

Preliminary C_n^2 Computations Using UAV Measurements

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Abstract—Presently, the prediction of atmospheric ducts and its influence on electromagnetic wave as they propagate through the atmosphere is an developing subject of study. The Radar and Electromagnetic Ducting in Stable Atmosphere over Water (REDSAW) field campaign seeks to further characterize and model the effects of stable atmospheric conditions on radio frequency propagation. As part of this initiative, OSU deployed two drone receiver systems at the Salton Sea Causeway which recorded both the vertical electromagnetic (EM) profile and meteorological (MET) parameters during the flights. This collected data will aid the investigation into the relationship between the environment and EM wave propagation. In this paper, an initial analysis into computing the turbulence utilizing the collected MET parameters from the drone systems is explored.

I. INTRODUCTION

Expanding on previous research completed during the CASPER and CLASI field campaigns [1] and [2], the Radar and Electromagnetic Ducting in Stable Atmosphere over Water (REDSAW) field campaign seeks to further quantify and investigate EM wave propagation within the stable boundary layer. This multi-institute project continues to pursue improvement in present representations of evaporation ducts within stable boundary layers. As the EM wave travels through the atmosphere, it is substantially impacted by slight changes in the index of refraction for air. This may be caused by turbulence which varies air density resulting in variation in the refractive index. These part-per-million deviations can also cause ducting, trapping traveling EM waves. These drone systems deployed in this project are designed to measure the signal transmitting through the atmosphere and sample the environment during its flights. This information will help with understanding how to characterize the environment under the influence of ducting and turbulence.

II. DEPLOYMENT

The REDSAW campaign was deployed from April to May 2024. Fig. 1 depicts the fully deployed system at the Salton Sea, CA. For this deployment, a tower was erected to the north of the Salton Sea on the Salton Sea State Recreation Area that transmitted radio frequency (RF) signals. Throughout the experiment, additional transmitters (TXs) were regularly deployed from the Twin Otter, an aircraft, and the JetYak, an autonomous boat. These TXs travelled specific paths along the RF path link. On the south-side of the Salton Sea is the Salton Sea Causeway (SSC) which was where the two OSU drone receiver (RX) systems and the OSU ultra-wideband system (UWB) were located. This paper focuses on the drone receiver

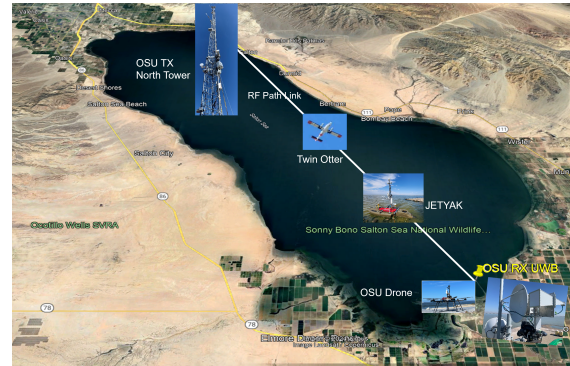


Fig. 1. REDSAW deployment including OSU transmitter and receiver systems.

systems which were designed to record both the EM signals and the atmospheric conditions during the UAV flights.



Fig. 2. OSU Drone Receiver systems where the left side shows the Hexacopter and right side shows the tethered Quadcopter setup.

A. OSU Drone Receiver Systems

Similar to the previous CLASI campaigns [2], the Hexacopter drone receiver system shown on the left in Fig. 2 has an attached RF payload which includes the following items: the Ettus E320 software defined radio (SDR), two custom-built limiter low noise amplifier (LNA) circuits, and two receiver (RX) antennas attached to the top and bottom mast of the drone [3]. It also included a MET payload of a Vaisala RS41 radiosonde attached to the upper mast. The drone routinely flew thirty minute flights from 5 - 300 m on the south side causeway of the Salton Sea. Research capability was extended with the addition of developed tethered drone receiver system. The system integrated the Aero Systems West Quadcopter with the Elistair tethering system. This system has the range of 0 - 100 m which allowed the drone to remain fully-powered

during its flights. The new quadcopter receiver system in Fig. 2 included a similar EM payload of the E320, limiter LNA circuit, and 1 RX antenna attached to the upper mast. Two Vaisala RS41 and a dropsonde were attached to the top mast and tethering line as part of the MET payload. Since it is fully-powered by a generator, the quadcopter RX system is capable of flying continuous flights up and down from 5 - 98 m for extended periods of time, an improvement to the previous drone receiver system. These sensors measured the temperature (T), pressure (P), and relative humidity (RH) during the drone flights. These parameters were then used to calculate the modified refractivity (M) profiles. This continuous recording of the MET parameters during these vertical drone flights provide the capability to look into the time variability and fluctuations within the profiles.

III. TURBULENCE THEORY

Turbulence is weather phenomena that is created through the irregular motion of air including eddies and vertical currents. In this paper, two methods were investigated in order to verify our initial computation of C_n^2 , the atmospheric refractive index structure constant and a key parameter for determining the intensity of turbulence.

A. Martini

The first method that was examined was a technique suitable for computing C_n^2 using high-resolution radiosonde data [4]. This method was applicable for clear-air conditions and for ranges from 0 - 20 km. This was an ideal method since Vaisala radiosondes were placed on the drone receiver systems that collected MET parameters of T, P, and RH from the environment. Eq. 1 represents the equation for C_n^2

$$C_n^2 = 2.8L_o^{\frac{4}{3}} X^2 \quad (1)$$

where L_o is the outer scale length and X is the mean vertical gradient. X is calculated using P, T, potential temperature, water vapor pressure.

B. Numerical C_n^2 Computation

The second method harnesses the ability to calculate a vertical profile of index of refraction (n) directly from the drone measurements which resulted in the following C_n^2 from [5]

$$C_n^2 = 1.91 \langle n^2 \rangle L_o^{\frac{-2}{3}} \quad (2)$$

where $\langle n^2 \rangle$ represents the variance of the index of refraction.

IV. RESULTS

A single M profile extracted from flight 12 is shown in Fig. 3. Flight 12 shows a result from the tethered quadcopter receiver system. Both M and n can be calculated from the MET parameters collected by the radiosonde attached to the drone. This information was entered into the two methods of C_n^2 ; the blue represents the numerical calculation and orange represents the calculation using Martini. Fig. 3 shows that the

two methods overlap each other and that the profiles follow each other closely. Work is still being done to compare and verify results.

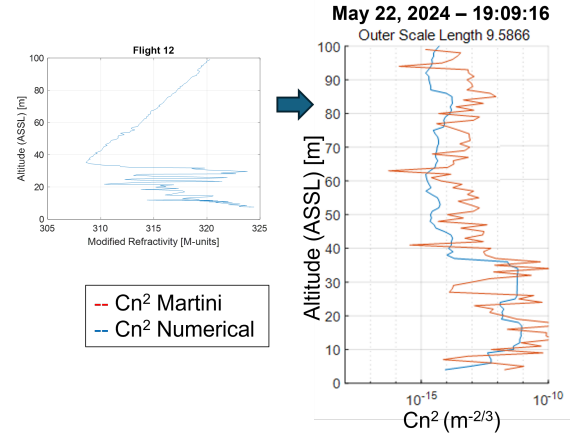


Fig. 3. Calculated M Profile from drone flights measured MET parameters is utilized in two different methods for calculating C_n^2 .

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