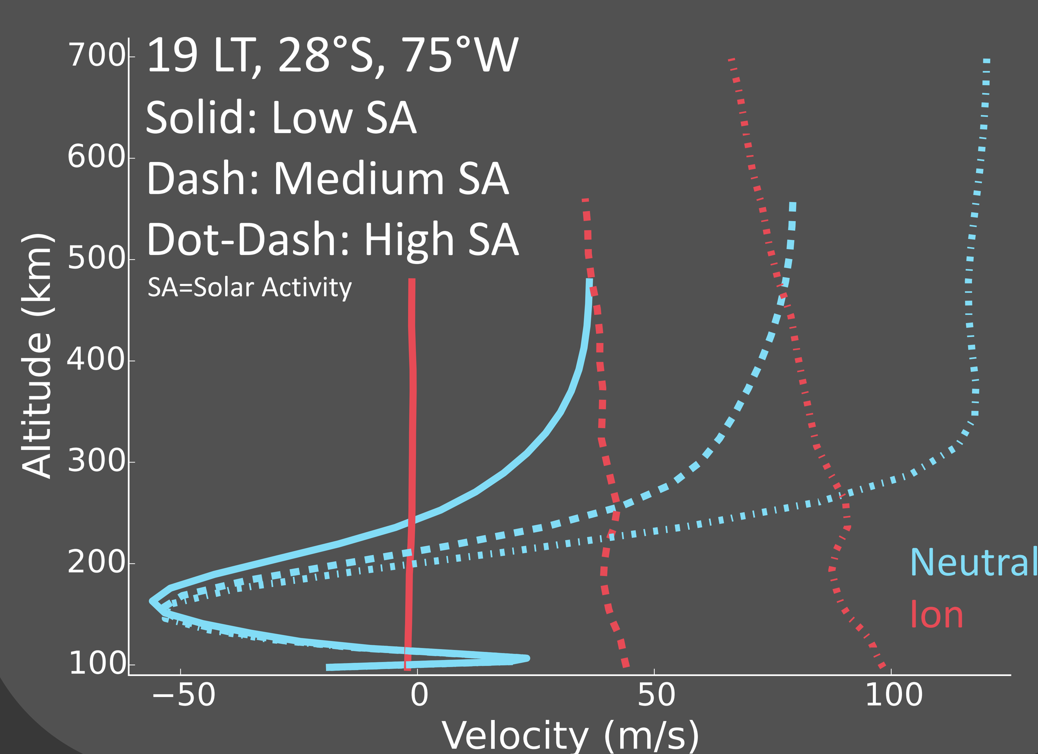
INTERACTIVE ION-NEUTRAL DYNAMICS IN THE LOW LATITUDE EVENING IONOSPHERE

William Evonosky[1] | Dr. A.D. Richmond[2] | Dr. A. Maute[2] | Dr. T.-W. Fang[3]

[1]University of Colorado Boulder, Boulder, Colorado, [2]NCAR HAO, Boulder, Colorado,
[3]CIRES, University of Colorado Boulder, Boulder, Colorado

INTRODUCTION

Winds in the ionosphere drive altitude variability of the atmosphere affecting satellite orbits and communication with spacecraft. This research examines the relationship between accelerations acting on neutral zonal winds in the ionosphere and the formation of a vertical shear of these winds in low latitudes and early evening local times. The study area was 75°W geographic longitude and magnetic latitudes between ±30°. The wind shear occurs from 180 km to 400 km presented in the figure below.



