Probing the plasmasphere using Jicamarca long pulse experiments

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Abstract

The **Jicamarca Radio Observatory (JRO)** located in Lima, Peru, is an Incoherent Scatter Radar (ISR) observatory used to study the equatorial upper atmosphere. In the current poster we describe renewed high altitude experiments utilizing a long pulse technique which allows us to probe the plasmasphere at heights of up to 10,000km.
Altitude functions of electron density, electron and ion temperature and light ion composition are derived using full profile analysis. This analysis uses measured lag products and transforms them into the functions above using ISR theory and inverse methods. Noise removal is achieved employing order statistics to account for moving space debris and satellites.

I. Introduction

The plasmasphere, also called the inner magnetosphere, is that region of the atmosphere which extends immediately after the ionosphere. It consists mainly of cold plasma in the range of 1-2 eV trapped by the earth's geomagnetic field and composed mainly of H^+, He^{++}, and O^+ ions. There is continuous flow of plasma upwards from the ionosphere in the daytime and downwards at night. It also shrinks and grows in response to the incoming solar wind.
The study of the plasmasphere is an extremely important area of atmospheric research as it plays a crucial role in radiation belt dynamics [1] and it is rather still poorly understood. This poster gives a brief description of the processes used to obtain meaningful parameters from this area of the atmosphere.

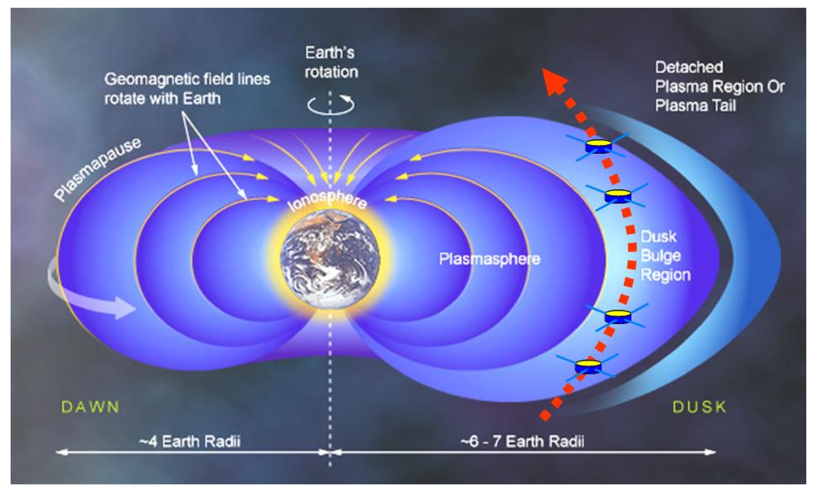

Figure 1 – Diagram of Earth's plasmasphere[1]

II. Long Pulse Technique for High Altitude Probing

Jicamarca's scattering wavelength of 3m is ideally suited for high altitude experiments, as it is much larger than the Debye length of the plasma at the altitudes of interest.
In the long pulse technique, shown in Fig 2, a pulse sequence is transmitted every 100ms which consists of a 1.6-4ms pulse followed by a short double pulse pair. Three different pulse widths of 4ms, 2ms and 1.6ms are used. We use 128 pulse sequences followed by a transmitter-off period lasting 2.2 sec. The duration of the entire sequence is 14.8 sec. The received backscatter signal is sampled at a rate of 100μm and further processed to yield 16 different lag products per range [2].
The data is the subjected to a full profile analysis which we explain in the next section.

