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Education:

Dec 2015	Ph.D. Geophysics and Space Physics	University of California, Los Angeles
	Dissertation: Configuration and Generation of Substorm Current Wedge	
Mar 2012	M.S. Geophysics and Space Physics	University of California, Los Angeles
Jun 2009	M.S. Space Physics	Peking University
Jun 2006	B.S. Space Physics	Peking University

Professional Experience

January 2018 – Present. Research Associate,	Laboratory for Atmospheric and Space Physics University of Colorado, Boulder
January 2016- January 2018. Postdoc fellow,	Department of Atmospheric and Oceanic Sciences University of California, Los Angeles
September 2009- December 2015. Research Assistant,	Department of Earth, Planetary, and Space Sciences University of California, Los Angeles

Publications:

1. Huang, S., Li, W., Ma, Q., Shen, X., Capannolo, L., **Chu, X.** (2024). Modeling Global Electron Precipitation Driven by Whistler Mode Waves: Integrating Physical and Deep Learning Approaches, JGR-Space Physics (accepted)
2. Ma, D., Bortnik, J., Ma, Q., Hua, M., & **Chu, X.** (2024). Simulating the Earth's outer radiation belt electron fluxes and their upper limit: A unified physics-based model driven by the AL index. Geophysical Research Letters, 51(10), e2024GL109169. https://doi.org/10.1029/2024GL109169
3. **Chu, X.,** Bortnik, J., Shen, X.-C., Ma, Q., Li, W., Ma, D., et al. (2024). Imbalanced regressive neural network model for whistler-mode hiss waves: Spatial and temporal evolution. *Journal of Geophysical Research: Space Physics*, 129, e2024JA032761. https://doi.org/10.1029/2024JA032761
4. Cao, X., **Chu, X.,** Hsu, H.-W., Cao, H., Sun, W., Liuzzo, L., et al. (2024). Science return of probing magnetospheric systems of ice giants. Front. Astron. Space Sci. 11:1203705. https://doi.org/10.3389/fspas.2024.1203705
5. Shen, X.-C., Li, W., Ma, Q., Qin, M., Capannolo, L., Hanzelka, M., Huang, S., **Chu, X. N.** (2024). Large

amplitude whistler waves in Earth's plasmasphere and plasmaspheric plumes. Geophysical Research Letters, 51(8), e2023GL105244. https://doi.org/10.1029/2023GL105244

