GGCMI phase 2 CTWN protocol

This is the protocol for the GGCMI phase 2 CTWN study, which is based on the wiki page at https://ebi-forecast.igb.illinois.edu/ggcmi/projects/ggcmi/wiki/GGCMI_phase_2_CTWN_protocol, version #75.

For further updates please visit https://ebi-forecast.igb.illinois.edu/ggcmi/projects/ggcmi/wiki/GGCMI_phase_2_CTWN_protocol.

scientific rationale

The overall scientific rational is to conduct a comparative analysis of the strategies and mechanisms used in different models to describe CTWN processes, interactions, and feedbacks. This analysis framework builds on the AgMIP Coordinated Climate-Crop Modeling Project (C3MP; Ruane et al., 2013; McDermid et al., 2015) efforts to compare models, sites, and uncertainty and extends the concept now to global gridded simulations. This also provides a basis for comparison between grids and site-based networks.

- Enhanced understanding of how models work
- Characterizing models by sensitivity to drivers
  - Why is model XYZ more sensitive to precip than model ABC?
  - How does CO_2 affect sensitivity of yields to water limitation?
  - What are the nitrogen effects on sensitivity to CO_2 fertilization?
- Looking globally in different climate KG (Köppen-Geiger) regions

papers/analyses planned

This is a first list of planned analyses that helps to define the number of outputs needed to allow for analyses. People are very welcome to propose additional analyses and papers here and to get involved in the planning, structuring and scrutinizing of things listed here.

1. Key model analysis paper with modular decomposition This is an extra activity that requires much higher levels of commitment than the regular phase 2 simulations. See [[GGCMI phase 2 decomposition track]] (see #149)
   scoping team: Tom, Delphine
   Notes: decompose models, define simplest model for all components, see where models differ to understand differences and improve if performance of some are better. Opposed to Medlyn et al. 2015 paper, do not compare to observations, but just to understand differences. Consider CO2 effects as example of key topic to understand w/ decomp.

2. Response to weather extremes (driest year, hottest year) as function of N or CO2 (see #150)
   scoping team: Alex Ruane

3. Emulator (see #151)
   scoping team: ??

4. Derivatives (1st, 2nd) and discontinuities 1. (see #152)
   scoping team: Joshua

5. Adaptation paper (see #153)
   scoping team: Joshua
   notes: separate losses from growing season shortening from losses in productivity

6. Viability and crop switching analysis (see #154)
   scoping team: Delphine, Alex

7. N effects on yield variability (see #169)
   scoping team: Xuhui, Philippe

data

input data

We'll be using the [[AgMERRA data set from 1980-2010 as in phase 1]]. Groups that require data on long-wave radiation are asked to use the data from the Princeton GF (version 1, **not** PGFv2), see #4 and [[FAQ]]. If requested, we will provide disturbed T and P data, but generally ask modelers to find a simple implementation themselves. The easiest is to have the offsets in CTWN as scenario-specific parameters. Nitrogen and CO_2 are specified at globally uniform levels and will not be provided as spatially explicit data sets. Again, the implementation is left to the modelers, but scenario-specific parameters seem to be the way to go. Nitrogen fertilizer is to be applied in 2 doses, 50% at planting and 50% at a crop- and pixel specific date (40 days after planting for all spring crops, case-specific for winter wheat). All other sources of nitrogen supply (mineralization, fixation by soy) have to be reported in the outputs, no deposition or soil-only fixation should be applied.

output data

We're asking for much more than just yield data to really allow for deep understanding of model behavior.

Table 1: output variables requested. **S1**: highest priority, all models must submit these data per growing season; **S2**: second priority, please make available if at all possible. S1 variables are listed in **bold** letters in the first column.

