Predicting Radiation Dose on Aircraft From Solar Energetic Particles

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Predicting when solar energetic particles (SEPs) will hit Earth, and in what concentrations, is important to mitigating space weather hazards ranging from communications outages to high radiation levels on polar aircraft routes. In response to increasing public and scientific interest in better understanding radiation dose as solar cycle 24 ascends, a half-day session entitled "Predicting Radiation Dose From Solar Energetic Particles" was held during the Japan Geoscience Union 2011 International Symposium on 24 May.

This was the first session held in Japan to discuss radiation hazards to aviation from SEPs and provided a unique starting point for an interdisciplinary approach. The main subject of this session was the radiation dose to airplane passengers from SEP events (Figure 1). About 50 participants attended the session, including solar-terrestrial researchers, radiological scientists, and airplane crews.

Of the 15 research papers presented in the session, several evaluated current observations. For example, Kazuaki Asada (Air Line Pilots' Association of Japan) talked about cosmic ray exposure during aircraft operation. He reported on various kinds of space weather influences that can affect aviation as well as the fact that the total dose to aviation from SEPs can be evaluated only after an event. In an invited talk, Seiji Yashiro (Catholic University of America and NASA Goddard Space Flight Center) evaluated automated detection techniques for important parameters of coronal mass ejections and flares in near real time.

Several papers focused on SEPs and the Sun-Earth connection: Satoshi Inoue (Japan's National Institute of Information and Communications Technology (NICT)) reported on the importance of characterizing the three-dimensional magnetic field structures around the Sun's active regions to better understand the open magnetic field possibly connecting to the Earth, based on his nonlinear force-free-field technique. Mitsue Den (NICT) reported on the importance of seed particles for SEPs based on models of SEP acceleration at interplanetary shocks. Shinichi Watari (NICT) reviewed the paradigm of SEP acceleration via solar flares versus via shocks and noted important issues involved with how solar radio bursts associated with SEPs are generated.

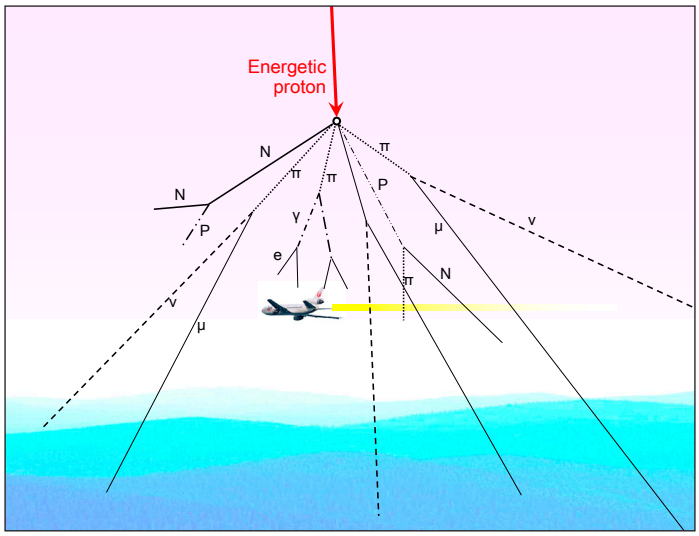

Fig. 1. Illustration of radiation exposure that an aircraft may encounter. Letters stand for several kinds of elementary particles associated with radiation exposure at high altitude: N, neutrons; P, protons; e, electrons; γ, gamma rays; μ, muons; υ, neutrinos; and π, pions.

The remainder of the papers ranged from those that modeled the acceleration and propagation mechanisms of SEPs to ones that predicted the radiation dose in the atmosphere using real-time spacecraft and ground-based observations. Kyoko Watanabe (Japan Aerospace Exploration Agency) and Takashi Minoshima (Japan Agency for Marine-Earth Science and Technology) reviewed the prediction capabilities of models that focus on flare acceleration of SEPs, and Takanobu Amano (Nagoya University) reviewed the prediction capabilities of the shock acceleration of

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SEPs associated with coronal mass ejections. Yoshizumi Miyoshi (Nagoya University) reported on the analysis of in situ observations of SEPs to quantify the entrance of SEP particles in the magnetosphere and ionosphere. Yuki Kubo (NICT) introduced the development of a real-time estimation technique for shock speed using solar radio bursts associated with coronal mass ejections. He also reviewed recent studies of SEP transport in the solar wind. Ayumi Asai (Kyoto University) reported on the detailed analysis and mechanisms of extreme ultraviolet waves as observed by Solar Terrestrial Relations Observatory (STEREO) satellites, which are potentially important for forecasting SEPs. Ken Tsubouchi (NICT) suggested that the probabilistic forecast based on his statistical method of SEPs is useful for making decisions.