6. Su, Y.-J., Carilli, J. A., Parham, J. B., **Chu, X.,** Galkin, I. A., & Ginet, G. P. (2024). Electron density specification in the inner magnetosphere from the narrow band receiver onboard DSX. Radio Science, 59(2), e2023RS007907. https://doi.org/10.1029/2023RS007907
7. Li, J., Bortnik, J., Tian, S., Ma, Q., An, X., Ma, D., **Chu, X. N.,** et al. (2024). Fine structure of magnetospheric magnetosonic waves: 1. Elementary rising-tone emissions within individual harmonic. Journal of Geophysical Research: Space Physics, 129(3), e2024JA032462. https://doi.org/10.1029/2024JA032462
8. Ma, D., Bortnik, J., Ma, Q., Hua, M., & **Chu, X.** (2024). Machine Learning Interpretability of Outer Radiation Belt Enhancement and Depletion Events. Geophysical Research Letters, 51, e2023GL106049. https://doi-org.colorado.idm.oclc.org/10.1029/2023GL106049
9. Aryan, H., Weygand, J. M., Bortnik, J., **Chu, X.,** Cao, X., & Tian, S. (2023). A statistical analysis of the auroral streamer current system. Journal of Geophysical Research: Space Physics, 128(11), e2023JA031686. https://doi.org/10.1029/2023JA031686
10. Ma, Q., **Chu, X.,** Ma, D., Huang, S., Li, W., Bortnik, J., & Shen, X.-C. (2023). Evaluating the performance of empirical models of total electron density and whistler-mode wave amplitude in the Earth's inner magnetosphere. Frontiers in Astronomy and Space Sciences, 10, 1232702. https://doi.org/10.3389/fspas.2023.1232702
11. Huang, S., Li, W., Ma, Q., Shen, X., Capannolo, L., Hanzelka, M., **Chu, X.,** Ma, D., Bortnik, J., & Wing, S. (2023). Deep learning model of hiss waves in the plasmasphere and plumes and their effects on radiation belt electrons. *Frontiers in Astronomy and Space Sciences*, *10*, 1231578. https://doi.org/10.3389/fspas.2023.1231578
12. Usanova, M., Delzanno, G. L., **Chu, X.,** Gallagher, D., Lee, J., Lund, E., et al. (2023). Cold ion heating in Earth's magnetosphere. Bulletin of the American Astronomical Society, 55(3), 405. https://baas.aas.org/pub/2023n3i405
13. Ma, D., Bortnik, J., **Chu, X.,** Claudepierre, S. G., Ma, Q., & Kellerman, A. (2023). Opening the black box of the radiation belt machine learning model. Space Weather, 21, e2022SW003339. https://doi.org/10.1029/2022SW003339
14. **Chu, X.,** Bortnik, J., Li, W., Shen, X.-C., Ma, Q., Ma, D., et al. (2023), Distribution and Evolution of Chorus Waves Modeled by a Neural Network: The Importance of Imbalanced Regression, *Space Weather*, 21, e2023SW003524. https://doi.org/10.1029/2023SW003524
15. Cao, X., **Chu, X.,** et al. (2023). The response of ionospheric currents to external drivers investigated using a neural network-based model. *Space Weather*, 21, e2023SW003506. https://doi.org/10.1029/2023SW003506
16. Li, J., Bortnik, J., **Chu, X.,** Ma, D., Tian, S., Wang, C.-P., et al. (2023). Modeling ring current proton fluxes using artificial neural network and Van Allen Probe measurements. Space Weather, 21, e2022SW003257. https://doi.org/10.1029/2022SW003257
17. Ripoll J-F, Pierrard V, Cunningham GS, **Chu X,** Sorathia KA, Hartley DP, Thaller SA, Merkin VG, Delzanno

GL, De Pascuale S and Ukhorskiy AY (2023) Modeling of the cold electron plasma density for radiation belt physics. Front. Astron. Space Sci. 10:1096595. https://doi.org/10.3389/fspas.2023.1096595

18. Aryan, H., Bortnik, J., Li, J., Weygand, J. M., **Chu, X.,** and Angelopoulos, V.: Multiple conjugate observations of magnetospheric fast flow bursts using THEMIS observations, Ann. Geophys., 40, 531–544, https://doi.org/10.5194/angeo-40-531-2022 , 2022.
19. Weygand, J. M., Bortnik, J., **Chu, X.,** Cao, X., Li, J., Aryan, H., & Tian, S. (2022). Magnetosphere-ionosphere coupling between north-south propagating streamers and high-speed earthward flows. Journal of Geophysical Research: Space Physics, 127, e2022JA030741. https://doi.org/10.1029/2022JA030741
20. Luke Cullen, Asadullah Galib, Andrew William Smith, Debvrat Varshney, Edward Brown, Peter J Chi, **Xiangning Chu**, Filip Svoboda (2022). Can We Forecast And Detect Earthquakes From Heterogeneous Multivariate Time Series Data? In I Can't Believe It's Not Better Workshop: Understanding Deep Learning Through Empirical Falsification. NIPS conference proceedings, Retrieved from https://openreview.net/forum?id=y0fs6PbGJWt
21. Huang, S., Li, W., Shen, X.-C., Ma, Q., **Chu, X.,** Ma, D., et al. (2022). Application of recurrent neural network to modeling Earth's global electron density. Journal of Geophysical Research: Space Physics, 127, e2022JA030695. https://doi-org/10.1029/2022JA030695
22. Hua, M., Bortnik, J., **Chu, X.,** Aryan, H., & Ma, Q. (2022). Unraveling the critical geomagnetic conditions controlling the upper limit of electron fluxes in the Earth's outer radiation belt. Geophysical Research Letters, 49, e2022GL101096. https://doi.org/10.1029/2022GL101096
23. Grimes EW, Harter B, Hatzigeorgiu N, Drozdov A, Lewis JW, Angelopoulos V, Cao X**, Chu X,** Hori T, Matsuda S, Jun C-W, Nakamura S, Kitahara M, Segawa T, Miyoshi Y and Le Contel O (2022) The Space Physics Environment Data Analysis System in Python. Front. Astron. Space Sci. 9:1020815. https://doi.org/10.3389/fspas.2022.1020815
24. Malaspina, D., Ergun, R., Goldstein, J., Andersson, L., Borovsky, J., **Chu, X.** et al, (2022). 'Follow the mass': the Science Case for Transformational Multi-scale Observations of Mass and Energy Flow Dynamics in Earth's Magnetosphere. Submitted to 2024-2033 Decadal Survey for Solar and Space Physics, https://ntrs.nasa.gov/api/citations/20220008629/downloads/PILOT_white_paper_SCIENCE_7pgs_20220516.pdf
25. Haiducek, J., Welling, D., Morley, S., Mukhopadhyay, A., **Chu, X.,** Helmboldt, J., et al. (2021). Substorm dynamics in MHD: Statistical validation tests and paths for improvement (preprint). Atmospheric Sciences. https://doi.org/10.1002/essoar.10509351.1
26. Ma, D., **Chu, X.,** Bortnik, J., Claudepierre, S. G., Tobiska, W. K., Cruz, A., et al. (2022). Modeling the dynamic variability of sub-relativistic outer radiation belt electron fluxes using machine learning. Space Weather, 20, e2022SW003079. https://doi.org/10.1029/2022SW003079
27. Malaspina D, Ergun R, Goldstein J, Spittler C, Andersson L, Borovsky J, **Chu X,** De Moudt L, Gallagher D, Jordanova V, Lejosne S, Link J, Maruyama N, Parker J, Thaller S, Unruh B and Walsh B (2022) Plasma Imaging, LOcal Measurement, and Tomographic Experiment (PILOT): A Mission Concept for

