Control of the Nightside Structure of the Venusian Ionosphere : Life's little surprises

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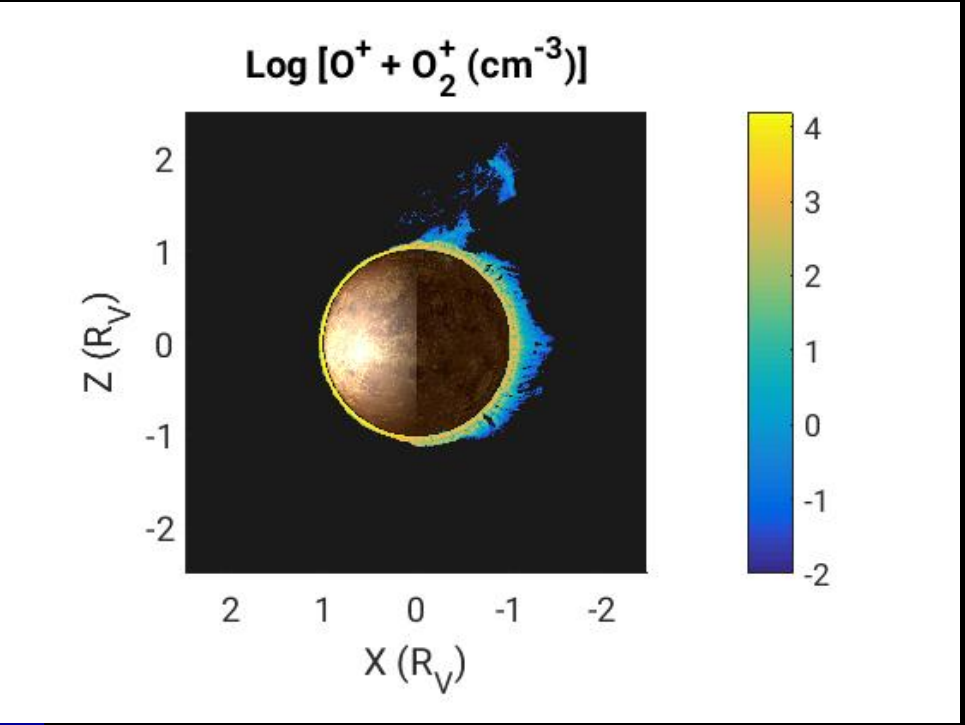
The Simulation Surprise



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Science Questions Addressed

- What is the source of the structure observed in the simulations?
- Is the night side ionospheric structure observed by Pioneer Venus Orbiter similar to that seen in the HALFSHEL simulations?
- Are the simulations sensitive to the neutral atmosphere being used?

PVO – Illustration from Brace et al. JGR 1987

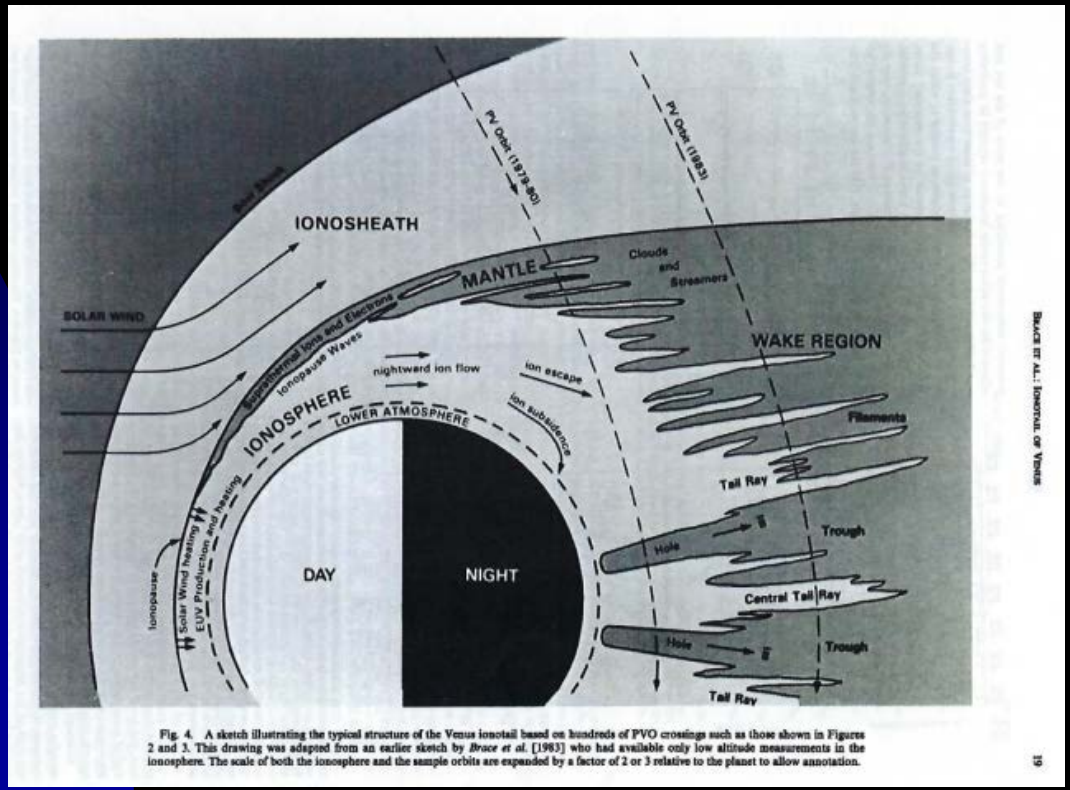

Fig. 4. A sketch illustrating the typical structure of the Venus ionotail based on hundreds of PVO crossings such as those shown in Figures 2 and 3. This drawing was adapted from an earlier sketch by *Brace et al.* [1983] who had available only low altitude measurements in the ionosphere. The scale of both the ionosphere and the sample orbits are expanded by a factor of 2 or 3 relative to the planet to allow annotation.

