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SIDEBAR 2.2: BUILDING A CLIMATE RECORD OF SOIL MOISTURE FROM HISTORICAL SATELLITE OBSERVATIONS

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Since the launch of the Nimbus-7 satellite in October 1978, there is a long legacy of satellite observations suitable for global soil moisture monitoring (Fig. SB2.4), but it took more than 20 years to develop the first satellite global soil moisture dataset. In 2002, a dataset was developed from scatterometer observations onboard the European Remote Sensing Satellites ERS-1 and ERS-2 (Wagner et al. 2003). Other research groups soon followed. De Jeu and Owe (2003) made a global soil moisture product from the historical Nimbus-7 SMMR data and Njoku et al. (2003) presented the first dataset based on AMSR-E observations.

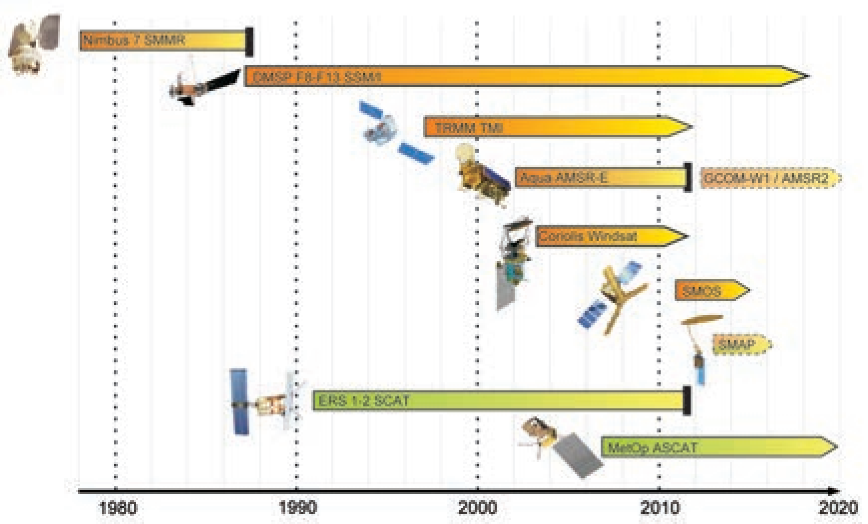

Fig. SB2.4. Timeline of past, current, and future space-borne coarse resolution radiometers (orange) and scatterometers (green) suited for soil moisture retrieval on a global scale. (Source: updated version of Dorigo et al. 2010)

Today, numerous global soil moisture products from various satellites and research groups are freely available. These datasets vary in quality but all provide global soil moisture estimates of the top few centimeters at a rather coarse spatial resolution of 25 km–50 km (GCOS 2011). Global datasets are increasingly important in environmental research. For example, Liu et al. (2007) demonstrated the impact of El Niño on water resources in eastern Australia using TRMM soil moisture. Brocca et al. (2010) showed that runoff prediction for the Tiber River in Italy can be improved by incorporating ASCAT soil moisture, and Jung et al. (2010) used TRMM soil moisture to investigate a recent decline in global evaporation.

These different datasets are even more valuable if combined into one consistent multidecadal climate data record. This was addressed as part of the Water Cycle Multimission Observation Strategy (WACMOS) project from the Support To Science Element (STSE) program of the European Space Agency (ESA). Within this project, two extensively validated soil moisture products were selected to create a harmonized dataset; one from the Vienna University of Technology (TU Wien) based on active microwave observations (Wagner et al. 2003; Bartalis et al. 2007) and one from the VU University Amsterdam in collaboration with NASA, based on passive microwave observations (Owe et al. 2008). The harmonization of these datasets incorporates the strengths of both microwave techniques and spans continuously from 1978 onwards (Fig. SB2.4). However, there were several challenges to developing such a dataset, e.g., differences in instrument specifications result in different absolute soil moisture values, the global passive and active microwave retrieval methods produce conceptually different quantities, and products vary in their relative performances depending on vegetation cover (Y. Y. Liu et al. 2012, manuscript submitted to *Remote Sens. Environ.*). This is clearly visible in Fig. SB2.5, where the original soil moisture retrievals from various satellites are plotted for a region in the Sahel. Here, both the active and passive soil moisture retrievals show similar seasonality but they have different magnitudes. TU Wien soil moisture retrievals are expressed as a degree of saturation (with a value between 0 and 1) while VUA retrievals are given in volumetric values ($m^3\ m^{-3}$). Besides this, the SSM/I-based estimates are less accurate than for the other sensors, owing to its limited soil moisture retrieval capabilities. It carries a Ku band (19 GHz) radiometer, which is less suitable for soil moisture retrieval than L (1.4 GHz), C (6.9 GHz), and X (10.7 GHz) band radiometers (Owe et al. 2008). A statistical methodology based on scaling, error characterization, ranking, and blending was developed to address these issues to create one consistent dataset (Liu et al. 2011, 2012). A third soil moisture dataset, provided by a land surface model (GLDAS-1-Noah), was used to scale the different satellite-based products to the same range. The blending of the active and passive datasets was based on their respective sensitivity to vegetation cover. While this approach imposes the absolute values of the land surface model dataset to the final product, it preserves the relative dynamics (e.g., seasonality, interannual variations) and trends of the original satellite-derived retrievals (Y. Y. Liu et al. 2012). The ranking and blending strategy used does not increase the accuracy of the final product with respect to the merged ones, but allows a selective use of the most accurate measurements and increases the temporal density of the observations available. Finally, this method allows the long-term product to be extended with data from other current (e.g., SMOS) and future operational satellites and will be further improved as part of ESA Climate Change Initiative program (http://www.esa-cci.org/).

