Transmitter Power Studies on Meteor Radar Head Echo Returns

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Abstract

Meteor "head echo" intensities are typically recorded by high-power large-aperture (HPLA) radar systems. These meteor observations have been analyzed extensively to measure parameters such as Doppler velocities, composition and mass estimates. The majority of observations conducted with these radar instruments utilize the maximum available transmitter power in an attempt to obtain the highest meteor flux rate. But there are not direct power law studies on the role of transmitter power and the received backscatter signal. We present observations from three HPLAs to better assess this effect. These results are vital to estimating the Earth's total meteor flux.

1. Introduction

Observations of sporadic radar meteors have been of increasing interest to the scientific community as the role of meteoroids in space weather, in the aeronomy of the meteor zone, and in various aspects of the plasma physics and radio science surrounding the meteoroid interaction with the atmosphere becoming increasingly apparent [1, 2]. In addition, the investigation of the near-earth meteoroid flux is crucial to understand its effect on satellite lifetimes [3] as well as contributing significantly to the metallic composition of the upper atmosphere and ionosphere [4, 5].

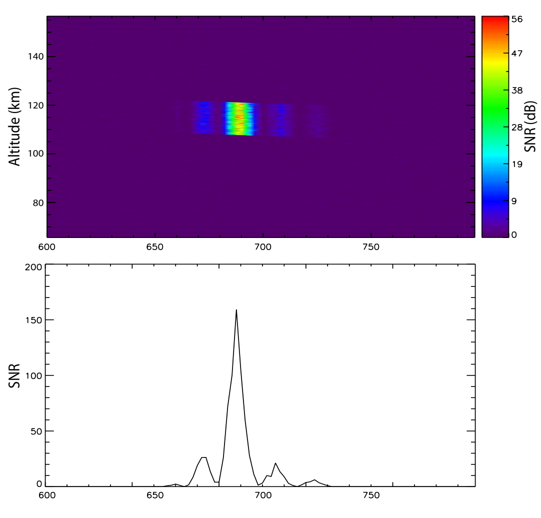

Figure 1. Typical RTI image for a meteor observed at Arecibo Observatory.

An advantage of using a high-power large-aperture (HPLA) radar for meteor observations is the use of high antenna gain available from these facilities. By transmitting at maximum available power one should expect to detect as many meteors as possible. An example of a typical Range-Time-Intensity meteor return collected with the 430 MHz Arecibo radar is shown on Figure 1. At this location, transmitting at maximum power level produces Signal-to-Noise Ratios (SNRs) values of over 1,000. However, each HPLA has its own instrument function, which contributes a bias to the observations. Examples of these biases include altitude and velocity distributions of the observed populations [6]. It has been proposed that the received power is also an instrumental bias; however, no proof of this postulate has been proposed.

The SNR of the signal received from a head-echo is traditionally defined as the ratio of the received signal power to the received signal noise. The received power from a meteor, assuming a point scatter is [7]

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$$P_S = \frac{P_T \lambda^2 G^2}{(4\pi)^3 r^4} \sigma_m \tag{1}$$

and the system noise power is

$$P_N = k_B T_{sys} B \tag{2}$$

where P_T is the transmitted power, G is the antenna gain, σ_m is the meteor cross section and B is the radar bandwidth. By combining equations (1) and (2) we can express the SNR as

$$SNR = \frac{P_S}{P_N} = \frac{P_T \lambda^2 G^2}{(4\pi)^3 k_B T_{sys} B r^4} \sigma_m \tag{3}$$

Equation (3) leads us to the assumption that by increasing the transmitter power at a single HPLA facility, the SNR would be proportionally increased. Additionally, by increasing P_T one would expect to be able to bring a portion of the population out of the noise floor and into the detectable range (SNR ~ 0.5).

We present results of meteor studies from three different HPLA radars. In all three instances the transmitted power has been varied during the course of the observations while keeping all other observation parameters constant (e.g., beam position, bandwidth, etc.). We also attempt to provide a power law dependence for detected meteors vs. the transmitted power.

