Analysis of the SMAP Daily Soil Moisture Time Series through Power Spectrum-Adjustment Methods Utilizing Additional Datasets

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INTRODUCTION

Process chains in **land-atmosphere (LA)** interactions connect soil moisture (SM) to surface fluxes, partly controlling the evaporation of accumulated precipitation under varying environmental conditions. Given the uneven global distribution of observationally-based flux tower data, satellite products present an excellent opportunity to analyze SM and assess LA interaction studies.

The **Soil Moisture Active Passive (SMAP)** satellite most closely aligns with in-situ observations. However, the stochastic random noise in SMAP can affect the accuracy of coupling estimates. Notably, the missing data in SMAP are patterned rather than random. These patterns are due to its 8-day repeating polar orbit, which influences data availability based on location. This study introduces a method to ***estimate and remove noise from SMAP time series***. This aims to enhance the quantification of how soil moisture influences global turbulent surface fluxes of sensible heat (SH) and latent heat (LE).

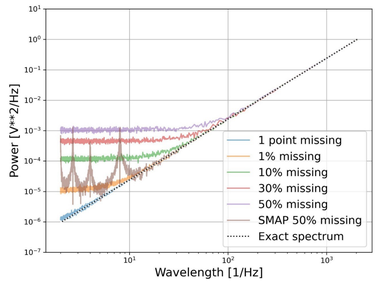
METHODOLOGY

Hypothesis: The ***Power Spectrum – Adjustment*** technique can be applied to SM from SMAP L3 to **identify and remove noise**.

The steps of our methodology include:

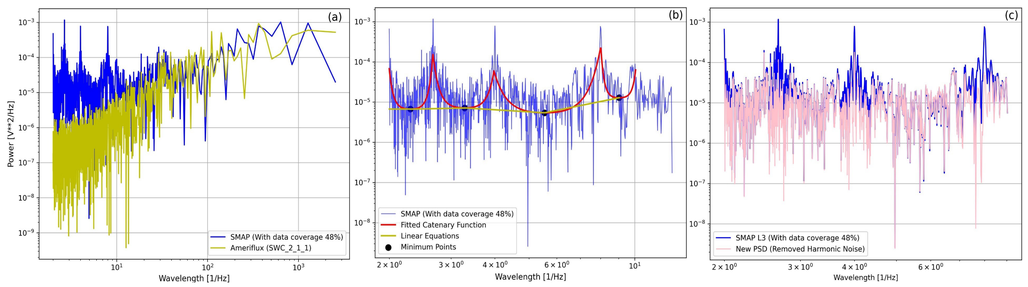
- Calculate Power Spectrum Density (PSD) based on **Lagged Autocovariance** (works with missing data)

Contrasted with an idealized time series constructed of superposed waves, SMAP's PSD displays a notable deviation at higher frequencies, influenced by the proportion of missing data. Additionally, it exhibits spikes at wavelengths corresponding to 8, 4 (8/2), 2 2/3(8/3), and 2 (8/4) days, representing **orbital harmonics**. This pattern reveals SMAP's unique 8-day orbital cycle, which varies based on geographical location.



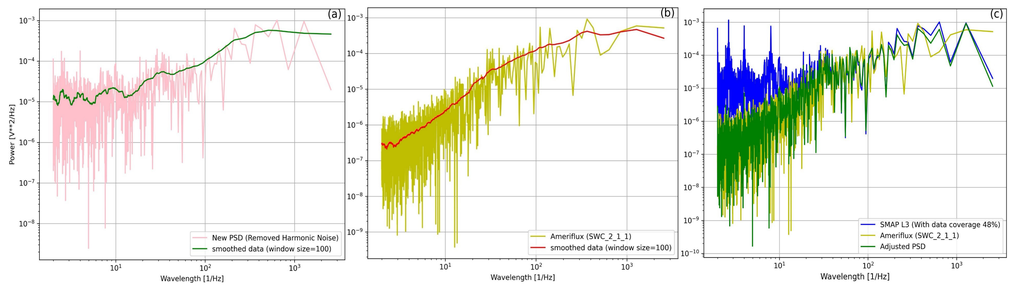
Power spectrum density for different fractions of random missing data. SMAP 50% missing PSD has a pattern of **1-0-1-1-0-1-0-0.**

- Remove the **Harmonic Noise** in PSD by ***Fitting Catenary Curves***



(a) PSD for SMAP L3 and Ameriflux from 2015 to 2022 in ARM Southern Great Plains – Lamont, (b) fitted catenary to PSD and lines connected minimum points of each curve, (c) new PSD in which harmonic noise is removed by dividing lines to fitted catenary.

- Remove the **White Noise** by Adjusting to ***Flux Tower PSD***

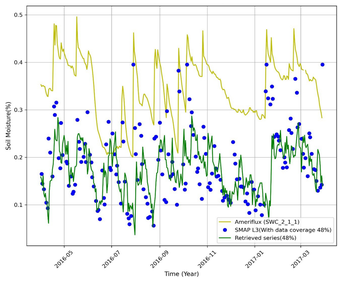


Removed harmonic noise PSD for (a) SMAP L3 and (b) Ameriflux with their smoothed spectra also plotted Adjusted PSD (c) in which white noise is removed by dividing smoothed removed harmonic noise PSD to smoothed Ameriflux PSD and then removed harmonic noise PSD divided by this ratio.

METHODOLOGY (Continued)

38% of PSD is removing >>> Harmonic Noise
78% of PSD is removing >>> White Noise

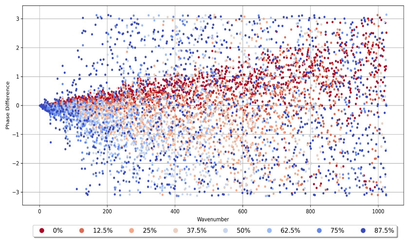
- Get phases using **"Slow" Fourier Transform** (SFT) (Fitting Sine & Cosine to the Time Series)
- Retrieve the time series using the **Backward Fourier Transform**



Daily soil moisture time series for SMAP L3, Ameriflux, and retrieved SMAP from 2016-04 to 2017-03 in ARM Southern Great Plains – Lemont.

RESULTS AND FINDINGS

- The proposed method is an efficient way to ***identify and remove the noise*** from time series with missing values.
- When phases are retrieved from SFT, in some frequencies, these phases and the real one have differences between $-\pi$ and π.



Phase Difference (Actual-SFT) for different percentages of missing data.

- Therefore, the lack of ability to get phases lead to ***less variability at higher frequency***, and **dry-downs cannot be predicted accurately**.
- ***Checking day-to-day variation*** of invented series with SMAP L3 and Ameriflux shows that there is no improvement in retrieved time series because it is not possible to get phases at some frequencies.

The table shows how many times the sign of day-to-day changes matches between the complete and invented series.

Lags	Fraction of common sign between complete series and retrieved and Ameriflux	Fraction of common sign between complete and retrieved series and SMAP L3
1	0.52	0.53
2	0.52	0.53
3	0.53	0.52
4	0.54	-----
5	0.55	0.53
6	0.57	0.58
7	0.56	0.58
8	0.57	0.59

FUTURE WORKS

- Identify an improved method for phase retrieval
- Extend this method to additional in-situ locations
- Develop a worldwide, gridded, noise-reduced SMAP L3 product
- Compute metrics to assess the coupling between the retrieved SMAP L3 and surface fluxes
- Apply a new method to find a noise-free coupling index such as the linear correlation between noisy time series of SMAP L3 and surface fluxes
- Apply this method across various locations

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