The first investigation of the Hp index

A Kp-like, high-cadence index available with 90, 60 and 30 minutes time resolution

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Introduction

Geomagnetic activity indices Kp and K

GFZ is in charge of deriving and disseminating the geomagnetic **Kp** index that dates back to 1932 and is endorsed by the International Association of Geomagnetism and Aeronomy (IAGA).

- "*Kp indicates the intensity of geomagnetic activity as an expression of solar corpuscular radiation, for every three-hour interval of the Greenwich day*" – Bartels (1957);
- A three-hourly geomagnetic disturbance (**range**) index with values from 0 (quiet), …, 3+ (moderate active), … to 9 (very active/disturbed);
- The **local K** (single station) **index**: the maximum disturbance range in the horizontal field components observed at 13 subauroral stations (see Figs. 1.2 & 1.2).
- The **standardized Ks** (single station) **index**: normalized for seasonal and local time effects;
- The **Kp index** is the (weighted) average of a number of Kp-stations' Ks values.

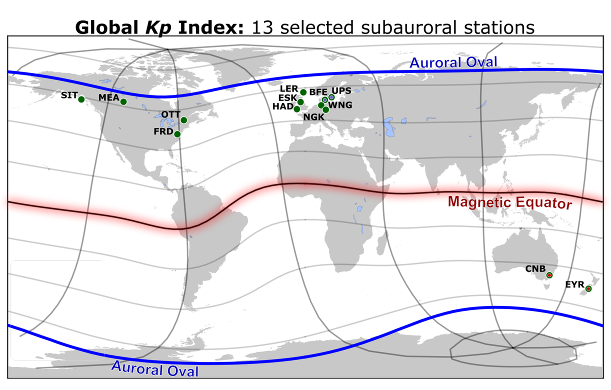

Fig. 1.1: Locations of 13 sub-auroral Kp-observatories.

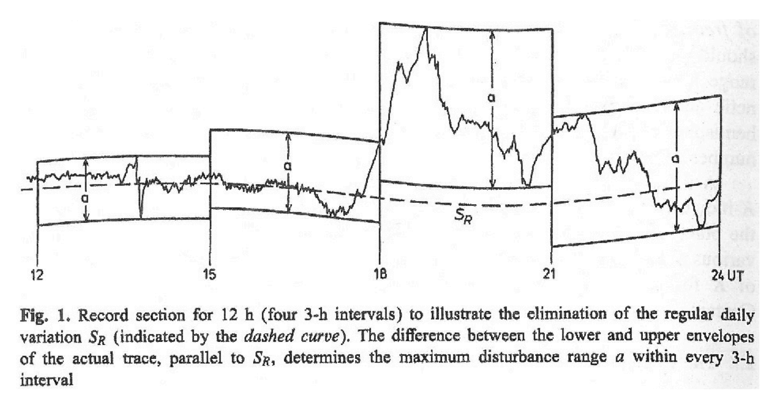

Fig. 1.2: From Siebert (1996).

New Hp indices

The improved geomagnetic indices are derived by algorithms developed for the 3-hourly Kp and ap indices but will be of higher temporal resolution: **Hp90** (90 min), **Hp60** (60 min) and **Hp30** (30 min). The **ap90**, **ap60** and **ap30** indices are derived the same way from Hp as ap from Kp.

- **Rescale** the range of magnetic variation that corresponds to a local K index (so-called K-table, Bartels, 1957). The **new local high cadence indices** are called **H indices** (H-table). By rescaling, we aim for **equal occurrence distribution of K and H indices** (see Fig. 1.3 for the example of Niemegk observatory);

