GC45C-09: Machine learning emulators and empirical models combining climate and global crop models for seasonal agricultural production

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AGU Fall Meeting – Chicago – December 15th, 2022

Goddard Institute for Space Studies
New York, N.Y.

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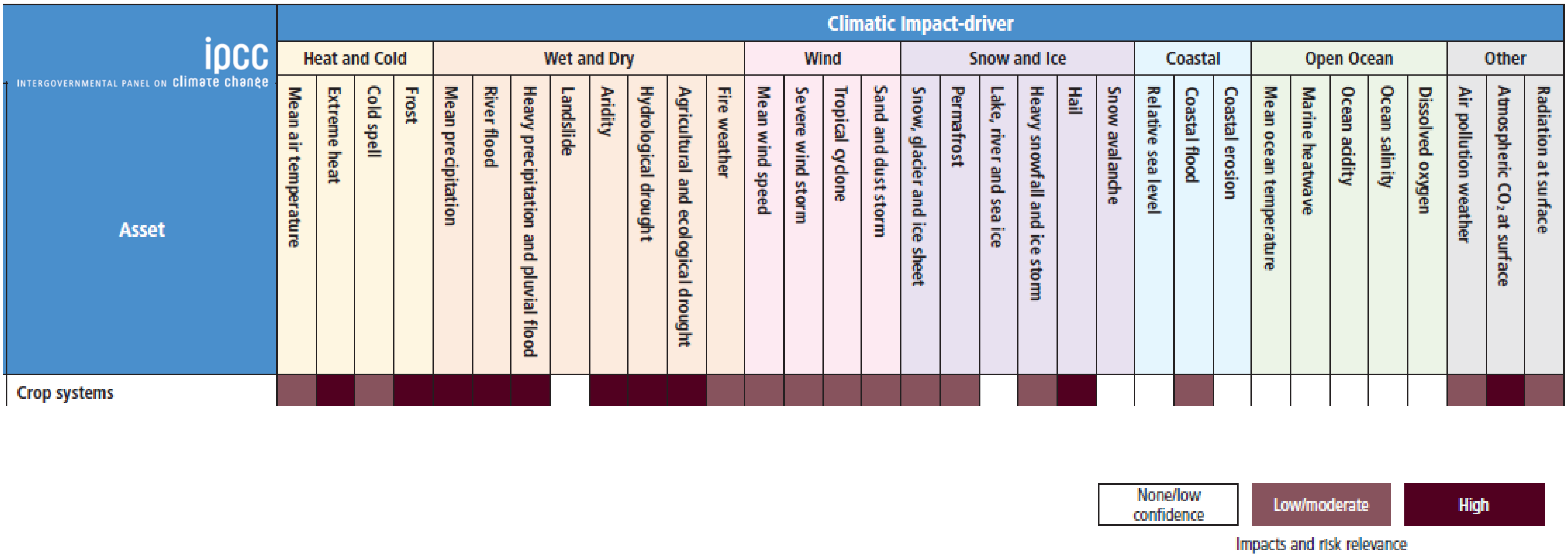
Climatic Impact-Drivers and Crop Modeling

CIDs identify the specific climatic conditions associated with biophysical responses:

Ruane et al., 2022: The Climatic Impact-Driver Framework – Earth's Future



Assessment of all impact sectors and climate changes in each region:

Ranasinghe et al., 2021: IPCC AR6 WGI Chapter 12

Synthesis outputs from AgMIP Global Gridded Crop Model Intercomparison using weather indices

GGCMI Phase 2 (Franke et al., 2020a,b):

- **12 models harmonized for planting date, fertilizers, cultivars**
- **Sensitivity tests across CO_2, Temperature, Water and Nitrogen**
  (+/- 1℃ tests with high N)
- **Maize, wheat, rice and soy; global 0.5˚ x 0.5˚ resolution; 30 years**

