European Commission

WARM

Modelling Solution

Reference documentation

Joint Research Centre

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Disclaimer

On any of the MARS pages you may find reference to a certain software package, a particular contractor, or group of contractors, the use of one or another sensor product, etc. In all cases, unless specifically stated, this does not indicate any preference of the Commission for that particular product, party or parties. When relevant, we include links to pages that give you more information about the references.

Feel free to contact us, in case you need additional explanations or information.

Contents

About this document

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This document is targeted to the users of the BioMA Software Framework.

In particular, is targeted to end users who load the WARM modelling solution and run it in BioMa. It provides detailed information on how this modelling solution is built and how it works.

Furthermore, it provides links to the Web-based reference documentation for users who want to further understand how the modelling solution has been developed from the technical and scientific point of view.

For scientific information about the models used please refer to the documentation of the specific components.

The topics are organized as follows:

Resources of interest

Resource	What you will find
Agri4Cast Software Portal	In the **Software Portal** page, the **Software Tools and Documentation** table links to all BioMA components' available documentation. In particular, the **BioMA Framework User Guide** provides an overview of all the BioMA main components.

Resource	What you will find
Composition Layer documentation	A document addressed to advanced users who want to deepen their knowledge on how the composition layer of the BioMA framework is coded.
Cassandra - Università degli Studi di Milano	The WARM model was developed by the University of Milan, Italy. For further information, visit the Web site.
CREA Web Site	Tools for Agro-Meteorology and Biophysical Modelling.

WARM modelling solution description

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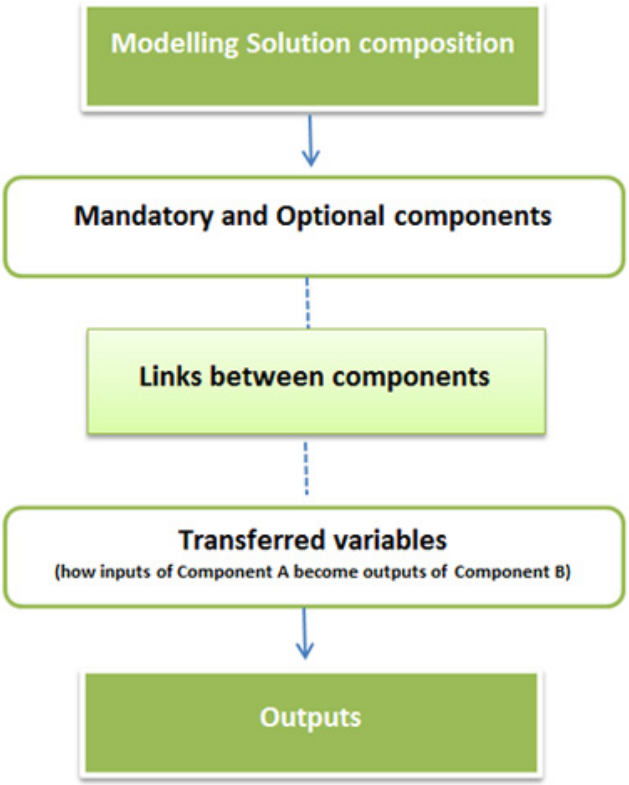
This section is organized into the following topics:

What is it and how it works

The WARM modelling solution is developed in the BioMA framework. It implements several approaches to model crop development and growth.

A modelling solution is the composition of many components. In this document you will find the details of the composition. However, this document does not cover the details of each component. Links to Web-based specific documentation is provided, when needed.

The following schematises how the WARM modelling solution works:



For further information, see:

- "Components of WARM" on page 7
- "How components are linked to each other" on page 10
- "WARM Modelling solution outputs" on page 16

Components of WARM

A component is a software library (or a set of libraries) that encapsulates a specific aspect of the simulated system.

A BioMA component must fulfill the constraint of the BioMA Composition Layer. Please refer to the Composition Layer Documentation for further details.