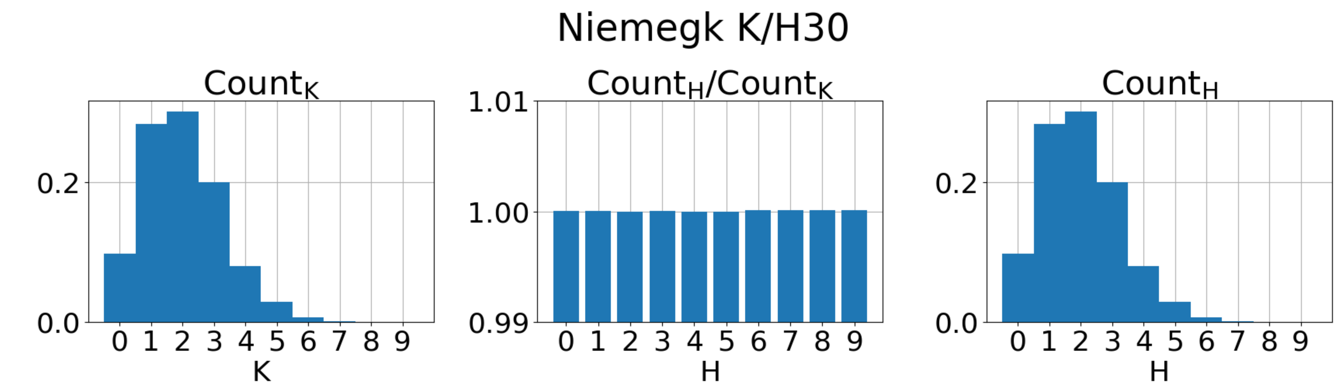

Fig. 1.3: Normalized frequency distribution of K and H30 indices for the Niemegk observatory.

- **The rescaled H** values were defined based on the statistical distribution of K values during the last 22 years **from 1995 to 2017**. This was done for each contributing observatory and Hp index separately.

Results 1

Hp vs Kp during geomagnetic storms

We first examine whether the occurrence distributions of Kp and Hp are in agreement during geomagnetic storms. Five strongest storm events are selected during 1995-2017 (see Fig.2.1).

- Overall agreement between Kp and Hp are very good, $R^2 > 95\%$ (Fig. 2.2)
- The occurrence distributions of Hp indices resemble that of Kp (Fig. 2.3).

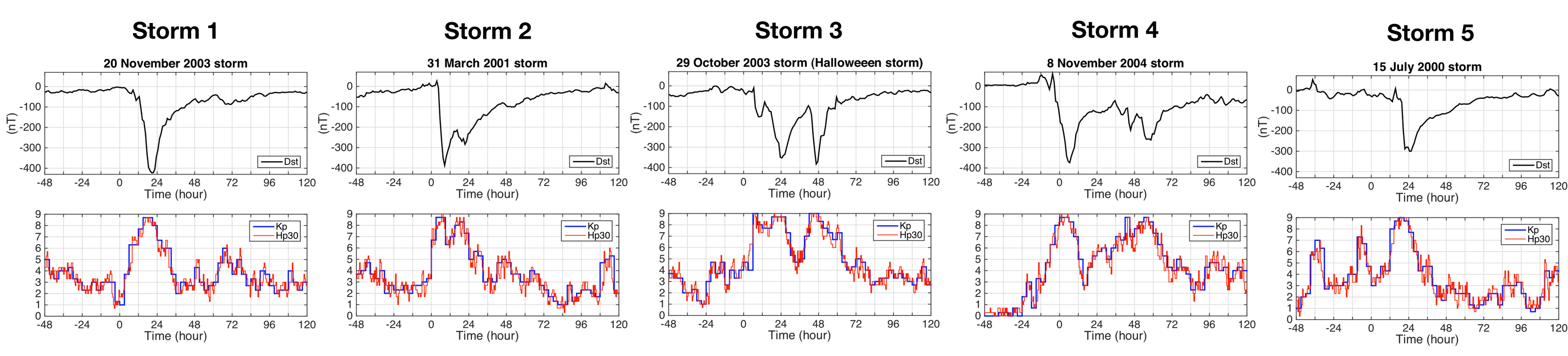

Fig. 2.1: Selected five storm events. (Top) Dst index and (Bottom) Corresponding Kp and Hp30.

