MEETING OF THE METEOROLOGY PANEL (METP) METEOROLOGICAL INFORMATION AND SERVICE DEVELOPMENT WORKING GROUP (WG-MISD)

FIRST MEETING

Washington DC, United States, 16 to 19 November 2015

Agenda Item 5: Matters Relating to WG-MISD Space Weather Work Stream
5.1: ConOps for Space Weather Information Services

DISCUSSION OF THE NOAA SPACE WEATHER SCALES AND THEIR RELEVANCE TO AVIATION SERVICES

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SUMMARY

This paper will serve to outline the strengths and weaknesses of the NOAA Space Weather Scales to support discussion about their role in the framework for space weather services in support of global aviation.

Action by the METP-WG/MISD Space Weather Work Stream is paragraph 3.

1. INTRODUCTION

1.1 The NOAA Space Weather Scales were created in the late 1990's by the NOAA Space Weather Prediction as a way to communicate, in a simplified form, space weather conditions and their possible effects. The scales describe the environmental disturbances for three event types: geomagnetic storms, solar radiation storms, and radio blackouts. The scales are numbered from 1 to 5, in order of increasing severity, analogous to the Saffir-Simpson Hurricane Wind Scale, the Enhanced Fujita (EF) Tornado Damage Scale, and the Richter Earthquake Magnitude Scale. Unlike Category 1 hurricanes or EF-1 tornadoes, however, level 1 space weather events do not necessarily have significant impacts, so the parallels begin to break down on the lower end of the scales. For each level, the space weather scales provide: a general description of possible effects, the climatological frequency per solar cycle, and the corresponding type and magnitude of the physical parameter upon which the scale is based. Although the NOAA Space Weather Scales have been emulated globally, they are neither universally accepted nor operationally comprehensive.

1.2 The NOAA Scales have both strengths and weaknesses. They quickly summarize space weather information for broad user groups. Additionally, the 5-level scales lend themselves to fairly straightforward inclusion into operational procedures and decision-making processes. For aviation purposes, the radio blackout scale effectively describes high frequency (HF) radio impacts on the sunlit side of the Earth from solar flares and the geomagnetic storm scale describes only the general potential for worldwide Global Navigation Satellite System (GNSS) performance degradation. The 3-hour resolution of the geomagnetic storm scale's physical measure, the planetary K-index, fails to capture the temporal variability which can be more reasonably described in the short-term forecast and nowcast timeframes. Additionally, the global nature of the geomagnetic storm scale fails to capture the spatial variability of the impacts to GNSS and none of the space weather scales are able to describe the naturally occurring diurnal variations that can affect GNSS performance at low latitudes. Finally, the radiation storm scale is insufficient for describing the increase in radiation exposure from space weather, and can occasionally provide misleading information in that regard. And although an event on the solar radiation storm scale can be indicative of HF polar cap absorption (PCA), the scale lacks the ability to characterize the temporal and spatial extent as well as the true intensity of such an event.

2. DISCUSSION

2.1 Radio Blackouts: While deterministic forecasts of radio blackouts are currently beyond the state of the art, probabilistic forecasts of future events, and nowcasts of ongoing events, are possible and can be conveyed in terms of the NOAA Radio Blackout scales. A good spatial and temporal description of a solar flare-driven radio blackout is possible given the characteristics of the driving solar flare. While the description of the impact could be refined (e.g. High Frequency Communication Blackout), the general form and function of the radio blackout scale is likely sufficient for solar flare-driven impacts to aviation.

2.2 Geomagnetic Storms: The NOAA Geomagnetic Storm Scale, as mentioned earlier, is tied to the Planetary K index, abbreviated Kp. Kp was introduced in 1938 and is generated from a collection of ground-based magnetometers that are distributed globally, although biased towards the northern and western hemispheres. Kp is a reasonable way to summarize the global level of geomagnetic activity, but lacks the spatial and temporal resolution required by some customers. In particular, the three-hourly synoptic periods (i.e. 00-03 UTC, 03-06 UTC…) upon which the index is based can mask the intensity of a storm that crosses these periods, and additionally, the index resets to zero every three hours, sometimes giving the false impression of a storm subsiding when it is in fact not.