METHODS

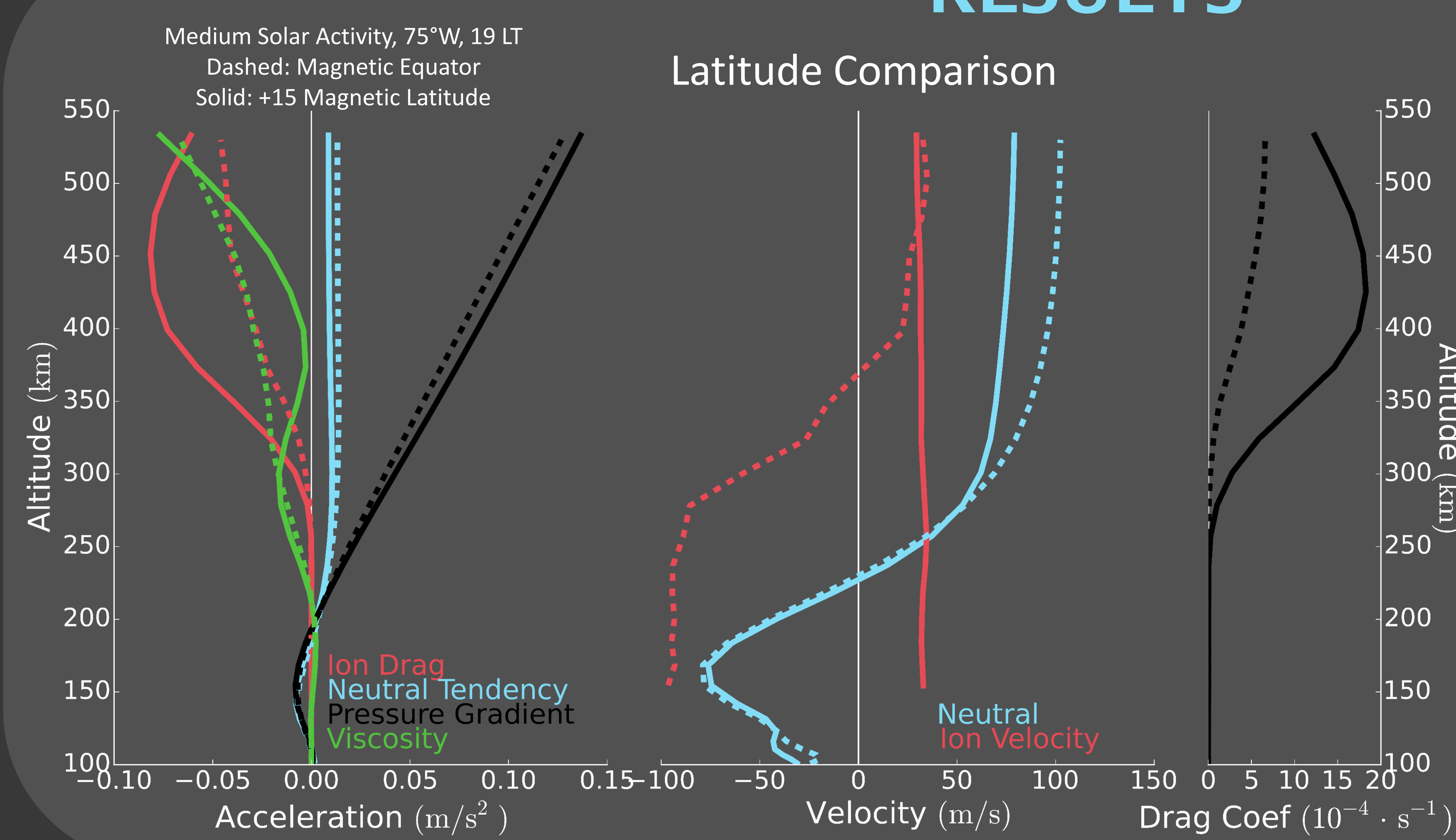
The Thermosphere Ionosphere Electrodynamics General Circulation Model coupled with the Global Ionosphere and Plasmasphere Model was used to simulate the upper atmosphere for different solar activity and night time ionization conditions. Using the output from the model, accelerations were calculated and plots created to elucidate the dependence of the wind shear on individual forces. The equation below describes the forces acting on the neutral winds. On the left side of the equation is the zonal wind tendency (local time derivative of the eastward wind) and on the right are accelerations due to the zonal pressure gradient, ion drag, Coriolis force, and viscosity respectively.

$$\frac{\partial U}{\partial t} = \frac{-g\Delta h}{R\Delta\varphi\cos(\lambda)} - \lambda_{xx}(U - u_i) + v2\Omega sin\Omega + \frac{1}{\rho}\frac{\partial}{\partial z}\left(\mu\frac{\partial u}{\partial h}\right)$$

U: Neutral eastward wind velocity
g : Gravity
Δh: Geopotential height difference
R: Radius of Earth
ρ: Neutral Density
ΔΦ: Difference in latitude
λ_{xx} : Neutral-ion collision frequency
u_i: Eastward ion drift velocity
v: Northward neutral velocity
λ: Latitude
μ: Viscosity coefficient

