Advancing Drought Monitoring using a Small Unmanned Aerial System for Conjunctive Water Management in a Changing Climate

Jae Ryu (1) and Jungjin Kim (2)

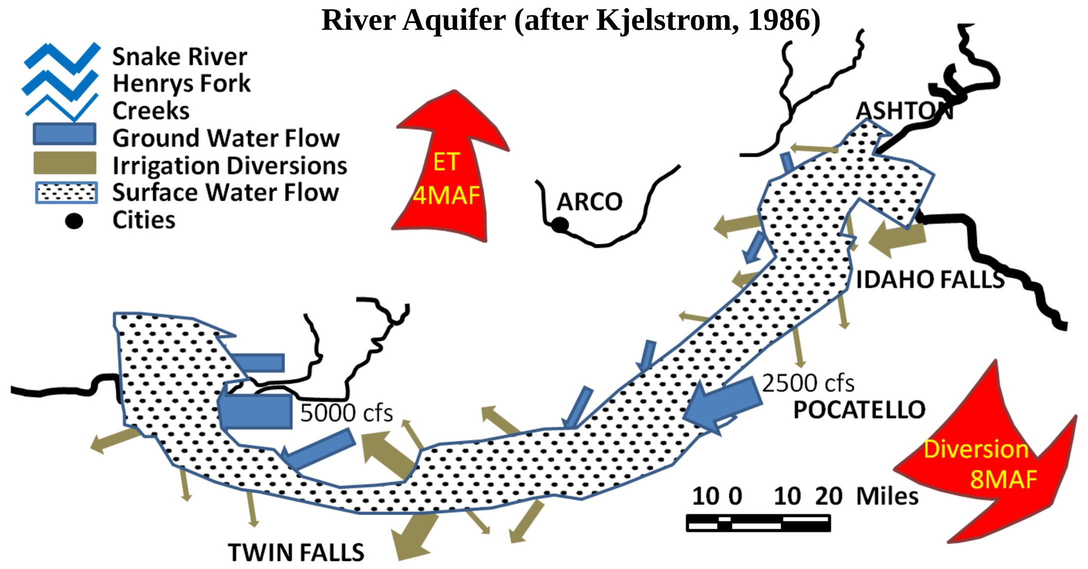
(1) Associate Professor, Department of Biological and Agricultural Engineering, University of Idaho, Boise, Idaho (jryu@uidaho.edu); (2) Graduate Research Assistant, Department of Biological and Agricultural Engineering, University of Idaho, Moscow, Idaho (kim5392@vandals.uidaho.edu)

Introduction

Climate variability, weather extremes and climate change continue to threaten the sustainability of water resources in the western United States. Given current climate change projections, increasing temperature is likely to modify the timing, form, and intensity of precipitation events, which consequently affect regional and local hydrologic cycles. As a result, drought, water shortage, and subsequent water conflicts may become an increasing threat in monotone hydrologic systems in arid lands, such as the Eastern Snake Plain Aquifer (ESPA). The ESPA, in particular, is a critical asset in the state of Idaho. It is known as the economic lifeblood for more than half of Idaho's population so that water resources availability and aquifer management due to climate change is of great interest, especially over the next few decades. In this study, we apply a small unmanned system (sUAS) to advance drought monitoring and outlooks so that planners and end users can more effectively manage and meter out limited water resources.

Water Resources Dynamics in ESPA

Recharge/Discharge in the Eastern Snake River Aquifer (after Kjelstrom, 1986)



Recharge to ESPA

SW Irrigation = seepage of surface water irrigation (Diversion – Returns + Precipitation – Evapotranspiration); Positive unit when recharge to the aquifer occurs and negative unit when discharge from the aquifer occurs.

Tributary Inflow = underflow from tributary drainage basins.

Precipitation = infiltration of precipitation.

Stream and River Losses = Non-Snake river losses.

