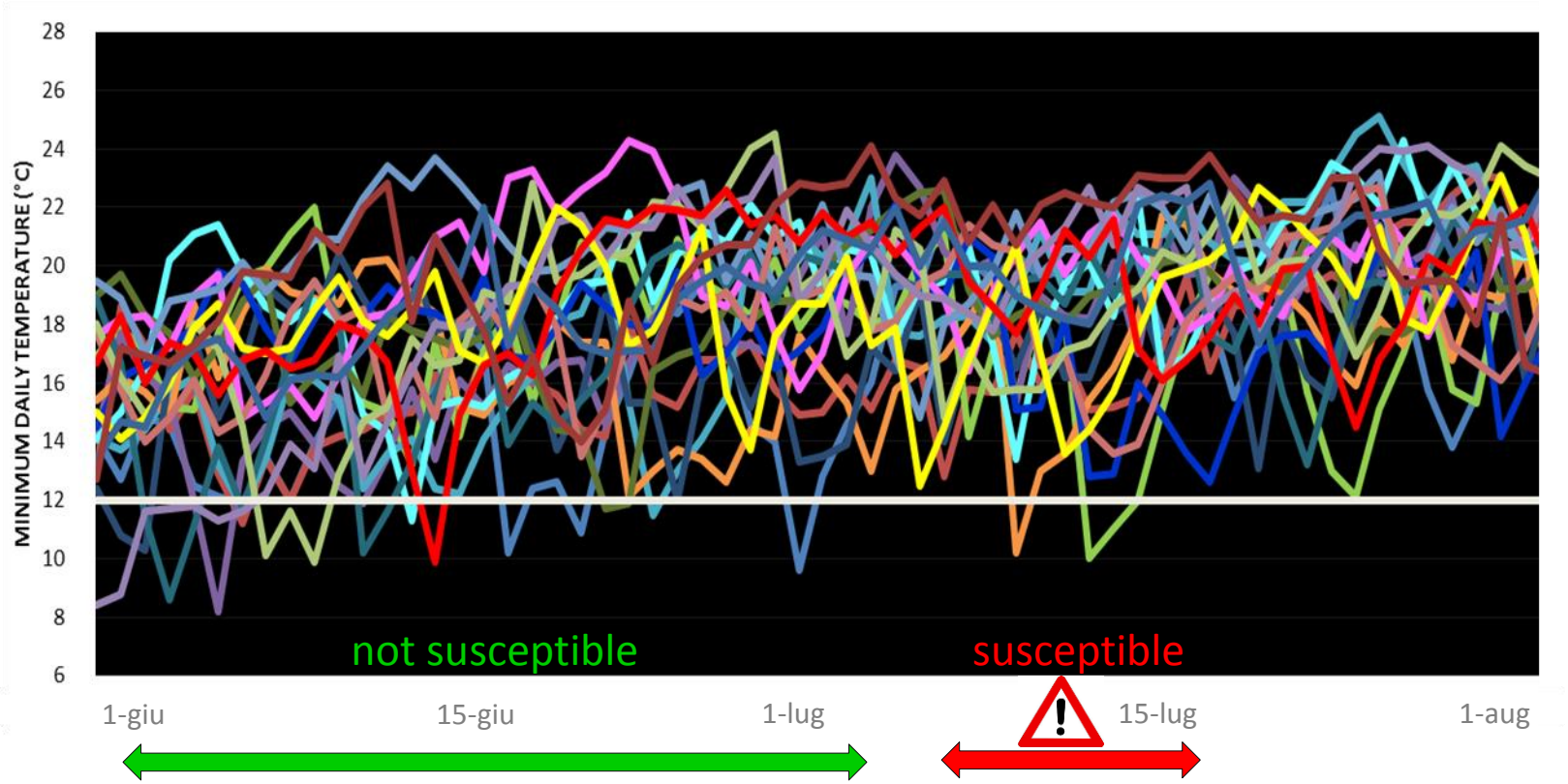
«Environmental variables assuming values – or evolving with dynamics – for which a crop is not prepared to cope with»

- **the crop is exposed** (e.g., hailstorm, severe drought)
- **the crop is going through a specific (susceptible) moment of its cycle** (e.g., cold temperatures during reproductive phase)



Extreme events

- Minimum daily temperature from 1991 to 2010 (Northern Italy)



Modelling abiotic stress

- Modelling approaches for estimating the impact of abiotic stress are available but:
  - **No systematic implementation**

MAIZE

Model	*Stress involved* [a]	*Type of water stress* [b]	*Type of heat stress* [c]
APSIM-maize	W, A, H	S	V
CropSyst	W, H, O	E	V, R
DSSAT-CERES maize	W, A	E	-
InfoCrop	W, H	E	V, R
LPJml	W	E	-
EPIC maize	W, O	E, S	
MONICA	W, A, H	E, S	V
STICS	W, H	S	V, R
WOFOST	W, A	S	V

[a] **Stress involved:** W=water stress; A=oxygen stress; H=heat stress; O=others (e.g., CropSyst model: salinity; EPIC model: soil strength, soil acidity, salinity)

[b] **Type of water stress:** E= Eta / Etp; S= soil available water in the root zone

[c] **Type of heat stress:** V= vegetative (source); R= reproductive organs (sink)

From Bassu et al. (2014) Global Change Biology doi: 10.1111/gcb.12520

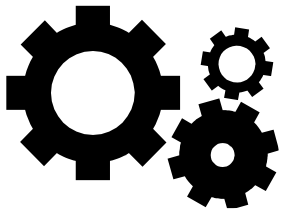
  - **Higher level of empiricism**

Objective

- **Development of a dedicated software component** which:
  - **extends** the simulation capabilities of alternative crop models for plant response to weather extremes
  - **implements a library of impact models** for the simulation of extreme weather events

Requirements

- **Fine granularity of implementation**, to allow extension, composition and comparison of alternative modelling solutions
- **Generic**, to be easily linked to different crop models
- **Framework indipendent**, to work properly in any platform
- **Control tools provided**, to verify simulation correctness and quality of I/O

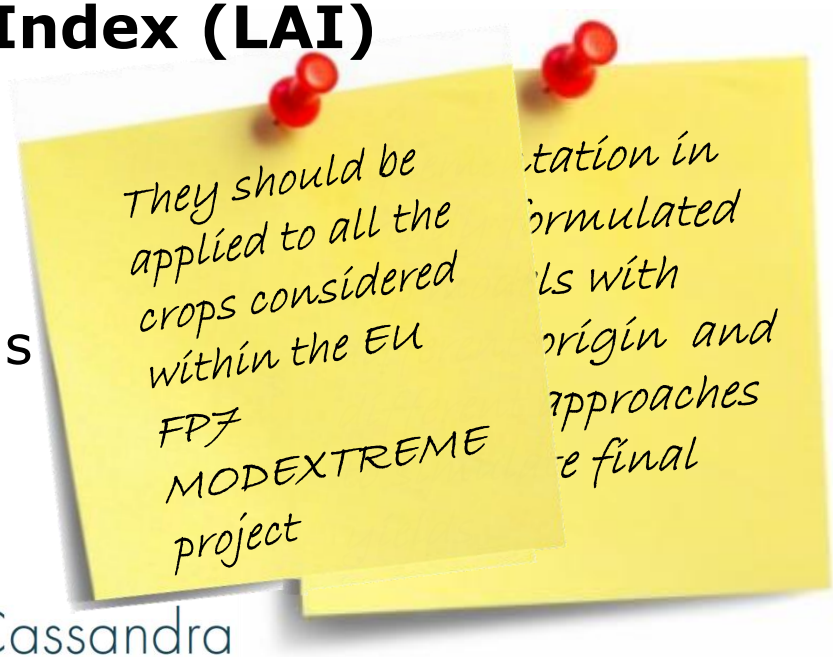


The software architecture of the **BioMA framework**

BioMA
Biophysical Model Applications

The implemented modelling approaches

- Conceptual models of yield reduction as a consequence of extreme weather events (**heat stress, frost stress, water stress**)
- Yield variations due to extremes are represented via a change in **Harvest Index (HI)** or mediated by a reduction of **Leaf Area Index (LAI)**
- **Criteria**:
  - Usability (MARS: yield forecast at EU level)
  - Generic (for both models and crops)