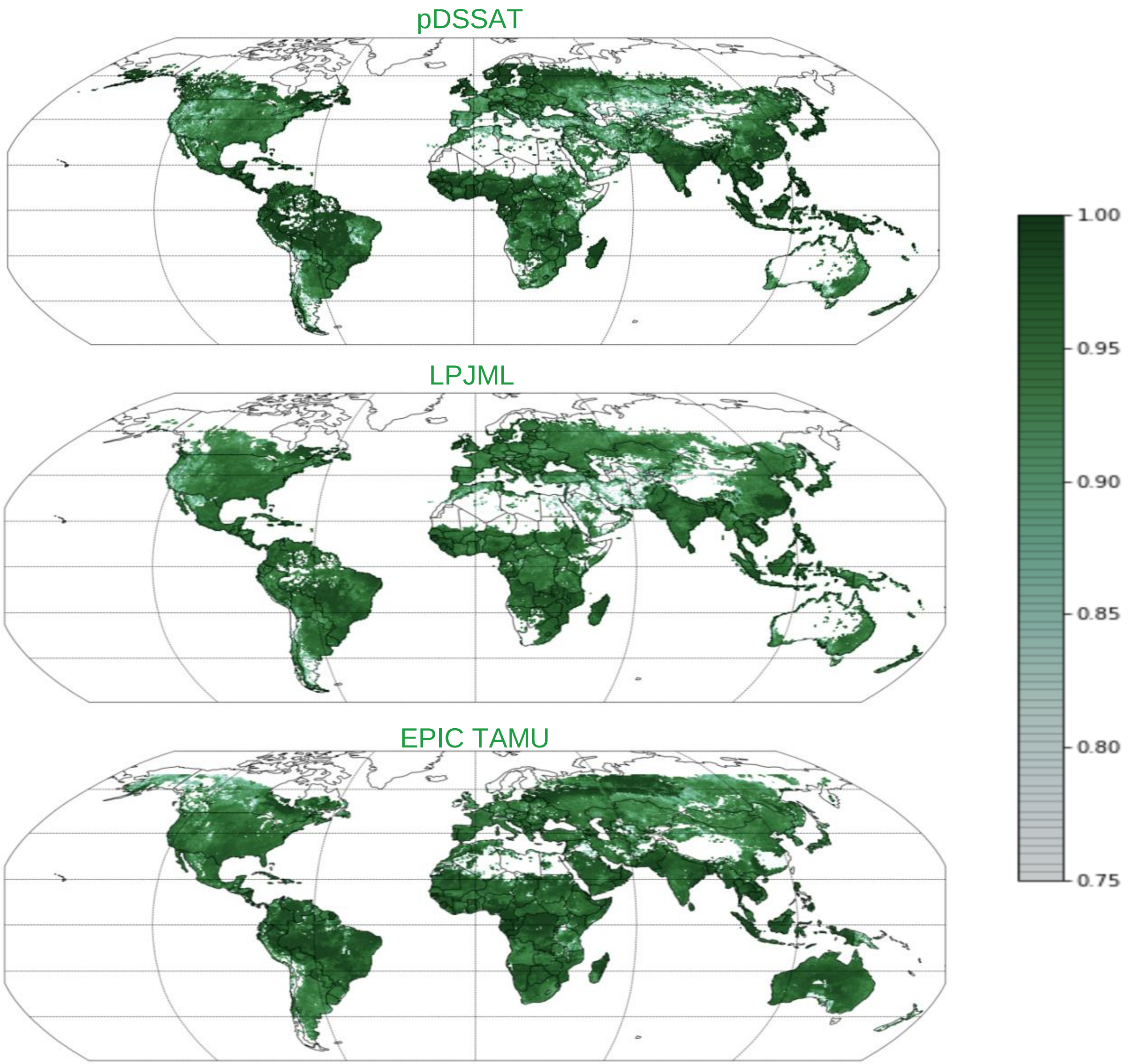
40 seasonal weather indices:

- **Mean temperature and precipitation**
- **High heat days (30℃ and 35℃) and cold day thresholds (5℃, 0℃)**
- **Number of rainy days, consecutive dry days**
- **5 growing season periods (full GS, planting, pre-anthesis, anthesis, post-anthesis)**

