Introduction

O+–O collision frequency is an important aeronomic value. It is associated with upper atmospheric momentum and energy exchanges between O+ and O.

A discrepancy between Fabry-Perot Interferometer (FPI) and Incoherent Scatter Radar (ISR) data led Burnside [1987] to suggest a modification factor (1.7) to the theoretical value. The study included data from 95 nights between 2010 and 2015. Nights with high AP were excluded, leaving 1235 data points in total.

Goals:
1. Use new Hi-Res FPI data to characterize neutral wind behavior.
2. Use new extended dataset to revisit the Burnside Factor using the same methods as Buonsanto et al.
3. Apply Bayes Estimation to produce a stronger estimate of the Burnside Factor

Instruments

Fabry-Perot Interferometer (FPI):
- The neutral wind speeds, both Zonal and Meridional, were retrieved from the new High Resolution Fabry-Perot Interferometer via Madrigal. New high-resolution instrument which began operation in 2009.

Incoherent Scatter Radar (ISR):
- The ISR system consists of two antenna: the Zenith pointing antenna and the MISA steerable antenna. Data was collected only when both antenna were in operation and the MISA collected data in two different directions at an elevation above 45°. The echo seen by the antenna can be used to determine the ion temperature, electron temperature, and the line of sight ion velocity.

Gridding the Data:
- The data is then binned by time and altitude to make a grid to derive first derivatives. These parameters are used in the equation below to calculate a principle component of the Burnside formula, the Diffusion Velocity.
- The line of sight velocities are projected into different coordinate frames to produce the Parallel velocity. The number densities of the neutral species, [O], [N2], and [O2], are

\[ n_i = -2 \omega_i \sin(i) \left( \frac{T_i + T_e}{T_i + T_e} \right) \begin{vmatrix} 1 & 1 & 1 \\ \frac{d}{d\eta} \frac{1}{T_i + T_e} & \frac{d}{d\eta} \frac{1}{T_i + T_e} + \frac{d}{d\eta} \frac{1}{T_i + T_e} + \frac{d}{d\eta} \frac{1}{T_i + T_e} + \frac{m_i g}{k(T_i + T_e)} \end{vmatrix} \]

based on the MSIS model but modified with neutral temperature measurements.

Diurnal Neutral Wind Structure

The Diurnal Neutral Wind Structure was analyzed using an aggregate data set of measurements taken between 2009 and 2014 from the new FPI.

The data set was divided into seasons and months to show how the diurnal trend can vary over the year.

Bayesian Estimation

Another goal of this study was to take a new approach to estimating the Burnside Factor, this time using Bayesian statistics. This type of estimation differs from the classical Frequentist approach because it describes a parameter with a probability distribution (PD) which should account for uncertainty. The prior PD is multiplied by the PD of a new datum to produce a new estimate of the parameter. The process is described below with both equation and cartoon.

\[ P(x|A) = P(x) \times P(A) \]

If the first prior distribution is the same, the result of Bayes method should be independent of the order which you measure each datum. Three tests were conducted to assess impartiality to random order.

Conclusions and Future Work

- Clear Diurnal trends present in Meridional and Zonal directions
- Frequentist Mean is within the uncertainty of Buonsanto et al. estimate. Actually closer to predicted mean.
- Frequentist Median is within 1% of Buonsanto et al. estimate.
- Bayes Estimation yields a Burnside factor significantly lower than frequentist methods and Buonsanto et al prediction.
- Bayes prediction should be rigorously tested and explained

Selected References


The Burnside Factor

The thermospheric winds were modeled using the conservation of momentum by Salah and Holt [1974]. Buonsanto [1997] rearranged the equations in this model to produce an equation for the Burnside Factor:

\[ F = \frac{V_{dr} \left[ c \sqrt{T_r}[O] + 6.9 [N_2] + 6.7 [O_2] \right] - 6.9 [N_2] - 6.7 [O_2]}{U_e \cos(I) - V_{\|}} \]

Values outside of the interval: [0.35 3.9] were excluded with physical reasoning

| Mean: 1.3581 |
| Median: 1.1386 |
| Standard-Deviation: 0.7609 |
| Buonsanto et al 1997: 1.15 ± 0.2 |

Selected References


An updated study of the O+–O collision frequency using corresponding FPI and ISR thermospheric wind experiments at Millstone Hill.

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