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PVO Data from Brace et al. JGR 1987

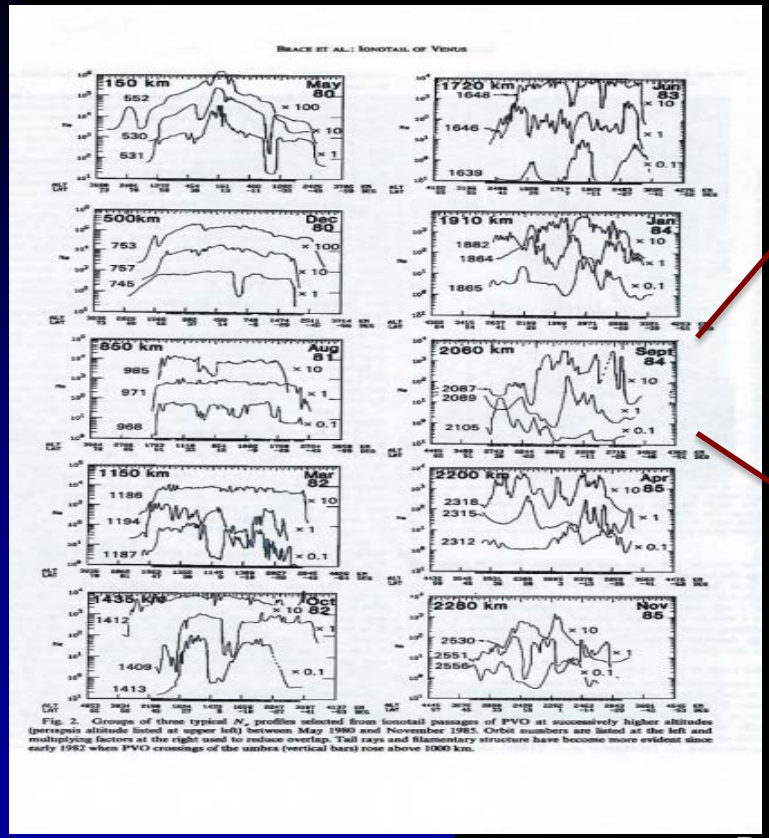
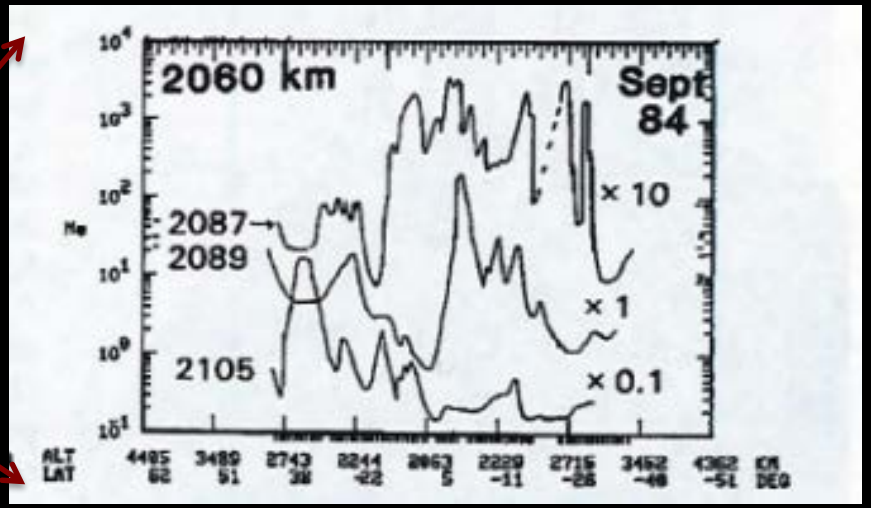


Fig. 2. Groups of three typical N_e profiles selected from ionotail passages of PVO at successively higher altitudes (periapsis altitude listed at upper left) between May 1980 and November 1985. Orbit numbers are listed at the left and multiplying factors at the right used to reduce overlap. Tail rays and filamentary structure have become more evident since early 1982 when PVO crossings of the umbra (vertical bars) rose above 1000 km.



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Status of the HALFSHEL code

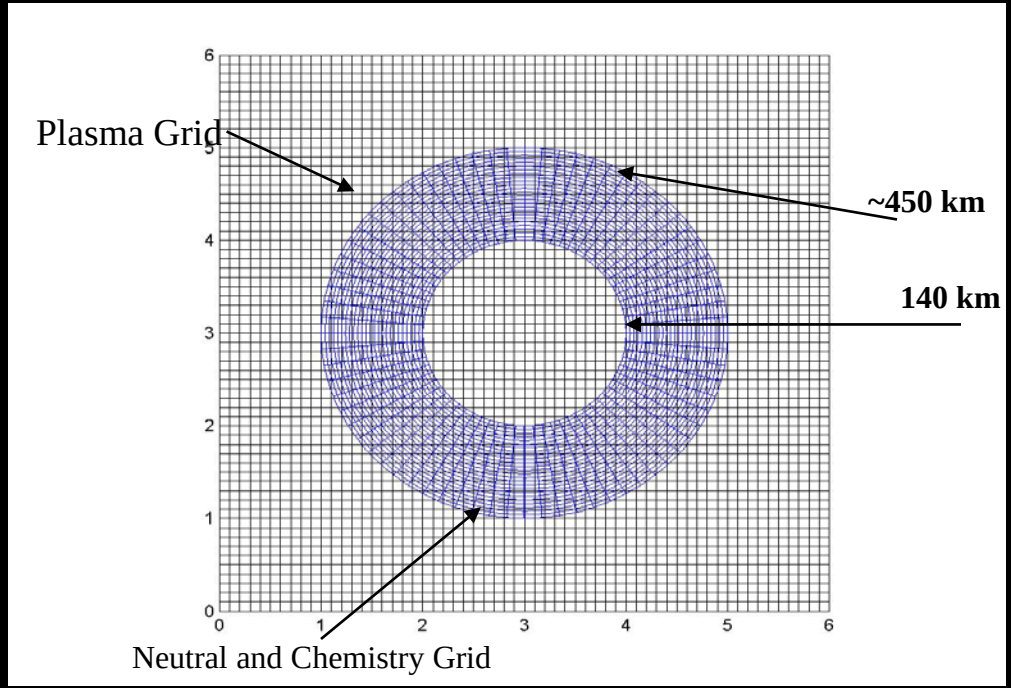
- HALFSHEL is a full 3-D hybrid particle code with full ion dynamics.
- We have a time dependent photo chemistry package on a refined grid.
- We have ion neutral and electron neutral collisions and Hall and Pedersen conductivities.
- The simulations contain the ambipolar electric field.
- The simulations have a neutral atmosphere and winds with and without super-rotation.

