Elucidation of Controls of Soil Water Storage in the Landscape Using Hilbert-Huang Transform

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1. Introduction

- Soil water is the main limiting factor in semi-arid agriculture and a key element in environmental health.
- Topography, texture, vegetation, and water table depth control soil water storage (SWS) at a location.
- These factors do not operate separately, resulting in scale-dependent spatial variability in SWS in the landscape.
- Spatial variability of SWS can be in the form of spatial trends, cyclic or acyclic variations, and therefore, is **NONSTATIONARY**.
- The effects of these factors and processes are not additive, thus showing **NONLINEARITY**.
- *New methods are needed to deal with nonlinear and nonstationary SWS.*

2. Objective

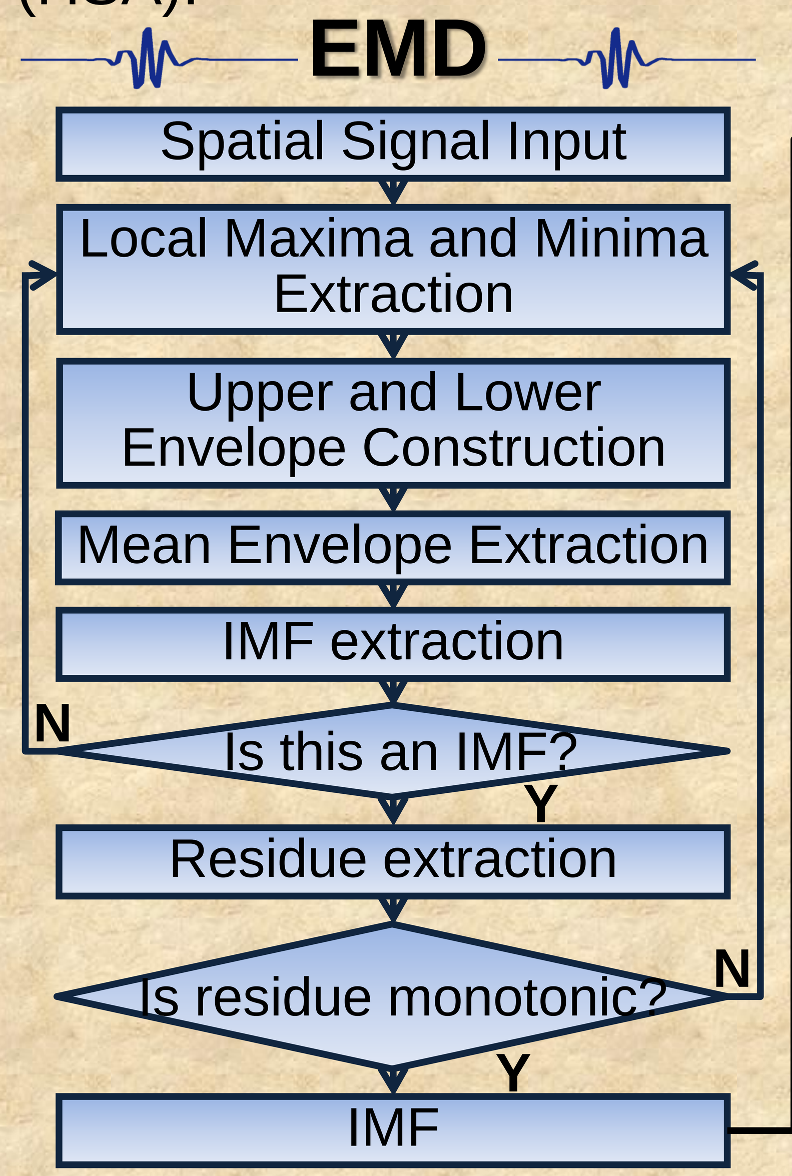
- To delineate the scale-specific controls of nonstationary and nonlinear soil water storage in a rolling landscape using Hilbert-Huang Transform.

