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Interactive comment on "A probabilistic approach to quantifying soil property change through time integration of energy and mass input" *by* Christopher Shepard et al.

Christopher Shepard et al.

cbs8h@email.arizona.edu

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Response to Reviewer J. Phillips.

We thank the reviewer for his helpful comments in the preparation of the manuscript titled: "A probabilistic approach to quantifying soil property change through time integration of energy and mass input". Below we have detailed our response to the reviewer's comments, including how the manuscript was edited.

Response to comments:

Lines 69-71: We have eliminated the first two "approaches".

Lines 128-131; 152-154. We choose the bivariate normal density function for its simplicity and ease of parameterization. We did not consider other bivariate distributions. We wanted to demonstrate the use of bivariate probability functions for modeling soil properties from a probabilistic viewpoint. We have added language to lines 134-136 to indicate that only the bivariate normal density function was considered for the present approach.

Lines 144-154: Modeling soil properties over time requires a number of assumptions, as such every soil formation model is an approximation of reality. We made these assumptions to reduce model complexity and to make the model as mathematically simplistic and easily parameterized as possible. We are aware of many issues with these assumptions, and we discuss at length the implications of these assumptions in lines 464-514 on model outputs and model failures. We disagree with the reviewer that these assumptions are unrealistic, as the present approach is effective at prediction soil property across wide variety of environments and ecosystems.

Line 159: We have replaced "over" with "more than" based on the reviewer's comment.

Line 161-162: We have edited the manuscript to reflect the reviewer's comment, and removed one of the phrases "within the present study" from the revised manuscript.

Lines 164-166: We agree with the reviewer that Southern Hemisphere and mid-latitude sites are underrepresented within the current dataset; however, we are limited about the availability of published datasets. A number of studies from South America, Africa and the Tropics were initially identified, but only a small number of these studies included horizon-level texture data or numerical or approximate ages for the described soil profiles.

Lines 168-177: Based on the reviewer's suggestion we have added additional explanation and description of EEMT, at lines 184-187 in the revised manuscript.

Lines 182: We agree there are many chemical and biological changes that occur over time that are not dependent on soil textural changes, we do discuss intrinsic changes in soil properties from lines 490-502. We have updated the manuscript based on the reviewer's comments, replacing the word "proxies" with "examples of soil property change with time".

Line 213: We have deleted the first "terrain" based on the reviewer's comment at lines 236 in the revised manuscript.

Lines 232-236, Lines 389-390: As discussed in the manuscript and acknowledged by the reviewer, soil depth is correlated to and dependent upon topography and hillslope redistributive processes. Soil depth varies systemically across hillslope as indicated by the contemporary work of Dietrich, Heimsath, Pelletier, amongst many more, and was discussed in the manuscript. We only stated that soil depth incorporates the strength of these processes in lines 232-234, and we have changed "correct" to "incorporate" based on the reviewer's comments. Further in lines 389-390, we simply state the soil depth acts as a proxy for hillslope processes, not that soil depth accounts for all hillslope processes or the complexity of sediment redistribution on a hillslope. We acknowledge the incomplete understanding of soil depth and weaknesses of soil depth predictions at lines 335-336. Soil depth only partly accounts for the complexity of hillslope processes.

Lines 248-263: The outputs from the process-based numerical soil depth model and the topographically resolved EEMT model were used to calculate the necessary model inputs to the probabilistic model. Soil depth was used to calculate soil residence time, and TPE values were calculated from topographically resolved EEMT and soil residence time values. TPE values were used in the probabilistic model to calculate depth weighted clay content values, and Eq. 9 was used along with predicted soil depth values to calculate mass per area clay across the small-forested catchment. Based on the reviewer's suggestion we have added language to clarify Section 2.4.1 from lines 306-309 in the revised manuscript and a flow chart to the revised manuscript.

Line 271: We updated line 271 to indicate that Pearson's correlation was used to pa-

rameterize the probability distributions. Further, we updated lines 276 and 281 to indicate the Pearson's correlation is represented in the reported statistics.

Lines 322: We have added the word "regression" to indicate that we are discussing the slope of the regression line presented in Fig 6b.

Lines 359-372: We agree with the reviewer's comment, the sand and silt fractions are both dominated by resistant primary minerals. We have added a statement to the revised manuscript at lines 423-425.

Lines 377-379: We have added additional references that indicate the non-linear dynamics of soil depth and soil deepening at lines 407 in the revised manuscript.

Lines 413: We agree with the reviewer that scale is likely an important factor in predicting soil properties. Finer spatial scales will likely better match the local variation in soil properties, but may also lead to greater potential for prediction errors. Further, finer scale information about local lithology differences and weathering rates are likely required. We have added discussion of the issue of scale in predicting soil properties in lines 464-467 in the revised manuscript. Further, the issue of scale in lithology and weathering rates is discussed from lines 468-479 in the revised manuscript.

Lines 421-424: We have added language clarifying the difficulty of including differing weathering rates based on lithology to the revised manuscript at lines 477-478 in the revised manuscript.

Lines 426-462: The model predicts ranges of clay contents. The bivariate normal distribution predicts the conditional parameters of a univariate normal distribution for the soil property of interest. With the conditional univariate parameters, the model user can determine the probability of observing a particular range of clay values. This approach represents a first attempt at a true probabilistic prediction of soil property values, more complex probabilistic approaches that incorporate explicit change with time are possible. However, these more complex probabilistic approaches would require an equation over which probabilistic predictions can be updated over time.

Lines 464-514: With the appropriate updates and additions to the probabilistic model many of these caveats and issues with the model are correctable. Further, many of these caveats specifically address the assumptions and simplifications that are discussed in lines 174-185 in the revised manuscript.

Lines 467-470: We agree with the reviewer's comment, parent material can greatly influence rates of pedogenesis or weathering, regardless of controlling for the other soil forming factors. We have added language to the revised manuscript at line 527 to reflect this issue.

Table 2: We have updated the caption for Table 2 with the explanations of the column headings. We use a "rho" or to represent Pearson's correlation.

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