In the forecast phase, predicting the maximum Kp or even the time evolution of Kp is generally at the limits of the state of science in space weather forecasting. Consequently, Kp may serve some role in the forecast phase for services to aviation. Like radio blackouts, a more intuitive translation to expected impacts may be needed. For the short-term warning or nowcast phase, a global index like Kp will not be sufficient. So although Kp certainly has a role to play, it is neither comprehensive nor sufficient to fully describe the geomagnetic storm impacts to aviation.

2.3 Solar Radiation Storms: Increases in radiation exposure at aviation altitudes can occur during significant radiation storms. The NOAA Solar Radiation Storm Scale is driven by a physical measure that is at a relatively low energy (10 MeV), on the order of 50 times below what drives increases in exposure at aviation altitudes. So while the scale does capture the occurrence of a radiation storm, it gives very little spectral information about the event itself, information necessary for characterizing the increase in exposure. The composition of each radiation storm is unique, and increases in radiation exposure are not always well-captured by this limited measure. Radiation risk is generally considered by evaluating the exposure itself, so there have been proposals to develop additional scales to characterize radiation exposure rather than the radiation storm level alone. There are solar radiation storm-driven aviation radiation exposure codes in development, but few have reached full operational maturity. As it stands today, the NOAA Radiation Storm Scale cannot sufficiently characterize increases in radiation of interest to aviation.

Additionally, although an event on the solar radiation storm scale can be indicative of HF polar cap absorption (PCA), the scale lacks the ability to characterize the temporal and spatial characteristics as well as the true intensity of such an event. The true spatial extent of a PCA event is also driven by the state of magnetosphere, something not reflected in the NOAA Radiation Storm Scale alone. Furthermore, better information regarding PCAs can be provided by products and services tailored to this phenomena.

2.4 Impacts Not Well-Served by the NOAA Scales: While the NOAA Scales can capture the bulk of impacts from significant space weather events (e.g. flares, geomagnetic storms), there are other daily processes that affect the environment. These are also considered space weather and continue even in the absence of significant solar eruptions. Of significance to aviation is the normal, diurnal variation of the ionosphere, particularly at low magnetic latitudes (geographic and magnetic latitude are different and space weather impacts are generally described in terms of magnetic latitude as it best defines their spatial extent and variability). These ionospheric disturbances can degrade the performance of GNSS and communication systems at low latitudes and are a significant concern in many equatorial regions. The current space weather scales do not capture these impacts but they can be captured by Total Electron Content (TEC) maps and scintillation indices. Additionally, there are high latitude ionospheric impacts to both communications and navigation systems that are not well-characterized by the NOAA Scales.

2.5 Overall, while the NOAA Space Weather Scales have an important role to play, there are inherent deficiencies that keep them from fully satisfying the space weather needs of the aviation community. Additionally, while the underlying descriptions and levels of space weather phenomena may be retained, it may be more useful to translate them into impact-based products and services (e.g. GNSS Degradation Expected rather than Geomagnetic Storm Expected). Given the limitations described above, and because the NOAA Space Weather Scales cannot fully describe the aviation impacts from space weather, careful consideration should be given to the emphasis they receive in this service development. Aviation meteorologists are beginning to focus on impact-based products and services, seen as more meaningful and easily interpreted by the user community. Space weather services for aviation should consider the same, where the science allows, to ensure the space weather products and services satisfy the user needs to the greatest extent possible.

3. ACTION BY THE METP-WG/MISD SPACE WEATHER WORK STREAM

3.1 The METP-WG/MISD Space Weather Work Stream is invited to:

a) note the information contained in this paper, and

b) consider the appropriateness of including NOAA’s Space Weather Scales in future versions on the ConOps for Space Weather Information Services.

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