Integrative Hydrometeorological Applications with Precipitation, Soil Moisture, and Water Vapor using Phone Apps, GIS, and Data Assimilation

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OGALLALAWATER.ORG OPTIMIZING WATER USE TO SUSTAIN FOOD SYSTEMS

1. Introduction

A group of unique integrative hydrometeorological applications are in development and use at Colorado State University (CSU). Advances in the use of these systems are leading toward additional system applications by local communities. These communities include:

1) **Local Colorado Farmers** via the USDA-NIFA Ogallala Water Coordinated Agricultural Project (OWCAP) with a cloud-based irrigation scheduler application and a new data management portal, and via the Foundation for Food and Agriculture Research (FFAR).
2) **National Weather Service (NWS) Forecasters** via blended rainfall, total precipitable water, and layered water vapor products for operational heavy rain forecasts and user impacts,
3) **US Army Engineers** that require estimates of soil moisture and soil strength for trafficability and mobility, including the abiotic context for biological environmental health issues, and
4) **Several other complex multi-partner collaborations**.

The broader collaborations range from community health improvements focused on multi-agency/organization human-centric issues **(via the CSU One Health Institute),** the **International Phytobiome Initiative** which evaluates plant health in the context of its full environment, and the **CSU Terraforma effort** that links animal-plant-soil pathogens in a controlled and testable environmental context in collaboration with the **CSU Infectious Disease Research Center (IDRC)**. These applications serve as a development guide for enabling technologies such as GIS for identification of human-animal-plant linkages, exploration of possible disease pathways, and communication and notification of community "events" as they occur. The system applications are research quality with operational scaling capabilities. Method development makes use of machine learning and data assimilation to optimize system resources and states, and to identify changes as they occur within a rich multi-level organizational network. These integrative hydrometeorological application frameworks are a necessary step toward exploring multi-party event-based systems that will dynamically interact with and benefit our future communities.

In this poster, we highlight several key examples and note that the rapid application integration using the CSU-developed software frameworks continue to show immense promise and utility. We have planned a series of key partnering symposia and summits across our Rocky Mountain region impacting aquifer water use, comprehensive economic ag/food system policy design, plant/ag environmental health, Rural/Urban agriculture interactions, and community health, more generally speaking. We seek partners for the utilization of hydrometeorological applications to expand the impact of these integrative systems from our region to the global scale.

2. Introduction to the CIRA Data Assimilation Testbed (CDAT) - http://cdat.cira.colostate.edu

Please see the CDAT web site for details

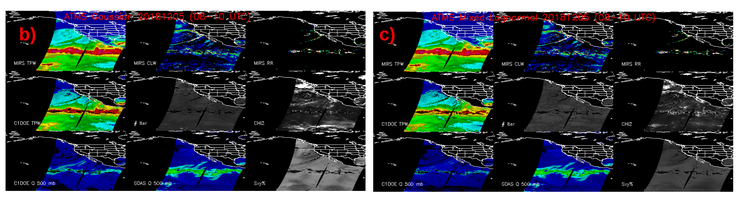

Figure 1: Near real-time results from the Suomi-National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (SNPP) Advanced Technology Microwave Sounder (ATMS) using (a) Transform Approach (b) Gaussian, and (c) Mixed-Lognormal C1DOE 1DVAR results for 5 December. You can see more results at: http://cdat.cira.colostate.edu/C1DOE_Graphics/C1DOE_Main.htm .

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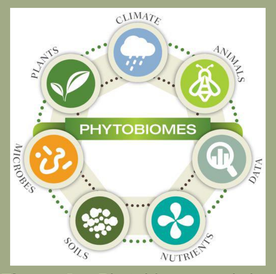
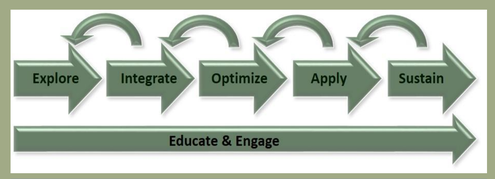
2. Connecting the Phytobiome to Improve Crop Health – Water/Climate and Crops are Integral System Components





COMING SOON!: International Phytobiome Conference, Denver, CO Dec. 1-4, 2020
https://phytobiomesconference.org/

Figure 2: Phytobiome work by its nature is transdisciplinary, comprehensive, and extensive: "a true team effort". Components are naturally conditionally dependent upon each other.

