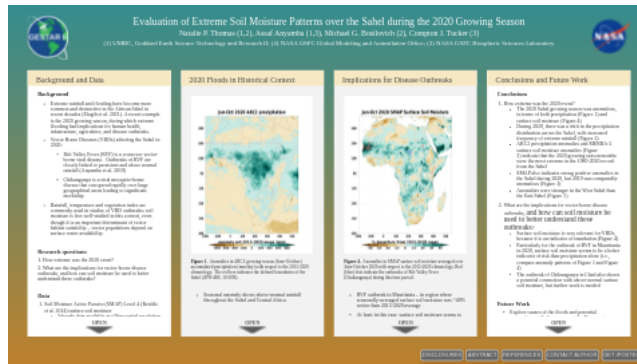


Evaluation of Extreme Soil Moisture Patterns over the Sahel during the 2020 Growing Season

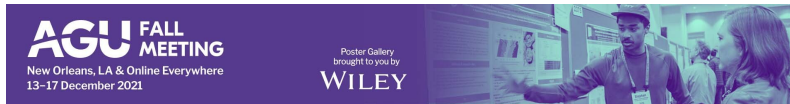


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PRESENTED AT:



BACKGROUND AND DATA

Background

- Extreme rainfall and flooding have become more common and destructive in the African Sahel in recent decades (Elagib et al. 2021). A recent example is the 2020 growing season, during which extreme flooding had implications for human health, infrastructure, agriculture, and disease outbreaks.
- Vector Borne Diseases (VBDs) affecting the Sahel in 2020:
 - Rift Valley Fever (RVF) is a crossover vector-borne viral disease. Outbreaks of RVF are closely linked to persistent and above normal rainfall (Anyamba et al. 2019)
 - Chikungunya is a viral mosquito-borne disease that can spread rapidly over large geographical areas leading to significant morbidity.
- Rainfall, temperature and vegetation index are commonly used in studies of VBD outbreaks; soil moisture is less well-studied in this context, even though it is an important determinant of vector habitat suitability – vector populations depend on surface water availability.

Research questions:

1. How extreme was the 2020 event?
2. What are the implications for vector-borne disease outbreaks, and how can soil moisture be used to better understand these outbreaks?

Data

1. Soil Moisture Active Passive (SMAP) Level 4 (Reichle et al. 2014) surface soil moisture
 - 3-hourly data available at a 9km spatial resolution from March 2015-present.
2. NASA Modern Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2; Gelaro et al. 2017) surface soil moisture
 - Hourly data available at a spatial resolution of 0.625° longitude by 0.5° latitude from Jan 1980-present.
3. African Rainfall Climatology, Version 2 (ARC2; Novella and Thiaw 2013) precipitation
 - Daily data are available at a spatial resolution of 0.1° from Jan 1983-present.
4. Disease Outbreak Data
 - Program for Monitoring Emerging Diseases (ProMED-Mail; <https://promedmail.org/> (<https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fpromedmail.org%2F&data=04%7C01%7Cnatalie.p.thomas%40nasa.gov%7C050fd23100224695e72608d9b8d2860a%7C7005d45845be48ac>))
 - World Organisation for Animal Health, OIE-WAHIS (Office International des Epizooties -World Animal Health Information System; <https://wahis.oie.int/#/home> (<https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwahis.oie.int%2F%23%2Fhome&data=04%7C01%7Cnatalie.p.thomas%40nasa.gov%7C050fd23100224695e72608d9b8d2860a%7C7005d4>))

