Extending Back in Time the Kp-Like, Open-Ended, High-Cadence Geomagnetic Hp60 and Hp30 Indices to Cover the Period Starting from 1985

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Three-Hourly Kp Index

The geomagnetic three-hourly Kp index is a measure of planetary geomagnetic activity **ranging from 0 to 9** and given with a resolution of thirds (e.g., 5–, 5o, 5+). The Kp index **goes back to 1932** (*Matzka et al., 2021, SW*) and is extensively used in the space physics community, both for scientific and operational purposes and has proven to be a **significant and reliable index**. But, still, **Kp has two important limitations**

- the **temporal resolution** – temporal features within a three-hour interval (180 minutes) are not resolved
- the **upper limit** – geomagnetic activity is not accurately represented under extremely disturbed conditions reaching the maximum value of 9o

A Kp-like geomagnetic index without these limitations would be extremely useful

New Hpo Index Family

- should resemble as much as possible the **original methodology** for the **derivation of** the **Kp** index
- use 1-min magnetic data from **the same 13 subauroral observatories**
- ensure that the **frequency distribution of H and K remains as consistent as possible** for each observatory by utilizing geomagnetic data from **1995 to 2017** (all available data when the construction of Hpo indices was initiated)

The new geomagnetic activity **high-cadence, open-ended Hpo indices**, developed under the EU H2020 project SWAMI, **consist of four indices**

- the Kp-like **hourly Hp60** and **half-hourly Hp30**
- their linear equivalents, the ap-like **ap60** and **ap30**

"**H**" stands for half-hourly or hourly, "**p**" for planetary, and "**o**" for open-ended

Hpo is an open-ended index

The open-ended Hpo > 9- indices are calculated according to the new, extended scale (*Yamazaki et al., 2022, GRL*) that provides a more nuanced description of the events with the highest levels of geomagnetic disturbance, e.g., 9o, **9+, 10-, …, 12-, 12o, 12+, …, open-ended**. It was designed for close agreement with Kp up to level 9o.

The **Hpo** indices **goes back to 1995** (1-minute digital data availability from all observatories), https://kp.gfz-potsdam.de/en/hp30-hp60/data

- **Hpo version 2** (*Matzka et al., 2022*, https://doi.org/10.5880/Hpo.0002)

Hpo Indices from 1985 to Present

Hpo Indices from 1985 to 1994

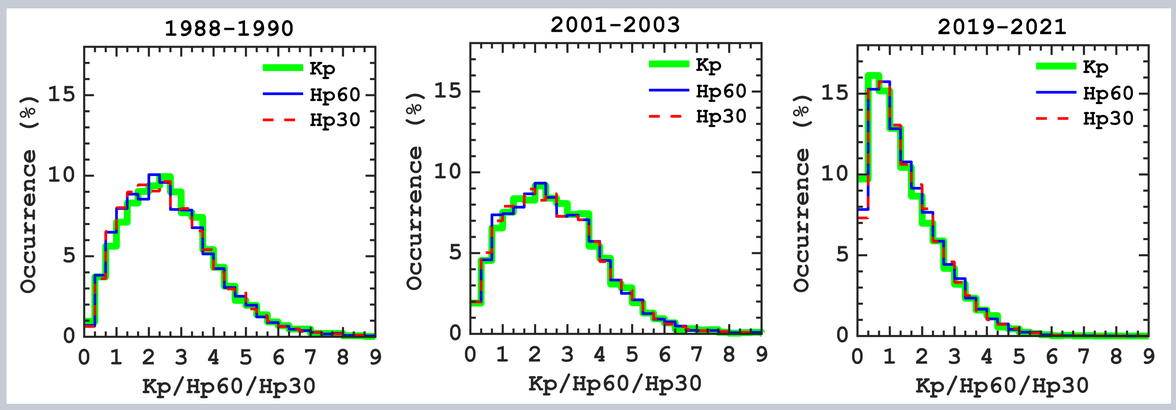
Due to the **unavailability of 1-minute digital data** from all 13 Kp observatories, **only data from 11** subauroral observatories were utilized

