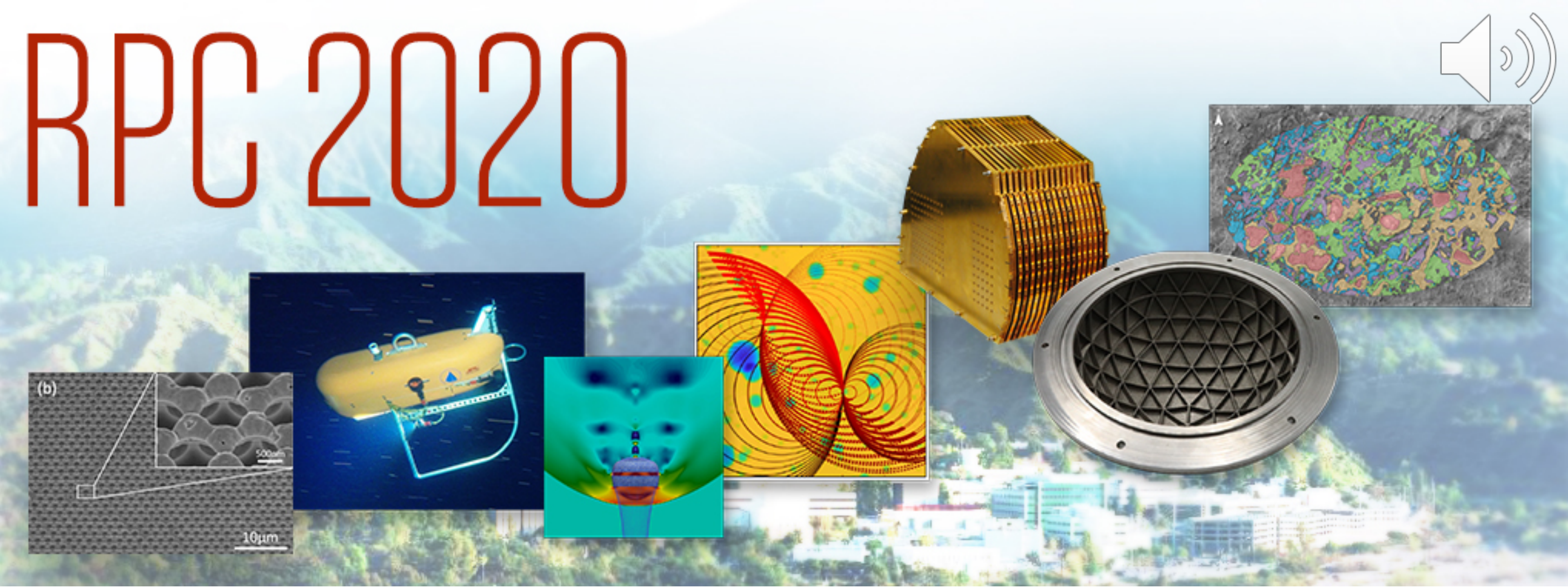

Virtual Research Presentation Conference

Drought tipping points | can satellite remote sensing provide improved early warning signals for food security?

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Program: SURP

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Jet Propulsion Laboratory
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Tutorial Introduction

Abstract

Food insecurity early warning can provide time to mitigate unfolding crises. Existing systems fail to anticipate some crises, resulting in loss of lives and resources; droughts are the major source of uncertainty. We find that tipping point theory with remotely sensed soil moisture and food prices yields dramatic improvement in the prediction of timing and intensity of food crises. We analyzed all drought-induced food crises since 2015. Changes in soil moisture autocorrelation signaled an accurate food security transition for all cases, with lead time between three and six months. Moreover, we predicted the magnitude of the food security change (R^2 = 0.81-0.83). The Soil Moisture Auto-Regressive Threshold (SMART) significantly advances the capabilities of food security early warning diagnostics, and could save lives and resources.

Problem Description

a) Context: Current food security early warning systems currently miss 30% of food crises – primarily due to the challenge of forecasting drought

b) Advancement: The proposed SMART model successfully identified *all* drought-induced food crises across the world since 2015, including those missed by status—quo early warning. Incorporating SMART into food security early warning systems can significantly enhance prediction capabilities.

c) Relevance to NASA and JPL: Our SURP research work is aligned directly with the JPL's Center for Climate Sciences aims of advancing our understanding of Earth's climate system, enhancing our ability to predict its change, and enabling and communicating multi-disciplinary climate science research – with a focus on food and water security applications.

Methodology

DIAGNOSTICS → FOOD PRICE SENSITIVITY → THRESHOLD DEFINITION

Calculate AR(1) and rolling average of SMAP soil moisture

$$AR(1) = \frac{\sum_{i=1}^{N-1}(Y_i - \bar{Y})(Y_{i+1} - \bar{Y})}{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}$$

$$rolling\ average = \frac{Y_1 + Y_2 + Y_3 + \ \dots + Y_n}{n}$$

SMAP SOIL MOISTURE

Where food price change >15%, calculate natural log of price change value and multiply for SMART coefficient:

$$SMART = \ SMAP\ AR(1)\times (1 + (|price|/(1 + |price|))$$

PRICE DATA

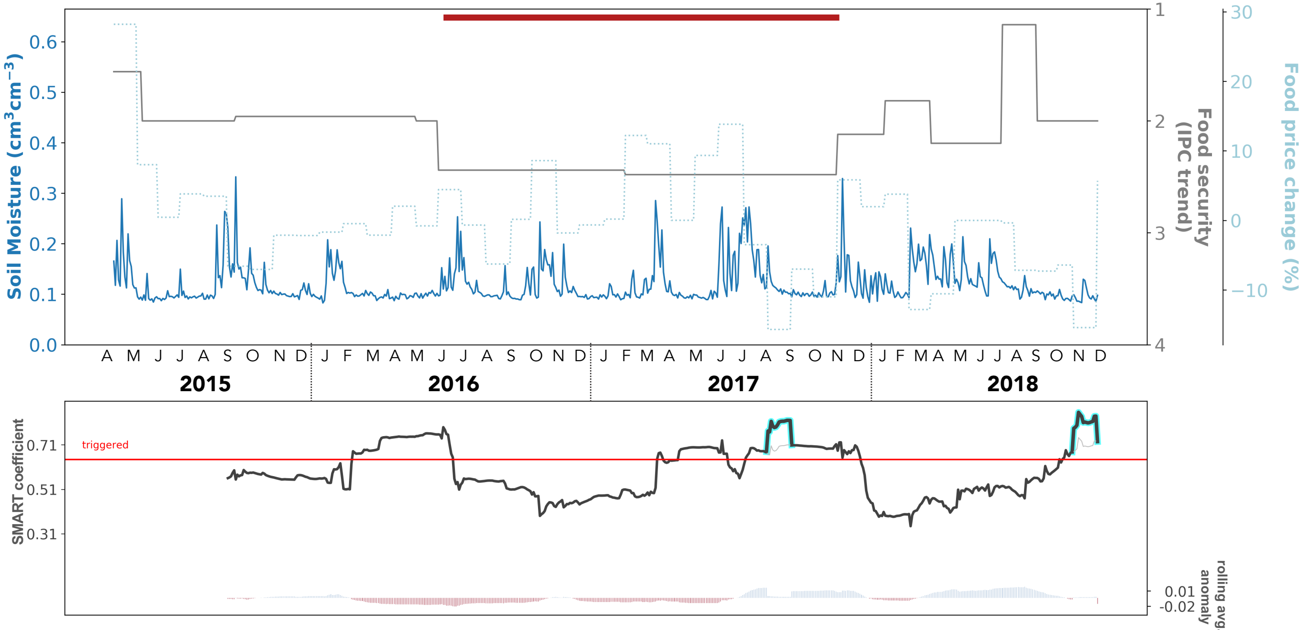
Threshold set from initial and maximum SMART values

$$threshold = SMART_1 + \frac{SMART_{max} - SMART_1}{2}$$

THRESHOLDS

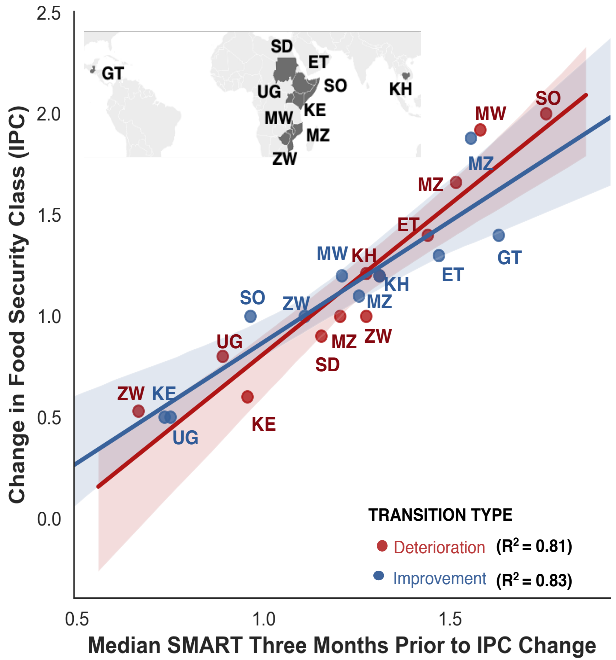
The Soil Moisture Auto-Regressive Transition (SMART) model integrates tipping point theory and remotely sensed soil moisture to predict food security tipping points. Autocorrelation coefficients and rolling averages for Soil Moisture Active Passive (SMAP) values are calculated, using a moving window of full rainy season (100 SMAP observations). Extreme price swings (>15% in either direction, relative to the previous month) are then incorporated into the autocorrelation coefficient. Finally, the threshold that indicates an approaching transition is defined using the first and the maximum SMART values. The model is applied to every case study without individual calibration for specific cases, allowing for replication in other contexts.

Results



Food security tipping points detected by tipping point statistics. Top panel: Integrated Food Security Phase Classification (IPC) (gray line), remotely sensed soil moisture (solid blue line), and food price anomalies (dashed blue line). Bottom panel: Soil Moisture Auto-Regressive Threshold (SMART) indicator (black line, with blue highlight when price-influenced), trigger threshold (red line), and soil moisture rolling average (red/blue bars).

Results



The 3-month median Soil Moisture Auto-Regressive (SMART) values forecast the size of the transition for both crises and exits. Data include all major drought-induced food crises over the soil moisture satellite record.

Publications and References

Published

P. Krishna Krishnamurthy, Joshua B. Fisher, David S. Schimel and Peter M. Kareiva (2020) Applying tipping point theory to remote sensing science to improve early warning drought signals for food security, *Earth's Future* 8 (3), e2019EF001456

P. Krishna Krishnamurthy, Richard J. Choularton and Peter M. Kareiva (2020) Dealing with uncertainty in famine predictions: How complex events affect food security early warning skill in the Greater Horn of Africa, *Global Food Security* 26, 100374

In preparation

P. Krishna Krishnamurthy, Joshua B. Fisher, Richard J. Choularton and Peter M. Kareiva. Detecting food security tipping points. To be submitted to: *Nature*