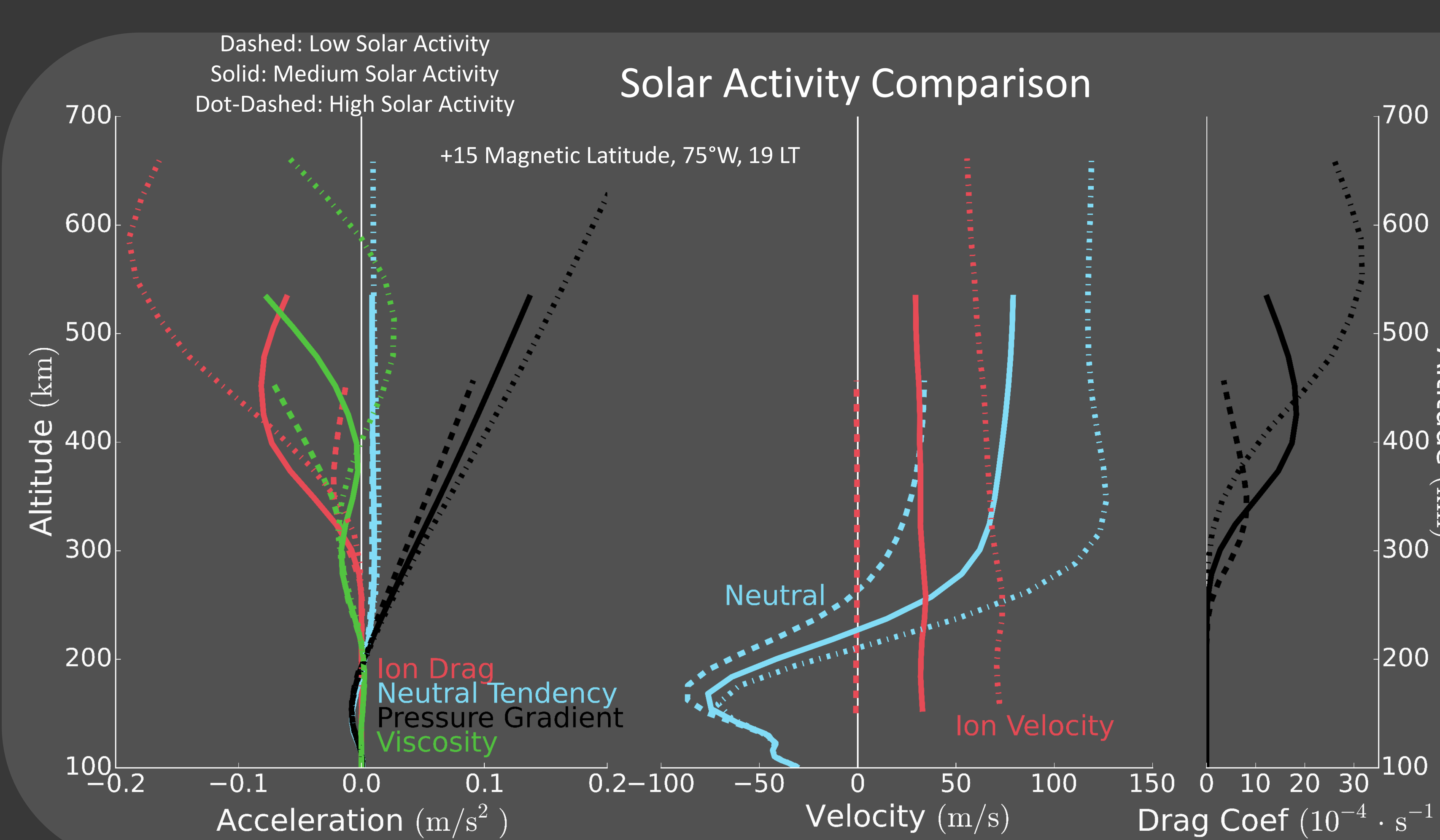
RESULTS

Latitude Comparison



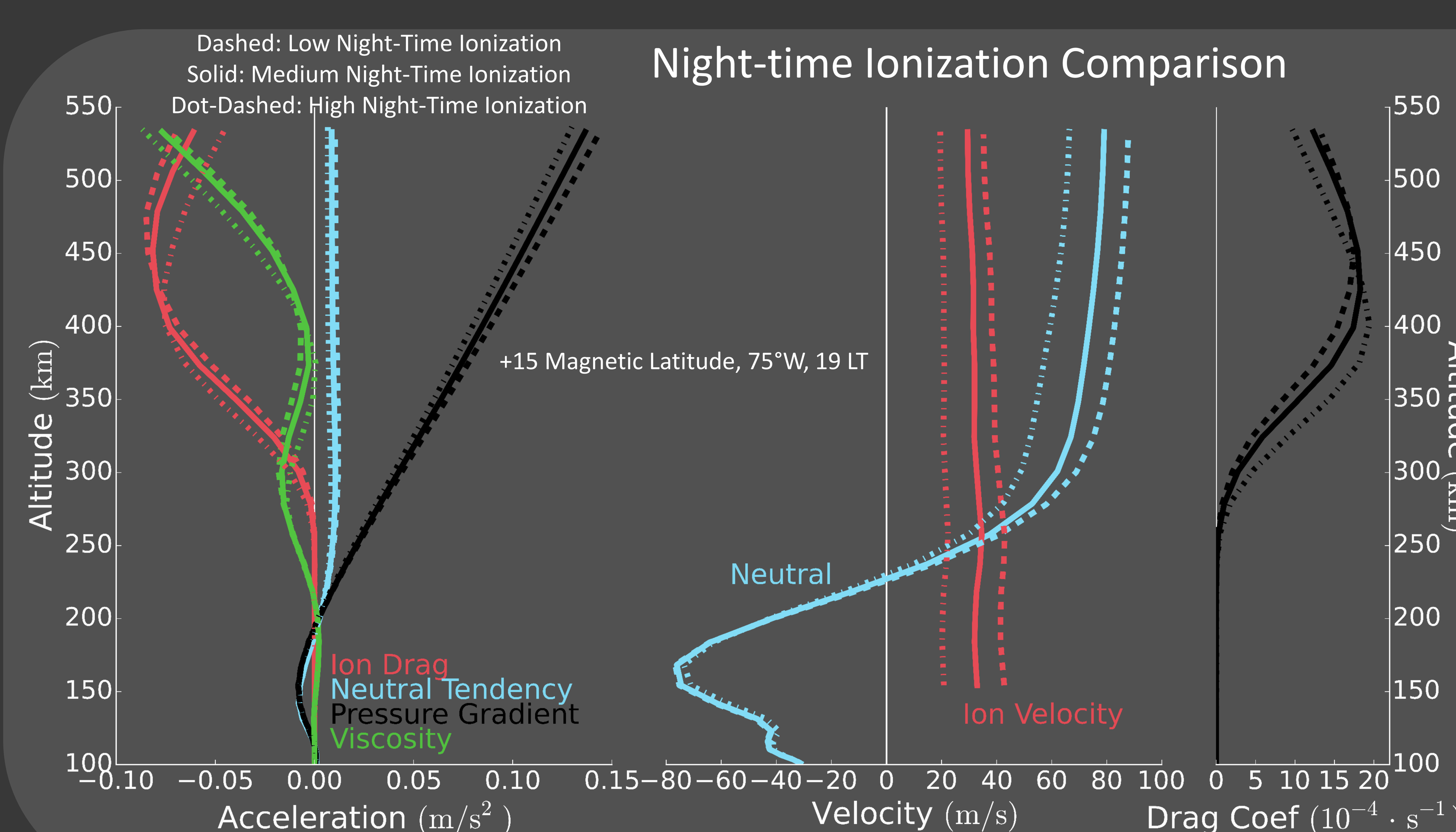
The pressure gradient (black, left) is fairly uniform at all latitudes and grows linearly with height above 200 km and is balanced by a combination of viscous (green, left) and ion drag (red, left) forces. The shear of the neutral winds (blue, middle) is set up by a westward wind tendency (blue, left) dominated by the pressure gradient below 200km, and by an eastward tendency above set up by the imbalance of the drag and pressure forces.

Solar Activity Comparison



The ion-drag coefficient (black, right) varies greatly with solar activity both in amplitude and the altitude of its peak. The neutral velocity (blue, middle) also responds to solar activity strongly but the height of maximum wind shear remains unchanged at around 220 km. The viscosity (green, left) from ~ 200 to 300 km becomes the most important drag force in balancing the pressure gradient and remains important in low solar activity conditions.

Night-time Ionization Comparison



The ion (red) and neutral (blue) velocities (middle) change markedly in different night-time ionization conditions while the difference between them tends to be conserved. The acceleration terms (left) respond only slightly in the different cases. At altitudes where ion-drag (red, left) is most dominant, its magnitude (via the conservation of ion and neutral velocity difference) tends to be conserved. However, where viscosity dominates this is not entirely true.

DISCUSSION and CONCLUSIONS

At most altitudes for different solar activity conditions and night-time ionizations, the ion drag force is primarily responsible for balancing the pressure gradient while viscosity and other drag forces play smaller roles. *Rishbeth* [1971 a,b] hypothesized this would be the case and suggested that the ion drag would automatically adjust to balance the pressure gradient in varying conditions by maintaining the difference between the neutral and ion velocities. Rishbeth's hypothesis however, fails to explain situations where viscosity plays the dominant role in balancing the pressure gradient and in low solar activity conditions when the viscosity dominates at most altitudes (solar activity comparison, green, left, dashed line). Rishbeth's hypothesis therefore tends to overestimate the electric field and plasma convection associated with the F-layer dynamo.

We also find that the vertical shear of the zonal wind is set up by a strong pressure gradient above 200km which dominates the neutral tendency reversing the day-time westward winds and a weak pressure gradient below 200 km which fails to reverse the day-time winds.

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REFERENCES

Evonosky, W., A. D. Richmond, T. -W. Fang, and A. Maute (2016), Ion-neutral coupling effects on low-latitude thermospheric evening winds, J. Geophys. Res. Space Physics, 121, doi:10.1002/2016JA022382
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