How do process-based crop models simulate the impact of frost and heat on the yield of annual grain crops?

Jonathan Richetti, Victor Sadras, Di He, Pengcheng Hu, Brenton Leske, Bangyou Zheng, David Deery, Yacob Beletse, Mariano Cossani, Ha Nguyen, Fernanda Dreccer, Jeremy Wish, Julianne Lilley

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Australia's National Science Agency

Today's food for thought…

- Should we care about frost and heat in crops?
- Why can't we really measure it?
- What are we doing about it?

Frost and Heat Impact

Plant’s Development and Growth

Lowering Yields

Severe Economic Loss

Frost and Heat Impact

- Climate Change effects increase the risk of extreme weather events (Lamichhane, 2021)
- Such pressures are occurring earlier than previously anticipated (Jägermeyr et al., 2021)
- We need to measure these impacts!

How to measure?

Step 1: modelling the crop growth

- Crop models can already simulate crop development every day.
- GxExM → APSIM NexGen (Holzworth et al., 2014)

Step 2: Understand effect/impact of frost and heat events on plants

- extensively studied at lower levels of the plant, such as gene expression, enzyme activities, and stomatal conductance (Hasanuzzaman et al., 2013; Kasuga et al., 1999; Levitt, 1980; Ruelland and Zachowski, 2010; Theocharis et al., 2012).

How to measure?

Step 3: impact of frost and heat on agronomical variables

- Reductions in yield (grain number, grain size) (Barlow et al., 2015)
- Time and duration of frost and heat events (Barlow et al., 2015)

Step 4: include all of it into crop models

- Such understanding has not yet been translated into modelled traits
- Frost and Heat damage functions are needed!

What are we doing about it?

