Comparison of the 2005 Weimer and HAO Empirical High Latitude Models of Energy Transfer in terms of Poynting Flux

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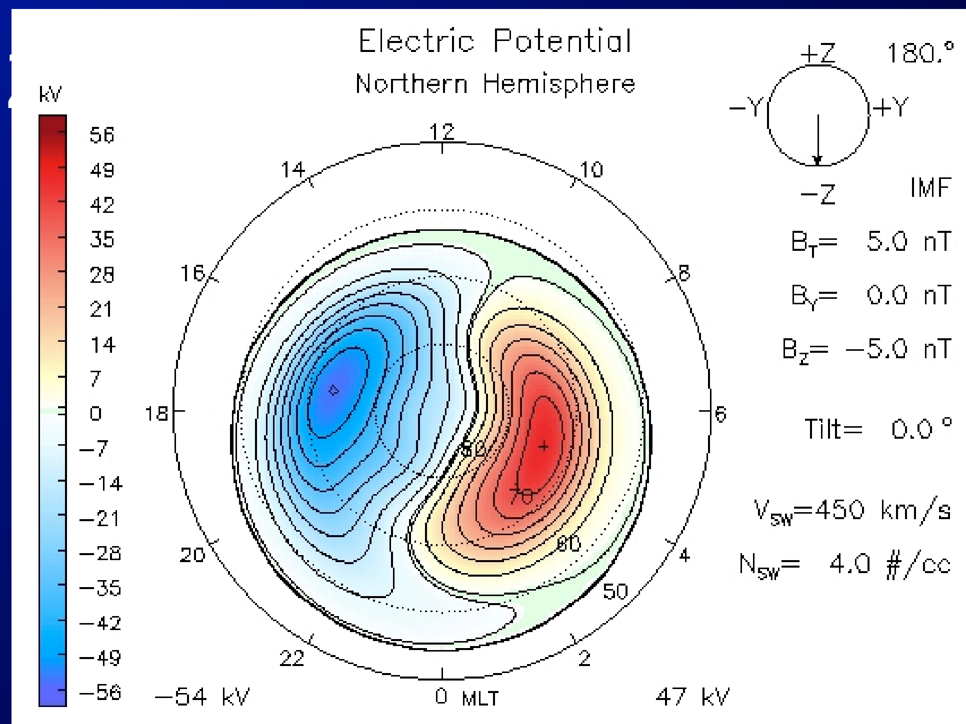
Background

- Two Models
  - Weimer 05
  - High Altitude Observatory (HAO)
- Predictions
  - Electric/Magnetic Potential
  - Electric/Magnetic Field
  - Poynting Flux
  - Joule Heating

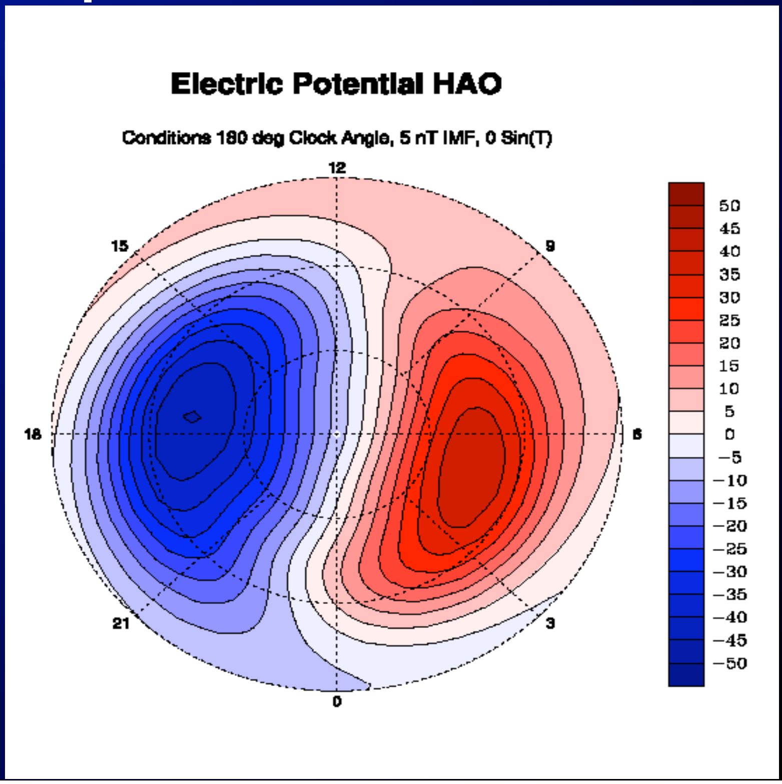
Weimer 05

- Developed by Dr. Daniel Weimer in 2005
- At the time, Mission Research Corporation
- Models made in 1996 and 2001
- Dynamics Explorer
- IDL



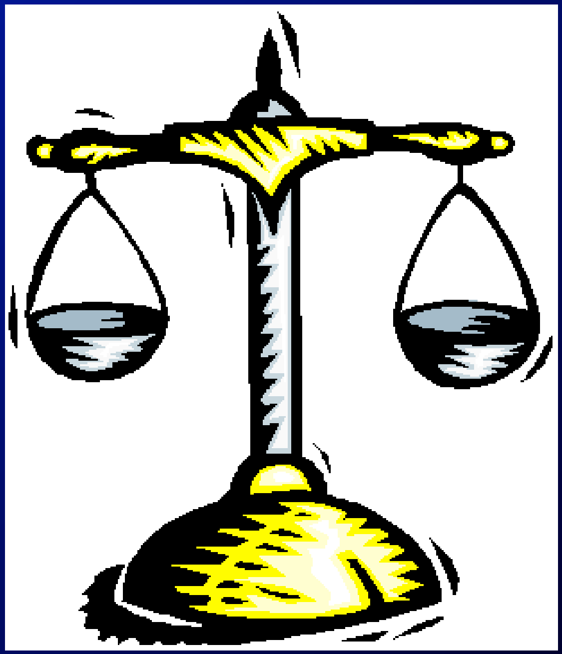
HAO

- Developed by Astrid Maute and Arthur Richmond
- National Center for Atmospheric Research: High Altitude Observato
- Dynamics Explorer 2
- FORTRAN



