The repeatability of InSAR decorrelation induced by soil moisture change: A case study in the hyper-arid southern Arabian Peninsula

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Introduction

Why study soil moisture in hyper-arid regions?

1) Hazard: Extreme rain events have increased in frequency worldwide, even in hyper-arid regions. One way in which the scientific community is working to better characterize these events is through the study of soil moisture variability and storage, and SAR data, with its high spatial resolution and relative insensitivity to cloud cover, is poised to become a key tool in the next generation of soil moisture research.

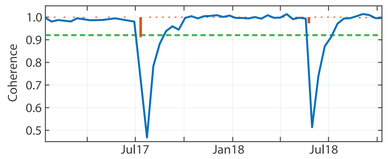
2) Improving InSAR measurements: With no vegetation, hyper-arid regions are ideal for probing the impact of soil moisture on InSAR coherence, phase, and amplitude.

Isolating soil moisture variablity in InSAR data

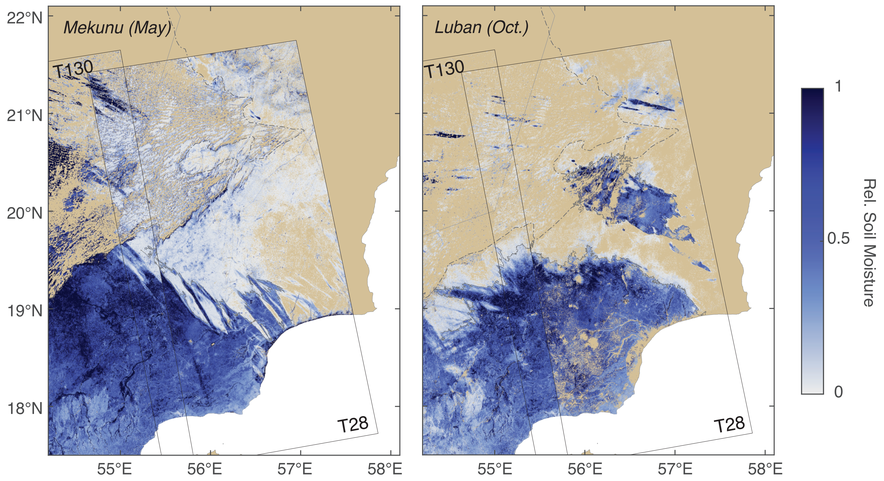
- Coherence measures the quality of InSAR data, and is affected by any change in surface properties between the two SAR images.
- Differences in soil moisture between two dates result in lower coherence Scott et al. (2017).

$\gamma = \gamma^0 \gamma^p \gamma^s \longrightarrow \log(\gamma) = \log(\gamma^0) + \log(\gamma^p) + \log(\gamma^p)$

γ = Coherence, $0 \le \gamma \le 1$ — γ^p = "Permanent term" — γ^0 = "Surface roughness term" — γ^s = "Soil moisture term"



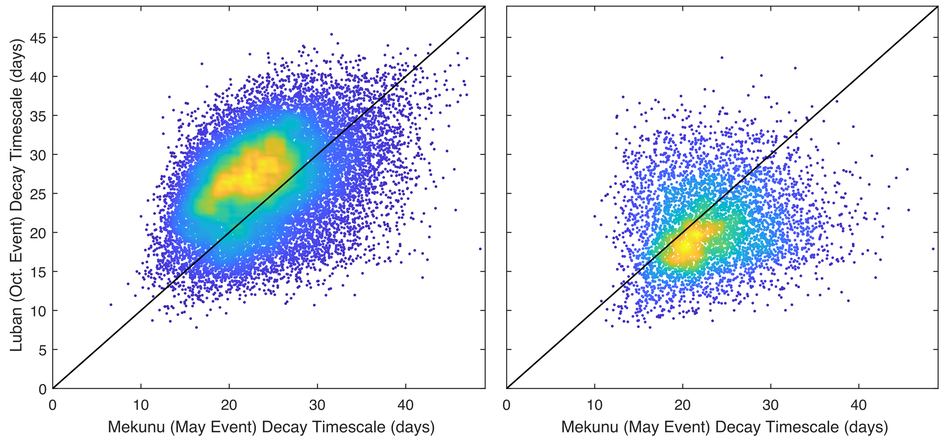
Soil Moisture Observations



Soil moisture retrievals two days post-storm following Cyclone Mekunu and Cyclone Luban for the coherence-derived data. The dashed line delineates the boundary between sand dunes (north of the dashed line) and Tertiary sediments (south of the dashed line).

The eastern edge of both rain events are roughly co-located, and the data show distinct boundaries between regions that experienced rain and those that did not.

