PUBLICATIONS AND DATA SETS

Lasher-Trapp, S., D. H. Moser, D. C. Leon, J. French, and A. M. Blyth, High Resolution Simulations of Cumulus Entrainment. *17th International Conference on Clouds and Precipitation*, Manchester, England, July 25-29, 2016.

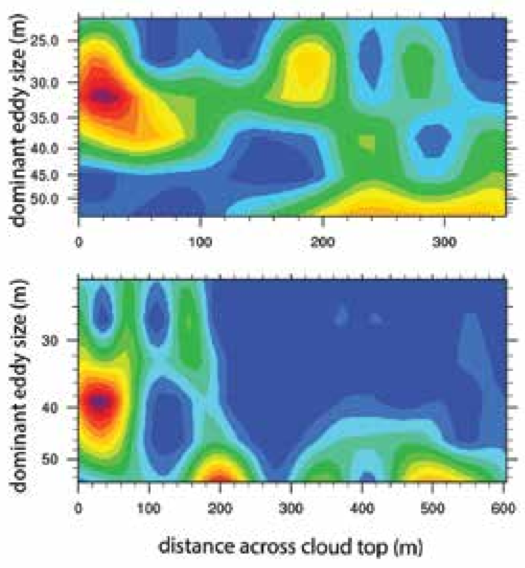

FIGURE 3: Examples of wavelet analysis performed from scans across the tops of two real cumulus clouds with an airborne cloud lidar. "Hot spots" (red) show areas where cloud top eddies of the size shown on the vertical axis are prevalent. This observational evidence thus warrants additional simulations at higher resolution to investigate if these smaller eddies contribute significantly to entrainment.

FORECASTING GLOBAL CROP PRODUCTIVITY USING NOVEL SATELLITE DATA AND PROCESS-BASED MODELS

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EXECUTIVE SUMMARY

The ultimate goal of this project is to improve predictability for global crop yield by integrating site measurements, advanced remote sensing observation, and process-based modeling. We took our first step forward by focusing on the high-temperature impacts on corn/soybean yield in the U.S. Corn Belt. Different pathways of high-temperature impacts on crop yield are considered in our newly developed CLM-APSIM modeling framework, which combines the strengths of earth system model and agronomy crop models. We are conducting parameter sensitivity analysis and optimization as well as a set of historical simulation experiments aimed at disentangling the contribution of different mechanisms to high-temperature impacts on crop yield. Projection runs will also be conducted shortly to explore the impact of high temperatures on crop yield under various climate change scenarios.

INTRODUCTION

Temperatures over the terrestrial areas of the planet are expected to increase at least twice the global average, with specific regions experiencing increases of between 3-4°C by the mid-2000s. With this expected climate change scenario, high temperature can severely affect crop productivity through different pathways. Individual processes have been well studied, but mostly in isolation, prompting a need for a holistic approach to quantify different processes at one time and in actual environments. Furthermore, when projecting future high-temperature impact on crop productivity under climate change, instead of lumping all effects into a single regression coefficient as done in most previous statistical studies, we should explicitly simulate different processes in a process-based manner which makes designing detailed climate change adaptation strategies for agriculture systems achievable.

Corn and soybean are the two most widely planted crops in the U.S., with planted acreage of 92.9 and 74.8 million acres in 2012. The U.S. produces about 40% of the global corn and soybean crops. Understanding the mechanisms of corn/soybean response to abiotic stresses and providing possible breeding priority for improved varieties has critical significance for the U.S. agricultural economy and also for individual farmers.

METHODS & RESULTS

In this study, we aim to quantify various processes of high-temperature impacts on corn/soybean yield at various scales. Specifically, we consider the following major processes: (1) direct temperature effects on photosynthesis and respiration; (2) sped-up growth rate and the shortening of growing season; (3) heat stress during reproductive stage (flowering and grain-filling); (4) high-temperature-induced increase of atmospheric water demands. By combing the strength of the Community Land Model (CLM) in modeling surface hydrology and photosynthesis and that of the Agricultural Production Systems sIMulator (APSIM) in modeling crop phenology, the newly developed CLM-APSIM crop modeling framework enables us diagnose the effect of high temperature stress through different processes on various crop phonology stages.

First, ground measurements obtained from the advanced SoyFACE facility at the University of Illinois at Urbana-Champaign are used to validate, tune, and improve the CLM-APSIM modeling framework at the site level. Second, parameter screening and sensitivity analysis (SA) experiments are conducted at the local site scale. We use the Sobol sensitivity analysis, which is a global SA method that decomposes the variance of the model output into contributions from each parameter. It's interactions with other parameters through tens of thousands of ensemble simulations of the CLM-APSIM model following the improved Monte Carlo scheme. Third, we calibrate the CLM-APSIM model at grid scale across U.S. through model-data fusion or data assimilation techniques. Novel satellite data, such as fluorescence from OCO-2, soil moisture from SMAP, backscattering information from RapidSCAT, will be used to constrain the CLM-APSIM model at grid scale. We finally use the CLM-APSIM modeling framework to project crop yield for the whole U.S. Corn Belt under different baseline climate scenarios (efficient versus business-as-usual ones).

WHY BLUE WATERS

The computational demand of our satellite data interpretation and modeling effort is huge (~5PB storage for satellite/model inputs and outputs) and the Blue Waters facility offers us the best solution for large processing element demands, high-frequency I/O, and output post-processing and visualization. Interactions with the system staff and those in NCSA lead to a strong technical support for our project.

NEXT GENERATION WORK

As described above, the ultimate goal of this project is to improve the forecasting skill of global crop yield under climate change, though we just focused on U.S. Corn Belt at present. We plan to extend our modeling work to the whole globe on a possible next-generation Track-1 system in the 2019-2020 timeframe. The global scale research is essential as climate change-induced temperature increasing has been diagnosed everywhere across the global terrestrial areas. Understanding the high-temperature impacts on crop yield at the global scale will be helpful to the world's food security and agriculture economy.