Predicting Global Auroral Power: A Merging Term Plus a Viscous Term Works Best

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Popular Coupling Functions
(In ascending order of merit)

B_z	
$\varepsilon = vB^2\sin^4(\theta_c/2)$	(Akasofu-Perrault)
Bs	
vBs	(half-wave rectifier)
$E_{KL} = vB_T\sin^2(\theta_c/2)$	(Kan-Lee electric field)
$E_{WAV} = vB_T\sin^4(\theta_c/2)$	(Wygant's "intermediate")

where $\theta_c = \arctan(B_y/B_z)$

Approach

Ten characterizations of the magnetosphere were examined over multiyear periods at relatively high cadence (hourly)

Scores of coupling functions were tested, searching for a pattern (performance of 32 functions documented)

ab inito: No use of the time history of the target index

Data

5 Traditional (ground-based magnetometer) indices: AE, AU, AL, Kp, and Dst

5 Space-age indices: Auroral power (Polar UVI), cusp latitude ($\sin(\Lambda_c)$) and b2i (ion equatorward boundary of multi-keV ion precipitation), both from DMSP, magnetotail inclination angle ($\arctan(v/h)$) from GOES-8, and polar cap flux (Φ_{PC}) from SuperDARN as calibrated to DMSP

Main Result

A single coupling function correlates best with 9/10 indices (11 data runs, counting multiple solar cycles)

$$d\Phi_{MP}/dt = v^{4/3} B_T^{2/3} \sin^{8/3}(\theta_c/2)$$

The exception is Dst. Dst correlates best (*r*=0.87) with

$$p^{1/2} d\Phi_{MP}/dt$$

Meaning of $d\Phi_{MP}/dt$

Dayside merging voltage is the product of three factors:

- **solar wind electric field, vB_T**
- **length of merging line, $\sim(B_{MP}/B_T)^{1/3}$**
- **% of lines which merge, $\sin^{8/3}(\theta_c/2)$**
- **Note that B_{MP} ($\sim v$)**