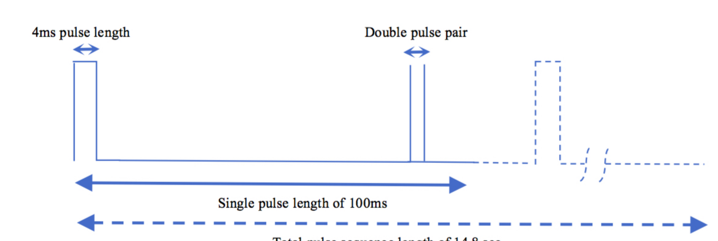

Figure 2 – 4ms long pulse sequence

III. Lag Product Measurements

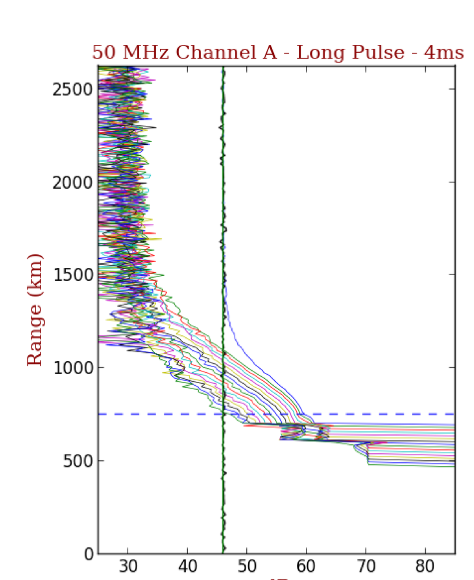

Figure 3 – Lag products vs altitude -4ms pulse

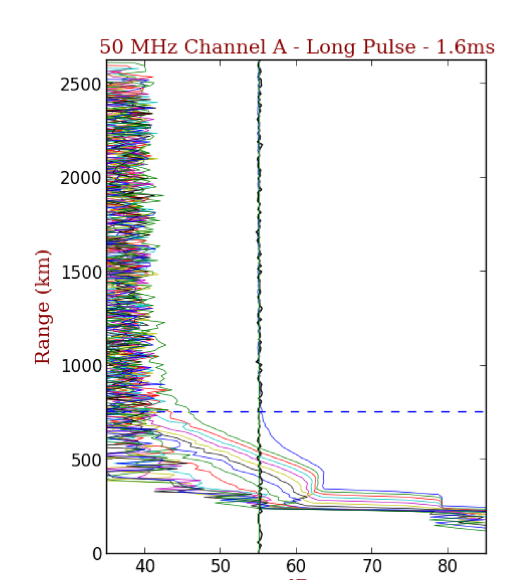

Figure 4 – Lag products vs altitude-1.6ms pulse

Fig 3 and Fig 4 above represent the 16 lag product curves as a function of altitude calculated for the 4ms pulse and a 1.6ms pulse used in previous topside experiments. We can see how the 4ms pulse has a superior signal to noise ratio for higher altitudes. We indicated a reference altitude of 750km with the dotted line for illustration purposes.

IV. Full Profile Analysis

The full profile analysis method combines experimental data with a grid search to derive estimates of atmospheric parameters, which are plasma electron density, electron/ion temperatures and light ion composition. The experimentally calculated lag products are compared to their estimated values and the cycle illustrated in Fig 5 is repeated for multiple iterations until a desired level of accuracy is achieved [3].

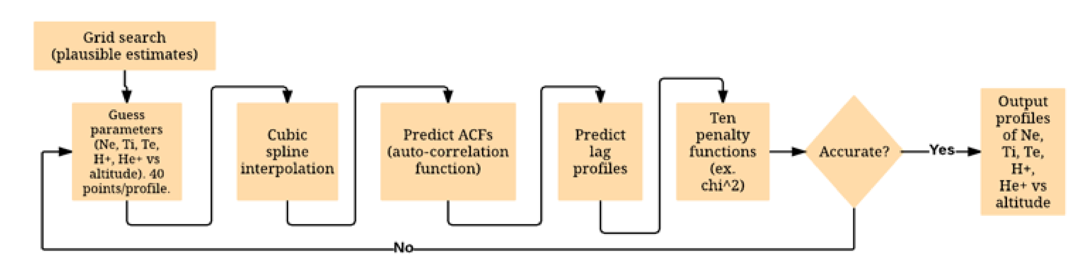

Figure 5 – Grayscales represent random medium.

V. Analysis Results

A full profile analysis was performed from data sampled in May 2016. Measurements were taken during periods where sky noise from the milky way was low. Figs 6 and 7 illustrate results for the electron density (N_e) vs altitude obtained for two different time periods within a 24 hour window, and for altitudes close to 10,000km. The violet curve represents measurements from the short pulses, green curves from the 1ms pulse, blue curves from the 2ms pulses, and cyan curves from the 4ms pulses [2].

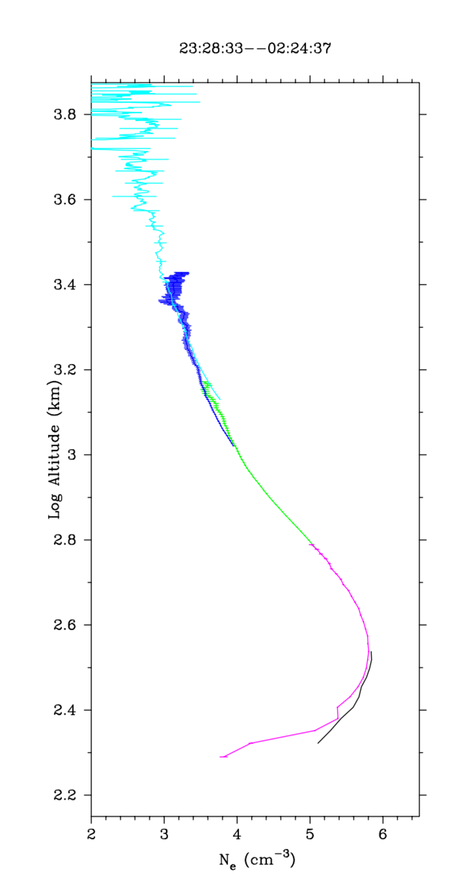

Figure 6 – N_e vs altitude on logarithmic scale (midnight window). Error bars are drawn every 12th range [2]