- Modelling assumptions
- Challenge with the temperatures
- Work on APSIM

Crop Modelling Assumptions

Acclimation

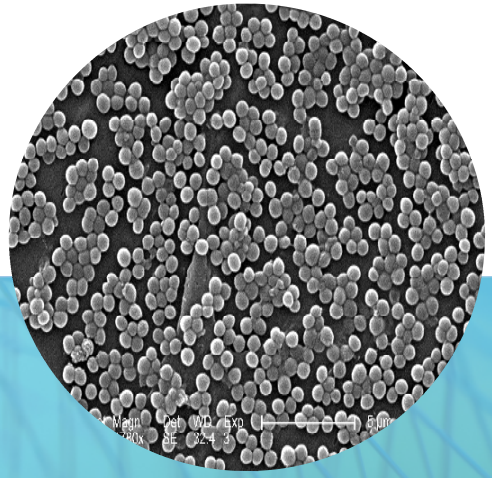
Compensation mechanisms

Single date phenology

Crop Modelling Assumptions

Duration of frost or heat event

Spatial footprint



Bacterial-induced ice nucleation

Simplified Low-level Biology

Temperature challenges

- Temperature Thresholds for modelling require data on response vs. temperature

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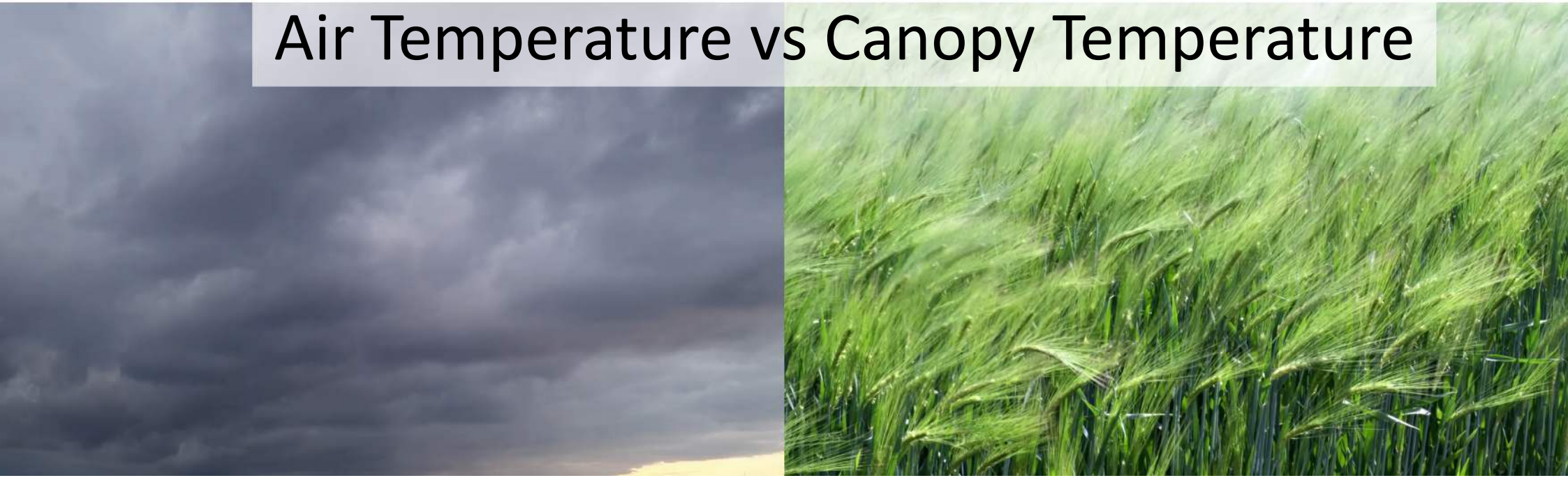
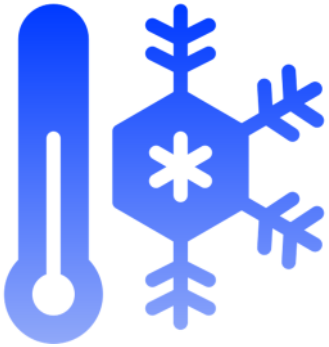
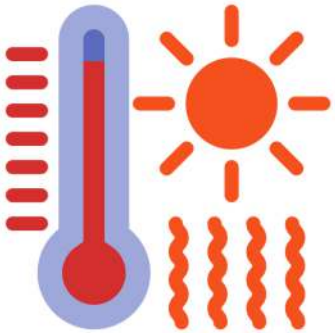
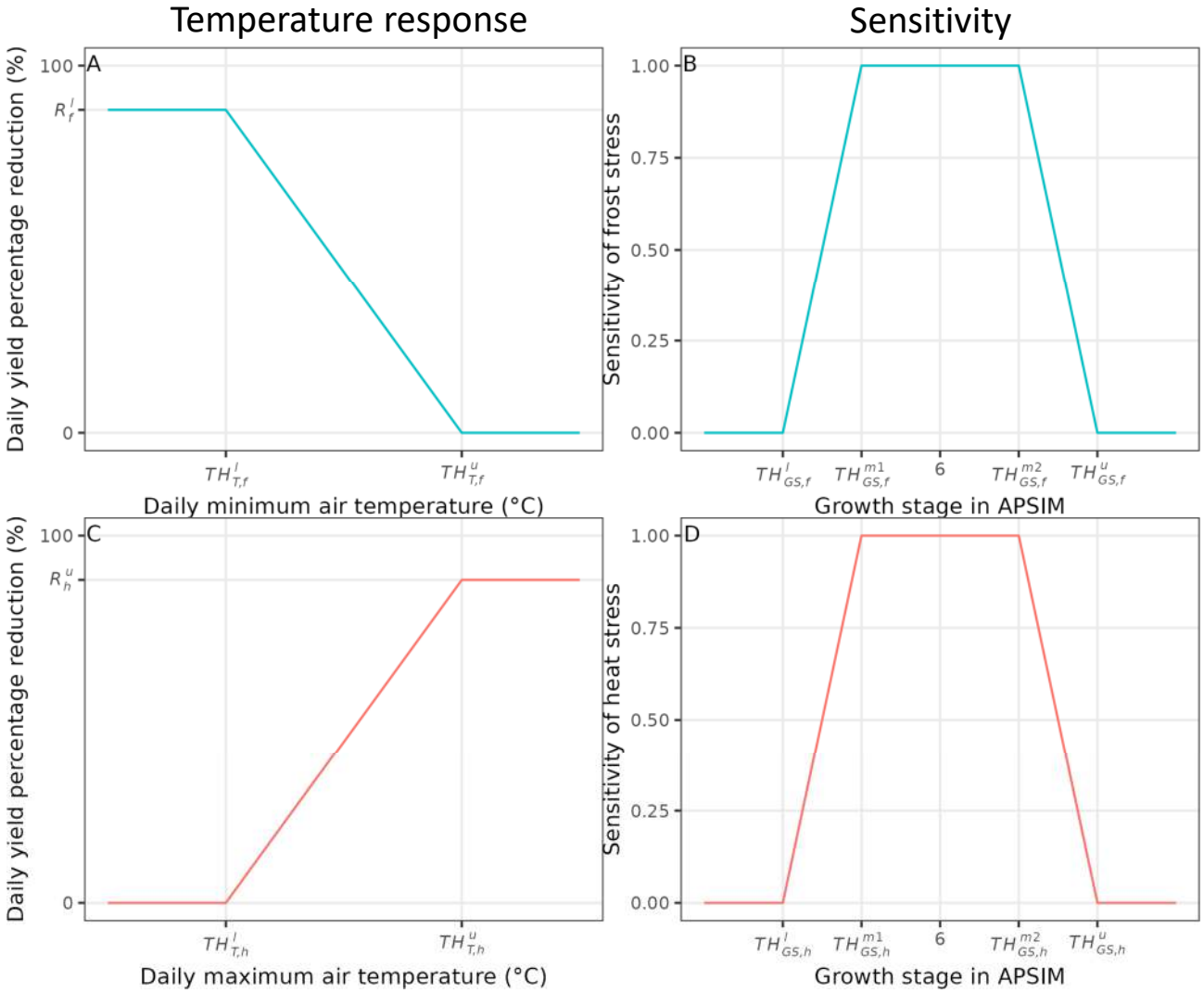