There are two types of components:

- “Mandatory components” on page 7
- “Optional components” on page 8

See also:

- “How components are linked to each other” on page 10
- “Required data providers” on page 15
- “WARM Modelling solution outputs” on page 16
- “Modelling solution simulation control” on page 16
- “Modelling solution switches” on page 16
- “Modelling solution agromanagement impacts” on page 18

Mandatory components

The following table lists the mandatory components that compose the WARM modelling solution. Click the link to go to a Web-based detailed description of the component, if any.

Component	Description
Weather provider	This component provides the weather data to the other components. This component is part of the library EC.JRC.MARS.CompositionLayer.PreBuiltComponents.

Component	Description
Agro management	This component reads the agro management configuration and, during the simulation, checks if some agro management rule is satisfied. When a rule is satisfied, the corresponding impact is triggered. The other components of the modeling solution can handle this impact. In the WARM modeling solution the component able to handle the agro management impacts is **WARM potential**. This component is part of the library EC.JRC.MARS.CompositionLayer.PreBuiltComponents.
WARM potential	This component performs the crop growth simulation in potential conditions. The name of the component is EC.JRC.MARS.Crop.CropML and the strategy used is **WARM**

Optional components

The optional components are not required to execute the modelling solution. However, these allow calculating additional variables, so improving the crop simulation. For example, you can simulate the impact of some plant's pathogens that might reduce the potential yield.

Currently, with this modelling solution you can simulate some plant diseases (based on the leaf wetness).

Please note that different versions of the modelling solution could contain different sets of optional components. Because of the modularity of the system, it is possible (and easy) to add a new optional component to the modelling solution and link it with the existing components. The list described in this document is the list of optional components used in a typical WARM modelling solution.

The following table lists the optional components that can be included. Click the link to go to a Web-based detailed description of the component, if any.

Component	Description
Leaf wetness	This component calculates the leaf wetness starting from the weather data. The name of the component is JRC.IPSC.MARS.Diseases.LeafWetness and several strategies could be used. The used strategy is set dynamically by a switch. See the switches section for further details.
Disease	This component calculates the diseases that might occur to some plants starting from the weather data and the leaf wetness. The name of the component is JRC.MARS.Diseases.Airborne.DiseaseProgress and the strategy used is **DiseaseSimulation**.
Disease impact on plant	This component calculates the impacts on the plant as calculated by the **Disease** component. The name of the component is JRC.MARS.Diseases.Airborne.ImpactsOnPlants and the name of the strategy used is **LinearRUEBasedModelC**.
WARM limited	This component rapresents the WARM simulation limited by the disease stress factor.

See also:

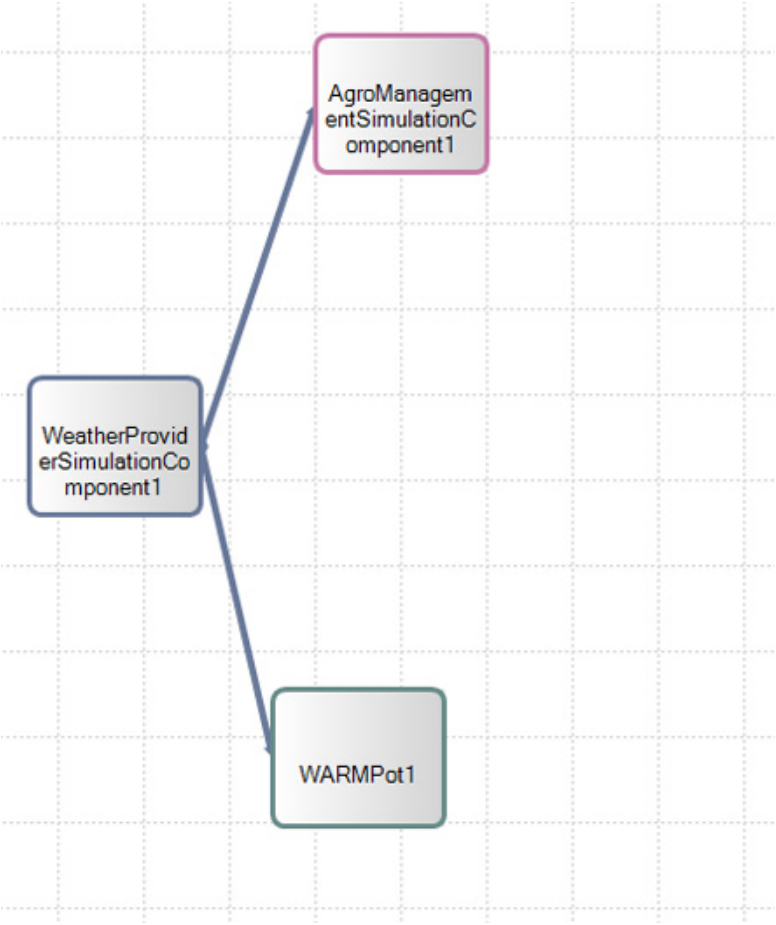
- “Mandatory components” on page 7
- “How components are linked to each other” on page 10
- “Required data providers” on page 15
- “WARM Modelling solution outputs” on page 16