During discussions a question was repeatedly raised: What kind of radiation dose forecasts are needed and useful for aviation operations? Tatsuhiko Sato (Japan Atomic Energy Agency) reported on the Excel-based Program for Calculating Atmospheric Cosmic-Ray Spectrum (EXPACS; see http://phits.jaea.go.jp/expacs/), a model for calculating dose to aircrew anywhere in the world during solar quiet time [*Sato et al.,* 2008]. This software is implemented and operated as the Japanese Internet System for Calculation of Aviation Route Doses (JISCARD; http://www.nirs.go.jp/research/jiscard/) for the management of cosmic radiation exposure for aircraft crew in Japan [*Yasuda et al.,* 2011]. The simulation technique is capable of estimating the aircrew doses from a given SEP energy spectrum and cutoff latitude. Daikou Shiota (Japan's Institute of Physical and Chemical Research (RIKEN)) and Ryuho Kataoka (Tokyo Institute of Technology) reported that real-time magnetohydrodynamic simulation models of the solar corona [*Shiota et al.,* 2010] and the solar wind [*Kataoka et al.,* 2009] can be modified to simulate the time-varying coronal mass ejection shock strength and the magnetic field connectivity to Earth, factors important for SEP prediction.

On the basis of Sato's, Yasuda's, Shiota's, and Kataoka's work, participants proposed a conceptual design for a new endeavor, called the Warning System of Aviation Exposure to SEP (WASAVIES), a system that will be able to estimate the minute-interval change of global atmospheric dose rates for 0 to 20 kilometers in altitude after a detection of ground-level enhancement of SEPs. As proposed, WASAVIES would also calculate automatically the dose along an aviation route for any flight operated during the prediction interval.

Polar cap absorption was a very active research target in Japan in the 1960s [e.g., *Obayashi,* 1962]. Half a century later, space weather threats to polar route aviation are real environmental problems, given that global business aims have connected Japanese commerce to Europe and North America. The usual aviation dose for a Tokyo to New York route, which follows a great circle path through the polar region, is around 0.05 millisievert; a dose during a very large ground-level enhancement can exceed 1 millisievert. To protect people from this harmful radiation, prediction efforts that involve a better understanding of flares and coronal mass ejections show the promise of significant breakthroughs. The forecast-based approaches as discussed in this session provide fundamental background solar wind and particle conditions for other quantitative space weather research, with possible extension to space weather environment predictions at other planets in the solar system.

References

Kataoka, R., T. Ebisuzaki, K. Kusano, D. Shiota, S. Inoue, T. T. Yamamoto, and M. Tokumaru (2009), Three-dimensional MHD modeling of the solar wind structures associated with 13 December 2006 coronal mass ejection, *J. Geophys. Res., 114,* A10102, doi:10.1029/2009JA014167.

Obayashi, T. (1962), Propagation of solar corpuscles and interplanetary magnetic fields, *J. Geophys. Res., 67*(5), 1717–1730, doi:10.1029/JZ067i005p01717.

Sato, T., H. Yasuda, K. Niita, A. Endo, and L. Sihver (2008), Development of PARMA: PHITS-based analytical radiation model in the atmosphere, *Radiat. Res., 170*(2), 244–259, doi:10.1667/RR1094.1.

Shiota, D., K. Kusano, T. Miyoshi, and K. Shibata (2010), Magnetohydrodynamic modeling for a formation process of coronal mass ejections: Interaction between an ejecting flux rope and an ambient field, *Astrophys. J., 718,* 1305–1314, doi:10.1088/0004-637X/718/2/1305.

Yasuda, H., T. Sato, H. Yonehara, T. Kosako, K. Fujitaka, and Y. Sasaki (2011), Management of cosmic radiation exposure for aircraft crew in Japan, *Radiat. Prot. Dosim., 146,* 123–125, doi:10.1093/rpd/ncr133.

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