CLIMATE & ATMOSPHERIC SCIENCE

Argonne NATIONAL LABORATORY

EVIDENCE OF DROUGHT AND DISEASE, AND RECOVERY IN ARM MEASUREMENTS AT OKMULGEE, OK FOREST

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ABSTRACT

The Okmulgee Forest, particularly oak trees, declined in health during drought conditions and the resulting fungus infestation of hypoxylon canker in 2008–2012, as shown in an earlier poster (Cook and Stoffel, 2013). The forest has recovered some since then, but not fully. We use SGP EF21 ARM data from 2008–2017 to look for evidence of forest recovery in radiation and eddy correlation flux measurements.

ANALYSIS

We analyzed ECOR, MET, and SIRS data from the SGP ACRF Okmulgee, OK EF21 for 2008–2017. We calculated warm season (May–September) mid-day (1000–1400 CST) averages of the data, plus total daytime precipitation and night-time (0000–0400 CST) CO_2 respiration. The drought, and recovery from it, are reflected in changes in the measurements. Nearly one third of the oak trees died during 2008–2012. Some recovery of the forest has occurred since then, in conjunction with generally increased precipitation (Figure 1).

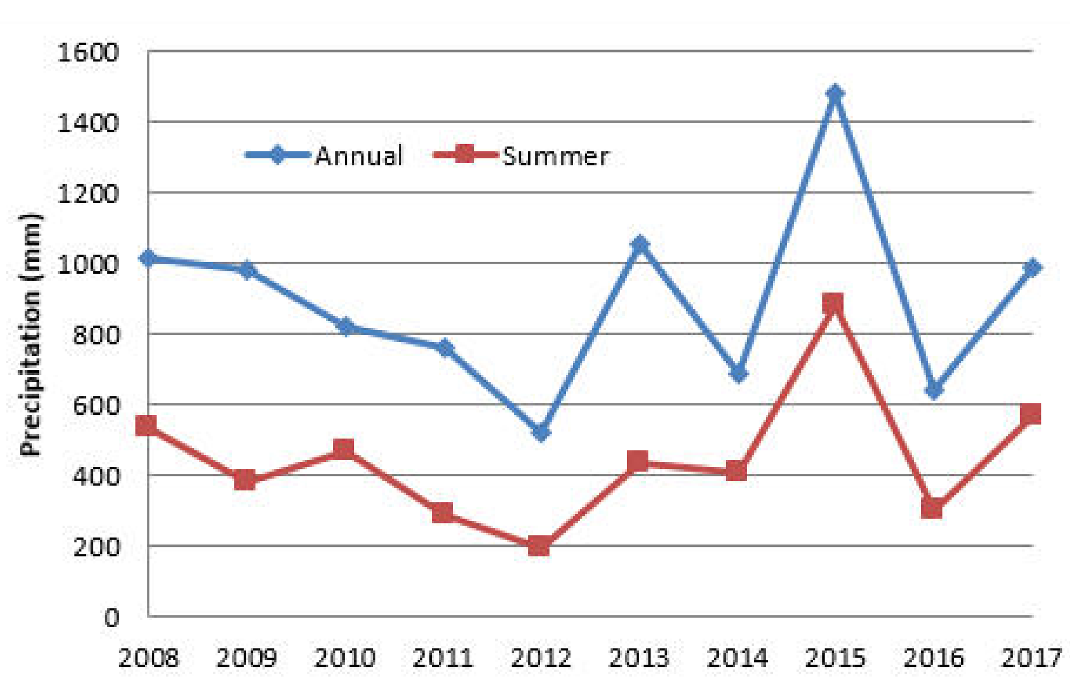

Figure 1. Precipitation

SUMMARY

Effects of the drought and recovery from it in the Okmulgee Forest reflect dramatic changes. The soil characteristics, in conjunction with shallow tree root depth, contributed heavily to the susceptibility of the forest to damage from drought and disease. However, the greatly defoliated forest has been recovering with increased precipitation.

The increases in CO_2 flux and respiration in Okmulgee Forest in 2013–2017 remind one of the characteristics of a younger forest, not of a mature stand such as was present in the Okmulgee Forest a decade ago. The damage to the forest from drought and hypoxylon canker was substantial enough to transform the forest into what now appears to be a younger, more vibrant, and faster growing forest than its age would seem to suggest.

