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The Potential Benefits of Satellite-Provided Soil Moisture Data

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Key Points

- Soil moisture content refers to the amount of water present within a given volume of soil. Soil moisture is an important factor that determines the properties of a soil, which can in turn determine its suitability for land use.
- In early 2015, NASA launched SMAP, a satellite designed to measure to global soil moisture content and freeze/thaw state over three years before being decommissioned.
- Accurate soil moisture content data is invaluable having many practical and academic uses, including in agricultural development, natural disaster prediction, and civil and military works.
- With the announcement of an Australian space agency, there is the potential for economic benefit for Australia to launch a satellite that monitors soil moisture content.

Summary

Soil Moisture Active Passive (SMAP) is an observatory orbiting Earth and mapping its soil moisture content and freeze/thaw state. Moisture in the topsoil (top 5cm) is measured via radar and radiometer on the observatory, while freeze/thaw state is measured via radar. Radio waves are beamed down to an area on Earth and the radar measures the echoes that return almost immediately. These echoes are then used to measure the soil moisture content. Radio waves emitted from the ground are detected by the radiometer; the strength of these waves is determined by the temperature of the ground, giving a measure of the freeze/thaw state. The radar *actively* emits and detects radio waves, while the radiometer *passively* measures temperatures. Unfortunately, after two and a half months operation in 2015, the radar malfunctioned and could not be repaired. Despite this, the radiometer is still able to produce highly accurate global soil moisture data, although at a coarse resolution.

The main objective of SMAP is to generate global maps of soil moisture to gain a deeper understanding of the water and carbon cycles, by estimating the surface flux of water and energy, and measuring carbon flux in sub-polar climates. The data has many practical applications it can be used in climate and weather studies to enhance predictive capability, resulting in more accurate forecasts; to help predict and monitor natural disasters such as droughts, wildfires, floods and landslides; to improve agricultural productivity; in improving public health via enhancing early warning systems related to famine and the spread of disease vectors such as mosquitoes; and to evaluate ground suitability for civil and military purposes.

Analysis

Soil moisture refers to the amount of water within pore spaces found in a volume of soil. Water is essential for photosynthesis, the process essential for plant growth and, therefore, soil moisture is an important agricultural consideration. The data provided by SMAP can provide farmers with useful information to help maximise crop productivity and yield. Crop Simulation Models are a tool used to estimate crop yield by inputting relevant data, and so soil moisture measures provided by SMAP can be entered into these models. This leads to a more accurate forecast, which allows farmers to better manage their resources in a way that results in increased harvests. Soil compaction is the compression of soil leading to a reduction in available pore space, which has an adverse effect on soil properties and functions. It reduces the rate of root proliferation as well as air and water mobility in the soil. This means less water is available to the plant, and therefore growth rate decreases. High soil moisture content increases the potential for compaction, so the data provided by SMAP can be vital in determining when farmers can use heavy machinery on their fields without soil degradation.

In the absence of other water sources due to shortages and drought, soil moisture is vital in plant growth and agricultural productivity. Lack of water can severely impact the output of farms, with droughts having the potential to cost the economy billions of dollars. In order to prepare against droughts, modelling is done to forecast when and where this may happen next, along with monitoring to predict when a drought will end. Soil moisture content data from SMAP can be factored into these models to help improve the accuracy of forecasting. Better forecasting provides policy makers, farmers and other stakeholders more reliable information on crop yield to improve decision making.

Soil moisture deficits have been found to correlate to the occurrence of larger and more destructive bushfires in Australia due to the subsequent lack of water available to plants, which dry out and become suitable fuel for the fire. Precise soil moisture data is extremely valuable in predicting which areas are at risk of a fire, allowing for governments, emergency services, and at-risk residents to make the appropriate preparations. Soil moisture is an important indicator on the forecasting of water-based natural disasters such as floods. When soil is saturated (i.e. when soil moisture is at its maximum level), rainwater is no longer able to enter the soil via infiltration. At this point it becomes surface runoff, which has the potential to lead to flooding. Soil is more likely to become saturated the higher its initial moisture content, and so having accurate data from SMAP can improve the reliability of flood prediction models. This can be seen in the images below: Figure 1 shows soil moisture content of Texas during hurricane Harvey, while Figure 2 shows regions where flooding has receded or increased. Flooding has increased the most in areas where soil moisture content is highest: saturation of 50 to 65 per cent correlates with increased flooding of 200-300km^2.

