P04

長期の宇宙天気活動に伴うスペースデブリ環境の推移予測

Long-term forecasts of space debris environment associated with space weather activities

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スペースデブリは宇宙ゴミとも呼ばれる、宇宙空間に存在する不要な人工物体の総称である。スペースデブリ生成・消失の要因のひとつは、太陽フレアや太陽高エネルギー粒子の放出、磁気嵐の発達などの宇宙環境変動による影響であり、宇宙天気と呼ばれる。この宇宙環境変動を考慮した長期的なスペースデブリ環境の推移を予測するため、我々は異なる宇宙天気活動度の下で、地球周回全領域デブリ環境推移モデル NEODEEM によるシミュレーションをおこなった。モデルでは、宇宙天気に関連するパラメータとして、F10.7 値と Kp 指数を用いた。シミュレーションの結果は、低調な太陽活動度（第 24 太陽周期相当）が続いた場合、新規の人工衛星打ち上げによる軌道物体の増加を無視しても、衝突によるデブリ生成のみでスペースデブリ環境は大きく悪化することを示唆した。

Space debris is the collection of defunct objects made by human being in space. One of the causes of space debris source/sink is space weather (for example, solar flare, solar energetic particle, geomagnetic storm) effect on space debris. To evaluate the effects of long term space weather activities on space debris environmental changes, this study conducts some simulations under different space weather activities using NEODEEM, a Near-Earth Orbital Debris Environment Evolutionary Model. F10.7 and Kp indexes are used as space weather related parameters. As a result, it is found that space debris environment would become significantly worse because of collision cascading even with no launches in the case of low solar activity, like as solar cycle 24.

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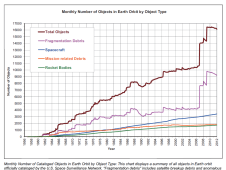
1.Introduction

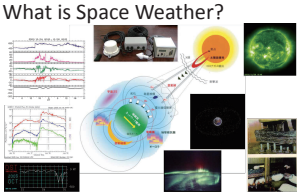
■What is Space Debris?

Space debris is the collection of defunct objects made by human activity in space(Payload, Rockets-body, Mission-related debris, Fragmentation debris). More than 170 million debris smaller than 1 mm, about 670,000 debris 1 cm, and around 29,000 larger debris are in orbit at July 2013(ESA).



NASA, 2012.

■What is Space Weather?



Space weather is environmental changes around the Sun-Earth system. It includes various phenomena, solar energetic particles, solar wind, geomagnetic storm, and so on. Space weather can affect human activity. For example, Solar energetic particles penetrate and break satellite electronics. Space weather survey of existing conditions and forecast is important for space utilization.

■Example of Satellite trouble caused by Space weather

1989/03/17	Trouble on CS-3b satellite
1994/01/20	Anik E1, Anik E2 (Canada) stabilizing momentum wheel trouble by solar activity
1997/01/11	Telstar 401(USA) was broken (remaining in GEO)
1997/04/11	Tempo 2(USA) repeater trouble
2000/04/09	BRAZILISAT-A2 trouble
2000/07/17	Astro-D attitude control trouble because of atmospheric expansion by solar flare, and atmospheric reentry at 2001/03/02
2003/10/24	ADEOS-II power failure(one possible cause is charging by geomagnetic activity)
2003/10/28	Mars Odyssey(USA) MARIE radiation experiment damaged by solar energetic particle
2003/10/28	DRTSgoes to safe mode because of solar energetic particle
2006/12/06	GPS receiver trouble because of radio burst by solar flare
2010/04/05	Galaxy15(USA) was out-of-control because of charge by auroral activity(back to normal mode 9 month later)
2012/03/07	Venus Express (ESA) star tracker trouble because of solar energetic particle
2012/03/07	SkyTerra1(USA) goes to safe mode because of solar energetic particle

2.Motivation

Solar activity has a cycle of the nearly periodic 11-year. Every solar cycle have different activities. For example, current cycle (solar cycle 24) is known as the period of relatively low solar activity. To evaluate the effects of long-term and various space weather activities on space debris environmental changes, this study conducts some simulations under different space weather activities using NEODEEM, a Near-Earth Orbital Debris Environment Evolutionary Model.

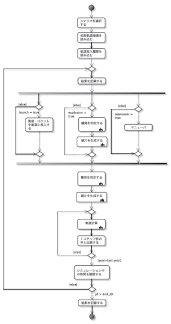
3.NEODEEM

NEODEEM(Near-Earth Orbital Debris Environment Evolutionary Model) is developed by Kyushu University and JAXA.