RESULTS

The forest decline in 2008–2012 was detected in several ARM measurements that reflect on the physical characteristics of the forest, including elevation angle (angle of attack of the wind) and friction velocity (ustar, an indicator of surface roughness), from the ECOR sonic anemometer (Figure 2). The significant variation in tree crown height and shape in the Okmulgee Forest yields a fairly large friction velocity. Friction velocity increased slightly and elevation angle decreased significantly during the drought years, as oak trees died, leaving the tree canopy less leafed, more open, and less "smooth" overall. During the recovery of 2013–2017, friction velocity returned to pre-drought values, but elevation angle decreased for three more years before recovering to near zero in 2017. The loss of canopy, particularly near the measurement tower, may have caused the decreasing elevation angles, until being reversed by canopy recovery in 2016–2017.

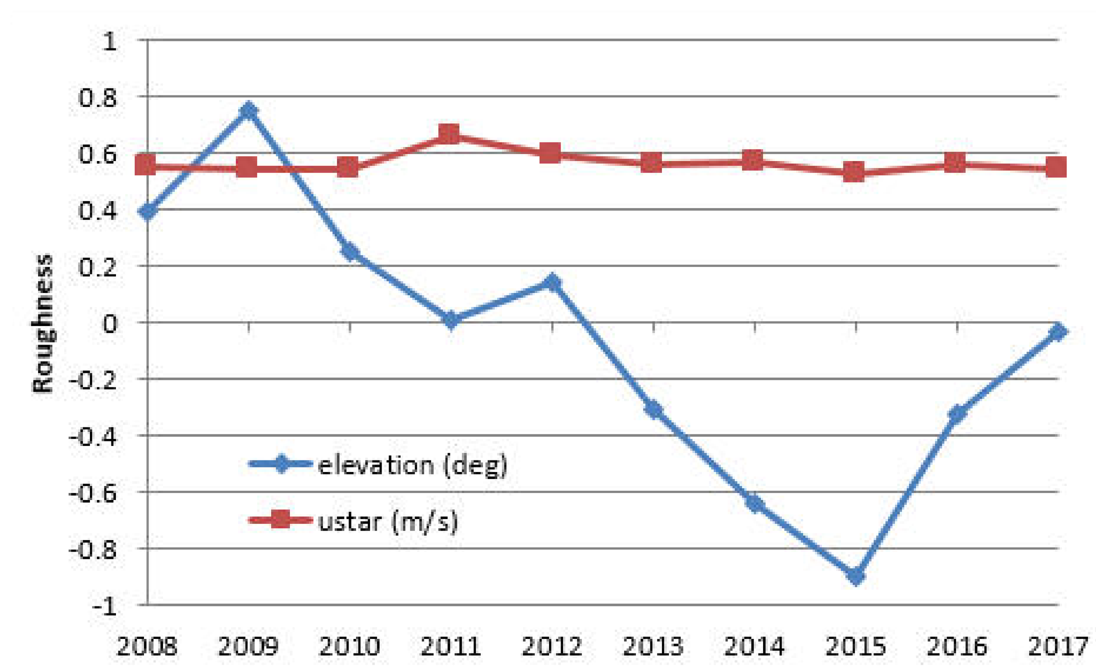

Figure 2. Roughness

Figure 3 shows an increasing trend in down-welling shortwave radiation, net radiation, and up-welling longwave radiation during the drought. The first is likely attributable to a reduction in cloudiness, the second from increased down-welling shortwave radiation and canopy defoliation, and the third in response to the resulting increased forest temperature. Down-welling shortwave radiation and net radiation decreased the two years after the drought period, with the former leveling out since. However, net radiation increased sharply and up-welling longwave radiation increased slightly in 2014–2017, possibly indicating a lack of forest canopy recovery directly under the radiometers. A visit to EF21 confirmed that the canopy around the measurement tower has largely not recovered and is mostly populated with dead trees. The ARM upwelling radiometric measurements may no longer be representative of the general Okmulgee Forest canopy.