$$d\Phi_{MP}/dt = v^{4/3}B_T^{2/3}\sin^{8/3}(\theta_c/2)$$

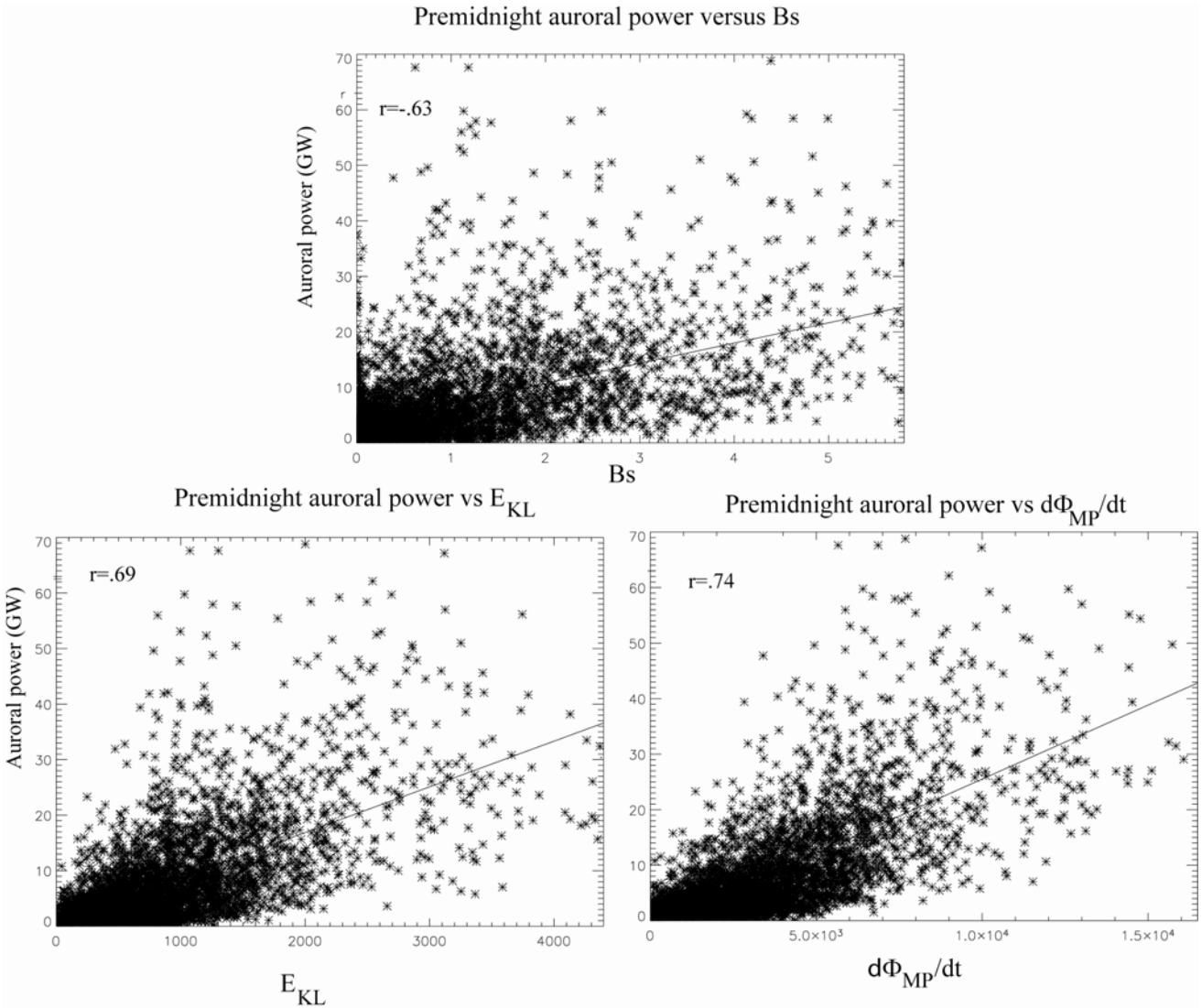
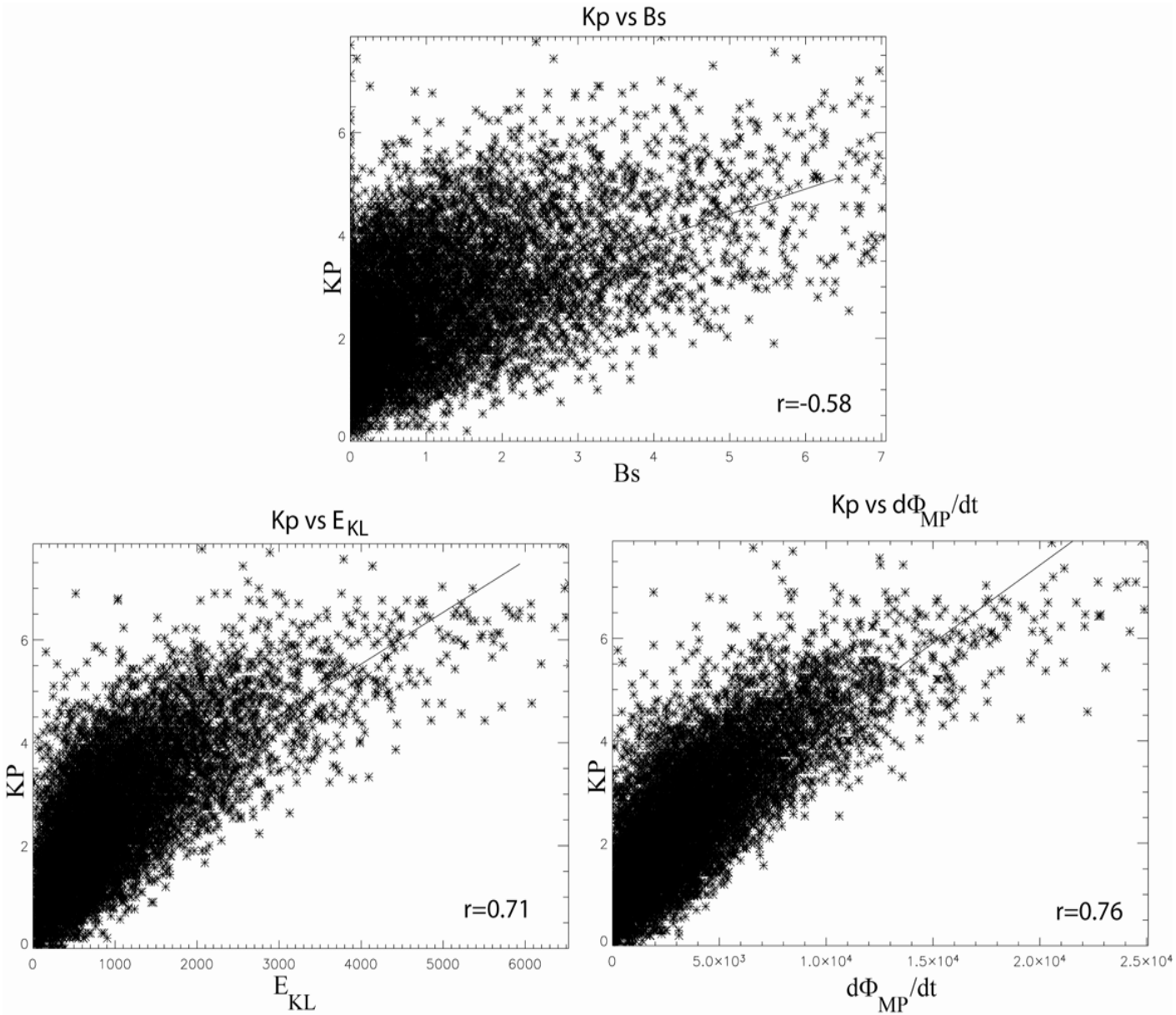