Features:

- Covers all orbit around the Earth(GEO, GTO, LEO,MEO)
- Many simulation scenario(Historical, Future, Target, Removal, Prop)
- Consider many disturbing forces(for example, gravitational potential, atmospheric drag, solar radiation)

NEODEEM uses F10.7 solar flux and Kp indexes as space weather related parameters.



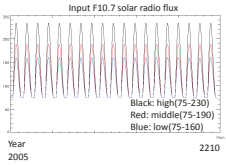
NEODEEM flowchart (Ariyoshi, 2012)

4.Simulations and Results

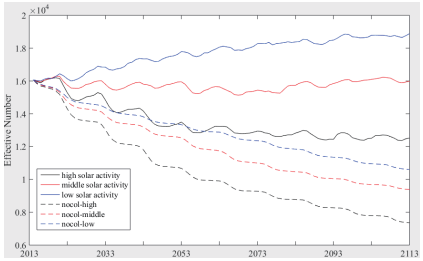
4.1 Evaluation of contributions of space weather disturbances as solar flux parameter

▼Input parameters

- Future scenario
- With Collision, no Launch, Explosion, PMD and ADR
- Jacchia-Roberts is used as atmospheric total density model
- Three input parameter F10.7
  Long term high solar activity
  Long term low solar activity
  Long term middle solar activity
- Constant Kp value = 4
- Simulation period 100years(2013/01/01-2112/12/31)
- 50 times Monte Carlo method



▼Result

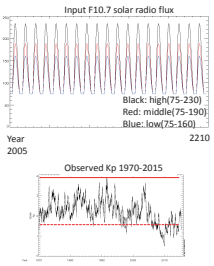


Space debris environment would become significantly worse because of collision cascading even with no launches in the case of low solar activity, like as solar cycle 24.

4.2 Evaluation of contributions of space weather disturbances as solar flux and geomagnetic activity parameter

▼Input parameters

- Future scenario
- With Collision, no Launch, Explosion, PMD and ADR
- Jacchia-Roberts is used as atmospheric total density model
- Three input parameter F10.7
  Long term high solar activity
  Long term low solar activity
  Long term middle solar activity
- Low and high KP value = 1 or 4
- Simulation period 100years(2013/01/01-2112/12/31)
- 50 times Monte Carlo method



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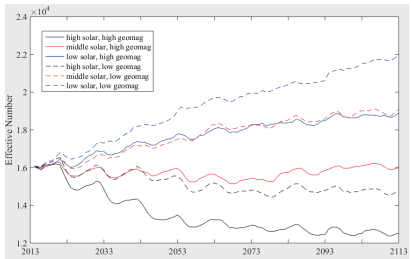
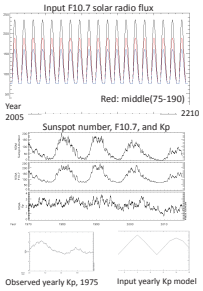


Space debris environment would become worse under low geomagnetic activity. Joule heating associated with the geomagnetic field is small under low geomagnetic activity. It causes low atmospheric drag effect to space debris.

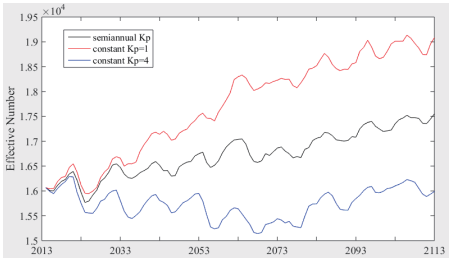
4.3 Evaluation of contributions of space weather disturbances as time series geomagnetic activity parameter

▼Input parameters

- Future scenario
- With Collision, no Launch, Explosion, PMD and ADR
- Jacchia-Roberts is used as atmospheric total density model
- Long term middle solar activity
- Semi-annual geomagnetic activity
- Simulation time 100years(2013/01/01-2112/12/31)
- 50 times Monte Carlo method



▼Result



For long-term space debris environmental changes, the average of geomagnetic activity is dominant.

5.Conclution

- To evaluate the effects of long term space weather activities on space debris environmental changes, this study conducts some simulations under different space weather activities using NEODEEM, a Near-Earth Orbital Debris Environment Evolutionary Model. F10.7 and Kp indexes are used as space weather related parameters.
- As a result, it is found that space debris environment would become significantly worse because of collision cascading even with no launches in the case of low solar activity, like as solar cycle 24.
- Concerning geomagnetic activity, space debris environment would become worse under low geomagnetic activity caused by low atmospheric drag effect.
- We will update the atmospheric model on NEODEEM for more accurate space debris environment forecasts associated with solar and geomagnetic activities.

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