Categories of processes

- The models currently implemented refers to **four categories of process**:

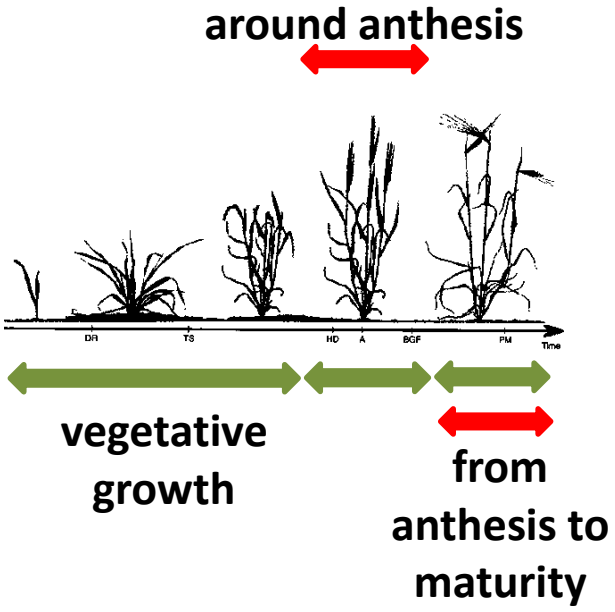
$0 \leq F_{(stress)} \leq 1$

$F_{(stress)}$ Water stress

$F_{(stress)}$ Heat stress

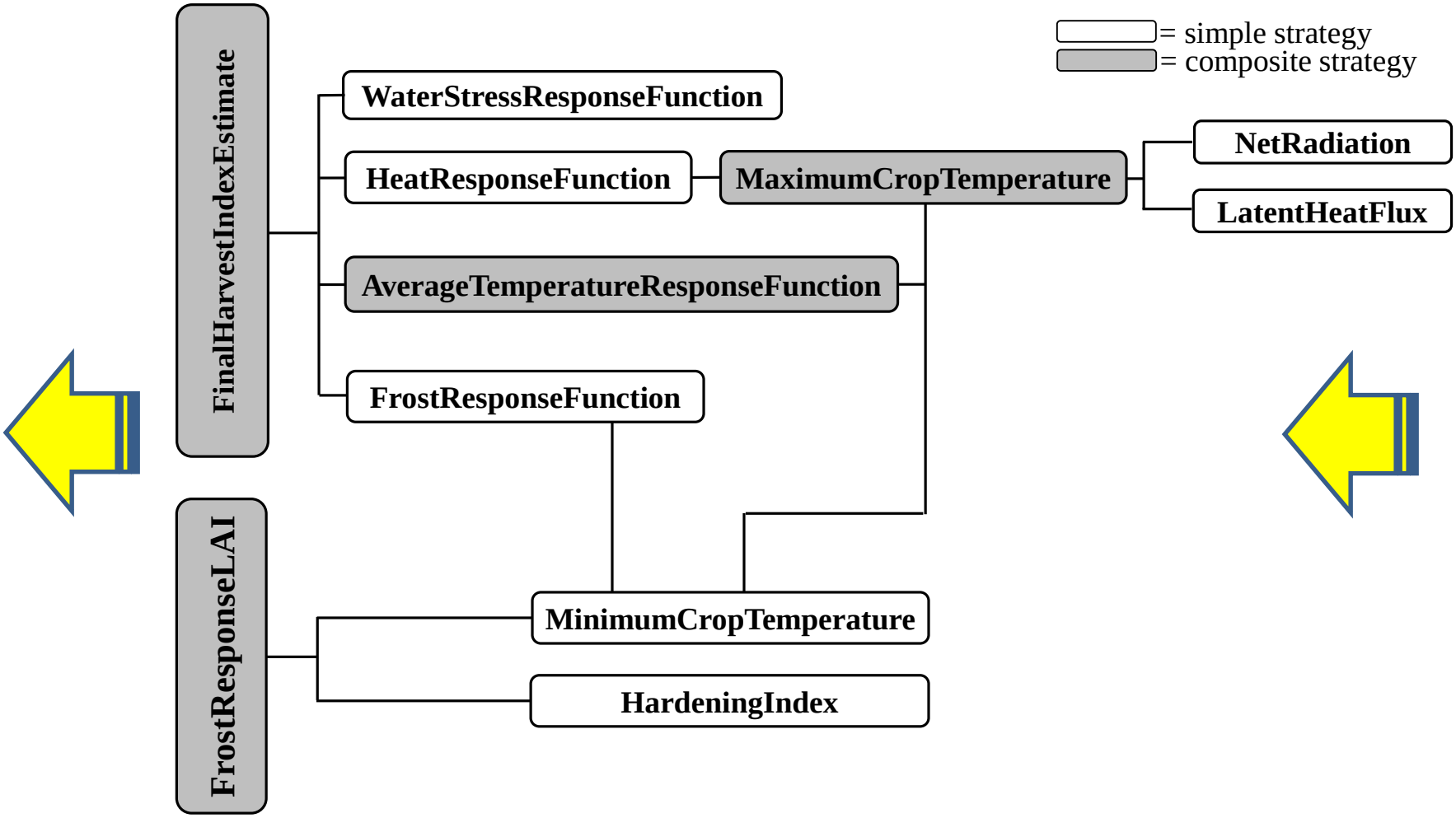
$F_{(stress)}$ Frost damage

$F_{(stress)}$ Mean temperature response



Daily time-step

Model implementation diagram



Model implementation

- For each model, **identify**:
  - **Input** variables (to run the model)
  - **Output** variables (to store the model results)
  - **Parameters** (defined by the user)
  - **Constants** (hardcoded)

HeatResponseFunction F_H =

$$F_H = \begin{cases} 1 & T_c \geq T_{100} \\ \dfrac{(T_{100}-T_c)}{(T_{100}-T_O)} & T_O \leq T_c \leq T_{100} \\ 0 & T_c \leq T_O \end{cases}$$

T_{100} = critical temperature (100%damage)

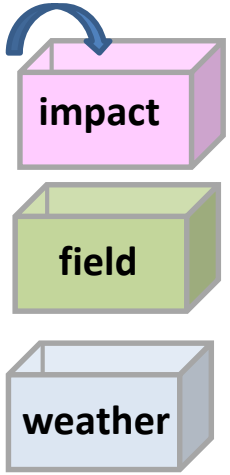
T_0 = threshold temperature (0%damage)

T_c = crop temperature

Model implementation

- Create the **Domain Classes**, to dispose of I/O variables (tool: **D**omain **C**lass **C**oder, **DCC**)

	Name	Min Value	Max Value	Default Value	Units	Type	Description	Domain class
F_H	**HeatResponse Function**	0	1	0.5	unitless	double	Response function to heat stress	**IMPACT**
T_{crop}	**MaximumCrop Temperature**	-10	50	25	°C	double	Maximum crop temperature	**FIELD**
	Daily Maximum Air Temperature	-10	50	20	°C	double	Maximum daily air temperature (at 2m)	**WEATHER**
	NetRadiation	0	1000	500	W/m^2	double	Net solar radiation	**WEATHER**
	LatentHeat Flux	0	1000	500	W/m^2	double	Flux of latent heat	**WEATHER**
	AirDensity	0	2	1.2	Kg/m^3	double	Air density	**WEATHER**

