Information Content and Dimensionality of High Precision Imaging Spectroscopy Measurements of the Earth.

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When imaging the Earth environment with remote sensing instruments, the question often arises, what is the potential information content in the measurements? For example, is one, ten, one hundred spectral bands enough to capture the dimensionality expressed in the available signal. The research presented here presents case study into this question for measurements in the solar reflected portion of the spectrum from 400 to 2500 nm at 10 nm sampling.

To investigate the measurement information content, a Minimum-Noise-Fraction (MNF) eigen analysis was performed on 250 million high precision spectra measured by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) spanning a range of Earth environments in the year 2000. The MNF algorithm normalizes the measurement noise to a eigen value of 1.0. MNF eigen values greater than 1.0 indicate image variance above the noise level. For this study, variance above the noise is interpreted as image information content. Analysis of the MNF results from the entire AVIRIS data set shows a dimensionality greater then 100 above the measurement noise level. This implies that more than 100 spectral measurements are required across this spectral range to capture the dimensionality present in upwelling spectral radiance.

As an extension of this analysis, the AVIRIS data set was partitioned into subsets of environmental type such as desert, mountain, forest, urban, coastal ocean, and agriculture. Analysis of these sub sets shows that the dimensionality present varies with the environmental type, but is typically more that 25 and sometimes reaches 50. Finally, spatial averaging was used to improve the measurement precision or signal-to-noise ratio of the data sub sets. Analysis of the precision enhanced data shows that the recorded dimensionality is a strong function of the instrument precision. The results of research suggest that to capture the available information, future remote sensing instruments in this spectral region should have more than 100 spectral bands across the spectral range and that the focus of the instrument design should be high signal-to-noise ratio.