Transformational Multi-Scale Observations of Mass and Energy Flow Dynamics in Earth's Magnetosphere. Front. Astron. Space Sci. 9:910730. https://doi.org/10.3389/fspas.2022.910730

28. **Chu, X.,** Ma, D., Bortnik, J., Tobiska, W. K., Cruz, A., Bouwer, S. D., et al. (2021). Relativistic electron model in the outer radiation belt using a neural network approach. *Space Weather*, 19, e2021SW002808. https://doi.org/10.1029/2021SW002808
29. Tsyganenko, N. A., Andreeva, V. A., Sitnov, M. I., Stephens, G. K., Gjerloev, J. W**., Chu, X.,** & Troshichev, O. A. (2021). Reconstructing substorms via historical data mining: Is it really feasible? Journal of Geophysical Research: Space Physics, 126, e2021JA029604. https://doi.org/10.1029/2021JA029604
30. Stepanov, N. A., V. A. Sergeev, M. A. Shukhtina, Y. Ogawa, **X. Chu** and D. D. Rogov (2021). Ionospheric Electron Density and Conductance Changes in the Auroral Zone During Substorms. Journal of Geophysical Research: Space Physics 126(7): e2021JA029572, https://doi.org/10.1029/2021JA029572
31. Shen, Y., Vasko, I. Y., Artemyev, A., Malaspina, D. M., **Chu, X.,** Angelopoulos, V., & Zhang, X.-J. (2021). Realistic electron diffusion rates and lifetimes due to scattering by electron holes. Journal of Geophysical Research: Space Physics, 126, e2021JA029380. https://doi.org/10.1029/2021JA029380
32. Li, J., **Chu, X.**, Bortnik, J., Weygand, J., Wang, C.-P., Liu, J., et al. (2021). Characteristics of substorm-onset-related and nonsubstorm earthward fast flows and associated magnetic flux transport: THEMIS observations. Journal of Geophysical Research: Space Physics, 126, e2020JA028313. https://doi.org/10.1029/2020JA028313
33. **Chu, X.,** McPherron, R., Hsu, T.-S., Angelopoulos, V., Weygand, J. M., Liu, J., & Bortnik, J. (2021). Magnetotail flux accumulation leads to substorm current wedge formation: A case study. *Journal of Geophysical Research: Space Physics*, 126, 2020JA028342. https://doi.org/10.1029/2020JA028342
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35. Haiducek, J. D., Welling, D. T., Morley, S. K., Ganushkina, N. Y., & **Chu, X.** (2020). Using multiple signatures to improve accuracy of substorm identification. Journal of Geophysical Research: Space Physics, 125, e2019JA027559. https://doi.org/10.1029/2019JA027559
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41. Camporeale, E., **X. Chu**, O. V. Agapitov, and J. Bortnik (2019), On the Generation of Probabilistic Forecasts From Deterministic Models, Space Weather, 17(3), 455-475, https://doi.org/10.1029/2018sw002026
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43. Ma, Q., W. Li, J. Bortnik, R. M. Thorne, **X. Chu**, L. G. Ozeke, G. D. Reeves, C. A. Kletzing, W. S. Kurth, G. B. Hospodarsky, M. J. Engebretson, H. E. Spence, D. N. Baker, J. B. Blake, J. F. Fennell and S. G. Claudepierre (2018). "Quantitative Evaluation of Radial Diffusion and Local Acceleration Processes During GEM Challenge Events." Journal of Geophysical Research-Space Physics 123(3): 1938-1952. https://doi.org/10.1002/2017ja025114
44. Bortnik, J., **X. Chu**, Q. Ma, W. Li, X. Zhang, R. M. Thorne, V. Angelopoulos, R. E. Denton, C. A. Kletzing, G. B. Hospodarsky, H. E. Spence, G. D. Reeves, S. G. Kanekal and D. N. Baker (2018). Chapter 11 - Artificial Neural Networks for Determining Magnetospheric Conditions, in Machine Learning Techniques for Space Weather, edited by E. Camporeale, S. Wing and J. R. Johnson, pp. 279-300, Elsevier, https://doi.org/10.1016/B978-0-12-811788-0.00011-1
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Dipolarizing Flux Bundles and Their Role as Wedgelets in the Substorm Current Wedge, in Electric Currents in Geospace and Beyond, edited, https://doi.org/10.1002/9781119324522.ch19