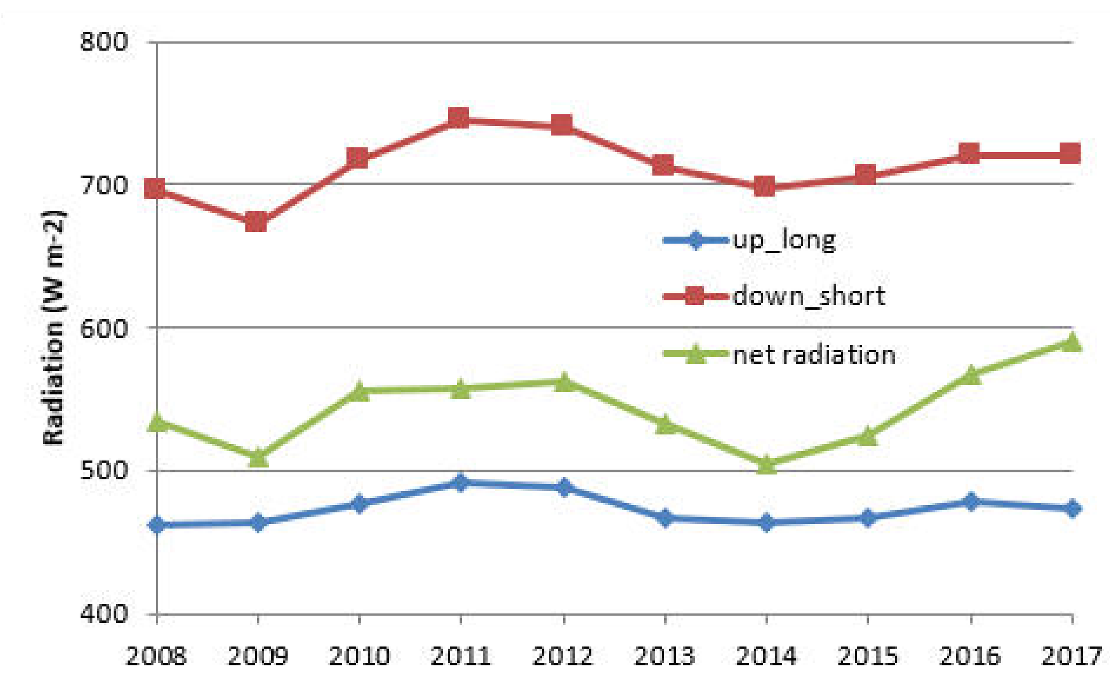

Figure 3. Radiation

Note the effect of increased precipitation on evapotranspiration since 2012 in Figure 4. Furthermore, decreased forest foliage may have increased exposure of the soil and understory, thereby contributing to the increased latent heat flux. Aside from 2016 (the lowest precipitation year since the drought), sensible heat flux has returned to pre-drought levels.