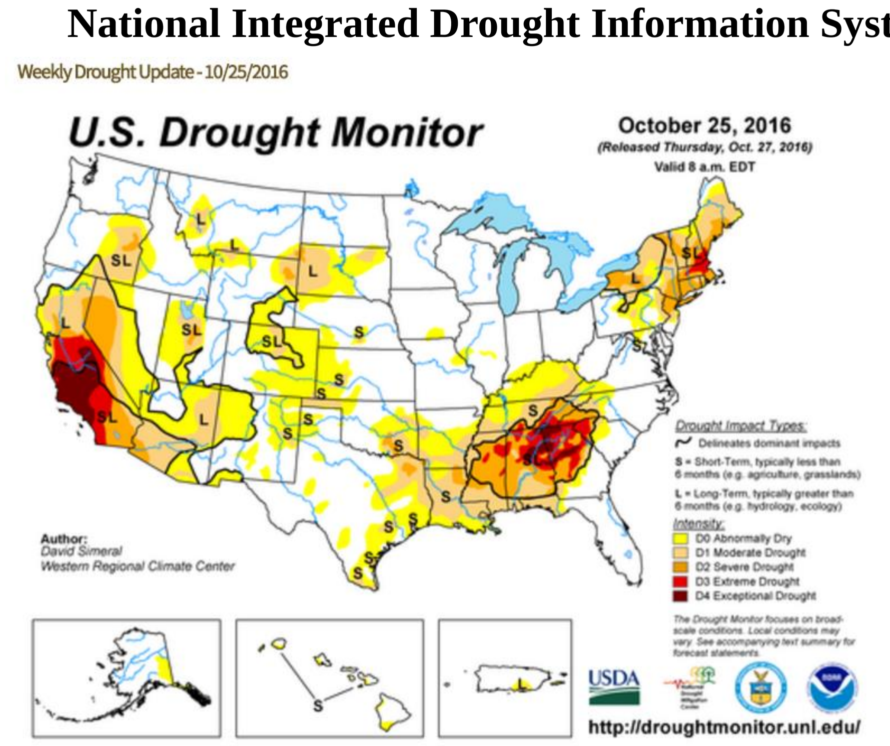
Canal Losses = seepage from irrigation canal.

Discharge from ESPA

River Gains = spring flow to Snake River.

Pumpage = water pumped from ground for irrigation.

National Integrated Drought Information System (NIDIS)