A simple trend analysis of this harmonized dataset is presented in Fig. SB2.6. Subtle soil moisture trends can be seen over the entire globe varying from -0.06 $m^3 m^{-3}$ to 0.06 $m^3 m^{-3}$ over the last 31 years. The strongest negative trends can be found in Russia, Kazakhstan, and the Sahel region. Strong positive trends are observed in northeastern Brazil and southern Africa. Most of these trends can directly be linked to the behavior of ocean oscillation systems. For example, the trends over Australia could be related to the polar movement of the Subtropical Ridge (STR), the Indian dipole, and the severe El Niño conditions within this period (Liu et al. 2007; Murphy and Timbal 2008; Y. Y. Liu et al. 2009).

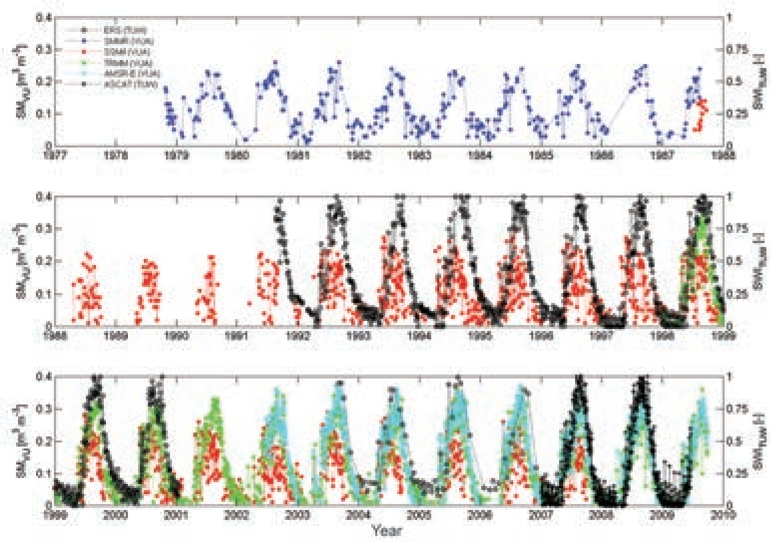

Fig. SB2.5. Soil moisture over an area in the Sahel region (7°N, 12°E) according to different satellite observations. Note that soil moisture derivations from scatterometer sensors (indicated in black) are expressed as an index (right axis) and the VU soil moisture retrievals are expressed in $m^3 m^{-3}$ (left axis). (Source: De Jeu et al. 2009)

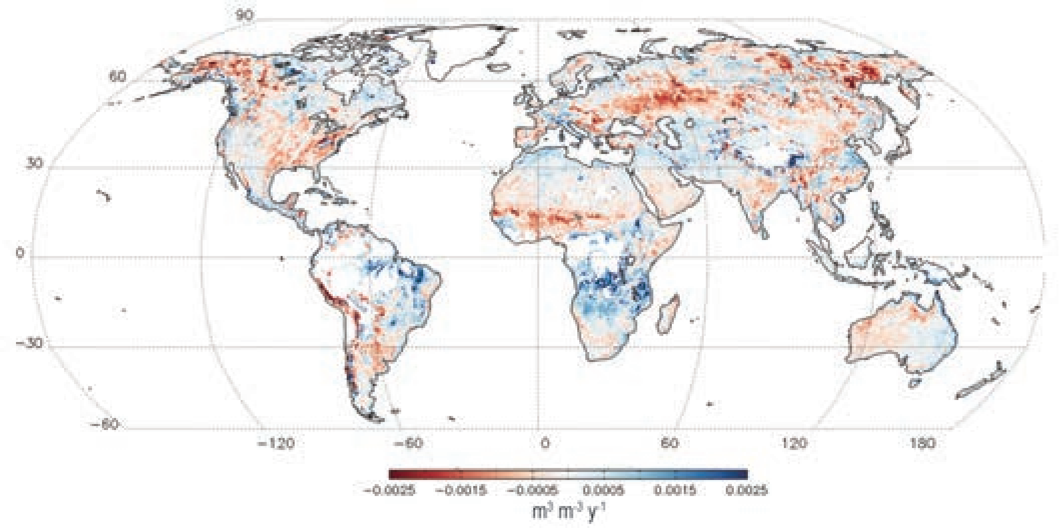

Fig. SB2.6. Trends in annual average satellite soil moisture (in $m^3 m^{-3} yr^{-1}$), 1979–2010 base period. These values were derived from the harmonized soil moisture dataset, a 30+ year harmonized satellite soil moisture data record based on (historical) passive and active microwave observations.