Observing the Diurnal Cycle of Corn Canopy Water Storage with Destructive and Microwave Measurements

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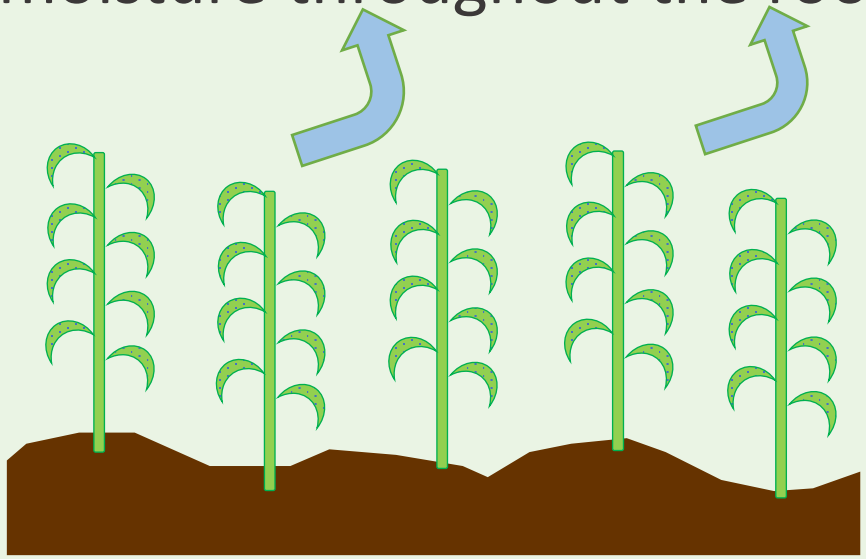
Joint 7 - Plants and Ecosystems' Water Use Strategies Under Limited Environmental Conditions and Disturbances (7.3) Tuesday, May 2nd 2:00 pm

Joint with the **35th Conference on Agricultural and Forest Meteorology** and Sixth Conference on Atmospheric Biogeosciences

Motivation

We hypothesize that we can make inferences about water stress by observing the diurnal cycle in vegetation canopy water storage