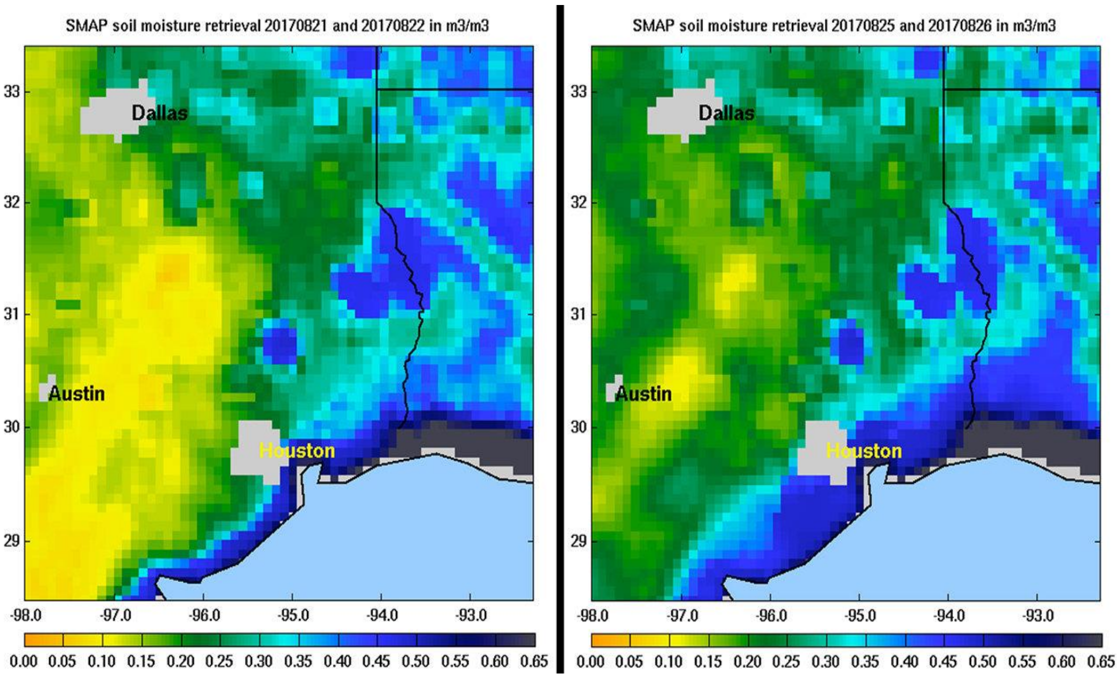

Figure 1: A map of Texas before (21st-22nd of August) and after (25th-26th of August) the landfall of Hurricane Harvey in 2017. High saturation in the left image from the 20-40% range increased the probability of flooding, as there was less potential for water to infiltrate the soil.