Figure 1. The ability to predict auroral power from solar wind conditions varies greatly according to the coupling function used. Bs (top) accounts for only 40% of the variance, while the best function, bottom left, accounts for 55%.


Kp vs Bs
KP
Bs
r=-0.58
Kp vs E_{KL}
KP
E_{KL}
r=0.71
Kp vs $d\Phi_{MP}/dt$
KP
$d\Phi_{MP}/dt$
r=0.76

We now know the optimized merging estimator. Here we pursue two follow up questions

- What is the form for the best viscous term?
- If two terms are used, is it best to used two highly performing coupling functions (both of which would be merging related) or one merging term and one viscous term?

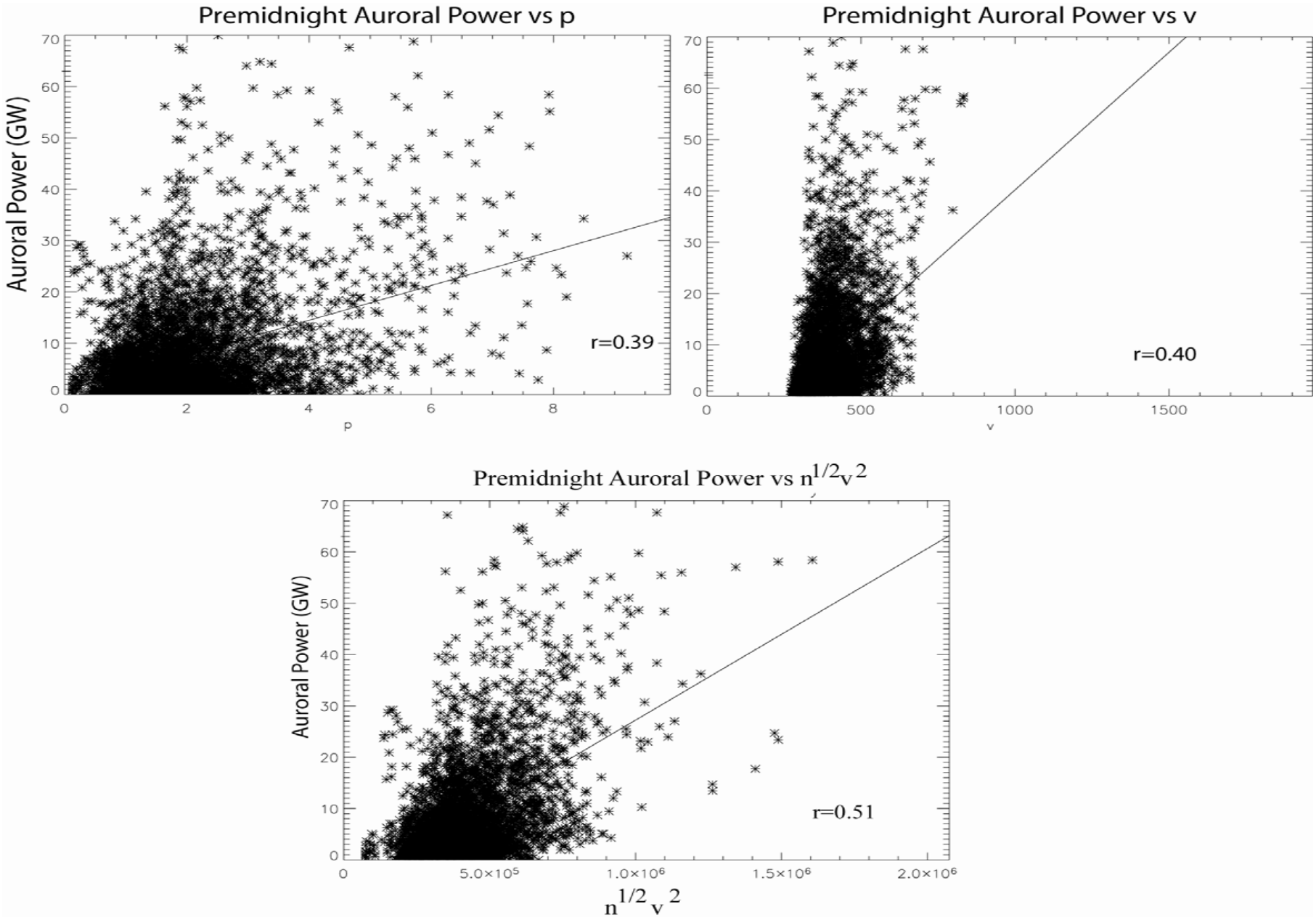


Figure 2. Premidnight auroral power from Polar UVI as predicted by the three different possible viscous terms.