Hpo Indices from 1995 to present

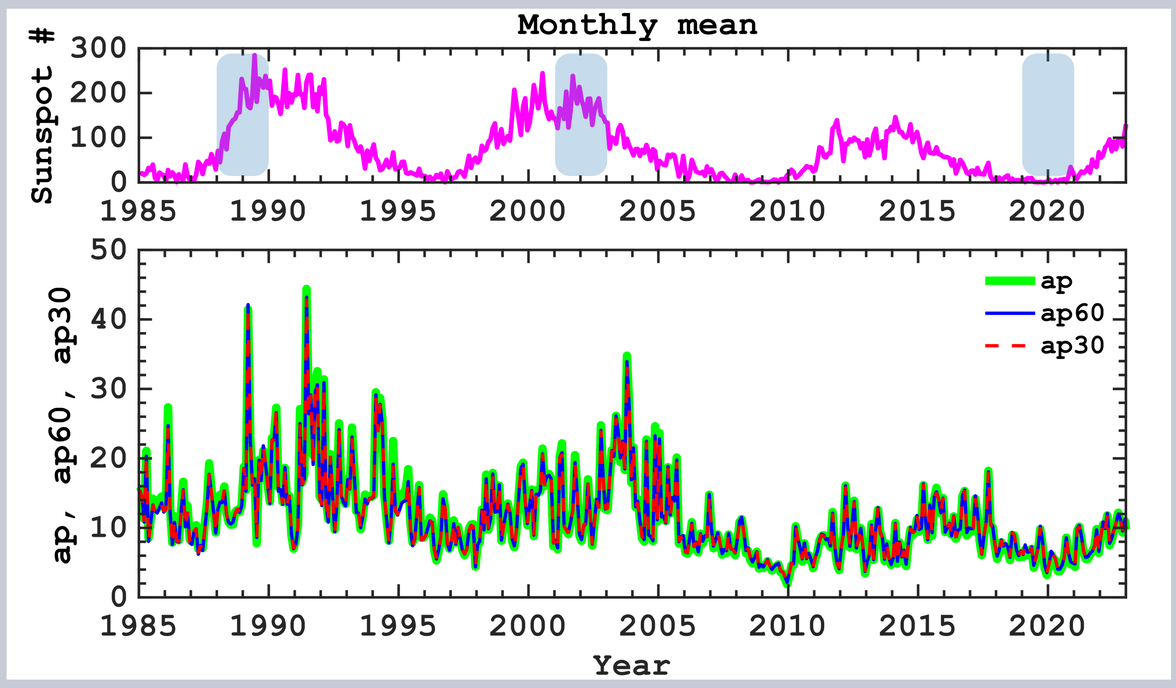
The 1-minute digital data are **available from all Kp** observatories

Frequency distributions

The figures presented below depict a detailed comparison of the **frequency distributions of the occurrence of Hp30, Hp60, and Kp** values over different time intervals around solar maximum and minimum between 1985 and 2023. **Hp30 and Hp60 accurately reflect** the varying distribution **patterns of Kp** during both **solar maximum and solar minimum** years.



Monthly mean values of **ap30 and ap60 from 1985 to 2023** are in **good agreement** with monthly mean **ap**, showing 11-year solar-cycle variation.



Severe Geomagnetic Storms since 1985

List of the **most severe geomagnetic storms since 1985**. The storms are selected based on their **maximum Hp60 or Hp30** values **reaching or exceeding 9o**. The events are divided by a red line, signifying before or after 1995. The minimum value of the Dst index is also shown.

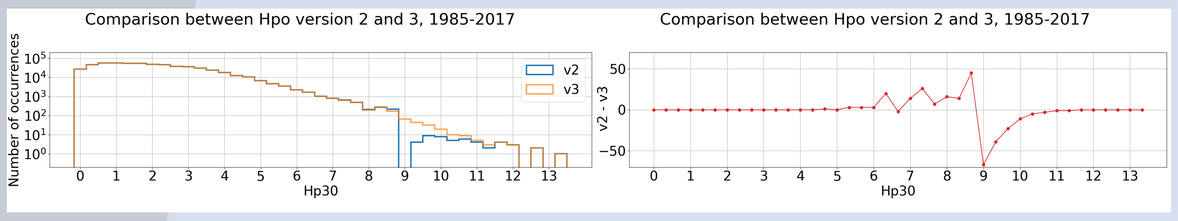
Year	Month	Day	Dst	Hp30	Hp60	Kp
1986	2	9	–307	11+	11–	9o
1989	3	14	–589	13+	13–	9o
1991	3	25	–298	10–	9–	9–
1991	6	5	–223	10+	10–	9–
1991	10	29	–254	10–	10–	8+
1991	11	9	–354	11+	9–	9–
1992	5	10	–288	10+	9–	9–
1998	5	4	–205	10–	9–	9–
2000	7	16	–301	11–	9+	9o
2001	3	31	–387	10o	10–	9–
2001	11	6	–292	11–	10o	9–
2001	11	24	–221	10–	10o	8+
2003	10	30	–383	12–	12–	9o
2004	7	27	–170	10–	9+	9–
2004	11	8	–374	11–	9–	9–
2005	5	15	–247	10–	10–	8+
2005	8	24	–184	9+	9–	9–

The Hpo indices (v2) indicate that the event on

- **March 14, 1989,** was the strongest between 1985 and 1994, as **Hp60** reached **13-** and **Hp30** reached **13+**
- **October 29-30, 2003**, was the strongest since 1995, as **Hp60** and **Hp30** both reached **12-**

Planned Updates: Hpo version 3

The **Hp60 and Hp30** indices were designed to be **as similar as possible** to the **Kp index up to 9o**. This was done by using two-step processing: re-calculate Hpo – if the initial Hpo value is 9o, all the H indices are re-evaluated using the extended conversion tables (H can go beyond 9). However, it turned out that this led to an **artificial gap in the statistical distribution** of Hpo (v2) indices around 9o.



A new version of Hpo indices (v3) is currently under development, which avoids the two-step processing. This version shows slight deviations from 6 but the **overall statistical distribution looks more natural**, even beyond 9. The new version (v3) of **Hpo data starting from 1985** will be made **available** in the **near future**.