Remote Sensing Using Remote Controlled Airplanes: Monitoring Vegetation near Eddy-Covariance Towers

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Rationale and Objectives

Spatial variation in soils and vegetation can complicate the interpretation of micrometeorological flux measurements. For example, the area sampled by eddy covariance instruments (i.e., footprint) is dependent on wind speed, wind direction, and atmospheric turbulence. Remote sensing can be used to characterize the leaf and soil components of the vegetation surrounding these monitoring sites. These data can be paired with a source area model to reach the 30-m scale measurements of the sampling footprint (Desjardins et al., 1997). Unmanned aerial vehicles (UAVs) as well as relatively low-cost digital near-infrared cameras are well suited for frequent low-altitude imaging of flux monitoring sites. The objective of this research was to examine the feasibility of using a small unmanned-controlled aircraft to collect images of the area source sampled by eddy covariance towers operating in tallgrass prairie near Manhattan, Kansas.

Design Criteria and Mission Description

The UAV was designed to fly the following mission:

• The pilot hands the engine (no batteries are available).
• Fly a circular pattern via radio control, the plane stays at a 2.5 ft altitude, while transmitting GPS and video information to the pilot.
• When the GPS information indicates that the plane is over the target altitude (300 ft min, 800 to 1000 ft max), the pilot activates altitude hold and wing leveler circuits. The plane automatically maintains the target altitude for the duration of the 8 to 10 minute mission.
• The pilot flies the plane in a pattern over the study site while viewing the video image from an on-board display facing camera. When the plane is over the target, the pilot triggers the shutter on the remote sensing camera.
• After it is 8 to 10 min flight, the batteries can be recharged in 20 minutes. If lithium polymer batteries are used, 24 minute flights are possible.

Power System

The plane is powered by a Manfrotto 135Watt brushless motor (www.manfrotto.com) running on 26S 3000 mA Nimh batteries. The motor turns at 2,100 rpm and is powered by a 10:1 gearbox. This configuration was capable of taking the aircraft to flight altitudes of 300 ft in less than two minutes. Total flight duration was about 8 min. Lithium polymer (Li-Poly) batteries (e.g., www.fms.com) would extend flight duration to 24 minutes and reduce weight.

Avionics and Flight Controls

The UAV was powered by a Futaba 135Watt brushless motor running on 36S 2000 mA NiMh batteries (or these batteries can be seen protruding through the body under the nose). When flying a 1000 to 2000 ft, the camera shutter on the remote sensing camera.

Cameras

The plane is configured to carry three different cameras. The Dycam and Tetracam are digital cameras capable of generating NDVI (Normalized Difference Vegetation Index) and other spectral indices.

• Canon SL2: 1.3 MB digital camera
• Dycam Agricultural Digital Camera (ADC): red (635-667 nm) and NIR (835-870 nm) (www.tetracam.com).
• Tetracam: digital resolution and near infrared camera, 1.5 million pixel sensor (www.tetracam.com). The Tetracam is the replacement for the Dycam.


Discussion and Recommendations

Many flights were made using the Super Frontier Senior and the JK Aerotech Big T equipped with different cameras and antennas. Most of the work during 2003 was aimed at perfecting the hardware and learning to operate the aircraft under various conditions. Many attempts were made to fly the planes on a propeller powered using GPS and a 300 W PC101 (www.3th.co.uk) controller. This proved to be quite difficult and research is still underway to obtain this objective. The propeller data was collected using digital data loggers and a laptop computer. The flight data (over 35 flights) are from a laptop computer. The data collected was 20 percent more power than the existing aircraft. Results showed that taking repeated images of a small research area was very feasible using remote controlled aircraft. Starting in the spring of 2004, we plan to collect images of our eddy covariance towers over a more intensive schedule throughout the growing season. Leaf area and biomass will be sampled at several points around the towers on the same dates. The post-processed images will be combined with a footprint model to gain a better understanding of the vegetation contributing to the flux measurements.

Images of the Rannells Flint Hills Prairie Preserve taken in October, 2003 at 460 m (1500 ft) using the Dycam ADC with a wide angle lens. An eddy covariance tower is in the middle image.

Historical UAV Flight

The history of drones (UAVs) and model aviation is not new. In 1907, a set of instructions was published in a French newspaper inviting anyone to attempt the flight across the English Channel. The reward was a gold medal, 2,500 francs, and the title "Chevalier de la Legion d'Honneur." In 1910, W. M. Miller of Elmira, New York built a model airplane and flew it across the Atlantic Ocean. The plane was made of wood and wire, over 10 feet long, and had a wingspan of 12 feet. The plane was flown by a remote controller. The project was the brainchild of Michael J. Fitzjarrald. The plane flew from Cape Spear, Newfoundland to Mannin Beach, Ireland. The 11-pound TAM 5 (Trans-Atlantic Model 5) made the 1,888-nautical mile flight at an average speed of 49 mph in just over 38.5 hours. Made of balsa wood and Styrofoam covered with red mylar, the plane is four feet long and 12 feet wide. The plane is controlled by a 12-volt battery and has 20 percent more power than the existing aircraft. Results showed that taking repeated images of a small research area was very feasible using remote controlled aircraft. Starting in the spring of 2004, we plan to collect images of our eddy covariance towers over a more intensive schedule throughout the growing season. Leaf area and biomass will be sampled at several points around the towers on the same dates. The post-processed images will be combined with a footprint model to gain a better understanding of the vegetation contributing to the flux measurements.

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An electronic version of this poster is available at
http://www.oznet.ksu.edu/envphys/Research/researchada.htm

Note: With the exception of the ADC camera, this photo was taken with the author's personal funds.

Photographic credits: Fairy flight line on the Rannells Prairie. Unmarked points are on the left and grained points are on the right side of each photograph. From left to right, the first image was taken in June, the second during the end of July, and the third in late August when the vegetation had recovered following a 100 mm rain on July 20. Eddy covariance towers were deployed on both pastures during this period.

Digital photographs of several eddy covariance towers and the headquarters buildings at the Rannells Flint Hills Prairie Preserve near Manhattan, KS.