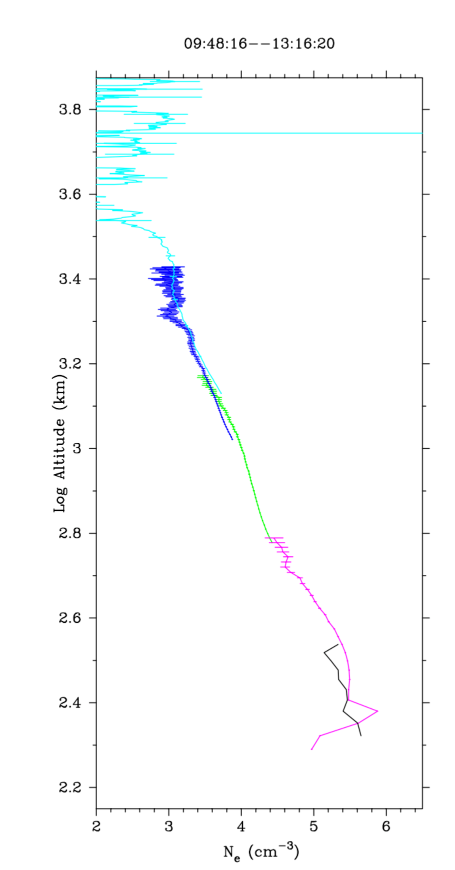

Figure 7 – N_e vs altitude on logarithmic scale (noon window). Error bars are drawn every 12th range [2]

Fig 8 illustrates an example of various parameter distributions obtained from the former topside experiments conducted at Jicamarca using 1.6ms long pulses. Software is being rewritten to extract these parameters for higher altitudes sampled with the 4ms long pulse.

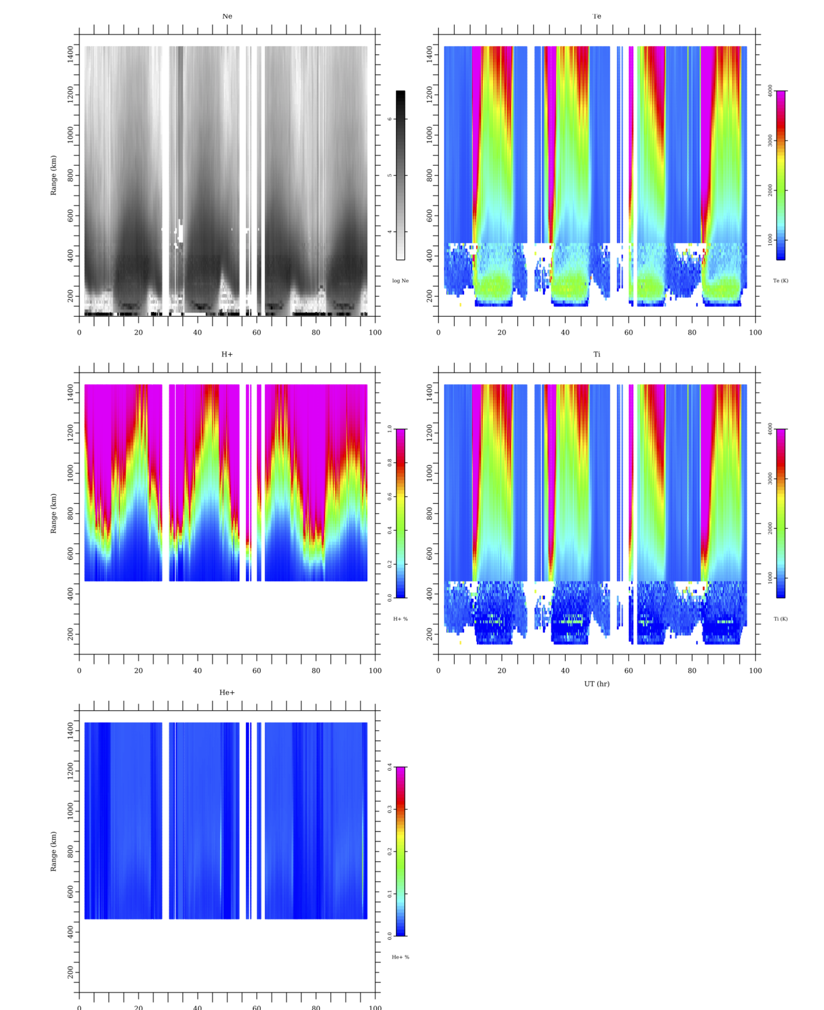
Figure 8 – N_e, T_e, T_i and ion composition vs altitude for topside 1.6ms long pulse experiments

Conclusions

- The long pulse technique and full profile analysis can be used to probe the plasmasphere
- Enabling a fourth transmitter at Jicamarca to increase overall power will be explored as a means to probe at even higher altitudes
- Transmitting long pulse pairs with different polarizations will be explored for higher signal to noise ratio and better range resolution

References

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[3] D. L. Hysell, F. S. Rodrigues, J. L. Chau, and J. D. Huba, Full profile incoherent scatter analysis at Jicamarca, *Annales Geophysicae, 26*, 59, 2008.

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