How components are linked to each other

Mandatory components connections

The following flow diagram shows the connections between the mandatory components of the modeling solution:

Figure 1 WARM - Connections between mandatory components



Note that a link starts from the ***source*** component and ends to the ***destination*** component. A link represents the transfer of values from the source to the destination component.

Tip:

For further details on the links between components, please refer to the BioMA Composition Layer Documentation,

The following table describes the links between the mandatory components:

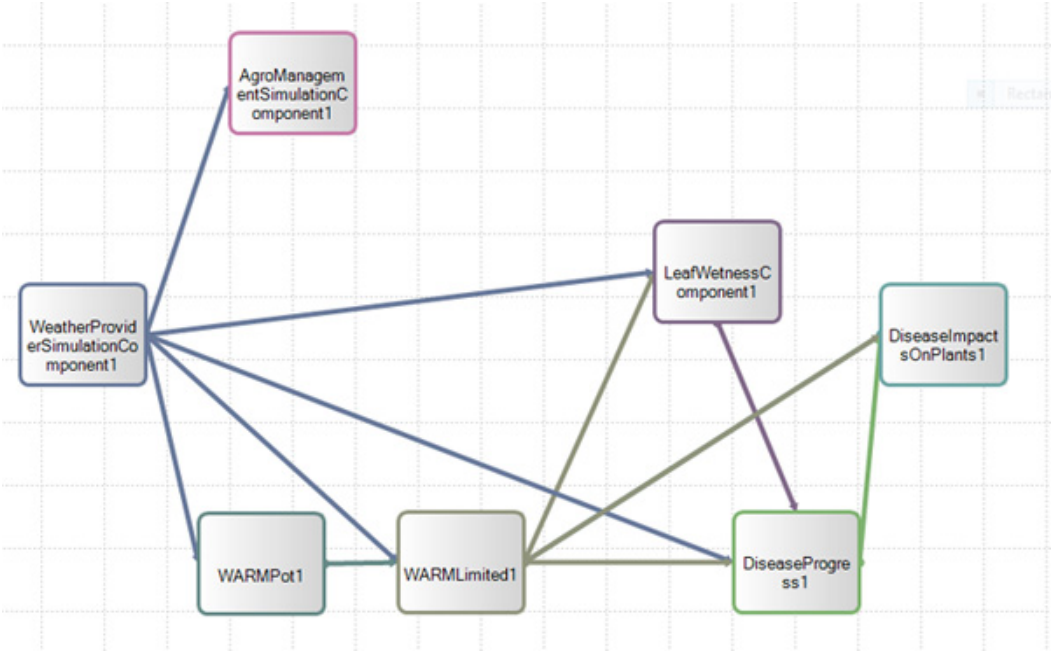
Table 1 - Mandatory components links description

Source component	Destination component	Transferred value
Weather provider	Agro management	Weather data (rain, temperature).
Weather provider	WARM Potential	Weather data and location data (rain, temperature, radiation, vpd, humidity, evapotranspiration, CO2 concentration, day length, latitude).