What are we doing about it?!







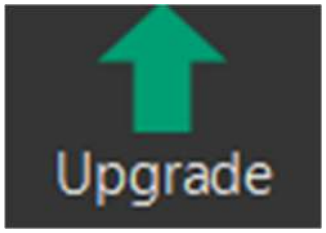
Frost and Heat damage function in APSIM NG

A yield penalising damage function is now available!

- Download APSIM NG

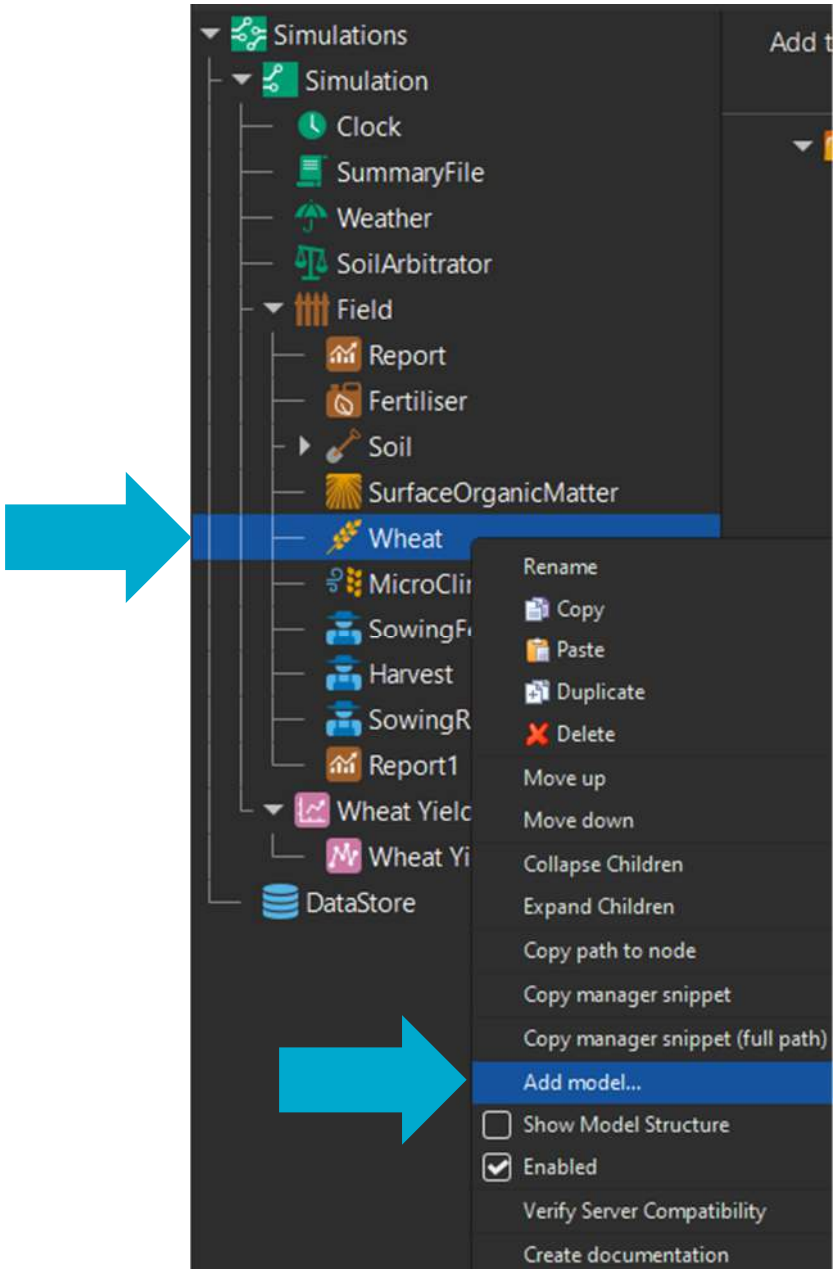
OR

- Click ‘Upgrade’



