Untold Stories About the Shue et al. Magnetopause Models

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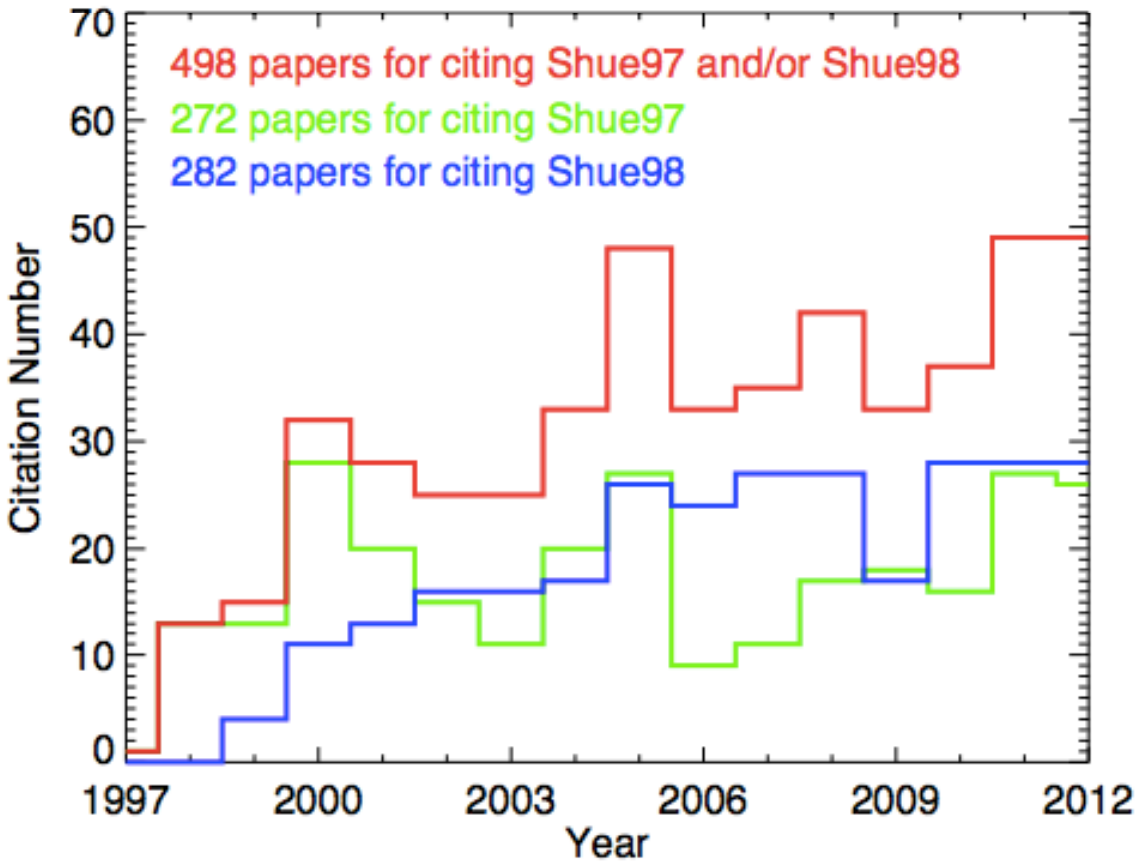
Outline

- Preamble
- Introduction of the Shue et al. models
- Development history
- Usage survey
- Final remarks

My Publications With Chris Between 1997 and 2011

1. Shue et al. [1997, JGR, Time Cited: 290]
2. Shue et al. [1998, JGR, Time Cited: 283]
3. Shue et al. [2000, ASR, Time Cited: 10]
4. Russell et al. [2000, ASR, Time Cited: 23]
5. Shue et al. [2000, JGR, Time Cited: 27]
6. Song et al. [2001, JGR, Time Cited: 4]
7. Shue et al. [2001, JGR, Time Cited: 16]
8. Yang et al. [2002, JGR, Time Cited: 17]
9. Cheng et al. [2009, ASR, Time Cited: 2]
10. Nowada et al. [2009, PSS, Time Cited: 1]
11. Shue et al. [2011, JGR, Time Cited: 0]

Citation Statistics (1997-2012)



The Affiliation of the Shue et al. papers

- The Shue et al. [1997] paper
  - National Central University, Taiwan
- The Shue et al. [1998] paper
  - Nagoya University, Japan