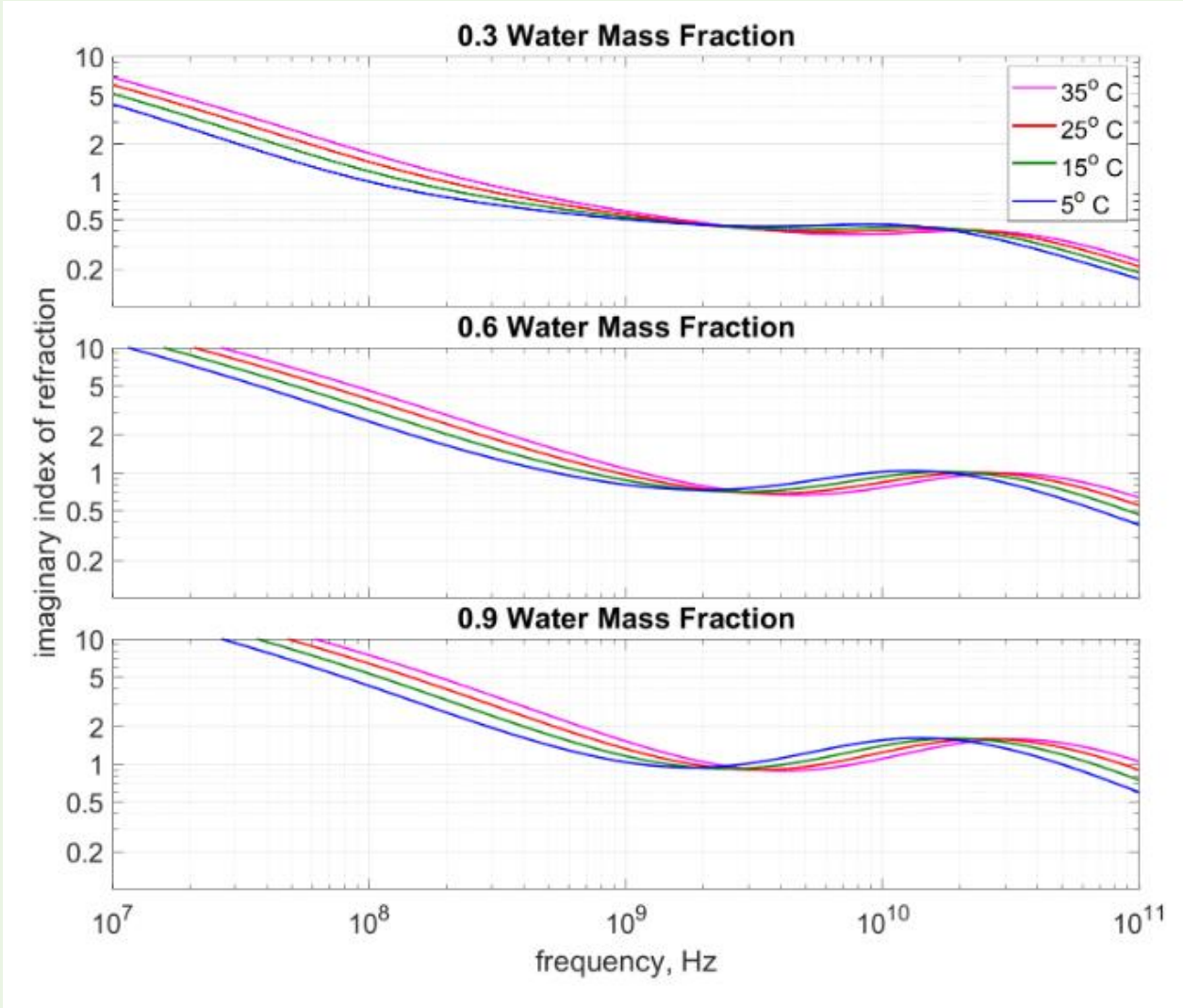
- Water stress reduces biomass accumulation, including yield
- Water stress reduces water vapor flux to the atmosphere and reduces growth, altering surface roughness. This influences weather and climate.
- This is also an indirect measurement of soil moisture throughout the root zone.



Theory

Microwave extinction in a corn canopy depends on frequency, temperature, and **water mass fraction**

- Combination of empirical model of El-Rayes and Ulaby (1987) for corn water content and Buchner, et al. (1999) for water temperature
- Increasing water fraction increases index of refraction (more loss)
- Below 2.5 GHz, increasing temperature increases index of refraction
- Above 2.5 GHz, increasing temperature increases index of refraction