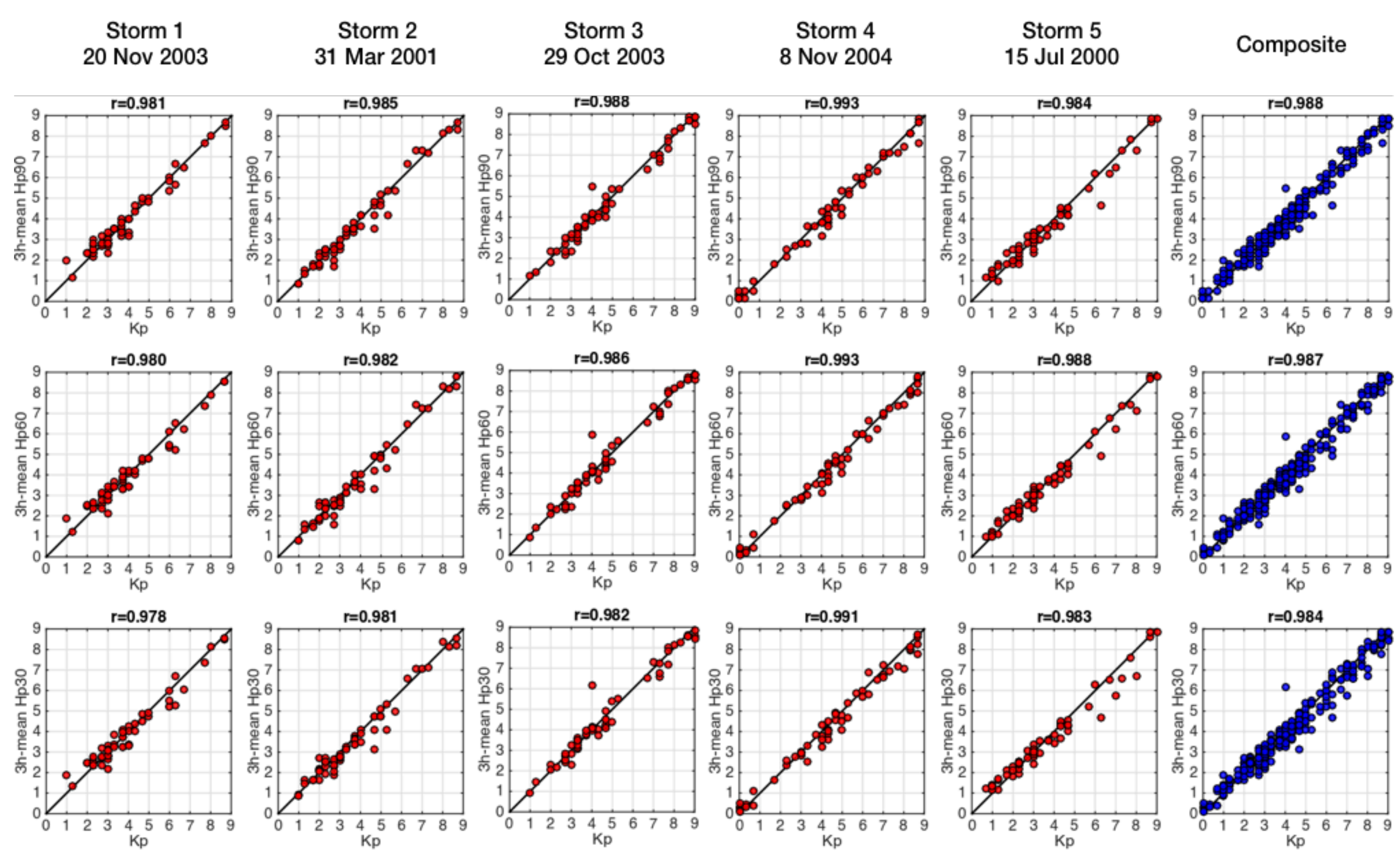

Fig. 2.2: Comparisons between Kp and Hp indices during the selected storm events.

