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Energy Balance Closure Analysis Based on Eddy Covariance Flux Tower Observations

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Energy balance closure is a fundamental principle in micrometeorology, ensuring that all energy fluxes within an ecosystem are properly accounted for. The eddy covariance (EC) method, widely used for measuring land –atmosphere exchanges of energy and mass, often exhibits energy closure discrepancies, particularly across different timescales. This study investigates ecological year energy closure using flux tower data collected over multiple years at Skukuza, Kruger National Park. Energy closure was assessed using the fundamental balance equation R_n-G=H+LE, where net radiation (R_n), soil heat flux (G), sensible heat flux (H), and latent heat flux (LE) were analyzed across different timescales. Radiation shields and soil heat flux sensors were employed to capture variations in energy fluxes. Statistical analysis of multiple ecological years revealed that energy closure varies significantly with seasons, with wetter years exhibiting lower energy imbalances compared to drier years.

The findings indicate that energy closure improves with increased turbulence (frictional velocity) but remains incomplete due to measurement uncertainties, sensor sampling scales, and ecosystem heterogeneities. Results highlight a persistent energy closure gap, with an average closure of approximately 80%, consistent with other EC studies globally. The study underscores the challenges in achieving full energy balance closure and emphasizes the need for improved sensor calibration, turbulence parameterization, and data correction techniques. These insights are crucial for refining EC methodologies and enhancing the accuracy of land-atmosphere energy exchange assessment in semi-arid ecosystems.

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