Thermal Remote Sensing and the Thermodynamics of Ecosystem Development

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Abstract

Thermal remote sensing can provide environmental measuring tools with capabilities for measuring ecosystem development and integrity. Recent advances in applying principles of nonequilibrium thermodynamics to ecology provide fundamental insights into energy partitioning in ecosystems. Ecosystems are nonequilibrium systems, open to material and energy flows, which grow and develop structures and processes to increase energy degradation. More developed terrestrial ecosystems will be more effective at dissipating the solar gradient (degrading its exergy content) and can be measured by the effective surface temperature of the ecosystem on a landscape scale.

Ecosystems are viewed as open thermodynamic systems with a large gradient impressed on them by the exergy flux from the sun. Ecosystems, according to the restated second law, develop in ways that systematically increases their ability to degrade the incoming solar exergy, hence negating it's ability to set up even larger gradients.

Thus it should be expected that more mature ecosystems degrade the exergy they capture more completely than a less developed ecosystem. The degree to which incoming solar exergy is degraded is a function of the surface temperature of the ecosystem. If a group of ecosystems receives the same amount of incoming radiation, we would expect that the most mature ecosystem would reradiate its energy at the lowest quality level and thus would have the lowest surface temperature (coldest black body temperature).

Initial development work was done using NASA's airborne Thermal Infrared Multispectral Scanner (TIMS) followed by the use of a multispectral visible and thermal scanner- Airborne Thermal and Land Applications Sensor (ATLAS). Luvall and his co-workers have documented ecosystem energy budgets, including tropical forests, mid-latitude varied ecosystems, and semiarid ecosystems. These data show that under similar environmental conditions (air temperature, relative humidity, winds, and solar irradiance) and within a given biome type, the more developed the ecosystem, the cooler it's surface temperature and the more degraded the quality of it's reradiated energy.

HyspIRI is a hyperspectral visible/Near IR and multispectral thermal future global satellite mission that will collect data to study the world’s ecosystems and will provide a benchmark on the state of the worlds ecosystems against which future changes can be assessed. HyspIRI will provide global data sets that will provide a means for measuring ecosystem development and integrity.