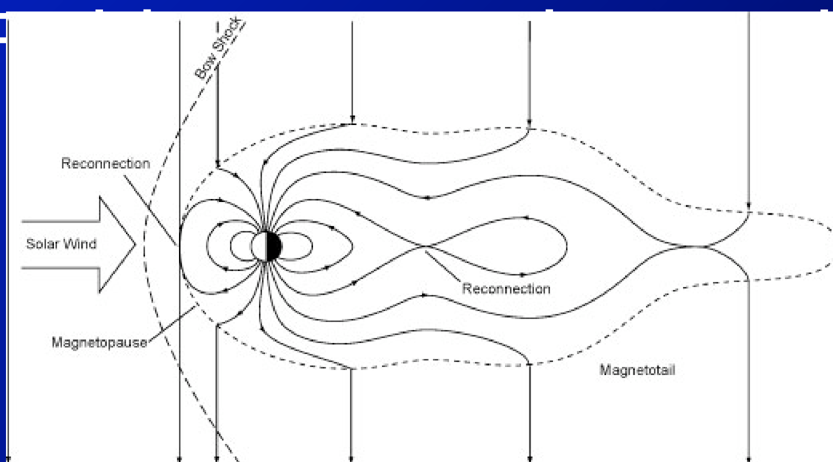
Why Model Comparison?

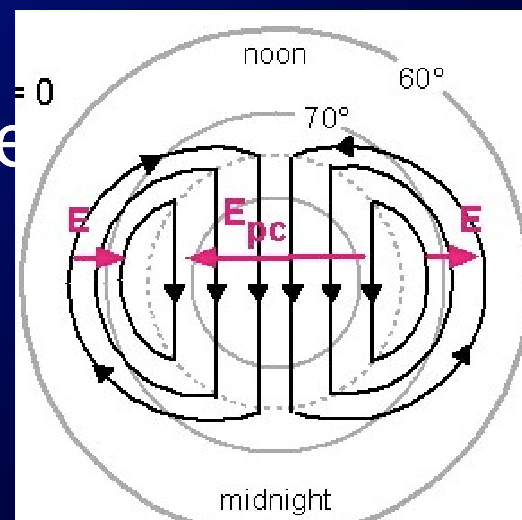
- Check for new model
  - Debugging
  - Biases
  - General behavior
- Check for old model
  - Still viable
  - Debugging
  - Biases
- Better Option
- Understanding



Why do we have E Fields?

- Magnetic Reconnection causes Geomagnetic Field lines to interact with IMF
- IMF feels a electric field
- Geomagnetic Lines are equipotential; feel the field
- F oser line = 0



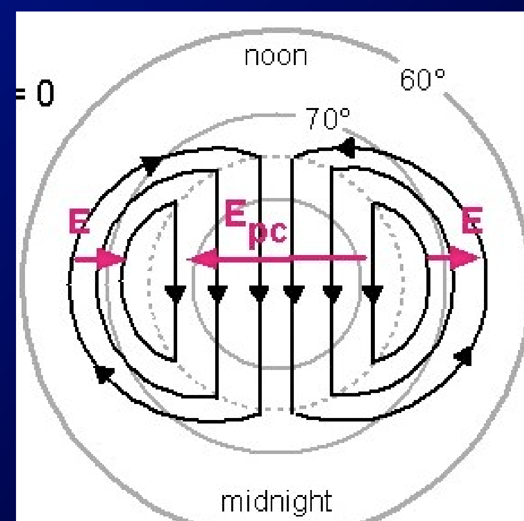


Why do we have B Fields?

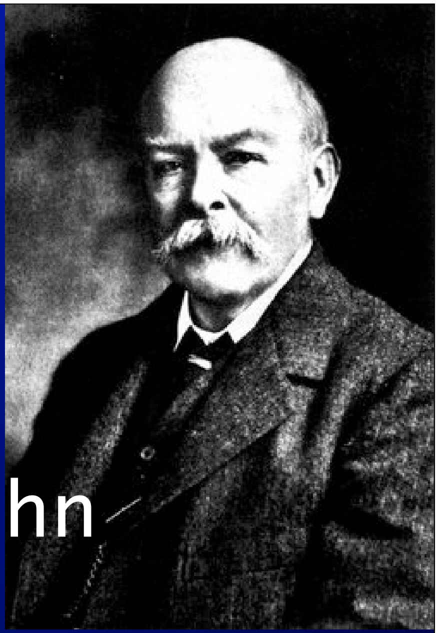
- E fields cause converges and diverges; currents form
- Using Ampere's Law, you got induced magnetic fields

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{enc}$$

$$\nabla \times \mathbf{B} = \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} + \mu_0 \boldsymbol{j}_c$$