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51. Li, J., J. Bortnik, W. Li, R. M. Thorne, Q. Ma, **X. Chu,** L. Chen, C. A. Kletzing, W. S. Kurth, G. B. Hospodarsky, J. Wygant, A. Breneman and S. Thaller et al. (2017), Coherently modulated whistler mode waves simultaneously observed over unexpectedly large spatial scales, Journal of Geophysical Research: Space Physics, 122(2), 1871-1882, https://doi.org/10.1002/2016JA023706
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53. **Chu, X. N.,** J. Bortnik, W. Li, Q. Ma, V. Angelopoulos, and R. M. Thorne (2017), Erosion and refilling of the plasmasphere during a geomagnetic storm modeled by a neural network, *J. Geophys. Res. Space Physics*, 122, 7118–7129, doi:10.1002/2017JA023948.
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Invited Talks:

1. **X.N. Chu** et al., (2024). Advancing Physical Insights using Machine Learning: Exploring the Near-Earth Space Environment, CGS workshop 2024, JHU APL, MD
2. **X.N. Chu** et al., (2024). AI-Driven Advances in Physical Insights: Exploring the Near-Earth Space Environment, AIAPC 2024, Huntsville, AL
3. **X.N. Chu** et al., (2024). Investigate the solar cycle variation of plasmaspheric dynamics using a neural network model, ISSI-BJ, Beijing, 2024
4. **Chu, X**., & McPherron, R. L. (2023). Application of the Midlatitude Positive Bay Index (MPB) to Substorm Research. AGU 2023.
5. **X. N. Chu** et al., (2022) Unravel the mystery of plasmaspheric refilling with artificial intelligence, Cold plasma seminar series at LANL (online seminar).
6. **X. N. Chu** et al., (2022), Plasmaspheric dynamics modeled by a neural network, workshop on low-energy plasma in the geospacer, Japan (online seminar)
7. **X. N. Chu** et al, (2022) What can we learn from the shapes of STEVE. Aurorasaurus Ambassador (online seminar)
8. **X. N. Chu** et al. (2022). Plasmaspheric dynamics modeled by a neural network. Workshop on Observation and Modeling of Plasmasphere (Japan & online)
9. **X. N. Chu** et al., (2021) The mysterious subauroral phenomenon - STEVE, space physics online seminars, Peking University (Online seminar)
10. **Chu, X. N.** et al. (2017), Learning plasmaspheric dynamics using neural network based empirical models, University of Colorado Boulder, Boulder, CO
11. **Chu, X. N**. et al. (2016), Erosion and refilling of the plasmasphere during a geomagnetic storm modeled by a neural network, University of Calgary, Calgary, Canada
12. **Chu, X. N** (2012), Introduction to high latitude electrodynamics, GEM student tutorial, Snowmass, CO