Adding the Function

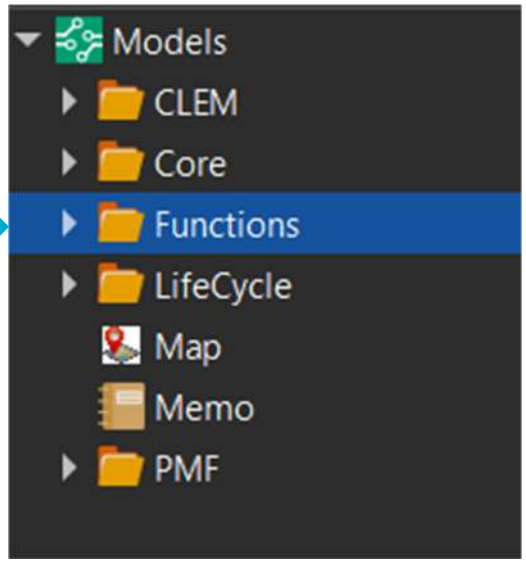
- Set-up your simulation!
- Right click on the crop (wheat or canola)
- Click ‘Add model…’



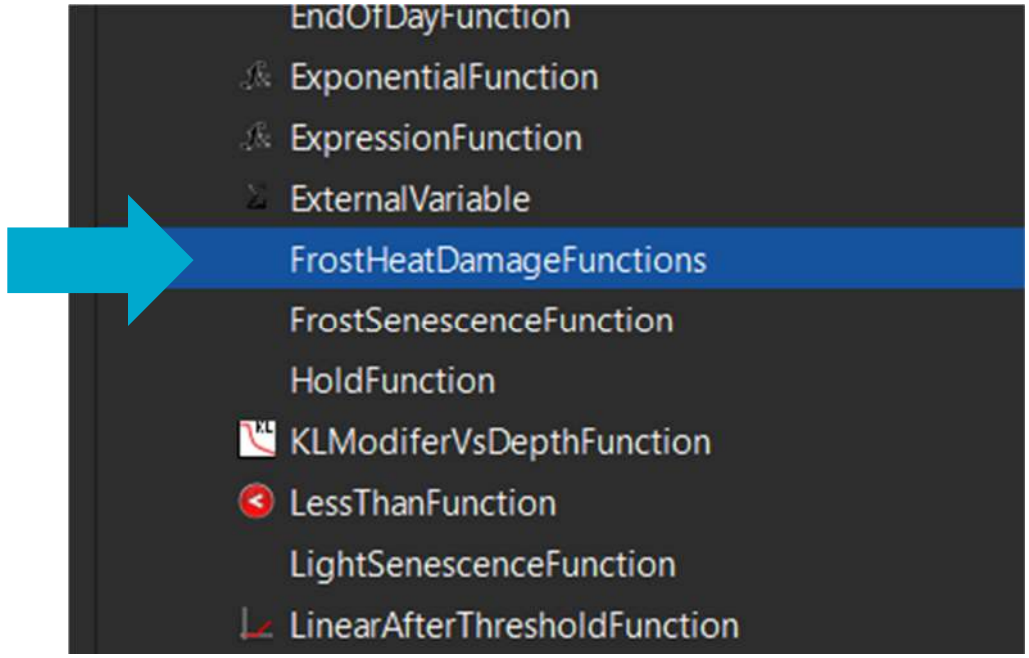
Download APSIM

Adding the Function

Click in ‘Function’



Scroll down and double click in the ‘FrostHeatDamageFunctions



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Remember to add it to the Report!

```
[FrostHeatDamageFunctions].FrostHeatYield as FrostHeatYield
[FrostHeatDamageFunctions].CumulativeFrostReductionRatio as CumulativeFro
[FrostHeatDamageFunctions].CumulativeHeatReductionRatio as CumulativeHeat
[FrostHeatDamageFunctions].FrostEventNumber as NumFrostEvents
[FrostHeatDamageFunctions].HeatEventNumber as NumHeatEvents
```

Take home messages

Download APSIM

- Be conscious of modelling assumption
- Request for more research to collect quality data and improve the model

Acknowledgments

- Frost and Heat Management Analytics project funded by Grains and Research Development Corporation (GRDC grant number: CSP2204-009RTX).

- The CSIRO FAHMA Data Modelling Team!