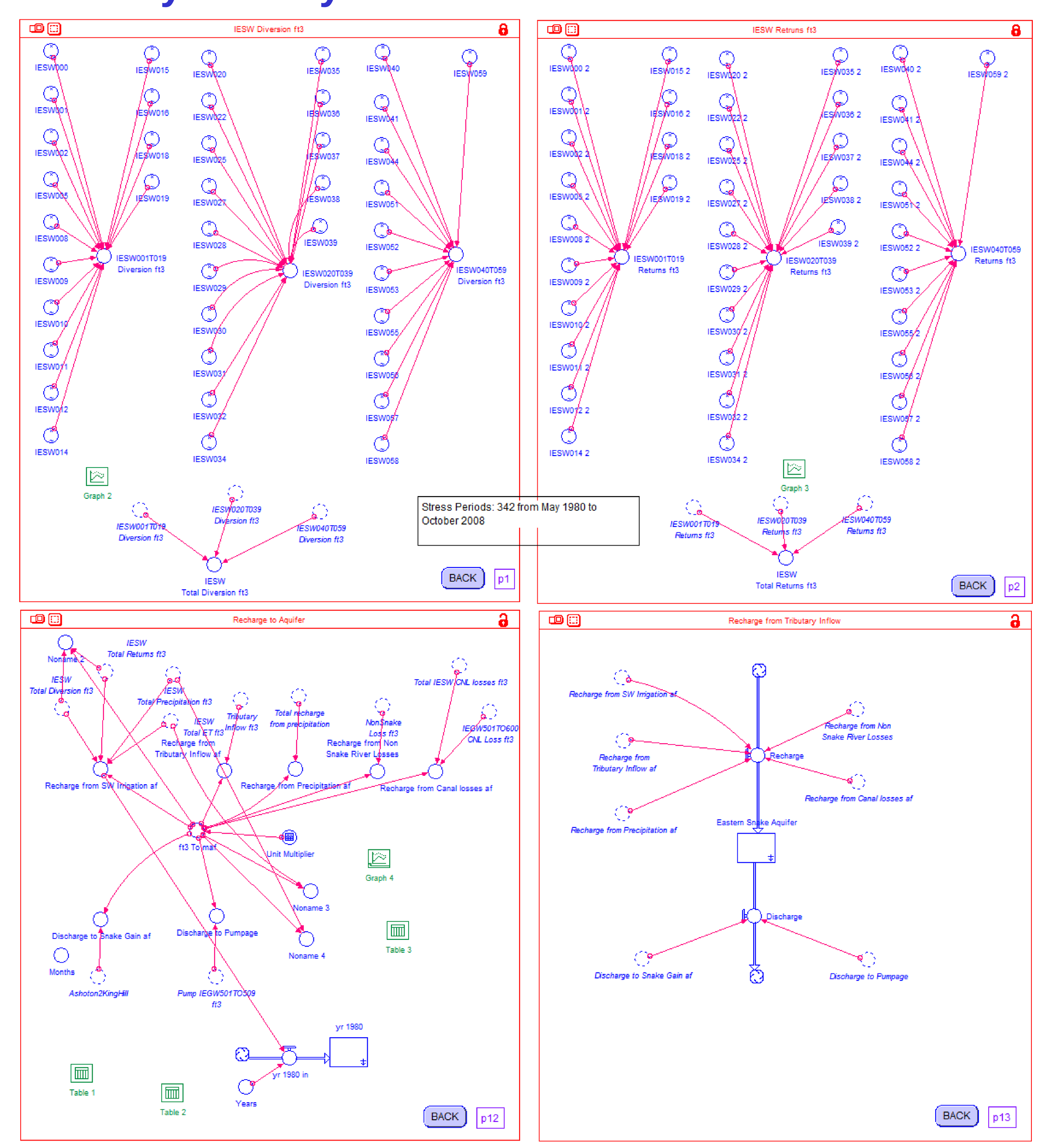


Percent Area in Continental U.S. (Full Statistics)

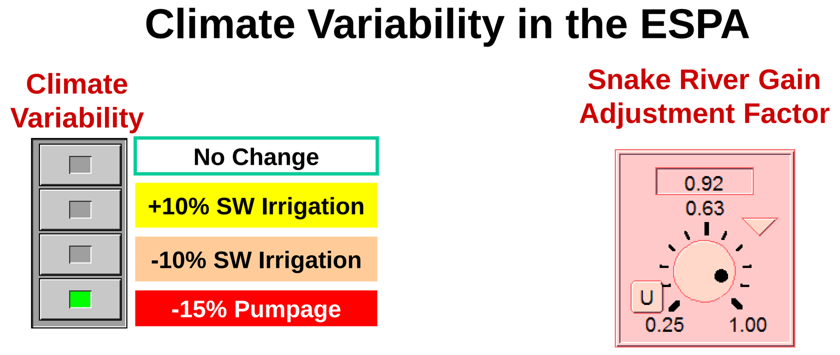
Week	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
This Week 10/25/2016	55.68%	44.32%	23.92%	10.25%	4.08%	1.54%
Last Week 10/18/2016	55.61%	44.39%	22.10%	9.66%	3.87%	1.31%

NIDIS is a comprehensive drought monitoring, forecasting, and management effort between the federal agencies: USDA/NRCS, and NOAA/CPC. The NIDIS highlights the best available information and tools to assess the potential impacts of drought, and helps interagency collaboration to mitigate the effects of drought (NIDIS, 2007)