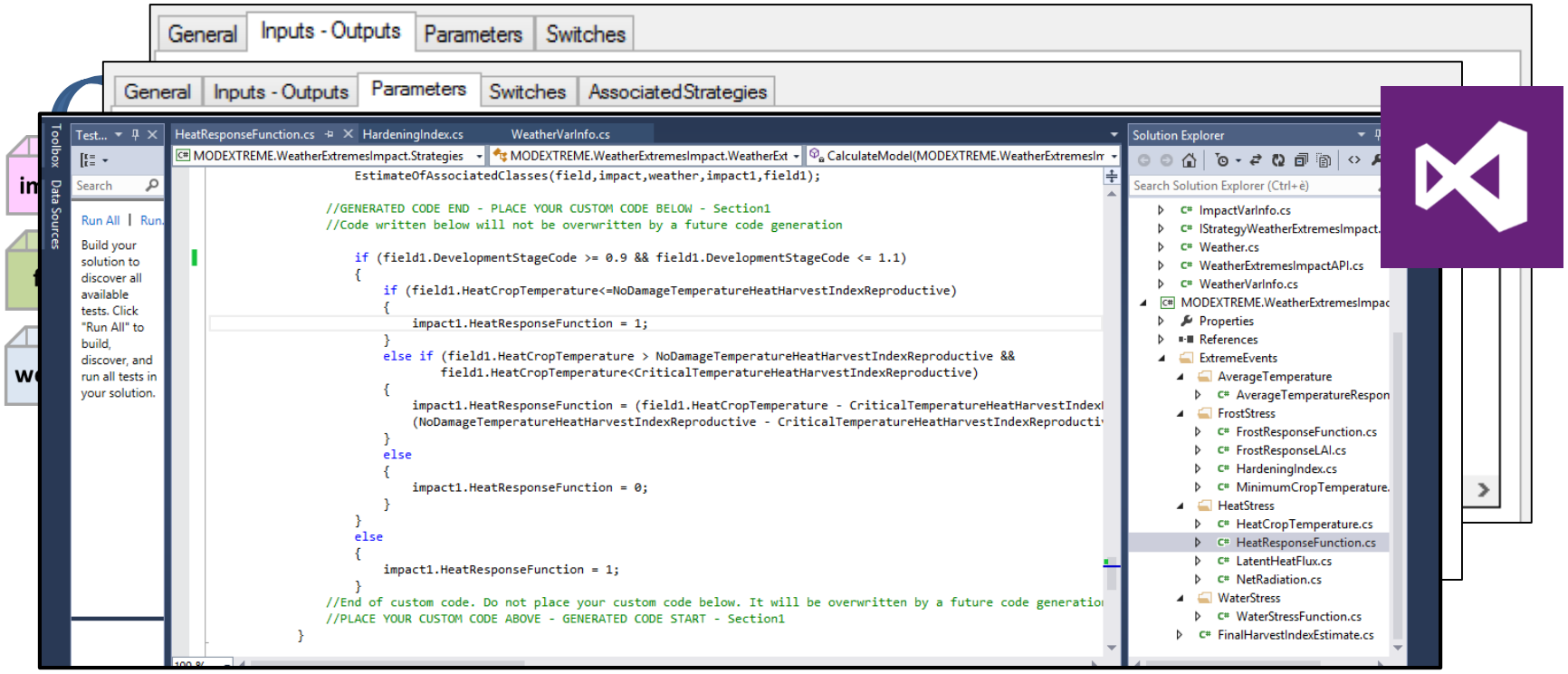


Model implementation

- Develop the **model assembly**

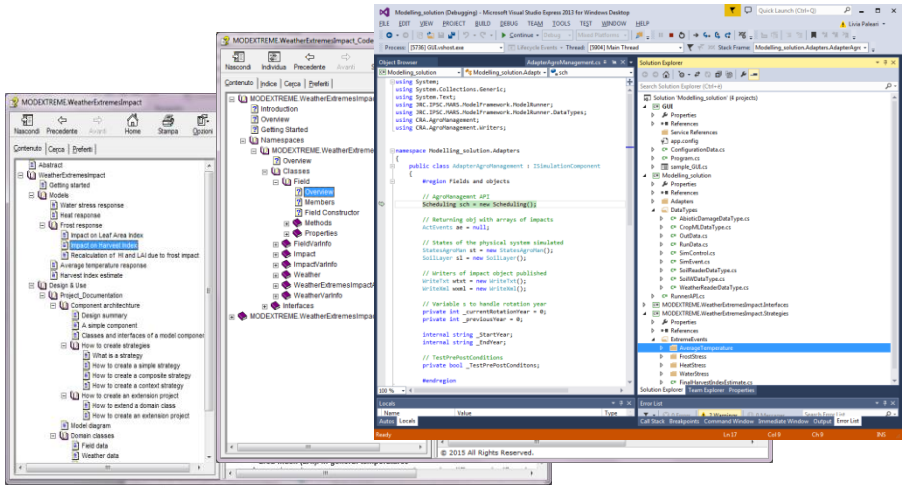
  (tool: **S**trategy **C**lass **C**oder, **SCC**)

HeatResponseFunction

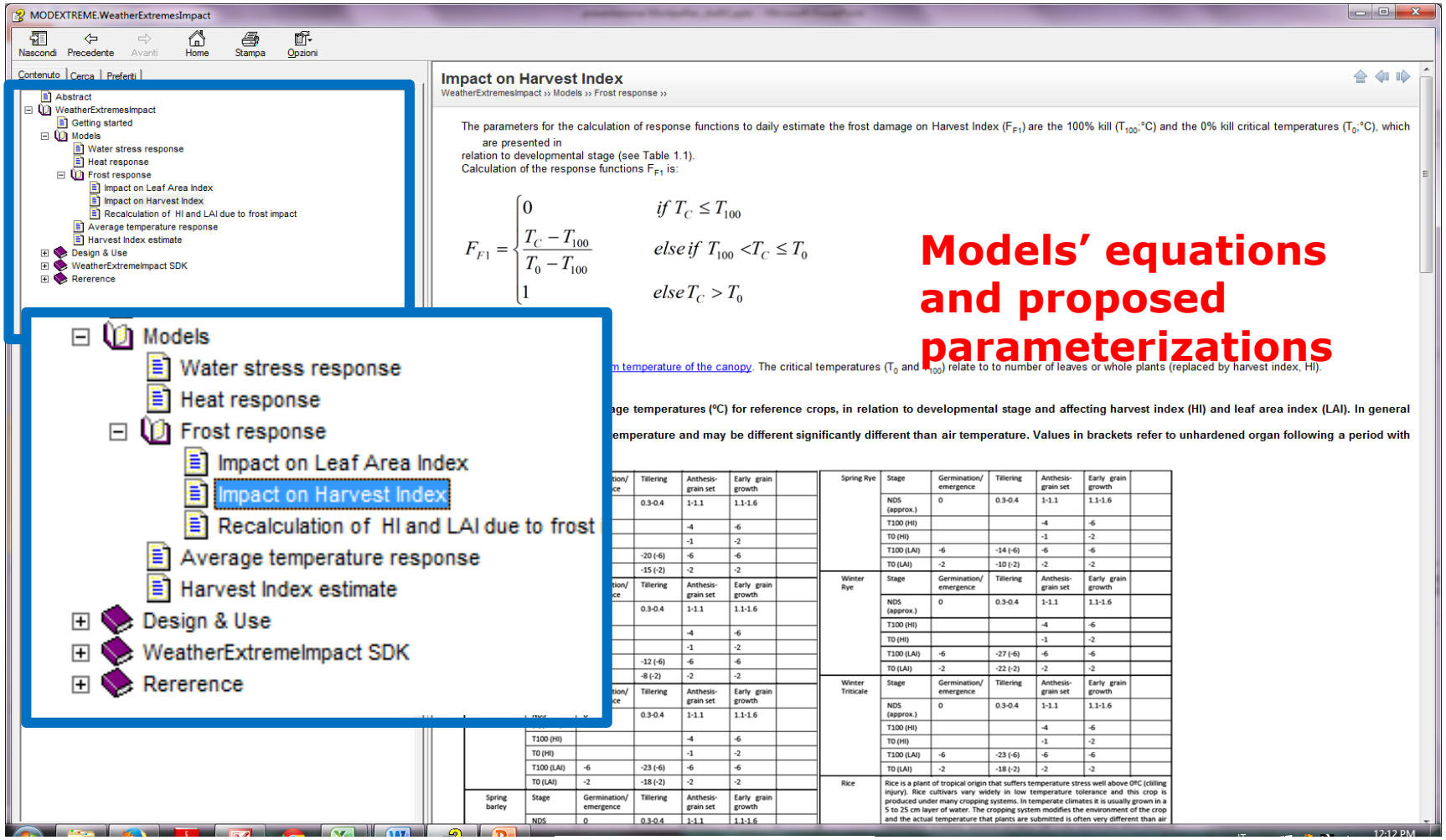


The software component MODEXTREME

- The software component is released as **.NET DLL**
- It is **extensible** by third parties without requiring the re-compilation of *MODEXTREME.WeatherExtremesImpact*
- It allows **testing the quality of I/O variables**
- It is provided with a SDK inclusive of:
  - **Help file**
  - **Code documentation**
  - **Sample application**