2020 FLOODS IN HISTORICAL CONTEXT

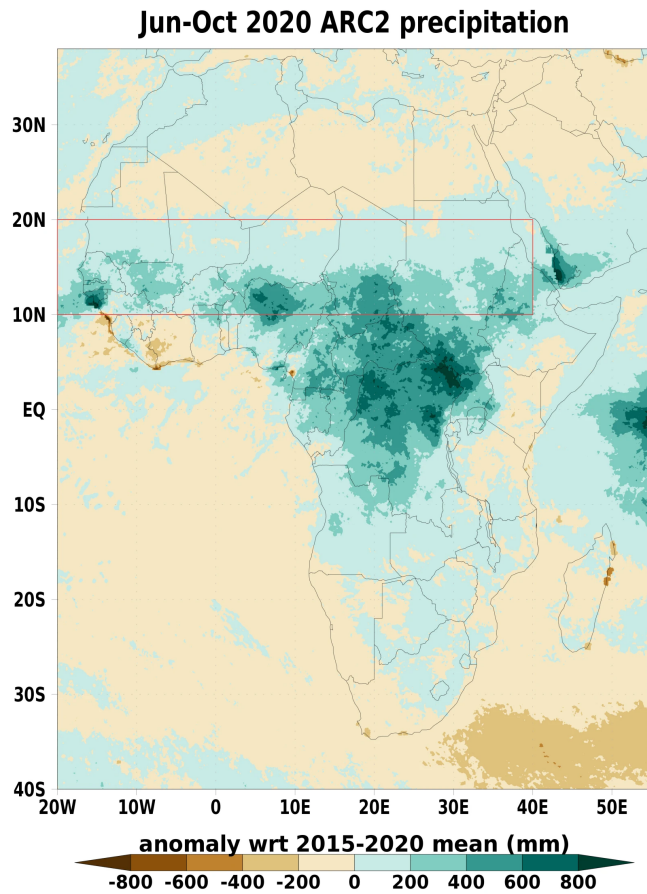


Figure 1. Anomalies in ARC2 growing-season (June-October) accumulated precipitation (mm/day) with respect to the 2015-2020 climatology. The red box indicates the defined boundaries of the Sahel (20W-40E; 10-20N).

- Seasonal anomaly shows above-normal rainfall throughout the Sahel and Central Africa

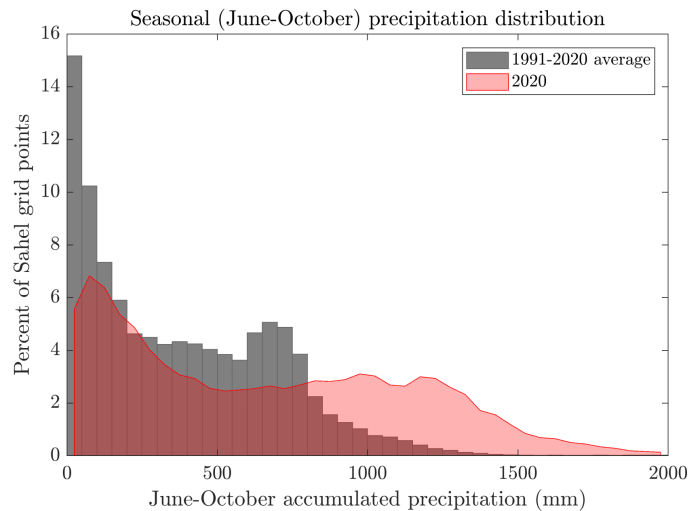


Figure 2. Distribution of June-October accumulated precipitation (mm) across all Sahel grid points for the 1991-2020 climatology (grey bars) and 2020 (red line).

- Clear shift in seasonal precipitation in 2020 - more extreme tail of precipitation compared to long-term mean.

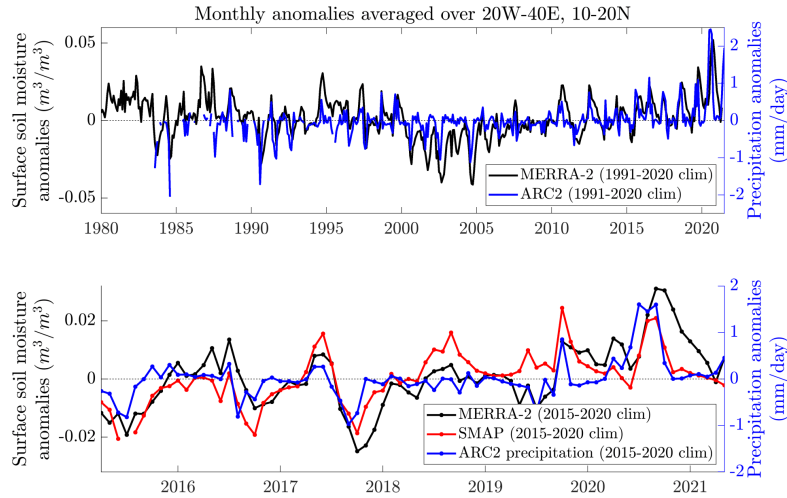


Figure 3. Monthly anomalies area-averaged over the Sahel (20W-40E; 10-20N; red box in Figure 1). The top row shows anomalies from 1980-2021 with respect to the 1991-2020 climatology for MERRA-2 surface soil moisture (black) and ARC2 precipitation (blue). The bottom row shows anomalies from 2015-2021 with respect to the 2015-2020 climatology for MERRA-2 surface soil moisture (black), SMAP surface soil moisture (red) and ARC2 precipitation (blue)

