Usage Report for Fiscal Year 2020

Project Title:

Particle Analysis Regarding Macro-Effects in Thunderstorms

Name:
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1. Background and purpose of the project, relationship of the project with other projects

High Energy Atmospheric Phenomena (HEAP), although the late discovery with the Terrestrial Gamma-ray Flashes (TGFs) [Fishman et al., 1994], are thought since much earlier as in (Wilson [1924], Wilson [1925] and Libby and Lukens [1973]). Different HEAP aspects have been observed over the years as; TGF spatial distribution and energy spectrum (Briggs et al [2010], Smith et al. [2005] and Tavani et al. [2011]), particle production – in particular, neutron production (Shah et al. [1985], Shyam and Kaushik [1999], Gurevich et al. [2012], Bratolyubova-Tsulukidze et al. [2004], Martin and Alves [2010]), as well as extended gamma-ray emissions so-called Gamma-ray glows or Thunderstorm Ground Enhancements (TGE) (Tsuchiya et al. [2007], Tsuchiya et al. [2012], Chilingarian [2013], Kelley et al. [2015] Wada et al. [2019]). All the HEAP sets have a common starting point with Relativistic Runaway Electron Avalanches (RREA) which implies a large multiplication of high-energy electrons (~1 MeV). Two factors are necessary for this phenomenon: a powerful enough energy source and an energetic particle to serve as a seed. The former sustains the particle energies as they keep colliding and lose energy randomly, this is usually the electric field role; and the latter serves as a multiplication starting point that promotes the avalanche itself. This project aims to analyze such phenomena by Monte Carlo simulations with GEometry ANd Tracking 4 (GEANT4) toolkit which provides the required physics and statistics to resolve such events with large particle numbers. Such simulations have a high computational cost due to the large particle and long simulations are required to achieve good statistical significance. The super-computer will reduce the simulation time and allow multiple analyses at the same time providing a better description of particle showers' behavior improving the research chances to connect RREA to all HEAP events aiming a realistic causality relation between them and explaining why such different events emerge from a similar physical process. Our results will be compared with Gamma-Ray Observation of *Winter Thunderclouds* (GROWTH) collaboration measurements.

2. Specific usage status of the system and calculation method

The current project uses HOKUSAI services to simulate particles' motion in the air with Monte Carlo program GEANT4 as described in (1). Extensive use of bulk jobs aimed the reported objective. Currently 5.8% of the disk quota is occupied. The project started in June/2020 and providing ongoing results parallel to the presented publication.

3. Result

The presented publication exploits the positron generation after a TGF due to atomic decay of photonuclear reactions leftovers. After the publication, a possible correlation with earlier GROWTH measurements were noticed that will be explored in the near future.

Also, a parallel simulation aiming for the description of particle beams modification due to moderate electric fiels is being implemented to investigate the gamma-ray glow and provide theoretical comparison with GROWTH results.

４． Conclusion

HOKUSAI services were able to provide the laboratory high quality simulation data. The high resolution calculation allowed the perception with correlation with previous measurements that displayed simultaneous research work possibilities.

５． Schedule and prospect for the future

The current main research of this project with HOKUSAI is the investigation of moderate electric field influence towards gamma-ray glow influence. The first data series is already under analysis to a new publication that will be used to provide estimates as input to the second, already being plan, publication.

６． If no job was executed, specify the reason.

N/A.

Fiscal Year 2020 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

Diniz, G. S., Ferreira, I. S., Wada, Y., & Enoto, T. (2021). Generation possibility of gamma-ray glows induced by photonuclear reactions. *Journal of Geophysical Research: Atmospheres*, 126, e2020JD034101. https://doi.org/10.1029/2020JD034101

[Oral presentation]

Generation possibility of gamma-ray glows induced by photonuclear reactions. AGU 2020, e-lightning presentation