Numerical Facts: Venus

- Particles per cell in Solar Wind: 8
- Particles per cell in ionosphere: ~< 30,000
- Solar Wind IMF is 10 nT with a 30^{o} Parker Spiral.
- The solar wind velocity is 400 km/s and density is 14 H^{+} cm^{-3}
- The plasma cell size is 60 km in all directions.

A second high resolution spherical grid is required.

- Current plasma cell size is 60 km.
- Chemistry grid cell size is ~5 km (radial) by 0.64°
- Neutral grid cell size is ~5 km (radial) by 0.64°
- All collisional processes are performed on the neutral grid.
- All chemistry is solved on the chemistry grid.



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Theoretical Predictions

- Lower Hybrid Drift instability has small scale sizes. Huba, J.D., JGR, (1992); Huba, J.D., and J.M. Grebowsky JGR (1993).
- Gradient Drift instability found in ionospheric Barium releases. Linson, L. M. and J. B. Workman, JGR,(1970)
- Both are driven by ambipolar currents and fields.

Ambipolar Electric Fields

The electric field equation solved in HALFSHEL

$$0 = -e\, n_e \mathbf{E} + \mathbf{J}_e \times \mathbf{B}/c - \nabla p_e + e\, n_e\, \eta\, \mathbf{J}$$

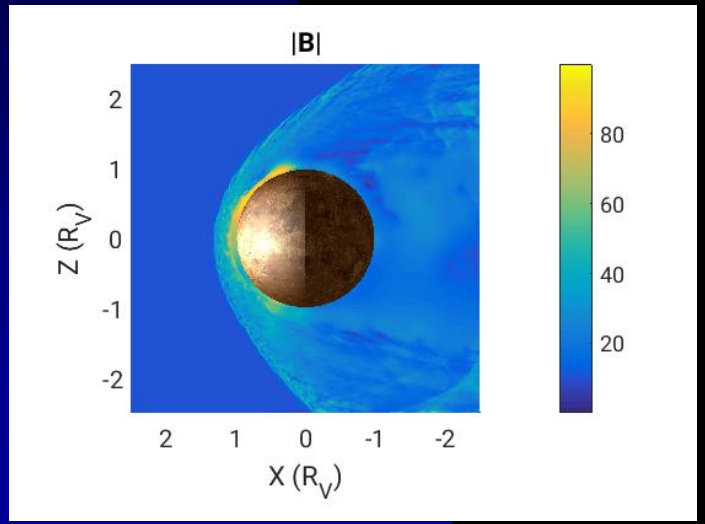
The ambipolar electric field is created by ∇p_e

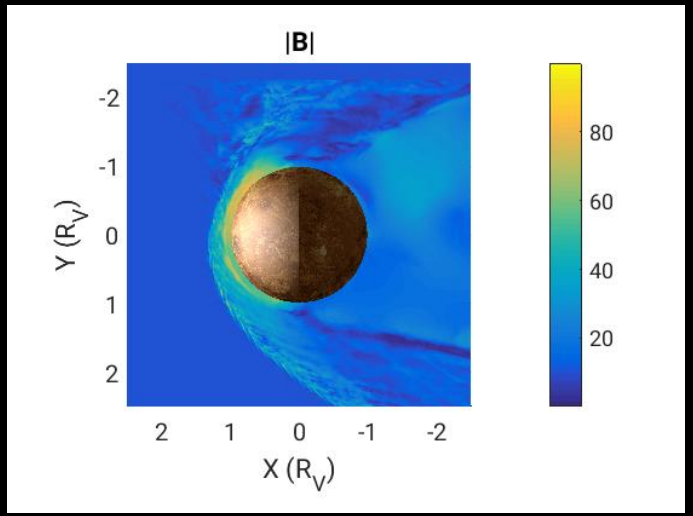
Outline of Presentation

- Results with the ambipolar electric field (Grad Pe) included.
- Results without the ambipolar electric field (Grad Pe).
- Some comparisons to PVO data as reported by Brace et al.
- Changes created by changing the neutral atmosphere model.
- Conclusions

The Simulation results including the ambipolar electric field (Grad P_e)