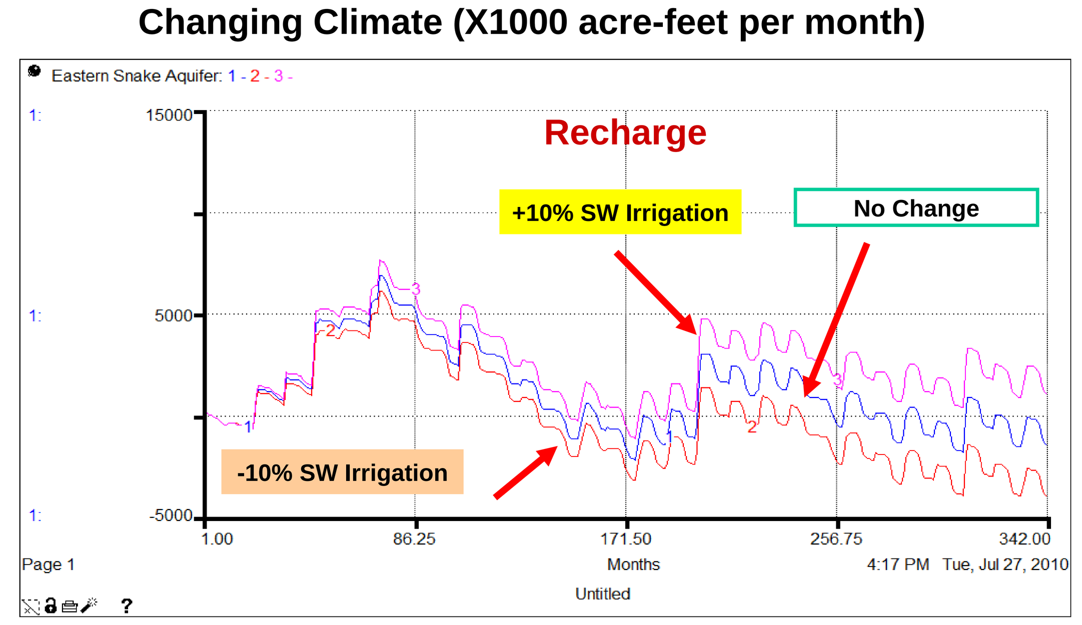
System Dynamics Simulation in the ESPA

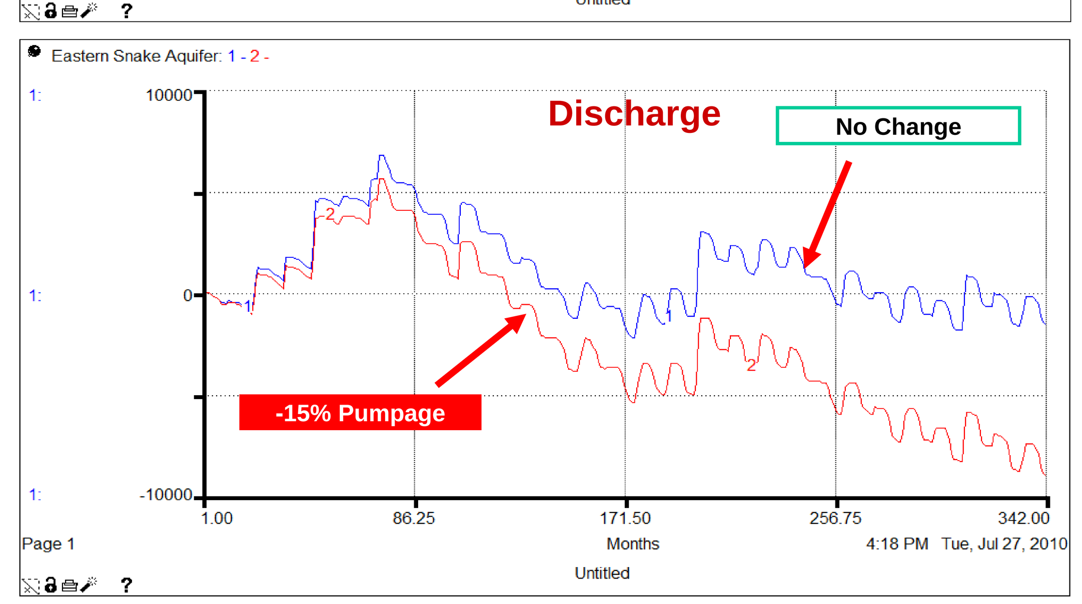


Climate Variability in the ESPA