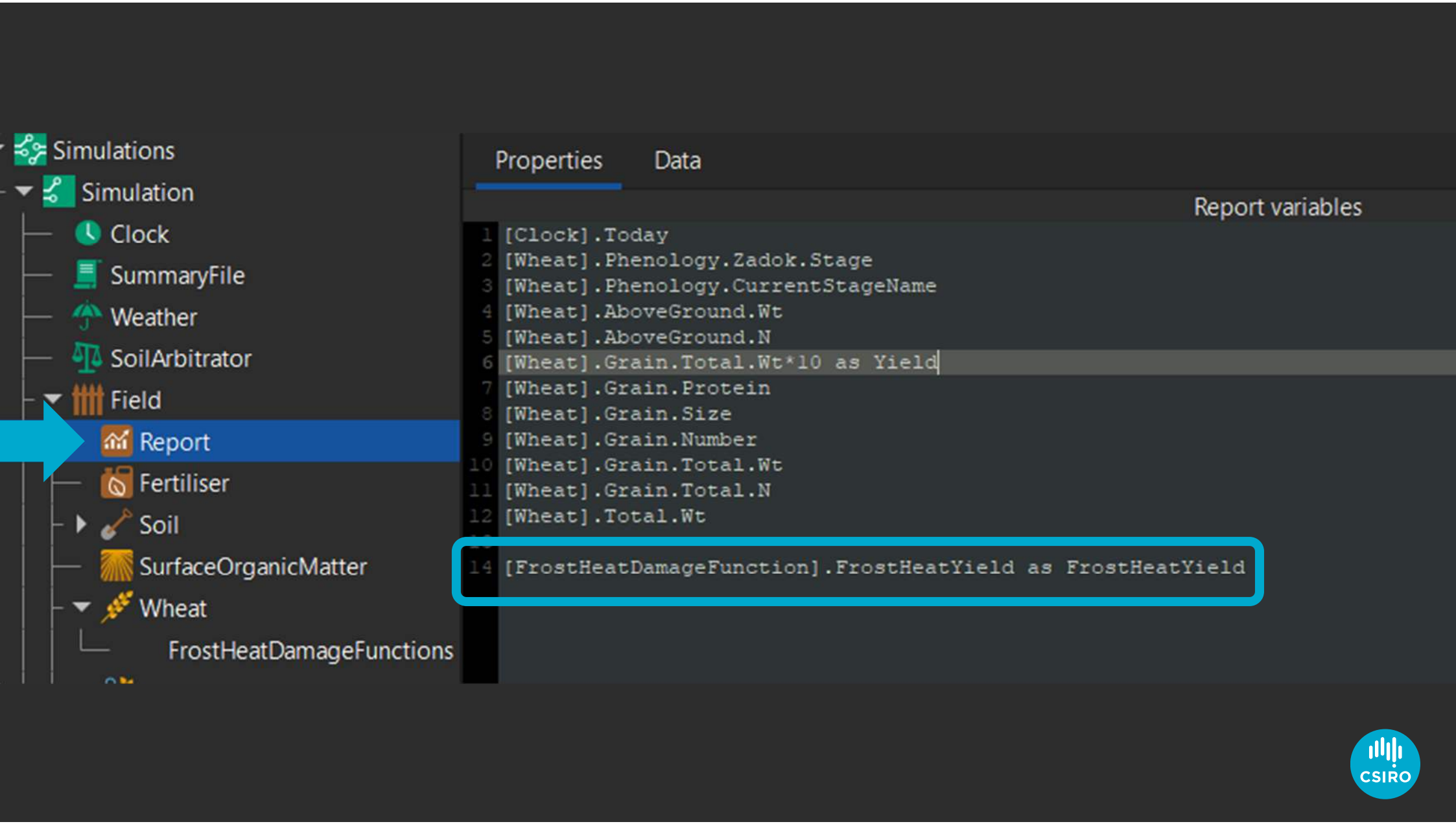
Thank you

Agriculture & Food
Jonathan Richetti PhD, Msc, Bsc

Research Scientist

M: +61 0411 150 425

Jonathan.Richetti@csiro.au
https://people-my.csiro.au/R/J/jonathan-richetti


Simulations
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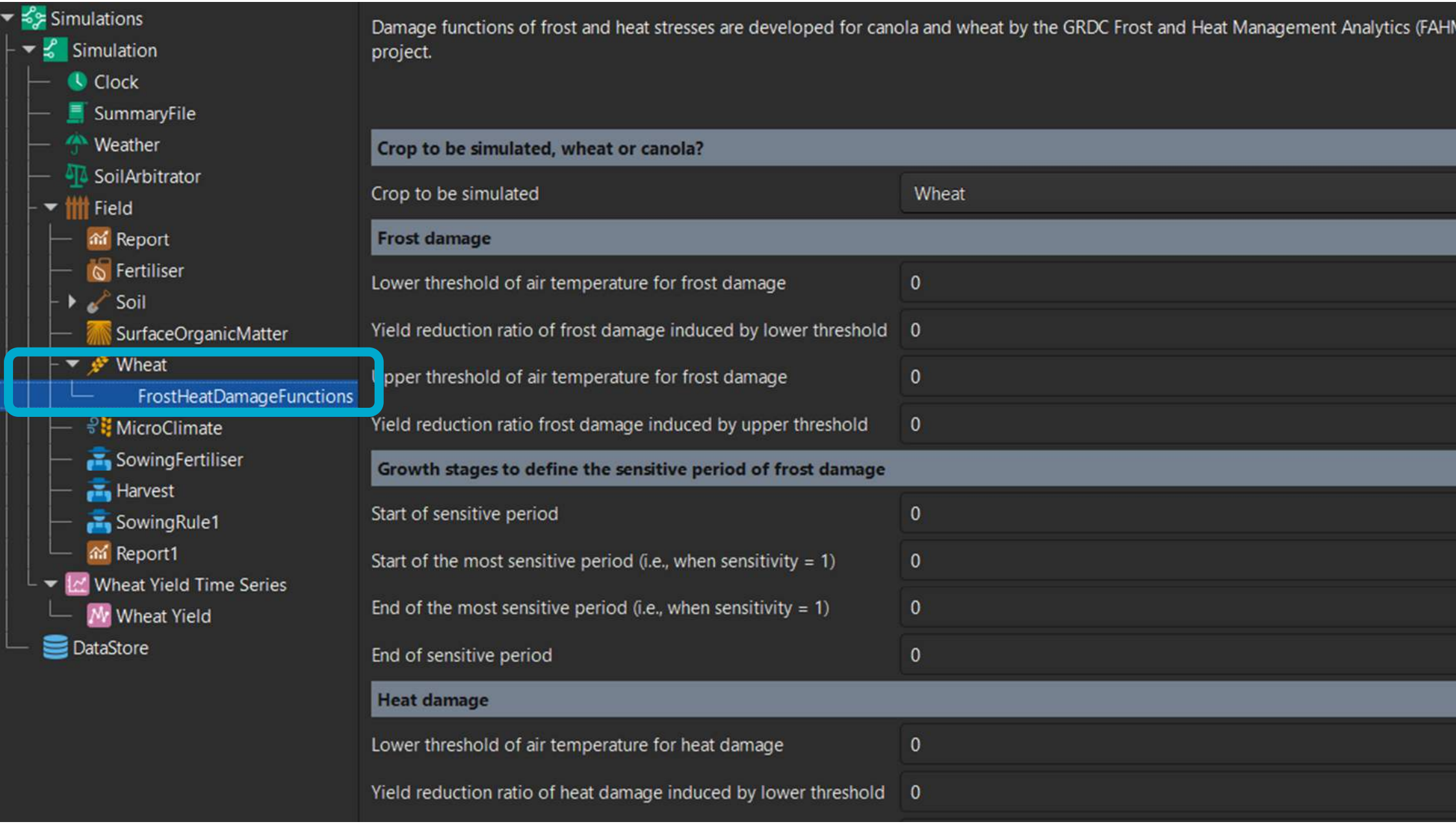
SummaryFile
Weather
SoilArbitrator
Field
Report
Fertiliser
Soil
SurfaceOrganicMatter
Wheat
FrostHeatDamageFunctions
Properties
Data
Report variables
1 [Clock].Today
2 [Wheat].Phenology.Zadok.Stage
3 [Wheat].Phenology.CurrentStageName
4 [Wheat].AboveGround.Wt
5 [Wheat].AboveGround.N
6 [Wheat].Grain.Total.Wt*10 as Yield
7 [Wheat].Grain.Protein
8 [Wheat].Grain.Size
9 [Wheat].Grain.Number
10 [Wheat].Grain.Total.Wt