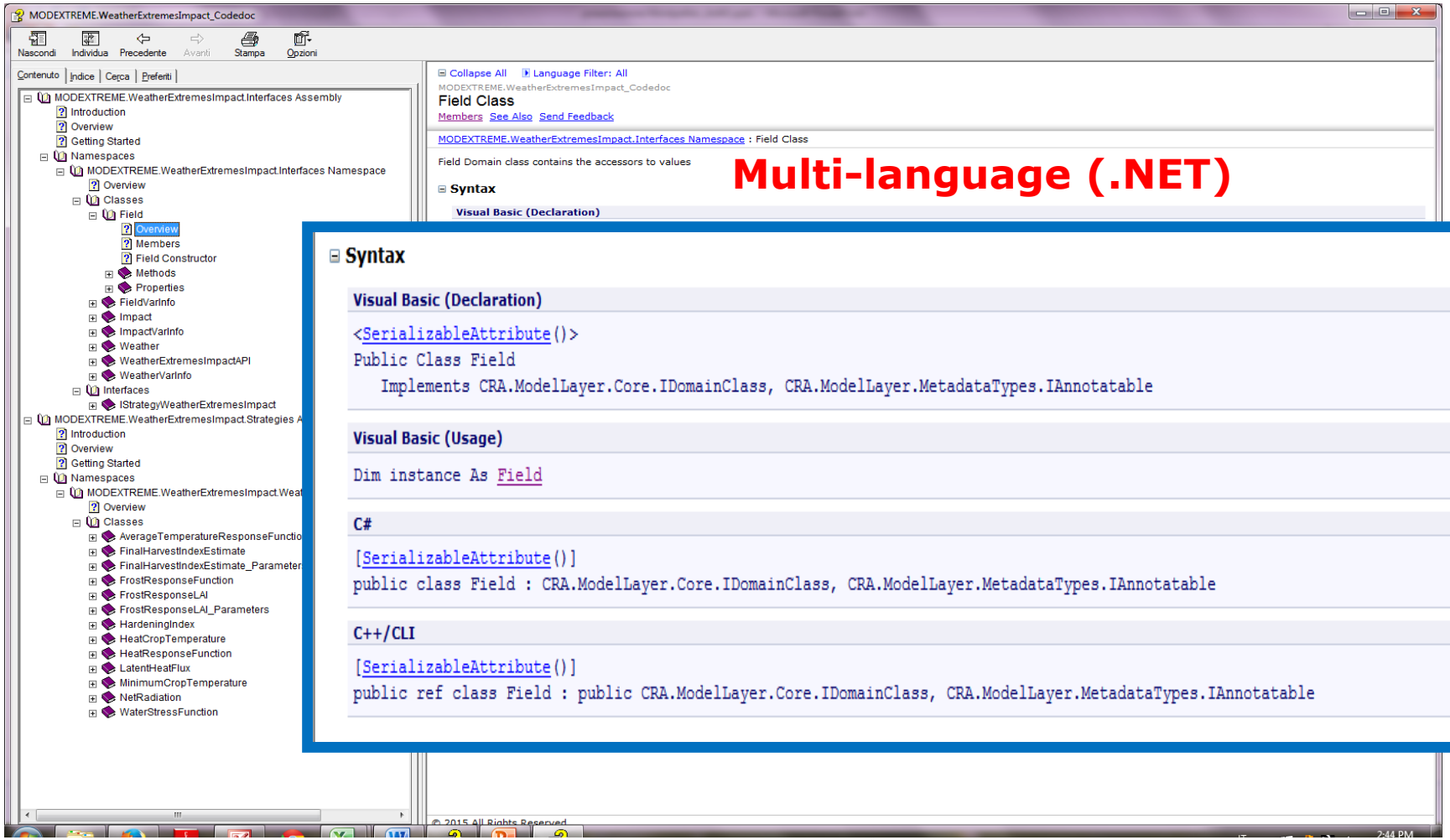


Help



Models' equations and proposed parameterizations

Codedoc


MODEXTREME.WeatherExtremesImpact_Codedoc
Nascondi
Individua
Precedente
Avanti
Stampa
Opzioni
Contenuto
Indice
Cerca
Preferiti
MODEXTREME.WeatherExtremesImpact.Interfaces Assembly
Introduction
Overview
Getting Started
Namespaces
MODEXTREME.WeatherExtremesImpact.Interfaces Namespace
Overview
Classes
Field
Overview
Members
Field Constructor
Methods
Properties
FieldVarInfo
Impact
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WeatherExtremesImpactAPI
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FrostResponseFunction
FrostResponseLAI
FrostResponseLAI_Parameters
HardeningIndex
HeatCropTemperature
HeatResponseFunction
LatentHeatFlux
MinimumCropTemperature
NetRadiation
WaterStressFunction
Collapse All
Language Filter: All
MODEXTREME.WeatherExtremesImpact_Codedoc