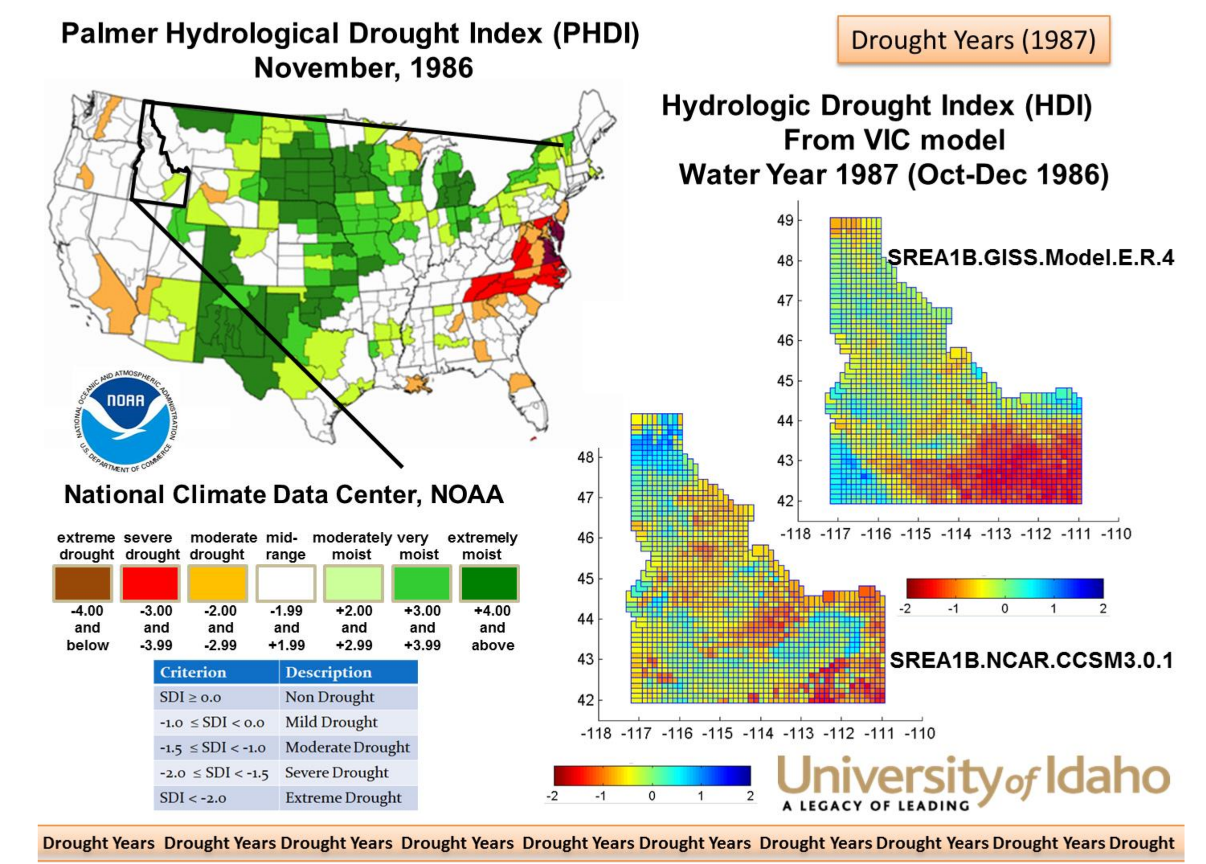


Recharge Variability [(S1-S4) w.r.t. (S0)] in Changing Climate (X1000 acre-feet per month)





