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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 sub-divided 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 Forecasting Kp application consists of a series of scripts and programs that download data from the NOAA Space Weather site, process the data into fifteen minute averages, input the data into a neural network, and create images of the ACE data and forecasted Kp. The user can then view these images via a web browser.

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 ACE data from the NOAA 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 every 15 minutes until termination.
2.3.4 The Executive Script shall terminate upon direction.
3 Data Acquisition Process

3.1 Functional Requirements

3.1.1 The data ingestion process shall access the NOAA SEC ftp site (ftp://sec.noaa.gov) to acquire data.

3.2 Interface Requirements

3.2.1 The data ingestion process shall ingest ACE/SWEPAM data from the NOAA SEC ftp site.
3.2.2 The data ingestion process shall ingest ACE/MAG data from the NOAA SEC ftp site.
3.2.3 The data ingestion process shall ingest ACE/spacecraft location data from the NOAA SEC ftp site.
3.2.4 The data ingestion process shall ingest ACE PKp data from the NOAA SEC ftp site.

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 ACE near real-time SWEPAM, MAG, spacecraft location and ACE PKp data to create input files for the neural network. These data are obtained from the NOAA/SEC ftp site.

4.1.2 The data processing software shall propagate, average and merge the ACE SWEPAM and MAG data into 15-minute intervals for output.

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

4.2 Interface Requirements

4.2.1 The software shall read and process the ACE SWEPAM data.

The following is a sample of the ACE SWEPAM data.

```
:Data_list: 20040520_ace_sweapam_1m.txt
:Created: 2004 May 21 0008 UT
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
# Please send comments and suggestions to SEC.Webmaster@noaa.gov
#
# Units: Proton density p/cc
# Units: Bulk speed km/s
# Units: Ion temperature degrees K
# Status(S): 0 = nominal data, 1 to 8 = bad data record, 9 = no data
# Missing data values: Density and Speed = -9999.9, Temp. = -1.00e+05
# Source: ACE Satellite - Solar Wind Electron Proton Alpha Monitor
#
# 1-minute averaged Real-time Bulk Parameters of the Solar Wind Plasma
#
#       Modified Seconds------- Solar Wind -------
# UT MO DA    HHMM  Day    Day S  Proton  Bulk  Ion
# YR  M O   D A   T i m e   Julian of the     Density    Speed    Temperature
#---------------------------------------------------------------
# 2004 05 20 0000 53145 0 0   5.5       385.1   1.22e+05
# 2004 05 20 0001 53145 60 0    5.9      383.4   1.34e+05
# 2004 05 20 0002 53145 120 0    6.3      383.9   1.28e+05
```

4.2.2 The software shall read and process the ACE MAG data.

The following is a sample of the ACE MAG data.

```
:Data_list: 20040520_ace_mag_1m.txt
:Created: 2004 May 21 0009 UT
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
# Please send comments and suggestions to SEC.Webmaster@noaa.gov
#
# Magnetometer values are in GSM coordinates.
#
# Units: Bx, By, Bz, Bt in nT
# Units: Latitude degrees +/- 90.0
# Units: Longitude degrees 0.0 - 360.0
# Status(S): 0 = nominal data, 1 to 8 = bad data record, 9 = no data
# Missing data values: -999.9
# Source: ACE Satellite - Magnetometer
#
# 1-minute averaged Real-time Interplanetary Magnetic Field Values
```
**4.2.3** The software shall read and process the ACE spacecraft location data, for use with propagation of the ACE SWEPAM and MAG data.

The following is a sample of the ACE spacecraft location data.

```
:Product: 200405.ace_loc_1h.txt
:Issued: 2004 May 26 0012 UT
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
# Please send comments and suggestions to SEC.Webmaster@noaa.gov
# Units: X, Y, and Z position in GSE coordinates in earth radii (Re)
# Accuracy 0.1 earth radii (about 600 km)
# Range: X 0.0 to 300.0
# Range: Y and Z -200.0 to 200.0
# Missing data values: -999.9
# Predicted ACE Satellite Locations in GSE Coordinates

# UT Date Time Julian of the --- GSE Coordinates ---
# YR MO DA HHMM Day Day S Bx By Bz Bt Lat. Long.
#-----------------------------------------------
2004 05 20 0000 53145 0 0 0.7 -1.0 11.8 11.9 84.3 305.6
2004 05 20 0001 53145 60 0 0.1 0.6 11.5 11.5 86.9 76.7
2004 05 20 0002 53145 120 0 0.0 0.8 11.5 11.5 86.1 89.4
```

