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

The thunderclouds act as energy source for the High Energy Atmospheric Phenomena (HEAP). They accelerate the trespassing charged particles promoting augmentation of energetic radiation in low-altitude atmosphere. The Gamma-Ray Observation of Winter THunderclouds (GROWTH) collaboration observes gamma-ray augmented flux related with thunderclouds for many years now (Tsuchiya et al. [2007], Tsuchiya et al. [2012], Enoto et al. [2017], Tsurumi et al. [2023]). The research group reports Terrestrial Gamma-ray Flashes (TGFs) and gamma-ray glows related with Japanese winter thunderclouds. Both events require electric fields strong enough to promote Relativistic Runaway Electron Avalanche (RREA). The RREA will sufficiently multiply electrons to generate the observed enhanced flux. Weaker electric fields may also produce dimmer gamma-ray glows but recent studies indicate that the average gamma-ray glow requires RREAs.

The current project studies how the incoming cosmic rays interact with the thundercloud through Monte Carlo simulations in the GEometry ANd Tracking 4 (GEANT4) framework using EXcel-based program for calculating Atmospheric Cosmic ray Spectrum (EXPACS). Monte Carlo simulations use high computational resources and the super-computer allows us to perform the analysis in shorten time and compare the results with GROWTH observations.

2. Specific usage status of the system and calculation method

The Monte Carlo framework GEANT4 simulates particles' motion in the air as described in (1). The bulk jobs of this project produced data that currently occupy 10.2% of the disk quota. The project started in June/2020 and it is providing a series of papers and ongoing analysis

3. Result

Electric fields nearby RREA regime provide the average gamma-ray glow observed spectrum. The data analysis of the Monte Carlo simulations show the necessary ambient conditions for the emission. The electric field length and vertical distance from the ground play a signifficant role for the spectrum shape (publication 1) and flux (on going analysis). We also analyzed the effect of the air density variation and modelled how the realistic atmosphere modulates the RREA behavior (publication 2). The RREA modulation shows how the gamma-ray glow source is isolated in the thundercloud and displays weaker electric field requirements for the emission, such electric field levels being easier to sustain

during the timescale of the gamma-ray glow emission.

4. Conclusion

HOKUSAI services allowed us to provide data with enough statistics for a high quality analysis within reduced timeframe. Both the statistics and time were crucial for the project.

5. Schedule and prospect for the future

We are currently analysing how the gamma-ray glow observation is affected by the non-homogenous density and at different distances frow the emission axes. Understanding the horizontal geometry of this phenomenon is crucial for further observation plans.

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

N/A

Fiscal Year 2023 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

Diniz, G. S., Wada, Y., Ohira, Y., Nakazawa, K., Tsurumi, M., & Enoto, T. (2023). Ambient conditions of winter thunderstorms in Japan to reproduce observed gamma-ray glow energy spectra. *Journal of Geophysical Research: Atmospheres*, 128, e2022JD038246. https://doi.org/10.1029/2022JD038246

Diniz, G. S., Wada, Y., Ohira, Y., Nakazawa, K., Tsurumi, M., & Enoto, T. (2023). Relativistic runaway electron avalanche development near the electric field threshold in inhomogeneous air. *Geophysical Research Letters*, 50, e2023GL105087. https://doi.org/10.1029/2023GL105087

[Conference Proceedings]

Diniz, G. S., Wada, Y., Ohira, Y., Nakazawa, K., Tsurumi, M., & Enoto, T. (2023). Ambient conditions to reproduce gamma-ray glow energy spectra assuming cosmic ray as source PoS(ICRC2023)209.

[Oral presentation]

RREA development near threshold in inhomogeneous air. Radio Observations and Theory of Atmospheric Discharge Processes 6th CTR Splinter meeting, Bath, England.
Theoretical understanding of gamma-ray glows observations from Japanese winter thunderclouds. 1st International Workshop on Lightning Physics. Sao Jose dos Campos, Brazil.

[Poster presentation]

Diniz, G. S., Wada, Y., Ohira, Y., Nakazawa, K., Tsurumi, M., & Enoto, T. (2023). Ambient conditions to reproduce gamma-ray glow energy spectra assuming cosmic ray as source (ICRC2023).