Honors and Awards:

Air Force Young Investigator Research Program		2023
NASA Heliophysics Early Career Investigator Program		2020
NASA Earth and Space Sciences Fellowship	NASA	2014
Outstanding Student Presentation Award	Geospace Environment Modeling Workshop	2014

Harold and Mayla Sullwold scholar Department of Earth, Planetary, and Space Sciences (UCLA) 2014

Harold and Mayla Sullwold scholar Department of Earth, Planetary, and Space Sciences (UCLA) 2015

President's Undergraduate Research Fellowship Peking University 2004

The Freshman Scholarship Peking University 2002

Grants Received:

Principal Investigator, **Air Force Young Investigator Research Program,** 2022
Title: Understand and Forecast Killer Electrons: coupling machine learning and first-principle simulations
Total efforts: 8.5 months/year for 3 years
Contributing amount: $444,439

Principal Investigator, NASA Heliophysics **Early Career Investigator Program,** 2018
Title: Coupling Machine Learning Models of Multi-Instrument Spacecraft Data and Physics-Based Simulations: Applications to Study and Forecast Ultra-Relativistic Electron Flux
Total efforts: 10 months/year for 3 years
Total amount: $446,836

Institution PI, NASA Living With a Star, 2023
Title: Investigation of Charged Particle Dynamics in the Inner Magnetosphere Using a Data-driven Machine Learning Electric Field Model and a Global Magnetospheric Simulation
Total efforts: 2.0 Months/year for 4 years
Total amount: $238,559

Institution PI, NSF Geospace Environment Modeling, 2023
Title: Investigating the Upper Limit of the Earth's Outer Radiation Belt Electron Fluxes
Total efforts: 2.0 Months/year for 3 years
Total amount: $135,211

Principal Investigator, NASA Living With a Star, 2021
Title: Understanding plasmaspheric refilling: an investigation using machine learning models
Total efforts: 4.0 months/year for 3 years
Total amount: $990,807

Collaborator, NASA Heliophysics Mission Concept Studies, 2021
Title: PILOT (Plasma Imaging LOcal and Tomographic experiment) Mission Concept Study
Total efforts: 0.0 months/year for 1 year
Total amount: $0

Collaborator, NASA Heliophysics Mission Concept Studies, 2021
Title: Plasmasphere Tomography (PlaTo) mission study
Total efforts: 0.0 months/year for 1 year
Total amount: $0

Co-investigator, NASA Heliophysics Supporting Research, 2019
Title: Event-driven Modeling of Earth's Radiation Belts
Total efforts: 1 month/year for 3 years
Total amount: $52,628

Co-investigator, NASA Heliophysics Supporting Research, 2019
Title: Quantitative assessment of effects of the broadband electrostatic turbulence in the inner magnetosphere

Total efforts: 3 months/year for 3 years
Total amount: $255,000

Co-Investigator, NASA Heliophysics Heliophysics Living With a Star Science, 2019
Title: Quantifying Wave-Induced Relativistic Electron Flux Variations in Earth's Radiation Belts Driven by Solar Wind Structures
Total efforts: 4 months/year for 4 years
Total amount: $261,988

Co-Investigator, NASA Heliophysics Space Weather Operations to Research, 2018
Title: A machine learning based specification and forecast model of the inner magnetospheric radiation environment
Total efforts: 2.4 months/year for 2 years
Total amount: $82,533

Co-Investigator, NASA Heliophysics Supporting Research, 2017
Title: Quantifying the response of ionospheric currents to substorm-time and non-substorm fast flows
Total efforts: 6 months/year for 3 years
Total amount: $165,828

Co-Investigator, NASA Earth and Space Science Fellowship, 2014
Title: What process creates the substorm current wedge? A study using observations from space, ionosphere, and ground
Note: I wrote the full proposal, I was a co-I and my Ph.D. advisor is the PI due to solicitation requirements