Field Class
Members
See Also
Send Feedback
MODEXTREME.WeatherExtremesImpact.Interfaces Namespace : Field Class
Field Domain class contains the accessors to values
Syntax
Visual Basic (Declaration)
Multi-language (.NET)
Syntax
Visual Basic (Declaration)
<SerializableAttribute()>
Public Class Field
Implements CRA.ModelLayer.Core.IDomainClass, CRA.ModelLayer.MetadataTypes.IAnnotatable
Visual Basic (Usage)
Dim instance As Field
C#
[SerializableAttribute()]
public class Field : CRA.ModelLayer.Core.IDomainClass, CRA.ModelLayer.MetadataTypes.IAnnotatable
C++/CLI
[SerializableAttribute()]
public ref class Field : public CRA.ModelLayer.Core.IDomainClass, CRA.ModelLayer.MetadataTypes.IAnnotatable
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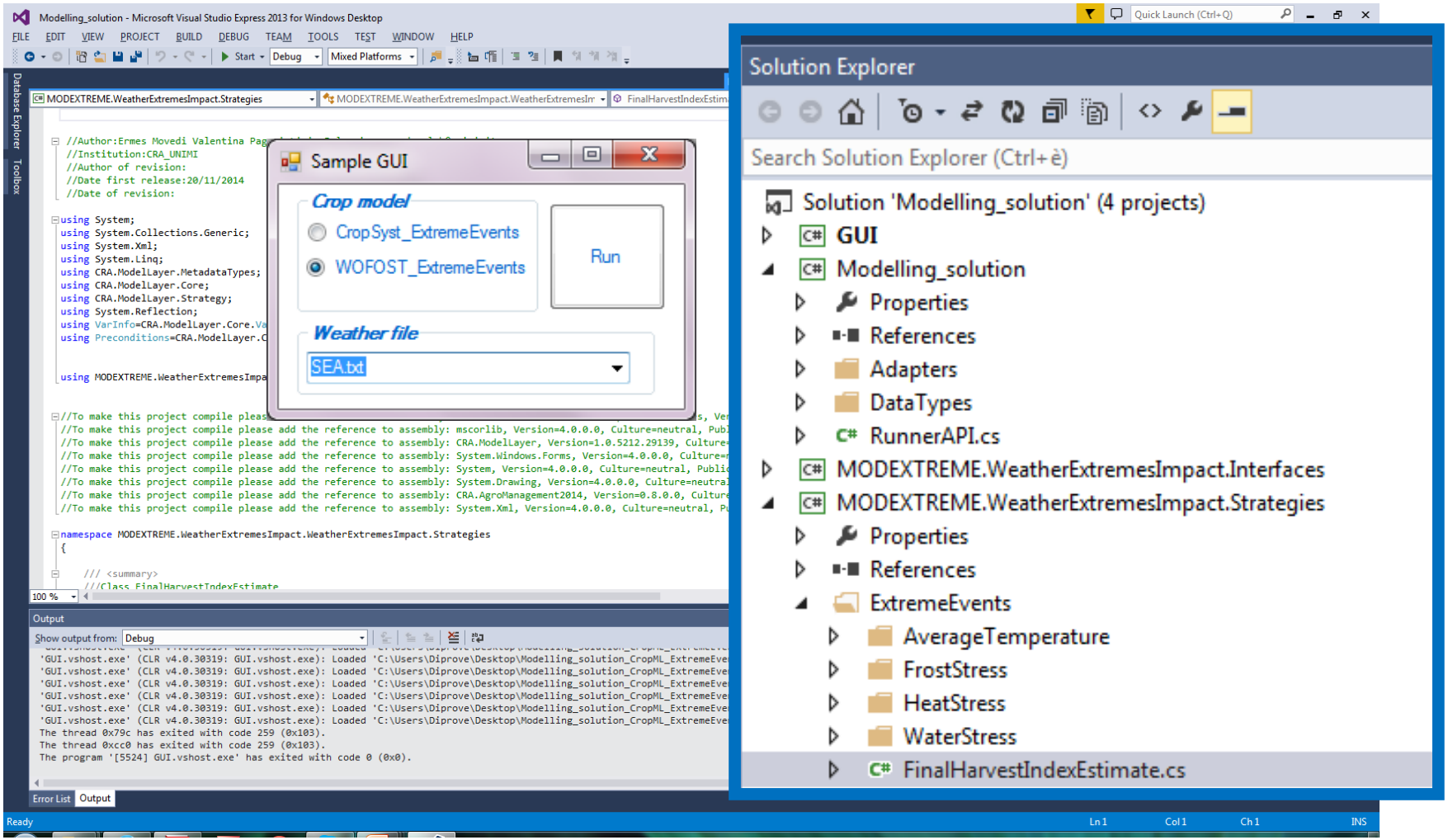
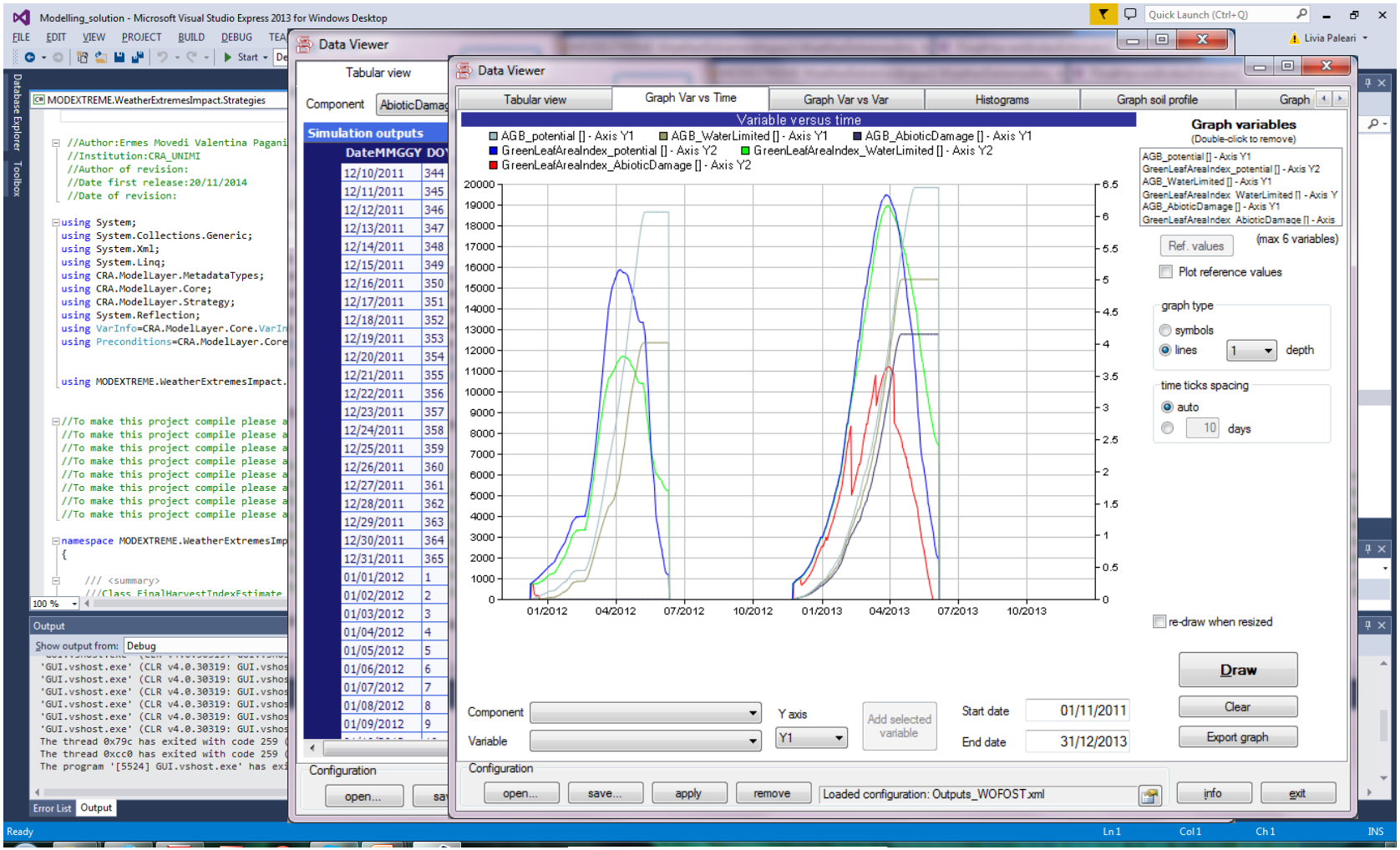
Sample Application

