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The idea of Space Weather – A historical perspective

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Abstract

This paper reports the results of a search to determine who originated the concept and/or the term Space Weather. Though many people have been identified with an early use of the term "Space Weather", the first one to have introduced the term seems to be Thomas Gold of Harvard College Observatory, in a 1959 publication in the *Journal of Geophysical Research*.

Keywords: Space weather; Space science history; Solar–terrestrial phenomena

The name "Space Weather" is now a popular scientific term and concept. Effects of solar-induced disturbances on our space environment ranging from degradations in spacecraft operations to disruptions of electrical power grids to the manufacturing of precision equipment have been well documented for more than 35 years (Donnelly, 1979; Simon et al., 1986; Thompson et al., 1990; Hruska et al., 1993; Heckman et al., 1997). At the Chapman Conference held in Manaus, Brazil in February 2005, there was an interesting discussion revolving around the questions of "Who initiated the idea of "Space Weather" and when was the term "Space Weather" first used"? Among the attendees, no one seemed to know the answers to these questions for certain, although many suggestions were made. The idea of comparing the space environment with terrestrial meteorology is relatively simple and also very fascinating. In doing research on solar–terrestrial relationships, probably many scientists had the idea of "space weather" in the back of their minds and perhaps often ventured to express this idea in public, but the origin of both the concept and the term "Space Weather" has not been documented.

During the discussion in Brazil, many names of individuals were suggested. This short paper is the result of an effort to determine the origin of the space weather concept and terminology. Professor Y. Kamide of Nagoya University, Nagoya, Japan said, "I really do not know who, when, and where this term was first used". Professor John Freeman of Rice University, Houston, Texas, USA had the following to say, "I used the phrase "Space Weather" and "space weathermen" in a presentation for a NSF program planning meeting at Boston College", probably in the *early 1990s*. Dr. William J. Burke of the Air Force Research Laboratory in Bedford, MA, USA commented, "As far as I know, I was the first to use the phrase "Space Weather" to describe what we (at AFRL) do". This was in the *mid-1980s*.

Kane (1973) noticed that during very severe geomagnetic storms, ionospheric storm behavior was erratic, violent and highly localized (geographically), reminding one "of meteorological storms which can be devastating and yet confined to small geographical locations and one is tempted to surmise that the severe localized effects in foF2 (the critical frequency of the ionospheric F2 layer) too are caused by severe localized wind typhoons". As noted, this concept of space weather was back in 1973; there must be many such examples in the literature in that decade.

Dr. Murray Dryer of the NOAA Space Environment Center, Boulder, CO, USA pointed out that the preface of "Solar Activity Observations and Predictions" (McIntosh and Dryer, 1970), states "It is certainly desirable to have accurate predictions of this space 'weather'." Thus, an early mention of the term Space Weather was *in 1970*.

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Dr. Gerd Prölss of Bonn, Germany said he first came across the term Space Weather in a tutorial report by Georges (1967) where it is written, "The ionosphere has recently become important as a sensor of other geophysical activity, for example, as a 'space weather' indicator, and as a tool for detecting clandestine nuclear-bomb detonations and missile launchings". This was *in 1967*.

While these references are in the mid-1960s and later, I was astonished to find one reference *preceding all these*. The idea of Space Weather was proposed by none other than Thomas Gold, back in 1959. Here is the story:

After Biermann (1951, and further papers) proposed that the pointing of comet tails always away from the Sun implies material flying out of the Sun on a continuous basis, and while Chapman (1957) still maintained his idea of a static but extended corona, Parker formulated his theory of solar wind at the University of Chicago (Hufbauer, 1991). Parker's paper (Parker, 1958) was accepted for publication reluctantly by his colleague Chandrasekhar who was then the Editor of *Astrophysical Journal*. The paper had a very lukewarm reception, bordering on hostility (Chamberlain, 1960), but Parker found one ally, namely, Thomas Gold then at the Harvard College Observatory, who immediately realised that here was a gold mine. In the next few months, both these individuals made it a point to attend important solar and geophysical meetings together and to expound their own viewpoints. The climax came on April 29–30, 1959 when both attended the first nationally (American) sponsored conference devoted to the special problems of space physics, held in Washington, DC under the auspices of the National Academy of Sciences, National Aeronautics and Space Administration, and the American Physical Society. The proceedings of this 'Symposium on the Exploration of Space' were published in the *Journal of Geophysical Research*, Vol. 64, November 1959. The following is an excerpt of the paper by Gold (1959).

"I am planning to talk about the interplanetary gas in the inner part of the solar system, in which we live. I should like to discuss the circumstances that we shall find when we send up suitable instruments to investigate that gas.

The subject is the *counterpart to meteorology on the earth*; we shall be concerned with the permanent and the variable features in the gaseous content of the inner part of the solar system. We first ask, what will be the experiments equivalent to the *meteorological measurements of temperature, pressure, and wind*? What are the quantities we should be interested in, and what are the orders of magnitude that we now expect we shall find?

Of course, we know little at present. We have only some very indirect methods of inference, and it is essential to carry out the space-vehicle experiments that are now in prospect. Nevertheless, it is best to state what can be inferred from the meagre data available, because this statement will suggest suitable experimentation". (The italics are mine.)

The paper by Gold (1959) where the idea of Space Weather was suggested is now referenced in that context by Kane (2005a,b). While Gold did not use the term 'Weather' as such, the Meteorological Glossary gives the definition: "Weather: the state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc." Thus, the meteorology-like measurements in space mentioned by Gold imply nothing else but "Space Weather".

Many of the surmises of Parker and Gold during 1959–1960 had no experimental basis whatsoever, but the validity of their ideas in the satellite observations which followed soon after (Lunik 2, Gringauz et al., 1960; Explorer 10, Bridge et al., 1962; Mariner 2, Neugebauer and Snyder, 1962) speaks volumes of the ingenuity and foresight of these two visionaries, who initiated Space Physics and revolutionized Geophysics. However, there were some slight differences of opinion also. Parker (1959) mentions, "the solar wind (not confirmed by observations at that time!) blowing outward from the sun must exert a pressure against the geomagnetic field, inasmuch as the ionized gas of the solar wind is unable to penetrate the field ... If the outer surface of the geomagnetic field is unstable, ... the region of the interface will be disordered ... normal solar wind, which has a velocity of 500 km/s and a density of 100 particles/cm^3, can penetrate no deeper than to within 5 earth's radii from the center of the field". On the other hand, Gold (1959) says, "The region in the vicinity of the earth in which the earth's magnetic field dominates all dynamical processes might be called the 'magnetosphere' (*thus, Gold was probably the originator of the term 'magnetosphere' also*). The laws of motion of ionized material in the magnetosphere are greatly affected by the fact that the entire magnetospheric conducting region is separated from the conducting earth by the insulating sheath of the non-ionized dense atmosphere. ... We are certainly forced to think that the greater part of the region is stable, owing to the particle fluxes and hot gases enmeshed in that field".

That solar flares are often followed by geomagnetic disturbances has been known for some time (Chapman and Bartels, 1940). However, even at a stage when no interplanetary data were available, Gold (1959) indicated the missing link between the sun and the earth. He discussed the effect of solar particles, which came from large solar flares with time delays of the order of an hour and showed storage for a matter of many days, and produced severe ionospheric effects (bad Space Weather!) as after the great flare of February. 23, 1956 (Bailey, 1957).