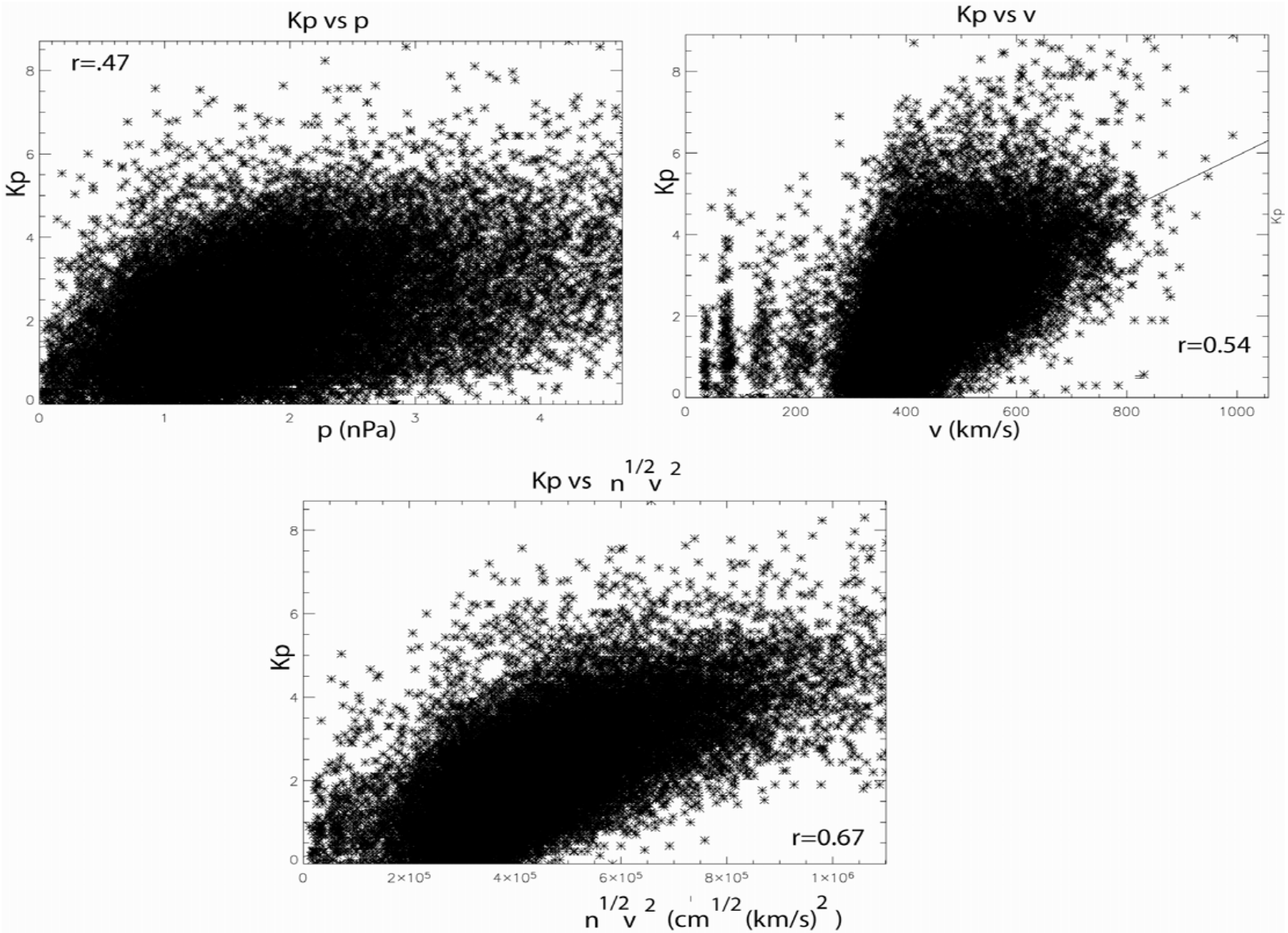


Figure 1. Three possible viscous terms (p, v, and $n^{1/2}v^2$), and their ability to predict Kp. The order shown is typical of the ability of these solar wind parameters to predict indices describing the magnetosphere.