Poynting Flux

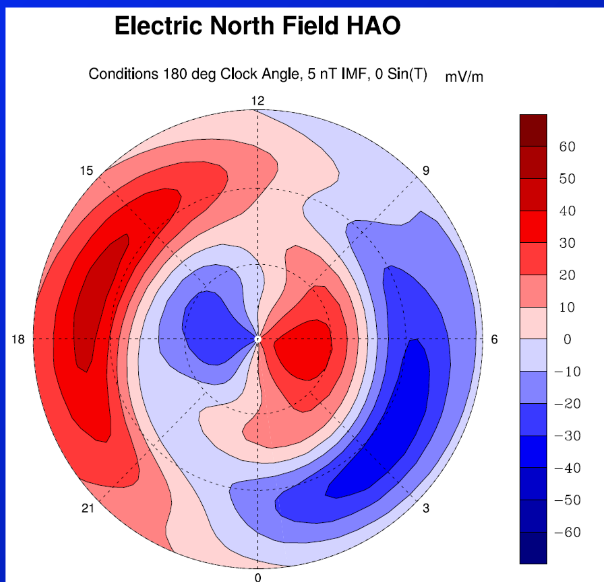


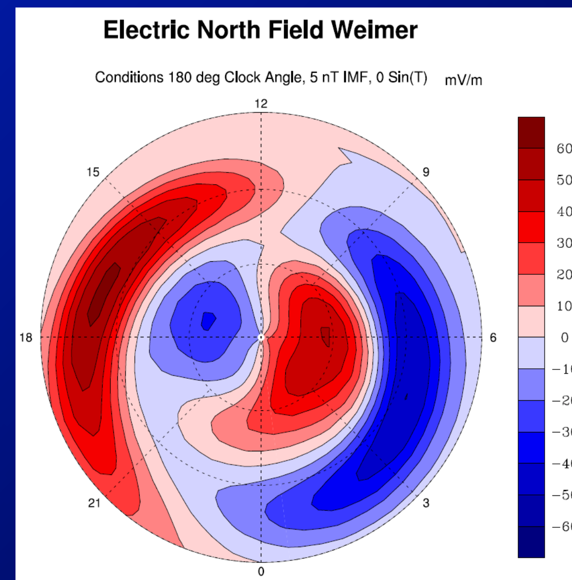
- Representation of energy flux
- Independently co-discovered by John Henry Poynting, Oliver Heaviside
- Joule Heating can be estimated by Poynting's Theorem

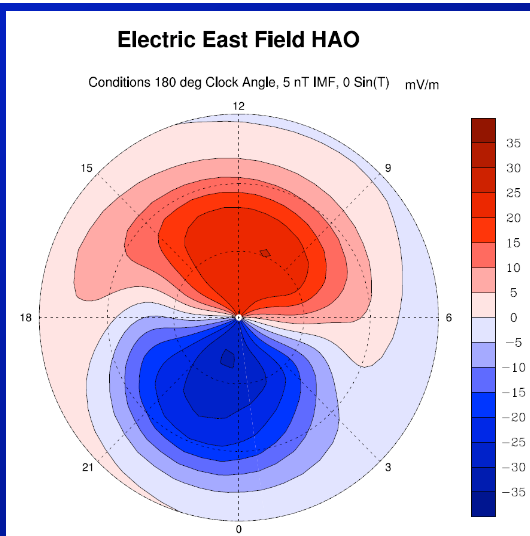
$$\frac{\partial u}{\partial t} + \nabla \bullet S = -J \bullet E$$

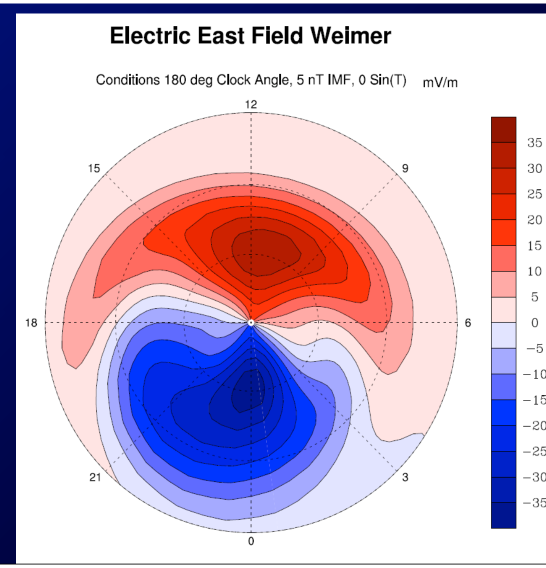
$$S = \frac{E \times B}{\mu_0}$$

Electric Field (EF)