Mandatory and optional components connections

The following flow diagram summarizes the connections between all components of the WARM modelling solution, including the optional components:

Figure 2 WARM - Connections between all components (including optional components)



The following tables describe the links:

Table 2 - Components links description (including optional components)

Source component	Destination component	Transferred value
Plant disease simulation		
Weather provider	LeafWetness	Several hourly weather variables are calculated starting from the daily weather variables provided by weather provider component. The hourly variables calculated are: radiation, temperature, rain, wind speed, dew point temperature, latent heat of vaporization, humidity, vpd, slope vapor pressure. The calculations are performed by CLIMA strategies.
Weather provider	Disease	Weather data (rain, wind, temperature)

Table 2 - Components links description (including optional components)

Source component	Destination component	Transferred value
LeafWetness	Disease	Hourly weather data (wind, humidity, temperature, vpd, rainfall) and hourly leaf wetness (a boolean that indicates whether the leaves are wet or not).
WARM Water Limited	LeafWetness	Crop variables (green leaf area index, canopy height)
WARM Water Limited	Disease	Crop variables (green leaf area index, dead leaf area index, total leaf area index, development stage)
WARM Water Limited	Disease Impact on Plant	Crop variables (green leaf area index, dead leaf area index, yield, radiation use efficiency)
Disease	Disease Impact on Plant	Hot tissue affected daily, hot tissue diseased daily
Disease Impact on Plant	WARM Water Limited	Values of green leaf area index and maximum radiation use efficiency decreased by the disease. The value of the maximum RUE is a parameter in WARM, so it was necessary to insert a new CropML Rate property (MaximumRUE). This rate is then set as the value of the MaximumRadiationUseEfficiency parameter of strategy WARM before calling it in the next time step.
Weather provider	WARM Limited	Weather data and location data (rain, temperature, radiation, vpd, humidity, evapotranspiration, CO2 concentration, day length, latitude).
WARM Potential	WARM Limited	Set the transpiration potential of WARM water limited component as the transpiration calculated by the WARM potential component. Set the values of the switches of the limited component to the same values of the switches of the potential component.

Related topics:

- “Mandatory components” on page 7

- “Optional components” on page 8
- “Required data providers” on page 15
- “WARM Modelling solution outputs” on page 16

Required data providers

Some components may require a data provider.

A data provider is a library for providing data of any type. It must fulfill the constraints defined in the BioMA composition layer.

Tip:

For a detailed description of what data providers are, please refer to the BioMA Composition Layer Documentation.

In the WARM modelling solution the required data providers are the following:

- “Weather data provider” on page 15
- “Agro management data provider” on page 15

Weather data provider

Required by: **Weather provider simulation** component.

This provider connects to a data source to get a set of daily weather data from a start date to an end date.

In the BioMA framework there are many implementations of weather providers, designed to connect to many different data sources. Typically weather data are stored in databases, but they can also be stored in textual CSV files or other standards.

When a user needs to use a new set of weather data, if the format of the data is not already managed by one of the existing weather providers, the user needs to create a new weather provider implementation (C# class). For the technical details of the implementation please refer to the composition layer documentation.

A weather provider must have methods to return daily weather data, location data (latitude, longitude, altitude) and other data like day length and CO2 concentration.

Agro management data provider

Required by: **Agro management provider simulation** component.

This provider connects to a data source to get a set of agro management data for a specific location and year. Agro management data include rules to trigger management events on the crop like sowing, irrigation, tillering, harvesting, etc.

In the BioMA framework it is already available an implementation of agro management data provider that reads data from an agro management XML file. The class name of this provider is "`XMLFileAgromanagementProviderBase`" and it is contained inside the library "`EC.JRC.MARS.AgromanagementProviderBaseInterfaces`".

When a user needs to use a set of agro management data, he can code his data in an agro management XML files (by using the AgroManagement Configuration Generator - ACG) or he can create a new data provider to access directly to its data. For the technical details of the implementation please refer to the composition layer documentation.

Please refer to the agro management documentation to understand the agro management concepts, the use of ACG and the XML data format.