Gold's simple idea of anology between Terrestrial Meteorology and Space has been elaborated by Siscoe (2004) in his paper "Space Weather – Terrestrial Weather: Fruitful analogies" where he says, "Take for example weather elements. In the troposphere these are pressure, temperature, precipitation, and the state of the sky. The analogs to these for space weather are solar wind speed and ram pressure, IMF Bz, energetic particle intensity, and auroras"; he gives many other anologies and mentions further, "Terrestrial weather forecasting has proceeded through a series of ages:

a preinstrument age (sky signs, e.g., solar halo) led to an instrumented but local (barometer) age then to synoptic weather maps (isobars) then to the concept of organized storm systems (traveling cyclonic depressions) then to air masses and weather fronts (the polarfront model) then to objective forecasts (empirically based algebraic algorithms) then to numerical forecasts (physics-based numerical codes) and finally to the same augmented with satellite imagery. Space weather forecasting has been proceeding through roughly analogous ages: *a pre-satellite age* (*sun signs*, *e.g.*, *solar flares*) followed by local satellite measurements (magnetometer measuring IMF Bz) followed by synoptic charts of the sun (magnetograms) followed by the concept of organized storm systems (coronal mass ejection from the sun and substorms within the magnetosphere) followed by models of these phenomena (magnetic clouds and the Hones model) followed by empirically based algebraic algorithms (e.g., the Wang–Sheeley model for solar wind speed and the Burton equation for Dst) followed by physics-based numerical codes (the MFM and global MHD simulation codes) followed by the same augmented with coronal imagery (halo CMEs). Despite the analogies, in the case of space weather the state of the art is still relatively primitive and mostly pre-operational''. In this connection, some attempts in the past (von Humboldt, 1808, 1845) related to the analogy between the description of space phenomena and phenomena in meteorology will be of historical interest. Incidentally, in addition to the term ''Space Weather'', and again in analogy to concepts in meteorology, the term ''Space Climate'' has recently emerged.

In the present paper, only the origin of the 'English term' ''Space Weather'' is explored. It is likely that a similar term in other languages is mentioned elsewhere. An elucidation from readers would be welcome. Also, additional aspects, e.g., the question of what the benefits of ''Space Weather'' are to either humanity or progress in scientific research, are not addressed here. That would be a vast topic, far beyond the scope of the present paper, restricted to explore only the *history* of the term ''Space Weather''. I expect many readers to come forward and contribute to the subject with additional input or with arguments about the relation between space weather and solar–terrestrial phenomena as well as its overall relevance. Also, science and science-policy aspects are addressed here only marginally. A few recent references on this topic are Lemaire (2001) and Scherer et al. (2005).

While we may never determine for certain who actually initiated the term ''Space Weather'', it appears that Gold was a pioneer, to advocate the analogy of solar induced disturbances to meteorological weather disturbances. As regards the solar–terrestrial effects of solar weather, it has taken a century to refine weather forecasting to the present state of the art; we can probably expect similar time scales to predict when and how a solar-induced disturbance (solar weather) will impact the earth and to precisely predict the solar–terrestrial effects this impact will have on our spatial and geophysical environment.

Recently, a new term ''Space Climate'' has received considerable attention. A special issue of *Solar Physics* was devoted to the topic ''Space Climate: Direct and Indirect Observations of Long-Term Solar Activity'', based on contributions presented at the First International Symposium on Space Climate organized in Oulu, Finland in June 20–23, 2004. In the Preface, Mursula et al. (2004) mention the following:

''The concept of Space Weather was launched some 10 years ago to describe the short-term variations in the different forms of solar activity, and their effects in the near-Earth environment and technoculture. As an analogy with the relation between the weather and climate of the neutral atmosphere, the concept of Space Climate was introduced more recently to extend the time span covered by Space Weather to the longer-term variations in solar activity, as well as their long-term effects on the heliosphere, near-Earth space, neutral climate and many other related systems''.

Thus, while the term ''Space Weather'' includes the status of the current space environment to forecasts of this environment over the next few solar rotations, the term ''Space Climate'' would encompass the studies and knowledge of the space environment (and the effects of this environment) extending from years to millennia.

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