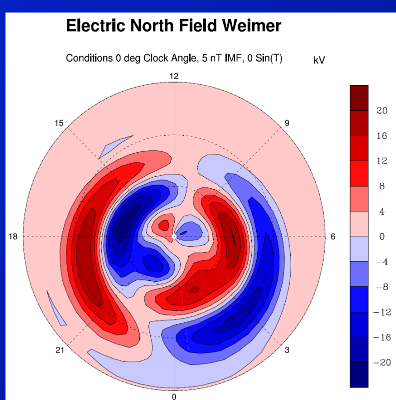


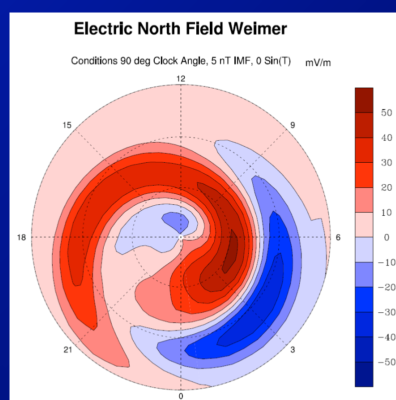


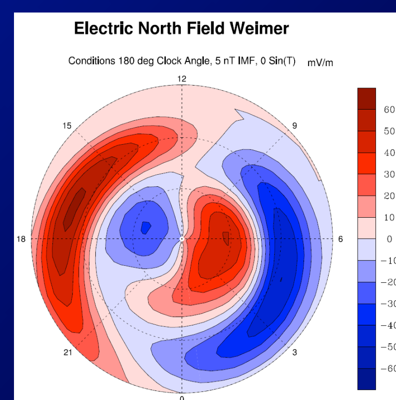


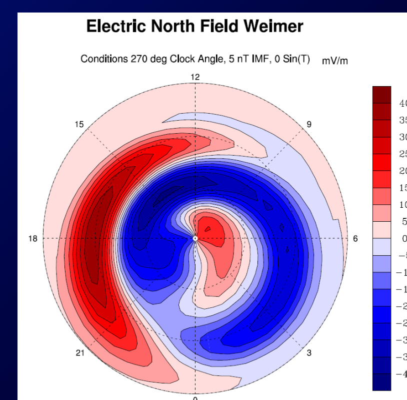
EF IMF Clock Angle Summery

- Weimer is consistently stronger than HAO
- Both show similar patterns
- Patterns are those that are expected
- Difference plot values not too large



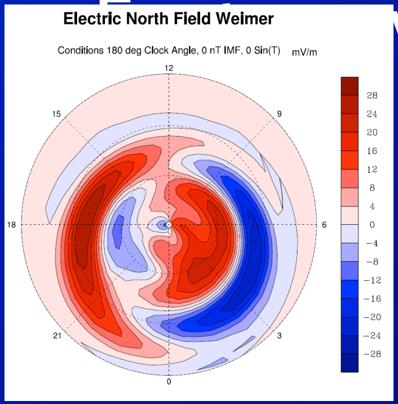


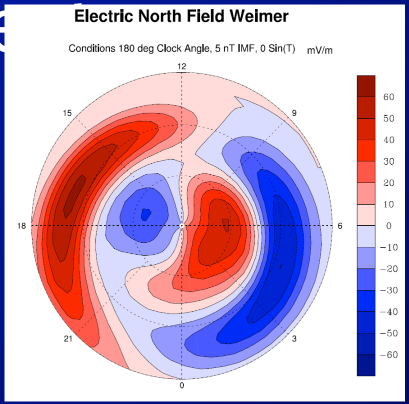


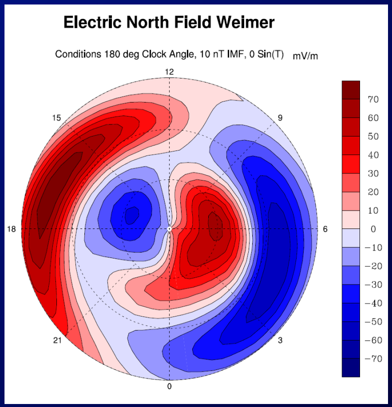


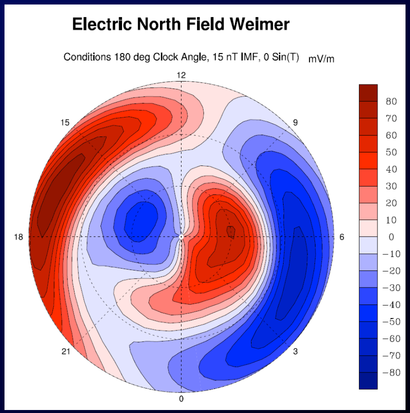
EF IMF Strength Summery

- Weimer Stronger peak values than HAO
- Models closer at 5 nT and 10 nT than 15 nT
- 0 nT patterns/strengths quite different
- More variation in Northern vector than



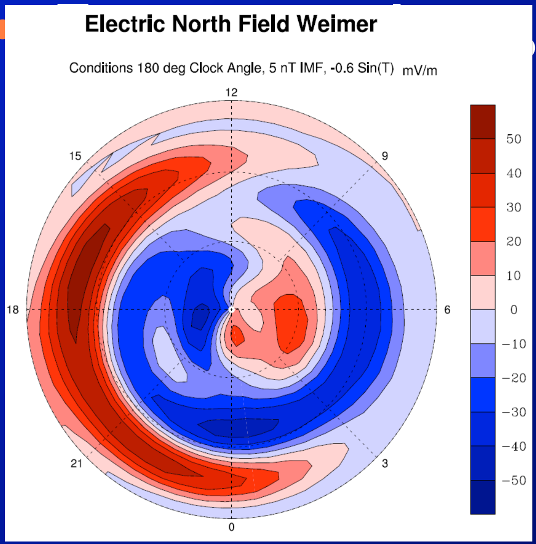


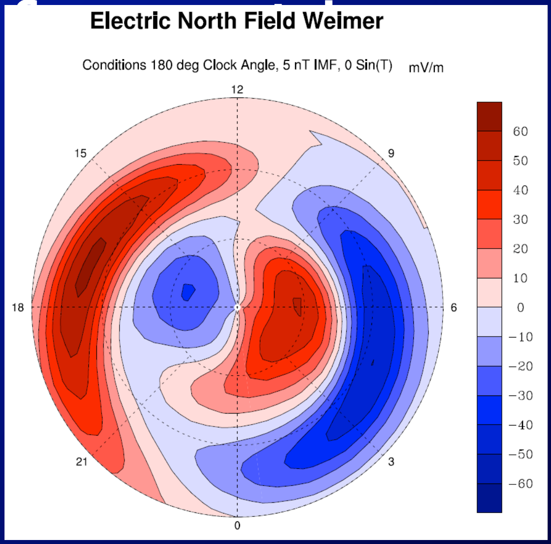


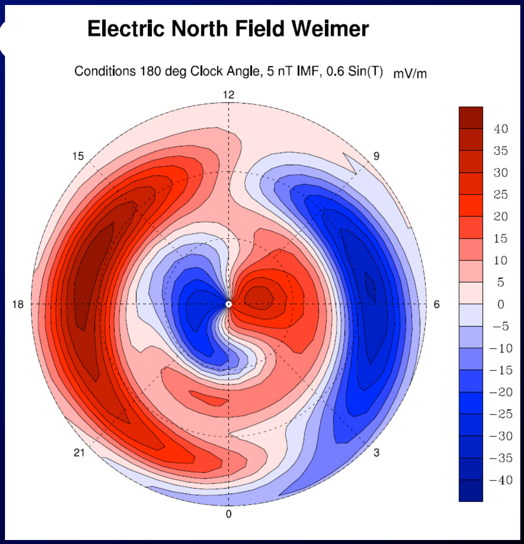


EF Season Summery

- Season causes great changes in E field
- Rotation around Midnight/noon (MN) line
- Sin(T) = -0.6 has larger differences than Sin(T) = 0.6