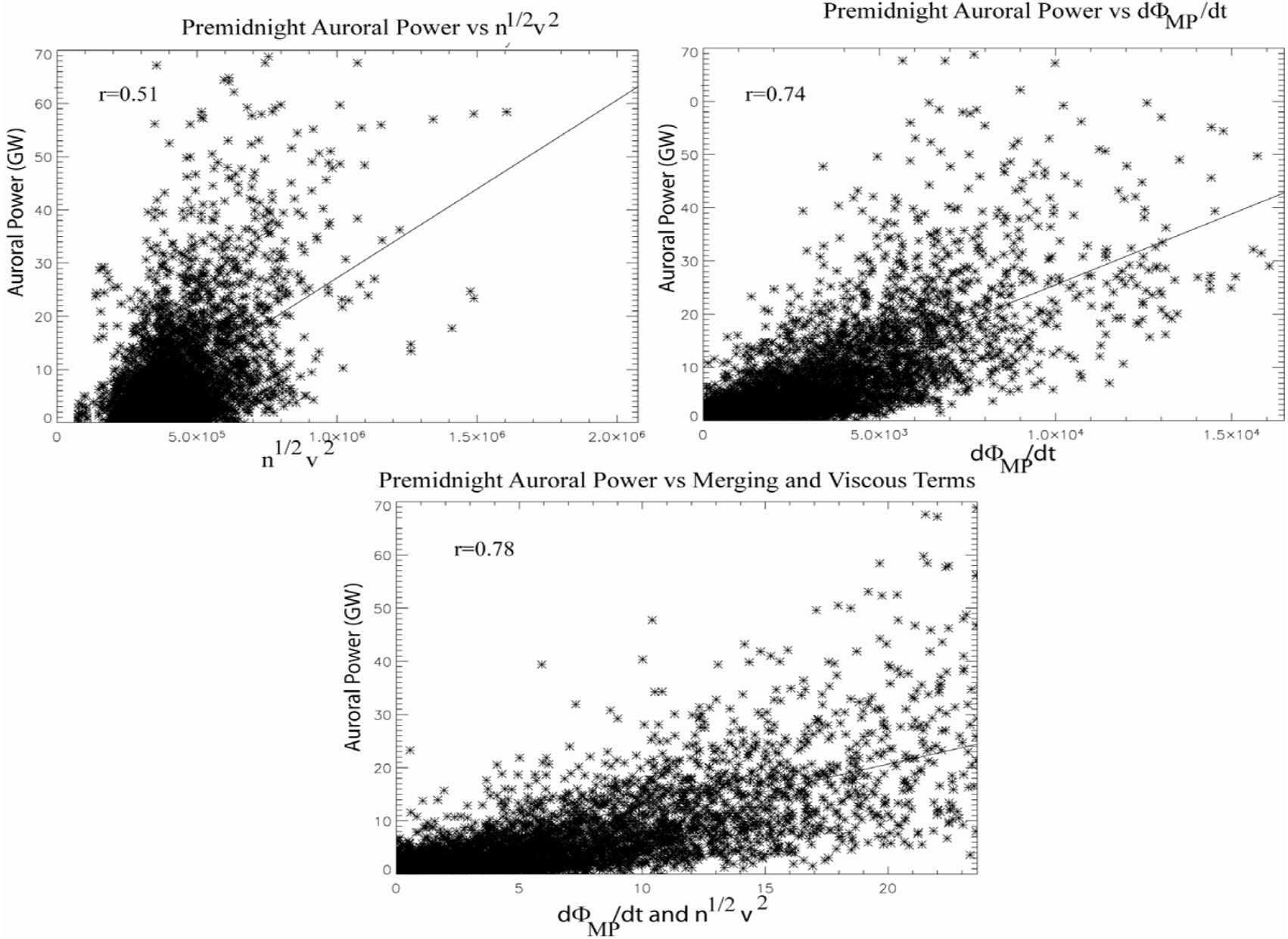


Figure 4. Premidnight auroral power from Polar UVI as predicted by the best viscous term (top left), the best merging term (top right), and the two combined (bottom).