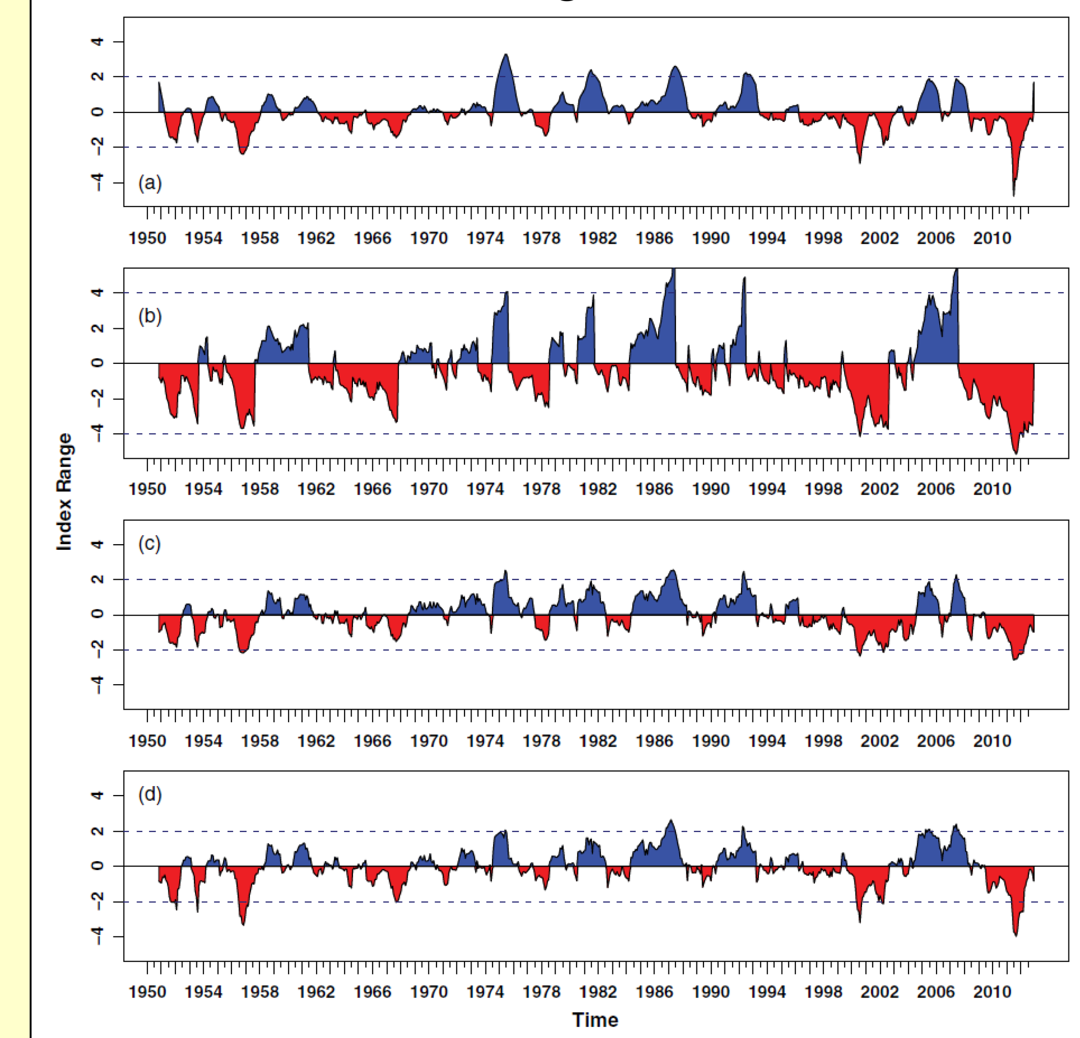
Advancing Drought Monitoring for the state of Idaho



Drought year back in 1987 is shown to represent drought condition in the state of Idaho using Hydrological Drought Index (HDI) to compare Palmer Hydrological Drought Index (PHDI) available at NOAA. Unlike PHDI indication drought for Idaho using few polygons, the HDI map on the right better represent drought condition at finer spatial resolution. In addition to spatial resolution issues, the existing drought indices may not represent well drought conditions in irrigated agriculture, which is mainly dominated in many watersheds in the northwest.

New drought index termed "Soil Moisture Drought Index (SODI)" would be a good alternative to better characterize droughts in a changing climate.