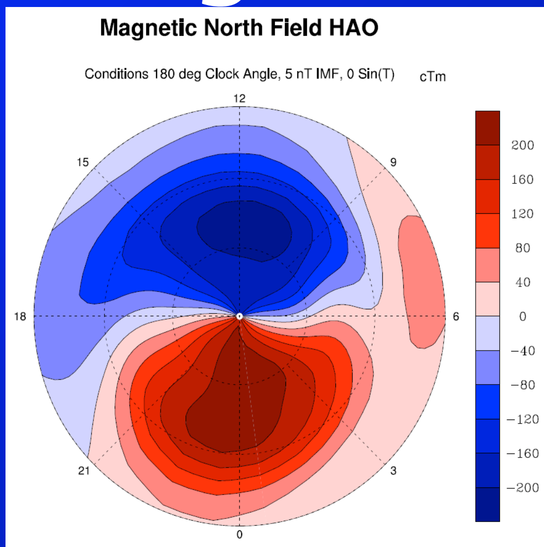


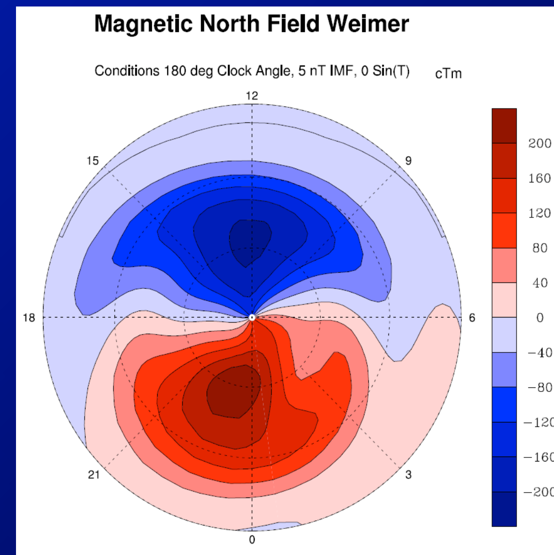


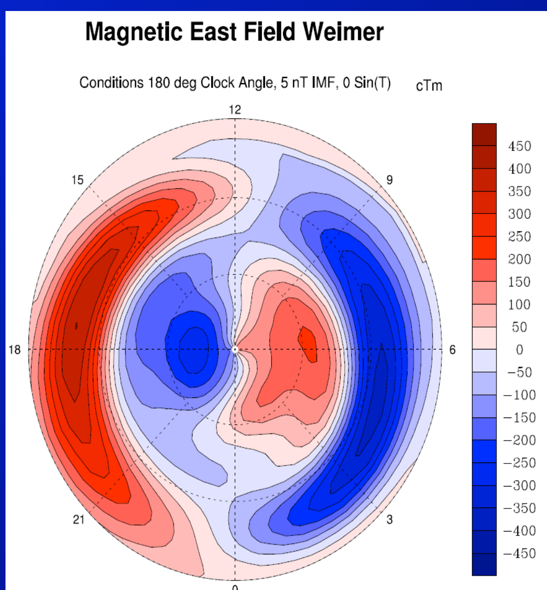
EF Summery

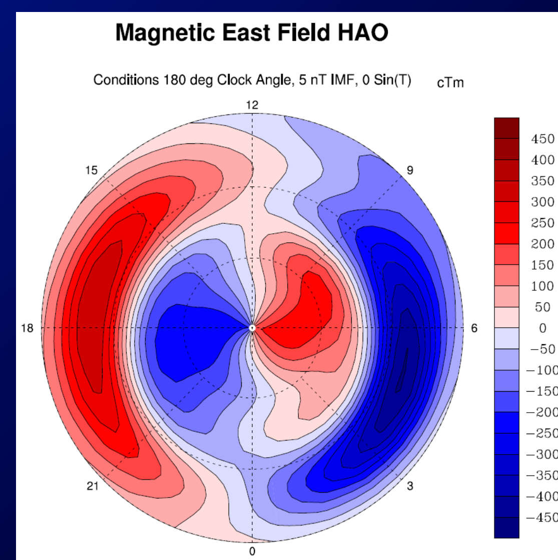
- Weimer consistently stronger than HAO
- Though there are areas of great differences, overall they are quite similar
- Pattern variations between the two models show up in a lot of the plots
- Some strength differences

Magnetic Field Perturbations (BF)