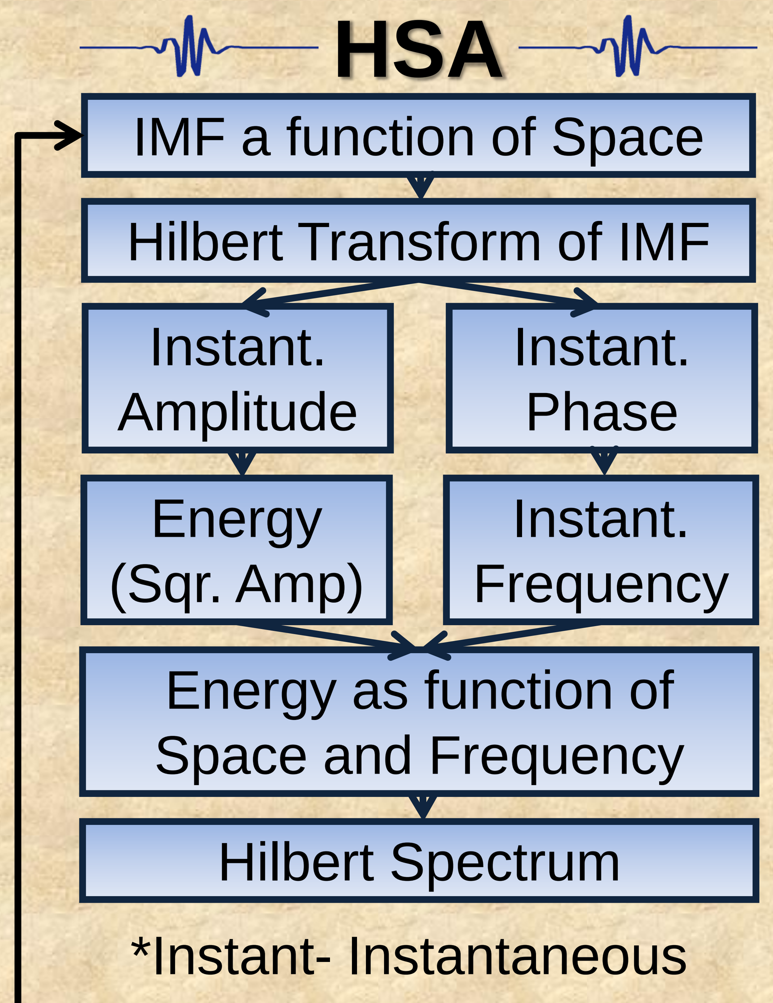
3. Materials and Methods

- Study Site: St. Denis National Wildlife Area (SDNWA) (52º12′N, 106º50′W), Saskatchewan, Canada.
- Study Area: Rolling landscape (Fig. 1), 10 to15% slope, loamy unsorted glacial till parent material, Borolls to Aquolls soil type, Grass cover.
- Sampling Point: 128 point transect with 4.5-m interval.
- Soil Water storage was measured at 20-cm vertical intervals to a depth of 140 cm using a Neutron Probe.

4. Theory

- Hilbert-Huang Transform (HHT) can deal with nonstationary and nonlinear data series through a combination of Empirical Mode Decomposition (EMD) and instantaneous frequency based Hilbert Spectral Analysis (HSA).





*Instant- Instantaneous

- HHT is intuitive, direct, *a posteriori* and adaptive.
- HHT does not impose any mathematical rule as in Fourier and wavelet analyses.
- It explains hidden physical mechanism directly from data.

Elevation (m)

555

Fig. 1: Transect position on rolling landscape

5. Results and Discussion

- Intrinsic Mode Functions (IMFs) were extracted from each dataset according to their characteristic scales (Fig. 2).
- IMF 1 represented the variations at very small scales.
- IMF 6 represented the variations at large scales.

