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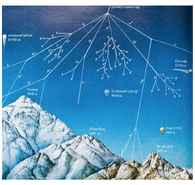
Increasing cosmic rays problematic for human space flight

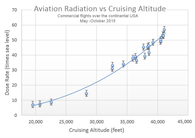
In this blog I have written several times on the proposed influence of galactic cosmic rays on global climate, the subject of the H. Svensmark's ongoing research. In this comment I will comment on two papers by N.A. Schwadron et al. which show that the ongoing solar minimum may cause a dangerous increase in cosmic rays induced radiation for human space travelers, and may cause a strong shortening of permissible extra-terrestrial flight time.

1. **Radiation from space.**

Simplifying the problem on can state that 2 categories of radiation are important for an extra-terrestrial astronaut: solar energetic particles (SEP, mostly protons and high energetic electrons) and galactic cosmic rays (GCR, mostly protons, electrons and nuclei of heavier elements, discovered by Victor Hess in 1912). The latter decompose in the atmosphere into a shower of secondary electrons, muons, gamma rays etc., as illustrated in the following picture:



The dose rate from this radiation is about 60nSv/h at sea-level. At meteoLCD we measure a background of about 80nSv/h. As the atmosphere is a shield against cosmic radiation, it is obvious that the dose-rate at higher altitudes is higher, with an exponential increase as shown by this graph:



Most trans-continental flight happen at about 40000 feet, so passengers and crew members are exposed to 50 times higher dose-rates, enough to classify pilots and stewards as radiation exposed workers. These "radioactive numbers" should always taken as indicative, and can not be precise. The next figure from www.radioactivity.eu.com (Radiation in flight) shows for different air trips the mean radiation dose rate in microSv/h and also the total dose for a flight:

So a flight from Paris to San Francisco would cause an average dose rate of 6400 nSv/h (to be compared to the previously mentioned 80nSv/h at Diekirch) or a total dose of 0.14 mSv (tiny when compared to the approx. 5 mSv per year one gets through background radiation and usual medical examination).

To quantify the biological risk, one often takes a dose of 250 mGy (approx. 250 mSv) as the upper acceptable limit (blood forming dose limit). The next table from a slide show by N.A. Schwadron (University of New Hampshire) gives the radioactive dose limits corresponding to a 3% risk of dying by exposure (cSv = centi-Sievert, I added the mSv boxes for clarity):

3% Risk for Exposure-Induced Death

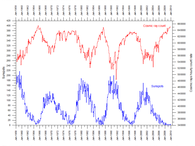
Age	3% REID Male E (cSv)		3% REID Female E (cSv)	
30	62	620 mSv	47	470 mSv
45	95	950 mSv	75	750 mSv
55	147	1470 mSv	112	1120 mSv

Managing Space Radiation Risk in the New Era of Space Exploration Committee on the Evaluation of Radiation Shielding for Space Exploration, National Research Council 2008

For us elder it is a consolation to see that we can tolerate much higher levels than the young ones!

2. **Cosmic radiation and solar activity**

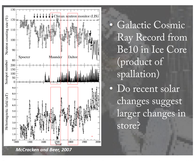
The sun is a very active nuclear fusion reactor, emitting with varying intensity huge quantities of charged particles and neutrons (the so-called solar wind). When the sun is very active (visible by many sun spots and measurable high magnetic field), the solar wind is strong, and deflects a big part of the galactic cosmic rays from reaching the earth. When the sun is in a lull (few sun spots, low magnetic field), more of these GCR's reach our atmosphere.



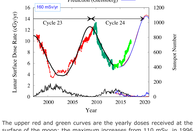
This plot shows the cosmic rays intensity (in red) and the number of sun spots for solar cycles 19 to 23: a low sun spot count (= an inactive sun) correlates with a higher cosmic radiation.

One theory is that this increased radiation creates more nuclei for condensing water vapour, and increases the lower cloud cover. This in turns diminishes the solar energy absorbed by the globe, and will (or could) produce a colder climate. This is the theory of the Danish researcher Henrik Svensmark, who has verified in his lab the creation of condensing nuclei by cosmic rays. The IPCC ignores this theory, and stubbornly sees the human emission of greenhouse gases as the main or even sole climate changing cause.

Now, Schwadron and coauthors have published an add-on to an earlier paper from 2014, where they show that we are heading into a period of very high cosmic radiation (see also this article in the archive of spaceweather). We are now in=midst solar cycle 24, which is exceptionally inactive: fewer sun spots and lower magnetic activity. At least three periods of low solar activity are known to exist: the Maunder minimum around 1700, the Dalton minimum (~1815) and the Gleisberg minimum (~1910).



The next graph shows at the bottom the sunspot number for cycles 23 (1996-2008) and the ongoing cycle 24 (start 2009):



The upper red and green curves are the yearly doses received at the surface of the moon: the maximum increases from 110 mSv in 1996 to 130 mSv in 2009 and possibly to ~140 mSv in 2020: that is an increase of nearly 20% ! If, as many solar researchers predict, solar cycle 25 will have a still lower sun spot count, the radiation dose could possibly be much higher. This does not bode well for manned space flight. It is quasi impossible to increase radiation shielding (for obvious reasons of weight), so the duration of flight time spent in space might well be forcibly shortened (arrow added to original figure):

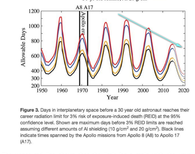


Figure 3. Days in interplanetary space before a 30 year old astronaut reaches their career radiation limit for 3% risk of exposure-induced death (REID) at the 95% confidence level. Shown are maximum days before 3% REID limits are reached assuming different amounts of Al shielding (10 g/cm² and 20 g/cm²). Black lines indicate times spanned by the Apollo missions from Apollo 8 (A8) to Apollo 17 (A17).

The upper red line shows that the limit for a male with the usual aluminium shielding diminishes from about 1100 to 750 days w.r. to the optimal situation in the 90's.

3. **Conclusion**

The authors conclude the update paper with:

"*We conclude that* ***we are likely in an era of decreasing solar activity****. The activity is weaker than observed in the descending phases of previous cycles within the space age, and even weaker than the predictions by Schwadron et al. [2014a]. We continue to observe large but isolated SEP events, the latest one occurring in September of 2017 caused largely by particle acceleration from successive magnetically well-connected CMEs.*
The radiation environment remains a critical factor with significant hazards associated both with historically large galactic cosmic ray fluxes both with historically large galactic cosmic ray fluxes *and large but isolated SEP events."*

Thus the natural changes in solar activity might not only lead to a possible new cooler period (comparable to the Dalton minimum) but also present new challenging obstacles for human space flight .

History:

13 Mar 2018: update with some added links and minor correction of spelling errors.

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