Magnetic Field Structure





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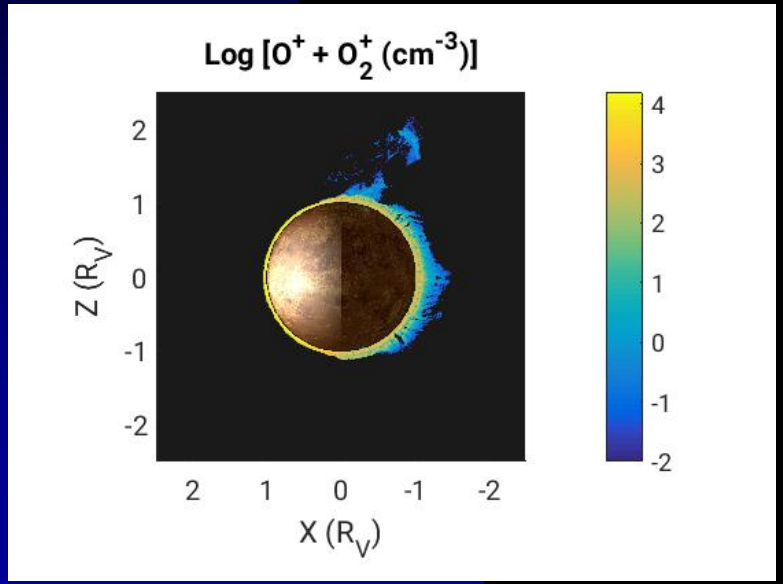
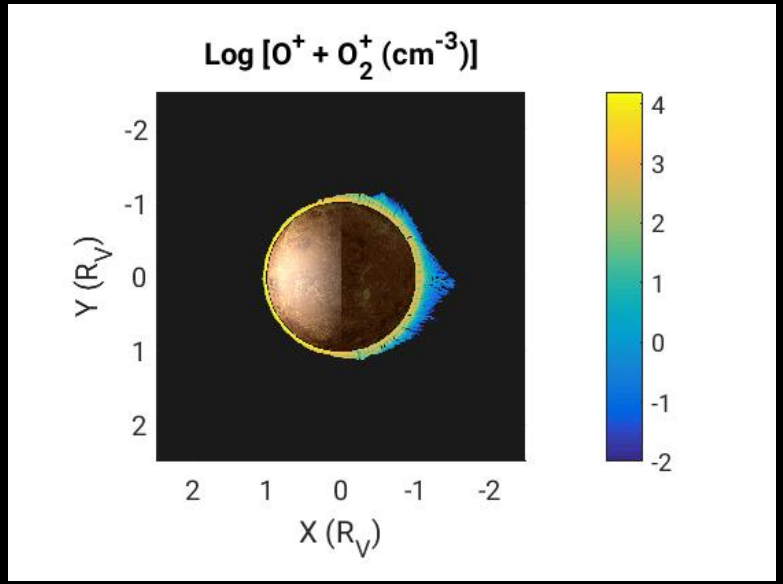
The Simulation results including the ambipolar electric field (Grad Pe)

Ionospheric Oxygen Ions





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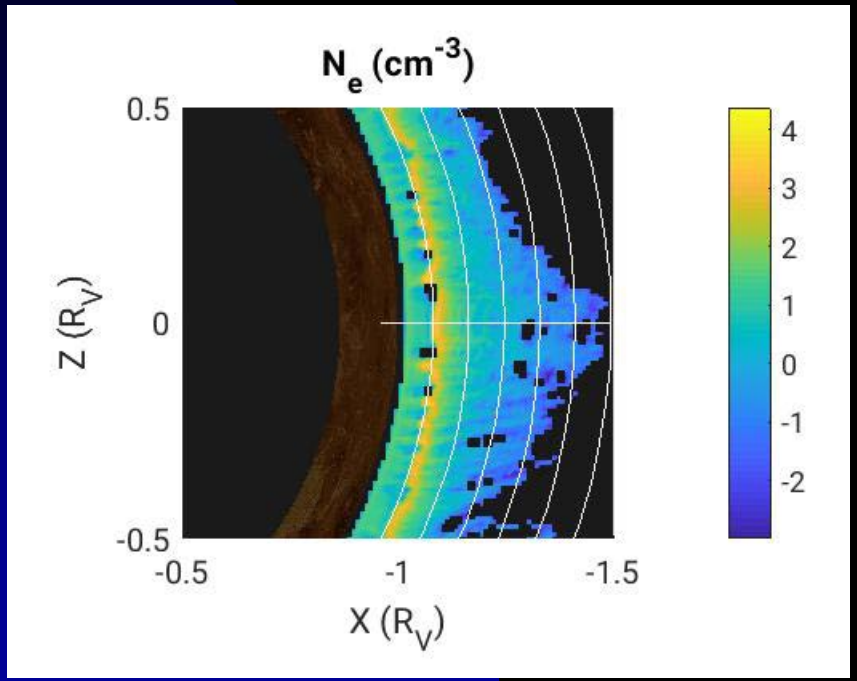
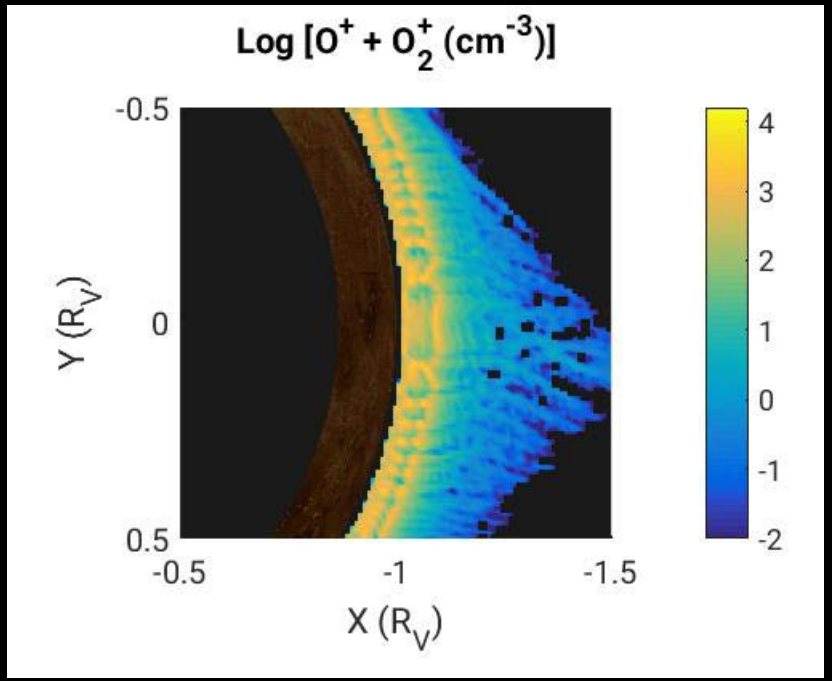
The Simulation results including the ambipolar electric field (Grad Pe)