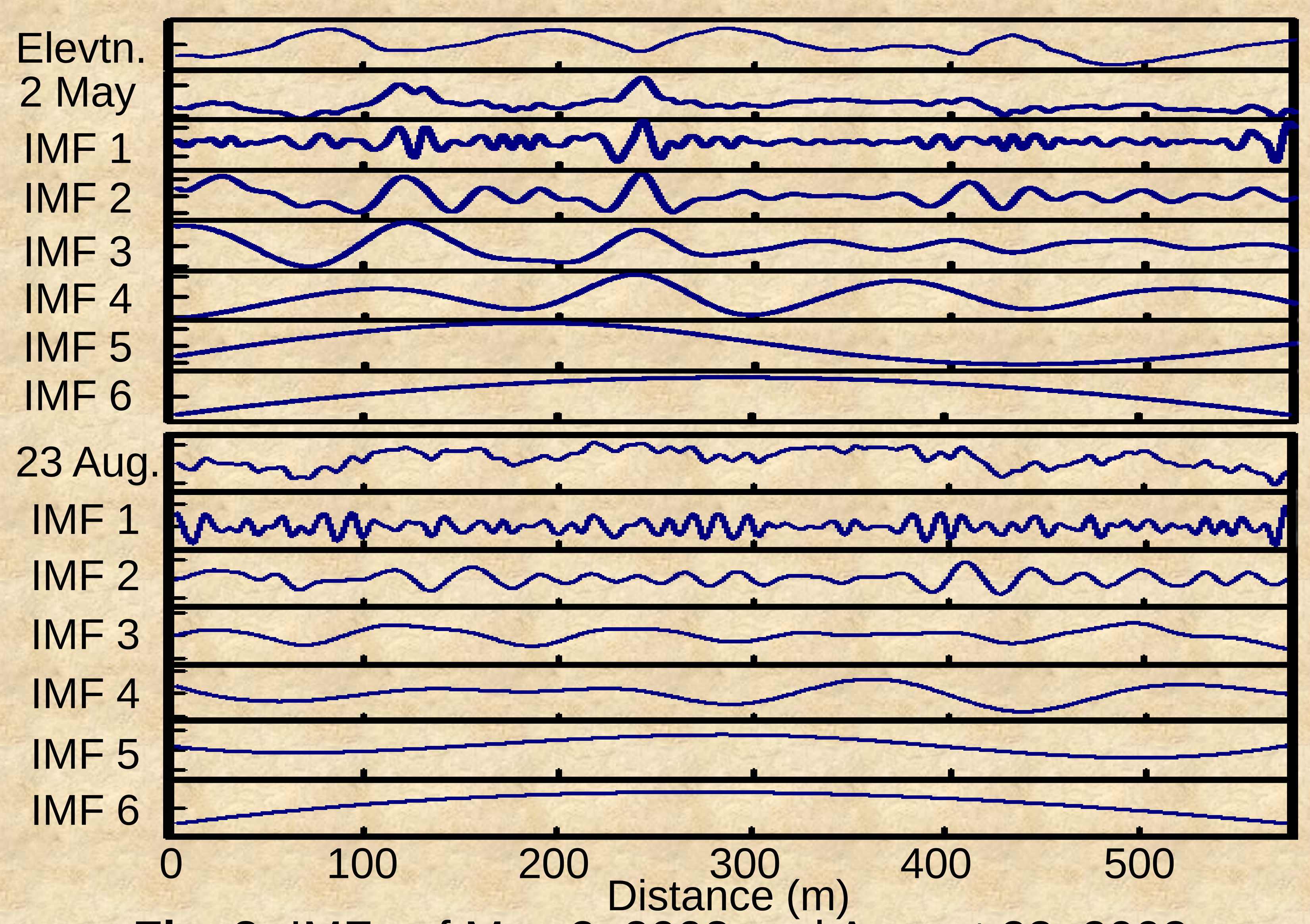


Fig. 2: IMFs of May 2, 2008 and August 23, 2008

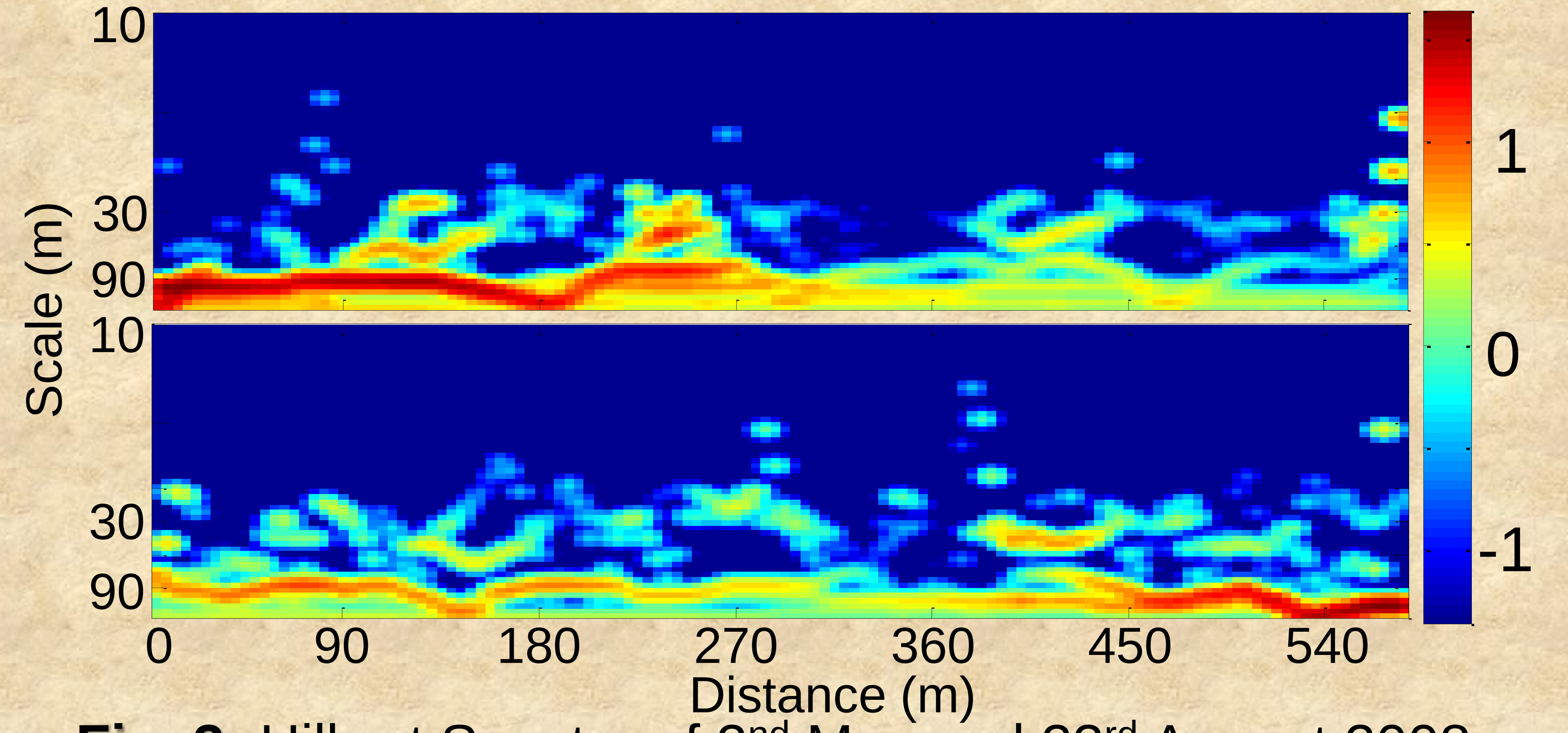


Fig. 3: Hilbert Spectra of 2nd May and 23rd August 2008

5. Results and Discussion (Cont.)

- IMF 2, IMF 3, and IMF 4 explained major variations which is representative of the controls from elevation and OC.
- Soil texture showed stronger correlations with IMF at large scales (IMF 6) than elevation.
- Elevation and OC were important predictors at major scales of SWS (Table 1).

Table 1: Scale specific relationship of SWS controlling factors and their percent contribution to total variation.

IMF	Model	% Contribution
0*	OC + sand + ele	
1	Intercept only	5-7
2	OC + ele	10-12
3	ele + OC	40-50
4	OC	10-12
5	sand + ele	7-10
6	sand + ele + OC	1-4

*-original data, ele-elevation, OC-organic carbon

- In Hilbert spectra, high energy zone (red color) represented the major control of soil water storage from elevation (Fig. 3) .

6. Conclusion

- Elevation is the major controlling factor of soil water storage irrespective of season at almost all scales except at very large scales.
- Scale specific relations should be used to predict SWS.

7. Acknowledgement

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