Simulation protocol for AMEI soil temperature model intercomparison 2 (of 4)
Maricopa, AZ, Wheat FACE data set

13 September 2024

Aim

The aim of this simulation exercise is to compare nine soil temperature models exchanged between and incorporated in seven modeling frameworks (platforms) to a wheat FACE experiment data set from Maricopa, Arizona. Here, we want to assess, in a hot and dry environment with a clay loam soil, (1) how the error in modeling other variables (e.g. LAI or soil water content) determine the error in soil temperature, and (2) how the error in soil temperature affect the simulation of other variables (e.g. soil mineralization, crop development and growth, and final yield), (3) by how much the error in soil temperature of a given soil temperature model depends on the crop model in which it is integrated (is their one best soil temperature model in all modeling platforms?), and (4) what are the causes of the errors in soil temperature (essential for model improvement).

The results from this exercise will be submitted to a peer-reviewed journal with results from two other datasets (Avignon, France, and Bushland, Texas), which will be distributed latter.

Data set

The data set consist of four years of FACE experiment carried out at Maricopa, Arizona, USA. In all years, the spring wheat Yecora Rojo was grown with near optimal nitrogen and water regimes under ambient and elevated atmospheric CO_2 concentrations. In two of the years, an additional treatment considering limiting water supply (50% of optimal) is available and in another two years when nitrogen was limiting.

The full data set has been published in Kimball et al. (2017). It has been used in several model evaluation and intercomparison studies, including an AgMIP-Wheat study (Webber et al., 2018), where 17 wheat models were evaluated (including APSIM Next Generation, SIMPLACE, *SiriusQuality*, and STICS, which are also part of this study) on their skill in simulating canopy temperature across these environmental conditions.

Available data for simulation

The following data are provided to setup the simulations:

- Field location, elevation, and slope
- Crop residue biomass and N concentration
- Initial soil layer water and N content
- Simulation start and end date (“harvest”)
- Detailed soil profile data
- Detailed soil profile layer data
- Date rate, and type of N fertilizer applications
- Date and rate of irrigation applications
- Weather station information, including atmospheric CO_2 concentration
- Daily weather data (Tmax, Tmin, Tave, solar radiation, rain, average air vapor pressure, average relative humidity, average wind speed)

Data to setup the simulations are provided in an ICASA Excel format (‘**MARICOPA Wheat FACE data_2023-11-28 (ICASA data format v4.0).xlsx**’). Even if this data set has already been simulated with your framework, you need to check that all the inputs are the same as those provided in the Excel file provided for this exercise as some previously missing information have been added in this version of the data set. The weather data are those provided by Webber et al. (2018).

All the data and resources for this exercise are available in the directory [Soil temperature datasets/Maricopa wheat FACE]() of the AMEI Google Drive.

If some inputs are not provided, please do not estimate them but inform Pierre Martre (pierre.martre@inrae.fr) so that we can provide the same estimate to all the groups.

Provided observed data and model calibration

The following observed data are provided and can be used for model calibration.

In-season daily data (on specific days):
- Key phenological stages (crop emergence, pseudostem erect, flag leaf ligule just visible, anthesis, physiological maturity, harvest)
- Zadoks stages
- Leaf number per main stem and tiller number per plant
- Plant height
- Leaf area index (both lamina and stem)
- NDVI
- Incident, reflected, transmitted, and absorbed PAR (at noon)
- Soil layers moisture content (for the whole soil profile)
- Dry mass and N content of plant components (leaves, stems, crown, roots, chaff, and grains)
- Yield components (ear and grain number, grain dry mass)
- Canopy evapotranspiration
- Canopy temperature

In-season hourly data (continuous):
- energy balance components (canopy temperature, latent heat flux, soil heat flux, sensible heat flux, net radiation)
- Soil temperature at depth (at 1, 2, 5, 10, 20 and 40 cm below the soil surface) – data not provided

In-season instantaneous data (on specific days):
- Net $C0_2$ assimilation
- Stomatal conductance

Use the anthesis and maturity dates (and other phenological stages, Haun stage, final leaf number is relevant for your model) data to calibrate your phenology model. If you calibrate crop or soil parameters other than those directly related to phenology, please upload on NextCloud (see below) a file describing the calibration procedure you used and the list of parameters that you calibrated with their default and calibrated values.

The soil temperature models should not be calibrated (the soil temperature data are not provided).