Variable	variable name[11]	Priority extreme[12]	Priority emulate[12]	Priority derivs[12]	Priority adapt[12]	Priority viable[12]	Priority nitro[12]	Grouping	units
Yield	yield_<crop>	S1	S1	S1	S1	S1	S1	Productivity	t ha^{-1} yr^{-1} (dry matter)
Total above ground biomass yield	biom_<crop>	S1	S1		S1		S1	Productivity	t ha^{-1} yr^{-1}
Actual planting date	plant-day_<crop>	S1	S2		S1	S1	S2	Phenology	DOY
Anthesis date	anth-day_<crop>	S1			S1	S1		Phenology	days since planting
Maturity date	maty-day_<crop>	S1			S1	S1	S2	Phenology	days since planting
Applied irrigation water[13]	pirww_<crop>		S1		S1	S1	S1	Water balance	mm yr^{-1} (irr scenarios only)
Evapotranspiration (growing season sum)	etransp_<crop>	S1						Water balance	mm yr^{-1}
Transpiration (growing season sum)	transp_<crop>	S2			S2			Water balance	mm yr^{-1}
Evaporation (growing season sum)	evap_<crop>	S2			S2			Water balance	mm yr^{-1}
Runoff (total growing season sum, subsurface + surface)	runoff_<crop>	S2						Water balance	mm yr^{-1}
Total available soil moisture in root zone (growing season sum, basis for computing average soil moisture)	trzpah2o_<crop>	S2						Water balance	mm yr^{-1}
Total root biomass	*rootm_<crop>*	*S2*						*Productivity*	*t ha^{-1} yr^{-1}*
Total Nr uptake (total growing season sum)	tnrup_<crop>						S2	Nitrogen balance: uptake	kg ha^{-1} yr^{-1}
Total Nr inputs (total growing season sum)	tnrin_<crop>						S2	Nitrogen balance: inputs	kg ha^{-1} yr^{-1}
Total Nr losses (total growing season sum)	tnrloss_<crop>						S2	Nitrogen balance: losses	kg ha^{-1} yr^{-1}
GPP	gpp_<crop>	S2			S2		S2	Primary Production	gC m^{-2} yr^{-1}
NPP	npp_<crop>	S2			S2		S2	Primary Production	gC m^{-2} yr^{-1}
CO$_2$ response scaler on NPP	co2npp_<crop>	S2			S2			Primary Production	- {0..1}
water response scaler on NPP	h2onpp_<crop>	S2			S2			Primary Production	- {0..1}
temperature response scaler on NPP	Tnpp_<crop>	S2			S2			Primary Production	- {0..1}
Nr response scaler on NPP	nrnpp_<crop>				S2			Primary Production	- {0..1}
Other nutrient response scaler on NPP	ornpp_<crop>				S2			Primary Production	- {0..1}
CO$_2$ response scaler on transpiration	co2trans_<crop>	S2						Primary Production	- {0..1}
maximum stress response scaler	maxstress_<crop>	S2						Primary Production	- {0..1}
Maximum LAI	laimax_<crop>	S2			S2			Primary Production	m^2 m^{-2}

[11] <crop> refers to the 3-letter variable codes (wwh, swh, mai, ric, etc.) from [[phase 1 protocol Table 4]], with wheat (whe) split into winter wheat (wwh) and spring wheat (swh).

[12] paper leads, please indicate priorities for seasonal (S) resolution. 0:= not applicable, 1:=highest, 2:=second tier

[13] applied irrigation water is Potential Irrigation Water Withdrawal (PIrrWW) with the harmonized assumption of no losses during conveyance and application. It is different from Potential Irrigation water Use (PIrrUse), as the latter only includes fluxes of irrigation water to the atmosphere, while the applied water also includes water that remains in the soil or runs off (runoff). Only required for the infinity level of W dimension (fully irrigated)

file formats

Output data is to be submitted in the [[very similar format as defined for phase 1]], but with **4 important differences:**

   1. spring wheat (swh) and winter wheat (wwh) will be considered separate crops and will be reported separately, increasing the number of crops from 4 to 5

   2. the file naming convention will **include 5 extra specifiers for the CTWN and A settings**, see [[Table 2]] and the keyword *global* to allow for regional simulations as well

   3. **all variables are to be stored in individual NC4 files**, but we'll provide a central script for combining these to more aggregate combinations such as all T and W steps as additional dimensions to reduce the number of files for transfer and archiving. As such, all modelers do their standard postprocessing as we had it before and will then run the script to combine various sims (e.g. along the T and W dimensions) within one NC file.