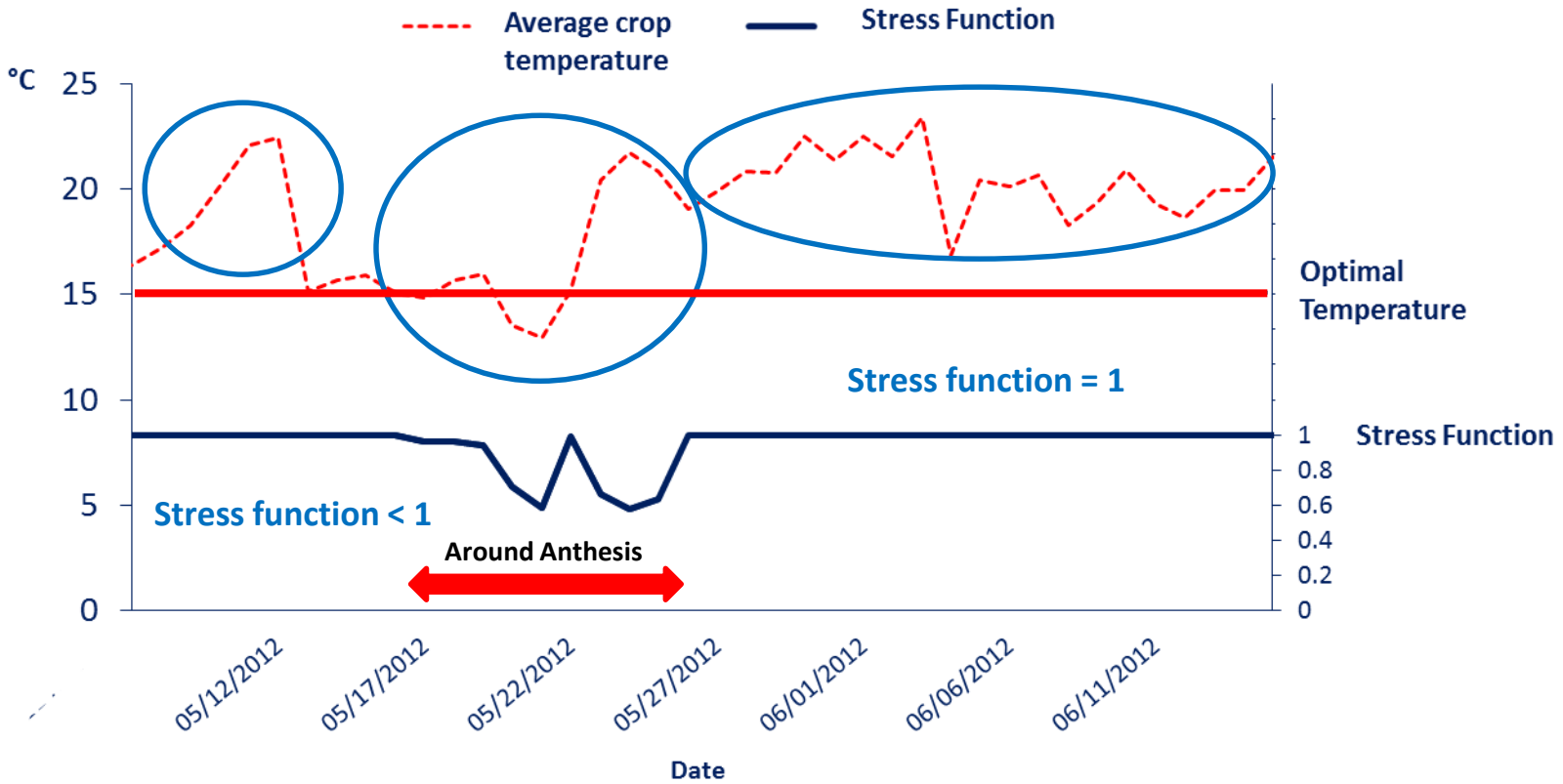


Sample Application



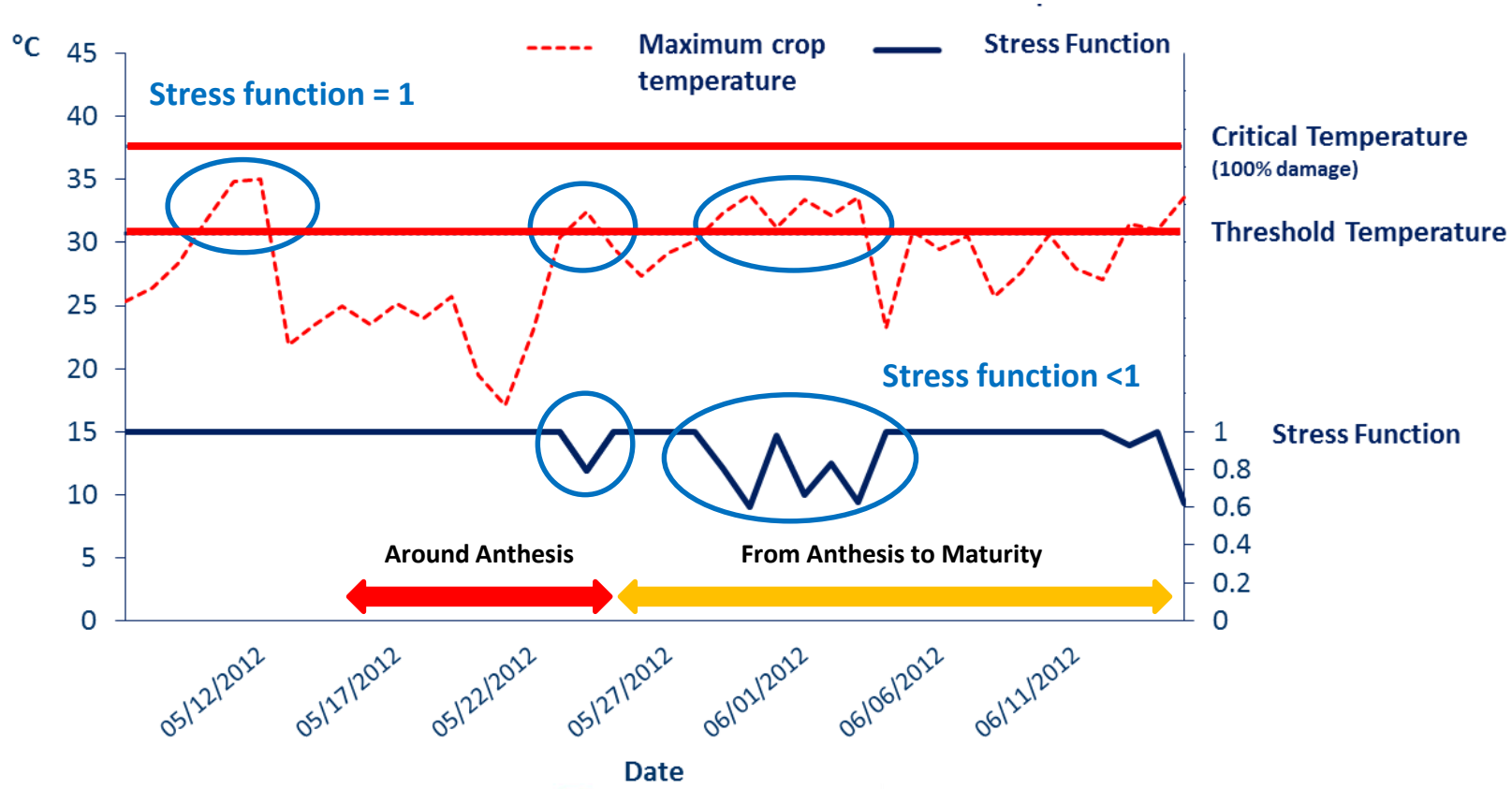
Sample results

- Response function to **average crop temperature** (Northern Italy; wheat)



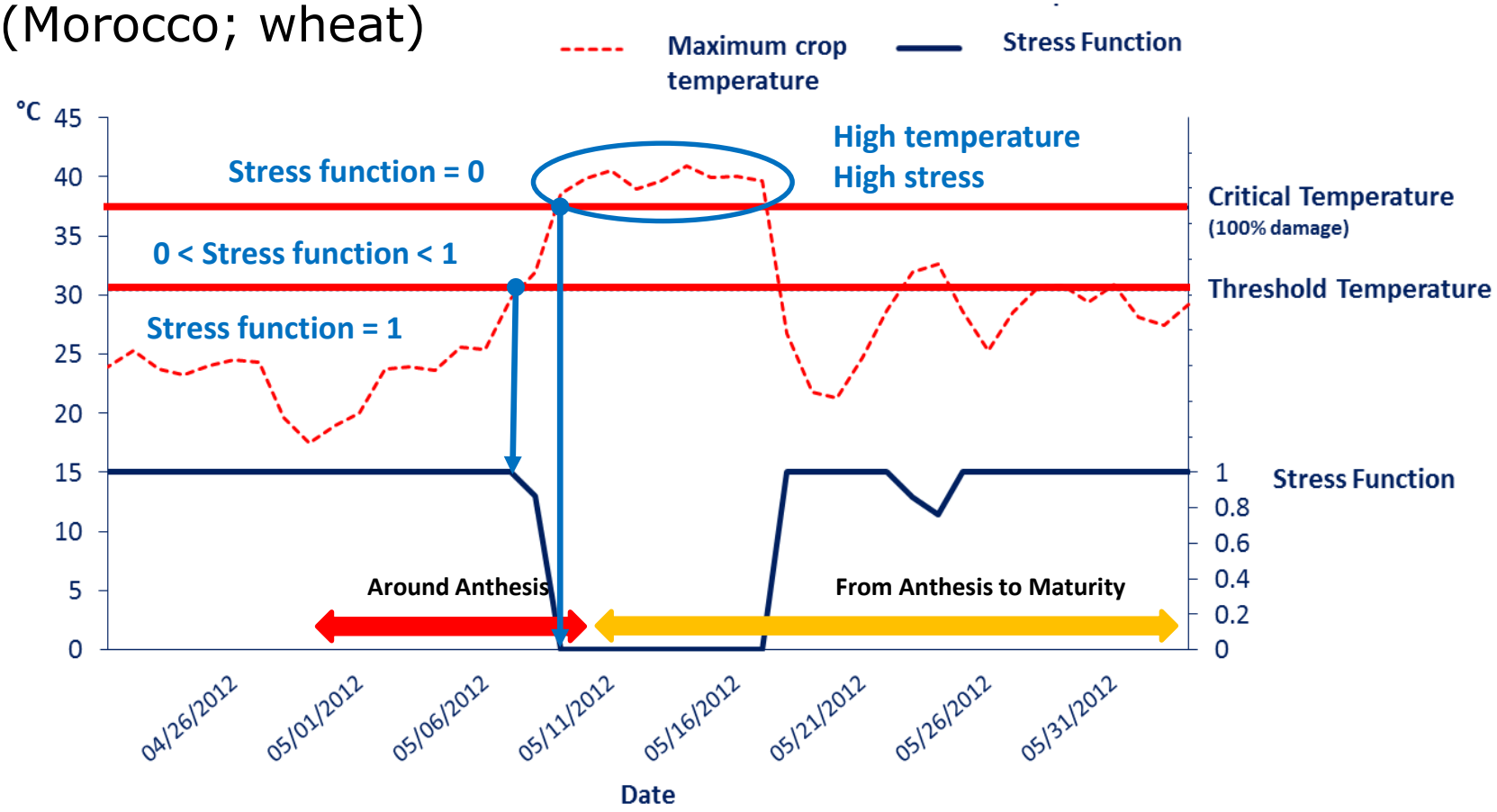
Sample results

- Response function to **heat stress**
  (Northern Italy; wheat)