- Monthly area-averaged anomalies over entire Sahel show how 2020 growing season months were the most extreme in the 1980-present time series
- Over SMAP time period, the extreme nature of 2020 is also apparent, although 2019 growing season was also extreme in SMAP (mostly due to flooding in the Eastern Sahel)

IMPLICATIONS FOR DISEASE OUTBREAKS

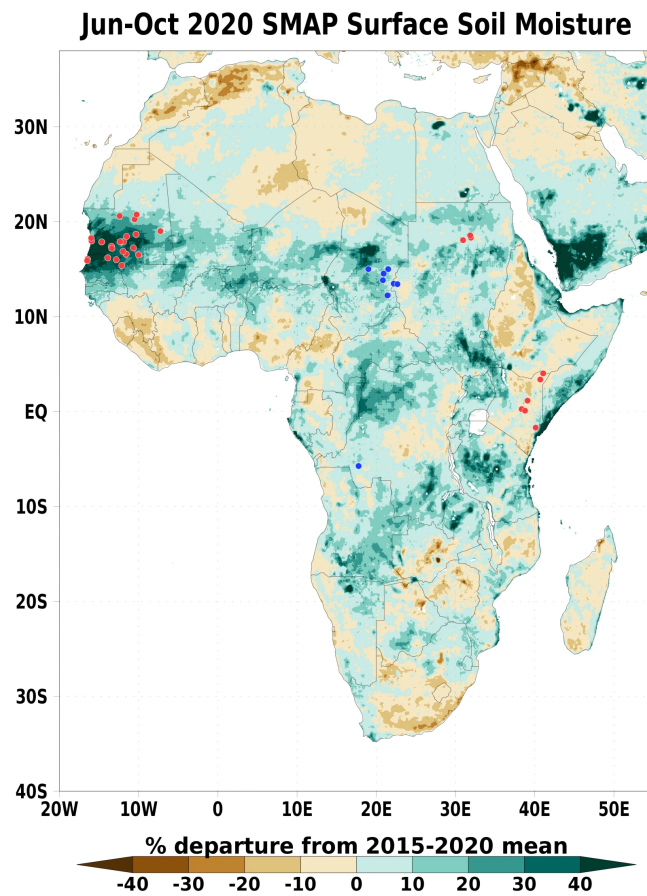


Figure 4. Anomalies in SMAP surface soil moisture averaged over June-October 2020 with respect to the 2015-2020 climatology. Red (blue) dots indicate the outbreaks of Rift Valley Fever (Chukungunya) during this time period.

- RVF outbreak in Mauritania – in region where seasonally-averaged surface soil moisture was ~40% wetter than 2015-2020 average
- At least in this case, surface soil moisture seems to be a better indicator of disease outbreak risk than precipitation (i.e., comparison of Figure 1 and Figure 4)