Ionospheric Oxygen Ions





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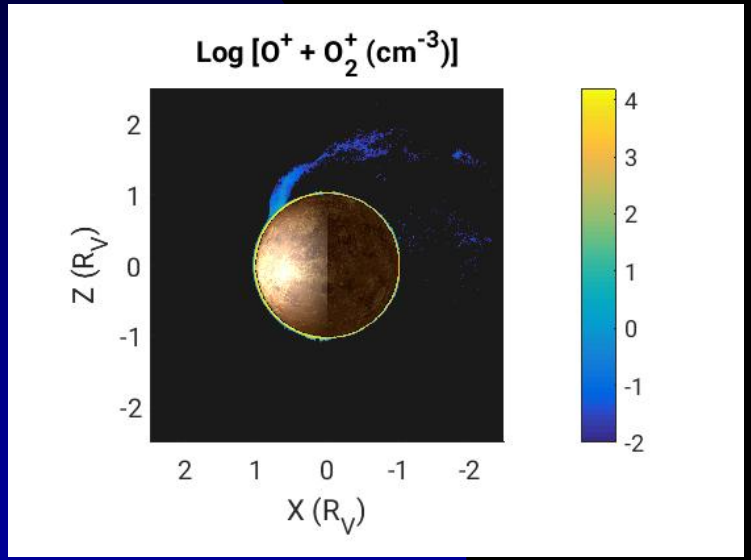
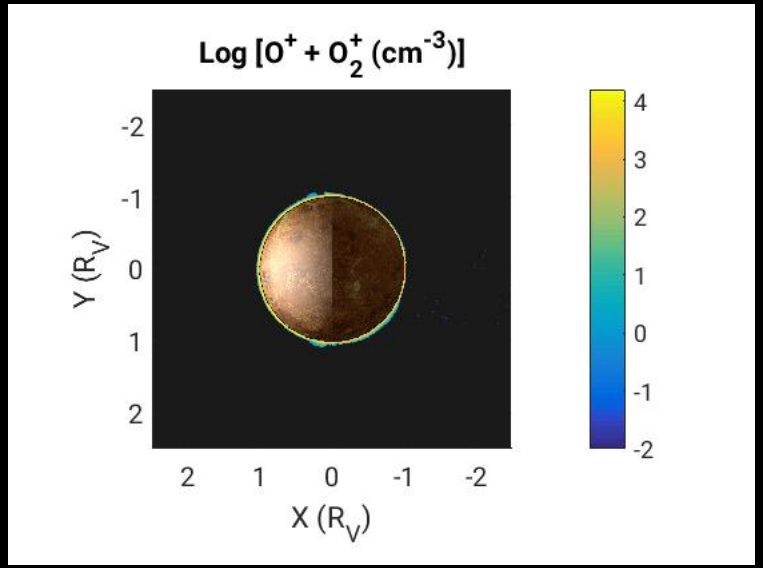
The Simulation results including the ambipolar electric field (Grad Pe = 0)