Simulation protocol

- Set up simulations for the four years (four treatments per year) with the data provided in the Excel file '**MARICOPA Wheat FACE data_2023-11-28 (ICASA data format v4.0).xlsx**'.

- Setup your model with **5 cm thick soil layer for the whole soil profile** (0 to 210 cm) and **report the soil temperature, and soil N and water content for these soil layers**. Note that all soil temperature models but STICS calculate the temperature for the middle of the defined soil layers. STICS calculates the soil temperature at the bottom of 1 cm thick soil layers (defined inside the STICS soil temperature model).

- Simulate the four years independently (no continuous simulation).

- Execute the simulations for each of the 16 year / treatment combinations with the seven soil temperature models (**Table 1**) in your frameworks (soil-crop modeling solution, not your soil temperature model standalone/drive).

Simulation results format

- Use the template AMIE_template_ MaricopaWheatFACE _summary_output.txt to save your results for the summary variables simulated at the canopy or soil profile level. Variables to report are defined in the sheet "summary" of the Excel file AMEI_MaricopaWheatFACE_Key_reporting_variables.xlsx. Create a single summary per soil temperature model (i.e. each file should have 16 rows of data).

- Use the template AMIE_template_ MaricopaWheatFACE _daily_output.txt to save your results for the daily variables simulated at the canopy or soil profile level. Variables to report are defined in the sheet "daily" of the Excel file named AMEI_MaricopaWheatFACE_Key_reporting_variables.xlsx. Create one daily canopy/soil profile file for each year, treatment, soil and temperature model.

- Use the template AMIE_template_MaricopaWheatFACE_daily_soil_layers.txt to save your results for the daily variables simulated by soil layers. Variables to report are defined in the sheet "soil layers" of the Excel file named AMEI_MaricopaWheatFACE_Key_reporting_variables.xlsx. Create one daily soil layers file for each year, treatment, soil and temperature model.

- Report soil temperature and water content every 5 cm down to the bottom of the soil profile (i.e. 42 soil layers of 5 cm thickness from 0 to 2.10 m below the soil surface). **The soil surface temperature should be reported in the daily output file for variables at canopy or soil profile level.**

- Report daily results from sowing date to maturity date (end of grain filling).

- Do not leave blank lines after the last simulation day.

- File format should be **txt** with **tab delimiters**.

- If a model does not simulate an output enter "**na**" in that column (please do not use any other character string for missing values).

Naming of simulation result files

Please rename the template files using the following naming rule:

ModelCodeModelingFrameworkCodeSummaryMaricopaTreatID.txt

ModelCodeModelingFrameworkCodeDailyMaricopaTreatID.txt

ModelCodeModelingFrameworkCodeLayersMaricopaTreatID.txt

Example: DCSISummaryMaricopa901.txt, DCSIDailyMaricopa901.txt, DCSILayersMaricopa901.txt for the DSSAT soil temperature model (DS) executed in the SIMPLACE framework (SI) for the treatment ID 901 for the summary, daily at canopy or siol profile level, and daily soil layer simulated variables, respectively.

The 2-letters codes for the modeling frameworks and the soil temperature models are given in **Tables 1 and 2**, respectively. The 3-digit codes for the treatments are given in the **Table 3**.

Table 1. Name, 2-letters code, and modelers of the seven modeling frameworks participating in this exercise.

Modelling framework	Model 2-letter code	Team member
1. APSIM	AP	Dean Holzworth, Rogerio Cichota
2. BioMA	BI	Davide Fumagalli, Davide Fanchini
3. DSSAT	DC	Fabio Oliveira, Gerrit Hoogenboom
4. MONICA	MO	Michael Berg-Mohnicke
5. Simplace	SI	Andreas Enders
6. SiriusQuality	SQ	Teiki Raihauti, Pierre Martre
7. STICS	ST	Christophe Lecharpentier, Hélène Raynal

Table 2. Name and 2-letters code of the nine soil temperature models evaluated in this exercise.

Modelling framework	Model 2-letter code
1. APSIM-Campell	AP
2. BioMA-Parton-SWAT	PS
3. BioMA-SWAT	DS
4. DSSAT-EPIC	DE
5. DSSAT-ST	DS
6. MONICA	MO
7. Simplace-APEX	SA
8. SiriusQuality	SQ
9. STICS	ST

Table 3. Treatment numbers for identification with description of treatment.