Soil Moisture Drought Index (SODI) Vs Existing Drought Indices

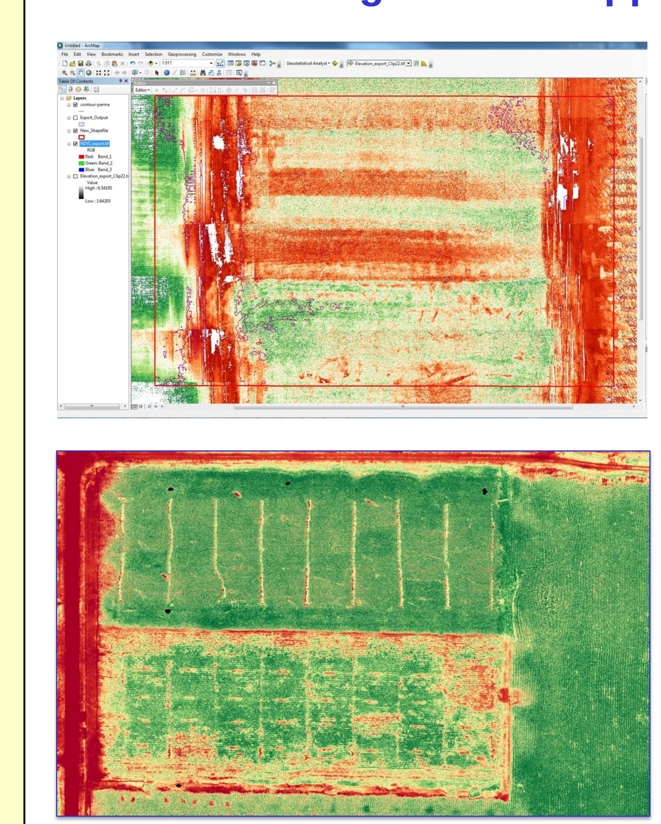


The monthly variability of 12-month SODI is clearly less than that in the other drought indices as it attains soil moisture conditions at the previous time step for the next time step during index computation. This, SODI outperforms the existing drought indices in the sense that SODI can detect and quantify the extended severe droughts associated with climate variability and change.

Unmanned Aerial Systems (UAS) Applications

Unmanned Aerial System (UAS) is commonly used for many applications, including but not limited to agriculture, shipping industry, film industry, national security, military operation, personal hobby, utility inspection, and survey activities.

Agricultural Applications



Normalized difference vegetation index (NDVI) is computed to evaluate how crops respond to different irrigation rate (Top) and variable manure application (Bottom) on alfalfa and potato fields, respectively. A small UAS was used to collect images every 2 seconds and conducted image processing to compute NDVI. Moisture signature was well detected to estimate evapotranspiration during growing seasons, consequently this will be a promising tool to advance drought monitoring and forecasting.

Future Work and Opportunities

Federal regulation and policy:

- **Part 107:** As of June 21, 2016, Federal Aviation Administration (FAA) released the new rules for non-hobbyist small unmanned aircraft (UAS) operations. The existing exemption, such as a Certificate of Waiver (COA) or Authorization under Section 333 exemption, is valid until it expires. Thus, the current COA holder can continue to fly but a remote pilot certificate is required if he/she wants to fly under the new Part 107 regulations.
- **Controlled airspace:** Regardless of your exemption, all UAS operators must get permission from FAA air traffic control by submitting applications at http://www.faa.gov/uas, as of August 29, 2016.

Advancing drought monitoring using UAS:

- It appears that the existing drought indices are limited to represent drought conditions at local levels. Current UAS technology is amazingly advanced in the sense that it can illustrate vegetation greenness in few inches per pixel in spatial resolution. It implies that you can detect insect activities based on drone images almost real-time basis. A remote sensing technology, such as satellite imagery, is still convincing to monitor drought at large coverage, but it often experiences some constraints due to cloud cover and time constraints to make final results available for a timely manner during growing season.
- Computer parallelism and cloud computing will be a new addition to advance drought monitoring and forecasting via advanced visualization technology in the near future.

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