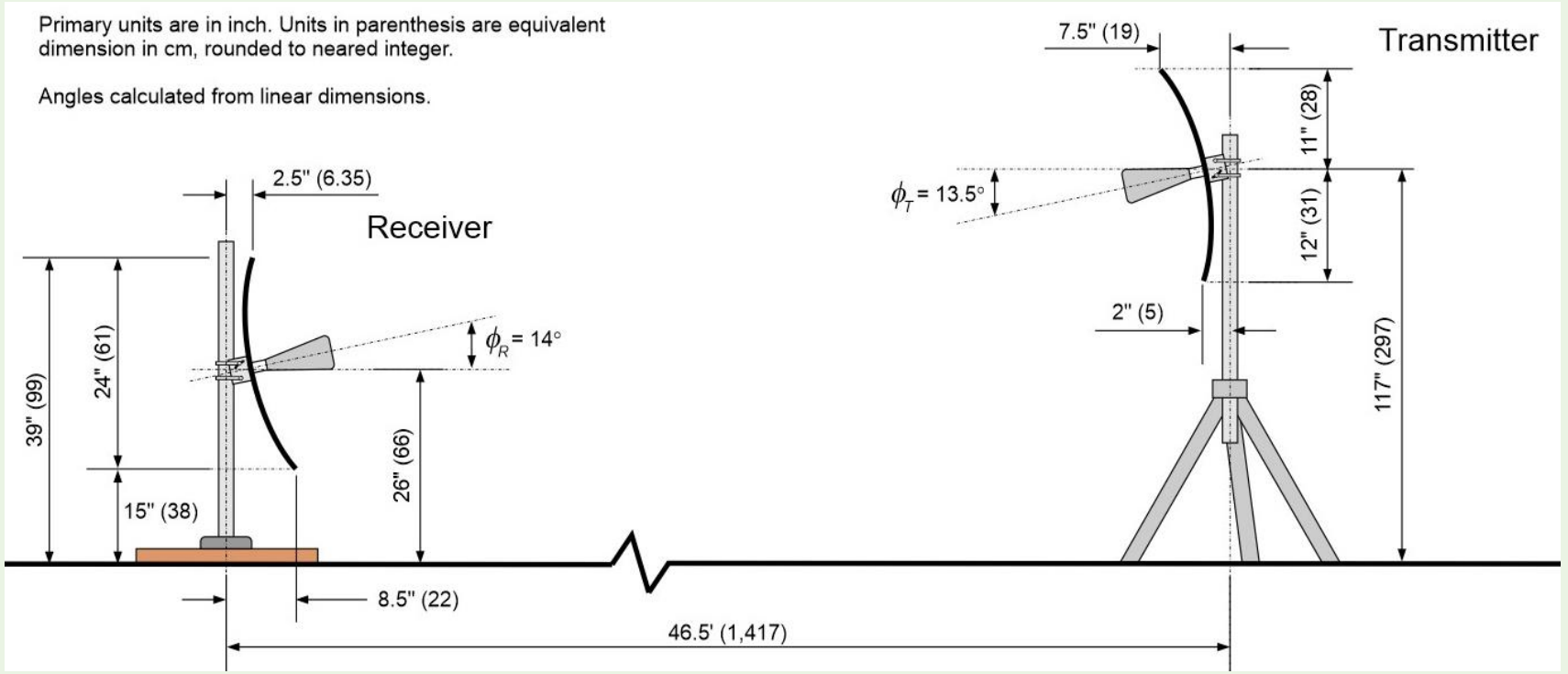


Methods - Instruments

Infrared thermometers to measure vegetation temperature
HMP45C thermometers for air temperature and humidity

Radio link antenna system in the corn canopy

- 900 MHz to 5 GHz



Methods – Destructive Sampling

Sampling on August 3, 2022

- Ames, IA
- US Drought Monitor drought intensity: D0 –Abnormally Dry

60 whole plants sampled per period

- Eleven sampling periods, between 6 am and midnight

Fresh mass measured in the field (water mass + dry biomass), dry mass measured after heating in an oven