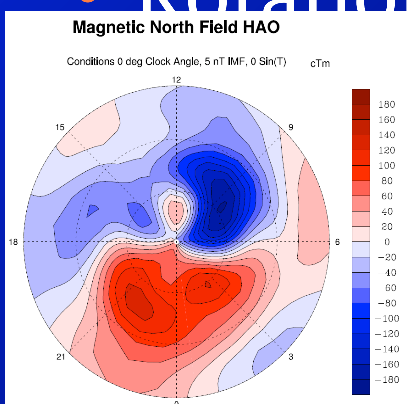


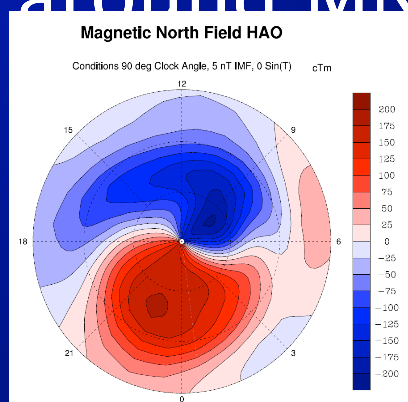


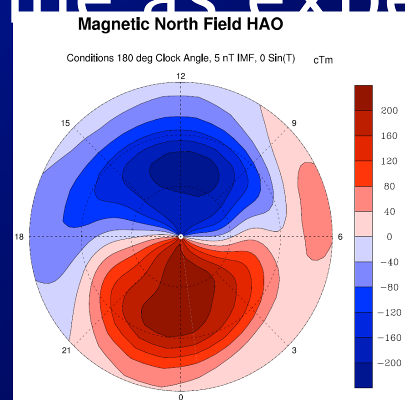


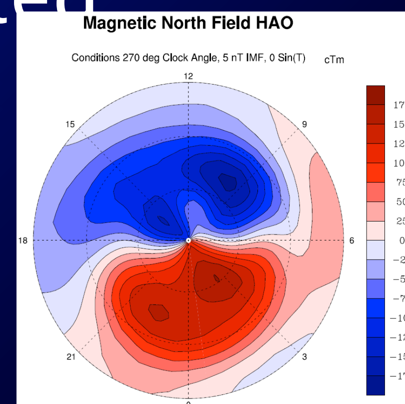
BF IMF Clock Angle Summery

- HAO peaks always stronger than Weimer
- 180° is strongest of all the clock angles
- 0° is weakest and has the greatest difference
- Rotation around MN line as expected



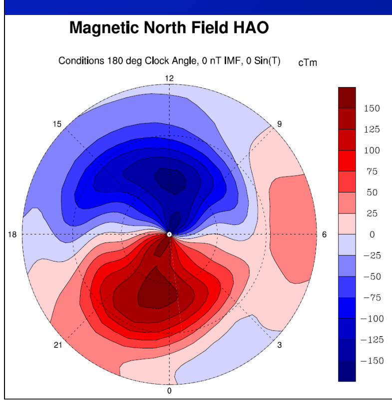


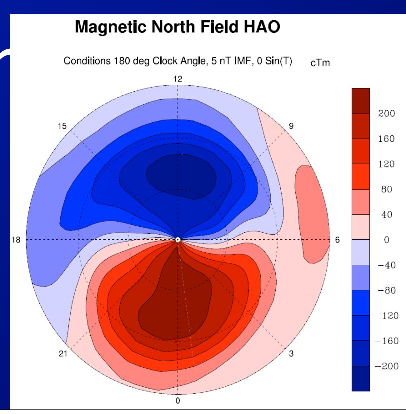


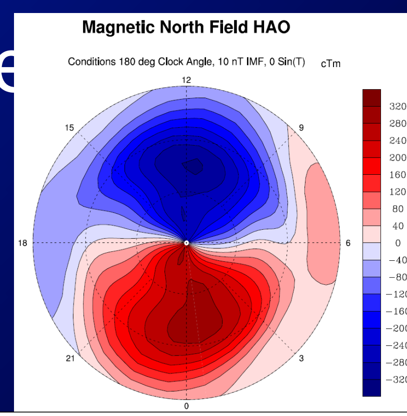


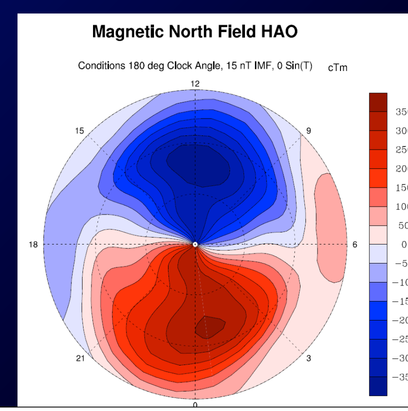
BF IMF Strength Summery

- HAO peaks always stronger than Weimer
- Some variation in pattern, but mostly strength
- Same patterns, with some expansion
- As IMF strength goes up, the differences in strength/pattern go up



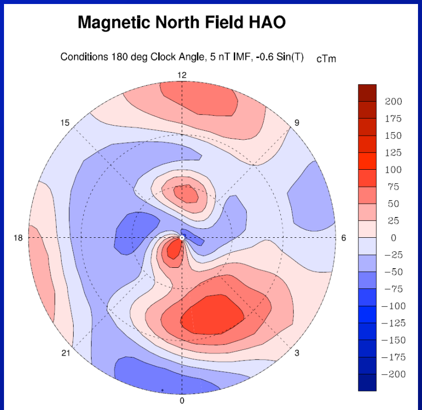


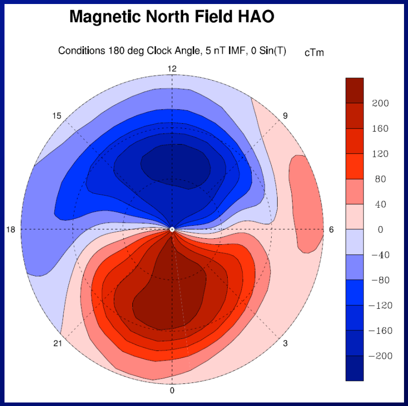


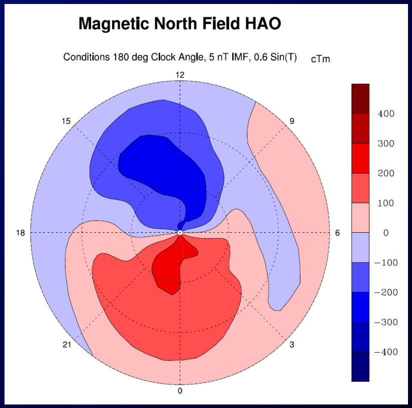


BF Season Summery

- Weimer is much larger than HAO when not at equinox
- Regions and patterns between the models vary
- Models are most alike at equinoxes