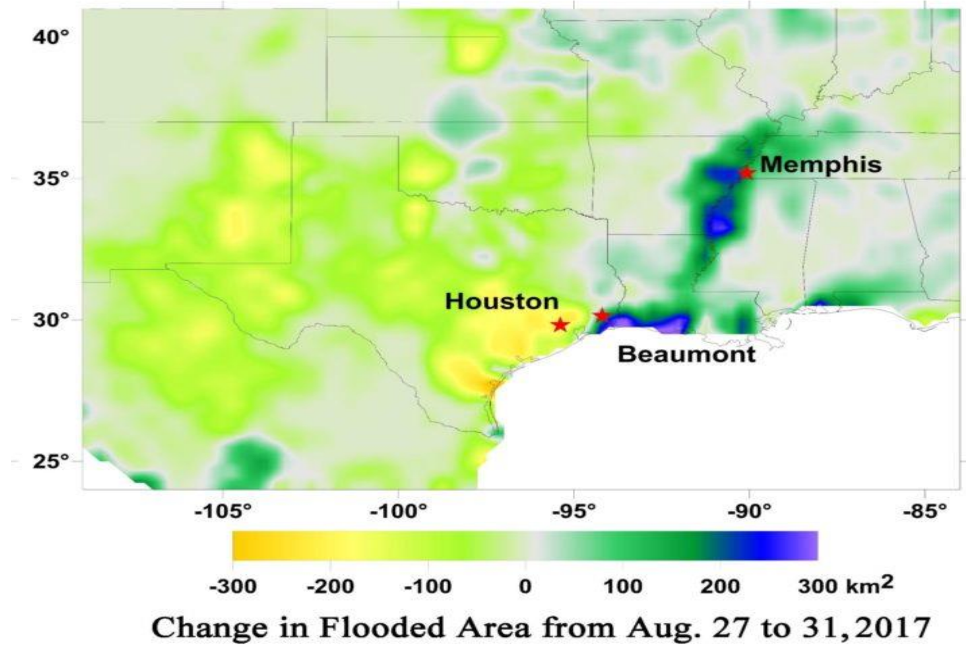

Figure 2: A map of Texas showing the areas where flooding has increased (shown as shades of purple and blue), and where it has receded (shades of orange and yellow).

Data from SMAP can be used to benefit public health, particularly in poorer countries that lack the resources to counter threats on a large scale. Seasonal soil moisture content maps can be factored into early-warning systems, allowing governments and NGOs in countries with high levels of food insecurity to prepare for shortages and potential famines. Disease vectors, such as mosquitoes, can lay eggs in pools and puddles which are linked to areas with high soil moisture content. Governments can use soil moisture data to identify areas where mosquitoes are likely to thrive and act to counter the threat of diseases like malaria

more effectively by distributing preventative measures such as mosquito nets, sprays, malaria drugs and other tools to at-risk areas.

Information regarding the soil moisture content of a region can have important civil and military applications. Soil moisture is a property that can fundamentally influence the behavior of a soil, making it an important factor in large scale civil engineering projects, such as highway engineering, bridge building, and dam construction. Soil moisture can also play a key role in determining ground conditions: high levels of soil moisture generally lead to poor trafficability and can contribute to fog development, while low levels of soil moisture can allow for dust generation. Accurate data is therefore invaluable for military and civil weather models in forecasting local weather conditions.

Soil moisture plays a key role in the global carbon cycle in which carbon moves between the atmosphere, hydrosphere, biosphere, and lithosphere (environmental systems that comprise all air, water, life, and land on Earth, respectively). Carbon in frozen soils found in the subarctic coniferous forests of northern Eurasia and North America is not in flux; the soil acts as a carbon sink, which provides a large degree of uncertainty in estimating the global carbon budget. The soil freeze/thaw state is the key factor in effectively estimating the carbon flux from soils, but this data is unavailable due to the radar malfunction. Fortunately, the moisture content of the soil in these sub-polar forests can still allow for a more complete picture of the carbon cycle, and lead to a greater understanding of how fluxes in the cycle affect the global ecosystem. Soil moisture is also an important part of the water cycle; the rate of transpiration (the process by which water travels through a plant and is evaporated via small pores) is positively related to the soil moisture content. Significant energy is required for the evaporation of water, and therefore soil moisture impacts surface energy flux and, on large scales, it influences weather and climate patterns. Accurate data from SMAP can be factored into prediction models, allowing for better predictions for meteorology and seasonal climate patterns.

Conclusions

Despite malfunctioning early into its lifespan, the data provided by SMAP still has many practical and academic uses. Soil moisture content data is vital in agriculture, where it can help farmers forecast their crop yields, avoid soil degradation and prepare for droughts. It can be a useful input into predictive models which forecast natural disasters such as floods, landslides, bushfires, and famines, as well as into early warning systems for public health issues such as population expansion of disease vectors. The data can also have important applications in civil and military works, in understanding the carbon and water cycles and in meteorological and climate pattern forecasting models.

With the recent announcement of the creation of an Australian space agency, a few important considerations for the federal government include the scope of the agency's operations, and determining projects that provide the most benefits to Australia. With SMAP set to be decommissioned in 2018, and the European Space Agency's SMOS (Soil Moisture Ocean Salinity) satellite reaching its eighth year of operations, there may be a niche for Australia to launch a state-of-the-art satellite that provides soil moisture data. Natural disasters have been found to cost Australia nine billion dollars per year and that number is forecasted to increase to $33bn in 2050. With soil moisture data's potential to improve forecasting to avoid and prepare for natural disasters, as well as increase crop modelling to improve yields, the economic impact of an Australian soil moisture monitoring satellite has the potential to provide the country with a substantial economic benefit.

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