Extended Forecasting Kp Requirements

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1 Introduction

1.1 Overview

The primary purpose of the Kp Forecast system is to provide AFWA the capability to predict Kp. Kp is a 3-hour index that is commonly used to characterize the global planetary geomagnetic disturbances caused by the solar wind over a 3-hour period. (The K indices are generally used to indicate the solar wind effects on the earth's magnetic field; the subscript "p" means “planetary” and designates a global magnetic activity index.) The official Kp index is derived using data acquired at the selected 13 ground-based magnetic observatories which lie between 46 and 63 degrees north and south geomagnetic latitude: Lerwick (UK), Eskdalemuir (UK), Hartland (UK), Ottawa (Canada), Fredericksburg (USA), Meannook (Canada), Sitka (USA), Eyrewell (New Zealand), Canberra (Australia), Lovo (Sweden), Rude Skov (Denmark), Wingst (Germany), and Witteveen (The Netherlands). Based mainly on the horizontal components of the magnetic field measured by these stations, the Kp index discriminates conservatively between the true magnetic field perturbations and the quiet-day variations.

The value of Kp ranges in 28 steps from 0 to 9, indicating very quiet to very disturbed level respectively, with fractional parts expressed in thirds of a unit. The scale is quasi-logarithmic and the integer values are subdivided into thirds commonly expressed with symbols + and -, e.g. 0, -1, 1, 1+, 2-, 2, ...9. For many applications, it is often easier to express the fractional values explicitly without using the + and - symbols. For example, Kp values of 3+ = 3.3 = 3 and 1/3, and 5- = 4.7 = 4 and 2/3, etc.

Many models for the near-Earth space environment need Kp to predict various parameters such as atmospheric density, ionospheric conductivities, auroral particle precipitation boundaries, ionospheric and magnetospheric electric field etc. Unfortunately, Kp indices are published with significant time delay. The purpose of the Forecasting Kp project is to provide a predicted Kp using inputs from the ACE satellite.

The Extended Forecasting Kp model is based on a neural network that ingests forecasted solar wind data from the HAF code (Fry, et al.) and outputs a kp forecast for 1 to 4 days in advance at a 6 hour cadence.

1.2 Summary of Architecture

The system architecture is based on software that is currently used for similar purposes at JHU/APL. Figure 1.1 shows a diagram of the architecture and data flow.
Once the Kp Forecasting system is started, it runs in the background. A perl script downloads HAF data from the UAF Space Weather site, compiles this data into 15-minute averages, and then feeds the data into a neural network. The results from this algorithm are then displayed on a web page along with the graphs of the IMF values and solar wind data.

1.3 Statement of Purpose

The purpose of this document is to provide a description of the Kp Forecasting system components and their requirements.
2 Executive Script

2.1 Functional Requirements

2.1.1 The Executive Script shall manage the data processing and plotting for the Kp Forecasting system.

2.2 Interface Requirements

2.2.1 The Executive Script shall produce status and error messages.
2.2.2 The Executive Script shall be editable using at least one UNIX-compatible editor.

2.3 Operational Requirements

2.3.1 The Executive Script shall run under the Solaris operating system on a Sun computer.
2.3.2 The Executive Script shall begin execution upon direction.
2.3.3 The Executive Script shall run once daily until termination.
2.3.4 The Executive Script shall terminate upon direction.
3 Data Acquisition Process

Please note that this process is taken care of by an overall script that runs for the UPOS website.

3.1 Functional Requirements

3.1.1 The data ingestion process shall access the UAF web page. (http://gse2.gi.alaska.edu/recent/) to acquire data.

3.2 Interface Requirements

3.2.1 The data ingestion process shall ingest HAF data from the UAF web page.

3.3 Operational Requirements

3.3.1 The data acquisition process shall run under the Solaris operating system on a Sun computer.
4 Data Processing

4.1 Functional Requirements

4.1.1 The data processing software shall use the HAF data to create input files for the neural network. These data are obtained from the UAF web page.

4.1.2 The data processing software shall propagate, average and merge the HAF data.

4.1.3 The data processing software shall output the USAF Estimated Kp index, as obtained from the HAF data file.

4.2 Interface Requirements

4.2.1 The software shall read and process the HAF data.

The following is a sample of the HAF data.

```
192 2005  7 9 0 2032 1.0 2
7.69 312.54 3.73 210.87
1.00 385.98 2.27  0.75 -0.83 -0.15  1.13
-6.54 312.28 3.74 210.91
  2.00 384.33 2.18  0.74 -0.82 -0.10  1.11
-4.95 312.01 3.74 210.95
  3.00 382.81 2.25  0.77 -0.87 -0.06  1.16
-3.01 311.78 3.75 210.99
  4.00 381.31 2.24  0.75 -0.84 -0.02  1.13
-0.85 311.60 3.75 211.03
  5.00 379.81 2.31  0.72 -0.82  0.03  1.09
  1.42 311.50 3.76 211.07
  6.00 378.33 2.30  0.70 -0.79  0.07  1.08
  3.68 311.48 3.76 211.10
  7.00 376.85 2.29  0.67 -0.76  0.10  1.02
  5.75 311.52 3.76 211.14
  8.00 375.38 2.27  0.65 -0.73  0.13  0.99
  7.55 311.59 3.77 211.18
```

4.2.2 The software shall propagate and calculate a 6 hour average for ingestion into the neural network. The format of this file should follow the requirements for the Kp prediction system (see section 5.2).

