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Sequential data assimilation of canopy attributes from multispectral bidirectional reflectance

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Many vegetation characteristics change over synoptic, seasonal, and interannual time scales. Monitoring changes in canopy photosynthetic capacity using NDVI over the annual cycle has been a key component in observing and modeling the dynamics of the carbon cycle. However, many other facets to changing vegetation attributes remain unexploited. For instance, daily changes in plant physiological status are not assimilated into weather forecasts, despite the key role of water stress in modulating droughts. In addition, many dynamic plant characteristics are ignored in retrievals of multitemporal satellite imagery, such as stem silhouette area, tree height, ground cover, or leaf biochemistry among others, although all of these parameters have sensitivity in particular bands and particular sun/view angles and could be retrieved.

We present here an effort to assimilate a number of plant architectural parameters used to drive the numerical 3-D canopy radiative transfer model DISORD. The assimilation procedure is to use a Kalman Filter to sequentially assimilate multispectral satellite reflectances using a monte carlo technique that uses an ensemble of model realizations to define the covariance between model parameters and the observed reflectances in each spectral band at the actual sun/view geometry. Each new observation provides information that can update the model parameters that are correlated with it; for satellites such as Terra or Aqua, the parameters can be updated as often as twice-daily.

The canopy parameters themselves have been directly measured at four sites in Hawaii Volcanoes National Park. These observed parameters are exploited in two ways. First, the statistics of these parameters are used in the development of the forward model, to determine the ecological parameter space for DISORD. Second, the observations are used after the assimilation to determine whether the a posteriori estimates of the model parameters have any meaning in the real world; it is entirely plausible that using wrong values for some model fixed parameters or another inherent model bias can result in parameter estimates that are implausible.

It was discovered early on that the numerical calculation of the reflectance for each ensemble member at each timestep for each pixel would be prohibitively expensive computationally, so we developed a neural network (NN) approximation of the model, trained on a large number of ensemble realizations for each band, for all possible sun/view geometries. This analytic NN approximation was approximately 1000x faster than the numerical model and ˜98% accurate with non-significant bias. The NN model was then incorporated into the data assimilation research testbed DART developed at NCAR. DART assimilated MODIS bidirectional reflectance in 7 spectral bands using the unique geometry of each observation to estimate the time-varying canopy attributes at each of the four sites where ground truth was available. The comparison between the assimilated and observed parameters is discussed.