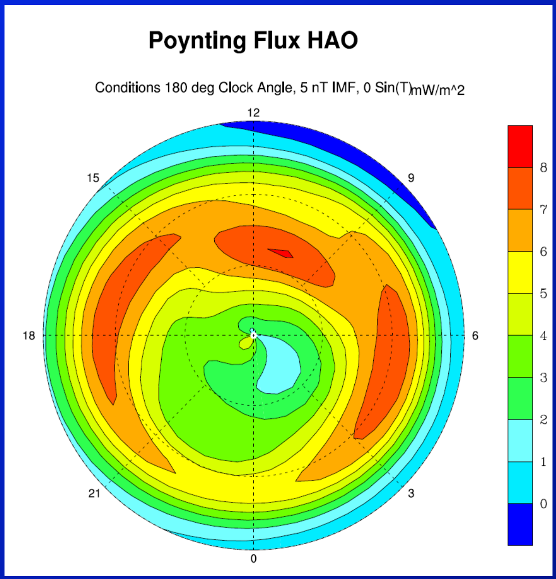


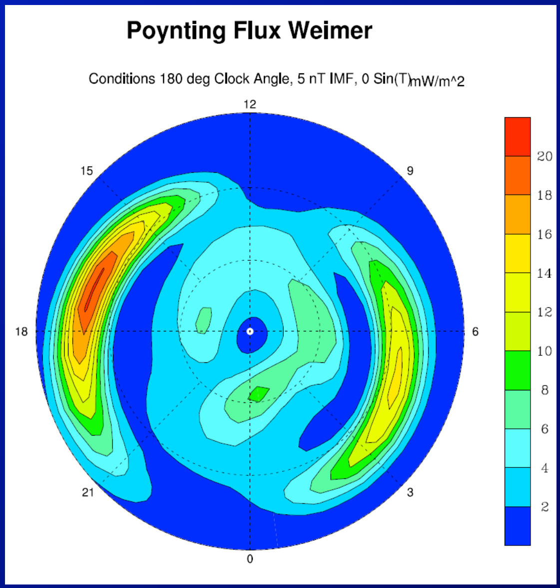


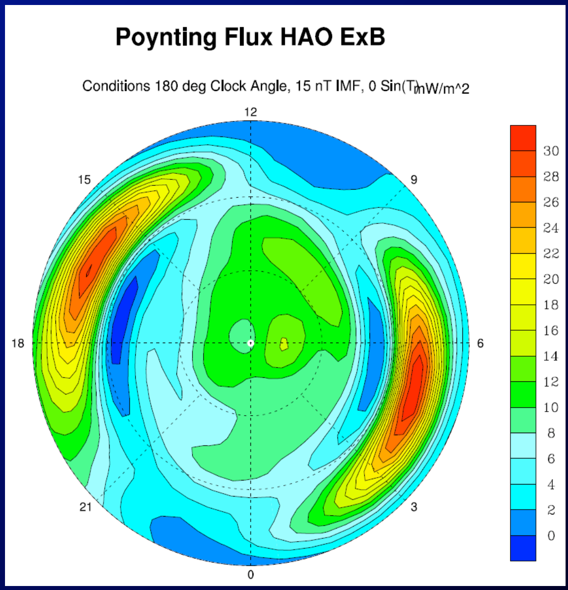
BF Summery

- HAO is stronger than Weimer, except away from equinox
- Pattern variation is small
- Strength variation is normal
- Behaves almost like E Field

Poynting Flux







Poynting Flux IMF Clock Angle Summery

- HAO's ExB and Weimer have similar structure and values for the Poynting flux
- HAO's Data Fitted values are larger than both of the other models
- Rotation around MN line can be seen between the different clock angles; except HAO's Data Fitted

Poynting Flux IMF Strength Summery

- Flux increase with IMF strength
- HAO's ExB and Weimer show similar structure, location varies
- HAO's Data Fitted becomes rings as saturation is reached
- Weimer has the highest peak values

Poynting Flux Season Summery

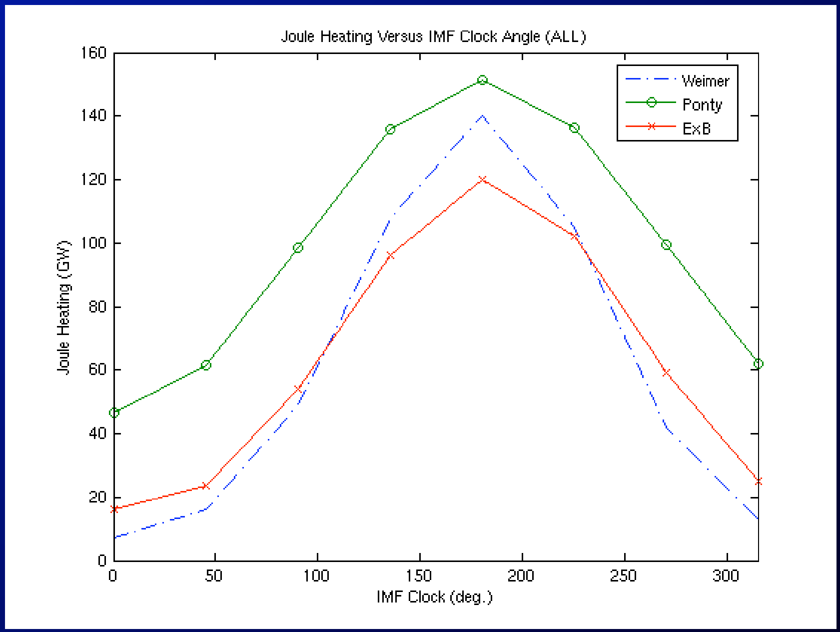
- Three model become more similar away from equinox
- HAO's ExB and Weimer peak at equinox while HAO's Data Fitted peak at extreme summer
- Large rotations around MN line with season change

