A Closer Look at Solar Wind Regime Speeds

MODEL STUDENT ACTIVITY

In this activity, you will design and conduct an investigation based on one of the questions that you had about solar wind as you completed the Student Activity, “A First Look.” As you follow the procedure below, you will be using the same method that scientific investigators use as they conduct research based on their observations. Have copies of your completed Student Activity, “A First Look,” and the Student Text, “Exploring Data,” available as you complete this student activity sheet.

Part 1. Designing Your Investigation

1) Select a question from your list of questions developed in Part 2 of the Student Activity, “A First Look.” Copy it in the space below.

   From my observation and reading, it appears that the three solar wind regimes travel at different speeds. How different are the speeds of the three regimes?

2) Rewrite your question in the form of a testable relationship between two or more variables. The question should include the specific test group(s) or variables, the area to be covered, or the time limits during which you will test this relationship.

   Was there a difference in the mean minimum and maximum speeds of the three solar wind regimes—slow, fast, and CME—as they interacted with the Genesis spacecraft during the month of December 2002?

3) Now rewrite your question in the form of a null hypothesis.

   There was no significant difference in the mean minimum and maximum speeds of the three solar wind regimes—slow, fast, and CME—as they interacted with the Genesis spacecraft during the month of December 2002.

4) Describe a procedure for testing your hypothesis. Include the method that you will use to test your hypothesis, the materials and supplies that you will need, the variables to be tested and the variables that you will hold constant. Be sure to include any safety precautions that you will observe as you conduct your experiment.

Materials needed:

- Data print outs of solar wind summary plots from the LANL Web site for the month of December 2002.
- Data tables or spreadsheets in which to record date, solar wind regime, minimum and maximum solar wind speeds.
- Graph paper or computer software to graph data obtained.
- Statistical analysis software to determine the significance of the data.
Variables to be tested:

The regime of solar wind vs. the minimum and maximum speeds of the solar wind during the regime.

Variables that will not be considered or recorded:

1) The length of time that a specific solar wind regime interacted with the Genesis spacecraft.
2) What type of regime precedes or comes after the specific regime being studied.
3) The changes in speed that occur during the transition period, one hour prior to and one hour after a regime change, or when an interplanetary shock occurs.

Procedure: List the specific details of your procedure in the order in which you will carry out your investigation.

1) Collect your materials, set up your equipment, and start collecting data. Obtain printouts (or examine on the computer screen) of the solar wind summary plots from the LANL Web site for the month of December 2002.
2) Collect data. For each day, record the following.
   a) Type(s) of solar wind regime present during the day.
   b) Minimum and maximum speeds for the day of each type of regime. (Disregard anomalous readings that occur within one hour preceding and one hour after a change in regime or an interplanetary shock.)
3) Analyze data:
   a) Determine the mean minimum and maximum solar wind speeds for each of the regimes—slow, fast, and CME.
   b) Graph the mean minimum and maximum solar wind speeds as a function of each of the regimes.
   c) Determine the statistical significance in the differences in the means of the minimum and maximum solar wind speeds between the regimes.
4) Draw conclusions with regard to the analyzed data.
Part 2. Carry out your procedure and record the results, including data tables and graphs resulting from your investigation, in the space below.

Results:

**Table 1. Raw data recorded from the LANL Web site**

<table>
<thead>
<tr>
<th>Date</th>
<th>Slow Regime Minimum (km/s)</th>
<th>Slow Regime Maximum (km/s)</th>
<th>Fast Regime Minimum (km/s)</th>
<th>Fast Regime Maximum (km/s)</th>
<th>CME Regime Minimum (km/s)</th>
<th>CME Regime Maximum (km/s)</th>
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</table>
**Part 3.** Analyze your data. You will need to select the appropriate analysis package for your investigation. If you are using a computer software program, read the specific data qualifications for using the program. You may also consult your science instructor or your mathematics teacher for help in selecting the appropriate analysis program.

**Analysis of Data:**

1) Determination of mean minimum and maximum wind speeds for the three solar wind regimes. We used a descriptive statistical package that calculated the mean for each type of solar wind data. In addition, it determined the standard error, standard deviation, and sample variance—factors that we needed to continue the analysis. We show this information in Table 2.

<table>
<thead>
<tr>
<th>Preliminary Statistical Results</th>
<th>Fast Solar Wind</th>
<th>Slow Solar Wind</th>
<th>CME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minimum Mean Speed (km/s)</strong></td>
<td>469</td>
<td>391</td>
<td>371</td>
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<tr>
<td><strong>Maximum Mean Speed (km/s)</strong></td>
<td>594</td>
<td>469</td>
<td>457</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>469</td>
<td>391</td>
<td>371</td>
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<tr>
<td><strong>Standard Error</strong></td>
<td>16</td>
<td>12</td>
<td>22</td>
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<tr>
<td><strong>Standard Deviation</strong></td>
<td>65</td>
<td>50</td>
<td>59</td>
</tr>
<tr>
<td><strong>Sample Variance</strong></td>
<td>4182</td>
<td>2495</td>
<td>3422</td>
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<tr>
<td><strong>Minimum</strong></td>
<td>400</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>625</td>
<td>500</td>
<td>450</td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>17</td>
<td>17</td>
<td>7</td>
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</tbody>
</table>

2) Graph of the mean minimum and maximum wind speeds for the three solar wind regimes.
Testing for Significance:

There is an obvious difference in the mean minimum speeds of CME and Fast, and between Fast and Slow, but are these differences significant? There are also differences in the mean maximum speeds of all three regimes, but are they significant? To determine the significance of these differences at the 0.05 level, we used a two-tailed $t$-Test for each pair of means. Table 3 contains the relevant results of these calculations.

<table>
<thead>
<tr>
<th>Mean Pairs</th>
<th>df</th>
<th>Significance Level</th>
<th>$t$-Stat</th>
<th>$t$-Critical two-tail at $\alpha = 0.05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Fast and Slow</td>
<td>17</td>
<td>&gt;.20</td>
<td>0.649</td>
<td>2.119</td>
</tr>
<tr>
<td>Minimum Fast and CME</td>
<td>9</td>
<td>.01$&lt;t&lt;0.02$</td>
<td>3.222</td>
<td>2.262</td>
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<tr>
<td>Minimum Slow and CME</td>
<td>7</td>
<td>&gt;.20</td>
<td>0.706</td>
<td>2.364</td>
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<tr>
<td>Maximum Fast and Slow</td>
<td>16</td>
<td>&gt;.20</td>
<td>0.863</td>
<td>2.120</td>
</tr>
<tr>
<td>Maximum Fast and CME</td>
<td>13</td>
<td>.001$&lt;t&lt;0.01$</td>
<td>3.192</td>
<td>2.160</td>
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<tr>
<td>Maximum Slow and CME</td>
<td>8</td>
<td>&gt;.20</td>
<td>0.052</td>
<td>2.306</td>
</tr>
</tbody>
</table>

According to this analysis, there were significant differences only between all means of minimum fast and CME regime speeds and maximum fast and CME regime speeds. These differences were significant at the 95% confidence level.

The differences in speeds between other pairs were not significant, even at the 80% confidence level.

**Conclusions:**

Therefore, we can reject the null hypothesis for both minimum and maximum fast and CME regime speeds, and conclude that the three solar wind regimes were traveling at significantly different speeds during the month of December 2002.

The null hypothesis was supported for the other pairs of compared regime speeds.