WARM Modelling solution outputs

The outputs of the WARM modelling solution are the following:

- The plant status consisting in the physical features of the plant for each simulated day: above ground biomass, leaf area index, height, development stage, dead leaf area index, total leaf area index, transpiration, water uptake, root depth, and other secondary variables.
- The variables that describe the disease damages: the amount of tissue affected by the disease, the decreased leaf area index, the decreased RUE, the impacts of disease on different plant aspects like leaves or CO2 assimilation (if the Disease component is activated).

Modelling solution simulation control

The simulation control of a modelling solution is the place where the modeller defines the simulation cycle in terms of starting date, ending date and time step interval. The WARM modelling solution requires a daily time step because all its components perform a calculation for each day. The modeller can use any simulation control that is based on a daily step cycle.

Modelling solution switches

The switches of a modelling solution are the options that the modeller can set to enable or disable an optional component or to change the internal behaviour of a component.

The switches of the WARM modelling solution are the following

- **Weather switch - Calculate evapotranspiration**: If this switch is set to `True` the Weather Provider component calculates the value of the daily evapotranspiration. The strategies used to calculate evapotranspiration are: **DRETHargreaves** and **DLHVHarrison** contained in the **CRA.Clima.dll** library. If the switch is set to `false`, the model uses the evapotranspiration read by the weather provider from the weather source.
- **Weather switch - Calculate VPD**: If this switch is set to `True` the Weather Provider component calculates the value of the daily vapour pressure deficit. The strategies used to calculate VPD are: **DMVPDAirT** and **DVPDVPDmax** contained in the CRA.Clima.dll library. If the switch is set to `false` the model uses the VPD read by the weather provider from the weather source.
- **Weather switch - Calculate humidity**: If this switch is set to `True` the Weather Provider component calculates the value of the daily maximum and minimum relative humidity. The strategies used to calculate humidity are: **HAirAndDewTemperature** and **HAirRelativeHumidity** contained in the CRA.Clima.dll library. If the switch is set to `false` the model uses the humidity read by the weather provider from the weather source.
- **WARM Pot - Use vernalization, WARM Pot - Use PhotoPeriod, WARM Pot - Use Senescence, WARM Pot - Use Saturation, WARMPot - Use temperature, WARMPot - Use CO2, WARMPot - Is C3**: These switches can change the internal behaviour of the WARM model.
- **Select leaf wetness strategy**: This switch is to select which strategy is used for calculated the leaf wetness. Leaf wetness is a requisite to calculate the plant disease. If this switch is set to `None`, the leaf wetness optional component is excluded from the modelling solution and leaf wetness is not calculated. By selecting one of the 6 alternative values, the corresponding strategy will be included in the model. The available strategies are: **CART**, **SWEB**, **ET**, **LWR**, **DP**, **FT**. If strategy **DP** or **SWEB** or **LWR** is included in the modelling solution, the modeler must configure its parameters before running the simulation.
- **Enable disease component**: If this switch is set to `True`, the disease damage optional component is included in the modelling solution, otherwise it is excluded. If this component is included, the modeller must configure its parameters before running the simulation.
- **Enable disease impacts on plants**: If this switch is set to `True` the **disease impact on plants** optional component is included in the modelling solution, otherwise it is excluded. If this component is

included, the modeller must configure its parameters before running the simulation.

Modelling solution agromanagement impacts

The WARM modelling solution was built to manage any kind of agromanagement impacts: the modeller has to manage properly the impacts inside the code of the components involved. In the basic implementation of the modelling solution some impacts is already implemented.

Here is the list:

- Sowing of a crop (managed by WARM and WARM water limited components).
- Harvesting of a crop (managed by WARM and WARM water limited components).

Using BioMA Spatial to configure a modelling solution

BioMA Spatial is the graphical user interface of the BioMA Framework that allows you to configure and run a modelling solution.

Using BioMA Spatial, you can:

- Select the weather source data to connect to
- Edit the model parameters
- Run the model simulation
- Use the graphic visualizer to view the simulation results

Tip:

For step-by-step instructions on how to configure and run a modelling solution, please go to the Agri4Cast Software Portal > **Software Tools and Documentation** table > **BioMA Spatial Help Online**, then navigate to **Using BioMA Spatial to run model simulations > Choosing and configuring the modelling solution**.