   4. **all NC4 files must contain the global attributes "institution" and "contact"**

Simulations are to be done using the following GGCMI scenario configurations:

- rainfed, with full irrigation (using "perfect" irrigation event thresholds) as an extra element ("inf") in the W-dimension
- fullharm
- AgMERRA
- only for the [[5 priority 1 crops]], **NB** wheat will have to be split into winter wheat (wwh) and spring wheat (swh).
  - sowing dates and maturity dates will be supplied separately for wwh and swh

[model]_[climate]_[sim.scenario]_[variable]_[crop]_[global]_[timestep]_[start-year]_[endyear]_[C]_[T]_[W]_[N]_[A].nc4

Table 2: Filename conventions for standardized model outputs.

Filename tag []	Values
[model]	pdssat, pegasus, epic, lpjml, etc.
[climate]	agmerra
[sim.scenario]	fullharm
[variable]	yield, pirrww, plant-day, anth-day, etc.
[crop]	mai, soy, whe, ric
[timestep]	annual, daily
[start-year]_[end-year]	1980_2010
[C]	C280,C480,C680,C880
[T]	T-1, T0, T1, T2, T3, T4, T6
[W]	W-50,W-30,W-20,W-10,W0,W10,W20,W30,Winf[21]
[N]	N10,N60,N200
[A]	A0,A1

[21] inf is infinite, meaning full irrigation at the lowest thresholds for triggering irrigation (irrigation at every day at any level below full field capacity)

Example of the filename format:
        pdssat_agmerra_fullharm_mai_annual_1980_2010_C480_T0_W30_N60_A0.nc4

CTWN intervals

We consider 3 nitrogen, 4 atmospheric carbon dioxide, 7 temperature and 9 precipitation levels. The total 4-D cube thus has 3*4*7*9 = 756 levels.
The adaptation analysis will be a 5th dimension but with only 2 points, so the total maximum simulation set per model and crop is 3*4*7*9*2=1512 levels.

carbon dioxide

We'll only consider 4 levels of atmospheric carbon dioxide concentrations: 360, 500, 650 and 800ppm

temperature

We'll consider temperature changes in 1°C steps ranging from -1 to +6 degrees, skipping 5.

precipitation

Precipitation changes will be implemented in relative terms, ranging from -50 to +50 percent in 10% steps, skipping -40 and +40%, using full irrigation as replacement for +50%. Irrigation is to be perfect, i.e. soils should always be kept at field capacity (or above if there's not water logging damage)

nitrogen

We only consider 3 levels of nitrogen supply: 10, 60, and 200 kgN/ha, i.e. 1, 6, 20 gN/m2, eventually use *harmnon* as additional point. This reflects very low levels, medium and high levels of nitrogen inputs. Full N balance, i.e., all inputs in form of mineralization, deposition, biological N fixation, fertilizer and all losses in form of N2, N2O, NOx, leaching, volatilization, need to be reported at the minimum at the lump-sum level of all input and all losses.

- **All fertilizer N to be applied in 2 doses: 50% at planting, 50% on a crop- and pixel-specific day!** Data will be supplied for the 2nd fertilizer day. A simple rule with just a static number of days does not work well at least for winter crops and GDD-based rules would also require to harmonize across phenology models.
    - **All other nutrient stresses need to be disabled!**
    - **All other stresses but TW-related ones (e.g. Al, salinity, ...) need to be disabled!**
    - **No additional N inputs (e.g. atmospheric deposition) should be considered!**

adaptation

We define adaptation here strictly in terms of the growing season. Under the standard simulation set (A0), we assume that cultivar parameters are completely fixed at historical levels, including GDD parameters that control phenological transitions and season length. In the "full growing season adaptation" scenario (A1) we assume that GDD parameters are adjusted so that the average (over the 31 year simulation period) length of the growing season (in days) is the same (as closely as possible) in all scenarios. Modelers are asked to implement this themselves using whatever methods available (precalculating changes in GDD based on fixed temperature shifts or adjusting by iteration). For models that separate phenology into multiple stages (e.g. planting to anthesis-and-anthesis-to-maturity) modelers are asked to scale both parameters equally, so that the timing of intermediate stages such as anthesis stays more-or-less the same.