The Prototype of the Shue et al. Models

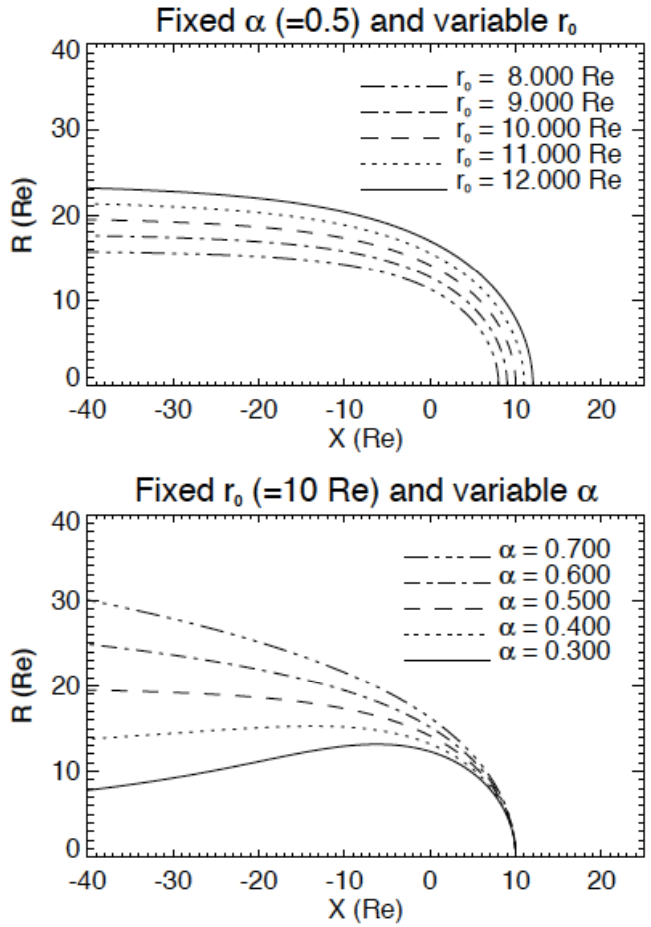
- was created at
  - UCLA (March 08 – April 22, 1995)
- in the office of Janet Luhmann
- under a supervision of
  - Chris Russell and Jerry Chao

Functional Form of the Shue et al. Models

$$r = r_0\left(\frac{2}{1+\cos\theta}\right)^{\alpha}$$

r_0: Subsolar standoff distance
α: Flaring level of the magnetopause
θ: Solar zenith angle
r: Standoff distance at given θ

A Demonstration of the Formula



- This formula was proposed by Paul Song.
- Unlike the formulas of ellipse and parabola, this formula can model both open and closed magnetopause.

The Work of the Shue et al. Models

Obtain r_0 and α in terms of Bz and Dp using multiple observations from ISEE 1-3, AMPTE/IRM, IMP-8, GOES, Geotail, Interball-1, and GMS-4 .

$$r_0 = r_0(B_z, D_p)$$
$$\alpha = \alpha(B_z, D_p)$$

Bz: The Z component of the IMF

Dp: Solar wind dynamic pressure

Fitting Method Used in Modeling

- The gradient-expansion least-squares method was suggested by Krishan Khurana.
- He even provided his fitting program to me.

The Shue et al. [1997] Model

$$r_0 = \begin{cases} (11.4 + 0.013B_z)(D_p)^{-\frac{1}{6.6}}, & \text{for } B_z \geq 0 \\ (11.4 + 0.14B_z)(D_p)^{-\frac{1}{6.6}}, & \text{for } B_z < 0 \end{cases}$$

$$\alpha = (0.58 - 0.010B_z)(1 + 0.010D_p)$$

Range of validity:

-18 < Bz < 15 nT

0.5 < Dp < 8.5 nPa

X > -40 Re

The Shue et al. [1998] Model

$$r_0 = \{10.22 + 1.29\tanh[0.184(B_z + 8.14)]\}(D_p)^{-\frac{1}{6.6}}$$

$$\alpha = (0.58 - 0.007B_z)[1 + 0.024\ln(D_p)]$$

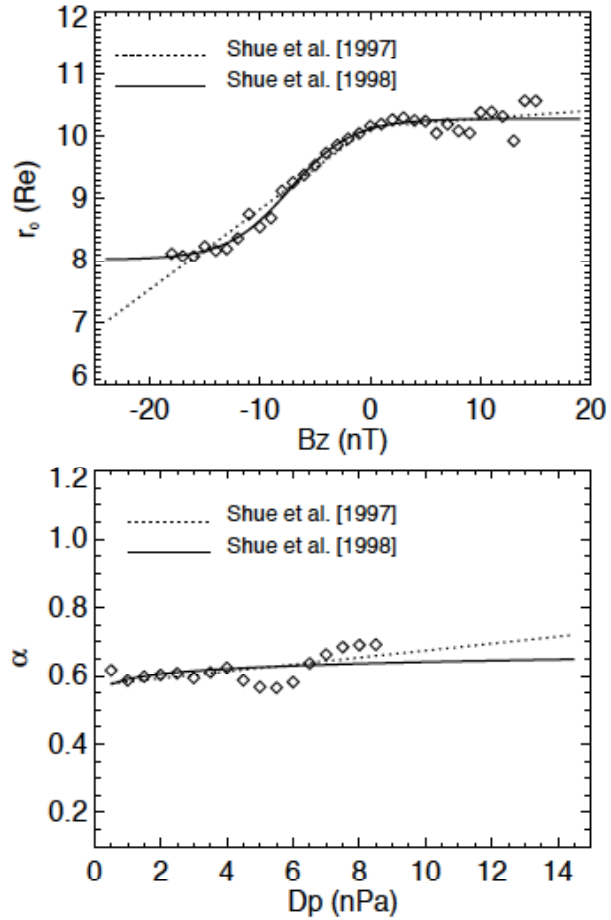
Range of validity:

-20 < Bz < 20 nT

0.5 < Dp < 60 nPa

X > -40 Re

Comparison Between the Models



- Shue et al. [1998] modeled the saturation of r_0 in terms of Bz and the saturation of α in terms of Dp.