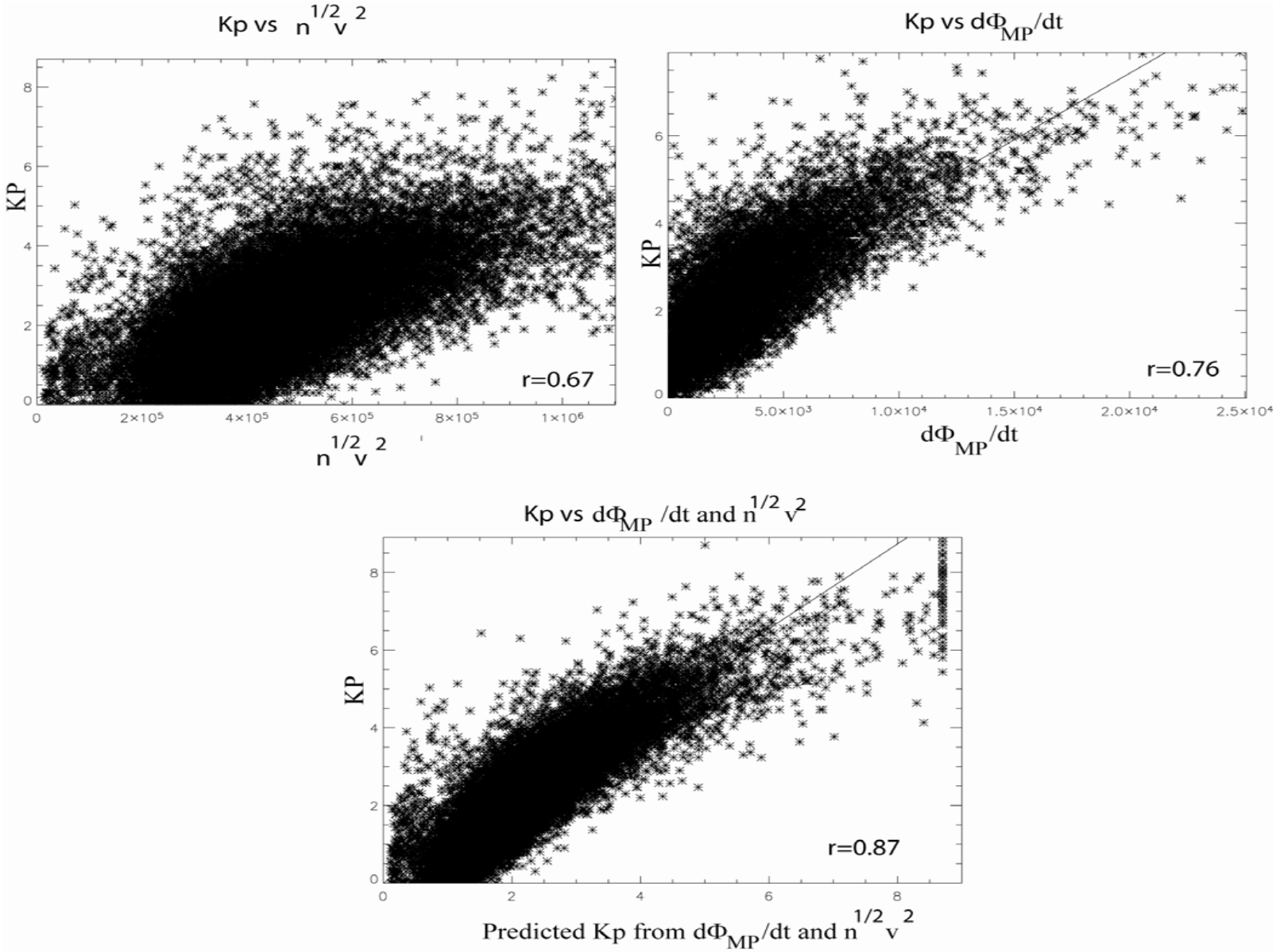


Figure 3. Kp is highly predictable from solar wind data (even without a time history) if both a merging term and a pressure term are used (bottom). Top left, a pressure term only. Top right, a merging term only. Since Kp is never more than 9 by definition, the predicted Kp (bottom) never exceeds that value.

Summary

- The best performing viscous term is $n^{1/2}v^2$
- Out of the 496 unique pairs from 32 coupling functions, the optimal pair is $d\Phi_{MP}/dt$ with $n^{1/2}v^2$
- Any reasonable merging term coupled with any reasonable viscous term does well
- $d\Phi_{MP}/dt$ and $n^{1/2}v^2$ together form a “tool kit” for model construction