Relation to solar wind and index prediction for the new Kp-like Hpo indices (Hp30, Hp60)

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The new Kp-like Hpo indices

The Hpo indices are described in Yamazaki et al. (2022). They are very similar to Kp, but have a higher time resolution and they are open-ended. Hpo comes in a half-hourly (Hp30) and hourly (Hp60) version as well as in a linear version (ap30, ap60). While Kp (e.g. Matzka et al., 2021) is limited to 9, Hpo can reach larger values for very strong space weather events. Nowcast values are provided in near real-time and as archive (back to 1995) through the new portal for Kp,while forecasts are provided by the GFZ space weather portal.

Relationship of solar wind parameters to the Hpo indices

The Kp index is a well-known proxy for the energy input from the solar wind into the magnetosphere-ionosphere-thermosphere system. In **Fig. 1** we show the relationship between Hp30 (top panels), Hp60 (middle panels) and Kp (lower panels) and the Newell coupling function, the geomagnetic auroral electrojet index AE, and the polar cap index PC. Each of these independent open-ended proxies for the solar wind energy input have very similar relationships to Hp30, Hp60 and Kp. **Fig.1** also shows that our Hp30, Hp60 extension to values above 9 fits nicely to the third-order polynomial fitted to values <9.
Hp60 has higher correlation than Kp to other geospace parameters like AE index, PC index, the Newell coupling function and the total field aligned current measured by the Ampere satellites (**Table 1**). Thus, Hp60 is a Kp-like index with increased time resolution and has a very good correlation to the solar wind and geospace parameters it is meant to represent.

Table 1. Correlation coefficient R between Kp, Hp60 and other geospace parameters (1995 to 2017)

Corr. Coeff. R	Kp	Hp60
AE index	0.75	0.79
PC index	0.76	0.78
Newell coupling function	0.70	0.72* (0.69**)
Ampere total current	0.78	0.80

* With 20 minute time shift
** Without time shift

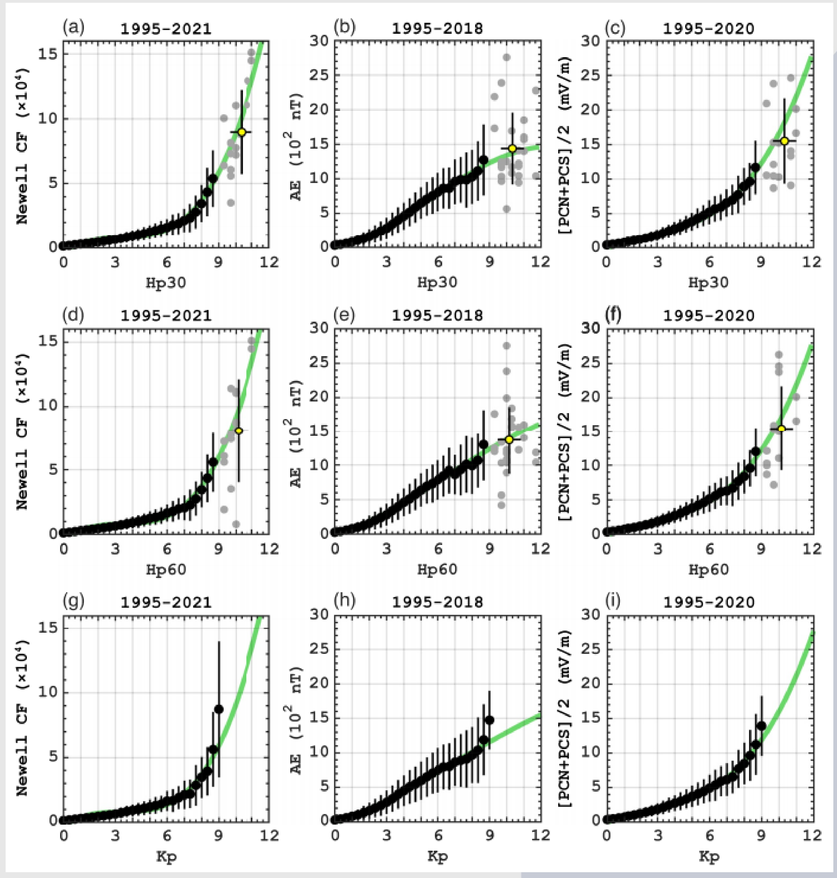
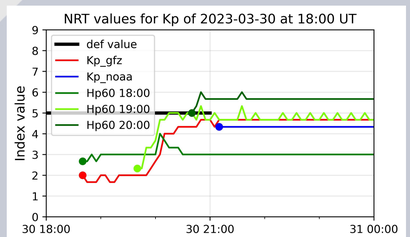