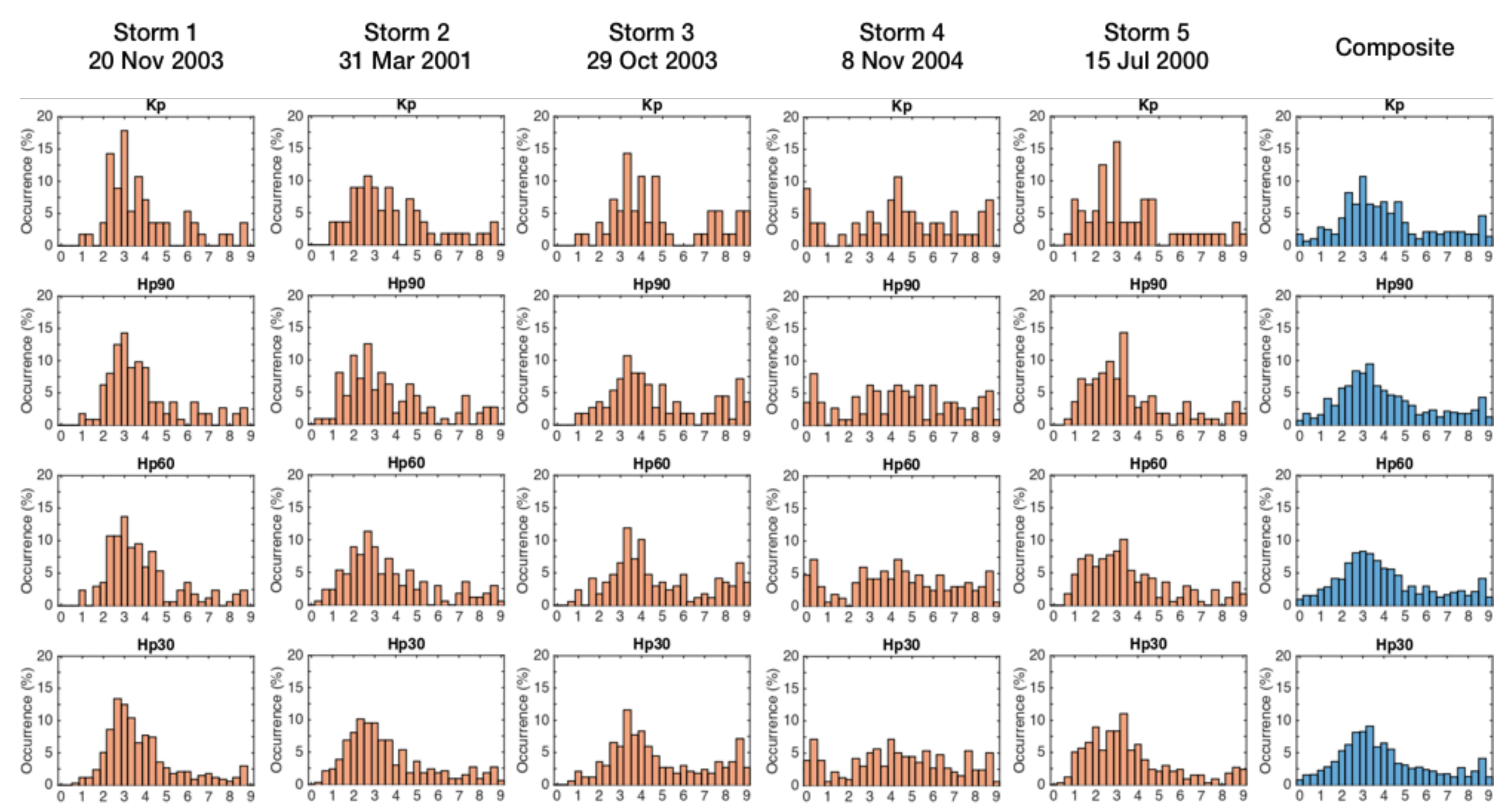

Fig. 2.3: Occurrence distributions of Kp and Hp during the selected storm events.

Results 2

Hp vs other parameters (1995-2017)

- Hp and Kp indices are interpolated to 1-min values. The indices are assumed to be constant within the time interval of the range calculation (e.g., 90 min for Hp90).
- For comparisons with other parameters, the linear version of the Kp index, ap (https://www.gfz-potsdam.de/en/kp-index/), is used (i.e., ap90, ap60, ap30, as well as traditional ap).

Correlation with other geomagnetic indices

- Hp (ap) indices correlate best with PCC, which is the average of the PC indices derived from the NH and SH. The correlation improves with increasing time resolution of the Hp index.

Correlation with solar wind parameters

- The correlations with the OMNI solar wind speed and interplanetary magnetic field (IMF) Bz component are poor (R < 0.5).
- The correlation with merging electric field is good with little seasonal dependency, especially when a 20-min time lag is considered for the signal propagation from the magnetosphere to the ionosphere.

vs. AE index

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	0.67	0.65	0.65	0.65
ap90	0.69	0.68	0.66	0.67
ap60	0.71	0.69	0.67	0.69
ap30	0.73	0.70	0.68	0.70

vs. SMR index — SMR: SuperMAG ring current index

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	-0.3805	-0.6538	-0.5550	-0.5023
ap90	-0.3707	-0.6384	-0.5428	-0.4898
ap60	-0.3690	-0.6324	-0.5362	-0.4854
ap30	-0.3677	-0.6282	-0.5311	-0.4821

vs. PCC index (PCN/PCS)