Treatment ID	Weather station ID	Harvest year	Treatment name
901	MARA	1993	Dry-High_N-Ambient_CO2
902	MARA	1993	Wet-High_N-Ambient_CO2
903	MARC	1993	Dry-High_N-Elevated_CO2
904	MARC	1993	Wet-High_N-Elevated_CO2
905	MARA	1994	Dry-High_N-Ambient_CO2
906	MARA	1994	Wet-High_N-Ambient_CO2
907	MARC	1994	Dry-High_N-Elevated_CO2
908	MARC	1994	Wet-High_N-Elevated_CO2
909	MARB	1996	Wet-Low_N-Ambient_CO2
910	MARB	1996	Wet-High_N-Ambient_CO2
911	MARC	1996	Wet-Low_N-Elevated_CO2
912	MARC	1996	Wet-High_N-Elevated_CO2
913	MARB	1997	Wet-Low_N-Ambient_CO2
914	MARB	1997	Wet-High_N-Ambient_CO2
915	MARC	1997	Wet-Low_N-Elevated_CO2
916	MARC	1997	Wet-High_N-Elevated_CO2

All files can be downloaded from Google Drive at the following url:

https://drive.google.com/drive/folders/1JFSpI5u-WcnazJgrmJIqvS9PNeoCu6eU?usp=drive_link

Please do not distribute this URL outside the AMEI team.

Please upload your result files (1008 daily canopy/profile and daily soil layers and 63 summary files) by **18 October 2024** on the AMEI NextCloud space at https://nextcloud.inrae.fr/s/kx9KT5RMrKwZF9T (folder named “Maricopa Wheat FACE”) in the sub-folder named after your modeling framework.

Please **use the checklist below** (**Table 4**) before uploading your results on NextCloud to check the format is correct (file checking and interactions with modelers can take a lot of time).

Table 4. Checklist for the simulation result files.

		No	Yes
1.	In all file types, simulation results **start line 8**	☐	☐
2.	Summary files have **16 data rows**	☐	☐
3.	The daily files **first simulated day** correspond to the sowing date	☐	☐
4.	The daily files **last row corresponds to the day of maturity** (end of grain filling)	☐	☐
5.	Summary files have **32 columns**	☐	☐
6.	Daily canopy/soil profile level files have **34 columns**	☐	☐
7.	Daily soil layer profile level files have **11 columns**	☐	☐
8.	Dates (“Date”) are reported as **YYYY-MM-DD**	☐	☐
9.	The name of the framework in which the soil temperature model was executed (first column, “FRAMEWORK_ID”) is the **two-letter code** given in Table 1	☐	☐
10.	The soil temperature model names (second column, “MODEL_ID”) is the **two-letter code** given in Table 2	☐	☐
11.	The treatment names (third column, “TREAT_ED”) is the **three-digit code** given in Table 3	☐	☐
12.	Missing values are reported as “**na**”	☐	☐
13.	All values are within expected **ranges** and are in the expected **units**	☐	☐
14.	All files are in **txt format with tabs** as column delimiters	☐	☐
15.	The names of the 63 files for the summary variables follow the schema ModelCodeModelingFrameworkCodeSummaryMaricopaTreatID.txt	☐	☐
16.	The names of the 1008 files for the variables simulated at canopy level follow the schema ModelCodeModelingFrameworkCodeDailyMaricopaTreatID.txt	☐	☐
17.	The names of the 1008 files for the variables simulated at canopy level follow the schema ModelCodeModelingFrameworkCodeLayersMaricopaTreatID.txt t	☐	☐

References

Kimball BA, Pinter Jr PJ, LaMorte RL, Leavitt SW, Hunsaker DJ, Wall GW, Wechsung F, Wechsung G, Bloom AJ, White JW (2017) Data from the Arizona FACE (Free-Air CO_2 Enrichment) experiments on wheat at ample and limiting levels of water and nitrogen. Open Data Journal for Agricultural Research **3:** 29-38

Webber H, White JW, Kimball BA, Ewert F, Asseng S, Eyshi Rezaei E, Pinter Jr PJ, Hatfield JL, Reynolds MP, Ababaei B, Bindi M, Doltra J, Ferrise R, Kage H, Kassie BT, Kersebaum K-C, Luig A, Olesen JE, Semenov MA, Stratonovitch P, Ratjen AM, LaMorte RL, Leavitt SW, Hunsaker DJ, Wall GW, Martre P (2018) Physical robustness of canopy temperature models for crop heat stress simulation across environments and production conditions. Field Crops Research **216:** 75-88