The **Phytobiome** links the entire plant ecosystem: top-to-bottom and inside-out, including transient visitors, long-term members, genetic materials, microbial communities, nutrient interactions, and their impact and use of management controls (e.g., such as tillage and irrigation practices) on the sustainability and inherent properties of the Phytobiome communities (for good or bad). **Understanding how Phytobiomes work and interact at all multi-scales is a critical need in our efforts to substantially enhance global food production levels while improving complex management decision capabilities.**

The **Phytobiome Initiative** (http://www.phytobiomes.org/Pages/default.aspx) is an exciting young community in a field that will rapidly transform agriculture as we know it. In particular there are several new coordinating activities:

1. The **Phytobiome Roadmap** explains the context and vision
2. A new ***APS Phytobiome Journal*** is sharing our new results
3. Industry, Universities, Govt., and Foundations working together within the **Phytobiome Alliance** that facilitates interactions and coordinating strategies

3. The Ogallala Water CAP Project Spatial Domain, the Wheat Supply Chain and the WISE Irrigation Scheduling Tool Data Flow

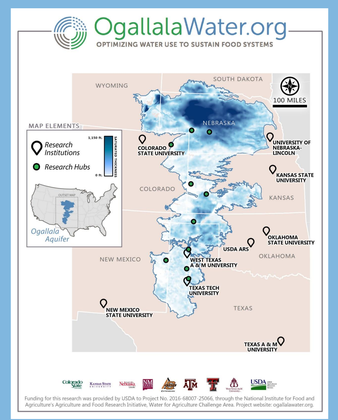


Figure 3: The OWCAP team consists of 9 partners in the High Plains region. Combined efforts and integration of complex hydrologic and agroeconomic systems, improve the management, education, and outreach for the Ogallala Aquifer Region.

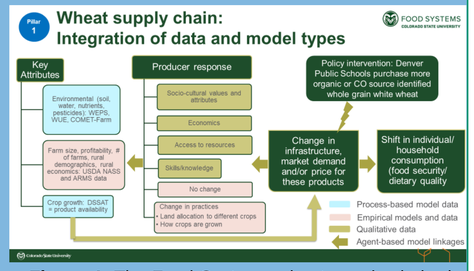


Figure 4: The Food Systems wheat supply chain is one of many tracked food systems supply chains that link the environment to agricultural practices and proposed food policies. This chart is from our USDA FFAR project. We track environmental data linkages to crop decisions and food system impacts via GIS-based systems using linked agent-based modeling and the CSU CSIP integrated framework.

Additional examples for irrigation decisions using the CSU WISE phone application are also available (see also Andales et al. 2014 and Jones et al., 2019a, 2019b) In that work we use predictive model precipitation data and data assimilation adjoint methods for soil depth-dependent moisture recharge.

4. The WISE Irrigation Scheduling Tool and the CSU CSIP/eRAMS Integrated Framework

US agricultural and Govt. lands have a unique co-dependent relationship, particularly in the Western US. More than 30% of all irrigated US agricultural output comes from lands sustained by the Ogallala Aquifer in the western Great Plains. Our USDA-NIFA funded Ogallala Aquifer Coordinated Agricultural Projects (OWCAP) team (see http://www.ogallalawater.org/) is **enhancing crop irrigation decision tools with predictive weather and remote sensing data to better manage water for irrigated crops within these important regions** (Jones et al., 2019a; 2019b). An integrated multi-model software framework is used to link irrigation decision tools, resulting in positive management benefits on natural water resources. Teams and teams-of-teams can build upon these multi-disciplinary multi-faceted modeling capabilities. For example, in addition to the OWCAP team, the CSU Catalyst for Innovative Partnerships program has formed a new transdisciplinary team that will address "Rural Wealth Creation" focusing on the many integrated links between economic, agricultural production and management, natural resource availabilities, and key social aspects of govt. policy recommendations. By enhancing tools like these with predictive weather and other related data (like in situ measurements, hydrologic models, remotely sensed data sets, and (in the near future) linking to agro-economic and life cycle assessment models) this work demonstrates an integrated data-driven future vision of inter-meshed dynamic systems that can address challenging multi-system problems.The CSU Water Irrigation Scheduler for Efficient (WISE) Application tool (Andales et al., 2014) makes use of a novel integrated and scalable cloud-based software framework, to link predictive weather information to crop and irrigation scheduling applications and other decision support tools such as WISE. WISE (see http://wise.colostate.edu/) was created by researchers at CSU in cooperation with growers throughout Colorado. The goal of WISE is to make recommendations for convenient and cost-effective irrigation scheduling to maximize crop yield and minimize water stress or excess irrigation. Currently, there are 329 WISE users and 810 active WISE projects. This work also demonstrates the linkages between crop health and water/climate feedbacks which are being explored in the Phytobiome Initiative (http://www.phytobiomes.org).

As we link these predicted irrigation-tied crop impacts to economic models, via crop production models and other applications used by the CSU science teams, the long-term data assimilation and predictive uncertainty quantification is an increasingly important inter-process analysis requirement of those transdisciplinary research activities. This work creates a vibrant test environment for linking weather and climate to the complex Phytobiome, One Health, and Ogallala Aquifer systems.

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