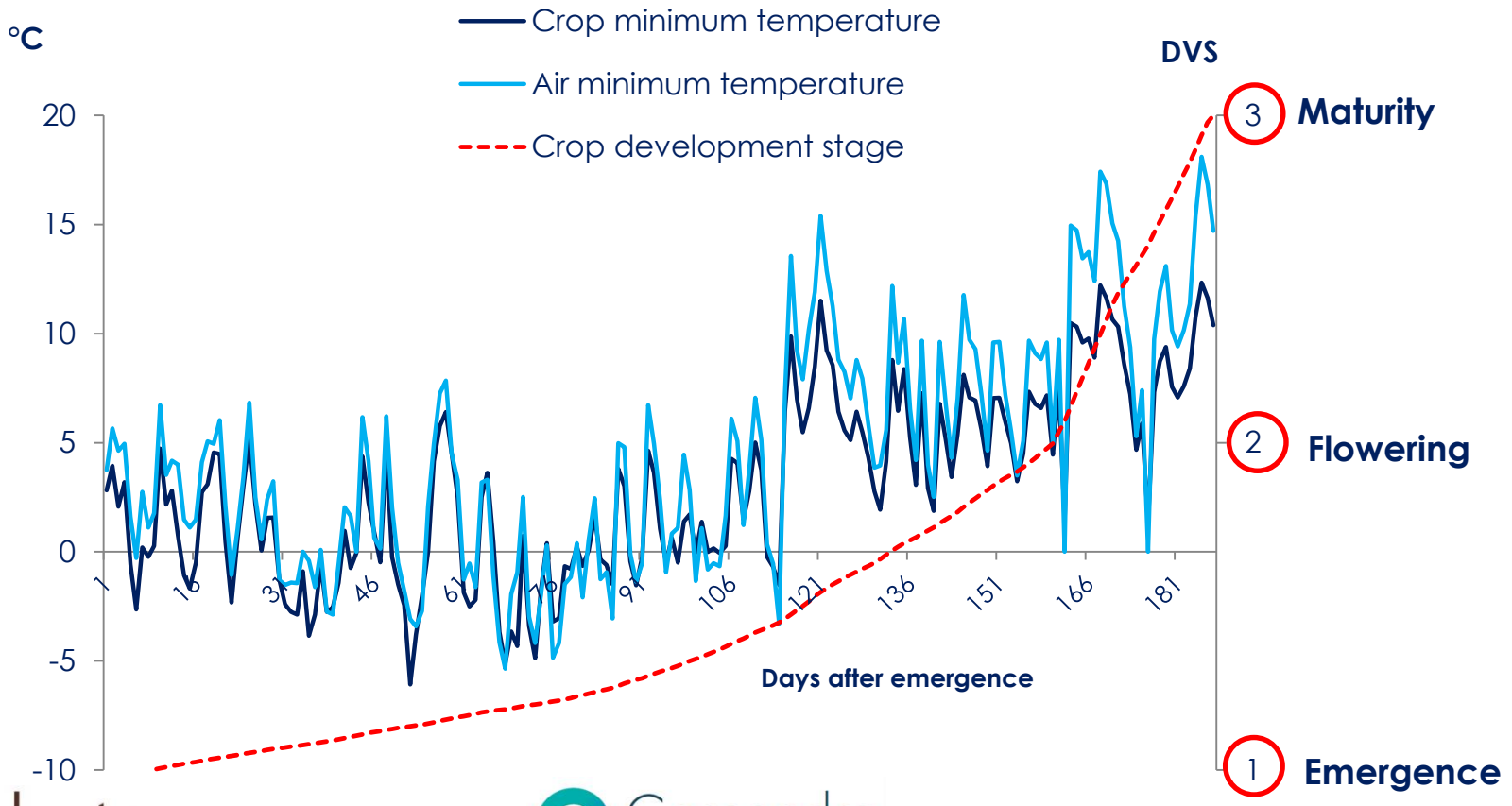
Sample results

- Response function to **heat stress**
  (Morocco; wheat)



Sample results

- **Crop** minimum temperature versus **air** minimum temperature during the crop cycle (crop:wheat)