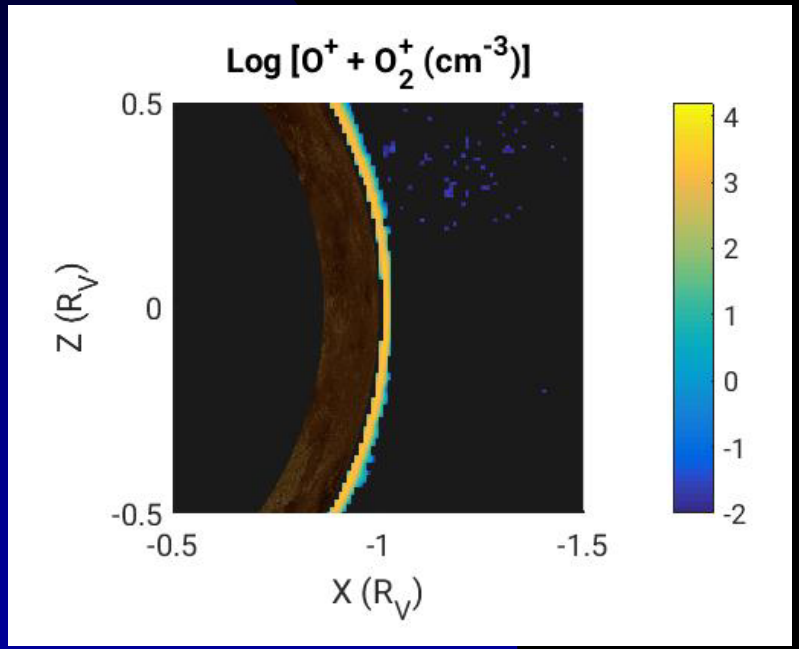
Ionospheric Oxygen Ions

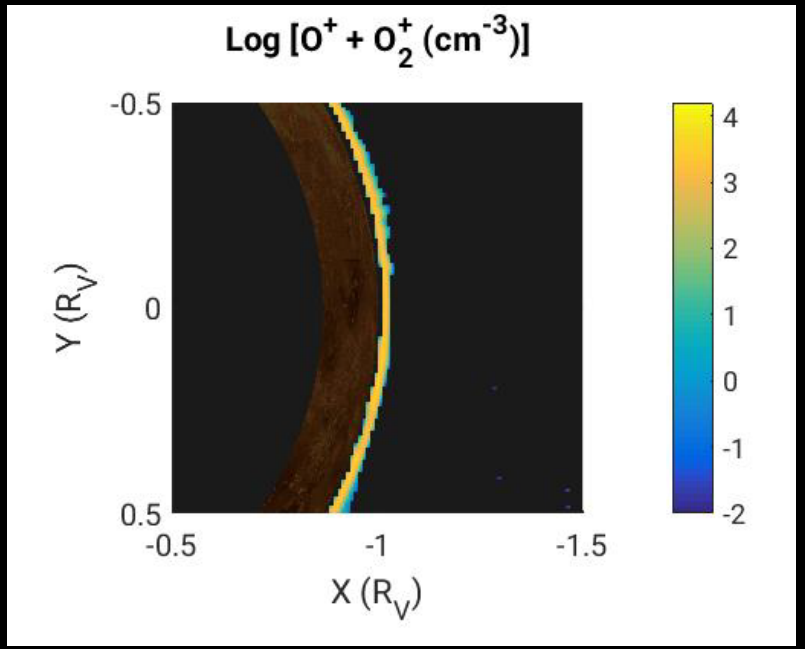




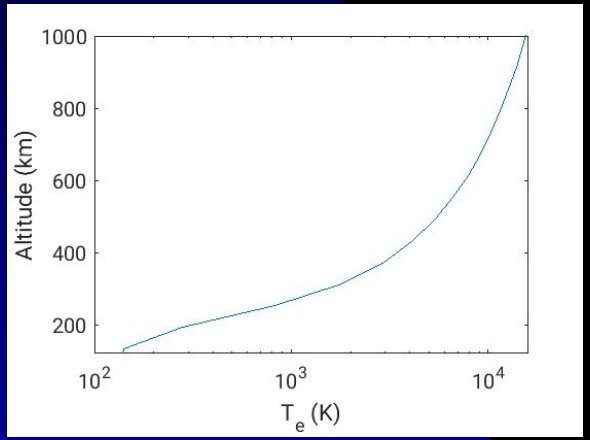
The Simulation results including the ambipolar electric field (Grad Pe = 0)

Ionospheric Oxygen Ions





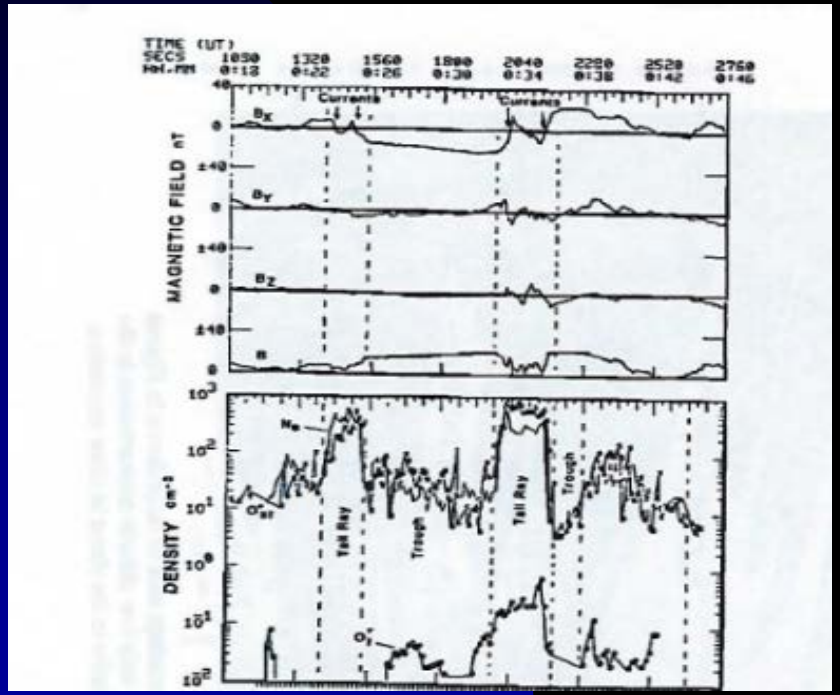
Electron Temperature

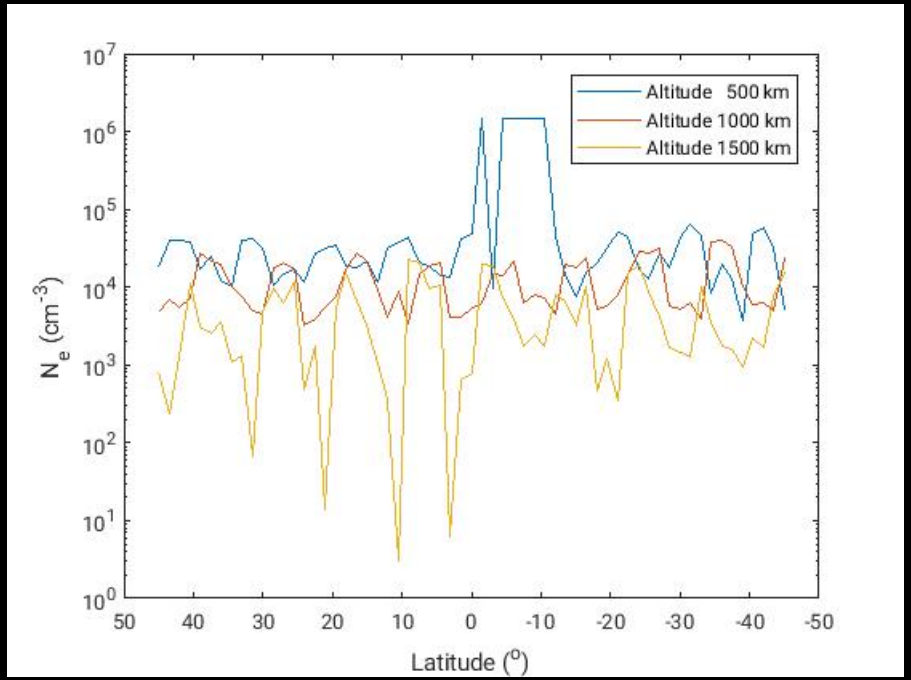


- The electron temperature is taken from Brace and Theis, Adv. Space Res.,1996.
- Worth noting that the night side electron temperature is higher during solar Min.
- The Martian electron temperature profiles as measured by MAVEN were found to produce differences in ratio of ion loss species due to changes in the ambipolar electric fields. [Brecht and Ledvina, JGR, 2017]