Extreme Gradient Boosting (XGBoost) Machine Learning model

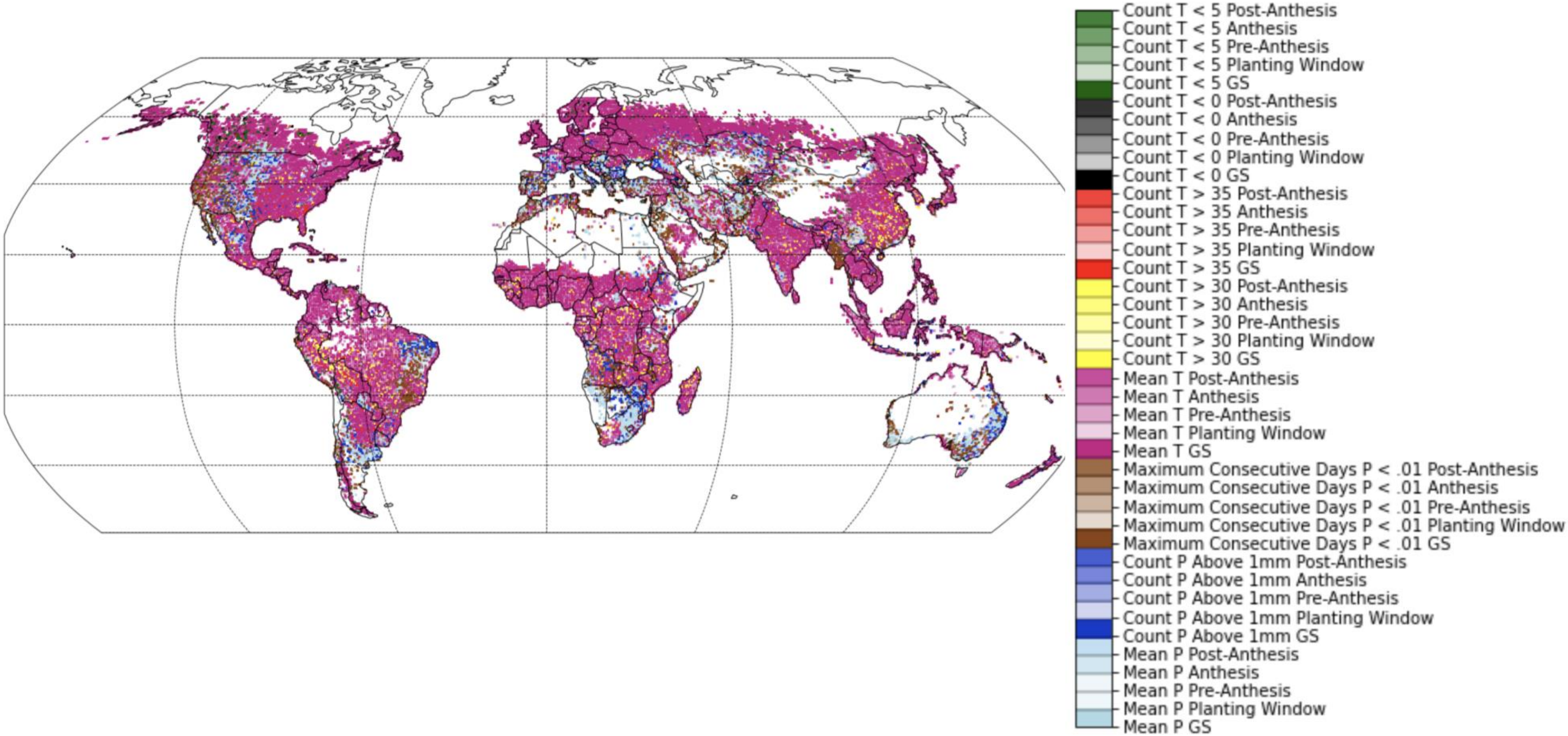
- **3 features targeting yield outputs independently at each grid cell**

Emulator Skill



R^2 vs. underlying GGCM
Rainfed Maize

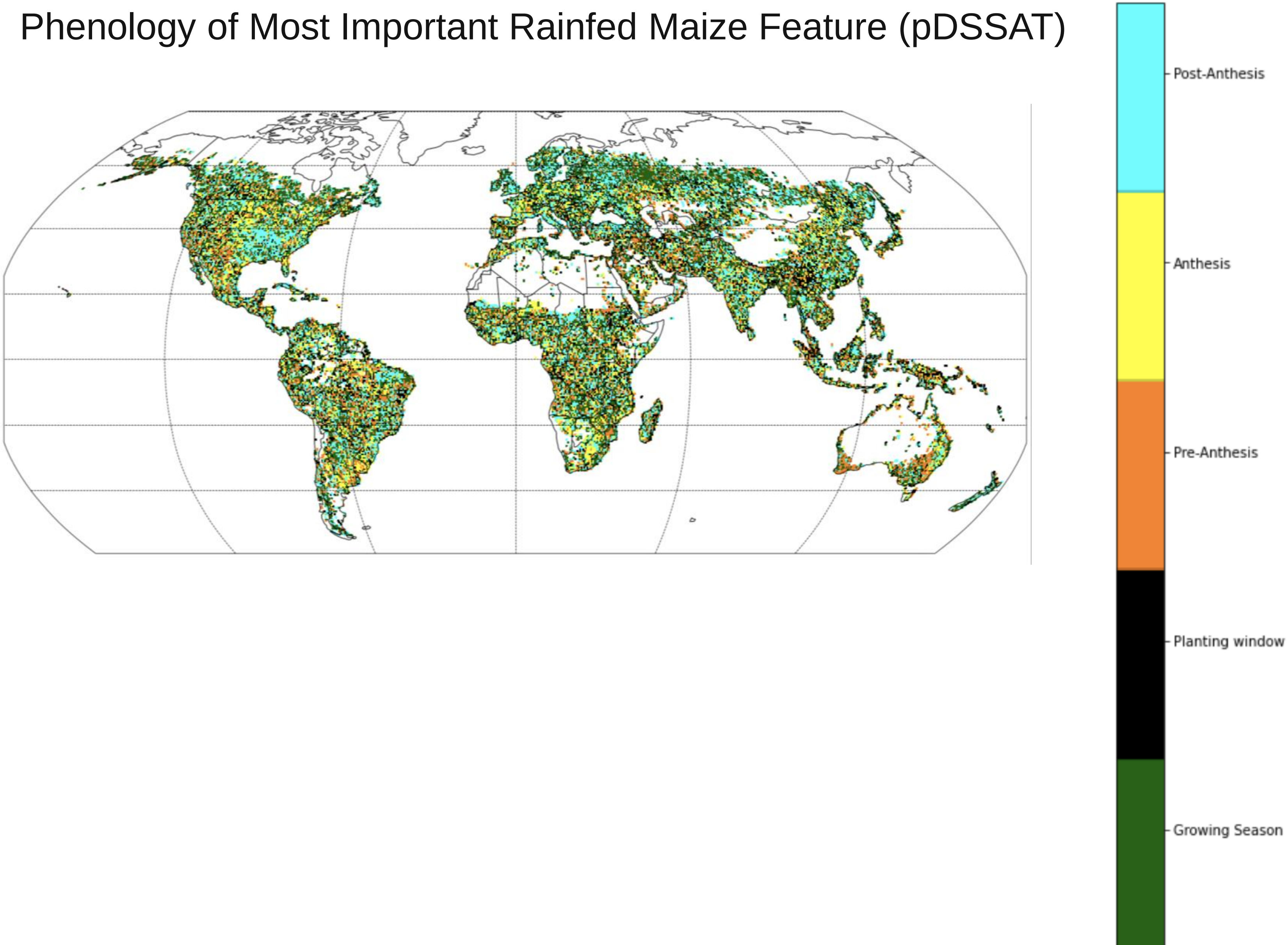
Most Important Rainfed Maize Feature (pDSSAT)