Poynting Flux Summery

- Weimer values are almost always larger than HAO's ExB
- Weimer and HAO's ExB show similar structure
- HAO's Data Fitted forms rings
- As expected, the models behave like E field and B field

Joule Heat v. IMF Clock Angle

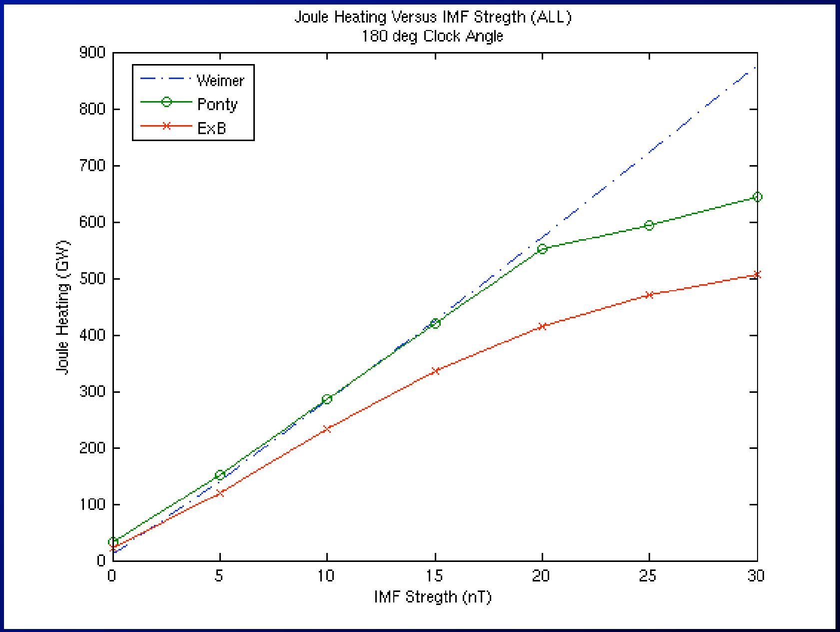
- HAO's Data Fitted is largest over all clock angles
- HAO's ExB and Weimer are close together
- All peak at 180°
- Behaviour expected



IMF Strength: 5 nT
Dipole Tilt Anlge: 0°

Joule Heat IMF

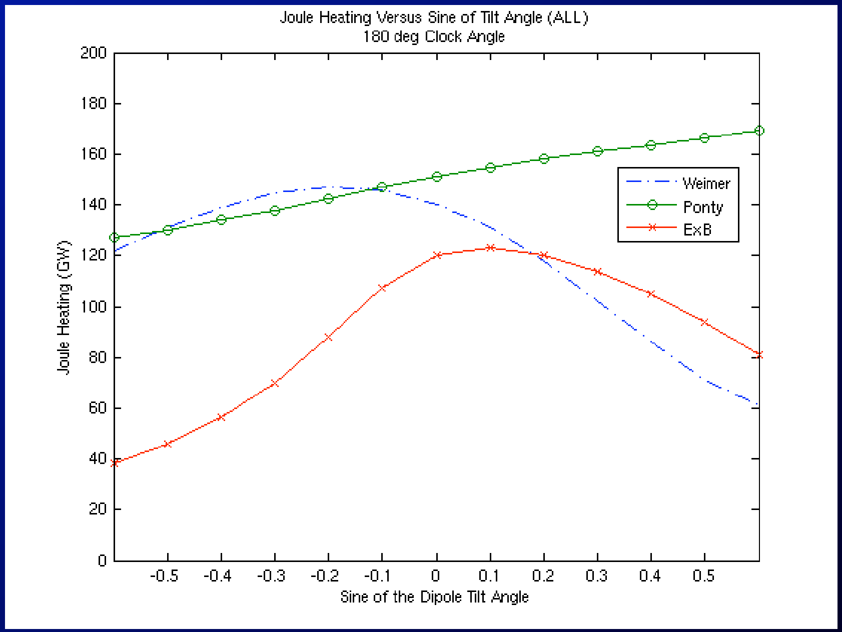
- Weimer and HAO's Data Fitted are close until around 20 nT
- Weimer appears linear
- Both HAO's Data Fitted and HAO's ExB level off



Clock Angle: 180°
Dipole Tilt Angle: 0°

Joule Heat Season

- HAO's Data Fitted appears linear; small bump around equainox
- Both Weimer and HAO's ExB have peaks
- Weimer peaks around Sin(T) = –0.2



Clock Angle: 180°
IMF Strength: 5 nT

Conclusions

- Two models show differences as conditions are varied (clock angle, IMF strength, dipole tilt)
- Strength and pattern variations
- Though there are local areas of great difference, globally the values are small
- With residuals, no major problems were seen except in Poynting flux

Future Plans

- HAO’s Data Fitted Poynting flux being reworked
- Incorporate model into a General-Circulation Model to study effects on Thermosphere
- Use model to find spatial and temporal properties of the energy input

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