Density as a Function of Altitude

Brace et al. JGR 1987





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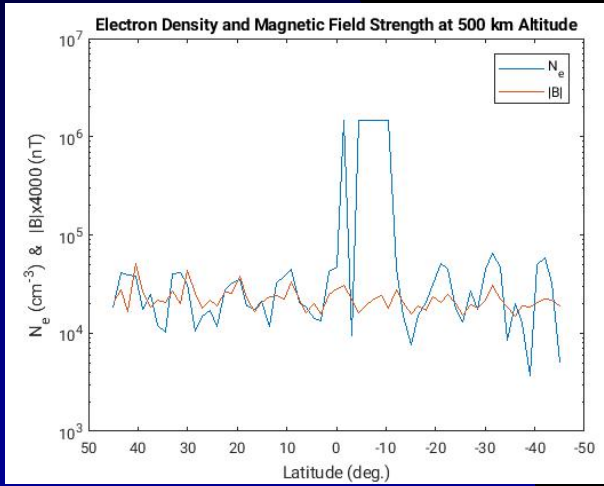
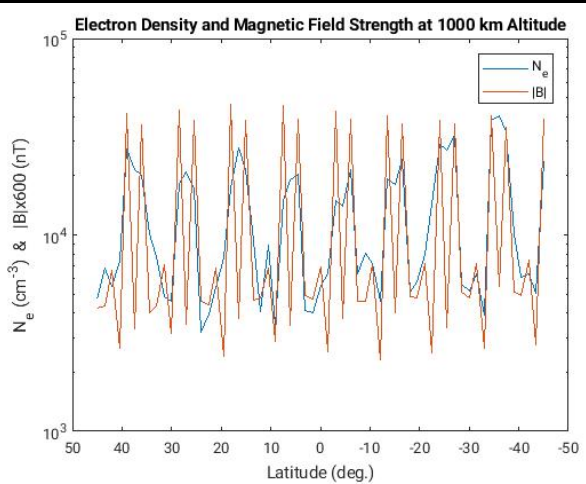
Electron Density vs. Magnetic Field

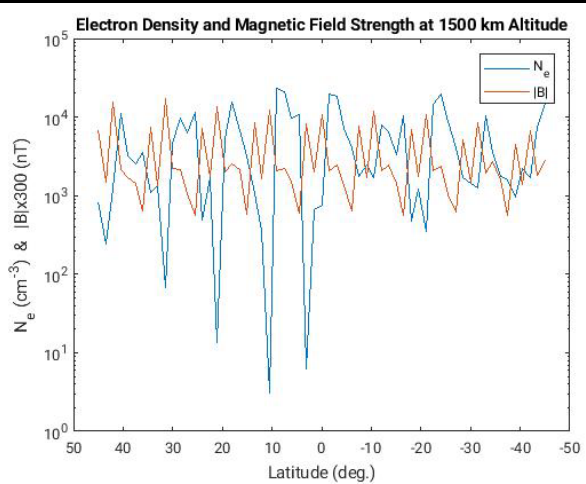
500 km



1000 km



1500 km



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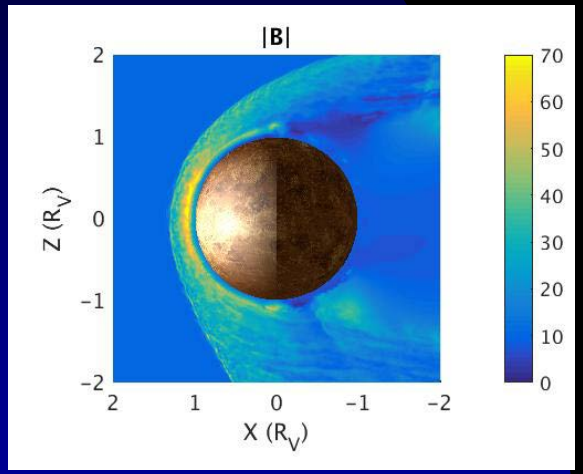
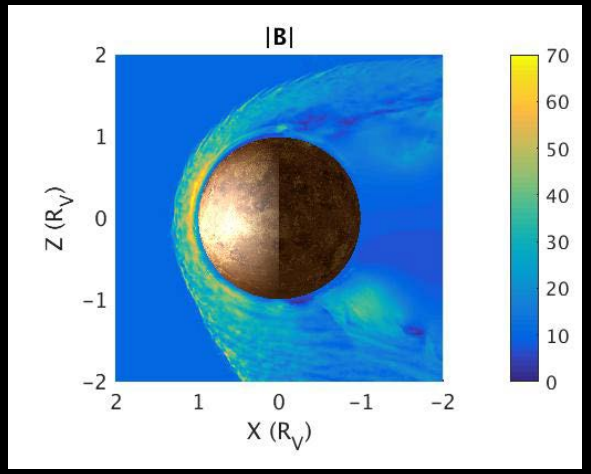
The results of changing neutral atmosphere and (Grad Pe)