**4.2.4** The software shall read and process the ACE PKp data.

The following is a sample of the ACE PKp data.

```
:Data_list: ace_pkp_15m.txt
:Created: 2004 May 25 2336 UT
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
# Please send comments and suggestions to SEC.Webmaster@noaa.gov
# Units: Predicted Index 0-9 in Kp units
# Status[S]: 0 = nominal solar wind input data,
# 1 to 5 = incomplete input data, but model output available
# >5 = incomplete input data, no model output
# Solar Wind Source: ACE Satellite
# Missing data values: -1
# 15-minute Costello Geomagnetic Activity Index

# UT Date Time -Predicted Time- Predicted Lead-time USAF Est.
# YR MO DA HHMM S YR MO DA HHMMSS Index in Minutes Kp
#-----------------------------------------------
2004 05 18 2100 0 2004 05 18 221843 1.33 78.7 0.67
```

**4.2.5** The software shall propagate, average and merge the ACE SWEPAM and MAG data into a single file of 15-minute intervals for ingestion into the neural network. The format of this file should follow the requirements for the Kp prediction system (see section 5.2).
4.2.6 The software shall convert the ACE PKp file into the required format for use by the Kp prediction system (see section 5.2).

4.2.7 The software shall separate the MAG data into a file of data for the day and a file of data for the week. The columns for this file should be the same as that described in 4.2.2, with additional columns for the Julian date and the propagated date added to the beginning of each line of data.

4.2.8 The software shall separate the SWEPAM data into a file of data for the day and a file of data for the week. The columns for this file should be the same as that described in 4.2.1, with additional columns for the Julian date and the propagated date added to the beginning of each line of data.

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 Kp Prediction Process

5.1 Functional Requirements

5.1.1 The Kp prediction software shall use the propagated and averaged ACE near real-time SWEPAM and IMF data, as well as the USAF Estimated Kp data.

5.1.2 Three predictive models, two 1-Hr forecast models and one 4-Hr forecast model, will be run simultaneously. Each is based on a trained neural network designed specifically to perform prediction for time series data.

5.1.3 Each model will produce a prediction when new ACE data arrives.

5.1.4 The system shall output a 1-Hr forecast and a 4-Hr forecast. If the last two values of the estimated Kp index are available, the 1-Hr forecast will come from the model requiring both of these values. If the Kp is not available, the 1-Hr forecast will be the prediction value from the other 1-Hr model.

5.1.5 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 process the USAF Estimated Kp data file. This data should contain columns for the Julian Time and the Estimated Kp index. The location of this data shall be specified in the configuration file, as NOWCAST_URL. Note that the value for invalid Kp should be −1.

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

<table>
<thead>
<tr>
<th>Julian Time</th>
<th>ACE</th>
<th>IMF</th>
<th>Density</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>53096.50000</td>
<td>-9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53096.54166</td>
<td>-9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53096.58333</td>
<td>-10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.2.3 The prediction software shall read and process the propagated, averaged ACE SWEPAM and IMF 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_input.dat.

<table>
<thead>
<tr>
<th>Julian Time</th>
<th>Bx</th>
<th>By</th>
<th>Bz</th>
<th>Density</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>53144.56663</td>
<td>-4.59</td>
<td>2.05</td>
<td>0.26</td>
<td>5.17</td>
<td>325.63</td>
</tr>
<tr>
<td>53144.57730</td>
<td>-4.21</td>
<td>-0.02</td>
<td>1.53</td>
<td>5.94</td>
<td>324.12</td>
</tr>
<tr>
<td>53144.58751</td>
<td>-4.03</td>
<td>-0.42</td>
<td>2.20</td>
<td>6.38</td>
<td>325.34</td>
</tr>
</tbody>
</table>

5.2.4 The prediction software shall output a 1-Hr forecast value and Julian time into the file specified as RESULT_1HR_URL in the configuration file.

5.2.5 The prediction software shall output a 4-Hr forecast value and Julian time into the file specified as RESULT_4HR_URL in the configuration file.
The following is a sample of a prediction output.

53153.114583 0.33

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-Hr and 4-Hr 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.
6.1.5 The plotting software shall create both 7-day and 24-hour versions of all plots.

6.2 Interface Requirements

6.2.1 The plotting software shall ingest 7-day and 24-hour 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 ingest 1-Hr and 4-Hr forecast results in the format specified in section 5.2.
6.2.3 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>