Results - Weather

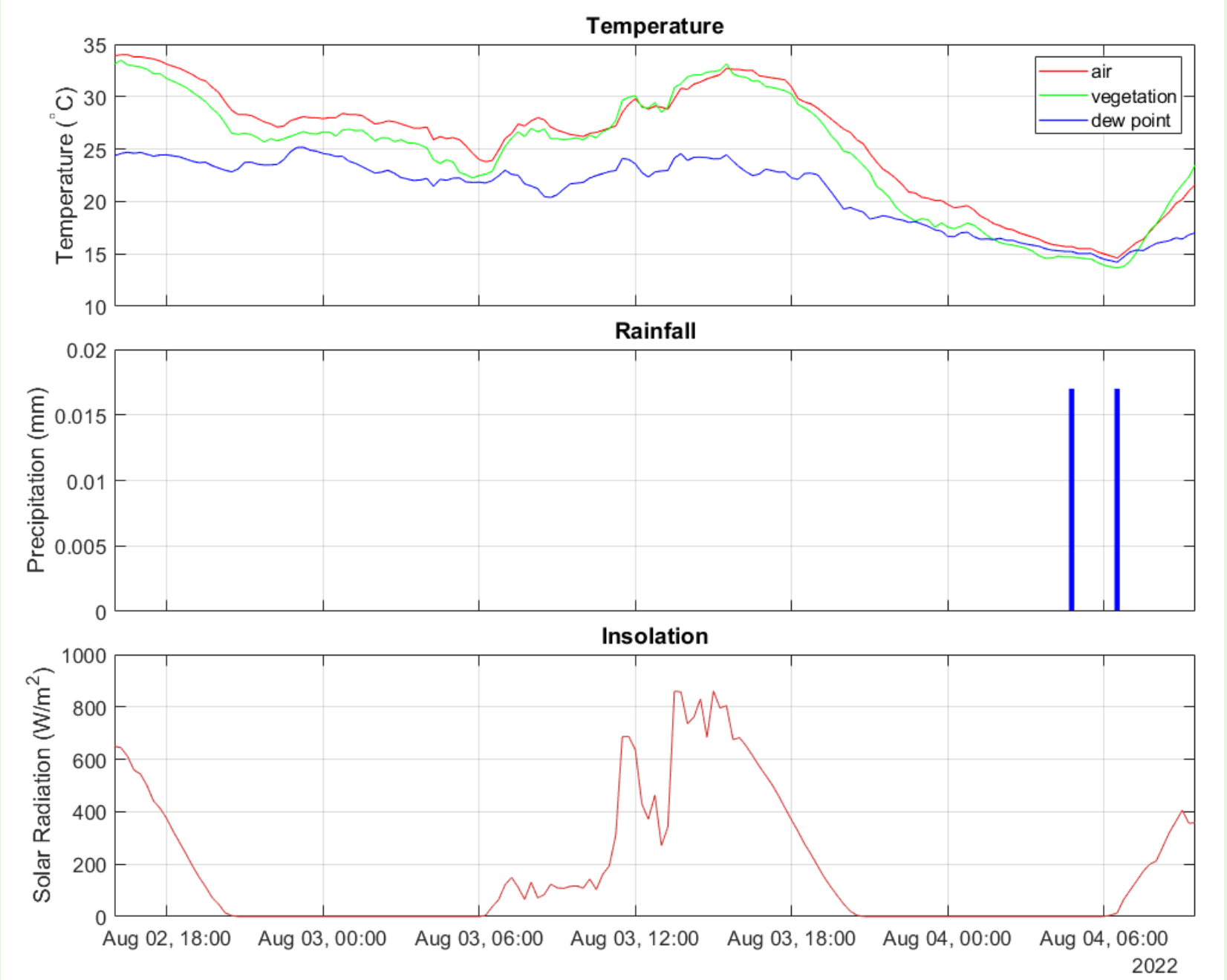
Mostly cloudy, warm, and dry in the morning