slicing the 4-D cube

Given the computational requirements of the 4-D data cube, we define 4 levels of participation, which may define the different levels of analysis that models can participate in (e.g. emulators may require some higher resolution as the basic level. **Ivy-league daily output delivery for the decomposition track, see [[GGCMI_phase2 decomposition track]], must not be at participation levels lower than one step than seasonal output delivery**. That is, if phase2 data is delivered at *total_high_tier*, daily outputs need to be delivered at least for *total_mid_tier*.
For the 12 CN combinations (3N*4C), the minimum level required is 4 settings, namely C280_N10, C280_N200, C680_N60, C880_N200, the larger setting is all 12.
For TW combinations, we have
- a minimum orthogonal 9-step setting, which will be based on some stratified
sampling (T-1W-10,T0W10,T1W-30,T2W-50,T2W20,T3W30,T4W0,T4Winf,T6W-20),
- a reduced set of alternating combinations, which uses different W for even Ts than for odd Ts. For even Ts (i.e. T0,T2,T4,T6), we use W = -40,-20,0,+30 = 4*4, for odd Ts (i.e. T1,T3,T5), we use W = -50,-10,+10,+30,inf = 3*5, that is we're not simulating W-30,
- and a full set (7T*9W).

participation levels

- total low tier = 4 x 9 = 36 [*2 for adaptation study]
- total mid tier = 4 x 31 = 124 [*2 for adaptation study]
- total high tier = 12 x 31 = 362 [*2 for adaptation study]
- total super tier = 3*4*7*9 = 756 [*2 for adaptation study]

pruning

To reduce the computational burden, we roughly cut out regions totally out of question. For this, we use a combination of unsuitable areas according to AEZ. There are a few cases, where (at the resolution of 0.5 degrees) the pixels is classified as dominantly unsuitable but the cropland masks assign cropland to these pixels. To ensure that all cropland currently used in the aggregation is also simulated by the groups, we exclude only pixels that are predominantly unsuitable (>=90%) and do not contain any cropland (according to MIRCA2000).
By pruning only out-of-question areas, simulation results (all crops everywhere) can be aggregated by any land-use pattern in subsequent analyses.

data transfer (I/O)

Data download/upload will be possible only via the globus online. See [[How to use the Ag-GRID globus archive]]

Shifted temperature and precipitation datasets are available for download at
https://www.globus.org/xfer/StartTransfer#origin=jelliott%23ggcmi/~/AgMIP.input/CTWN

Minimum cropland mask is available at
https://www.globus.org/xfer/StartTransfer#origin=jelliott%23ggcmi/~/AgMIP.input/CT
WN choose the file boolean_cropmask_ggcmi_phase2.nc4

Growing period data is available at
https://www.globus.org/xfer/StartTransfer#origin=jelliott%23ggcmi/~/AgMIP.input/other.inputs/AGMIP_GROWING_SEASON.HA
RM.v rsion1.25
please note: separate swh and wwh growing periods are not available yet and will be supplied ASAP

Fertilizer inputs are available at
https://www.globus.org/xfer/StartTransfer#origin=jelliott%23ggcmi/~/AgMIP.input/other.inputs/AGMIP_NUTRIENTS.HARM.versio
n1.1

The file specifying the 2nd fertilizer application date for wwh will be supplied ASAP and the location for download will be made
available then.

data processing pipeline

Data will not be preprocessed as in phase 1, but analyses will be supported with a script library to process data as needed. David
and James to be consulted about how that could look.

quality control

- any NEW (did not submit results for phase 1) modeling group that wants to participate in phase 2 will be asked to submit
ONLY the agmerra-fullharm simulation from phase 1 (which is the basis for the CTWN).
- we will do detailed evaluation and quality control on this data and once we are satisfied that the formats and data issues are
fine, we will ask the group to submit a full phase 2 dataset.
- we do NOT plan to do detailed quality control analysis on the phase 2 archive because we assume the groups have already
worked the kinks out of their data in phase 1. We will do a QC on the 4-zero sims (for which we need to prepare the scripts for the
new groups anyway) and will provide the scripts to modelers so that they can run the QC themselves.