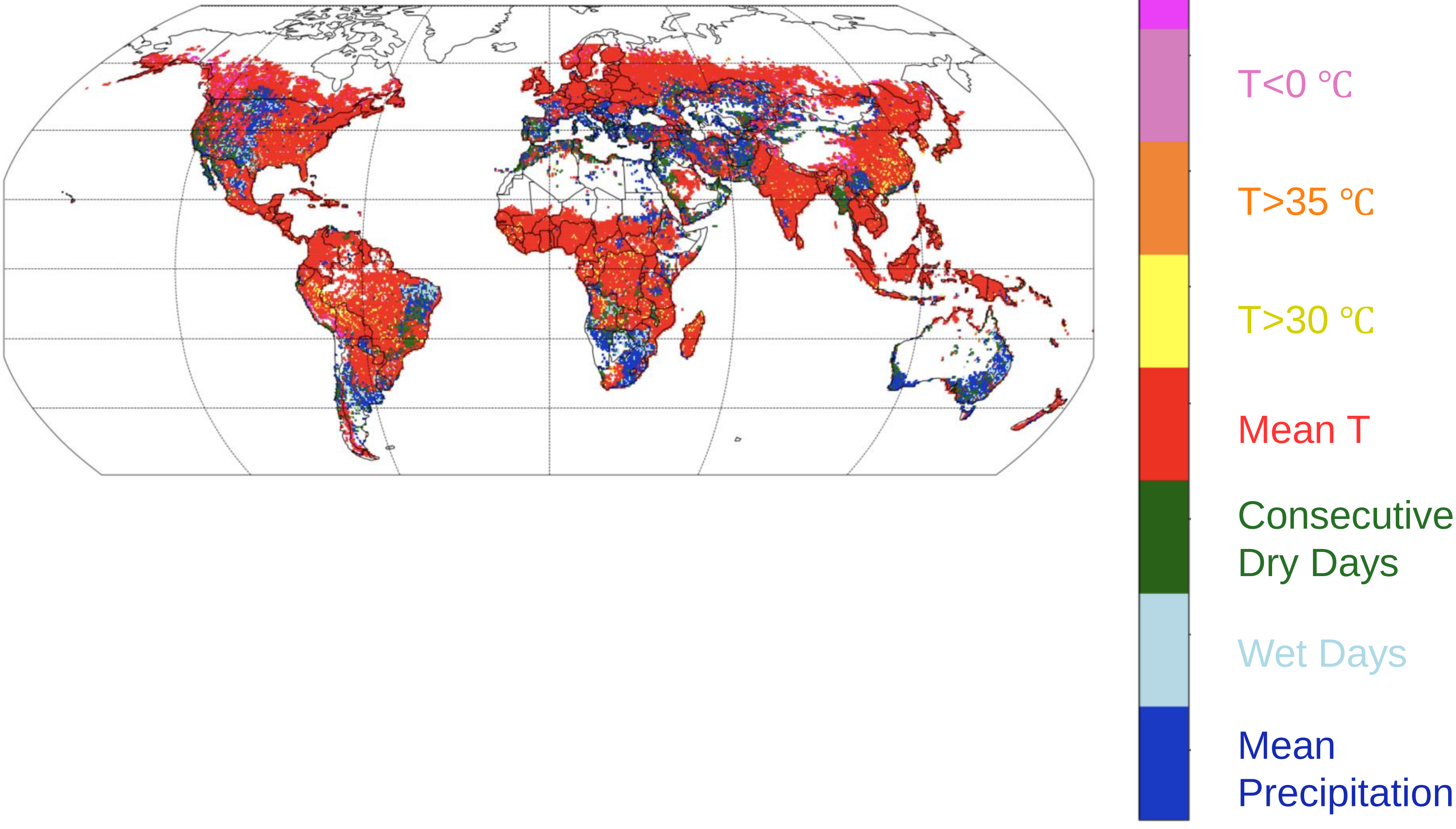
GGCMI Emulators

Seasonal Timing

Phenology of Most Important Rainfed Maize Feature (pDSSAT)



Most Important Rainfed Maize Variable (pDSSAT)



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