PCN: PC index from the Northern-Hemisphere station, Thule
PCS: PC index from the Southern-Hemisphere station, Vostok
PCC: [(PCN if>0 or else zero) + (PCS if>0 or else zero)]/2

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	0.71 (0.69/0.57)	0.71 (0.66/0.67)	0.69 (0.55/0.64)	0.70 (0.63/0.63)
ap90	0.73 (0.72/0.59)	0.73 (0.69/0.70)	0.70 (0.56/0.66)	0.72 (0.65/0.65)
ap60	0.74 (0.73/0.60)	0.74 (0.70/0.71)	0.70 (0.57/0.67)	0.73 (0.66/0.66)
ap30	0.75 (0.75/0.61)	0.75 (0.71/0.72)	0.71 (0.57/0.68)	0.74 (0.67/0.66)

vs. Solar Wind Speed

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	0.46	0.43	0.39	0.42
ap90	0.46	0.43	0.39	0.42
ap60	0.46	0.42	0.39	0.42
ap30	0.46	0.42	0.38	0.42

vs. IMF Bz — IMF: interplanetary magnetic field

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	-0.30	-0.34	-0.30	-0.31
ap90	-0.31	-0.35	-0.31	-0.33
ap60	-0.31	-0.35	-0.32	-0.33
ap30	-0.30	-0.34	-0.32	-0.32

vs. Merging Electric Field E_{KL} with 20-min Time Lag (w/o Time Lag)

$E_{KL}=V_{sw} B_T \sin^2(\theta/2)$
[*Kan and Lee*, 1979]

Corr. Coef.	Nov-Feb	Mar-Apr Sep-Oct	May-Aug	All
ap	0.69 (0.68)	0.69 (0.68)	0.69 (0.68)	0.69 (0.68)
ap90	0.70 (0.68)	0.70 (0.68)	0.70 (0.69)	0.70 (0.68)
ap60	0.70 (0.67)	0.70 (0.68)	0.70 (0.68)	0.70 (0.67)
ap30	0.70 (0.66)	0.70 (0.67)	0.70 (0.68)	0.70 (0.66)

Table 3.1: Correlation between

Future Work

Hp as potential inputs for TIE-GCM

- Hemispheric Power used in the TIE-GCM (Qian et al., 2014) is empirically derived from the Kp index. We applied the same formula for the Hp indices to calculate the Hemispheric Power with higher temporal resolution (Fig. 4.1).
- The total energy input estimated with the Kp index during 7-8 September 2017 is 1.59×10^7 GJ. When Hp indices are used, the total energy estimates are lower by 3.8-4.6% but temporal variability is improved.

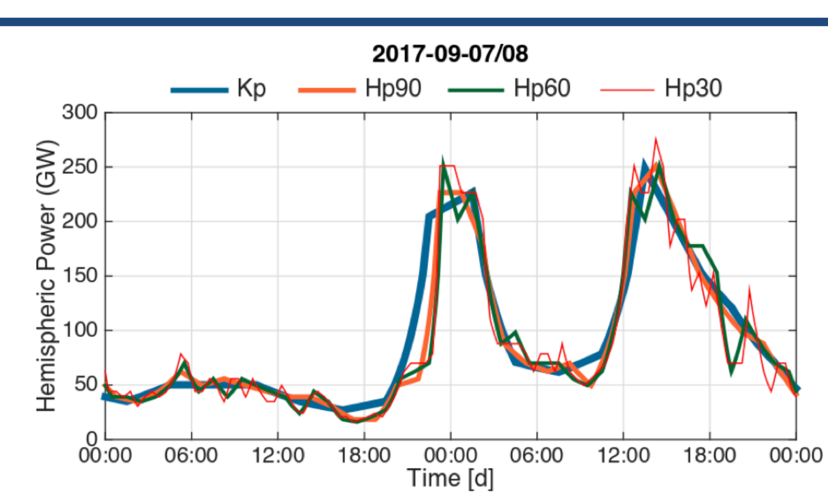

Fig. 4.1: Example of hemispheric power derived from Kp and Hp

Conclusions

- Storm-time behaviour of Hp indices is consistent with Kp.
- Hp indices (ap) correlate well with PCC and merging electric field.
- Hp potentially improves high-latitude forcing of TIE-GCM.

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