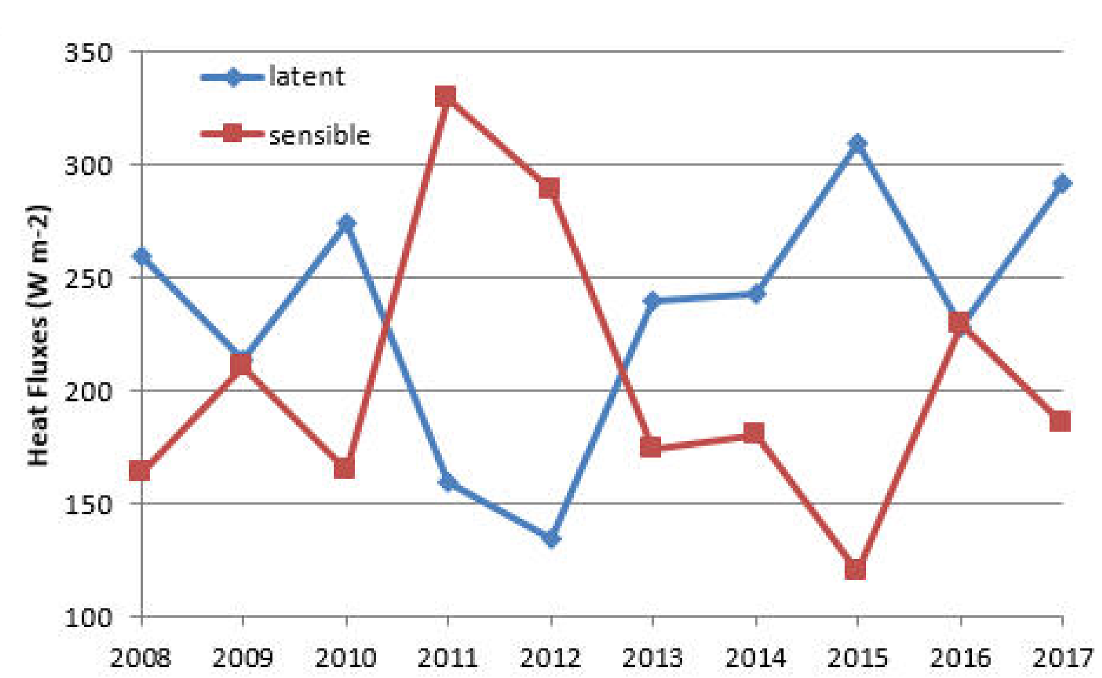

Figure 4. Heat Fluxes

Figure 5 best shows the recovery of the forest canopy. CO_2 flux steadily increased after 2012, with nighttime respiration of CO_2 also generally increasing. The soil at Okmulgee Forest is a very shallow silt, less than 40 cm deep in most areas, with bedrock below, squeezing tree roots into a small area. This greatly reduces the ability of the tree roots and soil to sequester CO_2. Thus, as the increase of tree and understory foliage allowed CO_2 flux to increase, with the subsequent increase in transport of CO_2 into roots and the soil, the loss of CO_2 at night through respiration also increased.

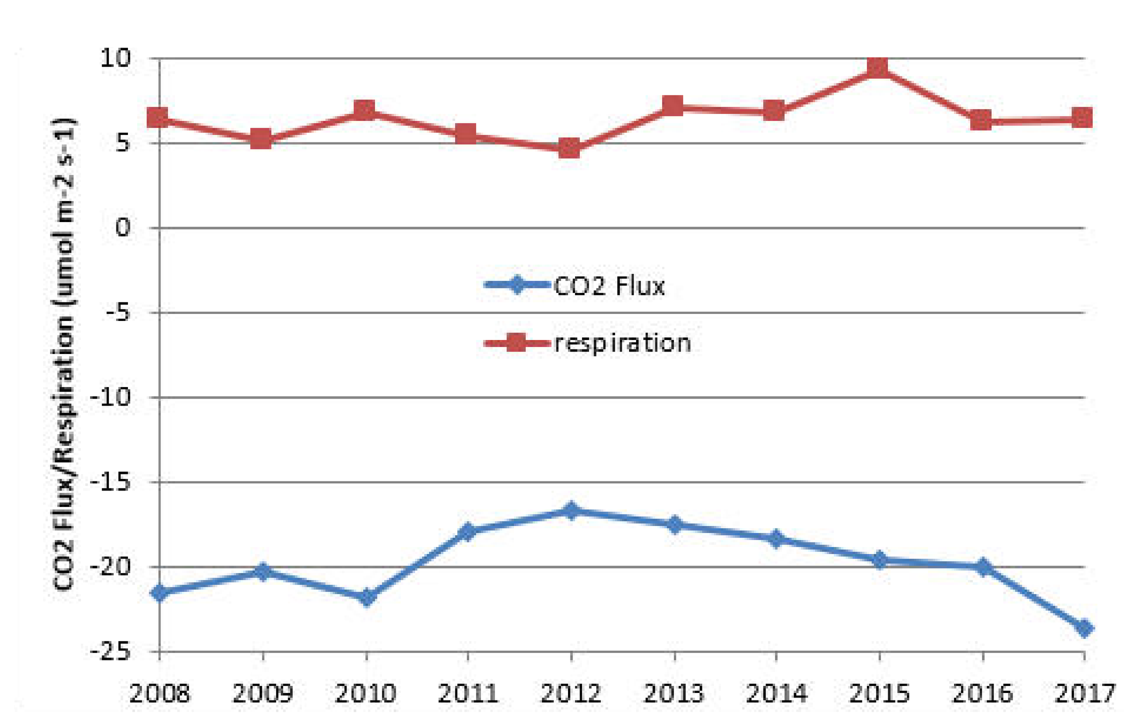

Figure 5. CO_2 Flux

ARM CLIMATE RESEARCH FACILITY

REFERENCES

Cook, D.R., T. Stoffel, "Is there evidence of Okmulgee Forest decline in ARM measurements", Fourth Atmospheric System Research Program Science Team Meeting, Potomac MD, Mar 18–21, 2013.

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