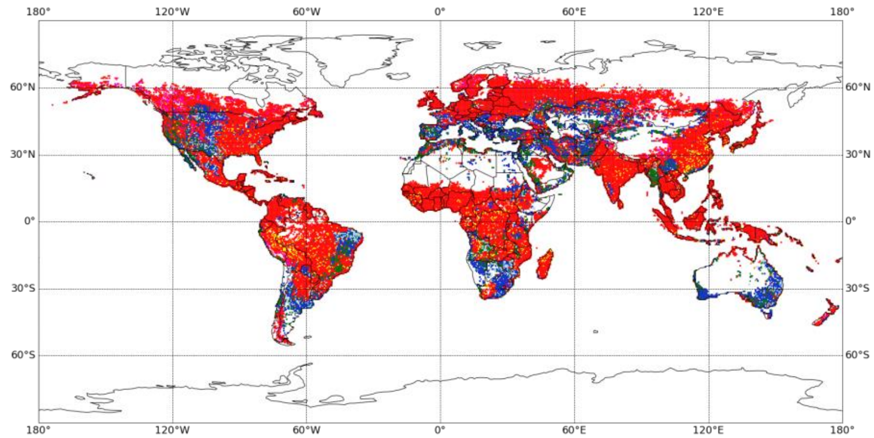
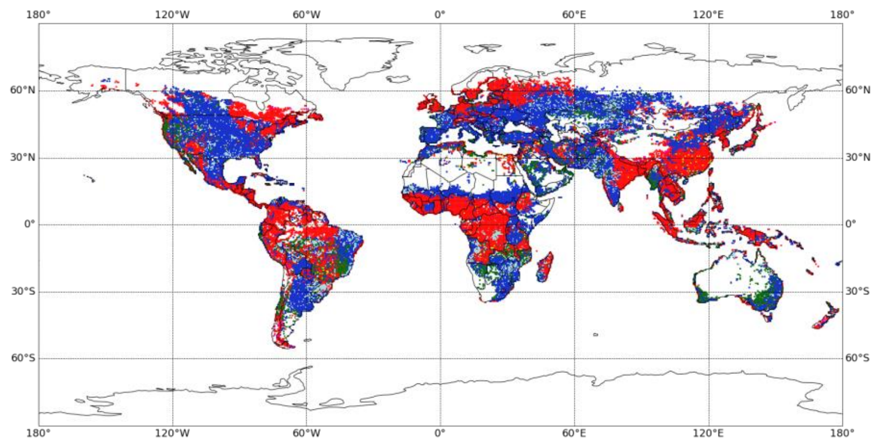
GGCMI Emulators

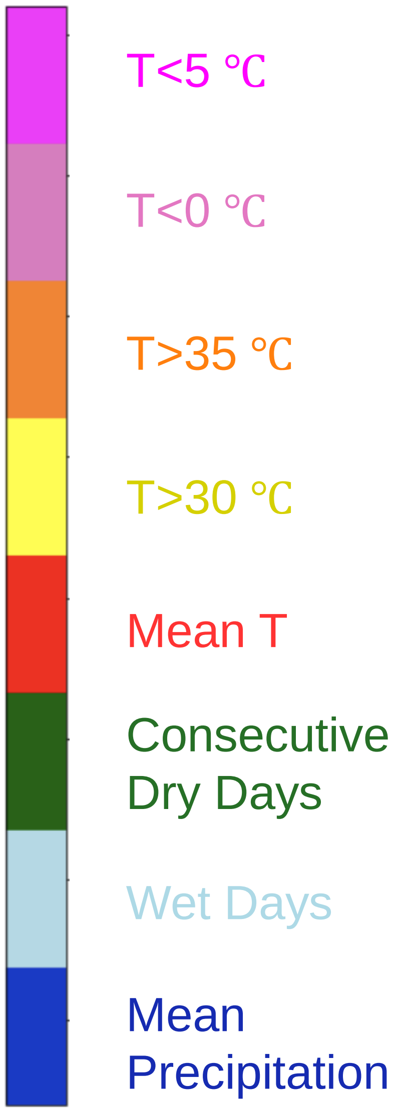
Model differences

pDSSAT Rainfed Maize top predictor variable:



LPJmL Rainfed Maize top predictor variable:

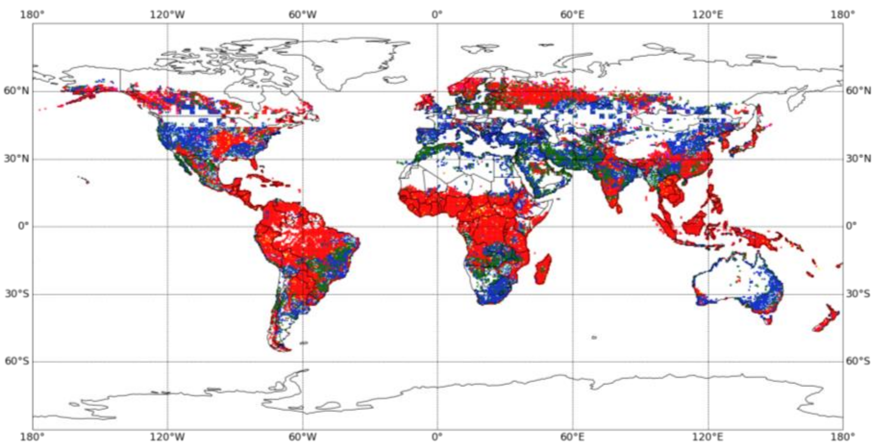




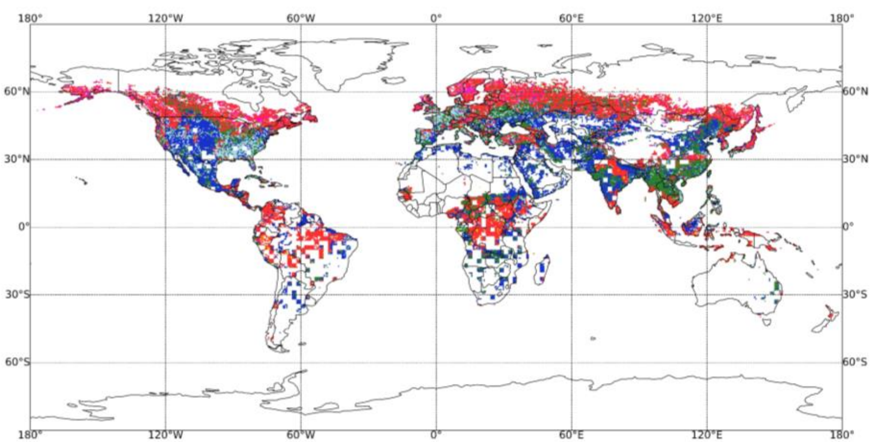
GGCMI Emulators

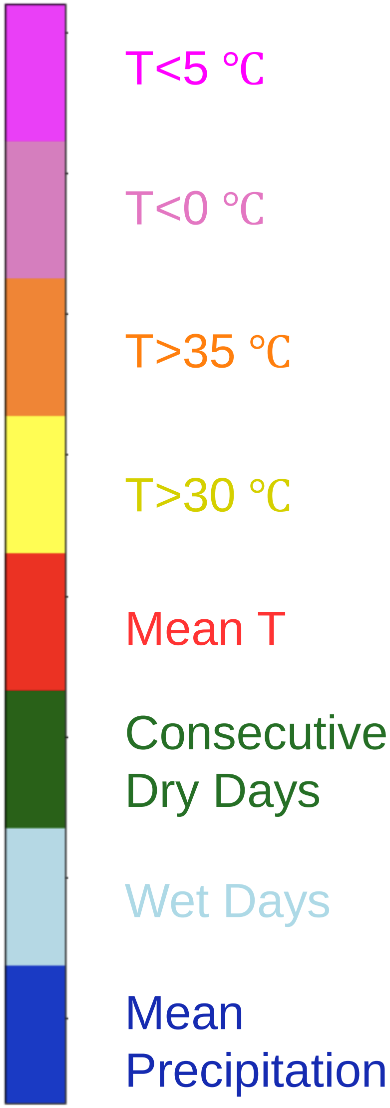
Crop Species differences

pDSSAT **Spring Wheat** top predictor variable:



pDSSAT **Winter Wheat** top predictor variable:





ML emulators can capture bulk of historical crop model simulations with as few as 3 climate variables

Leading predictor features vary across region, system and model

Results point to common climate drivers for regional responses

Models respond most strongly to mean climate conditions
- Likely underestimate role of extreme events

Outputs from AgMIP Global Gridded Crop Model Intercomparison compared against reported production