Teaching and Mentoring Experience

Mentor and full support for a postdoc (Xin Cao) June 2021 – present
University of Colorado Boulder

- Machine learning application geomagnetically induced currents (GIC)
- Response of GIC to external drivers

Mentor an undergraduate student (Lucas Jia) Fall 2023-present
University of Santa Barbara

- Imbalanced regressive models for auroral electrojet indices: predicting supersubstorms
- One peer-reviewed publication under review

Mentor and full support for undergraduate researcher (Evan McPherson) Fall 2023-present
University of Colorado Boulder

- Imbalanced regressive models of energetic electron flux in Earth’s outer radiation belt

Mentor and full support for undergraduate researcher (Jonathan Mellina) Fall 2023-present
University of Colorado Boulder

- Validation of lunar gravity effects on Earth’s plasmasphere

Co-mentor for a Graduate student (Sheng Huang) Fall 2020 – Fall 2023
University of California, Los Angeles

- Machine learning application on electromagnetic waves and electron precipitation

Co-mentor for a Graduate student (Donglai Ma) Fall 2020 – Fall 2023
University of California, Los Angeles

- Machine learning application on radiation belt dynamics

Mentor for NSF Research Experiences for Undergraduates (Max Doering) Summer 2022-Summer 2023
University of Colorado, Boulder

- Dynamics of Plasmaspheric Ions Modeled by a Neural Network

Mentor for NSF Research Experiences for Undergraduates (James Lende) Summer 2021-Summer 2022
University of Colorado, Boulder
- Statistical Analysis of Plasmaspheric Erosion and Refilling–Machine Learning Approach

Mentor for an undergraduate thesis (Hannah Ace) Winter 2020 and Spring 2021
University of Vermont
- Mentor an undergraduate student in analyzing the total plasma density in the ionosphere and inner magnetosphere
- Guided the student in developing a machine learning-based model for the plasma density in the ionosphere and magnetosphere

Mentor for NSF Research Experiences for Undergraduates (Hannah Ace) Summer 2020
University of Colorado, Boulder
- Mentor an undergraduate student in analyzing the total plasma density in the inner magnetosphere
- Guided the student in developing a machine learning-based empirical model for the plasma density

Mentor for an undergraduate student (Lukas Wolter) Summer 2018-Summer 2019
University of Colorado, Boulder
- Mentor an undergraduate student in analyzing the auroral data collected from citizen scientists and calibrating skymaps of photographs
- Guided the student to obtain properties of the newly discovered STEVE phenomenon
- One peer-reviewed publication on the morphological characteristics of STEVE

Mentor for a high school student (Samuel Hsu) Summer 2015
University of California, Los Angeles
- Mentor a high school student to build a database of the newly developed mid-latitude positive bay index to measure geomagnetic activity level

Mentor for a high school student (Irene Hsu) Summer 2010
University of California, Los Angeles
- Mentor a high school student to develop a procedure to remove solar quiet variation from magnetic field data from ground magnetometers

Organizer of a summer school and teaching Olympic physics Summer 2006
Huangshi, Hubei, China
- Organizing a summer school to tutor twenty high school students
- Teaching the physics of the Olympics

Professional experience:

Session Organizer: NRSM 2023 and 2024 at Boulder, URSI 2023 at Sapporo Japan, AGU fall meeting 2024

GEM steering committee member: 2024-present

GEM Resource Group Lead: Machine Learning as it pertains in the Geospace Environment

Book Editor: Predicting Near-Earth Space Environment: New Perspective and Capabilities in the AI Age

Seminar Organizer: Friend of Magnetosphere at LASP

Review Panelist for NASA LWS, NASA HGI, HSR, HARD, HFOS, and NSF CAREER

Outstanding Student Poster Judge, AGU, and GEM conferences, 2016-present

Manuscript Peer Review: AGU Book chapters, Journal of Geophysical Research, Geophysical Research Letter, Journal of Ambient Intelligence and Humanized Computing, Philosophical Transactions A, Annales Geophysicae, Journal of Atmospheric and Solar-Terrestrial Physics, Geoscience Letters, Astrophysical Journal