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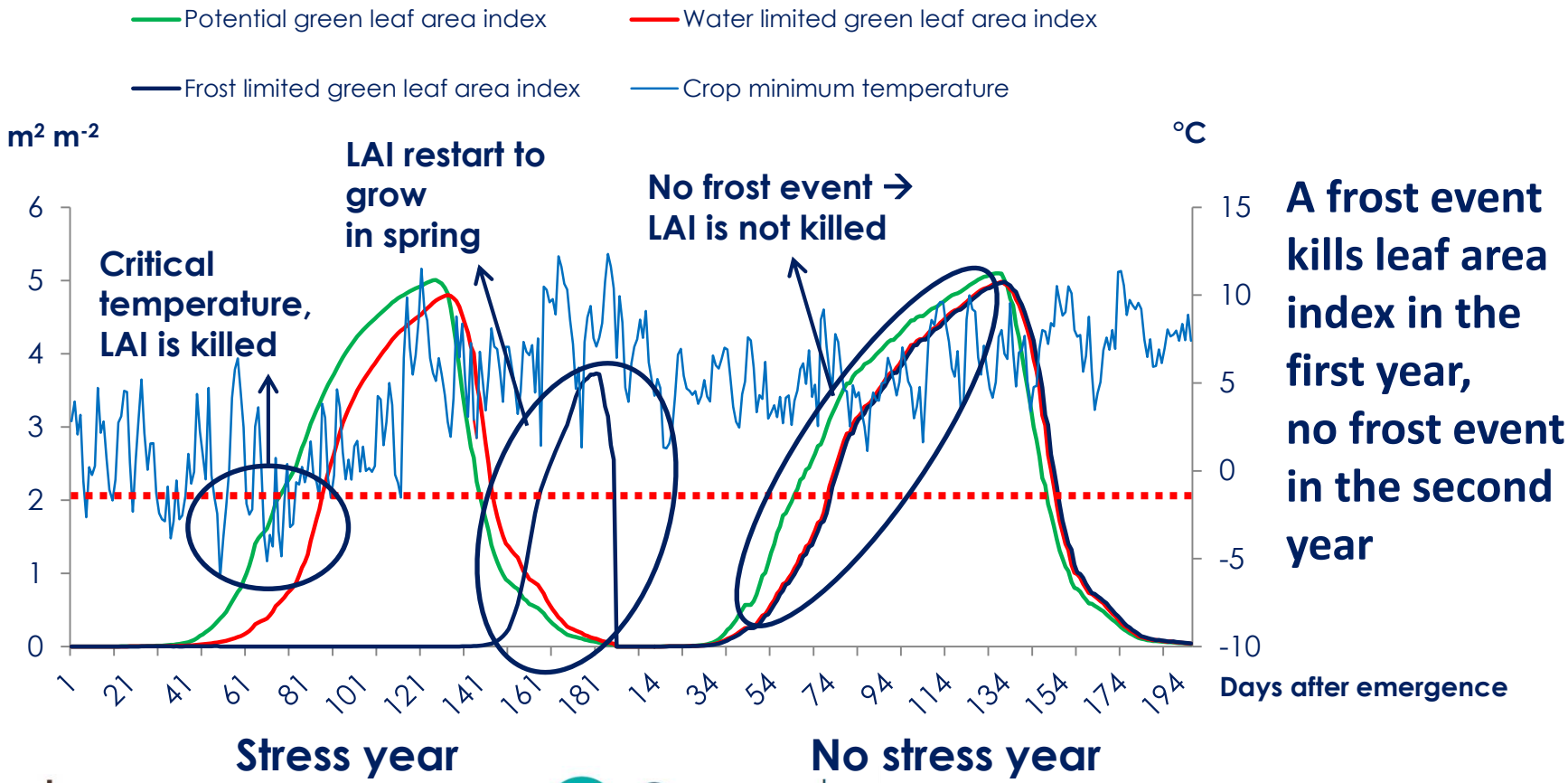
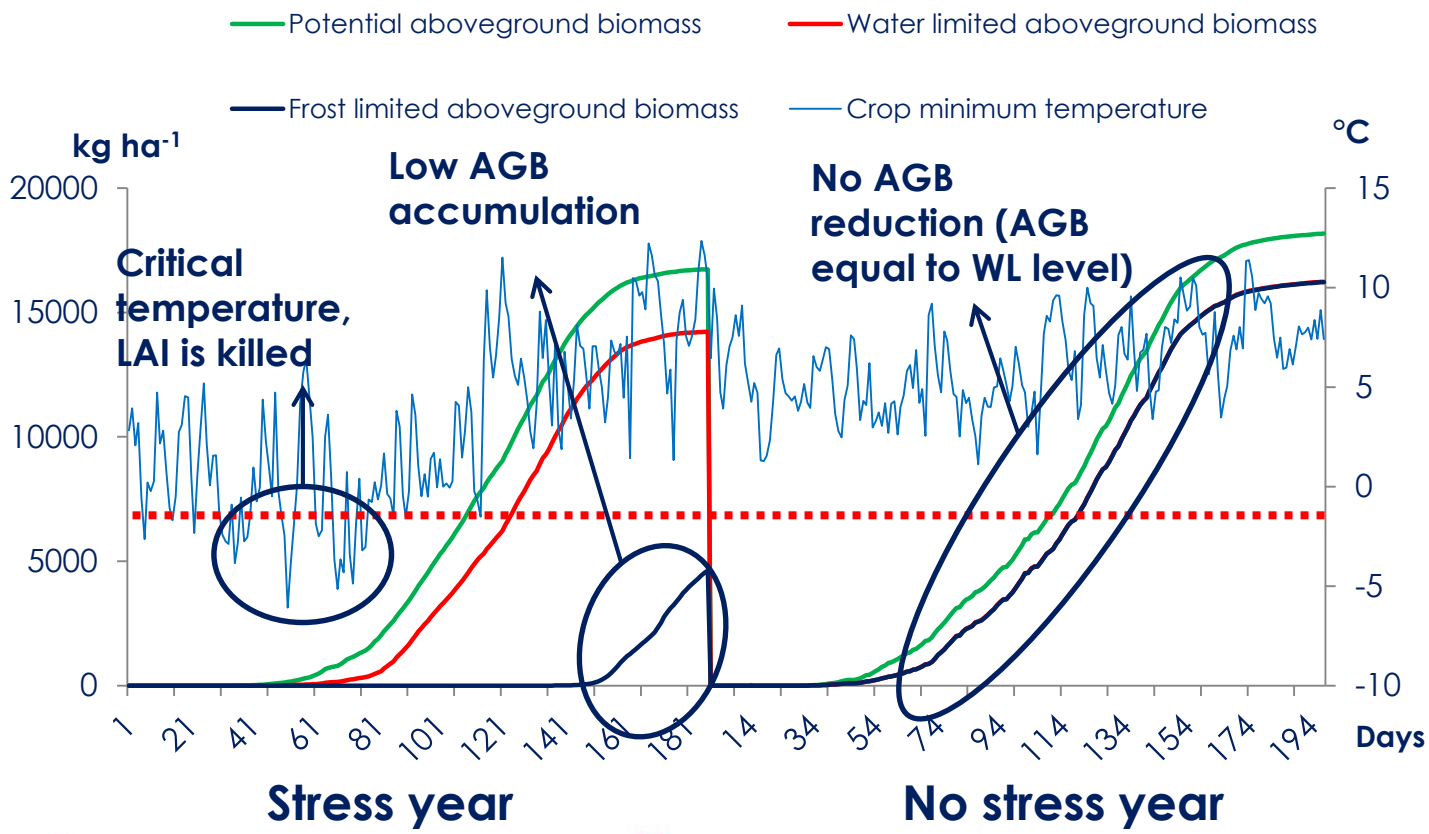
Sample results

- **Frost stress**: impact on Leaf Area Index (crop: wheat, Crop model: Cropsyst)



Sample results

- **Frost stress**: impact on Aboveground Biomass accumulation (crop: wheat, Crop model: Cropsyst)



A frost event kills leaf area index in the first year, no frost event in the second year

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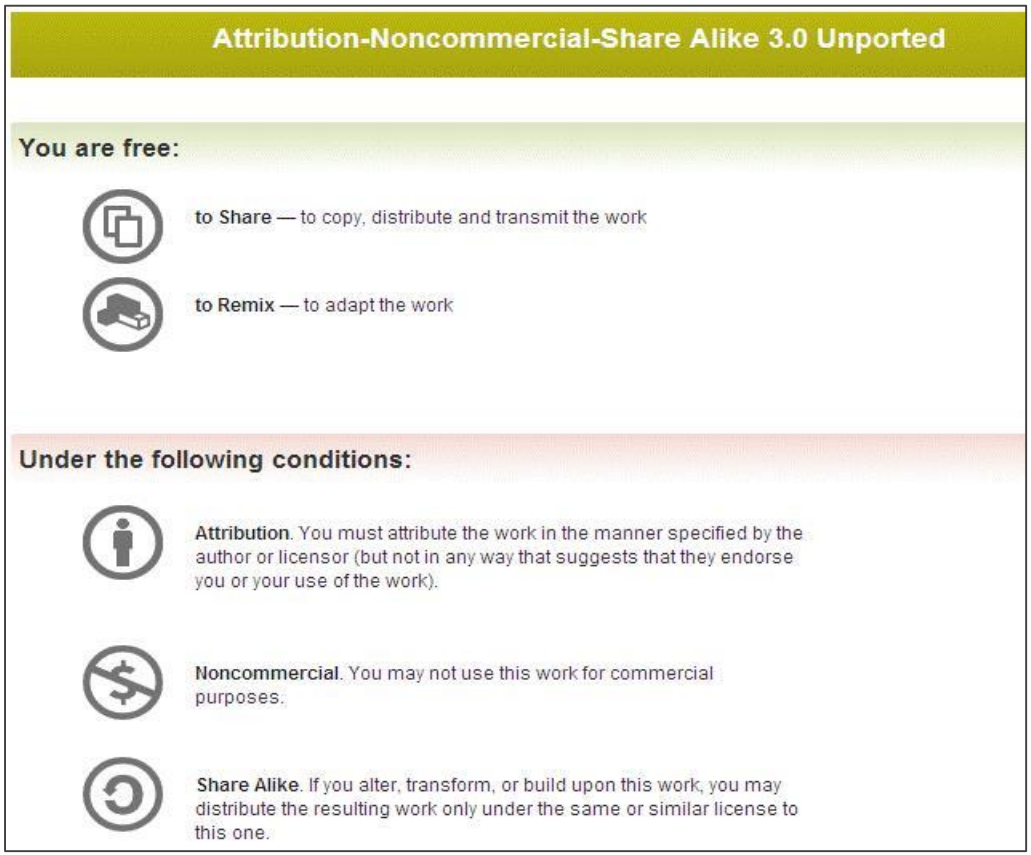
Conclusion

- The software component is currently available within the project consortium
- It will be made available soon also for third parties



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agriculture facing extreme climatic events

SEVENTH FRAMEWORK PROGRAMME

Acknowledgement

"The research leading to these results has received funding from the European Community's Seventh Framework Programme – FP7 (KBBE.2013.1.4-09) under Grant Agreement No. 613817, 2013-2016"