GGCMI Phase 3 (Jägermeyr et al., 2021) / ISIMIP Phase 3a:

- **10 harmonized GGCMs**
- **Maize, wheat, rice and soy; global 0.5˚ x 0.5˚ resolution**
- **1980-2100 (SSP1-2.6, SSP3-7.0, SSP5-8.5)**
- **Focus here on 1980-2010 period**

FAOStat Country-Level Production

- **Reports for top 20 producers for each crop species**

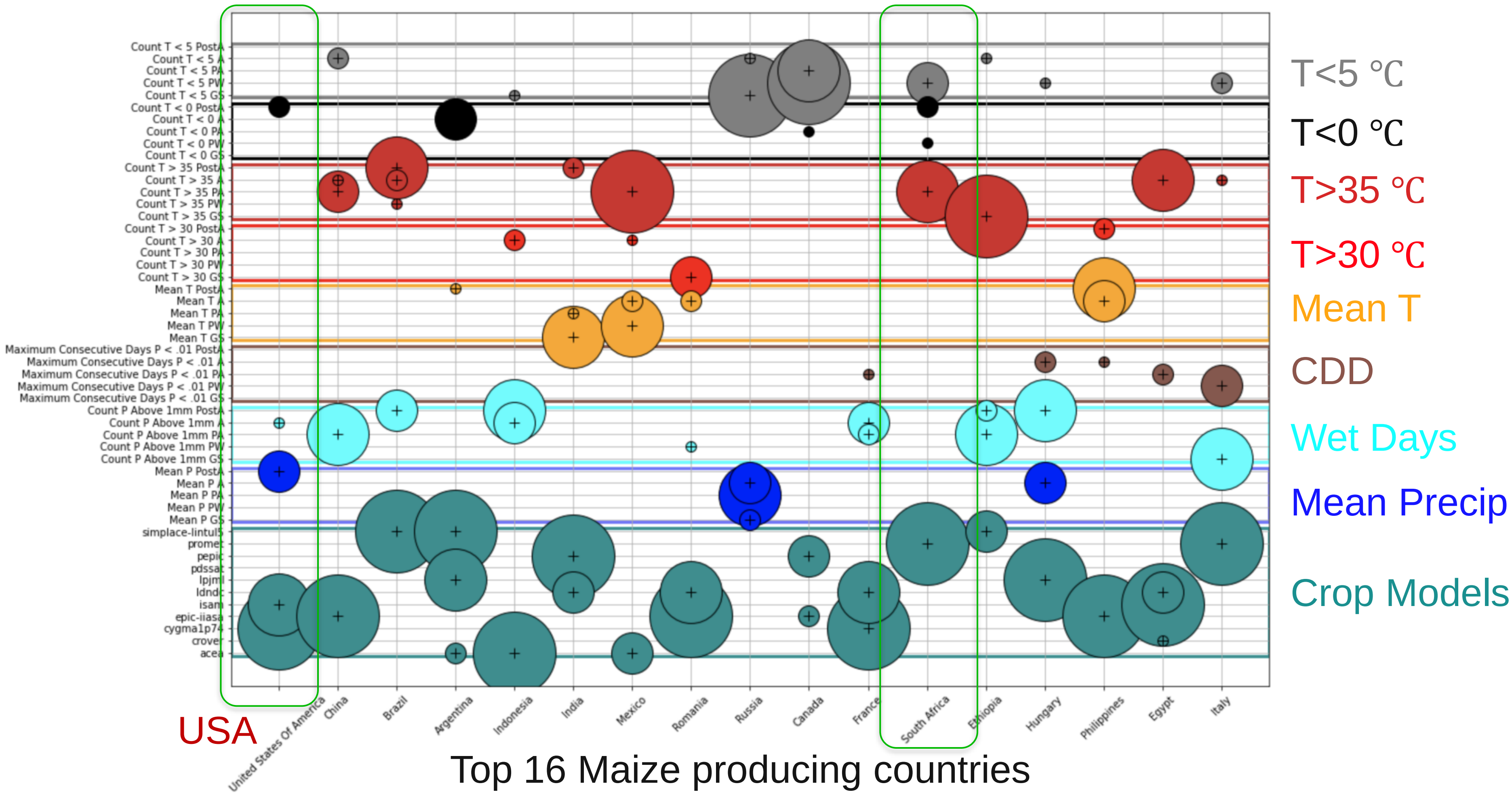
Extreme Gradient Boosting (XGBoost) Machine Learning model

- **5 features targeting yield outputs independently at each grid cell**
- **5-fold cross-validation**
- **40 climate variables** (8 variables x 5 seasonal timings)
- **10 GGCMs aggregated to country level**

Hybrid Weather and GGCM Models

Shedding new light on missing climate responses

5 feature model fit to FAO yields – size of circle represents prominence of features



Top 16 Maize producing countries

South Africa

Ruane and Castellano, in prep.

