Equatorial Plasma Bubble Growth: Preliminary Numerical Assessment

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Introduction

The linear instability growth rate as derived by [Sultan, 1996] provides a measure of the likelihood for bubble growth based on environmental factors along the geomagnetic flux tubes that plasma bubbles occupy. Previous numerical approaches for the estimation of the Rayleigh-Taylor linear growth rate utilizing observations of the vertical plasma drift and the SAMI2 model have explored the unique local time distribution of equatorial plasma bubble occurrence in specific seasons and longitudes during solar minimum [Ajith et al., 2016, Zhan and S. Rodrigues, 2017]. Here we discuss preliminary results of a broader exploration of this approach where the bubble growth rate as a function of local time is determined for and compared between zonal, seasonal, and annual periods.

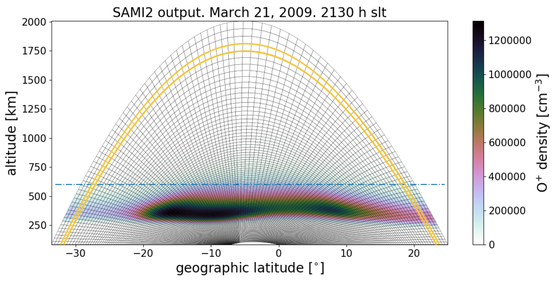

Figure 1: One magnetic flux tube is outlined here in yellow.

Growth Rate Equation

$$\gamma = \frac{\sigma_F}{\sigma_{total}} \left(V - U - \frac{g}{\nu_F} \right) K^F \quad (1)$$

equations and approximations:

$$\sigma = \frac{e}{B} \left[n_e \frac{\omega_e \nu_e}{\nu_e^2 + \omega_e^2} + \sum_{i=ion sp.} n_i \frac{\omega_i \nu_i}{\nu_i^2 + \omega_i^2} \right] \quad (2)$$

$$\nu_{in} = 2.6 \times 10^{-9} \left(n_n + n_i \right) A^{-1/2} \quad (3)$$

$$\nu_e = 5.4 \times 10^{-10} n_n T_e^{1/2} + \left[34 + 4.18 \ln T_e^3 / n_e \right] n_e T_e^{-3/2} \quad (4)$$

$$K^F = \frac{1}{N_e} \frac{\partial N_e}{\partial h} \quad (5)$$

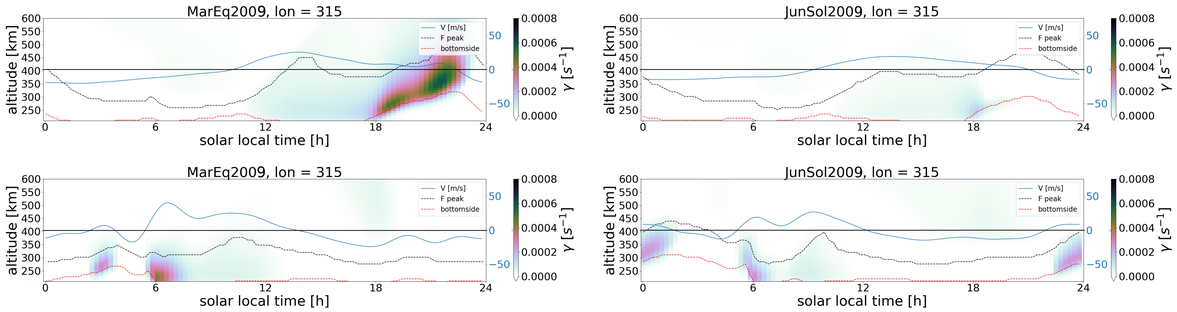

Figure 2: Equatorial growth rates in 2009 from 210 to 600 km as a function of local time.

Important Result

Fejer-Scherleiss drifts produce disparate growth rate from C/NOFS. Effects of solar activity are small(all F10.7 < 140). C/NOFS rates consistent with bubble occurrence distributions in local time [Smith and Heelis, 2017]. **June Solstice solar min growth rates unusually large.**

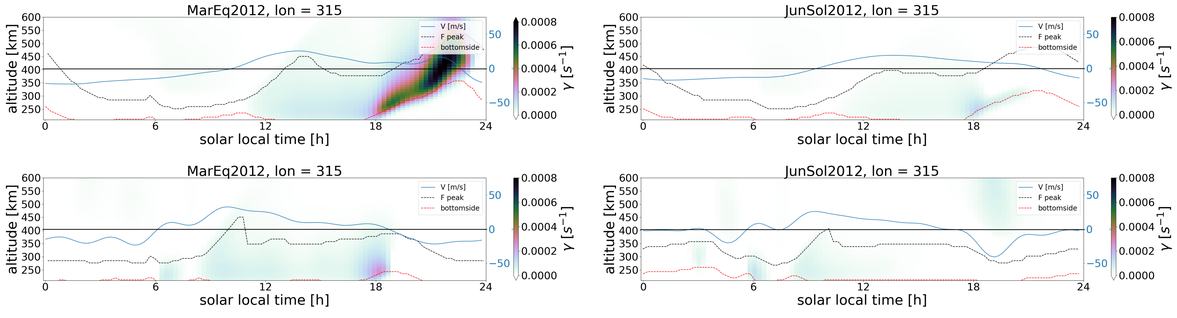

Figure 3: Equatorial growth rates in 2012 from 210 to 600 km as a function of local time.

Methodology

- Collate observed vertical plasma drift from C/NOFS IVM and take medians
- Data cleaning consists of removing drifts where:
- plasma density is less than 1000 cm^{-3}
- drifts are compromised by attitude control or photoionization
- Alternatively, extract Fejer-Scherleiss (FS) drifts from IRI
- Fit fourier series to drifts
- Provide SAMI2 model with Fourier fit
- Collect SAMI2, IGRF, HWM14, MSIS00 outputs
- Combine model outputs for calculation of flux tube integrated growth rate.
- calculate growth rates over 24 hrs of model data

Results

- 2009 drifts are similar to [Stoneback et al., 2011], no dusk enhancement and small postsunset drifts
- Solar min growth rates using C/NOFS drifts are largest during midnight and predawn hours
- Solar min growth rates using FS drifts are most positive during postsunset hours
- Solar min growth rates during June solstice are larger than solar moderate.
- Solar moderate growth rates using FS are very large from dusk until midnight.
- Solar moderate growth rates using C/NOFS drifts are always small, but largest at dusk.
- June solstice growth rates are small except where C/NOFS deep solar min drifts are used.

Discussion/Future Work

The contribution of the vertical drift has been discussed at length by [Smith and Heelis, 2018], but we can see immediately here that **prolonged weak and downward drifts are consistently colocated with small growth rates.** While these results are consistent with previous studies assessing vertical drifts and growth rates in solar minimum the foundation of this work is highly modular such that this approach **will be immediately expanded to other satellites, seasons, zones, and years.** This expansion and simultaneous use of bubble detection methods will be the foundation of an analysis into environmental drivers of bubble growth with an emphasis on the unique occurrence distribution during solar minimum observed in the previous solar cycle. Are the positive daytime growth rate and rapid change in F peak altitude real, an issue with SAMI2 or the approach? The tools used here are being developed **to be integrated into publicly available Heliophysics analysis packages currently available** at heliopython.org.

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- Timothy Duly: pyglow space physics package

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