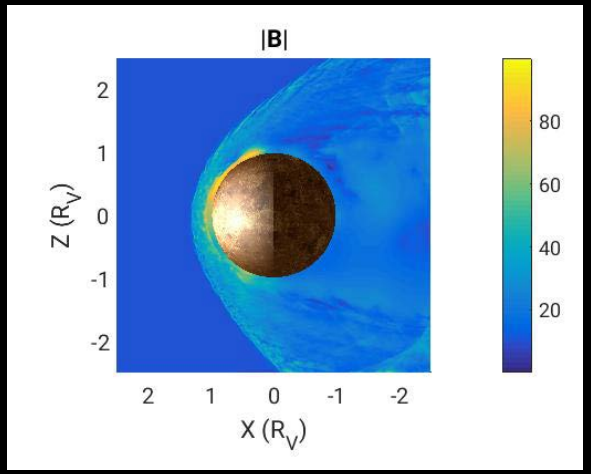
(Grad Pe) and no super-rotation



(Grad Pe) and with super-rotation

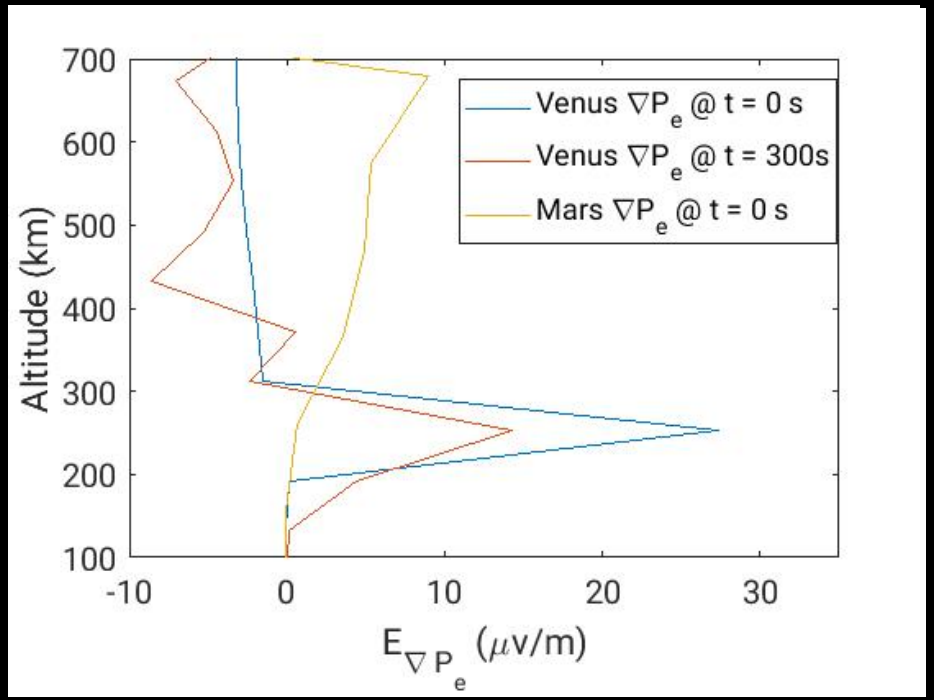


(Grad Pe = 0) and no super-rotation



Comparison of Ambipolar electric field strengths between Venus and Mars

- Mars has weaker temperature gradients.
- Mars has weaker density gradients.
- Therefore, Mars has a weaker ambipolar electric field.
- These facts Offers an explanation as to why Venus has night side structure and Mars does not.



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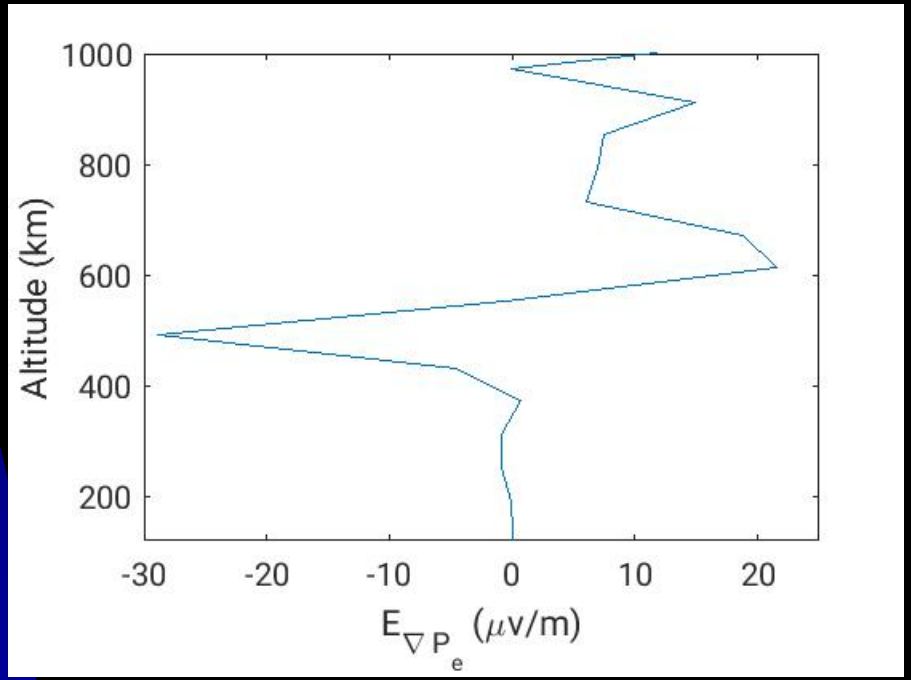
Conclusions

- Hybrid simulations show that ambipolar electric field lead to ionospheric structure similar to Brace et al. JGR 1987.
- The inclusion/exclusion of the ambipolar electric field changes global structure.
- Neutral models with super-rotation lead to differing global results.
- Mars does not have the night side structure due to its weaker gravity hence lower levels of ambipolar electric field.

Ambipolar Electric Field at Later Time



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