2. Meteor Observations

Our meteor observations are comprised of three separate campaigns at three HPLAs, the 430 MHz Arecibo Observatory (AO), the 440 MHz Millstone Hill (MH) radar and the 50 MHz Jicamarca Radio Observatory (JRO). The meteor observations at AO were conducted over the course of three different years on the same calendar dates. The MH observations were conducted on the same day by alternating full and half transmitter power every 30 minutes. The JRO observations were conducted on successive days with differing transmitted power. For each facility the same searching algorithm was used on the collected data of varying power to ensure the maximum meteor counts. These facilities were chosen for our experiments because unlike the modern phased-array radars (i.e. the Poker Flat and Resolute Bay ISRs), the transmitter power of these radars can be easily manipulated without deforming the beam pattern illuminated on the ionosphere.

3. Results and Discussion

The observations conducted at AO were obtained over the days of 22-24 Feb in 2001, 2006 and 2007 [8]. The transmitted powers were 1.8 MW, 2.5 MW and 2.65 MW, respectively. In order to remove time of day ambiguities only events detected from 0400-0800 LT were considered. This period was chosen as it was centered on local sunrise, hence maximizing the sporadic meteor flux. Figure 2 shows the Cumulative Distribution Function for the AO meteors detected at 105 km in altitude. This height was chosen as it corresponds to the peak of meteor flux at AO [8]. As it can be seen from the CDF, more meteor head-echoes are detected during observing periods with higher transmitted power. Even at low SNRs (<5) the CDFs of the higher P_T observations make it highly probable that not all events are detected at HPLA's maximum available power.

The meteors observed using both MH and JRO allow for a more direct comparison. In this case the number of events obtained at varying frequencies. At both facilities there is a clear difference in meteor counts at lower powers vs. collections at full power. While these relationships are not directly linear, combining them with the AO results allows us to form a more complete picture on the dependence of detected head-echoes versus the available transmitted power from the radar.

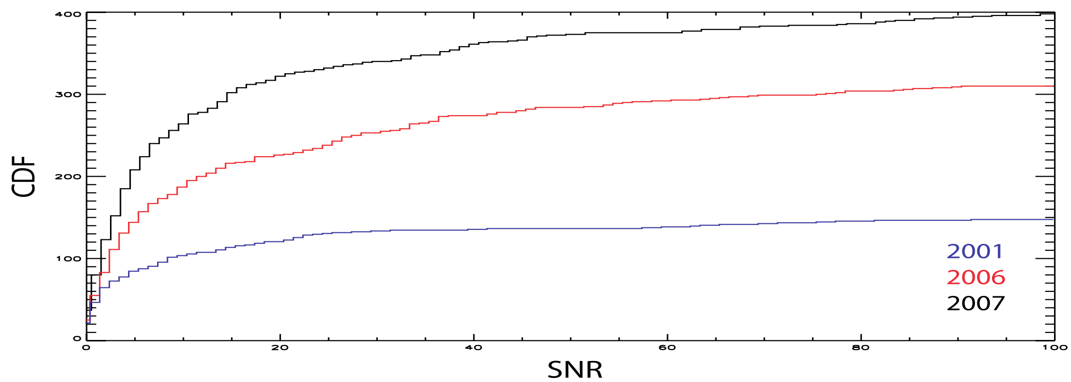

Figure 2. Cumulative distribution functions for meteors observed at AO for 105 km in altitude.

4. Conclusions

We have taken meteor observations at three separate HPLAs in an effort to link the observed meteor flux with the transmitted power of the facility used. In all three cases increasing the non-zero power shows a statistically significant increase in the number of meteors observed. These results should be considered when modeling mass deposition rates and atmospheric chemistry reactions. Previous studies have assumed that HPLAs such as AO can see every event during meteor observations [9, 10]. As the modeling of the total meteor mass deposition is based on the observed meteor count rate, it should be taken into account that it is highly likely that no HPLA can see every meteor event that passes through its beam.

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