Preliminary Comparisons

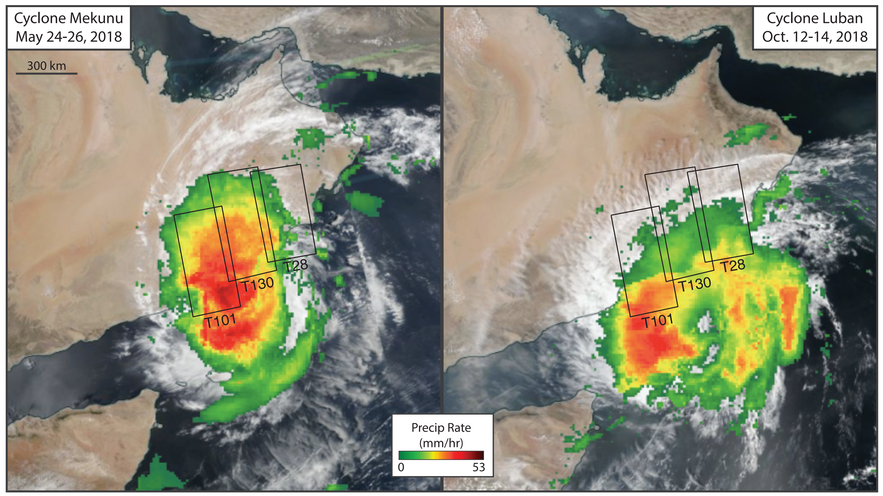


Scatter plots above are colored by point density compare the coherence-derived decay timescales for Cyclone Luban and Cyclone Mekunu. Both plots only show pixels sampled from the two SAR frame overlap regions. Left: pixels that experienced between 50 - 200 mm of total precipitation during both events, and right: pixels that experienced greater than 100 mm more rainfall during Cyclone Mekunu than Cyclone Luban.

The differences between the decay timescales that are consistent with:

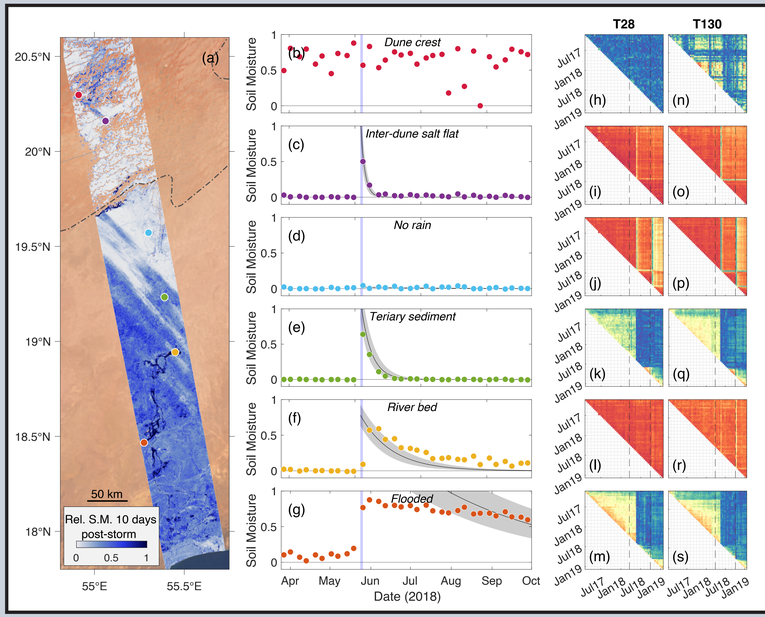
- A larger amount of precipitation during Cyclone Mekunu (right)
- Slightly warmer temperatures after Cyclone Luban (left)

Cyclones Mekunu & Luban



We intercompare the effect of soil moisture on both amplitude and phase following two large cyclones that impacted the southern Arabian Peninsula in May (Cyclone Mekunu, left) and October (Cyclone Luban, right) of 2018. Sources: NASA Worldview; IMERG; Suomi NPP/VIIRS.

Future Work



In the coming months, we hope to:

- Examine the impact soil moisture has on the phase and magnitude of differently-polarized SAR returns, and explore the implications of spatially averaged complex data.
- Compare the Cylcone Mekunu results for different land cover types (right) to those of Cyclone Luban
- Analyze data from Cyclone Gati, which hit the Somalia in late 2020, and compare these results with the southern Arabian Peninsula data.

(a) Coherence-derived soil moisture ten days after Cyclone Mekunu, in the overlap region between frames T28 and T130. Circles differentiated by color indicate the location of the time series shown in (b) - (g). (b) - (g) Coherence-derived soil moisture data (circles), exponential fit (black line), and fit uncertainty (grey regions) following Cyclone Mekunu, the timing of which is indicated by the vertical blue bar. (h) - (s) InSAR coherence for all possible interferometric pairs for each pixel in (b)-(g). Each row corresponds to the adjacent time series plot. The first and second columns show the coherence for T28 and T130, respectively. Vertical dotted lines indicate the time range of (b).