- Plants were free of dew

Hot, dry, and mostly sunny after 1:30 pm

Cloud – free and cooling in the evening

- Plants were still free of dew



Results – Destructive Sampling

W_f : Water mass fraction

W_g: Gravimetric water content

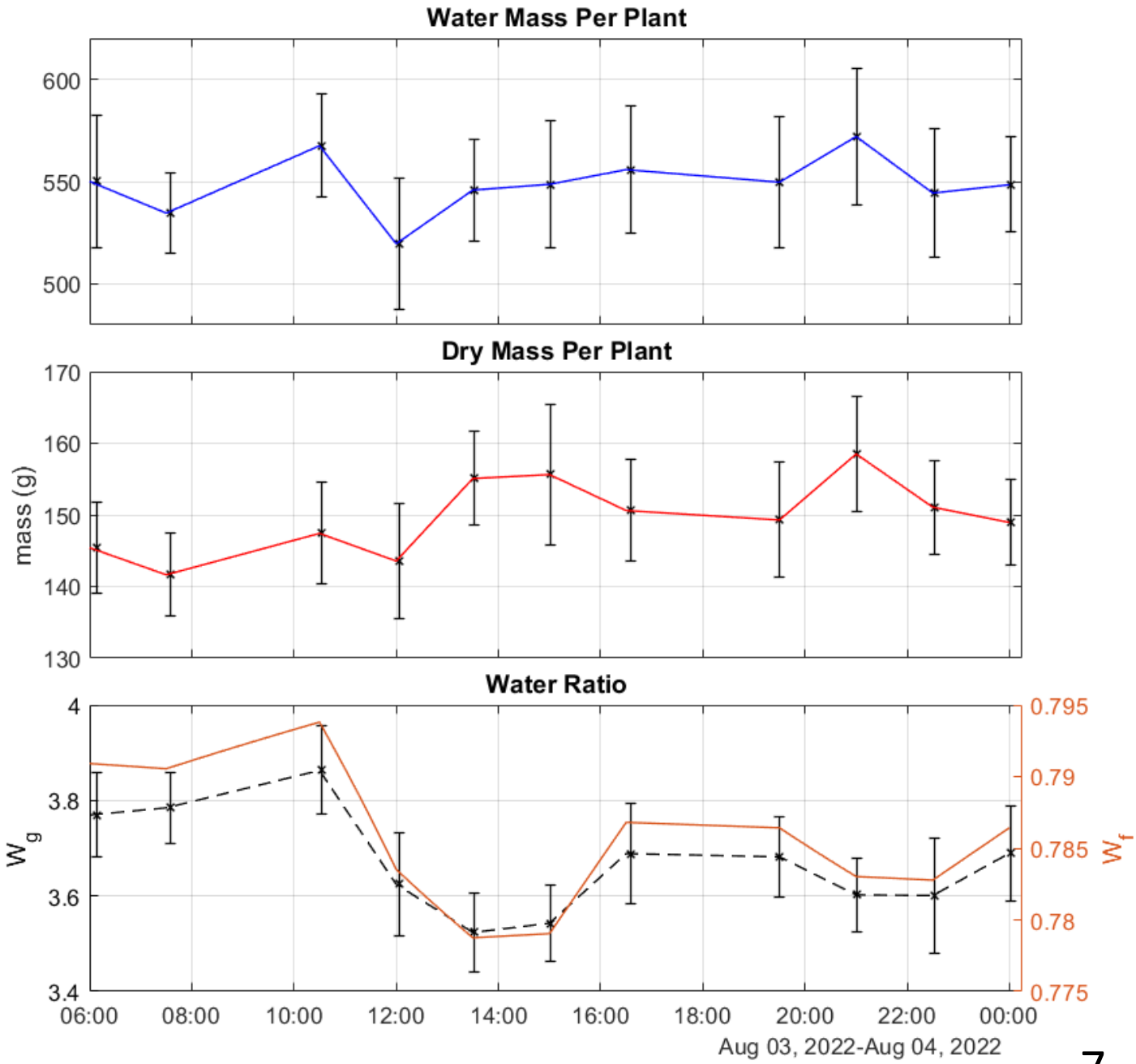
W_f = water mass / fresh mass

W_g = water mass / dry mass

$W_f = W_g / (W_g + 1)$

Significantly higher W_g at 10:30 vs afternoon samples

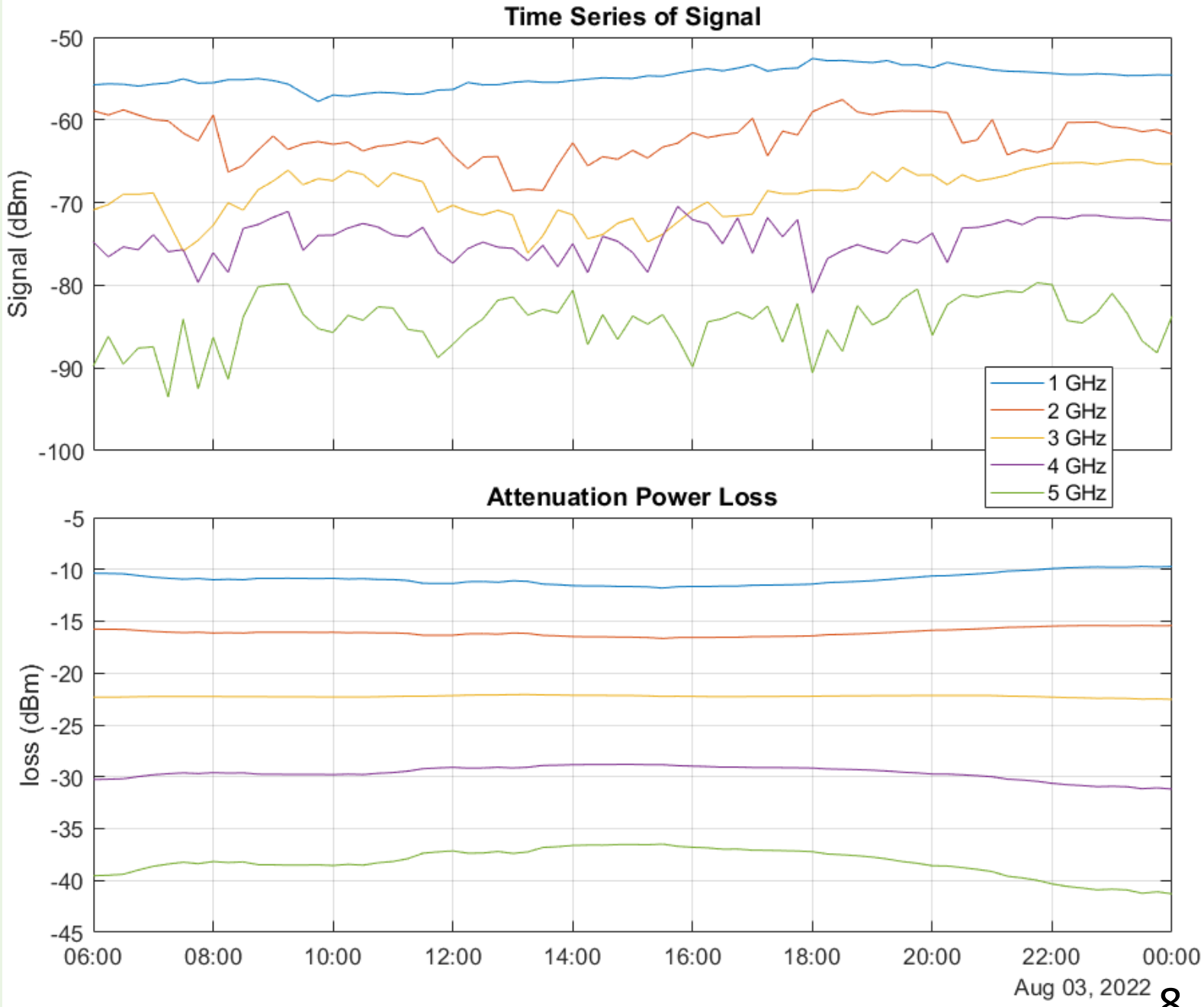
~0.06 mm water lost from 10:30 to 1:30



Results – Microwave Power

Stronger signals for longer wavelengths (modeled and observed)

Modeled power loss diurnal cycle mostly due to temperature, some signal strengths are stronger in the evening than midday



Conclusions

This was a rare weather day

- An Iowa corn canopy being dew – free in the morning and for an 18-hour period is unusual. This occurred because of hot temperatures the previous day followed by cloud cover overnight

Sample Size is everything

- The destructive sampling showed a diurnal pattern because of the large sample size (60 per period)
- Looking across 14 m of plants may not be enough to measure a diurnal cycle in signal strength by microwave radio links