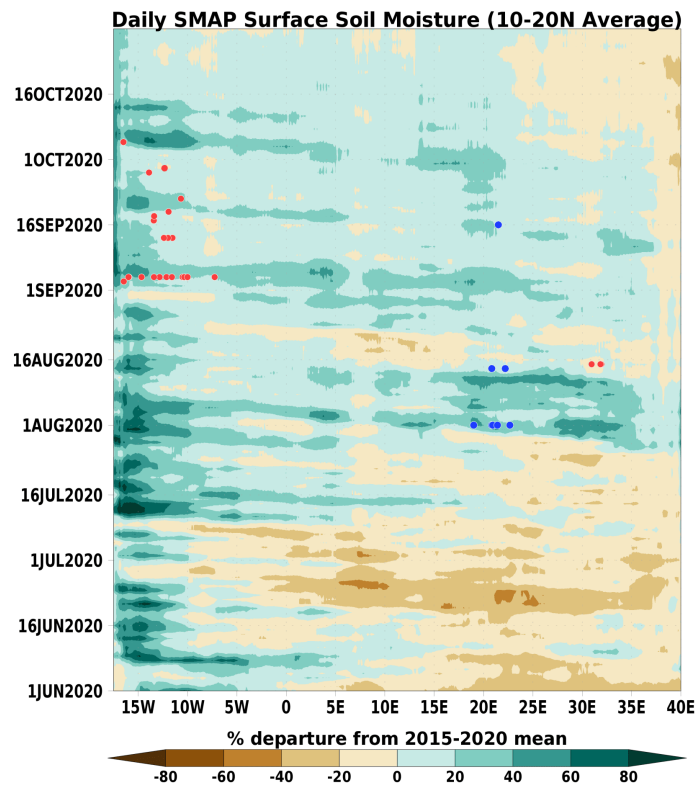


Figure 5. Daily surface soil moisture anomalies averaged over 10-20N for all Sahel longitudes (20W-40E) from 01 June-31 October 2020. Red (blue) dots indicate the outbreaks of Rift Valley Fever (Chikungunya) during this time period.

- Soil moisture anomalies are more prominent in the Western Sahel, and last for the entire growing season (June-October)
 - RVF outbreaks in Mauritania in early September-October
- Anomalies in Eastern Sahel most prominent in first half of August
 - RVF outbreaks in Sudan in mid August
 - Chikungunya outbreaks in Chad in early-mid August

CONCLUSIONS AND FUTURE WORK

Conclusions

1. How extreme was the 2020 event?
 - o The 2020 Sahel growing season was anomalous, in terms of both precipitation (Figure 1) and surface soil moisture (Figure 4)
 - o During 2020, there was a shift in the precipitation distribution across the Sahel, with increased frequency of extreme rainfall (Figure 2)
 - o ARC2 precipitation anomalies and MERRA-2 surface soil moisture anomalies (Figure 3) indicate that the 2020 growing season months were the most extreme in the 1980-2020 record from the Sahel
 - o SMAP also indicates strong positive anomalies in the Sahel during 2020, but 2019 was comparably anomalous (Figure 3)
 - o Anomalies were stronger in the West Sahel than the East Sahel (Figure 5)
2. What are the implications for vector-borne disease outbreaks, and how can soil moisture be used to better understand these outbreaks?
 - o Surface soil moisture is very relevant for VBDs, because it is an indicator of inundation (Figure 4)
 - o Particularly for the outbreak of RVF in Mauritania in 2020, surface soil moisture seems to be a better indicator of risk than precipitation alone (i.e., compare anomaly patterns of Figure 1 and Figure 4)
 - o The outbreak of Chikungunya in Chad also shows a potential connection with above-normal surface soil moisture, but further work is needed

Future Work

- Explore causes of the floods and potential connections with the concurrent La Nina event
- Examine soil-moisture-defined extreme events in other regions
- Eventual application is to use the relationships established here to employ SMAP soil moisture data in a suite of disease models

DISCLOSURES

This work was supported by the NASA Science Mission Directorate's Earth Science Division, Soil Moisture Active-Passive (SMAP) Mission Science Team, Grant # 80NSSC21K0777.

ABSTRACT

The African Sahel is an ecologically and climatically sensitive region, and thus is a valuable test case for examination of climate extremes. Above-average rainfall during the 2020 growing season (June-October) led to flooding in the West, Central and East Sahel, with implications for infrastructure, agriculture and disease outbreaks. In this study, we evaluate soil moisture patterns in the region during 2020 to assess and quantify the extremeness of the event. The primary tool is the NASA Soil Moisture Active Passive (SMAP) Level 4 surface soil moisture data. Daily, monthly, and seasonal anomalies are computed relative to SMAP's long-term mean (2015-2021). Additional comparisons are made with longer-time-series data sets, including surface soil moisture from NASA's Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2; 1981-present) and precipitation from the African Rainfall Climatology, Version 2 (ARC2; 1983-present). Possible drivers of the extreme wet event are examined, including potential links to the concurrent 2020-21 La Niña event. Finally, we explore the connections between the extreme soil moisture and vector-borne disease outbreaks in the region in 2020, namely, Rift Valley Fever in Mauritania and Chikungunya in Chad.

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