Statistical Analysis of Model Data for Operational Space Launch Weather Support at Kennedy Space Center and Cape Canaveral Air Force Station

William H. Bauman III
NASA Applied Meteorology Unit
ENSCO, Inc.
Cape Canaveral Air Force Station, Florida

Presented by:
William P. Roeder
45th Weather Squadron
Patrick Air Force Base, Florida
Outline

• Background/Objective
• Launch/Landing Weather Towers
• MesoNAM Grid
• Data and Methodology
• Data Formatting
• Results
• Graphical User Interface
• Summary and Conclusions
Background/Objective

- The 12-km NAM (MesoNAM) used
  - By 45 WS Launch Weather Officers
  - At KSC and CCAFS
  - To forecast T, T_d, and winds at launch and landing weather towers
- Model performance good anecdotally, but not measured objectively
- The 45 WS tasked the Applied Meteorology Unit (AMU) to conduct analysis of model versus tower observations
- Need to assess model performance at each tower and sensor height
Launch/Landing Weather Towers

<table>
<thead>
<tr>
<th>Tower Number</th>
<th>Supported Activity and Facility</th>
<th>Sensor Heights</th>
</tr>
</thead>
<tbody>
<tr>
<td>002</td>
<td>Delta II (LC-17)</td>
<td>6 ft, 54 ft, 90 ft</td>
</tr>
<tr>
<td>006/108</td>
<td>Delta IV (LC-37)</td>
<td>54 ft</td>
</tr>
<tr>
<td>110</td>
<td>Atlas V (LC-41)/Falcon 9 (LC-40)</td>
<td>54 ft, 162 ft, 204 ft</td>
</tr>
<tr>
<td>041</td>
<td>Atlas V (LC-41)</td>
<td>230 ft</td>
</tr>
<tr>
<td>393/394</td>
<td>Shuttle (LC-39A)</td>
<td>60 ft</td>
</tr>
<tr>
<td>397/398</td>
<td>Shuttle (LC-39B)</td>
<td>60 ft</td>
</tr>
<tr>
<td>511/512/513</td>
<td>Shuttle Landing Facility</td>
<td>6 ft, 30 ft</td>
</tr>
</tbody>
</table>

- Upwind sensor used

Diagram:

- NW Sensor
- SE Sensor

http://science.nasa.gov/amu
Data and Methodology

• Used MesoNAM textual forecasts from ACTA, Inc.
  – Hourly forecasts: 0 to 84 hours
  – Model initialization times: 00, 06, 12 and 18 UTC

• Verified operational MesoNAM
  – Sep 2006 → Jan 2010 (3+ years)

• Data sets stratified by
  – Month, Onshore/offshore flow, and Model initialization time

• Computed
  – Bias, Standard Deviation of bias, Root Mean Square Error, and Hypothesis Zero Test
Data Formatting

- **MesoNAM files:**
  - Space-delimited text files
  - Hourly forecasts
  - T and T_d in degrees °C

- **Tower observations:**
  - Tab-delimited text files
  - Five minute observations
  - T and T_d in degrees °F

- **QC’d, Imported, Manipulated, Merged into Excel™**
  - Result: 2,496 Workbooks
  - Four Worksheets per Workbook with 4,896 Charts
Model Error Trend

- LC 39A (Shuttle)
  - MesoNAM RMSE of temperature and wind speed
  - Model error increases during forecast period

[Graphs showing model error trend for temperature and wind speed]
Model Diurnal Bias

- Tower 006 (Delta IV)
  - MesoNAM temperature bias, 00Z and 12Z model initialization
  - Diurnal model bias
    - Warm bias local afternoon
    - Cool bias local night

![Graph showing temperature bias for 00 UTC and 12 UTC initializations.](image-url)
Model Forecast Level/Sensor Height

- Tower 002 (Delta II)
  - MesoNAM temperature bias, 6 ft and 54 ft sensor heights
  - Model temperature bias – model forecast at 2 m (~ 7 ft)
    - Bias smallest at 6 ft sensor height
    - Increases with height (54 ft sensor height and higher)

![Graphs showing model bias comparison at 6 ft and 54 ft sensor heights.](image-url)
Model Forecast Level/Sensor Height

- Tower 002 (Delta II)
  - MesoNAM wind speed bias, 12 ft and 54 ft sensor heights
  - Model wind speed bias – model forecast at 10 m (~ 33 ft)
    - Bias largest at 12 ft sensor height
    - Decreases with height (54 ft sensor height and higher)
Hypothesis Zero Test

• Tower 512 (Shuttle Landing Facility)
  – Hypothesis testing uses statistics to determine the probability that a given hypothesis is true
  – Determine if the model bias of any of the parameters assessed throughout the model forecast period was statistically zero
Graphical User Interface

- Difficult and time consuming to search thousands of Excel files
- Develop GUI
  - JavaScript and HTML-based
  - Easy to navigate through all stratifications
    - Month, Fcst start time, Ht, On/Off shore flow
  - Browser and computer OS independent
Summary and Conclusions

• LWO’s use MesoNAM for launch forecasts
• Model performance now evaluated objectively
• AMU conducted analysis of model versus observations
• Identifies model strengths and weaknesses
  – Model performance degrades during forecast period
  – Diurnal signals
  – Model bias vs. height varies with parameter
• Identifies when bias is not statistically different than zero
• GUI useful for navigation through data