***Fig. 1**. Dependence of (a–c) Hp30, (d–f) Hp60, and (g–i) Kp on (a, d, g) Newell's solar-wind coupling function [5] (b, e, h) AE index, and (c, f, i) PC index. Black dots indicate their average value at each Hpo or Kp value (0o, 0+, 1−, …, 9−), the green curve gives their third-order polynomial fit. Individual data points for Hpo ≥9o in (a-f) are shown in gray and their average in yellow. Error bars give the standard deviation.*



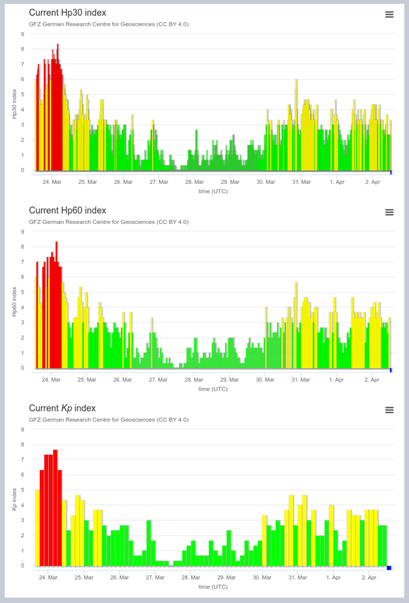


***Fig. 2.** Top panel: Example of near real time behavior of Kp (GFZ and NOAA) as well as Hp60 (see text). Bottom panel: 10 days of Hp30, Hp60 and Kp including recent geomagnetic storm on March 24, 2023.*

Nowcasting and forecasting Hpo 60

Nowcast values for Hp30, Hp60 and Kp (**Fig. 2**) are provided through GFZ's Kp portal (**Fig. 3**).

In **Fig. 2 upper panel**, an example for the near real-time development of the nowcast indices is given 2023-03-30 at 18-21 UT, when the definitive Kp was 5 (black). Forty minutes into the three-hour interval, the first GFZ Kp (red) and Hp60 (dark green) estimate are published with values of 2 and 3-, respectively. Their values increase according to increasing geomagnetic activity, but note that there is some delay due to data latency. Geomagnetic activity increases shortly before 20 UT and the GFZ NRT Kp ends up with a value of 5- around 21 UT. Shortly after 20 UT, NOAA publishes its nowcast Kp, which stays constant at 4+. The three Hpo values for 18-19, 19-20 and 20-21 UT (green) end up at 3, 5 and 6-, respectively.

GFZ's space weather portal (**Fig. 4**) provides **forecasts** for Hp60 and Kp. The predictions have a lead time of 72 hours and are updated hourly. The machine-learning algorithm is based on L1 solar wind and interplanetary magnetic field measurements as well as on historic index values. An additional prediction of L1 conditions from solar observations and solar wind ensemble predictions (see www.spacepager.eu) is in preparation. This will significantly improve the forecast quality for lead times exceeding a few hours and and it will also provide uncertainties in the form of confidence levels.

***Fig. 3.** The new data portal for Kp and the Hpo indices Hp30 and Hp60 nowcast and archive. The QR code links to the portal.*

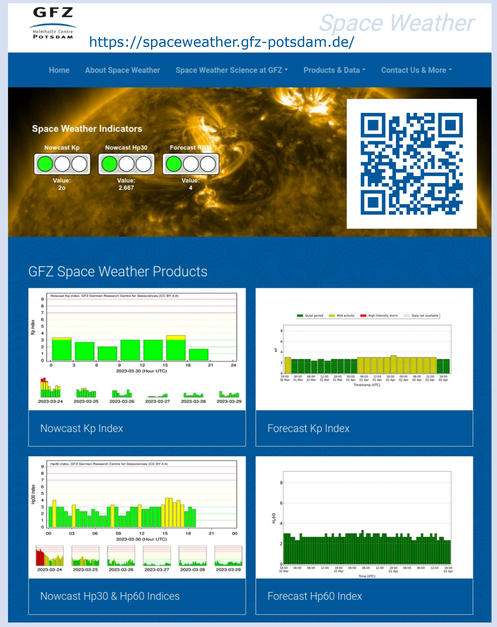


***Fig. 4.** The GFZ space weather portal with forecasts for Kp and Hp60. The QR-code links to the portal. The portal provides, among other things, radiation belt models (not shown).*

References (QR code to publication)

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