11 [Wheat].Grain.Total.N
12 [Wheat].Total.Wt
14 [FrostHeatDamageFunction].FrostHeatYield as FrostHeatYield
CSIRO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Wheat Yield Time Series
Wheat Yield
DataStore
Damage functions of frost and heat stresses are developed for canola and wheat by the GRDC Frost and Heat Management Analytics (FAH
project.
Crop to be simulated, wheat or canola?
Crop to be simulated
Wheat
Frost damage
Lower threshold of air temperature for frost damage
0
Yield reduction ratio of frost damage induced by lower threshold
0
pper threshold of air temperature for frost damage
0
Yield reduction ratio frost damage induced by upper threshold
0
Growth stages to define the sensitive period of frost damage
Start of sensitive period
0
Start of the most sensitive period (i.e., when sensitivity = 1)
0
End of the most sensitive period (i.e., when sensitivity = 1)
0
End of sensitive period
0
Heat damage
Lower threshold of air temperature for heat damage
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Yield reduction ratio of heat damage induced by lower threshold
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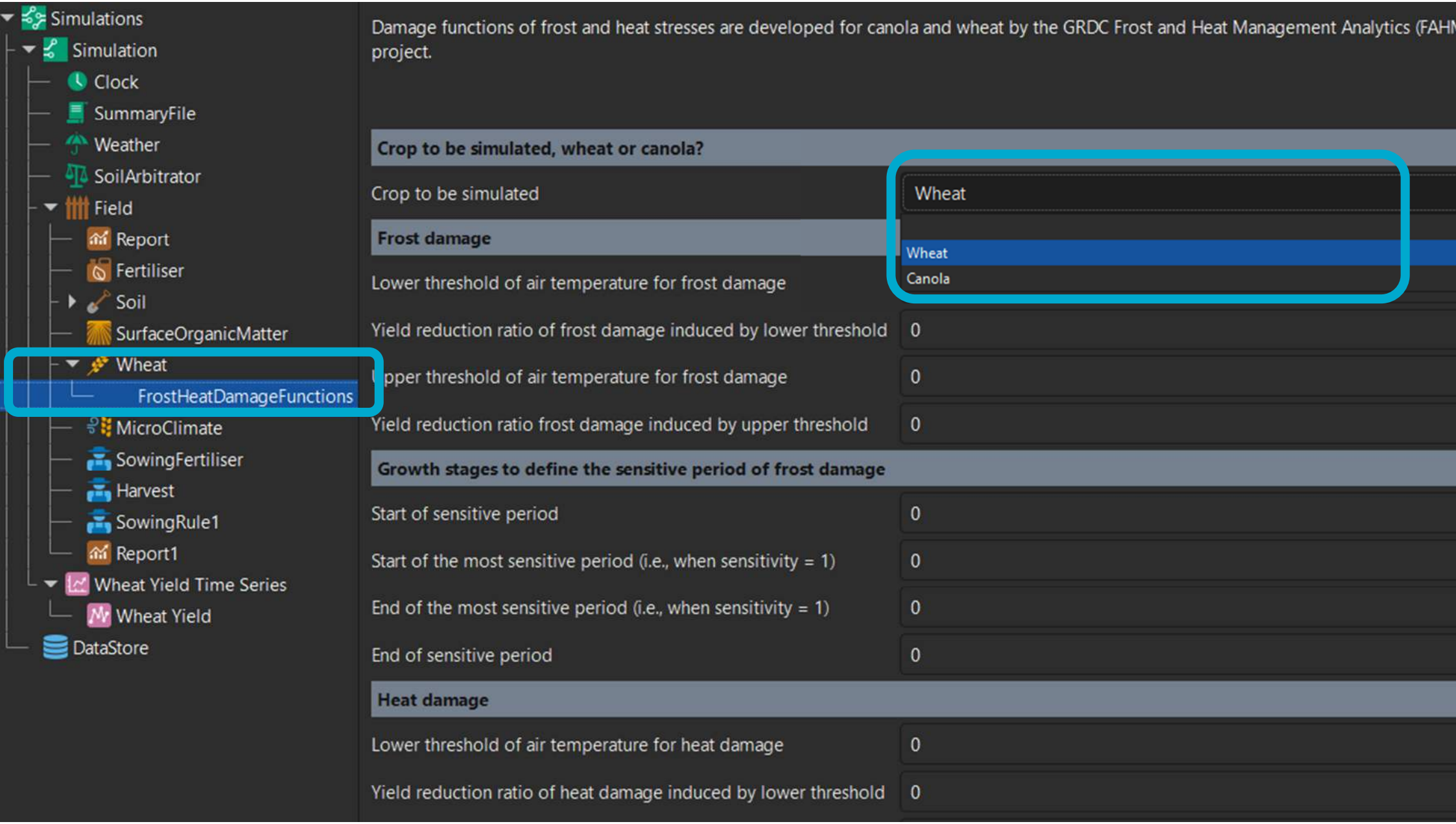
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Heat damage
Lower threshold of air temperature for heat damage
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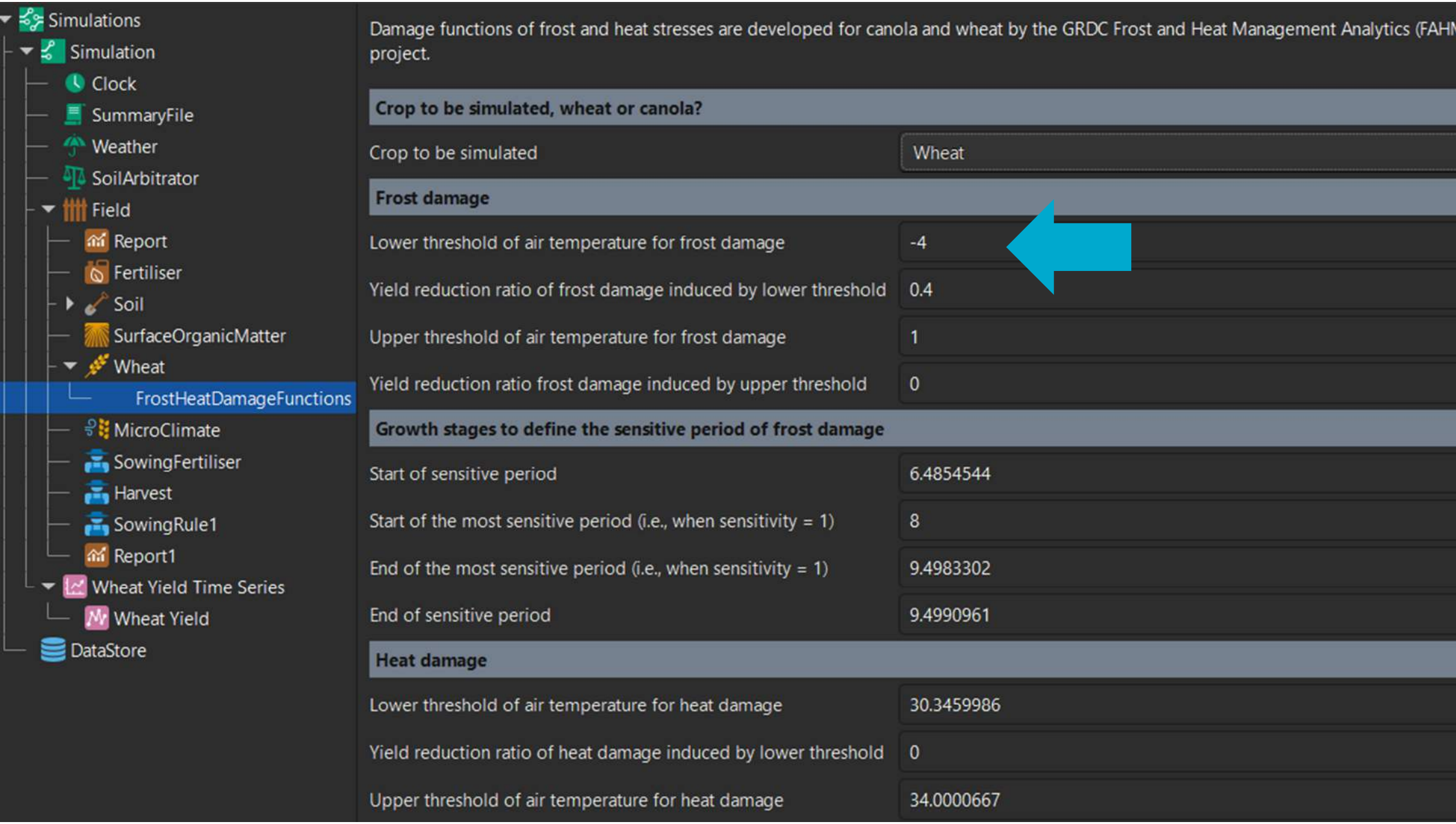
Yield reduction ratio of heat damage induced by lower threshold
0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Crop to be simulated
Wheat
Frost damage
Lower threshold of air temperature for frost damage
-4
Yield reduction ratio of frost damage induced by lower threshold
0.4
Upper threshold of air temperature for frost damage
1
Yield reduction ratio frost damage induced by upper threshold
0
Growth stages to define the sensitive period of frost damage
Start of sensitive period
6.4854544
Start of the most sensitive period (i.e., when sensitivity = 1)
8
End of the most sensitive period (i.e., when sensitivity = 1)
9.4983302
End of sensitive period
9.4990961
Heat damage
Lower threshold of air temperature for heat damage
30.3459986
Yield reduction ratio of heat damage induced by lower threshold
0
Upper threshold of air temperature for heat damage
34.0000667