4.2.3 The data processing software shall output the current time for use by the prediction software, so as to keep all software coordinated.

4.3 Operational Requirements

4.3.1 The data processing shall run under the Solaris operating system on a Sun computer.

4.3.2 The data processing shall begin execution by the direction of the Executive Script.
5 Extended Kp Prediction Process

5.1 Functional Requirements

5.1.1 The Extended Kp prediction software shall use the propagated and averaged HAF data.

5.1.2 The prediction software will input the current time from the file, as output by the data processing software. This setup allows for coordination among the times used within both pieces of software.

5.1.3 The 4 day predictive models will be based on a trained neural network designed specifically to perform prediction for time series data.

5.1.4 The model will produce a prediction once daily.

5.1.5 The system shall output a 1 to 4-Day forecast.

5.1.6 The system will be driven by a flexible configuration file, which allows input and output files or directories to be specified.

5.2 Interface Requirements

5.2.1 The prediction software shall read and the propagated, averaged HAF data file. This data file should contain columns for the Julian Time, Bx, By, Bz, density, and speed. The location of this data shall be specified in the configuration file, as IMF_SW_URL. Note that the value for invalid data should be –9999.

The following is a sample of data from nn_oneday.dat.

<table>
<thead>
<tr>
<th>4</th>
<th>2005</th>
<th>7</th>
<th>13</th>
<th>3</th>
<th>3</th>
</tr>
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<tbody>
<tr>
<td>3.00</td>
<td>600.19</td>
<td>0.87</td>
<td>-4.63</td>
<td>0.74</td>
<td>0.04</td>
</tr>
<tr>
<td>170.95</td>
<td>4.15</td>
<td>214.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.00</td>
<td>571.36</td>
<td>1.24</td>
<td>-4.54</td>
<td>1.07</td>
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</tr>
<tr>
<td>166.69</td>
<td>4.17</td>
<td>215.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.00</td>
<td>562.72</td>
<td>3.54</td>
<td>-3.85</td>
<td>3.42</td>
<td>-0.61</td>
</tr>
<tr>
<td>146.18</td>
<td>4.20</td>
<td>215.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.00</td>
<td>554.36</td>
<td>4.79</td>
<td>-4.00</td>
<td>1.11</td>
<td>0.13</td>
</tr>
<tr>
<td>164.49</td>
<td>4.22</td>
<td>215.48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2.2 The prediction software shall output a 1 to 4-Day forecast value and modified Julian time into the file specified as RESULT_1HR_URL in the configuration file.

The following is a sample of a prediction output.

53566.62500 53566.62500 3.70
53566.87500 53566.87500 1.00
53567.12500 53567.12500 2.70
53567.37500 53567.37500 0.70

If an invalid prediction is made, the time output will be the current time of the system, and the prediction value will be –9999.
5.3 Operational Requirements

5.3.1 The Kp prediction software shall be implemented in Java and run on top of the JRE.
5.3.2 The Kp prediction software shall begin execution upon direction of the user.
5.3.3 The Kp prediction software shall continue execution until terminated by direction of the user.
6 Data Plotting Process

6.1 Functional Requirements

6.1.1 The plotting software shall plot 1 to 4-day forecast values for Kp as generated by the Kp prediction process.
6.1.2 The plotting software shall plot Bx, By, and Bz data on one graph.
6.1.3 The plotting software shall plot solar wind bulk speed data.
6.1.4 The plotting software shall plot solar wind proton data.

6.2 Interface Requirements

6.2.1 The plotting software shall ingest 4-day flat files of Bx, By, Bz, solar wind bulk speed, and solar wind proton density data. This data shall be in the format described in section 4.2.
6.2.2 The plotting software shall create GIF images for display in a web browser.

6.3 Operational Requirements

6.3.1 The plotting software shall run under the Solaris operating system on a Sun computer.
6.3.2 The plotting software shall begin execution by the direction of the Executive Script.
7 Related Documentation


# Appendix A

## Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE</td>
<td>Advanced Composition Explorer</td>
</tr>
<tr>
<td>AFWA</td>
<td>Air Force Weather Agency</td>
</tr>
<tr>
<td>APL</td>
<td>Applied Physics Laboratory of Johns Hopkins University</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>Bx</td>
<td>X component of the Interplanetary Magnetic Field</td>
</tr>
<tr>
<td>By</td>
<td>Y component of the Interplanetary Magnetic Field</td>
</tr>
<tr>
<td>Bz</td>
<td>Z component of the Interplanetary Magnetic Field</td>
</tr>
<tr>
<td>GIF</td>
<td>Graphic Interchange Format</td>
</tr>
<tr>
<td>HTML</td>
<td>Hypertext Markup Language</td>
</tr>
<tr>
<td>IMF</td>
<td>Interplanetary Magnetic Field</td>
</tr>
<tr>
<td>JHU</td>
<td>Johns Hopkins University</td>
</tr>
<tr>
<td>Kp</td>
<td>Geomagnetic index that indicates the global geomagnetic disturbances</td>
</tr>
<tr>
<td>MAG</td>
<td>Magnetometer (ACE Instrument)</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>SWEPAM</td>
<td>Solar Wind Electron, Proton, and Alpha Monitor (ACE Instrument)</td>
</tr>
<tr>
<td>UPOS</td>
<td>University Partnering for Operational Support</td>
</tr>
<tr>
<td>USAF</td>
<td>United States Air Force</td>
</tr>
</tbody>
</table>
Appendix B  Contact Information

Refer all science/model questions to simon.wing@jhuapl.edu.