Application of Ensemble Detection and Analysis to Modeling Uncertainty in Non Stationary Processes

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1. INTRODUCTION

All elements of Nature exhibit characteristics that change when considered over sufficiently large temporal or spatial scales. Considerable effort and resources are applied to 'designing around' non stationary and non linear effects. Non linear effects of observation methodology pose the most perplexing aspects for modeling non stationary processes. The statistics one obtains depends upon the sampling of the process. Consider, for example, the difficulties associated with averaging high-resolution radar data to match passive microwave measurements for combined active/passive retrievals of soil moisture. The lack of well-developed techniques for modeling changing statistical moments in our observations has stymied the application of stochastic process theory in science and engineering. These limitations were encountered when modeling temporal effects of calibration frequency on the performance of a radiometer with non stationary receiver fluctuations.

2. ENSEMBLE DETECTION AND ANALYSIS

A generalized approach to modeling radiometer calibration system architectures is presented in Racette and Lang (2005). See Figure 1. The analytical approach is based upon stochastic process theory and entails using measurement uncertainty as a metric by which to compare radiometer calibration architectures and algorithms. The approach allows direct comparison of measurement uncertainty between analytical calculation and data analysis. The output of a radiometer that sequentially samples calibration references may be considered an ensemble measurement set of the receiver fluctuations, $g(t)$. The receiver fluctuations may be estimated from statistical analysis (or calibration) of the data set. For a stable receiver, measurement uncertainty is insensitive to temporal spacing of the references samples in a calibration algorithm. For fluctuating $g(t)$, the measurement uncertainty is sensitive to temporal spacing of the reference measurements in the calibration algorithm. Information about the fluctuations in $g(t)$ can be extracted by applying different calibration algorithms to the data. This approach has been generalized to the analysis of an external signal $g(t)$ driving the gain of an otherwise stable receiver that samples ultra-stable references. The result, Ensemble Detection and Analysis (EDA), is a means of noise assisted data analysis for studying non stationary processes. See Figure 2.

3. NOVEL FEATURES AND BENEFITS

EDA is a highly innovative approach to studying non stationary processes and their non linear behavior as inputs to linear and non linear systems. Data analysis is no longer limited to a single series. Rather, EDA uses a backdrop of ensemble sets of noise measurements with *a priori* statistical relationship to characterize non stationary processes. Stochastic-dynamic parameterization (for example see Palmer 2009) is made possible by using uncertainty to match model and observation. EDA provides the means of studying the influence of observation methodology on observed uncertainty.

EDA has been developed as a means for analyzing radiometer calibration data. Through modeling and analysis of radiometers, it's been shown that small deviations over intervals which the process transitions from exhibiting stationary statistics to non stationary statistics can be detected and novel information extracted. These effects are not limited to functional forms entailing calibration. Statistical properties of the function output, given the statistical properties of the reference samples (e.g. mean, variance, etc… for Gaussian random variables) can be evaluated for a large class of algorithms, i.e. analytic functions. Information about the stationarity of the process can be derived by comparing predicted uncertainty with that calculated from the ensemble data set. The ability to quantitatively evaluate uncertainty associated with sampling methods has tremendous potential for improving global climate models and evaluating observation strategies.

EDA is a data processing technique with a wide range of applications. For example,

- Change detection in multi-dimensional data, e.g. remote sensing, climate, …
- Adaptive control systems
- Data mining
- Detector noise cancellation
- Health monitoring

4. REFERENCE

Paul Racette and Roger Lang, *Radiometer design analysis based upon measurement uncertainty*, Radio Sci., 40, RS5004, doi:10.1029/2004RS003132.

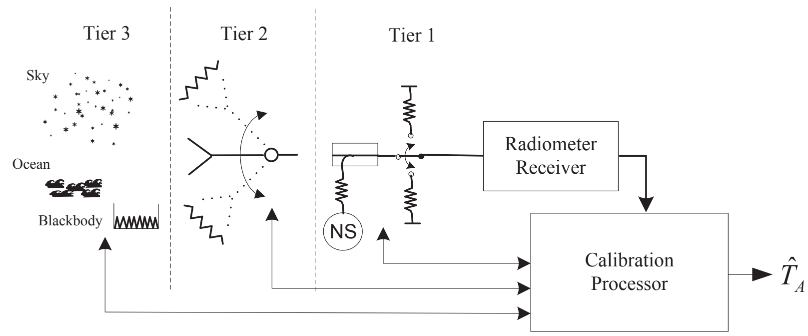

Figure 1: *Racette and Lang (2005)* present a method for analyzing a generalized radiometer design based on measurement uncertainty. **The approach brings consistency to over 50 years of disparate analyses.**

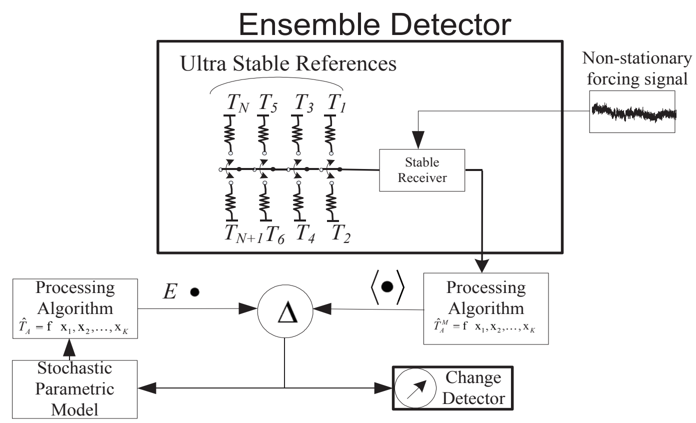

Figure 2: Using EDA it's possible to derive novel information about a process's changing statistical moments across multiple scales that is otherwise not possible using a single data series.