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Continuing Work

Models need enhanced cold and flood hazard responses

Agricultural decision support

- Seasonal detection and attribution
- Resilience planning and disaster risk reduction
- Suitability analysis for management and breeding approaches
- Climate change adaptation and risk management

Agricultural Model Intercomparison and Improvement Project (AgMIP) Machine Learning Team

- AgML launching soon!

Join us at AgMIP Town Hall Friday to learn more

Machine Learning Applications

- Determination of model parameters
- Crop model emulators
- Model diagnostics and improvement prioritization
- Hybrid model development and applications
- Combine with remote sensing and additional predictors

SAVE THE DATE!

9th AgMIP Global Workshop

June 26-30, 2023

Columbia University, New York, NY

Learn more at www.agmip.org

Thanks for your attention!

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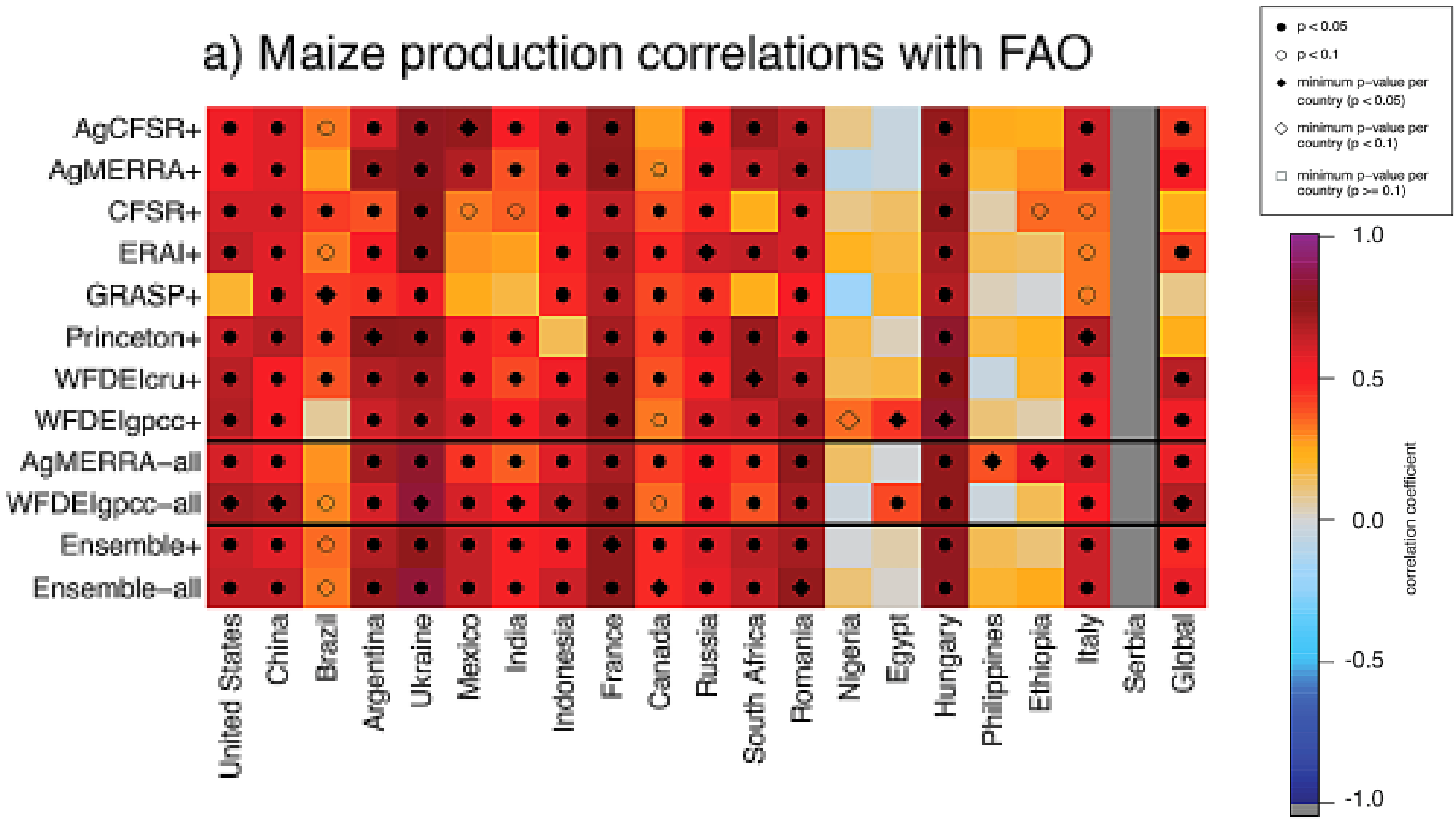
Model ensemble performance and climate information influence



Ruane et al., 2021 – Agricultural and Forest Meteorology