The Magnetopause Project

- Paul Song initiated the project.
- Jerry Chao took over the project.
- I worked as a postdoc under Jerry in Taiwan.
- Two of Jerry's students and I compiled a list of magnetopause crossings.
- Paul invited me to work in the US.
- Chris agreed to be the host of my visit.

Criticism During the Project

- Someone said
  - "You are doing something people don't want to do."
- Another way of thinking on this criticism
  - "Because I did something people don't like to do, my models became something special."

Encouraged by Chris

- At the end of my visit to UCLA, Chris said

  "Keep up with the good work"
- I listened and continued working on the model when I went back to Taiwan.
- I published the Shue et al. [1997] paper in Taiwan and the Shue et al. [1998] paper in Japan.

Financially Supported by Chris

- For some reason, I had a problem to pay for the publication fee of the Shue et al. [1998] paper.
- Chris and Howard Singer paid for the fee.

Invited by Chris

- 2000 Fall AGU Special Session SH02
  - Bow Shock, Magnetosheath, Magnetopause: A Tribute to J. R. Spreiter
- A Special Issue in Planetary and Space Science (April–May, 2002)
  - Solar System Magnetosheath-A Special Issue in Honor of John Spreiter

The Other Contributors

- The two students who helped identify magnetopause crossings using the UCLA BX data analysis software
  - H. C. Fu and Y. M. Hsiao
- Valuable discussion with
  - J. T. Steinberg, Z. Zastenker, O. L. Vaisberg, S. Kokubun, T. R. Detman, and H. Kawano.

Strengths of the Shue et al. Models

- Simple
- Accurate for most ranges of Bz and Dp
- Larger ranges of validity of Bz and Dp than other models'.

The Base of Usage Survey for the Shue et al. Models

- Through the Wiley Online Library or Web of Knowledge web sites, 460 papers were downloaded.
- I took a quick view on all of them, just focusing on how the Shue et al. models were used in these papers.
- The impacts are broad, covering many aspects.

What can a model calculate?

- The distance from a satellite to the magnetopause
- The normal direction of the magnetopause
- The solar wind propagation time from a solar wind monitor to the nose of the magnetopause
- The cross section of the magnetotail
- The size and shape of the bow shock
- The thickness of the magnetosheath

What Else Can a Model Do?

- Normalize, remove, and retain observations in reference to the magnetopause
- Test with global MHD models,
- Provide a boundary condition for some magnetosheath and magnetotail models

What is the Shue et al. [1998] model used in the other famous work?

- Used in the OMNI solar wind data set to calculate the nose location of the bow shock with Farris and Russell [1994]
- Used in the Tsyganenko magnetic field models to be the magnetospheric boundary

What Topics Can a Model Study?

- Space weather prediction for geoysynchronous magnetopause crossings
- Magnetopause shadowing
- Plasmaspheric dynamics
- Modeling of radiation belts

Applications in Planets and Moon

- The functional form of the Shue et al. models has been used in modeling the size and shape of Saturn's and Mercury's magnetopause [Arridge et al. 2006, Anderson et al., 2012].
- According to the Shue et al. [1998] model, the Moon spends about 15% of the time in the magnetosphere [Huang et al., 2009].

Applications in Exosphere and Stratosphere

- If the exosphere is expanded beyond the magnetopause, its constituents beyond the magnetopause can be ionized and eroded by the solar wind plasma [Lammer et al., 2009].
- Some correlation exists between the standoff distance of the magnetopause and ozone density, stratospheric electric fields and temperature [Makaova et al., 2004].

Weaknesses of the Models

- Steady state
- Axisymmetry along the Sun-Earth line
- Fail to represent the size and shape of the magnetopause when
  - the IMF is radial [Merka et al., 2003; Dusk et al., 2010]
  - both Dp and negative Bz are extremely large [Ober et al., 2002]

Future Works

- Constructing a dynamic model
- Constructing a “simple” 3-D model, including the cusp indentation
- Solving a problem of underestimated r_0 for radial IMF
- Solving a problem of overestimated α when both Dp and negative Bz are extremely large

Final Remarks

- There are many important persons who helped me go through the difficulties in my academic career.
- Without Chris, it won't have the prototype of the Shue et al. models.

Chris - Thank you very much for your help.